# Characteristics of Anomalous Coastal Upwelling Detected off the East Coast of Korea in Summer 2007

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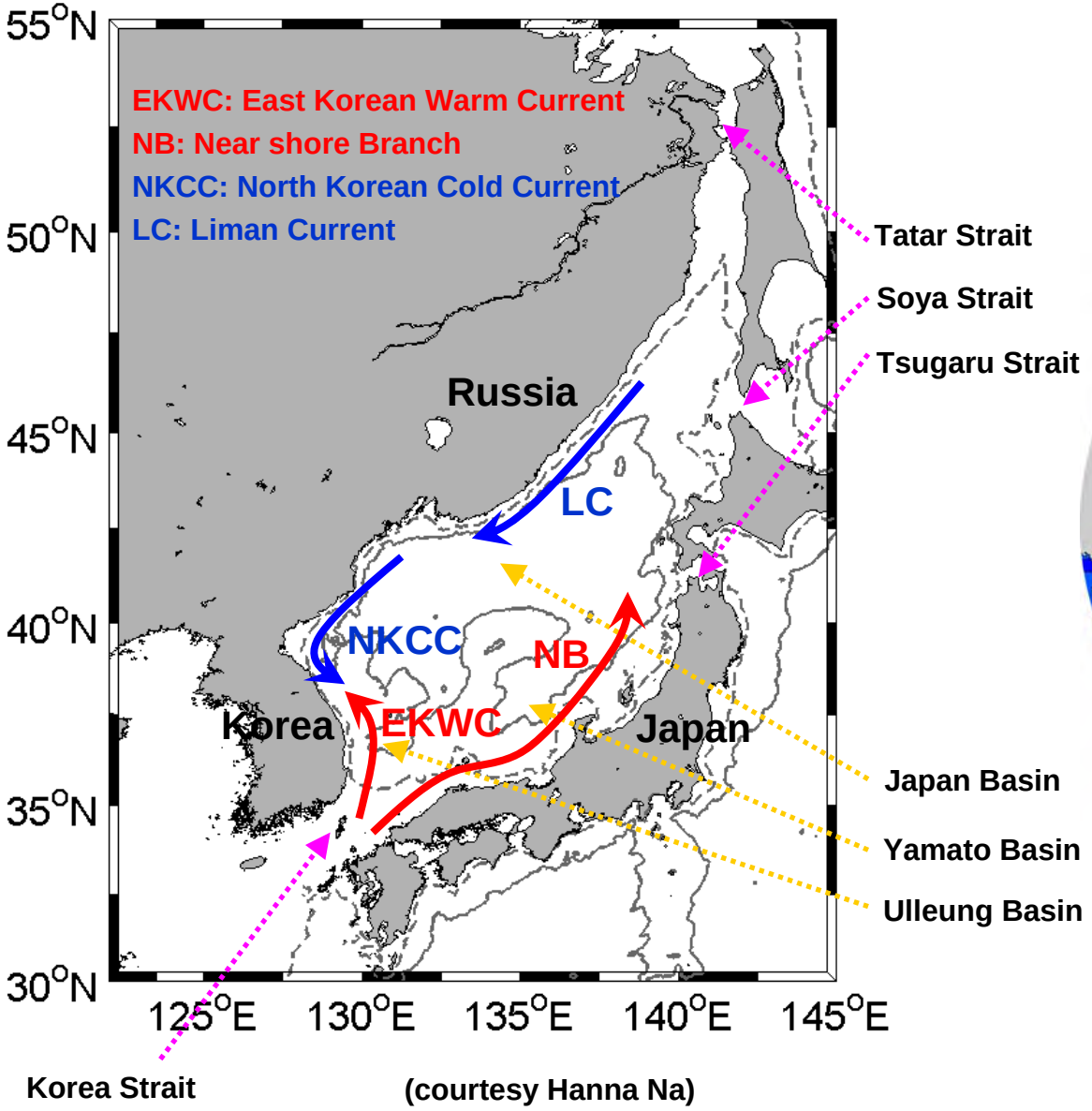
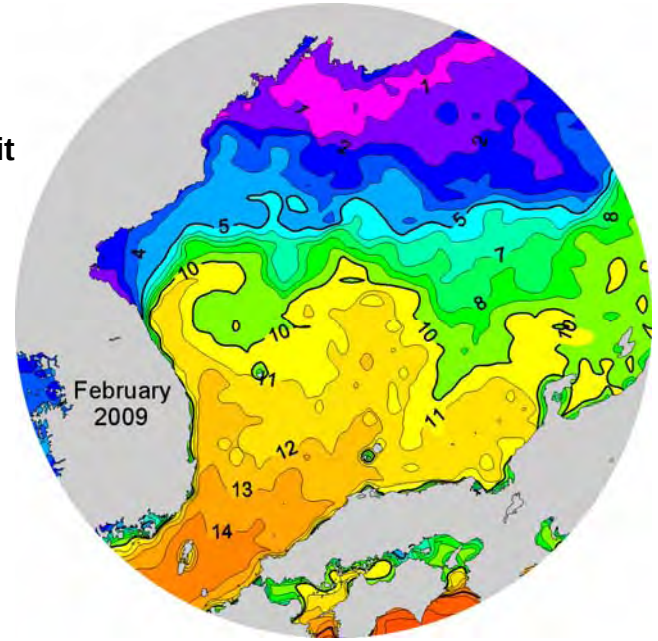
# Introduction: East Sea (Sea of Japan)

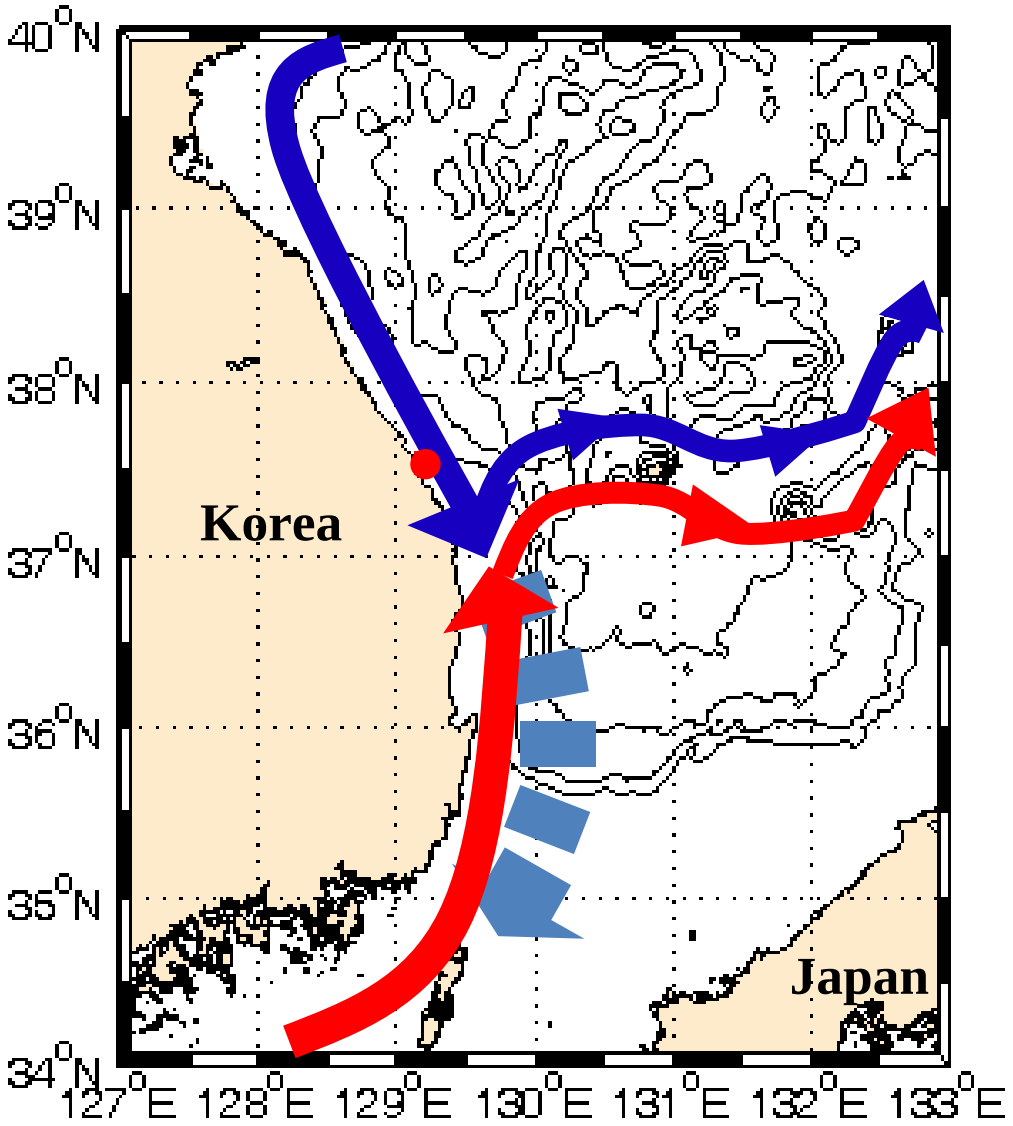



(courtesy Hanna Na)




SST in Feb. 2009
(courtesy Dr. S.W. Kim
at NFRDI)

