Toward CREAMS 3.0:
recent achievements of collaborative studies in the northern Asian marginal seas and future challenges for sustainable development of the region

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PICES

POI FEB RAS

CREAMS

Outline

1. Brief history of AP-CREAMS
2. Main results in the EAST-I

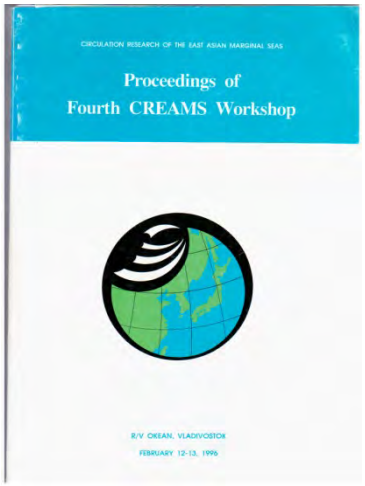
   -Mechanisms and changes in the deep ventilation system

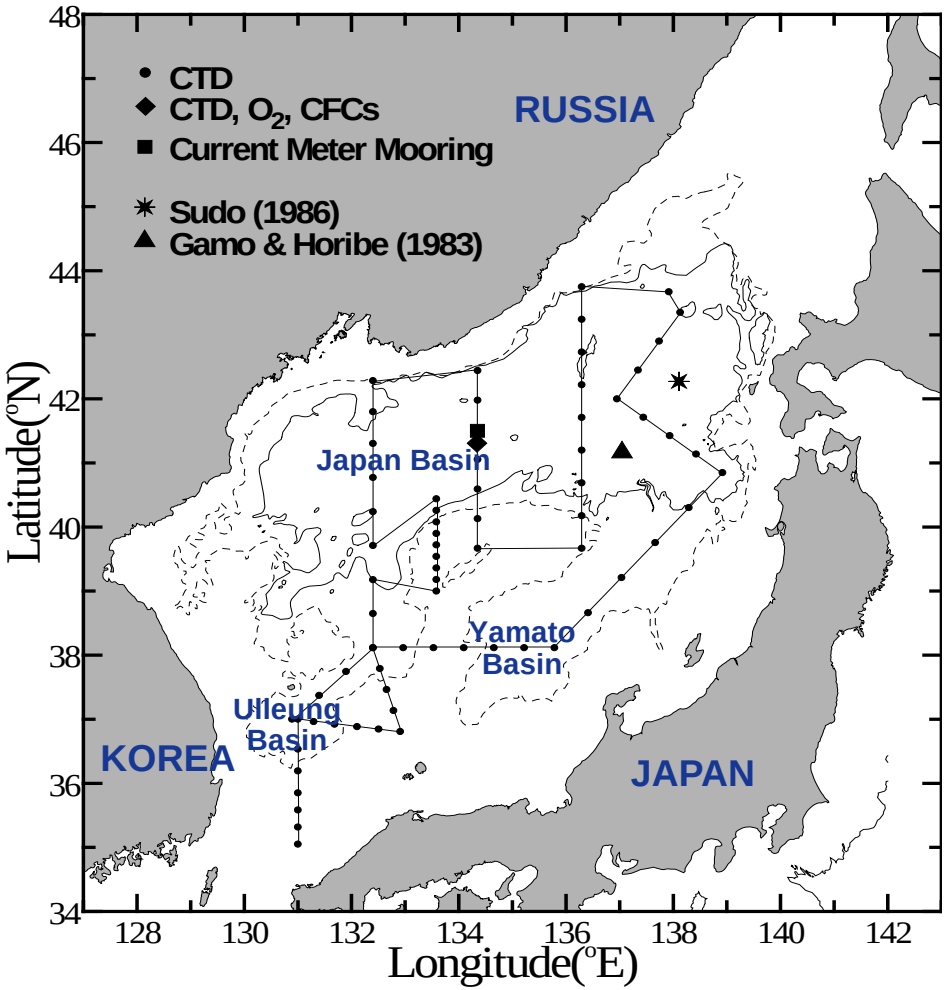
   -Mesoscale water dynamics (eddies, upwellings)
3. Further development – CREAMS 3.0

First international program - CREAMS 1993-1998

(Japan, Korea and Russia)

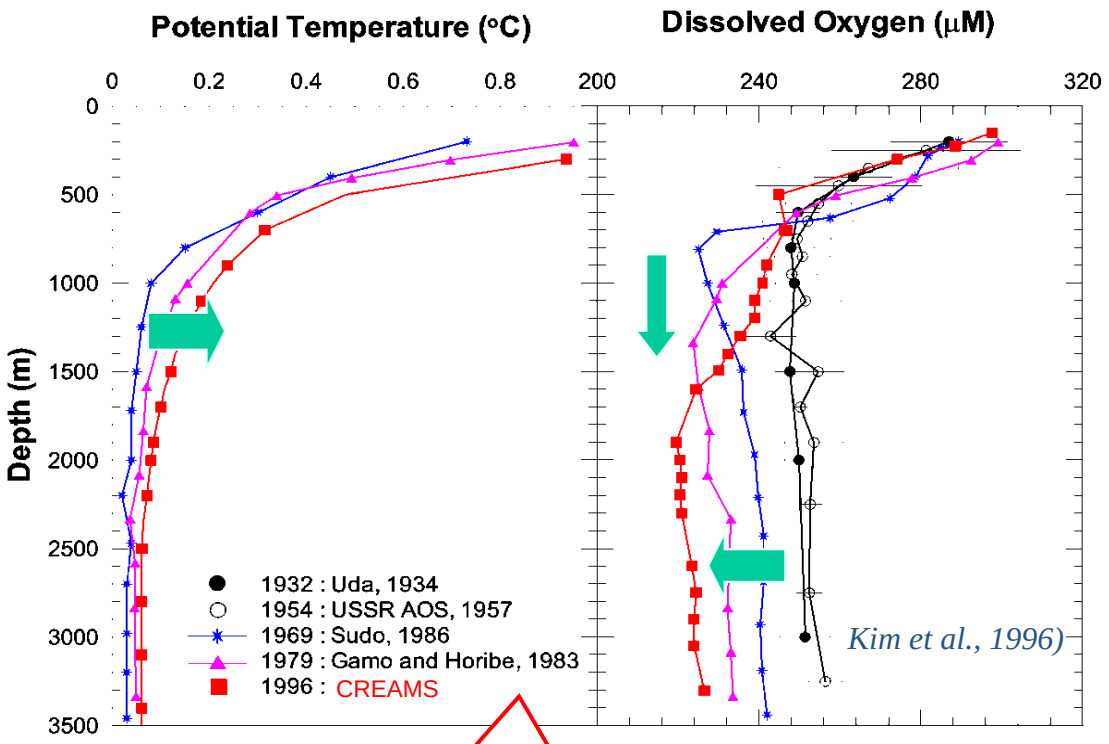
Circulation
Research of
East
Asian
Marginal
Seas





