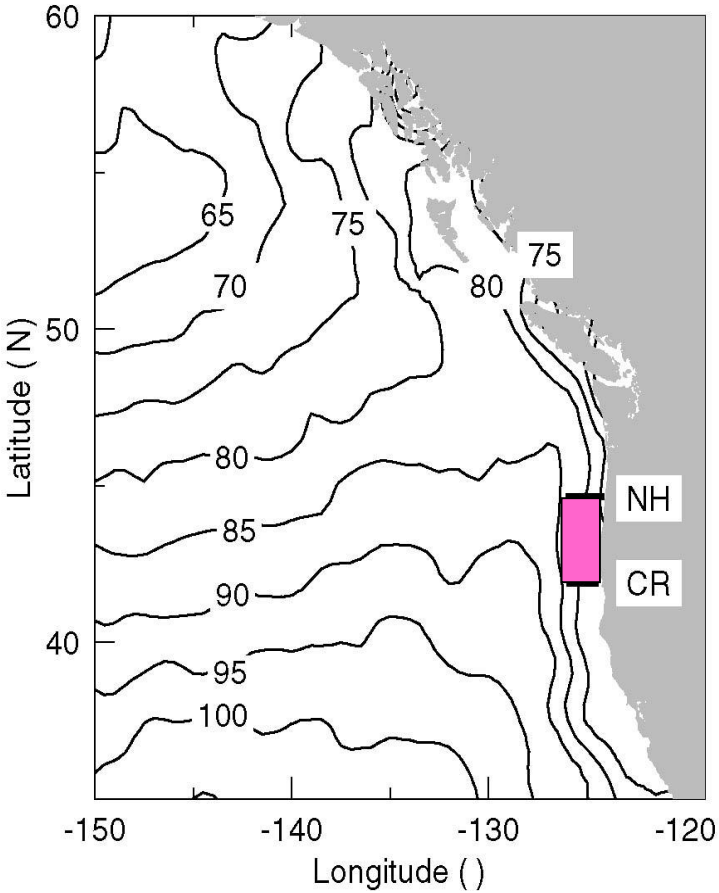
Changing Ocean Conditions in the Northern California Current, 1997-2003

A. Huyer, P. M. Kosro, R. L. Smith, P. A. Wheeler
COAS, Oregon State University



Introduction

- climate overview, location, seasonal cycle

Year-to-Year Variations

- winter & summer T anomalies
- water-mass changes (esp. in halocline)
- ecosystem response

