Climate variability : Which climate models? What questions?

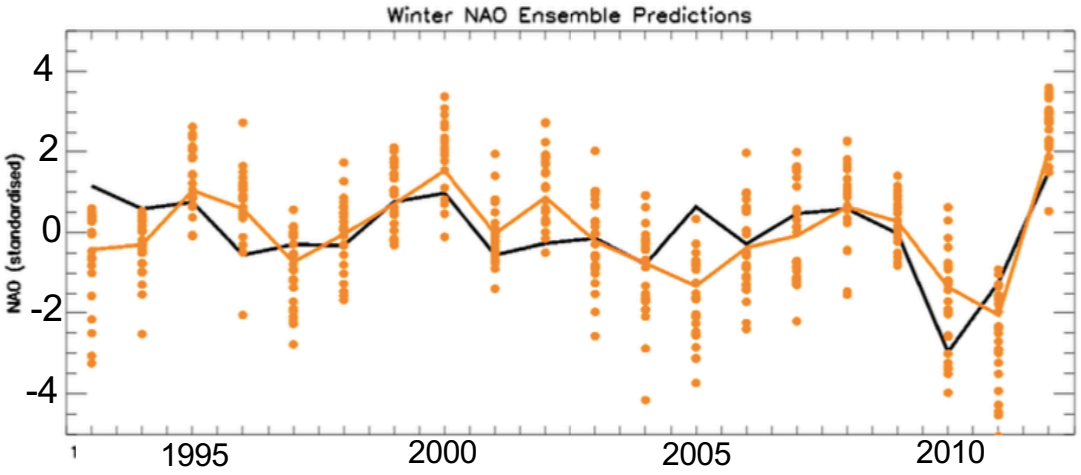
Frederique Cheruy, Francis Codron, Julie Deshayes, Brady Fester, Sébastien Fromang, Frederic Hourdin, Guillaume Gastineau, Eric Guilyardi, Juliette Mignot, Gwendal Rivière, Yona Silvy, Didier Swingedouw

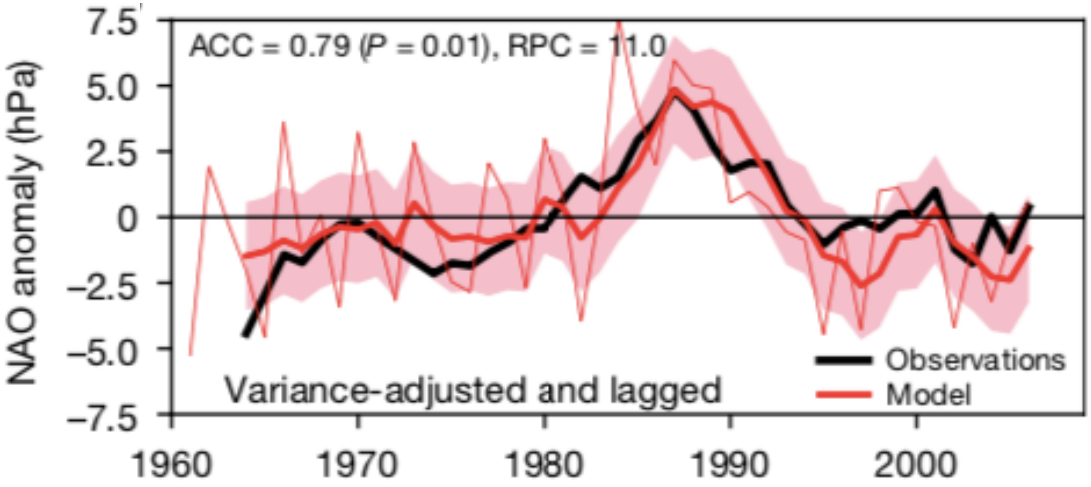
IPSL, Paris, France

Signal to noise issues in models

Seasonal forecast

Scaife et al. 2014





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Smith et al. 2020

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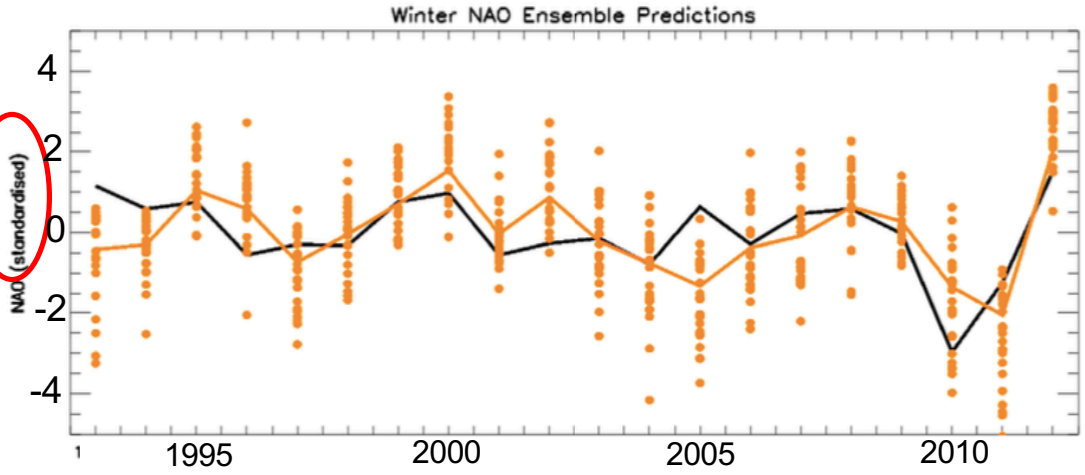

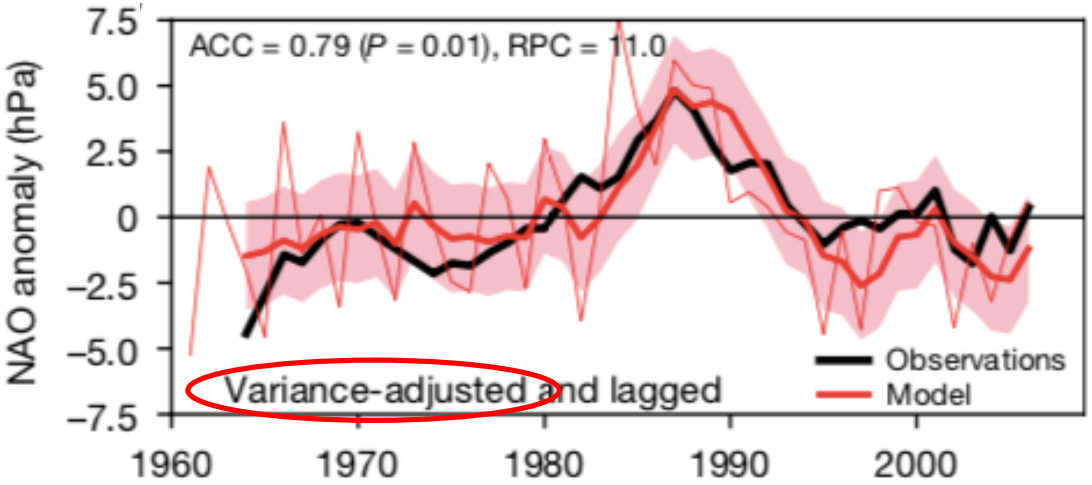

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Skillfull Anomalie are weak and amplified…

