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COMMISSION FOR ATMOSPHERIC SCIENCES

CAS/THORPEX ICSC/
DAOS WG

DAOS Working Group

Seventh Meeting

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DRAFT MEETING REPORT

Presentations available from
http://www.wmo.int/pages/prog/arep/wwrp/new/Presentations_DAOS_Montreal_2014.html

1. Organisation of the meeting

1.1 Opening remarks

Roger Saunders welcomed the participants to the meeting.

Tetsuo Nakazawa noted that he had retired from the WMO but is now employed as a consultant until the end of November 2014. THORPEX will finish at the end of 2014, but the DAOS WG will continue under the WWRP and will cover all the relevant WWRP activities. DAOS is expected to finalise the TORs and define its links with the other WWRP WGs and the projects, including HIWeather. He stressed that DAOS should be the WMO focal point for DA on all temporal and spatial scales with appropriate links to other WGs e.g. the MWFR. He hoped for a successful and productive meeting. Nakazawa-Sama noted that Paolo Ruti will assume his responsibilities at the WMO.

Mark Buehner welcomed the participants on behalf of Environment Canada and hoped that everyone would have an enjoyable visit to Montreal. Apologies were received from Chris Velden, Stefan Klink, Darryl Kleist, and Rolf Langland, who were unable to attend although they did provide input to the meeting.

1.2 Introduction of invited experts

The Co-Chairs introduced the new members of the WG, Nadia Fourrie (MeteoFrance) and Saroja Polavarapu (Environment Canada). It was hoped that they will find the meetings useful and productive. Observers from Environment Canada, Greg Smith, Louis Garand and Pierre Gauthier were also welcomed to the meeting.

1.3 Aims of the meeting

The Co-Chairs noted that the main aims of the meeting included reporting on recent progress, planning for the transition to a WG to the WWRP, gathering new ideas for a possible DAOS 5-year programme, and considering future DA symposia and conferences.

1.4 Adoption of the agenda

The agenda was discussed and agreed.

1.5 Working arrangements

The detailed working arrangements were agreed. It was also agreed that all presentations would be placed on the WMO website unless individuals requested otherwise.

2 **Review of actions**

2.1 Review of actions

A summary of the status of the actions from recent meetings was distributed. Only the actions requiring discussion were considered:

Action 4.18: It was provisionally agreed to adopt the FSO (forecast sensitivity to observations) terminology with the optional preface of "A" for Adjoint FSO or "E" for Ensemble FSO. Ron, Carla, and Rolf will continue to see if they can agree on a better consensus wording.

Action 7.1: Consider a discussion note on the recommended terminology for forecast sensitivity to observations (Ron, Carla, Rolf) to be distributed to DAOS members for comment by November 2014. This note should then be tabled at the next WMO CBS (Commission for Basic Systems) Workshop on the impact of observations.

Action 5.3: It was felt that the time is right to prepare the BAMS paper on targeting. This should link with the comprehensive THORPEX overview paper being prepared for BAMS by David Parsons. In discussion the following action was agreed:

Action 7.2: Sharan Majumdar will prepare a first draft of the BAMS paper on targeting by spring 2015. DAOS will act as the first reviewer of the paper and make contributions.

Action 5.5: On the distribution of ground-based GPS zenithal total delay measurements, the supply of data from the USA on the GTS has stopped.

Action 7.3: Roger Saunders will liaise with Zoltan Toth to establish what has happened.

Action 5.7: Comparing the impact of AMVs at NRL and GMAO a report was produced. GMAO has not pursued this topic further. There is some NOAA Sandy Supplement funding devoted to winds. The work has been transitioned to the Joint Centre and a Winds WG which has formed. This is being done in the context of the NOAA GFS with advice from the US Navy and University of Wisconsin. Work is underway and this national US effort will feed into the International Winds WG. Ron Gelaro will forward a status report on the work when available.

Action 7.4: Ron Gelaro to investigate positive impacts of AMVs and give a status report at the next meeting

Action 5.9: Concerning the field of view size of future CrIS instruments, this matter is being discussed in the International TOVS WG, which is making recommendations. This DAOS action is now closed.

Action 5.12: Approval of DAOS-WG membership. This item is on the agenda. Since the last meeting Tom Keenan (BoM) has stood down from the WG. Keenan noted that Peter Steinle (BoM) is willing to serve again and to act as a liaison to the WMO's MWFR group, pending WWRP/JSC approval. Roger Saunders declared his intent to step down as Co-Chair at the end of 2014, as he has served in this capacity for 5 years and felt it was time to let someone new take over.

Action 6.1: Regarding the introductory notes from the WMO Data Assimilation symposium to be placed in the American Meteorological Society special collection, this action is on the agenda – (see item 3.1 below).

