CLIVAR/PICES: Physics to Fish

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Climate variability and ecosystems?

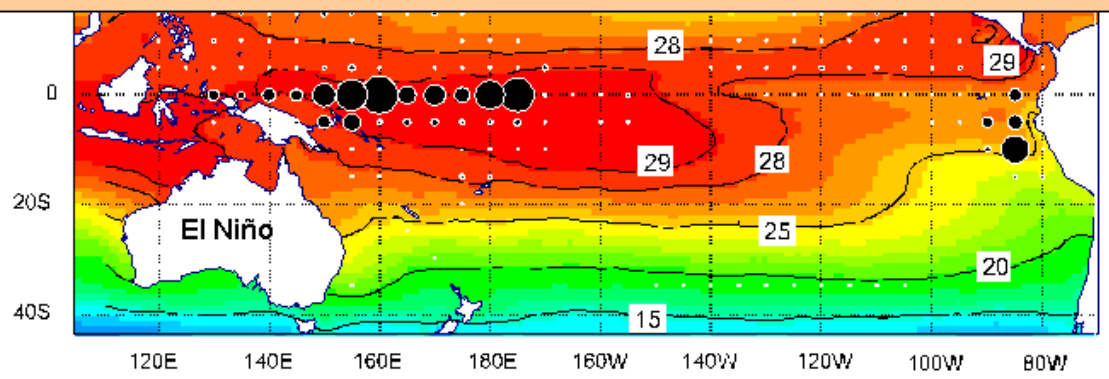
- SST has been a very useful product to provide a good ‘narrative’ for funding. But do the number of regime shifts depend on what variable you look at?
- Also being used to propose mechanisms (Schneider, Newman, and others: forecasting ENSO/PDO/NPI, etc.)
- Ecosystem/fisheries data can begin to provide the missing link to the subsurface processes (Nate made this point better than I ever will).
- Some example to build towards Earth System Models for ecosystems/fisheries.

Pacific Ocean Skipjack Movements

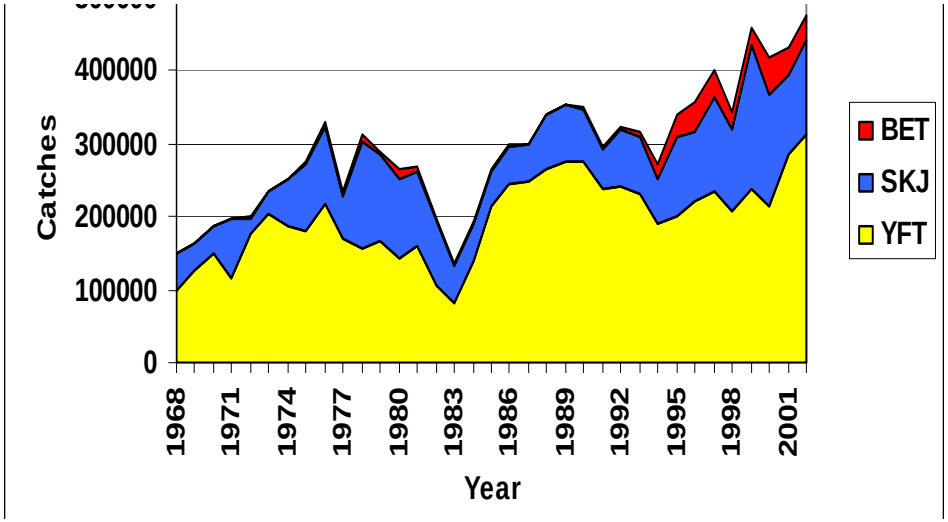
La
198

But what about changes in mean conditions?
Environmental impacts on spawning and migration patterns?
Resiliency of the ecosystems to environmental changes?

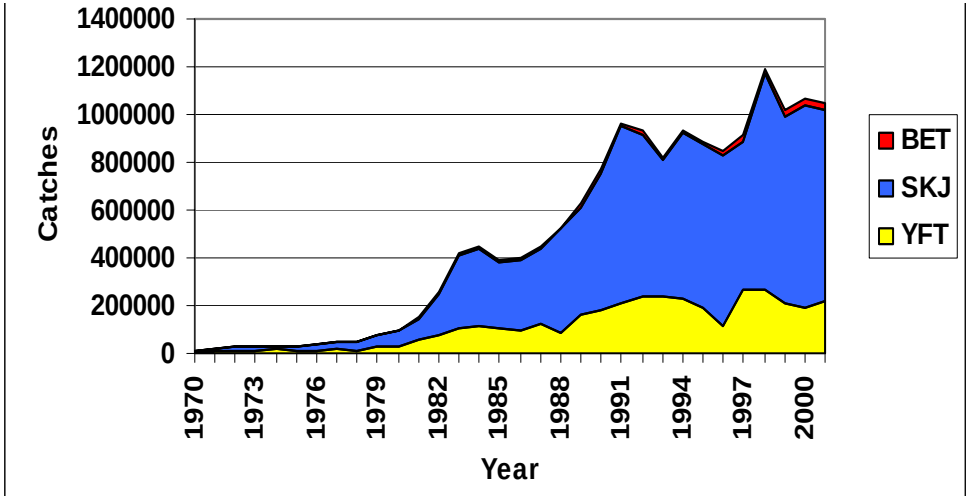
El N
1992



Eastern Pacific



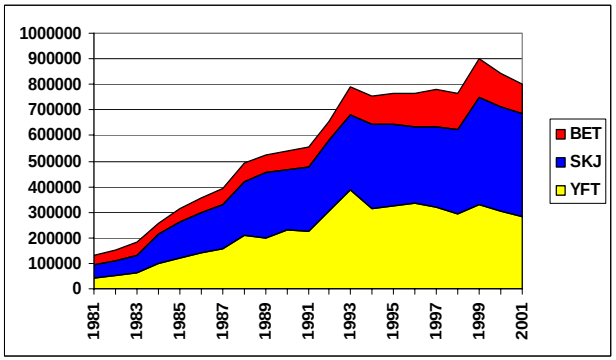
Western Pacific



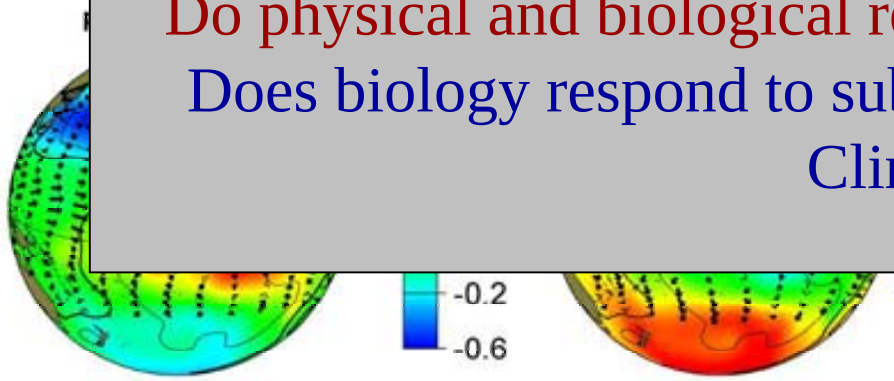
- The El Niño effects upon tuna fisheries cannot be questioned, (large changes in fishing zones)

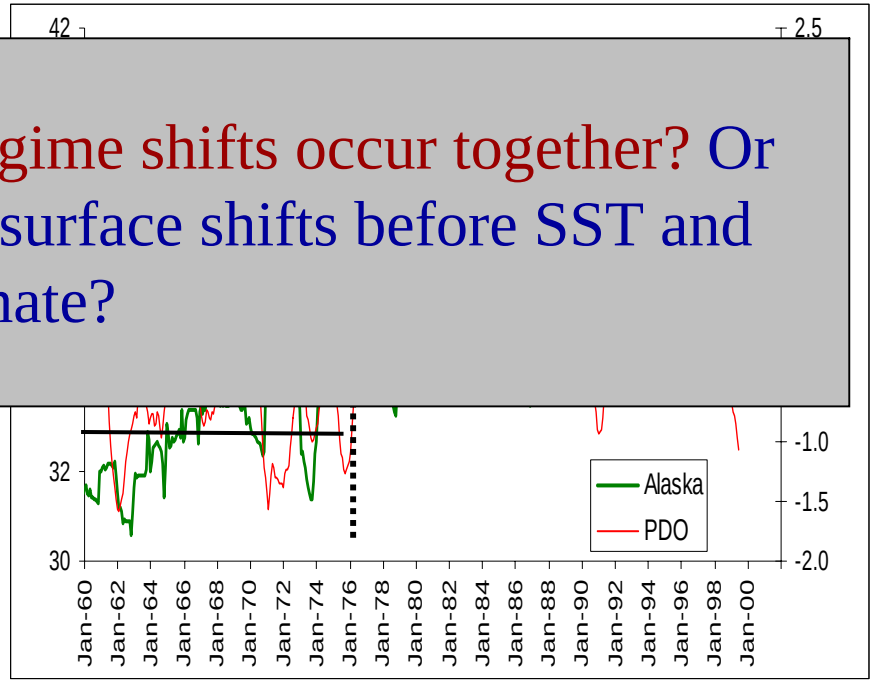
- but these changes are seldom visible in the trend of total tuna catches taken in each ocean

Indian ocean



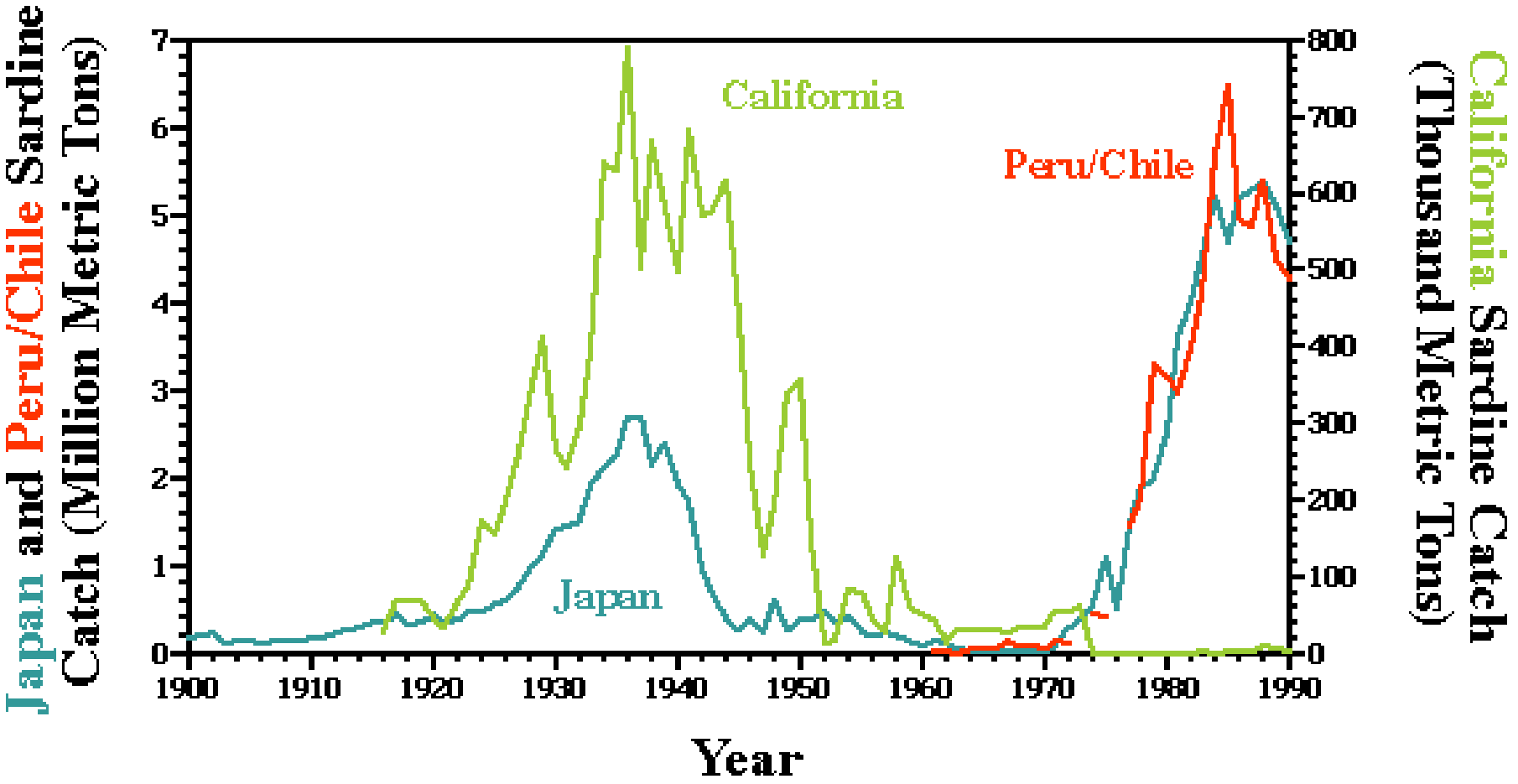
Do physical and biological regime shifts occur together? Or Does biology respond to subsurface shifts before SST and Climate?





Pacific Sardines: a history of 20th Century boom and bust cycles

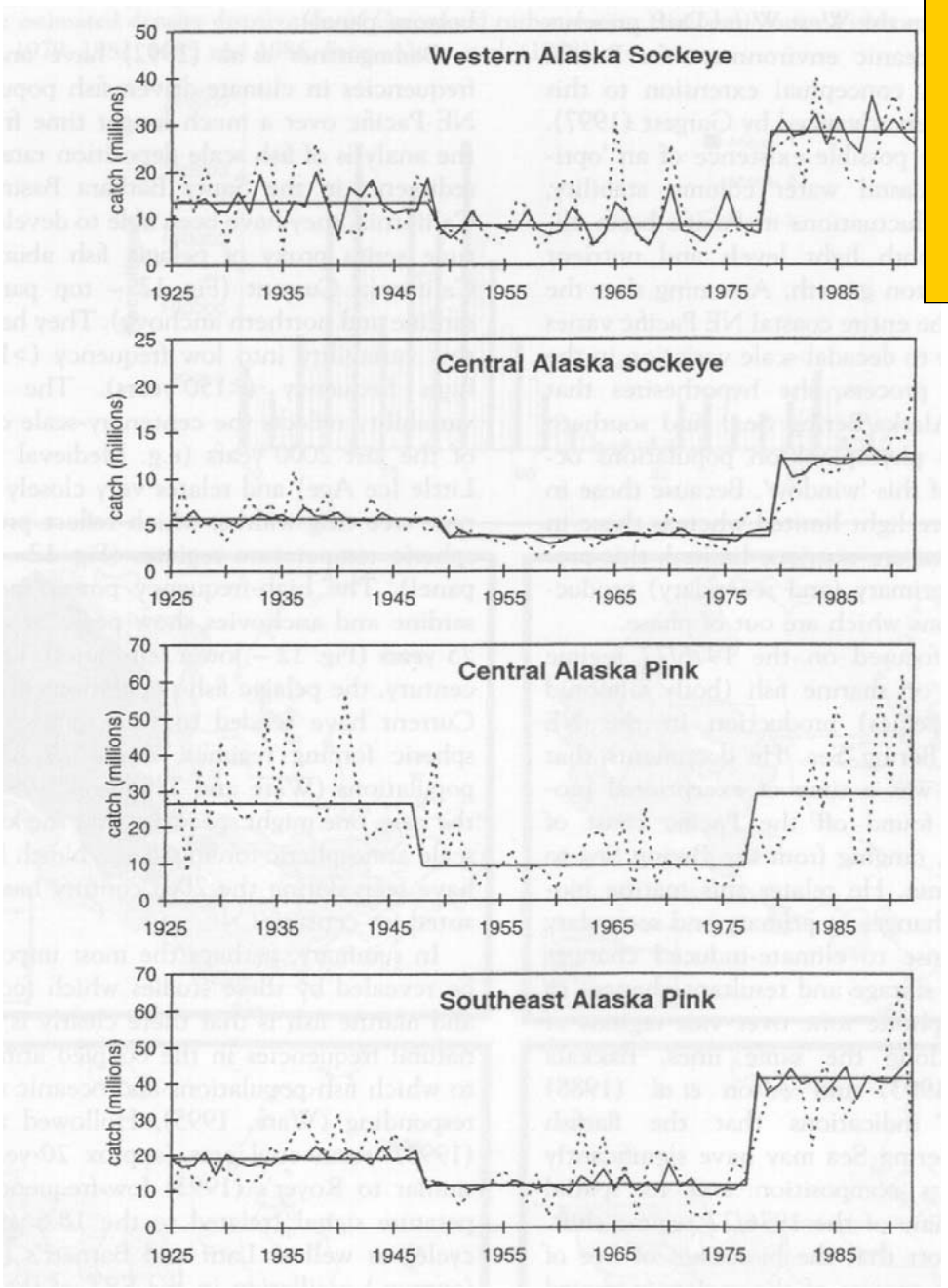
(Kawasaki and Omori 1988)

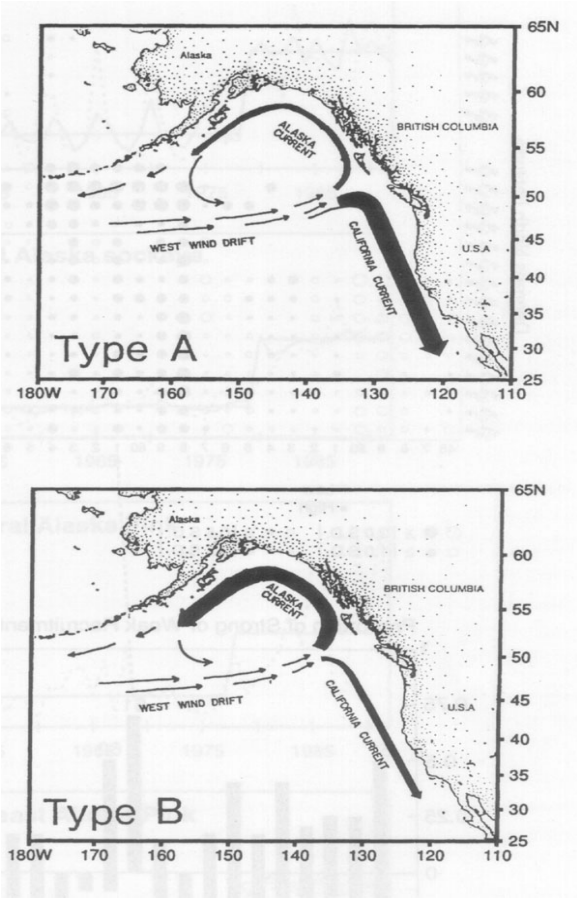


Courtesy N. Mantua

Alaska Salmon responded to 20th Century Climate Shifts

(Francis and Hare 1994, Fish. Oceanog.)





(Chelton and Davis 1982, JPO)

Long term Variability: CLIVAR/PICES/PAGES

Paleo-salmon abundance estimates from lakebed sediment cores with *Salmon Derived Nutrients* (Finney et al. 2000, Science)

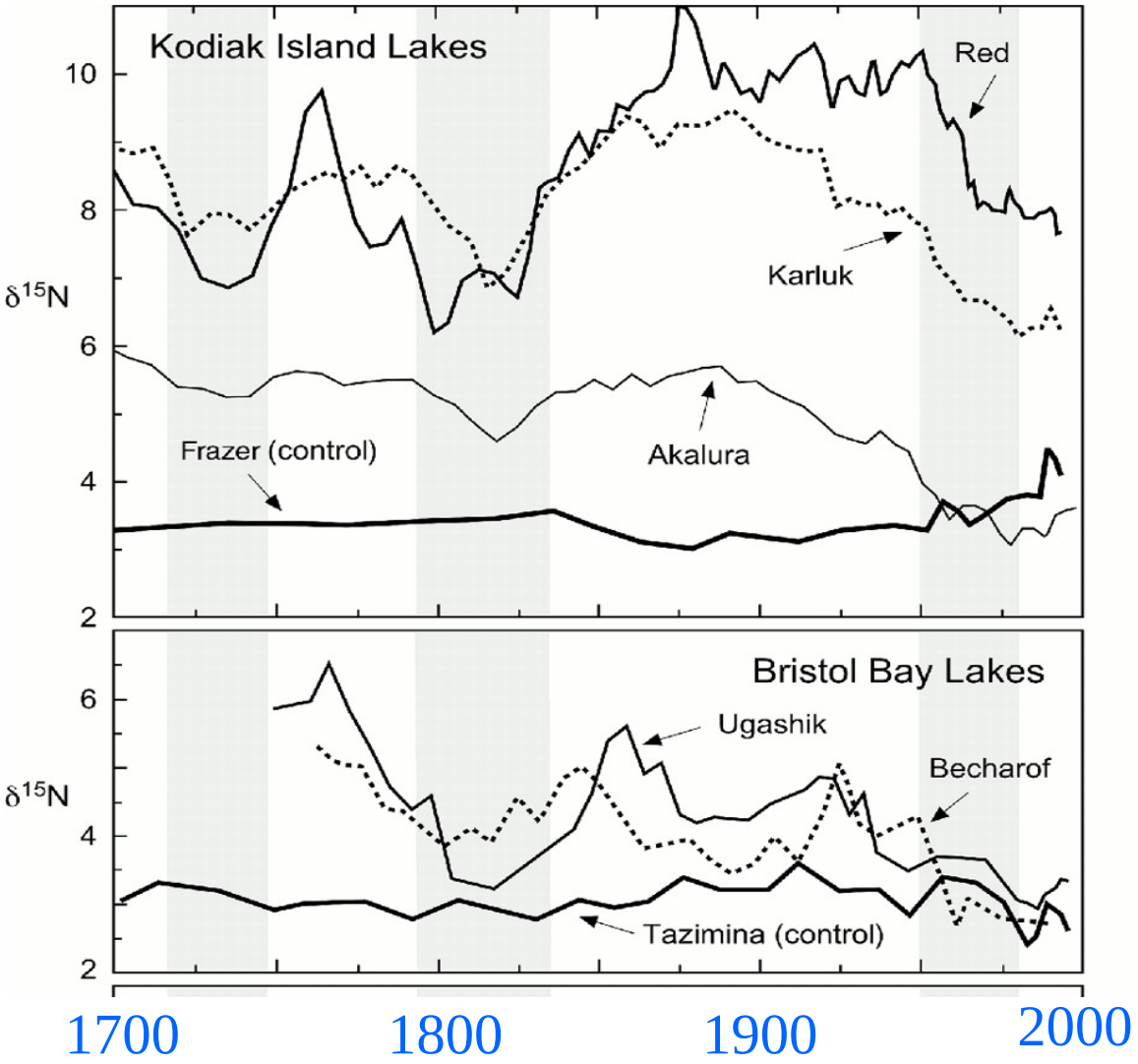
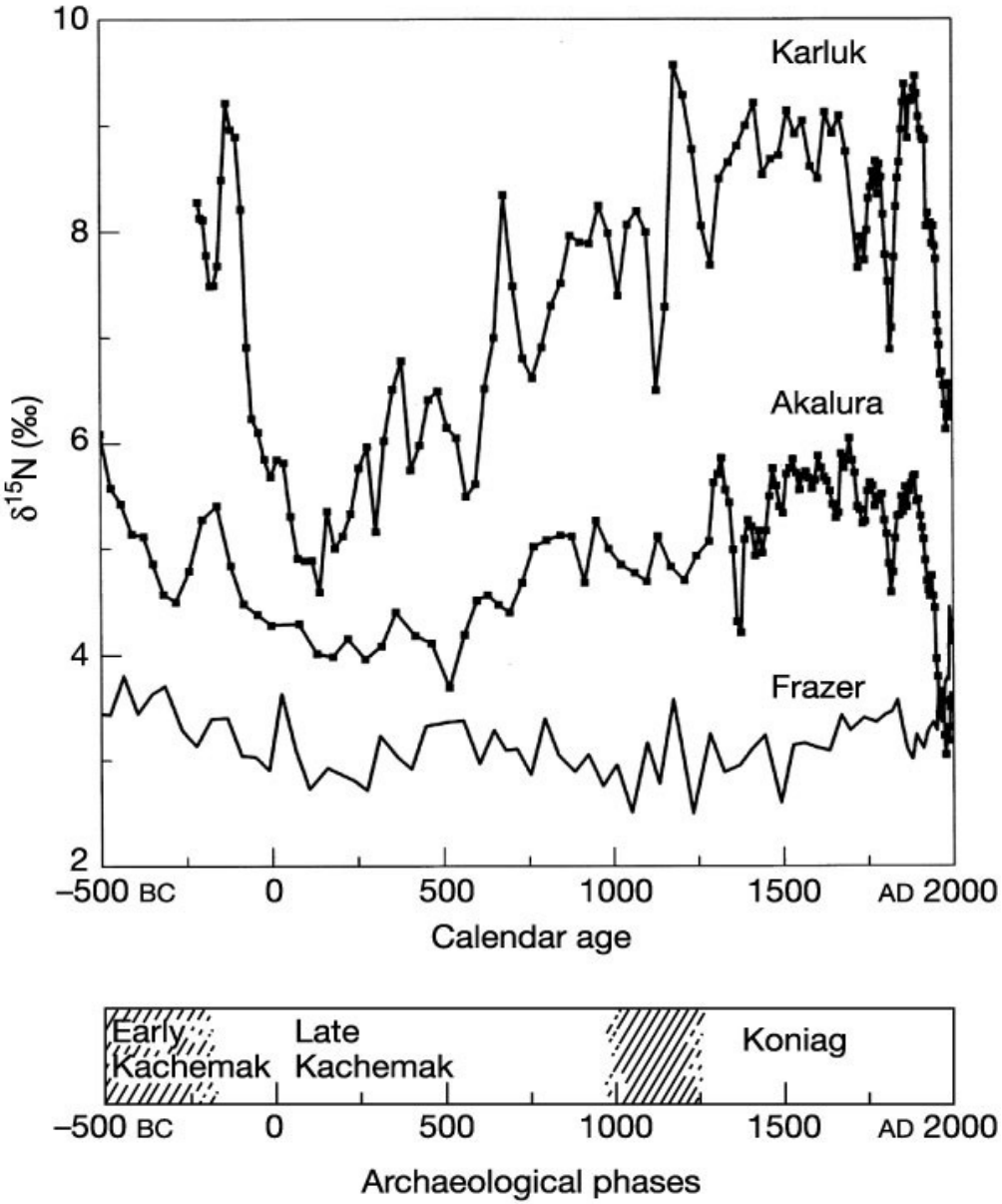


Figure 4. Comparison of 15N profiles from sockeye and control lakes from the Kodiak Island and Bristol Bay regions of Alaska over the past ~300 years (upper two panels). The sockeye lake profiles have many common trends in 15N, including lower values in the early 1700s, early 1800s, and the mid- to late 1900s. The two control lakes (Frazer and Tazimina) are similar to the sockeye lakes in morphometry and geography, but have waterfalls at their outlets impassable to sockeye. However, the construction of a fish ladder over the Frazer River waterfalls in the 1950s has allowed the migration of sockeye into this lake, and the associated SDN loading is faithfully tracked by the recent 15N enrichment in the Frazer Lake sediment profile. The lower panel compares 15N anomalies of the composite sockeye lake record with a reconstruction of Gulf of Alaska sea surface temperature (SST) (25) over this period. The composite sockeye lake record (calculated as the average deviation from the record mean of each of the five sockeye lake profiles) highlights the consistency of the variation in the sockeye lakes' 15N profiles. The SST reconstruction for the Gulf of Alaska (25-year smoothed) is based on coastal tree-ring data. **Such records have also been analyzeed going back over 2000 years**

Impacts of Climatic Change and Fishing on Pacific Salmon Abundance Over the Past 300 Years. Bruce P. Finney, Irene Gregory-Eaves, Jon Sweetman, Marianne S. V. Douglas, John P. Smol, 2000.

Longer-term variability

Paleo-sockeye abundance on Kodiak Island for the past 2,200 years. Finney et al. (2002), Nature



Requirements for CGCM capabilities (Grassl 2000)

i. Adequate representation of present climate.

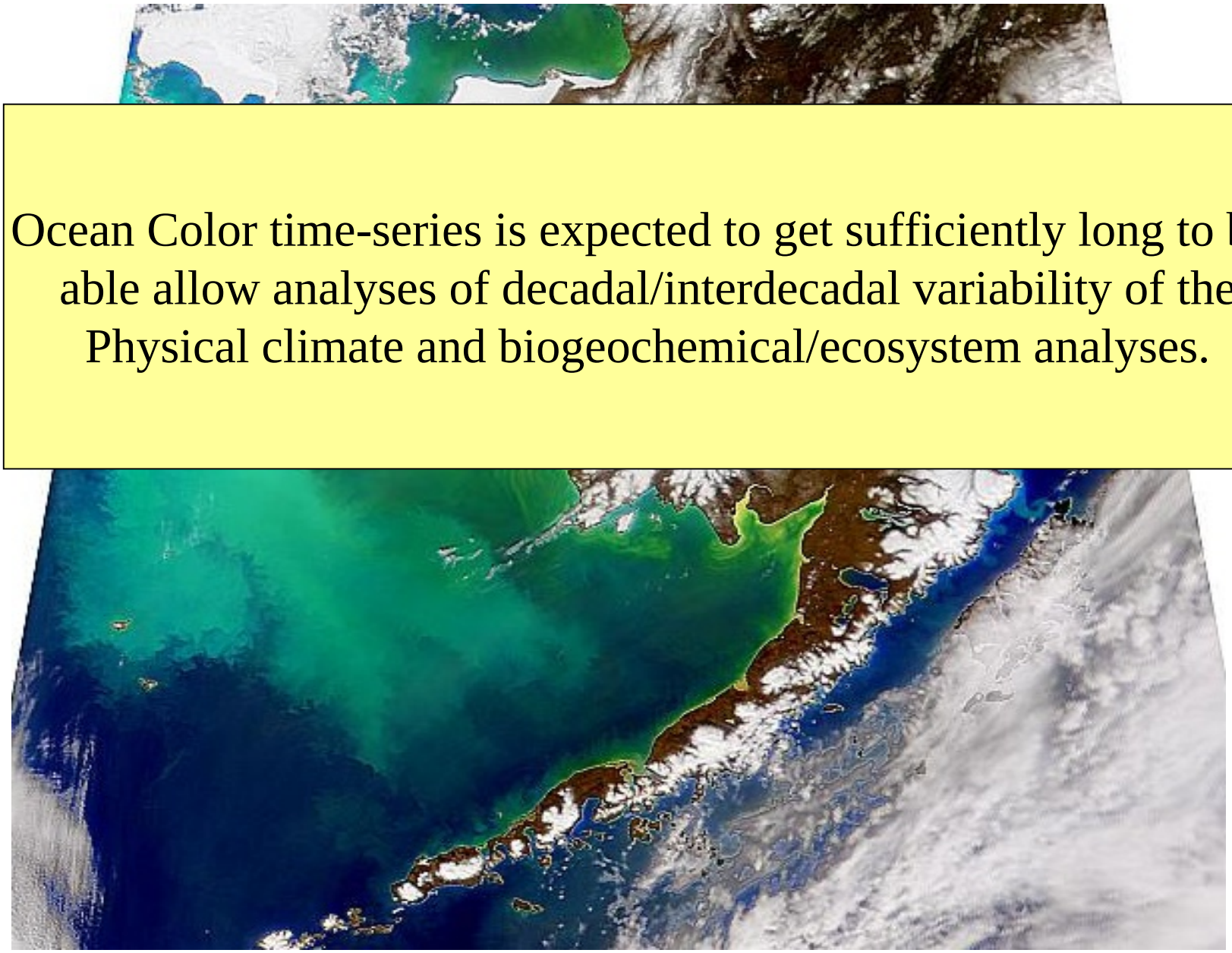
ii. Reproduction of instrumental record for given external forcings.

iii. Reproduction of an episode from paleo data for given external forcings.

iv. Successful simulation of an abrupt climate change event from the past.

Do we need to define ecosystem/fisheries criteria for an Earth System Models?

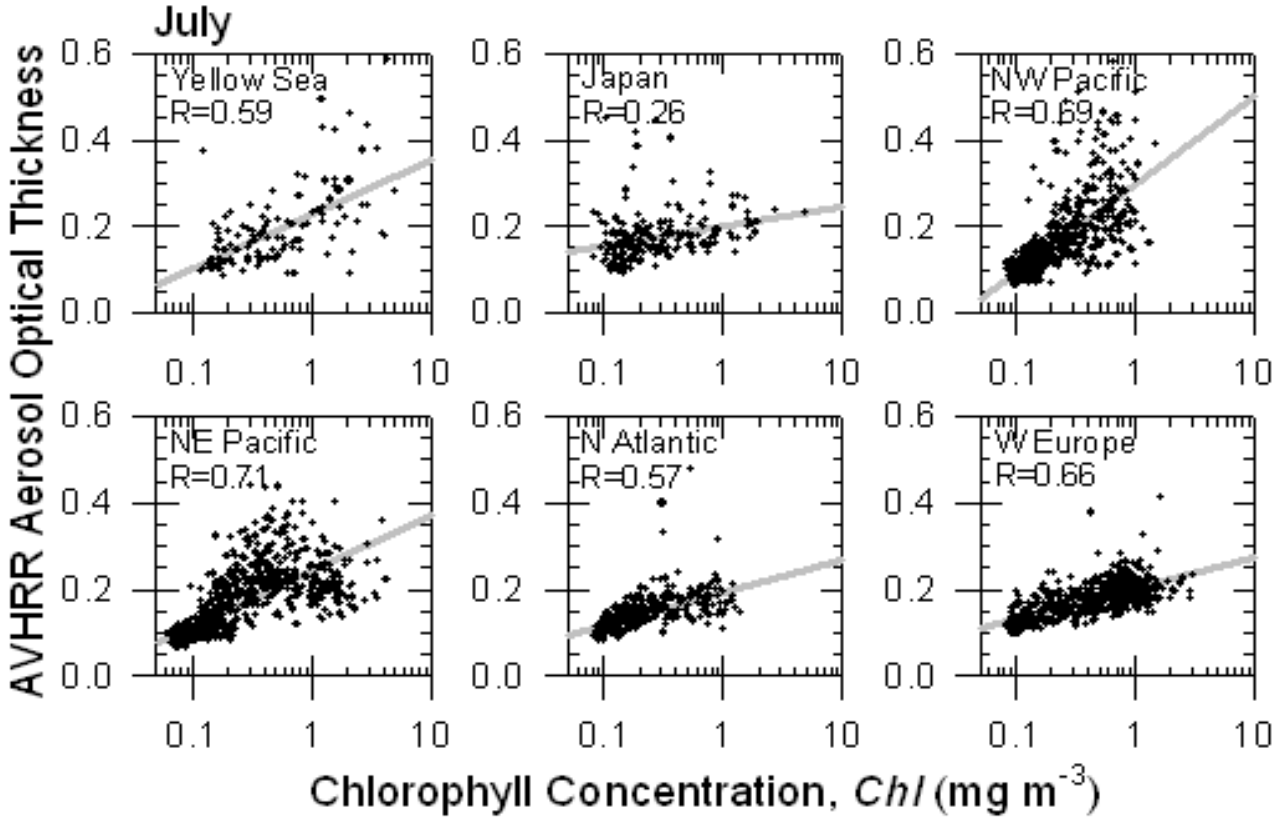
Ocean Color time-series is expected to get sufficiently long to be able allow analyses of decadal/interdecadal variability of the Physical climate and biogeochemical/ecosystem analyses.