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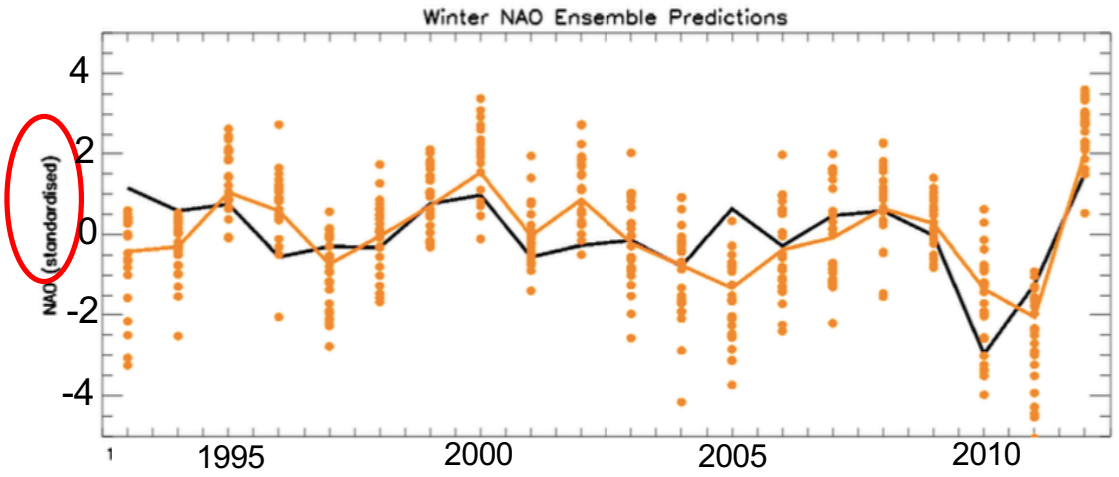

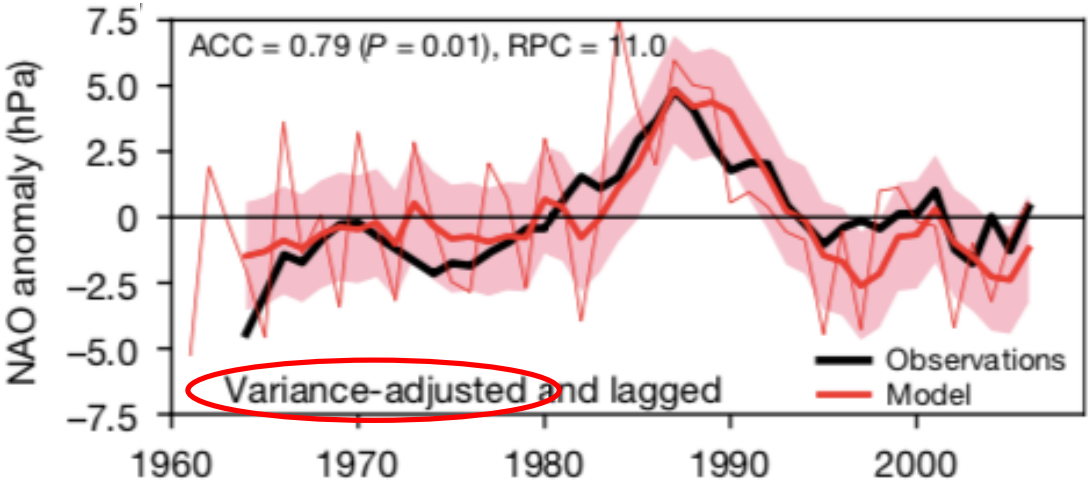

Decadal forecast

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Skillfull Anomalie are weak and amplified…

- overestimated chaotic/unpredictable climate variability,
- low sensitivity of atmosphere to its boundary conditions.

Signal to noise issues in models

Found in many context:

- response to volcanoes,
- ozone hole climate anomalies,
- response to sea-ice loss,
- …

-> large ensemble needed

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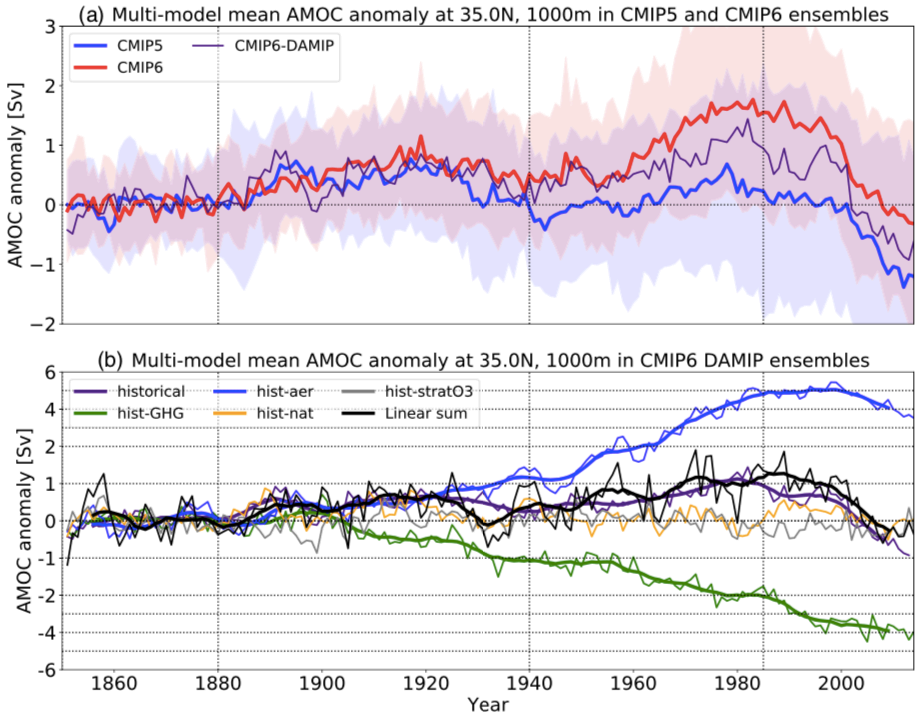
Explanation for these issues? ‘’ *lack of extratropical ocean–atmosphere coupling, weak eddy feedback in current resolution models, errors in remote teleconnections, or errors in parametrised processes such as atmospheric convection*’’ (Scaife and Smith, 2018)

