Opposite CMIP3/5 trends in the NAM explained by combined local sea-ice and remote tropical influences

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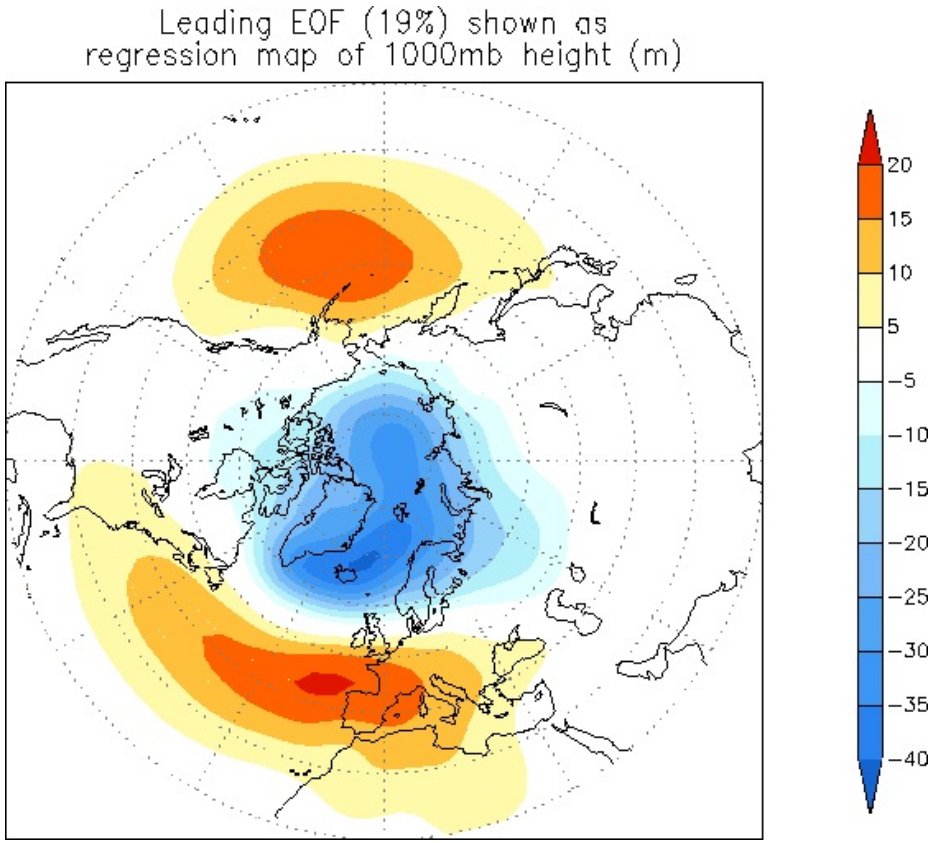
NAM: Northern Annular Mode

- First mode of atmospheric variability in the Northern Hemisphere.
- Classically derived from EOF1 of monthly SLP/Z500/Z1000, etc.



http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/loading.html

NAM: Northern Annular Mode

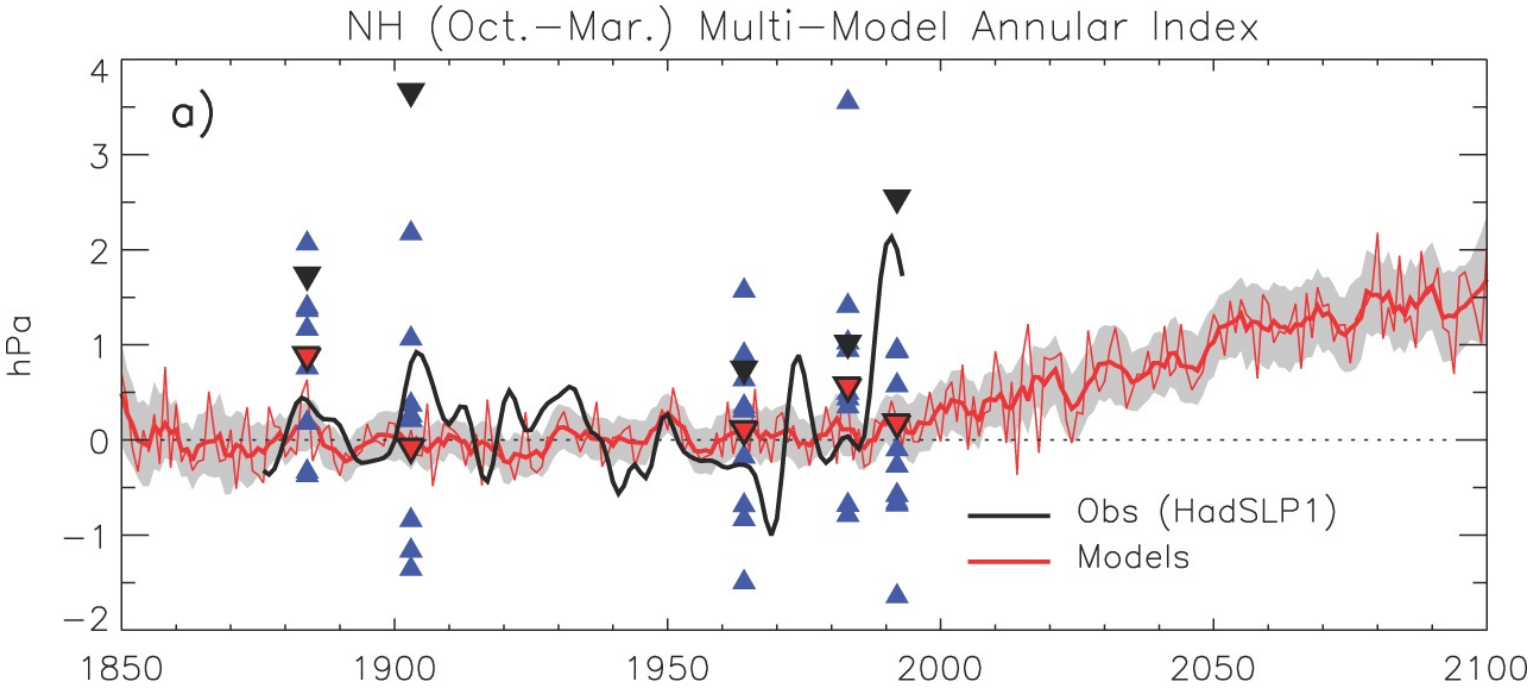
- First mode of atmospheric variability in the Northern Hemisphere.
- Classically derived from EOF1 of monthly SLP/Z500/Z1000, etc.

$\longrightarrow$ Does climate change project onto the NAM?