- Ventilation mechanism and locations
- Water mass structure
- Circulation
- Mesoscale eddies

CREAMS Highlights: slowing down ventilation system



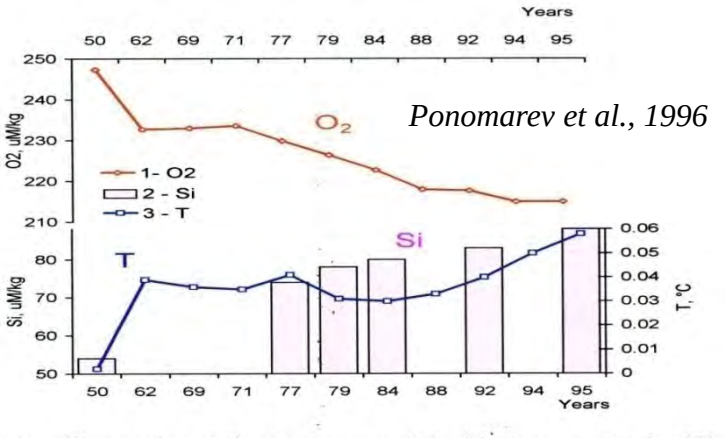
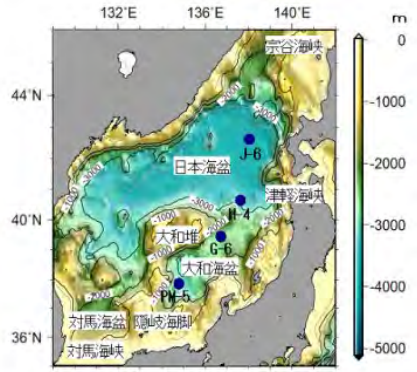


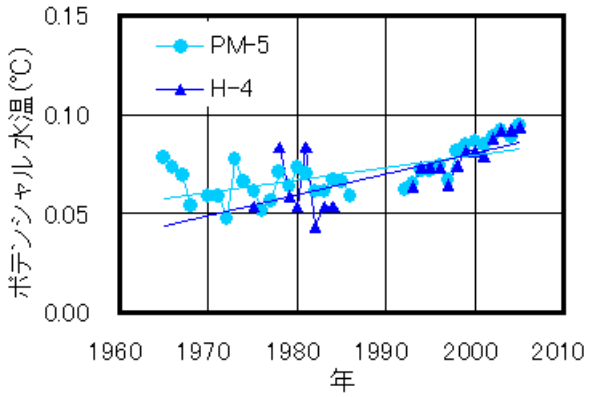
Fig. Time series of dissolved oxygen (1), silicate concentration (2) and potential temperature (3) in the bottom layer (2500-3500) of the Japan Sea from 1950 to 1995 years.

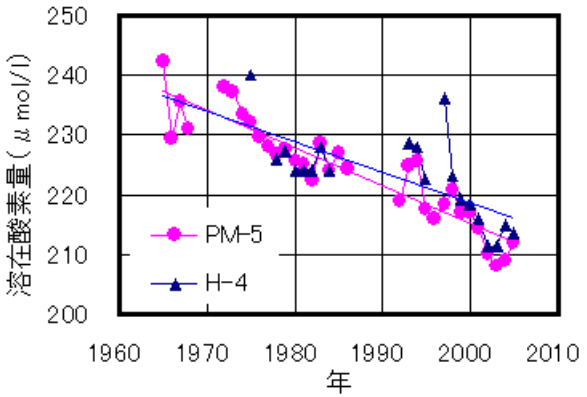
Long-term changes of T and DO at 2000 m in the Yamato basin by *Maizuru Marine Observatory, JMA*



Gamo, 2006

Warming and oxygen decreasing of bottom water- changes in ventilation system





WG 10 on Circulation and Ventilation of JES

PICES Press: Volume 5 Number 2 (July 1997)

Cochairmen of WG 10, Drs. Sang-Kyung Byun and Christopher N. K. Mooers

F1. A high-level of scientific background information exists (especially due to CREAMS), but a comprehensive understanding of the general circulation and ventilation that is sufficient to support fully the needs of future studies regarding climate variability and change, pollution, fisheries, ecosystems, and biogeochemical fluxes has not yet been achieved.

- R1. Proceed to achieve the necessary level of understanding and encourage the coordination of PICESGLOBEC, PICES-JGOFS, etc. activities with PAMS/JECSS, CREAMS II, NEAR-GOOS, and their follow ones.
- R2. Future international studies should build upon recent CREAMS and fisheries science experience, expertise, and infrastructure.
- R3. Encourage development of such studies (e.g., CREAMS II) on an international basis.

