Satellite Altimeter Observations of Nonlinear Rossby Eddy-Kuroshio Interaction at the Luzon Strait

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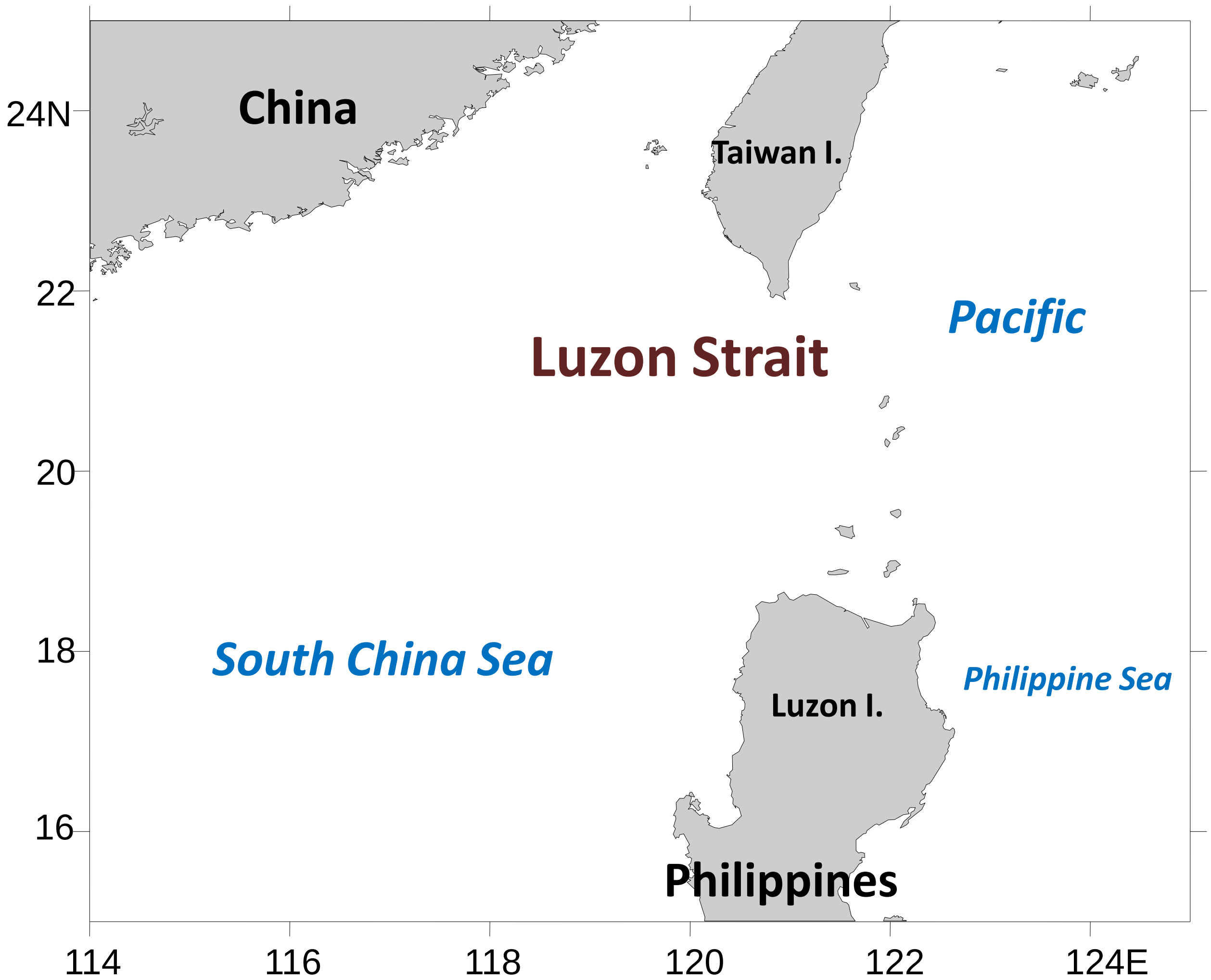
NOAA NESDIS
August 4, 2010

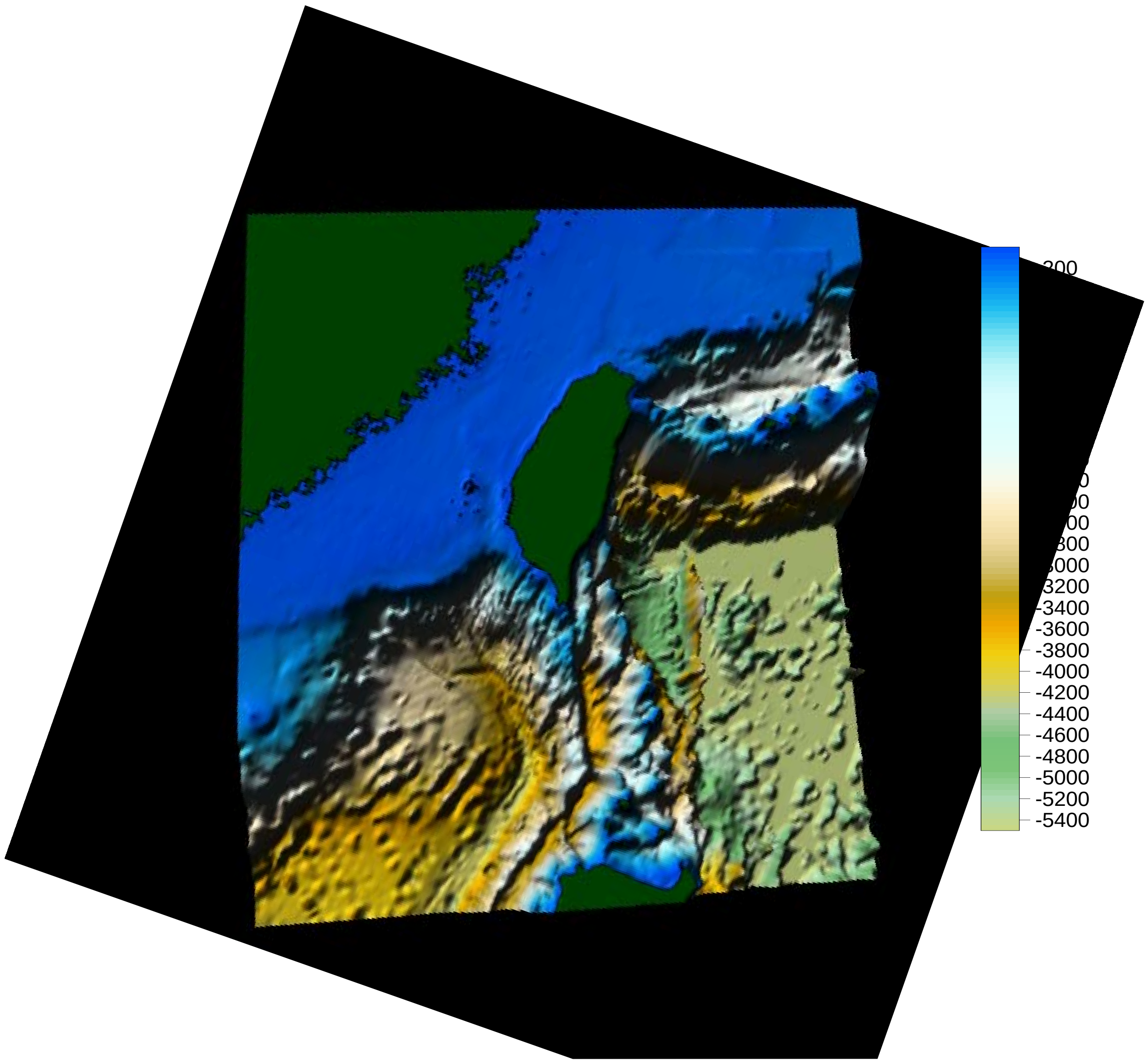
Study Area: Luzon Strait

from 18.5°N to 22.0°N and from 120°E to 122°E

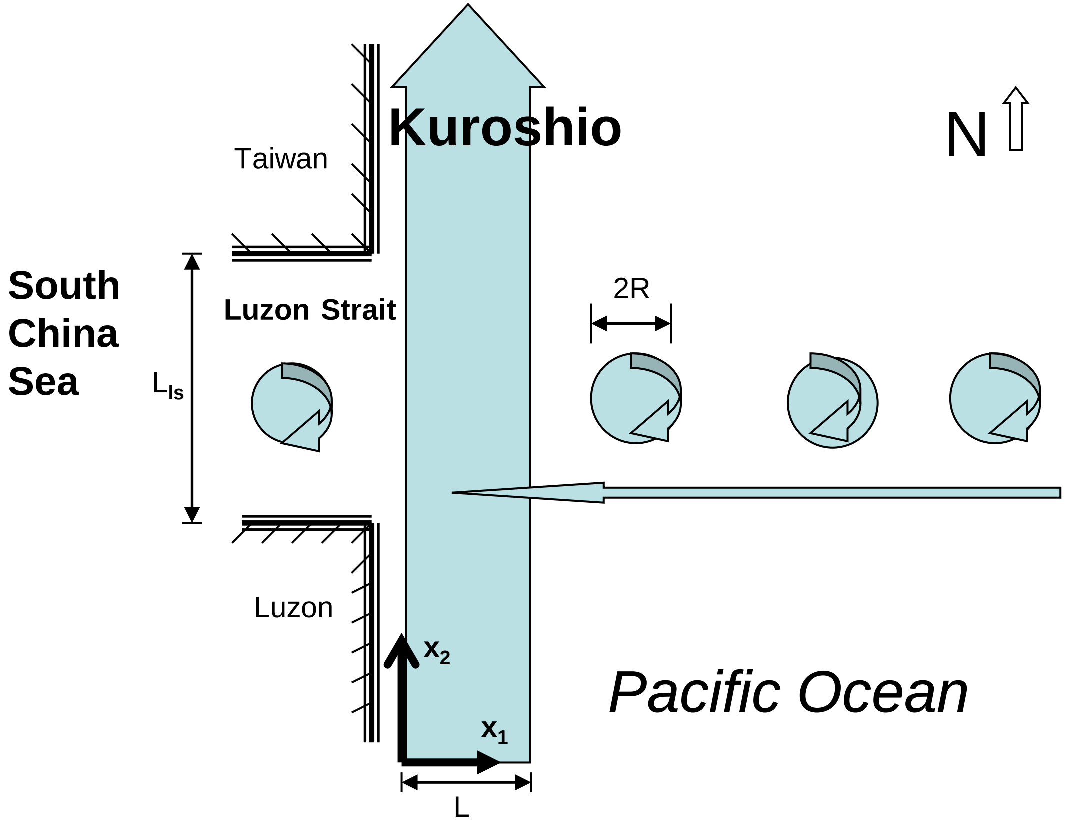


Study Area: Luzon Strait

Bottom Topography



Meso-scale Dynamics Model



Scientific Questions

- Can eddies penetrate LZ into SCS?
- What is the role of Kuroshio in the local meso-scale dynamics?

  A dynamical barrier or a solid wall?
- How does the Kuroshio branch?

  What is the role of eddies in the branching?
- Why does LS show a low SLA belt?

