

**THORPEX ICSC
DAOS Working Group
Fourth Meeting**

Item: Meeting Report

Original: ENGLISH

UK Meteorological Office
Exeter, 27-28 June 2011

Report of the 4th DAOS meeting

1. Organisation of the meeting

1.1 Aims of the meeting

The aims of the meeting were briefly outlined by the Co-Chairs as follows

- Discuss and finalise the comprehensive review paper on targeting
- Review the results from field campaigns e.g. T-PARC, CONCORDIASI etc.,
- Consider the latest state of the observations networks and satellite programmes
- Discuss developments in data assimilation
- Agree on future topics of interest to the group

1.2 Adoption of the agenda

The agenda was agreed with the addition of an additional topic (4.7) "Winter Storm Reconnaissance Programme"

1.3 Working arrangements and Tour de Table

Roger Saunders welcomed the group and invited experts to the Met Office and outlined the domestic and working arrangements for the meeting. The WG members and invited experts provided brief personal introductions.

2. Reports and actions

2.1 IPO Update

Jim Caughey outlined recent developments in the THORPEX Programme. The reports from meetings of the three THORPEX Working Groups have been published on the THORPEX web site: <http://www.wmo.int/thorpex>

GIFS-TIGGE Working Group

The number of registered TIGGE users is now over 1000, but a more meaningful statistic is the number of distinct active users per month – about 60. Users triggered data processing on some 37Tb in December 2010 and downloaded about 2.8Tb. The main focus of the GIFS-TIGGE working group is now the use of ensemble forecasts from multiple centres for research and development, including ongoing promotion of scientific investigations using the TIGGE datasets.

A new leaflet is available for download from both the WMO THORPEX website and the TIGGE website at <http://tigge.ecmwf.int> . To implement GIFS it has been agreed that the GIFS-TIGGE WG will work with the SWFDPs and other WMO pilot projects on the development and evaluation of GIFS products. Formal links have been established with the SWFDP SG. GIFS products, mainly based on combined ensembles, will be used to supplement products already available through the SWFDP, and will be evaluated in conjunction with the SWFDP (e.g. TC tracks, heavy rainfall, strong winds).

A consortium of European institutions led by ESA has submitted a proposal, GEOWOW (GEOSS Interoperability for Weather Ocean and Water), for funding through the European Union Framework Programme. The Weather element (led by ECMWF) has a focus on forecasting systems for hazards and extreme meteorological events. This element of the proposal involves further development and integration of the THORPEX Interactive Grand Global Ensemble (TIGGE) global weather forecast data and products into the GEOSS Common Infrastructure. Total project funding is c. 6.3 M€ - allocation to TIGGE is expected to be about 1.2M€

PDP Working Group

Some recent topics of interest to the group were outlined

Field experiments

The three related THORPEX experiments T-PARC, TCS08 and Winter T-PARC were aimed at increasing understanding of *how and why*

- (a) Typhoons form (or do not form) in the West-Pacific (TCS-08)
- (b) Typhoons or ex-Typhoon vortices interact with mid-latitude jet streams (T-PARC) – ET
- (c) Supplemental targeted observations reduce or fail-to-reduce forecast error (TCS08, T-PARC and Winter T-PARC).

The major findings in the area of dynamical atmospheric processes and the ability of models to predict observed processes and associated recommendations are being written up.

A few key topics have been identified, to which the PDP WG will pay particular attention. These are climatologies of specific weather phenomena (frequency, intensity), organized tropical convection (YOTC, T-PARC), ensemble-based data assimilation and forecasting, including stochastic parameterizations, atmospheric dynamics and diabatic processes (e.g., T-NAWDEX, HYMEX, Rossby wave dynamics, tropical-extratropical interactions, polar meteorology, role of surface fluxes), sub-seasonal and seasonal prediction (dynamics and physics of coupled systems) and new diagnostic techniques to understand the origin of model errors. The conclusions from the PDP Workshop in Zurich were described. Model error diagnosis has been identified as one area where universities and research institution can make substantial contributions to the further development of models, thereby supporting the relatively small community of model developers. The PDP has decided to start joint projects to look more closely at two phenomena:

- Indian Summer Monsoon which is a large-scale phenomenon poorly handled by most models
- Cyclonic systems

THORPEX Regional Committees

Europe

A revised European plan was published on the THORPEX website during 2010. A highly successful Workshop was held in Karlsruhe, Germany from 24-27 May 2011. The aim of this meeting was to review progress in European THORPEX research, to strengthen existing collaborations and initiate new links within the European THORPEX community, to identify further necessary revisions to the THORPEX European Plan as well as to discuss European involvement within new THORPEX initiatives. The main themes were: PDP, DAOS, SERA TIGGE, Field Programs (e.g. IPY Cluster, T-NAWDEX, CONCORDIASI and HYMEX).

Africa

Important presentations were made to the RA I meeting held in Marrakesh during Nov. 2010 – to help engage support from African PRs. Progress is being made with the implementation of the high impact weather information system for Africa – to facilitate research of selected important case studies and associated SERA studies. The main constraint to more rapid progress is lack of resources. A meeting is planned at WMO for July 2011 to review progress and agree on future strategy

Asia

The 7th meeting of the Asian Regional Committee (ARC) was hosted during June 2010 in Jeju Island, Korea and followed the 3rd Asian THORPEX Science Symposium.

This Asian THORPEX Science Symposium was held from 2 to 4 June 2010. There were five sessions in the meeting:

- (1) Opening and Invited talk
- (2) Overview of THORPEX related activities
- (3) Predictability, Observation system experiments, Observation field campaigns
- (4) Ensembles, TIGGE, Data assimilation
- (5) Dynamic processes and mechanisms and Applications

In all there were 30 oral presentations and 10 posters. About 70 researchers attended the meeting and the participants came from Japan, Korea, Russia, France and China.

The ARC meeting included updates on national activities in Korea, China, Japan and Russia. The meeting also agreed to the formation of 2 WGs to focus on GIFS-TIGGE and NWP activities and also agreed to hold Asian THORPEX Science Symposia about every 2 years.

North America

A NARC meeting was held during May 2010 in Morelos, Mexico. Amongst the topics covered were the many contributions to field experiments, TIGGE developments, SERA studies etc.

