Impacts of the Atlantic Multidecadal Variability on tropical climate and tropical cyclone activity

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and
Fred Castruccio, Steve Yeager, Gokhan Danabasoglu

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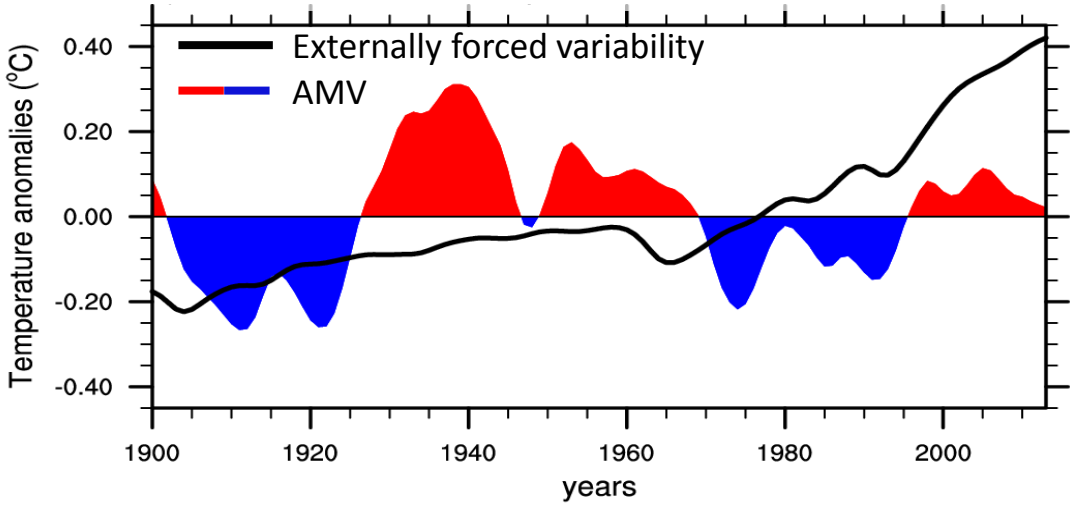
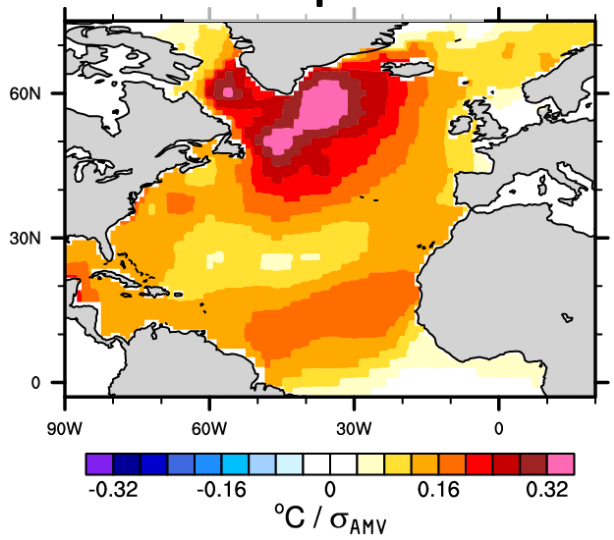
INADEC
H2020-MSCA-800154

AMV impacts on climate

North Atlantic SST time series (Ting et al. 2009)



AMV pattern



Atlantic Multidecadal Variability (AMV)

- Droughts over N. and S. America
- Europ. summer temperature
- Sahel drought
- Arctic sea-ice
- Occurrence of weather extremes
- Tropical cyclone activity
- Hiatus

<u>Motivations</u>:
AMV and impacts possibly predictable multiyear ahead

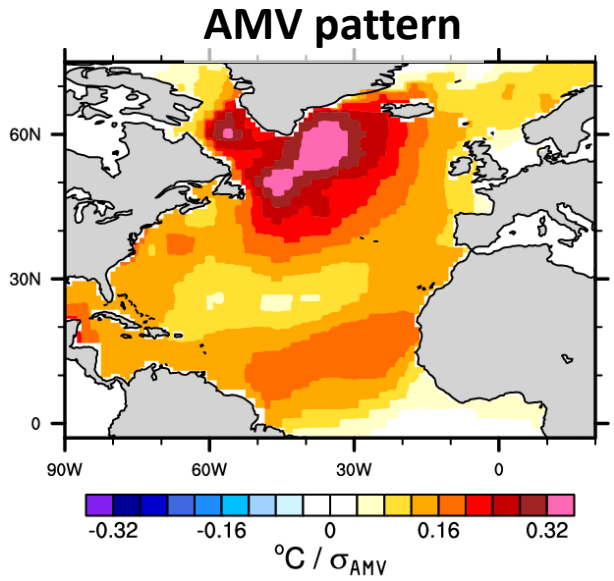
<u>Limits</u>:
Too short historical records
→ AMV teleconnections not fully understood

Experimental design

North Atlantic SSTs (5°N-70°N) restored to the **observed AMV pattern** with a 5/15-day restoring time scale

10yr long large ensemble experiments

Free ocean-ice-land-atmosphere interactions outside the Atlantic



AMV+ ensemble: daily North Atlantic SST → daily Climatology **+ AMV pattern**

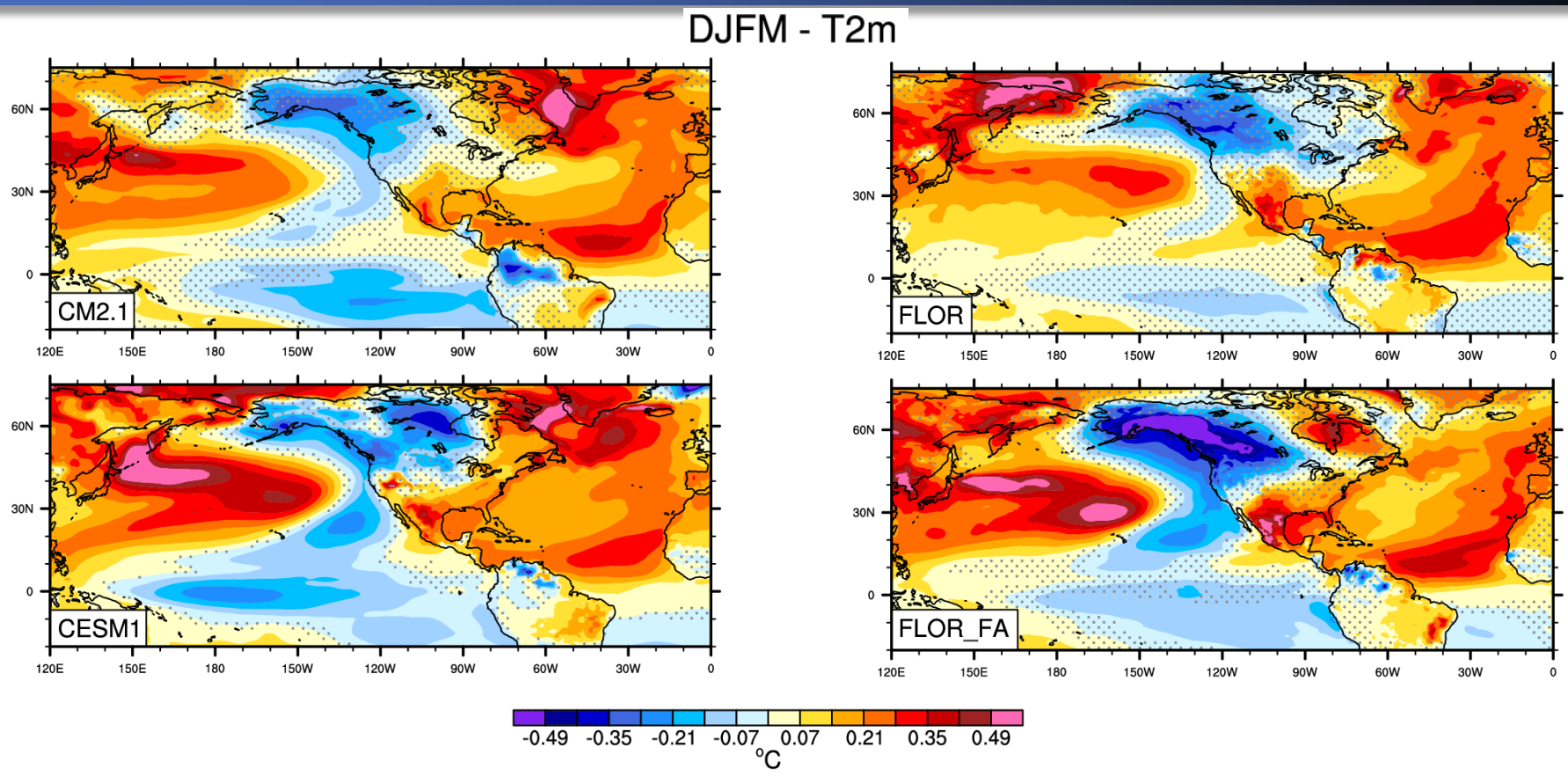
AMV- ensemble: daily North Atlantic SST → daily Climatology **- AMV pattern**