Forced climate variability

North Atlantic case

‘’The [SST] correlation in 38 forced (HIST) models […] explain up to 56% of the observed variance. […] There is an essential role for external forcing in driving the observed AMO.” (Murphy et al., 2017)



From Menary et al. 2020

-> large ensemble needed

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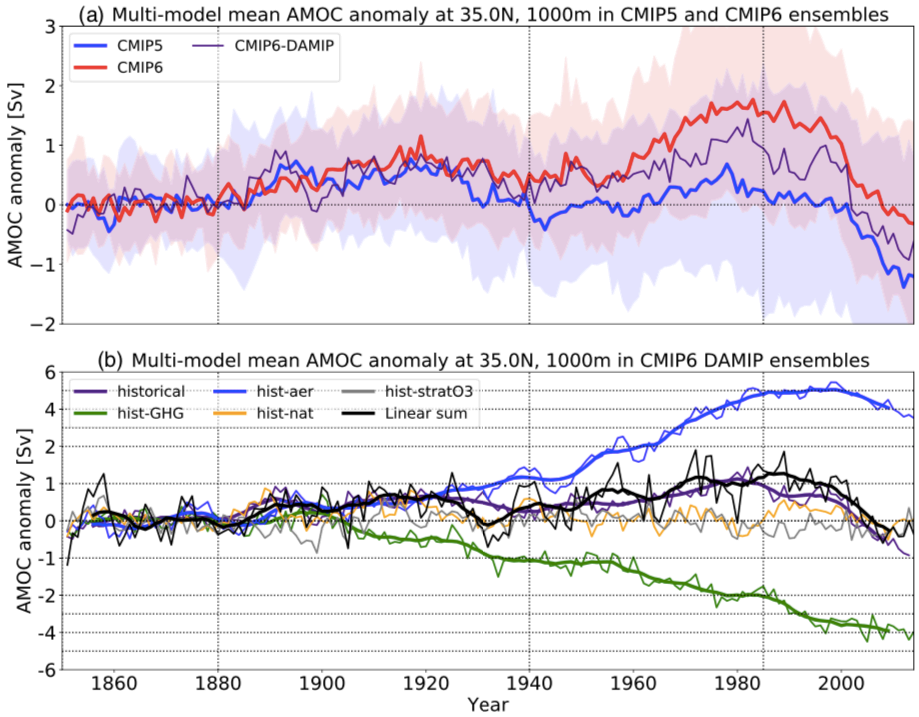

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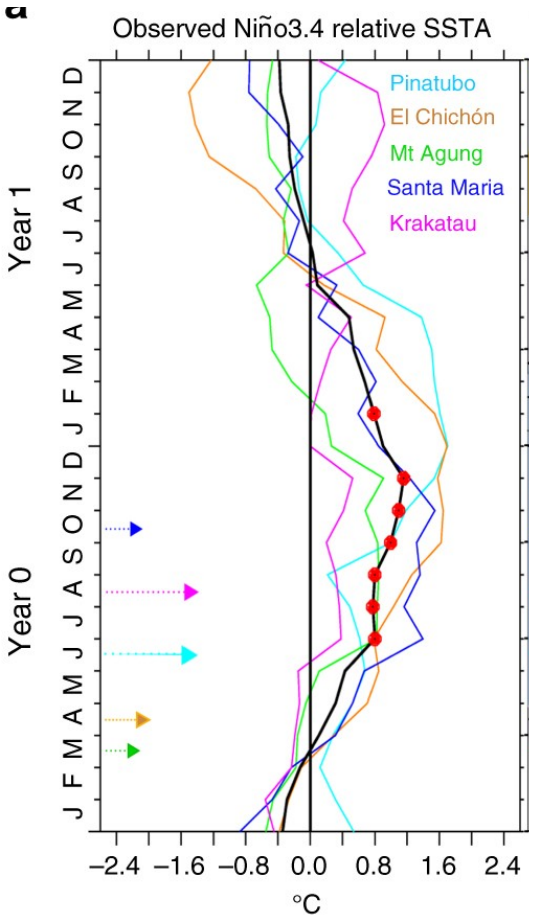
Equatorial Pacific case

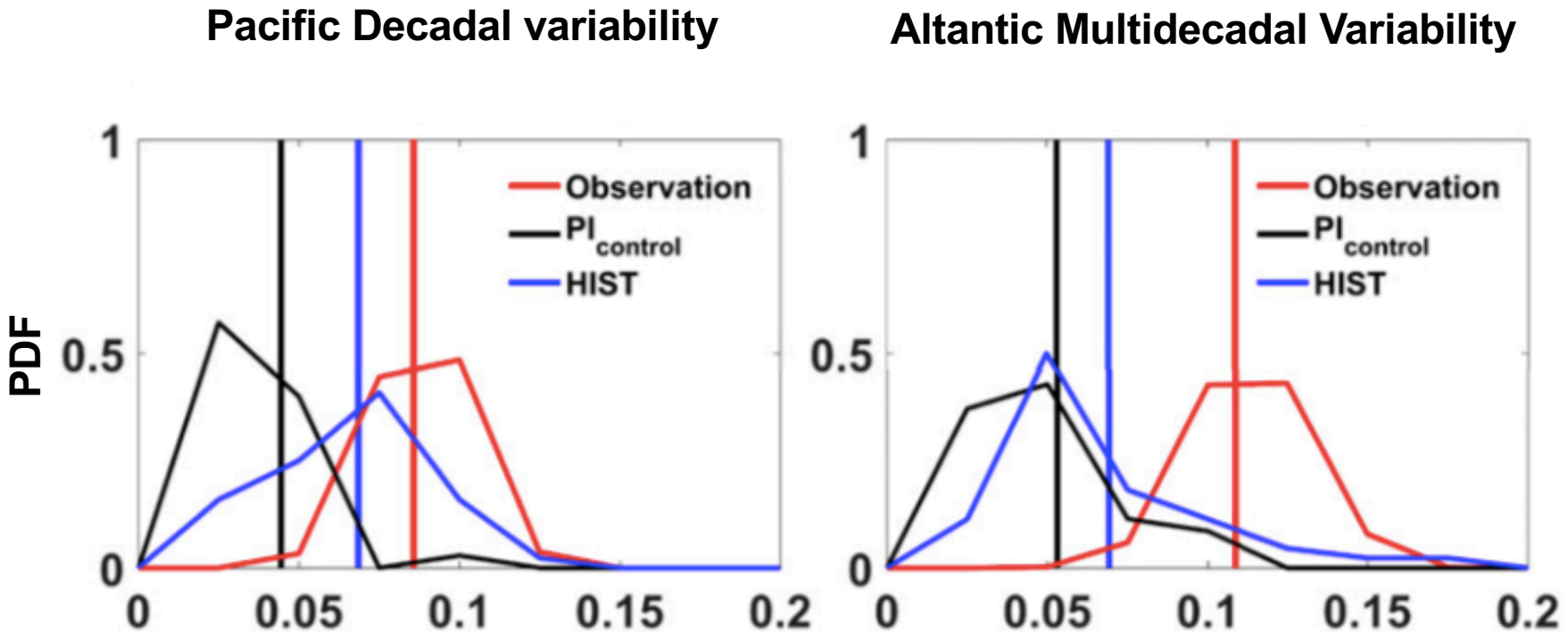
“El Niño tends to peak during the year following large eruptions in simulations.*” (Khodri et al., 2017)*



