Characteristics and Genesis Conditions of Polar Lows in between 2000-2012: Microwave satellites, Arctic System Reanalysis and Radiative Transfer Simulations

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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?

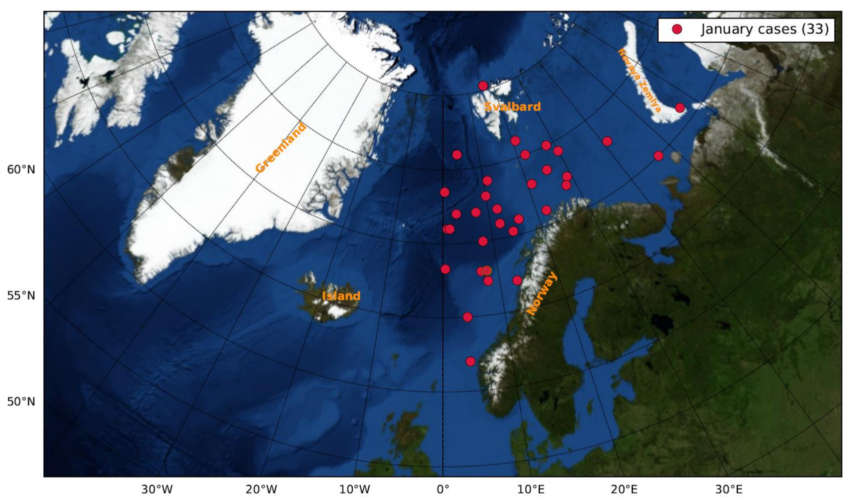


Fig. 1: Distribution of January polar low cases (red dots) between 2000-2012 using list of polar lows from Noer and Lien, 2010 [1]

Tools & 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

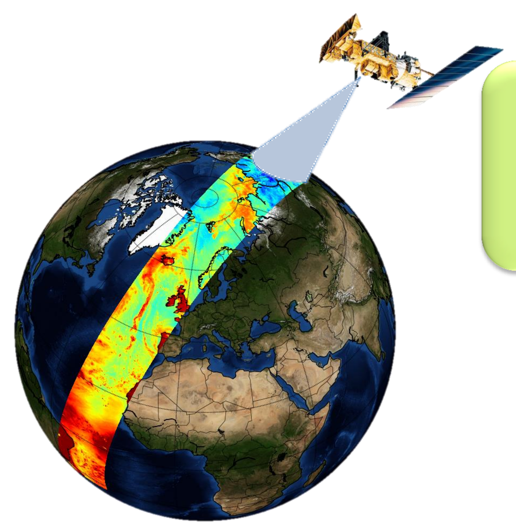


Fig. 2: AMSU-B swath

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)

PAMTRA – **P**assive and **A**ctive **M**icrowave **R**adiative **TRA**nsfer that connects ASR to AMSU-B and is able to simulate the 1-800 GHz frequency range using scattering

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

Surface fields of:
- wind
- ground temperature

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

OUTPUT
Simulated BT

Results

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
- BT signature difficult to see close to orography and sea ice due to emissivity change

ASR integrated values of PL
- 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

