Simulation of Intrathermocline Eddies in the Japan/East Sea

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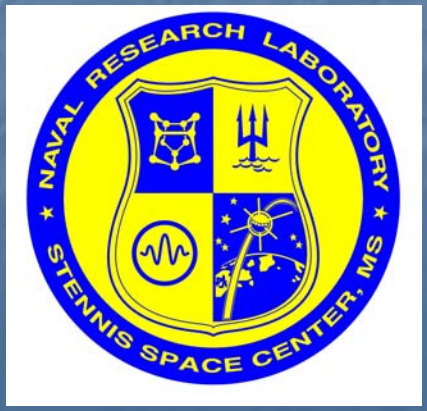

Outline

- Motivation
- General circulation of the Japan/East Sea (JES)
- JES-HYCOM
- Observed and simulated ITE's
- Summary

Motivation

1) Observations of Intrathermocline Eddies (Gordon et. al, 2002, JPO)

- Conceptually similar to “meddies”
- First time observed in the JES
- Lens-like features that form within the thermocline
- Primary formation mechanism: subduction along the subpolar front

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2) Utilization of Hybrid Coordinate Ocean Model to simulate ITE’s

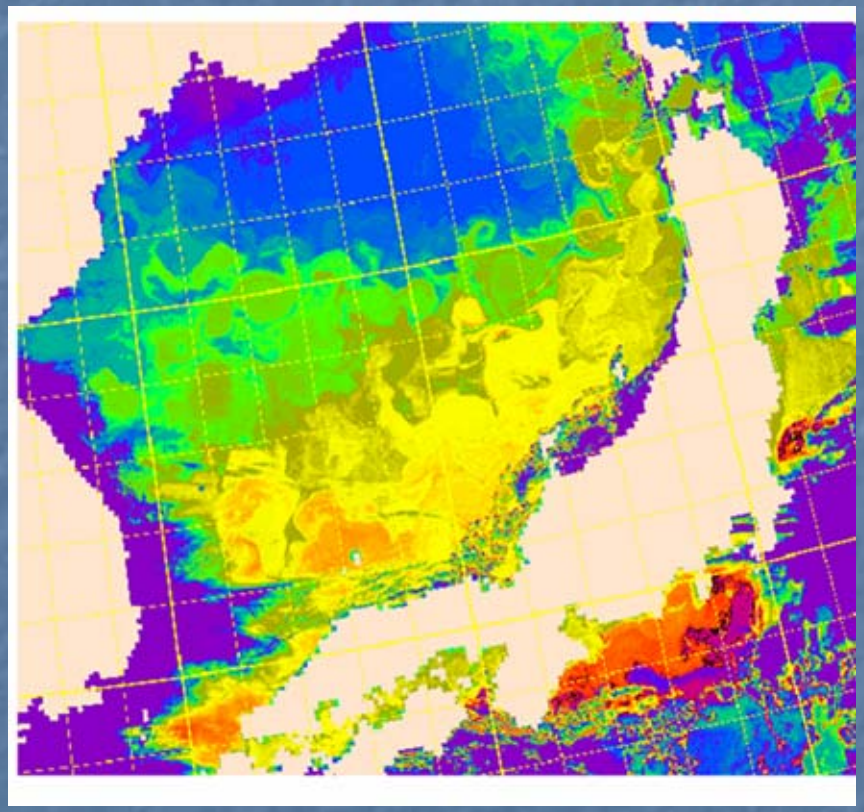
Generalized dynamical vertical coordinate system:

- Isopycnal in open stratified ocean
- Terrain-following (sigma) in shallow coastal regions
- Z-level in mixed layer and unstratified regions

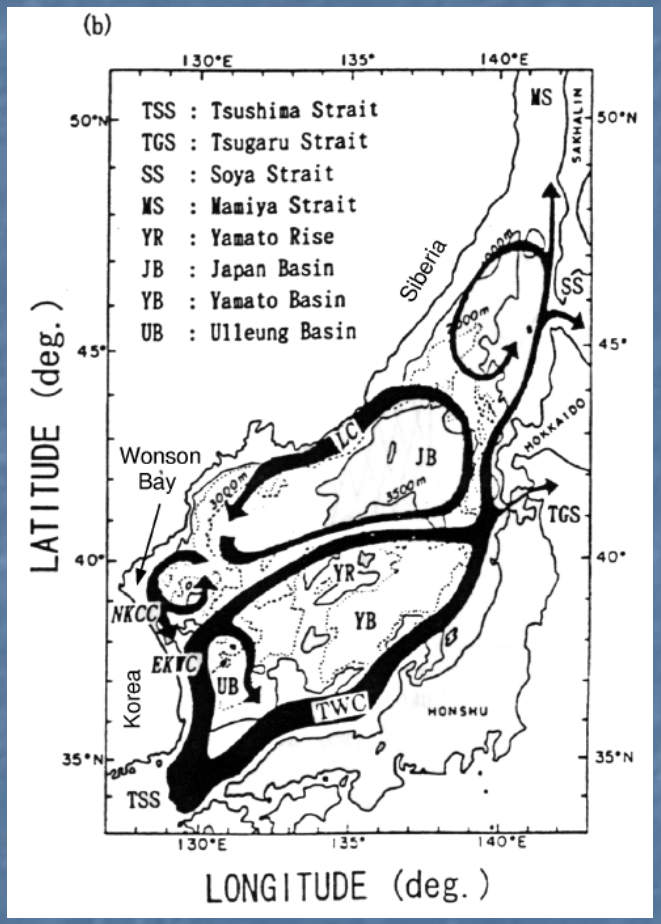
Retains the advantages of each coordinate system