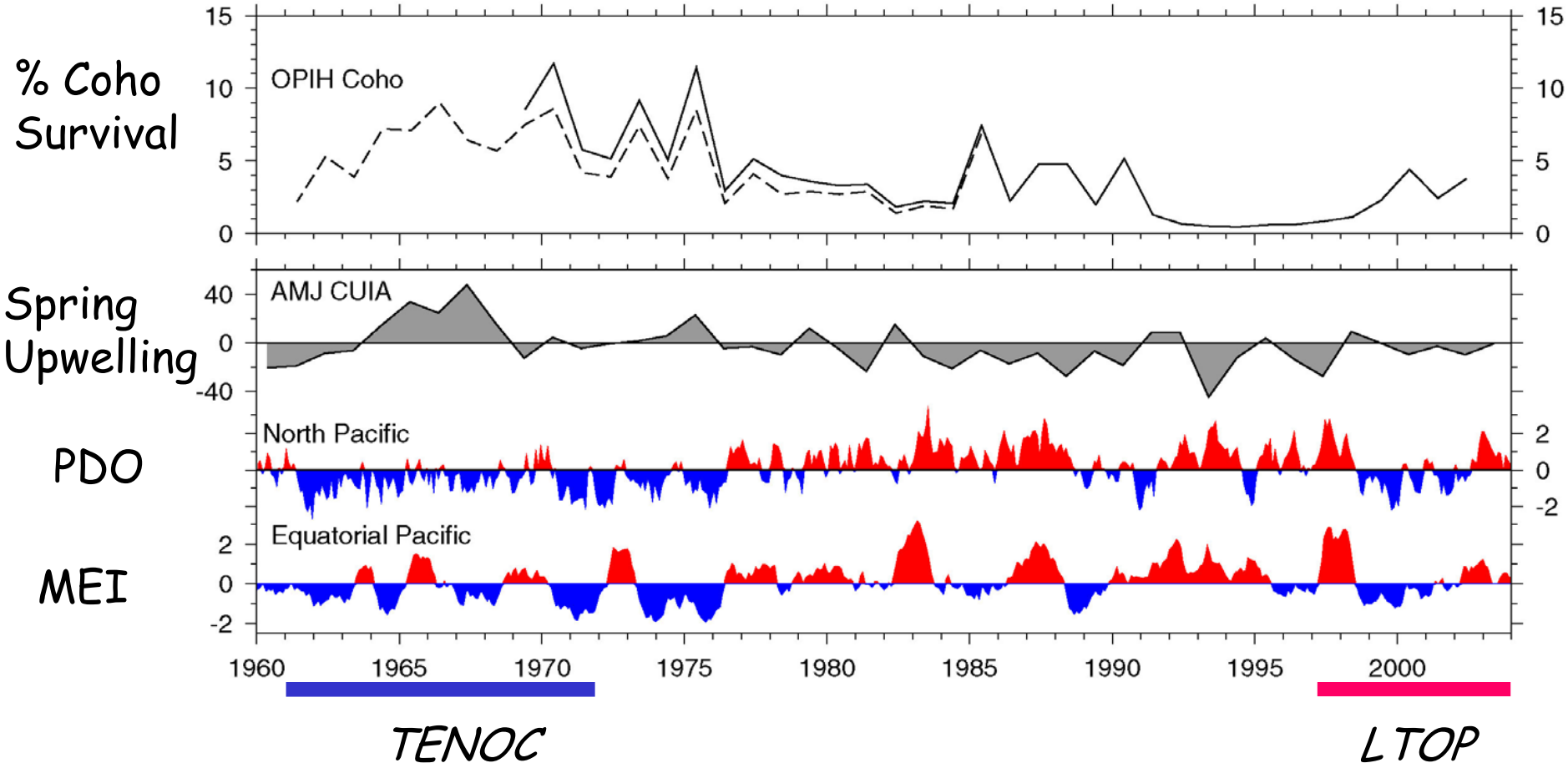
Epoch-Epoch Comparison

- average temperatures: winter & summer

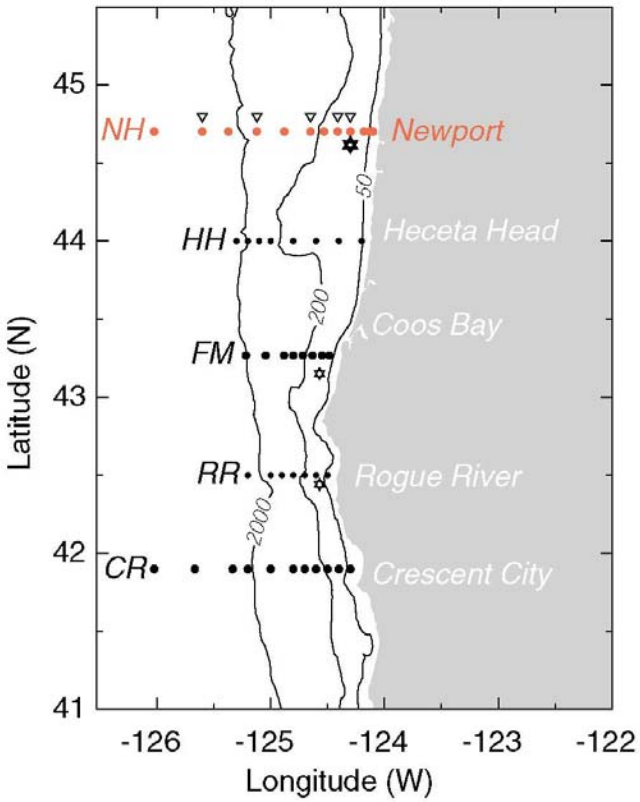
Conclusions

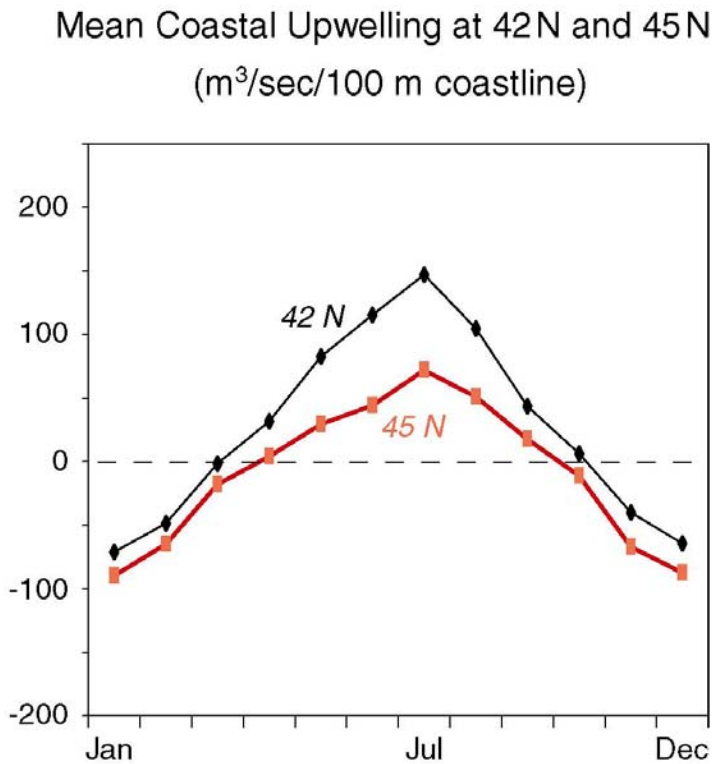
Coho Survival, Upwelling, PDO & ENSO

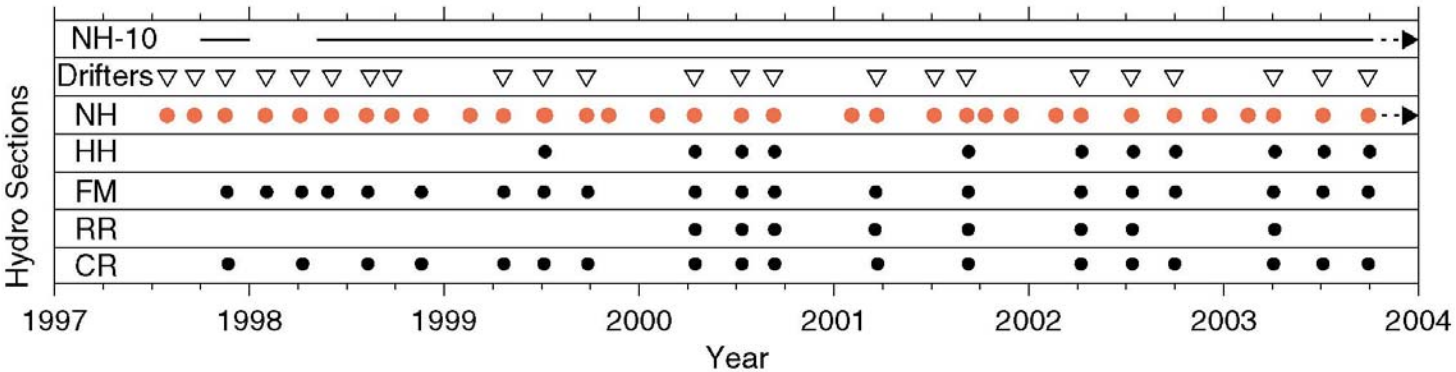
1960-2003



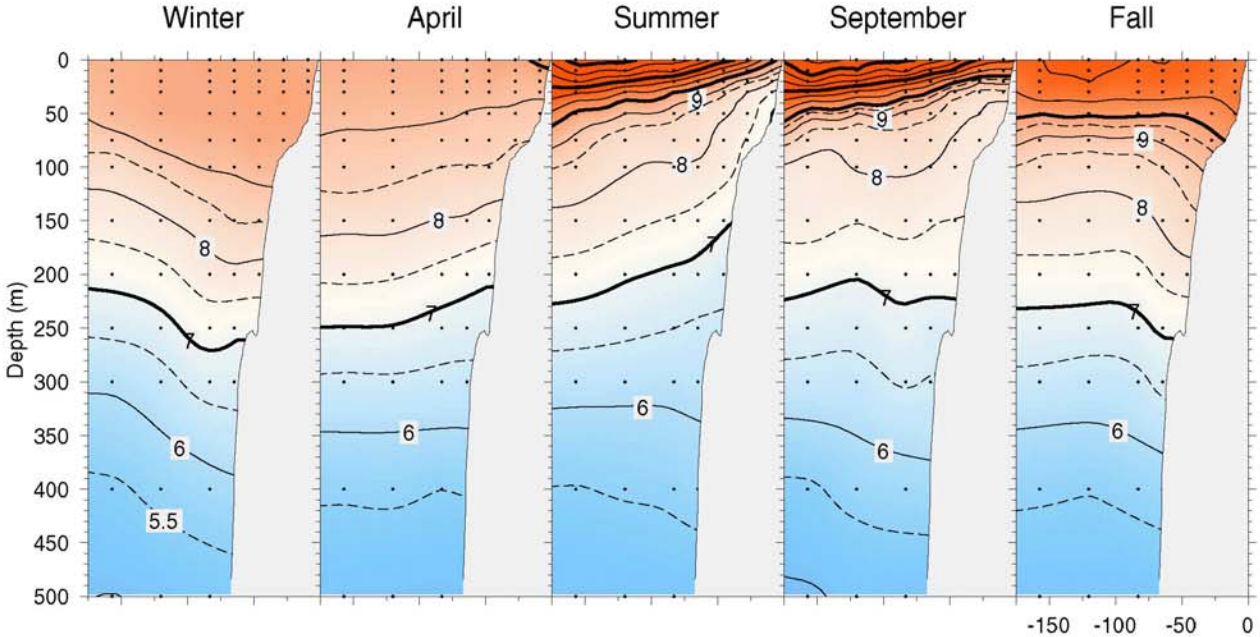
GLOBEC LTOP in NorCalCur







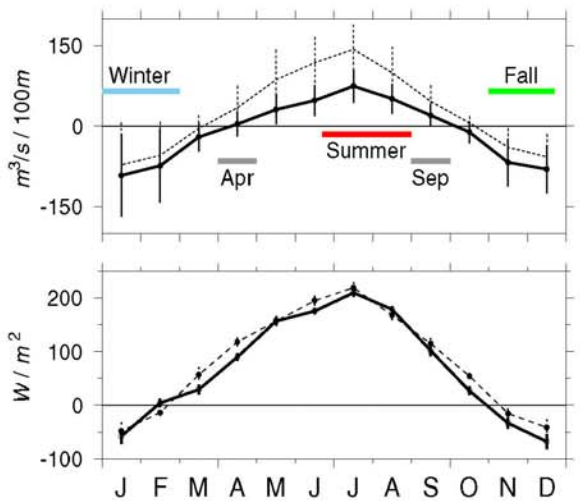
Seasonal Average Temperature (1961-71)



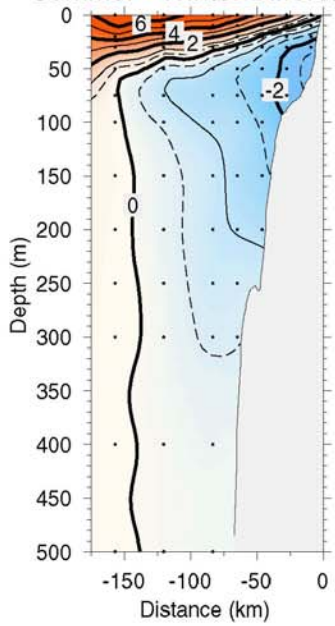
Seasonal Upwelling and Heat Flux

Offshore Ekman Transport at 45 N and 42 N (dashed)

Net Heat Flux at 45 N and 44 N (dashed)

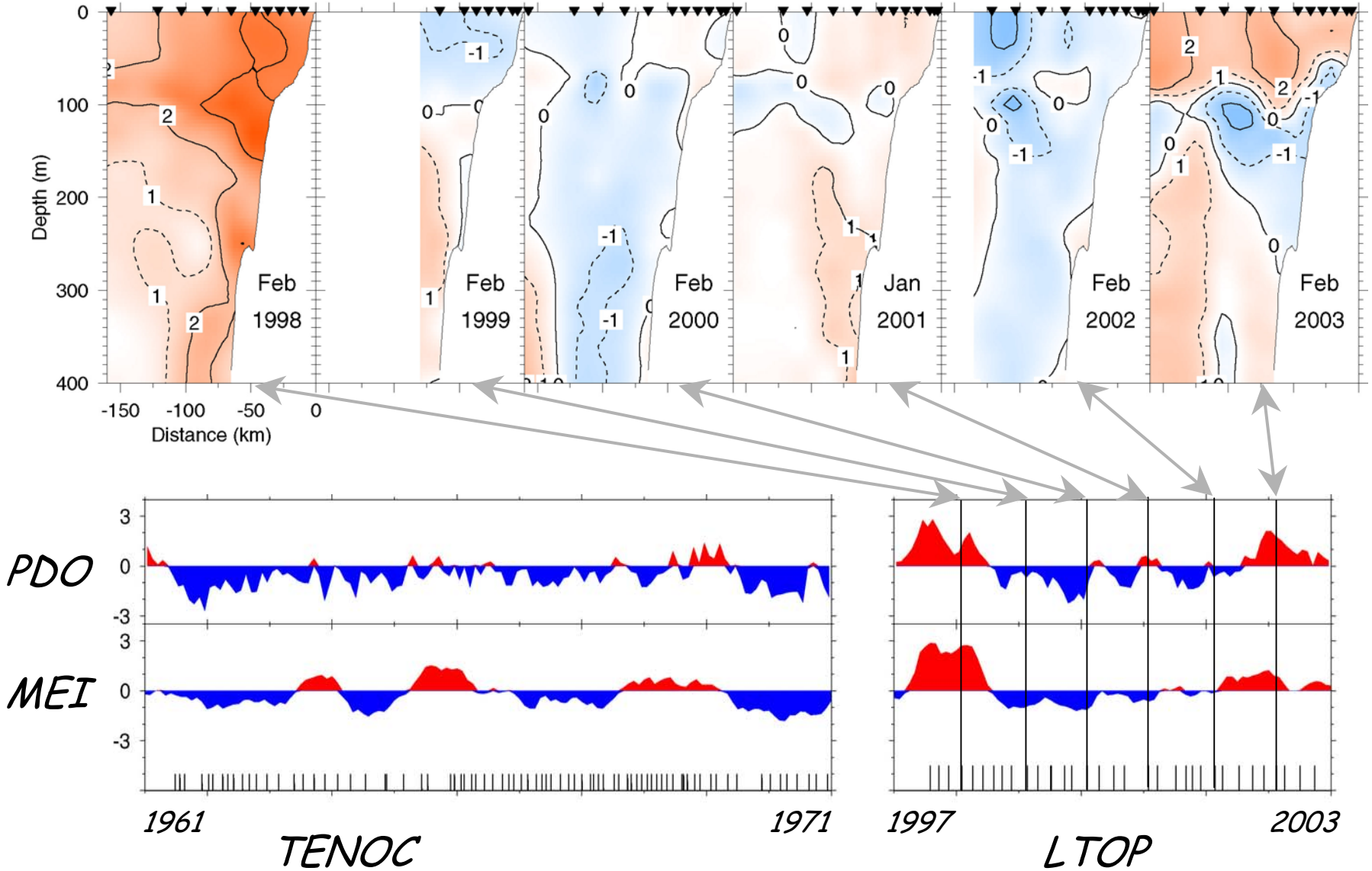


Summer - Winter Difference



Winter Temperature Anomalies

(normalized by 1961-71 winter std dev)