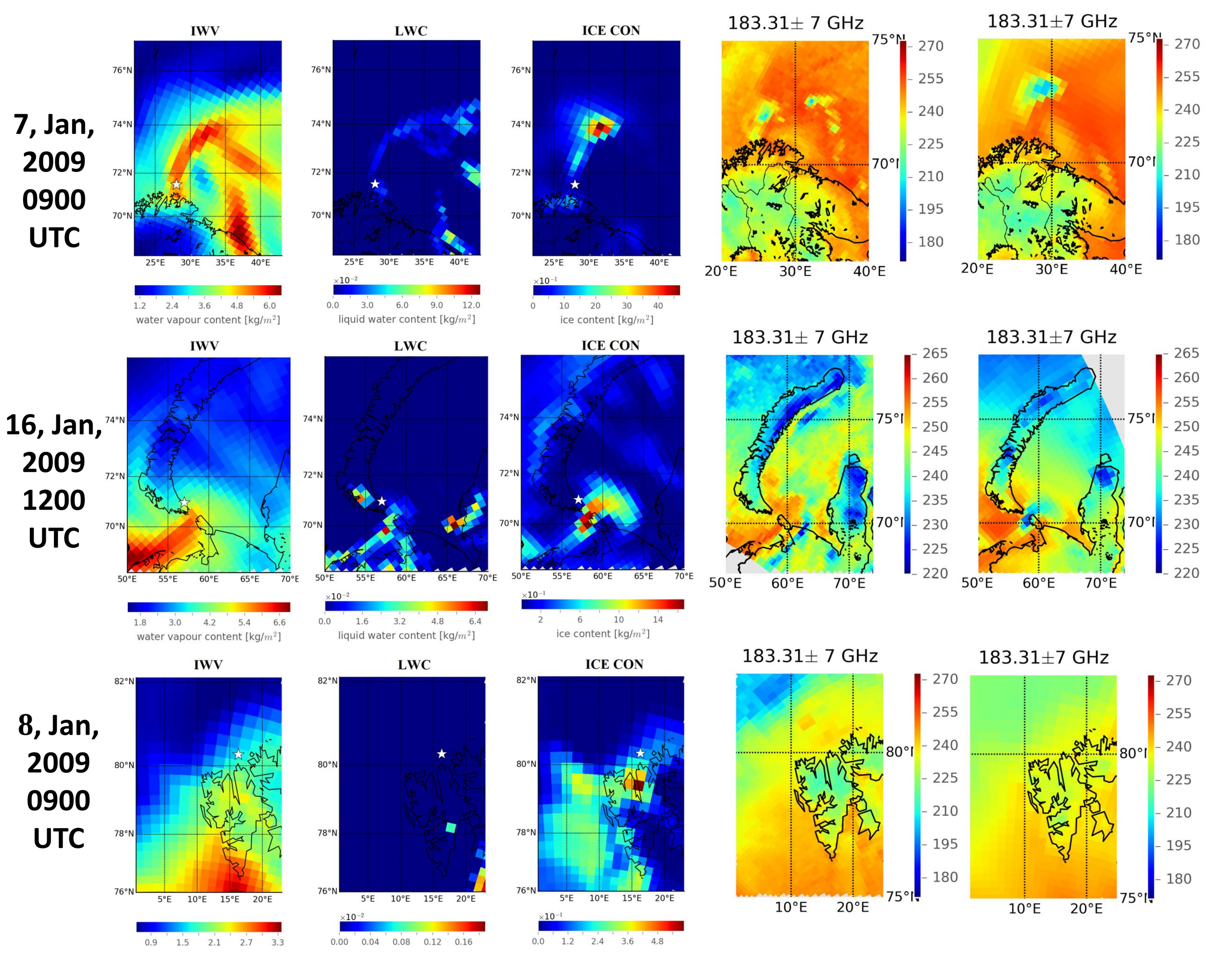


Fig. 3: PL case on 7th, Jan, 2009 (top), 16th, Jan, 2009 (middle) and 8th, Jan, 2010 (bottom). Integrated water vapour (IWV) (first column), liquid water content (LWC) (second column), ice content (ICE CON) (third column); AMSU-B observations at 183.31±7 GHz channel (fourth column), PAMTRA simulations at 183.31±7 GHz channels (fifth column). White star is the position of PL.

RQ2: Environmental conditions from ASR

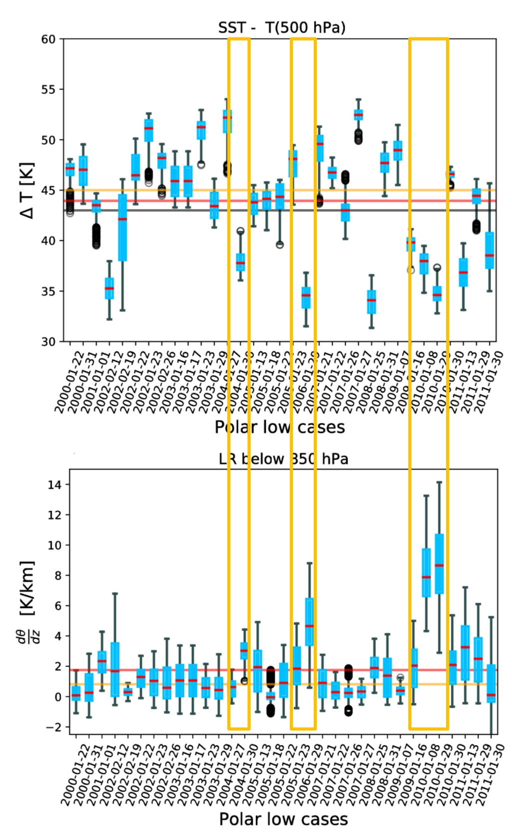


Fig. 4: Box-whisker representation (interquartile range in blue) of SST – T(500 hPa) (top) and lapse rate (LR) bellow 850 hPa (bottom) during genesis stage within a 200 km radius. Lines represent: literature threshold (black), ASRv1 (orange) and ASRv2 (red).

