

Response of the wintertime atmospheric circulation to current and projected Arctic sea ice decline

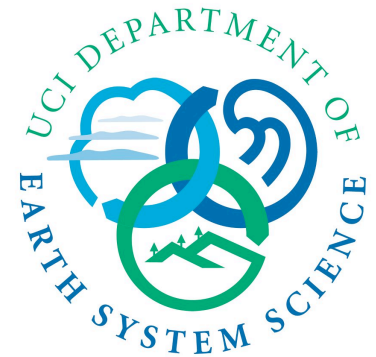
Gudrun Magnusdottir

and

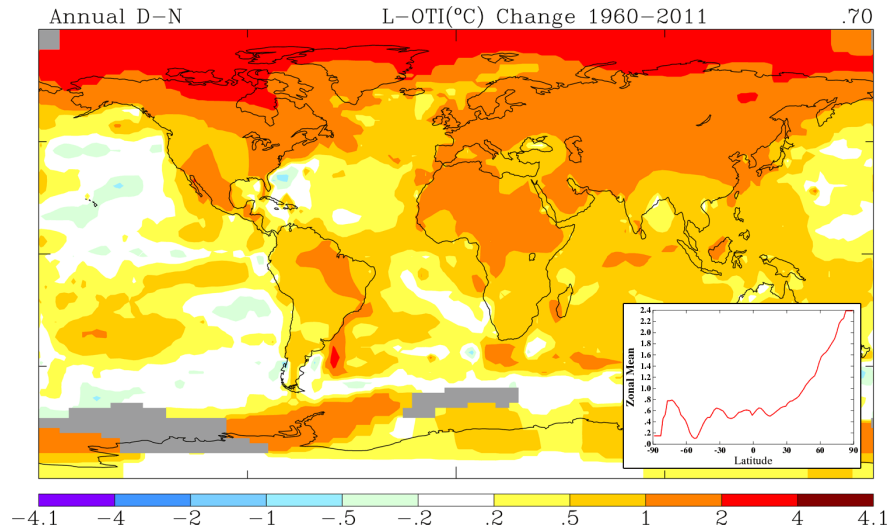
Yannick Peings

Earth System Science, UC Irvine

Paper is just out in J. Climate (Jan. 1, 2014)
Peings and Magnusdottir (2014)

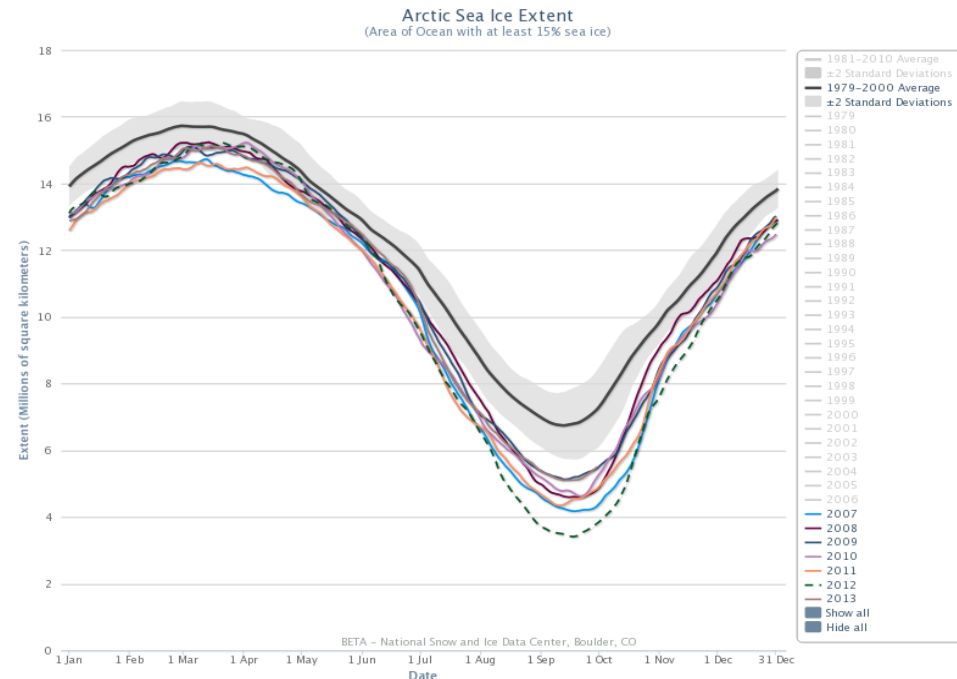


Recent acceleration of Arctic sea ice decline



Arctic Amplification (AA): over recent decades the Arctic has warmed approximately twice as fast as the entire NH

Seasonal cycle of Arctic sea-ice extent



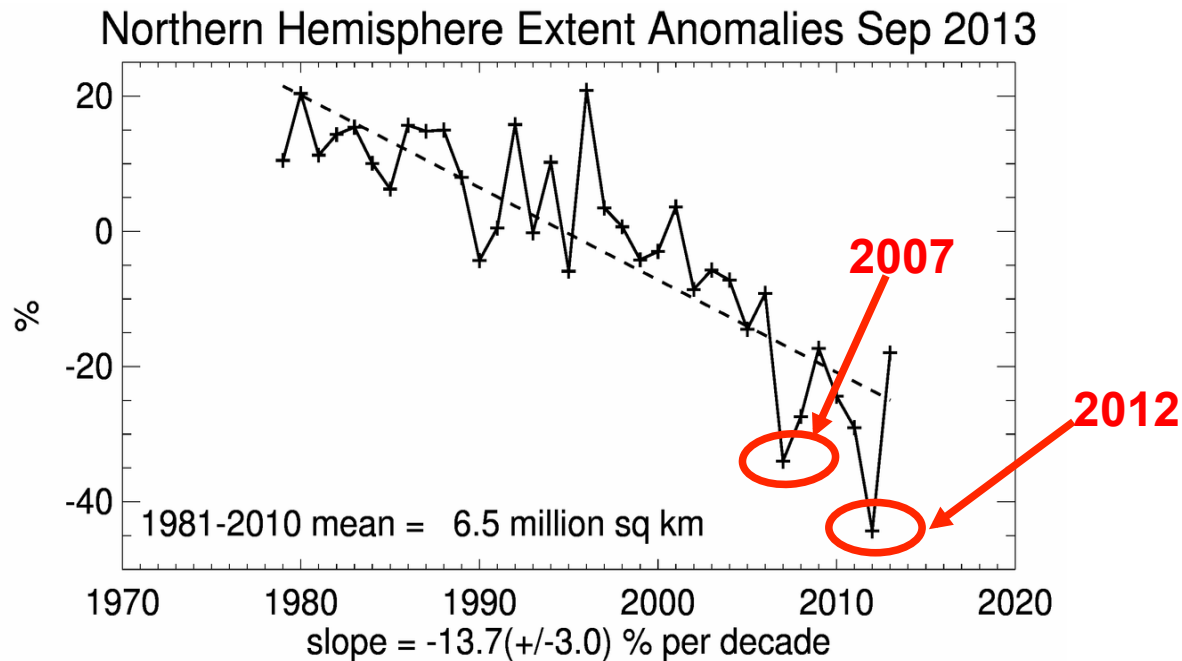
The sea-ice extent (area with > 15% sea-ice concentration (SIC)) has been **exceptionally low in recent years, especially in 2007 and 2012**

Source:
NSIDC

Arctic sea ice has declined in recent decades

The Sept sea-ice extent has declined by ~40% from 1979

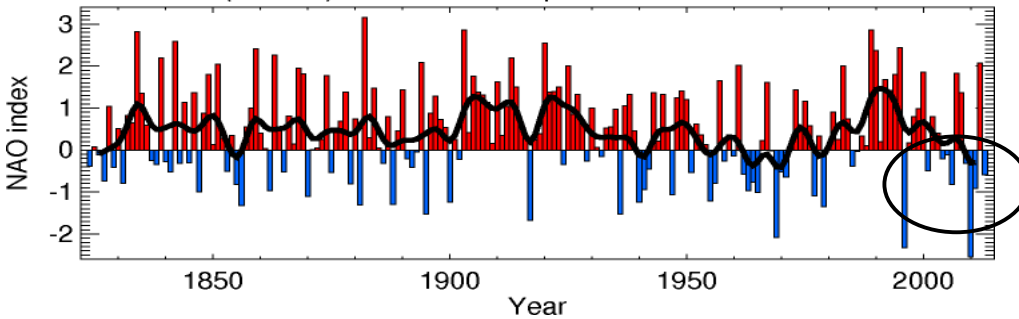
The sea-ice decline at an accelerated rate over recent years



