A numerical simulation of large-scale physical events in the North Pacific Ocean during the 1996-2003 period

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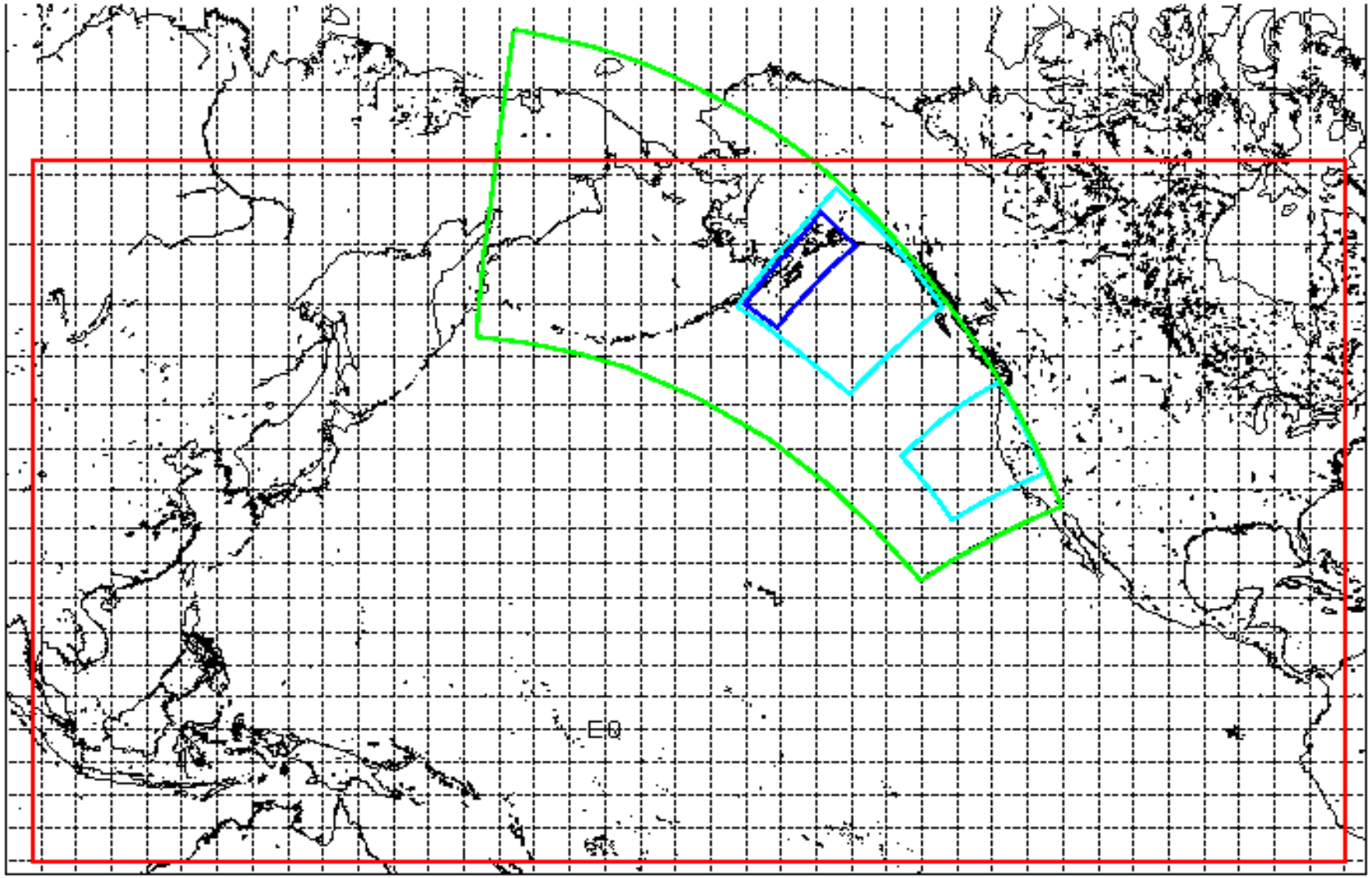
NOAA-PMEL

Purpose

- Scrutinize the basin-scale long-term variability in the model
- Analyze three robust large-scale signals
  - 97/98 El Nino
  - 1999 Regime shift
  - Cold Anomaly in NE Pacific



NPac (40 km) NEP (10 km) CCS&CGOA (3 km) PWS (1 km)

Model Setup

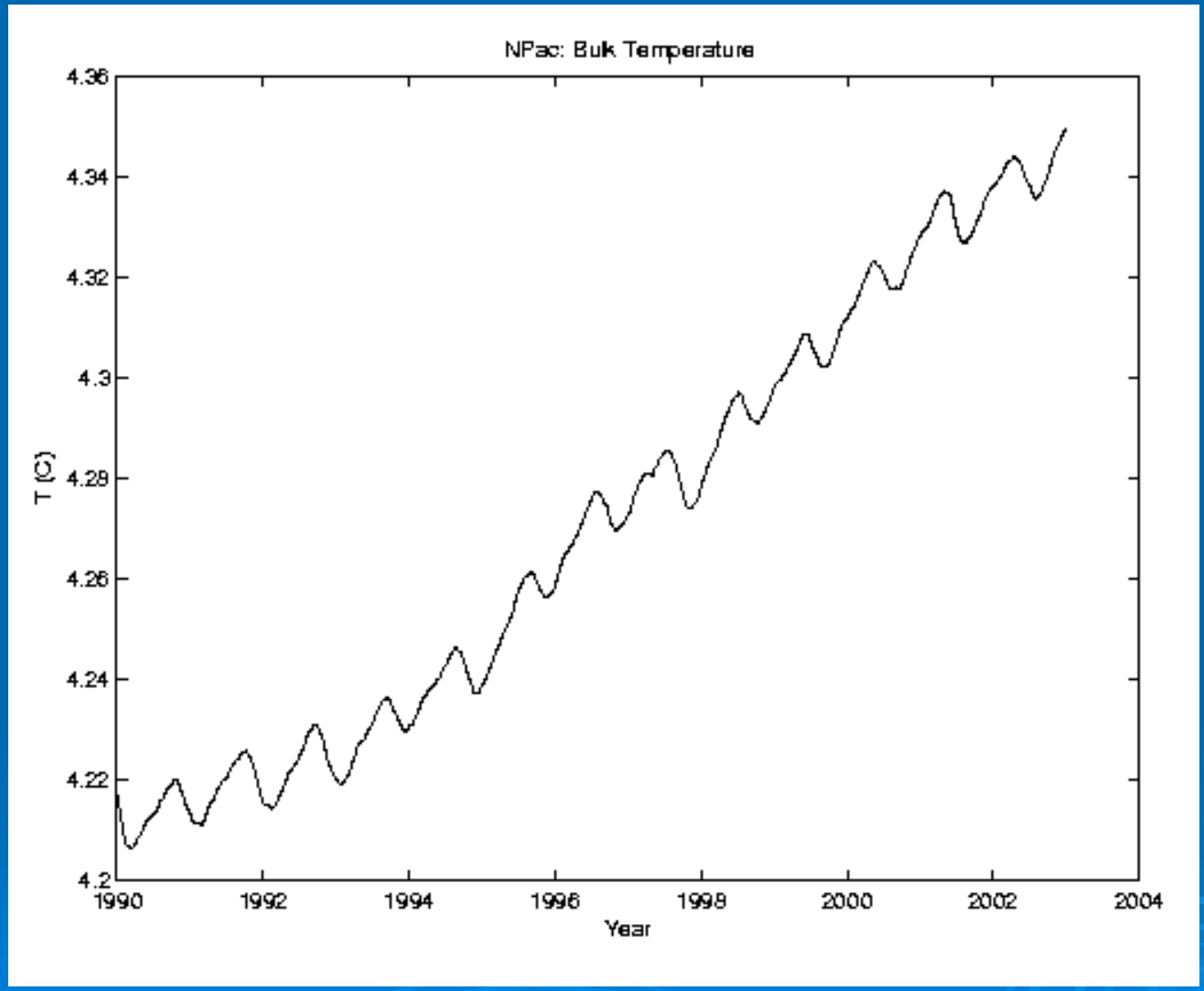
- Ocean Model: ROMS (community model)
- Domain: Pacific basin; 30S to 65N, 100E to 70W. 476x238 Horizontal points, 30 vertical layers
- Spinup: 10 years with climatological fluxes and daily winds
- Hindcast: 1990-2003, NCEP winds and fluxes. Also 2000-2002 Qscat winds

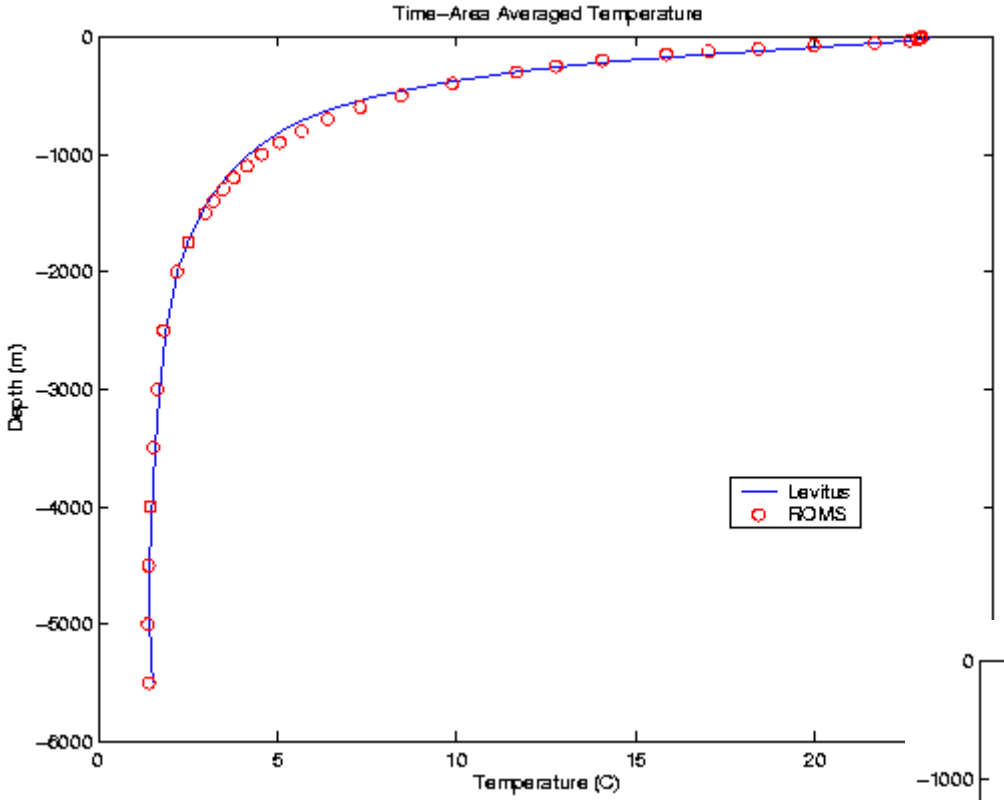
Model setup

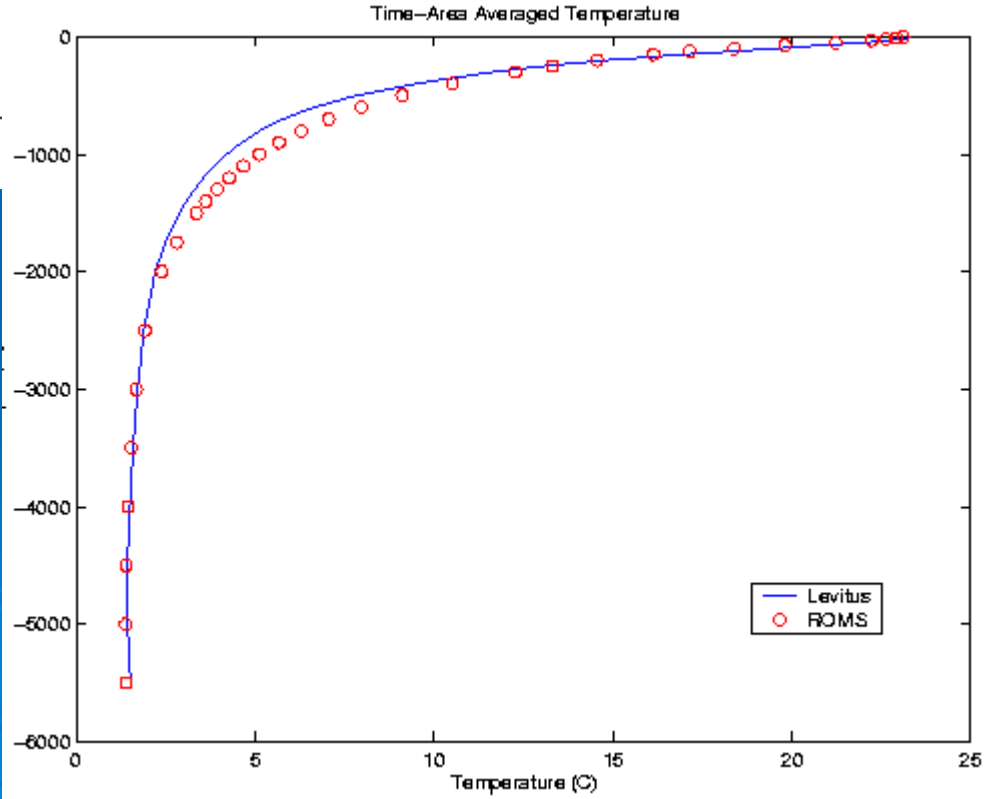
- Air-sea interaction boundary layer from COARE (Fairall et. al. 1996)
- Oceanic surface boundary layer (KPP; Large et. al. 1994)
- Bathymetry: ETOPO5, isobaths do not intersect coastline

ROMS Kernel Attributes

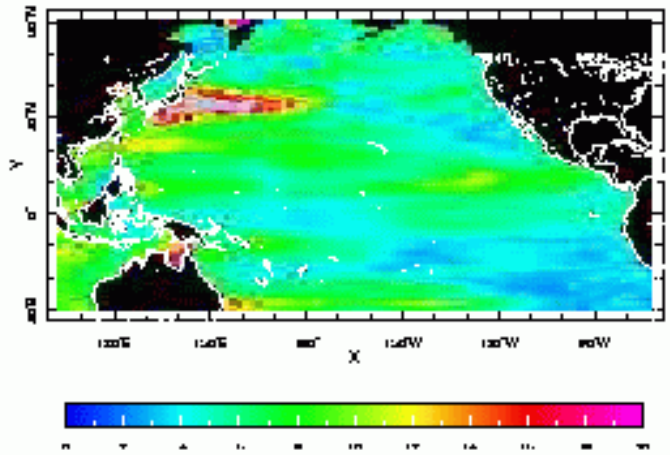
- Free surface hydrostatic primitive equations model
- Generalized, terrain-following vertical coordinates.
- Boundary fitted, orthogonal curvilinear, horizontal coordinates on an Arakawa C-Grid
- Non-homogenous time-stepping algorithm
- High-order advection scheme
- Continuous monotonic reconstruction of vertical gradients
- Accurate baroclinic pressure gradient (splines)


