The representation of blocking in current global climate models

Reinhard Schiemann

Panos Athanasiadis, David Barriopedro, Francisco Doblas-Reyes, Katja Lohmann, Malcolm J. Roberts, Dmitry Sein, Christopher D. Roberts, Laurent Terray, Pier Luigi Vidale

EGU General Assembly, 7th May 2020

Met Office NERC SCIENCE OF THE ENVIRONMENT
Joint Weather & Climate Research Programme

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

University of Reading

Summary

We have assessed representation of blocking in two newly available multi-model ensembles:

CMIP5 ➞ CMIP6 historical simulations

- improved simulation of blocking in CMIP6
- “robust”, i.e. seen for
  - Euro-Atlantic and Pacific
  - winter and summer
  - blocking frequency and persistence
  - (two different blocking indices)
- “sizeable”, e.g. median AGP ATL DJF bias equal to -33% in CMIP5 and -18% in CMIP6

CMIP6-HighResMIP resolution increase

- improved simulation of blocking frequency
  - ATL: DJF + JJA
  - PAC: JJA
  - predominantly seen in the spatial pattern of blocking frequency
- no evidence for improved simulation of blocking persistence
- conservative results, as these models are not re-tuned at higher resolution

The latest generation of global climate models suffers from well-known blocking biases, but the magnitude of these biases is reduced.

Schiemann et al., WCDD, submitted

Blocking biases in climate models

Climate models underestimate blocking, and a range of factors have been identified as potentially important for blocking simulation:

How *can* simulated blocking be improved?

- increases in horizontal resolution improving transient eddy forcing of blocks
- improved orography (at higher resolution) forcing enhanced stationary wave patterns
- reduction of SST biases
- increases in vertical resolution enabling better tropopause dynamics
- improved physical parameterisations, such as of convection and drag
- improved accuracy of the dynamical core and numerical scheme

Woollings et al., Curr. Clim. Change Rep., 2018
(and references therein)

Blocking biases in climate models

Here: Assess blocking performance in two recently available multi-model ensembles:

CMIP5 ➞ CMIP6
historical simulations

How *can* simulated blocking be improved?

- increases in horizontal resolution improving transient eddy forcing of blocks
- improved orography (at higher resolution) forcing enhanced stationary wave patterns
- reduction of SST biases
- increases in vertical resolution enabling better tropopause dynamics
- improved physical parameterisations, such as of convection and drag
- improved accuracy of the dynamical core and numerical scheme

controlled resolution increase (CMIP6-HighResMIP PRIMAVERA simulations),

AMIP and coupled

Woollings et al., Curr. Clim. Change Rep., 2018
(and references therein)

What is blocking?

large variation blocking situations:

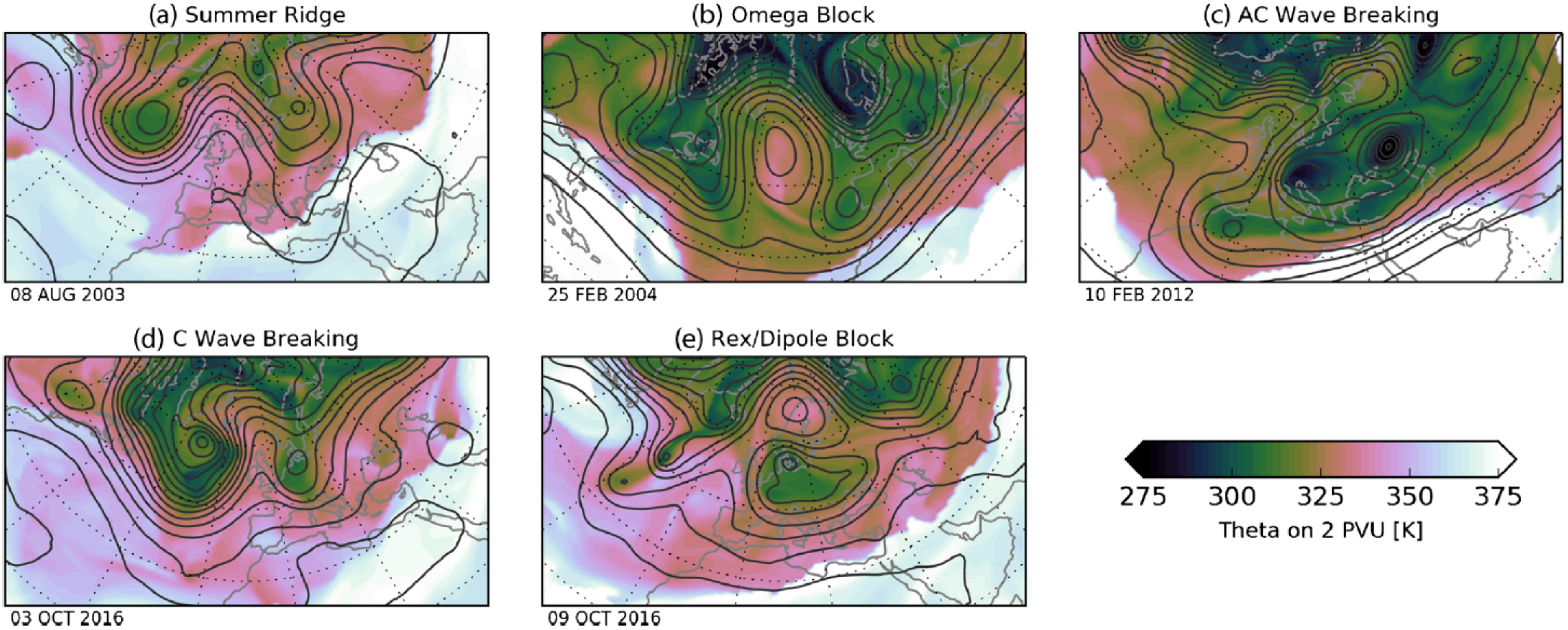
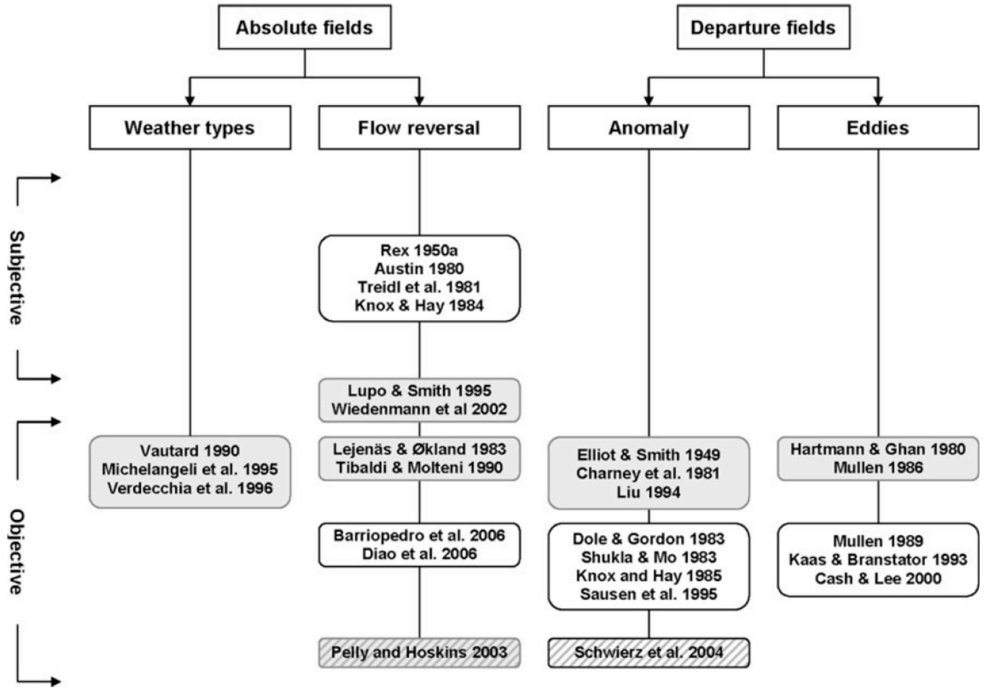


