First meeting of the WWRP PDEF working group
Karlsruhe, 21-22 May 2015.

Participants:
Craig Bishop – NRL, USA (on line);
Richard Swinbank – Met Office, UK;
Judith Berner – NCAR, USA;
Yuejian Zhu – NCEP, USA;
John Methven – U Reading, UK;
Munehiko Yamaguchi – JMA/MRI, Japan;
Masayuki Kyouda – JMA, Japan;
Olivia Martius – U Bern, Switzerland;
Oscar Alves – BoM, Australia;
Zhiyong Meng – U Peking, China;
Mark Rodwell – ECMWF;
Susanne Theis – DWD, Germany;
Manuel Fuentes – ECMWF (TIGGE panel chair);
George Craig – LMU, Germany (invited expert);
Heini Wernli – ETHZ, Switzerland (invited expert);
Sarah Jones – DWD, Germany (Chair, WWRP SSC);
Paolo Ruti – WMO, Switzerland (Chief, WWR).

1. Organisation of the meeting

The meeting opened at 14.00 on 21st May. The meeting participants briefly introduced one another.

2. Objectives of the working group

2.1 Aims of the group & science challenges

Richard Swinbank described the role of the new WWRP working group on Predictability, Dynamics and Ensemble Forecasting (PDEF). PDEF combine elements of the previous THORPEX GIFS-TIGGE and PDP groups, involving both operational and academic communities in scientific research and development challenges. PDEF will support the THORPEX legacy projects, S2S, PPP, and HIWeather and the WWRP FDPs and RDPs. PDEF was approved by CAS-16 as part of post-THORPEX plans.

RS presented the terms of reference (ToR) of the group; here are some key points:

1. To advance the science of dynamical meteorology and predictability research
2. To improve ensemble predictions
3. To support WWRP projects
4. To promote the use of TIGGE and TIGGE-LAM and other ensemble data-sets

After discussion with WGNE and others, it had been agreed that PDEF should initially focus on five scientific challenges:

1. Stochastic representation of the effect of sub-grid-scale uncertainty in numerical models
2. Construction of ensemble initial conditions
3. Interactions of diabatic processes with meso/synoptic scale dynamics

4. Assessment of multi-model ensembles and calibration techniques
5. Coupled modelling and assimilation (towards Earth System modelling)

To summarise, the overarching objectives of PDEF are: to facilitate and contribute to major advances in these 5 areas for the benefit of all WMO members; and to usefully advise HIW, PPP, S2S and other WWRP projects

COMMENTS AND QUESTIONS.
George Craig asked what is the link with WCRP regarding stochastic physics?
Sarah Jones commented that *Clouds and Circulation* is the WCRP grand challenge that PDEF should focus on.

2.2 Advice/suggestions from invited experts

Heini Wernli, as former co-chair of the THORPEX PDP working group, made some remarks from the PDP perspective. He first welcomed the prospect of PDEF continuing to build on the achievements of THORPEX. Particular areas that PDEF should focus upon include:

1. Pillars: academia, research centers, operational NWP
    a. Linking these pillars worked well in THORPEX for example in DIAMET and PANDOWAE.
2. Generations: PhD students, postdocs, senior experts
    a. Events such as THORPEX science meetings, WWRP OSC brought together early-career and experienced scientists.
3. Time scales: nowcasting, mesoscale NWP, global NWP, seasonal, climate
    a. Use opportunities to bring together expertise across different time-scales (for example, WCRP challenge on Cloud and Circulation)
4. Countries and continents: T-PARC as exceptional example
    a. There is a concern about conflicts between national interests and international cooperation (e.g., non funding of DOWNSTREAM).

