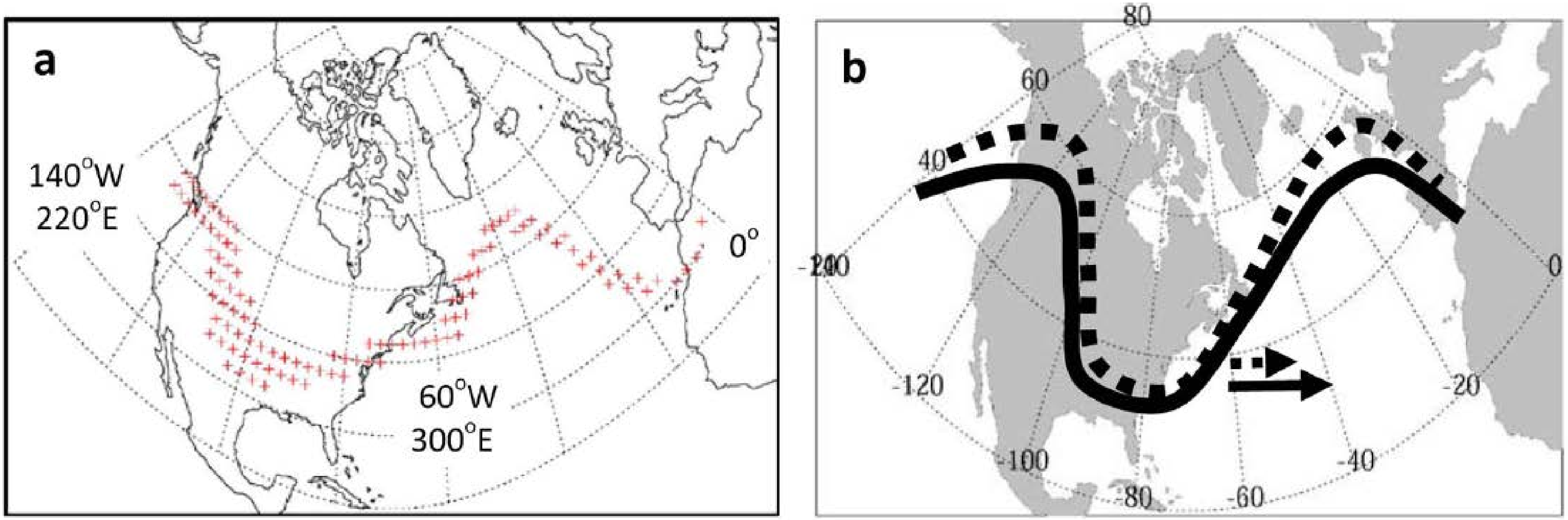
Arctic sea ice influences on mid-latitude weather

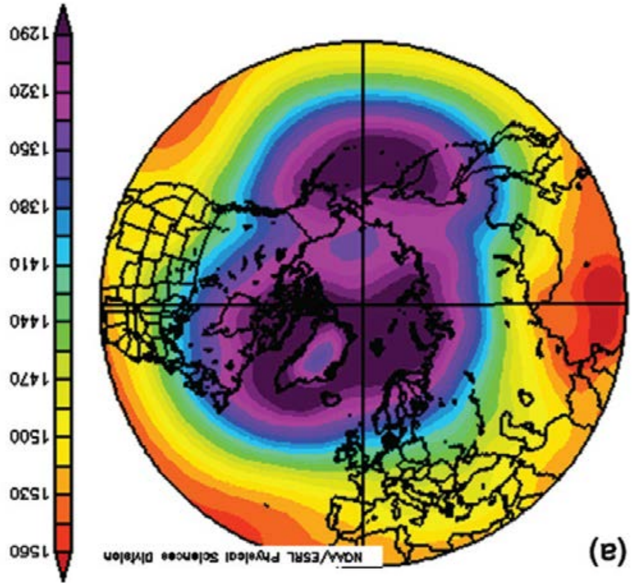


Peter L. Langen

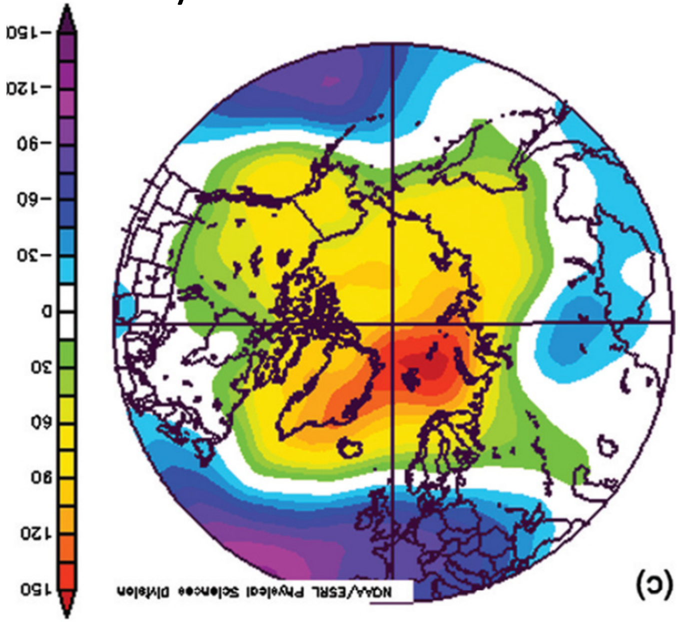
Climate and Arctic Research

DMI

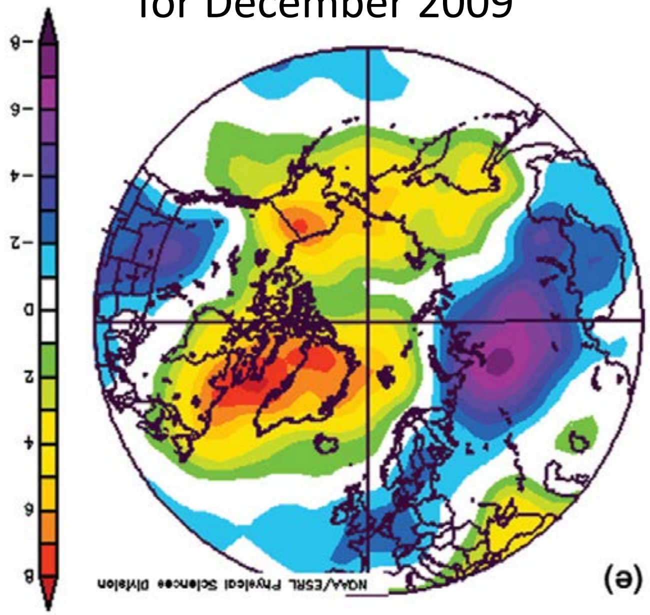
Climatological 850 hPa geopotential height field for December 1968-1996



850 hPa geopotential height anomaly of December 2009



Temperature anomalies at 850 hPa for December 2009



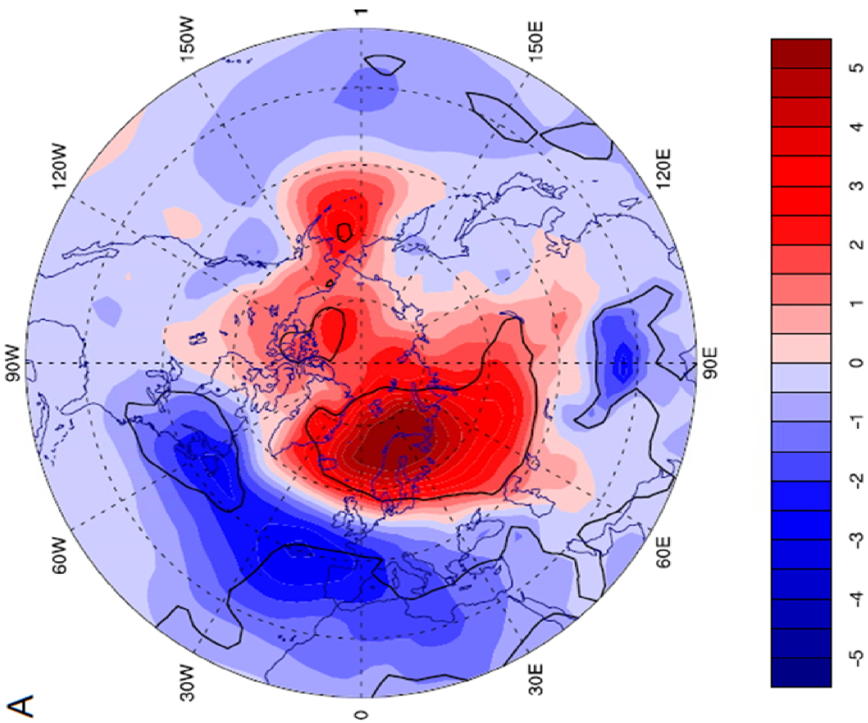
Overland et al. (2011)

Overview

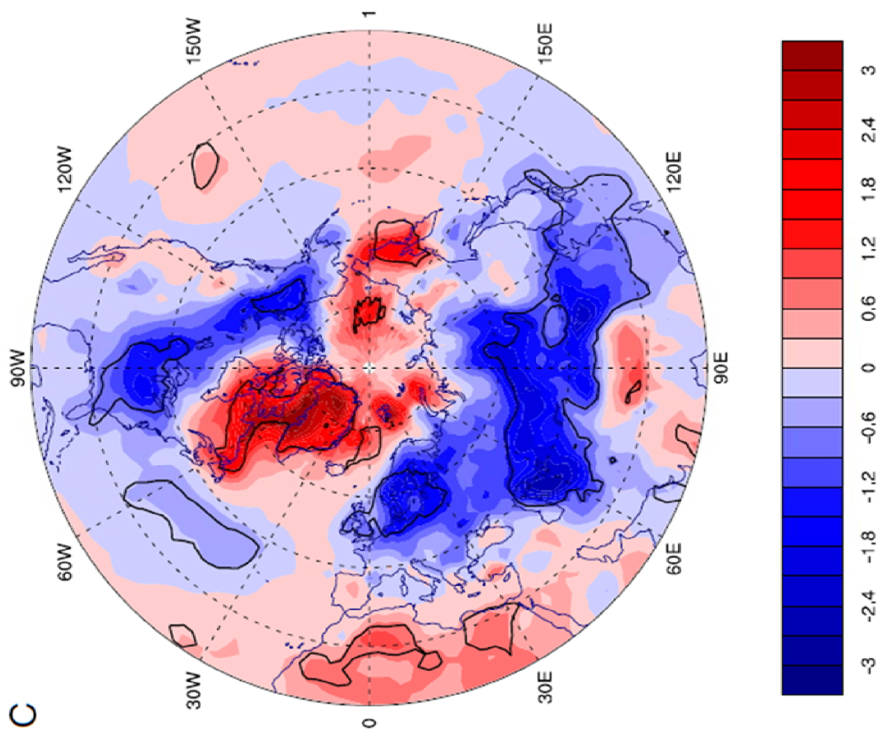
- **Reanalyses over roughly three decades**
- Modeling results – weak and strong effects
- Summary – and a few words of caution