NPac: Bulk Temperature
T (C)
Year
4.36
4.34
4.32
4.3
4.28
4.26
4.24
4.22
4.2
1990
1992
1994
1996
1998
2000
2002
2004

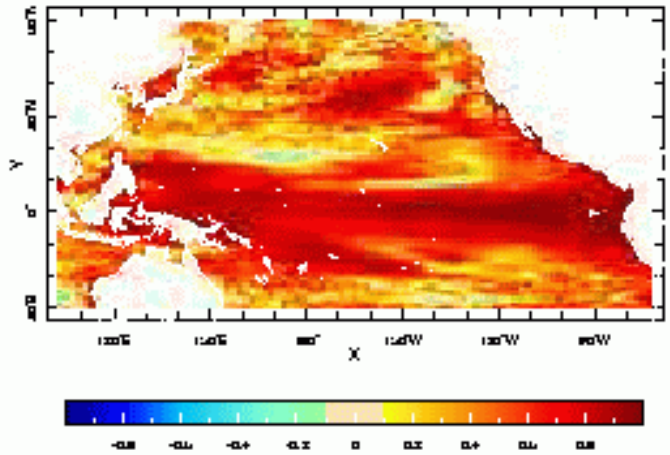

Time–Area Averaged Temperature
Depth (m)
Temperature (C)
Levitus
ROMS
0
−1000
−2000
−3000
−4000
−5000
−6000
0
5
10
15
20


Time–Area Averaged Temperature
Temperature (C)
Levitus
ROMS
0
−1000
−2000
−3000
−4000
−5000
−6000
0
5
10
15
20
25

RMS difference (cm)

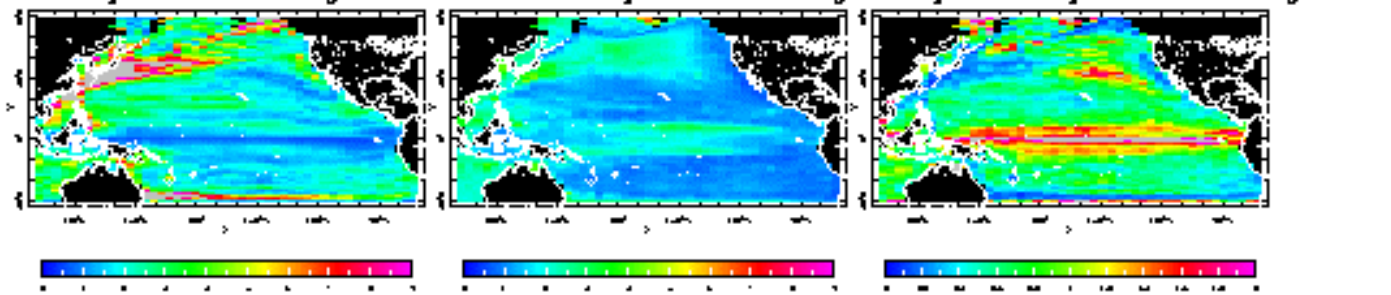


Correlation coefficient



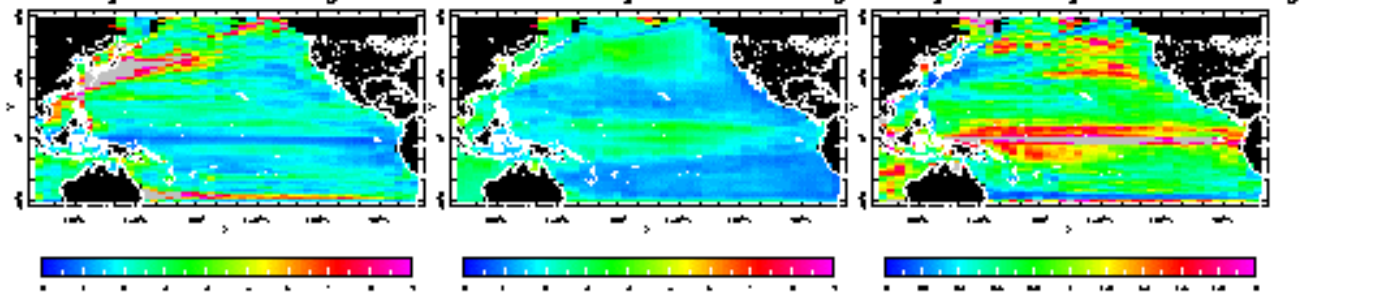
ROMS NPac run, forced by NCEP-NCAR Reanalysis fluxes

Small-scale spatial variability | Short-term temporal variability | Temporal-to-spatial variability ratio



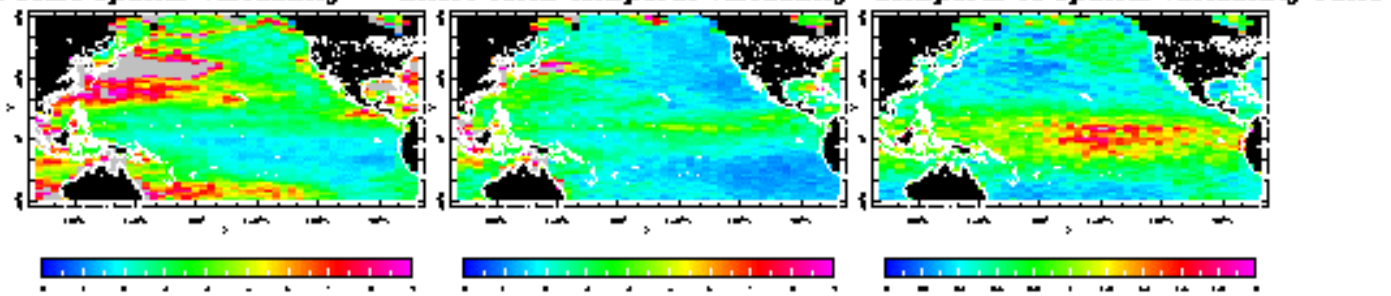
ROMS NPac run, forced by QuikSCAT winds

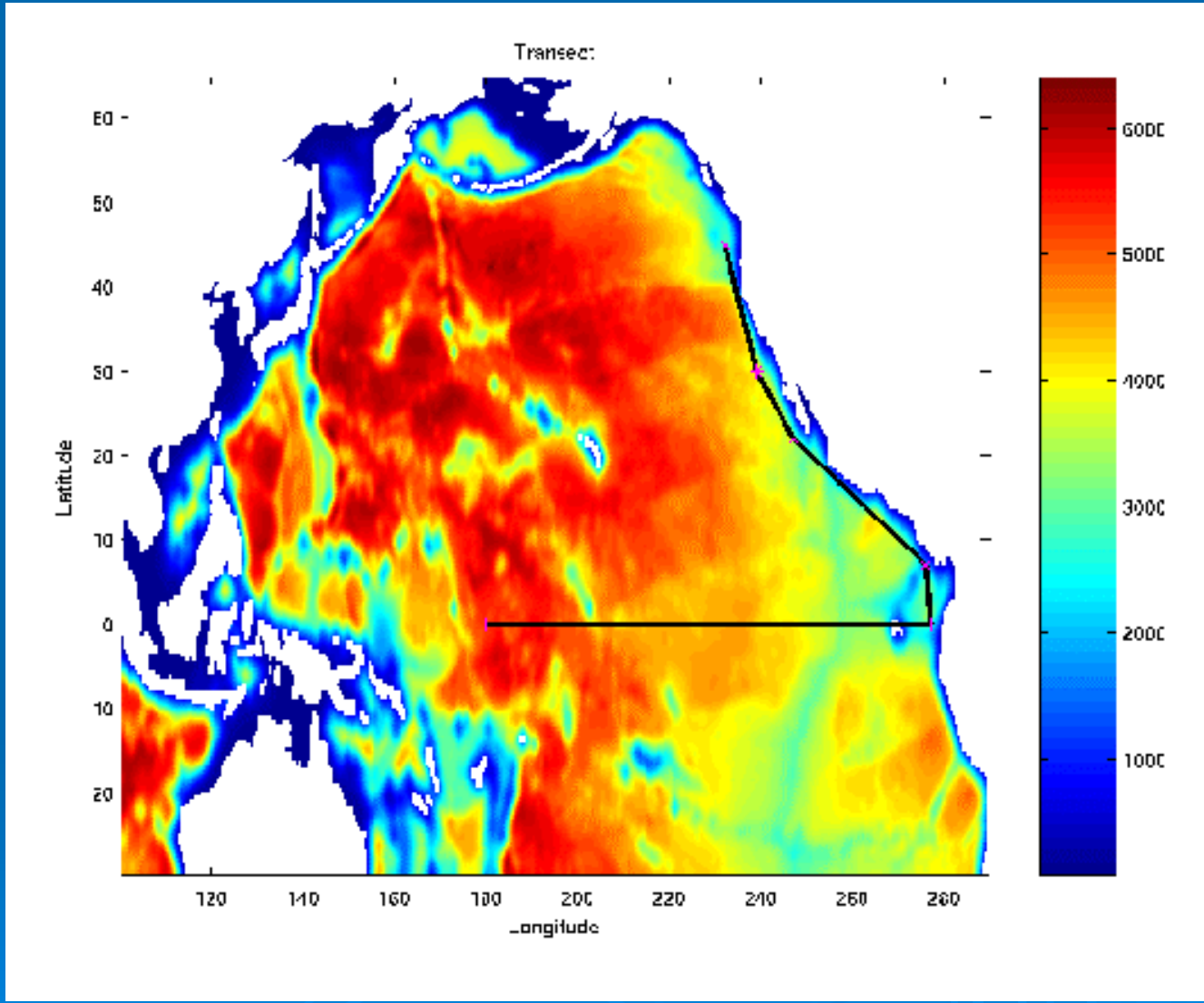
Small-scale spatial variability | Short-term temporal variability | Temporal-to-spatial variability ratio



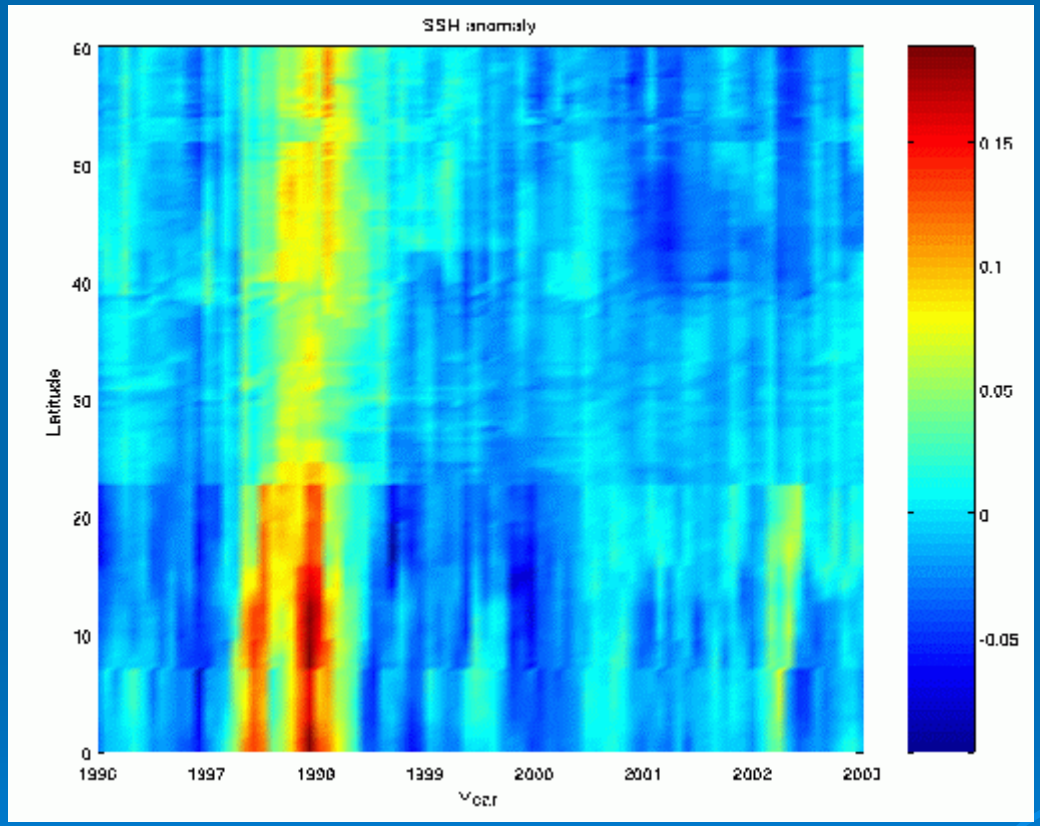
Satellite altimetry fields

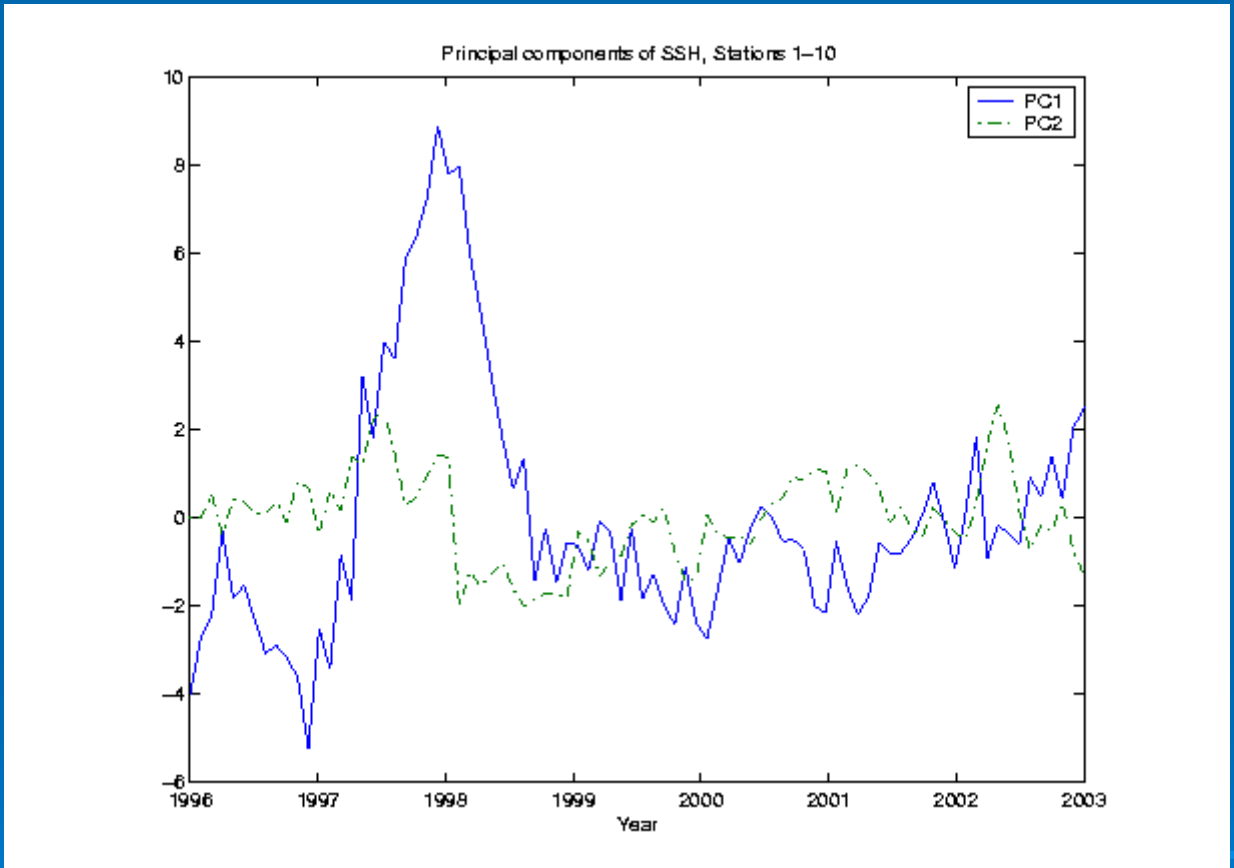
Small-scale spatial variability | Short-term temporal variability | Temporal-to-spatial variability ratio

