Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)

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Regional influences of ocean-atmosphere interaction on climate variability using partial coupling

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Introduction

- Sources of climate variability include
  - intrinsic atmospheric variability
  - atmospheric response to ocean variability
  - coupled ocean/atmosphere interactions
- Attribution difficult in fully coupled simulations
- Objective: distinguish regional contributions of air-sea coupling to climate variability and predictability through model runs using *partial coupling* in specified regions
- Preliminary results presented here

Model and partial coupling methodology

- Coupled climate model: CCCma CGCM3.7
  - AGCM3, T63L31, filtered physics
  - OGCM 1.4° lon × 0.94° lat × 40 levels (Δz = 10 m in upper ocean), anisotropic viscosity, KPP mixed layer, penetrative solar radiation

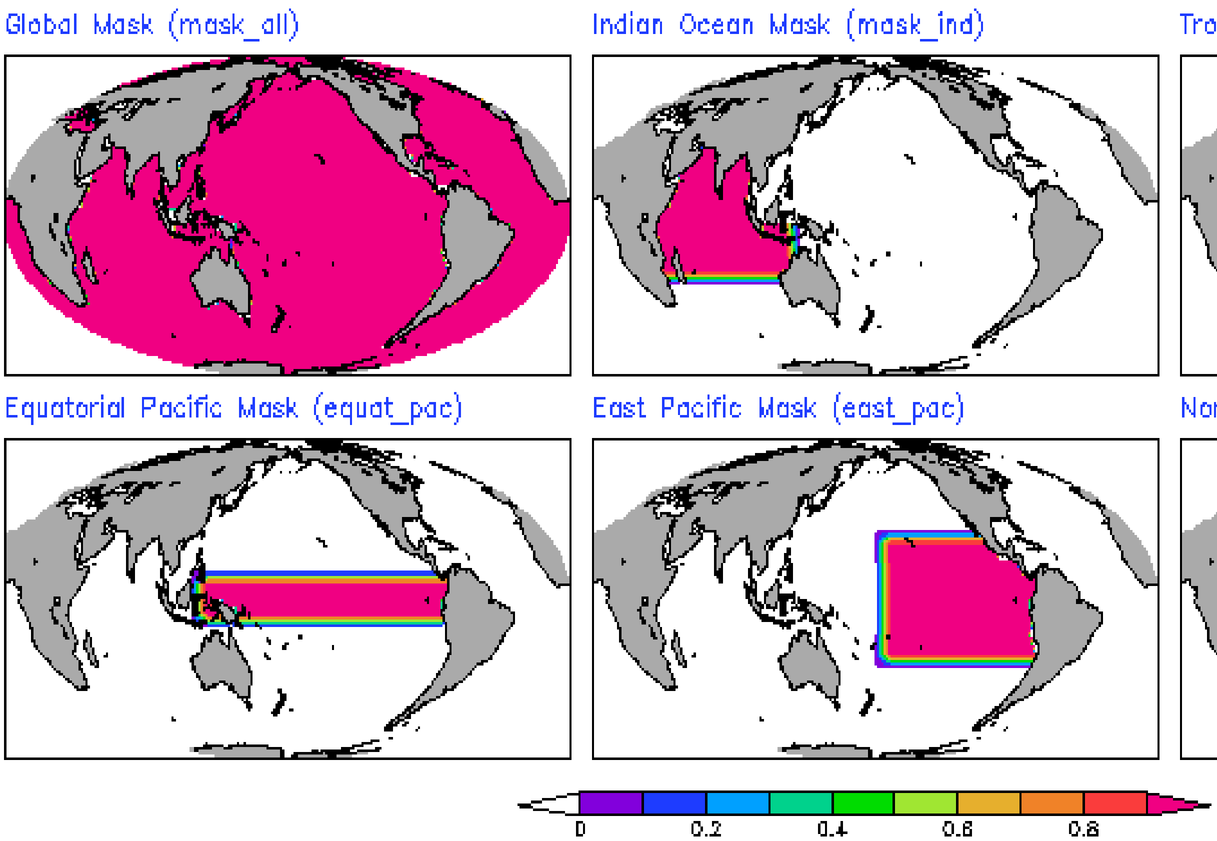
- ***Partial Coupling:*** atmosphere sees *specified* SSTs instead of interactive SSTs in specific regions

- In these experiments the specified SSTs consist of model climatological SSTs obtained from a fully coupled control run (→ SSTA = 0)

- Results presented here are based on 300 years of model output following 70-year spin-up period (runs are ongoing)

- Examine effects on climate variability and potential predictability

Partial Coupling Masks



Analysis

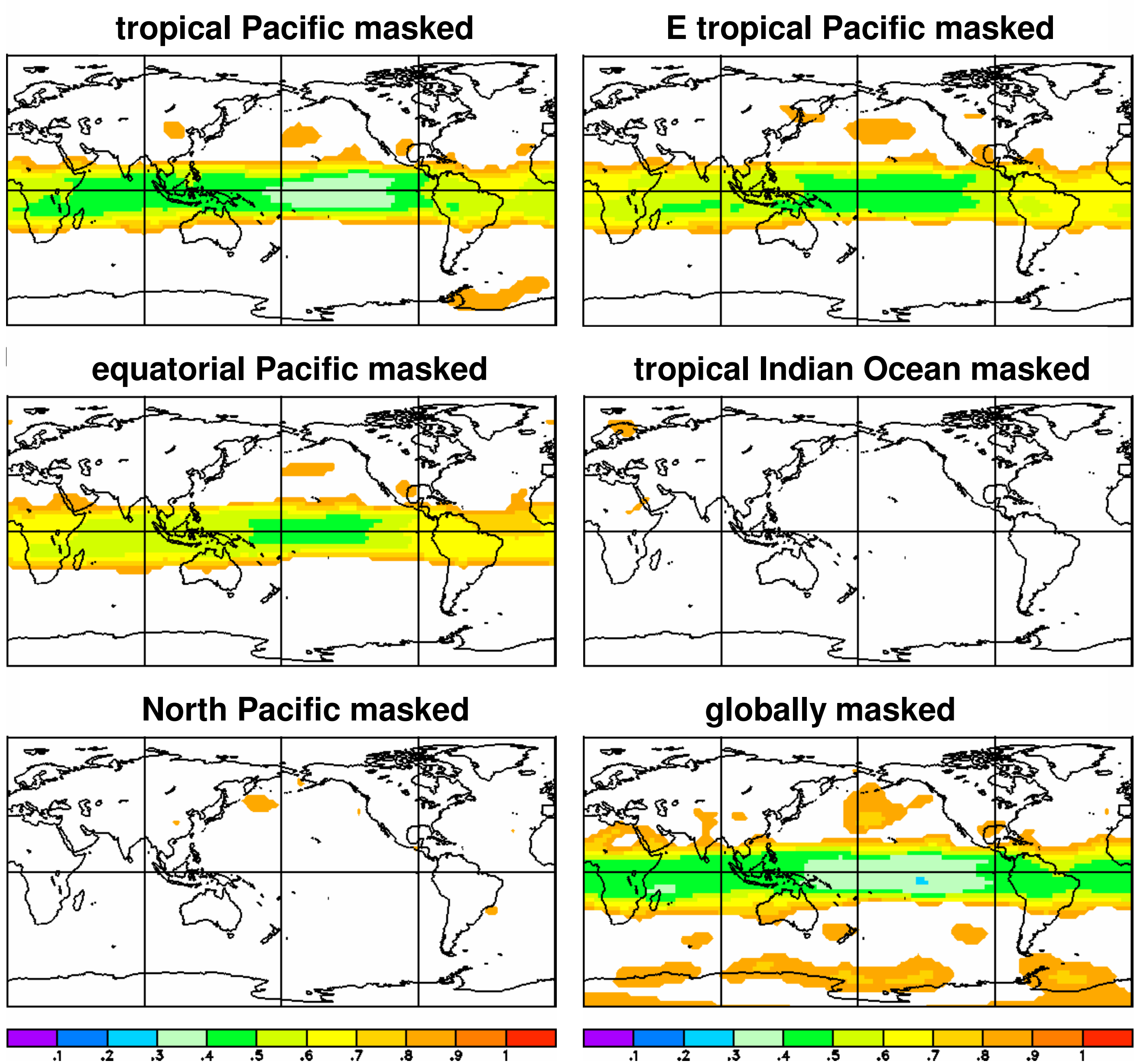
- 300 year model simulations for each of the 6 masked runs.
- Monthly mean data is used to evaluate
- Potential predictability of seasonal means
- Results presented for December-January-February (DJF)
- Variables considered:
  500hPa height,
  850hPa temperature
  Mean sea level pressure

