WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR ATMOSPHERIC SCIENCES

CAS/THORPEX ICSC/
PDP-3/ (Report)

Original: ENGLISH

THORPEX ICSC
PDP Working Group
Third Meeting

ETH, Zurich
5-7 July 2010

REPORT FROM THE THIRD MEETING OF THE THORPEX PDP WORKING GROUP

Participants: Istvan Szunyogh (Working Group co-Chair), Heini Wernli (Working Group co-Chair), Thomas Jung (Working Group member), Craig Bishop (Working Group member), Olivier Talagrand (Working Group member), Gilbert Brunet (Chair, WWRP JSC), Mitch Moncrief (YOTC), Andy Brown (WGNE), Andreas Dörnbrack (T-NAWDEX), John Methven (T-NAWDEX), David Burridge (WMO), David Parsons (WMO)

1. Organisation of the meeting

1.1 Aims of the meeting

The main objectives of this PDP working group meeting were to:

(i) To summarize key achievements and weaknesses of the Working Group's activities during the first years of THORPEX (preparation for mid-term report)
(ii) To identify key PDP research areas that should be particularly strengthened during the coming years
(iii) To start closer collaboration with the WGNE

1.2 Adoption of the Agenda

The agenda was adopted with minor changes.

2. Reports

2.1 Outcome of the ICSC 8 meeting

The eighth session of the ICSC (ICSC 8) was held in the DWD (Offenbach, Germany; 2 to 4 November 2009). This meeting of the ICSC was held in parallel with the 25th meeting of the WGNE and a joint ICSC/WGNE session was held to discuss closer collaboration between the THORPEX and the WGNE.

The ICSC 8 Decisions and the draft ICSC 8 report have been sent by email to all ICSC 8 participants and Working Group members. The Decisions/Actions from the ICSC 8 report which are of direct relevance to the PDP Working Group were outlined as follows.

Mid-term review

The ICSC has requested a review of the THORPEX programme. This should be completed during 2010 and involve all the THORPEX Working Groups and the Regional Committees. The action required from the PDP Working Group is set out below in section 7 of this report.

Scientific leadership of THORPEX

Following disbandment of the THORPEX Scientific Advisory Board, the ICSC recognised the need for better, and independent, scientific leadership for the THORPEX programme as a whole. To this end, the ICSC agreed that a strengthened WWRP Joint Scientific Committee (WWRP/JSC) could provide the appropriate scientific leadership that THORPEX requires. In this case the WWRP/JSC would advise the ICSC on the key scientific direction of the programme. The ICSC noted that similar proposals for strengthening the WWRP/JSC would be considered by the Commission on Atmospheric Sciences (CAS) and the ICSC would await the decision of CAS (see item 2.2 of this report).

Collaboration between the PDP Working Group and the WGNE

The key area for collaboration was seen as model error and model development and the ICSC and the WGNE agreed that there should cross-representation between the PDP Working Group and the WGNE. To this end, Thomas Jung would represent the PDP Working Group on the WGNE and Andy Brown would represent the WGNE on the PDP Working Group. One of the first results of this collaboration was the joint organisation of the PDP/WGNE Workshop on Model Errors (7-9 July, 2010, in Zurich).

The WGNE and the ICSC also agreed that:

Action PDP3-01 (Chairs and Thomas Jung): WWRP/THORPEX should be involved in the WCRP model development survey and the follow-up – THORPEX should consider what support can be given by the PDP Working Group.

Action PDP3-02 (Chairs and Thomas Jung): The PDP Working Group would be involved in the WGNE Parameterization Workshop.

Item 6 of this report sets out in more detail the collaboration between the PDP Working Group and the WGNE on errors in Forecasting Systems.

Action PDP3-03 (Chairs and IPO): Other PDP Working Group actions arising from ICSC 8.

i. The PDP Working Group should ensure that THORPEX figures prominently in the next IUGG meeting (Melbourne 2011) and IAMAS/IACS meeting (DACA-13 in Davos, Switzerland, 8-12 July 2013).

ii. The further involvement of the PDP/DAOS/SERA Working Groups in the analysis of T-PARC data sets is strongly encouraged (see item 4.1 of this report).

iii. The early publication of the draft science plan for T-NAWDEX was encouraged as was the full involvement of the PDP Working Groups in its further evolution (see item 4.2 of this report).

iv. Regarding THORPEX Africa, the Working Groups were asked to continue to support this initiative (see item 8.4 of this report).

2.2 Outcome of the CASXV meeting

The fifteenth session of the Commission of Atmospheric Sciences (CASXV) was held in Incheon, Republic of Korea (18 to 25 November 2009). The main recommendations of interest to the

THORPEX Community and the Working Group in particular may be found in the following paragraphs of the CAS XV report:

ftp://ftp.wmo.int/Documents/PublicWeb/mainweb/meetings/cbodies/governance/tc_reports/english/pdf/1050_en.pdf

Leadership of THORPEX

Amongst other things the CAS decided that

The WWRP Joint Scientific Committee (WWRP/JSC) has the following terms of reference:

i. To provide the overall scientific guidance for the World Weather Research Programme (WWRP), including The Observing System Research and Predictability Experiment (THORPEX)

ii. The Joint Scientific Committee of OPAG-WWRP shall consist of up to ten scientists selected for their scientific knowledge, capability and breadth of vision. The members of the Committee should be drawn to ensure geographical representation and an appropriate gender balance. The chairs of the working groups and expert teams of WWRP including THORPEX are ex-officio members of the Joint Scientific Committee.