4 climate models

GFDL-CM2.1 = 1° ocean / **200km** atmo ➔ 100 members
NCAR-CESM1 = 1° ocean / **100km** atmo ➔ 30 members
GFDL-FLOR = 1° ocean / **50km** atmo ➔ 50 members
GFDL-FLOR_FA = GFDL-FLOR + surface flux adjustment to reduce mean SST biases

Protocol adopted by Decadal Climate Prediction Panel of CMIP6 (Boer et al. GMD 2016)

AMV impacts on Pacific

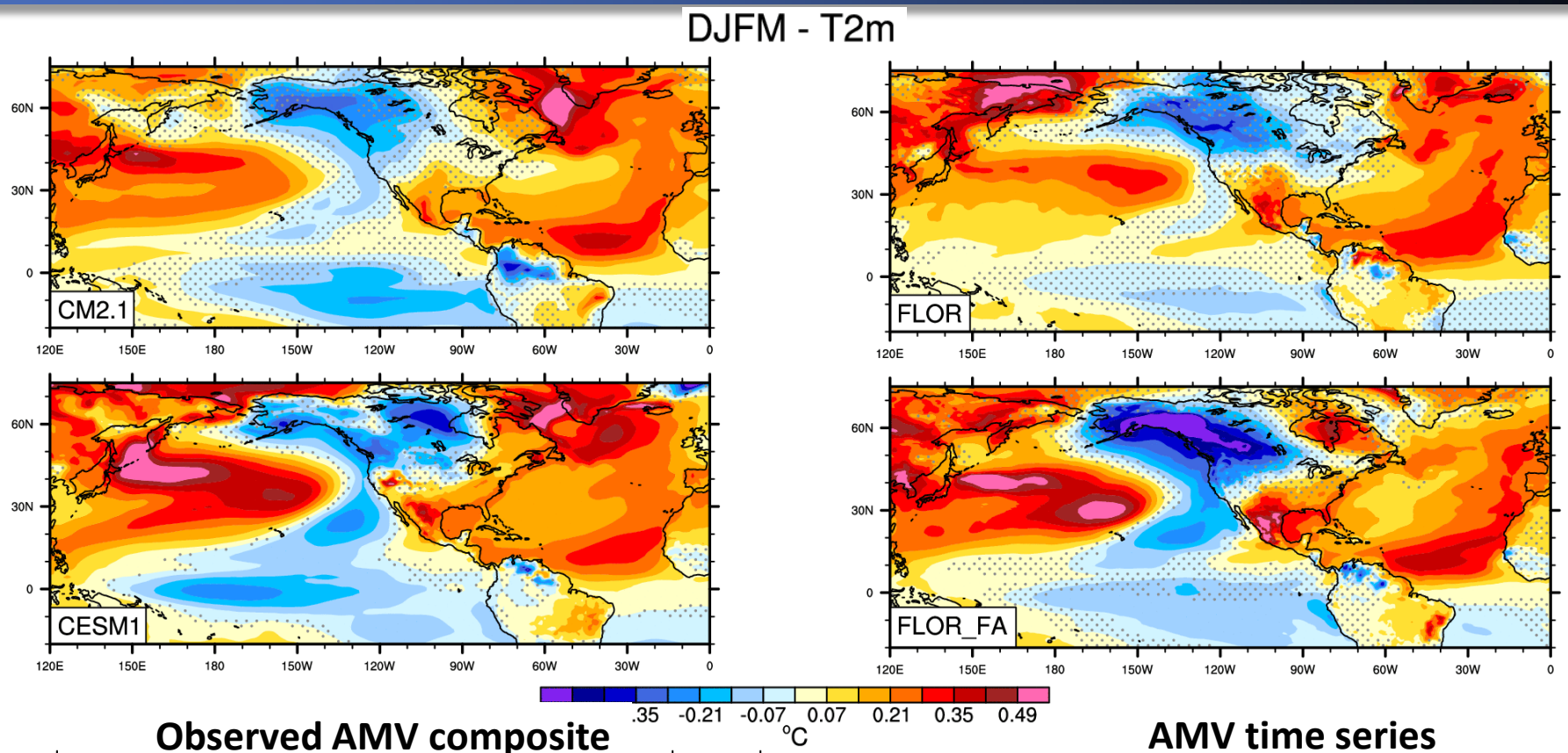


Response

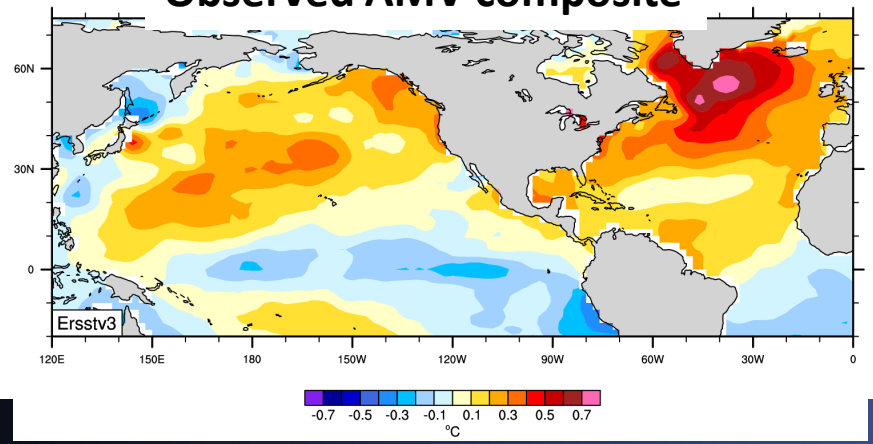
AMV+ minus **AMV-**

