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## **SEA ICE DISTRIBUTION AND ATMOSPHERIC FORCING IN THE SOUTHERN HEMISPHERE**

Co-authors: Ulrike Langematz

Observational studies have shown a zonally asymmetric change of the sea ice distribution around the Antarctica during the last decades: an increase of the sea ice area in the Ross and Amundsen sectors, and a retreat of sea ice in the Bellinghousen Sea sector. These changes seem to be attributable to the changes in the enhanced Ekman transport due to a more positive Southern Annular Mode (SAM) phase, favored by the springtime loss of Antarctic stratospheric ozone. At the same time, changes in the wave forcing have taken place, with a pronounced increase in the stationary wave forcing. As a consequence, an increase in winter stratospheric temperatures over the South Pole is observed, peaking in the sudden stratospheric warming (SSW) event in the year 2002. Have the observed dynamical changes in the stratosphere been induced by the absolute increase in SSTs, by SST gradient or by changes in the sea ice distribution around Antarctica. The contribution of each quantity on the atmospheric forcing will be assessed.

For this two simulations with the coupled atmosphere-ocean-chemistry-climate model EMAC-O (ECHAM MESSy Atmospheric Chemistry with MPIOM ocean) will be analysed, one representing a transient climate change (rcp6.0 scenario) and the other one a control simulation under 1960s conditions.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Peggy Achtert**

Institute for Climate and Atmospheric Science, University of Leeds, Leeds, UK

**Observations of the Arctic boundary layer during ACSE 2014**

Co-authors: Dominic J. Salisbury, John Prytherch, Joseph Sedlar, Georgia Sotiropoulou, Michael Tjernström, Barbara J. Brooks, Ian M. Brooks, Matthew D. Shupe, P. Ola G. Persson, Paul Johnston, Daniel Wolfe.

Boundary-layer structure and dynamics are intimately linked with both surface exchange processes and the properties of boundary-layer clouds, which in turn exert a strong control on the surface energy budget. Sea ice melt and formation are thus closely coupled with boundary layer clouds and turbulent exchange. Coordinated observations of boundary layer processes and cloud dynamics are sparse in the Arctic. This holds especially for observations that extend over the entire ice melt season.

Observations from the Arctic Clouds in Summer Experiment (ACSE) in the East Siberian Arctic Ocean made during the summer and early autumn of 2014 provide a detailed view of boundary layer properties such as boundary layer depth and development, cloud cover, vertical mixing processes, and the effect of overlaying cloud layers. Measurements with ground-based remote-sensing instruments and near-surface meteorological sensors as well as radiosounding were performed over a variety of surface conditions, from open ocean, through marginal ice and into dense pack ice, during the 3-month cruise. Here we present a detailed statistical analysis of boundary layer properties and case studies for different surface conditions.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Laurent Bertino**

Researcher  
NERSC

**A 20-years ice-ocean reanalysis with the TOPAZ system and an Ensemble Kalman Filter.**

Co-authors: François Counillon, Christoph Renkl, Pierre Rampal, Timothy Williams, Annette Samuelsen, Jiping Xie, Pavel Sakov

We will present a synthesis of the ice-ocean TOPAZ4 reanalysis for the period 1991-2010. TOPAZ4 is a modeling and data assimilation system based on the Nansen Center's version of the HYCOM model (at horizontal resolution of about 12 km) and an Ensemble Kalman Filter (EnKF), integrating a dynamical ensemble of 100 members. The multivariate properties of the EnKF allow the TOPAZ system to assimilate several ocean and sea ice data types simultaneously, both in real-time forecasts applications (exploited operationally at MET Norway) and in reanalysis mode. The TOPAZ system constitutes the Arctic component of the MyOcean system (<http://www.myocean.eu>).

The results from a 20-years reanalysis – the longest realistic EnKF run to our knowledge - show a good stability of the EnKF used in realistic settings and its ability to provide physically consistent error estimates for most variables assimilated, and only minor degradations compared to a model free run. The reanalysis also points to limitations of the sea ice model in terms of sea ice drift and motivates the further developments of new sea ice rheology models for the Marginal Ice Zone and the ice pack.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Ian Brooks**

Professor

University of Leeds

**In situ measurements of surface exchange over the Arctic Ocean**

Co-authors: John Prytherch, Dominic J Salisbury, Barbara J. Brooks, Peggy Aichtert, Joseph Sedlar, Michael Tjernström, Georgia Sotiropoulou, P. Ola G. Persson, Matthew D. Shupe, Paul Johnston, Daniel Wolfe, Benjamin I. Moat

Surface fluxes over sea ice are poorly represented in large scale models. Simple parameterization schemes fail to account for the spatial heterogeneity and the variety of ice conditions. Recently more complex parameterizations have considered the effect ice fraction, from drag, and leads, melt ponds, and ridges; however, they have yet to be extensively tested against in situ measurements. Here we provide an overview of an extensive set of in situ measurements of surface turbulent fluxes, made during a 3 month cruise around the East Siberian Arctic Ocean, from July to early October 2014, and supporting measurements of boundary-layer structure, surface and cloud conditions. Measurements were made in a wide range of sea-ice conditions ranged from open water, through marginal ice, to dense pack ice.

More detailed examinations of different aspects of the measurements, contributions to the surface drag, and comparisons with existing bulk parameterizations will be presented in associated talks and/or posters.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Barbara Brooks**

Head, NCAS Atmospheric Measurement Facility  
National Centre for Atmospheric Science

**Interactions between Arctic clouds, boundary-layer structure, and surface conditions over the Arctic Ocean**

Co-authors: Peggy Achtert, Ian M. Brooks, John Prytherch, Dominic J Salisbury, Joseph Sedlar, Michael Tjernström, Georgia Sotiropoulou, P. Ola G. Persson, Matthew D. Shupe, Paul Johnston, Daniel Wolfe.

Boundary layer clouds are closely coupled to both the thermodynamic and turbulent properties of the boundary layer as a whole, and are a strong control of the surface radiation budget. They remain poorly represented in models, and a major source of uncertainty for projections of future climate. In the Arctic these clouds may differ from those at lower latitudes, often being mixed phase with ice and water coexisting. During the Arctic summer turbulent surface fluxes are usually weak and radiatively driven turbulence in cloud may be a significant – perhaps dominant – control on boundary layer mixing.

During the Arctic Clouds in Summer Experiment (ACSE), boundary layer dynamics and cloud properties were studied with a combination of depolarising Doppler lidar and W-band cloud radar, with boundary layer thermodynamic structure measured with radiosoundings and microwave radiometers. Here we examine the interplay between cloud macro- and microphysical properties, boundary layer thermodynamic structure and turbulent mixing.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Andrew Carleton**

Professor

Dept. of Geography and Earth and Environmental Systems Institute, Penn State University

**Cold-air mesocyclone ("polar low") associations with upper ocean and atmosphere variables in the sub-antarctic, according to teleconnection phases.**

Co-authors: C. Claud, P. Mayewski, K. Maasch

Over middle and higher latitudes of the Southern Hemisphere, intense mesoscale cyclonic vortices that develop in cold air outbreaks -cold air mesocyclones- occur frequently all year, but especially in the winter and transition-season months. Polar mesocyclone inventories derived from satellite-image analysis are first compared to atmospheric and upper-ocean variables pertinent to mesocyclogenesis, as provided by the ERA-40 reanalyses. This procedure allows determination of the large-scale environments favorable to mesocyclone occurrence: low mid-tropospheric temperatures, greater sea ice extent, and large positive differences in the sea surface temperature (SST) minus low-altitude air temperature; the latter generally coinciding with enhanced low level winds having a southerly component. We then evaluate the composite associations between polar mesocyclone formation and dominant patterns of low-frequency variability in the atmospheric circulation, including the inter-seasonal; the El Niño Southern Oscillation (ENSO), the Southern Annular Mode (SAM), the Trans-Polar Index (TPI), and the Semi-Annual Oscillation (SAO). Climatic spatial areas favorable for polar mesocyclogenesis according to teleconnection phases -the Mesocyclogenesis Potential (MCP)- compare well with the available mesocyclone inventories for selected months representative of extremes in the teleconnections (e.g., El Niño and positive SAM 1999, La Niña and positive SAM 2004), but also points to the need for more comprehensive climatologies of mesocyclones. Finally, the MCP areas determined for different reanalysis datasets — and comparisons with the mesocyclone regimes identified in satellite imagery for time periods when and regions where they disagree—is helping us evaluate reanalysis performance for denoting cold-air meso-cyclogenesis over the Southern Ocean and sub-antarctic.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**John Cassano**  
Associate Professor  
University of Colorado

### **Observing the polar atmospheric boundary layer with unmanned aerial vehicles**

Co-authors:

Since 2009 our research group has used small (< 1 kg) and modest (~15 kg) sized UAVs to make observations of polar atmospheric boundary layer features. This presentation will discuss our use of UAVs to study the atmospheric boundary layer including key scientific findings from these UAV flights and lessons learned regarding the operation of UAVs in the Antarctic.

Observations with the smaller UAVs have focused on the hourly to sub-hourly time evolution of the boundary layer over the Ross Ice Shelf in the vicinity of McMurdo Station. The high vertical and time resolution of the UAV boundary layer profiles allows for an unprecedented view of polar boundary layer structure and evolution that provide physical insight into boundary layer processes as well as providing a unique dataset for process-based model evaluation.

The larger UAVs have been used to make observations of the atmospheric and oceanic state over Terra Nova Bay during September 2009 and September 2012. The primary scientific focus of these flights was to document the downstream evolution of the cold, dry continental air mass as it passed over the Terra Nova Bay polynya. Based on observations of the changing atmospheric state estimates of surface heat, moisture, and momentum fluxes were made from the UAV observations.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Dmitry Chechin**

research fellow

Obukhov Institute of Atmospheric Physics

**Low-level baroclinicity and the ABL evolution during cold-air outbreaks in high latitudes: a simple model**

Co-authors: Christof Lüpkes

Cold-air outbreaks (CAOs) in polar regions represent regimes with extremely large surface heat fluxes. During some CAOs a formation of a low-level jet (LLJ) is observed in the atmospheric boundary layer (ABL) over open water. The latter, in turn, can intensify the heat flux at the ocean surface. Here, we consider idealized CAOs over a straight and narrow marginal sea-ice zone. A simple steady-state eulerian dry mixed layer (ML) model is used to describe the effect of baroclinicity on the wind speed in the ABL during CAOs. The model is based on the prognostic equation for potential temperature averaged over the ABL height. The analytical solution of the latter is used to diagnose the ABL height as well as baroclinic components of the geostrophic wind in the ABL. The solutions of the ML model are compared with results of the numerical 3D non-hydrostatic model NH3D in a wide range of parameters typical for Arctic CAOs. It is shown that the ML model is reproducing the ABL growth and heating very well. Also, such parameters of the LLJ as its magnitude and its decay downwind the ice edge are well predicted by the ML model.

Session: **Extreme events in polar regions**

Oral/Poster: **P**

**Linling Chen**

Nansen Environmental and Remote Sensing Center

**What's the difference between these winters?**

Co-authors:

The rise in Arctic near-surface air temperatures has been almost twice as large as the global average in recent decades, but cold, snowy winters have been found over mid-latitude land areas since 2007. Because the Arctic sea ice decline is one of the dramatic indicators of the Arctic warming, and it has both local and remote effects on the other components of the climate system, several studies suggested a possible link between the Arctic sea ice cover and the change of weather pattern in the mid-latitude. However, the physical mechanism behind this possible link is still under debate. Here we choose the severe winters during recent decades, and analyzed the difference in terms of dynamical features in each of them. The purpose is to provide better understanding and long term perspective of the drivers of temperature and precipitation variability in the mid-latitude.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **P**

**Andrey Debolskiy**

Master student

Moscow State University

### **Evaluation of convective boundary layer parameterizations based on LES data**

Co-authors: Victor Stepanenko, Andrey Glazunov

Convective internal boundary layers (CBLs) develop over polynas and leads during cold-air outbreak events in the Arctic region throughout a year. These boundary layers contribute significantly to an overall Arctic surface heat balance. Therefore it's crucial to represent CBLs precisely in numerical weather prediction and global climate models. However, they still cannot be resolved explicitly on these models' grids, so their impact must be parametrized. The first analytic solutions for CBL growth over time was presented almost 80 years ago (Zubov 1945), since then a wide range of parameterizations was developed. This study is aimed to evaluate the most recent of them (e.g. Zilitinkevich et al. 2012) and their performance over a variety of different background flow conditions by comparison to Large Eddy Simulation results. Those parameterizations are based on a bunch of assumptions such as linearity of heat flux with height, horizontal homogeneity of buoyancy inside CBL, etc. The validation of these assumptions under different background flow and surface conditions and an assessment of respective errors in CBL parameters are presented.

N. N. Zubov, Arctic Ice (Izd. Glavsevmorputi, Moscow, 1945) [in Russian].

S. S. Zilitinkevich et al. (Izvestiya, Atmospheric and Oceanic Physics, 2012) Vol. 48, No. 1, pp. 133–142.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**James Doyle**  
Head Mesoscale Modeling  
Naval Research Laboratory

### **Multi-Scale Predictability Characteristics of Polar Lows and Cyclones**

Co-authors:

Intense polar lows and arctic cyclones are notoriously difficult to predict, particularly with regard to their mesoscale features such as near-surface jets. In this study, we compare and contrast initial condition sensitivity and multi-scale predictability aspects of two polar lows, and a severe arctic extratropical cyclone, Dagmar (2011), which was one of the strongest storms to impact Norway in the last 50 years. The adjoint, tangent linear, and nonlinear models for the atmospheric portion of the nonhydrostatic COAMPS system are applied with 15 and 5 km resolution nested grids. The adjoint diagnostics indicate that the intensity of severe winds in these storms prior to landfall was especially sensitive to perturbations in the moisture and temperature fields and to a lesser degree the wind fields. Polar lows are also sensitive to the surface flux distribution, which is linked with the ice edge location. The results of this study underscore the need for accurate moisture observations and data assimilation systems that can adequately assimilate these observations in order to reduce the forecast uncertainties for these severe cyclones. However, given the nature of the sensitivities and the potential for rapid perturbation and error growth, the intrinsic predictability of the mesoscale structure associated with polar lows and arctic cyclones appears to be limited.