The THORPEX Working Group Chairs were informed of this decision and will be invited to report and participate in the next meeting of the WWRP/JSC which is planned for the week beginning 17 January 2011.

Predictability and dynamical processes

The Commission noted that THORPEX activities in the area of predictability and dynamical processes include basic research to advance knowledge of atmospheric processes associated with high impact weather and that such research is valuable to the long-term development of forecast systems. The Commission encouraged those scientific funding agencies supporting basic atmospheric research to consider funding, as priority research, THORPEX research on predictability and dynamical processes and appreciated that the goals of the Predictability and Dynamical Process Working Group include the transfer of research findings to operations through a partnership between the academic and operational communities and in this regard the Commission encouraged the THORPEX PDP Working Group to work with the GIFS-TIGGE Working Group on ensemble predictions systems to support the development of a GIFS (see item 5 of this report).

2.2.1 Polar Workshop

At the eighth session of the ICSC (ICSC 8) the ICSC decided that a workshop should be convened to develop proposals for an IPY follow on THORPEX polar project. This decision was strengthened further at the fifteenth session of the Commission of Atmospheric Sciences (CASXV).

Action PDP3-04 (IPO): After discussion of the plans for the Polar workshop, there was agreement that the PDP Working Group should be represented at this Workshop (planned for 6-8 October 2010) and the IPO and the Working Co-Chairs should ask the ICSC to appoint an appropriate expert on Polar prediction to the PDP Working Group.

2.2.2 Sub-seasonal and seasonal prediction project

At its 15th session (November 2009), the WMO Commission of Atmospheric Sciences (CAS) requested the Joint Scientific Committees of the World Weather Research Programme (WWRP) and the World Climate Research Programme (WCRP) and also the THORPEX international Core Steering Committee (ICSC) to set up an appropriate collaborative structure to carry out an international research initiative on sub-seasonal to seasonal forecasting. The Manager of the THORPEX IPO (David Burridge) outlined the plans for a workshop to develop this initiative and invited the Working Group to consider how it could be involved in this Workshop and any future developments of a research initiative on sub-seasonal to seasonal prediction.

The THORPREX PDP working group discussed the Sub-Seasonal to Seasonal Prediction Project. The importance of the seamless approach to weather and seasonal prediction was realized by the PDP working group and it was decided that the PDP working group should be involved in the planning of this project. More specifically it was proposed that Thomas Jung should be part of the programme committee of the planning workshop (to be held in December 2010 in Exeter); this will help to promote the ideas deemed important to be considered in this project by the PDP working group. It was noted, for example, that the Sub-Seasonal and Seasonal Prediction Project would be an ideal opportunity to promote a seamless approach to the diagnosis of model error (initial tendencies and transient adjustment). Furthermore, it was noted that the preliminary workshop agenda, distributed before the meeting, does not cover tropospheric dynamical processes which are likely to be of importance on sub-seasonal and longer time scales (e.g., Rossby wave breaking). It was also highlighted that the PDP community is in a very good position to further our understanding how the atmosphere responds to external forcing (e.g., physical mechanisms and optimality of the forcing).

2.3 WWRP Strategic Plan

Gilbert Brunet (Chair of the WWRP/JSC) outlined the broad objectives of the WWRP strategic plan. These included improving public safety, accelerating the prediction of high impact weather, demonstrating improvements, increasing understanding of atmospheric processes and encouraging NMHSs to implement these advances. Future WWRP research would focus on high resolution convection permitting models, mesoscale data assimilation, the representation /parameterisation of convection, the role of the surface and reduction in model imbalance and “spin up”. The EC-RTT report encouraged an expanded scope including collaboration with the climate and environment communities. These aspects would be addressed. In addition, the WWRP would make efforts to link to the operational centres through WGNE, encourage DAOS Working Group and WGNE collaboration, as well as pursue advances in verification and physical processes

2.4 GEO – report on on-going activities and future opportunities

David Burridge presented some of the weather elements of the GEO Work Plan which provides the agreed framework for implementing the GEOSS 10-Year Implementation Plan (2005-2015). The particular GEO Tasks to which THORPEX contributes were then outlined.

The main Tasks with which WWRP-THORPEX is involved are:

(a) Societal Benefit Area: Climate

Task CL-09-01: Environmental Information for Decision-Making, Risk Management and Adaptation.

Sub-Task (a): Towards Enhanced Climate, Weather, Water and Environmental Prediction (essentially promoting a seamless approach to climate and weather prediction).

(b) Societal Benefit Area: Weather

There are two Tasks in this area. The first is:

Task WE-06-03: TIGGE and the Development of a Global Interactive Forecast System(GIFS) for Weather.

The second Task is

WE-09-01: Capacity Building for High Impact Weather Prediction Sub-Task (b): Socio-economic benefits in Africa from Improved Predictions of High Impact Weather.

The Working noted that these tasks provided broad support for three main PDP themes – seamless prediction, ensemble prediction and capacity building for Africa.

3. Review of recent achievements and outlook

The IGs filled a void in the beginning of THORPEX and helped raising the awareness of some key PDP issues in the (mainly academic) community. Most IGs have compiled a 5 page summary report about 2 years ago (see item 8.1); but since then, IG discussions have ceased and been replaced by more specific activities related to major THORPEX projects (e.g., T-PARC, YOTC).

