Blocking simulation in global models – are we getting there?

Reinhard Schiemann

Blocking and Extreme Weather in a Changing Climate, Boulder, 19 March 2024

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

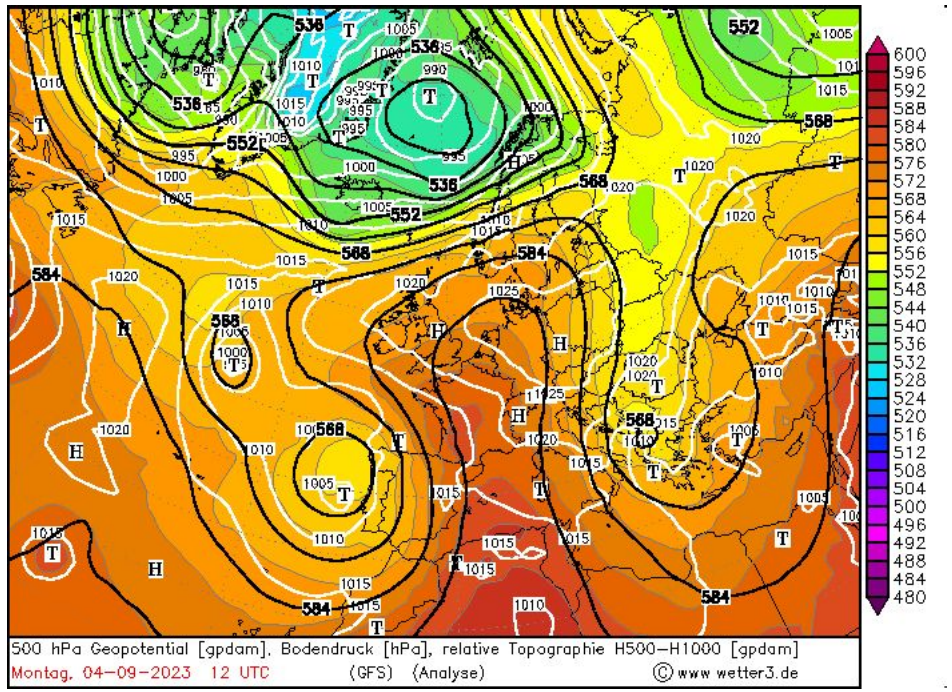
University of Reading

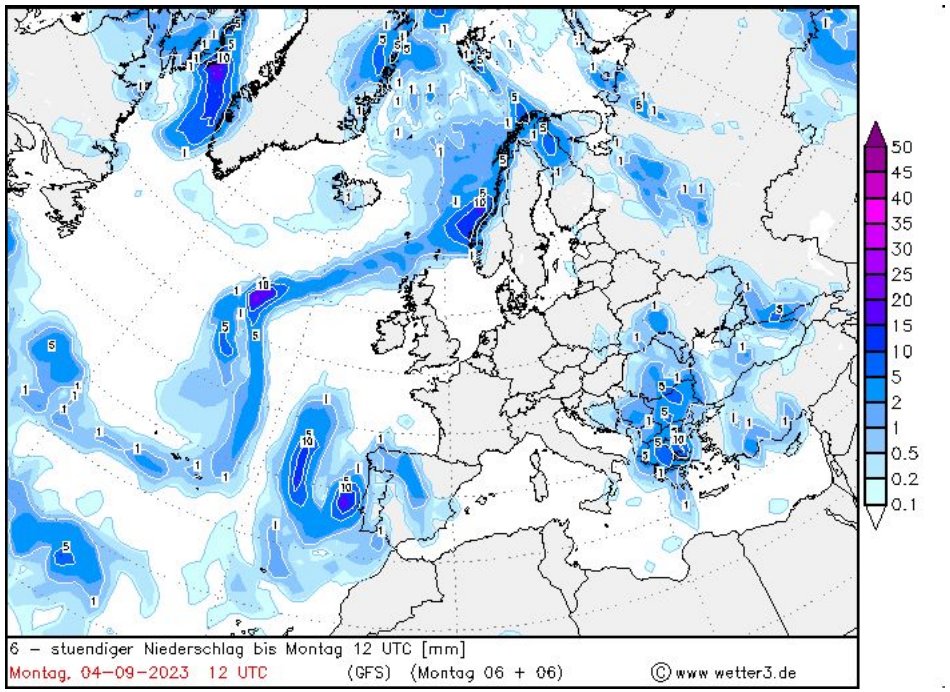
Outline

- Introduction
    - Blocking and surface impacts
    - Blocking identification and historical variation
- Blocking representation in models
    - Aggregate skill and long-term view
    - Examples of improvement
- 21st century projections and discussion

Example: Mediterranean flooding

- 4 September 2023





Example: Mediterranean flooding

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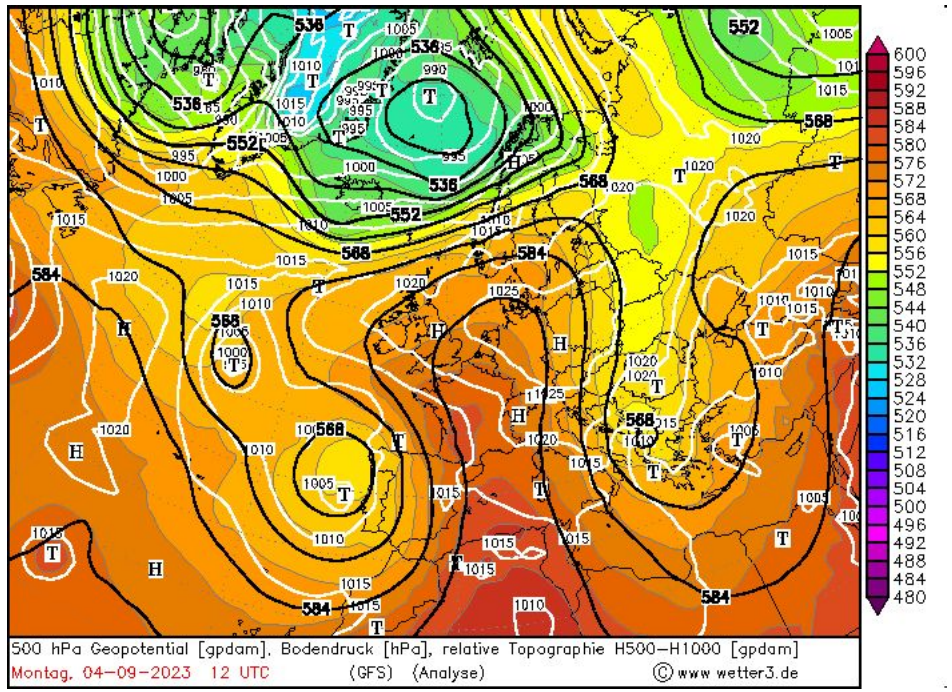


Greece – "Unimaginable Amounts of Water" as Floods and Rain Continue

7 SEPTEMBER, 2023

Heavy rain is continuing to fall in Greece, where catastrophic floods have caused devastating material damages and at least 3 fatalities. "I know the word unprecedented has been used many…

Read Full Article

Greece, Turkey and Bulgaria – 11 Dead After Record Rainfall Triggers Catastrophic Floods

6 SEPTEMBER, 2023

At least 11 people have lost their lives after catastrophic flooding brought by storms in Greece, Turkey and Bulgaria. Greece In Greece, the wave of severe weather, dubbed Storm Daniel,…

Read Full Article

Spain – Widespread Flooding After Storm Dumps Over 240mm of Rain in 24 Hours

4 SEPTEMBER, 2023

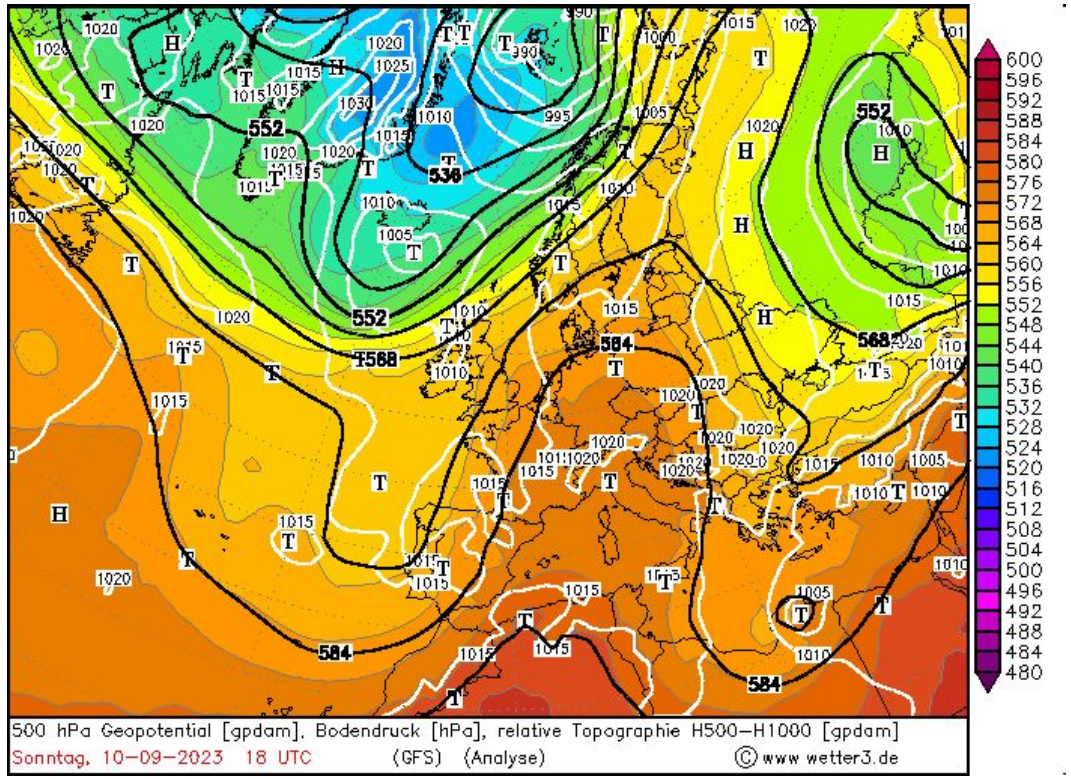
A slow-moving storm brought torrential rainfall and strong winds to parts of Spain from 02 September 2023. Emergency crews have responded to thousands of incidents across the regions of Catalonia,…

Read Full Article

floodlist.com

Example: Mediterranean flooding

- 10 September 2023



Libya – 5,300 Lives Lost in Derna Floods, Thousands Still Missing

13 SEPTEMBER, 2023

The death toll from massive floods that swept the city of Derna in eastern Libya rose to 5,300 people, according to statistics issued by the Ministry of the Interior of…