Session: **Polar predictability**

Oral/Poster: **O**

**Alice DuVivier**

CIRES/University of Colorado at Boulder

**Analysis of wintertime mesoscale winds and their impact on the oceans around southeastern Greenland**

Co-authors: John J. Cassano

The strong, mesoscale tip jets and barrier winds that occur over the oceans near southern Greenland have the potential for strongly impacting ocean circulation, particularly deep convection. Analysis using the self-organizing map (SOM) technique was performed using winter (NDJFM) 10 m wind data from the European Center for Medium Range Weather Forecasts Interim Reanalysis (ERA-I) and from two regional WRF simulations at 50km (WRF50) and 10km (WRF10) resolutions. Previously identified wind patterns were found to span a range of possible manifestations with different implications for driving an ice-ocean model. WRF50 had faster coastal winds than ERA-I and simulated patterns with strong barrier-parallel flow more frequently than ERA-I. The two WRF simulations had little significant difference in mean wind speed, but larger differences were found for extreme events. The magnitude and location of surface turbulent heat flux maxima can vary dramatically, even among similar wind patterns. The largest differences in mean turbulent fluxes were found over the marginal ice zone (MIZ) and are likely related to treatment of sea ice thickness and concentration in WRF. The response of the ocean component of the Regional Arctic System Model (RASM) to the different types of wind events is assessed for the Irminger Sea and the MIZ along Greenland's southeast coast.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Andrew Elvidge**

Research Associate

University of East Anglia

**Foehn warming distributions in non-linear and linear flow regimes: A focus on the Antarctic Peninsula**

Co-authors: Ian A. Renfrew, John C. King, Andrew Orr,  
Tom A. Lachlan-Cope

The structure of leeside warming during foehn events is investigated as a function of cross-barrier flow regime linearity. Westerly flow impinging on the Antarctic Peninsula provides one of the best natural laboratories in the world for the study of foehn, owing to its isolated, maritime setting and the Larsen C Ice Shelf (LCIS) providing an expansive, homogenous and smooth surface on its east side. Two highly contrasting cases are investigated using aircraft observations and the Met Office Unified Model.

In case A weak southwesterly cross-Peninsula flow and an elevated upwind inversion dictate a highly non-linear foehn event. The consequent strongly-accelerated downslope flow leads to high amplitude warming (associated with ice shelf melt) in the immediate lee of the Peninsula. However, this foehn warming diminishes rapidly downwind, due to upward ascent of the foehn flow via a hydraulic jump. In case C strong northwesterly winds dictate a relatively linear flow regime. There is no hydraulic jump and strong foehn winds flow at low levels right across the ice shelf, mechanically mixing the near-surface levels, preventing the development of a strong surface inversion, and delivering large sensible heat fluxes to the ice shelf. Consequently in case C mean ice melt rates over the LCIS are greater than in case A.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Igor Ezau**

Research Director

Nansen Environmental and Remote Sensing Centre

### **Planetary boundary layer depth as an essential climate variable**

Co-authors:

GCOS defines the atmospheric essential climate variables (temperature, wind, precipitation, earth's radiation budget etc), which are required to characterize the earth's climate system and its evolution. This list does not include the planetary boundary layer (PBL) depth, H. Recently, H has been recognized as a powerful moderator of the climate responses on climate forcing variability. Methods have been developed to retrieve H from satellite and ground-based observations. It opens an opportunity for more detailed consideration of the aggregated effect that H have on climate. We demonstrate that H induces a selective, asymmetric and non-linear responses on positive and negative climate anomalies. Anomalies preferably acting over the periods of shallow PBL have larger contribution to the observed climate variability. It partly explains the polar amplification and, more generally, the larger climate variability and sensitivity in the areas of cold climates where the shallow PBL dominates. We define a PBL-feedback as a deviation of the surface air temperature change from the expected change according to the bulk energy balance equation. The PBL-feedback hypothesis is supported with the in-situ, satellite and modeling data analysis. We show that the inter-model climate scatter in high latitudes should be partially attributed to drawbacks of the stably stratified PBL closures employed in the CMIP-5 models.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

Abstracts: Dynamics of Atmosphere-Ice-Ocean Interactions in the High Latitudes  
23-27 March, 2015 Rosendal, Norway

Abstract # **175**  
**Invited**

**Chris Fairall**  
Branch Chief  
NOAA ESRL Physical Sciences Division

### **Parameterization and Measurement of Surface Turbulent Fluxes at High Latitudes**

Co-authors: A. Grachev, P.O.G. Persson, E.L. Andreas

Air-surface interactions are characterized directly by the fluxes of momentum, heat, moisture, trace gases, and particles near the interface. In the last 15 years advances in observation technologies have greatly expanded the database of high-quality direct (covariance) observations at high latitudes – both over sea ice and from research vessels. In this paper, we will summarize recent observations, including the 1997-98 landmark Surface Heat Budget of the Arctic (SHEBA) field program and recent high latitude ship-based flux measurements. SHEBA's 1-year of continuous observations from 5 levels of sonic anemometers led to major advancements in theoretical understanding of and parameterization of stable surface layers. Advances in sea-going motion-corrected direct flux observations have also led to improvements in characterization of bulk transfer coefficients, gas transfer velocities, and the production of sea-spray aerosols. Much of the recent work at high latitudes has featured pushing the range of observations into the high wind regime ( $U_{10} > 20$  m/s). Ship-based systems also offer an opportunity to investigate wave-ice-atmosphere processes.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Christopher Fairless**

PhD Student

University of Manchester

**A climatology of North Atlantic polar lows and their phase space derived from thermal wind and thermal asymmetry**

Co-authors: Prof David Schultz, University of Manchester;

Dr Christian Franzke, University of Hamburg; Prof Geraint Vaughan, University of Manchester

The Arctic System Reanalysis is the first reanalysis suitable for the direct, automated detection of polar lows. Here it is used to create a climatology for 2000-2010. Relative vorticity maxima are tracked at 850 hPa. Polar lows are defined as systems in unstable polar air masses (a SST – 500 hPa temperature difference exceeding 43°C) with lifetime-maximum winds exceeding 15 m s<sup>-1</sup>.

An annual mean of 289 polar lows are found in the North Atlantic which is higher than previous studies, due to higher resolution and the chosen polar low definition. Polar lows occur from the midlatitude storm track to the ice edge, and are most frequent in the Norwegian Sea and between the Greenland tip and Iceland.

The climatology is used to populate a cyclone phase space (Hart, 2003), representing polar lows' life cycles by baroclinicity and cold-core/warm-core structure in two layers. Cold-core structures (48% of lows) are associated with forward-shear baroclinicity and make up the majority of polar lows near the storm track and ice edge. Lower atmospheric warm-core structures (52% of lows) are associated with reverse-shear baroclinicity (9% of lows) or low baroclinicity (45% of lows), and have higher precipitation rates and mean winds. They make up the majority of polar lows over open high-latitude oceans.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Jennifer Francis**

Professor

Marine and Coastal Sciences, Rutgers University

**Rapid Arctic warming and extreme weather events in mid-latitudes: Are they connected?**

Co-authors:

Arctic ice and snow cover continue to melt/retreat as the Arctic warms at least twice as fast as are northern-hemisphere mid-latitudes, which is reducing poleward temperature gradients. This fundamental change in a key aspect of the climate system is expected to affect large-scale atmospheric circulation patterns. Francis and Vavrus (2012) proposed a mechanism linking this so-called Arctic amplification to more persistent weather patterns in mid-latitudes, which would increase the likelihood of extreme weather events. While a great deal of new research on this linkage has been performed by many groups, an outstanding question is whether the planetary waves in the jet stream are becoming more highly amplified in response to AA. We will present new analysis showing that regionally and seasonally varying decreases (increases) in poleward temperature gradients are associated with: weaker (stronger) upper-level zonal winds, a more meridional (zonal) character to the upper-level flow, and an increasing (decreasing) frequency of high-amplitude jet-stream trajectories. These amplified patterns are known to be associated with slower planetary waves, thus the types of extreme weather events caused by persistent patterns are expected to increase as global warming continues unabated.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Rune Graversen**

Professor

Department of Physics and Technology, University of Tromsø

**Arctic warming induced by atmospheric transport of water vapour**

Co-authors: Mattias Burtu

The atmospheric northward energy transport plays a crucial role for the Arctic climate; the transport brings to the Arctic an amount of energy comparable to that provided directly by the sun. Climate models show that the atmospheric energy transport to the Arctic will remain almost unchanged or will even decrease in the future. This has led to speculations that changes of the atmospheric energy transport does not contribute or rather opposes Arctic warming. However we show here that the atmospheric energy transport will indeed contribute to Arctic warming even while decreasing. A split of the transport into latent and dry-static components reveals that a change of the latent transport compared to a change of the dry-static has a much larger effect on the Arctic climate. An increase of the latent transport at the Arctic boundary causes Arctic warming, both directly due to latent heat release, and indirectly due to increase of water vapour and formation of clouds, which enhances the local greenhouse effect. Climate models tend to agree that the latent energy transport will increase on the expense of the dry-static transport in future simulations. However the Arctic cooling induced by the reduction of the dry-static transport is more than compensated by the warming induced by the latent transport.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Chuncheng Guo**

post-doctor

Geophysical Institute, University of Bergen

### **Baroclinic Instability of the Faroe Bank Channel Overflow**

Co-authors: Mehmet Ilıcak, Ilker Fer, Elin Darelius, Mats Bentsen

The water exchange between the Nordic Seas and the North Atlantic plays an important role in modulating water mass properties and the thermohaline circulation in the Atlantic. Cold and dense bottom water formed in high latitudes passes across the Greenland-Iceland-Scotland Ridge mainly via the Danmark Strait and the Faroe Bank Channel (FBC) and eventually contributes to the formation of North Atlantic Deep Water.

The FBC overflow is studied in this work using the high-resolution regional MITgcm, with a focus on the generation mechanism of mesoscale eddies and their spatio-temporal characteristics. It is found that the volume transport downstream of the FBC sill exhibits strong variability. The cyclonic eddies are associated with a larger plume thickness and width, larger volume transport, colder and denser water, and a plume core located further downslope, whereas the opposite is true for the anticyclonic eddies.

Baroclinic instability is proposed to be the generation mechanism for the unstable plume and mesoscale eddies. A linear instability analysis of a two-layer analytical baroclinic model yields a most unstable mode that agrees favourably with the simulations. The calculation of the divergent eddy heat flux shows a substantial rightward (upslope)-directed component downstream of the FBC sill. This region is also associated with a strong baroclinic conversion rate.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **P**

**Günther Heinemann**  
University professor  
University Trier

### **Katabatic winds and polynya formation**

Co-authors:

The katabatic wind over polar ice sheets is an intensive mesoscale phenomenon and dominates the structure of the wind field over Greenland and Antarctica. The wind system is generated by the formation of a stable boundary layer over the sloped ice surfaces. The katabatic wind is associated with a low-level jet with high wind speeds in the boundary layer. On several occasions, extreme katabatic storms occur, when the katabatic wind system is enforced by synoptic processes. A well-known (and feared) phenomenon is the so-called 'piteraq', which is a strong synoptically enforced katabatic wind at the Greenlandic coast. Near the margins of the Greenland and the Antarctic ice sheet, scale interactions between katabatic storms and other phenomena occur, including the formation of mesocyclones and polynyas. Results of observational and modelling studies are presented for the Arctic and the Antarctic including aircraft-based studies and high-resolution sea-ice/ocean and atmospheric models.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Paul Hezel**

Post-doc

University of Bergen

**Influence of LGM boundary conditions on Greenland precipitation and the polar-front jet**

Co-authors: C.Li, M. Winstrup

High resolution visual stratigraphy of the central Greenland NGRIP ice core reveals individual precipitation events during the last glacial period. A change in frequency of storm events in warmer interstadials compared to colder stadial periods has been found and is hypothesized to be linked to changes in the position of the polar-front jet. We present here simulations with the Community Atmospheric Model 5 (CAM5) at roughly 1 degree resolution to test the effect of high latitude sea ice, sea surface temperature, and topographical boundary conditions on polar-front jet variability and storm frequency impinging on Greenland. We relate these changes to current and expected changes in the Arctic sea ice and North Atlantic SSTs.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **P**

**Christopher Horvat**

Harvard University

**The Floe Size Distribution of Sea Ice**

Co-authors:

In the Arctic, decreasing mean ice thickness and volume points towards an increasingly wide marginal ice zone made up of heterogeneous, thin first-year ice. Such regions require more realistic computation of ice thermodynamics, mechanics, and fracture than is currently available in modern GCMs which are biased towards thick, multi-year ice cover. This environment can be described with a floe distribution, detailing the fractional area occupied by floes in terms of their width and thickness, which we develop in generality.

To motivate this, we demonstrate that ignoring the distribution of floes below the grid-scale strongly affects grid-scale features of air-sea exchange and the ocean heat budget via nonlinear feedbacks between the floe size distribution and surface forcings through a series of GCM experiments designed to emulate the presence of ice floes. We additionally describe a fully dynamic-thermodynamic model for the floe size distribution that is designed for implementation in a GCM. We additionally describe the consequences of the model, particularly in the context of known issues with the ice-albedo feedback and ice thermodynamics in modern GCMs.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Scott Hosking**

Post Doctoral Researcher  
British Antarctic Survey

**Climate variability over West Antarctica: What has happened and what's to come**

Co-authors: Tom Bracegirdle, Hua Lu, Andrew Orr, Gareth Marshall, John Turner

Over the last 50 years West Antarctica has experienced one of the largest increases in regional temperature on Earth. Spatial patterns in observed temperature and sea-ice-extent trends indicate that these are likely linked to changes in the Amundsen Sea Low (ASL): a highly dynamic and mobile climatological low pressure system located in the Pacific sector of the Southern Ocean.

To date, it has been difficult to assess the impact that external influences, such as anthropogenic emissions and tropical variability, have had on the ASL due to the large regional climate variability and the relatively short satellite-based observational record.

