Past and projected future changes of North Atlantic polar low frequency

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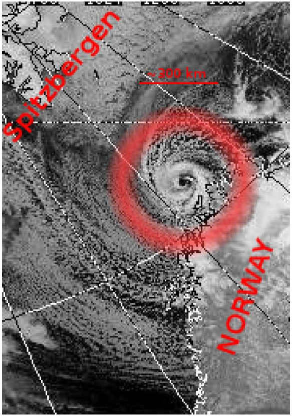
Polar Lows (meso-scale maritime storms)

Characteristics:

- diameter $< 1000km$
- strong winds $> 13.9\frac{m}{s}$
- heavy precipitation
- poleward Polar Fronts in winter
- develop in cold air outbreaks
- typically driven by convective processes



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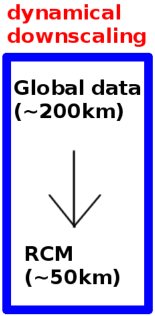
many case studies, but no long-term climatology

Data

Requirements:

- long in time
- high in spatial detail
- **homogeneous**
- Problem: no such data exist

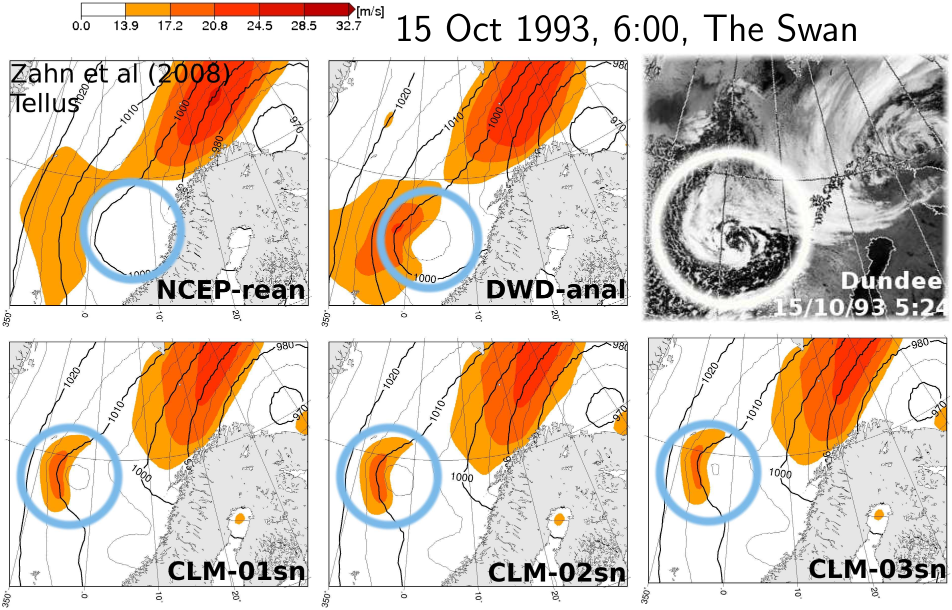


Solution:

- re-analysis and global model data long in time and homogeneous
- downscaled by Regional Climate Model (RCM) COSMO-CLM-2.4.6.
- band-pass filter based detection procedure

