POLAR LOW WORKSHOP

Günther Heinemann, Chantal Claud, and Thomas Spengler

The workshop[1] on polar lows (PLs) and mesoscale weather extremes attracted 30 scientists from China, France, Germany, Japan, Norway, Russia, the United Kingdom, and the United States to present the most recent findings on PL research and to summarize our present understanding of PLs and mesocyclones (MCs) as well as mesoscale weather extremes in the Arctic and Antarctic (see sidebar for the definition of PLs). The workshop had the following main themes: PL studies using satellite data and in situ observations, climatological aspects, PLs in reanalyses and model simulations, environments for PL genesis and operational aspects, polar mesoscale weather phenomena, and air–ocean–ice interactions. The workshop was concluded by a roundtable discussion resulting in recommendations for future research and actions.

14TH EUROPEAN POLAR LOW WORKING GROUP MEETING: "POLAR LOWS AND MESOSCALE WEATHER EXTREMES"

What: Atmospheric scientists and weather forecasters from eight countries focusing on polar mesocyclones in both hemispheres and other mesoscale weather phenomena, such as katabatic winds, tip jets, boundary layer fronts, cold-air outbreaks, and weather extremes in the polar regions, came together to present their latest work and findings on a variety of topics and to encourage discussions aimed at improving the forecasting and understanding of these phenomena. Topics included experimental, climatological, theoretical, modeling, and remote sensing studies.
When: 5–6 April 2018
Where: Trier, Germany

POLAR LOW STUDIES USING SATELLITE DATA AND IN SITU OBSERVATIONS.

Mikail Pichugin (Pacific Oceanological Institute, Vladivostok, Russia) presented case studies of MCs over the Sea of Japan. Using multisensor satellite data and analyses of the Japan Meteorological Agency, wind fields from scatterometers show a wintertime polar low with 10-m wind speeds exceeding 25 m s^{-1}. Erik Blixt [Norwegian Seismic Array (NORSAR), Norway] investigated the potential of infrasonic signatures to detect and track PLs over the Norwegian Sea. A network of seven infrasound sensors in northern Scandinavia is used to estimate the direction of the arrival of infrasound signals in frequency bands of 1–4 and 0.01–1 Hz. While some PLs are detected successfully by this method, the majority of the PL cases of the Norwegian Sea Surface Temperature and Altimeter Synergy for Improved Forecasting of Polar Lows (STARS) database (http://polarlow.met.no/stars-dat) cannot be sufficiently discerned from other signals in the data. More research is needed on the sources of infrasound and their relation to

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[1] The workshop was organized by the atmospheric working group of the International Arctic Science Committee (www.iasc.info) and the European Polar Low Working Group (www.uni-trier.de/index.php?id=20308).

PLs. Chantal Claud (Laboratoire de la Meteorologie Dynamique, Paris, France) showed observations of PLs and the associated sea state using data from oil and gas platforms in the North and Norwegian Seas (Fig. 1). Several cases are documented for PL passages over these stations, and significant wave heights of more than 10 m are observed and wind can exceed 30 m s^{-1}. Large, multiple, and fast-moving PLs generate stronger near-surface winds and higher waves. The differences and similarities between PLs and medicanes were studied by Stavros Dafis (Laboratoire de la Meteorologie Dynamique, Paris, France). A medicane is an MC occurring over the warm Mediterranean Sea associated with deep convection. While around 13 PLs are observed per year over the Norwegian Sea, the frequency of medicanes is only about one per year. The typical size is 250–500 km with a lifetime of 1–3 days. Cold-air outbreaks (CAOs) and mesocyclone activity over the Chukchi Sea were studied by Mikail Pichugin using satellite data of scatterometers, synthetic aperture radar (SAR), passive microwave sensors [Advanced Microwave Scanning Radiometer (AMSR)], and National Centers for Environmental Prediction (NCEP) Climate Forecast System, version 2 (CFSv2) analyses. CAOs are responsible for large amounts of sea ice transport, and signatures of an MC could be tracked in the SAR and scatterometer data as well as in moisture fields. Christian Melsheimer (University of Bremen, Germany) presented a method to detect PLs using data from the satellite microwave humidity sounder (MHS) and the Advanced Microwave Sounding Unit-B (AMSU-B) on polar-orbiting meteorological satellites of National Oceanic and Atmospheric Administration (NOAA) and the European Space Agency. Using the strong microwave scattering signal of ice clouds associated with PLs, the method applied image processing to detect them.