Impact of masking on interannual variability of DJF seasonal means

500mb height

Ratio of standard deviations:

$$\frac{\sigma_{masked}}{\sigma_{control}}$$



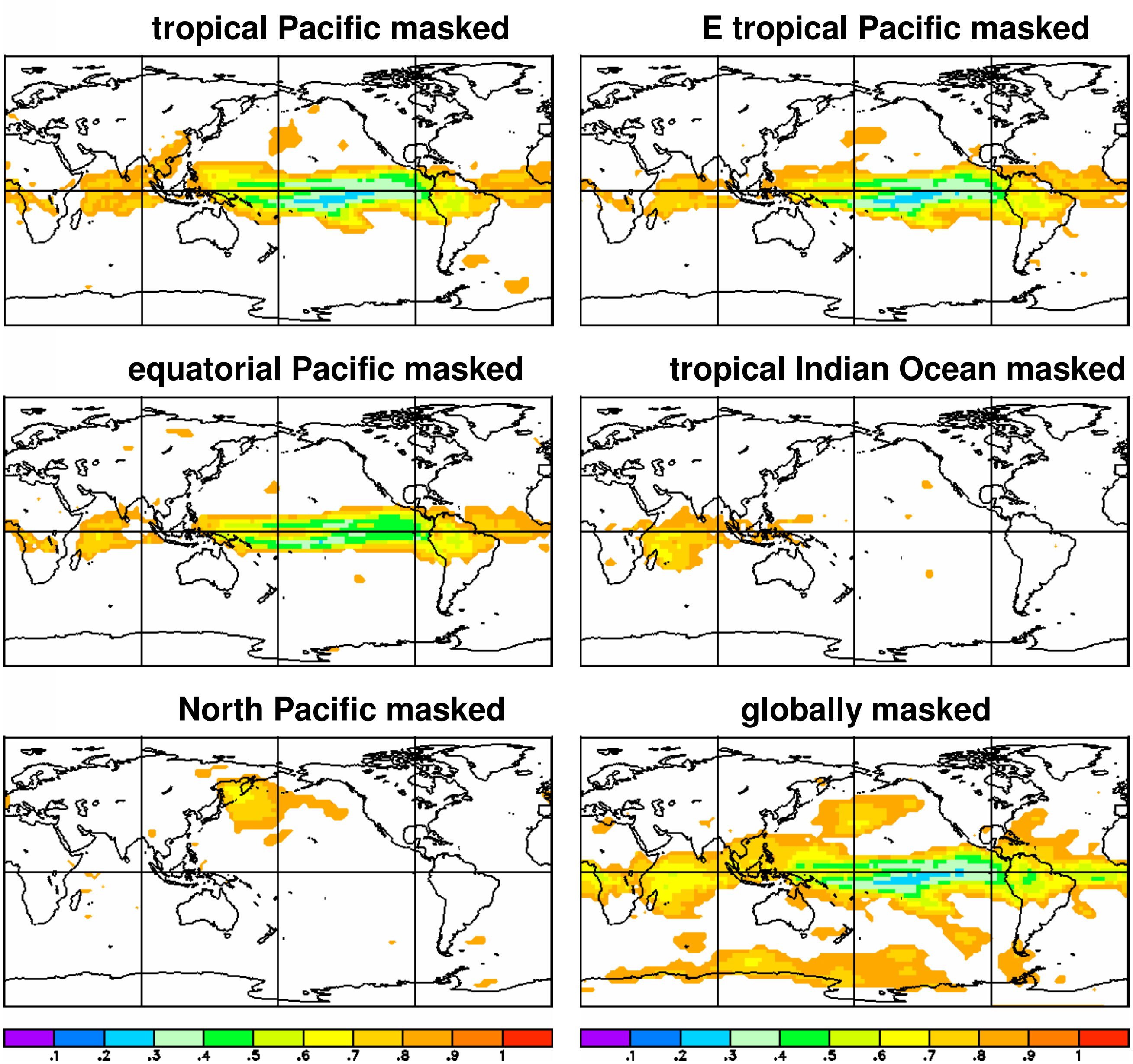
plotted where p<0.01

Impact of masking on interannual variability of DJF seasonal means

850mb temperature

Ratio of standard deviations:

$$\frac{\sigma_{masked}}{\sigma_{control}}$$



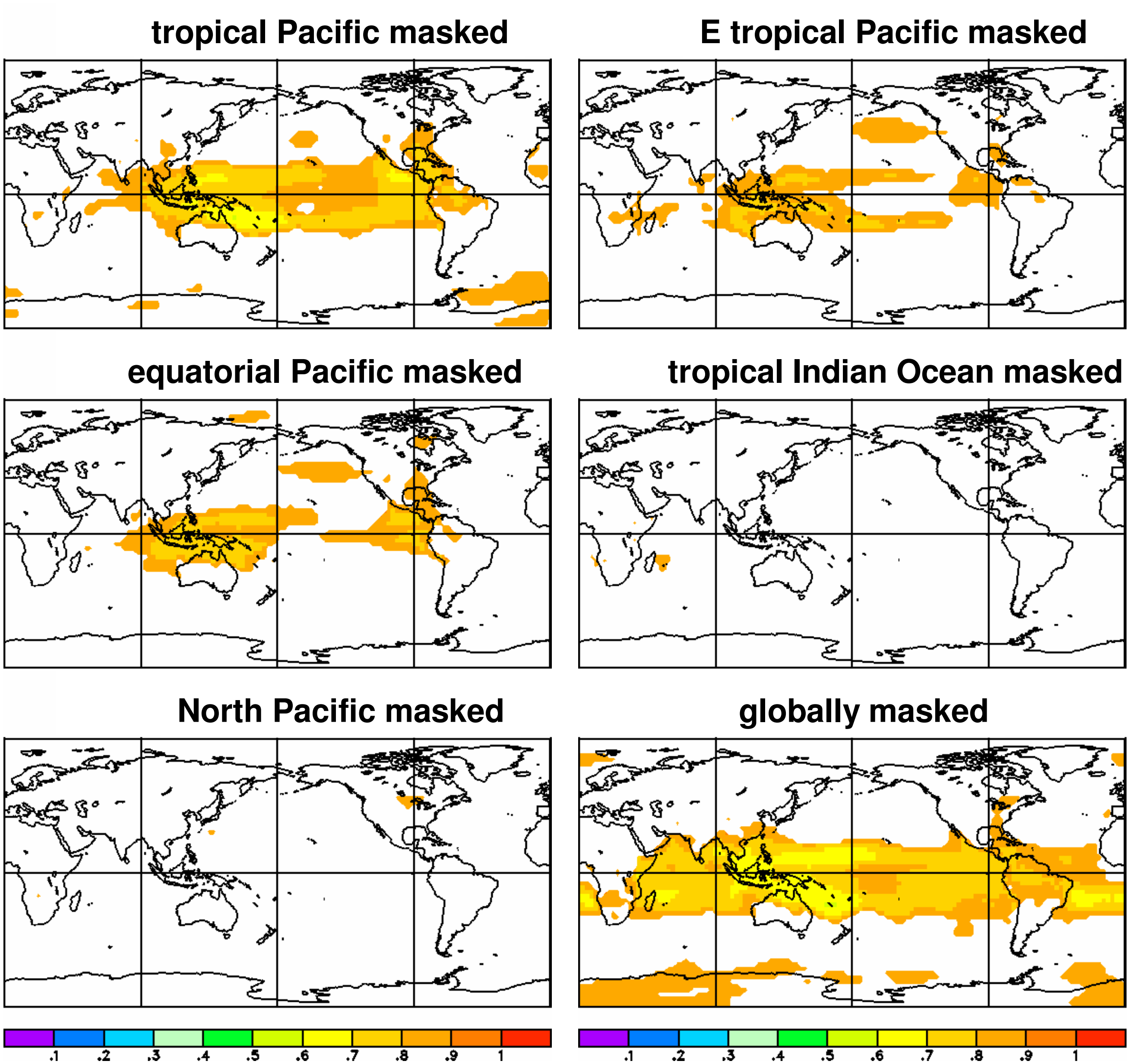
plotted where p<0.01

Impact of masking on interannual variability of DJF seasonal means

mean sea level pressure

Ratio of standard deviations:

$$\frac{\sigma_{masked}}{\sigma_{control}}$$



plotted where p<0.01

Calculation of Potential Predictability

Statistical model based on 1-way ANOVA (Zwiers 96, Zhengetal 2000)

$$X_{yt} = \mu + \beta_y + \varepsilon_{yt}$$

μ represents long term seasonal mean

β_y's represents year-to-year variations in the levels of X that are potentially predictable

ε_{yt}'s represent within season variations that are presumably not predictable on seasonal and longer time scales.

The total interannual variance of the seasonal mean of X_{yt} is

$$\sigma^2_{X_{yo}} = \frac{1}{(Y-1)} \sum_{y=1}^{Y} (X_{yo} - X_{oo})^2$$

X_{yo} denotes the year y seasonal mean and X_{oo} mean of seasonal means

$$\sigma^2_{X_{yo}} = \frac{1}{(Y-1)} \sum_{y=1}^{Y} (\beta_y + \varepsilon_{yo} - (\beta_o + \varepsilon_{oo}))^2$$

$$\sigma^2_{X_{yo}} = \sigma^2_{\beta} + \sigma^2_{\varepsilon_{yo}}$$

Total interannual variance of seasonal mean in the model contains Climate signal and weather noise components.

Whether the observed process is potentially predictable is determined by testing the null hypothesis that the seasonal means of X vary only because of weather noise.

$$H_o : \sigma^2_{\beta} = 0$$

We require an unbiased estimate of variance of the weather Noise that is statistically independent of the total variance. When only monthly means are available, an unbiased estimate of weather noise can be estimated by

$$\sigma^2_{\varepsilon yo} = SSE \frac{(3+4\rho_1+2\rho_2)}{6Y(3-2\rho_1-\rho_2)}$$

where $SSE = \sum_{y}\sum_{t=1}^{3}(X_{yt} - X_{yo})^2$ and ρ_1, ρ_2 are lag-1 month and lag-2 month auto-correlations.

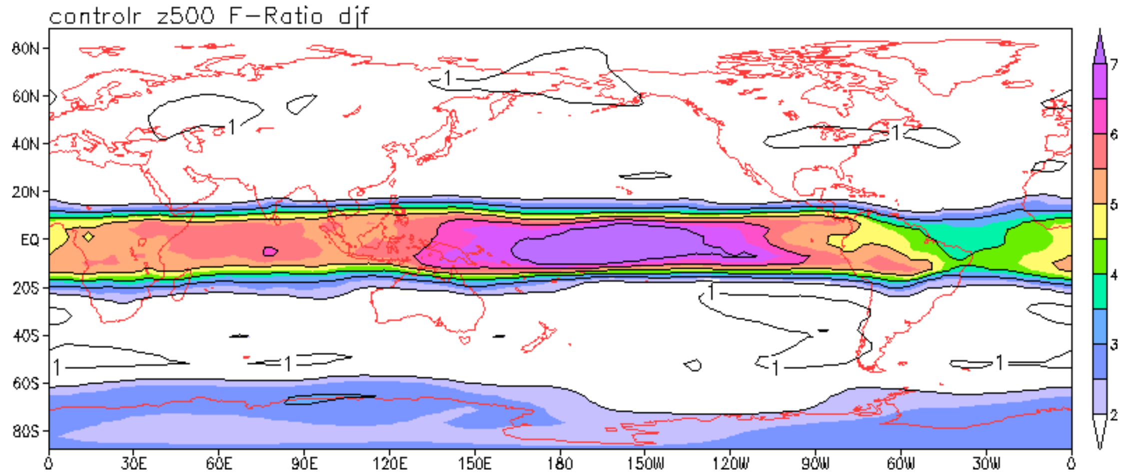
$$F = \frac{\sigma^2_{X_{yo}}}{\sigma^2_{\varepsilon yo}}$$

measure of potential predictability

→ *F-1 measures potentially predictable signal (vaiance exceeds noise)*

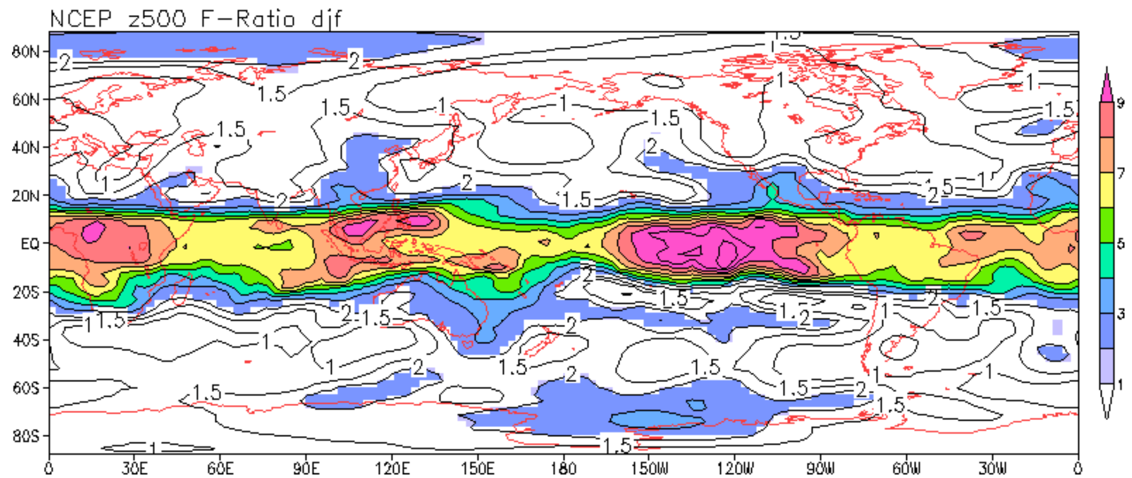
Comparison of potential predictability of DJF seasonal means
Model vs Observations