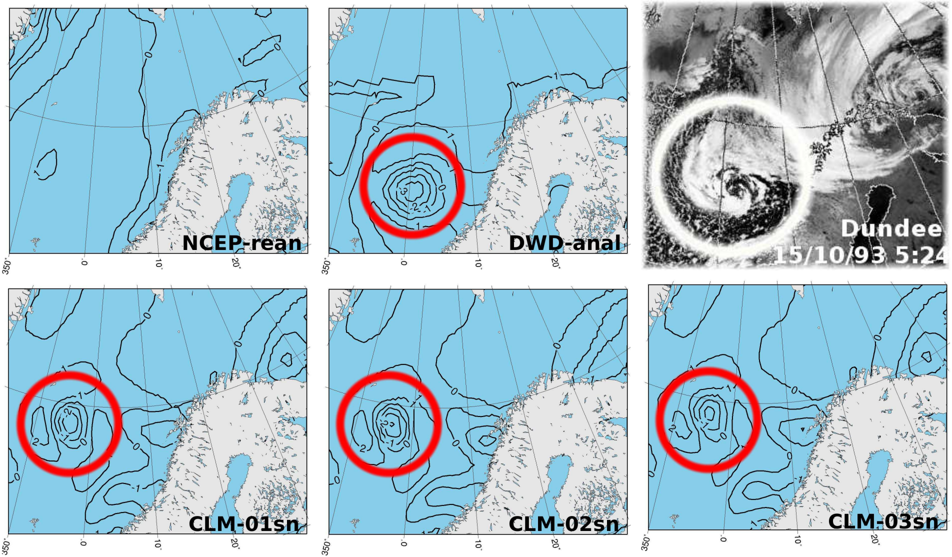
Example of a repoduced PL case

15 Oct 1993, 6:00, The Swan

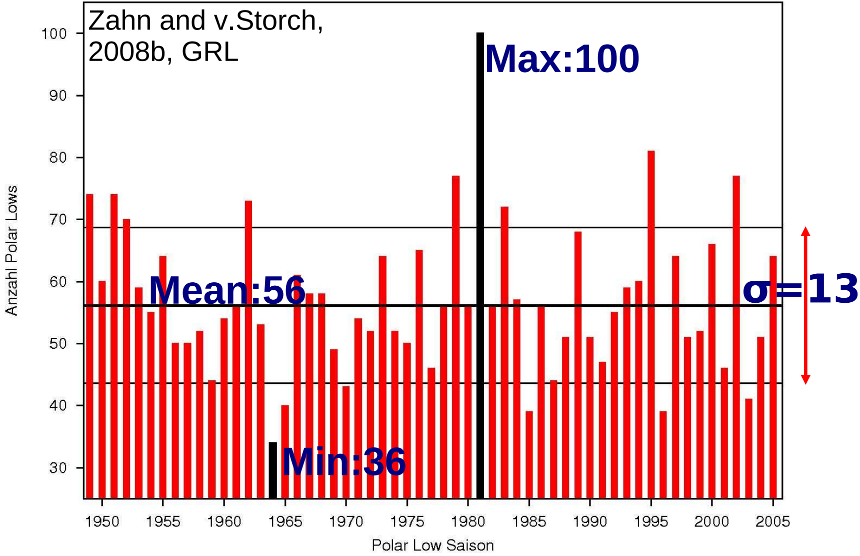


Example of band-pass filtered MSLP

200-600km retained, PLs emerge as distinct minima



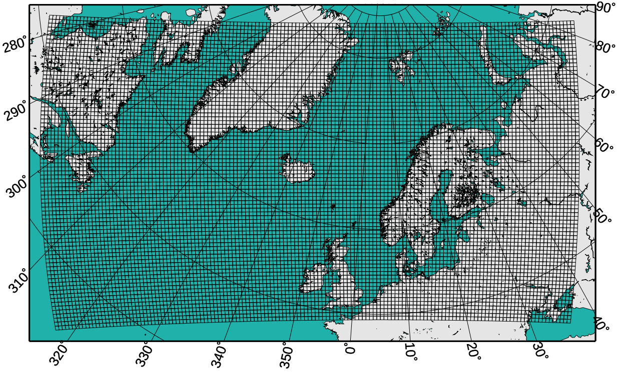
Annual numbers of PLs (1949-2005)