In order to diagnose the comparative importance of external forcing on observed change, we will use simulations from the Fifth Coupled-Model Intercomparison Project (CMIP5), which includes more than 40 state-of-the-art climate models with many simulations spanning historical and projected future emissions pathways from the year 1850 to 2100. By using a new set of indices which characterise the ASL, we show how wind patterns are likely to change over the coming century and the subsequent impact of these changes on West Antarctic climate.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **O**

Abstracts: Dynamics of Atmosphere-Ice-Ocean Interactions in the High Latitudes  
23-27 March, 2015 Rosendal, Norway

Abstract # **41**  
**Invited**

**Jun Inoue**  
Associate Professor  
National Institute of Polar Research

### **Arctic Research Collaboration for Radiosonde Observing System Experiment**

Co-authors:

The Arctic Research Collaboration for Radiosonde Observing System Experiment (ARCROSE) has been initiated since 2013 fall. This project consists of the intensified Arctic sounding network and data assimilation researches. The four Arctic stations (Ny-Ålesund: 6 launches per day, Alert & Eureka: 4 launches per day, and the R/V Mirai: 8 launches per day) made special sounding dataset during the 2-week campaign period in September 2013. All of data were sent to GTS, likely improving the accuracy of forecasting and reanalyses data over the Arctic Ocean when compared with other years. The effect of the ARCROSE observations on numerical simulation will be evaluated by using a data assimilation technique to propose a future observing network, leading to a better understanding of the uncertainty of the Arctic atmospheric circulation. The project is expanded in September 2014 in collaboration with the R/Vs Oden and Polarstern. The activity contributes to the preparation phase of the Year of Polar Prediction (YOPP) in 2017/2018, which is intended as intensive observational and modeling periods to advance polar prediction capabilities.

Session: **Polar predictability**

Oral/Poster: **O**

**Richard Jones**

PhD Student

University of East Anglia

**An evaluation of the latest generation of meteorological reanalysis products in the Amundsen Sea, Antarctica.**

Co-authors: Ian Renfrew, Andrew Orr

Meteorological reanalyses are used to force both oceanographic and glaciological models and examine why the glaciers that drain into the Amundsen Sea, Antarctica, are rapidly retreating and thinning. They are also valuable for climatological studies of the semi-permanent Amundsen Sea Low. However, little is known about the accuracy and reliability of global reanalyses in this observation-sparse region. Here we present a comparison between reanalysis fields and three years of data from automatic weather stations (AWS) at three coastal West Antarctic sites. ERA-Interim, CFSR, JRA-55 and MERRA all predict 2 metre temperatures that are cooler than those observed at the AWSs. The magnitude of the mean temperature bias varies from 2.69°C in ERA-Interim to 7.54°C in MERRA. Summertime temperature biases in both ERA-Interim and JRA-55 are  $> 2^{\circ}\text{C}$  smaller than wintertime biases. During strong wind events ( $> 15\text{m/s}$ ) all four of the reanalysis products significantly underestimate the observed wind speed. A series of 38 radiosondes, the first targeted launch campaign in the Amundsen Sea, were released in early 2014. These radiosondes will allow an evaluation of which reanalysis products are most accurately modelling the temperature and wind profile within the atmospheric boundary layer. These results will provide a comprehensive evaluation of reanalysis in the Amundsen Sea region.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Thomas Jung**  
Professor  
AWI

### **The WWRP Polar Prediction Project**

Co-authors:

Increased economic, transportation and research activities in polar regions are leading to more demands for sustained and improved availability of predictive weather and climate information to support decision-making. However, partly as a result of a strong emphasis of previous international efforts on lower and middle latitudes, many gaps in weather, sub-seasonal and seasonal forecasting in polar regions hamper reliable decision making in the Arctic, Antarctic and beyond.

In order to advance polar prediction capabilities, therefore, the WWRP Polar Prediction Project (PPP), has been established as one of three THORPEX legacy activities. The aim of PPP, a ten-year endeavor (2013—2022), is to “Promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hours to seasonal.” In order to achieve its goals, PPP will enhance international and interdisciplinary collaboration through the development of strong linkages with related initiatives; strengthen linkages between academia, research institutions and operational forecasting centres; promote interactions and communication between research and stakeholders; and foster education and outreach.

Flagship research activities of PPP include sea ice prediction, polar-lower latitude linkages and the Year of Polar Prediction (YOPP), an intensive observational and modelling period centred around the period mid-2017 to mid-2019.

Session: **Polar predictability**

Oral/Poster: **O**

**Sarah Keeley**

Scientist

European Centre for Medium-range Weather Forecasts

**Impact of using a dynamic-thermodynamic sea ice model on ECMWF ensemble forecasts**

Co-authors: Sarah Keeley, Frederic Vitart, Kristian Mogensen, Magdalena Balmaseda, Hao Zuo, Peter Janssen

During the melt and freeze up seasons the ice edge can evolve rapidly. In the current ECMWF ensemble forecast system the sea ice is persisted for the first 10 days and then relaxed towards a recent climatology. The presence of sea ice can influence the atmosphere for example through the surface energy budget; in winter the Arctic surface fluxes can be negligible over sea ice covered areas and as large as  $500\text{Wm}^{-2}$  over open water. Sea ice predictability depends upon the ice distribution both in terms of thickness and concentration, but observations of thickness remain limited. We have generated sea ice concentration and thickness initial conditions using 3DVar of sea ice concentration fields. Here we assess the impact of modelling the evolution of the sea ice explicitly using a single category dynamic-thermodynamic sea ice model (LIM2) into the ensemble forecast system. We assess improvement of the forecast skill of the atmospheric forecast in the polar regions as well as the extra-tropics, we find that there is greatest improvements in the forecast skill at weeks 3 and 4. We also find the the ensemble forecast system is able to largely capture the evolution of the sea ice for extreme events such as 2007.

Session: **Polar predictability**

Oral/Poster: **O**

**Seong-Joong Kim**

Division Director of Polar Climate Change Research  
Korea Polar Research Institute

**Sea ice reduction over the Kara/Barents sea and its impact on East Asia**

Co-authors: Ji-Won Kim  
Baek-Min Kim  
Joo-Hong Kim

The Arctic is warming about 3 times faster than global average and the rapid warming not only influence the local Arctic climate, but also influence on mid-latitude weather, especially in cold seasons. The marked warming over the Arctic has led to marked sea ice reduction. In autumn or early winter, less freezing of sea ice in the Arctic, especially in the Kara/Barents Seas increase atmosphere temperature at lower troposphere by releasing heat from the ocean. The local warming over the Kara/Barents Seas helps develop anticyclonic circulation pattern over Ural mountain region from surface to upper level. While at surface the anticyclonic anomaly strengthens with time, at upper level Rossby wave trains develops and low pressure anomaly at upstream of the Siberia strengthens the Siberian High underneath. At the same time, east Asian trough over North western coast of the Pacific is deepened with time. The strong frigid air blows from eastern Siberia to Northeast China and Korea through the passage between the Siberian High and east Asian trough. The cold surge is generally stronger when the sea ice over the Kara/Barents sea ice lower, indicating the role of the Arctic warming in mid-latitude weather.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **O**

**Martin King**

Researcher

Uni Research Climate; Bjerknes Centre for Climate Research

**Atmospheric mechanisms related to the autumn sea ice and winter circulation link in the Northern Hemisphere**

Co-authors: Momme Hell, Noel Keenlyside

The relationship of Barents-Kara sea ice concentration in October and November with atmospheric circulation in the subsequent winter is examined using reanalysis and observational data. The analyses are performed on high-pass filtered data to reduce the potential effects of slowly-varying external driving factors, such as global warming, on the variables independently. The month-to-month variations in the lag relationships of the atmospheric anomalies related to October and November sea ice concentration are presented. It is found that positive (negative) Barents-Kara sea ice concentration anomaly is associated with a positive (negative) North Atlantic Oscillation-like pattern with lags of up to three months. The evidence of the role of the stratosphere in providing the memory in the system by downward propagation are presented; this is a main finding for this study. Positive (negative) sea ice concentration anomaly in November is associated with a strengthened (weakened) stratospheric polar vortex and these anomalies propagate downward leading to the positive (negative) NAO-like pattern. In the final part, our results suggest that the autumn sea ice and winter atmosphere linkage found by statistical analyses may have a partial atmospheric origin in the pre-winter months with sea ice anomaly driven by the winds.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Svenja Kohnemann**

PhD

University of Trier

**Low-Level Jets and Orographic Effects in the Nares Strait: Model simulations of the ABL over the North Water polynya and comparison with aircraft data**

Co-authors: Guenther Heinemann and Lars Ebner

The high resolution atmospheric model COMSO (German Weather Service) is used to estimate the wind situation in the Arctic with focus on Greenland and the North Water polynya for June 2010. Comprehensive measurements of the wind structure of the boundary layer are available from an aircraft study and used for verification. The reproduction of the vertical wind pattern is highly realistic in the resolutions of 15 km, 5.5 km and 1.3 km. Through coupled analysis of the weather and wind situation, the measured data can be classified in synoptic conditions.

The strong southward low-level winds are associated with orographically channeled flow down the pressure gradient from Lincoln Sea to Baffin Bay and are highly correlated with the pressure difference along the Nares Strait. A strengthening effect of the wind speed is happening when the wind in front of Smith Sound overflows the Greenland coast. As a result the wind speed is reinforced behind the channel in the North Open Water region. Typical low level jets with wind speeds of around 19 m/s occur at the height of 100 m in that region.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Tsubasa Kohyama**

PhD student

University of Washington

**The role of stationary Rossby waves in explaining Antarctic sea ice variability**

Co-authors: Dennis Hartmann

Cross-spectral analysis shows that the intraseasonal time scale, between about 20 and 50 days in period, are at "sweet spot" where geopotential height and Antarctic sea ice extent are most coherent. Across this range of periods, one of the most dominant meteorological variabilities is associated with stationary Rossby waves (SRoW): waves that are excited by many random sources, such as orography and heat sources distributed around the Earth, and sustained by angular momentum conservation. The SRoW modes explain 50-70 percent of intraseasonal variability of Antarctic sea ice during the ice maximum season, depending on longitudinal sectors. These SRoW modes, however, are not correlated with El Niño Southern Oscillation (ENSO) nor Southern Annular Mode (SAM), which have received much attention for explaining Antarctic sea ice variability. Lag regression analysis shows that SRoWs gradually move eastward following the background flow, whose southerly (northerly) wind anomalies push sea ice northward (southward) and provide cold (warm) advection. For the interannual time scale, ENSO and SAM become important for sea ice, but SRoW modes also share comparable variance on this larger time scale. SRoW modes also show trends over the satellite era, but the trends do not appear large enough to explain the expanding Antarctic sea ice.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Erik Kolstad**

Uni Research / Bjerknes Centre for Climate Research

**Extreme small-scale wind episodes over the Barents Sea — when, where and why?**

Co-authors:

The Barents Sea is mostly ice-free during winter and therefore prone to severe weather associated with marine cold air outbreaks, such as polar lows. With the increasing marine activity in the region, it is important to study the climatology and variability of episodes with strong winds, as well as to understand their causes. Explosive marine cyclogenesis is usually caused by a combination of several mechanisms: upper-level forcing, stratospheric dry intrusions, latent heat release, surface energy fluxes, low-level baroclinicity. An additional factor that has been linked to extremely strong surface winds, is low static stability in the lower atmosphere, which allows for downward transfer of high-momentum air. Here the most extreme small-scale wind episodes in a high-resolution (5 km) 35-year hindcast were analyzed, and it was found that they were associated with unusually strong low-level baroclinicity and surface heat fluxes. And crucially, the 12 most severe episodes had stronger cold-air advection than 12 slightly less severe cases, suggesting that marine cold air outbreaks are the most important mechanism for extreme winds on small spatial scales over the Barents Sea. Because weather models are often unable to explicitly forecast small-scale developments in data-sparse regions such as the Barents Sea, these results can be used by forecasters as supplements to forecast model data.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Jørn Kristiansen**  
Division head NWP  
Met Norway

### **Short-range NWP in the polar regions: Status and developments at Met Norway**

Co-authors:

The present weather forecasting models show on average a reduction in forecast skill with increasing latitude in the Arctic. In order to reduce bias and quantify uncertainties in its short-range forecasts Met Norway is improving the modeling capabilities. The main tool is the convection-permitting limited area model HARMONIE-AROME. Higher model resolution increases the potential to resolve small-scale processes, some, like polar lows, unique to the Polar regions. An ensemble prediction configuration has been quasi-operational for the past two winter seasons forecasting on-demand the strike probability of polar lows and the associated severe weather. Future developments include a 2-way coupling with a wave model (WAM) and better understanding of the polar low formation and growth mechanisms. In parallel a deterministic configuration has been employed as input to a very high resolution model for forecasting severe turbulence at Svalbard Airport. At the same time as the AROME model domain is increased, the sea ice model and assimilation is improved, and assimilation of conventional and remote observations, e.g. ASCAT, ATOVS and IASI, are introduced. Recommendations for key areas in the observing system to improve the forecasting capabilities are also investigated. Forecast experience also suggests that the default physical parameterization settings may need re-tuning. Ensemble systems are well suited for such studies.

Session: **Polar predictability**

Oral/Poster: **O**

**Hanneke Luijting**

Senior Meteorologist

Norwegian Meteorological Institute

**Forecasting Polar Lows with an on-demand EPS system**

Co-authors: Eivind Støylen, Gunnar Noer, Jørn Kristiansen, Harold McInnes

The development of polar lows is generally well represented in numerical weather models, however, getting the location and timing right is a challenge. A new method for forecasting polar lows has been developed at the Norwegian Meteorological Institute by a collaboration between the research department, forecasters from Tromsø and the BarentsWatch portal.

A high-resolution EPS with a flexible (on-demand) domain is available over the Nordic and Barents Seas. The forecaster selects which domain to run based on the region with most potential for a polar low. The movement of a polar low is tracked by following vorticity maxima in each of the 10 + 1 members of Harmonie EPS (2.5 km resolution). The result is a strike probability map similar to those commonly used for tropical cyclone forecasting. These maps, together with the probability for wind and precipitation over a certain threshold are then used to issue a forecast on the BarentsWatch portal. This method has been in use for the past two polar low seasons and has proved very successful.

Harmonie EPS is run twice daily, with a run length of 42 hours. A new development is the use of the ECMWF EPS to provide early indications of polar low development 5-10 days ahead.

