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Future changes in ENSO teleconnections over the North Pacific and North America in CMIP6 simulations

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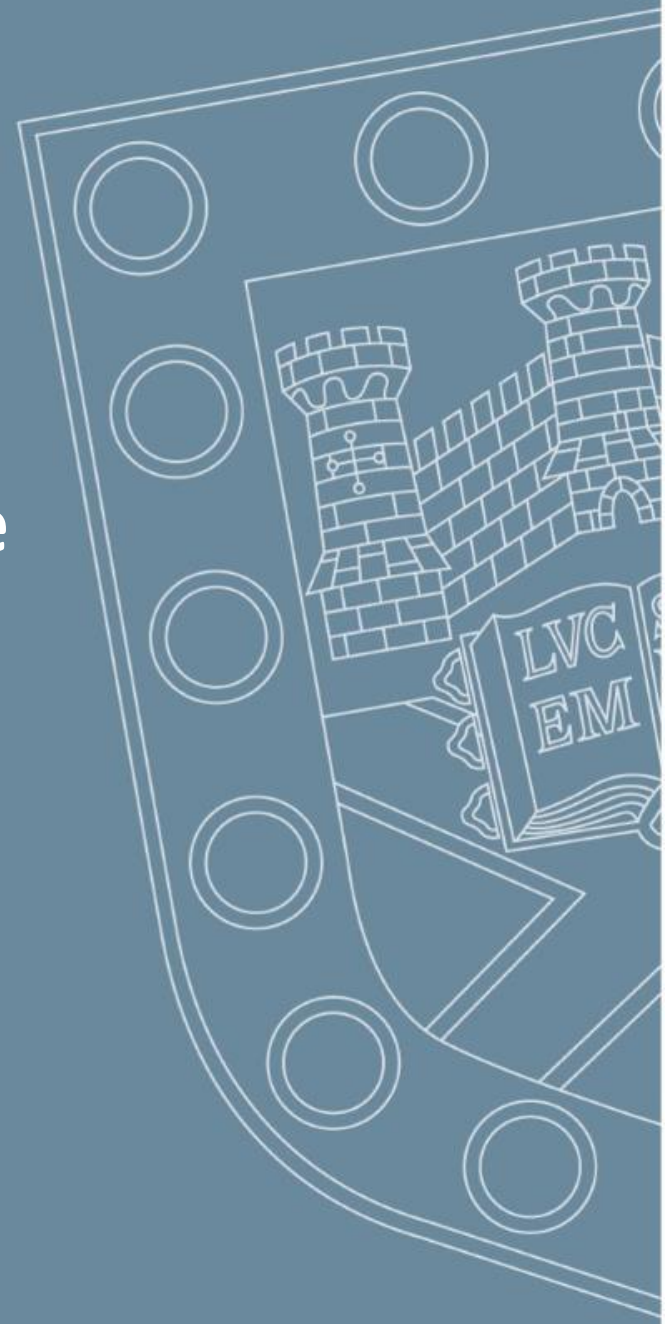

Overview

- El Niño-Southern Oscillation (ENSO) has major impacts on the weather and climate in many parts of the world
- It is therefore important to understand how the influence of ENSO may change under global warming

- The Coupled Model Intercomparison Project Phase 6 (CMIP6) provides a set of climate change simulations from the latest state-of-the-art climate models, performed using a common framework
- Here, we focus on the projected changes in El Niño teleconnections over North America

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Data and methods

- We use data from 17 CMIP6 models:
  - Pre-industrial control (piControl) – 450 years of data, with CO_2 concentrations set to represent conditions in 1850
  - abrupt-4xCO2 – 75 years of data, with CO_2 concentrations quadrupled from the global annual mean 1850 value
- ERA5 reanalysis data (1979-2018) is also used for comparison
- We focus here on northern hemisphere winter (DJF)

- When analysing the CMIP6 models, a year is defined as an El Niño year if the Niño 3.4 Index exceeds one standard deviation of the piControl DJF Niño 3.4 Index time series

