Roles of the in-situ observations in the detection of the Kuroshio frontal variability south of Japan

JAMSTEC
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Incorporated Administrative Agency
Fisheries Research Agency

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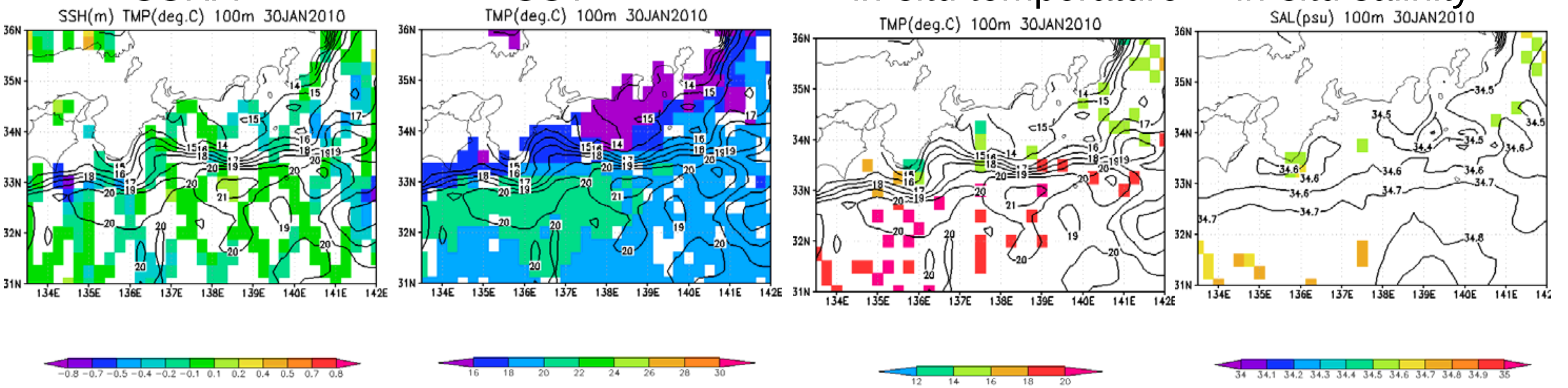
SSHA SST in-situ temperature in-situ salinity



The satellite data significantly contribute to the operational ocean forecasting .

But roles of the in-situ temperature and salinity profiles are still unclear.

We demonstrate that the assimilation of the in-situ data effectively capture the Kuroshio frontal variability south of Japan.

Introduction

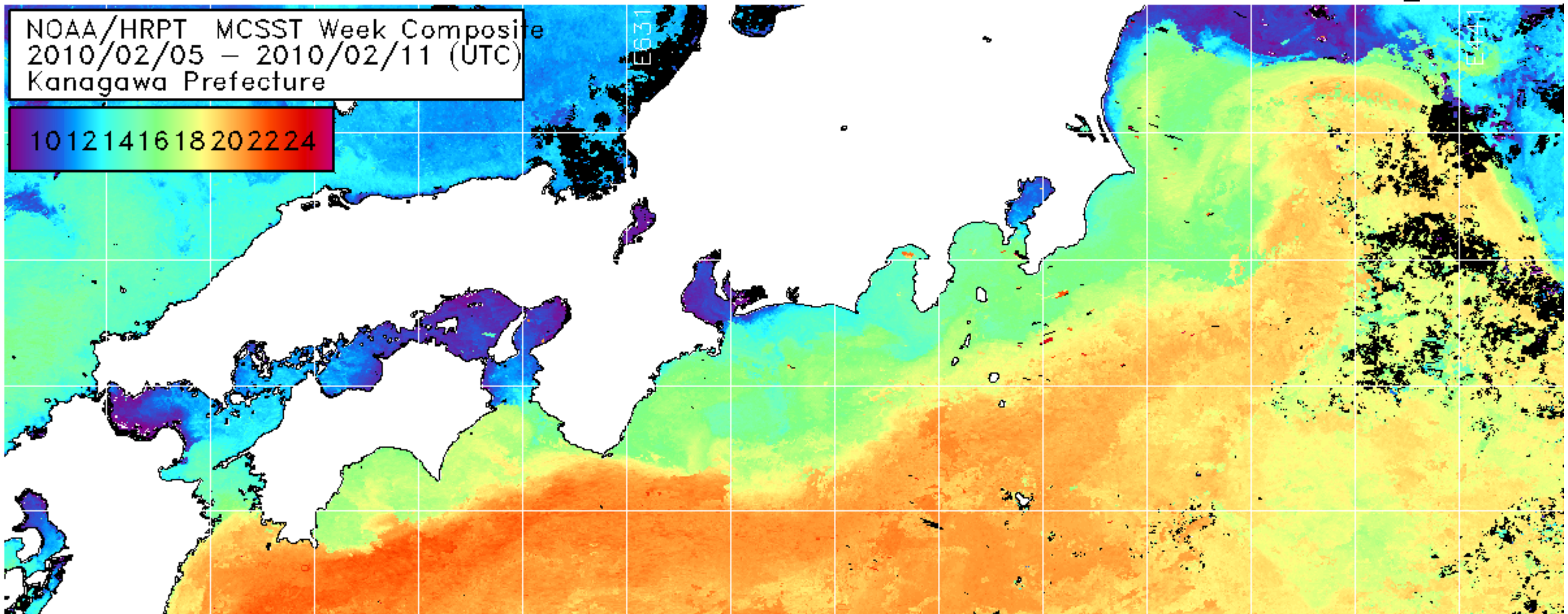
We have recently created new high-resolution reanalysis data, FRA-JCOPE2, for the period from January 1993 to December 2009, 17 years.

The new reanalysis has assimilated huge amount of the in-situ data around Japan, where the dense in-situ observation network has been maintained for past a few decades through the great efforts of fishery research agencies of Japan.

To clarify roles of the dense coastal in-situ observation network, we examined the sensitivity of the in-situ data to the quality of the reanalysis data.

We focus on the Kuroshio frontal disturbances south of Japan and the relevant warm water intrusions into the coastal areas.

Kuroshio front south of Japan



The Kuroshio front is formed between the Kuroshio warm water and the cold water near the coasts south of Japan.

The Kuroshio front is very active .

The wavelike disturbances propagating along there significantly affect the coastal regions through the Kuroshio warm water intrusions

[*Kimura and Sugimoto*, 1993; *Kasai et al.*, 1993].

FRA-JCOPE2 Reanalysis

Period:
1 January 1993 to 31 December 2009 (17 years)

Range:
10.5N-62N, 108-180E (Northwestern Pacific)

Resolution:
1/12 degree, 46 vertical levels, daily-mean

Model:
Princeton Ocean Model for Generalized coordinate of sigma (Miyazawa et al., 2009)

Forcing:
Wind stress and heat flux: NCEP/NCAR Reanalysis Data
Relaxation to monthly climatological salinity
Monthly mean Changjiang River Discharge (Jan. 1993 - Dec. 2008)

Data assimilation:
- 3-dimentional variational assimilation using temperature-salinity coupling vertical EOF modes (3DVAR; Fujii and Kamachi, 2003)
- Incremental Analysis Update (IAU; Bloom et al., 1996)

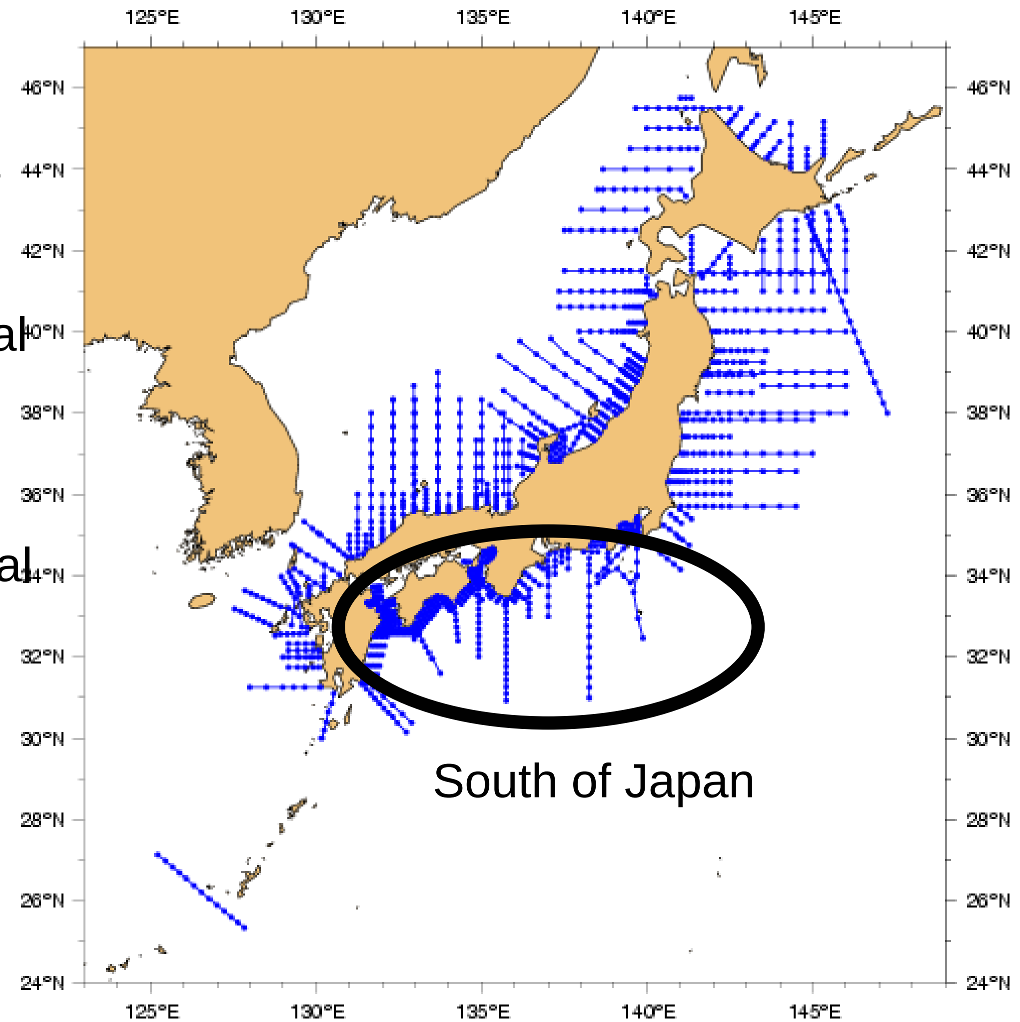
Data:
- Sea Surface height Anomaly (TOPEX/Poseidon, Jason-1,2, Geosat Follow-On, Envisat, ERS-1,2)
- Sea Surface Temperature (NOA A AVHRR MCSST)
- In-situ temperature and salinity profiles (GTSPP, WOD05, FRA-DATA)

FRA-DATA (at least once a month)

The coverage of in-situ hydrographic observation around the Japanese coasts has been very active and dense over past a few decades.

However, more than half of data on coastal repeated hydrographic observation lines conducted by local fisheries research agencies (hereafter referred as FRA-DATA) has not been included in the typical data archives (WOD/GTSPP).

We have created the new reanalysis data that assimilated all FRA-DATA for the period from 1993 to 2009.

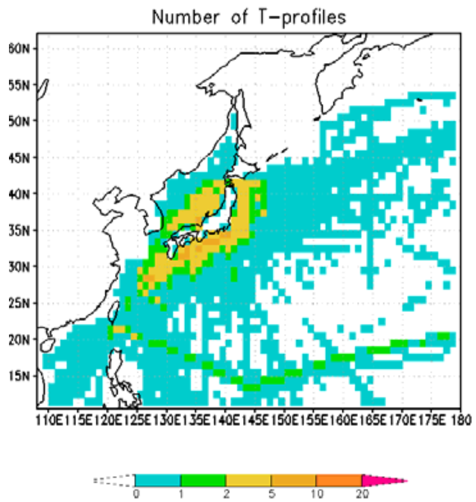


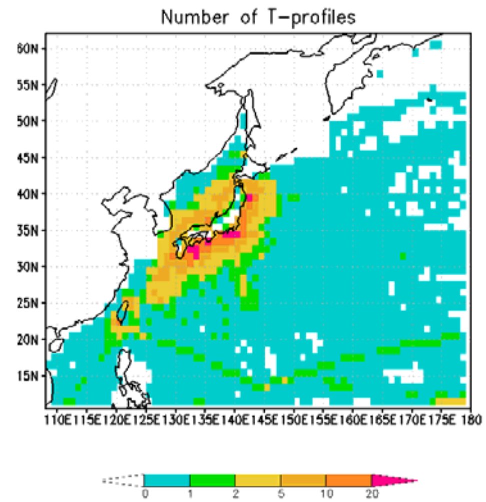
Sensitivity experiments: 1993-1999

'JCOPE2'
assimilated the data from only GTSPP

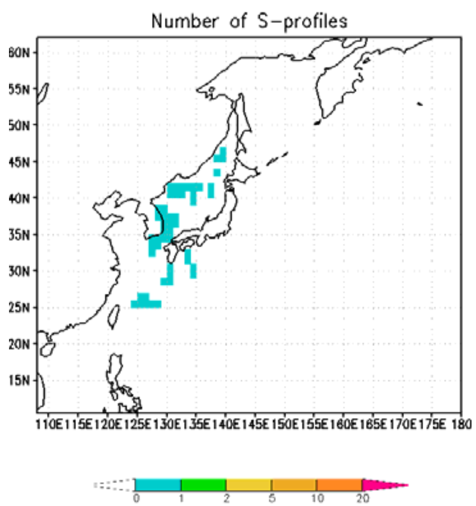
'FRA-JCOPE2'
assimilated the data from
GTSPP, WOD05, FRA-DATA

