Assessing the precipitation associated to ENSO, PNA and NAO in historical and future scenarios in CMIP6 models

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Aims

- We analyse the mean winter (Dec-Feb) precipitation associated to El Niño Southern Oscillation (ENSO), the Pacific North American (PNA) pattern and the North Atlantic Oscillation (NAO) in historical and future scenario simulations performed with three global coupled models.
- We analyse the impact of model resolution (ocean and atmosphere), on the ENSO-PNA-NAO relationship, and their connection to precipitation in different regions of the world.

Models and ensemble size used for this study

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| Model	Grid	Number of ensemble members
EC-Earth-Veg-LR	T159L62-ORCA1L75	3 (hist and ssp585)
EC-Earth-Veg	T255L91-ORCA1L75	9 (hist), 3 (ssp585)
HadGEM3-GC31-LL	N96; 192 x 144 longitude/latitude; L85, eORCA1	4 (hist and ssp585)
HadGEM3-GC31-MM	N216; 432 x 324 longitude/latitude; L85, eORCA25	4 (hist and ssp585)
CNRM-CM6-1	T127L91eORCA1L75	29 (hist), 6 (ssp585)
CNRM-CM6-1-HR	T359L91eORCA25L75	1 (hist and ssp585)

Change in atm-res

Change in ocean and atm-res

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The observed and future connection among ENSO, PNA and NAO

Schematic showing links of teleconnection chain.
Black boxes show standard eviation for
HIST and 21C
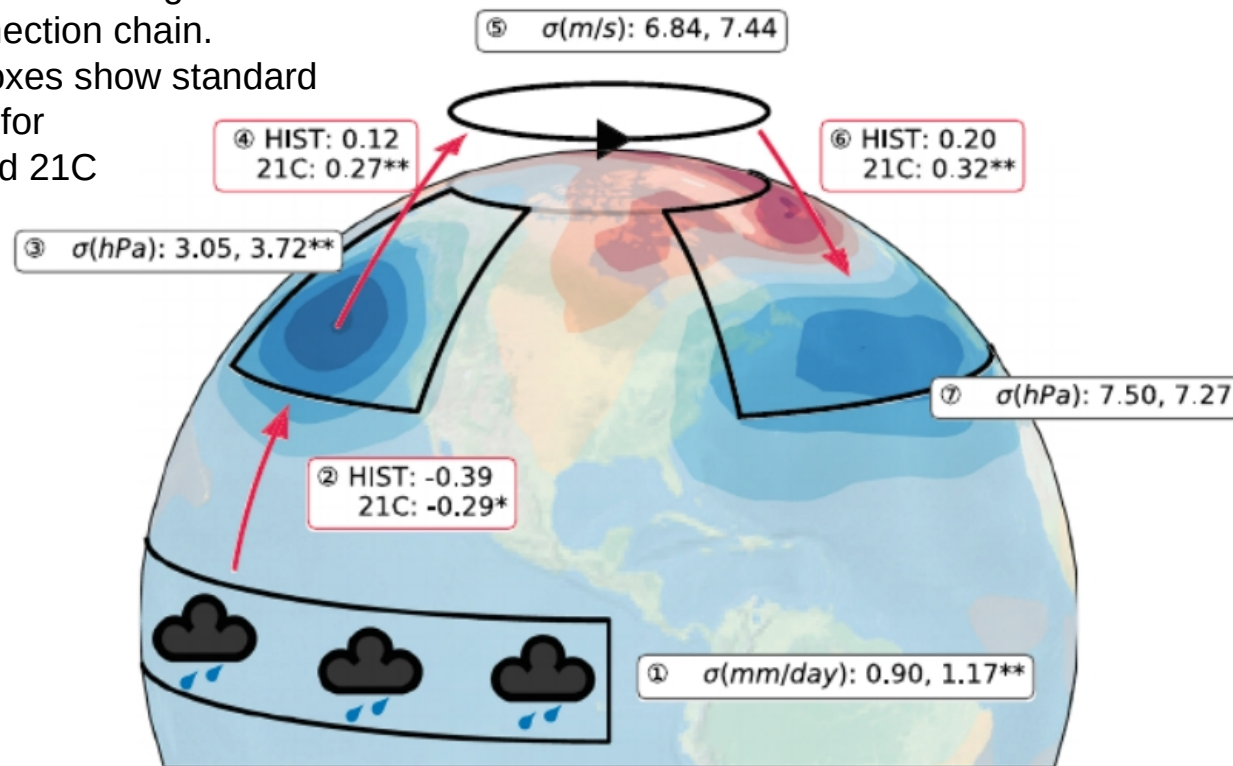
Boxes are (1) East Pacific rainfall, (3) Aleutian Low MSLP, (5) stratospheric polar vortex, and (7) NAO.