Session: **Polar predictability**

Oral/Poster: **O**

**Christof Lüpkes**

Senior Scientist

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung

**A parametrization of atmospheric transfer coefficients over fractional sea ice cover accounting for the stability dependence of form drag by floe and melt pond edges**

Co-authors:

A realistic modeling of air-ice-ocean interaction needs a detailed representation of the near-surface atmospheric fluxes of momentum and heat over non-homogeneous sea ice cover. Previous studies show that form drag caused by edges of ice floes and melt ponds needs to be taken into account in the parametrization of the drag coefficient. The derivation of such a recently developed parametrization will be presented with a focus on the stability dependence of the form drag coefficients. Stability corrections are proposed which account for the influence of different stabilities over ice and open water. The proposed parametrizations are available in different stages of complexity and can be used with stability functions based on Monin Obukhov similarity theory, but also with corresponding functions based on the traditional Louis (1969) concept. Furthermore, an idea is presented to account for the influence of floe and melt pond/lead edge generated turbulence on scalar transfer coefficients. The parametrizations can be easily implemented in climate models. An application of the new concept in a global climate model (ECHAM6-FESOM) reveals the potentially large impact of the new parametrizations on simulations of the coupled Arctic climate system.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Francois Massonnet**

FNRS Post-doctoral Research Fellow

Université catholique de Louvain (UCL), Belgium / Catalan Institute of Climate Sciences (IC3),  
Barcelona

**Impact of high-resolution on seasonal skill, reliability and predictability in the global EC-Earth simulations**

Co-authors: V. Guemas, L. Batté, C. Prodhomme, F. Doblas-Reyes

The resolution in climate models is thought to be an important factor for advancing our understanding of near-term climate change. We present here a batch of 10-member retrospective seasonal predictions (1993-2009) carried out with the European community model EC-Earth in three different configurations: coarse resolution ( $\sim 1^\circ$  and  $\sim 60$  km in the ocean and atmosphere models, respectively), mixed resolution ( $\sim 0.25^\circ$  and  $\sim 60$  km) and high resolution ( $\sim 0.25^\circ$  and  $\sim 30$  km). The hindcasts are initialized the 1st of May and November from oceanic and atmospheric reanalyses. We find positive impacts of increased resolution in the prediction of near-surface air temperatures anomalies in Scandinavia over winter, and in the North-Eastern U.S. in summer. At the same time, we note slight improvements in the simulation of interannual variations of the summer Arctic sea ice cover and the NAO. We examine meridional oceanic and atmospheric heat transports as possible factors for explaining these differences, as well as the impact of resolution on the statistics (dispersion) of our ensembles.

Session: **Polar predictability**

Oral/Poster: **O**

**Kelly McCusker**

Postdoctoral Fellow

University of Victoria / Canadian Centre for Climate Modelling and Analysis

### **Isolating the Impact of human-induced Arctic Sea Ice Loss on the Atmosphere**

Co-authors: John Fyfe, Michael Sigmond

Changes in Arctic sea ice play an important role in modulating surface fluxes of heat and moisture, and therefore local near-surface temperatures and precipitation. Whether or not historical sea-ice retreat has had a marked influence on remote climatic changes remains an open and important question. Here the effects of historical sea-ice loss on the atmosphere are isolated by prescribing Arctic sea ice loss from two different observational datasets to an atmosphere-only model. In addition, we prescribe to the atmosphere-only model sea ice loss patterns simulated by an ensemble of historical simulations with the corresponding coupled model. These simulations allow for the separation of the climate effects of forced (human-induced) sea ice loss and the climate effects of (random) sea ice changes induced by internal variability. We find that all scenarios exhibit a robust, shallow Arctic warming, a tendency for lower Arctic sea level pressure, and higher geopotential heights aloft in Autumn and Winter. However, the pattern and magnitude of circulation change outside the Arctic and at upper levels varies widely across simulations. We suggest that internal variability in the sea ice anomaly pattern itself is an important driver in determining midlatitude changes to observed Arctic sea ice loss.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Clio Michel**

Geophysical Institute, University of Bergen

**Environmental Conditions for Polar Lows in the Nordic Seas**

Co-authors: Annick Terpstra  
Thomas Spengler

Polar lows are maritime cyclones occurring in cold air outbreaks in the high latitudes. Their formation is still not well understood but previous studies have shown that the wind shear in their environment during formation is an important factor. The wind shear can be categorized into two main classes, forward and reverse shear. Forward shear indicates conditions when the thermal wind is aligned with the steering-level wind and reverse shear when the thermal wind has an opposite direction to the steering-level wind. An existing track dataset (STARS) over the Nordic Seas covering 9 years (2002-2011) is used to investigate the large-scale environment for PL formation. Our results show that these two types of wind shear feature very different environmental conditions at the initiation time of polar lows. We also present a further analysis based on automatic detected polar low tracks using an existing detection and tracking algorithm from the University of Melbourne, Australia. The analysis is based on ERA-Interim data from 1979 to 2014, which allows us to perform a long-term climatology of polar low densities and characteristics as well as the associated environmental conditions during their formation and development.

Session: **Extreme events in polar regions**

Oral/Poster: **P**

**Richard Moore**

Senior Scientist / Associate Professor  
Norwegian Meteorological Institute, University of Oslo

**Can Analyses of Polar Low Energetics Provide Insight into Observed Structure?**

Co-authors: Thomas Spengler

A fundamental focus of polar low research involves a better understanding of the formation and growth mechanisms that explain the variety of observed disturbances, ranging from comma cloud to hurricane-like vortices. It is a challenging problem, primarily due to the dearth of in-situ measurements over the high latitude oceans. Historically, a number of competing theories have been introduced, leading to contentious debate.

One overarching approach incorporates the framework of moist baroclinic instability. Idealized model studies have unequivocally shown that a spectrum of disturbances can be simulated ranging from larger scale, baroclinically-dominated to smaller scale, diabatically-dominated cyclones. In this manner, the structure of the system can be linked to its energetics.

The goal of this study is to examine the energetics of a number of observed polar lows that exhibit differing structural characteristics. The operational, limited area model of the Norwegian Meteorological Institute (HARMONIE) will be used to simulate the observed events at convective permitting resolution. Every attempt will be made to identify polar lows that have been observed in-situ (one possible source being the Norwegian IPY-THORPEX field campaign of 2008).

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Erlend Moster Knudsen**

PhD candidate

University of Bergen

**A wilder and wetter future?: Insights from two CMIP5 models**

Co-authors: John E. Walsh

Metrics of storm activity in Northern Hemisphere high- and midlatitudes are evaluated from historical output and future projections by the Norwegian Earth System Model (NorESM1-M). Corresponding output from the European Re-Analysis Interim (ERA-Interim) and the Community Climate System Model (CCSM4), a global climate model of the same vintage as NorESM1-M, provide benchmarks for comparison. The focus is on the autumn and early winter, the period when the ongoing and projected Arctic sea ice retreat is greatest. Storm tracks are projected to shift poleward in the future as climate changes under the Representative Concentration Pathway (RCP) forcing scenarios. Cyclones are projected to become generally more intense in the high-latitudes, especially over the Alaskan region, although there are some areas in which intensity is projected to decrease. While projected changes in track density are less coherent, there is a general tendency towards less frequent storms in midlatitudes and more frequent storms in high-latitudes, especially the Baffin Bay/Davis Strait region. Autumn precipitation is projected to increase significantly across the entire high-latitudes. Together with the projected increases in storm intensity and sea level and the loss of sea ice, this increase implies a greater vulnerability to coastal flooding and erosion, especially in the Alaskan region.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **P**

**Hisashi Nakamura**

Professor

RCAST, University of Tokyo

**Potential Importance of a Midlatitude Oceanic Frontal Zone in the Annular-Mode Variability**

Co-authors: Fumiaki Ogawa, Kazuaki Nishii, Takafumi Miyasaka, and Akira Kuwano-Yoshida

Annular-mode variability in the extratropical atmosphere is manifested as latitudinal shifts of an eddy-driven polar front jet (PFJ) and associated stormtrack, both of which are observed climatologically slightly poleward of a midlatitude oceanic front that maintains a surface baroclinic zone against poleward eddy heat transport. A set of “aqua-planet” AGCM experiments with zonally-uniform SST, which mimics the Southern Hemisphere, reveals certain sensitivity of the nodal latitude of anomalous westerlies associated with the annular mode to the latitude of frontal SST gradient. The sensitivity is evident for its positive phase, where PFJ is situated systematically poleward of the SST front wherever it is located. Insensitively to the frontal latitude, by contrast, PFJ for the negative phase resides near 40° latitude, which nearly corresponds to the climatological PFJ axis that is realized without frontal SST gradient. The annular mode can therefore be interpreted as wobbling of the atmospheric circulation system between a regime dominated by thermodynamic influence of frontal SST gradient and that by atmospheric internal dynamics, which is useful for understanding inter-basin differences observed in the Southern Annular Mode signature, with some implications for the observed tropospheric response to the Antarctic ozone depletion.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Thor Erik Nordeng**

Senior scientist

Norwegian Meteorological Institute

**The sea west of Spitzbergen, a cradle for polar low developments**

Co-authors:

Climatological studies of polar lows in the North-Atlantic show that they tend to be found in the warm part of the Norwegian and Barents Seas and that there is a weak maximum of occurrence in the western Barents Sea north of Norway. Little is however known with regard to their genesis areas and why the genesis areas are important in setting up structures which are prone for polar low developments. Our hypothesis is that the open sea area west of Spitzbergen is such a genesis area (“cradle”) for polar low developments and that it prepares the lower atmosphere to be favourable for (“being ready for”) triggering mechanisms such as approaching upper air disturbances. Physical mechanisms for this are discussed and case studies are used to illustrate.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Aleksi Nummelin**

PhD Student

Geophysical Institute, University of Bergen

### **Arctic Runoff, ocean stratification and vertical heat fluxes**

Co-authors: Camille Li

Lars Henrik Smedsrud

We investigate the effects of increasing Arctic river runoff – the largest freshwater source with a clear increasing trend – on the Arctic ocean water mass properties and vertical heat fluxes. We perform runoff perturbation tests with a 1-dimensional ocean-ice-atmosphere column model and a 3-dimensional coupled ocean-sea ice model. In both models the main response is a fresher surface which leads to stronger stratification and larger ocean heat content. However, despite the stronger ocean stratification the increased ocean heat content eventually leads to a larger vertical temperature gradient at the base of the mixed layer and thus the vertical heat flux towards the surface increases. In equilibrium the vertical heat flux at the base of the mixed layer balances the lateral heat convergence below and we show that it is possible to have a constant vertical heat flux with increasing runoff if the increase in temperature and density gradients compensate each other. Furthermore we examine the relationship between the runoff and ocean heat content as well as the compensation between stronger stratification and larger vertical temperature gradient in the CMIP5 ensemble using the RCP8.5 scenario and show that the mechanisms proposed by our idealized simulations are able to explain some of the changes seen in the Arctic ocean.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Tiina Nygård**

Finnish Meteorological Institute

**Humidity inversions – a key to understand polar clouds better?**

Co-authors:

Humidity inversions, i.e., layers where specific humidity increases with height, are very common in the lower troposphere in polar regions. Here we present climatology (2000–2009) and characteristics of humidity inversions in the Arctic and Antarctic, including comparison between these regions, based on data of the Integrated Global Radiosonde Archive. In both regions, roughly half of the humidity inversions were found within the same vertical layer with temperature inversions, whereas the existence of the other half may be connected to uneven vertical distribution of horizontal moisture transport. The most striking difference between the Arctic and Antarctic humidity inversions was the much larger seasonal cycle of inversion properties, such as inversion occurrence and inversion strength, in the Arctic. In neither of the regions, humidity inversion properties were directly linked with cloud cover. Previous studies, limited to short time periods and only to the Arctic, have, however, demonstrated that humidity inversions offer a moisture source aloft for cloud formation and maintenance. Based on our findings, it seems very probable that humidity inversions offer moisture sources nearly all the time in both polar regions, even on multiple levels. These results encourage for further studies on interactions between humidity inversions and clouds, which may offer significant advances to currently poorly-modelled polar clouds.

