# Intrinsic oceanic decadal variability in the North Pacific along the Eastern Boundary Current System

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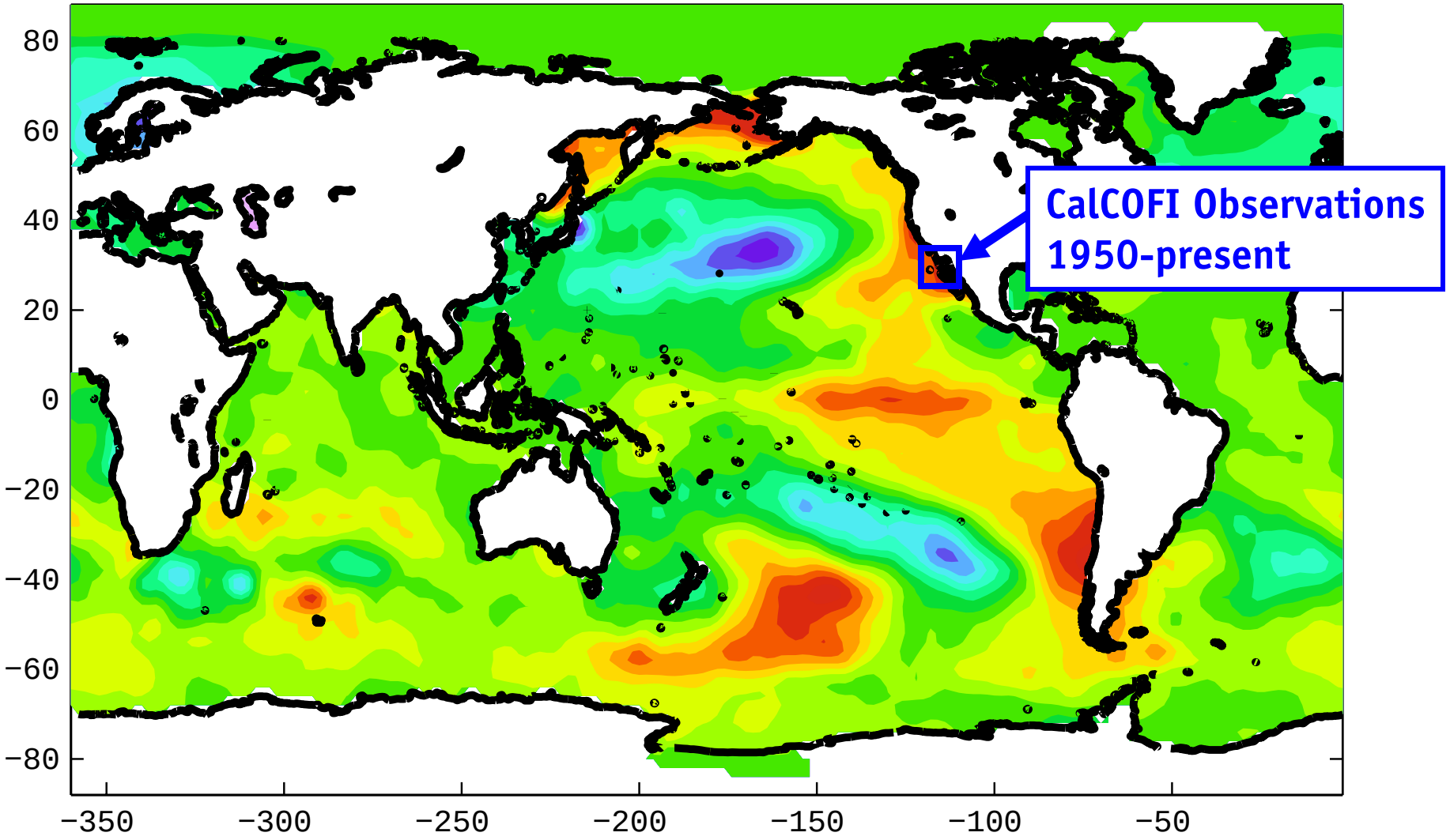
*Georgia Institute of Technology, USA*

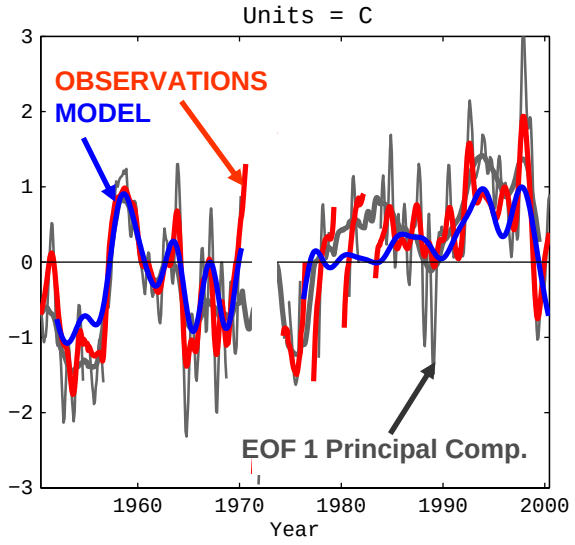
**Niklas Schneider**
*International Pacific Research Center, University of Hawaii, USA*

# SST Anomalies during positive phase of PDO



# California Current CalCOFI

## Observed and Model Temperature

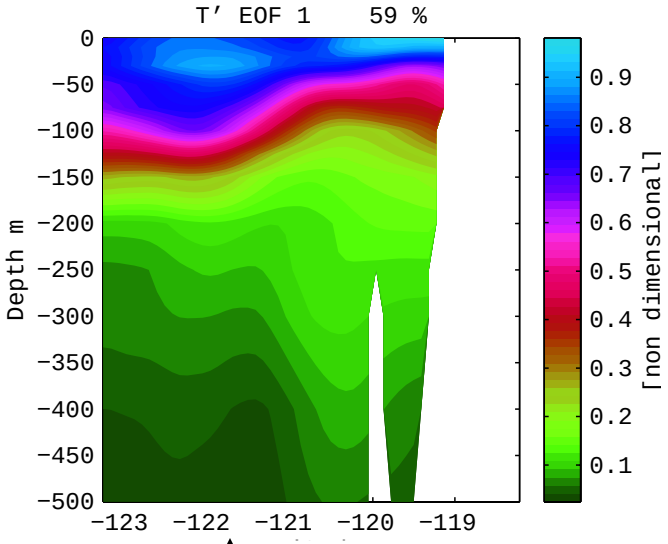


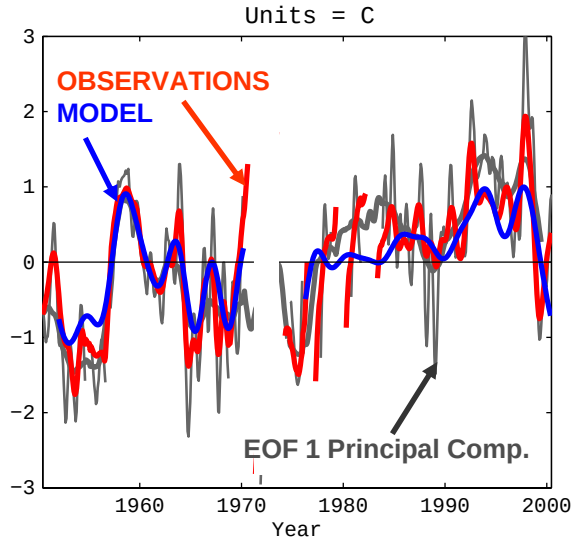

**Temperature variations driven by changes in heat fluxes**

Di Lorenzo et al. JPO 2005; Schneider et al. JPO 2005

# California Current CalCOFI

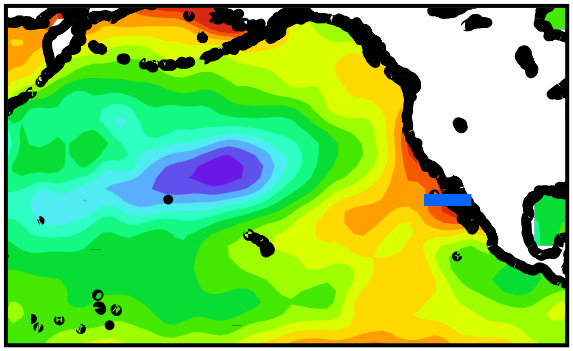
## Observed and Model Temperature




**Temperature variations driven by changes in heat fluxes**

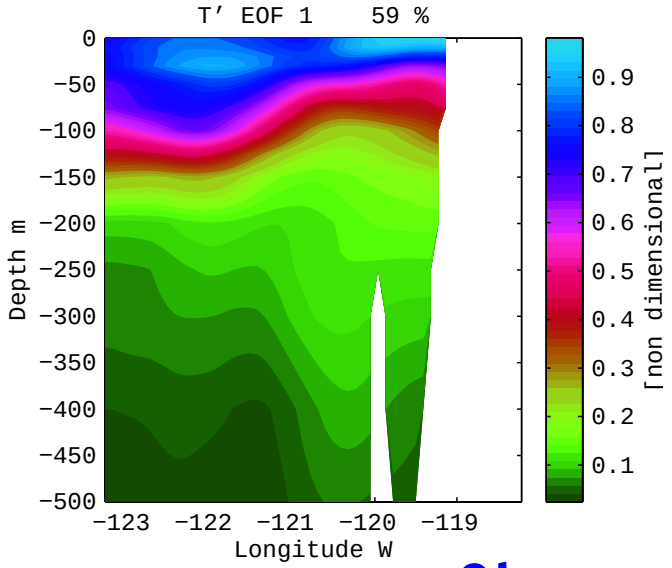
***Transect location***

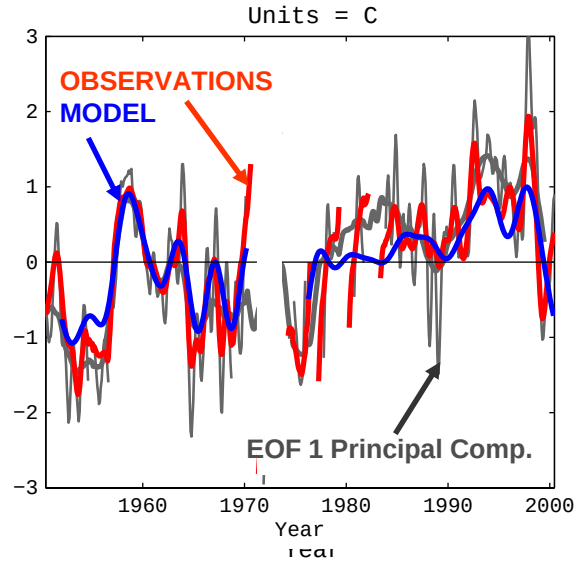


Di Lorenzo et al. JPO 2005; Schneider et al. JPO 2005

# California Current CalCOFI

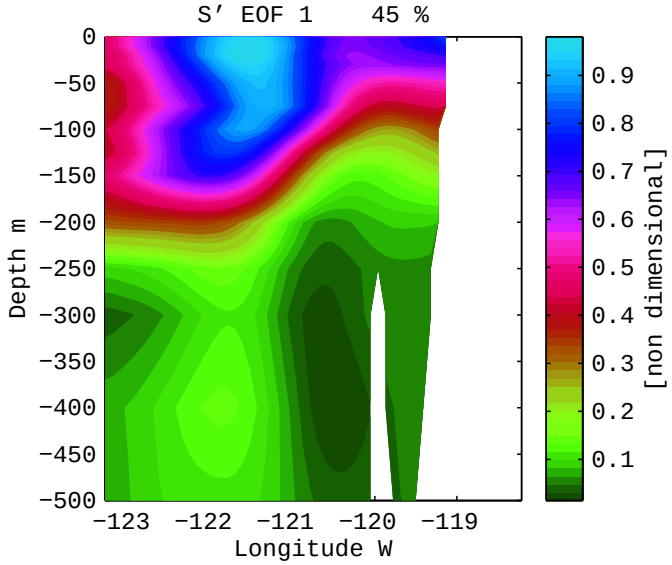
## Observed and Model Temperature

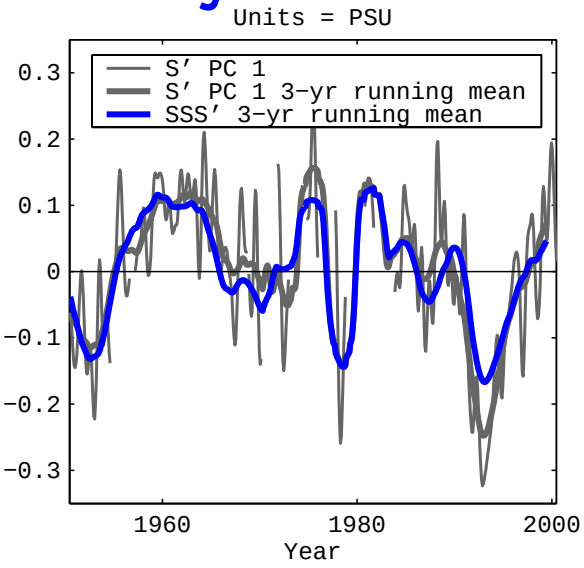



**Temperature variations driven by changes in heat fluxes**

## Observed Salinity



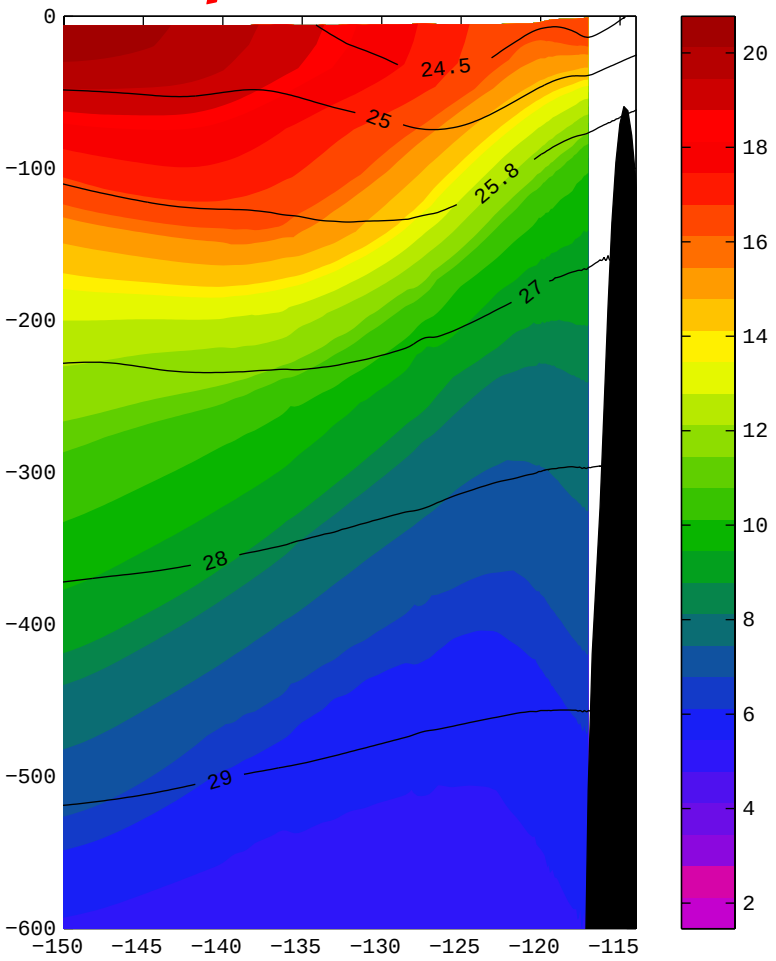



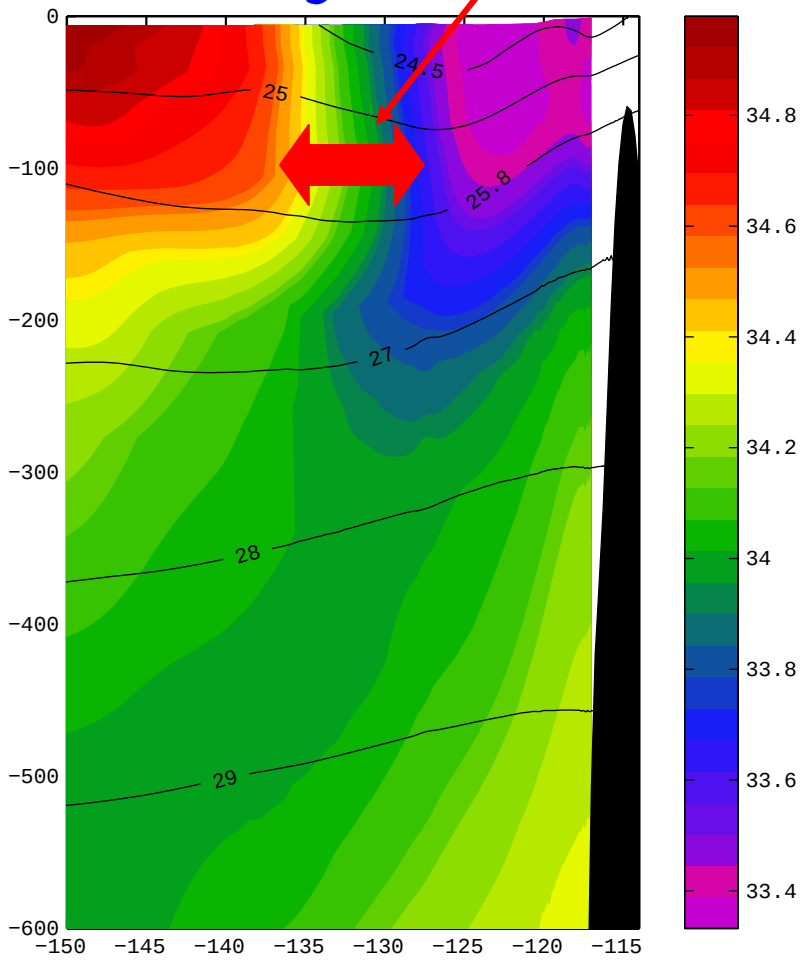

**Salinity variations remain unexplained**

**Di Lorenzo et al. JPO 2005; Schneider et al. JPO 2005**

# Why is Salinity a good indicator of changes in advection?

$$\frac{\partial S'}{\partial t} = -\mathbf{u}'\nabla\overline{S} - \gamma S'$$



## Hypothesis:

**Eastern boundary mesoscale eddy field is an additional source of *intrinsic* ocean low frequency variability (interannual to decadal timescales).**