Observed surface circulation in the Japan/East Sea

Ocean Color



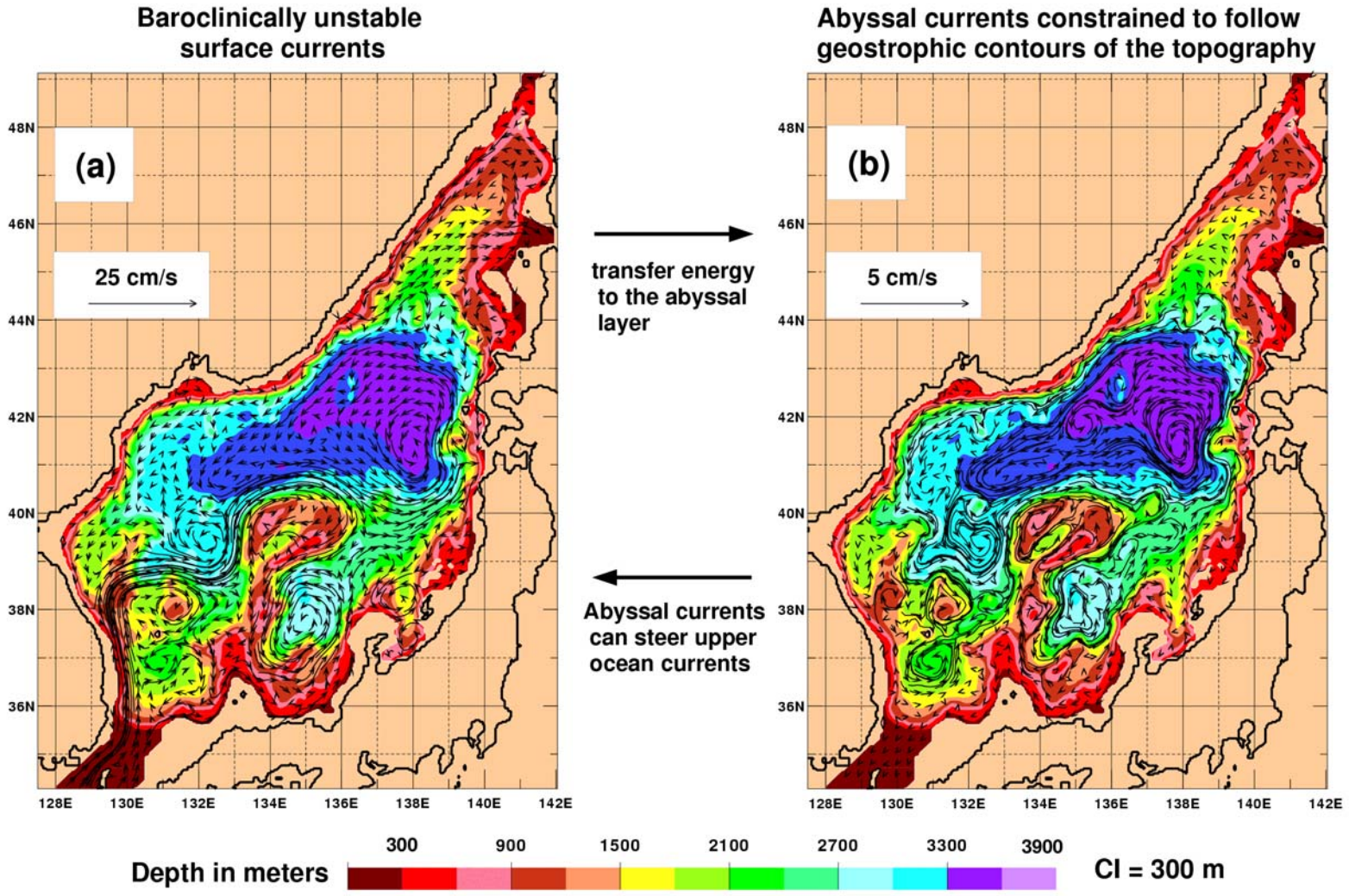
Courtesy: Dan Fox



Modified from Yarachin (1980)

Upper Ocean - Topographic Coupling

1/32˚ 4-layer Japan/East Model

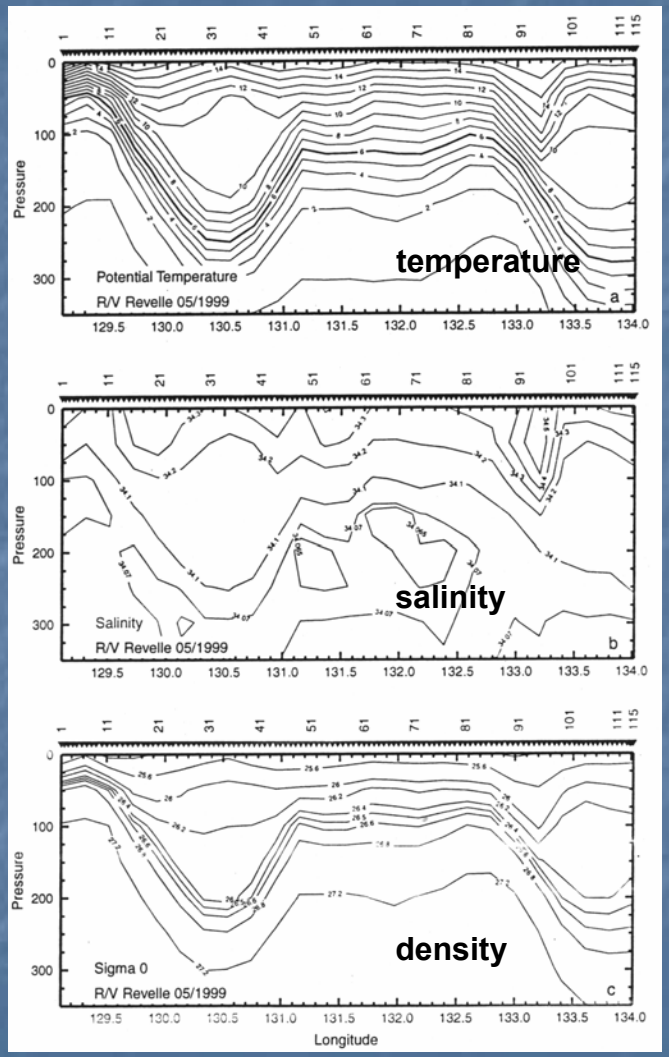


(Hogan and Hurlburt, 2000, JPO)

Intra-Thermocline Eddies (Pycnostads)

- Lens shaped; decreased surface expression due to compensating baroclinicity
- ~100km diameter, ~ 100m thick, 100-300m
- Salinity ~34.12, temperature ~10.0°C
- Iso-thermal/haline/pycnal; low potential vorticity
- Anticyclonic flowing core with relatively warmer and more saline water
- Cruises in May 1999/Jan. 2000

Cross-section along 37.7°N



(Gordon et. al, 2002)

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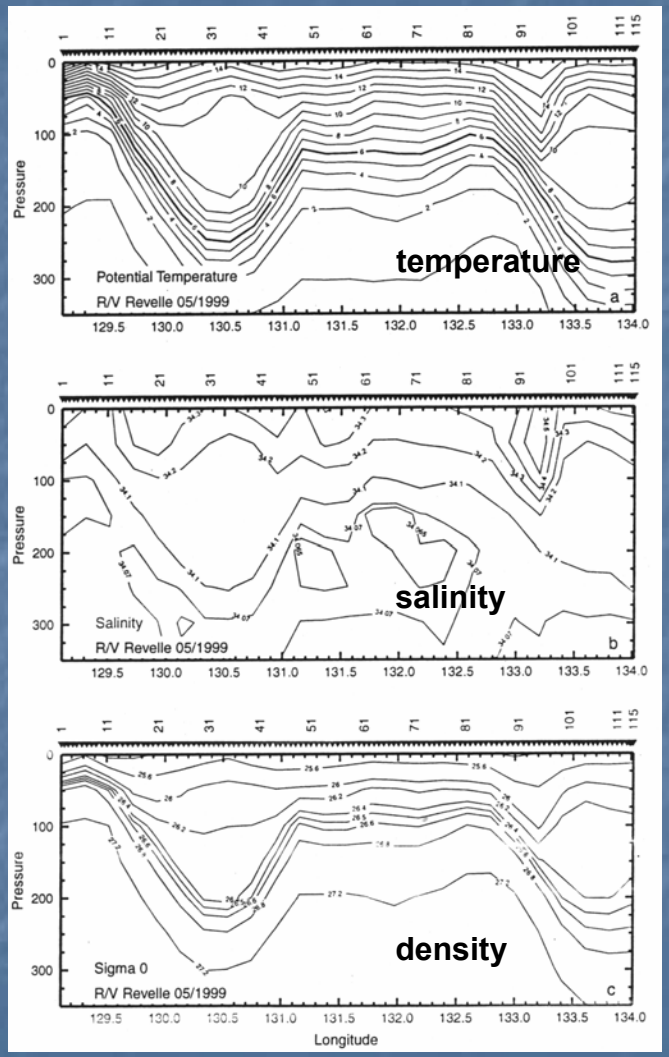
Possible Formation Mechanisms

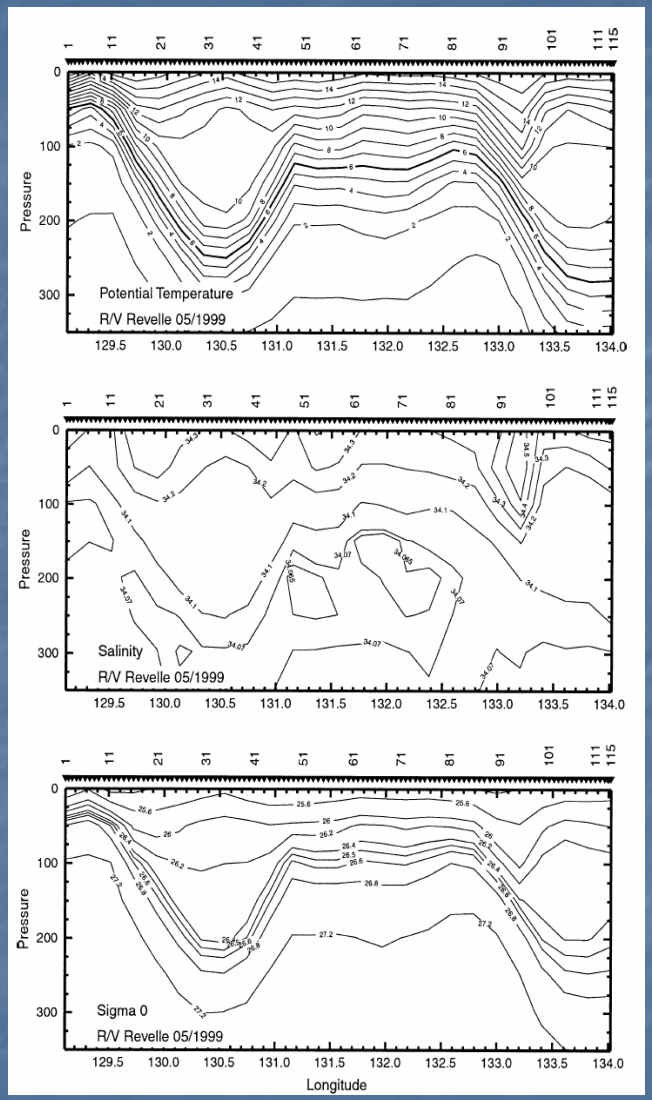
- Advection of seasonal T&S through the Korea Strait
- Restratification of the upper water column due to seasonal heating and cooling
- Frontal subduction along the subpolar front during winter (observed by Gordon et. al)