NCEP2 reanalysis 1979–2010

DJF 500 hPa-height vs
minus detrended sea ice extent SON

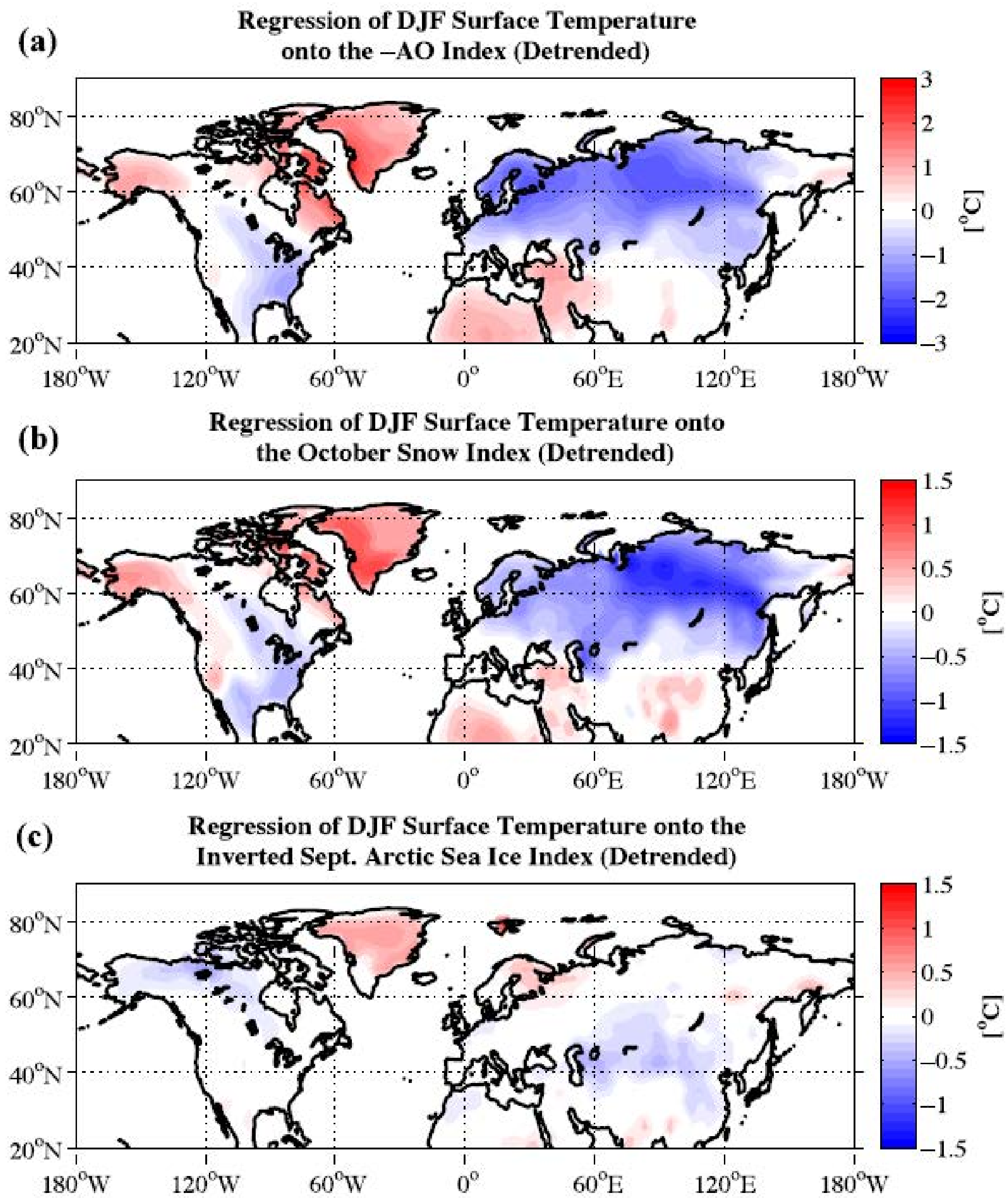


DJF Near-surface air temp vs
minus detrended sea ice extent SON



Autumn sea ice loss also increases the frequency of strong weather events, such as snow storms and cold-air outbreaks

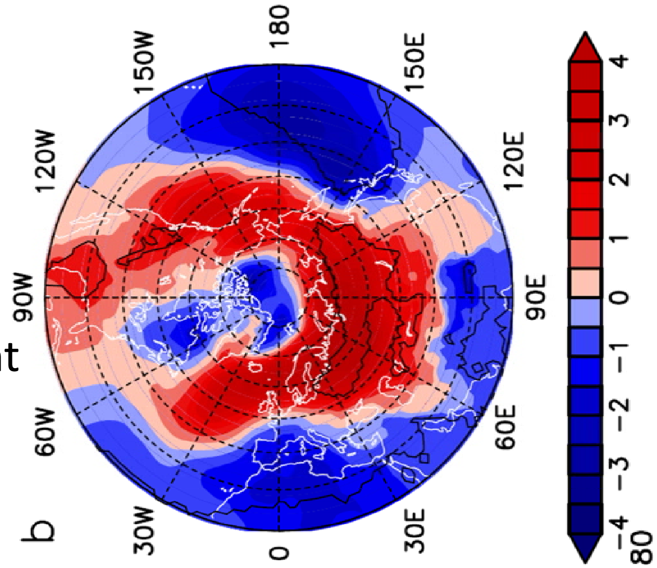
Liu et al. (2012)



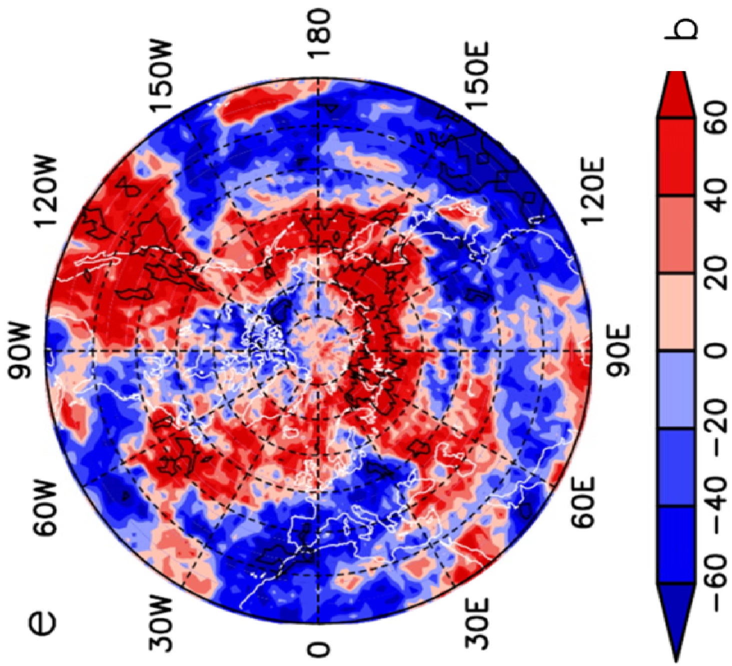
(NCEP reanalysis, 1988-2010)

Cohen et al (2012)

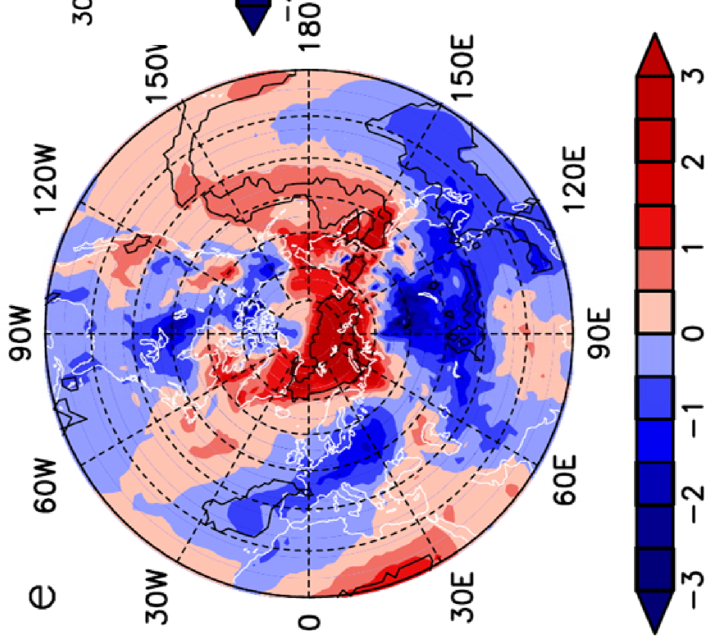
Tang et al (2013) find strongest correlation between winter weather and winter sea ice
- Despite smaller fractional changes (using ERA-Interim 1979–2011)