# Introduction: EKWC vs. NKCC

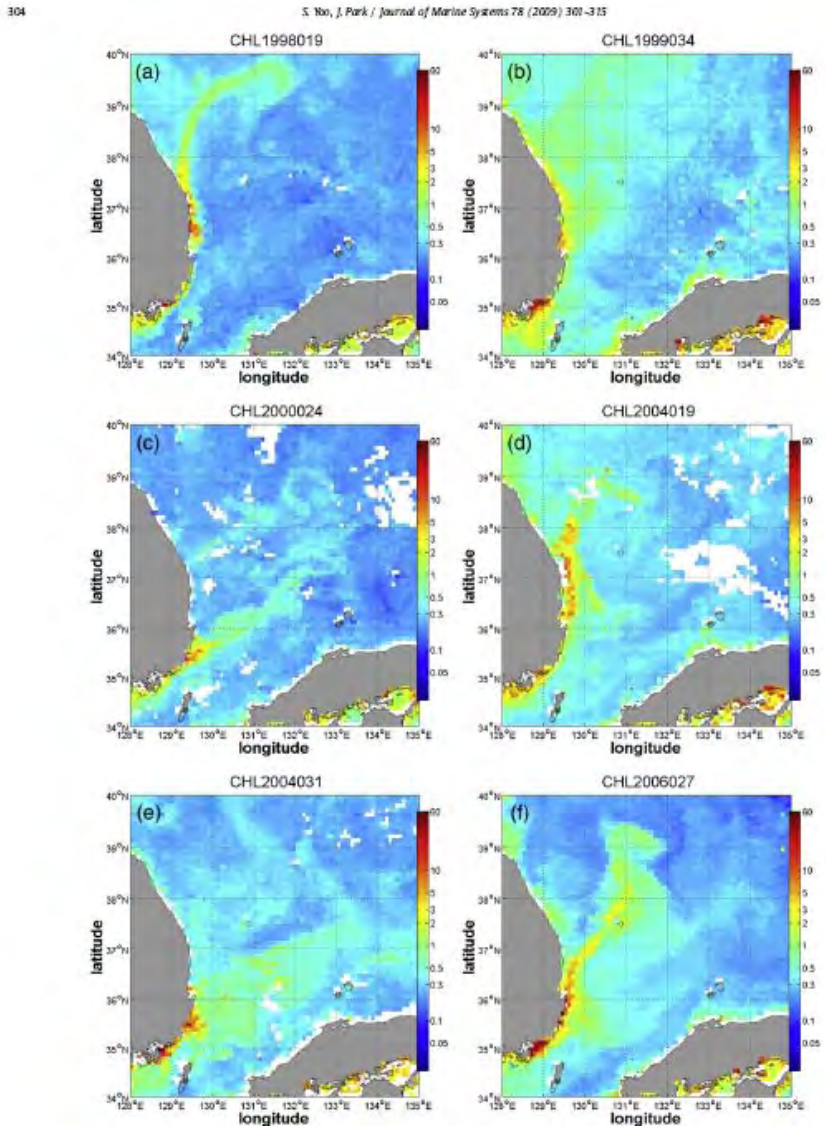



NKCC

EKWC

Collision of
two boundary currents,
separation from the coast,
meandering to the east

# Introduction: Importance of Coastal Upwelling in Ecosystem




**Yoo and Park., 2009 JMS**

The southwestern East Sea (Ulleung Basin) is highly productive due to the coastal upwelling and offshore advection of high-chlorophyll water.

A strong correlation between the interannual chlorophyll **a** variations of the coastal upwelling regions and that in the Ulleung Basin

# Coastal Upwelling in Summer 2007

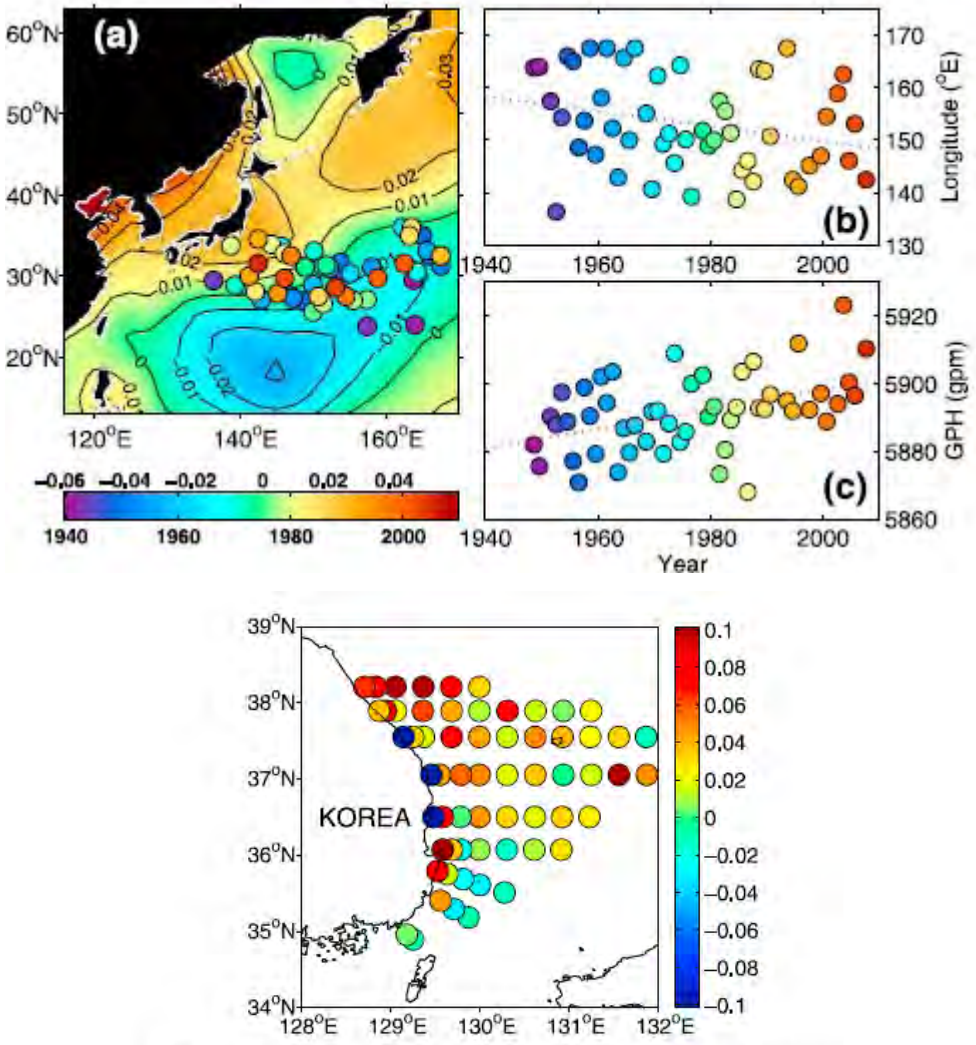


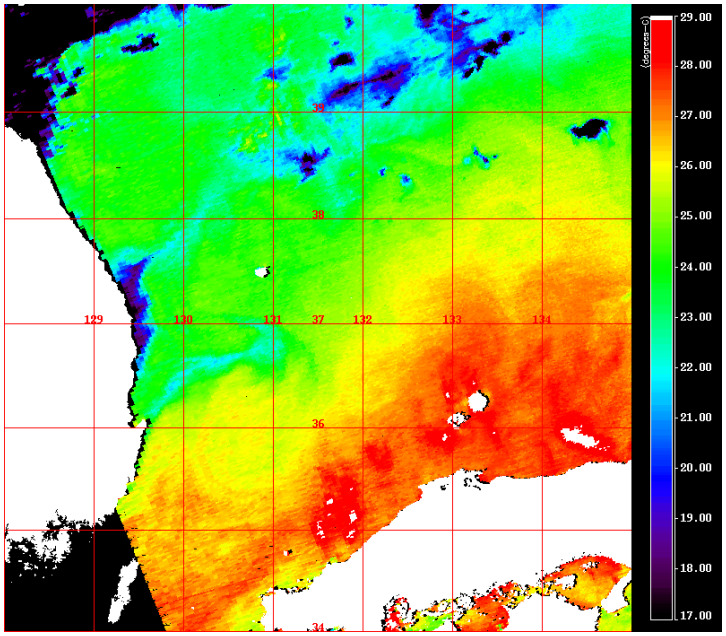

**Figure 5.** Trend of 10-m temperatures from 1961 to 2007 (°C year$^{-1}$) at KODC stations.

**Park and Kim,2010 GRL**

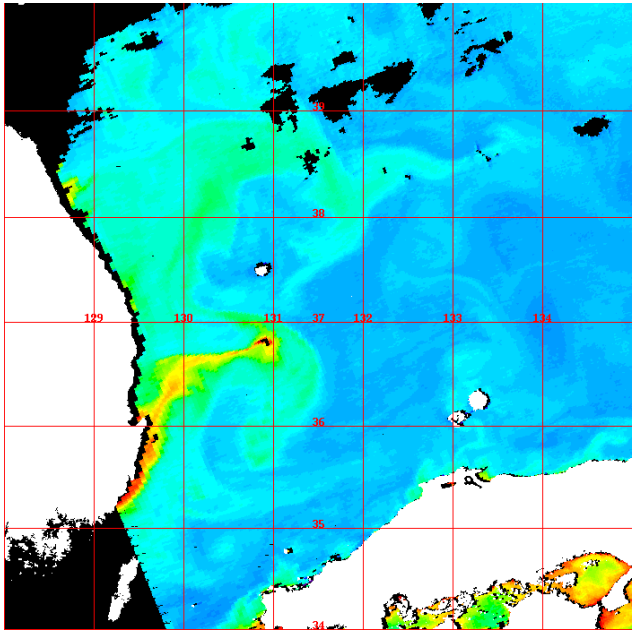
Unprecedented cold water was observed off the east coast of Korea in the summer of 2007.

Local coastal SST variations could be remotely affected by long-term large-scale variations.

# Coastal Upwelling in Summer 2007




SST, Aug. 11, 2007




Ocean Color, Aug. 11, 2007

# ESROB (East Sea Real-time Ocean Buoy)

CDMA transmit ion

Surface Buoy System

Surface Buoy System on real-time basis
(Data are transferred every 10 minutes.)

