WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

JOINT CBS-CCL EXPERT TEAM ON OPERATIONAL PREDICTIONS FROM SUB-SEASONAL TO LONGER-TIME SCALES (ET-OPSLS)

BEIJING, CHINA, 11-15 APRIL 2016

FINAL REPORT

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EXECUTIVE SUMMARY

Executive summary

The meeting of the WMO Joint Commission for Basic Systems (CBS)-Commission for Climatology (CCl) Expert Team on Operational Predictions from Sub-seasonal to Longer-Time Scales (ET-OPSLS) was opened at 9:00 am Monday, 11 April 2016 by its Chairperson Mr Richard Graham (UK). Opening remarks were made by Mr Zhang Peiqun on behalf of the Beijing Climate Centre (BCC), Mr Graham, and representatives of the WMO Secretariat, Mr Abdoulaye Harou (C/DPFS) and Ms Anahit Hovsepyan (Scientific Officer WCAS). Mr Graham noted excellent progress made since the last meeting in a number of areas including development of infrastructure for a more streamlined verification facility; setting up of a pilot for real-time sub-seasonal multi-model prediction; and continued informal exchange of near term climate predictions and noted that the current meeting was tasked with agreeing next steps in these areas of work. Mr Harou noted the importance of the work of the ET-OPSLS both in terms of facilitating the move to a Seamless Data-Processing and Forecasting System, required by the 17th Congress of WMO, and in the implementation of the Global Framework for Climate Services (GFCS). Ms Hovsepyan reminded the ET that close partnership and collaboration between Technical Commissions is highly encouraged by the WMO President and presidents of TCs, and the activity of ET-OPSLS serves as a good example for inter-commission collaboration, CBS with CCl, in achieving common goals and objectives. The representation of the research community at the meeting through participation of Mr Bill Merryfield (WGSIP) was warmly welcomed as strengthening important linkages between the research and operational contexts of climate prediction.

The ET reviewed decisions of the WMO constituent bodies relevant to its work including those of Cg-17 (2015), CBS-MG (2016) and CBS-Ext (2014). In particular Resolution 11 of CG-17 was noted – which requests Members to move towards an enhanced integrated and seamless Data Processing and Forecasting System as well as recent changes to the manual on the GDPFS which allow, under certain conditions, research centres access to products from the Lead Centre for Long Range Multi-Model Ensemble (LC-LRFMME). Resolution 60 of Cg-17 regarding international exchange of climate data and products was also noted. The ET was also briefed on a reorganisation of GDPFS Expert Teams – including creation of new Task Teams and a renaming of the ET-OPSLS to the "Inter-Programme Expert Team on OPSLS (IPET-OPSLS)". The creation of the Implementation Coordination Team for the Climate Services Information System (ICT-CSIS) was recalled and its plans for a scoping meeting for defining Climate Services Information System architecture, development of a related Technical Reference Manual and development and implementation of the Climate Services Toolkit (CST) were noted as highly relevant to the work of the ET. It was agreed that Mr Jean-Pierre Ceron will serve as focal point within the ET-OPSLS for liaison with ICT-CSIS. The ET also noted with interest the guidance document on RCC operations being prepared by the ET-RCC and the plans of the TT-RCOF to hold a global RCOF review in 2017. The ET was also briefed on new EU Copernicus Climate Change Service (C3S), specifically its seasonal forecasting component and noted the possibility to coordinate activities with Copernicus.

The status of the GPC and RCC network was reviewed. It was noted that 12 GPCs were operating and that no nominations for designation of new GPCs had been received. The RCC network currently stands at 5 RCCs and 1 RCC Network. A further 3 RCCs and 2 RCC Networks are expected to seek designation at the forthcoming CBS Session 2016. The ET considered its potential inputs (see below) to a new Polar RCC Network that is expected to start a demonstration phase in 2017.

The status of operational predictions systems operated by the GPCs was reviewed. It was noted that two further GPCs, Seoul and Pretoria, had implemented coupled ocean-atmosphere systems since the ET last met in 2014 – increasing to 10 the number of GPCs running coupled systems. Significant system upgrades had also been implemented by a number of GPCs including Tokyo and Beijing – with improvements in forecast skill noted. GPCs ECMWF, Toulouse and Montreal are planning major upgrades to their seasonal systems – some as early as 2017. GPC Montreal has developed and implemented a new sub-seasonal forecasting system. It was also welcomed that, under new data policy arrangements, ECMWF had (in March 2016) provided hindcast data from their seasonal system to the LC-LRFMME. The ET took note of capacity training materials on seasonal forecasting and software to aid forecast interpretation developed by some GPCs and was briefed on new research into known user requirements for tailored forecasts such as prediction of season onset timing. Regarding the latter GPC-CPTEC had found encouraging skill for onset prediction, supporting earlier conclusions reported by GPC-Exeter. The ET was also briefed on current research projects coordinated by WGSIP including on tropical-extratropical teleconnections, the impact of snow initialisation on forecast skill and assessments of different forecast initialisation techniques.

The ET reviewed the compliance of the GPCs against the designation criteria and found all GPCs to be fully compliant with regard to operational issuance, hindcast length and compatibility of hindcast and forecast systems. Some minor exceptions regarding product provision for 2 GPCs are expected to be resolved quickly. Because the arrangements for coordinated verification of GPC and multi-model products are in a state of flux it was not considered useful to review compliance on verification – and this was deferred to the next ET meeting after the new arrangements will be in place.

The ET reviewed the status of its two Lead Centres: the Lead Centre for Long Range Forecast Multi-Model Ensemble (LC-LRFMME) and the Lead Centre for the Standard Verification System for Long Range Forecasts (LC-SVSLRF). The LC-LRFMME has continued to collect GPC forecast data for an agreed range of variables and display individual GPC forecasts in a common graphical format on its website. The LC-LRFMME also generates and displays associated multi-model forecasts. Access to download forecast and hindcast data is also available on the website for those GPCs that allow it. Access to products is restricted by password protection to GPCs, RCCs, NMHSs, bodies coordinating RCOFs and to selected research organisations that support these entities. Following a comprehensive review and tightening of the implementation of access rules the ET noted with pleasure that there are now 240 registered users of the LC-LRFMME website including users from various RCOFs (e.g., FOCRAII for Asia, EASCOF for East Asia, SASCOF for South Asia, ASEANCOF for Southeast Asia, GHACOF for Greater Horn of Africa and SSACOF for Southern South America). Following actions from the previous meeting and requests from WMO constituent bodies the LC-LRFMME has also developed a new, more streamlined, facility for coordinated verification of GPC products and the associated multi-model and has developed a pilot exchange and display of real-time sub-seasonal multi-model forecasts. The ET noted that the LC-SVSLRF had been running successfully for more than 12 years providing GPC hindcast verification information to users as well as related information on the SVSLRF. The ET agreed a key challenge for the LC-SVSLRF will be to harmonise its activities and website with the new arrangements for coordinated verification that will be led by LC-LRFMME.

The ET reviewed progress on the Global Seasonal Climate Update (GSCU) including feedback received at the Pune workshop on Operational Climate Prediction and input from the Chair of the TT-GSCU. Recommendations for consideration at the upcoming TT-GSCU meeting were prepared and recorded (see below).

The ET next reviewed the activities of its seven Sub-teams (STs). ST1 had organised and held the first WMO Workshop on Operational Climate Prediction, hosted by IITM at its headquarters in Pune, India, 9-11 November 2015. The overarching aim of the workshop series is to facilitate increased interaction between and among the various operational climate prediction centres and the associated research communities, leading to better collective capacity to meet the climate information needs of decision makers, including support of the priority sectors of the GFCS: agriculture, health, water, energy and disaster risk reduction. The main discussion points at the workshop included review of the CST and the GSCU and a sharing of views on the development of a guidance document on procedures for preparing national/regional long range forecasts. In addition, recommendations of the ET-RCC concerning requests to provide GPC hindcast and forecast data in a format readable by IRI's Climate Predictability Tool (CPT format) were also reviewed by the ET.

The work of Sub-Team 2 on verification of GPC forecasts has been led by the LC-LRFMME which has developed a facility for generating and displaying verification results for all individual GPCs providing hindcast information and associated multi-model products using a common hindcast period of 1983-2001.

The ET was briefed on the pilot system for generation and display of real-time subseasonal multi-model forecasts developed by the LC-LRFMME as part of the work of Sub-Team 3. The pilot employs forecast and hindcast data from a subset of centres contributing to the ECMWF-hosted database for the WWRP-THORPEX/WCRP subseasonal to seasonal research project (S2S). Centres currently contributing to the pilot are ECMWF, Exeter, Tokyo and Washington. The range of multi-model forecast products generated includes probabilities for tercile categories of 2m temperature and precipitation as well as MJO and BSISO indices. Forecast verification diagnostics have also been generated. The ET also reviewed recent activities and outputs from the S2S project noting the forecast/hindcast database at ECMWF now includes data from 9 models, that access is also available through a mirror portal at CMA and that the S2S International Coordination Office (ICO – http://s2sprediction.net) hosted by the National Institute of Meteorological Sciences (NIMS), Jeju, Korea is an excellent source of information on the project. As part of a joint S2S and ST3 activity a questionnaire on current practices in verifying subseasonal forecasts had been developed and completed by the GPCs. A key result emerging was that very few centres are conducting verification of extremes predictions or of "tailored" forecasts such as rain day frequency or frequency/timing of in-season dry spells.

The ET reviewed Sub-Team 4's work to refine the roles and responsibilities of a proposed Lead Centre for Near Term Climate Prediction (LC-NTCP) first discussed at the 2014 ET meeting, noting that the Technical Commissions have welcomed the progress to date and requested the ET to continue its task and that the roles and functions for the LC-NTCP be finalized and submitted for consideration by CBS-16 for further action. The ET also acknowledged two new initiatives that support establishment of infrastructure of near term climate prediction, namely the WCRP/WGSIP Decadal Climate Prediction Project (DCPP) and the WCRP Grand Challenge of Near Term Climate Prediction (GC-NTCP). A revised proposal developed by ST4 that addresses feedback received from the Technical Commission meetings and includes an accelerated programme for providing forecast verification products was endorsed by a large majority of ET members.

The ET was briefed on the work of Sub-Team 5 on new approaches for distribution of GPC hindcast and forecast data, including use of OPenDAP technology. Results of a questionnaire on current GPC distribution practices indicated there was little consistency in approaches to data dissemination, with ftp transfer the most common method used and only a few using OPenDAP methods. It was noted that NetCDF format for GPC data was at least as widely requested (and used) as GRIB (the WMO standard).

The ET was briefed on the work of Sub-Team 6 on developing a guidance document on procedures for generating regional seasonal forecasts. It was agreed that outputs from a specific breakout session on this topic organised at the Pune WMO Workshop on Operational Climate Prediction, provided a good basis for proceeding with developing a framework for the guidance document.

The ET was also briefed on the work of ST7 on revision of sections of the new Manual on the GDPFS relevant to the GPCs. It was noted that further revisions were likely required and all GPCs were requested to send further comments by end of June 2016.

The ET reviewed and endorsed a revised Statement of Guidance (SoG) on observational data requirements for sub-seasonal to longer timescale predictions developed by Mr Yuhei Takaya and submitted to the Inter-Programme Expert Team on Observation System Design and Evolution (IPET-OSDE). The revision includes an expansion of scope to cover requirements of longer time scale (multi-annual to decadal) prediction.

The ET reviewed the mandatory and highly recommended GPC products in light of feedback from the Pune workshop. It was decided to add 850hPa and 200hPa zonal and meridional winds as highly recommended products. These variables had been requested by RCCs for their importance in diagnosing monsoon characteristics and model responses to large scale SST forcing.

The team reviewed and made minor adjustments to its Terms of Reference for review by ICT-DPFS – the suggested changes chiefly reflect the ET-OPSLS's role in development of the GSCU. The ET also reviewed the composition of its Sub-Teams and drafted their plans of work.

At a meeting in a side event the Expert Team joined with leaders and trainers from CMA Training Centre (CMATC/WMO RTC Beijing) as well as participants from the CMATC International Training Course on the GFCS – which was running concurrently with the ET meeting in the nearby CMATC building. At this 1-hour meeting, chaired by Mr Wang Bangzhong, Deputy Director-General of CMATC, the ET explained its role in guiding development of operational infrastructure for long-range forecasting in the context of the Climate Services Information System of the GFCS and the training course participants gave perspectives on the information needs of their organisations.

The decisions, recommendations and agreed actions from the meeting are summarised below.

Implementation of the new streamlined verification facility at LC-LRFMME and harmonisation with LC-SVSLRF: It was agreed that the LC-LRFMME should activate the new verification facility and website, coordinating with the LC-SVSLRF to ensure linkage to the verification maps across the two websites. LC-LRFMME should provide a clear indication of the period used for verification (1983-2001) and a warning that, because of the different period, results may appear different to those available on individual GPC sites. It was decided that the LC-SVSLRF website should remain active as a source of information and code for the SVSLRF and that the current verification maps should be removed and replaced with links to the new LC-LRFMME maps at the earliest opportunity, with a target for completion by end of June 2016.

Further development of the LC-LRFMME real-time sub-seasonal multi-model pilot: It was decided not to open up the LC-LRFMME real-time pilot sub-seasonal website products to NMHSs and RCCs at this stage. The ET preferred to wait until a) the number of models used had stabilized (GPC Beijing, GPC-Melbourne and GPC-Montreal agreed to join the real-time pilot), b) the day of nominal issuance had stabilized (currently this is Wednesday, but a change to Thursday is being considered; c) new requested additional products were included in the exchange and d) a larger sample of forecast verification statistics is available. A major point of discussion was the need to shorten the elapsed time between the initialization of the component models (the time of which varies) and the release of the multi-model products – to minimise loss of prediction skill. The LC-LRFMME are requested to convey their progress and results to the S2S project team at the next S2S steering group teleconference and through posting a short briefing note on the Project Office website. It was agreed that, because the methodology for multi-modelling of sub-seasonal forecasts is relatively unexplored it was important to get feedback on the pilot from the S2S steering group.

In addition, the ET strongly encouraged those GPCs that are currently issuing subseasonal forecasts to make available to WMO members a range of forecast products based on the minimum list of variables that was prepared by the expert meeting of ET-ELRF in 2012.

Development of roles and responsibilities for a Lead Centre for Near Term Climate Prediction: The revised document on roles and responsibilities was endorsed by a large majority of ET members. The ET advised Sub-Team 4 to further refine the document and submit to CBS-2016 (by July 2016), via the ET. The following changes to the document were requested: the phrase "contributing centres" should be used in place of "GPCs" – since, in general, centres making real-time decadal predictions are not the current 12 GPCs; contributing centres should not be designated by WMO, since they are, in the main, research and not operational centres. Rather, the LC-NTCP should be designated and act as WMO's main contact point with the contributing centres, through representation on the ET-OPSLS. The LC-NTCP should have an additional role of managing any loss of forecast contributions that might occur if a contributing centre decides to cease contributing; evidence of skill for all forecast products including the 1-year ahead range should be included in the submitted document.

Seamless Data-processing and Forecasting System: All GPCs to provide comments on the White Paper on Cg-17 Resolution 11 – regarding the move towards a Seamless Data-processing and Forecasting System to Mr Harou by end of April.

Potential requirements on GPCs from a Polar RCC (PRCC): It was agreed that Mr Denis would draw up a list of known requirements for a PRCC (variables, output frequency etc) and that GPCs were encouraged to consider including these variables in their hindcasts and forecasts. GPC Montreal will also consider coordinating a temporary informal exchange of GPC sea-ice related predictions to support the PRCC demonstration phase.

Next WMO workshop on Operational Climate Prediction: Sub-Team 1 were requested to begin consideration of the next workshop in the series to be scheduled for the last quarter of 2017. It was agreed that the next workshop should continue the theme of facilitating increased interaction between and among the various operational climate prediction centres and the associated research communities and could have focus points on a) reviewing the framework for the guidance document on preparing consolidated seasonal forecasts and b) reviewing operational experience with the GSCU – which by then should have reached its operational phase; c) review of the S2S real-time pilot.

GPC products and outputs: It was decided to add 850 hPa and 200 hPa zonal and meridional winds to the highly recommended products for GPCs. It was decided that the LC-LRFMME should not provide an option to download hindcast and forecast data in CPT (Climate Predictability Tool) format as had been requested by some RCCs, but that a GRIB-to-CPT conversion software should be made available from the LC-LRFMME website. It was agreed that the developers of CPT should also be requested to provide GRIB conversion software as an integral part of the CPT package.

Recommendations for GSCU development: The ET agreed to pass the following comments to the TT-GSCU. It was noted that a release plan would be required to promote the operationalisation of the product. Feedback on the GSCU, including from a dedicated breakout session at the Pune workshop on Operational Climate Prediction, included the following points: 1) the verification could be removed as the information will soon be available through the new streamlined facility developed by LC-LRFMME; 2) upgrade to 3-month rolling forecasts and inclusion of assessment of previous forecasts should be included after operationalisation; 3) the ET-OPSLS should be included as reviewers of the operational GSCU; 4) discontinuation of "mixed reference period" products (multi-model and consistency maps) should be considered – such that all issued products are verifiable.

Harmonisation of GSCU and LC-LRFMME website products: It is recommended that, prior to operationalisation of the GSCU, the individual GPC forecast products and multi-model products displayed on the LC-LRFMME website should use the same common reference period (currently 1983-2001) used in generation of the GSCU products, in order to ensure consistency.

Guidance document on procedures for generating consolidated regional seasonal forecasts: The ET concluded that the recommendations from the Pune workshop – together with other considerations - provide a good basis for proceeding with the development of a framework for a technical guidance document and agreed that Sub-Team 6 should remain active to begin the task – it was agreed that a first draft of the framework would be completed by the end of 2016.

ET-OPSLS / WGSIP collaboration on themes relevant to operational prediction: Potential themes for increased collaboration were agreed as:

- Interoperability of data standards (e.g. NetCDF, GRIB, ESGF). It was generally agreed that the issue of multiplicity in data formats was a key issue to address in light of the increased data sharing envisaged for the GFCS.
- The optimisation (in lagged ensemble approaches) of ensemble size versus increasing lead time needed to accumulate more lagged members.
- Experimentation to improve understanding of the impact of different observation platforms and types on the skill of sub-seasonal to longer timescale predictions.

It was also concluded that a sub-group within WGSIP could be set up with Terms of Reference that include horizon scanning for forecast product research that could be accelerated into operations.

Quality control of GPC products on the LC-LRFMME website: All GPCs and the LC-LRFMME were requested to monitor forecast products routinely to check for any potential errors in the data or its display and to contact the relevant party without delay if issues are found.

Temporary access to LC-LRFMME products: The LC-LRFMME are requested to arrange for temporary access IDs/passwords for use during training courses by both participants and trainers – allowing quick, but temporary, access for substantial numbers of users.

Review of the SVSLRF: It was agreed that Sub-Team 2 (verification) should consider a reassessment of the value of the Mean Square Skill Score (MSSS) - currently required as part of the core of the SVSLRF. The score can give inconsistent results across GPCs depending on the degree of calibration applied to issued products. Moreover, experience suggests the components of the MSSS (e.g. correlation and variance ratio) are often more informative than their (MSSS) sum. It was also agreed that ST2 would undertake a review of recommendations on observational datasets for seasonal forecast verification and update the LC-SVSLRF website if necessary.

Questionnaire on subseasonal verification practices in operational centres: Mr Coelho and Mr Takaya were encouraged to feed results back to the S2S at the next S2S steering group teleconference.

Questionnaire on GPC approaches for distribution of hindcast and forecast data: Mr Jones was requested to forward results of the questionnaire to the ICT-CSIS.

1. OPENING

1.1 The meeting of the WMO Joint Commission for Basic Systems (CBS)-Commission for Climatology (CCl) Expert Team on Operational Predictions from Sub-seasonal to Longer-Time Scales (ET-OPSLS) was opened at 9:00 am Monday, 11 April 2016 by its Chairperson Mr Richard Graham (UK). Opening remarks were made by Mr Zhang Peiqun on behalf of the Beijing Climate Centre (BCC), Mr Graham, and representatives of the WMO Secretariat, Mr Abdoulaye Harou (C/DPFS) and Ms Anahit Hovsepyan (Science Officer CLPA).

1.2 Mr Graham, welcomed the participants and thanked the BCC for offering the use of their new building and the first-ever use of the excellent facilities of one of its new conference rooms. He thanked the ET for progress made since the Exeter (2014) meeting and noted a number of related decisions that were on the agenda for action, notably: planning of the implementation of improved coordination in verification of individual and multi-model GPC forecasts; review of the newly developed sub-seasonal real-time pilot and review of revised roles and functions of a prospective Lead Centre for Near Term Climate Prediction (LC-NTCP). He invited Mr Zhang to deliver his remarks.

1.3 Mr Zhang, welcomed the participants to the brand new building of BCC, highlighting that this meeting is the first of its size to occur in the new BCC premises. He recalled that in 2005 they held a FOCRAII meeting in a building they qualified as new and highlighted that the move to this new environment is a sign of the growing importance of climate activities in China. He thanked the participants for their involvement and wished the meeting every success.

1.4 Mr Harou, also welcomed the participants on behalf of the Secretary General of WMO and thanked the government of China and the Permanent Representative of China, Mr Zheng Guoguang, for making the meeting possible. He recalled the importance of the work of the ET-OPSLS both in term of facilitating the move to a Seamless Data-processing and Forecasting System, required by the 17th Congress of WMO, and of the implementation of the Global Framework for Climate Services (GFCS). He added that, with the upcoming 16th Session of the Commission for Basic System (CBS) the Expert Team should also develop a work plan for the new financial period (2016-2019). He concluded by thanking again the host for its open-arm welcome.

1.5 Ms Hovsepyan conveyed greetings to participants on behalf of the Commission for Climatology and expressed high appreciation on the joint activities of the Commission for Basic Systems and CCl, particularly through the ET-OPSLS and Expert Team on Regional Climate Centres (ET-RCC). The close partnership and collaboration between Technical Commissions is highly encouraged by the WMO President and presidents of TCs, and the activity of ET-OPSLS serves as a good example for inter-commission collaboration in achieving common goals and objectives. She thanked the BCC for hosting this event and wished a successful meeting.

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda

The agenda was adopted with the inclusion of item 6.1.3, Report on WCRP/WGSIP Activities, and 6.1.4, Report back from the ET-RCC. The agenda is available at Annex 1 to this report.

2.2 Working arrangements

2.2.1 The ET agreed to its working arrangements. The meeting participants and contact details are listed in Annex 2. Tabled documents for the meeting are available at the link below.

http://www.wmo.int/pages/prog/www/DPFS/Meetings/ET-OPSLS_Beijing2016/DocPlan.html

2.2.2 Side event with the CMA Training Centre / WMO RTC Beijing:

On Thursday 14 April there was a joint 1-hour event which brought together the Expert Team with leaders and trainers from CMA Training Centre (CMATC/WMO RTC Beijing) as well as participants from the CMATC International Training Course on the GFCS – which was running concurrently with the ET meeting in the nearby CMATC building. This was a very successful and enjoyable event which a) gave the ET an opportunity to explain their role in guiding development of operational infrastructure for long-range forecasting in the context of the Climate Services Information System of the GFCS and b) the training course participants to express the needs of their organisations and to ask questions about ET activities.

The proceedings were chaired by Mr Wang Bangzhong, Deputy Director-General of CMATC. Mr Wang welcomed all to the joint event, made his introductory remarks and then invited Mr Abdoulaye Harou (WMO CBS Chief of the Data Processing and Forecasting System) and Ms Anahit Hovsepyan (WMO CCl Scientific Officer, World Climate Applications and Services) to introduce the CBS and CCl collaboration on GFCS development. Next, Mr Richard Graham introduced the work of the ET, focusing on its role in fostering collaboration in seasonal forecasting between the 12 GPCs, the channelling of information through the two lead centres (LC-LRFMME and LC-SVSLRF) and continual improvement of services to Regional Climate Centres and National Meteorological and Hydrological Services. Mr Wang then invited four participants in the CMATC International Training Course on the GFCS to present questions to the ET each of which was followed by open discussion. The four training course participants were: Mr Tabya Buddha Tamang (Bhutan), Mr Rudzani Malala (South Africa), Ms Shayvonne Moxey-Bonamy (Bahamas) and Ms Elikem Setsoafia (Ghana).

Mr Wang then called on Ms Dai Yang to provide a summary of the activities of the CMA Training Centre and more details on the International Training Course on the GFCS. This year's course comprised a total of 29 participants (55 in total since last year), 10 of which were visitors from other countries. Mr Wang then thanked all for their participation and closed the meeting.

3. INTRODUCTION

3.1 Review of recent decisions of WMO constituent bodies and related developments relevant to the ET-OPSLS

3.1.1 Mr Harou presented on decisions of Cg-17 (2015), CBS-MG (2016) and CBS-Ext (2014) of relevance to the work of the ET-OPSLS. With regard to Cg 17, he focused on the Resolution 11, whereby Congress requested Members to move "Towards an Enhanced, Integrated and Seamless Data-Processing and Forecasting System" and the Resolution 4.1(2)/2 (Cg 17) – Amendments to the Manual on the Global Data-processing and Forecasting System (GDPFS) (WMO-No. 485) approving a change to the access rules for GPC data and visualization products held by the LC-LRFMME. Formerly, access had been only to GPCs, RCCs, NMHSs and bodies coordinating RCOFs. This change, initiated by the ET (and recommended by the presidents of CBS and CCl), also extends access to include research organisations who have received an approved request for support from any of the above operational entities.

3.1.2 Mr Harou also informed the team about the organigram proposed at CBS-MG meeting held in Geneva, 5 to 19 February 2016. At the meeting, the MG decided, for the sake of a standardized approach to the naming of Expert Teams, to rename ET-OPSLS to Inter-Programme Expert Team OPSLS (IPET-OPSLS). He explained that the CBS-MG defined the IPET as a team between Programmes for which CBS has the primary responsibility. He noted that the new framework would include new Task Teams, including a TT-Audit that would be responsible for monitoring compliance of RCCs (and GPCs). In this context, the ET agreed to change the naming of their informal (and internal) Task Teams to "Sub Teams" – to avoid confusion with the TTs of the new framework, and this terminology is used hereafter in this report. Mr Harou finally reported on the plan for the next CBS Session (CBS-16): CBS-16 will be held in Guangzhou, China from 23 to 29 November 2016 and will be preceded by a TECO 21-22 Nov 2016.

3.1.3 Ms Anahit Hovsepyan presented on CCl (2014) decisions. She informed the team that CCl at its 16th session adopted the new structure of the commission with 5 Open Panels of CCl Experts that cover all the pillars of GFCS. She particularly mentioned that the Implementation Coordination Team for the Climate Services Information System (ICT-CSIS), was created to coordinate the implementation of CSIS and its commitments, as a substantial contribution of WMO to the GFCS implementation. The ICT-CSIS at its meeting held in Geneva in November 2015 prioritized a number of activities. The Team intends to conduct a Scoping Workshop on Defining Climate Services Information System Architecture for Effective Climate Service Delivery tentatively scheduled for the end of October 2016, which will bring together representatives from global, regional and national producers of climate information, the research community and major stakeholders to pursue the implementation of CSIS. The Team will develop a related Technical Reference Manual, which will provide a framework for CSIS implementation, including the mandate, specification of standards, outline of design and recommended partnerships. Ms Hovsepyan highlighted that this activity is closely aligned with GDPFS and potential input would be anticipated from ET-OPSLS. It was agreed that the Sub Team 6 of ET-OPSLS would be in a position to contribute to this work. Another important task for the ICT-CSIS is development and implementation of the Climate Services Toolkit (CST), to which GPCLRFs and LC LRFMME are considered as key contributing partners. CST is a suite of guidance, data, software tools, training resources, and examples for enabling climate services at global, regional, and national levels. The CST straw-man has been developed that includes four elements: climate data availability, management, climate analysis and monitoring, climate forecasts, and climate projections. This will be done through collaboration with CBS and WCRP to respectively develop formal mechanisms to undertake CSIS functions and to enable CSIS to deliver climate information required at the global, regional and national levels. It was agreed that Jean-Pierre Ceron will serve as a focal point within ET-OPSLS for liaising with the ICT-CSIS particularly on CST development.

3.1.4 Ms Hovsepyan also reported that the ET-RCC is developing a guidance document on RCC operations which is very relevant to GPCs, especially to those which are also RSMCs. In addition, she reported that the TT-RCOF is working to conduct a global RCOF review in 2017 so as to identify more objective approaches in developing consensus forecasts. The ET asked to be kept informed of progress with both activities – both of which can help GPCs to strengthen their services to RCCs and RCOFs.

