The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1968-49

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

Variability in the North Atlantic and North Pacific basins in CCSM3: Implications of both statistical equilibrium and global warming simulations

D'ORGEVILLE Marc and PELTIER W. Richard

University of Toronto Department of Physics
60 Saint George Street
M5S 1A7 Toronto
Ontario
CANADA

Implications of both statistical equilibrium and global warming simulations with CCSM3: on the decadal variability in the Northern Hemisphere

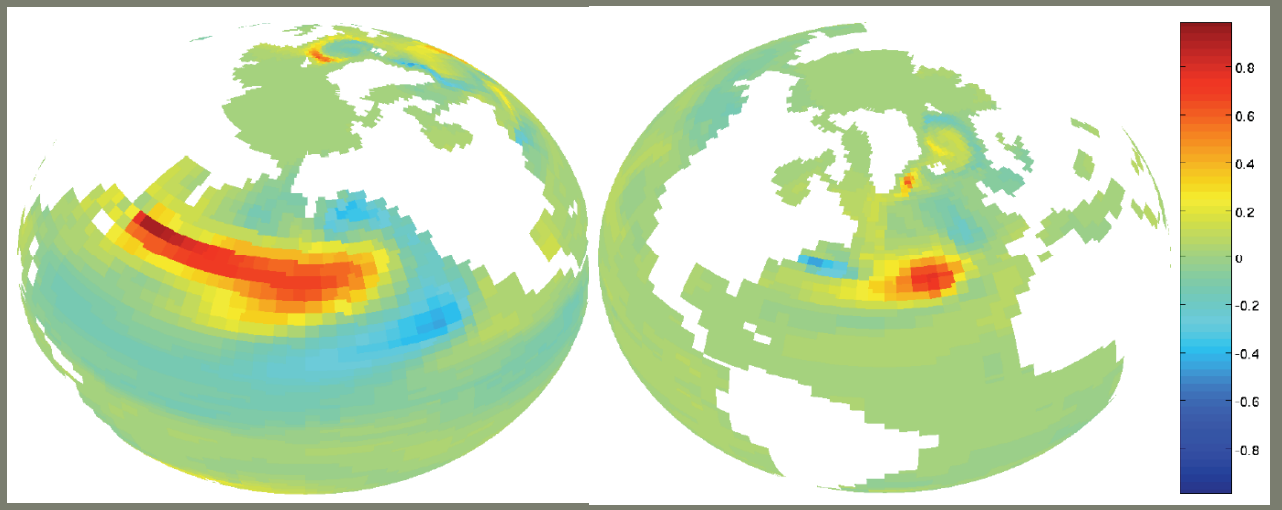
Marc d'Orgeville

W. Richard Peltier

University of Toronto

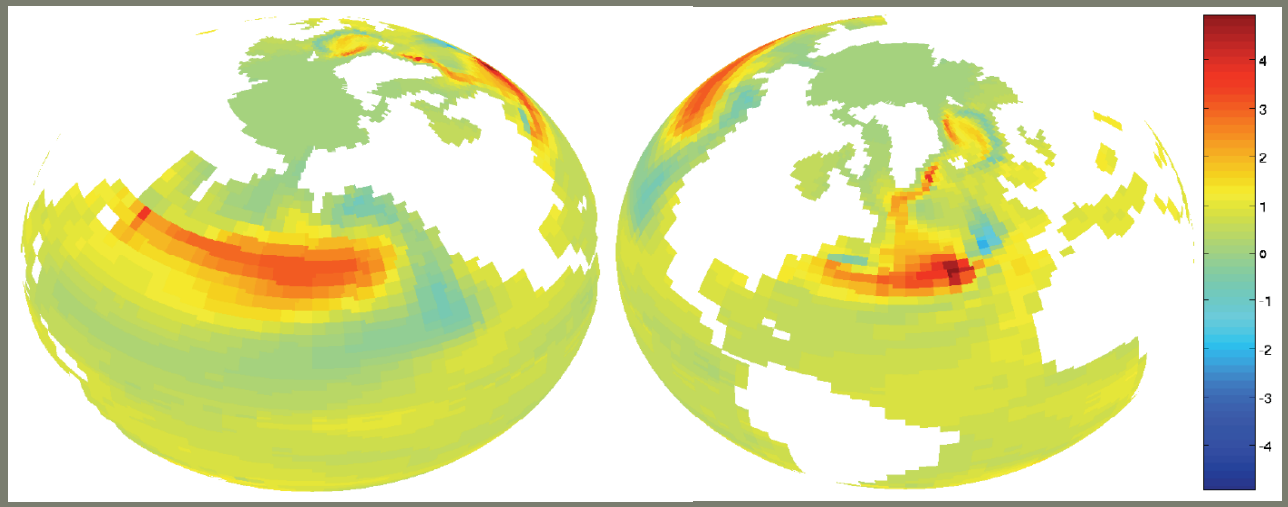
20th century numerical simulation with CCSM3

1st EOF of SST
North of 20N



yearly anomalies, detrended, low-pass filtered (10 years)

SST difference
between
1870-1879 and
1990-1999



center of action of SST decadal variability
= location of the maximum SST warming

Link between decadal variability and Global Warming ?

Numerical Simulations with CCSM3 (T31)

- characterization of the natural variability in statistical equilibrium runs
  - timescale? spatial pattern? mechanism of variability?
  - dependence on the climate condition?

  two 300 year control simulations
  1870-control and 1990-control

- effect of warming on the natural variability in forced runs
  - changes of timescale? spatial pattern?
  - dependence on the strength of the forcing?

  four 200 year simulations
  with 0.5% or 1% CO_2 concentration increase per year
  one 20th century simulation

on the decadal variability in the North Pacific basin

The Pacific Decadal Oscillation

1. Timescale in control simulations
2. Effect of warming in forced simulations
3. Underlying mechanisms in control simulations

The Pacific Decadal Oscillation (control)

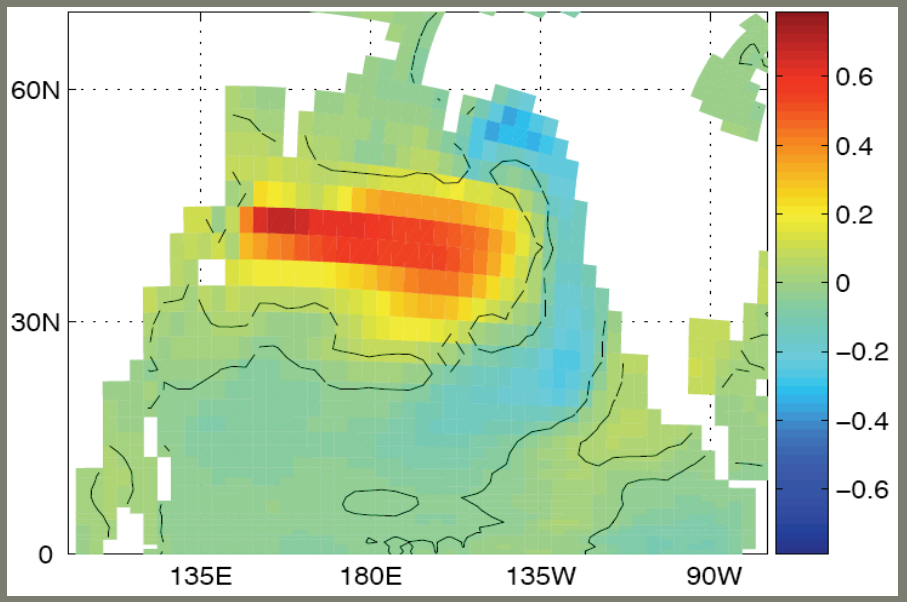
PDO = 1st EOF of SST

- observed horseshoe pattern

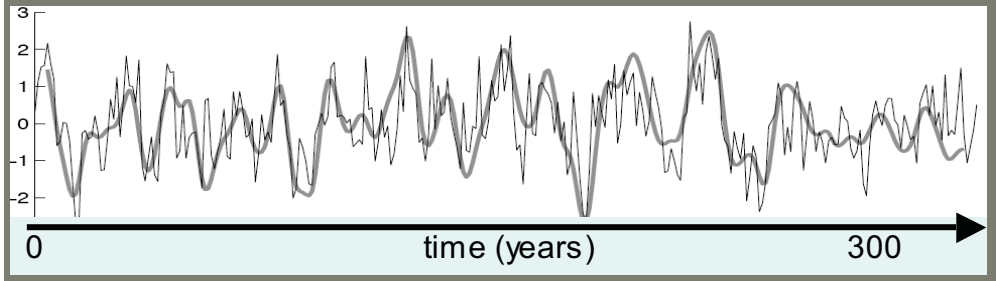
(Latif & Barnett, 1996)