Action PDP3-05 (Heini Wernli): In order to facilitate the exchange of key scientific results of THORPEX, the PDP WG will setup a webpage, which provides:

- key PDP publications for downloading (see item 8.1)
- a list of PDP-related publications
- links to T-PARC and YOTC web pages etc.
- links to (inter-)nationally funded PDP projects.

A few key topics have been identified, to which the PDP WG will pay particular attention to during the coming years. The status of research on these themes will be regularly revisited at future WG meetings, if possible with invited external experts. Each year, one of these topics will be selected for (co-)organizing a specific workshop (e.g., with WGNE).

The list of these key topics includes:

- Climatologies of specific weather phenomena (frequency, intensity) – Heini Wernli *& members from Africa / China / SHEM*
- Organized tropical convection (YOTC, T-PARC) – Mitch Moncrieff, Pat Harr & *member from Asia*
- Ensemble-based data assimilation and forecasting, including stochastic parameterizations – Craig Bishop, Istvan Szunyogh, Olivier Talagrand
- Atmospheric dynamics and diabatic processes (e.g., T-NAWDEX, HYMEX, Rossby wave dynamics, tropical-extratropical interactions, polar meteorology, role of surface fluxes) – John Methven, Andreas Dörnbrack, Heini Wernli *& member from SHEM, polar expert*
- Subseasonal and seasonal prediction (dynamics and physics of coupled systems) – Thomas Jung, Adam Scaife, Ben Kirtman *& others*

- New diagnostic techniques to understand the origin of model errors – Thomas Jung, Andy Brown

Action PDP3-06 (Chairs, Working Group members and experts as required): For every key topic, members of the WG and external experts will be responsible for following the research development and for summarizing the status quo at the WG meetings.

4. Review of field experiments

4.1 Involvement in the evaluation of TPARC

Action PDP3-07: Craig Bishop, Pat Harr (NPS), Carolyn Reynolds (NRL) and Yucheng Song (NCEP) are requested to provide a report on TPARC to future meetings of the PDP WG.

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) and (c) supplemental targeted observations reduce or fail-to-reduce forecast error (TCS08, T-PARC and Winter T-PARC). Major findings in the area of dynamical atmospheric processes and the ability of models to predict observed processes and associated recommendations include the following:

1. Despite the fact that the Easterly wave from which Typhoon Nuri formed could be tracked for 10 days preceding the TC formation, a suite of numerical forecast models failed to capture the formation until 48 hrs before the event (Lussier 2010). The inability of current weather forecast models to simulate the effect of moist processes on Easterly waves (Sean Milton, personal communication) is no doubt part of the reason for this failure. Such systematic errors will strongly limit our ability to predict high impact tropical vortex events. ***Further study of the effect of moist processes on equatorial waves such as Easterly waves is strongly recommended as is the development of parameterizations of moist processes that improve the realism of simulated tropical waves while not degrading representations of moist processes in mid-latitudes.***
2. Aircraft missions into pre-depression Hagupit revealed a developing cyclonic low-level circulation (LLC) four days prior to the issuance of a tropical cyclone formation alert (Bell and Montgomery 2010). Model analyses and satellite imagery suggested that the early circulation was part of a westward propagating disturbance at 18N latitude, well-displaced from the ITCZ and any southwesterly monsoonal flow. ***Studies comparing the frequency, persistency, size and location of cyclonic LLCs in numerical simulations of the tropics with those from analyses are strongly encouraged because both theory and observations confirm their importance in the development of intense tropical vortices.***
3. The analyses of *in situ* data obtained during the formations of TY Nuri and TY Hagupit have been generalized to a broad set of convective episodes using satellite data to examine 16 ring-like mesoscale convective events (Elsberry and Chollet 2010). Comparison with 25 km resolution ECMWF analyses from the Year of the Tropical Convection (YOTC) archive has revealed the three-dimensional structure of the synoptic environment of the mesoscale convective events. ***Studies comparing the frequency, persistency, size and location of ring-like meso-scale convective events in high resolution numerical simulations of the tropics with those from analyses are also encouraged. The YOTC data set may prove useful in providing initial and boundary conditions for high resolution regional simulations.***
4. The performance of the ECMWF, UKMO, GFS, and NOGAPS models in predicting tropical cyclone formation has been evaluated (Elsberry et al. 2009). When all four

global model forecasts were in agreement as to position and evolution, high confidence can be given to the prediction scenario with few false alarms. ***Studies on how to optimally combine information from forecasts and ensembles from distinct NWP centres is strongly encouraged. Such multi-centre ensembles are now readily accessible to the wider research community via the TIGGE data base.***

