

Studying Pacific Decadal Variability using a perfect model framework

Simon Borlace, Claude Frankignoul, Eric Guilyardi,
Jérôme Vialard, Sébastien Nguyen



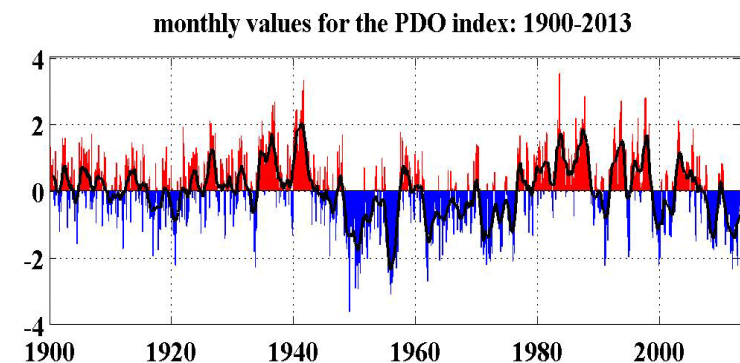
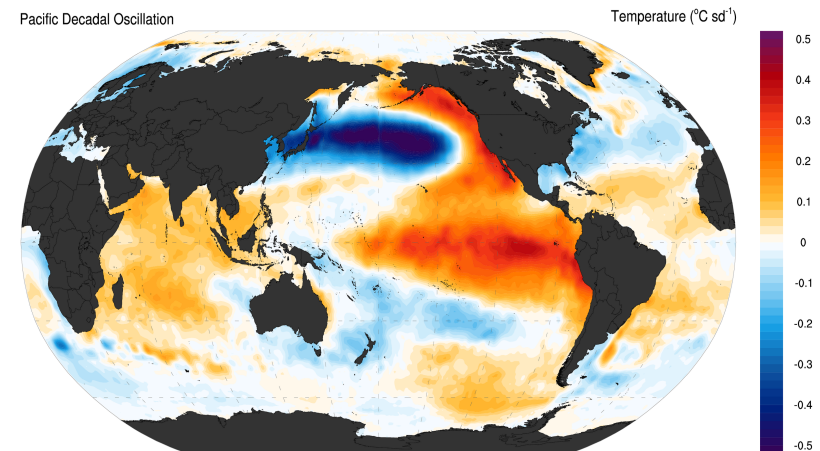
CLIVAR-ITCP International Workshop on Decadal Climate Variability
and Predictability: Challenge and Opportunity

Trieste, Italy

16-20 November 2015

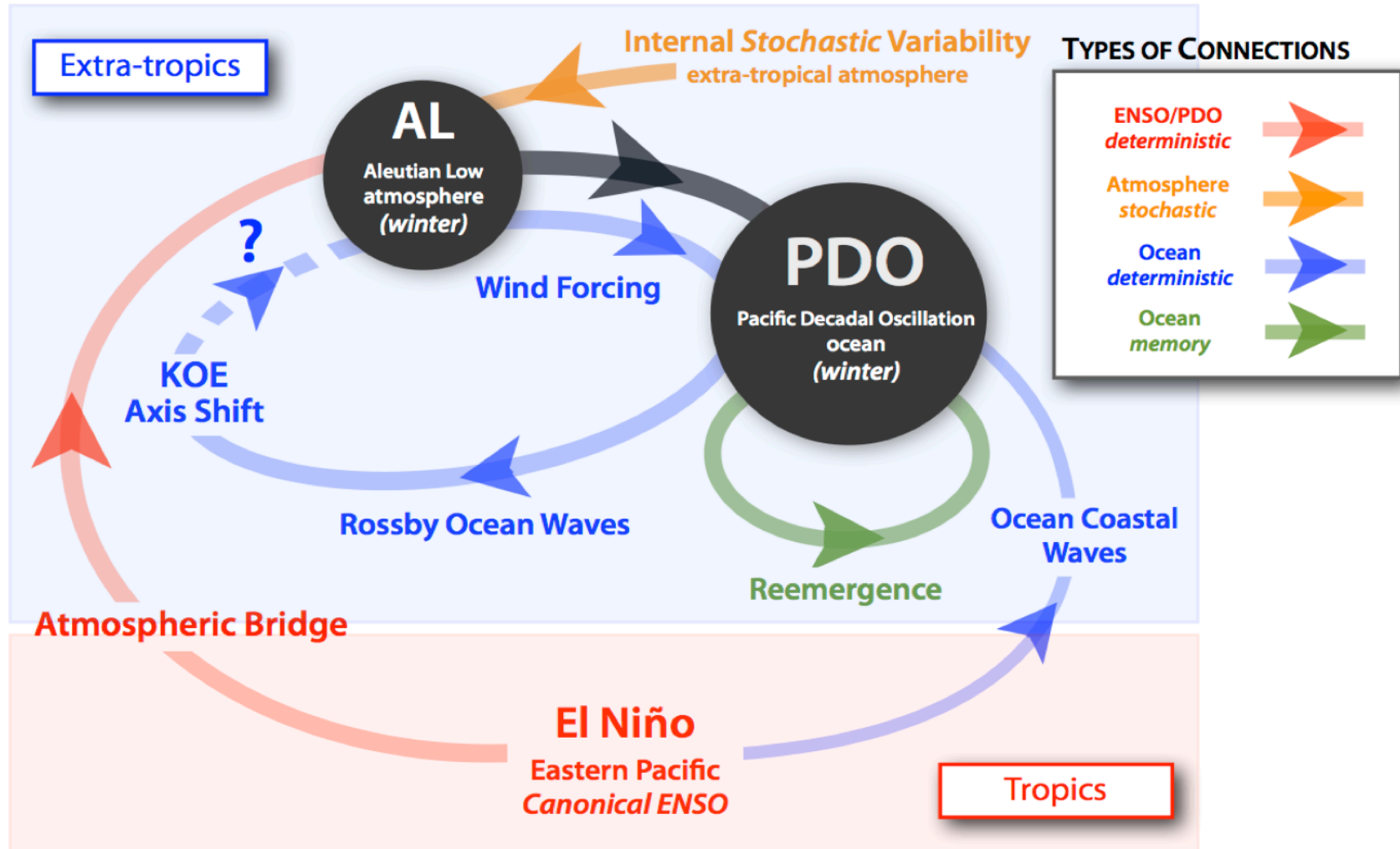
Pacific Decadal Variability (PDV)

- Two regions of low-frequency variability in the Pacific Ocean
 - Tropics
 - Tropical Pacific Decadal Variability; TPDV
 - Extratropics
 - Pacific Decadal Oscillation; PDO
 - Leading EOF of monthly SST anomalies over the North Pacific Ocean
 - Interdecadal Pacific Oscillation; IPO (Southern Hemisphere signature)