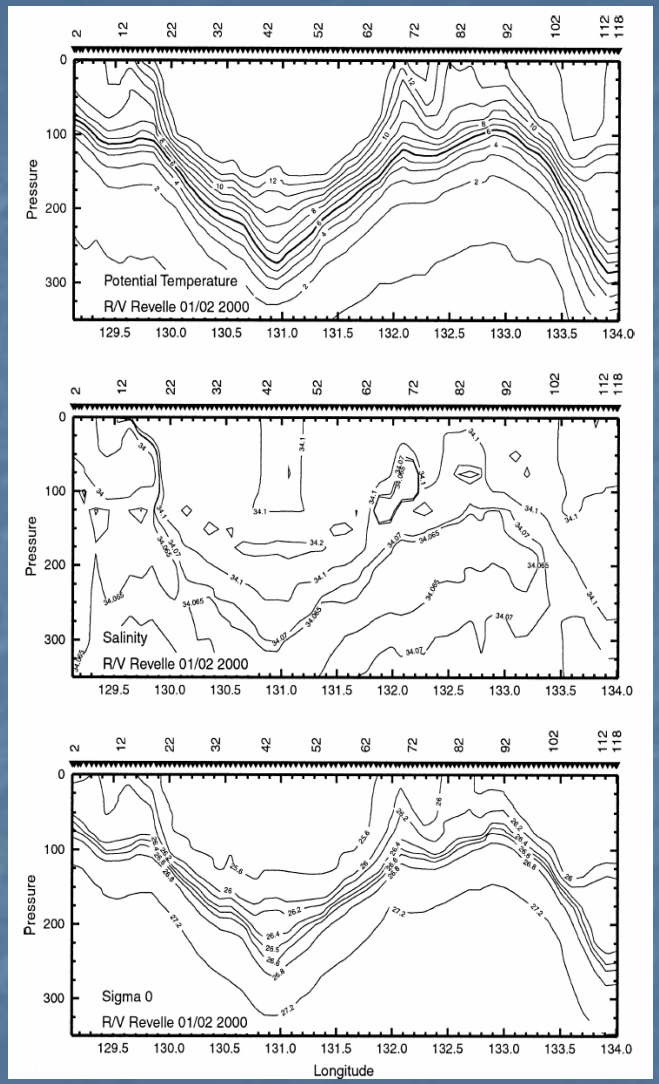
Cross-section along 37.7°N



(Gordon et. al, 2002)

Section along 37.5° From Gordon et al (2002)





Temperature

Salinity

Density

May 1999

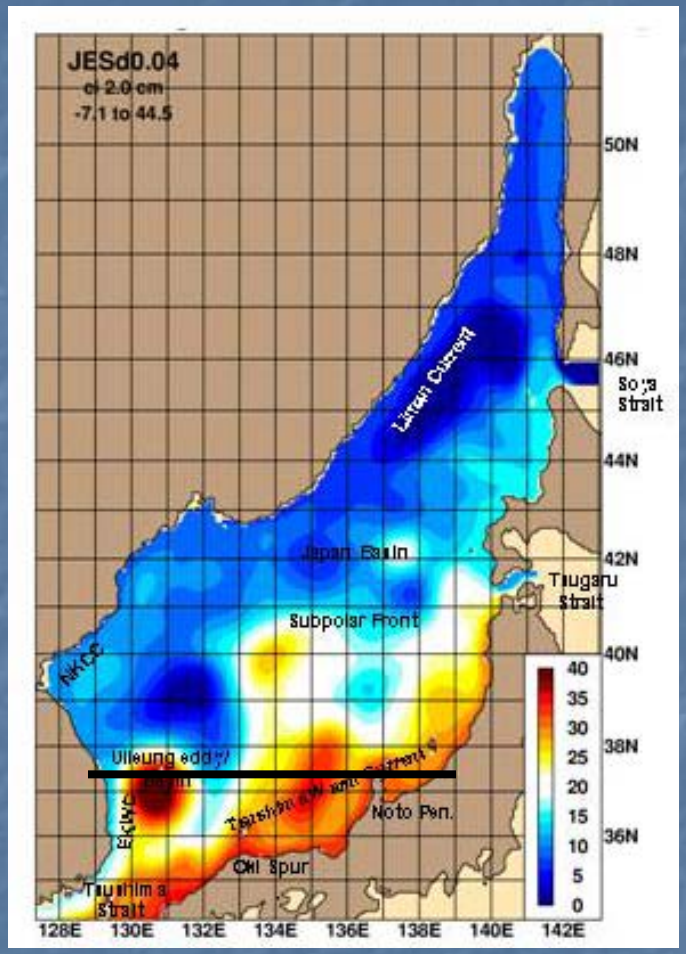
January 2000

JES-HYCOM

- version 2.0.09 (?)
- 1/25° (3.5 km) horizontal resolution
- 15 layers in the vertical
- KPP mixed layer
- 2 Sv barotropic throughflow with seasonal (baroclinic) component (inflow through Korea Strait, outflow through Tsugaru and Soya straits)
- Relaxation to MODAS surface salinity
- Biharmonic diffusion with Smagorinsky coefficient
- Run for 5 years with monthly ECMWF 10 m wind and heat flux forcing
- Continued with 1993-1994 6 hourly ECMWF 10 m wind and flux forcing
- energy ice loan