Red boxes (2, 4, and 6) show multimodel mean 50-year correlations between successive links of the teleconnection for HIST and 21C periods.
Double/single asterisks denote 5%/ 10% significant difference between HIST and 21C values

⑤ σ(m/s): 6.84, 7.44

④ HIST: 0.12
21C: 0.27**

⑥ HIST: 0.20
21C: 0.32**

③ σ(hPa): 3.05, 3.72**

⑦ σ(hPa): 7.50, 7.27

② HIST: -0.39
21C: -0.29*

① σ(mm/day): 0.90, 1.17**

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Regions with observed precipitation response to
ENSO (Cali, GoM, SEur, EAfr, Aus), PNA (Cali, GoM) and NAO (NEur and SEur)
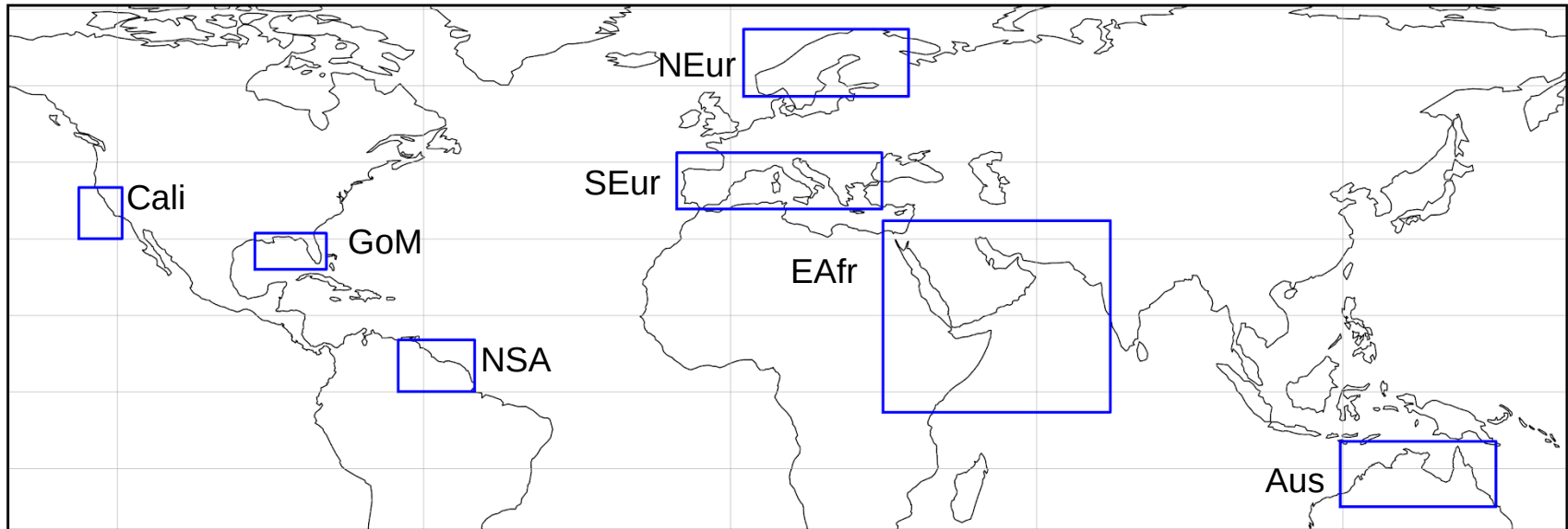
Mean power spectra of Nino3.4 index in historical and future (ssp5-8.5) simulations
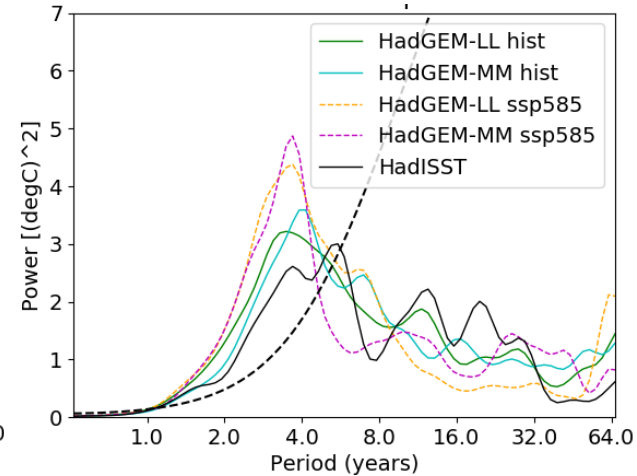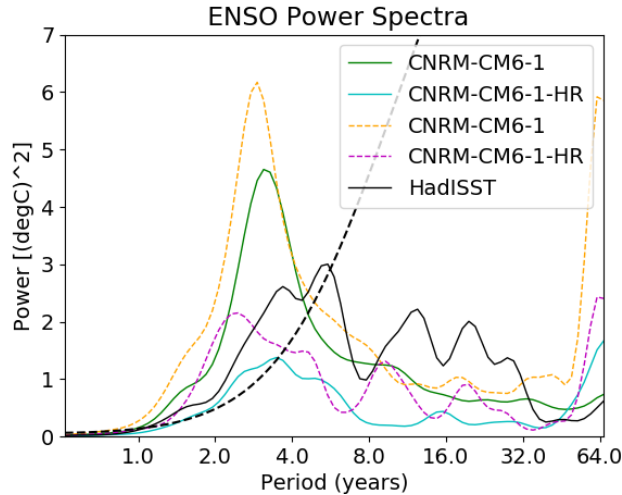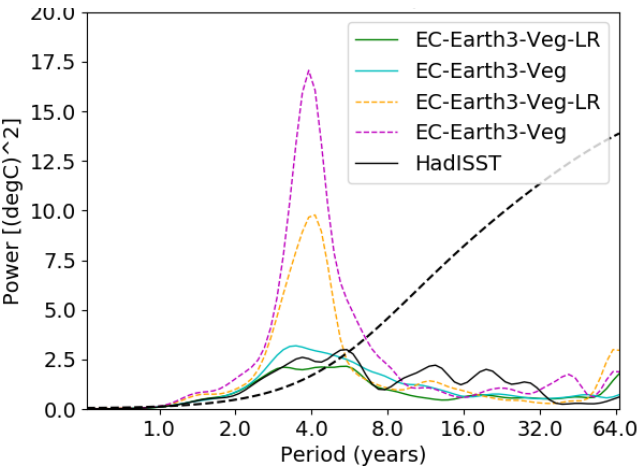
ENSO Power Spectra