Read Full Article

floodlist.com

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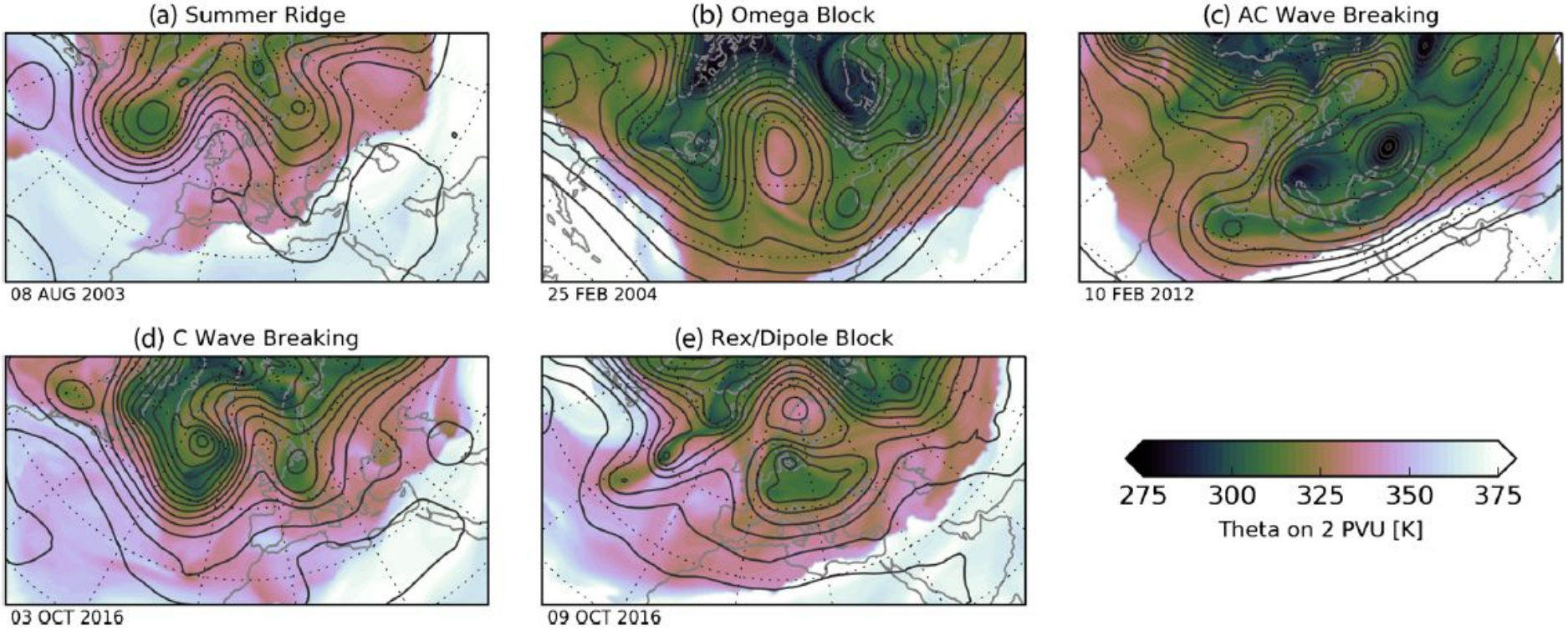
Types of blocking

- A range of blocking situations:

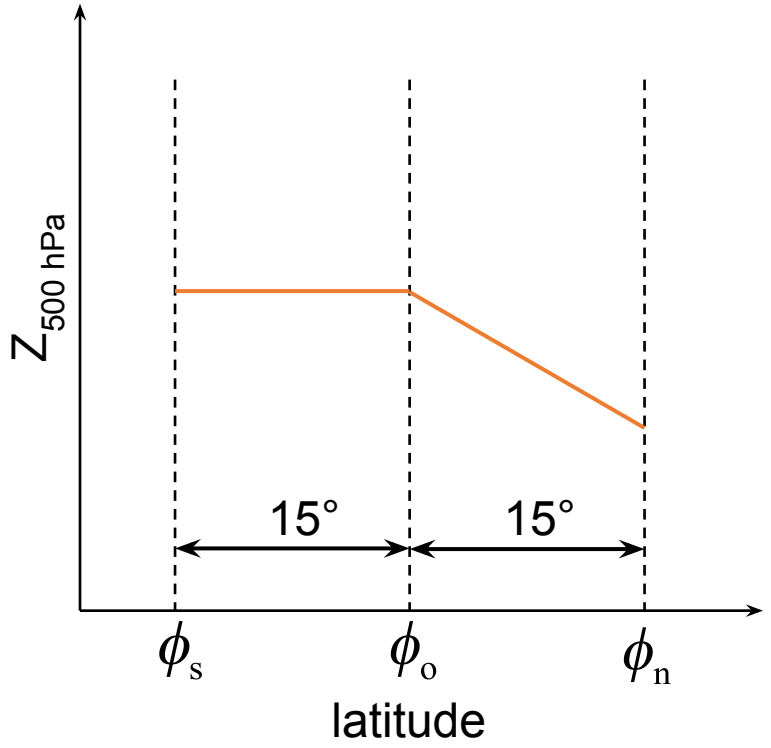


Woollings et al., 2018

A blocking index (“AGP”)

Based on the equator-pole gradient of geopotential height.

Uses daily-mean 500hPa geopotential height (Z500).



Three criteria for blocking at latitude ϕ_0:

1. reversal of the climatological Z500 gradient to the south of ϕ_0

$$\frac{Z(\phi_o) - Z(\phi_s)}{\phi_o - \phi_s} > 0$$

2. decreasing Z500 with latitude (westerlies) to the north of ϕ_0

$$\frac{Z(\phi_n) - Z(\phi_o)}{\phi_n - \phi_o} < -10 \ \frac{\text{m}}{\text{lat}}$$

3. persistence of 5 days or longer

Scherrer et al., Int. J. Climatol., 2006; Tibaldi & Molteni, Tellus, 1990

Reanalysis blocking climatology (1D)

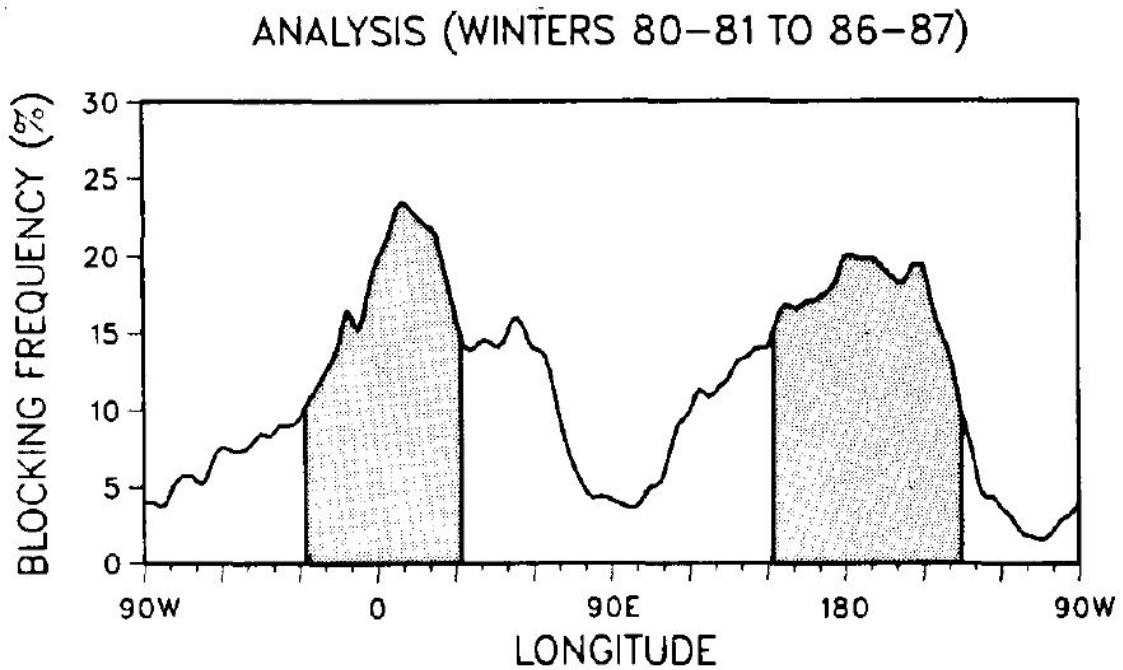


Fig. 1. **Percentage frequency of blocking (objectively defined in Section 2) as a function of longitude and computed on all ECMWF daily objective analyses of our database.**

Tibaldi & Molteni, Tellus, 1990

Reanalysis blocking climatology (2D)