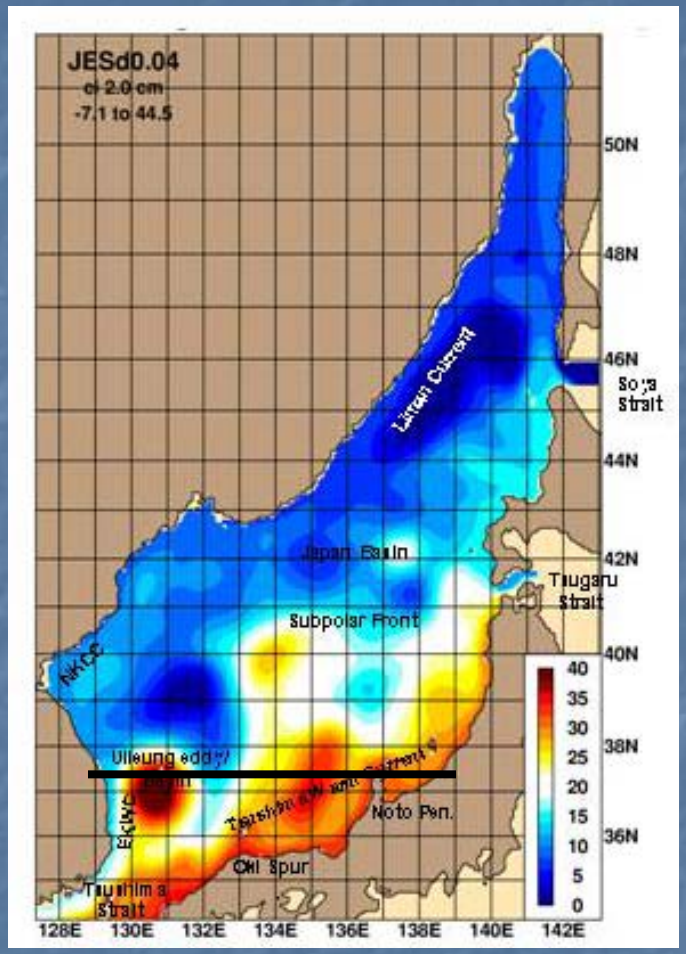
- No Data Assimilation

1/32° JES-HYCOM



4-year mean SSH from HYCOM

1/32° JES-HYCOM



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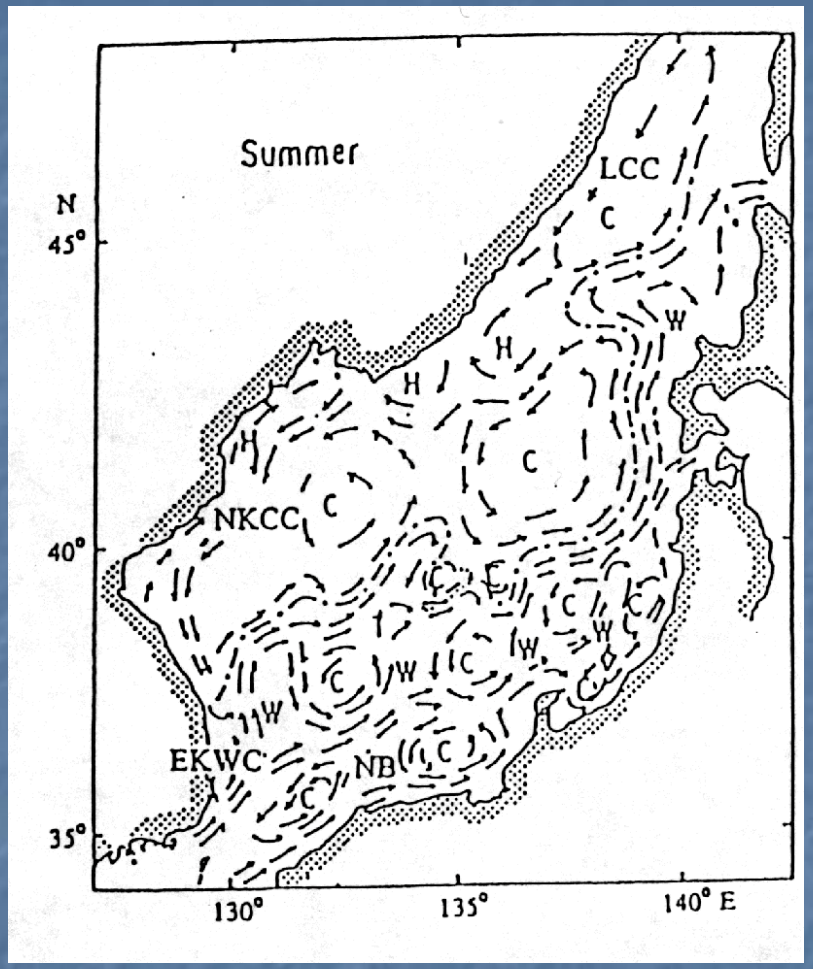
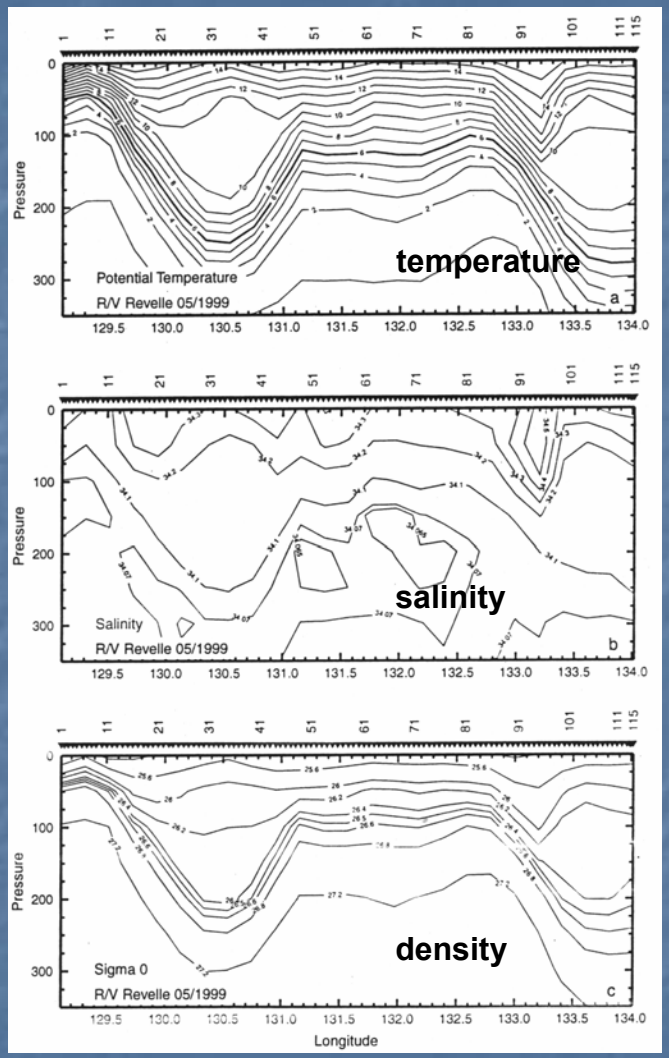


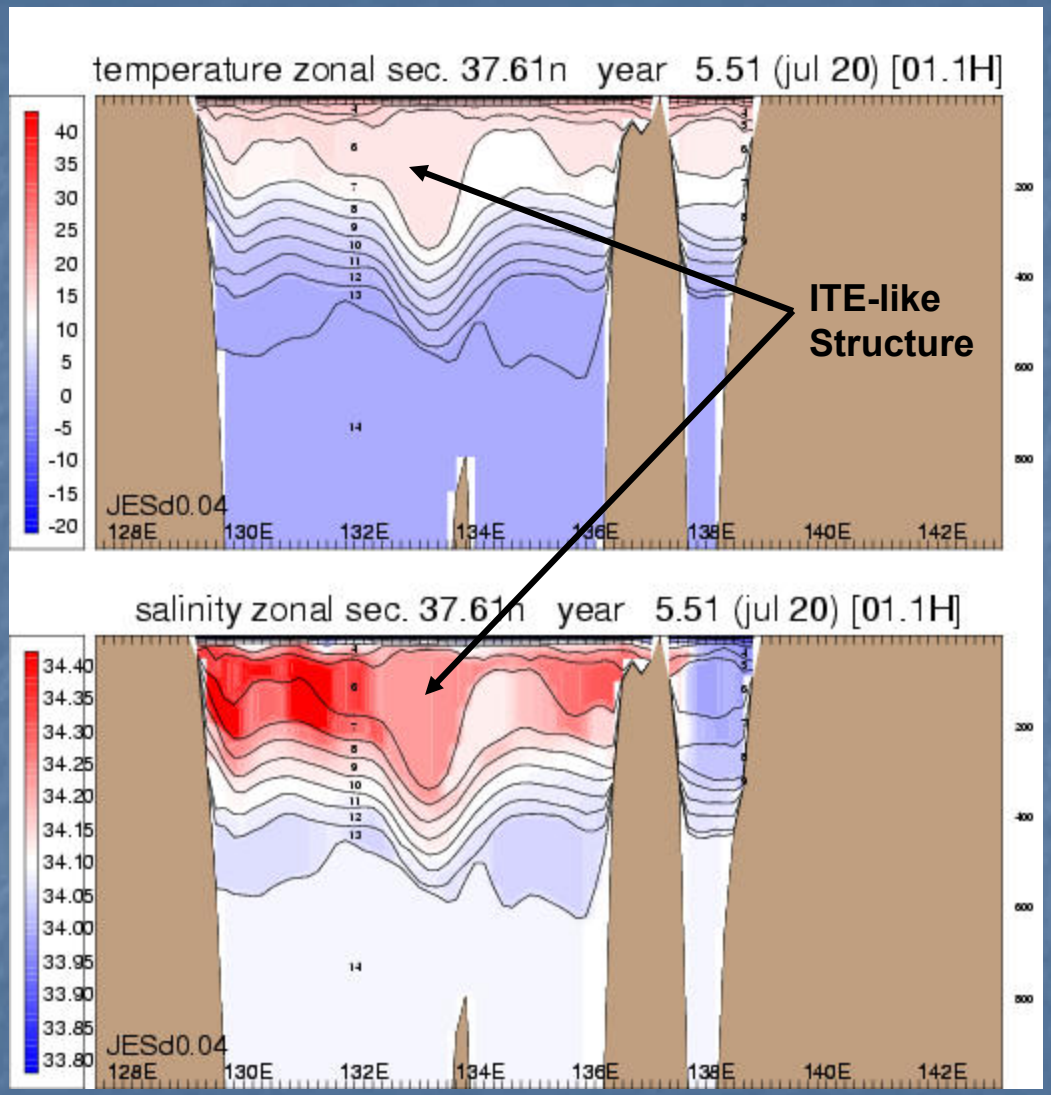
From Naganuma (1977)