- The future power spectra of the Nino3.4 index shows the main energy only in higher frequencies (2-4 years) in all models compared to historical simulations (2-8 years).
- The intensity of the future change is model dependent, with EC-Earth3-Veg showing the largest increase and CNRM-CM6-1-HR showing the smallest increase.
- No consistent behaviour due to different resolution across models.

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Seasonal precipitation anomaly obtained by regressing to NINO3.4 index as percentage of mean DJF precipitation

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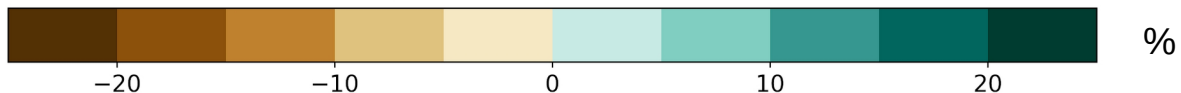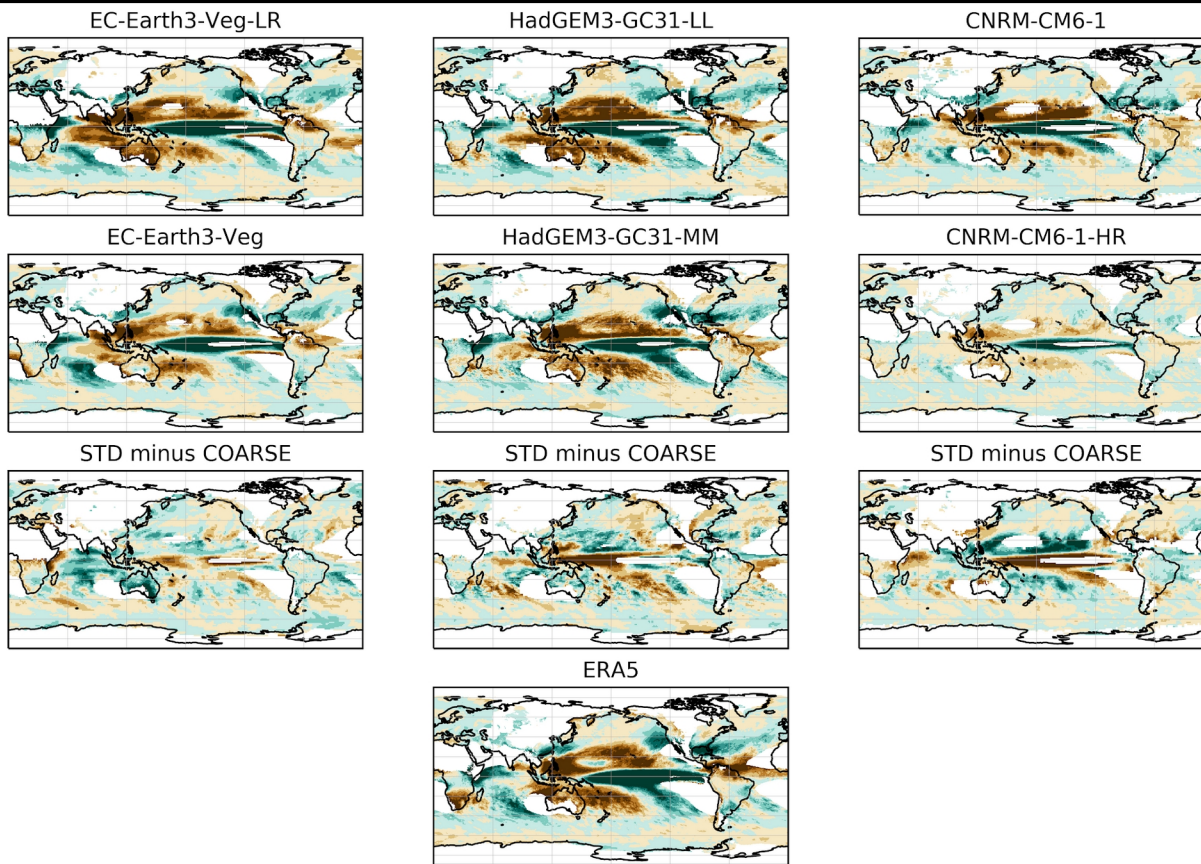
The higher resolution simulations show weaker ENSO teleconnection compared to the coarse version, except in HadGEM-MM where there is a stronger response over Cali, GoM and Northern Europe.

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Correlation of ENSO, PNA and NAO in historical (yellow) and future ssp5-8.5 scenario (red)