SLP vs
- sea ice extent

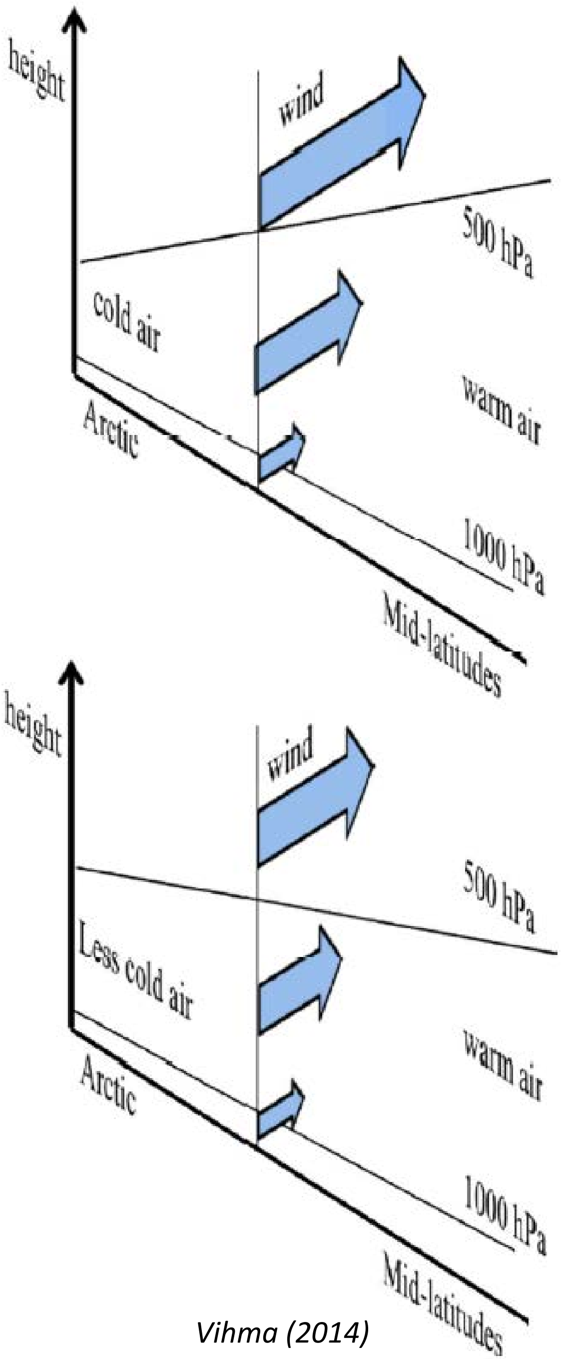


Blocking freq vs - sea ice extent



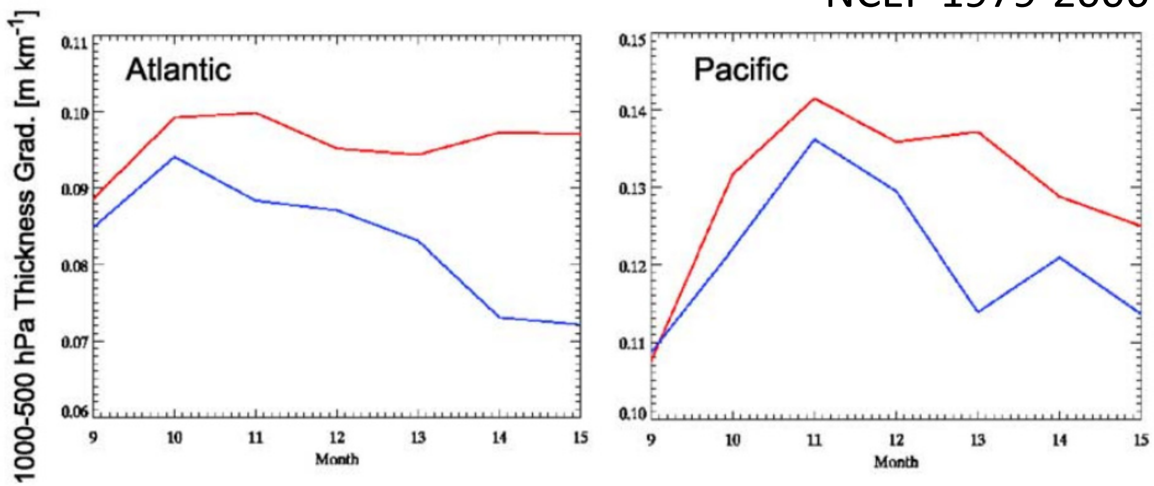
Surface temperature vs - sea ice extent

A thermal wind mechanism



Vihma (2014)

NCEP 1979-2006



Poleward gradient in the geometric thickness of the 1000 – 500 hPa layer [m km-1] during years with above- (red) and below-normal (blue) sea ice during summer.
(Beyond 0.5 std)

Francis et al. (2009)

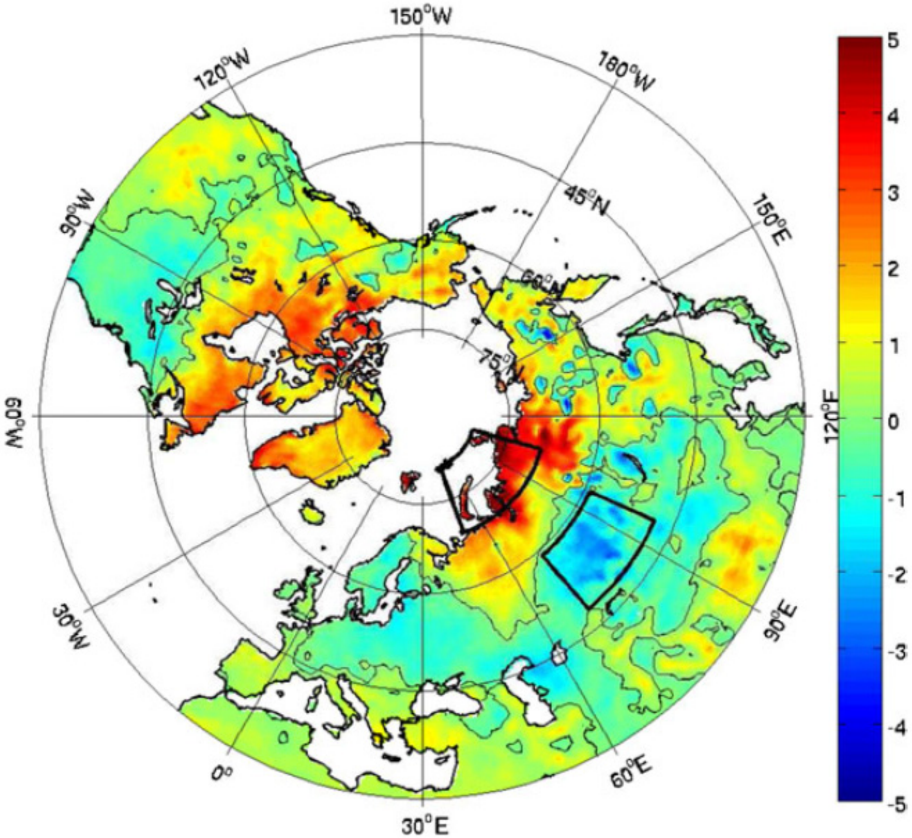
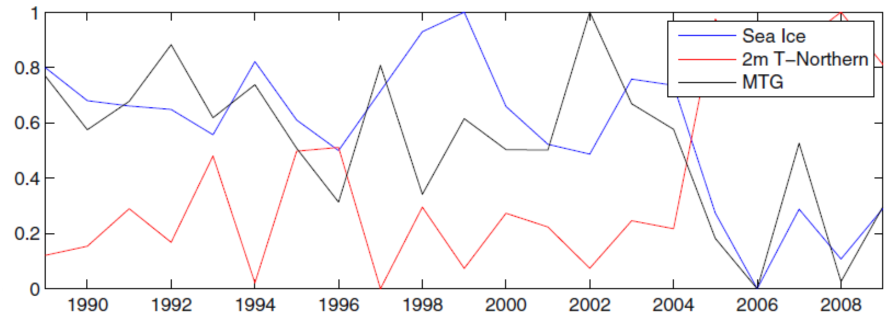
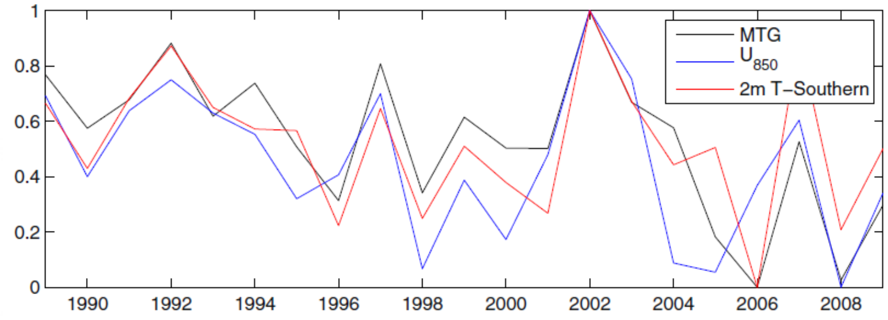


Fig. 1 Temperature trends [K/dec] for mean January SAT from 1989 to 2009, from ERA-Interim. A *black* contour is shown for 0 K/dec. The two outlined segments are the Northern domain over the Kara Sea and the Southern domain located over the region of maximum cooling in the mid laltitudes



