POLAR LOW WORKSHOP SUMMARY

Thomas Spengler, Chantal Claud, and Günther Heinemann

The 13th Polar Low workshop attracted 33 scientists to present most recent findings on polar low research and to identify possible research topics to improve our knowledge and predictive capabilities. We summarize the workshop around the following themes: climatological aspects, dynamics of polar lows and polar mesoscale phenomena, prediction, and operational aspects. We conclude with recommendations based on a roundtable discussion at the end of the workshop.

THE 13TH EUROPEAN POLAR LOW WORKSHOP

What: The 13th European Polar Low Workshop was organized by the European Polar Low Working Group (www.uni-trier.de/index.php?id=20308) and gathered scientists from nine 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 polar regions. Topics included experimental, climatological, theoretical, modeling, and remote sensing studies. The aim was to bring together scientists and forecasters to present their latest work and recent findings on these topics and to encourage discussions on improving forecasting and understanding of these phenomena.
When: 25–26 April 2016
Where: Paris, France

CLIMATOLOGICAL ASPECTS. Jean-Pierre Chaboureau showed that the representation of polar lows over the Nordic seas in ERA-Interim is improved compared to ERA-40 and has a positive impact on downscaled simulations owing to a better representation of the synoptic conditions. Helene Bresson confirmed the rather good representation of polar lows in ERA-Interim but found twice as many polar lows in the higher-resolution NCEP-CFS, pinpointing the problem of using identical thresholds for the definition of polar lows in two different datasets. Using the even higher-resolution Arctic System Reanalysis (ASR), Pavel Golubkin was able to reproduce up to 80% of polar lows from an operationally maintained polar low list at MET Norway. Kent Moore further stressed that the ASRv1 is able to capture finer-scale structures associated with polar lows compared to ERA-Interim, including details of the structure of the air–sea interaction associated with cold air outbreaks, pinpointing that ERA-Interim underestimates surface wind speeds by 5 m s^{-1} and total heat flux by 50 Wm^{-2} (10%) compared to the ASRv1. For state-of-the-art Arctic regional climate models, Mirseid Akperov showed that they can resolve 60% of polar lows and that nudging is beneficial to obtain better polar low characteristics over the Nordic seas.

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With more satellite data available for the polar regions, Christian Melsheimer showed that polar lows and polar mesoscylones can be detected in microwave humidity sounder data [Advanced Microwave Sounding Unit-B (AMSU-B), Microwave Humidity Sounder (MHS)]. However, these products offer no information on wind, limiting a distinction between polar lows and polar mesoscyclones. Based on such passive microwave radiometer satellite data, Julia Smirnova compiled a polar low climatology over the Nordic seas and Barents Sea for 1995/96–2008/09, finding the highest occurrence of polar lows in March and the main genesis region northeast of North Cape. Investigating mesoscale cyclones and cold air outbreaks using satellite multisensory measurements and reanalysis, Antonina Polezhayeva identified new regions of polar low development over the eastern part of the Eurasian Arctic with cyclogenesis shifted from the winter months to October. Thomas August further augmented the possibilities using polar orbiting atmospheric sounders, where he presented three-dimensional humidity structures of polar lows.

Polar lows also form in other regions of the globe. Using the Japanese 55-year Reanalysis (JRA-55) reanalysis, Wataru Yanase showed that polar lows develop over the Japan Sea within the East Asian winter monsoon between the Aleutian low and the Siberian high. Polar lows in this area develop on the western side of a synoptic-scale low pressure system concomitant with an upper-level cold low. Objectively tracking polar mesoscyclones for the Japan Sea, Shunichi Watanabe further found genesis conditions to comprise a surface trough extending from the east together with an upper-level trough associated with a convergence zone in a cold air outbreak (CAO). Over the Southern Ocean, Polina Verezemskaya showed that polar lows are primarily generated in the western and the eastern parts, representing 72% of all mesoscyclones detected from infrared satellite for winter 2004. She also indicated that reanalysis data underestimates mean (1–4 m s^{-1}) and maximum (5–10 m s^{-1}) wind compared to Quick Scatterometer (QuikSCAT). Regarding the mesocyclone activity around Antarctic, Andrew Carleton presented evidence that the large intra- and interannual variability of polar mesoscyclones occurrence on weekly/submonthly scales cannot be sufficiently explained by ENSO.

As polar lows are often difficult to detect automatically, especially in lower-resolution climate simulations, the community often resorts to investigating favorable environmental conditions for polar lows and their association with large-scale weather patterns or sea ice. Using weather regimes, such as the North Atlantic Oscillation (NAO), Scandinavian blocking (SB), and Atlantic Ridge (AR), Paul-Etienne Mallet identified different polar low occurrences depending on the respective polar low track data used. In fact, based on automatically tracked polar lows, Clio Michel found no dominant large-scale pattern at polar low genesis time, with a slight tendency of negative SB favoring polar low formation. Regarding sea ice extent, Chantal Claud presented evidence that positive anomalies in September favor formation of polar lows over the Nordic seas, while negative anomalies in January/February are favorable for polar lows in the Barents Sea in March. Even though the latter finding is consistent with the satellite-based study of Julia Smirnova, Clio Michel did not find any significant correlation of sea ice extent and polar low occurrence in her dataset.