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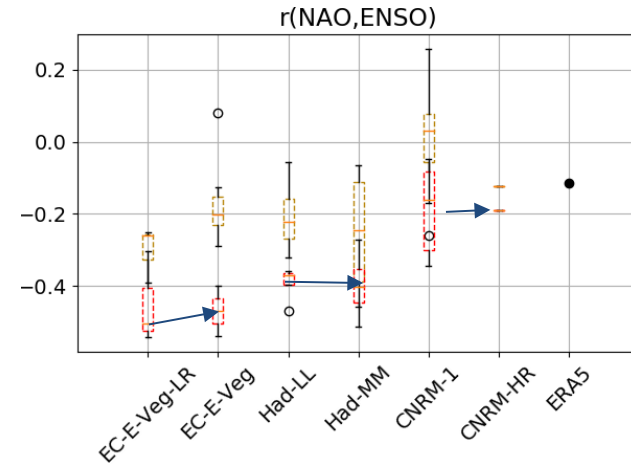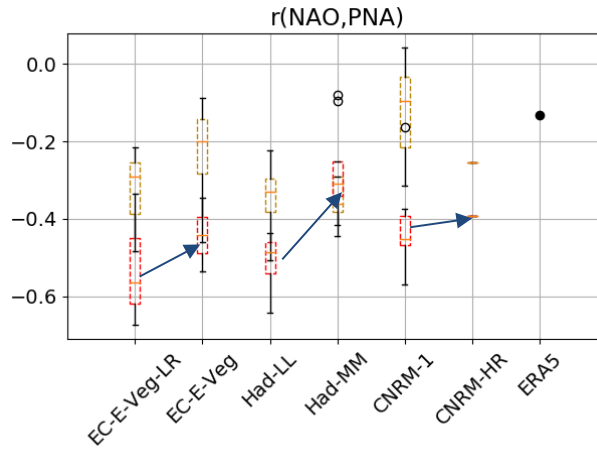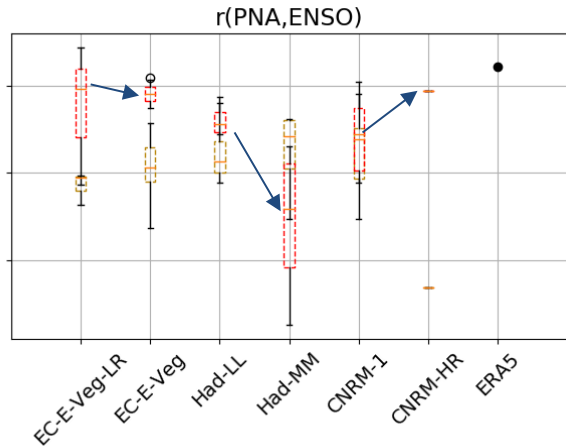
- There is a tendency to show stronger linkage among ENSO, PNA and NAO in ssp5-8.5 compared to historical simulations.
- The coarse model versions show a stronger ENSO-PNA-NAO linkage than the high model resolution counterparts.

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Correlation between NAO and precipitation over Northern and Southern Europe

