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Projected changes in the Arctic Oscillation: why do CMIP3 and CMIP5 disagree?

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Introduction

The AO is the first mode of atmospheric variability in the N. Hemisphere. Based on CMIP3, IPCC-AR4 reported a tendency towards positive AO in future projections (see [1]). Recent studies suggest that CMIP5 projections might disagree (see [2]). Here we investigate the origins of such a discrepancy, based on 13 models participating to both CMIP3 and 5.

AO in CMIP3 & CMIP5 projections

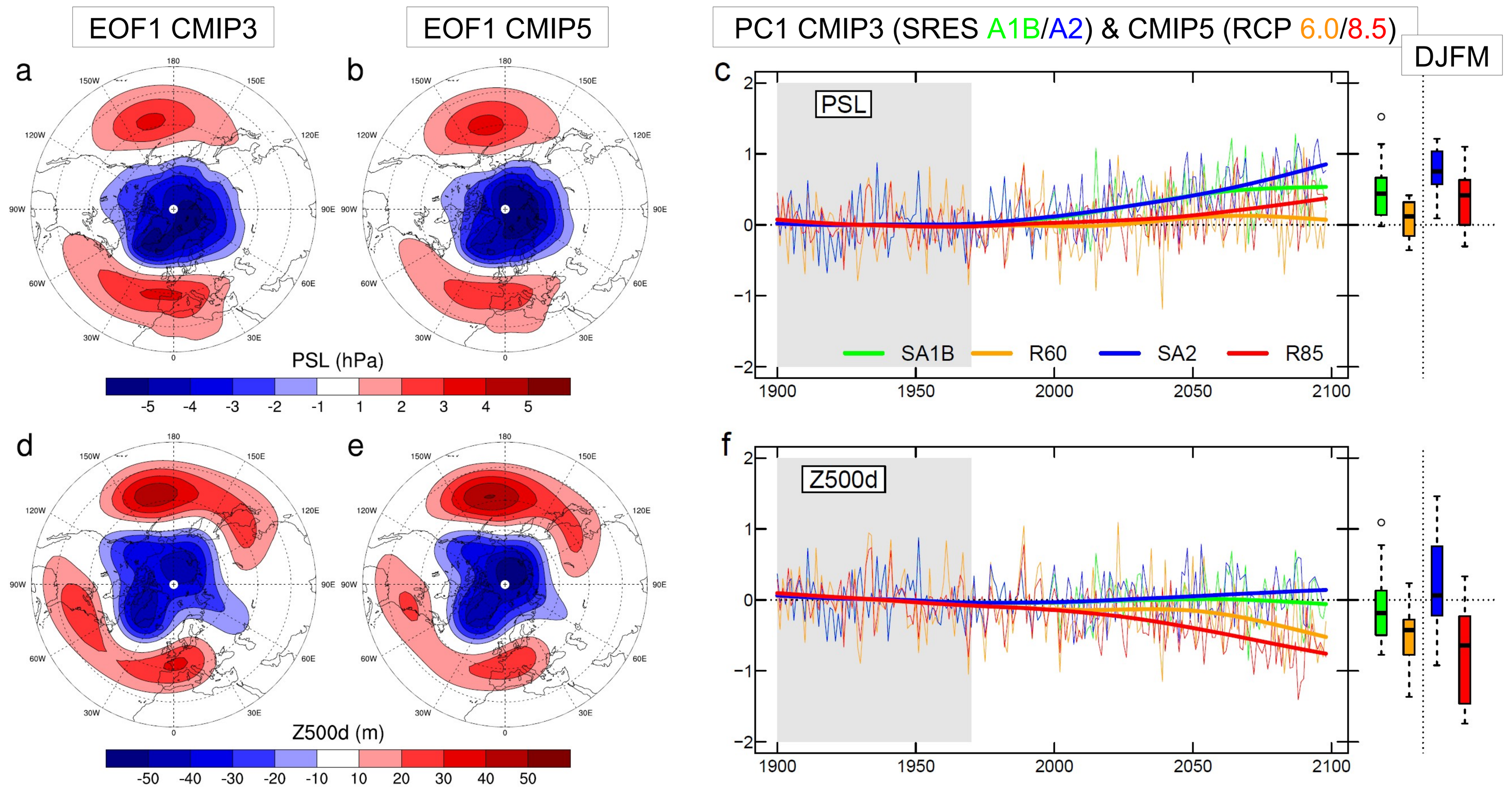