Summer Temperature Anomalies

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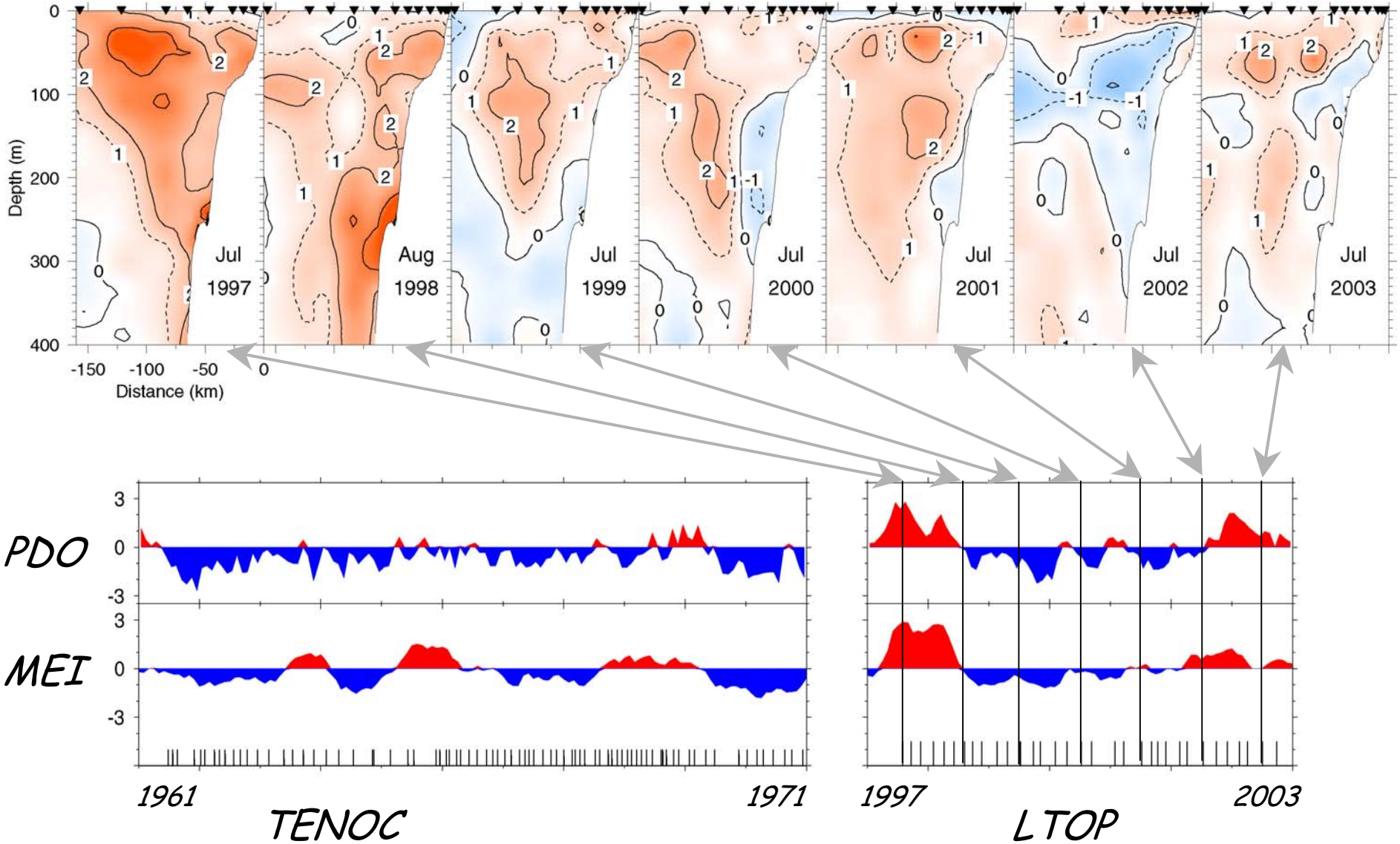
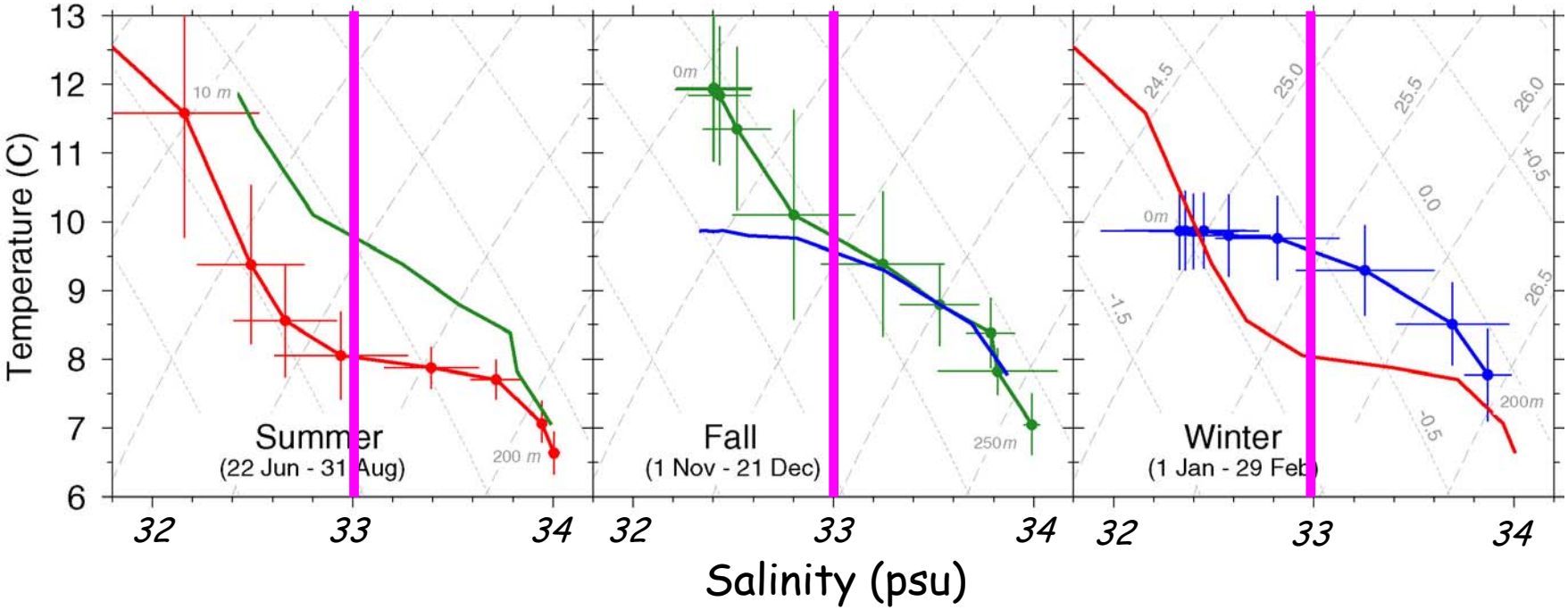


Seasonal Water-Mass Changes at Shelf-Break (NH-25)

(1961-71 Seasonal Averages)

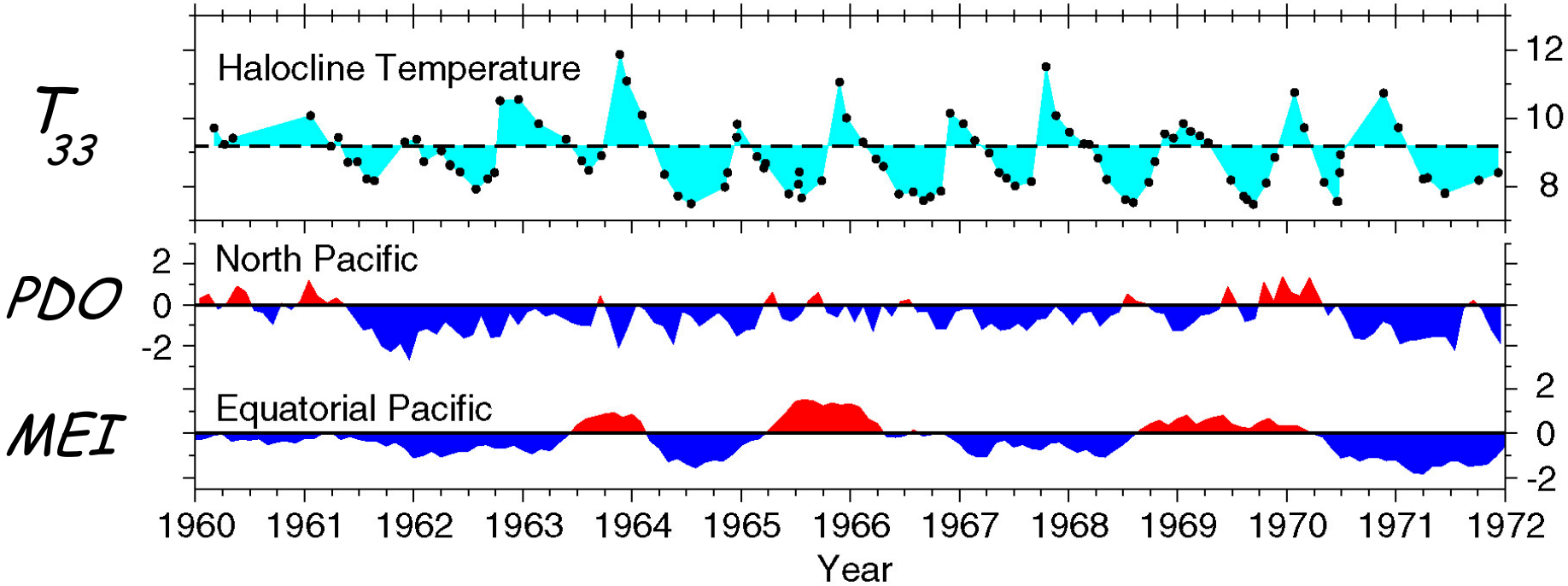
Summer → Fall Fall → Winter Winter → Summer



