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International Workshop on Ploar Lows in Oslo, May 2012

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1. Introduction

The International Polar Year (IPY) has brought new momentum to polar low research and a huge amount of new data on, and insight to, mesoscale processes in polar regions. The Oslo polar low workshop was the 12th workshop of the European Polar Low Working Group (EPLWG[1], http://www.uni-trier.de/index.php?id=20308). The EPLWG focuses its work on polar mesocyclones (MCs) in both hemispheres, but research includes other mesoscale weather phenomena such as katabatic winds, tip jets, boundary layer fronts, cold air outbreaks, and Arctic fronts. This workshop[2] was convened by EPLWG to summarize recent experimental, climatological, modeling, and remote sensing studies on polar lows and polar mesoscale processes.

The workshop started with an overview lecture on the influence of low-frequency variability on the life cycles of high-impact weather. It was highlighted that the large scale circulation in polar areas is connected to mid-latitudes and the tropics via Rossby waves. Subsequent presentations addressed observational studies, the climatology of polar lows, modeling and theoretical aspects, and related and future projects (see http://www.uni-trier.de/index.php?id=20290 for the full workshop program).

1The EPLWG workshops started 1989 in Cambridge, UK. An extended summary of the 1996 meeting was published by Heinemann and Claud (1997).

2The meeting took place at The Norwegian Meteorological Institute (met.no) and it was co-sponsored by the Support To Science Element (STSE) of ESA and the Norwegian Space Centre.

2. Observational studies of Polar Lows

Since polar mesocyclones occur in data-sparse regions, aircraft observations represent the only tool for obtaining detailed in-situ observations. However, the significant costs of a research aircraft campaign, the difficult logistics in harsh polar environments, and difficulties of locating a polar MC are major limitations for aircraft studies. During the IPY years 2007-09, two aircraft studies of polar lows were realized: one over the Iceland Sea and the other over the Norwegian Sea. The Iceland Sea study was performed using the British FAAM research aircraft and was able to capture a polar low on 25 February 2007. A distinct potential vorticity (PV) and an ozone anomaly were associated with the PL. Surface sensible heat flux was about 200 W/m^2. A verification of ERA-Interim analyses using the aircraft data showed good agreement. The second aircraft study took place during the IPY-THORPEX experiment as a contribution of the Norwegian IPY project. The German Falcon research aircraft was used for the investigation of MCs during February and March 2008. A PL development from 3-5 March 2008 could be studied in detail by three flight missions. The PL had a warm core and was associated with surface sensible heat fluxes of about 250 W/m^2. A suite of model simulations have been performed for this PL using the UK Met Office non-hydrostatic Unified Model with resolutions of 12 down to 1km. The model showed the best performance at the convection-resolving resolution when compared to the aircraft data.
Since the beginning of polar low research, satellite data has been the most important source of information for these phenomena. Multisensor studies of mesoscale cyclones over the Asian Marginal Seas and the Arctic using visible, infrared, passive microwave, and scatterometer data allow for the investigation of the climatology and the structure and life cycle of polar MCs. A climatological study using wind from scatterometer and cloud structure detection from MODIS data was presented for the Japan, Okhotsk and Bering Seas. For MCs in size from 100 km to 1000 km with wind speed exceeding 12 m/s, the average number of MCs was found as 56 for the Japan Sea, 64 for the Okhotsk Sea and 76 for the western Bering Sea and the Pacific Ocean from the Aleutian Islands to 47°N.
The use of Synthetic Aperture Radar (SAR) imaging of polar lows and deriving high-resolution wind fields was demonstrated for case studies in the Japan and Norwegian Seas. Integrated water vapour from passive microwave data (SSM/I and AMSR-E) was found to be useful for tracking PLs.

3. Model-based climatology of Polar MCs

While most climatological studies of polar MCs in the past were based on satellite data, new datasets of higher resolution reanalysis data (e.g., ERA-Interim), global operational models and regional climate models now offer new possibilities for analyzing the climatology of polar MCs and associated synoptic circulation patterns. ERA-Interim reanalyses have been used for the climatological investigation of North Atlantic winter weather regimes associated with polar lows over the Nordic and Labrador Seas for the period 2000-2011. Genesis zones of PLs are identified as significant anomalies in patterns of the geopotential at 500hPa, the temperature difference between the sea surface and the 500hPa level, the near surface wind, and the potential vorticity (PV) at 300hPa. A study of the dependence of PL frequency on the large scale circulation using NCEP reanalyses for 1957-2011 showed that a negative NAO phase favours PL developments over the Norwegian Sea. However, the most PLs (ca. 40%) occur during a blocking high over Greenland, being most favourable for cold air outbreaks over the Norwegian Sea.