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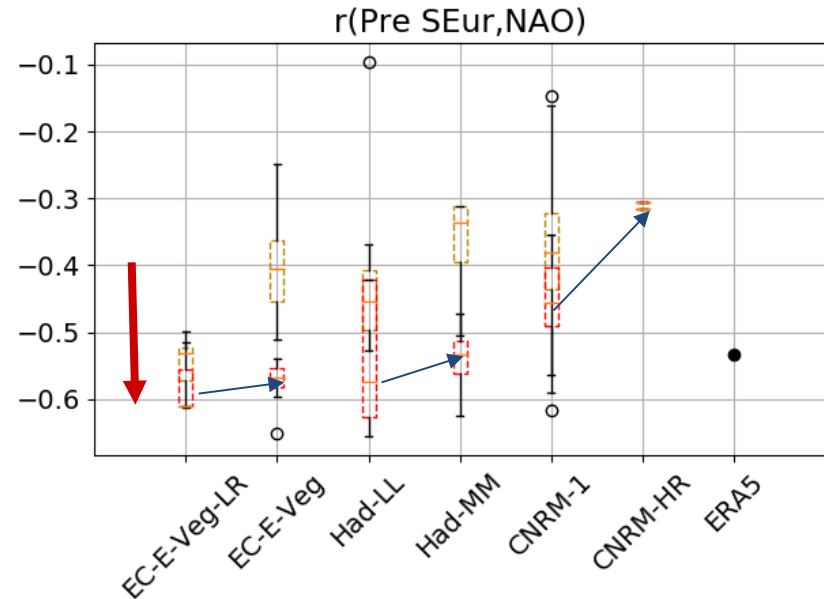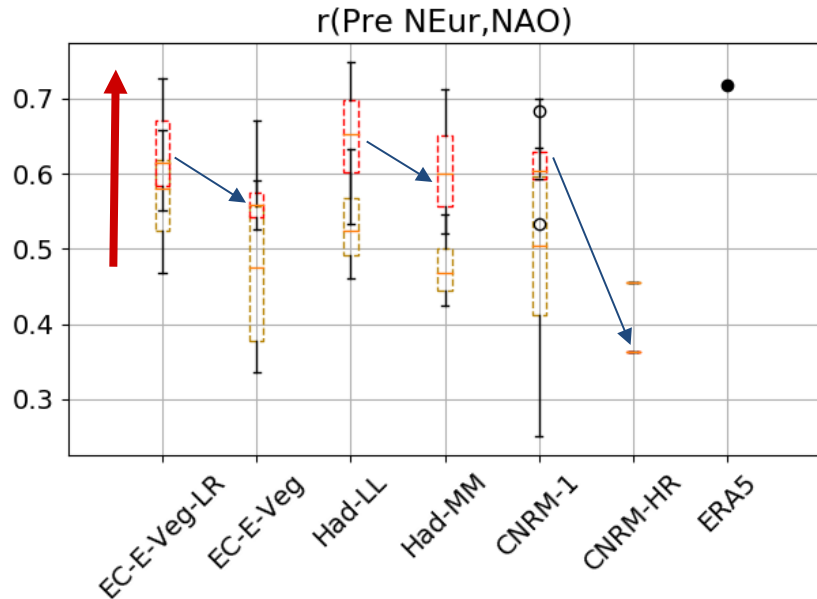
- All the models show an intensified correlation between