COMMENTS.
GC: link between WGs and WWRP Projects, what will PDEF be doing for HIWeather?
Craig Bishop: PDP played an advisory role for experimental design, while other WGs, such as DAOS, worked on developing experiments.
SJ: in terms of WG functions, each WG should specify key topics and related activities, they have an advisory role for the projects;
PR: YESS (Young Earth System Scientists) is the young scientists community which is cutting across WCRP, WWRP and GAW; WMO is working together with other funding agencies in such a way that WWRP objectives, and PDEF as well, should be considered in the development of research plans of other research and funding agencies.

Sarah Jones recalled the role of the WWOSC in establishing the scientific research pillars for the next decade. The ones which involve mostly the PDEF role are:
Seamless prediction from minutes to month; ensemble forecasting at all time scales; short time scales with a focus on convective processes linking to the activities of DAOS and of the new Nowcasting and Mesoscale WG; long term time scales, especially the monthly time scale, linking with the WCRP activities.
It has been recognized that a better understanding of storm tracks is certainly an area where PDEF could advise WCRP. In order to strengthen the link with the WWRP

SSC, PDEF should revise the new scientific implementation plan increasing the link with the Projects, and with other WMO technical commissions (for example, CBS and CIMO).

3. Report and actions from previous meetings

3.1 WWRP structure and activities

Paolo Ruti presented the new WWRP structure and related activities and the development needed in the next decade to address the societal challenges defined by the Commission for Atmospheric Sciences related to high impact weather and its socio-economic effects in the context of global change; to modelling and predicting the water cycle for improved disaster risk reduction and resource management; to urbanization and the need for research and services for megacities and large urban complexes; and to evolving technologies, their impact on science and its utilization. The World Weather Research Programme will address these challenges through promoting coordinated research activity at international level in an interdisciplinary framework, involving academic and operational research communities, and supporting the education and training of early career scientists. The WWRP will achieve these aims through the focus areas of the working groups, and the research carried out in the Polar Prediction Project, the Subseasonal to Seasonal Prediction Initiative, and the High Impact Weather Project.

QUESTIONS.
Mark, energy topic to be considered by CAS challenges.

> **Action 1.3.1:** PDEF WG to provide feedback on WWRP science implementation plan by October WHO: co-chairs DEADLINE: October 2015

3.2 Outstanding & ongoing actions from THORPEX WGs (RS)

Richard Swinbank reviewed the actions inherited from THORPEX. Some of the permanent actions from GIFS-TIGGE need to be continued by PDEF and/or the TIGGE panel (see list of actions below). Action on exchange of information on forming tropical storms will be continued under PDEF.

> **Action P.1:** TIGGE panel chair to update statistics on TIGGE and TIGGE-LAM data users on an annual basis. WHO. Manuel Fuentes DEADLINE. Before each PDEF meeting
>
> **Action P.2:** YZ to carry out literature search for papers based on TIGGE data on an annual basis (end of each year), and summarise results. Archive centres to ask users to inform them when TIGGE papers are written, to enable the list of TIGGE publications to be kept up to date. WHO: Yuejian Zhu DEADLINE: Before each PDEF meeting
>
> **Action P.3:** Co-chairs to request reports before each working group meeting on all actions, plus relevant progress reports. WHO: Co-chairs DEADLINE: before each PDEF meeting.
>
> **Action P.4:** Working Group members to consider adding to training material on the TIGGE data portals, including data access and manipulation examples, to help potential users of the TIGGE archive. WHO. Members. DEADLINE. No-deadline

Action 1.3.2: Secretariat and co-chairs to request TIGGE providing centres to include information on forming storms in CXML messages (initially using location / time as identification and subsequently discuss a naming convention). WHO: RS & PR. DEADLINE: Sept 2015.

4. Links with WWRP projects

4.1 HIWeather project (OM)

Olivia Martius presented an overview of HIWeather and its cross cutting activities. The scope of HIWeather is defined by a set of 5 hazards:

- Urban Flood
- Disruptive winter weather
- Wildfire
- Urban heat waves and air pollution
- Extreme local wind

The project includes five research pillars:

- Understanding the processes and predictability of weather systems – most relevant to PDEF;
- Multiscale forecasting of hazards;
- Forecasting the human impacts, exposure vulnerability and risk of hazards;
- Communicating forecasts and warnings;
- Evaluation of forecasts, alerts and warnings;

And is supported by eight cross-cutting activities.