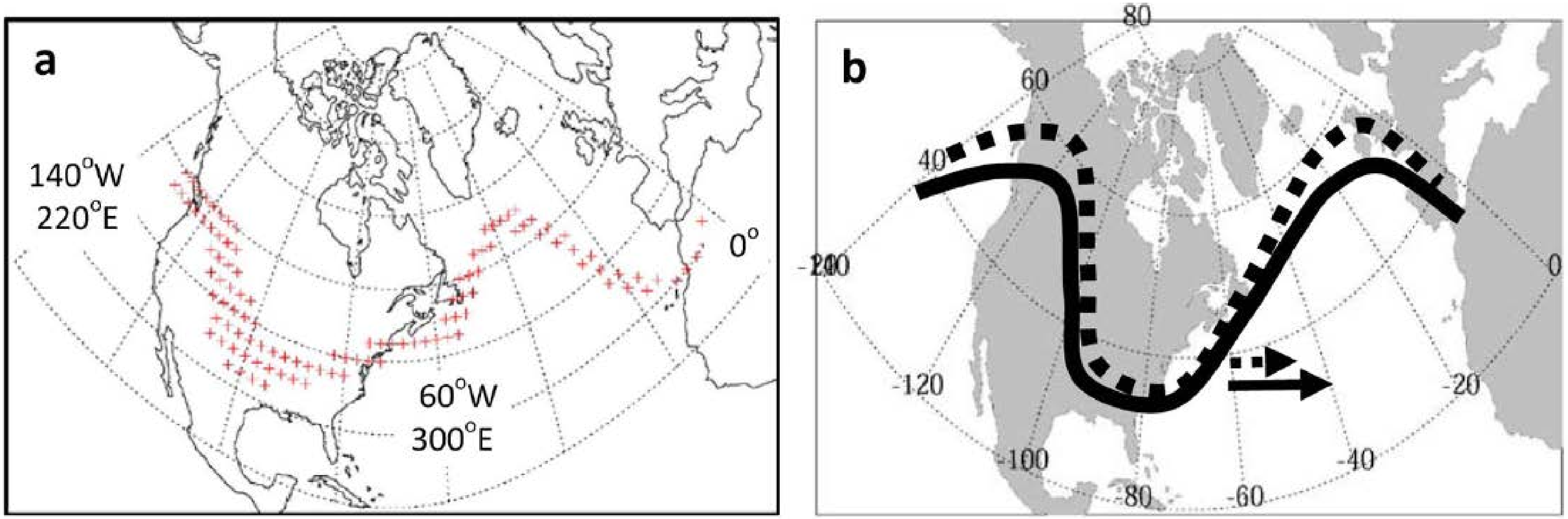


Correlations:

Sea ice and MTG	0.64
MTG and zonal wind	0.77
Zonal wind and T2m (south)	0.72

Outten and Esau (2012)

An increase in waviness – ”sticky weather”



Select a narrow range of 500 hPa heights for each season that captures the daily wave pattern in the height field.

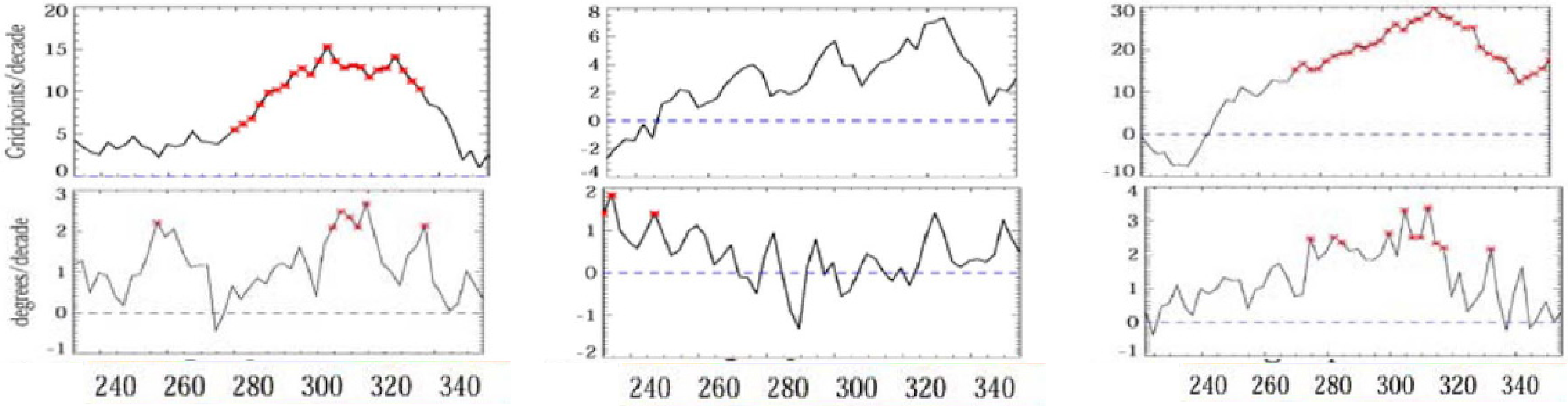
The following ranges were used for
Fall: 5600 m +-50 m,
Winter: 5400 m +- 50 m,
Summer: 5700 m +- 50 m.

Francis and Vavrus (2012)

NCEP reanalysis 1979 to 2010

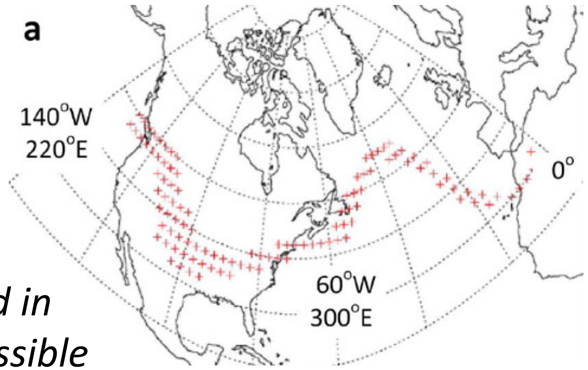
Trend in number of gridpoints north of 50N (60N for JFM) that are occupied by the isopleth

OND JFM JAS



Longitude Longitude Longitude

Trend in meridional extent of wave amplitude



But, using various Fourier-based metrics,
Screen and Simmonds (2013) find:

*…**two different measures** of amplitude show notably different trends, and in many cases the trends **are of opposing sign**. Therefore, we argue that possible connections between AA and planetary waves, and implications of these, are **sensitive to how waves are conceptualized**. We find that statistically significant changes in either metric are **limited to a few seasons, wavelengths, and longitudinal sectors**.*

Francis and Vavrus (2012)

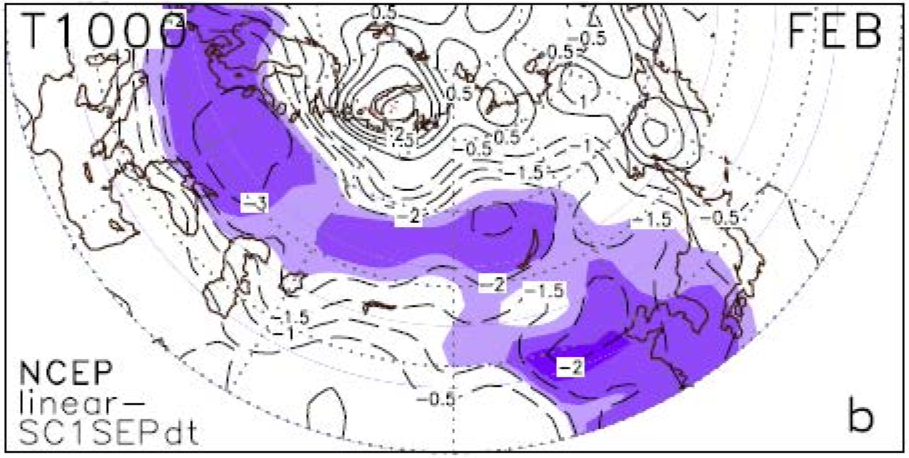
Sea ice decline appears to be associated with

- a pressure pattern reminiscent of the negative AO phase
- a reduction in the meridional temperature gradient and 1000-500 hPa thickness gradient which tends to weaken the zonal winds
- increased evaporation, earlier snow cover and a strengthened Siberian High
- increased winter blocking and extreme cold events at mid-latitudes - through one or more of the above effects

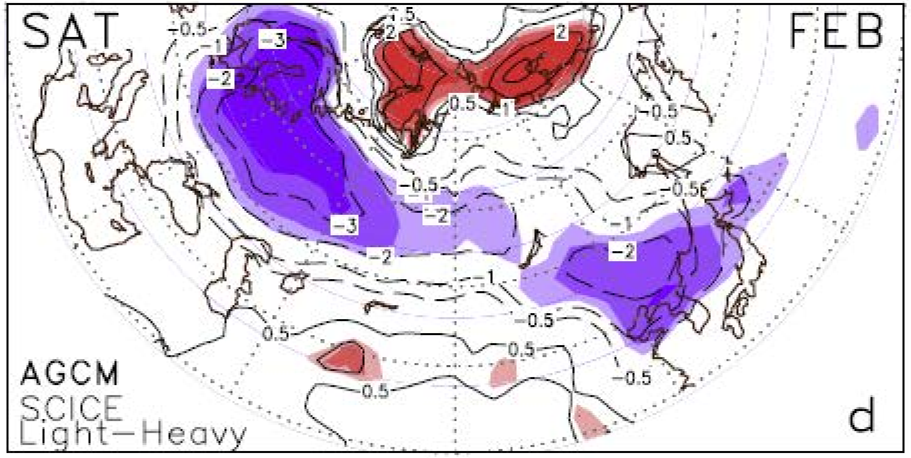
It is still unclear whether

- weakend 1000-500 hPa thickness and associated weakening of the westerlies have yet led to an increase in the planetary wave amplitude and a slower propagation (sticky weather)
- the observed winter changes are associated with the relatively large sea ice changes in summer-autumn or the considerably smaller ones in winter

Modeling results – weak and strong effects



NCEP 1979-2006



AGCM with sea ice changes in Sep-Dec

Does the recent rapid decrease in the summertime Arctic sea-ice extent enhance the wintertime cold anomalies over Eurasia?

Perhaps, but perhaps not, since other surface conditions in addition to sea ice display anomalies (e.g., SST, snow, and land parameters) that can impact the atmospheric circulation.