500mb height



300-year control simulations

Monthly means used



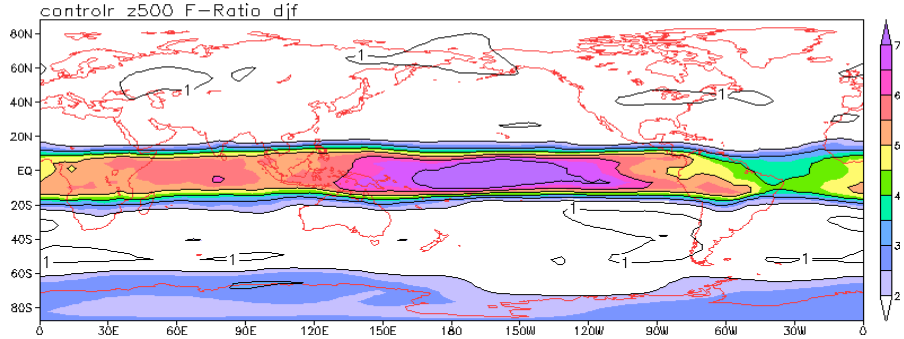
28-years, 1979-2007

Monthly means used

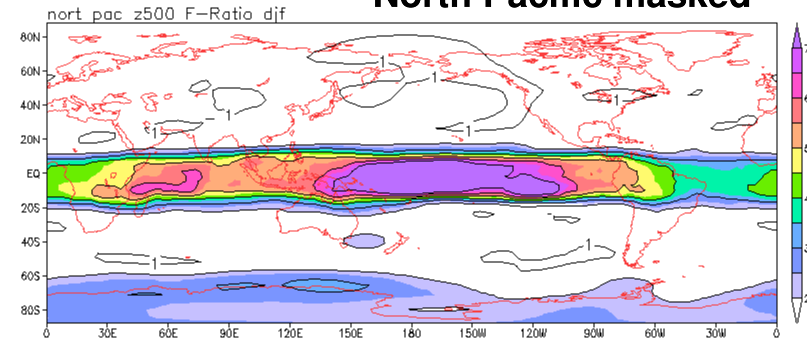
Impact of masking on potential predictability of DJF seasonal means