PICES meets CREAMS: PICES VI, Pusan, Korea, Oct. 1997

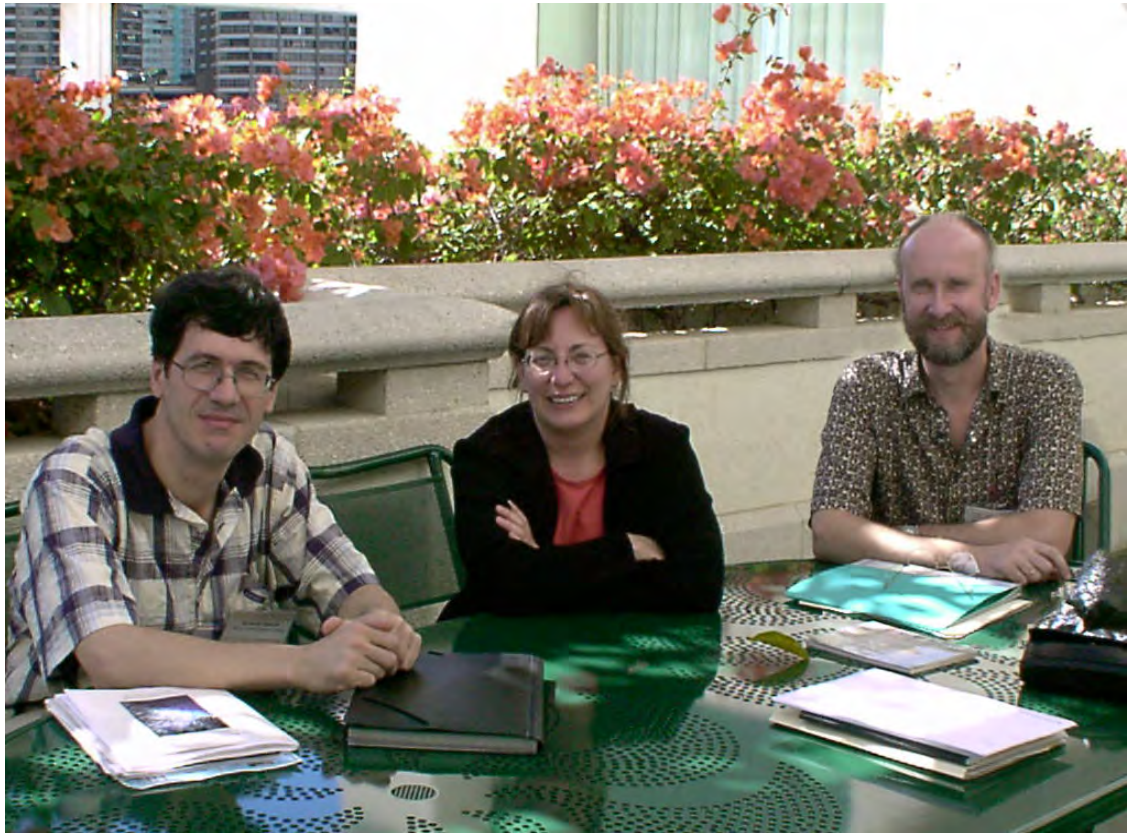
PICES Press: Volume 6 Number 1 (January 1998)

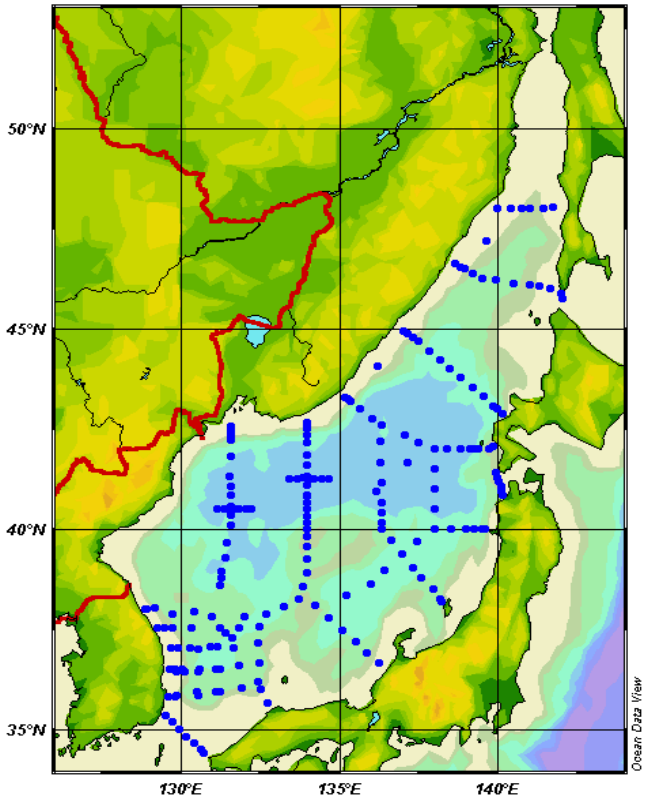
Drs. M. Takematsu, K. Kim and M. Kashiwai at the PICES VI Annual Meeting, Haeundae Beach, Pusan, Korea

Another potential but important achievement was the proposed initiation of a new research program under PICES on East Asian Marginal Seas. At the opening session, **Dr. Kuh Kim proposed a collaboration between PICES and CREAMS** and an extension of the program to involve biological and ecosystem studies. The POC and the Science Board recognized the scientific value of the second phase of CREAMS (CREAMS-II) as a valuable component of research to be conducted within the PICES framework. The PICES Governing Council accepted Science Board's proposal to hold a CREAMS workshop in conjunction with PICES VII.


CREAMS-II (1998-2002)
International Meeting
April 28 - 29, 1998 Seoul, Korea

PICES supported CREAMS-II (ONR JES DRI), 1999-2001





JES Basin scale hydrography *(PI - Lynne Talley*) - one of the most referenced results of CREAMS-II. 1999 Summer, 2000 and 2001 Winter cruises on *r/vs R.Revell* and *Prof. Khromov*

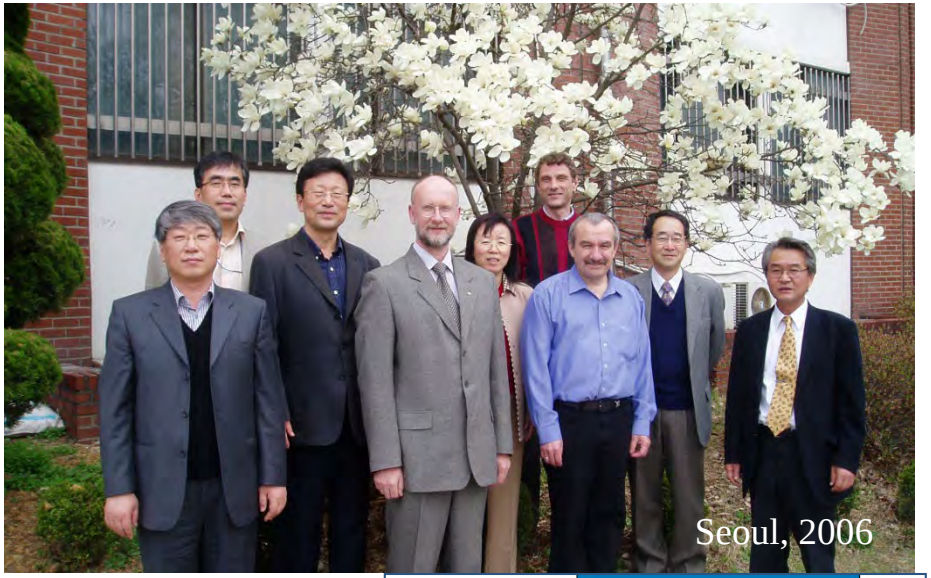
AP-CREAMS - Advisory Panel for a PICES Program in East Asian Marginal Seas, 2005