→ *Large Variation on 33.0 isohaline!*

Variation of Halocline Temperature

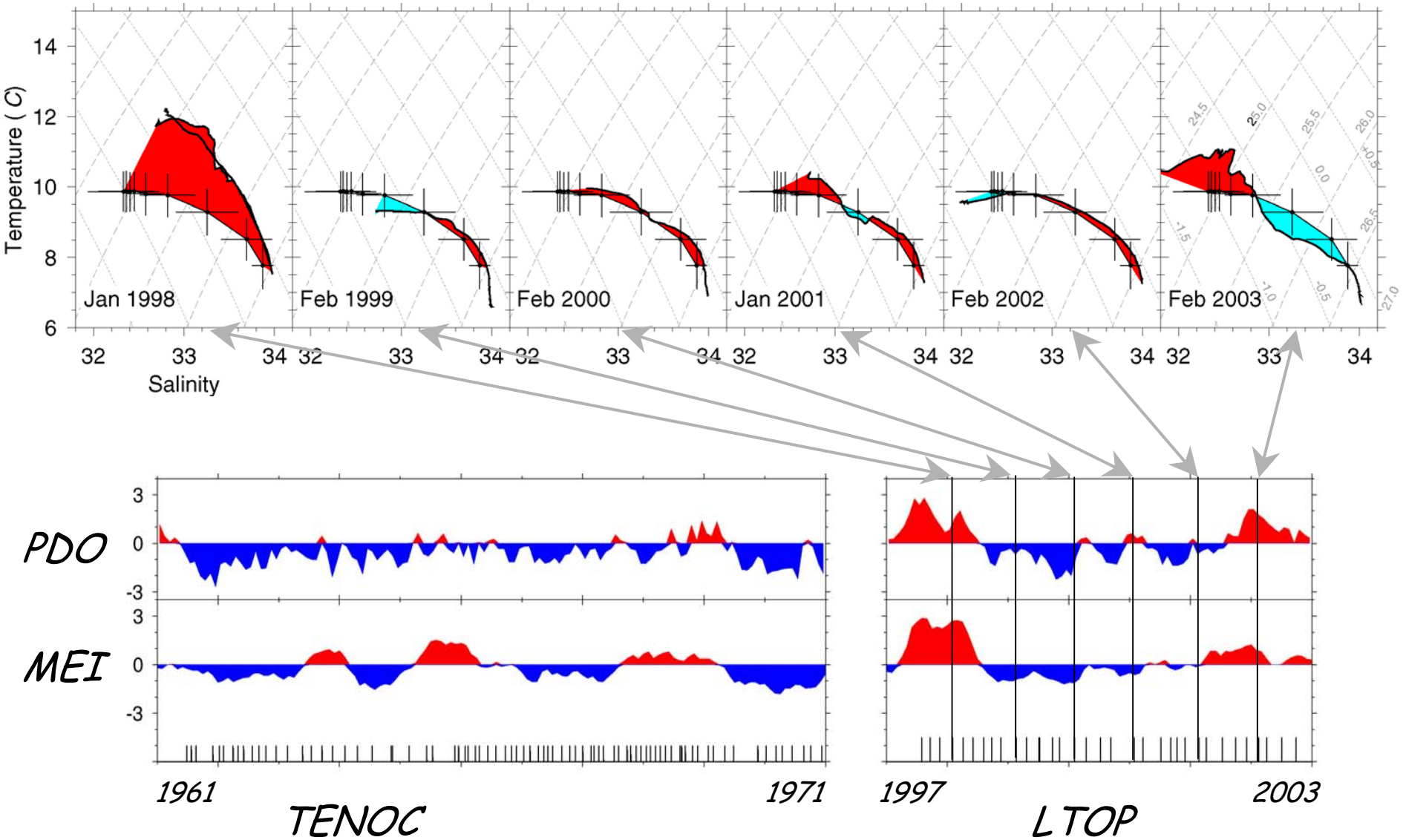
1961-1971



→ *Seasonal Cycle dominates!*

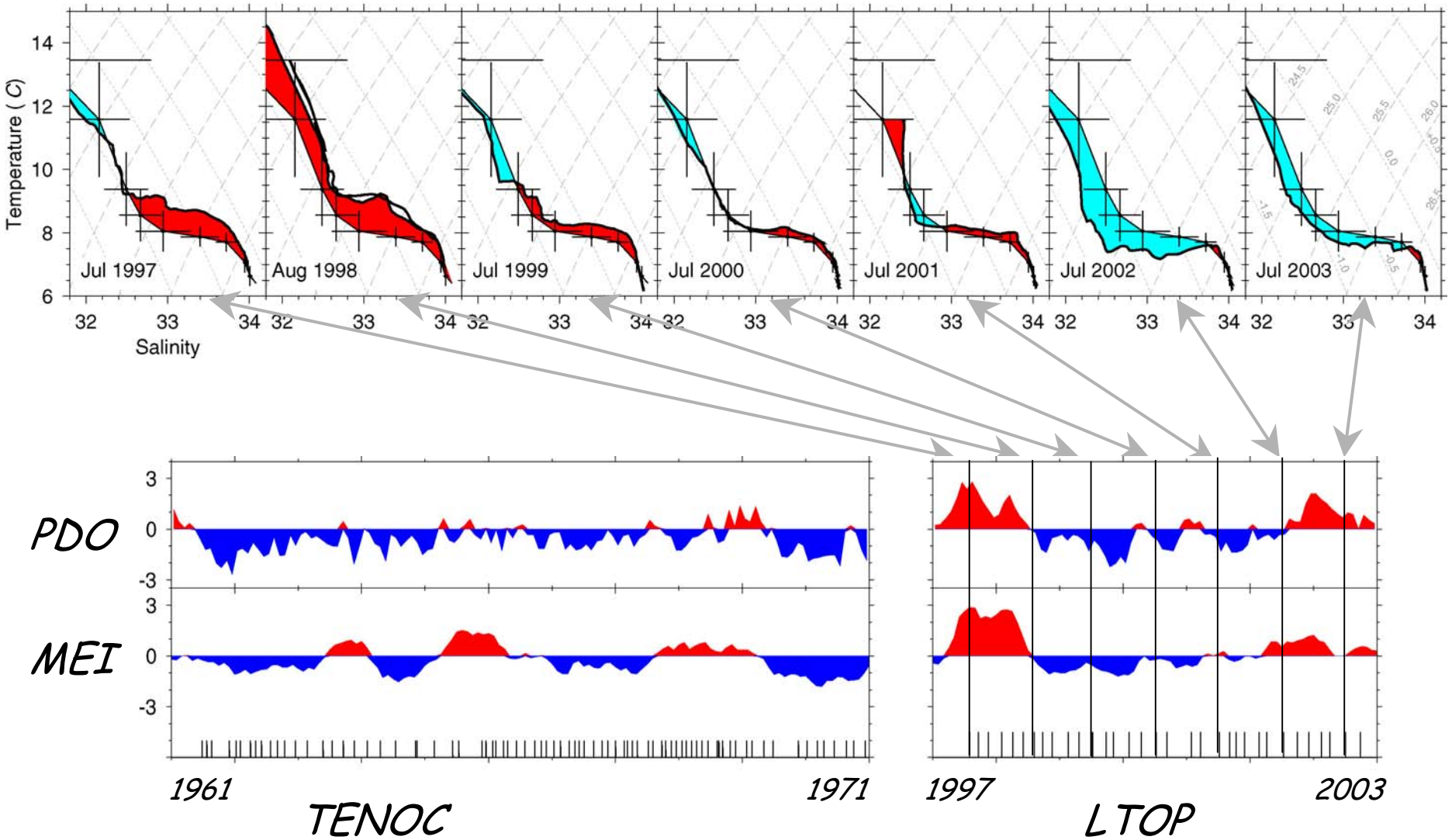
Shelf-break T-S in LTOP Winters

(compared to 1961-71 winter average)



Shelf-Break T-S in LTOP Summers

(compared to 1961-71 winter average)



Local Ocean Indices

Coho Survival (%)

Ave. Integrated Chlor. (mg/m^2)

NH-25 Halocline Nitrate
(μM at S = 33 psu)

NH-25 Halocline T (C at 33)

Coastal Current Shear
V_{10}-V_{60} (cm/s^{-1})