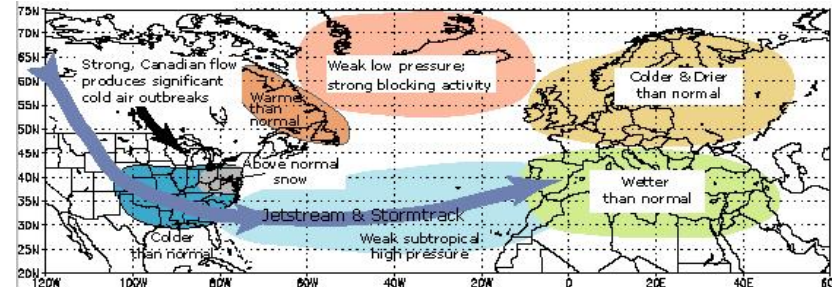
Source :
NSIDC

NH atmospheric winter circulation index – NAM index

Negative values of the wintertime NAO index over some recent winters



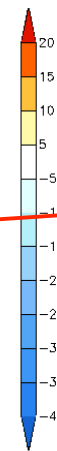
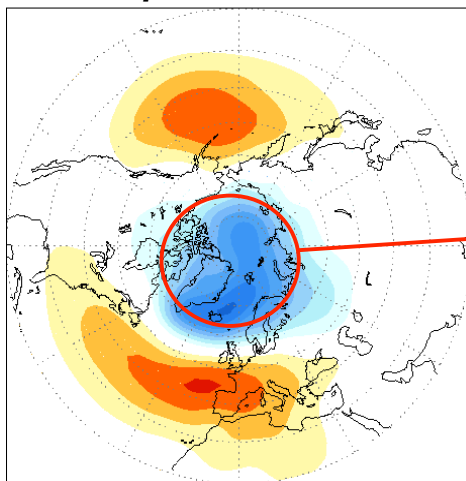
Source : CRU



Source : NCDC

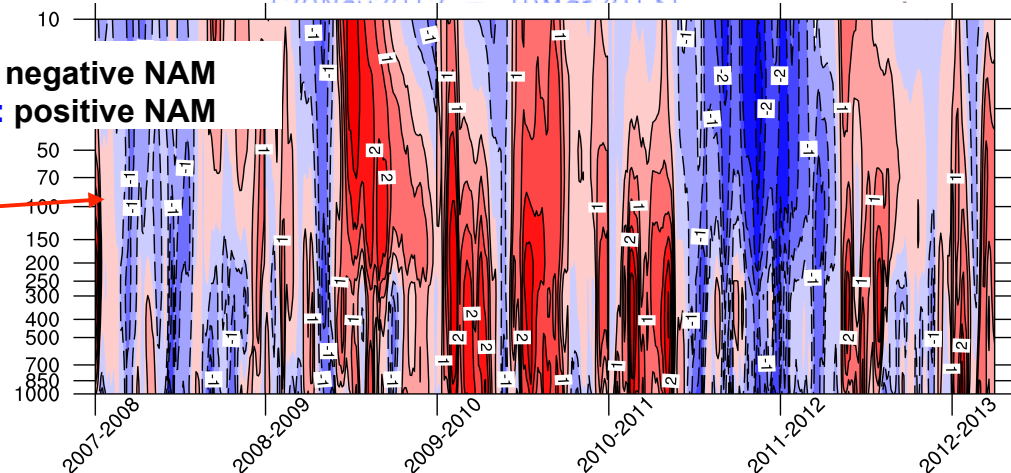
- also referred as the Northern Annular mode (NAM)

NAM pattern in surface



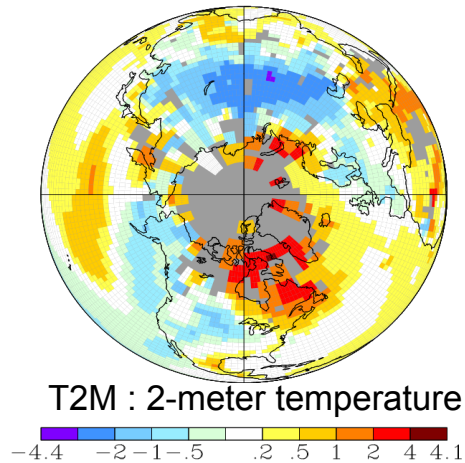
Daily NAM anomalies along the vertical (DJFM)

(geopotential Normalized averaged SFP anomalies (65°N–80°N) (20N–2012, 10N–2013))

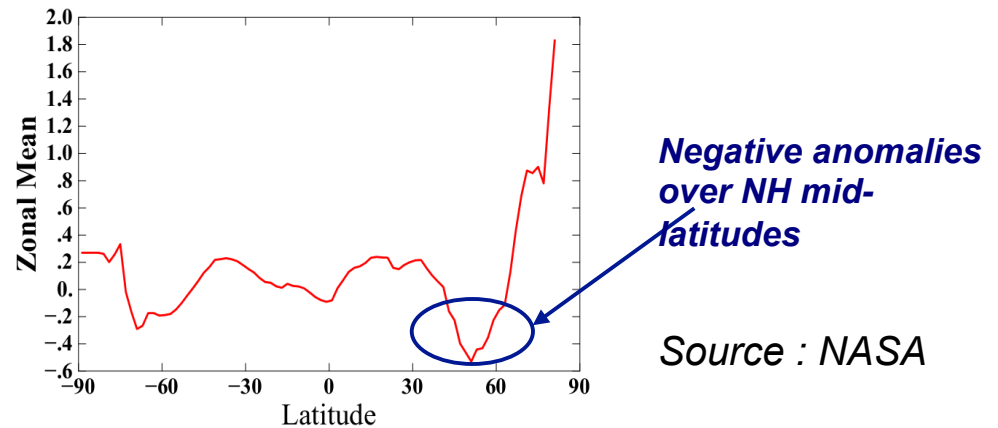


Colder temperatures over the NH mid-latitudes

Cold temperatures over mid-latitudes in winter



2008-2013 anomalies of DJFM T2M (relative to 1961-1990)



Severe cold spells over Europe, Asia and North America :



2009/2010: cold winter with extensive snowfall over Eurasia & N. America

2012: deadly cold spell over central Europe in Jan-Feb

2013: anomalously cold & snowy winter/spring over Northern Europe and USA (coldest March in UK since 1962)

What caused these climate anomalies ?

These recent cold winters have been presented by certain groups as proof that global warming has stopped, or never existed ...

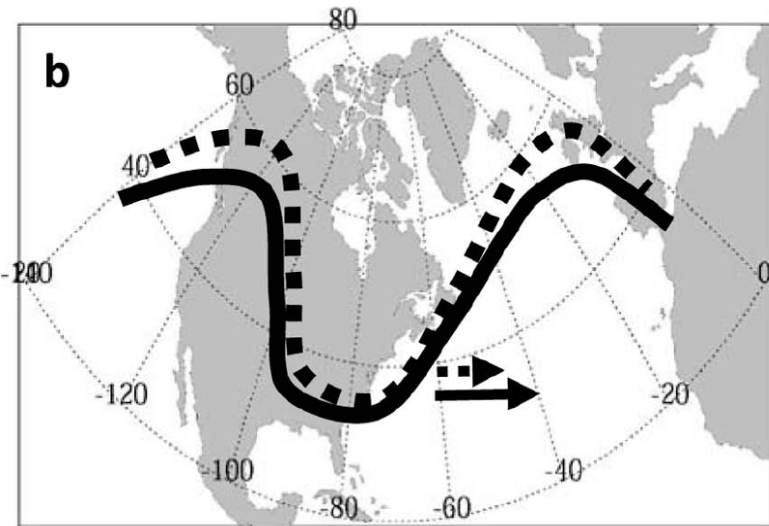


What are possible reasons for more severe winter conditions over NH mid-latitudes in recent years?

Natural variability? (in atmosphere, oceanic modes, solar variability, volcanic eruptions,...)

Unexpected effect of anthropogenic forcing? What is the role of Arctic sea-ice decline?

Less Arctic sea ice => slowdown of the westerly flow and more cold extremes ?



from Francis and Vavrus (2012)

Decreased north-south temperature gradient

Slower westerly winds

Increased north-south wave amplitude

Slower wave propagation

More persistent weather

More extreme weather events

However, this result is metric dependent and **is not supported by two recent studies** (Screen and Simmonds 2013, Barnes 2013)

Our modeling study (Peings & Magnusdottir 2013) forcing an AGCM with sea-ice concentrations over recent years of large sea-ice loss showed modest response and response to projected end of century sea-ice loss was no greater

Goals of the study

Investigate the response of the winter atmospheric circulation to
recent Arctic sea-ice anomalies (2007-2012) and
projected sea-ice anomalies (2080-2099)
using the latest version of the Community Atmospheric Model (**CAM5**).

Examine seasonal-mean response as well as the intraseasonal response,
response in terms of extreme weather events.

Questions:

What is the wintertime response to observed sea-ice anomalies?

→ **Negative NAO/NAM pattern?**

What is the response to a stronger sea-ice loss expected at the end of the 21st century?

