13th PICES

CCCC W3 PID=2012

15/10/2004 13:30-14:10

Modeling of transportation of phyto- and zooplankton in the Kuroshio and Kuroshio Extension

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Today's my talk

- **Introduction**
  - Background
  - Objectives
- **Transportation of phyto- and zooplankton**
  - NEMURO applied to 3D-OGCM with DA
  - Advective effects in the Kuroshio and KE
  - Size-dependent variation of plankton biomass
- **Transportation of eggs, larvae and juveniles**
  - Effect of eddies in the East China Sea
  - Effect of wind- and wave-induced currents
- **Future plan**

Introduction

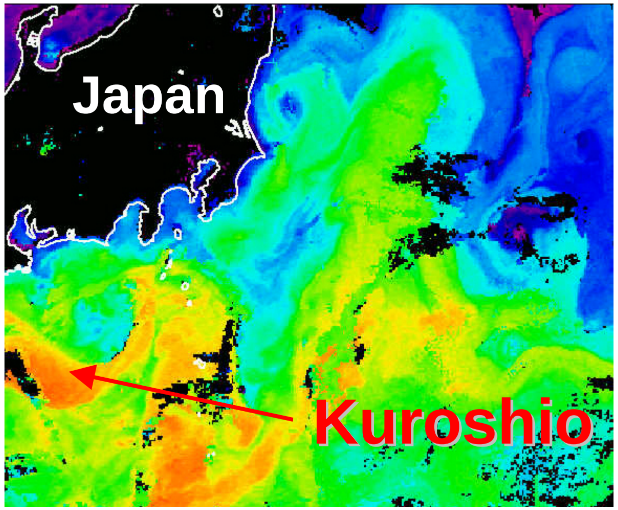
- Background
- Objectives

Background

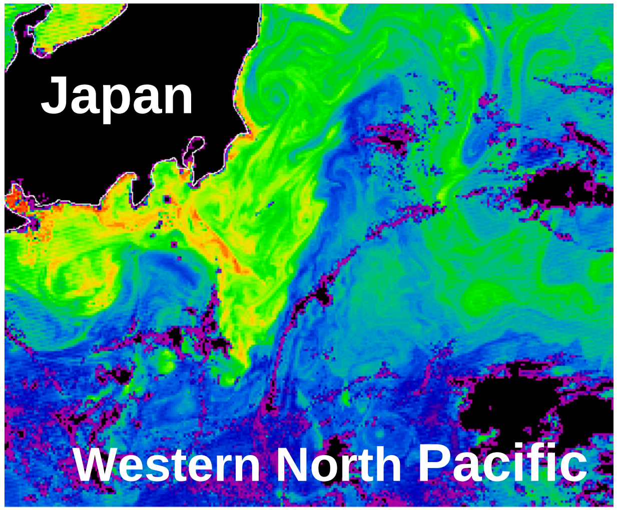
- **Necessity of developing 3-D numerical model for understanding interaction between open ocean and coastal ecosystems**

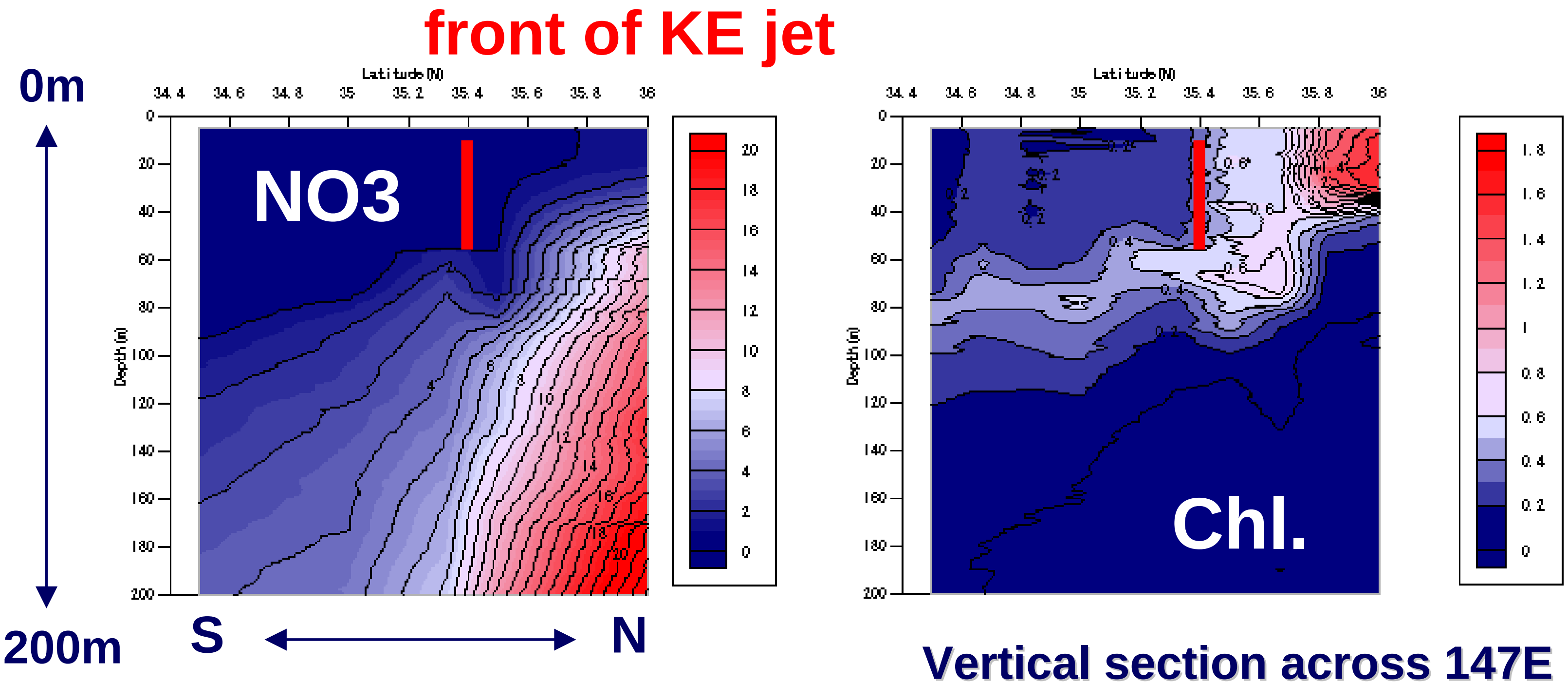
  - 3D structure of ocean environment

SST [NOAA/AVHRR]



Chl. [ADEOS/OCTS]





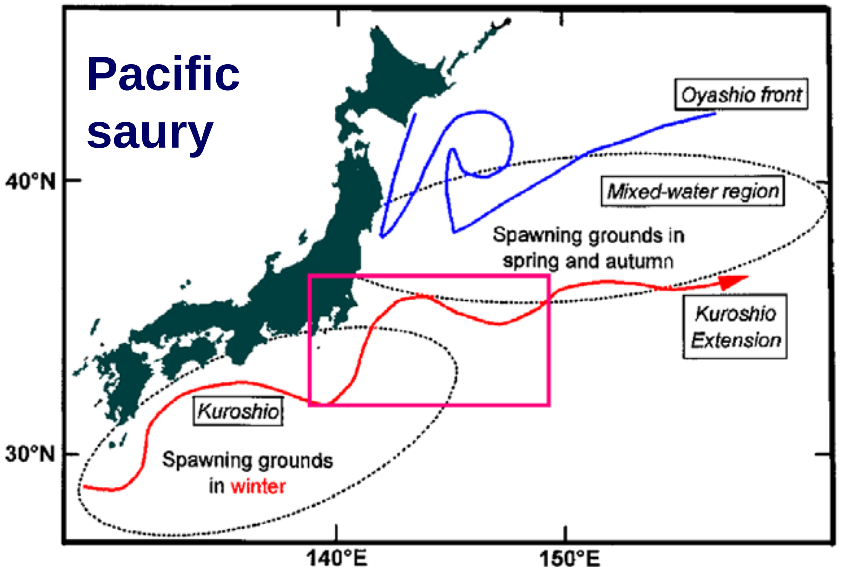
Vertical section across 147E in Jun. 1997 (Sasaki et al. 2004)

- **Advective effect on distribution of plankton biomass and production around jets (e.g., GS: Anderson et al. 2001; Kuroshio: Komatsu et al. 2004)**

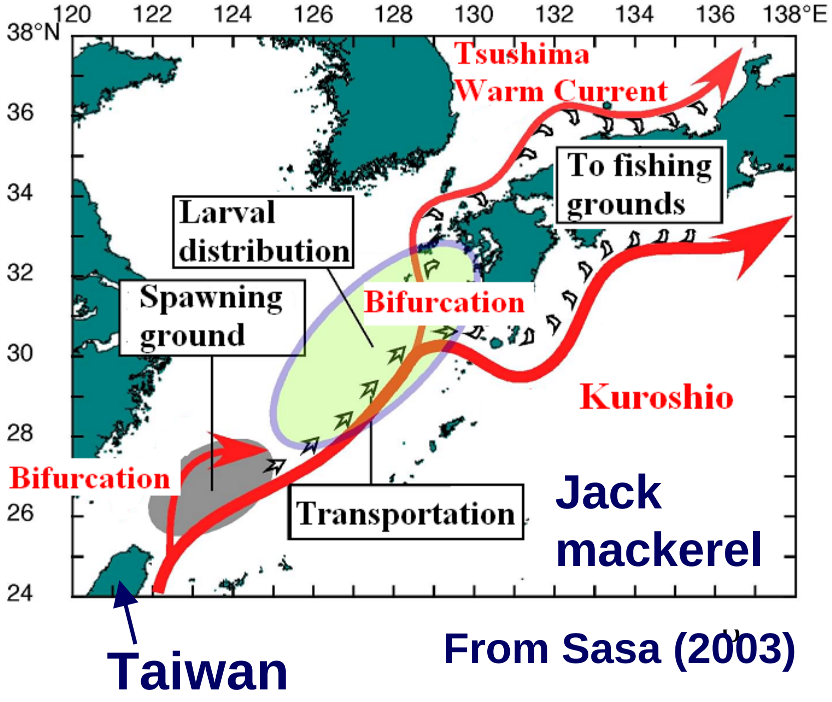
- **Advective effect on feeding grounds and migration routes of larvae and juveniles**

  - *** Kuroshio downstream: Pacific sardine, Pacific saury, …**

  - *** Kuroshio upstream: Jack mackerel, Yellowtail, Ommastrephid squid, …**



Watanabe et al. (1997)



From Sasa (2003)

- **Recent progresses of numerical model**
  - **- OGCM with data assimilation**
    JCOPE (JAMSTEC/FRCGC)
    NLOM (US Navy)
    …..
  - **- Ecosystem model**
    NEMURO, NEMURO.FISH (PICES)
    ECOPATH/ECOSIM
    …..
- **Coupling ecosystem model with 3D OGCM is ongoing.**

Objectives

- **To clarify advective effects on spatial distribution of phyto- and zooplankton biomass, coupling NEMURO with a 3D-OGCM**
- **To clarify effects of eddy and wind on transportation of eggs and larvae, coupling a tracer model with a 3D-OGCM**

Transportation of phyto- and zooplankton in the Kuroshio and Kuroshio Extension

1. **NEMURO applied to 3D-OGCM assimilated to satellite altimetry**
2. **Advective effects on the spatial distribution of plankton biomass**
3. **Size-dependent variation**

Development of a lower-trophic level ecosystem model at NRIFS

Driving force
NCEP/NCAR

PAR
GMS-5/NASDA

Physics

C-HOPE

(MPI Me)

$u, v, w,$

S, T, K_v, K_H

Biogeochemistry

NEMURO

(PICES)

Data assimilation

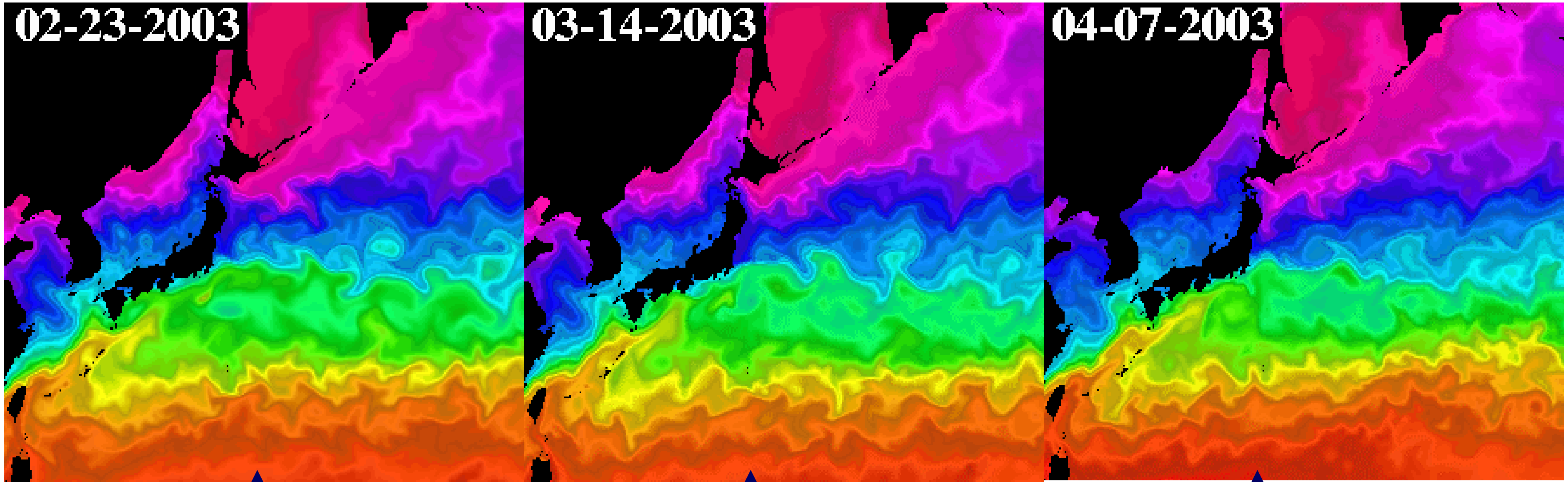
Satellite altimetry

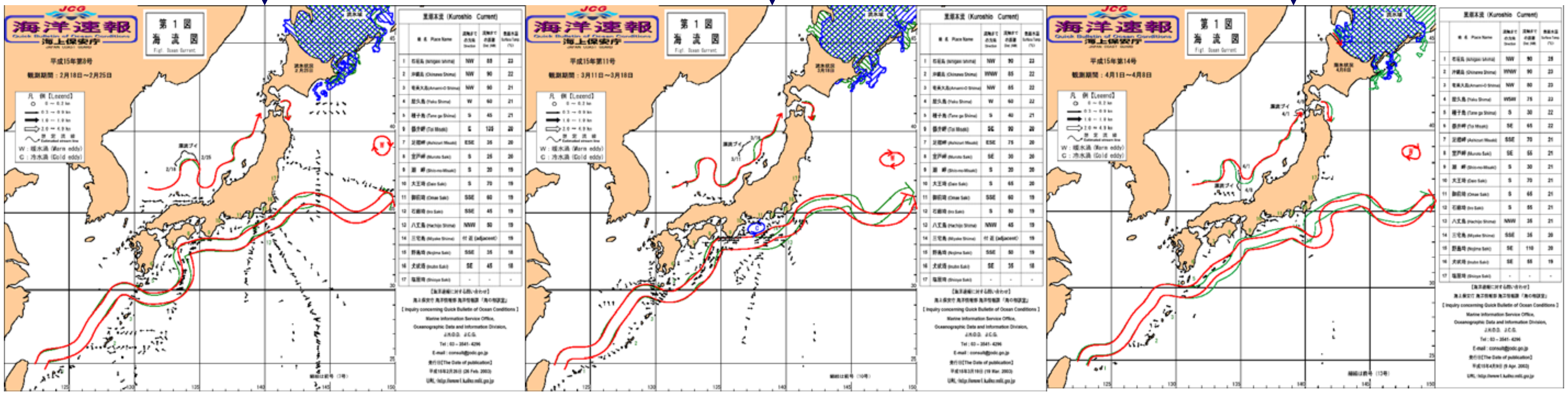
(TP, ERS-1/2, Jason-1)

1/16º resolution near the coast

Reproduction of Kuroshio by C-HOPE

(20days later SST)



