The UK's contribution to the Year of Polar Prediction
A report from the YOPP-UK discussion meeting of 9-10 November 2015

Ed Blockley, Chawn Harlow & Ian Renfrew

Background

The Year of Polar Prediction (YOPP) is an initiative of the World Meteorological Organisation, promoted by the Polar Prediction Project (PPP) - a decade long WMO project with an international steering group and a coordination office located at AWI in Germany. The mission of the YOPP is to *"Enable a significant improvement in environmental prediction capabilities for the Polar Regions and beyond, by coordinating a period of intensive observing, modelling, verification, user-engagement and education activities."* The YOPP itself will take place over the period from mid-2017 to mid-2019. This will be preceded by a 'preparation phase' during 2013-2017 and followed by a 'consolidation phase' over 2019-2022.

YOPP is starting to gain momentum within the international community: over 120 invited scientists, stakeholders and delegates from operational weather and climate centres, funding agencies, etc. attended the YOPP Summit in July 2015. The Summit was held at the WMO in Geneva, with attendees from over 20 countries. Attendees from the UK included Ian Renfrew (PPP scientific steering group & UEA), Jonny Day (PPP scientific steering group & U. Reading), John Methven (U. Reading), Tom Bracegirdle (BAS); and from the Met Office Ed Blockley (Manager, Polar Climate Group) and Chawn Harlow (Manager, Atmospheric Radiation Research Group). Proceedings from the YOPP Summit were streamed live and watched online by approximately 750 viewers.

YOPP-UK – The Workshop

In the run up to and following the YOPP Summit there has been much discussion to try and define how the UK can best contribute towards this exciting initiative. To facilitate discussion and explore possibilities for UK involvement, an open workshop was hosted in Exeter, jointly organised by Ed Blockley, Chawn Harlow and Ian Renfrew. This open workshop was advertised on NERC listservers, etc., and throughout the Met Office. The workshop took place on 9-10 November 2015 and was attended by 40-45 scientists from the Met Office and the NERC community - including representatives from BAS, NCAS, CPOM and NOC as well as the Universities of East Anglia, Edinburgh, Exeter, Leeds, Manchester, and Reading. Invited guest presentations were given by attendees from the European Centre for Medium-range Weather Forecasts and from the International Association of Antarctica Tour Operators.

The aim of the workshop was *"to review the current status of environmental prediction in the polar regions, and beyond, on timescales from hours to seasons and discuss how the UK can contribute to a major international effort to improve prediction."* The workshop had three sessions of invited talks

and discussions, followed by a final general discussion session. These sessions covered: (i) background and drivers for YOPP; (ii) environmental prediction in the polar regions; and (iii) processes and observations. In addition to a wide range of scientific topics, the invited speakers also covered tourism, ship routing and natural resource industries.

Abstracts from the invited speakers are reproduced below, organised by session; following on there is a summary of the general discussion at the end of the workshop as well as a list of recommendations.

SESSION 1 – OVERVIEW AND DRIVERS – CHAIR: JONNY DAY (YOPP SSG, U. READING)

The Year of Polar Prediction: Overview and International context – Ian Renfrew (UEA/YOPP SSG)

The Year of Polar Prediction is an initiative of the World Meteorological Organisation, promoted by the Polar Prediction Project. YOPP will:

- cover an extended period of coordinated intensive observational and modelling activities in order to improve polar prediction capabilities on a wide range of time scales in both polar regions.
- strongly engage in forecast-stakeholder interaction, verification and a strong educational component.
- foster relationships with partners, provide common focussed objectives, and be held over a bit more than a one-year period in association with a field campaign providing additional observations.
- coincide with, support, and draw on other related planned activities for polar regions.
- be implemented in three different stages: a preparation phase (2013-2017), YOPP itself (mid-2017 - mid-2019), and a consolidation phase (2019-2022).
- more information can be found on the YOPP website (http://www.polarprediction.net/).