Key Points of this Talk

- Nonlinear Rossby eddies in the Pacific observed by satellite altimeters
- Dynamic comparison of the Kuroshio to eddies
- EOF analysis of sea level field
- A case of eddy penetration through Luzon Strait
- Kuroshio bifurcation or branching
- Statistics of eddy distribution
- Possible mechanism for low SLA belt across LS

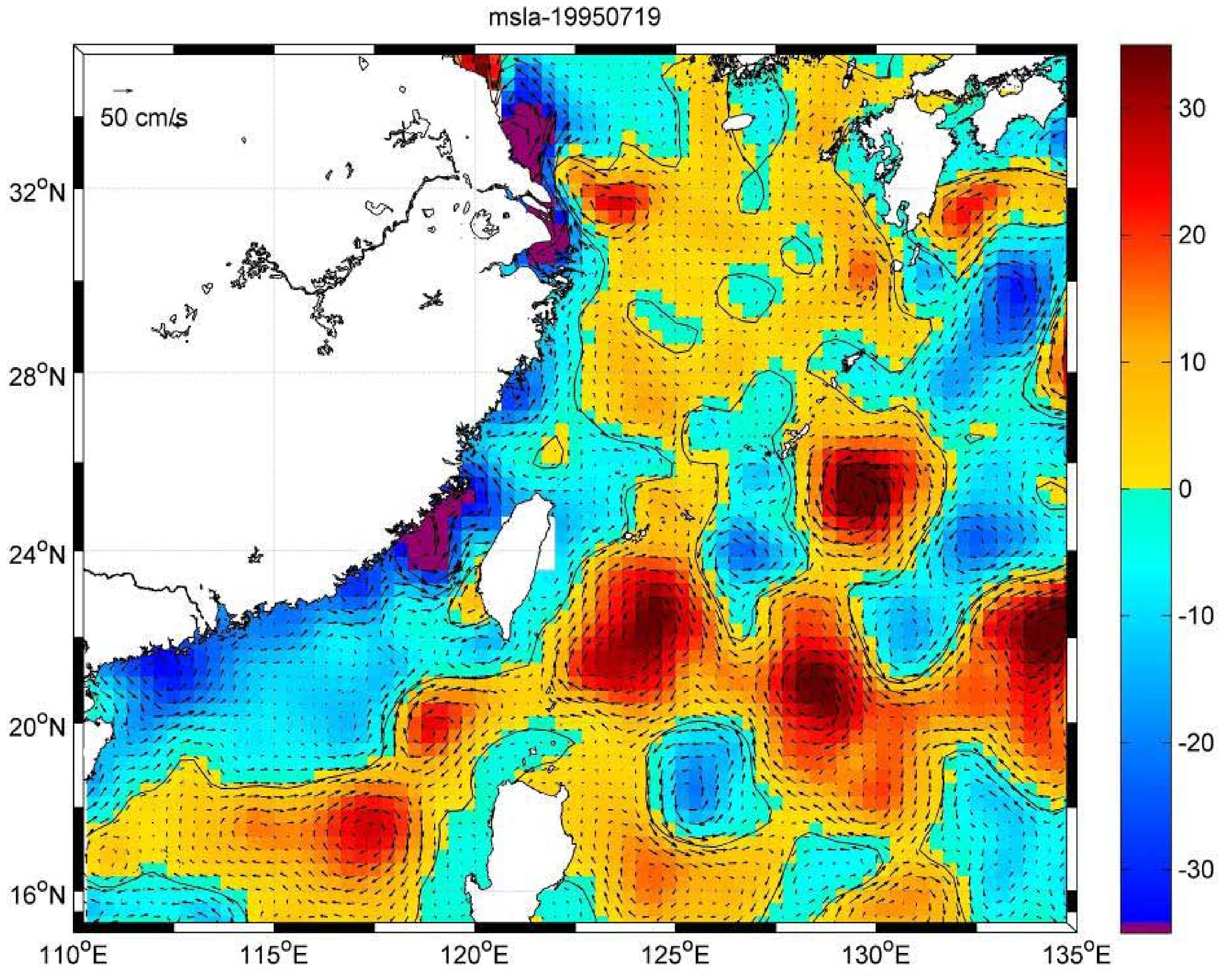
Data

Maps of See Level Anomalies (MSLA)

- From 1993 to 2008
- Cartesian gridded with a spatial resolution of $1/4^\circ$ by $1/4^\circ$
- The temporal interval is 7 days

Maps of Absolute Dynamic Topography (MADT)

- From 1993 to 2008
- Cartesian gridded with a spatial resolution of $1/4^\circ$ by $1/4^\circ$
- The temporal interval is 3-4 days


msla-19950719
50 cm/s
32°N
28°N
24°N
20°N
16°N
110°E
115°E
120°E
125°E
130°E
135°E
30
20
10
0
-10
-20
-30

Standards for identifying an eddy

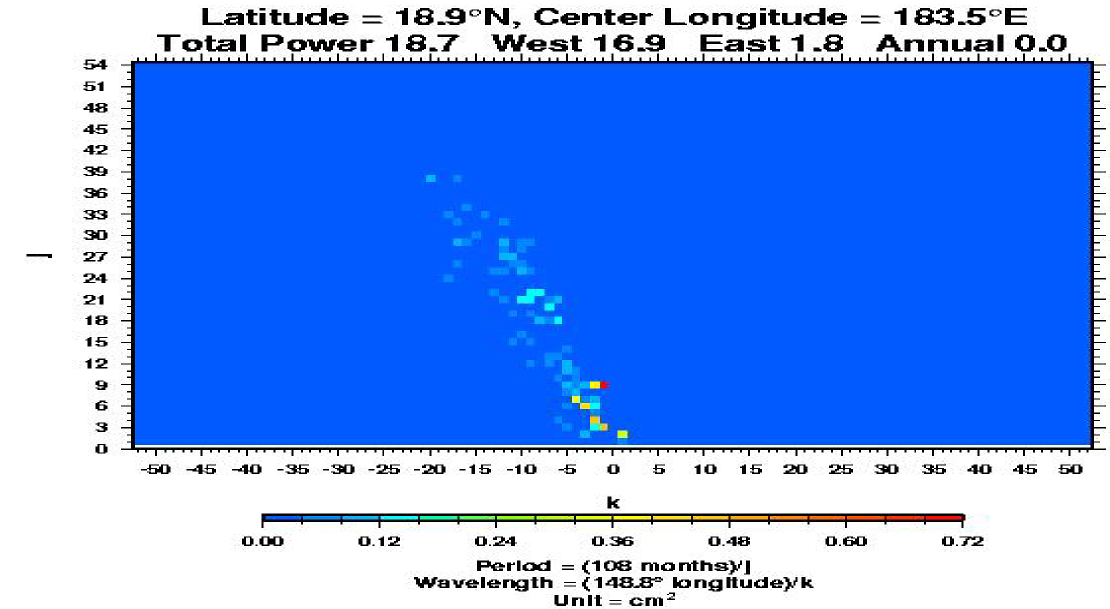
1) Close SLA or ADT contour lines

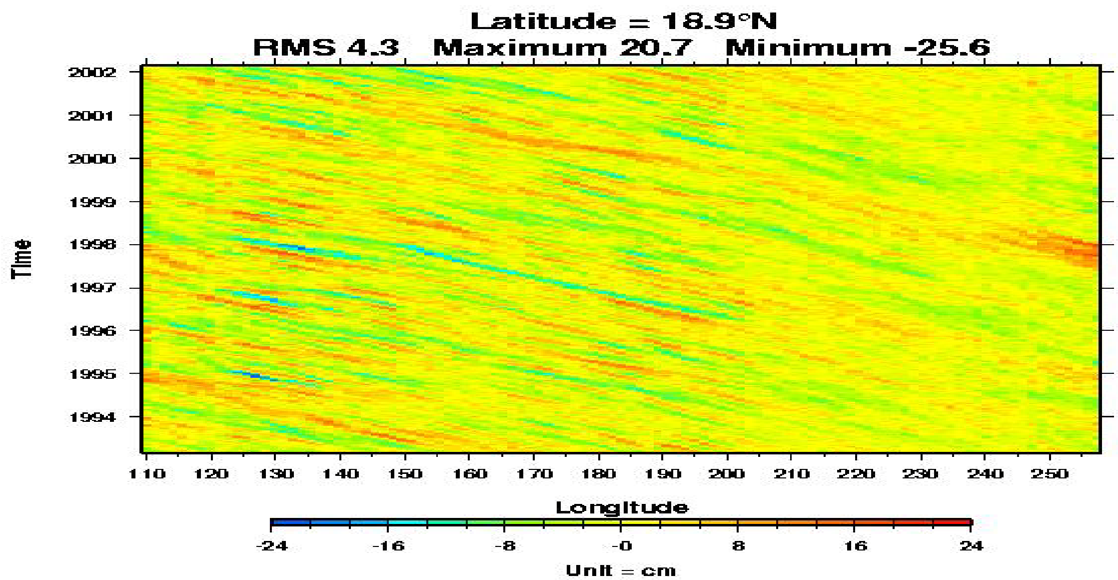
2) Depth at eddy center deeper than 1000m

3) Sea level height deference between the eddy center and the outmost close contour line greater than 7.5cm

4) Continuously sustaining time of the eddy longer than 4 weeks

Rossby Eddies in the Pacific





Scale Analysis

Mesoscale eddies

- **Horizontal length scale : *O*(300 km)**
- **Vertical depth scale : *O*(2000 m)**
- **Average angular velocity : *O*(5×10^{-6} s^{-1})**
- **Average wavelength: 800-1000 km**
- **Average phase speed: *O*(-10 cms^{-1})**

Kuroshio

- **Horizontal length scale : *O*(100 km)**
- **Vertical depth scale : *O*(1000 m)**
- **Average speed: *O*(1 ms^{-1})**

Total momentum

For the Kuroshio

$$M_k = \rho \cdot Volume \cdot v_k = 2\rho R L_k D_k v_k$$

For the eddy

$$M_e = \sqrt{M_{horizontal}^2 + M_{rotation}^2} = \sqrt{\left(\rho \cdot Volume \cdot u_e\right)^2 + \left(2\pi\rho D\omega\int_0^R r^2 dr\right)^2}$$

$$= \pi\rho R D\left(u_e^2 + \frac{4}{9}\omega^2 R^4\right)^{1/2},$$

Total momentum ratio of Kuroshio to eddy

$$\Gamma_1 = \frac{M_k}{M_e} \approx \frac{3}{2\pi}\frac{v_k L_k}{\omega R^2}.$$

Total kinetic energy

For the Kuroshio

$$E_k = \frac{1}{2}\rho \cdot Volume \cdot v_k^2 = \rho R L_k D_k v_k^2$$

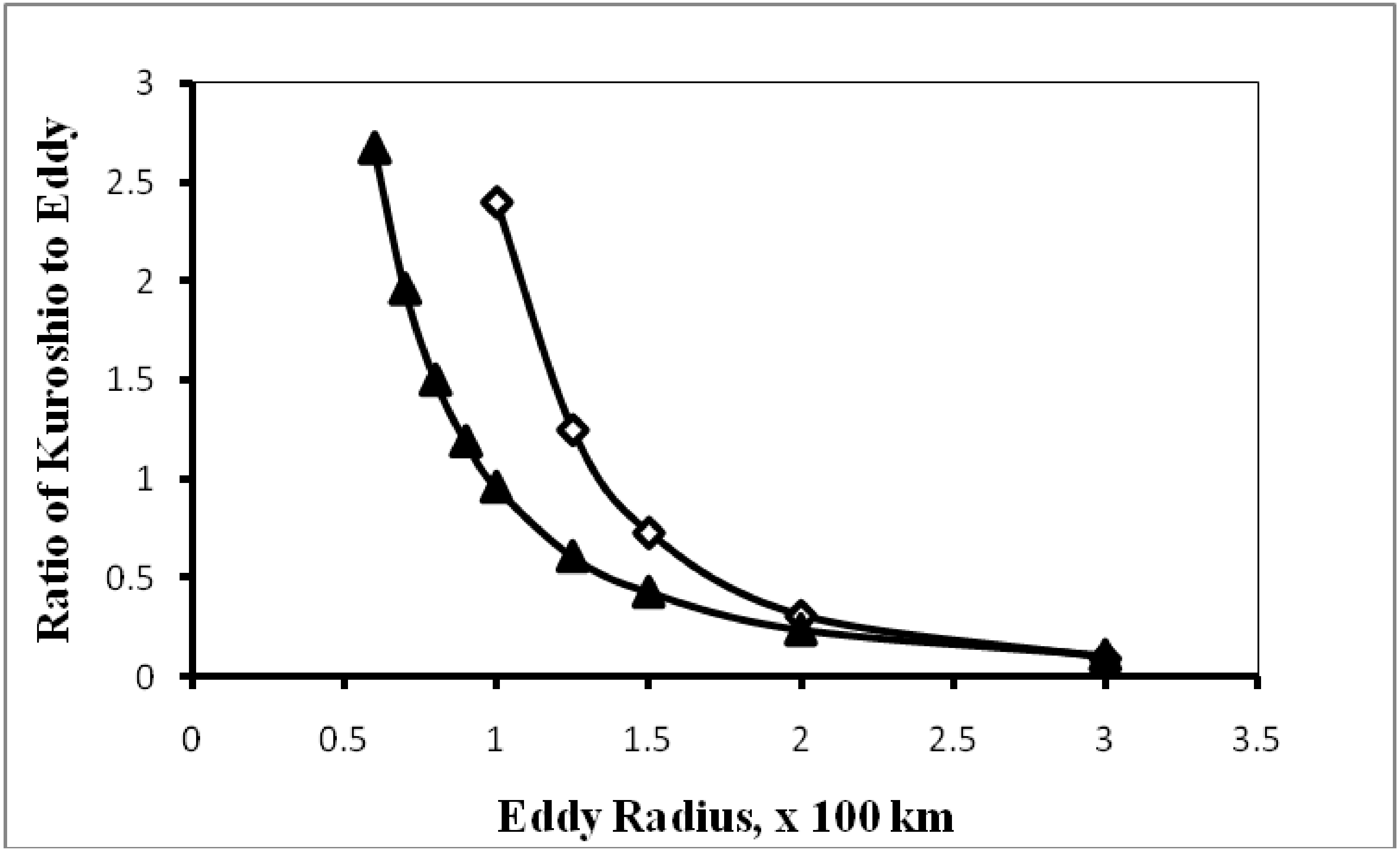
For the eddy

$$E_e = E_{horizontal} + E_{rotation} = \frac{1}{2}\rho \cdot Volume \cdot u_e^2 + \pi\rho D\omega^2 \int_0^R r^3 dr$$