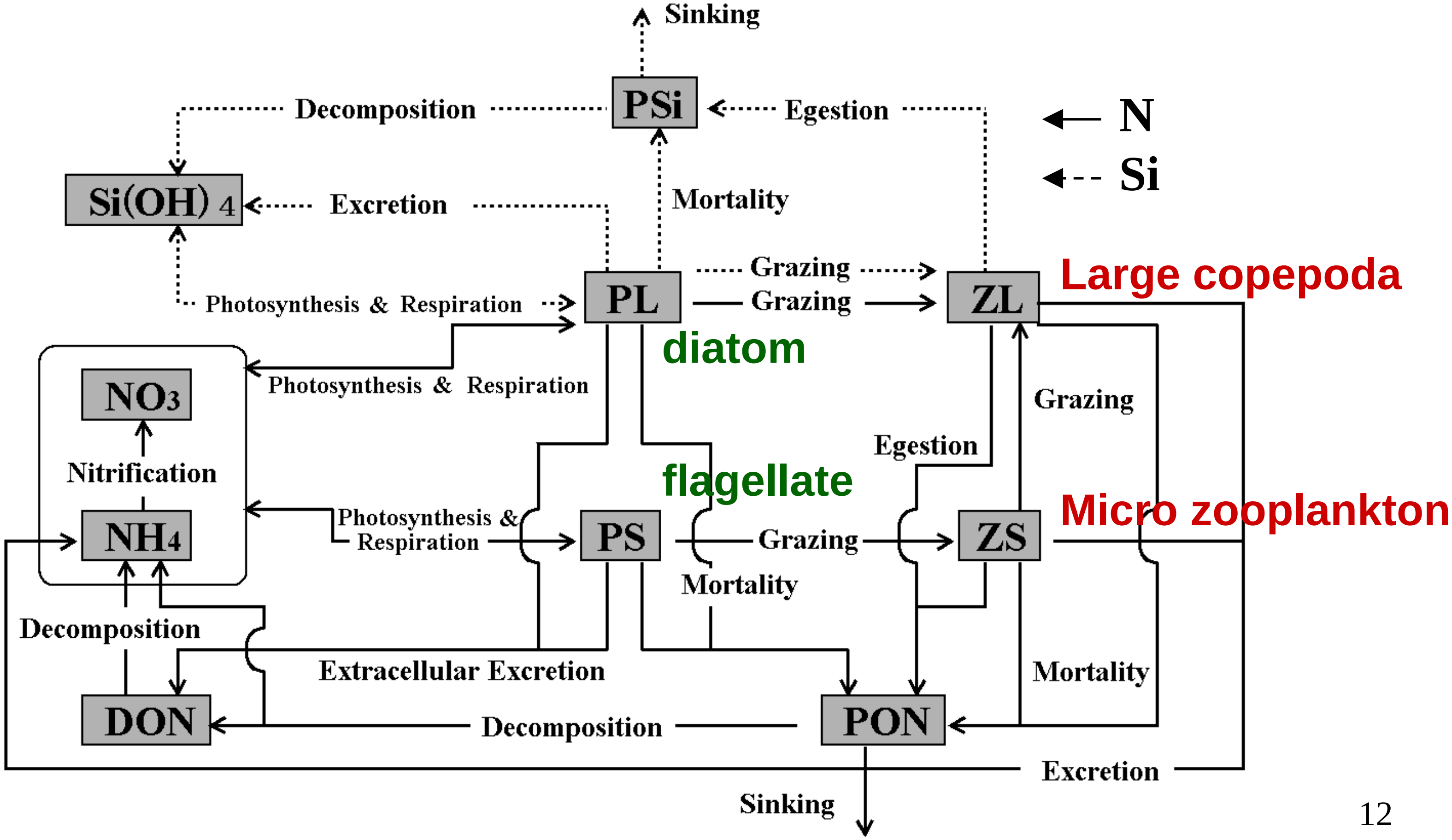


(Japan Coast Guard)

Biogeochemistry

NEMURO (PICES): no ZP, no vertical migration of ZL

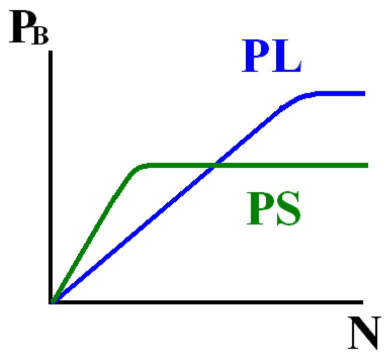
Initial: Nut.←Climatology, Phyto←OA[1], Zoo←Extrapolation



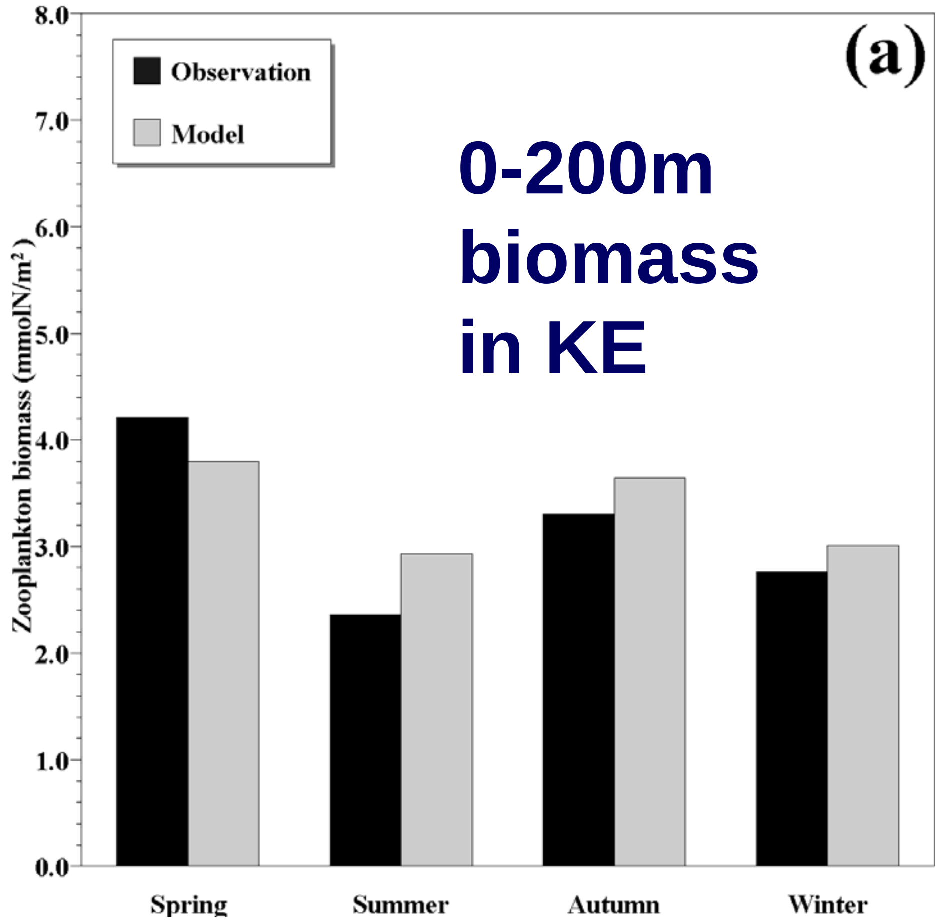
1. Anderson et al. (2000)

Adjustment of biological parameters

- Main target area is the subtropical region, but parameters of the original NEMURO are adjusted to the subarctic region.
- Maximum photosynthetic rate at 0^{o}C (V_{max}) and half saturation constant for inorganic nitrogen (K_{NO3}, K_{NH4}) for phytoplankton, and maximum grazing rate at 0^{o}C (G_{Rmax}) and Ivlev constant (λ) for zooplankton are changed, comparing simulated zooplankton-biomass with observation data (Nakata et al. 2004).



Comparison of zooplankton biomass between model and observation



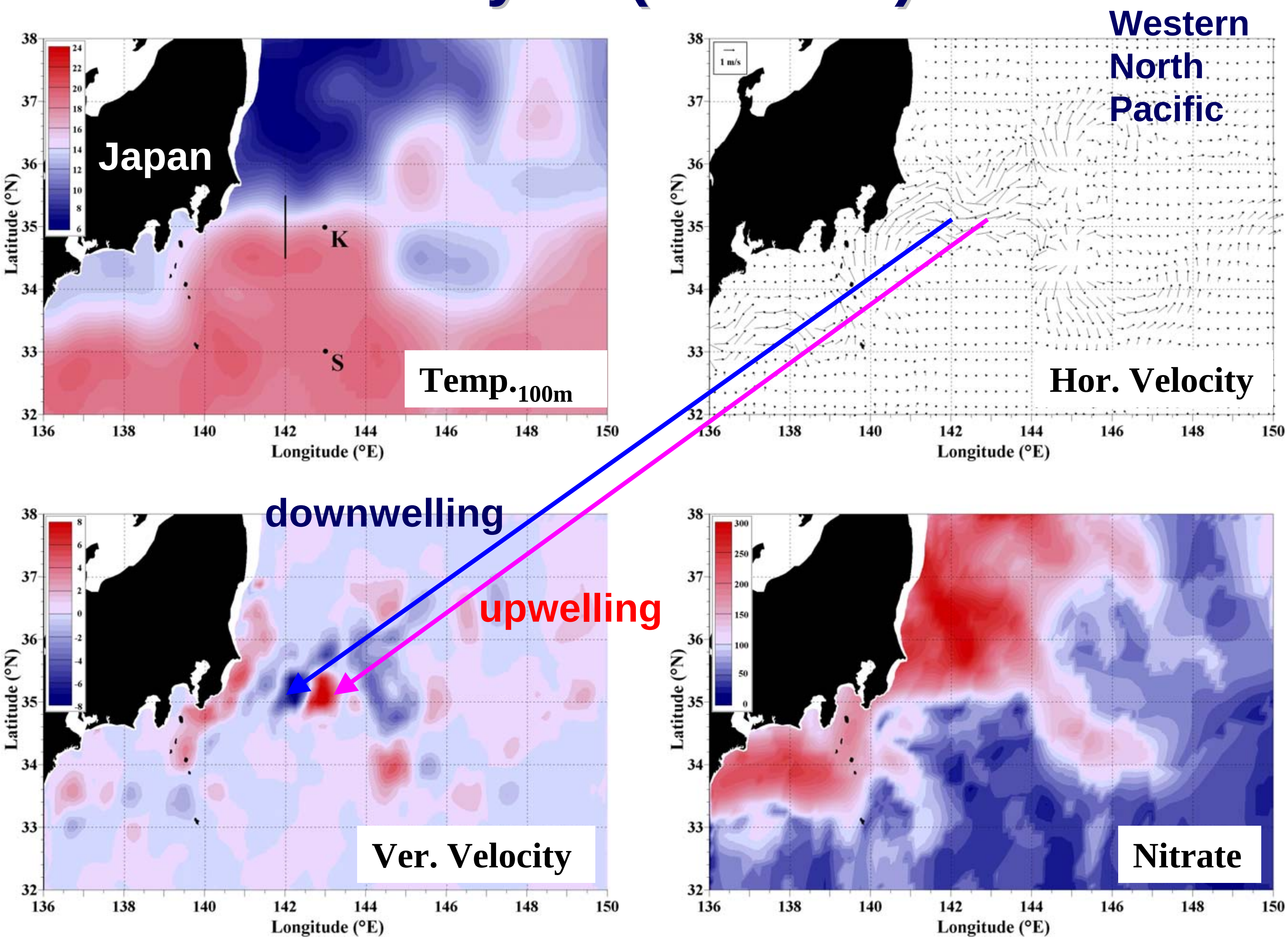
Model: ZL+ZS

Horizontal distribution of plankton biomass in the Kuroshio and KE

1997 April 1

- **Before the bloom in the subarctic region**
- **After the bloom in the subtropical region**
- **Enhancement along the jet, particularly in the convergence zone**

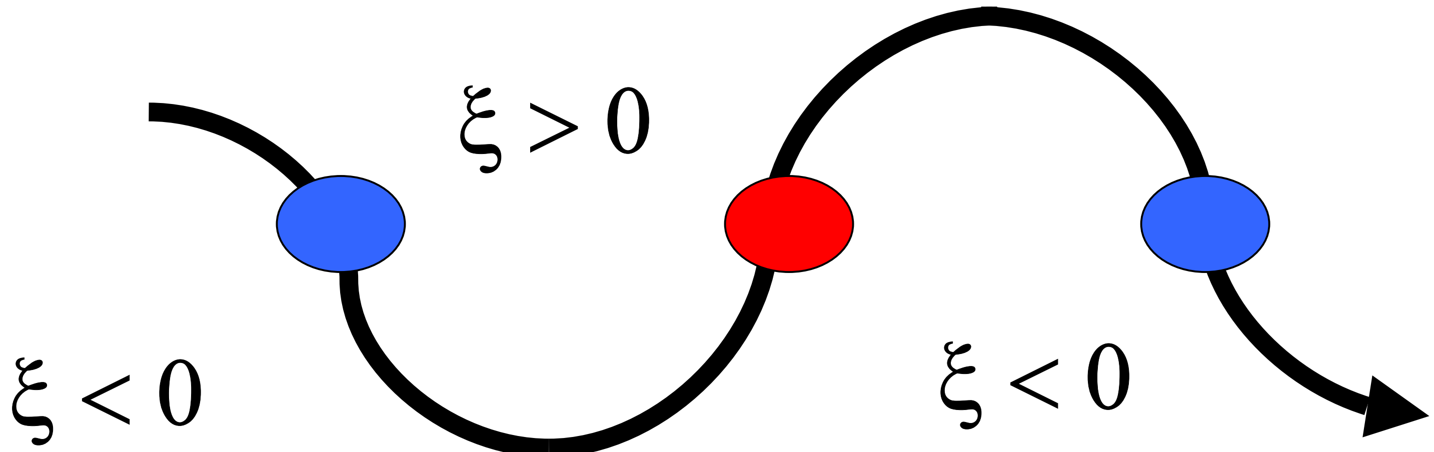
Day 90 (1997/4/1)



PV conservation (Onken, 1992)

