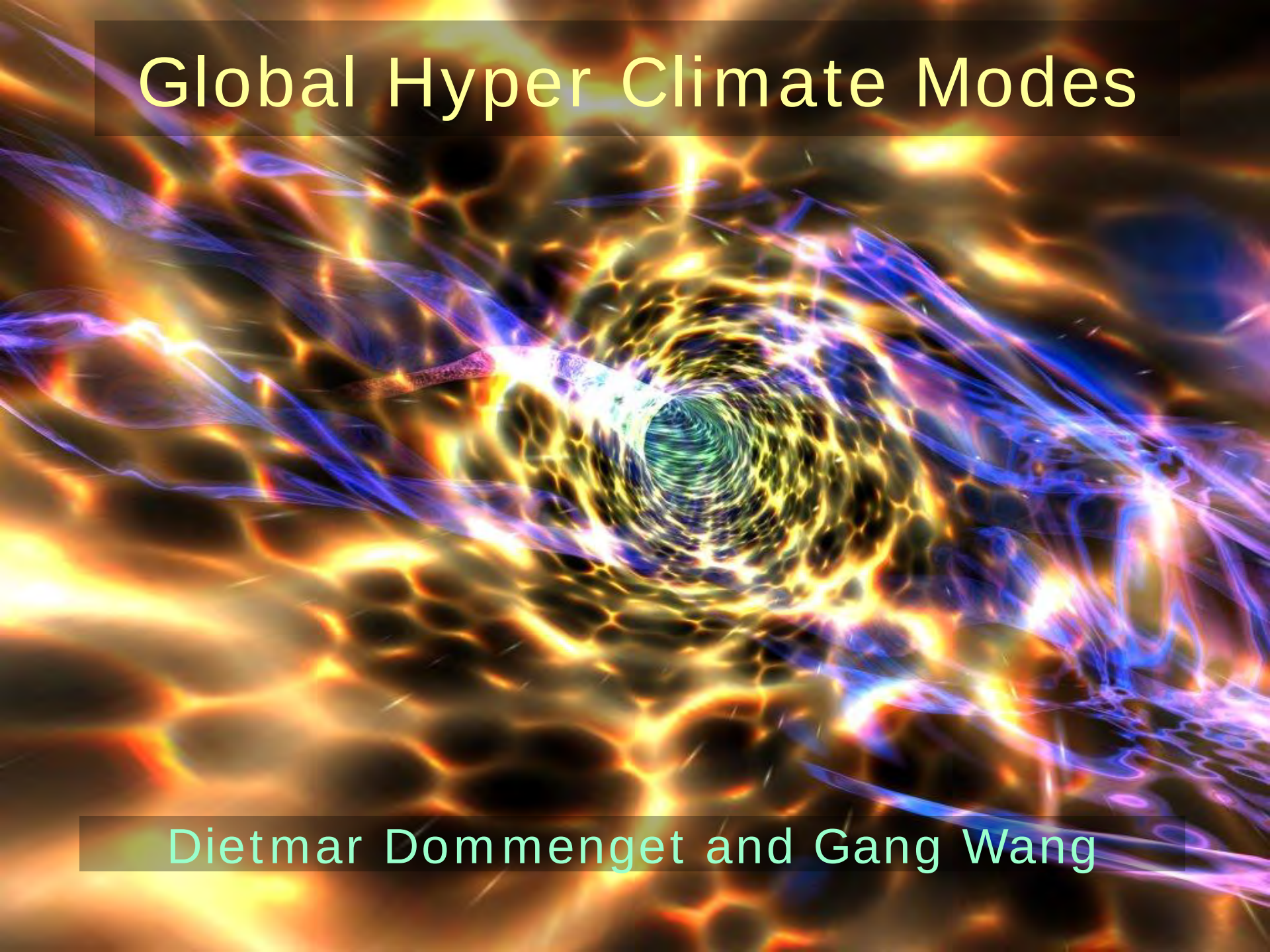
Global Hyper Climate Modes

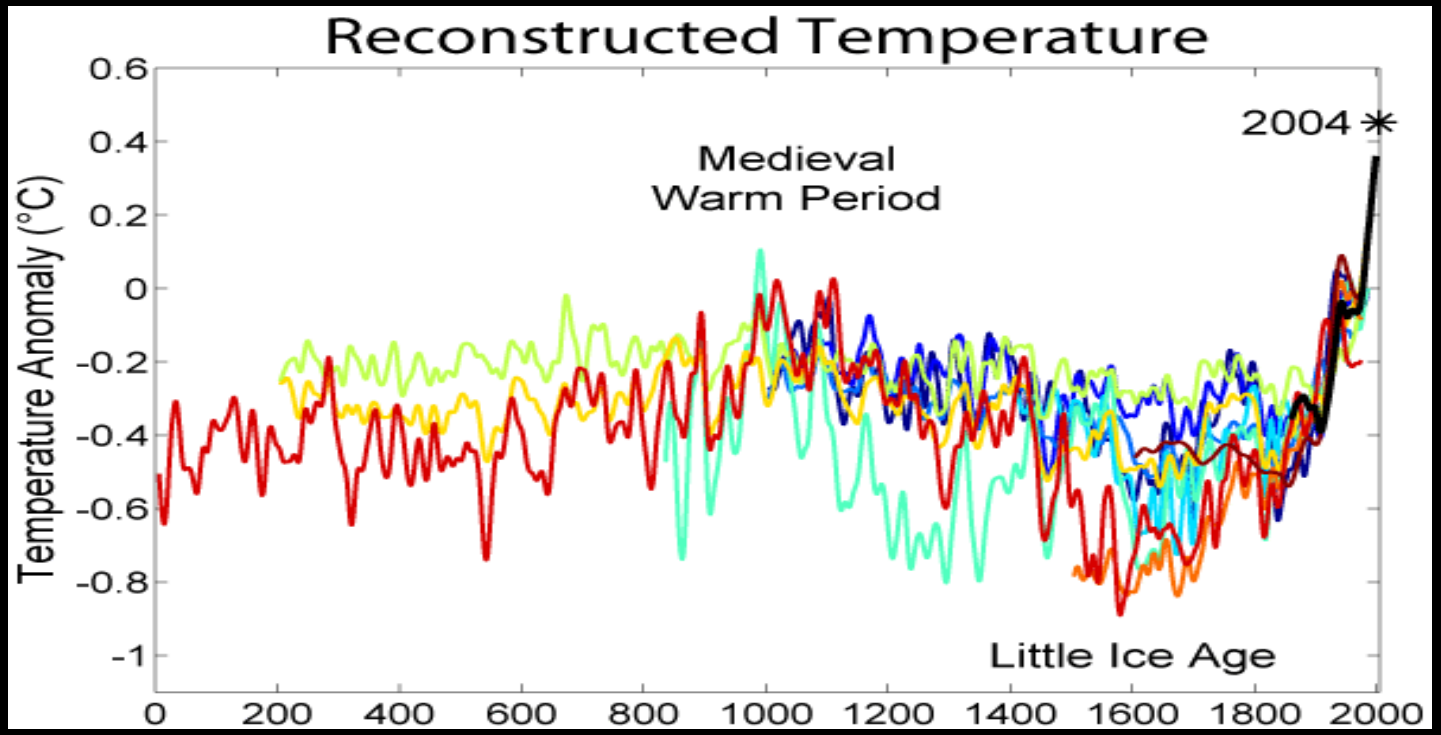


Dietmar Dommenget and Gang Wang

Outline

- Motivation
- Introduction
  - Known climate modes
  - Null hypothesis time scales
  - Null hypothesis spatial pattern
- Spatial pattern
  - Global mode
  - Model limitations
  - Tropical link
- Time scales
- Discussions /conclusions

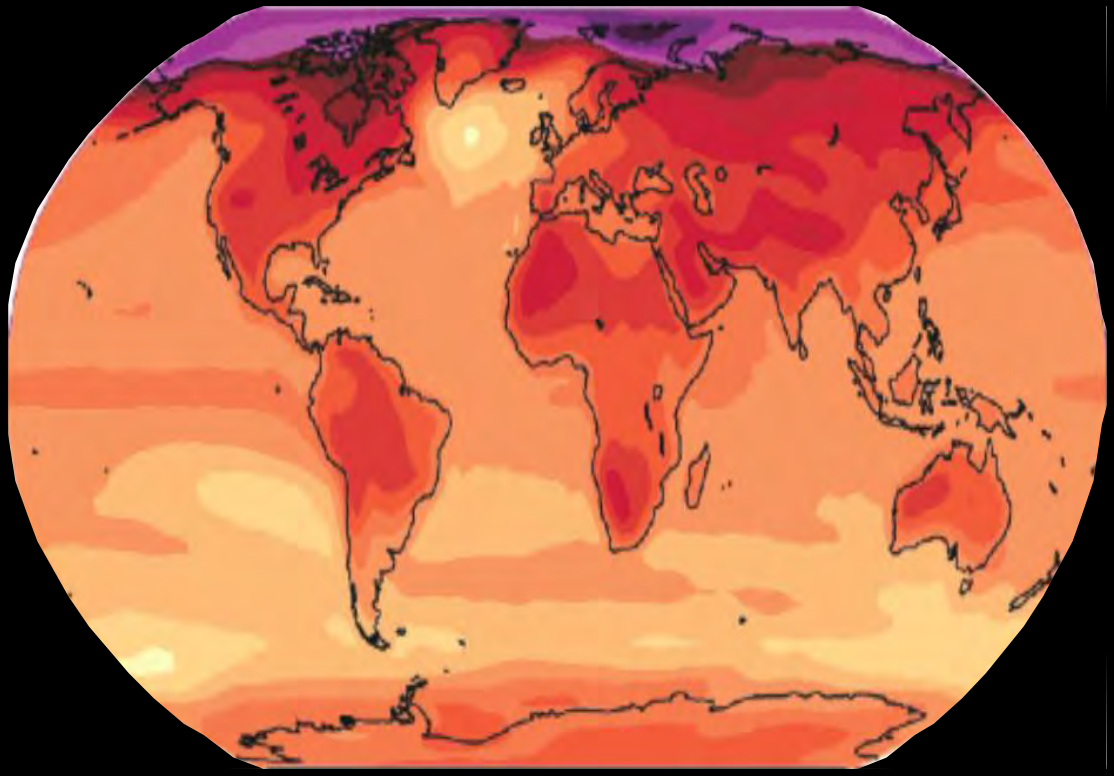
Motivation



How does global scale multi-decadal climate variability look like?

Motivation

Global warming pattern



How does global pattern of natural variability look like?

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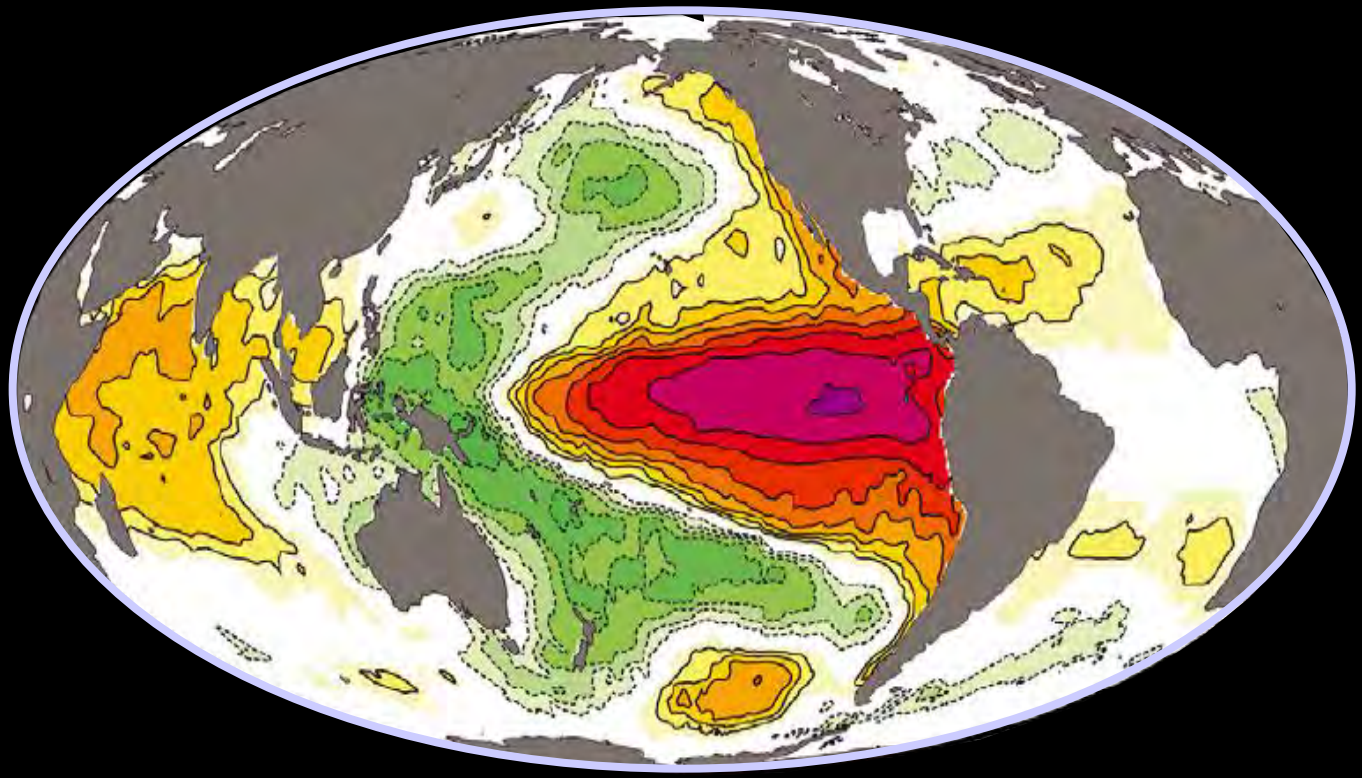
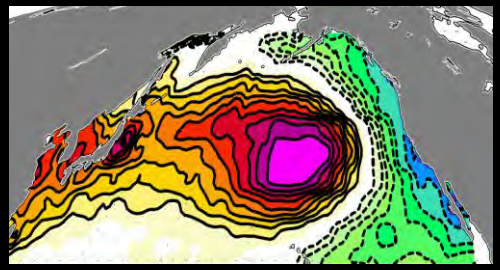
- ✧ Discussions /conclusions