Fig. 1 Example North Atlantic blocks. Snapshots of (colour shading) potential temperature θ on the dynamical tropopause (PV = 2 PVU) and (contour lines) geopotential height at 500 hPa (contour spacing 60 m) for the dates indicated. Data is from ERA-Interim

Woollings et al., Curr. Clim. Change Rep., 2018

How is blocking identified?

large variation in identification methods (blocking indices):



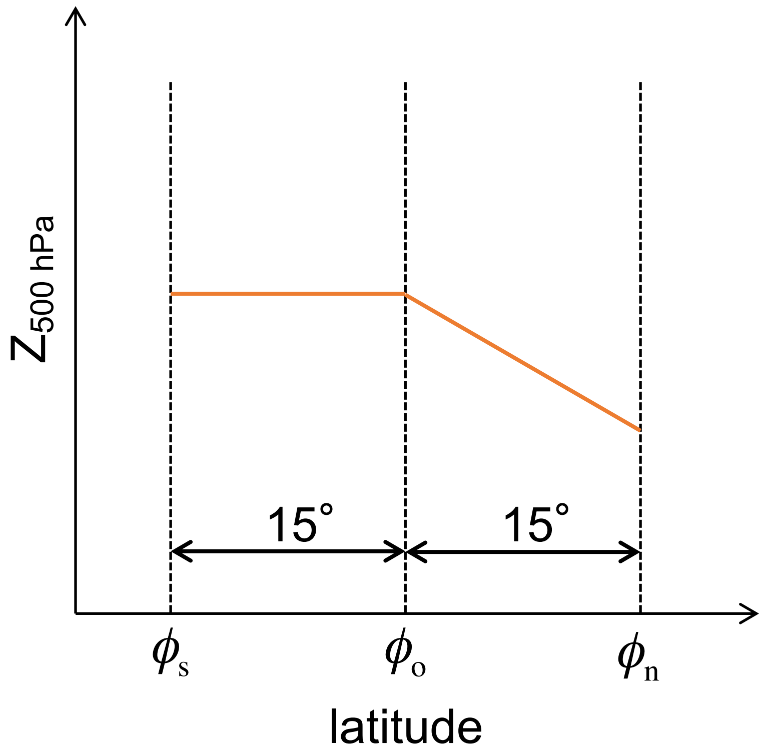
Barriopedro et al., Climate Dyn., 2010

➢ use two different indices here:

1. Absolute Geopotential Height index (AGP)
2. Anomaly Index (ANOM)

Absolute geopotential height index (AGP)

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

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

3. persistence of 5 days or longer

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

Anomaly index (ANOM)