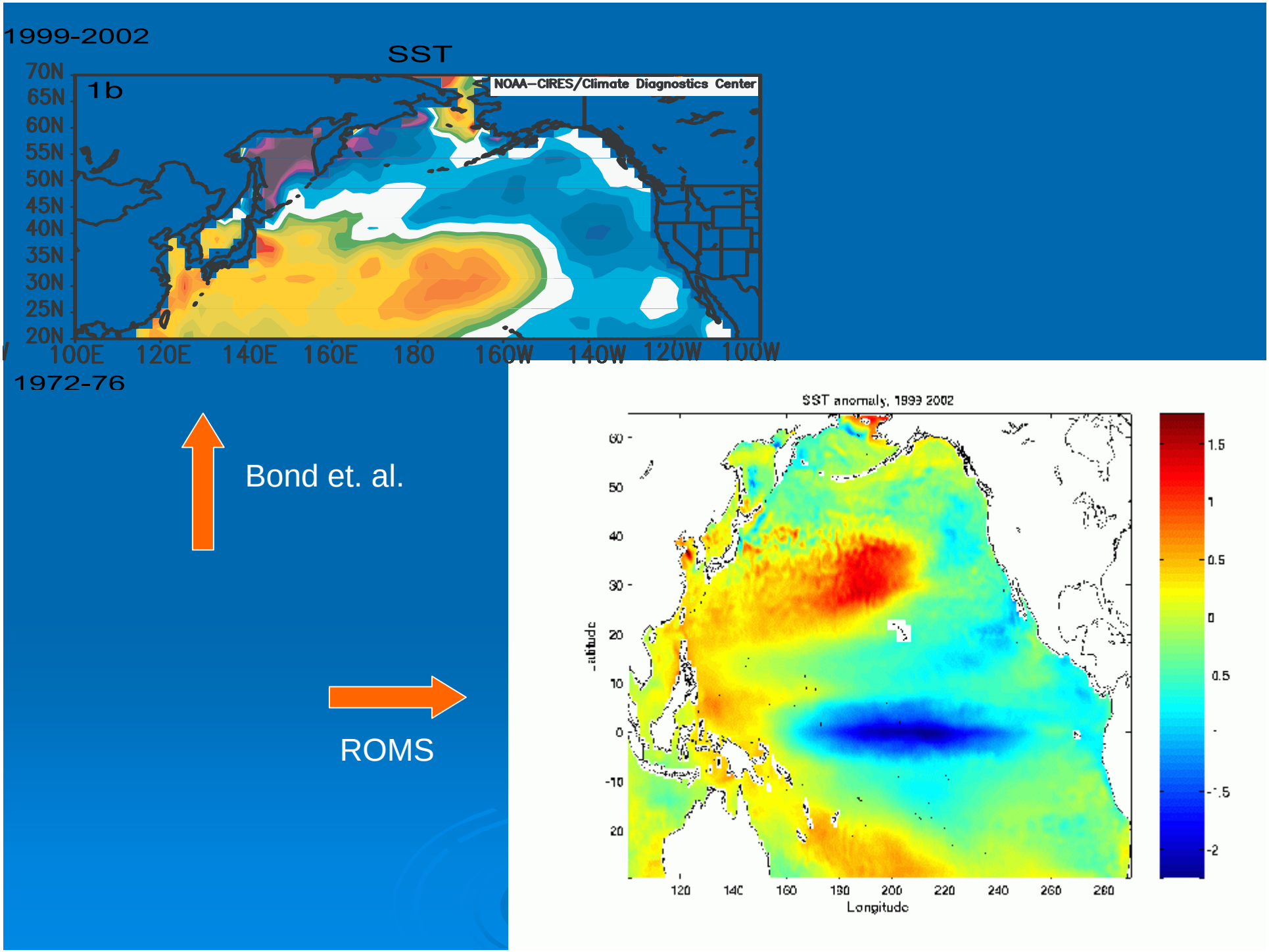



Transect
Latitude
Longitude
60
50
40
30
20
10
0
10
20
120
140
160
180
200
220
240
260
280
6000
5000
4000
3000
2000
1000

Sea surface height anomaly




Principal components of SSH, Stations 1–10
PC1
PC2
10
8
6
4
2
0
−2
−4
−6
1996
1997
1998
1999
2000
2001
2002
2003
Year


1999-2002
SST
1b
NOAA–CIRES/Climate Diagnostics Center
70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
100E
120E
140E
160E
180
160W
140W
120W
100W
1972-76
Bond et. al.
ROMS
SST anomaly, 1999 2002
60
50
40
30
20
10
0
-10
20
120
140
160
180
200
220
240
260
280
Longitude
1.5
1
0.5
0
0.5
-2

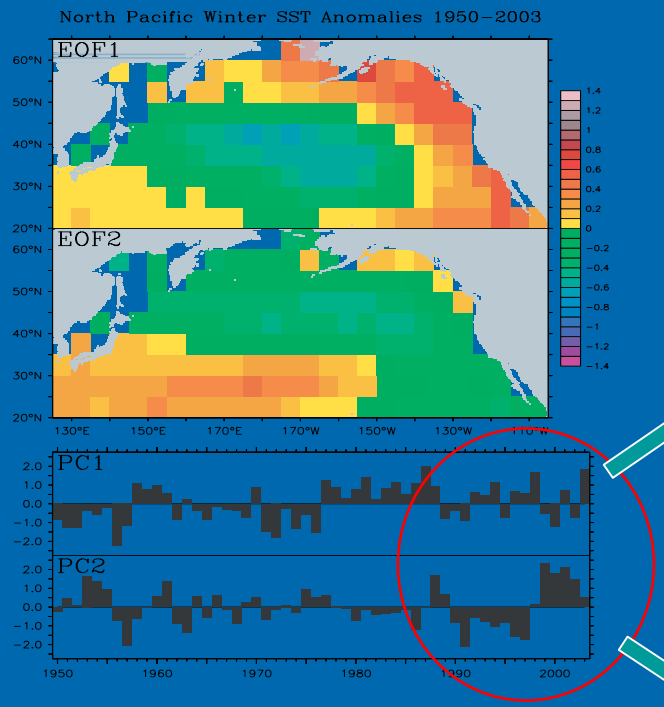
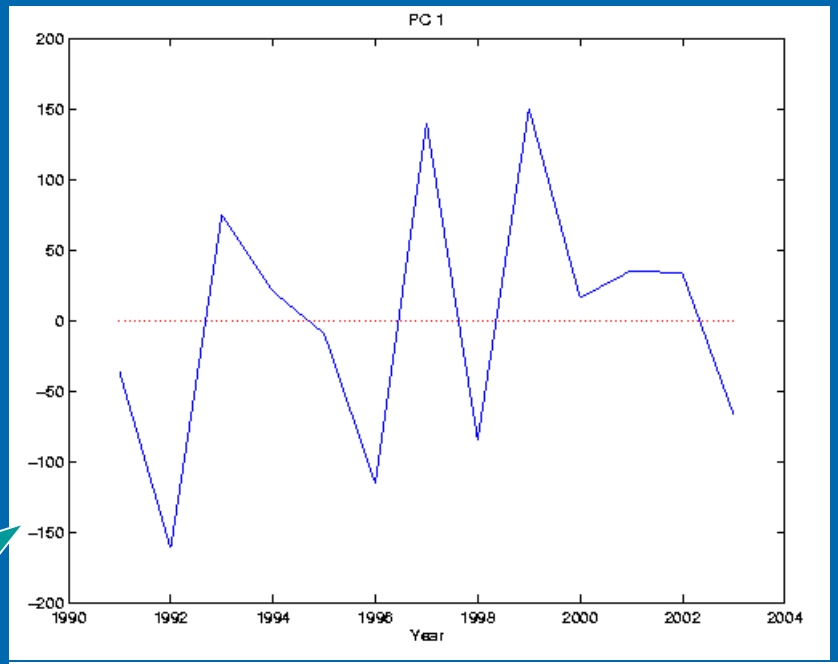
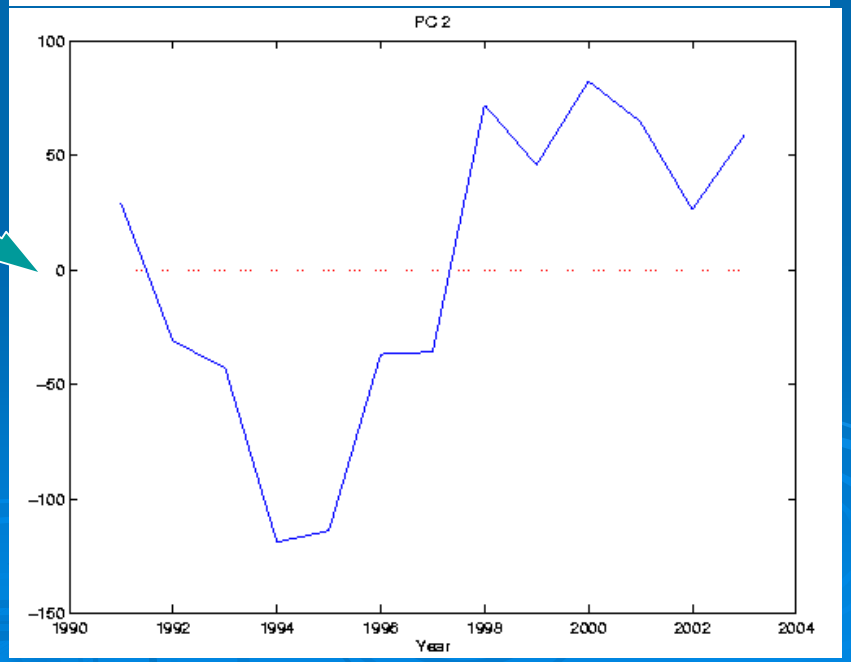
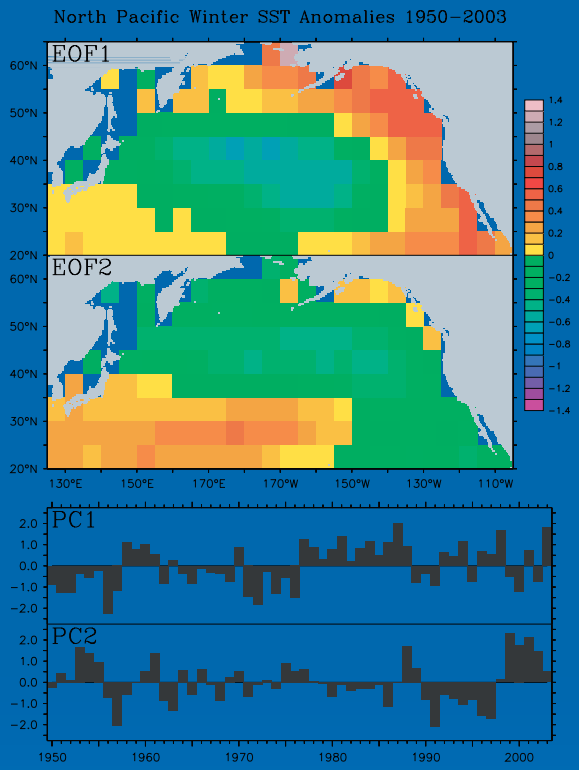


Figure 5. Principal Component Analysis of North Pacific winter (November–March) SST fields north of 20. The first EOF (top) corresponds to the PDO pattern and its time evolution is given by PC1. The evolution of the second EOF pattern shows large magnitudes since the 1990s with a shift to large positive values for 1999–2002.







