WORLD METEOROLOGICAL ORGANIZATION

Distr.: RESTRICTED
CBS/OPAG-IOS (ODRRGOS-4)/ Doc. 5
(23.I.2002)

COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMME AREA GROUP
ON INTEGRATED OBSERVING SYSTEMS

ITEM: 7

EXPERT TEAM ON OBSERVATIONAL DATA REQUIREMENTS
AND REDESIGN OF THE GLOBAL OBSERVING SYSTEM

Original: ENGLISH

FOURTH SESSION

GENEVA, SWITZERLAND, 28 JANUARY-1 FEBRUARY 2002

The Draft Statement of Guidance for Seasonal to Inter-annual Forecasts

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Summary and Purpose of Document

The document provides a draft Statement of Guidance (SOG) for seasonal to inter-annual (SIA) forecasts. In this SOG, the requirements for SIA forecasts are based on a consensus of the coupled atmosphere-ocean modelling community, and they represent only those variables that are known to be important for initialising models or for testing and validating models. For the most part, aspects that remain purely experimental are not included. There is some attempt to capture the impacts aspects; that is, those variables that are needed for downscaling and/or regional interpretation.

ACTION PROPOSED

The meeting is invited to take into consideration the information contained in this document when discussing the progress in critical review and further development of SOGs for various application areas.

Draft Statement of Guidance for Seasonal to Inter-annual Forecasts

Introduction

1. Coupled atmosphere-ocean models are used to produce seasonal to inter-annual forecasts of climate. Whilst such forecasting is still subject to much research and development, many seasonal forecast products are now widely available. The complexity of the component models range from single baroclinic models to full general circulation model representations of both the ocean and atmosphere. There is also a large variation in the approach to assimilation, with some of the simpler models just assimilating wind information while the more complex models usually assimilate subsurface temperature information and satellite surface topography and temperature data. Indeed, major challenges remain in the development of assimilation techniques that optimise the use of observations in initialising models. At present, useful forecast skill (as measured against ocean and atmosphere indices) is restricted to around 6-8 months lead-time and is largely confined to the tropical Pacific and those regions directly impacted by El Niño.

2. The time and space scales associated with seasonal-to-interannual variability (large scale, low frequency) suggest the key information for forecasts will mostly derive from the slow parts of the climate system, in particular the ocean. The initial conditions for the atmospheric model component are not so significant. However, when considering impacts such as rainfall deficiencies or increased temperatures over land, there are often very good reasons for considering variables associated with the land surface conditions.

3. Empirical and statistical methods are also used to predict climate conditions a season ahead. However in this document, the assessment of how well observational requirements are met is related to the coupled model inputs only. Historical data sets play in important role in SIA prediction by supporting calibration and verification activities, but this SOG does not address the requirements for historical data sets.

4. Comprehensive statements on requirements have appeared in several places, most recently in the proceedings of *First International Conference on Ocean Observing Systems for Climate*, and published separately in *Observing the Oceans in the 21st Century* (published by the GODAE Office and the Bureau of Meteorology). In terms of key variables, the priorities have changed little since the Tropical Oceans-Global Atmosphere Experiment of 1985-1994. The above references also provide details of ocean-based and space-based platforms capable of meeting these requirements. The report of the IGOS Ocean Theme Team provides a consolidated and integrated perspective for the oceans that embraces SIA forecasts explicitly.

5. In this SOG, the requirements for SIA forecasts are based on a consensus of the coupled atmosphere-ocean modelling community, and they represent only those variables that are known to be important for initialising models or for testing and validating models. For the most part, aspects that remain purely experimental are not included. There is some attempt to capture the impacts aspects; that is, those variables that are needed for downscaling and/or regional interpretation.

6. The data requirements for each major function (model development, initialisation, and validation) can be somewhat different. For example, integrated data sets, such as blended SST products or atmospheric reanalysis products, are generally more important for validation than for initialisation.

Sea Surface Temperature

7. Accurate SST determinations, especially in the tropics, are important for SIA forecast models. Ships and moored and drifting buoys provide observations of good temporal frequency and acceptable accuracy, but coverage is marginal or worse over large areas of the Earth. Instruments on polar satellites provide information with global coverage in principle, good horizontal and temporal resolution and acceptable accuracy, except in areas that are persistently cloud-covered (which includes significant areas of the tropics). Geostationary imagers with split window measurements are helping 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 to up 4 C in cloud free regions with relatively calm seas). Microwave measurements provide acceptable resolution and accuracy and have the added value of being able to "see through" clouds. Blended products from the different satellites and in situ data can be expected to be good for SIA forecasts.

Ocean Wind Stress

8. Ocean wind stress is a key variable. Current models use winds derived from NWP, from specialist wind analyses or, in some cases, winds inferred from atmospheric models constrained by current SST fields. The tropical moored buoy network has been the mainstay for surface winds over the last decade, particularly for monitoring and verification, providing both good coverage and accuracy in the equatorial Pacific. Fixed and drifting buoys and ships outside the tropical Pacific provide observations of marginal coverage and frequency; accuracy is acceptable.