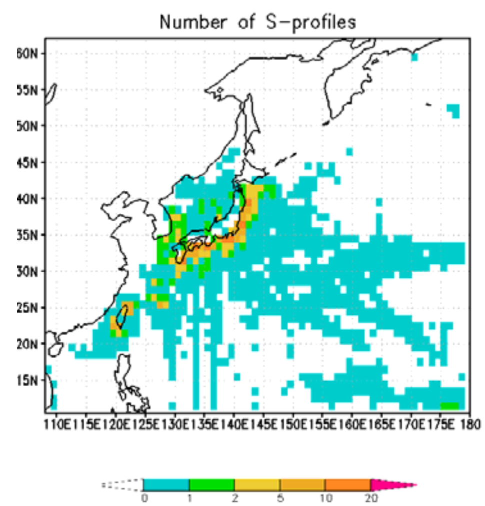
T





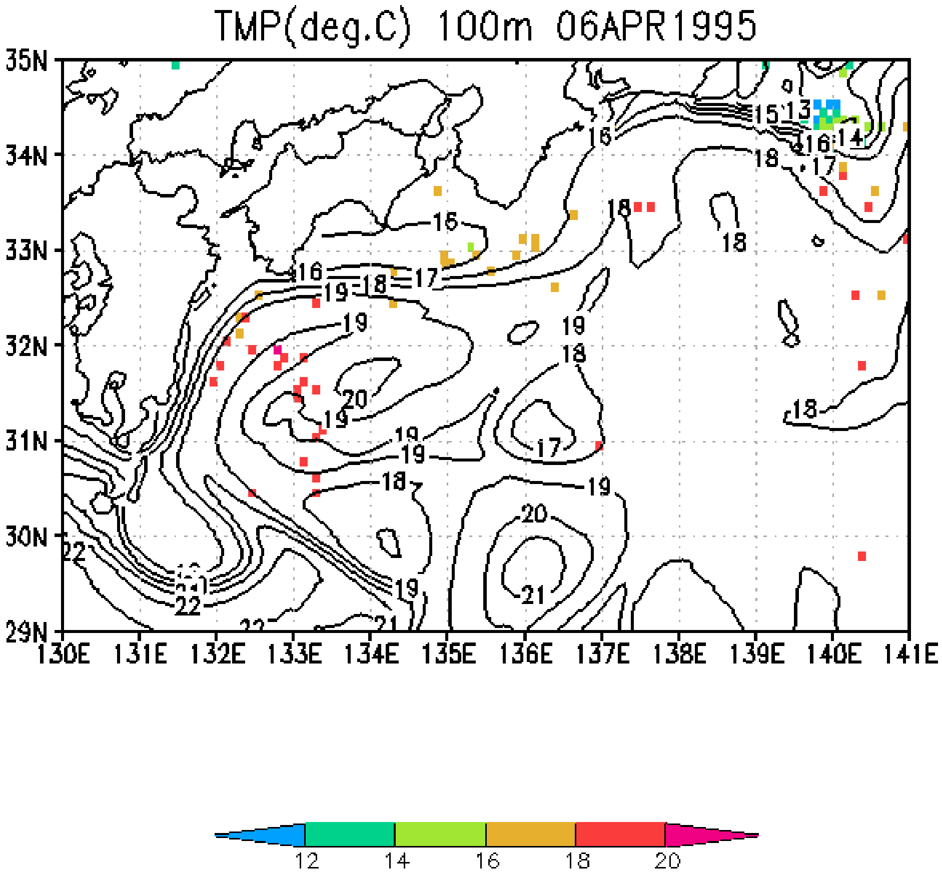
S



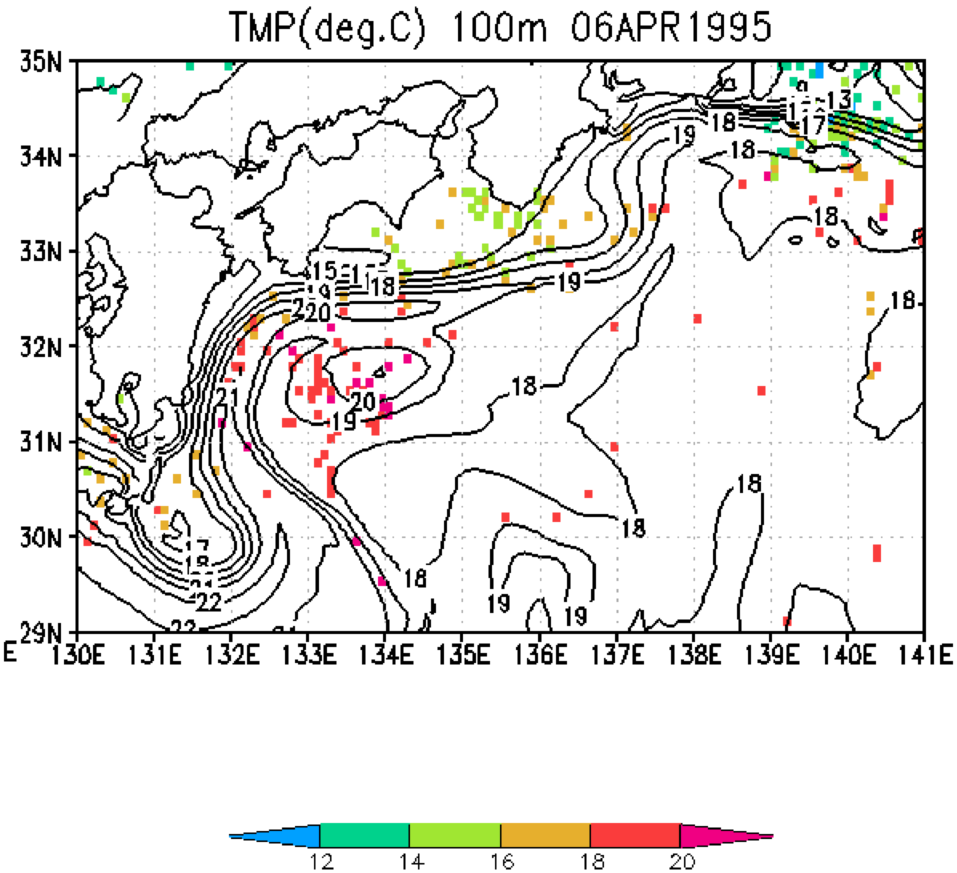


Comparison of snapshots

‘JCOPE2’



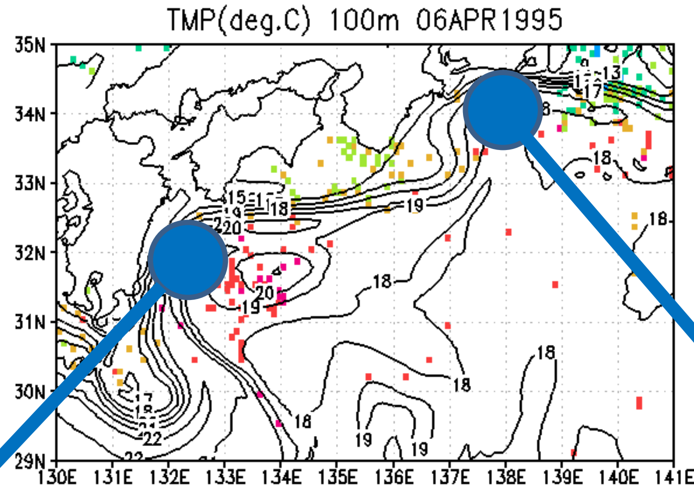
‘FRA-JCOPE2’



Inclusion of the additional in-situ data seems to intensify the horizontal temperature gradient associated with the Kuroshio front south of Japan.

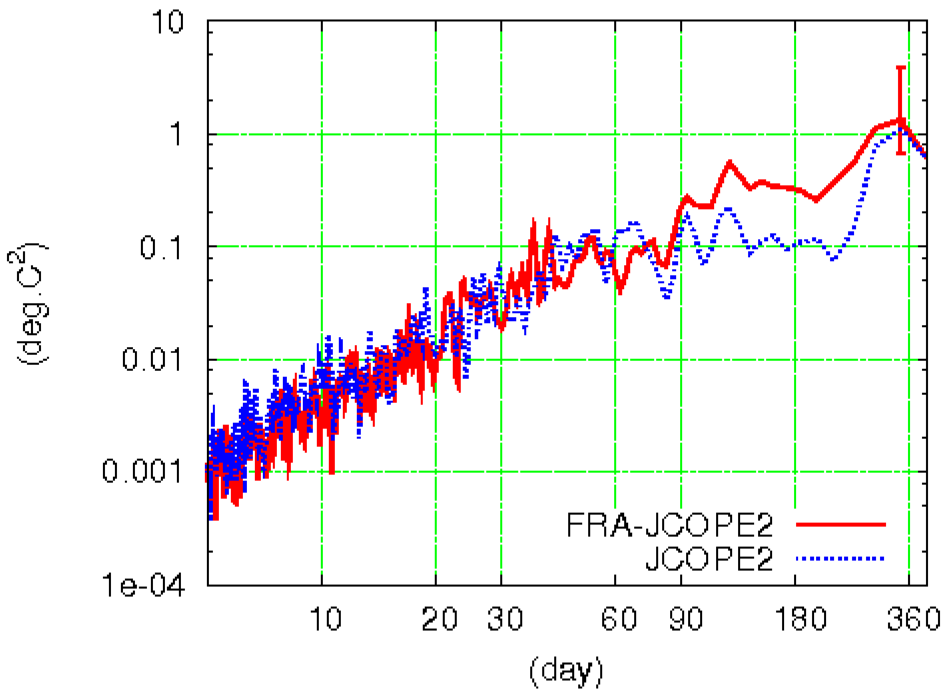
Power spectra

Around the upstream region, 100-day periodic variation was enhanced.

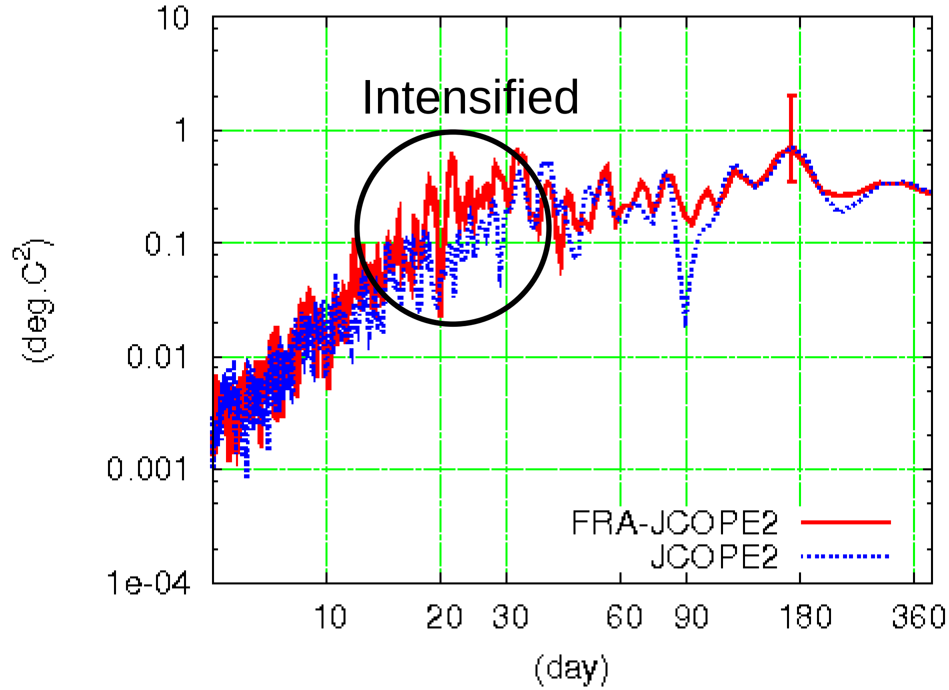


Around the downstream region, 20-day periodic variation was enhanced..