Coccolith blooms in the Gulf of Alaska observed by SeaWiFS

How reliable will ocean color be for detecting climate signals?

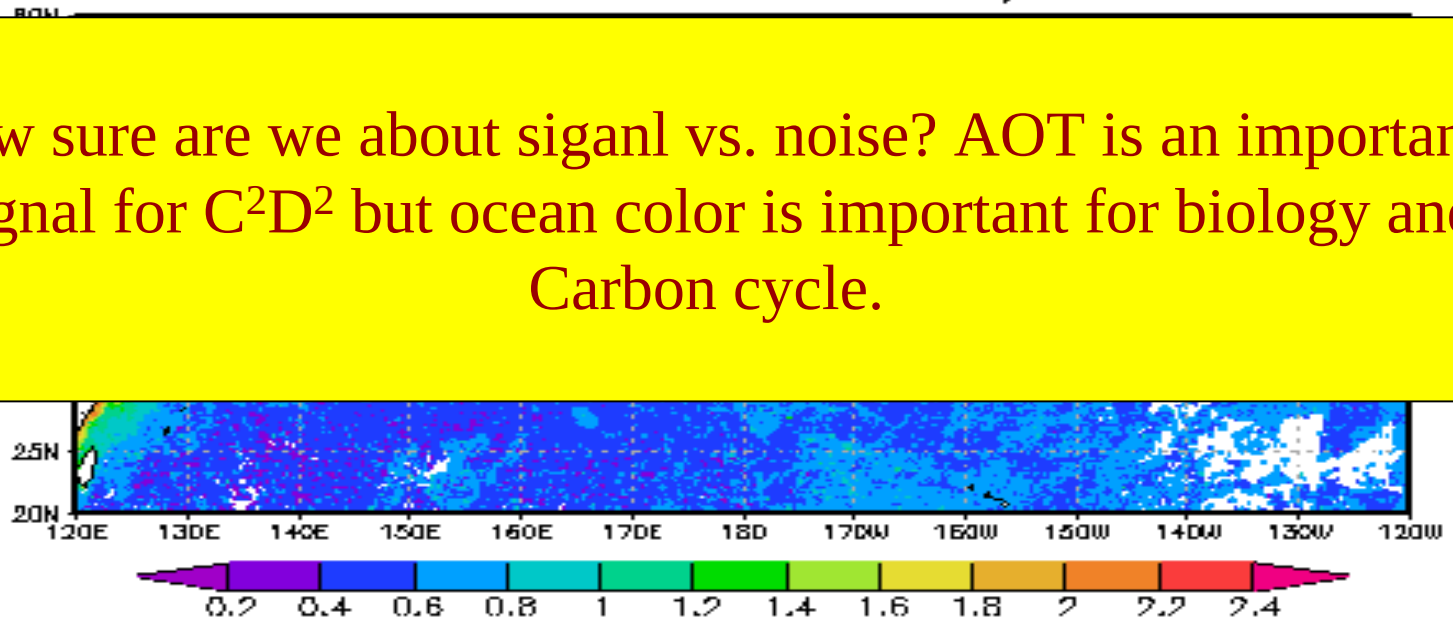
East Asia and North Pacific

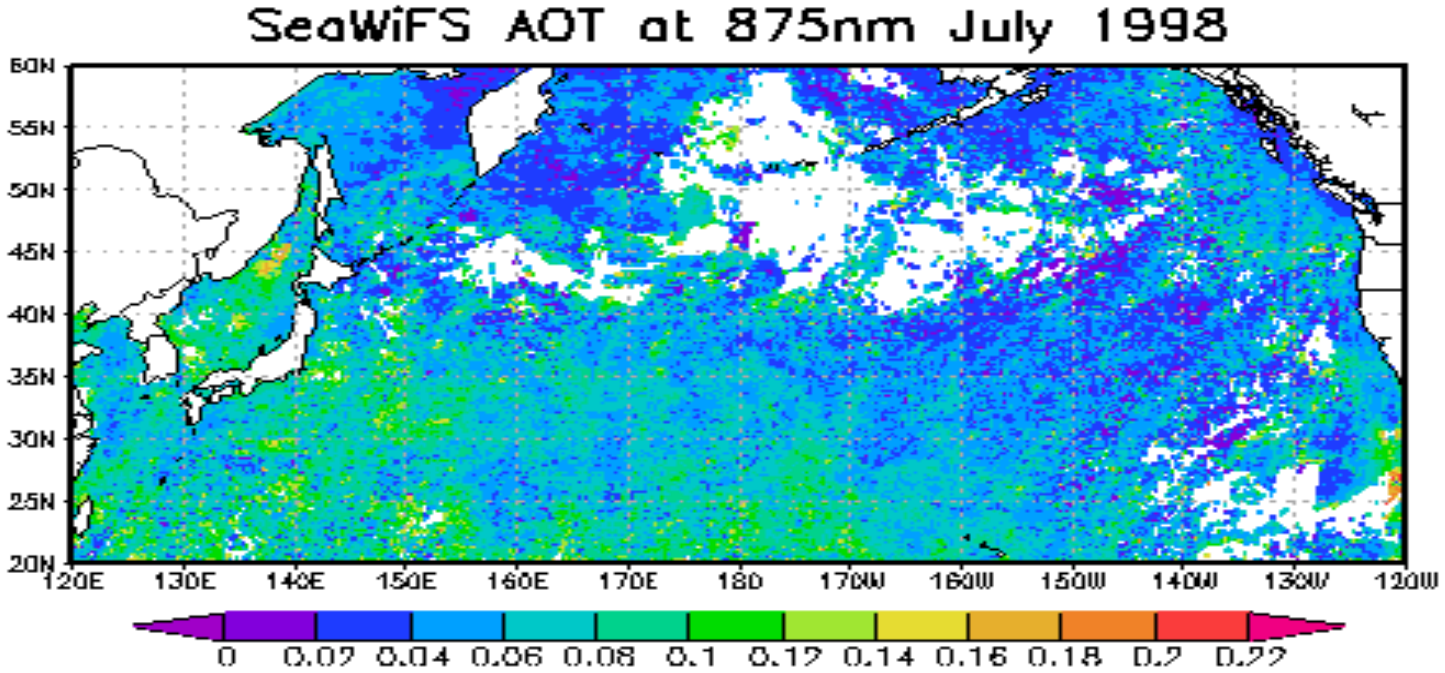


Correlation between chlorophyll concentration and AVHRR AOT suggesting a couple of possibilities…

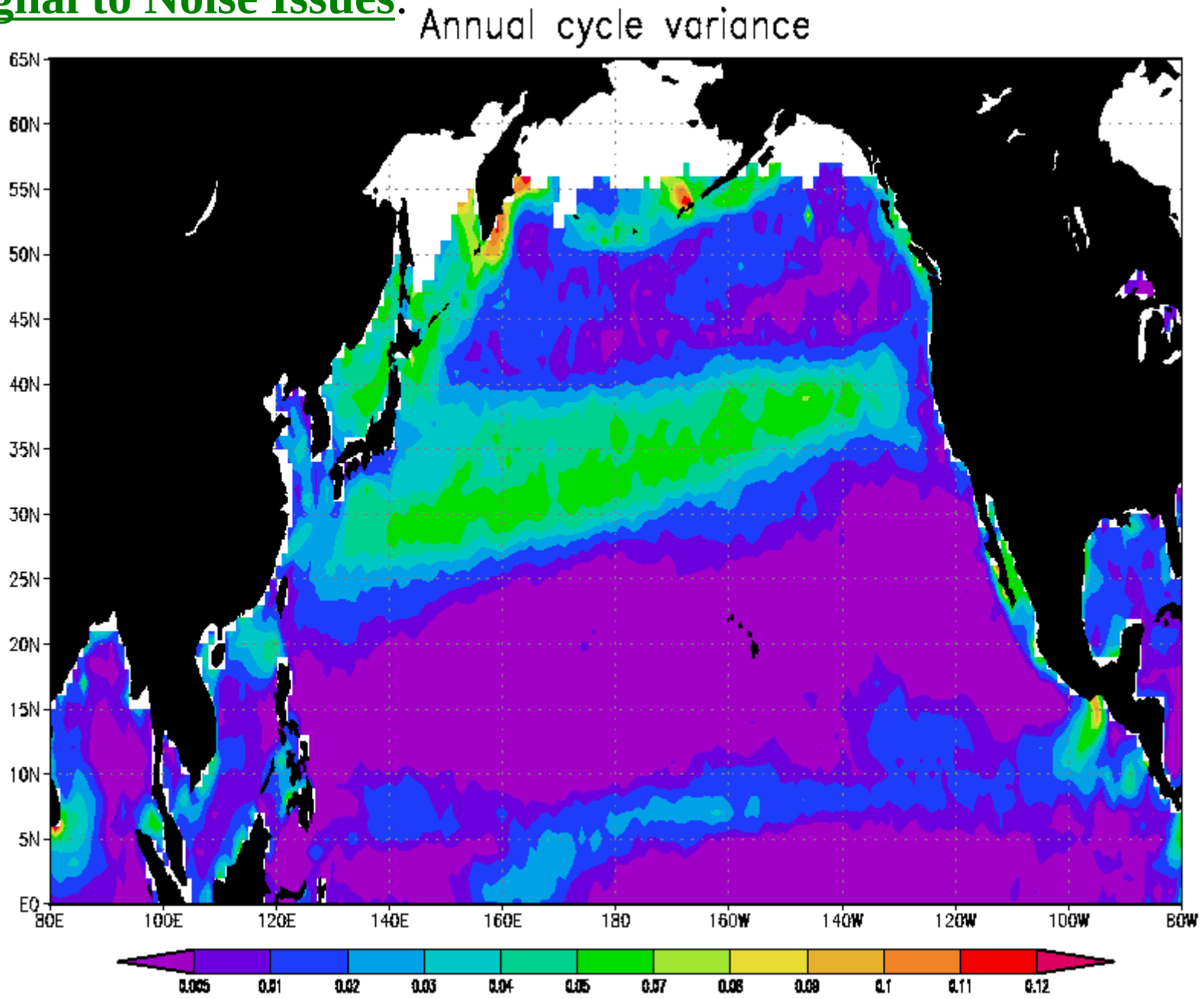
- **Sediment / ocean color contamination**
- **Contribution of local sources ? (e.g., DMS-derived sulfate)**
- **Cloud contamination ?**

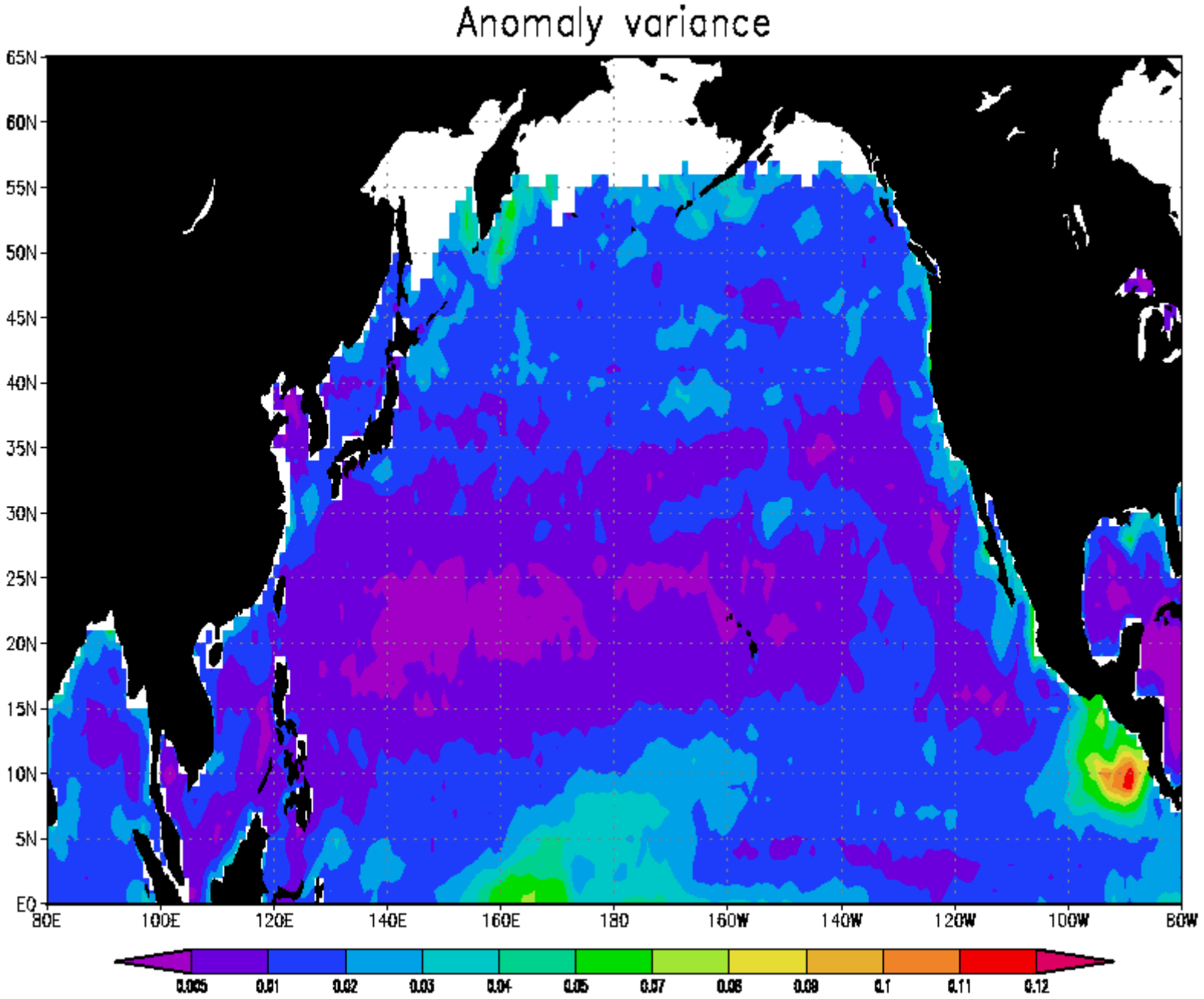
How sure are we about siganl vs. noise? AOT is an important Signal for C^2D^2 but ocean color is important for biology and Carbon cycle.

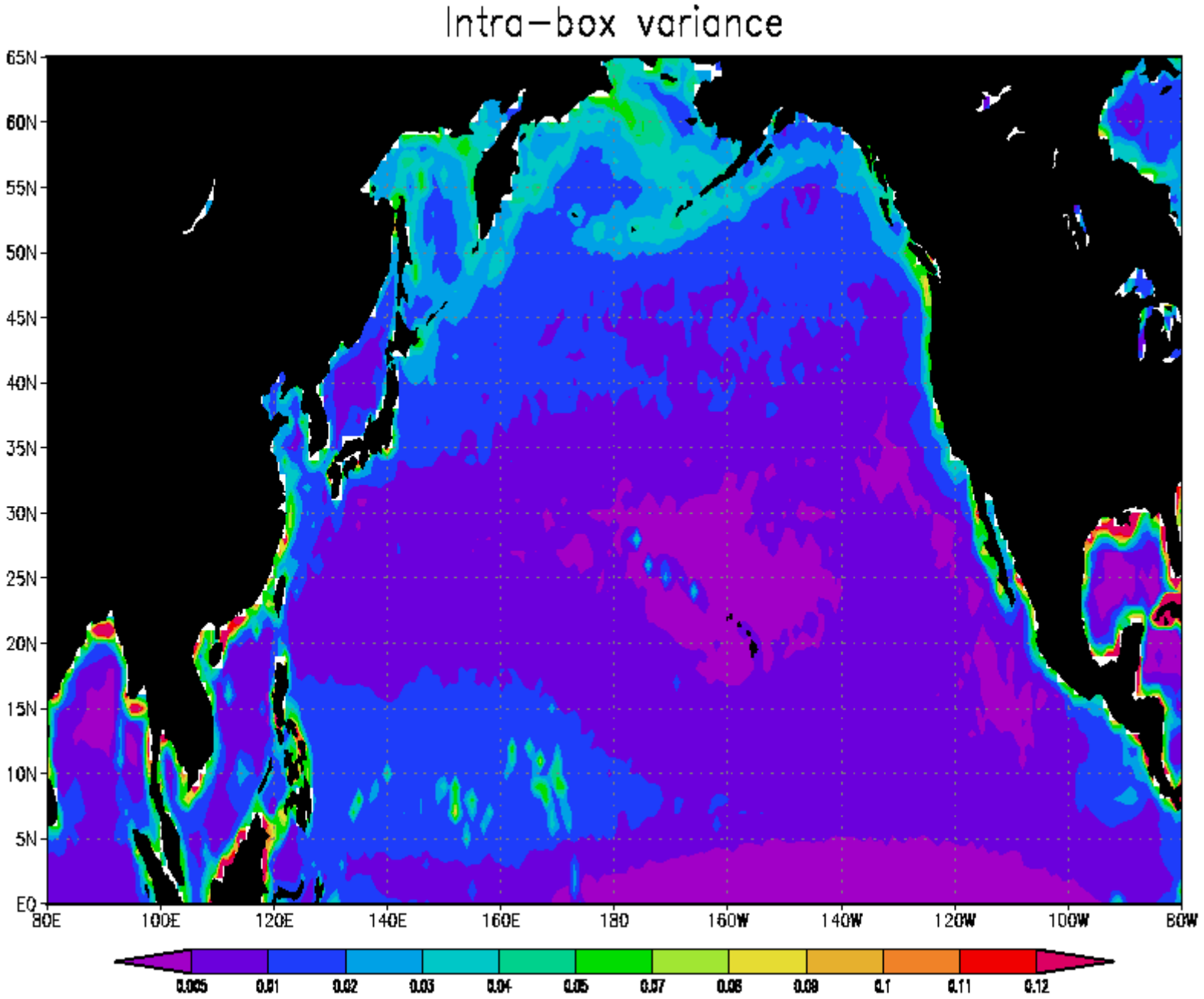


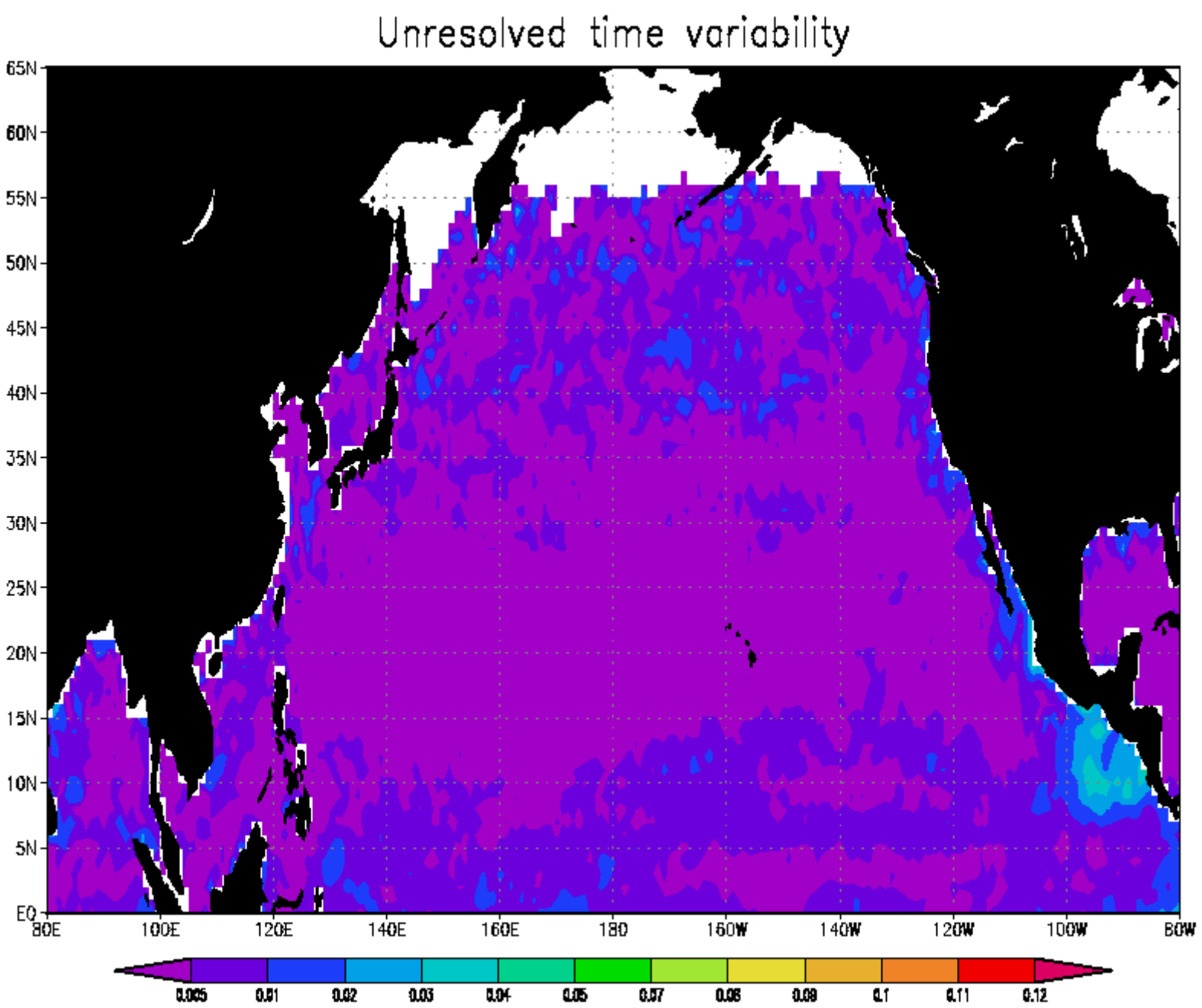


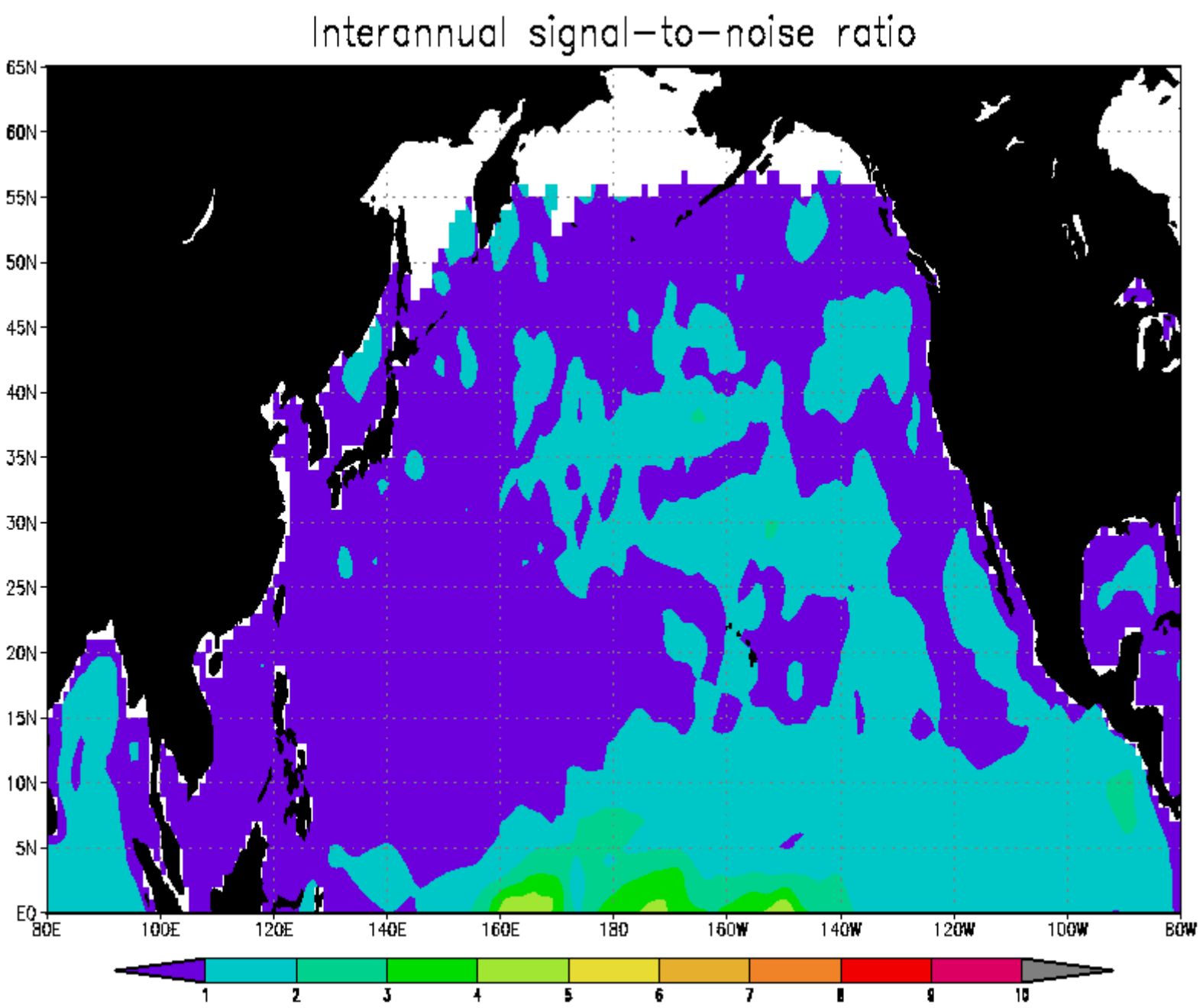
Signal to Noise Issues:

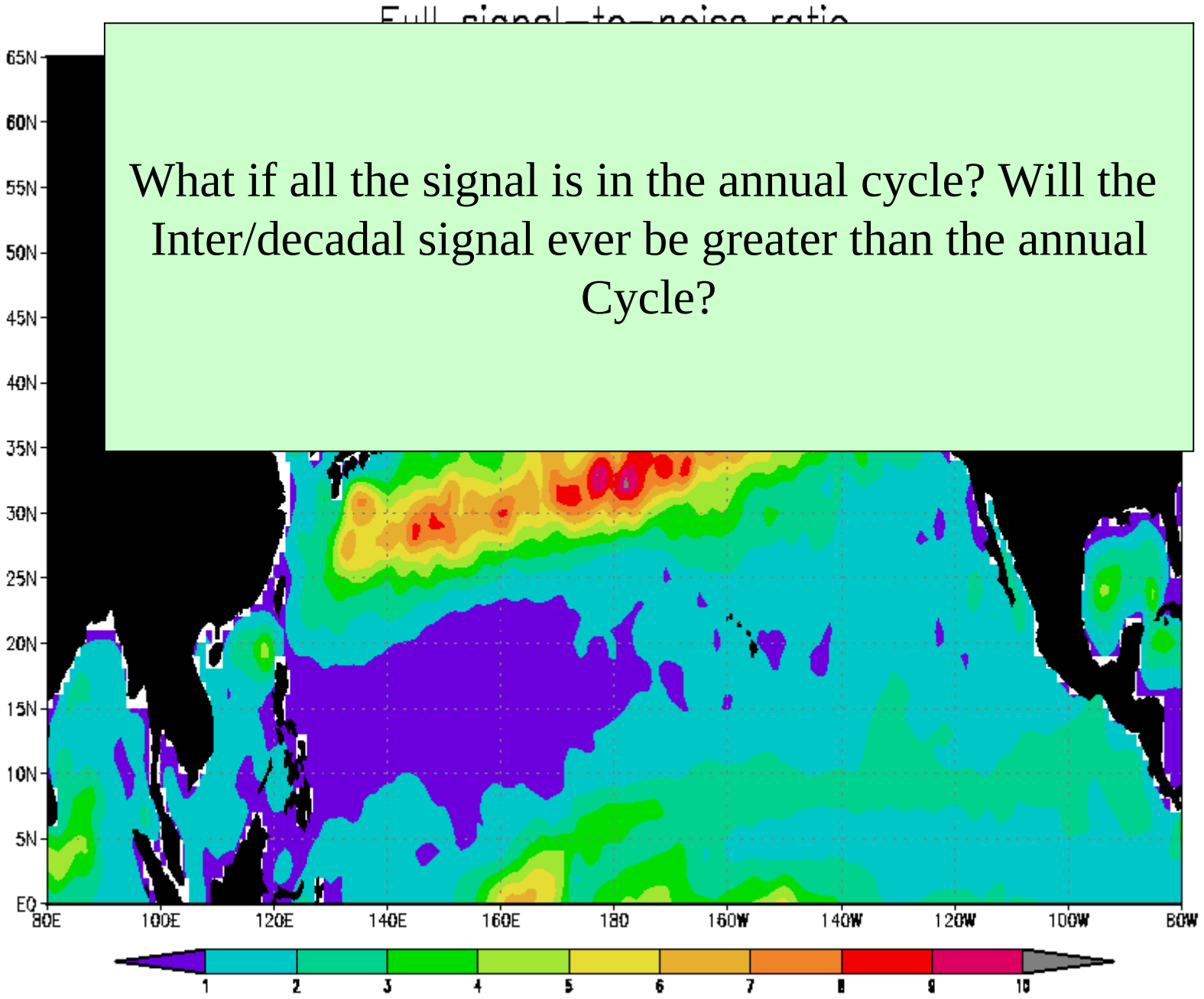



Anomaly variance
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
0.005
0.01
0.02
0.03
0.04
0.05
0.07
0.08
0.09
0.1
0.11
0.12


Intra−box variance
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
0.005
0.01
0.02
0.03
0.04
0.05
0.07
0.08
0.09
0.1
0.11
0.12

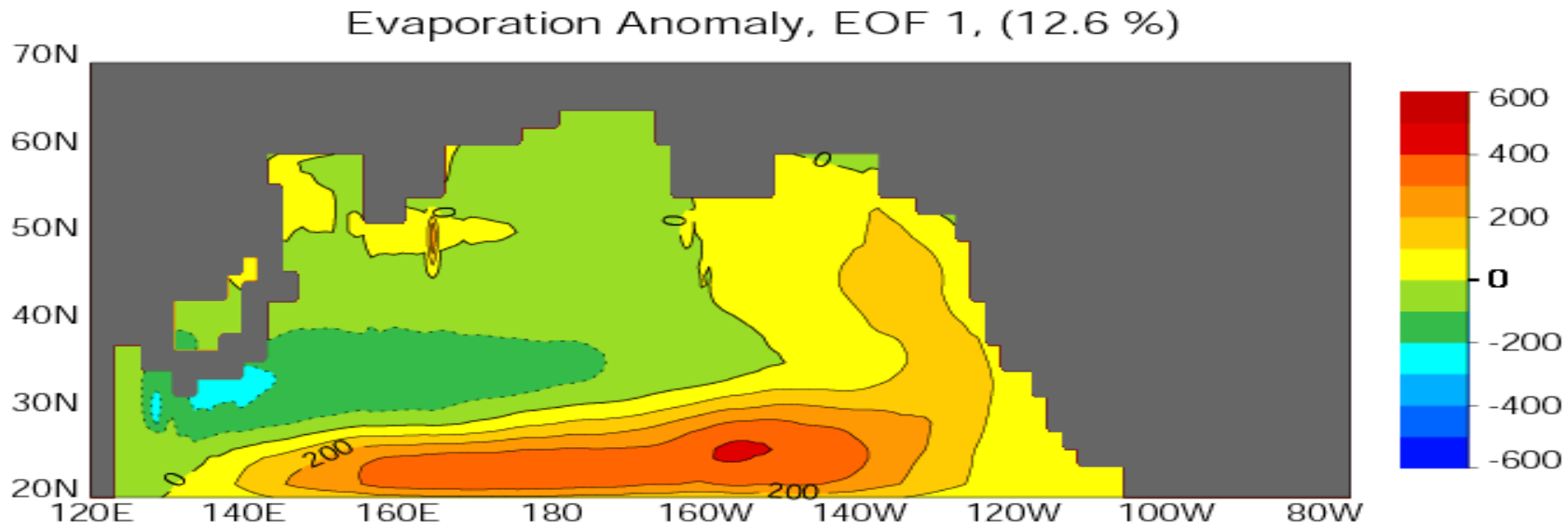

Unresolved time variability
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
0.005
0.01
0.02
0.03
0.04
0.05
0.07
0.08
0.09
0.1
0.11
0.12