5. Adding stochastic forcing to the NOGAPS ensemble improved the rate of detection of genesis in the WPAC during the TPARC period (Snyder et al., 2010). False alarm rates also went up, but false alarm rates went up less than the detection rate, indictating some promise for stochastic convection to help with this forecast problem. ***Further study of the representation of the stochastic nature of unresolved sub-grid scale processes and their representation in parameterization schemes and/or stochastic model forcing is strongly encouraged.***
6. Data denial experiments from the Typhoon part of the experiment showed that while 20-40% improvements in track could be attributed to targeted observations in the NCEP and WRF prediction systems, the benefit to the ECMWF and JMA systems was much less (Weissmann et al. 2010). In winter T-PARC, targeted observations were shown to impart a 10-15% improvement within the verification regions of the 1-3 day forecasts for which targeting was performed. These winter-T-PARC results are consistent with results from the winter storms reconnaissance (WSR) program that has been operated by NCEP over the last 10 years. The extent to which the WSR and winter T-PARC results are inconsistent or consistent with those from the ECMWF based on the denial of satellite observations over the Pacific is unclear due to significant differences in the set-up of the targeting problem. Thus, the degree of sensitivity of the impact of targeted observations on forecasts to the forecasting and data assimilation system employed remains unclear. This is unfortunate as many currently planned field experiments are based on the notion that supplemental observations will significantly reduce analysis and forecast error. Theory predicts that the relative value of targeted observations is a strong function of the quality of the forecasting system – so a system dependent result for targeted observations is to be anticipated. Indeed, a theoretical basis for quantitatively predicting and evaluating the error variance reduction due to targeted observations was given in Majumdar et al. (2001). It would greatly assist the design and efficacy of future field programs if the accuracy of such quantitative predictions of the reduction in forecast error due to targeted observations could be further improved. Due to the fact that targeting has now taken place for more than a decade over the tropical summertime Atlantic and the wintertime mid-latitude Pacific, large targeted observational data sets now exist and the time is ripe for a concerted investigation of the aforementioned issues. ***Further research is strongly encouraged on (a) the dependence of the effect of targeted observations on the forecasting/assimilation system for mid-latitudes and the tropics (b) improving our ability to quantitatively predict the reduction in forecast error variance due to targeted observations.***

References

Bell, M. M., and M. T. Montgomery, 2010: Development of pre-depression Hagupit observed during TCS-08. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Berger, H., C. S. Velden, R. Landland, and C. A. Reynolds, 2010: Special satellite data analysis and NWP impact studies during T-PARC. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Chen, S.-G., S. J. Majumdar, and C. C. Wu, 2010: Properties of the ensemble transform Kalman filter adaptive sampling strategy for tropical cyclones. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Cisneros, J., C. Lopez-Carrillo, and D. J. Raymond, 2010: High resolution analysis of the structure of a convective system in developing Typhoon Nuri. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Elsberry, R. L., and A. Chollet, 2010: Role of mesoscale convective rings and mesoscale convective blowouts in tropical cyclone formations during the TCS-08 experiment. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Grams, C. M., 2010: The interaction between the outflow of Typhoon Jangmi (2008) and the midlatitude jet during T-PARC. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Harnisch, F., and M. Weissmann, 2010: Sensitivty of typhoon forecasts to different subsets of targeted dropsonde observations. *Mon. Wea. Rev.,* in press.

Harr, P. A., E. R. Sanabia, and A. B. Penny, 2010: Typhoon Sinlaku during T-PARC: Sensitivity of the re-intensification and downstream development to the track following recurvature. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Lussier, L. L., 2010: The genesis of Typhoon Nuri as observed during the tropical cyclone structure 2008 (TCS-08) field experiment. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Raymond, D., and C. Lopez-Carillo, 2010: Vorticity budget in developing typhoon Nuri. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Reynolds, C. A., J. D. Doyle, R. M. Hodur, and H. Jin, 2010: Naval Research Laboratory Multi-scale Targeting Guidance for T-PARC and TCS-08. *Wea. Forecasting,* **25**, 546-564.

Sanabia, E. R., and P. A. Harr, 2010: Scale interactions during the re-intensification of Typhoon Sinlaku prior to extratropical transition. 29th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA.

Snyder, A., Z. Pu and C. A. Reynolds, 2010: Impact of stochastic convection on ensemble forecasts of tropical cyclone development. Submitted to *Mon. Wea. Rev*.

Weissmann, M., F. Harnisch, C. C. Wu, P. H. Lin, Y.Ohta, K. Yamashita, Y. H. Kim, E. H. Jeon, T. Nakazawa, and S. Aberson, 2010: The influence of assimilating dropsonde data on typhoon track and mid-latitude forecasts. *Mon. Wea. Rev*., in press

NOGAPS adaptive observing and data denial experiments during T-PARC/TCS-08, C. A. Reynolds, NRL, Monterey, CA; and R. Langland, C. Velden, and H. Berger

http://ams.confex.com/ams/29Hurricanes/techprogram/paper_168007.htm An overview of the COAMPS-TC system applied during HFIP and T-PARC, James D. Doyle, NRL, Monterey, CA; and S. Chen, J. Cummings, R. M. Hodur, E. Hendricks, T. Holt, H. Jin, Y. Jin, C. S. Liou, J. R. Moskaitis, M. Peng, K. D. Sashegyi, and J. Schmidt

http://ams.confex.com/ams/29Hurricanes/techprogram/paper_168004.htm Initial condition sensitivity and predictability of tropical cyclogenesis, James D. Doyle, NRL, Monterey, CA; and C. M. Amerault, C. A. Reynolds, and J. R. Moskaitis

4.2 Involvement in the planning of TNAWDEX

THORPEX - North Atlantic Waveguide and Downstream Impact Experiment (T-NAWDEX) Current Status and Plans for Advancement - A. Dörnbrack, J. Methven, H. Wernli

i) T-NAWDEX goals

T-NAWDEX has been proposed by the THORPEX working group Predictability and Dynamical Processes and is a key element of the European THORPEX Science Plan. Its overarching scientific goal is to investigate in detail the link between skill in forecasts on the 1-7 days range, systematic model errors and the representation of physical processes that contribute most to model error. The focus will be on the diabatic modification of air masses, the influence this has on the development of Rossby waves as they propagate across the North Atlantic and the subsequent effects on high impact weather forecasts for Europe. Although regional in experimental focus, the results and conclusions will be pertinent to the extra-tropics world-wide.