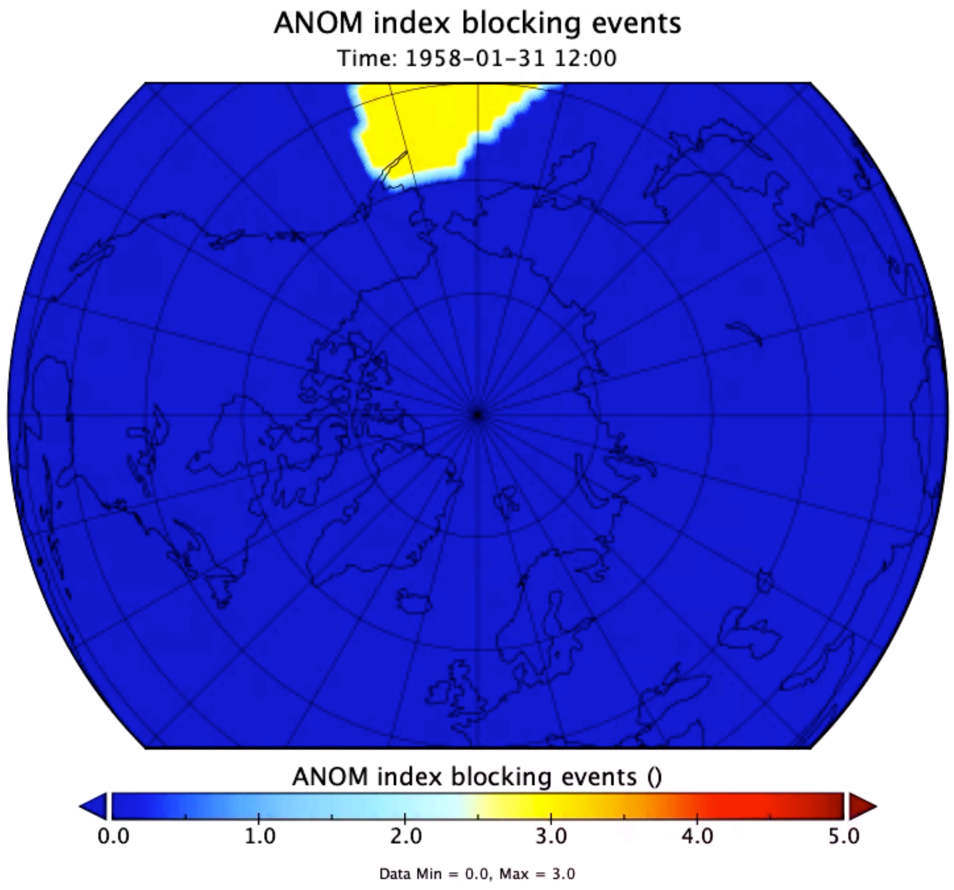
Based on tracking contiguous daily-mean Z500 anomalies.

1. Calculate a ‘smooth’ daily Z500 climatology in a reference period (1981-2010).

2. Calculate a monthly Z500 anomaly threshold as the 90^{th} percentile of daily Z500 anomalies throughout 50-80°N.

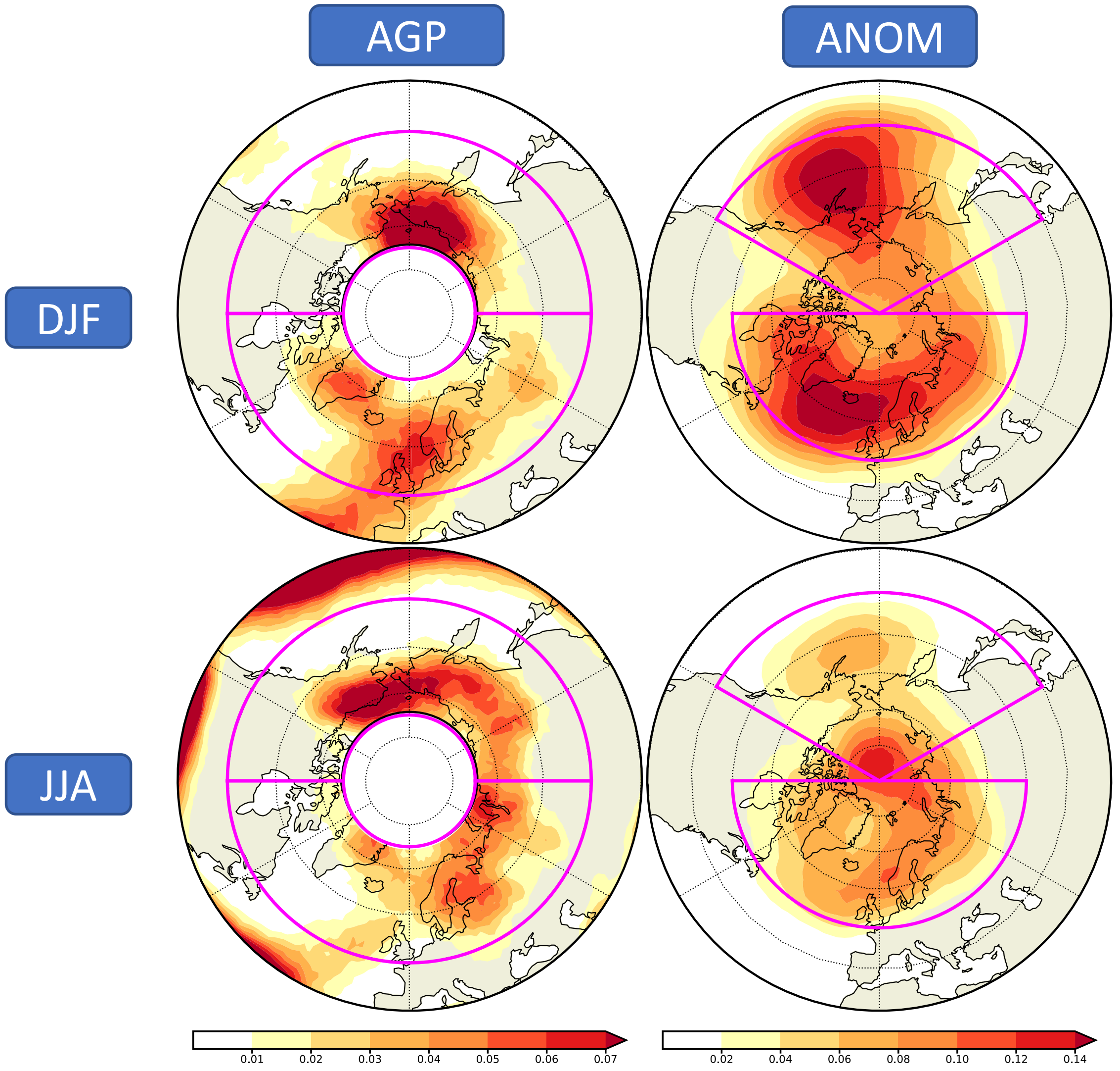
3. Potential blocking events are contiguous areas of at least 2×10^6 km^2 where the Z500 anomaly exceeds the monthly anomaly threshold.