$Q=(\xi+f)/H, \; dQ=0 \longrightarrow dH=d\xi/Q$

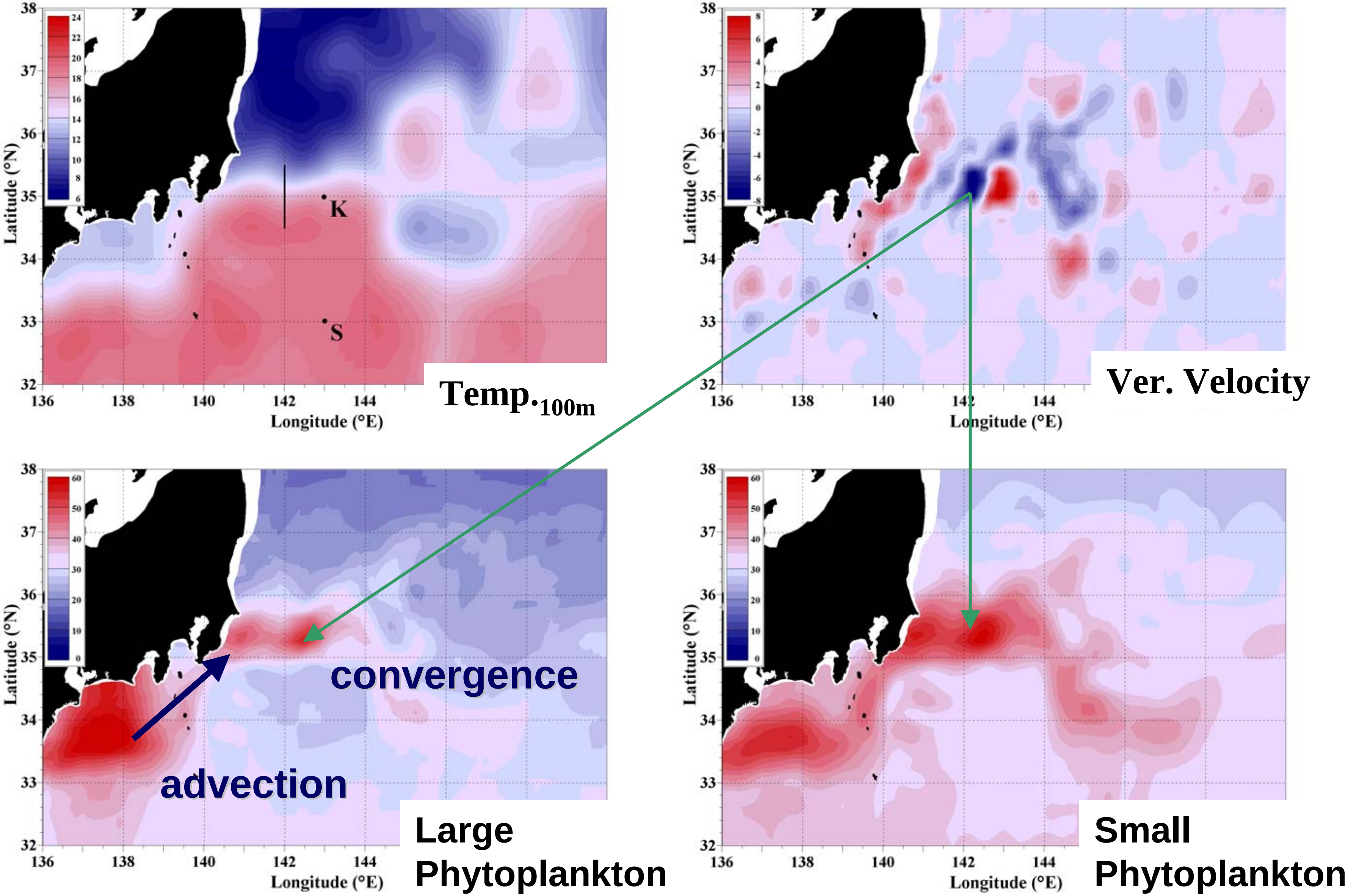
compression



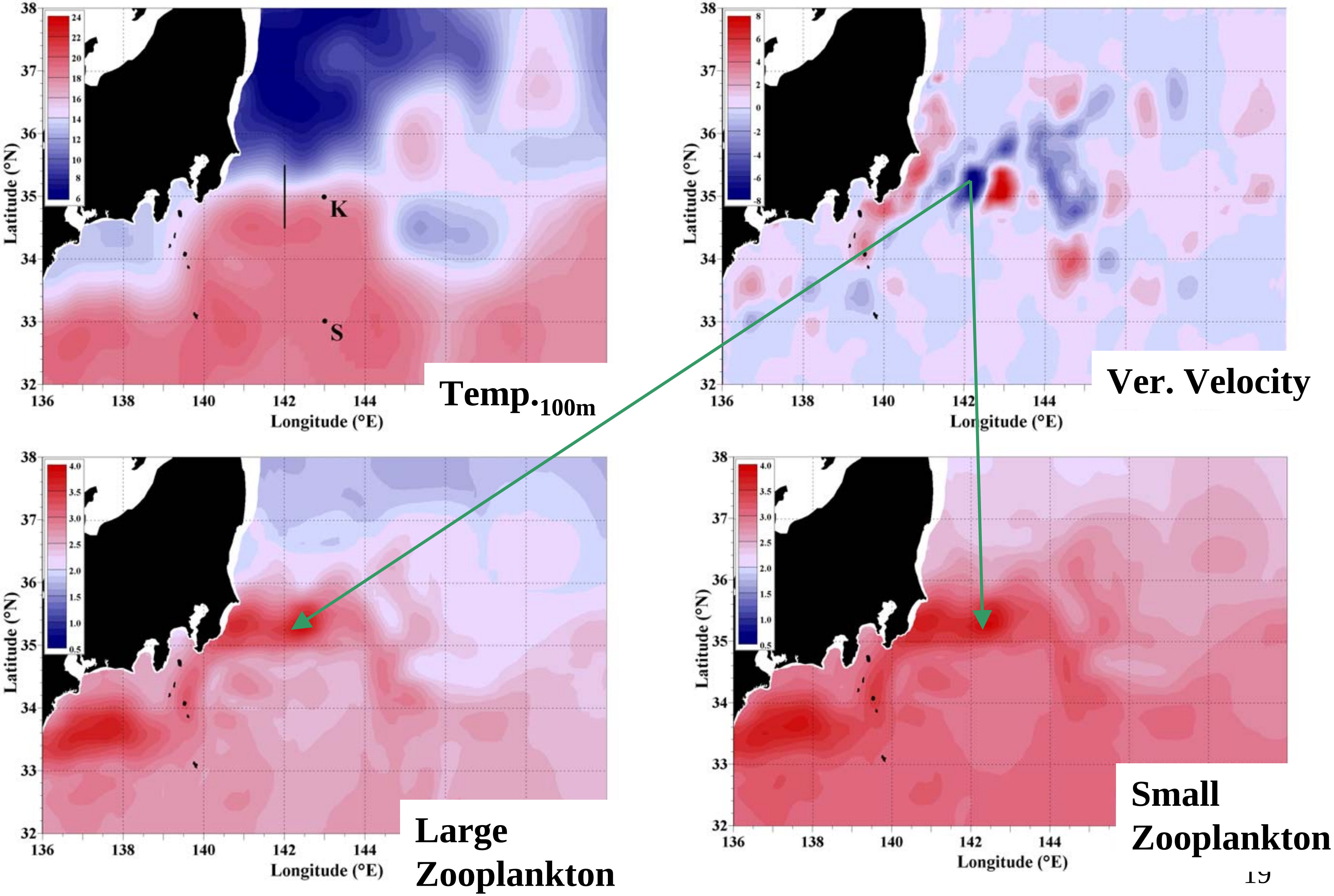
stretching

stretching

Day 90 (1997/4/1)



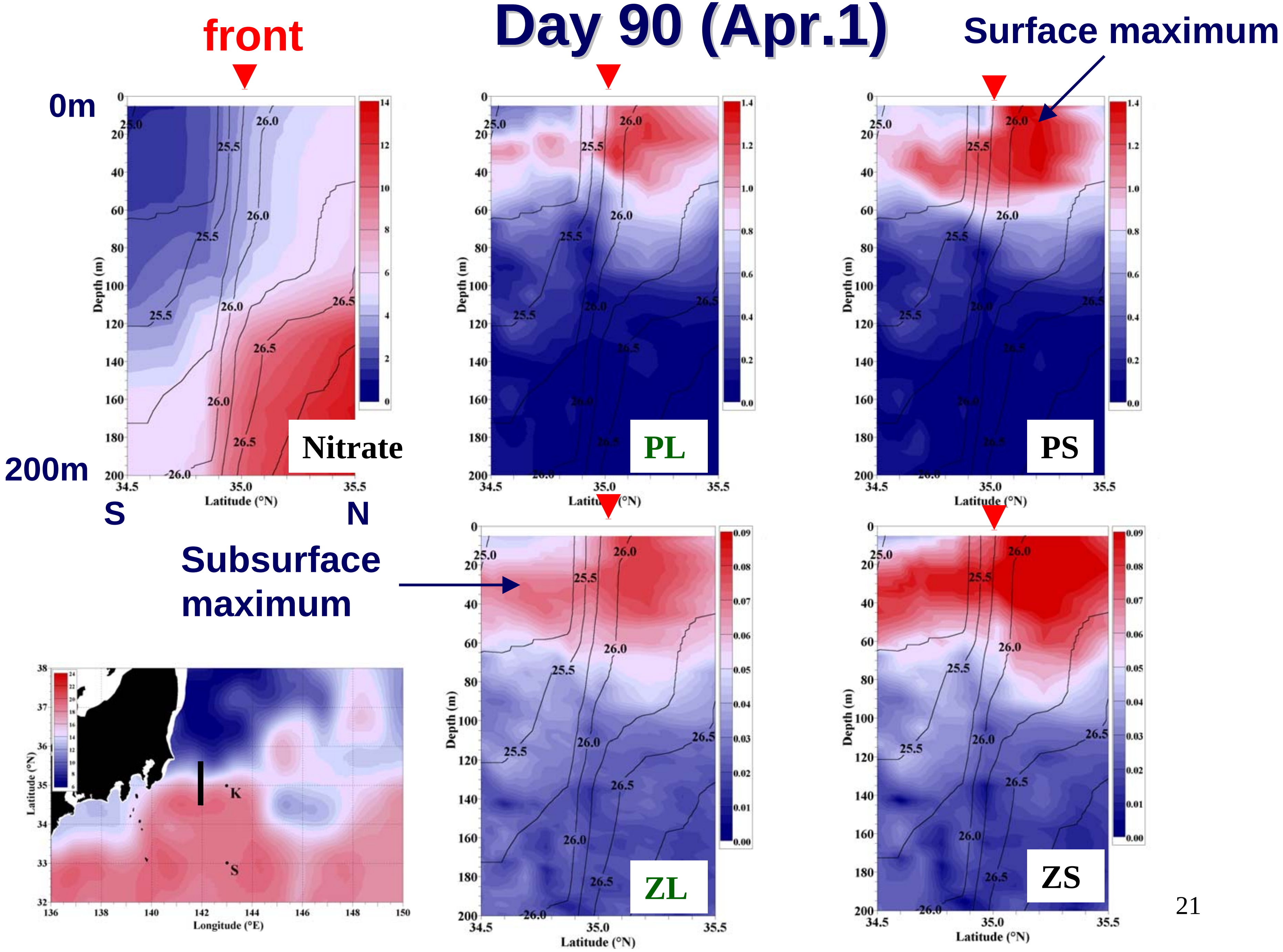
Day 90 (1997/4/1)



Vertical distribution of plankton biomass across the Kuroshio jet

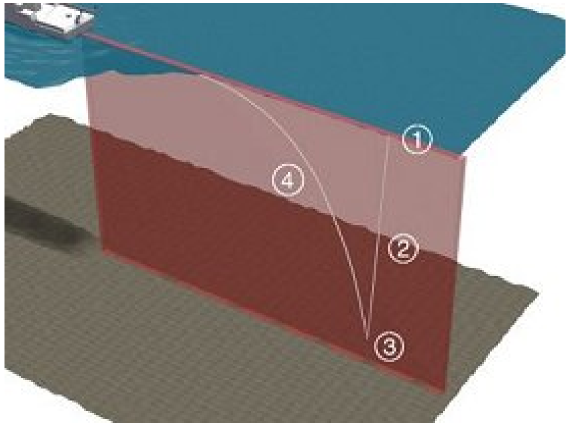
- **April 1: Discontinuity of maximum layer across the Kuroshio front**
- **June 3: depletion in the subtropical region**
- **Downward shift of surface maximum**

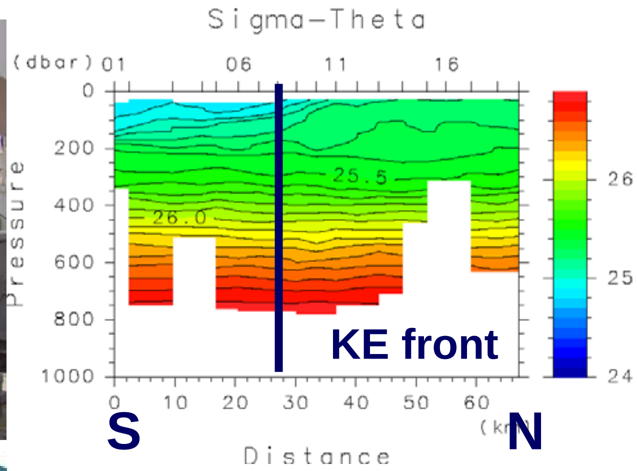
Day 90 (Apr.1)

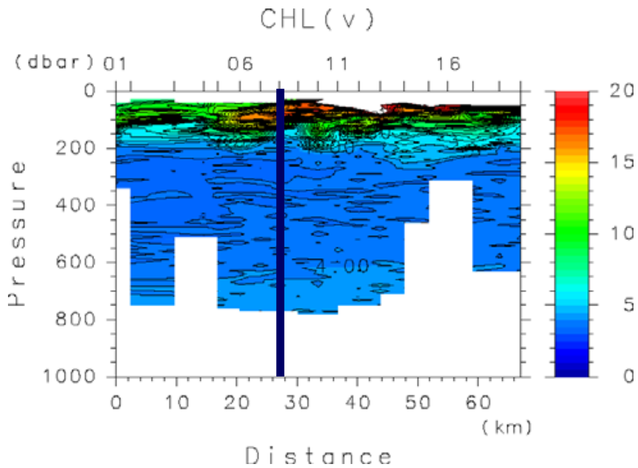


front
Surface maximum
0m
200m
S
N
Nitrate
PL
PS
Subsurface maximum
ZL
ZS
Depth (m)
Latitude (°N)
Longitude (°E)
K
S

MVP observation in Mar. 2004 (Hiroe et al. 2004)

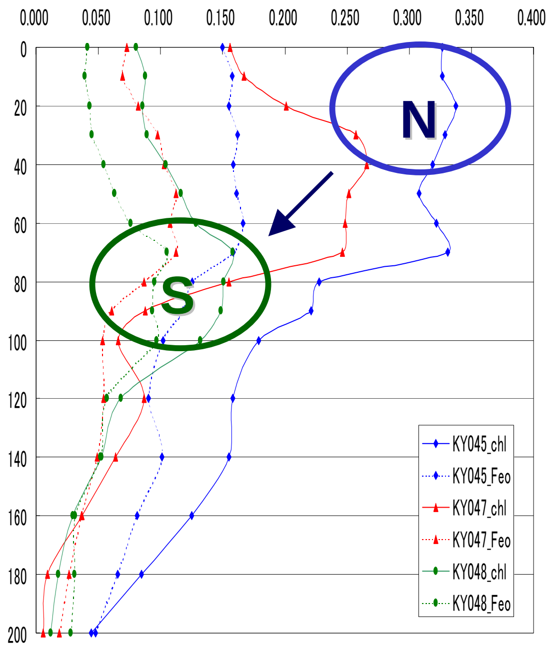


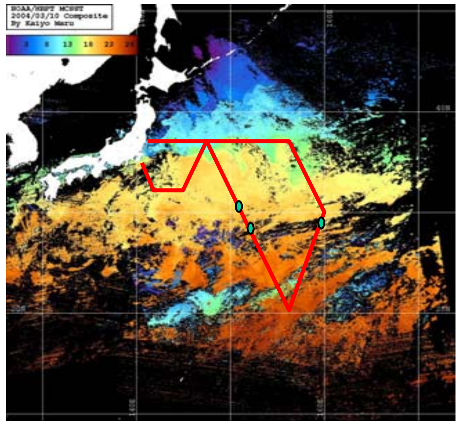




Moving Vessel Profiler
(Brooke Ocean Tech. Ltd.)