May 1999 Cross-section along 37.5°N



(Gordon et. al, 2002)

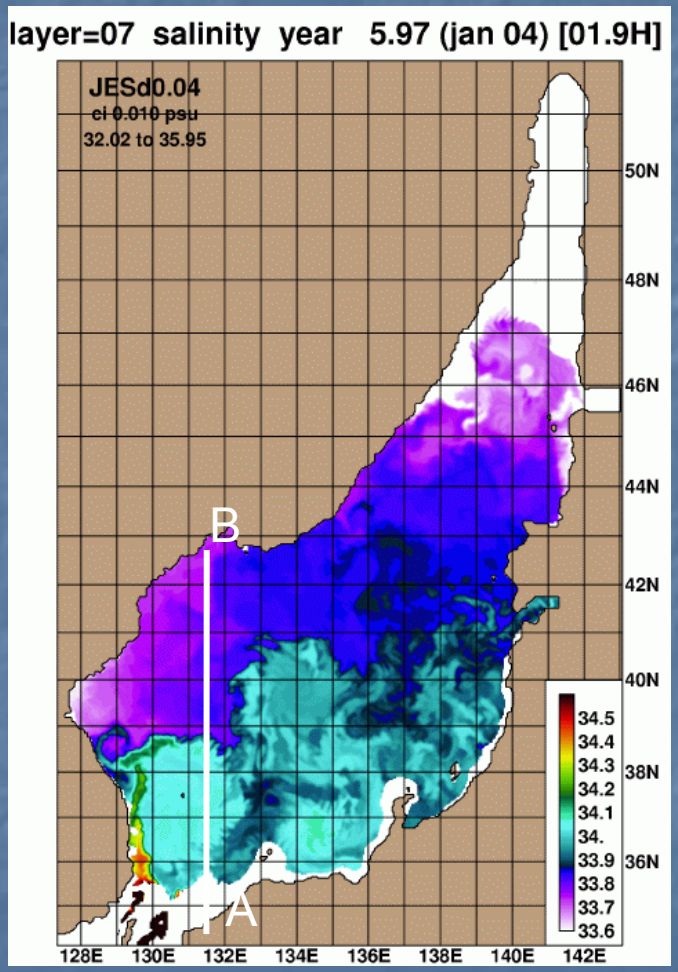
1/25° JES-HYCOM cross-section 37.6°



At the time: are these realistic features or artifacts?