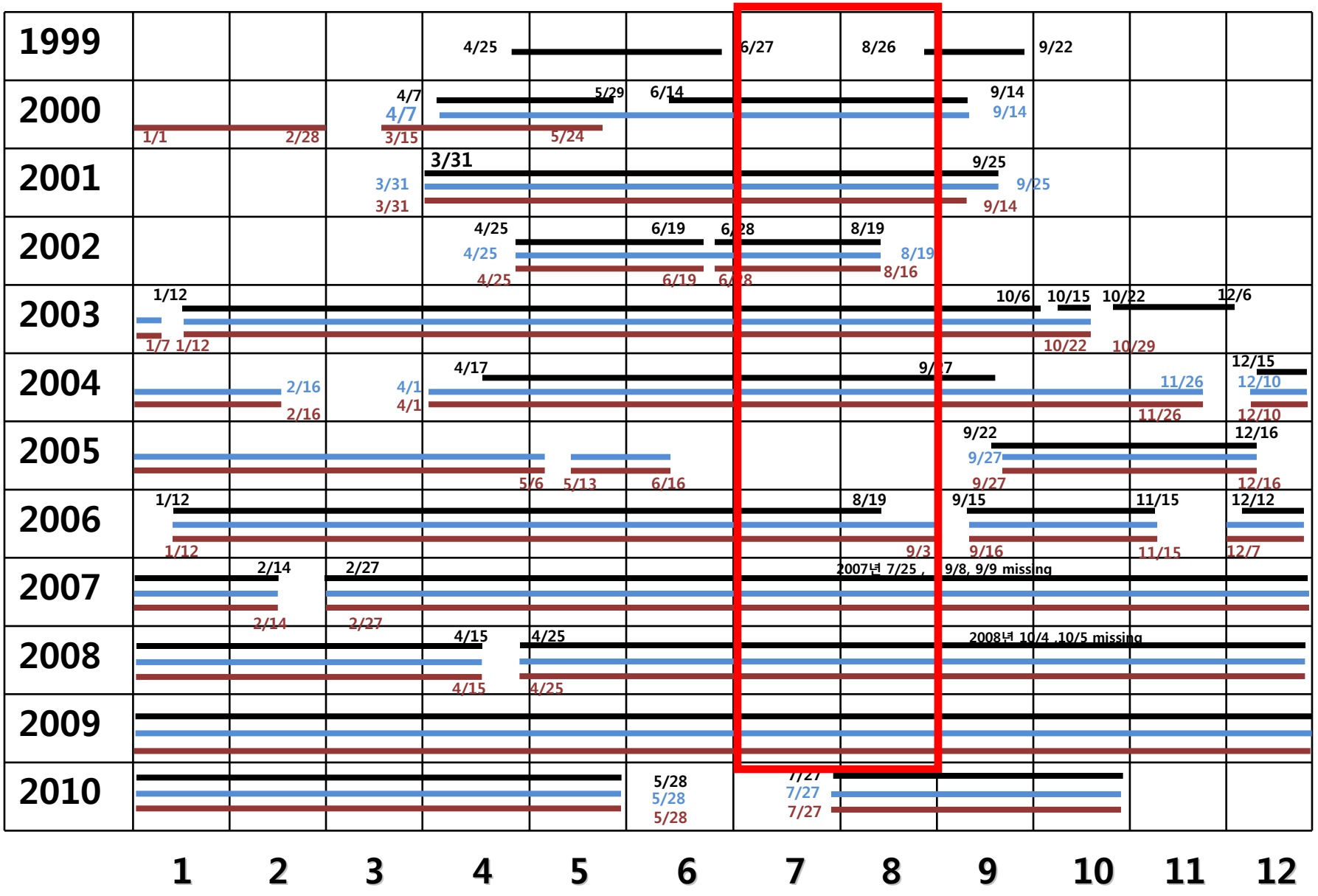
**ADCP**
300Khz
Bin interval : 5m

## Surface Sensors
- **Met Suit**
- **Wave Sensor**
- **DGPS**

- CTD 1 : 2m
- CTD 2 : 20m
- CTD 3 : 40m
- CTD 4 : 60m
- CTD 5 : 130m

**CTD(SBE37)**
- Salinity
- Temperature
- Depth

# ESROB Data


ADCP
Atmosphere
CTD
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
4/25
6/27
8/26
9/22
4/7
5/29
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1/12
8/19
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12/12
9/3
9/16
12/7
2/14
2/27
2007년 7/25 , 9/8, 9/9 missing
4/15
4/25
2008년 10/4 ,10/5 missing
5/28
7/27
1
2
3
4
5
6
7
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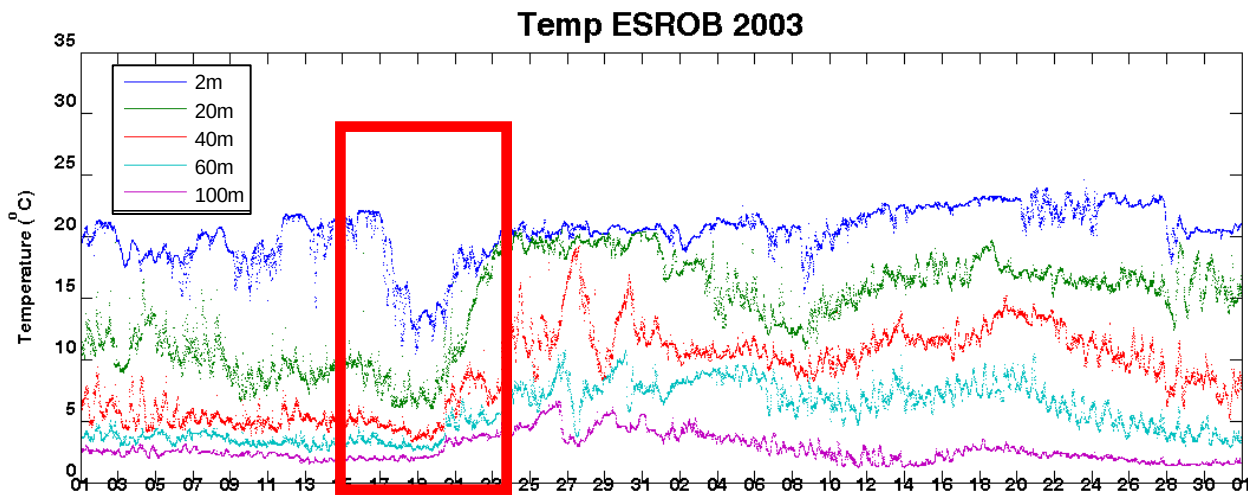
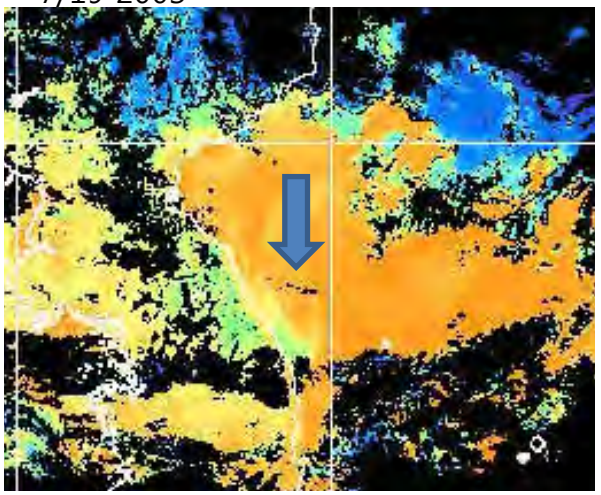
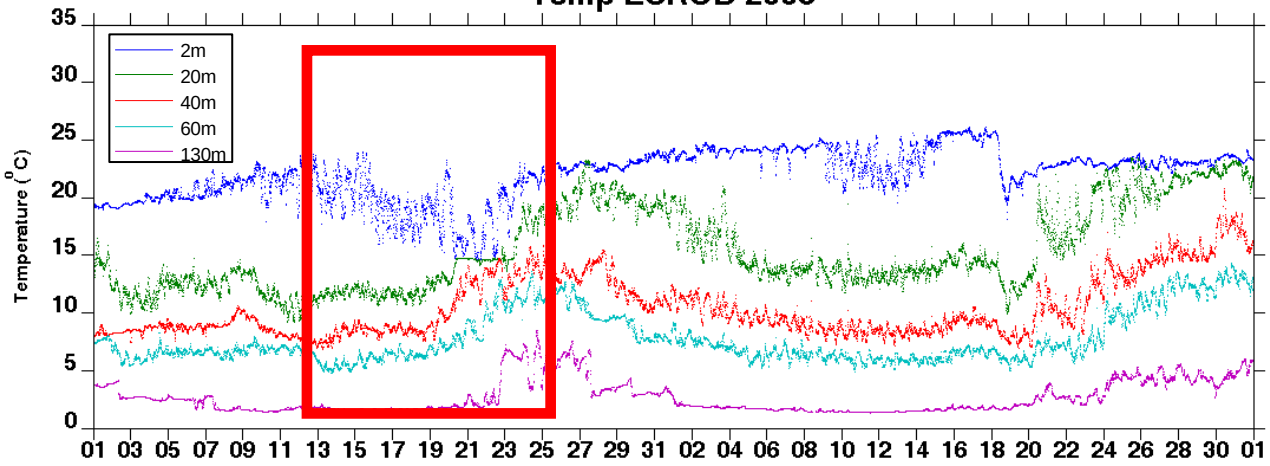
11
12