AMV+ leads negative phase of Pacific Decadal Oscillation

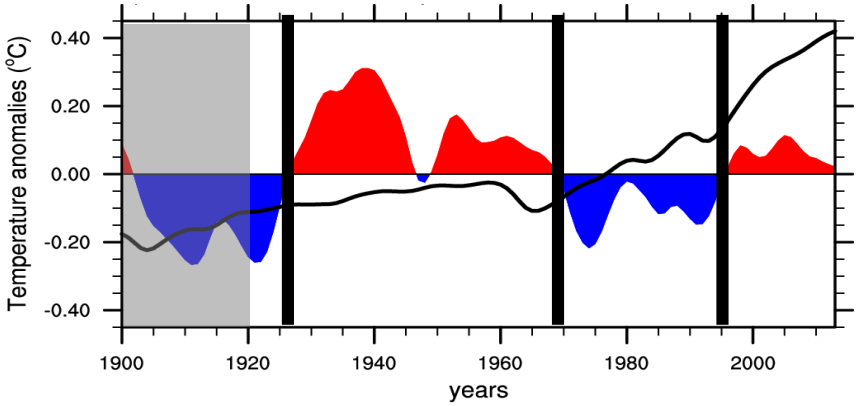
AMV impacts on Pacific



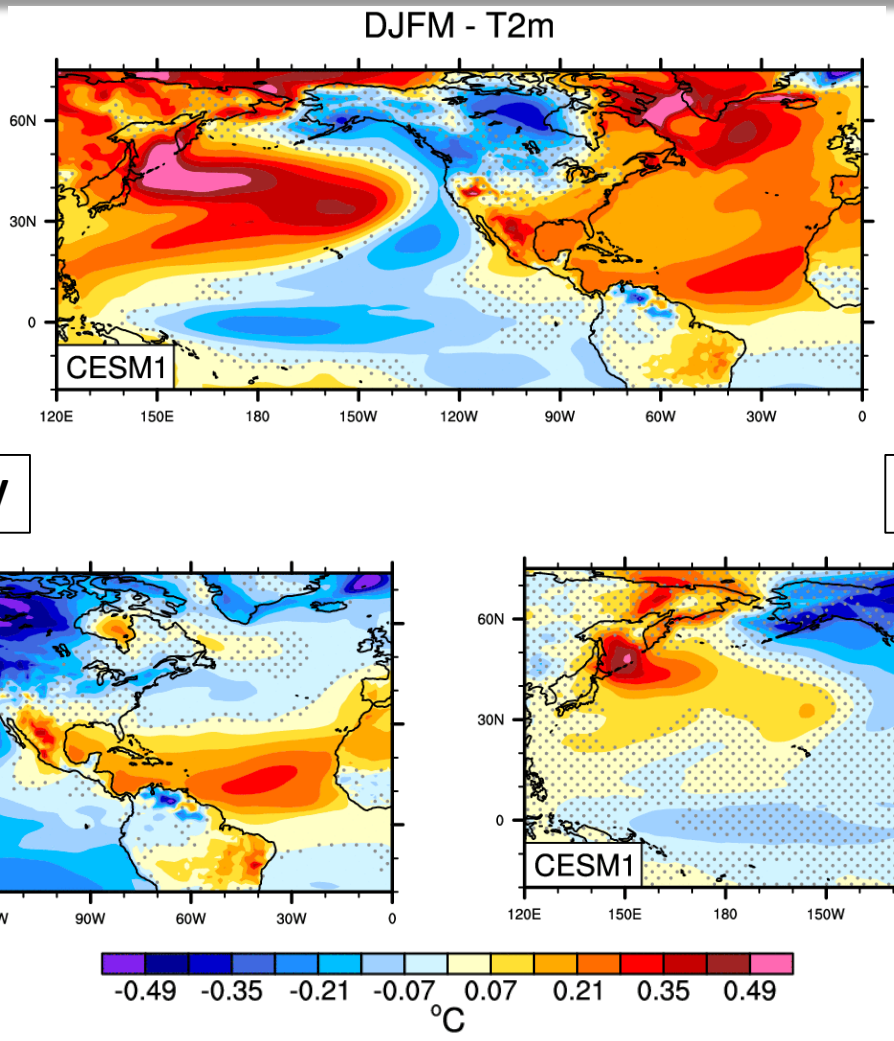
Observed AMV composite



AMV time series



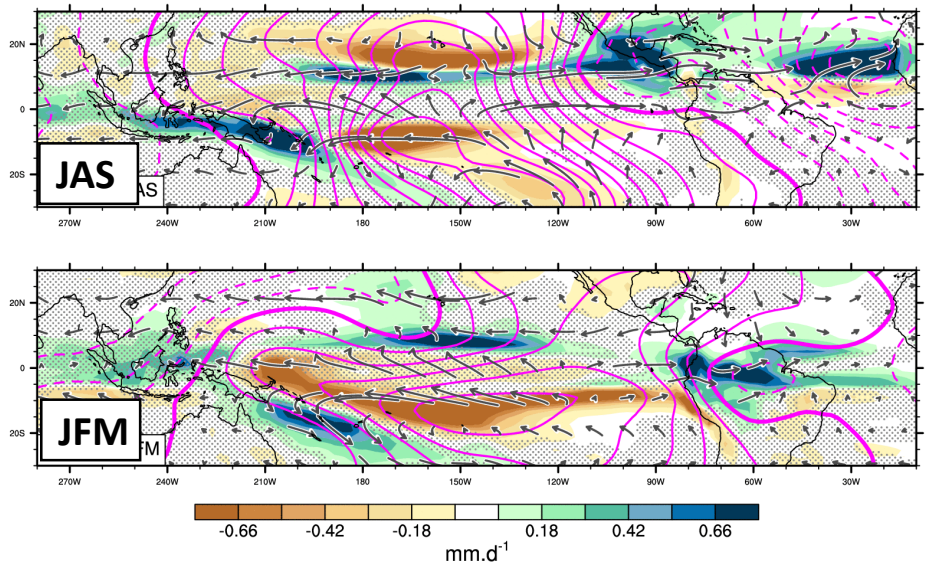
Origins of AMV impacts on Pacific



Tropical part of AMV forces Pacific response

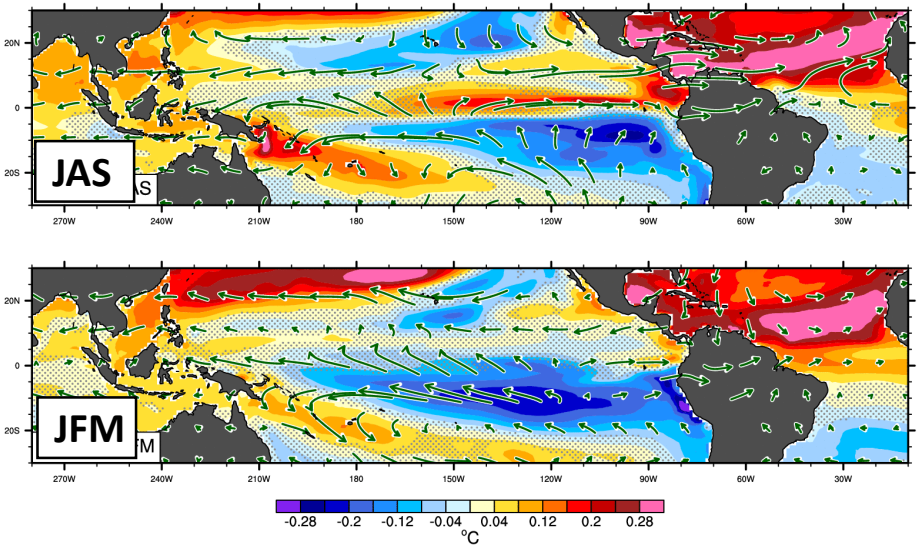
AMV impacts on Pacific: mechanism

CM2.1 – Full_AMV



Colors: precipitation
Contours: velocity potential@200hPa (wind divergence)
Arrows: wind@850hPa