3.5 km Japan/East Sea HYCOM

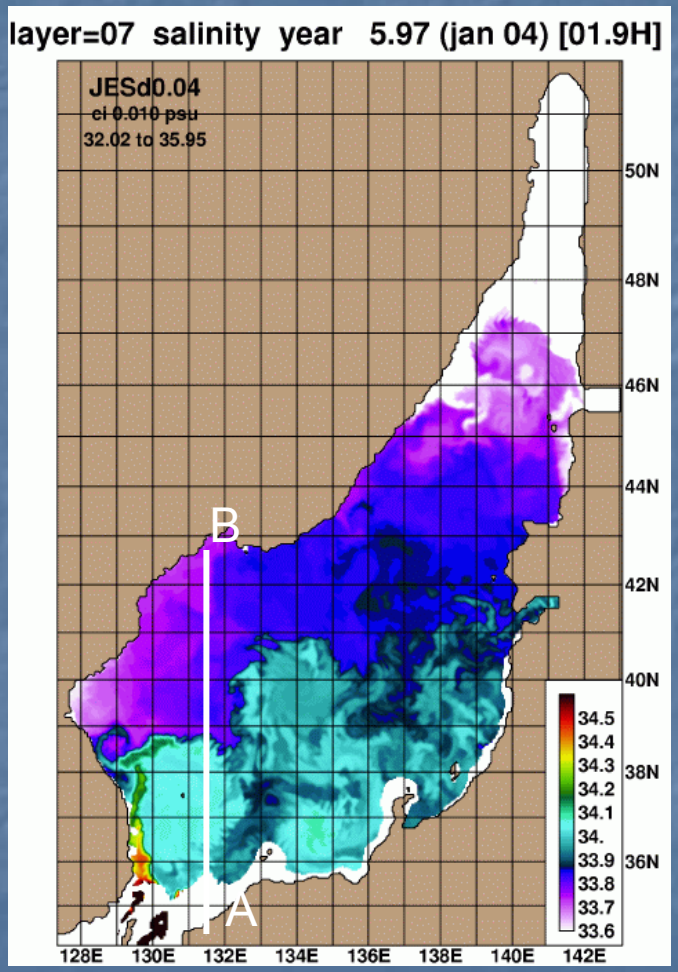
Intra-Thermocline Eddy Formation



Salinity on the 26.0 isopycnal surface (layer 7) carries ITE-type water

3.5 km Japan/East Sea HYCOM

Intra-Thermocline Eddy Formation



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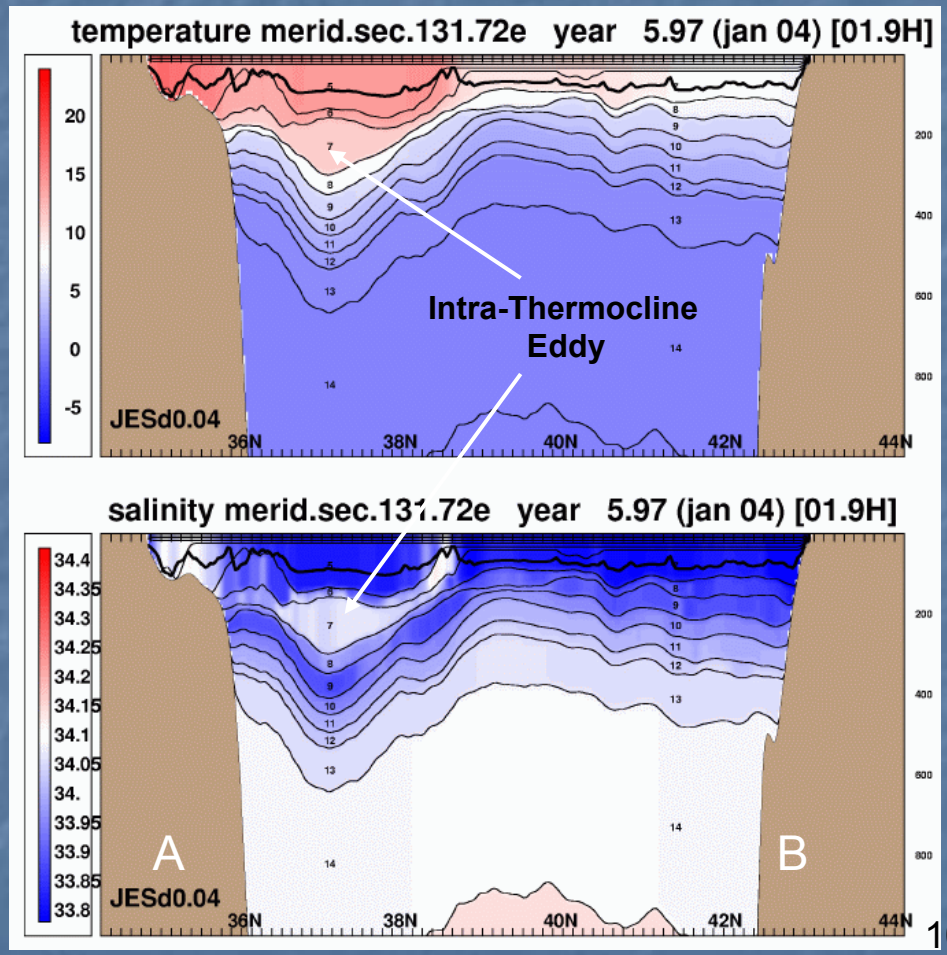
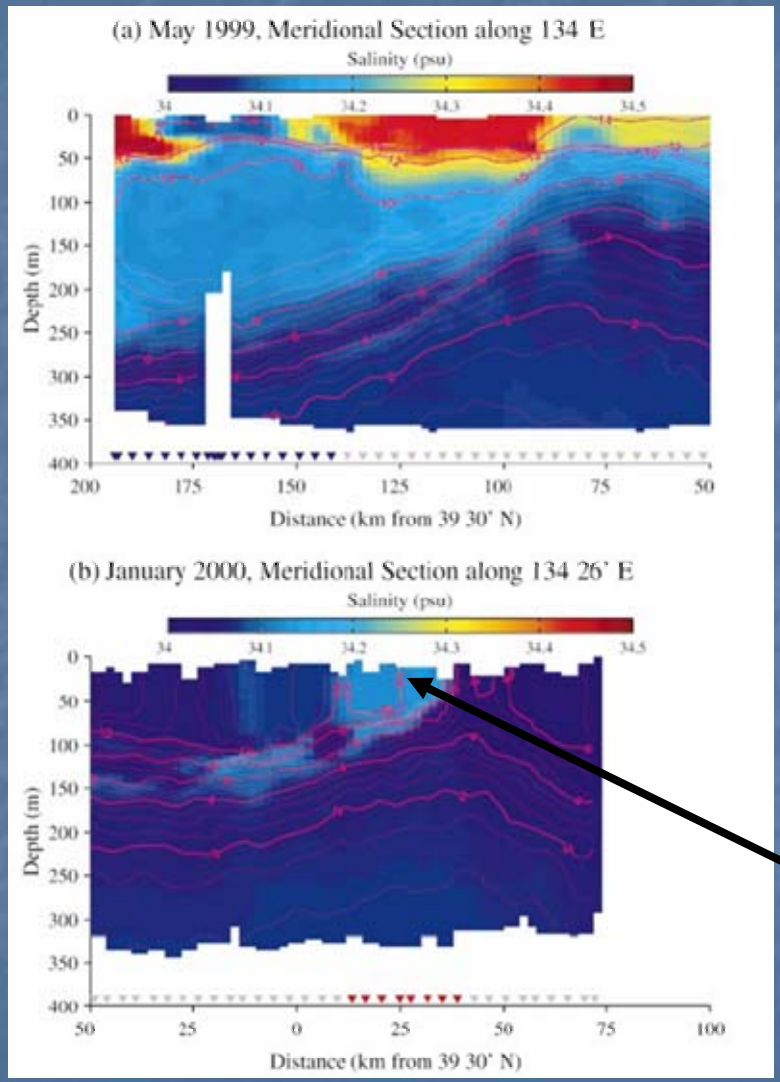