Southern Hemisphere

Southern Hemisphere plans can be downloaded from <http://thorpex.cptec.inpe.br/> and the THORPEX website. One of the main benefits of THORPEX is in terms of scientific interaction and collaboration amongst SH scientists, but even with a relatively modest plan progress is slow. There is a need to leverage opportunities for THORPEX-related activities, including components in projects such as SWFDPs, and collaboration in the context of funded research. Enhancing overall links with WGs is also important.

Sub-seasonal to seasonal prediction

The Report from the Workshop on “Sub-seasonal to Seasonal Prediction” (Met Office, Exeter 1 to 3 December 2010) has been published on the web

(http://www.wmo.int/pages/prog/arep/wwrp/new/documents/recommendations_final.pdf)

The major Workshop recommendation was that a Project for sub-seasonal prediction research should be established. Panel members should include representatives from WWRP-THORPEX, WCRP, CBS and CCI and their relevant programme bodies. The first task for the Panel should be the preparation of a Project Implementation Plan which is consistent with the contents of the Workshop Report and Recommendations.

It is proposed that a small Planning Group, supported by a WMO consultant, is established to prepare a draft Implementation Plan for a “Sub-seasonal Prediction Research Project”.

Polar Prediction Project

The Report from the Workshop on “Improvement of Weather and Environmental Prediction in Polar Regions” (Met No Oslo, 6 to 8 October 2010) has been published on the web

(http://www.wmo.int/pages/prog/arep/wwrp/new/documents/recommendations_final.pdf)

The outcome of this workshop was the establishment of a basis for an IPY legacy project which is intended to provide a framework for cooperative international research and development of efforts to improve high impact weather, climate, and environmental predictions. Three forecast prediction ranges are of interest: short-term regional forecasts (one hour to 48 hours), medium-range forecasts (one day to two weeks) and sub-seasonal to one season forecasts. This project will require a Steering Group (consisting of members with scientific and operational expertise and representatives of the user community). The first task for the Steering Group (supported by a WMO consultant) will be the preparation of an Implementation Plan which includes estimates of resources and a strategy for the coordination of polar prediction research. If the plan is well received by the community, and if the YOTC model is followed, a Project Office should be established at an institution with a major interest in polar prediction.

Year of Tropical Convection

YOTC (www.ucar.edu/yotc) is focused on the fundamental problems of understanding mechanisms for and the effects of organized tropical convection, which is vital to improving weather and climate predictions. YOTC is now established with a small project office at NCAR. It is a joint initiative between WWRP/THORPEX and WCRP, and was highlighted in a series of papers provided for the WCC-3 and in forthcoming publications in BAMS. Research spans weather and climate on timescales from diurnal out to seasonal. Close links are maintained with other activities such as the GEWEX (GCSS). An important legacy of YOTC will be data sets collected from May 2008 to April 2010 (the “year”), which include high resolution analyses and forecasts from ECMWF, NCEP and GMAO and satellite data available through NASA Giovanni.

The first WCRP-WWRP/THORPEX International Science Symposium for the Year of Tropical Convection (YOTC) was held in Beijing from 16-19 May 2011. The meeting format included theme-based sessions spanning the YOTC science focus areas, with 20 invited talks, 5 poster sessions (with over 80 posters) and 5 plenary discussion sessions. Additional details regarding the Symposium, including the agenda and presentations can be found on the YOTC website

2.2 Outcomes and recommendations from the fourth meeting of the WWRP JSC

A comprehensive review of DAOS WG activities was presented to JSC 4. During discussion, the JSC acknowledged the valuable work carried out by the DAOS Working Group in its comprehensive study of the impact of targeted observations. The JSC recommended that the DAOS Working Group establishes good links with the Mesoscale and Nowcasting Working Groups and improves its connections with groups involved in land-surface data assimilation. It noted that assimilation of radar data is an issue for the global scale and that there is a need to develop common formats, which includes quality information, for the exchange of radar data and noted that this action benefits mesoscale data assimilation.

***Decision/Action from WWRP JSC 4 to the DAOS WG:
WWRP/JSC 4 requested the Chair of the Nowcasting Research Working Group in collaboration with the Co-Chairs of the DAOS Working Group to keep the JSC informed on the development of common formats for the exchange of radar data.***

The DAOS WG noted this action and agreed to take it forward in the context of Item. 5.6 of the agenda.

2.3 Progress with the mid-term review of THORPEX

Inputs to the review have been received from most WGs, RCs and projects but these were of rather variable quality. The intention is to present a draft review paper to the ICSC 9 meeting to be held in Geneva from 21-22 Sept. 2011.

2.4 Reports and actions from the previous meeting – DAOS 3

Action 1: *DAOS WG to provide input to the THORPEX mid-term review - completed*

Action 2: *Re-evaluation of WSR impacts should be performed for at least the two recent years, and more if feasible. Various verifications areas should be considered, those used for the original targeting and also larger areas (e.g. East Coast, West Coast and Alaska). To be able to compare with other results, common metrics should be used.- some progress was being made although this was quite limited – a report would be given later in the meeting (agenda item 4.7)*

Action 3: *Operational centres to consider the treatment and tuning of AMVs for regional models - only limited use of AMVs was being made in regional models although use was increasing.*

Action 4/5: *DAOS WG is invited to send comments on the polar prediction and seasonal workshop announcements and suggestions for the agenda and speakers to the IPO ASAP - inputs have been provided*

Action 6: *Sharan Majumdar to prepare a draft of the paper during the next few months seeking input as appropriate from WG members and others. The target should be for a definitive draft agreed by the WG for the next ICSC meeting in Jan 2011 - the preparation of the paper was nearing completion.*

Action 7: *The DAOS-WG recommended that the ICSC accepts the nomination of Prof. Bin Wang as a member of the DAOS-WG - Bin Wang will be proposed as a new member of the WG to the ICSC-9. It was agreed to present all the proposed changes to the WG in an annex to the WG Report to the ICSC 9.*

Action 8: *In consultation with WG members the Co-Chairs should make a recommendation for the appointment of a new Co-Chair to the IPO as soon as possible. - Ron Gelaro will be proposed to ICSC 9 as a Co-Chair to replace Pierre Gauthier.*

Action 1: It was agreed that all proposed changes to the WG membership would be included in an annex to the ICSC-9 DAOS Report (Co-chairs)

2.5 Report on the European THORPEX meeting

The European Meeting recommended a co-ordinated DAOS web-page on data monitoring should be set up – it should include in-situ observations not only satellite data. Firstly there is a need to create dedicated WMO DAOS web pages. The web pages should also provide links to data sets from field campaigns, to the EUMETSAT NWP SAF etc. It was agreed that WMO would be asked to set this up.

