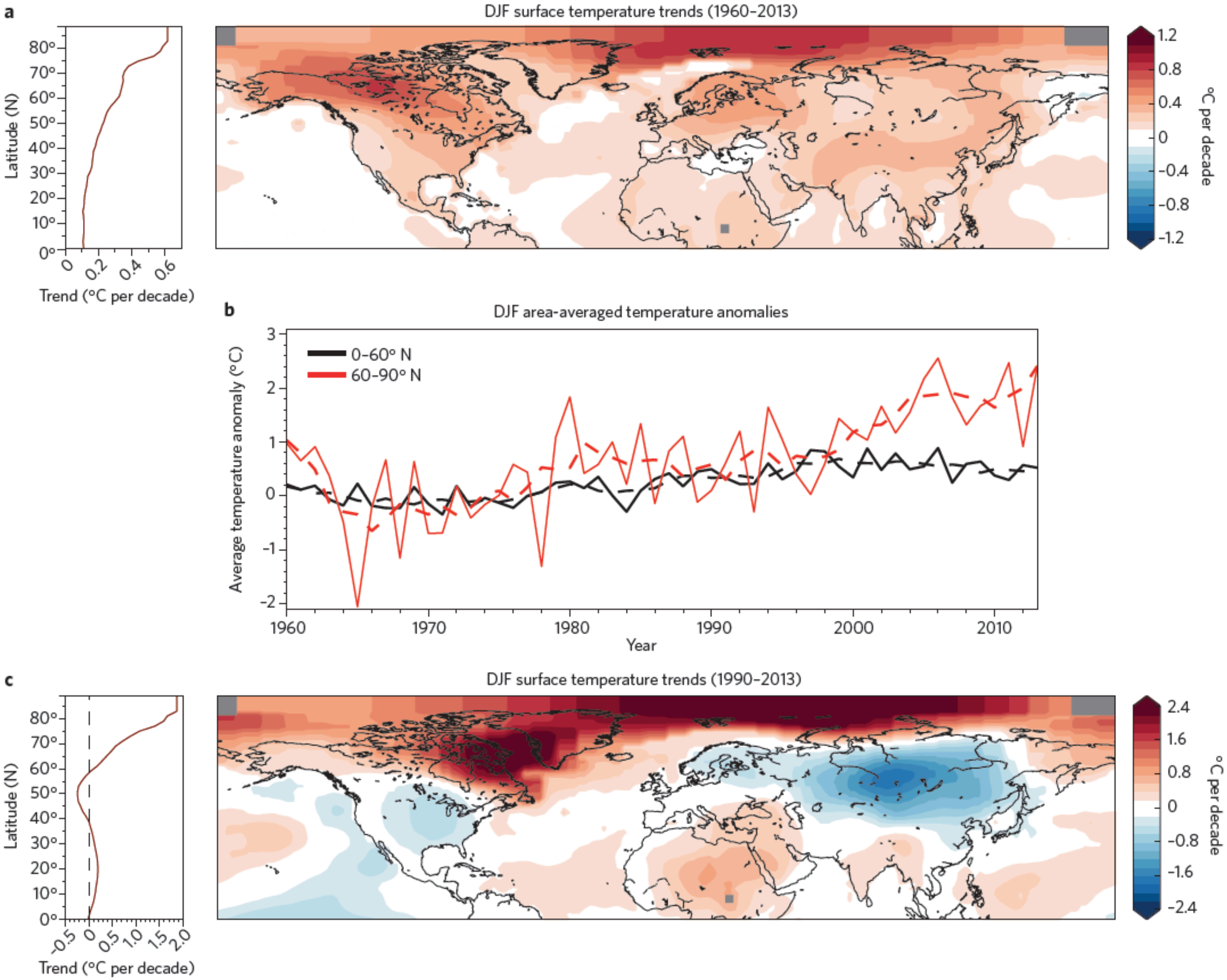
Arctic influence on mid-latitude weather and climate?

Thomas Jung

Alfred Wegener Institute
Helmholtz Centre for Polar and Marine Research
Germany

Background



Cohen et al. (2014), Nature Geosci.

Background

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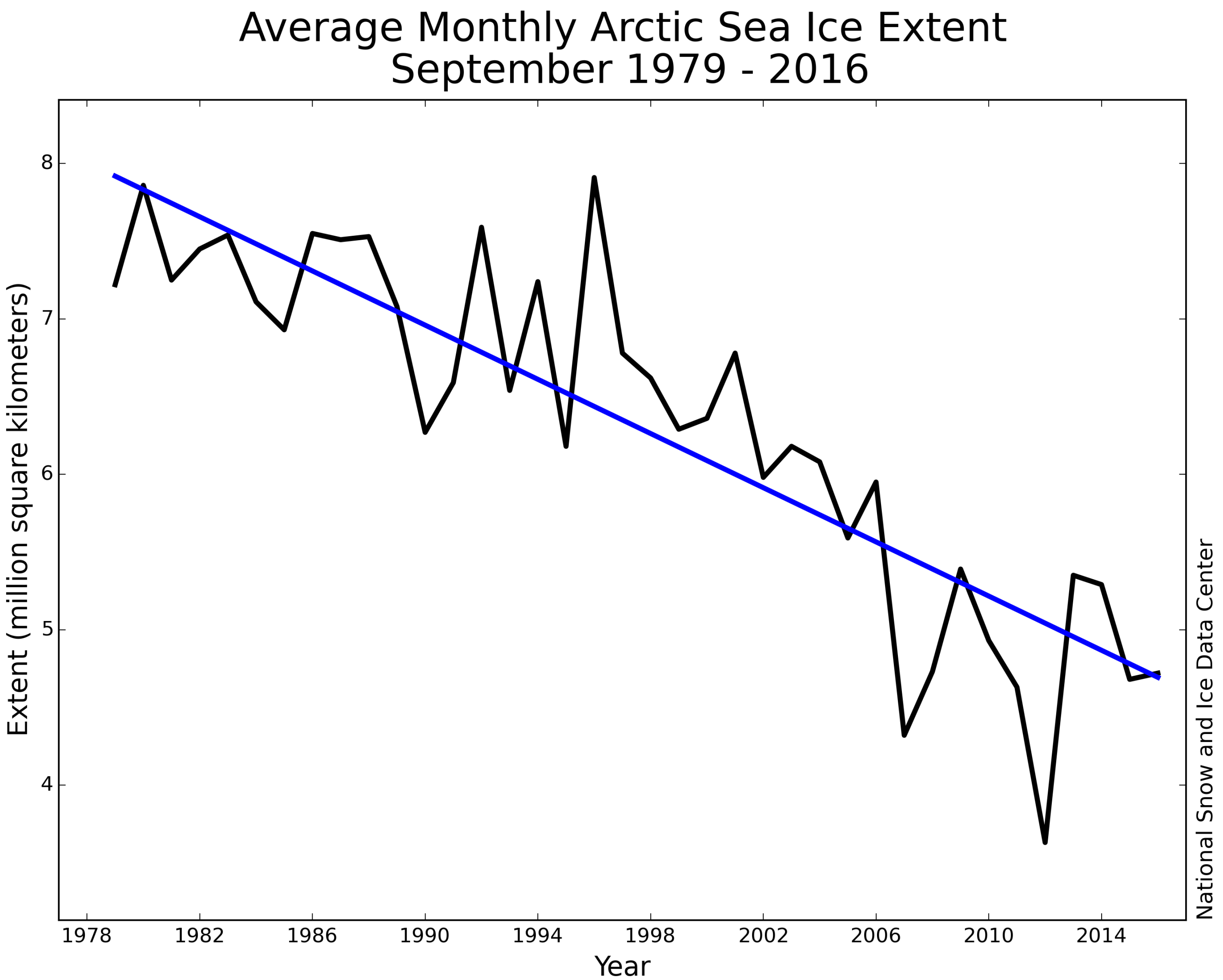
UND MEERESFORSCHUNG



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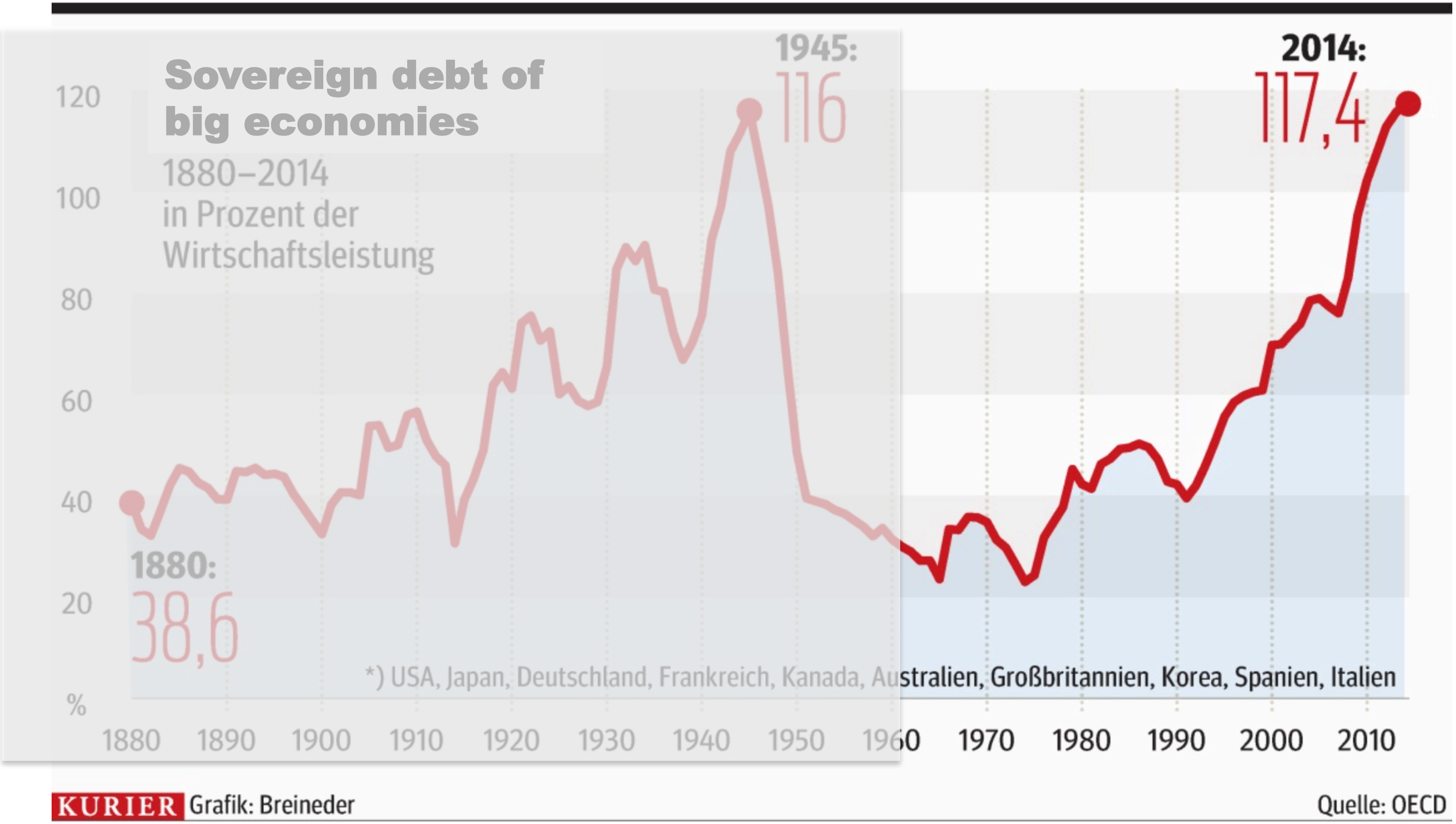
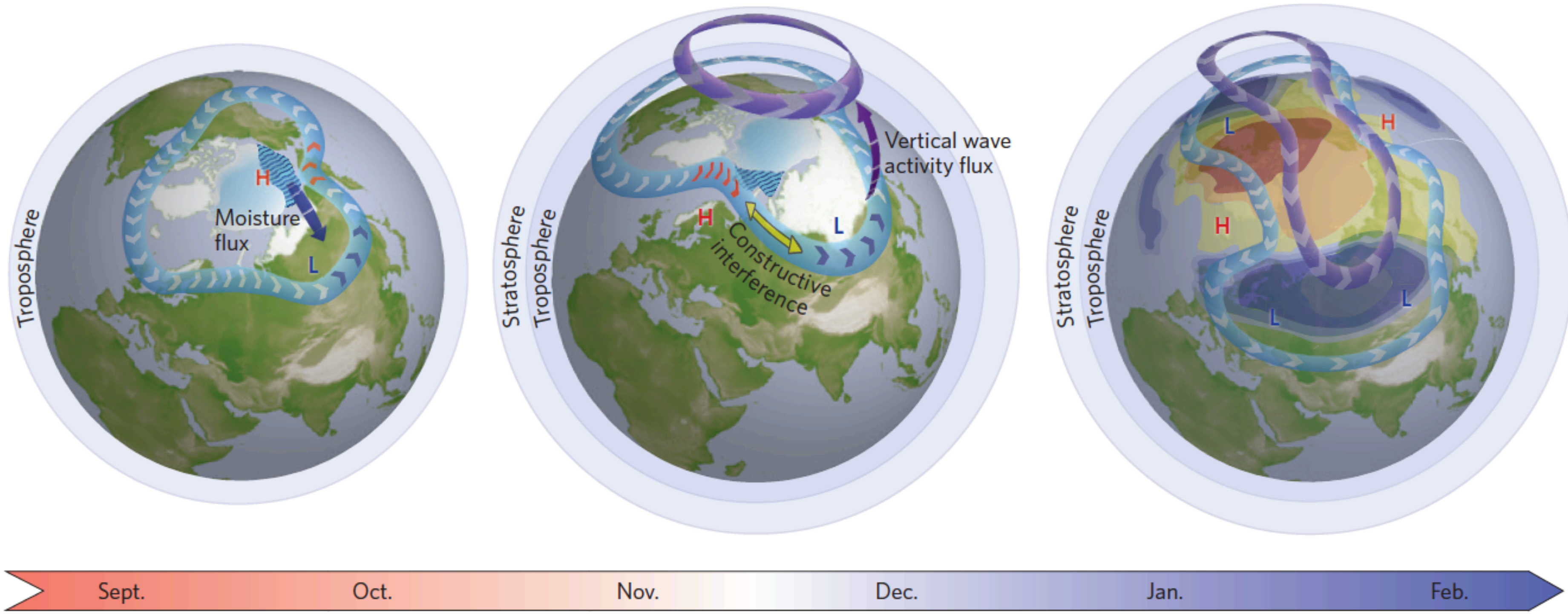
Background



Sovereign debt of big economies
1880–2014
in Prozent der Wirtschaftsleistung
1945:
116
2014:
117,4
1880:
38,6
120
100
80
60
40
20
%
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
*) USA, Japan, Deutschland, Frankreich, Kanada, Australien, Großbritannien, Korea, Spanien, Italien
KURIER Grafik: Breineder
Quelle: OECD

Background



Cohen et al. (2014), Nature Geosci.

Climate models

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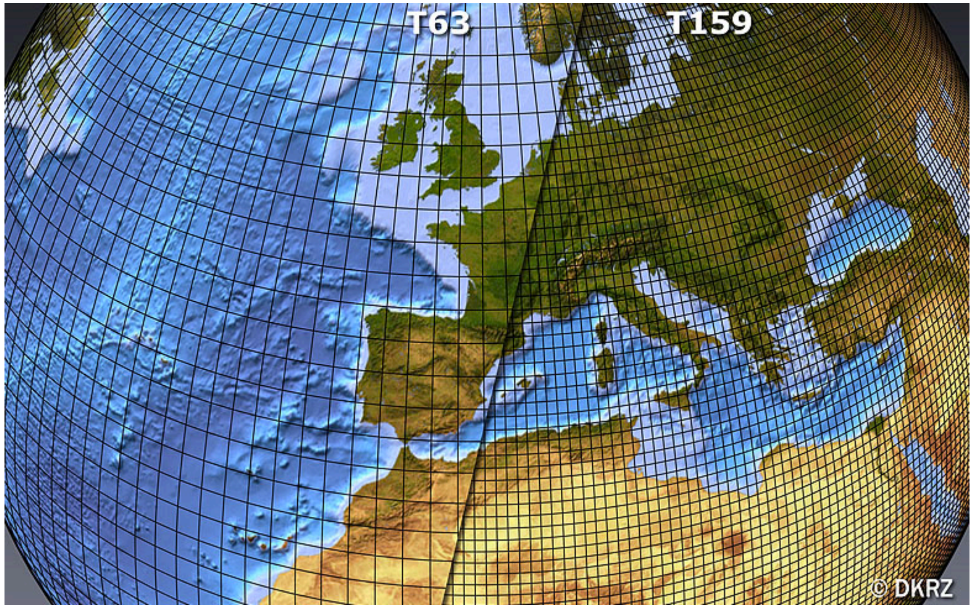
The Basis

$$\frac{d\mathbf{v}}{dt} = -\alpha\nabla p - \nabla\phi - 2\boldsymbol{\Omega} \times \mathbf{v} + \mathbf{F}$$
$$\frac{\partial\rho}{\partial t} = -\nabla \cdot (\rho\mathbf{v})$$
$$c_p\frac{dT}{dt} = \alpha\frac{dp}{dt} + Q$$
$$p\alpha = RT$$
$$\frac{\partial\rho q}{\partial t} = -\nabla \cdot (\rho\mathbf{v}q) + \rho\,(E - C)$$