→ **Is the response to sea-ice loss linear?**

Is there an increase in extreme weather events in mid-latitudes? Future increase?

→ **More extreme cold temperatures?**

Model and experiments

Model: Community Atmospheric Model version 5 (CAM5) from NCAR

Atmospheric part of CESM1

1.9° latitude x 2.5° longitude, 30 vertical levels

Prescribed sea surface temperature (SST) and sea-ice concentration (SIC)

Greenhouse gases and aerosol concentrations of year 2000

CAM5 physics (F_2000_CAM5 compset)

Experiments

- 50-yr control (CTL) simulation, annually repeating sea ice concentration (SIC) & sea surface temperature (SST) that represent 1979-2000 climatology (from the monthly HadISST)
- Two perturbation experiments, each is a 50 member ensemble. Each ensemble member is run for 13 months, started from 1. April of each yr of CTL:
 - 2010C is forced with the annual cycle of the mean SIC for 2007-2012 (from HadISST).
 - 2090C is forced with the annual cycle of the mean SIC corresponding to climate model projections for 2080-2099

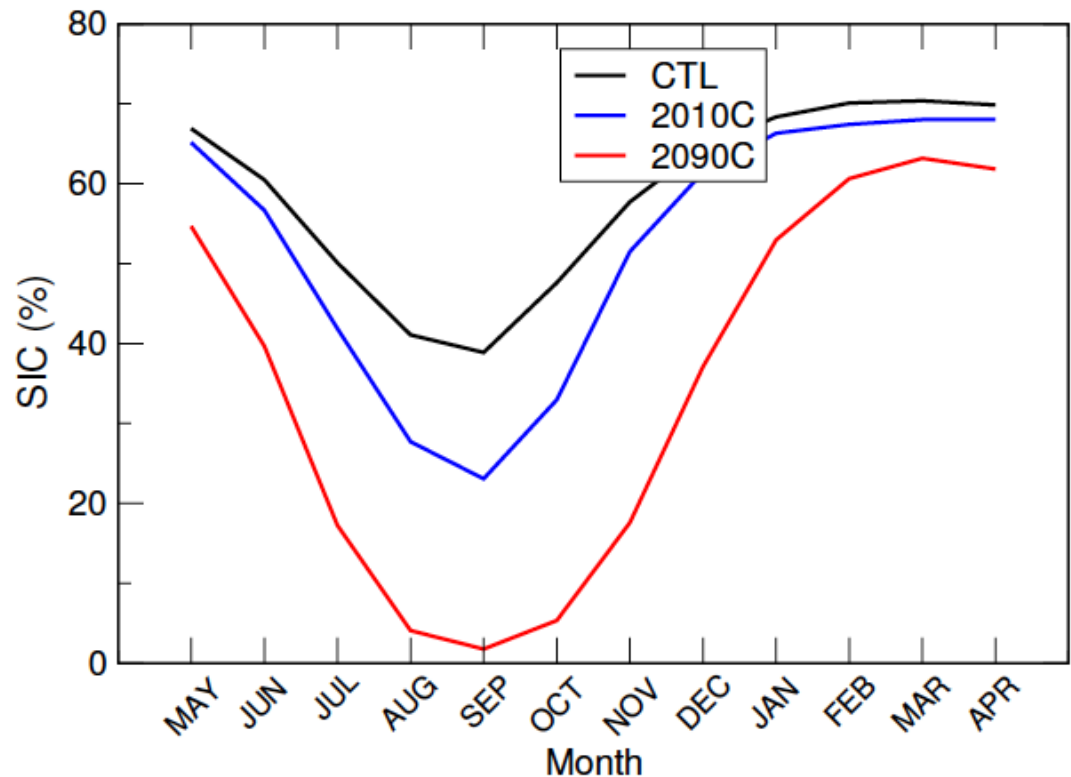
Model experiments

CTL: 50 yr CAM5 simulation forced with average annual cycle of observed SST and SIC over 1979-2000

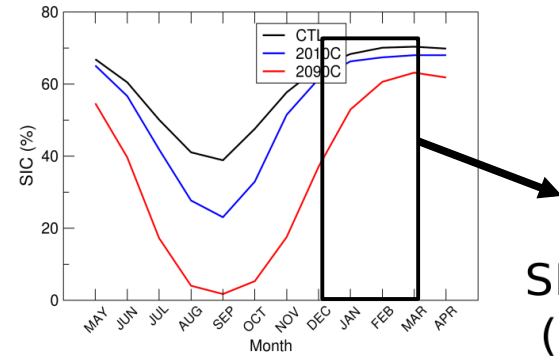
2010C: Ensemble of fifty 13-month simulations forced with average annual cycle of SIC over 2007-2012

2090C: Ensemble of fifty 13-month simulations forced with average annual cycle of SIC projected for 2080-2099

Annual cycle of SIC
averaged north of 60N

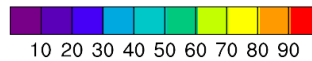
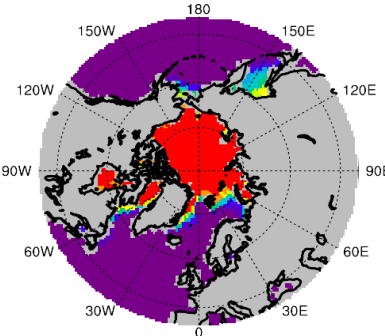


Sea-ice forcing in winter

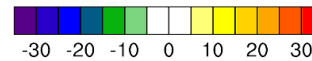
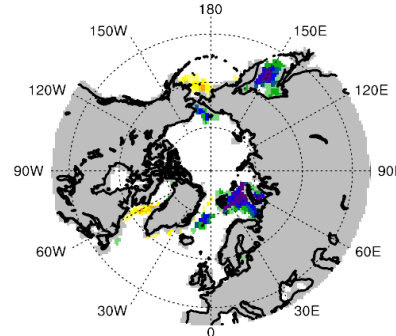


SIC (%)

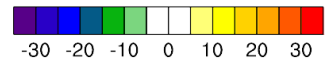
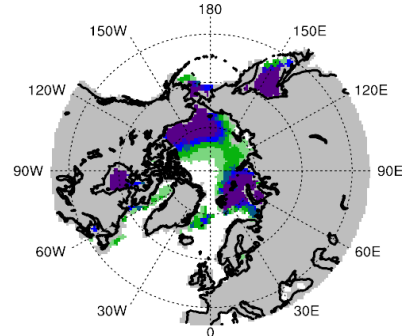
CTL



2010C-CTL

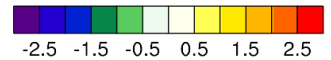
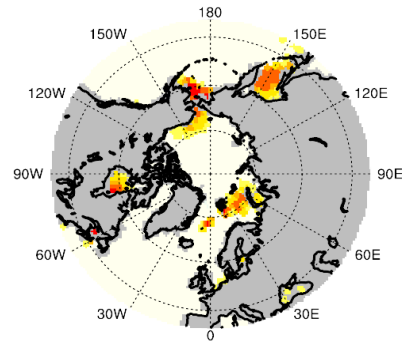
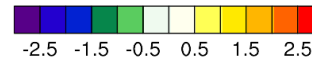
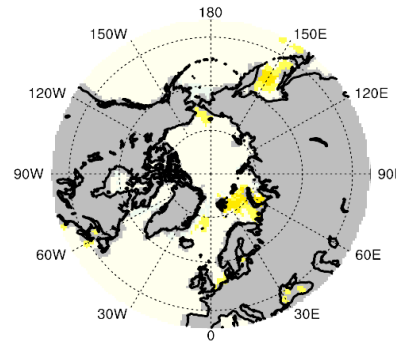
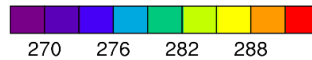
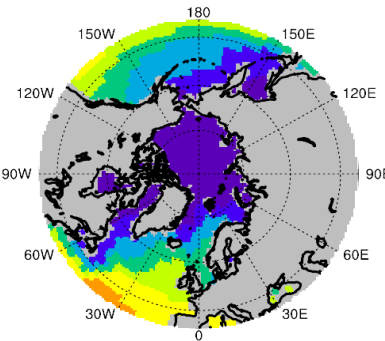