Previously in CMIP

- IPCC-AR4 (2007):

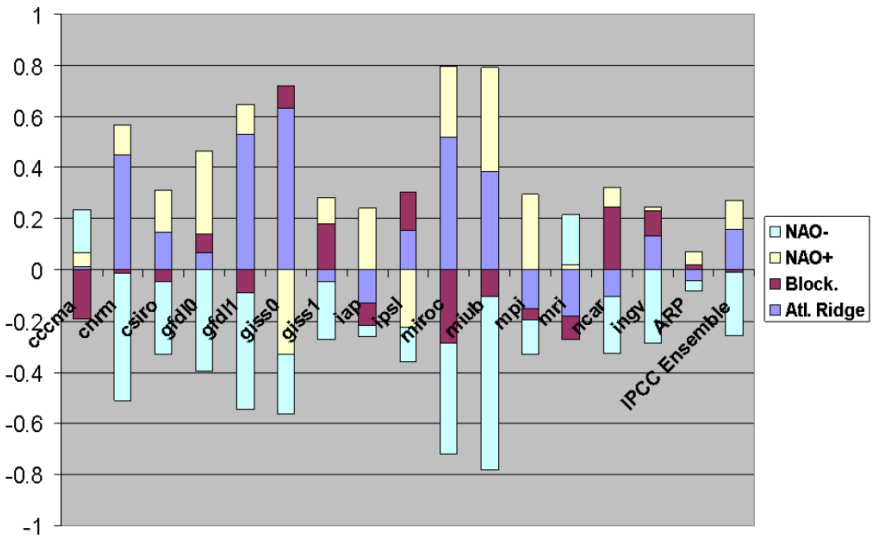
⟶ *More than half of the models exhibit a positive trend in the NAM.*
⟶ *Miller et al. (2006) find than none of the 14 models exhibit a negative trend.*



Miller et al. 2006 – SLP index, 14 CMIP3 GCMs, SRES A1B, ONDJFM.

CMIP3/5 NAE weather regimes

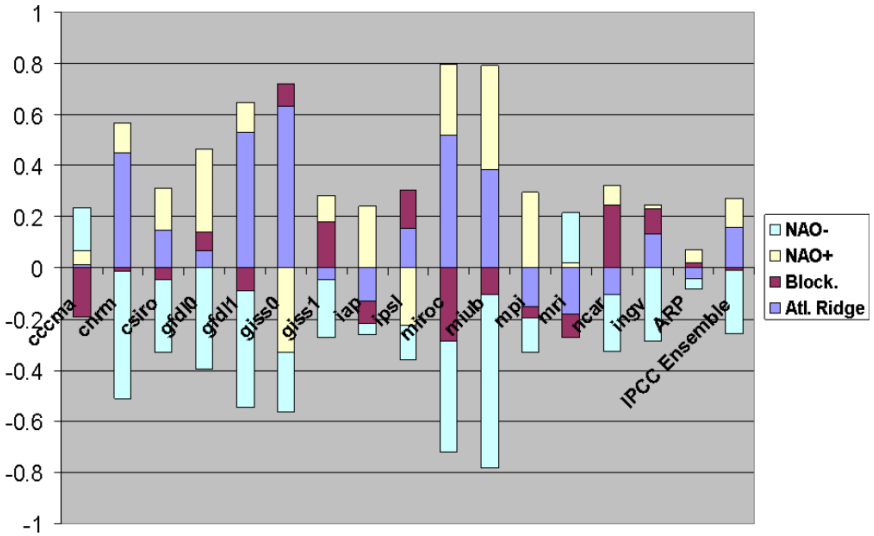
- CMIP3: increased frequency of NAO+ (Boé 2007).

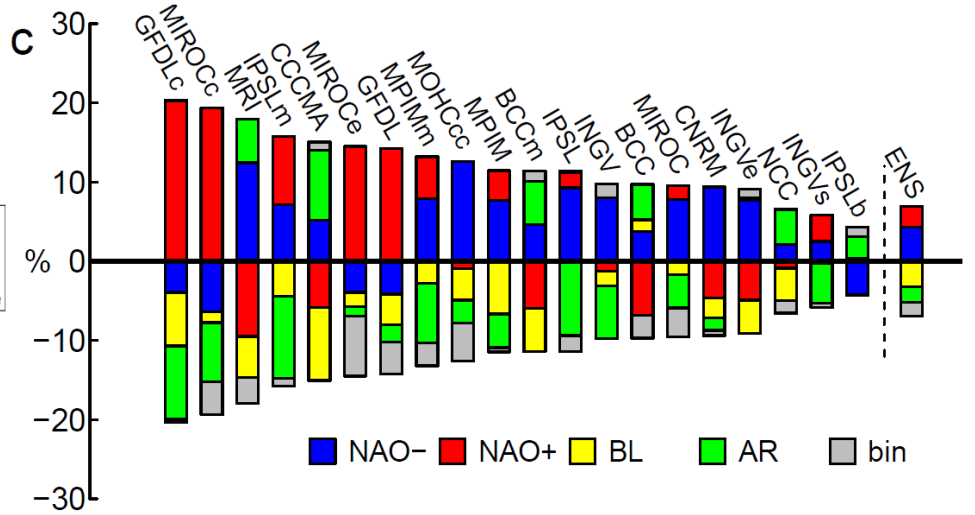


Boé (2007): CMIP3-A1B, SLP DJF

CMIP3/5 NAE weather regimes

- CMIP3: increased frequency of NAO+ (Boé 2007).
- CMIP5: increased frequency of NAO− (Cattiaux et al. 2013).