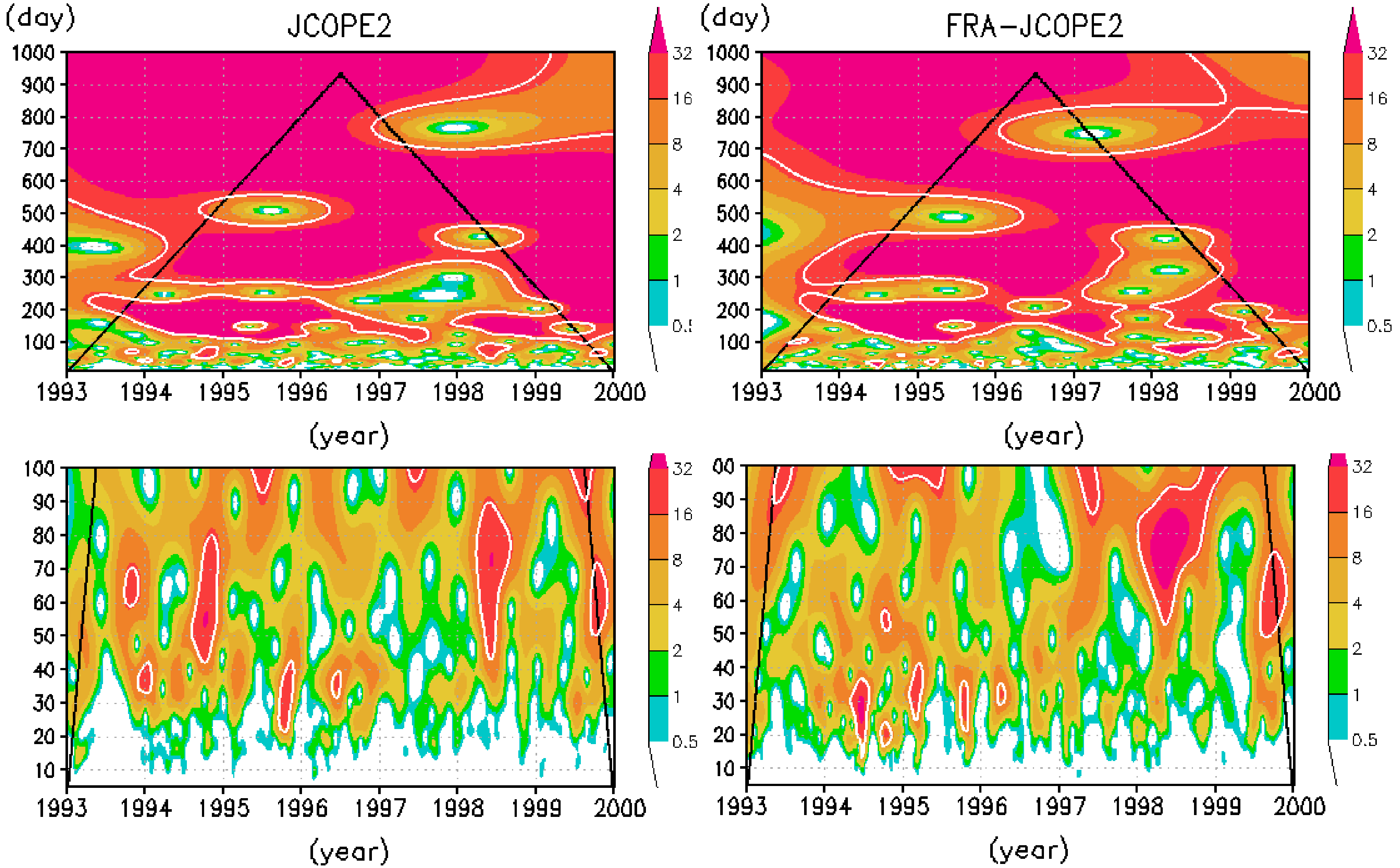
Upstream region
32N,132E,100m



Downstream region
34N,138E,100m



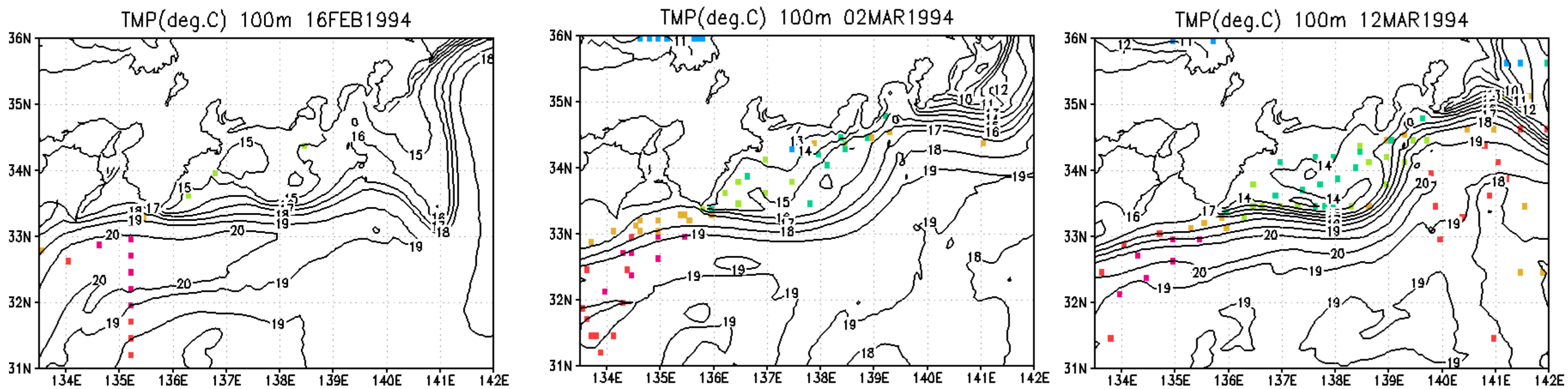
Wavelet spectra: 34N,138E,100m



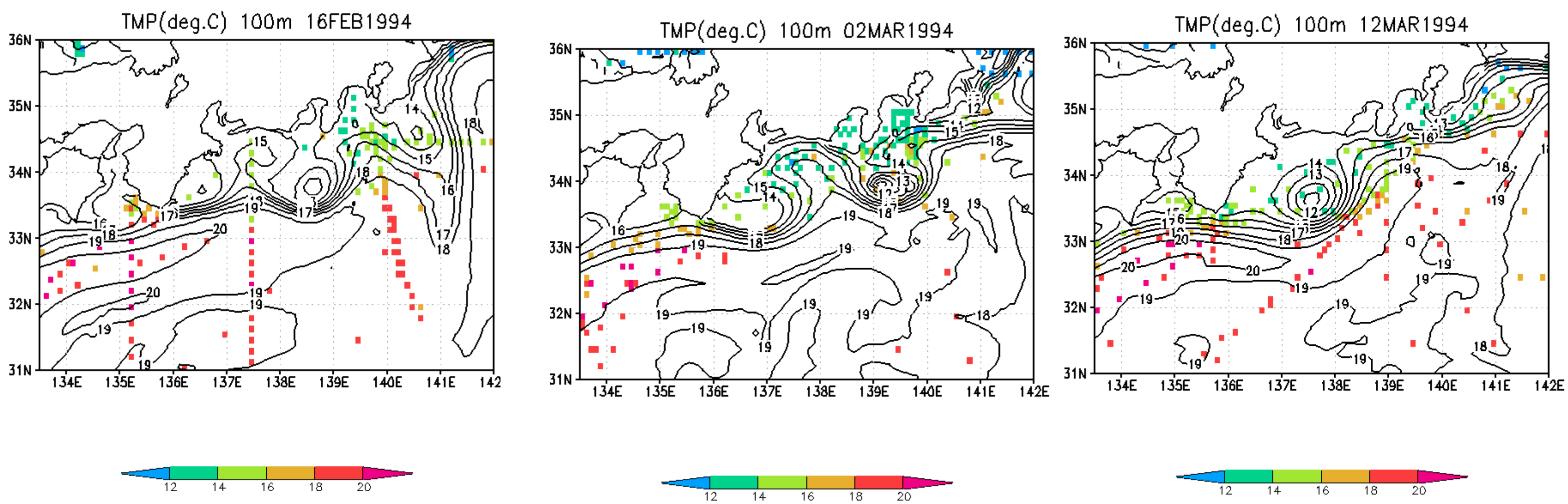
The disturbances with the period shorter than 30 days were intensified.

Comparison of snapshots

JCOPE2



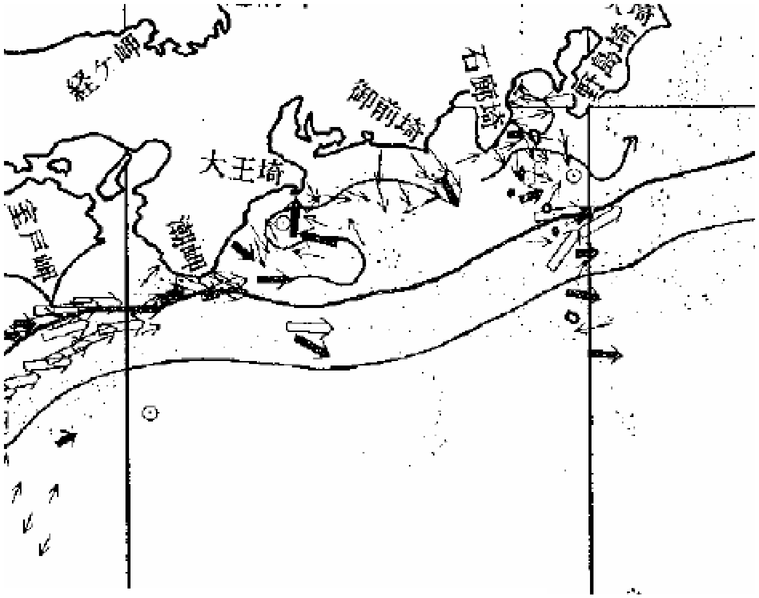
FRA-JCOPE2



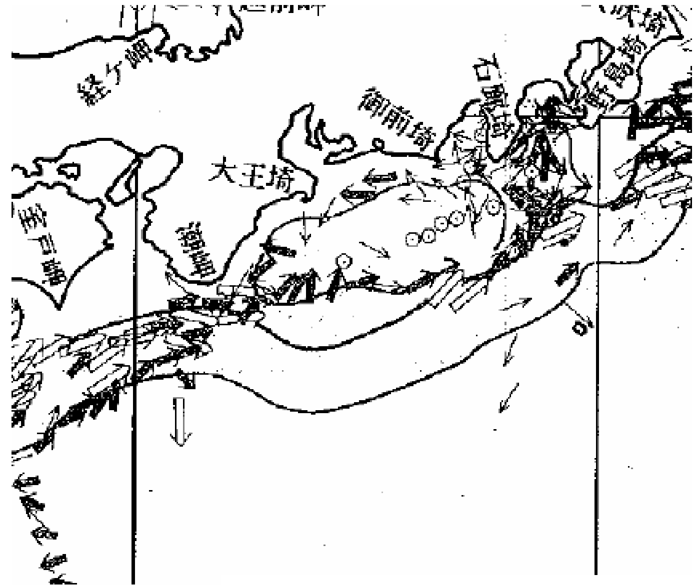
The Kuroshio frontal waves with the intrusion were enhanced in FRA-JCOPE2.