Summary View

MECHANICS OF THE PACIFIC DECADAL OSCILLATION



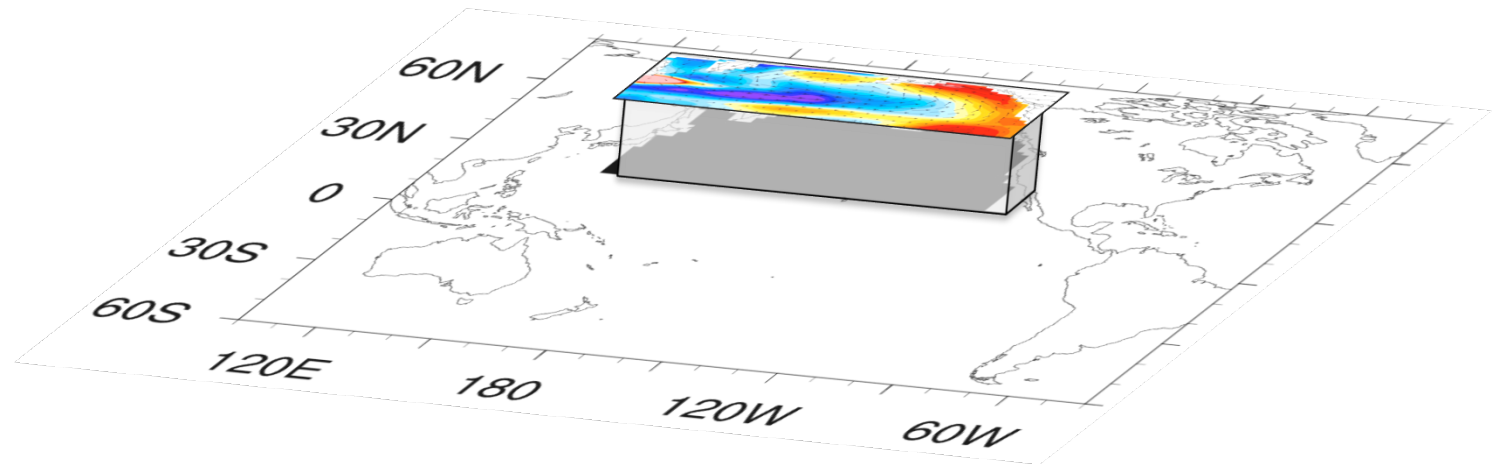
Newman et al. 2015

Pacific Decadal Variability (PDV)

- Low-frequency modulation of both regions is likely governed by the interplay of both local and remote processes
- We aim to understand; how much low-frequency variability in the extratropics can be attributed to tropical forcing alone?
- As well as whether North Pacific low frequency variability feeds back on low frequency tropical variability
- However, short observational record provides only a limited understanding of the interplay between these physical processes

Systematic Modeling Approach

- Coupled Global Climate Models (CGCMs) are now capable of multi-centennial integrations, at reasonable computational expense, provide an invaluable tool to study decadal variability
- Here we employ a CGCM to understand how these natural processes may modulate the PDO over decadal timescales
- We employ a systematic approach of partially coupling and regional forcing to constrain physical processes; and thus determine their relative contribution

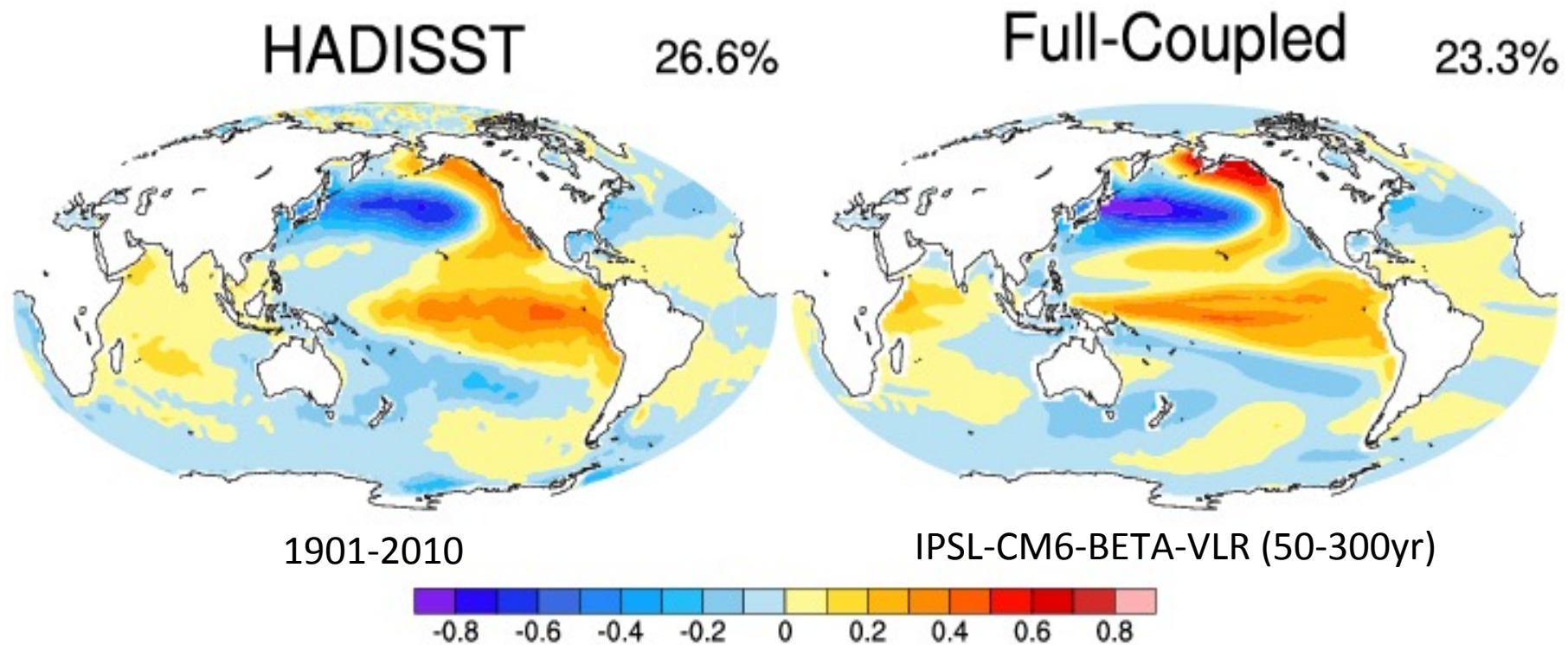


Coupled Global Climate Model Setup

- Institut Pierre Simon Laplace (IPSL) coupled global climate model
 - Currently using IPSL-CM6 BETA-VLR
 - IPSL-CM5A-LR physics with improved computational performance
- All simulations are forced with the piControl forcing scenario in which there is no external forcing (ie. greenhouse gases, aerosols, volcanoes)
- Allow model to spin-up for 50-years (0-50yr)
- Focus on 250-year period between that extends between (50-300yr)
- At present the model climatology comes from the period (200-1200yr) (this requires modification)