3. **Reports**

3.1 Update on the WMO DA Symposium

Daryl Kleist briefed the meeting on the recent 2013 WMO DA symposium. It took place against the background of a partial shutdown of the US Federal government. The University of Maryland stepped in at the last moment, enabling the meeting to go ahead. It was supported by a great amount of voluntary effort. The symposium went smoothly, with only a small reduction in participants from an expected 330 to about 310. The agenda remained largely intact. The presentations can be found at http://das6.umd.edu. A collection of around 35-40 papers are expected for the AMS journals' special collection. About ten are currently being reviewed.
Many people felt that the 15 min talks were a bit too short. The poster session was welcome. Significant sponsorship was needed to keep the price reasonable. A question arises as to whether the other International Data Assimilation meeting may be in conflict with the WMO Symposium in the future? However, overall the symposium was judged a great success. It was noted that Brazil may be interested in hosting the next one.

Action 7.5: WG members to encourage and solicit proposals to host the next WMO DA symposium (All, Co-chairs to email symposium list after contacting Brazil)

3.2 Report on the Munich International Symposium on Data Assimilation

Mark Buehner briefed DAOS participants on this symposium. He said it was constructed to be somewhat like an ECMWF workshop and with longer talks on topics of particular interest to DWD, but this seems to be changing with the next symposium to take place in Kobe, Japan. The focus was very much on the convective scale, including use of cloudy radiances, assimilation of cloud information, ensemble methods in DA, multi-scale issues, uncertainty in DA and forecasting. Some aspects of global DA important for the convective scale were also discussed. It was noted that convective scale DA provides most impact relative to nowcasting methods and global predictions in the timescale T+6 to T+12. Over the UK, for example, the forecasts are about 8% better than from the global model.

The relationship between the WMO DA symposium and the European event was discussed. The main issue was seen to be one of timing of the events.

The DA aspects of the WWOSC meeting were also noted. It was agreed that DAOS should comment on the white papers of relevance.

Action 7.6: Roger Saunders to co-ordinate the timing of future WMO DA symposium with the European DA meeting (Roland Pothast, DWD is the current German symposium representative).

Action 7.7 DAOS to comment on WWOSC white papers of relevance.

3.3 T-NAWDEX plans

Roger Saunders presented some slides from Heini Wernli on recent progress to organize T-NAWDEX (the THORPEX- North Atlantic Waveguide and Downstream Experiment). Amongst the scientific objectives they will be investigating are the systematic errors in model representation of waveguide perturbations that are attributable to diabatic processes. These errors are manifest as PV distribution errors. Other topics include strong cyclone activity, tropical cyclones and HIWeather over Europe.

Some pilot T-NAWDEX flights have already taken place. These were in November 2009 and looked at the transformation of air masses by diabatic processes. It is hoped that the main T-NAWDEX campaigns will be held in Sep-Nov 2016 and will involve aircraft from the UK, USA, and Germany. The USA will carry out the activity 'dynamics and observations of the waveguide' whilst Canada will organize 'the Canadian North Atlantic forecast experiment'. These various contributions to T-NAWDEX will co-ordinate together. It is expected that scientists from the USA, Canada, UK, Germany, Switzerland and France will participate.

The work contains some unique aspects and has synergies with the ESA Doppler Wind Lidar.

Funding bids are currently being made. A USA bid is under review. At the moment UK participation is not funded.

3.4 HyMEX report

Nadia Fourrie described recent developments in HyMEX (Hydrologic Cycle in the Mediterranean Experiement). Field campaigns occurred in Autumn 2012 and Winter 2013, with a special observing period in the NW Mediterranean. The first campaign focused on heavy precipitation and flooding, the second on severe winds and dense water formation. During the first special observation period, a data targeting system was activated. More than 400 radiosondes were launched at 6 and 18 UTC between 11 September and 30 October 2012. Two studies on the impact of these additional observations have been conducted in AEMET (Campins et al, 2014) and at Météo-France in limited-areas models. The impact was slightly positive in the Spanish study for all the parameters, and neutral to slightly positive benefit for short-range precipitation forecasts was found at Météo-France. Other studies on the assimilation of new observations or on the improvement of observation assimilation are conducted in the frame of the HyMeX science team. These include impact studies of profiles from ground microwave sounder and lidars, polarimetric parameters and refractivity of radars, enhancement of satellite usage over land and in cloudy conditions. Studies on the B matrix computation from an ensemble are also conducted. The 8th HyMEX Workshop will take place in Valetta, Malta from the 15-18 Sept. 2014.

3.5 Polar Prediction Project update

Greg Smith from CMC described recent progress in the Polar Prediction Project (PPP). He leads the EC group on ocean-ice systems and has a strong polar focus. The main purpose of the PPP project is to promote international research in improved weather and environmental services on timescales from hourly to seasonal. An implementation plan is available (see www.polarprediction.net). There are many scientific challenges addressed by PPP ranging across extreme events, the harsh environment, verification problems, characteristics of observation error and deployment of instruments etc., Research objectives include improving services and forecasting systems in polar regions and carrying out underpinning research. The need for use of coupled models in polar regions is evident, including sea-ice models, ocean models etc., There are considerable DA problems, including characterization of observing system and representativeness errors, and the treatment of polar model errors in the assimilation cycle. The interaction with the mid-latitudes is also a key topic. Four flagship themes have been identified: sea-ice prediction, polar-mid latitude linkages, improved availability of polar observations, and the Year of Polar Prediction (YOPP). The YOPP is scheduled for 2017-2019 and is expected to be comparable to the IPY. A preparation phase is underway (2013-2017) and the main YOPP period will be followed by a consolidation phase (2019-2022) consisting of data-denial experiments, model development, dedicated reanalysis development, and such. The YOPP will link with MOSIAC (a polar observations grid) and include extra observations from ships and buoys as well as satellite and aircraft data. Satellite systems include Cryosat2 and IceSat2. Plans were in place to deploy many of these independently, but under PPP will be coordinated for co-deployment.