From Khodri et al. 2017

Underestimated variability in models

- Decadal to multi-decadal variability underestimated in climate models?



Cheung et al. (2017)

-> understanding of mechanisms needed (and large ensemble)

Toward a higher horizontal / vertical resolution

- Interest to investigate ocean-atmosphere coupling at higher horizontal resolution:
  -> Thermal feedback in the atmosphere (Froussard et al., 2019; Plougonven et al. 2018)
  -> Current feedback in the ocean
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  -> heat wave, cold spells
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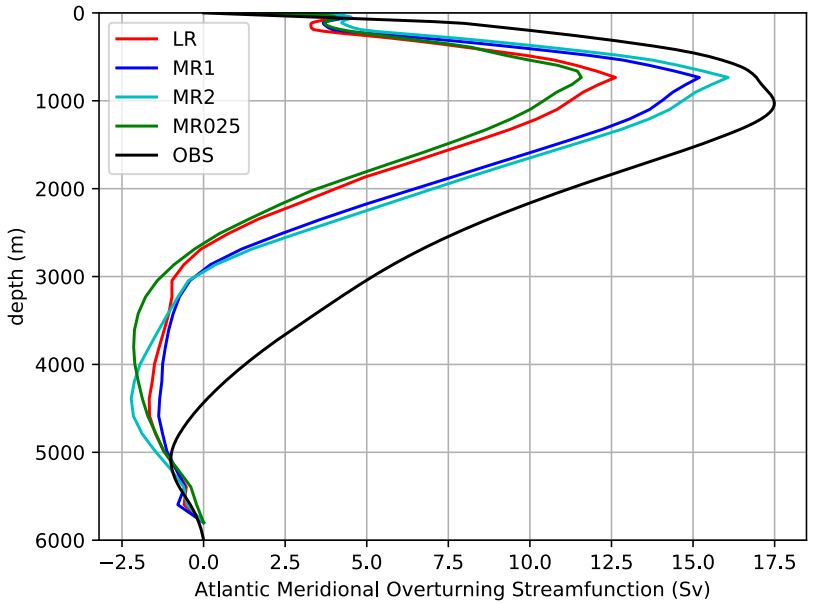
- Interest to investigate the stratosphere-troposphere (low-top / high-top) interaction for teleconnection

Toward a higher horizontal resolution



- No improvement from increased horizontal resolution
  -> need for systematic adjustment
- Possible improvement from increased atmospheric resolution

From Julie Deshayes

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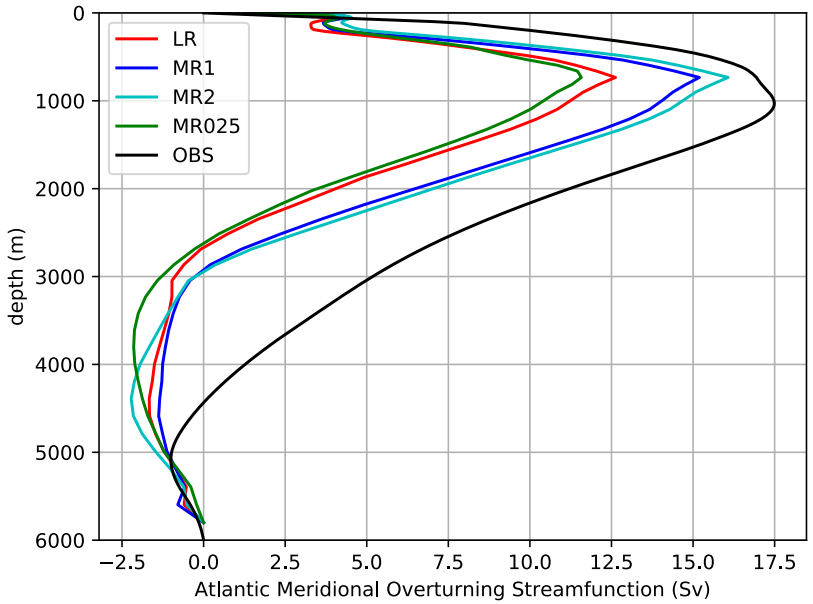