- but
  - no tropical linkage
  - amplitude twice as large as observed

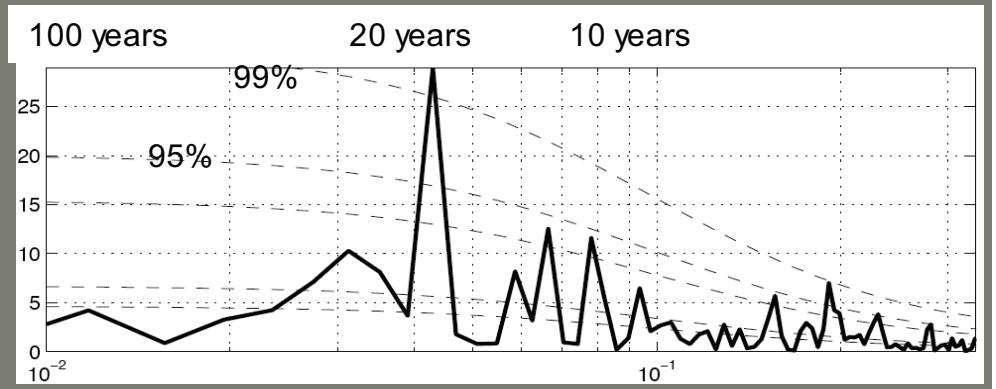
(Pierce et al. 2001; Latif 2006; Kwon & Deser 2007)



PDO index = principal component



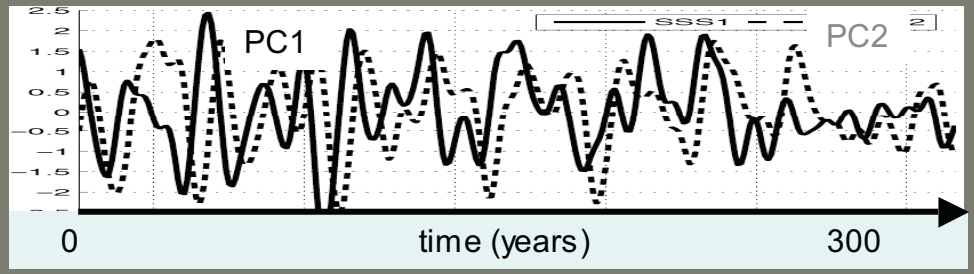
Power spectrum analysis
20 year period peak (above 99%)

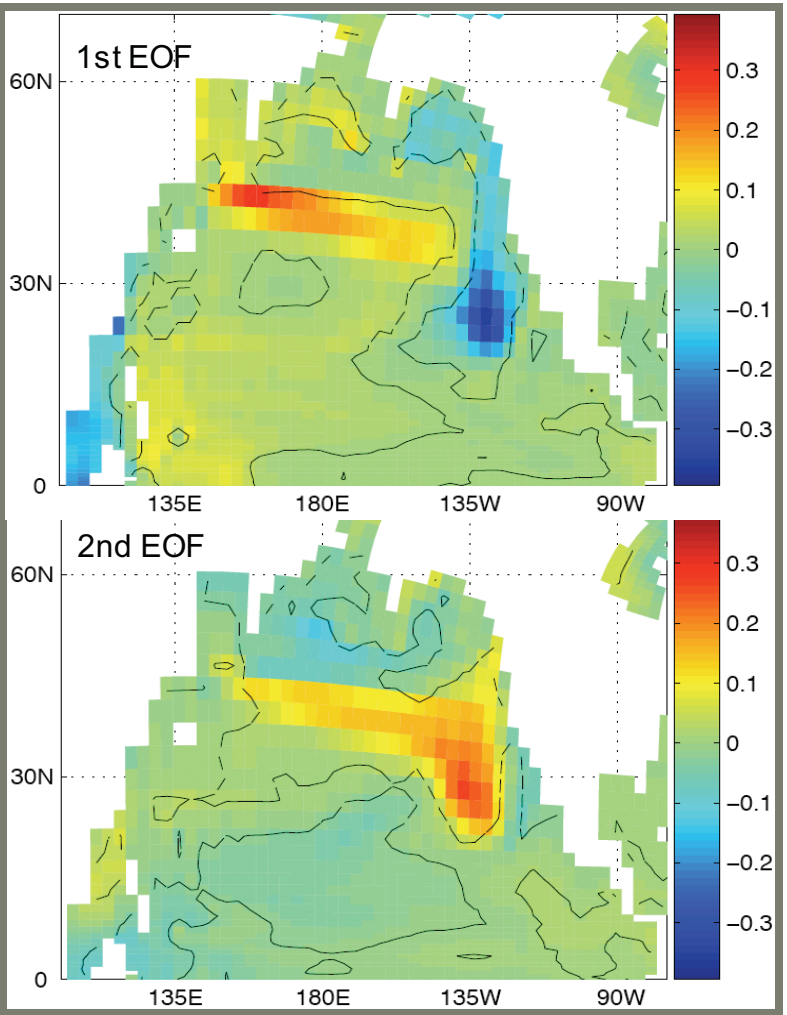


modeled PDO: independent of control simulations
20 year period

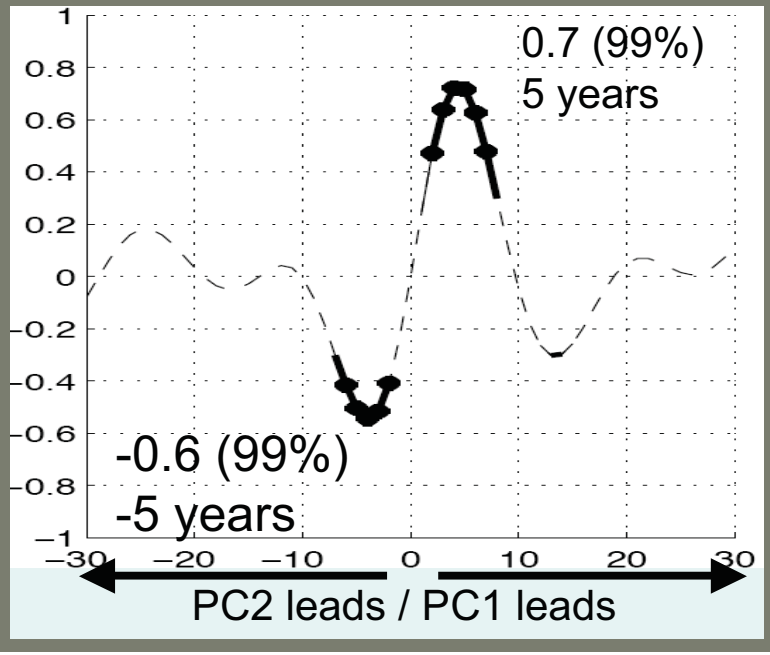
PDO timescale in terms of SSS (control)