Action 7.8: DAOS to review the PPP and particularly the YOPP IP and to send comments to Greg Smith.

It was felt that that DAOS could contribute to the PPP by: (a) promoting research into polar DA; (b) conducting observing system experiments (e.g. the value of surface buoy data), and (c) conducting selected observing system simulation experiments, e.g. what is the optimal deployment of observational equipment for the YOPP?

Discussions noted that previously drift buoys have been at the top of the list of impact per observing system unit cost and should be supported by PPP. The augmentation of the ARGO floats to provide surface-pressure measurements would also be extremely valuable.

3.6 Sub-seasonal to Seasonal Prediction project update

Tetsuo Nakazawa briefed the WG on developments in the sub-seasonal to seasonal prediction project (S2S). The project was approved by the WMO Executive Committee in 2013, and a Trust Fund and ICC (International Coordination Centre) have been set up, the latter hosted in Jeju Island by Korea. The work is seen as helping bridge the gap between weather and climate and will focus on improving forecast skill, especially that of high-impact weather, as well as promoting the uptake of improved forecasts by operational centres. The project will include demonstration projects and research activities. There are five research themes; monsoon forecasting, the Madden-Julian Oscillation, African forecasts, extreme weather, and verification.

One key database to facilitate research will be a 'TIGGE-like' database. However, TIGGE forecasts run out to only +15 days lead, whilst S2S will extend to +60 days. This database has been established at ECMWF. The archive will contain daily means of forecast data, delayed by 3 weeks, and will include most of the TIGGE variables, plus some ocean variables as well as soil moisture and some stratospheric data. CMA will also act as an archive centre whilst the UK Met Office will archive a sub-set of the data. The process will start in 2014, with initially 11 centres contributing atmospheric data. Ocean data will follow in 2015. This still needs to be defined and a committee will be formed to monitor progress of the database.

Close links will be kept with the MJO Task Force, the Joint WG on verification and the HIWeather project. The 1st International Conference on the S2S project was held at the new NCEP building, College Park, Maryland during June 2014.

3.7 HIWeather project update

Sharan Majumdar updated the status of the HIWeather (High-Impact Weather) project, which was formally approved by the WMO Executive Council in June 2014. The mission is to promote international research to increase resilience to high-impact weather via improved forecasts at timescales of minutes to 2 weeks. Based on the Second HIWeather Workshop in June 2014, the Implementation Plan has been substantially revised and will be finalized for presentation to the WWRP SSC in November 2014. It is hoped an international trust fund can be established and activities can begin in 2015.

Examples of challenges and activities relevant to DAOS were summarized. There exist several challenges related to observations and nowcasting, given the complex high-resolution and coupled nature of the system. These include the need to utilize new observing strategies to capture HIWeather hazards and impacts, for example via remote sensing, crowd sourcing, high density and cheap networks such as cellular phone data. The rapid initialization and use of a coupled nowcasting system is another major challenge. Numerous challenges related to data assimilation also exist, including how to handle non-linearity of complex processes, and assimilating observations continuously in time. Issues such as the observation density being coarser than the fine-scale model grid, and the interplay between small-scale and large-scale errors will require addressing.

Possible activities to address these challenges include: (1) the improved use of high-resolution, four-dimensional observing, for example of surface data and all phases of precipitation (2) the development of new nowcasting techniques, blending in forecast information from rapid-update data assimilation and NWP systems. (3) assessments of model error (perhaps in collaboration with other working groups); (4) inter-comparison studies of multi-scale, coupled data assimilation for selected cases such as FDPs. (5) development of tools to assess the sensitivity of hazard forecasts to observational inputs.

Action 7.9: Sharan Majumdar to distribute the HIW implementation plan (IP) and to identify those sections that would benefit from DAOS input. DAOS members to send comments on the IP to Sharan.

3.8 WGNE report

Ton Hamill briefed DAOS on WGNE developments. WGNE fully supports the transfer of the DAOS WG to the WWRP after the end of THORPEX. WGNE noted also noted that THORPEX's GIFS-TIGGE and Predictability and Dynamical Processes WGs will also be merged and transfer to the WWRP as a Predictability, Dynamics and Ensemble Forecasting (PDEF) WG. A coupled data assimilation workshop with DAOS involvement is considered desirable by WGNE. Jean-Noel Thépaut noted that ECMWF has tentative plans for such a workshop, so it may be possible for DAOS to co-sponsor such an event.

Discussion at WGNE included whether DAOS should have a role in the configuration of the global observing system. Jean-Noel Thépaut noted that the operational centres coordinated admirably on this topic within the last year without DAOS, though that did not preclude a useful role for the group in the future.