precipitation in Northern and Southern Europe with NAO.
- Coarse resolution models tend to show a stronger NAO-precipitation correlation in the ssp5-8.5 scenario than std resolution models.
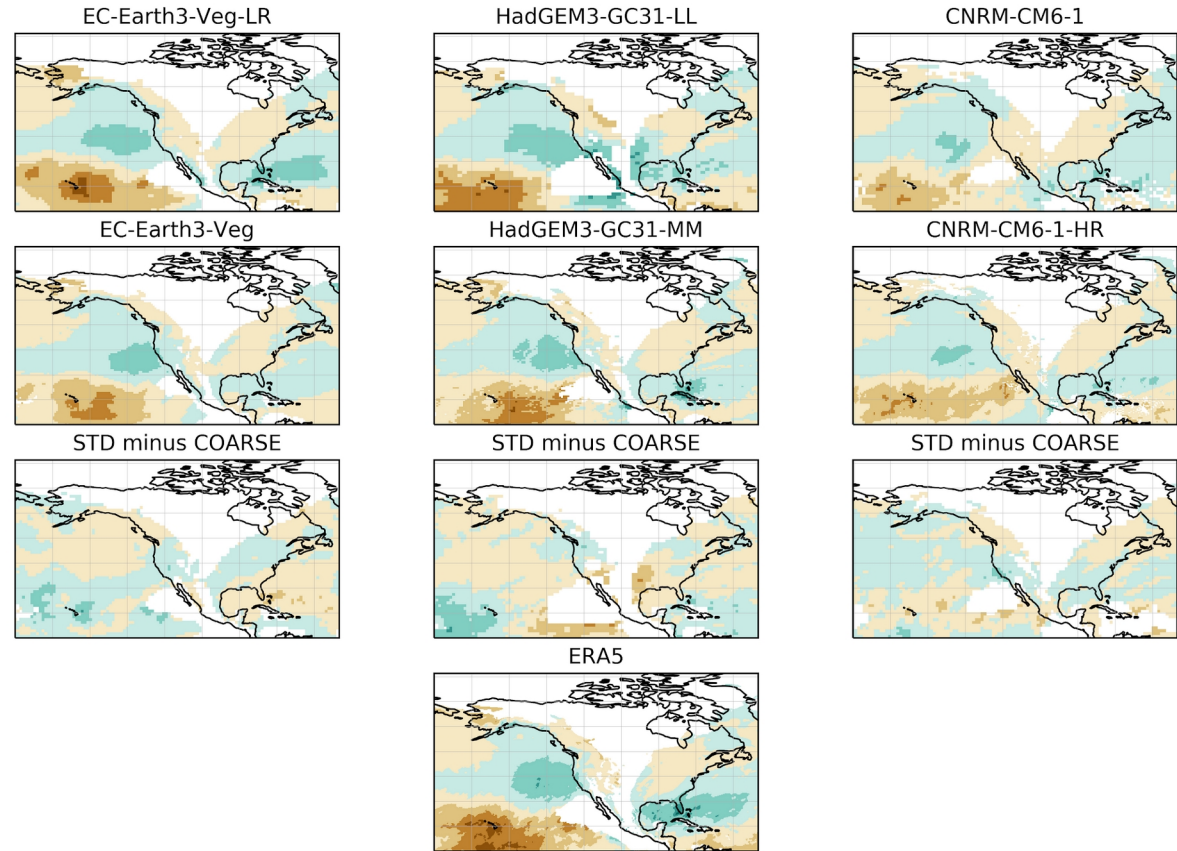
Correlation of mean seasonal precipitation on NINO3.4 index as percentage of mean DJF precipitation
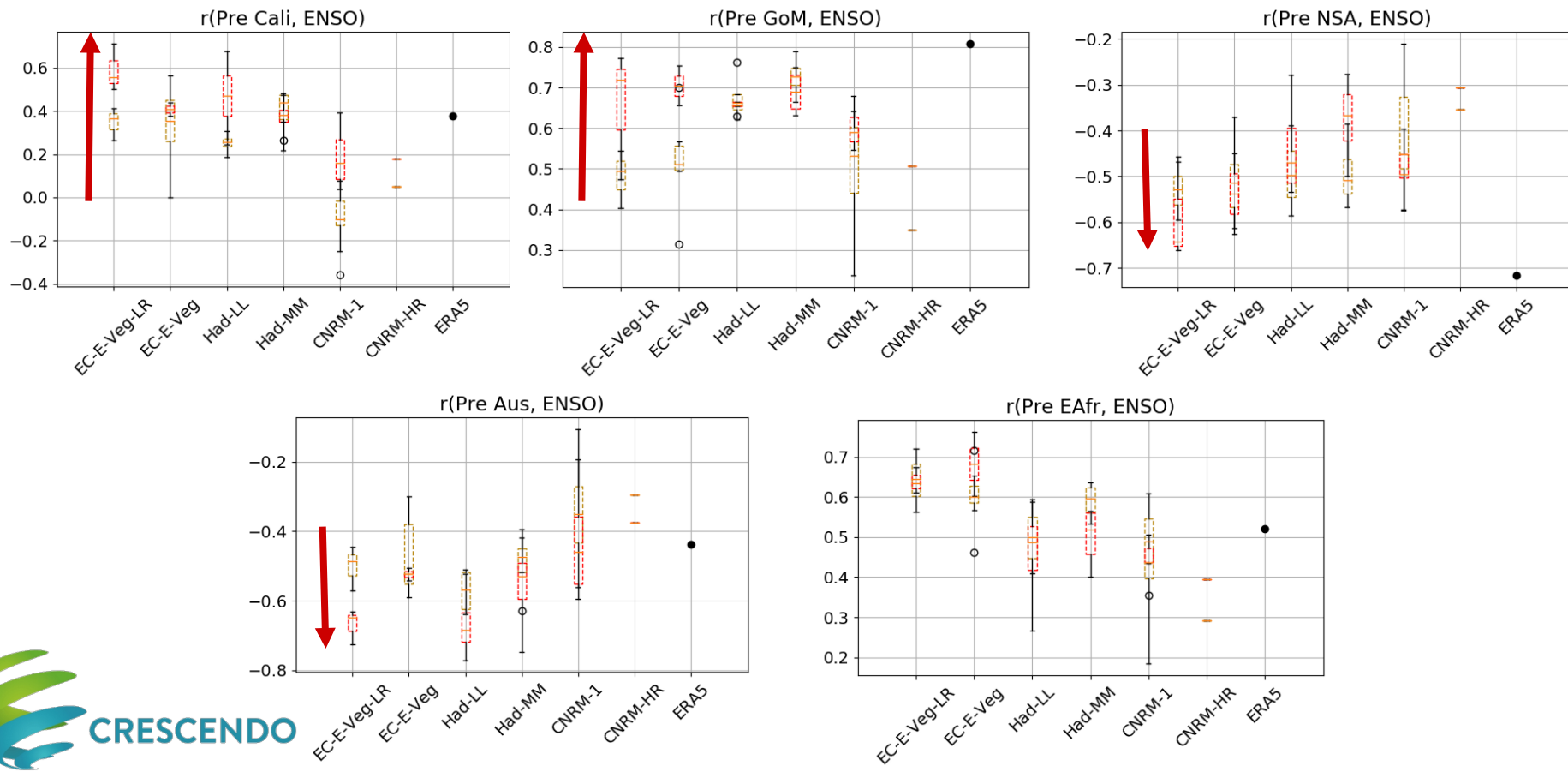
Some remarks