Discretisation



Numerical solution

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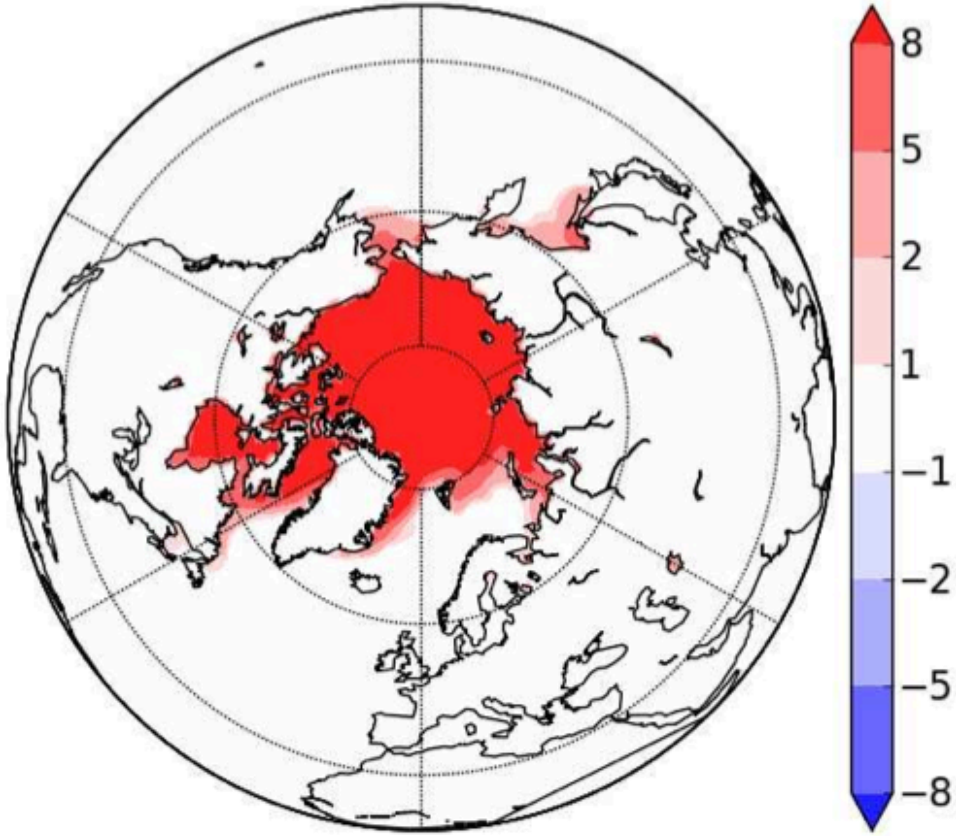
Atmospheric response to reduced sea ice thickness

AGCM experiment



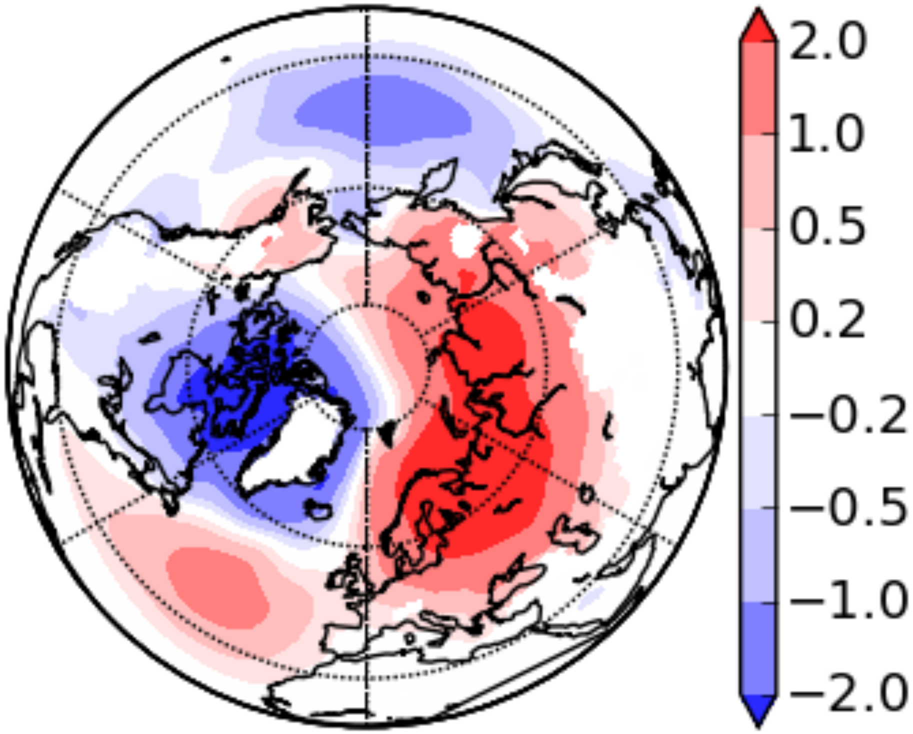
Setup

- ECMWF model
- 10 *K* T_{sfc} perturbation
- AMIP-style integrations
- Weather and seasonal forecasts

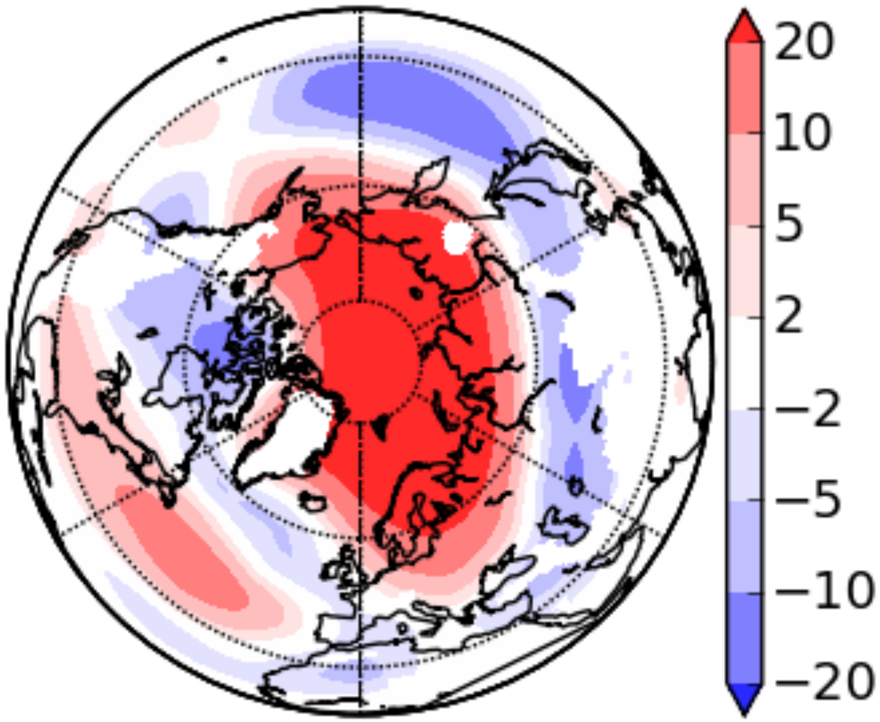
$$\frac{\partial T}{\partial \phi} = -12\,K/deg \rightarrow \frac{\partial T}{\partial \phi} \approx -3\,K/deg$$

Simulated atmospheric response (DJF)

Sea Level Pressure

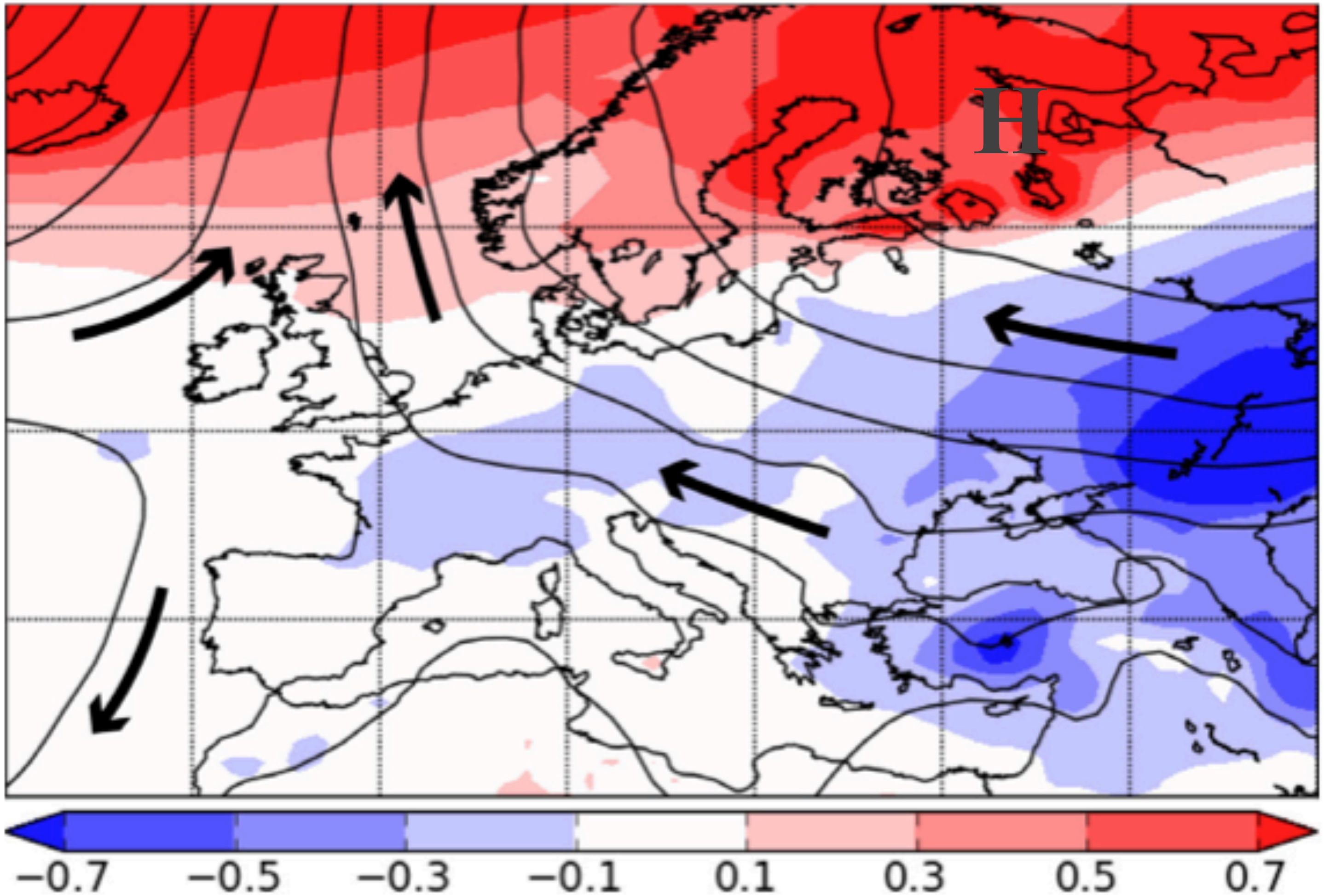


500 hPa Geopotential Height



AMIP-style experiment

Colder European winters?



AMIP-style experiment

Coupled experiments

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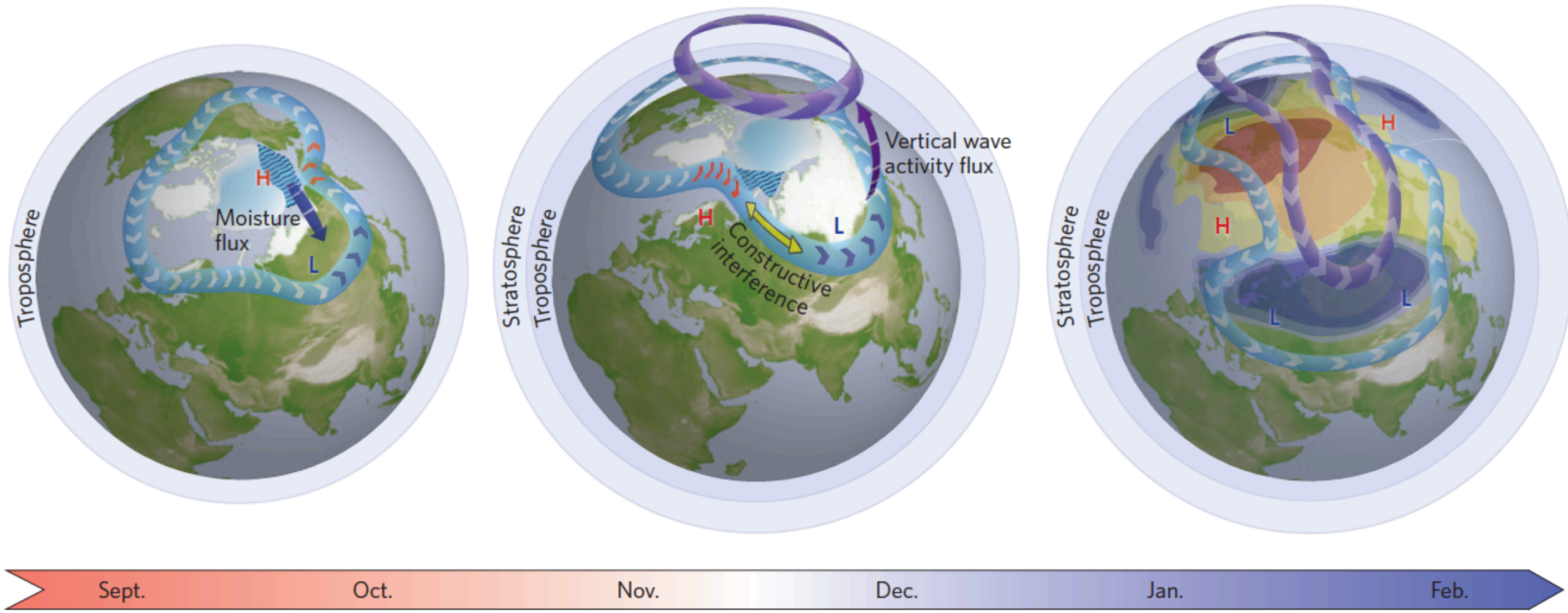
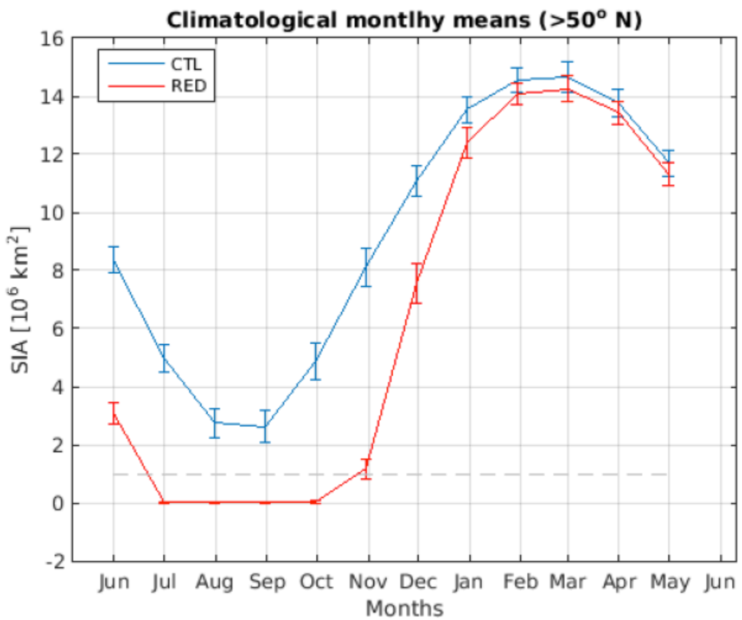
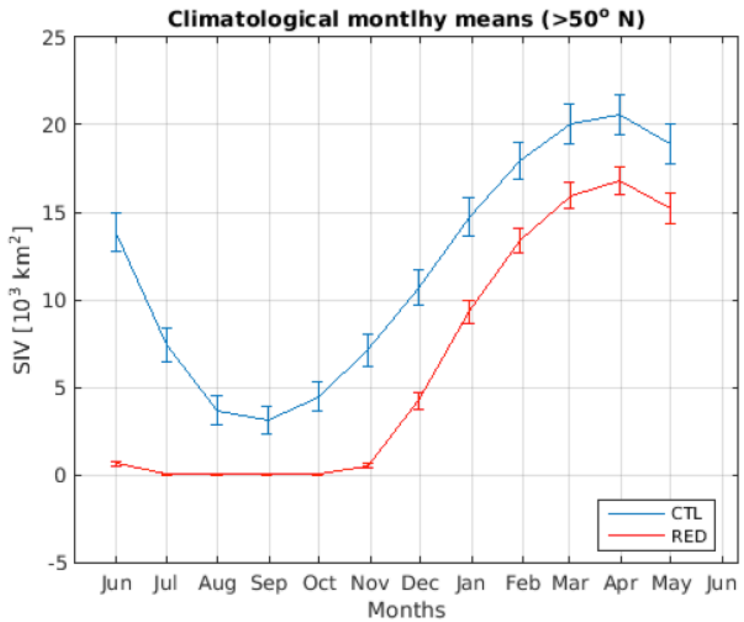
Testing the Cohen et al. hypothesis



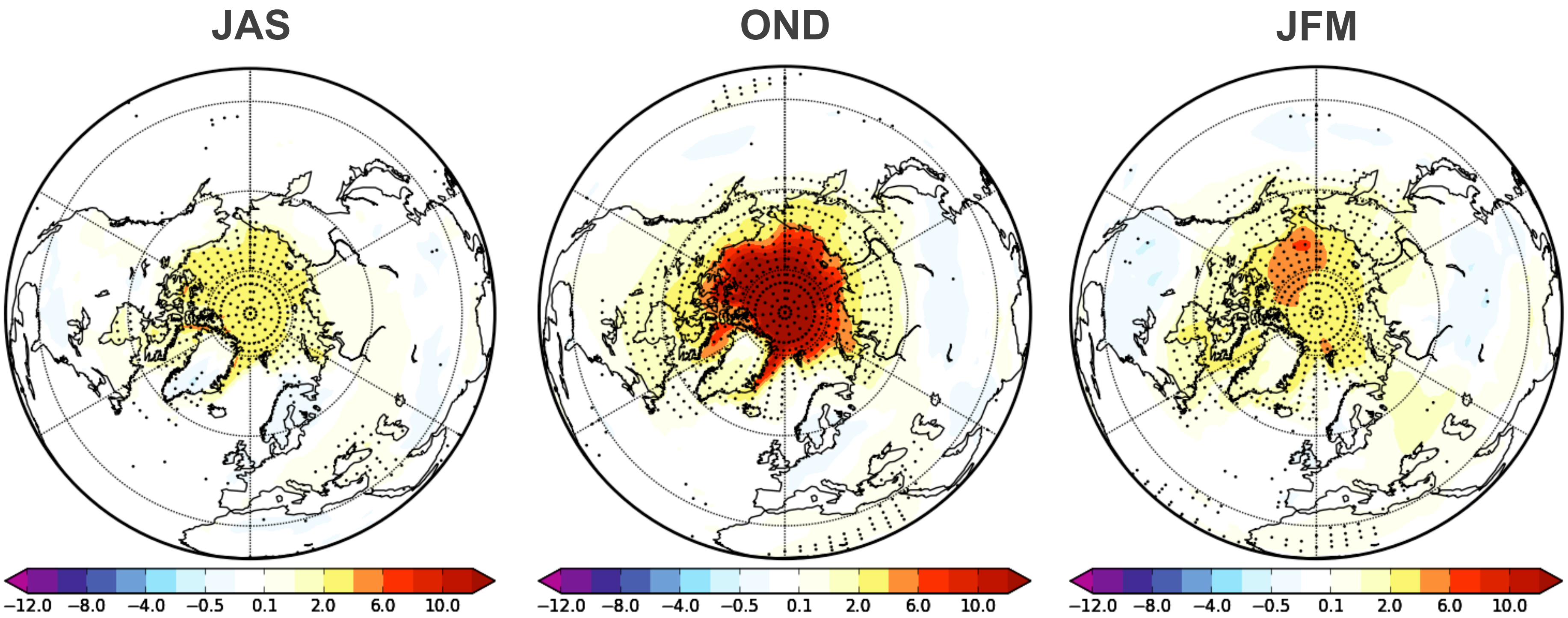
Coupled experiments

- Coupled model ECHAM6-FESOM
- Long multi-centennial control run
- Sensitivity experiments
  - ➢ A total of 100 12-months experiments
  - ➢ Reduced Arctic sea ice thickness by 80% on 1 June