Global data of the GME model of the German Meteorological Service (25-40km resolution) and ERA-Interim data are used for cyclone and mesocyclone tracking in the Antarctic region and southern polar ocean. Tracking of mesoscale cyclones is performed by applying a band pass filter for spatial scales of 200 to 700 km, a 850hPa vorticity anomaly threshold of 2.0 x 10^{-5} s^{-1}, and a surface wind speed threshold of 15 m/s. Compared to larger scale cyclone tracking, additional filtering has to be applied in order to exclude stationary confluence zones forced through orographic structures, and frontal zones from synoptic scale cyclones, which are often falsely indentified as mesoscale cyclones.

Ensemble prediction system output from the non-hydrostatic UK Met Office Unified Model (UM-EPS) is applied for the tracking of polar lows. For a case of multiple polar lows on 22 February 2011 over the Norwegian Sea, UM-EPS was applied at 4-km resolution with 21 ensemble members. In order to summarize the vast amount of information in the EPS, PL tracks are computed to estimate polar low strike probabilities. This uncertainty information will be further evaluated as a tool for weather forecasters and useful products for the general public.

The change in synoptic conditions and cyclone statistics during global climate change is studied using the Geophysical Fluid Dynamics Laboratory (GFDL) climate model simulations for IPCC scenarios with 50km resolution. Runs have been performed for 10 years slices of the present climate, 2026-2035 and 2086-2095. Cyclone strength, position and tracks are investigated.

Long-term simulations of the regional climate model CCLM show past and projected future changes of North Atlantic polar low frequency. Polar low activity is investigated for the period 1948 through 2006 by dynamical downscaling of global NCEP/NCAR reanalysis data. On average a number of 56 polar low cases is found per polar low season. Comparison with limited observational evidence of polar lows reveals similar statistical properties such as same peak years and annual cycles. The downscaling using different global climate models for the present climate and for IPCC scenarios (B1, A1B and A2) shows a dramatic decrease of 50% in PL cases towards the end of the 21st century. The decrease in PL frequency is associated with a mean increase in vertically stable atmospheric conditions, and PL genesis regions are projected to move northwards.

4. Modeling and theory

Case studies of polar MCs using high-resolution NWP models are important for the understanding of formation processes and the dynamics of the MCs. The quality of PL simulations in operational forecasts has generally improved in recent years, but in some cases poor predictions of PL still occur. Such a case was encountered during IPY-THORPEX Andøya field campaign 2008, where a polar low developed over the Norwegian Sea during the night from March 15-16. Hindcast runs using the WRF model driven by ECMWF analyses with resolutions from 30km down to 3km were applied to study the sensitivity with respect to the initial times. Higher resolution did not improve the forecast, but a systematically considerable better performance was found when aircraft data of dropsondes launched in the morning hours of March 15 were included in the initial fields.
A numerical study on a polar MC over the Japan Sea with a horizontal scale of about 150km and a cloud-free eye was presented using the nonhydrostatic mesoscale model of the Japan Meteorological Agency (JMA-NHM) with a horizontal resolution of 2km. In this area, most MCs develop in the vicinity of Japan Sea Polar Air mass Convergence Zone (JPCZ). The JPCZ is associated with a strong low-level convergence and strong cyclonic shear. Barotropic shear instability is found to be a dominant mechanism of MC development in the initial stage, while thermal instability such as CISK and WISHE seem to be important in the mature stage.
Despite numerous studies of polar MCs and other mesoscale weather extremes, their impact on ocean processes is relatively unknown. A study was presented which uses a high-resolution ocean circulation model (MITgcm, 18km) driven by ERA-data. Based on the comparison of ERA winds with scatterometer data, a parameterization scheme was developed that corrects ERA winds at the short-wave part of the spectrum, thus including polar mesoscale storms and other mesoscale processes. This more realistic atmospheric forcing leads to an enhancement of open-ocean deep convection in the Nordic Seas. It is concluded that polar lows play an important role in driving the large-scale ocean circulation. Taking into account the expected decrease in the number of polar lows over the Northeast Atlantic in the 21st Century, this implies a reduction in deep convection and a potential weakening of the Atlantic Meridional Overturning Circulation.
Theoretical studies were presented on different forcing mechanisms for polar low development. For the Norwegian Sea, there seems to be a preference for developments when the background environments show reversed shear conditions, i.e. low-level wind and thermal wind have opposite directions. Idealized numerical experiments using the WRF model were presented demonstrating the development of a solitary low-level vortex. The disturbance growth rate depends both on the environmental baroclinicity and available moisture.