Fig 1. a AO pattern CMIP3 PSL (ensemble-mean EOF1 ONDJFM 1950-1999). **b** Same for CMIP5. **c** Corresponding DJFM AO index in CMIP3 and CMIP5. Lines: ensemble mean. Boxplot: spread. **d-f** Same as a-c for detrended Z500 (i.e. uniform thermal expansion removed).

CMIP3 and CMIP5 disagree in their projected changes in the winter AO.

- The CMIP5-3 difference projects onto the **negative phase** of the AO (Fig 1).
- A feature common to most of the **13 models** used here (Fig 2).
- The difference is rather **baroclinic (barotropic)** in early (late) winter (Fig 3).

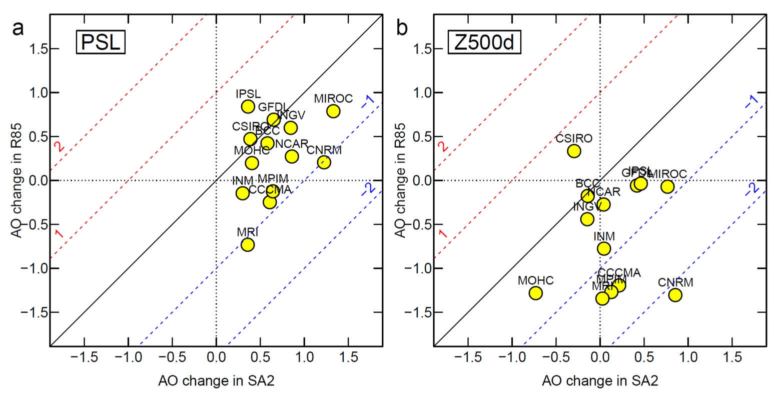
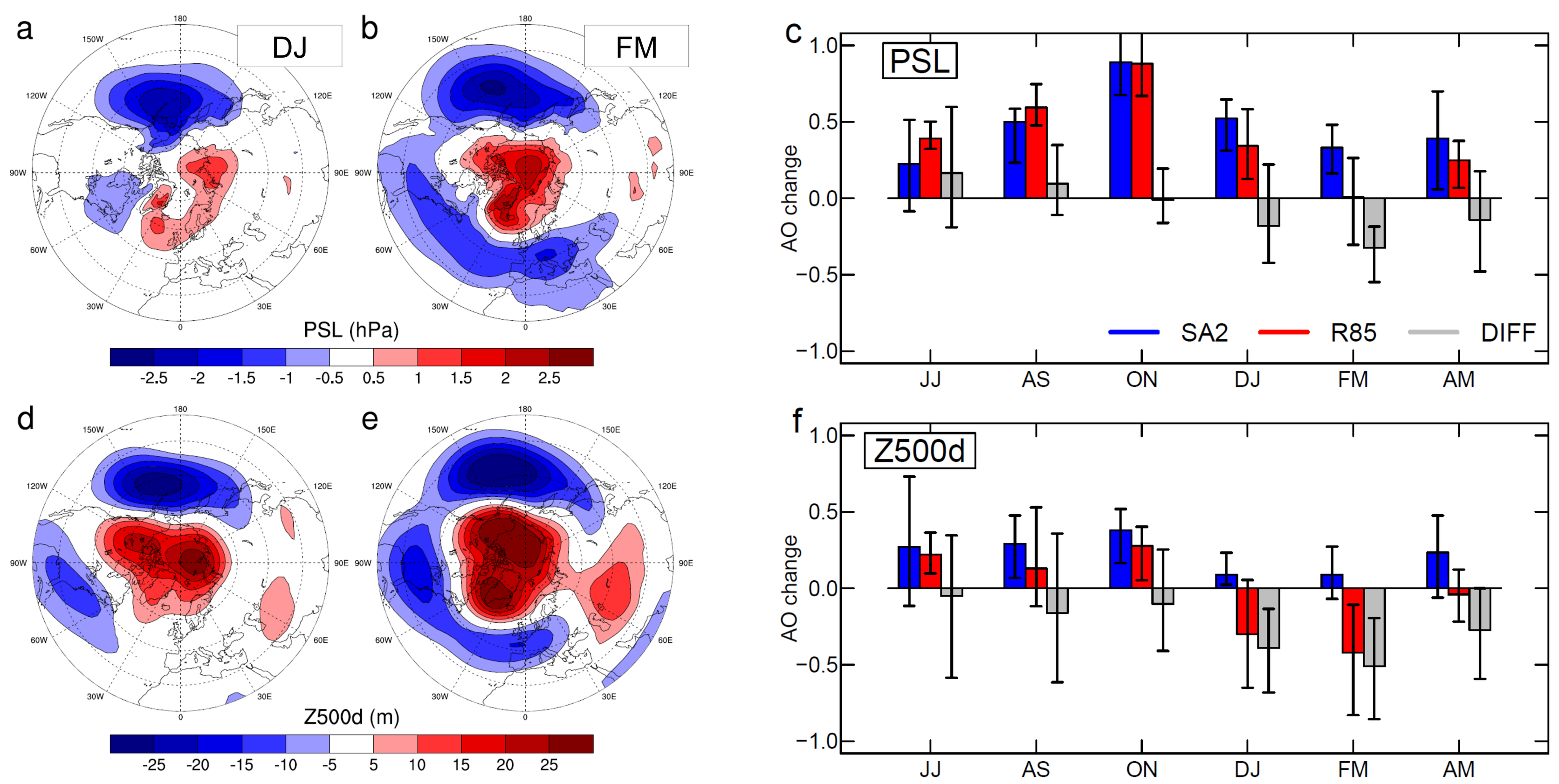