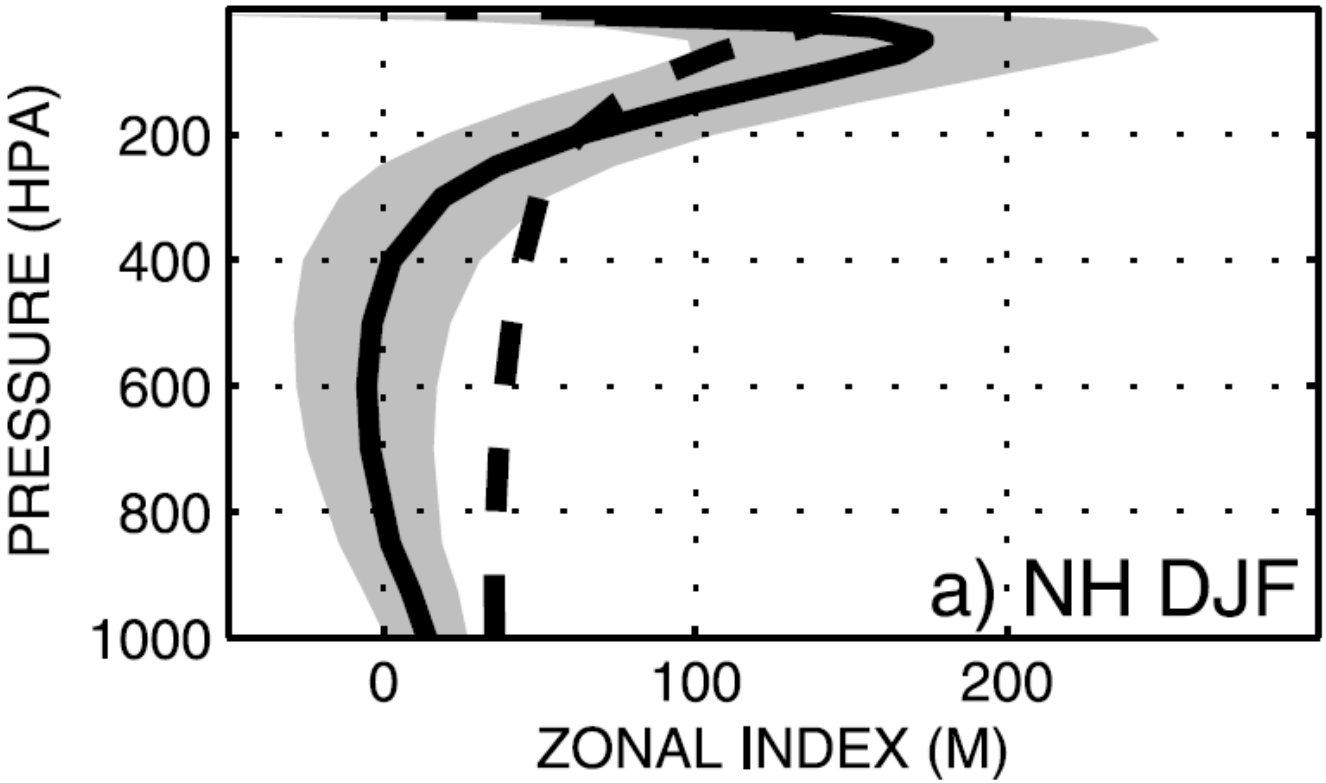




Boé (2007): CMIP3-A1B, SLP DJF — Cattiaux et al. (2013): CMIP5-RCP8.5, Z500 DJFM.

A barotropic mode but a baroclinic response?

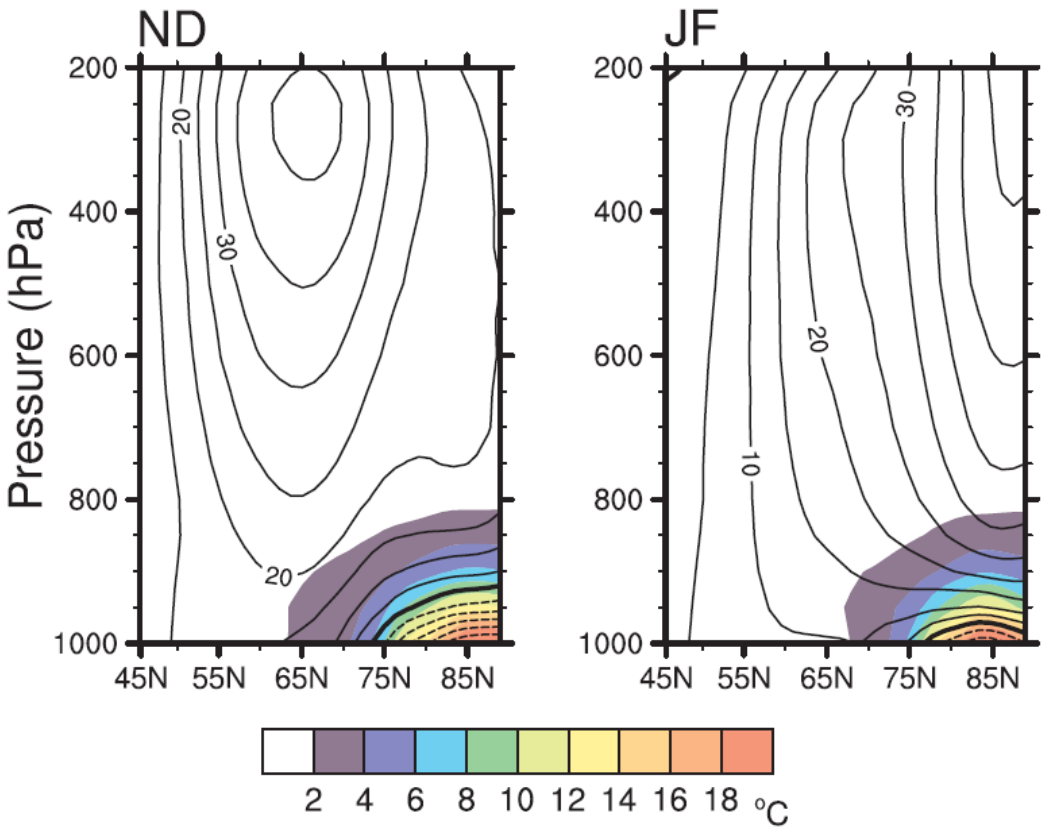
- Different responses at the surface and aloft (Woollings 2008).



Woollings 2008 — Zonal index, 22 CMIP3 GCMs, SRES A1B, lat-height EOF1, DJF.

An influence of the Arctic sea ice?

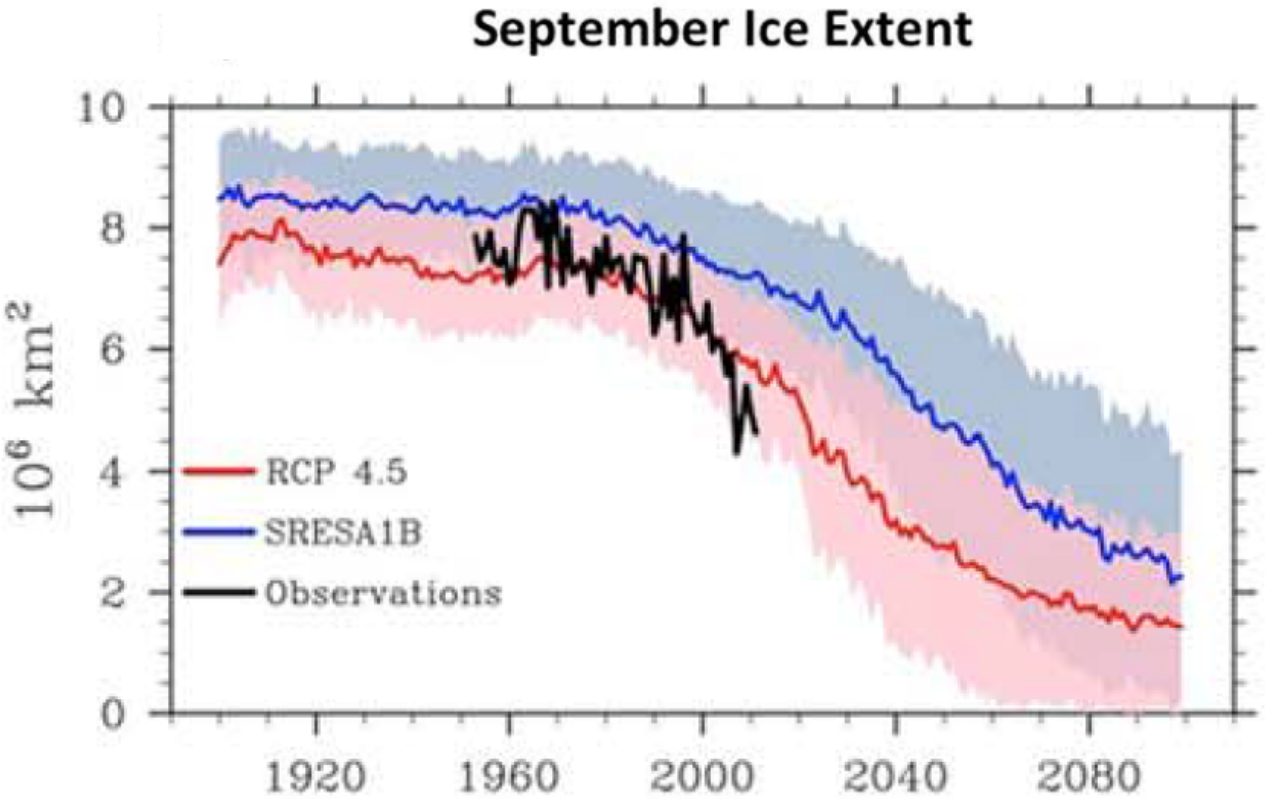
- Sea ice loss may affect the NAM (Deser et al. 2010 + many others).