There was interaction with EUMETSAT at the meeting and the general feeling was that not much use was made of rapid scan winds. EUMETSAT now has the facility to validate their winds using field campaign data and would appreciate easier access to the data.

The meeting also considered cloudy radiances and it was noted that HyMex should lead to good data impact studies. COSMO will have a leading role to play in evaluation for HyMeX. There was a desire to share the lessons learnt from CONCORDIASI with DIAMET.

Action 2: WMO to set up the DAOS web pages and implement appropriate links to other projects and monitoring sites (T. Nakazawa)

Action 3: All DAOS members to provide recommendations on links to data monitoring sites and to other field campaign sites of interest.

2.6 Links to the WWRP/MWFR WG

The MWFR addresses the “grey zone” and DA<1 day. Their next meeting is 10-11th Sept in Berlin. The focus is on the regional 0.5 to 5km scale - convective and mesoscale which complements THORPEX on the global 1-14 day time scale. They were promoting research through RDPs e.g. COPs, D-PHASE etc., and were in close liaison with TIGGE – LAM. Joint workshops with the Verification WG and Nowcasting Groups proved valuable to agree strategy. They were working to achieve worldwide standards for mesoscale verification and model quality assessment.

Potential interactions with DAOS could be in areas such as shared DA expertise, guidance on high resolution (HR) DA, provision of optimal LCBs for MWFR RDPs/FDPs, and the treatment of the large scale in HR DA and observation selection for DA. It was agreed to consider organising a joint session with the MWFR through a “back to back” meeting in 2012 at which a report on DAOS DA activities would be presented and general DA issues of common interest discussed.

Action 4: Consider organising DAOS 5 “back to back” with the next MWFR meeting (Co-Chairs).

Action 5: The Report of the DAOS 4 meeting should be circulated to MWFR members (Dale Barker).

2.7 Links to ET-EGOS

This group sits under CBS. Its activities were outlined by J. Eyre. Through the Rolling Review of Requirements (RRR) process, it deals with user requirements for observations and draws up “statements of guidance” (gap analyses). It has developed a long term vision for global observing systems in 2025 and has produced a draft Implementation Plan to realise that vision. It was agreed that the DAOS WG should comment on the Plan.

ET-EGOS considers a wide range of “application areas” across the operational activities covered by all WMO programmes, including NWP. As input to the RRR process, it considers the results of studies of the impacts of real/hypothetical changes to observing systems and networks, and it is in this area that advice from THORPEX is particularly welcome.

The 4th WMO Workshop on the impact of observations in NWP is being organised by ET-EGOS for 22-25 May 2012 in Arizona. The DAOS WG members agreed to support and participate in this Workshop. It was recognised that links between research and operations needs to be improved. There should also be a clear focus on regional and mesoscale issues at the Workshop.

Action 6: The DAOS WG is invited to comment on the WMO Implementation Plan for the evolution of the global observing systems (EGOS-IP).

Action 7: DAOS WG members are encouraged to participate in the ET-EGOS Workshop on Observations Impacts – May 2012 and produce a summary of the main conclusions from the Workshop

2.8 Report of the discussions on data assimilation at WGNE

Pierre Gauthier reported on the DAOS WG activities at WGNE including the impact of targeted observations, the observability of structure functions given the current level observations errors, inter-comparison experiments on the impacts of observations in different models, singular vector based thinning of satellite data – adaptive thinning and the community paper on targeting which attempted to reconcile seemingly opposing views on the impact of targeted data.

He noted that the DAOS WG has reached a more “mature” stage and was focussing on more fundamental issues in DA and improving links with CBS groups, satellite agencies and operational centres. It was also noted that WMO does not have a specific WG devoted to DA. No-one seemed to be responsible for the WMO DA Symposium which was of considerable interest to a number of groups e.g. SPARC, the WCCR Obs and DA Panel etc. It was agreed that DAOS should consider taking a leading role in the organisation of the next symposium. The possible need for a central structure for all DA matters was discussed – there were pros and cons and it would be essential to preserve the link between modelling and DA and not to disrupt current groups. Joint sessions between groups could be a good way ahead as recommended earlier for DAOS and the MWFR. It was noted that the WGNE theme for 2010 was DA.

Action 8: The DAOS WG should consider taking a leading role in organising the next WMO DA Symposium

3 Data Targeting

3.1 Perspective on targeting

Sharan Majumdar outlined the main conclusions from the review of targeting. The draft paper was nearing completion and it was his intention to finalise it by the end of July. In the mid-latitudes the conclusions were weakest. Although the NCEP GFS system regularly showed improvements (e.g. 70% of 128 cases) and “large” improvements (10-20%) in some cases this work had not been peer reviewed. It was also noted that target areas are often cloudy baroclinic areas and difficult to monitor comprehensively. ETKF demonstrated an ability to predict reduction in forecast error variance in zonal flow. Target areas are traceable from Japan to N. America over 4-7 days. Other THORPEX experiments provide small data sets that make it difficult to draw firm conclusions. However, a main conclusion is that in mid-latitudes the targeting impact is generally small, but positive.

Regarding the tropics the situation was more definite and positive – targeted observations have the power to be statistically useful especially in relation to TC tracks.

Some general conclusions from this work were,

- The spatial and temporal coverage that can be provided by aircraft is limiting
- The cumulative impact of targeted aircraft observations is smaller than that of individual routine observing systems, such as radiosondes, commercial aircraft, etc.
- Results are heavily dependent on the flow regime, numerical model and the treatment of routine and targeted observations in the DA scheme.
- Current DA systems make only limited use of flow-dependent structure functions for broadcasting observational information (this is changing with moves to hybrid DA, or pure ensemble and ensemble 4DVAR)

During the discussion of the paper, several suggestions were made on how to improve it, primarily through inclusion of better figures to illustrate the quantitative impacts of targeted observations.