The issue of verification against own analysis was again discussed at WGNE; the results presented from Chaishi Muroi (JMA) and Jean-Noel Thépaut (ECMWF) showed that verification against own analysis is not just a problem for short leads, but for intermediate leads in the tropics as well. Also, different conclusions can be drawn with regards to medium-range ensemble spread when verified against own analysis (appears adequate) vs. when verified against observations (somewhat inadequate). WGNE suggested:

– Emphasize verification against observations, including non-conventional, e.g., radiances. (In discussion, DAOS participants noted some practical concerns of this approach, such as the bias that can contaminate the radiances).
– Perhaps verify against consensus analysis instead, but the exact methodology needs to be established by further research.
– DAOS might be a better place to coordinate future research on this topic than within WGNE.

Action 7.10 Prepare for a coupled DA workshop potentially with ECMWF in 2016 (Tom Hamill, Carla Cardinali).

3.9 Hierarchical Bayes Ensemble Variational Data Assimilation

Michael Tsyrulnikov described a new approach to ensemble-variational data assimilation. The core idea is to treat the background-error covariance matrix as a random matrix, specify its prior probability distribution, and update it in an extended analysis along with the state. In this update, ensemble members are assimilated as generalized observations. An importance sampling based numerical algorithm for the extended analysis is proposed. In a toy problem, numerical experiments with synthetic truth show that the new technique outperforms the existing variational, ensemble Kalman filter, and traditional ensemble-variational analyses.

In discussion, there was concern as to whether the problem was solveable, a general property of other than quadratic closure.

3.10 Links to other groups

The WG discussed the extent to which re-analysis is covered by other groups. It was agreed that DAOS should have some contact/involvement in this work.

4. Longer discussion topics

4.1 Possible cooperation on global OSSEs (Observing System Simulation Experiments) facilitated by DAOS

Lidia Cucurull, remotely from ESRL/GSD in Boulder, introduced this topic. OSSEs can be used to evaluate new methodologies for processing and assimilating remotely sensed data and for evaluation of the potential value of new sensors prior to their building and deployment.

One important principle for the conduct of OSSEs is to avoid use of the same model for nature run and assimilation, as such systems don't simulate model uncertainty. Typical OSSEs have 5 steps: (a) generation of a nature run (assumed truth), (b) computation of synthetic observations from that run, (c) characterization of observational error attributes to be applied to the synthetic observations, (d) assimilation of these observations into a forecast model (different from the nature model) and (e) evaluation of the assimilated observations in terms of forecast skill and metrics. Previous OSSEs have considered the relative impact of temperature, wind and moisture data as well the relative importance of upper or lower level wind data and determined the data requirements for space based lidar winds.

Within the US there is an initiative to develop a NOAA OSSE test bed that would lead to a series of experiments such as consideration of trade–offs in observing system design. The Quantitative Observing System Asessment (QOSA) programme was set up in NOAA in 2013 and records an inventory of all OSEs and OSSEs.

There are several reasons why international collaboration on OSSEs may be desirable. These include: (a) the desirability of producing and sharing nature runs from multiple centres to ensure robustness of conclusions; (b) comparing OSSE results produced by several independent DA systems, again to ensure robustness; and (c) spreading the personnel expense associated with generating methods for developing synthetic observations. Ideally, different centres might lead on different components, one producing a nature run, another producing generalized forward operators. Ideally, OSSE results would be available to all, and an international WG like DAOS to assist in validation might be very helpful.

In discussion it was note that the main objective was really to get the impact of future data in future NWP systems. This is not achievable, as we don't know the future global observing system nor the configuration of future models. This was agreed, but it was noted that OSSEs can still provide an upper bound for impact, such that if a proposed new sensor does not provide value under today's comparatively data-sparse, model-poor conditions, it should provide even less value in the future, with more observations and better models.

The high costs of OSSEs and the associated nature runs were recognized as was the potential complexity of involving many centres – perhaps limit to just a few. There was a view that international organisation (e.g. setting up of a WG) in this area needs further consideration.

Action 7.11 DAOS to ask the operational centres and other organisations to identify the key questions about the GOS they would like to be addressed by the use of OSSEs. Sharan Majumdar to provide some draft questions.

4.2 Assimilating surface-sensitive IP channels and update on PCW

Louis Garand presented ongoing research carried out at Environment Canada on the assimilation of surface sensitive infrared radiances over land and sea ice. Results were based on two-month EnVar assimilation cycles (Feb-March 2011) that included the correction of skin air temperatures and humidity. New radiances assimilated are from AIRS and IASI (from pre-selected 142 channels for each instrument). Strict conditions were imposed based on topography (low local standard deviation), emissivity (>0.97) and cloud amount (clear) before data were selected for assimilation. First results were negative in the polar regions, potentially due to cloud contamination. However, a second attempt not considering regions above latitude 60 degrees indicated overall positive impact over most of the troposphere up to day 5, both against independent ECMWF analyses and radiosondes. The impact was most evident in the Northern Hemisphere extratropics. Next experiments will allow a less strict criterion on surface emissivity, making use of the University of Wisconsin emissivity atlas available with RTTOV.