Motivation/ climate modes

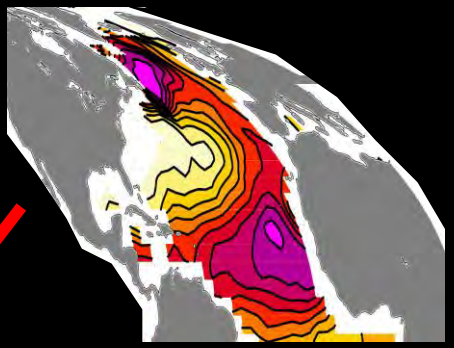
El Nino Southern Oscillation



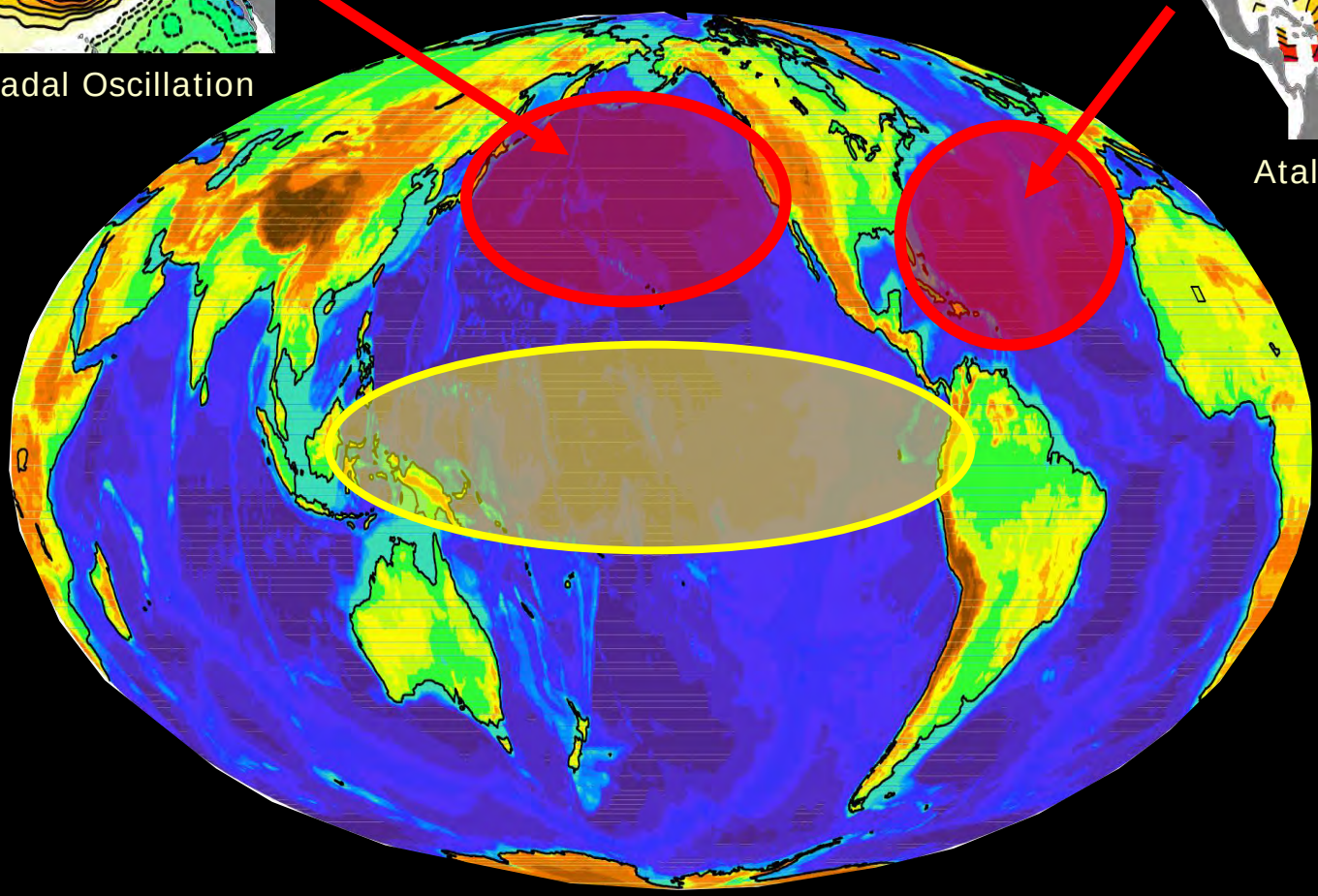
Motivation/ climate modes



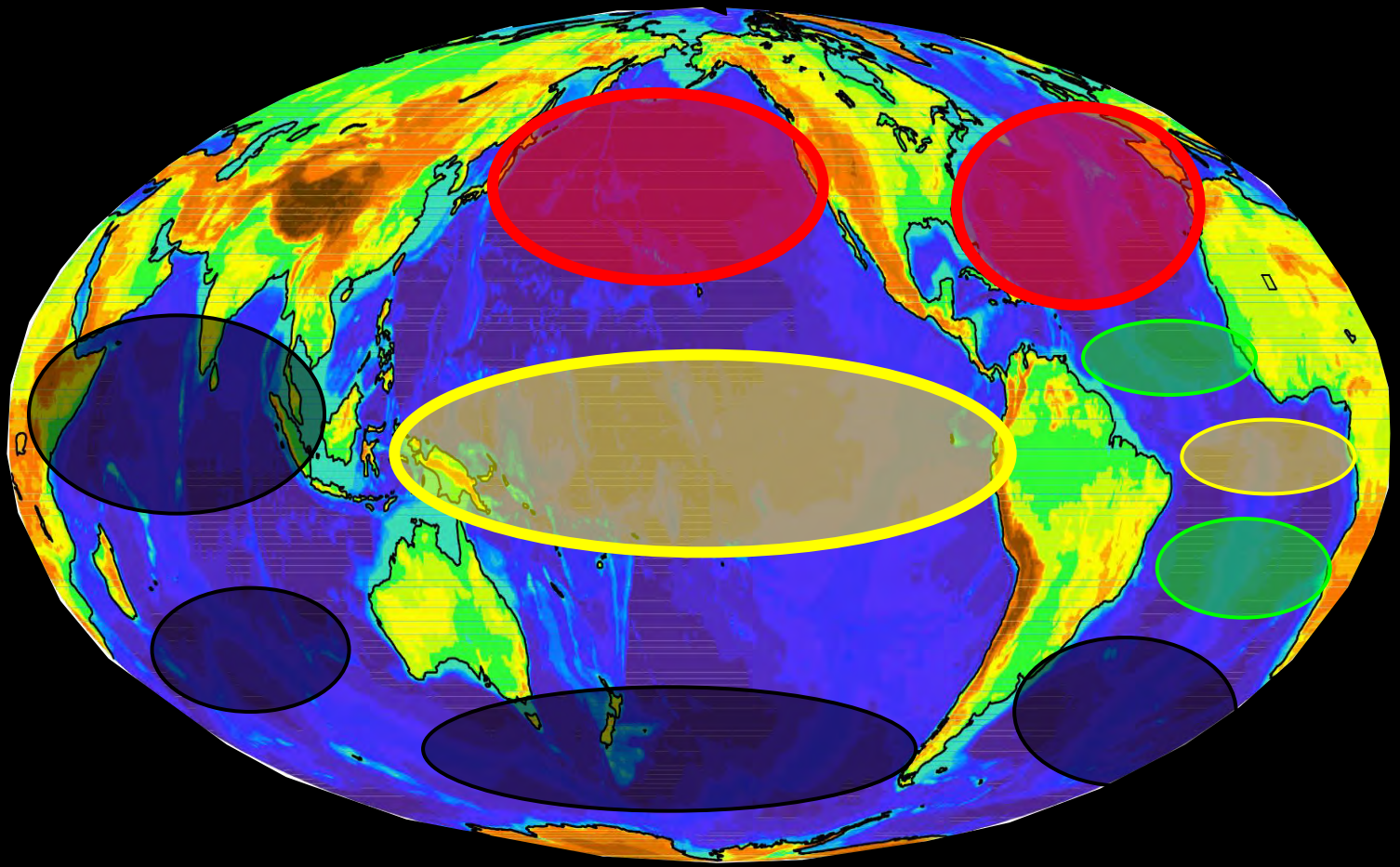
Pacific Decadal Oscillation



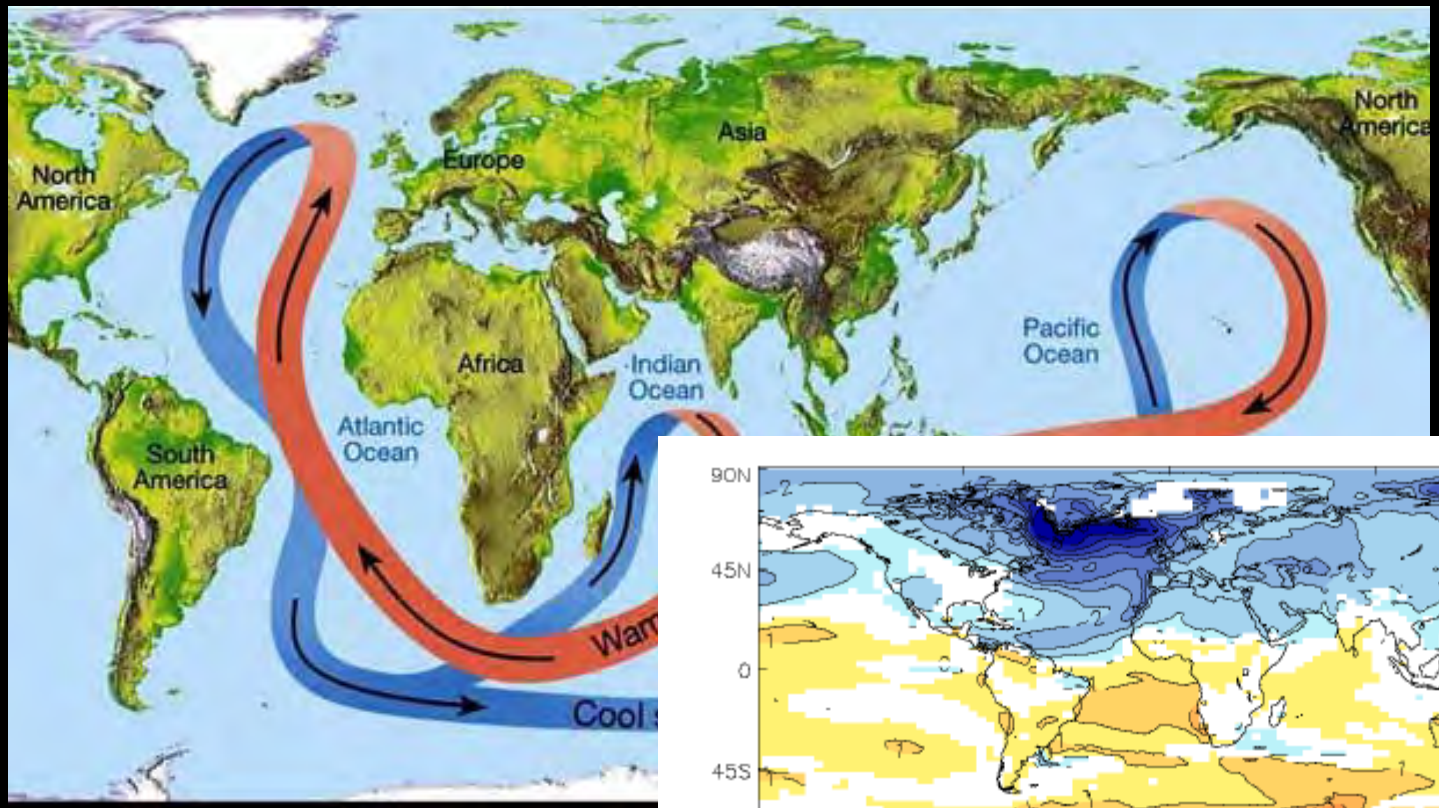
Ataltic Decadal Mode



Motivation/ climate modes



Motivation/ ocean modes



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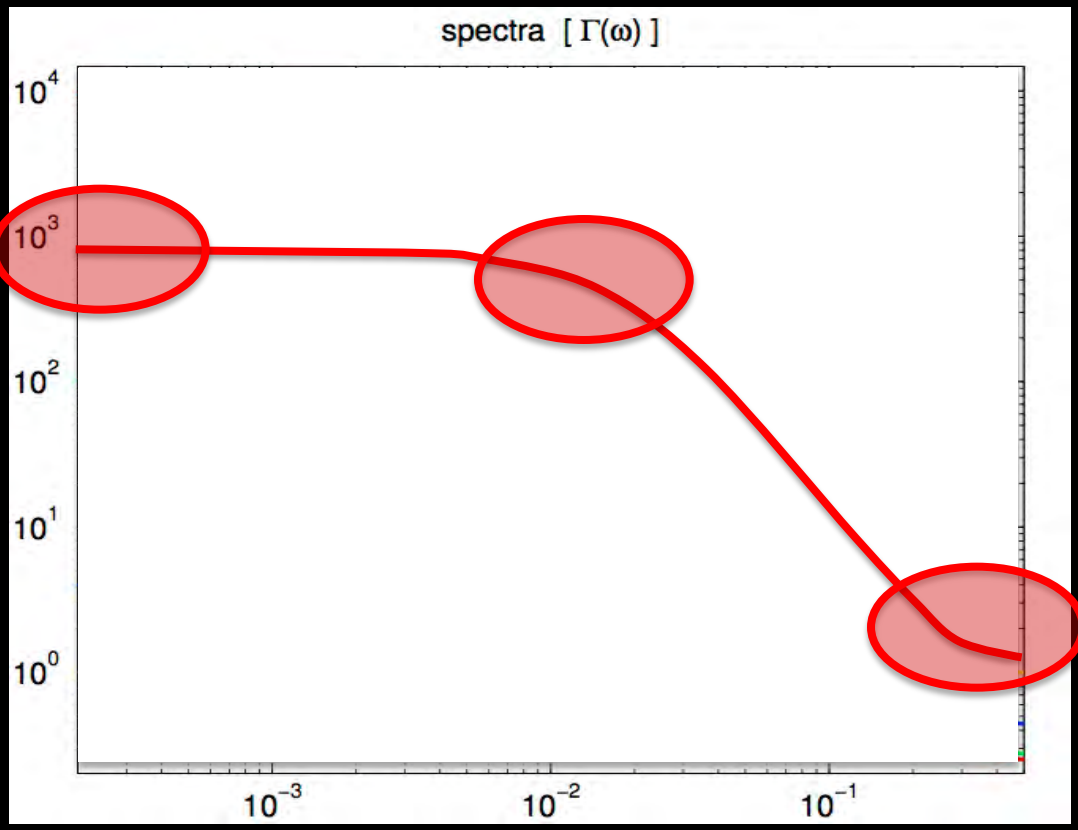
Red Noise Null Hypothesis



$$g\frac{dT}{dt} = -cT + x$$

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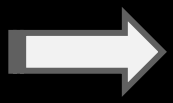
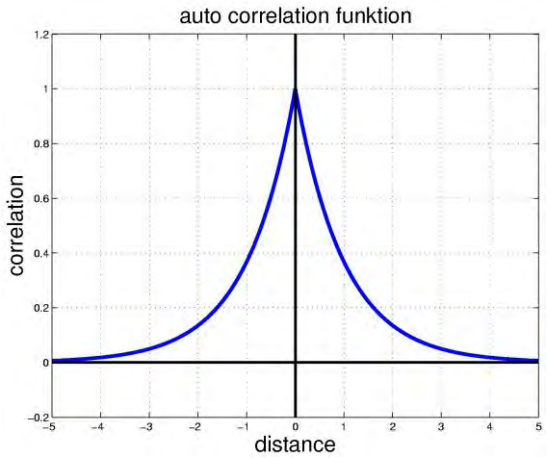
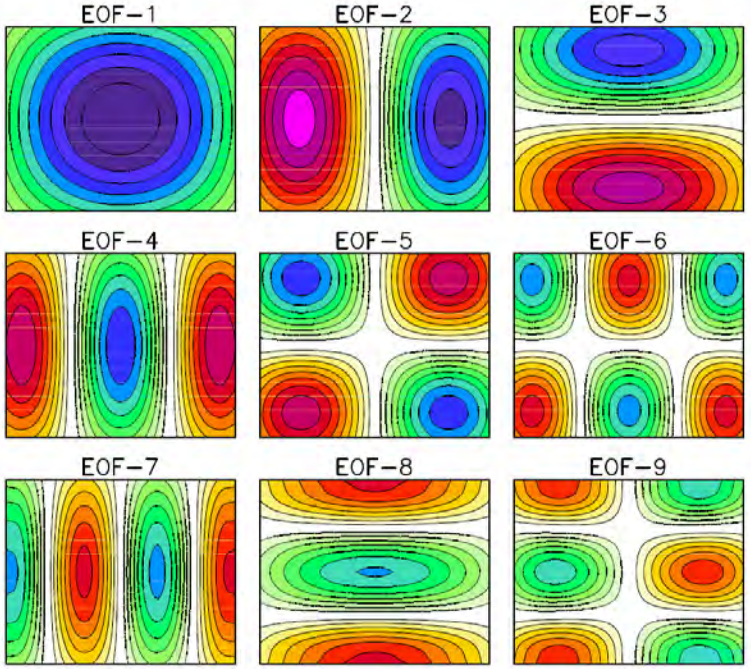


Spatial Red Noise Null Hypothesis

Isotropic Diffusion

$$\frac{\mathrm{d}}{\mathrm{d}t}\Phi = c_{\mathrm{damp}} \cdot \Phi + c_{\mathrm{diffuse}} \nabla^2 \Phi + f$$





$$g\frac{dT}{dx} = -cT + x$$

Dommenget [2007]

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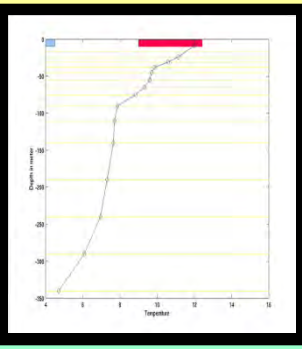
Approach

Observations: 1870-2004 (HADISST)

CMIP3 Simulations: 7x340yrs, preindustrial control
(GISS, CCCA, CISRO, MPI, HADLEY, METEO, MRI)

ECHAM5-OZ: 2000yrs, no ocean dynamics
-> spatial structure forced from atmos.



global mode

What is the leading mode of global SST variability on multi-decadal time scales?

long time scales

How does the SST spectrum continues at longer time scales?