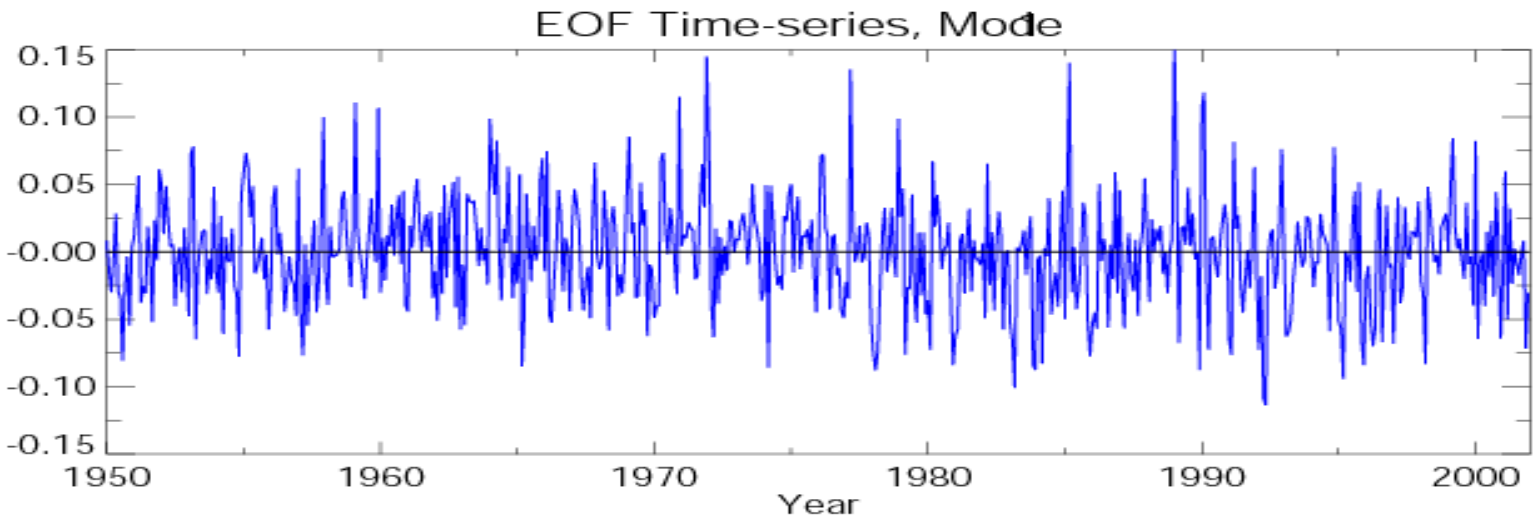

Interannual signal-to-noise ratio
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
1
2
3
4
5
6
7
8
9
10

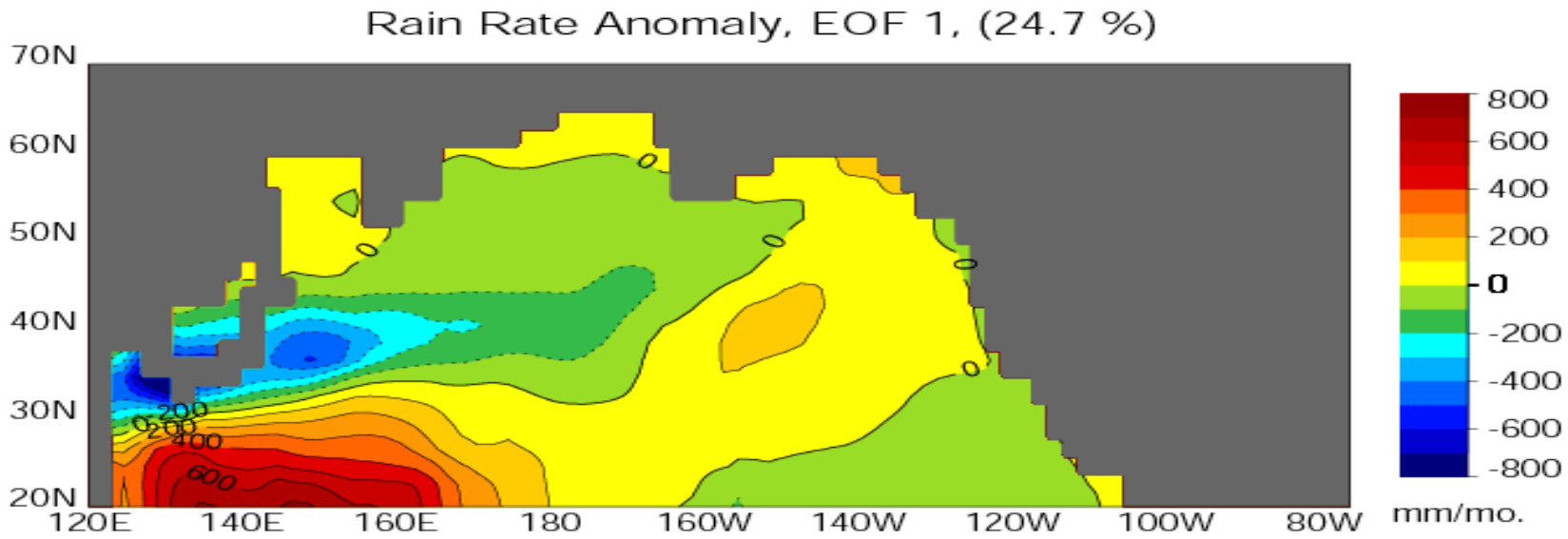


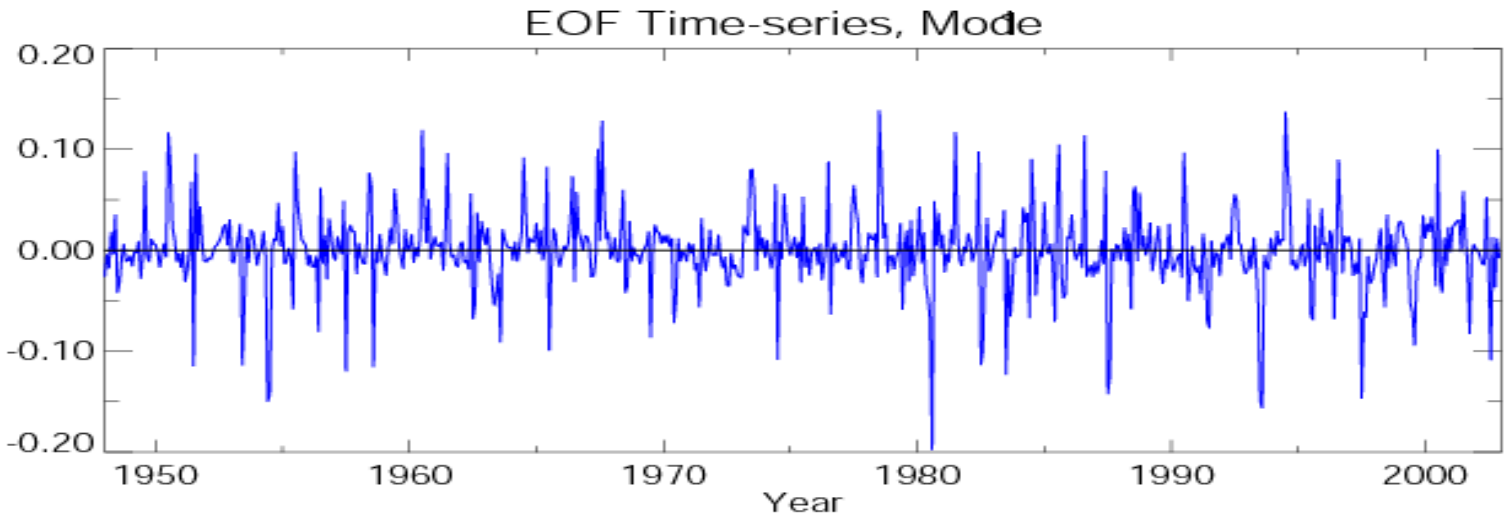
What if all the signal is in the annual cycle? Will the Inter/decadal signal ever be greater than the annual Cycle?

Physics to CO_2: Freshwater forcing of the North Pacific and alkalinity?

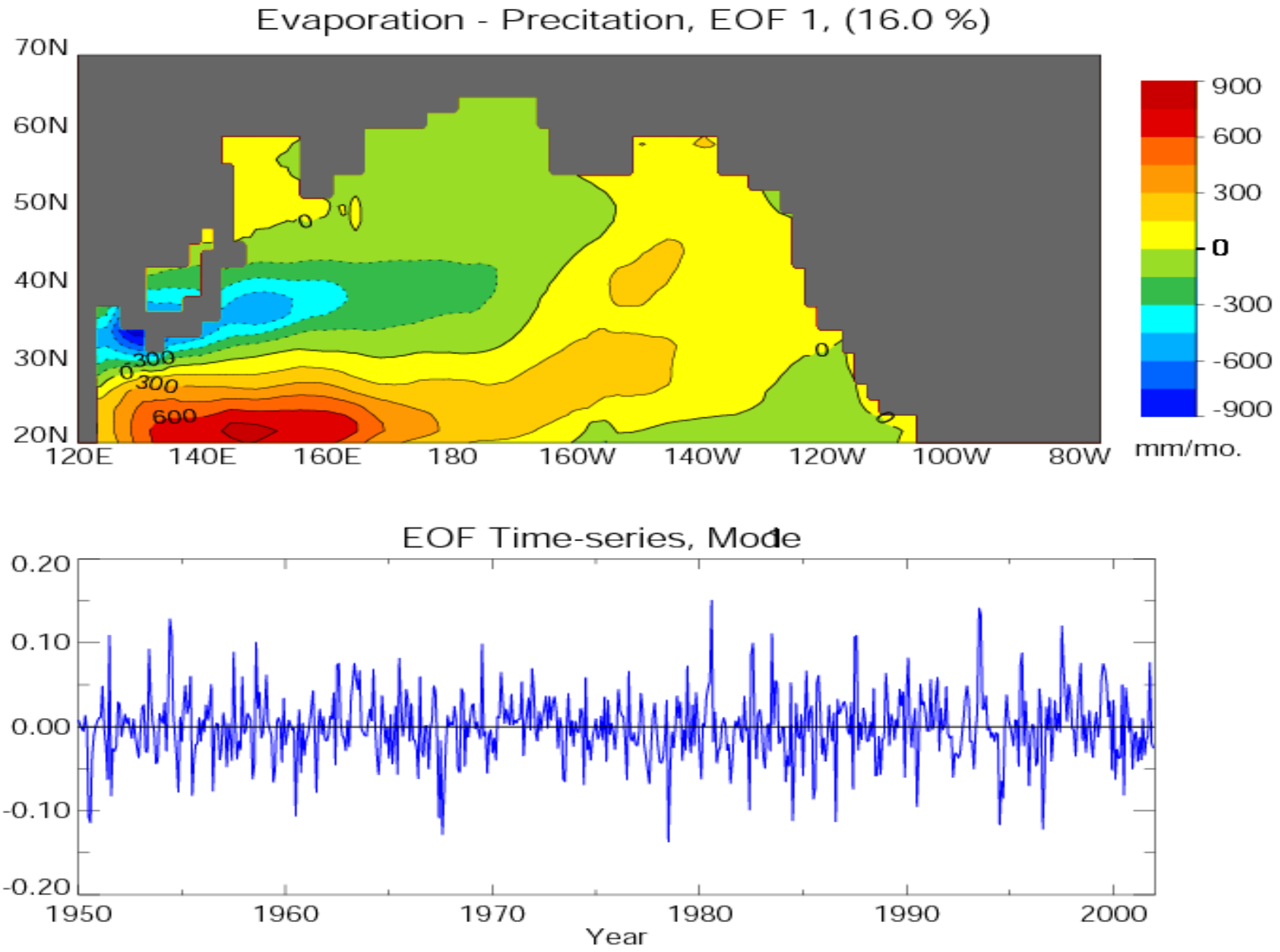




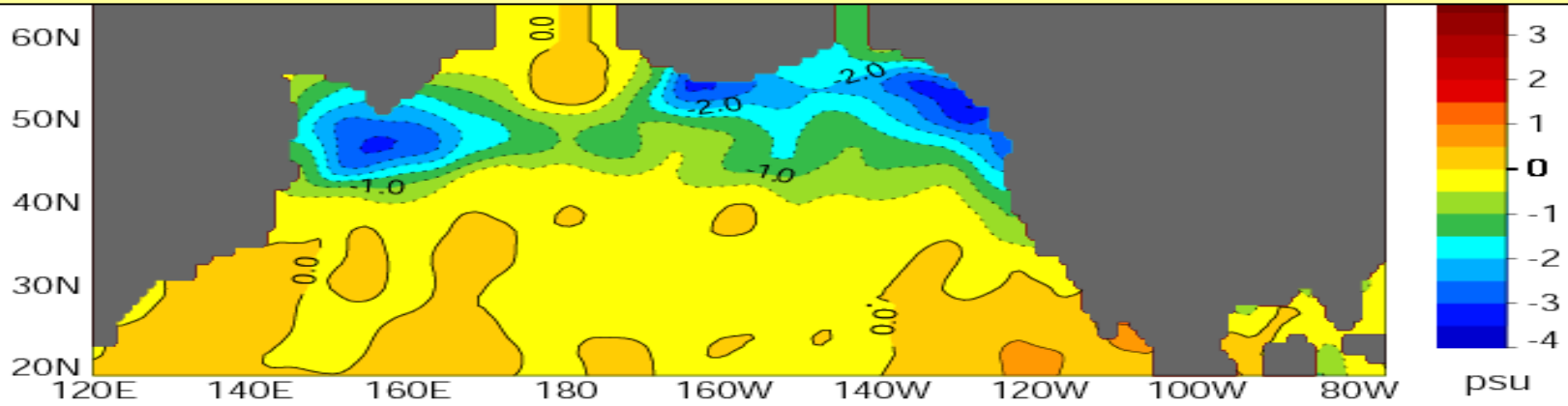


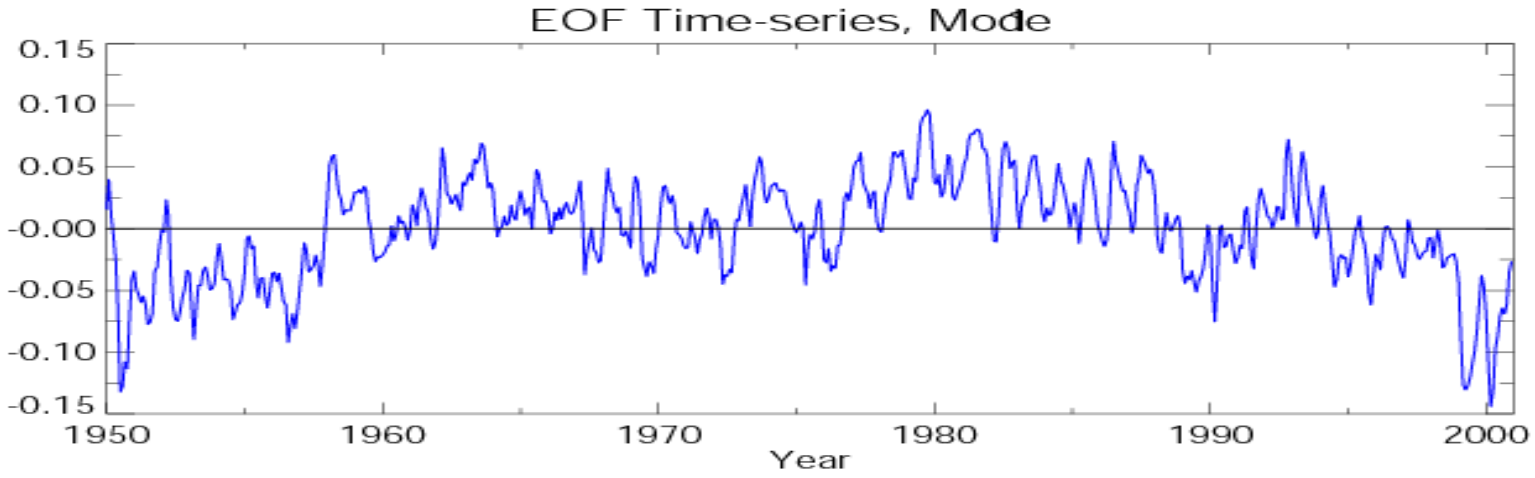


Precip doesn't show any clear trends either. Is that related to the reconstruction methodology used or is it real?

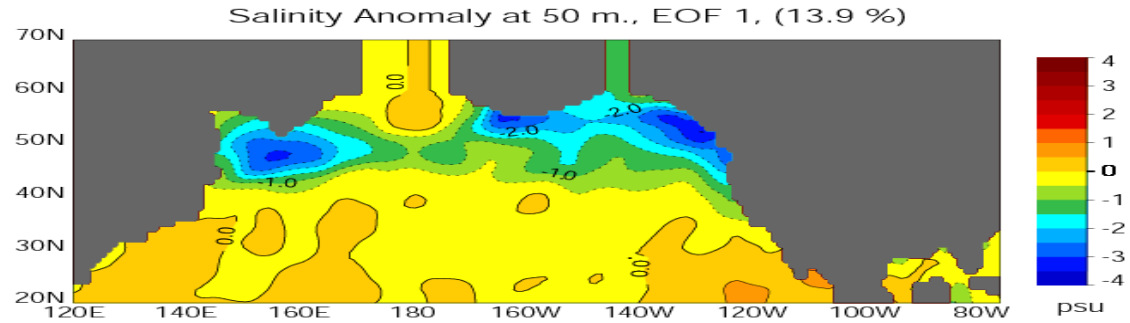

Evaporation - Precitation, EOF 1, (16.0 %)
70N
60N
50N
40N
30N
20N
120E
140E
160E
180
160W
140W
120W
100W
80W
0
300
0
300
600
0
0
900
600
300
0
-300
-600
-900
mm/mo.
EOF Time-series, Mode 1
0.20
0.10
0.00
-0.10
-0.20
1950
1960
1970
1980
1990
2000
Year

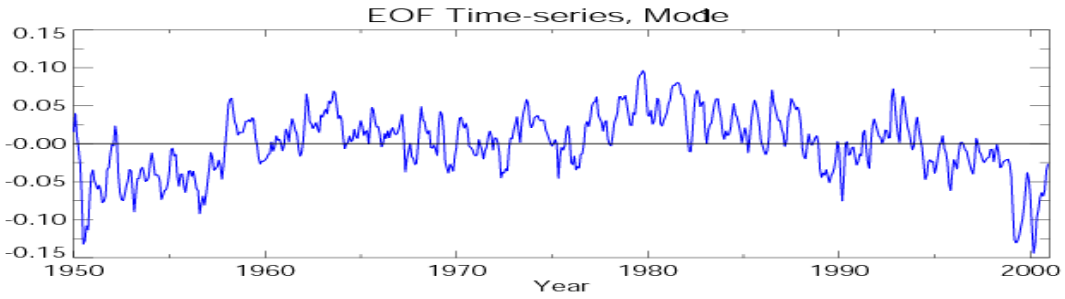
Ocean Reanalyses (SODA-POP): CLIVAR to PICES…..
Biogeochemical Reanalyses?



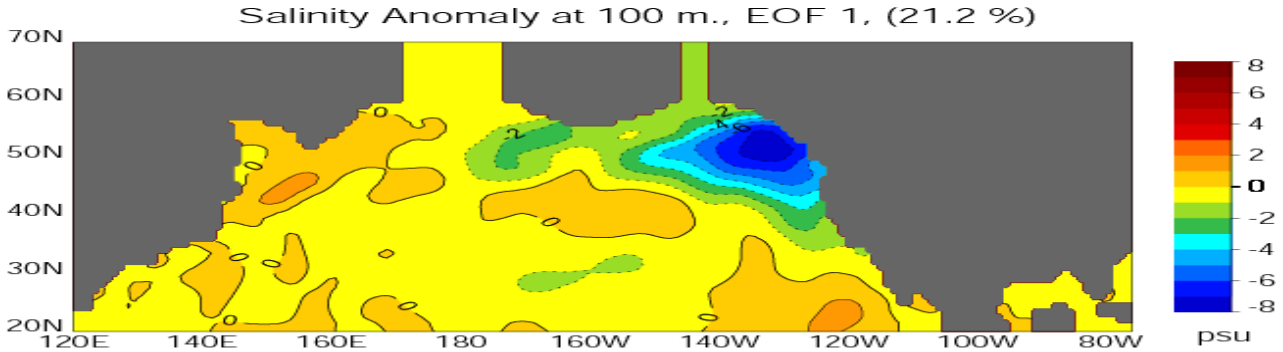


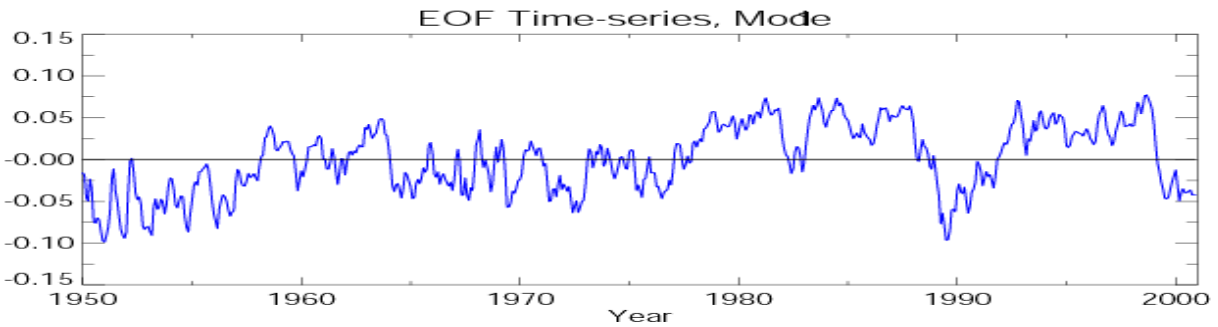
But subsurface salinity has a decadal character

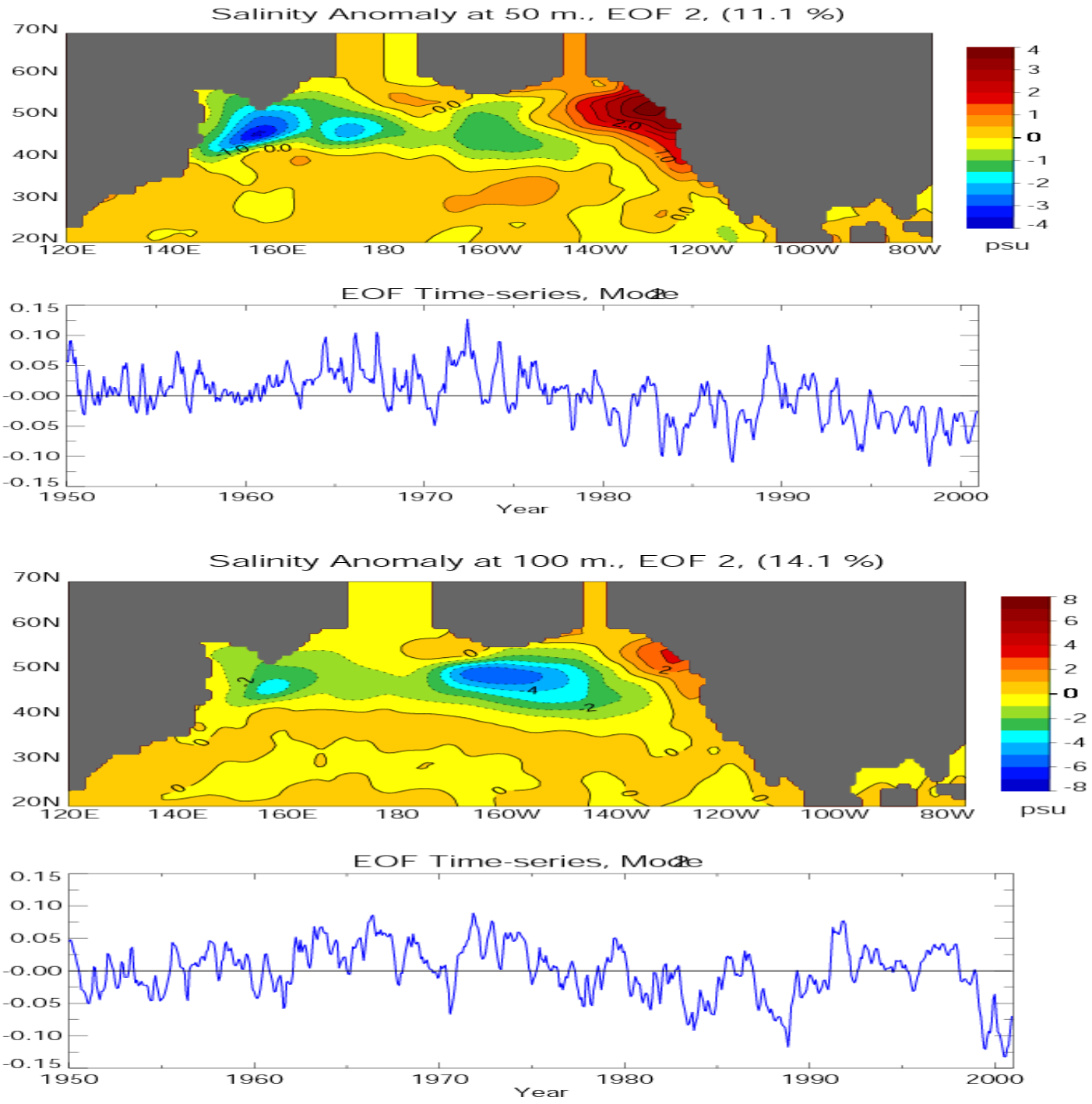


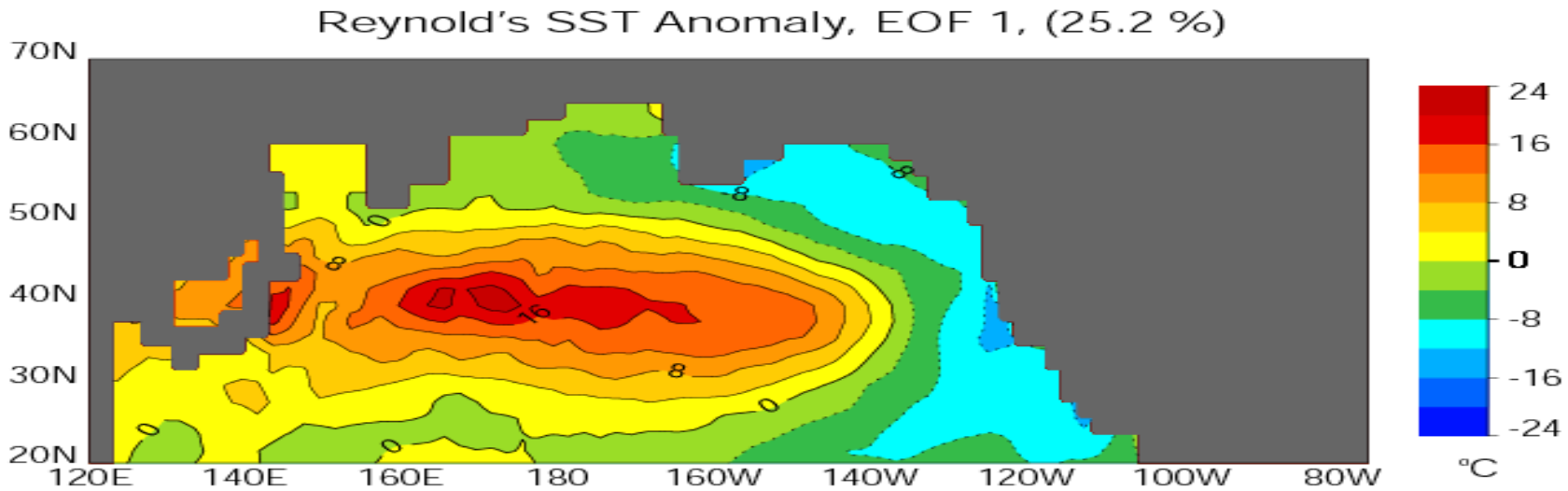


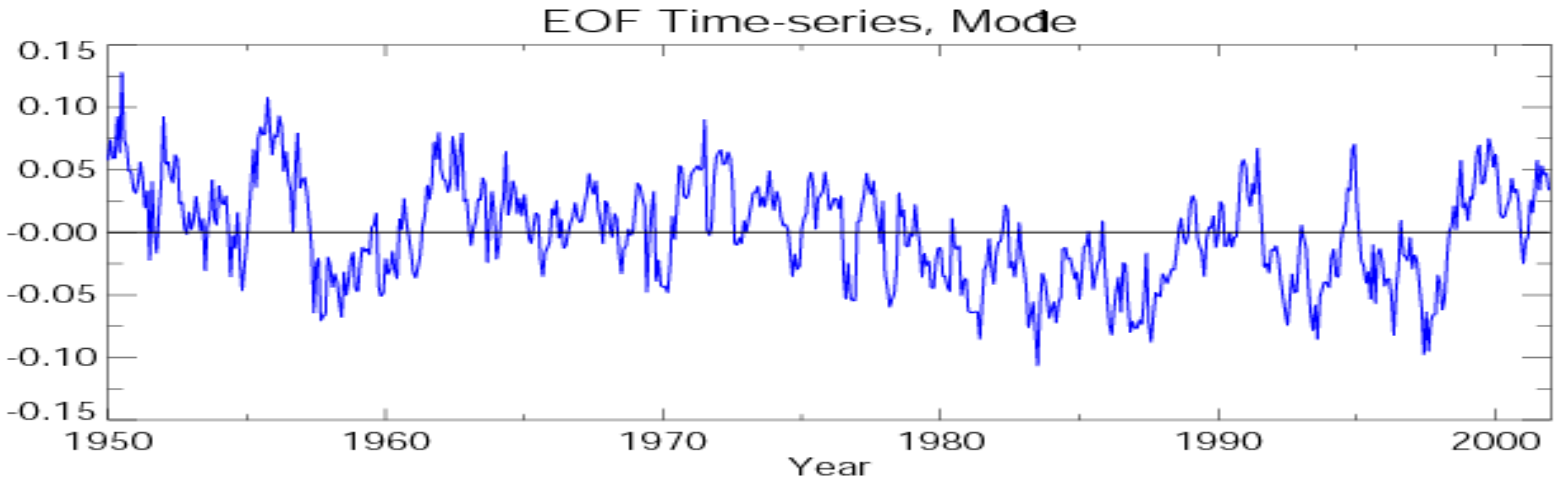
Can the differences in salinity at 50m and 100m tell us anything? Any connection to Alaska Gyre/Salmon variability?



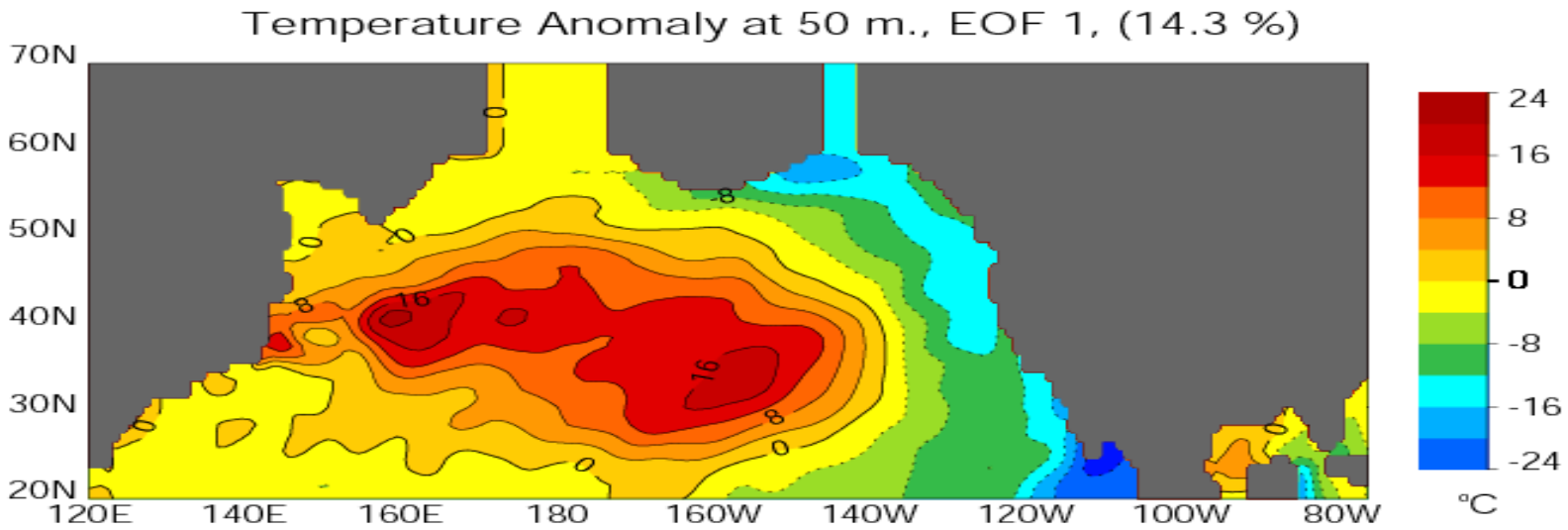


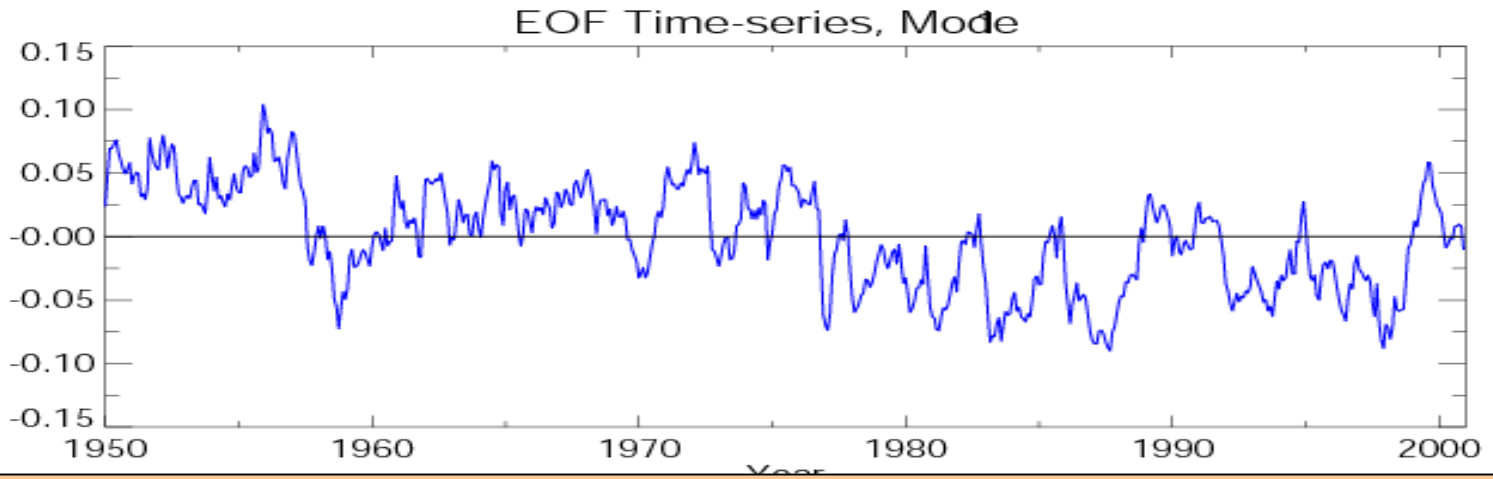

Salinity Anomaly at 50 m., EOF 2, (11.1 %)
70N
60N
50N
40N
30N
20N
120E
140E
160E
180
160W
140W
120W
100W
80W
4
3
2
1
0
-1
-2
-3
-4
psu
EOF Time-series, Mode 2
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year
Salinity Anomaly at 100 m., EOF 2, (14.1 %)
8
6
4
2
0
-2
-4
-6
-8
EOF Time-series, Mode 2





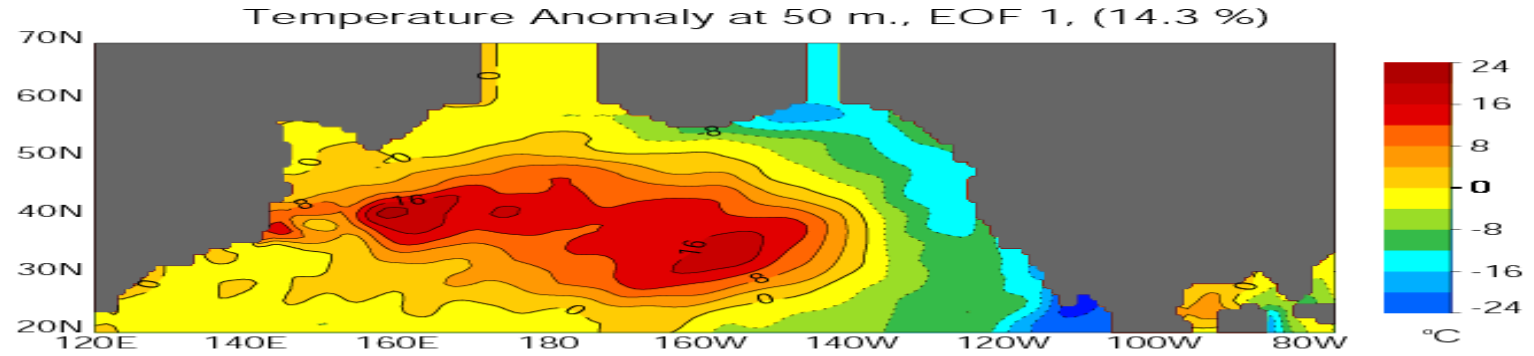
If you squint hard enough, you can see the 1957-58, 1976-77, and 1989 shifts.