**Hypothesis:**

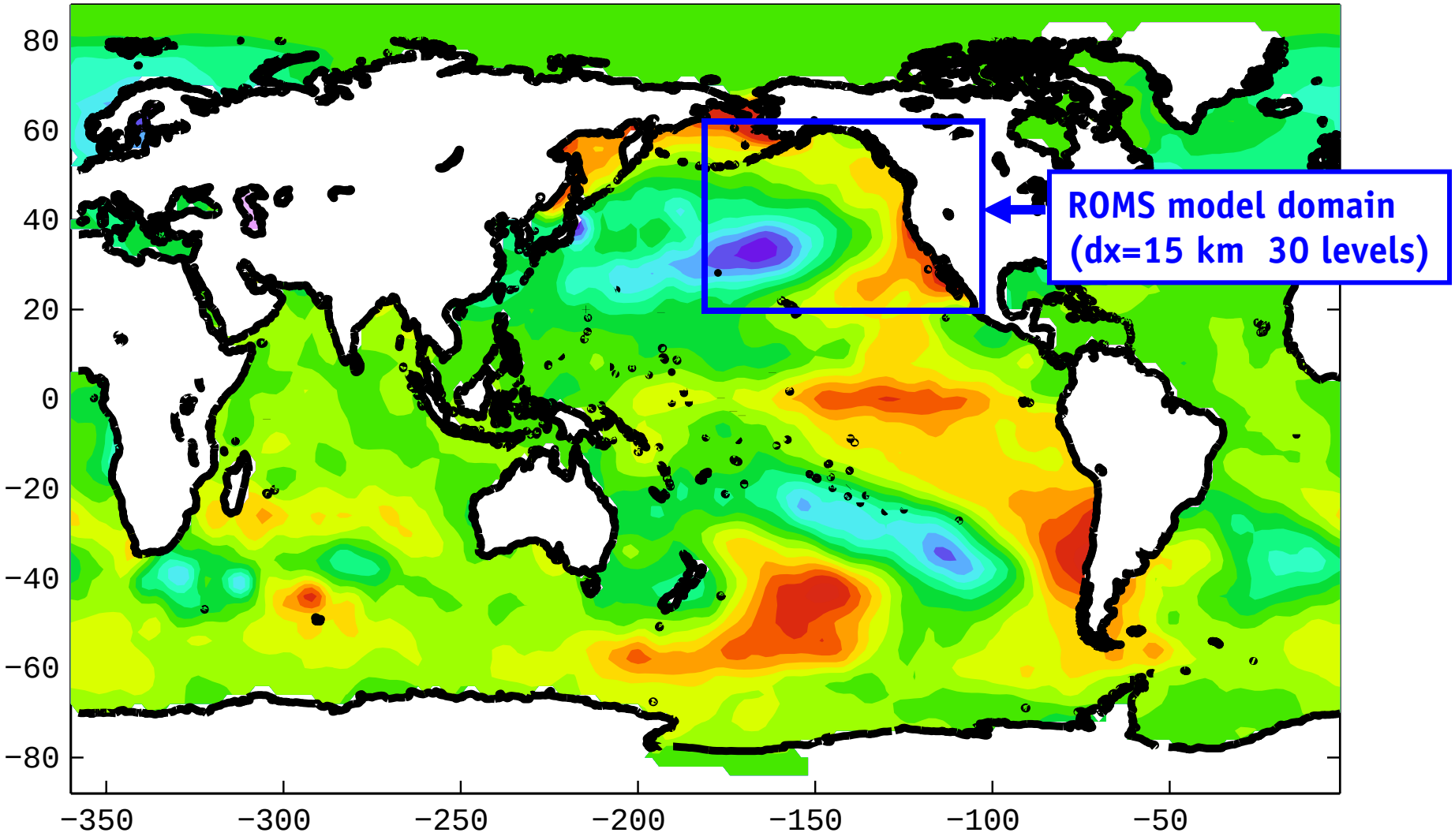
**Eastern boundary mesoscale eddy field is an additional source of *intrinsic* ocean low frequency variability (interannual to decadal timescales).**

**If this hypothesis is confirmed:**

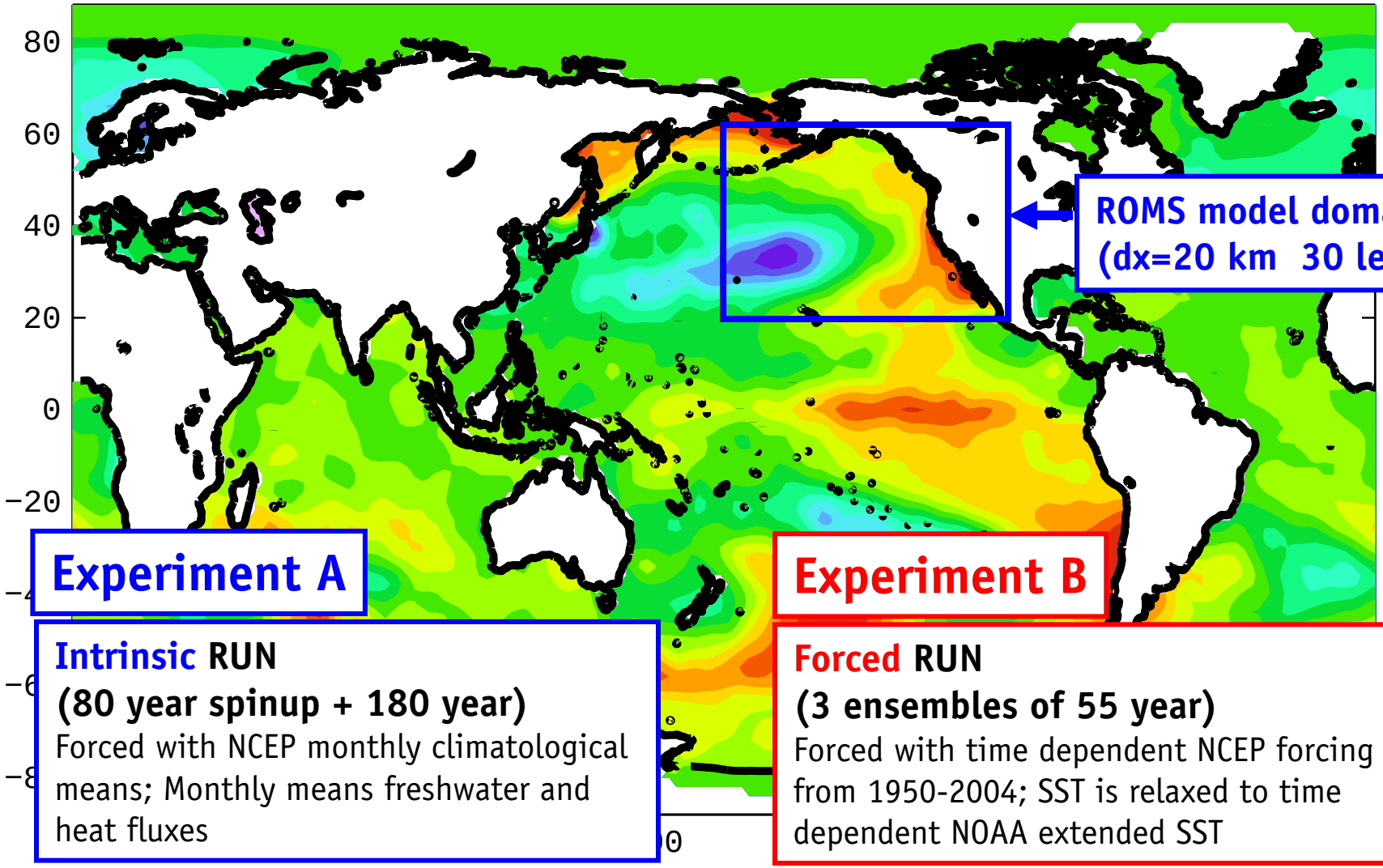
1) **Improve our understanding of the dynamics of eastern boundary currents.**

2) **Important implications on decadal scale changes in the cross-shelf transports and distribution of material properties (biological and physical)**

# SST Anomalies during positive phase of PDO



# SST Anomalies during positive phase of PDO




## Experiment A

**Intrinsic RUN**

**(80 year spinup + 180 year)**

Forced with NCEP monthly climatological means; Monthly means freshwater and heat fluxes

## Experiment B

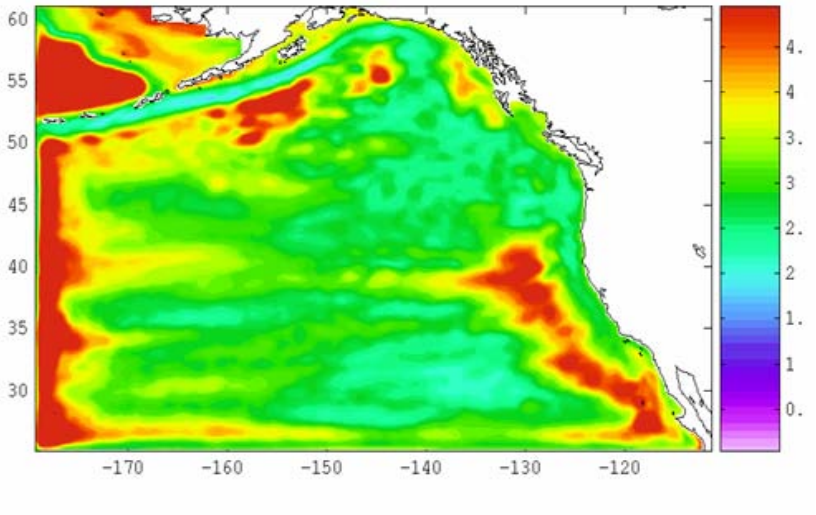
**Forced RUN**

**(3 ensembles of 55 year)**

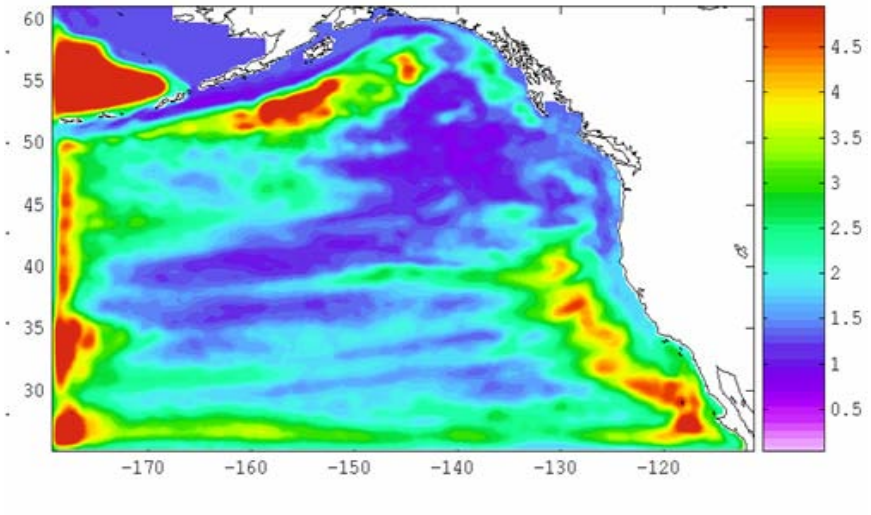
Forced with time dependent NCEP forcing from 1950-2004; SST is relaxed to time dependent NOAA extended SST