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- The future power spectra of the Nino3.4 index shows the main energy only in higher frequencies (2-4 years) in all models compared to historical simulations (2-8 years).   No consistent behaviour due to different resolution across models.

- We find a stronger connection between ENSO, PNA and NAO in the future simulations, causing even an intensification of the correlation (with statistically significance >95%) between the winter precipitation over Europe and ENSO, being the coarse resolution models that show this much stronger than in higher resolution.

- The mean DJF precipitation in all analysed regions shows a stronger correlation with ENSO (and/or NAO) in the future simulations under ssp5-8.5 scenario (except East Africa and Middle East). Being stronger this correlation in low resolution models.

Regression of mean seasonal precipitation on PNA index as percentage of mean DJF precipitation

The PNA-associated precipitation shows different regional responses at high resolution, with stronger precipitation response over the western North American coast, but decreased precipitation response over Hawaii, Florida and the Midwest US when compared with coarse resolution.

Regression of mean seasonal precipitation on NAO index as percentage of mean DJF precipitation
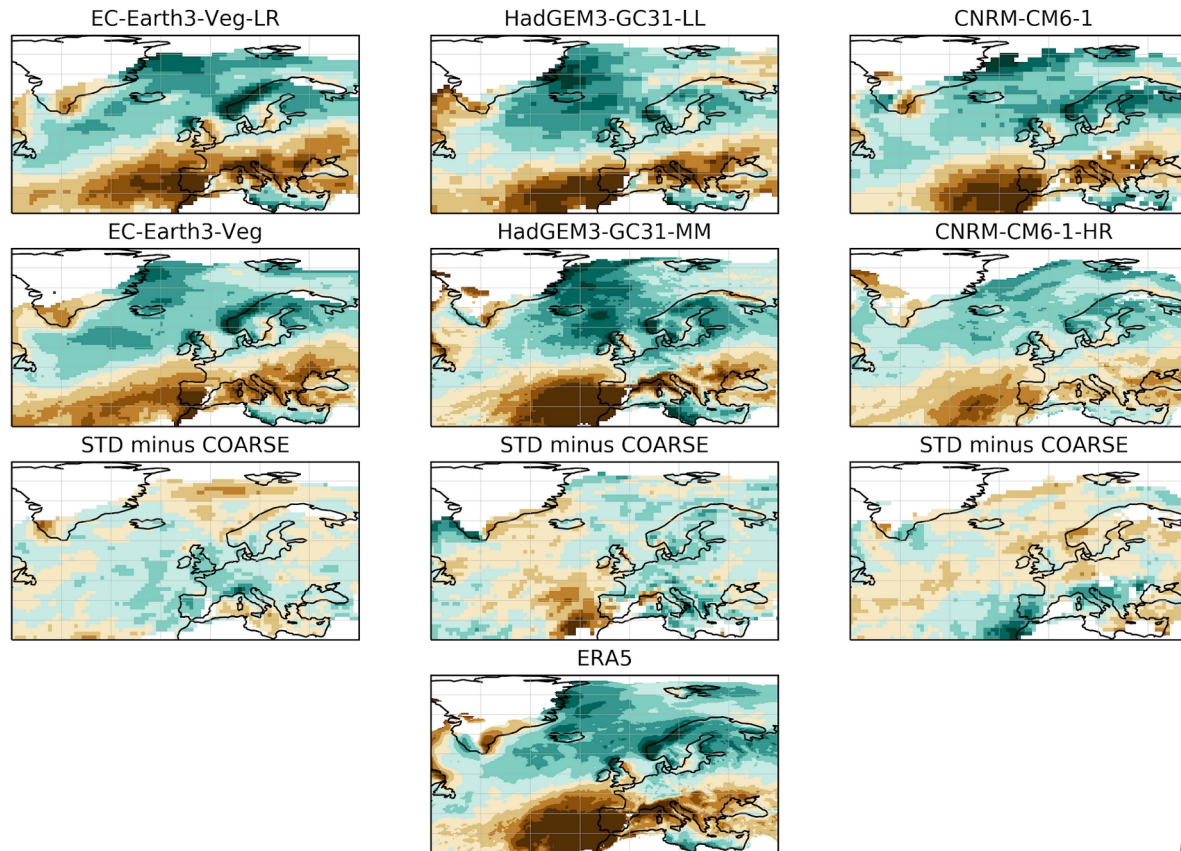
The coarse resolution models have a stronger precipitation response to NAO than the standard resolution models.