

# **Data Assimilation and Observing Systems Working Group Report**

to the

WORLD METEOROLOGICAL ORGANIZATION

CAS/ COMMISSION FOR ATMOSPHERIC SCIENCES

**INTERNATIONAL CORE STEERING COMMITTEE □ FOR THORPEX**

**Twelfth Session**

WMO, Geneva (Nov 2014)

(Submitted by Roger Saunders and Tom Hamill)

## **1. Introduction: DAOS WG activities**

The Data Assimilation and Observing Systems (DAOS) WG was formed in 2008 as part of the THORPEX project. With the ending of the THORPEX project it has been agreed that DAOS would become a working group within the WWRP programme. The proposed terms of reference of the DAOS-WG under the WWRP are:

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). 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 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 observation 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 (e.g. WGNE, IPET-OSDE, MWFR).
4. To organize and provide the scientific steering committee for the WMO Data Assimilation Symposium, which is to be held approximately every 4 years.

A summary of activities involving DAOS members since the last meeting of the ICSC in July 2013 is provided below. The list of actions after the Montreal DAOS-WG meeting is given in Annex A. The list of current DAOS WG members is provided in Annex B.

## **2. Recent and future meetings relevant to the DAOS-WG**

### ***2.1 WMO Data Assimilation Symposium 7-11 October 2013***

The DAOS-WG organized the recent WMO Data Assimilation Symposium in October 2013. 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 and particular thanks must go to Daryl Kleist and Kayo Ide for facilitating the change of venue at the last minute. In the event the symposium went smoothly, with only a small reduction in participants from an expected 330 to about 310 and the programme remained largely intact. The presentations can be found at <http://das6.umd.edu> and a meeting report here: [http://das6.cscamm.umd.edu/docs/WMO6DA\\_Foreword.pdf](http://das6.cscamm.umd.edu/docs/WMO6DA_Foreword.pdf). A collection of around 35-40 papers are expected for the AMS journals' special collection. About ten are currently being reviewed. Significant sponsorship was obtained and needed to keep the registration price affordable to most scientists. A question arises as to whether the annual International Data Assimilation meeting organized by Roland Pothast at DWD may be in conflict with the WMO Symposium in the future (see also 3.1 below). DAOS will need to liaise closely with their organizing committee. A request for proposals to host the next symposium in 2017 will be sent out shortly.

### ***2.2 Sixth DAOS-WG meeting at College Park, Maryland, USA 11 October 2013***

A short meeting of the WG was held immediately after the Data Assimilation Symposium at the University of Maryland on 11 October 2013 and a meeting report is available here:

[http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex\\_daos\\_index.html](http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex_daos_index.html)

The move of the group to WWRP and terms of reference were discussed along with the usual status reports on the observing system. Developments in data assimilation were covered during the symposium. The interaction with the three new WWRP research projects, S2S, PPP and HIW was discussed and Sharan Majumdar volunteered to represent the DAOS-WG on the new HIW project. Proposals for two new members of the group to replace Florence Rabier and Bertrand Calpini who had stepped down were also gathered. After the meeting a vote from the group selected two candidates which were then proposed to and approved by the ICSC[r1] (see Annex B).

### ***2.3 Seventh DAOS-WG meeting at Montreal, Canada 15-16 August 2014***

Environment Canada hosted the seventh DAOS-WG meeting in Montreal on 15-16<sup>th</sup> August 2014, immediately before the Open Science Conference. Apologies were received from Chris Velden, Stefan Klink, Daryl Kleist and Rolf Langland, who were unable to attend, although they all provided input to the meeting, and Daryl reported via teleconference. A report on the meeting is available

[http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex\\_daos\\_index.html](http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex_daos_index.html).

The Co-Chairs introduced the new members of the WG, Nadia Fourrie (MeteoFrance) and Saroja Polavarapu (Environment Canada) and observers to the meeting from Environment Canada: Greg Smith, Louis Garand and UQAM: Pierre Gauthier (a previous co-chair) were also welcomed to the meeting. Lidia Cucurull also presented remotely from ESRL/GSD in Boulder. A summary of some of the discussions and list of actions from the meeting are given below and in Annex A of this report.

### ***2.4 Joint DAOS and MWFR WG meeting at Montreal, Canada 16 August 2014***

A joint meeting of the DAOS and MWFR WGs was organized following the normal DAOS WG meeting. The meeting was seen as a good opportunity for the two working groups to get to know each other and their respective programmes of work. Now that both groups will exist under the WWRP, it is important that there is clarity between the areas of responsibility of both groups and to ensure there are no gaps. It was noted that areas of overlap in data assimilation is not a major issue so long as there is regular communication between both groups. It would also be very useful to identify those topics on which they might collaborate and others that would be better handled separately. It is important to ensure that there are no gaps i.e. all important research areas are covered.

A meeting report is available at: [http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex\\_daos\\_index.html](http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex_daos_index.html).

Presentations were given by several members of the groups followed by a discussion on potential areas for collaboration which are listed below. In order to remain coordinated there should ideally be a member who attends both meetings and can report on the work of the other group. Efforts will be made to ensure this happens once the future of the MWFR WG is clear and the new DAOS WG membership has been approved.

Areas identified for possible collaboration were:

- (i) The Winter Olympics in S. Korea at Pyeong-Chang in 2018 may provide a good opportunity for a mesoscale FDP. Several Met Services are likely to be involved in this and both DAOS and MWFR members could engage with it.
- (ii) Sharing experiences on new observations for global and mesoscale data assimilation through reports from members of both groups.
- (iii) The concept of OSSEs for the mesoscale is a new one and could be explored further in both groups to evaluate the impact of new observations such as MTG-IRS, Lidars, etc. Regional nature runs nested in global nature runs could be one option.
- (iv) The provision of optimal LBCs for MWFR RDP/FDPs.
- (v) Developments in ensemble-based observation sensitivity tools for the mesoscale.
- (vi) Forecast verification metrics for mesoscale models and the development of comparisons of global vs mesoscale model performance over specific regions (as shown recently for UK Met Office models).