3.1.5 The team was informed of the adoption by the Cg-17 of Resolution 60 on "WMO Policy for the international exchange of climate data and products to support the implementation of the Global Framework for Climate Services". Briefly stated, Resolution 60 extends and complements resolution 40 so as to include prediction-related data types.

3.1.6 Continuing the theme of data policy, the ET briefly discussed the role of the EU Copernicus Climate Change programme, specifically its seasonal forecasting component. Copernicus will have a free data policy. This differs from WMO policy which restricts access e.g. to data from the LC-LRFMME, to WMO entities such as NMHSs, RCCs and RCOFs – to help assist these bodies to strengthen their position as the national/regional point of contact for climate information and services. It was concluded that Copernicus was not setting a precedent in this regard as other sources of climate information are free at source – such that available from NOAA NCEP and IRI, and that the main requirement at this stage was for the Team to keep informed of Copernicus activities and policies and opportunities for coordination with ET-OPSLS related activities. It was proposed that a joint workshop with RCCs could be one way to address this issue. The Secretariat reported that a Copernicus debriefing is planned for 22 April 2016 at the WMO Secretariat to start to build the required understanding. Some ET members expressed the view that making data and services freely available was a false economy because observational data for seasonal forecasting, particularly ocean data, is very expensive and some moored buoy arrays are suffering attrition because of lack of funding. It was noted that with the increasing use of coupled systems in short-range prediction there was an opportunity for the seasonal forecasting community to join with the NWP community in expressing our joint needs for maintenance of the ocean data network.

3.2 Status of the GPC network – new applications for designation

The Secretariat indicated that there was no official request for nomination for any new designation of a GPC.

3.3 Status of the RCC Network

3.3.1 Ms Hovsepyan presented on RCC implementation. Five RCCs (RCC-Beijing, RCC-Tokyo, NEACC, RCC WSA-CIIFEN, RCC Africa-ACMAD) and one RCC network (RAVI RCC-Network) are operational up to 2016. Two RCCs were successfully designated in 2015: ACMAD and CIIFEN. The RCC IGAD, hosted by ICPAC, continues in a demonstration phase and intends to seek formal designation during the upcoming Session of CBS.
The Team was informed that five candidates (RCC-IGAD, RCC-Network-North Africa, RCC-IMD, RCC-Network-Southern South America and RCC-CIMH), are expected to seek designation at the forthcoming CBS session in 2016, subject to review by CCl/CBS ET-RCC. If the designation is successful, there will be a total of 8 RCCs and 3 RCC Networks by 2017.

3.3.2 It was noted that this increase in designated RCCs and RCC-Networks will be likely to increase the demand on GPC products and may require further review of mandatory and highly recommended products for GPCs. The Workshops on Operational Climate Prediction will be a suitable forum to gain required feedback regarding potential new products.

3.4 Report back from the workshop on a polar RCC and implications for GPCs

3.4.1 Mr Bertrand Denis briefed the team on the results of the scoping workshop on a polar RCC which took place 17-19 Nov 2015, in Geneva, and its implications for GPCs. Mr Denis noted the proposed Polar RCC (PRCC) involves 3 RAs and that the objectives of the workshop were:

- Appraisal of opportunities and challenges including governance aspects relating to development and delivery of climate services in the Polar Regions, including climate data, monitoring and prediction aspects, and in identifying the associated user needs;
- Scoping of the Arctic PRCC-Network concept and implementation:
  a. List of priority PRCC functions;
  b. Description of the PRCC implementation strategy including the structure of the Arctic PRCC-Network
- Identification of Member capacities to engage users at national and regional levels and to deliver PRCC services for their benefit; and
- Recommendations on the next steps in establishing an Arctic PRCC-Network.

Specific goals of the workshop relevant for the ET-OPSLS were:

- Discuss potential products that may be of particular interest to this region and to the users in this region;
- Mapping requirements and capacities.

3.4.2 The ET thanked Mr Denis for representing their interests at the PRCC workshop and for communicating the work of the ET-OPSLS, including on the products issued by GPCs and LCs. At the PRCC scoping workshop participating countries presented their views of the would-be PRCC operational structure (network-node vs geographically distributed) as well as their potential contributions in term of products and services. The need for those were discussed and listed during breakout sessions. The list of identified parameters of interest is reported here:

- Cryosphere

a. Sea and Freshwater Ice
b. Snow Cover
c. Glaciers, Ice Caps, and Ice Sheets
d. Permafrost

- Atmosphere
  a. SLP, T2m, precipitation
  b. Storminess, winds, atmospheric circulation patterns
- Polar oceanography
  a. Water temperature, Salinity
  b. Sea level
  c. Waves
  d. River runoffs
- Land issues
  a. Coastal and river erosion
  b. Fresh water runoffs

3.4.3 Mr Denis noted the potential to develop new GPC products to support Polar RCC requirements, for example, the provision of products on polar stereographic projection, sea-ice (predictions and verification) and snow related quantities (snow water equivalent and snow cover). Sea ice information is very important for the user communities and the requirement is for 6-month lead time. He noted that sea-ice predictions could not be made mandatory for GPCs, since only 5 currently have models with interactive sea-ice. It seems that sea ice is for the Polar Regions as important as precipitation is for low and mid-latitude regions, and that the cryosphere as a whole would need much more attention from a PRCC than is usually required for a RCC covering other regions of the world.

3.4.4 Mr Denis noted that the ET must consider whether sea ice products can be made available by GPCs and the LC, and whether this can be achieved to facilitate the PRCC demonstration phase scheduled to start in 2017. It was possible that GPC Montreal could coordinate an informal exchange of sea-ice related predictions in time for the demonstration phase – but later it should be considered for transfer to the LC-LRFMME. He noted that as a follow-up of the workshop, the Secretariat sent out a letter asking for details of potential national contributions from the participating countries. It should be noted that since Canada, The Federation of Russia and The United State of America and France would be contributing countries; their own GPC should have normally already been consulted for inputs through their NMHS agency (GPC-Montreal, GPC-Washington, GPC-Moscow, GPC-Toulouse). As of April 2016, the Secretariat was in the process of making the primary consolidation of the inputs, and analyzing the capabilities and commitments to perform the mandatory PRCC functions. It was expected at the time of the workshop that an Arctic-RCC-Network Implementation Plan would be produced by September 2016, with a demonstration project starting in early 2017.

3.4.5 Further details on the PRCC workshop are at Annex 3. Next steps by the WMO secretariat include:

- EC-68 (15-24 June 2016) to consider a decision to endorse the Arctic PRCC-Network as a joint initiative between RAs II, IV and VI;
- Secretariat to finalize a concept paper on the implementation of the Arctic PRCC-Network based on the capabilities and commitments provided by potential hosts and contributing institutions, for consideration by EC-PHORS;
- Secretariat to facilitate the drafting of an Arctic PRCC-Network Implementation Plan (including identifying Node leads and consortia, Arctic PRCC-Network Web Portal, open vs restricted product access, etc.), in consultation with the potential hosts/contributors, CCl/CBS ET-RCC and EC-PHORS.

3.4.6 The discussion that followed Mr Denis' presentation clarified that Canada was proposed as the co-lead country with another unspecified northern country to have main responsibility for long-range sea-ice predictions. It was also concluded that the ET will wait for the requests before developing related solutions. The team noted that effort is being made at the Canadian Centre for Climate Modelling and Analysis (CCCma) to look at the predictability of freeze up and ice break up dates and that an implementation of forecast products based on these variables would require daily model outputs of sea-ice concentration (in hindcasts and forecasts). It was noted that potential predictability studies for sea-ice indicated reasonable room for improvement in predictions. GPCs are therefore encouraged to archive model hindcast data relevant to sea-ice (and snow) products, noting that sea-ice related products would need further skill assessment. The ET thanked Mr Denis for agreeing to develop a list of requirements (variables, output frequency, units, etc..) for consideration by GPCs for incorporation in their hindcast/forecast outputs.

4. STATUS REPORTS FROM GPCs

4.1 Discussion of GPC reports on systems development and other activities

4.1.1 All 12 GPCs were represented at the meeting and presented status reports. These included updates on prediction system changes, contributions to multi-model ensembles, additional information provided (above GPC minimum requirements), capacity building and training undertaken, future plans and system developments, users of the GPC's forecasts and any specific needs. Summaries of GPC reports are provided in Annex 4. The ET congratulated a number of GPCs who have made significant advances to their systems since the Exeter (2014) meeting. These include GPC Tokyo which has implemented a higher resolution model, with improved physics, interactive sea-ice and a more advanced representation of greenhouse gases. The model shows improved prediction skill over the previous system. GPC Seoul has adopted a coupled prediction system – having implemented the GloSea5 system in 2014. GPC Pretoria has also developed and implemented a coupled seasonal prediction system in 2015. The 12 GPC systems now comprise 10 coupled systems and 2 uncoupled systems (Note: in 2010, there were 7 coupled and 5 uncoupled systems). GPC Montreal has developed and implemented a new sub-seasonal forecasting system, and there are plans to add a third model (GEM-NEMO) to the CanCM3 and CanCM4 seasonal ensemble. GPC Beijing has upgraded its model, including with improved resolution. Other GPCs, such as ECMWF and Toulouse have major upgrades planned for implementation by 2017. ECMWF noted large skill improvements in NAO predictions from their monthly forecast system since 2005 – and analysis had shown this can be attributed to improving representation of the MJO.

4.1.2 On other aspects the ET welcomed that ECMWF had now provided seasonal hindcast data for their system to the LC-LRFMME and acknowledged the work in capacity training (at RCCs and NMHSs) being undertaken by a number of GPC organisations. The encouraging work by GPC CPTEC showing skill for onset prediction was noted. In addition, CPTEC was thanked for coordinating a capacity development activity on increasing RCC/NMHSs access to GPC digital data. This included coordinating work with NOAA to develop and make available a code to convert GPC data from GRIB to CPT format. GPC Moscow was congratulated for trialing a coupled model system and also for developing the "long-range forecaster" GPC data interpretation and verification software.

4.1.3 There ensued some discussion regarding whether or not GPCs should provide their hindcast and forecast data in CPT format – as is often requested by RCCs and NMHSs, including at the Brasilia and Pune workshops where establishment of RCC and NMHS needs was a major focus. The ET-RCC had reviewed the matter and Ms Khan, the ET-RCC Chair, was thanked for leading a report on the issue (see section 6.1.4). The ET-RCC concluded that the most appropriate solution was for the LC-LRFMME (and/or GPCs) to make conversion software available for users to convert the data themselves if desired. CPT does not follow WMO data standards and therefore WMO should not recommend that GPCs provide data in CPT format. Some GPCs expressed reservations about the (WMO-designated) LC-LRFMME making conversion software available on its website, since this may imply support for a data format that does not follow WMO standards. Nevertheless, it was agreed that while provision of ready-converted GPC data in CPT format was not acceptable, provision of conversion software was an acceptable compromise given the evident very high demand from RCCs and NMHSs. It was also recommended that the ET-OPSLS should contact the developer of CPT and request that an integral conversion module be included within the package.

4.1.4 There was discussion around developing a mechanism for monitoring and detecting suspect forecast output on the LC-LRFMME website. On some occasions forecast maps have appeared that clearly show "non-physical" scenarios. Potentially, such cases can degrade the multi-model products used on the website and also in the GSCU. It was agreed that data quality was the responsibility of the submitting GPC in the first instance. To ensure high quality of the LC-LRFMME forecast products provided to RCCs, NMHSs and the GSCU, all the GPCs, are urged to check the forecast results on a regular basis, and to report any problems found. If the LC-LRFMME discover potential problems with any GPC data, they are urged to notify the GPC at the first opportunity.

4.1.5 A Table describing basic developments, since 2012, in the systems operated by GPCs is provided in Annex 5

4.2 Review of GPC compliance

4.2.1 The compliance of each GPC was also assessed – it was agreed this was a worthwhile activity as temporary periods of non-compliance can occur (and are acceptable) – e.g. when there is a transition period to a new model system. All 12 centres are fully compliant with regard to routine operational issuance, hindcast size and compatibility of hindcast and forecast ensembles.

4.2.2 All centres will be fully compliant with regard to forecast product provision within the next few months (there were just 2 minor exceptions). Because of the introduction of new, more streamlined, arrangements for coordinating verification of GPC and multi-model forecasts (see Section 6.2), verification provision is in a state of flux and it was not considered useful to review compliance on verification in detail. When this facility is implemented in June 2016 at least 11 GPCs that submit hindcasts to the LC-LRFMME will be fully compliant on verification.

5. STATUS REPORTS: LEAD CENTRES AND GLOBAL SEASONAL CLIMATE UPDATE

5.1 Discussion of LC-LRFMME report on status and developments

5.1.1 Mr Park reported on the status and developments of the LC-LRFMME. The team noted that the Korea Meteorological Administration (KMA) and NOAA/NCEP have joint responsibility to sustain and develop LC-LRFMME activities. This initiative was recognized by the WMO and inclusion of the LC-LRFMME in the Manual on GDPFS was recommended at the 14th Session of the WMO CBS held in Croatia from 25 March to 2 April 2009. He recalled that the goal of the Lead Centre is to provide a conduit for sharing of model data for long-term climate predictions and to develop a well-calibrated Multi-Model Ensemble (MME) system for mitigating the adverse impact of unfavourable climate conditions and maximizing benefits under favourable conditions.

5.1.2 The Team noted with gratitude that, currently, the global seasonal forecasts from 12 WMO Global Producing Centres (GPCs) for 2-meter air temperature, precipitation, mean sea level pressure, 850hPa air temperature, 500hPa geopotential height, and sea surface temperature (if available) are collected at the LC-LRFMME between the 1st and 20th of each month and that the forecast data are used in displaying various seasonal forecast products. The LC-LRFMME provides GPC and multi-model graphical products in standard format. The team also noted that members of GPCs, RCC, NMHSs and related institutions that produce LRF forecasts can download forecast and hindcast data from the LC-LRFMME website for those the GPCs which allow redistribution of their digital data. The products displayed at the lead centre website include monthly and seasonal mean anomalies from individual GPCs, multi-model forecasts, and a range of other products including a synthesis of information in terms of consistency in the sign of anomalies from all GPCs. In addition, 4 types of deterministic MME (Simple Composite Mean, Regular Multiple Regression, Singular Value Decomposition and Genetic Algorithm) and probabilistic MME prediction are shown on the LC-LRFMME website (http://www.wmolc.org). Access to the forecasts and data is password protected and information about how to gain access to the forecast products is provided on the website. Current users of the LC-LRFMME products are various RCOFs (e.g., FOCRAII for Asia, EASCOF for East Asia, SASCOF for South Asia, ASEANCOF for Southeast Asia, GHACOF for Greater Horn of Africa) and RCCs as well as NMHSs and some GPCs. Additionally, LC-LRFMME products are also primary information for the WMO's developing Global Seasonal Climate Update (GSCU) product. Following a comprehensive review and tightening of the implementation of access rules after the previous meeting the LC-LRFMME report 240 registered users of the LC-LRFMME website.

5.1.3 The ET thanked Mr Marko Markovic of CMC who had visited CariCOF as a capacity trainer and had provided feedback on use of the LC-LRFMME and LC-SVSLRF. It was noted that action on Mr Markovic's comments on the SVSLRF products would be covered by the plan for the new supplementary (to GPCs own verification) streamlined verification facility. His comment on the password access required for the LC-LRFMME led to a resolution to provide a temporary access ID and password for training course participants and trainers – to facilitate quick, but temporary, access for substantial numbers of users.

5.1.4 In anticipation of discussion in 6.2, Mr Park added that the LC-LRFMME had now completed a first version of a facility for calculating SVSLRF scores for individual GPCs and the multi-model using hindcasts from those GPCs that supply them. SVSLRF scores (for GPCs supplying hindcasts) are verified using identical software, verification datasets and reference period (1983-2001). Moreover, the centralised approach guarantees that verification is performed on the currently operational forecast models. Verification generated is supplementary to verification required from individual GPCs as part of the designation criteria. A website for display of verification results has also been developed but not yet activated.

5.1.5 In terms of hindcast provision to LC-LRFMME, the team noted that, in March 2016, ECMWF provided their hindcast data. This has allowed the LC-LRFMME to make both forecast products, and verification products with the common reference period (1983-2001, total 19 years) for the ECMWF model and to include the ECMWF model in the PMME forecast. GPC Toulouse hindcast data was not as yet available to LC-LRFMME.

5.1.6 The LC-LRFMME also reported that it had now developed a pilot system for real-time multi-model subseasonal forecasts using real-time forecasts (and hindcasts) from a subset of models contributing to the S2S research project. Forecast products are displayed on a password protected website and access has been provided to the ET and feedback has been requested. Discussion on the real-time pilot is recorded under Section 6.3.

5.2 Discussion of LC- SVSLRF report on status and developments

5.2.1 Mr David Jones recalled that the Standardized Verification System (SVS) for Long-Range Forecasts (LRF) defined in the WMO Manual on the Global Data-Processing System (GDPS), Volume I (SVSLRF), outlines requirements for Global Producing Centres (GPCs) to verify their forecasts. The Manual also outlines how a Lead Centre for the Standard Verification System for Long Range Forecasts(LC-SVSLRF) may assist GPCs in the verification process.

5.2.2 The team noted with gratitude that the LC-SVSLRF has been running for more than 12 years. However, it would appear that only a few GPCs have formally updated forecast verification results since the last ET meeting held in April 2014, meaning that the LC-SVSLRF has functionally ceased to be used. Mr Jones recalled that the ET-OPSLS, at the 2014 meeting in Exeter, adopted a plan for new arrangements for coordinating the verification of GPC forecasts, supplementary to verification conducted by each GPC, that follows a "centralized" approach in which the LC-LRFMME calculates the SVSLRF diagnostics using hindcast data from those GPCs that provide it. Under these arrangements, GPCs may delegate generation of the SVSLRF scores to the LC-LRFMME. All GPCs must also continue to make verification available on their own websites – since the forecast and verification baseline periods may be different to the common period that will be used by LC-LRFMME (see section 6.2). The centralized activity has some notable advantages (see Sections 5.1.3 and Section 6.2) and allows harmonization with the verification activities undertaken for the GSCU. In fact, development of a verification capability to serve the Global Seasonal Climate Updated (GSCU) had led to the capability of the LC-LRFMME to host a centralized verification activity. This facilitates the provision of historical skill along with the real-time forecasts as part for the GSCU. Some GPCs had expressed concerns over potential inconsistency of the centralized verification results with those generated by individual GPCs, particularly if different hindcast periods were used. At the current meeting it was agreed that the LC-LRFMME should provide, with its display of centralized verification, a clear indication of the hindcast period used and a warning regarding the potential difference in scores with those available from individual GPCs.

5.2.3 Mr Jones indicated that a review of the skill scores used in the verification could be considered, noting in particular the MSSS score which can give a distorted view of the comparative forecast skill depending on whether bias correction or constraining of the variance has been used. The more comparable score of the three MSSS components is the MSSS1 which is similar to a correlation - which is much more widely understood by the wider science community. Though it is recognized there is value in identifying any biases or areas of too little/ too much variance in the forecast models.

5.2.4 Under the new streamlined arrangement the LC-LRFMME will perform verification calculations and generate associated graphics. Discussions on how these new arrangements will be harmonised with current activities of the LC-SVSLRF resulted in the team decision to maintain the LC-SVSLRF website, but to remove the verification maps, inserting some text to inform users that the service will be resumed, in a new format, in June 2016. It was agreed to keep the website as the repository of verification information and link to LC-LRFMME for the verification products. The ET also agreed to task ST2 to revisit the SVSLRF standards for real time verification and the role of Lead Centres. It was also agreed that ST2 and the LC-SVSLRF would review and update if necessary the recommendations made on the LC-SVSLRF website regarding observational datasets for verification of seasonal forecasts.

5.3 Discussion of Global Seasonal Climate Update (GSCU): forecasts and verification

5.3.1 Ms Hovsepyan updated the ET on progress with the GSCU and also summarised feedback from the Pune workshop. It was noted that a meeting of the TT-GSCU is planned for the second half of 2016 to set out the implementation phase. A concern from Anca Brookshaw (Chair of the TT-GSCU) on producing broad-based expert assessments of the monitoring and LRF products was raised for consideration as well as the need to identify resources for preparing and reviewing the text sections of the GSCU. NCEP CPC re-iterated their willingness to contribute resources to preparation and review.

5.3.2 The ET agreed that in due course a release plan would be needed for the GSCU to both promote the operationalisation and to prepare for media interest. This could be a subject for discussion at the upcoming TT-GSCU meeting.

5.3.3 It was noted that the GSCU supplementary document is large and could be hosted on the LC-LRFMME website rather than circulated by attachment. It was also noted that the verification information in the supplementary document could potentially be removed as this will soon be available on the LC-LRFMME website. Other suggestions from the Pune workshop included moving as soon as possible to rolling 3-month seasons and including verification of the previous forecast. The ET agreed that these should be considered, but as possible early upgrades to the GSCU after it becomes operational. It was suggested that the ET-OPSLS should be included as reviewers of the developing and operational GSCU. Responses would be required within a given time interval – with lack of response by the deadline interpreted as satisfaction with the text and contents. These possibilities could be covered by the TT-GSCU at their upcoming meeting.

5.3.4 Finally Mr Park of the LC-LRFMME emphasised that the cut-off date for GPC outputs to be included in the GSCU is the 15th of the month and urged GPCs to bring their forecast issue times forward to accommodate this where possible.

6. ET-OPSLS SUB TEAM ACTIVITIES: REPORT BACK AND FUTURE DIRECTIONS

6.1 Sub Team 1: Workshop on Operational Climate Prediction

6.1.1 Report Back from Pune Workshop

6.1.1.1 Mr Graham reminded the ET that the First WMO Workshop on Operational Climate Prediction (OCP1) was hosted by the Indian Institute of Tropical Meteorology (IITM) at its Headquarters in Pune, India, 9-11 November 2015. The overarching aim of the workshop series, of which this was the first, is to facilitate increased interaction between and among the various operational climate prediction centres and the associated research communities, leading to better collective capacity to meet the climate information needs of decision makers, including support of the priority sectors of the GFCS: agriculture, health, water, energy and disaster risk reduction. The workshop gathered together participants from GPCs, RCCs, RCOFs and NMHSs as well as a representative from the research community (WGSIP) and was deemed by all to be successful. Mr Graham thanked Sub Team 1 (with responsibility for organising the workshops) for their planning and preparation and particularly the acting Chair of ST1, Mr Kumar. A brief write up with presentations from break out groups on a) the Climate Services Toolkit (CST), b) the GSCU and c) on developing a framework for a guidance document for recommended long-range prediction practices, is available at: http://www.wmo.int/pages/prog/wcp/wcasp/workshops-opc.php. A full report is in preparation.

6.1.1.2 Mr Graham focused on reporting back on discussions around development of a framework for a guidance document for recommended long-range prediction practices. This had been a major focus of the workshop. The workshop had been briefed on the operational practices for producing long-range forecasts used at four NMHSs, three RCOFs, three RCCs and three GPCs. These were, respectively:

- **NMHSs**: Cote d'Ivoire, Myanmar, Jamaica and the Philippines.
- **RCOFs**: The Central American Climate Outlook Forum (CACOF); the Association of Southeast Asian Nations Climate Outlook Forum (ASEANCOF); and the Caribbean Climate Outlook Forum (CARICOF).
- **RCCs**: RCC-Africa; RA VI (Europe) RCC-Network and RCC-Tokyo.
- **GPCs**: Washington (CPC); Montreal (CMC) and Melbourne (BoM)

6.1.1.3 The floor had then been opened up first to other participating NMHSs, RCOFs, RCCs and GPCs to brief the meeting on methodologies used at their centres, and then for general discussion. A key finding, also confirmed by a pre-workshop questionnaire, was the very wide diversity in methodologies used to generate seasonal outlooks: ranging from unmodified use of GPC output to multi-system methods relying on many inputs (statistical and dynamical) as well as subjective modification. To operate collaboratively in a Global Framework, some convergence on standards is required and a guidance document on methodology will facilitate that. Other key points noted were:

- Where several forecast inputs are used – there is frequently little information or understanding on the relative skill levels of the inputs
- Improved access to GPC hindcast and forecast digital data is needed
- Capacity training as well as institutional development are ongoing requirements at many NMHSs and some RCCs.

- Clear and systematic verification of GPC outputs is needed as well as guidance on how to use verification to select appropriate models for use for in a particular region.
- With some centres now issuing subseasonal forecasts and with the real-time S2S pilot developing at LC-LRFMME, there is a growing need to develop verification products for sub-seasonal forecasts.
- Verification of real-time forecasts is conducted by some GPCs and NMHSs, but guidance on procedures for this are still needed.
- There is a need for new GPC output variables, e.g. tropical winds, AMO as well as derived parameters such as rainy season onset timing and duration and the frequency of dry days/heavy rain days.
- There is a need for tools and guidance on how to calibrate and combine different GPC outputs (reinforcing the need for access to hindcast and forecast data).
- WMO guidance on protocols for preparing seasonal forecasts needs to cover not just technical aspects but should be sufficiently broad-based to assist wider institutional policy in supporting scientific rigour e.g. encouraging centres to resist pressures to hedge forecasts to the average category (a tendency reported by some participants).
- A clear statement on the key climate drivers for a season from the RCC would be very helpful to NMHSs to bolster their own communications to users.
- Guidance is needed on how to determine the optimum sub-national or sub-regional zones for presenting the seasonal forecast – and how centres may test the validity of their forecast zones (i.e. can forecasts be expected to distinguish differences in variability across neighbouring zones?).
- Diagnostics to help "deconstruct" the influence of climate drivers on the forecast temperature and rainfall signals (e.g. comparisons of observed and GPC teleconnection responses).
- It was recommended that the ET-OPSLS review/rationalise advice on use of single model output versus multi-model output. Since most GPCs appear not to be using a multi-model approach when preparing their seasonal forecasts.

6.1.1.4 With these inputs from the Pune workshop, and other general considerations, ST6 agreed that it had sufficient information to begin planning their first draft framework for a guidance manual.

6.1.2 Discussion of next workshop and theme

The potential theme of the next workshop was discussed. This workshop is likely to be scheduled for the last quarter of 2017 and Mr Coelho kindly agreed to resume his position as Chairperson ST1 with responsibility for organisation. It was agreed that the next workshop should continue the theme of facilitating increased interaction between and among the various operational climate prediction centres and the associated research communities and could have focus points on a) reviewing the framework for the guidance document on preparing consolidated seasonal forecasts and b) reviewing operational experience with the GSCU – which by then should have reached its operational phase; c) review of the S2S real-time pilot.

6.1.3 Report on WCRP/WGSIP Activities

6.1.3.1 The team thanked Mr Bill Merryfield for representing the interests of WGSIP at the meeting and invited him to give a description of its activities and projects. These include: 1) Drifts and Shocks; 2) SNOWGLACE and 3) Teleconnections. The Drifts and Shocks project will include investigations into the influence of different initialization methods on the transient behaviour of climate system components and any impacts of such on climate forecast quality. The SNOWGLACE project is an extension of the GLACE (Global Land Atmosphere Coupling

Experiment) which was concerned largely with soil moisture impacts. SNOWGLACE aims to quantify the snow impact in the cold season. More precisely this initiative will evaluate how individual state-of-the-art dynamical forecast systems vary in their ability to extract forecast skill from snow initialization. The Teleconnections project will investigate tropical rainfall teleconnections to climate variability in the extratropics.

6.1.3.2 There was a discussion on how to improve interaction between ET-OPSLS and WGSIP. It was concluded that a sub-group within WGSIP could be set up with Terms of Reference that include horizon scanning for forecast product research that could be accelerated into operations. Ms Ferranti who sits on both WGSIP and the ET-OPSLS agreed to be the linkage point. Ms Ferranti also co-leads the WGSIP Teleconnections project.

6.1.3.3 Other operationally relevant areas where WGSIP and ET-OPSLS might fruitfully increase collaboration include:

- Interoperability of data standards (e.g. NetCDF, GRIB, ESGF). It was generally agreed that the issue of multiplicity in data formats was a key issue to address in light of the increased data sharing envisaged for the GFCS.
- The optimisation (in lagged ensemble approaches) of ensemble size versus increasing lead time needed to accumulate more lagged members. It had already been noted, in anticipation of Section 6.3, that elapsed time required to gather a multi-model ensemble can readily erode benefits in skill – since typically, the skill levels drop very quickly in the first few days of the forecast.
- Experimentation to improve understanding of the impact of different observation platforms and types on the skill of sub-seasonal to longer timescale predictions.