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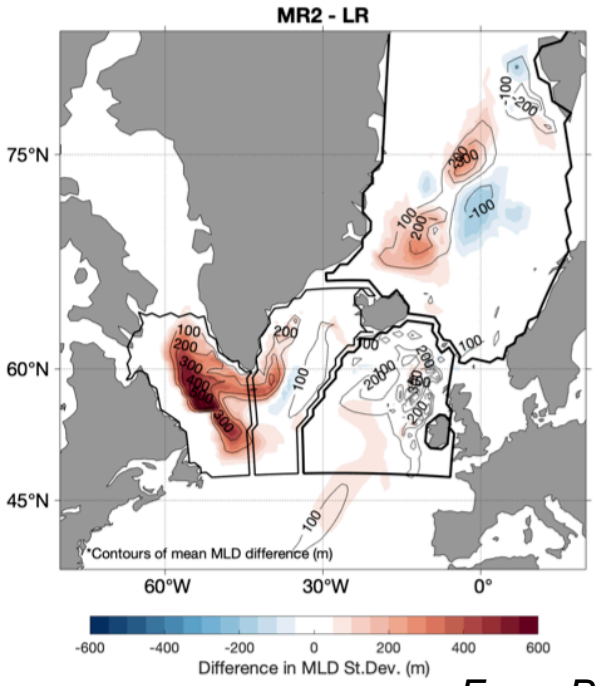
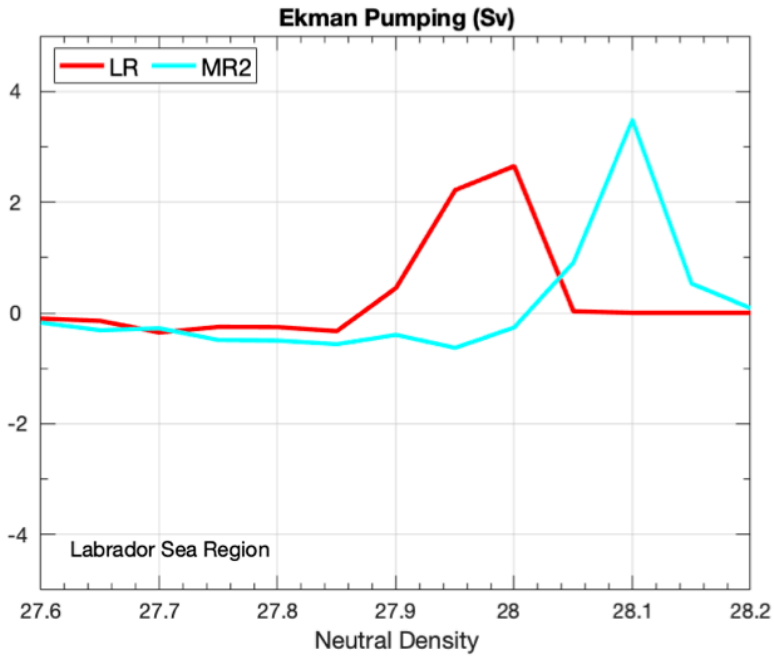
From Julie Deshayes

- Increased winter mixed layer depth in the Labrador Sea
- Ekman pumping results in a shift to formation of higher density class and diapycnal mixing
- Increased meridional overturning by 1.6 ± 1.1 Sv



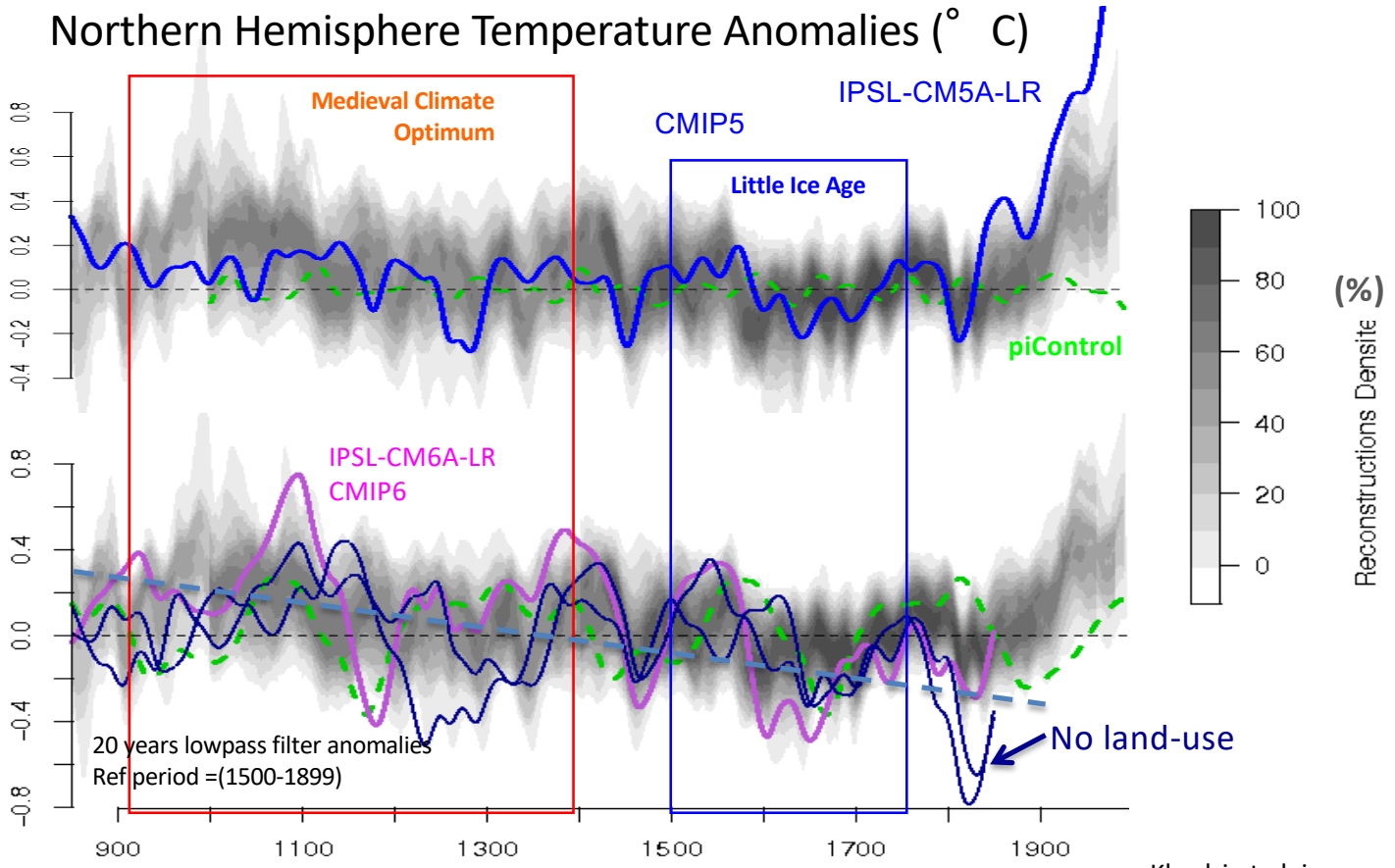


From Brady Fester & Juliette Mignot

Towards an improved low resolution (less costly) and fast coupled model version

Mechanisms for natural climate variability at decadal to secular timescale:

- Role of internal variability and it's sensitivity to natural (solar, volcanoes) forcings during the last 2000 years



Khodri et al, in prep.

-> Large ensembles needed

Understanding of mechanisms: large diversity of tools for sensitivity simulations

Coupled model with flux anomalies

- Using prescribed wind stress,
- SST and SSS nudging,
- Sea-ice nudging (PAMIP, CMIP6),
- Atmospheric 3D nudging,
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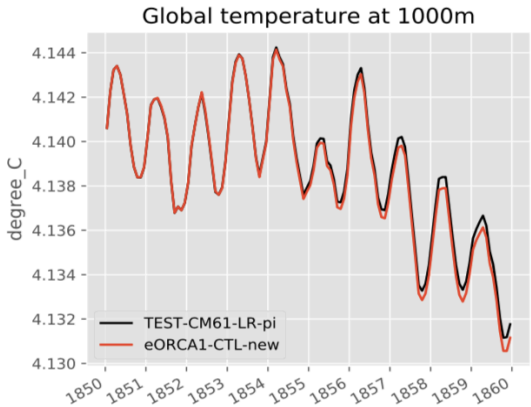
Using individual model component

Need to **reproduce the coupled model** climate using individual components.