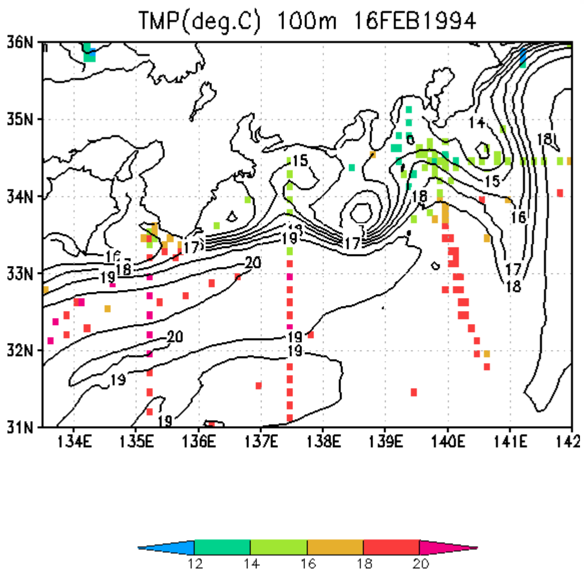
Observed frontal waves

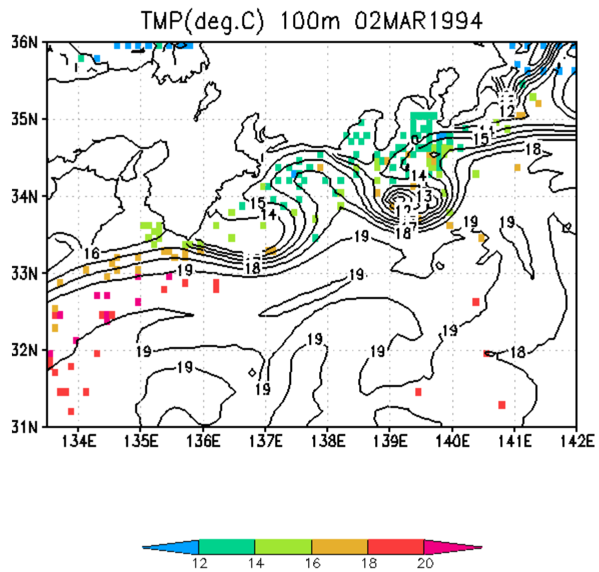
1994.02.16-1994.03.02

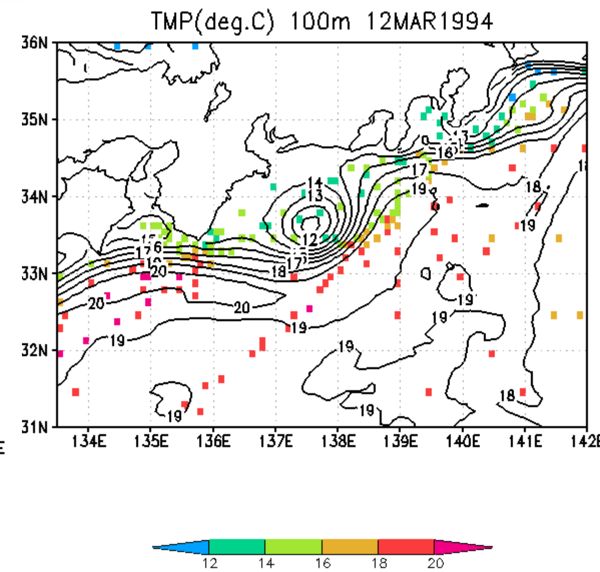


1994.03.01-1994.03.16



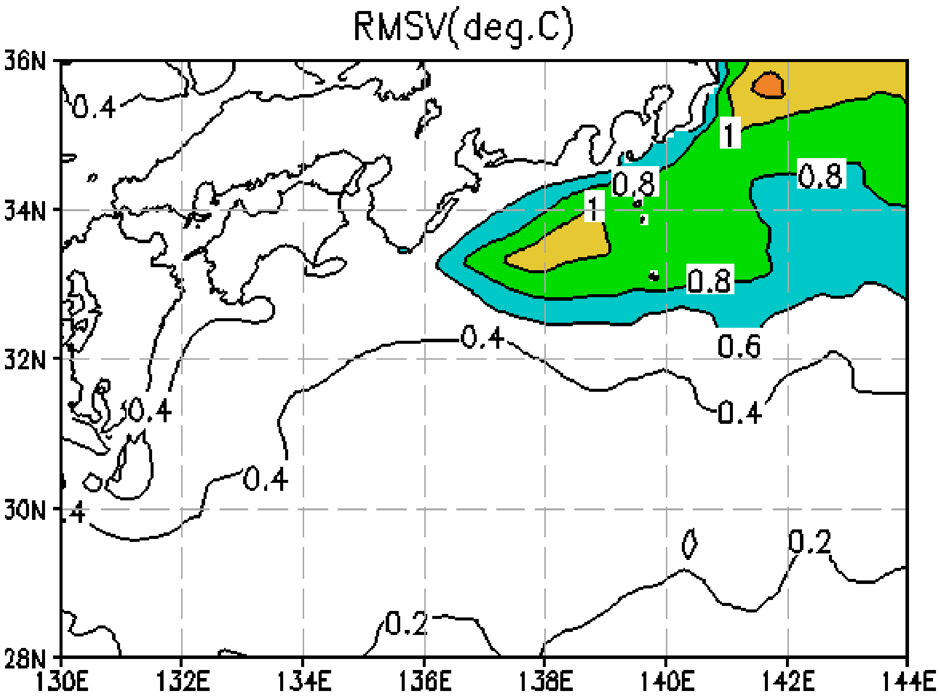




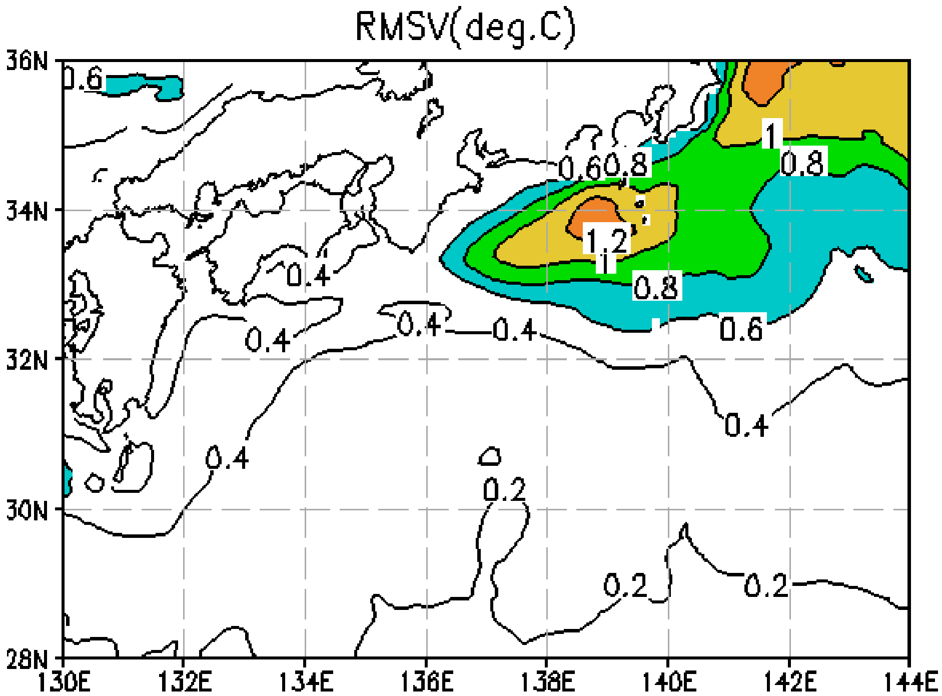


Intensity of the 20-day variation

JCOPE2



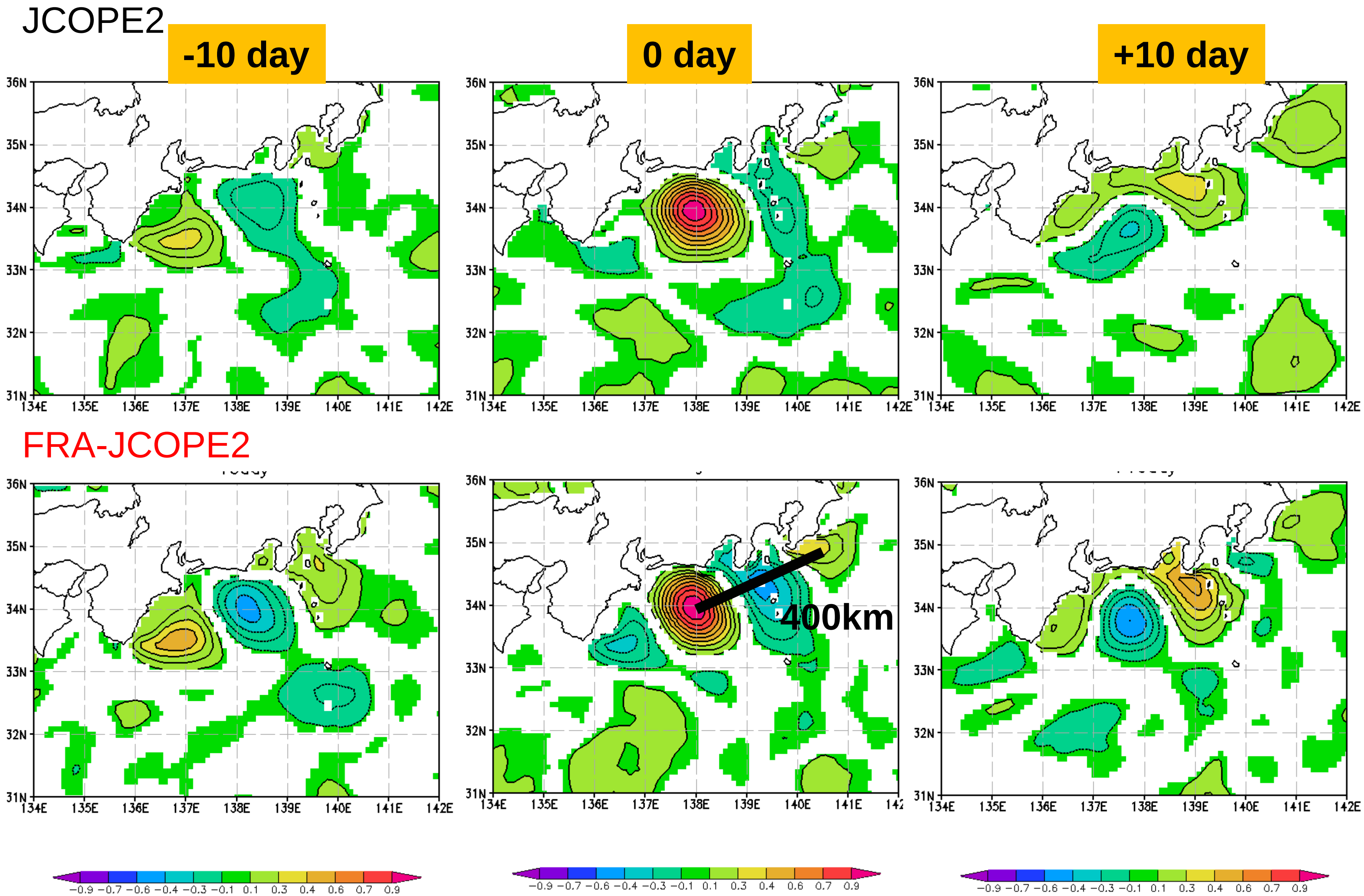
FRA-JCOPE2



RMSV of the filtered temperature time sequences at 100m. The time scale of the filter is shorter than 30 days.

The intensity of the variation was enhanced east of the Kii Peninsula.

Lag-correlation pattern analysis 34N,138E



The waves with 400km scale with the warm water intrusions were enhanced.

Summary

We have created a new version of the gridded data of temperature (**FRA-JCOPE2**), salinity, horizontal velocities, and sea surface height with horizontal resolution of 1/12 , degree using a data-assimilative ocean model.

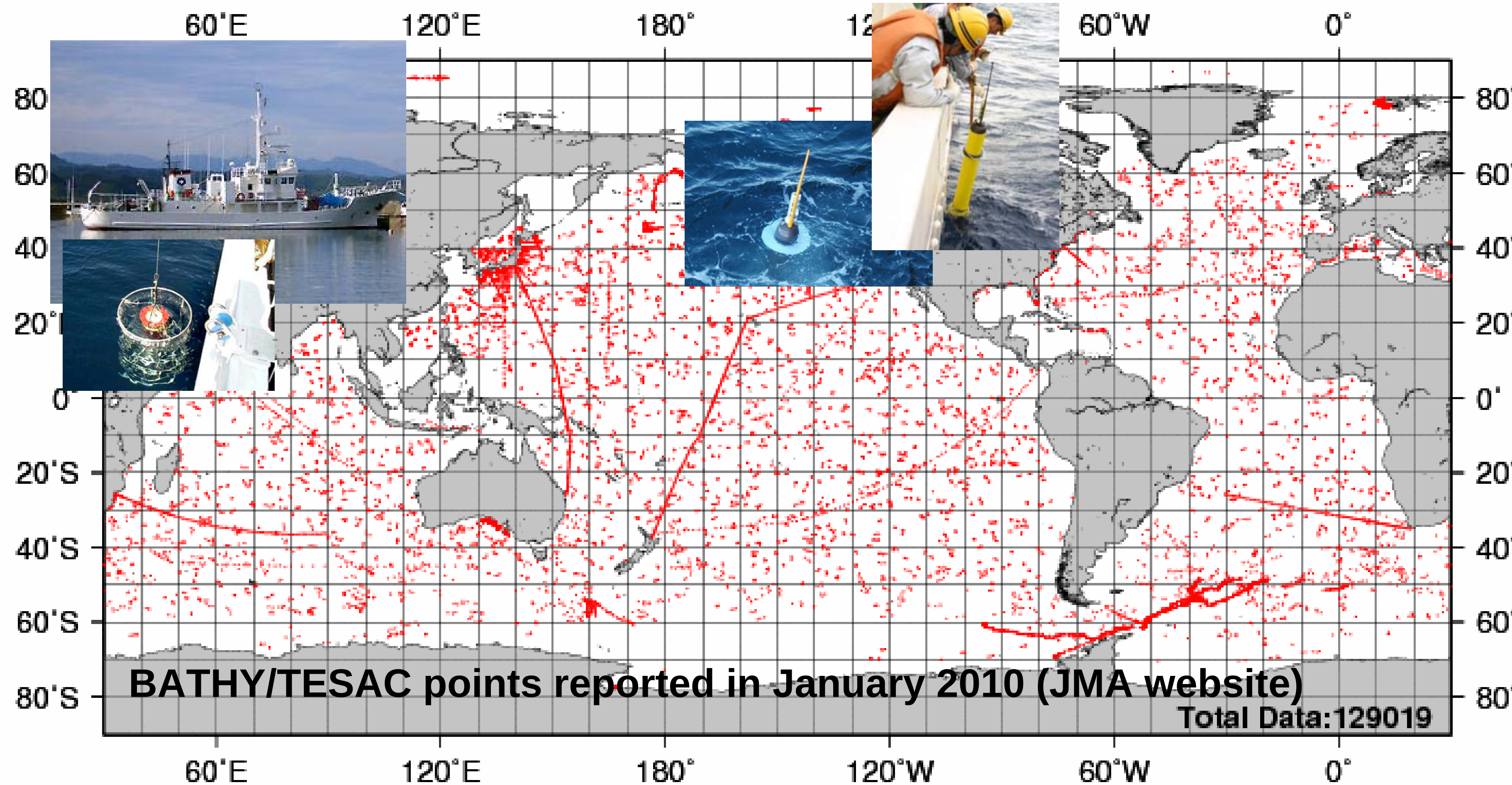
We investigated the sensitivity of including in-situ observations on the quality of the ocean reanalysis with an emphasis on the Kuroshio frontal variability south of Japan.

By increasing the number of the in-situ hydrographic profiles, more enhanced Kuroshio front variations with approximately 20 days time scale were reproduced south of Japan.

The enhanced features exhibited the wavelike disturbances east of the Kii Peninsula with the wave length of 400 km and considerably affected coastal areas through the consequent warm water intrusion.

The assimilation of operational in-situ observations in coastal regions south of Japan is effective to capture the Kuroshio frontal variability.

Global in-situ observation network



FRA-DATA have been reported to the Global Telecommunication Systems in real-time from April 2007. FRA-DATA are enhancing the real-time in-situ monitoring network around .Japan.

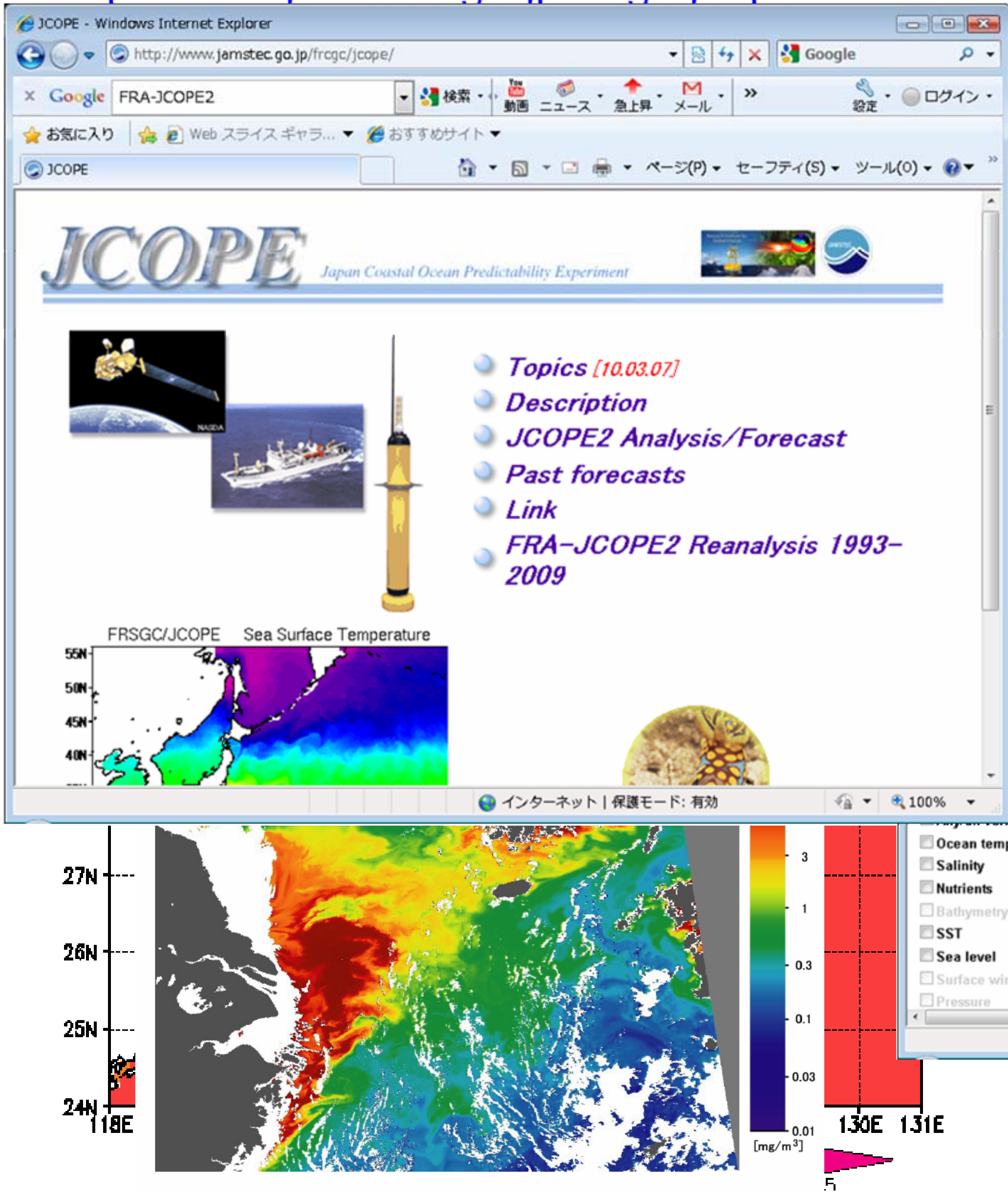
We suggest the complementally roles of in-situ observations in the nearshore regions (FRA-DATA) and in the open oceans (ARGO)

Hierarchy of Kuroshio frontal variability How predictable/observable?