EOF1: dipole pattern as SST first EOF
PC1: correlation of 0.9 with the PDO index





Time-lag correlation between PC1 and PC2



20 year period of the PDO can be characterized by SSS

Role of Salinity in the PDO mechanism ?
(decadal density variability = salinity)

on the decadal variability in the North Pacific basin

The Pacific Decadal Oscillation

1. Timescale in control simulations
2. Effect of warming in forced simulations
3. Underlying mechanisms in control simulations

Initialization: 1870-control

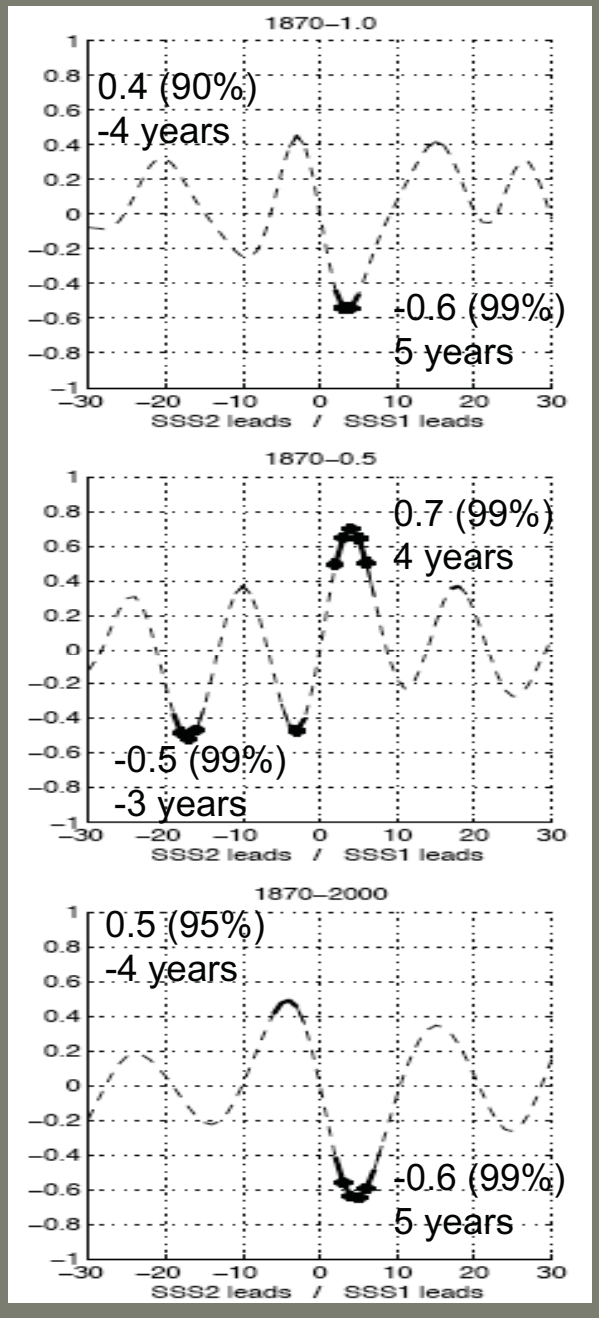
1990-control

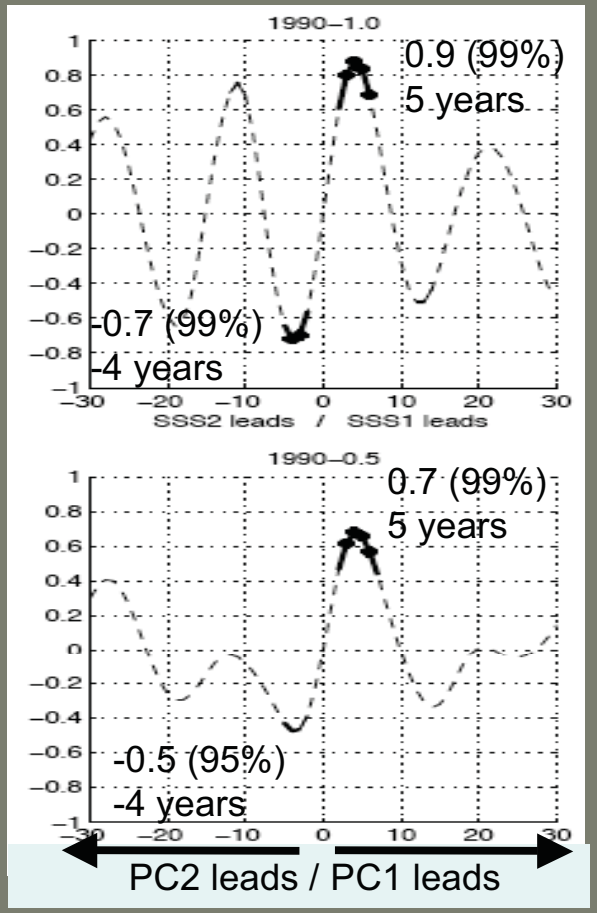
PDO in warming simulations

1% CO2 increase

0.5% CO2 increase

20th century simulations





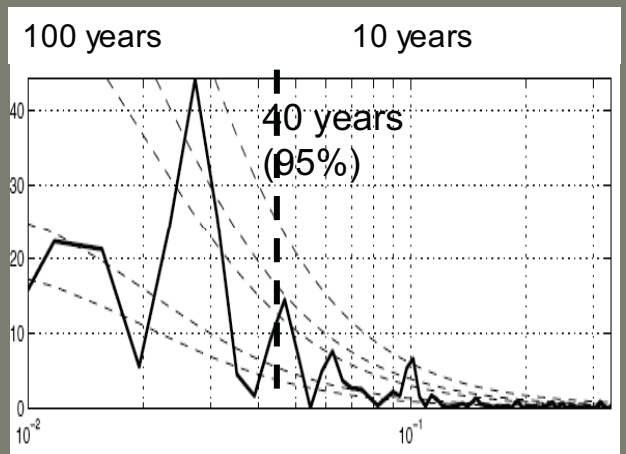
Time-lag correlation between the first two PCs of SSS

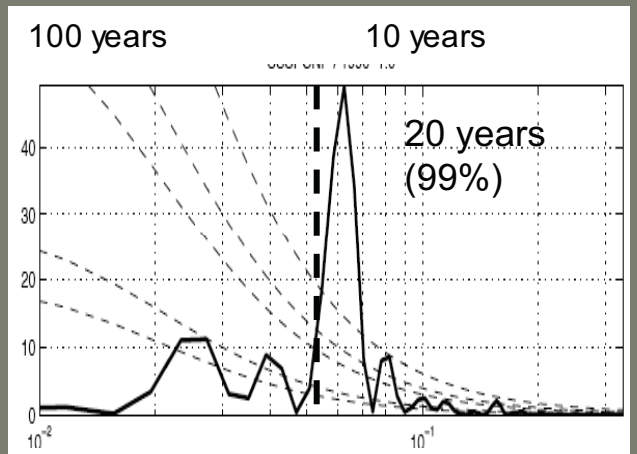
The 20 year period of the PDO is present in all the warming simulations as seen in SSS variability