# Summer Coastal Upwelling in Other Years

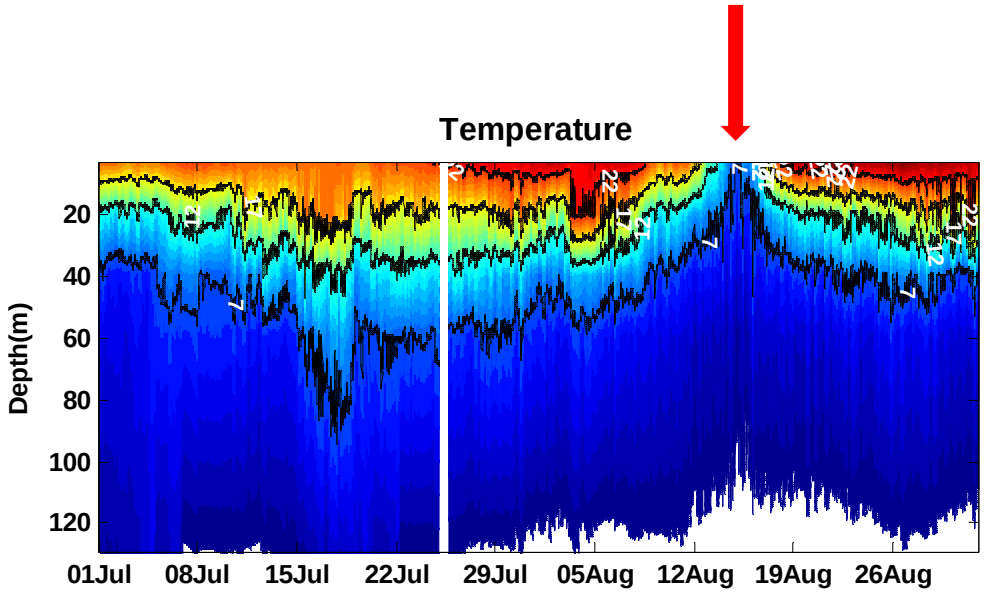



7/19 2003

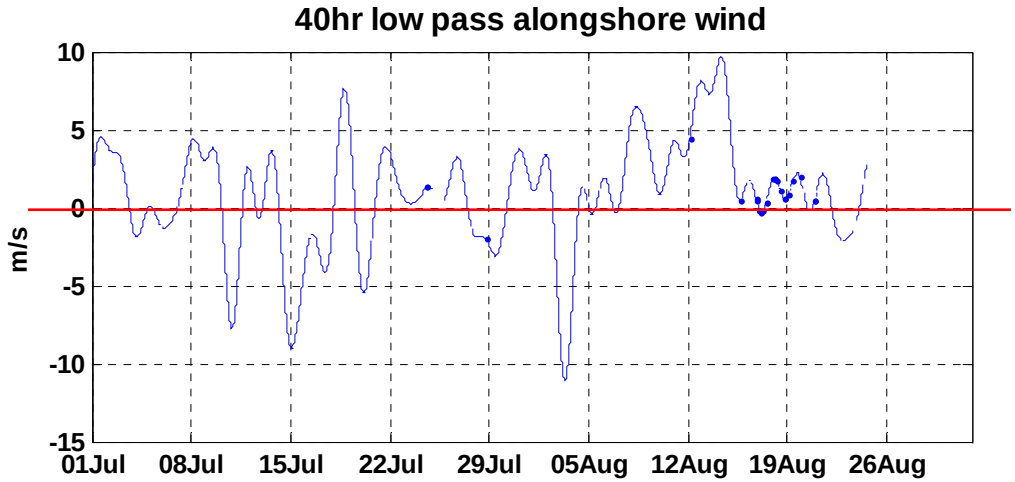


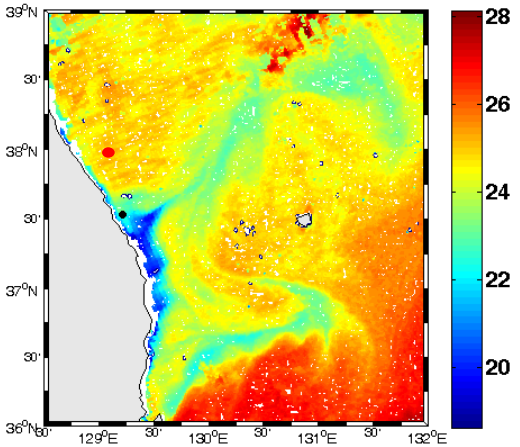


# Upwelling in Summer 2007 Observed by ESROB



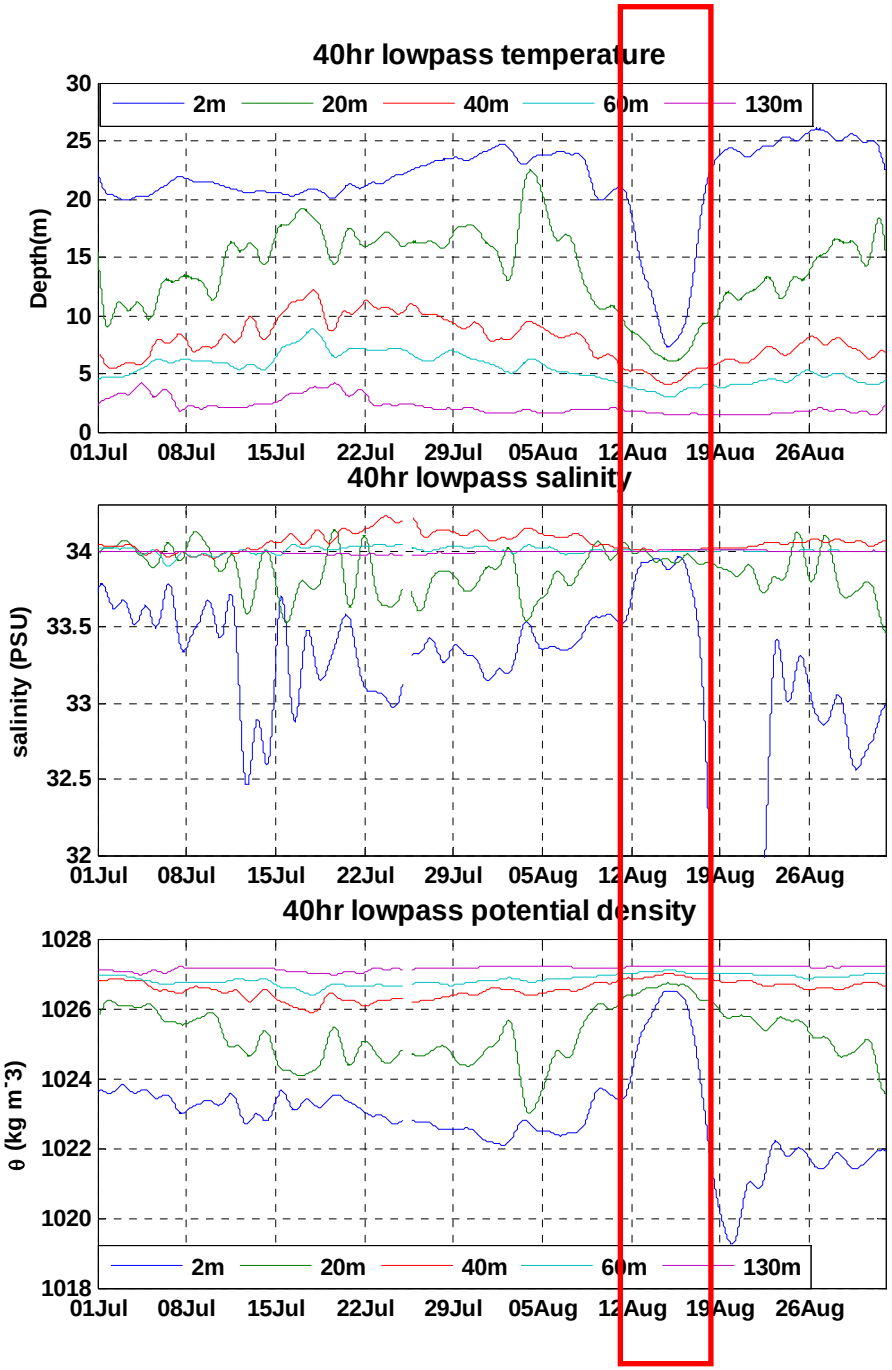

Surface temperature decreased by 18°C and strong (>5 m/s) southerly wind persisted for about ten days.