Concerning changes in polar low formation for future climates, Romu Romero presented statistical–deterministic projections based on CMIP5 models searching for hurricane genesis conditions. He indicated a 10%–15% future reduction in overall frequency of North Atlantic polar lows, though highlighted the great uncertainty among models. Furthermore, changes are not uniform across the North Atlantic basin with a very robust regional shift of polar low activity from the south Greenland–Icelandic sector toward the Nordic seas closer to Scandinavia. One caveat of this analysis is the focus on hurricane-like polar lows, mainly driven by convection. Along similar lines, Paul-Etienne Mallet found the strongest future change in the difference between the temperature at the sea surface (SST) and that at 500 mb (T500), henceforth SST-T500, for the weather pattern AR, indicating a reduction of polar low likelihood. However, based on automatic tracking of polar lows in Geophysical Fluid Dynamics Laboratory (GFDL) high-resolution climate simulations, Clio Michel found no clear trend for future occurrence of polar lows and also pinpointed a high sensitivity to the model choices. She also has not been able to identify a trend in the number of polar lows for the ERA-Interim period analyzed until 2014.

DYNAMICS OF POLAR LOWS AND POLAR MESOSCALE PHENOMENA. Kent Moore showed that flow distortion around Greenland plays an important role in local weather and global climate. He showed that a resolution of around 15 km is needed to adequately represent the surface wind field, though, according to Oliver Gutjahr, differences between a high-resolution regional climate simulation

(CCLM with 15 km) and ASR in capturing extreme winds associated with mesoscale phenomena are not only due to horizontal resolution. Lukas Papritz associated mesoscyclones with the erosion of CAOs via cyclonic circulation and latent heat release, which might be underrepresented in coarse-gridded climate simulations. There are still competing paradigms for polar low development, either focusing on baroclinic or convective growth and polar lows are often categorized into forward and reverse shear polar lows. Thomas Spengler proposed a unifying moist baroclinic paradigm on polar low development consistent with the diabatic Rossby vortex and showed that forward shear conditions bear great resemblance to standard baroclinic instability environments, whereas reverse shear environments are similar to frontal wave development with a low-level jet.

Motivated by a unique aircraft observational dataset for a shear-line polar in the Norwegian Sea, Denis Sergeev presented a model simulation with the UM at 2.2-km grid spacing. Using in situ as well as cloud radar satellite data, he concluded that the shear line is well represented. However, the model produced too much cloud ice and overestimated surface sensible heat fluxes and underestimated surface latent heat fluxes. Annick Terpstra investigated the influence of surface fluxes on polar low development and showed that the moisture is not locally recycled in polar lows and that horizontal transports are essential for latent heat release, which further complicates assessing the direct impact of surface energy exchange on polar low development. Also related to surface fluxes, Polina Verezemskaya carried out numerical simulations of a polar low in the Kara Sea and found the wind-induced surface heat exchange (WISHE) mechanism to be negligible, as the polar low developed in a region with high stability with strong upper-level forcing. Thor-Erik Nordeng hypothesized that the warm wedge in sea surface temperatures west of Svalbard might be important for polar low genesis environment.

PREDICTABILITY OF POLAR LOWS AND OPERATIONAL ASPECTS. Prediction of polar lows is still a great challenge for operational forecasting because of their rapid growth and mesoscale nature. However, as shown by Maxence Rojo, polar lows over the Norwegian Sea can lead to high waves, intense wind, and rapid changes of wind direction, posing a threat to livelihoods and operations in these waters. Günther Heinemann presented a case study of orographically forced mesocyclones in the Weddell Sea during the summer season 2015/16, which were not well captured in numerical analyses. Teresa Valkonen showed that polar low forecasts at MET Norway could be improved by Assimilation of ASCAT scatterometer winds. Assimilation of these data are operationally possible, but there is a bias for strong winds, with the model having higher wind speeds than ASCAT, though it is unclear if the problem resides with the model or the ASCAT retrieval. Eivind Støylen presented probability strike density maps, based on tracks of polar lows in MET Norway's regional ensemble.

Because of model limitations, especially when it comes to positioning polar lows, forecasters still often rely on environmental criteria for polar low forecasting, where Gunnar Noer explained that the main criteria used at MET Norway are the existence of a cold air outbreak with a significant SST-T500, and the presence of an upper-level trough, together with a suitable MSLP and precipitation signature. He also pointed out that March 2010, 2011, and 2013 were particularly intense with polar low activity. Using Weather Research and Forecasting (WRF) Model simulations, Antonina Polezhayeva confirmed that temperature gradients, latent heat fluxes, and convection are among the main predictors for polar low development. She furthermore presented a new assimilation technique, where she assimilated surface pressure into regional models using satellite winds over ocean employing suitable balance assumptions.