CM2.1 – Full_AMV



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AMV impacts on Pacific: mechanism

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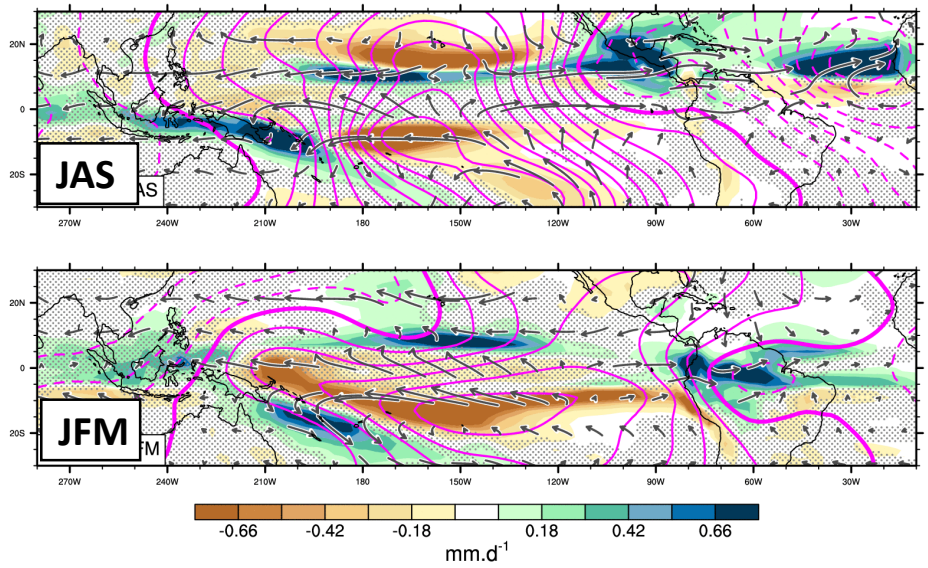

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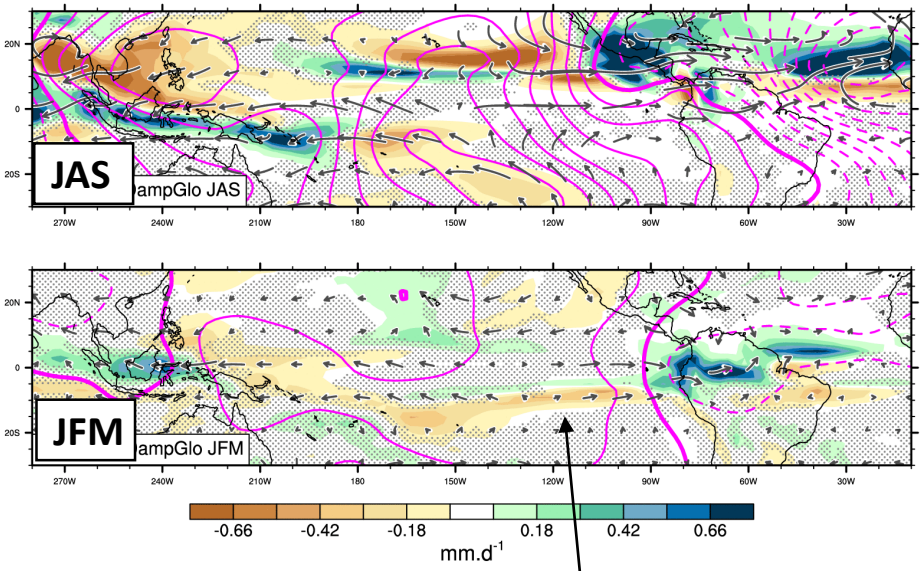
CM2.1 – Damped_Global_AMV



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SST restored to its climatology

AMV impacts on Pacific: mechanism

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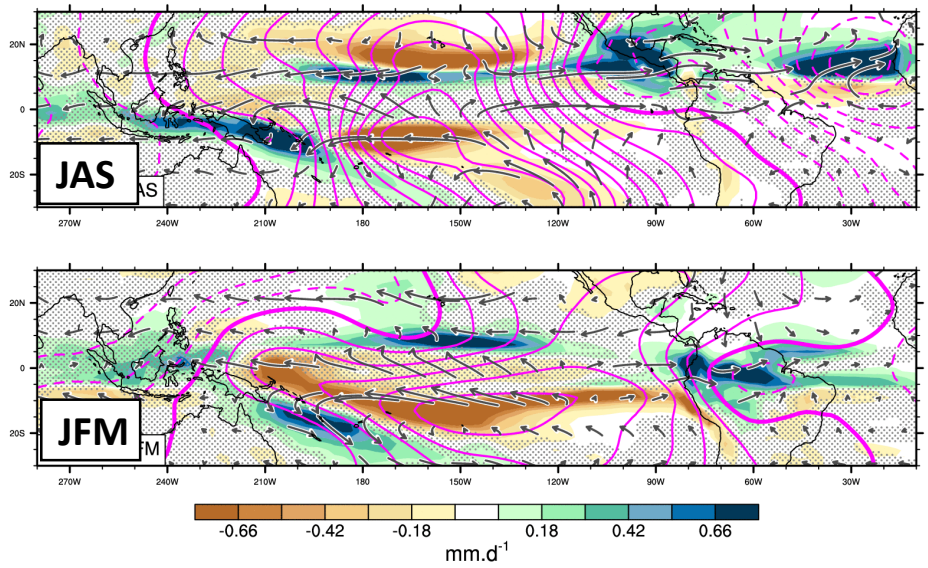