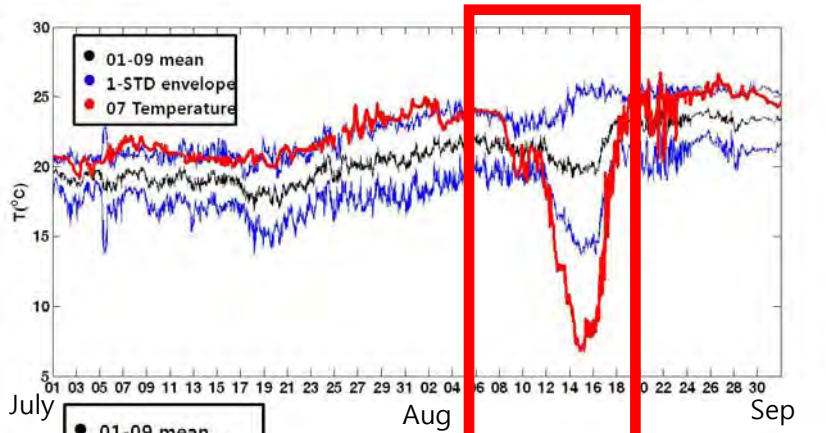

SST image 8/11

# Temperature, salinity, density

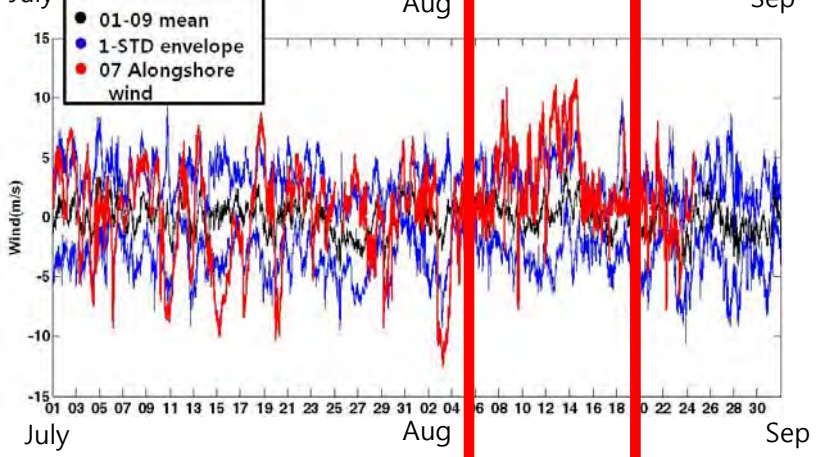


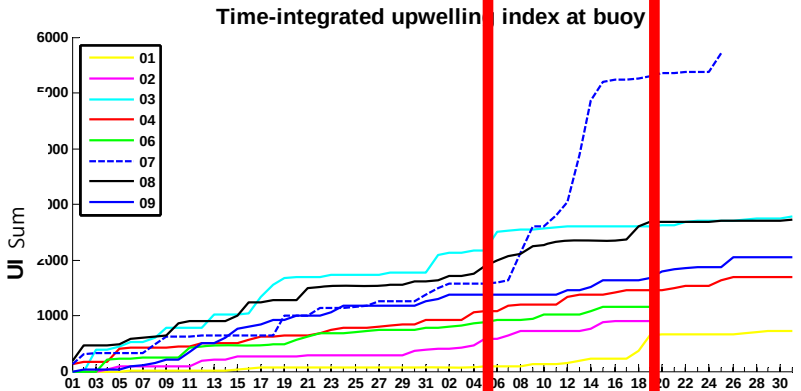
# Was 2007 upwelling an anomalous event ?

T




$\tau_y$




Mean surface temperature in summer (July~Aug., 2000-2009)

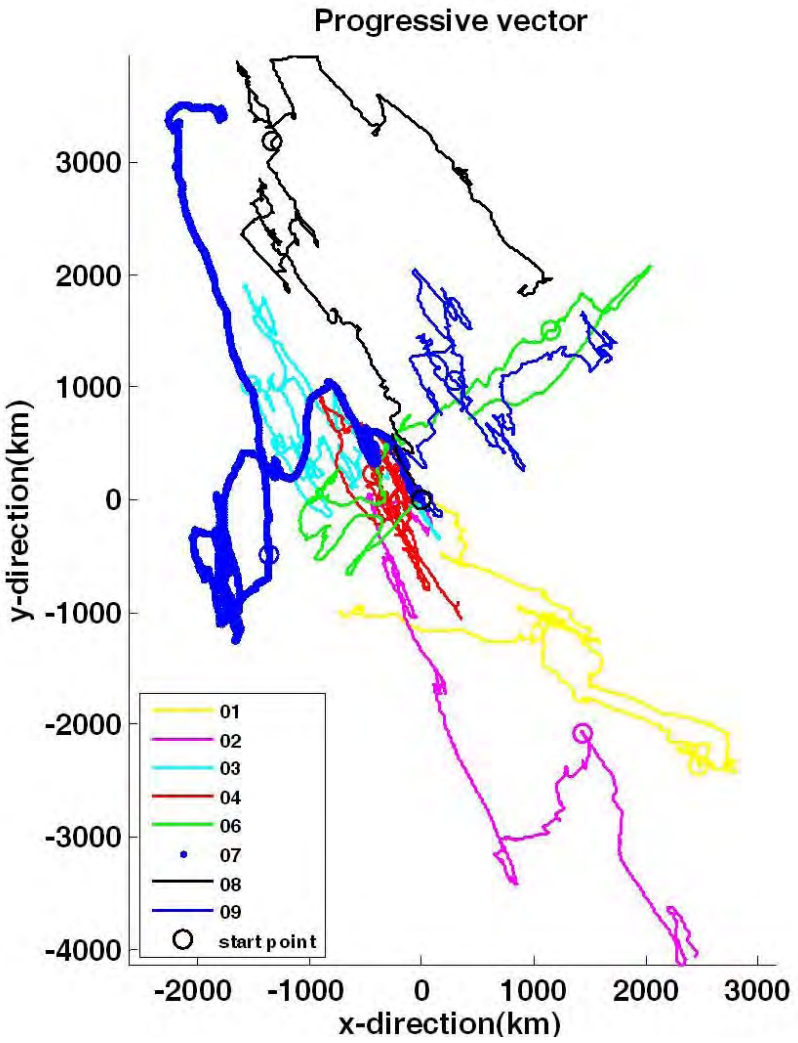
1-std envelopes

Surface temperature in 2007

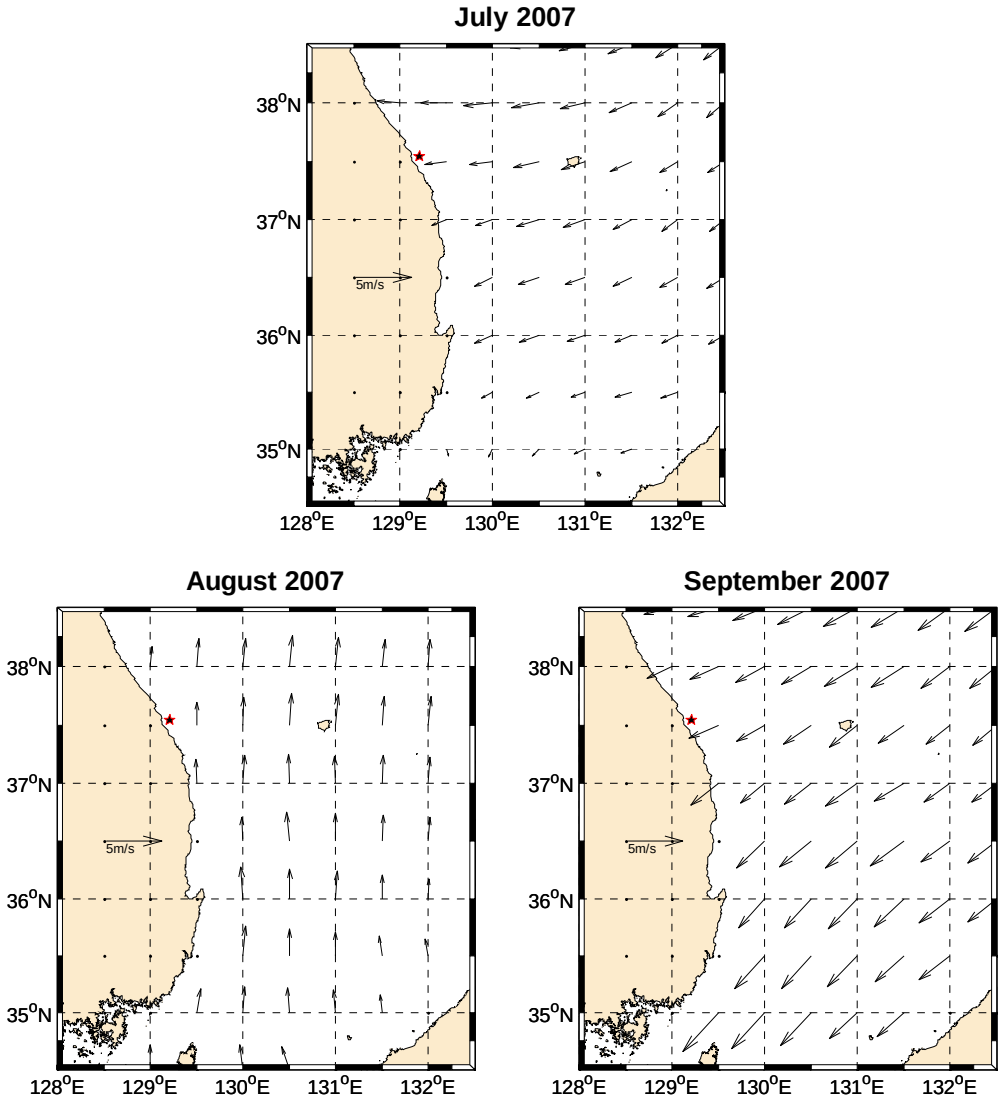
Cold water appeared from 8/8 to 8/20 in 2007. The temperature during this period was about 13°C lower than the mean temperature.

Stronger southerly winds than the mean.