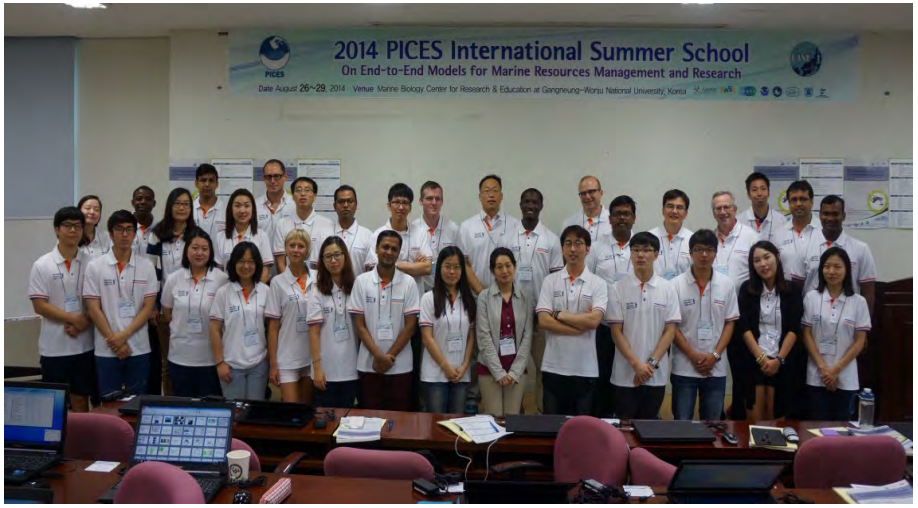
Terms of reference:

1.To initiate and oversee a program to study the hydrography, circulation, and biology and their variability in East Asian Marinal Seas in the PICES area and effect of climate and long-term changes in the abiotic and biotic environments of this region

2.To facilitate the establishment of permanent observation and data exchange networks in this region;

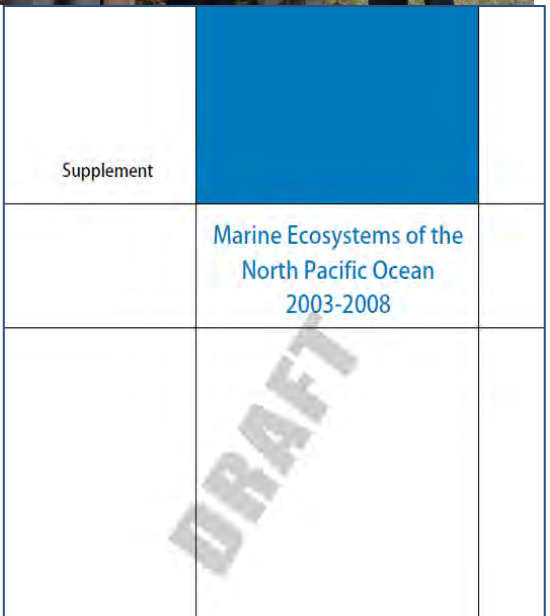
3.To convene workshops/sessions to evaluate and compare results from the program.


Seoul, 2006

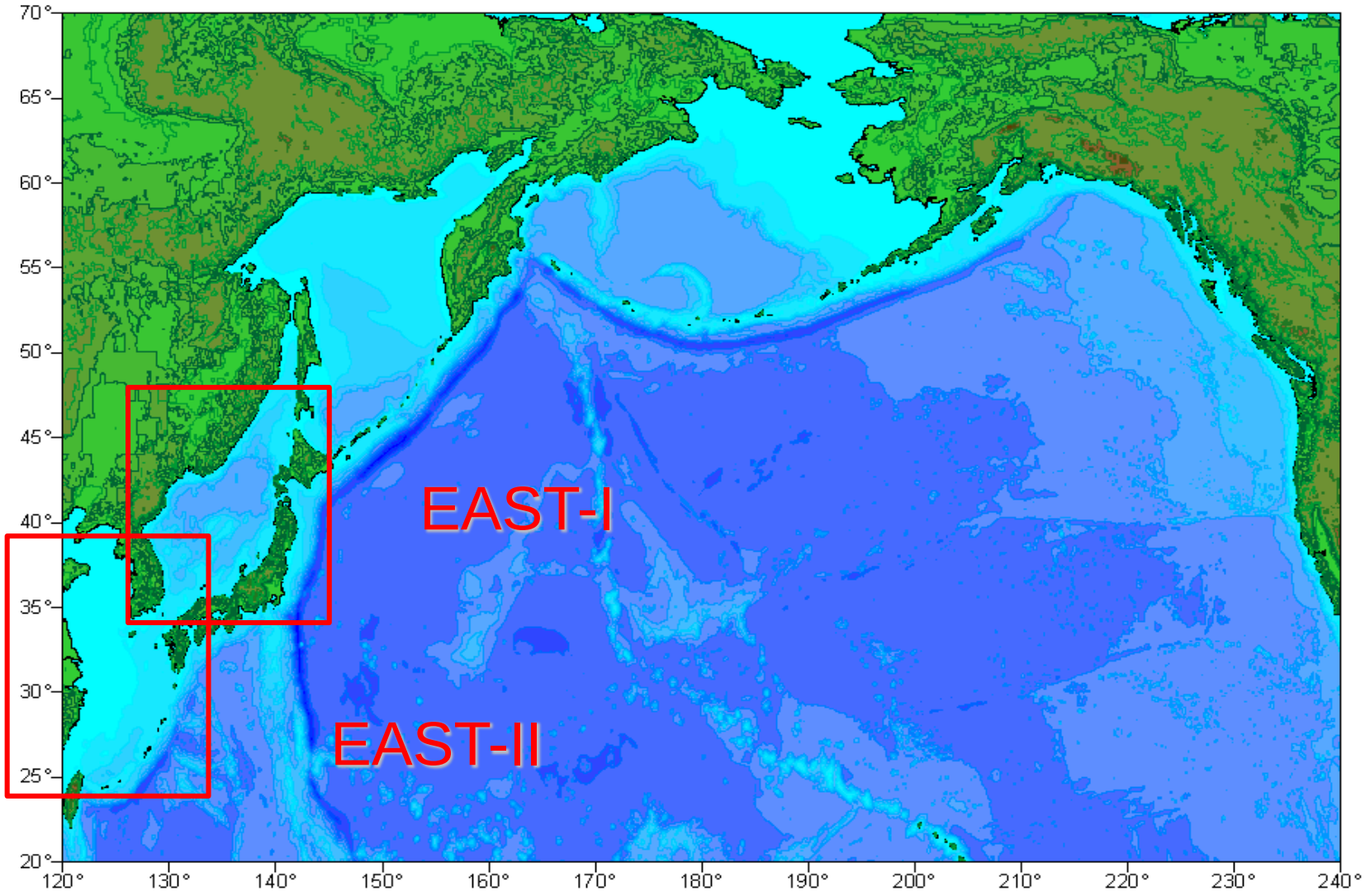


Co-conveners: Kyung-Ryul Kim, Yasunori Sakurai (Joji Ishizaka, Vyacheslav Lobanov, Fei Yu, Jae-Hak Lee