Ocean-only

Flux-forcing

From *Yona Silvy & Eric Guilyardi*



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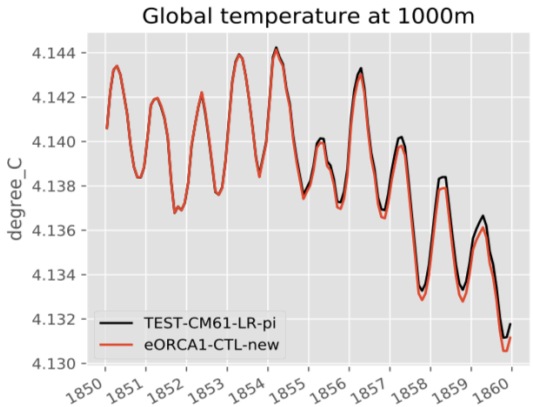
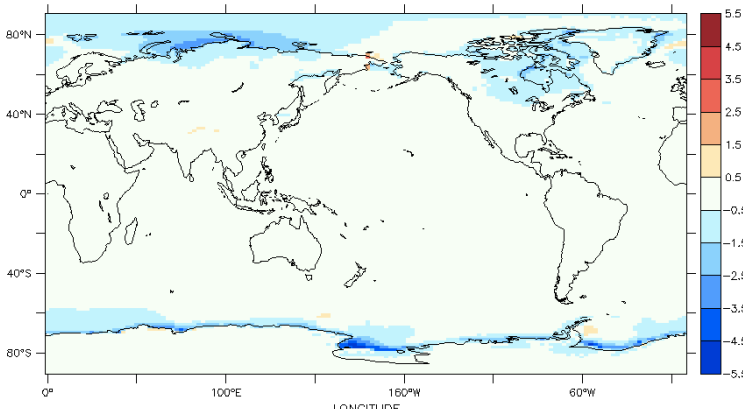


Land-atmosphere only

- Zoom using SST / unbiased SST from coupled model – downscaling *(Frederique Cheruy)*

Atm-only minus coupled

(RFMIP minus CMIP)



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Idealized configurations

- Mixed layer ocean (*Francis Codron*),
- Idealized atmospheric physics using simplified diabatic heating to investigate stormtracks (*Gwendal Rivière & Sébastien Fromang*)

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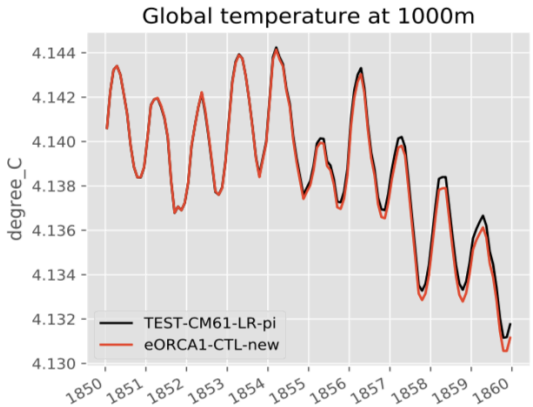

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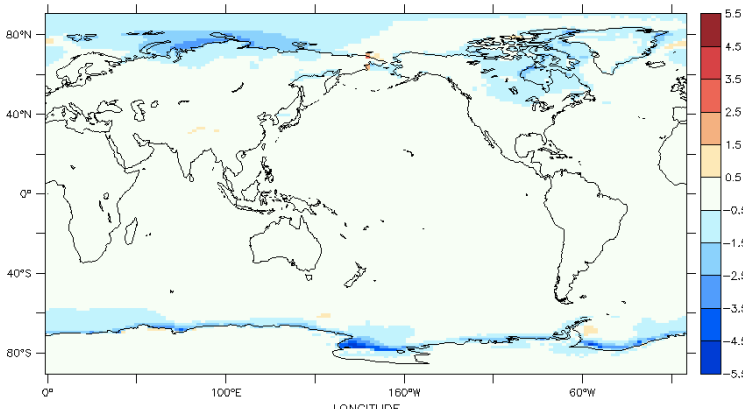
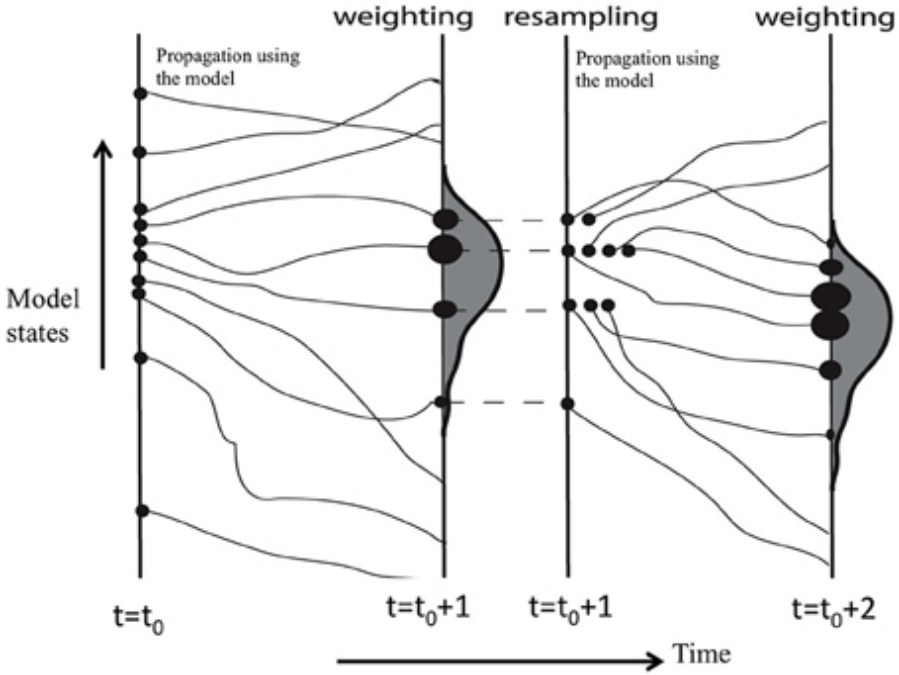


Methods to combine data and models

Particle filtering

Myriam Khodri



Goosse et al. 2012

- Reconstruct coupled ocean-atmosphere variability in last millennium using proxy records/obs

