Global Hyper Climate Modes

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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?
Motivation/ climate modes

El Nino Southern Oscillation
Motivation/ climate modes

Pacific Decadal Oscillation

Atlantic Decadal Mode
Motivation/ climate modes
Motivation/ ocean modes
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Red Noise Null Hypothesis

\[ \frac{dT}{dt} = -cT + x \]
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**Spatial Red Noise Null Hypothesis**

**Isotropic Diffusion**

\[
\frac{d}{dt} \phi = c_{\text{damp}} \cdot \phi + c_{\text{diffuse}} \nabla^2 \phi + f
\]

![Auto-correlation function graph]

![EOF images]

\[
\frac{dT}{dx} = cT + \]

Dommengen [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?
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Observed Leading Mode

(HADISST 1870-2004 annual mean / 10yrs running mean / exp. detrended)
Model Leading EOF Mode

CMIP3 models (10%)

Observed (32%)

ECHAM5-OZ (29%) >40yrs
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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

CMIP Pattern Errors

EOF eigenvalues

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

EOF error

5yrs runmean

monthly means
CMIP Pattern Errors

North Atlantic

- EOF error
- 5yrs runmean
- Sampling uncertainty
- Red noise
- Red noise with known stdv
- CMIP3 mean
- CMIP5 mean
- Slab ocean

EOF eigenvalues

Observed
Model projected

EOF error

monthly means
Model Leading EOF Mode

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Model Leading Mode

observed

Model: no ocean dynamics
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

500hPa (40yrs run-mean)
tropical – extra-tropical connection
tropical – extra-tropical connection

ECHAM5 500Hpa spectra

- OZ-model
- No-Tropics
- Fix-SST

frequency [1/years]
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Observed SST spectrum
Model SST spectra
a simple model

\[ c \frac{dT}{dt} = -\gamma_{surf} \cdot T + K_{\zeta} \cdot \nabla_{\zeta}^2 T + \xi_{surf} \]  

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 \(\sim 5000\) m

\(-\gamma_{surf}\) = damping

\(\sim 20\text{W/K/m}^2\) (local & remote / interannual)

\(\sim 3\text{W/K/m}^2\) (local only / multi-decadal)

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

\(K_z\) = vertical differential mixing \(\sim\) exp. decreasing

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

Elements of global Hyper Modes:

I.) Regional Climate Modes
Summary

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II.) Persistent Midlatitudes SST
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II.) Persistent Midlatitudes SST
III.) Persistent forcing of tropics
Summary

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III.) Persistent forcing of tropics

IV.) Global tropical teleconnections
Discussion

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I.) Regional climate modes
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On what time scales does the variance of Ocean-Atmosphere interaction saturates?
How does global climate modes interact with global warming?
Discussion

I.) Regional climate modes
II.) Persistent Midlatitudes SST
III.) Persistent forcing of tropics
IV.) Tropical teleconnections

What is the role of ocean dynamics here?
Global scale atmospheric teleconnections lead to global synchronised hyper modes on long time scales.

Dommenger and Latif, GRL, 2008
The role of ocean dynamics is still unclear.

Dommengnet and Latif, GRL, 2008
Thank you!
Discussion

IPCC-models multi-decadal variance