AGP index

DJF

MAM

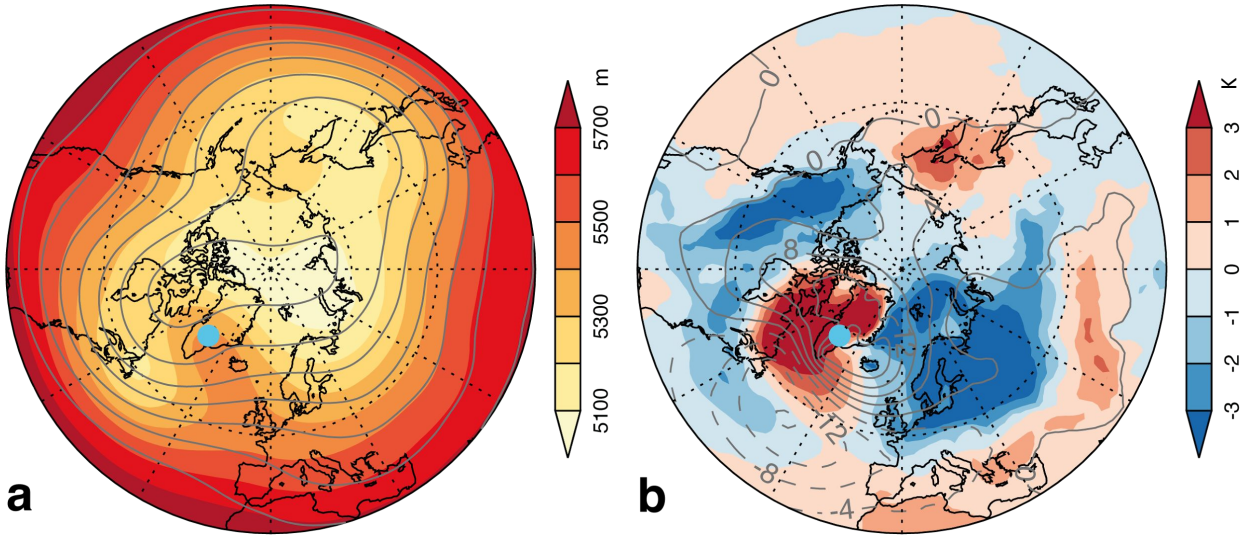
JJA

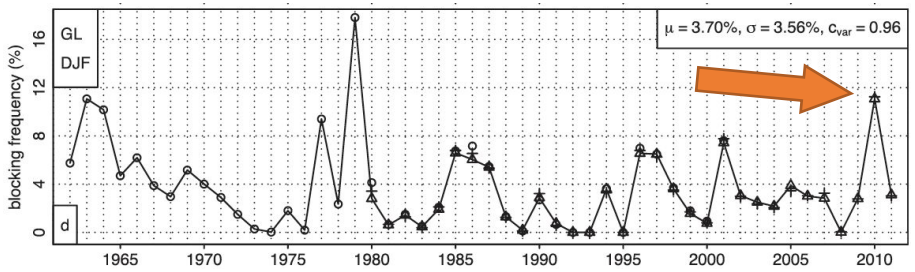
SON

Schiemann et al., 2017

Historical blocking and surface weather

Example: Greenland blocking and cold European winters





Schiemann et al., 2017

Oxford Canal in Banbury, 19 Dec 2010

Wikipedia

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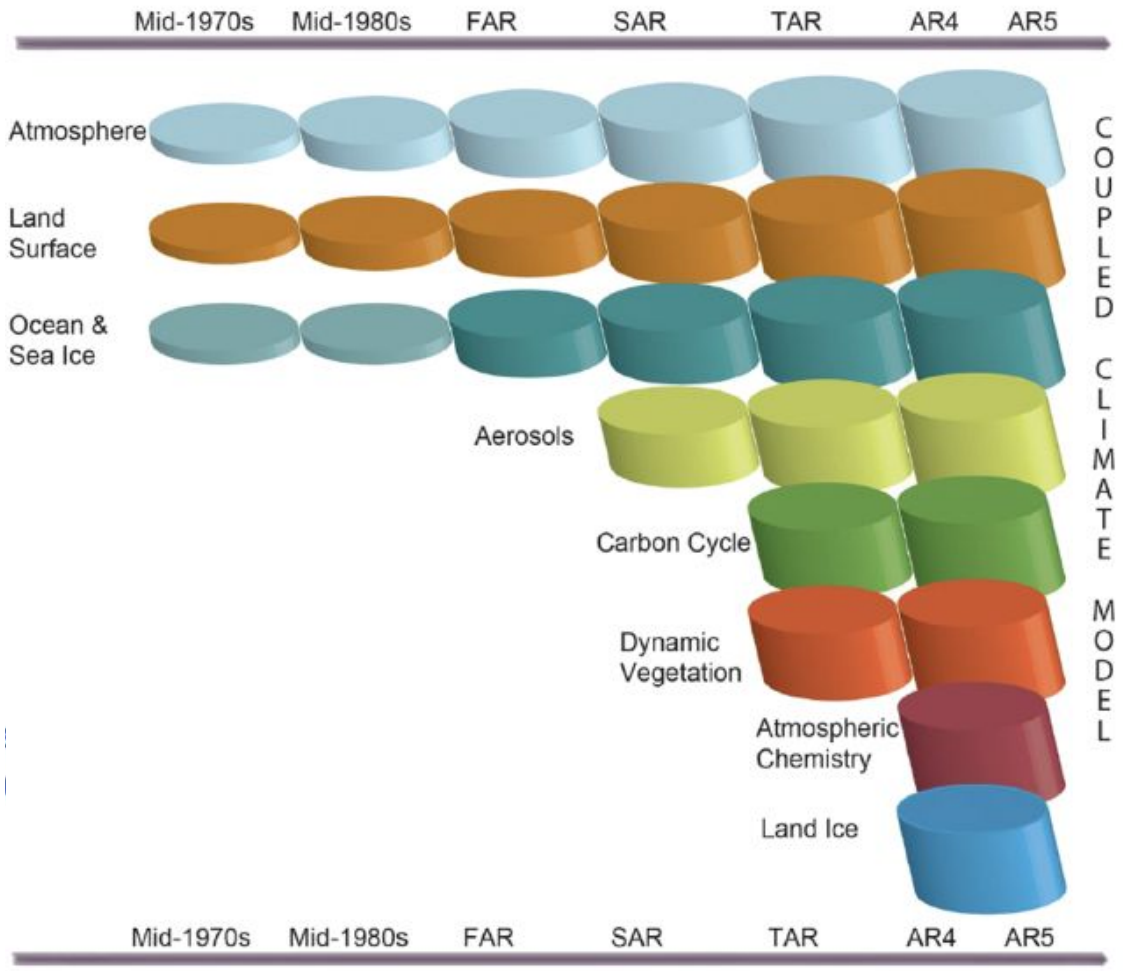
Climate models and CMIP

- Climate Model Intercomparison Project (CMIP)
  - AMIP (1990s)
  - CMIP1&2 (~1996)
  - CMIP3 (~2007)
  - CMIP5 (~2012)
  - CMIP6 (~2017)



Jones, 2020

Climate models and CMIP

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  - AMIP (1990s)
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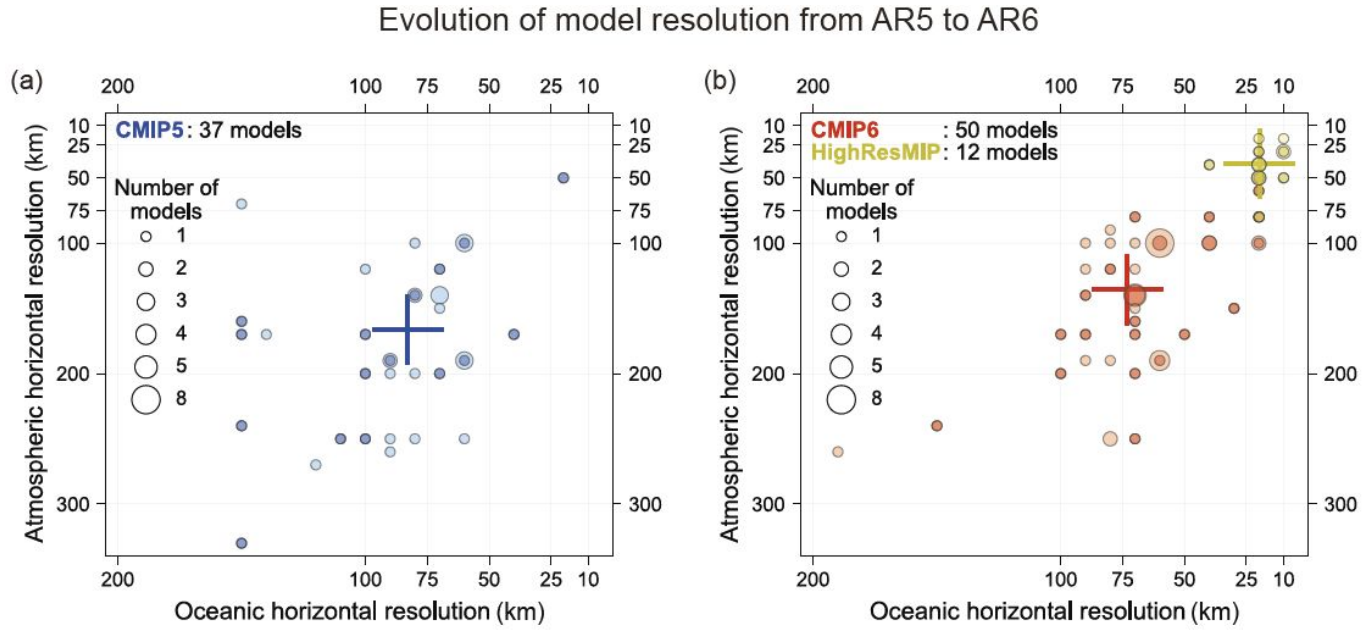
  - CMIP6 (~2017)
- HighResMIP in CMIP6

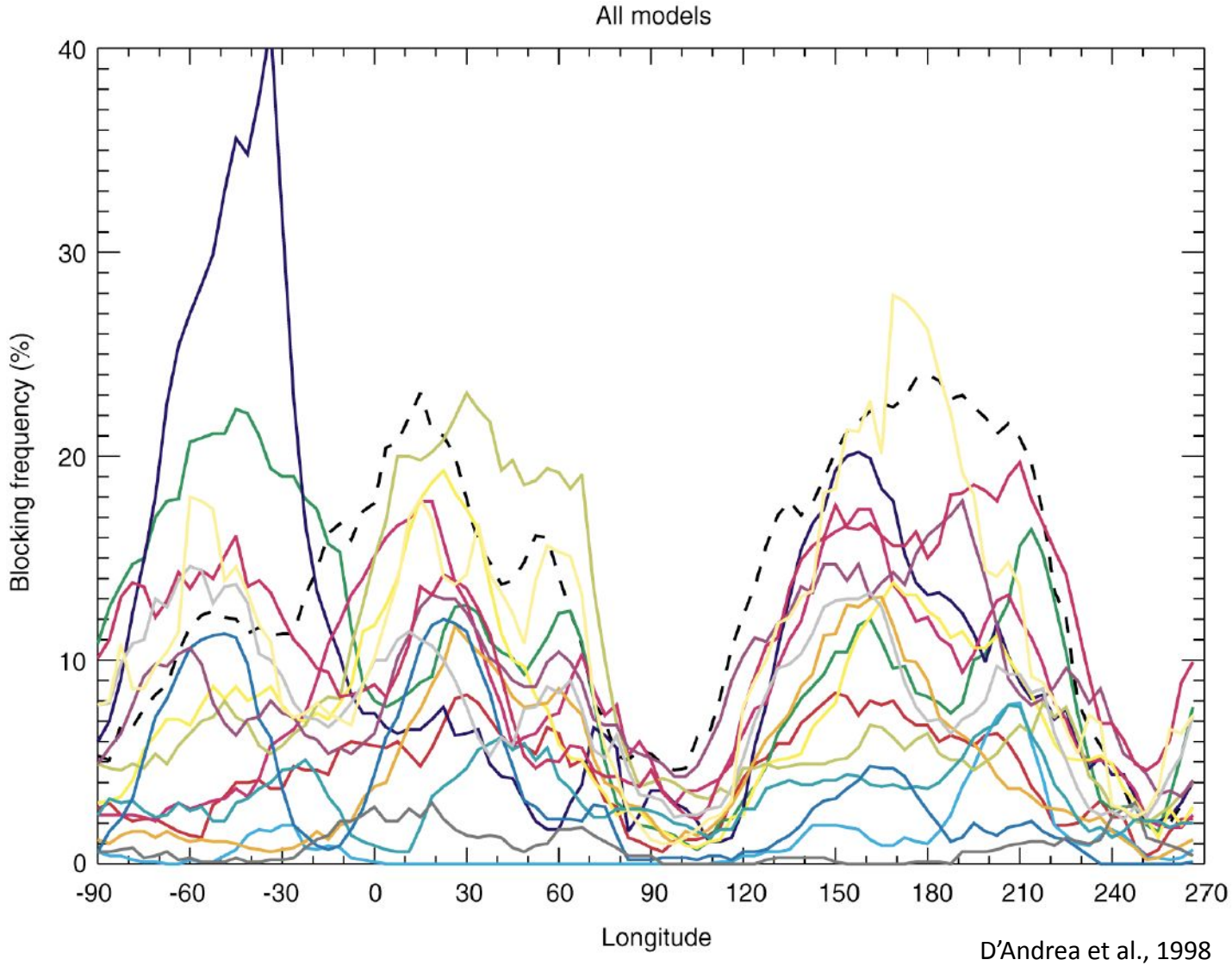


IPCC, AR6, Ch 1

Blocking in climate models

Climate models tend to underestimate blocking.

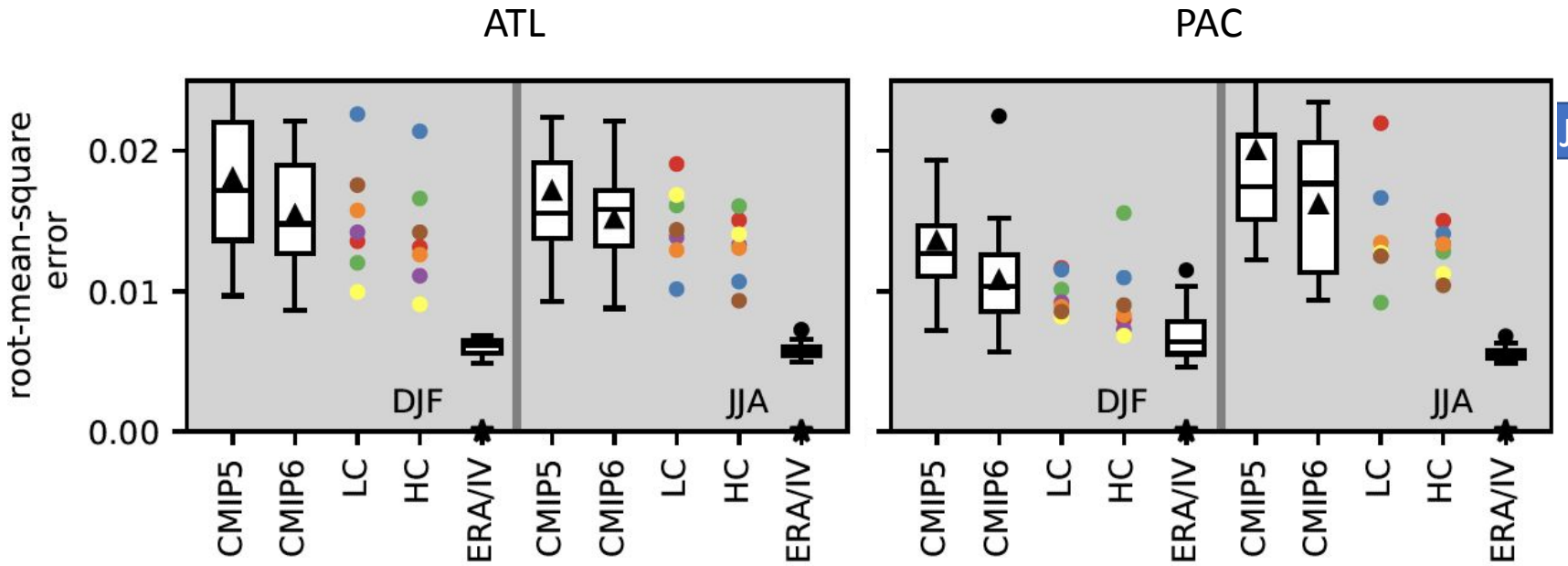
This is a long-standing problem.