$$= \frac{\pi}{4}\rho R^2 D\left(2u_e^2 + \omega^2 R^2\right).$$

Kinetic energy ratio of Kuroshio to eddy

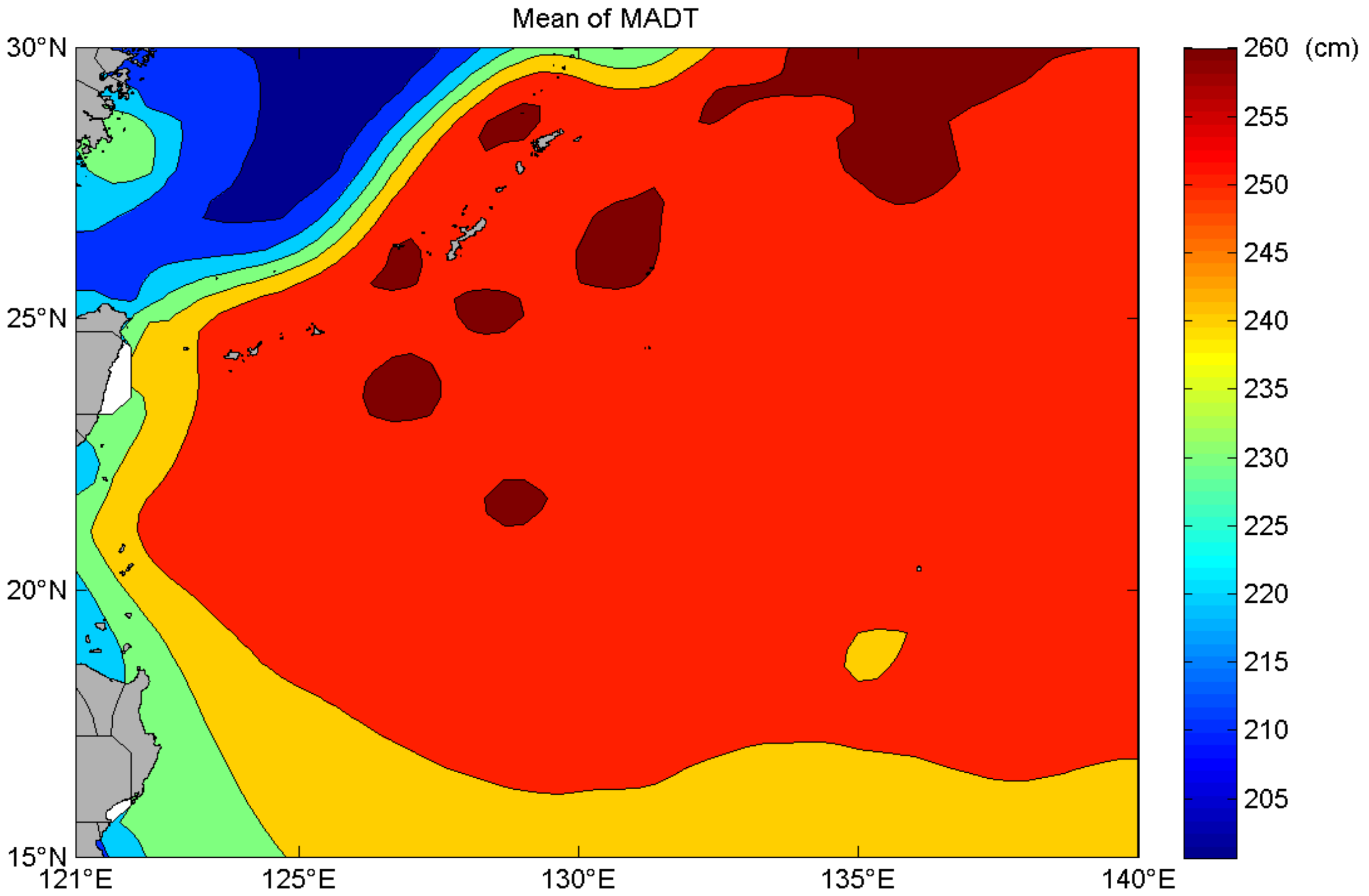
$$\Gamma_2 = \frac{E_k}{E_e} = \frac{4}{\pi}\left(\frac{L_k}{R}\right)\left(\frac{D_k}{D}\right)\left(\frac{v_k^2}{2u_e^2 + \omega^2 R^2}\right).$$



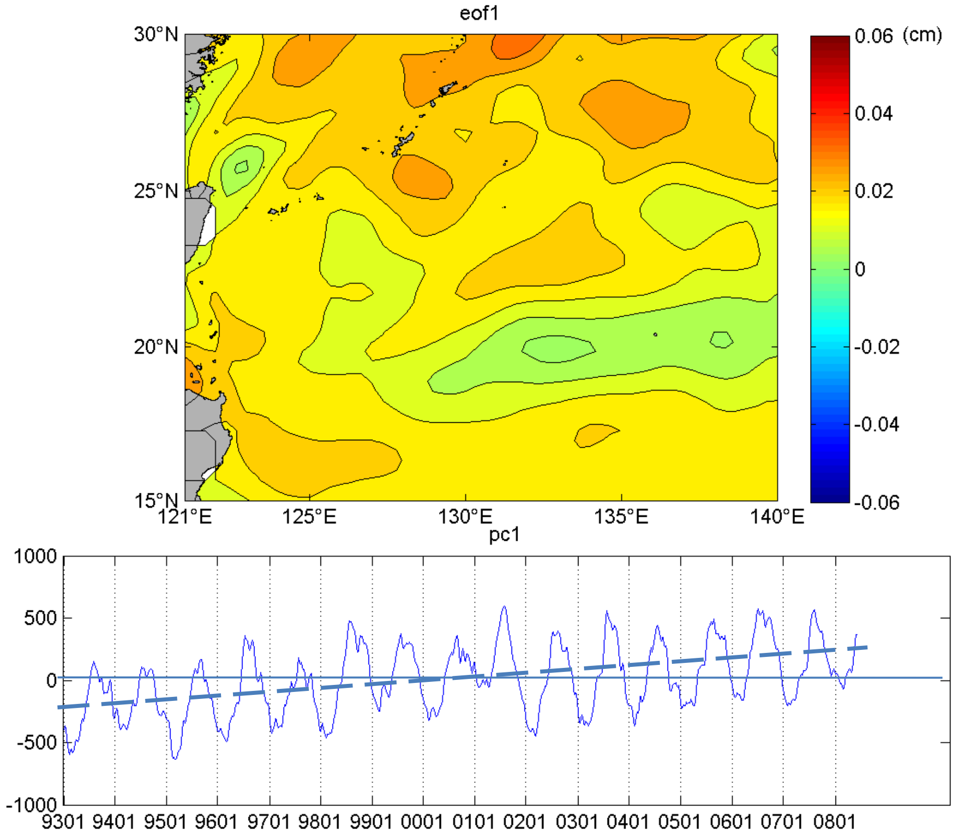
Momentum (triangles) and kinetic energy (diamonds) ratios of Kuroshio to eddy vs. eddy radium.

EOF analysis

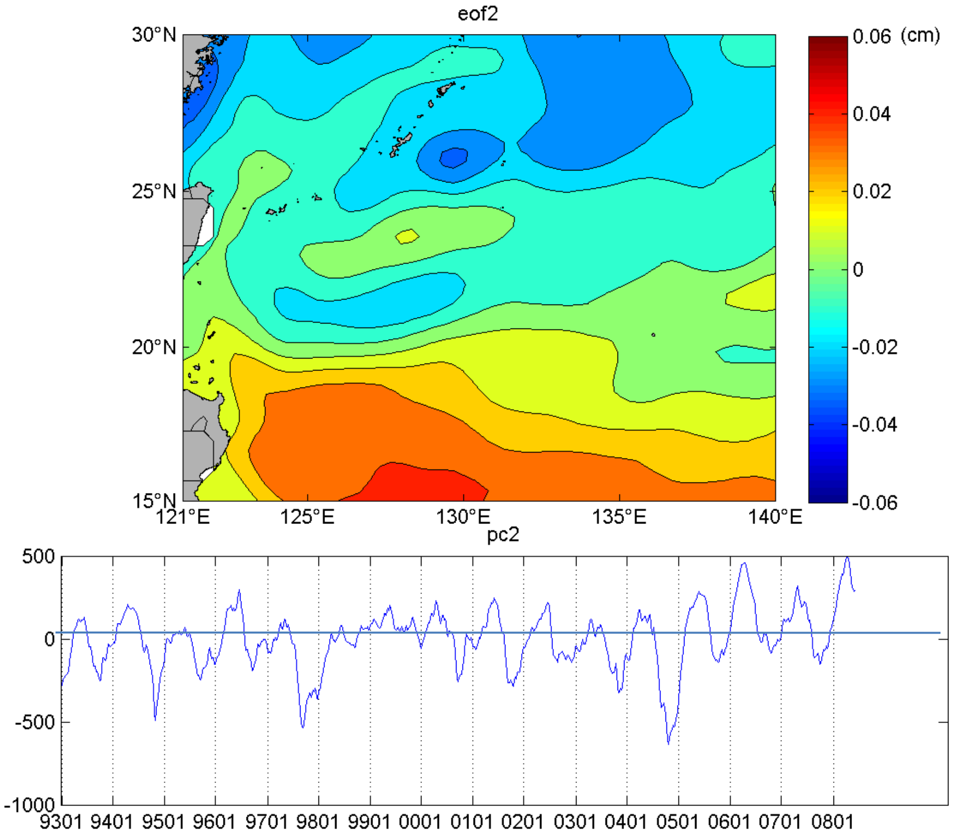
Mean ADT from 1993 to 2008



Mode1

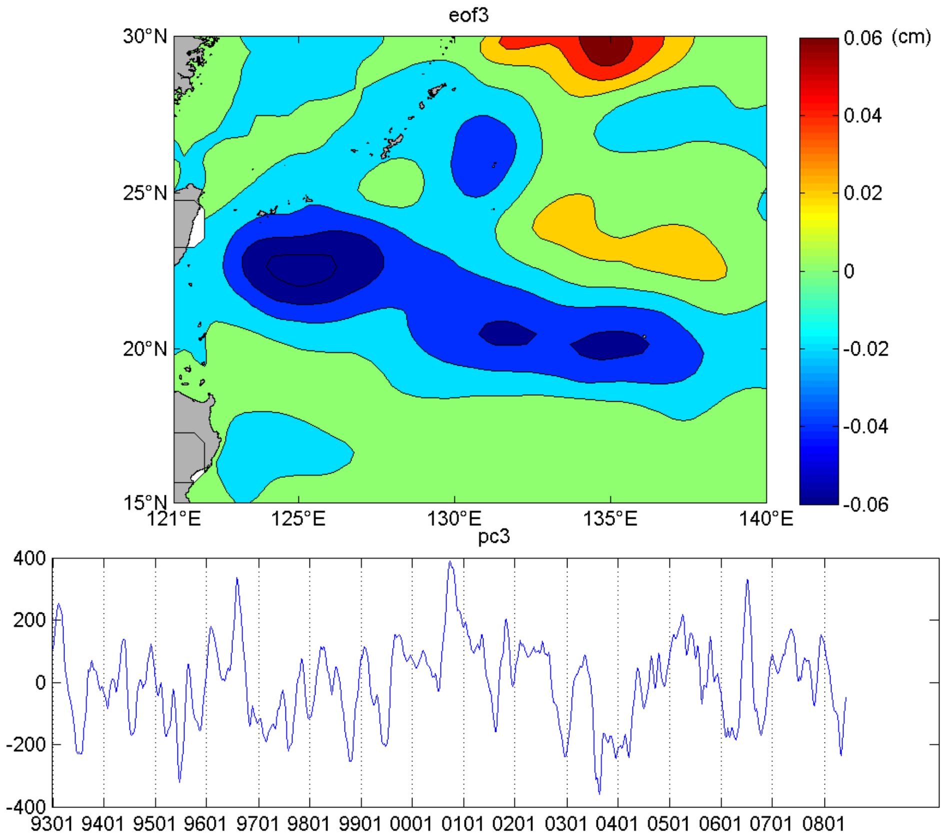

eof1
30°N
25°N
20°N
15°N
121°E
125°E
130°E
135°E
140°E
0.06 (cm)
0.04
0.02
0
-0.02
-0.04
-0.06
pc1
1000
500
0
-500
-1000
9301 9401 9501 9601 9701 9801 9901 0001 0101 0201 0301 0401 0501 0601 0701 0801

Mode2


eof2
30°N
25°N
20°N
15°N
121°E 125°E 130°E 135°E 140°E
0.06 (cm)
0.04
0.02
0
-0.02
-0.04
-0.06
pc2
500
0
-500
-1000
9301 9401 9501 9601 9701 9801 9901 0001 0101 0201 0301 0401 0501 0601 0701 0801