# Interannual Standard Deviation SSH [m]

## FORCED run

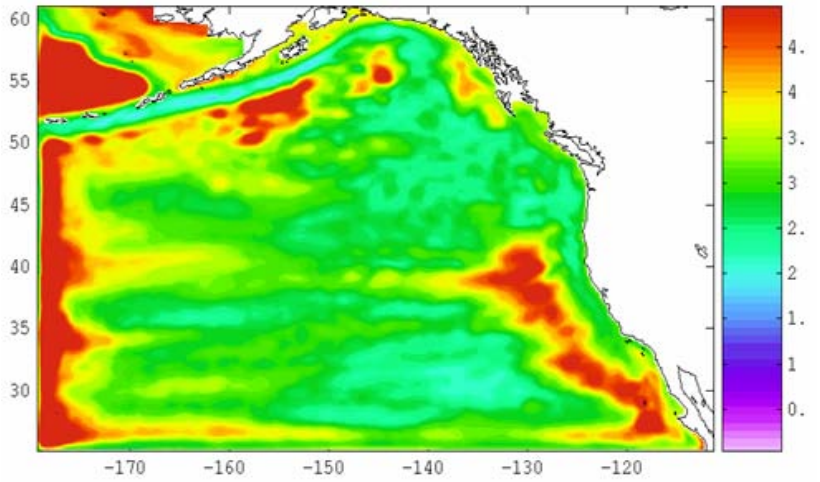



## INTRINSIC run

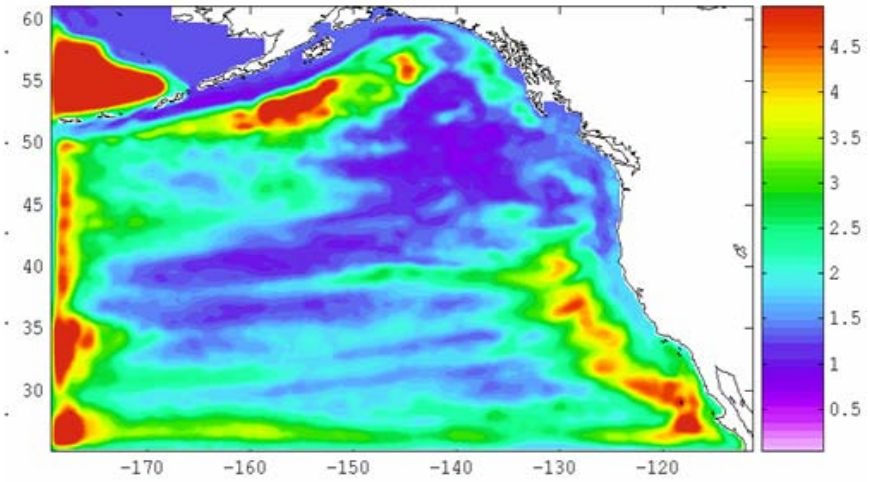


# Interannual Standard Deviation SSH [m]

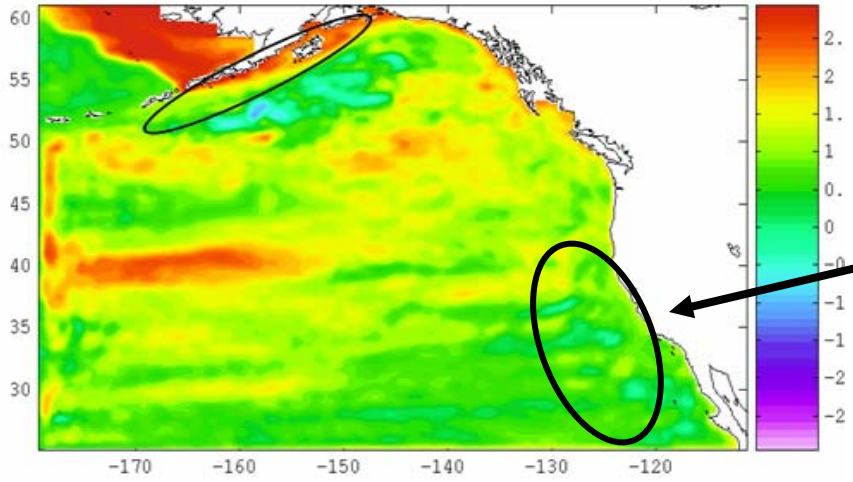
## FORCED run




## INTRINSIC run



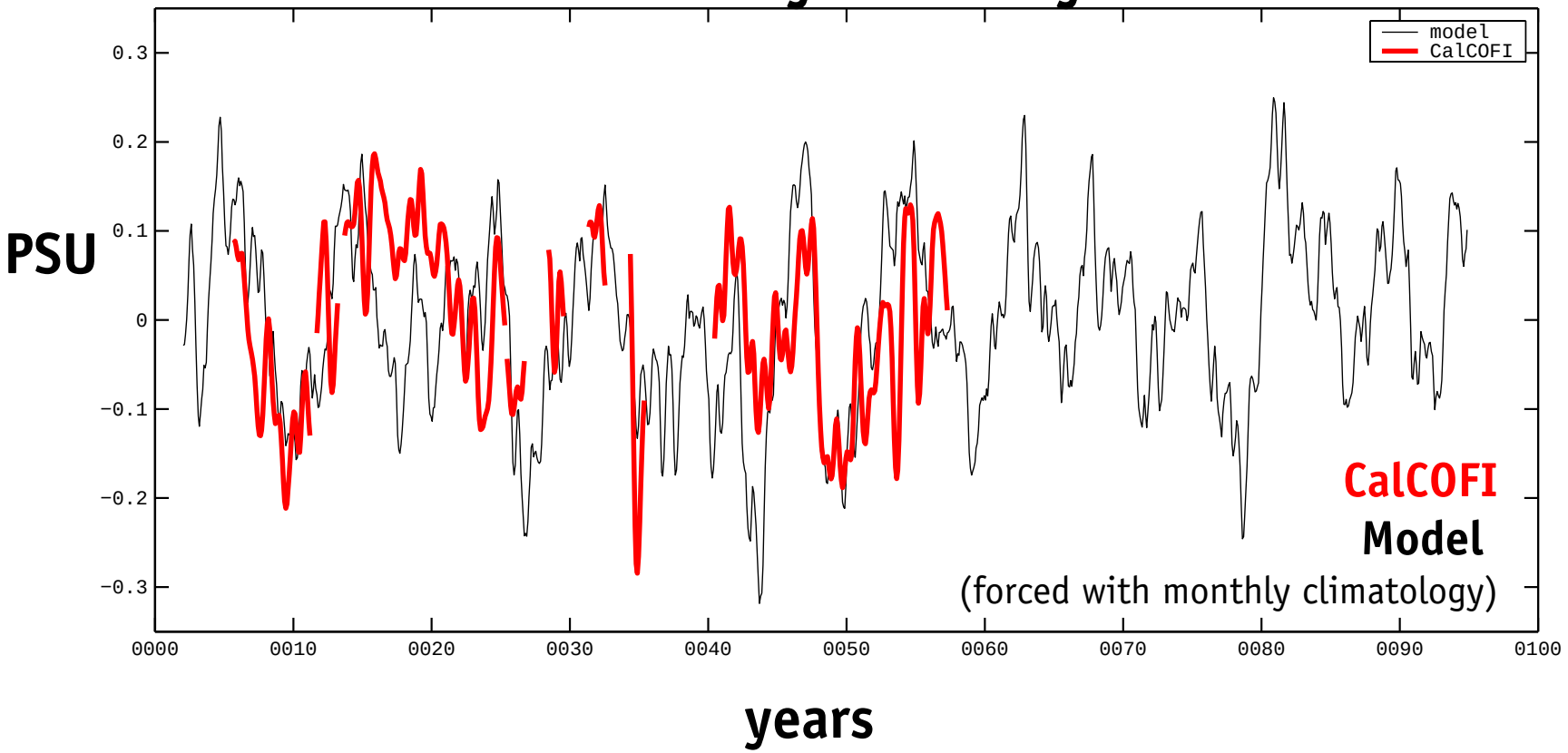

## Difference FORCED - INTRINSIC




**Insignificant differences in variance in the CCS eddy field**

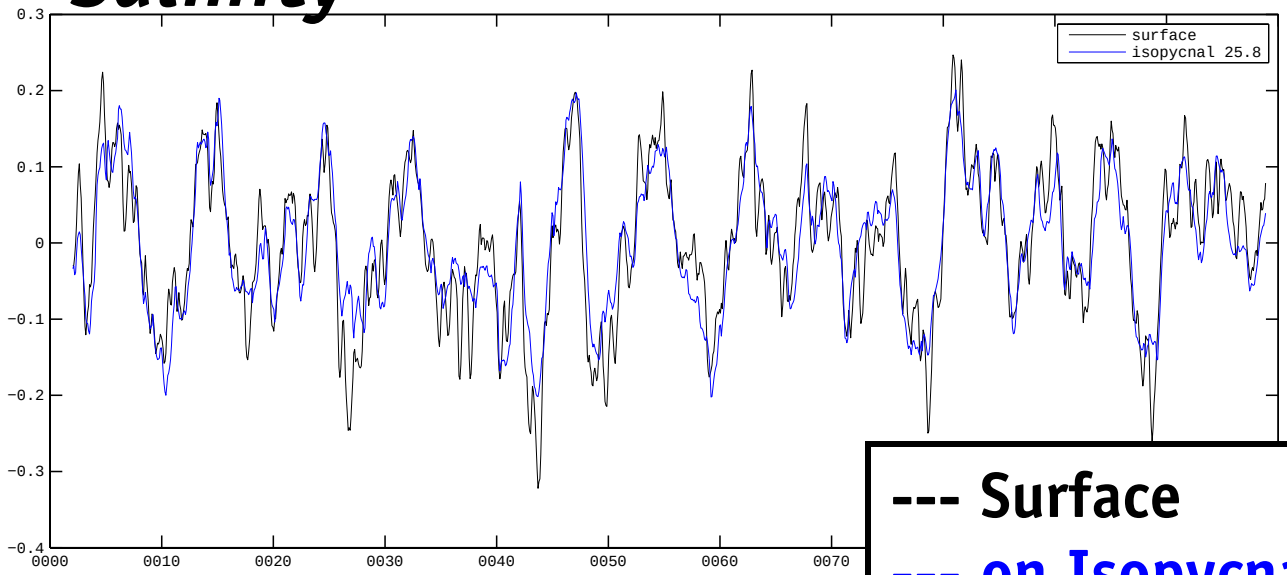
**INTRINSIC run**

# Time Series of Salinity Anomaly



## *Salinity*

PSU

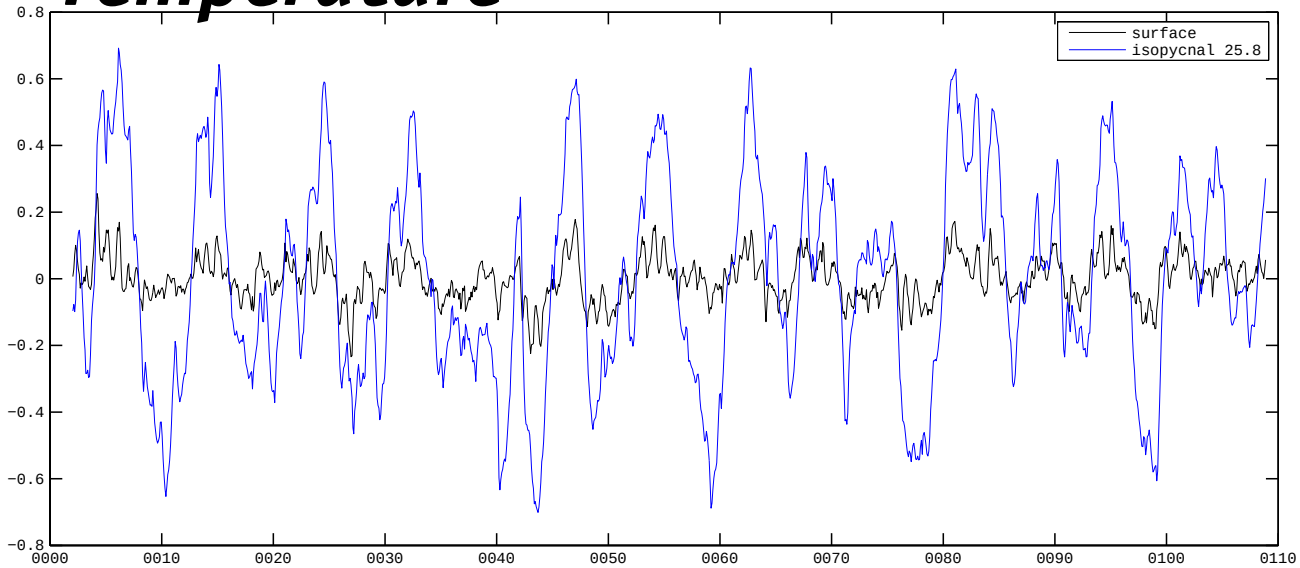



**--- Surface**

**--- on Isopycnal 25.8**

## *Temperature*

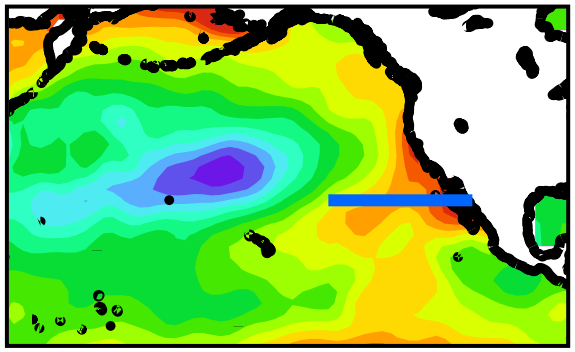
C

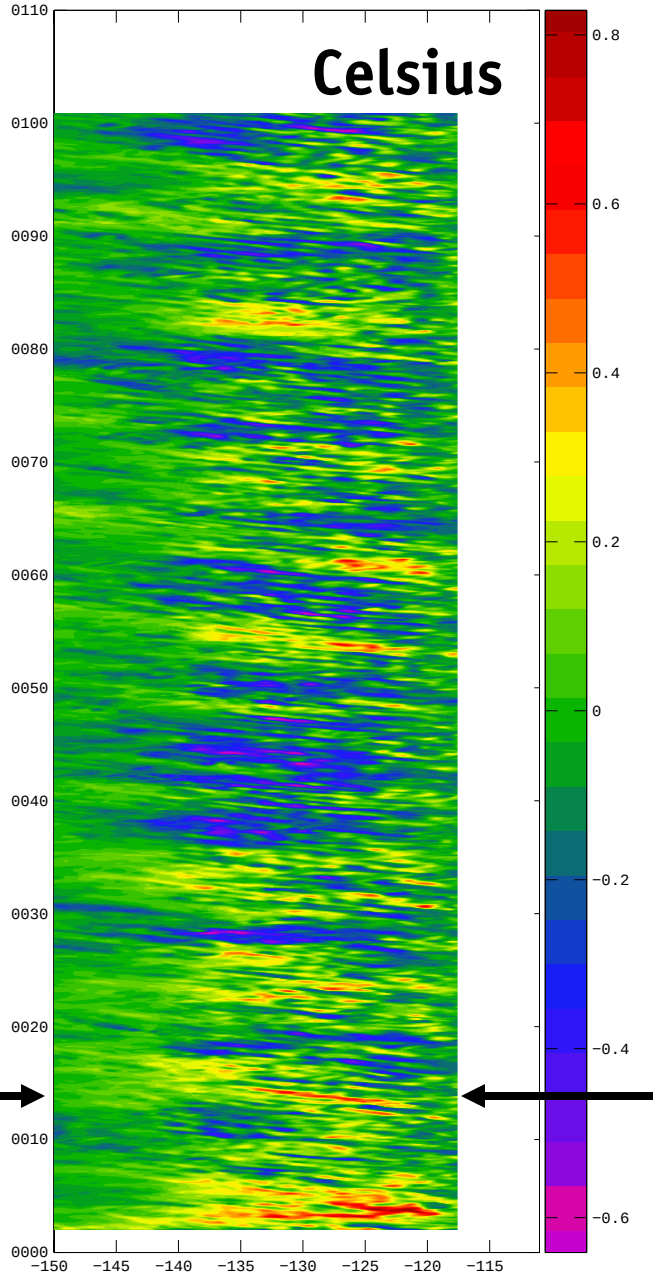



years

# Temperature Anomalies 28.5N – 30.5N

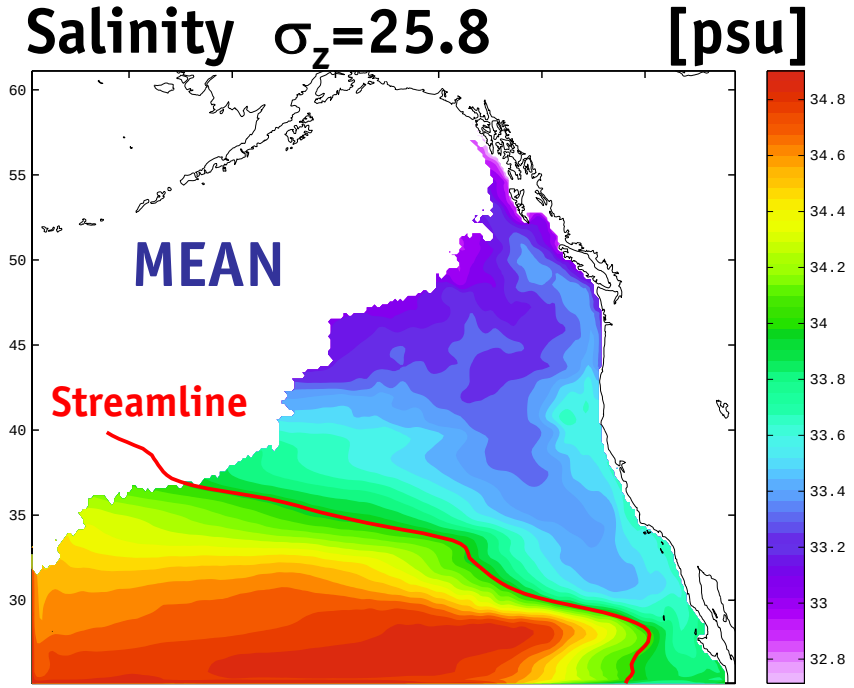
*Transect location*

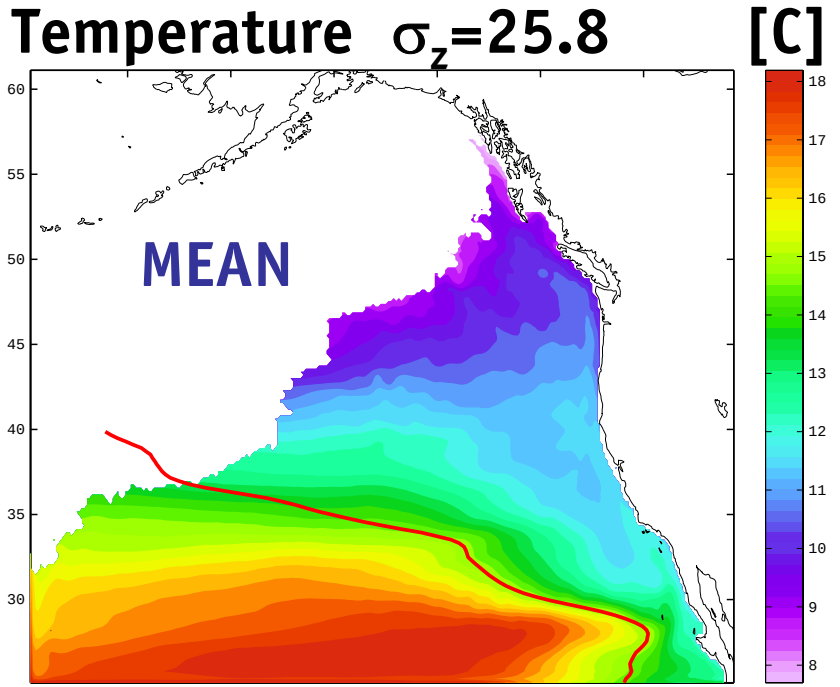


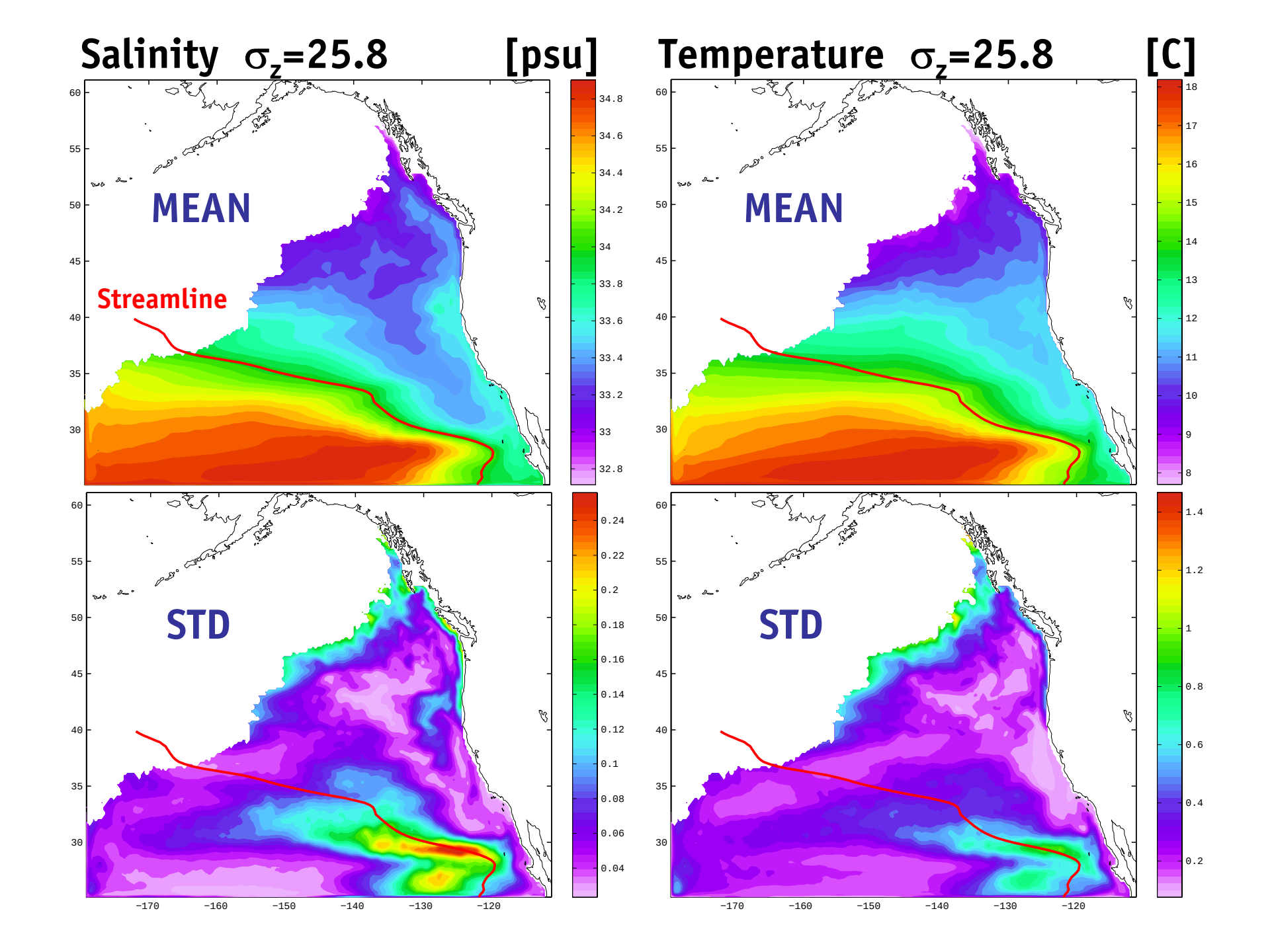


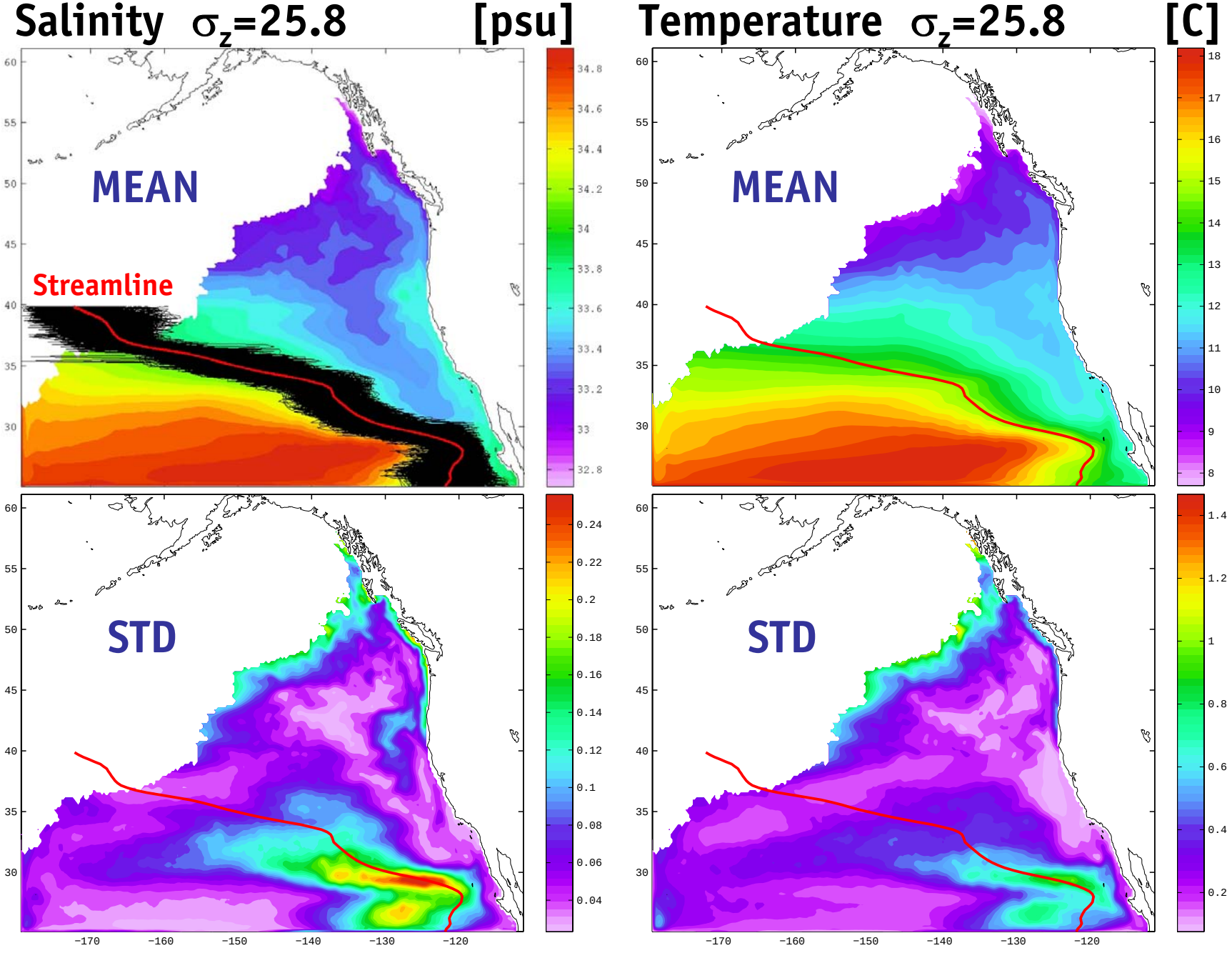

*Offshore in Subtropical Gyre* →

← *California Coast*


Salinity $\sigma_z$=25.8 [psu]
MEAN
Streamline
60
55
50
45
40
35
30
34.8
34.6
34.4
34.2
34
33.8
33.6
33.4
33.2
33
32.8


Temperature $\sigma_z$=25.8 [C]
MEAN
60
55
50
45
40
35
30
18
17
16
15
14
13
12
11
10
9
8

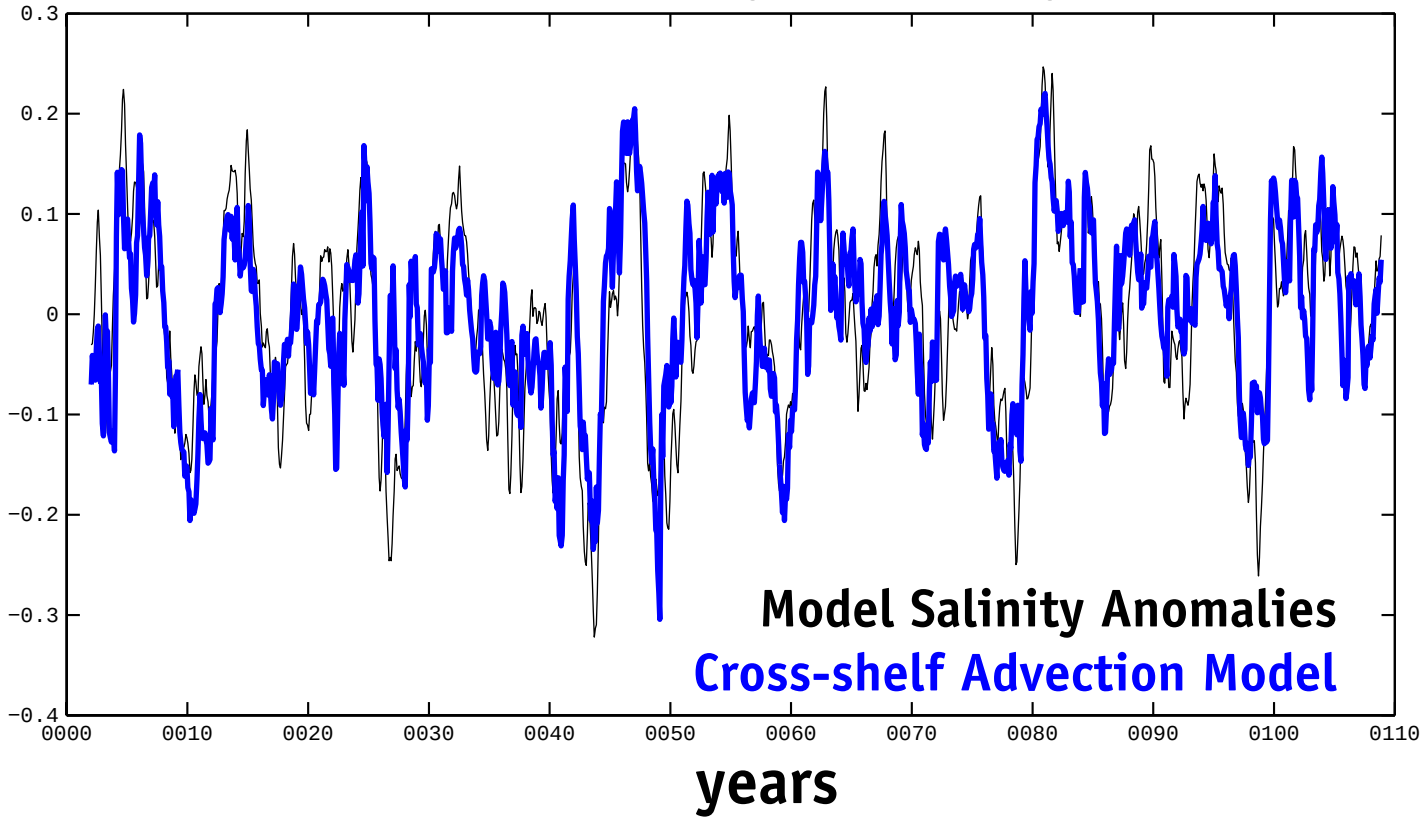

Salinity σz=25.8 [psu]
Temperature σz=25.8 [C]
MEAN
Streamline
MEAN
STD
STD
60
55
50
45
40
35
30
-170
-160
-150
-140
-130
-120
34.8
34.6
34.4
34.2
34
33.8
33.6
33.4
33.2
33
32.8
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
18
17
16
15
14
13
12
11
10
9
8
1.4
1.2
1
0.8
0.6
0.4
0.2


Salinity $\sigma_z$=25.8 [psu]
Temperature $\sigma_z$=25.8 [C]
MEAN
Streamline