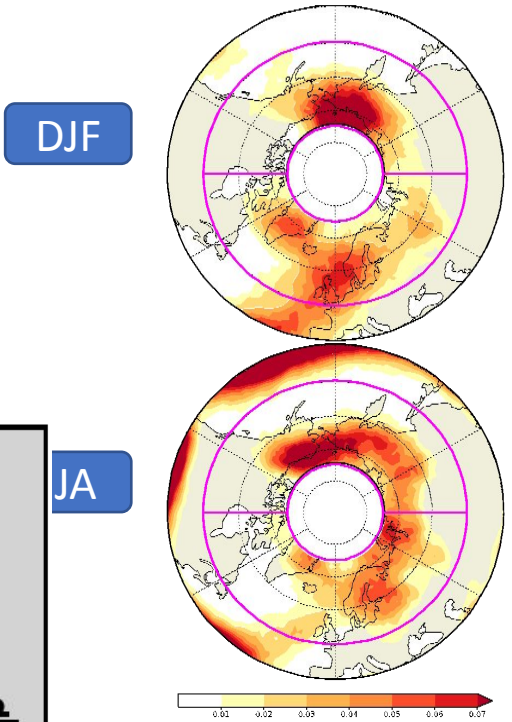


AMIP (1)
15 models

D'Andrea et al., 1998

Blocking in climate models





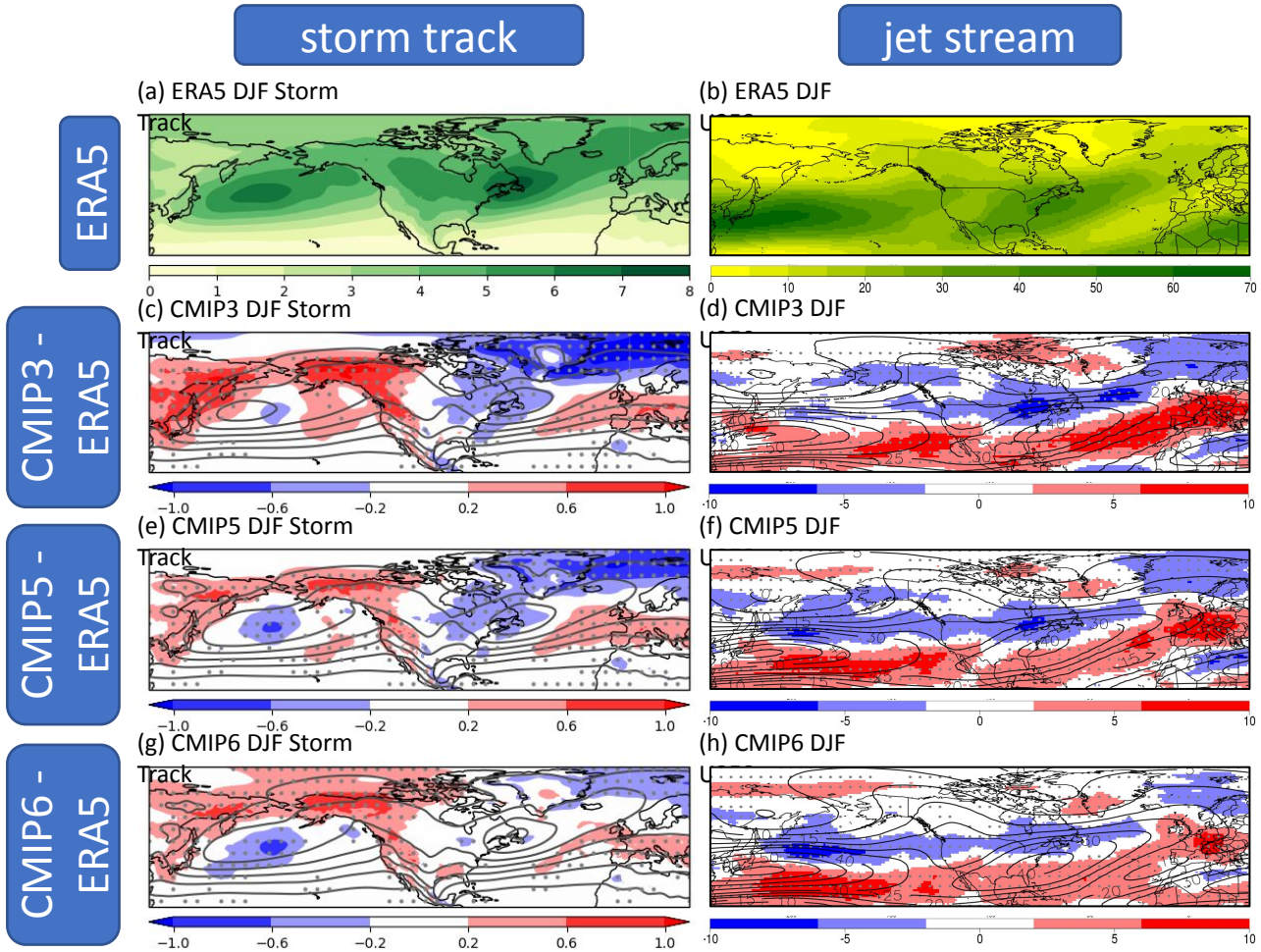
Blocking biases are smaller in the most recent generation of models, although biases remain.

Large spread between models.

IPCC AR6; Schiemann et al., 2020

Blocking and midlatitude circulation

- in the observed variability, blocking is related to modes of variability (NAO), the eddy-driven jet, and storm tracks
- there are also such relationships in model biases, including between blocking and the "mean-state"
- improvement in blocking in CMIP6 models consistent with improvement in storm track and jet stream



Harvey et al., 2020

Source of blocking biases / improvements

How *can* simulated blocking be improved?

- increases in resolution
- improved orography (at higher resolution)
- reduction of SST biases
- increases in vertical resolution
- improved physical parameterisations
- improved accuracy of the dynamical core and numerical scheme

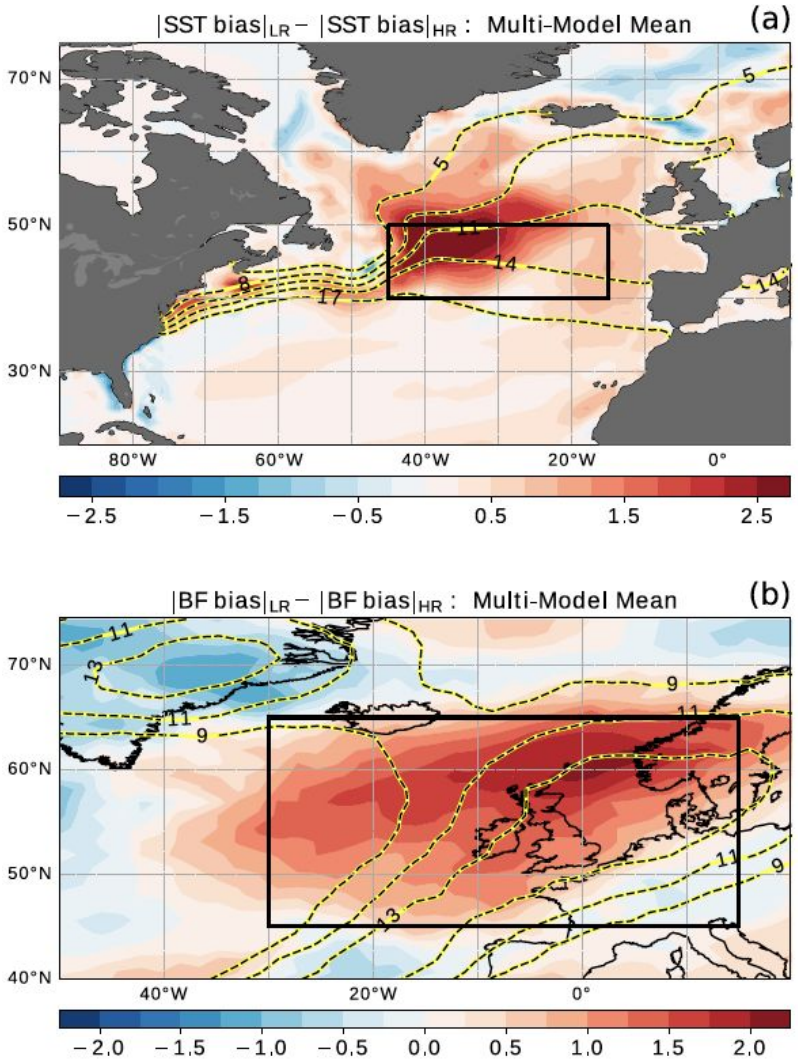
HighResMIP

CMIP5 → CMIP6

Woollings et al., 2018

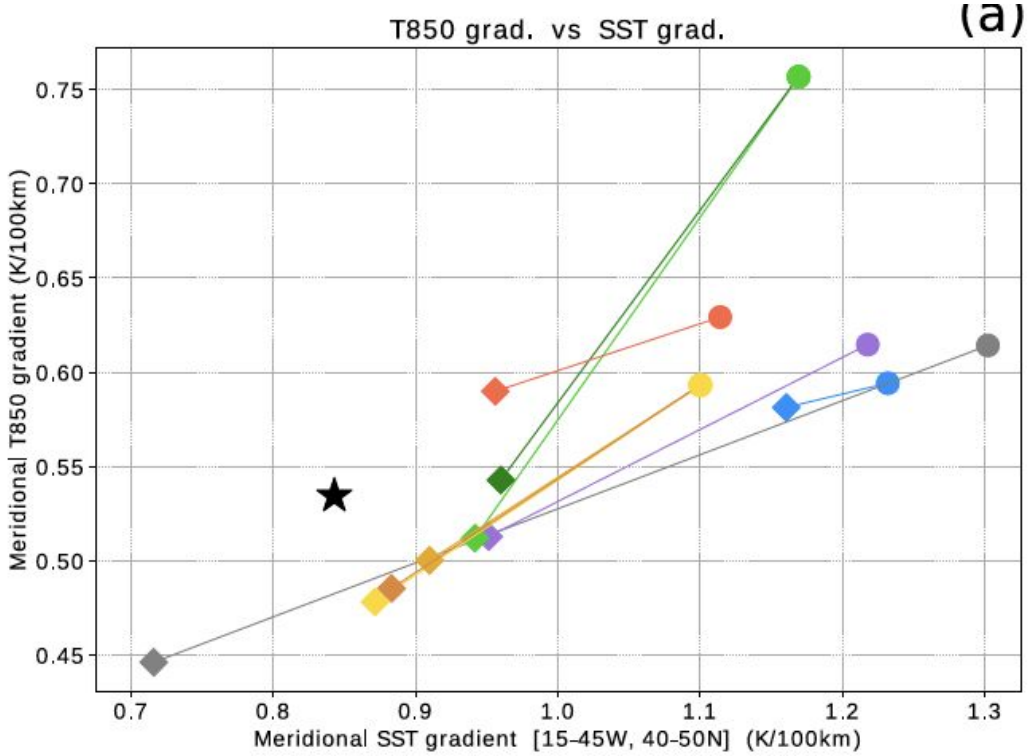
Example: Resolution and SST biases

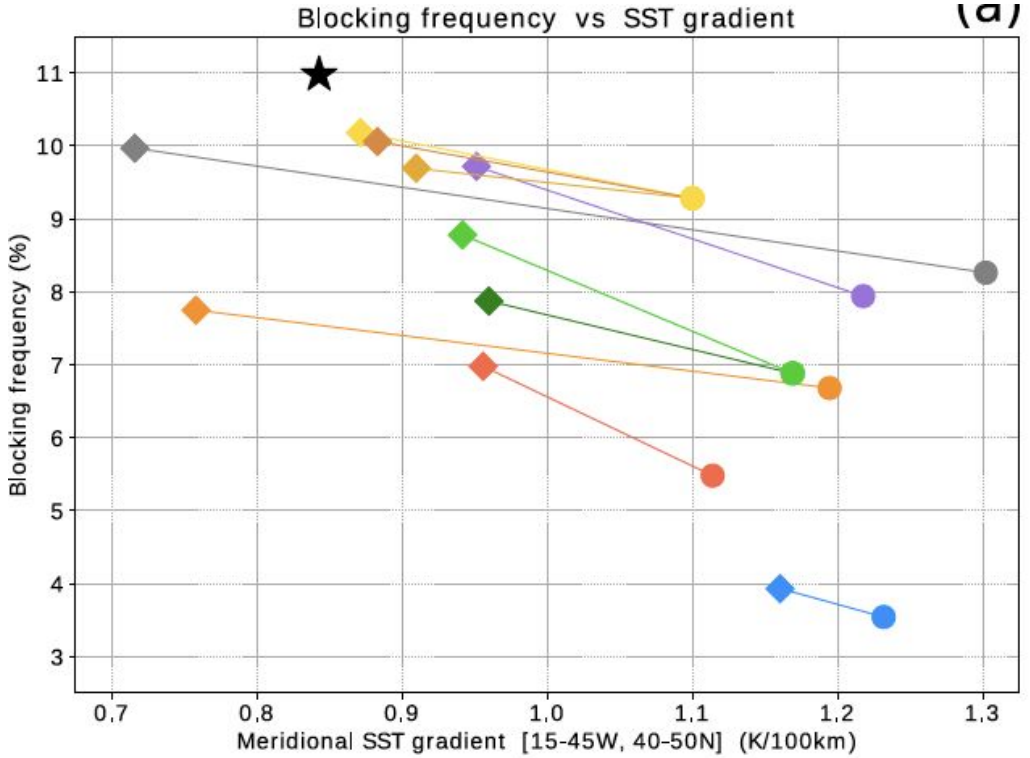
SST and blocking bias
in CMIP6-HighResMIP