Programs: East Asian Seas Time series (EAST-I and EAST-II) (since 2007)

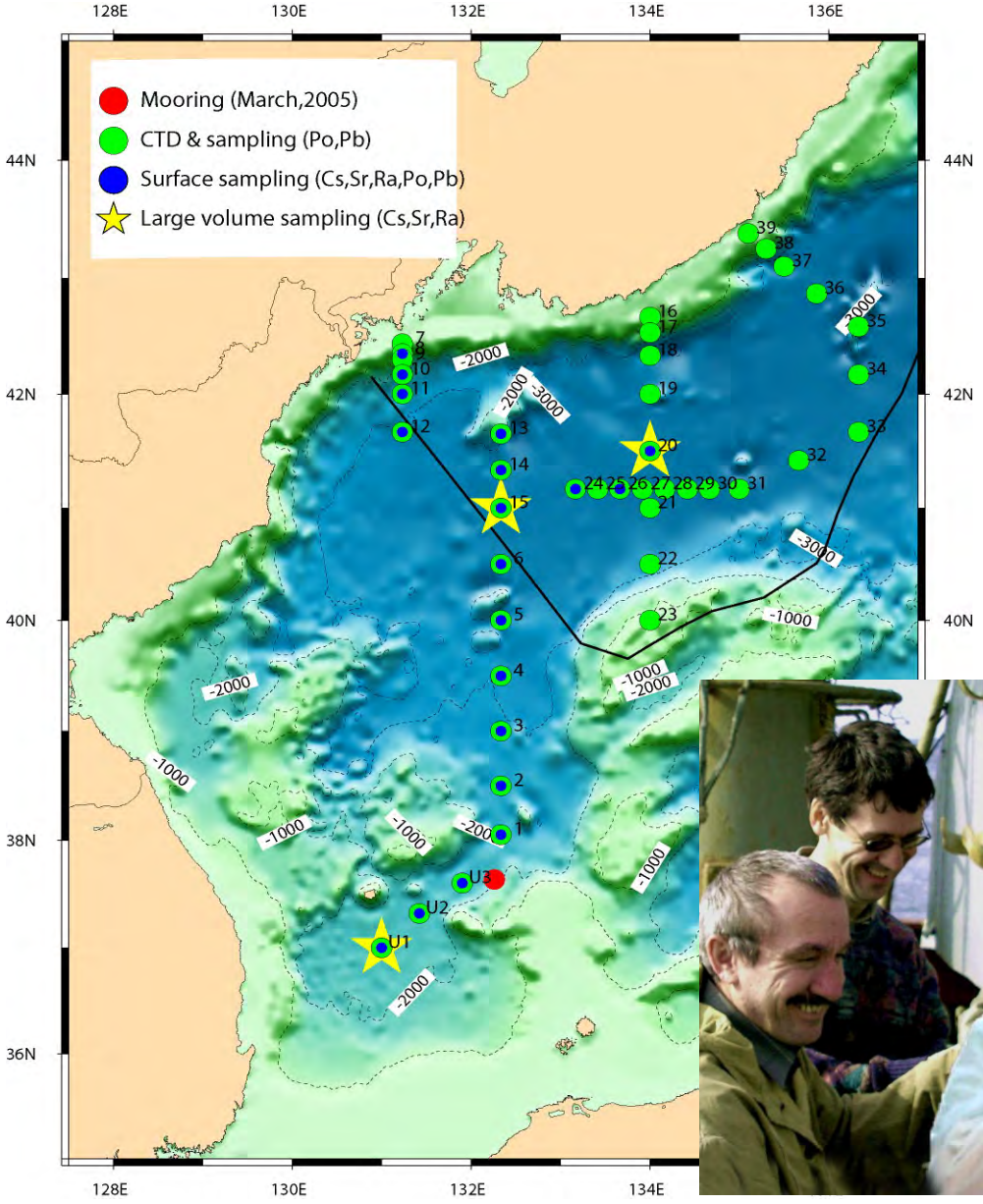


AP-CREAMS Areas



EAST- East Asian Seas Time-series

EAST-I International Cruises (POI-SNU, since April 2001)



EAST-I International Cruises (POI-SNU, since April 2001)

Outline

1. Brief history of AP-CREAMS
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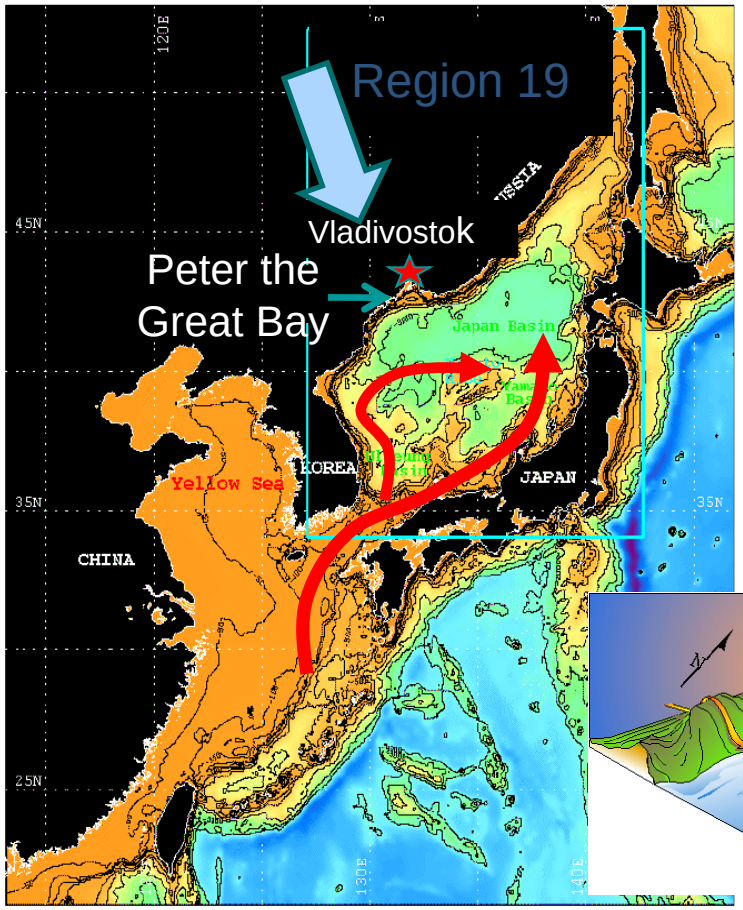
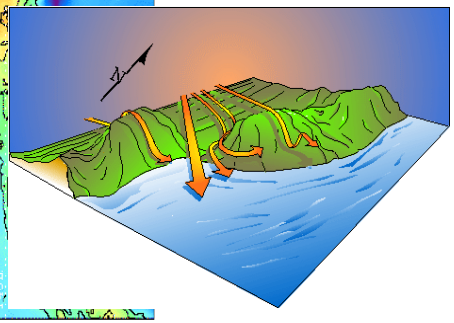
   -**Mechanisms and changes in the deep ventilation system**