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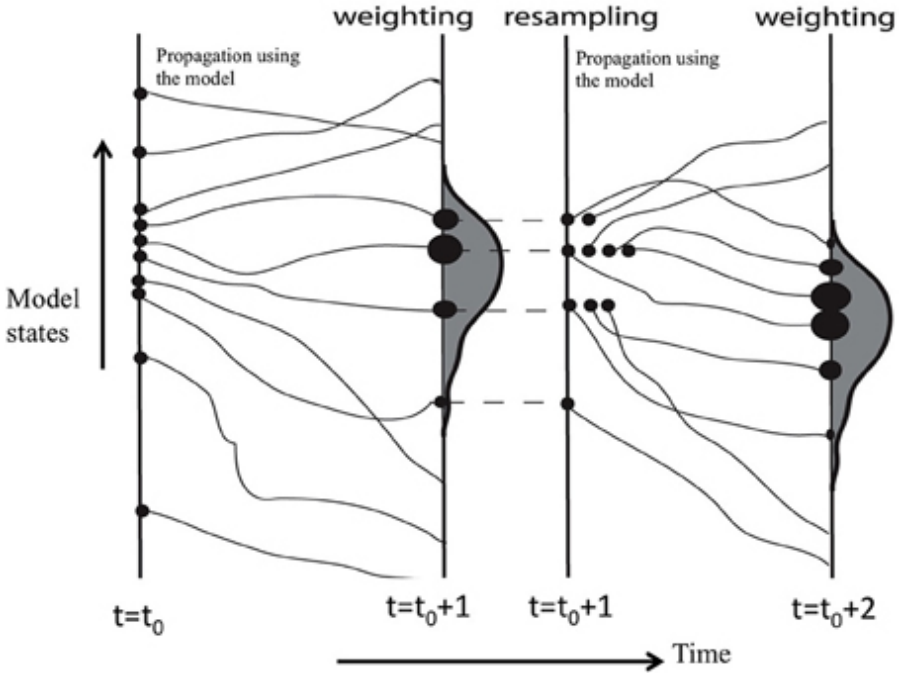

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Ensemble Kalman Filter

Juliette Mignot & Didier Swingedouw

- Under Gaussian hypothesis, use of covariances to propagate the information from observed (SST, sea ice concentration, deep ocean, etc...) anomalies to the ocean,
- Use of an hybrid method to diminish CPU cost in collaboration with NERSC in Bergen (Counillon et al. 2014).
- Reconstruct oceanic variability
- Improvement of oceanic initial state of decadal forecast

Which climate models?

- Need to rely on large ensemble (implement ensemble as dimension to reduce inodes) and well-adjusted existing ocean-atmosphere models configuration.

  -> strong phasing with existing coupled model configurations

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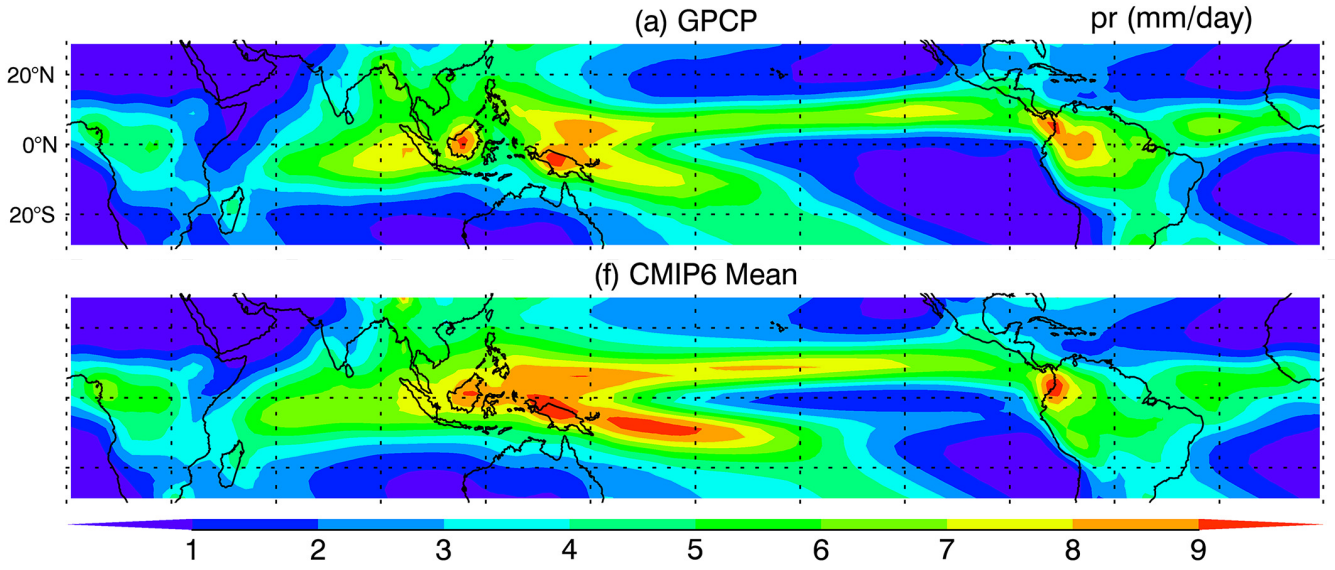
Thank you for your attention

Dominant model biases

- Double ITCZ and overestimated cold tongue bias in the tropical Pacific

‘’*Interaction among convection, clouds, atmospheric and ocean circulation*” (Zhang et al. 2019)