Deser et al. 2010 – CAM3 exps with ASI late 21C vs. ASI late 20C.

An influence of the Arctic sea ice?

- Sea ice loss may affect the NAM (Deser et al. 2010 + many others).
- Sea ice disappears earlier in CMIP5 than in CMIP3 (Stroeve et al. 2012).



Stroeve et al. 2012 – September ASI in CMIP3 and CMIP5.

What we did

Data

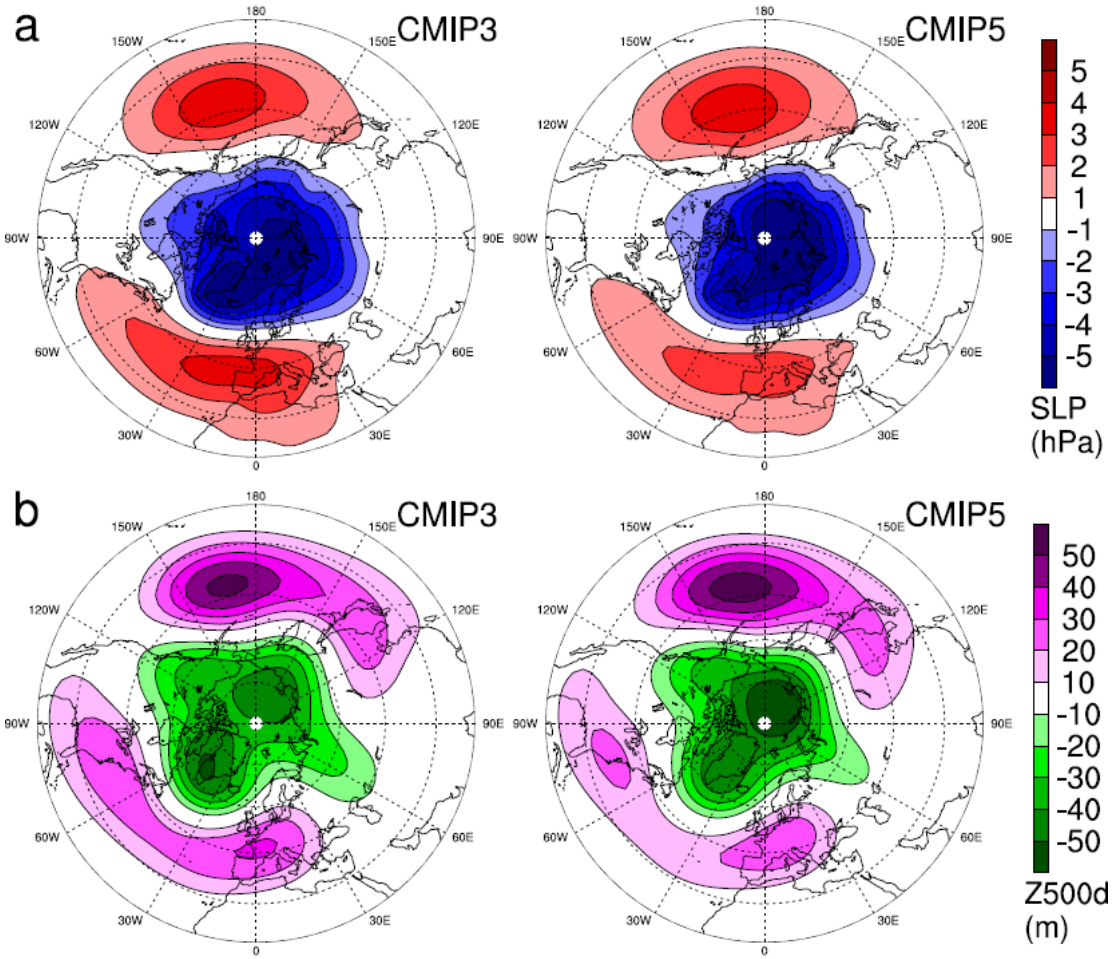
- 13 GCMs with both CMIP3 (SRES A2) and CMIP5 (RCP 85).
- Only 1 run per simulation (run 1).

Methods

- EOF1/PC1 computed individually over DJFM.
- SLP + Z500d (patterned anomalies).
- 1pctCO2 common experiments (9 GCMs).