Tourism in Polar Regions – Tudor Morgan (International Association of Antarctica Tour Operators)

Tudor gave an overview of tourism in the polar regions, demonstrating where the growth and diversity of activities are occurring and gave an outline on the role and responsibilities of the two trade associations which monitor and manage tourism in these multi-national regions. Focusing on the Antarctic in particular, Tudor outlined both the challenges and opportunities facing the industry. He highlighted the growing need for in the field near real time ice information as well as accurate weather and ice forecasting, and noted that with the advent of the IMO's Code for ships operating in polar waters there would be a need for historic data on ice coverage, type and density, and also mean lowest daily air temperature.

Sea ice forecasting for optimised Arctic ship routing – Bjoern H. Fock (CEN, U. Hamburg now Met Office)

The Arctic shipping industry needs environmental predictions. During the years 2011-2014 a German consortium of universities, research institutes, SMEs and a governmental agency worked on a project to develop a system for ship routing using sea ice forecasts. The project, funded by the German Federal Ministry for Economic Affairs and Energy, developed an integrated system which includes remote sensing, combined sea ice-ocean data assimilation, a regional coupled model, a ship speed model, a route optimization package and onboard visualisation. The system was tested during a forecast and field experiment in the Barents Sea in March 2014.

An industry perspective: the importance of met ocean, ice, iceberg monitoring and forecasting to support Arctic oil & gas exploration operations – Nicolas Fournier (Met Office)

The presentation provides an overview of the current Arctic operations in the oil & gas industry. This focuses especially on the Shell Greenland 2011-14 exploration operations to illustrate the main climatic challenges and the associated risk mitigation needs. These challenges include the sea ice season strong inter-annual variability, the high density of icebergs, low visibility and darkness as well as icing on structures. To achieve safely the campaigns' objectives, a comprehensive ice management strategy was developed with robust ice management systems and decision protocols. These monitoring and forecasting systems provided reliable weather, sea ice and iceberg information to the field operations and planning managers.

YOPP in the Southern Hemisphere – Tom Bracegirdle (British Antarctic Survey)

YOPP activities in the Southern Hemisphere (SH) are being coordinated by a steering committee – YOPP-SH (see http://polarmet.osu.edu/YOPP-SH/). This steering committee includes representatives of the Southern Ocean Observing System (SOOS) and the CLIVAR-CliC-SCAR Southern Ocean Region Panel (SORP). In terms of scientific activity a range of process-based field campaigns are planned and/or funded and are being encouraged to seek YOPP endorsement. A special observing period (SOP) is currently planned for Austral spring 2018 to Austral spring 2019, which will include embedded intensive observing periods. A number of countries have already committed additional observational effort during this SOP, such as increased radiosonde releases.

SESSION 2 – ENVIRONMENTAL PREDICTION – CHAIR: CHAWN HARLOW (MET OFFICE)

Global prediction and the polar regions – Sean Milton (Met Office)

Drivers for Arctic prediction at a variety of timescales from short-range weather forecasts to climate projections were reviewed. Met Office global modelling research on the Arctic has typically been driven by questions around climate change and sea ice projections, although process based research aimed at improving the atmosphere model has also focused on shorter NWP timescales, evaluating the MetUM forecasts with field campaign measurements from ARM sites in Alaska, AOE, ASCOS and ACCACIA campaigns in collaboration with various NERC-funded scientists. The YOPP field campaign(s) combined with the seamless prediction capability for initialised coupled atmosphere(MetUM)-ocean(NEMO)-sea ice(CICE)-land(JULES) (AOIL system) provides a unique opportunity for (i) improving the physical basis of the coupled AOIL model, (ii) improving predictability for Arctic regions at all timescales and (iii) improving predictability for regions influenced by Arctic teleconnections (e.g. Europe). Four key science areas for coupled model improvements were highlighted:

- Arctic Focus #1: Sea ice prediction.
- Arctic Focus #2: Boundary-layer processes, clouds and radiation.
- Arctic Focus #3: Coupled modelling across timescales - process based evaluation.
- Arctic Focus #4: Snow processes.