Regression between SST and North Pacific Ocean EOF1

Empirical orthogonal function (EOF) of monthly SST anomalies over region
[20°N-60°N,120°E-120°W]



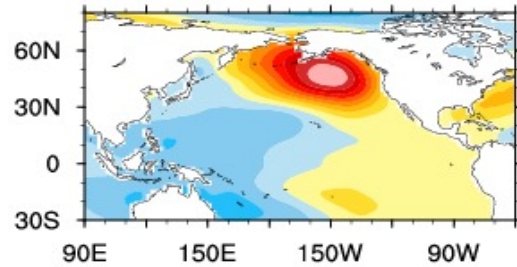
IPSL-CM6 BETA-VLR satisfactorily reproduces the observed IPO pattern despite

- a slightly too strong extra-tropical variability
- maximum PDO cooling shifted to the west

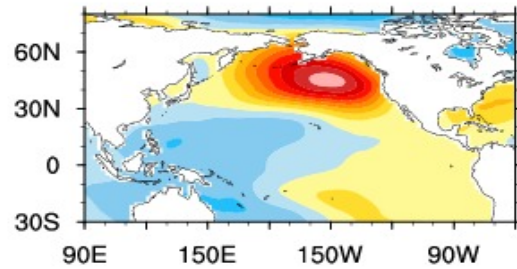
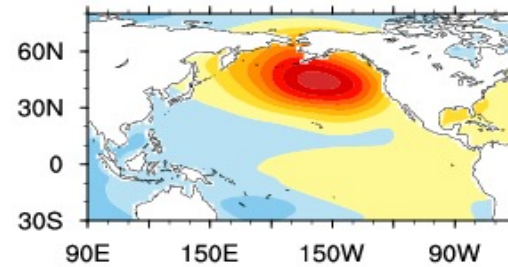
Regression between SLP and tropical Pacific Ocean EOF1

NCEP SLP and HADISST 1950-2010

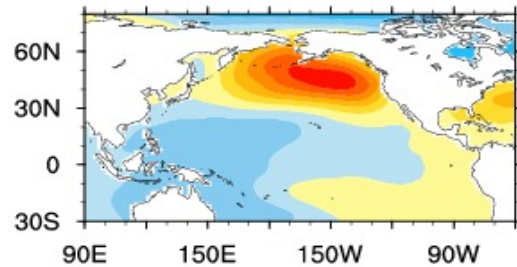
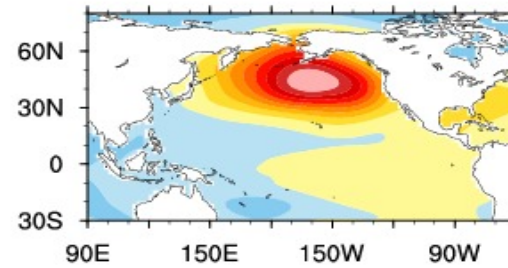
IPSL-CM6-BETA-VLR (50-300yr)



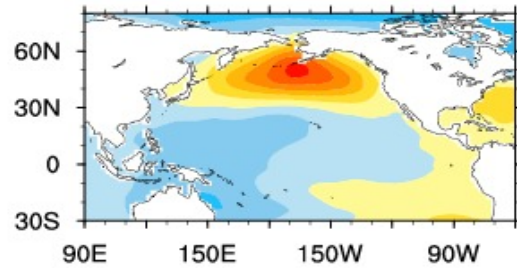
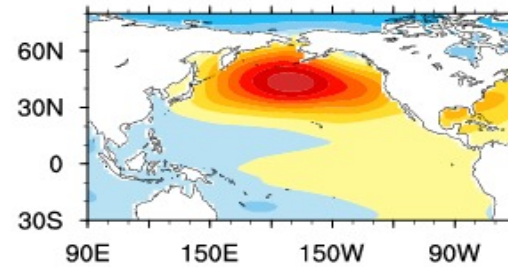
DJF



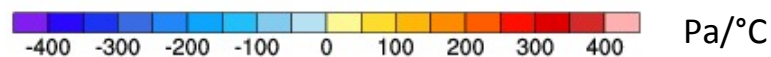
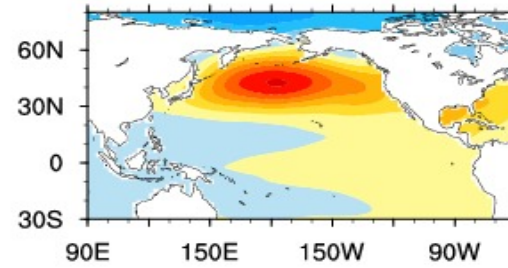
JFM