CLIMATOLOGICAL ASPECTS. Polina Verezemskaya (Lomonosov Moscow State University, Russia) applied a deep convolutional neural network to track MCs in the Antarctic. This technique was used to identify MCs from satellite mosaics provided by the Antarctic Meteorological Research Center with 5-km spatial and 3-hourly temporal resolution. A more classical MC tracking method using the vorticity at 850 hPa was presented by Patrick Stoll (Arctic University, Tromsø, Norway). Data from the European Centre for Medium-Range Weather Forecasts (ECMWF) interim reanalysis (ERA-Interim) and the Arctic System Reanalysis (ASR) were used to derive PL climatologies for both hemispheres for the period 1979–2016. A variety of criteria are used in order to avoid false detection of MCs. The most effective criteria for separating PLs from all other kinds of synoptic and mesoscale cyclones are the mean sea level pressure (MSLP) anomaly, the difference in the potential temperature between the sea surface and the 500-hPa level, and the tropopause wind poleward of the PL.

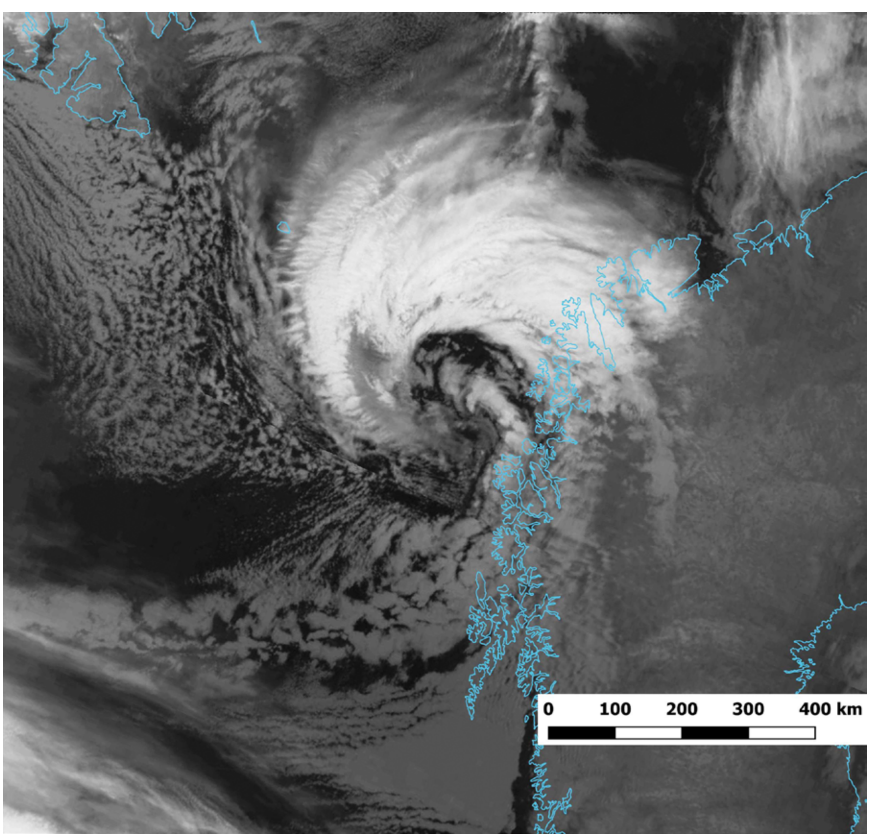

Fig. 1. Polar low over the Norwegian Sea on 24 Mar 2014 (MODIS infrared image, data from NASA Worldview).