Tian and Dong 2020

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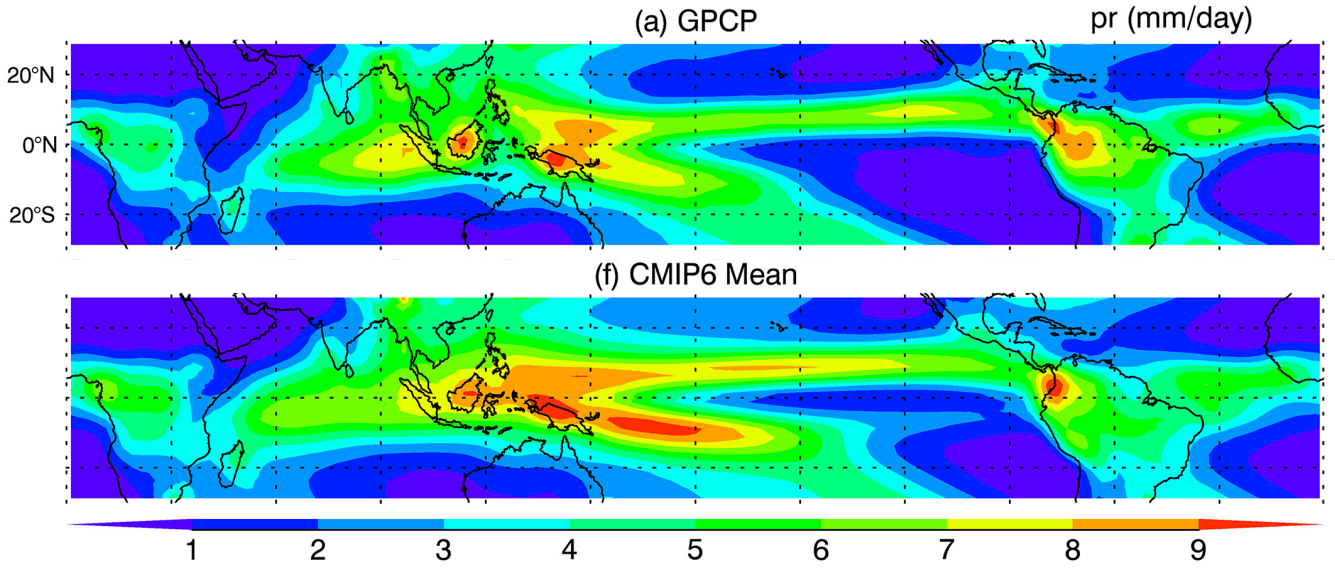
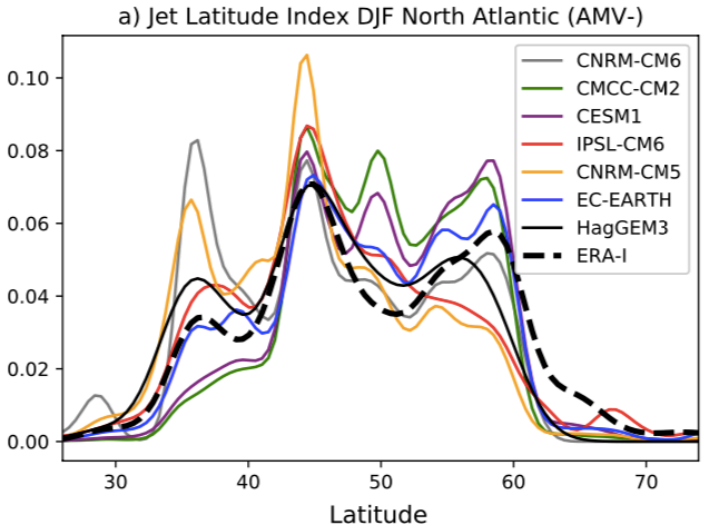


Tian and Dong 2020

- Atmospheric jet that tend to be too zonal in Northern Hemisphere.

=> Impact teleconnection



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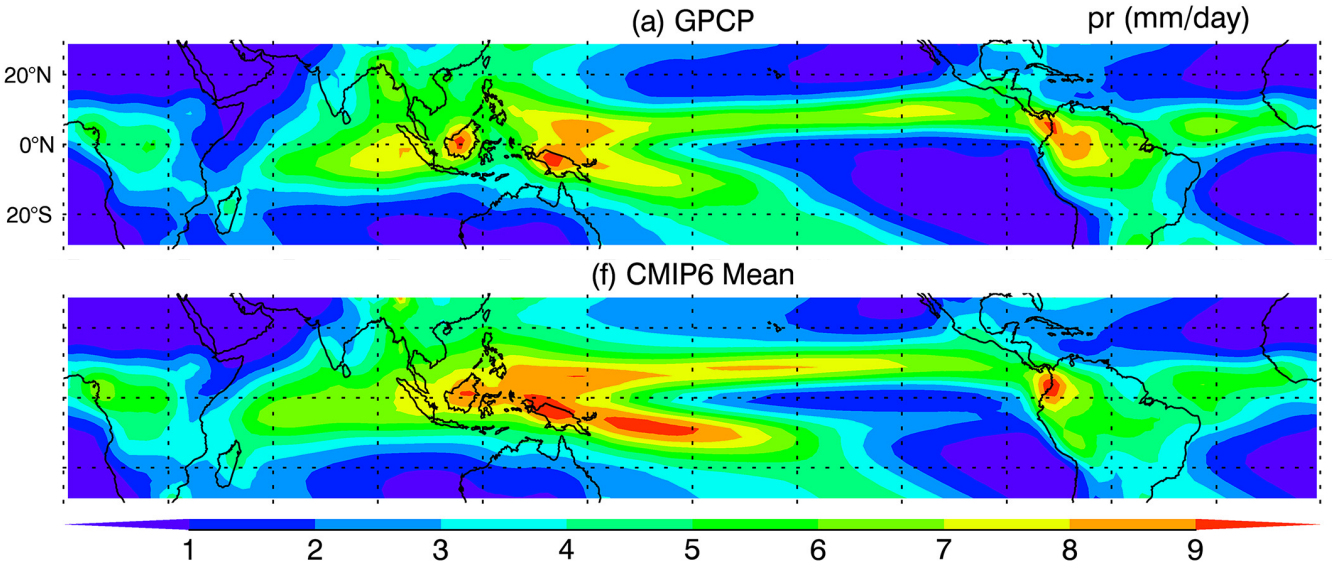

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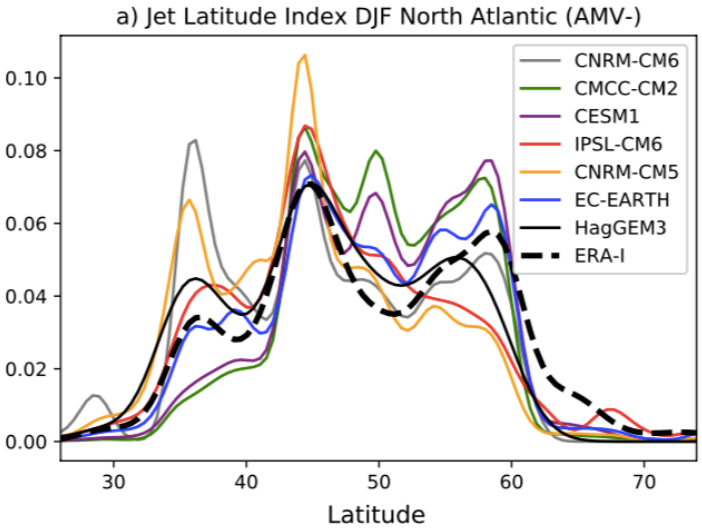

Ruggieri et al. 2020

- Atlantic Meridional Overturning circulation tends to be weak in IPSL models.

=> Impact on sea-ice, North Atlantic cold bias
=> Impact for energy transports