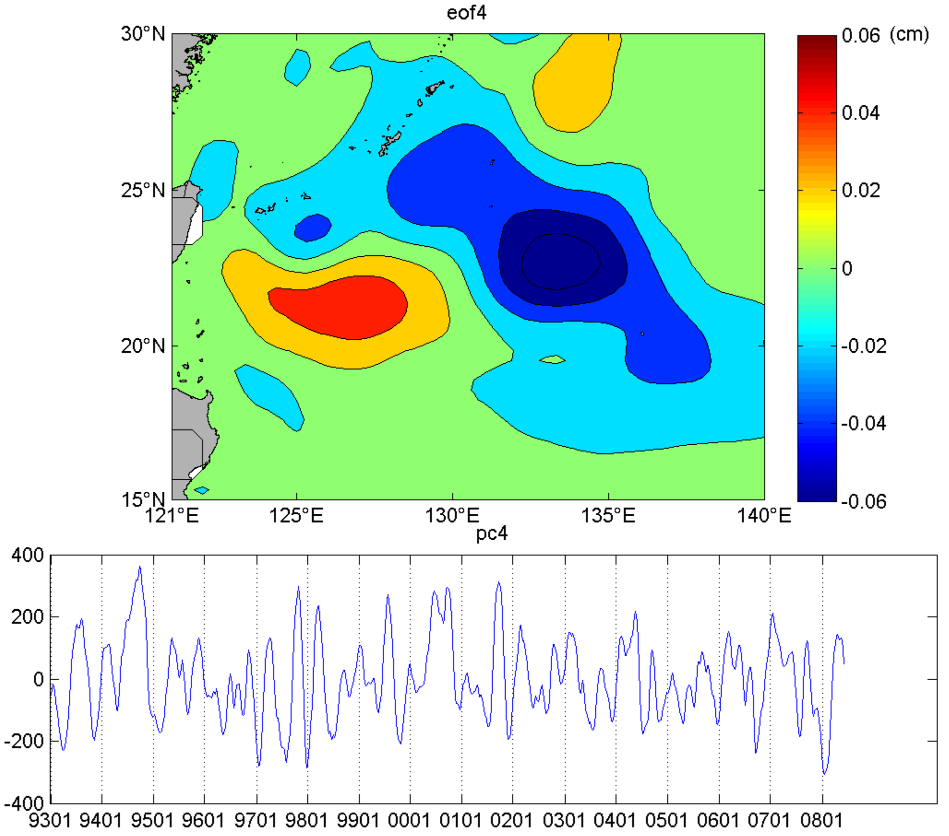
EOF analysis

Mode3

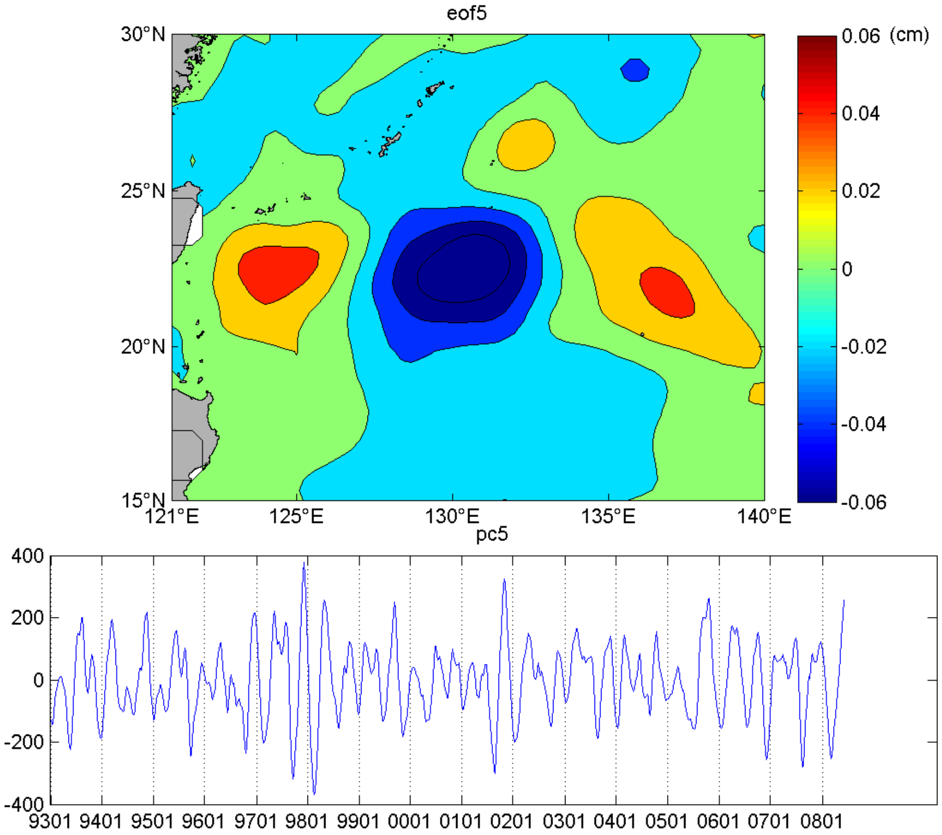


EOF analysis

Mode4

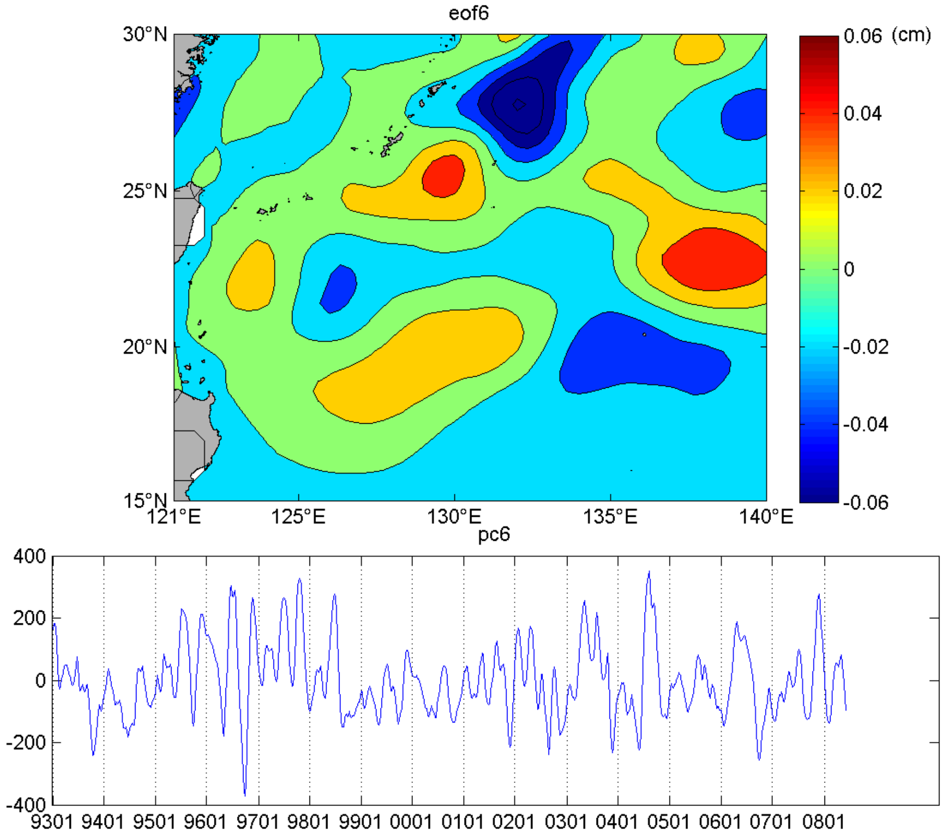


Mode5


eof5
30°N
25°N
20°N
15°N
121°E
125°E
130°E
135°E
140°E
0.06 (cm)
0.04
0.02
0
-0.02
-0.04
-0.06
pc5
400
200
0
-200
-400
9301 9401 9501 9601 9701 9801 9901 0001 0101 0201 0301 0401 0501 0601 0701 0801

