Investigation of polar low formation and development over the Nordic Sea: Synergetic approach using the Arctic System Reanalysis, Microwave satellites and Radiative Transfer Simulations

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Introduction

Polar lows (PLs) are high latitude maritime cyclones whose characteristics are:

- small diameter (< 600 km)
- strong winds (> 15 m/s)
- short life time (can be only 3h)

These cyclones bring large amounts of precipitation that combined with strong winds cause great damage to coastal communities but due to sparse observationional network are still hard to predict.

Tools and Methods

ASR v1 and v2 – **A**rctic **S**ystem **R**eanalysis version 1 (2) with 30 (15) km spatial resolution and 29 (34) vertical levels that has best estimate of atmospheric state including precipitation[2].

Analyse 200 km around genesis point and time using:

Conditions	Threshold
SST –T(500 hPa)	> 43 K[3]
SST – T(2m)	~ 6 – 7 K[4]
Lapse rate (LR) below 850 hPa	Unstable[4]
RH (850 -950 hPa)	~ 82 % [4]
Near surface wind speed	> 15 m/s[5]
Geopotential height (GPH) anomaly at 500 hPa	~ 160 gmp[6]

Advanced **M**icrowave **S**ounding **U**nit – **B** (AMSU-B) and **M**icrowave **H**umidity **S**ounder (**MHS**)

- coverage of the Arctic (≅**10 times/day**) with 5 channels

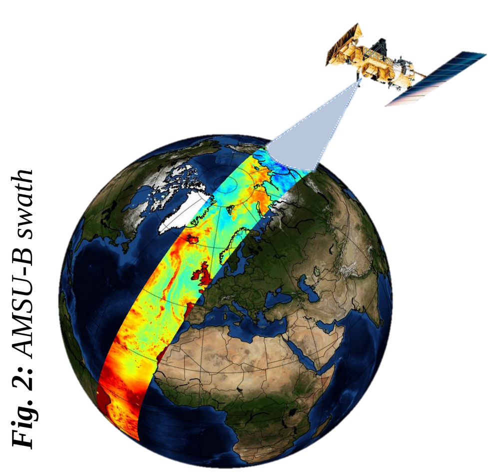

Fig. 2: AMSU-B swath

3 within strong water vapor line: 183.31 ± 1, 183.31 ±3, 183.31 ± 7 GHz (190 GHz MHS)

2 window: 89 and 150 GHz (157 GHz MHS)

ASR
Use vertical profiles of:
- temperature
- relative humidity
- pressure
- hydrometheors

Surface fieleds of:
- wind
- ground temperature

→ **PAMTRA**
Radiative transfer simulator used to derive brightness temperatures (BT) at AMSU-B frequncies

→ **OUTPUT**
Simulated BT

Research Questions

RQ1. Is the Arctic System Reanalysis (ASR) able to represent polar lows (PLs) and their precipitation signature?

RQ2. Can we identify thresholds in environmental conditions or combinations of them that are required for PL formation?

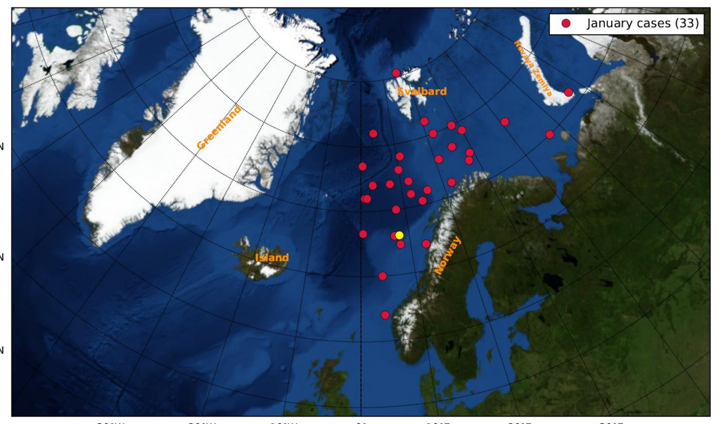

Fig. 1: Distribution of January polar low cases (red dots) between 2000-2012 using list of polar lows from Noer and Lien, 2010 [1]