FMA



MAM

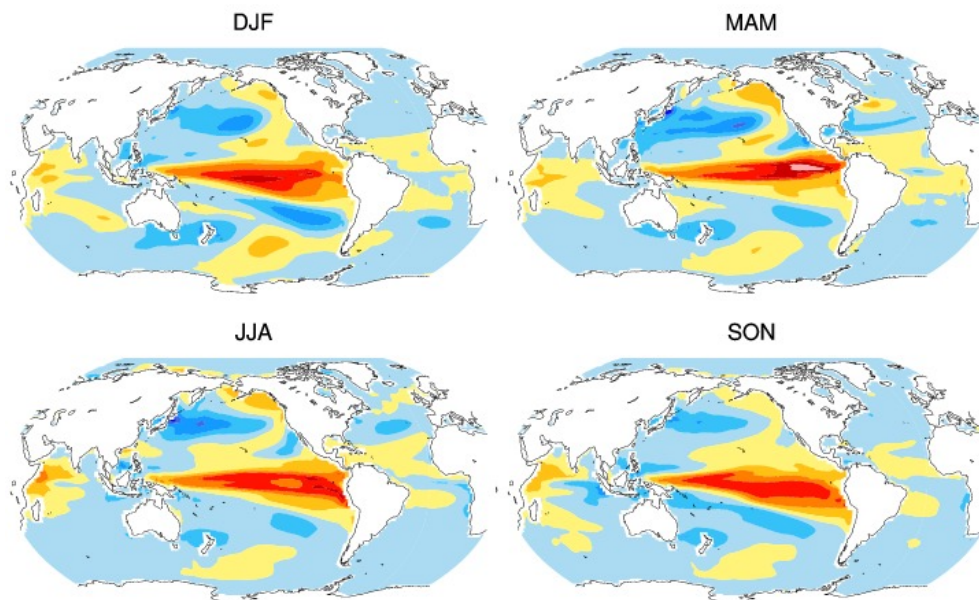
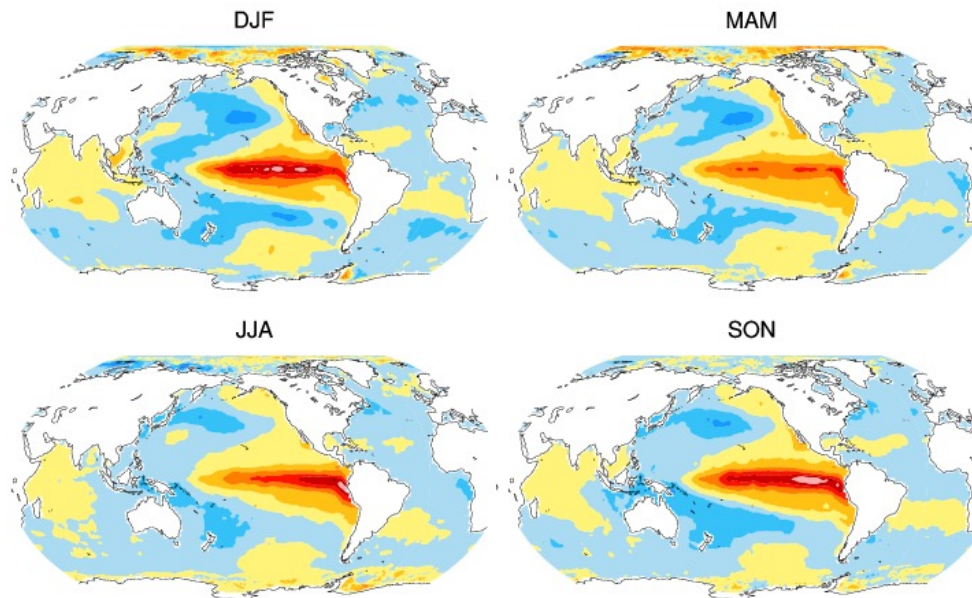


Delayed maximum ENSO teleconnection to the North Pacific with respect to observations

Regression between SST and tropical Pacific Ocean EOF1

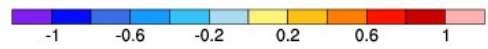
EOF 1 domain [20°S-20°N,120°E-80°W]

HADISST 1901-2010 →



← IPSL-CM6-BETA-VLR (50-300yr)

ENSO peaks in MAM...
but is still strong during DJF



What is the influence of the tropical Pacific Ocean?

- Nudge toward the model's climatological SST in the tropical Pacific Ocean
- Constrain SST variability over the tropical Pacific
- Determine the relative influence of ENSO on PDO
- Nudging implemented through heat flux term

$$Q_{\text{ocn}} = Q_{\text{atm}} - \gamma(\text{SST} - \text{SST}^*)$$

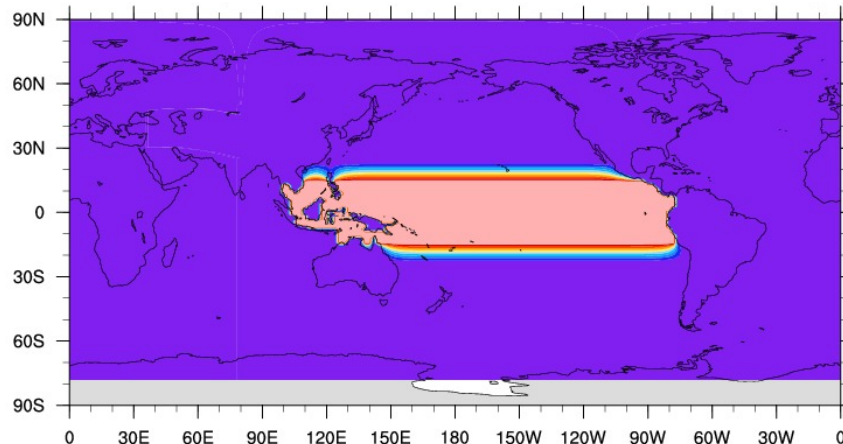
Q_{ocn} = Heat flux into ocean

Q_{atm} = Heat flux from atmosphere

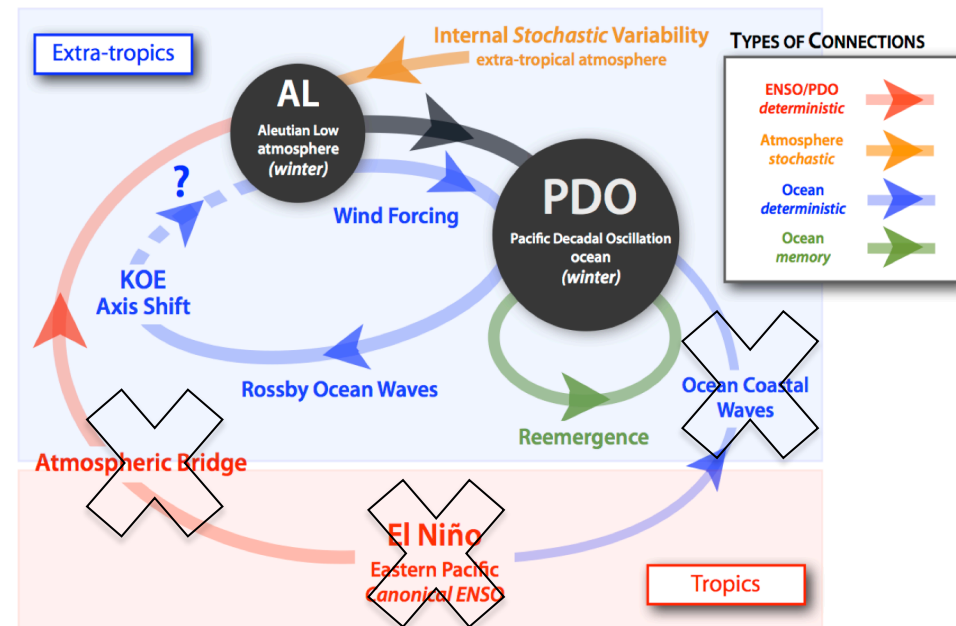
γ = Restoring coefficient ($-80 \text{ W/m}^2/\text{K}$)