Initialization: 1870-control 1990-control

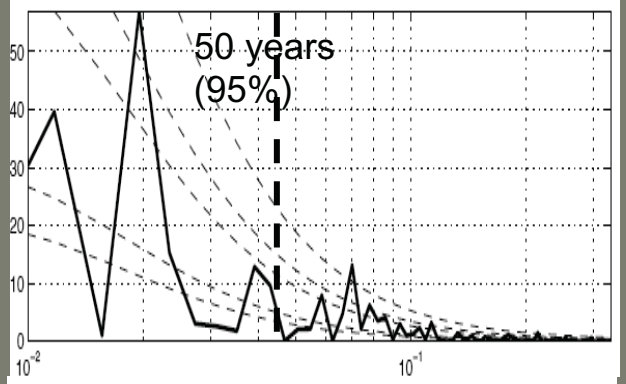
PDO in warming simulations

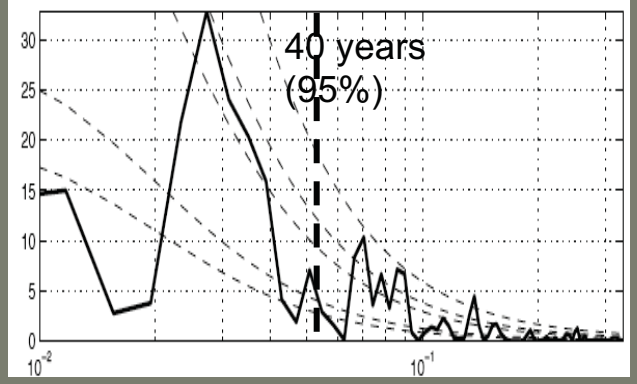
1% CO2 increase



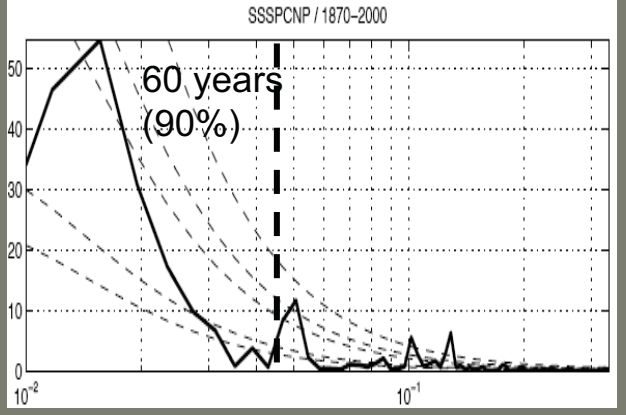


0.5% CO2 increase





20th century simulations



Power spectrum of the PDO index (1st PC of SST)

BUT the PDO index is dominated by lower frequencies.

A forced warming does affect the PDO

on the decadal variability in the North Pacific basin

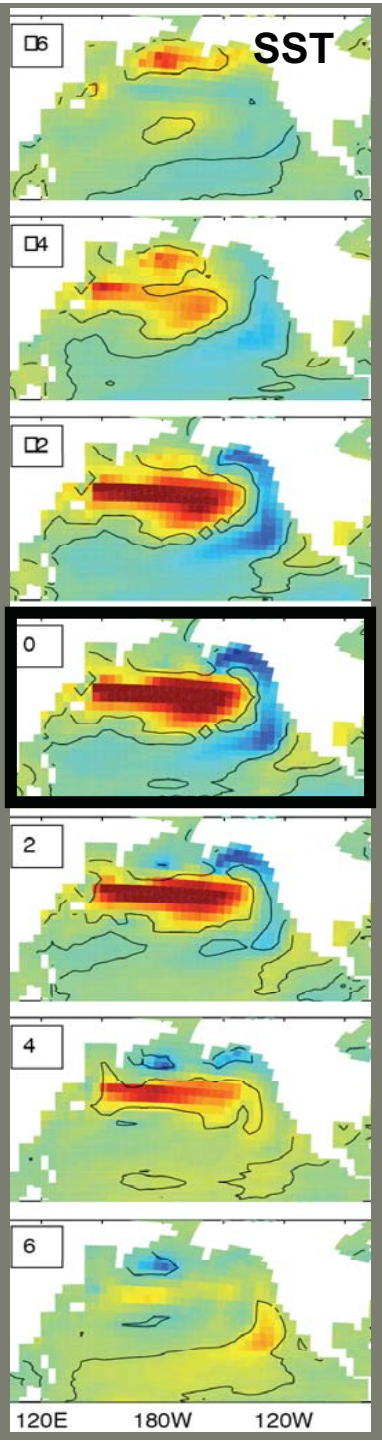
The Pacific Decadal Oscillation

1. Timescale in control simulations
2. Effect of warming in forced simulations
3. Underlying mechanisms in control simulations

Timing of the PDO

Time-lag regression on the PDO index

PDO mechanism ?



-6y

-4y

-2y

0y

2y

4y

6y

Timing of the PDO

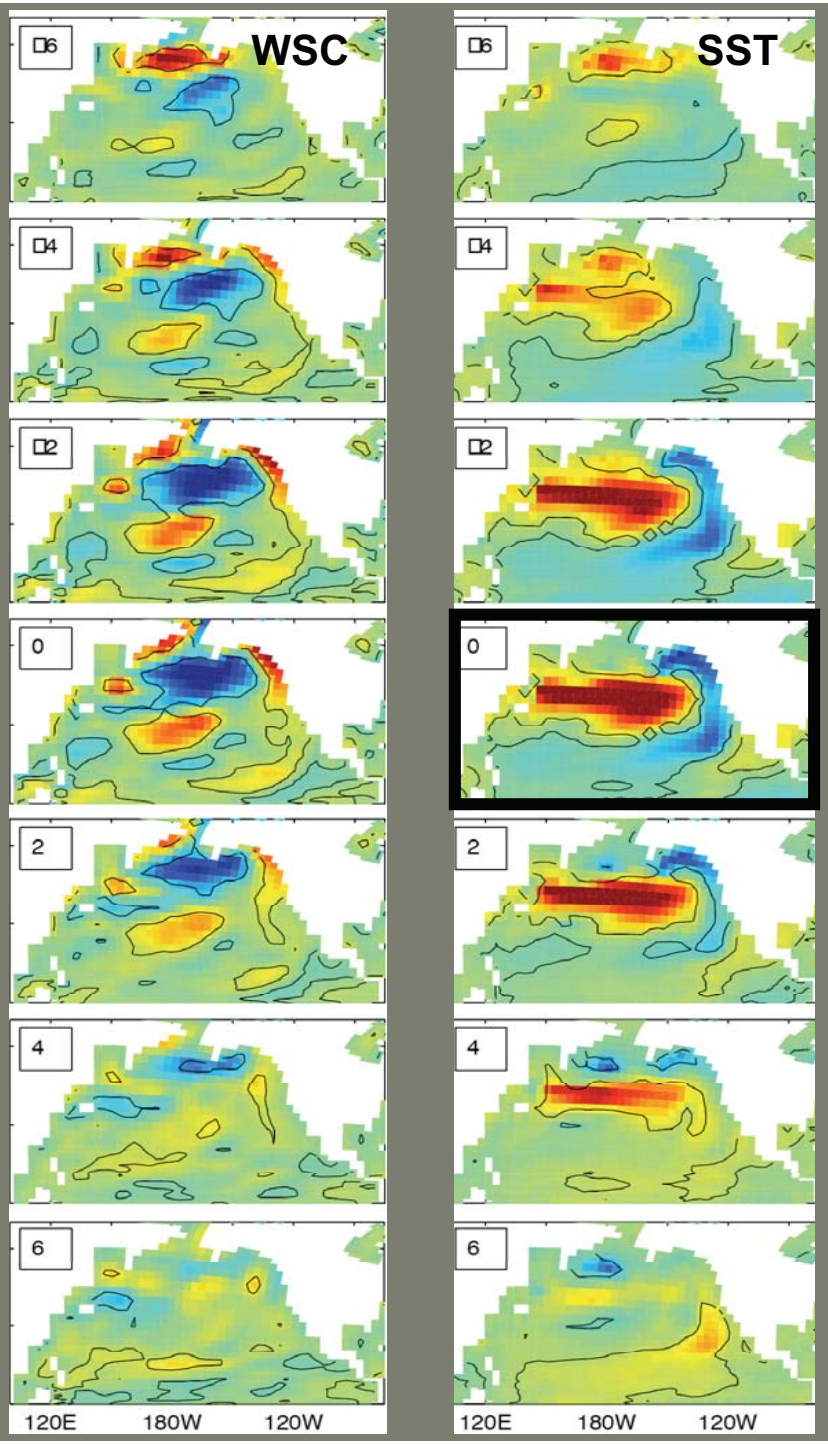
Time-lag regression on the PDO index

PDO mechanism

Growth?