4. Potential blocking events are further screened by requiring a spatial overlap of at least 50% between consecutive days for at least 5 days.



Woollings et al., Curr. Clim. Change Rep., 2018; Schwierz et al., GRL, 2004

Reanalysis blocking climatologies

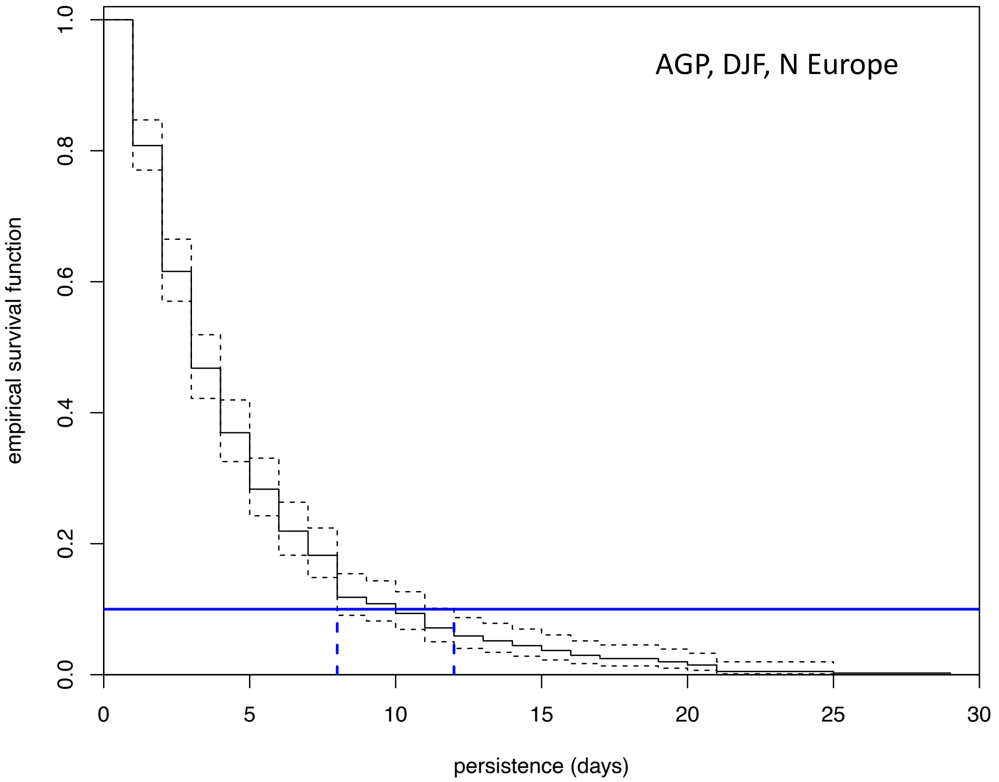


These are the reference fields for evaluation (slides 10&11).

Magenta lines show ATL and PAC domains for domain-aggregate metrics (slides 12-15).

Blocking persistence ("survival")

Example: Non-parametric (Kaplan-Meier) estimate



- the 90th persistence (survival time) quantile is 10 days, with a 95% confidence interval of [8,10] days
- a parametric (exponential) fit was found to work well with the ANOM index (not shown)

