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OBSERVING SYSTEM STUDIES

UPDATE ON RECENT OBSERVATION IMPACT EXPERIMENTS

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SUMMARY AND PURPOSE OF DOCUMENT

The document provides a report of the work of the Rapporteurs on Scientific Assessment of Impact Studies (R-SAIS) since the seventh Session of the ET-EGOS.

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.

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Appendix: **A.** Proposed science questions to be addressed for observing system design

UPDATE ON RECENT OBSERVATION IMPACT EXPERIMENTS

INTRODUCTION

In this report, the Rapporteurs on Scientific Assessment of Impact Studies undertaken by NWP Centres (R-SAIS) summarize recent progress on the several observing systems in terms of benefit to NWP after the Seventh session of ET-EGOS.

1. UPDATE ON RECENT OSEs/OSSEs

1. **Impact studies for the early morning orbit satellite:** A meeting of WMO-CGMS Tiger Team on "assessment of the benefits of a satellite mission in an early morning orbit" was held in April 2013 at Beijing, China. At the meeting, several NWP centres such as China Meteorological Administration (CMA), Japan Meteorological Agency (JMA), European Centre for Medium-Range Weather Forecasts (ECMWF), Joint Center for Satellite Data Assimilation (JCSDA) and Deutscher Wetterdienst (DWD) presented their OSE results. Most of the studies were based on the assumption that NOAA-15 satellite could serve as a proxy for the early morning orbit satellite, and the impact was assessed by suppressing its use in data denial observing system experiments (OSEs). Korea Meteorological Administration (KMA) and UK Met Office introduced adjoint sensitivity studies using "forecast sensitivity to observation (FSO)" for NOAA-15 and the other polar-orbiting satellites. UKMO also presented a conceptual study for the assimilation of regular interval observation and irregular one. JCSDA presented their OSSE results. There is overall consensus on the benefits that will be brought by a satellite mission in the early morning orbit. A detailed report from the WMO-CGMS Tiger Team is available on the web[1].

2. **Impact studies for AMSR2**: JMA performed OSEs for the advanced microwave scanning radiometer 2 (AMSR2) onboard the global change observation mission 1st – water (GCOM-W1) satellite. Since GCOM-W1's equatorial crossing time (ECT) is 13:30, the AMSR2 data can fill the gap of the current microwave imager coverage, which consists of special sensor microwave imager sounder (SSMIS) onboard DMSP-F16 (ECT: 05:22), F17 (ECT: 05:49) and F18 (ECT: 08:06). It was confirmed in the OSEs that the AMSR2 data can fill the data gap and its assimilation contribute for the better precipitation prediction of JMA's Meso-Scale Model. With this result, JMA started AMSR2 data assimilation in September 2013.

3. **Impact of radiosonde balloon over the stratosphere**: JMA conducted an OSE about denying all the radiosonde data over 100 hPa for the period of August 2013. All other observations including satellite data were used as normal at JMA. Significant forecast degradation was found after 96 hours on 500 hPa geopotential in the southern hemisphere. The experiment will be repeated for the other season to confirm the result and to investigate whether the result is regionally or seasonally dependent.

4. **Impact of radiosonde balloon position information**: Although the traditional TEMP report does not include information about the position and elapsed ascent time of the balloon, the information will be available in TEMP-BUFR report. Under this situation, Environment Canada (EC) developed a method to estimate the

1 http://www.wmo.int/pages/prog/sat/documents/CGMS_LEO-TigerTeam-Final-Report-April-2013.pdf

balloon drift by using its horizontal wind information and assessed the analysis an forecast impact of estimating the balloon position in this way. Their result showed that the impact of balloon position is significant in short-range forecast in the upper troposphere and stratosphere, especially for the zonal wind field in the Northern Hemisphere winter season. JMA also assessed the impact by using own radiosonde data with accurate position information. It was confirmed the radiosondes travel a few hundred km during the ascent. The preliminary OSE in the Meso-Scale Model showed the positive impact of assimilating the radiosonde data with position information, in some case studies.

5. **Impact studies for FY3C**: CMA is starting observation system experiments for the newer instruments such as MWTS2 (Microwave Temperature Sounder 2), MWHS2 (Microwave Humidity Sounder 2) and GNOS (GNSS Radio Occultation Sounder) onboard FY-3C polar orbiting satellite. The data from the other instruments are under evaluation (Liu 2014, personal communication).

6. **The international Joint OSSE**: NOAA reported about OSSE activities in the 4th NOAA testbed & proving ground workshop, 2–4 April 2013. The global OSSEs, which completed the first phase, are to test the impact of unmanned aircraft systems (UAS) and weather in situ deployment optimization method (WISDOM) balloons. The conducted OSSE is for the alternatives for the Defence Weather Satellite System (DWSS) as mentioned above, alternatives of space-based lidar winds and advanced hyper-spectral sounders. It was also reported that they generated 1km nature run over a 13 day period for regional OSSE. JCSDA and ECMWF have agreed to produce a new nature run using ECMWF IFS T1279L91 in May 2013.