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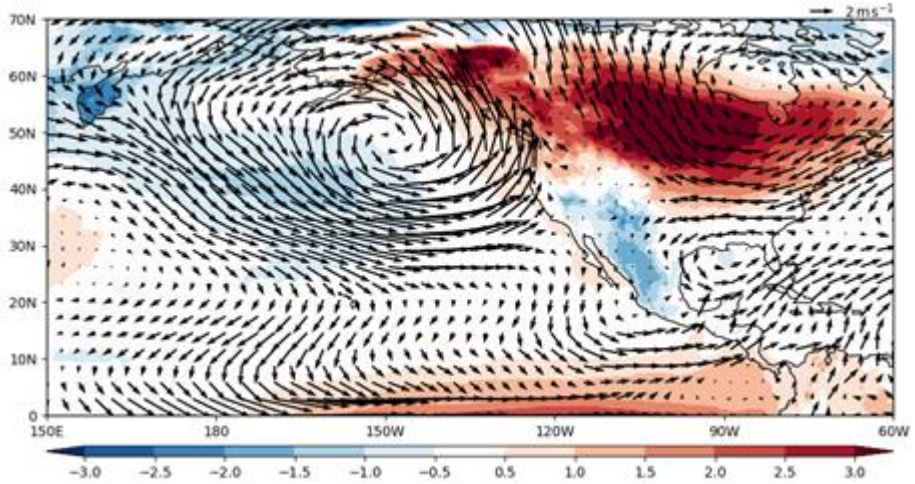
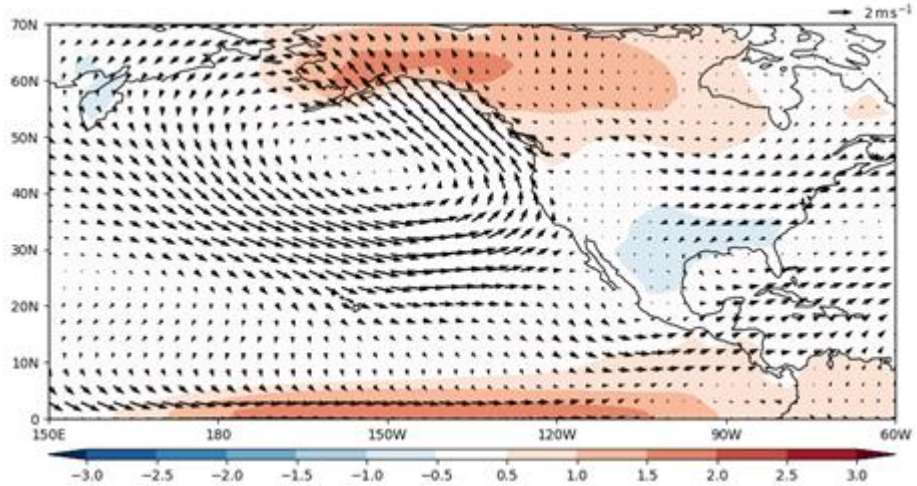
Present day teleconnection

ERA5 El Niño 2m temperature/850 hPa wind anomalies (DJF)



As above, but for the multi-model mean (MMM) piControl simulations (DJF)



- In the present day, El Niño events are associated with an anomalously deep Aleutian low and positive temperature anomalies across much of northern North America in DJF (top figure)
- This pattern is broadly captured by the CMIP6 models, with most models showing anomalous low pressure over the North Pacific and positive temperature anomalies over North America (bottom figure)
- The difference in magnitude between these two figures is largely an artefact of the averaging for the multi-model mean – individual models are generally closer in magnitude to the ERA5 anomalies