The project steering group will comprise the leaders of the 5 research task teams, and be co-chaired by Brian Golding and a social scientist (to be announced). The project is supported by an International Coordination Office based in the Republic of Korea.

COMMENTS.
CB. What is a perfect metric to evaluate the skill of HIWeather prediction. Would it be possible to have an historical catalogue of extreme events (for instance floods)?
Mark Rodwell. At ECMWF there is a catalogue of extremes. It would be interesting to look at the false alarms (members with a wrong forecast of extreme events), and vice-versa.
CB: A sampling strategy along the lines of sampling each event category with a frequency inverse proportional to its climatological annual/decadal frequency would clearly have a strong focus on extreme events but would not entirely neglect run of the mill events.
Olivia Martius. Catalogue based on stakeholders (re insurance) exists at least in a aggregated way.

Action 1.4.1: It was agreed that the designated PDEF representative (OM) should participate in HIWeather conference calls, reporting to PDEF co-chairs. WHO: Olivia Martius. DEADLINE: October 2015.

4.2 Polar Prediction Project

John Methven reported that PPP has a lot of overlaps with PDEF. Prediction of sea ice and other key variables such as fog, wind, precipitation are central to YOPP.

Central international experiment under the YOPP umbrella is MOSAiC, polar research vessels will be engaged especially in 2018.

John suggested that the main activities PDEF could advise and cover include:

- Design of polar observing system (especially long term legacy of YOPP) with DAOS
- How to design ensembles for polar regions
  - Obtaining IC spread in global ensembles for polar regions
  - Challenges in coupled assimilation, coupled error covariance
  - Polar LAM systems
- Dynamics for mesoscale and finer
  - Design of model and tuning for polar regions
  - How best to couple information involving structure on grid-scale and time-step
  - Consideration of resolution for forecast system
- Evaluation of ensemble prediction systems in polar regions
  - How to evaluate high resolution multi model ensembles and value of coupling
  - How to design scale dependent verification diagnostics (obs density)?
- Design of the YOPP data archive system
- Using outcomes of NAWDEX2016 to inform the YOPP experiments

Action 1.4.2: JM is attending the YOPP summit meeting. JM to clarify how best the PDEF group might support PPP, reporting back to co-chairs. WHO: John Methven DEADLINE: July 2015.

4.3 S2S project

Oscar Alves described the S2S structure including six sub-projects:

- Interactions and teleconnections between midlatitudes and tropics
- Madden Julian Oscillation
- Monsoons
- Africa
- Extremes
- Verification

He highlighted three main areas where PDEF could support S2S:

- Improving ensemble methods in coupled systems.
- The coupling issue: What is the strategy for coupling on this time scale.
- Multi-model approach

5. Other linkages

5.1 WGNE

Oscar Alves summarised the WGNE priorities:

- Weeks 3 and 4 next challenge
- Seamless prediction
- Verification relevant to users
- Earth system forecasting, adding the human dimension

- CREATE IP reanalysis intercomparison project
- Transpose CMIP, a discussion paper is under development.

6. TIGGE and TIGGE-LAM

6.1 Status report

Manuel Fuentes presented a report on TIGGE.

TIGGE global. There are several gaps due to modelling system changes, for instance:

- BoM stopped in July 2010
- KMA upgraded model in December 2010, and resumed feed in July 2011
- Met Office resumed feed in Nov 2014
- CMA upgraded model in Sep 2014, resumed feed in March 2015
- NCAR stopped archiving TIGGE data at the end of 2014.