Opposite CMIP3/5 trends

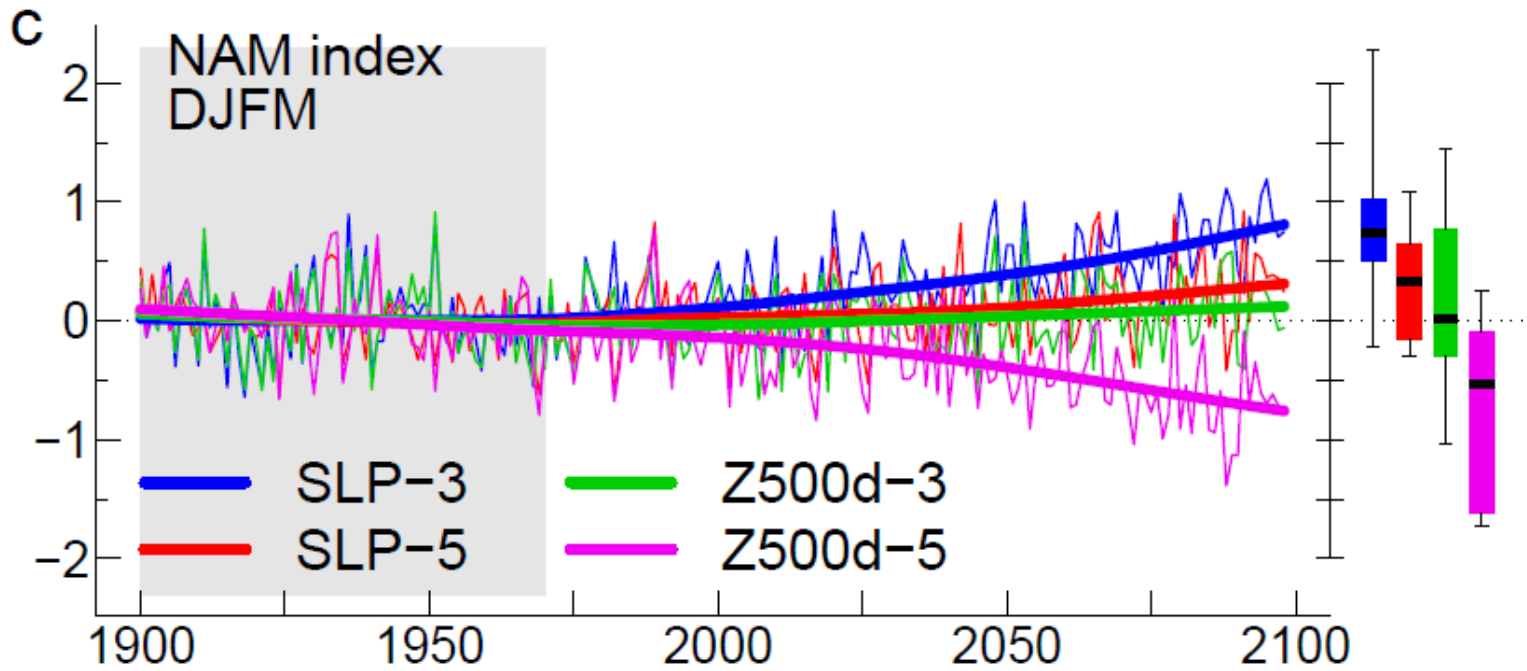
- No change in 20C EOF1



© CC13 Fig. 1.

Opposite CMIP3/5 trends

- No change in 20C EOF1 but shift towards NAM− over 21C.



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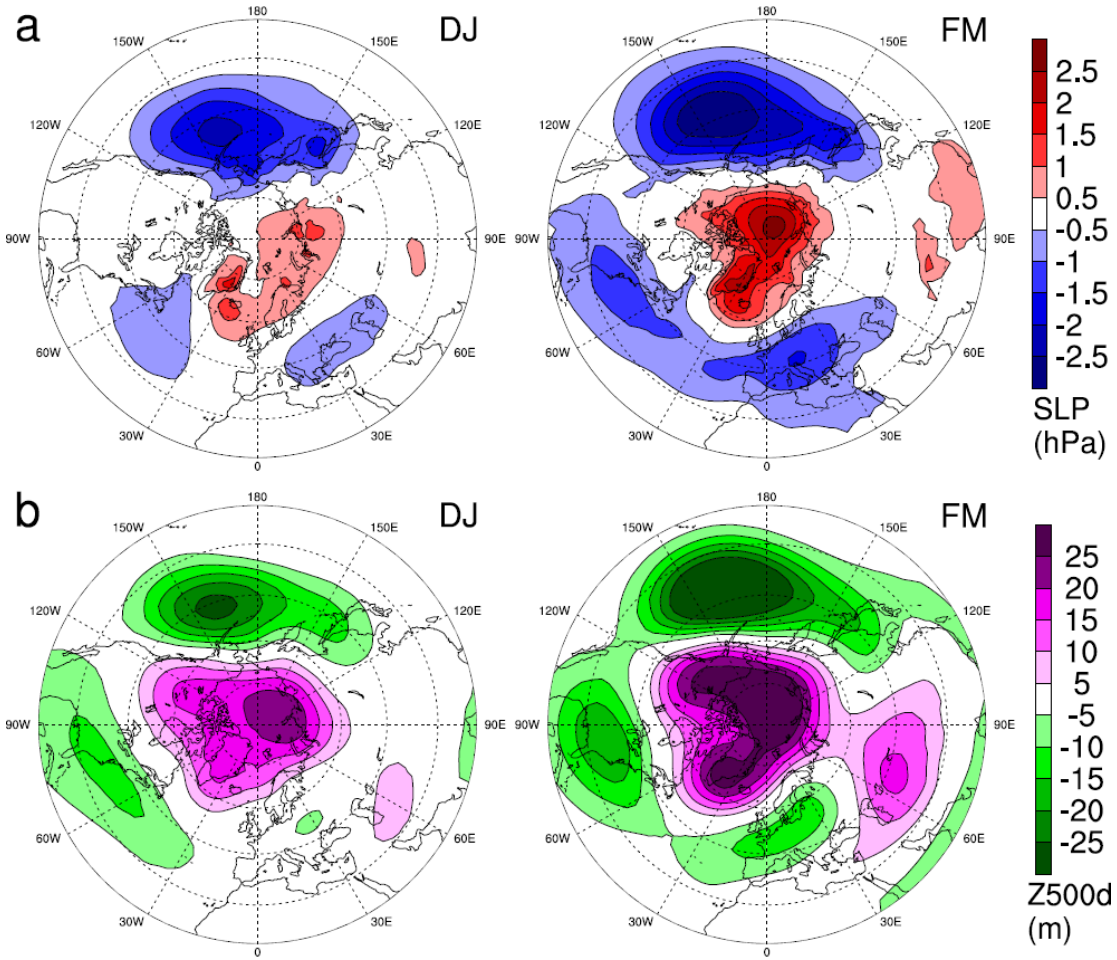
Seasonality & baroclinicity of the CMIP3/5 difference

- Local & baroclinic in DJ vs. hemispheric & barotropic in FM.



© CC13 Fig. 2. – All maps: CMIP5−CMIP3 difference of 2070–2100 vs. 1900–1970 response.

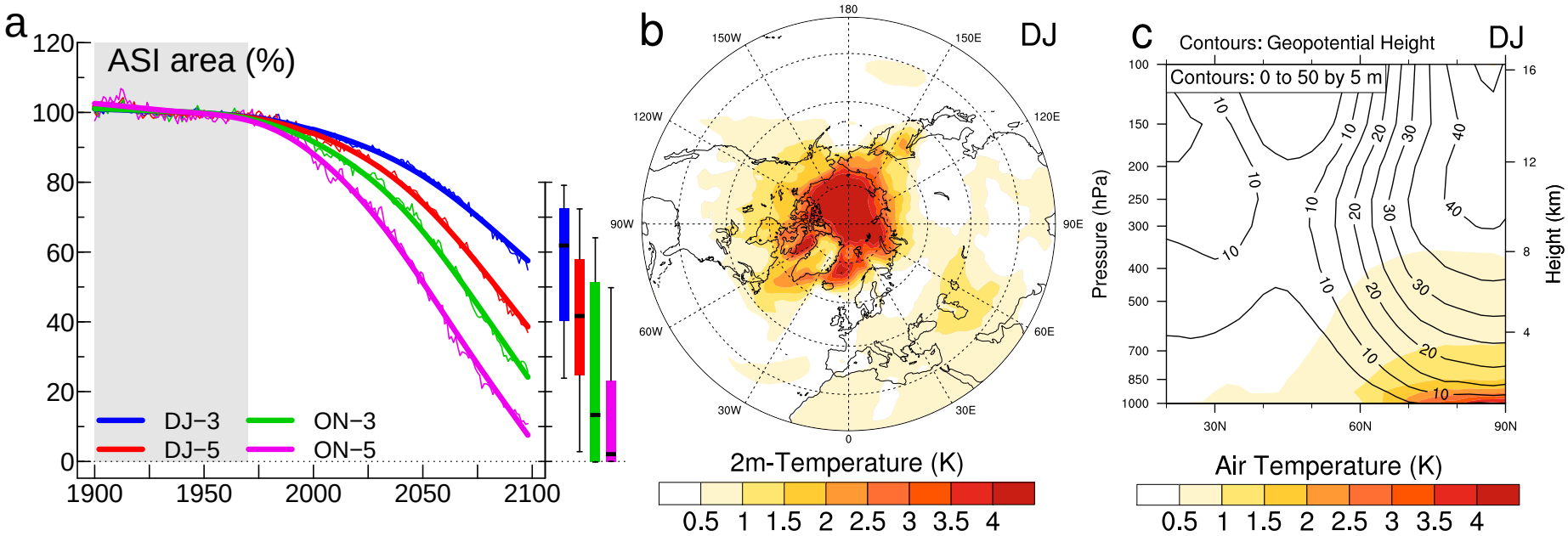
So?

