WORKSHOP ON POLAR LOWS

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The International Polar Year (IPY) has brought new momentum to polar low (PL) 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]; www.eplwg.uni-trier.de). 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 PLs 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. Subsequent presentations addressed observational studies, the climatology of PLs, modeling and theoretical aspects, and related and future projects (see www.eplwg.uni-trier.de/index.php?id=46884&L=2 for the full workshop program; extended abstracts of the presentations can be found at www.eplwg.uni-trier.de/index.php?id=46883&L=2).

2012 INTERNATIONAL WORKSHOP ON POLAR LOWS

WHAT: Twenty-five scientists from universities, weather forecasting and space centers, and national research institutions in France, Germany, Norway, Russia, Sweden, the United Kingdom, Canada, and Japan presented and discussed recent developments in polar low research.
WHEN: 21–22 May 2012
WHERE: Oslo, Norway

DEFINING POLAR MESOCYCLONES AND POLAR LOWS

A long discussion has been taking place about the terms "mesocyclones" and "polar lows." The European Polar Low Working Group (EPLWG) defines the term "mesoscale cyclone" or "mesocyclone" (MC) for all polar cyclones poleward of the main polar front having scales smaller than 2000 km. The classical "polar low" (PL) is included as a subtype that is restricted to maritime systems with near surface winds exceeding 15 m s^{-1}.

OBSERVATIONAL STUDIES OF POLAR LOWS. Since polar MCs 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 PLs were realized: one over the Iceland Sea and the other over the Norwegian Sea. The Iceland Sea study was performed using the British Facility for Airborne Atmospheric Measurements (FAAM) research aircraft and was able to capture a PL on 25 February 2007. A distinct

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

[2] The 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.

potential vorticity (PV) maximum and an ozone anomaly were associated with the PL. Surface sensible heat flux was about 200 W m^{-2}. A verification of the European Centre for Medium-Range Weather Forecasts (ECMWF) Interim Re-Analysis (ERA-Interim) using the aircraft data showed good agreement. The second aircraft study took place during IPY-THORPEX (The Observing System Research and Predictability 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. PL development from 3 to 5 March 2008 was 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 Met Office nonhydrostatic Unified Model with resolutions from 12 km down to 1 km. The model showed the best performance at a convection-resolving resolution of 1 km when compared to the aircraft data.

Since the beginning of PL research, satellite data have 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, structure, and life cycle of polar MCs. A climatological study using wind from scatterometer and cloud structure detection from Moderate Resolution Imaging Spectroradiometer (MODIS) data was presented for the Seas of Japan and Okhotsk as well as the Bering Sea. For MCs from 100 to 1000 km with wind speeds exceeding 12 m s^{-1}, the average number that occurs in the Sea of Japan is 56, with 64 on average in the Okhotsk Sea and 76 in the western Bering Sea and the Pacific Ocean from the Aleutian Islands to 47°N.

The use of synthetic aperture radar (SAR) imaging of PLs to derive their high-resolution wind fields was demonstrated for case studies in the Sea of Japan and the Norwegian Sea. Integrated water vapor from passive microwave data [Special Sensor Microwave Imager (SSM/I) and Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E)] was found to be useful for tracking PLs.

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 PLs over the Nordic and Labrador Seas for the period 2000–11. Genesis zones of PLs are identified as significant anomalies in patterns of the geopotential height at 500 hPa, the temperature difference between the sea surface and the 500-hPa level, near-surface winds, and PV at 300 hPa. A study of the dependence of PL frequency on the large-scale circulation using NCEP reanalyses for 1957–2011 showed that a negative North Atlantic Oscillation (NAO) phase favors PL development over the Norwegian Sea. However, the most PLs (~40%) occur with a blocking high over Greenland, which favors cold air outbreaks over the Norwegian Sea.

Global data from the German Meteorological Service's Global Model Extended (GME) model (25–40-km resolution) and ERA-Interim data are used for cyclone and MC tracking in the Antarctic region and southern polar ocean. Tracking mesoscale cyclones is performed by applying a bandpass filter for spatial scales of 200 to 700 km, an 850-hPa vorticity anomaly threshold of -2.0×10^{-5} s^{-1}, and a surface wind speed threshold of 15 m s^{-1}. 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 identified as mesoscale cyclones.