5. Summary, Conclusions, and Recommendations

This workshop summarized the current state of polar low research in the Arctic and Antarctic. A couple of related projects are in the planning phase or already funded. The creation of a polar low database for the Norwegian Sea in the frame of the Sea Surface Temperature and AltimeteR Synergy (STARS) project (http://projects.met.no/stars) will provide a valuable resource for future research and, potentially, predictability improvements. The maintenance of this database and the creation of similar databases for other polar areas including satellite and NWP data are highly recommended. There is also a need for free and timely access to satellite data, in particular to SAR data to fill the gap caused by the mission end of ENVISAT. With the increasing resolution of climate models, mesoscale processes such as polar mesocyclones will have to be considered in international research programs such as the World Climate Research Programme (WCRP) Polar Climate Predictability Initiative and the World Weather Research Programme (WWRP) Polar Predictability Project.

6. Figures

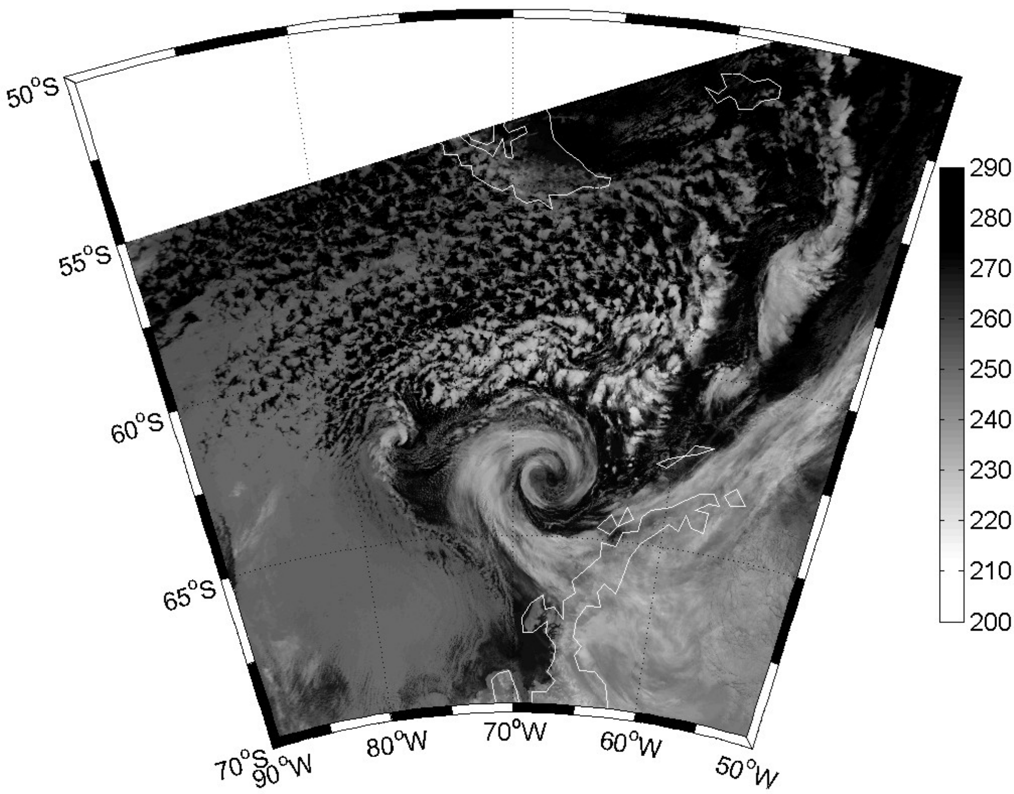

Fig.1: Advanced Very-High Resolution Radiometer (AVHRR) infrared image (brightness temperatures in K) for 0159 UTC 28 April 2009 showing a polar mesocyclone near the Antarctic Peninsula.