- **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

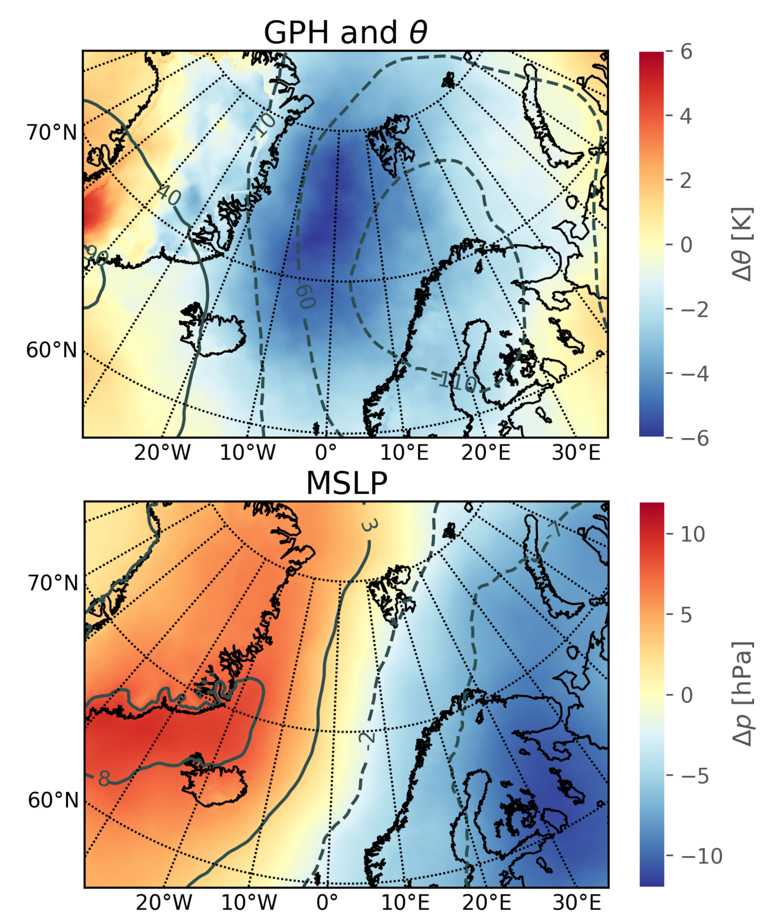
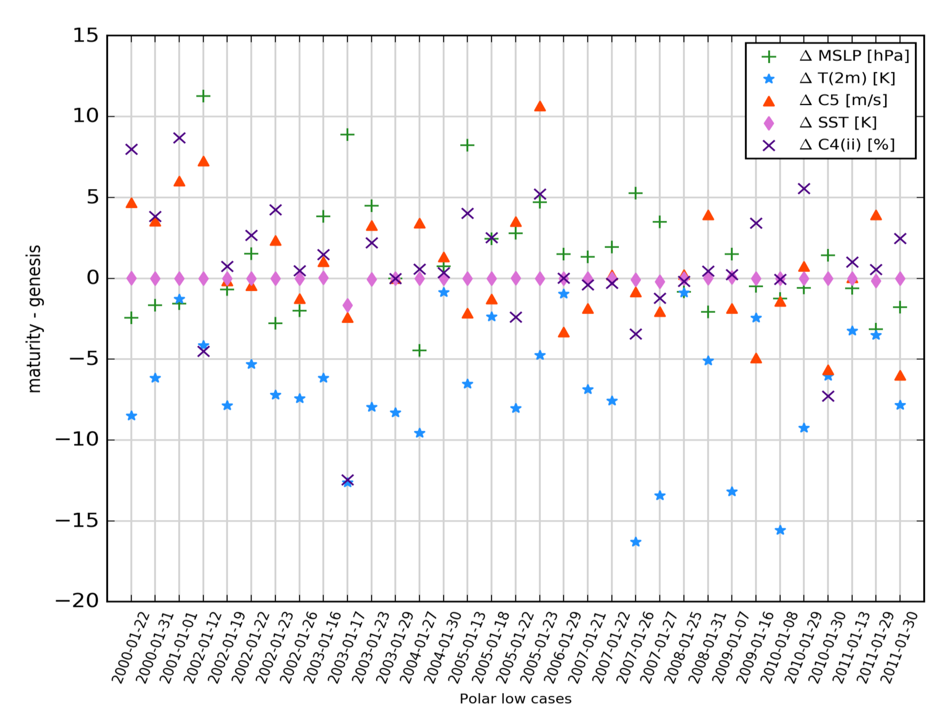


Fig. 5: GPH and potential temperature anomaly(top); MSLP anomaly (bottom).



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

Conclusions and next steps

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

} add RCM HIRHAM5

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

Acknowledgements

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References

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