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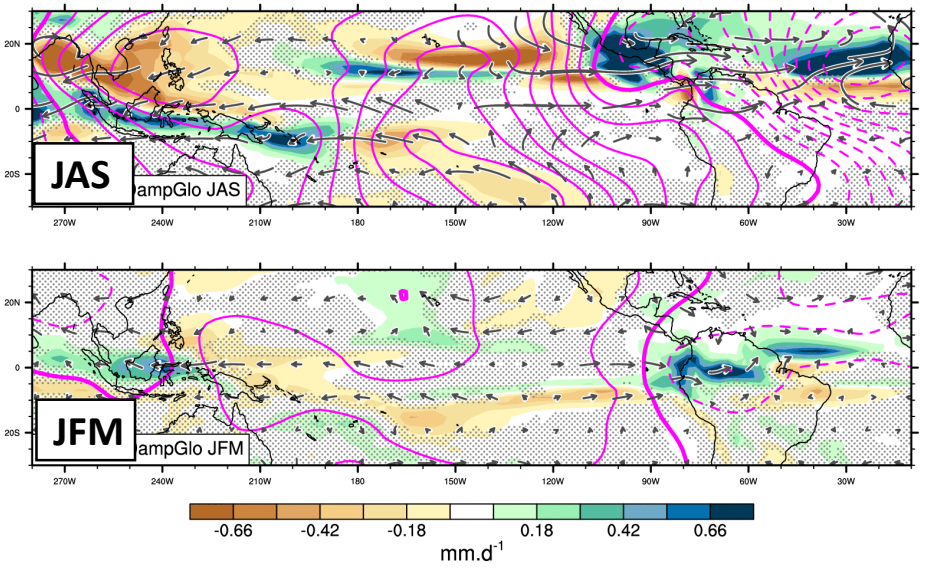

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Winter Tropical Pacific response = lagged adjustment to summer AMV forcing

Cf. Li et al. 2015: Atlantic-induced pan-tropical climate change over the past three decades
+ McGregor et al. 2014, Kucharski et al. 2012, 2015

AMV impacts on Tropical Cyclones

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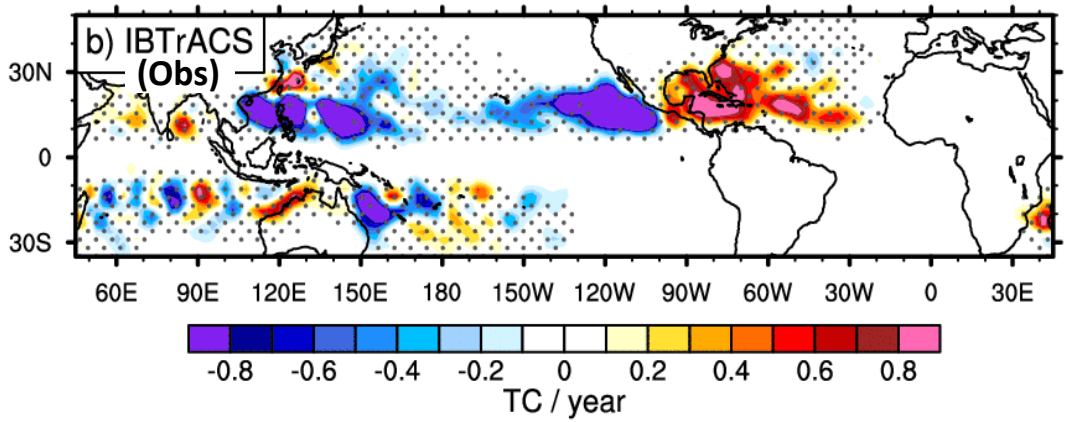
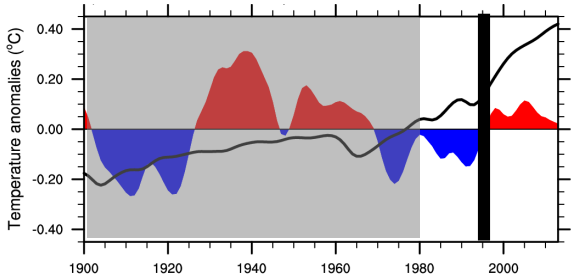
MJJASON Tropical Cyclone Density





Obs = 1996-2011 vs 1980-1995

AMV impacts on Tropical Cyclones

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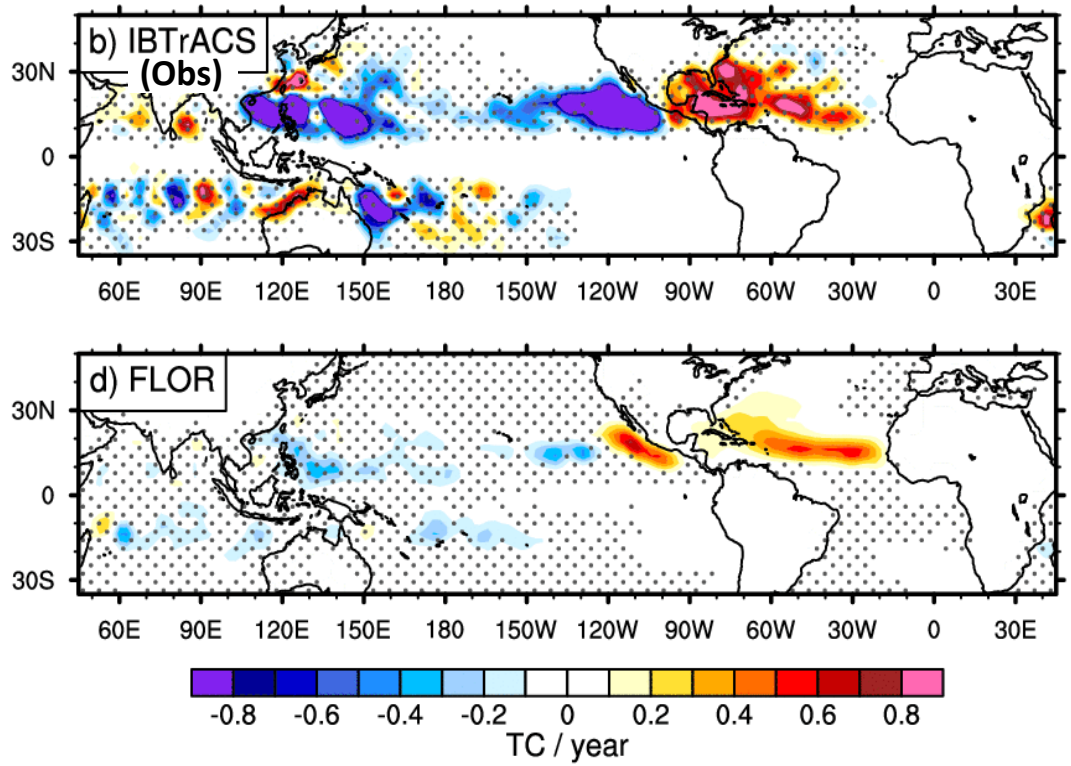