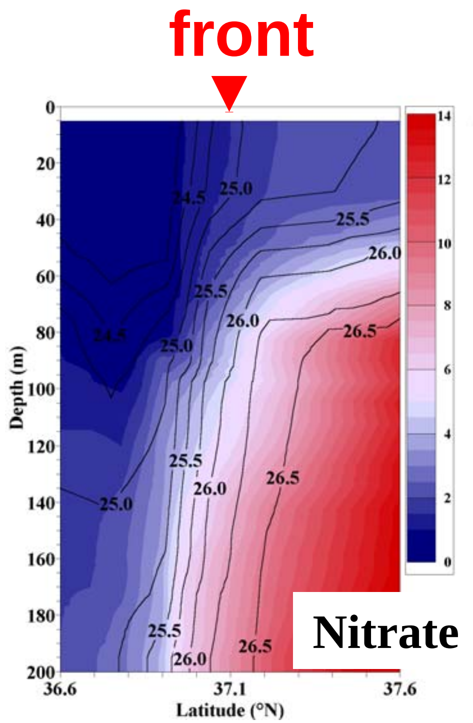
Fish: CTD, DOmeter, Fluorometer

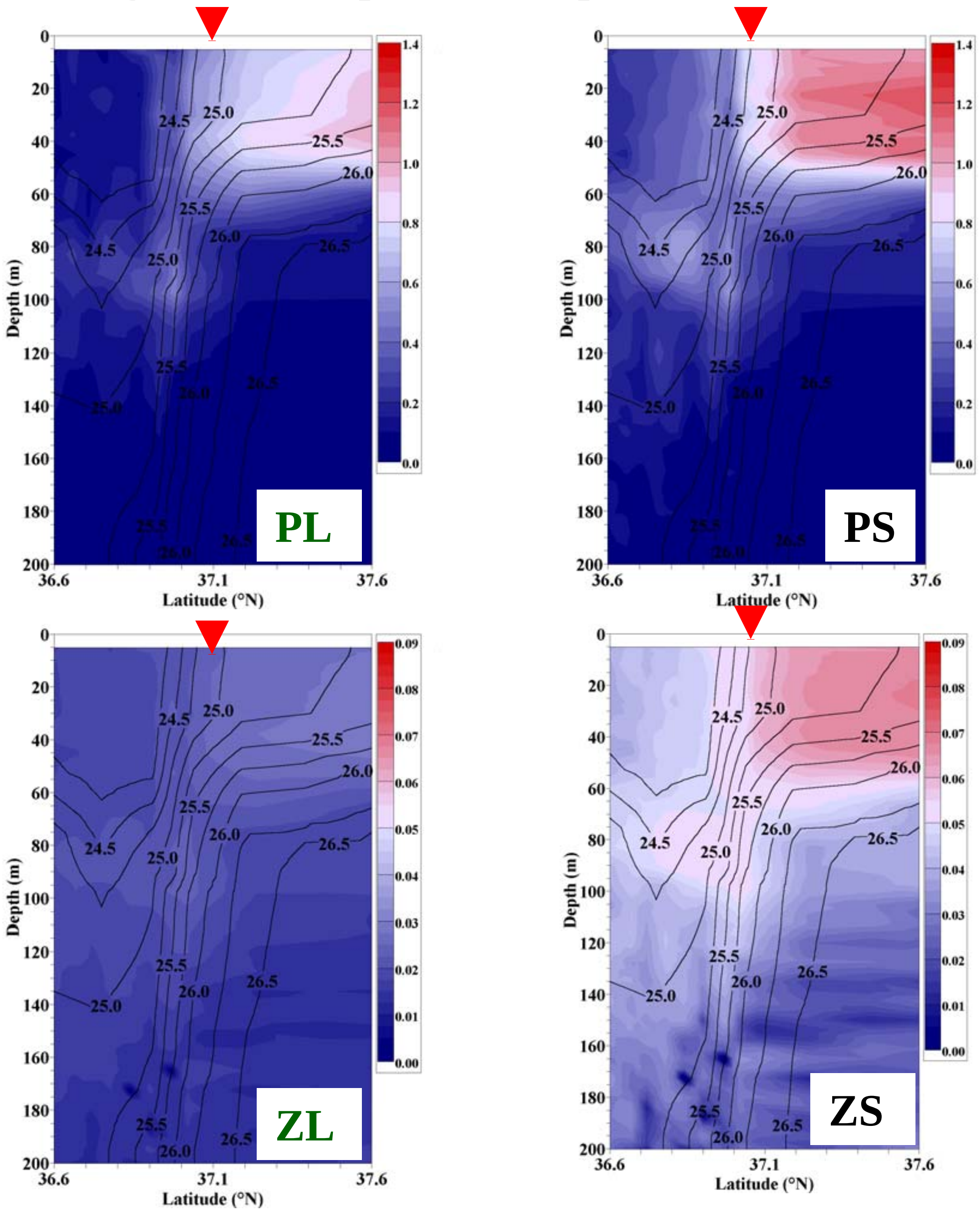




Subsurface max. in the subtropical region

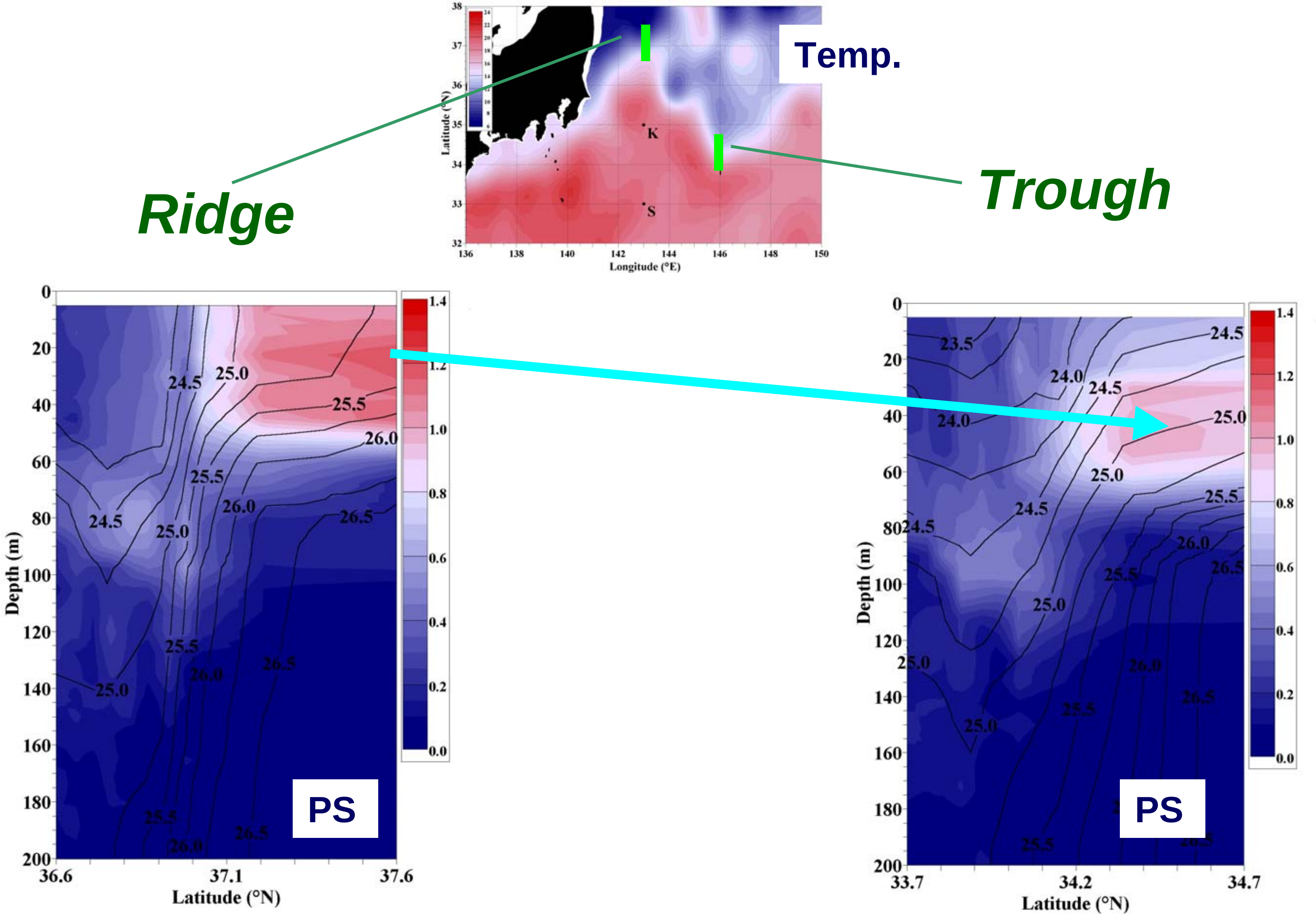
Day 180 (Jun.3)



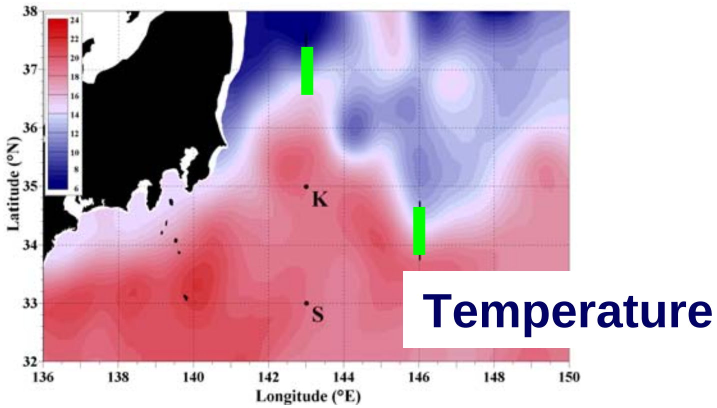


Depleted on the subtropical side

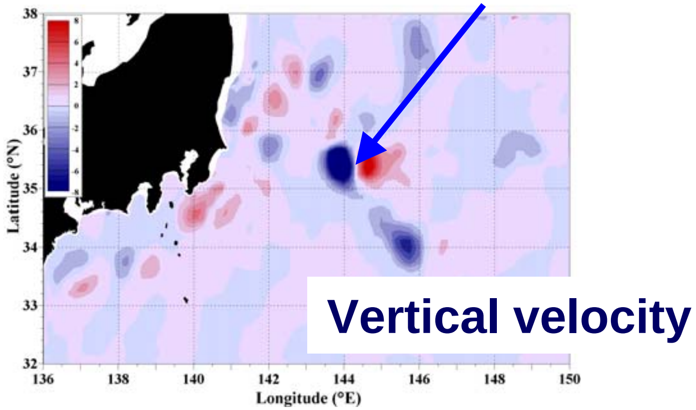
Downward advection along the jet



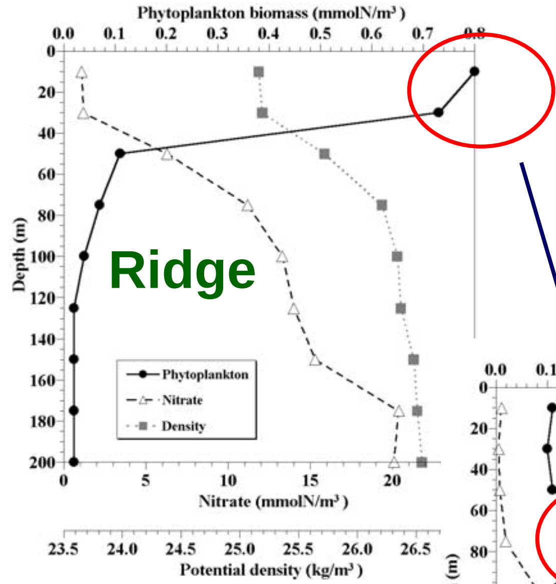
Downward shift of maximum layer due to downwelling



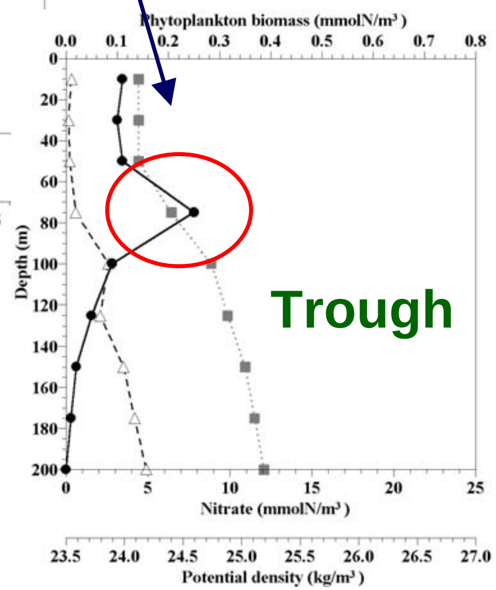
Convergence/
Downwelling



Observation in KE in 1997 Jun.

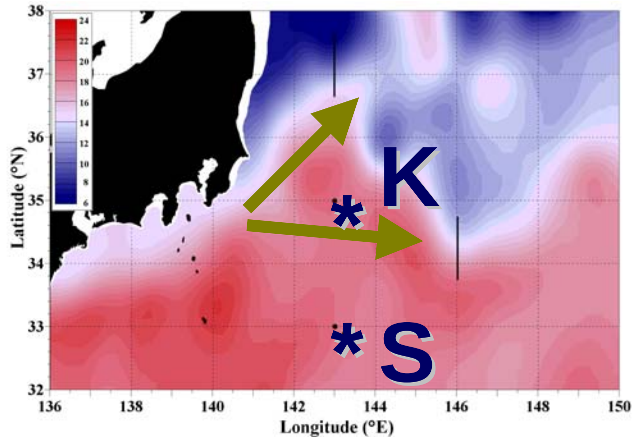


Sasaki et al. (2004)



Size-dependent characteristics of temporal variation of plankton biomass

Fluctuation of the Kuroshio path



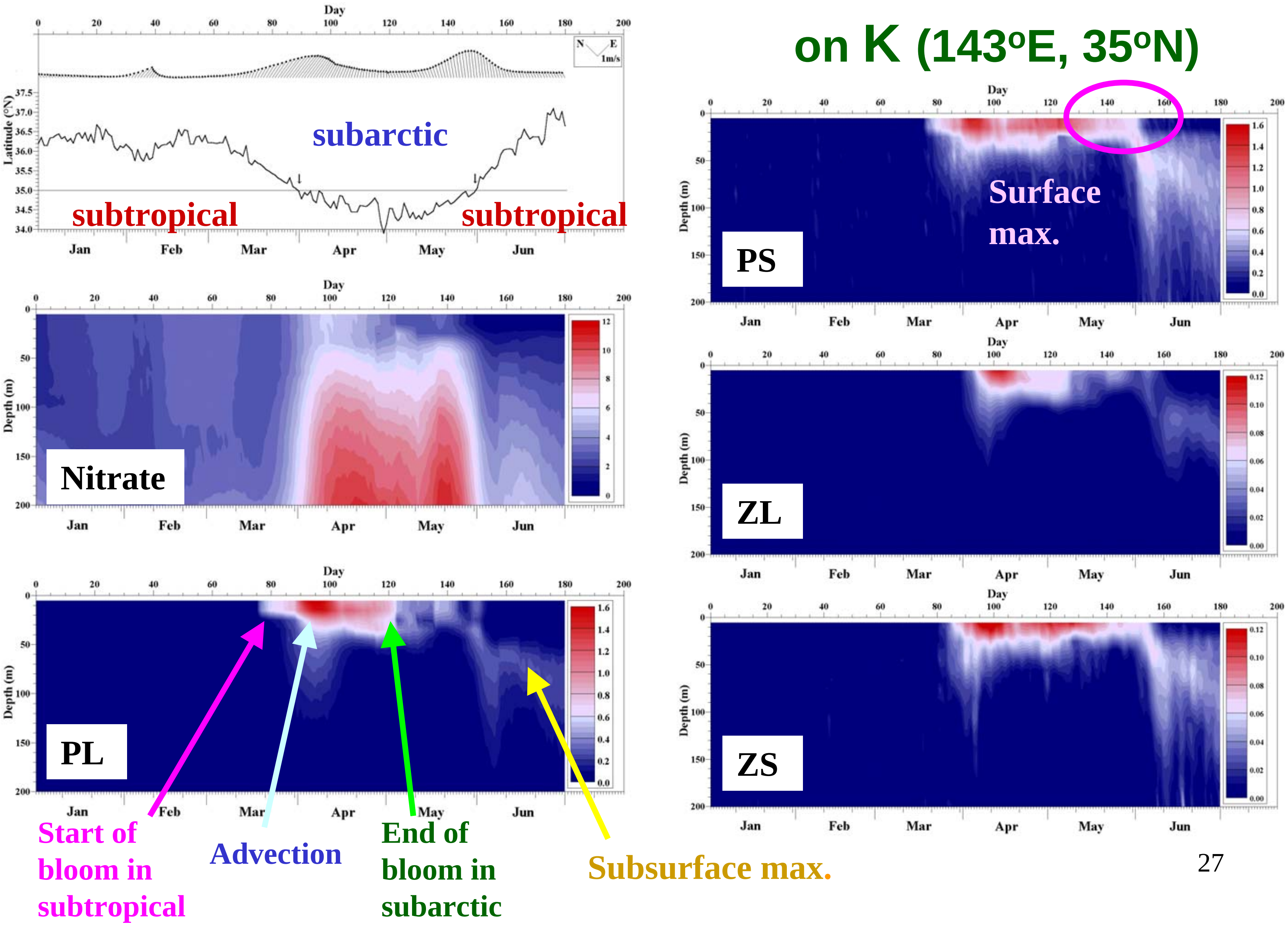
- on K: Water abruptly changed due to

  fluctuation of the Kuroshio path

- on S: all the time in the subtropical region
- Size-dependent variation

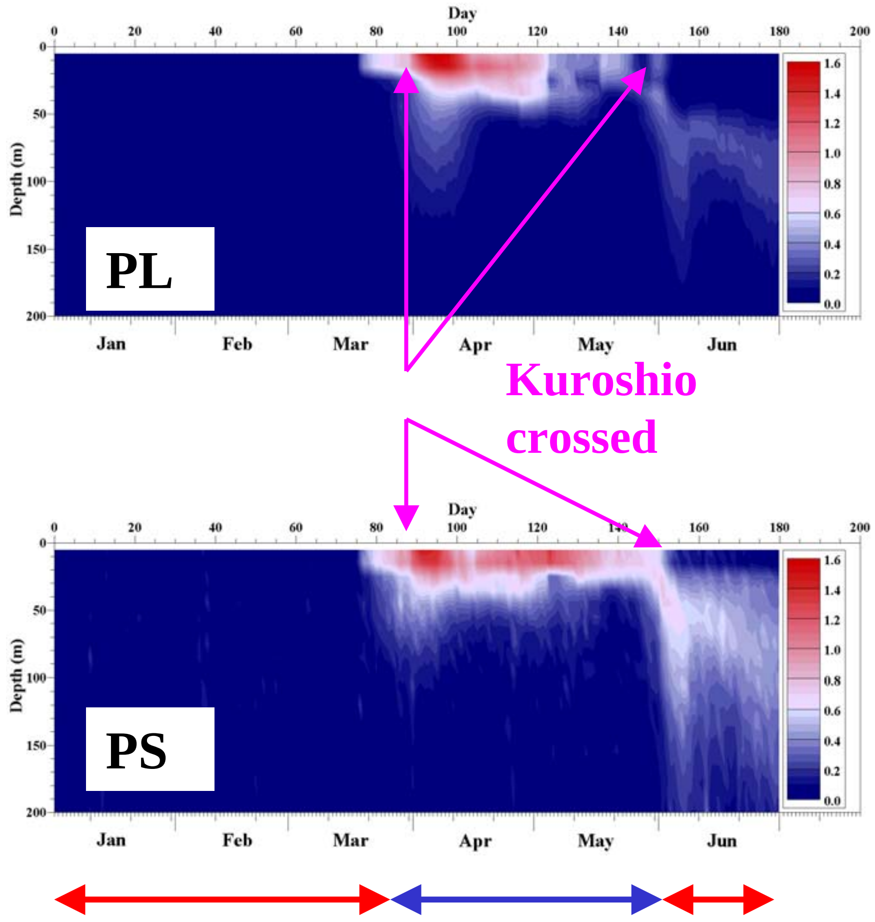
T-Z distribution affected by Kuroshio path

on K (143°E, 35°N)