   A series of OSSEs are currently being conducted to evaluate the impact of the infrared and microwave sounders, Cyclone Global Navigation System (CYGNSS) and lidars on hurricane track and intensity forecasting. For these OSSEs, the nature run is a 13 day integration of the WRF ARW model at 1km resolution, embedded within an ECMWF T511 global nature run. Experiments to date have shown significant potential for wind profilers to improve the prediction of Hurricane track forecasts.

   Two new OSSE activities in the Joint OSSE framework have been launched for (1) geostationary hyper spectral infrared sounders targeting GIFTS and HES, (2) Indian radiosonde evaluation and Japanese DWL (Masutani 2014, personal communication).

   The impact of supplementary rawinsonde observations is evaluated in Joint OSSE framework at NASA/GMAO. When supplementary rawinsondes at 06 and 18UTC are added to the global rawinsonde network, there is a small but statistically significant improvement in the Northern Hemisphere analysis quality at all cycle times. This improvement is retained into the medium-range forecast, with 1 to 3% improvement in root-mean-square error of wind and temperature at the 24 and 48 hour forecast times, and slight improvement in 5-day anomaly correlations, see website[2].

2 https://ams.confex.com/ams/94Annual/webprogram/Paper232394.html

To the **Arctic Observing Summit**, which was held in April to May 2013, the community of the international OSSE led by National Centers for Environmental Prediction (NCEP) submitted a white paper describing the benefit of OSSE for justifying new Arctic observation capabilities. In the white paper, the concepts and procedures of OSSE are well explained. And the proposed themes are, such as, satellite gap analysis with planned high elliptical orbit (HEO) satellite, optimizing the use of GPS Radio Occultation observations, optimizing the surface and upper air network in the Arctic, unmanned aircraft system observations, use of ground / space based lidars for aerosol, ozone and water vapour profiling. The white paper is available on the web[3].

7. **Other OSSE activities**: With the evidence of growing and converging interests for Air Quality monitoring from the geostationary orbit (GEO) in America, Asia and Europe, the Committee on Earth Observation Satellites / Atmospheric Composition Constellation (CEOS/ACC) has recommended to organize a workshop dedicated to study the contribution of future GEO/Air Quality instruments to the global observing system of atmospheric composition using OSSEs. A workshop on "Atmospheric Composition Observation System Simulation Experiments" was held in October 2012 at ECMWF. In the workshop, OSSE capabilities, several OSSEs for CO, O3 and relating species were presented (e.g. POGEQA (Plateforme d'Observation GEostationnaire pour la mesure de la Qualité de l'Air) / MAGEAQ (Monitoring the Atmosphere from Geostationary orbit for European Air Quality) projects, APOLLO (Air POLLution Observation from the international space station) projects

8. **During the Deepwater Horizon oil spill**, nine airborne surveys conducted by NOAA WP-3D hurricane research aircraft collected upper-ocean temperature, salinity, and velocity profiles over the interior eastern Gulf of Mexico. OSSEs are performed and these experiments demonstrate that airborne surveys substantially reduce errors in data-assimilation ocean analyses beyond the error reduction achieved by satellite altimetry assimilation, see website[4].

9. **Adjoint-based sensitivity to forecast error:** UK Met Office successfully applied the adjoint-based Forecast Sensitivity to Observations (FSO) tool for the convective scale UK model to confirm and quantify the scale of benefits derived from the existing wind profilers and for future design of observing networks. The tentative impact result showed much larger impact of aircraft and radiosonde observation relative to the result of global system (Marriott, 2013). The study clearly demonstrated that profiler stations in relatively isolated locations have larger analysis and forecast impact than similar stations in well observed regions.

   FSO tool for WRF system has also been used for the adjoint sensitivity study for regional models. Korea Institute of Atmospheric Prediction Systems (KIAPS) studied the sensitivity in East Asia and the western North Pacific for the 2008 typhoon season. In this study, the satellite data has the greatest impact and the fraction of beneficial observations was approximately 60%–70%, which is higher than that reported in previous studies. For several analyses of Typhoons Sinlaku (200813) and Jangmi (200815), dropsonde soundings taken near the typhoon had similar or greater observation impacts than routine radiosonde soundings (Jung et al., 2013).

3 http://www.arcticobservingsummit.org/pdf/white_papers/matsutani_et_al_observing_system_simulation_experiments.pdf
4 https://ams.confex.com/ams/94Annual/webprogram/Paper241071.html

10. **Observation impact tool for ensemble Kalman filters**: NCEP conducted one month observation sensitivity study using the NCEP Global Forecasting System ensemble Kalman filter (EnKF). The result quantifies the overall positive impacts of the assimilated observations and the relative importance of the satellite radiance observations compared to other types of observations, especially for the moisture fields (Ota et al. 2013).