SST = Sea surface temperature

SST* = Climatological SST

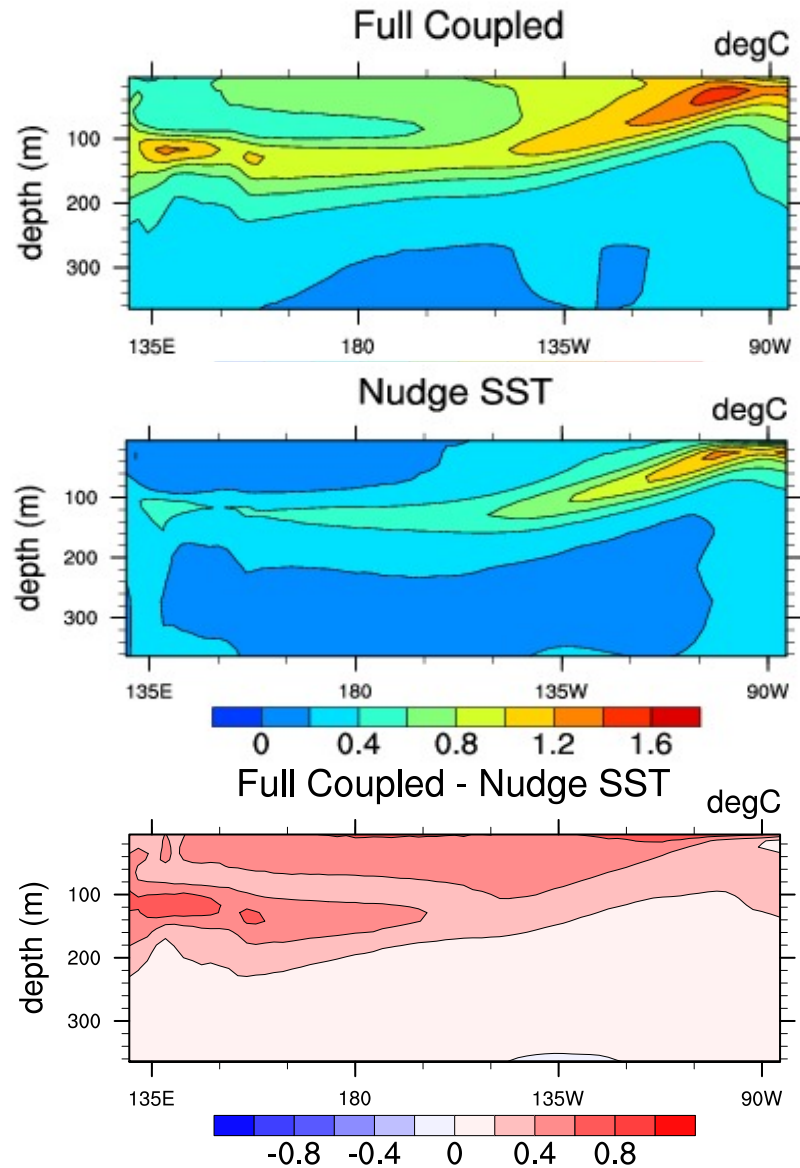


Summary View MECHANICS OF THE PACIFIC DECADAL OSCILLATION



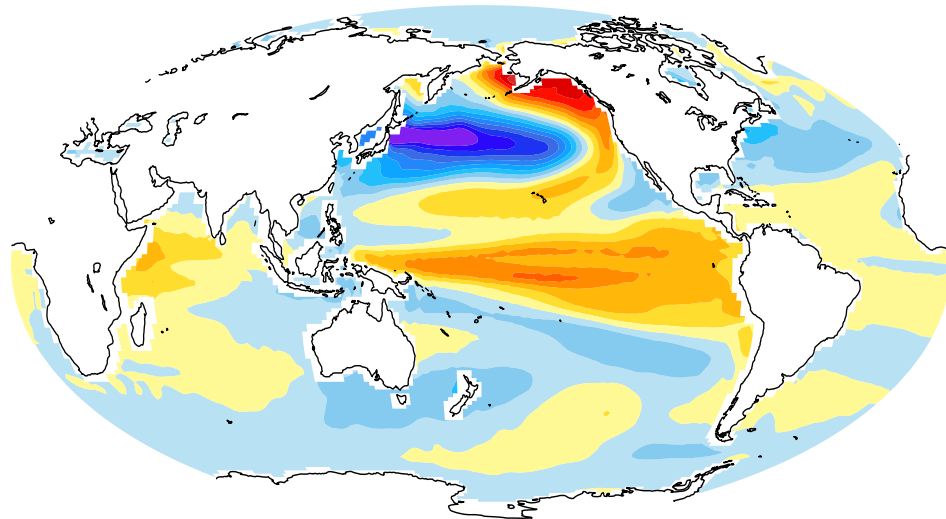
Simulated Tropical Pacific Ocean [2°S-2°N]

Climatological monthly standard deviation



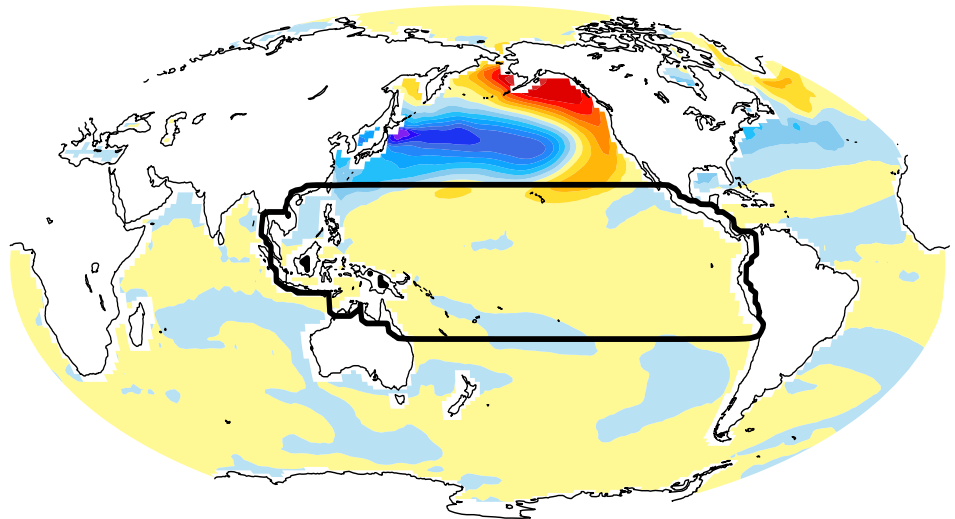
Regression between SST and EOF1 of North Pacific Ocean monthly SST anomalies

Full-Coupled

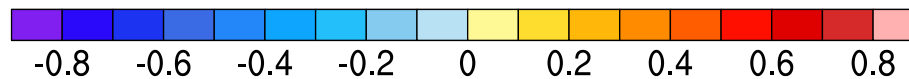


IPSL-CM6-BETA-VLR (50-300yr)