Affected by fluctuation of the Kuroshio path

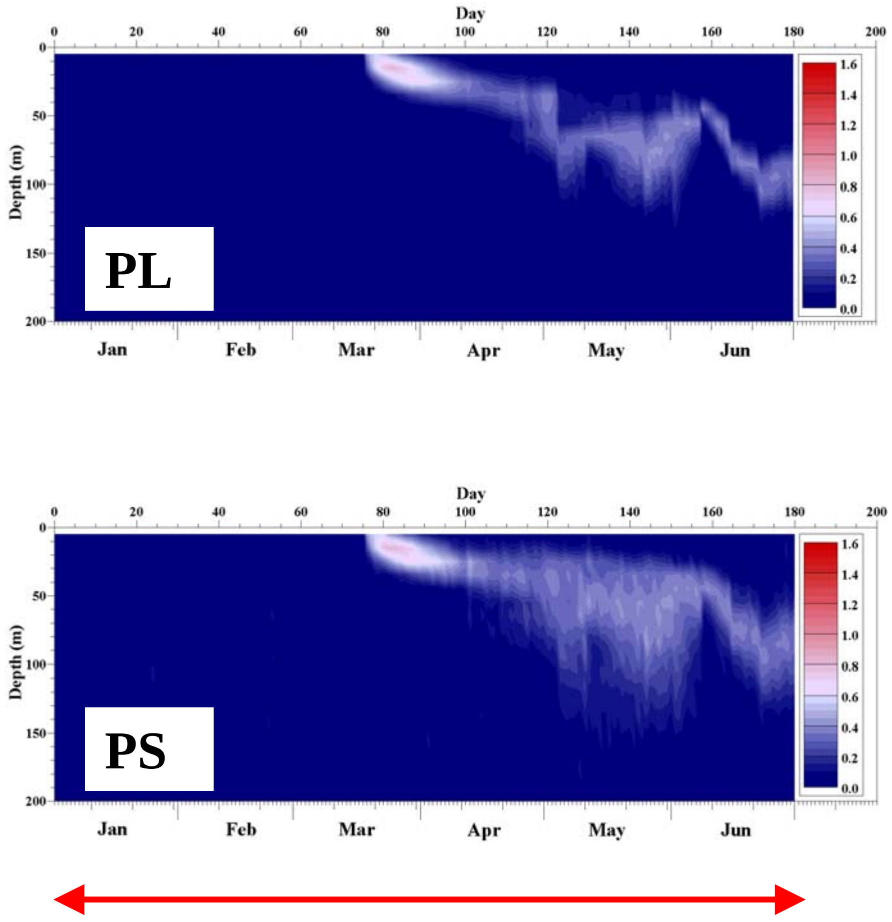
on K (143°E, 35°N)



subtropical subarctic subtropical

All the time in the subtropical side

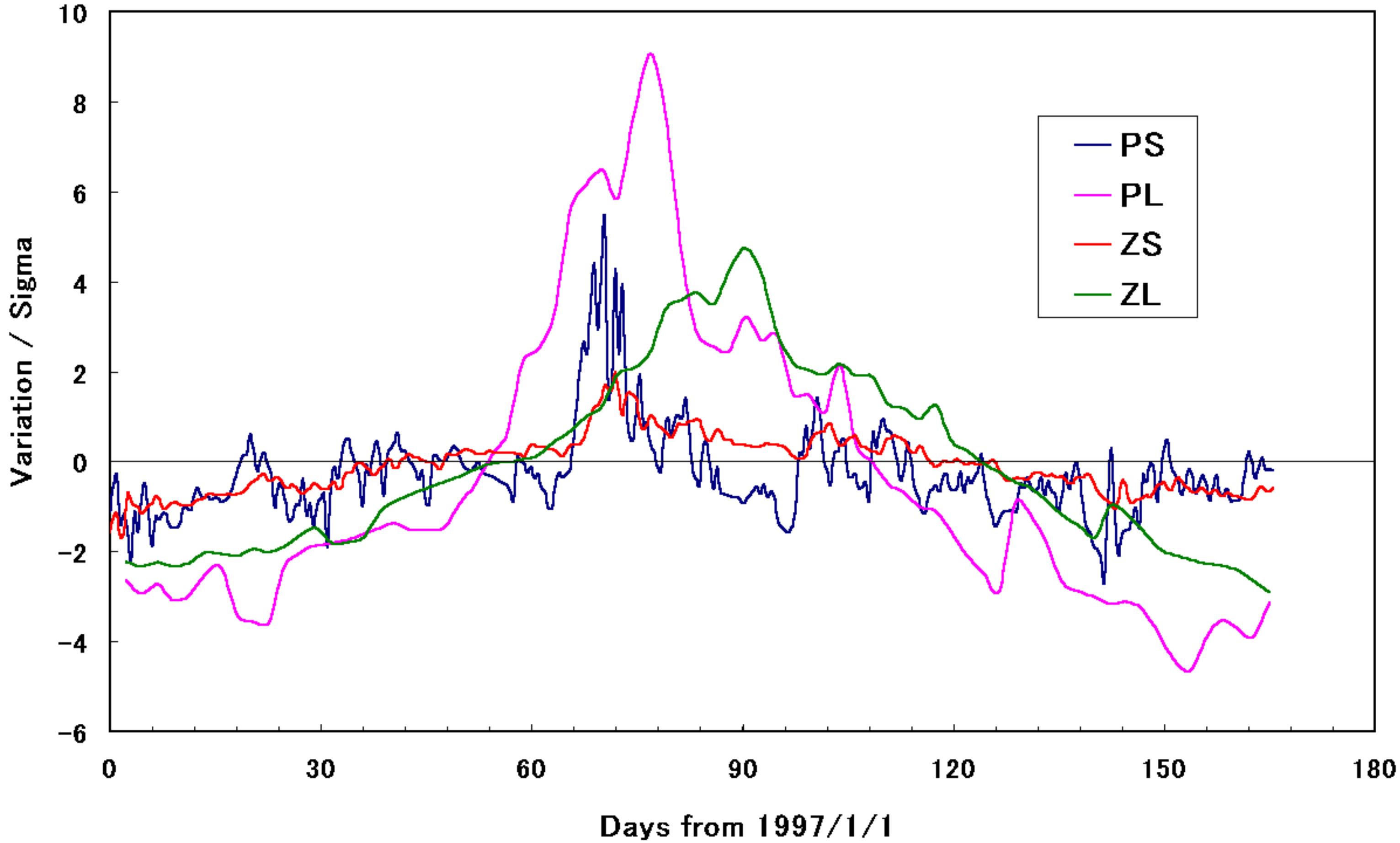
on S (143°E, 33°N)



subtropical side

Size-dependent temporal variation

Average biomass in the region (34.5-35.5N, 141-144E) at 0-200m



Small one indicated robust biomass against abrupt change of environment.

Summary 1-1/2

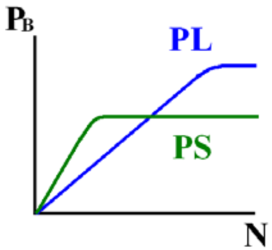
- **Advective effects in the Kuroshio and Kuroshio Extension**

  - High concentration along the jet from the slope water

  - Enhancement in convergence zones

  - Downward shift of maximum layers by downwelling

- **Size-dependent variation of plankton biomass**



  - Daily change: Large < Small

  - Monthly change: Large > Small

  ← Maximum photosynthetic rate: PL > PS

  Half saturation constant: PL < PS

Summary 1-2/2

- **Small plankton biomass was relatively robust against abrupt changes of the environment by Kuroshio fluctuation**

→ Small copepods show smaller annual change than large copepods (Nakata et al. 2001)

→ A possible reason for stability of resource of winter-spawned Pacific saury

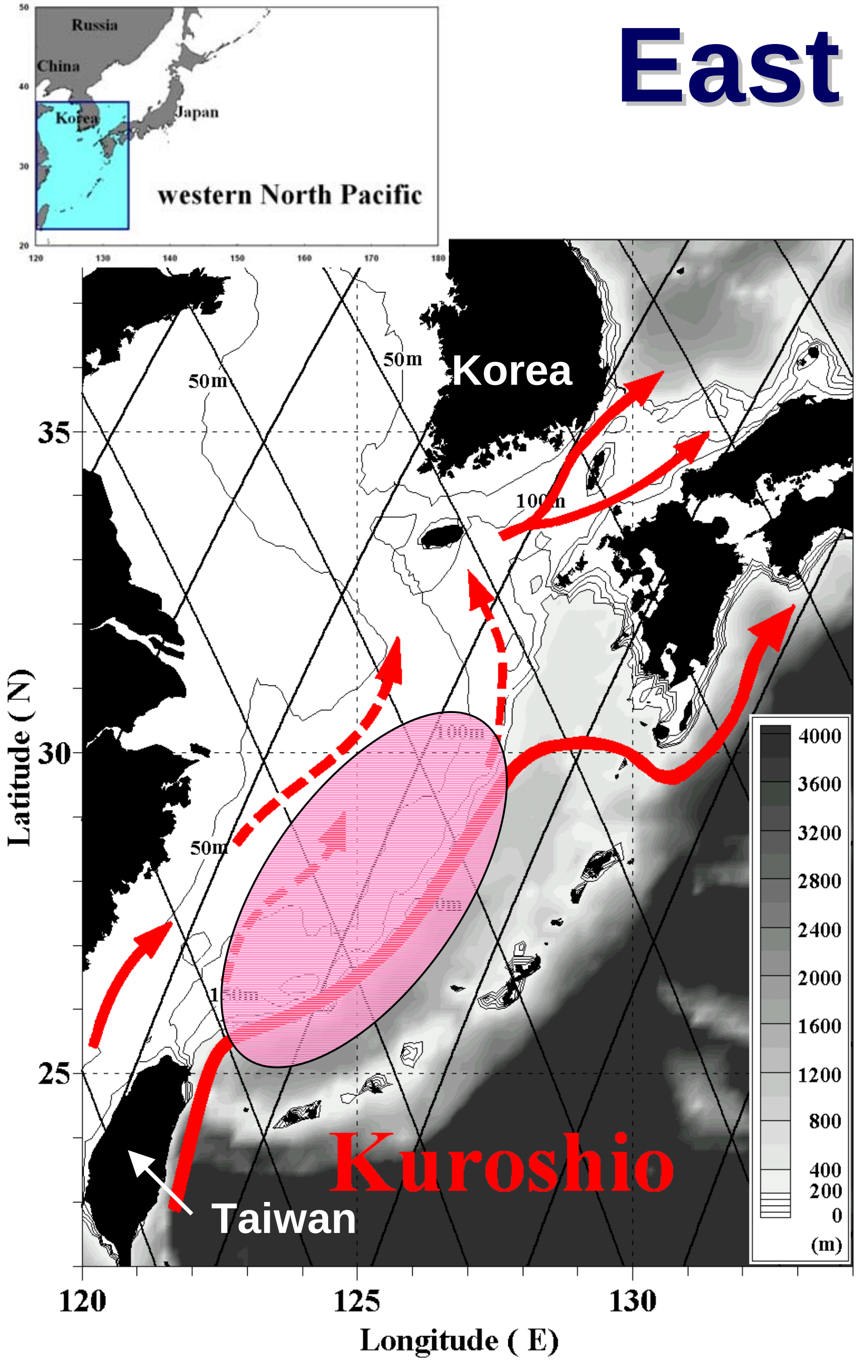
Transportation of fish eggs, larvae and juveniles

1. Effect of eddies in the East China Sea
   - Bifurcation of transportation route

2. Effect of wind- and wave-induced currents
   - transportation across the jet

Bifurcation of transportation route of eggs and larvae
- interaction between jet and eddies -

East China Sea

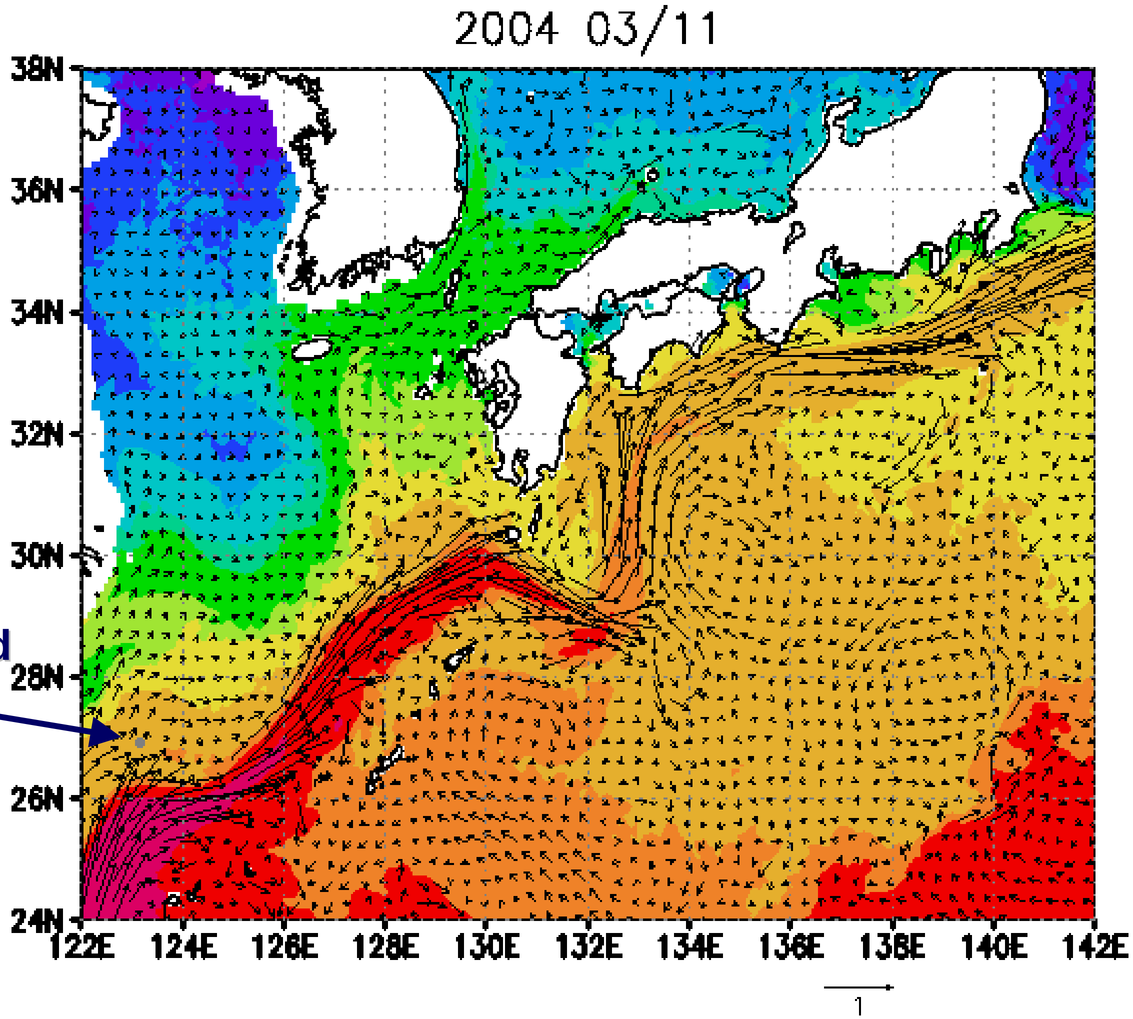


- Spawning ground of jack mackerel, Ommastrephid squid, yellowtail …
- Eggs and larvae are transported to the Pacific, the Japan Sea and coast.

↓

- Mechanism of the Kuroshio bifurcation is unclear（e.g. Katoh et al. 2001, Ichikawa et al. 2001).