Medium-range prediction and the polar regions – Sarah Keeley (ECMWF)

The current status of polar prediction in the medium range is about 7 days in terms of large scale flow. Predicting surface parameters and their uncertainty remains a challenge. Limited observations make it difficult to diagnose model error sources and challenges remain with representation of the boundary layer, clouds and snow, and ice covered surfaces. Observation errors can be large due to assumptions made about the state of the system.

This leaves many future challenges and opportunities for the research community. Weather and climate models provide tools for diagnosis and process understanding. We need to confront our models with observations and there is a clear role for observational campaigns in YOPP to contribute significantly towards this. New tools are available to the research community to help with experimentation and process understanding for example the ocean-ice reanalysis ORAP5,

which has been shown to compare well to the relatively limited independent satellite data that we do have for polar regions, and higher resolution medium range coupled forecast systems will be running operationally during YOPP.

Seasonal prediction and the polar regions – Doug Smith (Met Office)

Many recent papers have suggested that reductions in Arctic sea ice could impact the lower latitude atmospheric circulation affecting winter climate in Europe and eastern USA. However, there is no consensus over the sign of the relationship, with some studies finding that reduced sea ice drives a negative North Atlantic Oscillation (NAO) and others finding the opposite. Here we show that the sign of the NAO response in the Met Office coupled model (HadGEM3) depends on the model background state (or bias). Specifically, a negative (positive) NAO response is simulated when the Atlantic eddy driven jet is too far north (south) and too weak (strong) compared to reality. This relationship would suggest very little response when the jet is close to reality. However, further work is needed to understand the physical processes that give rise to this relationship between background state and response, and hence to assess the fidelity of the model simulations.

Predictability and the polar regions – Ed Hawkins (U. Reading)

The APPOSITE project studied the potential to make seasonal to interannual predictions of Arctic sea ice. There is significant variability in the Arctic, but we concluded that there was some predictability for a year or more ahead, especially for sea ice volume and for winter. There also appears to be a predictability 'barrier' for forecasts of the September minimum started before June. Observations and assimilation of sea ice thickness are crucial for improving operational predictions.

Boundary-layer processes and MOSAiC – Ian Brooks (U. Leeds)

Polar boundary layers present a number of challenges for modelling. Strong surface cooling can produce shallow, stable boundary layers where turbulent exchange becomes intermittent and its behaviour is poorly understood. Conversely, strong surface temperature gradients between ice or land surfaces and the open ocean can result in strong convective forcing and rapidly evolving BL and cloud structures down stream. On smaller scales, surface heterogeneity such as marginal ice cover, complicates the parameterization of surface fluxes. Boundary-layer dynamics are closely coupled to cloud processes, with radiatively driven turbulence in cloud being an important, perhaps dominant, source of mixing during the Arctic summer when surface forcing is weak. Cloud radiative processes are in turn controlled by the cloud microphysical properties and hence by the availability of cloud condensation nuclei and ice nucleating particles. Polar clouds are often mixed phase and poorly represented in models, impacting the representation of both the surface radiation budget and cloud-driven turbulent mixing.

SESSION 3 – PROCESSES AND OBSERVATIONS – CHAIR: ED BLOCKLEY (MET OFFICE)

Large Eddy Simulations in the polar regions – Bob Beare (U. Exeter)

The boundary layer plays an important role in polar weather prediction. Examples include: surface temperatures, fog and the spin-down of polar lows. Large-eddy simulation (LES), in combination with observations, provides a way of guiding the parametrization of the boundary layer in weather prediction models (e.g. Beare et al 2006). With increased computer power, and higher quality observations, there is an opportunity for new LES, which improve the parametrization of polar boundary layers. For YOPP, we propose novel LES of polar boundary layers.