Fig 2. CMIP5 (R85) vs. CMIP3 (SA2) FUT-PRE changes in DJFM AO index (FUT-PRE: 2070/99-1970/99).

Fig 3. a CMIP5-3 difference in FUT-PRE changes in PSL in DJ. **b** Same for FM. **c** Bimonthly FUT-PRE changes in AO index. **d-f** Same as a-c for detrended Z500.



The role of the Arctic sea ice

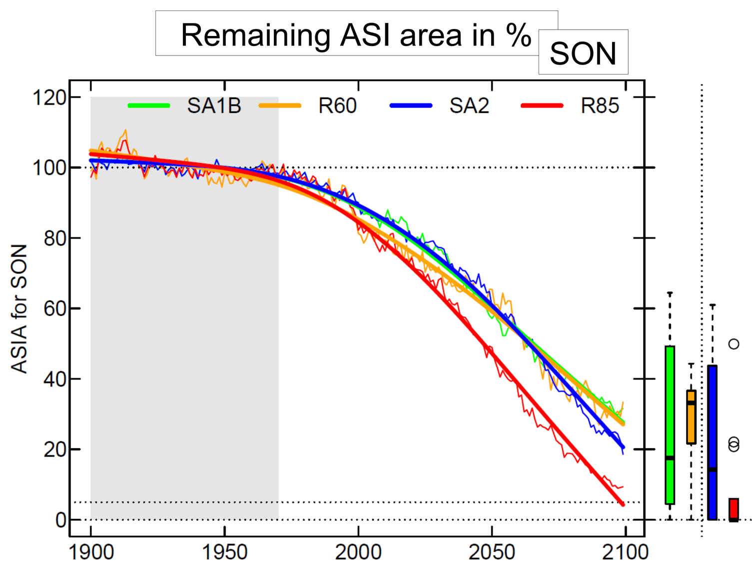


Fig 4. Remaining ASI area (in %) for SON in CMIP3 and CMIP5 projections. Lines: ensemble mean. Boxplot: spread.