Large-Scale Indices

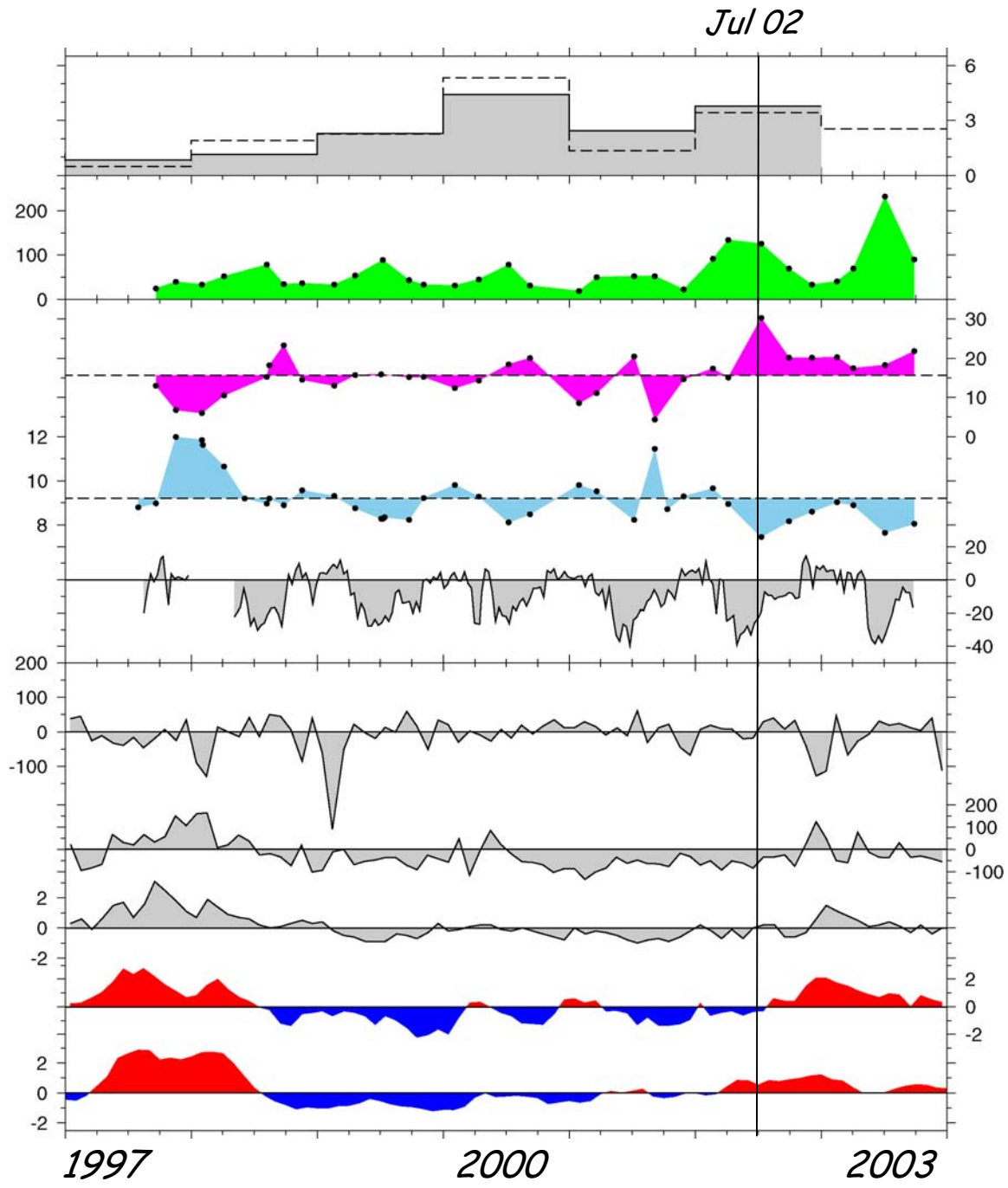
Upwelling Anom at 45N

Sea Level at 42N

SST at 48.5 N

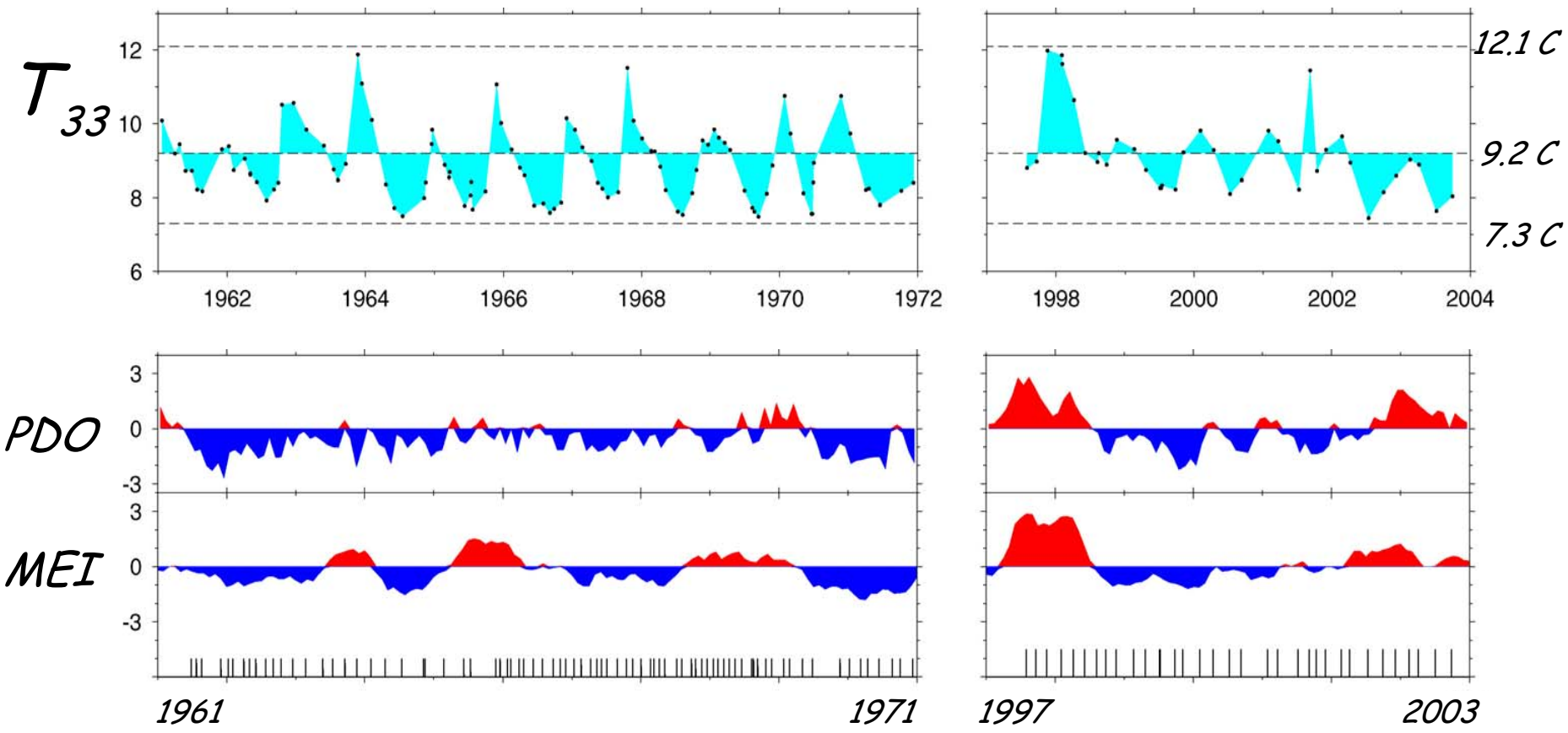
PDO (North Pacific)

MEI (Equat. Pacific)



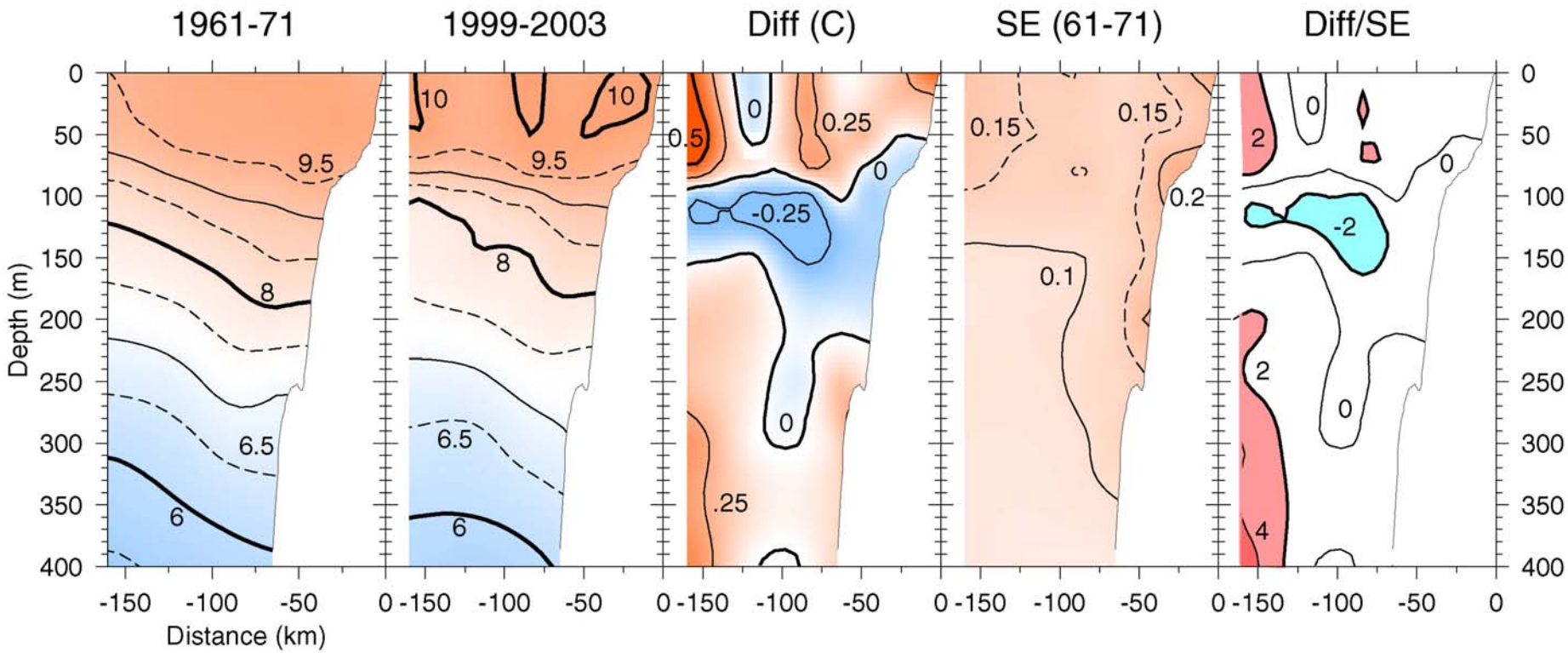
Shelf-Break Halocline Temperatures

1961-1971 and 1997-2003



Has Winter Average Changed?

(97-98 El Niño omitted to avoid bias)

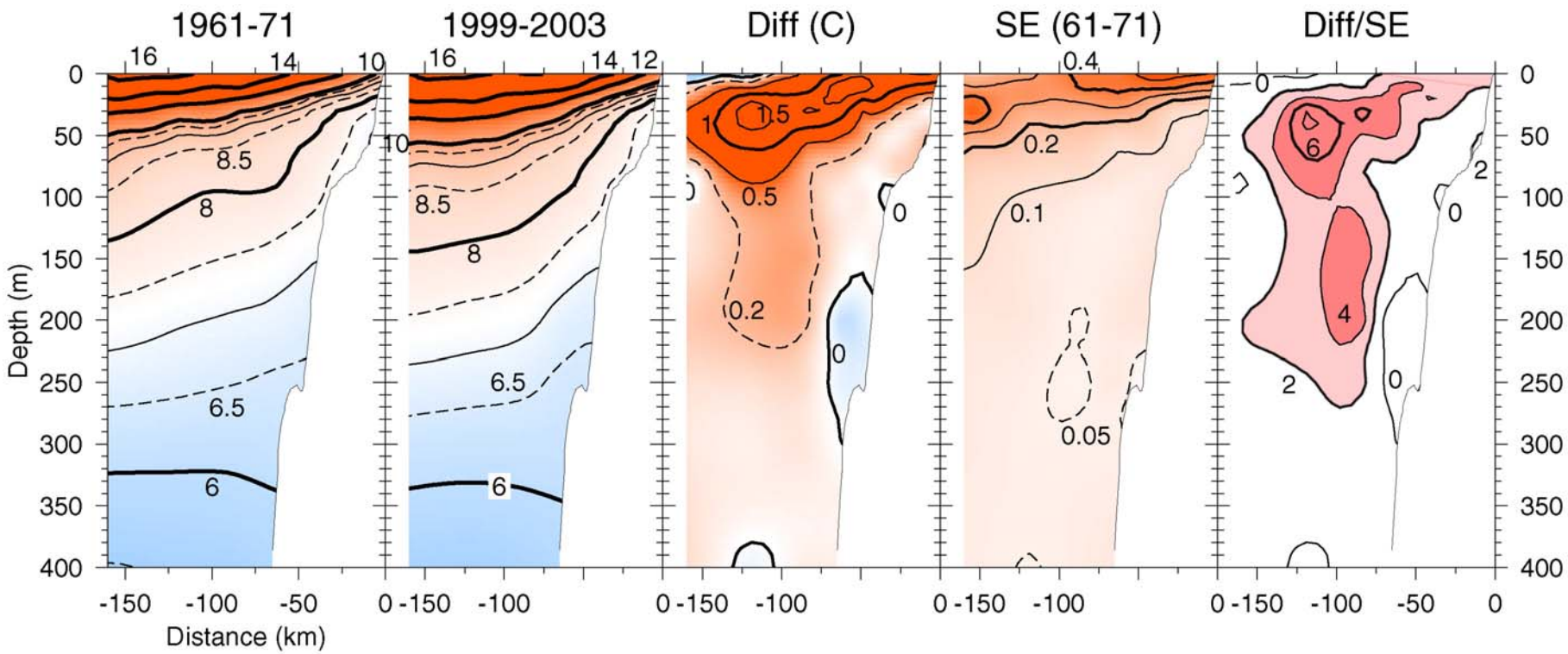


Tentative Answer:

Halocline layer is slightly cooler (0.2 C; P> 90%)

Has Summer Average Changed?