RQ1: Representation of PLs in AMSU-B and ASR

AMSU-B observations

- strong brightness temperature (BT) depression in precipitating ice cores
- BT difference to environment can reach more than 40 K

AMSU-B simulations using PAMTRA

- general structure of the PL from ASR is captured in the simulations
- general structure of the PL from ASR is visible in simulations

Possible reasons for the disagreement

- satellite has coarser resolution of the ASR (at nadir point doubled)
- parametrization of precipitation processes including assumptions of hydrometheor size and shape

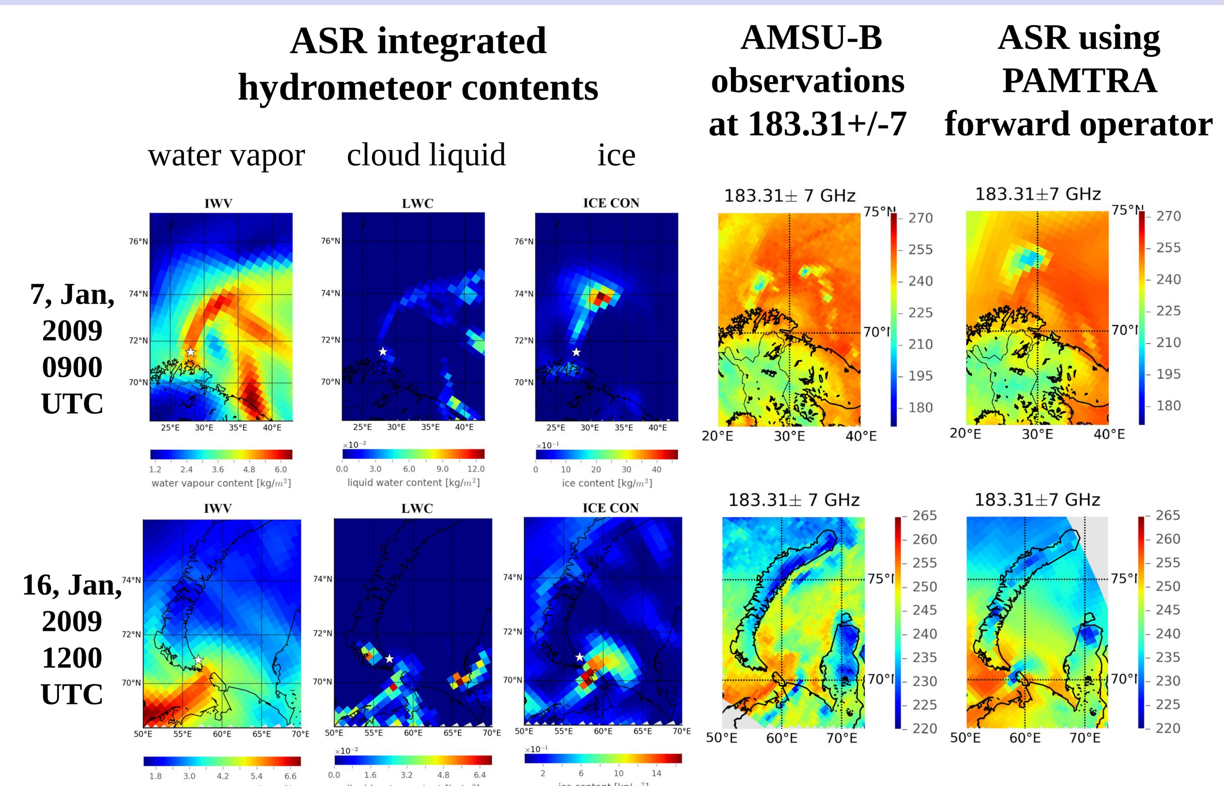

Fig. 3: PL case on 7th, Jan, 2009 (top) and 16th, Jan, 2009 (bottom). Integrated water vapour (IWV) (first column), liquid water content (LWC) (second column), ice content (ICE CON) (third column); AMSU-B observations at 183.31±7 GHz channel (fourth column), PAMTRA simulations at 183.31±7 GHz channels (fifth column). White star is the position of PL.