- positive feedback between SST and Aleutian Low anomaly
- SST anomaly due to barotropic and baroclinic adjustment to WSC

Latif & Barnett (1996)
Schneider et al. (2002)
Kwon & Deser (2007)



Timing of the PDO

Time-lag regression on the PDO index

PDO mechanism

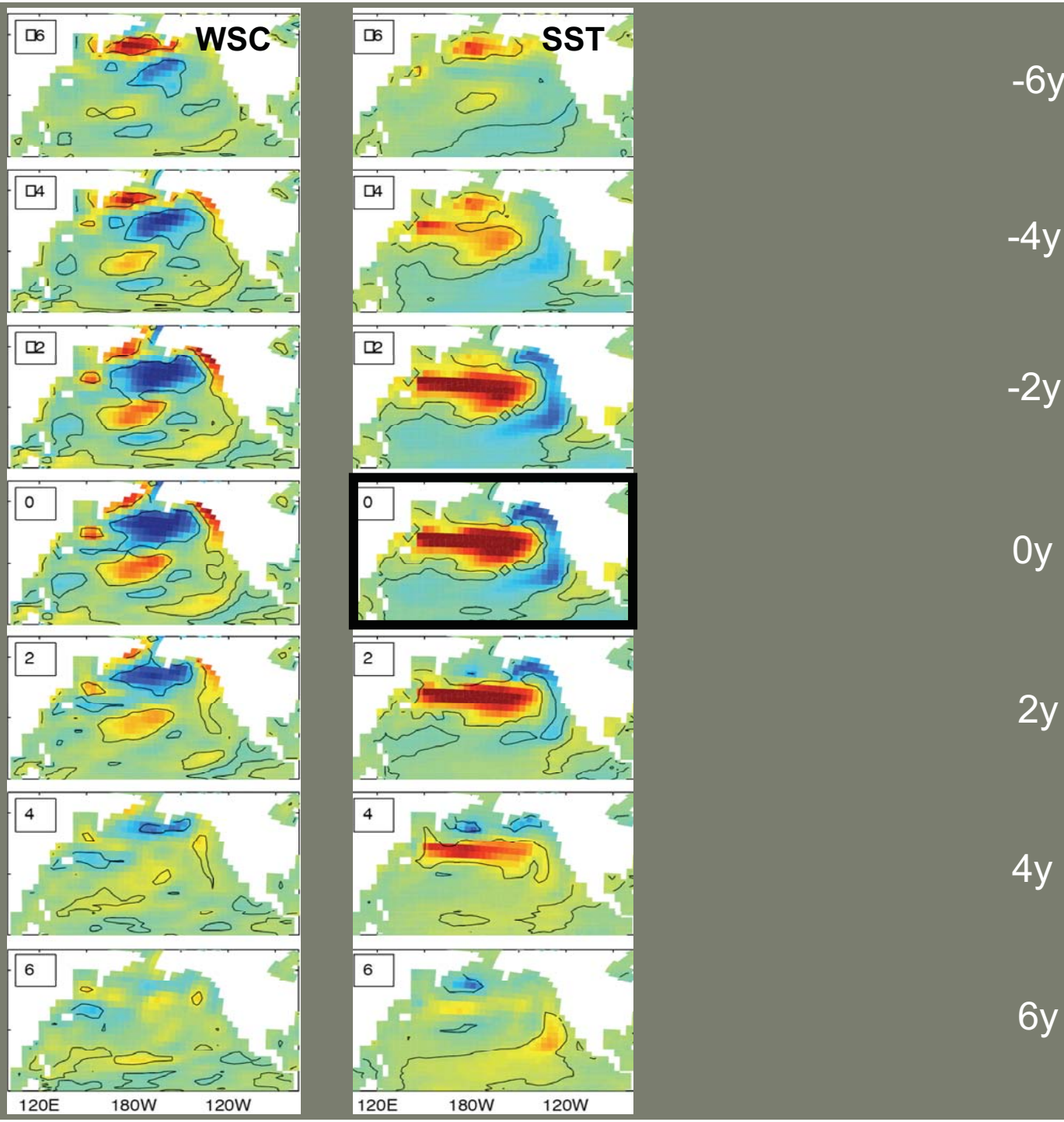
Growth?

• positive feedback between SST and Aleutian Low anomaly

• SST anomaly due to barotropic and baroclinic adjustment to WSC

Decrease?

Reversal?