MEAN
STD
STD
60
55
50
45
40
35
30
−170
−160
−150
−140
−130
−120
34.8
34.6
34.4
34.2
34
33.8
33.6
33.4
33.2
33
32.8
18
17
16
15
14
13
12
11
10
9
8
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
1.4
1.2
1
0.8
0.6
0.4
0.2

$$\frac{\partial S'}{\partial t} = -\mathbf{u}'\nabla\overline{S} - \gamma S'$$

***Cross-shelf streamline displacement***

# Time Series of Salinity Anomaly




$$\frac{\partial S'}{\partial t} = -\mathbf{u}'\nabla\overline{S} - \gamma S'$$

*Cross-shelf streamline displacement*

**Hypothesis:**

**Eastern boundary mesoscale eddy field is an additional source of *intrinsic* ocean low frequency variability (interannual to decadal timescales).**

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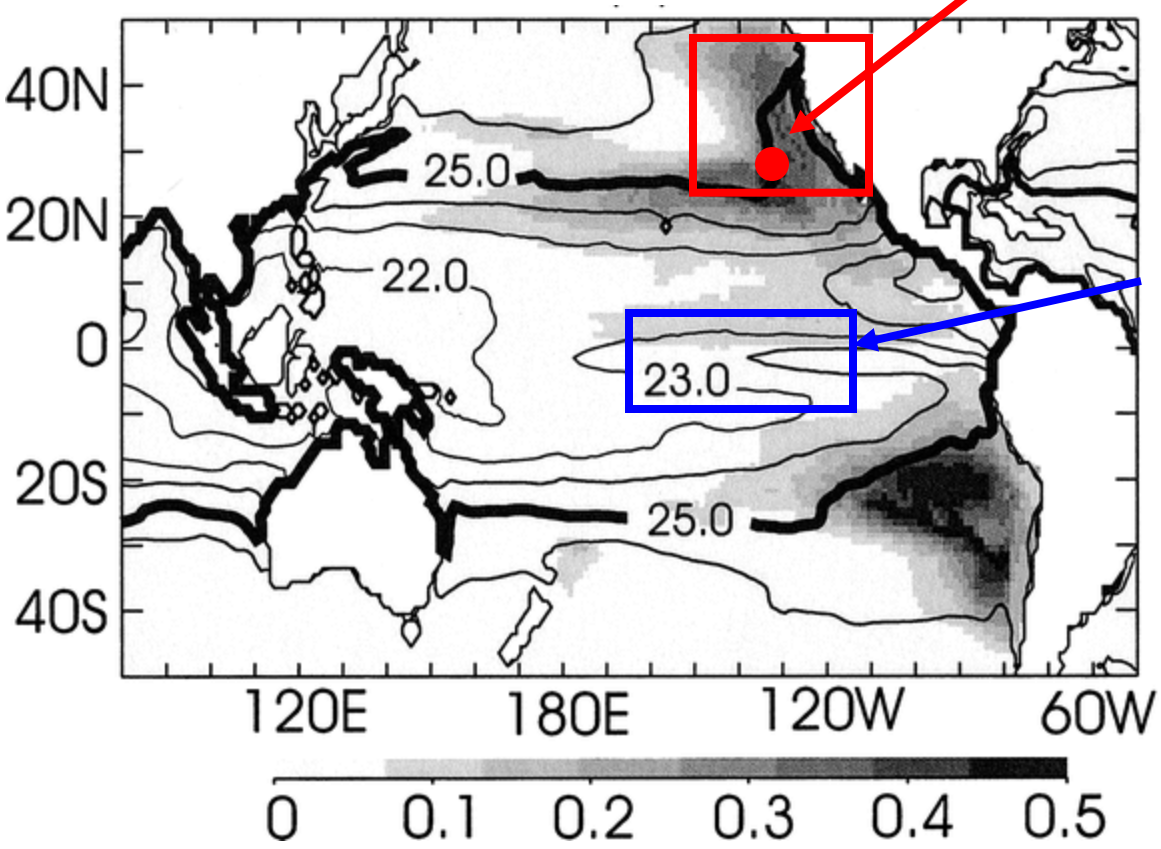
## Findings:

**Low frequency variations in CalCOFI observed salinity may be intrinsic and capturing the effect of changes in the cross-shore advection (which are hard to measure).**

**These variations reflect low frequency variations in the displacement of the "streamlines" of the southward California Current (with potential impacts on ecosystem dynamics (?) and large scale NP variability over the subduction regions (not shown here) ).**

**The displacement of the streamlines is induced by disturbances generated at the coast and propagating westward (e.g. eddy field, Rossby waves) (however a more detail analysis shows that the structure of the anomalies propagation is more complex at depth, where interactions with mean currents may be important). A comparison with the forced run will further clarify if/how the eddy field is modulated by the atmospherc forcing.**