- ✧ Motivation
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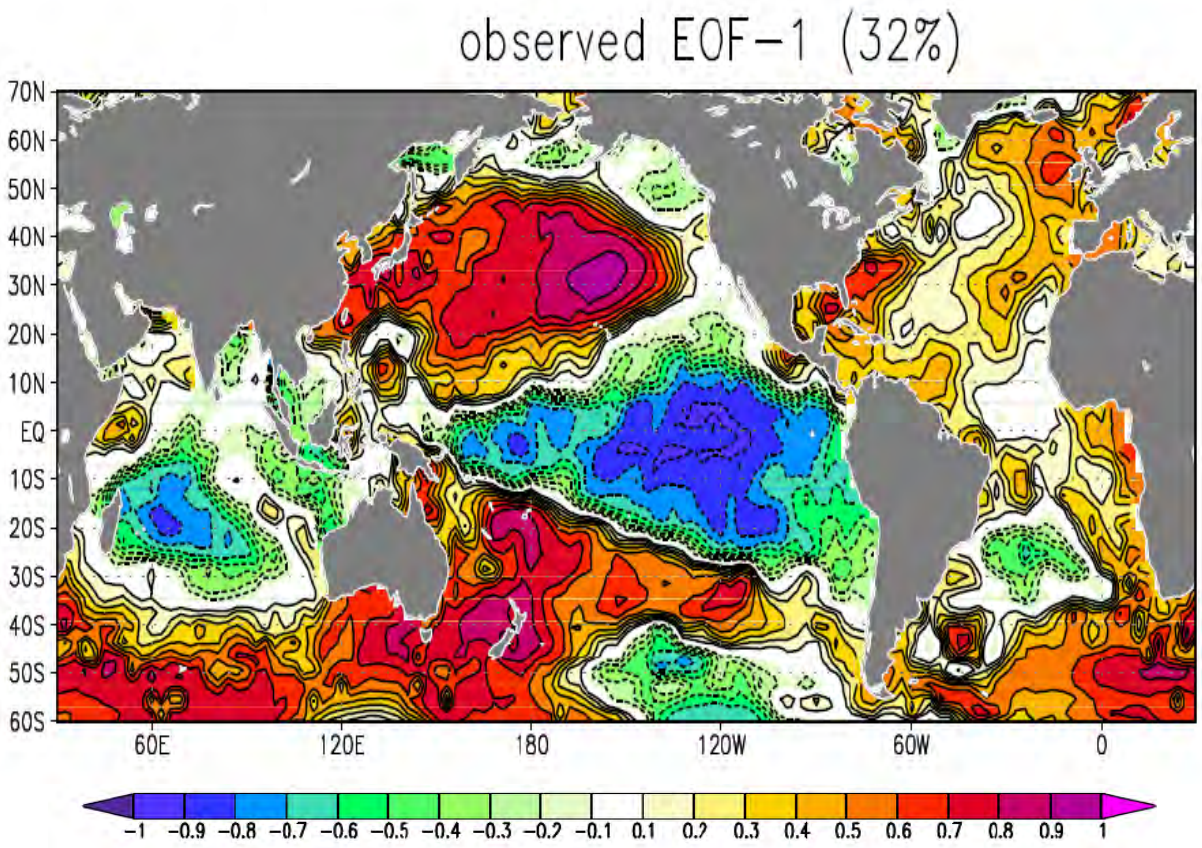
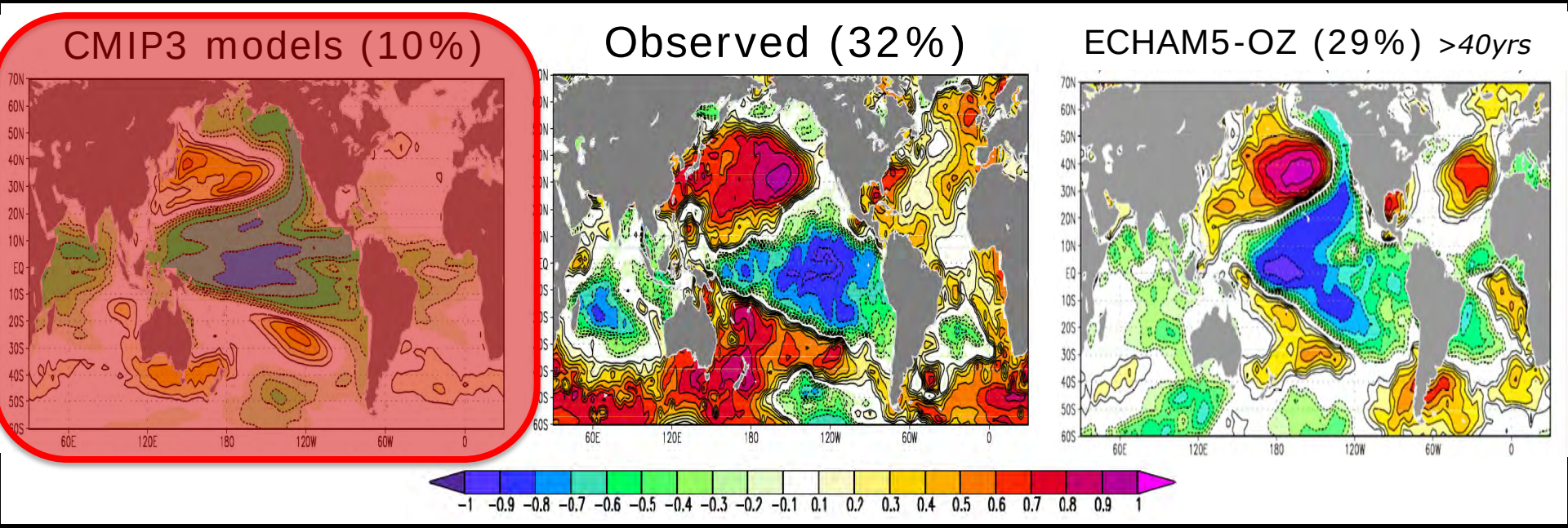
Observed Leading Mode



(HADISST 1870-2004 annual mean / 10yrs running mean / exp. detrended)

Model Leading EOF Mode



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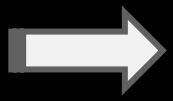
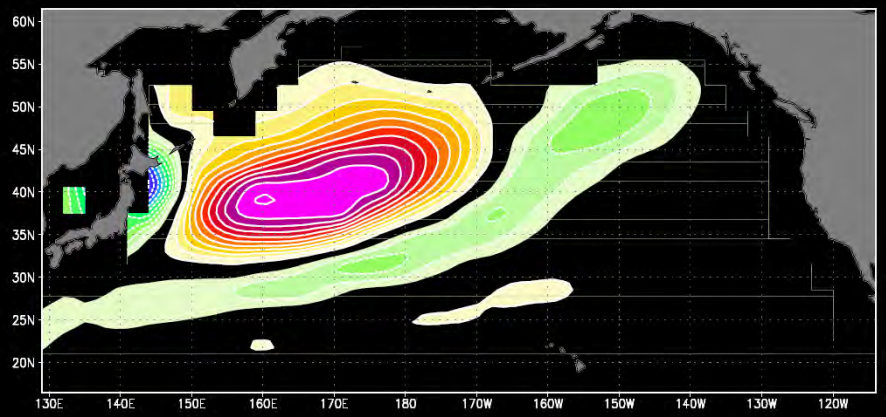


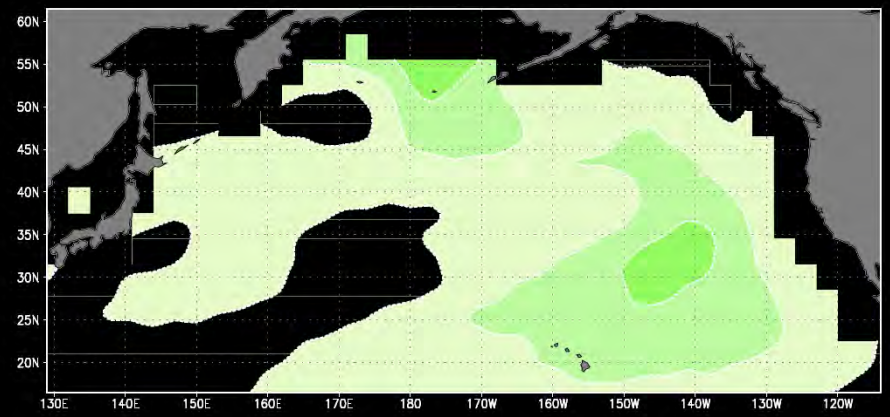
CMIP Pattern Errors

EOF-1 CMIP3-models North Pacific

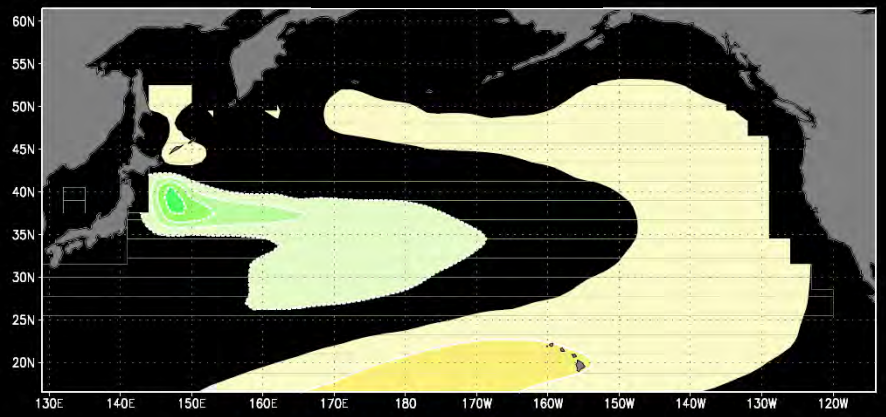
GISS 47%



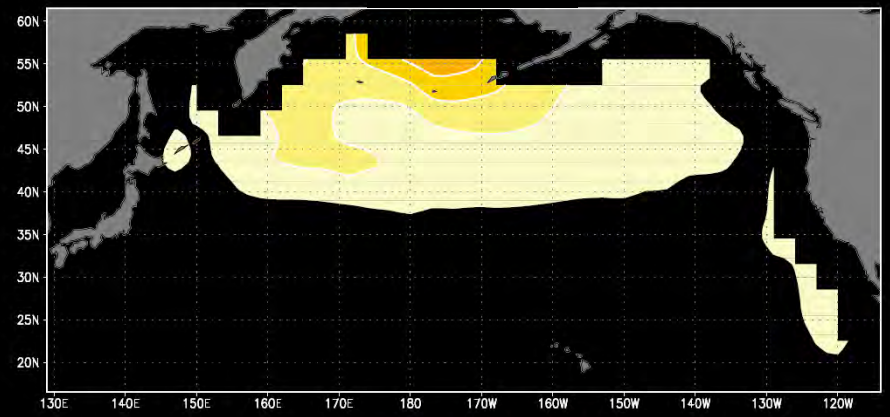
METEO 42%



HADLEY 46%



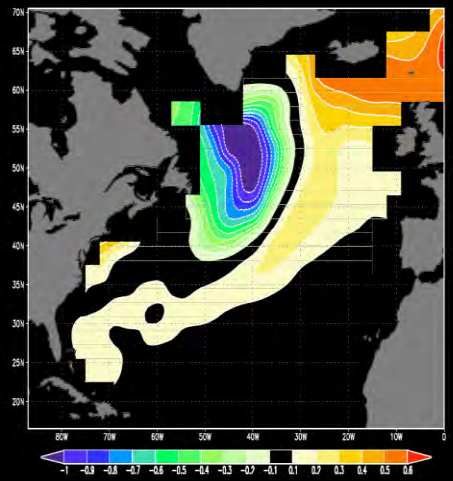
MPI 32%



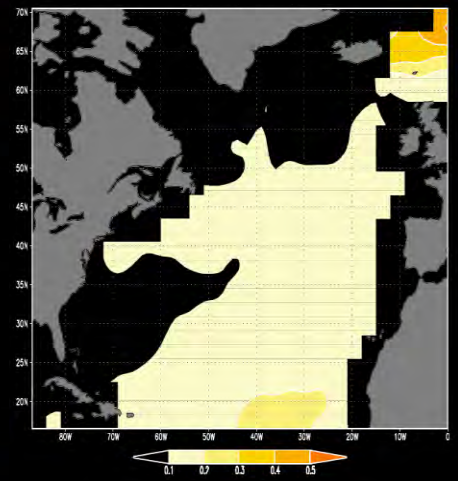
CMIP Pattern Errors

EOF-1 CMIP3-models North Atlantic

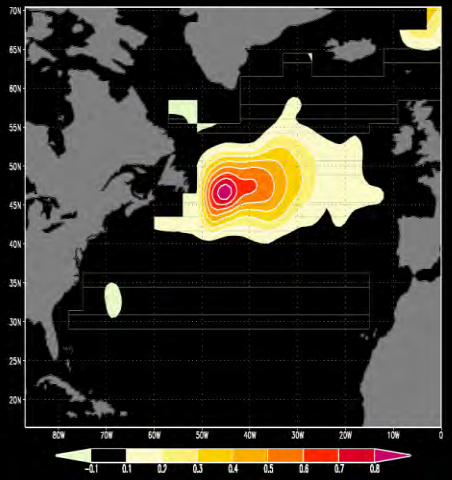
GISS 50%



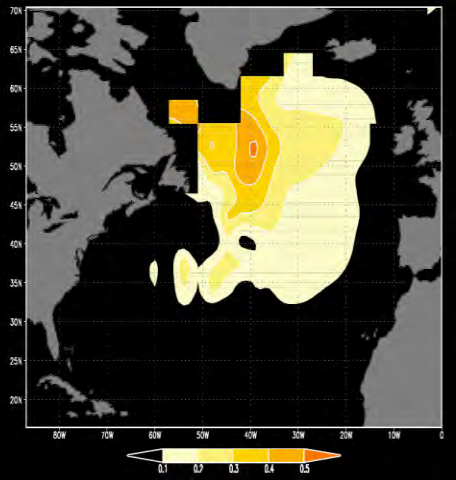
METEO 54%



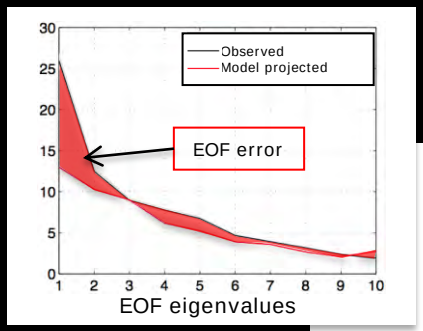
HADLEY 33%



MPI 45%



CMIP Pattern Errors



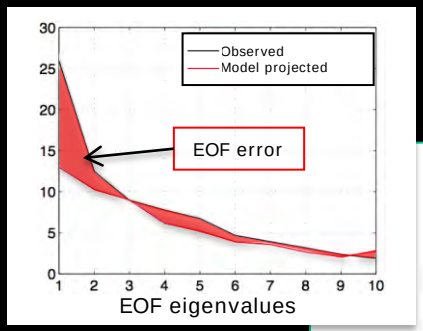
North Pacific

EOF-error *5yrs runmean*

EOF-error ***monthly means***

Sampling uncertainty
Red noise
Red noise with known stdv
CMIP3 mean
CMIP5 mean
Slab ocean