500mb height

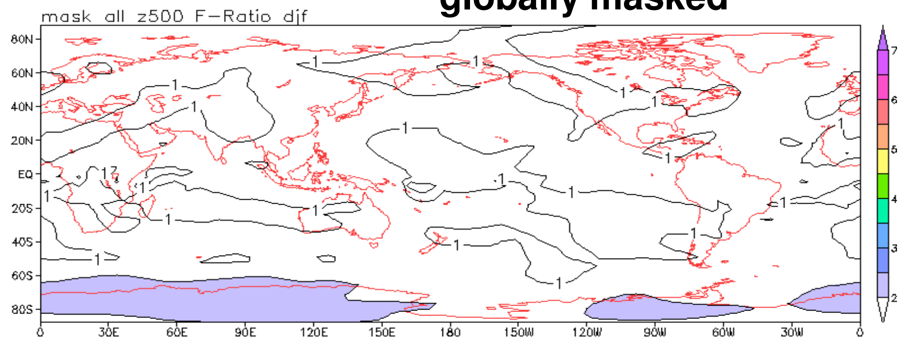
Control run



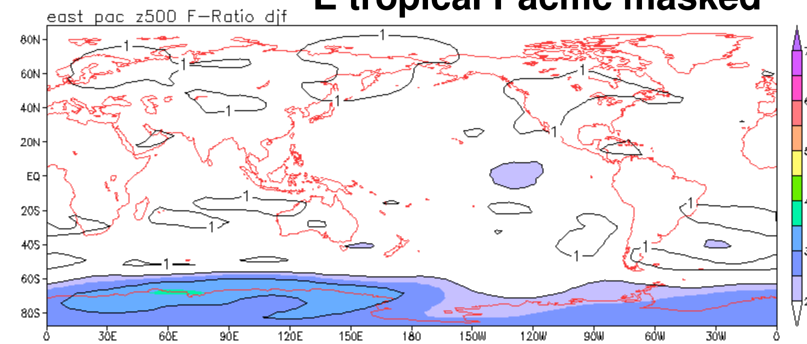
North Pacific masked



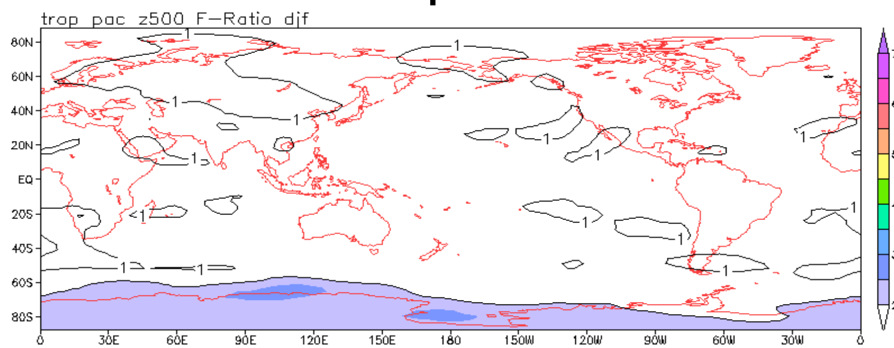
globally masked



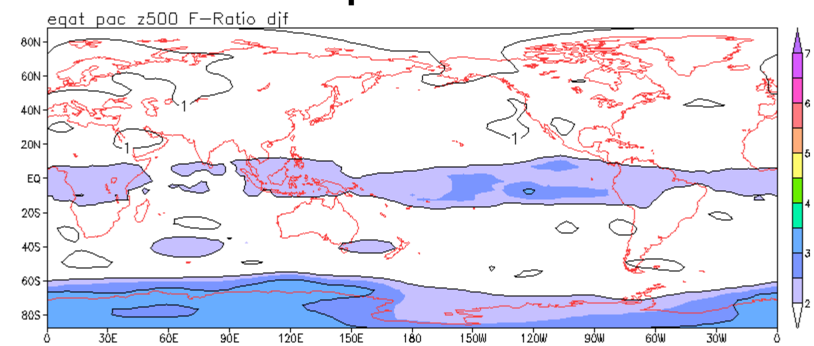
E tropical Pacific masked



tropical Pacific masked

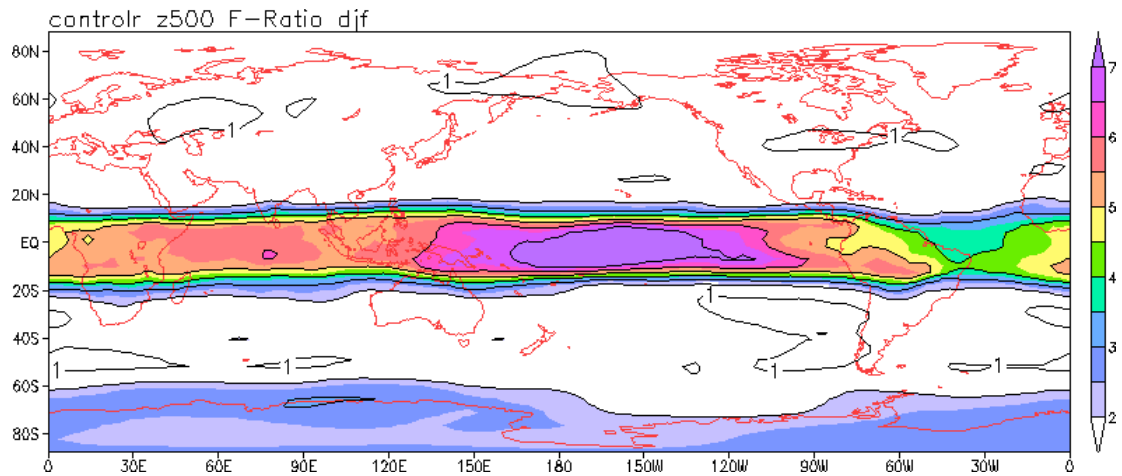


equatorial Pacific masked

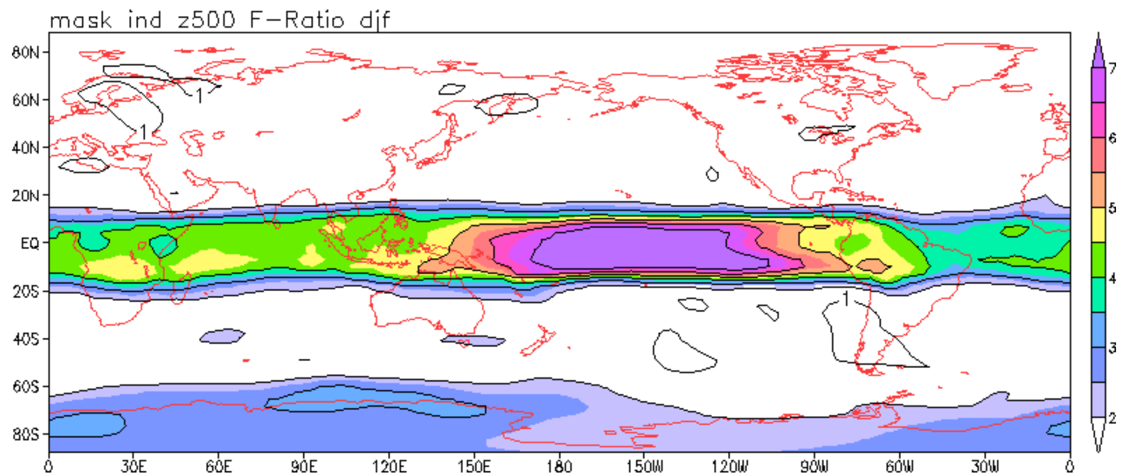


Impact of masking on potential predictability of DJF seasonal means

500mb height



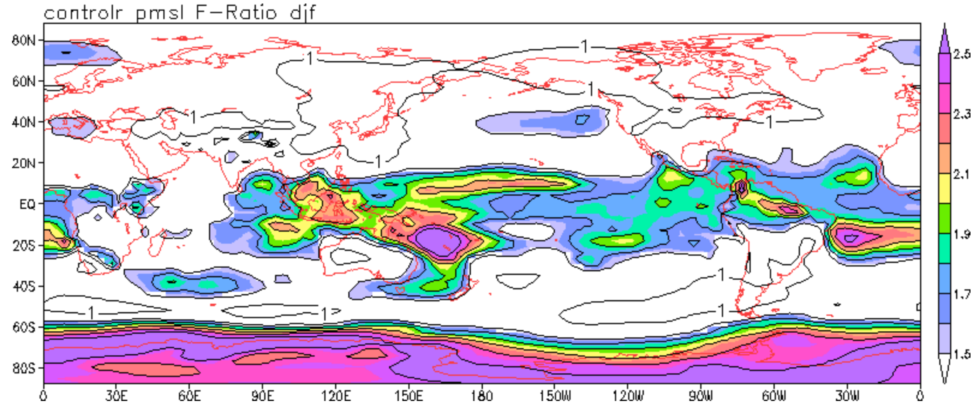
→ Model Control run



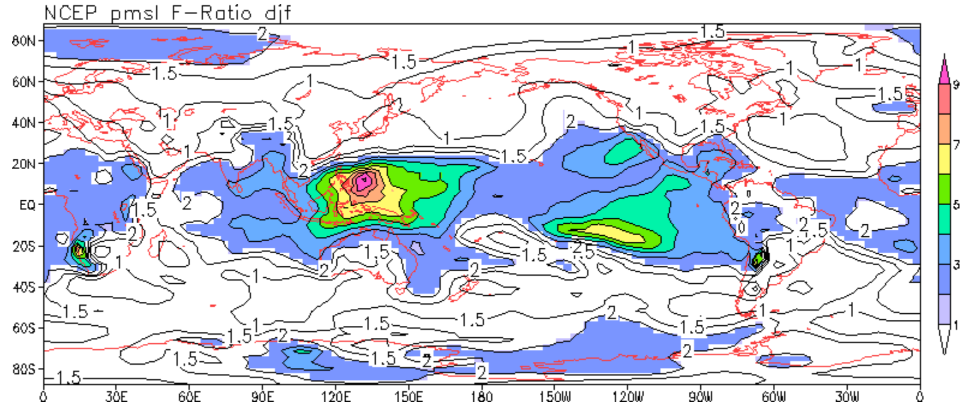
→ Masked IO run

Comparison of potential predictability of DJF seasonal means
Model vs Observations