Garand also reported on the status of the development of Polar Communications and Weather (PCW) satellites. PCW is anticipated to consist of two satellites in highly elliptical orbits which will allow seamless (15 min refresh or less) meteorological imaging over the region 50-90 N. The imager will be of ABI/FCI class (16-20 channels, 1 km VIS, 2.5 km IR). Phase A was completed in 2012. Recently, a Research For Information (RFI) process was carried out. A strong response from industry indicated all requirements can be met, this with various orbital configurations. It is planned to get formal approval by the Canadian Government to proceed with a Research For Proposal (RFP) process in 2015. The target for launch is 2021.

PCW data is anticipated to provide imagery similar in quality to geostationary data, which will make it suitable for use in deriving atmospheric motion vectors. The data is also anticipated to be useful for satellite inter-calibration.

4.3 Satellite data assimilation in limited-area models

Nadia Fourrie of Meteo France noted that satellite data are assimilated in ALADIN and AROME modeling systems, with beneficial impacts on the forecast quality. Many issues have to be addressed for a better exploitation of the satellite data in limited-area models. The mismatch between the satellite observation resolution and the model grids, especially for scanning sensors, should be taken into account by developing new observation operators accounting for all the model profiles contained in the instrument field of view, some of which may be highly oblique. The radiance bias correction requires a large sample for its estimation. For lack of a large sample, the bias corrections in regional modeling systems are often inherited from the global modeling system. Characterization of inter-channel errors and spatial errors may be important for the successful assimilation of dense multi-channel radiance data. In the cloudy/rainy areas, the background error matrix has to be also appropriately defined for cloud variables.

Radiance data assimilation over land has been recently developed with appropriate surface parameters (skin temperature and surface emissivity) in the radiative transfer model in order to increase the observation coverage over the continents. Cloud-top pressure and cloud fraction estimates are used to constrain the assimilation. The assimilation of cloudy/rainy radiances with cloud variables included in the control vector and advanced radiative transfer model seem promising, but it requires further validation. The choice of the scattering property database for ice crystals appears to be important.

4.4 Carbon flux data assimilation

An overview of carbon flux data assimilation was provided by Saroja Polavarapu (Env. Canada). The primary science goal is to better understand and quantify the terrestrial biospheric uptake since that is where the greatest uncertainty in the global carbon budget lies. Consequently, key science questions involve characterizing the observing system needed to reduce uncertainty on biospheric fluxes in order to identify anthropogenic fluxes on policy relevant scales. Additionally, a desire to predict the long-term evolution of sources and sinks raises the question of whether nonlinear feedback processes are sufficiently well represented in carbon-climate models.

While similar tools and techniques to NWP data assimilation are being used in carbon flux estimation, important differences exist. For the carbon flux problem, the dynamical system is not chaotic since tracer transport is assumed linear. So the challenge is to estimate highly variable surface fluxes with too few data, in contrast to the NWP problem of finding an accurate analysis (and uncertainty) with which to make forecasts. It is difficult to know, when mismatches occur between measurements and forecasts, whether this is due to error in flux estimates or to model errors.

With the recent launch of greenhouse gas dedicated satellite missions such as GOSAT (2009) and OCO-2 (2014) it is hoped that fluxes may be estimated on a more regional scale. Some operational weather prediction centers (ECMWF, GMAO) are developing coupled meteorology-greenhouse gas prediction and assimilation systems primarily to support these satellite missions. The process of developing such coupled models may also lead to the improvement of model processes which affect

greenhouse gas distributions: advection, boundary layer mixing, convective transport and evapotranspiration. The HIWeather project will address related topics e.g. pollution in mega-cities.

5 Shorter Discussion Topics

5.1 Verification against analyses

Discussed earlier, in item 3.8.

5.2 Verification by forecasters using simulated satellite imagery

Roger Saunders described a new verification system used by forecasters with simulated satellite data. A fast radiative transfer model is used to produce simulated cloud fields from numerical weather prediction guidance. Meteosat IR and WV imagery is simulated using T+6, T+12, T+18 etc forecast data. Simulated imagery is also generated from ensemble forecasts. A more automated verification process is being considered. The hope is that such data can be used for the verification of clouds and moisture fields. Additionally, if discrepancies are noted for particular ensemble forecast members, those members can be de-weighted.

5.3 Observation impact

Carla Cardinali and Ron Gelaro introduced this topic. They have investigated FSO (Forecast Sensitivity to Observations) using a new cost function and are evaluating this with forecasts out to 24h. The advantage is that it is similar to the cost function in 4D-Var, and this can produce differences in estimations of observation impact relative to the more commonly used energy norm. Previously, little or no impact was found from ozone measurements with the energy norm, but a positive impact is now found with the cost-function norm. This method is in validation, with further results expected by the end of 2014.

Ron Gelaro is exploring the possibility of extending estimates of observation impact to beyond 24 h. When Gaussian quadrature was used for the adjoint calculation, there was an indication that 48-h results were as accurate as previous 24-h results.