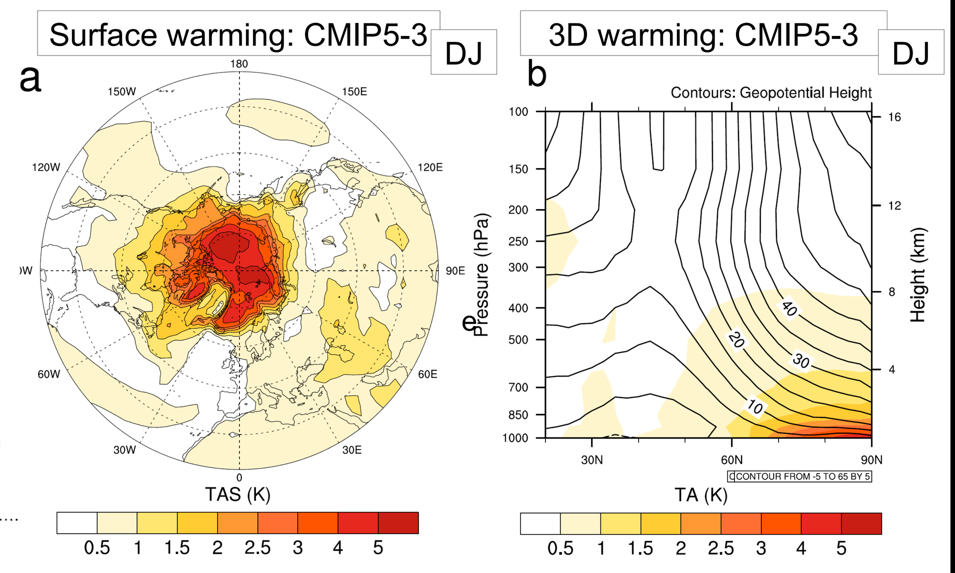


Fig 5. CMIP5-3 (R85-SA2) difference in FUT-PRE changes in **a** TAS and **b** zonally-averaged TA (colors) and ZG (contours) for DJ.

A faster decline in CMIP5 and a stronger impact on the early-winter AO.

- Stronger **Arctic amplification** (Fig 5) due to faster sea ice loss (Fig 4). Timing and vertical profile consistent with [3].
- Stronger **negative AO** response for similar sea-ice conditions (Fig 6), possibly linked to a northward shift of the polar vortex (Fig 7, see [4]).

Fig 6. a FUT-PRE individual changes in AO index (DJ) vs. remaining ASI area in SON. **b** PDF of AO index (DJ) conditionnally to remaining ASI area in SON (by 20%-ranges).

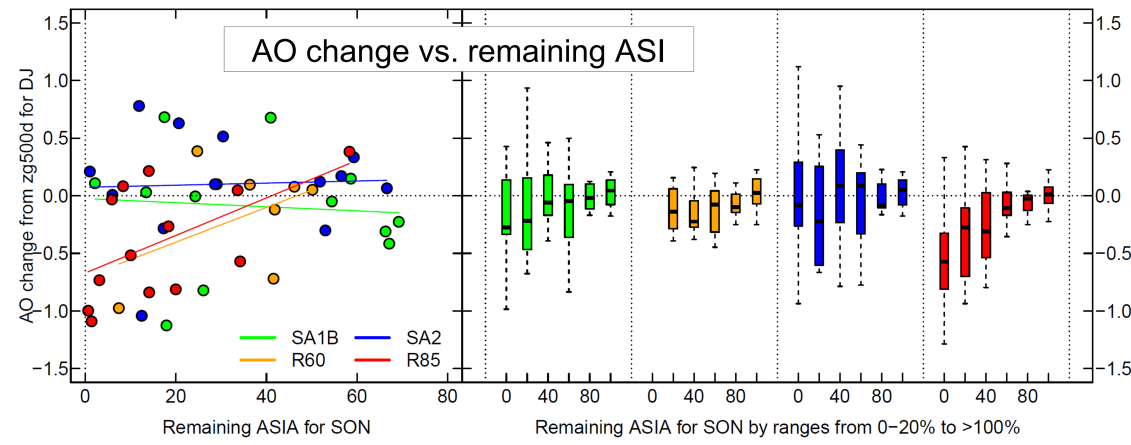
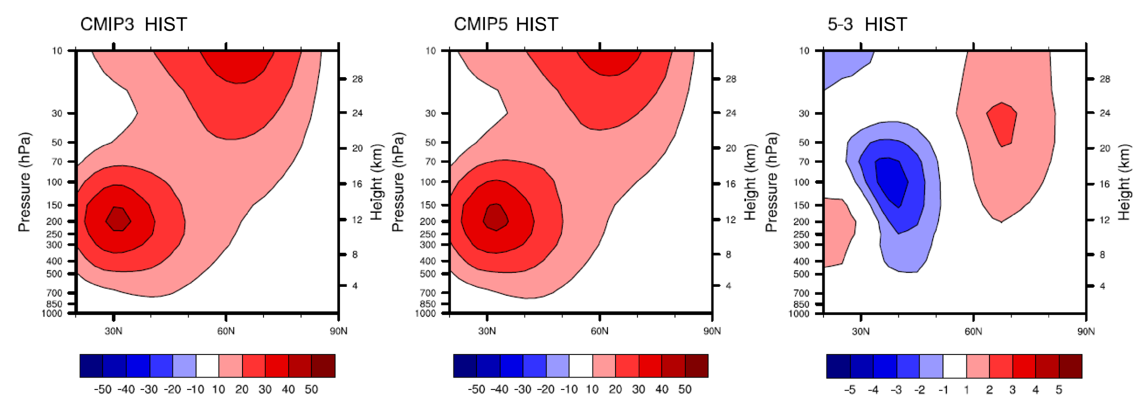