M. Tableman: Survival Analysis in S, 2003, 251pp

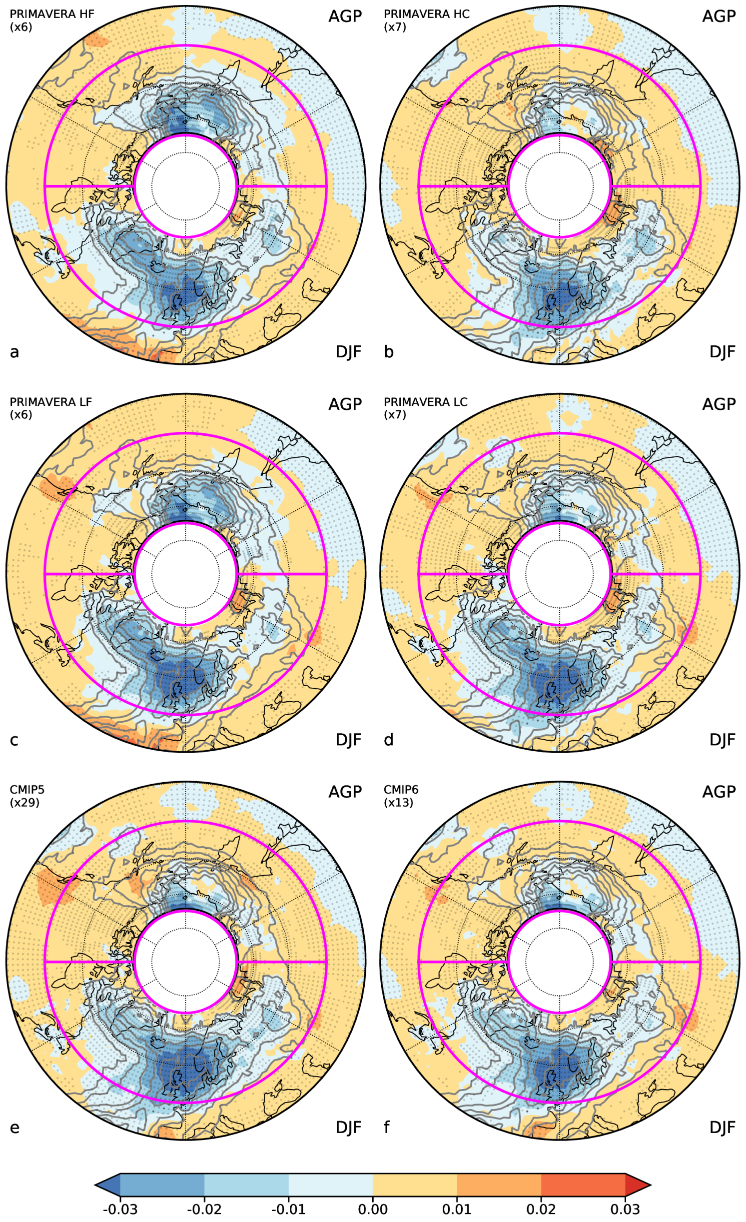
Bias pattern

CMIP6-HighResMIP resolution increase

- similar pattern of bias
- reduced bias magnitude at high resolution
- smaller sensitivity over the Pacific and for forced simulations

CMIP5 ➞ CMIP6

- similar pattern of bias (underestimation)
- reduced bias magnitude in CMIP6
- smaller sensitivity over the Pacific



AGP

DJF

LF – low resol. forced
LC – low resol. coupled
HF – high resol. forced
HC – high resol. coupled

Schiemann et al., WCDD, submitted

Bias pattern

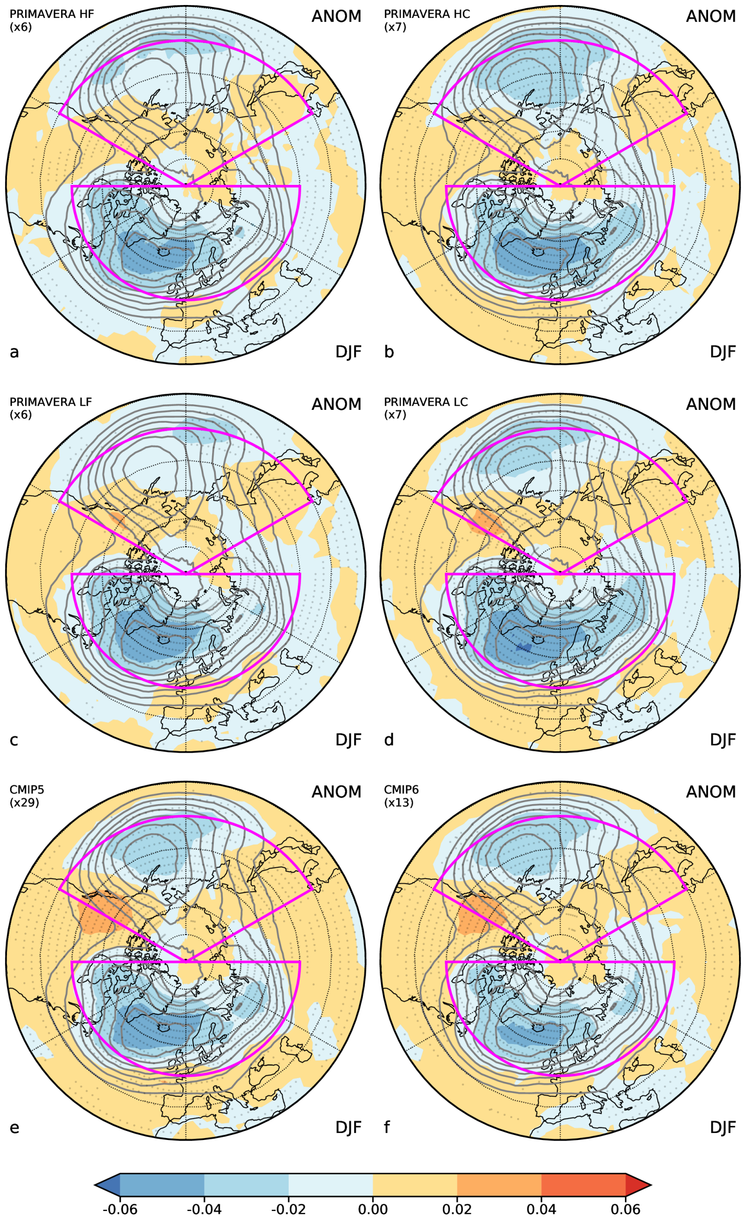
CMIP6-HighResMIP resolution increase

- similar pattern of bias
- reduced bias magnitude at high resolution
- smaller sensitivity over the Pacific and for forced simulations

CMIP5 ➞ CMIP6

- similar pattern of bias (underestimation)
- reduced bias magnitude in CMIP6
- smaller sensitivity over the Pacific