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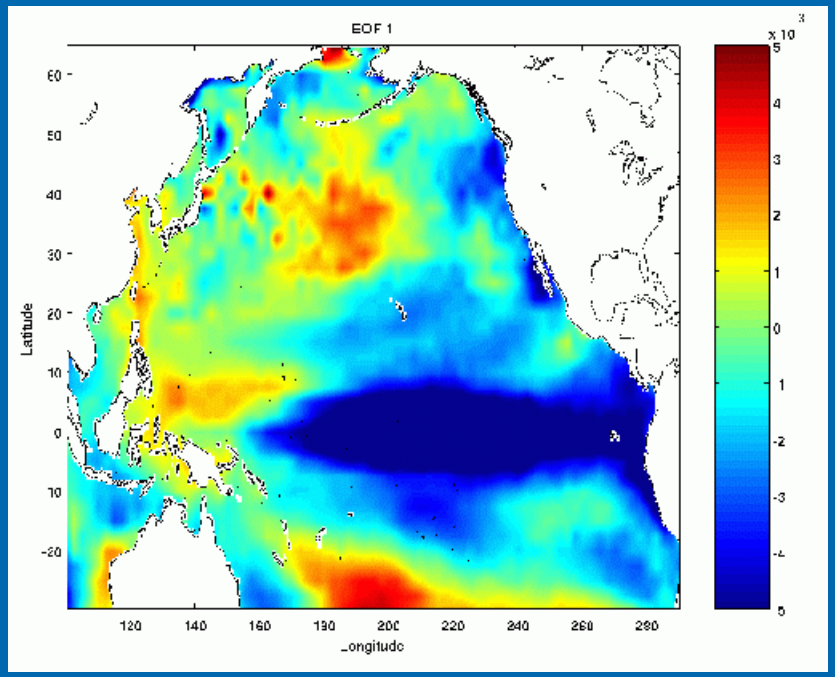
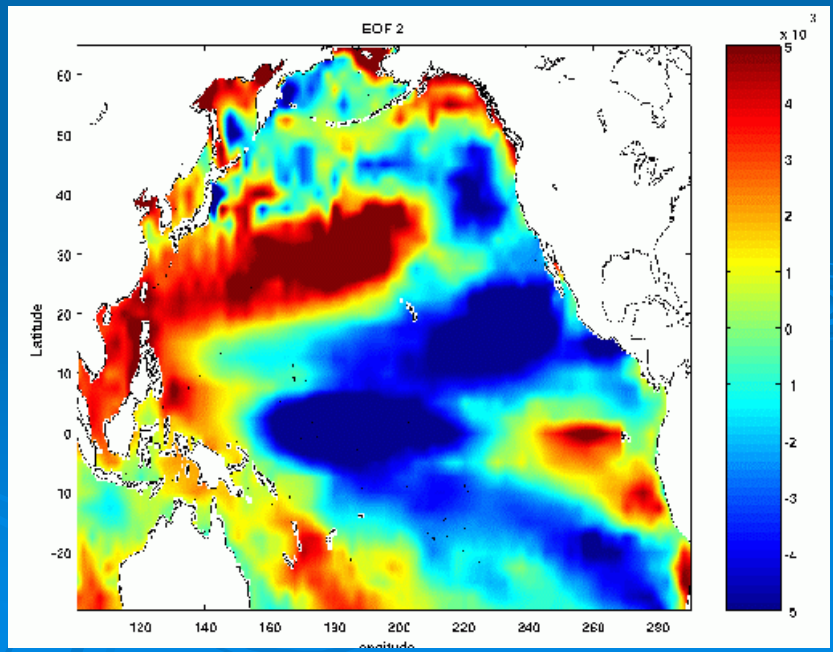
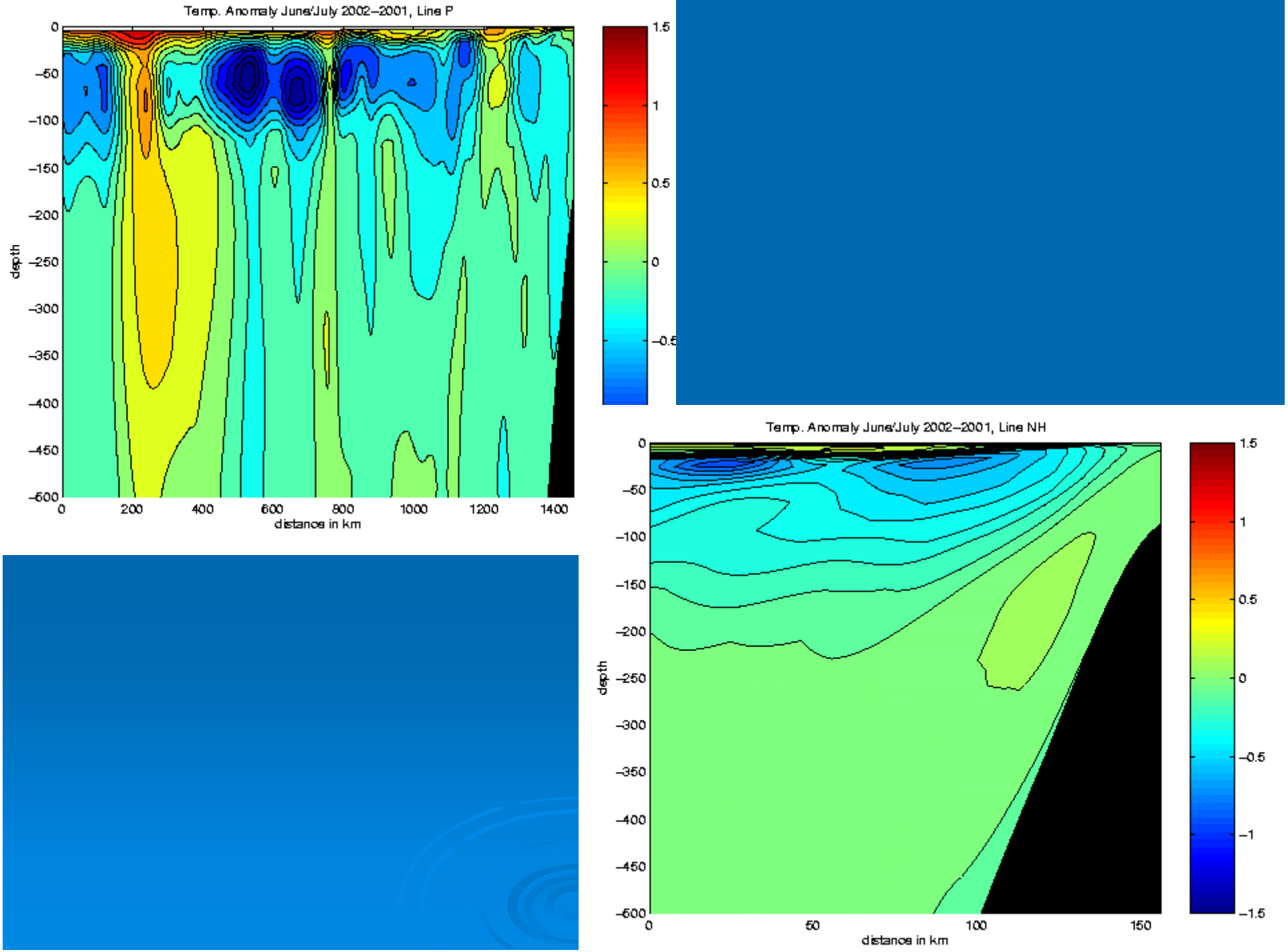
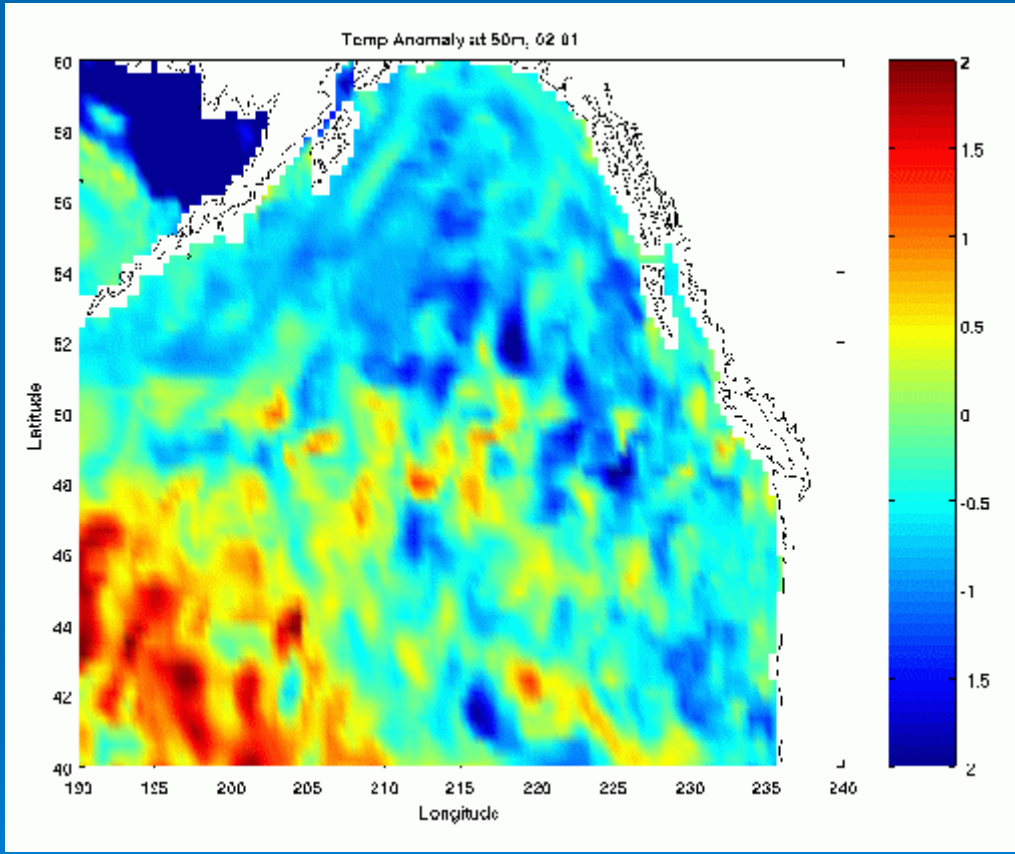


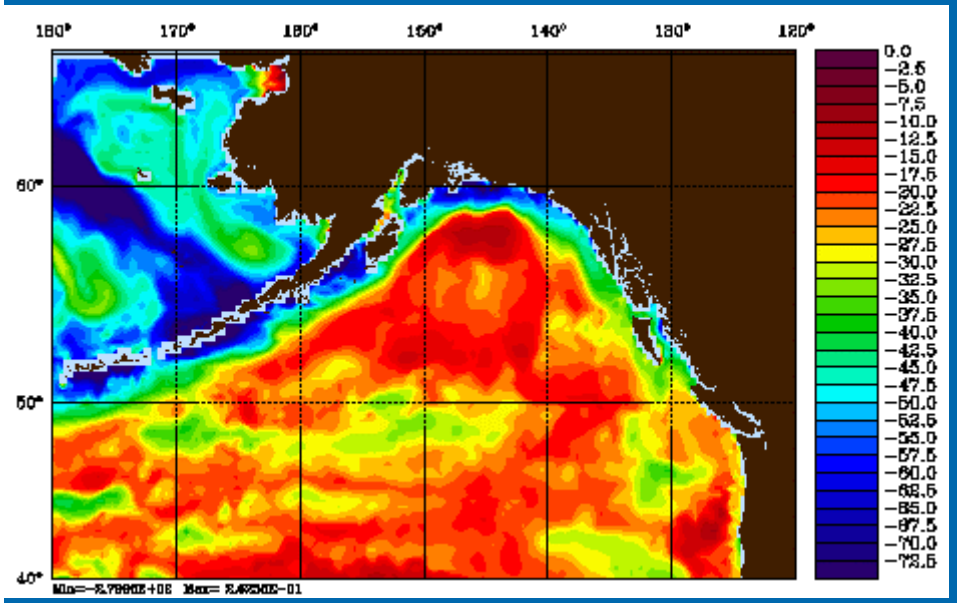


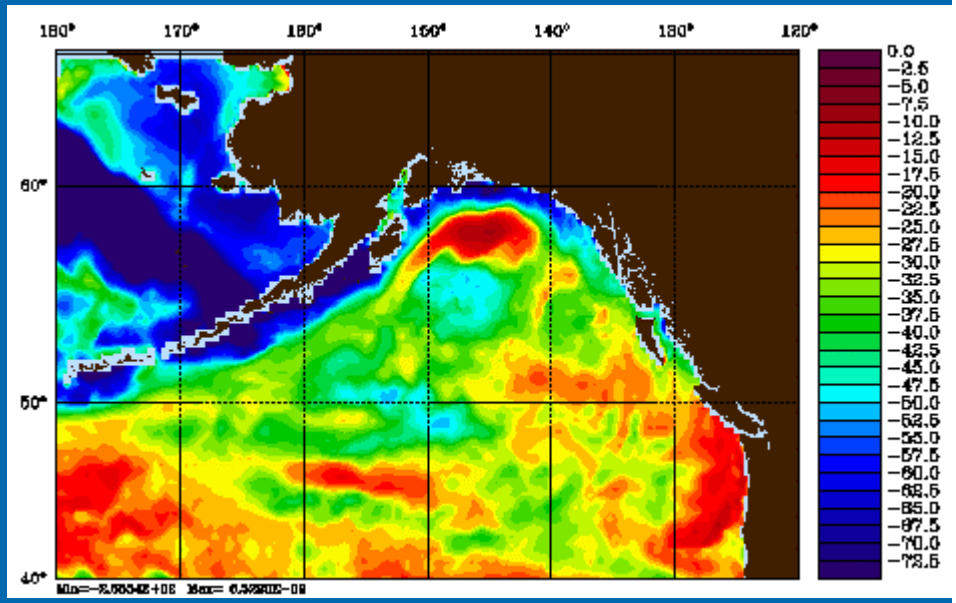

Temp. Anomaly June/July 2002–2001, Line P
depth
distance in km
0
−50
−100
−150
−200
−250
−300
−350
−400
−450
−500
0
200
400
600
800
1000
1200
1400
1.5
1
0.5
0
−0.5
Temp. Anomaly June/July 2002–2001, Line NH
depth
distance in km
0
−50
−100
−150
−200
−250
−300
−350
−400
−450
−500
0
50
100
150
1.5
1
0.5
0
−0.5
−1
−1.5