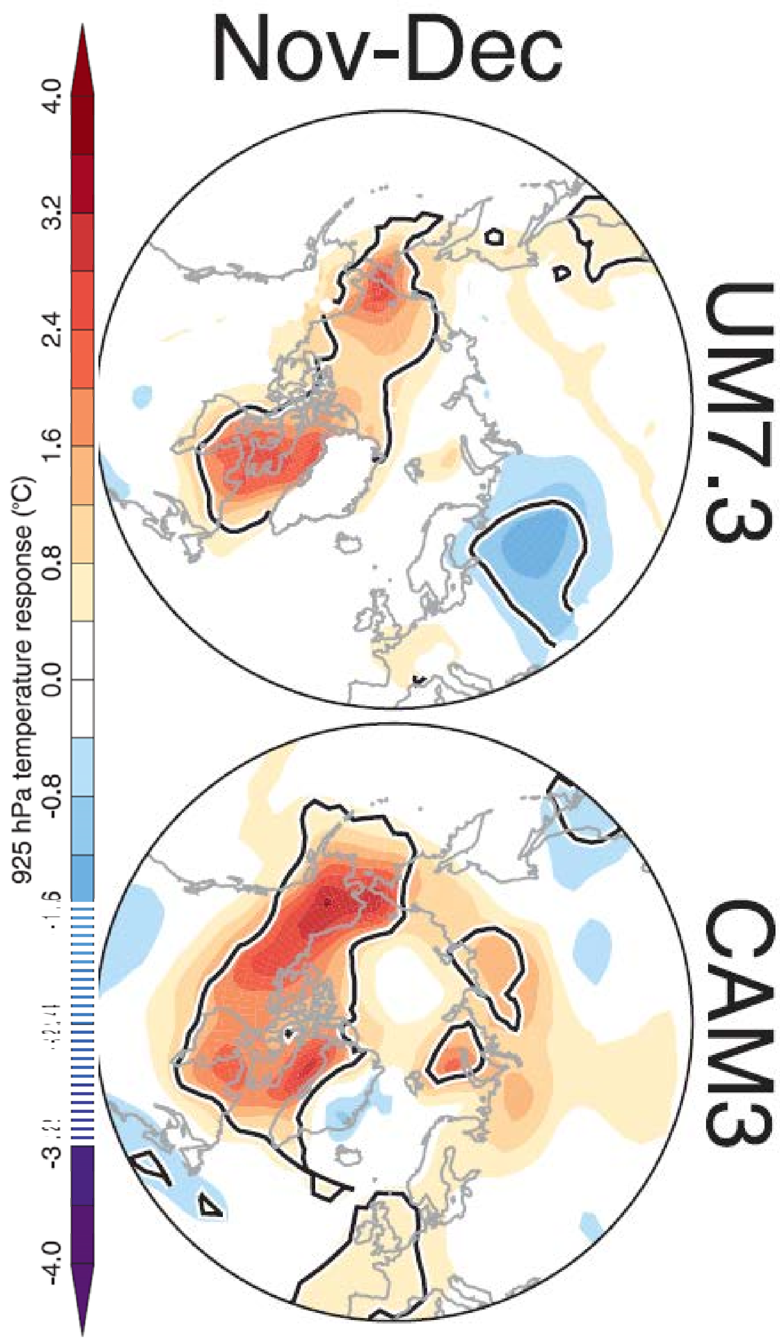
Further, since the basic state of the atmospheric circulation is gradually changing, atmospheric responses to a future decrease of the sea-ice may differ from that for the present one.

Honda et al (2009)

Two different GCMs forced by observed 1979- sea ice

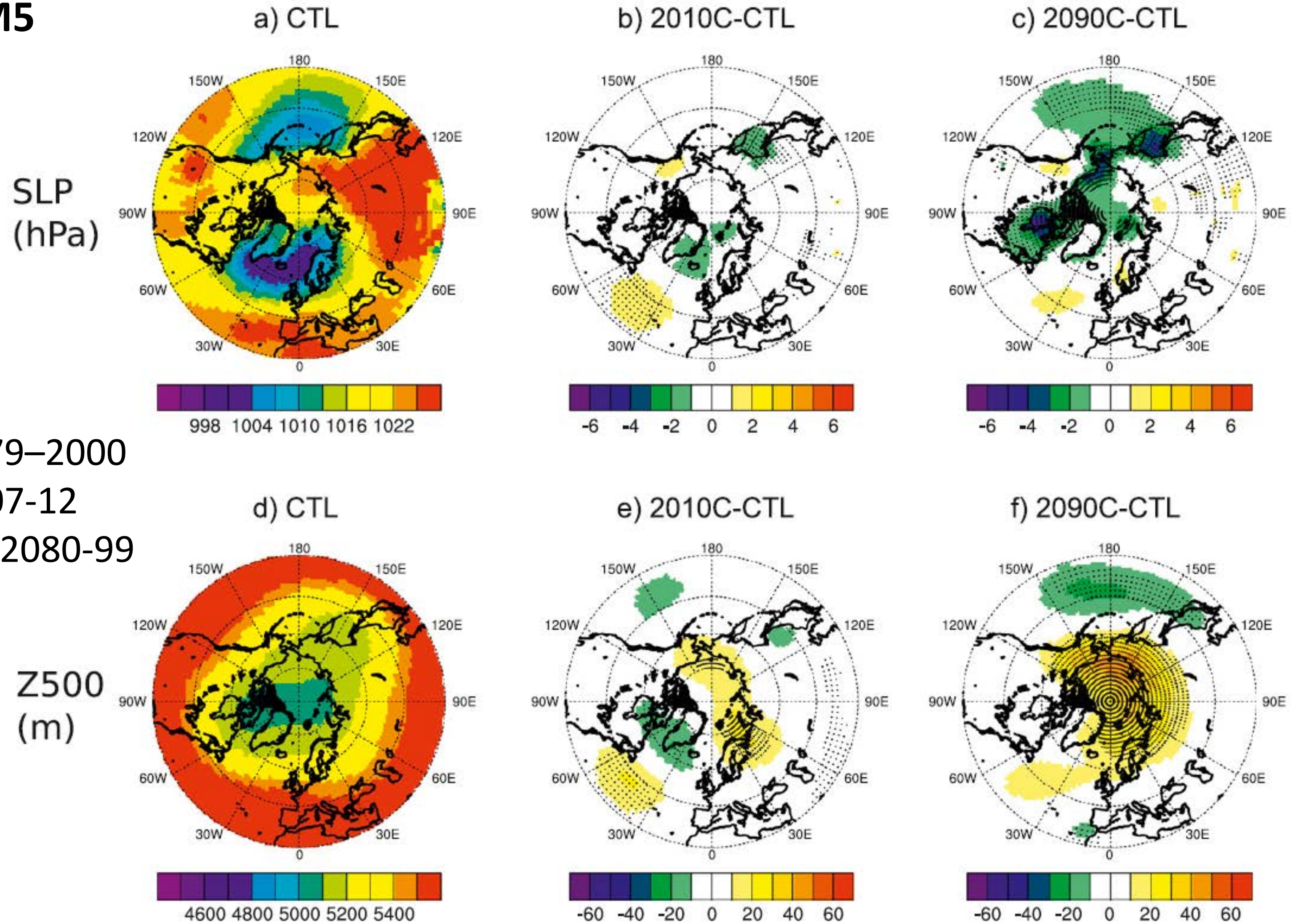
- Localized surface and low-level cooling over northeast Europe in early winter in UM7.3 (but not CAM3)

- No robust (between models) or widespread cooling, or increased snowfall, in response to the Arctic sea ice loss over the last three decades.



Screen et al (2013)

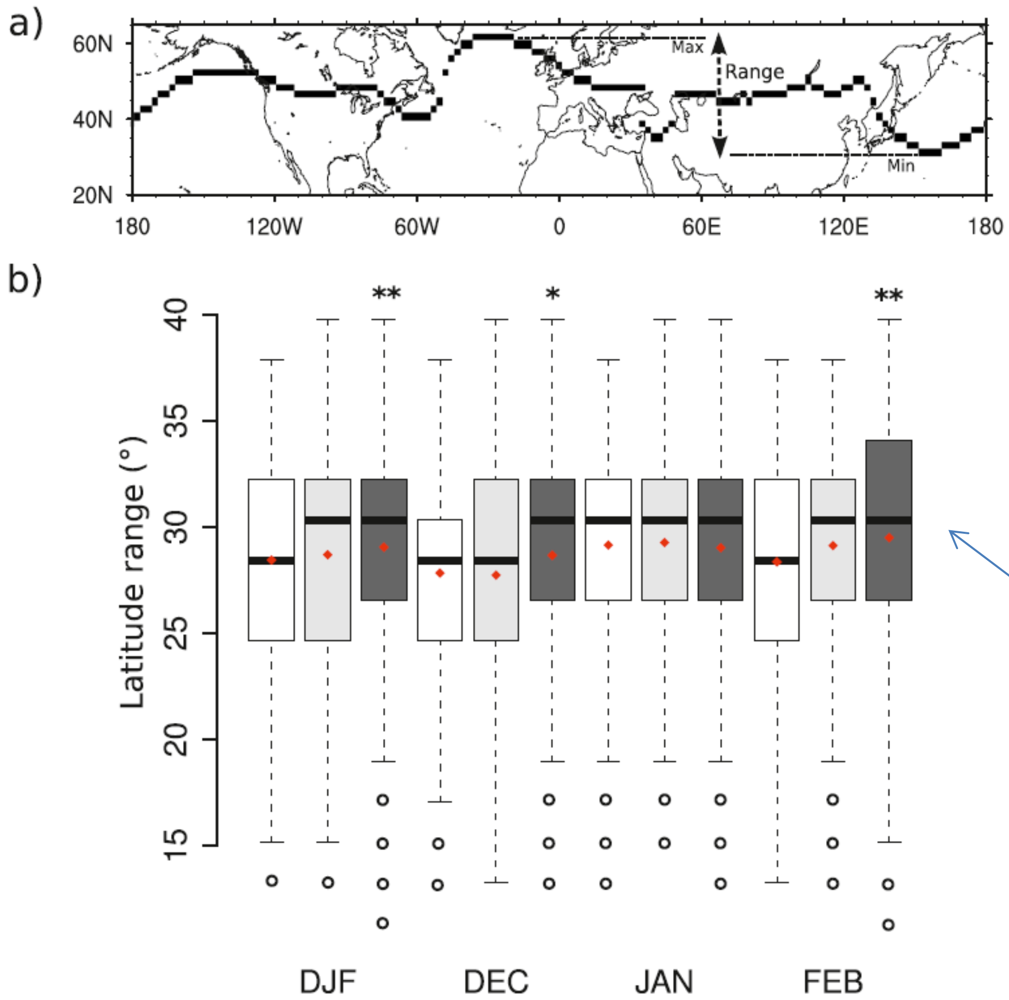
Current vs strong future sea ice decline in CAM5



CTL: obs 1979–2000
2010C: obs 2007-12
2090C: RCP8.5 2080-99

- A small response to current decline but a stronger, baroclinic response to future projected decline.
- Z500 pattern resembles the negative AO phase

Peings and Magnusdottir (2014)



Increased February waviness in RCP8.5

FIG. 13. (a) Example of the latitudinal position of the 5400-m isopleth along longitude for one day of February in CTL. The minimum, maximum, and range of the latitudinal positions are indicated. (b) Distribution of the daily ranges (° lat) of the 5400-m isopleth for CTL (white boxplots), 2010C (light gray boxplots), and 2090C (dark gray boxplots) in winter (DJF). Boxplots and whiskers indicate the maximum, upper quartile, median, lower quartile, and minimum of the distribution (horizontal bars). Outliers are represented by circles. The mean of the distribution is shown by red diamonds, and asterisks indicate the significance level of the change of the mean in 2010C and 2090C, compared to the CTL value (*: $p < 0.1$; **: $p < 0.05$, according to a Student's t test applied on the seasonal means of the range; see text).