6.1.4 Recommendations of the CCl/CBS Expert Team on Regional Climate Centres about the conversion of GPC forecast and hindcast data in CPT format

6.1.4.1 Ms. Khan reminded the meeting that the CBS/CCl Expert Team on Operational Predictions from Sub-seasonal to Longer time Scales (ET-OPSLS) at its last meeting (Exeter, UK, March 2014) discussed ways to facilitate the conversion of GPC output data from GRIB to CPT format and suggested to consider the possibility of the WMO Lead Centre for Long Range Forecast Multi Model Ensemble (LC-LRFMME) or Regional Climate Centres (RCC) taking responsibility for converting data to CPT format. This issue provoked discussion during the meeting, and it was agreed that the matter should be referred to the CCl/CBS Expert Team on Regional Climate Centres (ET-RCC) to consider and make recommendations on whether conversion of GPC data from GRIB to CPT format should be the role and responsibility of the RCCs. The ET's further discussions on this issue are recorded in Section 4.1.3.

6.1.4.2 With this request, the ET-RCC members reviewed this issue in detail, analyzed the current status of the use of the tool, conducting a short survey among the team members, and formulated conclusions and recommendations. Ms. Khan briefed the meeting on the recommendations produced by ET-RCC, which are copied below.

- The RCC Mandatory Functions do not imply development of softwares, tools, and data conversion services;
- The only mention relevant to this issue is under the Highly Recommended Functions (Assisting RCC Users in the development and maintenance of software modules for standard applications), which is not considered obligatory, and largely depends on the availability of necessary technical capabilities and resources;
- Therefore, RCCs may only consider optionally supporting users on converting data in CPT format upon their request;
- In view of aforesaid, the conversion of GPC data from GRIB to CPT format should not be the responsibility of RCCs;

- Furthermore, to avoid inconsistency of techniques and duplication of efforts, it would be highly desirable, if IRI could consider the possibility of developing a special software (application to CPT) for conversion of commonly used data formats (GRIB, NetCDF, etc.) to CPT format.

6.2 Sub Team 2: Verification of GPC seasonal forecasts

6.2.1 Progress with the streamlined "centralized" verification activity

6.2.1.1 Mr Kumar (chair of ST2) recalled that at the previous ET-OPSLS meeting held in Exeter, UK, 10-14 March, 2014, the Sub Team on Verification of Seasonal Forecasts, after extensive consultations among its members, recommended to adopt a "centralized" approach to calculation and display of GPC forecast verification in place of the distributed method currently used in which individual GPCs calculate scores and send results to the LC-SVSLRF for display. Further, the recommendation was that a supplementary verification activity (i.e. supplementary to each GPC's own verification activities) would be performed by the LC-LRFMME (for those GPCs that provide the required information) and would include: hindcasts and real-time forecasts for individual (GPC) systems and hindcasts and real-time forecasts for multi-model ensembles. At the same time, ST2 also noted that implementation of real-time verification would need to follow the identification/development of appropriate verification scores and procedures as part of the SVSLRF.

6.2.1.2 The ST2 recommendation was adopted by ET-OPSLS (2014), with the proviso that GPCs which do not delegate the verification to the LC-LRFMME would provide equivalent verification graphics or data to the centralized display utility so that their verification scores could also appear alongside that of the other GPCs, or provide the equivalent information on their own GPC website. The LC-LRFMME had already developed some capacity to perform the verification on 10 of the 12 GPCs as a consequence of its work on developing the GSCU – for which a supply of verification measures for the GPC multi-model is a key requirement. At the 2014 meeting, the LC-LRFMME were invited to further develop this capacity extending to all the SVSLRF scores (deterministic and probabilistic) and report back to the ET at the next meeting.

6.2.2 Discussion of next steps, including division of roles between LC-LRFMME and LC-SVSLRF

6.2.2.1 The ET expressed its gratitude to LC-LRFMME for having now completed substantial work to develop a facility to generate and display SVSLRF verification results using standardized methods and verification datasets, for all GPCs that submit hindcasts and for the multi-model products. Mr Park informed the ET that a website to display the SVSLRF verification for all GPCs and the multi-model was prepared and ready for activation. The LC requested authorization to activate the website and the ET agreed. Verification is performed over the common hindcast period 1983-2001 that is used in construction of the multi-model, except for 2 GPCs with hindcasts that do not span this period. Forecasts from one GPC not providing hindcasts cannot be verified by the centralized system. Real-time verification has also been prepared.

6.2.2.2 There followed some discussion around whether the GPC systems should be verified and displayed using two periods: the common period 1983-2001 and the "GPC's own period" (as already available at GPC's own websites). This would have the advantage that GPCs could more readily check LC-LRFMME results for consistency with their own verification results – which they will be invited to do. One disadvantage of two sets of verification is that it could confuse users.

6.2.2.3 A recommendation on the above was helped by consideration of how forecast products on the LC-LRFMME website and the GSCU should be harmonized. It was concluded that a procedure in which all displayed forecast products are, in principle, verifiable should be adopted, this requires: 1) discontinuation of all GPC-own period multi-model forecasts (these are still used in the GSCU supplementary document and for individual models products on the

LC-LRFMME website); 2) all single GPC forecasts to be created using the common period if available (9 models) and the GPC's Own period for the remaining 3 models . The model consistency map should also be generated using the current common period (using 9 models), to avoid inconsistencies regarding different model baselines.

6.2.2.4 With this arrangement only verifiable multi-model products will be displayed in the GSCU and on the LC-LRFMME website. Individual GPC products will be verified over the common period used in the multi-model where the GPC hindcasts spans the common period and the hindcast is available. Where the GPC's hindcast does not span the common period, the GPCs own hindcast period will be used. Adopting this format has the consequence that two GPCs (Exeter and Seoul) will not be used in either the DMME or PMME forecasts.

6.2.2.5 It was requested that the common period be clearly displayed on the GSCU product and the LC-LRFMME website. With regard to the new streamlining of the supplementary verification facility it was decided that a statement should be suitably placed informing viewers that the verification results shown may differ from those available on the corresponding GPC website (because of the different verification period used) and that a link to the GPCs own verification pages be provided.

6.2.2.6 The Team concluded that the proposals regarding the GSCU should be put to the TT-GSCU in its upcoming meeting for their consideration and action (several ET members will be present at the meeting). With regard to the future roles of LC-SVSLRF and LC-LRFMME it was concluded that the verification displays on the BoM site should be removed and replaced with an information note that the website was being re-designed and that service would be resumed in a new format by the end of June 2016. The ET agreed that ST2 should remain active to assist with the implementation of the streamlined verification facility and the manner in which the BoM and CMC websites will respond to this change. It was agreed that it was desirable to keep other LC-SVSLRF functions such as verification code and guidance on the CMC website and to "merge in" results from the LC-LRFMME centralized verification facility. Additional work for the ST2 (which ST2 will need to prioritise) was agreed as below.
Provide recommendations on:

- The value of the MSSS in the SVSLRF – there is a growing feeling in the ET that this score is of little use to users and that the individual components are more useful than their sum
- Verification for subseasonal forecasts, working with the WWRP-THORPEX/WCRP S2S project;
- Verification of real-time forecasts;
- Verification of extreme events (e.g. Generalised Rank Probability Score);
- Confidence interval/significance values for scores
- A score for measuring success at probabilistic prediction of the onset of El Nino / La Nina events.

6.2.2.7 The team also agreed some changes to the composition of ST2. Mr Kumar will remain Chairperson, Ms Ferranti will join the team (transferring from ST6 on the technical guidance manual). Mr Coelho will also join ST2 as point of contact with the S2S project (Mr Coelho is joint lead of the S2S Verification and Products and Verification sub-project).

6.3 Sub Team 3: Sub-seasonal forecast

6.3.1 Review of real-time products from the LC-LRFMME pilot

6.3.1.1 Mr Park briefed the ET on progress in setting up a system at the LC-LRFMME for real-time generation and display of multi-model subseasonal predictions based on a selection of models available in real-time in the ECMWF archive for the WWRP-THORPEX/WCRP S2S research project. Subseasonal models from 4 GPCs are currently used: ECMWF, Exeter, Tokyo and Washington. A range of forecast products has been developed including probabilities for tercile categories of weekly averages of 2m temperature and rainfall as well as the MJO and BSISO indices. Verification has also been generated using SVSLRF diagnostics (ROC curves and scores) as well as correlation for a few case studies. Further details are provided at Annex 6

6.3.1.2 The ET thanked KMA and the LC-LRFMME for committing the very substantial resource required to achieve the reported progress and expressed pleasure at seeing the first results after several years of planning. The ET also thanked ECMWF for their cooperation in providing access to quasi real-time forecasts through the S2S database.

6.3.2 Discussion of next steps, including schedule for release to NMHSs and RCCs

6.3.2.1 Written input from Mr Paolo Ruti (Chief, World Weather Research Division, WMO) and Mr Michel Rixen (World Climate Research Programme) - prepared with contributions by members of the S2S sub-project on verification and products - was noted, including an emphasis on the challenges around the need for coordination of S2S research and the ET-OPSLS real-time pilot as well as between forecasters and stakeholders and of timely provision of skilful products tailored to decision contexts.

6.3.2.2 After some discussion it was decided it would not be appropriate at this stage to open up the LC-LRFMME real-time pilot subseasonal website products to NMHSs and RCCs. The ET preferred to wait until a) the number of models used had stabilized (GPC Beijing, GPC-Melbourne and GPC-Montreal agreed to join the real-time pilot), b) the day of nominal issuance had stabilized (currently this is Wednesday, but a change to Thursday is being considered; c) new requested additional products were included in the exchange, such as 500hPa height and low-level wind (currently, 10 variables are exchanged : SST, T2m, precipitation, mslp, u200, v200, h500, u850, v850 and OLR) and d) a larger sample of forecast verification statistics is available.

6.3.2.3 A major point of discussion was the need to shorten the elapsed time between the initialization of the component models (the time of which varies) and the release of the multi-model products. Because of the rapid decline in skill in the first few days the time taken to construct the multi-model can erode any skill increase gained by the multi-modelling process. Currently the delay is up to a week. The LC-LRFMME was encouraged to consider ways of shortening this delay and to estimate the delay that may be experienced in an operational mode – in which data would be sent directly to the LC rather than via ECMWF.

6.3.2.4 The ET recommended that the LC-LRFMME convey their progress and results to the S2S project team at the next S2S steering group teleconference and consider posting a short briefing note on the Project Office website. It was agreed that, because the methodology for multi-modelling of sub-seasonal forecasts is relatively unexplored it was important to get feedback on the pilot from the S2S steering group. The ET recommended that ways to achieve this be explored at the next S2S steering group teleconference.

6.3.2.5 It was further noted that results may be of interest to the CCl Climate Watch activity since the sub-seasonal timescale is a bridge between the medium range and seasonal forecasting timescales and could potential be used in preparing Climate Watches or updates to the same.

6.3.2.6 As a more general point it was noted that to help minimize, in the long-term, delays in issuance of real-time multi-model subseasonal forecasts, centres running subseasonal prediction systems should be encouraged to initialize their systems on the same days of the week – so that multi-model ensembles may be constructed without requirement to wait for some contributing models' forecasts to become available.

6.3.2.7 The ET strongly encourages those GPCs that are currently issuing subseasonal forecasts to make available to WMO members a range of forecast products based on the minimum list of variables that was prepared by the expert meeting of ET-ELRF in 2012. The list includes the MJO diagnostic particularly relevant to the sub-seasonal range and contains all the variables that are currently part of the pilot real-time exchange with the LC-LRFMME.

6.3.3 Update of the WWRP-THORPEX / WCRP S2S research project

6.3.3.1 Mr Kumar provided a summary (and relevant links) for the activities of the WWRP-THORPEX/ECRP S2S Research Project:

- The S2S data portal hosted by ECMWF now includes data from nine models: 1. Bureau of Meteorology; 2. China Meteorological Administration; 3. ECMWF; 4. Hydrometcentre of Russia (HMCR); 5. Institute of Atmospheric Sciences and Climate (CNR-ISAC, Italy); 6. Japan Meteorological Agency; 7. Meteo France; 8. NCEP; 9. UKMO. The ECMWF data portal is at: http://apps.ecmwf.int/datasets/data/s2s
- The S2S database is also mirrored at China Meteorological Administration Data Portal http://s2s.cma.cn/index
- A report by US National Academy of Science on "Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts", 290 pages. The free PDF can be obtained at http://www.nap.edu/catalog/21873/next-generation-earth-system-prediction-strategies-for-subseasonal-to-seasonal The report has several mentions of LC-LRFMME. For example, "Other nations have similarly developed seasonal prediction systems that include models developed specifically for this purpose, and the WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble, coordinated by the Korea Meteorological Administration and NOAA, collects seasonal forecasts from 12 such seasonal prediction systems (Global Producing Centers) and combines them into multi-model seasonal forecasts that are used by regional and local climate centers around the world (see Box 2.1).
- The 4th S2S Steering Group Meeting was held in November, 2015, Reading, UK, in conjunction with the ECMWF Workshop on Sub-seasonal Predictability. Minutes of the meeting are available from http://s2sprediction.net/file/meetings_documents/Minutes_S2S_ECMWF_SG_v5.pdf and the details from the ECMWF workshop are at http://www.ecmwf.int/en/learning/workshops-and-seminars/past-workshops/workshop-sub-seasonal-predictability
- S2S real-time forecast data is now being accessed by the LC-LRFMME to develop real-time products
- S2S International Coordination Office (ICO) is hosted in Korea by the National Institute of Meteorological Sciences (NIMS), Jeju. See http://s2sprediction.net/. This website is also a good source of latest information about the S2S project.
- A new publication appeared in Bulletin of American Meteorological Society (BAMS), "Improving and Promoting Subseasonal to Seasonal Prediction", by A. W. Robertson, A. Kumar, M. Pena, and F. Vitart, and provides the summary of S2S workshop held in February, 2014, at NCEP/USA. http://journals.ametsoc.org/doi/10.1175/BAMS-D-14-00139.1
- In the "First WMO Workshop on Operational Climate Prediction" held in Pune, India, 9-11 November, 2015. Mr Yuhei Takaya from JMA provided a summary and status of the S2S project. http://www.wmo.int/pages/prog/wcp/wcasp/documents/workshop/pune2015PPT/day1/Session2-Takaya_WMO_workshop_S2S_201511.pdf

6.3.3.2 The ET agreed that ECMWF had done excellent work in bringing together quickly and efficiently an extremely valuable archive of S2S forecast and hindcast data and thanked them for this service to the research and prediction community.

6.3.3.3 Mr Kumar concluded by recommending that the website of the S2S ICO (http://s2sprediction.net) be reviewed regularly for information on progress and training activities and confirmed that the target audiences for training are NMHSs and researchers. Ms Khan agreed to keep the ET-RCC informed of progress on S2S and of the potential for upcoming training courses.

6.3.4 Discussion of questionnaire results on subseasonal verification practices in operational centres

6.3.4.1 Mr Coelho presented the results of a questionnaire on sub-seasonal verification practices in operational centres, prepared by himself and Mr Takaya. The purpose of the questionnaire was to share current practices used by operational centres to verify subseasonal forecasts (both for operations and research) and also help identify gaps and guide novel developments. It was designed to support verification research activities of the WWRP/WCRP Subseasonal to Seasonal (S2S) prediction project, which has linkages with the Joint CBS-CCl Expert Team on Operational Predictions from Sub-seasonal to Longer-time Scale (ET-OPSLS) activities on subseasonal forecasts through Sub Team 3 (ST3): Development of sub-seasonal forecasts.

6.3.4.2 Some key results from the questionnaire include that very few centres are conducting verification of extremes prediction and very little is done on verification of "tailored" forecasts such as rain day frequency, monsoon breaks etc. For most centres, verification of weekly-mean forecast products is the main focus (e.g. week 1, 2, 3 and 4 mean temperature and rainfall accumulation). The ET thanked Mr Coelho and Mr Takaya for developing and analyzing the questionnaire and agreed that the results were useful to guide the focus of future activities. More details are available at Annex 7. Mr Coelho was encouraged to feed results back to the S2S at the next S2S steering group teleconference.

6.4 Sub Team 4: Development of multi-annual to decadal forecasts

6.4.1 Background

6.4.1.1 At the Exeter (2014) meeting of the ET it was noted that CBS-15 had encouraged GPC Exeter to prepare a written submission to CBS and CCl recommending how multi-annual to decadal predictions (hereafter Near Term Climate Predictions, NTCP) might be incorporated into the CSIS of the GFCS. The request was made in the context of the ongoing informal international exchange and display of real-time decadal predictions hosted by GPC Exeter, which has now completed 5 forecast cycles (1 per year). At the Exeter (2014) meeting, GPC Exeter tabled a proposal, generated by the ET's Sub Team 4, recommending the establishment of infrastructure similar to that in place for seasonal forecasting: specifically, identification of contributing centres for generating NTCP and a coordinating Lead Centre (LC), each with specific roles and functions. The ET reviewed this first submission and noted that there would be challenges in ensuring judicious use of the predictions, in promoting understanding of their limitations and in harmonizing them with national decadal outlooks prepared by NMHSs.

6.4.1.2 At the request of the ET, a summary of the GPC Exeter submission was tabled at CCl-16 (Jul 2014) and the proposal for a LC-NTCP has also been discussed at CBS-Ext 14 (Sep 2014) and Cg-17 (May 2015). To summarize, the Technical Commissions have welcomed the progress and requested the ET to continue its task and that the roles and functions for the LC-NTCP be finalized and submitted for consideration by CBS-16 for further action. In doing this, the ET has also been requested to consider the following concerns:

- Demonstration of the adequacy of real-time multi-annual to decadal forecasts for operational use;
- harmonization of output from a LC-NTCP with national decadal outlooks prepared by NMHSs;
- How to ensure judicious use of the predictions and enhance user understanding of their limitations.

6.4.1.3 Since the Exeter (2014) meeting, two further initiatives that support establishment of infrastructure for real time NTCP have started, namely the WCRP/WGSIP Decadal Climate Prediction Project (DCPP) and the WCRP Grand Challenge of Near Term Climate Prediction (GC-NTCP). It was recommended that ST4 harmonise their planning with these initiatives.

6.4.1.4 In addressing the first concern, Mr Graham showed evidence that anomaly correlation skill for typical quantities predicted by decadal systems, such as 2-5 year ahead average temperature, is similar to that obtained for quantities typically predicted in seasonal forecasting (e.g. 3-month averages). Since seasonal forecasts have been made operational on the basis of such levels of skill, there seems no good reason not to do the same for decadal predictions. Other examples of similarity in the skill levels of seasonal and multiannual predictions were presented. For instance, correlation scores for 2-5 year ahead predictions of Atlantic Multi-decadal Variability (AMV) are of order 0.9, similar to 1-month lead seasonal forecasts of ENSO (e.g. Nino3.4) – and AMV has known connections with decadal rainfall variability in the Sahel, North America and Europe, as well as connections with Atlantic hurricane frequency. For the Sahel, correlation scores for 2-5 year July-September rainfall are order 0.5, generally considered a reasonable level of skill for seasonal forecasts.

6.4.1.5 The concerns stated in the second and third bullets above will be addressed in the same way as they are being addressed for seasonal forecasts – and Mr Graham emphasized that such concerns still exist for the seasonal timescale as well as the decadal timescale predictions. Specifically, the LC-NTCP would be password protected with the same rules as the LC-LRFMME website – allowing access only to NMHSs, RCCs, GPCs and research centres who are supporting the same.

6.4.1.6 To facilitate judicious use of predictions a technical guidance manual on NTCP will be generated following the example of the current activity now underway within the ET under ST6 for seasonal forecasts (see Section 6.6).

6.4.1.7 Additionally, an accelerated schedule for implementing verification has been included as a revision in the new submission. Hindcast verification (for deterministic forecasts) will now be an immediate requirement (this is underway in the Met Office informal decadal exchange project). Development of probabilistic verification, following the SVSLRF, will follow as a second phase. Further details of the proposed roles and functions of the LC-NTCP are available in the document at Annex 8.

6.4.2 Discussion of updated proposal on establishing a Lead Centre for Near Term Climate Prediction (LC-NTCP)

A large majority of the ET endorsed the concept of a LC-NTCP and recommended that the activity should proceed. The ET thus advised ST4 to refine the tabled document and submit to CBS-2016, via the ET for further review. Key refinements requested include: terminology – the use of the term "GPC" for centres contributing decadal predictions risks confusion with GPCs for seasonal forecasts. Currently only one such GPC (Exeter) is contributing to both the informal decadal exchange and the LC-LRFMME seasonal exchange. The phrase "contributing centres" should be used. It was the view of the ET that contributing centres should not be designated by WMO, since they are, in the main, research and not operational centres. Rather, the LC-NTCP should be designated and act as WMO's main contact point with the contributing centres, through representation on the ET-OPSLS. The LC-NTCP should have an additional role of managing any loss of forecast contributions that might occur if a contributing centre decides to cease contributing, and of maintaining the service to WMO members through such eventualities. Also, it would be helpful to include – in the submitted document - evidence of skill for all forecast products including the 1-year ahead range. Finally, the ET thanked ST4 for its work and acknowledged the commitment of the Met Office in coordinating the informal decadal exchange for more than 5 years. Mr David Jones (Australia) offered to be part of the future ST4, noting the growing importance of NTCP as a result of climate change.

6.5 Sub Team 5: New Approaches for distribution of GPC hindcast and forecast data

6.5.1 Review and discussion of questionnaire results and next steps

6.5.1.1 Mr Jones recalled that at the previous ET-OPSLS meeting held in Exeter, UK, 10-14 March, 2014, it was agreed to form a new Sub Team (ST5) on: New approaches for distribution of GPC hindcast and forecast data. ST5 is led by Mr David Jones, supported by Mr Suhee Park and Mr Bertrand Denis. ST5 was asked to explore the pros and cons of different means for distributing GPC hindcast and forecast data, including the use of open data platforms (OPenDAP technology). ST5 submitted a survey of GPC practices and views, as a first step in understanding the approaches to data dissemination. Completed surveys from GPCs Exeter, Seoul, Washington, Pretoria, Montreal, ECMWF, Toulouse, CPTEC, Tokyo, and Melbourne provided a representative sample of current practices and suggestions for new approaches.

6.5.1.2 The results from the survey included the following:

- Across the GPCs, there is very little consistency in approaches to data dissemination;
- Ftp was found to be the most common method of provision
- Although a few centres are using OPenDAP technology – these remain in the minority. Lack of adoption of OPenDAP technology may be a consequence of corporate issues that make such technology not the optimum choice for the wider (beyond climate division) organisation (e.g. firewall issues).
- NetCDF format was at least as widely used as GRIB

In general discussion it was noted that with increasing volumes of data transfer (e.g. between GPCs, RCCs, NMHSs) expected as the GFCS develops it is becoming increasingly important to a) resolve the continuing lack of a universally adopted standard data format. GRIB is the WMO WIS standard, but much of the climate community use NetCDF; b) promote use of technology such as OPenDAP that allows users to cut, slice and visualise data at source – minimising the need to download large data volumes. In a counter to this last point it was noted that the ECMWF S2S archive is easy to use and works very well and is in GRIB format, so perhaps it is more a problem of strengthening RCC and NMHS infrastructure and internet bandwidth so that optimum use can be made (though this will be expensive).

6.5.1.3 The ET thanked ST5 for its work and welcomed the results which provide a useful snapshot of data distribution approaches. It was recommended that results of the survey and subsequent discussion be communicated to the ET-CSIS ahead of their upcoming meeting.

6.6 Sub Team 6: Guidelines on Procedures for generating regional seasonal forecasts

6.6.1 Mr Kumar recalled that at the ET-OPSLS meeting Exeter, UK, 10-14 March, 2014, one of the recommendations was to form a ST on "Scoping the development of a technical guidance document to assist with and provide some standardization for generating regional seasonal outlooks". The recommendation was based on discussions at the Brasilia workshop which confirmed a need for technical guidance to assist with and provide some standardisation in procedures for using GPC output in the production of regional seasonal forecasts. The ET agreed to scope the development of such a guidance document using a Sub Team (ST6: on scoping development of a guidance document on procedures for generating regional seasonal forecasts).

6.6.2 To follow up on this recommendation ST6 developed a focused breakout session during the "First WMO Workshop on Operational Climate Prediction" held in Pune, India, 9-11 November, 2015. The breakout session on "Framework for a guidance document for recommended long-range prediction practices based on the review of current long-range forecast practices" was chaired by Mr Adrian Trotman from CIMH (Caribbean Institute for Meteorology and Hydrology), Barbados. A summary presentation by Mr Trotman included recommendations for the guidance document. Recommendations are stratified according to the following themes:

- Guidelines for best science practices for developing seasonal outlooks
- Guidelines on presentation of seasonal outlooks
- Guidelines on procedures for developing seasonal outlooks
- Guidelines on documenting rationale behind the final seasonal forecast guidance released to the users

A more detailed summary of recommendations can be found in http://www.wmo.int/pages/prog/wcp/wcasp/documents/workshop/pune2015PPT/day3/Breaout3-Trotman_Summary_Forecast_Procedures.pdf

6.6.3 The ET concluded that the recommendations from the Pune workshop – together with other considerations - provide a good basis for proceeding with the development of a framework for a technical guidance document and agreed that ST6 should remain active to begin the task – it was agreed that a first draft of the framework would be completed by the end of 2016.

6.7 Sub Team 7: Amendment to GPC-relevant sections of the Manual of GDPFS

The ET noted the work of ST7 in reviewing the sections of the Manual on the GDPFS relevant to the GPCs. The chair of ST7, Richard Graham, alerted the ET to sections that require further review – and requested that all respond to him with any further comments by end of June 2016 so that revisions may be prepared for 2016 session of CBS.

7. STATEMENT OF GUIDANCE (SoG) FOR SUB-SEASONAL TO LONGER TIME SCALE PREDICTIONS

7.1 Mr Yuhei Takaya reported on the work outlining observational data requirements for the sub-seasonal to longer predictions for input to IPET-OSDE use. He indicated that the information was updated in March 2016 by the Point of Contacts with consolidated inputs from Global Producing Centres of Long-Range Forecasts (GPCs) for consideration by the Joint CBS-CCl Expert Team on Operational Predictions from Sub-seasonal to Longer-time Scales (ET-OPSLS). The information is summarized Annex 9. The team noted that, although the information has already been provided to IPET-OSDE, adjustments can still be done by the team. The submitted document includes an expansion of scope to cover requirements of longer time scale (decadal) prediction, and thus now includes guidance on observation requirements for all timescales in the ET-OPSLS Terms of Reference.

7.2 The ET thanked Mr Takaya for his first revision of the SoG since agreeing to take on the role of point of contact. The SoG is well stated, has been expanded to include requirements for sub-seasonal and multi-annual to decadal timescale predictions, and has also been restructured.

8. GPC POTENTIAL FUTURE ACTIVITIES

8.1 Potential new GPC Products (mandatory or highly recommended)

8.1.1 Recalling the ET's deliberations to this point there now followed a discussion on the potential to add new products to the existing list of GPC mandatory and highly recommended products. Referring back to the outcomes of the Pune workshop it was decided to include 850 hPa zonal and meridional winds as highly recommended outputs. These variables are of use in diagnosing monsoon characteristics and are used in some specific monsoon indices. It was noted that in due course lower level winds (e.g. 925 hPa) might be added.

8.1.2 It was also decided to include high level zonal and meridional winds (200 hPa) as highly recommended outputs. These variables are of use in diagnosing the average sub-tropical jet position and also for generating the 200 hPa stream function and velocity potential – which are widely thought to be useful in diagnosing the model response to SST and convection anomalies.

8.1.3 It was noted that the required resolution for data sent to the LC-LRFMME was 2.5°x2.5°. It was felt that this needed to be kept in review and an increased resolution considered. It is well known that geographical features such as coastlines and mountain ranges may significantly modulate forecast signals on scales below 250km.

8.1.4 The ET's response to the likely future requirement for new output variables to serve the needs of a Polar RCC is recorded under Section 3.4. Briefly GPCs are encouraged to include variables discussed in their hindcasts and forecasts and to continue skill assessment. Additionally, GPC Montreal may coordinate an informal exchange of sea-ice related predictions in time for the PRCC demonstration phase. Further discussions with the PRCC and a formal request for services from the GPCs are needed to help identify the variables that might be included in GPC mandatory or highly recommended products.