# Origin of source waters to the NINO 3.4 upwelling region on decadal timescales



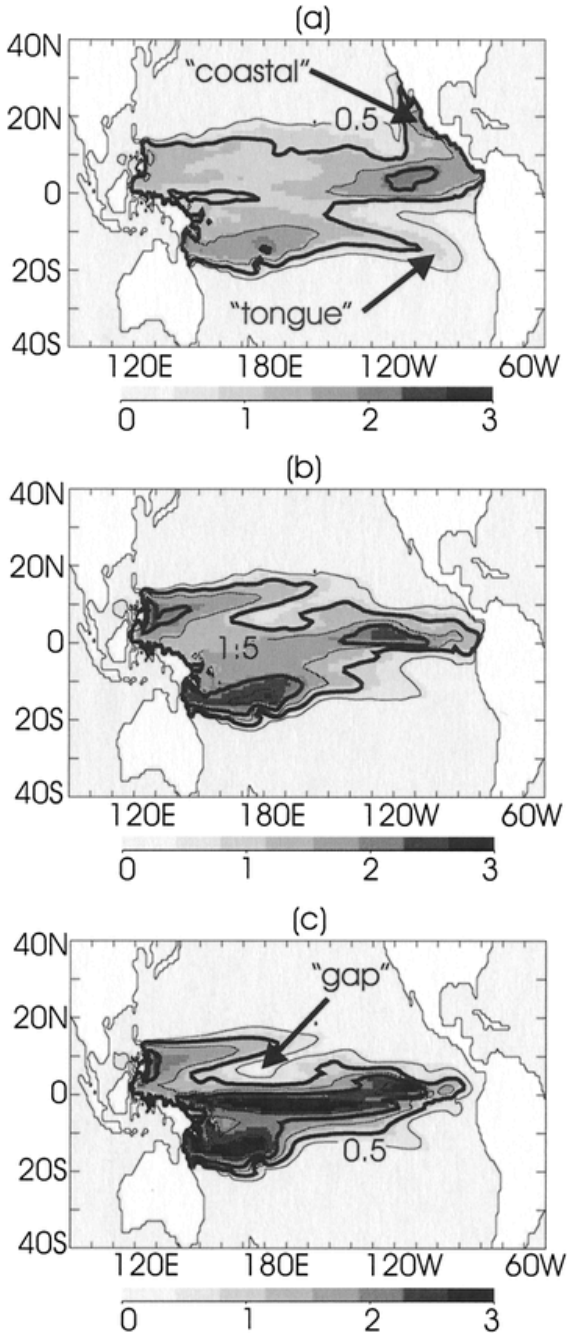

Fukumori et al. JPO 2004

# Aliasing of source waters

a) Using time dependent circulation →

b) Using Seasonal Circulation →

c) Using Mean Circulation →



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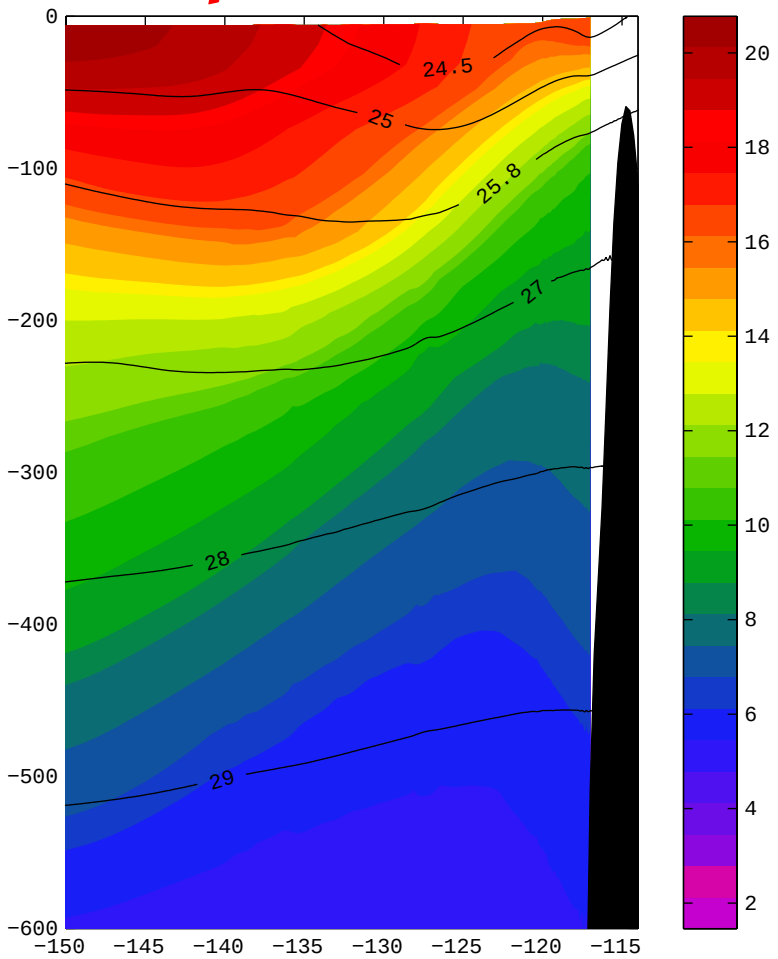
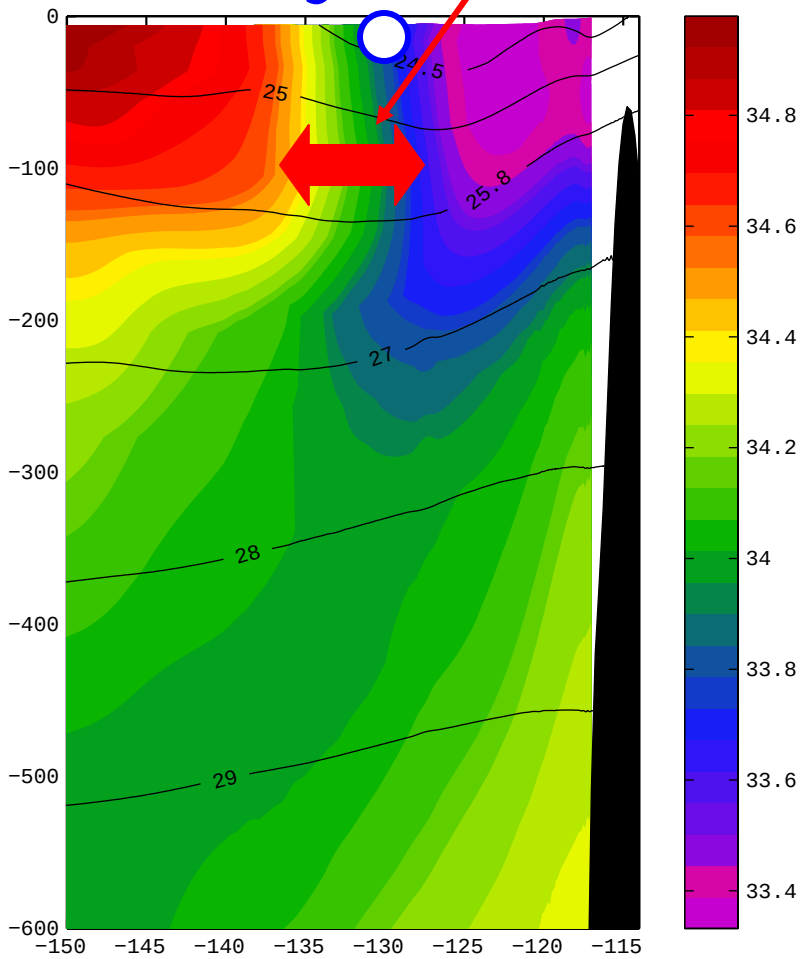
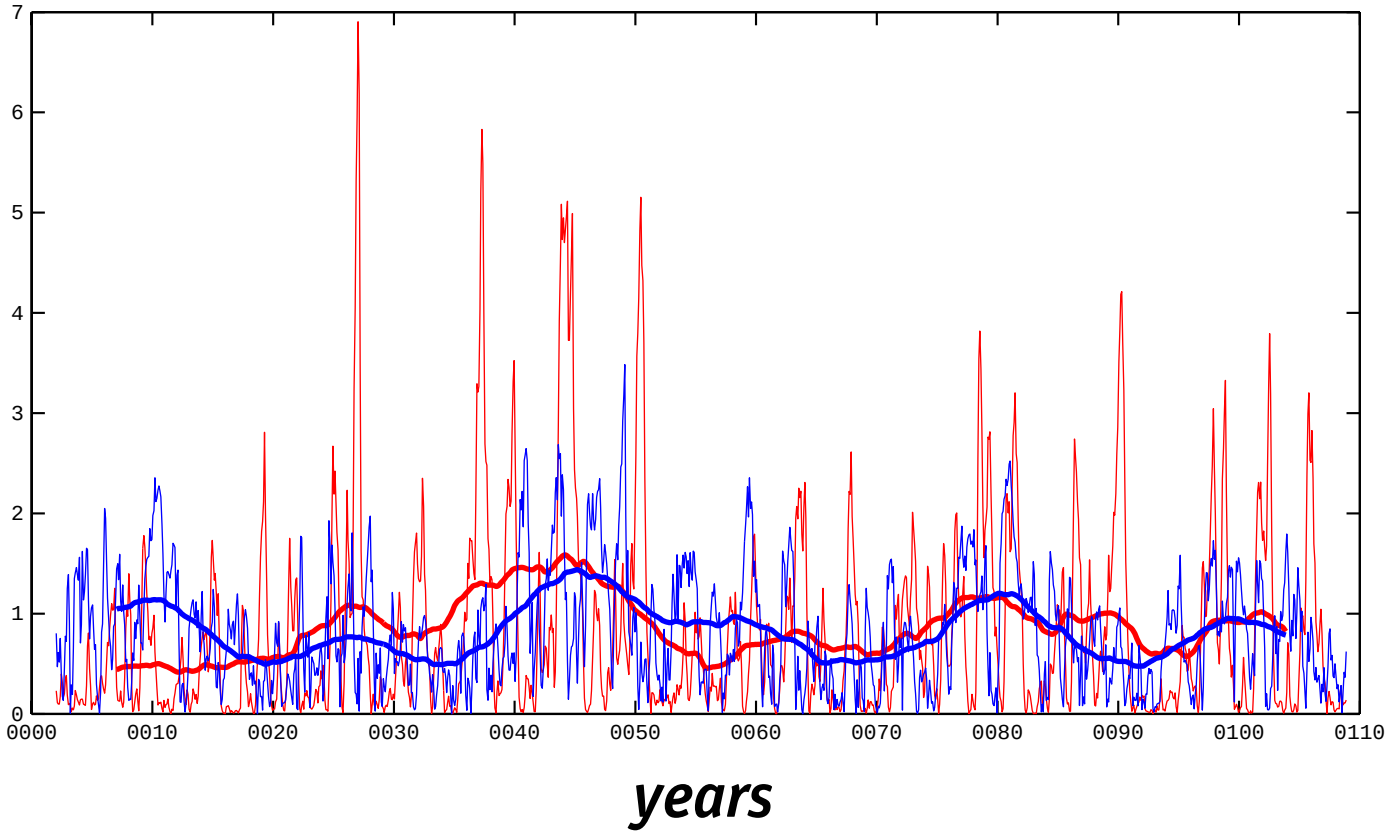
$$\frac{\partial S'}{\partial t} = -\mathbf{u}'\nabla\overline{S} - \gamma S'$$

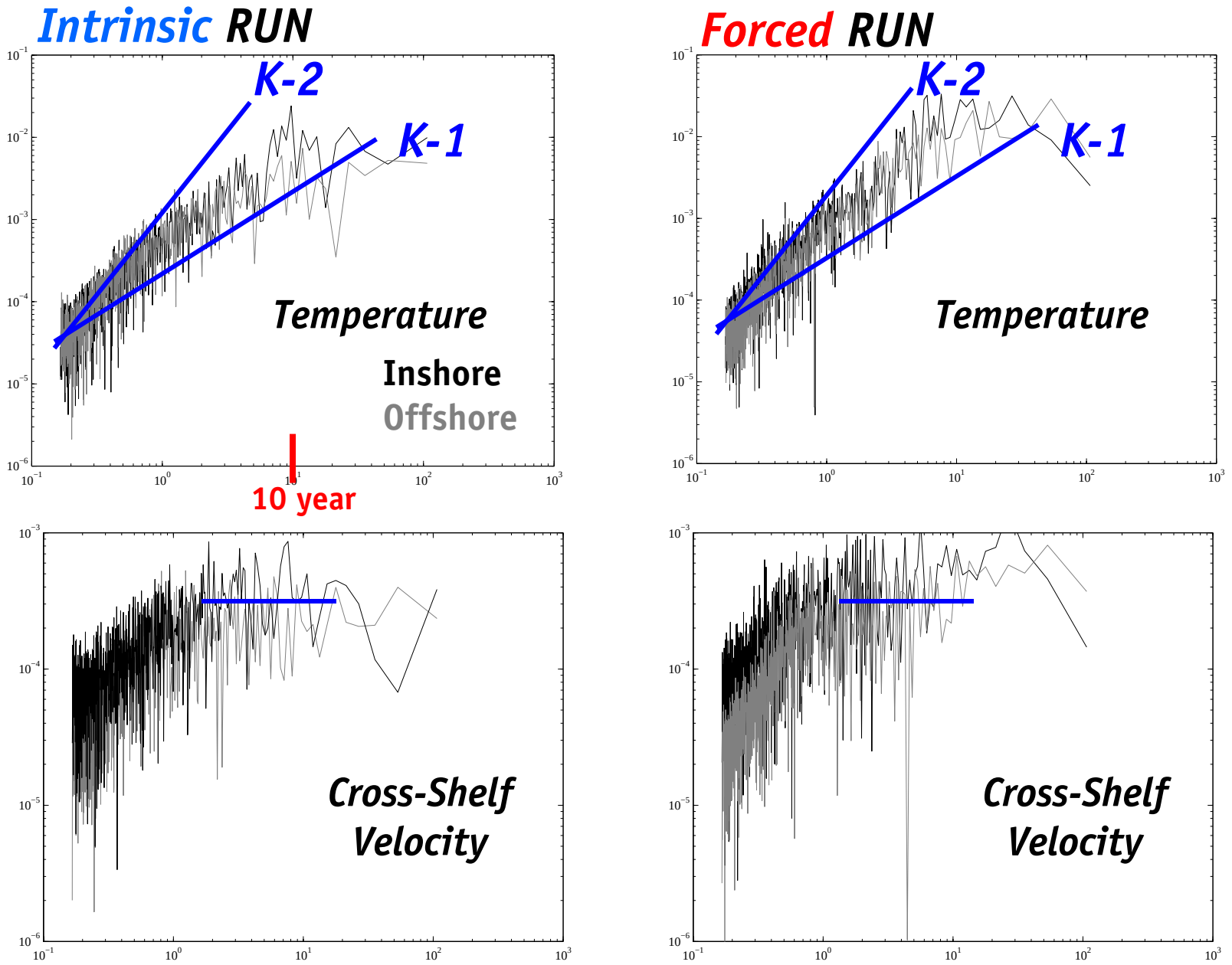


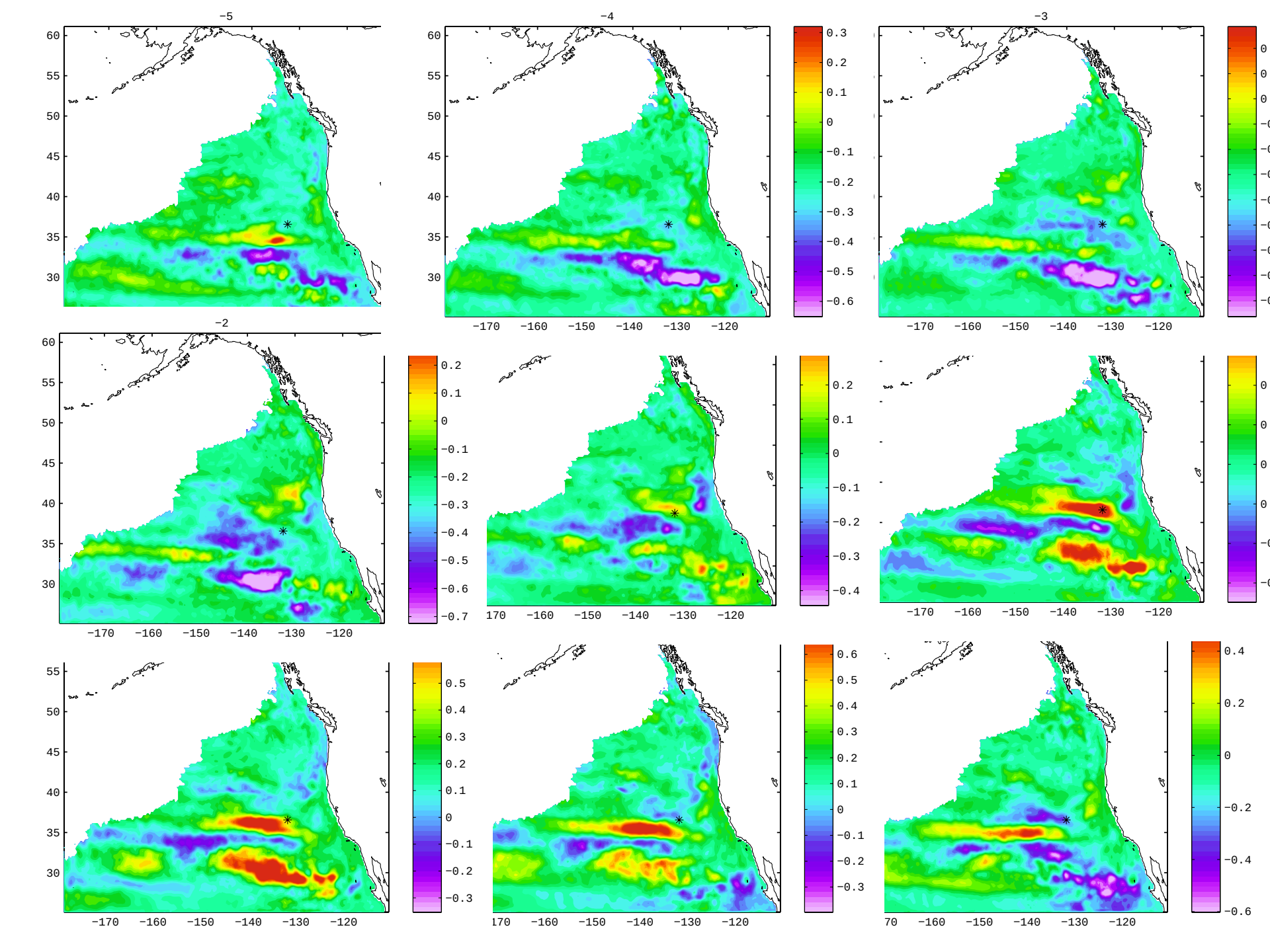



*Cross-shelf Displacement of Isoline*

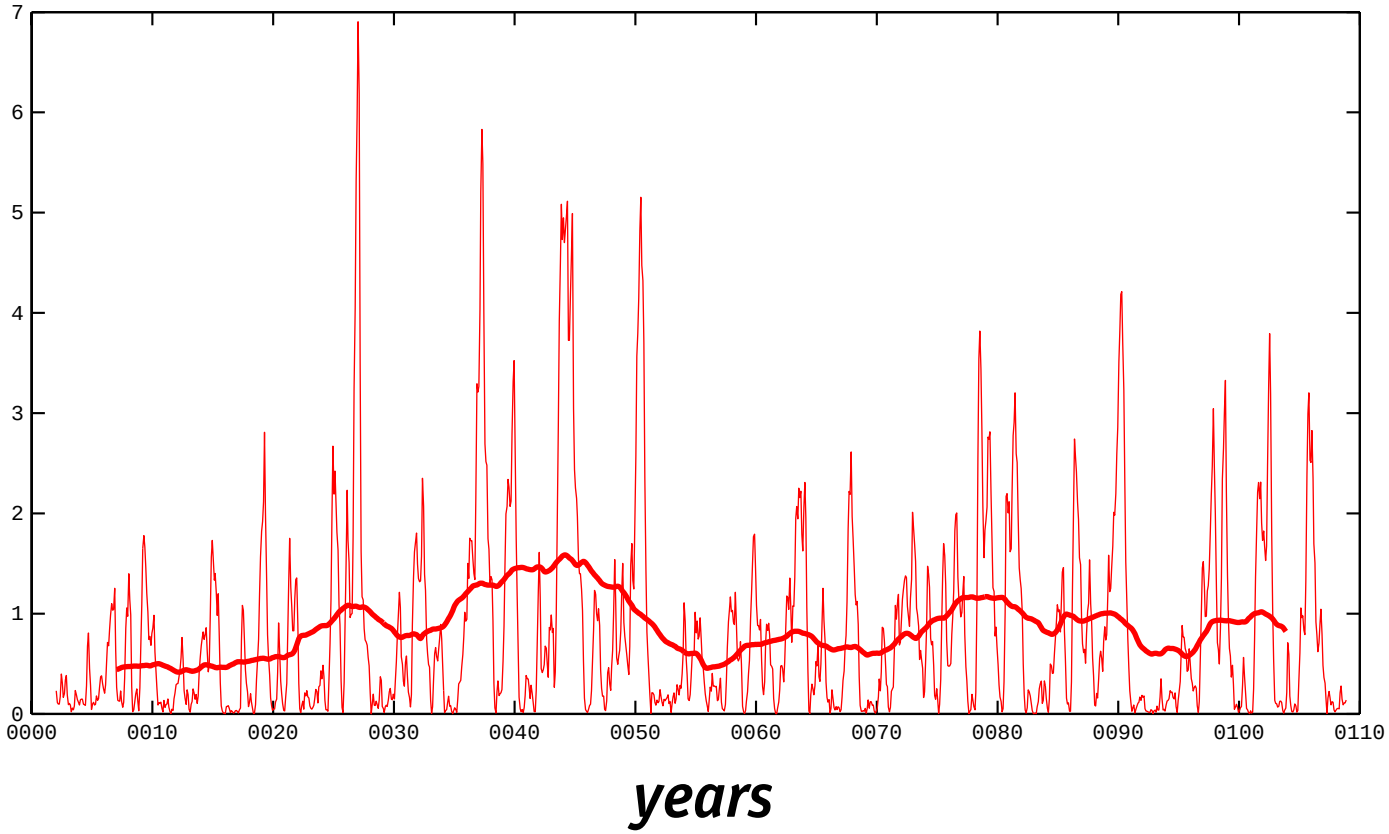
*Eddy Kinetic Energy* *(units of standard deviation)*