Session: **Polar predictability**

Oral/Poster: **P**

**Fumiaki Ogawa**

Post Doctoral Researcher

Geophysical Institute, University of Bergen

### **Role of the Mid-latitude Oceanic Front in the Ozone-induced Climate Change in the Southern Hemisphere as Revealed in Aqua Planet Experiments**

Co-authors: Nour-Eddine Omrani (GEOMAR/University of Kiel),

Kazuaki Nishii (RCAST/University of Tokyo)

Hisashi Nakamura (RCAST/University of Tokyo),

Noel Keenlyside (GFI/University of Bergen)

The Southern Hemisphere Annular Mode (SAM) is the dominant mode of low-frequency atmospheric variability in the extratropical Southern Hemisphere, exerting substantial climatic impacts on extensive regions. A decadal trend of SAM observed in the troposphere during the late 20th century is considered to be related to the intensification of the stratospheric polar vortex induced by the ozone depletion. Known as a manifestation of meridional displacements of the eddy-driven polar-front jet (PFJ) and associated storm-track, the tropospheric SAM and its trend may be sensitive to the near-surface baroclinicity associated with the midlatitude oceanic frontal zone. In the present study, aqua-planet experiments with an atmospheric general circulation model are conducted by prescribing two different latitudinal profiles of zonally symmetric sea-surface temperature (SST) with and without frontal gradient in midlatitudes. A comparison of the tropospheric response to the assigned stratospheric ozone depletion between the two SST profiles reveals critical importance of the frontal SST gradient for translating the direct response of the stratospheric polar vortex to the ozone depletion down to the surface by enhancing the SAM variability and allowing the SAM its deep structure into the stratosphere in late spring through early summer.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Einar Olason**

Researcher  
NERSC

### **Heat fluxes through leads in modelled sea ice**

Co-authors: Pierre Rampal, Sylvain Bouillon, Philipp Griewank

Heat and fresh-water fluxes through leads are an order of magnitude larger than those through the ice itself. The proper representation of leads in sea-ice models is therefore important for atmosphere-ocean interactions, as well as ice production and the ice mass balance. Here we examine the fluxes in a winter long simulation using neXtSIM, a sea-ice model with an exceptionally good representation of leads and fractures. We consider the impact of leads in general, contrasting the modelled fluxes through the leads with those through the ice. We also consider model runs with and without a special thin-ice category and examine the effects of including such a category in the model.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Ingrid Husøy Onarheim**

Phd student

Geophysical Institute, University of Bergen

**Loss of sea ice during winter north of Svalbard**

Co-authors: L. H. Smedsrud, R. B. Ingvaldsen, F. Nilsen

Sea ice loss in the Arctic Ocean has up to now been strongest during summer. In contrast, the ice concentration north of Svalbard has experienced a larger decline during winter since 1979. The trend in winter ice area loss is close to 10%/decade, and concurrent with a 0.3°C/decade warming of the Atlantic Water (AW) entering the Arctic Ocean in this region. Simultaneously, there has been a 2°C/decade warming of winter mean surface air temperature north of Svalbard. Generally, the ice edge north of Svalbard has retreated northeastward, along the AW pathway. By making reasonable assumptions about the AW transport, we show that the extra oceanic heat brought into the region is likely to have caused the ice loss. Reduced ice cover leads to more oceanic heat transferred to the atmosphere, suggesting that part of the atmospheric warming is driven by larger open-water area. In contrast to significant trends in ice concentration, AW temperature and air temperature, there is no significant temporal trend in local winds. Thus, winds have not caused the long-term warming or sea ice loss. However, the dominant winds transport sea ice from the Arctic Ocean into the region north of Svalbard, and the local wind has influence on the year-to-year variability of the ice concentration.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Yvan ORSOLINI**

Senior Scientist

Norwegian Institute for Air Research (NILU)

**Impact of snow cover and sea ice on sub-seasonal to seasonal predictions in the Arctic**

Co-authors: R. Senan, G. Balsamo, F. Doblas-Reyes, F. Vitart, A. Weisheimer

Surface conditions at high northern latitudes, such as snow cover or sea ice, act as a boundary forcing which influences not only local meteorological conditions, but also atmospheric teleconnections. We present model results on the impact of such boundary conditions on Arctic predictability on the sub-seasonal to seasonal timescale, using the coupled atmosphere-ocean ensemble prediction system of the ECMWF.

We have performed a suite of forecasts to investigate the impact of snow initialisation on sub-seasonal forecasts, with a focus on the recent cold European winters (e.g. 2009/10). Pairs of two-month ensemble forecasts with either realistic or else “scrambled” snow initial conditions are used to demonstrate how the influence of an anomalously thick snowpack turns from an initial cooling over the continental land masses of Eurasia, to a dipolar pattern with warming over the Arctic and cooling over middle latitudes of Eurasia in association with an intensification of the Siberian High. The maintenance of a negative NAO phase is also seen, with enhanced vertical wave propagation into the stratosphere, highlighting the role of the stratosphere in mediating the rapid influence of the Eurasian snow cover into the North Atlantic regions. We draw a parallel with the warm Arctic/cold continent paradigm associated to sea ice melt.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Stephen Outten**

Researcher

Nansen Environmental and Remote Sensing Centre

### **Role of Sea Ice Reduction in Eurasian Wintertime Cooling**

Co-authors: Igor Esau

Despite a general warming of the Northern Hemisphere in recent decades, a pattern of extremely cold winters has emerged as a robust feature in observations over the last few years over northern continental Europe, Asia and North America. In this study, a region of cooling over mid-latitude Eurasia is identified in the wintertime surface air temperatures of the ERA-Interim and NCEP/NCAR reanalyses. This Eurasian wintertime cooling is related to the decrease of sea ice concentrations in the Arctic. Singular value decomposition (SVD) is used to identify the temporal and spatial pattern of co-variability between the Arctic sea ice concentrations and mid-latitude Eurasian wintertime temperatures. For ERA-Interim, the primary mode explains approximately 59% of the co-variability between these two fields with a strong coupling correlation of  $R=0.68$  ( $p \leq 0.05$ ). The study is extended by examining 20 CMIP5 models for the same pattern of co-variability. While wintertime cooling over Eurasia is found in only a few of the models, the majority do show the same pattern of co-variability between decreasing Arctic sea ice and wintertime Eurasian surface temperatures. This suggests that the Eurasian cooling may be a secondary response to the warming climate of the Arctic.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Stephan Paul**  
PhD Student  
University of Trier

**Long-term statistics of coastal polynyas in the Weddell-Sea using satellite-based thin-ice retrievals**

Co-authors:

Based upon high-resolution thermal-infrared MODIS satellite imagery in combination with ERA-Interim re-analysis data, we derived long-term statistical polynya parameters such as polynya area, thin-ice thickness distribution and ice-production rates from daily cloud-cover corrected thin-ice thickness composites. So far, only short-term investigations were done using thermal- infrared spaceborne measurements, while this study is based on a twelve year investigation period (2002-2013) in the Antarctic Weddell Sea region. The focus lies on the coastal polynyas which are important hot spots for new-ice formation and hence bottom-water formation and heat release into the atmosphere. They also act as biological habitats. The here used MODIS data has the capability to resolve even very narrow coastal polynyas which would stay otherwise undetected in comparison to rather coarse resolution passive-microwave data. Its major disadvantage is the sensor limitation due to cloud cover. We introduce a new spatio-temporal weighted interpolation scheme to account for missing spatial coverage as a result of cloud covered areas. Our findings are discussed in comparison to recent studies based on coupled sea-ice/ocean models and passive-microwave satellite imagery investigating polynya area, heat exchange and ice-production rates in different parts of the Weddell Sea.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Pauline Maury**

Post-Doctoral position

Laboratoire de Météorologie Dynamique

**Exploring Stratospheric-Tropospheric dynamical coupling associated with stratospheric warmings events.**

Co-authors: Chantal CLAUD, Alain HAUCHECORNE  
and Philippe KECKHUT

Stratospheric Sudden Warmings (SSWs) dominate the variability in the Northern Hemisphere's wintertime polar stratosphere. SSWs remain the most impressive dynamical events in the physical climate system. In some dramatic cases, the stratospheric temperatures may rise by 40-50K and the stratospheric polar flow can reverse its direction in the span of few days. These events result from the interaction between the upward tropospheric propagating waves and the polar vortex. Owing to this interaction, the vortex weakens and the stratospheric circulation becomes highly asymmetric, allowing for a strengthening, an equatorward displacement, and, even, a splitting of the stratospheric vortex. SSWs are arbitrary classified as major or minor events if the zonal mean zonal wind at 60°N is sufficient to reverse the zonal mean flow.

SSWs play a key role in the coupling of the stratosphere-troposphere system. For instance, tropospheric cold air outbreaks can struck the midlatitudes, and may relate to a displacement or a strengthening of the stratospheric polar vortex. However, the tropospheric impact of the warming events is poorly known, and only the major warmings are accounted for.

In this context, we propose to classify all the stratospheric warming events in the atmospheric reanalyses to evaluate and discuss the potential impact of such stratospheric pathological polar situations on the troposphere.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **P**

**Will Perrie**

Research Scientist

Bedford Institute of Oceanography

**Waves and wave-attenuation in the marginal ice zone**

Co-authors: Hui Shen

We developed new models for detection of sea ice, and wave-ice interactions within the marginal ice zone (MIZ), using RADARSAT-2 SAR (synthetic aperture radar), and our wave retrieval methodology, we can obtain the wave spectra. We show an example of big waves impacting the ice off the east coast of Greenland. Waves from the open ocean penetrate into the MIZ, to distances of 100s km, with wave attenuation and scattering, and transfer of energy to the ice floes. On Feb. 03 2013, a strong low pressure system dominated the weather off southeast Greenland, reaching 950hpa, with high winds and waves. Altimeter data from satellites Jason-2 and HY-2 indicate wave heights of 4.5-8.0 m in the open ocean. Winds reached 25-30 m/s, with estimated wind directions from the northeast, from satellites ASCAT and HY-2, and Environment Canada. We show the wave transformation as waves propagate through the MIZ, using altimeter-derived wave heights and the SAR image, and deriving wave modulations by the MIZ sea ice. Dominant wave directions shift, as waves propagate from open water into the MIZ; estimates for wave attenuation are made from the SAR image data. Using a forecast model for wave-ice interactions, we verify the wave attenuation, and directional shifts.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Ola Persson**

Research Scientist

CIRES/University of Colorado/NOAA/ESRL

**Atmosphere-Ice-Ocean Interactions During Summer Melt and Early Autumn Freeze-up:  
Observations from the ACSE Field Program**

Co-authors: Matthew D. Shupe, Michael Tjernström, Joseph Sedlar, Ian M. Brooks, Barbara J. Brooks, Göran Björk, John Prytherch, Dominic J Salisbury, Peggy Achtert, Georgia Sotiropoulou, Paul Johnston, and Daniel Wolfe

Surface energy fluxes are key to the annual summer melt and autumn freeze-up of Arctic sea ice, but are strongly modulated by interactions between atmospheric, ocean, and sea-ice processes. This paper will examine direct observations of energy fluxes during summer melt and the onset of autumn freeze-up from the Arctic Clouds in Summer Experiment (ACSE), and place them in context of those from other observational campaigns. The ACSE field program obtained measurements of surface energy fluxes, boundary-layer structure, cloud macro- and microphysical structure, and upper-ocean thermal and salinity structure from pack-ice and open-water regions in the eastern Arctic from early July to early October 2014. Summer measurements showed energy flux surpluses leading to significant surface melt, while late August and September measurements showed deficits, leading to freeze-up of sea ice and the ocean surface. The surface albedo and processes impacting the energy content of the upper ocean appear key to producing a temporal difference between the freeze-up of the sea ice and adjacent open water. While synoptic conditions, atmospheric advection, and the annual solar cycle have primary influence determining when energy fluxes are conducive for melt or freeze, mesoscale atmospheric phenomena unique to the ice edge region appear to also play a role.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Ruth Petrie**

Research Scientist

NCAS-Climate, University of Reading

**Summertime atmospheric circulation response to Arctic sea ice loss in uncoupled and coupled simulations**

Co-authors:

In this work the summertime mid-latitude circulation response to the loss of Arctic sea ice is investigated as it has received relatively less attention than the wintertime response. Since summer has an inherently lower range of natural variability a signal of circulation change may possibly be seen in summertime first.

This presentation will discuss the observed summertime circulation anomalies and present results from atmosphere only and fully coupled ice-ocean-atmosphere experiments that simulate the recent loss of Arctic sea ice in an idealised manner. The fully coupled experiments account for the thinning of the Arctic sea ice and allow for more complex interactions between the ice, ocean and atmosphere in contrast with atmosphere-only experiments in which the sea ice concentration and sea surface temperatures are prescribed.

Results from both the uncoupled and coupled experiments suggest that there is a significant circulation response in the Northern Hemisphere mid-latitudes in summertime. Positive surface heat flux anomalies in the Labrador Sea and Hudson Bay region result in positive tropospheric temperature anomalies which influence the strength of the jet stream over the North Atlantic. The physical mechanism which links the loss of Arctic sea ice to the summertime mid-latitude circulation, including the contribution of ice-ocean-atmosphere fluxes, will be discussed.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Andreas Preußner**

Dept. of Environmental Meteorology, University of Trier

**Thin-ice dynamics and ice production in Storfjorden, Svalbard, based on MODIS thermal infrared imagery**

Co-authors: Günther Heinemann, Sascha Willmes and Stephan Paul

Spatial and temporal characteristics of the Storfjorden polynya, which forms regularly in the proximity of the islands Spitsbergen, Barentsøya and Edgeøya in the Svalbard archipelago under the influence of strong north-easterly winds, have been investigated using thermal infrared satellite data. Thin-ice thicknesses were calculated from MODIS ice-surface temperatures, combined with ECMWF ERA-Interim atmospheric reanalysis data in an energy balance model for the winters of 2002/2003 to 2013/2014 (November to March). Based on calculated thin-ice thicknesses, associated quantities like polynya area and total ice production were derived. A simple coverage-correction scheme was applied to account for cloud-gaps in the daily composite images. During the investigated period, the mean polynya area is  $4555.7 \pm 1542.9 \text{ km}^2$ . The average ice production in the fjord is estimated with  $28.3 \pm 8.5 \text{ km}^3$  per winter and hence lower than in previous studies. Despite this comparatively short record of 12 winter-seasons, a significant positive trend of  $20.2 \text{ km}^3/\text{decade}$  could be detected, which contrasts earlier reports of a slightly negative trend in accumulated ice production prior to 2002. Derived estimates underline the importance of this relatively small coastal polynya system considering its contribution to the cold halocline layer through salt release during ice-formation processes.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**John Prytherch**  
PDRA  
University of Leeds

**Wave state and surface turbulent exchange over low fractional ice cover**

Co-authors: Dominic J. Salisbury, Peggy Achtert, Joseph Sedlar, Georgia Sotiropoulou, Michael Tjernström, Barbara J. Brooks, Ian M. Brooks, Matthew D. Shupe, P. Ola G. Persson, Paul Johnston, Daniel Wolfe, Ben Moat.

In marginal ice or regions of low sea ice concentration within the pack ice, the surface turbulent wind stress depends on a combination of the drag over ice floes and that over wind waves forming over regions of open water. Floating ice both damps wave motions and limits the fetch over which wind waves can form. While the latest drag parameterizations for sea ice include terms for form drag and the influence of ridges and melt ponds, little work has been undertaken on the influence of wind waves in regions of low ice concentration. Similarly, bulk flux parameterizations for ocean-atmosphere exchanges do not consider the impact of low concentrations of sea ice. To date there have been very few measurements of wave state within regions of sea ice coincident with direct estimates of the turbulence stress.