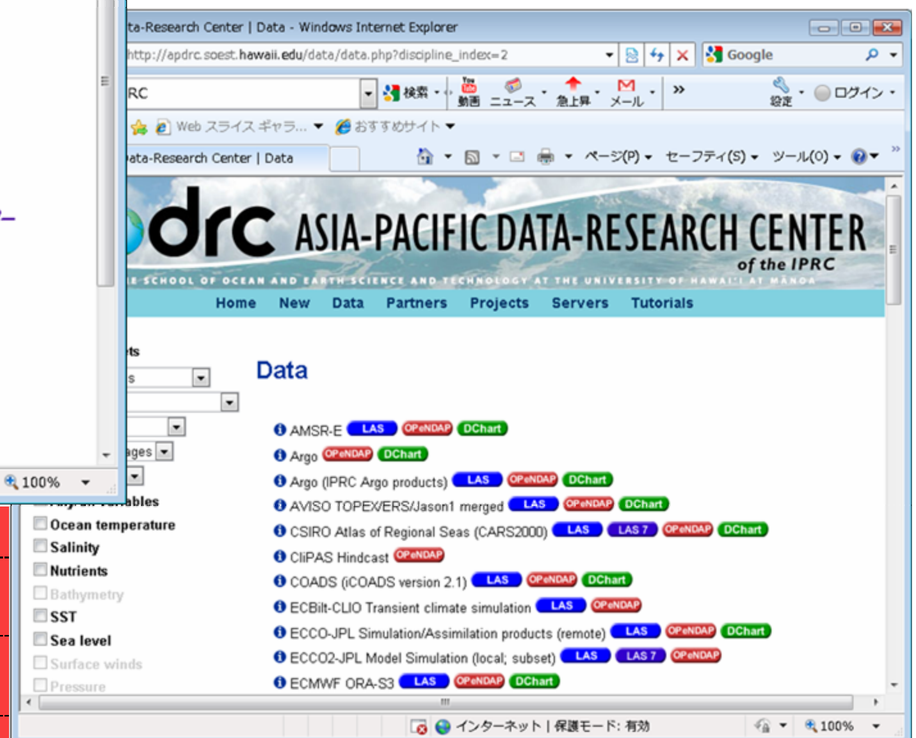
	Mesoscale (Kimura and Sugimoto, 1993)	(Kimura and Sugimoto, 1993)	(Kimura and Sugimoto, 1993)	Submesoscale (Capet et al., 2008)	…
Horizontal scale	400km	200km	100km	10km	…
Time scale	20-30 days	10 days	5 days	1 day	…
Vertical scale	~1000m	~ 1000m	~ 1000m	~ 100m	…
Dominated balance	Geostrophic	?	?	Semi-geostrophic	…
Observation	FRA-DATA	Satellite SST	Satellite SST	Satellite SST	…

FRA-JCOPE2 Reanalysis Data Set

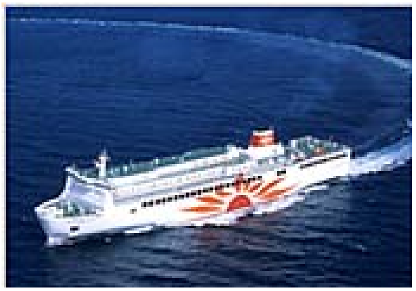
http://www.jamstec.go.jp/frcgc/jcope/

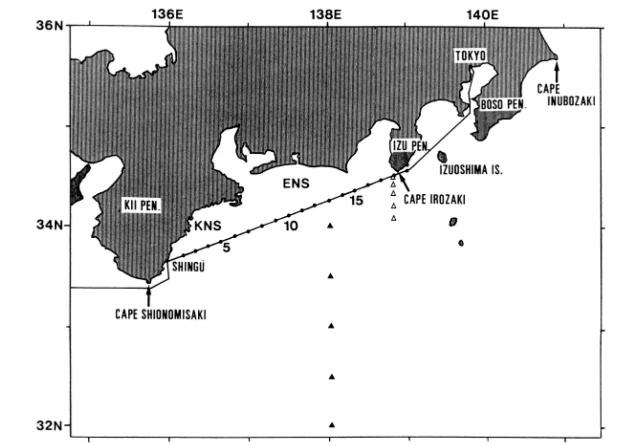


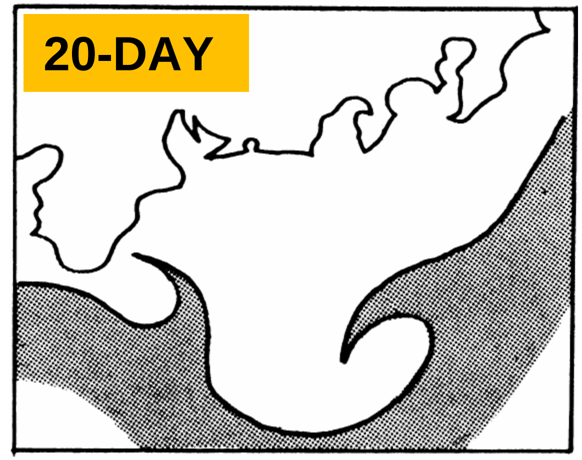
http://apdrc.soest.hawaii.edu/data/



Kuroshio warm water intrusions



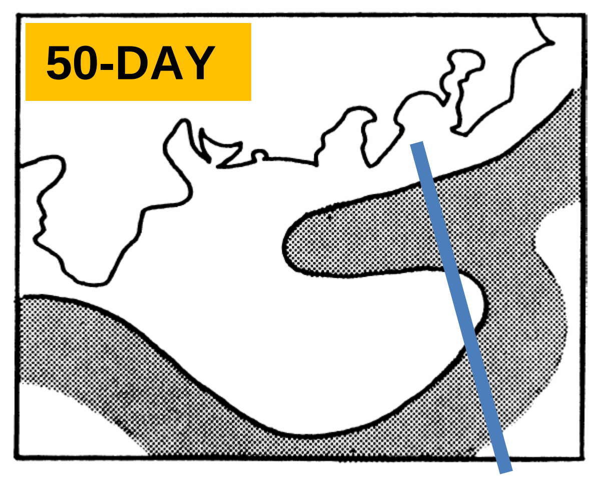




By examining the high-resolution, operational SST data obtained by the ferry ship cruises, Kasai et al. (1993) found two types of the intrusions:

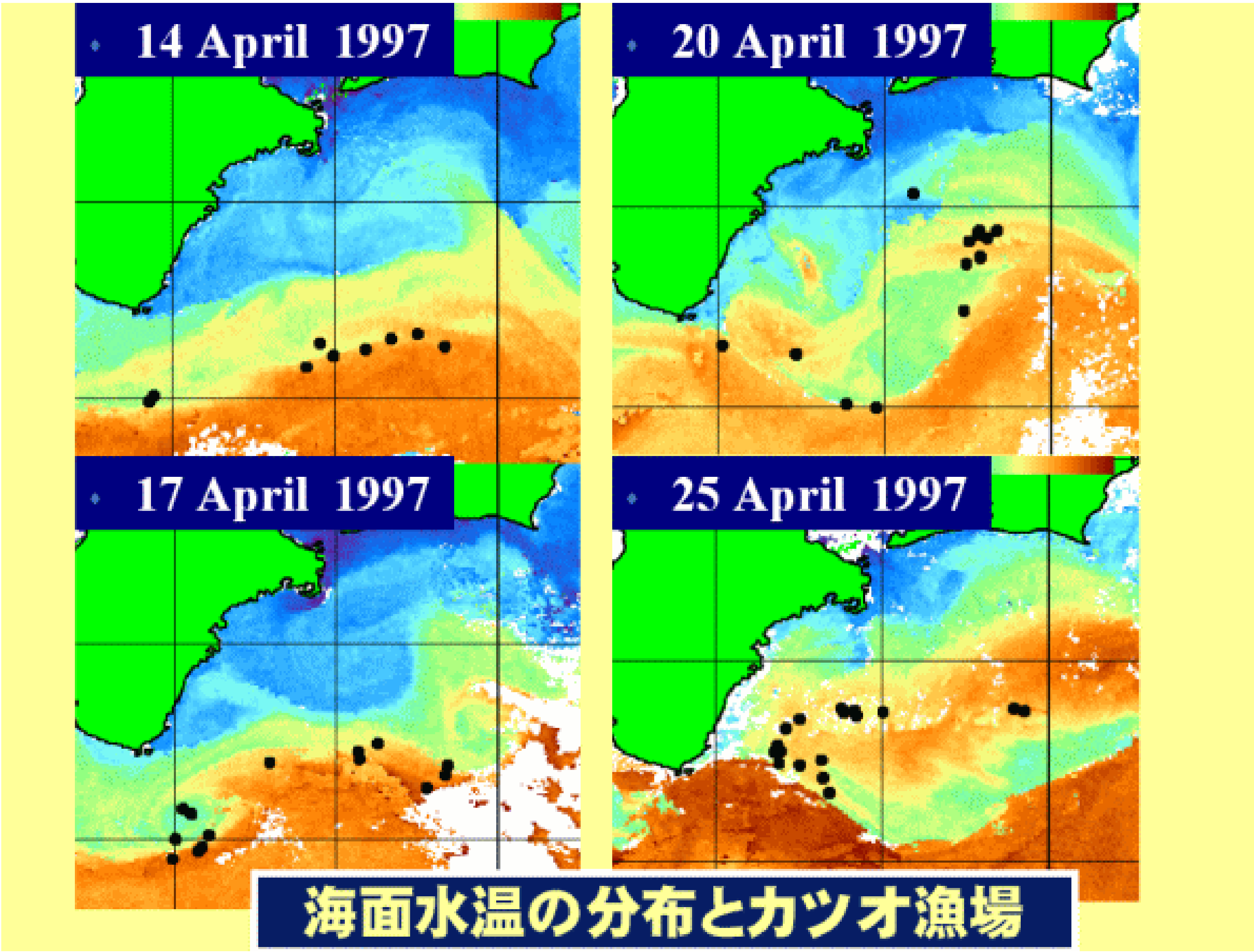
1. The intrusion associated with the Kuroshio frontal waves of 20-day period.

2. The intrusion occurring when the Kuroshio meandering path fluctuates around the Izu-Ogasawara Ridge with 50-day period



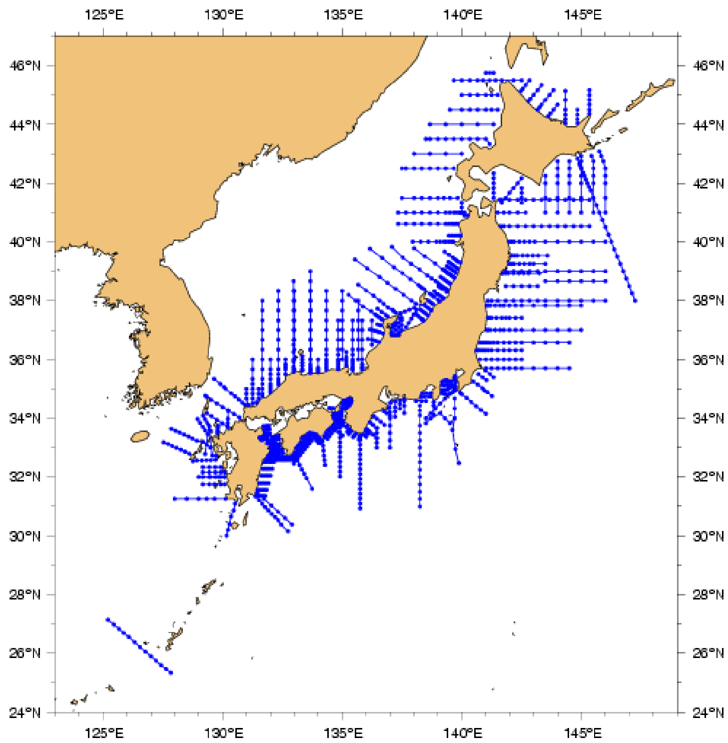
Izu-Ogasawara Ridge

Implications to Fisheries



Observed Kuroshio front variability and skipjack fishery points
(from website of the fishery research agency of Mie prefecture)

Revision: FRA-DATA



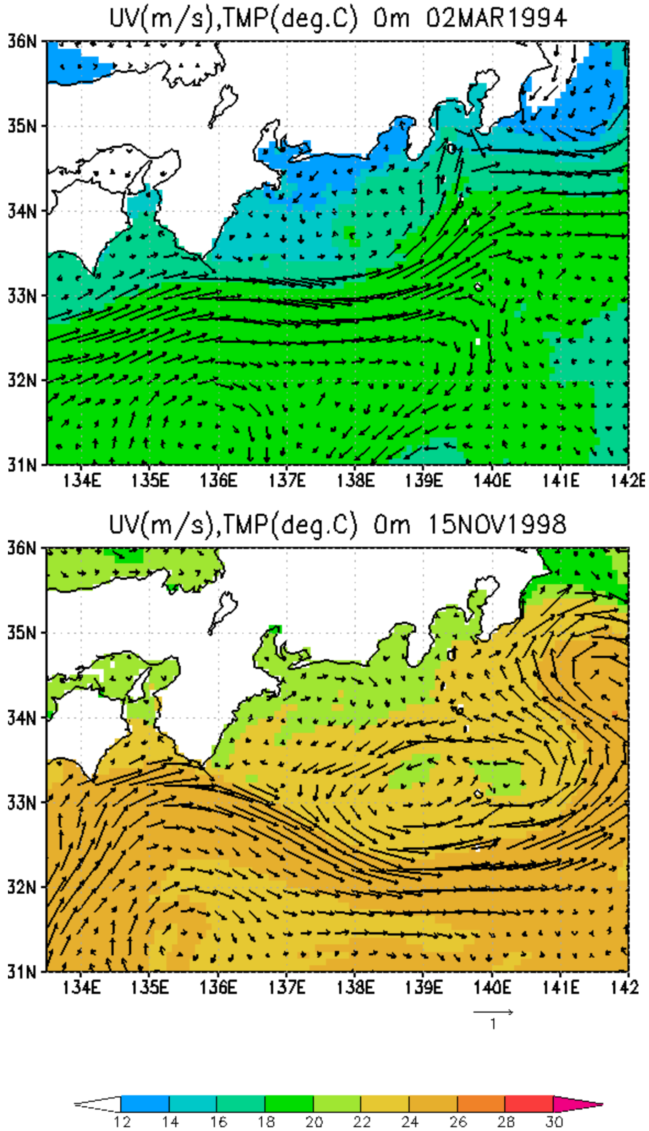
So far, the target phenomena of FRA-DATA south of Japan have been unclear.

But now we suggest that the target phenomena of FRA-DATA is the Kuroshio frontal waves with the time scale of 20 days and the spatial scale of 400km.

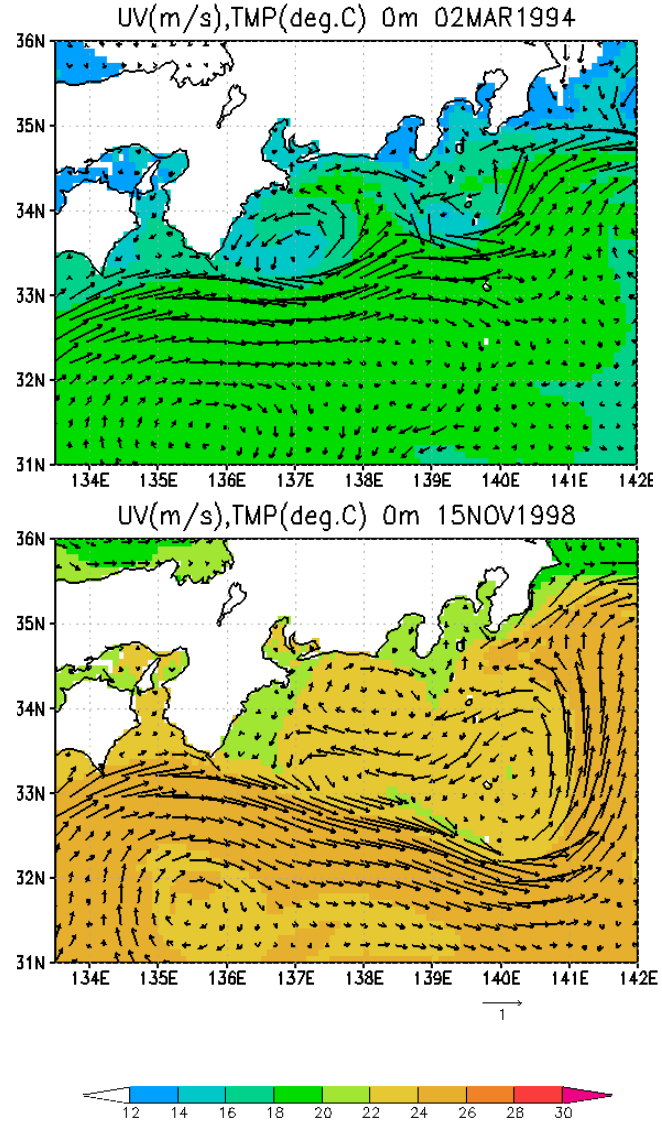
If FRA people wish to re-organize the FRA-DATA network south of Japan, this Information may be useful for the policy making of FRA.