Peings and Magnusdottir (2014)

Changes in cold events (10th percentiles)

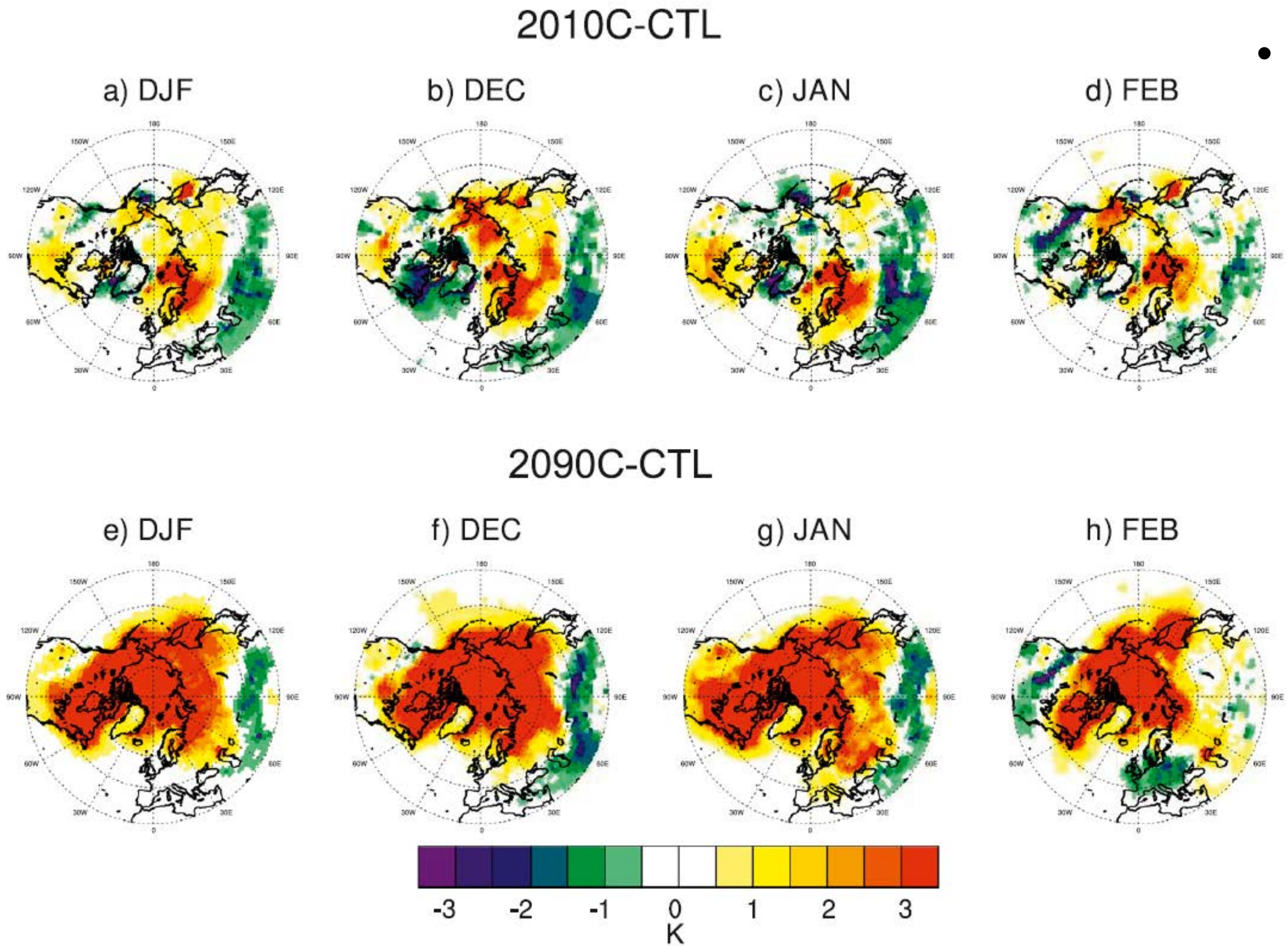


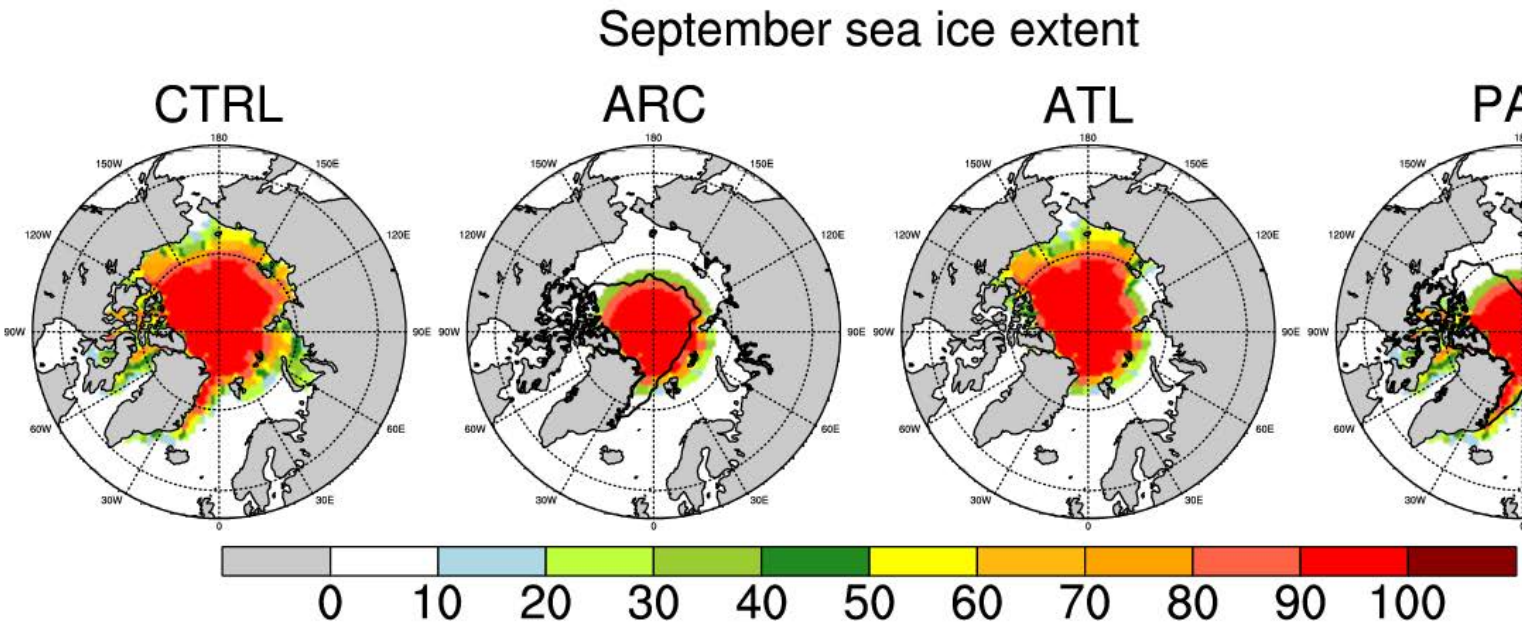
FIG. 14. Response of the 10th percentile of the 1000-hPa daily temperature (K) in 2010C in (a) winter (DJF), (b) December, (c) January, and (d) February; (e)–(h) as in (a)–(d) but for 2090C.

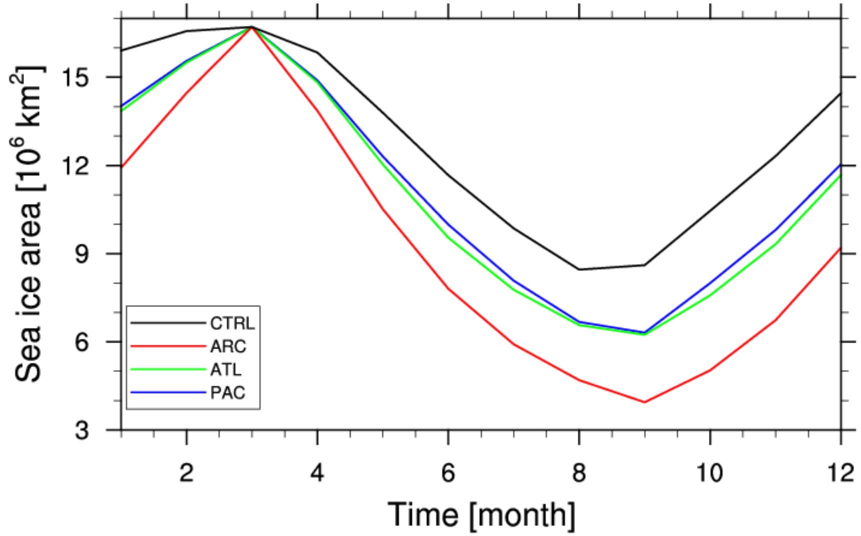
- Current Arctic sea ice conditions (2010C) favor the intensity of cold extremes over mid-latitudes, although mostly limited to the Asian sector.

- In 2090C, the intensity of cold extremes decreases everywhere north of 45N
- In 2090C (as in 2010C), cold extremes are more intense south of 45N.