Fig 7. Zonally-averaged UA (in m/s) in CMIP3 and CMIP5 historical simulations (DJ).



The influence of the tropical Pacific

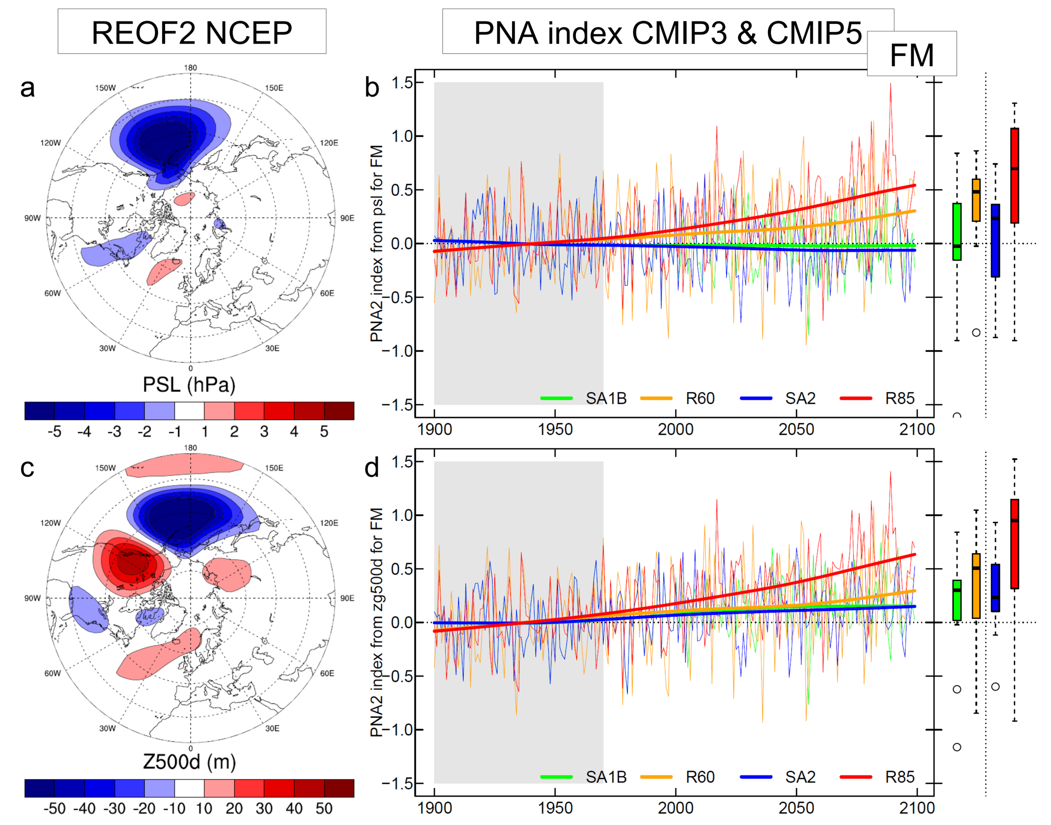
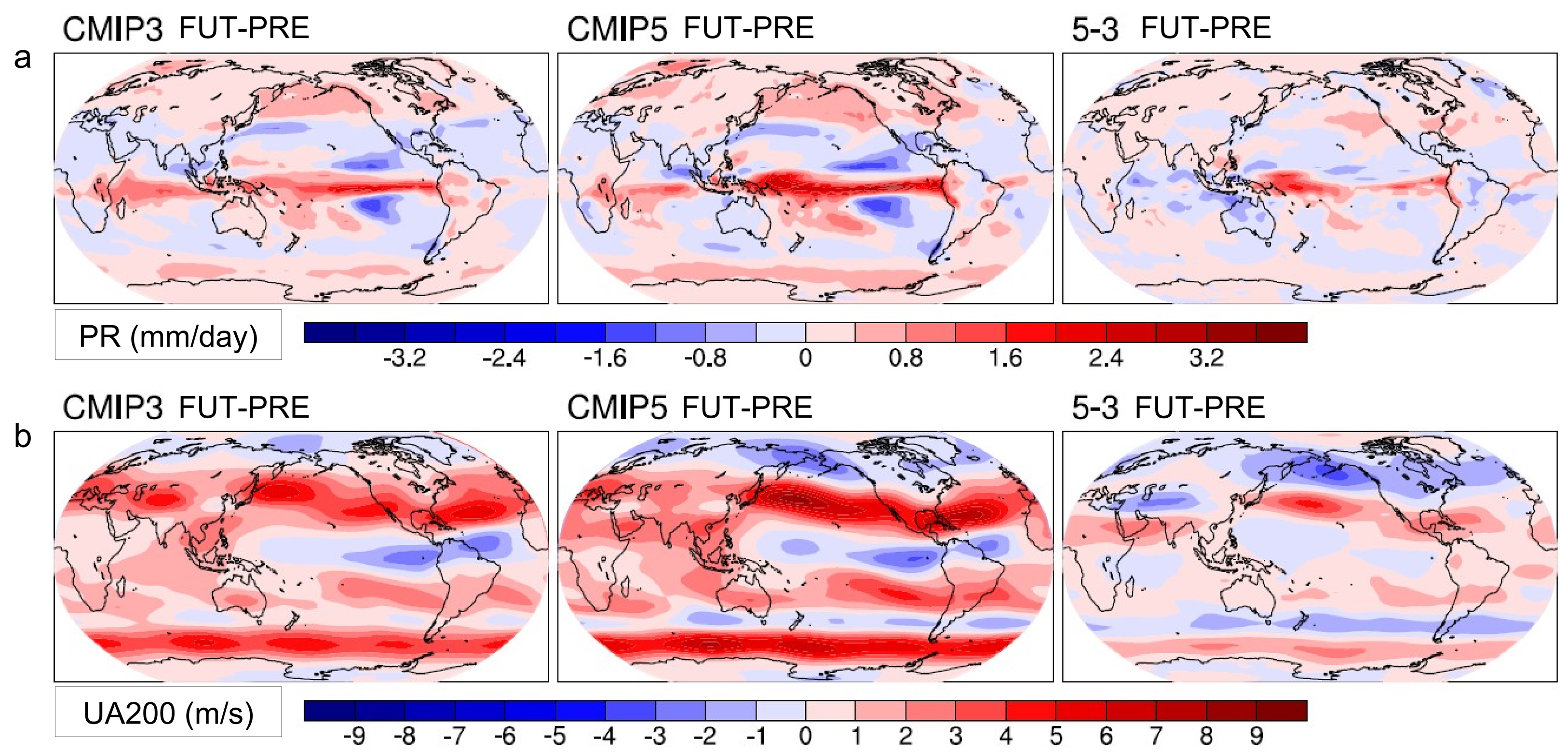


Fig 8. a PNA pattern NCEP PSL (rotated EOF2 ONDJFM 1950-1999). **b** Corresponding FM PNA index in CMIP3 and CMIP5. Lines: ensemble mean. Boxplot: spread. **c-d** Same as a-b for detrended Z500.