1. LES interrogated by new observations.

2. LES coupled to an ice surface.
3. LES using larger horizontal domains, permitting sub-mesoscale motions.

The work will involve close linkages with the other research groups within YOPP, including: observers (point 1), ice and land-surface modellers (e.g. JULES, point 2), and process modellers (point 3). The work will also complement the current WMO-endorsed GABLS intercomparison over Antarctica (GABLS-4).

Beare, R. J., et al. (2006), 'An intercomparison of large-eddy simulations of the stable boundary layer', Bound. Layer Meteorol., 118, 247-272.

Clouds in the polar regions – Tom Choularton (U. Manchester)

Key issues surrounding boundary layer cloud in Polar regions include:

1. The Liquid /ice water path of the cloud
2. The extent of cloud cover
3. The break-up of the cloud
4. Transition from layer cloud to cellular convection

Airborne studies in the Arctic region as part of ACCACIA and flights in cold air outbreaks over the Atlantic have provided results concerning the processes controlling these key issues involving: the formation of super-cooled drizzle causing rain out of the cloud; the generation of snow; entrainment of dry air.

Orographic processes in the polar regions – Andy Elvidge and Simon Vosper (Met Office)

The polar regions not only provide an excellent test bed for the study of orographic processes, they also lend themselves to unique and important orographically-forced phenomena and impacts, presenting challenges to understanding and model representation. The successful 'OFCAP' and 'SGWEX' projects provide recent examples of where polar mountains have been the focus in the study of orographic processes, both studies employing a powerful combination of observations and multi-resolution modelling. YOPP provides an excellent opportunity here, with the potential to provide new and much-needed targeted observations, and coinciding as it does with newfound appetite in the community to improve the model representation of orographic processes.

Snow modelling – Richard Essery (U. Edinburgh)

The high albedo and low thermal conductivity of snow influence underlying ground and sea ice thermodynamics, leading to persistent forcing of the atmosphere. Models of how microstructure and aerosol deposition determine snow properties are beginning to be adapted for NWP, and new methods for field measurement of snow properties will inform necessary model developments. Improved understanding of microwave scattering by snow will enable exploitation of existing sensors not currently assimilated in NWP for surface mapping and near-surface atmospheric sounding. YOPP provides a unique opportunity for coordinated surface, airborne, satellite and modelling studies to determine potential contributions of snow cover to predictability.

Remote sensing with FAAM to evaluate model performance – Chawn Harlow (Met Office)

Although there is a large quantity of pertinent satellite data available, surface temperature and emissivity remain poorly monitored in the Unified Model particularly in the polar regions. Current microwave and infrared channels sensitive to the temperature of the surface and lower troposphere over land and sea ice are given extremely low weight (or blacklisted) within the data assimilation system. This means that vital information about the current state of tropospheric air temperature and humidity as well as land and ice surface thermodynamic state is being thrown away in regions which are otherwise poorly constrained by conventional observations. YOPP provides an opportunity to improve on the current situation with regards to assimilation of

surface sensing channels over cold land and ice: JULES has a new multi-layer snow scheme, the YOPP international community hope to produce coupled atmosphere-ice-ocean models, and microwave signals have been shown to be sensitive to both the properties of the atmosphere and the properties of the underlying snowpack. YOPP observation and modelling efforts could close the loop on a coupled atmosphere-snow assimilation system. Such a system would reap forecasting benefits to those studying weather, climate and hydrology in Arctic regions and improve the seasonal forecast in mid-latitudes.

Sea ice modelling – Danny Feltham (CPOM, U. Reading)

Sea ice models are formulated as continuum expressions of local balances of momentum, mass, and heat, mediated through various processes. Many of these processes are represented in models using parameterisations but these are often tied to particular length and time scales and are not grid-scale invariant. Globally the trend in sea ice modelling is towards the use of higher resolution models particularly for weather forecasting applications where high resolution is important. Existing sea ice models, however, have been built for climate-type modelling. Use of these models at higher resolutions can be physically invalid and inaccurate. Moreover, changes in the Arctic, including the reducing Arctic sea ice cover, are bringing new physical processes into prominence, e.g. melt ponds are becoming more important. Adequate representation of such processes requires more work.