   -Mesoscale water dynamics (upwelling, eddies)
3. Further development – CREAMS 3.0

Changes in deep ventilation system

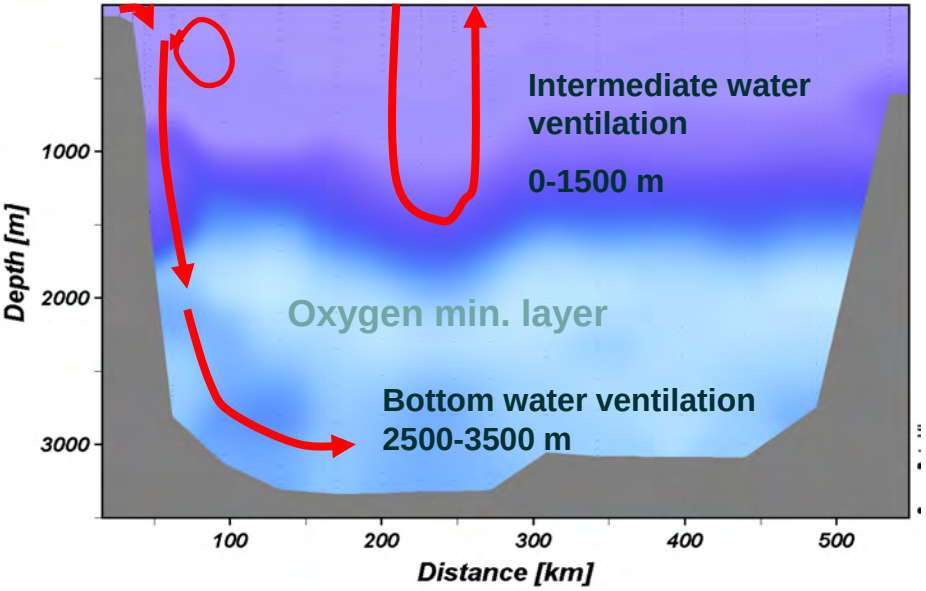


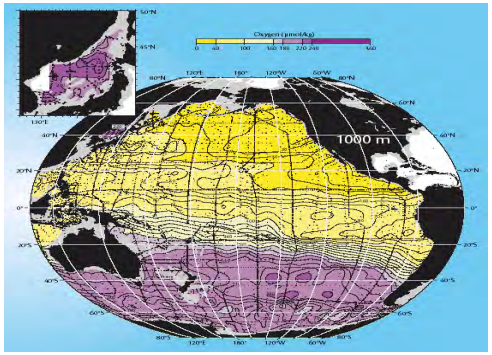
- **Deep semi isolated basin (>3500 m)**
- **Inflow of Tsushima Warm Current from the south**
- **Strong seasonal variations, ice formation**
- **Winter monsoon winds bring cold dry air mass**
- **Convective processes in the northern area control water mass properties**
- **Deep convection and fast renewal of deep water**