Surface temperature response



Atmospheric response

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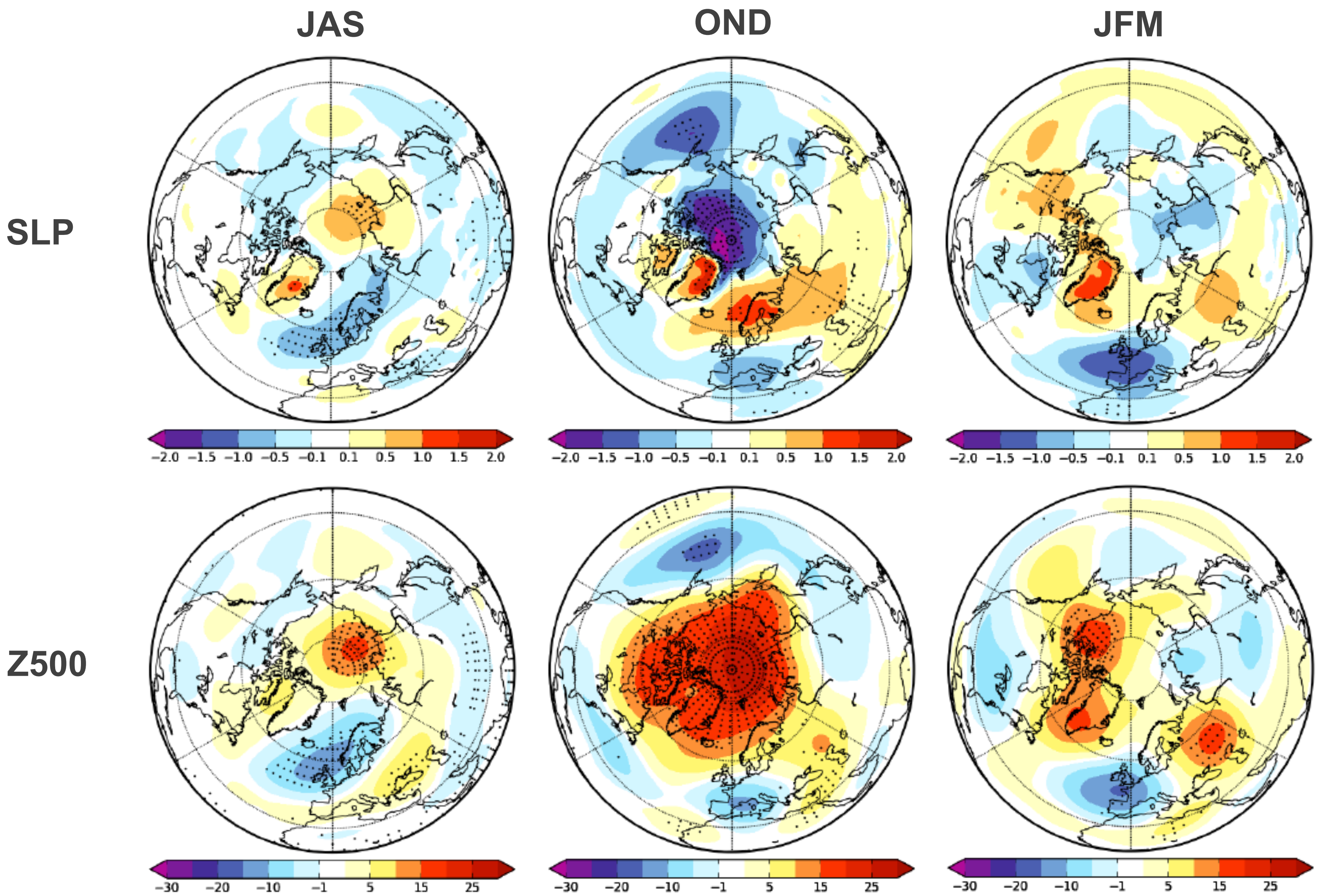

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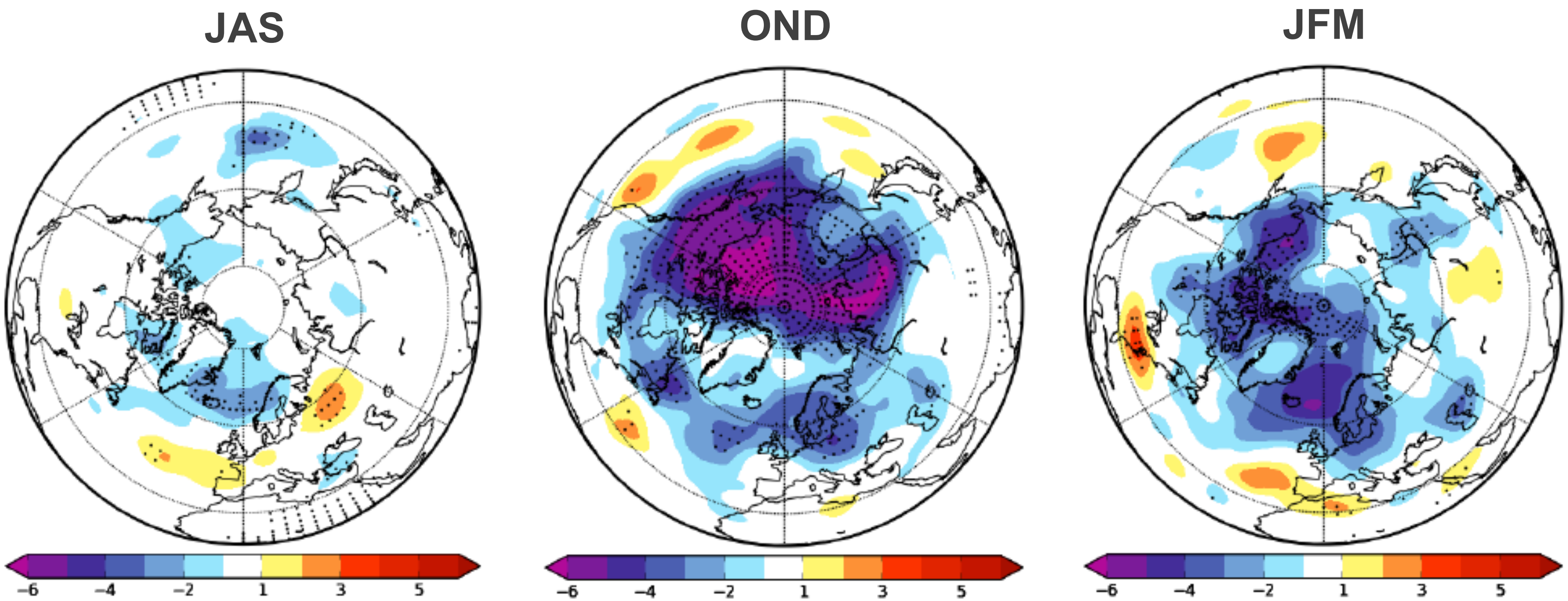
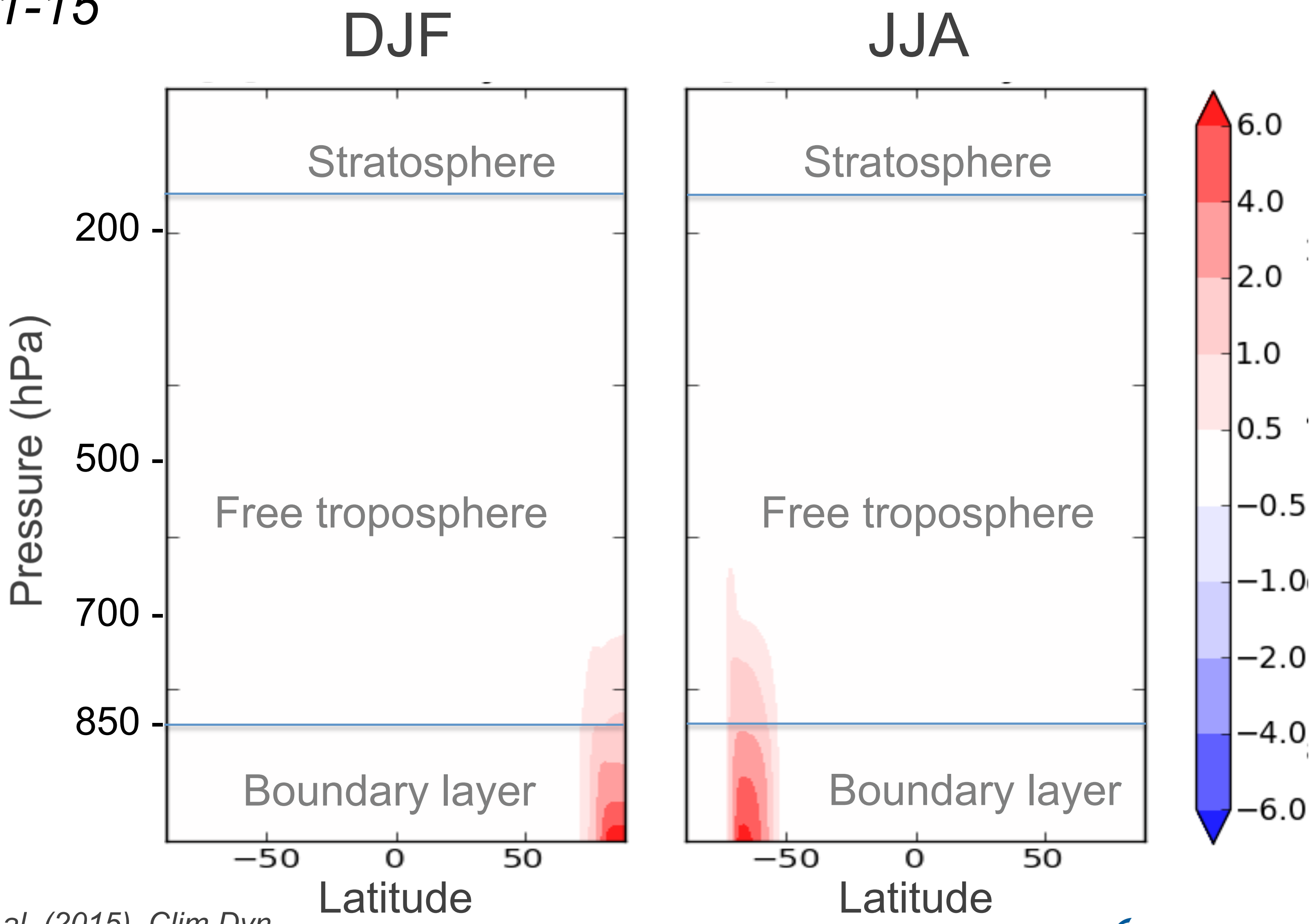
Synoptic activity response



Atmospheric temperature response

Days 1-15



Semmler et al. (2015), Clim Dyn.

Atmospheric temperature response

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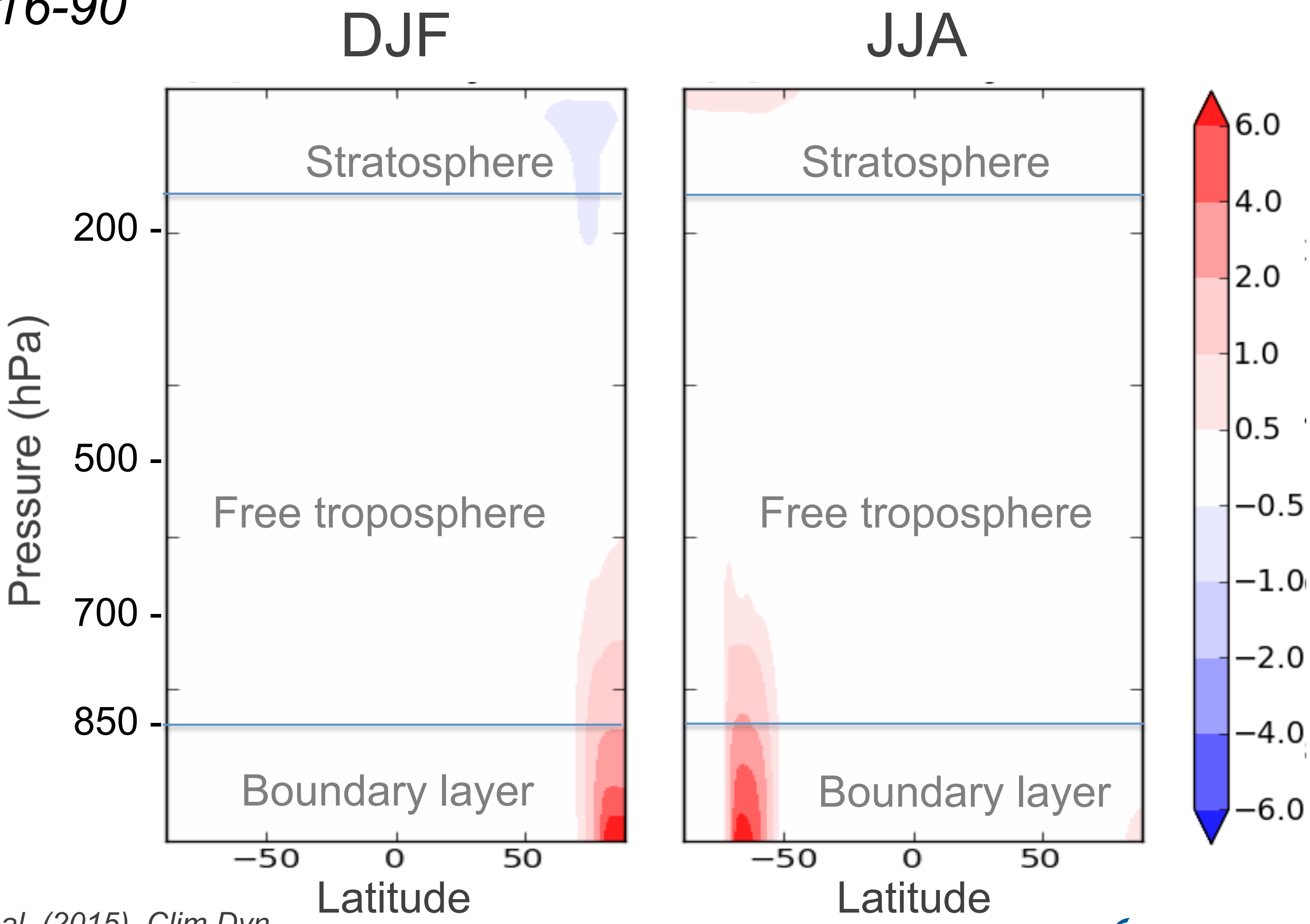
Days 16-90



Semmler et al. (2015), Clim Dyn.

Atmospheric temperature response

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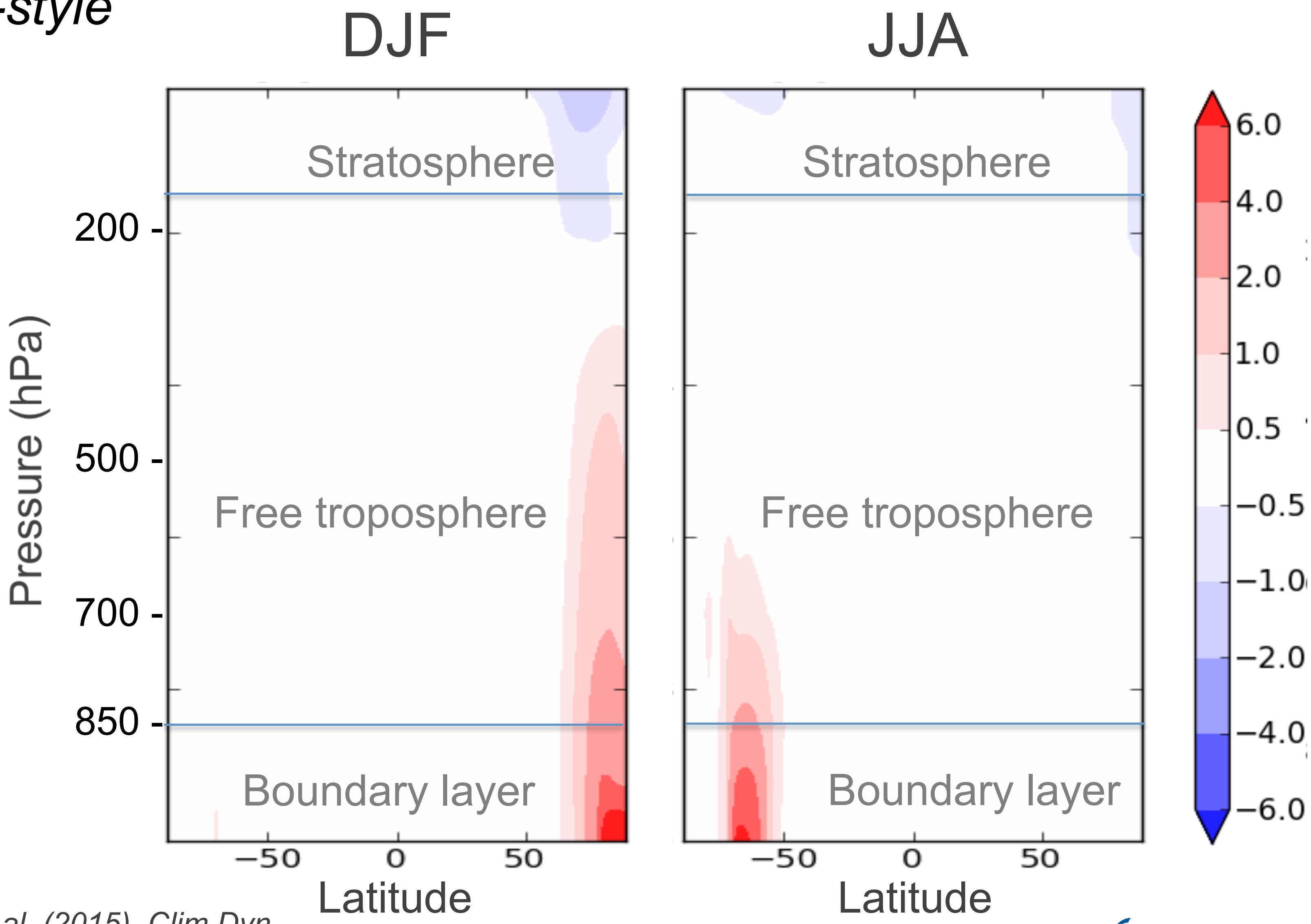
AMIP-style



Semmler et al. (2015), Clim Dyn.