7. Workshop abstracts

The influence of low-frequency variability on the life cycles of high-impact weather: simulations, predictions and observations

M. A. Shapiro
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Hoskins and collaborators demonstrated in idealized experiments that the life cycle of cyclone scale eddies can be classified by their background flow environment, leading to a distinction between cyclonic and anticyclonic wave breaking at the tropopause. Subsequent studies revealed that this
characterization is valid in both idealized and studies and observations and also modulates frontal structures and precipitation distributions, as first described by Shapiro et al, 199r9x.

It has been widely noted that the anomalously extreme weather events of the recent winter seasons coincided with large-amplitude sub-seasonal to seasonal anomalies, particularly in the arctic modes of variability (i.e., Northern Annular Mode and North Atlantic Oscillation). We hypothesize that
these amplitude variations in the Arctic modes were sufficient to alter the breaking behavior of the eddies and their internal mesoscale weather characteristics. The present study uses the current version of the NCAR CCSM in an hierarchy of studies ranging from idealized dynamical experiments
to full-physics, global mesoscale resolution forecasts, to test this hypothesis and illustrate the relevance of the subseasonal anomalies on the events of he past winters and beyond.

Shapiro, M. A., Wernli, H., Bao, J.-W., Methven, J., Zou, X., Doyle, J., Holt, T., Donall-Grell, E. and Neiman, P. (1999). A planetary-scale to mesoscale perspective of the life cycles of extratropical cyclones: The bridge between theory and observations. In `The life cycles of extratropical cyclones', Eds. Shapiro, M. A. and Gronas, S., Am. Met. Soc., 139-185.

Missing' polar lows enhance open-ocean deep convection in the Nordic Seas

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Every year, thousands of storms pass over the subpolar North Atlantic that are too small to be resolved in global meteorological analyses/reanalyses or state-of-the-art climate models. Yet, these storms are frequently associated with the strong atmospheric forcing (high wind speeds and large air-sea temperature differences) that are a prerequisite for triggering deep, open-ocean, convection, a process that is fundamental for large-scale ocean circulation and

climate. Here we use a realistic parameterization scheme to include polar mesoscale storms – polar lows – in the forcing of a high-resolution ocean circulation model. Power spectra of the perturbed surface wind field show a remarkable improvement, and an agreement with observations that implies the correct surface fluxes are now being applied to the ocean in the atmospheric mesoscale (50-500 km). Our more realistic wind field increases the frequency and area of deep convection in the Greenland and Irminger Seas, and results in surprisingly large increases in the volume of deep water overflowing Denmark Strait (by up to 0.5 Sv). Recent studies predict a decrease in the number of polar lows over the Northeast Atlantic in the near-future which, based on our work, implies a reduction in deep convection and potentially a weakening of the Atlantic Meridional Overturning Circulation (AMOC).

On forward and reversed shear baroclinic flow for polar low developments

Thor Erik Nordeng
Norwegian Meteorological Institute, Research Department

Polar lows are known to develop under a variety of environmental conditions, but there seems to be a preference for developments when the background environments show reversed shear conditions.
In a reversed shear flow wind and thermal wind have opposite directions, i.e. facing the low level wind, cold air is on the left hand side. In addition, cold and warm fronts associated with the developing baroclinic low apparently change position from the regular pattern. The warm front is "trailing" the low in the case of reversed shear.
The differences between reversed shear and forward shear for polar low developments will be discussed. Examples from real cases will be given.

Angular momentum as the sole forcing of polar lows

Torsten Linders
University of Gothenburg

The forcing of polar lows is a question of considerable debate. One plausible mechanism is the input of ambient angular momentum. Linders et al. (2011) tested this using numerical simulations. They found that the input of angular momentum was as important as the sea-surface heat fluxes. Here I revisit those simulations with a look on how the transfer of angular momentum to kinetic energy is estimated. According to the WISHE theory the transfer should be evaluated at a large radius from the cyclone centre. This gives the ambient atmosphere loss of kinetic energy. However, we are interested in the gain by the polar low. Therefore we should make the evaluation where the transfer takes place, i.e. in the polar low boundary layer. The difference is substantial. The energetic input from angular momentum doubles so that this forcing can account for the entire intensity of the polar low. Further more, at every radius from the cyclone centre there is an almost perfect match between the pressure gradient, the increase of kinetic energy and the decrease of angular momentum. The residual is very small but always positive and hence indicates a missing force term. I assume this is the input from the sea-surface heat fluxes. The importance of these fluxes is most likely still crucial since they sustain the convection and thereby also the convergence and the input of angular momentum.