Nudge SST



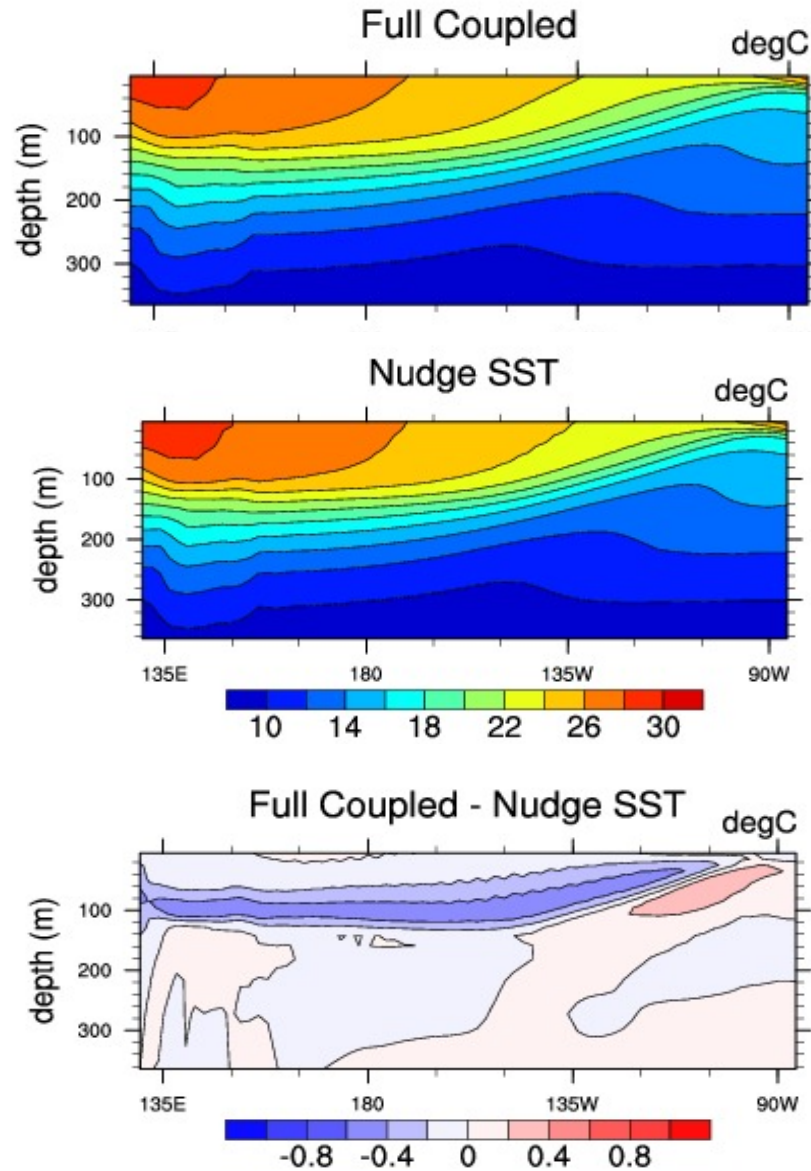
IPSL-CM6-BETA-VLR (50-300yr)



- SST variability reduced by approximately 40% over the North Pacific
 - Inter-hemispheric pattern disappears

Simulated Tropical Pacific Ocean [2°S-2°N]

Climatological monthly mean



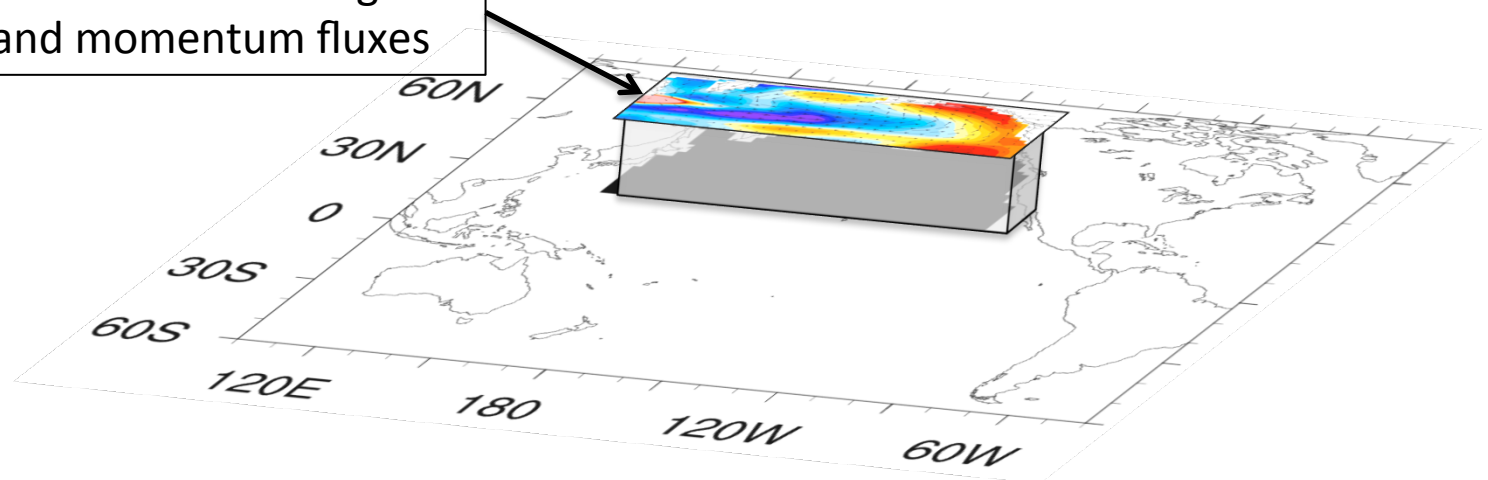
Present Conclusions

- The IPSL-CM6 VLR-BETA model reproduces IPO variability reasonably well, despite a seasonal shift in the to North Pacific teleconnections
- Sensitivity experiments are setup to explore the interactions between tropical and extratropical Pacific Decadal Variability using a perfect model framework
- ENSO contributes to about 40% of the SST variability in the PDO western pole, but seems to influence the eastern pole less
- Constraining tropical variability also induces a slight change in the tropical Pacific mean state in the model
- The potential influence of midlatitude variability on ENSO decadal fluctuations will have to be explored in a future set of experiments.

Currently...