CMIP Pattern Errors



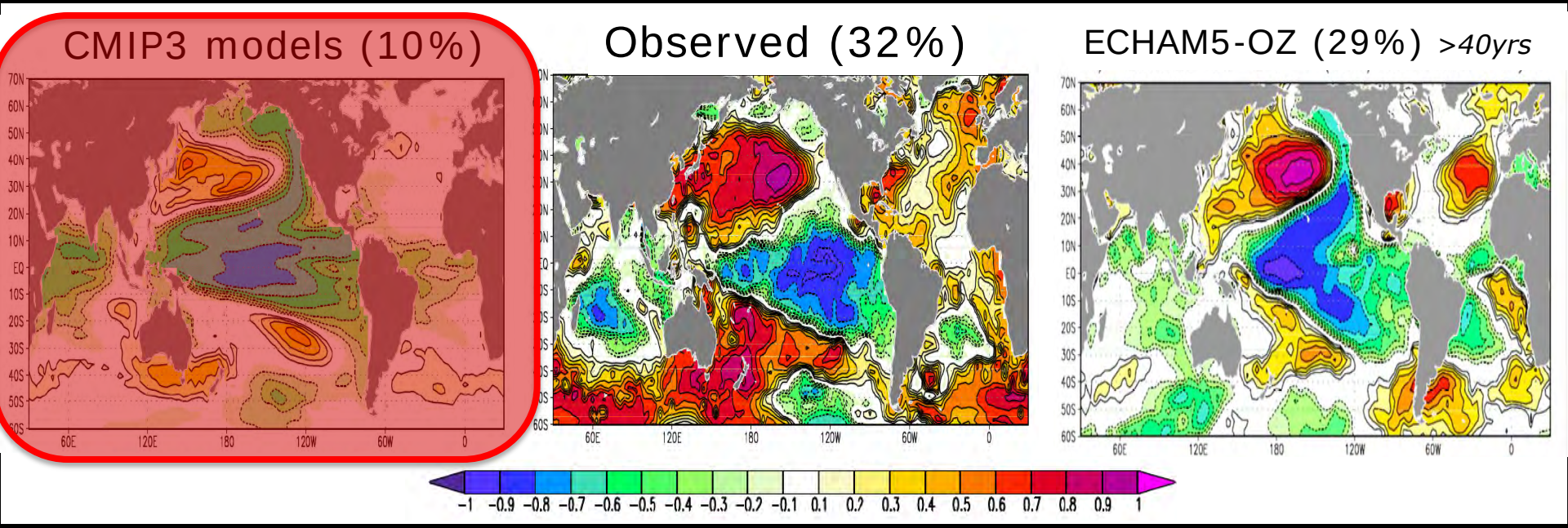
North Atlantic

EOF-error *5yrs runmean*

EOF-error *monthly means*

Sampling uncertainty
Red noise
Red noise with known stdv
CMIP3 mean
CMIP5 mean
Slab ocean

Model Leading EOF Mode



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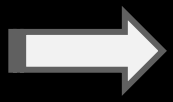
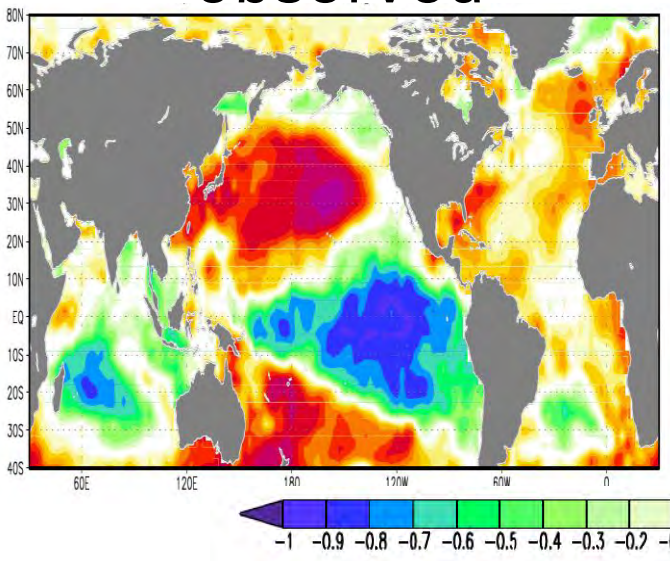
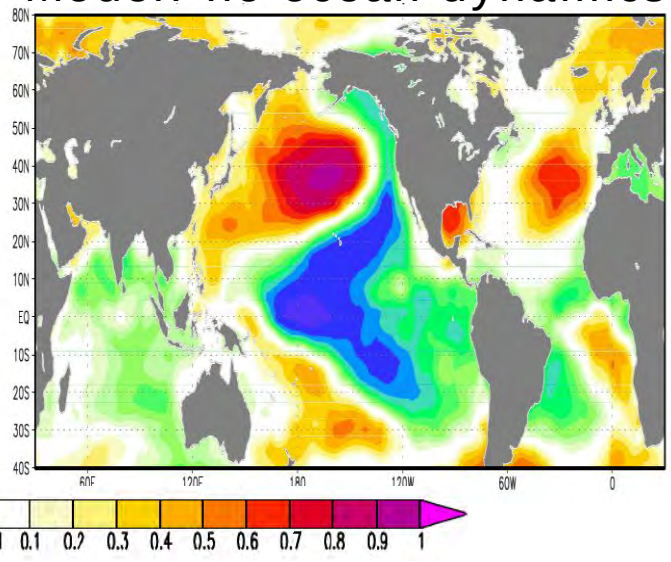


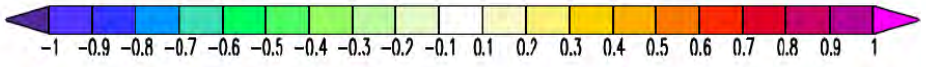
Model Leading Mode

observed



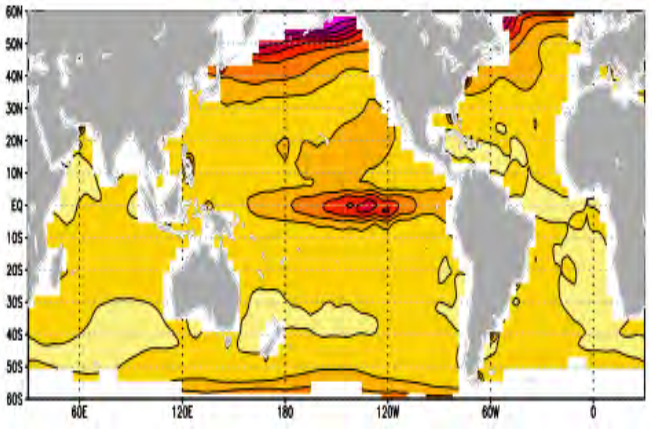
Model: no ocean dynamics





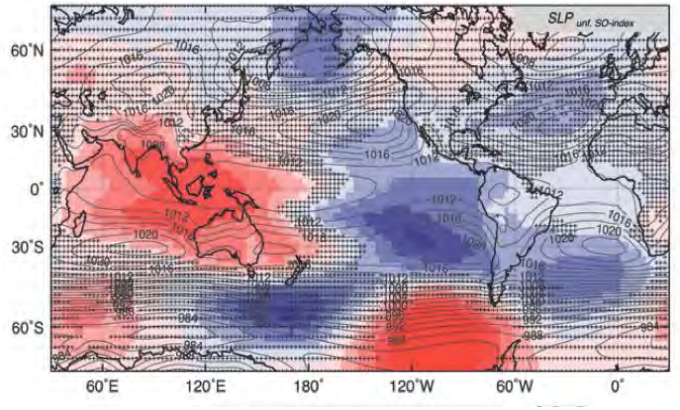
ENSO without Ocean Dynamics?

Slab Ocean
El Nino



Dommenget [2010]

Slab Ocean
Southern oscillation



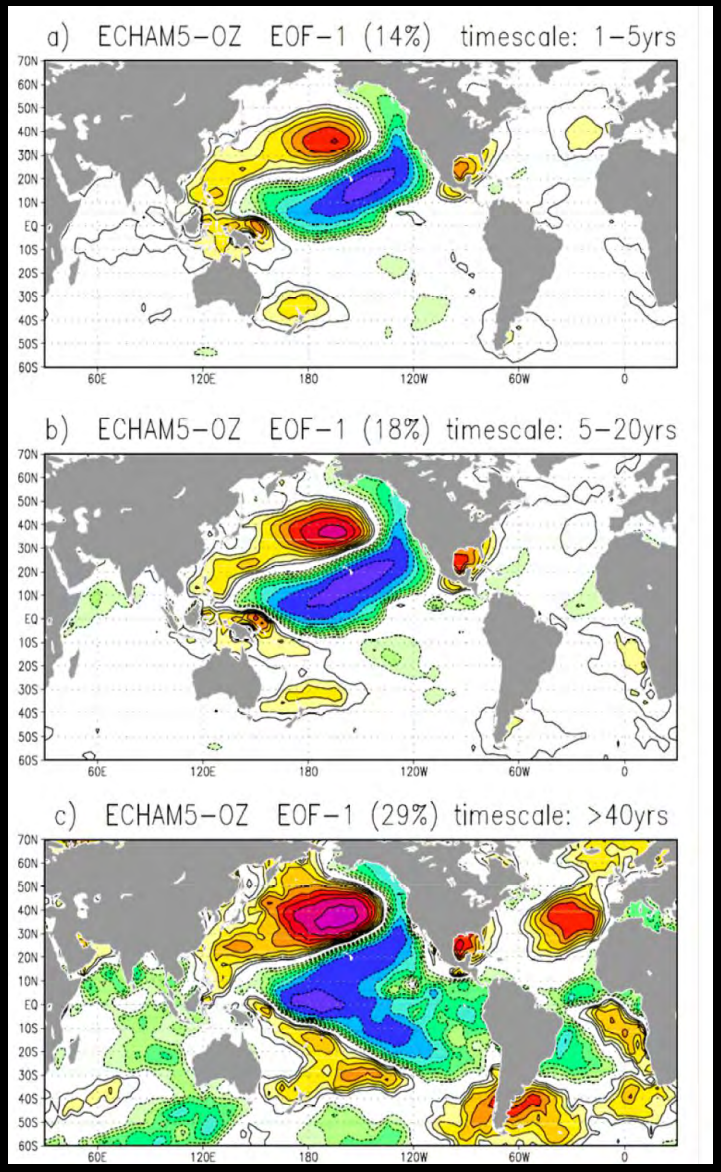
Clement et al. [2011]

Yes, the ENSO pattern can exist without Ocean Dynamics!