(97-98 El Niño omitted to avoid bias)



Tentative Answer -- Yes!

- by >1C at base of seasonal thermocline (deeper CR Plume?)
- by 0.3C in patch over continental slope (150-200m at NH-45)

(Note: 1999-01 warm anomalies overwhelm 2002-03 cold anomalies!)

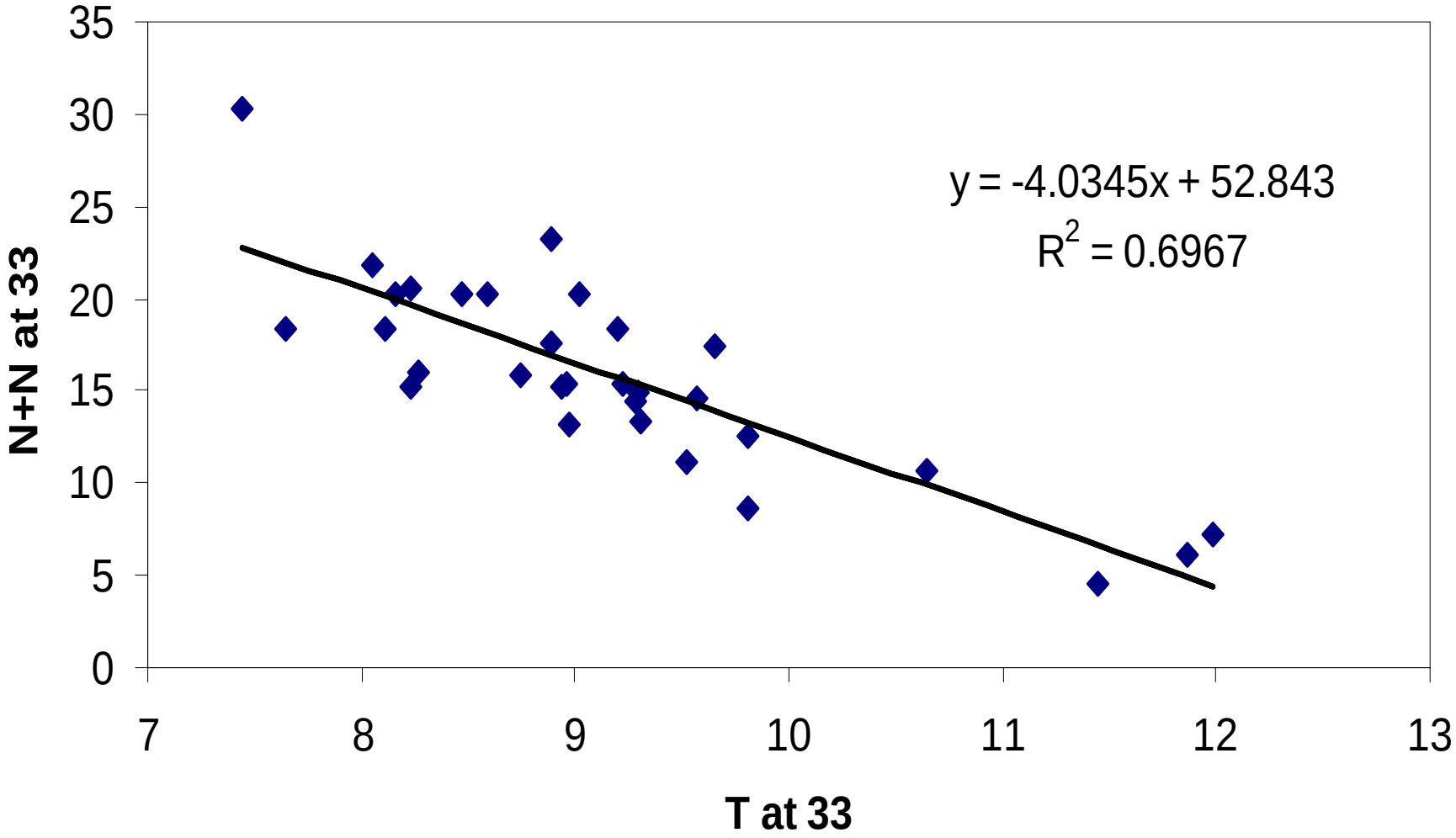
Conclusions

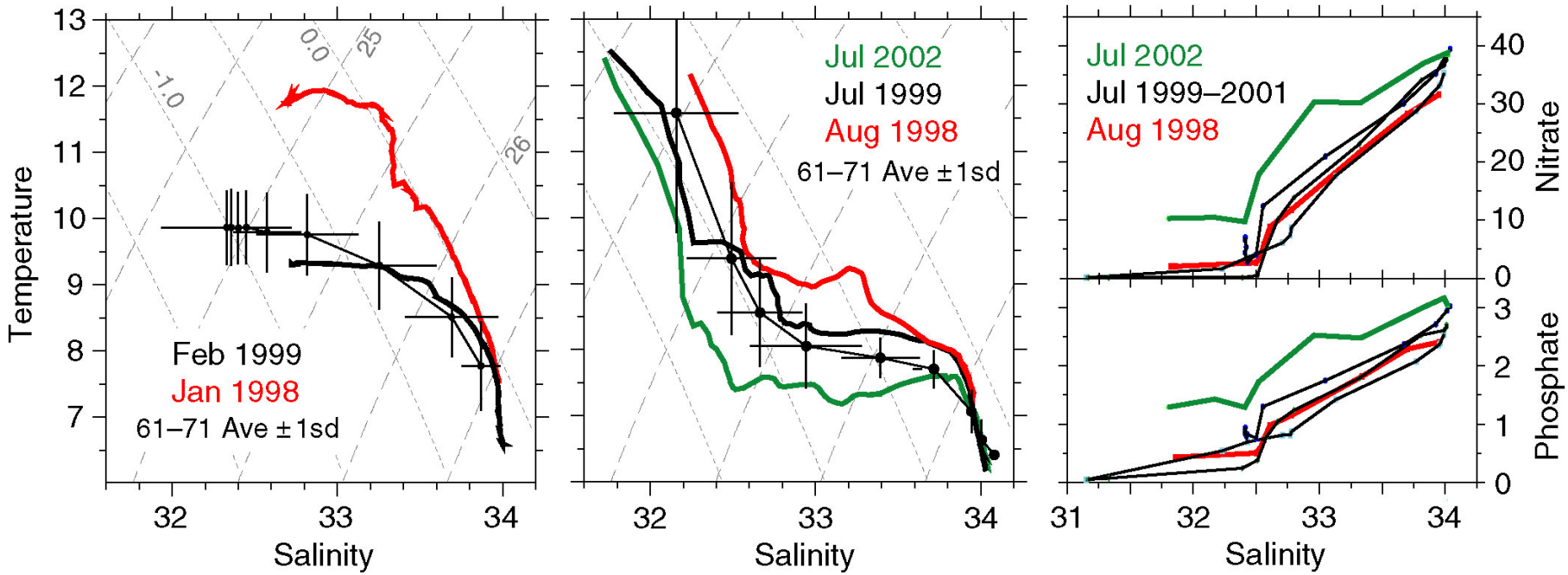
- **MEI & PDO highly variable** during LTOP (cf 1961-71).
- **T_{33} highly variable** during LTOP (cf 1961-71).
- 1997-8 **warm anomalies** clearly associated with **El Niño.**
- 2002-3 **cold halocline anomaly** occurred **in spite of** positive MEI and positive PDO.
- excluding 1997-8 El Niño, the **LTOP winter average** temperature is similar to 1961-71 winter average except that **halocline is slightly cooler** (by 0.2 C, P >90%).
- Excluding 1997-8 El Niño, but including 2002-3 cold anomaly, the **LTOP summer average** temperature **is warmer** than 1961-1971 summer average **in two locations**:
  - by >1 C at base of seasonal thermocline, and
  - by 0.3 C in subsurface patch over continental slope.