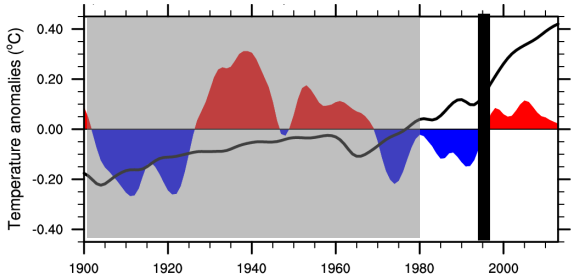

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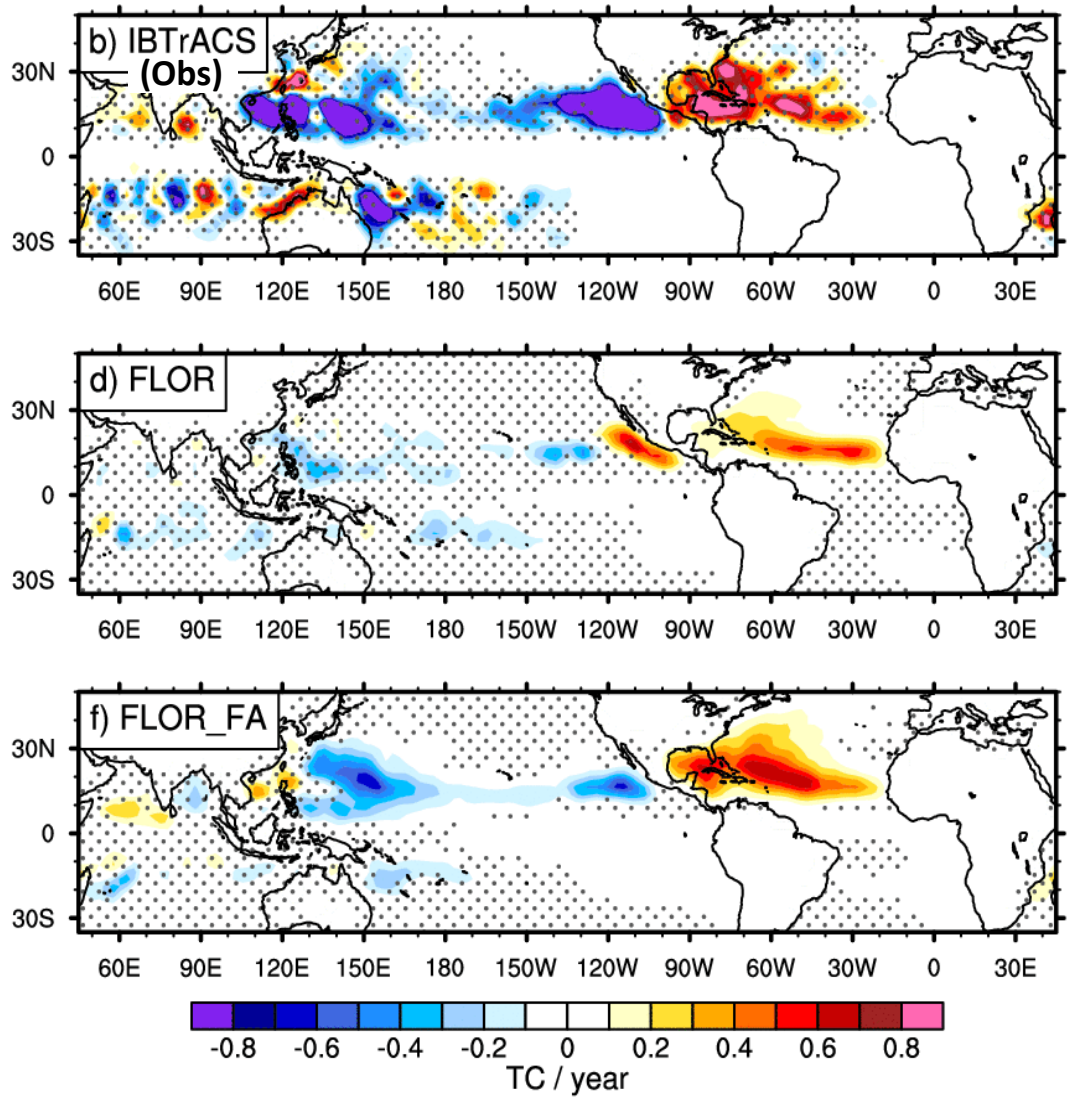

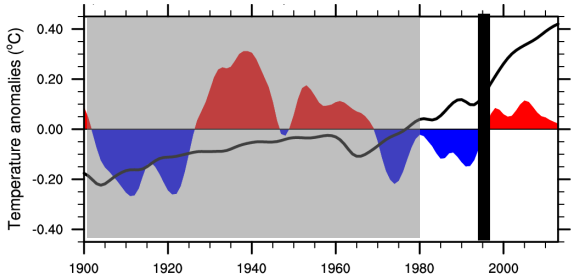

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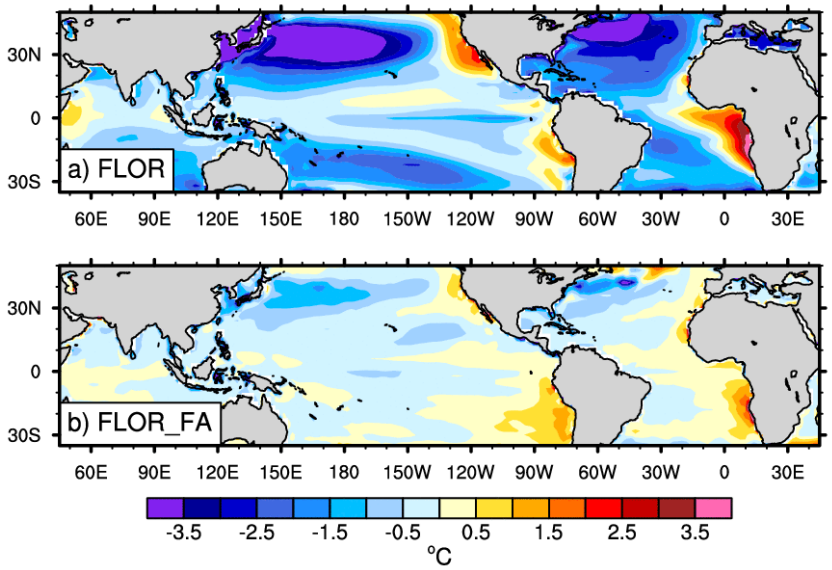
MJJASON sst biases



Conclusion

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Modulation of CO2 forced response by AMV / AMOC

Geophysical Research Letters
AN AGU JOURNAL

Research Letter

Influence of the Atlantic meridional overturning circulation on the tropical climate response to CO_2 forcing

Jessica Vial, Christophe Cassou, Francis Codron, Sandrine Bony, Yohan ruprich-robert

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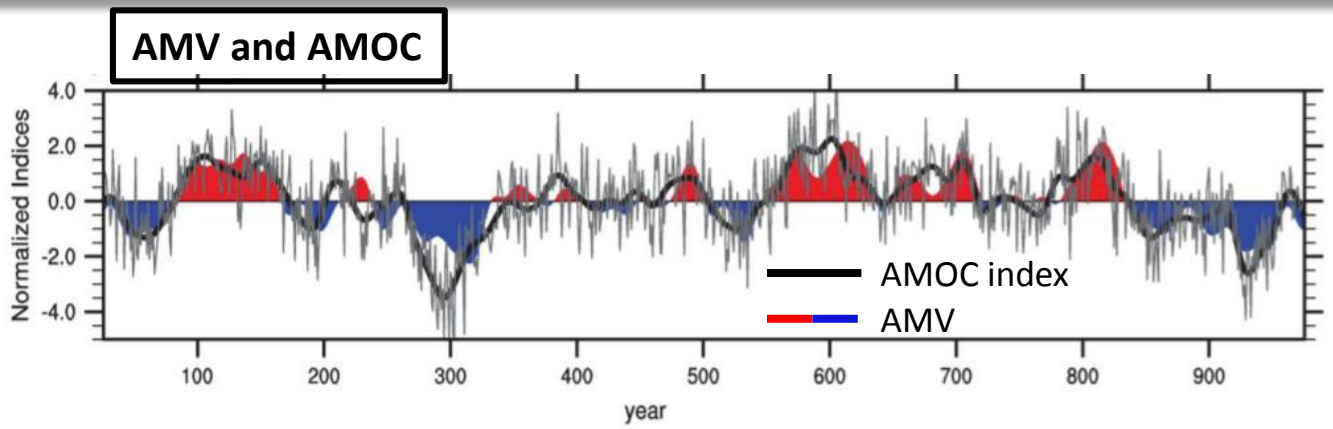
Abstract