Athanasiadis et al. 2022

Example: Resolution and SST biases

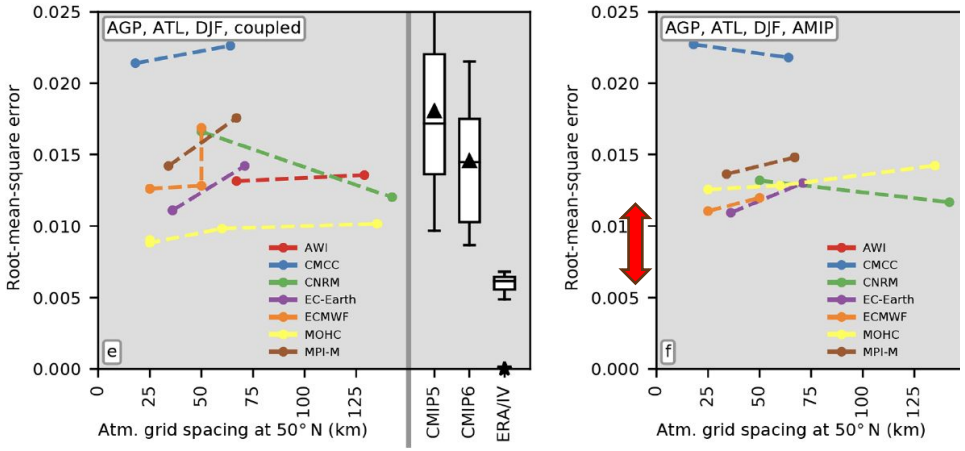




Athanasiadis et al. 2022

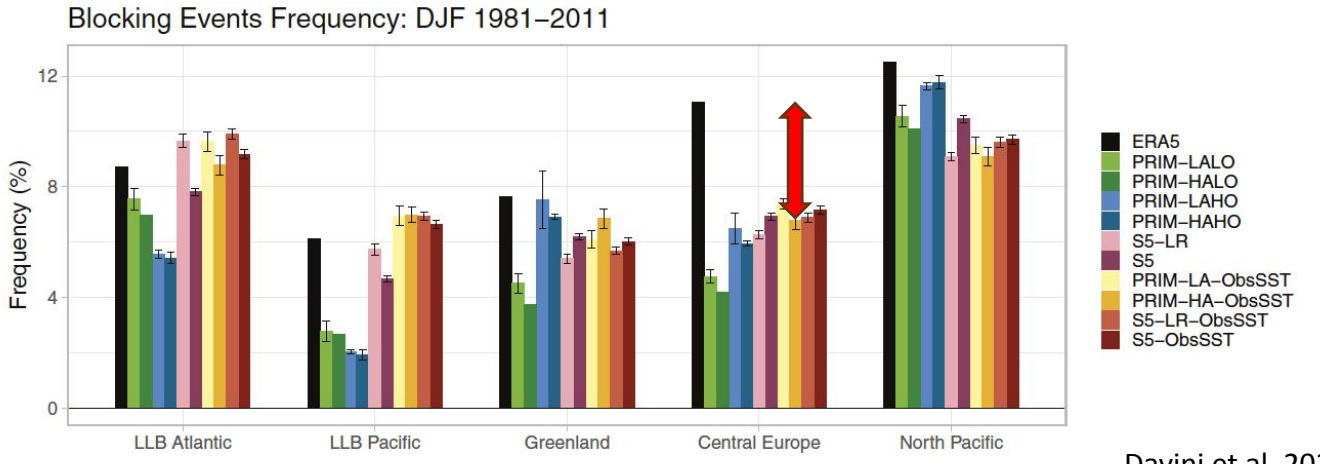
Is it all just SST biases?

Blocking biases in HighResMIP coupled vs AMIP:



Schiemann et al. 2020

… in IFS HighResMIP and seasonal forecast:



Davini et al. 2021

- No. Intrinsic atmosphere biases remain important.

Example: Parameterisation

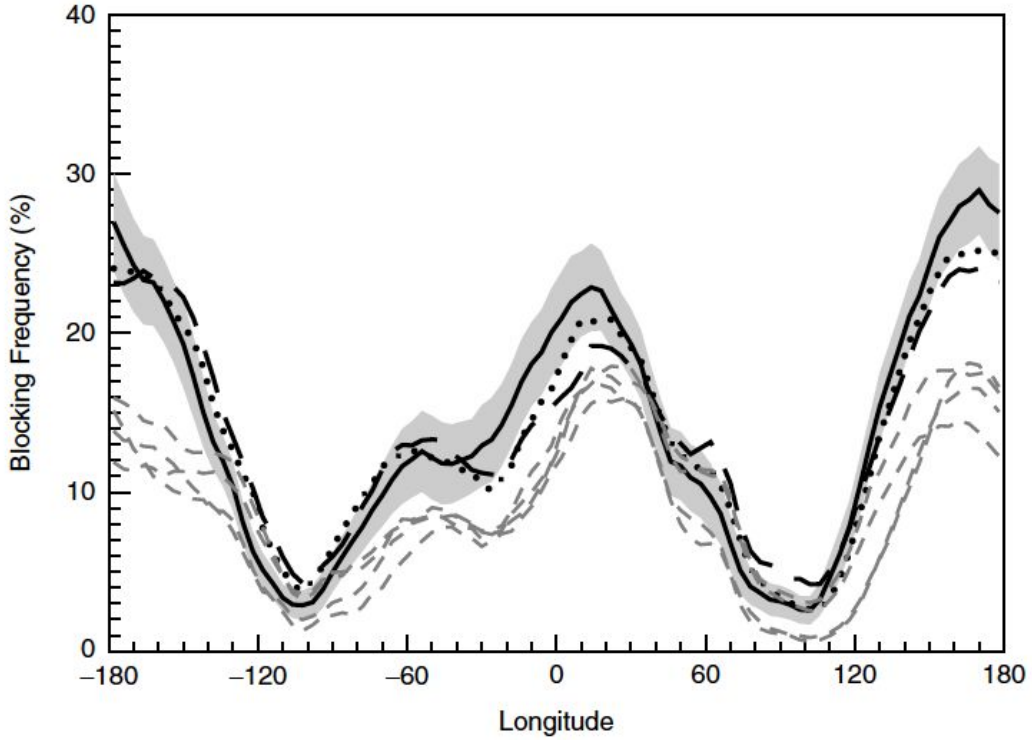


Figure 4. Frequency of occurrence of wintertime Northern Hemisphere blocking events (December–February) for the period 1962–2005: ERA-40 (black solid), version 33R1 (black dotted), version 32R3 (black dashed) and versions 29R2 to 32R2 (grey thin dashed). Blocking frequencies have been determined using the methodology by Tibaldi and Molteni (1990). Also shown are 95% confidence intervals for ERA-40 data (grey shading).

Table I. Main characteristics of the ECMWF model versions used in this study.

Version	Introduced	Modifications
29R2	28 Jun 2005	Change to convection scheme.
30R1	1 Feb 2006	Increased vertical resolution (L60 to L91).
31R1	12 Sep 2006	Revised cloud scheme (ice supersaturation + numerics); implicit computation of convective transports; introduction of turbulent orographic form drag (TOFD) scheme; revised parametrization of subgrid-scale orographic drag.
32R1	Not operational	New short-wave radiation scheme; introduction of McICA cloud radiation interaction; MODIS land surface albedo; retuned ice particle size; retuning of GWD (increase by a factor of two).
32R2	5 Jun 2007	Minor changes to the forecast model.
32R3	6 Nov 2007	New formulation of convective entrainment and relaxation time-scale; reduced vertical diffusion in the free atmosphere; modification to GWD scheme at the top of the model; new soil hydrology scheme.
33R1	3 Jun 2008	Slightly increased vertical diffusion; increased orographic form drag; retuned entrainment in the convection scheme; bugfix scaling of freezing term in convection scheme; changes to surface model.