There is some discussion about whether moisture should be included in the norm. Carla Cardinali noted that moisture inclusion tends to add noise; Andrew Lorenc noted that one can have a tunable variable that indicates how much to de-weight humidity, and such an approach has apparently worked well in MetOffice applications. Ron Gelaro noted a 0.3 weight was used in NASA systems, giving moisture a similar contribution to T, U, and V.

It was agreed that, as in the past, DAOS should continue to support CBS in the preparation of the regular observation impact workshops.

Action: 7.12 DAOS WG to advise CBS in the preparation of the next Observation Impact Workshop. Carla Cardinali and Rolf Langland to be DAOS representatives.

5.4 Ensemble forecast sensitivity to observations (EFSO) and flow-following localization in 4D-En-Var

Andrew Lorenc noted that an important question will be how to maintain an ability to calculate FSO in future EnVar methods when adjoints of the forecast model are no longer available. 4D-En-Var has some distinct advantages for use in data assimilation; it does not need require the maintenance of adjoint or linear models. However, ensemble covariances are noisy, so filtering is essential for accurate EFSO results.

A brief description was given of flow-following localization in 4D-En-Var and the Met Office FSO system. The ETKF-based system developed by Kalnay et al. was then described. This is similar to the Met Office system but with no flow following localization.

For application of EFSO with longer-lead forecasts, the following issues may need to be addressed: (a) flow-following localisation is likely to be necessary to estimate impact correctly; ensemble methods are likely to be more accurate for longer windows given their modeling of covariances with ensembles of nonlinear trajectories. (b) Convective-scale methods will need a new definition of 'impact' *J* since accurate verification analyses are not available. Further, it's unlikely that we will be able to design a catch-all single impact measure, which will not be helpful for observations managers. (c) Effects of boundary conditions. One can in principle measure impact on the larger scales via boundary conditions, but is it worth the effort?

5.5 Status of satellites

Roger Saunders provided a review of the status of GEO and polar satellite systems (see the presentation for full details). Oceansat-2 failed in Feb. 2014. Future GEO systems included from Eumetsat, MTG (2017/20) and from NESDIS GOES-R (2016). JMA plans to launch Himawari-8 in Sept. 2014 whilst CMA plans FY-4 in 2015-2020. KMA is developing COMS (next). The ESA wind lidar is expected to be launched in 2016 and JPSS in 2017 in a PM orbit. GPM–Core has been launched to replace TRMM. NASA is expecting to operate RapidScat on the ISS for scatterometer winds in late 2014. COSMIC-2, which is a GPS Radio-Occultation mission follow on, is still waiting funding. The Canadian PCW mission was reviewed in section 4.2. EUMETSAT continues to plan for a 2nd Generation Polar System. CMA plans FY-3D (2015), FY-3E (2017), FY-3F (2019). NESDIS is now providing hourly AMVs and the low level AMVs from Meteosat-10 have been improved.

5.6 Status of non-satellite observing systems

Roger Saunders gave a presentation prepared by Stefan Klink. Some developments in E-AMDAR aircraft observations were noted. These included adding new destinations and wider coverage in Europe. The number of global aircraft observations now exceeds 500,000 per day from more than 40 airlines. The WMO has developed an AMDAR Onboard Functional Requirements Specification (AOSFRS) to be used by any new participating airline or new AMDAR programme worldwide. The European E-ASAP programme has 18 ships operating in the North Atlantic. Japan has 3 ships providing data mainly from the N Pacific whilst some further research ships transmit data to the GTS. E-GVAP provides ground based GNSS data. This is done in close collaboration with the geodetic community in Europe. This provides humidity data for the models and these have been shown to increase skill. Wind profilers provide vertical profiles of wind automatically and in nearly all weather conditions. There are networks in Europe, Canada, United States, Japan, China and Australia. They show a positive impact in NWP. There are growing national networks of ceilometers and automatic lidars. Following the Icelandic volcano eruptions there has been a big investment in European networks. Sea-level pressure remains an essential observation for NWP that cannot be provided from space. Barometer buoys are the most efficient way to measure surface pressure in the marine environment. Voluntary observing ships provide complimentary observations. For weather radar the main thrust is to move to dual polarization. Several NWP models are starting to assimilate reflectivity and doppler velocity data. Data transmission in Traditional Alphanumeric Code (TAC) is planned to cease in Nov. 2014.

6 **Data assimilation developments at operational centres**

6.1 MeteoFrance

Nadia Fourrie reported that since January 2014, the operational models are running on the new Bull supercomputer. The increase of computational power will allow the upgrade of the resolutions of the models. The horizontal resolution of the global ARPEGE model will vary between 7.5 km over France up to 36 km over the antipodes, with 105 levels. The cloud-resolving AROME will be run at a 1.3 km resolution with a 1-hour assimilation cycle and an increased density for the radar data (8km). The data assimilation ensemble will have 25 perturbed global members (instead of 6 members currently) and the EPS resolution will also be increased with a set of 10 physical packages for the forecast. A nowcasting version and an ensemble prediction system for AROME are prepared and should be

operational by late 2015 or 2016. In the longer term, 4D-En-Var is under development for AROME and ARPEGE models at Météo-France.