Targeting using routinely available data was then discussed (the ECMWF triplet of papers). This showed that the impact of Pacific observations was more significant on N. America than N. Atlantic observations on Europe. Observations from sensitive areas were on average more valuable than those from randomly selected areas. Also removal of observations in SV sensitive areas degraded skill more than observations from randomly selected regions.

For the medium range the results were not mature enough to draw any definite conclusions. It was expected that the influence of local observations would diminish with time as forecasting and observing systems improve. There is a need to move to broader scale regime based sampling (e.g. adaptive use of satellite data).

Regarding case selection there is the open question of whether low impact cases can be predicted in advance.

In relation to verification there are a number of questions. Generally large fixed verification regions had been used in studies, which diluted impact statistics. Small mobile verification regions centred on the weather event that is targeted may be better. Studies tend to evaluate “average” improvements – it may be better to focus on individual systems. Also there is the issue of the number of forecast “busts” or “drop-outs” – can targeting help with these?

Overall it is expected that with continuing improvements in models, DA and observations networks the average improvements due to targeted data may well reduce.

Some broad conclusions were

- For TC tracks the impact can be significant and positive
- In mid-latitudes the impact is generally positive but small
- Some progress is being made on quantifying the impact of targeting in the medium range, but no definite conclusions can be drawn a present
- Advances in adaptive observing are taking place with satellite data
- Adjoint based methods for assessing observation impacts are very useful and now widely used
- Data from recent field campaigns e.g. CONCORDIASI should yield new information

Some recommendations arising from this work included the need to better establish the benefits of “on request” data from existing networks and satellites, the need to continuously evaluate data from routine field campaigns (e.g. the WSR), to better understand forecast busts and the role of flow dependence in data assimilation.

Action 9: DAOS WG members are requested to provide Sharan Majumdar with ideas for figures and plots for the targeting paper ASAP. The intention is to finalise the paper by the end of July 2011.

3.2 Review of the DAOS authoritative statement on the impact of targeted data in NWP

Due to lack of time the text of the statement was reviewed outside the meeting and the latest version is at Annex 3.

3.3 Agreement on publication

The full text of the review of targeting paper would be completed by the end of July and presented to ICSC 9. A much reduced version will be submitted to BAMS. WG members were asked to make suggestions to Sharan Majumdar on how to reduce the length of the paper.

4 Updates on Campaigns and activities

4.1 DIAMET

John Methven introduced DIAMET which is a NERC funded project designed to look generally at diabatic influences in storms. It will consider aspects such as the extent to which predictability of precipitation is linked to the mesoscale structure of cyclones, the role of diabatic processes in generating mesoscale PV, what is the nature of balance on the smaller scales, the effect of anomalies on subsequent evolution etc., The focus is on convection, cloud microphysics and air-sea fluxes of heat and moisture. It is part of the NERC Storm Risk Mitigation Programme (total funding of £4.9M over the period 2010-2014). The DIAMET component involves modelling and measurements, development of parameterisations and investigating predictability. Some pilot flights have been conducted in 2009 through rain bands. The project has 3 main Work Packages: WPA - observation and modelling of mesoscale structure and associated diabatic processes; WPB - parameterisation of embedded convection, BL fluxes over oceans and cloud microphysics; WPC - predictability and data assimilation for high resolution (convection resolving) forecasts. The experimental flying programme will take place in autumn 2011 and summer 2012. Attempts were being made to link to T-NAWDEX and HyMeX in the longer term. More details can be found at: <http://ncasweb.leeds.ac.uk/diamet/>

4.2 T-NAWDEX

Plans are emerging for this field experiment which is scheduled for the period 2014/2015.

The focus of T-NAWDEX is on medium-range weather forecasts, as distinct to DIAMET which focuses on lead times shorter than 2 days. T-NAWDEX aims to investigate link between errors in the representation of model processes at the upstream end of the North Atlantic storm-track and their subsequent influence on Rossby wave packets, downstream development and high impact forecasts over Europe. However, considerable work still needs to be done since the involvement of the HALO or DLR Falcon remains uncertain. There is a possibility that the DLR Falcon can be used in autumn 2012 to take a preliminary look at T-NAWDEX aims in conjunction with HYMEX, although the water vapour LIDAR may not be available. In 2014/2015 it is expected that the USA HIAPER and UK FAAM aircraft will be included. For parameterisation studies it is planned to run many versions of the models with various convection and microphysics schemes.

4.3 HyMeX

Details can be found at www.hymex.org. This is a wide ranging programme with interests on timescales from daily to centuries and includes, heavy precipitation (flooding), intense air-sea interactions, the water budget and hydrology on the continental scale. It includes Enhanced Observations Periods (EOPs) and Special Observing Periods (SOPs). A wide range of platforms is involved e.g. radiosondes and AMDAR, pressurised drifting balloons, wind profilers, GPS, radars, research vessels etc. Non standard data will be archived. Upstream monitoring will be included to define the broader environment. A wide range of data will be assimilated – including satellite data- more data over land and in cloudy conditions etc., Water vapour lidar and moisture data from profilers will also be assimilated. HyMEX DA will use an EPS Research Test bed which provides a well defined research environment. The project is endorsed by WWRP and WCRP and funded as part of the wider MISTRALS programme. There is an International Steering Committee and 5 WGs. The data sets will be freely available after 2 years. The metrics for impact assessment/verification are still being developed.

4.4 FROST

This project is providing support to the 2014 Winter Olympic Games and involves the Russian Weather Service, COSMO, DWD, ARPA, Environment Canada, TIGGE-LAM and Viasala. The FDP modelling will be at 2 km resolution, the RDP at 0.5 to 1km, the Ensemble at 7km and the Ensemble RDP at 2km.

The project involves DA, nowcasting, verification and societal aspects overseen by 4 WGs. Observation capabilities are being expanded – including weather radars, 30 automatic stations and an additional 20 on cell phone towers, data buoys, profilers etc.,

The Russian 3DVAR global model is undergoing pre-operational tests and the intention is to develop a hybrid 3DVAR ensemble approach. They will try to extract flow dependent information from the ensemble. Rapid scan data from EUMETSAT may be requested.