8.2 Potential new verification/validation diagnostics (ENSO composites)

This agenda item had already been discussed under Agenda item 6.2 and ST2 on verification was invited to take on new responsibilities to consider new forms of verification, including for the sub-seasonal time scale.

9. ET-OPSLS RESPONSE TO Cg-17 RESOLUTION 11: "TOWARDS A FUTURE ENHANCED, INTEGRATED AND SEAMLESS DATA-PROCESSING AND FORECASTING SYSTEM"

Mr Harou summarized the work achieved since Cg-17 adopted Resolution 11. The team noted that Experts representing the Technical Commissions met during February 9-11, 2016 to discuss how to address the issue. The group of Experts developed the elements of the White Paper and an outline of the implementation plan. Mr Harou requested comments from the team by end of April 2016 for consideration in the White Paper and the Implementation Plan.

10. REVIEW OF THE ET-OPSLS TERMS OF REFERENCE

The ET proposed a number of changes to its Terms of Reference, including addition of a specific activity to support CBS in the implementation of a seamless GDPFS. The proposed changes are at Annex 10

11. ANY OTHER BUSINESS (AOB)

The ET reviewed the composition and tasks of its seven Sub Teams – full information is provided in Annex 11.

Mr Ceron informed the ET of some outcomes of the recent meeting of the CCl/Opace 3/TT on Tailored Climate Information. Especially the development of a specific framework including the building of the relationship with stakeholders, the provision of Climate Services and the monitoring and evaluation of the entire process was presented.

12. CLOSING

The meeting of the Expert Team on Operational Predictions from Sub-seasonal to Longer time-Scales (ET-OPSLS) closed at 1:00 pm, Friday, 15 April 2016.

Annex 1: PROVISIONAL AGENDA

1. OPENING

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda
2.2 Working arrangements

3. INTRODUCTION

3.1 Review of WMO CBS and CCl decisions and developments relevant to ET-OPSLS and progress with CSIS workshop
3.2 Status of the GPC network – new applications for designation
3.3 Status of the RCC network
3.4 Report back from the WMO Scoping Workshop on Establishing Polar Regional Climate Services and an Arctic Polar RCC

4. STATUS REPORTS FROM GPCs

4.1 Discussion of GPC reports on systems development and other activities
4.2 Review of GPC compliance

5. STATUS REPORTS: LEAD CENTRES AND GLOBAL SEASONAL CLIMATE UPDATE

5.1 Discussion of LC-LRFMME report on status and developments
5.2 Discussion of LC-SVSLRF report on status and developments
5.3 Discussion of Global Seasonal Climate Update (GSCU): monitoring, forecasts and verification

6. ET-OPSLS TASK TEAM ACTIVITIES: REPORT BACK AND FUTURE DIRECTIONS

6.1 Task Team 1: Workshops on Operational Climate Prediction
- 6.1.1 Report back from Pune workshop
- 6.1.2 Discussion of next workshop and theme
- 6.1.3 Report on WWRP/WGSIP activities
- 6.1.4 Report back from the ET-RCC

6.2 Task Team 2: Verification of GPC seasonal products
- 6.2.1 Progress with centralized verification
- 6.2.2 Discussion of next steps, including division of roles between LC-LRFMME and LC-SVSLRF

6.3 Task Team 3: Development of sub-seasonal forecasts
- 6.3.1 Review of real-time products from the LC-LRFMME pilot
- 6.3.2 Discussion of next steps, including schedule for release to NMHSs and RCCs
- 6.3.3 Update on the WWRP-THORPEX/WCRP S2S research project
- 6.3.4 Discussion of questionnaire results on subseasonal verification practices in operational centres

6.4 Task Team 4: Development of multi-annual to decadal forecasts
- 6.4.1 Discussion of updated proposal on establishing a Lead Centre for Near Term Climate Prediction (LC-NTCP)

6.5 Task Team 5: New Approaches for distribution of GPC hindcast and forecast data
- 6.5.1 Review and discussion of questionnaire results and next steps

6.6 Task Team 6: Manual on Procedures for generating regional seasonal forecasts
6.7 Task Team 7: Amendments to GPC-relevant sections of the Manual of GDPFS

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8.1 Potential new GPC Products (mandatory or highly recommended)
8.2 Potential new verification/validation diagnostics (ENSO composites)

9. ET-OPSLS RESPONSE TO Cg-17 Resolution 11: "TOWARDS A FUTURE ENHANCED, INTEGRATED AND SEAMLESS DATA-PROCESSING AND FORECASTING SYSTEM"

10. REVIEW OF THE ET-OPSLS TERMS OF REFERENCE

11. ANY OTHER BUSINESS (AOB)

12. CLOSING

Annex 2: List of Participants

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Annex 3: Report back from the WMO Scoping Workshop on Establishing Polar Regional Climate Services and an Arctic Polar RCC

(Submitted by B. Denis)

1) Introduction

A scoping workshop in preparation of the establishment of an Arctic Polar Regional Climate Centre was held In Geneva, 17-19 November 2015. Workshop Participants included various stakeholders in Arctic climate matters that are involved in the operational activities and in the development and delivery of products and services. The workshop included experts in associated research and selected representatives of user sectors and policy domains. As member of the ET-OPSLS, Dr. Bertrand Denis (GPC-Montreal) was invited to give a presentation on the role of the WMO Operational Global Producing Centres (GPCs) for Subseasonal and Longer Time Scale Predictions

As we know, WMO RCCs are mandated to deliver high-quality regional-scale products (primarily to NMHSs) by using data and products from GPCs and other global centres that benefit from national data, products, know-how and feedback they receive from the NMHSs. Because of the extend of the domain, the high-latitude physical environment, and the specific user needs, it is expected that a Polar RCC would request products and services from GPCs and LRF Lead Centres not commonly provided to traditional RCCs.

This report summarizes the workshop with an emphasis on the talk presented on behalf of the ET-OPSLS. It gives the meeting participants an overview of potential implications for the GPCs and LRF Lead Centres. More information on the Polar RCC scoping meeting, including the workshop concept note, the list of participant and the presentations are available here:

https://www.wmo.int/pages/prog/wcp/wcasp/meetings/PRCC_Scoping_Workshop2015.html

2) Workshop summary

The scoping workshop objectives/potential outcomes were:

- Appraisal of opportunities and challenges including governance aspects relating to development and delivery of climate services in the Polar Regions, including climate data, monitoring and prediction aspects, and in identifying the associated user needs;

- Scoping of the Arctic PRCC-Network concept and implementation:
    a. List of priority PRCC functions;
    b. Description of the PRCC implementation strategy including the structure of the Arctic PRCC-Network

- Identification of Member capacities to engage users at national and regional levels and to deliver PRCC services for their benefit; and

- Recommendations on the next steps in establishing an Arctic PRCC-Network.
    - **Goal of the workshop relevant for the ET-OPSLS:**
        - **Discuss potential products that may be of particular interest to this region and to the users in this region;**
        - **Mapping requirements and capacities; and**

Dr. B. Denis kindly accepted to represent the ET-OPSLS and to give a talk the first morning of the workshop on the supporting role of GPCs and LRF Lead Centres and how they could contribute to a PRCC network by providing polar predictions, including potentially sea-ice predictions.

The actual presentation can be found here (link to be verified): https://www.wmo.int/pages/prog/wcp/wcasp/meetings/documents/presentations/2.4-Bertrand-role-of-GPCs-PRCC_final.pdf

The talk presented to the audience touched upon these topics:

- Role and functions of the ET-OPSLS
- Role and functions Global Producing Centres of Long-range Forecasts (GPCs)
- Lead Centres for Long Range Forecasts: purpose and functions, websites
  - Lead Centres for Long-range Forecast Multi-Model Ensembles (LC-LRFMME)
  - Lead Centres for the Standard Verification System for Long-range Forecasts
- Current product examples
- GPCs and RCC's requests for new products
- Next steps

The audience was informed by the speaker that GPCs and LRF Lead Centres have in the past fulfilled RCC's requests for new products, for example:

- Sea Surface Temperature (SST)
- Ocean Climate Indices (Nino3.4 and others)

and in the context of a Polar RCC, the GPCs could potentially:

- Provide maps with polar projections
- Consider adding new products relevant to Polar regions, for example:
  - Snow related quantities (water equivalent, cover)
  - Sea ice (forecasts, verification, expected skill)

The scoping workshop attendance was also briefed on the following considerations:

The ET-OPSLS would consider RCCs requests for new products:

- Timing was good. Next ET-OPSLS meeting in April 2016
- Forecast products would need R&D for predictability studies and suitable packaging
- The degree of comfort with current sea ice forecast skill is variable amongst the GPCs
- Some GPCs data policy might need to be amended
- Sea ice forecast cannot be mandatory since not all GPCs have sea ice model component
- Such products would be on the list of GPCs Recommended Products to produce

It has to be noted that a week prior to that scoping workshop, Dr. B. Denis had set up an informal side-meeting with some of GPC representatives present at the First WMO Workshop on Operational Climate Prediction held in Pune, India. The objective was to obtain a preliminary idea of the GPCs potential contributions, in particular in terms of LRF of sea-ice conditions. Out of the 12 GPCs, 5 GPCs mentioned having some sea-ice prediction model capability with their current system, another 5 would expected to get that capability with their upcoming next system version, and 2 had no existing capability currently or in the near future.

Later during the workshop, participating countries presented their views of the would-be PRCC operational structure (network-node vs geographically distributed) as well as their potential contributions in term of products and services. The need for those were discussed and listed during breakout sessions. The list of identified parameters of interest is reported here:

- Cryosphere
  - Sea and Freshwater Ice
  - Snow Cover
  - Glaciers, Ice Caps, and Ice Sheets
  - Permafrost
- Atmosphere
  - SLP, T2m, precipitation
  - Storminess, winds, atmospheric circulation patterns
- Polar oceanography
  - Water temperature, Salinity
  - Sea level
  - Waves
  - River runoffs
- Land issues
  - Coastal and river erosion
  - Fresh water runoffs

It seems that sea ice is for the Polar Regions as important as precipitation is for low and mid-latitude regions, and that the cryosphere as an whole would deserve from a PRCC much more attention than what is usually required for a RCC covering other regions of the world.

It has also been reported that the prediction timescales needed for the products to be provided by a PRCC to their users would cover a large range, from weeks to about a year. Shorter timescale are also needed but are traditionally out of scope for a RCC. Long-lead forecasts such as 6 months are needed for sea ice for transportation purposes, for instance.

It must be noted that by the end of the scoping workshop, no formal requests to the ET-OPSLS had had been formulated but that was expected to happen within the following months.

3) Implications for GPCs and LRF Lead Centres

There are a number of potential implications for GPCs and LRF Lead Centres :

- Do they can provide maps with polar projections with various orientations (for instance, the ability to have North America, Asian, Europe at the bottom of the map)?

- Do they can provide sea ice predictions? If yes,

  - Is the predictability high enough for the predictions to be useful? If yes, up to which lead time?

    - Which variables (concentration and/or thickness or other related parameters)?
    - At which temporal resolution? Daily sea ice output would be best for predicting probability of breakup, for example
    - Can sea ice forecasts be easily add to the GPCs model output?
    - Is sea ice already available from hindcasts?
    - What verification metrics should be used?

  - Do the GPCs data policy need to be modified?
  - Implications for the LRFMME Lead Centres

    - Change of map projections to included polar views

  - Would need to collect and distribute sea ice forecast data from contributing GPCs
  - Would need to add sea ice forecasts products (to be defined) and hindcast verifications to the product offering on the LRFMME web site

- Would we be ready for the demonstration phase (due in early 2017)?

As we can see, the list of potential implications is important. It is clear that sea ice prediction output cannot be put on the mandatory list of variables but the ET should discuss the possibility of adding it the list of recommended products.

It should be noted that Canada has offered to co-lead, with potentially another GPC (TBD), the development of sea ice LRF capabilities in support of the PRCC. That would include development of experimental forecast products, expected skill based of hindcasts, and MME predictions amongst other things. It is expected that some or all of these capabilities would eventually be transferred to the LRFMME Lead Centre for operationalization.

4) The next steps

As a follow-up of the workshop, the WMO secretariat has sent out a call letter for asking precisions on potential national contributions of the participating countries. Also, it was expected that the GPCs and LRF Lead Centres would be formally consulted through the ET-OPSLS for inputs on the LRF functions in support of the PRCC operations. It should be noted that since Canada, The Federation of Russia and The United State of America would be contributing countries; their own GPC should have normally already been consulted for inputs through their NMHS agency (GPC-Montreal, GPC-Washington, GPC-Moscow).

As of April 2016, the Secretariat is in the process of making the primary consolidation of the inputs, and analyzing the capabilities and commitments to perform the mandatory PRCC functions.

It was expected at the time of the workshop that an Arctic-RCC-Network Implementation Plan would be produced by September 2017, with a demonstration project starting in early 2017.

Annex 4: GPC status summaries

GPC Tokyo

Mr Yuhei Takaya informed the team GPC Tokyo operates separate forecast systems for LRF, and ELF. He indicated that the Japan Meteorological Agency (JMA)/Meteorological Research Institute-Coupled Prediction System version 2 (JMA/MRI-CPS2), which was implemented recently (June 2015), is used for LRF. Changes in JMA/MRI-CPS2 from the previous system (JMA/MRI-CPS1) include improved resolution and physics in the model's atmospheric (T159L60) and oceanic components (1x0.5-0.3 degrees, L52+BBL) as well as the introduction of an interactive sea ice model. In the new real-time operational suite, 51-member ensemble integrations are carried out from consecutive initial dates with intervals of five days. In addition he reported that for ERF JMA runs the JMA's global circulation model, JMA-GSM1403. The model resolution is TL319L60 and an ensemble size for the operational real-time forecast is 50. More details on the JMA/MRI-CPS2 and the JMA-GSM1403 can be found, respectively, at
http://ds.data.jma.go.jp/tcc/tcc/products/model/outline/cps2_description.html and at http://ds.data.jma.go.jp/tcc/tcc/products/model/outline

Mr Takaya also reported that the new model system shows improvement for 2m Temperature in the Arctic (60N -90N) and that the summer anomaly correlation is much improved. The team noted that a sophisticated greenhouse gas concentration scheme and the recommended SST indices were included in the model's output.

GPC Washington

Mr Arun Kumar reported that GPC Washington's current dynamical seasonal prediction is based on the National Centers for Environmental Predictions (NCEP's) Coupled Forecast System (CFSv2) implemented in March 2011. Since its implementation the data assimilation, analysis, and forecast system has not been changed. Only changes have been to implement some fixes in the data assimilation system due to changes in the observing system and incremental increase in observational data. He indicated that the atmospheric component of the CFSv2 is the NCEP Global Forecast System (GFS) with a horizontal resolution of T126 (~100 km) spectral truncation with 64 vertical levels in the atmospheric model with topped at 0.26 hpa. The team noted that the oceanic component of the CFS is the GFDL Modular Ocean Model V.4 (MOM4) which is almost global, extending from 74S to 64N. The meridional resolution of the ocean model is 1/4 Degree between 10S and 10N, and gradually increases in the extratropical latitudes becoming fixed 1/2 Degree poleward of 30^{o}S and 30^{o}N. The zonal resolution is 1/2 Degree. The CFSv2 configuration of MOM4 has 40 layers in the vertical with 27 layers in the upper 400 meters. The vertical resolution is 10 meters from the surface to the 240 meters depth. In terms of hindcasts and forecasts, the team noted that for the CFS.v2 they are initialized from the Climate Forecast System Reanalysis (CFSR). The CFSR is the latest version of the NCEP climate reanalysis with the first guess from a weakly coupled atmosphere-ocean model consisting of the NCEP global forecast system (GFS) for the atmosphere and the Geophysical Fluid Dynamics Laboratory MOM4 for the ocean. In the CFSR the atmospheric component (GFS) is run at a horizontal resolution of T382 (~38 km).

Mr Kumar also reported that for calibrating real-time prediction, an extensive set of hindcasts is available. For CFSv2 seasonal hindcasts, four runs for nine target months were made every five days starting January 1st without considering Feb 29 in leap years. The real time forecast configuration includes four-daily runs for 10 months, and forecast is constructed based on a 40-member lagged ensemble comprising of latest seasonal forecasts from past 10 days. The data from hindcasts and the real-time forecasts is freely available. The next upgrade is planned for 2019. The team noted that instructions for downloading the model data can be found at: http://cfs.ncep.noaa.gov and at
http://nomads.ncep.noaa.gov/pub/data/nccf/com/cfs/prod/ while forecasts are displayed in real-time at: http://origin.cpc.ncep.noaa.gov/products/people/wwang/cfsv2fcst/

GPC Exeter

Mr Richard Graham reported that the GPC Exeter's current prediction is the Global Seasonal forecast system version 5 (GloSea5). It is a fully coupled system with interactive sea ice and has atmospheric resolution of 0.83°E-W; 0.56° N-S; 85 vertical levels and ocean resolution of 0.25°; 75 vertical levels. Output is configured for both seasonal and sub-seasonal forecasting. In February 2015 a major upgrade to the model was made, incorporating the following scientific advances as below (Global Coupled 2.0); a) Implementation of new dynamical core ENDGAME: http://www.metoffice.gov.uk/research/news/2014/endgame-a-new-dynamical-core ; b) Improvements to oceanic vertical mixing scheme to improve the mixed layer representation of the world's oceans, which is important to seasonal forecasting, marine ecosystems, and many other aspects of the climate system. Changes have also been made to the NEMOVAR assimilation scheme to improve the initialisation of sub-surface temperature and salinity; c) Improvements to the albedo and surface roughness of the sea ice to achieve a more realistic seasonal cycle of sea ice.

The team noted that GPC Exeter and GPC Seoul now both run the GloSea5 system as their operational forecast system, as the first stage in developing a joint seasonal forecasting system. GPC Seoul plan to upgrade their model to Global Coupled 2.0 in 2016. The team also noted that hindcast is run at the same time that the forecast is run.

GPC Exeter have developed a modular seasonal forecasting training course and delivered it in collaboration with ICPAC (Nairobi), ACMAD (Niger, to 18 West African NMHSs); the Rwanda Meteorology Agency, the Ethiopian National Meteorological Agency (as part of the DFID BRACED project). Modules in the course have also been delivered as part of the China Meteorological Administration Training Centre (CMATC) training course on the GFCS, at ASEANCOF-3 and the 7th International Training Workshop on Climate Variability and Prediction (2015). The modules include basic familiarisation with output from dynamical ensemble prediction systems. An interactive spreadsheet tool is used to study ensemble characteristics, measure hindcast skill of GPC systems for the region concerned (using SVSLRF skill measures) and generate regional real-time forecasts. Modules also include use of IRI's Climate Predictability Tool (CPT) to carry out advanced statistical post processing of GPC output – to correct for systematic biases in GPC output.

GPC Seoul

Mr Suhee Park reported that the operational forecasting system of GPC-Seoul for sub-seasonal to seasonal time scale is a Global Seasonal forecast system version 5 (GloSea5), a joint seasonal forecasting system with Met Office and which comprises the following components: a) For the Atmoshere, the Met Office Unified Model; b) For the land surface, the joint UK Land Environment Simulator; c) For the Ocean, the Nucleus for European Modeling of the Ocean and; d) For sea-ice, the Los Alamos Sea Ice Model. The team noted that, although forecasting system of GPC-Seoul and GCP-Exeter (Met Office) are same, there are sufficient ensemble-spreads between two products, because of difference in initial conditions of atmosphere for real-time forecast phase (from its own NWP analysis data) and stochastic physics scheme in GloSea5.

GPC Toulouse

Meteo-France produces since January 2013 operational seasonal forecasts with its system 4. This system is based on CNRM-CM5 coupled model. According to the evolution of ECMWF Syst 4, we prepared last year a system 5 including GELATO sea-ice model, and increasing horizontal and vertical resolution of the atmosphere: 75 km resolution and 91 vertical levels (Tl255l91, which is the same resolution as ECMWF system 4 currently in use in EUROSIP). The 12 hindcasts have been produced and archived in the MARS system. The real-time forecasts of system 4 and system 5 run in parallel since April 2015.

Because of the System 5 should be in the multi-model EUROSIP System 5 is described by a technical documentation available at
http://www.cnrm.meteo.fr/IMG/pdf/system5-technical.pdf

Another document, explaining the differences between system 4 and system 5 on the basis of the standard ECMWF basic facts, and including diagrams of scores and maps of model systematic errors can be found at
http://www.cnrm.meteo.fr/IMG/pdf/system4-to-system5.pdf

Besides the change in resolution and the inclusion of a sea ice model, the other changes is the update of the ARPEGE-IFS cycle (cycle 37 instead of cycle 32), minor refinements in the soil-vegetation model (Masson et al., 2013), and the inclusion of stochastic perturbations (Batté and Déqué, 2012). This last modification has an implication on the lagged-average technique used for generating the forecast ensembles (see section 1.4).

A detailed algorithmic description of the atmosphere model ARPEGE can be found at:
http://www.cnrm.meteo.fr/gmgec/arpege-climat/ARPCLI-V5.1/index.html

The sea-ice model GELATO is described at:
http://www.cnrm.meteo.fr/spip.php?rubrique225

The ocean model NEMO is described at : http://www.nemo-ocean.eu/

Jean-Pierre to provide text: No change still working with the model. Downscaling not implemented. In their way to change but will wait for Coppernicus before changing the model. Moving to system 5 with better resolution. Hindcast 15 members.

GPC ECMWF

Ms Laura Ferranti presented on the status and plans of GPC-ECMWF seasonal and sub-seasonal systems. The team noted that, for seasonal range, the ECMWF seasonal forecasting system (System 4) has been operational since November 2011 and has not changed since the 2014 ET-OPSLS meeting (held in Exeter). The system consists of an ocean analysis and a global coupled ocean-atmosphere general circulation model. The ocean model used is NEMO in ORCA1 configuration with 1x1 Deg. resolution in mid-latitudes and an equatorial refinement. The atmospheric component is IFS model version Cy36R4 with 91 vertical levels. Documentation on this system is available at: www.ecmwf.int/en/forecasts/documentation-and-support/long-range/seasonal-forecast-documentation. The team also noted that an upgrade of the system (System5) is planned for 2017 and will run with higher spatial resolution for both oceanic (1/4deg NEMO V3.4) and atmospheric components (Tco 319~36Km vertical level 137). It will have a dynamical sea-ice model (LIM2), and wave-ocean coupling in ocean mixing, stokes drift, non-local wave breaking. The ocean initial conditions will be created by ORAS5 (5 ens members reanalysis of 1/4 deg Ocean and sea ice from 1979 onwards). The atmospheric component will be based on CY43R1.The atmospheric initial condition will be based on ERA-Interim. The system will have interactive stratospheric ozone. It is expected that by the end of 2017 the digital data of ECMWF seasonal forecast will be freely available under Copernicus Climate Change service. The reforecast data of the current operational system (System 4) is available to LC-LRMME.

The team noted that the extended-range forecasts (sub-seasonal range) provide an overview of the forecast for the coming 46 days, focusing mainly on the week-to-week changes in the weather. The configuration of the sub-seasonal range system is the same as of the ECMWF medium range system, in fact, the extended range forecasts are just an extension of the medium range forecasts. Real-time forecasts are initialized from the atmospheric values of ECMWF operational analysis. Re-forecasts are initialized from ERA Interim, except for soil conditions (soil temperature, soil moisture, snow initial conditions) which are provided by an offline soil reanalysis. Oceanic initial conditions are provided by the real-time suite of NEMOVAR (since Nov. 2011). The extended range ensemble has 51 members starting from slightly different initial atmospheric and oceanic conditions, which are designed to represent the uncertainties inherent in the operational analyses. The atmospheric perturbations are the same as for ECMWF medium range ensemble. Documentation on this system is available at: www.ecmwf.int/en/forecasts/documentation-and-support/extended-range-forecasts.

The team noted that the extended range products are similar to seasonal products but with weekly means (bias corrected). Weekly means anomalies and terciles probabilities maps are provided for a number of regions and a number of parameter (surface temperature, 2-metre temperature, total precipitation and mean sea level pressure). The weekly means are based on the real-time forecast distribution and on the model climate distribution based on 660 members of the re-forecast (11 members x 20 years x 3 forecast runs). Since the Madden-Julian Oscillation (MJO) is a main source of predictability on the sub-seasonal time scale, several MJO forecast products are made available. The Multivariate MJO index displaying the time evolution of the MJO predicted by the ensemble is among them. Tropical storm frequency and tropical storm strike probability (probability of a tropical storm passing within 300km), calculated over weekly periods are also available. The most likely flow pattern and Hovmoellers tracing Rossby Wave Train are among other products that are appreciated by users. The range of products on sub-seasonal time scale is growing.

Ms Ferranti added that ECMWF is looking at extending the Extreme Forecast Index (EFI), currently available at medium range, to sub-seasonal range.

GPC Beijing

Mr Peiqun Zhang introduced the team to GPC Beijing prediction system. The team noted that since Dec. 2013 GPC Beijing has produced operational climate prediction using its 2nd generation operational climate model system, named BCC_CSM1.x.(Wu T. et. al. 2014). It is is a fully coupled climate model containing BCC_AGCM2.2, BCC_AVIM1.0, MOM4_L40v2, and SIS as its atmosphere, land, ocean and sea ice component respectively. In addition, the team noted that with its atmospheric general circulation model, BCC_AGCM2.2(T106L26), driven by the persisted SSTA, BCC issues its ERF a monthly forecast for 0-45day (Integrated 45 days forced by persisted SST anomalies), global in the first day of every pentad, i.e., 1st, 6th, 11th, 16th, 21st and 26th, with 20 members. The products provide 10-day and 30-day ensemble mean forecast for the globe and Asia. Mr Zhang further explained that with its coupled general circulation model BCC_CSM1.1 which has the same atmospheric component BCC_AGCM2.2(T106L26) as in ERF, BCC issues its seasonal forecast each month for following 0-6month (2 seasons). The initial conditions of AGCM come from NCEP analysis and the BCC GODASv2 provides OGCM initial conditions. Total number of forecast ensemble members is 24, including15 by lagged-average-forecast and 9 by singular-vector (SV) method.

Mr Zhang explained that based on BCC_CSM1.1, BCC developed the Forecast Products of ENSO Indices and Related Dynamical Diagnosis from BCC's System of ENSO Monitoring, Analysis and Prediction (SEMAP2.0) and launched it into operation in 2015. The products of SEMAP2.0 consist of ENSO indices (beside the traditional indices, two new indices for the two types of El nino (NEPI: NINO Eastern Pacific index, NCPI: NINO Central Pacific index) are provided), and related dynamical diagnosis based on ENSO feedback processes. The products are updated monthly with maximum lead time of 1 year (Ren H-L and Jin F-F, 2011, 2013, Ren H-L. et. al. 2014).

GPC CPTEC

Mr Caio Coelho reported seasonal climate forecasts are operationally produced using CPTEC Atmospheric General Circulation Model (AGCM) with persisted sea surface temperature (SST) anomalies. For example, for a forecast made in March 2016 and valid for the six month period from March to August 2016, the observed SST anomaly of February 2016 is added to the climatological (i.e. long term mean) SST of these six months during the integration of the model. The team noted that the model resolution is T062L28, which represents triangular truncation of 62 waves in the horizontal coordinate and 28 levels in the vertical sigma coordinate (21 in the troposphere and 7 in the stratosphere). Deep cloud convection is parameterized using the scheme developed by Kuo (1974). Initial conditions for these operational forecasts are obtained from NCEP. A total of 15 initial conditions from the previous

December in the example above, representing 15 different days of December 2015, are used for producing an ensemble of operational global forecasts. These forecasts and verification products are available at *http://clima1.cptec.inpe.br/gpc/in.*
The team also noted that the AGCM has been used operationally since 2010 with hindcasts covering the period 1979-2001 and that GPC CPTEC is about to conclude hindcast production for extending this period to 1979-2010 (10 ensemble members).

Mr Coelho reported on the use of a NOAA software, during a training workshop for the Southern South America RCC in October 2015, that grab GRIB data from Lead Centres and convert them to Climate Predictability Tool (CPT) and recommended its use. The team discussed this proposal and concluded that CPT is one tool among many and considering the issue of following WMO data standards (CPT is not one) and the upcoming CSIS workshop for the development of climate services toolkits, it would be wise to consider the outcome of this workshop to clarify the path forward.