A key motivation is to tackle the attribution of forecast model error to process head-on; acknowledging that the non-local nature of large-scale wave propagation and balance makes this a challenging task. Wernli (and others) have shown that same of the worst forecasts for Central Europe are associated with a common sequence of events, tracing Rossby wave activity along the jet at tropopause level back to a large-amplitude trough-ridge system oriented along the East coast of North America. The rationale for stopping the chain of events there is that the associated PV anomalies are substantially modified by non-conservative processes and it is this aspect which is not well represented in the models. Extra-tropical transition of cyclones also takes place over the western Atlantic, is uncertain in models but has an important influence on waves along the jet and downstream development. It has also been established that latent heat release is a key player in violent wind storms hitting Western Europe, such as Lothar and Martin in 1999. Such events are smaller scale, feature rapid low-level development and typically occur crossing the exit of strong westerly jets. Forecasts of these events are sensitive to model structure as well as initial conditions. The origin of model error is not well characterised, but key processes include upright and slantwise convection, microphysics for ice and liquid and turbulent transfer of heat and humidity within and above the boundary layer.

The approach for T-NAWDEX will to focus on three stages:

(1) Diabatic modification of air-masses as they are advected meridionally within developing (moist) Rossby waves and its effects on PV anomaly structure and amplitude
(2) Propagation of wave activity along the waveguide and further diabatic modification of PV anomalies across the Atlantic
(3) Downstream impact of diabatically-modified PV anomalies, propagating along the jet or developing below it, on precipitation and high winds over Europe

The original idea was to organize the international field phase of T-NAWDEX in the time period of the German demonstration mission HALO-THORPEX which was jointly proposed by DLR, KIT and University of Hohenheim. HALO-THORPEX was selected by the HALO Scientific Steering Committee (WLA) as one of 8 missions. This field phase would be ideally combined with HYMEX in autumn 2012. Active international contributions are expected from the UK, France, Switzerland, USA, Canada et al.

ii) Selected Activities 2009/2010

- 1st Planning Workshop in Erding, Germany, in Feb. 2009
- T-NAWDEX pilot campaign conducted with the FAAM aircraft from the UK in Nov. 2009
- Presentations of the T-NAWDEX mission at several international conferences (e.g., MOCA Montreal 2009, TISS Monterey 2009, ECSS Landshut 2009)
- NERC application by G. Vaughan, J. Methven, D. Parker, I. Renfrew et al. in the Storm Risk Mitigation Call, entitled DIAMET (Diabatic influences on mesoscale structures in extratropical storms). Funding decision due late summer 2010, and if successful start of project in September 2010 for 3 years
- CNRS funding for analysis by G. Rivière

iii) Current HALO status

There is significant delay in instrumentation of the German research aircraft HALO due to difficult certification issues. Therefore, the series of HALO demonstration missions has had to be postponed possibly by 2 years. Currently, the selection of demonstration missions is made on a case-by-case basis by the HALO-WLA (the consortium governing the use of HALO). We cannot expect HALO to be reliably available for international research missions in 2012. This has hindered the advance of the T-NAWDEX project.

HALO-WLA are keen to push missions focussing on installation and evaluation of new instruments (mostly microphysical, chemical, and aerosol) due to the time pressure caused by the delay in delivery and test phase of HALO. Currently, there is no member of the WLA advocating weather research and THORPEX ideas. The IOP was asked to help clarify the situation.

iv) Plans

Work towards a T-NAWDEX experiment in September 2012, with modified aims to reflect the emphasis of HYMEX on the influx of water vapour to the Mediterranean region as well as the influence of wave breaking at the end of the Atlantic waveguide. Progress the international field experiment by:

- joining forces between DLR and KIT to deploy HALO or the DLR Falcon during the 1st HYMEX SOP in September 2012, with emphasis on the capability for remote sensing of water vapour profile and its assimilation (responsible: A. Dörnbrack, end Oct 2010)
- plan for coordinated flights of the UK FAAM aircraft as part of DIAMET with those of the German aircraft, both northwest of the Mediterranean, spanning UK, France and Atlantic approaches
- Build in the use of the dense ground-based observation network across UK and France, including Doppler radar, profile instruments and radiosondes

Consider carefully the use of NWP model and data assimilation experiments to address the identification of upstream model errors and processes contributing to them. Build on the outcomes of the joint THORPEX PDP – WGNE workshop in Zurich, 7/7/10, to develop the scientific approach and to foster involvement of the WGNE community. Emphasise the role of additional aircraft observations to characterise diabatic processes and identify model deficiencies within air masses such as warm conveyor belts. The non-local influence of PV anomalies and wave propagation will be dealt with by numerical simulation and assimilation of data using the existing observation network, especially satellite data, following the example of the YOTC virtual experiment.