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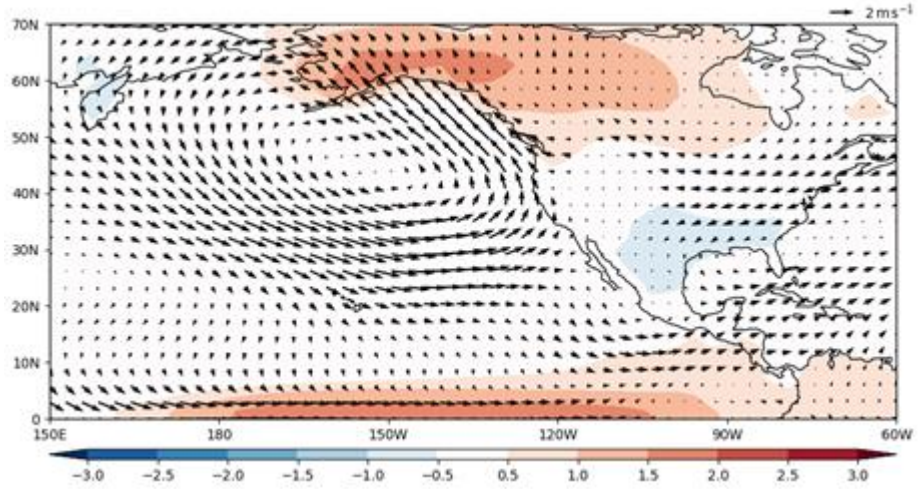
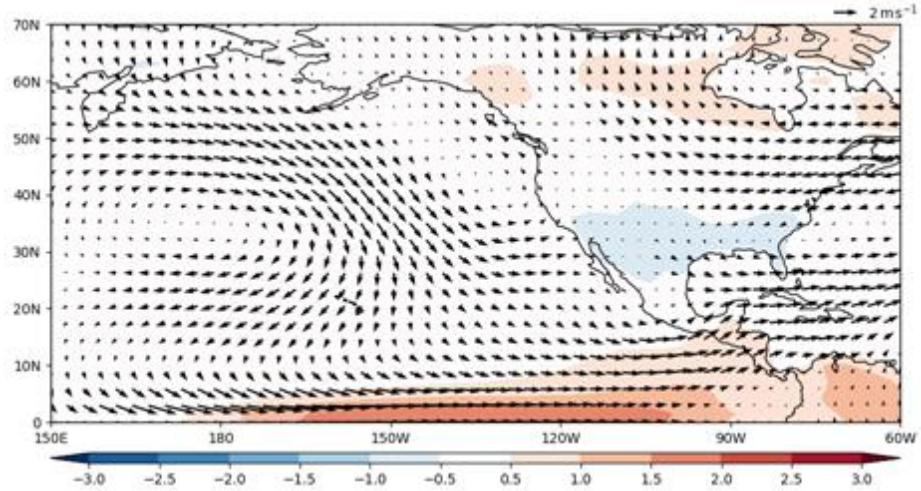
Future teleconnection changes

piControl multi-model mean El Niño surface temperature/850 hPa wind anomalies (DJF)



As above, but for the abrupt-4xCO2 simulations (DJF)



- In the abrupt-4xCO2 simulations, the temperature anomalies in El Niño years over northern North America are much weaker (15 out of 17 models agree on sign of change)
- This is partly associated with an eastward shift of the teleconnection pattern, as El Niño precipitation shifts eastwards due to faster warming in the eastern Pacific
- The anomalous circulation is also generally weaker, with most models simulating a weakening of the anomalous low pressure over the North Pacific, in addition to the eastward shift

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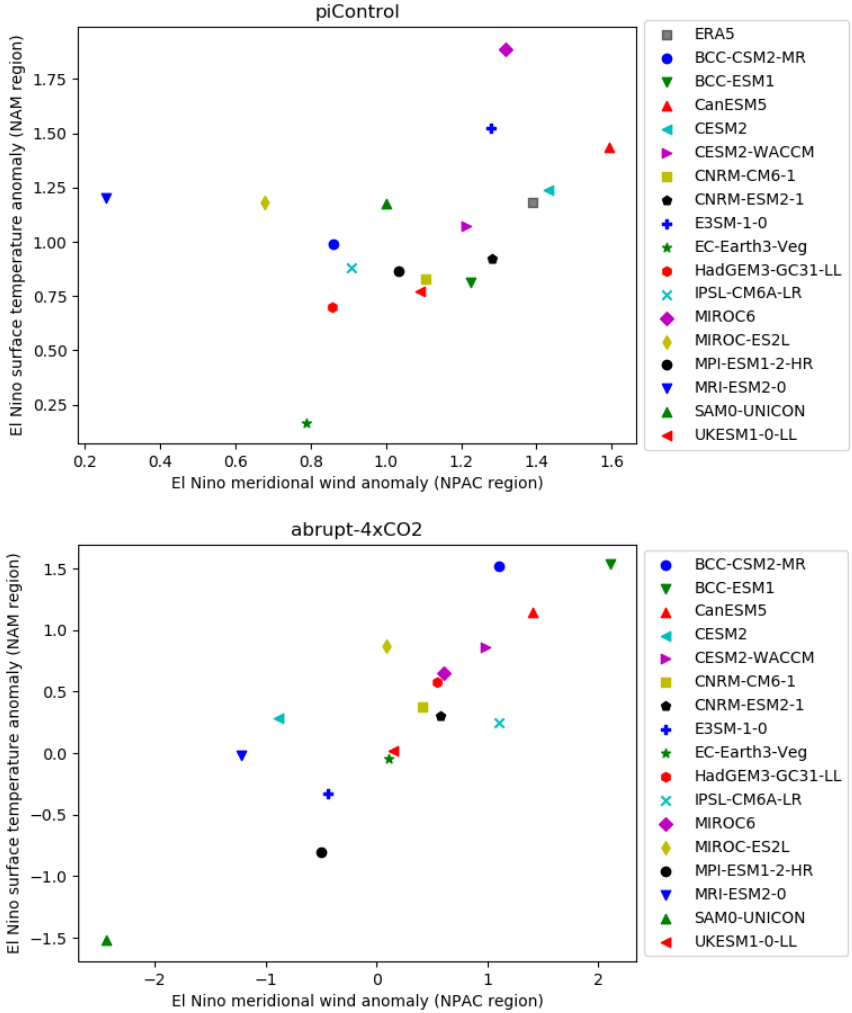
Future teleconnection changes