Number of PLs per Polar Low Season (PLS), one PLS from July until June next year

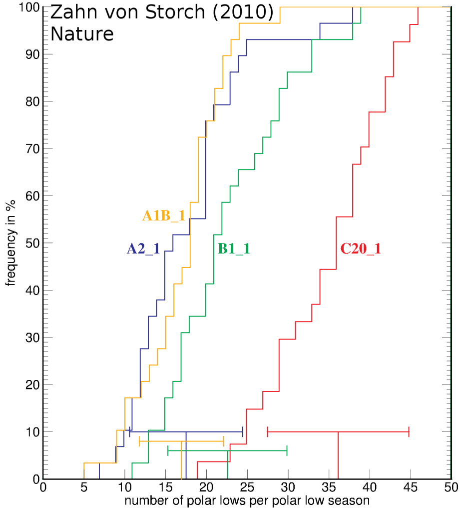
Future projections

- driven by ECHAM5/MPI-OM
- C20: control with GHG 1960-1990
- B1,A1B,A2: projected GHG for 2070-2100 (AR4)

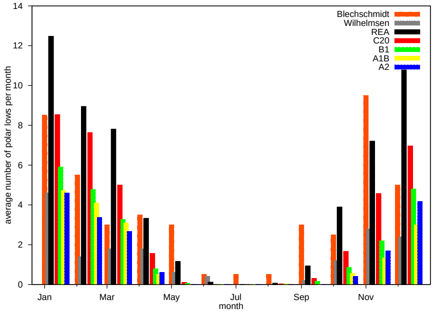


Model grid

Projected cumulative frequency of PLs in IPCC-scenarios and annual cycle

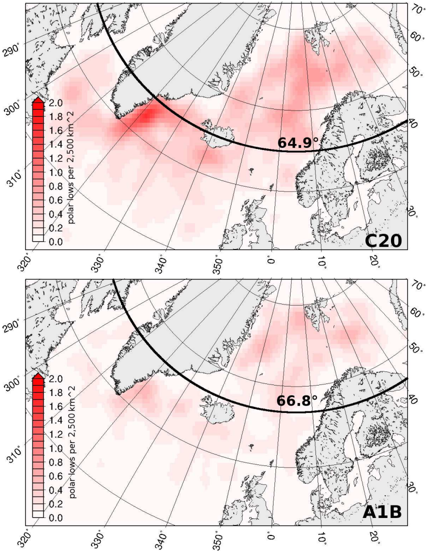


significant decrease in the number of PLs per winter

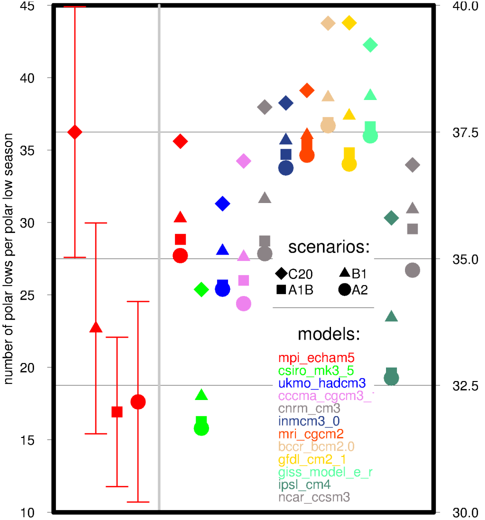


Number of PLs per month

Spatial density distribution, northward shift of genesis region

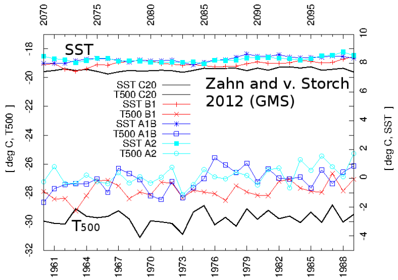


Polar Lows and projected vertical stability



Area and time-averaged icefree $SST - T_{500hPa}$ over maritime northern North Atlantic