In terms of storage 1.2 PB, 4.6 billion fields. This large effort is growing by 550 GB/day. Web infrastructure upgraded in 2014 (WebAPI and wiki). Concerning the users, the most active are from China, US and UK.

TIGGE-LAM. An archive has now been set up at ECMWF, but only for European models. Forecast data starts on 1st Jan 2013, 8 Tbytes at present. There are only a few users so far - an effort to advertise to WMO members and other potential users is required.

Manuel pointed out that the S2S data licence allows the redistribution of data, whereas the TIGGE licence does not. He proposed that, for consistency, the TIGGE licence be amended to allow redistribution.

> **Action 1.6.1:** All members to publicise the TIGGE-LAM database to their national research communities and at international conferences. WHO: All members. DEADLINE: Before next PDEF meeting.

6.2 Possible Future Developments

Yuejian Zhu raised the possibility of the future addition of the FNMOC ensemble to TIGGE. The meeting agreed that this would be a welcome development, provided suitable technical arrangements could be agreed.

> **Action 1.6.2:** The working group welcomed the possibility of FNMOC ensemble prediction data to the TIGGE database. CHB, YZ to ensure necessary support is provided by NRL and NCDC, and secretariat to assist if necessary with the provision of a WMO identifier for the data. WHO: Yuejian Zhu and Craig Bishop. DEADLINE. No deadline

The meeting adjourned until 09.00 on 22nd May

7. Stochastic physics

7.1 Scientific Challenges

Judith Berner introduced the stochastic physics challenge. Two widely-used schemes are:

- Stochastic kinetic energy backscatter scheme. Up-scale projection of unrepresented sub-grid scale state onto resolved flow.

- Stochastic perturbed parameterization tendency scheme. Perturbation of physical tendencies to represent uncertainties resulting from sub grid variability.

The stochastic physics significantly reduces the systematic error for low-resolution global forecast models. However a similar, and much stronger, reduction can be obtained by increasing resolution and improving parameterizations. The most consistent approach would be that, when a parameterization is developed, a consistent uncertainty scheme is developed alongside.

Stochastic physics is also important to address systematic errors in convective-scale models. For example, more realistic development of showers occurs when small temperature perturbations are added in boundary layer to represent upscaling of eddies.

Model errors can be approached from two directions: quantifying uncertainties in the way that processes are represented; or inverse analysis (e.g., data assimilation diagnostics). There is a strong need to go towards a unified treatment of uncertainties. Representation of model errors is important in data assimilation systems as well as ensemble forecasts. This is key to the formulation of a successful scheme to generate ensemble initial conditions. Currently, singular vectors are often used as a pragmatic technique to represent fast-growing modes in ensemble initial conditions in the absence of better understanding of analysis errors.

George Craig reviewed the basic of the stochastic parameterisation issues.

- Kinds
  - Physically based (subgrid model), or
  - Pragmatic (e.g., SPPT)
  - Maybe there is a spectrum in between (e.g., representation of uncertainties in key physical parameters)
- Scaling properties
  - Resolution
  - Amplitude
- Relevant processes depend on model resolution
  - Convection (for res 20 km)
  - PBL (for res 2 km)

Noise could be indirectly produced by several components, including interaction with dynamical core (numerical noise, damping, upscale growth) and interaction with other parameterisations (correlated perturbations, double-counting)

During the discussion it was noted that the stochastic perturbations as they are used for weather forecasting increase spread and increased forecast skill can be demonstrated by probabilistic verification. Due to the limited size of verifying climate records, the benefits of stochastic parameterizations on the climate scales are not as easily demonstrated.

7.2 Future Activities

It was agreed that the future activities would include a) the use of coarse-graining studies to help understand model errors and b) sponsoring a future workshop on

stochastic techniques to represent model errors. The general consensus was that the latter would best be done as part of a more general workshop on model errors.