The increase of atmospheric greenhouse gases is expected to affect the hydrological cycle and large-scale precipitation patterns. In parallel, unforced natural variability on decadal to multidecadal timescales can also modulate forced changes at the regional scales. Based on multi-member ensembles from a coupled General Circulation Model, we investigate the sensitivity of CO_2-forced changes in tropical precipitation and atmospheric circulation to fluctuations of the Atlantic Multidecadal Overturning Circulation (AMOC). We show that contrasted AMOC states yield considerable differences in equatorial Pacific precipitation forced changes, by impacting the direct (within a year) CO_2-induced weakening of the Walker circulation. We use global atmospheric energetics, as a theoretical backdrop, to explain the relationship between the tropical atmospheric circulation and the AMOC state. A physical mechanism is then proposed, relating the direct CO_2-forced weakening of the atmospheric tropical

Modulation of CO2 forced response by AMV / AMOC

CNRM-CM5
Preindustrial
Control simulation



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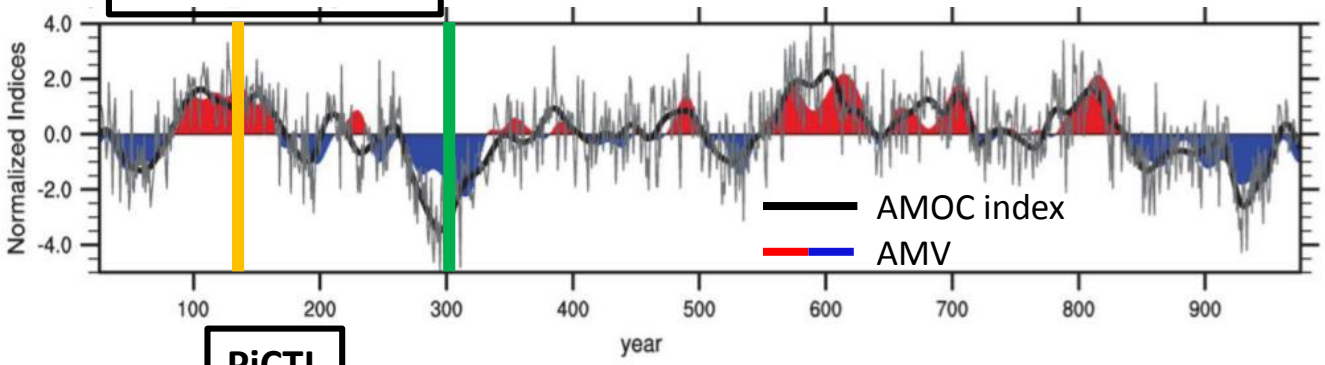
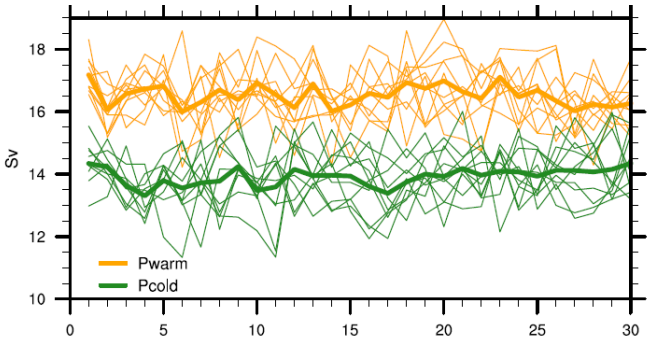
AMV and AMOC

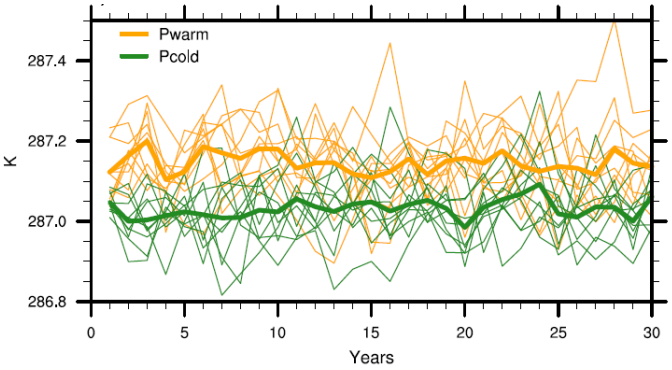


PiCTL

AMOC index



Global mean temperature



10 members with perturbed initial conditions
(perfect model framework predictability)

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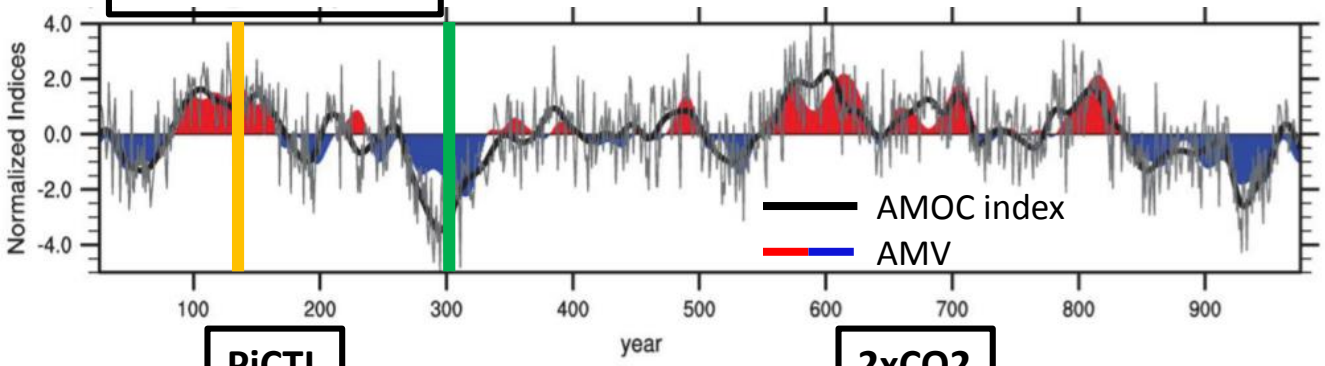
AMV and AMOC