2090C-CTL



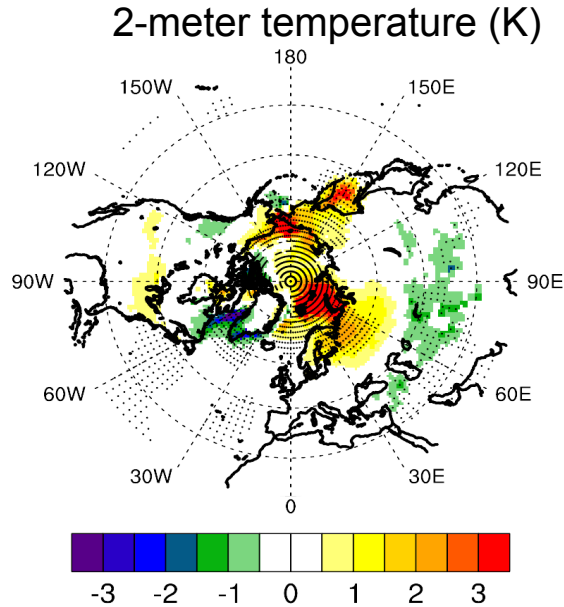
Also changed SST where SIC was changed by more than 10%

SST (K)

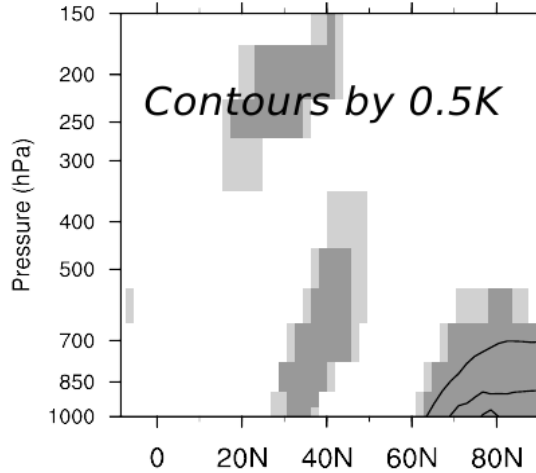


Thermal response in winter (DJF)

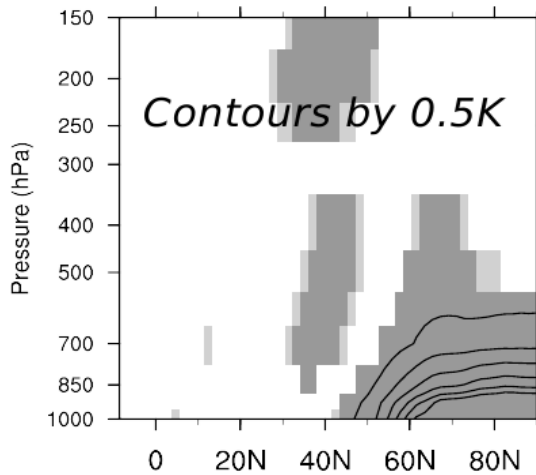
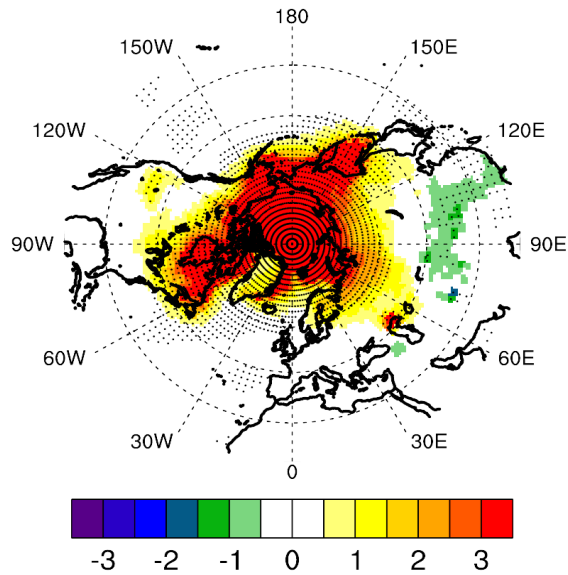
2010C



Vertical profile of temperature (K)



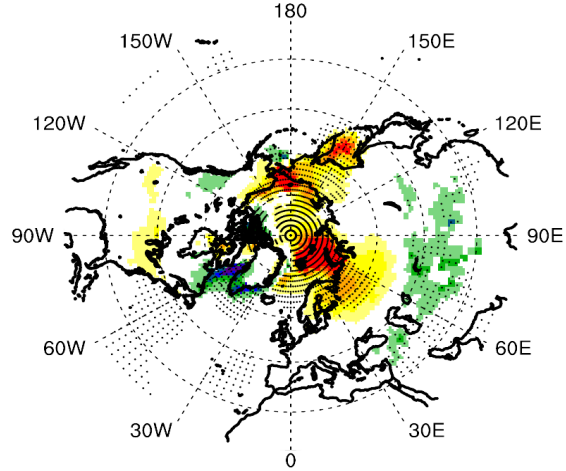
2090C



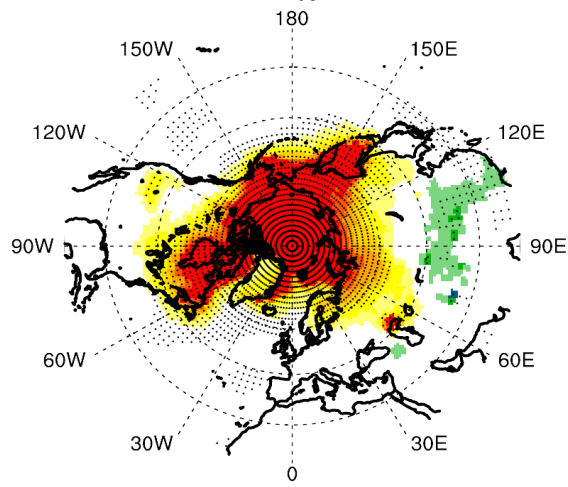
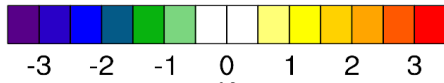
**Stipples and shading :
95% confidence level**

Thermal response in winter (DJF)

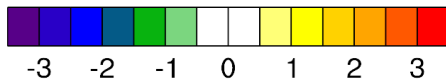
2-meter temperature (K)



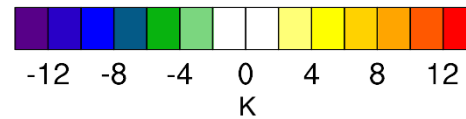
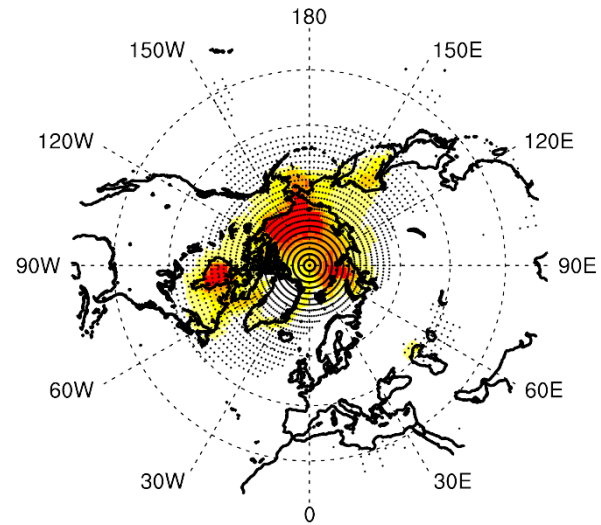
2010C



2090C



2090C - 2010C



DJF mean response

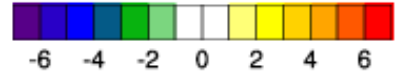
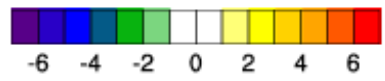
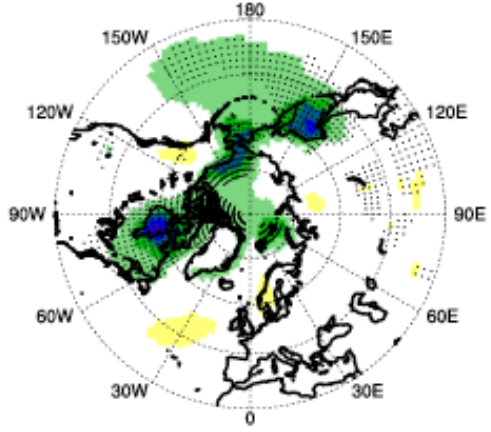
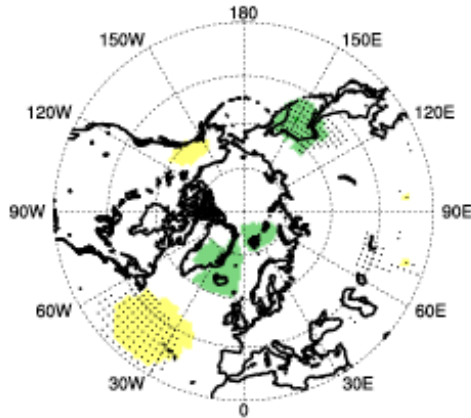
2010C

2090C

SLP (hPa)

b) 2010C-CTL

c) 2090C-CTL



2010C

Rather weak winter mean response (see Screen et al (2013))