Action 1.7.1: The working group agreed that stochastic physics should be part of the planned WGNE workshop on systematic model errors. OA to liaise with WGNE, as a first step towards organising the relevant workshop session(s). WHO: Oscar Alves DEADLINE: as soon as possible, by October 2015.

Action 1.7.2: A small task team to review possibility of running high-resolution models for coarse graining experiments for stochastic physics studies. Reporting to PDEF co-chairs. WHO: Judith Berner, Mark Rodwell and Craig Bishop (with George Craig). DEADLINE: October 2015.

8. Dynamics and Diabatic Processes

8.1 Interactions of diabatic processes with meso/synoptic scale dynamics

John Methven outlined how diabatic processes influence dynamics and predictability.

1. Influence on Rossby waves
    a. Phenomenon dominating predictability on medium range and longer
    b. Ex. Diabatic PV near the tropopause
2. Moist processes within atmosphere
    a. Extratropical transition of tropical cyclones
3. The grey zone – handover from sub-grid params to resolved flow
    a. Cross-front experiments. Wind bands and sensitivity to high-resolution (from 12 km to 500 m). The highest res experiments do perform worse than 1.5 km.
4. Coupled processes
    a. Air sea interaction and influence of ocean surface waves on fluxes
    b. Influence of topography on phenomena (fog ..)

Challenges for the PDEF WG include

1. Rossby waves and downscale influence on high impact weather
    a. Spread excitement – especially to WCRP grand challenge, SPARC storm tracks
    b. Transpose AMIP style experiments spanning NAWDEX period to be proposed at SPARC meeting
    c. The upscale effect from weather system to Rossby wave trains, this is a direct link to the Grand Challenge on Cloud and Circulation
2. Moist processes within atmosphere
    a. Diagnostics tracing back systematic forecast error to the processes responsible
3. The grey zone
    a. Emergent phenomena as resolution increases
    b. Upscale influence on synoptic scale predictability via integral effects
4. Coupled processes and environmental prediction
    a. Influence of topography-land on phenomena (fog, precip, winds) HIW
    b. Air-sea interaction and influence of surface waves. Sea ice interaction PPP
    c. Coupling with ocean mixed layer and sea surface temperature S2S

8.2 Links with clouds & circulation grand challenge – storm tracks

Action 1.8.1: JM and OM are attending SPARC meeting on storm tracks. JM and OM to discuss possible PDEF collaborations with WCRP, including transpose-AMIP style experiments spanning NAWDEX, and diabatic effects on storm tracks, then reporting to PDEF co-chairs. WHO: John Methven and Olivia Martius DEADLINE: September 2015.

8.3 Proposed workshops on Blocking and Predictability

Olivia Martius presented a proposal to have a Blocking workshop, provisionally in Reading on 6-8 April 2016. The workshop would address the following questions:

- What is blocking and how do the different indices in the literature describe its physical-dynamical aspects? How does blocking compare across different reanalyses?
    - Link to WCRP Grand Challenges, input for CMIP6 post-processing.
- Is there a trend in Blocking frequency.
- How well do NWP and climate models simulate blocking and what is blocking response to forcings?
    - WCRP GC input for idealised model experiments with modified forcings (SST, land surface …)

There is currently sufficient funding to run the workshop, but not enough funding to pay for invited speakers. The possibility of other sources of funding, e.g., IAMAS, will be pursued.

Decision 1.8.2: The PDEF working group supported plans to hold an international workshop on blocking next Spring.

John Methven also a proposal for another workshop on the influence of diabatic processes on weather phenomena. That workshop would be held in conjunction with a conference on high-impact weather and organised by NCAS and RMetS in Manchester on 6-8July 2016.

9. Other Challenges

9.1 Transitioning PDEF research to operations

Masayuki Kyouda gave a presentation about how collaboration between research and operational activities is being strengthened in Japan:

- TIGGE museum.
- Early warning products for extreme weather events.
- Link established between JMA and climate community, with an advisory panel on extreme climate events, 2007.