mean sea level pressure

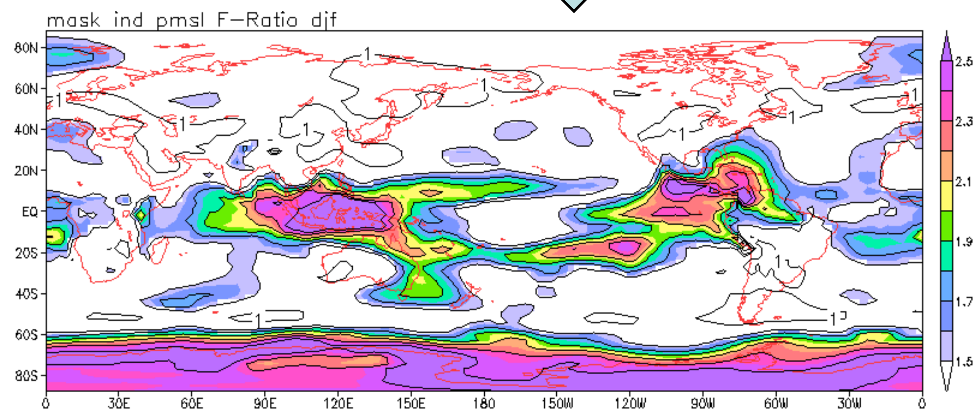


→ Model Control run



→ NCEP Reanalysis

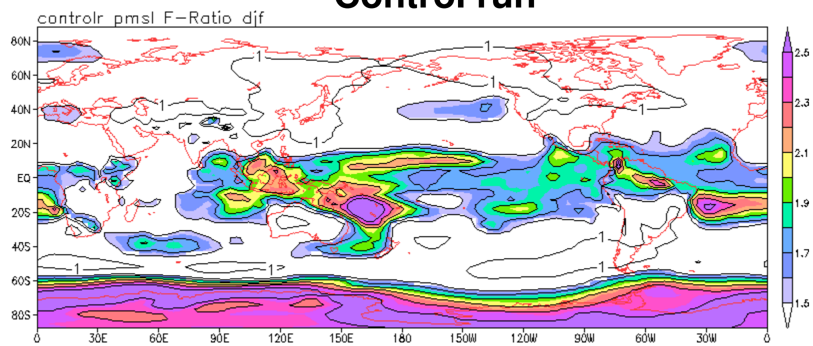
Masked Indian Ocean Run



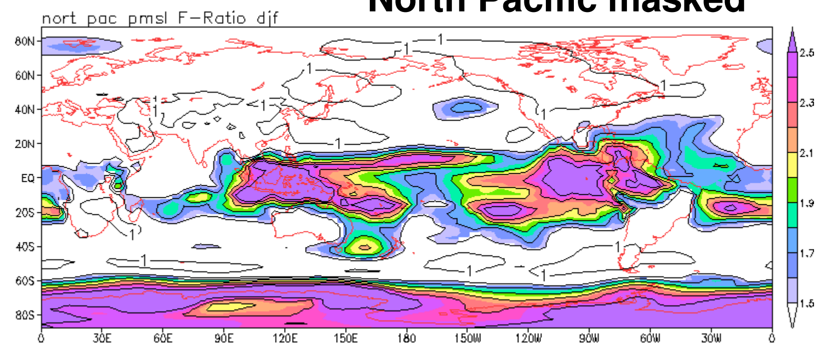
Impact of masking on potential predictability of DJF seasonal means

mean sea level pressure

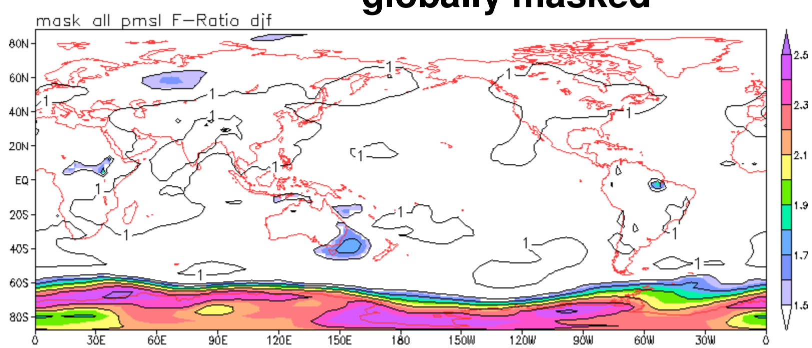
Control run



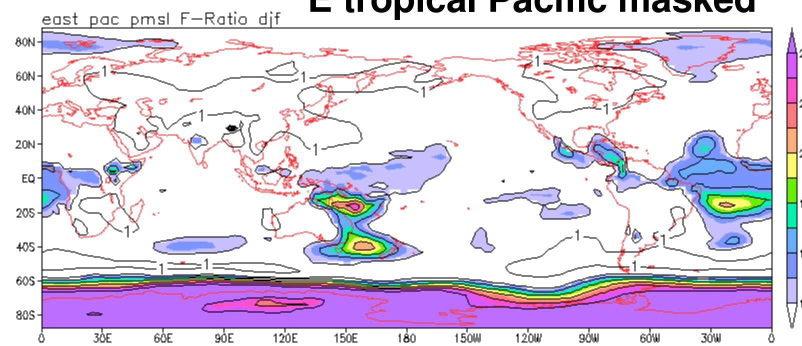
North Pacific masked



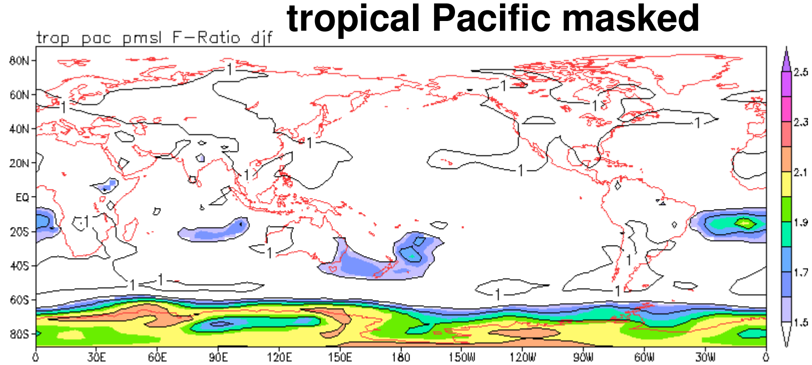
globally masked



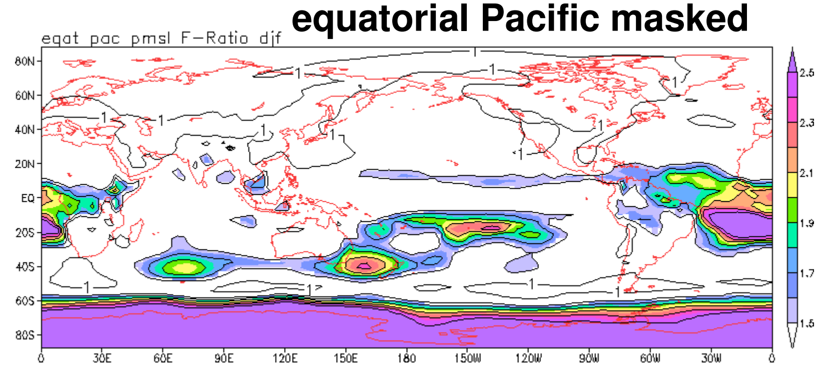
E tropical Pacific masked



tropical Pacific masked



equatorial Pacific masked



Summary

- Partial coupling procedure enables effects of local and remote air-sea interactions to be distinguished from intrinsic atmospheric variability
- Initial results presented here
- ENSO SSTA are responsible for much (but not all) of climate variability (wrt to z500, t850 and mslp) both locally (in tropical Pacific) and remotely.
- Ongoing work includes
  - longer time series
  - other seasons
  - more detailed analysis on climate variability wrt to larger modes of climate variability like ENSO, IOD etc
  - comparison with CGCM3.8 which has a stronger ENSO

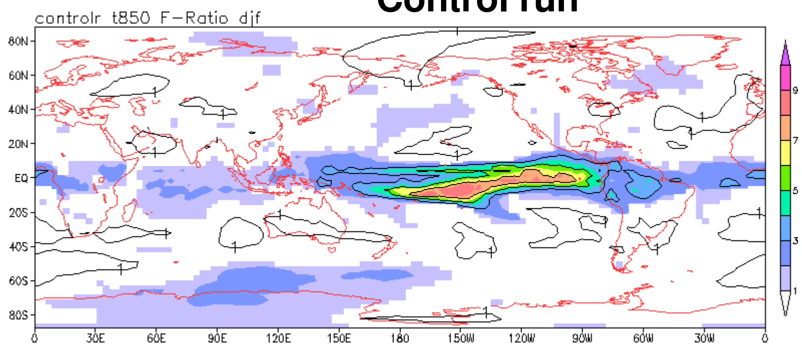
Assumptions

- We assume that the random variables {$\hat{a}_y$,y=1,…Y} to be independently distributed random variables with mean zero and variance $\sigma^2_{\hat{a}}$.
- Weather noise time series {$\mathring{a}_{yt}$, t=1,..T} are assumed to be independent realizations of the same Gaussian stochastic process.
- The weather noise process is assumed to be independent of the potential predictable process {$\hat{a}_y$,y=1,…Y}
- Each weather noise time series {$\mathring{a}_{yt}$, t=1,..T} is assumed to behave as red noise.
- Clearly there are limitations to the utility of this model.
- Nonetheless departures from this assumptions would appear mild enough that the model remains as a useful device for partitioning variance into potentially predictable and non-predictable components.