6.2 NCEP

Tom Hamill led a discussion of slides provided by Daryl Kleist. Concerning hybrid 3D-En-Var, Ensemble Kalman Filter (EnKF) covariances are now blended in the regional data assimilation applications in a one-way hybrid fashion, including in the hurricane specific model (HWRF), regional/mesoscale model (NAM), hourly rapid refresh (RAPv2), and soon within the high resolution rapid refresh (HRRR).

In relation to the GFS, by late 2014, the NCEP global system is set for a significant upgrade, including a modification to the dynamic core (to Semi-Lagrangian), spatial resolution (T1534), and a variety of physics parameterizations (radiation, convective gravity wave drag, boundary layer, and land surface). High resolution SST and sea-ice data will be incorporated. The hybrid data assimilation will be modified through a resolution increase in the 80-member EnKF from Eulerian T254 to Semi-Lagrangian T574. The additive inflation will be significantly reduced and replaced with the use of stochastic physics (SPPT, the Stochastically Perturbed Physical Tendencies of ECMWF; SKEB, the Stochastic Kinetic Energy Backscatter of ECMWF and the Met Office, and SHUM, stochastically perturbed boundary-layer relative humidities). Lastly, a new satellite bias-correction scheme will be implemented which includes the angle-depenedent component inline as part of the variational bias correction (see Zhu et al. 2014). In ~ Nov 2015, NCEP plans to extend its 3-D Hybrid En-Var to 4-D. This implementation will also likely include some all-sky radiance work. In 2016-2017, the remaining projects that have been supported through the Sandy Supplemental Relief bill will be implemented. There is a target to move to non-hydrostatic T2000+ and to double the number of vertical layers while moving the model top higher.

NCEP is also pursuing the use of ensemble forecast sensitivity to observations (EFSO) as a means to monitor observation usage and assist in data quality control. This information will be comparable to the adjoint-based diagnostics produced at many of the other operational centers.

EnKF/GEFS: The ensemble team is working toward the utilization of the data assimilation-based initial perturbations for use in the GEFS (ensemble prediction system) starting sometime after Nov 2014.

6.3 UK Met Office

Andrew Lorenc described some recent developments in DA at the Met Office. The objectives were improved accuracy, stability and scalability. Changes to the global model were introduced in July 2014 and will be applied in Feb. 2015 to limited-area models. The resolution of the global model becomes 17km. Most but not all scores have increased and there is better definition of jets, TC forecasts and weather. 4D-Var resolution has increased to 40 km, and there is a package of satellite DA improvements. The new dynamical core, ENDGAME, implemented in July 2014, is more accurate, has more realistic synoptic and mesoscale activity, and handles downstream gravity waves and tropical cyclone forecasts better. The new model scales much better and this should assist computer upgrades for at least the next ten years. ENDGAME also allows time for development of a new model design (Gung Ho) and software infrastructure.

Regarding assimilation system development, 4D-En-Var is being developed as a bridge technology and possible long-term replacement for 4D-Var. The 4D-Var system development is on hold until a decision is made on a more mature and stable 4D-En-Var and ENDGAME system.

The regional model has been dropped. There is now a UK 1.5-km model nested directly in the global. This has a 3-hr cycle of 3D-Var. There is a plan to move to 1-h 4D-Var for nowcasting on a new computer during 2016, and development of a UK ensemble with 12 members at 2.2 km, nested in and

initialized using the global model. An important challenge remains to fully establish the added value of the convective scale over global predictions.

6.4 ECMWF

Carla Cardinali noted that many organizational changes are taking place at ECMWF along with consideration of future strategy. There is a move to a more project-based structure rather than sections. The continued development of long window 4D-Var is being discussed, and there are ongoing challenges with formulating a **Q** matrix for model error in long-window 4D-Var. Tests with their experimental EnKF system do not show much degradation with respect to strong-constraint 4D-Var, and hence there are questions as to whether it makes sense to continue to use the computationally expensive set of parallel 4D-Vars to estimate the background-error covariance **B** for their 4D-Var. Other preliminary tests have suggested that 6-h window, strong-constraint 4D-Var may be as accurate as 12-h window. ECMWF will lead assessment of ozone assimilation impact.

In discussion, it was suggested that perhaps the next DAOS meeting should be focused on one topic e.g. coupling? – i.e., the degree needed and the strategy being considered or adopted by different centres.

6.5 US Navy

No report

6.6 CMC, including sea-ice assimilation

Environment Canada is currently performing the final parallel mode real-time testing of a major upgrade to the global and regional deterministic NWP systems. In both systems, 4D-EnVar will replace 4D-Var, using the 256 members from the operational EnKF system to specify hybrid background-error covariances with analysis increments at 50-km horizontal grid spacing (vs. 100-km in the current operational system). Other improvements include a new satellite radiance bias correction scheme, better treatment of radiosonde observations that accounts for the changing horizontal location and time during the ascent, assimilation of ground-based GPS data over North America, an increase in number of IR channels assimilated from AIRS and IASI, a new sea-ice concentration analysis, and replacement of non-incremental digital filter with 4D incremental analysis update for initialization. The new systems provide significant improvements to forecasts, especially in the short range, at a significantly reduced computational cost, primarily due to the use of 4D-En-Var, which parallelizes much more effectively.