# Winds measured at buoy & QSCAT/NCEP



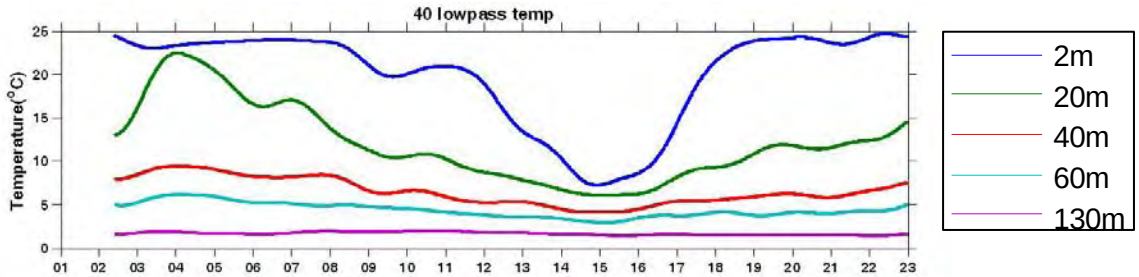

Progressive vector diagram of wind at ESROB



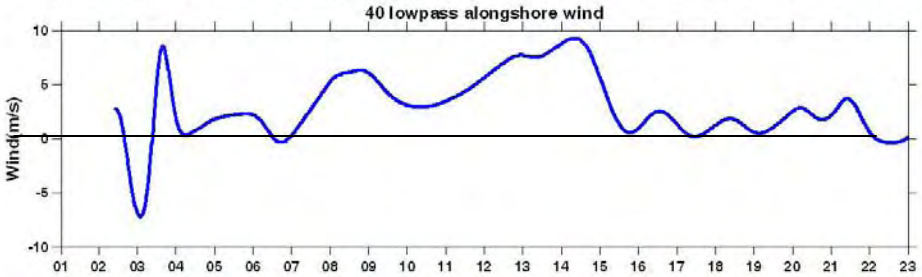

Monthly mean wind vector map from QSCAT/NCEP blended data

# Temperature, alongshore wind, and cross- & alongshore currents

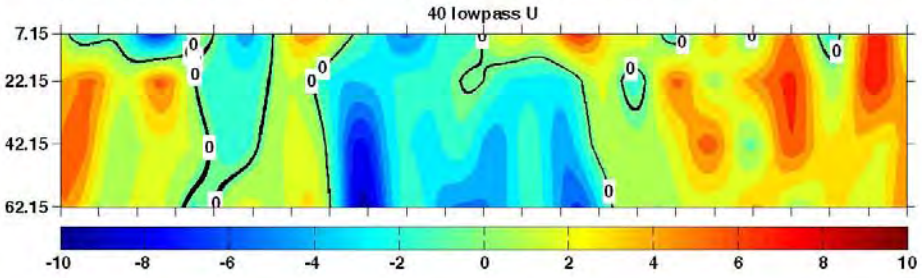
T



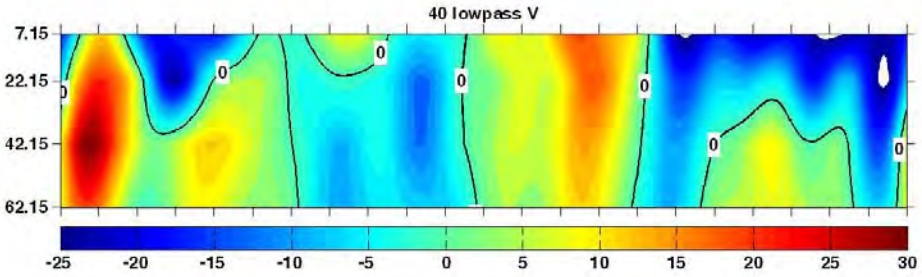

$\tau_y$




U




V

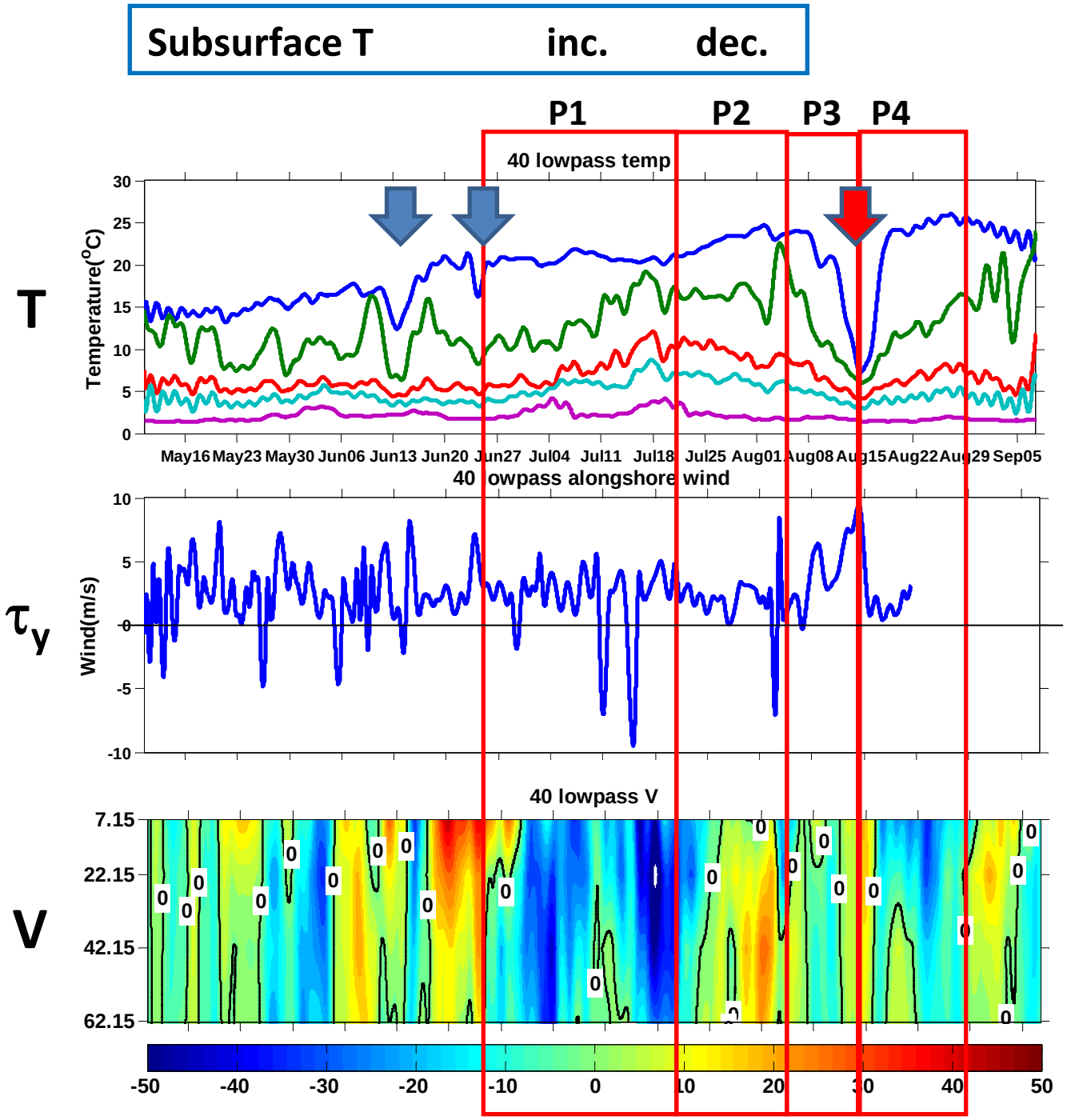



1. Onshore flow at the surface & Offshore flow below.

2. Strong northward alongshore currents during the upwelling period

3. Relaxation of the upwelling associated with a sharp decrease in the southerly wind

4. Southward alongshore currents (upper layer) during the relaxation period




Prior to the upwelling, alongshore currents were mainly northward with a decrease in subsurface temperature (lifting of isotherms)