- Force with the model's climatological fluxes over the extratropical North Pacific Ocean
 - Constrain atmospheric stochastic variability over the North Pacific Ocean
 - Determine if climatological forcing alone is efficient to produce realistic subsurface properties (ie. mixed layer depth)
 - Again some surface restoring to model climatology may be required to prevent model drift
 - Apply teleconnection pattern

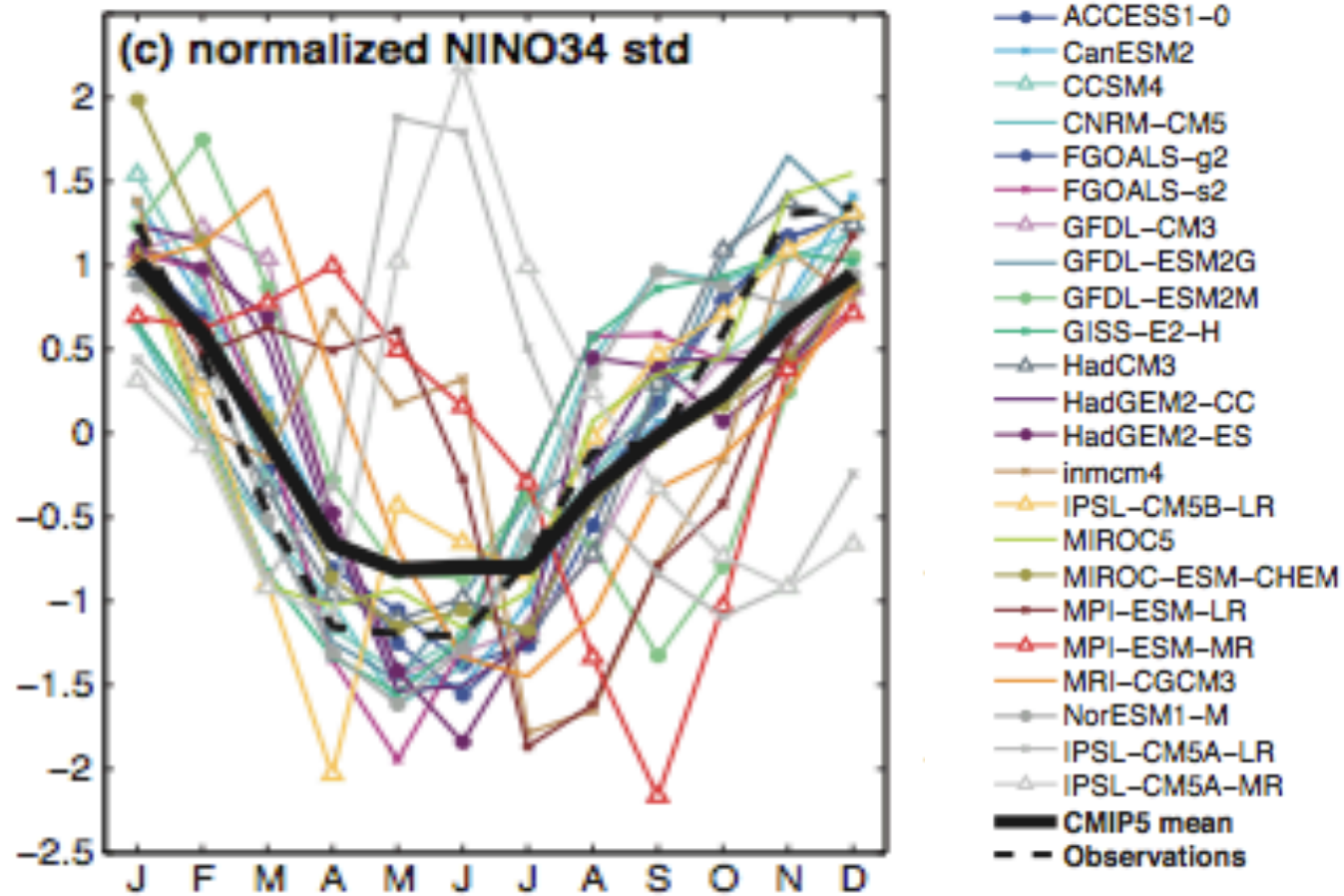
North Pacific region forced climatological heat, freshwater and momentum fluxes