9. Satellite surface wind speed and vector measurements are potentially an important source. Currently their data reaches SIA models mostly through the assimilated surface wind products of NWP, where their positive impact is acknowledged. Overall, a two-satellite scatterometer system, or its equivalent, would provide good coverage and acceptable frequency, and it would complement the ocean-based systems. At this time, continuity and long-term commitment are a concern. Irrespective of these issues, improved integration of the data streams and operational wind stress products from NWP and other sources will be needed to achieve acceptable or better coverage, frequency and accuracy.

Subsurface Temperature and Salinity profiles

10. Many, but not all, SIA forecast models assimilate subsurface temperature data, at least in the upper ocean (down to ~500 m depth). No current model assimilates salinity data (subsurface or surface), principally because of the paucity of data and inadequate knowledge of the variability. The Tropical Atmosphere Ocean (TAO) moored buoy network provides data of good frequency and accuracy and acceptable spatial resolution for the tropical Pacific, at least for the current modelling capability. The tropical moored network in the Atlantic (PIRATA) is better than marginal but does not yet have the long-term resource commitments to be classified as acceptable. There is no array in the Indian Ocean. Ship-of-Opportunity provide data of acceptable spatial resolution over some regions of the globe but the temporal resolution is marginal. The *Argo* Pilot Project offers the potential for global coverage of temperature and salinity profiles to ~1500 m, mostly with acceptable to good spatial resolution, but only marginal temporal resolution in the tropics. In all cases the accuracy is acceptable for SIA purposes. The complementarity between surface wind and surface topography measurements is important.

Ocean Altimetry

11. Ocean altimetry provides a measure of the sea surface topography relative to some (largely unknown) 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* will provide a good system for initialising the thermodynamic state of SIA models. There are currently no operational altimeters. Experimental satellites are providing a mix of data with acceptable accuracy and resolution and data with good spatial resolution (along the satellite tracks) but marginal accuracy and frequency. The "synoptic" global coverage, particularly the tropical beyond the Pacific, is an important attribute.

Surface heat and freshwater flux

12. There are a few sites in the tropical ocean where the data on surface heat flux are of some value. At a selected number of sites the accuracy and temporal resolution will be good. NWP products, in principle, have good resolution but the accuracy is marginal. Satellite data provide prospects for several of the components of heat flux, particularly shortwave radiation, but at present none is used on a routine basis for SIA forecasts. Precipitation estimates are important for validation because of the fundamental role of the hydrological cycle in SIA impacts. They also have potential importance in initialisation because of the links to salinity. Experimental satellite data are acceptable for the tropics.

Ocean current data

13. No model currently assimilates ocean current data. However, because of the central importance of dynamics and advection, current data are important for testing and validation. For example, experimental fields of surface current 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. Drifting buoys are acceptable in terms of accuracy and temporal resolution but marginal in spatial coverage (only the surface). Moored buoys are good in temporal coverage and accuracy, but marginal otherwise.

Sea level

14. In situ sea level measurements provide an additional time-series approach (good temporal resolution and accuracy; marginal spatial coverage), particularly for testing models.

Atmospheric data

15. Since several SIA systems are driven by operational winds and, in several cases, operational surface heat flux products, the global (atmospheric) observing system is important for SIA forecasts. See the section on global NWP.

Other data

16. There are many other data sets that potentially may play a role in future-generation SIA forecasts models. Because these roles are largely unknown, it is premature to discuss the adequacy of observing systems to meet these needs. In no case are they expected to rank near the above data in terms of priority. These include:

- Surface salinity, particularly from new space-based approaches. No present model uses surface salinity.

- Snow cover. Research suggests snow cover may be important, particularly at short lead times (Intraseasonal-to-seasonal). No current model ingests snow cover data or

uses it for impacts or applications.

- Ice cover. Ice cover is important for the global properties of the global atmospheric climate model. It is implicitly included in most SST products.

- Soil moisture and terrestrial properties. Research suggests proper initialisation of soil moisture can be important. There are also some indications that terrestrial properties may be important, particularly in downscaling and impacts/applications.

- Ocean colour. Ocean transparency is already included in several ocean models and is thought to be a factor in SIA models. Ocean colour measurements provide a means to estimate transparency.

- Clouds. Poor representation of clouds remains a key weakness of most SIA models. Better data are needed to improve parameterisations but these needs are adequately covered under NWP and elsewhere.

Summary of the Statement of Guidance for Seasonal to Inter-annual Forecasting

17. The following key points summarise the SOG for Seasonal to Interannual forecasts:

- The requirements for seasonal-to-interannual modelling and forecasts are documented in various GCOS and WCRP documents;

- The WCRP has concluded that models show useful skill in predicting variability of the El Niño-Southern Oscillation but there is less useful predictability beyond the Pacific. The exploitation of skill is dominated by the signal of El Niño;

- Integrated and complementary approaches to the atmospheric and oceanic observing systems is required, exploiting synergies with other areas;

- The continuation of the TOGA Observing System (SST and winds; subsurface temperature; sea level and currents) provides the backbone of the system in place today;

- Enhancements from satellite wind vector and surface topography estimates, from new autonomous instruments such as *Argo*, and from enhanced surface flux reference sites will be a substantial contribution;

18. The key observational problems affecting improvements in seasonal to inter-annual forecasting are:

- The transition of research networks and outputs to operational status;

- The timely operational acquisition of data from research and non-governmental systems/sources.