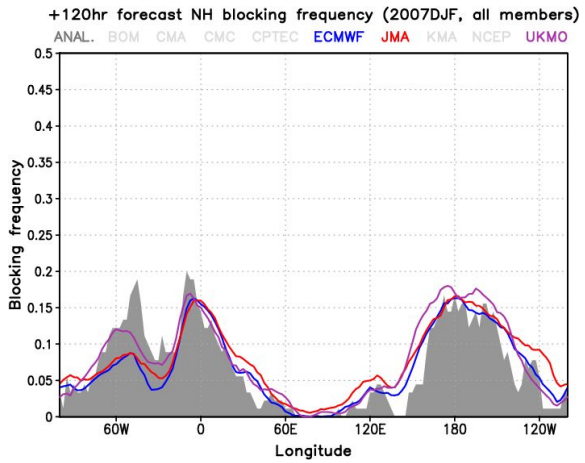
convection

orogr. form drag

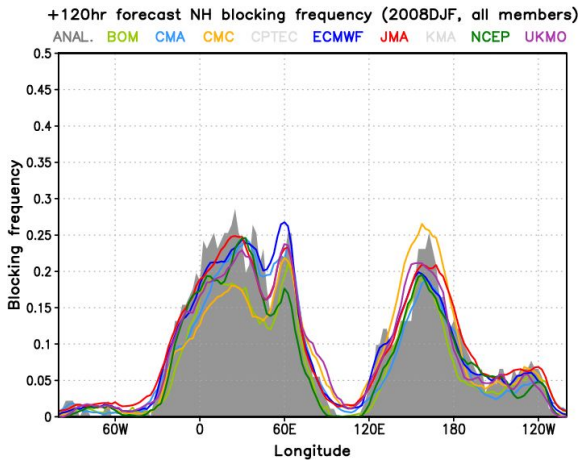
Jung et al. 2010

Medium range blocking skill

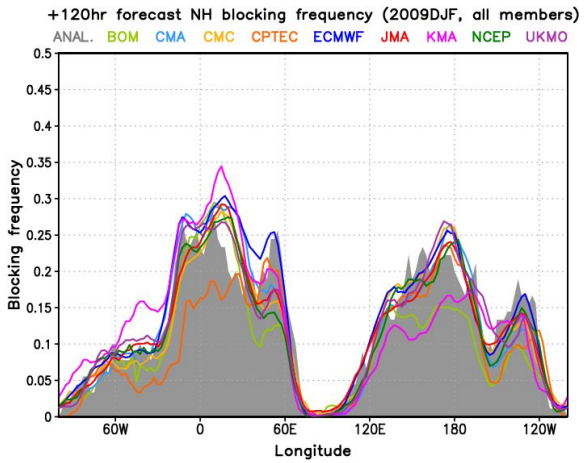
2007



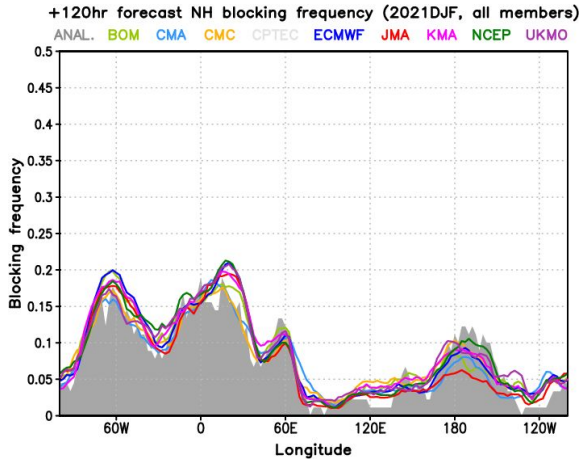
2008



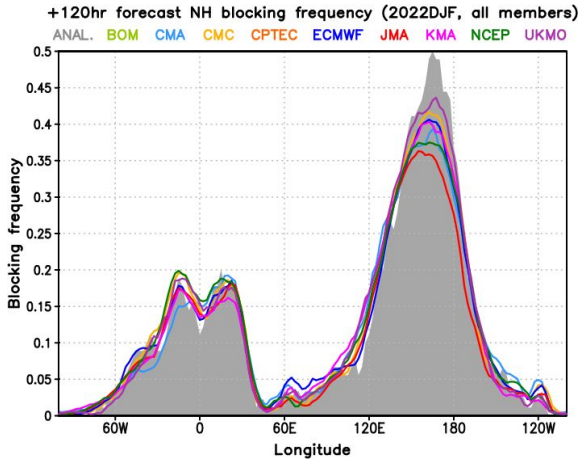
2009



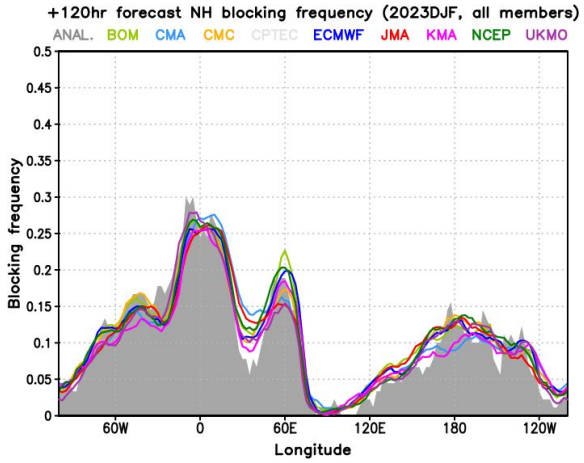
2021



2022



2023

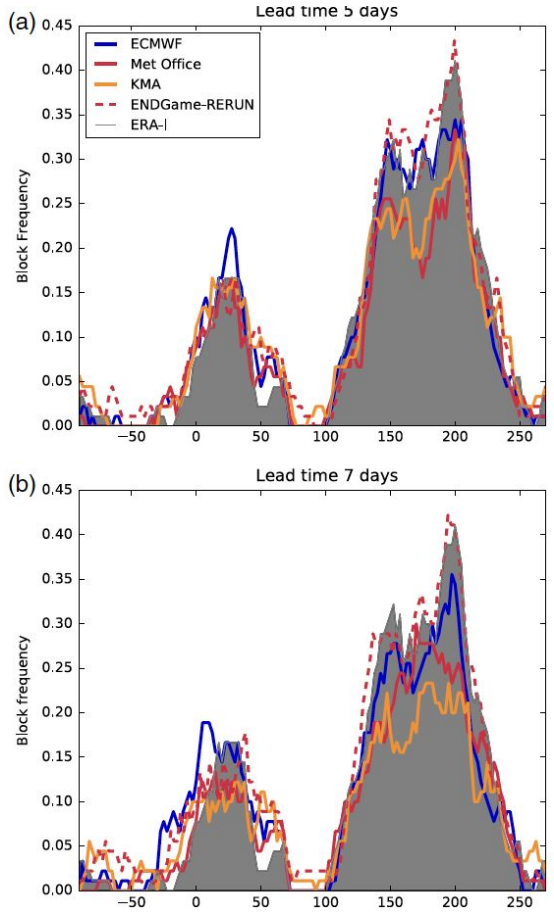


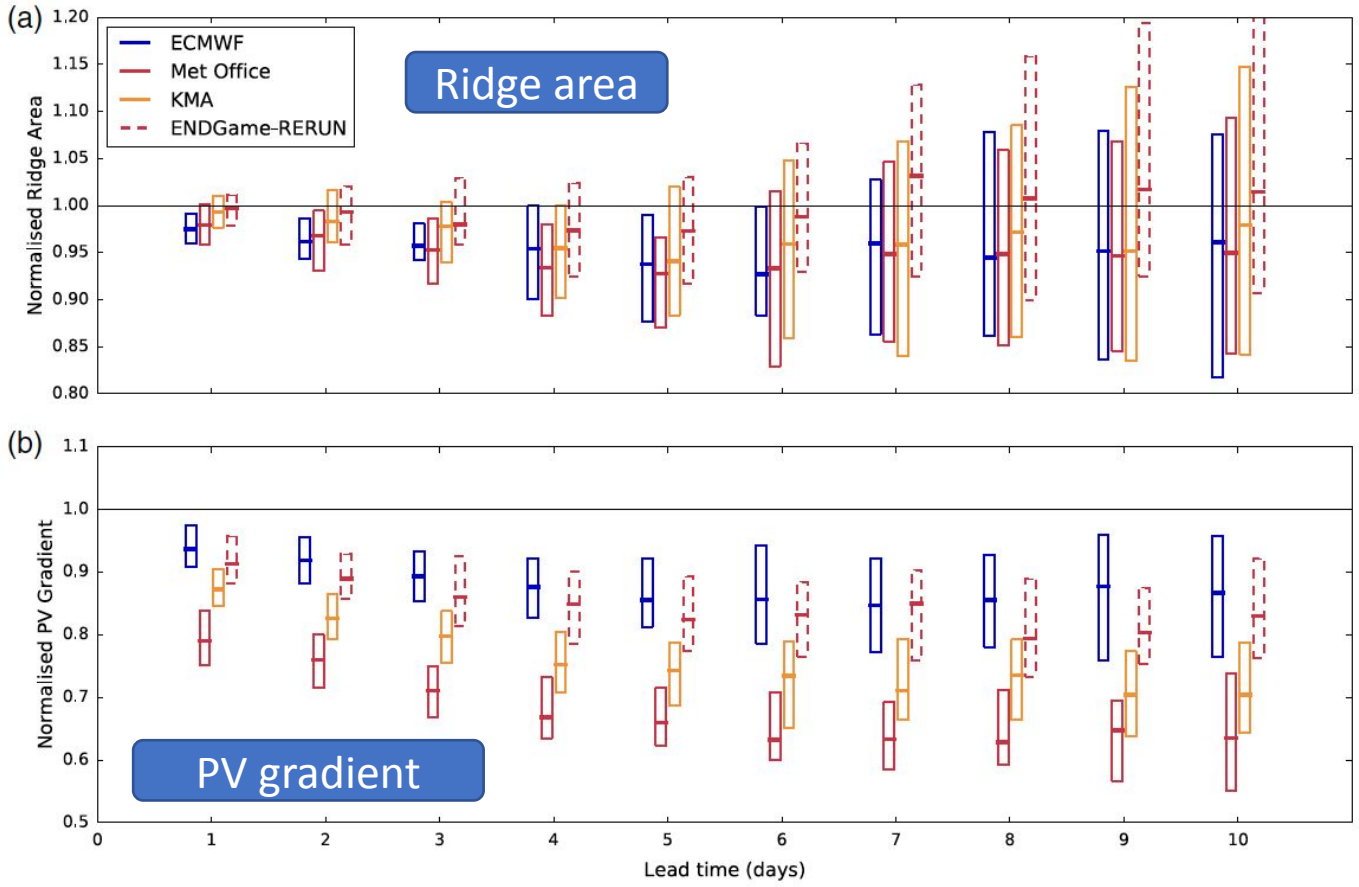
Mio Matsueda,
TIGGE Museum,
http://gpvjma.ccs.hpcc.jp/TIGGE/tigge_blocking_freq.html

Example: Dynamical Core

Beneficial NewDynamics to ENDGame change in MOGREPS (=MO-EPS):

Blocking frequency





Martínez-Alvarado et al., 2018

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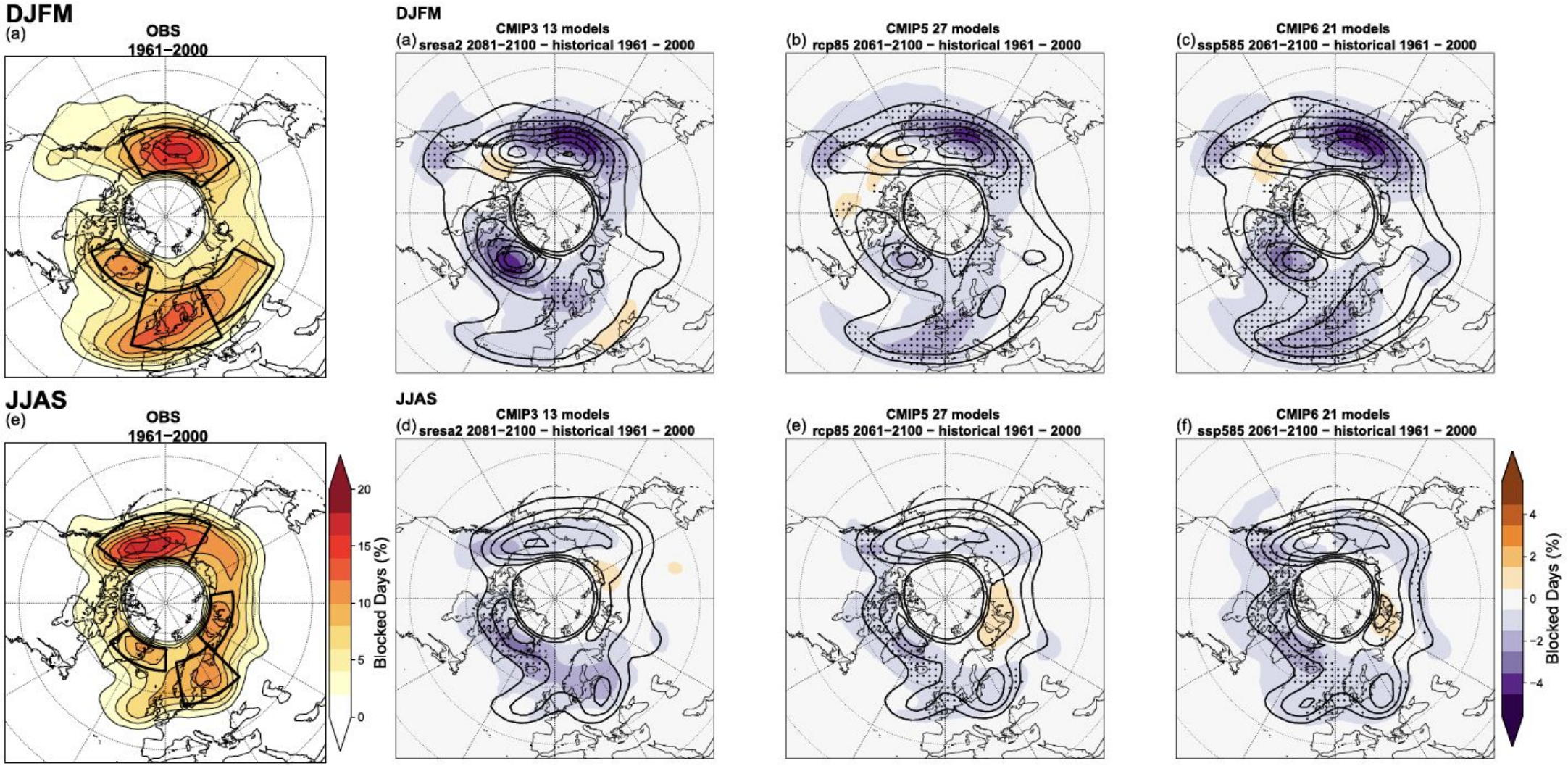
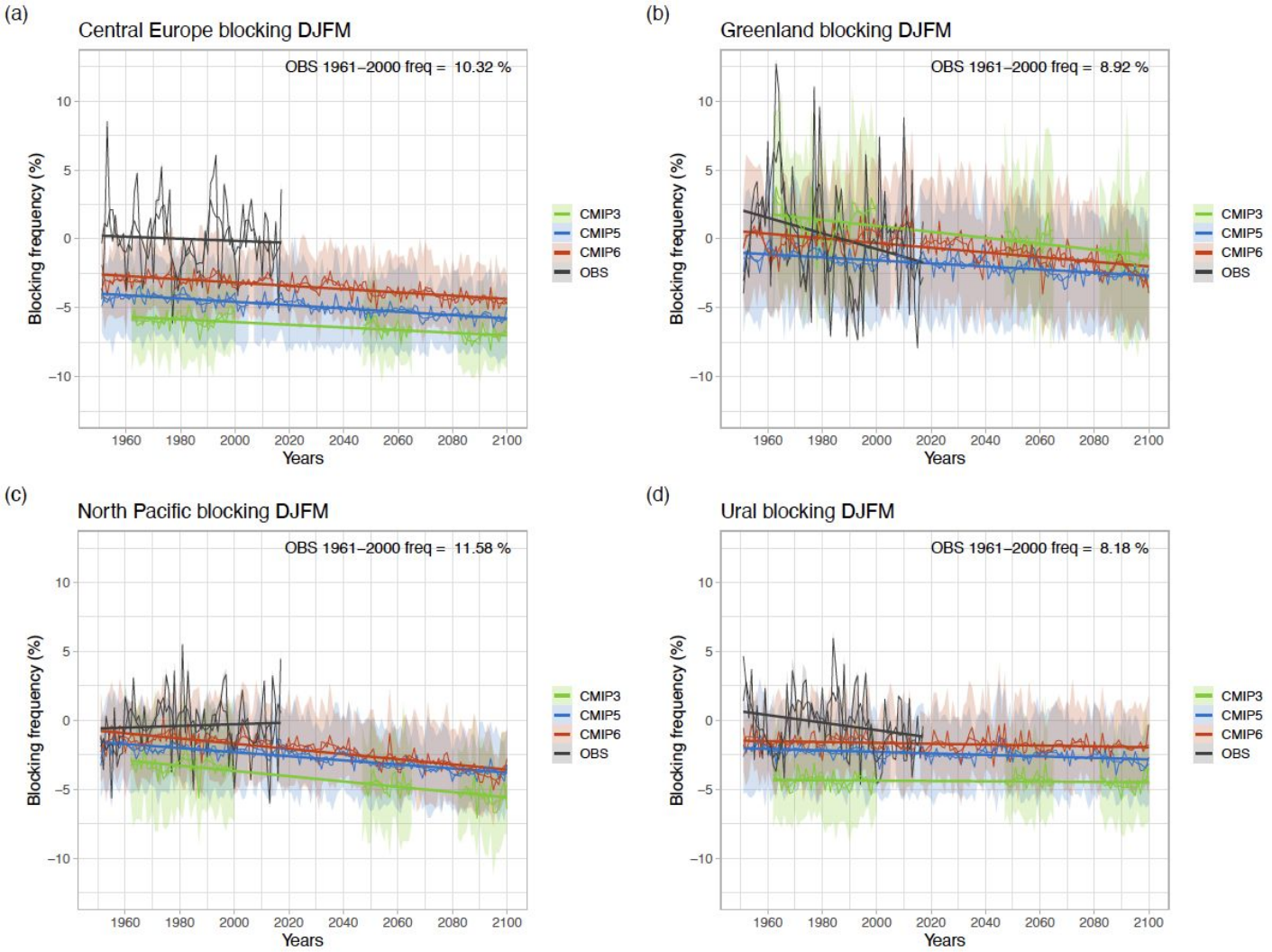
21st century projections of blocking