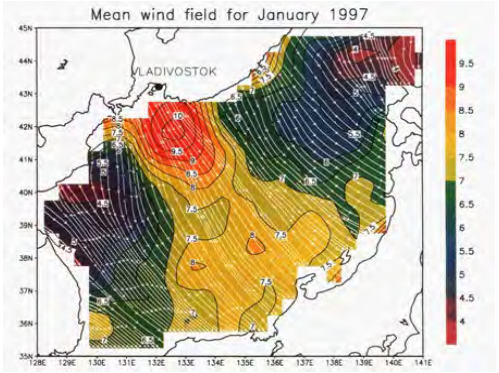


Brine rejection and slope convection

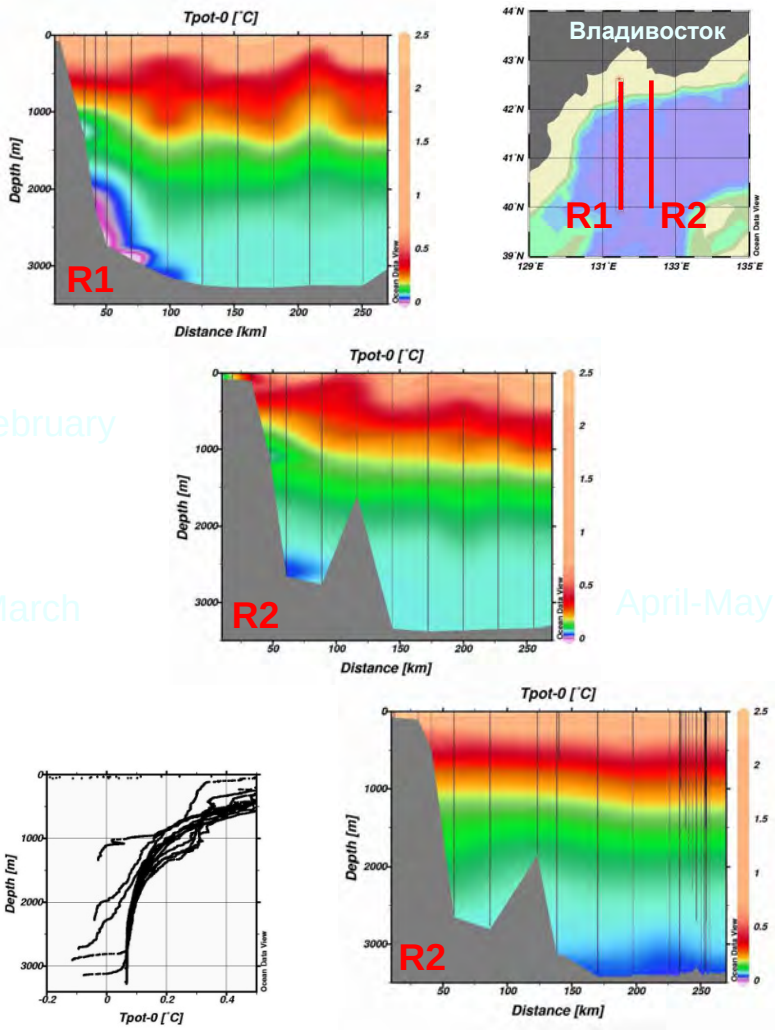
Open sea convection

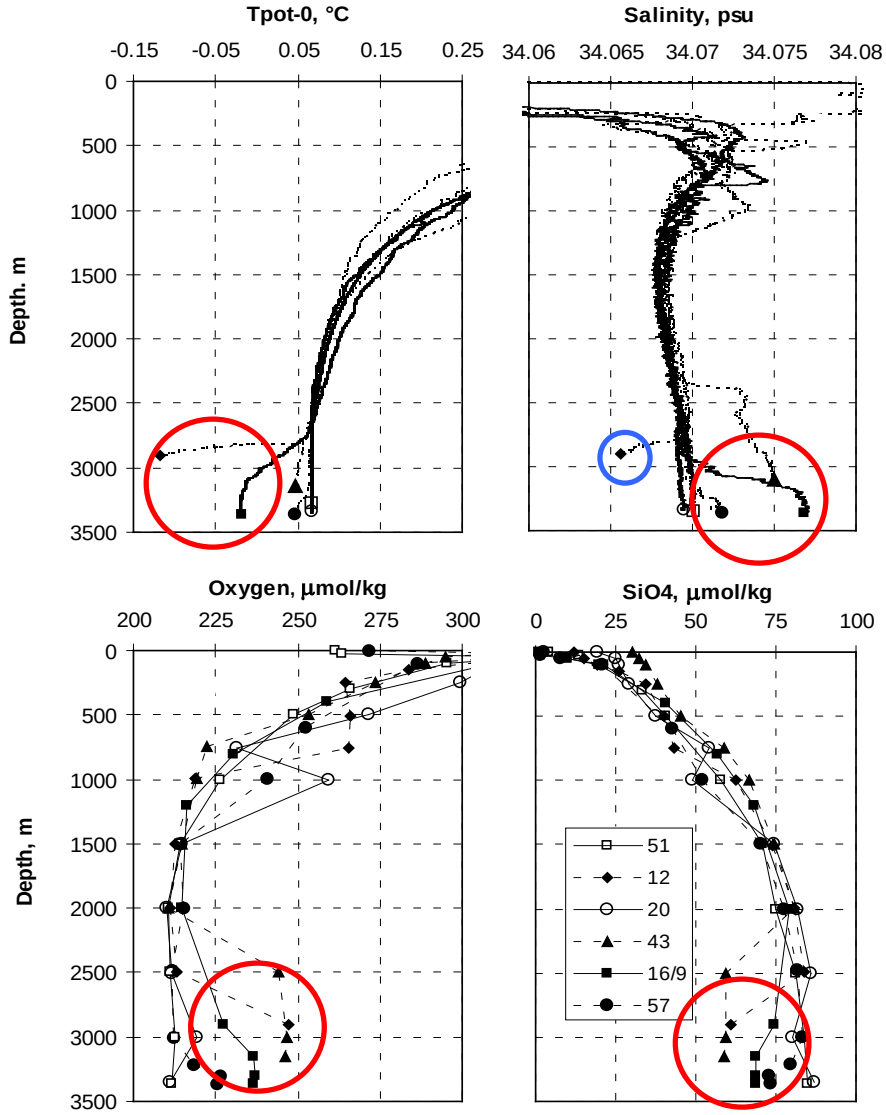






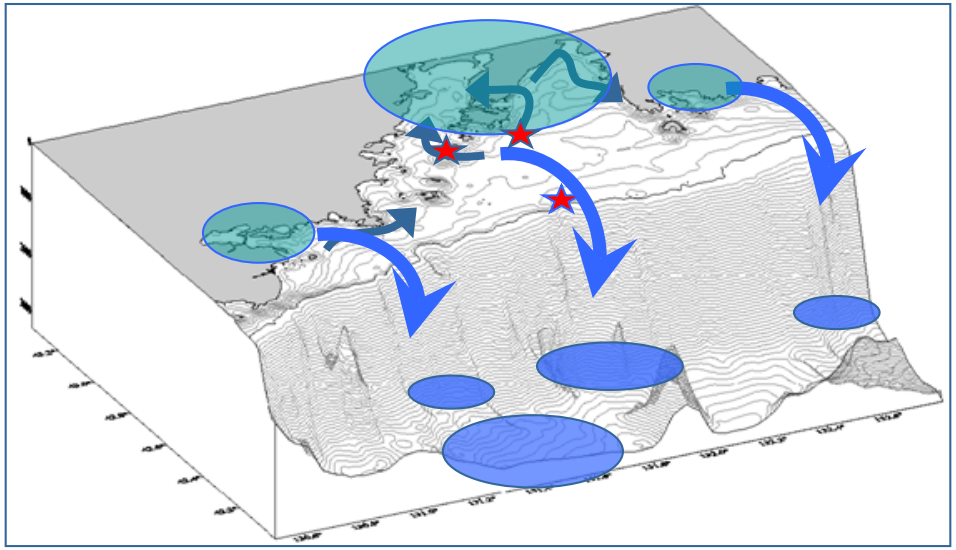
First Evidence of Bottom Water Ventilation
in a severely cold winter of 2001and Ventilation of Bottom Water



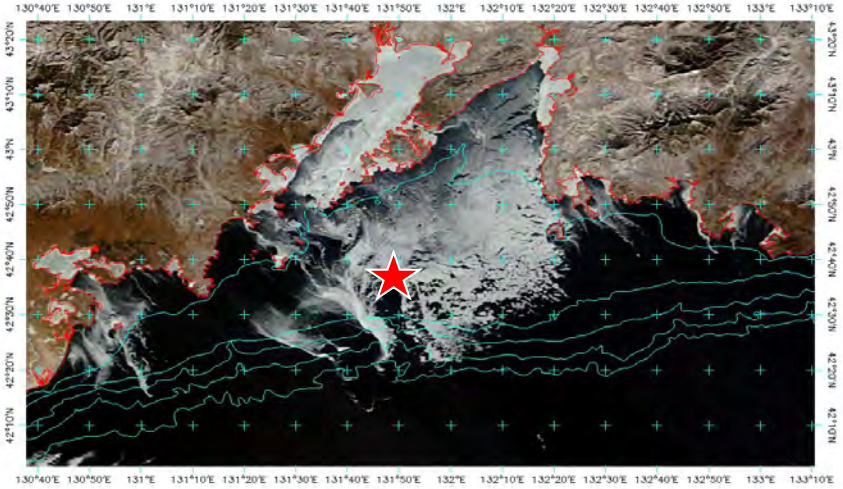


Lobanov et al., 2002; Kim et al., 2002; Senjyu et al., 2002; Talley et al., 2003; Tsunogai et al., 2003