Layer 7 = 26.0 isopycnal surface

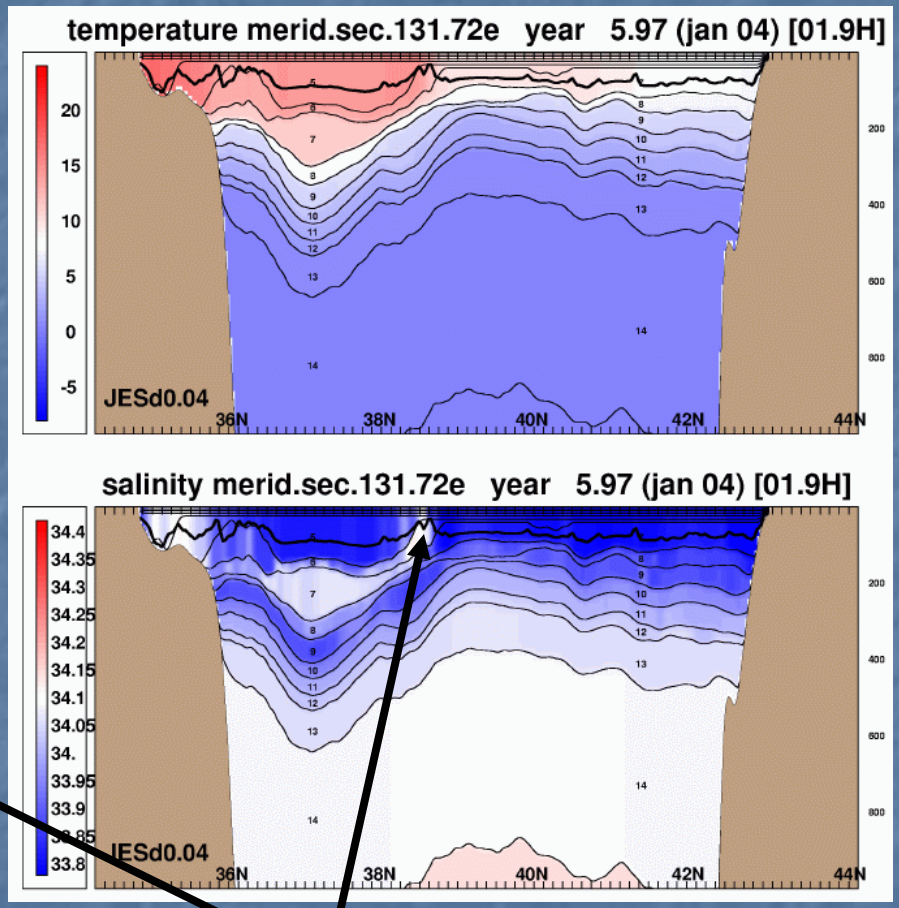
JES Intra-Thermocline Eddy Formation

May 1999

Jan. 2000



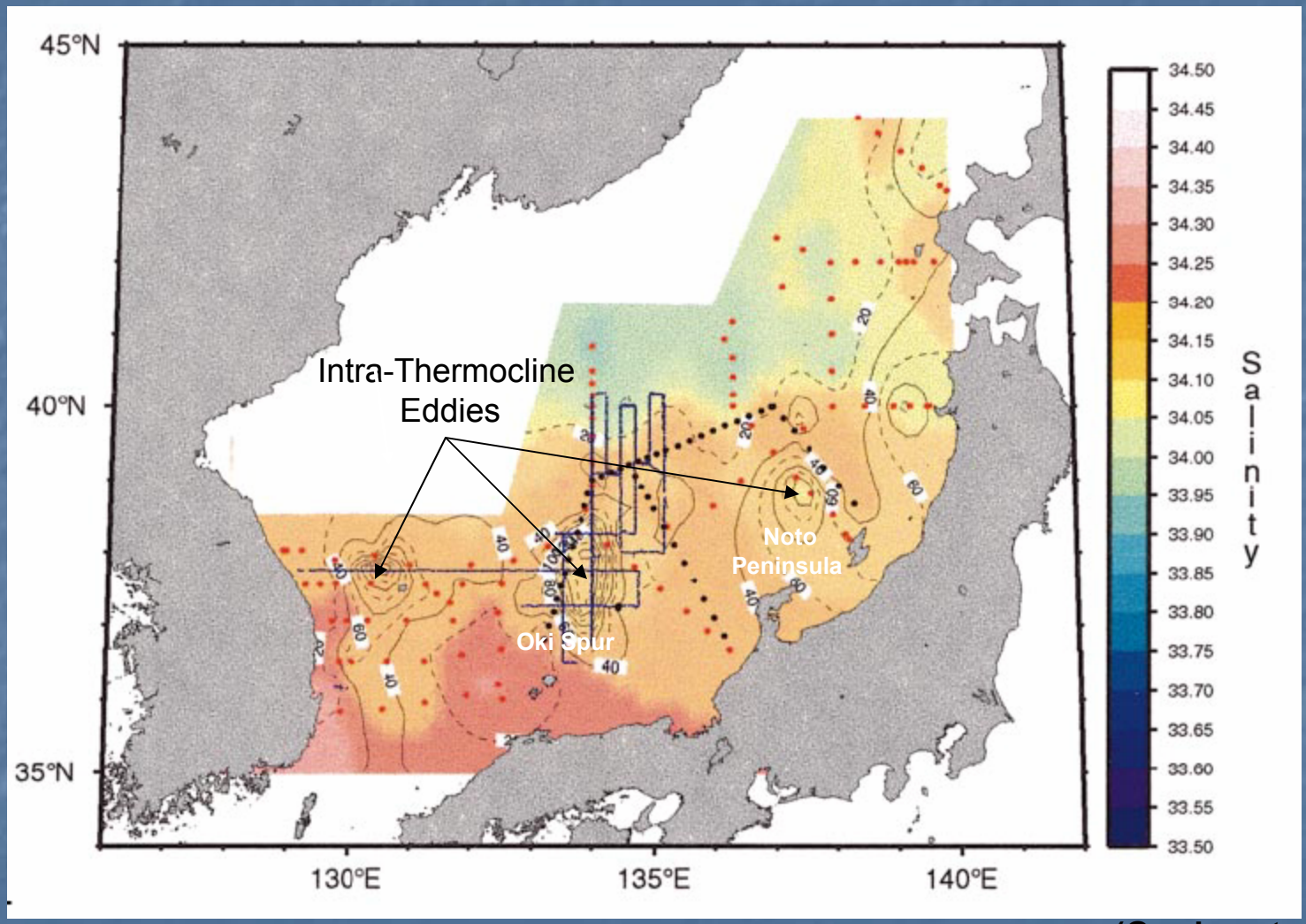
Jan 04 snapshot 3.5 km JES-HYCOM



Subduction along the subpolar front

Gordon et al., 2002, JPO

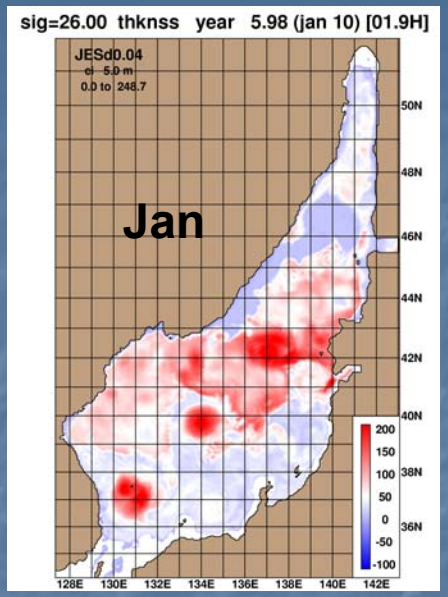
Observed distribution of ITE's based on thickness between 8-11°C

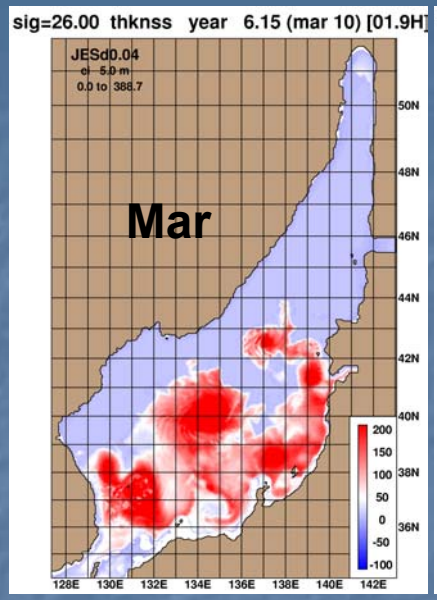


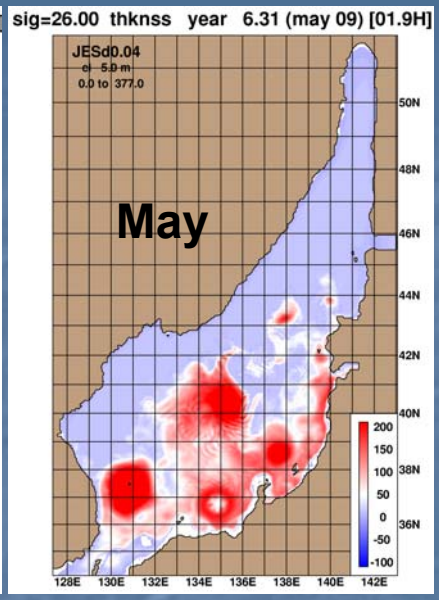
(Gordon et. al, 2002)

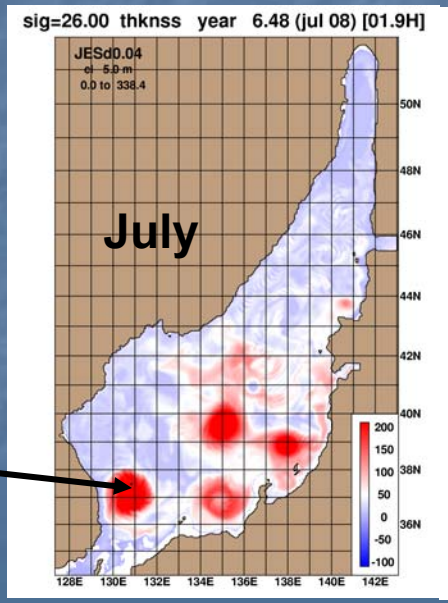
Composite of January 1999 and May 2000 cruises

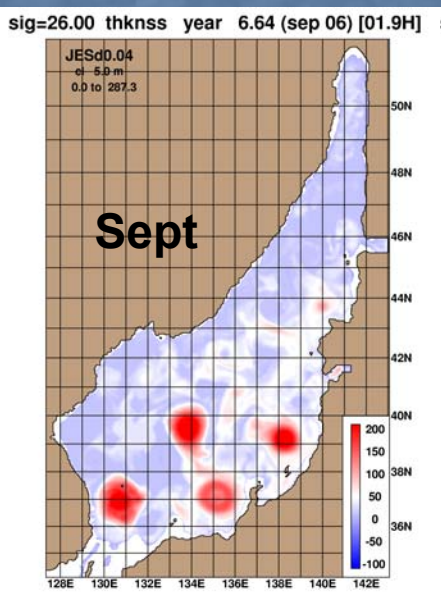
Bi-monthly snapshots of Layer thickness on 26.0 isopycnal surface