4.5 CONCORDIASI

Florence Rabier indicated that this project has provided unprecedented data coverage over the Antarctic. Dropsondes were launched out of 13 super-pressure balloons (50 from each balloon). The measurements were successful. Some dropsondes were deployed during MetOp overpasses others were in sensitive areas. The dropsonde impact on the 24h error norm was generally positive. Assimilation of the gondola data was taking place at a few centres and was found to be positive, in particular in a data impact study at DWD. There are problems with the models near the surface e.g. they are not cold enough over land. The

situation is more mixed over ice. In general therefore it can be concluded that the dropsondes provided great coverage, they gave generally positive impacts as did the additional radiosondes and the largest model errors were in areas of strong gravity waves. Better modelling of snow may help improve the lowest level model temperatures. Assimilation of IASI data is at a very early stage – this will be taken forward by the IASI Science Sounder WG.

Ron Gelaro described GMAO impact studies using CONCORDIASI data. The dropsondes showed a positive impact over the region 60S-90S. The u,v,T and q components were considered – impact on T appears more mixed than that of u and v. However the dropsonde impact was smaller than that from other platforms. The fraction of forecasts improved was RAOB 79%, ship/buoy 72% and dropsonde 67%. The impact from MODIS AMVs was only 55% and very variable.

Carla Cardinali described some studies at ECMWF. Dropsondes showed the largest impact in October. The impact per observation was higher than conventional observations. The impact of the gondola data was not high but more significant in the height range 70-50 hPa.

There was discussion about the results obtained so far and the need to understand negative impacts as well as obtain results from more centres, models etc.

Action 10: The means to access CONCORDIASI data should be advertised (F.Rabier)

Action 11: A co-ordinated observations impact study using the CONCORDIASI data set should be considered (F.Rabier)

4.6 T-PARC

Amongst the many objectives was a desire to improve 1-3 day forecasts by targeted observations in regions with high sensitivity. TC Sinlaku measurements had resulted in more than 50 publications. Some models showed reductions in track error by up to 200km (NCEP and KMA WRF) whilst others only showed improvements after 72 hours (JMA and ECMWF). This difference in behaviour of the models emphasises that the benefit depends strongly on the quality of the first-guess field and the DA system. Also the location of the observations was relevant – measurements in the typhoon vicinity showed the largest impact in the ECMWF system. In remote sensitive areas the impact was either small positive or zero. In the typhoon core the impact was neutral. ECMWF also found a 50 km improvement in the TC track from the Falcon wind lidar data.

Rapid scans from MTSAT were also investigated – hourly AMVs improved the 3- 5 day forecast reducing errors by 6-10%. Also AMVs assimilated into the WRF research model improved Sinlaku positions and the hourly AMVs catch the rapid intensification of the typhoon. In addition the associated rain bands are better represented. The improved track forecasts also improved forecasts in the mid-latitudes out to 3 days. It has been shown that dropsondes in T-PARC provided some global improvements in the NCEP GFS.

4.7 Winter Storms Reconnaissance Programme

The impacts of targeted dropsondes were being re-evaluated as requested by the DAOS 3 meeting, but a large sample of cases has not been processed. It was agreed to continue to encourage NCEP to process the larger sample, with the latest DA methods and recommended metrics. ECMWF may be able to process some of the cases for comparison purposes with their 4DVAR system to be able to assess the impact. However, it was

recognized that this work would not be completed in time to be included in the review paper or in the BAMS article.

Action 12: Carry out data denial runs for the WSR months for 2009-2011 at ECMWF (Carla Cardinali) whilst continuing to encourage NCEP to complete their investigation of these years (Tom Hamill).

Action 13: Investigate options for the analysis of the ECMWF and NCEP WSR runs (Tom Hamill)

5. General Observational Developments

5.1 Satellite status

Roger Saunders summarized the current operational status. GOES 11 and 13 are operating normally and GOES 12 is providing coverage over S. America. JMA has switched from MTSAT 1 to 2. There are some new geostationary satellites coming on line – the Korean COMS and Russian GOMS -2. Both are looking good and monitoring of AMVs has started. Chinese FY-3 polar orbiting satellite microwave sounder data are showing good potential for NWP assimilation. The US NPP and MetOp-2 launches are planned for 2011/12. For research satellites extensions to EOS (until 2015) and ENVISAT (until 2014) are planned. The McMurdo receiving station is coming on line and will reduce data time delays. New MetOp polar AMVs are planned from image pairs. The Oceansat-2 scatterometer winds look promising when compared with ECMWF model winds.

For the future, planning for the Meteosat 3rd Generation system is proceeding. It will be a twin-satellite configuration using 3-axis stabilized platforms. The 1st satellite will carry an improved visible/infra-red imager and a lightning imager. The 2nd satellite will have an advanced infra-red sounder and a UV sounder. GOES-R (2015) and S (2017) will include advanced imagers. China is planning a new FY4 series of geostationary satellites and Korea is planning COMS NEXT. The Asian plans look very ambitious with a long series of satellites planned. The US is planning an advanced hyper-spectral sounder in geostationary orbit which will proceed as a commercial venture and may be launched in 2014. If it proceeds NOAA will purchase the data it requires. It was noted that this way of operating could have implications for normal data sharing within WMO.

In the USA JPSS replaces NPOESS with the first JPSS launch planned for 2017 in the PM orbit (instruments will be VIIRS, CrIS, ATMS, etc.) The DWSS will replace the DMSP series with a first launch in 2018 and will include a microwave imager.

The main challenges in DA of satellite data were from optimizing the thinning of microwave sounder data, assimilation of more of the hyper-spectral measurements and assimilation of higher density satellite data in mesoscale models.

Chris Velden then outlined improvements to AMVs including better height assignment using an optimal cloud analysis (NESDIS nested tracking method). This shows significant gains in accuracy and removes the AMV slow bias, reduces RMSE etc.

Action 14: The DAOS WG requested a report on the GMAO tests with NRL superobbed AMV data (Ron Gelaro)

5.2 Use of satellite data over land and sea-ice

Florence Rabier described the impact of AMSU A and B data over land and ice. The ice situation was trickier due to difficulties in modeling the emissivity of these sensors over ice. In the ARPEGE system the data improved the quality of analysis and forecasts. There now needed to be further research work on snow surfaces.

John Eyre spoke on behalf of Ed Pavelin on DA of IR sounder data over land. To date for IASI IR emissivity was assumed to be 0.98 and the channels below 400hPa were not used. A new approach is to use a 1DVAR retrieval and then pass the retrieved variables including emissivity to the 4DVAR system. This showed promising results in a test and a positive impact on the Met Office global NWP index. However, there were problems with daytime data over very dry surfaces e.g. deserts.