- ✓ CMIP3/5 difference in winter NAM change projects onto NAM−.
- ✓ Early winter (DJ): rather baroclinic and limited to the polar area.
- ✓ Late winter (FM): rather barotropic and more hemispheric.

⟶ Local influence of Arctic sea-ice in early winter?
⟶ Remote influence of large-scale teleconnections in late winter?
⟶ Due to changes in emission scenarios or in model properties?

DJ: local influence of Arctic sea-ice

- (a) Faster decline ⇒ (b) Stronger A.A. ⇒ (c) Enhanced baroclinicity.
- Timing and vertical response consistent with Deser et al. 2010.



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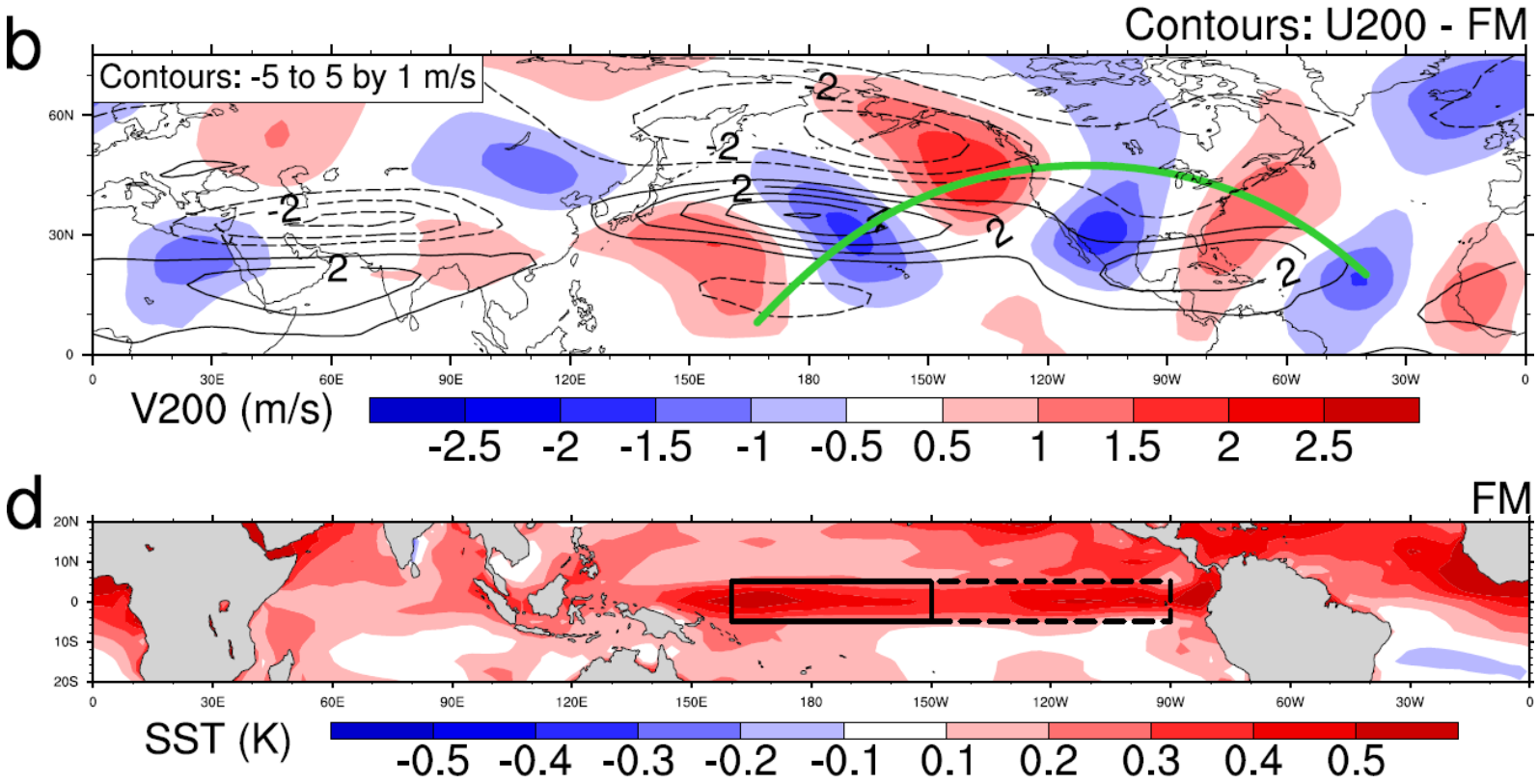
FM: remote influence of the Tropical Pacific

- Rossby wave emerging from Western tropical Pacific (Niño 4 box).



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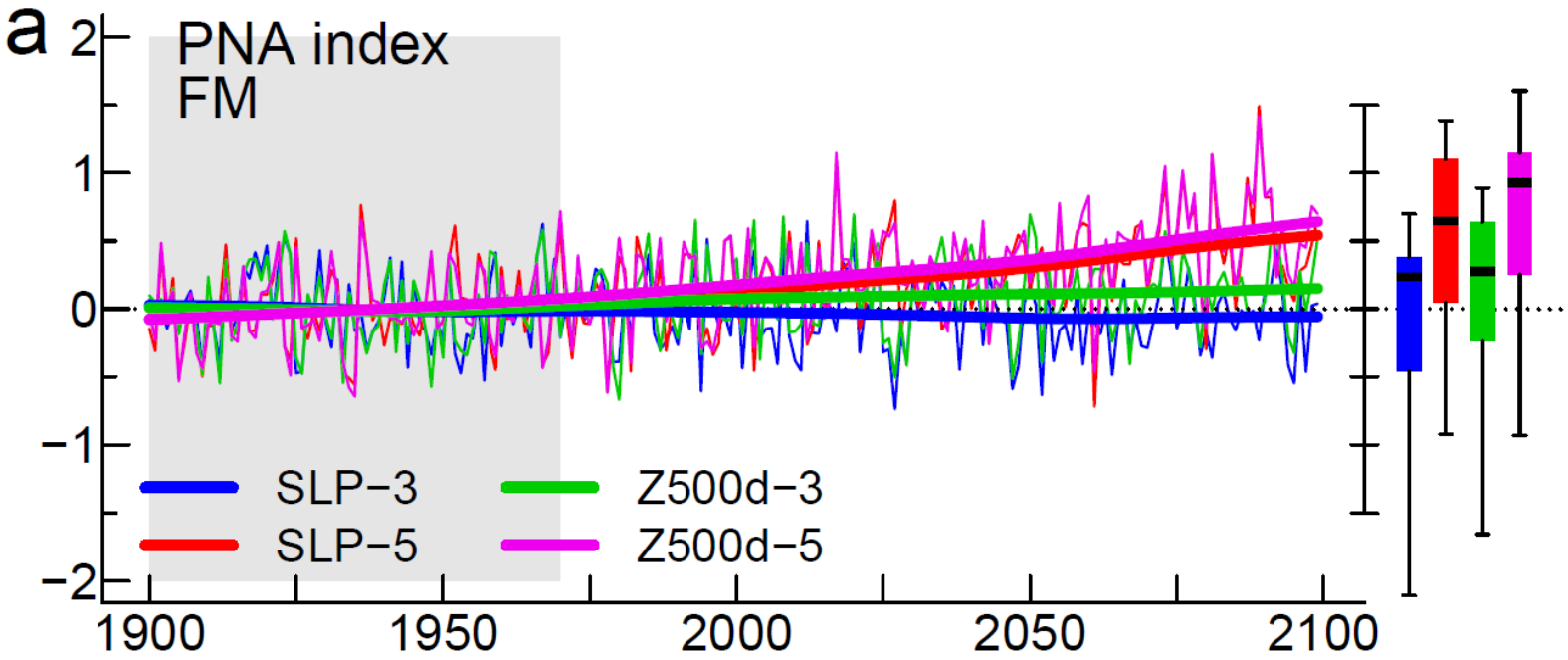
FM: remote influence of the Tropical Pacific