COMMENTS

CMA organized a common meeting between operational forecasters and scientists for specific convective systems.

9.2 Ensemble Initial Conditions

Craig Bishop gave a presentation covering treatment of non-gaussian variables and ensemble initialization.

A main question: Could we use DA to identify model errors?

A main caveat: Operational ensemble generation techniques cannot deal with near zero positive definite variables such as aerosols and H_2O. New techniques needed.
PDEF actions

- Follow through with WGNE on workshop focusing on stochastic physics with sub foci on:
  - Ensemble initialization for near zero positive definite variables
  - Stochastic parameterizations based on first principles
  - Methods of deriving and refining stochastic physics from coarse graining
  - Using DA diagnostics to identify model error and constrain stochastic physics.
- Be sure to involve young scientists and representatives from HIW PPP S2S…

9.3 Assessment of multi-model ensembles and calibration techniques

Yuejian Zhu addressed multi-model ensemble and calibration techniques.

- There are various MME systems in our daily operational application.
- Skill of multi-model ensemble
  - There is an added value from combining models of similar skill
  - Model performance will be degraded from adding less skilful models
- Applications of multi-model ensemble
  - Provide reliable forecasts and skilful probabilities

Recommendations.

- Estimate analysis uncertainty and model uncertainty quantitatively for multi system ensembles
- Ensemble post processing to enhance forecast reliability and forecast skills
- Ensemble users workshop.

9.4 Coupled modelling & assimilation (OA)

Oscar Alves gave a summary covering coupled modelling and assimilation.

- Earth system modelling adding the human dimension
- Atmosphere/ocean/land/ice/hydrology/waves/biology …
- Global coupld processes (NWP/monthly/season)
- Regional coupled processes (coastal air/sea interaction)
- Initialisation and ensemble generation
- Biases and representing model error (stoch physics in ocean)
- Seamlessness … across time, modelling systems, products
- Predictability and windows of opportunity (ENSO, MJO phases)
- S2S databases and projects

Coupled assimilation

- Weakly coupled – already being done – benefits?
- Strongly coupled ?
- How to involve all components (waves, land ice etc)
- Coupled ensemble perturbations?
- Time scale differences – issue or not ?
- General or timescale specific
- Global and regional

Action 1.9.1: It was agreed that PDEF could play an advisory role in improving ensemble methods in coupled systems, coupling methods, and the multi-model approach. A PDEF representative should participate in future S2S teleconferences, reporting to PDEF co-chairs. WHO: Oscar.Alves DEADLINE: October 2015.

10. Any other business

None

11. Review of meeting outcomes

It was proposed that the next meeting of the PDEF working group (and some other WWRP groups) be held in conjunction with the planned kick-off meeting of the HIWeather project in Exeter in April 2016.

Actions & Decisions from 1st PDEF WG meeting

Permanent actions

Action P.1: TIGGE panel chair to update statistics on TIGGE and TIGGE-LAM data users on an annual basis. WHO. Manuel Fuentes DEADLINE. Before each PDEF meeting

Action P.2: YZ to carry out literature search for papers based on TIGGE data on an annual basis (end of each year), and summarise results. Archive centres to ask users to inform them when TIGGE papers are written, to enable the list of TIGGE publications to be kept up to date. WHO: Yuejian Zhu DEADLINE: Before each PDEF meeting

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Actions from 1st meeting

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Action 1.6.3: Secretariat and TIGGE panel co-chair to discuss how to organize all weather-related ensemble databases at the international level and organise a plan. WHO: Secretariat and Manuel Fuentes DEADLINE. Long term.

Action 1.7.1: The working group agreed that stochastic physics should be part of the planned WGNE workshop on systematic model errors. OA to liaise with WGNE, as a first step towards organising the relevant workshop session(s). WHO: Oscar Alves DEADLINE: as soon as possible, by October 2015.

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