During the Arctic Clouds in Summer Experiment (ACSE) measurements of wave state were obtained with a Datawell DWR-G4 waverider buoy in regions of mixed open water and sea ice in the Arctic Ocean. Simultaneous measurements of wind stress were made by eddy covariance. Here we examine the relationships between surface fluxes, ice concentration, and wave state, and compare them with bulk parameterizations for both open water and sea ice surfaces.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Jamie Rae**

Polar Climate Scientist  
Met Office Hadley Centre, United Kingdom

**Arctic Cyclones and Sea Ice in HadGEM3**

Co-authors: Alexander Todd  
Ann Keen  
Jeff Ridley

Over the past few decades the summer minimum Arctic sea ice extent has demonstrated a significant downward trend, while exhibiting a large degree of interannual variability. While a number of factors contribute to this variability, several recent observational studies have suggested that cyclones entering the Arctic may play an important role. Here, we investigate the impact of cyclones on sea ice area and extent in simulations made with the fully-coupled model HadGEM3. We show that, while Arctic-wide mean-sea-level pressure anomalies in the model significantly impact the simulated large scale ice motion, divergence and melting, the correlations between synoptic-scale cyclone characteristics and sea ice area and extent noted in observations are not seen in the HadGEM3 output. Further investigation is required to identify developments most likely to improved the modelled response of the Arctic sea ice to cyclones.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Roger Randriamampianina**

Researcher

Norwegian Meteorological Institute

**The impact of observations on the quality of numerical weather forecasting over the Arctic**

Co-authors: Harald Schyberg, Thomas Nipen, Maté Mile, and Stéphanie Guedj

The Norwegian Meteorological Institute is participating in the EU funded ACCESS (Arctic Climate Change, Economy and Society) project where some of our tasks are to: a) describe the present weather forecasting capabilities in the Arctic; b) identify the key factors limiting the monitoring and forecasting capabilities, with particular emphasis on the observing system, and give recommendations for key areas to improve the mentioned capabilities. Along the project execution period, the operational models (global – ECMWF; regional – HIRLAM and HARMONIE) were used. While task a) was executed using the ECMWF and HIRLAM models, the HARMONIE non-hydrostatic mesoscale model is used for tasks b). The tasks b) are assessed through observing system experiments (OSEs) and observing system simulation experiments (OSSEs) taking into consideration various types of conventional and satellite observations.

Since this work is under progress, the preliminary results clearly show that surface analysis and satellite radiances (ATOVS and IASI) have strong impact on improving the Arctic analyses and forecasts in lower-troposphere and troposphere in general, respectively. We will also report the results of the OSSE based on a nature run driven by a free run using the French global ARPEGE model and our analysis of the possibilities for future evolutions in the observing system.

Session: **Polar predictability**

Oral/Poster: **O**

**Ian Renfrew**  
Professor  
University of East Anglia

### **Orographic flows in the polar regions**

Co-authors:

The polar and subpolar regions include many of the stormiest locations on the globe. Climatological studies suggest that low-level winds can be gale force up to 15% of the time in the vicinity of high and steep orography, such as the coasts of Greenland, and Antarctica. These locations are prone to orographic jets, such as barrier jets, tip jets and katabatic flows; such mesoscale phenomena (typically order 100 km wide) can be reasonably well simulated given appropriate physical parameterizations and sufficient model resolution (~10 km in this case). Furthermore, as these orographic jets are generally forced by the larger-scale flow reacting to the orography, in theory, they can be predicted as well as this larger-scale flow. A smaller-scale set of orographic jets (~10s km wide) are also common in the polar regions, including gap flows, foehn jets and smaller-scale barrier and katabatic winds. Such jets require significantly higher model resolution (~1 km) for accurate simulation. Other mesoscale weather systems that are presently not well-simulated in global NWP models include polar lows and arctic fronts.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Andrew Roberts**  
Research Assistant Professor  
Naval Postgraduate School

**A new tool to develop and evaluate high resolution coupled atmosphere-ice-ocean physics for the next generation of global Earth System Models**

Co-authors: Wieslaw Maslowski  
Robert Osinski  
Alice DuVivier  
Mimi Hughes  
John Cassano  
Bart Nijssen  
Joe Hamman  
Elizabeth Hunke  
Daniel Feltham  
Michel Tsamados

Up to now, the typical workflow for improving the sea ice component in Global Climate and Earth System Models (GC/ESMs) has been to develop new model physics in stand-alone ice-ocean simulations, and then apply these developments to GC/ESMs. This approach was born of a necessity to use existing, stand-alone sea ice, ocean, land and atmospheric models in untested coupled frameworks, thus ensuring that they had been validated against observations prior to coupling. But this approach can introduce bias into GC/ESMs because the stand-alone tests lack feedbacks inherent in coupled systems. As ESMs become more complex, a new development strategy is needed. In this talk, we demonstrate the the Regional Arctic System Model (RASM) as a new high resolution coupled evaluation platform used to develop the necessary model numerics and physics to create an atmosphere-ice-ocean inertial resolving version of the Community Earth System Model (CESM). Using RASM to evaluate the anisotropic, inertial resolving sea ice component against in-situ buoy and spaceborne observations, we then demonstrate the use of the improved model physics in CESM, and show that improved transient Ekman transport in CESM significantly increases the interaction of the ice-ocean boundary layer with atmospheric storms, resulting in significantly reduced simulated sea ice mass in the Antarctic.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Maxence Rojo**

PhD

Laboratoire de Météorologie Dynamique

**Polar low tracks over the Nordic Seas: a 14 winter climatological analysis.**

Co-authors:

Based on a polar lows climatology for the Nordic Seas between 1999 and 2013, systems have been tracked using satellite images. The dominant polar low characteristics, such as temporal and spatial distributions, size, lifespan, distance traveled, speed of propagation and directions, have been determined.

We will show that, although systems may form and travel over the whole Nordic Seas, genesis is enhanced in areas characterized by warm oceanic currents. At the start of the season (October-November), systems mainly form over the Greenland and Norwegian Seas, but further into winter, they form increasingly over the Barents Sea. In connection with the sea-ice loss in recent years, the number of polar lows has increased especially in late winter to the west of Spitzbergen and in the Barents Sea. Their speed of propagation ranges between 5 and 13 m/s but is observed to be highly variable among cases and even during the lifespan of individual polar lows. Although they generally move southward or southeastward, a substantial number of polar lows have westward and even northward tracks. To a considerable extent, the direction of movement is controlled by the large-scale flow in the lowest atmospheric layers, but mesoscale binary interactions have been noted for some dual polar low systems.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Bert Rudels**

Research Professor

Finnish Meteorological Institute

**Arctic Ocean stability, cooling, freshwater input and sea ice melt**

Co-authors:

The upper Arctic Ocean has two regimes. In most of the deep basins the stability is strong due to input of low salinity shelf water, net precipitation and low salinity Pacific water. The Nansen Basin is different. The stability is weak and the less saline upper layer is created by sea ice melting on top of Atlantic water entering through Fram Strait. This situation depends upon the availability of sea ice formed elsewhere in the Arctic Ocean and driven by the wind towards the Nansen Basin. In an Arctic Ocean with less net ice formation not enough melt water may be formed in the Nansen Basin to create an upper layer that remains at the surface and maintain an ice cover throughout the winter. If the stability disappears, the upper layer convects into the Atlantic water below, removing freshwater. As the Atlantic water subsequently rises to the surface, the remaining ice would quickly melt and a convective regime be established. The Arctic Ocean would change from being primarily a source of low salinity surface water to become a contributor to the Meridional Overturning Circulation. An ice free Nansen Basin in late winter would release more oceanic heat to the atmosphere possibly affecting the atmospheric circulation.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Dominic Salisbury**  
Research Fellow  
University of Leeds

### **Evaluating surface flux parameterizations over Arctic sea ice**

Co-authors: John Prytherch, Michel C. Tsamados, Ian M. Brooks, Barbara J. Brooks, Peggy Achtert, Joseph Sedlar, Michael Tjernström, Georgia Sotiropoulou, P. Ola G. Persson, Matthew D. Shupe, Paul Johnston, Daniel Wolfe, Ben Moat.

Bulk flux algorithms are used in climate and numerical weather prediction models to estimate surface exchange, but over sea ice these algorithms often perform poorly. The paucity of direct surface flux estimates in polar regions is a major limiting factor for the testing and improvement of the algorithms. Their performance is also compromised by failure to account for the spatial and temporal heterogeneity of sea ice due to, for example, the appearance of leads and melt ponds in summer, and the dependence of roughness on ice morphology and age. State of the art parameterizations of turbulent exchange that consider such dependencies have recently been developed.

Here, using direct measurements of surface stress, heat and moisture fluxes obtained during a three month cruise in the Arctic Ocean during summer 2014, we test several parameterizations to evaluate their performance and highlight atmospheric and surface regimes that adversely impact the bulk flux estimates.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Kazutoshi Sato**

The Graduate University for Advanced Studies

**Influence of the Gulf Stream on the Barents Sea ice retreat and Eurasian coldness during early winter**

Co-authors:

Abnormal sea-ice retreat over the Barents Sea during early winter has been considered a leading driver of recent midlatitude severe winters over Eurasia. However, causal relationships between such retreat and the atmospheric circulation anomalies remains uncertain. Using a reanalysis dataset, we found that poleward shift of a sea surface temperature front over the Gulf Stream likely induces warm southerly advection and consequent sea-ice decline over the Barents Sea sector, and a cold anomaly over Eurasia via planetary waves triggered over the Gulf Stream region. The above mechanism is supported by the steady atmospheric response to the diabatic heating anomalies over the Gulf Stream region obtained with a linear baroclinic model. The remote atmospheric response from the Gulf Stream would be amplified over the Barents Sea region via interacting with sea-ice anomaly, promoting the warm Arctic and cold Eurasian pattern.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **P**

**Elisabeth Schlosser**

FWF Fellow  
Inst. of Meteorology and Geophysics  
Univ. Innsbruck

**An extreme precipitation event in coastal Antarctica - a study with Polar WRF**

Co-authors: J. G. Powers, K. W. Manning, M. G. Duda, S. Gillmeyer

An extreme precipitation event that was outstanding in the more than 30 yr - time series of weekly accumulation measurements at the German wintering base Neumayer, coastal Dronning Maud Land, Antarctica, was investigated using Polar WRF. The event was associated with extreme warming in large parts of the Antarctic continent. This was caused by a strong amplification of Rossby waves leading to a persistent northerly flow that advected warm and moist air from relatively low latitudes, yielding precipitation amounts within two weeks that correspond to about 60% of the total annual accumulation at Neumayer Station and a temperature increase of 20 centigrade within a few days at South Pole. The northerly flow ultimately continued across South Pole (thus becoming a “warm” “southerly” flow by definition) to the Pacific part of the Southern Ocean.

Comparison to a case with similar upper-air flow but different surface pressure conditions showed that a necessary requirement for high precipitation is a strong northerly flow at both surface and higher levels. Amplification of Rossby waves above the Southern Ocean is more likely in the negative state of the Southern Annular Mode (SAM), when the pressure gradient between middle and high latitudes is relatively small and the meridional exchange of heat and moisture increased.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**James Screen**  
NERC Research Fellow  
University of Exeter

**The impact of Arctic warming on midlatitude weather: Can it? Has it? Will it?**

Co-authors: Elizabeth Barnes

The Arctic region has warmed more rapidly than the globe as a whole, and this has been accompanied by unprecedented sea ice melt. Such large environmental changes are already having profound impacts on Arctic weather. An open question, however, is whether these Arctic changes have an effect on weather patterns further south. This broad question has recently received a lot of scientific and media attention, but conclusions appear contradictory rather than consensual. I will argue that one point of confusion has been ambiguities in the exact question being posed. This talk will review the evidence around three clear and tractable questions: Can Arctic warming influence midlatitude weather? Has Arctic warming significantly influenced midlatitude weather already? Will continued Arctic warming significantly influence midlatitude weather in the future? Framing the Arctic-midlatitude linkages debate around the three questions - Can it? Has it? Will it? - reveals common insights emerging in the literature; however, these three questions are still a long-way from being fully answered. The community must make appreciable progress towards addressing each of these questions, and even if our efforts ultimately lead us to answer to all three with “not really”, there’s still a good chance we’ll learn a lot about our climate system along the way.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **O**

**Joseph Sedlar**

Stockholm University

**Observed structure of static mixing dependence on liquid condensate and vertical velocity within Arctic mixed-phase clouds**

Co-authors:

Large cloud fractions, containing both liquid and ice hydrometeors, are a semi-persistent feature of the Arctic atmosphere. Such mixed-phase clouds have a dominant forcing on the radiative energy balance at the surface and control the boundary layer structure, surface temperature and surface ice and snow melt/freeze. Generally these clouds persist via large-scale advection, buoyant overturning from radiative divergence producing cloud-scale vertical motions, subsequent microphysical interactions, and their coupling with the surface. Due to the vast nature of the Arctic region and difficult conditions for deploying instruments capable of measuring these processes, much of the understanding of Arctic mixed-phase is based on numerical model studies. In this study, observations of mixed-phase clouds from both long-term (Barrow; SHEBA) and seasonal (ASCOS; ACSE) high-latitude Arctic observatories/expeditions are examined. The static mixing structure in the cloud- and subcloud-layers are presented. A dependence on the cloud liquid water path is highlighted, suggesting the increased emissivity enhances near-cloud top radiative divergence and mixing potential. A radiative-thermodynamic feedback loop is hypothesized and presented. Additionally, statistical analysis of derived in-cloud vertical motions reveals the coupling/decoupling nature of the cloud-surface system is determined by synoptic-scale forcing and cloud radiative shielding, as opposed to variation in cloud vertical velocity strength.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Raymond Sellevold**  
Student  
Universitetet i Bergen

**Investigating the potential influence of anomalous heating related to Arctic amplification on wintertime stationary wave activity: an idealized approach**

Co-authors: Camille Li, Universitetet i Bergen  
Stefan Sobolowski, Uni Research

There has been a raft of manuscripts which claim to show that Arctic amplification (AA) is responsible for changes in the large-scale wintertime mid-latitude atmospheric circulation. Responses to these studies have shown that the results are likely artifacts of the chosen methodology, but do not discount the potential influence of AA on the mid-latitude circulation. Few have investigated the physical mechanisms that might link the anomalous heating to mid-latitude circulation. In this investigation we employ a linear stationary wave model to investigate the hypothesis that AA, in the form of a low-level anomalous heating of the atmosphere, can drive a mid-latitude circulation response. The model is well suited to the question due to its ability to reproduce the observed atmospheric circulation, and its simplicity as it requires only four forcing components plus the zonal mean state from reanalysis. Interpreting the model results is relatively straightforward. Reanalysis data from ERA-I show that while AA is a phenomenon that is present in all seasons the heating anomaly maximas occur in the Barents Sea in October and in the Kara-/Beaufort Seas in December. In this study an ensemble of simulations are performed with diabatic heating imposed in these regions. The preliminary results are presented here, with an evaluation of the atmospheric response.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **P**

**Vladimir Semenov**

A.M. Obukhov Institute of Atmospheric Physics RAS

**Atmospheric model simulations forced with realistic Arctic sea ice anomalies: implications for the recent cold winters and related mechanisms**

Co-authors: Shuting Yang (Danish Meteorological Institute)  
Torben Königk (Swedish Meteorological and Hydrological Institute)  
Yongqi Gao (Nansen Environmental and Remote Sensing Center)  
Noel Keenlyside (Geophysical Institute, University of Bergen)

The early 21st century was marked by several severe winters over Central Eurasia linked to a blocking anti-cyclone centered south of the Barents Sea (BS). The increased occurrence of anomalously cold winters coincided with reduced winter Arctic sea ice cover (ASIC), especially in the BS. Simulations with a high-resolution AGCM forced by sea ice anomalies observed during the last decades are used to investigate possible links. The regional circulation response to reduced ASIC in 2005-2012 exhibits a statistically significant anti-cyclonic surface pressure anomaly and a surface temperature response similar to that observed. The results suggest that the recent BS sea ice reduction may have been responsible for the recent anomalously cold winters in Central Eurasia. Moreover, a non-linear atmospheric circulation response to the ASIC decline during the last 40 years is suggested. Simulations with ASIC anomalies prescribed for winter months only reproduce very similar circulation changes thus implying direct response mechanism rather than delayed response due to preceding autumn sea ice reduction.