Tracer experiment by C-HOPE 2004.3.11-4.30



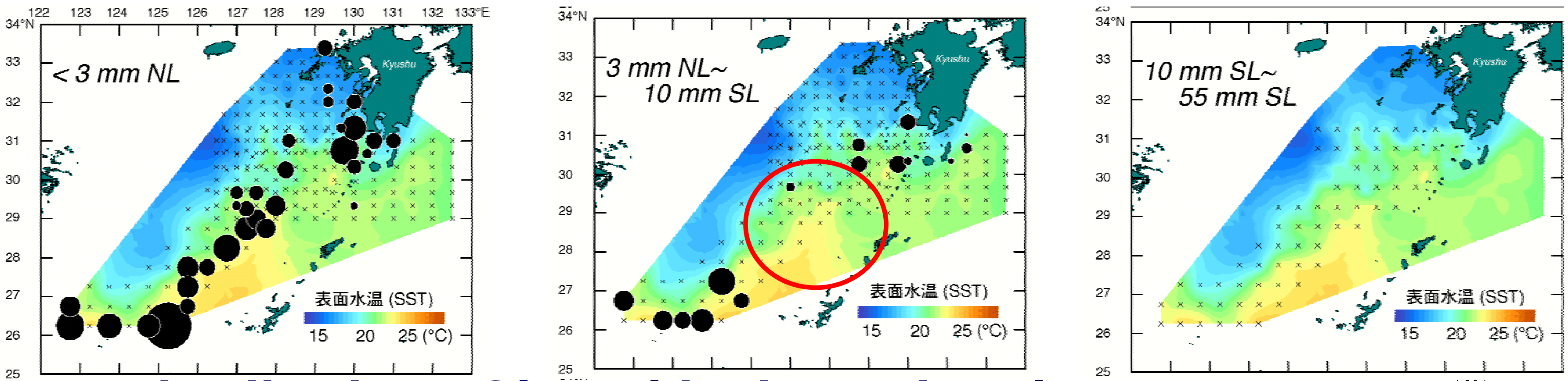
Deployed here

- **400 particles were drifted without death.**
- **Smagorinsky type diffusivity.**

Animation **Temperature & velocity at 20m**

Tracer experiment compared with in-situ sampling 2001.2.15

0-6days | 7-16days | 17-30days



Distribution of larval jack mackerel (Sasa et al. 2002)

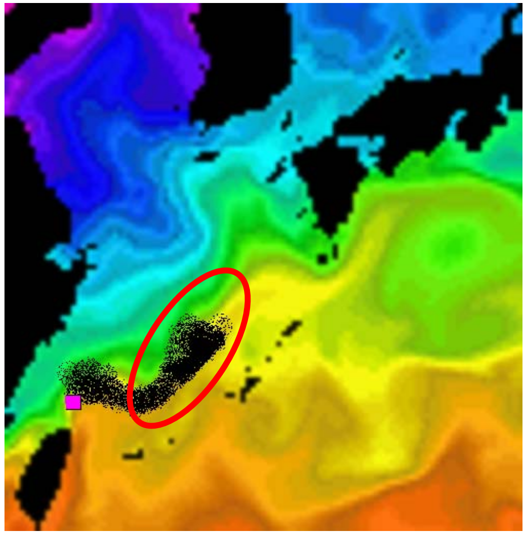
Comparison of larval distribution in Feb. between 2001 and 2002

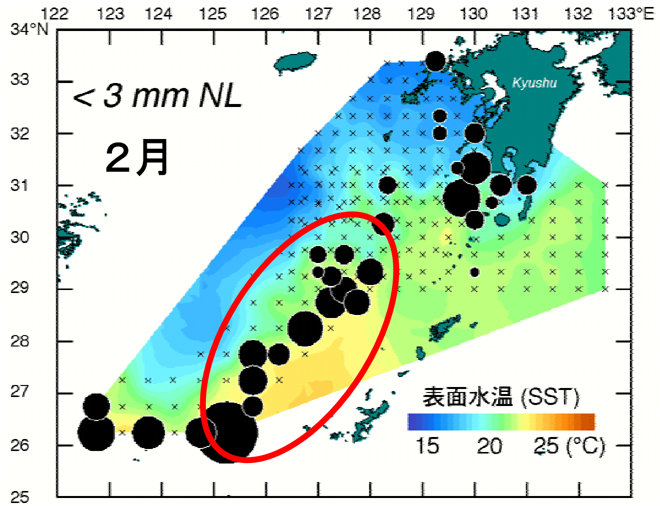
0-6days

< 3mmNL (Sasa et al. 2002)

2001

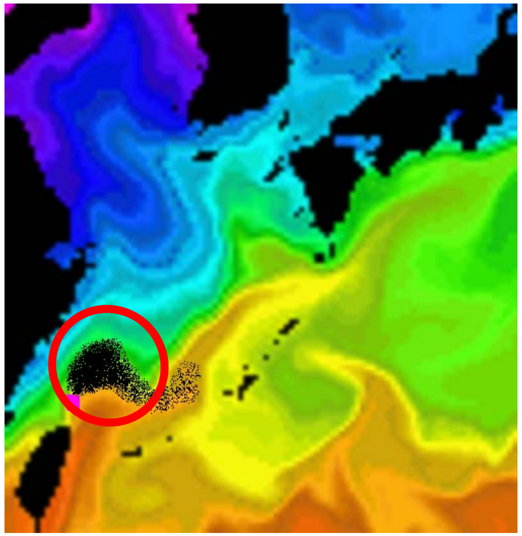
Feb.15-

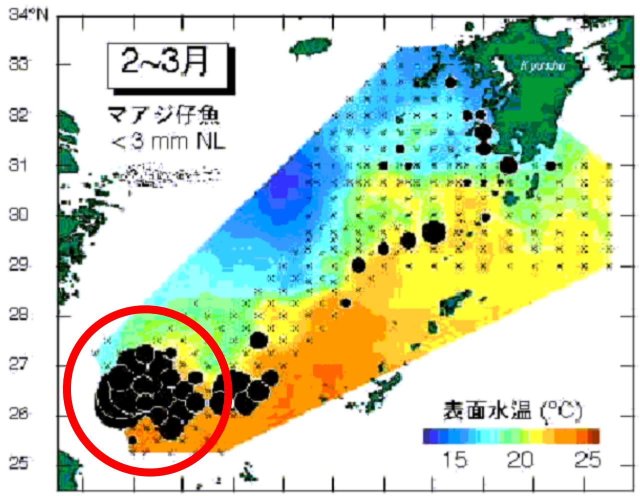




2002

Feb.15-



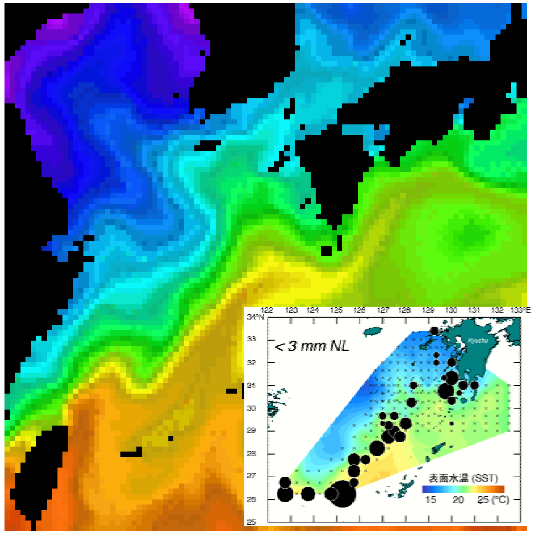


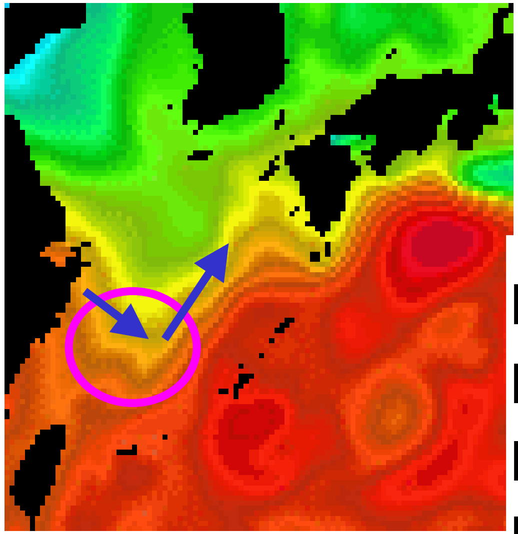
A reason for the discrepancy between 2001 and 2002

MODEL 2/25 SST | **SSH**

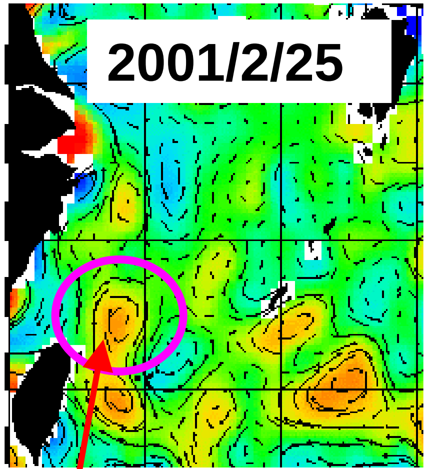
2001

Distributed along the northern edge of the front





Strong clockwise current

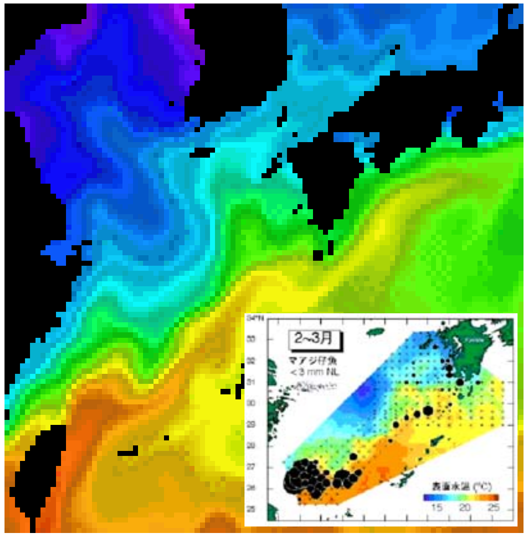


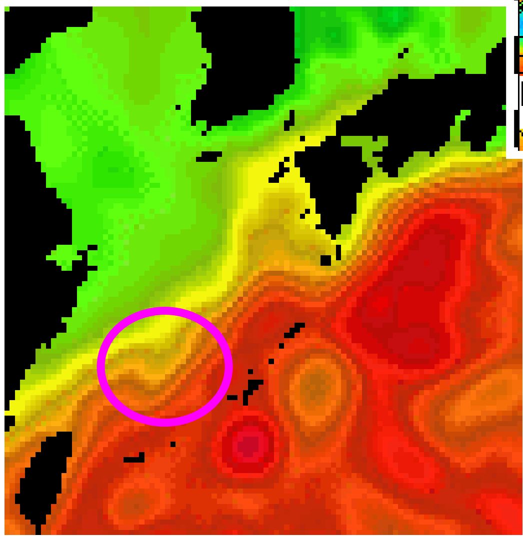
positive anomaly

SSHA (CCAR)