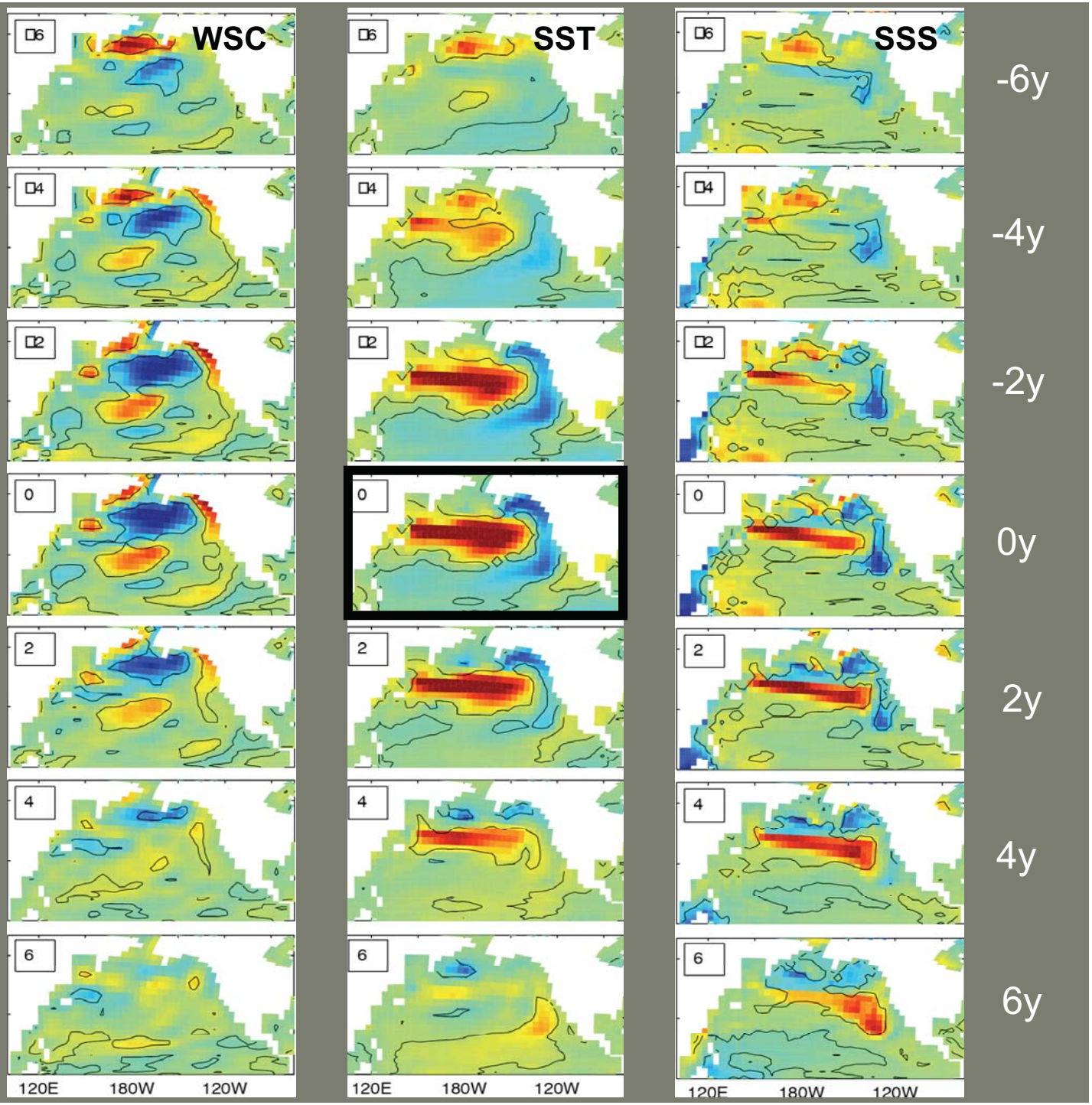
Timing of the PDO

Time-lag regression on the PDO index

PDO mechanism

Decrease?

- Amplification and advection of SSS anomaly



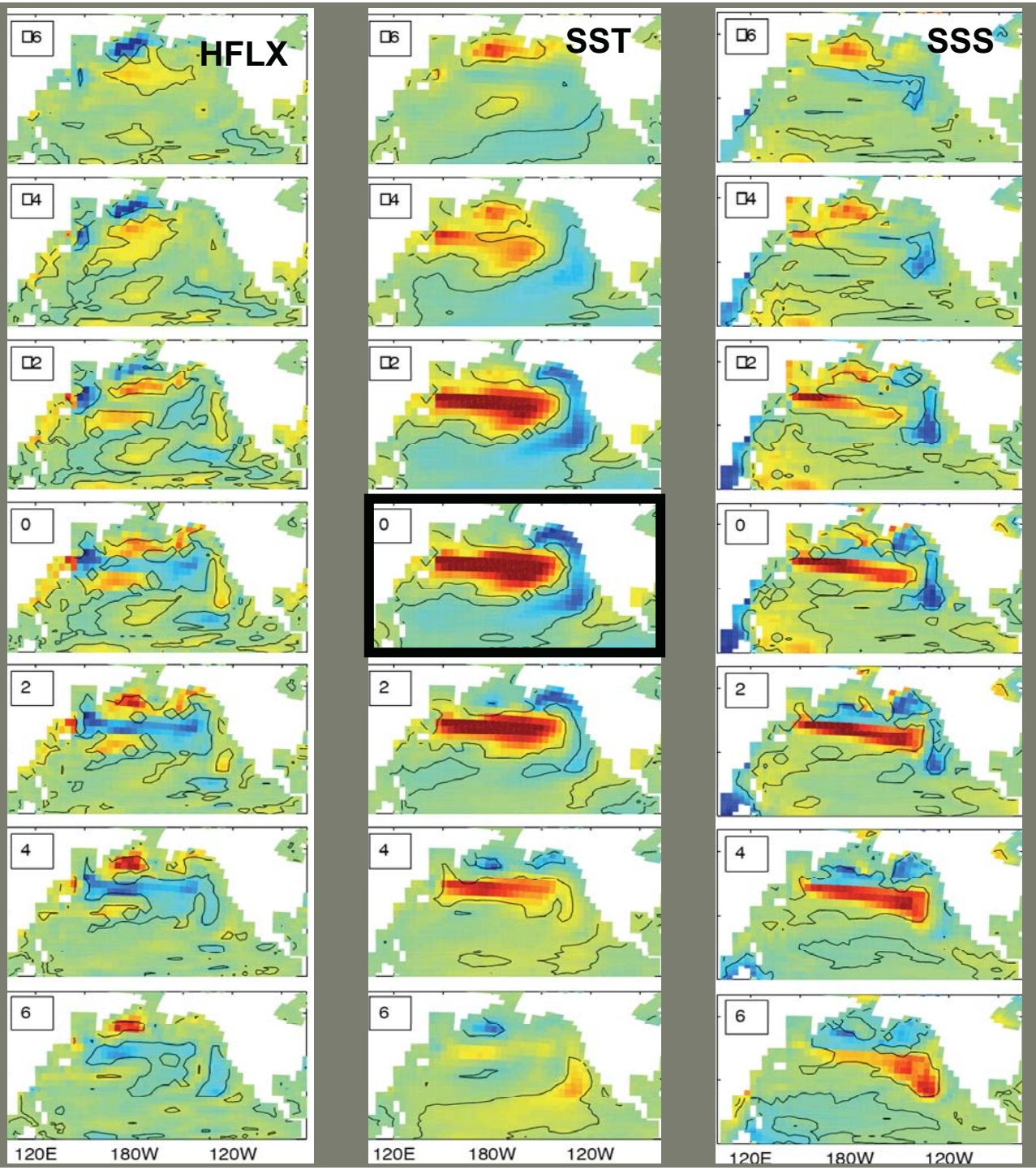
Timing of the PDO

Time-lag regression on the PDO index

PDO mechanism

Decrease?

- Amplification and advection of SSS anomaly
- due to Evaporation which dominate heat and fresh water fluxes