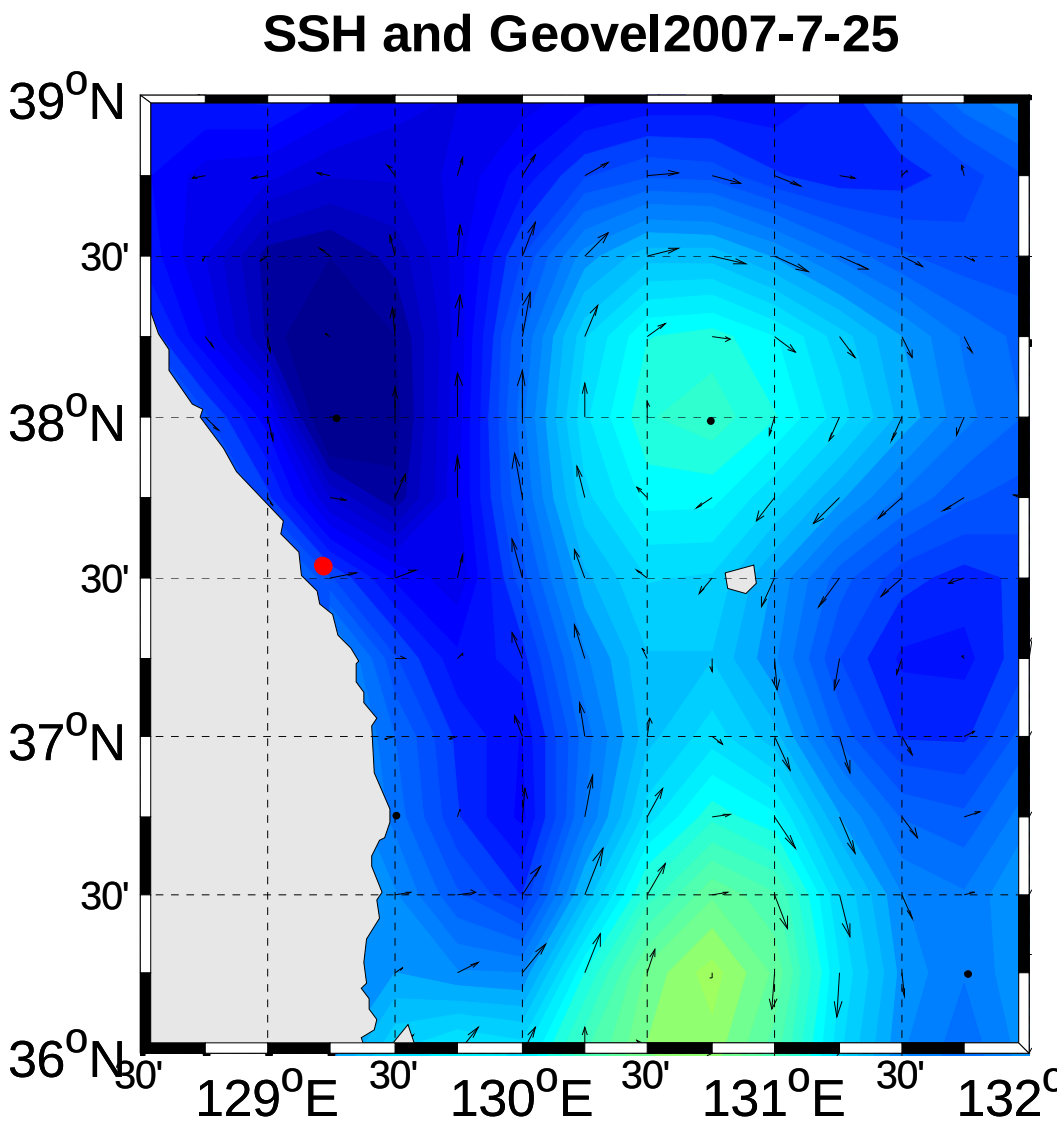
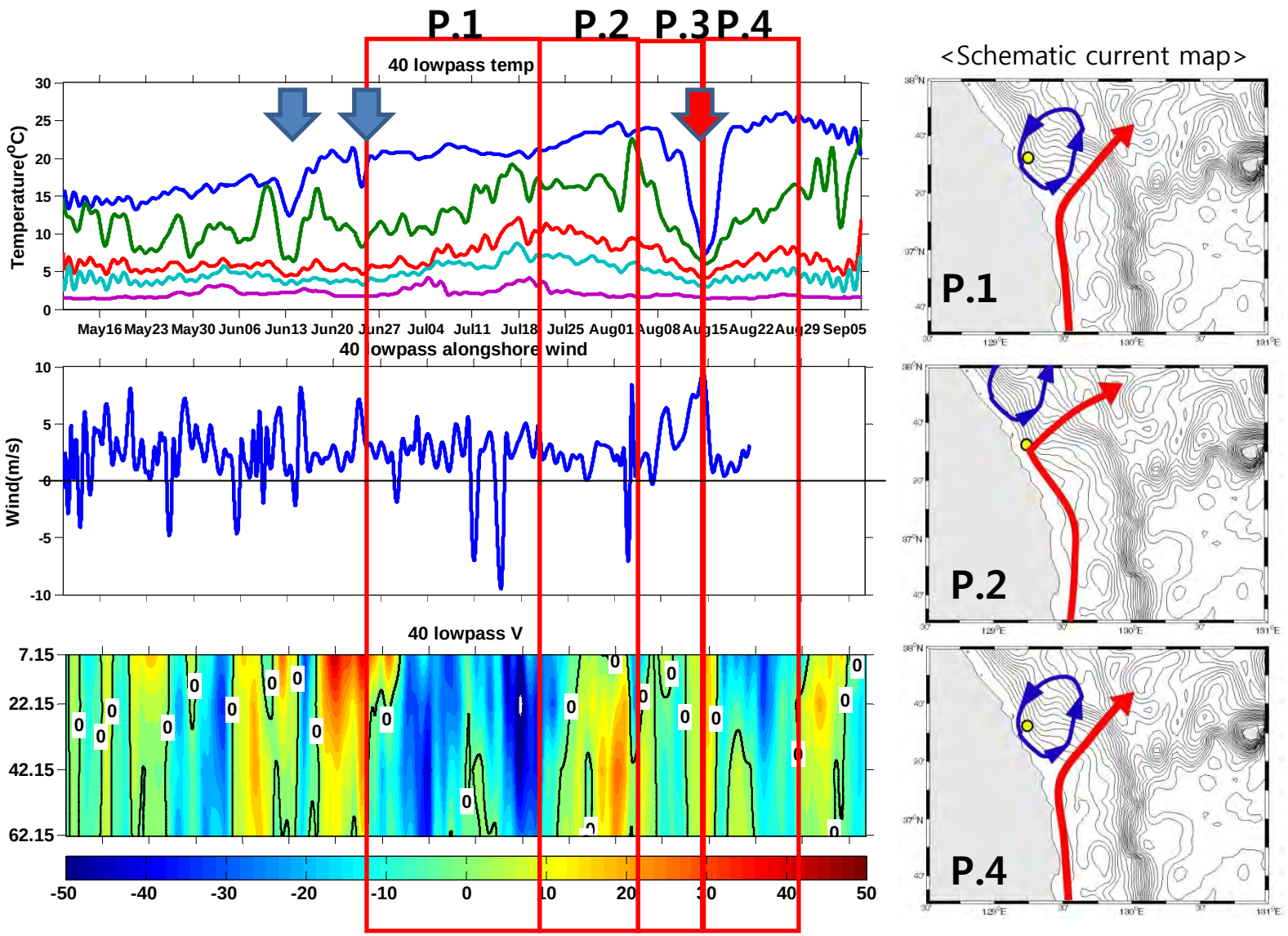
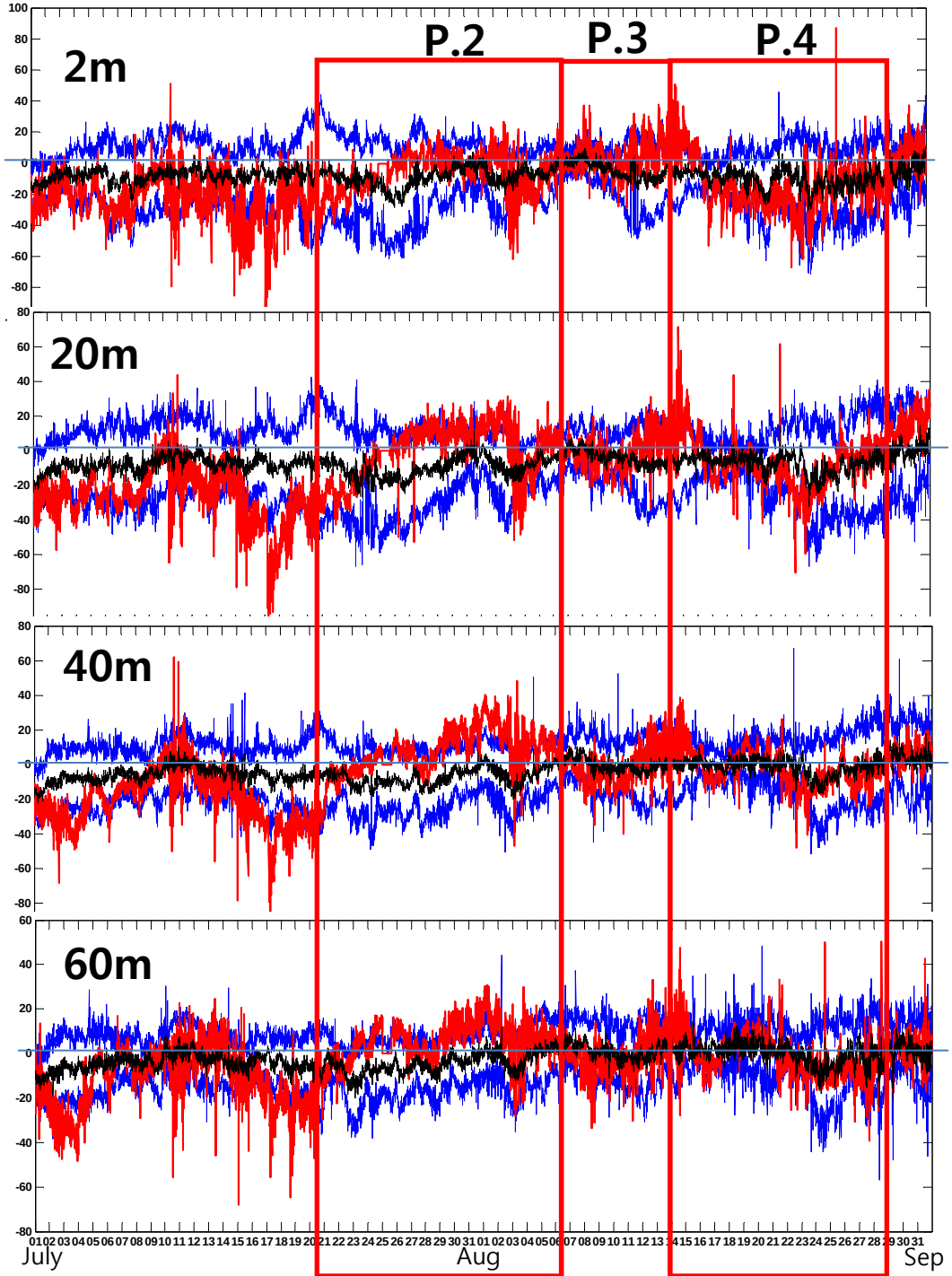



Figure shows SSH & surface geostrophic currents based on the gridded AVISO product and coastal sea level data.
We noted that the calculated surface currents are not **“always”** consistent with the observation at ESROB.

But the combination of the buoy data with the SSH field suggests that general surface circulation during the periods of upwelling, and before and after it consists of northward EKWC and a cyclonic eddy between the EKWC and the coast.


P.1
P.2
P.3
P.4
40 lowpass temp
Temperature(°C)
30
25
20
15
10
5
0
May16 May23 May30 Jun06 Jun13 Jun20 Jun27 Jul04 Jul11 Jul18 Jul25 Aug01 Aug08 Aug15 Aug22 Aug29 Sep05
40 lowpass alongshore wind
Wind(m/s)
10
5
0
-5
-10
40 lowpass V
7.15
22.15
42.15
62.15
-50 -40 -30 -20 -10 0 10 20 30 40 50
<Schematic current map>
P.1
P.2
P.4