In the NordForsk GREENICE project we assess the robustness of these results with coordinated experiments with four different AGCMs. Twin experiments are performed: one with time varying SST and sea ice cover, and another with climatological SST and time varying sea ice cover. Preliminary results will be presented.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **O**

**Tido Semmler**

Scientist

Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

### **Fast atmospheric response to a sudden thinning of Arctic sea ice**

Co-authors: Thomas Jung, Soumia Serrar

Due to record-breaking Arctic sea ice extent minima in the last decade, a lot of attention has been paid to the atmospheric large-scale circulation response to decreased Arctic sea ice area. However, also a substantial thinning of Arctic sea ice has been observed which modifies the heat flux through the ice. We focus on the fast atmospheric response to a sudden thinning of Arctic sea ice to disentangle the role of various different processes. Overall the response of the atmospheric large-scale circulation is relatively small with up to 2 hPa in the Arctic mean sea level pressure and even smaller changes in the mid-latitudes during the first 15 days; the quasi-equilibrium response reached in the second and third month of the integration is about twice as large. During the first few days the response tends to be baroclinic in the whole Arctic. Already after a few days an anti-cyclonic equivalent-barotropic response develops over north-western Siberia and north-eastern Europe. The structure resembles very much that of the atmospheric equilibrium response indicating that fast tropospheric processes such as fewer quasi-barotropic cyclones entering this continental area are key opposed to slower processes such as those involving, for example, stratosphere-troposphere interaction.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **P**

**Denis Sergeev**

PhD student

University of East Anglia

### **Structure and dynamics of a shear-line polar low during a cold-air outbreak over the Norwegian Sea**

Co-authors: Ian Renfrew

During the Aerosol-Cloud Coupling And Climate Interactions in the Arctic (ACCACIA, 2013) field campaign, a polar low (PL) developed on a 'rolling up' horizontal shear zone inside a prolonged marine cold-air outbreak over the Norwegian Sea. It was one of less than a dozen PLs and the first shear-line case ever to be observed with an instrumented aircraft. Comprehensive airborne data provided by unique range of onboard equipment is applied to study the structure and dynamics of the vortex. The developing PL was measured by dropsonde and lidar observations taken south of Svalbard. Examination of operational forecasts and satellite imagery suggested that the upstream presence of Svalbard in the northerly flow may have played a significant role in determining the location and strength of the shear line. This hypothesis will be tested via idealised and case study sensitivity experiments using the UK Met Office Unified Model (MetUM). High values of relative vorticity and small horizontal gradients of potential temperature in the lower troposphere indicate that barotropic instability may be a key mechanism in triggering the PL; although high surface heat fluxes and convective clouds were also present, indicating a convective instability may also be at work. The contributions of shear instability and other potential factors will be assessed.

Session: **Extreme events in polar regions**

Oral/Poster: **P**

**Matthew Shupe**

Research Scientist

CIRES / University of Colorado and NOAA

**Enhancing process understanding in the coupled Arctic atmosphere-ocean-ice system through MOSAiC**

Co-authors: Klaus Dethloff and the MOSAiC planning consortium

There exist many uncertainties in our understanding of the coupled Arctic climate system that inhibit our abilities to comprehend the recent decline in sea ice, to draw large-scale linkages, and to represent these processes in numerical models. Leading uncertainties involve mesoscale processes related to clouds and aerosols, stable boundary layers, vertical mixing, energy fluxes through sea ice, the buildup and release of upper ocean heat, and the influences of these on biogeochemical processes. Substantial advancement requires unraveling the coupled interactions among these processes including numerous feedbacks and responses that vary as a function of season, ice coverage, and/or meteorological state.

To gain the process-level knowledge needed to address these critical gaps requires year-round, coordinated, and comprehensive measurements extending from the atmosphere through the sea ice into the central Arctic Ocean. The Multi-disciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) is an international, inter-disciplinary initiative designed to provide such detailed process observations from an icebreaker drifting with the ice pack for a full year, combined with a constellation of distributed observations, and a hierarchy of coordinated modeling and synthesis efforts. This presentation will lay out the scientific motivation and foci for the initiative within the context of central Arctic coupled system processes.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Harald Sodemann**

University of Bergen

**Synoptically driven extremes of poleward moisture transport**

Co-authors:

Atmospheric moisture transport to the polar regions is strongly coupled to the prevailing large-scale circulation. A limited number of events occurring on the synoptic time scale can be responsible for the bulk of poleward moisture transport during one season. Recently, there have been indications that anticyclonic wave breaking favors strong interaction between polar latitudes and mid-latitudes. Here we investigate the 10 largest events during the ERA-Interim period in terms of the duration, the moisture source regions, moisture lifetime, and transport pathways in relation to the prevailing circulation. The principal tool thereby is a Lagrangian moisture source diagnostic. It is furthermore investigated how applicable the Atmospheric River concept is as a framework for describing the such extreme moisture transport events.

Session: **Large scale circulation and mid-latitude interactions**

Oral/Poster: **O**

**Georgia Sotiropoulou**

PhD student

Department of Meteorology, Stockholm University

**The thermodynamic structure of summer Arctic stratocumulus and the dynamic coupling to the surface**

Co-authors: Joseph Sedlar, Michael Tjernström, Matthew D. Shupe, Ian M. Brooks and P. Ola G. Persson

The vertical structure of Arctic low-level clouds and Arctic boundary layer is studied, using observations from ASCOS campaign, in the central Arctic, in late summer 2008. Two general types of cloud structures are examined: the “neutrally-stratified” and “stably-stratified” clouds. Neutrally-stratified are mixed-phase clouds where radiative-cooling near cloud top produces turbulence that generates a cloud-driven mixed layer. When this layer mixes with the surface-generated turbulence, the cloud layer is coupled to the surface, whereas when such an interaction doesn’t occur, it remains decoupled; the latter state is most frequently observed. The decoupled clouds are usually higher compared to the coupled; differences in thickness or cloud water properties between the two cases are however not found. The surface fluxes are also very similar for both states. The decoupled clouds exhibit a bimodal thermodynamic structure, depending on the depth of the sub-cloud mixed layer (SML): clouds with shallower SMLs are disconnected from the surface by weak inversions, whereas those that lay over a deeper SML are associated with stronger inversions at the decoupling height. Neutrally-stratified clouds generally precipitate; the evaporation/sublimation of precipitation often enhances the decoupling state. Finally, stably-stratified clouds are usually lower, geometrically and optically thinner, non-precipitating liquid-water clouds, not containing enough liquid to drive efficient mixing through cloud-top cooling.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Thomas Spengler**  
Associate Professor  
University of Bergen

### **Polar Low Development in forward and reverse shear Arctic moist-baroclinic Environments**

Co-authors:

Polar lows are maritime cyclones occurring in cold air outbreaks in high latitudes. Their formation and intensification is still not fully understood but previous studies have shown that wind shear, baroclinicity, latent heat release, and surface fluxes are important factors during formation. The wind shear can be categorized into two main classes, forward and reverse shear with respect to the thermal wind. This study examines the influence of moisture, baroclinicity, and static stability on developing disturbances at high latitudes by utilising an idealised baroclinic channel model. The set-up is composed of environmental baroclinicity defined by a zonally uniform jet in thermal wind balance with a meridional temperature gradient and moisture content defined by relative humidity profiles. Initiation of disturbance growth is achieved by superimposing a weak, surface-based warm-cored cyclonic disturbance to the set-up. The experiments show that the disturbance is able to amplify within such an environment in the absence of an upper-level perturbation, surface fluxes, friction, or radiation.

Separation between developing and non-developing disturbances is feasible by considering the baroclinic and diabatic contributions to eddy available potential energy. Developing disturbances show a clear diabatic dominance during the early stage of development, whereas experiments lacking this diabatic boost fail to intensify within a 3-day time window. A comparison with the conceptual framework of the Diabatic Rossby Vortex (DRV) growth mechanism provides insight into the dynamical pathway potentially underlying the enhanced amplification. A suite of sensitivity experiments examines the range of atmospheric conditions in which enhanced amplification by diabatic processes is possible. Threshold values for moisture content and isentropic slopes are identified.

The role of reverse shear is also discussed, where the different wind shear features very different environmental conditions at the initiation time of polar lows. Surface fluxes have, in general, an intensifying influence on the development of polar lows, yet the physical processes leading to this intensification are dominated by non-linear interactions between sensible and latent heat fluxes as well as latent heat release, which renders a clear attribution to individual forcing mechanisms difficult.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

Abstracts: Dynamics of Atmosphere-Ice-Ocean Interactions in the High Latitudes  
23-27 March, 2015 Rosendal, Norway

Abstract # **184**  
**Invited**

**Sharon Stammerjohn**  
Senior Research Associate  
INSTAAR/University of Colorado Boulder

### **Polar Sea Ice Changes over the Last 36 Years**

Co-authors:

Major changes are apparent in the global distribution of sea ice, a key modulator of Earth's climate system, a sensitive indicator of climate variability and a critical ecological habitat. A recent assessment of polar sea ice extent changes over 1979 to 2013 shows an annual decrease in the Arctic ( $-54.6 \times 10^3 \text{ km}^2/\text{a}$ ) and an increase in the Antarctic ( $+15.3 \times 10^3 \text{ km}^2/\text{a}$ ), the latter now almost one-third the magnitude of the Arctic trend (Simmonds, 2014). It has been suggested that the different hemispheric sea ice changes are largely resulting from different topographic factors and land/sea distribution (Turner and Overland, 2009). However, in both polar regions there are distinctly different sea ice changes at regional and seasonal scales. These are investigated and compared in terms of air-sea-ice interactions and ice-ocean feedbacks. This approach helps identify the different regional/seasonal sensitivities of sea ice and lends deeper insight into why these two polar regions appear to be responding differently to climate change.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **O**

**Eivind Støylen**  
Scientist  
MET Norway

### **A tracking algorithm for forecasting Polar Lows**

Co-authors:

Polar Lows (PL) are intense mesoscale low pressure systems developing over a few hours in the Arctic region. Accurately forecasting PLs with respect to location and timing is a challenge, motivating the development of a dedicated automatic PL forecasting system at MET Norway. This system has been operational at MET since October 2012, see presentation by Hanneke Luijting for details on the application and experiences from three years of PL forecasting.

Here we present the details on the PL forecasting algorithm; that is, the tracking procedure utilized on the wind field from a high resolution non-hydrostatic ensemble model system. Individual model tracks are combined into a strike probability map providing the forecasted probability of PL occurrence within the forecast period. We present the sensitivity of the resulting map to varying model parameters, and show some verification for the 2012/2013 season.

Session: **Polar predictability**

Oral/Poster: **P**

**Irene Suomi**

Finnish Meteorological Institute

**Wind gusts over Arctic sea ice**

Co-authors: Timo Vihma

Wind gusts, defined as short duration wind speed maxima, represent the high extremes in the turbulent wind field. The mechanisms that create gustiness are wind shear, buoyancy and in stable conditions also gravity waves. Majority of gust related research is based on studies in the mid-latitudes. In the Arctic, gusts have received less attention. However, over the Arctic sea ice zone there are large variations in both the surface roughness and stability. Ice ridges and other changes in ice thickness cause differences in the surface roughness, whereas the near-surface stability conditions may have abrupt changes due to leads and polynias. Moreover, in the Arctic the prevailing stable conditions especially during winter are favourable for gravity wave formation. In this study we will use measurements from research aircraft campaigns over the Arctic sea ice to analyse the overall gustiness conditions within a few hundred meters deep layer above the sea surface. In addition, the aircraft measurements provide a new insight to gust parameterizations. Traditionally gust parameterizations are based on data at one point only, whereas aircraft measurements provide gustiness information over a larger area. The aim of this study is to test existing parameterization methods on aircraft data and thereby further develop the methods to predict gusts in the Arctic.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Annick Terpstra**  
PhD student  
University of Bergen

### **Influence of Surface Fluxes on Polar Low Development: Idealised Simulations**

Co-authors:

Polar lows develop during marine cold air outbreaks in regions with relative large sea surface temperature (SST) gradients favourable for large surface sensible and latent heat fluxes. Furthermore, the differential heating can provide a source for baroclinicity.

We utilize an idealized channel model to gain insight in the role of surface fluxes on the dynamical evolution of polar lows. The initial setup consists of a baroclinic jet in thermal wind balance. To mimic cold air outbreaks we introduce an SST distribution which is warmer than the low level surface air temperature, where the SST has a meridional gradient similar to the SST gradient in the Nordic Seas during winter.