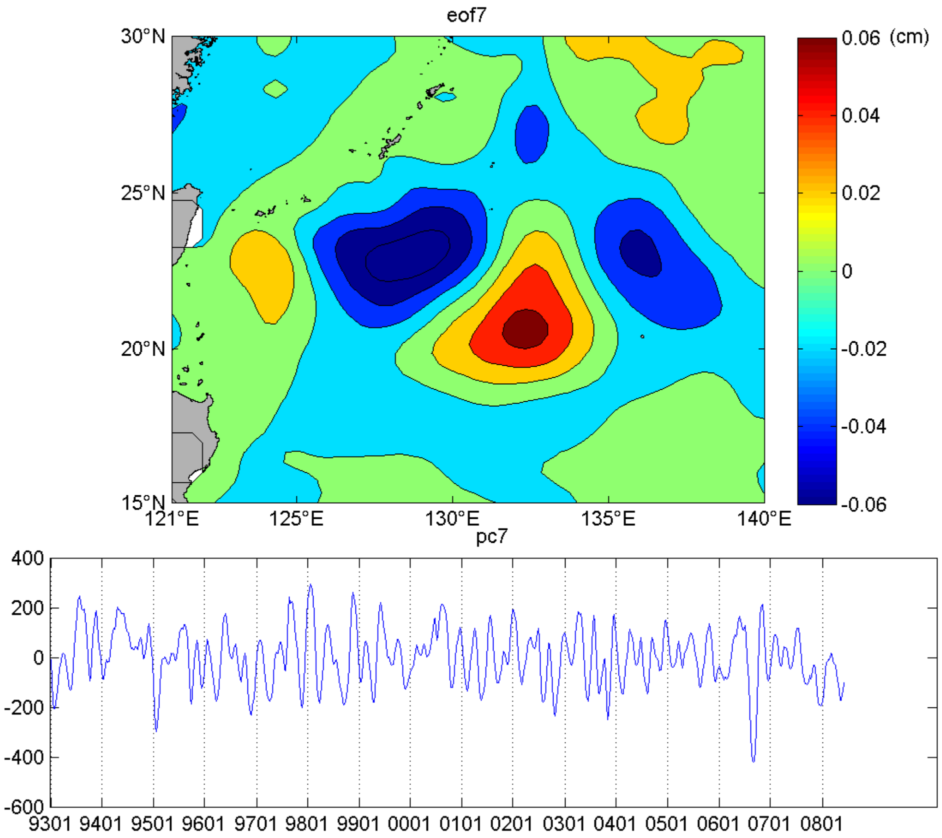
EOF analysis

Mode6

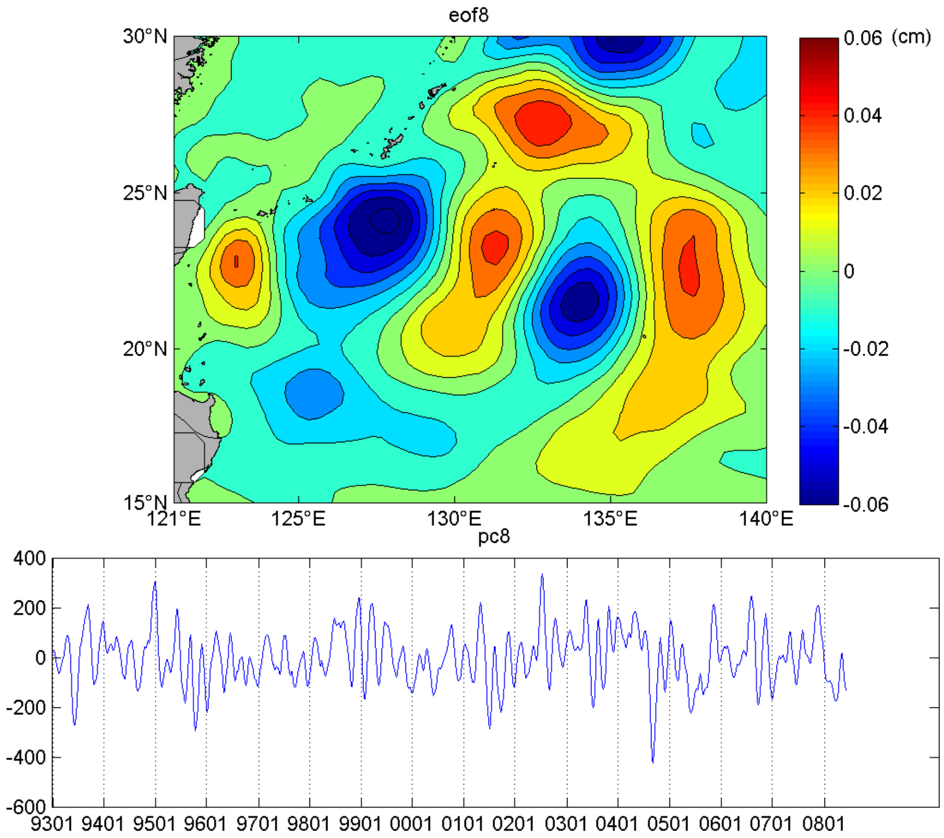


EOF analysis

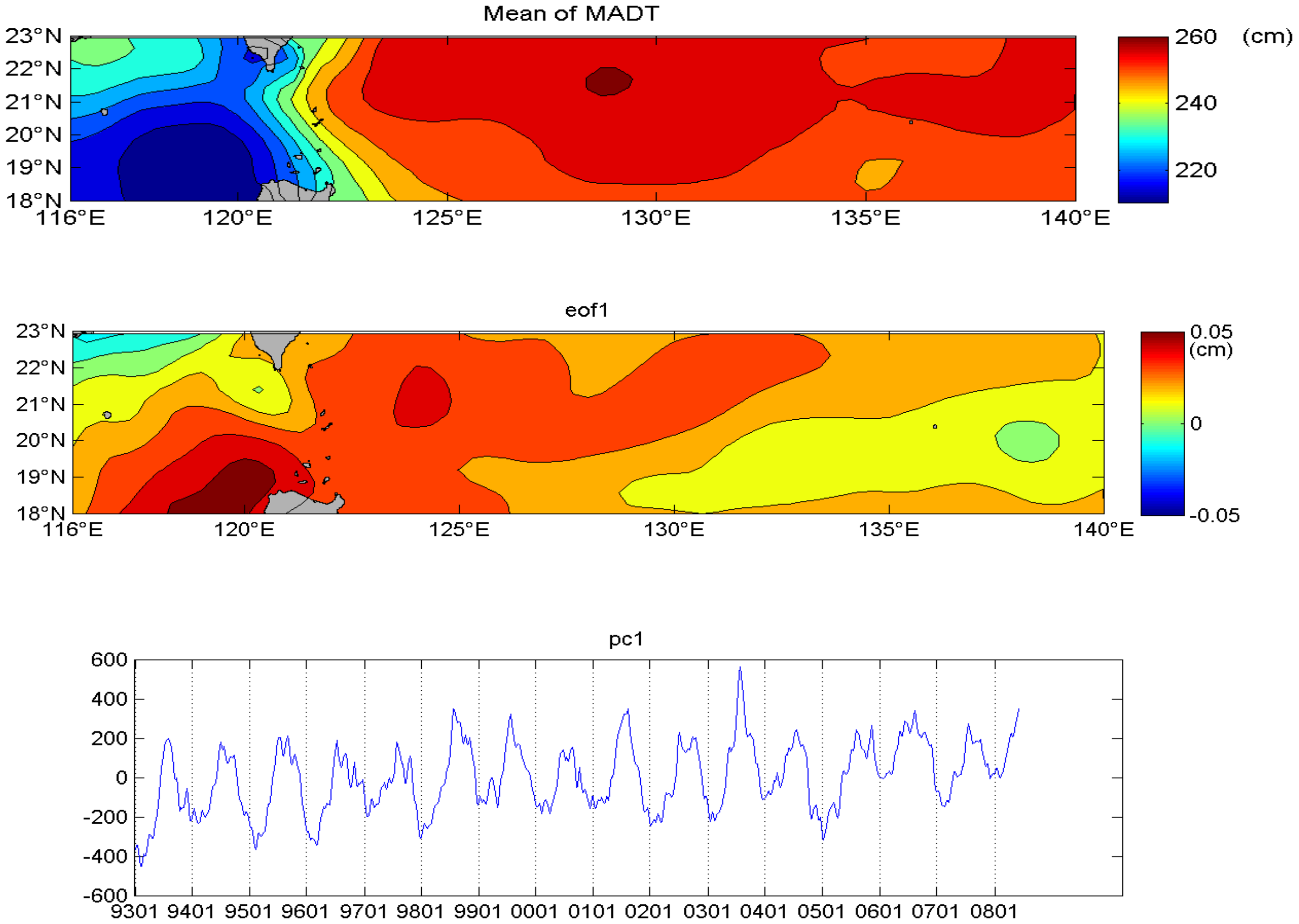
Mode7



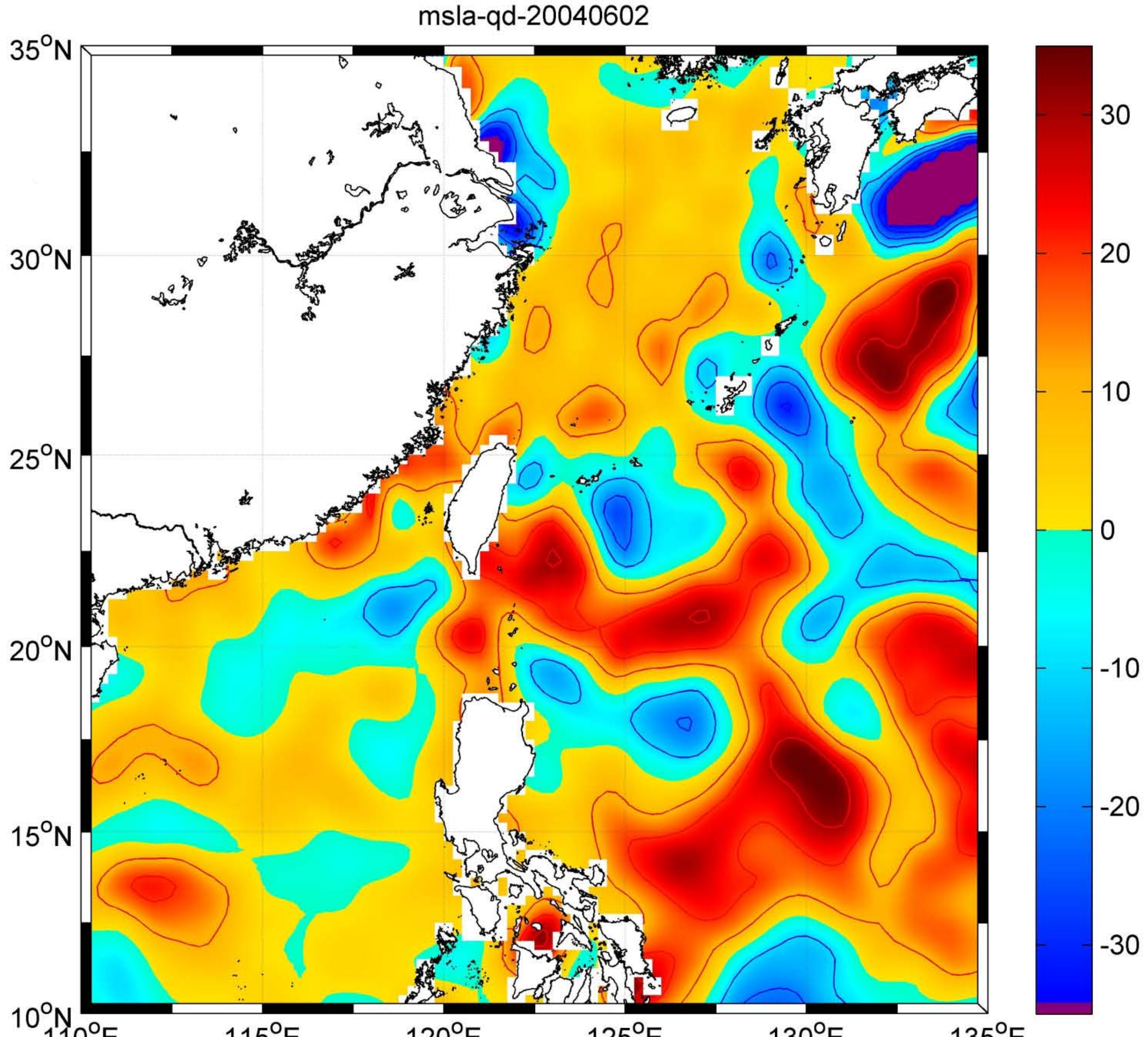
Mode8


eof8
30°N
25°N
20°N
15°N
121°E
125°E
130°E
135°E
140°E
0.06 (cm)
0.04
0.02
0
-0.02
-0.04
-0.06
pc8
400
200
0
-200
-400
-600
9301 9401 9501 9601 9701 9801 9901 0001 0101 0201 0301 0401 0501 0601 0701 0801