END

Miscellaneous Extras

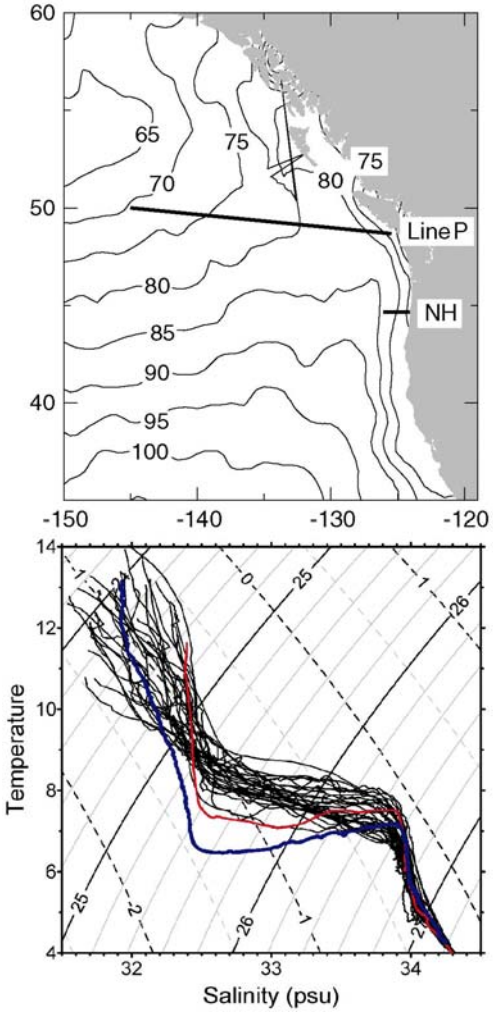
Halocline Nitrate and Temperature
LTOP (1997-2003)
(both at S = 33 psu)

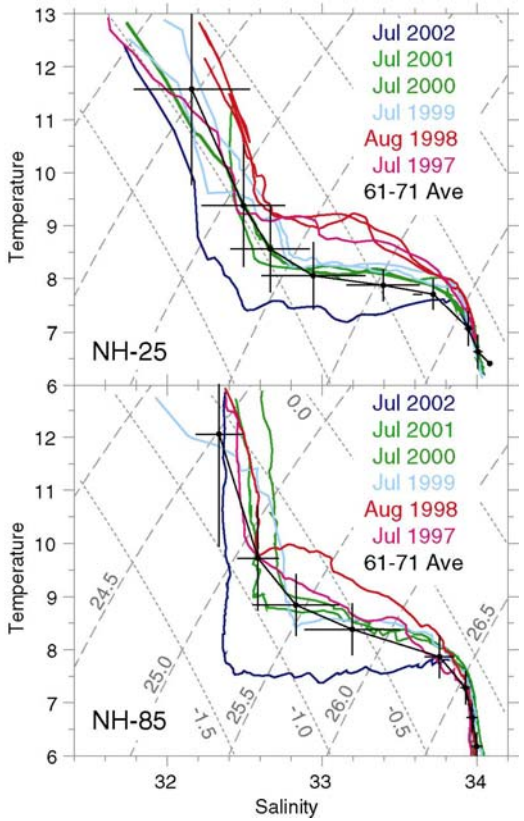



Temperature
Salinity
Feb 1999
Jan 1998
61–71 Ave ±1sd
-1.0
0.0
25
26
Jul 2002
Jul 1999
Aug 1998
61–71 Ave ±1sd
Jul 2002
Jul 1999–2001
Aug 1998
Nitrate
Phosphate

Subarctic Invasion in 2002

caused extreme anomalies in T, S, nutrients, chlorophyll & oxygen



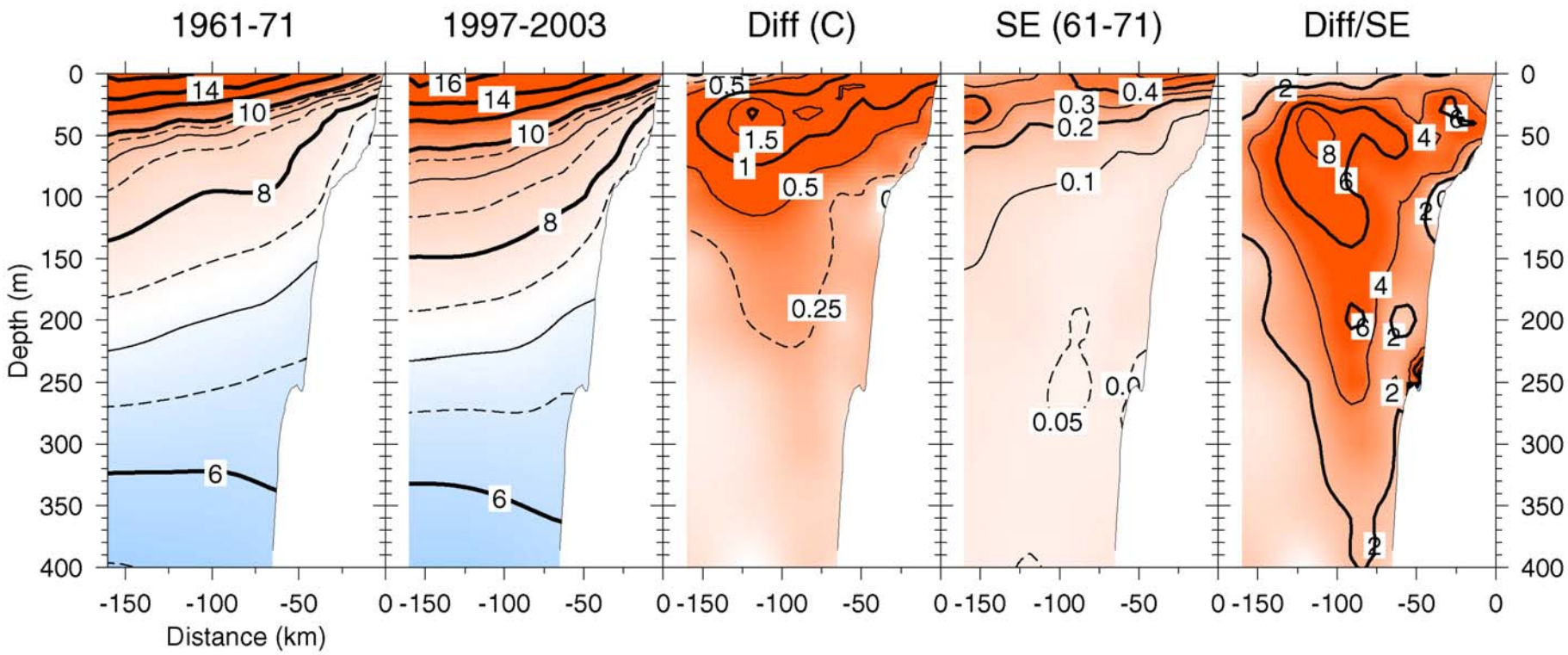


See Freeland et al, 2003 GRL 30(3), and Special Section of GRL 30 (15):

Huyer, 2003;
Bograd & Lynn, 2003;
Wheeler et al, 2003;
Kosro, 2003;
Barth, 2003;
Strub & James, 2003;
Thomas et al, 2003;
Murphree et al, 2003.

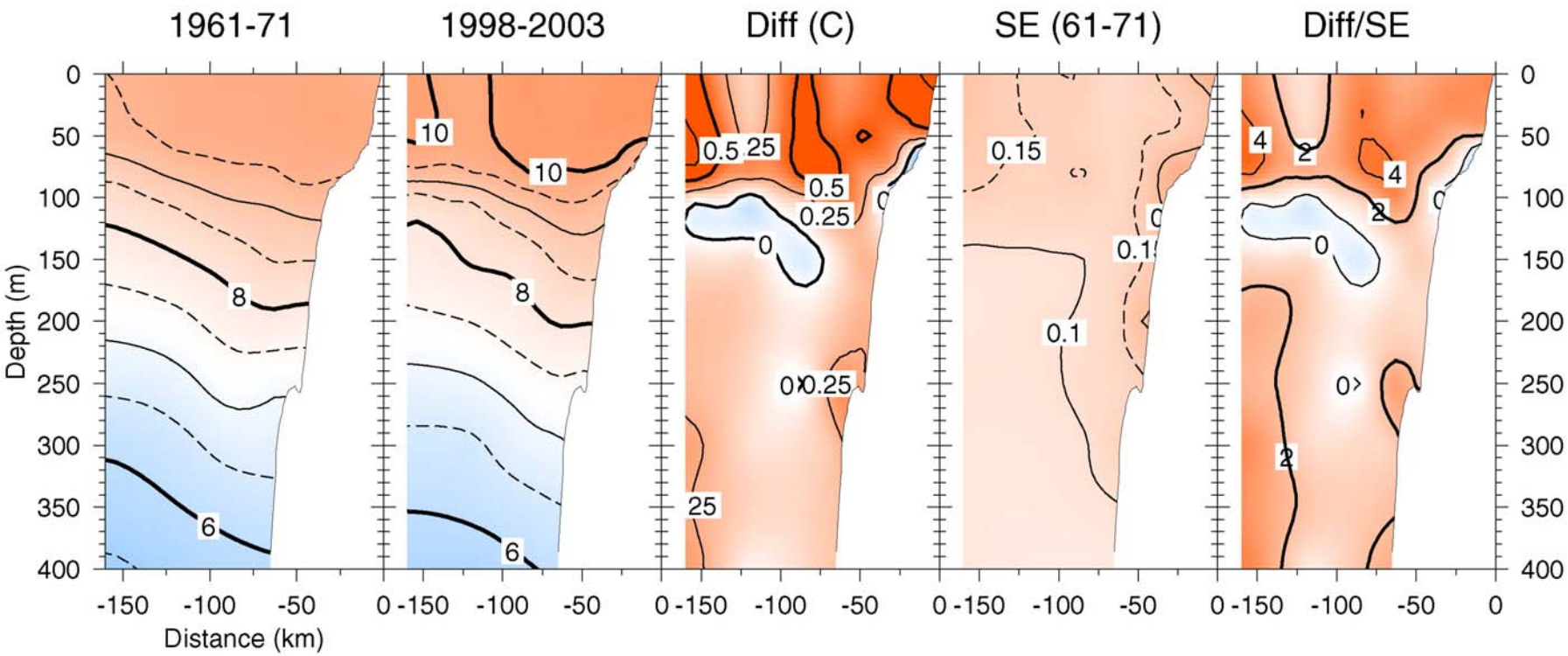
Summer TemperagesAverages

(entire LTOP cf TENOC)