GPC Pretoria

Seasonal operational forecasting system of GPC Pretoria relies on a Coupled (ocean-atmosphere) General Circulation model (CGCM) referred to as the SAWS Coupled Model (SCM; Beraki et al., 2014; 2015). The CGCM uses T42 (triangular truncation at wave number 42) horizontal resolution and 19 unevenly spaced hybrid sigma layers, the OGCM (Ocean General Circulation Model) has a 0.58° uniform zonal resolution, with a variable meridional resolution of 0.5° between 10° S and 10° N, gradually increasing to 1.5° at 30°S and 30° N and fixed at 1.5° in the extratropics. In the vertical, the OGCM uses 25 layers with 17 layers in the upper levels between 7.5m and 450m. The model is initialized with the NCEP/DOE daily atmospheric initial states, suitably transformed and interpolated into the AGCM's vertical and horizontal resolution. The ocean initial states are taken from ODA (Ocean Data Assimilation) system produced at the GFDL (Geophysical Fluid Dynamics Laboratory) for the handcast integrations. However, the real-time forecasts use the Global Ocean Data Assimilation System (GODAS) pentad ocean state anomalies added to the GFDS ODA climatology to minimize the potential mismatch between the hindcast and forecasts. The hindcast (1982-2009) and real-time forecasts consist of 10 and 40 ensembles respectively. Each forecast integration is of 9 months length. This CGCM has been used operationally since 2014.
Forecasts are displayed in real-time at:
http://www.weathersa.co.za/home/seasonal

Beraki A.F., W. Landman, and D. DeWitt, 2015: Comparison on the seasonal predictive skill of global circulation models: coupled versus uncoupled, *Journal of Geophysical Research Atmosphere*, 120, doi:10.1002/2015JD023839.

Beraki, A.F., D. G. DeWitt, W.A. Landman, and C. Olivier (2014) Dynamical seasonal climate prediction using an ocean-atmosphere coupled climate model developed in partnership between South Africa and the IRI, J. Climate, 27,1719-1741.

Landman, W. and A. Beraki 2010: Multi-model forecast skill for mid-summer rainfall over southern Africa, *International Journal of Climatology, Vol. 32,303-314*

GPC Montreal

Dr. Bertrand Denis presented on the status and plans of GPC-Montreal sub-seasonal and seasonal systems. The sub-seasonal forecast system is a new prediction system operational since 2015 and based on CMC weather Global EPS, whereas the seasonal forecast system (CanSIPS) is still based on CCCma climate models.

Sub-seasonal system description

The sub-seasonal system is based on the Global Ensemble Prediction System (GEPS, see Houtekamer et al. 2014), by extending the lead time of the ensemble medium-range weather forecast out to 32 days once a week (see Gagnon et al. 2013 and Gagnon et al. 2014a). Although it is still a two-tier system, i.e., an uncoupled system with specified SST and sea ice conditions, it likely captures most of the major sources of predictability on the subseasonal time scale. Compared to CanSIPS, the GEPS based monthly forecast takes advantage of the increased model resolution and improved initialization, leading to improved forecast skill. The heart of the GEPS system is the Canadian Global Environmental Multi-scale model (GEM; Cote et al. 1998a, b). The current GEPS has a horizontal resolution of 0.45º×0.45º, and 40 vertical levels. GEPS is run twice daily out to 16 days with 20 perturbed members and one control member. The initial conditions are produced with the Ensemble Kalman Filter (EnKF; Houtekamer et al. 2009; Houtekamer et al. 2014), which receives observations that are background-checked and bias-corrected by the Global Deterministic Prediction System (GDPS; Buehner et al. 2015). Different members of GEPS have different model configuration perturbations (multi-parametrization physics). They also make use of stochastic perturbations of physics tendencies, and stochastic energy back-scattering. Land properties are initialized with the real-time CMC analysis. Once a week (Thursday 00Z), the forecast of GEPS is extended to 32 days, that makes the real time component of the monthly forecast.

Sub-seasonal performance evaluation

Verification of the GEPS monthly forecasts is recently performed by Lin et al. 2016 (submitted). The new monthly system takes the advantage of the improved initial conditions and high resolution in order to produce better skill than the previous monthly forecasting system which was based on CanSIPS (our seasonal forecasting system). Variables such as temperature and precipitation have shown to have better skill in GEPS system comparing to the previous monthly CanSIPS forecasts. These conclusions are based on the monthly hindcasts evaluation in boreal summer and winter.

An overview of the design and the operational implementation as well as an extensive performance evaluation of the GEPS are available in the technical note obtainable through this web address:
http://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/lib/technote_geps-400_20141118_e.pdf

Please note that this assessment considers mostly results of the first two weeks due to the initial forecasting integration time of the GEPS system (16 days).

Availability of official sub-seasonal forecast products

The main official products are posted on the Government of Canada web site for weather information: http://weather.gc.ca/. A dedicated section for monthly forecasting is found more precisely here: https://weather.gc.ca/saisons/image_e.html?img=mfe1t_s and includes forecast for temperature only. More information on the monthly forecasts including precipitation can be found using this link:
http://collaboration.cmc.ec.gc.ca/cmc/ensemble/monthly/prev_mens_geps.html

Seasonal system (CanSIPS) description

The Canadian Meteorological Centre (CMC) has been using since 2011 a global coupled seasonal prediction system for forecasting monthly to multi-seasonal climate conditions. The system named CanSIPS for Canadian Seasonal to Interannual Prediction System has replaced both the uncoupled (2-tier) prediction system previously used for producing seasonal forecasts with zero and one month lead times and the CCA statistical Prediction system previously used for forecasts of lead times longer than four months. With CanSIPS, Environment Canada is able to issue on monthly basis predictions of seasonal climate conditions covering a full year. This represents substantive progress with respect to the previous system. CanSIPS can also skillfully predict the ENSO phenomenon and its influence on the climate up to a year in advance.

The development and the implementation of this multi-seasonal forecast system is the result of a close collaboration between CMC and the Canadian Center for Climate Modeling and Analysis (CCCma).

CanSIPS is a multi-model ensemble (MME) system based on two climate models developed by CCCma. It is a fully coupled atmosphere-ocean-ice-land prediction system, integrated into the CMC operational prediction suite and relying on the CMC data assimilation infrastructure for the atmospheric, sea surface temperature (SST) and sea ice initial states.

The two models used by CanSIPS are:

- CanCM3 which uses the atmospheric model CanAM3 (also known as AGCM3) with horizontal resolution of about 315 km (t63) and 31 vertical levels, together with the ocean model CanOM4 with horizontal resolution of about 100 km and 40 vertical levels and the CLASS land model. Sea ice dynamics and thermodynamics are explicitly modeled.

- CanCM4 which uses the atmospheric model CanAM4 (also known as AGCM4) also with an horizontal resolution of about 315 km (t63) but with 35 vertical levels. The CanOM4 ocean, CLASS land and sea ice components are essentially the same as in CanCM3.

Further information on these models is given on the CCCma web site at the following link: http://www.ec.gc.ca/ccmac-cccma/default.asp?lang=En&n=4A642EDE-1

CanSIPS has two modes of operation:

- Assimilation mode: CanSIPS uses a continuous assimilation cycle for 3D atmospheric temperatures, winds and specific humidity as well as sea surface temperatures and sea ice. The assimilated data comes from the six hour CMC 4D-VAR global atmospheric final analyses and the daily CMC SST and sea-ice analyses. Additionally, just before launching the production of the forecasts, an NCEP 3D ocean analysis is assimilated into the CanSIPS ocean model background state. The initial conditions of 20 CanSIPS ensemble members are independent but statistically equivalent in the sense that their differences are of the same order as observational uncertainties. More details on the models and their initialization are given in Merryfield *et al.* (2013).

- Forecast mode: CanSIPS forecasts are based on a 10-member ensemble forecasts produced with each CCCma climate model for a total ensemble size of 20. Monthly to multi-seasonal forecasts extending to 12 months are issued the first day of each month. Additionally, a one-month forecast is issued at mid-month (15th).
CanSIPS climatology is based on a hindcast period covering 1981-2010 and was produced during phase 2 of the Coupled Historical Forecast Project (CHFP2) research effort. The ensemble size (20) is the same for the forecast and the hindcasts. It should be noted that since June 2013, the probabilistic forecasts are all calibrated.

Seasonal system (CanSIPS) performance evaluation

Objective verifications over the overlapping hindcast periods of the previous and new system have shown improvements in prediction skill at the global scale as well as over Canada. Improvement is clearly seen in seasonal surface temperature forecasts but far less for precipitation, which still remains a major challenge over extra-tropical countries for all seasonal prediction systems. An overview of the design and the operational implementation of CanSIPS as well as an extensive performance evaluation are available in the technical note obtainable through this web address:
http://collaboration.cmc.ec.gc.ca/cmc/CMOI/product_guide/docs/lib/op_systems/doc_opchanges/technote_cansips_20111124_e.pdf

Availability of official Seasonal forecast (CanSIPS) products

The main official products are posted on the Government of Canada web site for weather information: http://weather.gc.ca/. A dedicated section for seasonal forecasting is found more precisely here: http://weather.gc.ca/saisons/. Other means of accessing the forecasts are detailed further down this document.

GPC Melbourne

Since 2012 GPC-Melbourne has produced operational climate predictions using the Predictive Ocean Atmosphere Model for Australia (POAMA) version M24. This is a coupled ocean-atmosphere model with an atmospheric resolution of T47L17. POAMA-M24 features several upgrades from the previous version P24, with improvements made to both the model and the operation of the forecasting system (e.g. changes to the ensemble creation for producing both hindcasts and forecasts).

Further details of the M24 model physics, data assimilation scheme and ensemble generation are available in Hudson et al. (2013) and are summarised in Table 1. The hindcast (retrospective forecasts) set consists of 6 forecast initialisations per month i.e. a forecast initialised every 5 days spanning the 30-year period from 1981 to 2010.

Real-time forecasts are now generated twice per week (00z Mondays and Thursdays), although prior to January 2013 they were only generated once per week (00z Thursdays). For the real-time running of POAMA a 33 member ensemble is produced with each member containing forecasts with out to 9 months.

The multi-configuration ensemble makes use of three versions of the POAMA2 model:

M24a: which uses standard atmospheric physics;

M24b: a flux corrected version, using the same physics as M24a but with ocean-atmosphere fluxes corrected in the model in real-time to reduce climatological biases; and

M24c: modified atmospheric physics which uses an alternative shallow convection physical parameterization scheme.

The use of this multi-configuration ensemble approach has been shown to improve the overall reliability of the model forecasts.

For the production of operational outlooks, ensemble runs from several start dates are combined to produce a lagged ensemble with the current practice using 165 members in total (i.e., five start times/lags in total). This approach has been shown to yield largely reliable forecasts, while keeping the forecast lead time to a relative minimum (and hence maintaining near "optimal" skill).

GPC Melbourne has developed and maintains a website which delivers long range outlooks to WMO member states and other users. This website integrates broad scale, site-based and climate index outlooks using a map-based interface. Data is available from this site for both gridded and time series outlooks (http://poama.bom.gov.au/experimental/pasap/). All forecasts and hindcasts are available to the community through an OpenDAP server (http://poama.bom.gov.au/data_server.shtml) .

There have been only minor changes to POAMA M24 since the 2014 ET meeting (held in Exeter).

The model configuration is currently the same across all time-frames – weeks, months and seasons. The current multiweek forecasts are considered experimental, and continue to be tested and described in the scientific literature (see Hudson et al. 2015a/b). The relatively course resolution of the POAMA M2.4 and its atmospheric initialisation scheme currently limit using multiweek forecasts operationally.

GPC Moscow

Ms. Khan reported that the forecasting system at GPC-Moscow based on the computationally efficient global finite_difference atmospheric general circulation model SL_AV which was developed at the Institute of Numerical Mathematics RAS and Hydrometeorological center of Russia. The distinct features of the dynamical core of this model are the fourth_order finite differences on the unstaggered grid applied for approximation of the non_advective terms in governing equations and the use of the vertical component of the absolute vorticity and divergence as prognostic variables. The dynamical core of this model is presented in [Tolstyh et al., 2001], numerical methods for horizontal for horizontal discretization are described in more details in [Tolstyh et al., 2002]. The model includes a set of parameterizations for subgrid_scale processes (short and long wave radiation, deep and shallow convection, planetary boundary layer, gravity wave drag, parameterization of heatand moisture exchange with the underlying surface) developed in МйтЙо_France and meteorological services of RC_LACE (Limited Area modeling for Central Europe) (http://www.rclace.eu) consortium for French operational global model ARPEGE and the regional model of the international consortium ALADIN [Geleyn et al. 1994]. The atmospheric model is integrated for 4 months at 1.125 lat x 1.40625 lon/L28 L28 resolution forced by persisted SST anomalies. There are 20 ensemble members per month (breeding method) for operational forecasts and 10 members for hindcasts. Re-Forecasts period is 1981-2010. The team was informed about plan to implement another period which is encompassing from 1986 to 2015. CHFP and S2S standards were implemented for subseasonal forecasting. The model is integrated for 63 days every week. Improvements related to new snow parameterization, cloudiness tuning and better ozon description were introduced in the model (Tolstyh et al. 2014). The team noted the comparison of skill scores of old and new model hindcasts has demonstrated the advantage of new version of the model.

M. A. Tolstykh, D. B. Kiktev, R. B. Zaripov, Yu. Zaichenko, and V. V. Shashkin, "Simulation of the seasonal atmospheric circulation with the new version of the semi_Lagrangian atmospheric model, Izv., Atmos. Ocean. Phys. **46** (2), 133–143 (2010).

D. B. Kiktev, I. V. Trosnikov, M. A. Tolstykh, and R. B. Zaripov, "Assessments of successful forecasts of seasonal anomalies in meteorological fields for the SL_AV model in the the SMIP_2 experiment," Meteorol. Gidrol., No. 6, 16–26 (2006)

Tolstyh M.A., N.A. Diansky, A.V. Gusev, D.B. Kiktev Simulation of seasonal anomalies of atmospheric circulation using coupled ocean-atmosphere model, Izv.,Atmos. Ocean. Phys. **50** (2), 131–142 (2014).

Annex 5: Record of GPC system upgrades

GPC's system specifications (updated 2016)

GPC name (last update)	Centre	System Configuration (ensemble size of forecast)	Resolution (atmosphere)	Hindcast period used
Beijing (2005, 2015)	Beijing Climate Centre	Coupled (48) Coupled (24)	T63/L16 T106/L26	1983-2004 1991-2013
CPTEC (2009)	Centre for Weather Forecasts and Climate Studies	2-tier (15)	T62/L28	1979-2001
ECMWF (2010)	European Centre for Medium range Weather Forecasts	Coupled (41) Coupled (51)	T159/L62 T255/L91	1981-2005 1981-2010
Exeter (2010, 2012)	Met Office Hadley Centre	Coupled (42)	1.85°x1.25°/L38/L85 0.83°x 0.56°/L85	1989-2002 1996-2009
Melbourne (2010, 2015)	Australian Bureau of Meteorology	Coupled (30) Coupled (99) Coupled (165)	T47/L17	1980-2006 1961-2010 1981-2010
Montreal (2010)	Meteorological Service of Canada	2-tier (40) Coupled (20)	T32/T63/T95/2.0°x2.0° (4model combination) CanCM3+CanCM4 T63/L31 and T63/L35	1969-2004 1981-2010
Moscow (2007, 2010)	Hydromet Centre of Russia	2-tier (10) 2-tier (20)	1.1°x1.4°/L28	1979-2003 1981-2010
Pretoria (2007, 2015)	South African Weather Service	2-tier (6) Coupled (40)	T42/L19	1983-2001 1982-2009
Seoul (1999, 2010, 2012, 2014)	Korean Meteorological Administration	2-tier (20) Coupled (42)	T106/L210.83°x 0.56°/L85	1979-2007 1979-2010 1979-2012 1996-2009
Tokyo (2010, 2012, 2015)	Japan Meteorological Agency	Coupled (51)	T95/L40 T159/L60	1979-2008 1979-2010 1979-2015
Toulouse (2008) (2013, YEAR?)	Météo-France	Coupled (41) Coupled (51)	T63/L91 T127/L31 T255L91?	1979-2007 1991-2010
Washingto	National Centres	Coupled (40)	T62/L64	1981-2004

n (2004, 2010)	for Environmental Prediction		T126/L64	1981-2010

Table 1: System changes reported at the 2012 (Geneva) meeting (red), at the 2014 (Exeter) meeting (blue) and at the 2016 (Beijing) meeting (green). Note: latest configurations may be viewed at http://www.wmolc.org

Annex 6:
STATUS / PROGRESS REPORT FOR LC-LRFMME SUBSEASONAL REAL-TIME PILOT

1. INTRODUCTION

The WMO and many operational centers realized the necessity of international collaborations to improve the predictability on the sub-seasonal time-scale. In 2011, Cg-XVI requested the LC-LRFMME to explore the possibility of extending its role to include exchange of extended range predictions, and invited GPCs to also provide data from their monthly forecast systems so that the LC-LRFMME would be able to provide sub-seasonal forecast products through the LC-LRFMME web pages. The expert meeting of ET-ELRF in 2012 prepared a minimum list of variables based on the minimum products list for seasonal forecast exchange and extended to include the MJO diagnostics particularly relevant to the sub-seasonal range. The extraordinary meeting of the Implementation Coordination Team of the Open Programme Area Group (OPAG) for the DPFS (ICT-DPFS) in 2013 set up a Task Team (ST3) under the CBS ET-OPSLS to scope the implementation of real-time sub-seasonal forecasts, and to establish the necessary links with the WWRP-THORPEX/WCRP research project on sub-seasonal to seasonal prediction (S2S).

In December 2015, the pilot real-time sub-seasonal MME prediction system was developed with agreed subset of S2S models. Currently, WMO LC-LRFMME is downloading the real-time data of GPC ECMWF, Exeter (UKMO), Washington (NCEP/CPC) and Tokyo (JMA) from the ECMWF S2S archive and producing MME products on a regular basis. Displays in the website of WMO LC-LRFMME are available about a week delayed date from starting date of MME prediction, because of the time required for data collection. This report describes main features of sub-seasonal MME prediction system and its website for display of MME products.

2. OPERATIONAL SET UP: PILOT REAL-TIME SUB-SEASONAL MME PREDICTION

This section describes the operational set up of pilot MME prediction system.

2.1 Getting data

- How to get the data: Access to ECMWF S2S archive
- Variables: SST, T2m, precipitation, u200, v200, u850, and OLR
- Frequency of model output: Daily model output
- Data types: Full fields of both forecast and hindcast (reforecast)
- Participating Models: ECMWF, UKMO, JMA, NCEP/CPC (Note: KMA will be included soon.)

2.2 Deriving the multi-model

The ensemble initialization for the multi-model is described in Figure 1. For simplicity, we select an optimal issuing date of ‘Wednesday’ in order to minimize lead-times of individual models. And, then The first four weeks (i.e. Thursday to Wednesday) of each forecast ensemble member are time averaged into 5 forecast lead times: Period 1 (forecast week 1, days 1 to 7), Period 2 (forecast week 2, days 8 to 14), Period 3 (forecast week 3, days 15 to 21), Period 4 (forecast week 4, days 22 to 28), Period 5 (forecast weeks 3 and 4, days 15 to 28) and Period 6 (forecast weeks 1 to 4, days 1 to 28) are averaged together from daily data. Because initialization dates of individual models are slightly different as shown in Figure 1, forecast time ranges of each model are also different as in Table 1. To estimate the model’s climatological distribution at each forecast start date, the same hindcast start dates (ECMWF and Washington) or the closest hindcast start dates (Tokyo and Exeter) are chosen for the common period 1999 to 2009 as in Table 2.

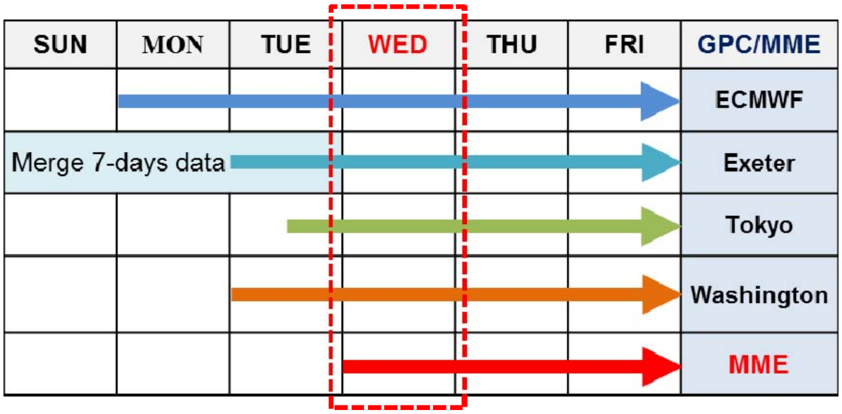


Figure 1. The issue timing of sub-seasonal prediction for 4 GPCs and MME (Red).

Table 1. Characteristics of sub-seasonal prediction systems of participating Centres

Center	Forecast Frequency	Forecast Time range	Forecast Ens. Size	Hindcast Frequency	Hindcast Ens. Size	Hindcast length
ECMWF	2/week (Mon,Thu)	0-46 days	51	2/week (Mon, Thu)	11	1996-2015 (Past 20 years)
Tokyo (JMA)	2/week (Tue,Wed)	0-34 days	25	3/month (10/20/last day)	5	1981-2010
Washington (NCEP/CPC)	Daily	0-44 days	16	Daily	4	1999-2010
Exeter (UKMO)	Daily	0-60 days	4	4/month (1,9,17,25 day)	3	1996-2009

Table 2. Inputs of sub-seasonal MME prediction system

Center	Forecast Init. date	Forecast Time range	Forecast Ens. Size	Hindcast Init. Date	Hindcast Ens. Size	Hindcast length
ECMWF	Mon	3-30 days	51	Same date as fcst	11	1999-2009
Tokyo	Tue	2-29 days	25	Closest date to fcst	5	1999-2009
Washington	Tue	2-29 days	16	Same date as fcst	4	1999-2009
Exeter	Last Wed - Tue	2(8)-29(35) days	28 (4x7)	Closest date to fcst	3	1999-2009

2.3 Producing probabilistic MME prediction: 2-m air temperature and precipitation

The parametric estimation approach is adopted to produce probabilistic forecast. When defining tercile boundaries, a theoretical distribution is assumed as Normal distribution for 2-m air temperature and Gamma distribution for precipitation. And then forecast probabilities are calculated with a distribution of forecast ensemble compared to hindcast distribution. Probabilistic MME (PMME) is produced in the form of tercile-based categorical probabilities: the below-normal (BN), near-normal (NN) and above-normal (AN) categories with respect to climatology, where the tercile boundaries are defined at each grid point.

Meanwhile, there is alternative method to generate probabilistic forecast, which is non-parametric estimation method, so called "Ranking and counting method". When defining tercile boundaries, hindcast data are ranked with ascending order and values of 1/3 and 2/3 boundaries are determined by averaged value between biggest value of lower boundary and smallest value of upper boundary. And then, forecast probabilities are calculated with counting the number of forecast ensemble based on two tercile-boundary values. This method is free of variable's distribution properties and easy to understand, but strongly influenced by local characteristics. We had investigated the sensitivity of two estimation method on skill of global probabilistic forecast. The results indicated that, in case of temperature, two methods showed almost similar probabilistic forecast and its skill scores are also no significant difference (not shown here). In case of precipitation, general features are similar between both methods, but there are two advantages in parametric estimation method compared with non-parametric method. First, non-parametric estimation method cannot determine appropriate two boundary values in extremely dry regions, such as a desert area, but, parametric estimation method can produce it (Fig. 2). Because two boundary values in extremely dry regions are equal values of "zero", we cannot determine categories of each forecast ensembles. Of course, there are different viewpoints on how to treat forecast category in extremely dry regions. But, because the primary purpose of MME prediction of WMO LC-LRFMME is to provide global prediction data, we choose a parametric estimation method that can produce forecast values over whole globe. Second, skills of probabilistic forecast using a parametric estimation method are slightly better than those of a non-parametric method (Fig. 3).

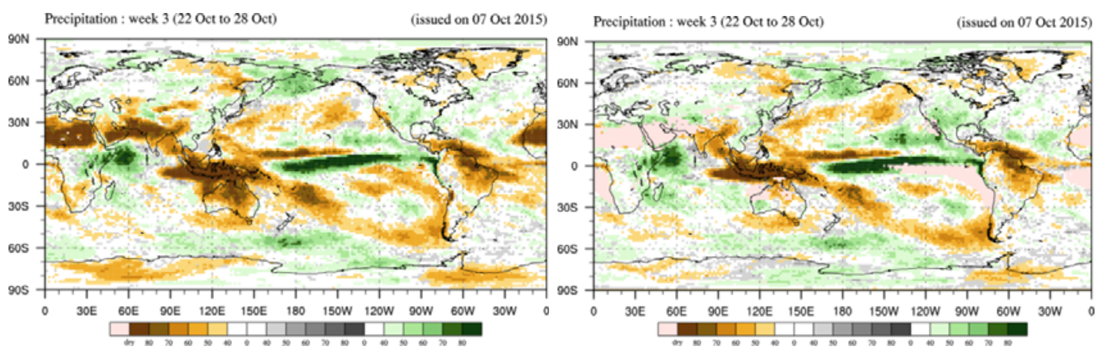


Figure 2. Probabilistic forecast of precipitation using parametric estimation method (left) and non-parametric estimation method (right) for week-3 forecast issued 7th October 2015. In the result from non-parametric method, grid points that cannot be determined to a specific tercile category are shaded by pale pink color.

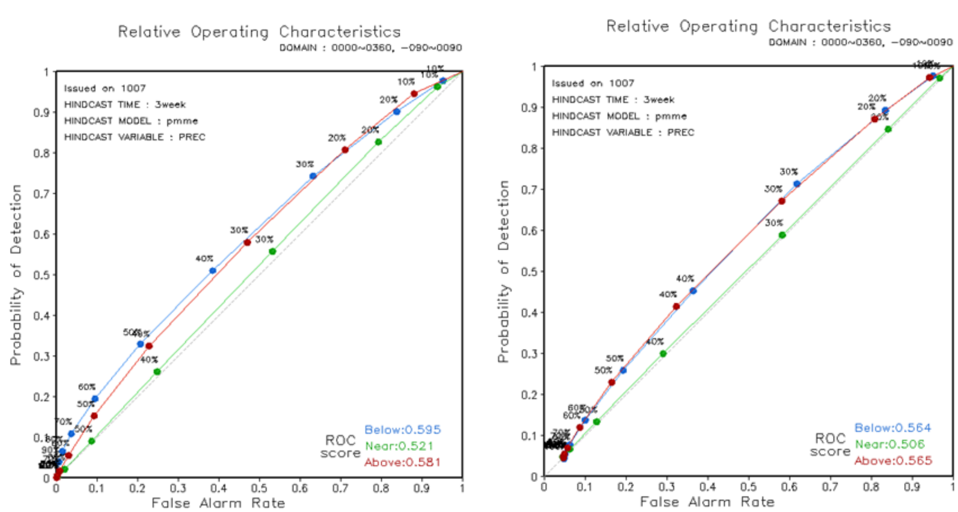


Figure 3. Relative operating characteristics (ROC) score over globe of probabilistic forecast of precipitation using parametric estimation method (left) and non-parametric estimation method (right) for week-3 forecast issued 7th October 2015.

2.4 Producing deterministic MME prediction: MJO/BSISO and Atmospheric circulation

The deterministic MME (DMME) forecast is constructed with the simple arithmetic mean, which is equal-weighting average so that the contribution of each single-model is equal.

2.4.1 Madden-Julian Oscillation (MJO)

The MJO index follows closely that developed by Wheeler and Hendon (2004). The input data for this index are latitudinally-averaged (15°S-15°N) fields of zonal winds at the 850 hPa and 200 hPa levels, and outgoing longwave radiation. After some pre-processing procedures proposed by Gottschalck (2010), these fields are projected onto a pair of observationally-derived global structures of the MJO, giving a pair of numbers to measure its state each day, called the Real-time Multivariate MJO (RMM) indices (RMM1 and RMM2).