Action PDP3-08: Development of T-NAWDEX

Write T-NAWDEX Science Plan (responsibility: A. Dörnbrack and authors already identified as H. Wernli, S. Jones, P. Harr, G. Rivière, J. Methven, G. Craig, T. Jung; Autumn 2010 in preparation for PANDOWAE stage 2).

Contact Pat Harr to apply at NSF (deadline Dec 2010) for HIAPER flight hours for autumn 2012 participation in upstream measurements during T-NAWDEX (A. Dörnbrack).

Contact NOAA to discuss possibility of C-130 aircraft flights off North American East Coast within warm conveyor belts and their inflow.

Try to include in the German Weather Service into the HALO-WLA with a view to the promotion of weather-related research flights.

Submit application to DFG for the 2nd phase of PANDOWAE with a clear focus on T-NAWDEX activities (Wernli and Dörnbrack, Autumn 2010).

4.3 Year Of Tropical Convection (YOTC) – a virtual field experiment

The international YOTC project, jointly coordinated by WWRP-THORPEX and WCRP, provides the framework and infrastructure for an integrated observational-computational resource or 'virtual field experiment'. Critical processes at the intersection weather and climate (seamless prediction) can be examined at high resolution on time scales up to seasonal. With this motivation the YOTC project addresses organized precipitation systems and their effects on the large-scale atmospheric circulation. Emphasis is on phenomena that are known to be problematic: the MJO and convectively coupled waves, the intraseasonal variability of monsoons, the ITCZ, easterly waves and tropical cyclones, tropical-extra-tropical interaction, and the diurnal cycle. The approach is based on global analyses, forecasts and special diagnostics from the ECMWF T799 (25-km-mesh) deterministic prediction system; multi-sensor satellite, field-experiment and in-situ observations; and research that encompasses observations, parameterized, super-parameterized and explicit convection in numerical models and dynamical models. La Niña and El Niño climate states occurred during the "Year" (1 May 2008 - 30 April 2010) and an Arctic Oscillation and the T-PARC and TCS08 field campaigns took place. The YOTC Science Plan and Implementation Plan were prepared by a team of experts at workshops and via the internet. YOTC science sessions have been convened at various international conferences. The NASA Goddard Giovanni system has been adopted to facilitate the analysis, dissemination and visualization of multi-sensor satellite data. A YOTC MJO Task Force has been formed and its first meeting took place recently in Busan, Korea. The objective of various collaborative projects involving institutions and academia are to assess and improve the performance of weather/climate models, e.g., hindcast experiments focused on meteorological events during the "Year", such as efforts in collaboration with the CLIVAR Asian-Australian Monsoon Panel (AAMP), and the WCRP Asian Monsoon Years (AMY). In particular, cloud-system resolving models with computational domains up to global are employed to advance explicit and parameterized representations of moist convection including attention to organized convection, which is a process missing from current climate models. The research phase is growing steadily in tune with the integrative and collaborative nature of the YOTC project and includes nations directly affected by the variability of tropical weather and climate. Detailed information can be found at the website www.ucar.edu/yotc maintained by the YOTC Project Office under the support of NSF, NOAA and NASA and administered by the US-THORPEX Executive Committee (USTEC).

5. Predictability

5.1 Ensemble Prediction Systems. New developments

More than a dozen meteorological services now run operational ensemble prediction systems, both global and regional. These systems provide *a priori*, situation dependent estimates of the uncertainty of the forecast, an information that a purely deterministic system, whatever its intrinsic quality, cannot provide. Thanks to the TIGGE data base (see below), a large fraction of those ensemble predictions is made available to the scientific community, for study and comparison, within a short delay.

Among recent developments, one can mention that ECMWF has introduced a system of Ensemble Variational Assimilation which complements the singular vectors already used for the definition of the initial ensembles.

Active research is being pursued in numerous places on the definition of initial ensembles, as well as on the evaluation of ensemble predictions. Concerning the definition of initial ensembles, several methods are used at present: singular (linear) modes, bred modes, Ensemble Transform Kalman Filter (ETKF), Ensemble Kalman Filter (EnKF) and Ensemble Variational Assimilation. All these methods (except singular modes, which are partially or totally defined in several services over the early period of the forecast), use only past information and are meant to sample the present uncertainty on the state of the atmosphere, or at least to identify components of the flow where recent instabilities have taken place. Ensemble Kalman Filter and Ensemble Variational Assimilation are full-fledged assimilation algorithms. One point of view is that the best initial ensembles are those that sample best the present uncertainty on the state of the flow. That point of view, which is supported by idealized experiments, is not as strongly supported by real life comparisons. Further research is required on that aspect.

Regional ensemble prediction requires the definition of appropriate lateral boundary conditions. The problem is in essence similar to the problem of the definition of initial conditions, but research on that aspect is still in its infancy.

A number of statistical scores are used for objectively assessing the quality of ensemble predictions (Brier score and its various generalizations, measures of 'spread-skill' relationship ….). Those various scores evaluate different aspects of ensemble prediction, and full understanding of their exact significance requires further work. A particularly important point, in view of the fact that verification requires large validation samples, is clear identification of the limits of what ensemble prediction can achieve. Results suggest that scores saturate for ensemble dimension on the order of a few tens of units. The implications of that fact, if it is confirmed (see below 5.4), can be of great importance.