Implications to Marine Biology

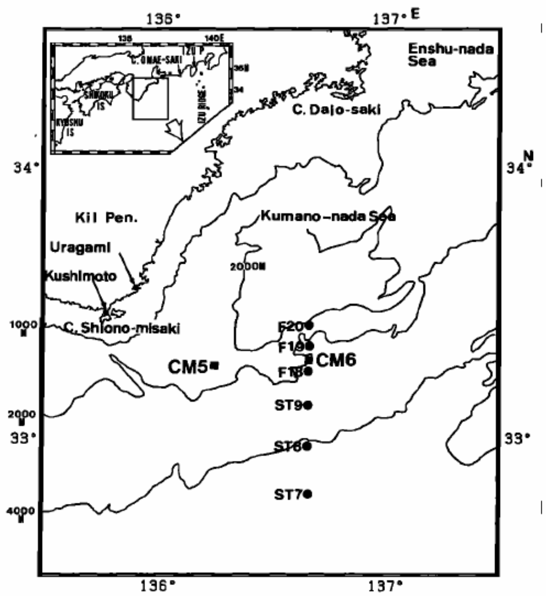
JCOPE2

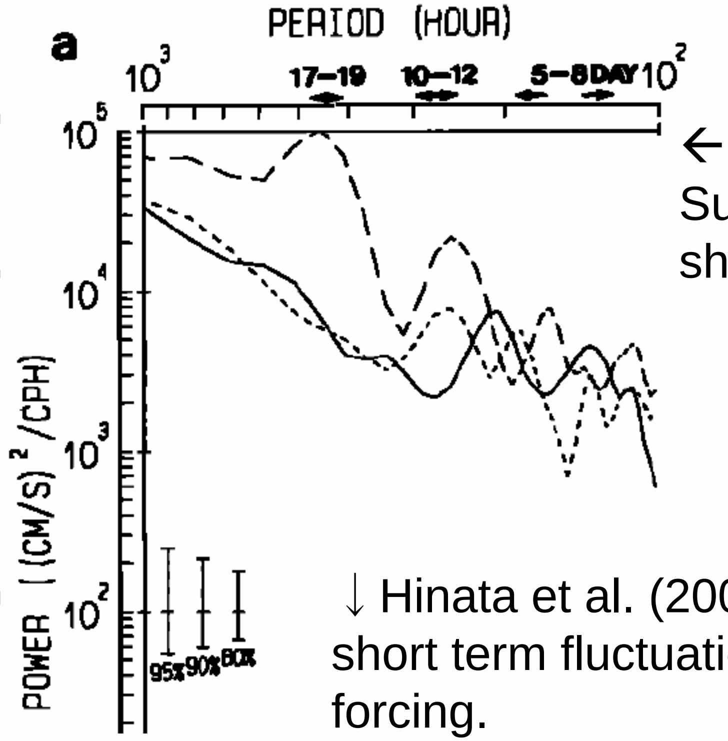


FRA-JCOPE2



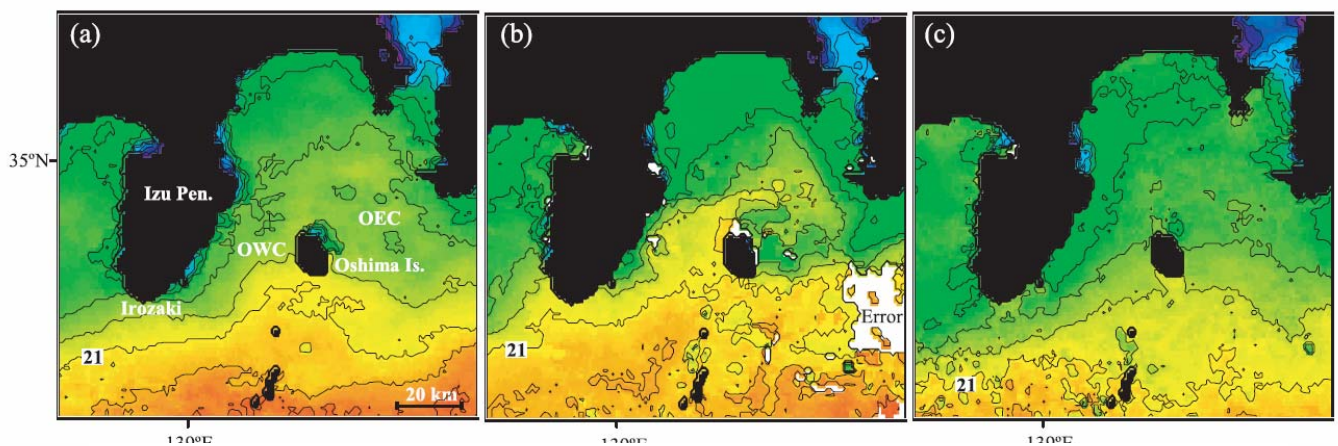
Downscaled Kuroshio variation





←Kimura and Sugimoto (1993) Suggest the frontal waves with shorter time scales.

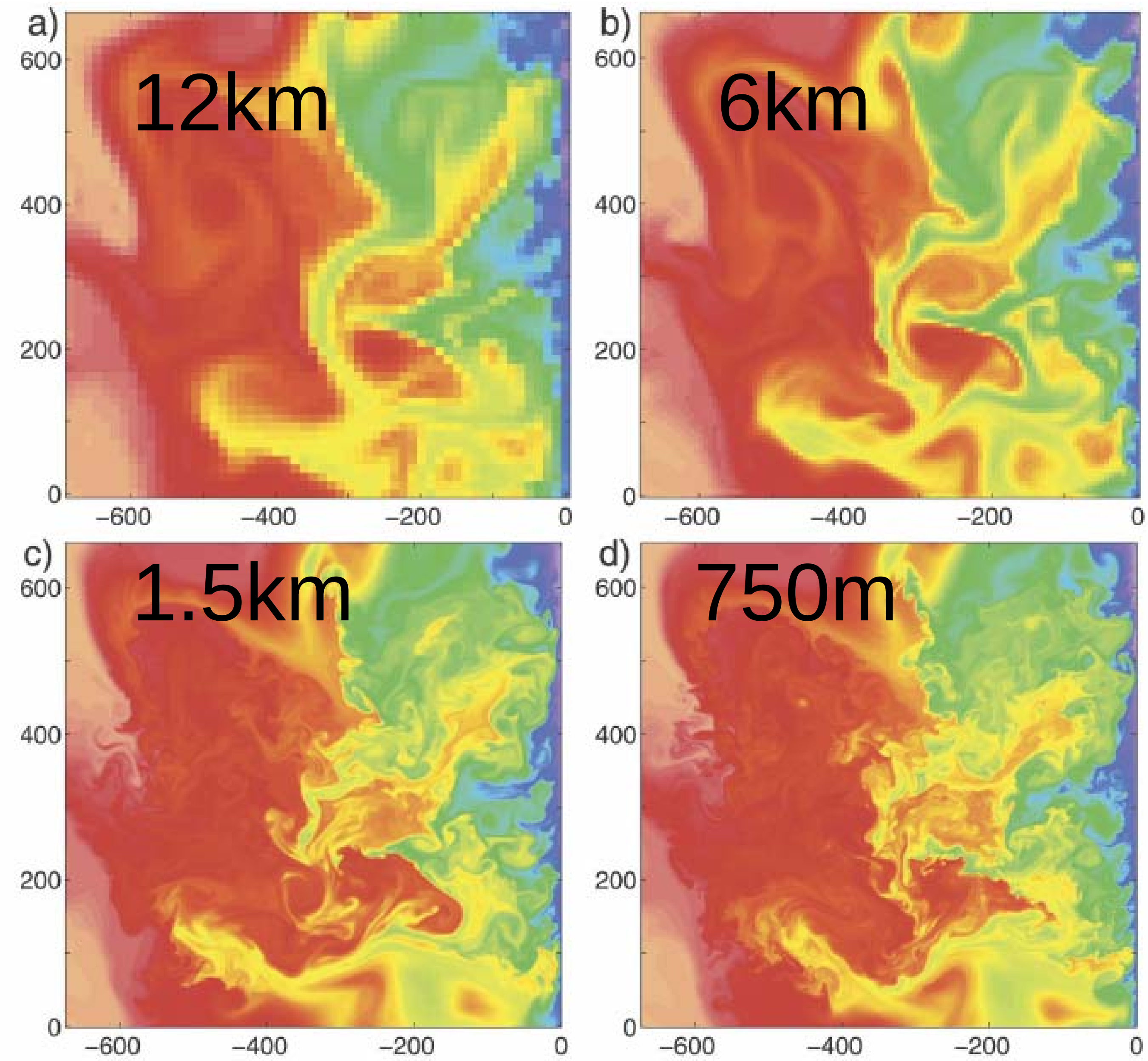
↓ Hinata et al. (2005) indicated the short term fluctuation strongly affected the wind forcing.



22-26 Dec. 2000 27-31 Dec. 2000 1-5 Jan. 2001

10 12 14 16 18 20 22 (°C)

Mesoscale to Submesoscale transition



Ideal Off California Current System

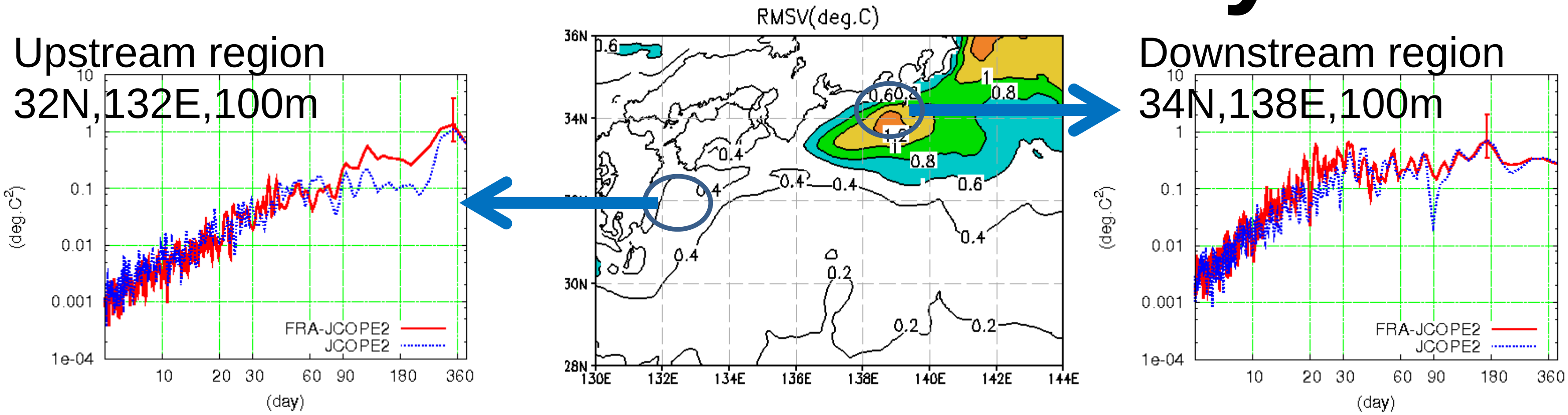
Simulated by ROMS

(Capet et al., 2008)

East-West Contrast of dynamics

Upstream region
32N,132E,100m

Downstream region
34N,138E,100m



Consistent with

1.Large available potential energy APE east of the Kii Peninsula (136E)

APE ~ (L0/R0) (h0/H)/2   (Oey, 1988)
L0: cross-stream distance of the main flow axis from the coast
R0: Rossby internal deformation radius
h0: main thermocline depth
H: ocean basin depth

→ L0 is larger east of the Kii Peninsula than west.

2. Intensified kinetic energy of the main stream east of the Kii Peninsula due to the geostrophic hydraulic jump   (Miyama and Miyazawa, 2010)

3-D Variational Assimilation

Minimize a cost function:

$$
\begin{aligned}
J(X) = \quad & (X - X^f)^t B^{-1} (X - X^f) \\
& + (y^o{}_T - H_T X)^t R^{-1}{}_T (y^o{}_T - H_T X) + (y^o{}_S - H_S X)^t R^{-1}{}_S (y_S - H_S X) \\
& + (y^o{}_{SSHA} - H_{SSHA}(X))^t R^{-1}{}_{SSHA} (y^o{}_{SSHA} - H_{SSHA}(X)) \\
& + (y^o{}_{SST} - H_{SST} X)^t R^{-1}{}_{SST} (y^o{}_{SST} - H_{SST} X)
\end{aligned}
$$

X State variables: Temperature and salinity, 0m→1500m, 24 levels

X^f First guess: Model forecast + GDEM Climatology

y_T^o, y_S^o Temperature/salinity profile data

y_η^o Sea surface height anomaly data

$y_{T_s}^o$ Sea surface temperature data

$$X = X^f + \sum_{i=1}^{12} \alpha_i C_i X_{EOF_i}$$

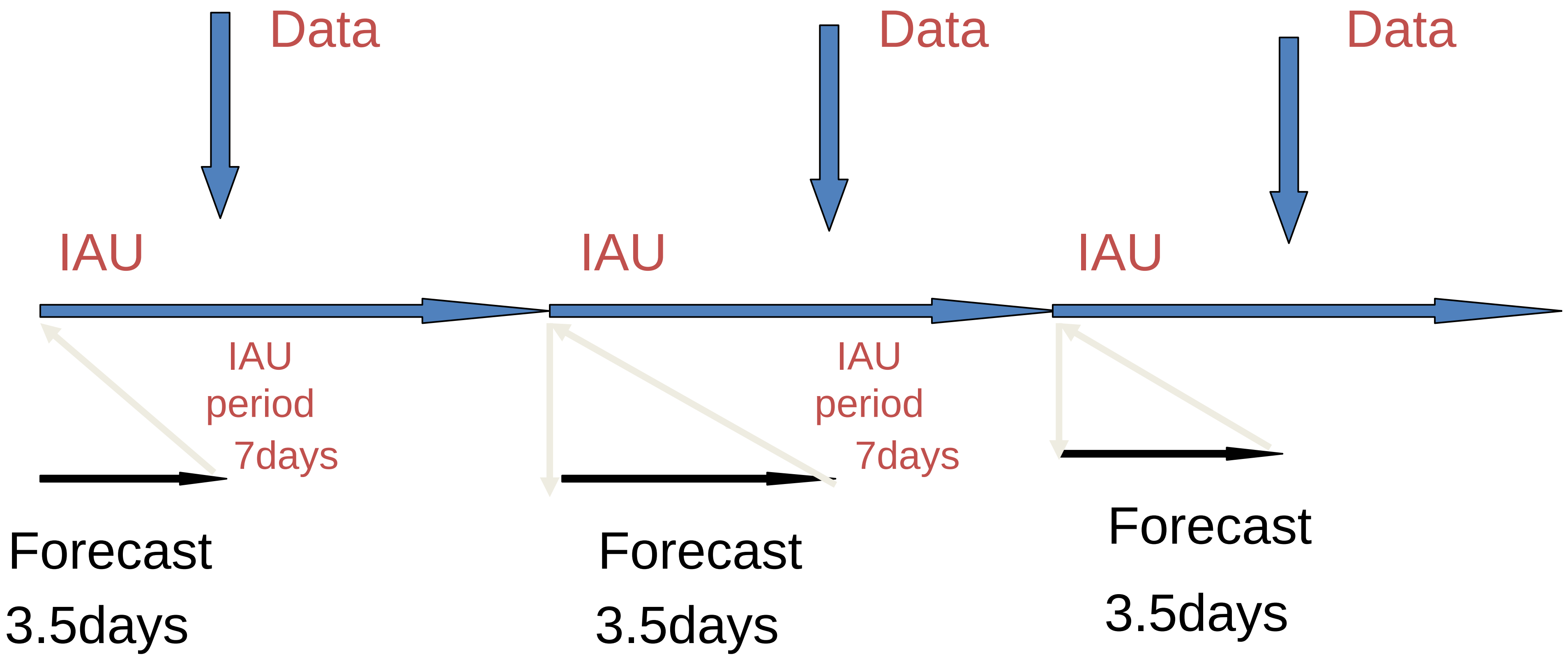
Control variables are amplitudes of T-S coupling EOF modes