time scale of global mode

annual

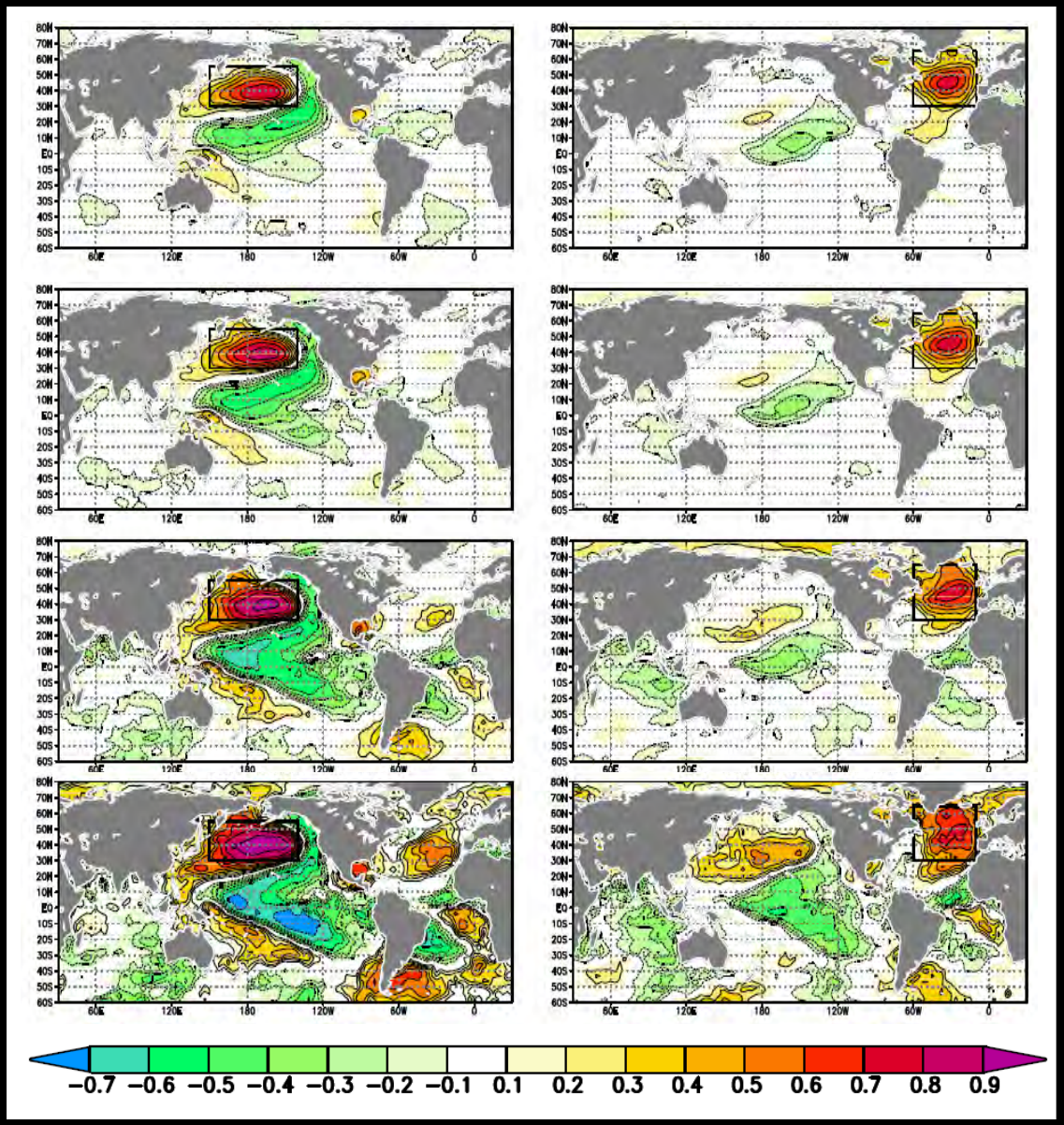
Multi decadal



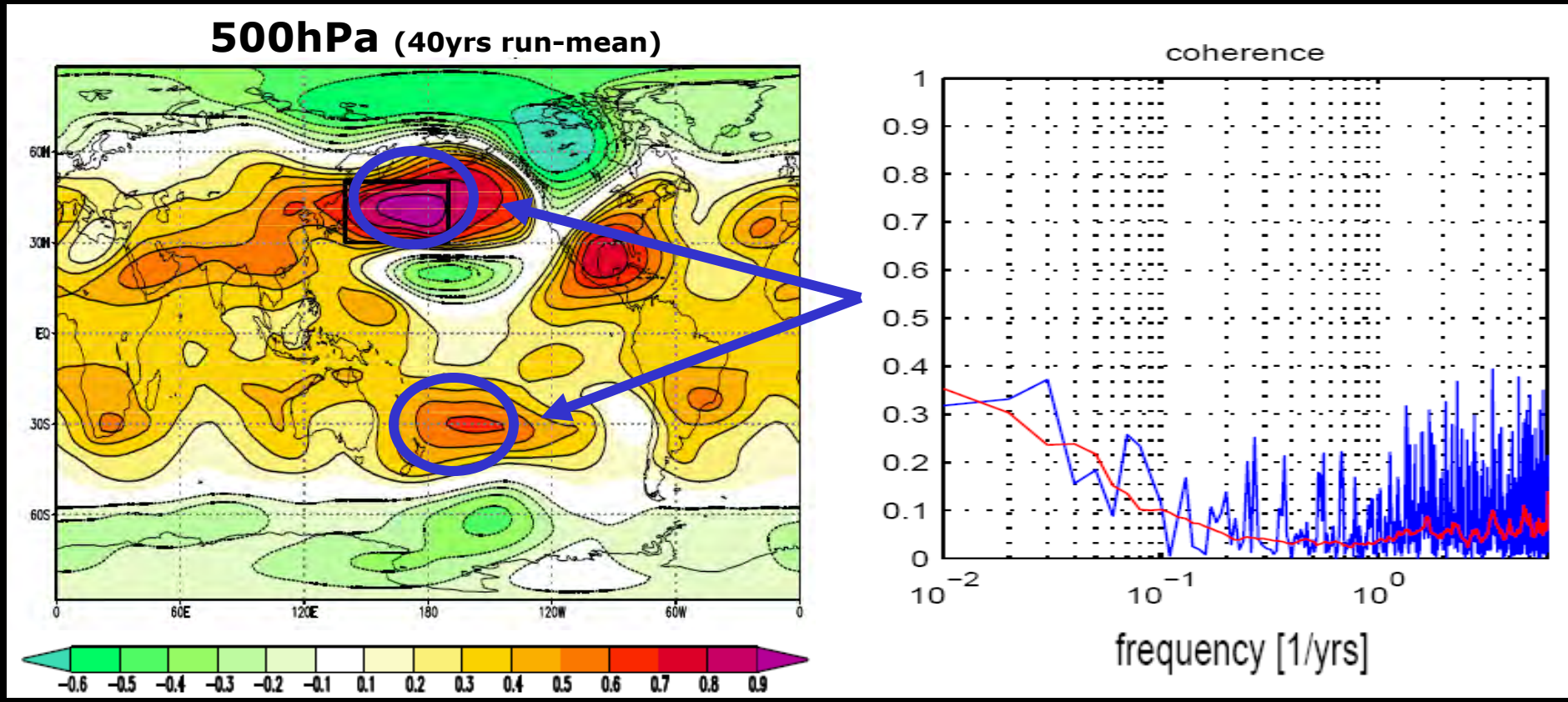
global spread of signal

annual

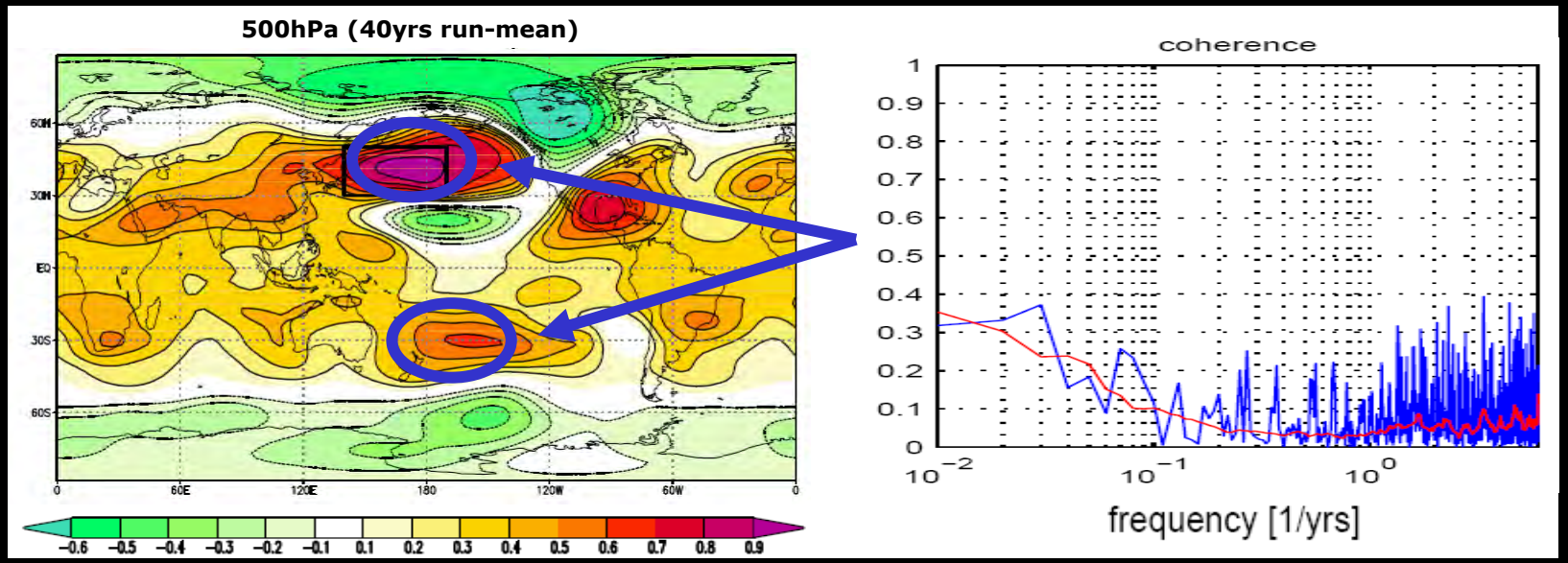
Multi decadal

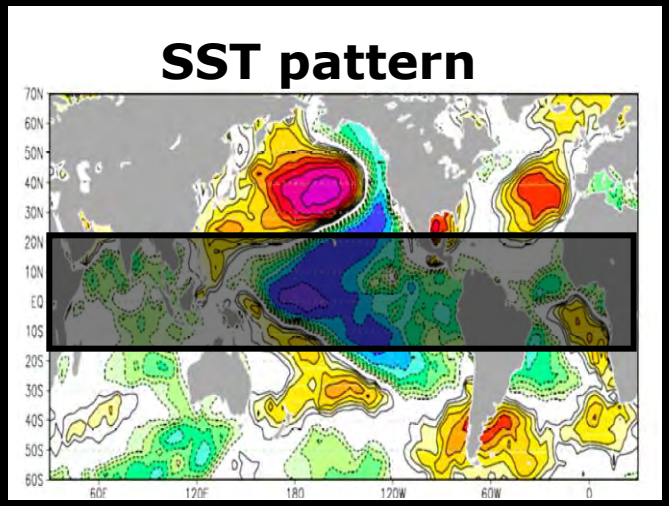


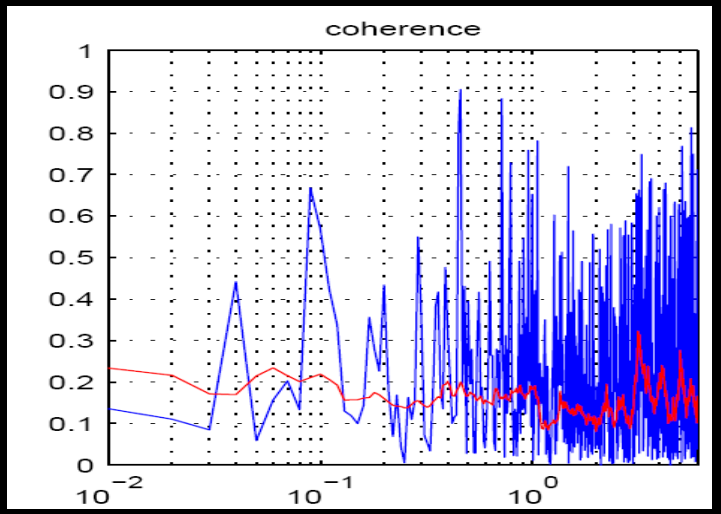
Atmospheric Teleconnections



tropical – extra-tropical connection







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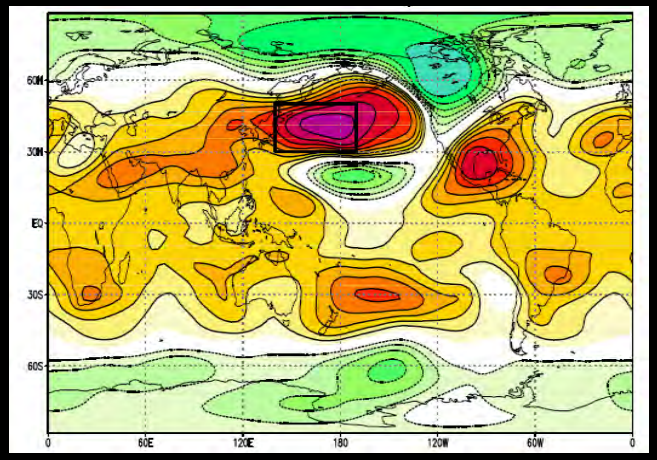