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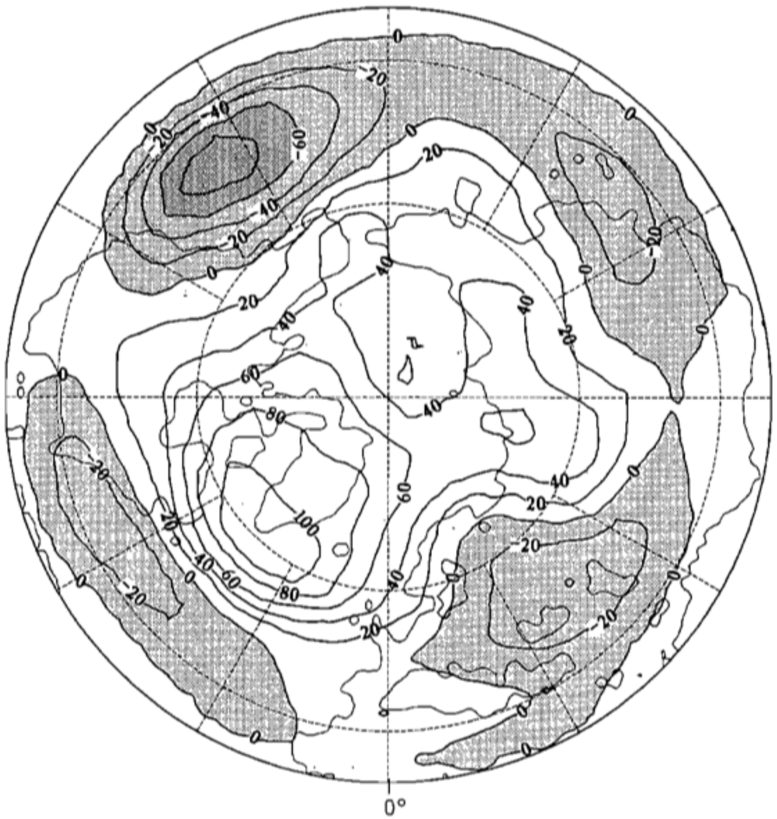
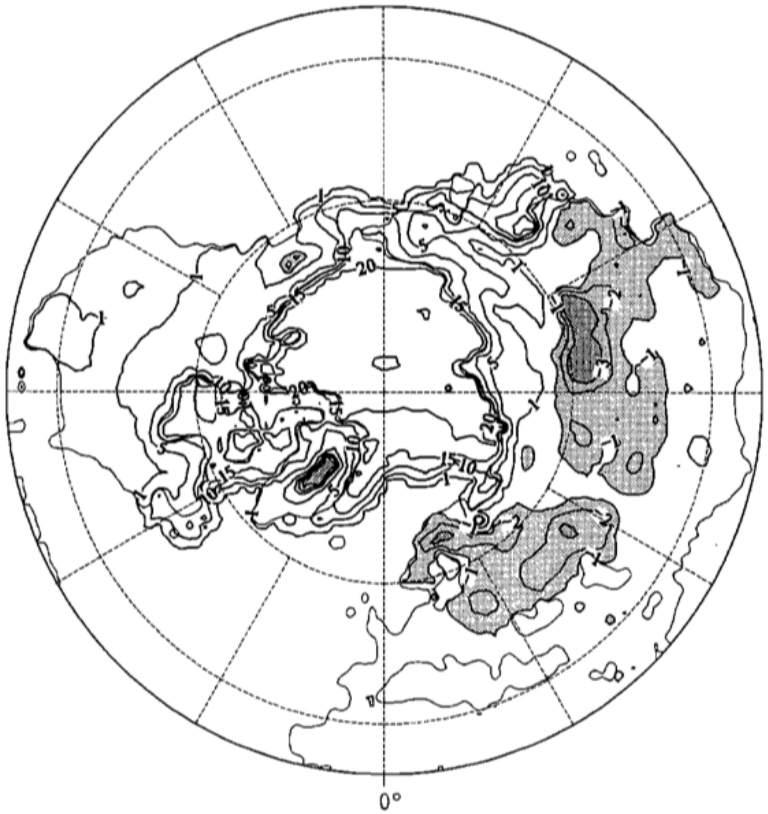
Earlier numerical studies

Z500 Response



T_{sfc} Response



Royer et al. (1990), *Clim. Dyn.*

Arctic influence on mid-latitude subseasonal prediction

Jung et al. (2014), Geophys. Res. Lett.

Motivation

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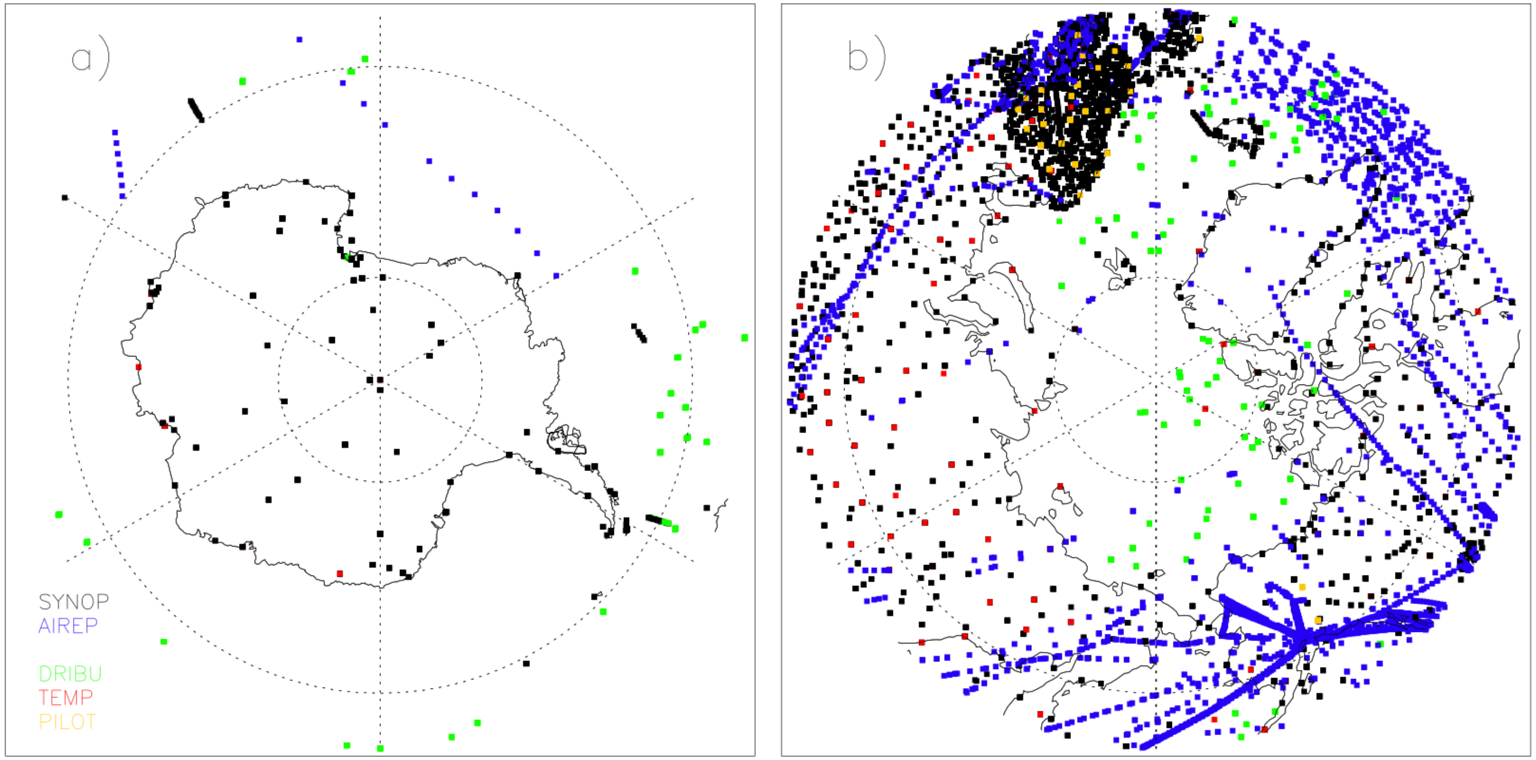


Synop, AIREP, DRIBU, TEMP and PILOT

Polar data coverage of conventional observations in the ECMWF operational analysis on 1 January 2012

Figure courtesy of Peter Bauer, ECMWF

The relaxation method

- Take an atmospheric model:

$$\frac{d\mathbf{x}}{dt} = F(\mathbf{x})$$

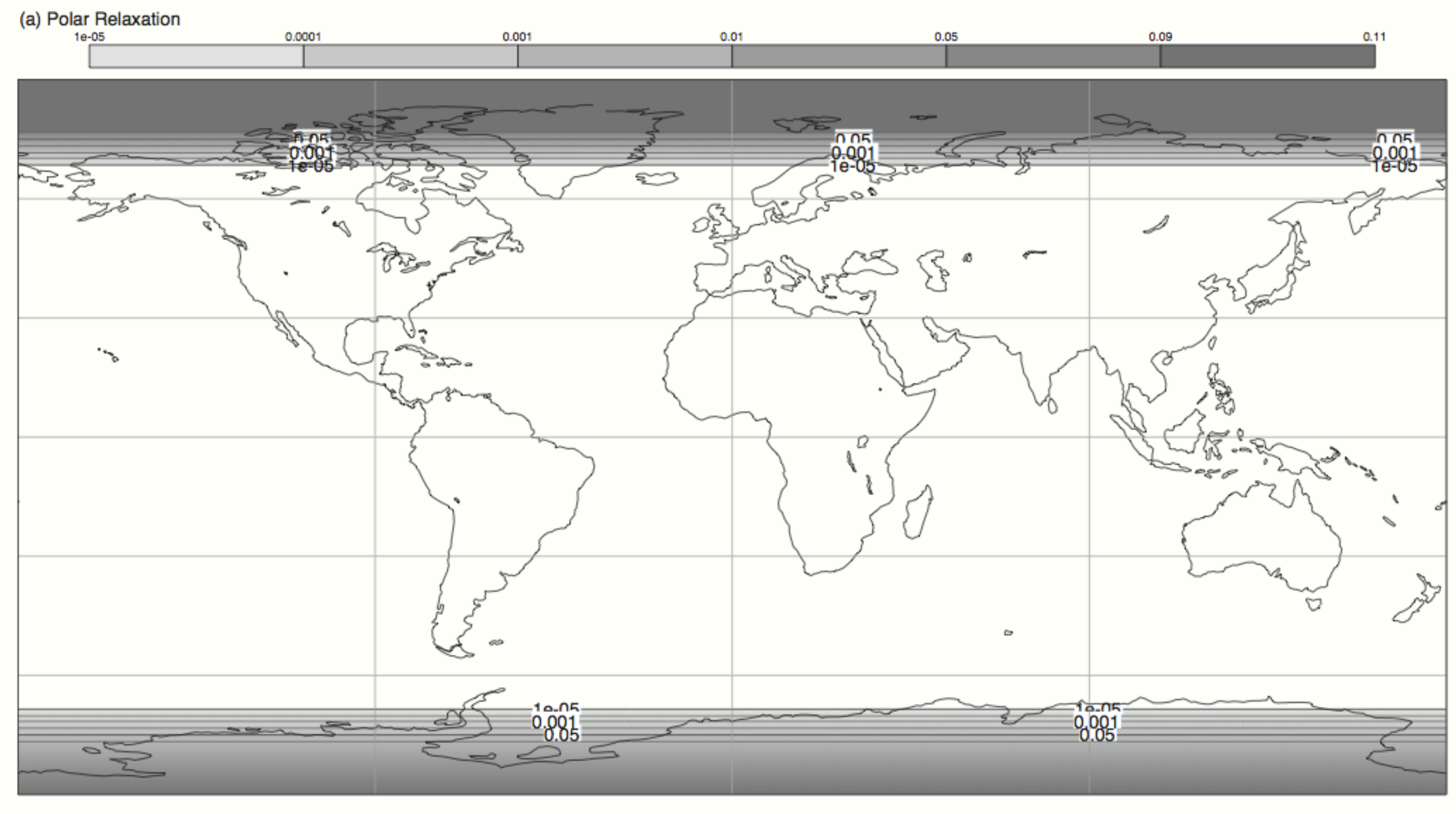
- Add a relaxation term that "pulls" the model towards some reference field:

$$\frac{d\mathbf{x}}{dt} = F(\mathbf{x}) - \lambda(\mathbf{x} - \mathbf{x}_{ref})$$

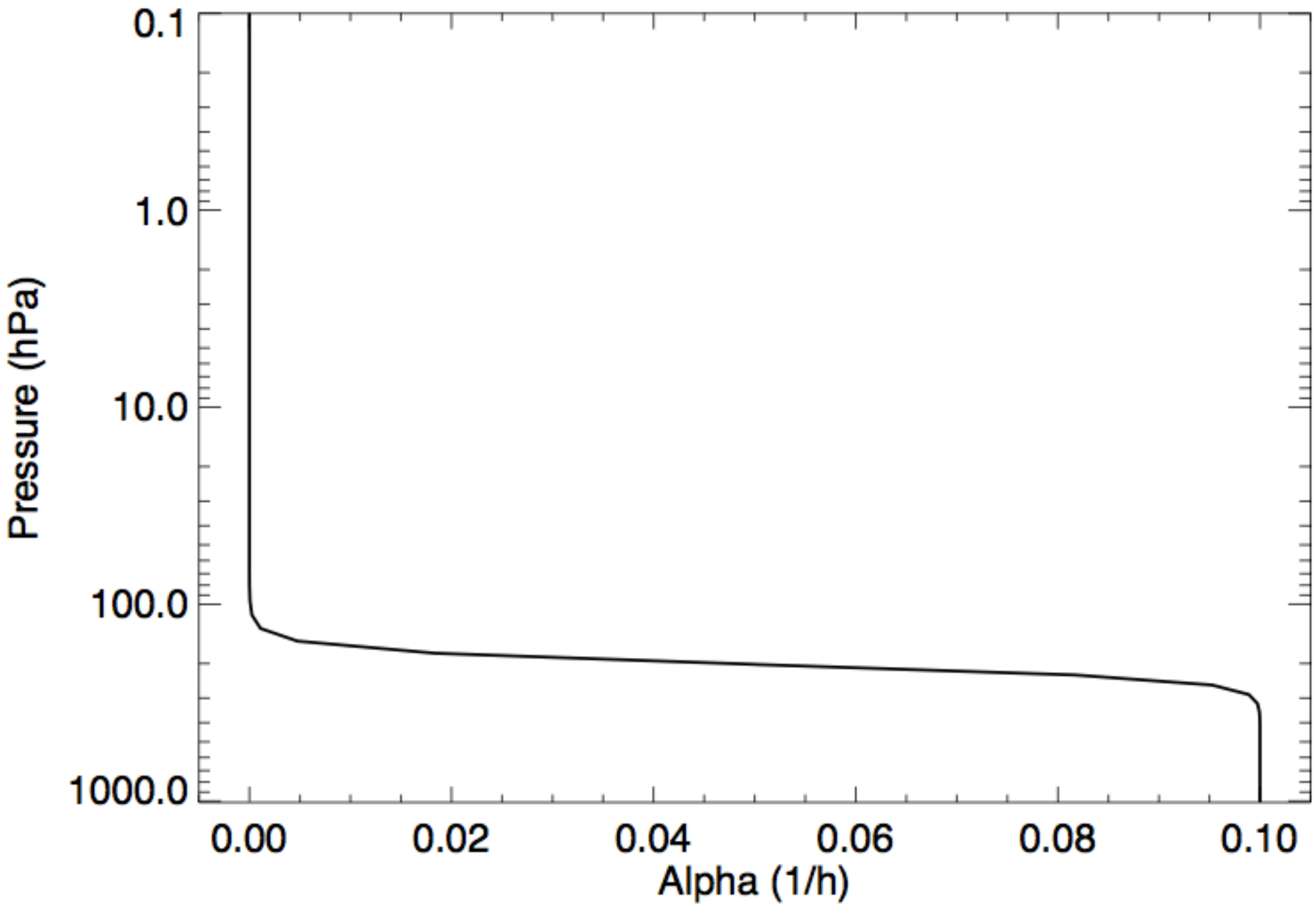
  - Make λ dependent on latitude, longitude and height (localization)
  - Choose analysis or reanalysis data as reference fields

Method: Pull the model in certain regions towards observations and study the impact elsewhere!