- In both the piControl (top) and abrupt-4xCO2 (bottom) simulations, the magnitude of the temperature anomalies over North America in El Niño years is closely related to the strength of the wind anomalies over the North Pacific, in almost all models
- This suggests that the changes to the El Niño circulation anomalies under global warming are the dominant cause of changes to the strength of the temperature anomalies over North America

NPAC (North Pacific) region = 50-60N, 160-130W
NAM (North America) region = 50-70N, 160-100W

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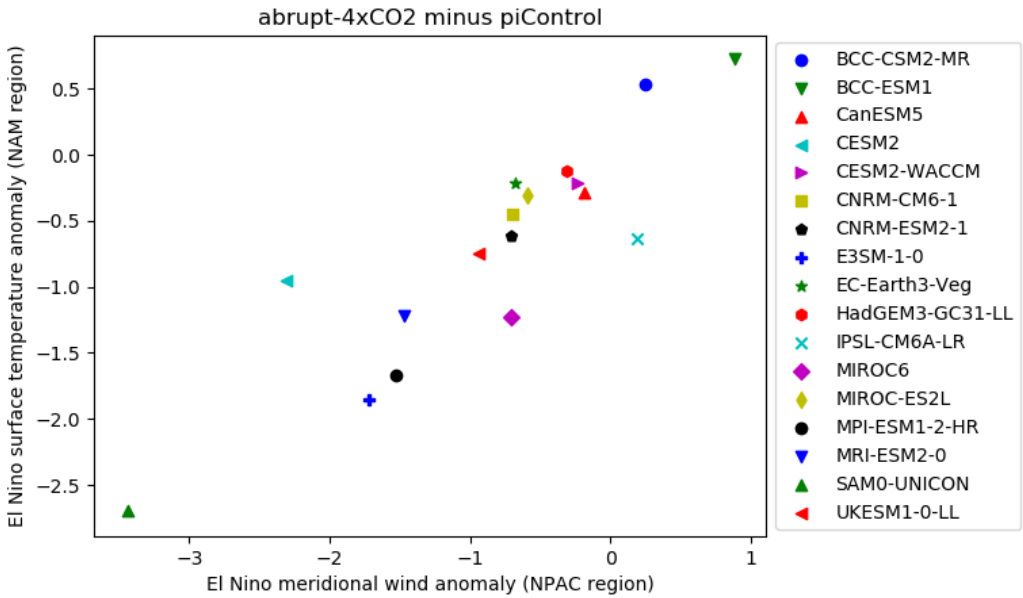
Future teleconnection changes



El Niño North America surface temperature anomaly change (abrupt-4xCO2 minus piControl) vs El Niño North Pacific meridional wind anomaly change (abrupt-4xCO2 minus piControl)

NPAC (North Pacific) region = 50-60N, 160-130W
NAM (North America) region = 50-70N, 160-100W

- This is further emphasised when looking at changes in both the temperature and wind anomalies over North America and the North Pacific, respectively, between piControl and abrupt-4xCO2
- There is a very strong correlation between the change in the temperature anomalies and the change in the wind anomalies (left)
- This further suggests that the change in the North America temperature teleconnection is largely related to the circulation changes, as opposed to changes in the temperature gradient (i.e. high latitudes warming faster than low latitudes)
- In addition, the spatial pattern and magnitude of the future change in El Niño temperature teleconnection can be predicted using only the change in North Pacific meridional wind anomaly and the present day wind-temperature relationship for around two-thirds of the CMIP6 models