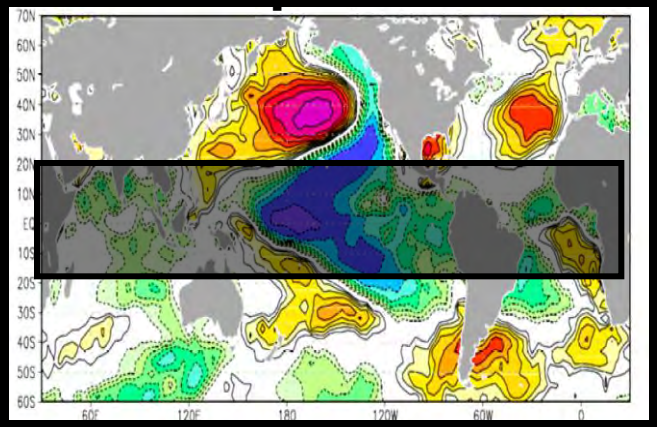

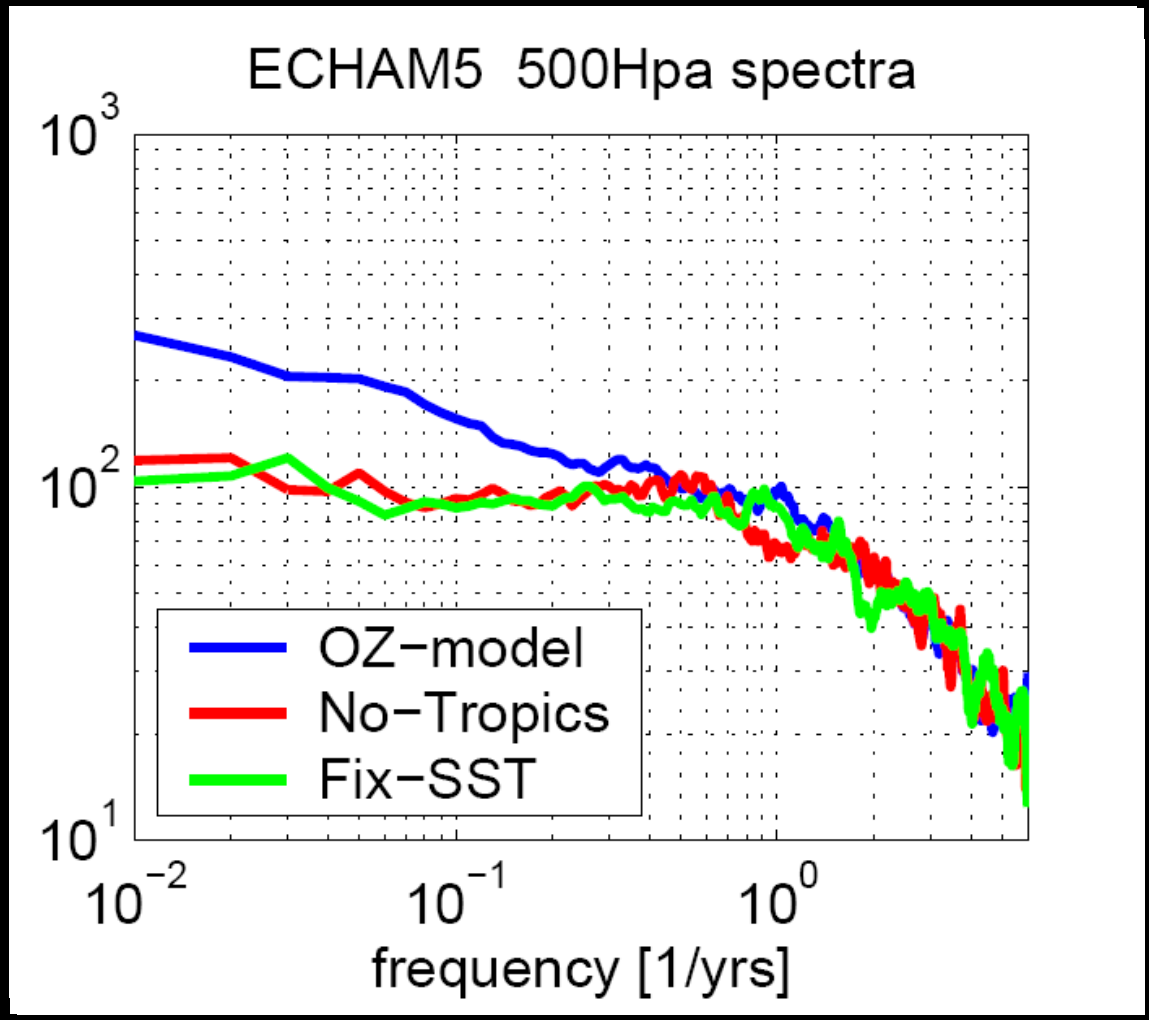

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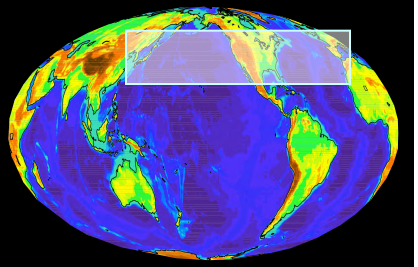
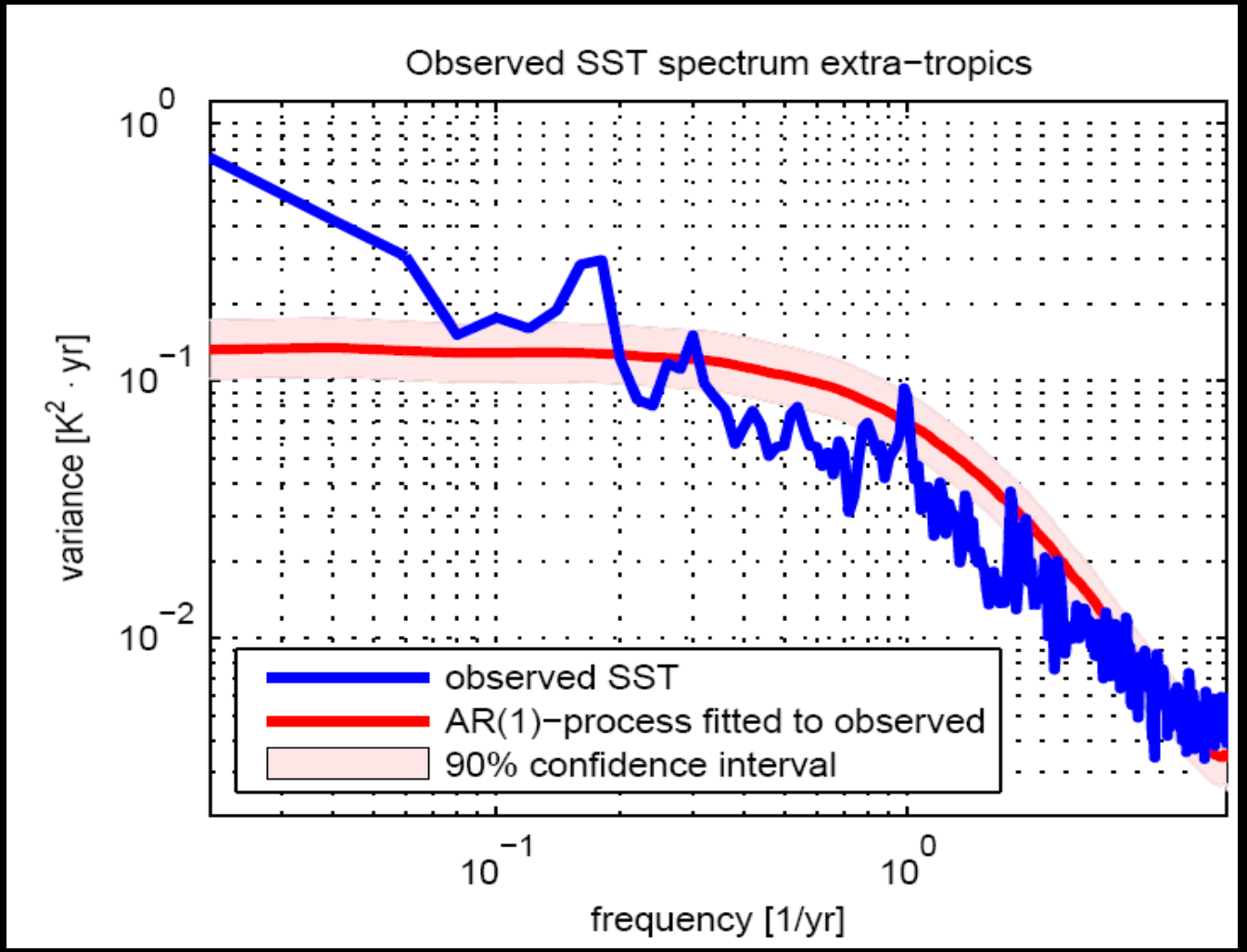
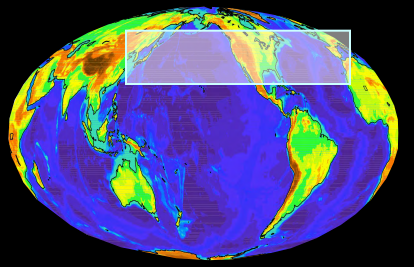
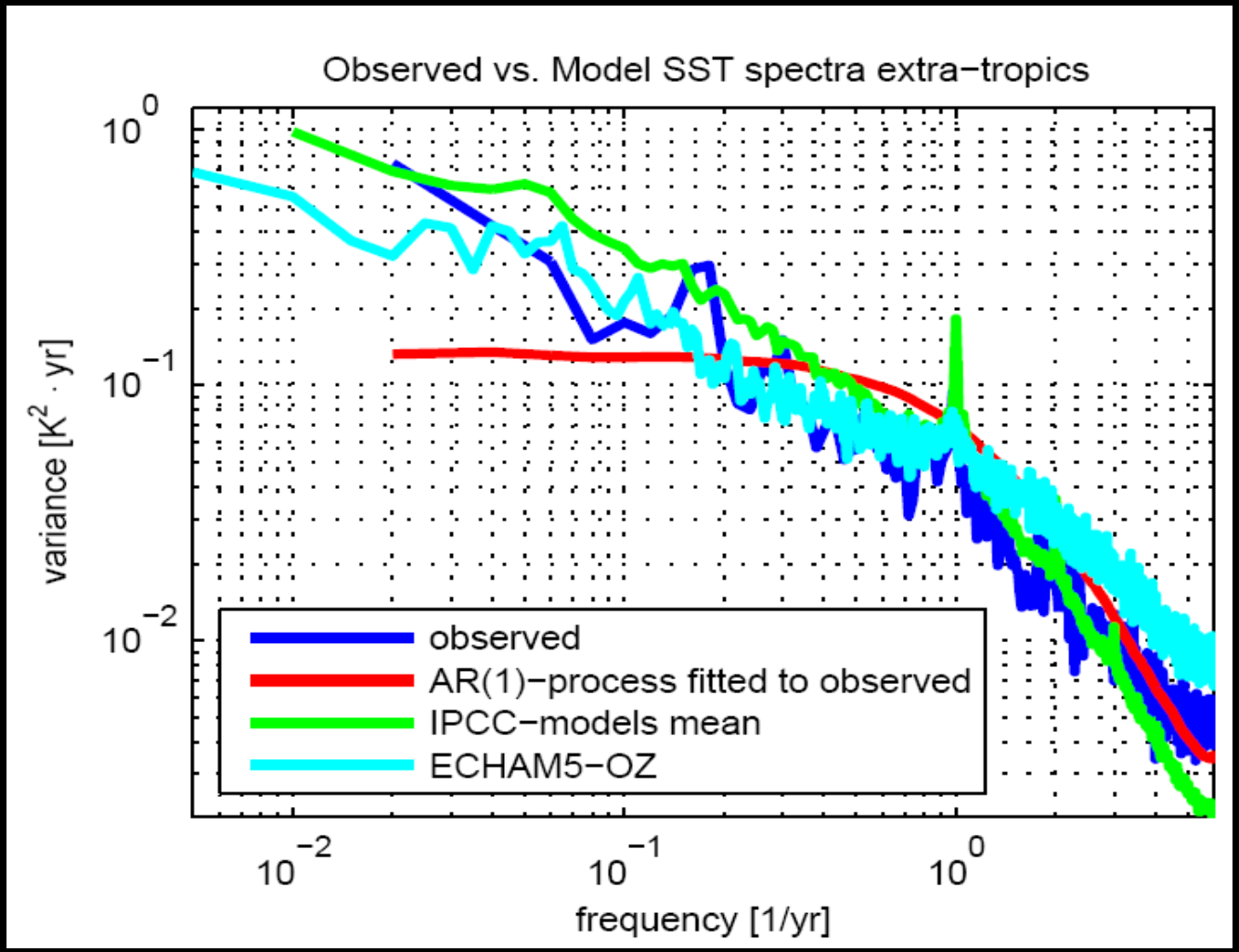
Observed SST spectrum



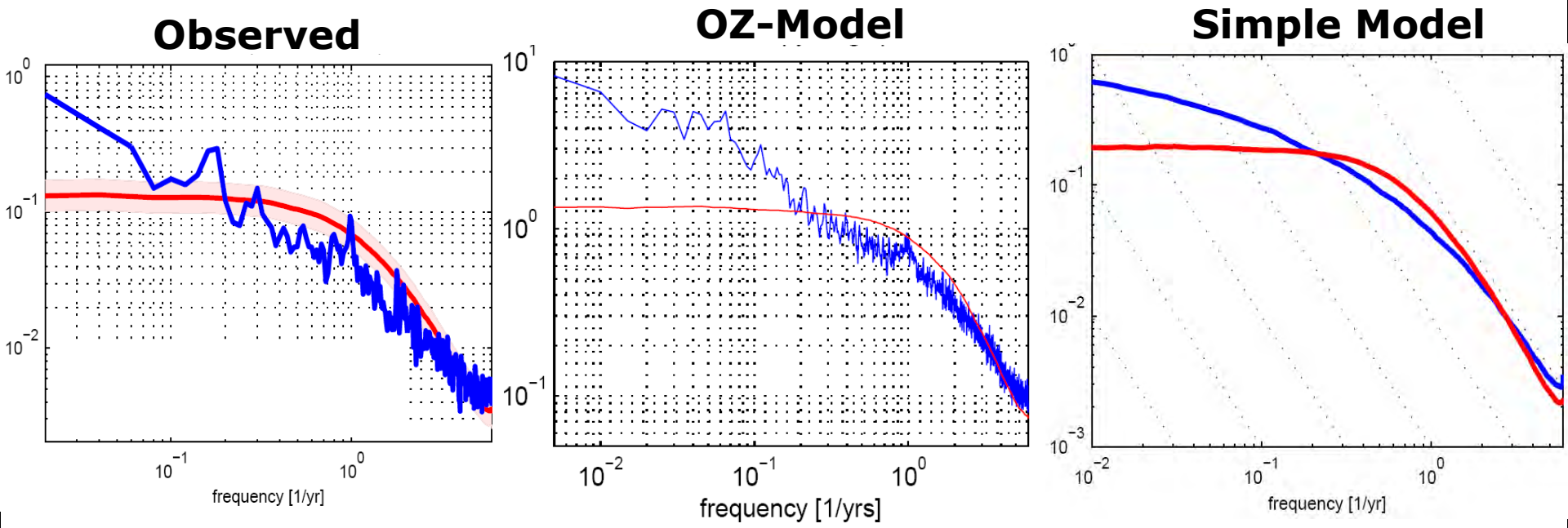


Model SST spectra





a simple model



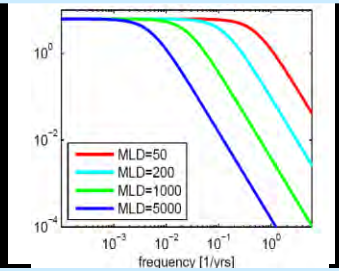
$$c\frac{dT}{dt} = -\gamma_{surf} \cdot T + \boxed{\kappa_z \cdot \nabla_z^2 T} + \xi_{surf}$$

vertical diffusion

Time Scales of the Simple Model

$$c\frac{dT}{dt} = -\gamma_{surf} \cdot T + \kappa_z \cdot \nabla_z^2 T + \xi_{surf}$$

c = heat capacity of the ocean ~5000m

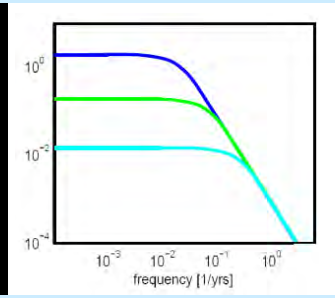


$-\gamma_{surf}$ = damping

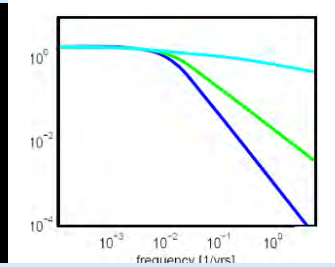
~ 20W/K/m^2 (local & remote / interannual)

~ 3W/K/m^2 (local only / multi-decadal)

< 1W/K/m^2 (positiv feedbacks)



κ_z = veritical differential mixing ~ exp. decreasing



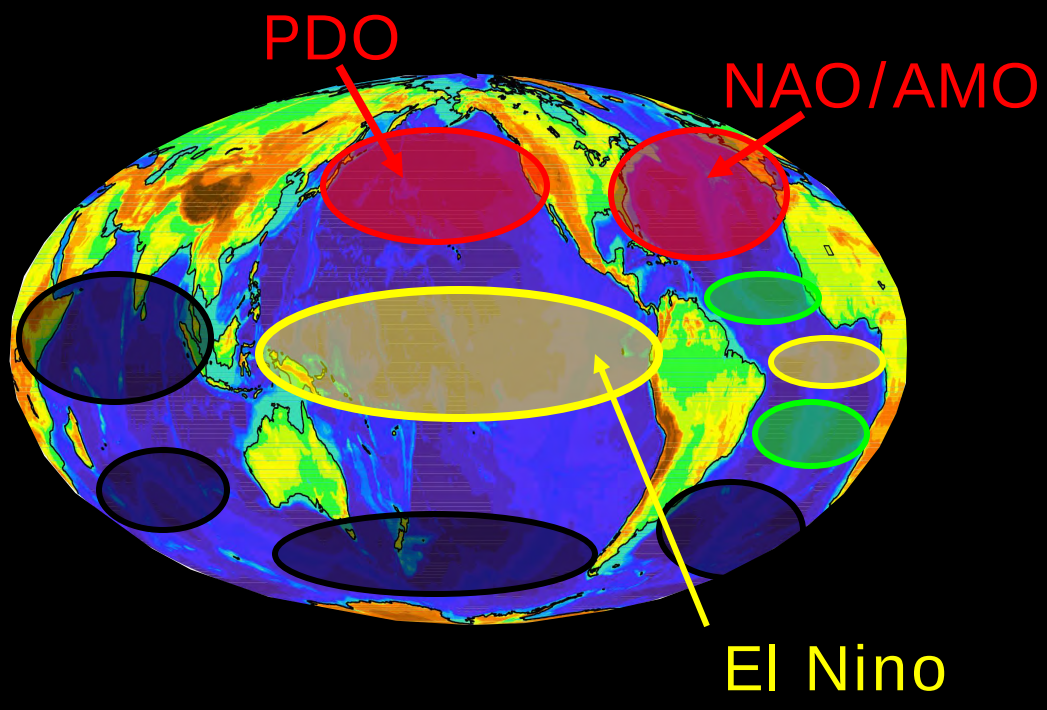
=> Variance increase until 1,000 to 10,000 years