Intense Mesoscale Cyclones over the Asian Marginal Seas: Multisensor Study

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Screening of Terra and Aqua MODIS and NOAA AVHRR visible and infrared images acquired during cold seasons of 2003-1011 (October – April) allowed to create data base of mesoscale cyclones (MCs) over the Japan, Okhotsk and western Bering seas. The main areas of their formation were revealed and number of MCs was estimated for each sea. Fields of the total cloud liquid water content *Q*, total atmospheric water vapor content *V* and sea surface wind speed *W* were retrieved from the Aqua AMSR-E brightness temperatures at 23.8 and 36.5 GHz with vertical polarization and at 10.7 GHz with horizontal polarization with the use of developed algorithms. The satellite data included also *W* fields derived from QuikSCAT and ASCAT scatterometers and WindSat radiometer data. Fine structure of wind fields as well as of the marginal ice zone manifested itself on the Envisat ASAR images acquired for several MCs in wide swath mode. Signatures of vertical structure of cloudiness and precipitation of several MCs were revealed by analysis of CloudSat radar reflectivity profiles. Number of mesocyclones N changed from year to year. For MCs in size from 100 km to 1000 km with $W \geq 12$ m/s, N was equal, on the average, 56 for the Japan Sea, 64 for the Okhotsk Sea and 76 for the western Bering Sea and the Pacific Ocean from the Aleutian Islands to 47°N. Mesoscale cyclogenesis over the Asian Marginal Seas has the peculiar features. Types of MCs and the areas of their localization depend strongly on the sea surface temperature regime and coast orography. Various synoptic situations and physical mechanisms were responsible for MCs formation that follows from analysis of weather maps and cloud fields. Downslope winds play an important part in this process. Life cycle of the most intense MCs (polar lows) was studied using all available remote and *in situ* data. Ground-based data consisted of the surface analysis maps provided by the Japan Meteorological Agency (JMA) and the Korean Meteorological Administration (KMA), the radiosondes and oceanic buys reports. The satellite passive and active microwave data were provided by the European Space Agency and the Japanese Aerospace Exploration Agency; ancillary remote and in situ data were downloaded from Internet.

Aircraft Observations of a Polar Low over the Iceland Sea

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University of East Anglia

G. N. Petersen
Icelandic Meteorological Office

In this talk, we report on instrumented aircraft observations of a polar low over the Iceland Sea near Jan Mayen in February 2007. We show that this system was associated with high levels of upper-tropospheric ozone and potential vorticity that were the result of a tropopause fold that contributed to the system's development. At low-levels, the interaction of the

northerly flow behind the low with the high topography of Greenland resulted in the presence of a barrier jet in the vicinity of Scoresby Sund. Data from the Summit Observatory in the center of the Greenland Ice Sheet recorded the passage of the fold prior to the development of the low. The fold resulted in surface ozone concentrations that exceeded the 95 percentile of all observations at the site during the month of February. This observation suggests that it may be possible to use the Summit data to augment our understanding of the role of stratosphere-troposphere interaction in high latitude cyclogenesis over the Nordic Seas.

Diabatic Rossby Vortex as a new paradigm for polar low development.

Annick Terpstra, Geophysical Institute, University of Bergen
Richard W. Moore, Department of Meteorology, Naval Postgraduate School
Thomas Spengler, Geophysical Institute, University of Bergen

Theories concerning the dynamical processes for polar low development cover a spectrum between baroclinicity and convection. Furthermore, it is unclear whether the upper level features often apparent during polar lows serve as a forcing mechanism for polar low development or are a feature of the existing polar low. To gain further insight into the dynamics of polar lows we hypothesize that polar low formation and intensification is captured by the Diabatic Rossby Vortex (DRV) paradigm. A DRV consists of a solitary low-level vortex, which propagates and intensifies independent of the far field. The disturbance growth rate depends both on the environmental baroclinicity and available moisture, where the former provides rising motion and the latter the release of latent heat. Propagation and intensification of the DRV is by phase locking and mutual amplification of the diabatically generated PV anomalies. The DRV is presented as a paradigm that unifies the current set of theories on polar low development and accounts for the low-level spin up often observed prior to the period of rapid intensification.