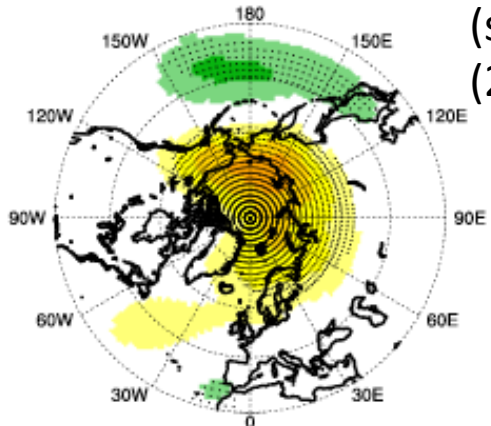
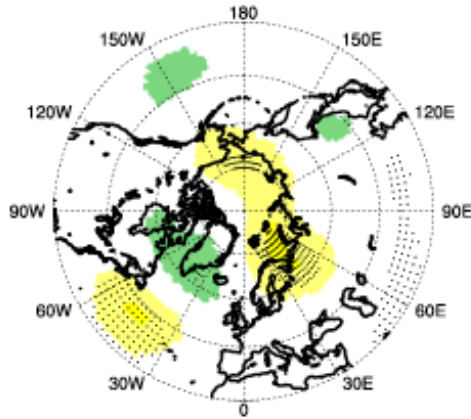
2090C

NAM signal in free troposphere (see Deser et al (2010))

e) 2010C-CTL

f) 2090C-CTL

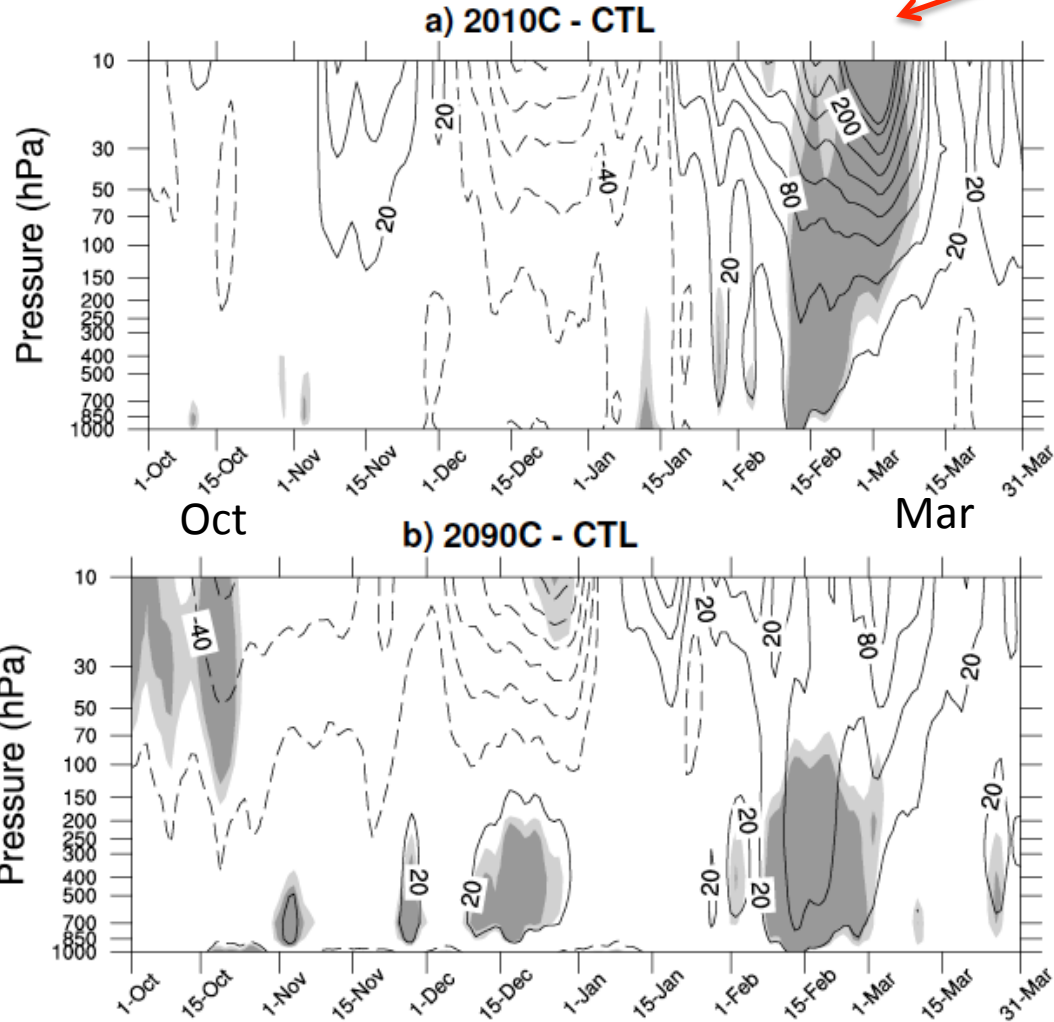
Z500 (m)