Results from tracking PLs in ERA-Interim using maxima in the Laplacian of MSLP for the Nordic seas was shown by Annick Terpstra (University of Bergen, Norway) with a focus on genesis conditions for forward and reverse (vertical wind) shear. In contrast to previous claims, no significant relation of MC genesis and sea ice conditions was found. While forward-shear MCs develop in a deep baroclinic zone with an upper-tropospheric jet, reverse-shear MCs are associated with a low-level jet. Ana Radovan (University of Köln, Germany) presented results for conditions of PL formation using the ASR, version 1 (ASRv1; 30 km), where a combination of different criteria (such as the temperature difference between the surface and at 500 hPa, lapse rate, and relative humidity below 850 hPa) is needed to characterize PLs. A PL climatology for present and future climate derived from a downscaled climate model ensemble was shown by Oskar Landgren (Norwegian Meteorological Institute, Oslo, Norway). Community Earth System Model (CESM) Large Ensemble model runs were used as boundary conditions for dynamical downscaling to 12 km with the regional climate model High Resolution Limited Area Model (HIRLAM) Aire Limitée Adaptation Dynamique Développement International (ALADIN) Regional Mesoscale Operational NWP in Europe (HARMONIE) for the Nordic seas. Vorticity maxima at 925 hPa were tracked after filtering for scales smaller than 600 km. With decreasing sea ice at the end of the twenty-first century, the area of PL occurrence extends more to the north and east, but the overall number of PLs and their lifetime decreases.

POLAR LOWS IN REANALYSES AND MODEL SIMULATIONS. Matilda Hallerstig (ECMWF, United Kingdom) showed two PL case studies using the high-resolution ECMWF global model (9 km) and the Applications de la Recherche à l'Opérationnel à Méso-Echelle (AROME) Arctic limited-area model (2.5 and 5 km). The comparison to observations of coastal stations shows that the AROME simulation at 2.5 km yielded the best results for the 10-m wind. High-resolution simulations (2.2 km) with the Met Office Unified Model for PL cases near Svalbard were presented by Thomas Spengler (University of Bergen, Norway). The sensitivity of the evolution to orography and sea ice was investigated. Lowering or removing the orography of Svalbard leads to different PL tracks and vorticity contributions. A change in the sea ice cover has a larger effect for PL tracks exposed to higher air–sea heat fluxes.

Hélène Bresson (University of Reading, United Kingdom) studied the response of PLs to climate change in a high-resolution version (25 km) of the Met Office Hadley Centre Global Environment Model, version 3, with global atmosphere-only simulations (HadGEM3-GA3) Unified Model for recent climate (1985–2010) and the representative concentration pathway 8.5 (RCP8.5) future climate scenario (2085–2110). Vorticity at 850 hPa was used for PL tracking with additional criteria on wind speed and static stability. Beacuse of an overall increase of the static stability, the formation of PLs is hindered for the future climate, especially in the North Atlantic. Annick Terpstra examined the influence of surface fluxes on the development of PLs using idealized simulations. A dominance of diabatic processes during the early stage of development is shown, which scales with the air–sea temperature difference.

WHAT IS A POLAR LOW?

A definition of a polar low was given by the European Polar Low Working Group in 1994 (see Heinemann and Claud 1997): the term "polar mesoscale cyclone" (polar mesocyclone) is the generic term for all meso-α- and meso-β-scale cyclonic vortices poleward of the main polar front (horizontal scale of 20–2,000 km). The term "polar low" should be used for intense maritime mesocyclones with scales up to about 1,000 km with a near-surface wind speed exceeding 15 m s^{-1}.

ENVIRONMENTS FOR POLAR LOW GENESIS AND OPERATIONAL ASPECTS. Natalya Vazayeva (Russian Academy of Sciences, Moscow, Russia) investigated the potential of using helicity in the atmospheric boundary layer for the diagnosis of PL development. She pointed out that the integral helicity increases during the generation of PLs and that helicity may be used as a diagnostic tool. Characteristics and synoptic environments of PLs over the Barents Sea for the period 1999–2013 were studied by Chantal Claud. A large interannual variability of PL occurrence is found, where a majority features comma clouds and more activity is observed toward the end of the cold season. The question of polar low identification and classification for operational weather forecasters was addressed by Gunnar Noer (Norwegian Meteorological Institute, Tromsø, Norway). In contrast to some decades ago, forecasters nowadays have powerful tools for identifying PLs in near–real time, such as high-resolution satellite imagery, scatterometer winds, and high-resolution models (2.5 km).