5.3 Adjoint sensitivity tool applied to satellite observations over land

Sangwon Joo (KMA) introduced this topic. Radiance data contributes more to reducing forecast error than radiosonde profiles but there are difficulties with using radiance data over land. The assessment can be improved using an adjoint sensitivity method. Using more IASI and AIRS data over land impacts are improved. However, some puzzling results need consideration e.g. use of ATOVS data over land seems to be affected by one point over the coast of Antarctica for AMSU-A channels 6/7 where there is possible "super sensitivity" which is being investigated.

5.4 Short update on the use of the IR sounder data in cloudy regions.

Florence Rabier introduced the study on use of IASI over cloud at different centres being done by Lydie Lavanant. Cloud pressure scatter plots compared well and in general showed reasonable agreement, although the results from different centres showed some variations. For overcast thick layers there was better agreement. Results are being published in the QJRMS. Comparison with A-Train Caliop is ongoing during CONCORDIASI but there are differences in representivity and so a need to average Caliop data. It was noted that the YOTC A-Train datasets may be of some use.

5.5 In-situ status

Roger Saunders (on behalf of Bertrand Calpini) outlined some recent developments in in-situ observations. He noted the recent WMO CIMO inter-comparison of rain gauges. There was also an ECMWF paper specifying the representivity error of rain gauges for DA. Regarding temperature and humidity it has been shown that some of the lower cost screens performed

rather well (WMO CIMO webpage). An international comparison of radiosondes had shown that a pressure sensor was no longer needed. The group recommended that the implications of only having height not pressure data should be assessed. The GCOS Reference Upper Air network (GRUAN) now comprised 15 sites and included ozone and cloud measurements.

Concerning aircraft coverage the E-AMDAR programme was expanding over Europe following the recruitment of EasyJet. The WVSS water vapour data was also now increasing in Europe. For GPS total zenith delay measurements available to NWP centres there was now very good coverage in Europe from E-GVAP. More work was needed in this area to encourage exchange of data in other parts of the world. There was good impact from these data in regional models for heavy rainfall events. Amongst the key issues identified were the transition to BUFR and the new opportunities this provided for DA, the need for global GPS ZTD coverage, the emerging requirement for in-situ soil moisture and temperature measurements, a common format needed for exchange of radar precipitation data and the new observations that are needed for mesoscale models.

The DAOS statement on observations was noted i.e. the need for more aircraft observations over the Pacific and Atlantic Oceans etc., and the importance of additional radiosonde/AMDAR data over coastal regions e.g. E. Siberia, Polar regions, Africa, S.America etc. based on the adjoint sensitivity experiments carried out.

5.6 Use of precipitation radar for NWP

Tom Keenan outlined developments in the use of radar data for NWP. There is limited impact from radar precipitation data and so full volume reflectivity data and radial wind data are needed. The latter are due to be exchanged in Europe through Opera in 2013. Developments in HIRLAM are currently being handicapped by lack of these data. The area of exchanging radar data is complex and potentially involves many groups within the WMO – also it is clear that WWRP/THORPEX expects progress. There is need to involve ET-EGOS as well as the CBS groups on codes and communications. What is needed is consultation across many areas and a careful specification of requirements especially in terms of data quality. There will be issues of coping with the large data volumes. The recommended approach is for WMO to form a Task Team on this topic.

Action 15: Tom Keenan is asked to provide feedback from DAOS-4 on radar data standardisation and exchange discussions to relevant WMO groups.

5.7 Assimilation of radar data

Florence Rabier outlined developments at MeteoFrance on the assimilation of radar reflectivity data. Pre-processing is necessary before DA and thinning of reflectivities. There were positive impacts on precipitation scores e.g. probability of detection and false alarm rates. The importance of quality control was emphasized as was the need for considerable interaction with the data producers.

6 Advances in Data Assimilation

6.1. Ensemble data assimilation at Météo-France

Florence Rabier presented recent developments at Météo -France. They are using a small ensemble of lower-resolution 4D-Var assimilations to provide background error variance estimates “of the day” to their main quality control and 4D-Var assimilation. Recent experiments have shown further benefit from also using more complete wavelet descriptions of error covariances from the same ensemble. Research in the use of ensembles to characterise model errors is underway.

6.2. Development and testing of a hybrid EnKF-variational data assimilation system for the NCEP GFS.

Tom Hamill presented developments in NOAA of a scheme to add covariances “of the day” by using localised perturbations from an Ensemble Kalman Filter in their operational 3D-Var scheme. A trial for 3 months from July 2010 gave very encouraging results: significant improvements in tropical cyclone and precipitation forecasts and largely positive impact on other scores. Poor results in the stratosphere were believed to be caused by the coupled assimilation of ozone observations – that is being addressed. It is planned to implement the system in 2012. Further developments are planned, including an extension to 4-dimensional use of the ensemble trajectories.

6.3. Recent developments at Met Office

Dale Barker showed recent developments in the global DA system at the Met Office. He mentioned newly developed adjoint-based observation sensitivity and impact diagnostics – the Met Office can now participate in projects to use such tools to evaluate observations. Upgrades to the global DA system are implemented in major packages – in November 2010 the 4D-Var inner-loop resolution was increased to N216 and the covariance statistics updated. Work on the efficiency of 4D-Var algorithms has enabled this upgrade without a computer enhancement and further upgrades are planned when the IBM power7 is delivered. In July 2011 a hybrid ensemble-4D-Var will be implemented; as for the NCEP developments this uses an existing ensemble system to enhance the covariances of the operational variational system – in this case 4D-Var. Trialling of these covariance changes highlighted the misleading signal given by verification of NWP forecasts against analyses from the same system. The November 2010 change showed a large positive signal in the tropics which was cancelled by an apparent degradation from the hybrid system. Other measures, such as verification against observations or an independent analysis, show that both signals were spurious. It was recommended that this should be raised at WGNE (F. Rabier) and at the WWRP Verification WG. The Met Office will also be conducting an investigation into improved verification metrics for NWP.

Action: 16: Dale Barker and Florence Rabier to raise the issue of misleading signals from verification of NWP forecasts against their own analyses with the WWRP Verification WG and WGNE respectively..