Polar relaxation: Mask



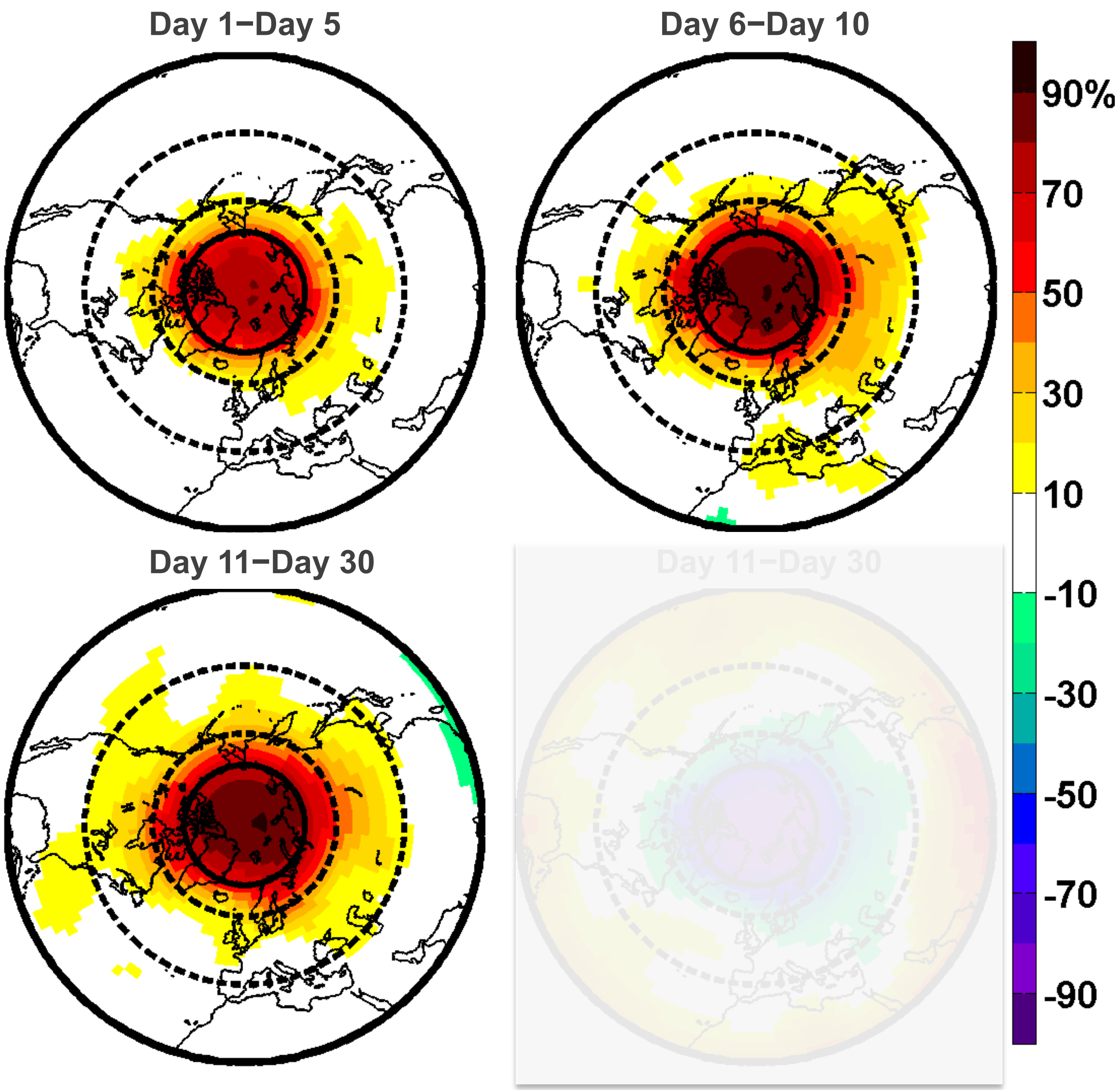
Polar relaxation: Mask



Experimental setup

- ECMWF model
- T_L159L60 (32r1)
- 88 30-day forecasts (15th of Nov, Dec, Jan and Feb; 1980/81-2000/01)
- Initial and boundary conditions from ERA-40
- Relaxation towards ERA-40
- Persisted SST and sea ice
- Control, tropical relaxation and polar relaxation

Arctic relaxation



Interpretation

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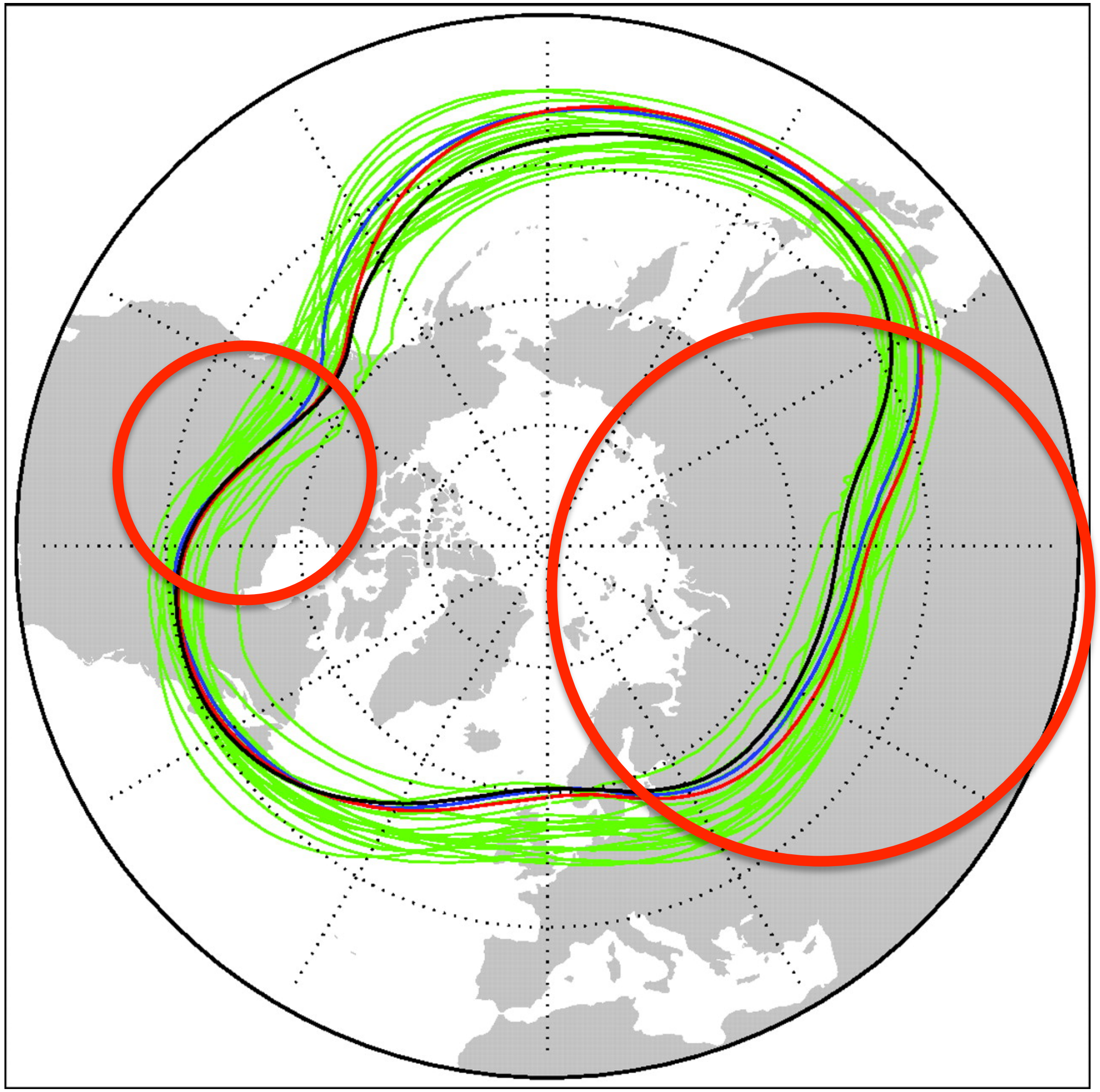

Woolings (2010)

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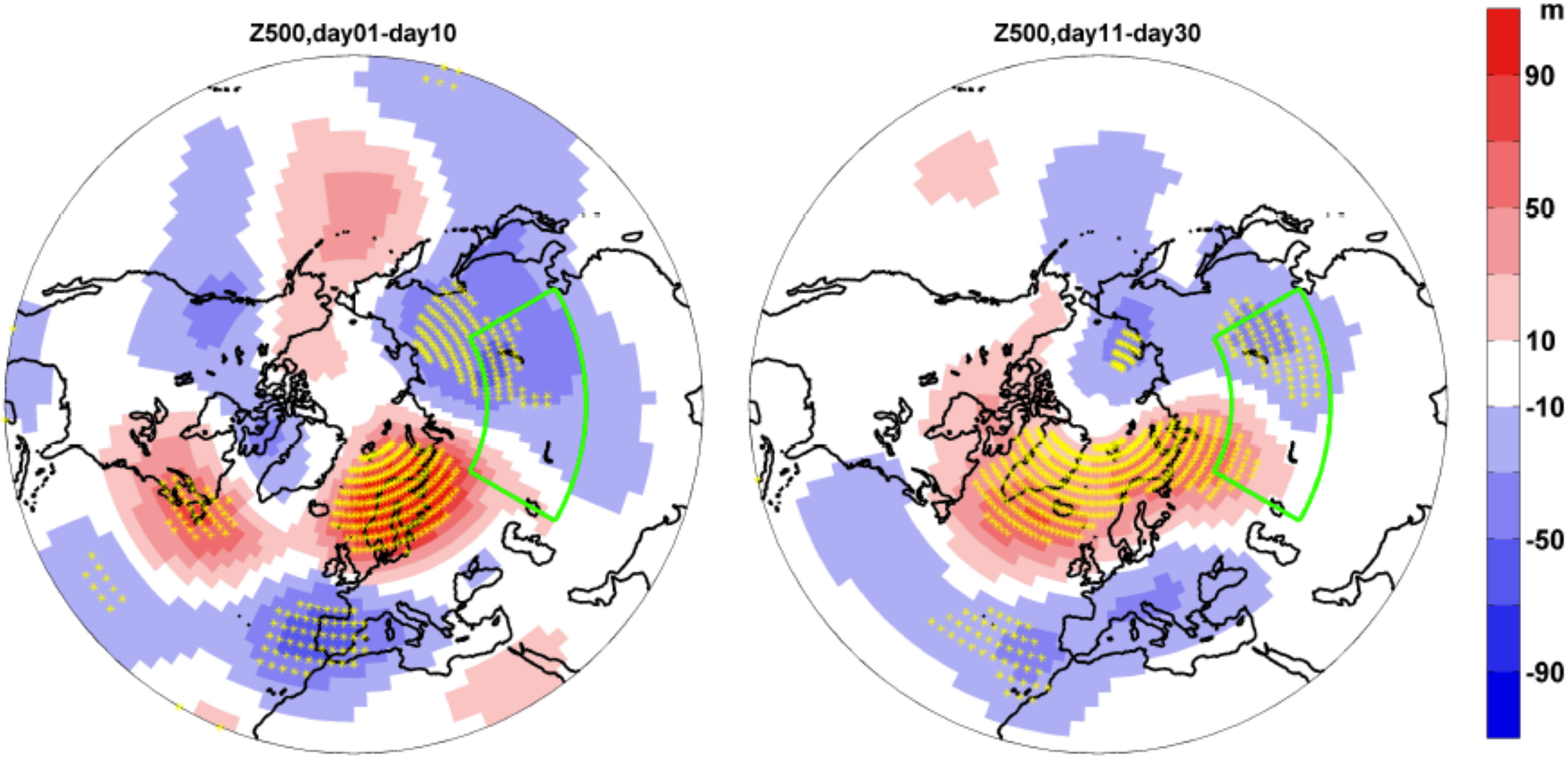
Flow-dependence: Asia



The dynamics of recent winters

Z500 anomalies: DJF 2005/06

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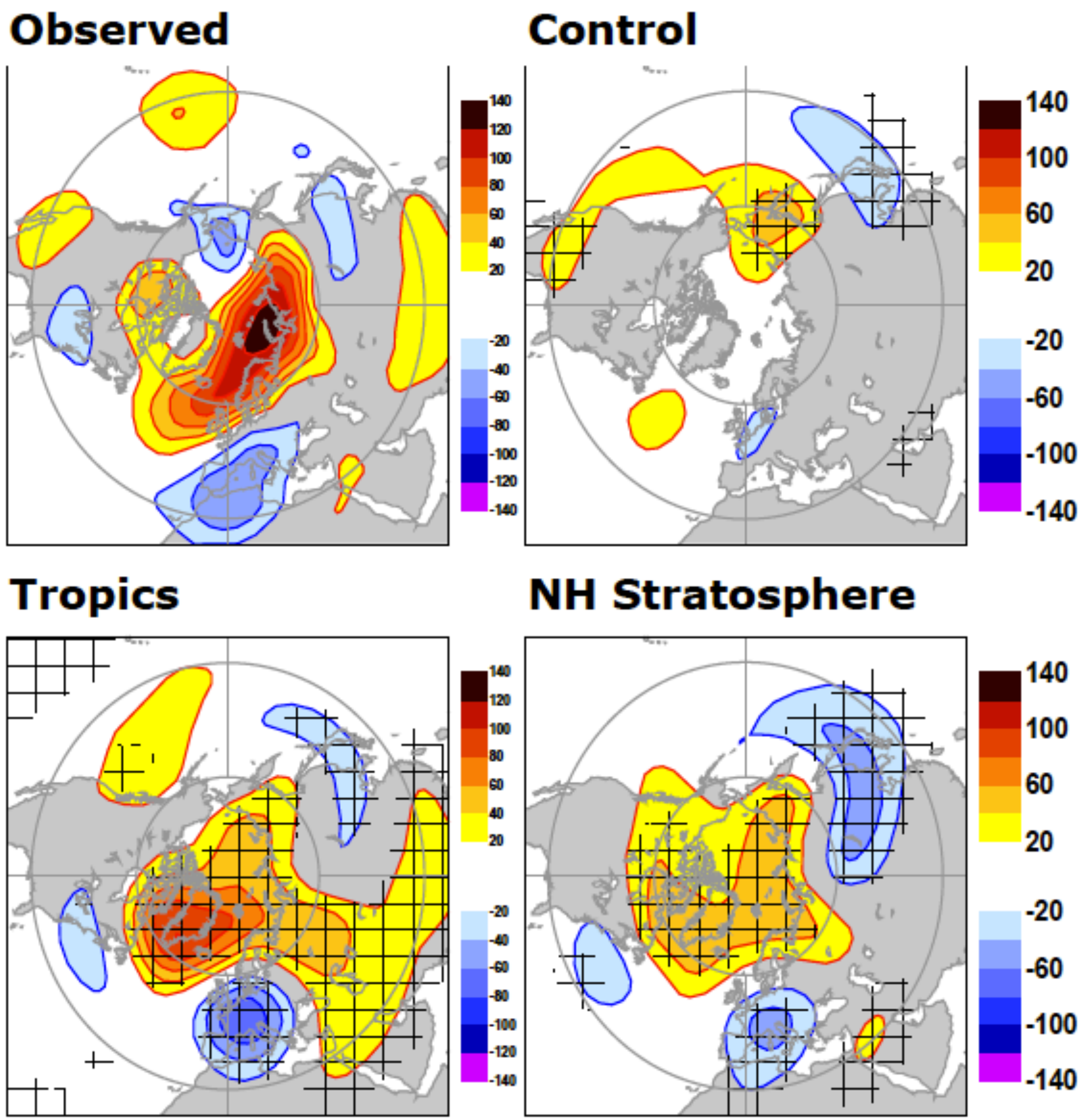

Jung et al. (2011), *Mon. Wea. Rev.*

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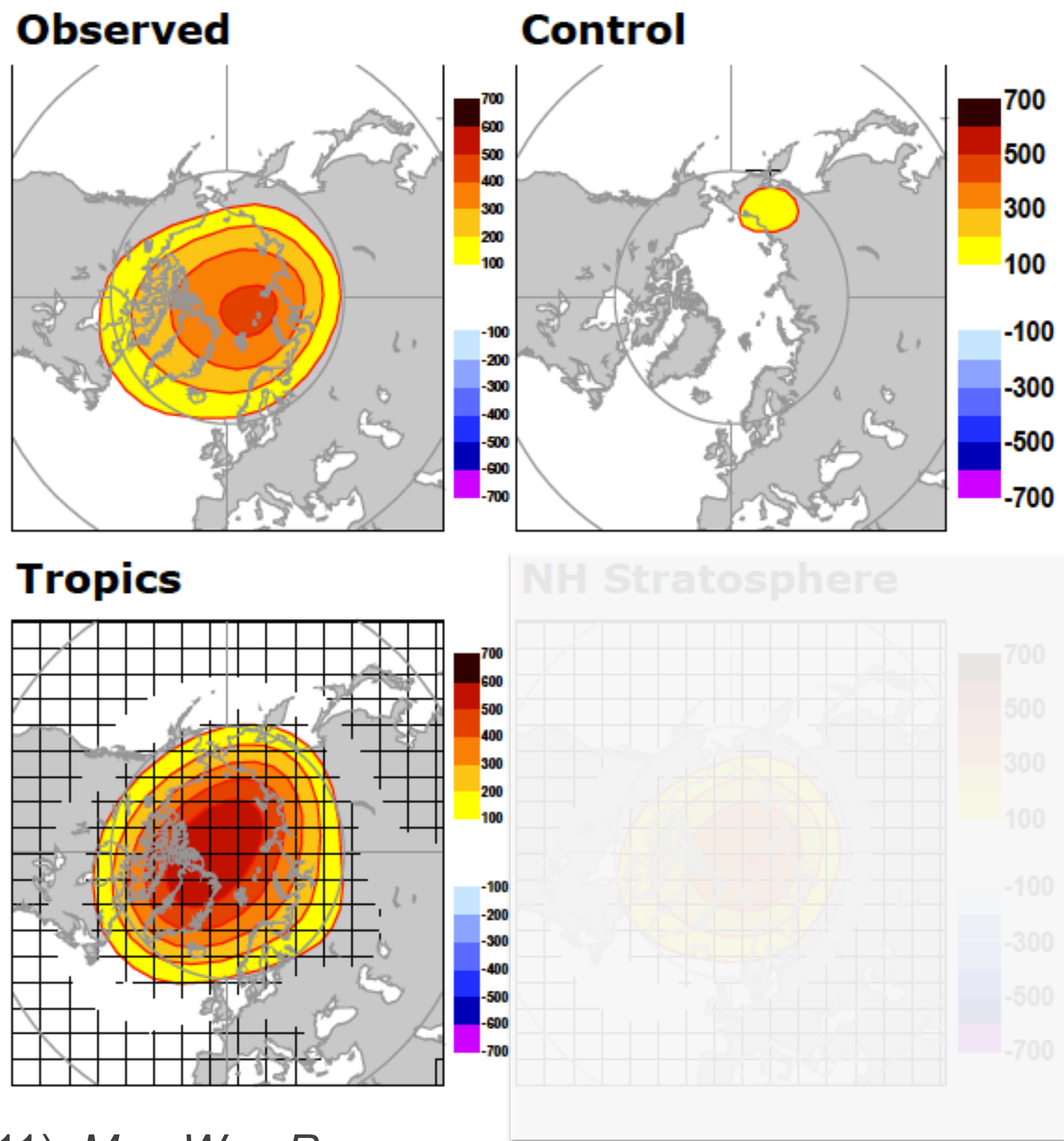
Z50 anomalies: DJF 2005/06



Jung et al. (2011), *Mon Wea Rev*

Summary

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- Observations:
  - ➢ Strong link implied
  - ➢ Arctic sea ice decline and simultaneous increase in the frequency of occurrence of cold European and North American winters
  - ➢ Underlying mechanisms (causality) not really understood
- Models:
  - ➢ Consistent model response is found over North America and especially Eurasia
  - ➢ Main pathways supported by NWP experiments
  - ➢ Simulated response is small-*ish*
  - ➢ Expected sea ice decline leads to a reduced warming over Europe
  - ➢ Are models sufficiently responsive?
- Prediction:
  - ➢ Improved polar prediction capabilities lead to increased prediction skill over NH continents (especially winter)