Numerical Study on a Polar Mesocyclone Development
in a Shear Zone over the Japan Sea

Shunichi Watanabe, Hiroshi Niino and Wataru Yanase
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A polar mesocyclone that developed over the western part of the Japan Sea on 30 December 2010 is studied by a numerical simulation using a nonhydrostatic mesoscale model [Japan Meteorological Agency Nonhydrostatic Model (JMA-NHM)] with a horizontal resolution of 2km.

Satellite images show that several vortices were initially formed in an east-west oriented row and moved southward. These vortices resulted in the polar mesocyclone which had a horizontal scale of ~150km and an “eye-like” cloud-free area.

The simulation succeeds in reproducing well the movement and development of the polar mesocyclone. When a cold air breaks out from the Eurasian Continent, an east-west oriented shear zone is formed between cold air flows from the north and from the south over the northwestern part of the Japan Sea, and moves southward. About ten vortices having a horizontal size of about 25km appear along the shear zone. The shape and spatial scale of the vortices are consistent with the linear theory of barotropic instability of the shear zone. The vortices merge into a polar mesocyclone which has a horizontal scale and an “eye-like” cloud-free area similar to the observation. An energy budget analysis will be made to elucidate the development mechanism of the polar mesocyclone.

Cyclone and mesocyclone tracking in the Antarctic region and southern polar ocean

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An approach of tracking mesocyclone activity in the Antarctic region and southern polar ocean has been undertaken by using ERA-Interim reanalysis data. The automatic tracking algorithm TRACK is applied to the 850 hPa vorticity field for several years. Sensivity studies with different filter options are carried out in order to compare the results of mesocyclone activity with former subjective studies which used satellite imagery. Case studies of mesocyclones combined with high-resolution simulations of a numerical weather prediction model demonstrate the performance of our methodology. The relation between cyclone/mesocyclone activity, sea ice concentration and polynya dynamics is investigated.

USING SATELLITE PASSIVE MICROWAVE DATA TO STUDY ARCTIC POLAR LOWS

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An approach for detection and tracking polar lows is developed based on satellite passive microwave data from three sensors: Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager and Sounder (SSMIS) onboard Defense Meteorological Satellite Program (DMSP) satellites and Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) onboard Aqua satellite. This approach consists of two stages. During the first stage total atmospheric water vapor fields are retrieved from SSM/I and AMSR-E measurement data using precise Arctic polar algorithms, applicable over open water, and having high retrieval accuracies under a wide range of environmental conditions. During the second stage the vortex structures are detected by visual analysis in these fields, and polar lows are identified and tracked. Few polar low cases were selected for studies using Envisat ASAR-derived wind field vortex structure analysis. These cases were comprehensively studied using multi-sensor approach. SSM/I, SSMIS and AMSR-E measurements and other satellite data, including visible, infrared and synthetic aperture radar images, scatterometer wind fields, surface analysis maps and re-analysis data, were used for polar low study.

Polar lows over the Nordic and Labrador Seas: Synoptic circulation patterns and associations with North Atlantic Winter Weather Regimes.

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Due to their relatively small scale, polar lows are generally not well represented in reanalyses. Nevertheless, reanalyses are a valuable tool to study their typical synoptic environment. In a first part, using previously-published polar lows observational datasets over the North Atlantic region and ERA-Interim reanalysis, we will present the typical conditions during which polar lows form. It will be shown that these conditions exist over an approximate 8 days-window centered on the outbreak day. Then, an evaluation of the associations between North Atlantic weather regimes and polar low de- velopments over the North Atlantic during the period November-March will be presented. These regimes can be seen as peaks in the density function of the climate phase space, and have a typical 8-10 days persistence. In mid-latitudes, they correspond to preferred and/or recurrent quasi-station-ary atmospheric circulation patterns produced by the interaction between planetary-scale and synop- tic-scale atmospheric waves. We will show that polar lows form preferentially for some particular weather regimes, which depend on the area of polar low formation which is considered.

What did we learn about polar lows from the Andøya 2008 campaign?

Jón Egill Kristjánsson[1] + rest of IPY-THORPEX team
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During the International Polar Year of 2007/08, a 3-week aircraft-based measurement campaign focusing on mesoscale Arctic weather phenomena was operated out of Andøya in Northern Norway (69°N, 16°E). Three significant polar low developments were captured by dropsonde measurements and LIDAR retrievals, one over the Barents Sea and two over the Norwegian Sea. In one case (3-4 March), the full life cycle of a polar low was captured by three consecutive flights. These measurements provide a unique opportunity to study polar low evolution by: a) Mapping the structures of polar lows at different stages of development; b) Validating model simulations in an otherwise data sparse region. Following the campaign, the collected data have been the subject of thorough investigations within the framework of the Norwegian IPY-THORPEX project. We will review the main findings from these investigations. In particular, we will summarize how the campaign data have contributed new knowledge about polar lows, and we will identify the main remaining challenges.