- Rossby wave emerging from Western tropical Pacific (Niño 4 box).
- Barotropic PNA+ response in CMIP5, contributing to NAM−.



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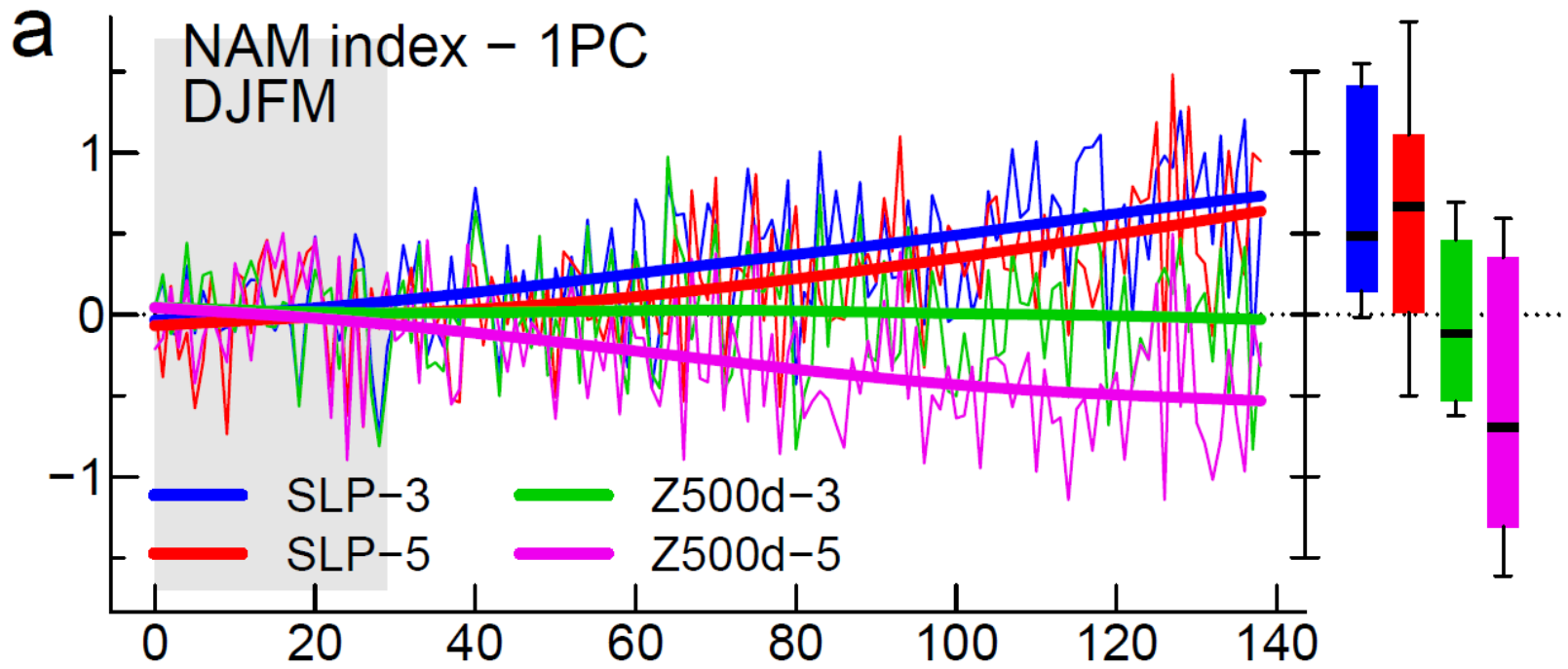
Emission scenarios or model characteristics?

- NAM difference: only the baroclinic part in 1pctCO2 (1PC).