B Background error covariance matrix

Incremental Analysis Update

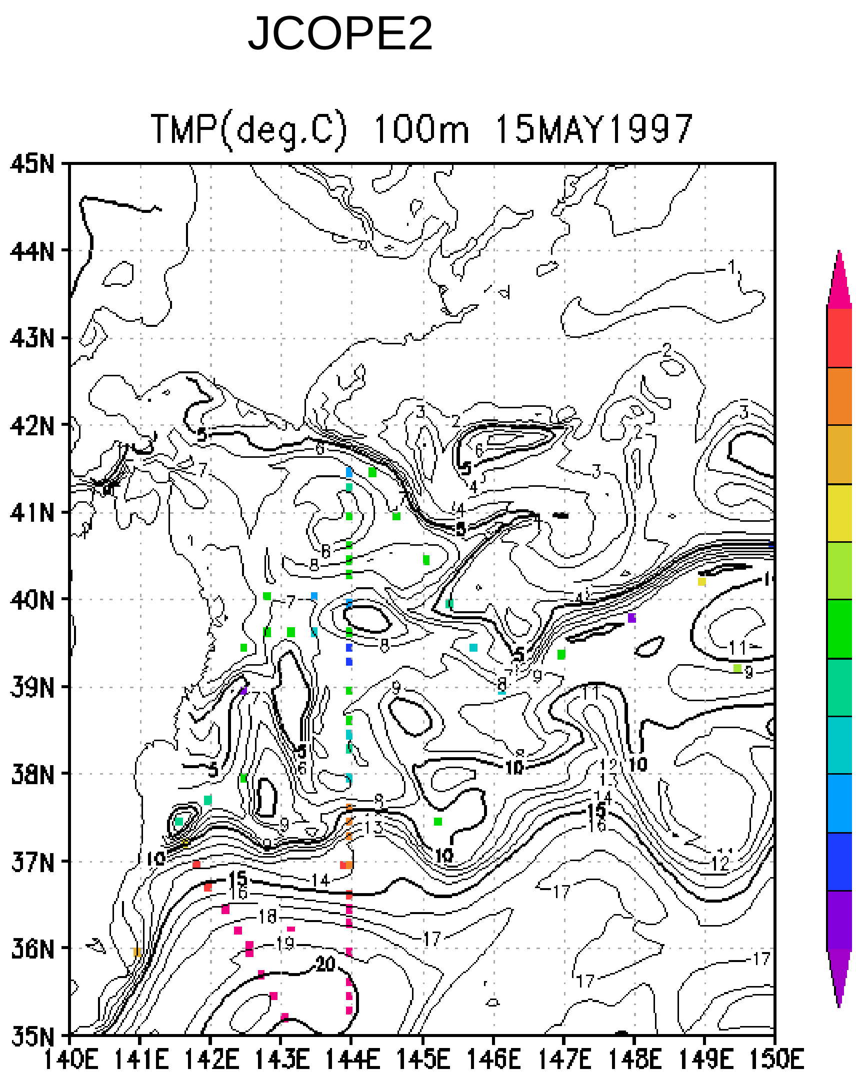
$$\frac{dT}{dt} = Physics + \frac{(T^a - T^f{}_{obs\_day})}{\Delta T}$$

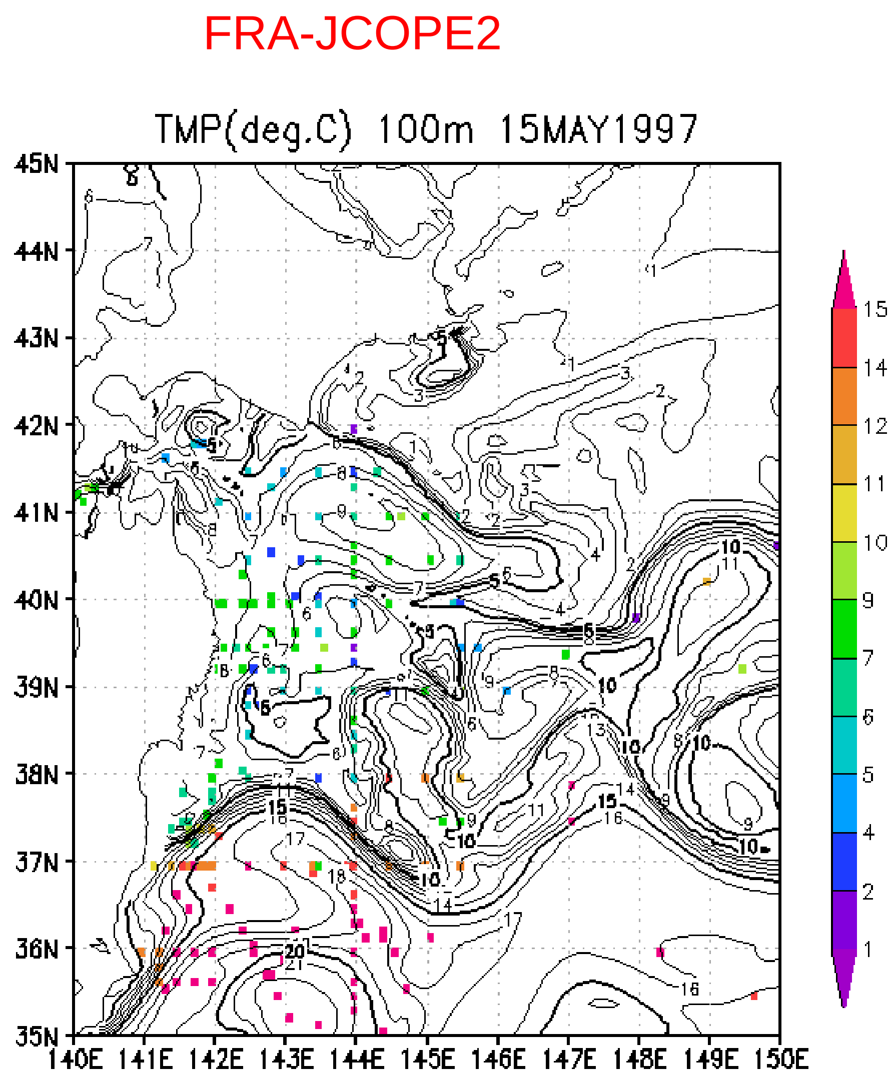
ΔT ← 7days ← Time Constant



(Bloom et al. 2000)

MAY 1997


JCOPE2
TMP(deg.C) 100m 15MAY1997
45N
44N
43N
42N
41N
40N
39N
38N
37N
36N
35N
140E 141E 142E 143E 144E 145E 146E 147E 148E 149E 150E


FRA-JCOPE2
TMP(deg.C) 100m 15MAY1997
45N
44N
43N
42N
41N
40N
39N
38N
37N
36N
35N
140E 141E 142E 143E 144E 145E 146E 147E 148E 149E 150E
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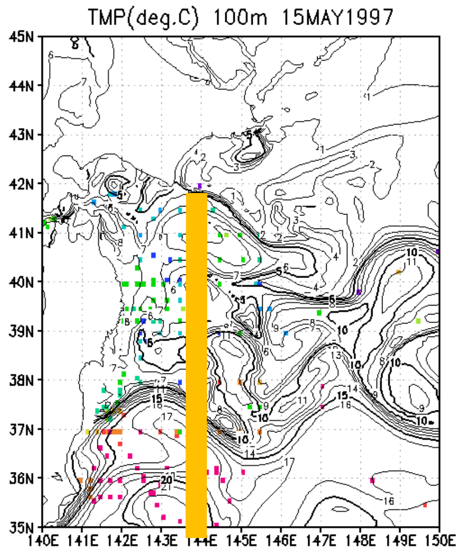
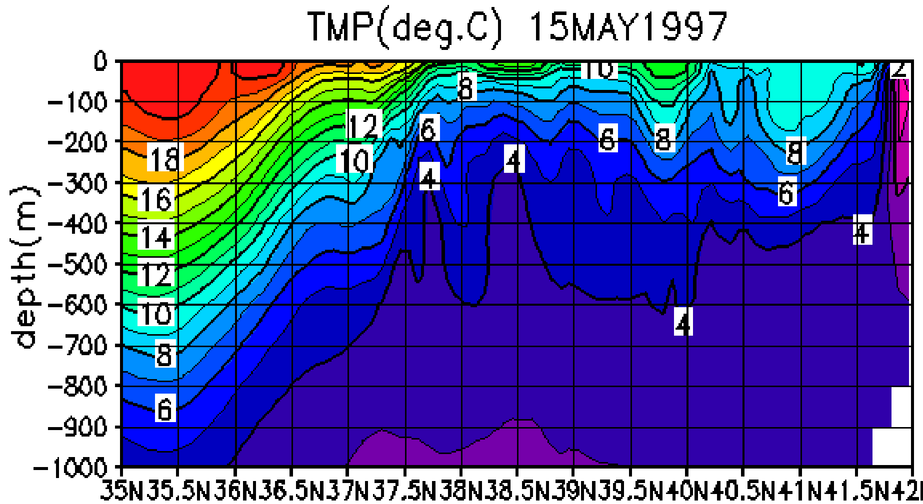
1