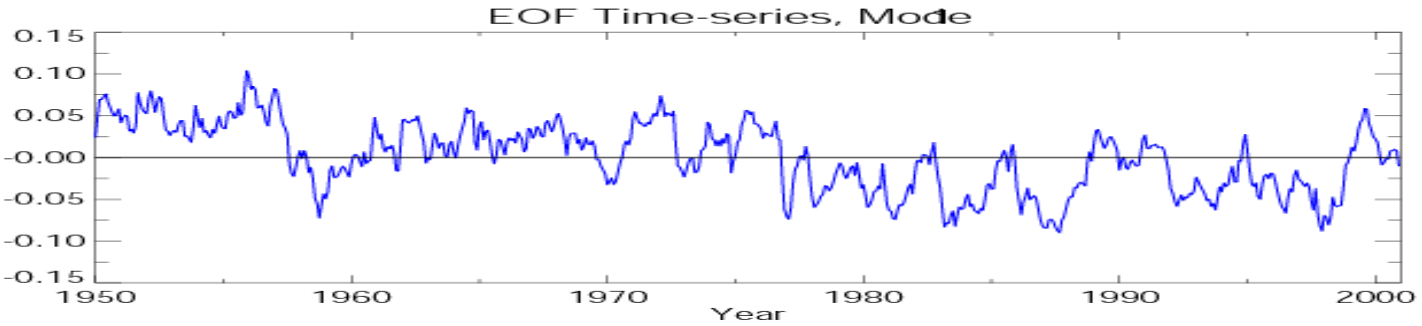


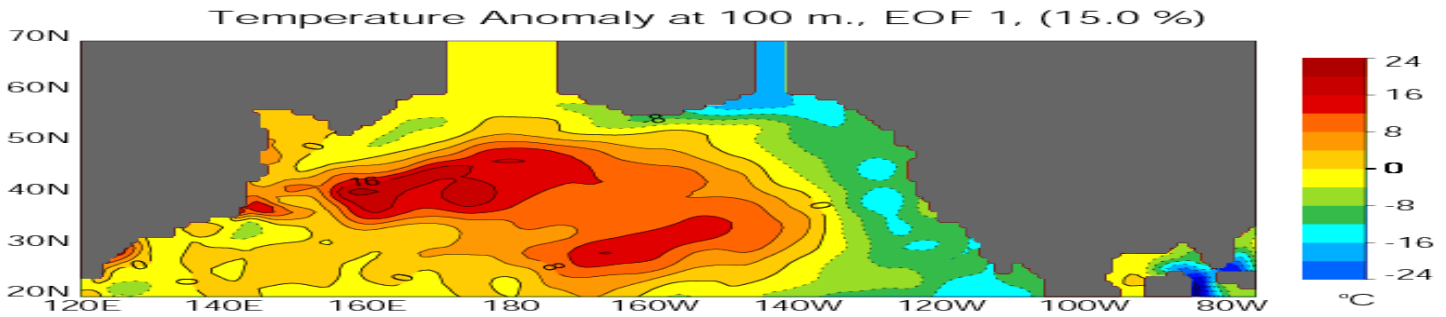


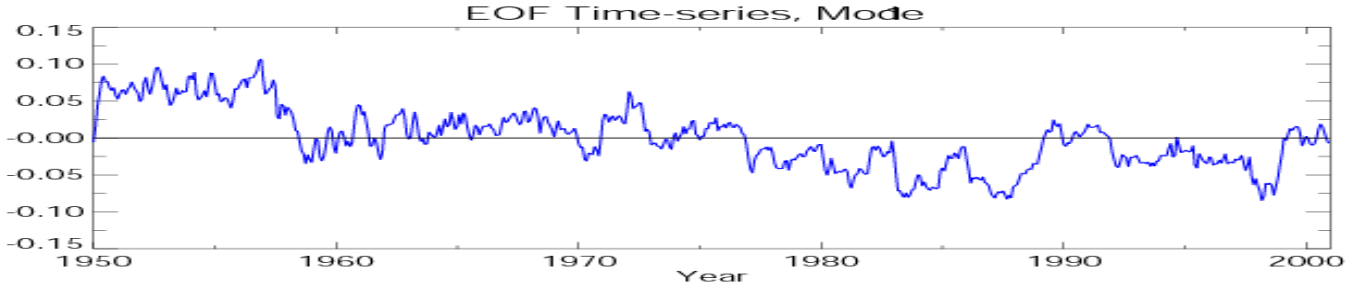
The first mode of temperatures at 50m is simply consistent with SSH variability. So there is a coherent variability in the upper 100m.

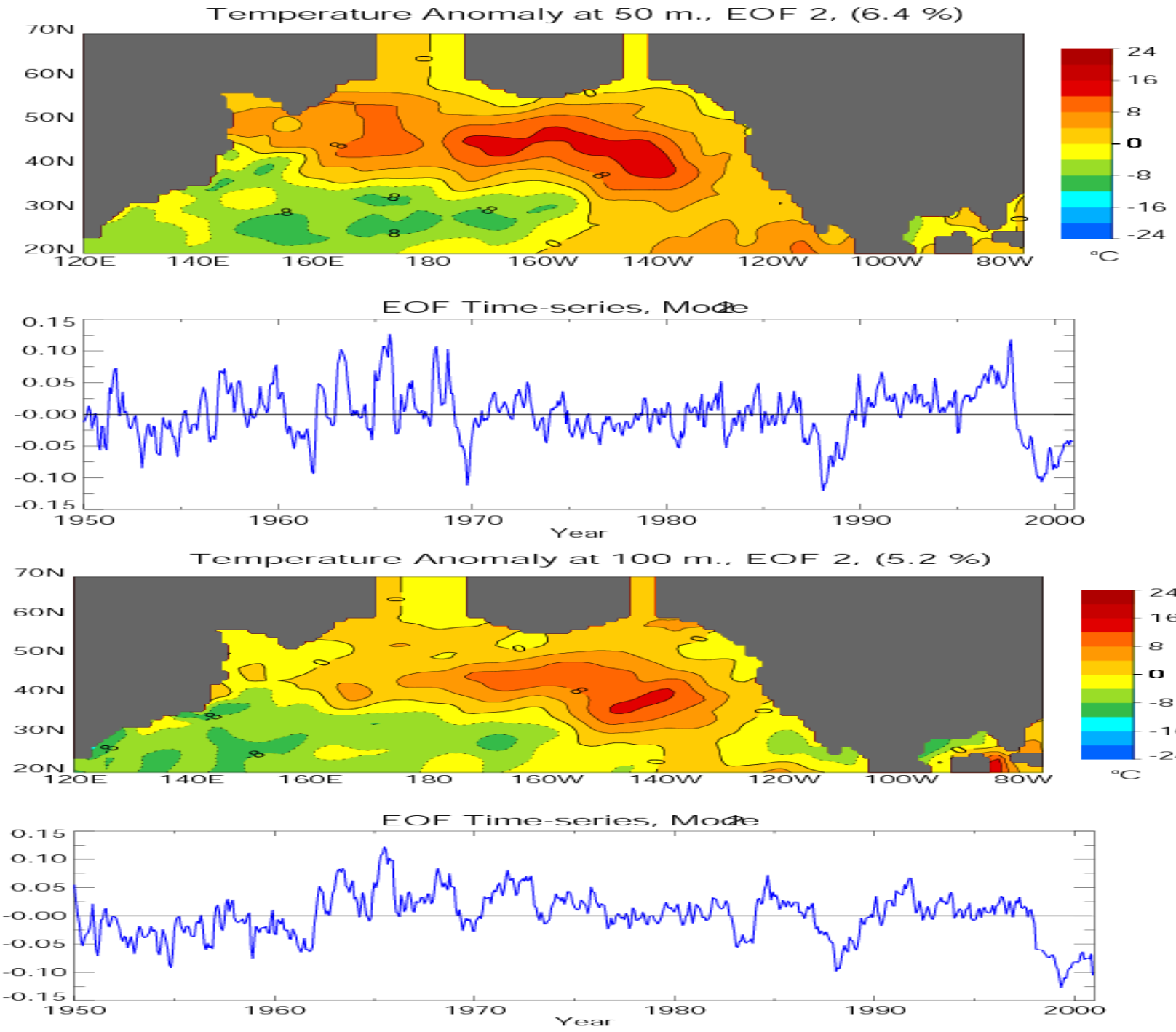
FISH KNOW THAT!!!

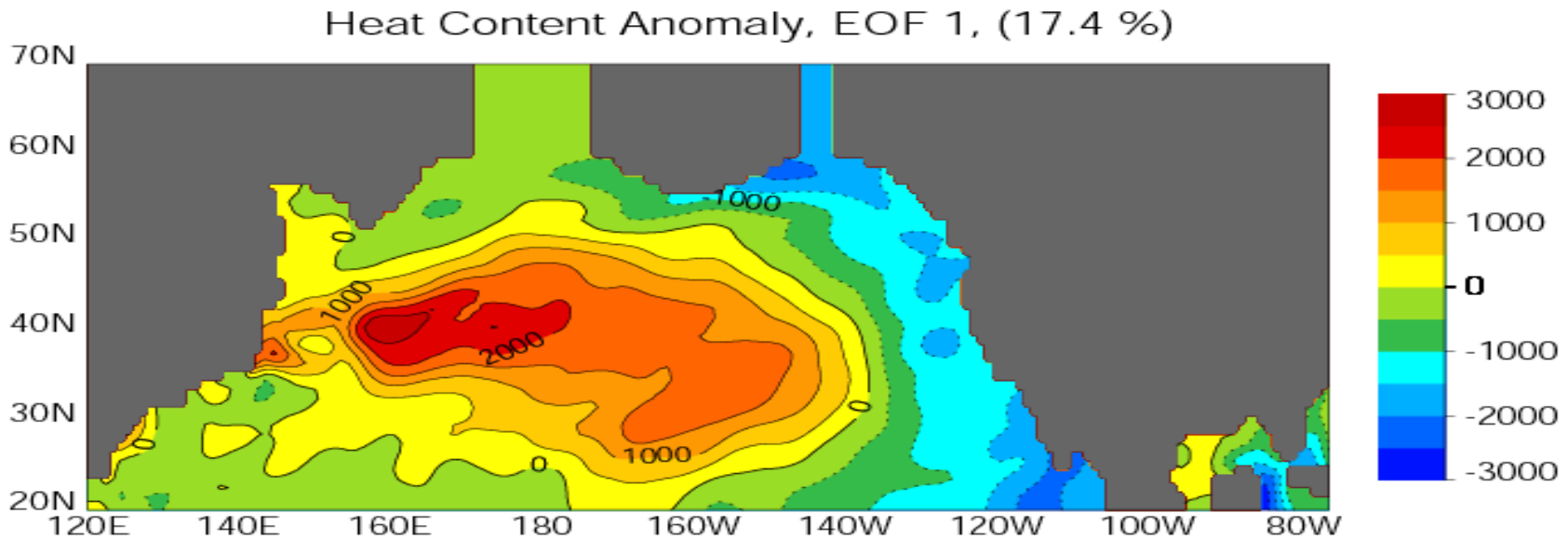

Temperature Anomaly at 50 m., EOF 1, (14.3 %)
70N
60N
50N
40N
30N
20N
120E
140E
160E
180
160W
140W
120W
100W
80W
24
16
8
0
-8
-16
-24
°C

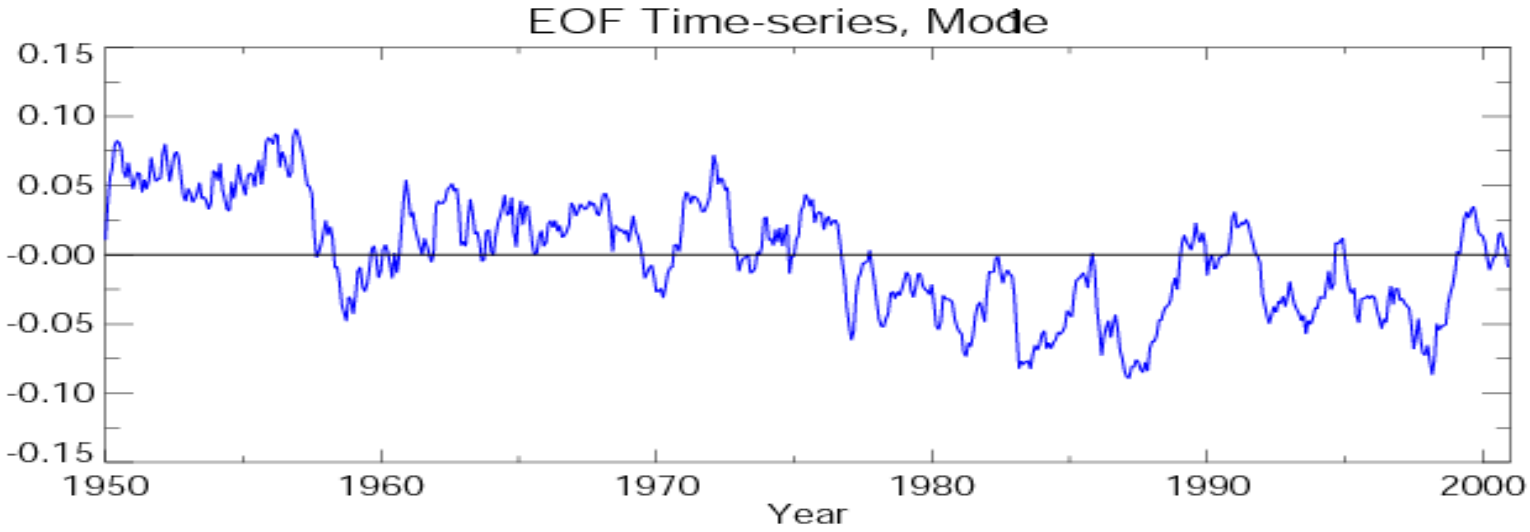

EOF Time-series, Mode
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year


Temperature Anomaly at 100 m., EOF 1, (15.0 %)
70N
60N
50N
40N
30N
20N
120E
140E
160E
180
160W
140W
120W
100W
80W
24
16
8
0
-8
-16
-24
°C

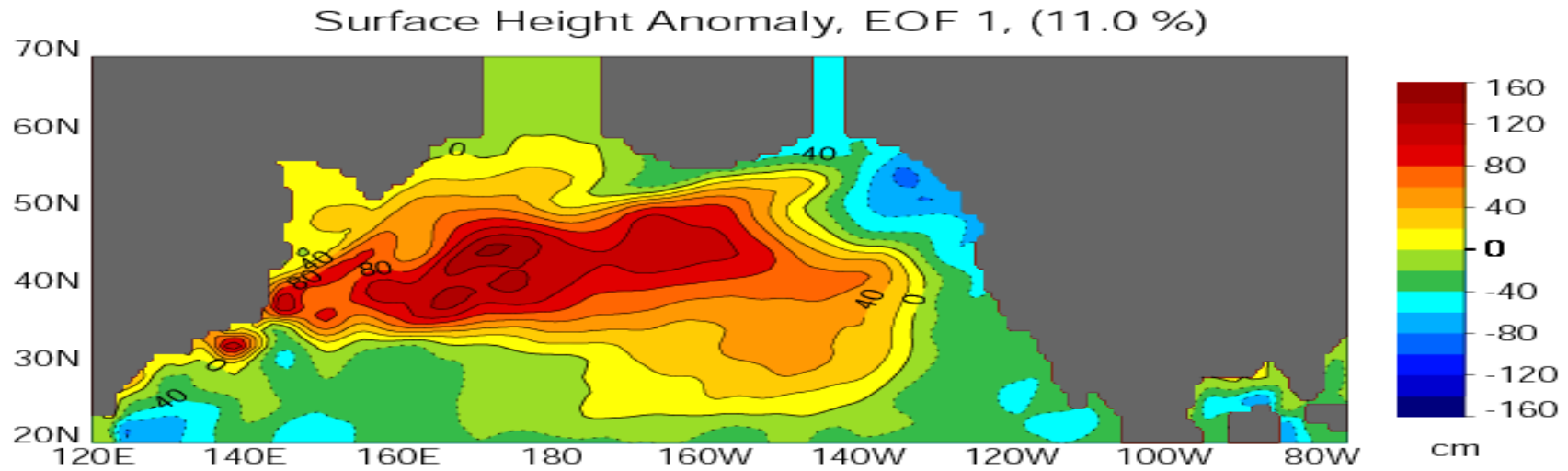

EOF Time-series, Mode
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year

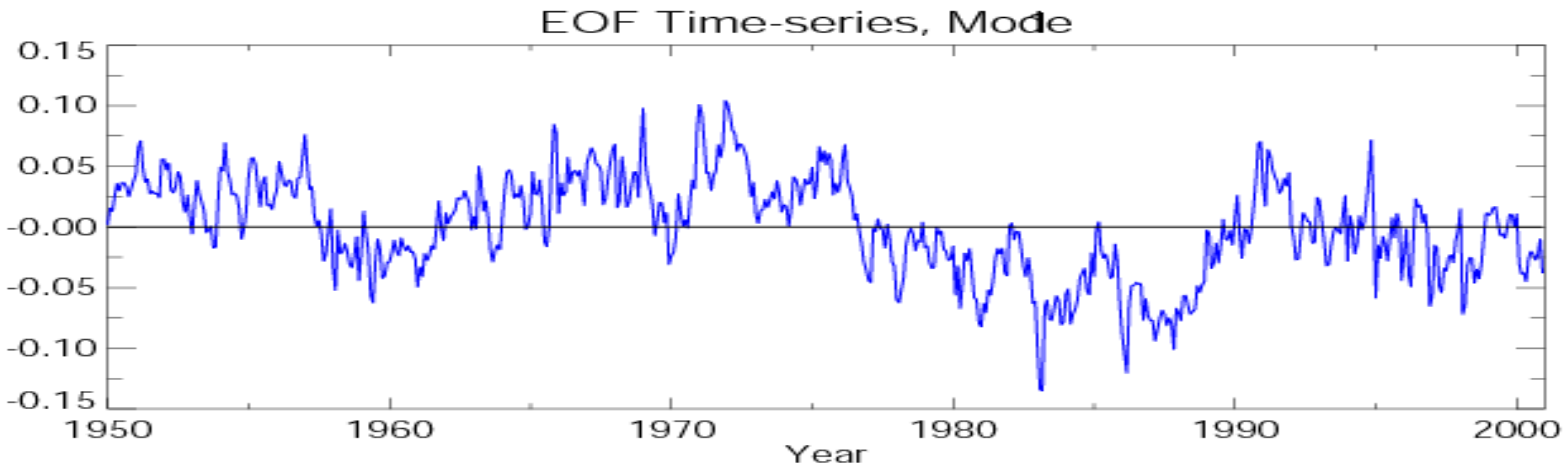

Temperature Anomaly at 50 m., EOF 2, (6.4 %)
70N
60N
50N
40N
30N
20N
120E
140E
160E
180
160W
140W
120W
100W
80W
24
16
8
0
-8
-16
-24
°C
EOF Time-series, Mode 2
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year
Temperature Anomaly at 100 m., EOF 2, (5.2 %)
70N
60N
50N
40N
30N
20N
120E
140E
160E
180
160W
140W
120W
100W
80W
24
16
8
0
-8
-16
-24
°C
EOF Time-series, Mode 2
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year





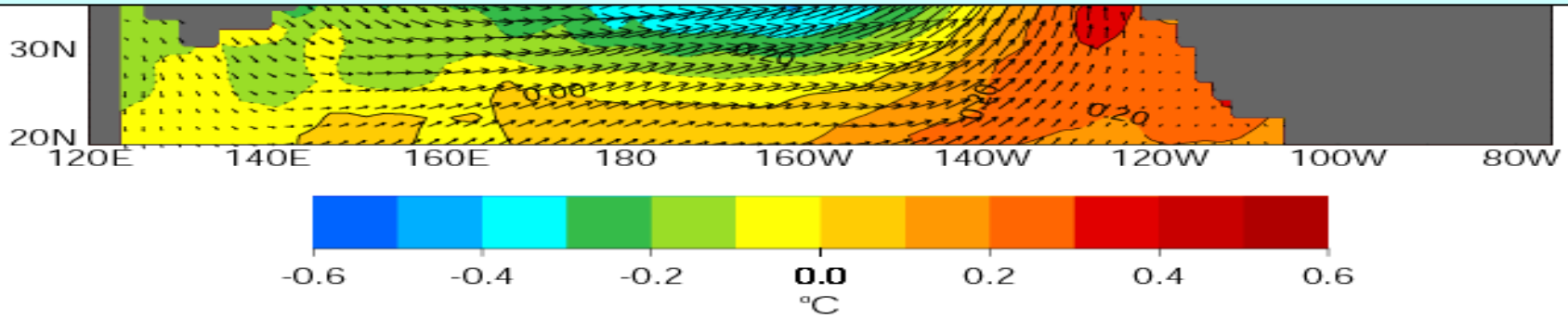
What does it say about the mechanism for decadal variability (tropical vs. extratropical origin) ?

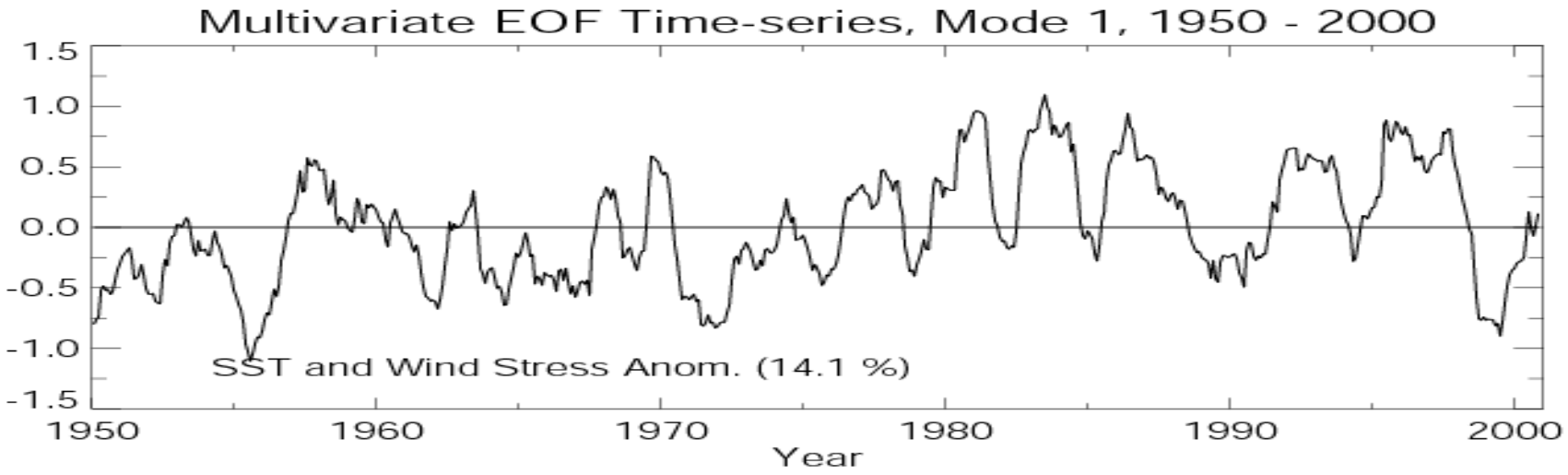




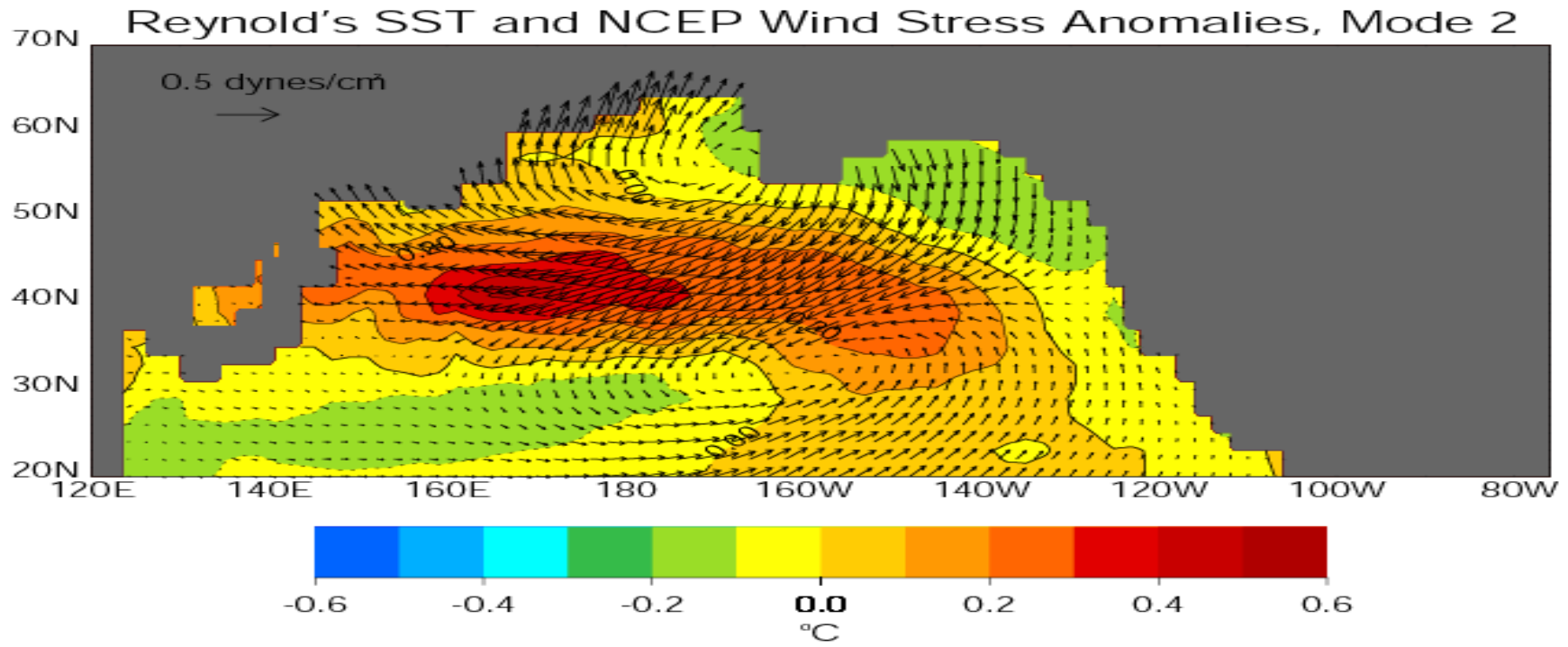
Sea surface height anomalies capture the low-frequency variability. So climate change in the North Pacific may be detectable from space if it projects on to similar Interdecadal variability.

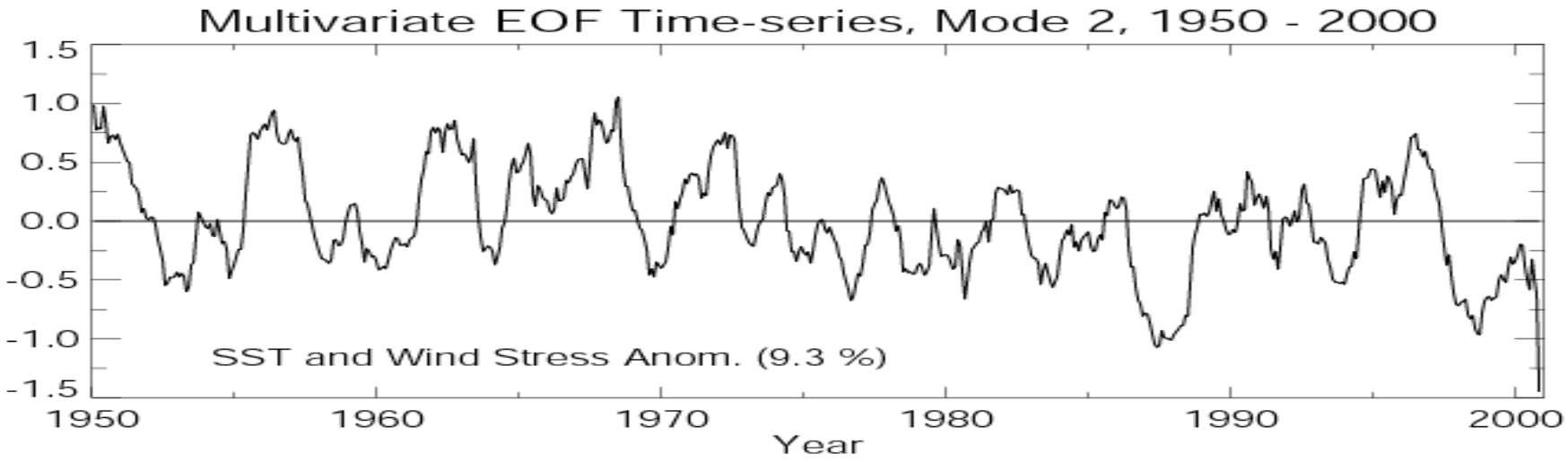
Surface flux problems: Combined SST-wind EOFs can be a good measure of validation for both forced OGCMs and Coupled GCMs



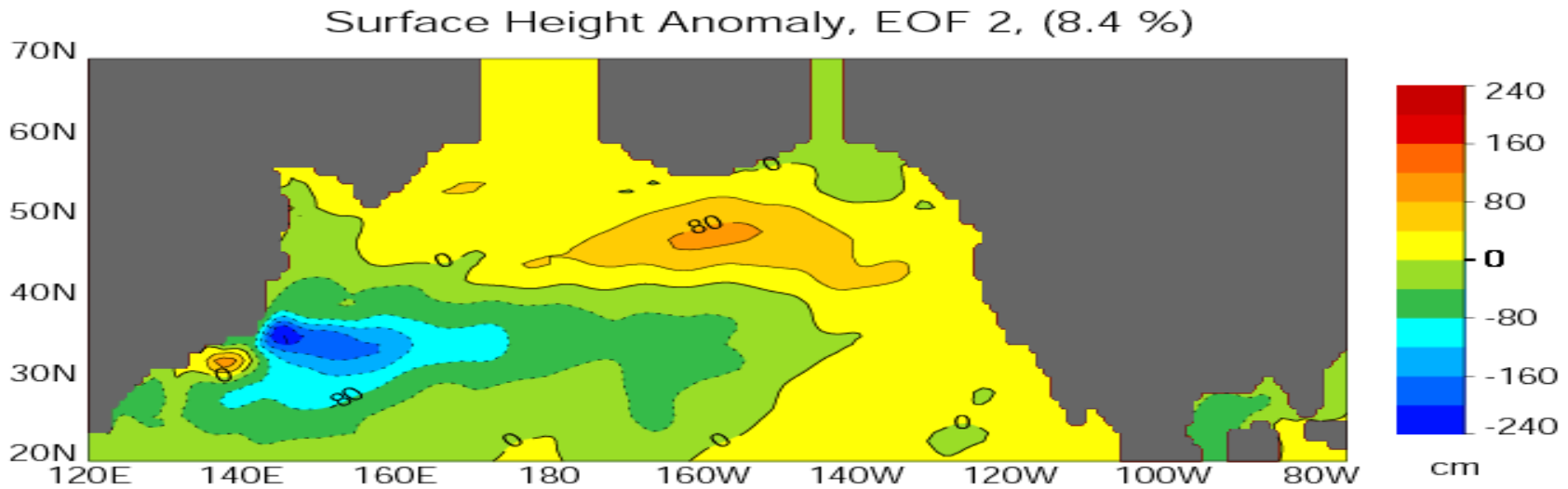


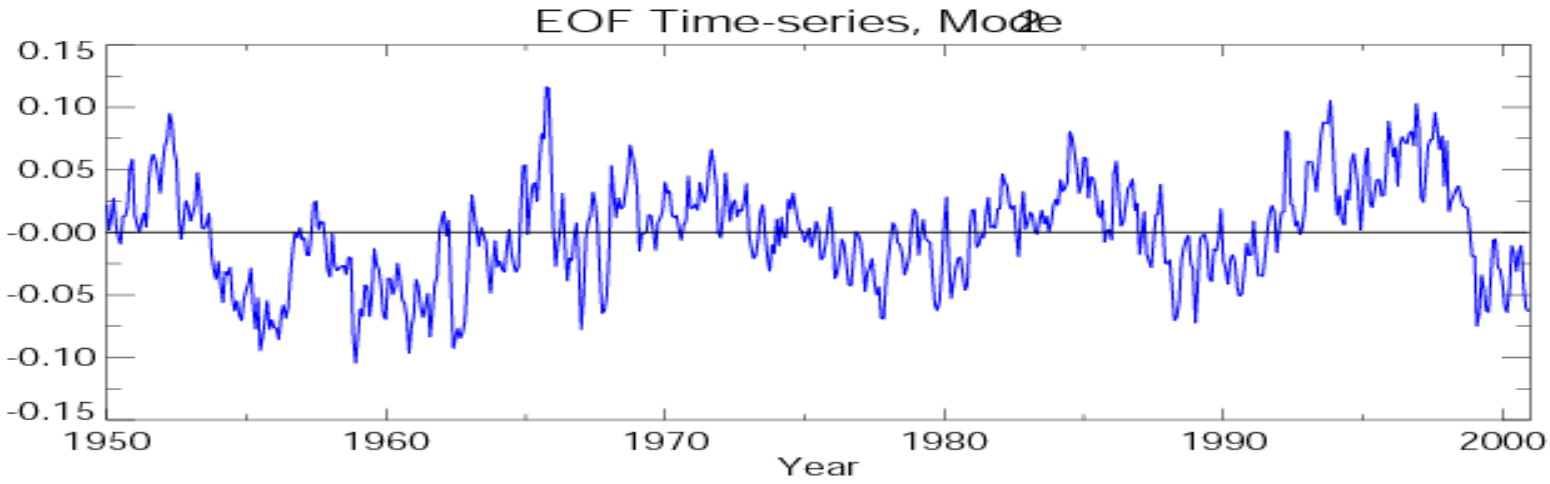
Do we know the oceanic response/role in the Aleutian High variability?