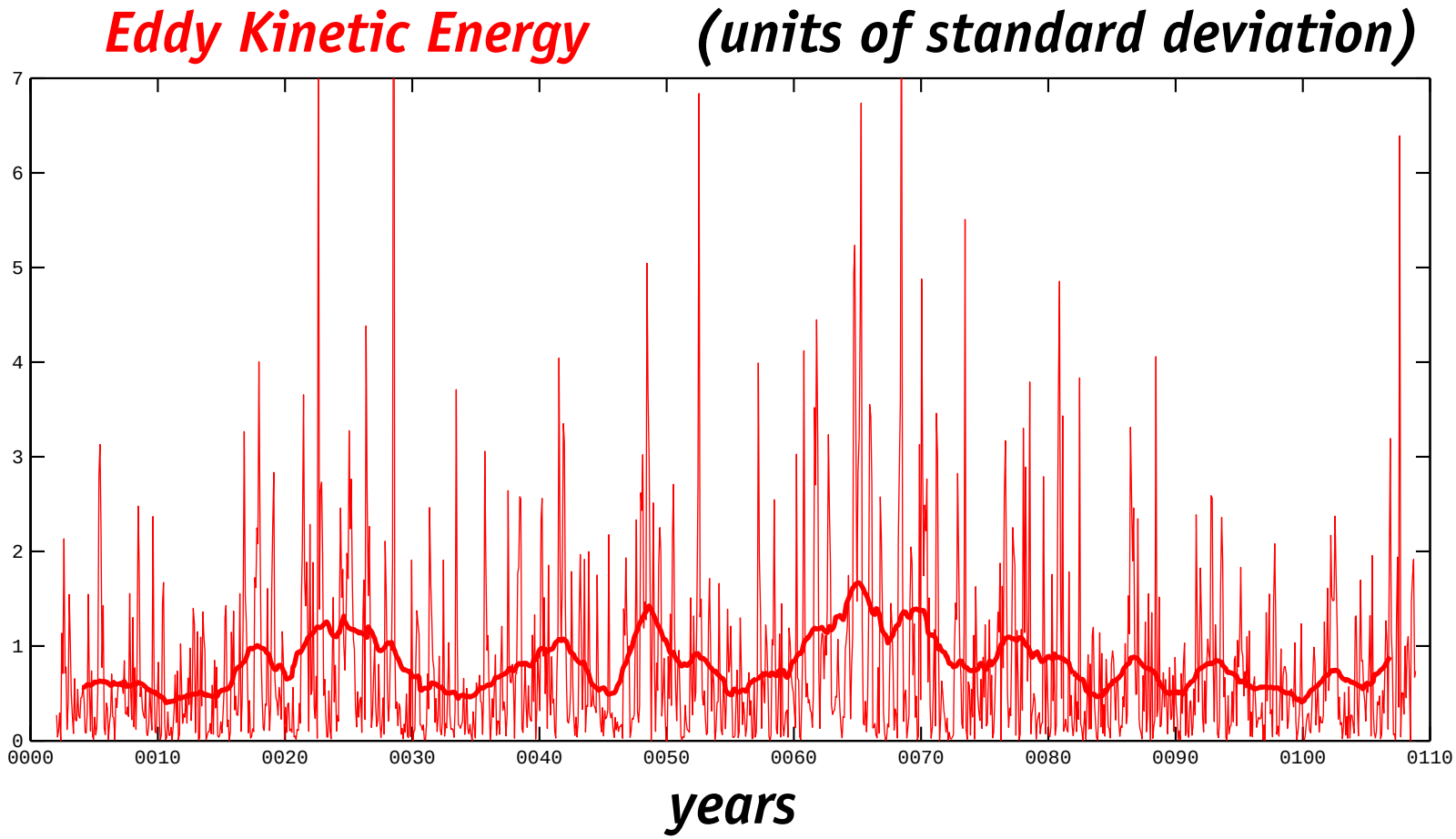


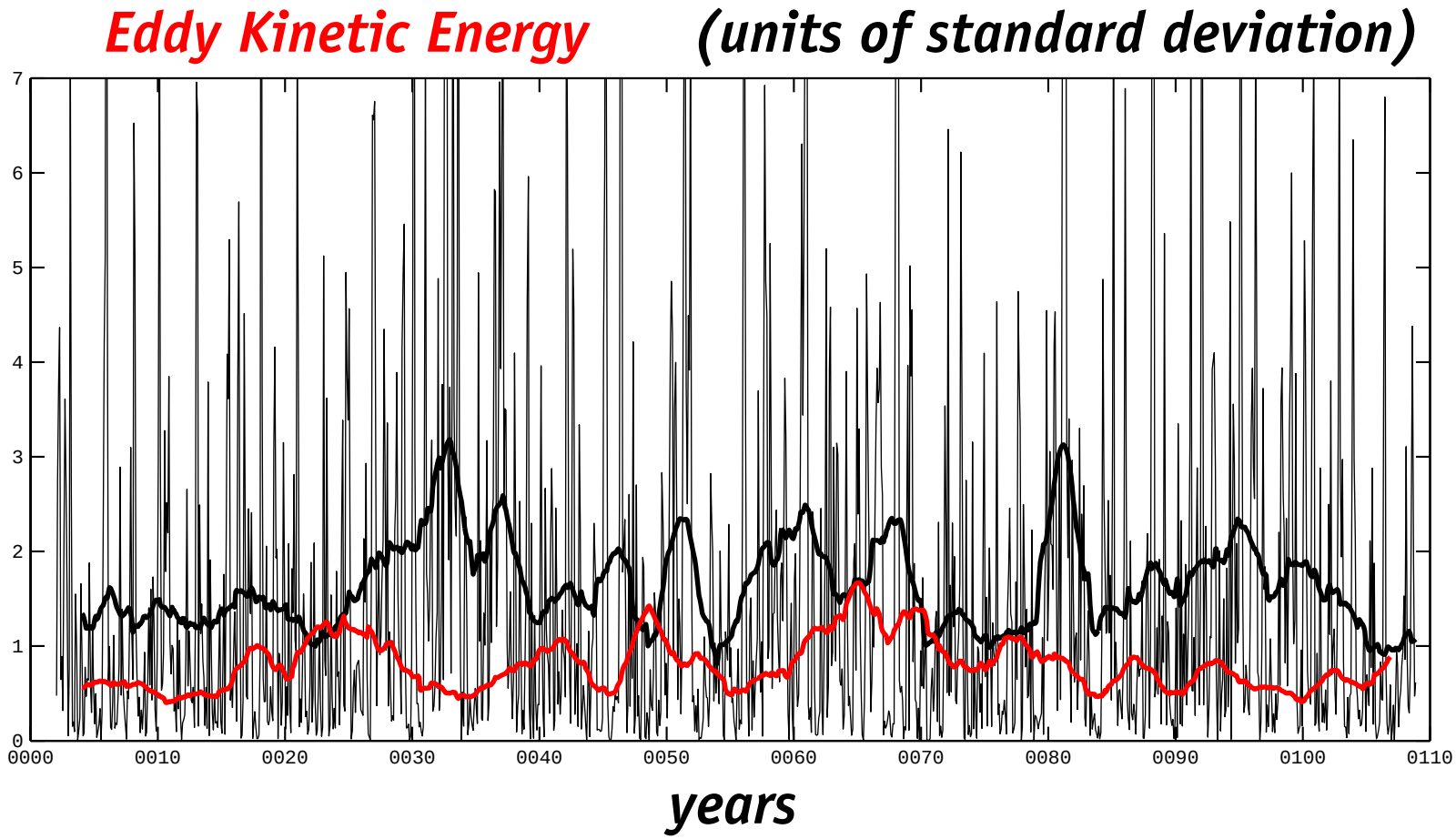

Intrinsic RUN
K-2
K-1
Temperature
Inshore
Offshore
10 year
Cross-Shelf
Velocity
Forced RUN
K-2
K-1
Temperature
Cross-Shelf
Velocity

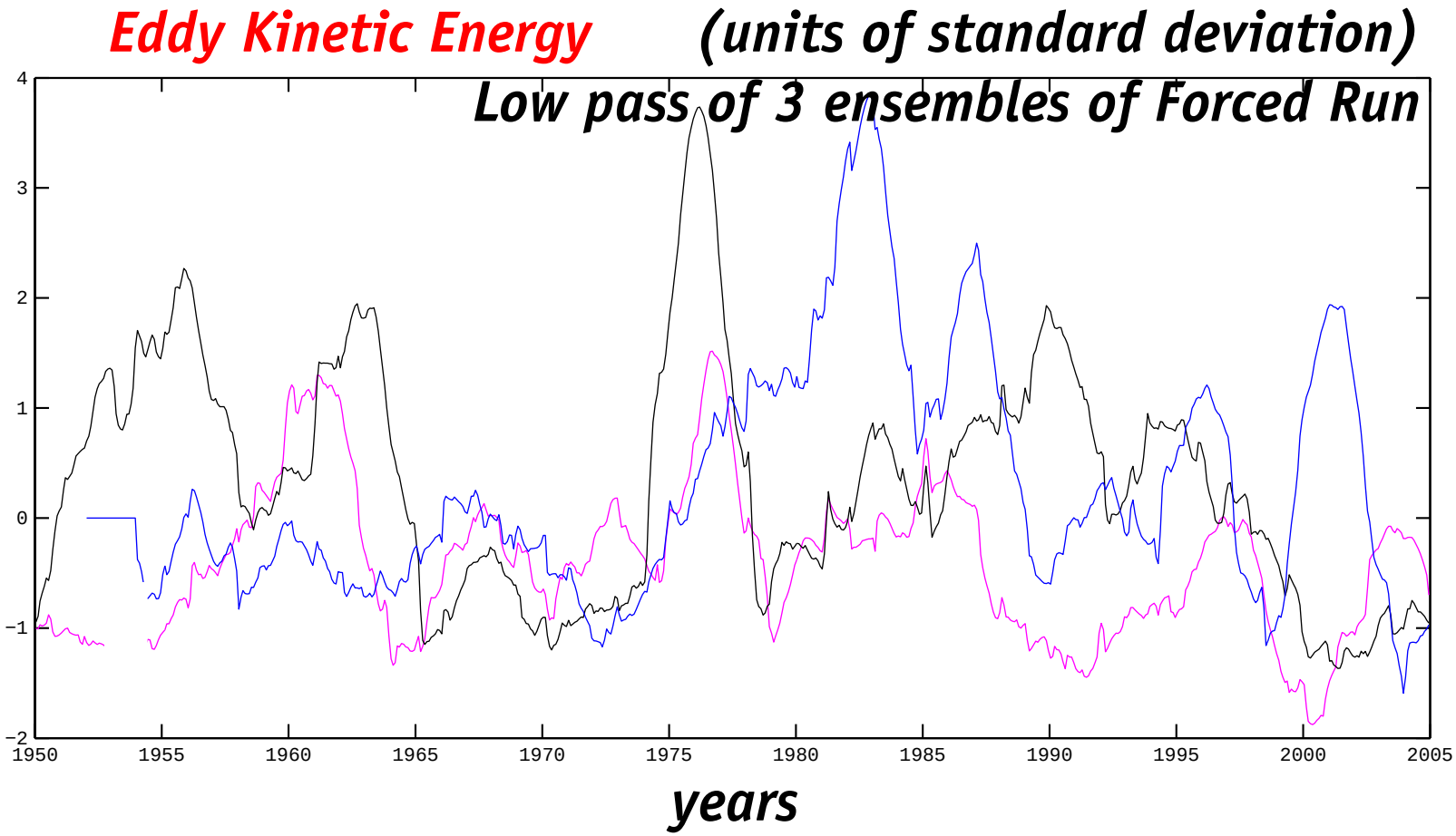

-5
-4
-3
-2
60
55
50
45
40
35
30
-170
-160
-150
-140
-130
-120
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7

## *Eddy Kinetic Energy* *(units of standard deviation)*

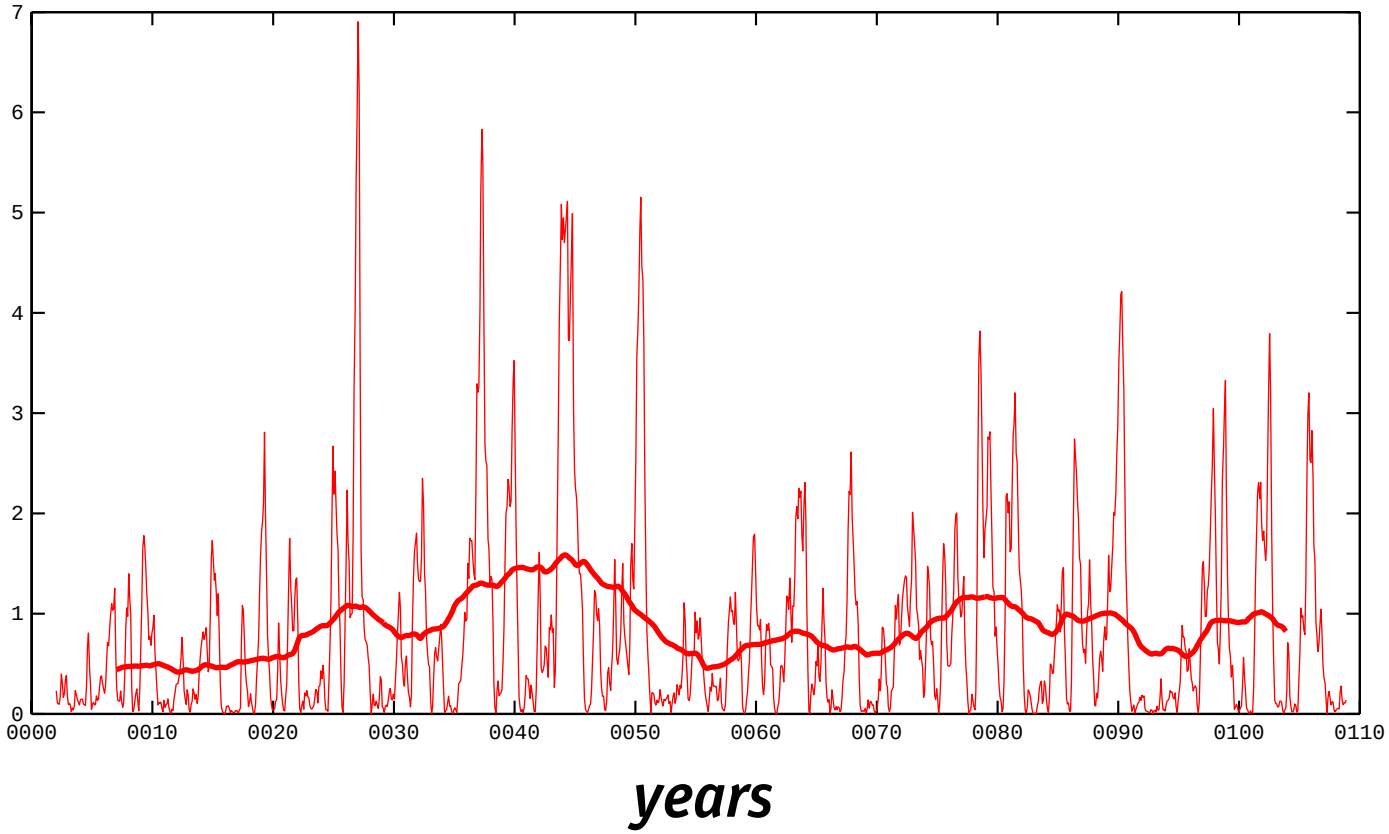



Eddy Kinetic Energy
(units of standard deviation)
7
6
5
4
3
2
1
0
0000
0010
0020
0030
0040
0050
0060
0070
0080
0090
0100
0110
years

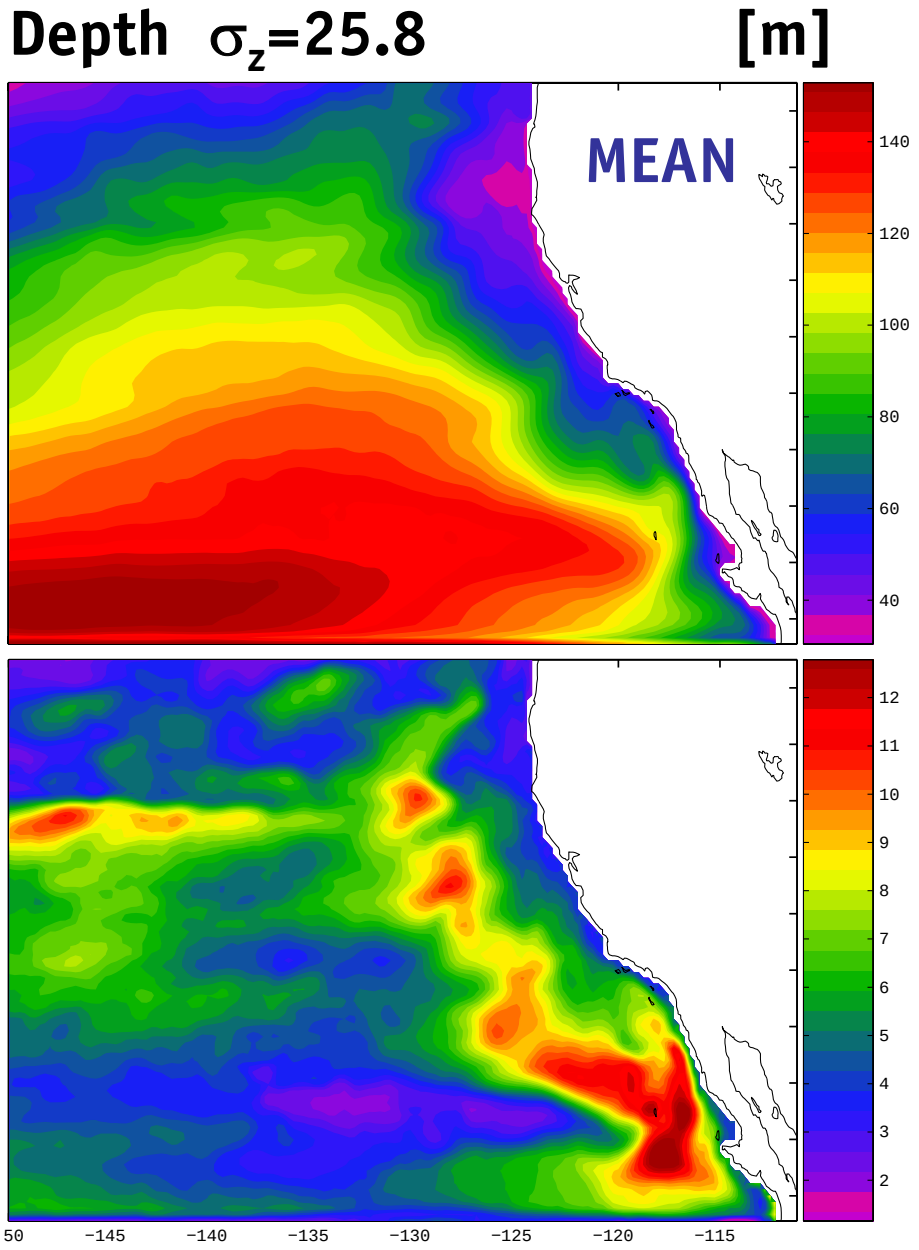

Eddy Kinetic Energy
(units of standard deviation)
7
6
5
4
3
2
1
0
0000
0010
0020
0030
0040
0050
0060
0070
0080
0090
0100
0110
years


Eddy Kinetic Energy
(units of standard deviation)
Low pass of 3 ensembles of Forced Run
4
3
2
1
0
−1
−2
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
years