This setup allows for a systematic investigation of the relative contributions from surface sensible and latent heat fluxes on polar low development by varying the intensity of the initial baroclinicity, moisture, and SSTs. In addition, we performed all simulations with either sensible or latent heat fluxes switched off.

The simulations are evaluated in terms of structural evolution and the relative importance of the generation of eddy available potential energy via diabatic versus baroclinic processes, where the diabatic contributions are separated into different parameterized subgrid-scale processes such as latent heating from cumulus convection or micro-physical processes as well as surface fluxes.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

**Amelie Tetzlaff**

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung

**The impact of leads in sea ice on the atmospheric boundary layer: results from the aircraft campaign STABLE 2013 in the Northern Fram Strait**

Co-authors:

Leads in sea ice play an important role for the heat and moisture exchange between the polar ocean and atmosphere. Large differences between the air and surface temperatures over leads induce the formation of internal boundary layers with strong convective plumes often penetrating the lowest layers of the capping inversion.

In this contribution we present results of the campaign STABLE (Spring Time Arctic Boundary Layer Experiment) that was carried out by the Alfred Wegener Institute in March 2013 using the aircraft Polar 5 for meteorological measurements over the sea ice of the Northern Fram Strait.

We show results concentrating on the overall effect of lead ensembles supplemented by case studies of four individual leads differing by geometry, thin-ice cover, and atmospheric forcing conditions. Near-surface heat fluxes over the individual leads were measured in a range from 25 to 250 W/m<sup>2</sup> and convective plumes were visible in flux profiles of sensible heat and momentum. In addition, our measurements indicate that the development of internal boundary layers depends on the lead width, the prevailing ice conditions on the leads, and the inflow boundary layer thickness. On a larger scale, we found a strong dependence of the near-surface mean atmospheric temperature on the lead concentration.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Steffen Tietsche**

Postdoctoral Research Scientist

NCAS/Department of Meteorology, University of Reading

**Simulated Arctic Ocean heat budget in seasonal to interannual predictions**

Co-authors: Ed Hawkins

Jonny Day

The relative role of oceanic versus atmospheric heat fluxes in natural variability of sea ice and ocean heat content in the Arctic is unclear, yet crucial for progress in understanding and predicting Arctic climate. Here, we determine the relative contributions of oceanic and atmospheric heat fluxes to ensemble spread in upper Arctic Ocean heat content in a set of idealised interannual predictability experiments with the climate model MPI-ESM. We find that, for Arctic surface water down to 100m depth, atmospheric heat flux dominates ensemble spread for the first lead year. However, the oceanic contribution is as large as the atmospheric contribution in the second lead year, and even larger than that in the third lead year. There is strong anticorrelation between atmospheric surface heat flux and vertical ocean heat flux at 100m depth. These results suggest that sub-surface oceanic processes play an essential role in polar predictions, especially at longer lead times.

Session: **Polar predictability**

Oral/Poster: **O**

**Michael Tjernström**  
Professor  
Stockholm University

### **The role of clouds in shaping Arctic climate**

Co-authors: To many to list!

Clouds remain the largest uncertainty in understanding climate; this is more true for the Arctic than for other region on Earth.

This due to a paucity of both routine and research-grade observations in the Arctic, and to several peculiarities in the Arctic system that makes cloud effects on the surface different context compared to other very cloudy regions on Earth.

The Arctic has a dominant annual, but much weaker diurnal, cycle in solar radiation. Even in summer, when the sun is up all day, the solar zenith angle is typically large. Combined with a high surface albedo, longwave radiation effects dominate over solar, and clouds typically warm the surface most of the year, at least over the ice covered ocean.

The warming is sensitive to cloud characteristics: phase (liquid or ice) and microphysics. Mixed-phase clouds are very common, and this type of cloud, where liquid and ice coexist, is naturally unstable. It is critically dependent on the vertical turbulent circulation in the cloud which in the Arctic contribute to droplet formation at the same rate as droplets form frozen precipitation. This circulation, in turn, depends on cloud top cooling, which needs liquid water.

And all of this is linked back to the large scale circulation through the aerosol climate.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Teresa Valkonen**

Researcher

Norwegian Meteorological Institute

### **Impact of ASCAT scatterometer winds on the numerical forecasting of polar lows**

Co-authors: Harald Schyberg, Hanneke Luijting, Gunnar Noer

Polar lows are intense mesoscale cyclones causing major challenges for activities in the Arctic. One factor limiting the forecasting capability of polar lows is shortage of observations from the region. Satellite based scatterometer observations provide information of ocean surface winds, and help to improve the initial state of NWP model through data-assimilation methods.

For selected polar low cases, Advanced Scatterometer (ASCAT) ocean surface winds from polar-orbiting MetOp satellites are applied in the 3-dimensional variational (3DVAR) data assimilation system available in the high-resolution HARMONIE model system. Quality and coverage of these wind data, and impact on forecast performance are studied.

Polar lows are found to be observed by scatterometer winds, although temporal and spatial coverage of data is limited by satellite orbits and instrument geometry. The impact of ASCAT data assimilation is weak on average verification statistics, but most benefit is gained during the time of the polar low event. The sensitivity of data thinning and assimilation window length are also discussed.

The results suggest that 3DVAR assimilation of ASCAT winds could be beneficial for forecasting of polar lows in a limited area model. However, the results indicate limitations in the present assimilation system and call for evolution in assimilation methodology for better use of scatterometer winds in high-resolution NWP.

Session: **Polar predictability**

Oral/Poster: **O**

**Marie Vicomte**  
postdoctoral  
LMD

### **On associations between surface conditions and polar lows**

Co-authors:

Polar lows are intense meso-cyclones forming in winter at high latitudes over open water. The sudden development of the phenomenon together with the sparsity of conventional measurements in the genesis and development areas, generally result in a low forecasting skill. In addition, their relatively small-scale and short life time mean that they are usually not well represented in model outputs and meteorological reanalysis data sets. Reanalyses can however be used for studying the large scale circulation associated with such developments. Indeed, geopotential height at 500 hPa, the temperature difference between the ocean surface and 500 hPa, lower layer winds and the potential vorticity at 300 hPa show significant anomaly patterns over large areas centered over polar lows genesis areas during a 8-10 day period.

In this presentation, the associations between surface conditions and large scale environment prone to the development of polar lows are investigated. First, we will show that positive (negative) extent anomalies of arctic sea ice at the end of the summer lead to favourable (unfavourable) atmospheric conditions for the formation of polar lows in December/January. Besides, sea ice anomalies in the Barents Sea in mid-winter tend to impact the occurrence of polar lows at the end of the season.

Session: **Extreme events in polar regions**

Oral/Poster: **O**

Abstracts: Dynamics of Atmosphere-Ice-Ocean Interactions in the High Latitudes  
23-27 March, 2015 Rosendal, Norway

Abstract # **178**  
**Invited**

**Timo Vihma**  
Research Professor  
Finnish Meteorological Institute

**Air moisture, clouds and net precipitation in the Arctic: processes, changes and research challenges**

Co-authors: James Screen, Michael Tjernström, Xiandong Zhang, Valeria Popova, Brandi Newton, Clara Deser, Marika Holland, John Walsh, Terry Prowse

As a part of the Arctic Freshwater Synthesis, we present a review on the atmospheric component of the Arctic freshwater system, including its interactions with the ocean, sea ice and terrestrial waters. The estimates for moisture transport from lower latitudes to the Arctic as well as evaporation and precipitation in the Arctic will be reviewed, also addressing the variability of these terms during the recent decades. The existing knowledge on the effects of net precipitation on (a) the mass balance of ice sheets, glaciers and sea ice, (b) the ocean and terrestrial freshwater budgets, and (c) surface energy budget will be summarized. The drivers of the variations will be evaluated including the effects of changes in the large-scale atmospheric circulation, storm tracks, sea ice and snow cover, as well as sea surface temperatures. The present knowledge on the water vapour and cloud-radiation feedbacks will be evaluated, and projections for the evolution of the air moisture, clouds, evaporation, and precipitation during the 21st century will be summarized.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Hans Volkert**

IAMAS, DLR-Oberpfaffenhofen, Institut für Physik der Atmosphäre

**Dealing with the dynamics of local weather and global climate –  
tracing Jacob Bjerknæs’s impact as Bergen school scientist and IAM(AS) activist**

Co-authors:

Jacob Bjerknæs (1897-1975) formed the third generation of renowned Norwegian fluid-dynamicists after his grandfather Carl Anton (1825-1903) and his father Vilhelm (1862-1951). He worked in Bergen from 1917-40. His renowned article of 1919 “On the structure of moving cyclones” marks the beginning of the Bergen-school of meteorology. Starting 1936 and during a difficult political period, Jacob served for 18 years the International Association of Meteorology (IAM) and the over-arching International Union of Geodesy and Geophysics, voluntary cooperation networks on quite a personal basis. From 1940 onwards J. Bjerknæs worked at the physics department of UCLA, California, teaching weather forecasting. The presentation seeks to combine the textbook contributions made by Jacob Bjerknæs regarding the dynamics of mesoscale weather systems as well as the El Niño/Southern Oscillation climate anomaly with background information of his role as an early science manager in the global arena. Non-standard material from the Munich university library and IUGG-proceedings will be presented. Factual knowledge of an important contributor to the Bergen-school of dynamical meteorology is regarded as an archetypical example for the work pursued later within ICDM after its formal foundation in 1967 under Reginald Sutcliffe (who followed J. Bjerknæs’s example of service for IAM during 1954-60 and 1967-71).

Session:

Oral/Poster: **O**

**Alexandra Weiss**

Scientist

British Antarctic Survey BAS Cambridge

### **Boundary layer in the Antarctic sea ice zone**

Co-authors:

In this presentation we give a summary of airborne observations of the atmospheric boundary layer in the Antarctic Sea ice zone conducted by the British Antarctic Survey. On the basis of the boundary layer observations we discuss the influence of various sea ice conditions on the energy and radiation budget in different Antarctic sea ice zones and investigate their parameterization in numerical models. We determine values which are representative for certain sea ice zone adjacent to the Antarctic Peninsula. For the testing and validation of model parameterizations we determine typical areal-averaged effective boundary layer and surface parameters. We determined the effective temperature and aerodynamic roughness length which are highly variable in the Weddell and Bellingshausen Sea ice areas. Moreover, we determined the effective radiative fluxes over various sea ice conditions and investigate the parameterization of sea surface albedo with surface temperature data. The sea surface albedo of the Weddell and Bellingshausen Sea ice areas show significant regional differences and the effective sea surface albedo varied between 0.13 and 0.81.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **P**

**Heini Wernli**

ETH Zurich

**The impact of extratropical cyclones and associated moist airstreams on Arctic summer anticyclones**

Co-authors:

Recent studies, e.g., by Ogi and Wallace (2012) indicated that summer anticyclones over the Arctic Ocean contributed during the last years to establishing the record-low Arctic sea-ice extent in late summer. In this study it is first shown that the low-level anticyclonic winds are driven by strong upper-tropospheric blockings characterized by very low potential vorticity (PV) and secondly investigated how these Arctic blockings form. Backward trajectories are calculated from these upper-tropospheric low-PV anomalies to investigate the origin of these airmasses and the PV evolution along the trajectories. A substantial part of the trajectories reveal a strong latent heating during the days before the air parcels enter the blocking. The latent heating occurs preferentially in so-called warm conveyor belt-like flows, i.e., in moist ascending airstreams associated with extratropical cyclones. This indicates that the extratropical storm track in summer, i.e., cloud-diabatic processes associated with warm season cyclones, can directly influence the formation of persistent Arctic anticyclones and in turn modulate Arctic sea ice. The year-to-year variability of this link between extratropical cyclones, diabatic ascent and Arctic anticyclones will be investigated.

Session: **Large scale circulation and mid-latitude interactions**  
Oral/Poster: **O**

**Sascha Willmes**  
Research Associate  
University of Trier

**A quasi-daily pan-Arctic lead product derived from MODIS thermal infrared imagery**

Co-authors: Günther Heinemann

Polynyas and leads are key elements of the wintertime Arctic sea-ice cover. They play a crucial role in surface heat loss, potential ice formation and consequently in the seasonal sea-ice budget. We apply and evaluate lead segmentation techniques based on sea-ice surface temperatures as measured by the Moderate Resolution Imaging Spectroradiometer (MODIS). Daily lead composite maps indicate the presence of cloud artifacts that arise from ambiguities in the segmentation process and shortcomings in the MODIS cloud mask. A fuzzy cloud artifact filter is implemented to mitigate these effects and the associated potential misclassification of leads. We present daily pan-Arctic lead maps and monthly lead frequencies for the months of January to November from 2002 to 2014. The quasi-daily lead product can be used to deduct the occurrence, structure and dynamics of wintertime sea-ice leads and to assess seasonal divergence patterns of the Arctic Ocean.

Session: **Coupled atmos-ice-ocean system**

Oral/Poster: **O**

**Tobias Wolf**

PhD student

Nansen Environmental and Remote Sensing Center

**Atmosphere, ocean, ice interaction during the ‘Great Arctic Cyclone of 2012’**

Co-authors: Masha Tsukernik

Ioana Colfescu

Eric Stofferahn

The NABOS 2013 expedition hosted a summer school on ‘Climate Change in the Arctic Ocean. During the course of this summer school students collaborated in projects. I will be presenting some of the results obtained during the student project on ‘Great Arctic Cyclone’ of 2012’.

We used the Weather Research and Forecasting Model (WRF) and the Nucleus for European Modelling of the Ocean (NEMO) to study the interaction between the Arctic sea-ice and the cyclone.

WRF simulations with different sea-ice conditions suggest that the transition of the cyclone from land over open water and over sea-ice was crucial for the explanation of the strength of the cyclone. When assuming a larger sea-ice cover or an ice-free arctic ocean, the cyclone intensity decreased. NEMO simulations with different wind-speed regimes suggested that the effect of the storm on the sea-ice is small. The main mechanism for the loss of sea-ice was bottom melting. This is only poorly reproduced in the NEMO model since there is no parameterisation of flow size or for the fracturing of the sea-ice by the cyclone.

Session: **Extreme events in polar regions**

Oral/Poster: **P**