- consistent results from both indices



ANOM

DJF

Schiemann et al., WCDD, submitted

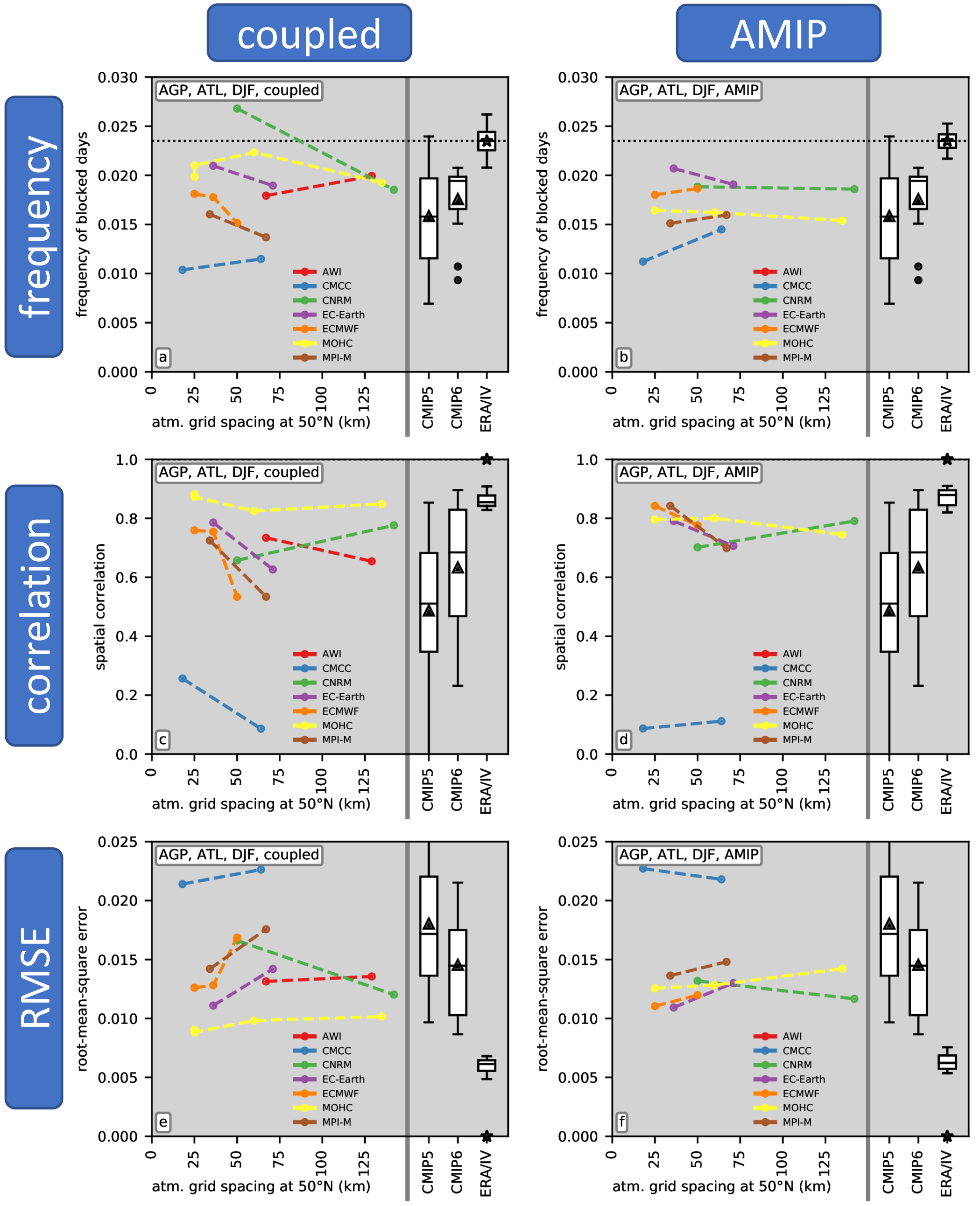
Domain metrics

CMIP5 ➞ CMIP6 (boxplots on right of plots)

- ➢ clear improvement in all three metrics

CMIP6-HighResMIP resolution increase
(left side of plots)

- ➢ improvement in most models
- ➢ seen in the pattern correlation, less so in the domain-mean blocking frequency
- ➢ sensitivity to resolution and spread in blocking performance across models smaller in AMIP than in coupled simulations
- ➢ AMIP performance not clearly better