2002

Piling up on the northern side of Taiwan

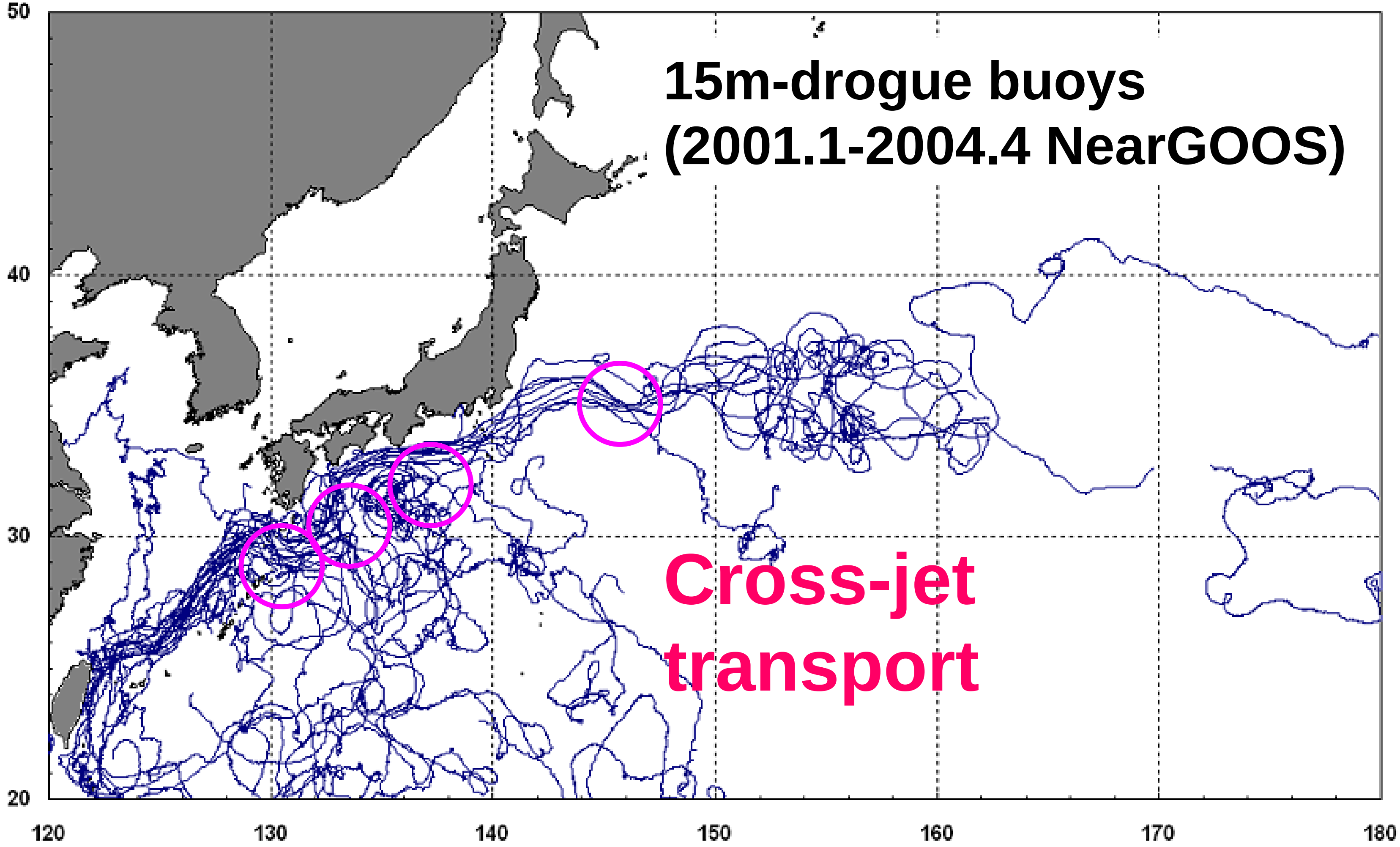




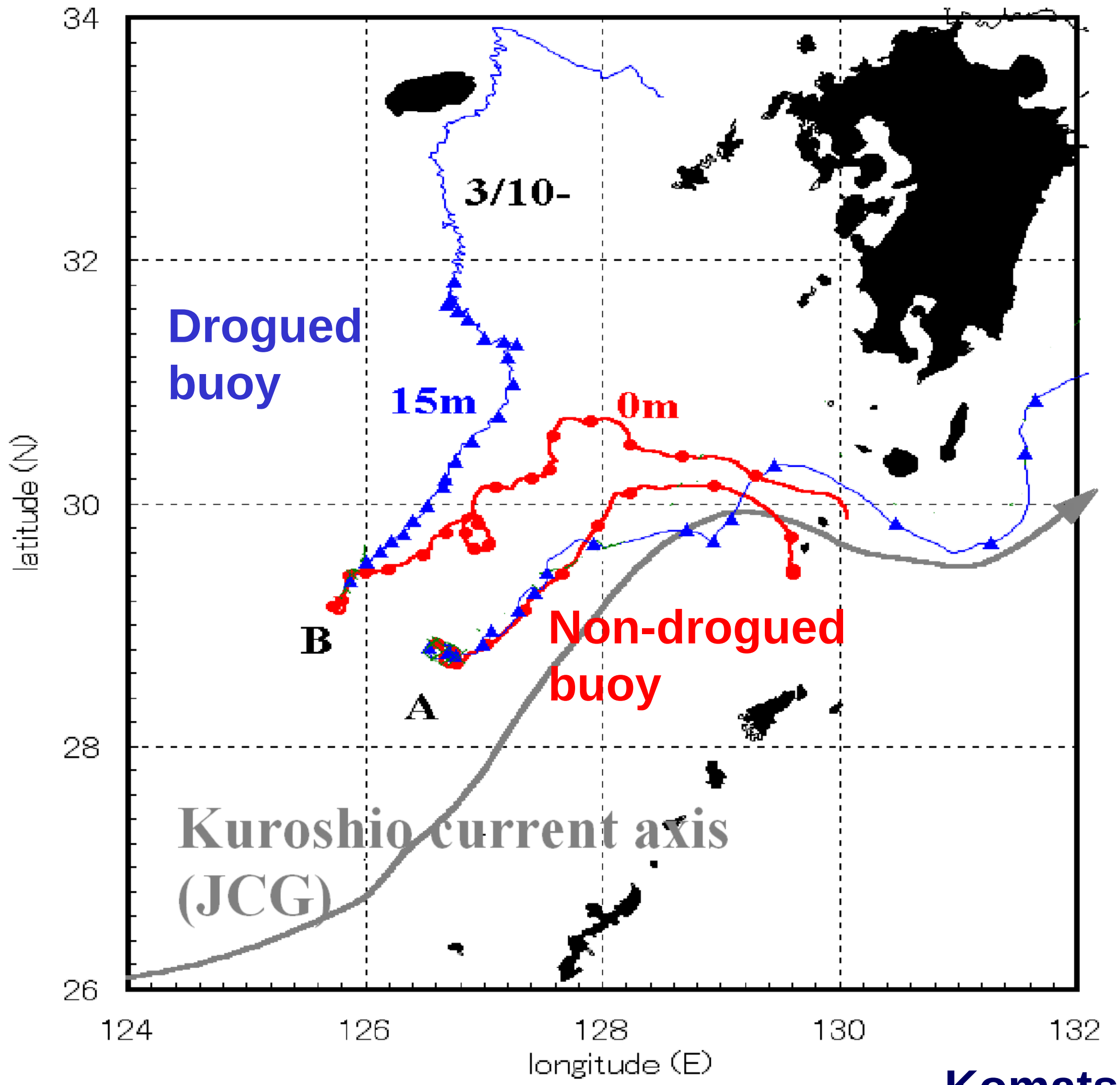
Cross-jet transportation

- Effect of wind- and wave-induced currents -

Trajectories of drifting buoys in the Kuroshio region

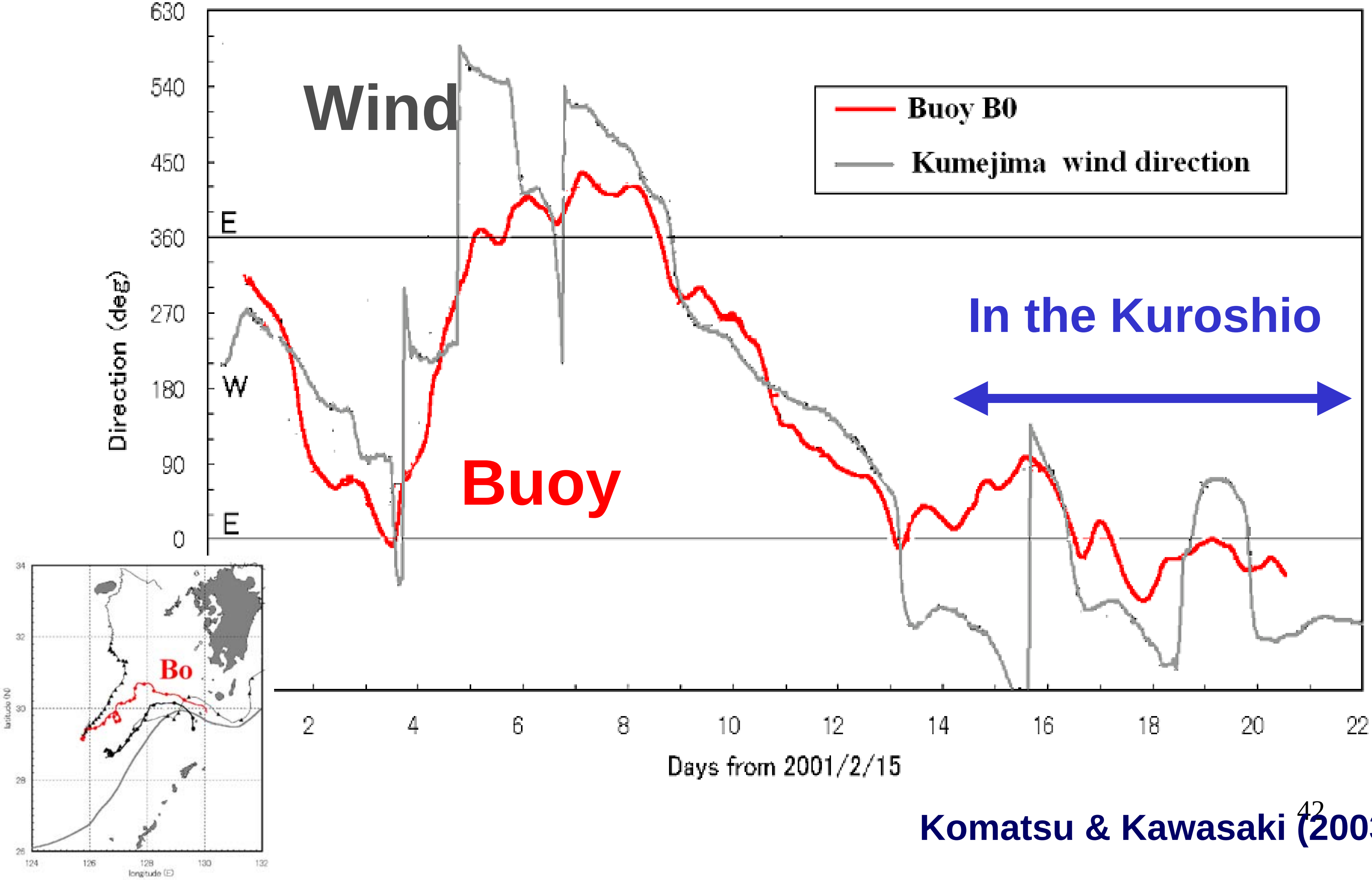


Trajectories of drifting buoys 2001.2.15-3.9



Komatsu & Kawasaki (2003)

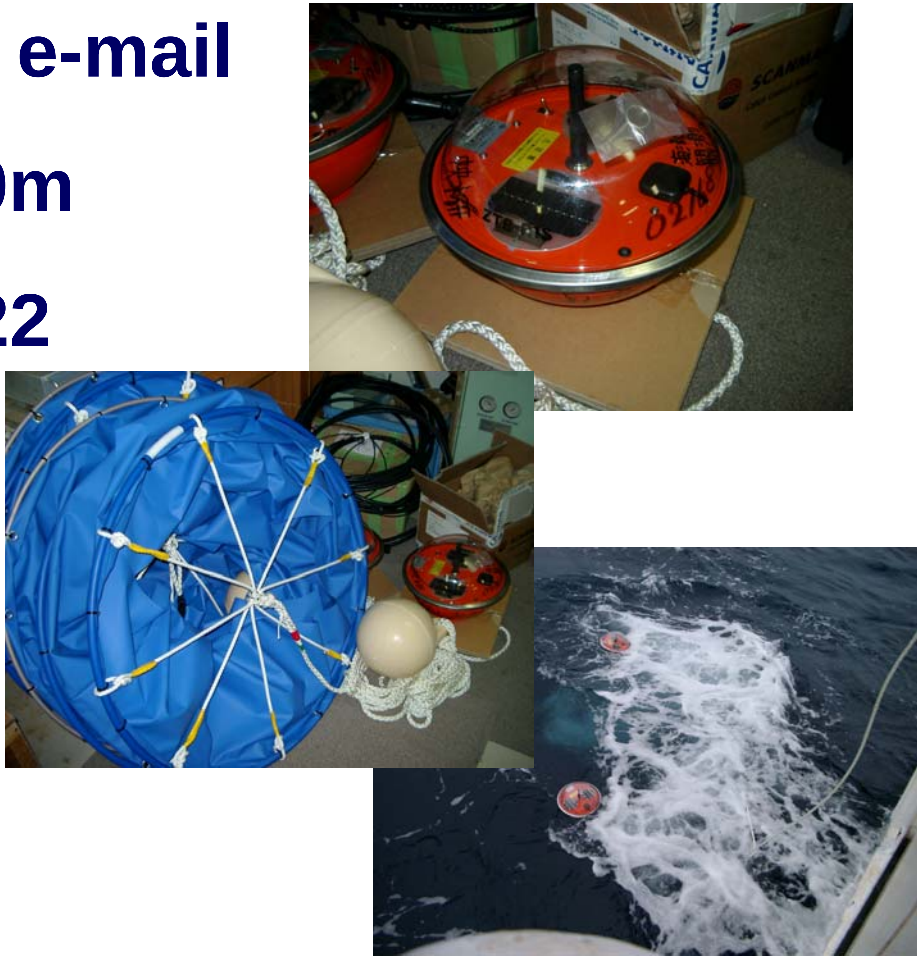
Buoy direction vs. Wind direction in Kumejima Is.



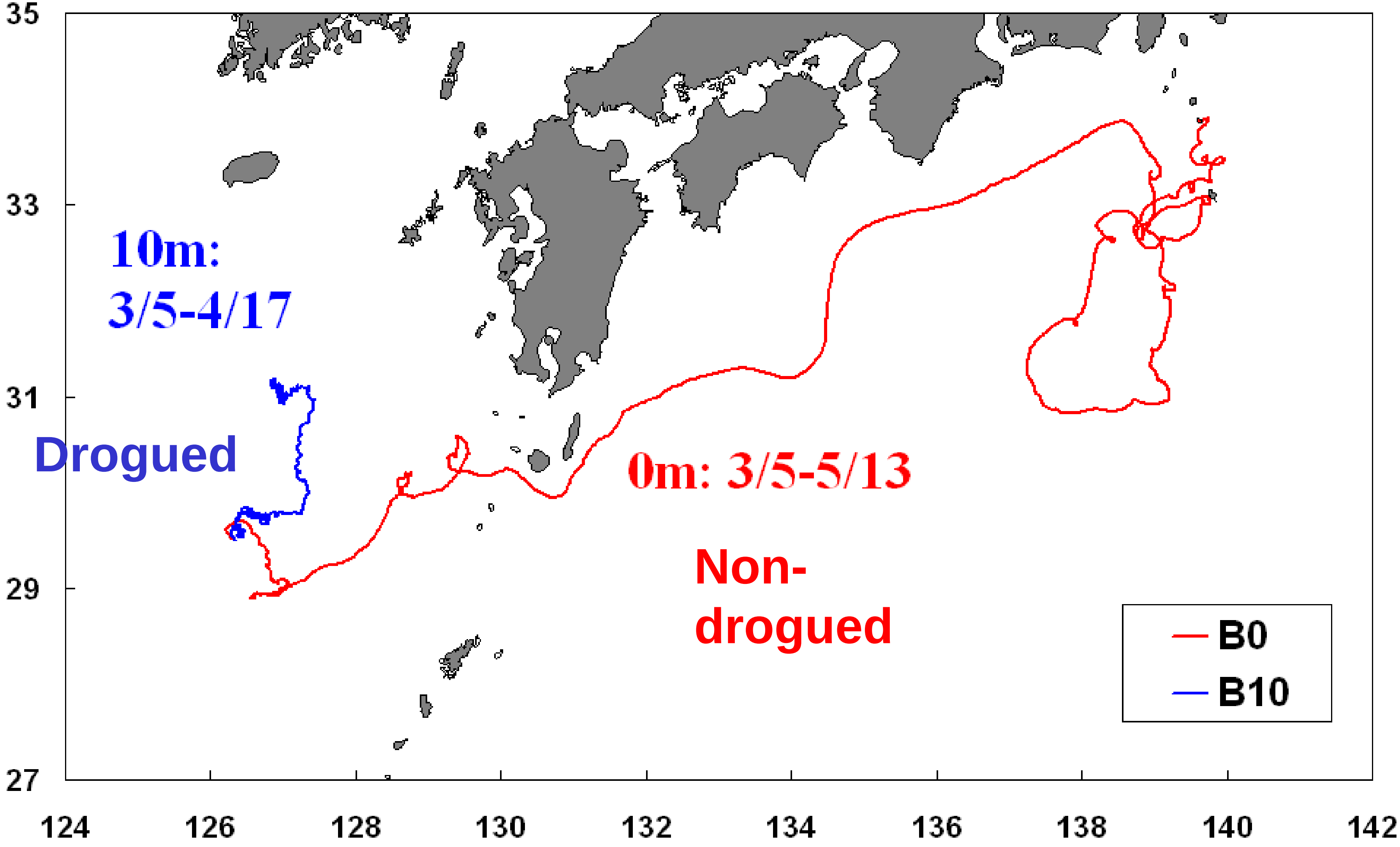
Komatsu & Kawasaki (2003)

Buoy Observation in 2003

- Orbcomm GPS buoy (Zenilite buoy Co.)
- Data transmission by e-mail
- Position accuracy: 10m
- Period: 2003.3.05-5.22
- Data interval: 60min
- Drogue: none/10m



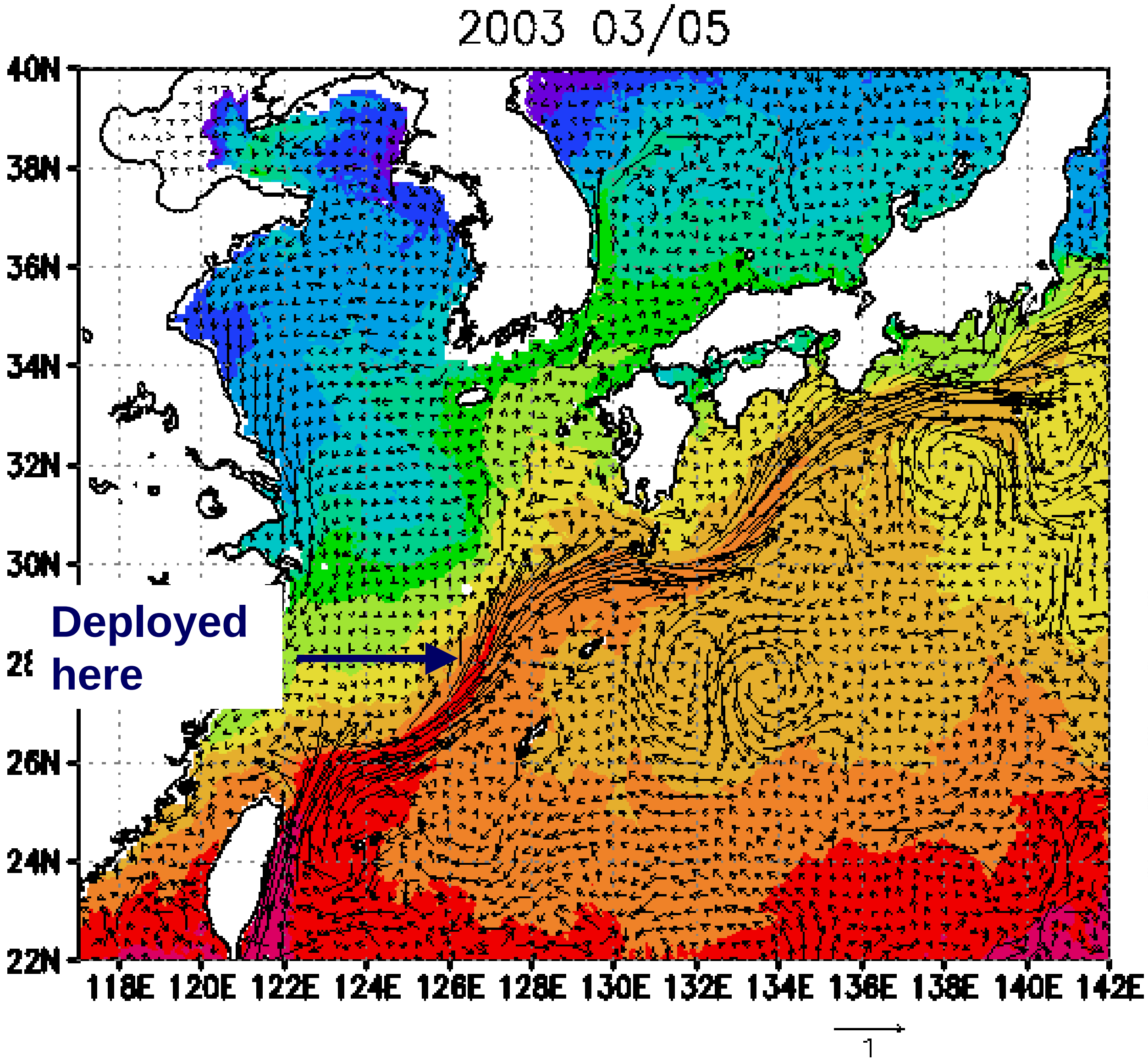
Buoy Trajectories in 2003.3.5- 4.13

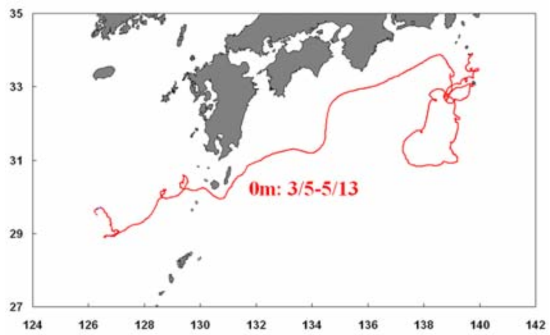


Tracer experiment compared with drifting buoy observation

- **Number of pseudo-particles: 400**
- **Velocity: JCOPE reanalysis (2days mean)**
- **Period: 2003.3.05-5.29**
- **Layer: 0m, 10m**
- **Resolution: 1/12^{o}**
- **Diffusion: Smagorinsky type**