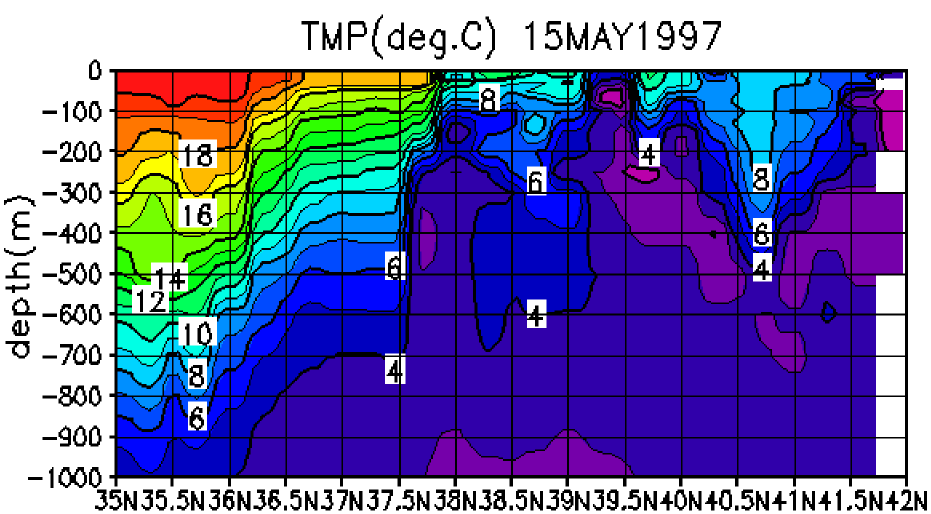
144E line: MAY 1997



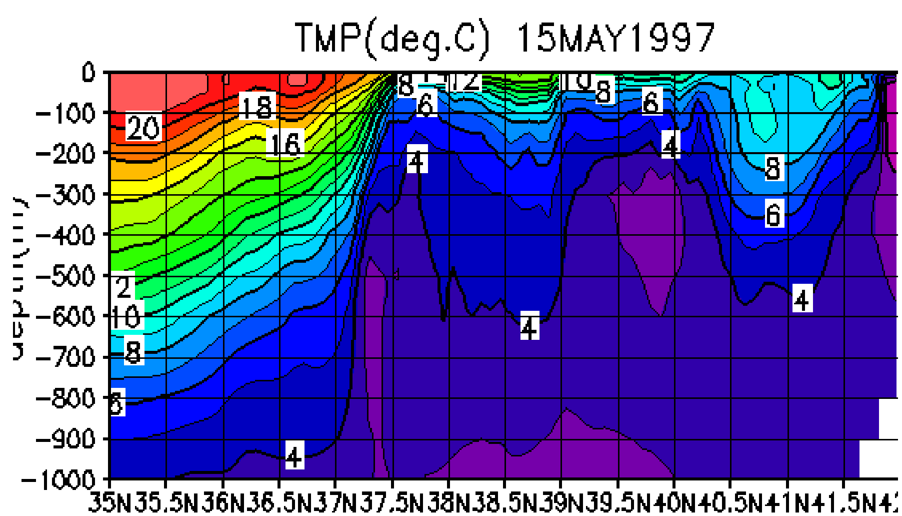
JCOPE2



In-situ observation



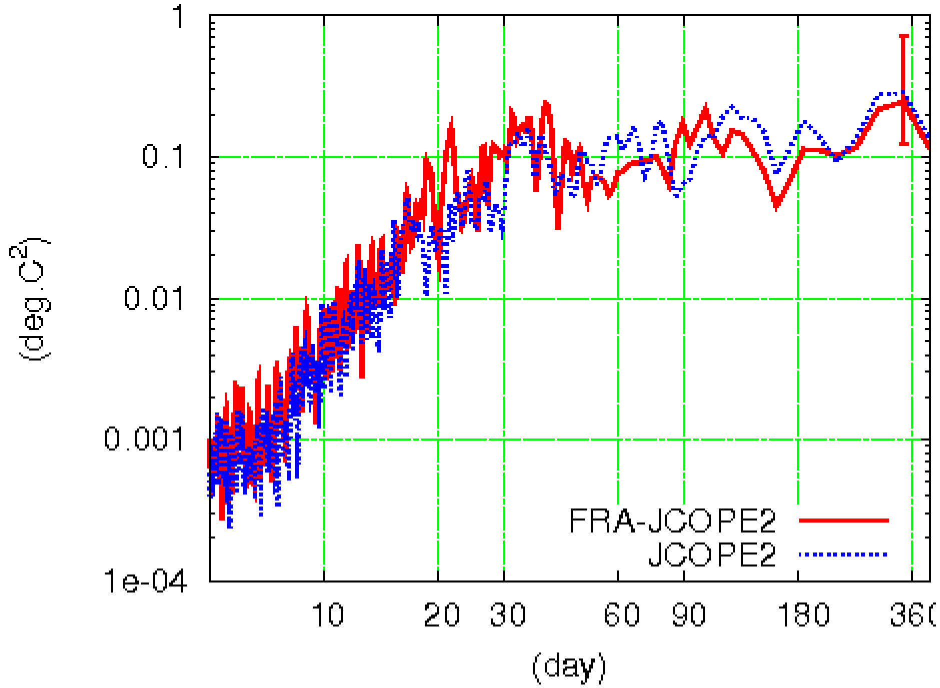
FRA-JCOPE2



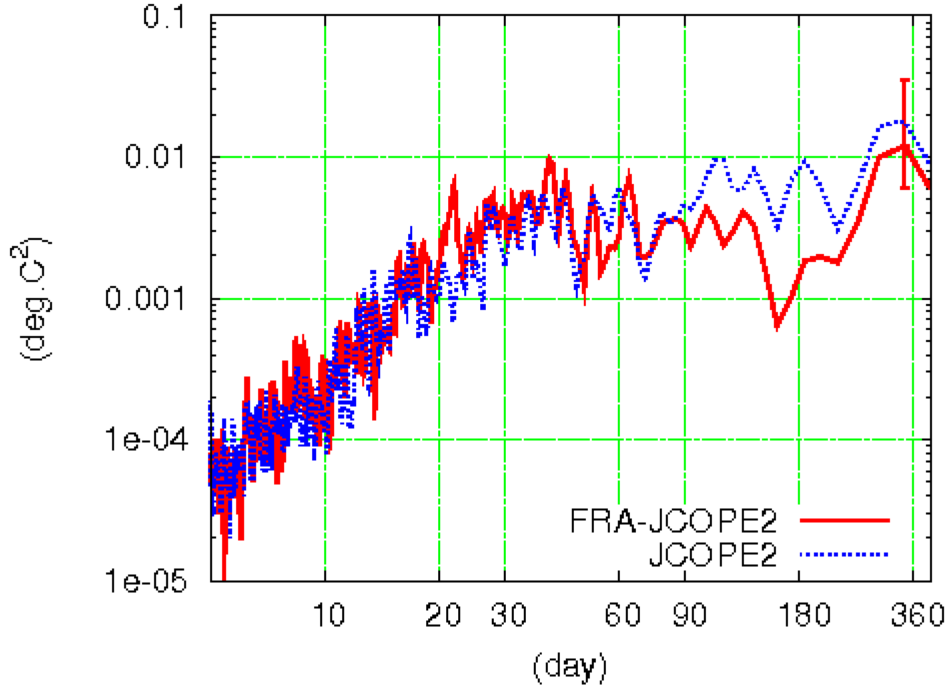
Power Spectra : deeper levels

Downstream region
34N, 138E

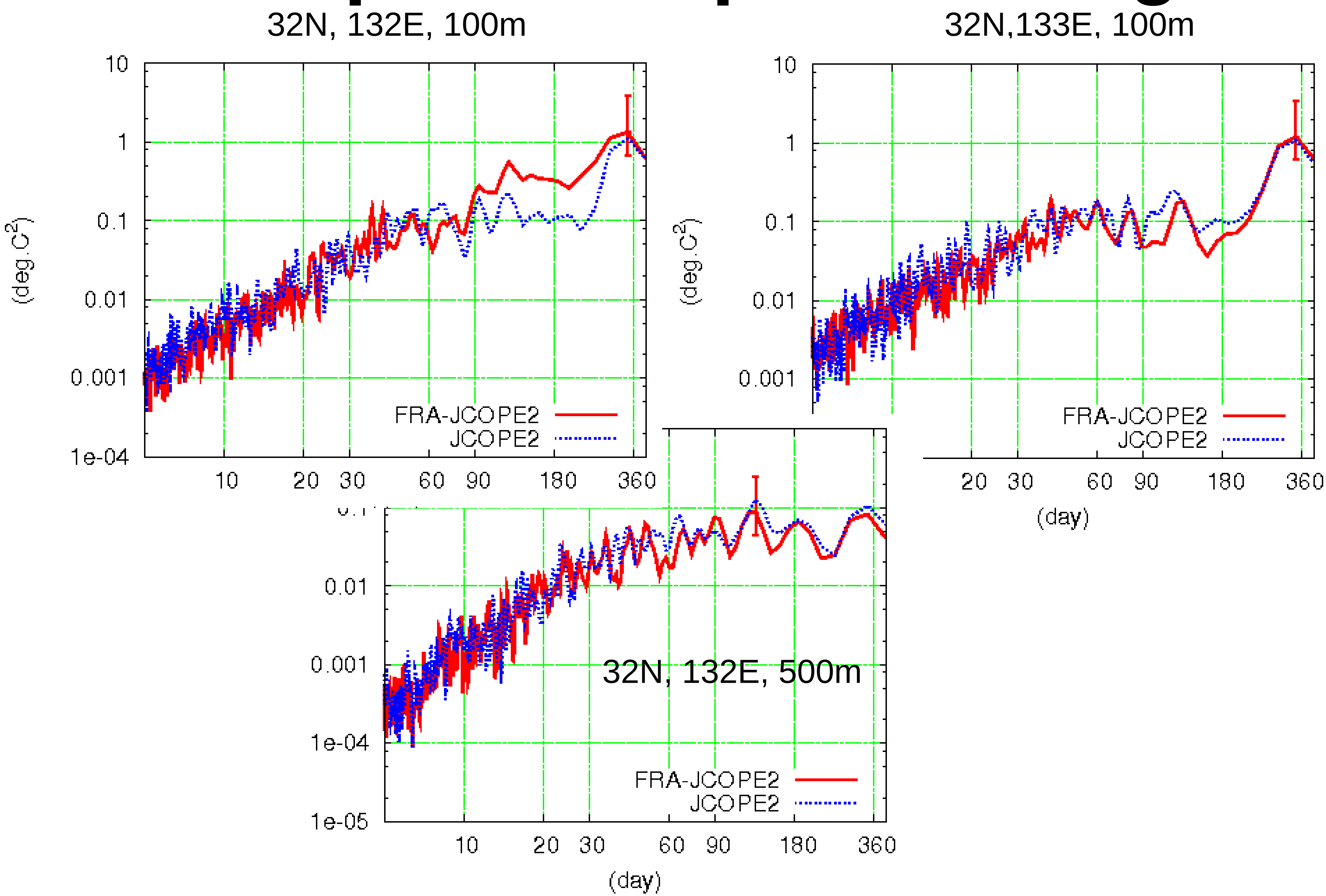
500m



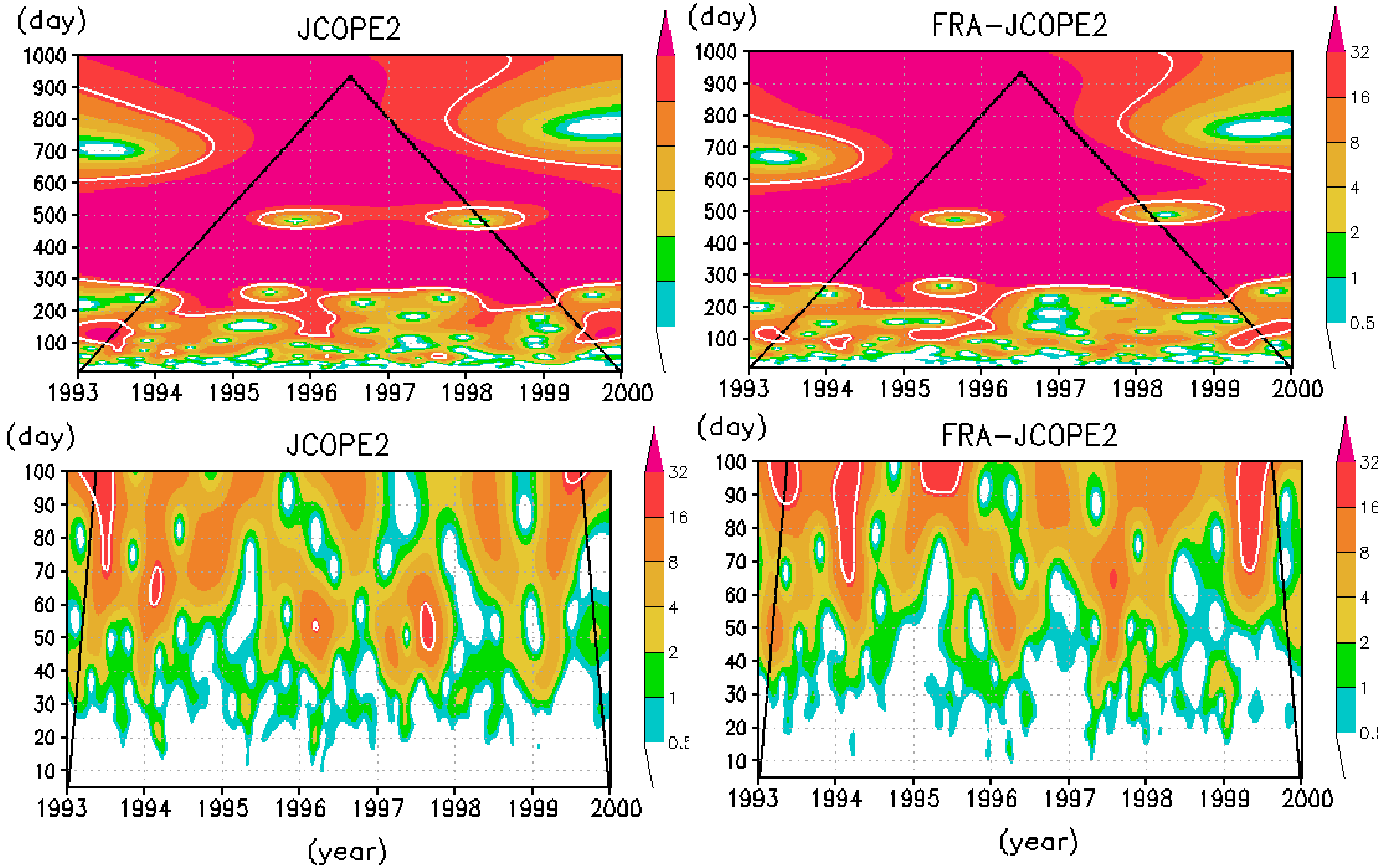
1000m



Power Spectra : upstream region



Wavelet spectra: 32N,132E,100m

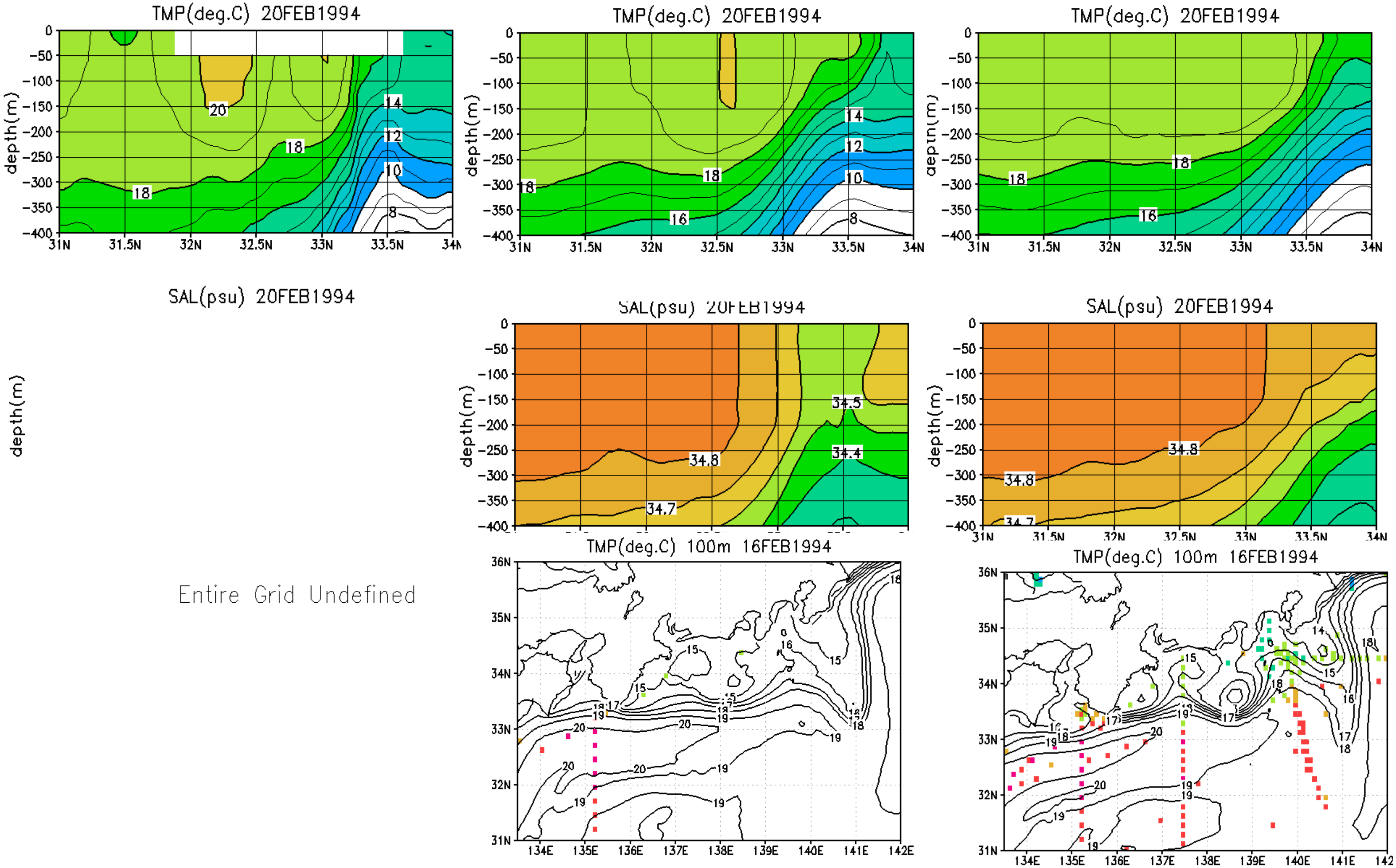


Vertical sections 137.5E

Observation

JCOPE2

FRA-JCOPE2



Vertical sections 138.5E