## *Eddy Kinetic Energy* *(units of standard deviation)*

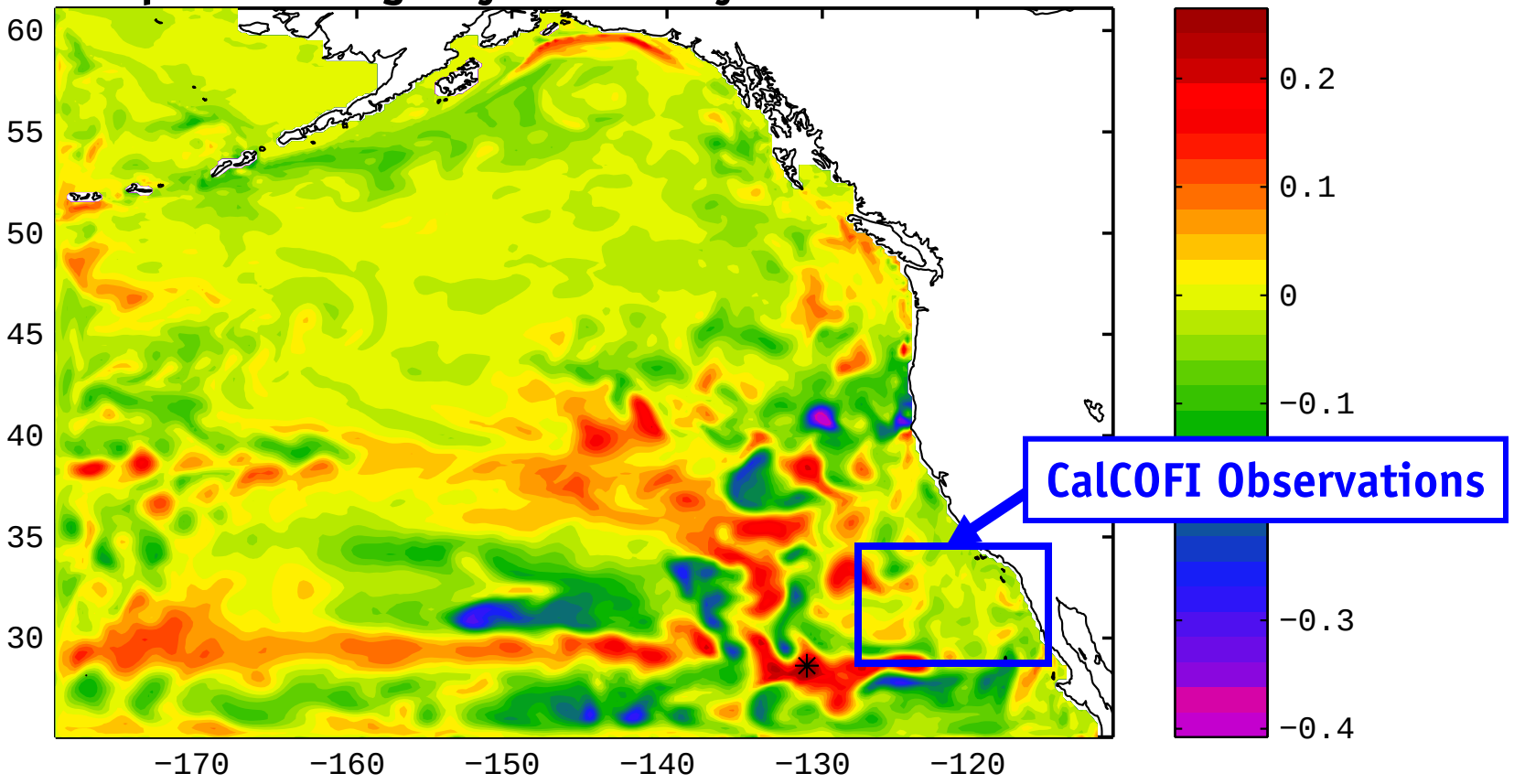


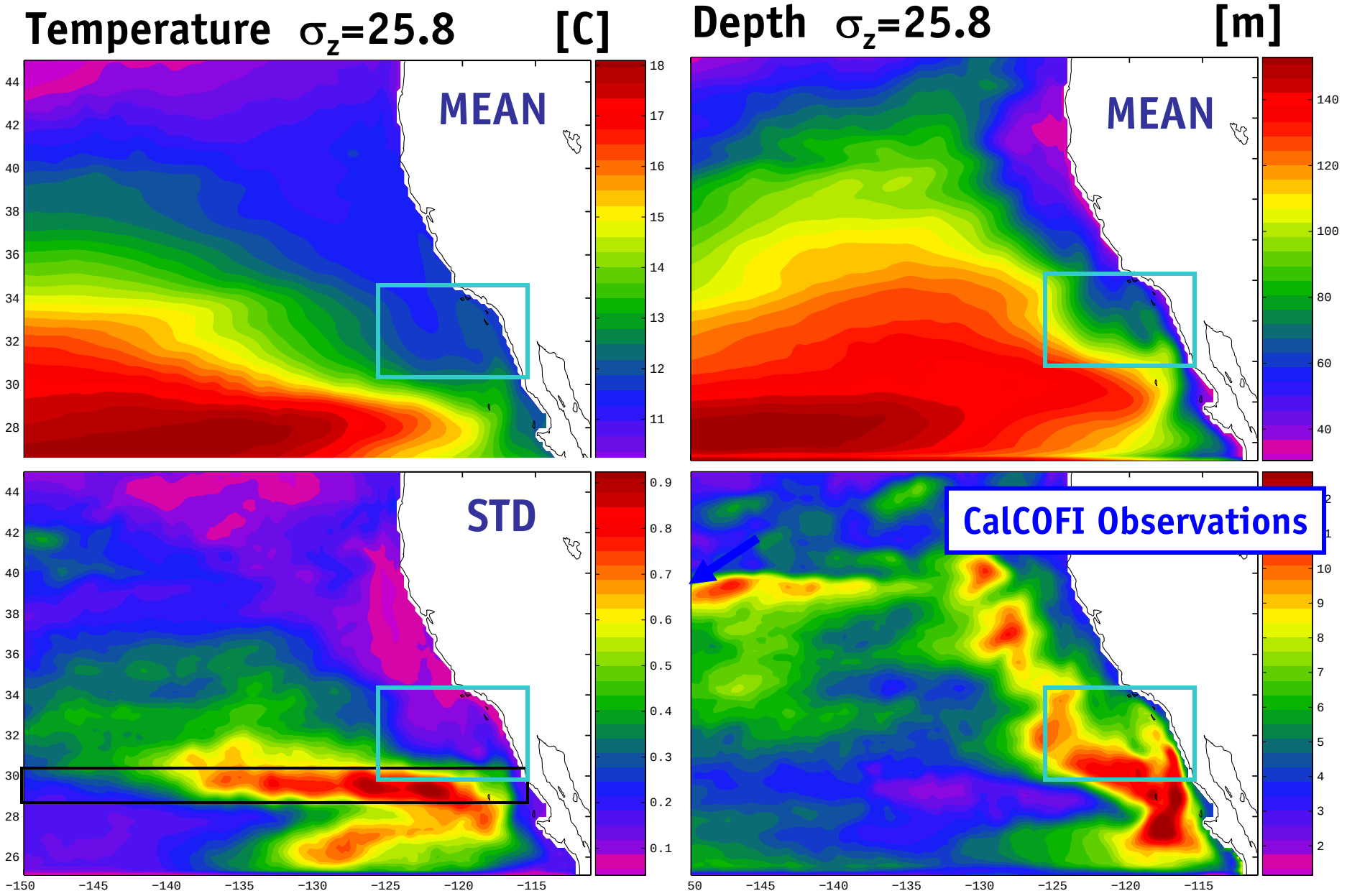
# The Effects of the eddy field extend in the subsurface

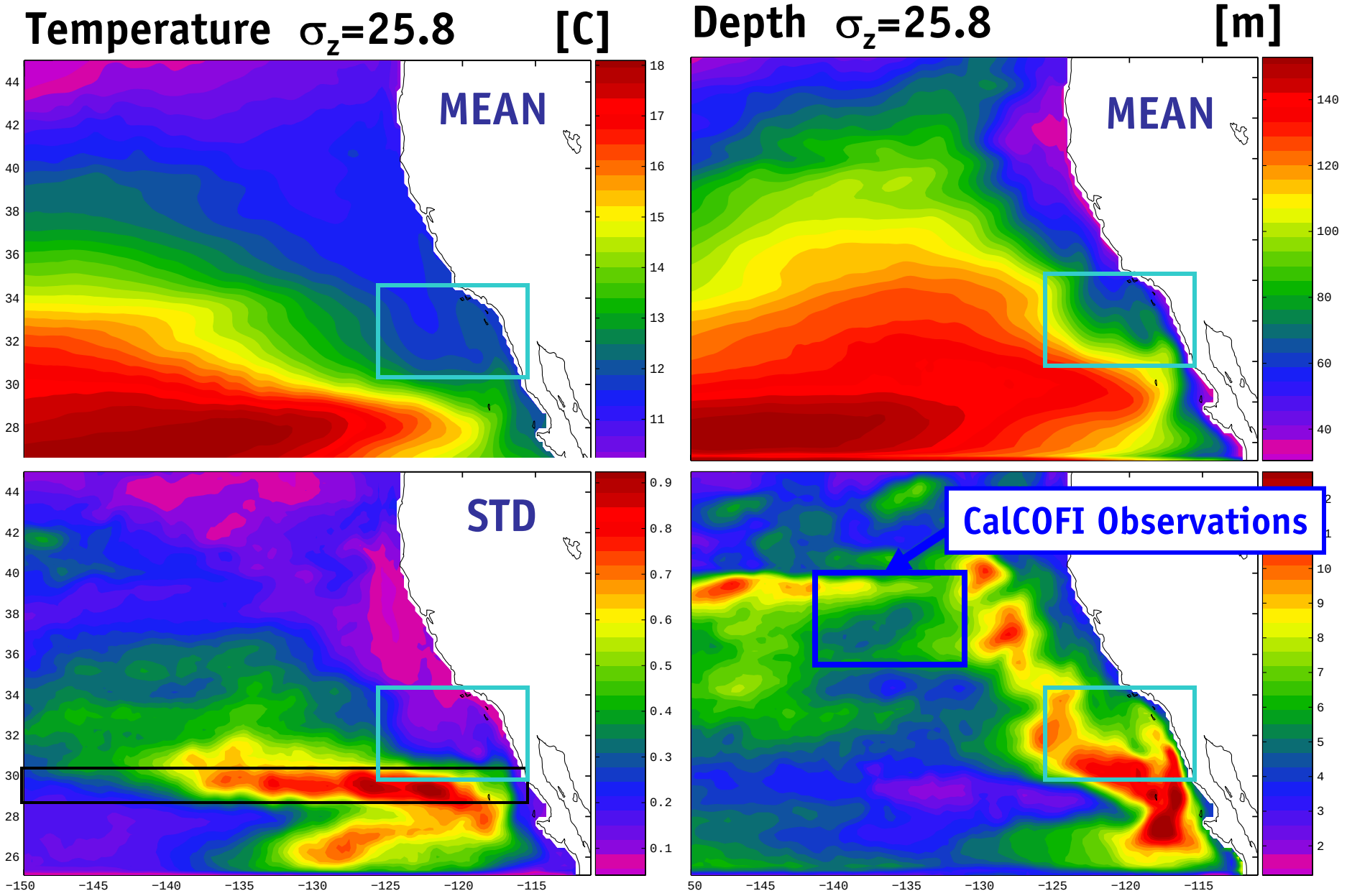


# Surface Salinity Anomaly

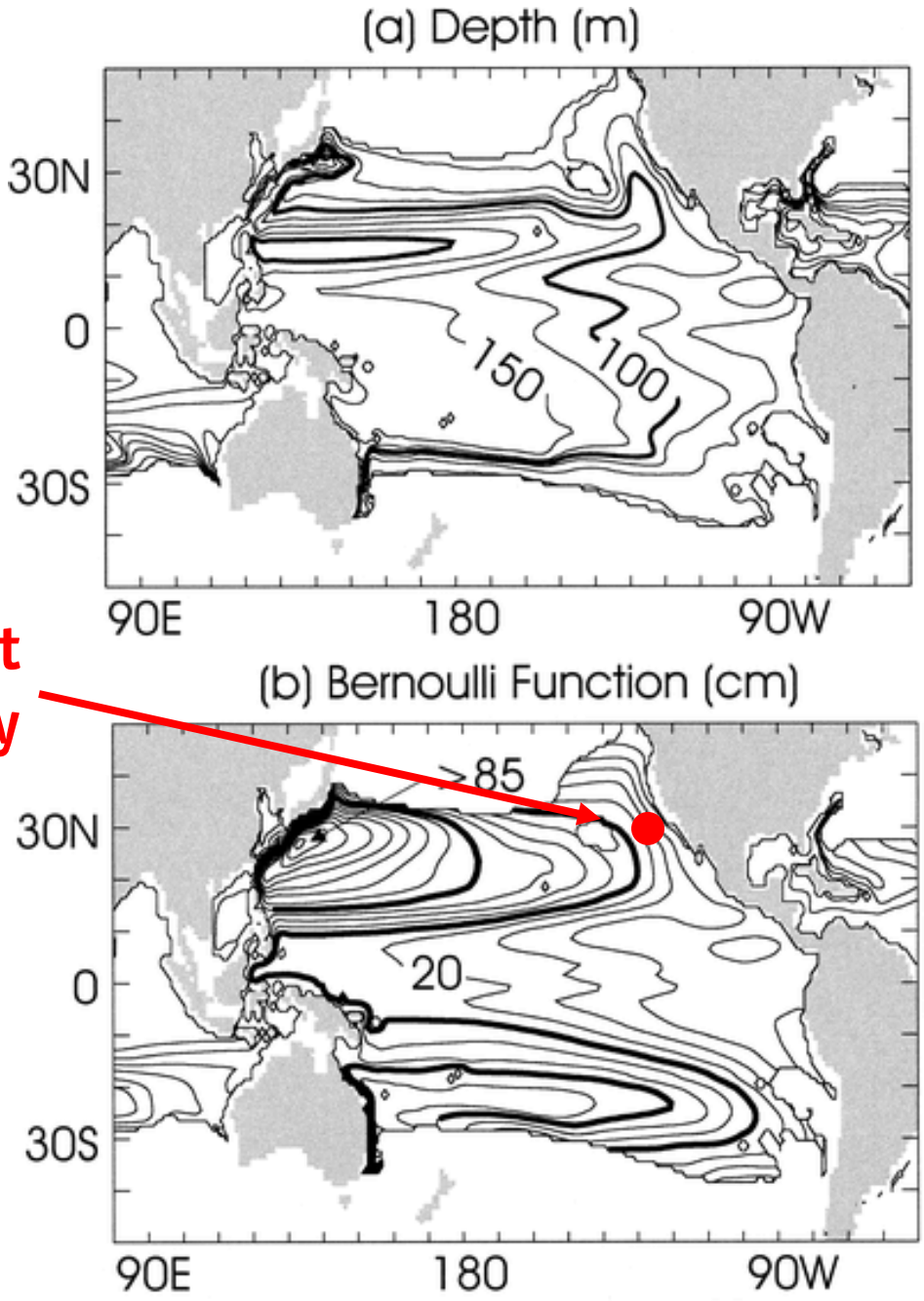
## snapshot during May of model year 150




Temperature $\sigma_z$=25.8 [C]
Depth $\sigma_z$=25.8 [m]
MEAN
MEAN
STD
CalCOFI Observations
44
42
40
38
36
34
32
30
28
26
−150
−145
−140
−135
−130
−125
−120
−115
18
17
16
15
14
13
12
11
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
140
120
100
80
60
40
50
10
9
8
7
6
5
4
3
2
1

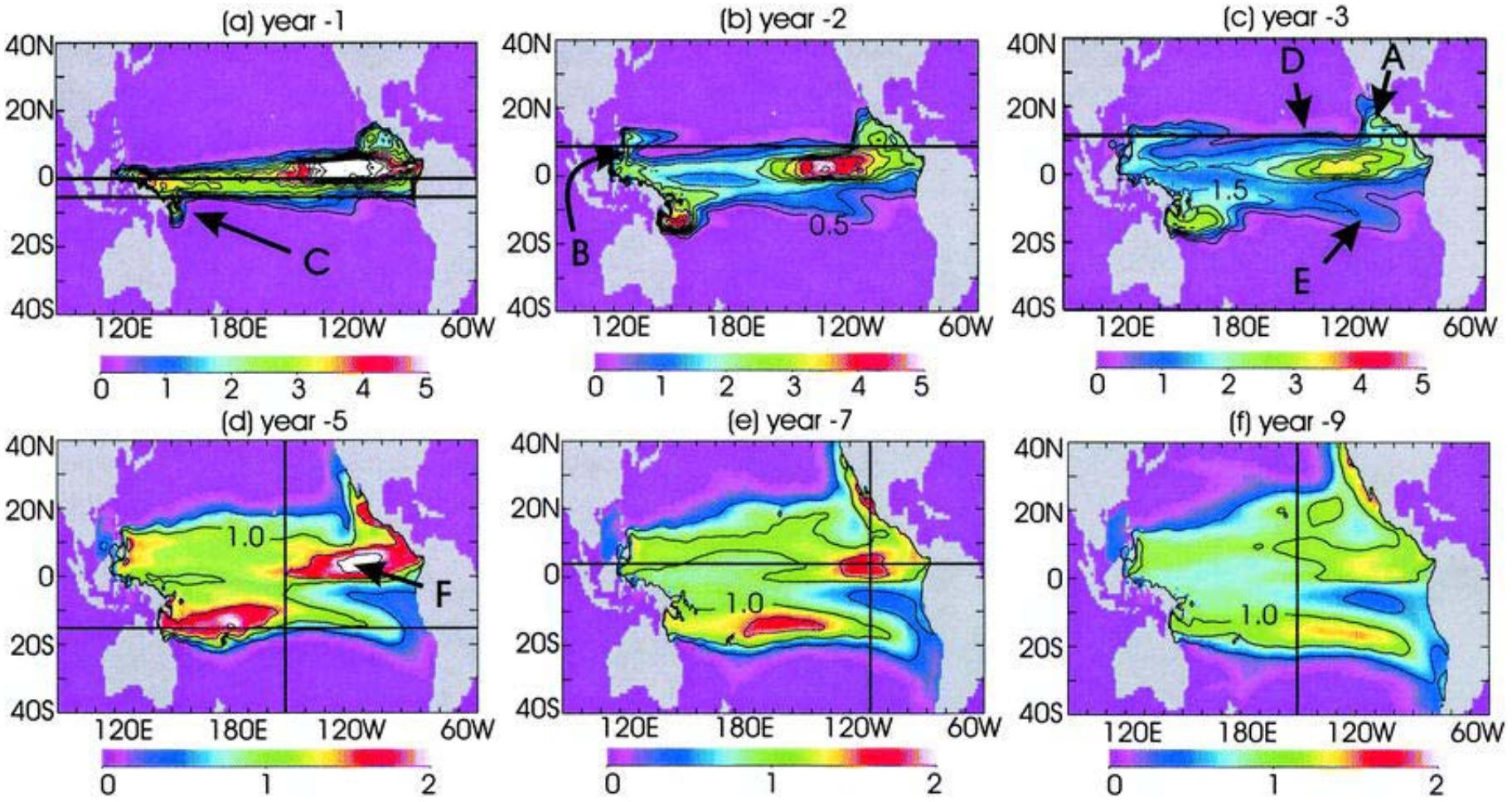

Temperature $\sigma_z$=25.8 [C]
Depth $\sigma_z$=25.8 [m]
MEAN
MEAN
STD
CalCOFI Observations
44
42
40
38
36
34
32
30
28
26
−150
−145
−140
−135
−130
−125
−120
−115
18
17
16
15
14
13
12
11
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
140
120
100
80
60
40
50
10
9
8
7
6
5
4
3
2

