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

Jón Egill Kristjánsson

+ IPY-THORPEX team
Documentation
Where do Polar Lows in the Nordic Seas occur?

Noer et al. (2011: QJRMS)
8 January 2010: A First-Ever Wintertime Polar Low North of Svalbard
Research Questions

• What are the roles of various dynamical and physical factors (surface fluxes, deep convection, upper-level forcing, low-level baroclinicity) in PL developments?

• To what extent can PL predictions be improved by additional observations?

• To what extent do current NWP models capture PL structure, and what model resolution is needed to do so?
The Field Campaign

• Field programme: 25 Feb – 16 Mar 2008
• Base of operations: Andenes, Norway (69°N, 16°E)
• **DLR Falcon aircraft**: 56 flight hours; 150 dropsondes
• Coast Guard vessels: KV Senja, KV Svalbard
• Unmanned Aerial Vehicles (UAV) at Spitzbergen
• Additional radiosondes at Norwegian and Russian sites
• Drifting buoys

• Unique data set for validation of NWP models
Falcon payload for IPY-THORPEX-Norway 2008

**Dropsondes:**
\( u, v, P, T, q \)

**Doppler lidar:**
Horizontal & vertical wind

**DIAL:**
\( H_2O, Aerosols \)

\( u, v, w, TAS \)

\( T, P, q \)
The Andøya Campaign

Kristjánsson et al. (2011: BAMS)
Polar Low Structure
The 3-4 March Polar Low

Baroclinic Development Phase

12:21 UTC on 3 March

16:01 UTC on 3 March

Kristjánsson et al. (2011: BAMS)
The 3-4 March Polar Low

Mature Convective Phase

03:07 UTC on 4 March

11:28 UTC on 4 March

Kristjánsson et al. (2011: BAMS)
W-E sections at 11:40 UTC 3 March

Potential Temperature

Horizontal Wind

Sloping frontal surface

Low-level jet of 27 m s\(^{-1}\)

Kristjánsson et al. (2011: BAMS)
SW-NE sections at 11:05 UTC 4 March

Relative Humidity

- Dry slot (eye of the PL)

Potential Temperature

- Warm air in the eye (descent?)

Kristjánsson et al. (2011: BAMS)
10:30 – 13:30 UTC 3 March 2008

Føre et al. (2011: QJRMS)

M
S
L
P

SST – $T_{500}$

Pot.temp. at 925 hPa

Spec.hum. at 925 hPa

$Føre$ et al. (2011: $QJRMS$)
10:30 – 13:30 UTC 4 March 2008

Føre et al. (2011: QJRMS)
Surface Fluxes on 3 March

Latent Heat flux

Sensible Heat flux

Føre et al. (2011: QJRMS)
Surface Fluxes on 4 March

Latent Heat flux

Sensible Heat flux

Føre et al. (2011: QJRMS)
PV at 290 K

12 UTC 2 Mar

12 UTC 3 Mar

12 UTC 4 Mar

00 UTC 3 Mar

18 UTC 2 Mar

00 UTC 4 Mar

12 UTC 4 Mar

Føre et al. (2011: QJRMS)
The role of CAPE in Polar Low development

Van Delden et al. (2003)

Linders & Saetra (2010: J. Atmos. Sci.)
Observation Systems
03 March 2008
ETKF Sensitive Area Prediction

Flight 1: 19 sondes in 12Z forecast
Flight 2: 13 sondes in 18Z forecast

From: Emma Irvine
T+24 Forecast of Polar Low Landfall

- Improvement to forecast of polar low position and intensity

Kristjánsson et al. (2011: BAMS)
Polar Low Central Pressure and Track in the 18Z forecast

- Polar low intensity and location are both improved in the 18Z targeted forecast – but, improvement is moderate compared to EPS forecast spread

*Irvine et al. (2011: QJRMS)*
Polar Low 16-17 March 2008: HARMONIE simulations at +24 h

With IASI radiances

Without IASI radiances

Randriamampianina et al. (2011: QJRMS)
Model - LIDAR: Wind

Wagner et al. (2011: QJRMS)
Model - LIDAR: Vapor

Wagner et al. (2011: QJRMS)
Modeling Aspects
UM simulations

McInnes et al. (2011: QJRMS)
Wind at 925 hPa: 18 UTC 3 Mar (+42 h)

McInnes et al. (2011: QJRMS)
MSLP+thickness: 18 UTC 3 Mar (+42 h)

McInnes et al. (2011: QJRMS)
1 h acc precip (mm) 17-18 UTC 3 Mar (+42 h)
Summary of findings

• **Polar Low Structure**: Low-level jets in developing stage, eye formation in mature stage
• **Systematic precursors** identified: SST-T500 threshold, propagating UPV anomaly, low-level baroclinicity
• **Predictability** of Polar Lows highly variable from case to case – **not well understood**
• **Targeted observations** can improve the forecasts in some cases – **not well understood**
• **New satellite data** (IASI) can improve the forecasts
• **LIDAR retrievals** can yield useful information on mesoscale features despite cloud limitations
• **Sensitivity simulations**: Latent heating and surface fluxes crucial; sensible heat flux often larger than latent heat flux
Thank you!

http://ipy-thorpex.no/en/the-research

Photo: Gudmund Dalsbø
Forecast Improvements at *met.no*

- **New probabilistic weather prediction system** (NORLAMEPS)

- **Exploitation of new satellite data** (IASI)

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Aspelien et al. (2011: *Tellus*)

Randriamampianina et al. (2011: *QJRMS*)
## Sensitivity simulations

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*Føre and Nordeng (2012: QJRMS, in press)*
### Forecast errors as a function of latitude

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Error statistics for MSLP for selected SYNOP stations in the North Sea, Norwegian Sea and the Barents Sea in units of hPa.
The table shows a composite of all forecast lengths from +18 to +42 hours with the Norwegian operational limited area model HIRLAM between 1 Jan 2010 and 30 Sept 2010.

*From: Thor Erik Nordeng*
Figure 16: Position of polar low from UM12 (light blue), UM12_70L (black), UM4 (red), UM1 (gray) UM4_Lat10 (green) and analysis (dark blue). For the analyses the position is shown between 3 March 18 UTC and 4 March 18 UTC at 6 hours intervals, except for 4 March 000 UTC. For the model runs the positions are shown between 3 March 18 UTC and 4 March 12 UTC with exceptions for UM4_Lat10, where we have not shown the position for 3 March 18 UTC and UM1, where we only have shown the positions for 3 March 18 UTC and 4 March 00 UTC.
Probabilistic Forecasting (LAMEPS)

Sea-Level Pressure

Precipitation

Kristjánsson et al. (2011: BAMS)
Polar Lows in the Future

Blue: Fewer polar lows than now
Red: More numerous polar lows than now

Note increase in the Barents Sea

Where do we find polar lows today?

Red: Marine cold air outbreaks => polar lows

Contributions from different PV anomalies

Førø et al. (2011: QJRMS)
Model - LIDAR: Vapor

Wagner et al. (2011: QJRMS)
High SSTs in the area of interest

Føre et al. (2011: QJRMS)
Sensitivity of forecast error north of 70N to initial conditions

(a) Mean Vertically Integrated: SG VO (DJFM 2001/02)

(b) Mean Vertically Integrated: SG VO (DJFM 2004/05)

Jung & Leutbecher (2007: QJRMS)