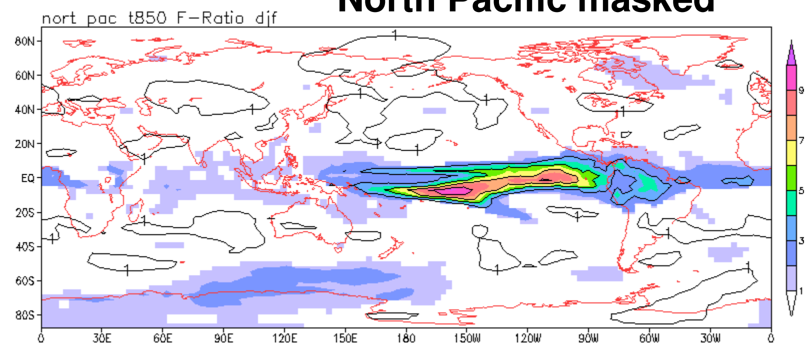
Impact of masking on potential predictability of DJF seasonal means

850mb temperature

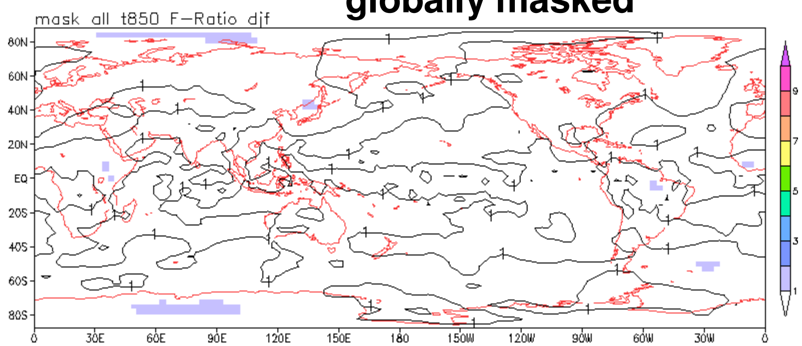
Control run



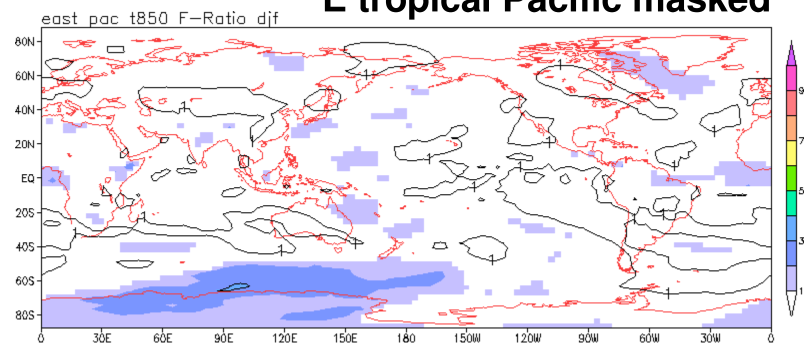
North Pacific masked



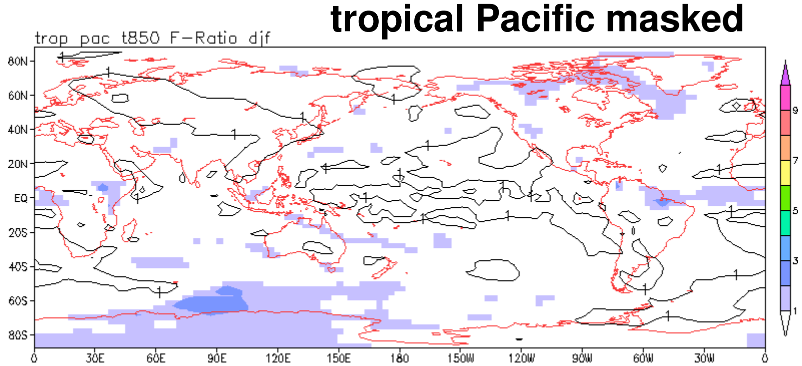
globally masked



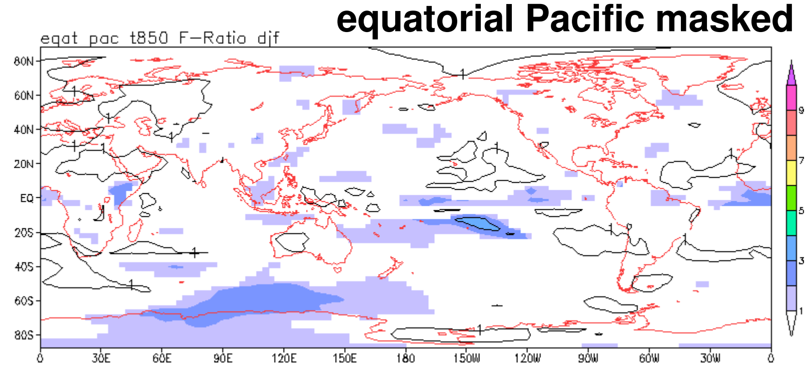
E tropical Pacific masked



tropical Pacific masked

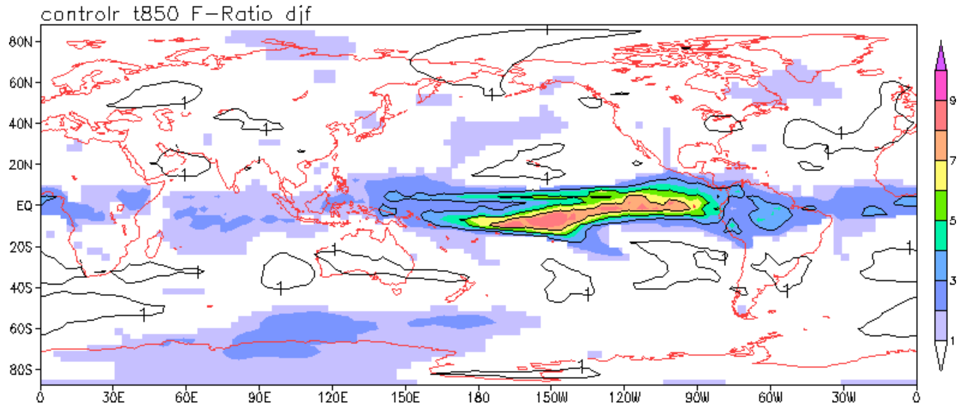


equatorial Pacific masked

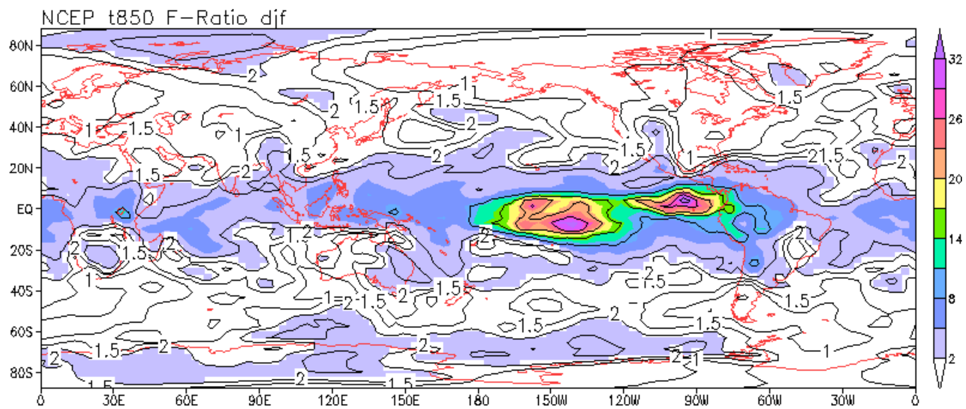


Comparison of potential predictability of DJF seasonal means
Model vs Observations