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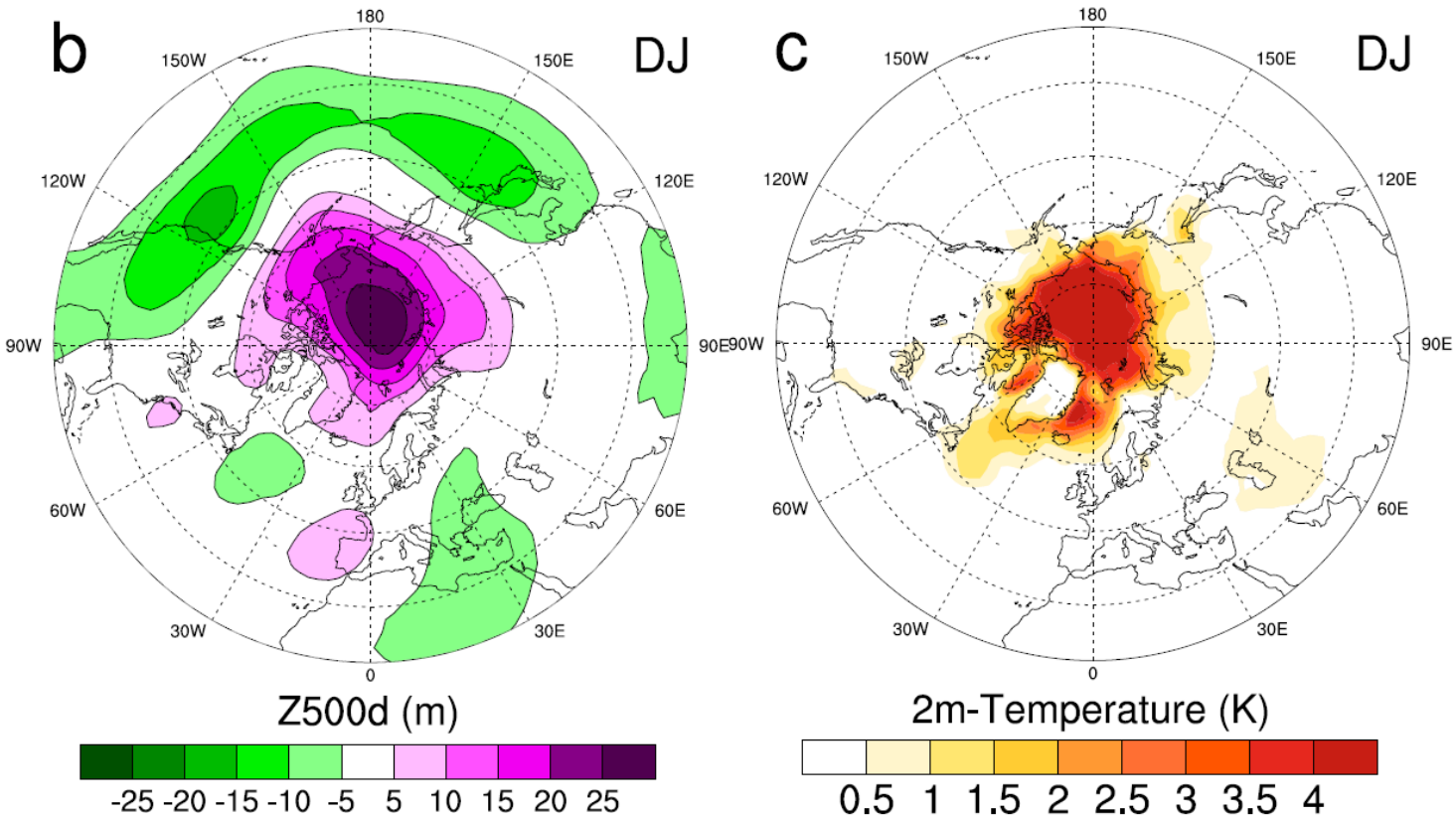
Emission scenarios or model characteristics?

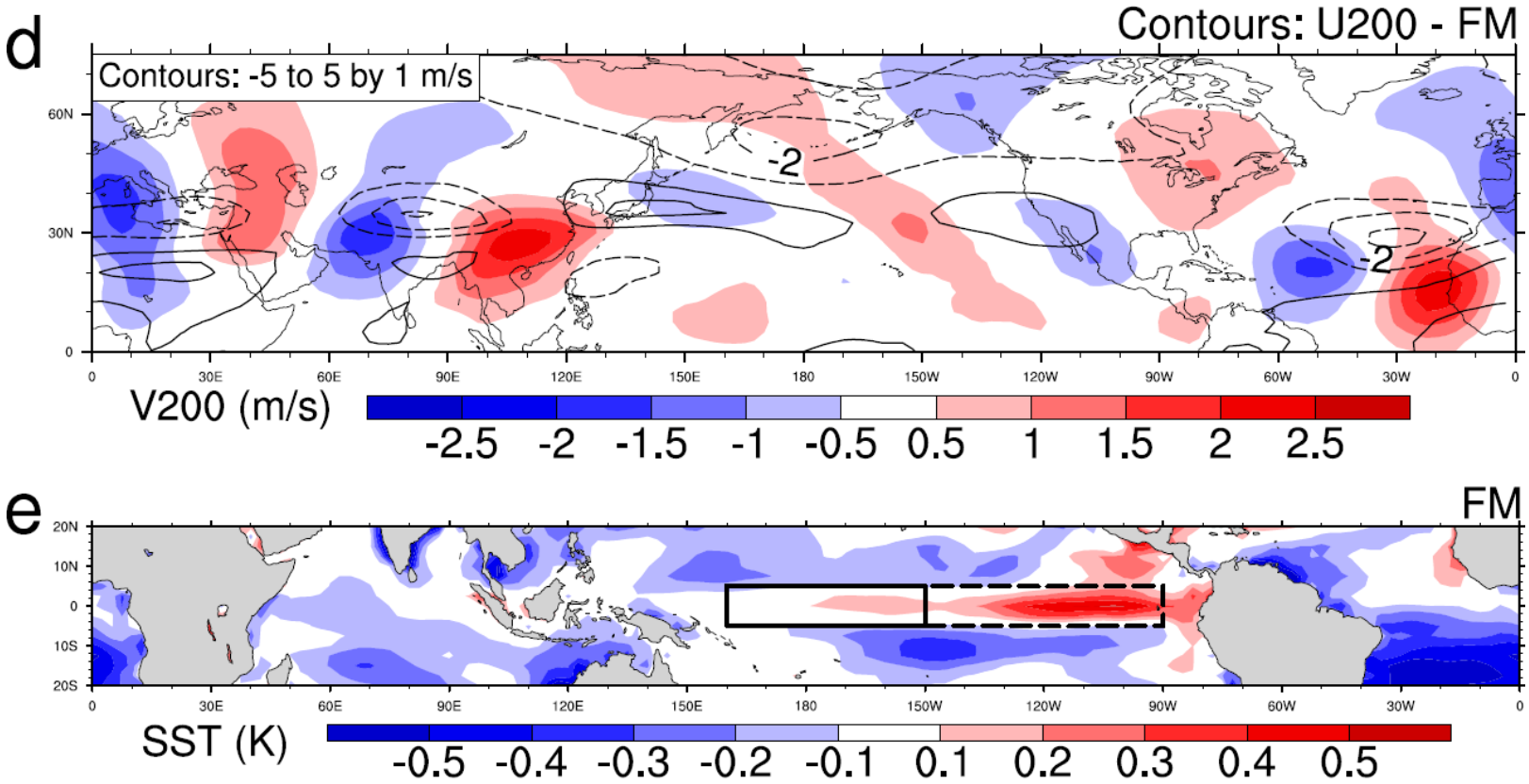
- NAM difference: only the baroclinic part in 1pctCO2 (1PC).
- Faster sea-ice decline also in 1pctCO2 ⇒ due to model characteristics.



© CC13 Fig. 5.

Emission scenarios or model characteristics?

- NAM difference: only the baroclinic part in 1pctCO2 (1PC).
- Faster sea-ice decline also in 1pctCO2 ⇒ due to model characteristics.
- No Pacific teleconnection in 1pctCO2 ⇒ due to emission scenarios.



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Summary

- ✓ CMIP3/5 difference in winter NAM change projects onto NAM−;
- ✓ Early winter (DJ): rather baroclinic and limited to the polar area;
- ✓ Late winter (FM): rather barotropic and more hemispheric.

- ✓ Local sea-ice influence: stronger A.A. from surface to upper-air;
- ✓ Remote tropical influence: Rossby wave from warmer Niño 4 region;
- ✓ Sea-ice: model properties / Tropics: emission scenarios.

⟶ Internal variability? Stratosphere (ozone)? Model resolutions?

Cattiaux, J. and C. Cassou (2013), Opposite CMIP3/5 trends in the NAM explained by combined local sea-ice and remote tropical influences, *GRL*, 40 (14), 3682–3687. doi:10.1029/2013GL056495