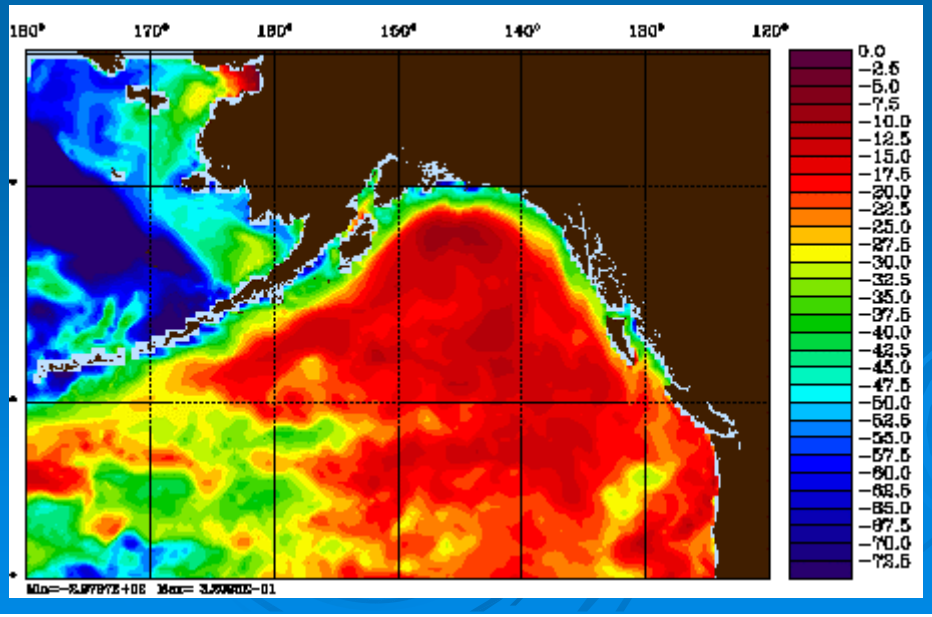
2002-2001 Temp. anomaly at 50m



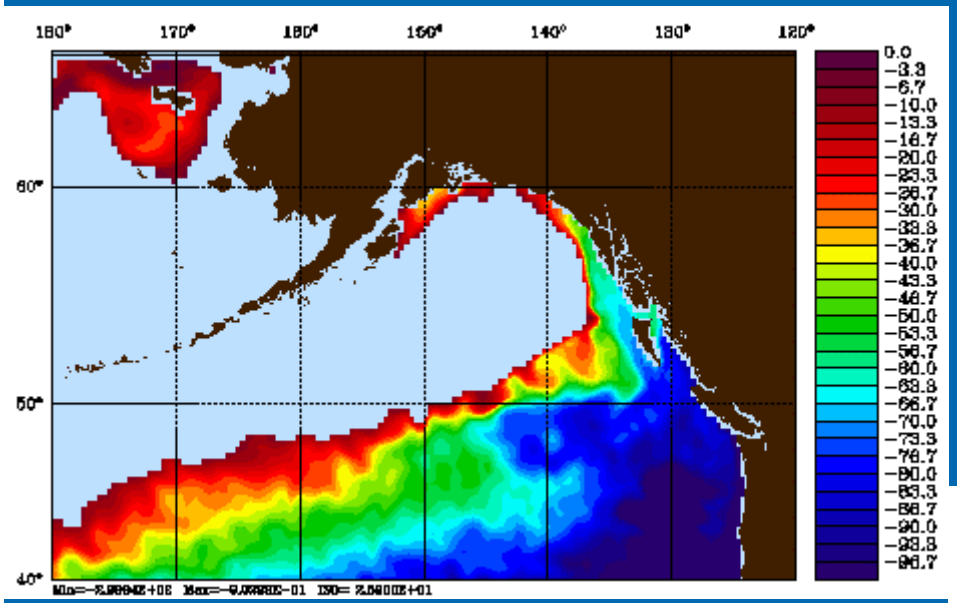
Mixed layer depth

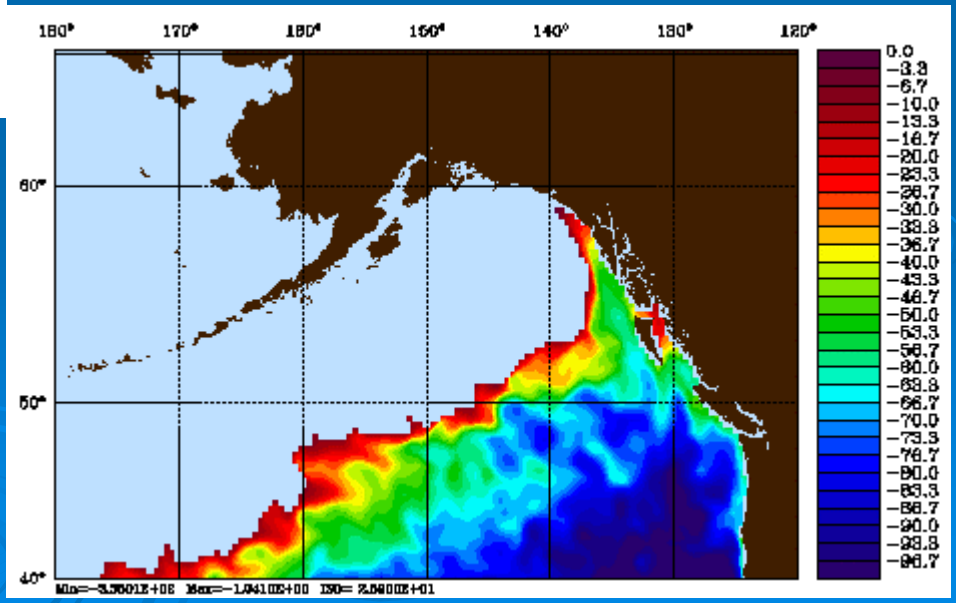






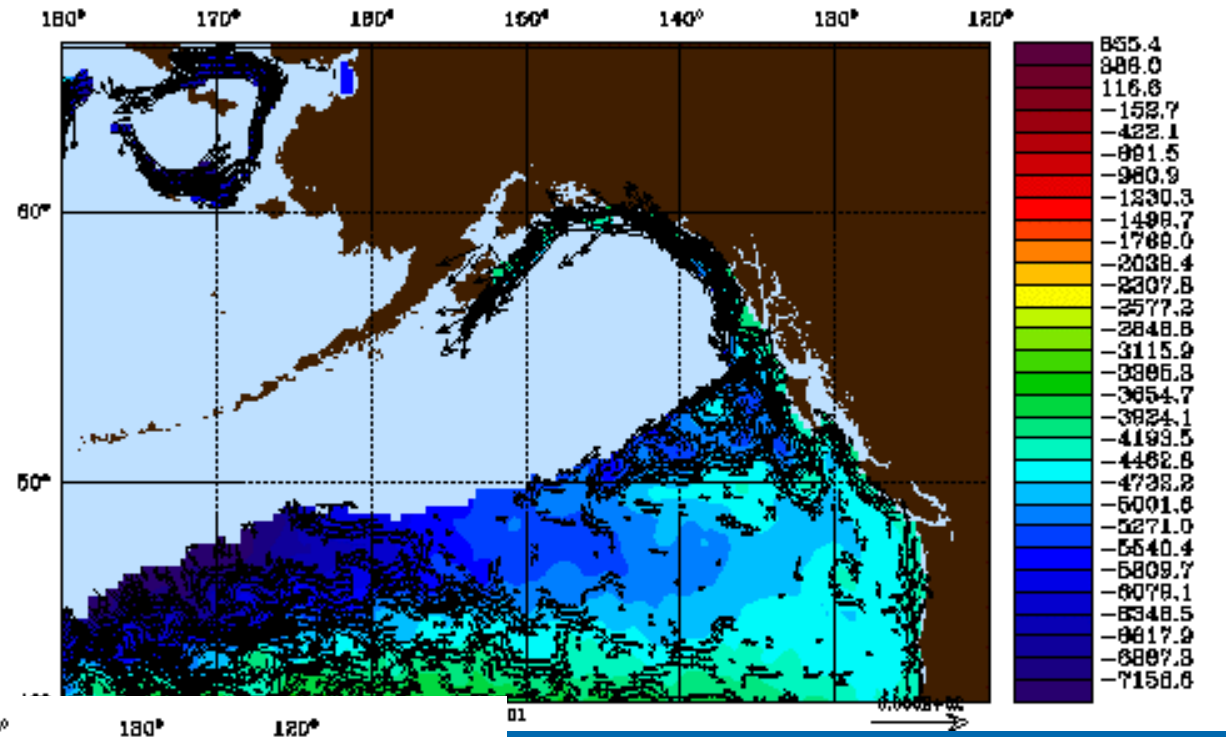
Isopycnal layer depth

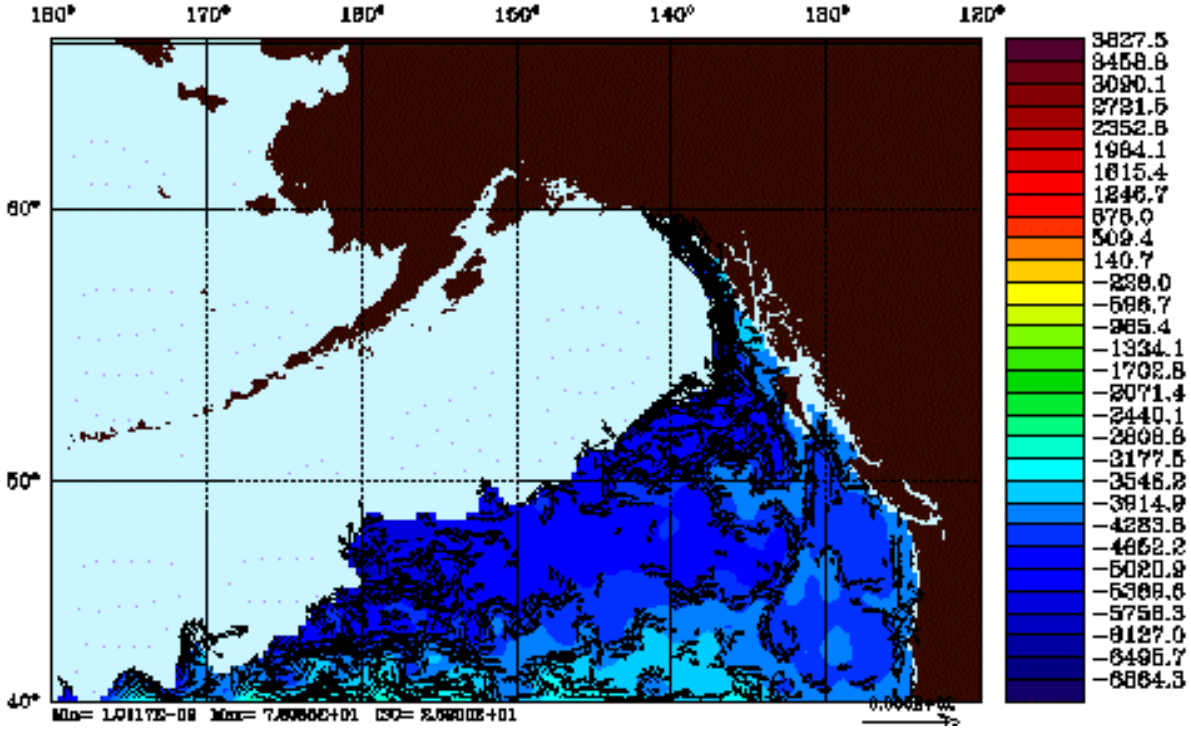


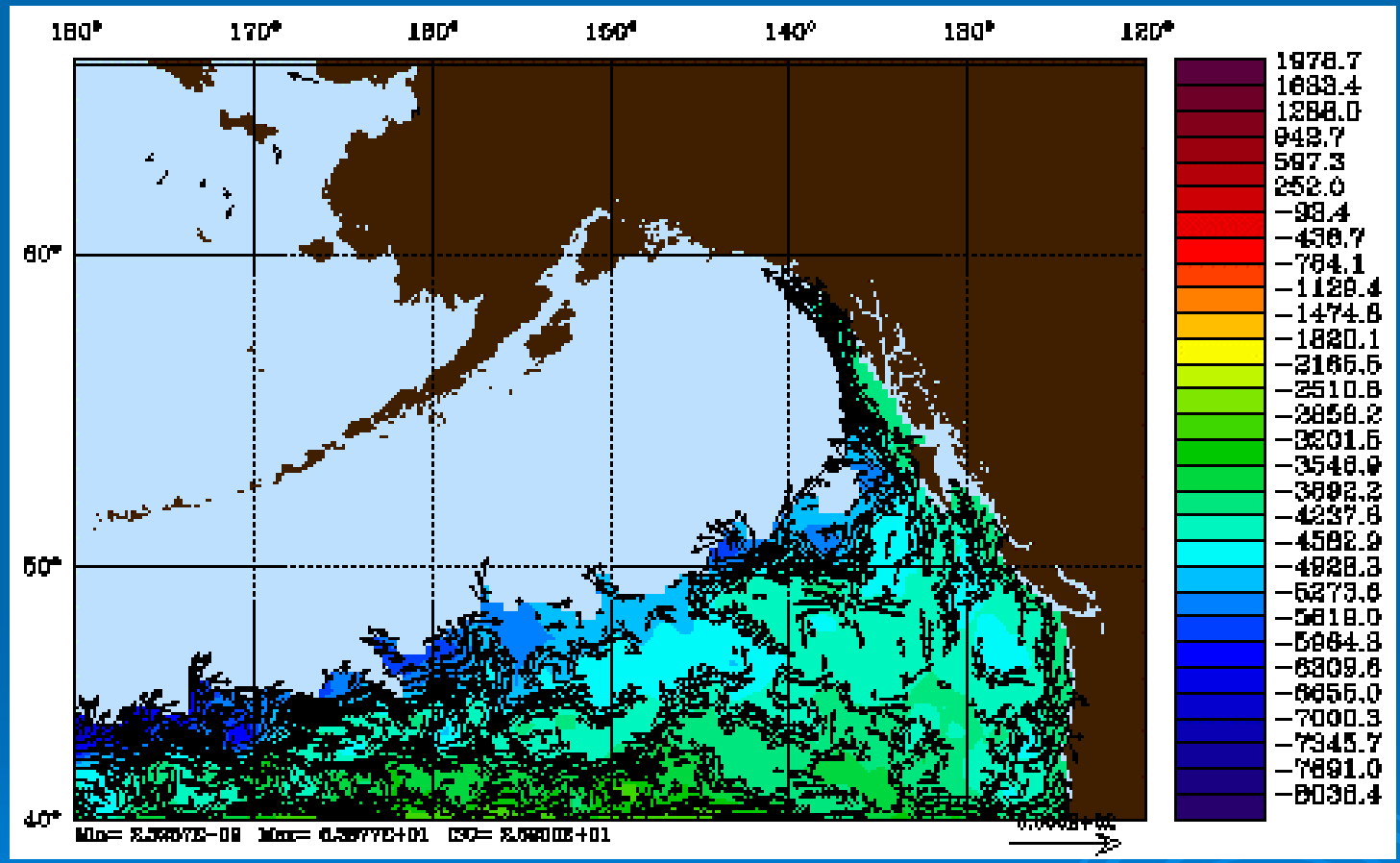


Bernoulli Function

$$B(\sigma) = \rho_o g \eta + g \int_{z(\sigma)}^{0} [\rho - \rho(\sigma)] dz$$

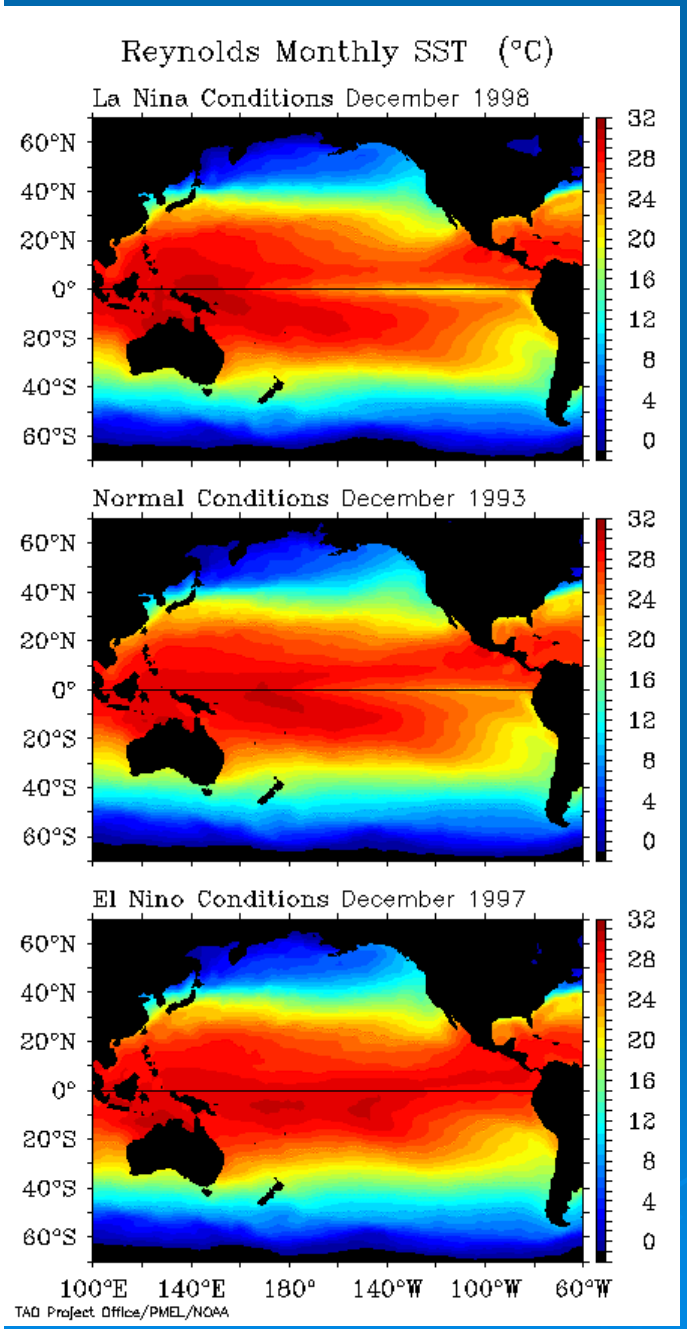

180°
170°
160°
140°
120°
60°
50°
855.4
886.0
116.6
-152.7
-422.1
-691.5
-960.9
-1230.3
-1499.7
-1769.0
-2038.4
-2307.8
-2577.2
-2846.6
-3115.9
-3385.3
-3654.7
-3924.1
-4193.5
-4462.8
-4732.2
-5001.6
-5271.0
-5540.4
-5809.7
-6079.1
-6348.5
-6617.9
-6887.3
-7156.6

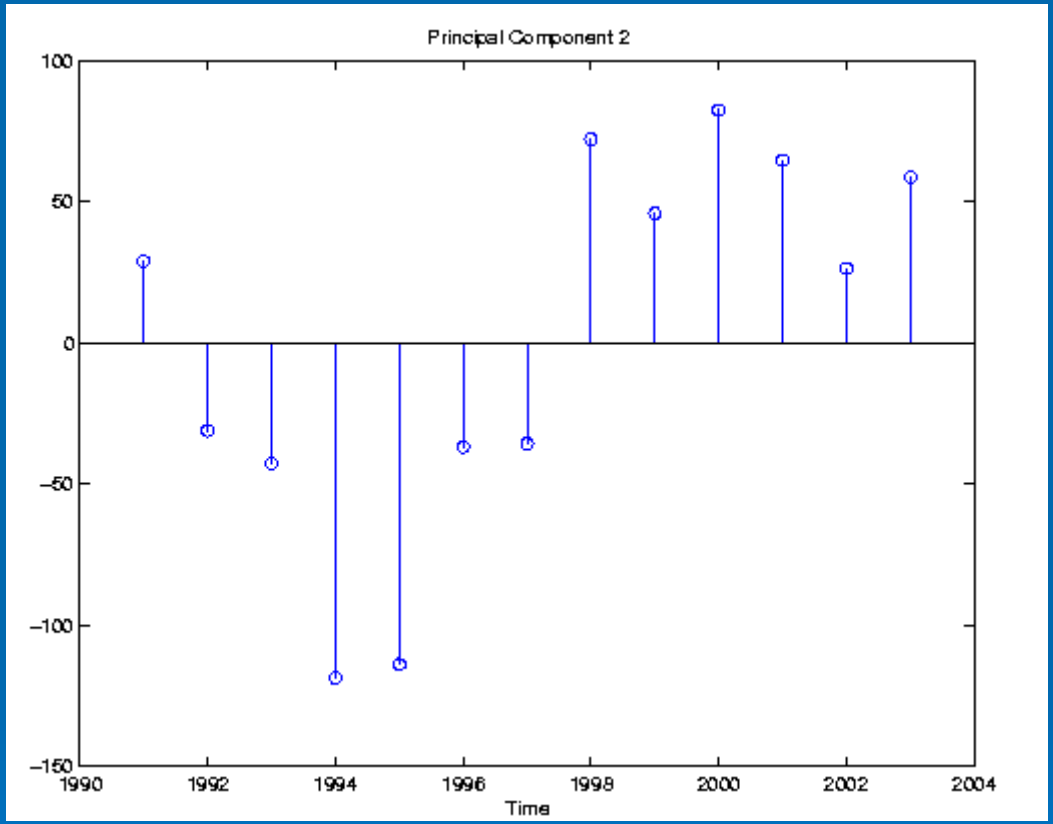

180°
170°
160°
140°
120°
60°
50°
40°
3827.5
3558.8
3290.1
3021.5
2752.8
2484.1
2215.4
1946.7
678.0
409.4
140.7
-238.0
-506.7
-865.4
-1334.1
-1702.8
-2071.4
-2440.1
-2808.8
-3177.5
-3546.2
-3914.9
-4283.6
-4652.2
-5020.9