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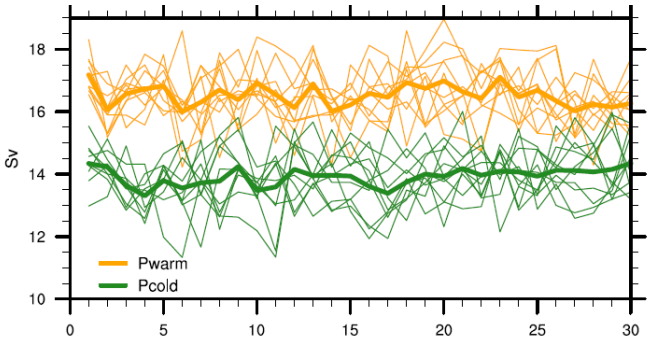
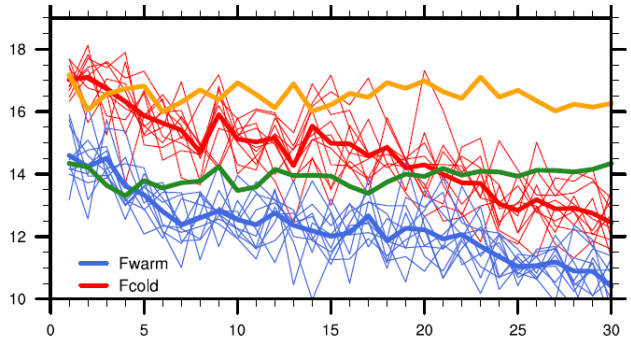
2xCO2

AMOC index





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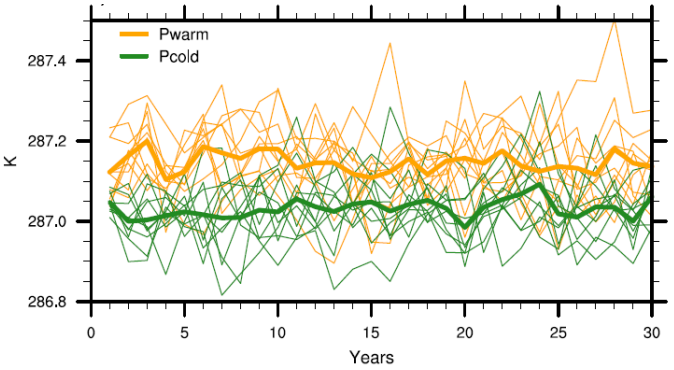

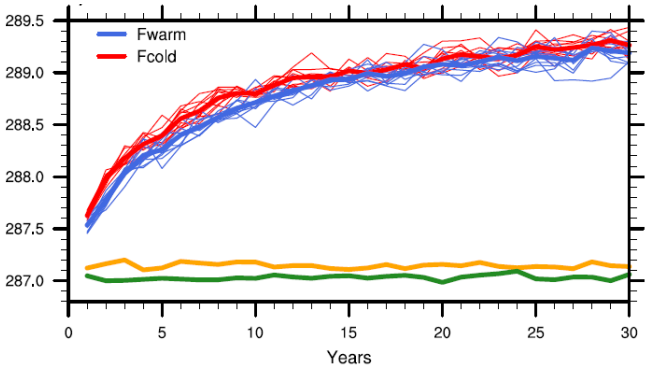

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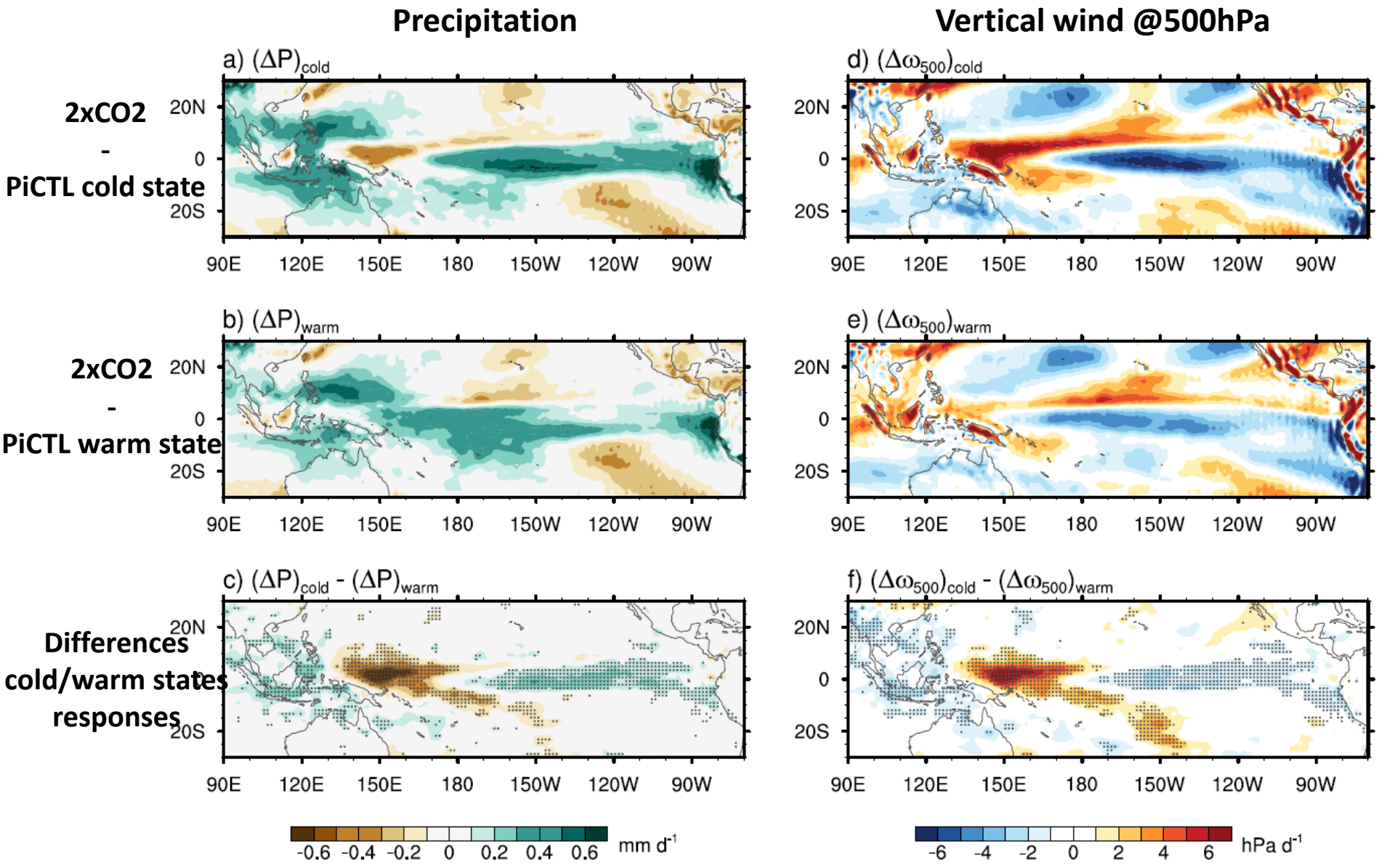

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- AMV+ drives TC+ over Atlantic → SST and Wind Shear (+ humidity?)
- AMV+ drives TC- over Pacific → Wind Shear and Vorticity

Need to correct mean SST biases to capture the observed signal

- AMV / AMOC has the potential to modulate future response to CO2 increase
  - ➢ Modulation of Walker circulation response: the rapid adjustment of atmospheric circulation to radiative forcing is dependent of mean state.

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Ruprich-Robert et al. (2018): Impacts of the Atlantic Multidecadal Variability on tropical climate and tropical cyclone activity. In prep.
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Thank you!

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