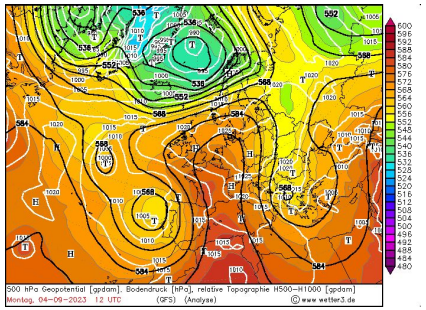
Davini and D'Andrea, 2020

21st century projections of blocking



Davini and D'Andrea, 2020

Are we getting “there”?



We are getting there!

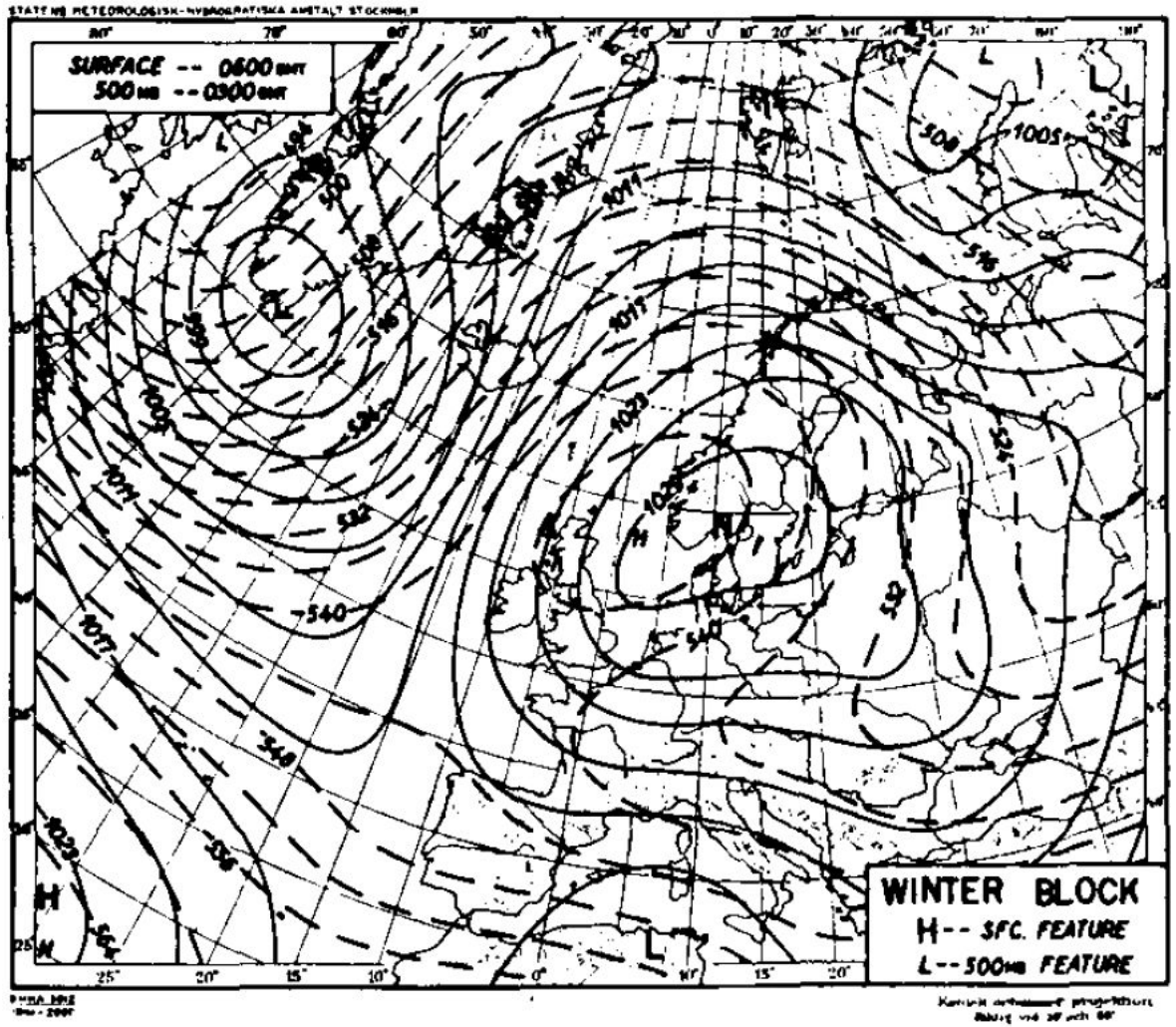
- Over the last ~30 years, blocking performance in climate and weather models has slowly improved, due to parameterisation development and increases in resolution, in the atmosphere and ocean.
- Some climate models are now ‘not so bad’.
- Multi-model projections agree own a decline in blocking frequency, although it is fairly small compared to variability.

We are not there yet!

- Models continue to underestimate blocking and intrinsic atmospheric biases remain important.
- Spread between models is large. (Larger than the bias of the best models.)
- Model performance is not always consistent (e.g. for winter and summer) and is difficult to engineer.
- Model agreement vs. confidence …

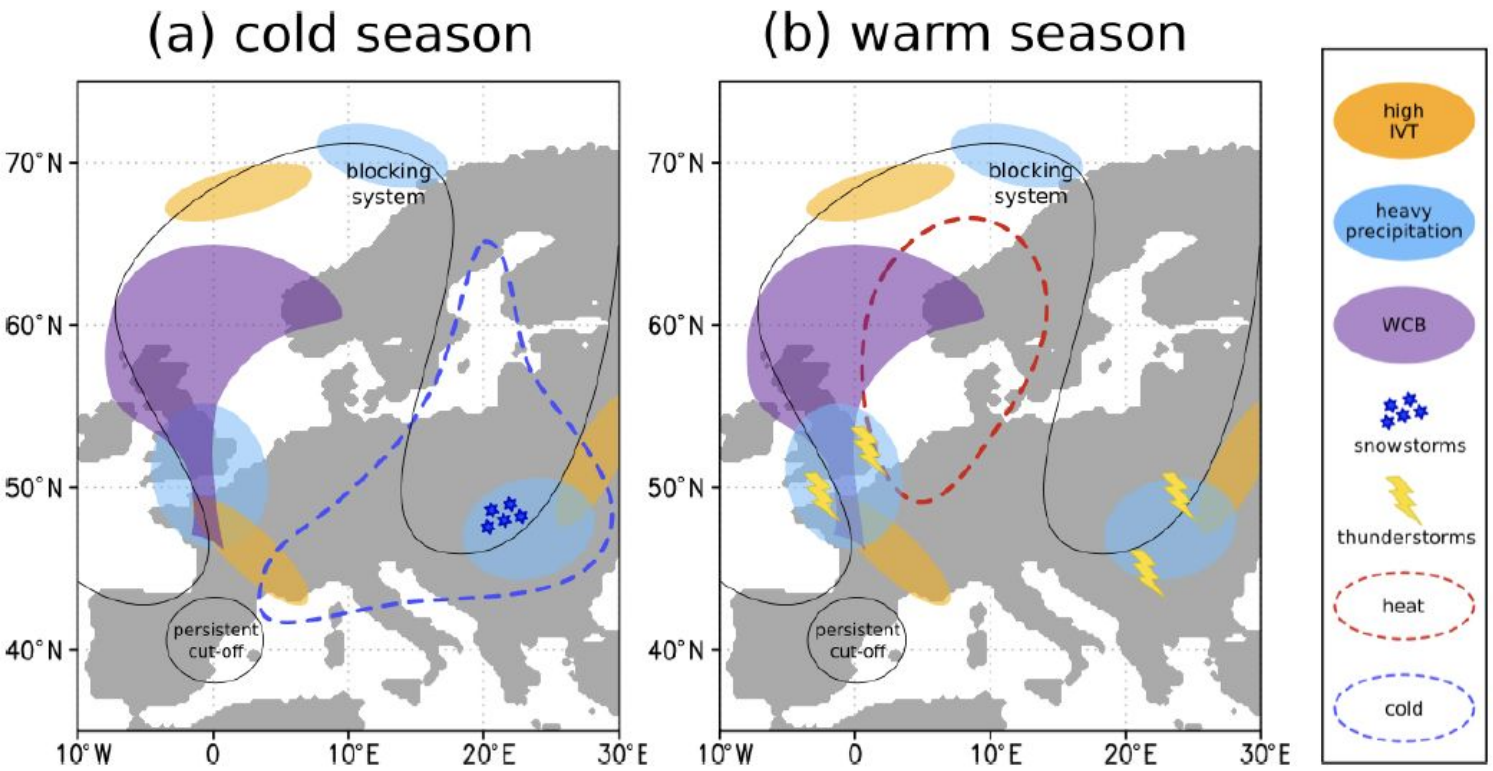
Types of blocking

- Atmospheric blocking:
  - Normal westerly flow in the midlatitudes is *blocked*
  - Degree of persistence (5 days or more)