ATL

DJF

Schiemann et al., WCDD, submitted

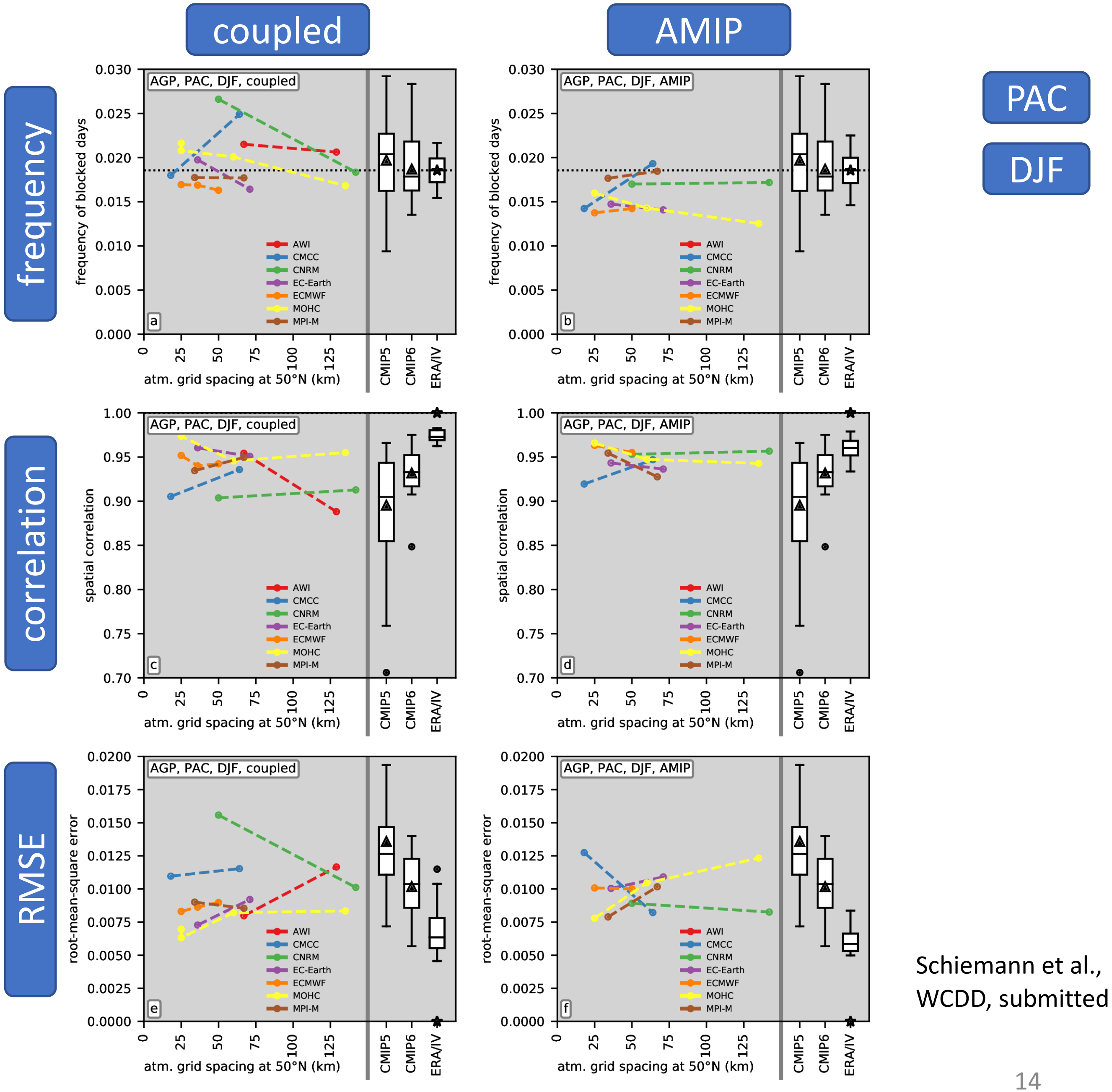
Domain metrics

CMIP5 ➞ CMIP6 (boxplots on right of plots)

- clear improvement in all three metrics
- underestimation smaller than in Atlantic sector (some compensation in large domain)

CMIP6-HighResMIP resolution increase
(left side of plots)

- no robust sensitivity to resolution



Schiemann et al., WCDD, submitted

Persistence

ATL

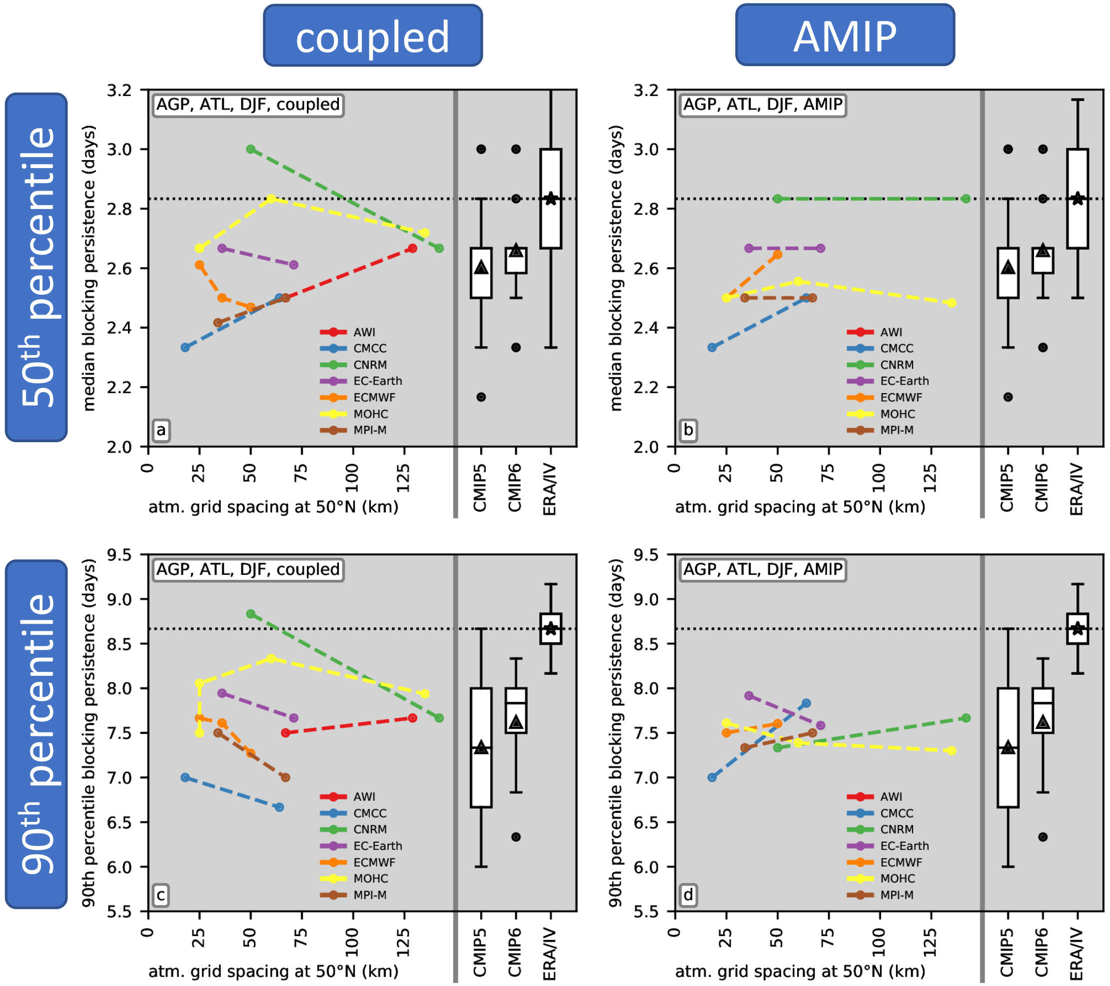
DJF

CMIP5 ➞ CMIP6 (boxplots on right of plots)