### ***2.5 WWRP Open Science Conference 16-21 August 2014***

The theme on Observations and Data Assimilation at the Open Science Conference was co-ordinated by many DAOS-WG members, and they are also contributing to the White Papers from the conference. The sessions on observations and data assimilation were all of high quality and generated some interesting discussions. The presentations are now available at: <http://www.wmo.int/pages/prog/arep/wwrp/new/wwosc/presentations.html>

### ***2.6 Plans for 8<sup>th</sup> DAOS-WG meeting***

There was an invitation from China to host the 8<sup>th</sup> DAOS-WG meeting in 2015. This proposal is being considered along with other options. There was also a general feeling among members to allocate more time for discussions amongst the members and to have fewer presentations for future meetings.

## **3. Summary of main activities of DAOS-WG during 2013/14**

### ***3.1 Munich International Symposium on Data Assimilation***

Several DAOS members attended the International Symposium on Data Assimilation in Munich (24-28 Feb 2014). Mark Buehner briefed DAOS participants on this symposium. He said it was constructed to be somewhat like an ECMWF workshop, with longer talks and breakout groups making recommendations. 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 not to coincide.

### ***3.2 T-NAWDEX plans***

The recent progress to organize T-NAWDEX (the THORPEX- North Atlantic Waveguide and Downstream Experiment) was reviewed by the DAOS-WG. Amongst the scientific objectives they will be investigating is systematic error 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 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 N 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 to participate are currently being made. The DAOS-WG will monitor developments in this project and advise where necessary.

### ***3.3 HyMEX status***

The status of the HyMEX (Hydrologic Cycle in the Mediterranean Experiment) campaign was reviewed by the group. 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. Two studies on the impact of these additional observations have been conducted in AEMET (Campins et al, 2014) and at Météo-France in limited-area 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.

### ***3.4 Polar Prediction Project***

It was felt 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.

### ***3.5 High Impact Weather project update***

The HIWeather (High-Impact Weather) project 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 earlier 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 the DAOS-WG were discussed. 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.

### **3.6 Interactions with WGNE**

Ton Hamill briefed the WG on WGNE developments. WGNE fully supports the transfer of the DAOS WG to the WWRP after the end of THORPEX. WGNE also noted that THORPEX's GIFS-TIGGE and Predictability and Dynamical Processes WGs will also be merged and transferred to the WWRP as a Predictability, Dynamics and Ensemble Forecasting (PDEF) WG. A coupled data assimilation workshop is considered desirable. Should this be sponsored by DAOS? 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 and DAOS has an action to follow this up.

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.

Verification against own analysis was 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.

### **3.7 Cooperation on global OSSEs**

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 Assessment (QOSA) programme was set up by 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 assessing the results might be very helpful.

Although the main objective is 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 data assimilation systems. However 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 an international organisation for OSSEs (e.g. setting up of a WG) in this area needs further consideration.

### **3.8 Carbon flux data assimilation**

An overview of carbon flux data assimilation was provided by Saroja Polavarapu (Env. Canada) at the Montreal DAOS meeting. 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.

### **3.9 Forecast sensitivity to observations**

The DAOS-WG reviewed the status of the forecast sensitivity to observations (FSO) tool for both the variational and ensemble data assimilation systems. The possibility of extending estimates of observation impact to beyond 24h is being explored. 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 was some discussion about whether moisture should be included in the energy norm. A weight of 0.3 was used in NASA systems, giving moisture a similar contribution to T, U, and V. Another important development will be to develop similar tools for convective scale models and some efforts are underway to address this.

It was noted that an important question will be how to maintain 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 ensemble FSO (EFSO) results.

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

### **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 with GMAO and ECMWF represented in the group to provided input

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

### **4.1 Terms of reference**

The new Terms of reference given in section 1 above were agreed to be presented to ICSC in November.

#### ***4.2 Membership***

The current DAOS WG membership is listed in Annex B. The only change to the membership this year has been the retirement of Tom Keenan (BoM).

With the move of the DAOS-WG out of THORPEX to become a WWRP expert group the membership of the group has to be reviewed under the terms of reference for WWRP groups. A proposal for the revised group membership has been tabled at the WWRP SSC meeting for their approval. Roger Saunders is standing down as co-chair after 5 years of being a co-chair of the group and will need to be replaced.

## **Annex A: Actions from 7<sup>th</sup> DAOS WG Meeting**

### **Summary of DAOS-WG 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 B: Current DAOS-WG Membership**

Roger Saunders, Met Office, UK, co-chair

Tom Hamill, NOAA/ESRL, co-chair

Mark Buehner, Environment Canada, Canada

Carla Cardinali, ECMWF

Nadia Fourrie, Météo-France, France – *New member in 2014*

Ron Gelaro, NASA, USA

Tom Keenan, CAWCR, Australia - *Retired during 2014*

Daryl Kleist, University of Maryland, USA

Rolf Langland, NRL, USA

Andrew Lorenc, Met Office, UK

Stefan Klink, DWD, Germany

Sharan Majumdar, University of Miami, USA

Saroja Polavarapu, Environment Canada, Canada - *New member in 2014*

Michael Tsyrlnikov, HydroMet Centre, Russia

Chris Velden, University of Wisconsin-CIMSS, USA

Bin Wang, Chinese Academy of Sciences, China