Dynamical response : intraseasonal scale

Daily polar cap (north of 65N) Z response

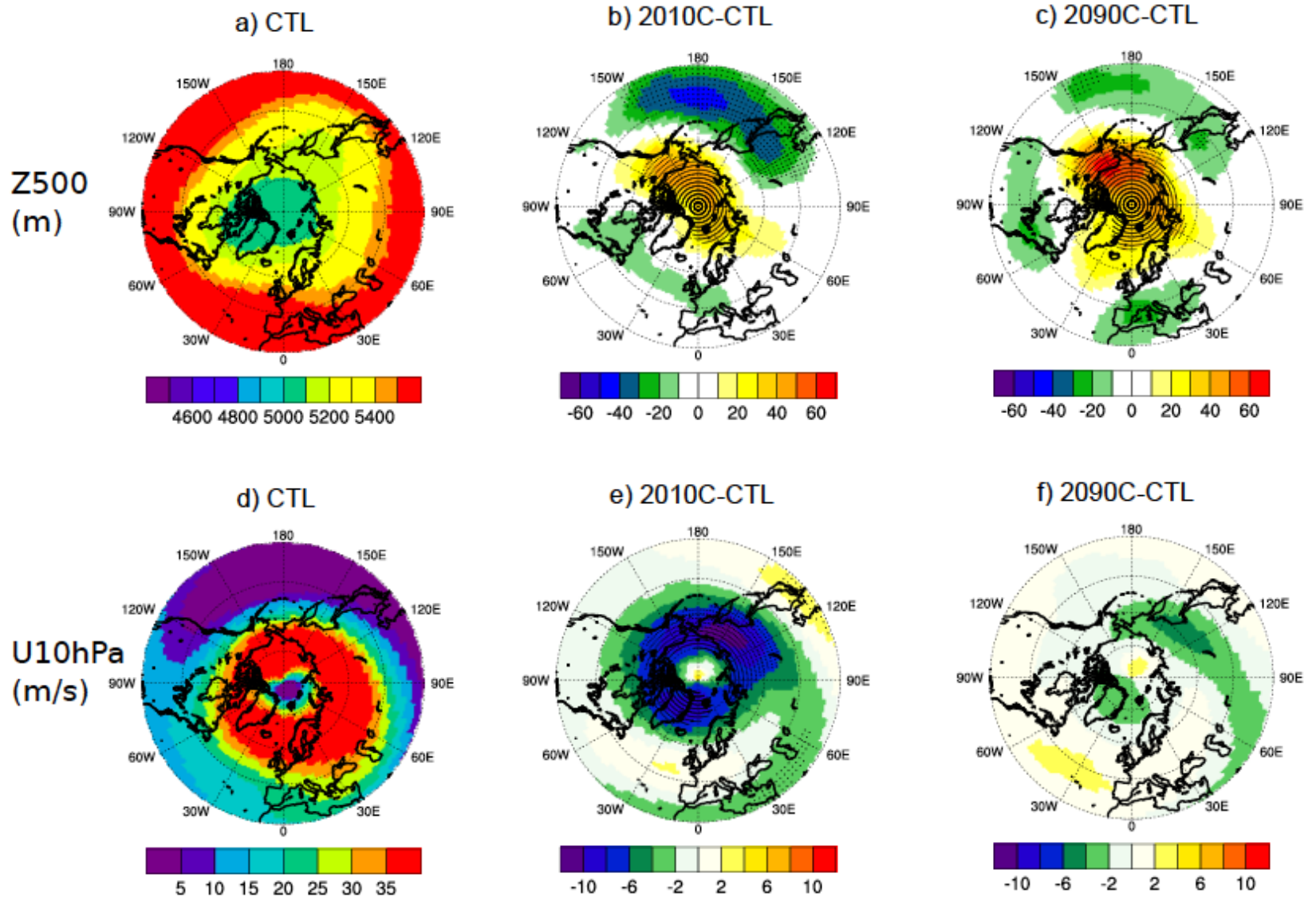
Note Feb



Summary so far

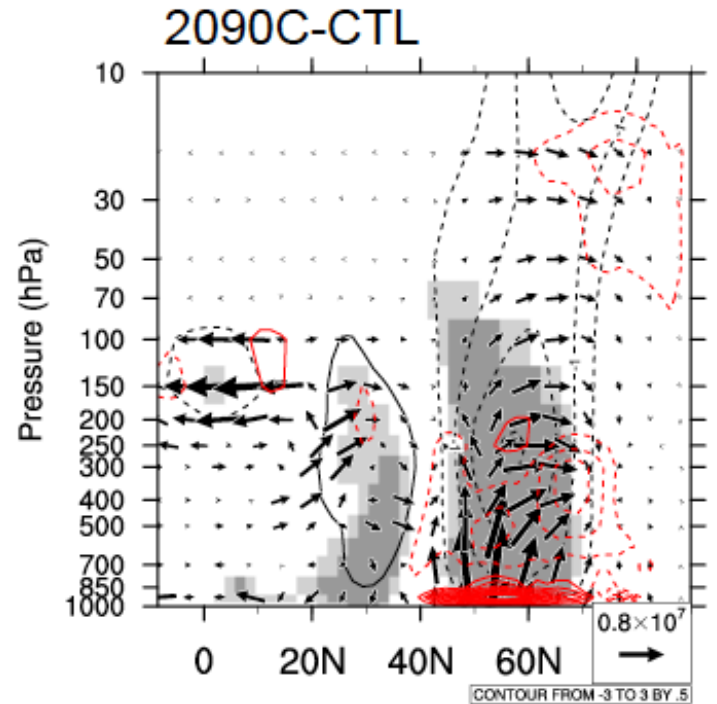
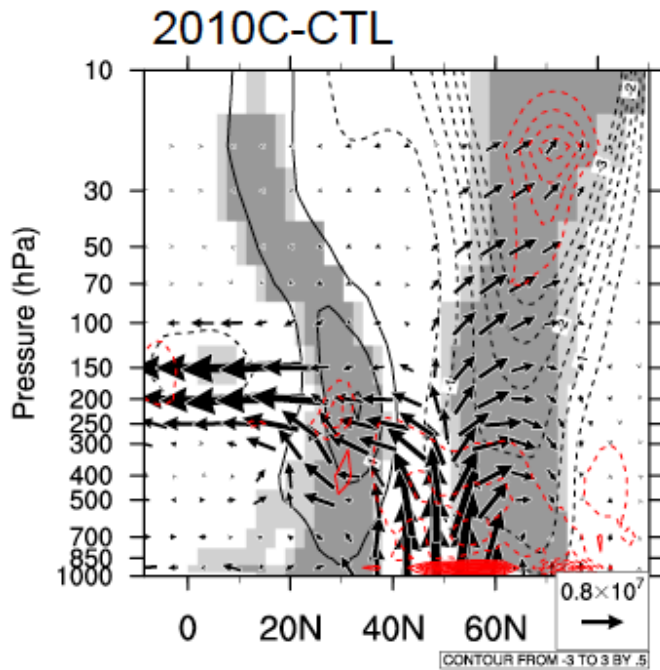
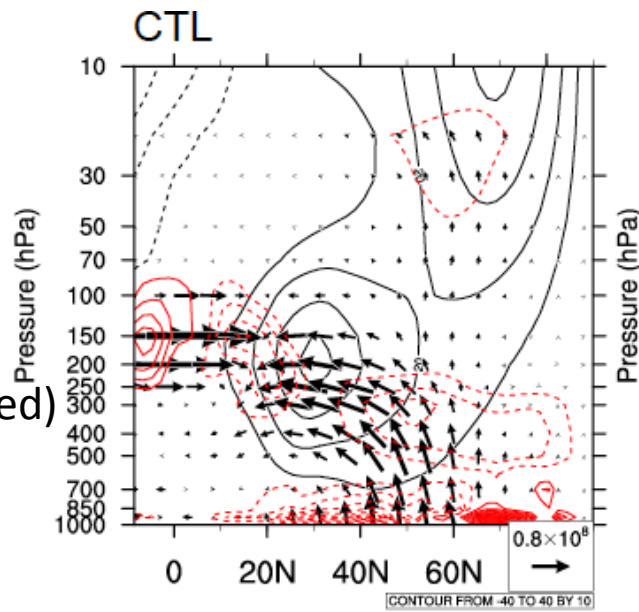
- Both experiments (from xsection): negative NAM response in late winter. It is especially strong for 2010C despite the weaker forcing
- Late winter response in 2010C has a stratospheric signature whereas 2090C does not show clear stratosphere-troposphere coupling.
- 2090C has stronger tropospheric response than 2010C.
- 2090C also has negative NAM response in Dec.

Focusing on Feb – response in Z500 and U at 10hPa



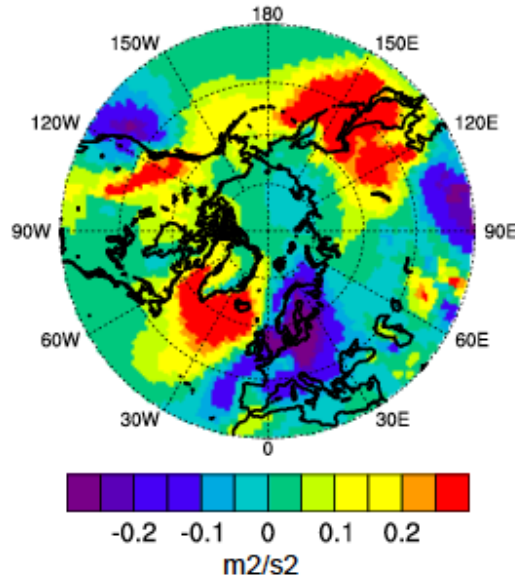
February

EP flux (arrows) and divergence (red)
Zonal mean zonal wind (black)

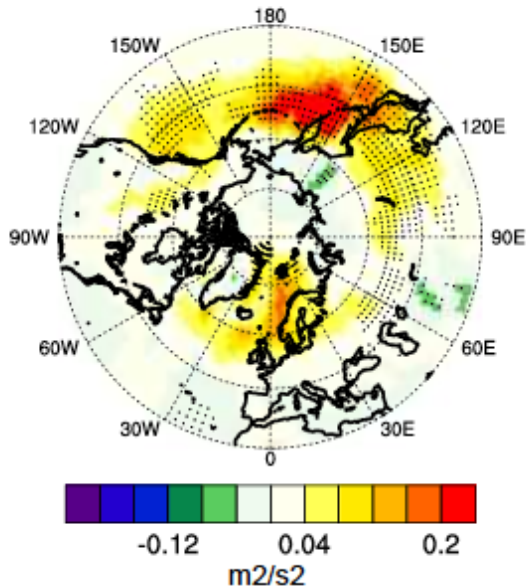


February, vertical component of Plumb flux 850hPa

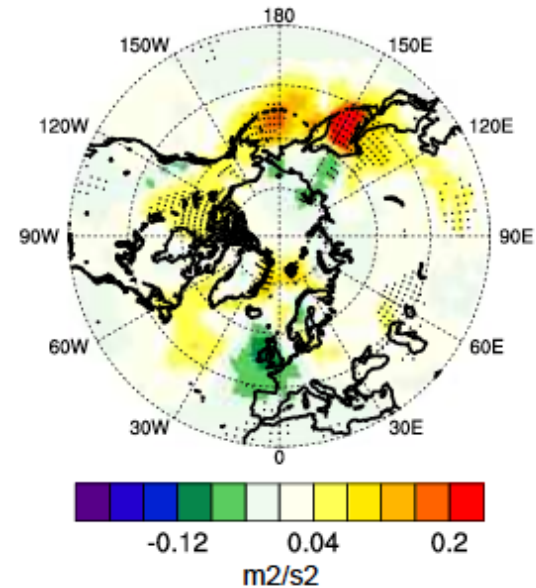
a) CTL



b) 2010C-CTL



c) 2090C-CTL



Strong seasonality of the response

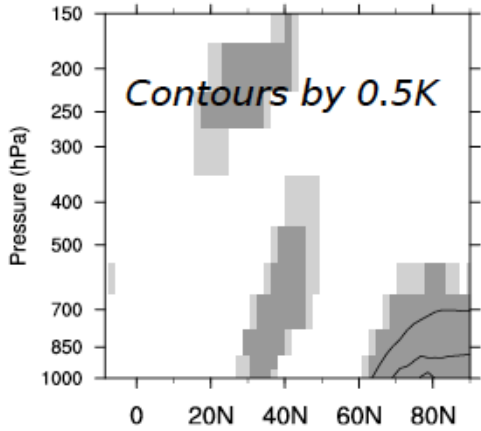
- Recent studies have emphasized the importance of linear interference between the forced and climatological waves
- The phase of the anomalous waves resulting from the external forcing is critical for getting a significant impact
 - Constructive interference – when in phase
 - Destructive interference – when out of phase
- For 2010C, the forced wave is in phase with the climatological wave in Feb, but not earlier in the season.
- May also explain differences between experiments, although difference in spatial correlation (forced/clim waves in the two experiments) is only modest.