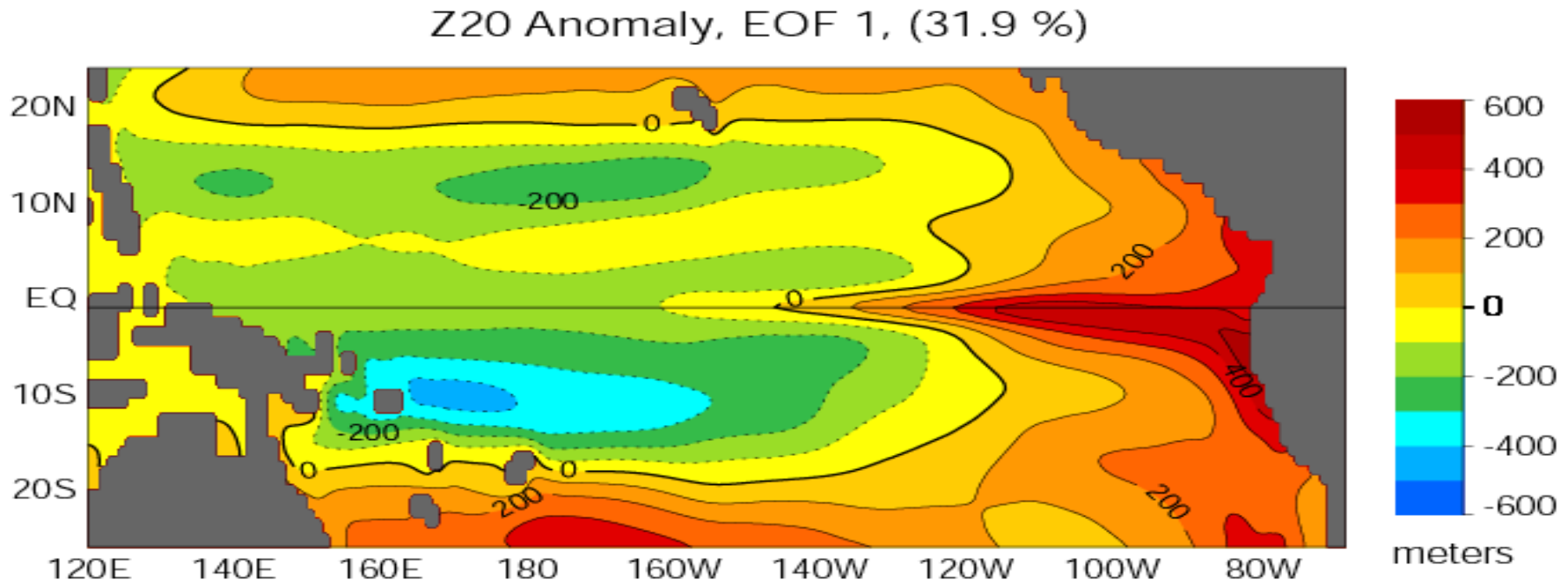
Is this an independent subarctic mode of variability?

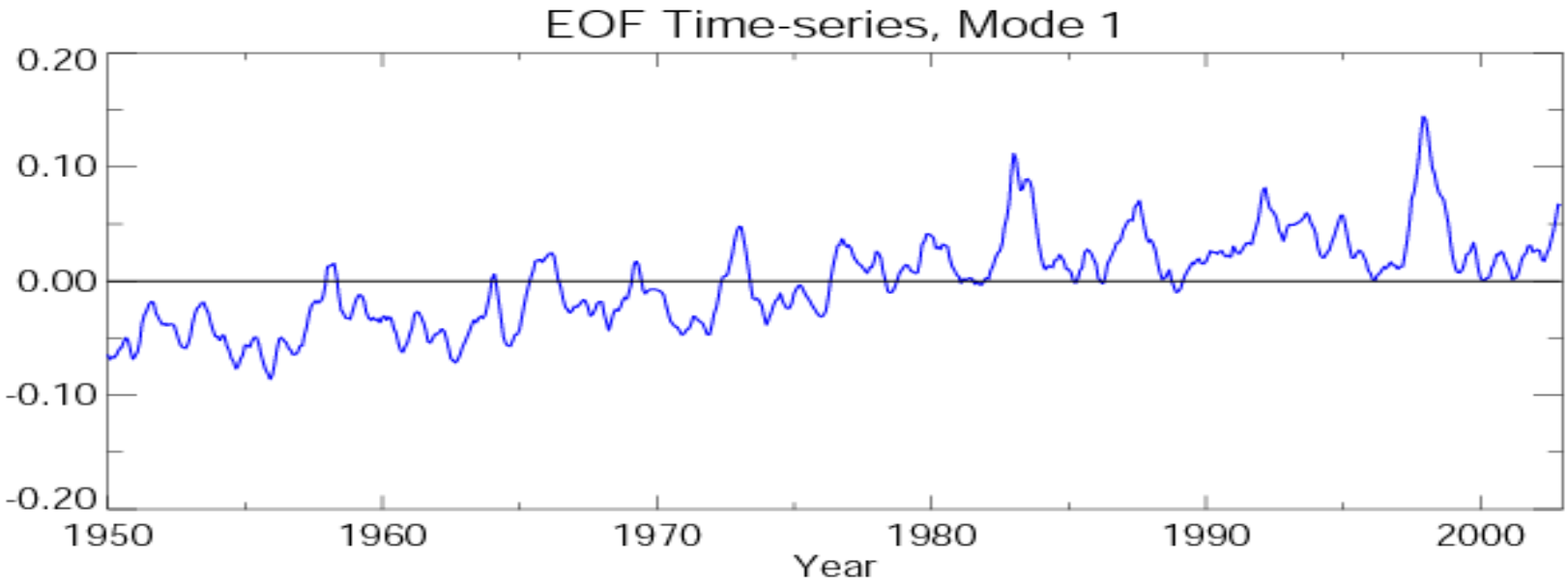


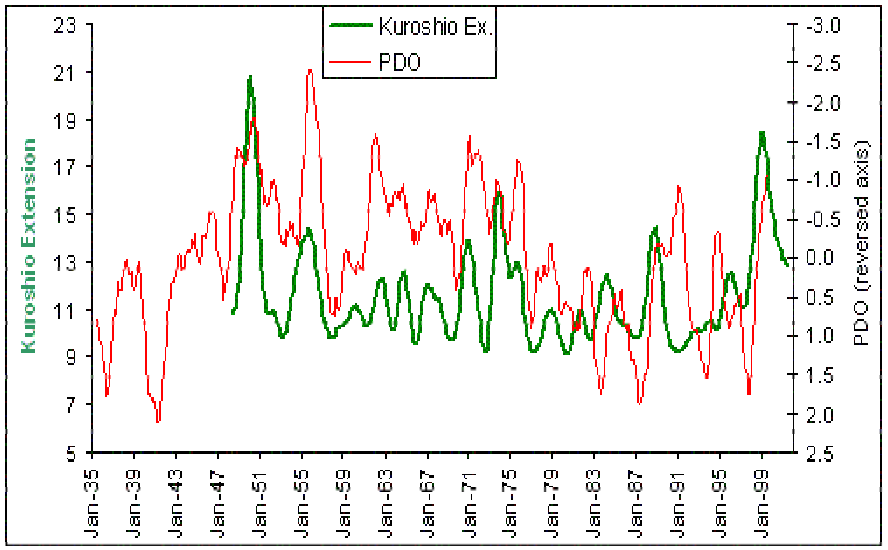


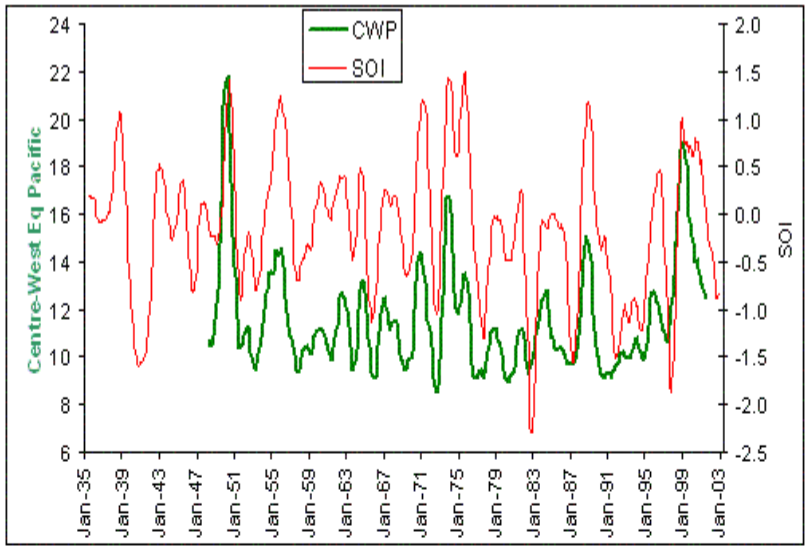
The second mode may say more about the ‘gyre’ mode. Can we quantify the Biogeochemical signals associated with the first and second modes?

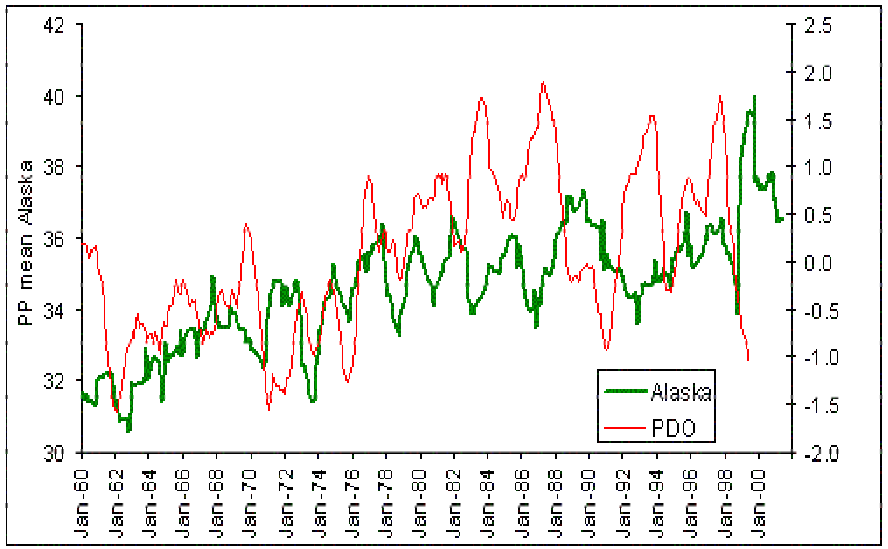
Connection to the tropics and Ecosystem response

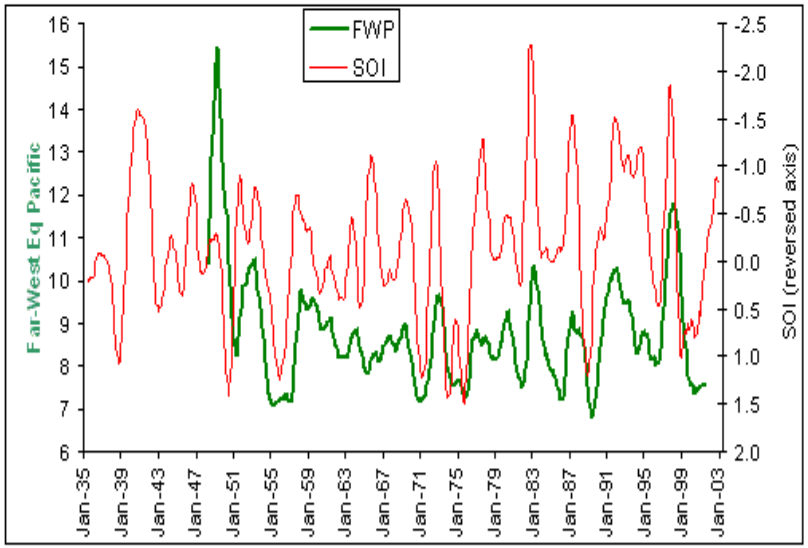




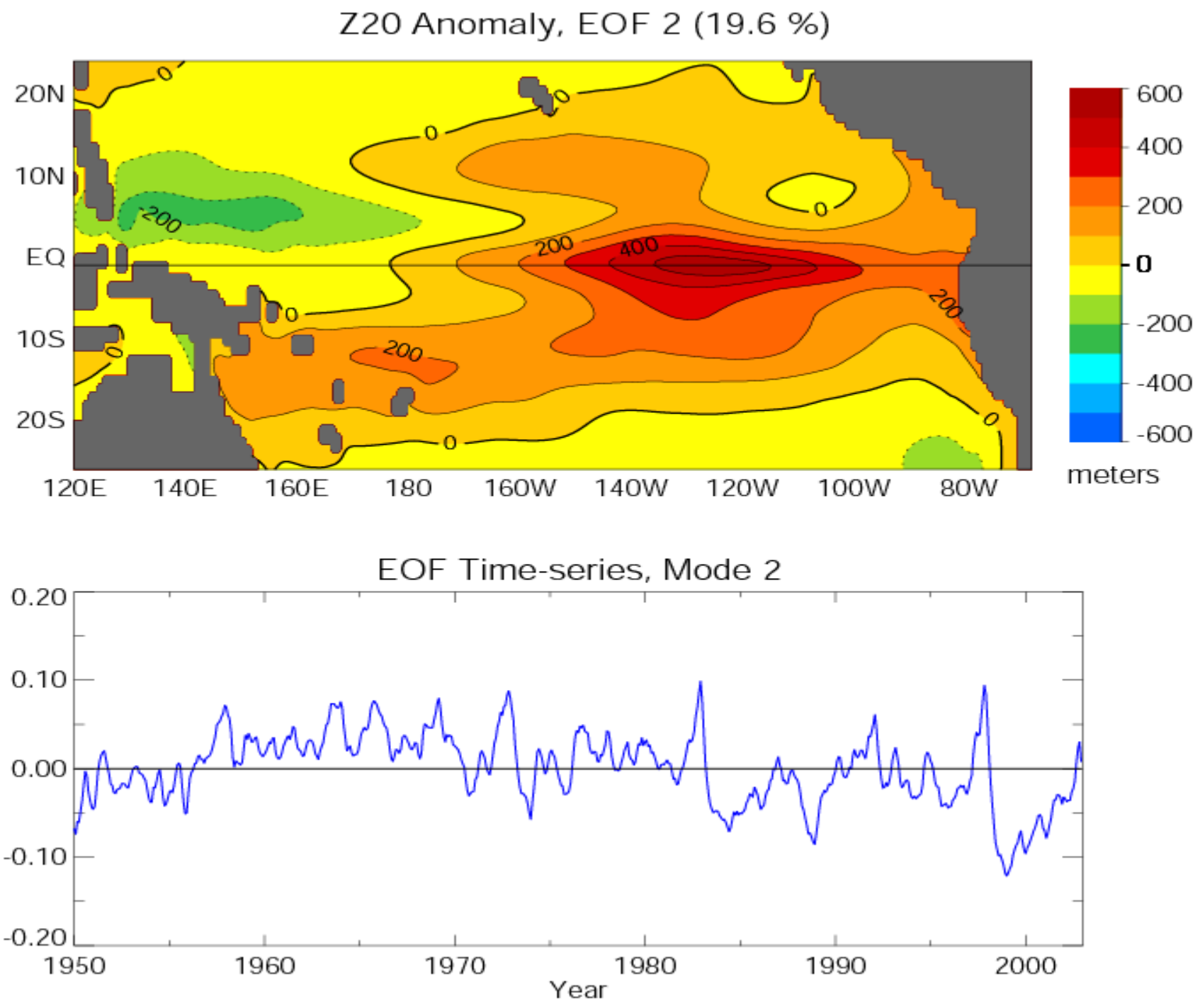


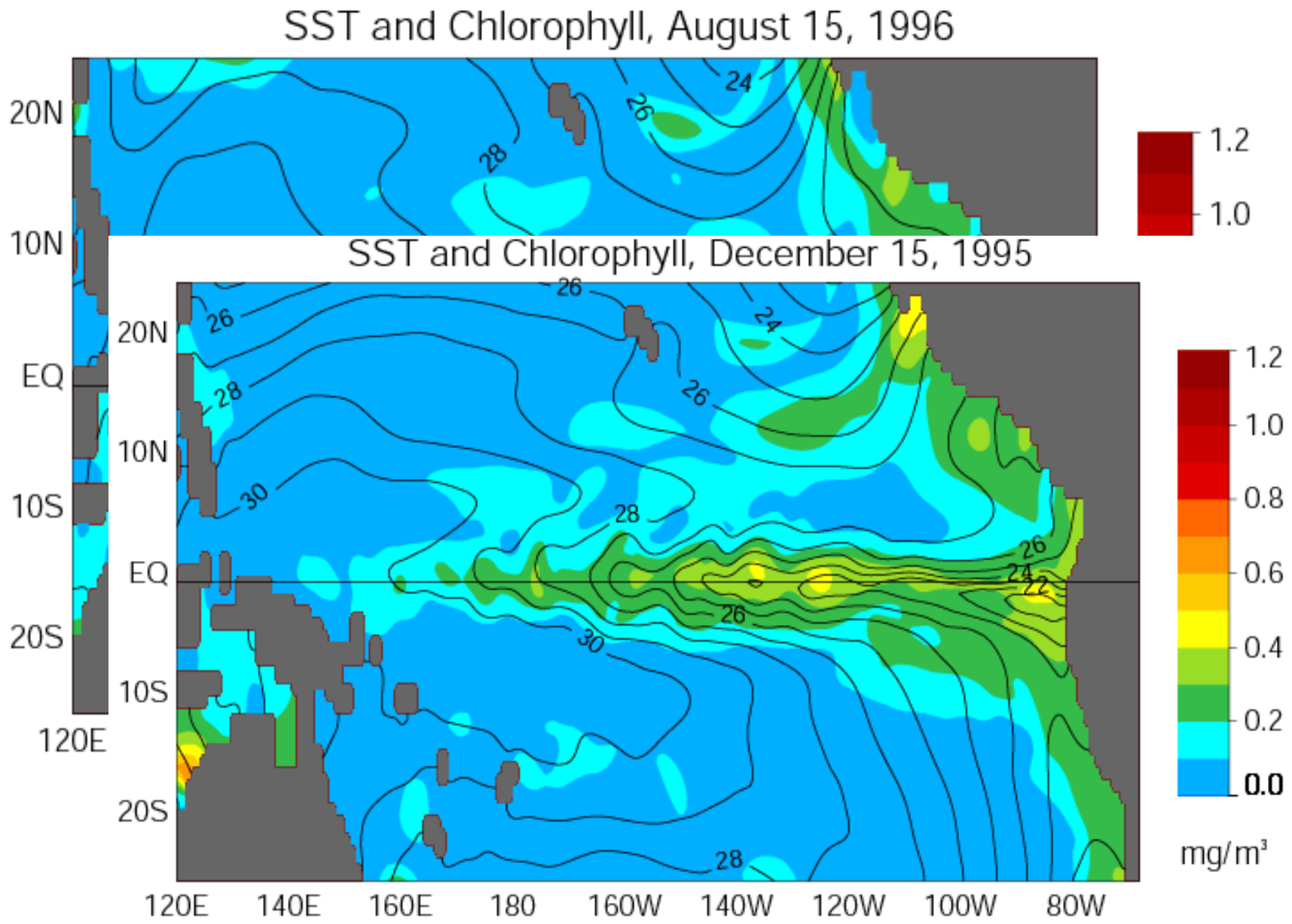


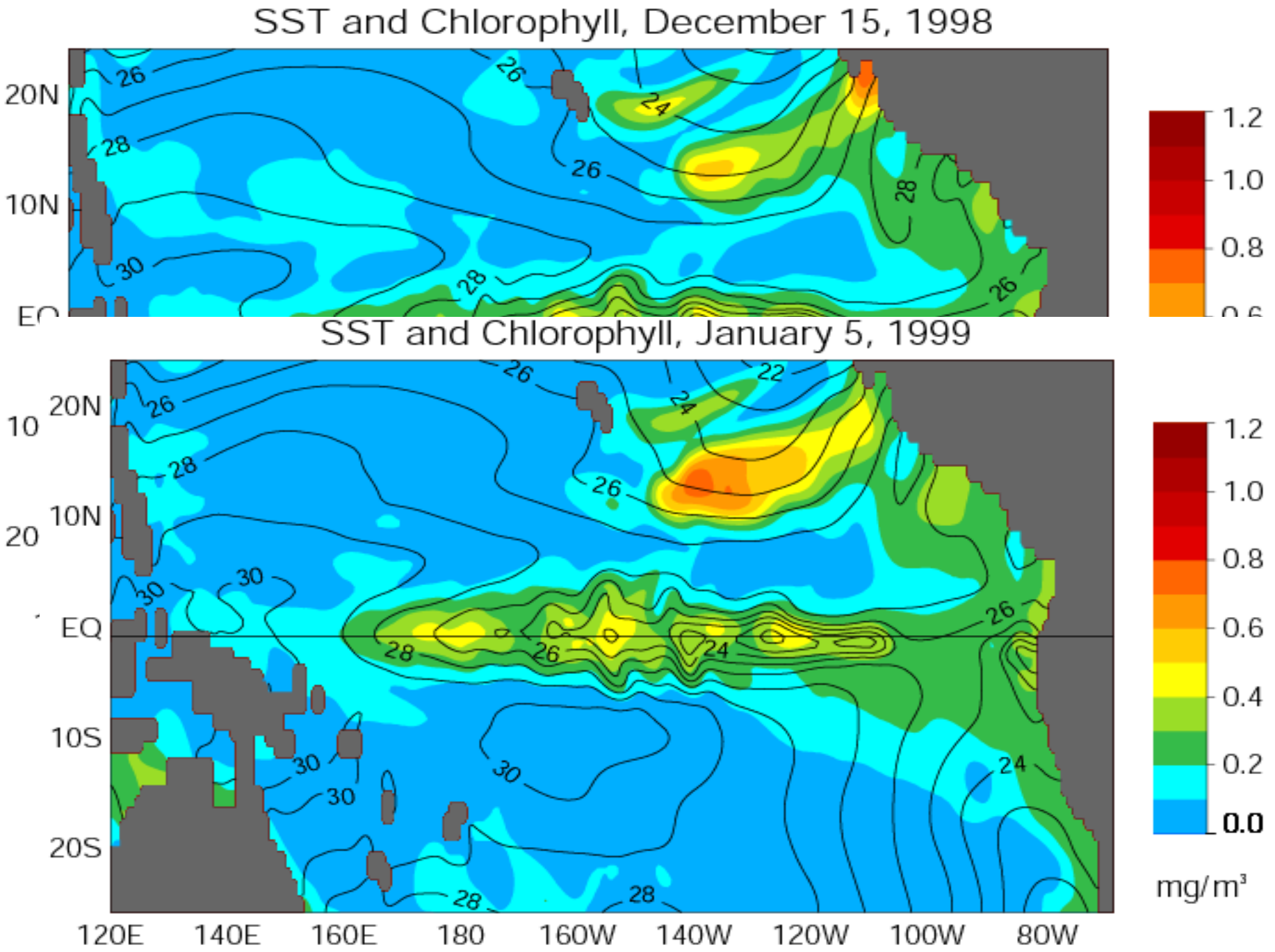


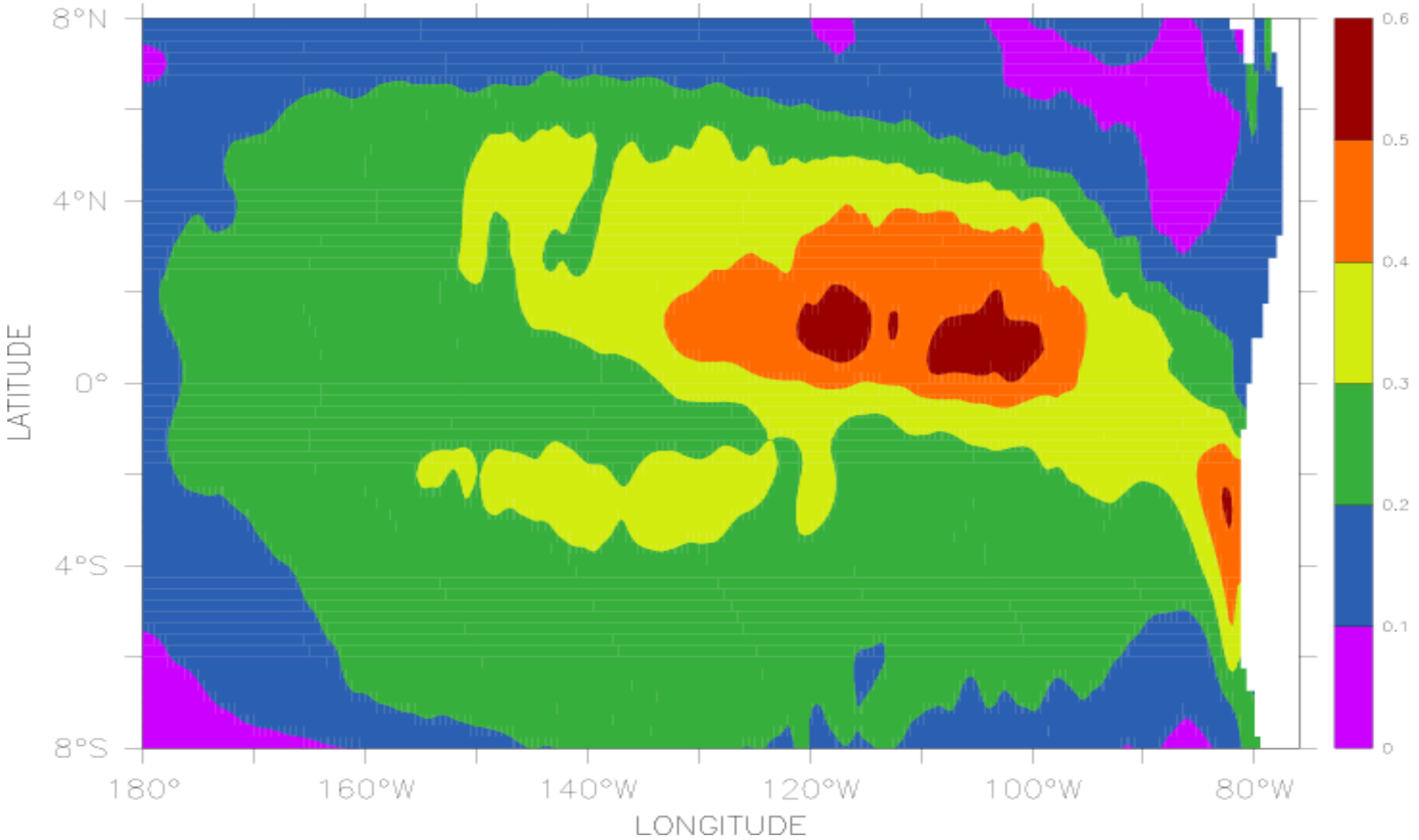


Primary production from the ecosystem model.


Z20 Anomaly, EOF 2 (19.6 %)
20N
10N
EQ
10S
20S
120E
140E
160E
180
160W
140W
120W
100W
80W
0
200
400
600
-200
-400
-600
meters
EOF Time-series, Mode 2
0.20
0.10
0.00
-0.10
-0.20
1950
1960
1970
1980
1990
2000
Year

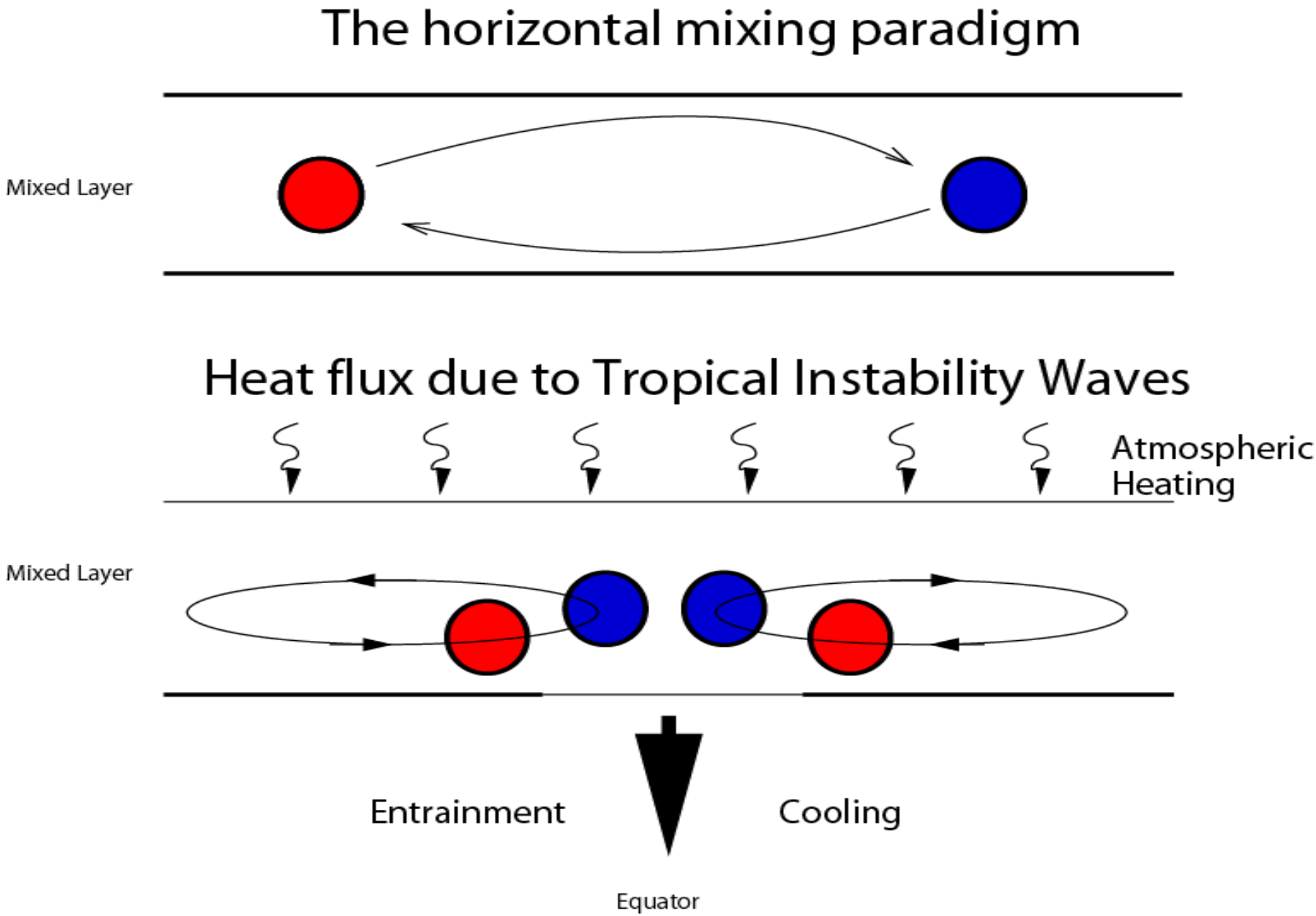

SST and Chlorophyll, August 15, 1996
20N
10N
24
26
28
1.2
1.0
SST and Chlorophyll, December 15, 1995
20N
EQ
10S
20S
120E
26
24
28
30
22
1.2
1.0
0.8
0.6
0.4
0.2
0.0
mg/m³
120E
140E
160E
180
160W
140W
120W
100W
80W


SST and Chlorophyll, December 15, 1998
20N
10N
EQ
SST and Chlorophyll, January 5, 1999
10
20
20N
10N
EQ
10S
20S
120E
140E
160E
180
160W
140W
120W
100W
80W
1.2
1.0
0.8
0.6
0.4
0.2
0.0
mg/m³

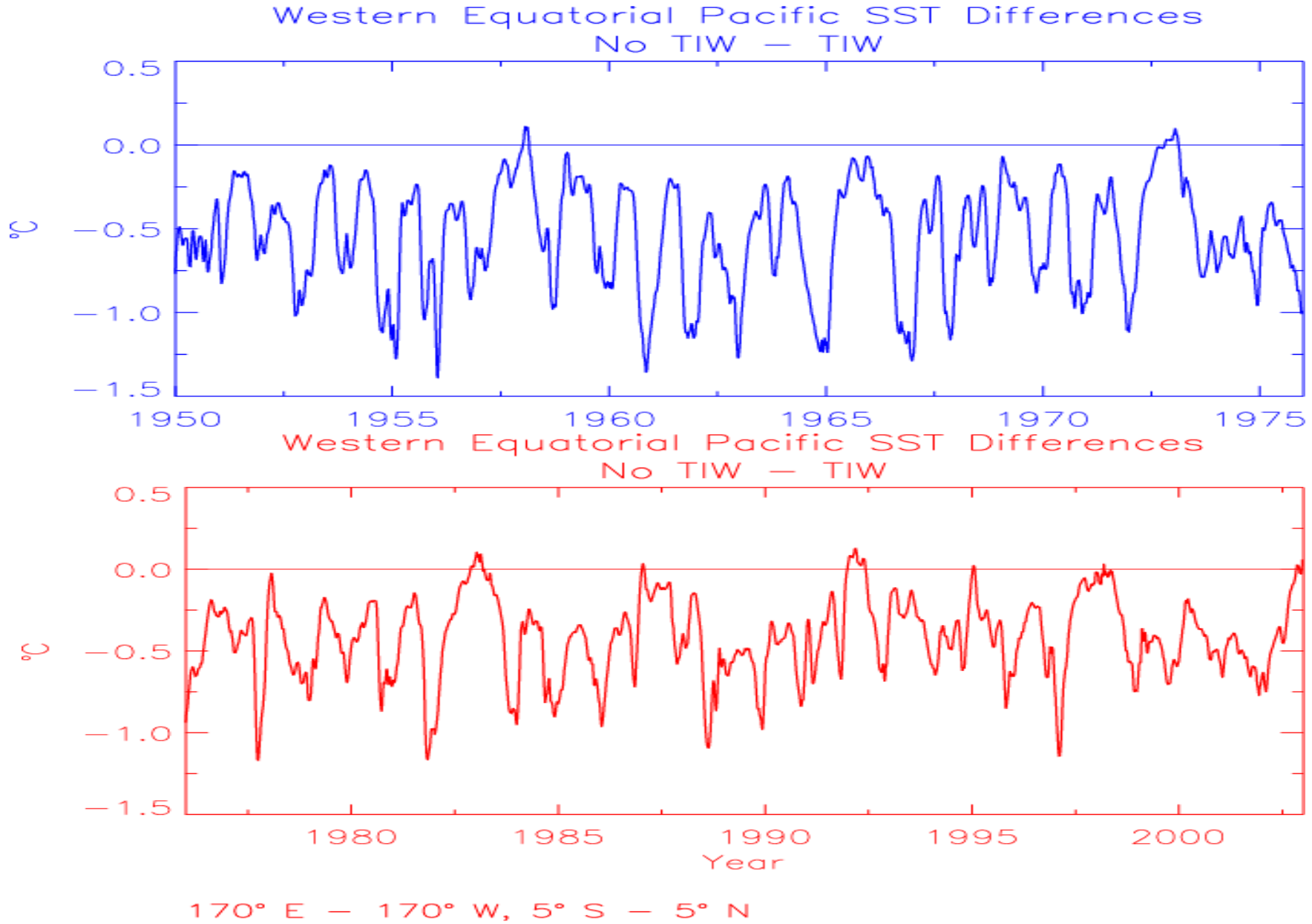


The variance of SST due to internal variability is comparable to any other source of stochastic forcing or changes due to STCs.