Why was the 16-17 March 2008 Polar Low poorly predicted by operational models?

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Near the end of the IPY-THORPEX 2008 Andøya campaign, a major cold air outbreak took place over the Norwegian and Barents Seas, creating favourable conditions for polar low development. On 16 March, a series of vortices formed in a baroclinic zone south of Spitzbergen. The operational models at the time predicted a further deepening of the westernmost vortex into a full-scale polar low at 0-5°E. In reality, only the easternmost vortex (at 11°E) intensified into a polar low, which made landfall near Trondheim on the following day. The poor NWP guidance for this polar low contrasts to the quite accurate operational forecasts of the polar low that developed in the same area two weeks earlier (3-4 March). We cast a light on the evolution of the 16-17 March polar low by: (i) a careful analysis of the events leading up to the polar low formation; (ii) a series of sensitivity runs with the high-resolution non-hydrostatic WRF model, in which model resolution and lead time, as well as the treatment of surface fluxes and latent heating have been varied. In doing so, we also seek answers to the question of what might have made this polar low less predictable than the previous one.

Diabatic Rossby Vortex as a new paradigm for polar low development.

Annick Terpstra, PhD candidate UiB

Theories concerning the dynamical processes for polar low development cover a spectrum between baroclinicity and convection. Furthermore, it is unclear whether the upper level features often apparent during polar lows serve as a forcing mechanism for polar low development or are a feature of the existing polar low. To gain further insight into the dynamics of polar lows we hypothesize that polar low formation and intensification is captured by the Diabatic Rossby Vortex (DRV) paradigm. A DRV consists of a solitary low-level vortex, which propagates and intensifies independent of the far field. The disturbance growth rate depends both on the environmental baroclinicity and available moisture, where the former provides rising motion and the latter the release of latent heat. Propagation and intensification of the DRV is by phase locking and mutual amplification of the diabatically generated PV anomalies. The DRV is presented as a paradigm that unifies the current set of theories on polar low development and accounts for the low-level spin up often observed prior to the period of rapid intensification.

Arctic Cyclone Climatology: Present and Future

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The Arctic waters and coastal areas have always been prone to severe weather due to high impact cyclone events, such as polar lows or major cold air outbreaks. Here we present a climatology of cyclones obtained with the University of Melbourne cyclone tracking routine. The data used is from a high-resolution model currently under development at GFDL, namely the cubed sphere global model. The model is run with a resolution of 50 km and with a full suite of physical processes in the atmosphere. In a first step the model data and its cyclone climatology for the current climate is compared to the interim reanalysis from the European Centre for Medium Range Weather Forecast (ERA Interim). Cyclone strength, position and tracks are investigated for systematic differences and the capabilities of the model to represent the current cyclone statistics are discussed. In a second step model data for two 10 years slices, 2026-2035 and 2086-2095, are analyzed. Changes in strength, location and tracks of the cyclones compared to the current climatological values are investigated. A comparison of dynamical processes sheds light on the nature of the changes and highlights potential reasons for the identified shifts.