- blocking events generally too short
- improvement in CMIP6

CMIP6-HighResMIP resolution increase
(right side of plots)

- no robust improvement across the ensemble (coupled & AMIP)



Schiemann et al., WCDD, submitted

Persistence

PAC

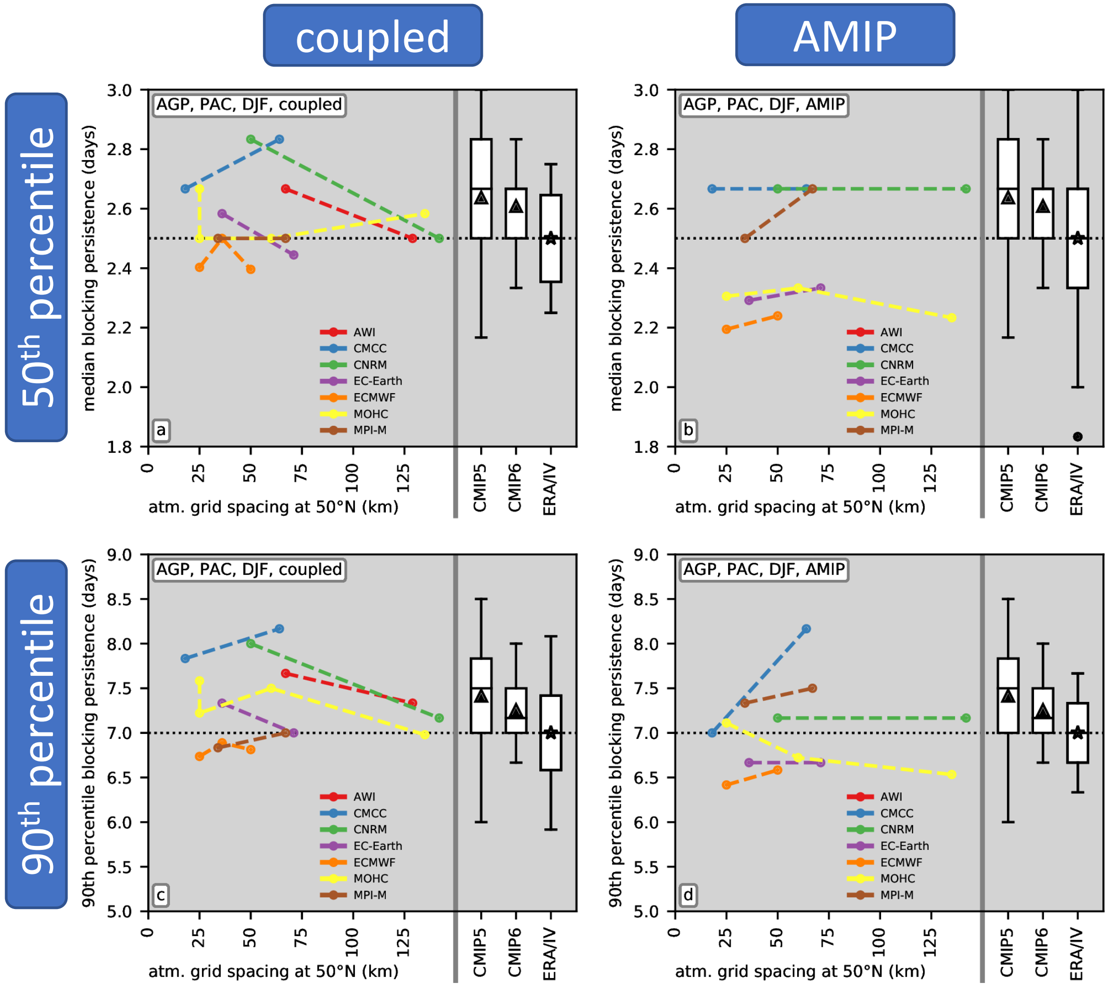
DJF

CMIP5 ➞ CMIP6 (boxplots on left side of plots)

- blocking events generally too long
- improvement in CMIP6

CMIP6-HighResMIP resolution increase
(right side of plots)

- no robust improvement across the ensemble (coupled & AMIP)



Schiemann et al., WCDD, submitted

Summary

Have assessed representation of blocking in two newly available multi-model ensembles:

CMIP5 ➞ CMIP6 historical simulations

- improved simulation of blocking in CMIP6
- “robust”, i.e. seen for
  - Euro-Atlantic and Pacific
  - winter and summer
  - blocking frequency and persistence
  - (two different blocking indices)
- “sizeable”, e.g. median AGP ATL DJF bias equal to -33% in CMIP5 and -18% in CMIP6

CMIP6-HighResMIP resolution increase

- improved simulation of blocking frequency
  - ATL: DJF + JJA
  - PAC: JJA
  - predominantly seen in the spatial pattern of blocking frequency
- no evidence for improved simulation of blocking persistence
- conservative results, as these models are not re-tuned at higher resolution

The latest generation of global climate models suffers from well-known blocking biases, but the magnitude of these biases is reduced.

Schiemann et al., WCDD, submitted