- ✧ Motivation
- ✧ Introduction
  - ✧ Known climate modes
  - ✧ Null hypothesis time scales
  - ✧ Null hypothesis spatial pattern
- ✧ Spatial pattern
  - ✧ Global mode
  - ✧ Model limitations
  - ✧ Tropical link
- ✧ Time scales
- ✧ Discussions /conclusions

Summary

Elements of global Hyper Modes:

I.) Regional Climate Modes



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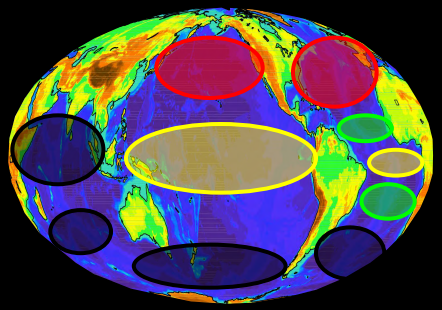
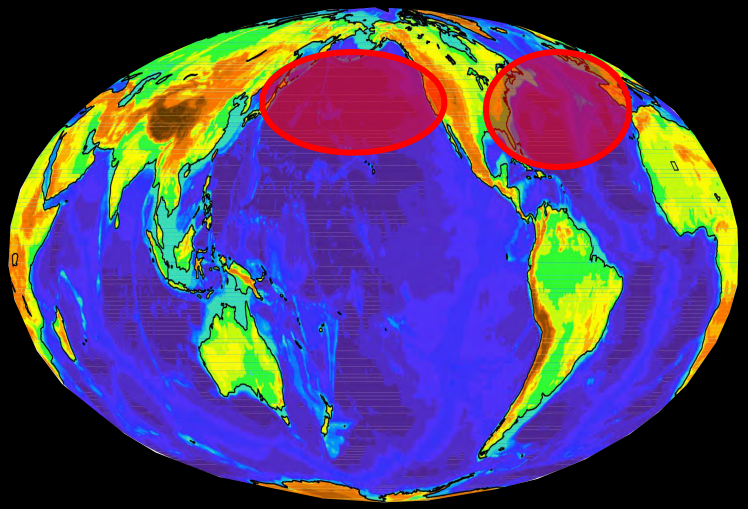
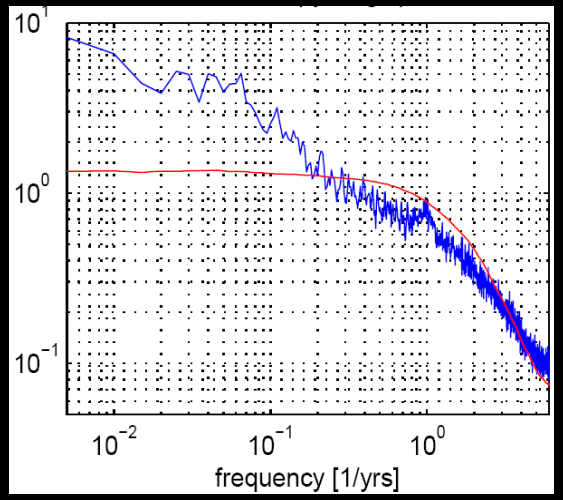


II.) Persistent Midlatitudes SST





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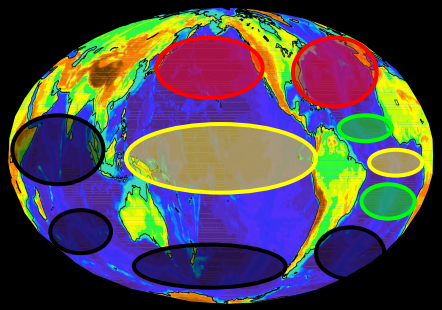

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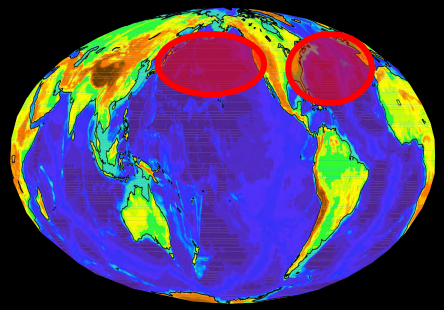
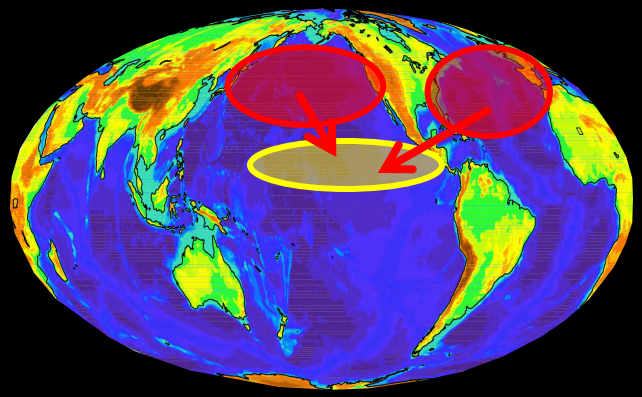
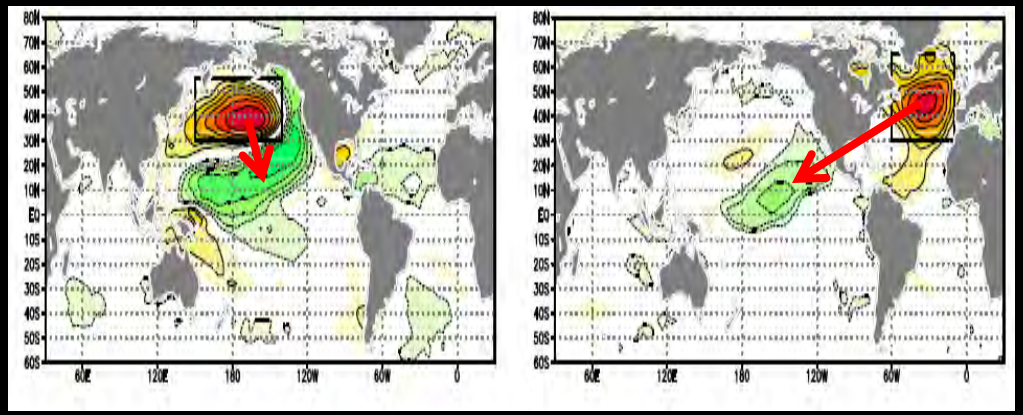


III.) Persistent forcing of tropics





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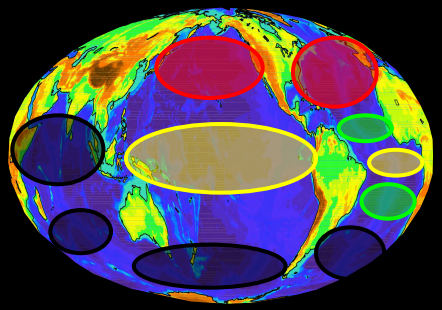

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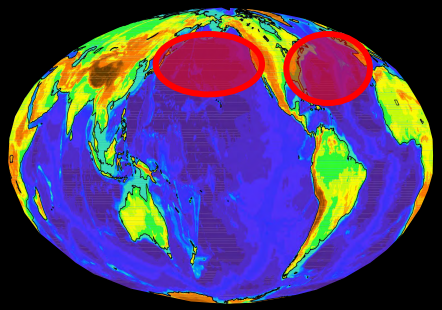

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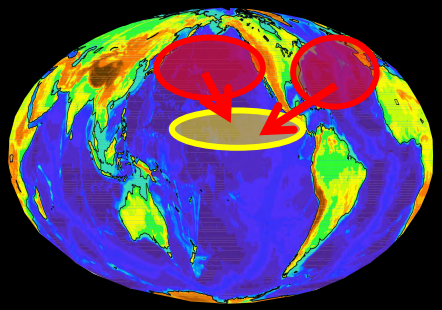
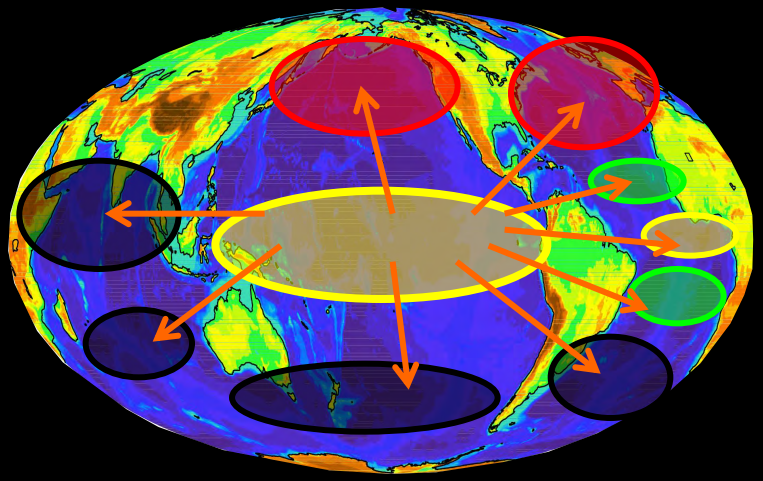
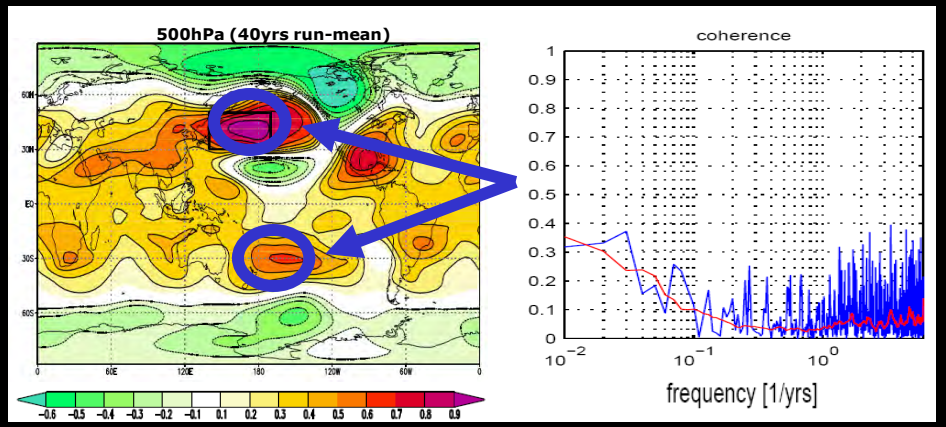


IV.) Global tropical teleconnections





Discussion

Elements of global Hyper Modes:

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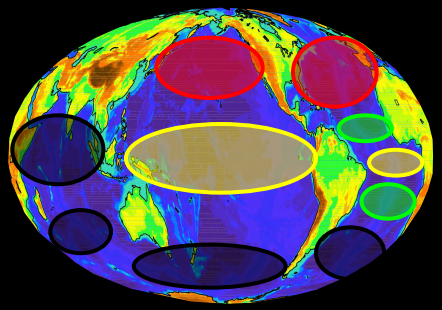

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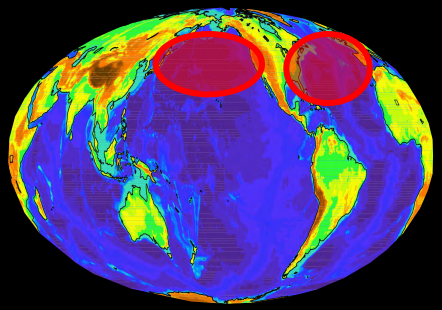

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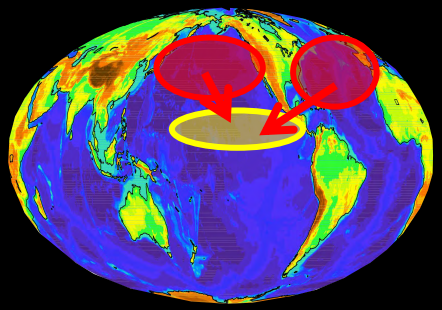

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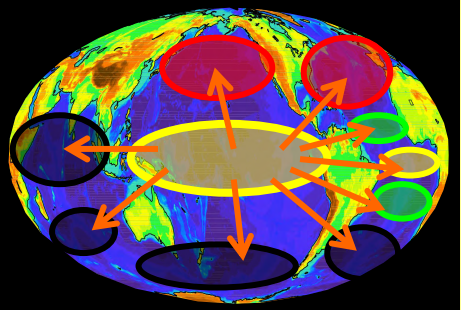
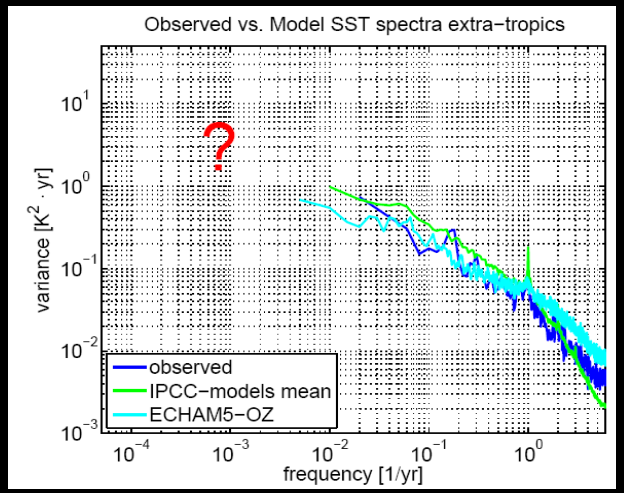
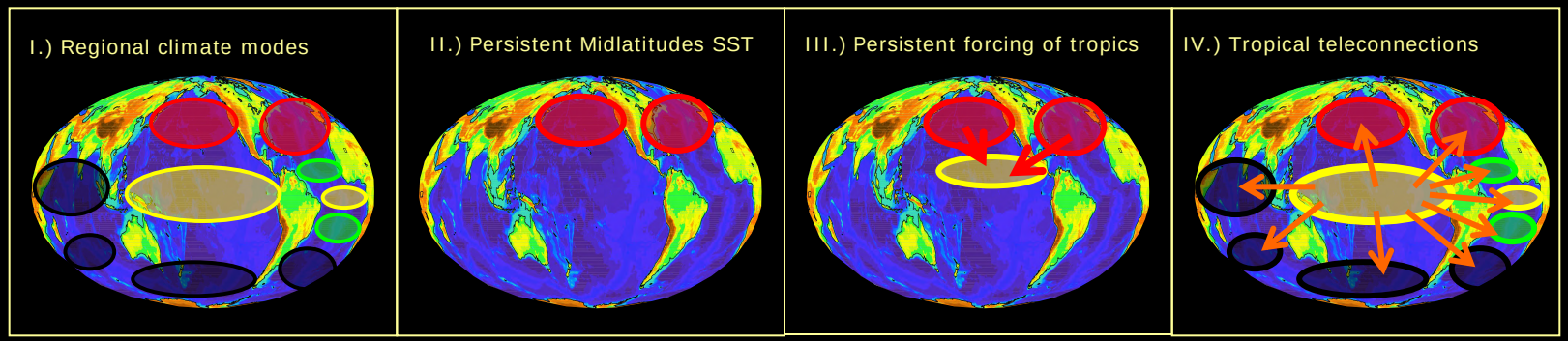


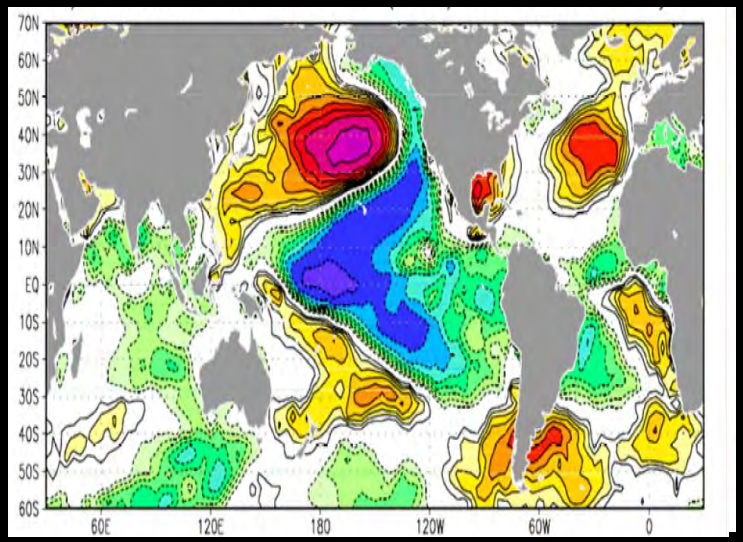
On what time scales does the variance of Ocean-Atmosphere interaction saturates?