6.4. Recent developments at ECMWF

Carla Cardinali presented recent developments at ECMWF. The increasing importance of and diversity of methods for NWP diagnostics has led to a major reorganisation of their diagnostics effort, which is now coordinated by a cross-cutting working group with effort from each section. Data assimilation diagnostics such as adjoint-based impacts are part of this common diagnostic system, which was used for instance to investigate causes of forecast “busts” in Spring 2011. Recent significant developments included land-surface assimilation

(use of a snow analysis and a simplified Extended KF for soil moisture) and assimilation of 6-hour precipitation accumulation data over the USA. The core DA system (4D-Var with input from an ensemble of 4D-Vars) is regarded as fairly mature and stable; effort is going into improving the software and extending the time-window to 24 hours.

6.5 Recent developments at Environment Canada

Pierre Gauthier described recent developments. EC are unique in having operational systems for both 4D-Var and an EnKF. This has enabled a recent study (Buehner et. al) comparing results from the two and also from a hybrid similar to those being developed by NCEP and the Met Office. Their 4D-Var and EnKF both have advantages, but also weaknesses: 4D-Var requires the maintenance of linear and adjoint forecast models – this is proving increasingly difficult as the full forecast model develops, while the EnKF is difficult to extend to high resolution and the use of high-density observations. Methods for using the ensemble within 4D-Var are being considered, as are methods of using a variational solution method to handle dense observations within the EnKF. A common software base is desired and probably a single hybrid system will emerge.

6.6 Discussion on future developments in data assimilation

A major goal of the DAOS WG at the start of THORPEX was research into the use of increased understanding of predictability and error growth to improve data assimilation. A consensus has now emerged that an attractive way to achieve this is by a hybrid using information from an ensemble system to improve the covariances in existing operational variational systems. Many centres are now developing such systems. There remain major design options to be studied, both in theory and practice – these could form a focus for future DAOS studies and intercomparisons:

1. Ensembles must of necessity be too small to fully define covariances. Should we filter the ensemble perturbations by fitting a covariance model, whose parameters are then used in the variational assimilation, or use the perturbations more directly, localised using the “alpha control variable” method?
2. Can we replace the forecast model and its adjoint within the 4D-Var system by the use of ensemble trajectories? This has attractive practical advantages, but might degrade results.

The WG noted the need for a common terminology for hybrid ensemble variational methods.

Action 17: Andrew Lorenc & Pierre Gauthier to agree a proposal for a common terminology for hybrid ensemble variation methods and circulate it for comment.

Action 18: The terminology for adjoint sensitivity impacts should be discussed and agreed (Ron Gelaro and Carla Cardinali)

7 Working Group issues

7.1 Membership

It was agreed that the proposed changes to membership would be incorporated in annex 2 of this report and presented to ICSC-9. These include Prof. Bin Wang, Mark Buehner, Prof. Sharan Majumdar and Dr Stefan Klink being invited to join the WG and Ron Gelaro assuming

the role of Co-Chair. Peter Steinle and Pierre Gauthier are both standing down as members of the group and Jochen Dibben has declined the invitation to join.

7.2 Review of meeting outcomes, decisions and actions

The Co-Chairs reviewed the main actions from the meeting – these can be found at Annex 1.

7.3 Representation at forthcoming meetings

It was noted that Roger Saunders would not attend the GIFS TIGGE meeting on 30 August - 2 September representing DAOS but would liaise closely with Richard Swinbank the co-chair. Any member willing to attend was asked to inform the Co-Chairs.

7.4 Linkages to other group

It was proposed to arrange a back to back session with the MWFR WG during 2012.

8 Any other business

There was no other business

Annex 1 : Summary of actions from DAOS 4

Action 1: It was agreed that all proposed changes to the WG membership would be included in an annex to the ICSC-9 DAOS Report (Co-chairs)

Action 2: WMO to set up the DAOS web pages and implement appropriate links to other projects and monitoring sites (T. Nakazawa)

Action 3: All DAOS members to provide recommendations on links to data monitoring sites and to other field campaign sites of interest.

Action 4: Consider organising DAOS 5 “back to back” with the next MWFR meeting (Co-Chairs).

Action 5: The Report of the DAOS 4 meeting should be circulated to MWFR members (Dale Barker).

Action 6: The DAOS WG is invited to comment on the WMO Implementation Plan for the evolution of the global observing systems (EGOS-IP).

Action 7: DAOS WG members are encouraged to participate in the ET-EGOS Workshop on Observations Impacts – May 2012 and produce a summary of the main conclusions from the Workshop

Action 8: The DAOS WG should consider taking a leading role in organising the next WMO DA Symposium

Action 9: DAOS WG members are requested to provide Sharan Majumdar with ideas for figures and plots for the targeting paper. The intention is to finalise the paper by the end of July 2011.

Action 10 The means to access CONCORDIASI data should be advertised (F.Rabier)

Action 11 A co-ordinated observations impact study using the CONCORDIASI data set should be considered (F.Rabier)

Action 12 Carry out data denial runs for the WSR months for 2009-2011at ECMWF (Carla Cardinali) whilst continuing to encourage NCEP to complete their investigation of these years (Tom Hamill).

Action 13 Investigate options for the analysis of the ECMWF and NCEP WSR runs (Tom Hamill)

Action 14 The DAOS WG requested a report on the GMAO tests with NRL superobbed AMV data (Ron Gelaro)

Action 15 Tom Keenan is asked to provide feedback on DAOS 4 radar data standardisation and exchange discussions to relevant WMO groups.

Action: 16 Dale Barker and Florence Rabier to raise the misleading signals from verification of NWP forecasts against their own analyses with the WWRP Verification WG and WGNE respectively.

Action 17 : Andrew Lorenc & Pierre Gauthier to agree a proposal for a common terminology for hybrid ensemble variation methods and circulate it for comment.