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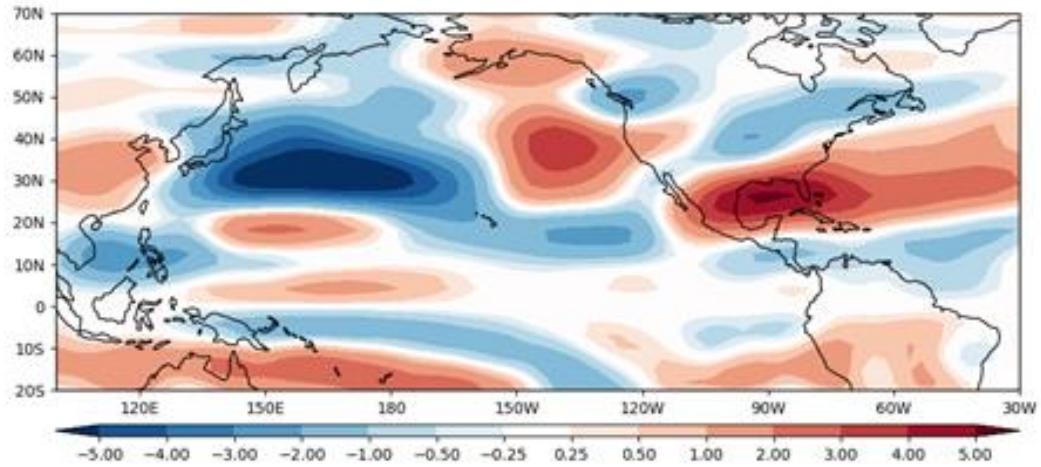
Possible causes – weaker forcing?

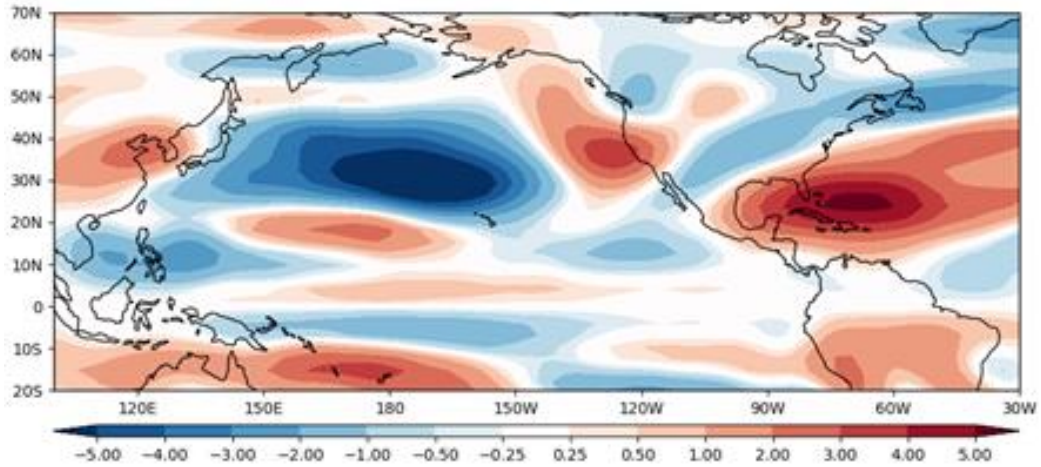
piControl multi-model mean El Niño 200 hPa fD anomaly

f = Coriolis parameter
D = divergence



abrupt-4xCO2 multi-model mean El Niño 200 hPa fD anomaly

f = Coriolis parameter
D = divergence



- Despite overall increases in precipitation associated with El Niño in the equatorial Pacific, the divergence at upper levels associated with this precipitation shows a future weakening at 200 hPa (left)
- This could result in weaker Rossby wave propagation from the equatorial Pacific to North America, and so a weakening of the El Niño anomalies in this region
- However, under future warming scenarios the tropopause height is expected to increase, so it could be that this divergence is occurring at higher levels – this requires further investigation, and barotropic model experiments are currently underway to help investigate this

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Summary

- El Niño is an important driver of temperature variability over much of northern North America
- In the CMIP6 abrupt-4xCO2 simulations, the anomalies associated with El Niño in the northern hemisphere winter (DJF) are projected to both shift eastwards and generally weaken
- 15 out of 17 models show a weakening of the El Niño temperature anomalies over North America/Alaska in abrupt-4xCO2
- This weakening of the temperature teleconnection is largely driven by changes in the anomalous circulation, as opposed to changes in the equator-to-pole temperature gradient
- One possible cause of this weakening over North America is a weaker forcing from the El Niño equatorial Pacific precipitation
- Divergence at upper levels (which drives Rossby waves) is weaker in abrupt-4xCO2 compared to piControl
- However, divergence is also expected to occur at higher levels as the tropopause height increases in a warmer atmosphere
- Barotropic model experiments are currently underway to help further understand the varying contributions of changes to the forcing and changes to the basic state

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