## Path of Water Masses on Isopycnal 24.5

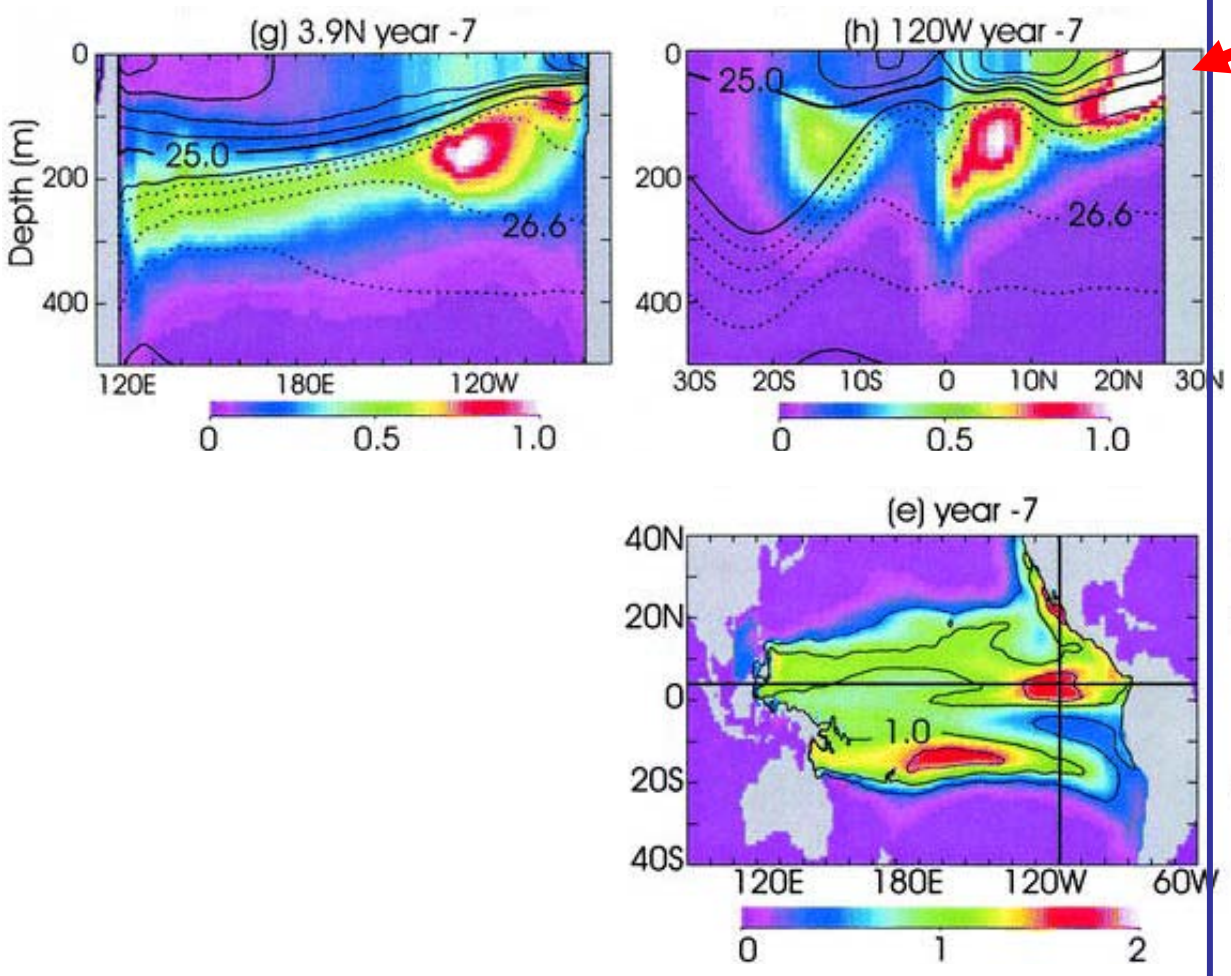



**California Current eddy variability**

# Origin of source waters to the NINO 3.4 region

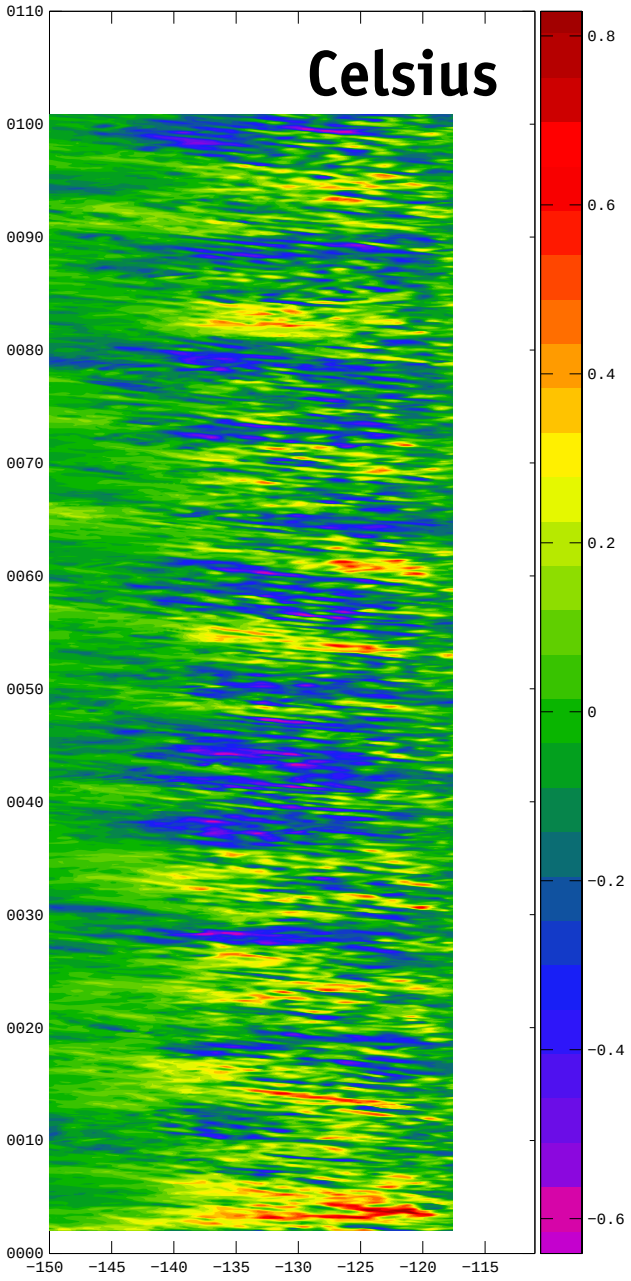


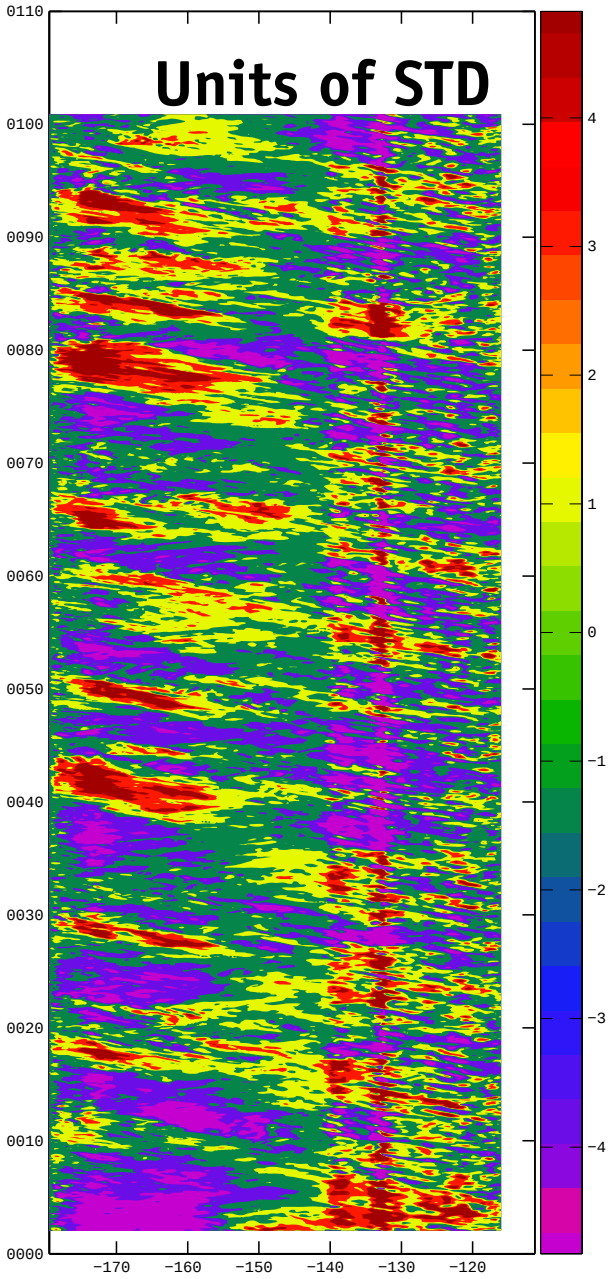
# Vertical Sections -7 years



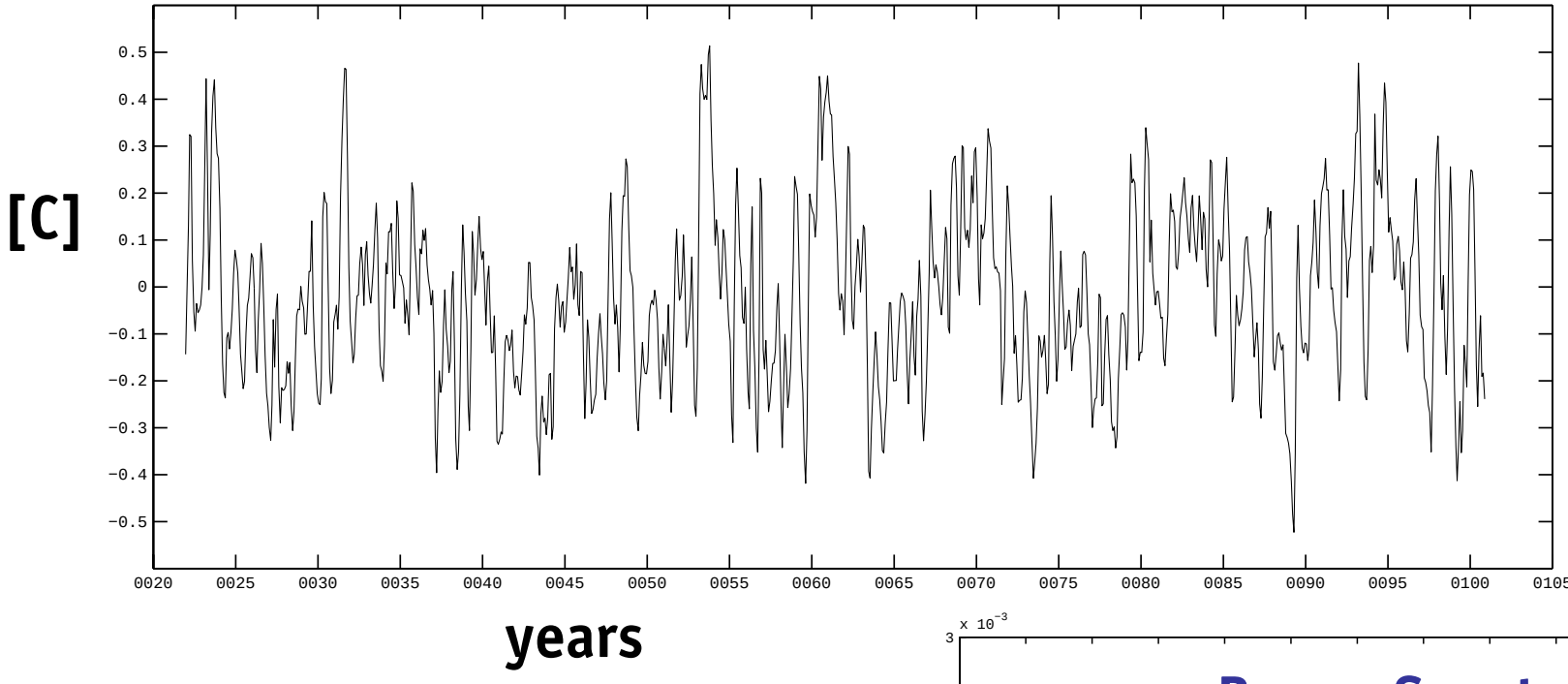

Subduction in the California Current

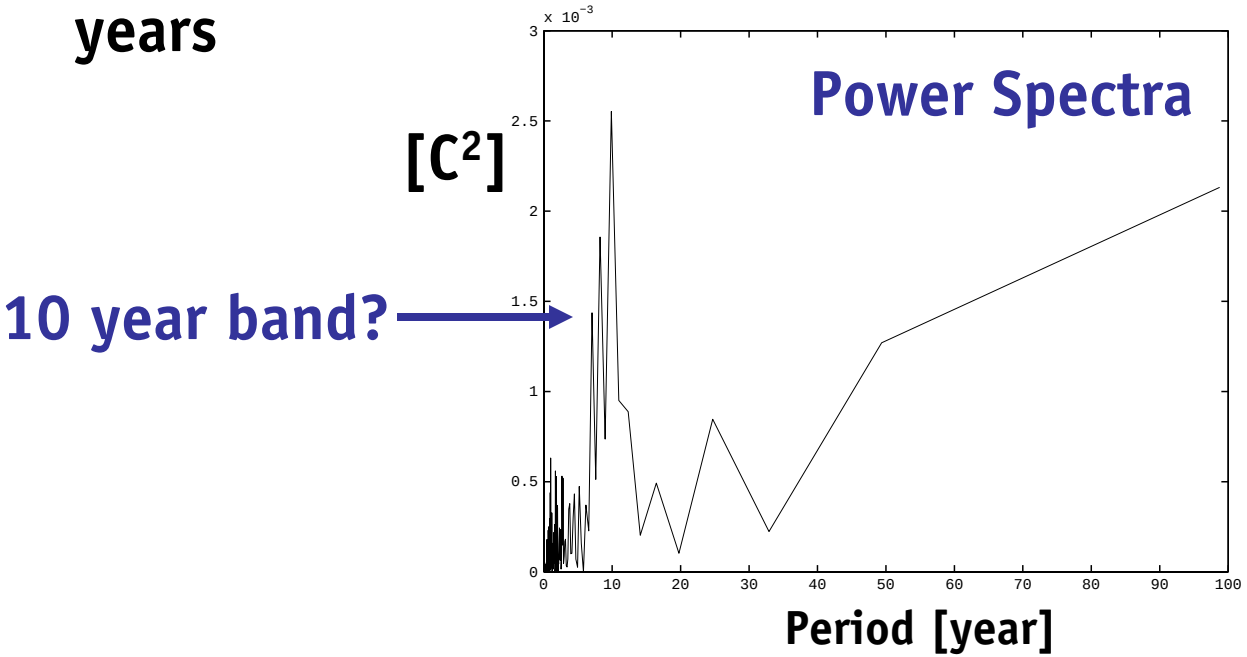
# Temperature Anomalies 28.5N – 30.5N



# Temperature Anomalies (120-125W; 28.5-30.5N) $\sigma_z$=25.8

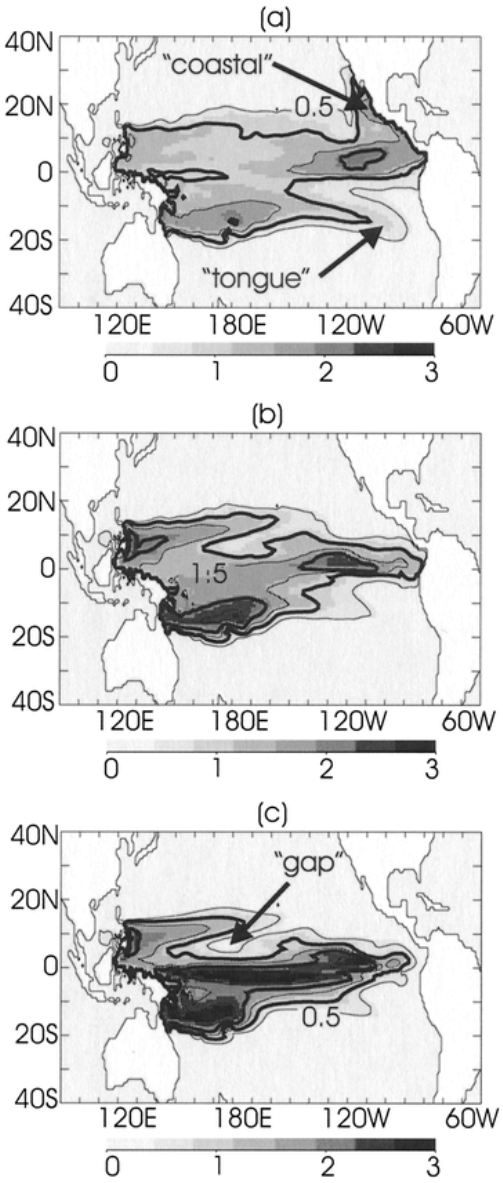



10 year band? →

# Additional

## Aliasing




## Transit timescale in years