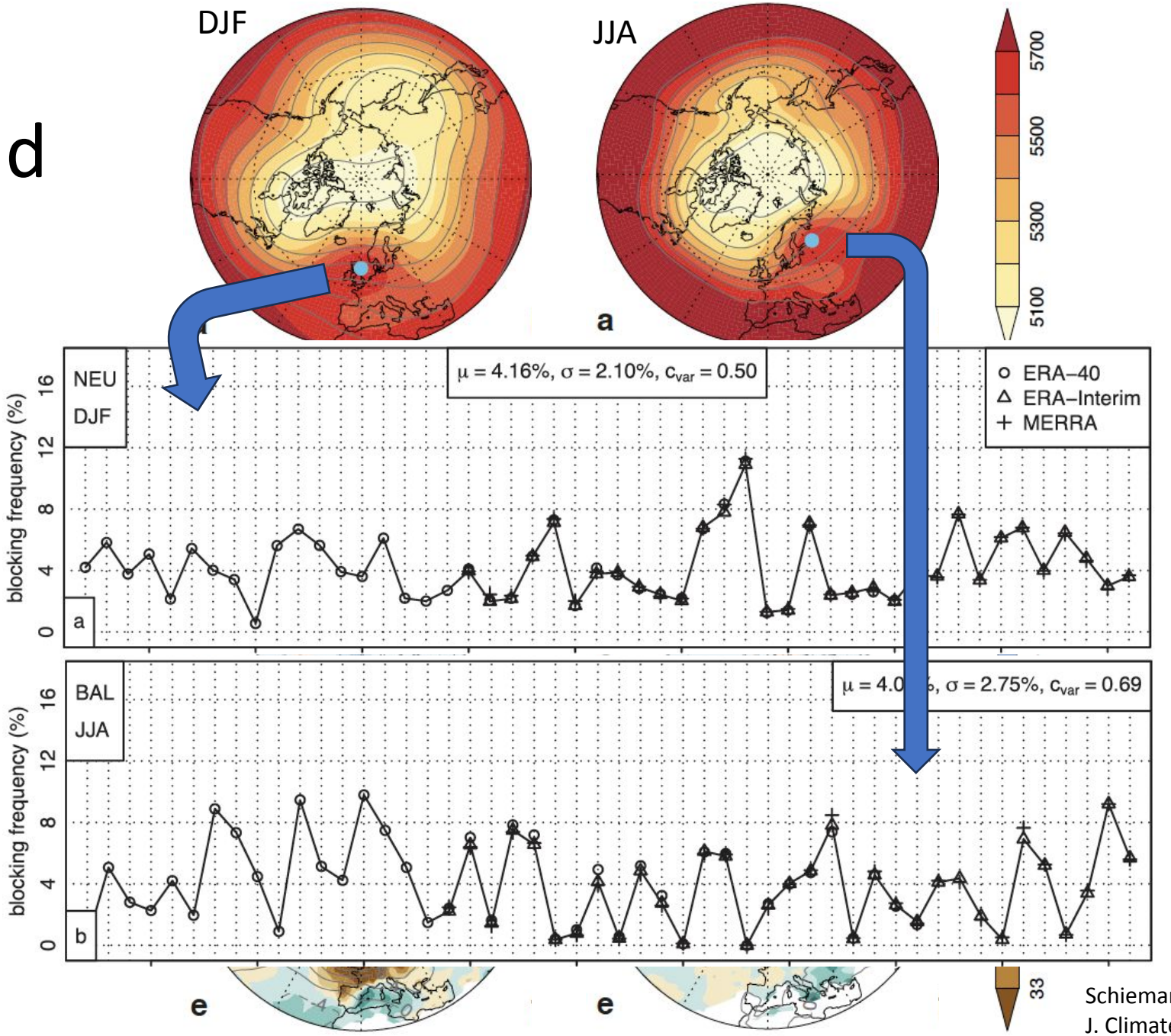
Rex, 1951

Surface impacts of blocking



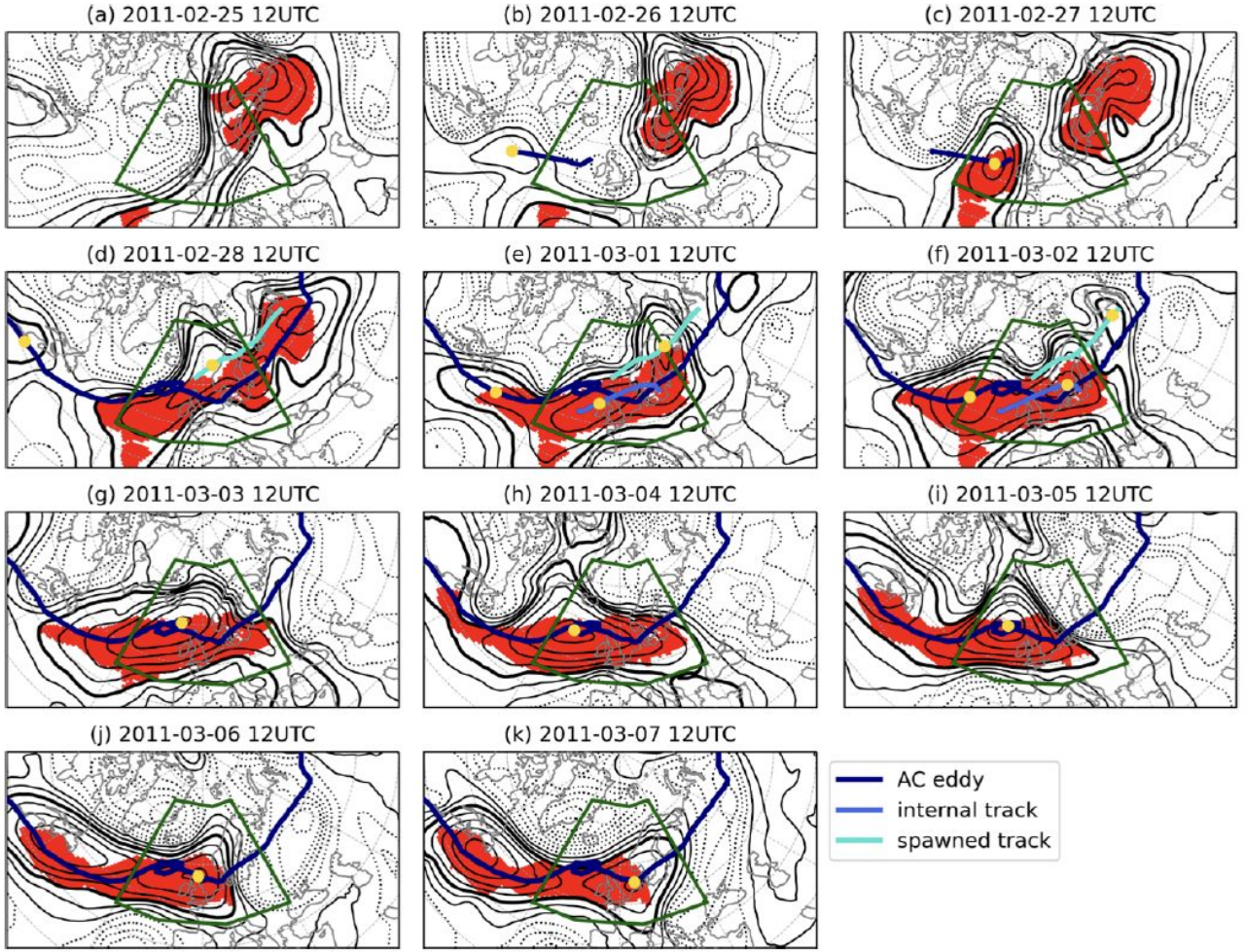
Kautz et al., 2022

Historical blocking and surface weather



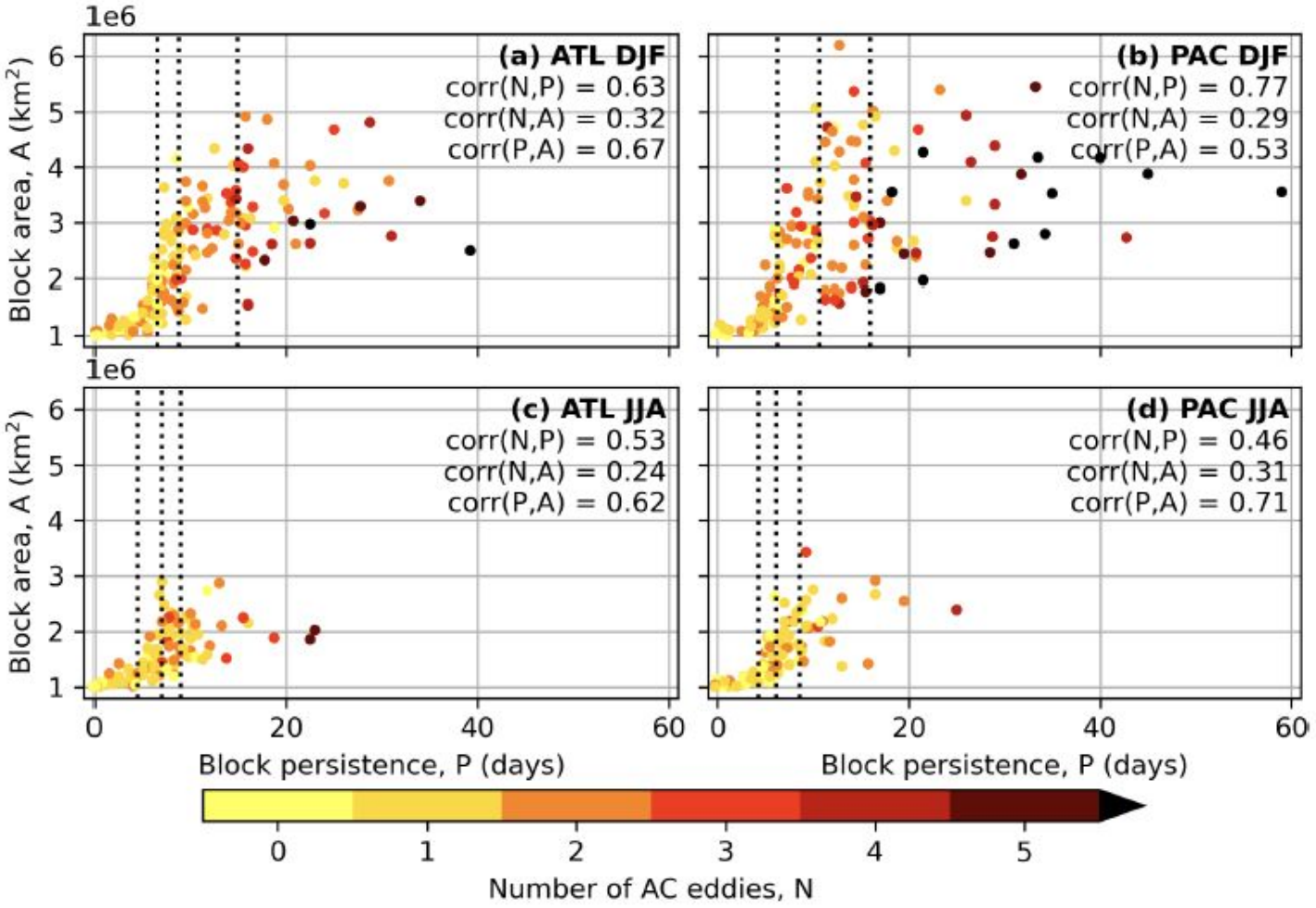
Schiemann et al., J. Climate, 2017

Example:
Interaction with eddies and persistence



Suitters et al. 2023

Interaction with eddies and persistence



Suitters et al. 2023