Tracking of polar lows using EPS

Hanneke Luijting
The Norwegian meteorological Institute

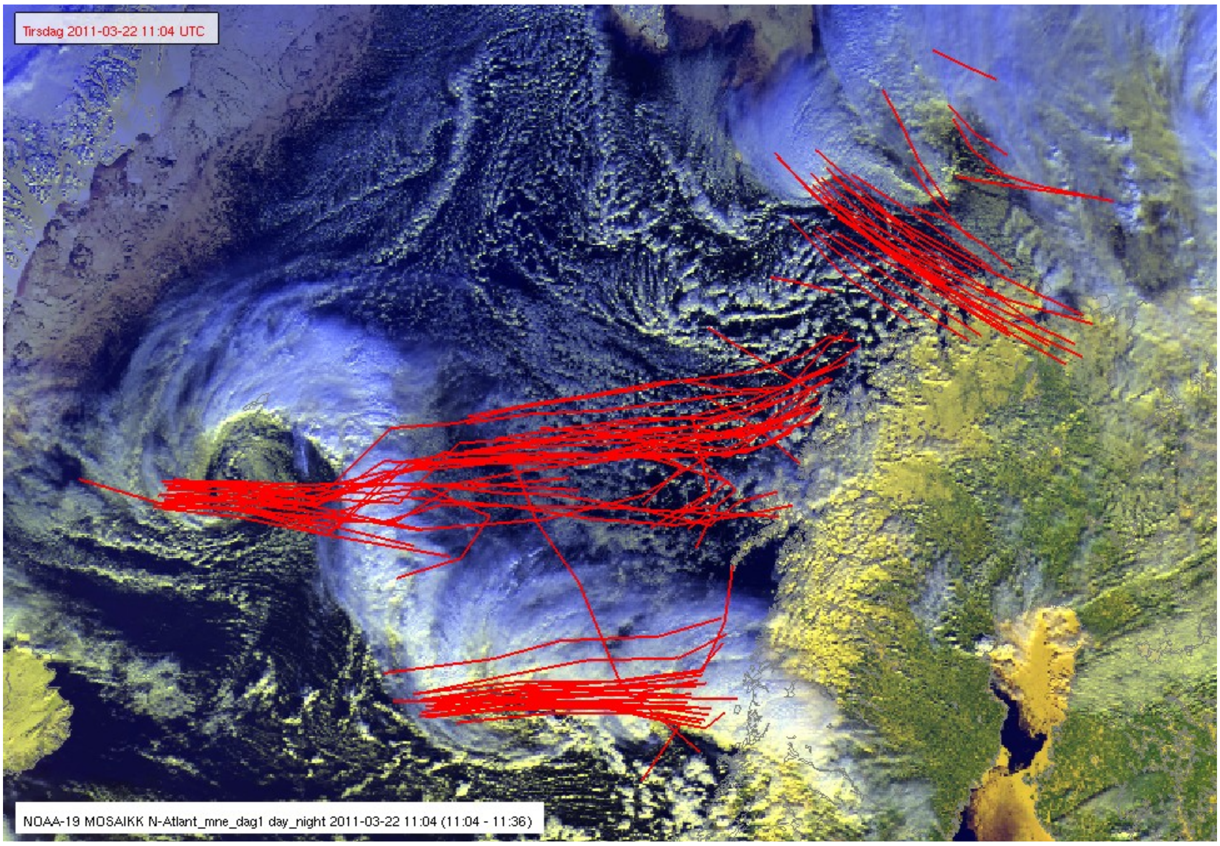
Numerical models are generally capable of forecasting the development of a polar low, however the location and timing are not always right. There are often large differences between model runs, which is a challenge for operational forecasting.

A method has been developed to track the movement of a polar low by following vorticity maxima. When a vorticity maximum is found, the script searches for another maximum in the next time step, within a certain (variable) radius of the previous maximum. In this way, a track is built up. To check that the conditions are right for the development of a polar low, the temperature difference between the sea surface and the temperature at 500 hPa is calculated. If a track is found in an area where this temperature difference is smaller than a (variable) threshold value, the track is removed.

To get an indication of the most likely path of a polar low, this method is used on all 20 ensemble runs from the Unified Model (UM-EPS). The resulting track map (see figure 1 for an example) can be further developed into a probability strike map. This is a very useful tool in operational forecasting of polar lows.

This method is currently being tested on several case studies from February and March 2011. At the same time, a way of visualising the probability strike map (easily understood by the general public) needs to be found. Eventually the aim is to develop a tool for weather forecasters which also produces useful maps that can be shared with the general public.

Figure 1: example of UM-EPS tracks of multiple polar lows on 22 February 2011



Past and projected future changes of North Atlantic polar low frequency
Matthias Zahn and Hans von Storch

I would like to present the results of our recent work on frequency changes of North Atlantic polar lows, over the past six decades and in a projected IPCC future. I will show that by means of dynamical downscaling it is possible to simulate these storms with a Regional Climate Model (RCM). The results are used to develop an automated detection procedure for polar lows, which then is applied to the output fields of long-term RCM simulations. The RCM was driven by NCEP reanalysis data for the past on the one hand side and by global data of IPCC future projections on the other. While there could not be found any systematic changes of polar low frequency for the past, a significant decrease was discovered associated with projected atmospheric warming. This decrease is linked to an increase in atmospheric stability with warming, which is a result of faster rising air temperatures compared to sea surface temperatures.