Action 18: The terminology for adjoint sensitivity impacts should be discussed and agreed (Ron Gelaro and Carla Cardinali)

Annex 2 : Proposed DOAS-WG Membership

<i>Ron Gelaro,</i>	<i>co-chair</i>	Roger Saunders,	co-chair		
<i>NASA, USA</i>		Met Office,	UK		

Carla	Cardinali	Chris	Velden	Tom	Hamill
ECMWF		Univ	Wisconsin-CIMSS,	NOAA, USA	
		USA			
Tom	Keenan	Michael	Tsyroulnikov	Rolf	Langland
CAWCR, Australia		HydroMet	Centre, Russia	NRL, USA	
Andrew	Lorenc	Bertrand	Calpini	Florence	Rabier
MetOffice, UK		MeteoSwiss,	Switzerland	Météo-France,	France
<i>Mark</i>	<i>Buehner,</i>	<i>Prof. Bin Wang,</i>	<i>Chinese</i>	<i>Sharan Majumdar</i>	
<i>Environment</i>	<i>Canada,</i>	<i>Academy of</i>	<i>Sciences,</i>	<i>RSMAS, Univ Miami</i>	
<i>Canada</i>		<i>China</i>		<i>USA</i>	
<i>Stefan Klink,</i>	<i>DWD,</i>				
<i>Germany</i>					

The entries in italics need to be ratified by ICSC-9.

Annex 3: DAOS-WG Statement on impact of targeted data

Mid-Latitude Systems

The science behind synoptic-scale global NWP is relatively mature. Forecasts have been improving by approximately a day of predictive skill per decade due to improvements in model resolution, in observations and their processing and in model physics (Simmons and Hollingsworth 2002). This is a larger average improvement than seen in targeted observation experiments, albeit with different verification metrics. Associated with this general increase in skill, the average marginal impact of individual observing systems is decreasing; a single observation type such as AMSU-A radiances or radiosonde profiles, now only improve skill by 6-12 hours (WMO 2008). The conclusions below are therefore most influenced by recent published studies with current state of art assimilation systems and models.

- **For extratropical systems, the value of targeted data is found to be positive but small on average when evaluated over continental or hemispheric areas. In observing system experiments using aircraft data from field experiments, the results are mixed; while the Atlantic A-TREc study found very little impact from targeted observations, the ongoing Winter Storms Reconnaissance (WSR) programme has found that targeting results in some improvement in 2-3 day forecasts over N. America.**
- **The actual impact of any observation on a particular forecast depends on: (a) the errors that are present in the prior forecast, (b) the errors in the observation, and (c) the data assimilation and forecast methods. Hence, we can only predict these in an average statistical way. Commonly, nearly half of all observations have small or even negative impact, and we depend on the cumulative effect from many observations to produce a positive average impact.**
- **Observations that sample dynamically sensitive areas have a bigger average impact per observation than those deployed randomly. However, unless these observations cover the entirety of the sensitive regions regularly, which is rarely the case, they cannot be expected to have a large systematic impact on the forecasts. The cumulative benefit of a small number of targeted aircraft observations to forecast accuracy over broad verification regions is smaller than that of other observing systems that provide observations with a more complete coverage.**
- **The justification of significant expenditure, for instance for a dedicated aircraft system dropping sondes, requires statistically significant results from well designed experiments. These do not currently exist in published papers for mid-latitude synoptic-scale NWP.**
- **The marginal cost of using more data from an existing system can be much lower than the total cost and may not require such rigorous justification – important case studies showing a clear benefit might suffice. Programs such as the WSR (which uses an aircraft system justified for TC targeting) and the EUCOS DTS (which targets extra observations from existing systems like AMDAR and sondes) may fall into this category, as do developments in the targeted thinning and processing of satellite observations. We recommend more work of this type.**

Tropical Cyclones

While the forecasting of TC tracks by global NWP is relatively mature, improving along with the general improvement in global NWP systems, results are still rather variable from model to model. Methods for predicting the detail and intensity of TCs are much less mature. It remains an open question if objective tropical cyclone targeting principles based on global data assimilation and forecast systems will need to be adjusted for mesoscale systems.

- **For forecasts of the track of TCs targeted observations have proven to be beneficial statistically. The benefit to society is also more straightforward to define than for mid-latitude weather. A simple sampling strategy of observing uniformly around the TC has been shown to be effective, with most models exhibiting an improvement. However, the quantitative benefit differs from model to model, due in part to their respective treatment of routinely-available satellite and aircraft observations in their assimilation schemes.**
- **Recent studies have demonstrated that observations targeted for TCs can also improve the skill of forecasts in distant regions. The mechanisms behind how TC forecasts are improved, and can be improved further, by targeted observations are still being investigated.**

Research Priorities for Observation Impact Assessments

The following bullets outline the main issues identified by the DAOS-WG for future research into the use of targeted observations for NWP systems.

- **There is a need to assess the impact of targeted observations with more user-focused measures of the value of forecast improvements to society, while retaining the ability to get significant results from relatively short experiments. The ongoing move away from deterministic forecasts toward *probabilistic forecasts* means the scores should reflect reductions in initial condition uncertainty introduced through targeted observations, and the subsequent impact of these reductions on forecast uncertainty.**
- **Targeting has mostly been to improve *short-range* forecasts. A few studies for *medium and long-range forecasts* have given mixed results. In some studies, targeted observations made negligible differences to forecasts downstream, while others gave positive impacts in both mid-latitudes and tropics. More research is needed.**
- **Given that we depend on the cumulative effect from many observations to have a positive average impact, broader-scale, regime-based sampling (e.g. adaptive use of satellite data) may be an effective method for ameliorating the sampling issue and increasing the impact of targeted observations on both short- and extended-range forecasts.**
- **The development of a better theoretical basis for quantitatively predicting and evaluating the error variance reduction due to any potential deployment of targeted observations should result in their more effective use.**
- **Targeting for the *mesoscale* with mobile observational systems is still in its infancy and needs further development. Potential examples include targeting a**

mobile mesonet for forecasts of severe weather, and airborne Doppler radar for forecasts of TC structure and intensity.

References

Simmons, A. J. and Hollingsworth, A. (2002), Some aspects of the improvement in skill of numerical weather prediction. Quarterly Journal of the Royal Meteorological Society, 128: 647–677. doi: 10.1256/003590002321042135

WMO (2008) WMO 2008: Fourth WMO Workshop on the Impact of Various Observing Systems on NWP. Geneva, Switzerland, May 2008. Summary and Conclusions.

<http://www.wmo.int/pages/prog/www/OSY/Meetings/NWP-4-Geneva2008/Summary-Conclusions.pdf>