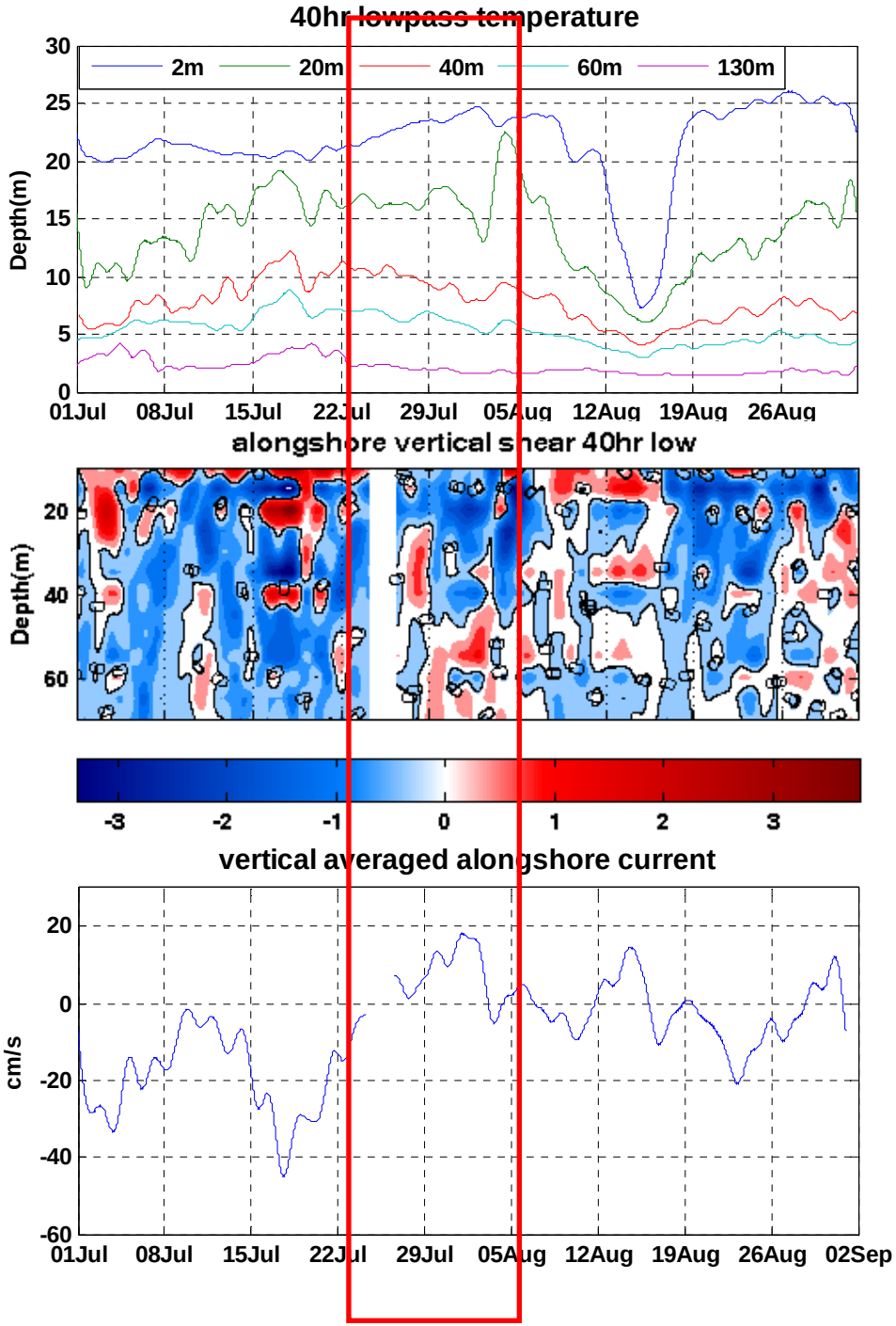

Mean alongshore currents in summer (July~Aug., 2000-2009)

1-std envelopes

alongshore current in 2007

The northward currents at 20-60m are stronger than the nine-year mean value (strongest at 40m) prior to the upwelling (P.2).

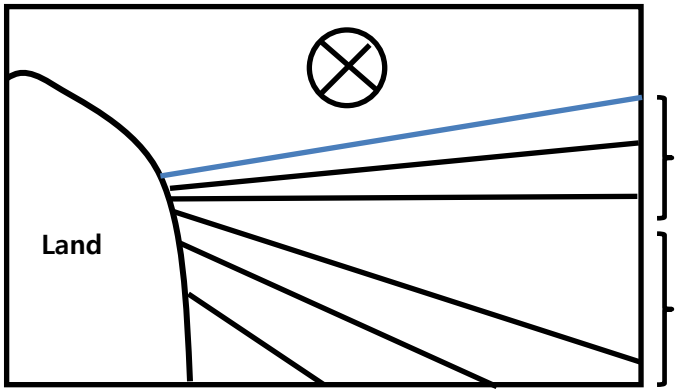
This result highlights that the presence of the northward currents (cooling of subsurface layer & associated lifting of isotherms) prior to the upwelling partly contributes to the occurrence of the anomalous upwelling.




Prior to the upwelling event

The vertical shear of alongshore currents are positive below 40 m and negative in the upper layer.

# Schematic of the Development of the Anomalous Upwelling

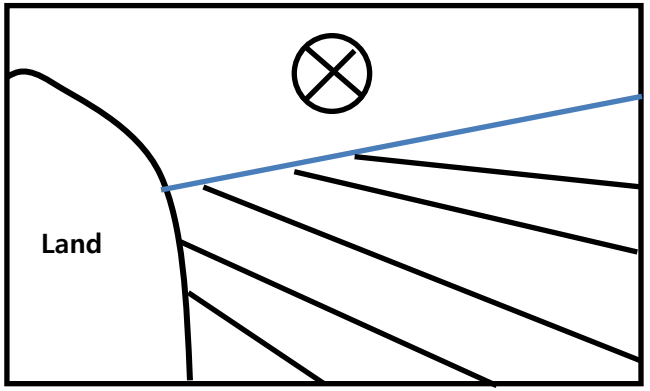



Surface : negative vertical shear

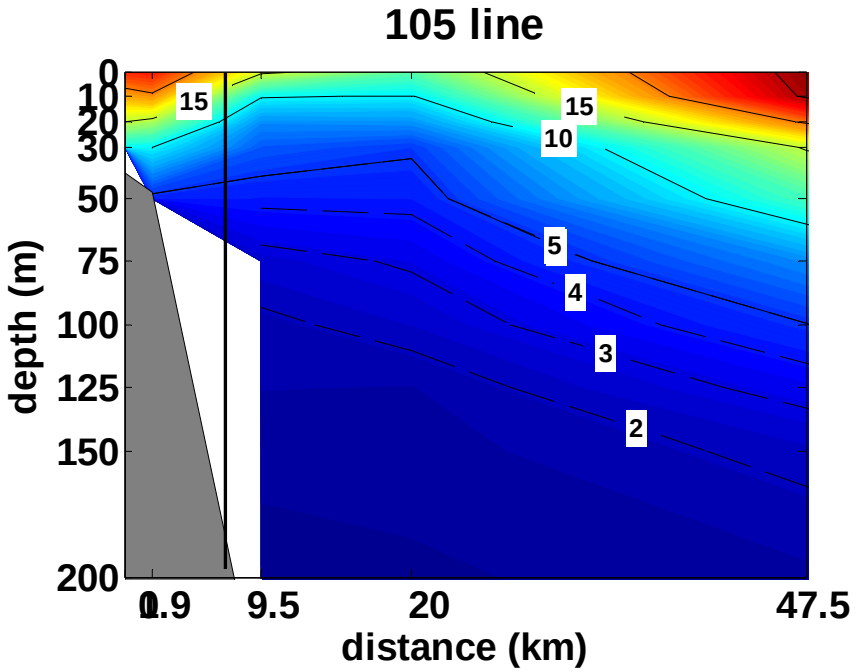
Subsurface : positive vertical shear
-> Isopycnals slope upwards toward the coast.

**Strong and persistent southerly winds.**

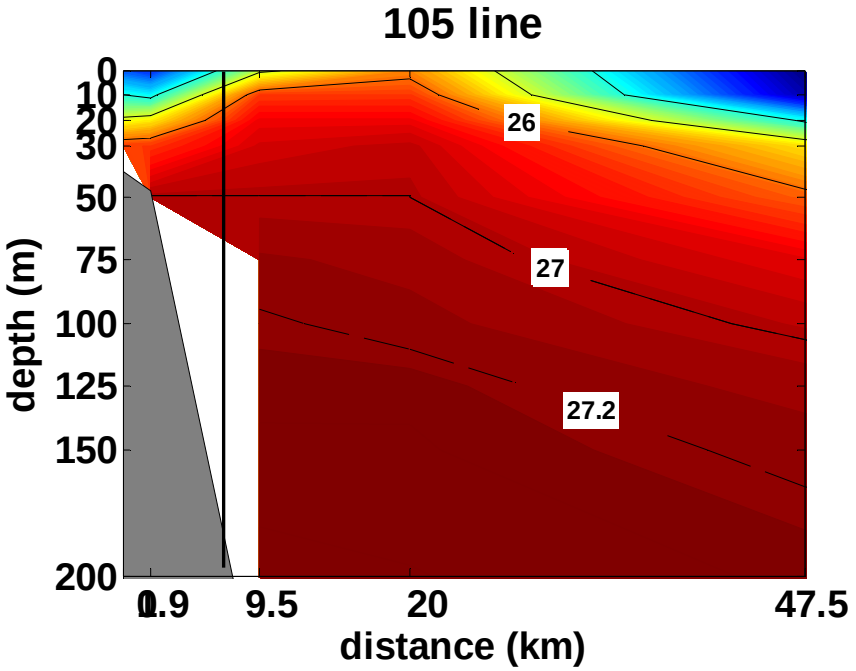
**<An anomalous upwelling>**



# Vertical Sections of Temperature and Density




8/17~18 (after the upwelling)
Cyclonic eddy & restratification



# Summary

- An anomalous coastal upwelling in mid east coast of Korea was observed in Aug 8 -20, 2007, when the surface temperature dropped by 18°C.
- Summertime southerly wind is a key factor for the generations of the coastal upwelling, and strong ( >5m/s) and persistent southerly wind for 10 days resulting in the anomalous upwelling in 2007.
- Northward alongshore currents and the vertical shear of the alongshore currents also contribute to the anomalous upwelling.
- Occurrence of the deepening of surface layer isotherms (negative vertical shear), hence the enhanced surface stratification, and the lift of subsurface isotherms towards the coast (positive vertical shear) prior to the upwelling, and then the strong & persistent southerly winds led the outcropping of deep isotherm.
- How about the situation in other years ?
- Ecosystem implications ?

# Thank you