RQ2: Environmental conditions from ASR

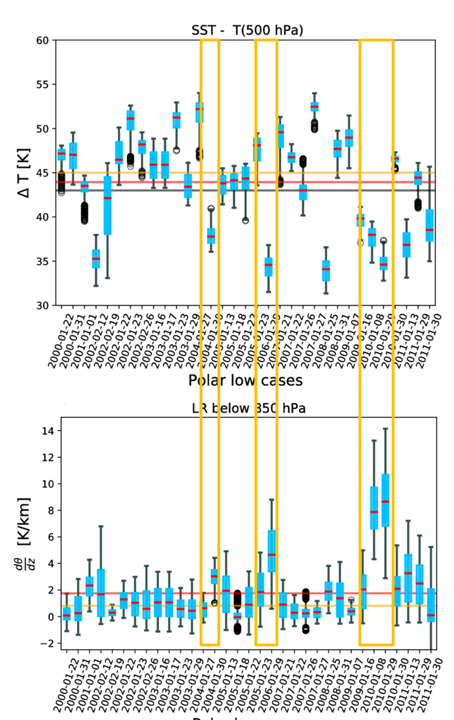

Fig. 4: Box-whisker representation (interquartile range in blue) of SST – T(500 hPa) (top) and lapse rate (LR) bellow 850 hPa (bottom) during genesis stage within a 200 km radius. Lines represent: literature threshold (black), ASRv1 (orange) and ASRv2 (red).

- **ASRv2** shows:
  - lower values of mean SST –T (500 hPa)
  - higher LR below 850 hPa

  when compared to ASRv1
- for the majority of the cases the SST – T(500 hPa) threshold of 43 K is reached (**Fig. 4**).
- cases with stronger static stability show stronger and steeper lapse rates:
  → convection acts as driving mechanism

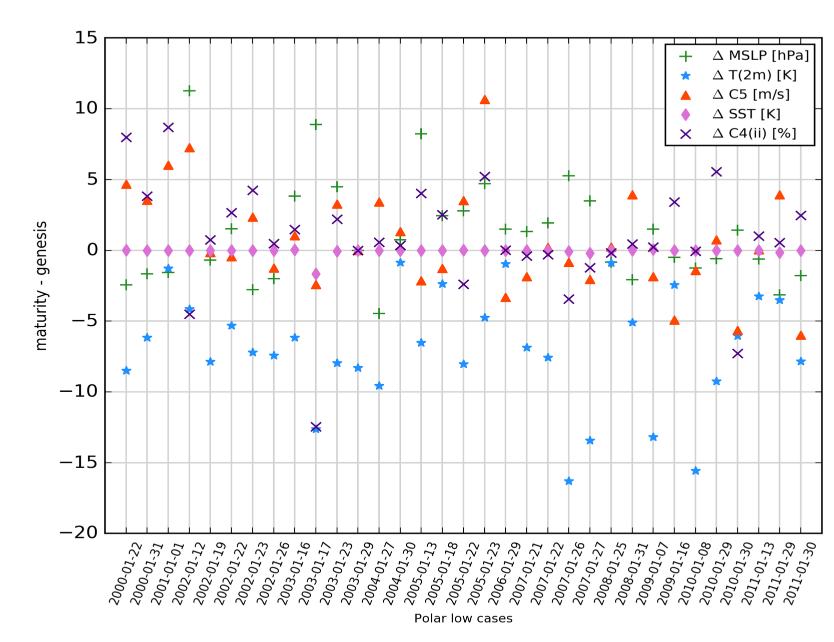

Fig. 6: Difference between genesis and maturity stage for the variables: MSLP difference (+), temperature at 2 m (*), near-surface wind speed (C5: ▲), SST (♦), and RH in the layer between 850 and 950 hPa (C4(ii): x).