2.4.2 Boreal Summer Intraseasonal Oscillation (BSISO)

The BSISO index developed by Lee et al. (2013) is adopted. This index is similar to the RMM indices of Wheeler and Hendon (2004), except that the focus is on the intraseasonal variability that is specific to the Asian monsoon region (10.5°S-40.5°N, 39°E-160.5°E). Two propagating modes, each comprising a pair of multivariate EOF, are respectively called BSISO1 and BSISO2. BSISO1 captures the canonical northward-propagating BSISO component and BSISO2 captures the higher-frequency pre-monsoon and onset component. Compared to the MJO monitoring and prediction activity, which uses only latitudinally-averaged data, the BSISO indices require latitude-longitude grids of outgoing longwave radiation and 850-hPa zonal wind.

3. WEBSITE DESIGN

New 'subseasonal' menu are developed in WMO LC-LRFMME website (http://www.wmolc.org). Currently, this content is protected with password. There are 4 sub-menus: Information, data exchange, plot and verification.

- Information: MME configuration and information about adopted methods.
- Data exchange: daily MME raw data in format of grib
- Plot: prediction graphics of PMME and DMME
- Verification: verification graphics using hindcast data for DMME and PMME

4. VERIFICATION: PRELIMINARY RESULTS

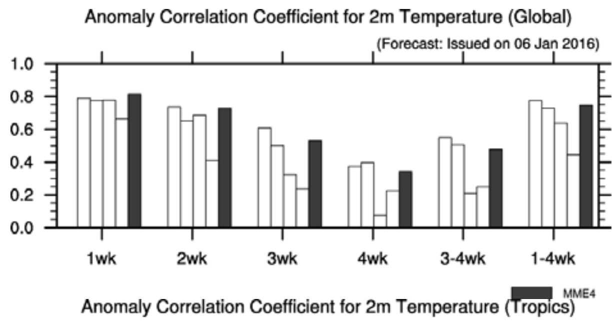
For assessment of benefits of multi-model ensemble approach, forecast skills of between individual model and MME were compared. We selected January 2016 case, because there are strong cold spells over Europe, East Asia and eastern North America.

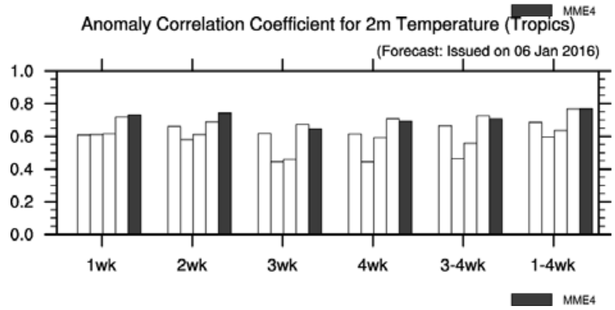
Preliminary results show that forecast skills of deterministic MME (simple averaged MME) in both real-time forecast and hindcast dataset are similar with those of best model, but skills of probabilistic MME are better than best model.

However, further evaluation with sufficient samples is needed to get more robust assessment.

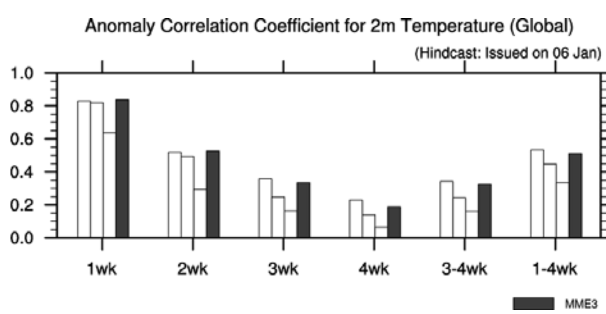
4.1 Deterministic forecast: Anomaly pattern correlation over globe and Tropics

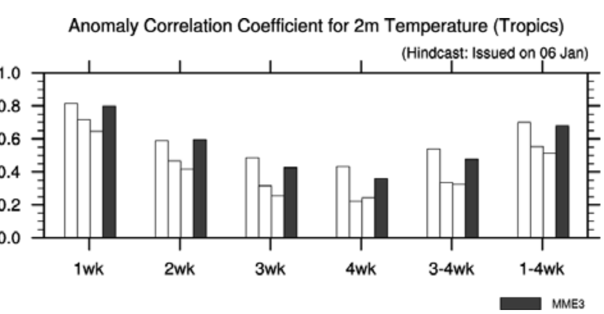
- Forecast issued on 6th January 2016 (2m air temperature)
- ECMWF, Tokyo, Washington, Exeter and MME results





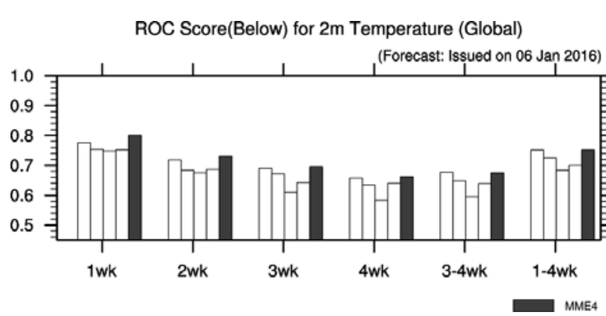
- Hindcast (6th January for 1999-2009) corresponded to forecast of 6th January 2016
- ECMWF, Washington, Exeter and MME results

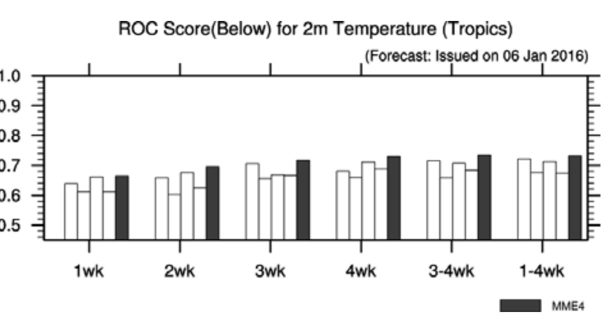




4.2 Probabilistic forecast: ROC score over globe and Tropics

- Forecast issued on 6th January 2016 (2m air temperature)
- ECMWF, Tokyo, Washington, Exeter and MME results





- Hindcast (6th January for 1999-2009) corresponded to forecast of 6th January 2016
- ECMWF, Washington, Exeter and MME results
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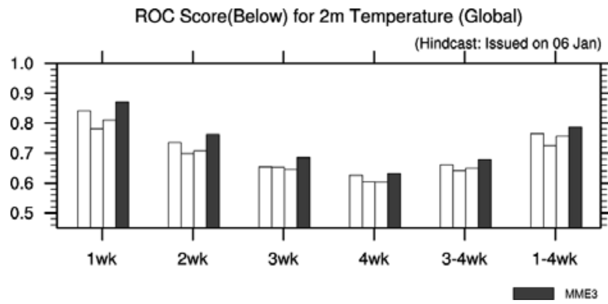

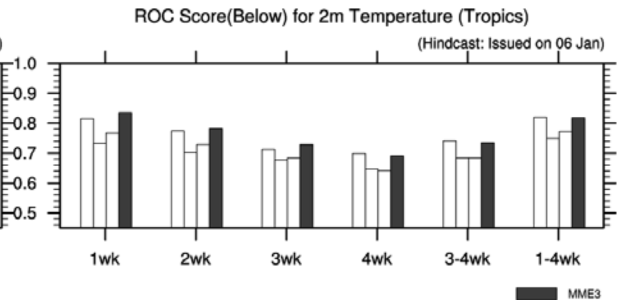

5. FUTURE PLANS TO BE DISCUSSED

There are necessary steps to move to the operational phase.

5.1 Improvement of usefulness

- Change 'week' range in forecast: From 'Thursday to Wednesday' to 'Monday to Sunday (Calendar week)'
- Expand forecast period: From '4 weeks' to '6 weeks (for available model)'

5.2 Development of additional products

- Graphical products for Individual model results
- Deterministic forecast (forecast anomalies) for 2m air temperature and precipitation
- New variables: 500hPa geopotential height, Mean sea level pressure, 850hPa wind
  - ✓ Note that it means we have to agree adding 'Z500, MSLP and v850' in exchange variables.

5.3 Improvement of user conveniences for use of web site

- Multiple 'pop-up window' function
- Consistency in web-page design, etc.

5.4 Satisfaction of timeliness

- Currently, sub-seasonal forecast products by LC-LRFMME are available on 1-week delayed date from issuing date of MME prediction, because of the time required for data collection from ECMWF S2S archive. Therefore, alternative approach to reduce a data-collection time should be investigated to move to the operational phase.

6. MILESTONE

- February 2016: Start to be reviewed by WMO CBS/CCl ET-OPSLS
- April 2016: Discussion in the meeting of ET-OPSLS
- December 2016: Improvement of sub-seasonal MME system and website

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Annex 7:
Questionnaire results on subseasonal verification practices in operational centers

1. Introduction

This document summarizes the responses of GPCs to the questionnaire on subseasonal verification practices in operational centres sent to all GPCs in advance of the ET-OPSLS meeting, Beijing 11-15 April 2016. The questionnaire, which is enclosed in the annex at the end of this document, was designed to support verification research activities of the WWRP/WCRP Subseasonal to Seasonal (S2S) prediction project, which has linkages with Joint CBS-CCl Expert Team on Operational Predictions from Sub-seasonal to Longer-time Scale (ET-OPSLS) activities on subseasonal forecasts through Task Team 3 (ST3): Development of sub-seasonal forecasts.

The purpose of the questionnaire was to share current practices used by operational centres to verify subseasonal forecasts (both for operations and research) and also help identify gaps and guide novel developments.

The questionnaire was designed in six sections. The following section presents a summary of GPCs responses for each of the six sections, prepared by the S2S sub-project on Verification and Products, to help guide S2S verification research activities and for discussion with ET-OPSLS.

2. Summary of GPCs responses for each of the six sections of the questionnaire

2.1 Section 1: Identification

In the first section of the questionnaire respondents were asked to provide identification and information about their organization. All 12 GPCs responded the questionnaire, providing a complete and updated set of information about the current practices used by operational centres to verify subseasonal forecasts.

2.2 Section 2: Verification documentation of S2S systems

In the second section of the questionnaire respondents were asked to provide documentation where verification information in terms of forecast quality assessment of their S2S forecast systems is available. Respondents provided various documentation information including peer reviewed journals, conference/workshop publications/presentations, technical reports and websites where verification information about their S2S forecast systems is disseminated. The responses indicated that subseasonal forecast verification is well established in some GPCs but is still an under development activity for a large number of GPCs.

2.3 Section 3: Reference verification datasets

In the third section of the questionnaire respondents were asked to provide information about reference verification datasets used for assessing forecast quality of their subseasonal retrospective forecasts (reforecasts; hindcasts). GPCs indicated the use of a variety of datasets for the verification of their subseasonal forecasts including reanalysis products, satellite estimates and station data. Below is a summary of responses provided by GPCs indicating the used datasets for verification of subseasonal hindcasts in terms of different parameters:

<u>Atmospheric parameters (e.g. geopotential height, temperature, SLP, etc)</u>

- NCEP/NCAR Reanalysis 1 (http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html)

- NCEP-DOE Reanalysis 2 (http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis2.html)
- ECMWF era-interim and the operational analysis for the most recent months for which era-interim is not available (http://apps.ecmwf.int/datasets/data/interim-full-daily/)

- JRA-55 reanalysis: http://jra.kishou.go.jp/

Oceanic parameters (e.g SST, subsurface temperature, etc.)

- NOAA Optimum Interpolation (OI) Sea Surface Temperature (SST) V2 (http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html)
- NOAA Optimum Interpolation (OI) Sea Surface Temperature (SST) V2 High Resolution Dataset (http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.highres.html)
- NCDC daily OI SST analysis https://www.ncdc.noaa.gov/oisst
- Era-interim SST (http://apps.ecmwf.int/datasets/data/interim-full-daily/)
- Extended Reconstructed Sea Surface Temperature (ERSST): https://www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v3b
- Sub-surface ocean parameters: Global Ocean Data Assimilation System (GODAS) products http://www.cpc.ncep.noaa.gov/products/GODAS/

Precipitation and other parameters such as near surface temperature, wind, etc

- CPC Merged Analysis of Precipitation (CMAP) Pentad Dataset (http://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html)
- ECMWF short term forecasts (precipitation), era-interim and the operational analysis for the most recent months for which era-interim is not available (http://apps.ecmwf.int/datasets/data/interim-full-daily/): Precipitation, surface temperature and surface wind
- FEWS-NET ARC2 blended gauge satellite data and TRMM to validate predictions of onset timing
- NCEP/NCAR reanalysis precipitation dataset: http://www.esrl.noaa.gov/psd/cgi-bin/db_search/DBSearch.pl?Dataset=NCEP+Reanalysis+Daily+Averages+Surface+Flux&Variable=Precipitation+rate
- Global Precipitation Climatology Project (GPCP) version 2 dataset: http://precip.gsfc.nasa.gov/
- Climate Anomaly Monitoring System (CAMS) and OLR Precipitation Index (OPI), CAMS-OPI monthly mean precipitation: http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cams_opi.html
- Global Historical Climate Network (GHCN) Climate Anomaly Monitoring System (CAMS) monthly mean surface temperature: http://www.esrl.noaa.gov/psd/data/gridded/data.ghcncams.html
- UK station data aggregated to UK climate regions (precipitation, maximum and minimum temperature)
- Australian region local high-quality rainfall and temperature datasets described at Jones DA, Wang W, Fawcett R. (2009) High–quality spatial climate data–sets for Australia. *Australian Meteorological and Oceanographic Journal*. 58:233–248.
- NOAA outgoing long-wave radiation (OLR) and 850 and 200 hPa zonal winds from NCEP/NCAR reanalysis used for MJO indices RMM1 and RMM2.

2.4 Section 4: Reforecast setting

In the fourth section of the questionnaire respondents were asked to provide information about reforecast setting of their subseasonal forecast systems. Table 1 shows the diverse configuration of GPCs subseasonal forecast systems reforecasts in terms of reforecast period, reforecast initial dates and number of reforecast ensemble members, illustrating the challenge for performing forecast verification intercomparison assessments.

	Reforecast period	**Reforecast initial dates**	**Number of reforecast ensemble members**
GPC Beijing	1994-2014	every day	4 for each initial date
GPC CPTEC	To be defined	To be defined	To be defined
GPC ECMWF	The most recent 20 years	Twice per week	11
GPC Exeter	1996-2009 (soon to be 1993-2015)	1st; 9th; 17th and 25th of each month	3 for each initial date
GPC Melbourne	1981-2010	1, 6, 11, 16, 21, 26	33
GPC Montreal	1995-2014	Date of Thursday of the current forecast	4
GOC Moscou	1981-2010	Every week on Wednesday	10
GPC Pretoria	2000-2013	04th , 11th , 18th and 25th (flexible for change)	24 (4x daily)
GPC Seoul	1996-2009 (1991-2010 from May2016)	1st; 9th; 17th and 25th of each month	3 for each initial date
GPC Tokyo	1981-2010	10th, 20th and end of month of each month	5 for each initial date
GPC Toulouse	1993-2014	1st and 15th of each month	15 for each initial date
GPC Washington	1999-2010	Daily	4/day

Table 1: Configuration of GPCs subseasonal forecast systems reforecasts in terms of reforecast period, reforecast initial dates and number of reforecast ensemble members.

In terms of time averaging the questionnaire revealed some GPCs verify reforecast weekly, monthly and week 3-4 (2nd forthnight) averages, but the definition of averaging period is slightly different among GPC (e.g. week 1 is either defined as day 2 to 8 or day 1 to 7 by different GPCs). Table 2 summarizes the number of GPCs indicating the averaging period for which their reforecasts are verified. The relatively small number of GPCs (6 or less) indicating the practice of verifying weekly, monthly and week 3-4 (2nd forthnight) averages suggests that verification procedures for these averaging periods still need to be adopted and consolidated by several GPCs.

Averaging period	**Number of GPCs**
Week 1	5
Week 2	6
Week 3	4
Week 4	4
Monthly	5
Week 3-4 (2nd forthnight)	3

Table 2: Number of GPCs indicating the averaging period for which their reforecasts are verified.

Some GPCs reported that the procedure for generating daily information prior to producing weekly and monthly averages for verifying subseasonal reforecasts depends on the variable of interest. Table 3 summarizes the number of GPCs indicating averaging procedures prior to producing weekly and monthly averages.

Averaging procedure	**Number of GPCs**
Daily information is generated by averaging hourly instantaneous fields for 24 hours	1
Daily information is generated by averaging 6-hourly instantaneous fields at 00, 06, 12 and 18 UTC	4
Daily information is output directly by the forecast model	1
Averaging all instantaneous fields at every time-step	1
Depends on the field/variable.	2

Table 3: Number of GPCs indicating the averaging procedure prior to producing weekly and monthly averages.

The questionnaire also requested GPCs to indicate which model parameters of their subseasonal reforecasts were verified. Table 4 summarizes GPCs responses to this question. The most common variables verified by most GPCs are 500 hPa Geopotential Height, 2 metre temperature and precipitation.

Variable	**Number of GPCs**
500 hPa Geopotential Height	9
Sea level pressure	6
850 hPa temperature	4
2 metre temperature	9
Precipitation	9
200 hPa Velocity potential	2
200 hPa Stream function	2
Surface temperature	1

Table 4: Number of GPCs indicating which model parameters are verified in their subseasonal reforecasts.

In terms of spatial resolution Table 5 shows that most GPCs verify their subseasonal reforecasts at either 2.5 by 2.5 or 1.5 by 1.5 degrees in latitude and longitude.

Spatial resolution	**Number of GPCs**
2.5 by 2.5 degrees in latitude and longitude	5
1.5 by 1.5 degrees in latitude and longitude	4
1.0 by 1.0 degrees in latitude and longitude	1
At model grid	1

Table 5: Number of GPCs indicating at which spatial resolution their subseasonal reforecasts are verified.

Table 6 summarizes the spatial domain for which GPC subseasonal reforecasts verification products are displayed. A total of 8 GPCs display their products globally, and a reduced number of GPCs (3 or less) display regionalized products over selected continental regions where they are located.

Spatial domain	**Number of GPCs**
Global	8
Africa	
Asia	3
Europe	3
South America	
North America	2
Oceania	1
Tropics	3
Southern Hemisphere	3
Northern Hemisphere	4
Artic region	1

Table 6: Number of GPCs indicating which spatial domain their subseasonal reforecasts verification products are displayed.

2.5 Section 5: Verification metrics

In the fifth section of the questionnaire respondents were asked to provide information about verification metrics used to assess forecast quality of their subseasonal forecast systems.

Table 7 shows which deterministic metrics are used by GPCs to assess forecast quality and biases of their subseasonal reforecasts. The most commonly used deterministic metrics are mean bias, correlation between forecast and observed anomalies and RMSE (or MSE).

Deterministic metrics	**Number of GPCs**
Mean bias (map displaying model climate minus observed climate)	8
Variability bias (map displaying model standard deviation (or variance) divided by observed standard deviation (or variance))	2
Correlation between forecast and observed anomalies displayed as a map	8
Root mean squared error (RMSE) or mean squared error (MSE) displayed as a map	7
Mean squared error skill score (MSSS) displayed as a map	5

Table 7: Number of GPCs indicating which deterministic metrics are used for assessing forecast quality and biases of their subseasonal reforecasts.

Table 8 summarizes which events are assessed by GPCs when investigating probabilistic forecast quality of their subseasonal reforecasts. The most commonly used events are 3 categories (tercile probabilities) as traditionally used in seasonal forecasting.

Events	**Number of GPCs**
2 categories (above/below median or mean)	2

3 categories (above normal, near normal, below normal)	10
Quintile categories	2
Probability of exceedance	1

Table 8: Number of GPCs indicating which events are assessed when investigating probabilistic forecast quality of their subseasonal reforecasts.

Table 9 shows which probabilistic metrics are used by GPCs when investigating probabilistic forecast quality of their subseasonal reforecasts. The most commonly used probabilistic metrics are reliability diagrams, ROC curves, area under ROC curve and the Brier score, all commonly used when assessing seasonal forecasts.

Probabilistic metrics	**Please indicate Y/N**
Reliability diagrams	8
Brier score	7
Reliability, resolution and resolution components of the Brier score	5
Continuous Ranked Probability Score (CRPS)	3
ROC curves[1]	6
Area under ROC curve displayed as a map	8
Ignorance score	1
Hanssen-Kuipers score	1
Heidke Skill Score	1

Table 9: Number of GPCs indicating which probabilistic metrics are used to assess forecast quality of their subseasonal reforecasts.

Table 10 summarizes which regional and large scale indices are used by GPCs when investigating forecast quality of their subseasonal reforecasts. Large scale teleconnection indices are assessed by 6 GPCs and regional average indices are assessed by 4 GPCs, suggesting that such assessment still needs to be considered for adoption and consolidation by a number of GPCs.

Indices	**Number of GPCs**
Teleconnection indices	6
Regional average indices	4

Table 10: Number of GPCs indicating which regional and large scale indices are used to assess forecast quality of their subseasonal reforecasts.

Table 11 shows which intraseasonal oscillation indices are used by GPCs when investigating forecast quality of their subseasonal reforecasts. The real-time multivariate MJO index is used by 8 GPCs and the boreal summer intraseasonal oscillation index is used by 4 GPCs. One GPC indicated that the real-time multivariate MJO index is used for monitoring purposes but is not operationally verified.

Intraseasonal oscillation indices	**Number of GPCs**
Real-time Multivariate Madden and Jullian Oscillation (MJO) index	8
Boreal Summer Intraseasonal Oscillation (BSISO) index	4

Table 11: Number of GPCs indicating which intraseasonal oscillation indices are used to assess forecast quality of their subseasonal reforecasts.

Table 12 summarizes which verification indices and/or diagram/curve are used by GPCs when investigating forecast quality of extreme events in their subseasonal reforecasts. Reliability diagrams are used by only 3 GPCs, ROC curves are used by only 2 GPCs and EFI is currently being investigated by a single GPC, illustrating that verification of extreme events is an area that deserves more attention for an adequate forecast quality assessment of these events.

Indices and/or diagram/curve for assessing forecast quality of extreme events	**Number of GPCs**
Reliability diagrams for events in the 90th and 10th percentiles (or similar thresholds)	3
ROC curves for events in the 90th and 10th percentiles (or similar thresholds)	2
Extreme forecast index (EFI) and/or its weighted version EFIR	1
Extremal dependence indices (e.g. EDI and SEDI)	0

Table 12: Number of GPCs indicating which indices and/or diagram/curve are used to assess forecast quality of extremes in their subseasonal reforecasts.

2.6 Section 6: Tailored products verification

In the sixth section of the questionnaire respondents were asked to provide information about verification of tailored products when assessing forecast quality of their subseasonal forecast systems.

Table 13 shows which sector specific verification quantities are used by GPCs when investigating forecast quality in their subseasonal reforecasts. Frequency of heat-wave days and frequency of cold-wave days is assessed by a single GPC. Frequency of heavy rain days is under development by a single GPC, and frequency of heat-wave is also under development by a single GPC. Another GPC reported that is currently investigating predictability of heat and cold waves. These results illustrate that sector specific verification is an area that deserves more attention for a more comprehensive forecast quality assessment of sector specific quantities.

Sector specific verification quantities	**Number of GPCs**
Frequency of heavy rain days	1 (under development)
Frequency of no-rain days	0
Frequency of heat-wave days	1 (under development by another GPC)
Frequency of cold-wave days	1
Cluster of heavy rain days (e.g. probability of n consecutive days of heavy rain)	0
Cluster of no-rain days (e.g. probability of n consecutive days of no-rain)	0
Cluster of heat-wave days (e.g. probability of n consecutive days with temperature above a high threshold)	0
Cluster of cold-wave days (e.g. probability of n consecutive days with temperature below a low threshold)	0
Predictability of heat and cold waves	1

Table 13: Number of GPCs indicating which sector specific verification quantities are used to assess forecast quality of their subseasonal reforecasts.

Forecast quality assessment of active and break rainfall phases and wet/dry spells was reported by a single GPC based on research experience with seasonal (not sub-seasonal) forecasts by the use of correlation of the ensemble mean number of rain days (no-rain days).

Forecast quality assessment of rainy season onset and demise was reported by the same single GPC as being performed based on experience gained with seasonal forecasts by using a tercile description (early/average/late) and generating ROC scores for probabilistic forecasts – calculating the onset tercile category for each member.

3. Summary and final considerations

The questionnaire responses are summarized as follows :

- All 12 WMO GPCs responded the questionnaire providing a timely update on current practices used by operational centres for verifying subseasonal forecasts.
- The responses indicated that subseasonal forecast verification is well established in some GPCs but is still an under development activity for a large number of GPCs, contrasting with verification of seasonal forecasts that is a well established activity (guided by SVSLRF) in all 12 GPCs.
- GPCs indicated the use of a variety of datasets for the verification of their subseasonal forecasts including reanalysis products, satellite estimates and station data.
- The diverse configuration of GPCs subseasonal forecast systems, in terms of reforecast period, reforecast initial dates and number of reforecast ensemble members, illustrated the challenge for performing forecast verification intercomparison assessments.
- The relatively small number of GPCs (6 or less) indicating the practice of verifying weekly, monthly and week 3-4 (2nd forthnight) averages suggested that verification procedures for these averaging periods still need to be adopted and consolidated by several GPCs.
- The most common subseasonal forecast variables verified by most GPCs were found to be 500 hPa Geopotential Height, 2 metre temperature and precipitation, the latter two generally considered of great relevance for a number of societal applications.
- Most GPCs indicated to verify their subseasonal reforecasts at either 2.5 by 2.5 or 1.5 by 1.5 degrees in latitude and longitude, although the original model configuration may be able to output forecasts at a more refined spatial resolution.
- A total of 8 GPCs indicated to display their subseasonal forecast products globally, and a reduced number of GPCs (3 or less) indicated to display regionalized products over selected continental regions where they are located and therefore have a particular regional interest.
- The most commonly used deterministic metrics by GPCs when assessing subseasonal forecasts were found to be mean bias, correlation between forecast and observed anomalies and RMSE (or MSE).
- The most commonly used events by GPCs when assessing subseasonal forecasts were found to be 3 categories (tercile probabilities) as traditionally used in seasonal forecasting.
- The most commonly used probabilistic metrics by GPCs when assessing subseasonal forecasts were found to be reliability diagrams, ROC curves, area under ROC curve and the Brier score, all commonly used when assessing seasonal forecasts.
- Large scale teleconnection indices were indicated to be assessed by 6 GPCs and regional average indices by 4 GPCs, suggesting that such assessment still needs to be considered for adoption and consolidation by a number of GPCs.
- The real-time multivariate MJO index was indicated to be used by 8 GPCs and the boreal summer intraseasonal oscillation index by 4 GPCs. One GPC indicated that the real-time multivariate MJO index is used for monitoring purposes but is not operationally verified, suggesting room for improved verification practices of the MJO, including the development of appropriate verification approaches for this purpose.
- Forecast quality assessment of extreme events in subseasonal reforecasts were found to be performed using reliability diagrams by only 3 GPCs, ROC curves by only 2 GPCs

and EFI by a single GPC, illustrating that verification of extreme events is an area that deserves more attention for an adequate forecast quality assessment of these events.
- Sector specific verification (tailored products) was found to be address by a very limited number of GPCs, illustrating that this is an area that deserves more attention for a more comprehensive forecast quality assessment of sector specific quantities.
- Forecast quality assessment of active and break rainfall phases, wet/dry spells, rainy season onset and demise was reported by a single GPC as a research initiative, suggesting also that this is an area that deserves more attention.

The purpose of the questionnaire was to share current practices used by operational centres to verify subseasonal forecasts (both for operations and research) and also help identify gaps and guide novel developments. Although some GPC responses mentioned both operational and research verification practices, the overall summary of responses is likely to be more heavily weighted towards operational activities, with some subseasonal forecast verification research practices performed by some GPCs not necessarily fully incorporated. An interesting aspect that deserves consideration is the distinct possible approaches for subseasonal verification, namely verification of real-time forecasts, verification of reforecasts and verification of outlooks, the latter being an official forecast produced by combining model forecast and expert judgment information. One GPC indicated the common practice of assessing forecast quality of subseasonal outlooks because this is considered the official subseasonal forecast information disseminated to the public. Another GPC indicated that forecast quality assessment of subseasonal operational forecasts is based on verification of the real-time forecasts in line with the practice currently used in numerical weather prediction. For this GPC the assessment of reforecasts is mainly used for diagnostic and predictability studies due to the reduced number of ensemble members in reforecasts when compared to real-time forecasts.

Although the questionnaire was designed to address verification of subseasonal reforecasts, the title of the questionnaire "Questionnaire on subseasonal verification practices in operational centres" might have caused some confusion when contrasted with the focus of the questions on reforecast (model) data verification.