11. **Land surface data assimilation:** Land surface processes and their initialization are of crucial impotence for NWP. Current land data assimilation system used to initialize NWP model include snow depth analysis, soil moisture analysis, soil temperature and snow temperature analysis. A range of approaches of various complexities, for example simple Cressman interpolation, optimal interpolation or extended Kalman filters, are used by NWP centres for their surface analysis. Soil moisture products are provided by Advanced Scatterometer (ASCAT) and Soil Moisture and Ocean Salinity (SMOS) mission. SMOS data are monitored at ECMWF and the brightness temperature data assimilation based on Extended Kalman Filter (EKF) is being developed. NASA/GMAO is also developing the data assimilation system based on ensemble Kalman Filter technique. Snow analysis experiments at ECMWF have demonstrated forecast impact of using in situ observations from national networks. A new, simple BUFR template is being used by several countries for exchange of the data via the GTS.

12. **Regional observation networks in Europe:** The EUMETNET Observations Programme manages the composite observing network for Europe. Its Scientific Expert Team (OBS-SET) reviewed an extensive range of OSEs with relevance for the development of the observing programmes. Currently there is a focus on assessing the impact of aircraft humidity observations, based on data available in the US. The German weather service (DWD) have demonstrated the value of these observations and assimilated the data operationally since October 2013. Recent OSEs have studied various scenarios for the collection of AMDAR profile data at European airport. Results indicate that a more uniform coverage across the continent and extension to Northern Africa are priorities for the future.

13. **Saturation of the number of Radio occultation profiles:** ECMWF have conducted a study with varying numbers of radio occultation profiles in global NWP. The study used the ensemble based impact assessment technique where reduction of ensemble spread is interpreted as observation impact. The results show that benefits can be derived from GPSRO observations in excess of 10,000 per day, globally.

2. Next OSE/OSSE workshop

Since 1997, a comprehensive review of the impact of the different operational observing systems has been carried out through the WMO Workshops on the Impact of Various Observing Systems on NWP in Geneva 1997, Toulouse 2000, Alpbach 2004, Geneva: 2008 and Sedona: 2012. The series of workshops has proved very successful providing substantial input for reviewing the Statements of Guidance for Global and High-resolution NWP, the Vision of the GOS for 2025 and the ET-EGOS IP

With this fruitful result, CBS-15 requested OPAG-IOS to organize the Sixth WMO Impact Workshop in 2016. Since the last workshop provided very successful result, the next workshop should be organized with similar size and set-up. The location and date are under consideration.

3. Recommendations on observing system design

1. Recommendation 1 – Encourage continued development and research of adjoint-based observation impact assessment tools, as a complement to traditional OSEs.

2. Recommendation 2 – Encourage OSEs for the optimisation of regional composite networks

3. Recommendation 3 – Encourage NMHSs to conduct OSEs and OSSEs to address the specific science questions listed in Appendix A.

APPENDIX A

PROPOSED SCIENCE QUESTIONS TO BE ADDRESSED FOR OBSERVING SYSTEM DESIGN

Short name: Full name	Science question
	Surface-based
S1MarinePs: Surface pressure over ocean	What density of surface pressure observations over ocean is needed to complement high-density surface wind observations from satellites? Suggestions: (a) network density reduction OSE in N. Atlantic, (b) southern oceans OSSE.
S2Strat: In situ observations of the stratosphere	What network of in situ observations is needed in the stratosphere to complement current satellite observations (including radio occultation)? What about the tropics?
S3AMDAR: Coverage of AMDAR	What is the impact of current AMDAR observations? What are the priorities for expansion of the network?
S4ASAP: Coverage of ASAP	What is the impact of current coverage of profiles from the Automated Shipboard Aerological Programme (ASAP)? How might coverage be optimised for a given level of resources?
S5Radar: Radar observations	What are the impacts of current radar observations, including radial winds and reflectivities?
	Space-based
S6RO: Radio occultation saturation	At what level, in terms of profiles per day, does the impact of radio occultation observations start to saturate?
S7SatLand: Satellite radiances over land	What is the impact of new developments in the assimilation of radiance data over land?
S8Sounders: Impact of multiple satellite sounders	What benefits are found when data from more than one passive sounder are available from satellite in complementary orbits, e.g. multiple AMSU-As, AIRS + IASI ?
S9AMVs: AMVs	What impacts are currently found from AMVs?
	General
S10Thinning: Data density and data thinning	What impacts/benefits are found from data density/thinning strategies from various observation types?

S11PBL: Observations of the PBL for regional / high-resolution NWP	What should be the focus of improvements for observations of the PBL in support of regional/high-resolution NWP? Which variables and what space-time resolution?
S12UA: EUCOS-like upper air OSEs	Can EUCOS-like upper air studies be performed for other regions?
S13AdjEns: Regional application and adjoint and ensemble methods	What insights can be gained from more tailored use of adjoint- and ensemble-based measures of observation impact, for example, in the tropics or at the meso-scale where metrics other than global energy may be appropriate?
S14ExtRange: Impact of observations on extended range forecasts	Which observations are particularly important for the 7-14 day forecast range?
S15Targeting: Targeted observations	What do experiments on targeted observations tell us about observing system design?
S16aAMMA, **S16bIPY**: AMMA and IPY legacy	What impacts/benefits could be expected by sustained components of the AMMA and IPY special observing systems?
S17 Time interval	What time interval data from GEO satellites and ground based remote sensing observations (such as Doppler radar, wind profiler, ground based GNSS receivers) should be needed (exchanged) for the global / regional NWP?