A possible switch of coordinate systems is in development, the use of the “Yin-Yang” grid.

A brief summary was also provided on development work on new regional and global sea ice analysis systems. These systems are based on 3D-Var and assimilate ice concentration information from multiple types of satellite data (SSM/I, SSMIS, ASCAT) and manual analyses. Current research on improving these systems focus on the implementation of an ensemble data assimilation approach (ensemble of EnVar's) and the assimilation of higher-resolution satellite data.

6.7 Russian Federation

No report

6.8 China

Prof. Bin Wang described the establishment of the new NWP centre at CMA. He briefly outlined the mission of the new centre. As well as carrying out routine NWP the centre would also conduct R&D. CMA has developed GRAPES for global and mesoscale predictions.

7 **Transforming to a new DAOS WG under the WWRP (from 2015)**

7.1 Terms of reference

The new TORs were agreed. The finalized text is attached in annex 1 of this document.

7.2 Membership

It is recommended that Peter Steinle (BoM) replaces Tom Keenan (BoM) who has retired and will leave the WG. (Subsequent to the DAOS meeting in Montreal, following unanimous consent by DAOS members, Carla Cardinali of ECMWF was nominated as incoming co-chair, and this recommendation was forwarded to WWRP management). The committee thanks Roger Saunders for his excellent service to DAOS and the WMO.

Action 7.13: Co-chairs to prepare a paper for ICSC/SSC meeting on Nov 14 in Geneva including specific proposals for membership and co-chairs

8 **Date/place of next meeting**

CMA has invited the DAOS WG to meet in Beijing during 2015.

9 **Any other business**

None

Summary of actions

Action 7.1: Consider a discussion note on the recommended terminology for forecast sensitivity to observations (Ron, Carla, Rolf) to be distributed to DAOS members for comment by October 2014. This note should then be tabled at the next WMO CBS Workshop on the impact of observations.

Action 7.2: Sharan Majumdar will prepare a first draft of the BAMS paper on targeting by spring 2015. DAOS will act as the first reviewer of the paper.

Action 7.3: Roger Saunders will liaise with Zoltan Toth to establish what has happened.

Action 7.4: Ron Gelaro to investigate positive impacts of AMVs and give a status report at the next meeting

Action 7.5: WG members to encourage and solicit proposals to host the next WMO DA symposium (All, Co-chairs to email symposium list after contacting Brazil)

Action 7.6: Roger Saunders to co-ordinate timing of the future WMO DA symposium with the International DA meeting. (Roland Pothast, DWD is the current German symposium representative).

Action 7.7: DAOS to comment on WWOSC white papers of relevance

Action 7.8: DAOS to review the PPP and particularly the YOPP IP and to send comments to Greg Smith.

Action 7.9: Sharan Majumdar to distribute the HIW implementation plan (IP) and to identifying those sections that would benefit from DAOS input. DAOS members to send comments on the IP to Sharan.

Action 7.10: Prepare for a coupled DA workshop potentially with ECMWF in 2016 (To Hamill, Carla Cardinali).

Action 7.11: DAOS to ask the operational centres and other organisations to identify the key questions about the GOS they would like to be addressed by the use of OSSEs. Sharan Majumdar to provide some draft questions.

Action: 7.12: DAOS WG to advise CBS in the preparation of the next Observation Impact Workshop. Carla Cardinali and Rolf Langland to be DAOS representative.

Action 7.13: Co-chairs to prepare a paper for ICSC/SSC meeting on Nov 14 in Geneva including specific proposals for membership and co-chairs.

Annex 1: DAOS Terms of Reference

WMO / WWRP
Data Assimilation and Observing Systems Working Group

Proposed new terms of reference

The Data Assimilation and Observing Systems (DAOS) working group (WG) will provide guidance to the WWRP on international efforts to optimise the use of the current WMO Global Observing System (GOS) and to advise on the strategy for its evolution. It will also provide guidance on which data assimilation methods may provide the highest-quality analysis products possible from the GOS. Through these activities, the DAOS-WG will facilitate the development of advanced numerical weather prediction (NWP) capabilities, especially to improve high-impact weather forecasts. DAOS will be primarily concerned with data assimilation and observing system issues from the convective scale to planetary scales and for forecasts with time ranges of hours to weeks.

To achieve its mission, the DAOS WG, in collaboration with the *CBS ET-EGOS*, will:

1. Provide community consensus guidance on data assimilation issues, including the development of advanced methods for data assimilation.
2. Promote research activities that will lead to a better use of existing observations and that will objectively quantify the impact of current and future observations for NWP.
3. Assist WWRP projects and other WMO working groups in achieving their scientific objectives by providing expert advice on the use of observations and data assimilation techniques.
4. To organize and provide the scientific steering committee for the WMO Data Assimilation Symposium, which is to be held approximately every 4 years.