A stronger Niño-like response influencing the late-winter AO through a positive PNA.

- A barotropic response towards **PNA+ in CMIP5** (Fig8)...
- … linked to a **stronger Niño-like response** in the tropics (Fig 9, see [5]).

Fig 9. FUT-PRE changes in FM for **a** PR and **b** UA200 in CMIP3 (SA2) & CMIP5 (R85).



What about changes from SRES to RCPs?

We find similar features in idealized 1pctCO2 experiments.

- Only 7 models...
- … but a **similar negative AO signature** in the CMIP5-3 difference.

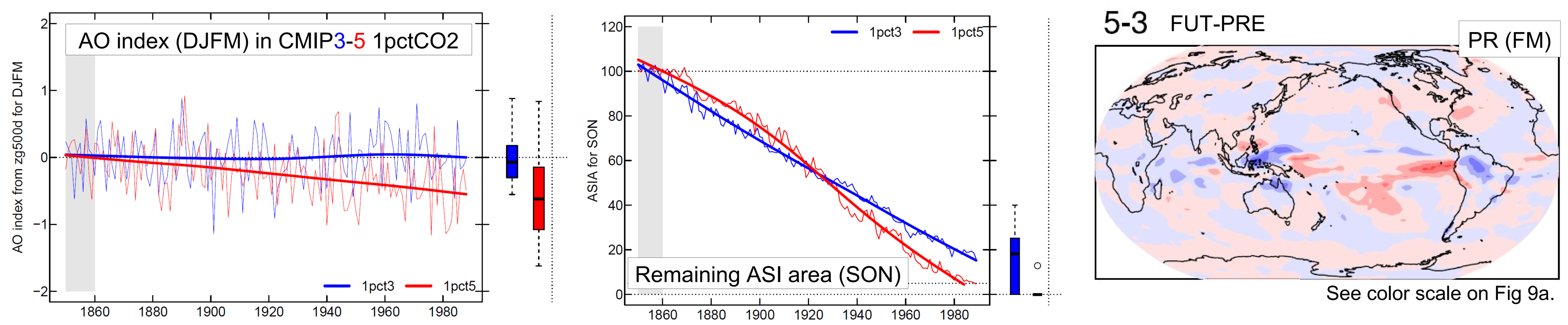


Fig 10. Same as Figs 1f, 4 and 9a for 1pctCO2 experiments: AO index (DJFM), remaining ASI (SON) and CMIP5-3 FUT-PRE PR (FM).

References

[1] Miller, RL., GA. Schmidt and DT. Shindell (2006), Forced annular variations in the 20th century IPCC AR4 models, *J. Geophys. Res.*, 111, D18101.

[2] Cattiaux, J., H. Douville and Y. Peings (2012), European temperatures in CMIP5: origins of present-day biases and future uncertainties, *Clim. Dyn.*, submitted.

[3] Deser, C. et al. (2010), The seasonal atmospheric response to projected Arctic sea ice loss in the late 21st century, *J. Clim.*, 23, 333-351.

[4] Peings, Y., D. Saint-Martin and H. Douville (2011), A numerical sensitivity study of the influence of Siberian snow on the Northern Annular Mode, *J. Clim.*, 25, 592-607.

[5] Cassou, C. and L. Terray (2001), Oceanic forcing of the low-frequency atmospheric variability in the North-Atlantic European sector, *J. Clim.*, 14, 4266-4291.

Conclusions

CMIP3 and CMIP5 differ in their projected changes of the winter AO. The difference projects onto negative AO, with a baroclinic (barotropic) profile in early (late) winter associated with CMIP5-3 differences in the Arctic sea ice decline (tropical Pacific response). Idealized 1pctCO2 experiments suggest that such discrepancies are linked to changes in GCMs, rather than in scenarios.