-5389.6
-5758.3
-6127.0
-6495.7
-6864.3


180°
170°
160°
150°
140°
130°
120°
60°
50°
40°
1978.7
1683.4
1388.0
942.7
597.3
252.0
-38.4
-436.7
-784.1
-1129.4
-1474.8
-1820.1
-2165.5
-2510.8
-2856.2
-3201.6
-3546.9
-3892.2
-4237.6
-4582.9
-4928.3
-5273.6
-5618.9
-5964.3
-6309.6
-6656.0
-7000.3
-7345.7
-7691.0
-8036.4

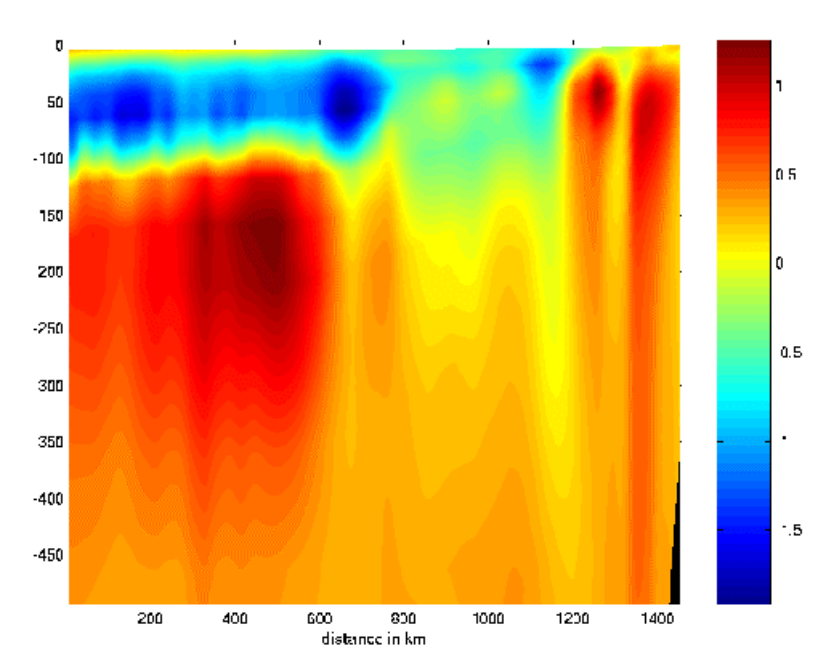
Final Comments

- Outer scale model is giving the correct response; Proceed on to the higher-resolution limited-area domains (NEP, CCS, CGOA)
- Having said that…
  - Poor shelf representation
  - No messoscale eddies

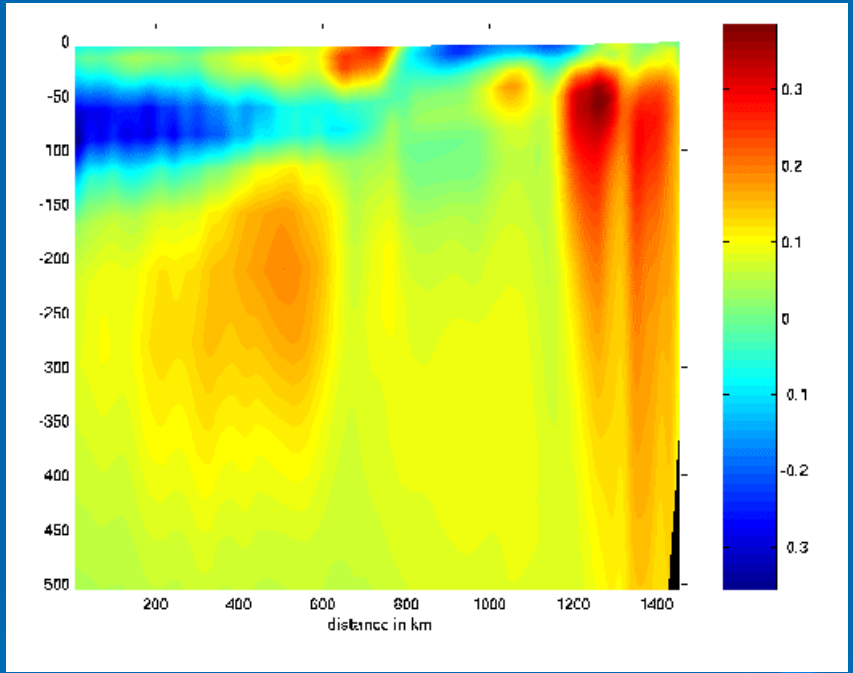

Reynolds Monthly SST (°C)
La Nina Conditions December 1998
Normal Conditions December 1993
El Nino Conditions December 1997
60°N
40°N
20°N
0°
20°S
40°S
60°S
32
28
24
20
16
12
8
4
0
100°E
140°E
180°
140°W
100°W
60°W
TAO Project Office/PMEL/NOAA

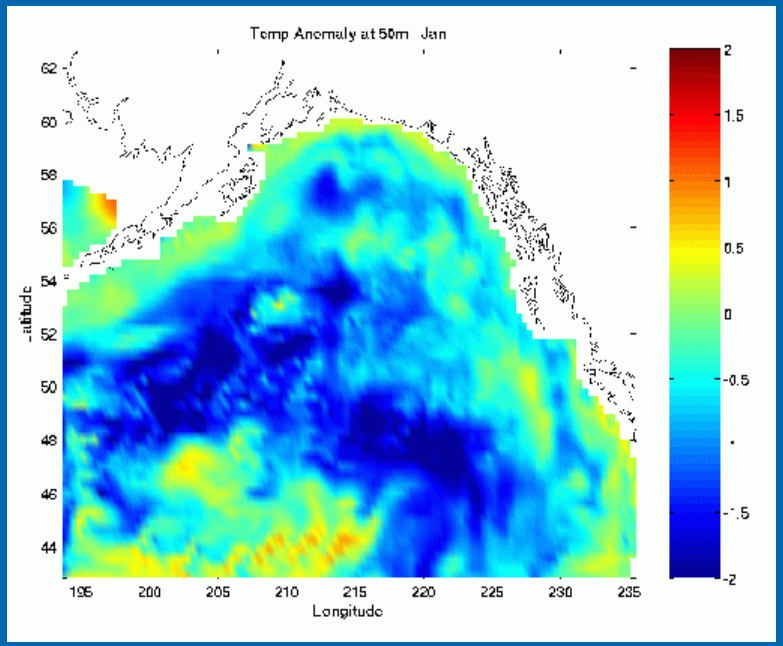

Principal Component 2
100
50
0
−50
−100
−150
1990
1992
1994
1996
1998
2000
2002
2004
Time