Summary

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Opinion

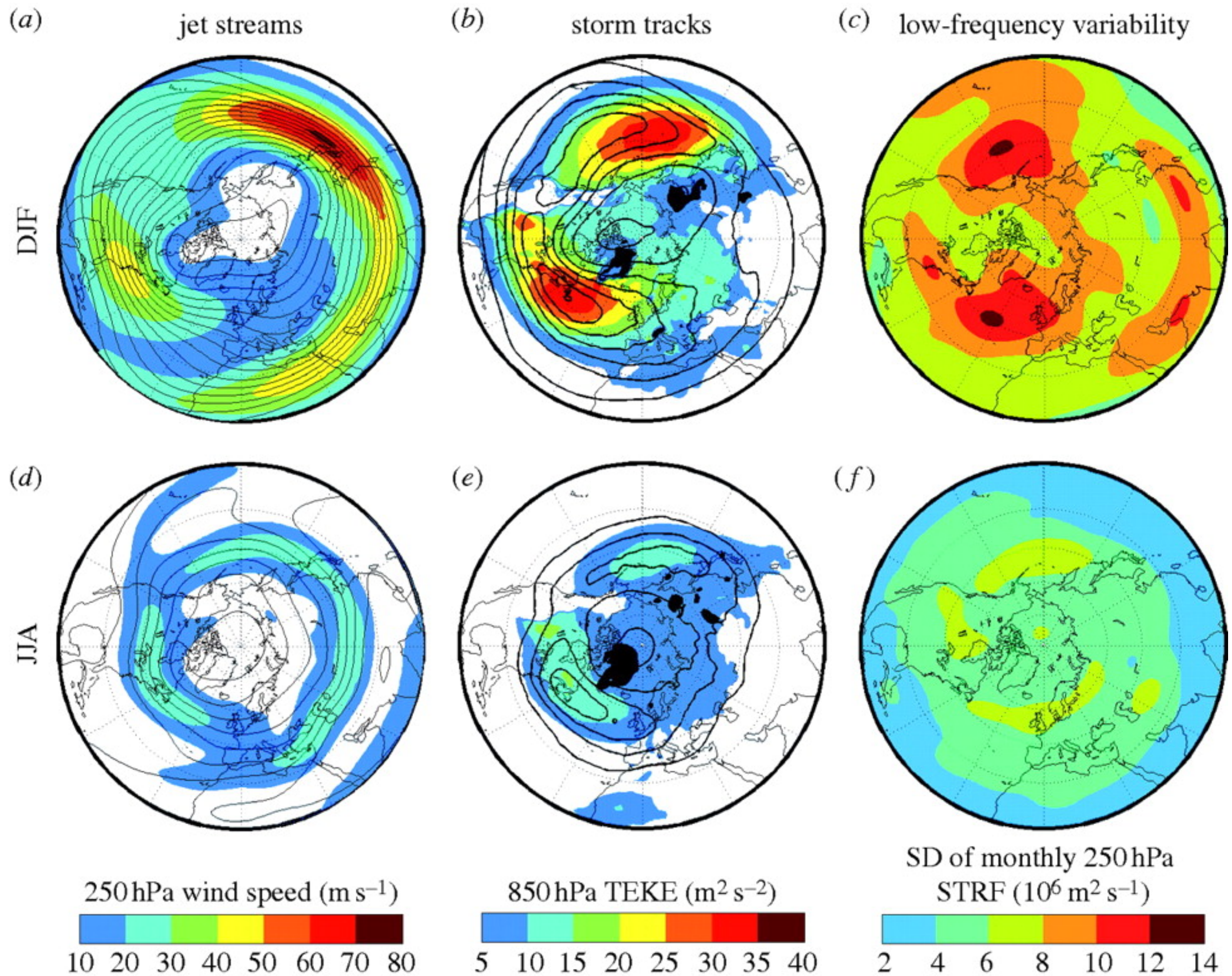
The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it?

Elizabeth A Barnes[1]* and James A Screen[2]

The Arctic lower atmosphere has warmed more rapidly than that of the globe as a whole, and this has been accompanied by unprecedented sea ice melt. Such large environmental changes are already having profound impacts on the flora, fauna, and inhabitants of the Arctic region. An open question, however, is whether these Arctic changes have an effect on the jet-stream and thereby influence weather patterns farther south. This broad question has recently received a lot of scientific and media attention, but conclusions appear contradictory rather than consensual. We argue that one point of confusion has arisen due to ambiguities in the exact question being posed. In this study, we frame our inquiries around three distinct questions: *Can Arctic warming influence the midlatitude jet-stream? Has Arctic warming significantly influenced the midlatitude jet-stream? Will Arctic warming significantly influence the midlatitude jet-stream?* We argue that framing the discussion around the three questions: *Can it?, Has it?, and Will it?* provides insight into the common themes emerging in the literature as well as highlights the challenges ahead.

How to cite this article:
WIREs Clim Change 2015, 6:277–286. doi: 10.1002/wcc.337

Interpretation



Woolings (2010)

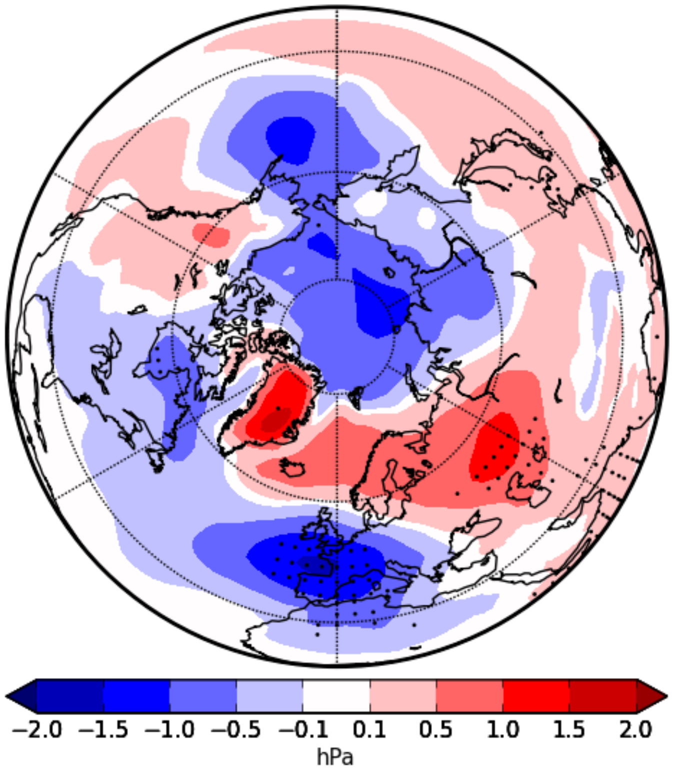
Rossby wave source

$$
\begin{aligned}
\frac{\partial \zeta}{\partial t} + \mathbf{v}_\psi \cdot \nabla \zeta &= -\nabla \cdot (\mathbf{v}_\chi \zeta) \\
&= -\zeta \nabla \cdot \mathbf{v}_\chi - \mathbf{v}_\chi \cdot \nabla \zeta.
\end{aligned}
$$

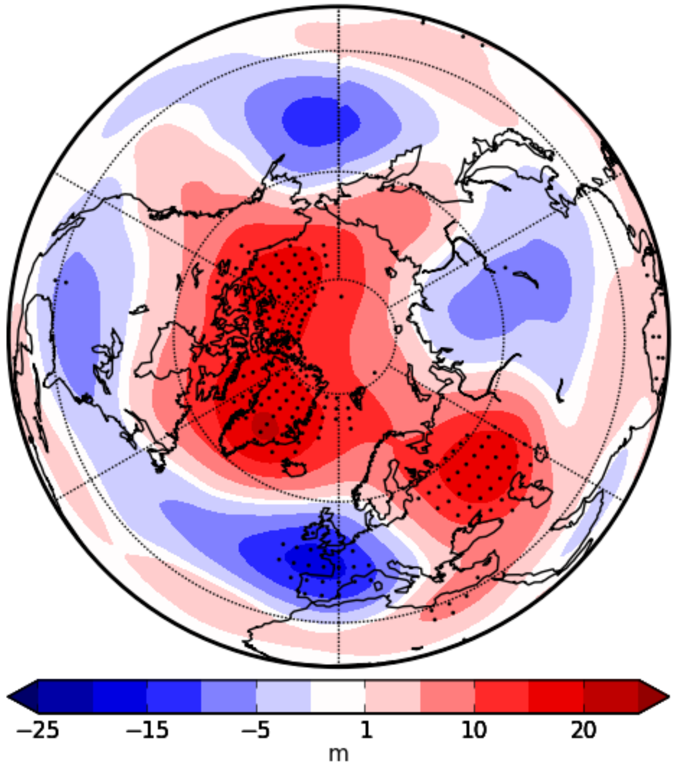
Woolings (2010)

Atmospheric response: Coupled model

Sea Level Pressure



500 hPa Geopotential Height



Experimental setup

- T_L95L60 (32r1)
- Atmosphere-only with observed SST and sea ice
- Lagged ensemble (17 members) with and without relaxation started in the middle of November 2005
- Calibration runs with and without relaxation (1990-2006)

Experimental setup

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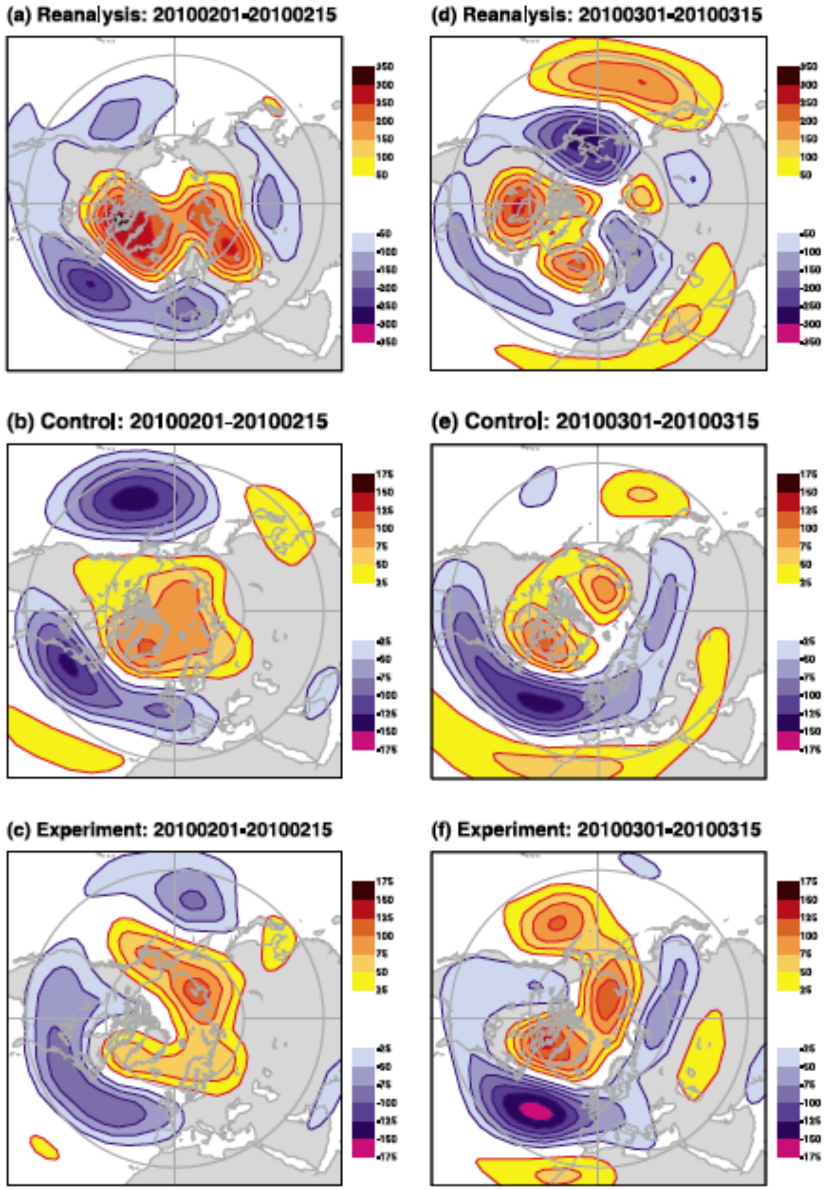
- T_L159L60 (36r1)
- ECMWF monthly forecasting systems (VarEPS)
- Forecasts started on 1 November 2009
- 40 Ensemble members
- Control integrations
- Various experiments
- Hindcast for each of the configurations
  - 1991-2008
  - 4 ensemble members

Sensitivity experiments: D+18-D+32

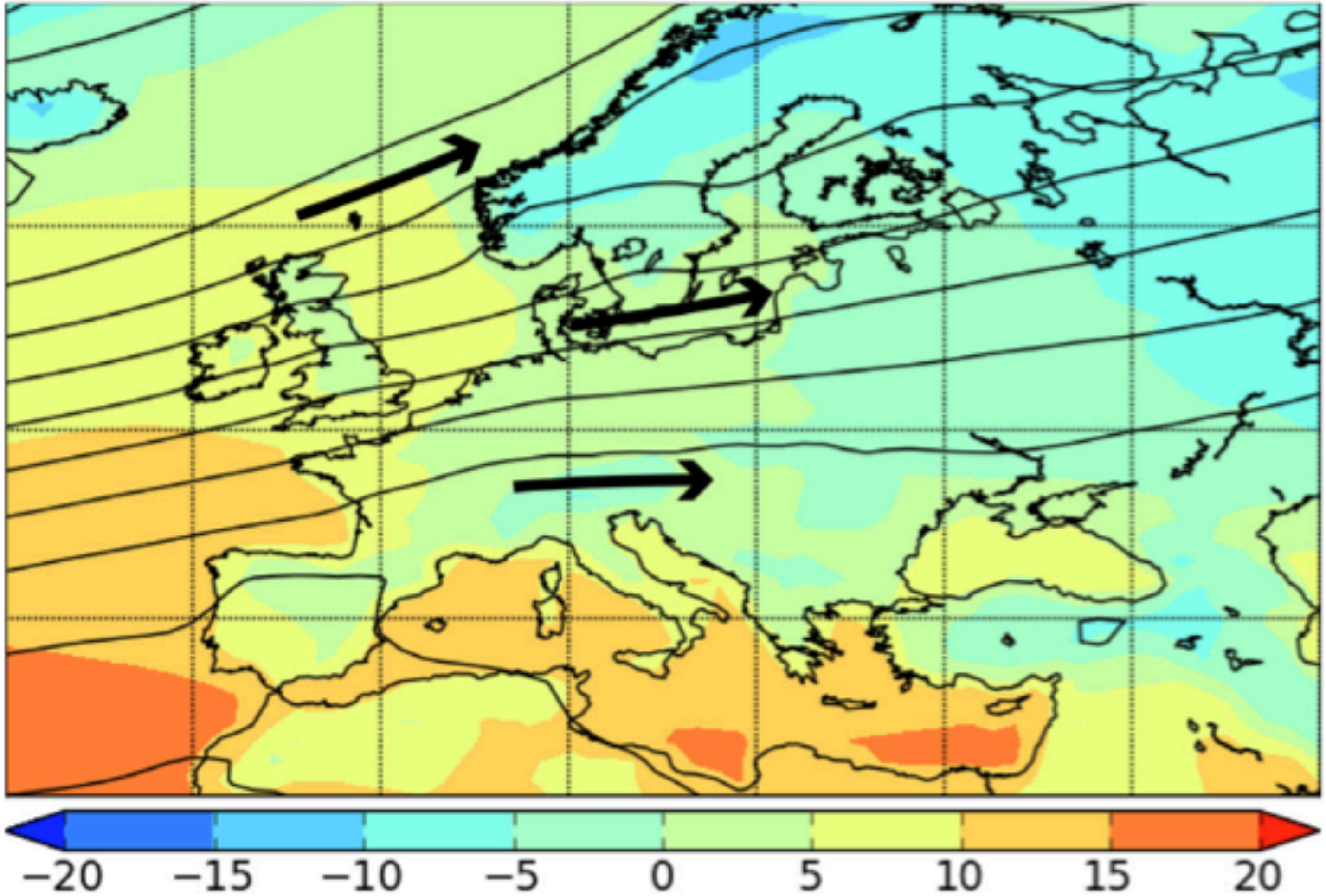
Verifying analysis

Control

Changed BCs



Mean European winter climate



Semmler et al. (2012), *Clim. Dyn.*

Ensemble mean anomalies: Polar Z50

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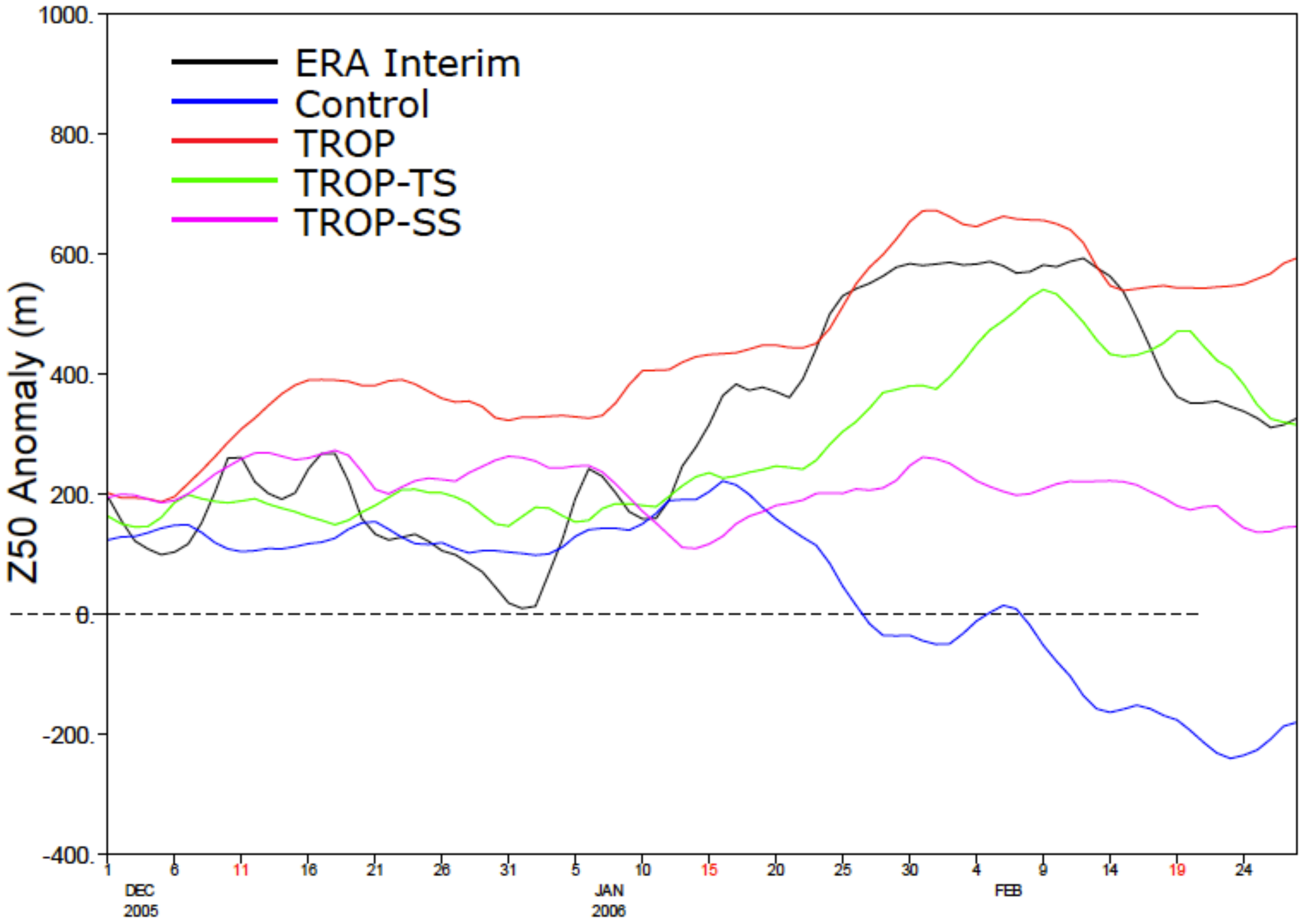