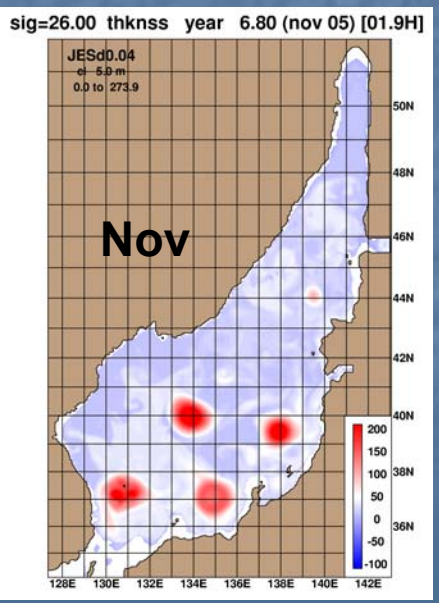








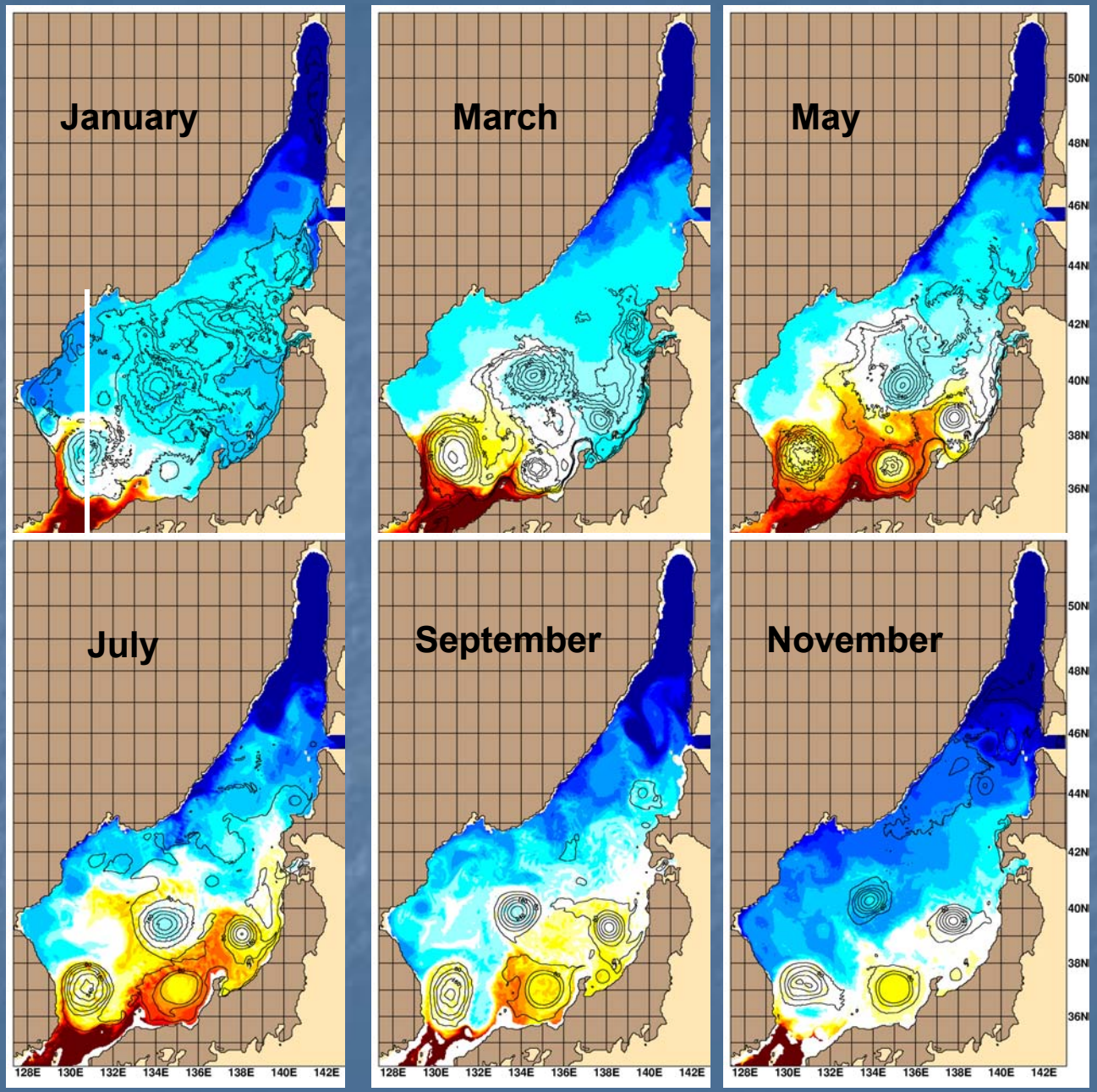




Ulleung ITE

3.5 km JES HYCOM; Straits and ECMWF forcing

Layer 7 thickness (contours) and Layer 6 salinity



Hogan and Hurlburt (2006)

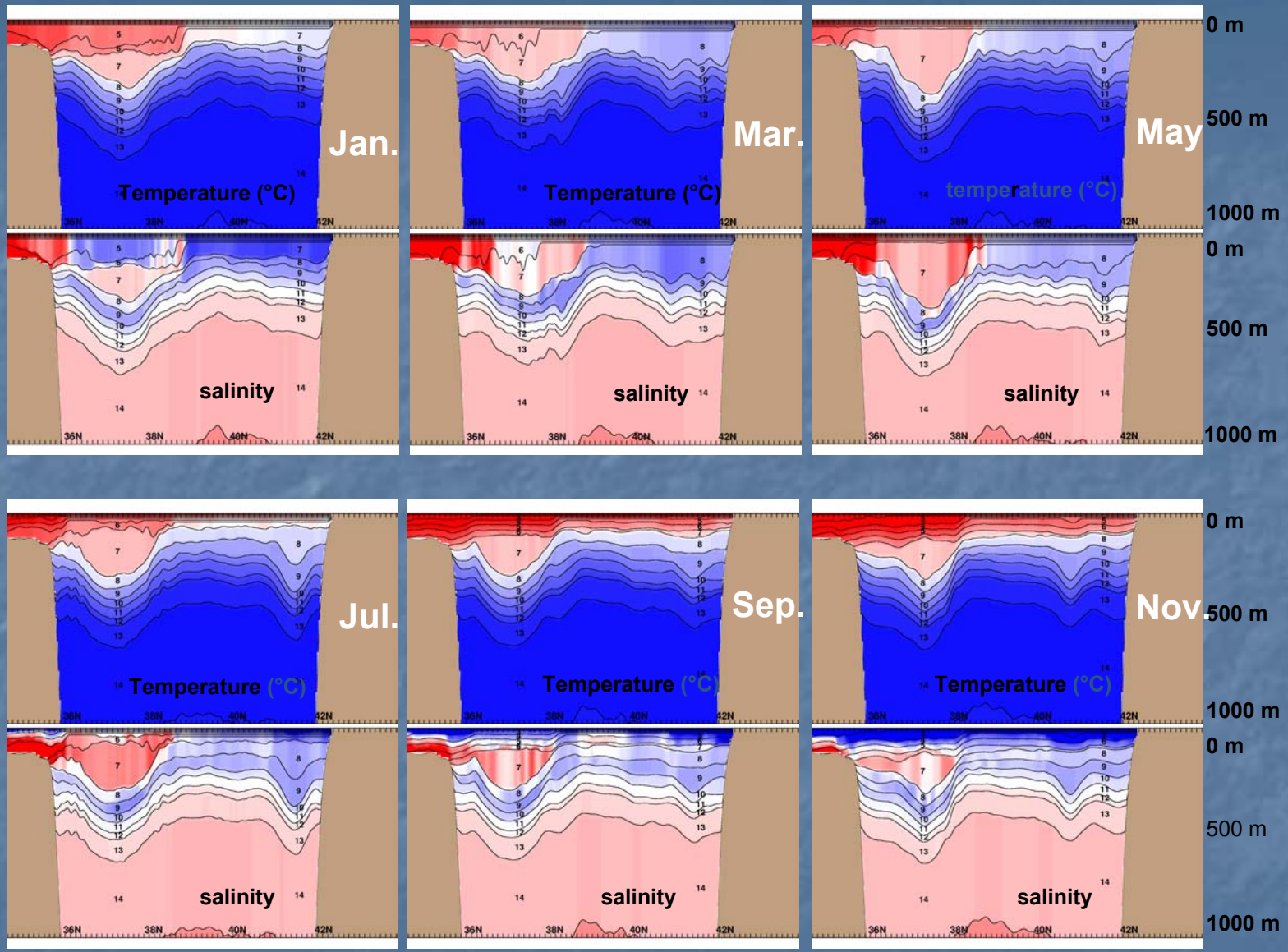
Feb-March:
Near surface in winter erodes the top of the ITE

Mar-June:
advection of higher salinity water through Tsushima Strait results in doming of ITEs; surface heating results in restratification

Sept-Nov:
stratification and ITE doming strongest

Dec-Jan: density of water Entering through Tushima Strait similar to ITE Density, frontal subduction Is possible

Bi-monthly cross-sections snapshots of temp and saln from 3.5 km JES-HYCOM



Summary

Of the possible Formation Mechanisms:

1) Advection of seasonal temperature and salinity through the Tsushima Strait.

2) Seasonal restratification of the thermocline due to seasonal heating and cooling in the JES.

3) Frontal subduction of ITE water along the subpolar front during winter

The seasonal advection and restratification mechanism occured in all ITE's, but subduction along the subpolar front only occurred in the Ulleung ITE (and played a relatively minor role).

Hogan, P.J. and H.E. Hurlburt, 2006. Why do Intrathermocline eddies form in the Japan/East Sea? A modeling perspective, *Oceanog*., v. 19, no. 3, 134-143.