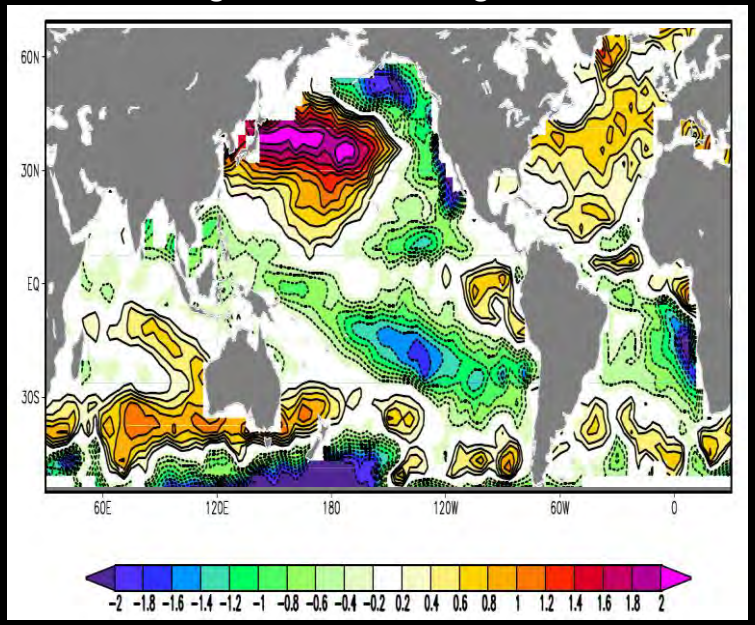
Discussion



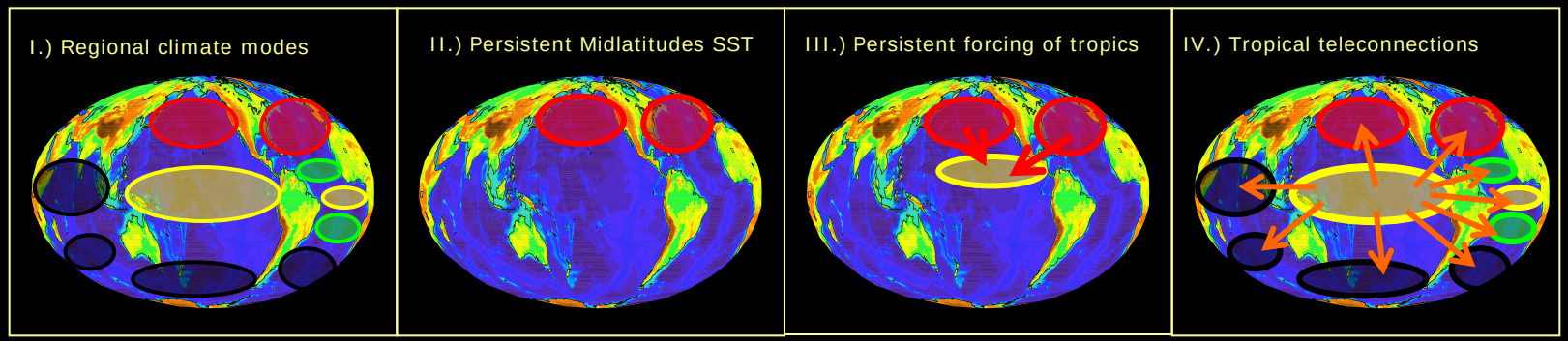
How does global climate modes interact with global warming?



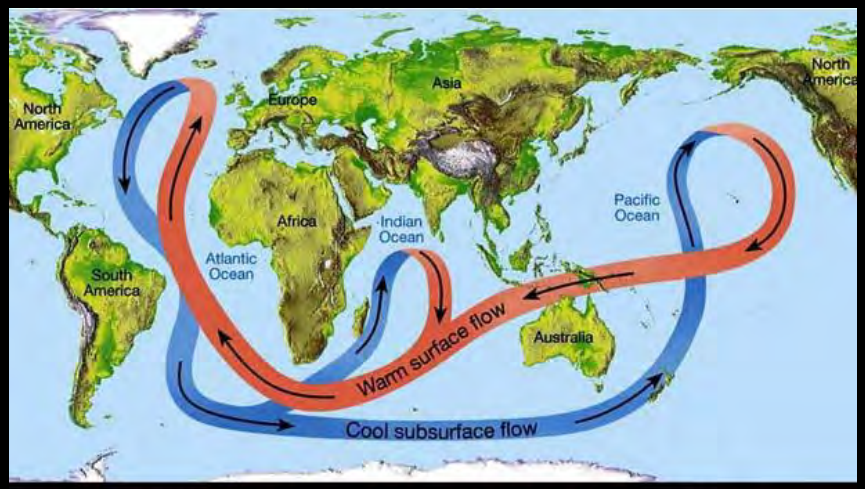
SST global warming - mean



Discussion

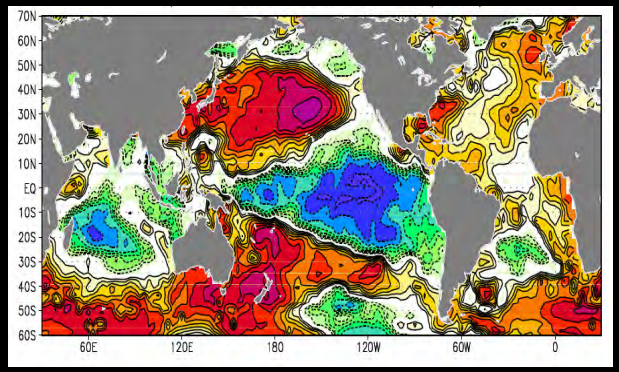


What is the role of ocean dynamics here?



THERMOHALINE CIRCULATION - GREAT OCEAN CURRENT

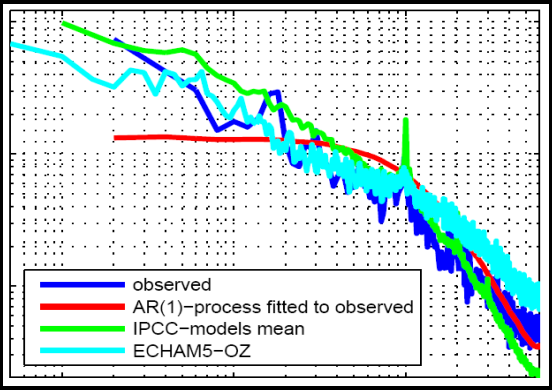
Conclusion



Global scale atmospheric teleconnections lead to global sychronised hyper modes on long time scales.

Dommenget and Latif, GRL, 2008

Conclusion



The power spectrum has a tail on long time scales and is not saturated yet.

?

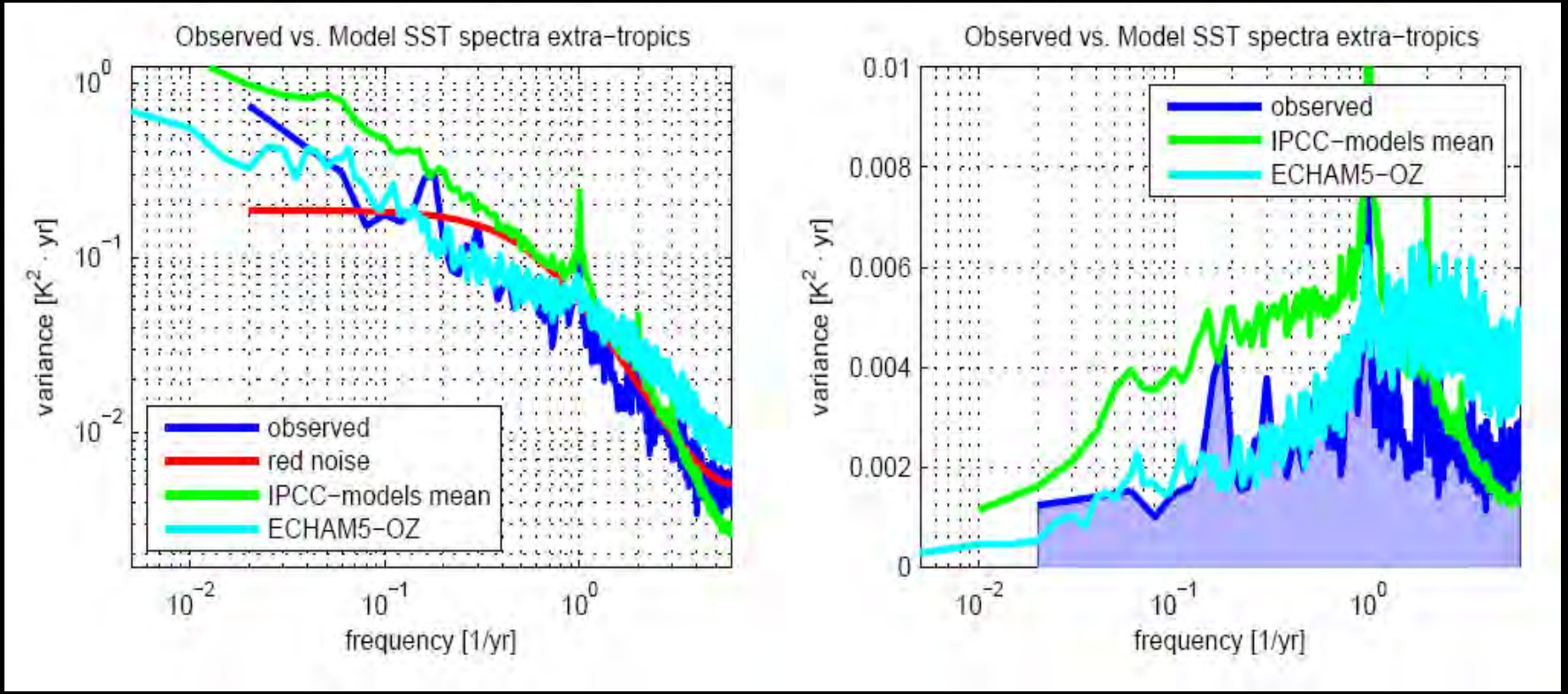
The role of ocean dynamics is still unclear

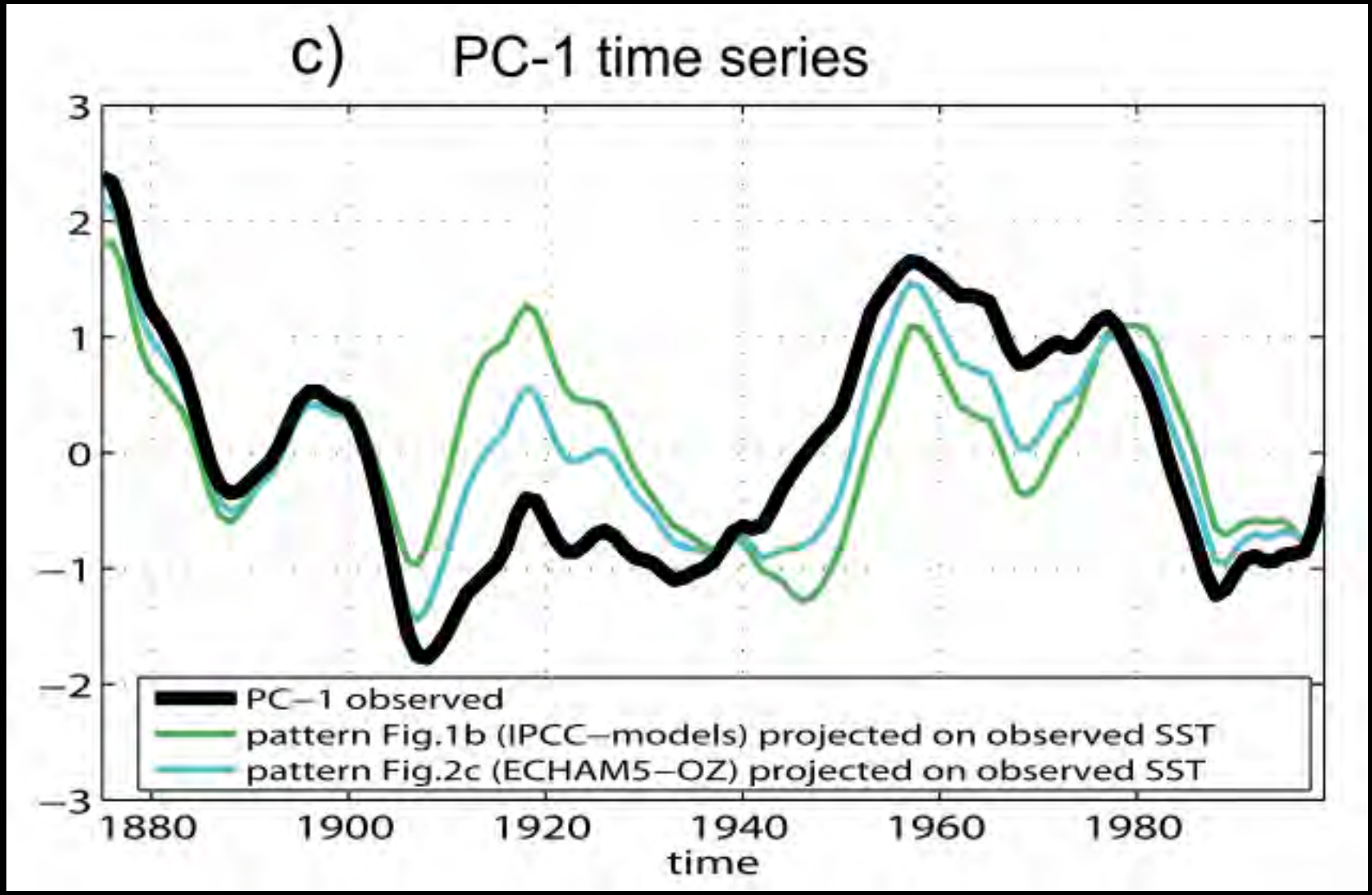
Dommenget and Latif, GRL, 2008


Thank you!

Discussion

IPCC-models multi-decadal variance




c) PC-1 time series
3
2
1
0
−1
−2
−3
1880
1900
1920
1940
1960
1980
time
PC−1 observed
pattern Fig.1b (IPCC−models) projected on observed SST
pattern Fig.2c (ECHAM5−OZ) projected on observed SST