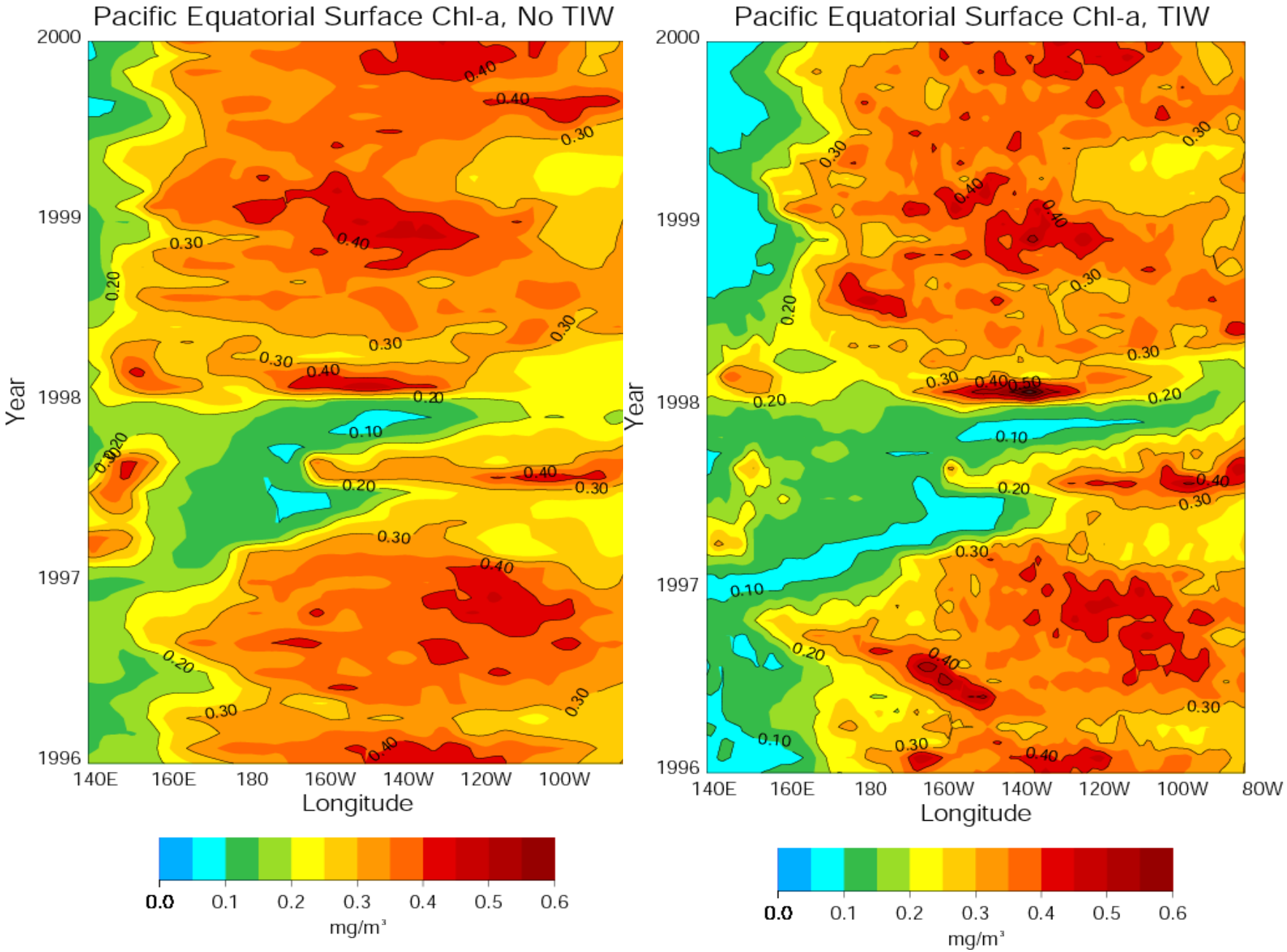
MORE IMPORTANTLY, the decorrelation length scales are ~1000Km!!!

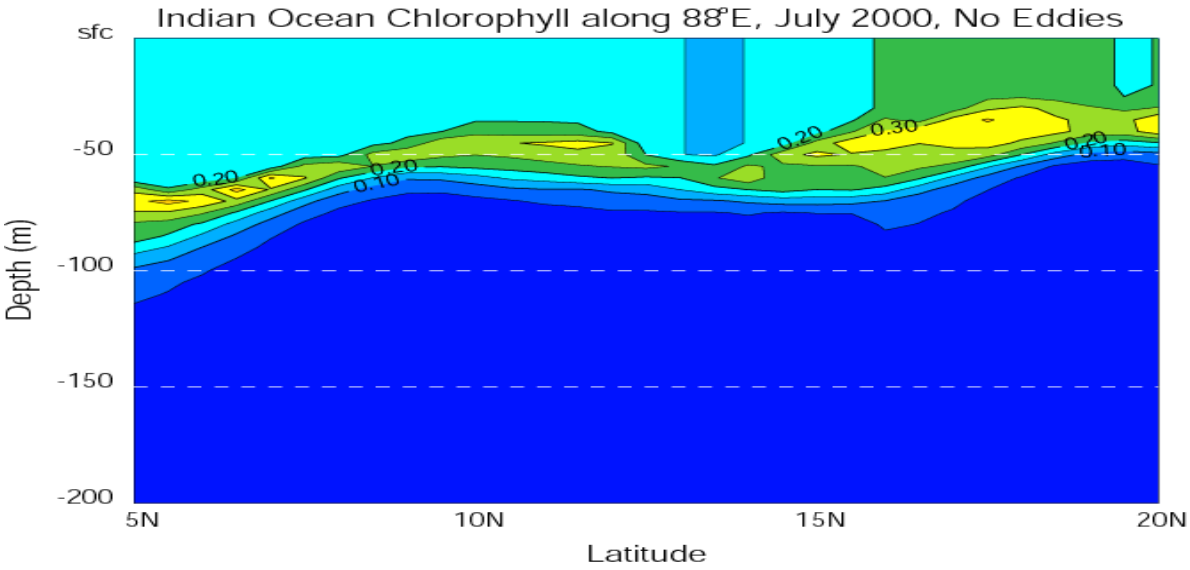

The horizontal mixing paradigm
Mixed Layer
Heat flux due to Tropical Instability Waves
Atmospheric
Heating
Mixed Layer
Entrainment
Cooling
Equator

The warm pool gets warmer SSTs through zonal advection from the cold-tongue.

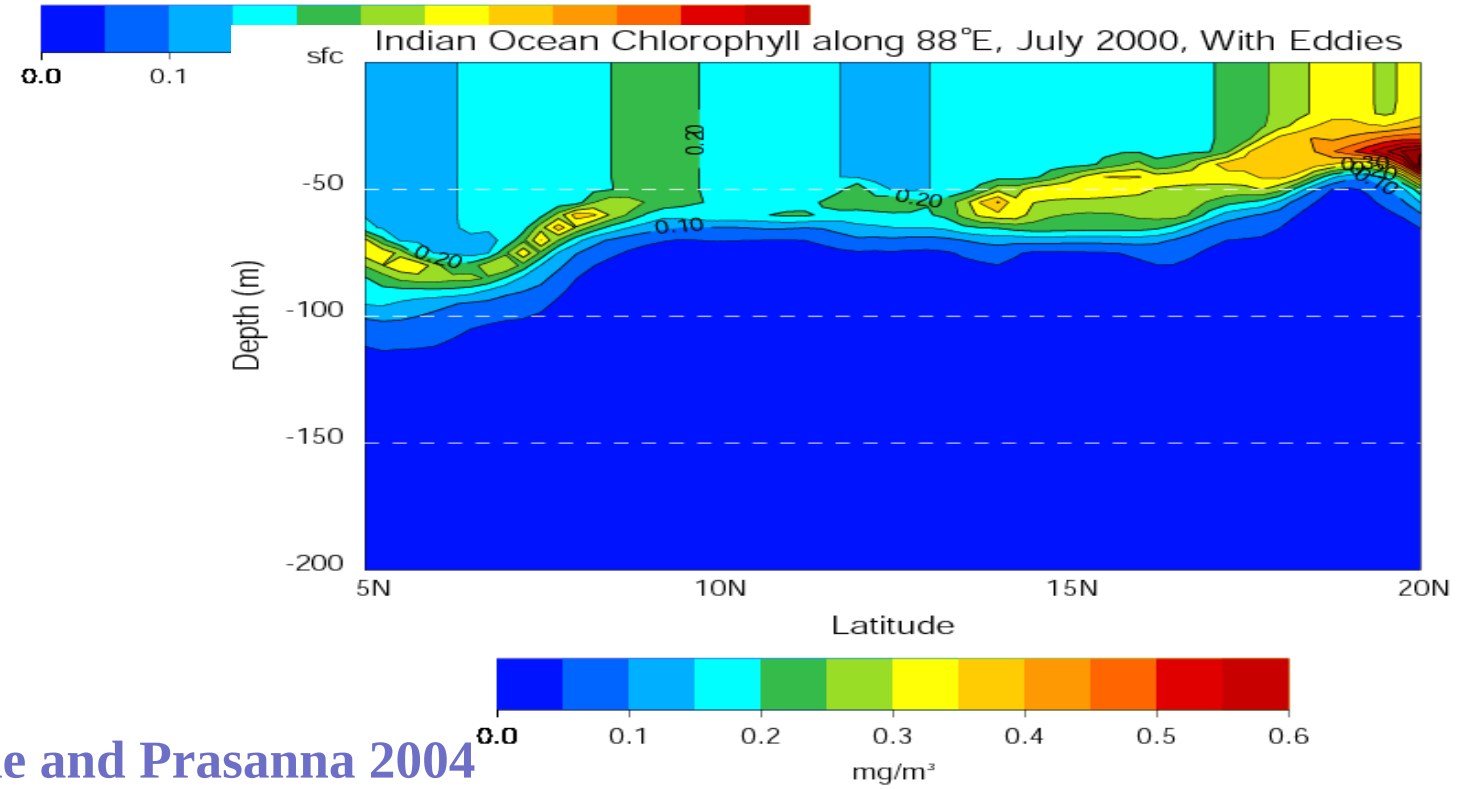


Biogeochemical Consequences of TIWs: The 1998 El Niño-La Niña Transition



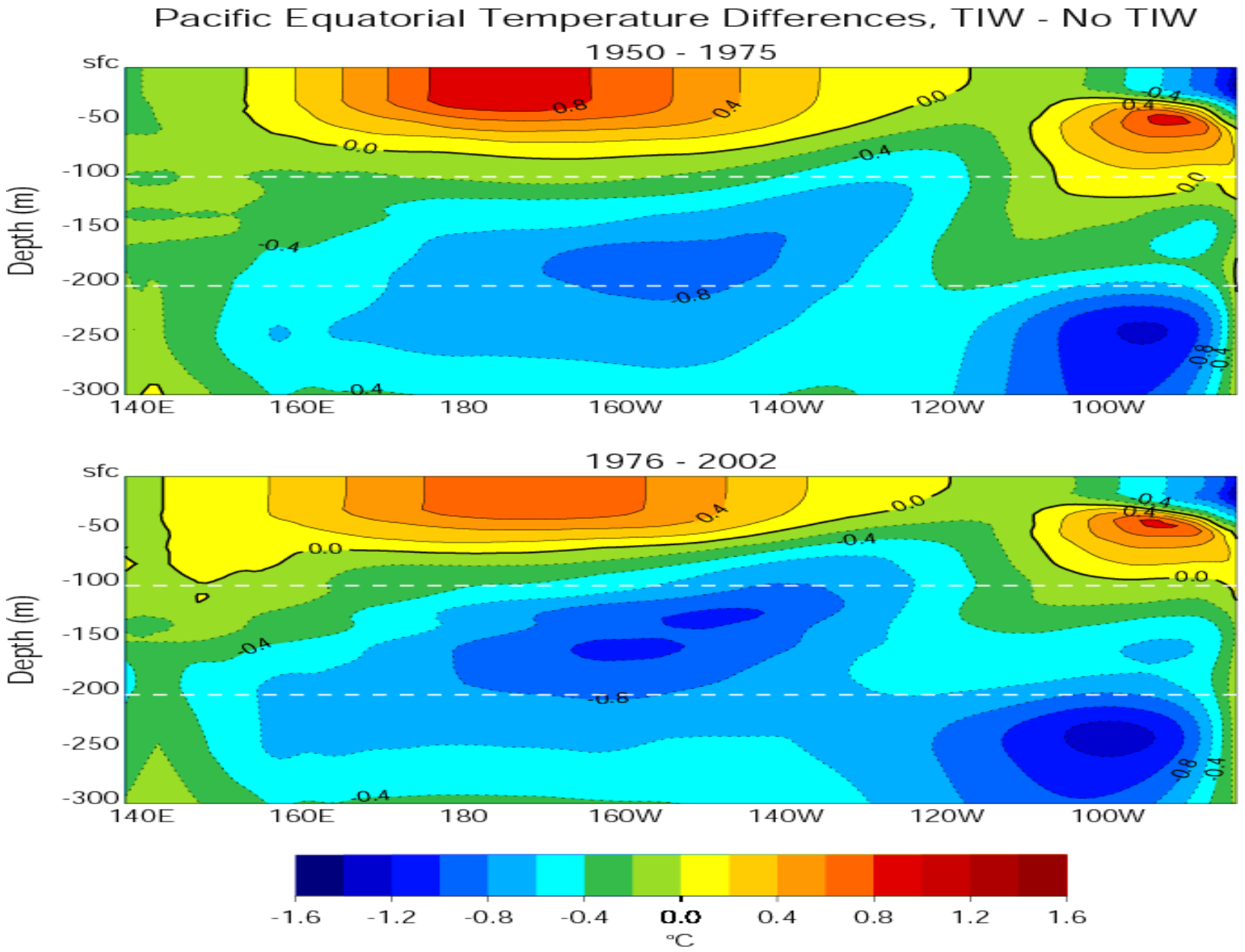


What drives the productivity in the Bay of Bengal?

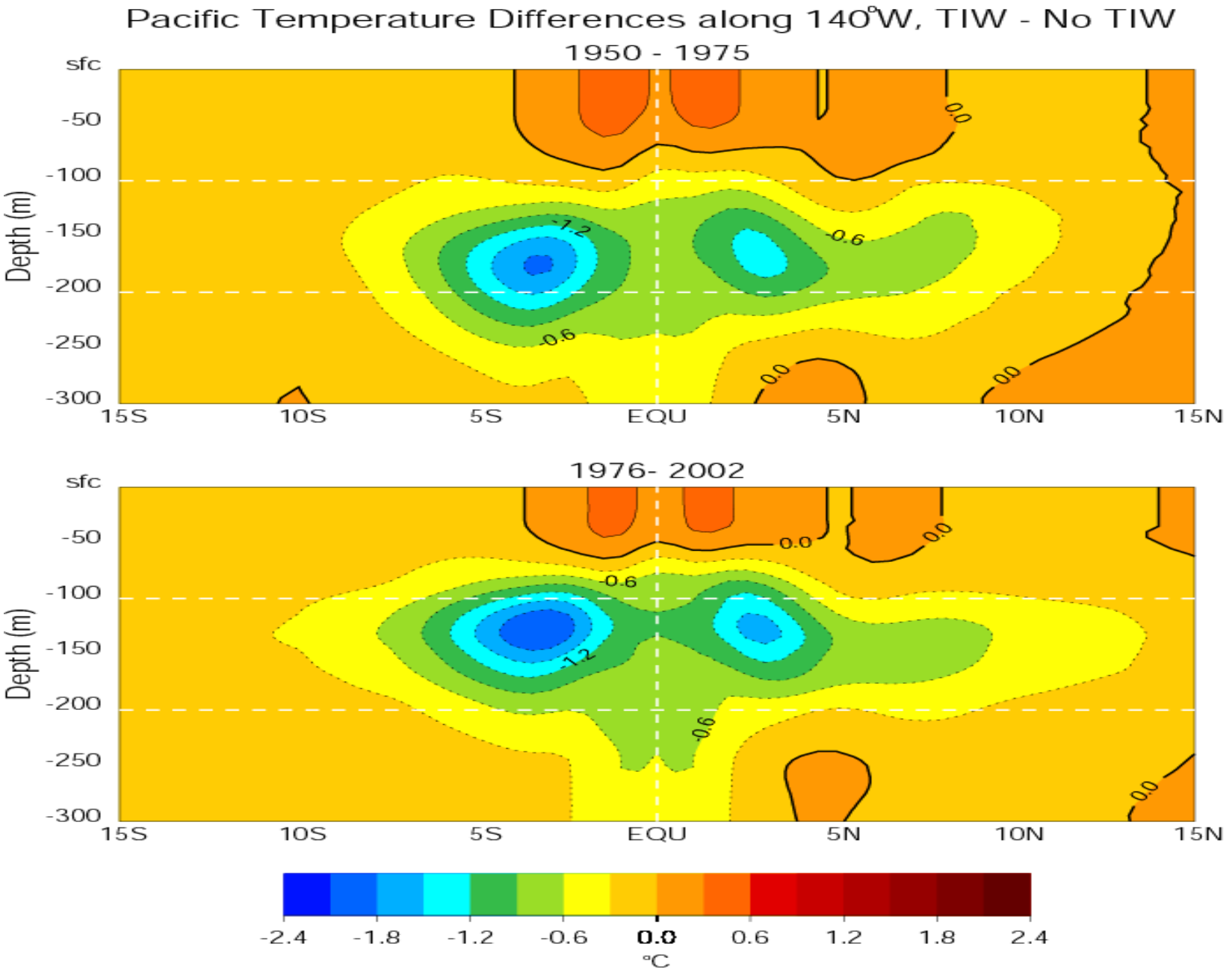


Murtugudde and Prasanna 2004

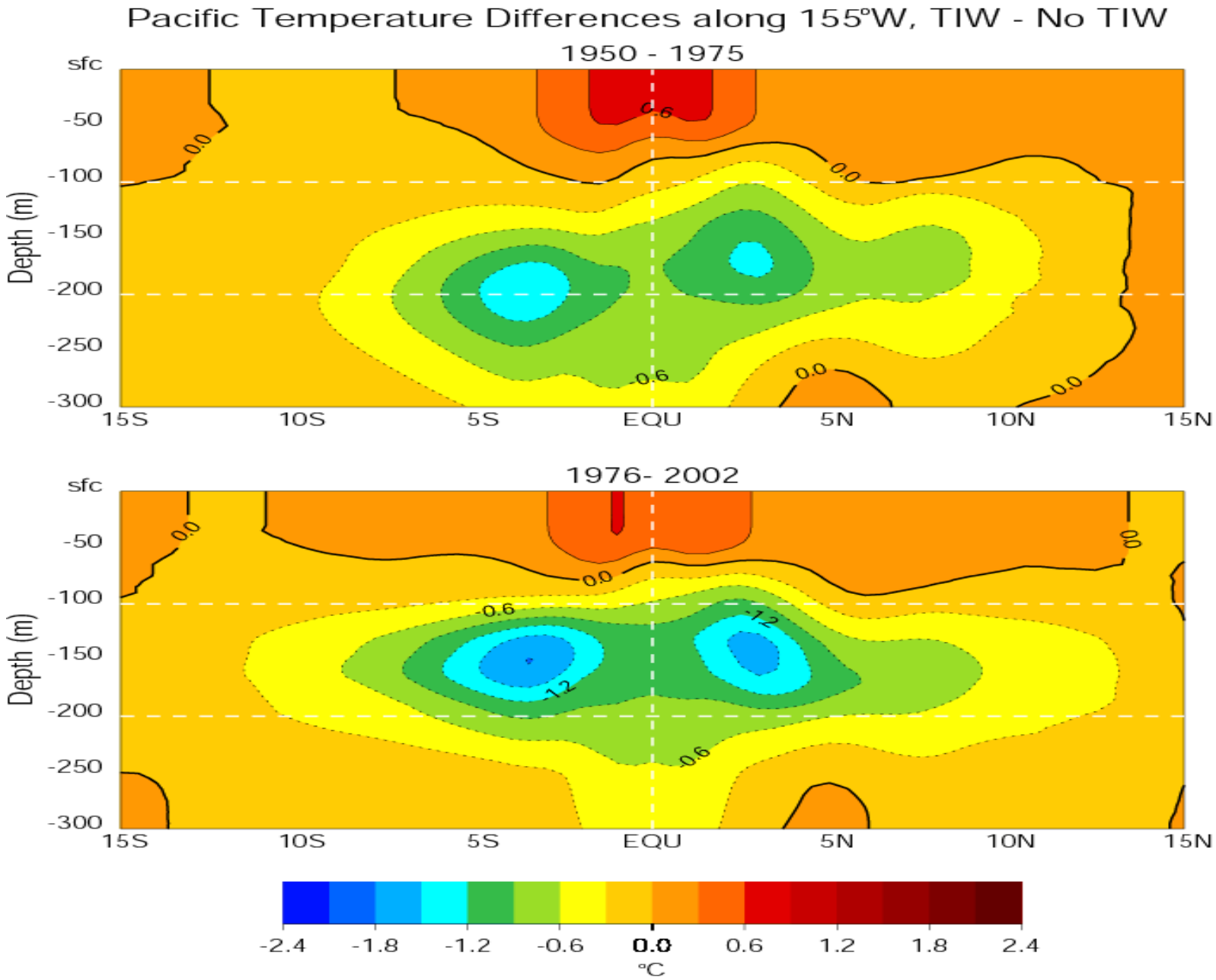
TIWs reduce the cold-bias in SST, restratify the thermocline better in the east, And improve the thermocline gradient over much of the equatorial ocean.

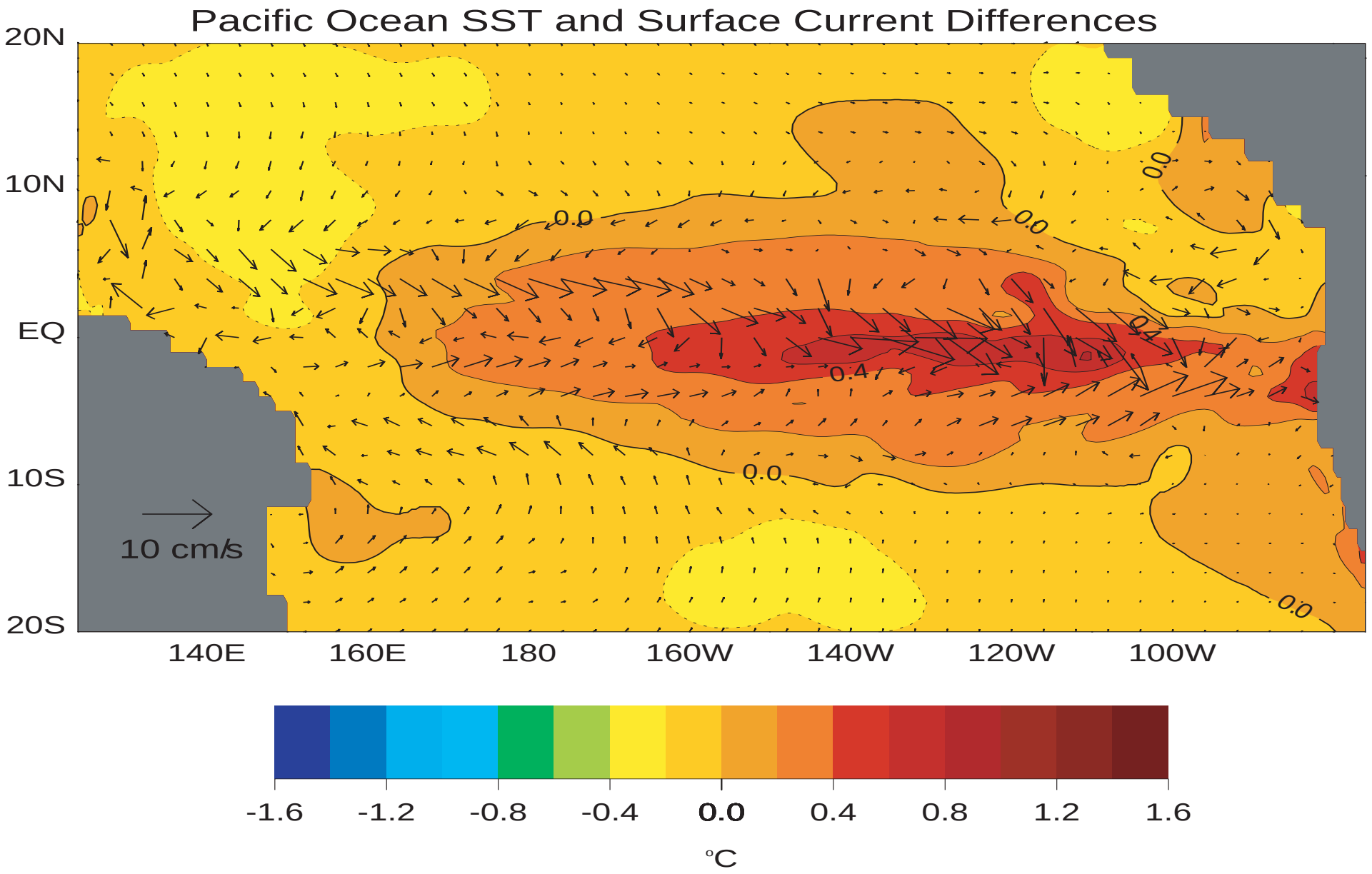


The thermocline differences are restricted to the TIW scales.