Tropospheric winter response in the two experiments, current sea-ice forcing (2010C) and projected end of century sea-ice forcing (2090C).

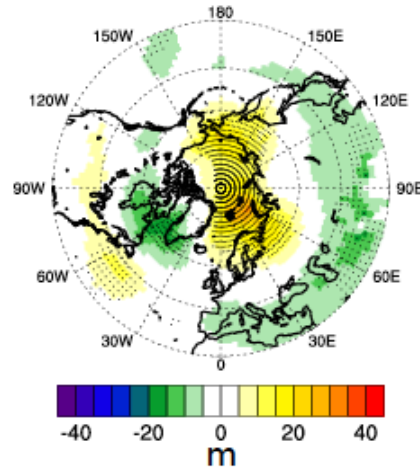
What about mid-latitude extreme events?

DJF mean

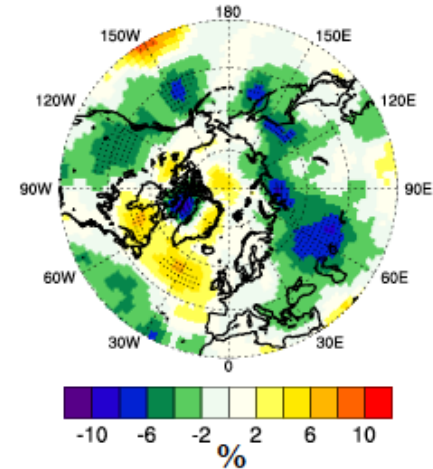
Zonal mean T response



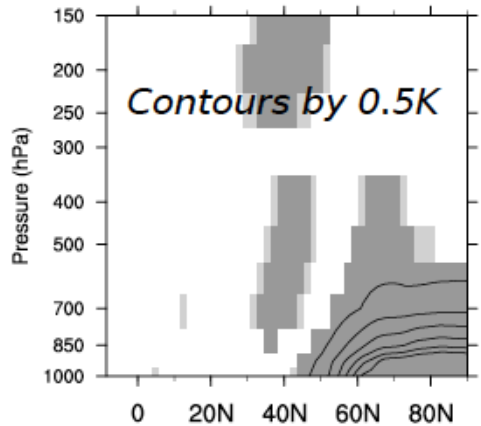
Thickness response 1000 to 500hPa



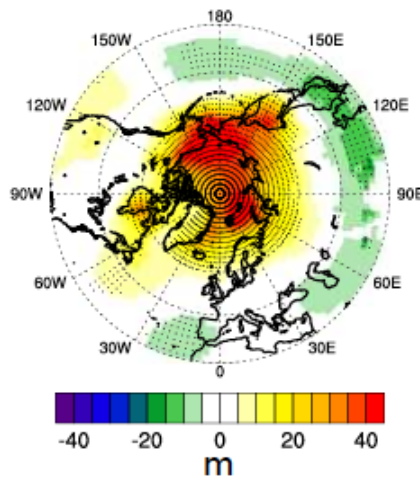
Stormtrack response (variance of Z500)



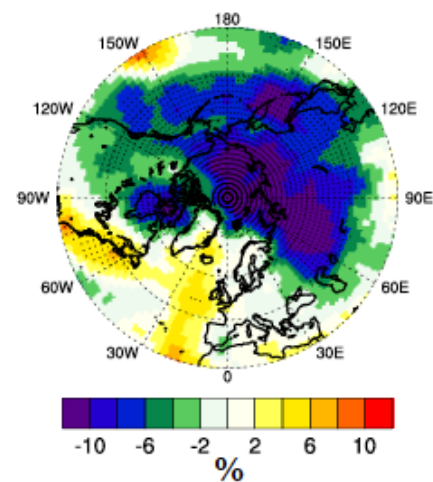
d)



2090C-CTL

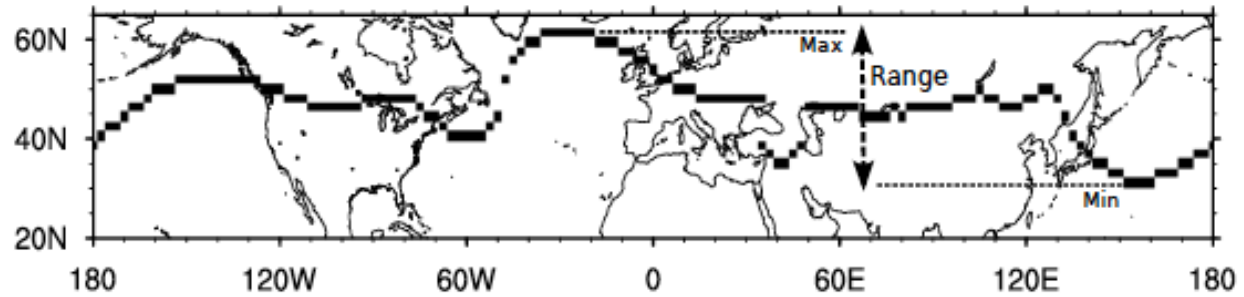


f)

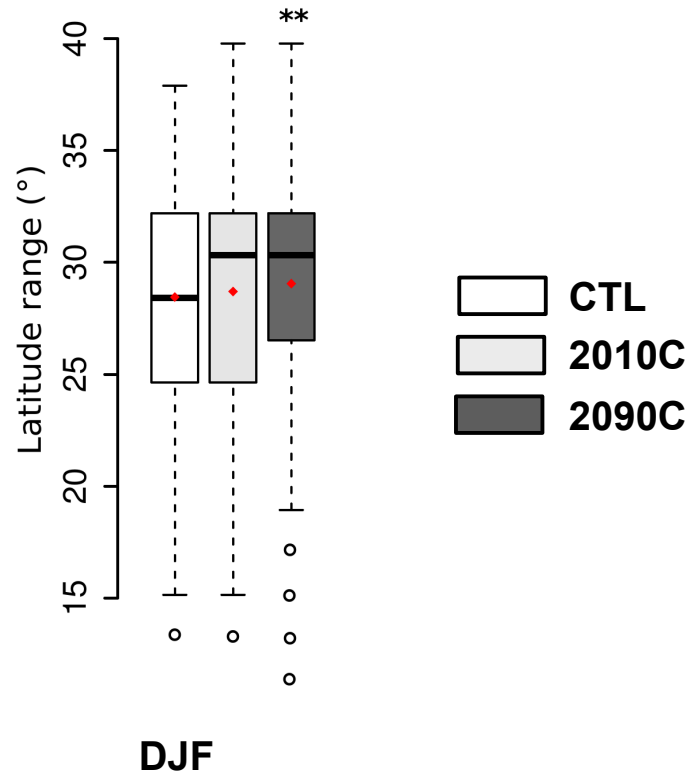


Is there an increase in “meanders” over mid-latitudes?