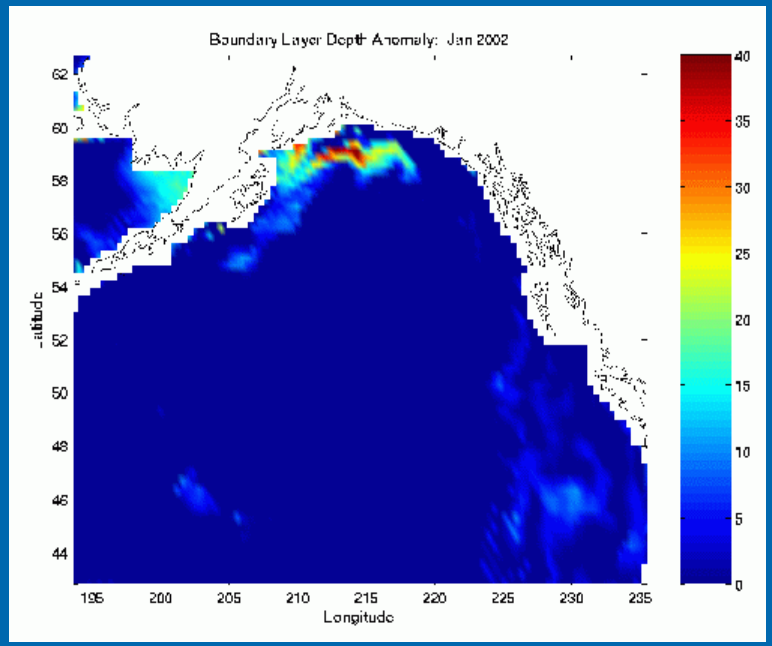
Temperature anomaly at Line-P

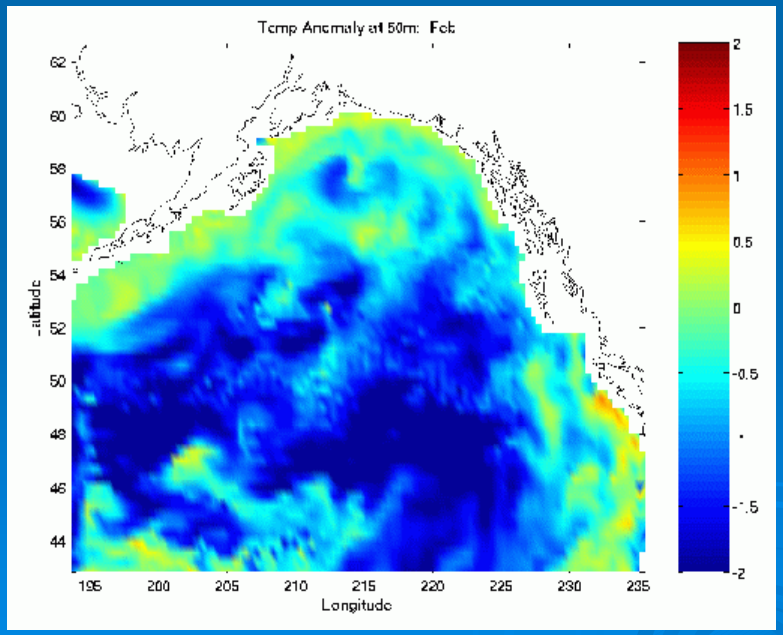


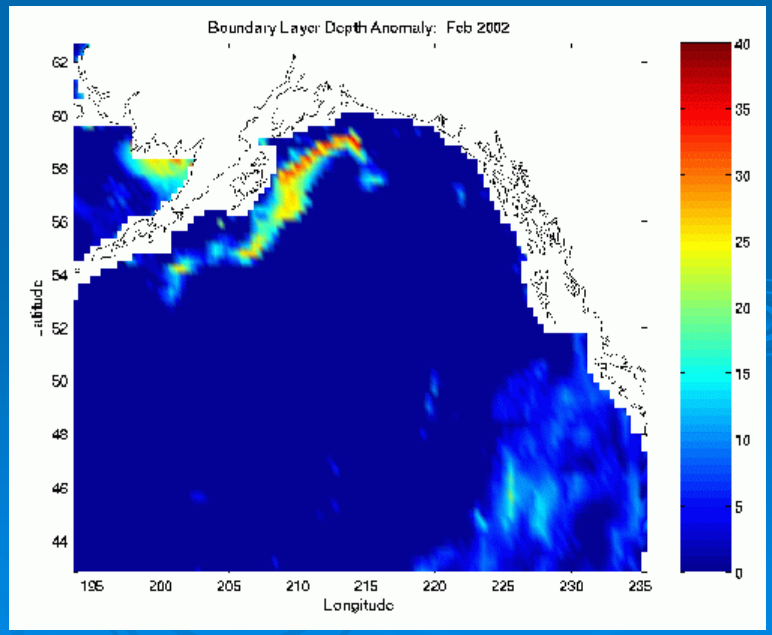
Salinity anomaly at Line-P

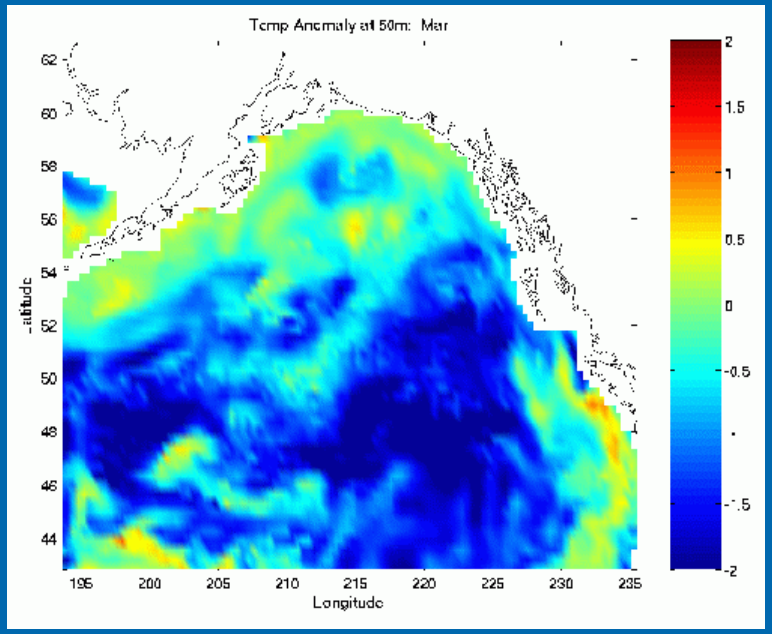


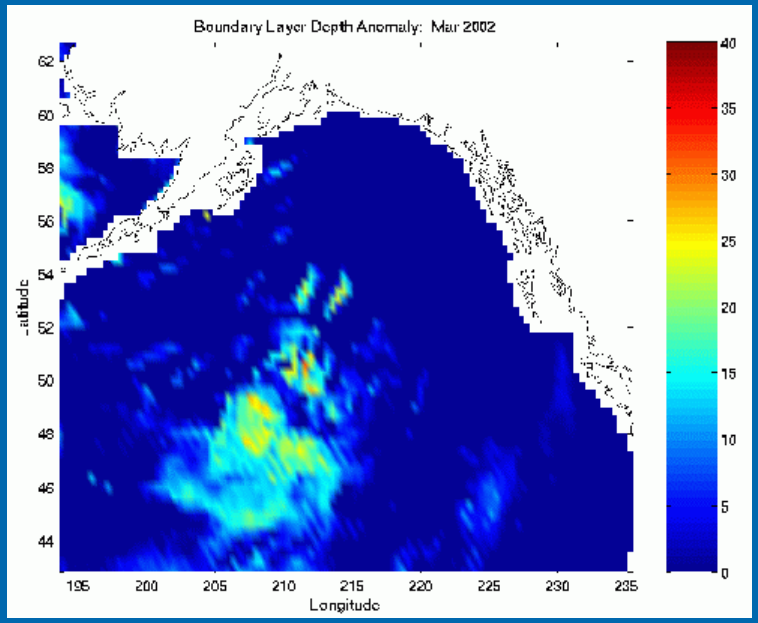

Temp Anomaly at 50m Jan
Latitude
Longitude
62
60
58
56
54
52
50
48
46
44
195
200
205
210
215
220
225
230
235
2
1.5
1
0.5
0
-0.5
-1.5
-2

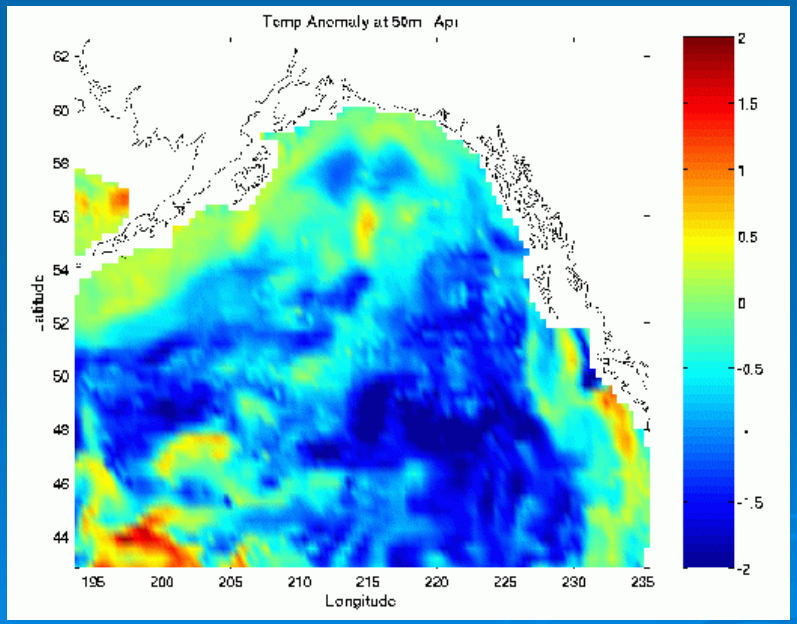

Boundary Layer Depth Anomaly: Jan 2002
Latitude
Longitude
62
60
58
56
54
52
50
48
46
44
195
200
205
210
215
220
225
230
235
40
35
30
25
20
15
10
5
0

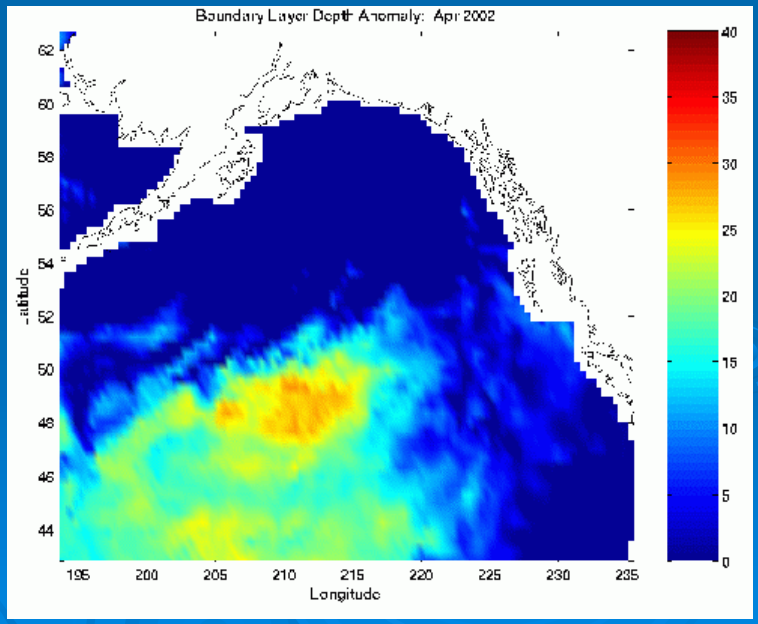

Temp Anomaly at 50m: Feb
Latitude
Longitude
62
60
58
56
54
52
50
48
46
44
195
200
205
210
215
220
225
230
235
2
1.5
1
0.5
0
-0.5
-1.5
-2

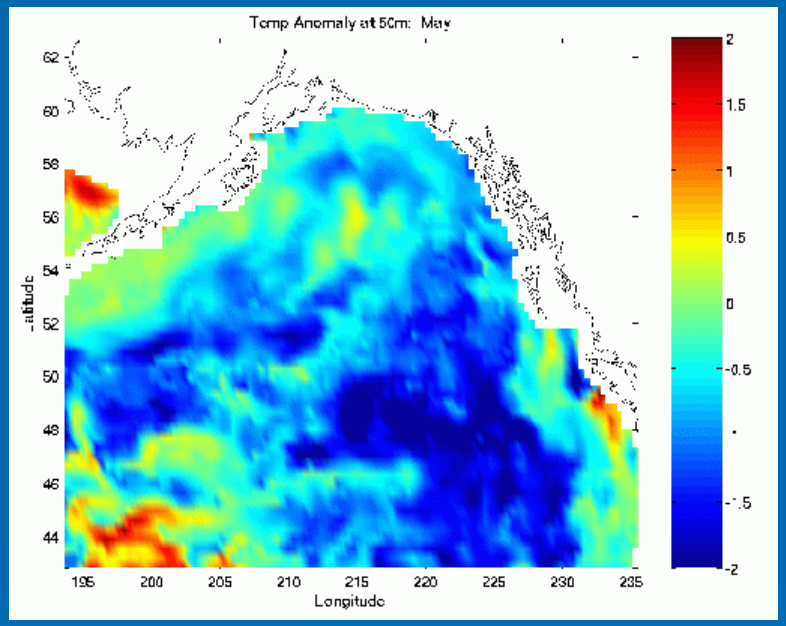

Boundary Layer Depth Anomaly: Feb 2002
Latitude
Longitude
62
60
58
56
54
52
50
48
46
44
195
200
205
210
215
220
225
230
235
40
35
30
25
20
15
10
5
0