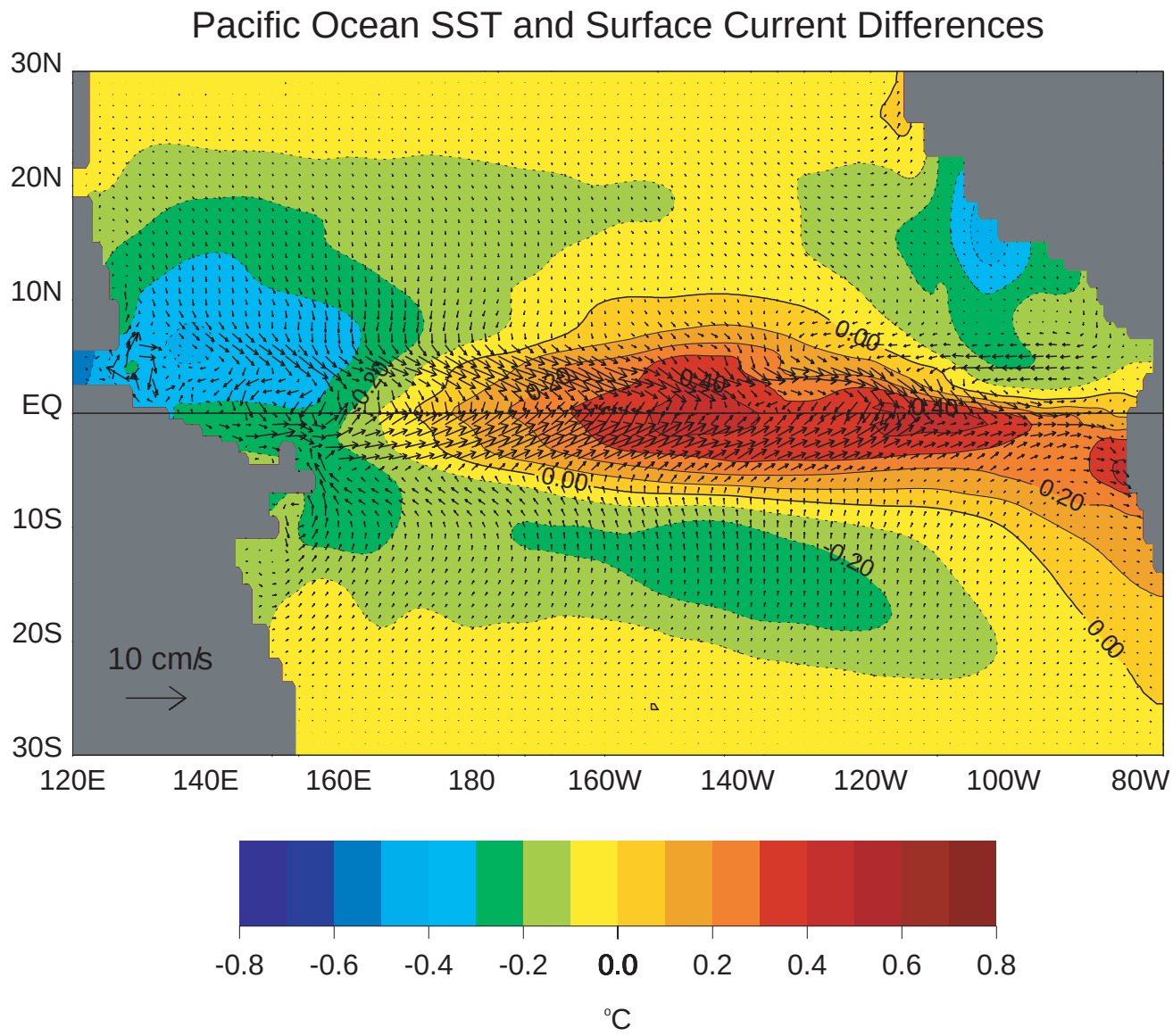


Even in the central-western Pacific, TIWs determine the differences

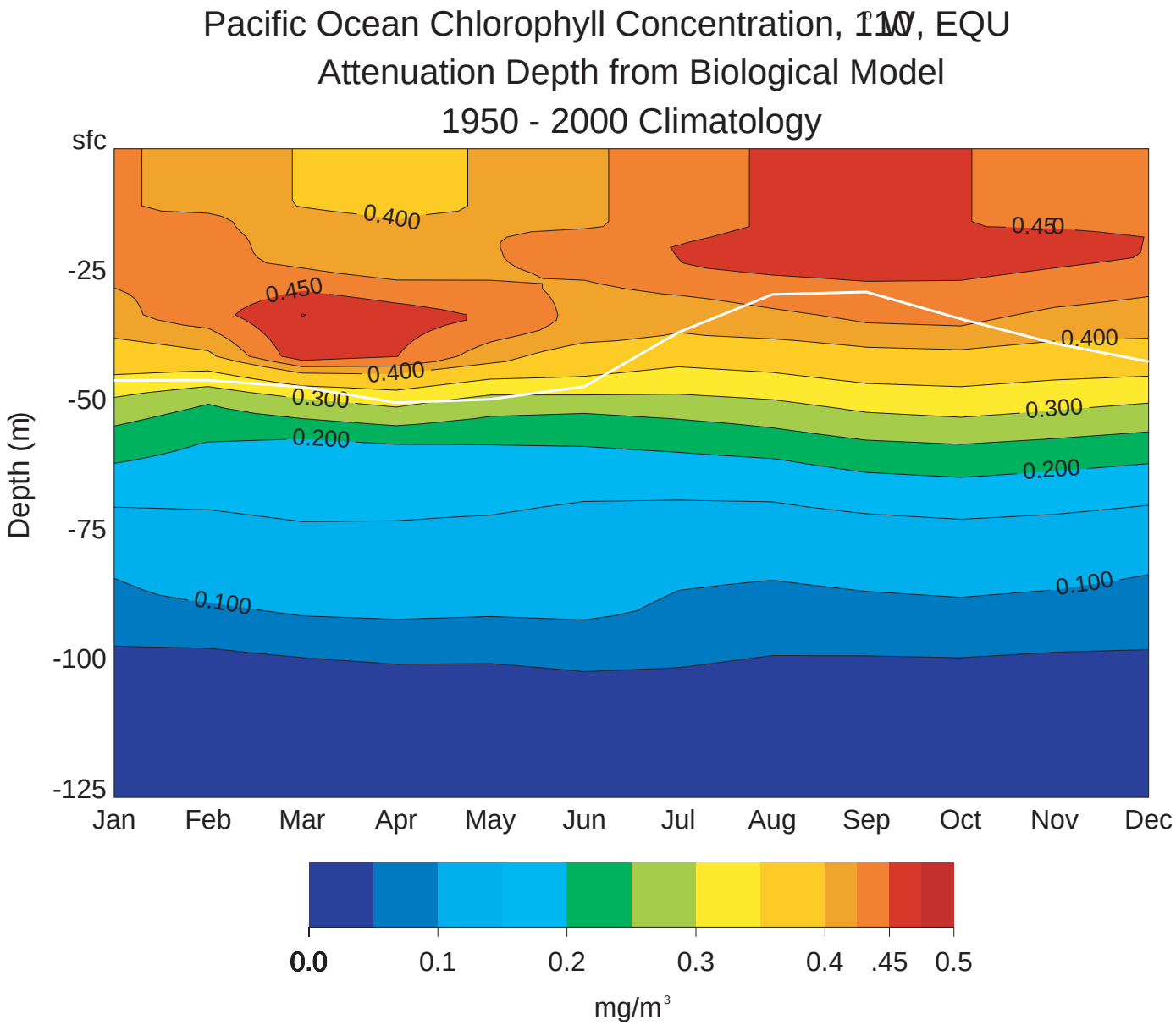




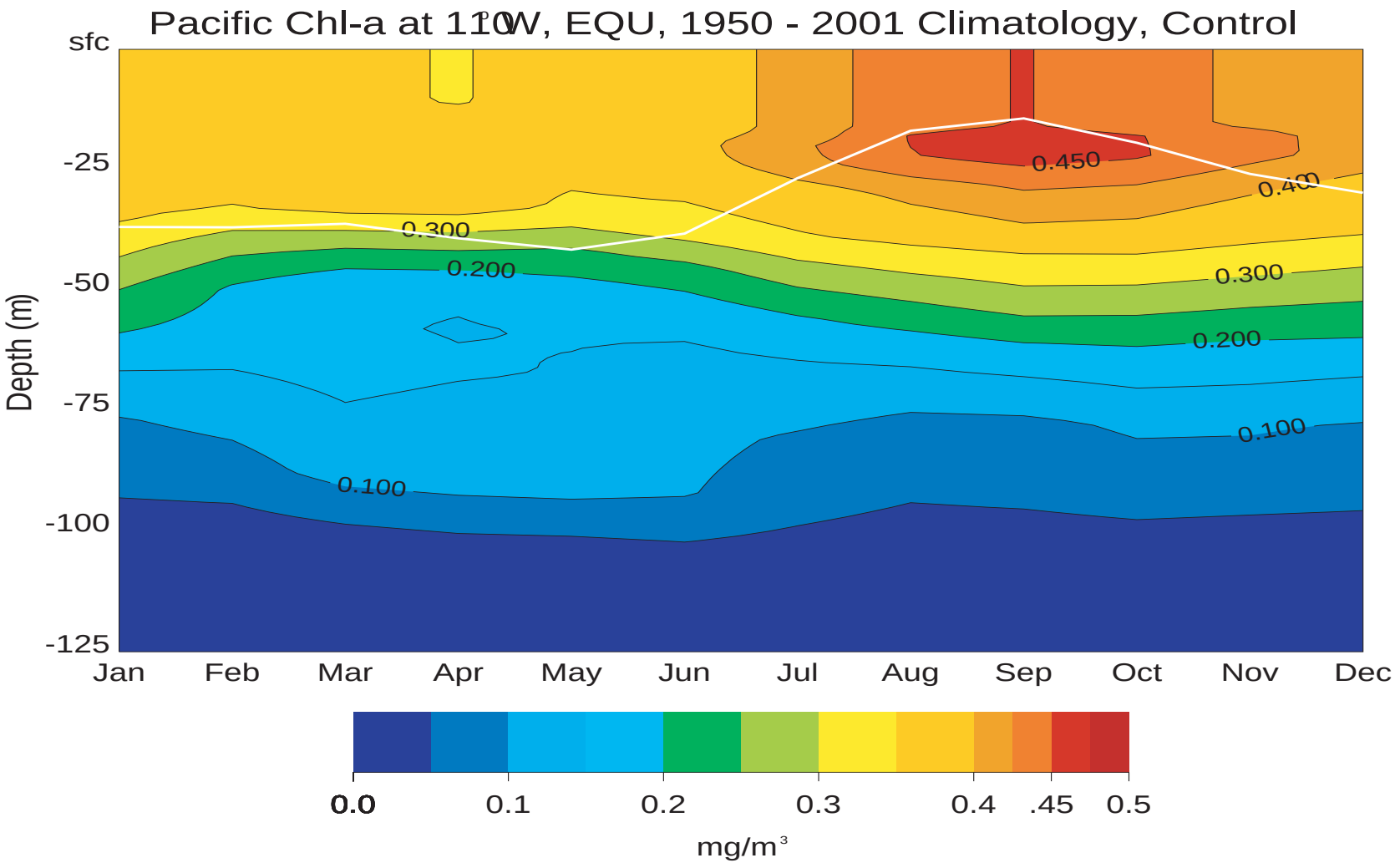
Annual mean SST and current differences for the Pacific.



SST and current differences between runs with and without Feedbacks between biology and physics.

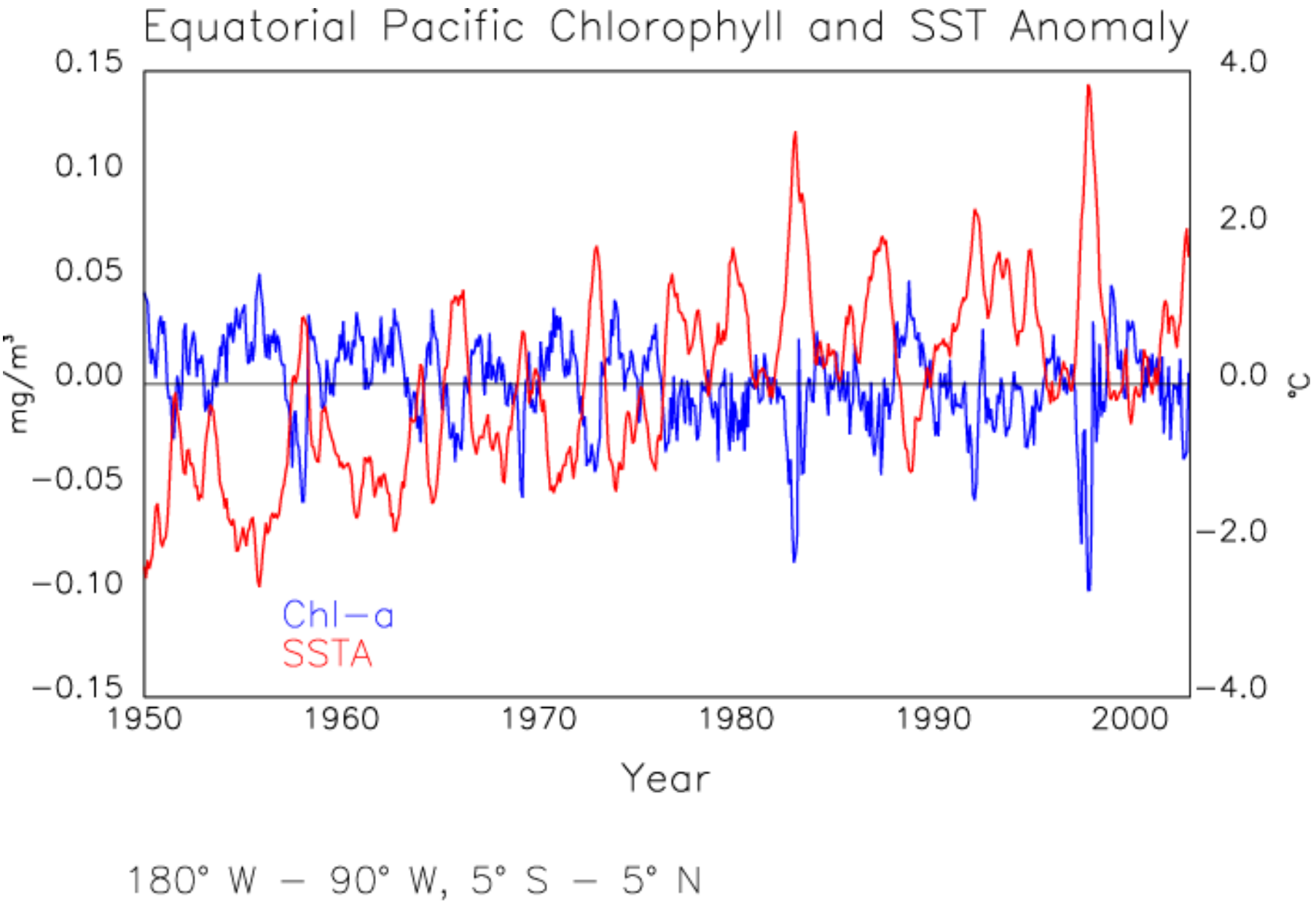


There is indeed a deep Chl-a maximum in March/April.

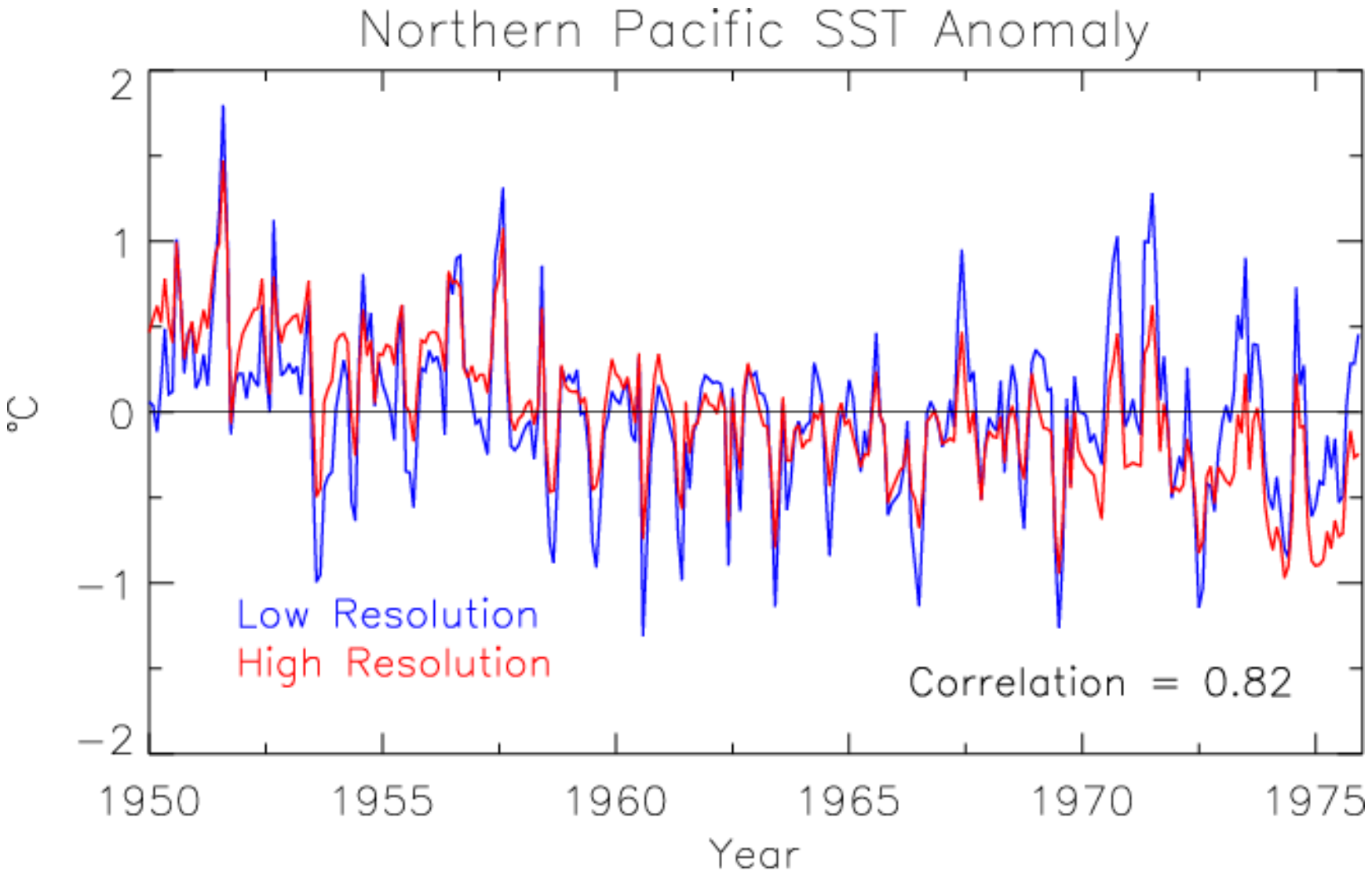


The seasonal cycle of the Chl-a is dramatically different when the feedbacks to ocean circulation are ignored.

High frequency SST variability gets damped by fluxes but not Chl-a.

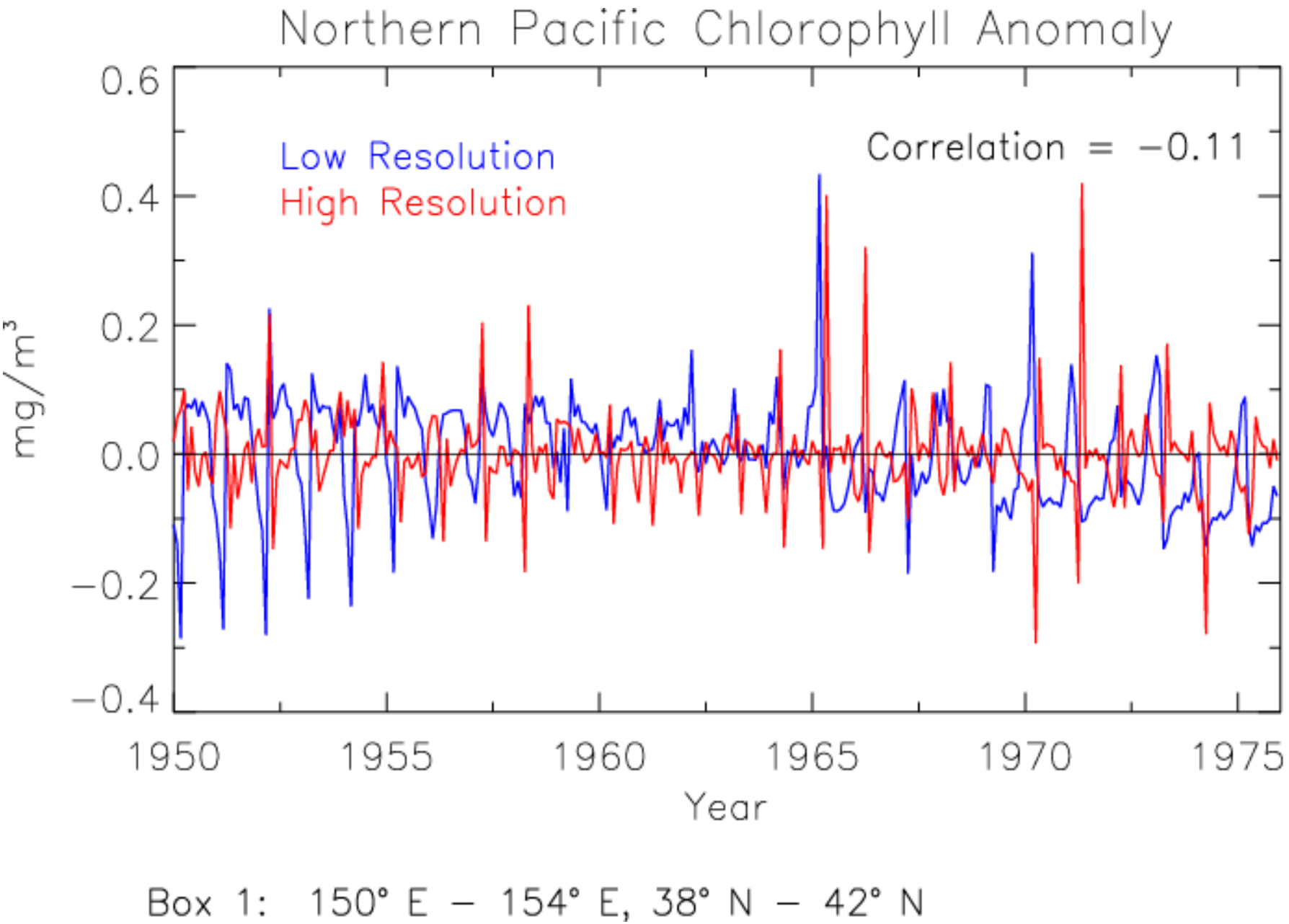


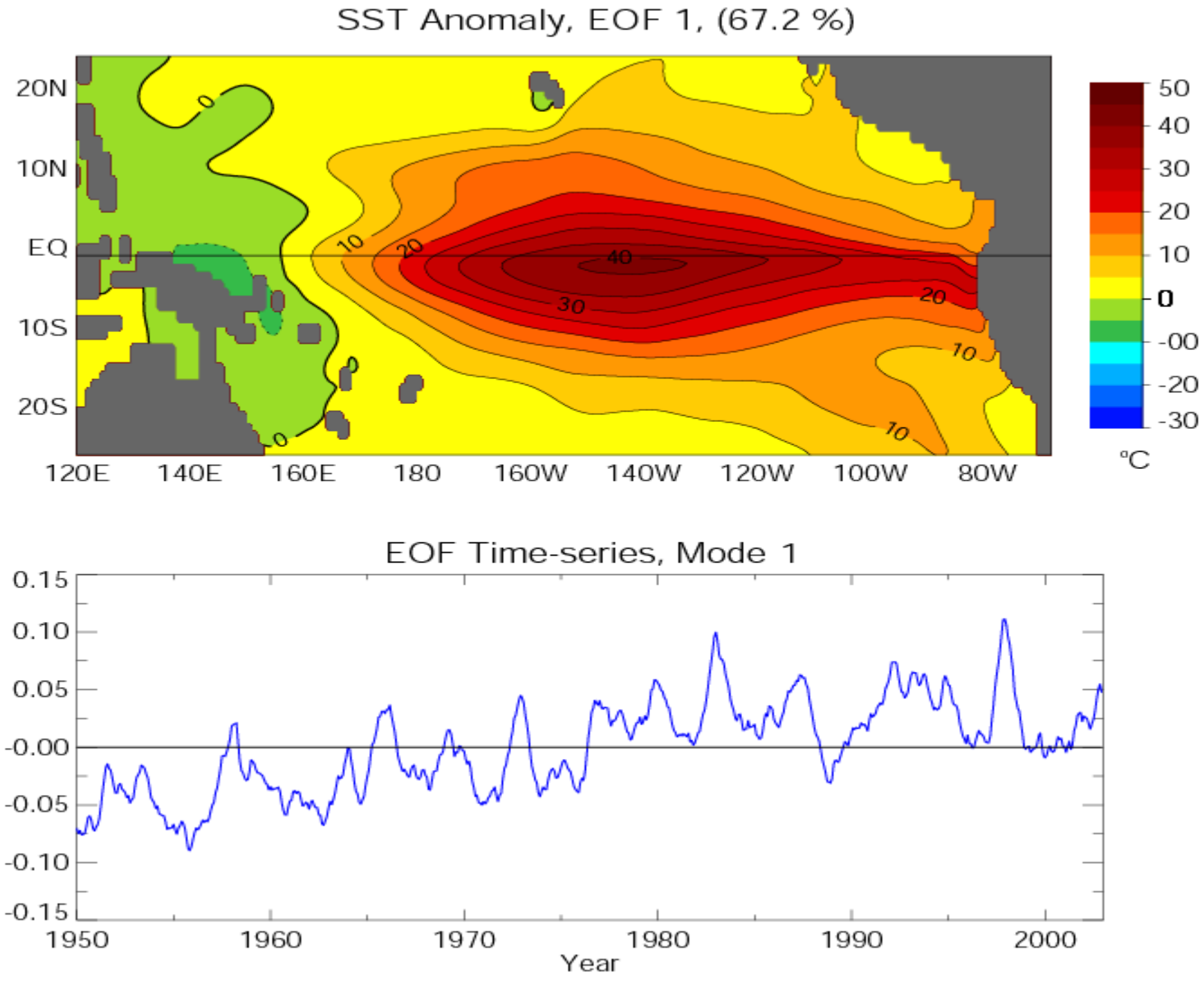
Resolving eddies does not affect SST variability significantly

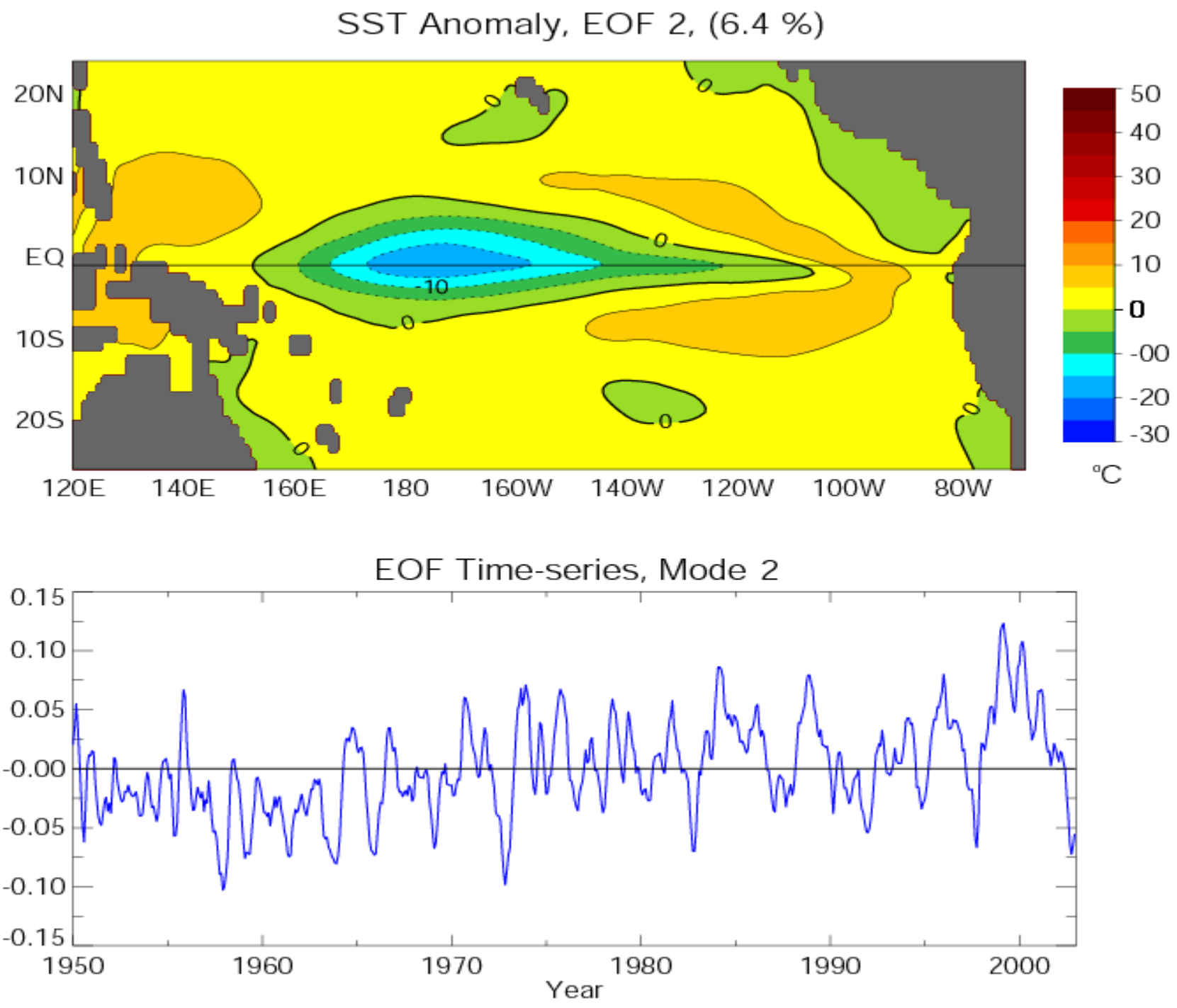


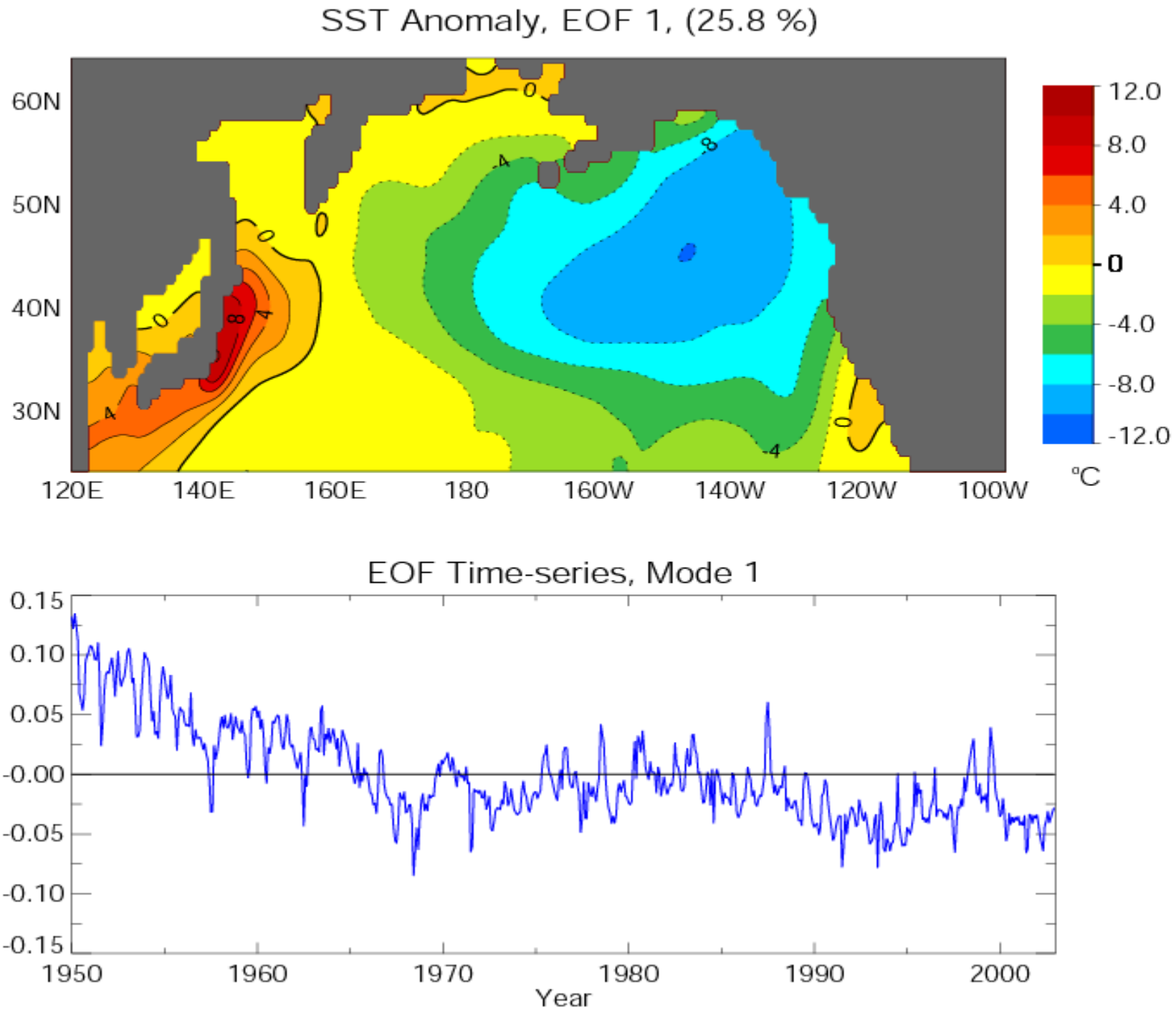
Box 1: 150° E – 154° E, 38° N – 42° N

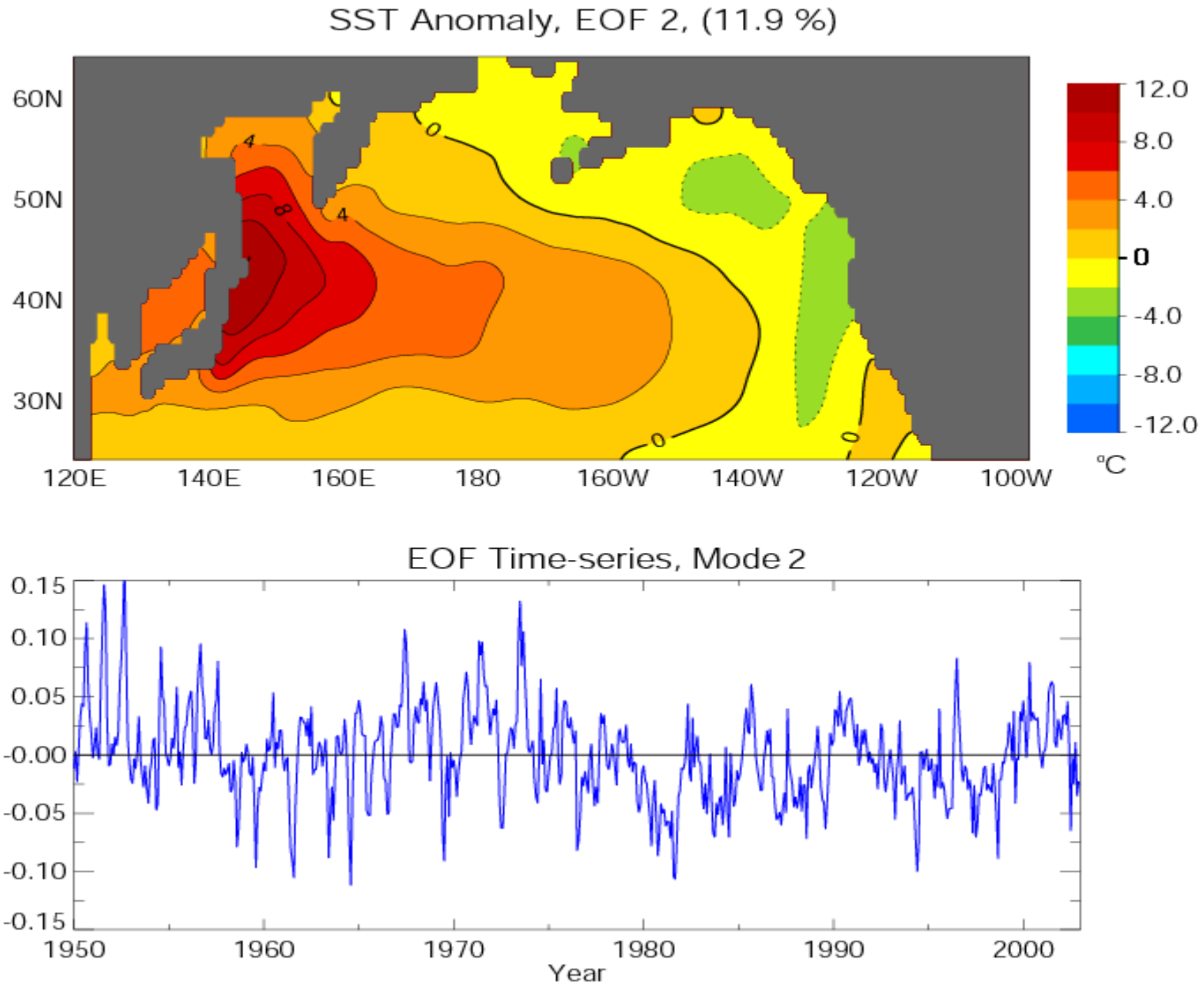
But chl-a variability changes dramatically. Is that realistic?