Extras

Not to be included in presentation

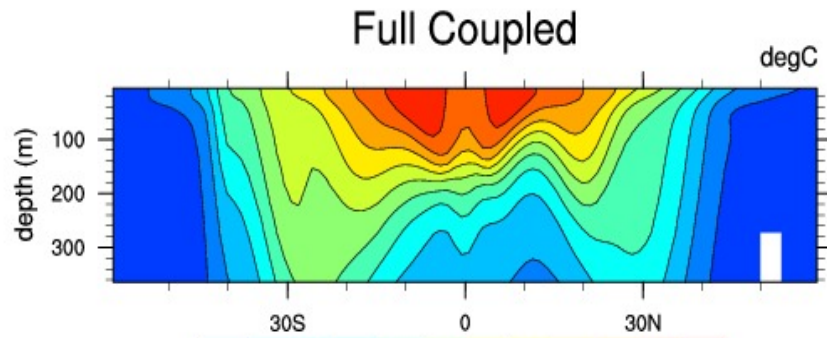
Extra: ENSO Seasonality



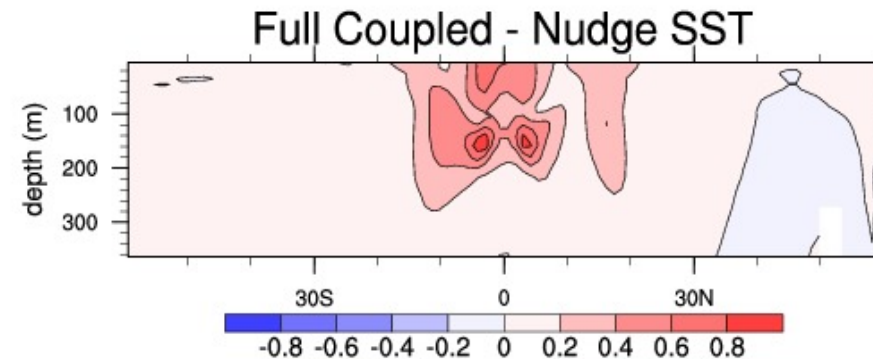
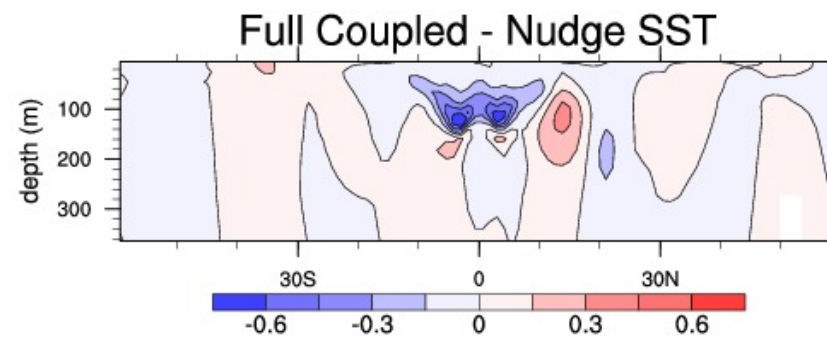
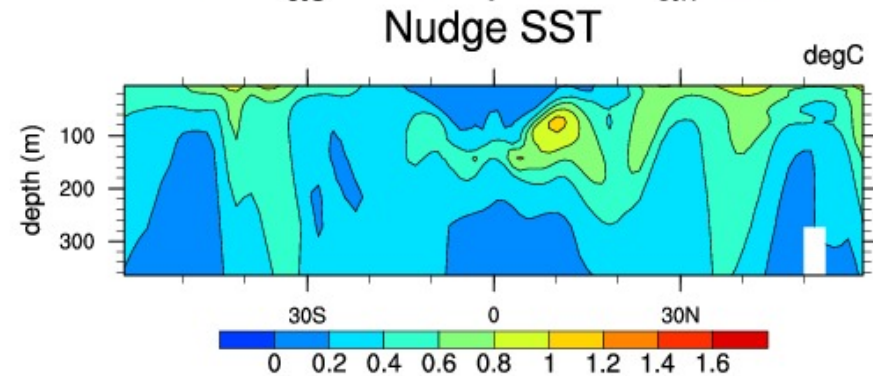
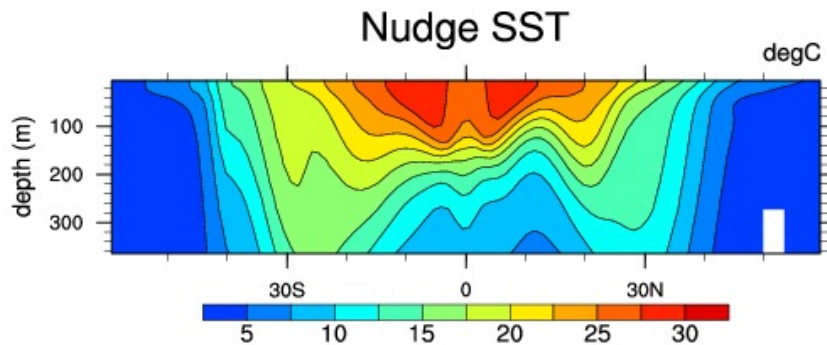
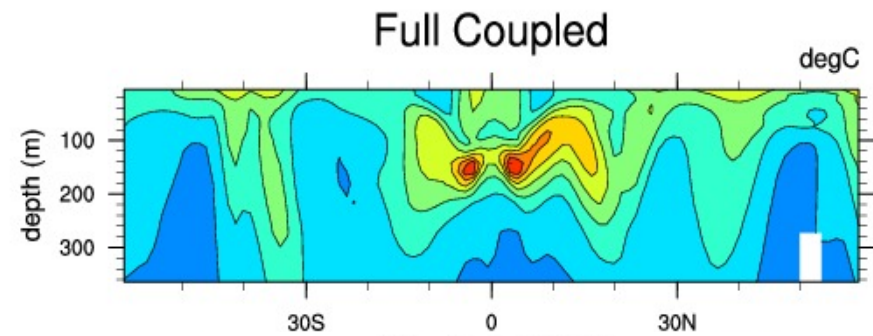
Jourdain et al. (2015)

Meridional Transect along Dateline

Climatological monthly mean

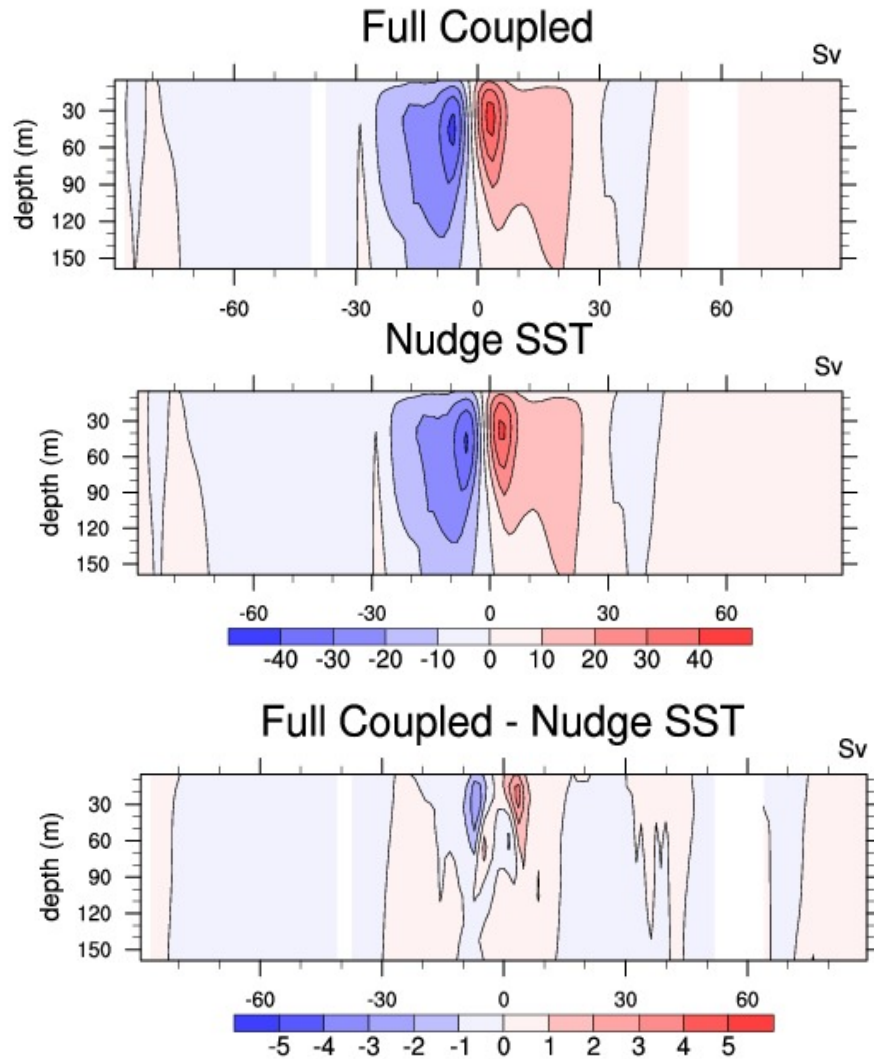


Climatological monthly standard deviation



Pacific Ocean Meridional-Stream Function

Climatological monthly mean



Climatological monthly standard deviation