Timing of the PDO

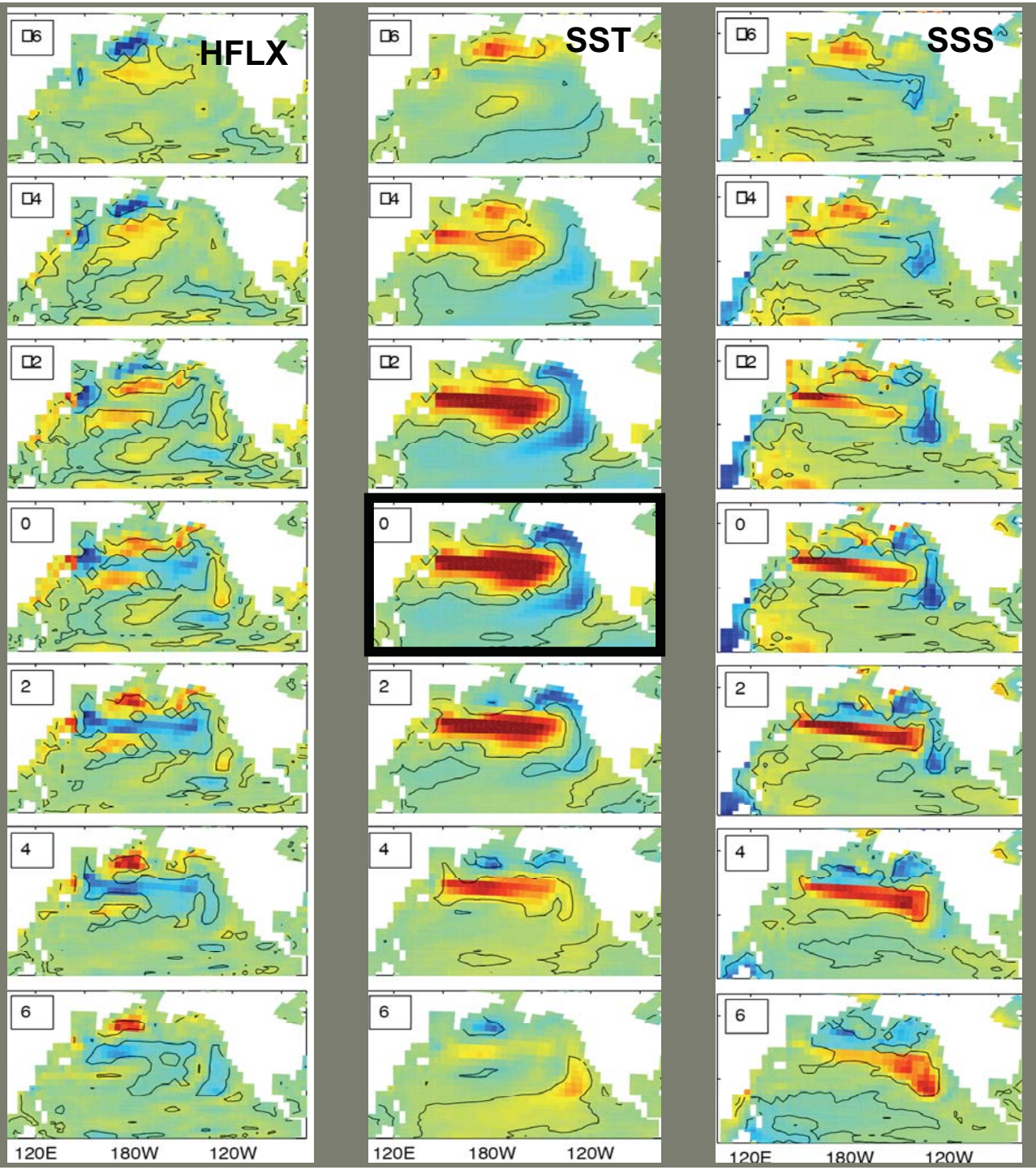
Time-lag regression on the PDO index

PDO mechanism

Decrease?

- Amplification and advection of SSS anomaly
- due to Evaporation which dominate heat and fresh water fluxes

Reversal ?



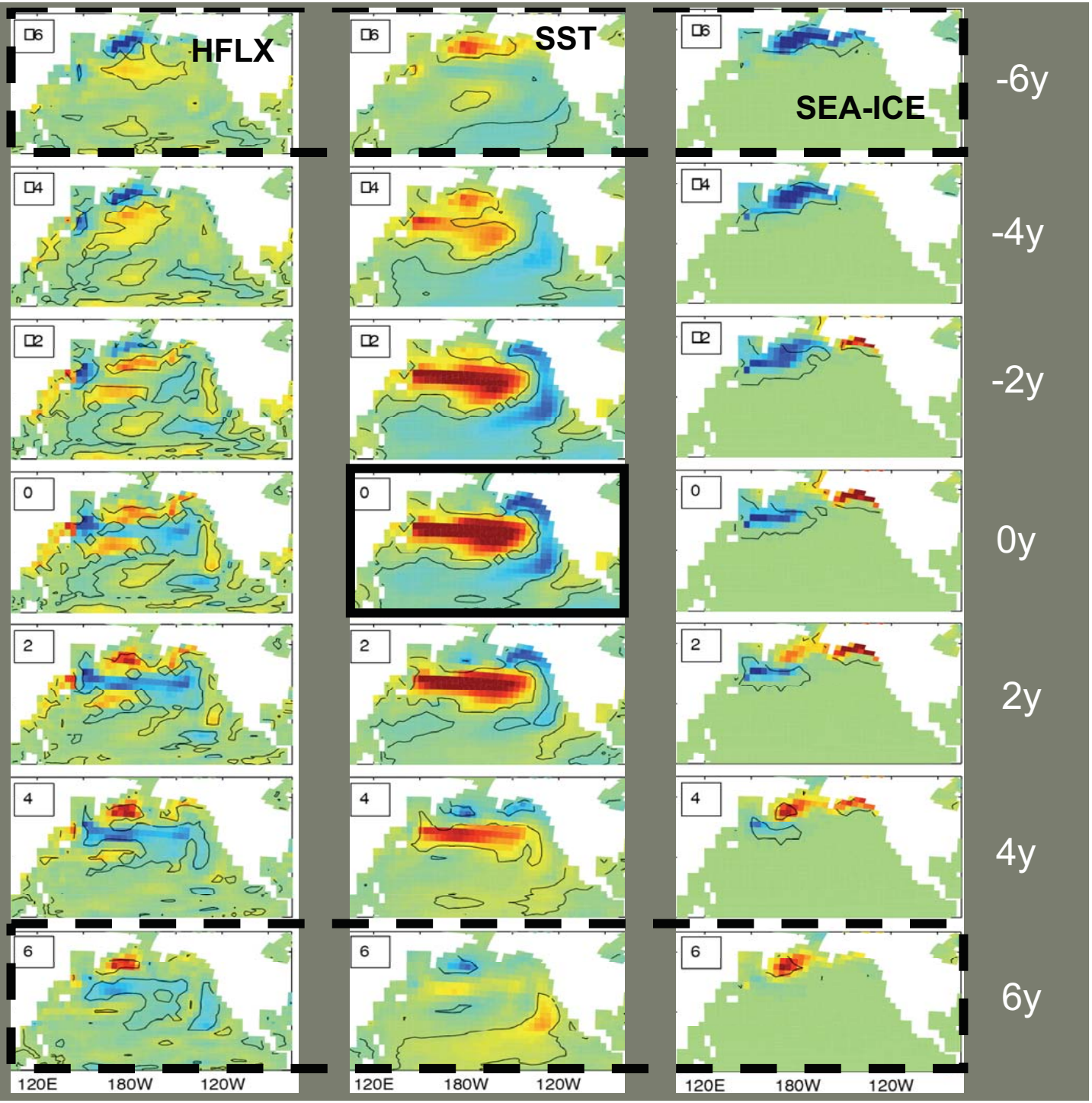
Timing of the PDO

Time-lag regression on the PDO index

PDO mechanism

Reversal

- region and variables in quadrature of phase with the PDO?
- in the BERING SEA, SST, Heat flux and Sea-Ice anomaly