Eddy penetration through Luzon Strait

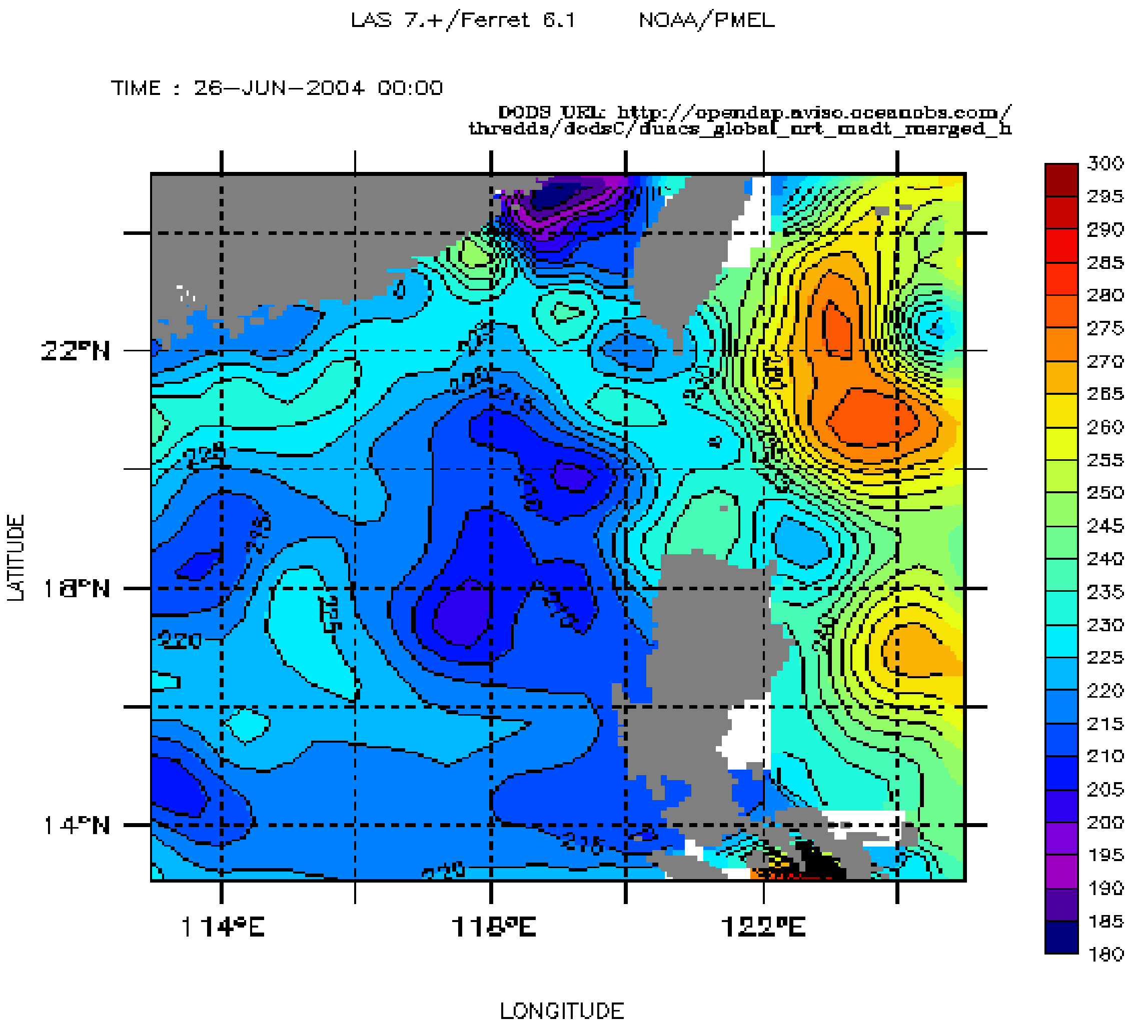


14.988%

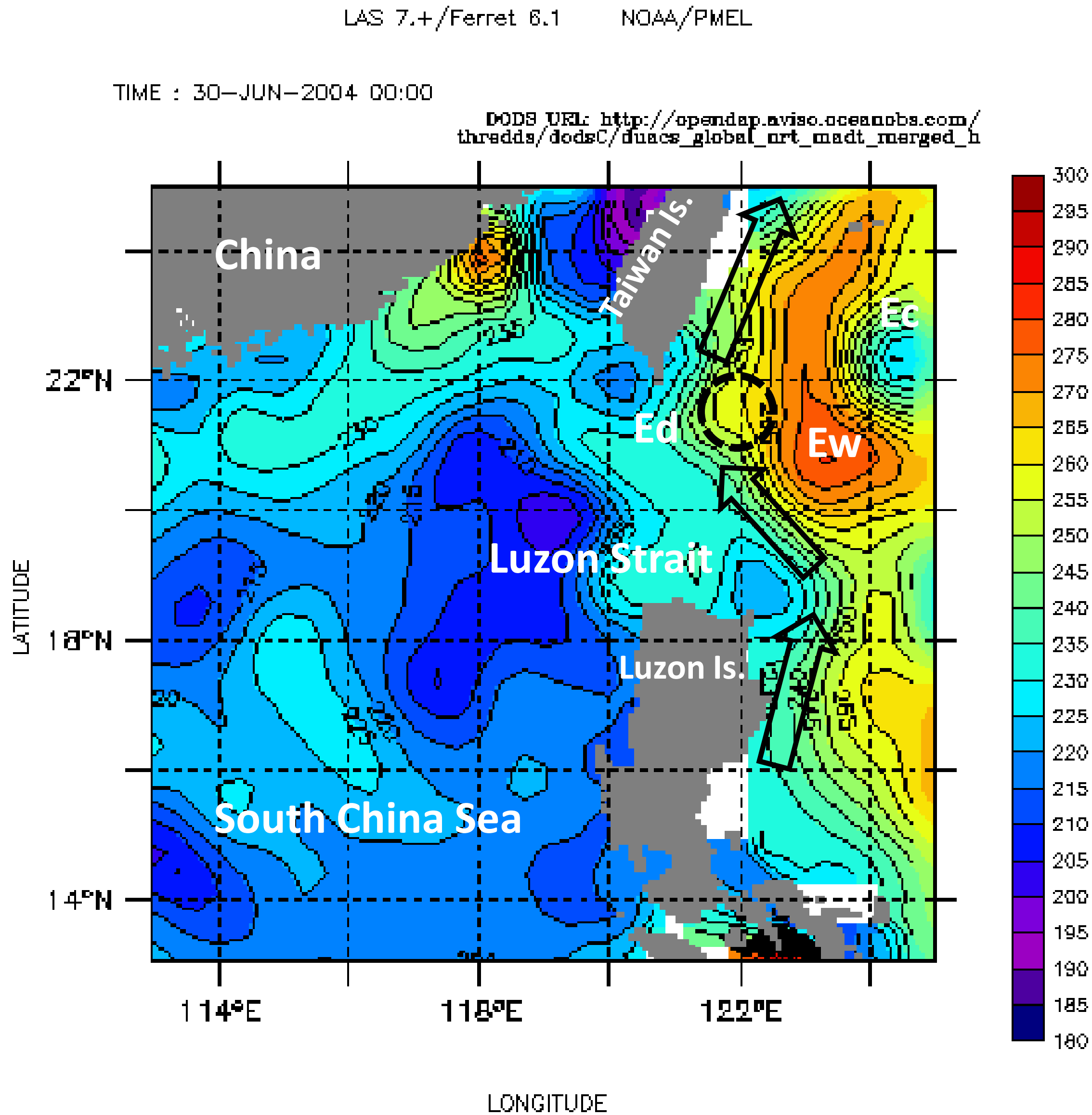


msla-qd-20040602
35°N
30°N
25°N
20°N
15°N
10°N
110°E
115°E
120°E
125°E
130°E
135°E
30
20
10
0
-10
-20
-30

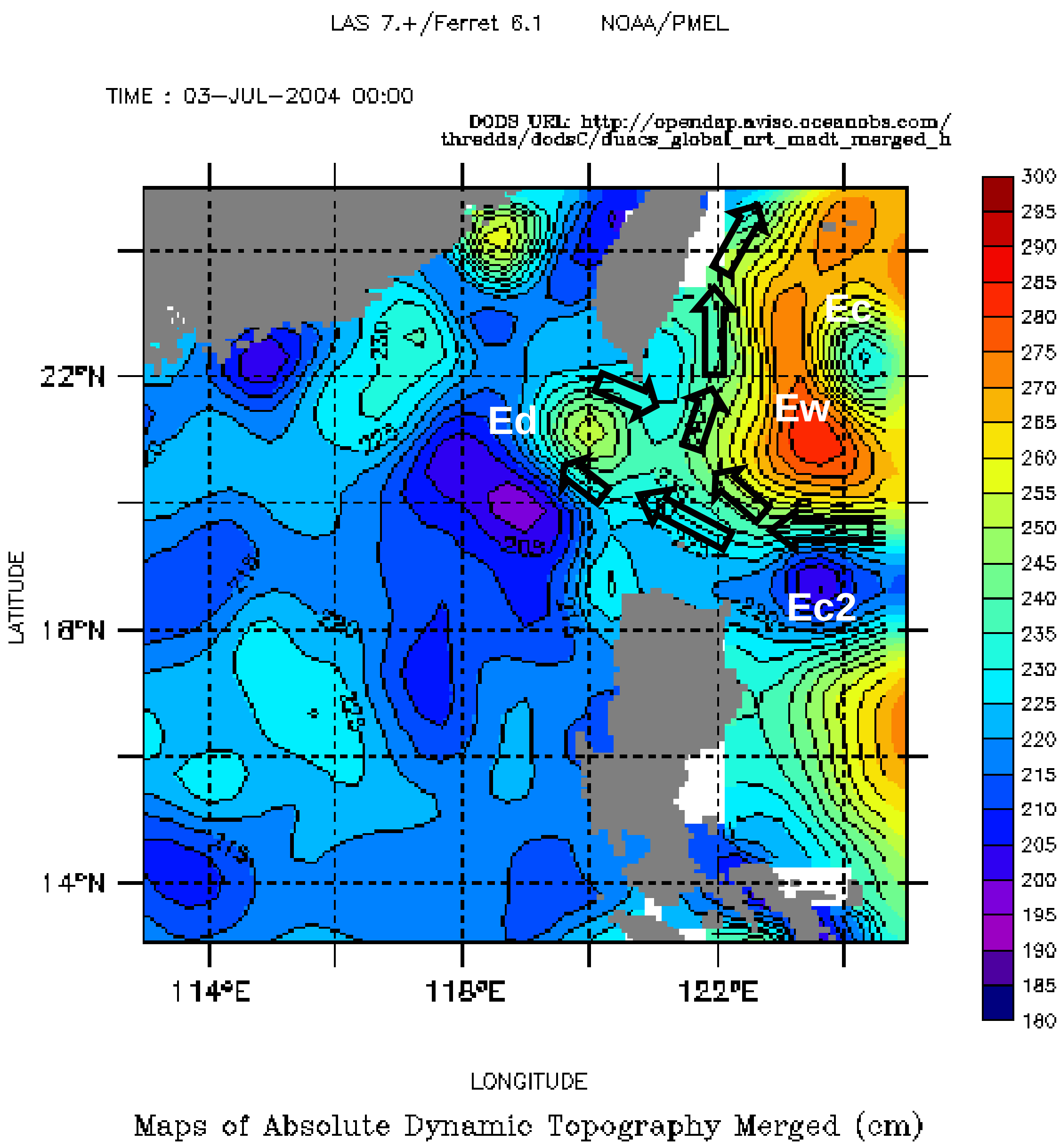
A case of eddy penetration through Luzon Strait



Maps of Absolute Dynamic Topography Merged (cm)



Maps of Absolute Dynamic Topography Merged (cm)


LAS 7.+/Ferret 6.1 NOAA/PMEL
TIME : 03-JUL-2004 00:00
DODS URL: http://opendap.aviso.oceanobs.com/thredds/dodsC/duacs_global_nrt_madt_merged_h
Ec
Ew
Ed
Ec2
22°N
18°N
14°N
LATITUDE
114°E
118°E
122°E
LONGITUDE
300
295
290
285
280
275
270
265
260
255
250
245
240
235
230
225
220
215
210
205
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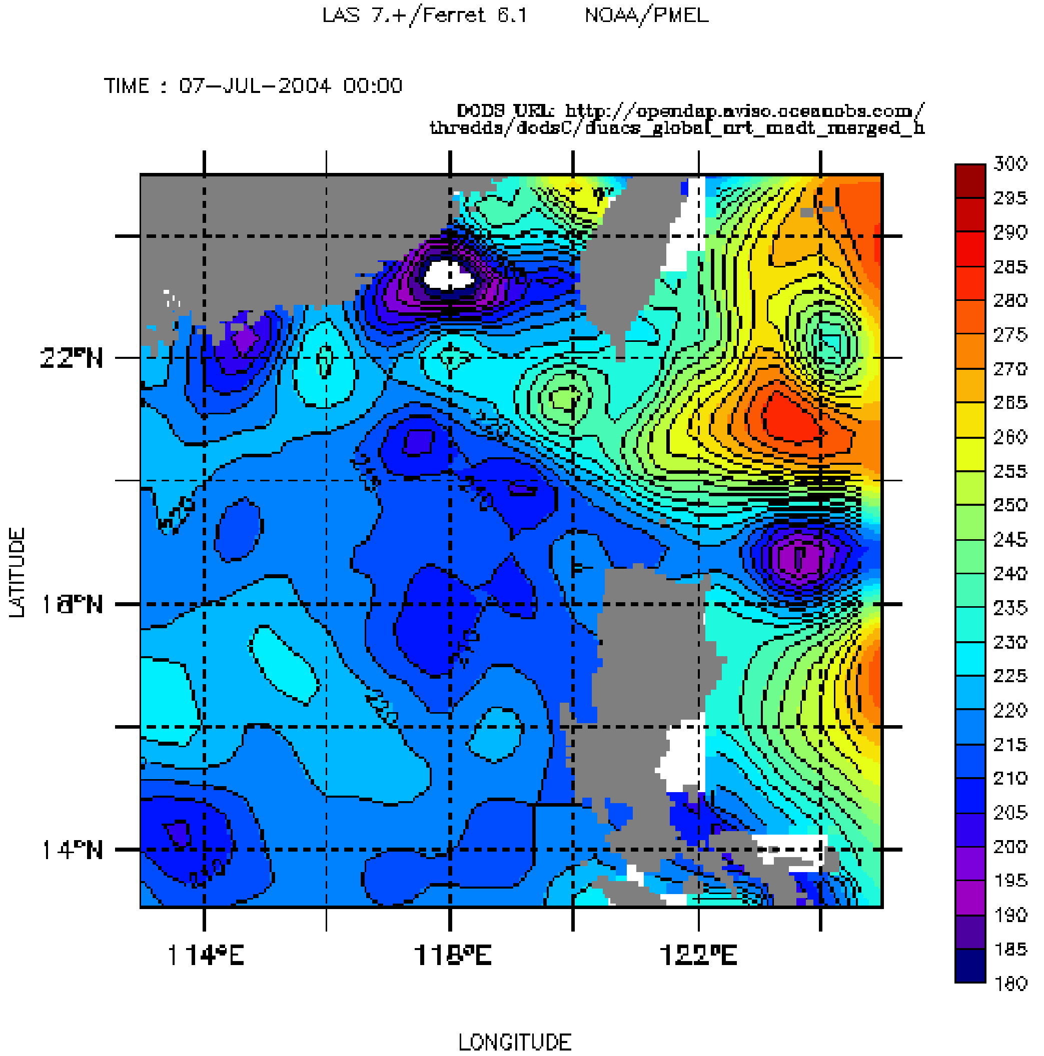
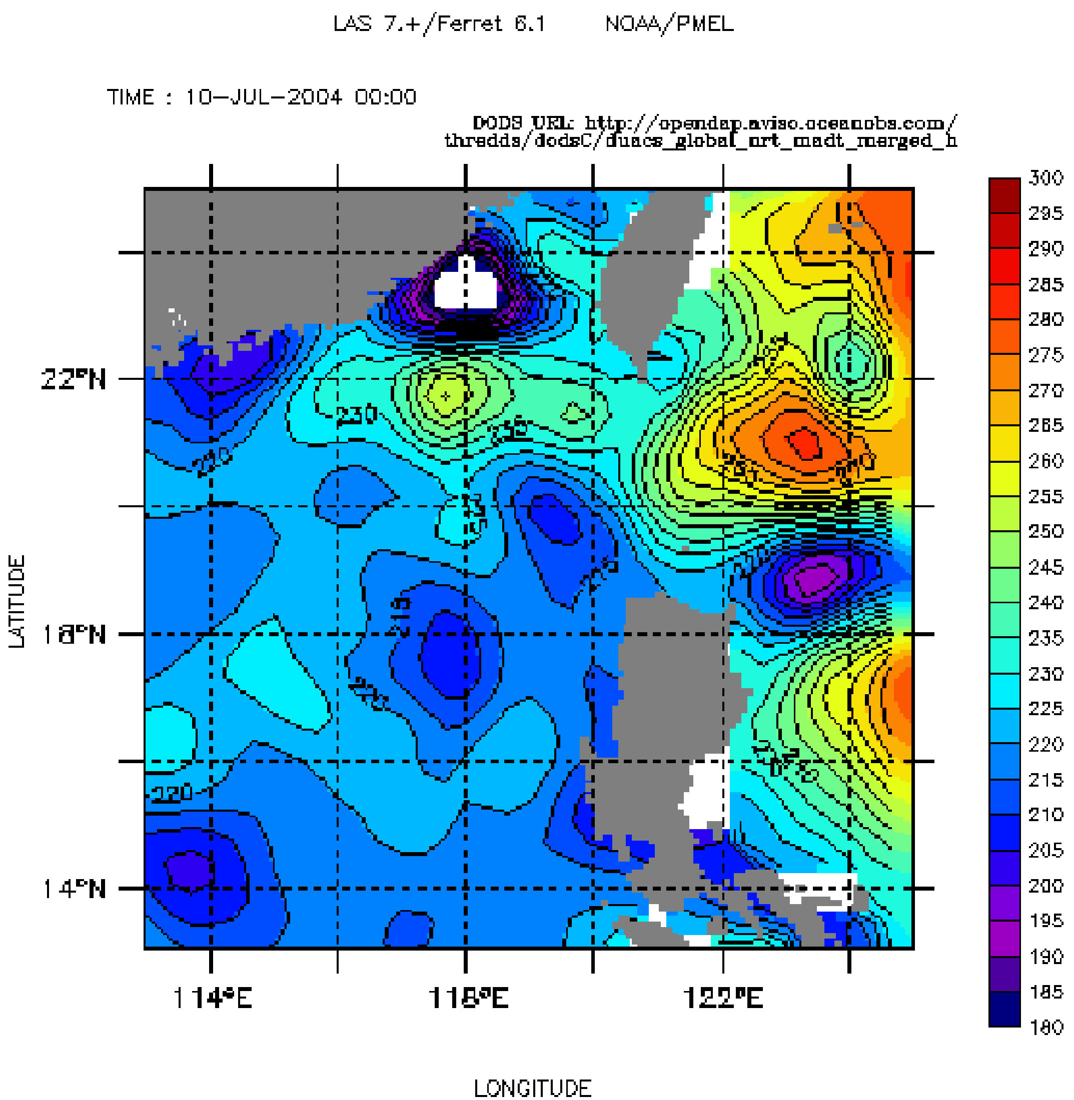
195
190
185
180
Maps of Absolute Dynamic Topography Merged (cm)