850mb temperature

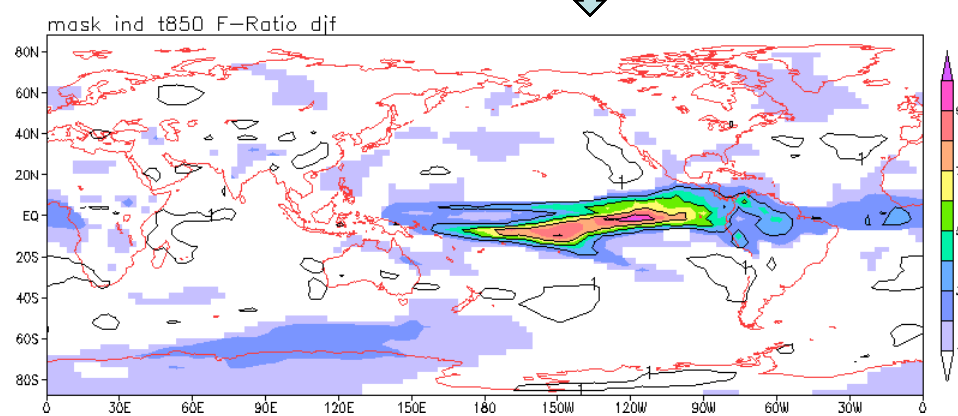


→ Model Control run

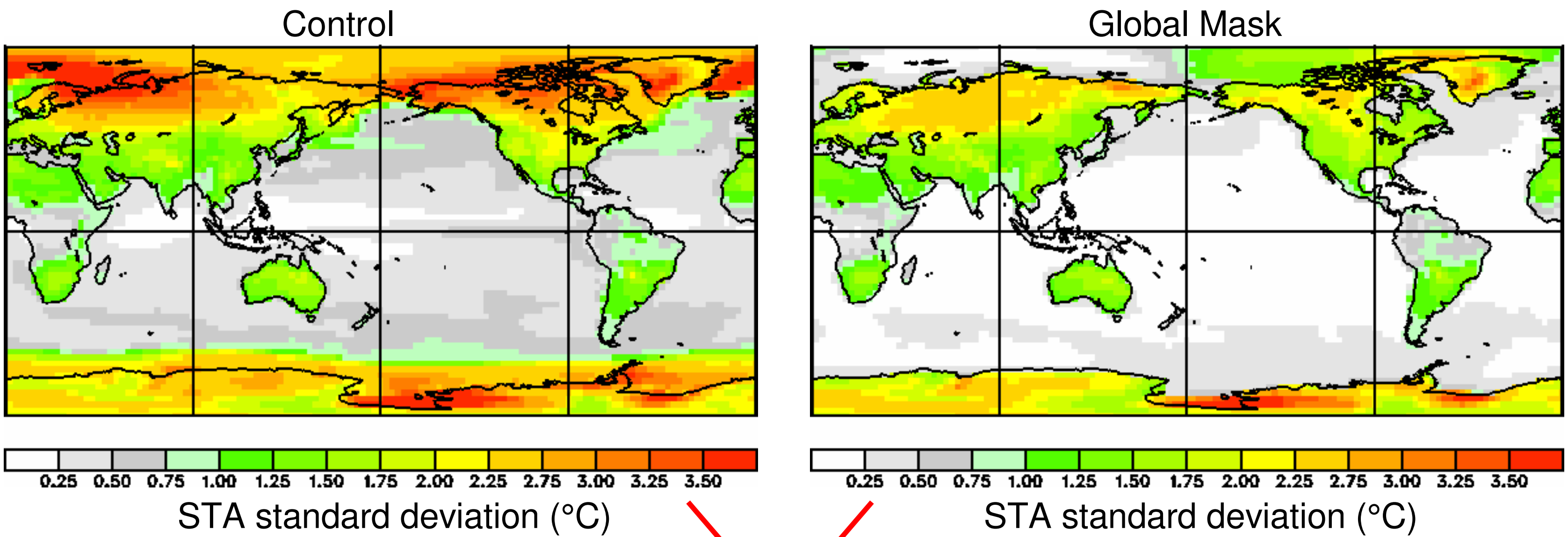


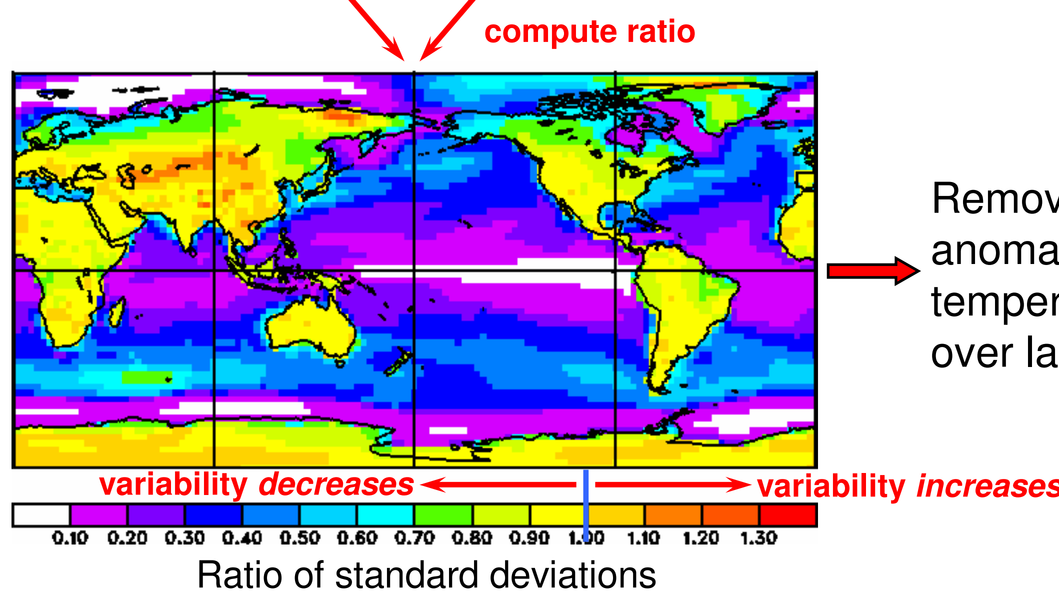
→ NCEP Reanalysis

Masked Indian Ocean Run



Example: Effect of SSTA on standard deviation of monthly surface temperature anomalies





Removal of SST anomalies damps temperature variability over land