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Arctic relaxation: Day 7-9

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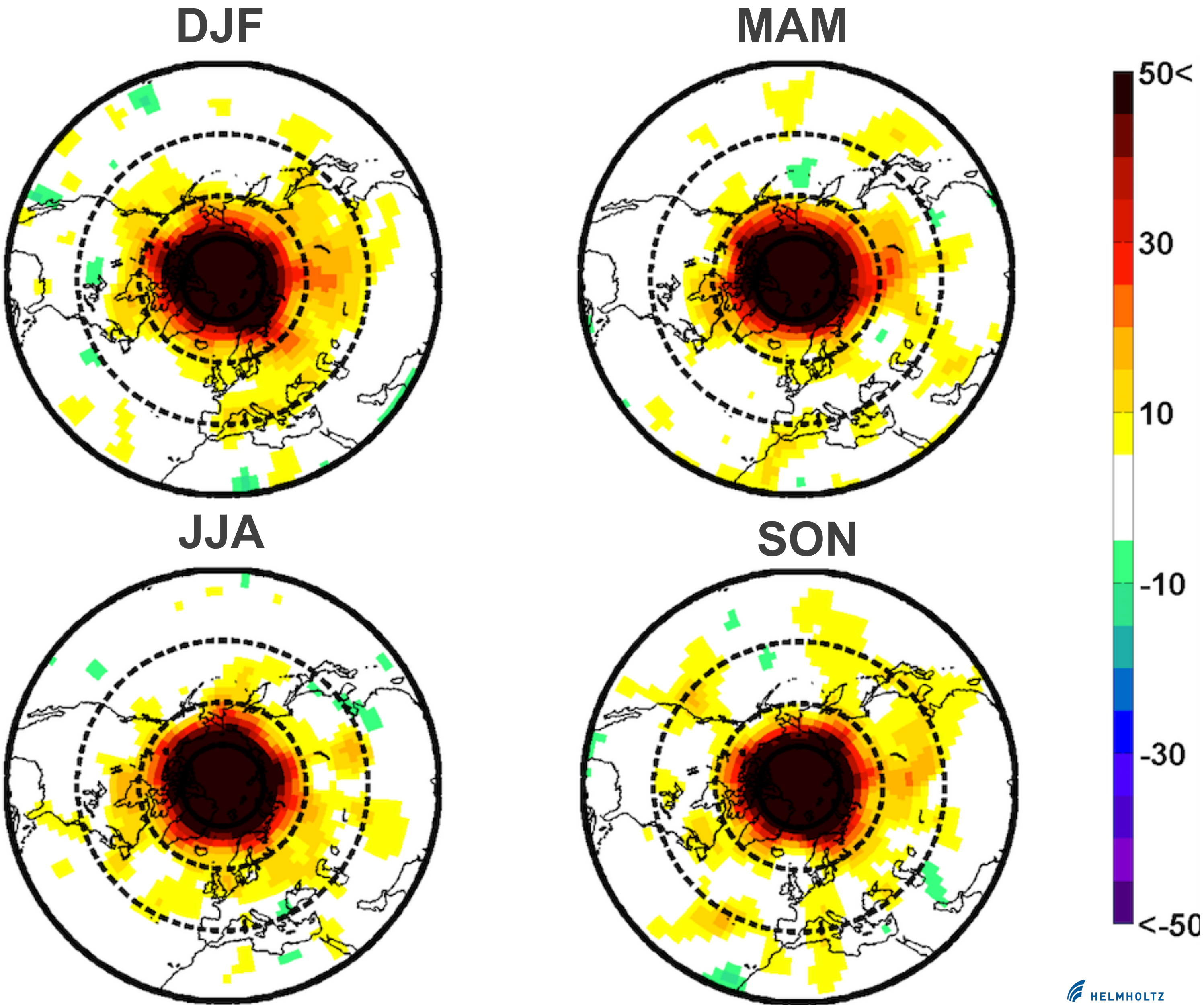

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Observational studies

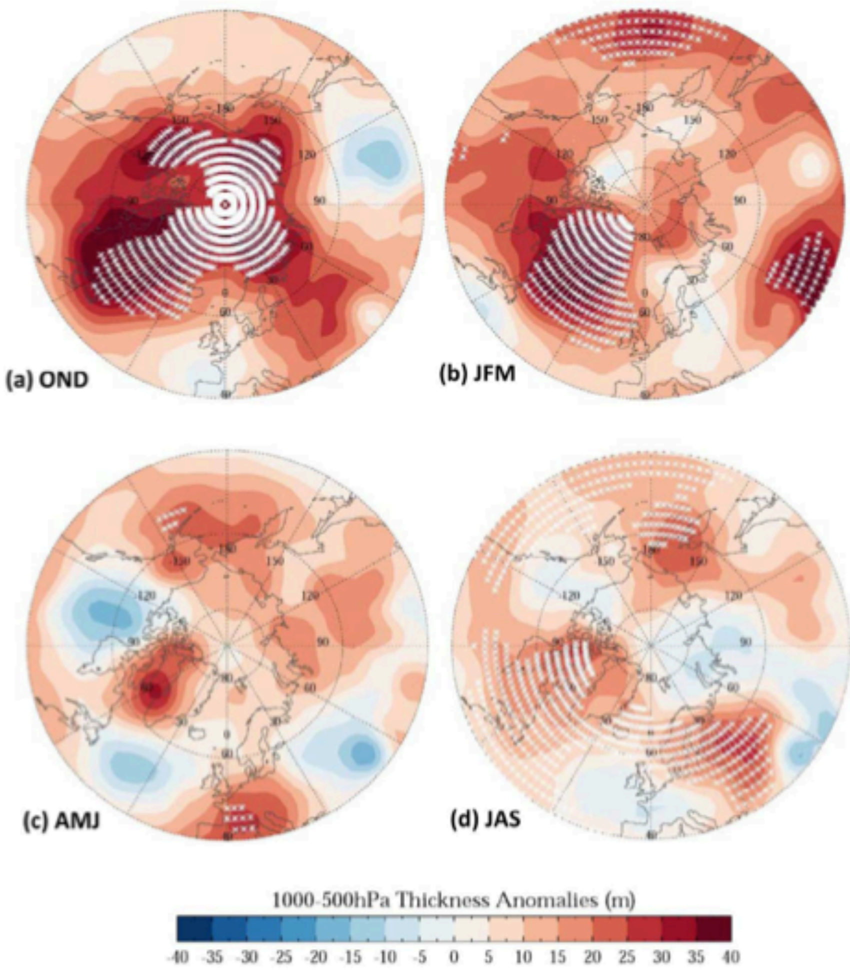
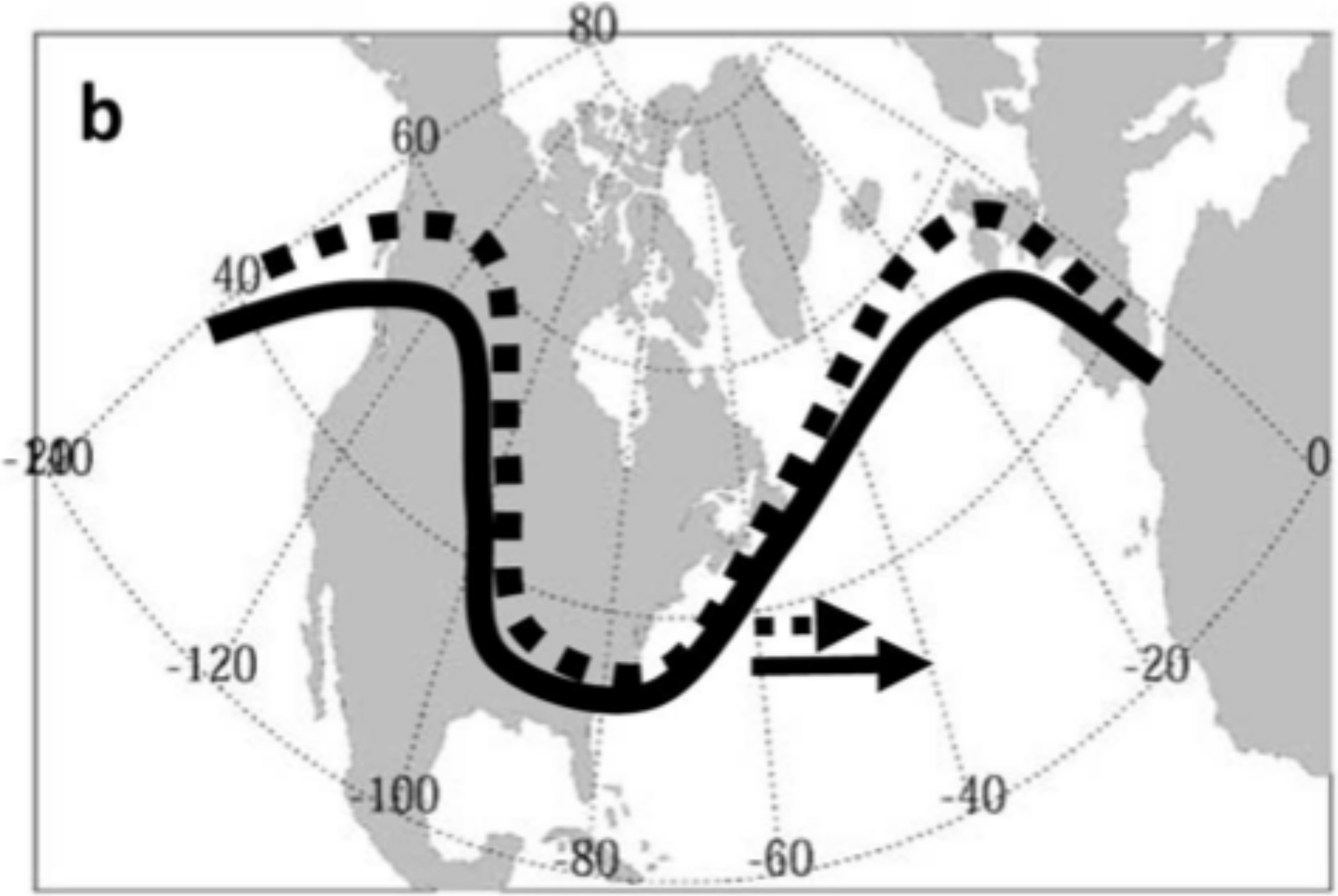


Figure 1. Seasonal anomalies in 1000-500 hPa thicknesses (m) north of 40°N during 2000–2010 relative to 1970–1999: (a) autumn (OND), (b) winter (JFM), (c) spring (AMJ), and (d) summer (JAS). White asterisks indicate significance with $p < 0.05$. Data are from the NCEP/NCAR Reanalysis.

Francis and Vavrus (2012), *Geophys. Res. Lett.*

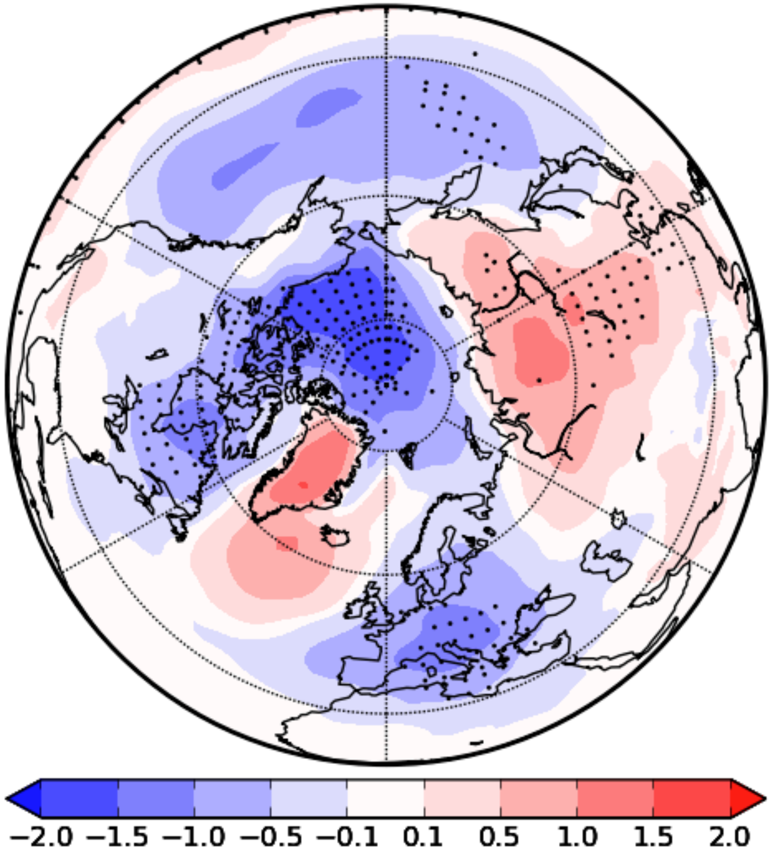
Observational studies



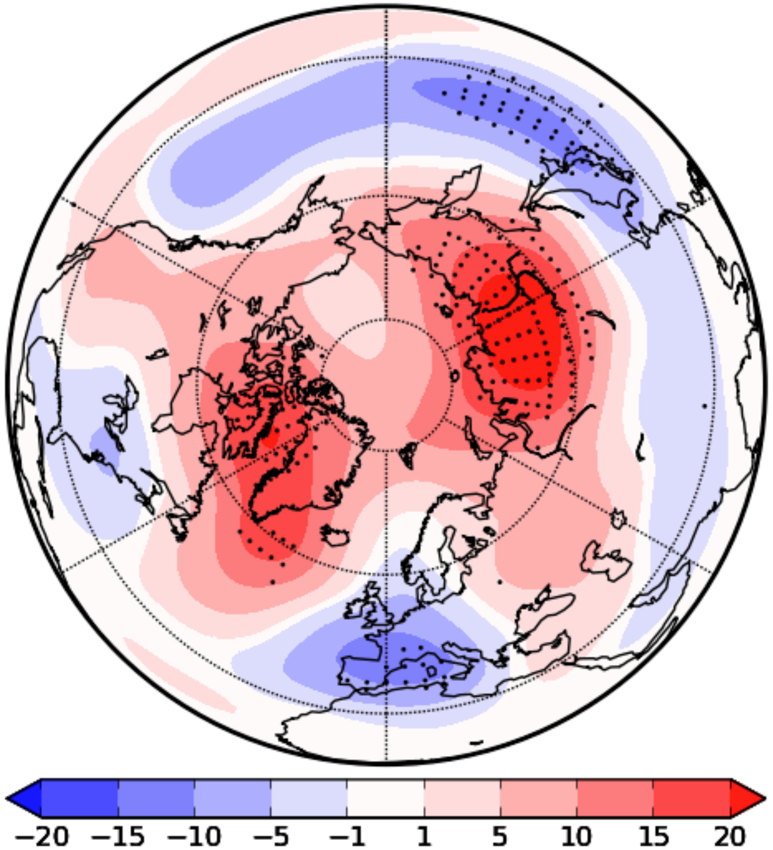
Francis and Vavrus (2012), *Geophys. Res. Lett.*