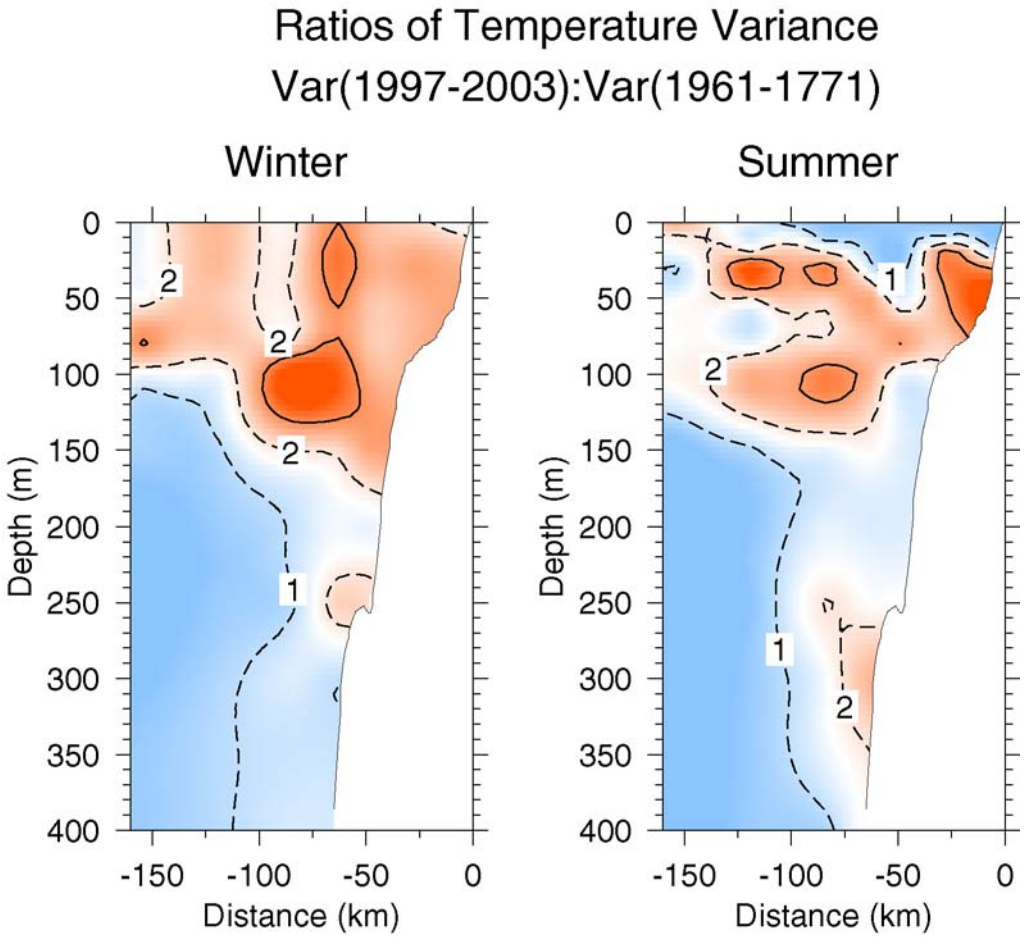
Winter Temperature Averages

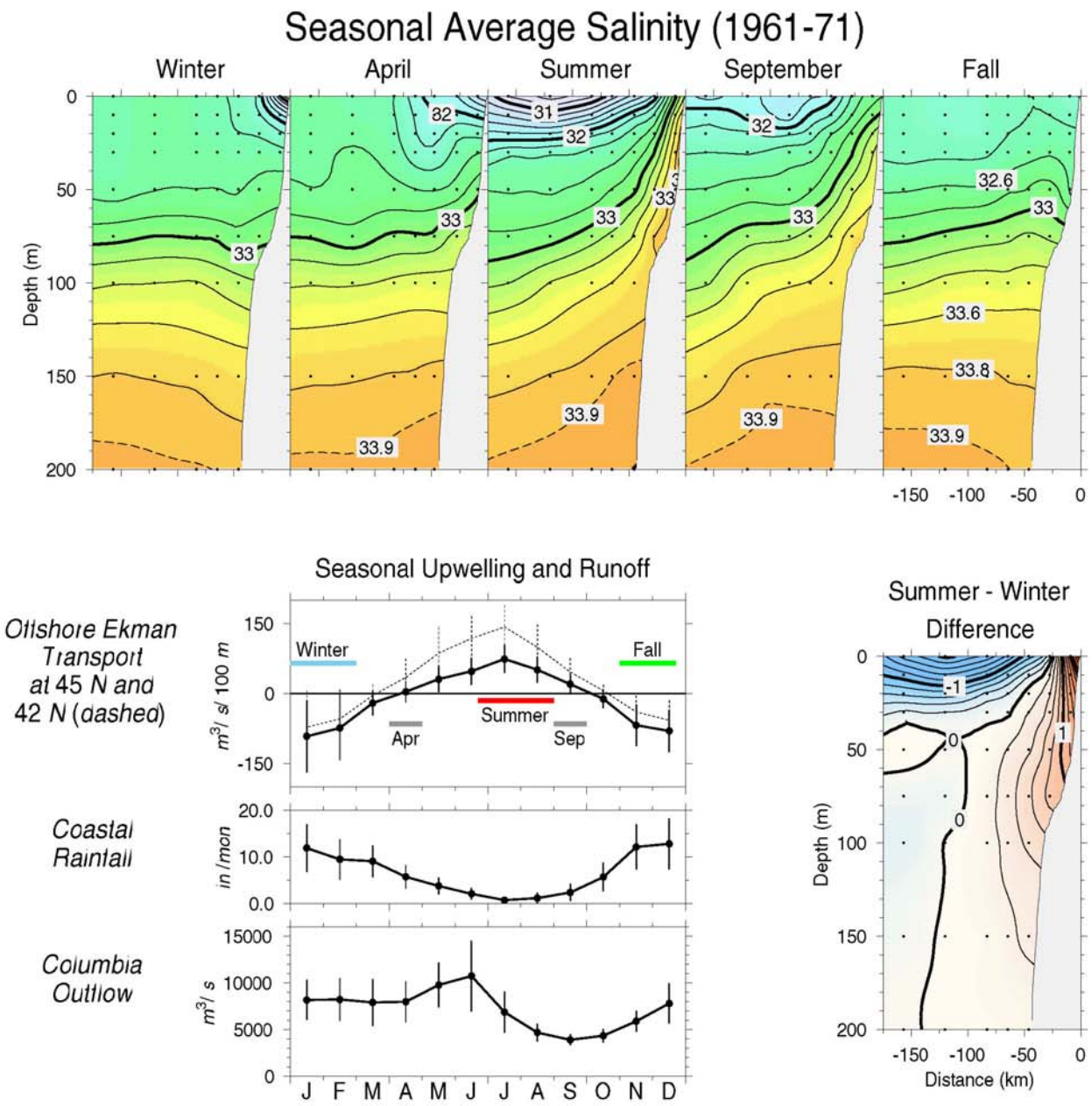
(entire LTOP cf TENOC)



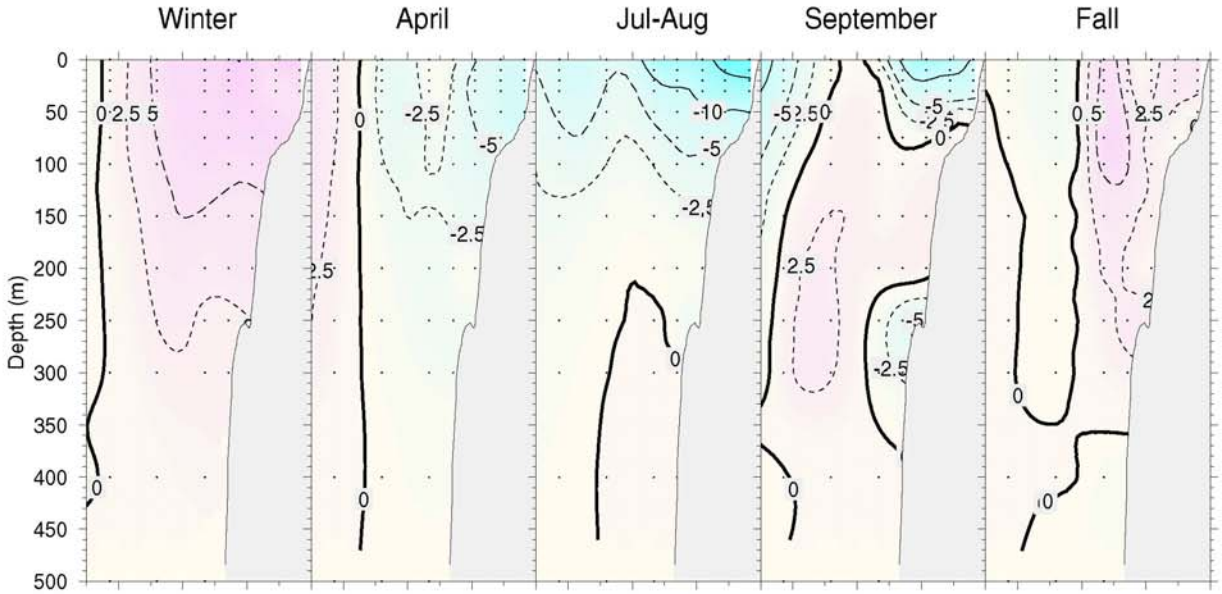
Temperature Variance Ratio

(solid contours are 5% levels of F-test: 3.33 & 3.14)

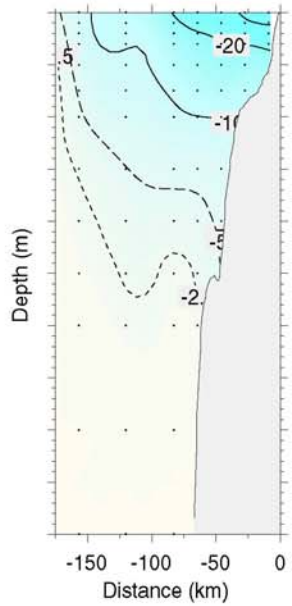



Seasonal Average Salinity (1961-71)
Winter
April
Summer
September
Fall
Depth (m)
0
50
100
150
200
-150
-100
-50
0
31
32
33
33.9
32.6
33.6
33.8
Seasonal Upwelling and Runoff
Offshore Ekman Transport at 45 N and 42 N (dashed)
m3/ s/ 100 m
150
0
-150
Winter
Fall
Summer
Apr
Sep
Coastal Rainfall
in /mon
20.0
10.0
0.0
Columbia Outflow
m3/ s
15000
10000
5000
0
J F M A M J J A S O N D
Summer - Winter Difference
-1
0
1
Distance (km)

Seasonal Average Geostrophic Velocity (1961-71)



Summer - Winter Difference



Seasonal Upwelling and Sea Level

Offshore Ekman Transport at 45 N and 42 N (dashed)

Adjusted Sea Level at 42N