Ocean modelling – Maria Luneva (National Oceanography Centre)

Using a novel pan-Arctic sea ice-ocean coupled model we examine the effects of tides on sea ice and the mixing of water masses. Two 30-year simulations were performed: one with explicitly resolved tides and the other without any tidal dynamics. We find that the tides are responsible for a ~15% reduction in the volume of sea ice during the last decade and redistribution of salinity, with surface salinity in the case with tides being on average ~1.0-1.8 higher (on the practical salinity scale) than without tides. The three following mechanisms of tidal interaction appear to be significant: (a) increase of heat exchange with atmosphere due to opening and closing of leads due to tides, resulting in stronger short-wave solar radiation in summer time and stronger heat loss in winter, (b) thicker subsurface ice-ocean and bottom boundary layers; and (c) intensification of quasi-steady vertical motions of isopycnals (by ~50%), induced by tides. The combination of these effects leads to entrainment of warm Atlantic Waters into the colder and fresher surface waters, supporting the melting of the overlying ice.

Luneva M.V., Y.K. Aksenov, J.D. Harle, J.T. Holt, 2015: The effects of tides on the water mass mixing and sea ice in the Arctic Ocean, J. Geophys. Res, doi: 10.1002/2014JC010310

SESSION 4 – DISCUSSIONS – CHAIR: IAN RENFREW (YOPP SSG, UEA)

The meeting finished with a general discussion covering a number of issues:

- What the priorities are for environmental prediction as far as UK scientists are concerned.
- Where the UK could best contribute to an international programme.
- What assets and expertise the UK has that could contribute to international programmes: for example, we have a extremely well-equipped and versatile research aircraft with the capability to go into the far North; we have well established scientific research and operational infrastructure in place in both the Arctic and Antarctic through the British Antarctic Survey; we have one of the leading global numerical weather and climate prediction models; we have world-leading scientists with expertise in climate processes and systems in the polar regions.
- Routes to funding a UK programme of research could include:

    - a NERC Large Grant – with submission during 2016
    - a NERC/Met Office Joint Strategic Response
- The pros and cons of each of these options were discussed and at present both of these options are being actively pursued.

Participants List

Abel, Steve (Met Office)
Beare, Robert (U. Exeter)
Blockley, Ed (Met Office)
Bower, Keith (U. Manchester)
Bracegirdle, Tom (British Antarctic Survey)
Brooke, Jenn (Met Office)
Brooks, Ian (U. Leeds)
Brown, Andy (Met Office)
Choularton, Tom (U. Manchester)
Cotton, Richard (Met Office)
Day, Jonny (U. Reading)
Edwards, John M. (Met Office)
Essery, Richard (U. Edinburgh)
Elvidge, Andy (UEA - now Met Office)
Feltham, Danny (CPOM, U. Reading)
Field, Paul (Met Office)
Fock, Bjoern H. (U. Hamburg - now Met Office)
Fournier, Nicolas (Met Office)
Gornall, Jemma (JWCRP/Met Office)
Harlow, Chawn (Met Office)
Hawkins, Ed (U. Reading)
Haywood, Jim (Met Office/U. Exeter)
Johnson, Helen (Met Office)
Keeley, Sarah (ECMWF)
Langridge, Justin (Met Office)
Lee, Clare (Met Office)
Lloyd, Gary (U. Manchester)
Luneva, Maria (National Oceanography Centre)
Melia, Nathanael (U. Reading)
Milton, Sean (Met Office)
Morgan, Tudor (International Association of Antarctica Tour Operators)
Mylne, Ken (Met Office)
Petch, Jon (Met Office)
Renfrew, Ian (UEA)
Smith, Doug (Met Office)
Vosper, Simon (Met Office)
Weiss, Alexandra (British Antarctic Survey)