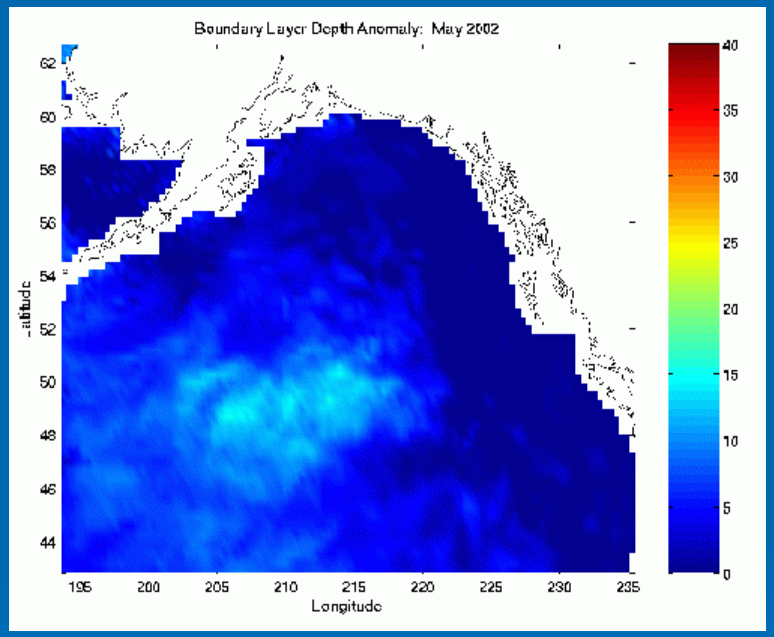

Temp Anomaly at 50m: Mar
Latitude
Longitude

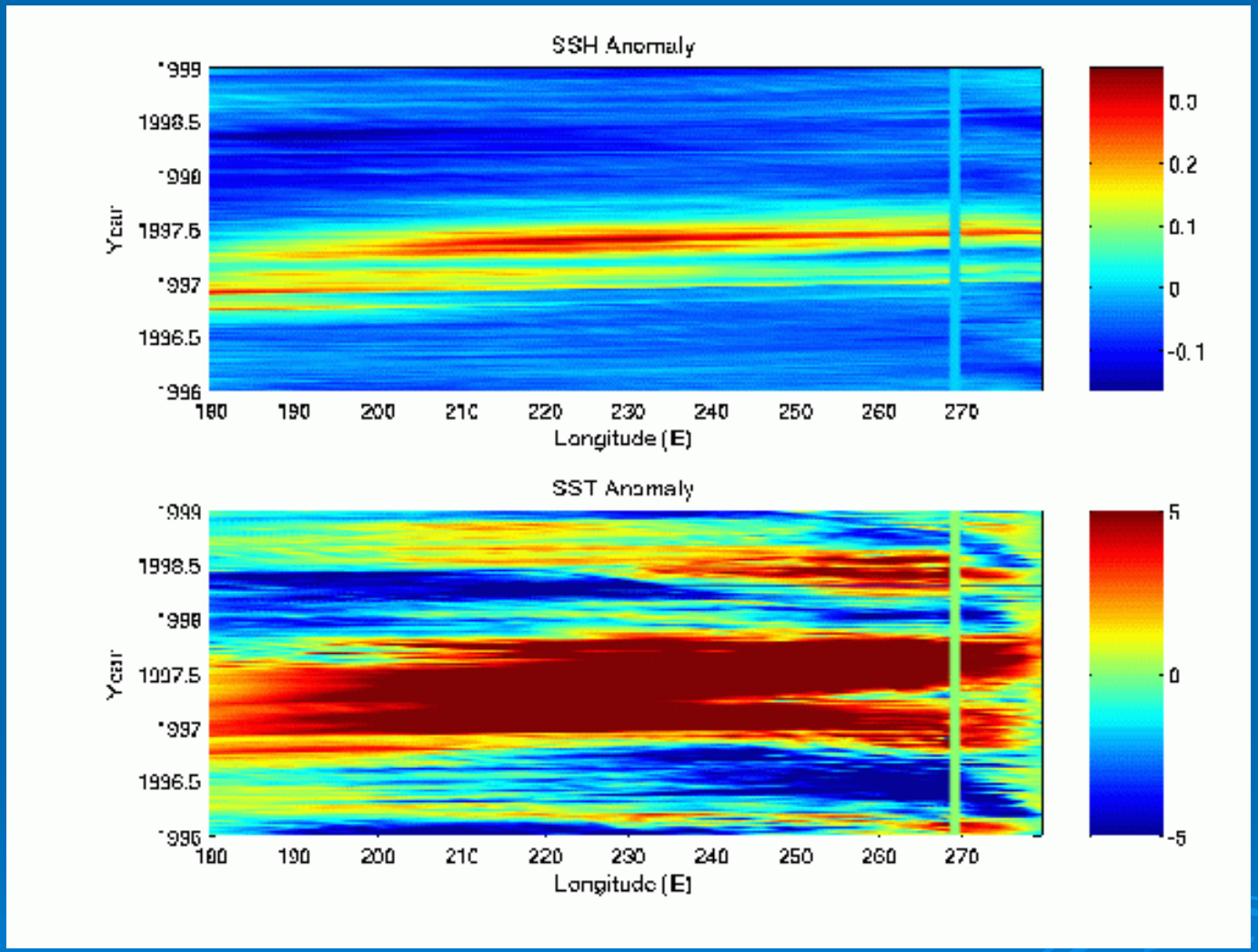

Boundary Layer Depth Anomaly: Mar 2002
Latitude
Longitude

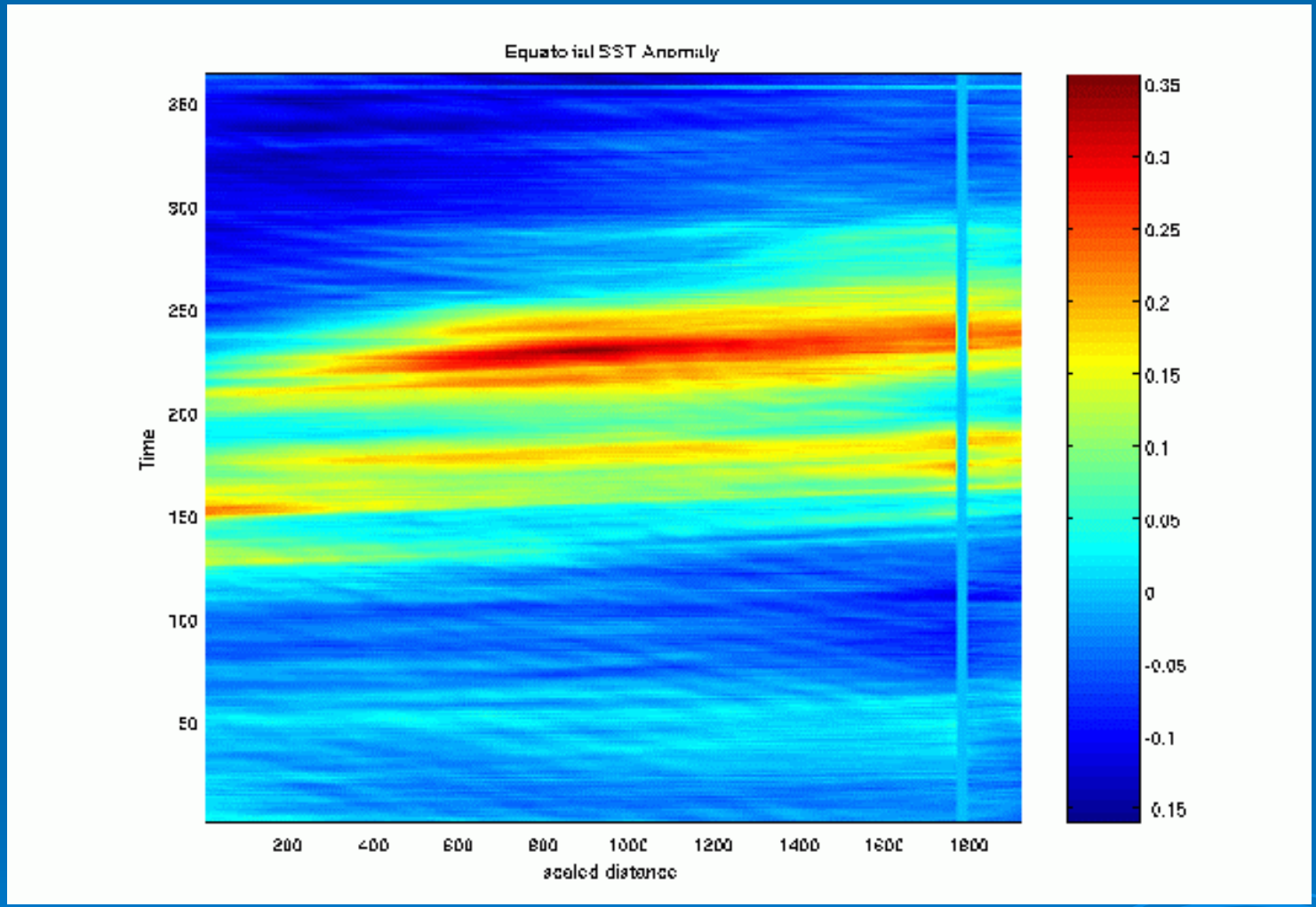

Temp Anomaly at 50m Apr
Latitude
Longitude

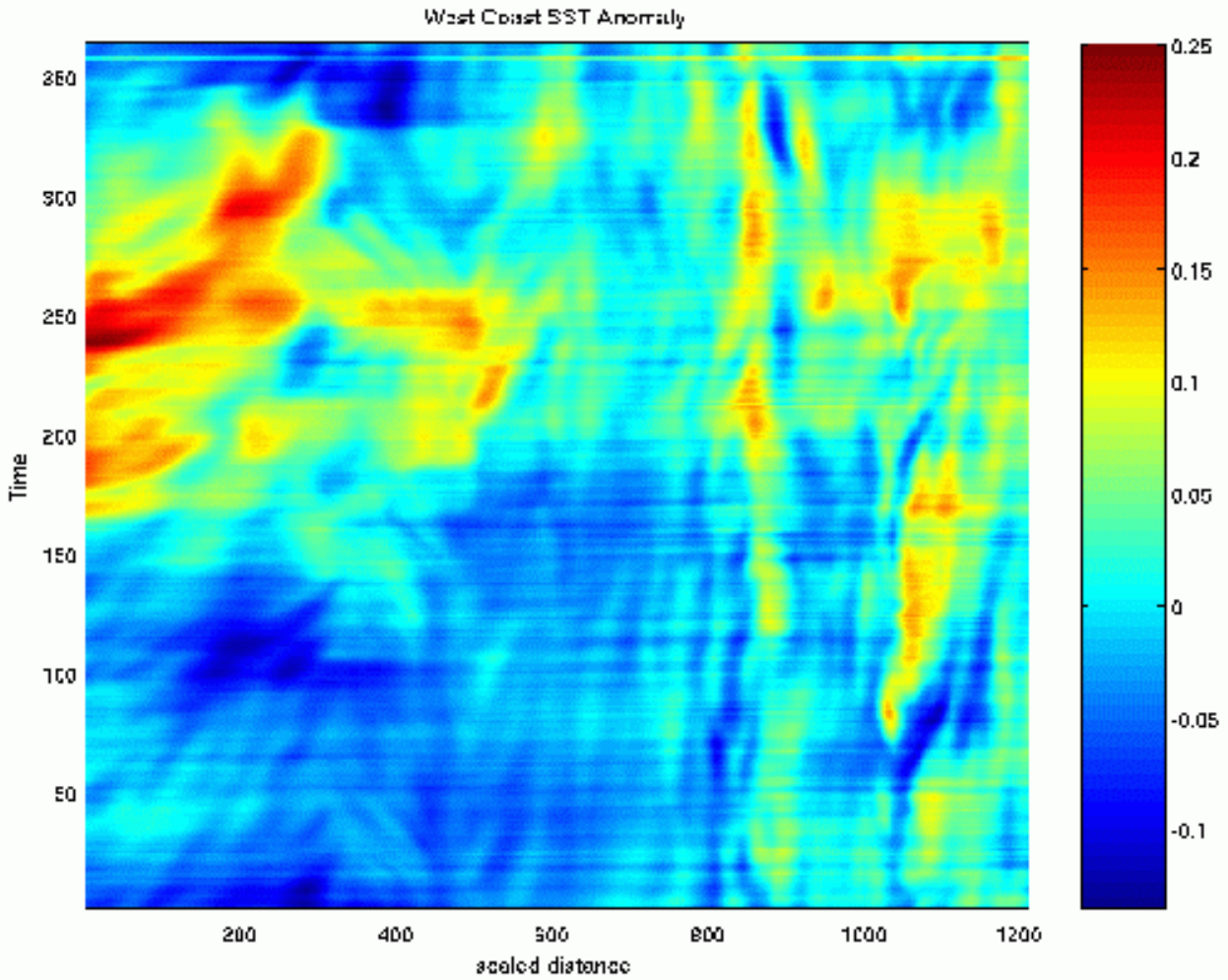

Boundary Layer Depth Anomaly: Apr 2002
Latitude
Longitude

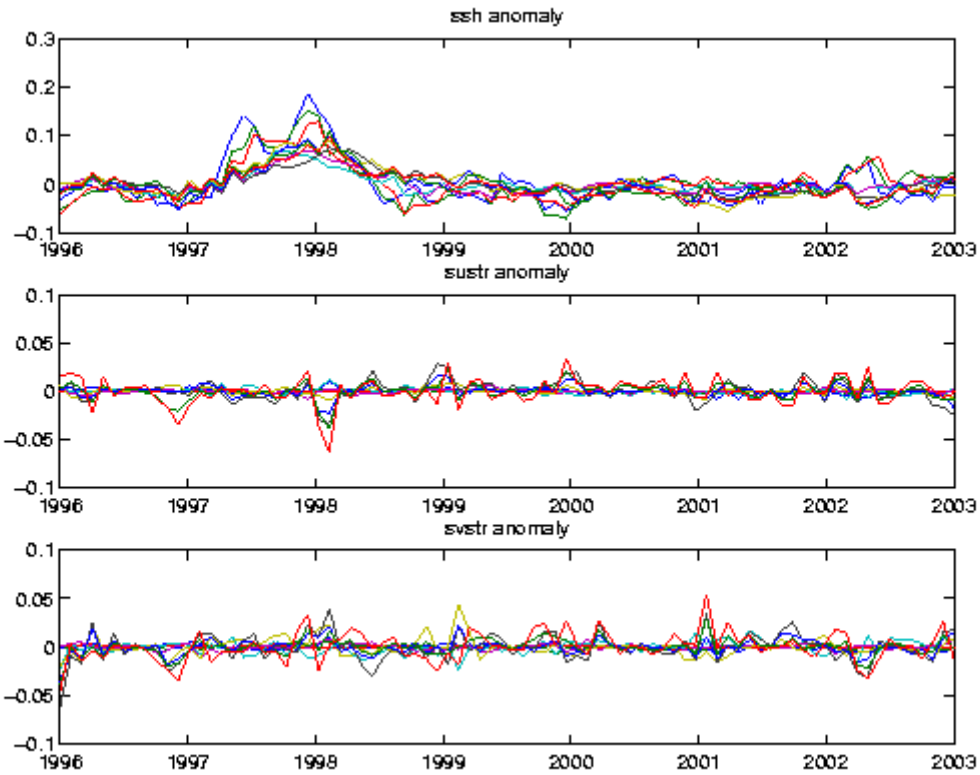

Temp Anomaly at 50m: May
62
60
58
56
54
52
50
48
46
44
195
200
205
210
215
220
225
230
235
Longitude
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2


Boundary Layer Depth Anomaly: May 2002
62
60
58
56
54
52
50
48
46
44
195
200
205
210
215
220
225
230
235
Longitude
40
35
30
25
20
15
10
5
0


SSH Anomaly
Year
1999
1998.5
1998
1997.5
1997
1996.5
1996
180
190
200
210
220
230
240
250
260
270
Longitude (E)
0.3
0.2
0.1
0
-0.1
SST Anomaly
Year
1999
1998.5
1998
1997.5
1997
1996.5
1996
180
190
200
210
220
230
240
250
260
270
Longitude (E)
5
0
-5


Equatorial SST Anomaly
Time
scaled distance
350
300
250
200
150
100
50
200
400
600
800
1000
1200
1400
1600
1800
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15


West Coast SST Anomaly
Time
350
300
250
200
150
100
50
200
400
600
800
1000
1200
scaled distance
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1


ssh anomaly
0.3
0.2
0.1
0
−0.1
1996
1997
1998
1999
2000
2001
2002
2003
sustr anomaly
0.1
0.05
0
−0.05
−0.1
1996
1997
1998
1999
2000
2001
2002
2003
svstr anomaly
0.1
0.05
0
−0.05
−0.1
1996
1997
1998
1999
2000
2001
2002
2003