Past and projected future changes of North Atlantic polar low frequency

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Polar Lows (meso-scale maritime storms)

Characteristics:

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

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 reproduced PL case

15 Oct 1993, 6:00, The Swan


NCEP-rean

DWD-anal

CLM-01sn

CLM-02sn

CLM-03sn
Example of band-pass filtered MSLP

200-600km retained, PLs emerge as distinct minima

NCEP-rean  DWD-anal

CLM-01sn  CLM-02sn  CLM-03sn
Annual numbers of PLs (1949-2005)

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

Zahn and v. Storch, 2008b, GRL

Max: 100
Mean: 56
Min: 36
σ = 13
Future projections

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

Regression with ocean circulation

Woollings et al (2012), GRL

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

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


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 $\leq -1\, hPa$

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

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

OR: strength of minimum in band-pass filtered MSLP $\leq 6\, hPa$ once
Link to large scale flow 1949 - 2005

Canonical Correlation Analysis, CCA 1, statistically linking vectors of $\overrightarrow{\text{mean MSLP}}$ and $\overrightarrow{\text{No PL per PLS}}$
CCA 2 between mean \( \overrightarrow{MSLP} \) and \( No \overrightarrow{PL} \) per PLS