POLAR MESOSCALE WEATHER PHENOMENA AND ATMOSPHERE–OCEAN–SEA ICE INTERACTIONS. A series of talks and posters addressed the characteristics and impacts of explosive cyclones (ECs). Gang Fu [Ocean University of China (OUC), Qingdao, China] pointed out that ECs may cause serious losses of life and property. The intensity of ECs is defined by the surface pressure deepening rate in units of Bergerons (1 Bergeron = 1 hPa h^{-1}). He showed the influence of large-scale atmospheric and oceanic environments for ECs over the northern Pacific. ECs are found to be most frequent on the poleward side of the 300-hPa jet, and a relation to the warm ocean current of the Kuroshio was found for the rapid development of ECs. A similar study for the northern Atlantic was presented by Ya Wen Sun (OUC). Peng Yuan Li (OUC) showed a numerical model study using the Weather Research and Forecasting (WRF) Model for an intense EC (a deepening rate of almost 3 Bergerons) over the northwestern Pacific. A broader view on coastal weather extremes and simulations of small synoptic features conditioned by the large-scale environment was given by Hans von Storch (Helmholtz Center Geesthacht, Germany). He pointed out that pattern recognition methods are needed to determine spatial features like low-level jets and PLs from model simulations. Methods for describing and detecting wind gusts from measurements and models were presented by Irene Suomi (Finnish Meteorological Institute). These wind extremes on time scales of a few seconds cause severe damage and are a safety risk. Thomas Spengler introduced a climatology of wintertime CAOs in the Irminger Sea and Nordic seas and their influence on air–sea interactions in a Lagrangian framework. He showed that CAOs contribute significantly to overall heat exchange and that their pathways are important. The role of the coastline and orography in the formation of convergence zones in CAOs was studied by Shun-ichi Watanabe (University of Tokyo, Japan). Using idealized numerical experiments together with theory, he showed that only concave coastlines or mountains can yield convergence lines. Günther Heinemann (University of Trier, Germany) presented a case study of a boundary layer front (BLF) on 13 March 2014 near the marginal ice zone (MIZ) north of Svalbard using aircraft measurements and high-resolution numerical model simulations. The BLF was associated with a strong convergence zone and low-level jets north and south of the BLF and exceptional high frontogenesis in the lowest 500 m.

FUTURE RESEARCH PROGRAMS RELATED TO PLS AND MESOSCALE WEATHER EXTREMES. Bart Geerts (University of Wyoming, United States) showed plans for an airborne and ground-based field campaign to study CAOs and PLs in the Barents and Norwegian Seas during January–May 2020. G. Heinemann reported on the campaign Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC), where the research icebreaker *Polarstern* will be the basis for a manned drifting station in the sea ice during September 2019 to September 2020 (www.mosaicobservatory.org).

ROUNDTABLE DISCUSSION. The community discussed the necessity of databases for PL climatologies. The polar low database of the Norwegian weather service was appreciated as one of the most used references for recent PL studies with a focus on the Nordic seas. However, comparable databases do not exist for other regions. It was recognized that satellite-based climatologies should also be made available as databases.

A discussion came up about the definition of a PL. The European Polar Low Working Group definition (see sidebar) focuses on the horizontal scale, the wind speed, and the occurrence poleward of the polar front, but in model or satellite-derived climatologies adjusted (because of resolution) or additional thresholds (e.g., on stability or signals of convection) are often used. The problems for defining a generally valid set of characteristics for PLs in all regions on the globe were discussed. The community also recognized the need for further improvements of PL forecasts. Although operational models are now at a horizontal scale of a few kilometers, they are still in the "gray zone" with respect to convection parameterization. A further discussion focused on the role of PLs under the conditions of climate change.

Overall, the community recommended model intercomparisons for PL detection and tracking, which could be part of the Year of Polar Prediction (YOPP) within the World Meteorological Organization (WMO) Polar Prediction Project (PPP), where, for example, the polar Coordinated Regional Downscaling Experiment (CORDEX) groups are already participating (www.climate-cryosphere.org/activities/targeted/polar-cordex).

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