RQ2: Environmental conditions from ASR

- More intense winds and higher amount of low level RH during maturity stage (**Fig. 6**)
- **T(2m)** is lower at maturity stage after passage of PL
- MSLP and RH have opposite behavior considering PL stages

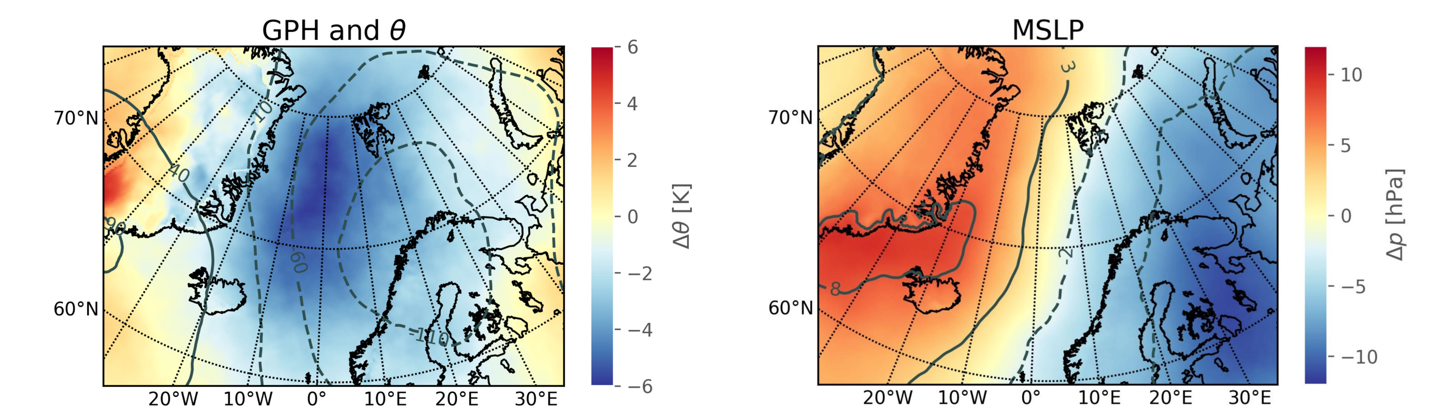

Fig. 5: GPH and potential temperature anomaly(top);MSLP anomaly (bottom).

- **GPH** anomaly shows values of 110 m below climatological mean
- **MSLP** establishes a sharp boundary close to 0° lat during PL events (**Fig. 5**)

Conclusions

RQ1: • ASR transformed into the observation space using forward simulator reproduces PL as detected by satellite measurements; validation technique difficult close to sea ice and orography

RQ2: • environmental conditions reveal the importance of thermal instability and convection for PL genesis

Next step

- investigate the role of moisture intrusions or atmospheric rivers prior to a PL event
- analyze precipitation produced by PL

} add RCM HIRHAM5

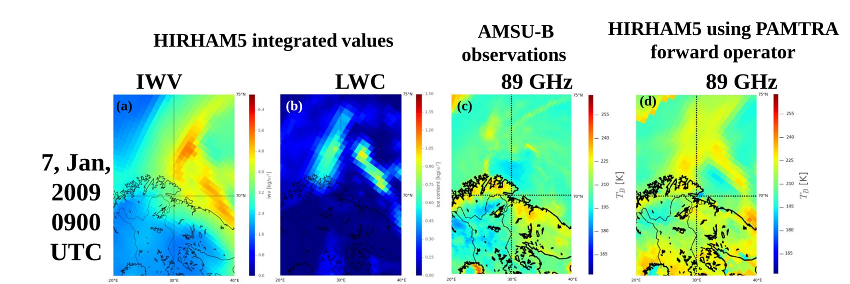

Fig. 7: PL case on 7th Jan 2009. IWV (a) and LWC (b) from HIRHAM5, AMSU-B observations (c) and PAMTRA simulations (d).

Atmospheric river prior to PL

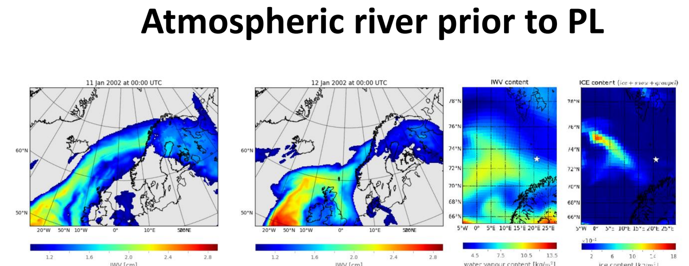

Fig. 8: Atmospheric river on 11-12 Jan at 00:00 UTC 2002 (a and b) and IWV and ICE CON for the PL case on 12th Jan 2002 at 12:00 UTC.

References

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