Range of the 5400m isoline of height on the 500hPa surface

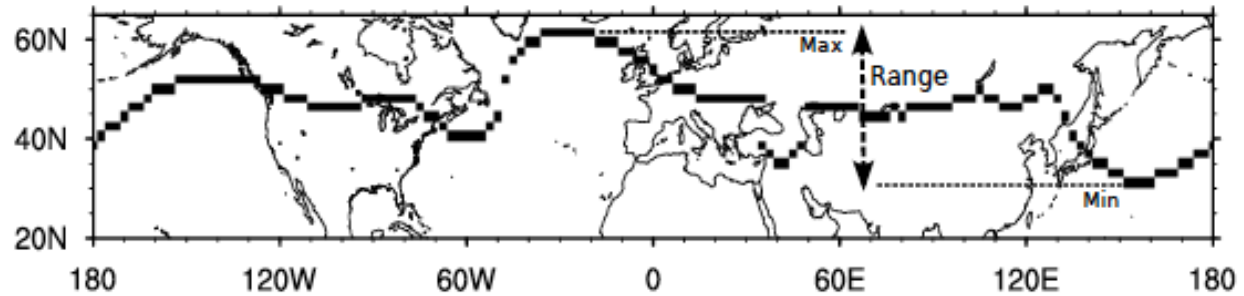


Distribution of daily ranges

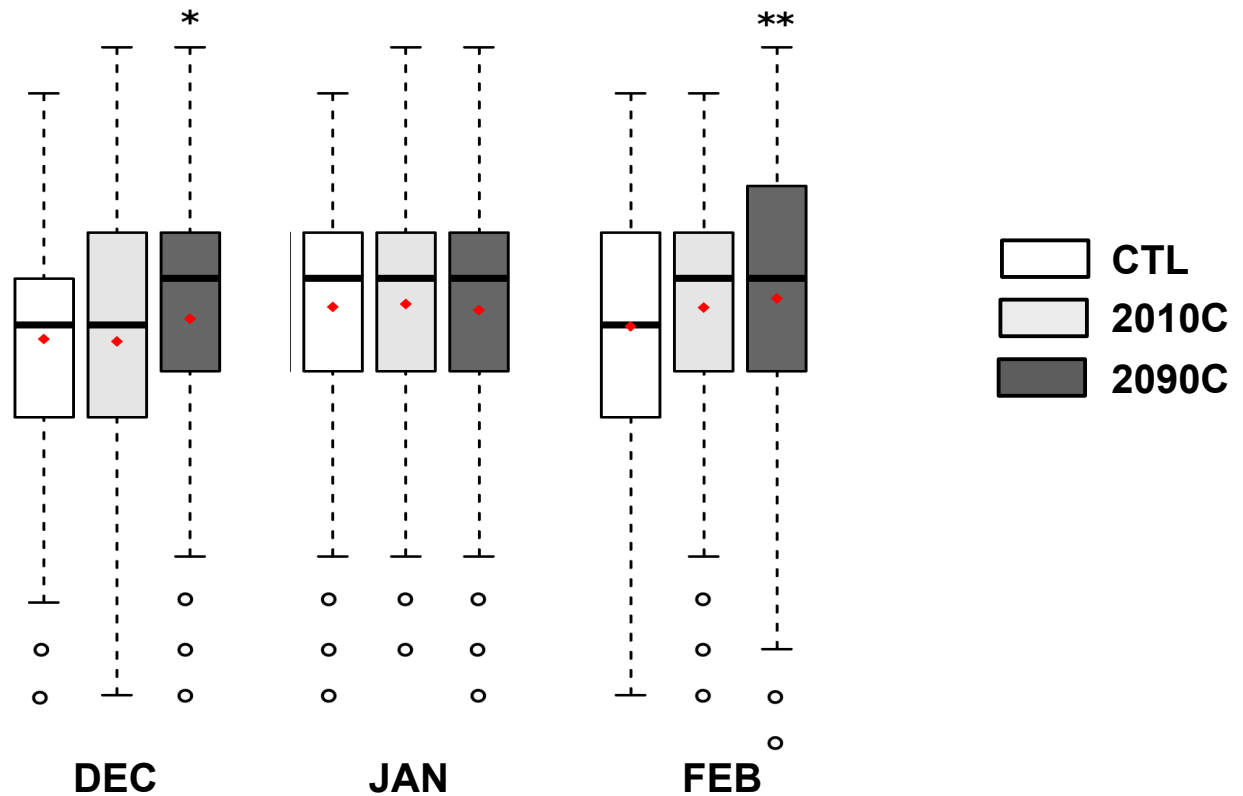


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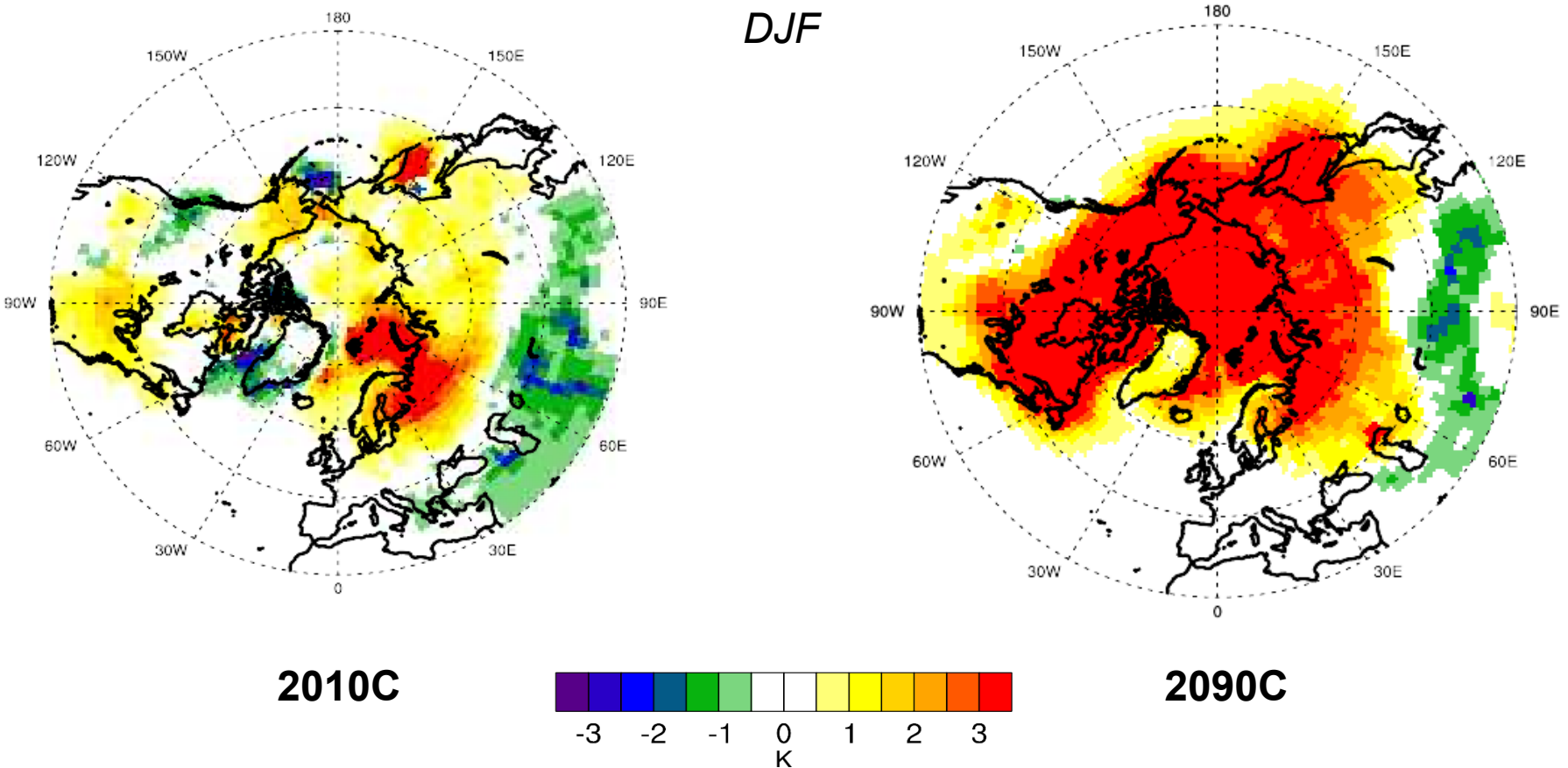
Distribution of daily ranges



Is there an increase in cold events in mid-latitudes?

10th percentile of daily surface T

DJF



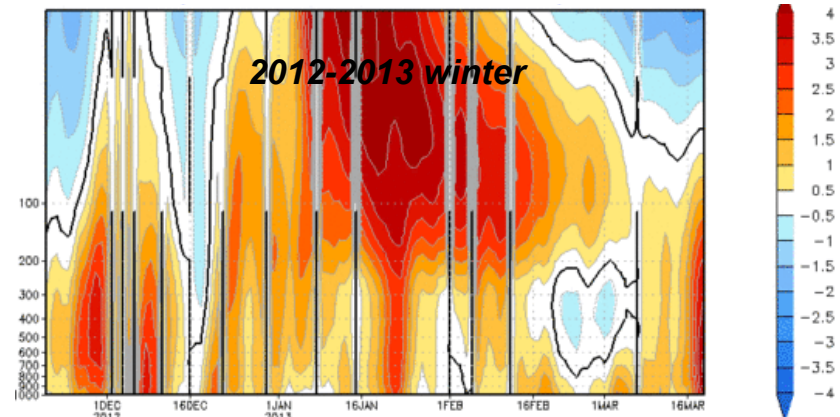
The intensity of cold extremes increases over mid-latitudes, especially over Asia

The intensity of cold extremes does not increase in 2090C compared to 2010C

Conclusions

Based on these modeling experiments :

The recent sea ice anomalies favor the observed trend towards the negative phase of the NAM in winter (especially in late-winter).



Source : Climate Prediction Center

A stronger sea-ice decline should not increase the cold extreme temperature in mid-latitudes (but we consider the effect of Arctic sea ice only).

Future studies with the inclusion of recent observations and the use of other climate models will help to clarify the role of Arctic sea ice decline on cold weather events in winter. Other processes may also play a role, in particular the positive phase of the Atlantic Multidecadal Oscillation (Peings and Magnusdottir, in review).