A case of eddy penetration through Luzon Strait



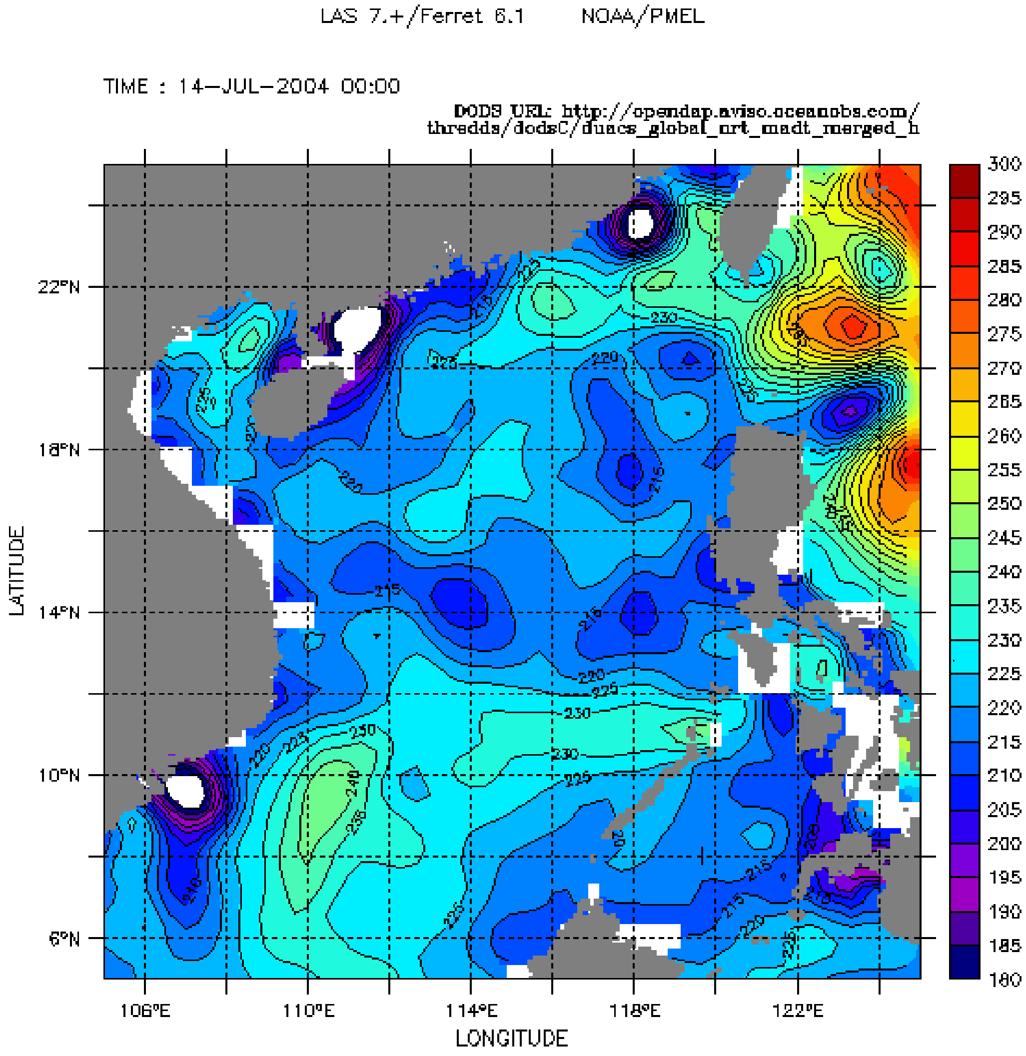
Maps of Absolute Dynamic Topography Merged (cm)

A case of eddy penetration through Luzon Strait



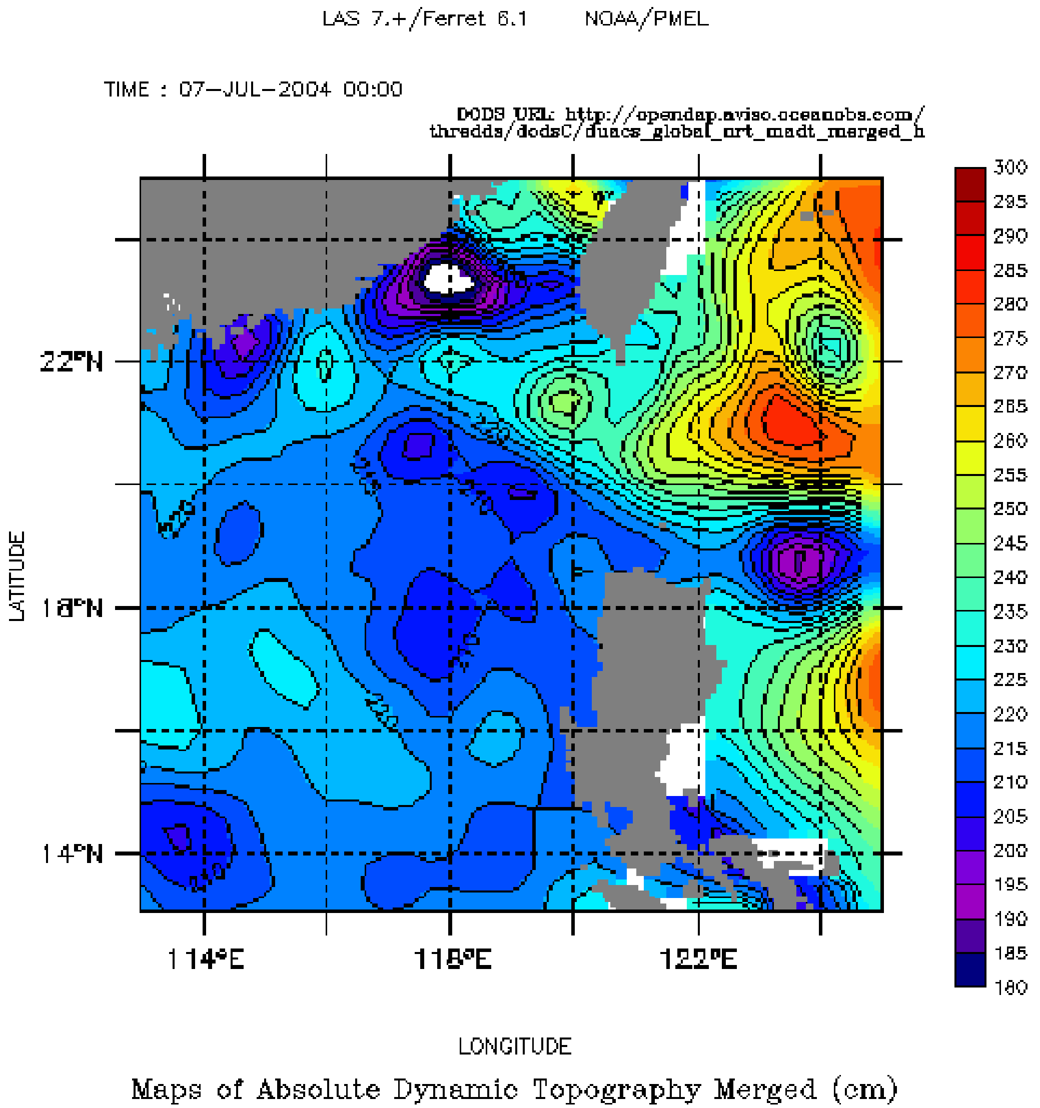
Maps of Absolute Dynamic Topography Merged (cm)

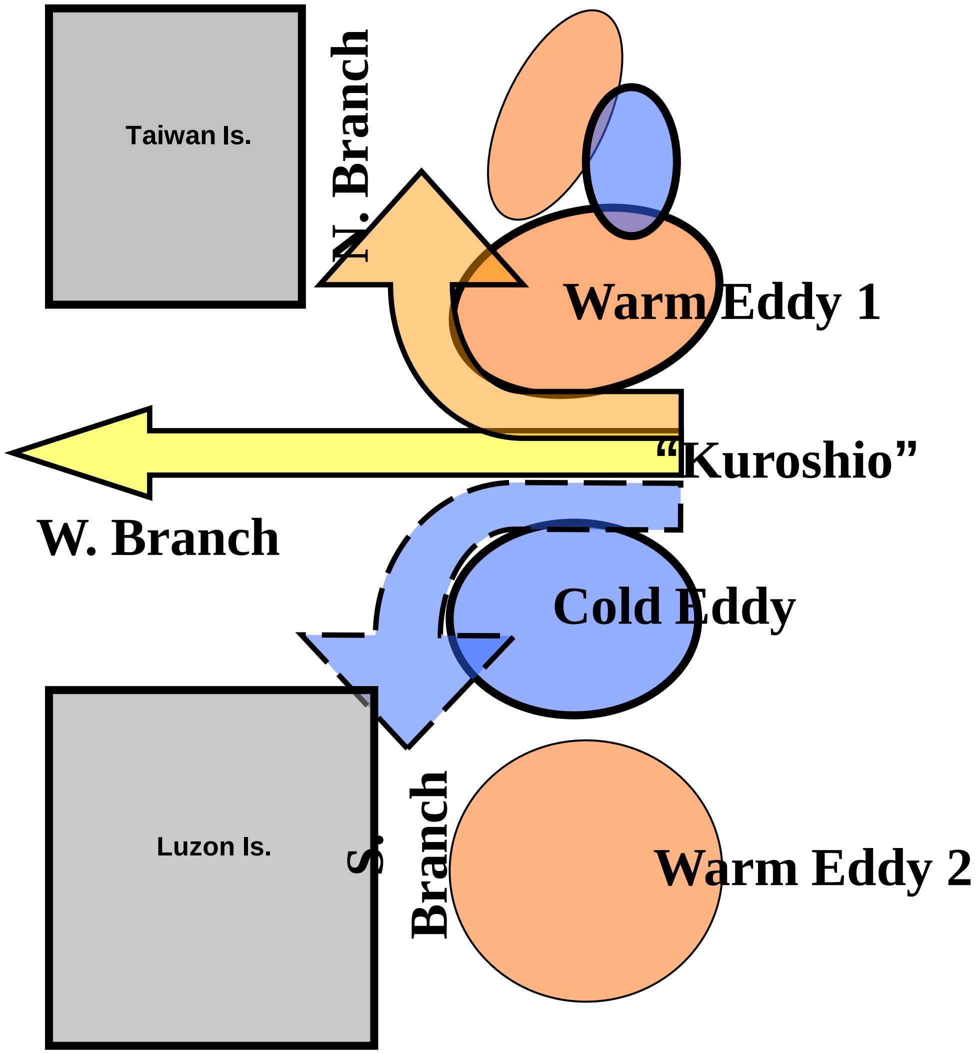
A case of eddy penetration through Luzon Strait



Maps of Absolute Dynamic Topography Merged (cm)