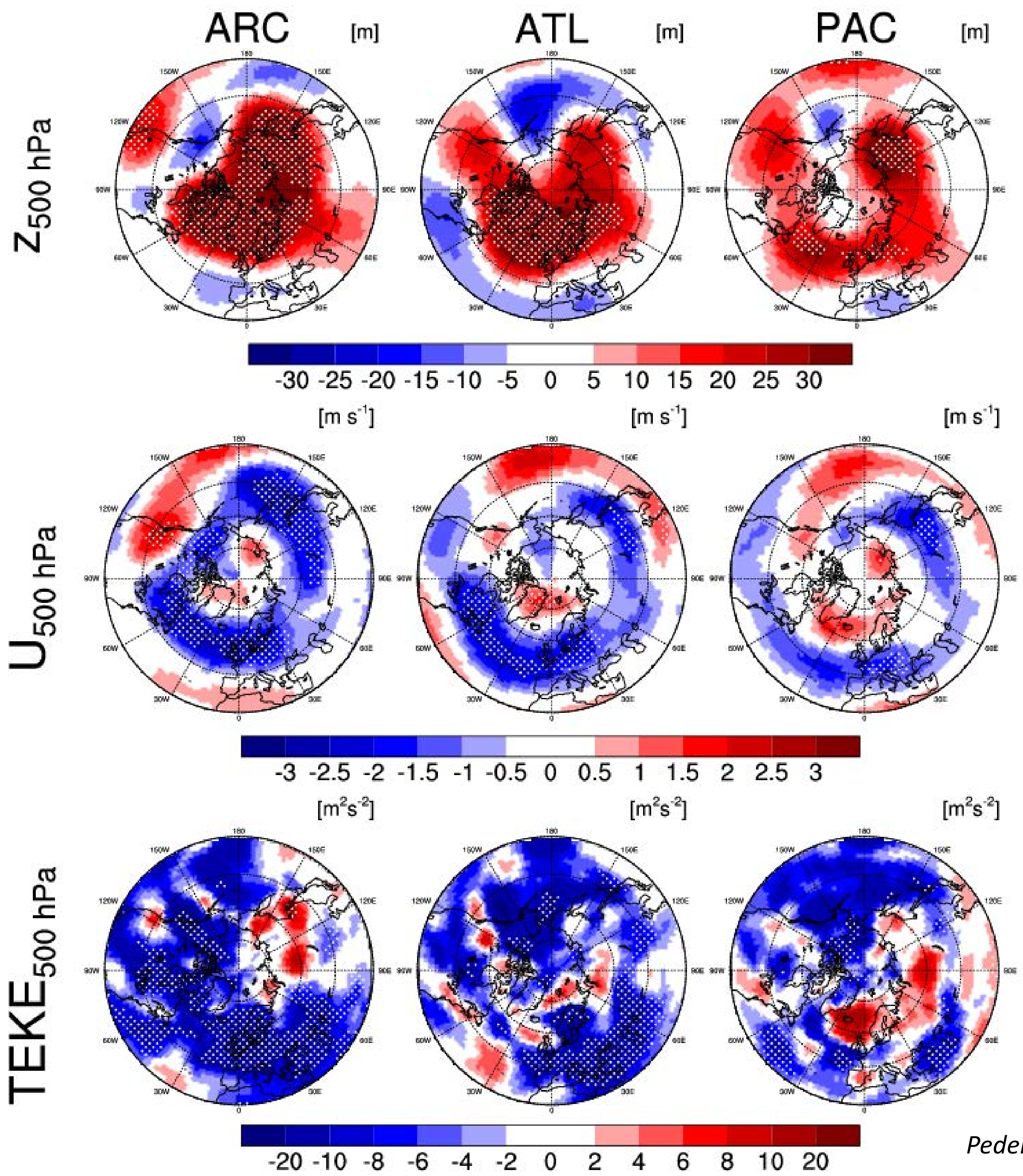
Peings and Magnusdottir (2014)

Sensitivity to geographical distribution of sea ice loss



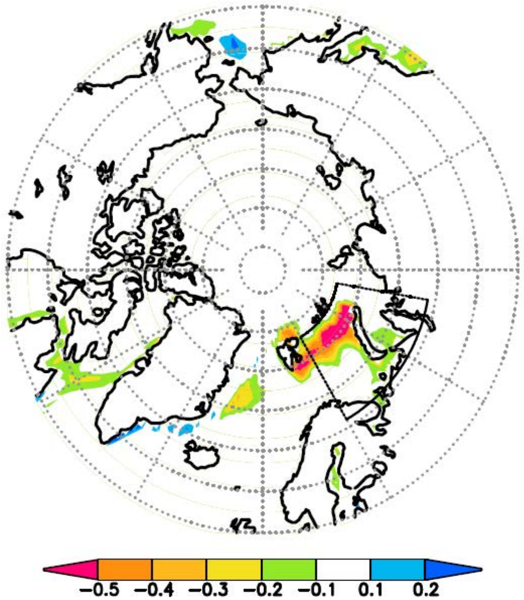


Pedersen et al. (revised, JClim)

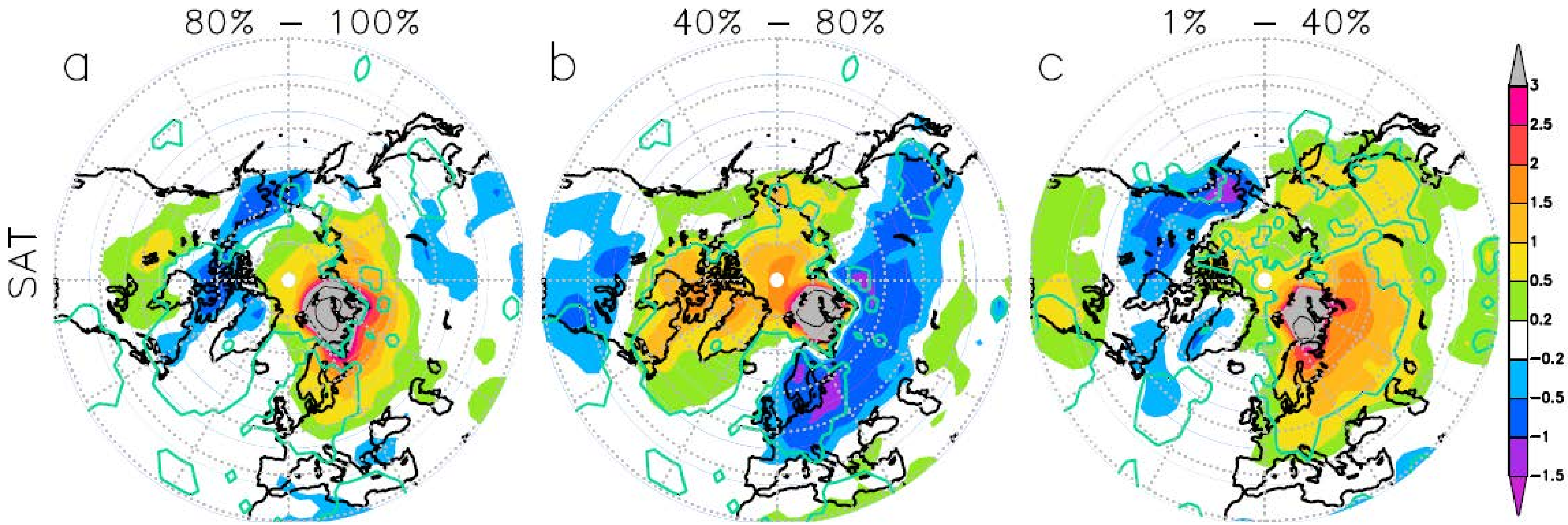


Pedersen et al. (revised, JClim)

Non-linear response

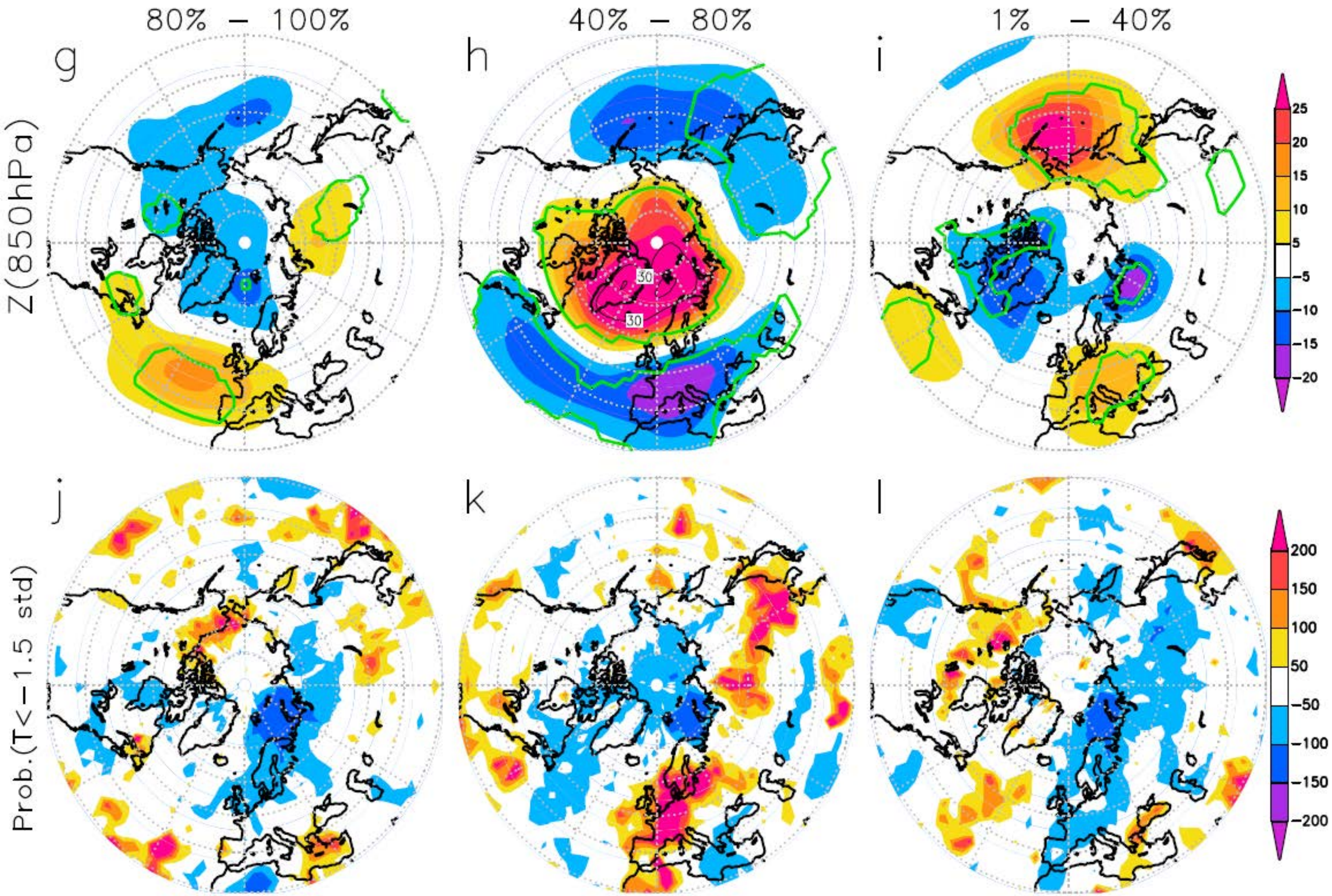


DJF 2006-07
sea ice anomaly
(rel 1981-2000)