Atmospheric response in DJF

Sea level pressure

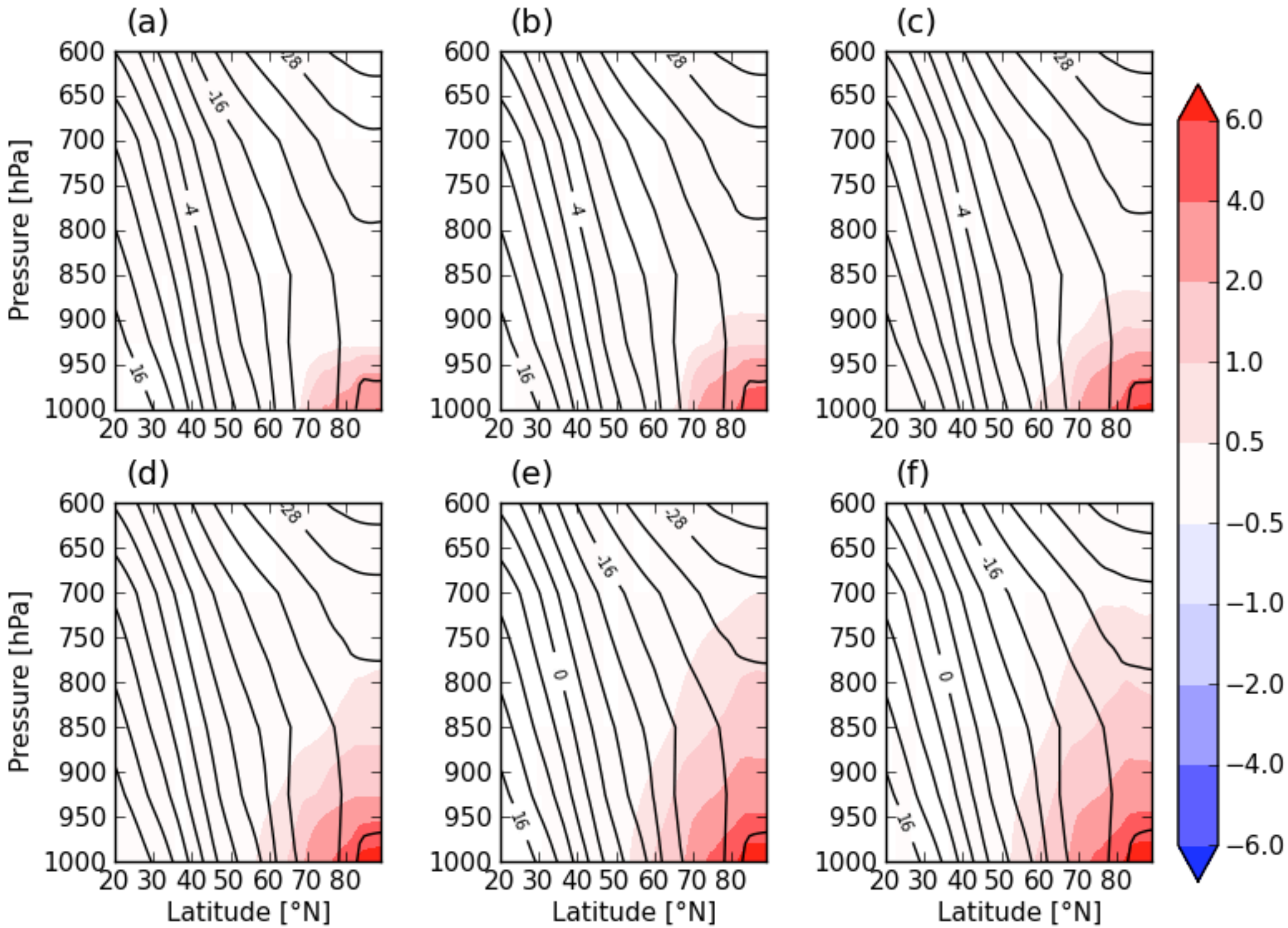


500 hPa geopotential

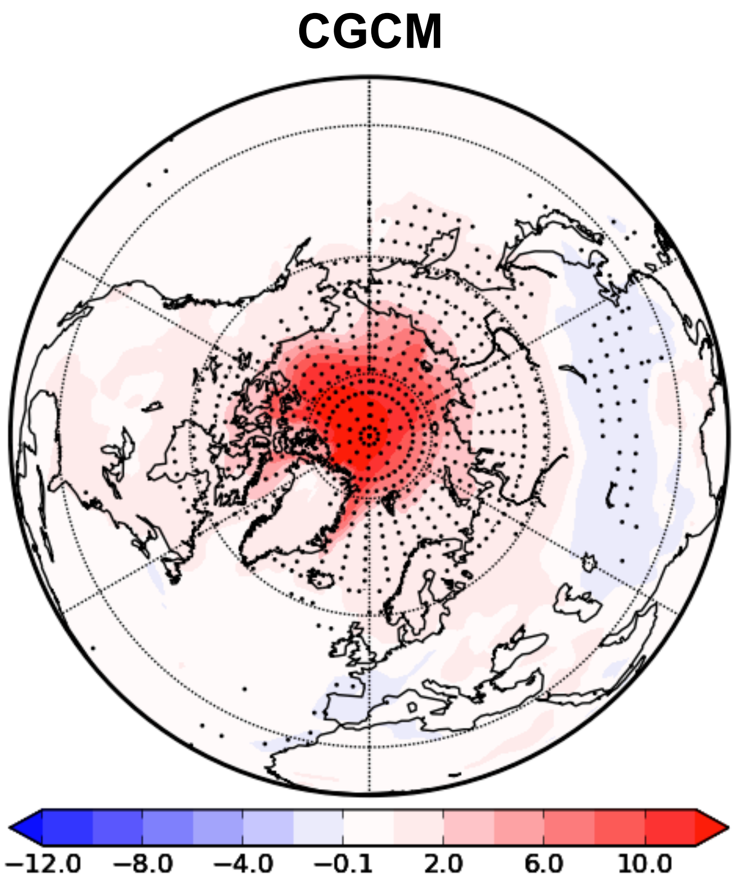


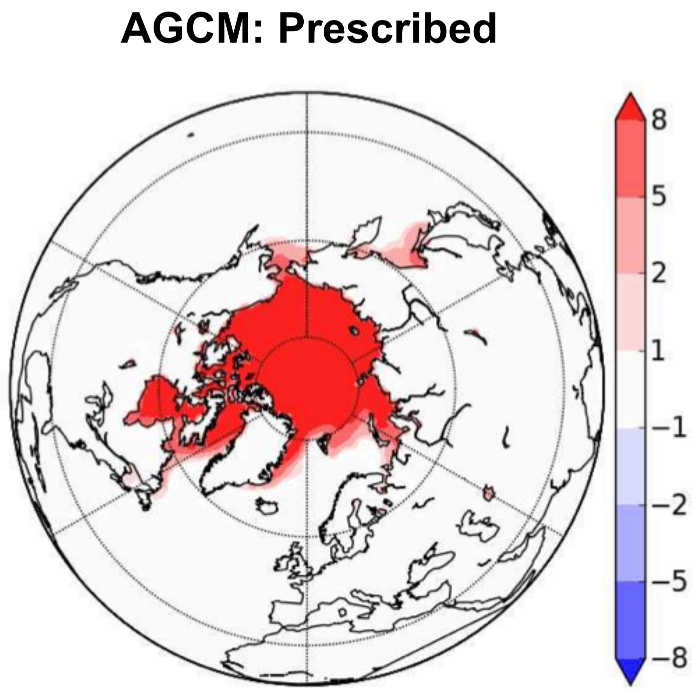
Coupled model experiments

-
-



Coupled vs uncoupled experiments





Winter T_{sfc} response

Fast atmospheric response

QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY
Q. J. R. Meteorol. Soc. **134**: 1479–1497 (2008)
Published online 20 August 2008 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/qj.298

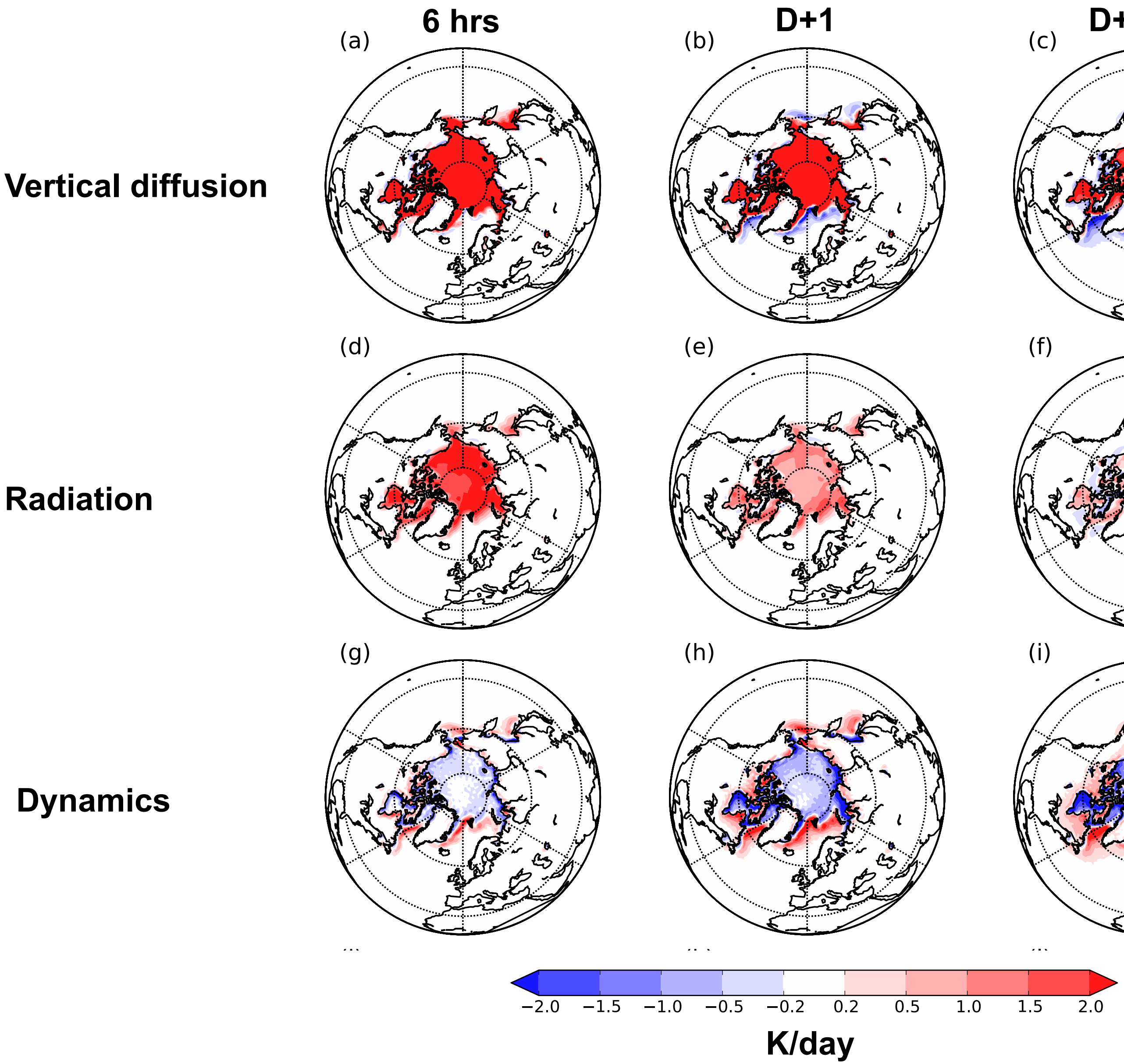
RMetS
Royal Meteorological Society

Understanding the local and global impacts of model physics changes: An aerosol example

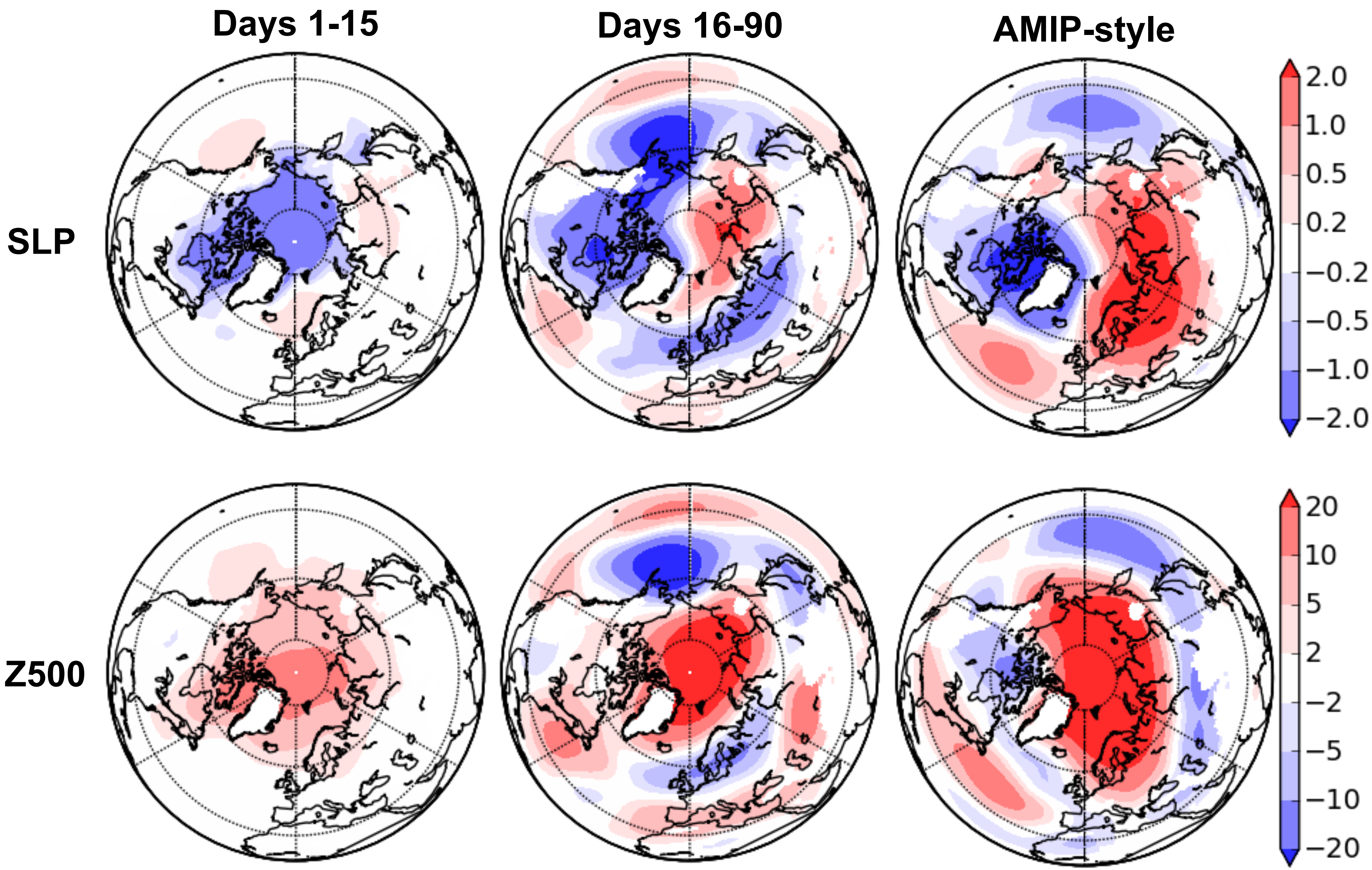
Mark J. Rodwell* and Thomas Jung
European Centre for Medium-Range Weather Forecasts, Reading, UK

ABSTRACT: This study demonstrates the use of a package of diagnostic techniques to understand the local and global responses to a given physics change within a general circulation model. Here, the package is applied to the case of a change in the aerosol climatology in the forecast model of the European Centre for Medium-range Weather Forecasts. The largest difference between old and new climatologies is over the Sahara where, in particular, soil-dust aerosol is reduced. Conventional diagnostics show that the change lead to improvements in local medium-range forecast skill and reductions in seasonal-mean errors throughout the globe. To study the local physics response, short-range tendencies in weather forecasts are diagnosed. These tendencies are decomposed into the contributions from each physical process within the model. The resulting 'initial tendency' budget reveals how the local atmosphere responds to the aerosol change. The net tendencies also provide strong evidence to confirm that the new aerosol climatology is superior. Seasonal integrations demonstrate that the tropic-wide response can be understood in terms of equatorial waves and their enhancement by diabatic processes. The so-called 'Rossby-wave source' is made applicable to general circulation models and used to understand how the tropical anomalies subsequently impact on the global circulation. The mean response in the extratropics is found to be a stationary wave field. Precipitation anomalies that are co-located with extratropical divergent vorticity sources suggest the possibility for diabatic modification of the tropically forced Rossby-wave response.

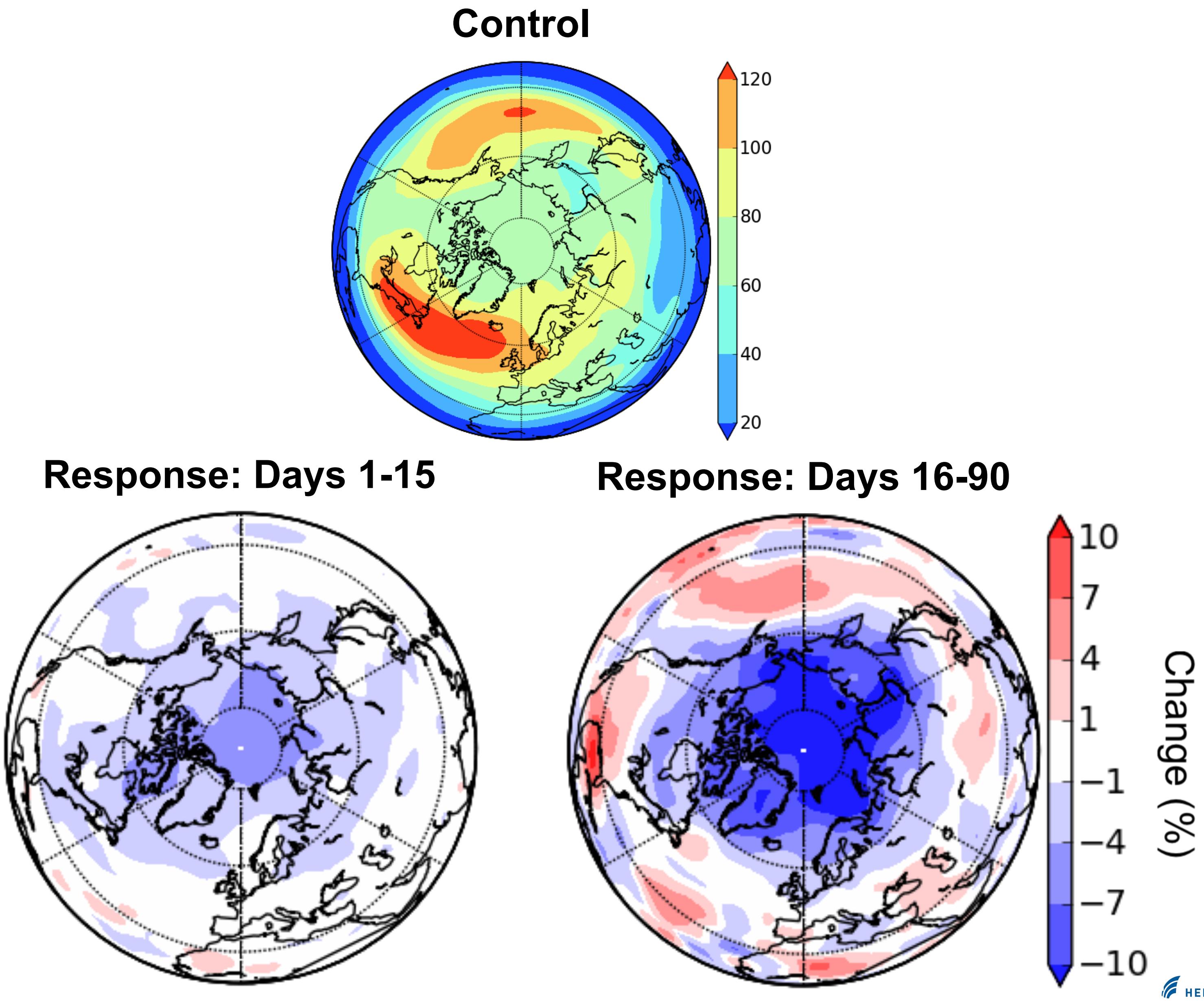
Mean T-tendency response (PBL)



Atmospheric response



Synoptic Z500 activity



Background