Questionnaire:
Questionnaire on subseasonal verification practices in operational centers

You have received this questionnaire as a World Meteorological Organization (WMO) Global Producing Centre of Long-Range Forecasts (GPC). The questionnaire is designed to support verification research activities of the WWRP/WCRP Subseasonal to Seasonal (S2S) prediction project.

The purpose of the questionnaire is to share current practices used by operational centres to verify subseasonal forecasts (both for operations and research) and also help identify gaps and guide novel developments. Responses will be summarised by the S2S sub-project on Verification and Products to help guide S2S verification research activities and shared with the Joint CBS-CCl Expert Team on Operational Predictions from Sub-seasonal to Longer-time Scale (ET-OPSLS).

Please return the questionnaire by 11 March 2016 to: Caio Coelho (caio.coelho@cptec.inpe.br) with copy to Richard Graham (richard.graham@metoffice.gov.uk) and Yuhei Takaya (ytakaya@met.kishou.go.jp).

Many thanks in advance for completing the questionnaire.

Questionnaire

Section 1: Identification

Q1. Identification and information on your organization

Country	
Name of your organisation	
Your name (optional)	
Your email address (optional)	

Section 2: Verification documentation of your S2S system

Q2. Please list in the space provided below all available references [e.g. peer reviewed journal publications (preferably), conference/workshop publications/posters/talks and/or technical reports] where the verification (forecast quality) of your S2S system is documented. If possible, please provide the URL where this documentation is available or send the electronic files (e.g. pdf files) containing these documents together with your response to this questionnaire.

Section 3: Reference verification datasets

Q3. Please indicate in the space provided below which reference verification reanalysis datasets are used to assess atmospheric parameters (e.g. geopotential height, temperature, SLP, etc.), of your subseasonal retrospective forecasts (reforecasts; hindcasts). Where available please also indicate below the URL where the used datasets are available and/or the URL or full reference where the datasets are documented (e.g. in peer reviewed journal publications):

Q4. Please indicate in the space provided below which reference verification datasets are used to assess oceanic parameters (e.g SST, subsurface temperature, etc.) of your subseasonal retrospective forecasts (reforecasts; hindcasts). Where available please also indicate below the URL where the used datasets are available and/or the URL or full reference where the datasets are documented (e.g. in peer reviewed journal publications):

Q5. Please indicate in the space provided below which reference verification datasets are used to assess precipitation and other parameters such as near surface temperature, wind, etc (if any different from answers provided in Q3 above) of your

subseasonal retrospective forecasts (reforecasts; hindcasts). Where available please also indicate below the URL where the used datasets are available and/or the URL or full reference where the datasets are documented (e.g. in peer reviewed journal publications):

Precipitation: **Other parameters (please specify the parameter and indicate dataset used for verification):**

Section 4: Reforecast setting

Q6. Please provide the following information about your subseasonal reforecast (hindcast)

	Response
Reforecast period (e.g. 1981-2010)	
Reforecast initial dates (e.g. 10th, 20th and end of month of each month)	
Number of reforecast ensemble members (e.g. 5 for each initial date)	

Q7. Please indicate if your centre verifies subseasonal reforecasts for the following time averaging:

	Please indicate Y/N
Weekly average for week 1 (e.g. day 2 to 8)	
Weekly average for week 2 (e.g. day 9 to 15)	
Weekly average for week 3 (e.g. day 16 to 22)	
Weekly average for week 4 (e.g. day 23 to 29)	
Monthly average (e.g. day 2 to 29)	
Other (please specify)	

Q8. Please indicate how your centre generates daily information prior to producing weekly and monthly averages for verifying subseasonal reforecasts:

	Please indicate Y/N
Daily information is generated by averaging hourly instantaneous fields for 24 hours	
Daily information is generated by averaging 6-hourly instantaneous fields at 00, 06, 12 and 18 UTC	
Other (please specify)	

Q9. Please indicate which model parameters of your subseasonal reforecasts are verified:

	Please indicate Y/N
500 hPa Geopotential Height	
Sea level pressure	
850 hPa temperature	

2 metre temperature	
Precipitation	
200 hPa Velocity potential	
200 hPa Stream function	
Others (please specify)	

Q10. Please indicate at which spatial resolution your subseasonal reforecasts are verified:

	Please indicate Y/N
2.5 by 2.5 degrees in latitude and longitude	
1.5 by 1.5 degrees in latitude and longitude	
Others (please specify)	

Q11. Please indicate for which spatial domain your subseasonal reforecasts verification products are displayed:

	Please indicate Y/N
Global	
Africa	
Asia	
Europe	
South America	
North America	
Oceania	
Tropics	
Southern Hemisphere	
Northern Hemisphere	
Others (please specify)	

Section 5: Verification metrics

Q12. Please indicate which deterministic metrics are used to assess forecast quality and biases of your subseasonal reforecasts:

	Please indicate Y/N
Mean bias (map displaying model climate minus observed climate)	
Variability bias (map displaying model standard deviation (or variance) divided by observed standard deviation (or variance))	
Correlation between forecast and observed anomalies displayed as a map	
Root mean squared error (RMSE[1]) or mean squared error (MSE) displayed as a map	
Mean squared error skill score (MSSS[1]) displayed as a map	
Other metrics (please specify)	

[1] Please see, Manual on the GDPFS, Volume 1, Part II, Attachment II.8. http://www.wmo.int/pages/prog/www/DPFS/Manual/documents/485_Vol_I_en.pdf

Q13. Please indicate for which events your subseasonal probabilistic reforecasts are assessed:

	Please indicate Y / N
2 categories (above/below median or mean)	
3 categories (above normal, near normal, below normal)	
Other events (please specify)	

Q14. Please indicate which probabilistic metrics are used to assess forecast quality of your subseasonal reforecasts:

	Please indicate Y / N
Reliability diagrams[1]	
Brier score	
Reliability, resolution and resolution components of the Brier score	
Continuous Ranked Probability Score (CRPS)	
ROC curves[1]	
Area under ROC curve displayed as a map	
Other metrics (please specify)	

Q15. Please indicate which regional and large scale indices are used to assess forecast quality of your subseasonal reforecasts:

	Please indicate Y / N
Teleconnection indices (if you answer is Y, please specify which indices are used in your centre)	
Regional average indices (if you answer is Y, please specify which indices are used in your centre)	

Q16. Please indicate which intraseasonal oscillation indices are used to assess forecast quality of your subseasonal reforecasts:

	Please indicate Y / N
Real-time Multivariate Madden and Jullian Oscillation (MJO) index[2]	
Boreal Summer Intraseasonal Oscillation (BSISO) index[3]	
Other indices (please specify)	

Q17. Please indicate which verification indices and / or diagram / curve are used to assess forecast quality of extremes in your subseasonal reforecasts:

	Please indicate Y / N
Reliability diagrams for events in the 90th and 10th percentiles (or similar thresholds)	
ROC curves for events in the 90th and 10th percentiles (or	

[2] Wheeler MC and Hendon HH, 2004: An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction. Monhtly Weather Review, 132, 1917-1932

[3] June-Yi Lee, Bin Wang, Matthew C. Wheeler, Xiouhua Fu, Duane E. Waliser, and In-Sik Kang, 2012: Real-time multivariate indices for the boreal summer intraseasonal oscillation over the Asian summer monsoon region. Climate Dynamics on-line first. Doi:10.1007/s00382-012-1588-5

similar thresholds)	
Extreme forecast index (EFI[4]) and/or its weighted version EFIR[5]	
Extremal dependence indices[6] (e.g. EDI and SEDI)	
Other metrics (please specify)	

Q18. Any other metrics you would recommend for the subseasonal forecast verification? Any additional comments and/or suggestions? If any, please describe in the space provided below.

Section 6: Tailored products verification

Q19. Please indicate which sector specific verification is performed to assess forecast quality of your subseasonal reforecasts within time specific periods (e.g. within weeks 1-2, 2-3, 3-4):

	Please indicate Y/N
Frequency of heavy rain days	
Frequency of no-rain days	
Frequency of heat-wave days	
Frequency of cold-wave days	
Cluster of heavy rain days (e.g. probability of n consecutive days of heavy rain)	
Cluster of no-rain days (e.g. probability of n consecutive days of no-rain)	
Cluster of heat-wave days (e.g. probability of n consecutive days with temperature above a high threshold)	
Cluster of cold-wave days (e.g. probability of n consecutive days with temperature below a low threshold)	
Others (please specify)	

Q20. How do you assess forecast quality of active and break rainfall phases and wet/dry spells in your subseasonal reforecasts? Please report in the space provided below how you perform this assessment if you have this practice.

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Q21. How do you assess forecast quality of rainy season onset and demise in your subseasonal reforecasts? Please report in the space provided below how you perform this assessment if you have this practice.

Annex 8:
Proposed Recommendations on operational provision of interannual-to-decadal (near-term climate) predictions

1. Background

At the Exeter (2014) meeting of the ET it was noted that CBS-15 had encouraged GPC Exeter to prepare a written submission to CBS and CCl recommending how multi-annual to decadal predictions (hereafter Near Term Climate Predictions, NTCP) might be incorporated into the Climate Services Information System (CSIS) of the GFCS. The request was made in the context of the ongoing informal international exchange and display of real-time decadal predictions hosted by GPC Exeter. GPC Exeter tabled a proposal recommending the establishment of infrastructure similar to that in place for seasonal forecasting: specifically designated centres for generating NTCP and coordinating Lead Centre (LC), each with specific roles and functions. The ET reviewed the submission and noted that there would be challenges in ensuring judicious use of the predictions, in promoting understanding of their limitations and in harmonizing them with national decadal outlooks prepared by NMHSs. The ET advised on a number of issues that should be considered in revision of the document, including making adherence to a protocol for hindcast generation part of the designation criteria.

At the request of the ET, a summary of the GPC Exeter submission was tabled at CCl-16 (Jul 2014) and the proposal for a LC-NTCP has also been discussed at CBS-Ext 14 (Sep 2014) and Cg-17 (May 2015). To summarise, the Technical Commissions have welcomed the progress and requested the ET continue its task and that the roles and functions for the LC-NTCP be finalized and submitted for consideration by CBS-16 for further action. In doing this, the ET has also been requested to consider the following concerns:

- Demonstration of the adequacy of real-time multi-annual to decadal forecasts for operational use;
- harmonization of output from a LC-NTCP with national decadal outlooks prepared by NMHSs;
- How to ensure judicious use of the predictions and enhance user understanding of their limitations.

In Section 2 of this document we present proposed strategies for addressing these concerns.

At the Exeter (2014) ET meeting it was noted that the growing need for decadal climate predictions had been recognized by the inclusion of a protocol for historical tests in the latest model inter-comparison project (CMIP5) which has informed the IPCC fifth assessment report. Since then two further initiatives that support establishment of infrastructure for real time NTCP have started, namely the Decadal Climate Prediction Project (DCPP) and the WCRP Grand Challenge of Near Term Climate Prediction (GC-NTCP).

The DCPP (Boer et al 2016) is an endorsed component of the 6th Coupled Model Intercomparison Project (Eyring et al., 2015). The DCPP is a coordinated multi-model investigation into decadal climate prediction, predictability and variability, and the underlying physical processes. It consists of three components: A, production of a comprehensive set of decadal hindcasts ; B, ongoing production of real-time decadal forecasts; C, targeted experiments aimed at understanding the physical mechanisms that give rise to predictability. The DCPP will be a major resource to support the WCRP Grand Challenge of Near Term Climate Prediction (GC-NTCP). In particular, a key goal of the GC-NTCP is to produce annually-updated climate outlooks for the coming years based on DCPP real-time forecasts.

2. The case for operational real-time multi-annual to decadal climate predictions

Assessments of the adequacy *of NTCP for operational use*

There is good evidence in the literature documenting skill in NTCP: the reader is referred, for example, to Smith et al 2007, 2010, Pohlmann et al 2009, 2013, Chikamoto et al 2012; Eade et al 2012, Hazeleger et al 2013, Doblas-Reyes et al 2013, Robson et al 2013, Hermanson et al 2014, Knight et al 2014 and Meehl et al 2014. Here we present some examples using the Met Office's decadal prediction system, DePreSys. Since seasonal forecasting is an operational activity we can assess the adequacy of NTCP for operational use by comparing the skill of NTCP with that typical of seasonal forecasts. We also show evidence that understanding of the sources of good predictability for some high-impact phenomena are well advanced - providing a sound physical basis for advice to users.

Predictions of multi-annual averages of temperature and precipitation out to ~5 years ahead typically show levels of prediction skill that are comparable (or better) than those obtained from seasonal predictions (e.g. for 3-month means, typically to 6 months ahead). On this basis, there is a clear case to develop operational infrastructure for multi-annual to decadal forecasts – to allow WMO members full access to and to gain benefit from the forecast information. Evidence that skill is comparable is shown in Fig. 1 which compares correlation skill for forecasts of year 2-5 averages of temperature and precipitation from the DePreSys system (left) with correlation skill for 1-month lead seasonal forecasts (for Dec-Feb) from one of the 12 GPC seasonal systems (right). It is quite clear that skill is at least comparable. For tempeErature, skill for year 2-5 predictions is higher and more widespread than for seasonal prediction (see e.g. northern Asia, North America, Africa and Australia). In part the high DePreSys skill derives from good predictability of regional temperature change associated with the global warming trend. The value of this skilful regional information to users should not be underestimated: moreover, the validation over extensive retrospective forecasts, available for NTCP, is precisely what users need to make use of the forecasts (and what they find lacking from the longer-term climate predictions). Note that a detrended analysis (not shown) gives skill levels that are still comparable to those found with seasonal prediction, though lower than when the trend is included. Year 2-5 skill for precipitation is also comparable with that for 1-month lead seasonal prediction (Fig. 1, bottom row). Skill varies with geographical region, but this is a challenge faced equally by operational seasonal predictions.

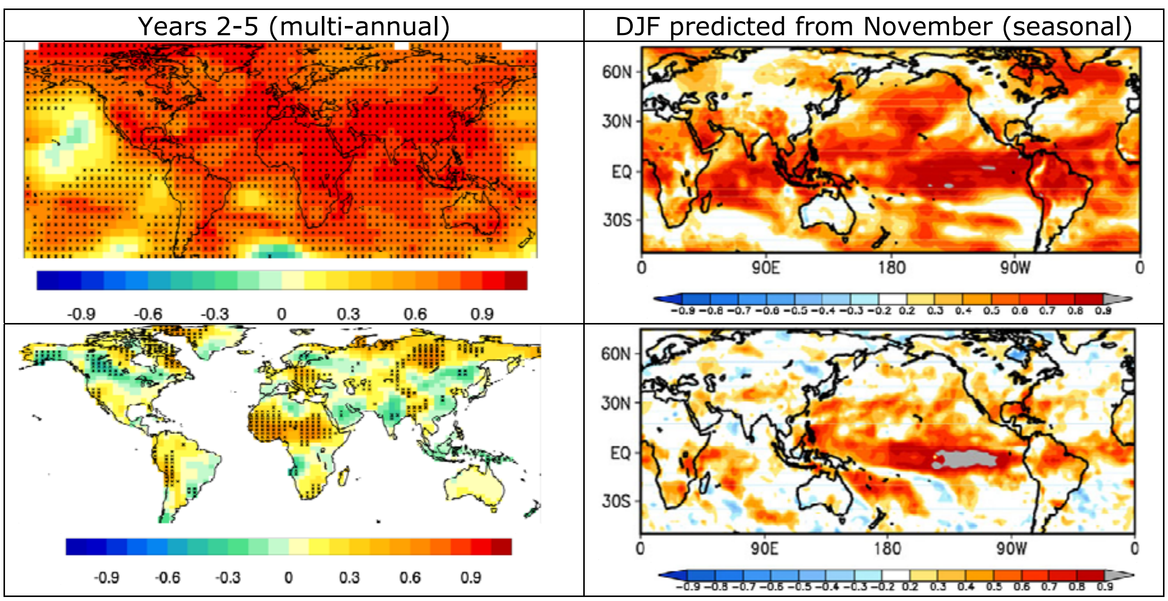

Figure 1: Correlation skill for: Top row, left: year 2-5 average near surface temperature from the Met Office decadal prediction system (ensemble mean), calculated from hindcasts started annually over the period 1960 to 2005 Right: correlation score for November predictions (ensemble mean) of DJF temperature from one of the WMO GPCs (calculated over 1982-2010?). Bottom row, as top row but for precipitation. Stippling on left-hand plots is plotted where skill is significant at the 95% level.

Sources of regional predictability

Atlantic Multi-decadal Variability (AMV) in sea surface temperature (SST) is well known to be associated with decadal variability in teleconnected regions: for example in Atlantic hurricane frequency (Smith et al 2010), Sahel and Indian monsoon rainfall (Fig. 2a). Figure 2b (Hermanson et al. 2014) demonstrates that such SST variability is predictable. A correlation score of 0.87 is achieved between hindcasts and observations – a score that is equivalent to those seen for the more predictable seasonal modes (e.g. ENSO). Corresponding model responses to important observed and predicted shifts in AMV phase confirm the causality of the relationships of Fig. 2a and also reveal important predictability of decadal regime changes of high interest to socio-economic sectors. Figure 2c shows the response of 5-year Atlantic hurricane numbers to the warming sub-polar gyre in the mid-1990s – note the predicted numbers are the highest in the timeseries (in agreement with the subsequent observations). Figure 2d shows high correlation skill (order 0.5, again comparable with the more skilful seasonal predictions of precipitation) for year 2-5 averages of July-September Sahel rainfall – indicating predictability of multi-year succession of drier and wetter seasons.

In summary there is strong evidence that predictions of multi-annual/decadal variability have skill levels that are at least similar to those of operational seasonal prediction. There is a challenge to engage the user community to co-develop best approaches to exploit the skill, but this is a challenge that is also still ongoing (in fact in its infancy – in terms of being addressed) with operational seasonal prediction. As is now the case for seasonal forecasts, operationalisation of NTCP within CBS/CCI protocols, will raise the profile of the potential benefits, ensure prudent delivery, increase availability to NMHSs and RCCs and provide impetus to accelerate development of applications.

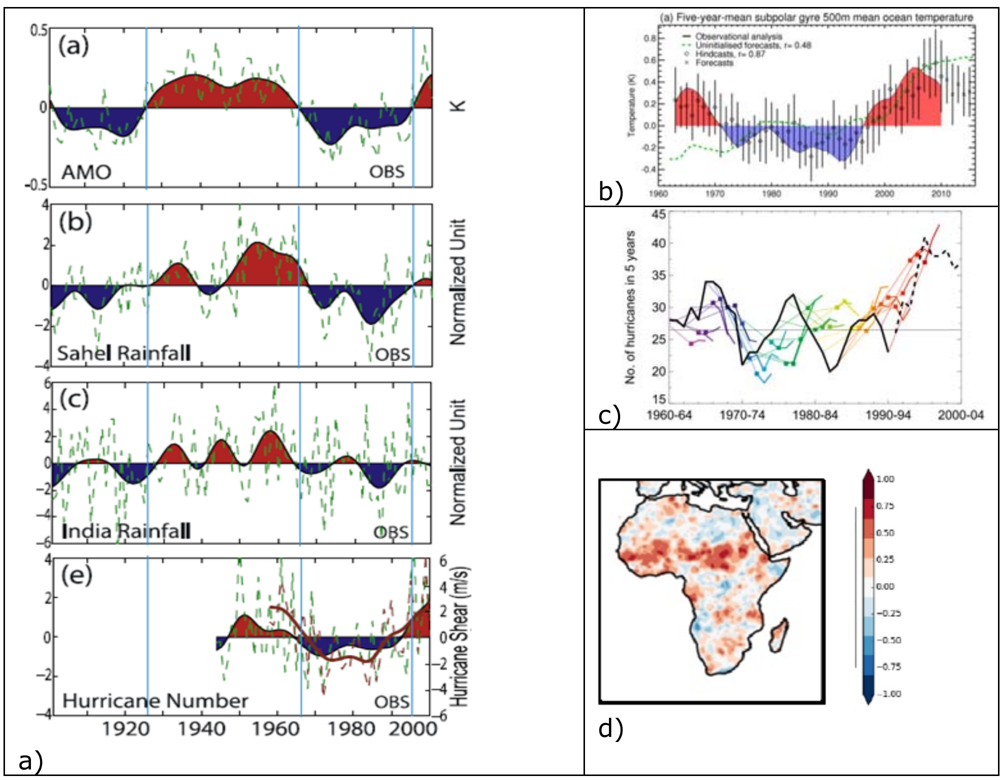

Figure 2: a) Atlantic decadal SST variability and associated impacts (from Zhang and Delworth, 2006); b) Observations (solid line and shading) and DePreSys hindcasts (diamonds and whiskers) of subpolar gyre 500m ocean temperature (from Hermanson et al. 2014); c) DePreSys hindcasts (coloured lines and squares) and observations (solid and dashed black line) of 5-year numbers of Atlantic hurricanes (note: predicted and observed step-change increase in numbers for 1990-94, corresponding to sub-polar gyre warming); d) correlation skill for year 2-5 July to September rainfall from the latest version of the Met Office system.

Predictions are initialised in November of the years 1960-2014: note coherent correlations >0.5 in the Sahel.

Other considerations

It is recognised that, in making multi-annual to decadal predictions operational, there will be a need for information to be channelled to users through the appropriate national (NMHS) and/or regional (RCC) authorities. For this reason, operational forecast output from an LC-NTCP would not be freely accessible, but would be provided through password protected website access as is currently the case for seasonal predictions. Following the protocol for seasonal predictions, access would be provided to NMHSs, RCCs and GPCs as well as research organisations that support the operational functions of NMHSs, RCCs and GPCs. The latter access by selected research organisations will be important given the collaborations with WCRP through the Grand Challenge and DCPP.

It is further recognised that many NMHSs and RCCs will not be familiar with NTCP outputs and will need guidance in making use of them in preparation of advice for customers. This need also exists for seasonal products and has led to formation of a Task Team within the ET-OPSLS to develop a technical guidance document on preparing regional seasonal predictions. We propose that a similar Task Team (or an extension of the existing Task Team) is established that will work with the WCRP Grand Challenge on Near Term Climate Prediction to develop corresponding guidance material.

3. The informal exchange hosted by the Met Office Hadley Centre (MOHC)

Many centres involved in NTCP research are also making real-time predictions and the MOHC is coordinating an informal exchange of these real-time forecasts with the aim of assessing and understanding differences and similarities between forecasts, identifying a consensus (multi-model ensemble) view in order to prevent over-confidence in a single model, and establishing current collective capacity. In addition, the informal exchange is a necessary step in developing infra-structure and protocols such that multi-annual to decadal predictions can be incorporated into the Climate Service Information System (CSIS) of the GFCS. Five exchanges have taken place so far: specifically for forecasts starting nominally on 1st January 2011-15 Details of the first two exchanges, including a description of forecasts and verification, are provided in Smith et al. 2012. Each exchange consists of up to 9 dynamical climate models and 3 empirical techniques (Table 1). Both initialized and uninitialized predictions are exchanged so that the impacts of initialization can be assessed. Analysis so far has focused on generating, for each individual model and the multi-model mean, global maps of forecast near-surface temperature averaged over the first year and subsequent 5 year periods. With support from the EU SPECS project the variables exchanged has been expanded to include precipitation, mean sea level pressure, and the Atlantic Meridional Overturning Circulation. A website (http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel) has also been developed under SPECS to display all individual contributor forecasts and multi-model products in a standard format

As an example of the exchange, the 2011 year-1 predictions and verification are provided in Fig.3. The observed temperature anomalies are dominated by La Niña conditions in the Pacific (with a tongue of cool temperatures in the tropics and a horseshoe pattern of warm temperatures to the north, west and south), a cool Australia, warm high latitudes and USA and a warm north Atlantic sub-polar gyre and tropical Atlantic. Most of the individual models capture these features well with typical pattern correlations of 0.5, which increases to 0.62 for the multi-model mean. In contrast the multi-model mean of the uninitialized predictions has spatial correlation skill of 0.31, showing a substantial benefit from initialization.

The results represent good evidence that the forecasts, accompanied by information on track-record performance, can be of benefit to WMO members. We therefore recommend that:

- The forecasts are made widely and routinely available through WMO CBS procedures and protocol. This would include WMO designation of centres willing to commit to a continued exchange defined by a minimum set of products and service criteria.
- A Lead Centre for coordinating the exchange and displaying individual and multi-model forecasts is designated. The Met Office has developed the capacity for this Lead Centre role and offers to continue coordination of the existing decadal exchange under these more formalized arrangements.

Establishment of an operational multi-annual to decadal prediction capability will be a significant contribution to the CSIS of the GFCS. In the next section we propose minimum requirements for the designated centres and Lead Centre.

4. Proposed minimum requirements for near-term climate prediction centres and associated lead centre

It is evident from Table 1 that only one of the contributing centres (Met Office, Exeter) is also a WMO-designated Global Producing Centre for long-range forecasts (GPC). Thus an optional extension of the GPC minimum requirements to include near-term climate prediction does not seem the best way forward. A possible alternative approach is to define GPC areas of specialization, for example GPC(subseasonal); GPC(seasonal); GPC(near-term climate). A centre may then apply for GPC designation in one or more of these areas of responsibility. In the following sections we propose designation criteria and minimum product requirements for GPCs with specialization in near-term climate prediction. We also propose similar criteria for an associated Lead Centre. A staged implementation is envisaged beginning with ensemble mean real-time forecasts and deterministic hindcast verification and developing within 2 years of designation to include full hindcast exchange, probabilistic forecast products and verification. Designated centres would need to be prepared to participate in Stage 1 and Stage 2.

It is a question of discussion for the ET-OPSLS whether centres using empirical methodology would be eligible to apply for GPC status. They may not be able to supply all the global fields listed below. However, there are precedents for making exceptions if the input increases the value of the proposed annual consensus statement (see section 2.2). For example in the seasonal forecast exchange GPCs operating 2-tier systems are exempt from supplying SST forecasts.

4.1 GPCs with specialization in near-term climate prediction (NTCP)

Stage 2 activities are marked with an asterisk.

Designation criteria

Global Producing Centres (GPCs) specialising in near-term climate prediction shall:

- Prepare, with at least annual frequency, global forecast fields of parameters relevant to multi-annual to decadal prediction;
- Follow common, agreed protocols in the preparation of forecasts and hindcast sets;
- Make available on the WMO Information System (WIS) a range of these products; The proposed minimum list to be made available is below;
- Provide an agreed set of forecast and hindcast* variables to the associated Lead Centre;
- Prepare verification statistics as defined below;
- Make available on a website up-to-date information on the characteristics of its global decadal prediction system.

Minimum forecast products

1. Global maps of ensemble mean anomalies with indications of ensemble spread for the following variables averaged over at least year 1 and years 1-5 of the forecast:

- near-surface air temperature;
- precipitation;

- sea level pressure.

2. *Global maps of probability for tercile categories (or other events) for the following variables averaged over at least year 1 and years 1-5 of the forecast:
   - near-surface air temperature;
   - precipitation;
   - sea level pressure

3. Ensemble mean annual global mean near-surface temperature and indications of ensemble spread, for every year of the forecast.

Verification

Scores should be calculated over multi-decadal periods of at least 40 years (preferably 1960-present day) with at least 20 retrospective forecasts distributed over this period. Consistent with the WMO Standardised Verification System for Long Range Forecasts the verification products that should be made available for near-surface temperature, precipitation and sea level pressure are:

global maps of grid-point Mean Square Skill Score (MSSS) and decomposition, including temporal correlation of the ensemble mean

- *global maps of Relative Operating Characteristic (ROC) scores for specified categories
- *Reliability and sharpness diagrams for specified categories for the agreed geographical regions.

Real-time:

- Side-by-side global maps of ensemble mean predicted and observed anomalies for temperature, precipitation and sea level pressure for at least year 1 and years 1-5. Regions where the observations lie outside the 5-95% model range will be highlighted with stippling;
- Spatial pattern correlation coefficients between observations and ensemble mean forecasts for global fields of temperature, precipitation and sea level pressure
- Observed annual mean global temperature over plotted on previous forecasts.