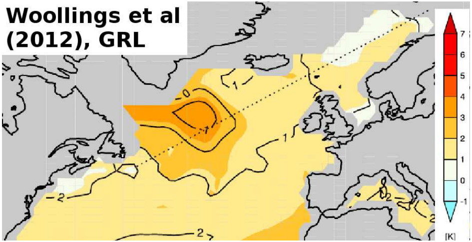
- atmosphere warms stronger than ocean surface
- proxy for frequency of favourable PL conditions decreases



Evolution of SST and T_{500hPa}

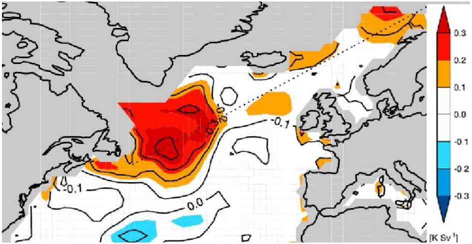
Linkage of vertical stability changes to ocean circulation

Spatial response vertical stability



Multi-model mean response (A1B - C20) in vertical stability S = $T_{500hPa} - SST (= -vdT)$ over ice free ocean (Black iso-lines: SST response)

Regression with ocean circulation



S regressed on the AMOC response across CMIP3 model (A1B - C20) space over ice free ocean (Black iso-lines: regression SST-AMOC)

Frequency changes of Polar Lows

No change in recent past, but high interannual variability

Significant decrease of annual number in response to global warming

Decrease linked to more stable mean conditions

Thank you very much for your attention

http://coast.hzg.de/staff/zahn/

Zahn, M., H. von Storch, and S. Bakan, 2008: Climate mode simulation of North Atlantic polar lows in a limited area model. *Tellus A*, **60A**, 620 – 631, doi:10.1111/j.1600-0870.2008.00330.x.

Zahn, M. and H. von Storch, 2008b: Tracking polar lows in CLM. *Meteorologische Zeitschrift*, **17**, 445–453, doi:doi:10.1127/0941-2948/2008/0317.

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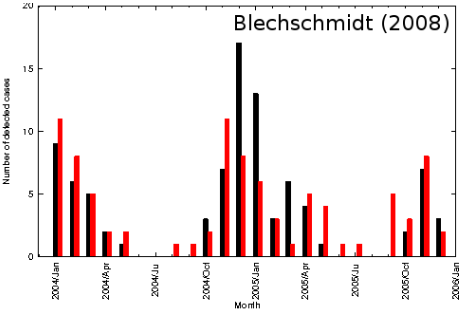
Zahn, M. and H. von Storch, 2012: Investigation of past and future polar low frequency in the North Atlantic. *Extreme Events and Natural Hazards: The Complexity Perspective, Geophys. Monogr. Ser.*, A. S. S. et al., Ed., Vol. 196, doi:10.1029/2011GM001091.

Additional material

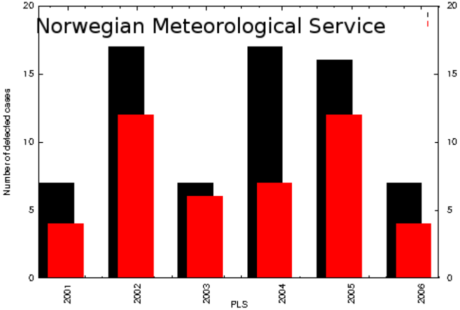
http://coast.hzg.de/staff/zahn/

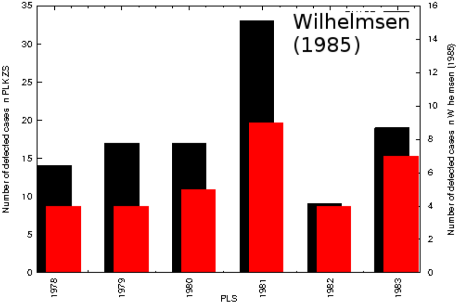
Comparison with observed cases

bias, but **qualitative similarity** to observation data



black: our data (Zahn and v.Storch, 2008) adjusted to observation data
red: MetNo (pers. comm.)
Wilhelmsen (1985)
Blechschmidt (2008)