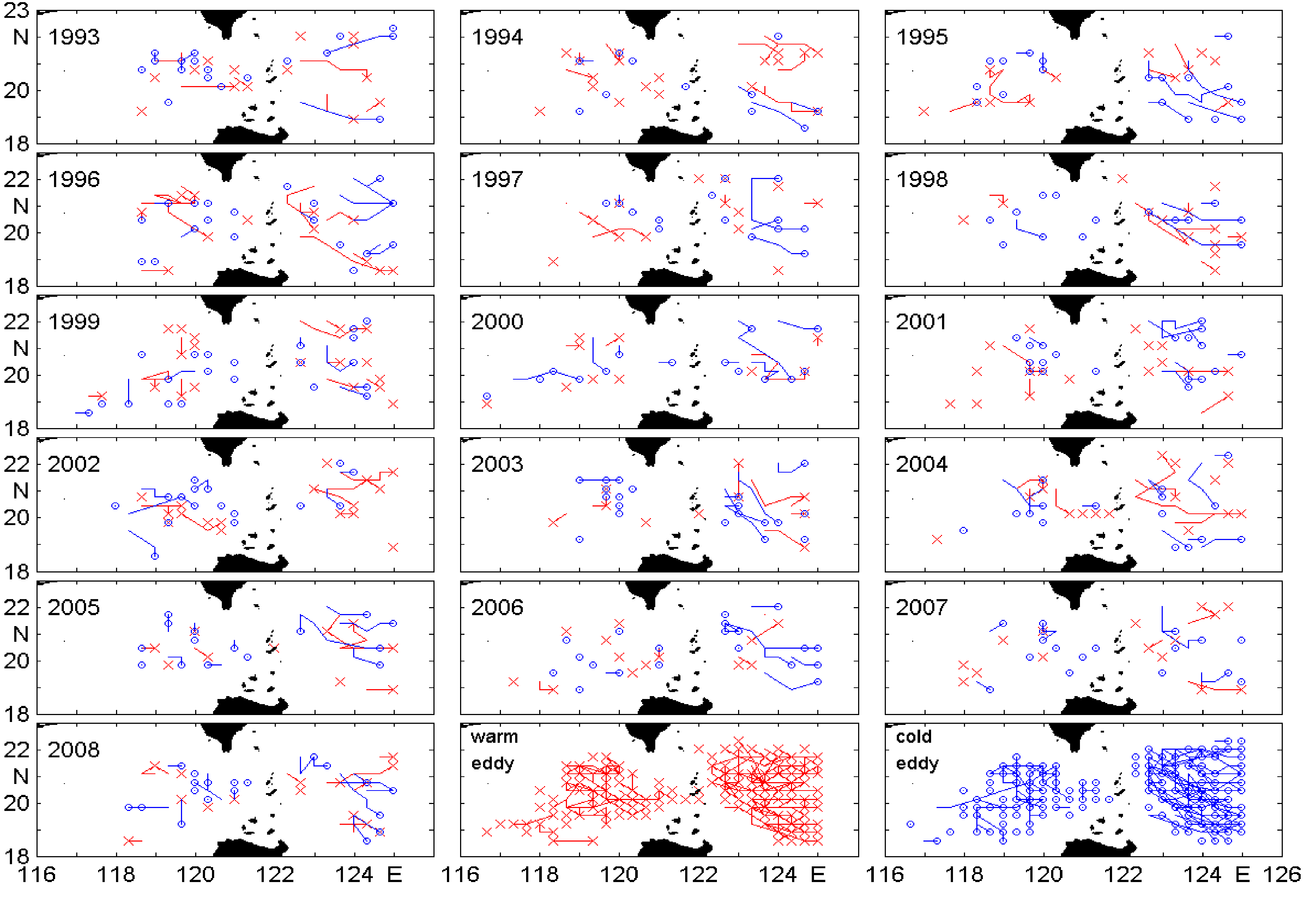
Kuroshio bifurcation



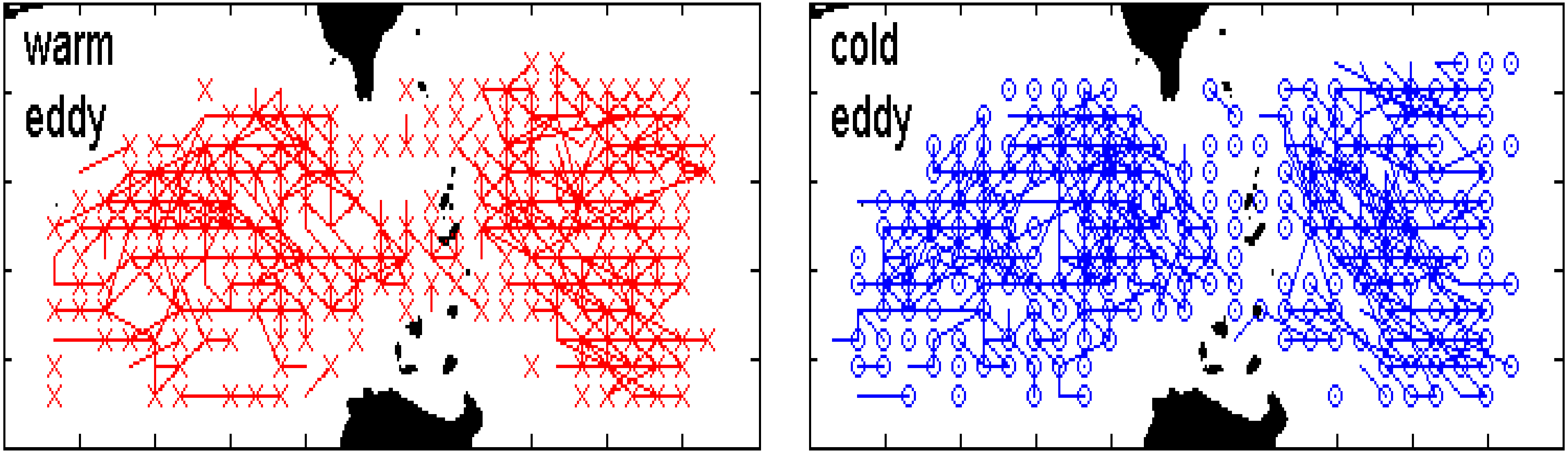


Taiwan Is.
N. Branch
Warm Eddy 1
"Kuroshio"
W. Branch
Cold Eddy
Luzon Is.
S. Branch
Warm Eddy 2

Yearly distribution of eddies near LS

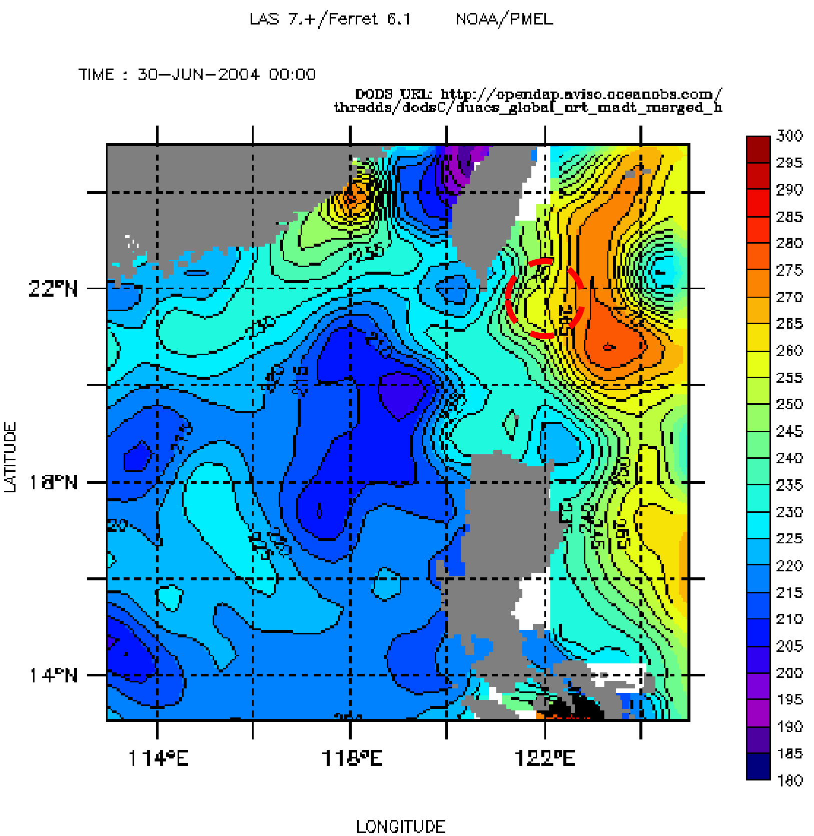


Possible mechanism for low SLA belt across LS

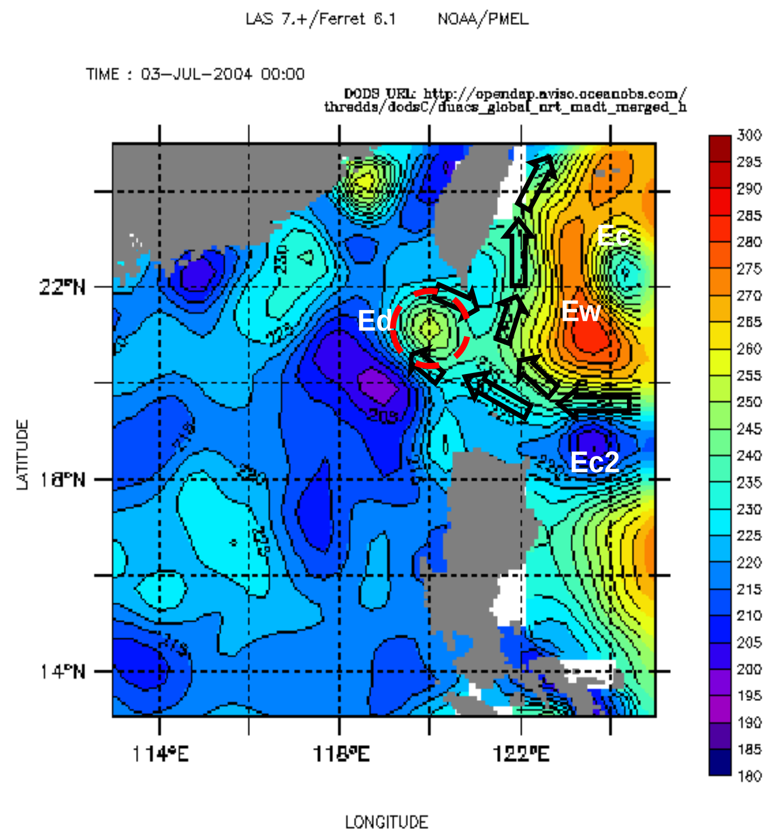


1993-2008

June 30	July 3	July 7	July 10
WP	WP-SCS	SCS	SCS
-0.099	-0.669	-0.071	-0.082 m/s

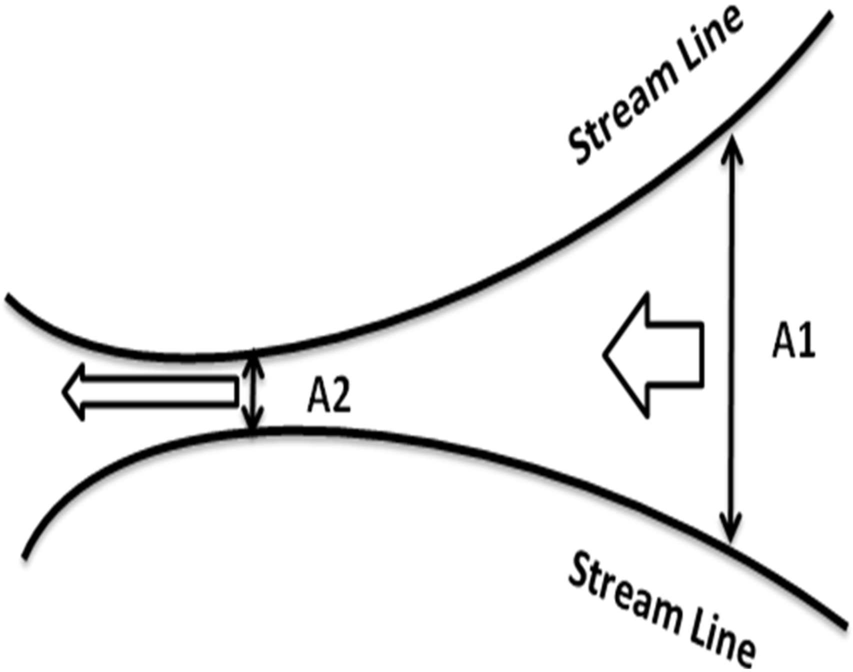


Maps of Absolute Dynamic Topography Merged (cm)



Maps of Absolute Dynamic Topography Merged (cm)

An escape orifice model



$$u_2 = \frac{A_1 u_1}{A_2}.$$

Implications of our preliminary results

- **Impacts of non-linear Rossby eddies on the circulation in LS and SCS should be considered in dynamic analysis and modeling.**
- **The stability of Kuroshio east of LS should be reconsidered.**

Acknowledgement

- **This research is supported by NOAA NESDIS through ORS Program 05-01-11-000 (without 2010 funding delivered).**

Thanks!