4.2 Lead Centre for Near-Term Climate Prediction (LC-NTCP)

Centres designated as Lead Centre for Near-Term Climate Prediction (NTCP) shall:

- Collect an agreed set of hindcast and forecast data from Global Producing Centres specializing in NTCP;
- Make available on a web site agreed lead centre (LC) products in standard format, including multi-model products
- Generate verification for individual GPC forecasts and the multi-model and display in standard format;
- Redistribute digital hindcast* and forecast data for those GPCs that allow it;
- Maintain an archive of the real-time GPC and MME forecasts;
- Promote research and experience in NTCP techniques and provide guidance and support on NTCP to GPCs, RCCs and NMHSs;
- Based on comparison among different models, provide feedback to GPCs about model performance;
- coordinate an annual consensus prediction product giving global prospects for the next 1-5 years.

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Annex 9:
STATEMENT OF GUIDANCE FOR SUB-SEASONAL TO LONGER TIME SCALE PREDICTIONS

1. Introduction

This State of the Guidance (SoG) outlines observational data requirements for the sub-seasonal to longer predictions. In this revision, the scope of the SoG was expanded to reflect emerging user requirements of operational services to provide predictions at sub-seasonal to decadal timescales (herein roughly two weeks to 10 years). The sub-seasonal and seasonal predictions are often made using dynamical models either atmospheric general circulation models (AGCMs) or coupled general circulation models (CGCMs). A sea ice component is also coupled in some CGCMs. Therefore, this SoG focuses on the requirements to exploit the predictions with the dynamical models.

The physical basis for seasonal and inter-annual prediction lies in components of climate that vary slowly compared with individual weather events, i.e. ocean and land (including cryospheric components). Among them, the ENSO (El Niño Southern Oscillation) cycle is, for instance, the most relevant phenomenon with predictability on the seasonal time-scale. ENSO consists of a coherent large-scale fluctuation of ocean temperatures, rainfall, and atmospheric circulation across the tropical Pacific, but has a vast influence on global climate conditions. It is a coupled ocean–atmosphere phenomenon, and can be relatively well predicted a few seasons ahead. This predictability, together with its widespread influence on climate variability, makes ENSO the dominant source of predictive skill for any seasonal to inter-annual forecast systems. Other coupled ocean–atmosphere phenomena are also recognized and predictable to some extents (e.g. Indian Ocean Dipole). Ocean observations are essential to initialize CGCMs in order to predict these phenomena. Other observations are also essential. For instance, land surface conditions play a role during the first two months of the forecast. Sea ice becomes increasingly important for the seasonal prediction. It is also noted that some modelling groups now include the stratosphere in their seasonal forecast systems. On time scales beyond one or two months, the models would also need to include up-to-date long-term forcing (e.g. greenhouse gases, volcanic aerosol, solar irradiance).

In order to predict seasonal climate by dynamical means, fully coupled ocean–land–atmosphere models are generally used. Just as in weather prediction, ensemble forecasts using these coupled models give probabilistic risk forecasts of climate events. To initialize the coupled model, observations of the atmosphere, land and ocean are used. There is large variation in the approach to initialize the ocean component (e.g. Martin et al. 2015), with some of the simpler schemes using only wind information while the more complex models usually assimilate sub-surface temperature and salinity data, and satellite surface topography and temperature data. Indeed, major challenges remain in the development of assimilation techniques that optimize the use of observations in initializing coupled models. For example, coupled data assimilation techniques are a major area of current research. It is noted that historical data sets also play an important role in sub-seasonal and longer predictions by supporting calibration and verification activities, since the error characteristics are flow-dependent and long-term consistent observations are needed for their correction.

In recent years the capabilities in sub-seasonal predictions have developed substantially. By sub-seasonal predictions we mean predictions beyond 10 days but not extending to a full season. In 2013 a joint WWRP/WCRP project on sub-seasonal to seasonal prediction started. The main goal of this research project is to improve forecast skill and understanding on the sub-seasonal to seasonal timescale, and promote its uptake by operational centres and exploitation by the applications community. Forecasting in the intermediate range between medium and seasonal range is difficult as the importance of atmospheric initial conditions wanes and the effect of slower boundary conditions of the atmosphere such as sea surface temperature increases. Coupled ocean-atmosphere modes that modulate variability on subseasonal and seasonal timescales (respectively e.g. MJO and ENSO) require CGCMs for comprehensive prediction and these are the preferred tool, although for windows when persistance of SST anomalies is reasonable uncoupled systems can be used. The observational data requirements for sub-seasonal forecasts are the same as the ones for seasonal and inter-annual forecasts, with emphasis on higher spatial and time resolutions to facilitate better initialization of models with higher resolution compared with those used for the seasonal prediction.

Efforts have been made to the multi-annual to decadal prediction in the research, and informal exchange of real-time multi-annual prediction data has been continued in the last few years. Currently one operational centre and several research groups contribute to this exchange. The decadal prediction needs observations of the ocean, favourably including the deep ocean, to be initialized, and climate forcing (e.g. greenhouse gases, volcanic aerosol, solar irradiance) to be specified. In addition, some observation and reconstruction data are required to address the key decadal variability (e.g. Atlantic Meridional Overturning Circulation (AMOC), Atlantic Multidecadal Variability (AMV), Pacific Decadal Oscillation (PDO)).

In this SoG, the observational requirements and the gap analysis of sub-seasonal to longer forecasts are based on a consensus of the coupled ocean–atmosphere modelling community. The gap analysis between user requirements and current observing system capability is given in the following sections. Since the scope of the SoG is relatively wide, and requirements are essentially the same for the Global NWP or Ocean Applications in some relevant parts, here we focus on elements, which are particularly important for initialization, validation and calibration of the sub-seasonal to longer time scale predictions, and development of their systems. With regards to requirements for initialising the atmosphere and land, please refer to the SoG of Global NWP. It is also noted that there is on-going research and development to integrate medium-range and seasonal prediction systems into coupled models/assimilation systems.

2. Gap Analysis: User Requirements and Observing System Capability

2.1 Ocean and Ocean-related variables

As mentioned above, success in the sub-seasonal to longer time scale forecasting derives, to large degree, from predictable fluctuations in the (mainly tropical) ocean and ocean observations are therefore of key importance. The ocean observing system has been implemented based on the international coordination under the Intergovernmental Oceanographic Commission (IOC, UNESCO), WMO and the Global Ocean Observing System (GOOS, WMO/UNEP/ICSU). In response to the Framework for Ocean Observing (FOO) the "Essential Ocean Variables[7]" (EOVs) were identified (Lindstrom et al. 2012). The regional panels for the ocean observation were developed, for instance, TPOS2020 for the tropical Pacific, AtlantOS for the Atlantic Ocean, IndOOS for Indian Ocean (see the CLIVAR Exchanges Special Issue No. 67). There are other activities for evaluation of ocean observations in the CLIVAR Global Synthesis and Observations Panel (GSOP)[8], GODAE Ocean View (GOV) Observing System Evaluation Task Team (OSEval-TT)[9]. The current status of the real-time in situ Global Ocean Observing System was reviewed by Legler et al. (2015), and the satellite observation part was reviewed by Le Traon et al. (2015). Oceanic observation requirements relevant to the subseasonal to longer time scale predictions were also discussed in some reports of these activities (e.g. Fujii et al. 2015; Balmaseda et al. 2014).

2.1.1 Sea-surface temperature

Accurate Sea Surface Temperature (SST) determination is important for sub-seasonal to seasonal prediction models. Ships and moored and drifting buoys provide in situ observations with *acceptable* accuracy, but coverage and frequency are *poor or marginal* over

[7] http://ioc-goos-oopc.org/obs/ecv.php
[8] http://www.clivar.org/panels-and-working-groups/gsop/gsop.php
[9] https://www.godae-oceanview.org/science/task-teams/observing-system-evaluation-tt-oseval-tt/

large areas of the Earth. Instruments on polar satellites provide information with global coverage in principle, *good* horizontal and temporal resolution and *acceptable* accuracy (once they are bias-corrected using in situ data), except in persistently cloud-covered areas (which cover significant areas in the tropics). Geostationary imagers with split window measurements help to expand the temporal coverage by making measurements hourly and thus creating more opportunities for finding cloud-free areas and characterising any diurnal variations (known to be up to 4 degrees Celsius in cloud free regions with relatively calm seas). Microwave measurements provide *acceptable* resolution and accuracy and have the added value of being able to retrieve SST in cloud-covered areas. Blended products from the different satellites and in situ data are *good* in terms of temporal frequency, accuracy and coverage for sub-seasonal to seasonal forecasts. Observation of the diurnal cycle is becoming increasingly important, for which present and planned geostationary satellites offer a capability. High quality, fast delivery SST products are very important for the progress of sub-seasonal to seasonal predictions. Currently the accuracy and spatial scale of such diurnal SST products are only *marginally adequate*.

2.1.2 Ocean wind stress

Ocean wind stress is a key variable for driving ocean models. Current ocean data assimilation systems used for the initialization of the ocean employ winds derived from Numerical Weather Prediction (NWP) or, in some cases, winds inferred from atmospheric models specified with current SST fields. The tropical moored buoy network has been a key contributor for surface winds over the last decade, particularly for monitoring and verification, providing both *good* coverage and accuracy in the equatorial Pacific for calibration and validation of satellite data and assimilation products. Fixed and drifting buoys and ships outside the tropical Pacific provide observations of *marginal* coverage and frequency; *acceptable* accuracy for the same purpose. Although the coverage and frequency of in situ oceanic surface wind data are *not sufficient (or poor)* for atmospheric data assimilation systems, assimilating those data has a pronounced impact on the analysed wind speed, contributing to better oceanic initial conditions. The data have good accuracy and frequency, and *acceptable* coverage for purposes of ocean data assimilation.

Satellite-derived surface-wind speed and direction assessments by scatterometers are now the dominant source of this information, complemented with wind speed measurement by passive microwave imagers. Currently ocean initialization for the sub-seasonal to seasonal prediction is benefited mostly through the assimilated surface wind products of NWP, where their positive impact is acknowledged. Overall, the scatterometers provide *good* coverage and *acceptable* frequency and accuracy, and it complements the ocean-based observations. High-quality scatterometer winds are the best products available at the moment and need to be maintained operationally.

2.1.3 Sub-surface temperature

Most of operational ocean/coupled assimilation systems for the sub-seasonal to seasonal prediction take advantage of sub-surface temperature and salinity observations, at least in the upper ocean (down to ~500 m depth). The Tropical Atmosphere Ocean (TAO)/Triangle Trans-Ocean Buoy Network (TRITON) moored buoy network provides data of *good* frequency and accuracy, and *acceptable* spatial resolution, of sub-surface temperature for the tropical Pacific, at least for the current modelling capability. Although the TAO/TRITON network has been a backbone of observational monitoring in the tropical Pacific, data return decreased from 80-90 % to below 30 % in 2013–2014 due to logistic and funding problems. This situation was recovered by provisional logistics this time. On the other hand, the TRITON array has also gradually been decommissioned due to lack of research funding and changes in the supporting agency. These situations urged the operational and research communities to coordinate and redesign a sustainable and cost-efficient observation system (TPOS2020). The tropical moored buoy network in the Atlantic, Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) has better than marginal spatial resolution. The Research Moored

Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) array provides coverage over the Indian Ocean.

The sub-surface measurement of the Expandable Bathy Thermographs (XBTs), coordinated by Ships-Of-Opportunity Programme (SOOP), provides data of acceptable spatial resolution over some regions of the globe, but the temporal resolution is marginal. It is noted that SOOP is evolving to provide enhanced temporal resolution along some specific lines.

Free-drifting profiling floats deployed under the Argo project (Riser et al. 2016) provide global coverage of temperature and salinity profiles to ~2000 m depth, mostly with good spatial resolution globally, and acceptable frequency, except for the regions around the equator, western boundary current regions and marginal seas. Around the equator, their coverage is marginal due to the surface divergent current. It is also noted that the general types of Argo floats are also unable to sample in ice-covered and shallow areas (e.g. the Maritime Continent), but new research floats are successfully deployed in Antarctic sea ice areas (Wong and Riser 2011). In all cases the accuracy is acceptable for sub-seasonal to seasonal prediction purposes. The Argo floats derive substantial benefit for the global ocean analysis for sub-seasonal to seasonal forecasts, thus the Argo are currently indispensable component of the global ocean observing system. Moorings at and near the equator are important to complement the ARGO float measurement in this area.

2.1.4 Salinity

Salinity is an important parameter, and is becoming increasingly used in assimilation for sub-seasonal to decadal prediction systems. Many ocean data assimilation systems make use of the temperature and salinity profiles instead of temperature profiles only (e.g. Fujii and Kamachi 2003, Ricci et al. 2005, Troccoli et al. 2002). The Argo is a major source of salinity observations. It provides *good* global coverage of temperature and salinity profiles to ~2000 m, mostly with *acceptable*-to-*good* spatial resolution, and *acceptable* temporal resolution in the tropics. Valuable data also comes from some of the tropical moorings, in particular from the TRITON buoys, although data coverage is rather limited. Surface salinity is also measured by satellite such as Aquarius and SMOS with *good* coverage, *acceptable*-to-*good* spatial resolution and *poor-to-marginal* accuracy and frequency. Despite the limitation of accuracy, the satellite sea surface salinity has potential in the ocean assimilation (e.g. Toyoda et al. 2015), and there will be a need for continuity of these measurements. Constraining salinity in the ocean data assimilation is still a challenge, since there is large uncertainty in the fresh water flux (precipitation, evaporation and river runoff), affecting the surface salinity and mixed layer properties.

2.1.5 Ocean topography

Ocean altimetry provides measurements of the sea surface topography relative to the geoid (or mean sea-surface position) that in turn is a reflection of thermodynamic changes over the full-depth ocean column. In principle, the combination of altimetry, tropical mooring and Argo provides a useful observing system for initialising the thermodynamic state in sub-seasonal to seasonal prediction models. Altimetry from Jason-2, CryoSat-2 and AltiKa are currently used in operational ocean assimilation systems. Long-term commitments for satellite altimetry observation are required. It is noted that recently Jason-3 was successfully launched in January 2016, and expected to continue measurement of altimetry. Research satellites are providing a mix of data with *acceptable* accuracy, spatial resolution and frequency. Provision of global coverage beyond the tropical Pacific is an important requisite, in particular, for higher resolution coupled models (ocean resolution of ~30 km), in which there is partial representation of ocean eddies. In situ sea level measurements are useful particularly for testing models and validating altimetry.

2.1.6 Surface heat, radiative and freshwater fluxes

There are a few sites in the tropical ocean where the data on surface heat flux are of value for validation and are required at a number of sites in the tropical oceans. NWP products (derived from predictions in the assimilation window), in principle, have *good* resolution and frequency, but the accuracy is at best *marginal*. Satellite data provide prospects for several of the components of heat and radiative fluxes, particularly shortwave radiation, but at present, none is used on a routine basis in assimilation for sub-seasonal to seasonal predictions, due to some technical difficulty in use over sea ice areas. Precipitation estimates are important for validation because of the fundamental role of the hydrological cycle in sub-seasonal to seasonal prediction impacts. They also have importance in initialisation because of the links to salinity. However, there remain significant uncertainties in estimates of rainfall over the oceans. In addition the fresh water run-off information from rivers (large estuaries) will become important in coastal areas and regional parts of the oceans (e.g. the Bay of Bengal). Additional data would always be useful, for example, data to allow better estimation of heat fluxes and P−E (precipitation minus evaporation) could help give a better definition of the mixed layer structure.

2.1.7 Ocean current data

Most ocean data assimilation systems do not use ocean current data but some systems update ocean current fields using either dynamical or statistical relationships. Because of the central importance of dynamics and advection, the ocean current data are important for testing and validation. The ocean current is measured and analysed by in situ or remotely-sensed observations. For example, surface currents measured by drifting buoys are *acceptable* in terms of accuracy and temporal resolution but *marginal* in spatial coverage. Moored buoy observation has *good* in accuracy and frequency but *poor-to-marginal* in spatial coverage. Satellite altimetry is also being used to infer the distribution of near-surface ocean currents. The Ocean Surface Current Analyses (OSCAR) for the tropical Pacific and Atlantic are now being produced routinely by blending geostrophic estimates from altimetry with Ekman estimates from remotely-sensed wind observations.

2.1.8 Sea ice

Sea-ice cover is important not only for high latitudes, but for mid-latitudes. It is provided together with many SST products. Sea-ice concentration products like the EUMETSAT OSI SAF, derived from SSMIS brightness temperatures, are valuable. Daily global observations are provided routinely since 1979. However uncertainties are large in presence of melt ponds and young ice. The sea-ice cover data have *acceptable* accuracy and temporal resolution and *good* coverage.

Sea-ice thickness is also required to better determine the sea-ice initial state and the conductive heat fluxes through the ice. In situ sea-ice thickness is rather limitedly available. Sea-ice thickness assessments produced with satellite observations like ICESat (Ice, Cloud and land Elevation Satellite) have high spatial resolution but narrow swath width. CryoSat and CryoSat-2, through use of a satellite in low Earth orbit, monitor variations in the extent and thickness of polar ice. SMOS sea-ice thickness data are restricted to detect thin sea ice (< 1 m) and has complex error characteristics. These satellite-based sea-ice thickness products are overall poor to *marginal* accuracy. Although they have *acceptable* temporal resolution and spatial coverage currently (after CryoSat). How to assimilate the thickness data effectively is still an on-going area of research. The sea-ice observations may have potential benefit for the multi-annual prediction in the future, although to date the impact has not been fully evaluated.

2.1.9 Deep sea

The observation of the deep sea has relied on ship-based measurements for several decades, but it was rather limitedly available due to the cost. In recent years, the deep Argo program has been developing the free-drifting profiling floats that are capable of observing the deep ocean below 2000 m to 4000 m or 6000 m depending on the float types. The deep Argo floats cost more than the regular Argo floats, but much less than the ship-based measurements. More than 50 deep temperature/salinity sensors are also deployed by the OceanSITES project (http://www.oceansites.org/index.html), and the project plans to increase the number of the sensors further. Although it is still difficult to assess impacts of those new platforms, deep sea observations may be beneficial for decadal prediction and climate projection, at least for purposes of validating predictions. Monitoring of the Atlantic Meridional Overturning Circulation (AMOC) with the RAPID array along 26°N is also important for validating decadal predictions.

2.2 Land variables

Requirements of the land observation for sub-seasonal to seasonal predictions coincide with those of the Global NWP application. It is noteworthy that sub-seasonal to seasonal prediction requires long-term data with consistent quality over periods that include the model reforecast period (typically the past 20 years or longer) to facilitate optimum calibration of the predictions.

2.2.1 Snow

Snow depth and snow cover have major effects on surface albedo and energy balance, and modify surface temperature and overlying atmospheric conditions. Snow cover is remotely measured by visible and near infra-red satellite imagery. The information has *good* horizontal and temporal resolution and accuracy but it is provided only during daytime and in cloud-free areas. Snow depth observations are *insufficient (poor)* for the purose of initialising sub-seasonal to seasonal predictions. Although surface SYNOP stations report measurements of local snow depth with high accuracy, the coverage of SYNOP stations reporting snow depth is *not adequate (poor)* (see also SoG for the Global NWP). Microwave imagery has also the potential for improvement of snow mass assessment in the land analysis.

2.2.2 Soil moisture

Soil moisture is a crucial element in the sub-seasonal and seasonal forecast performance in mid-latitudes in boreal spring/summer. Due to its extended memory, the relevant quantity to initialise is the soil water in the root layer (a soil layer with a depth of about 1 m). Low-frequency microwave imagery and scatterometer measurements are sensitive to surface wetness with an insufficient penetration depth (i.e. they do not penetrate the full root layer). At present only the Soil Climate Analysis Network (SCAN) provides a network of real-time vertical profiles of soil moisture and coverage is limited to the whole United States' area. A network of similar measurements covering the global domain would be very useful. The current operational soil moisture product from ASCAT has *acceptable* spatial resolution but *marginal* accuracy. Passive L-band microwave imagers such as SMOS and SMAP have great potential.

2.2.3 Other land variables

As for the Global NWP application, vegetation type and cover is provided by operational satellite imagery and near infrared channels. The accuracy of such products is generally *marginal*. However MODIS has a considerably improved accuracy.

2.3 Climate forcing variables

2.3.1 Aerosol and greenhouse gases

As for the NWP models, aerosols data (including volcanic aerosols) and stratospheric ozone concentration data have been recently used in several sub-seasonal to decadal prediction systems. Especially stratospheric sulfate aerosols injected by large explosive volcanic eruptions such as that of Mount Pinatubo in 1991 had significant impacts on global climate, and its influence can last a few years. Sub-seasonal to decadal predictions require geographical distributions of aerosol loading with 1–2 km in the vertical and monthly time resolutions.

Satellite instruments such as high resolution infrared sounders and solar backscatters provide accurate measurements of total column ozone. However, vertically resolved ozone information is needed. Microwave limb sounders have the potential to offer good vertical resolution and accuracy.

2.3.2 Solar irradiance

Observed solar irradiance is utilized in some seasonal to decadal prediction systems, and its use has been shown some impacts on the predictions at these time scales (e.g. Ineson et al. 2011). Spectral irradiance is measured by Spectral Irradiance Monitor (SIM) and SOLar STellar Irradiance Comparison Experiment (SOLSTICE) instruments aboard the Solar Radiation and Climate Experiment (SORCE) satellite mission. Although data are currently available for the limited period (2004–present), and it would be hard to evaluate the accuracy, continuous observation of the spectral irradiance is required for the seasonal to decadal predictions. Some studies suggested that UV (200–400 nm) irradiance analysis with monthly time resolution are required for seasonal to decadal predictions.

2.4 Atmospheric data

Similar to the NWP models, the atmospheric components of most sub-seasonal to seasonal prediction systems are initialized by an accurate analysis of the state of the atmosphere and earth’s surface. Therefore the observational requirements are similar to those for the Global NWP application (see SoG for Global NWP). However, the longer integrations relative to NWP increase forecast susceptibility to model climate “drift” and consequently biases are generally larger in long range forecastsm and require calibration with hindcasts. Typically a set of hindcast integrations going back 20 years or more in the past is used to calibrate the sub-seasonal to seasonal predictions. The hindcast initialization relies on the capability of the re-analysis in providing consistent time series of data covering a sufficient long period of years. In this respect a general requirement for sub-seasonal to seasonal prediction is the availability of consistent historical observational data sets as well as a continuous provision of accurate observational data in the future.

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ACTION PROPOSED

The Meeting is invited to note the information contained in this document when discussing how it organises its work and formulates its recommendations.

Annex 10: Proposed revisions to the Terms of Reference of the ET-OPSLS

Terms of Reference – proposed revisions

a. On the basis of requirements from Regional Climate Centres (RCCs), Regional Climate Outlook Forums (RCOFs) and NMHSs, and in the context of the Climate Services Information System (CSIS) of the Global Framework for Climate Services (GFCS), guide future development, outputs including e.g. the GSCU and coordination of components in the production of LRF. The components include Global Producing Centres (GPCs), Lead Centres for Long-range Forecast Multi-model Ensembles (LC-LRFMME), the Lead Centre for the Standardized Verification System for Long-range Forecasts (LC-SVSLRF) and other relevant bodies generating and providing LRF products;

b. Support CCl and CBS to collaboratively promote the use of GPC and LC forecast and verification products by RCCs, RCOFs and NMHSs, develop interpretation guidance to facilitate their use, and encourage feedback on usefulness and application;

c. Support CBS in the implementation of a seamless GDPFS;

d. Report on production, access, dissemination and exchange of LRF products and provide recommendations for future consideration and adoption by CAS, CCl, CBS, WCRP and other appropriate bodies;

e. In consultation with relevant experts in CAS and CCl and with the CBS Expert Team on Operational Weather Forecasting Process and Support (ET-OWFPS), review developments in verification scores and practices with a view to updating the Standardized Verification System for Long-range Forecasts (SVSLRF);

f. Assess applications for GPC status against the designation criteria and make recommendations on designation to CBS;

g. Review the rules regarding user access to GPC and LC-LRFMME forecasts products;

h. Review the status of sub-seasonal forecasting activities, and promote the availability and exchange of sub-seasonal forecasts and verification products;

i. In close collaboration with WCRP, promote international cooperation and research on initialized predictions for timescales longer than seasonal and report on potential for operational predictions to CBS and CCl;

j. Review the *Manual on the GDPFS* (WMO-No. 485) and propose updates as necessary concerning extended and long-range forecasts.

Annex 11: Sub Teams defined under the ET-OPSLS

Four Sub Teams (STs) were implemented under the ET-OPSLS following the Meeting of the extraordinary meeting of the Implementation Coordination Team of the OPAG on Data Processing and Forecasting System (ICT-DPFS), Geneva (January 2013). The Task Teams, their objectives and membership are provided below.

At its meetings the ET-OPSLS will review the objectives of the Sub Teams, consider new Sub Teams for the upcoming period and make recommendations.

ST1: Workshops on Operational Climate Prediction – to be held in **last quarter of 2017**
a) November 2016: Organising committee in place
b) February 2017: Theme, scope and aims, funding, dates and venue of next workshop
c) July 2017: Invitations to participate issued; pre conference tasks allocated (e.g. questionnaires)
d) September 2017: near-final conference programme available
e) November 2017: workshop held and report completed

Potential themes include:

a) reviewing the framework for the guidance document on preparing consolidated seasonal forecasts and b) reviewing operational experience with the GSCU – which by then should have reached its operational phase; c) review of the S2S real-time pilot.

Membership: Caio Coelho (Chair), Richard Graham, Jean-Pierre Ceron, Andre Kamga, Rupa Kumar Kolli, Alice Soares

ST2: Develop revised strategies for verification exchange, including for LC-LRFMME multi-model products, real-time verification and support to GSCU.

a) May 2016: remove current verification plots and replace with text explanation
b) June 2016: activate LC-LRFMME website verification and link it into the LC-SVSLRF website. Add caveats and links to GPCs own verification displays
c) December 2016: Review and update if necessary the recommendations made on the LC-SVSLRF website regarding observational datasets for verification of seasonal forecasts.
d) June 2017: Complete LC-LRFMME changes to express website products relative to the common hindcast period (where possible).
e) December 2017: Brief reports on the following:
    - The value of the MSSS in the SVSLRF – there is a growing feeling in the ET that this score is of little use to users and that the individual components are more useful than their sum

- verification for subseasonal forecasts, working with the WWRP-THORPEX/WCRP S2S project;
- verification of real-time forecasts;
- verification of extreme events (e.g. Generalised Rank Probability Score);
- confidence interval/significance values for scores
- a score for measuring success at probabilistic prediction of the onset of El Nino / La Nina events.

Membership: Arun Kumar (Chair), David Jones, Bertrand Denis, Suhee Park, Anca Brookshaw, Yuhei Takaya, Laura Ferranti, Caio Coelho

ST3: On scoping / implementation of sub-seasonal forecasts

August 2016: Clarify channels for attaining S2S feedback on the real-time pilot methodology and implement
December 2016: include additional models that wish to contribute. Finalise the starting date and change the target dates to be Monday to Sunday periods;
December 2017: Report on 1 year+ verification statistics. Recommend steps for making the pilot available to RCCs and NMHSs. Report to the 2nd WMO Workshop on Operational Climate Prediction

Membership: Suhee Park (Chair), Richard Graham, Laura Ferranti, Yuhei Takaya

ST4: Scoping / implementation of longer than seasonal forecasts
June 2016: Revise document on recommended roles and functions of a LC-NTCP on the basis of comments from the ET's Beijing (2016) meeting and submit to ET for review.
July 2016: Revise accordingly and submit to CBS for consideration and action at CBS-16 (November 2016)

Membership: Richard Graham (Chair), Doug Smith, Arun Kumar, David Jones

ST5: New approaches for distribution of GPC hindcast and forecast data.
August 2016: submit results of the questionnaire to GPCs on data dissemination practices to the ET-CSIS ahead of their upcoming meeting (last quarter of 2016).
December 2017: report to ET on developments in the field

Membership: David Jones (Chair), Suhee Park, Bertrand Denis

ST6: Guidelines on procedures for generating regional seasonal forecasts.
December 2016: Generate first draft a framework for a (globally distributable) guidance document on procedures for generating regional/national seasonal forecasts.

August 2017: final framework document ready for (potential) discussion at the 2nd WMO Operational Climate Workshop on Operational Climate Prediction.
Membership: Arun Kumar (Chair), Jean-Pierre Ceron, Caio Coelho, Richard Graham

ST7: Amendments to the GPC-relevant sections of the Manual on the GDPFS.
June 2016: coordinate ET review of all GPC-relevant sections.
July 2017: finalise edits and submit to CBS for action at CBS-16.

Membership: Richard Graham (Chair), Arun Kumar, David Jones, Yuhei Takaya