5.2 The representation of uncertainty in sub-grid scale parameterization schemes

While significant progress has been made with developing the theoretical basis of accounting for the effects of initial condition uncertainties in ensemble forecasting, a similar theory of accounting for the effect of model errors is yet to be developed. In particular, while the uncertainty in sub-grid scale parameterization schemes is generally viewed as one of the prime sources of forecast uncertainty, the exact mechanism through which parameterization schemes contribute to the degradation of forecast accuracy is little understood. The PDP WG expects the development of techniques to account for the effect of uncertainty in the parameterization schemes to be one of the most important areas of ensemble research in the coming years. The PDP WG discussed a proposal by Tom Hamill of WGNE, Istvan Szunyogh of the PDP WG, and Tim Palmer of ECMWF for a 4-day joint THORPEX-PDP/WGNE Workshop on Stochastic Processes and the Representation of Model Error during June 2011 at ECMWF. The members

of the PDP WG strongly supported the proposal and recommended it for further discussion at the PDP WG/WGNE Workshop on Diagnosis of Model Error, which followed the PDP WG Meeting with a broader participation from WGNE. It was agreed that the first goal should be to identify those aspects of the uncertainties in the parameterization schemes that are the results of inherently random processes. Such understanding is crucial to develop a theoretical framework to design stochastic parameterization schemes.

5.3 The use of perturbed parameter ensembles to improve NWP models

Generating ensembles by perturbing the model parameters is an approach that is particularly popular among scientist developing limited area ensemble systems. This approach is also used in the global setting at Environment Canada. While the PDP WG recognizes the motivation, rooted in the Monte-Carlo approach view of ensemble forecasting, to account for the uncertainties by perturbing all potential sources of uncertainty, it also finds, that the current approach of making largely ad hoc perturbations of the parameters is not firmly based on scientific arguments. The PDP WG views the development of stochastic parameterization schemes (see discussion under 5.2) as the scientifically justifiable approach to account for the uncertainties in the parameters of the parameterization schemes.

5.4 The TIGGE-PDP linkage and collaboration

The TIGGE dataset is unprecedented as a means for the study of atmospheric predictability. It has been used so far mostly for comparing the performance of the various ensembles included in the dataset and for optimally combining those ensembles. One obvious use of the dataset is the evaluation of the saturation, or otherwise, of the scores with the dimension of ensembles. The TIGGE dataset will also allow, by comparison of the forecasts produced in the same situation by different models and initial conditions, in-depth case studies of predictability. The PDP WG recommends close collaboration with the GIFS-TIGGE Working Group.

6. Collaboration with the WGNE

Both the ICSC and CAS recommended closer cooperation between the THORPEX PDP working group and WGNE. Better communication between the two groups has been established by naming focal points in each of the working groups (Thomas Jung from PDP and Andy Brown from WGNE) and by attendance of these people at the respective working group meetings (Andy Brown attended this meeting). Diagnosis of model error has been identified as one of the key areas of future collaboration and it was decided to aim to formulate a set of specific joint projects (e.g. detailed numerical experimentation in support of T-NAWDEX). The joint workshop on the diagnosis of model error, held from 7-9 July 2010 in Zurich, was jointly organized by THORPEX-PDP and WGNE representatives with support from the THORPEX IPO.

Action PDP3-09 (Chairs and Thomas Jung): It was recommended that a paper with a summary of the outcomes of the 2010 PDP/WGNE workshop should be written and published.

The other area in which close collaboration between THORPEX-PDP and WGNE would be beneficial is the area of stochastic processes and the representation of model uncertainty in ensemble and data assimilation systems. A workshop on this topic is planned to be held in June 2011 at ECMWF.

Action PDP3-10 (Tom Hamill, Istvan Szunyogh, Tim Palmer): The proposed committee (Tom Hamill, Istvan Szunyogh, Tim Palmer) was supported and it was requested that they propose a draft agenda which should be circulated around members of PDP and WGNE for comment and iteration.

7. THORPEX mid-term review

Action PDP3-11 (Chairs and IPO): The ICSC has requested a review of the THORPEX programme. The IPO will invite contributions to this review from the THORPEX Working Groups, Regional Committees and Field Experiment PIs and will produce a first draft for review by the WWRP/JSC in January 2011. A revised review will be presented to the THORPEX ICSC. Subject to agreement from the ICSC, a few independent scientists will be invited to assess the review and to provide further input.

8. Plans of future activities

8.1 WMO THORPEX publication of the IG reports

Action PDP3-12 (Chairs): It is decided to publish the reports written by the IGs about 2 years ago on the PDP webpage. The texts should be published "as is" – however, the authors will be offered the chance to do some final editing if they like within a few weeks.

8.2 Joint PDP publication

The paper submitted by the PDP WG to BAMS has been rejected. Currently no clear benefit for writing another similar joint BAMS paper is envisaged. However, the WG strongly encourages the submission of a summary report from the WGNE-PDP workshop in order to promote research on model error diagnostics.

8.3 PDP summer school in Banff

The PDP WG is organizing a 2011 summer school on *Advanced Mathematical Methods to Study Atmospheric Dynamical Processes and Predictability*. The meeting will take place at the Banff International Research Station (BIRS) for Mathematical Innovation and Discovery, Canada, from July 10 to July 15, 2011. The BIRS Program Selection Committee selected the proposal of the PDP WG from a large number of proposed programs. BIRS will provide the conference facilities, accommodation and meals at no cost to the 42 participants of the meeting. BIRS will also send out the official invitation to the participants and will also provide the documents that some participants may need for the visa application.