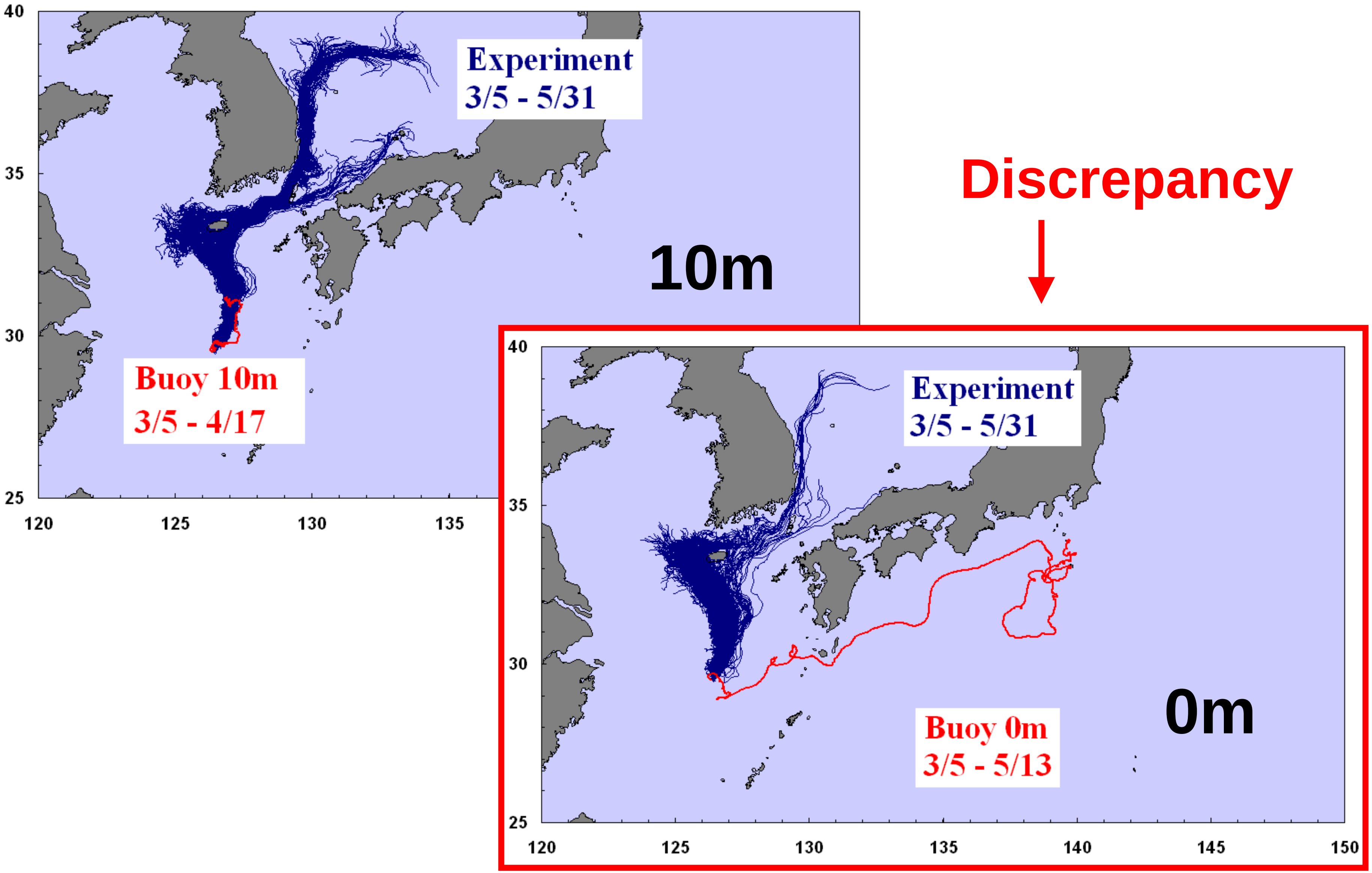
Tracer experiment for no-drogue buoy



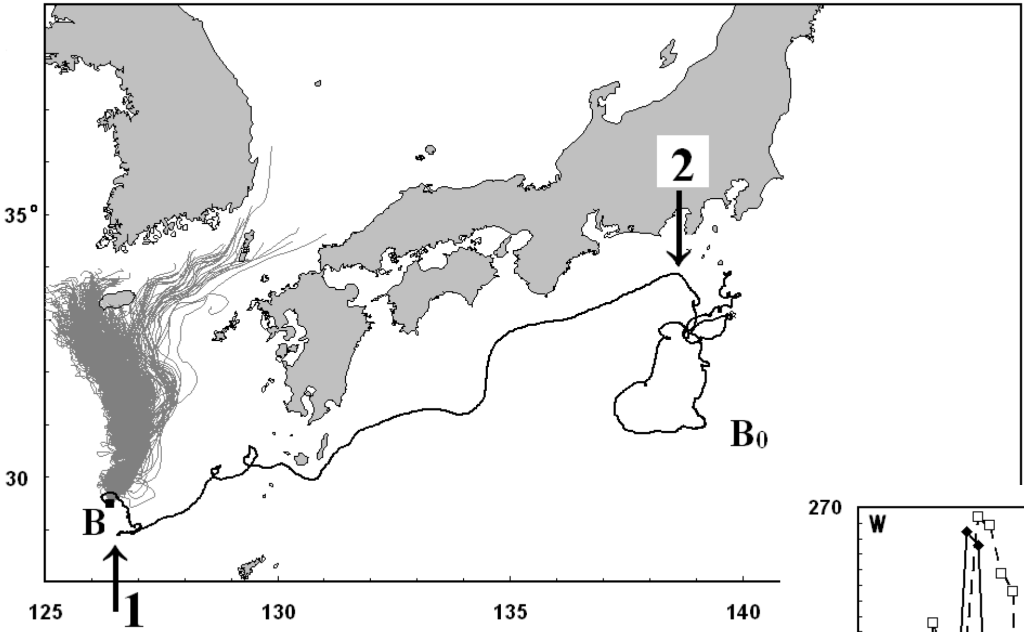


Animation **Temperature & velocity at surface**

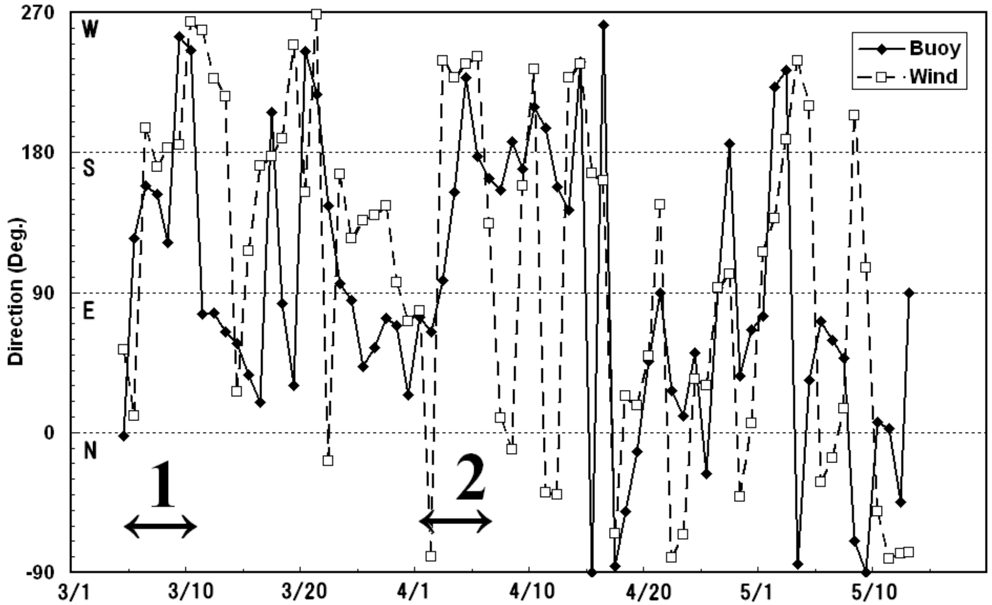
Tracer experiment vs. Buoy



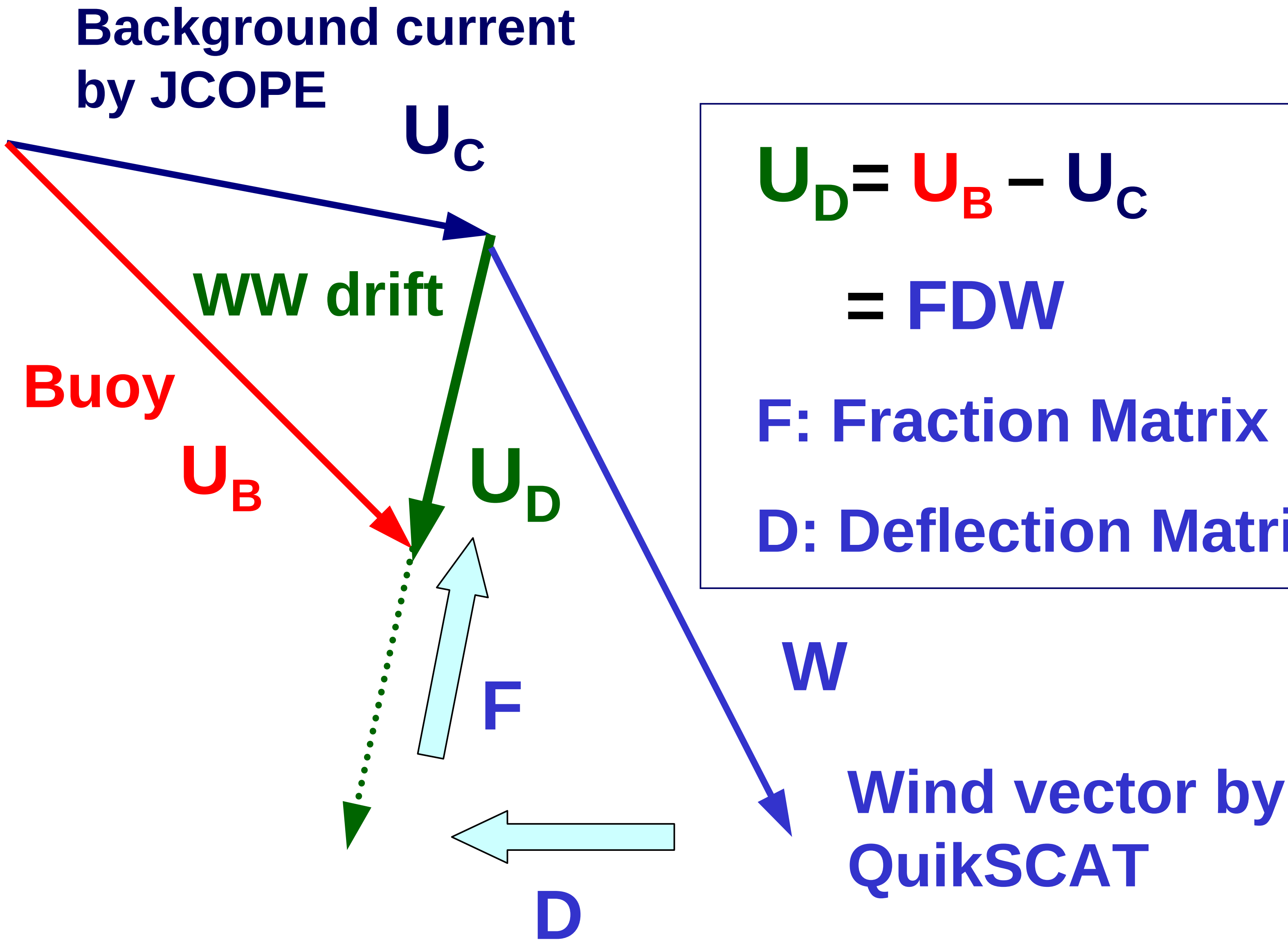
A reason for discrepancy: Wind effect



Buoy drift direction vs. Wind direction



Estimation of Wind- and Wave-drifting effects



$U_D = U_B - U_C$

$= FDW$

F: Fraction Matrix

D: Deflection Matrix

Seek Deflection angle θ and Fraction β

as to make Cor. between $U_B - U_C$ and FDW maximum

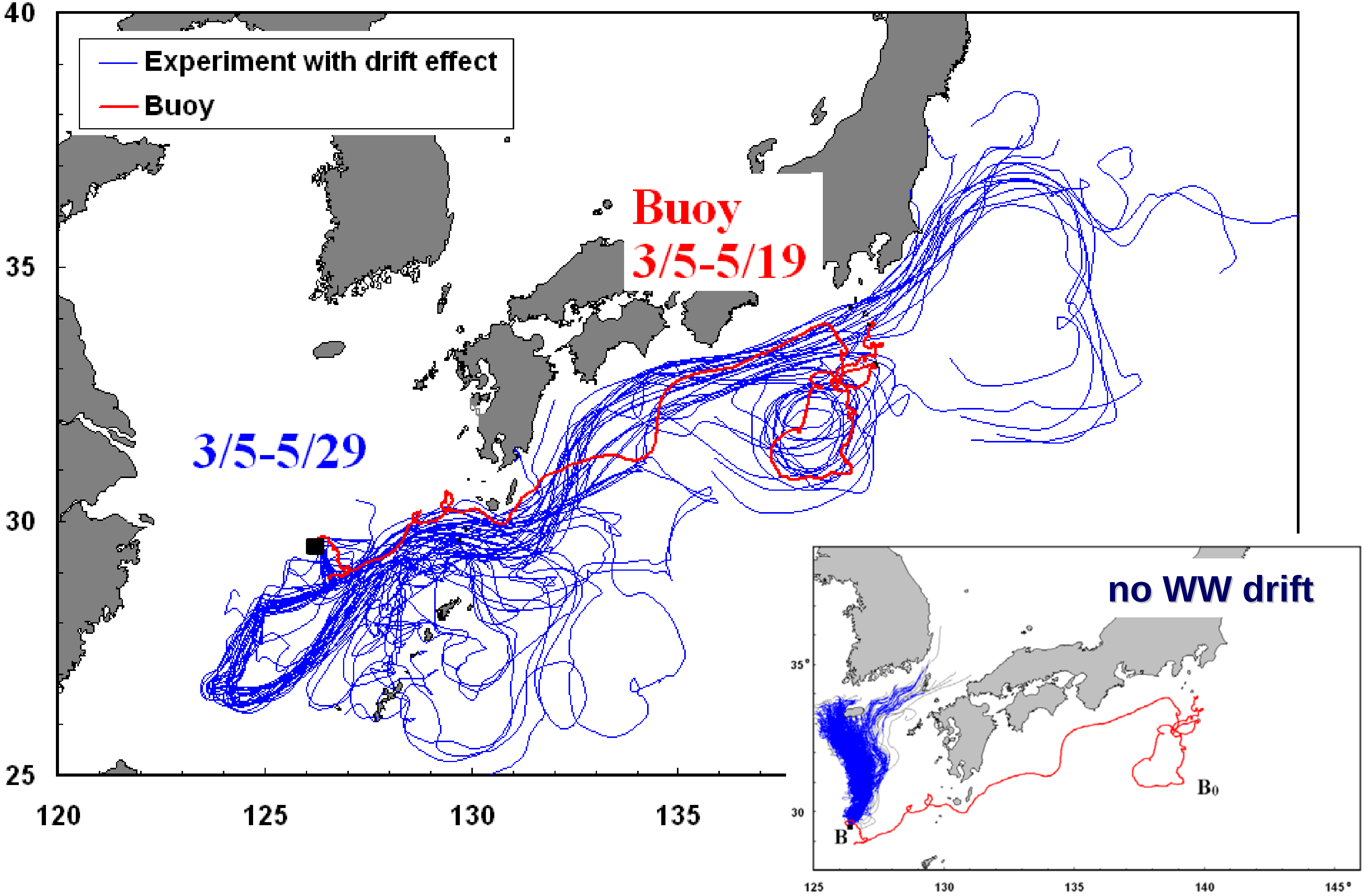
Buoy	drogue	CC (no drift effect)		CC (with drift effect)	θ	β
B	none	0.58 / 0.43	→	0.69 / 0.59	25	0.041
B	10m	0.15 / 0.67	→	0.40 / 0.81	-16	0.024

+0.15

$\beta = |U_D| / |W|$

Author(s)	Test condition	θ	β
Weber (1983)	Theoretical (Steady)	23-30	0.031-0.034
Jenkins (1986)	Theoretical (Variable)	23-30	0.03

Tracer experiment with WW drift effects



Summary

- Distribution of larval jack mackerel is almost determined by current field, when it is critically affected by interaction between jet and eddies.
- Wind- and wave-induced currents possibly bifurcate transportation routes of surface matters (eggs, larvae, seaweeds,…).
- A small difference of the horizontal (vertical) position of matters makes their routes drastically by eddy- (wind-) effect.

Future plan

- **Refinement and extension of 3D-NEMURO**

  - Utilizing e-NEMURO applicable to both the subarctic and subtropical regions (Yoshie& Yamanaka 2004)

  - Coupling with NEMURO.FISH

  - Coupling with a tracer model with biological processes and wind- and wave-drifting effects

- **Reaction experiment for the Pacific-wide climate change**

  - Effect of warming-up (changes of current and wind systems, change of hydrographic structure,…) on biomass change and species transition

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