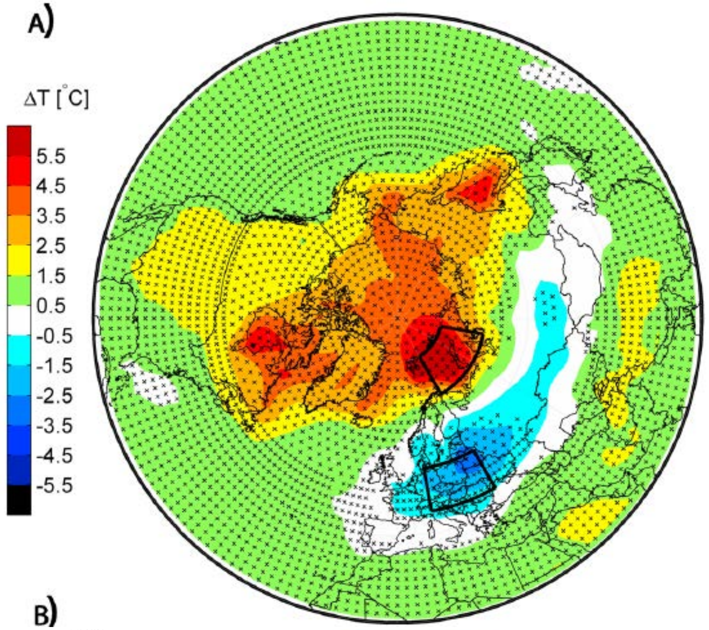
Sea ice reduced Nov-Apr in ECHAM5

Petoukhov and Semenov (2010)

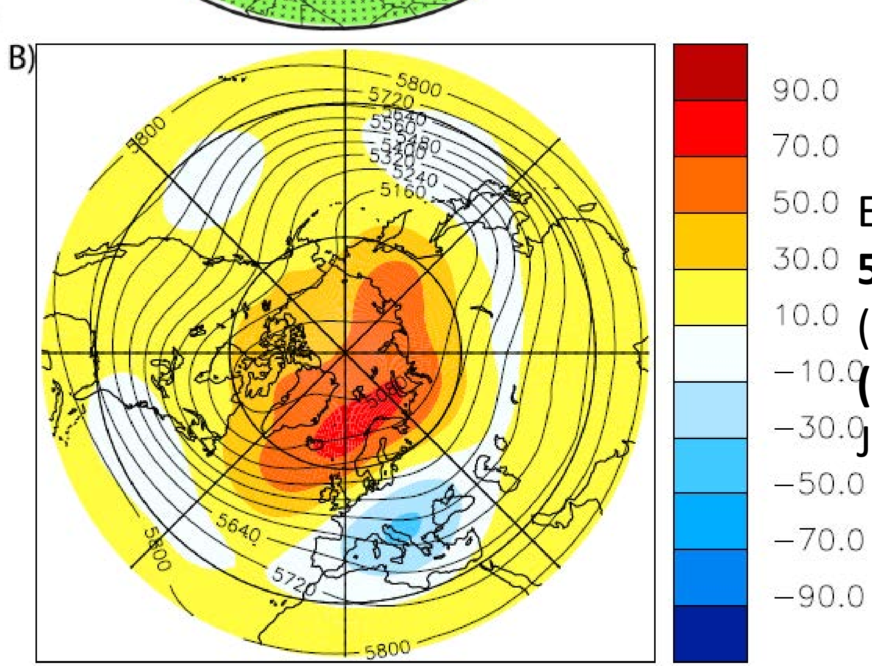


Petoukhov and Semenov (2010)

CMIP5 multi-model analysis



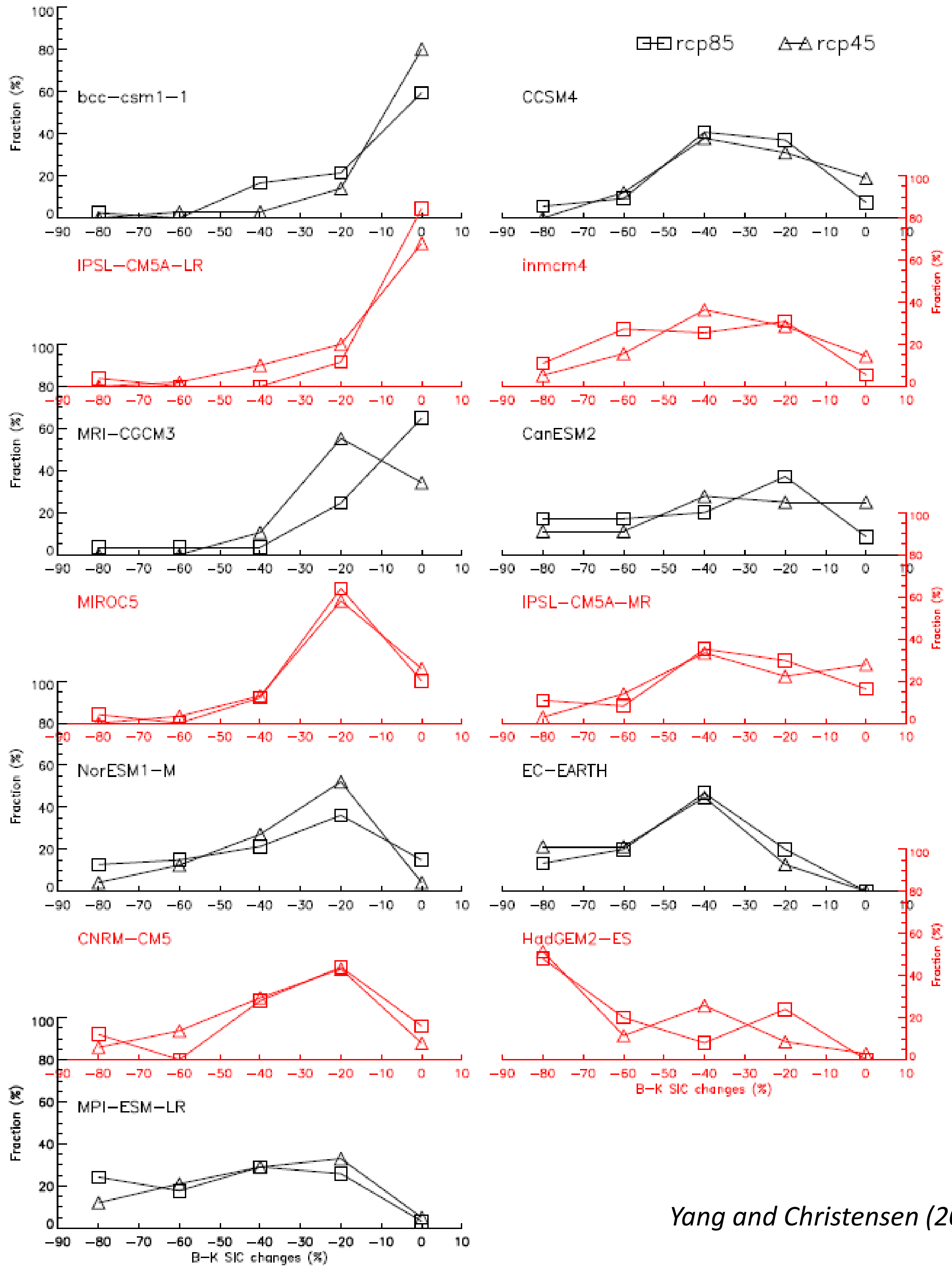
Ensemble mean of composites of **SAT anomalies** for European cold Januaries in 2006–2050 (RCP4.5)



Ensemble mean of composites of **500 hPa geopotential height** (contour lines) and its **anomalies (color shadings)** for European cold Januaries in 2006–2050 (RCP4.5)

Yang and Christensen (2012)

Occurrence of **cold European winters** stratified **by SIC in Barents-Kara Seas** in future warming scenarios



Yang and Christensen (2012)

Summary
- and a few words of caution

Modelling studies indicate that Arctic sea ice decline leads to pressure patterns resembling the negative AO phase - but the vertical structure may be baroclinic

The two-model simulations by Screen et al. (2013) did not agree on mid-latitude effects of the observed sea ice decline. To the degree that such effects are present, they are model-dependent or drown in internal variability.

Petoukhov and Semenov (2010), Yang and Christensen (2012) and to some extent Peings and Magnusdottir (2013) find that strong sea ice decline tends to eliminate the occurrence of cold winters in northern mid-latitudes.

On the increased waviness and increased occurrence of extreme warmth and cold:

> *It's an interesting idea, but alternative observational analyses and simulations with climate models have not confirmed the hypothesis, and we do not view the theoretical arguments underlying it as compelling.*

On the link between summertime Arctic sea ice and wintertime climate at mid-latitudes:

> *[It] deserves a fair hearing. But to make it the centerpiece of the public discourse on global warming is inappropriate and a distraction. Even in a warming climate, we could experience an extraordinary run of cold winters, but harsher winters in future decades are not among the most likely nor the most serious consequences of global warming.*

Wallace, Held, Thompson,
Trenberth and Walsh
(Science 2014)