Ensemble prediction system output from the nonhydrostatic Met Office Unified Model (UM-EPS) has been used for the tracking of PLs. For a case of multiple PLs on 22 February 2011 over the Norwegian Sea, UM-EPS was applied at 4-km resolution with 21 ensemble members. To summarize the vast amount of information in the EPS, PL tracks

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are computed to estimate PL strike probabilities. This uncertainty information will be further evaluated as a tool for weather forecasters and for creating 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) global High Resolution Atmospheric Model (HIRAM) climate model simulations for Intergovernmental Panel on Climate Change (IPCC) scenarios with 50-km resolution. Runs have been performed for 10-yr slices of the present climate and for the periods 2026–35 and 2086–95. Cyclone strength, position, and tracks are investigated for two climate realizations using the coupled physical model CM3 and the Earth system model ESM2M (with three ensemble members for each realization). The comparison with cyclone statistics from ERA-Interim data for the present climate shows good agreement. The changes in the patterns of cyclone statistics for future periods are not conclusive, since areas with significant decreases but also with increases in activity are found, and relatively large differences exist between the CM3 and ESM2M realizations.

Long-term simulations of the regional climate model CCLM [Consortium for Small-Scale Modeling (COSMO) Climate Limited-Area Modeling] show past and projected future changes of North Atlantic PL frequency. PL activity is investigated for the period 1948 through 2006 by dynamical downscaling of global National centers for Environmental Prediction (NCEP)–National Center for Atmospheric Research (NCAR) reanalysis data. On average, 56 PL cases occur each PL season. Comparison with limited observational evidence of PLs 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 toward the end of the twenty-first 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 northward.

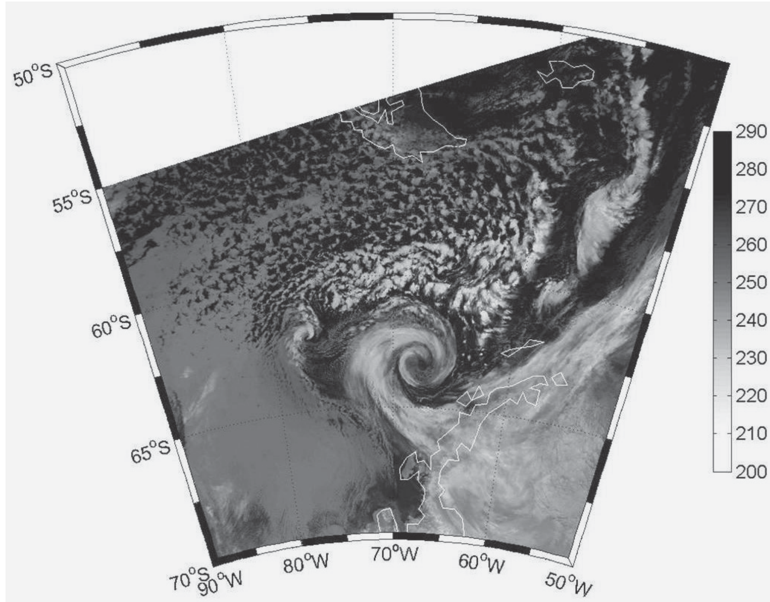

Fig. 1. Advanced Very-High Resolution Radiometer (AVHRR) infrared image (brightness temperatures in K) for 0159 UTC 28 Apr 2009 showing a polar MC near the Antarctic Peninsula.

MODELING AND THEORY. Case studies of polar MCs using high-resolution NWP models are important for understanding formation processes and the dynamics of 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 the IPY-THORPEX Andøya field campaign 2008, where a PL developed over the Norwegian Sea during the night of 15–16 March. Hindcast runs using the Weather Research and Forecasting (WRF) model driven by ECMWF analyses with resolutions from 30 km down to 3 km were applied to study the sensitivity of the forecasts with respect to the initialization time. Higher resolution did not improve the forecast, but a systematically and considerably better performance was found when data from dropsondes launched from the IPY-THORPEX research aircraft during the morning of 15 March were included in the initial fields.

A numerical study on a polar MC over the Sea of Japan with a horizontal scale of about 150 km and a cloud-free eye was presented using the nonhydrostatic mesoscale model of the Japan Meteorological Agency (JMA-NHM) with a horizontal resolution of 2 km. In this area, most MCs develop in the vicinity of the Japan Sea polar airmass convergence zone (JPCZ). The JPCZ is associated with 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 convective instability of the second kind (CISK) and wind-induced surface heat exchange (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 that uses a high-resolution ocean circulation model [the Massachusetts Institute of Technology general circulation model (MITgcm), 18 km] driven by ERA data. Based on the comparison of ERA winds with scatterometer data, a parameterization scheme was developed that corrects ERA winds in the shortwave 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 PLs play an important role in driving the large-scale ocean circulation. Taking into account the expected decrease in the number of PLs over the northeast Atlantic in the twenty-first 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 PL development. For the Norwegian Sea, there seems to be a preference for development when the background environment exhibits reversed shear conditions (i.e., the 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.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS. This workshop summarized the current state of PL research in the Arctic and Antarctic. A couple of related projects are in the planning phase or already funded. The creation of a PL 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 MCs 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.

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