In the proposal for the meeting, the PDP WG proposed the invitation of 8-10 lecturers and 32-34 graduate students. The proposal promised the invitation of students from five continents and to provide travel support to students from developing countries from THORPEX funds. At the Meeting the PDP WG asked for the help of the IPO to secure the funding needed to fulfil this commitment.

The lecturers who were proposed, and all agreed to participate, are A. Majda, O. Talagrand, P. Lynch, E. Ott, T. Jung, C. Bishop and I. Szunyogh. Potentially, two more lecturers can be added, if needed to cover the lectures included in the final program of the summer school. The proposal included the following specific topics: PDEs that govern atmospheric motions; Wave solutions of the governing equations; Numerical techniques for the solution of the governing equations; Data Assimilation; Idealized models of atmospheric motions; The concept of atmospheric balance; The basics of dynamical systems theory; Ensemble forecasting; Predicting the impact observations (observation targeting); Verification of probabilistic forecasts. The PDP WG agreed to have a total of 24 lectures: six lectures on Monday, Tuesday and Thursday and three lectures on Wednesday and Friday. Each lecture will consist of a 40-minute talk by the invited lecturer and a 20-minute question and answer session. The final program will be developed by the end of summer 2010.

The PDP WG agreed that the most urgent task was to send out an announcement of the meeting. This announcement will include information about the application deadline (September 30) and the application material required from each applicant. This application deadline is driven by the constraint that the PDP WG is required to provide a full list of participants (including about 5 backup persons for potential cancellations by the original invitees) to the BIRS program organizers. The required application material consists of (i) a no more than one page essay from the applicant, in which he/she explains how he/she expects his/her thesis research to benefit from the summer school and (ii) a recommendation letter from the applicant's thesis advisor or from another well established member of the research community. All application materials will have to be submitted electronically, preferably in pdf format.

Action PDP3-13 (Istvan Szunyogh): The WG agreed that a call for applications for the summer school in Banff should be set out as soon as possible.

8.4 PDP activities in Africa and Southern Hemisphere

Both regions have very good plans and specific suggestions for PDP activities. It would be highly beneficial to have WG members from the two regions (see item 9).

9. Membership

Action PDP3-14 (Chairs and IPO): The Working Group chairs and IPO will make suggestions for additional members from

- Asia
- The Polar Region
- Africa
- The Southern Hemisphere
- North America

The new members will be invited to the PDP WG meeting in 2011. The IPO will confirm and contact/invite the new members.

10. Review of outcomes, decisions and actions

Action PDP3-01 (Chairs and Thomas Jung): WWRP/THORPEX should be involved in the WCRP model development survey and the follow-up – THORPEX should consider what support can be given by the PDP Working Group.

Action PDP3-02 (Chairs and Thomas Jung): the PDP Working Group would be involved in the WGNE Parameterization Workshop.

Action PDP3-03 (Chairs and IPO): Other PDP Working Group actions arising from ICSC 8 (see section 2.1 above).

Action PDP3-04 (IPO): After discussion of the plans for the Polar workshop, there was agreement that the PDP Working Group should be represented at this Workshop (planned for 6-8 October 2010) and the IPO and the Working Co-Chairs should ask the ICSC to appoint an appropriate expert on Polar prediction to the PDP Working Group.

Action PDP3-05 (Heini Wernli): In order to facilitate the exchange of key scientific results of THORPEX, the PDP WG will setup a webpage

Action PDP3-06 (Chairs, Working Group members and experts as required): For every key topic, members of the WG and external experts will be responsible for following the research development and for summarizing the status quo at the WG meetings (see section 3 above).

Action PDP3-07 (Craig Bishop, Pat Harr (NPS), Carolyn Reynolds (NRL) and Yucheng Song (NCEP)): A report on TPARC is requested for to future meetings of the PDP WG.

Action PDP3-08: Development of T-NAWDEX (see section 4.2 above).

Action PDP3-09 (Chairs and Thomas Jung): It was recommended that a paper with a summary of the outcomes of the 2010 PDP/WGNE workshop should be written and published.

Action PDP3-10 (Tom Hamill, Istvan Szunyogh, Tim Palmer): The proposed committee (Tom Hamill, Istvan Szunyogh, Tim Palmer) was supported and it was requested that they propose a draft agenda which should be circulated around members of PDP and WGNE for comment and iteration.

Action PDP3-11 (Chairs and IPO): The ICSC has requested a review of the THORPEX programme. The IPO will invite contributions to this review from the THORPEX Working Groups, Regional Committees and Field Experiment PIs and will produce a first draft for review by the WWRP/JSC in January 2011. A revised review will be presented to the THORPEX ICSC. Subject to agreement from the ICSC, a few independent scientists will be invited to assess the review and to provide further input.

Action PDP3-12 (Chairs): It is decided to publish the reports written by the IGs about 2 years ago on the PDP webpage. The texts should be published “as is” – however, the authors will be offered the chance to do some final editing if they like within a few weeks.

Action PDP3-13 (Istvan Szunyogh): The WG agreed that a call for applications for the summer school in Banff should be set out as soon as possible.

Action PDP3-14 (Chairs and IPO): The Working Group chairs and IPO will make suggestions for additional members.