ROUNDTABLE DISCUSSION. Satellite data with increasing polar coverage and resolution was identified as a great asset to polar low research that should be exploited more in the future. Furthermore, multisensory facilities expand the possibilities for analysis; in particular, the IASI L2 v6 processor offers unprecedented sounding capabilities and 3D humidity fields. European Space Agency (ESA) and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and other satellite communities will be invited to the next workshop to continue a dialogue about other pertinent variables retrievable for polar low research. Many satellite climatologies still rely on manual inspection. Hence, new ways to automatically detect polar lows or to crowd source cyclone tracking should be explored in the future—for example, mirroring the efforts of Cyclone Center (www.cyclonecenter.org).

The community also discussed caveats in polar low climatologies due to chosen thresholds. Another issue was the value of statistically and environmental condition–based versus feature-based climatologies of polar lows. Each has their advantages and disadvantages and should ideally be used in conjunction with each other. There was a general agreement that there is a need for a defined set of characteristics that should be used to define a polar low. Overall, the community suggested having an intercomparison project for polar low detection and tracking that could be coordinated within the World Meteorological Organization (WMO) Polar Prediction Project. Such an intercomparison should also include higher-resolution data to determine the minimum resolution needed to appropriately represent polar lows in reanalysis and model data.

Regarding typical environmental conditions for polar lows, it became evident that standard measures, such as SST–T500, might not be a good parameter for all types of polar low environments, as they are biased toward reverse shear and more convectively driven polar lows. The community discussed if there are other valuable parameters to describe conducive environments for polar lows and inquired about the role of orography and the sea ice edge, in particular as the correlation of polar low occurrence with sea ice extent appears to be controversial. The use of cloud thickness to distinguish polar low types as additional criteria was also discussed.

To improve prediction of polar low tracks it is not obvious what leads to the shift of polar lows in the forecasts and if there are systematic biases for different types of polar lows. It was pointed out that more observations could help to constrain the positions, but data assimilation is a limiting factor for mesoscale prediction and it is difficult to evaluate a good performance owing to the lack of observational data. From a dynamical point of view, the scale of polar lows is close to the limits of validity for quasigeostrophy and balanced PV thinking. There are other concepts, such as conditional instability of the second kind (CISK), wind-induced surface heat exchange (WISHE), and moist baroclinic instability. In particular, the contribution of surface fluxes in polar low growth is still not well understood. The sources of latent heat (i.e., the water paths) and the influence of the surface fluxes on these are still open questions. Case studies and idealized simulations will be invaluable tools for this debate.

Last but not least, the community pointed out that the time is ripe for a new review paper on polar lows because of significant developments. Such a publication should also include the expanding research on how polar lows change in future climates.

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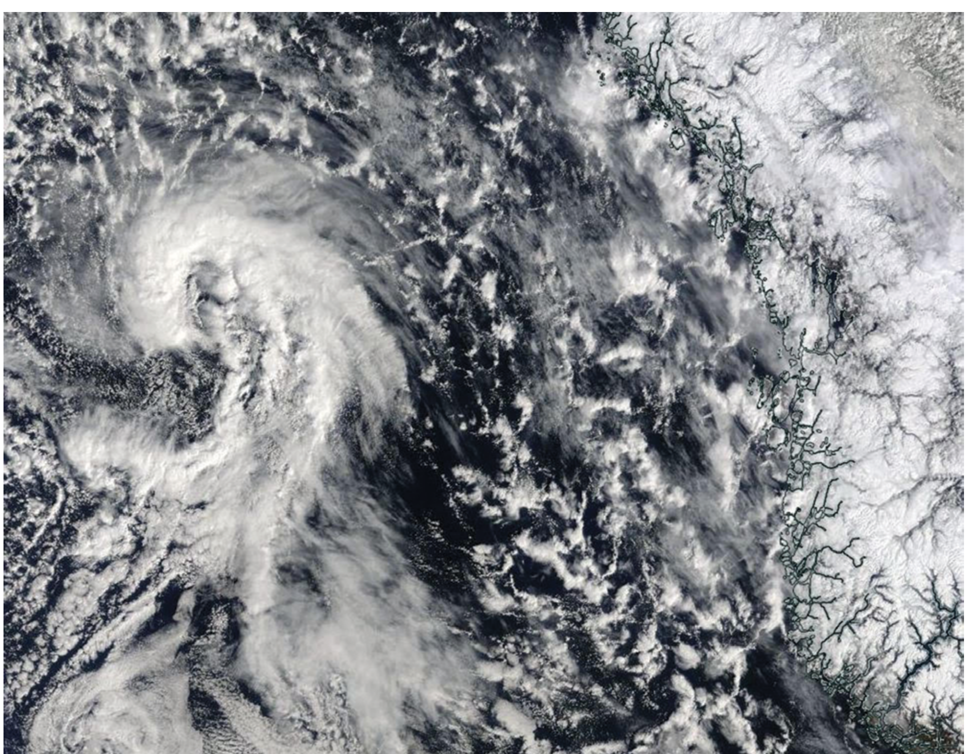

MODIS satellite image (VIS) of a polar low west of the Norwegian coast on 24 April 2016. (Source: https://worldview.earthdata.nasa.gov**)**