Setup of detection algorithm

1. record all locations with filtered MSLP minimum $\leq -1hPa$

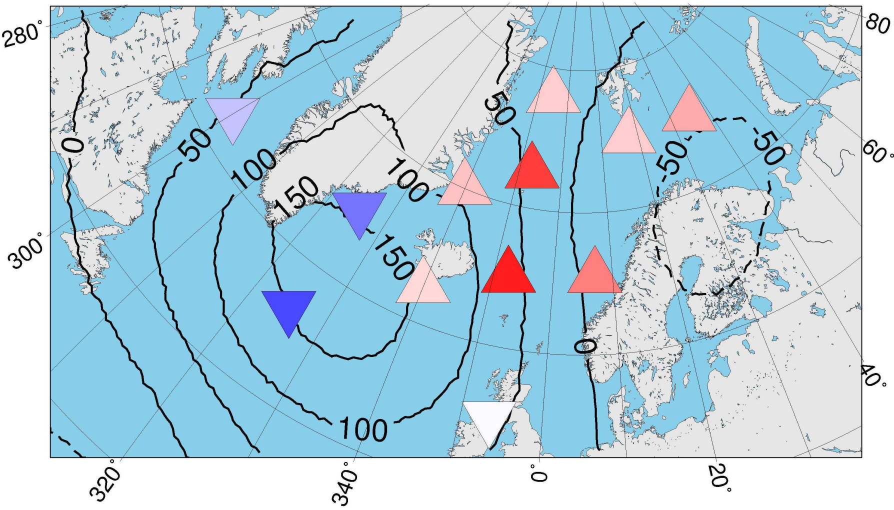
2. combine detected positions to individual tracks, distance to next (3h) pos $\leq\ 200km$

3. checking further constraints along tracks:

   - strength of the minimum ($\leq -2hPa$ once along track)
   - wind speed ($\geq 13.9\frac{m}{s}$ once along track)
   - air-sea temperature difference ($SST - T_{500hPa} \geq 43K$)
   - no northward direction of track
   - limits to allowable adjacent grid boxes

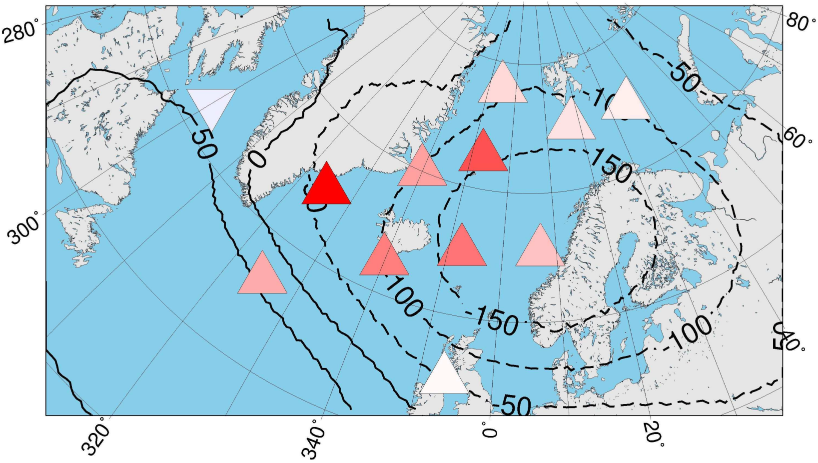
OR: strength of minimum in band-pass filtered MSLP $\leq 6hPa$ once

Link to large scale flow 1949 - 2005



Canonical Correlation Analysis, CCA 1, statistically linking vectors of $\overrightarrow{\textit{mean MSLP}}$ and $\overrightarrow{\textit{No PL}}$ **per PLS**

Link to large scale flow 1949 - 2005



CCA 2 between *mean* $\vec{MSLP}$ and $No\,\vec{PL}$ per PLS

Dec 1993 case

Dec 1993 case

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