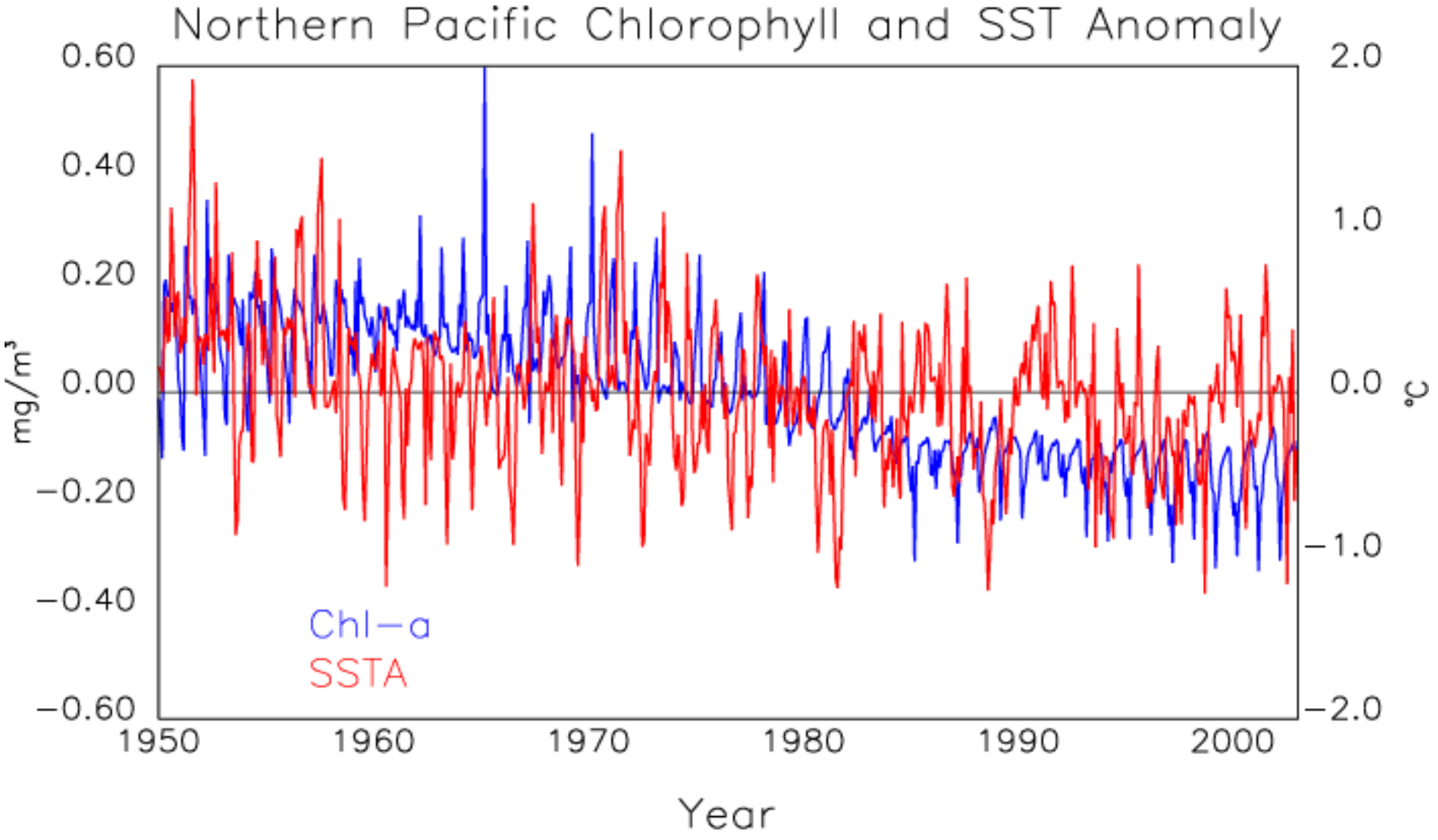

SST Anomaly, EOF 1, (67.2 %)
20N
10N
EQ
10S
20S
120E
140E
160E
180
160W
140W
120W
100W
80W
0
10
20
40
30
20
10
10
0
50
40
30
20
10
0
-00
-20
-30
°C
EOF Time-series, Mode 1
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year


SST Anomaly, EOF 2, (6.4 %)
20N
10N
EQ
10S
20S
120E
140E
160E
180
160W
140W
120W
100W
80W
50
40
30
20
10
0
-00
-20
-30
°C
EOF Time-series, Mode 2
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year

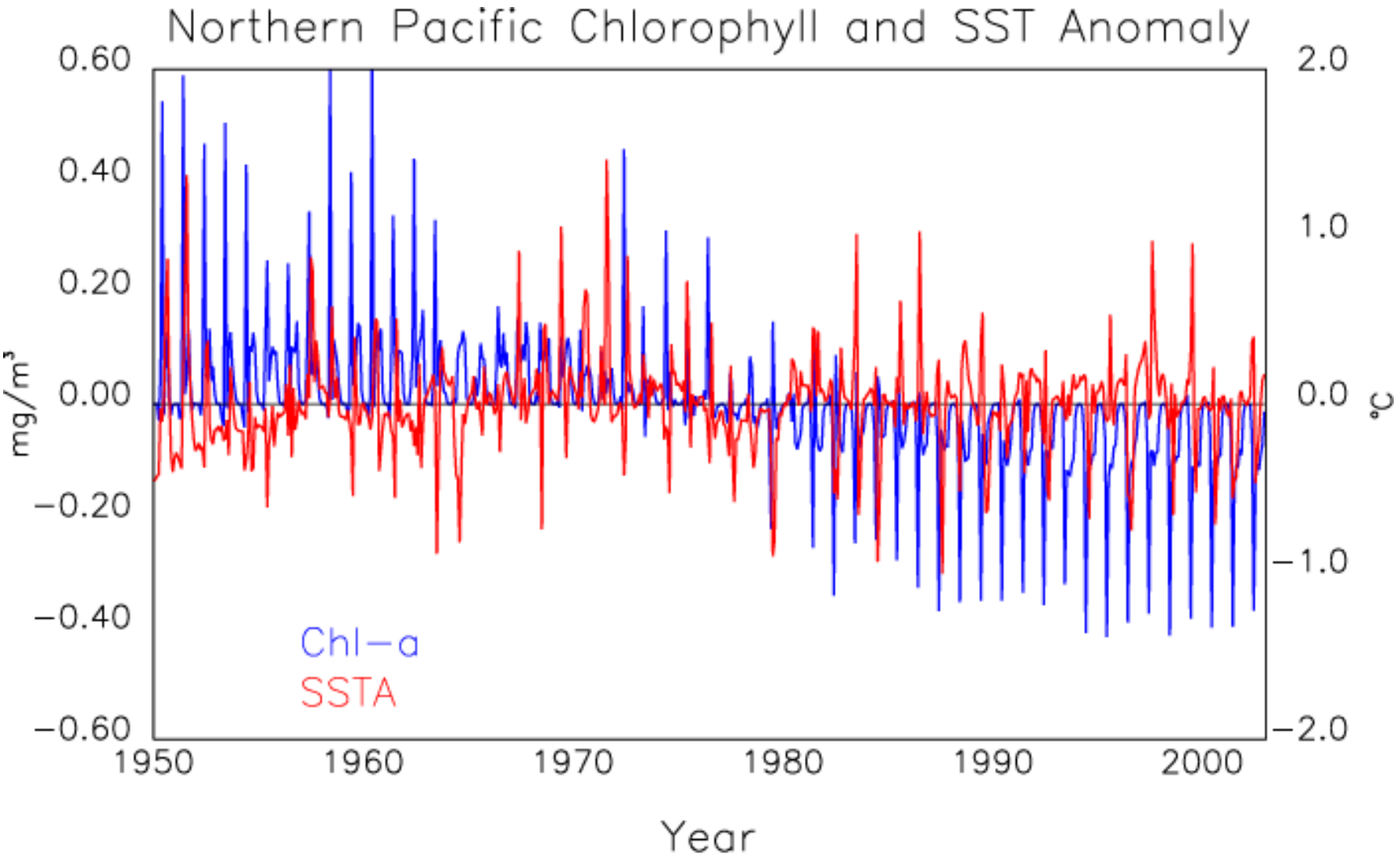

SST Anomaly, EOF 1, (25.8 %)
60N
50N
40N
30N
120E
140E
160E
180
160W
140W
120W
100W
12.0
8.0
4.0
0
-4.0
-8.0
-12.0
°C
EOF Time-series, Mode 1
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year


SST Anomaly, EOF 2, (11.9 %)
60N
50N
40N
30N
120E
140E
160E
180
160W
140W
120W
100W
12.0
8.0
4.0
0
-4.0
-8.0
-12.0
°C
EOF Time-series, Mode 2
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1960
1970
1980
1990
2000
Year

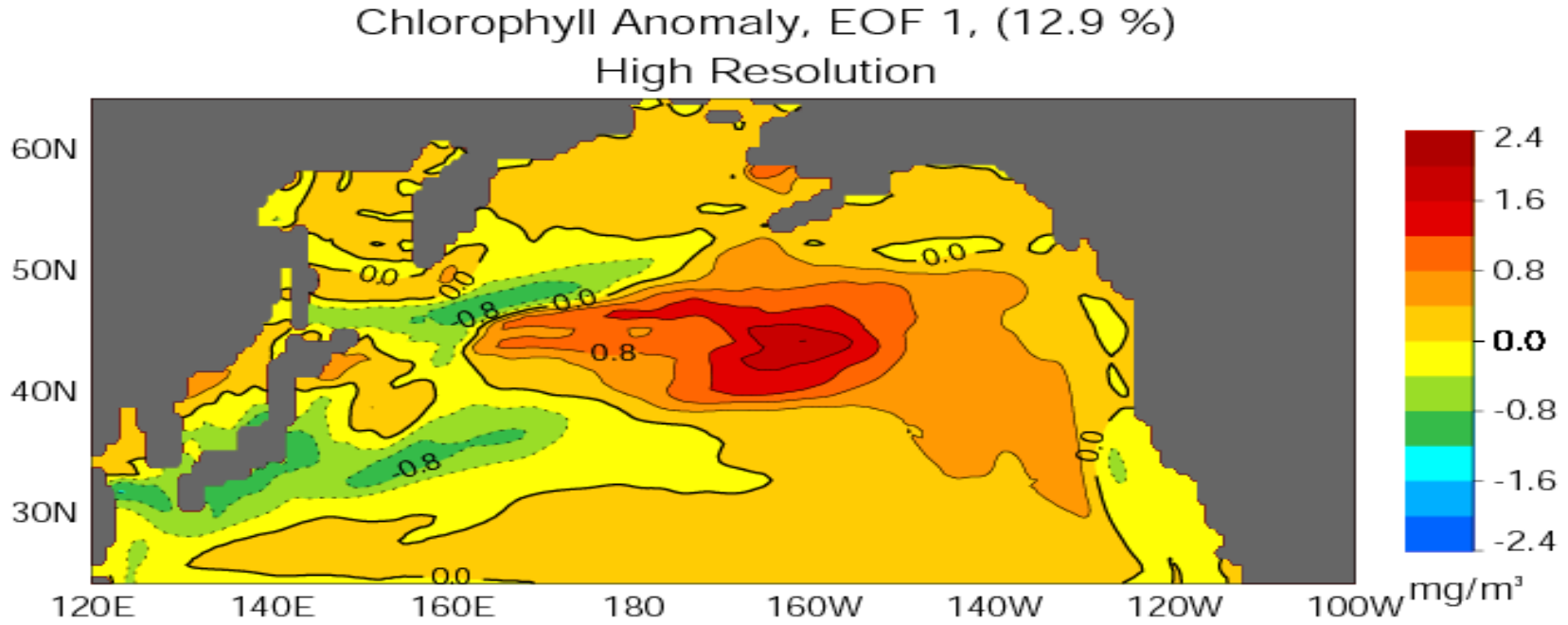
But at mid-latitudes, both SST and Chl-a display high-freq character.
Does the ecosystem have a regime shift-like behavior?

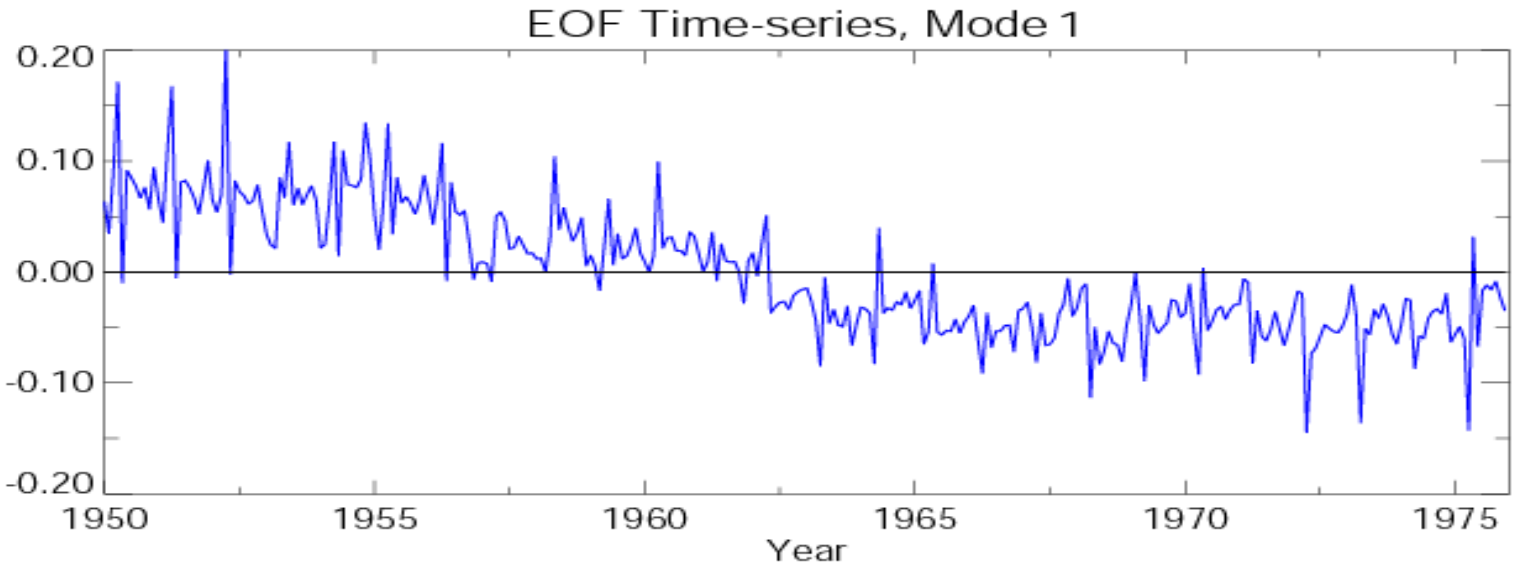


Similar behavior further east…

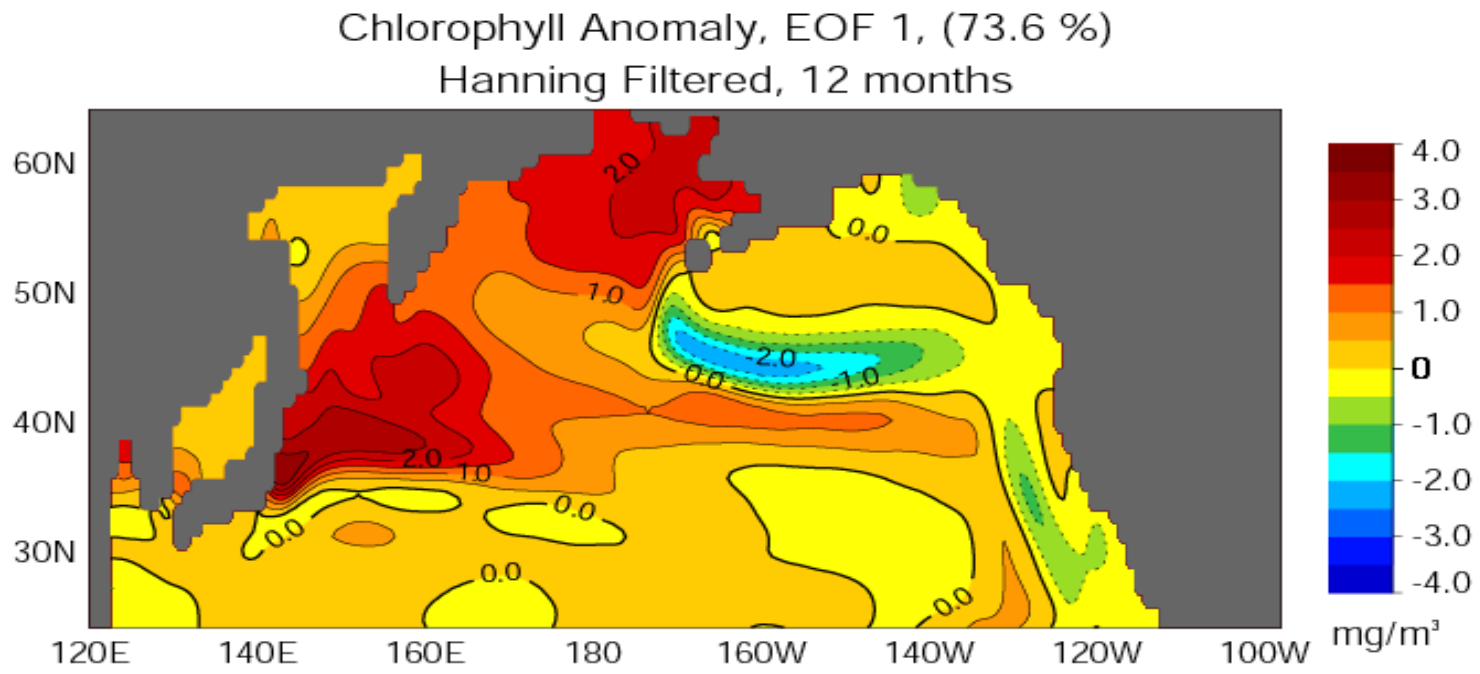


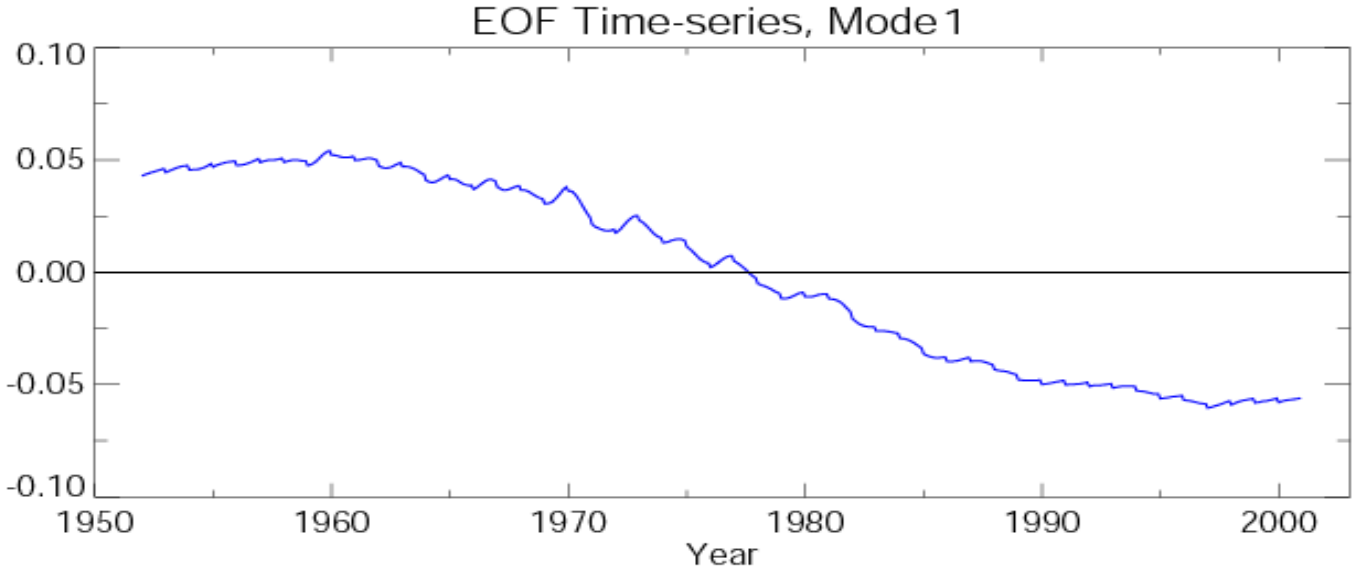
Subannual variability (shifts in spring blooms?) dominates the EOFs

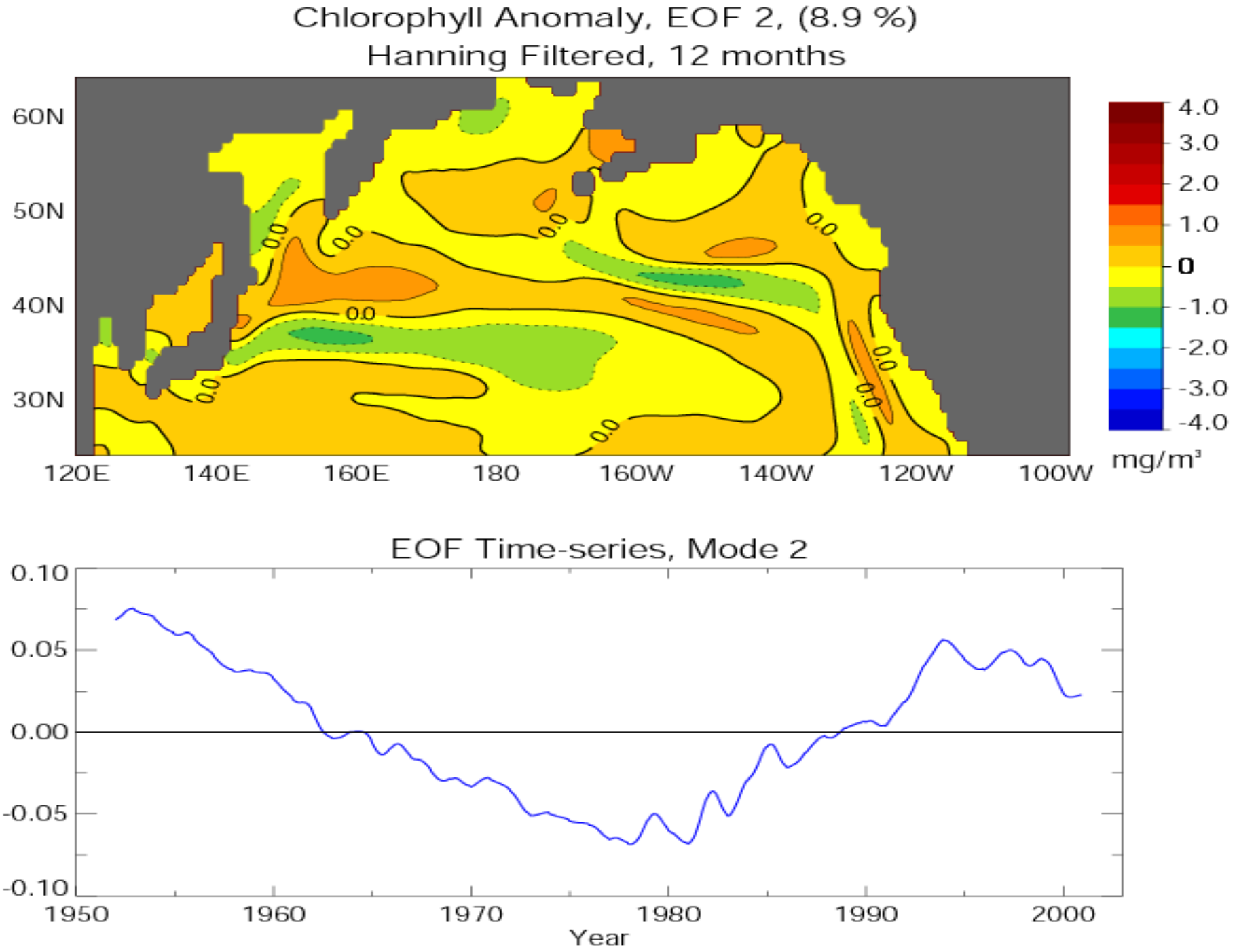




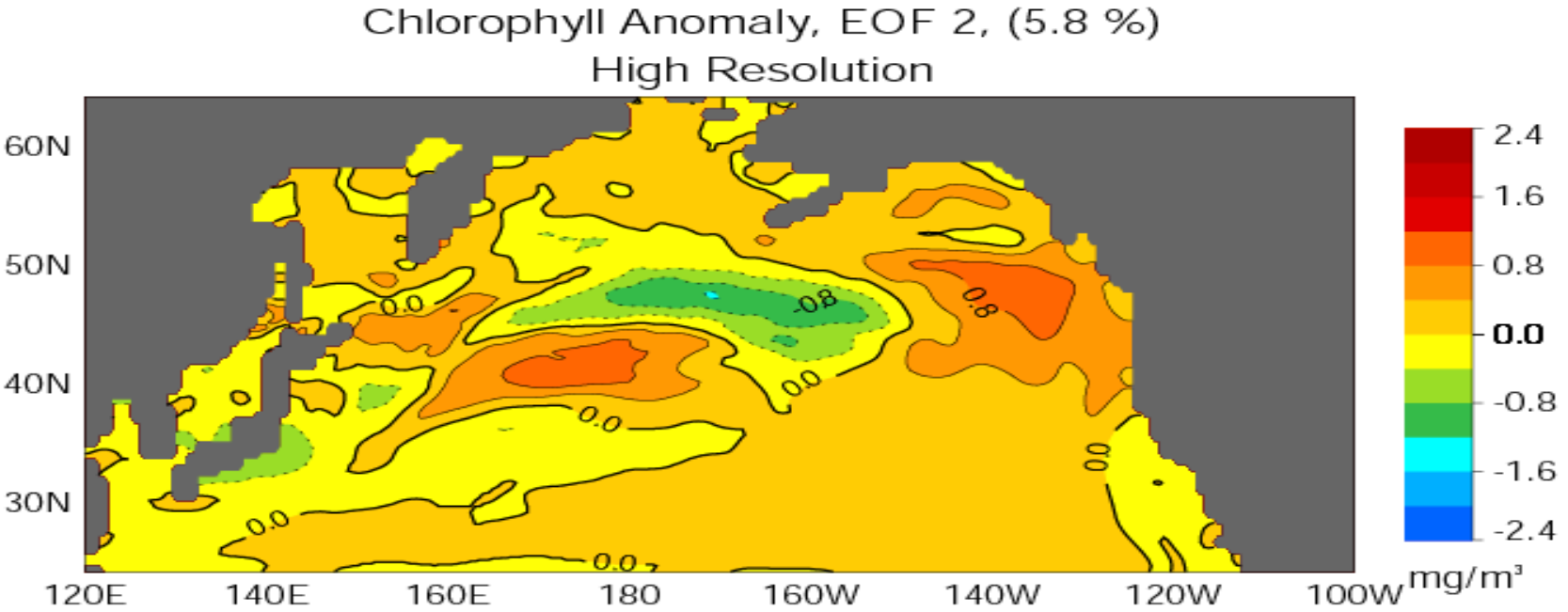
12-month Hanning Filter

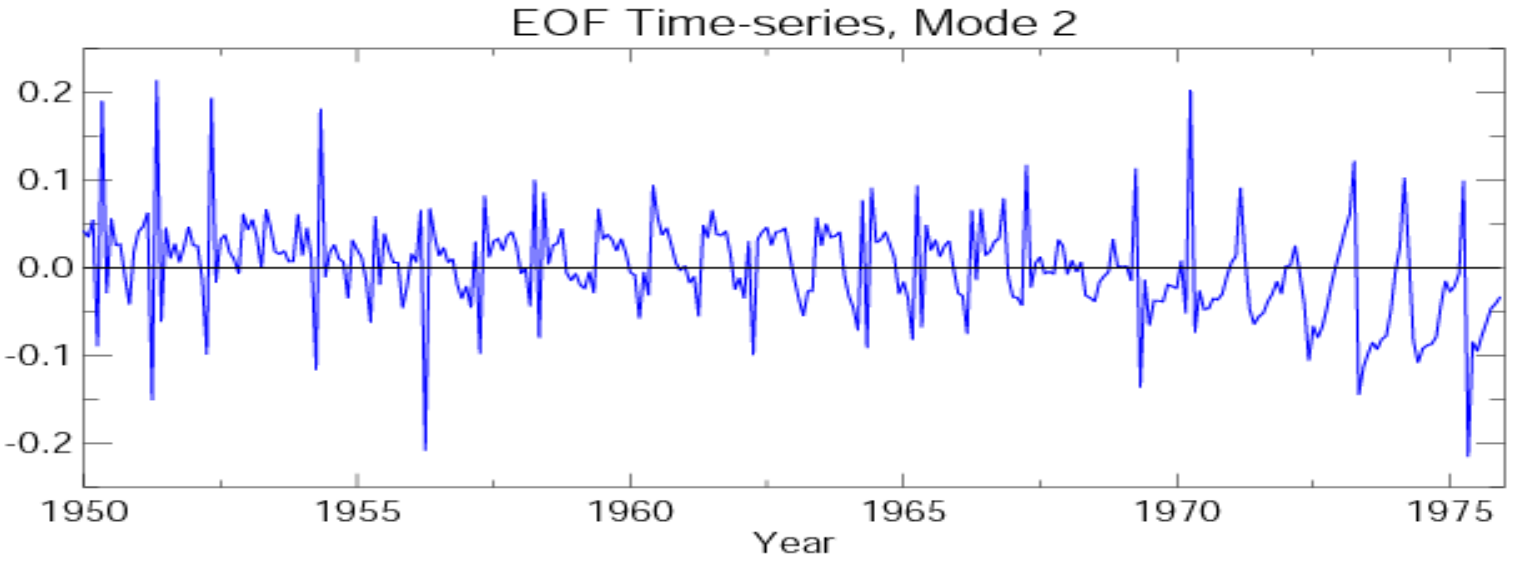




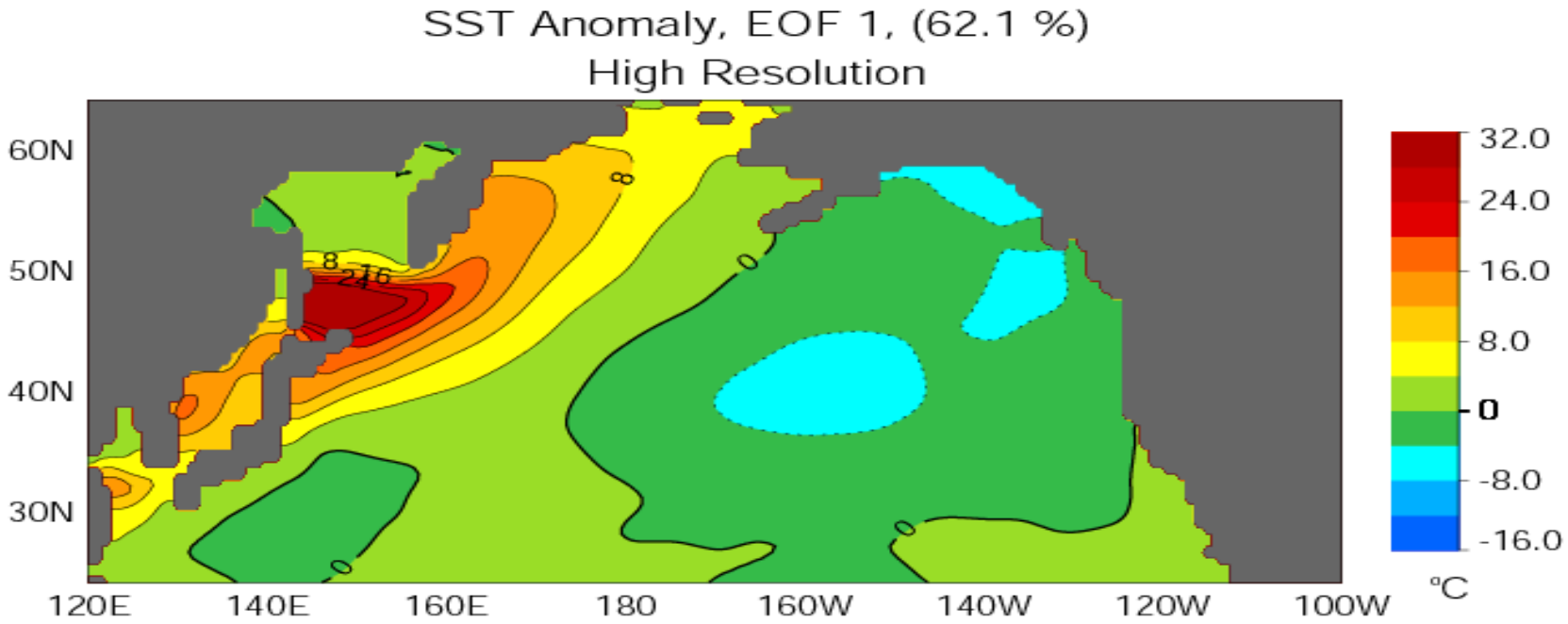

Chlorophyll Anomaly, EOF 2, (8.9 %)
Hanning Filtered, 12 months
60N
50N
40N
30N
120E
140E
160E
180
160W
140W
120W
100W
0.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
mg/m³
EOF Time-series, Mode 2
0.10
0.05
0.00
-0.05
-0.10
1950
1960
1970
1980
1990
2000
Year

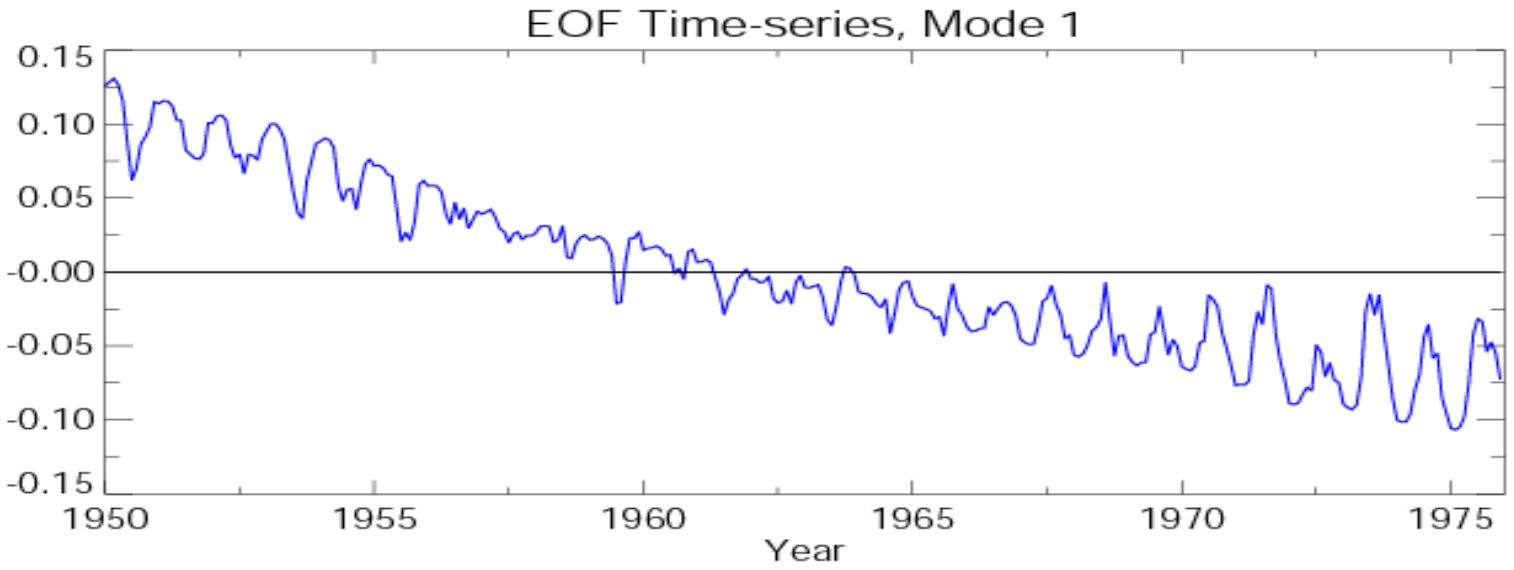
Mesoscale variability?





Crap?


SST Anomaly, EOF 1, (62.1 %)
High Resolution
60N
50N
40N
30N
120E
140E
160E
180
160W
140W
120W
100W
32.0
24.0
16.0
8.0
0
-8.0
-16.0
°C


EOF Time-series, Mode 1
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1950
1955
1960
1965
1970
1975
Year

Fake trends are spooking the first EOF?