Timing of the PDO

Time-lag regression on the PDO index

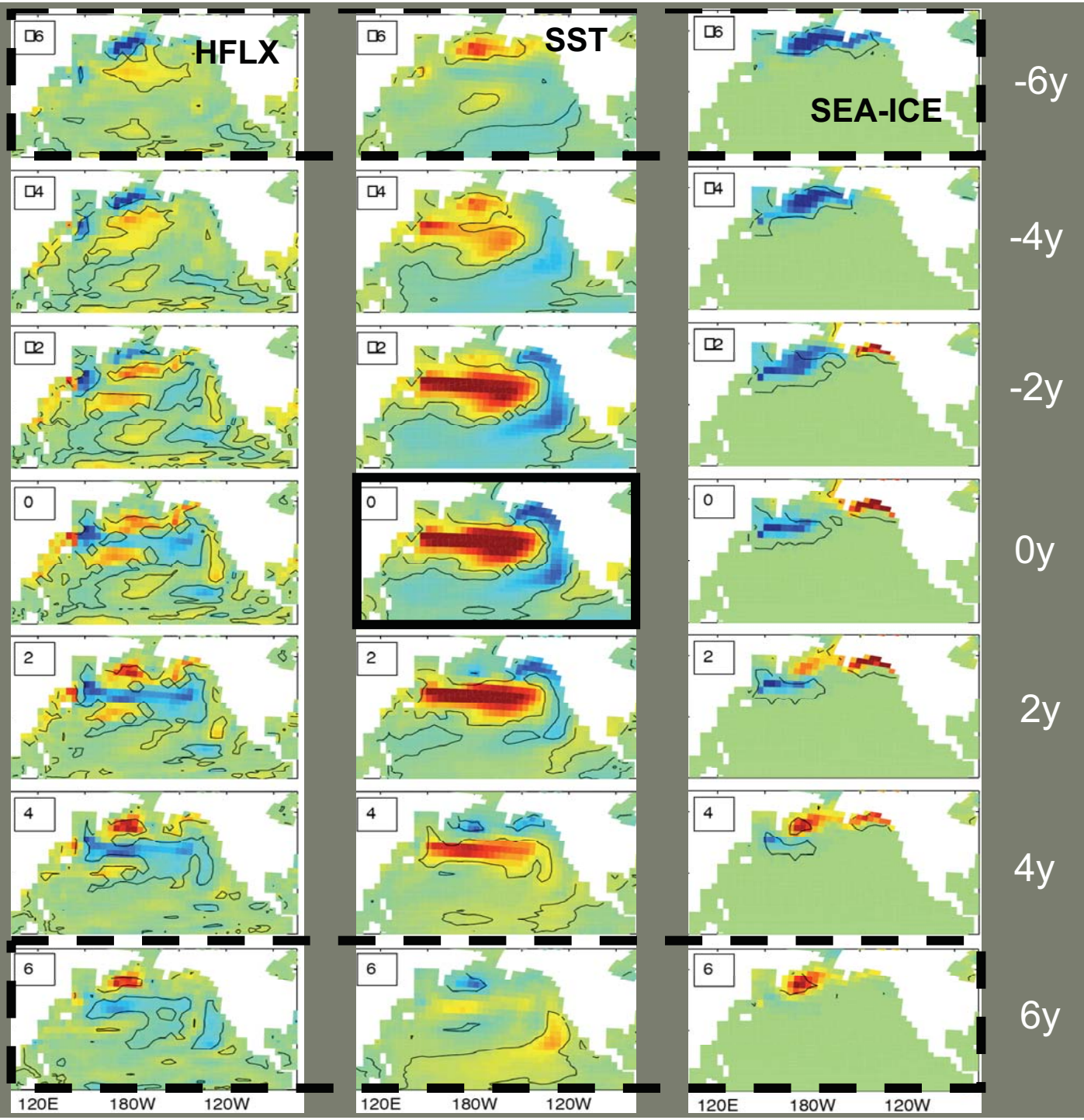
PDO mechanism

Reversal

- region and variables in quadrature of phase with the PDO?
- in the BERING SEA, SST, Heat flux and Sea-Ice anomaly

Honda et al. 1999
Alexander et al, 2004

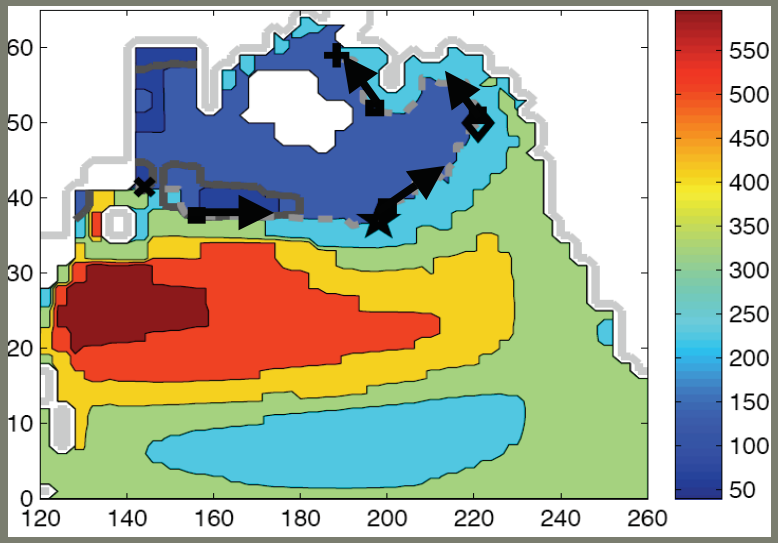
modification of the Aleutian Low by a wave train from the Bering Sea



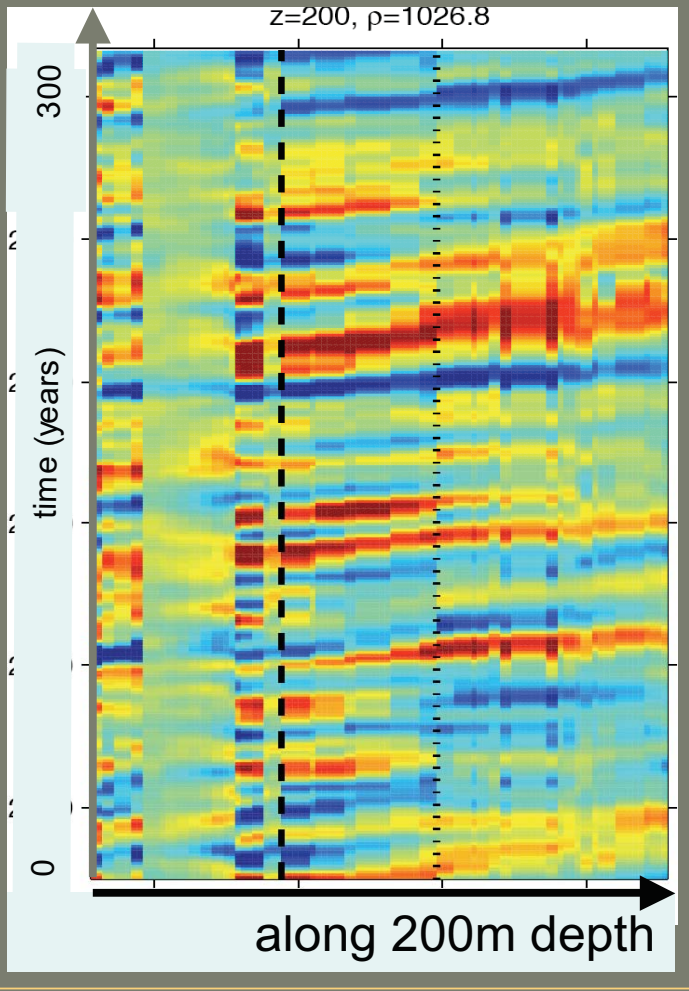
Role of the Salinitiy in the PDO (control)

Subsurface advection
of density compensated temperature anomaly
with a typical 10 year timescale between the
PDO center of action to the Bering Sea

depth of 1026.8 isopycnal



T anomaly
on 1026.8 isopycnal



Novel hypothesis: PDO reversal due to emergence of T anomaly in the Bering Sea

in contrast with the Tropical (Gu & Philander 1997) and the Stochastic theory of the PDO (Schneider et al 2002)

Conclusions

- On the North Pacific decadal variability
  - control simulations
    - PDO independent of the mean climate conditions: 20 years
    - importance of Salinity in setting up the PDO timescale
      - subsurface advection of spice anomaly
      - SST-SSS coupling via evaporation
    - importance of Bering Sea anomalies
      - possible triggering for the phase reversal
      - in quadrature of phase with the PDO
  - warming runs
    - 20 year timescale in SSS variability always present
    - but SST variability dominated by lower frequencies
- On the North Atlantic multidecadal variability

Natural low frequency variabilities can be affected by forced warmings

d'Orgeville & Peltier 2008a,b in revision for J. Clim.