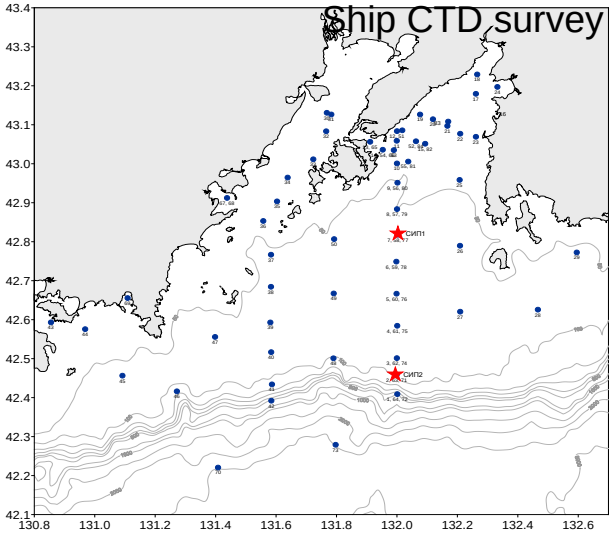
Observations of cascading in Peter the Great Bay 2010-2018

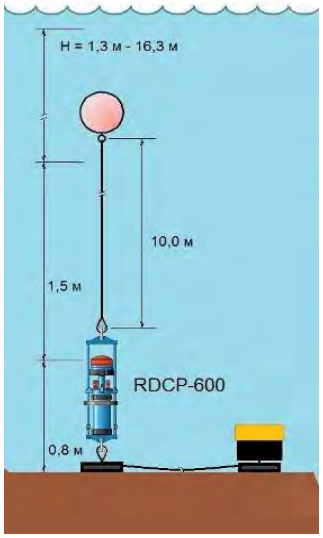


Fasten and drifting sea ice on satellite image



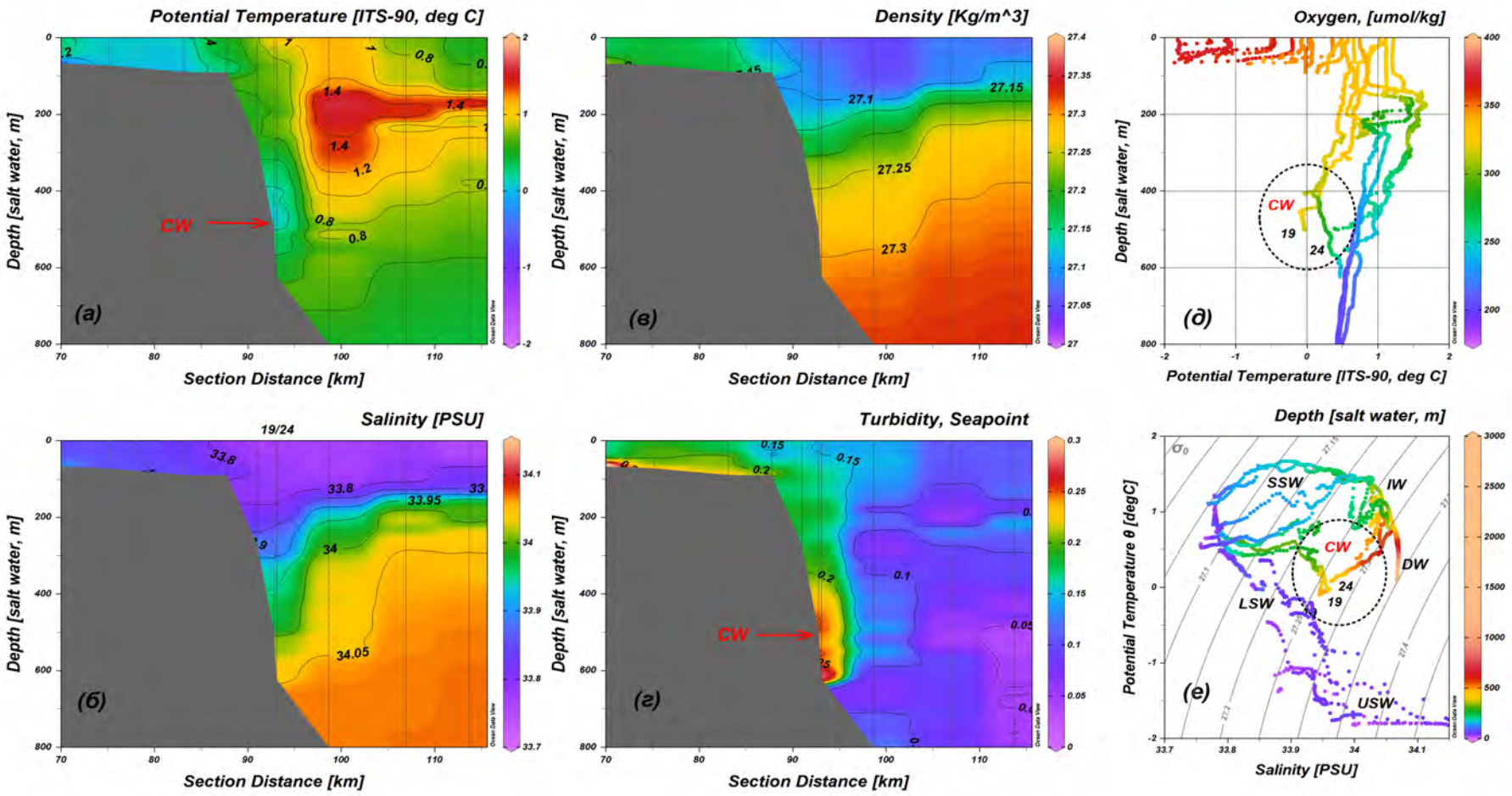
Moorings with T, S, DO, Turb, Flu and current meters (SBE37, RBR-XR, S4, Infinity EM, RDCP600, WHS300)





Bottom mooring system

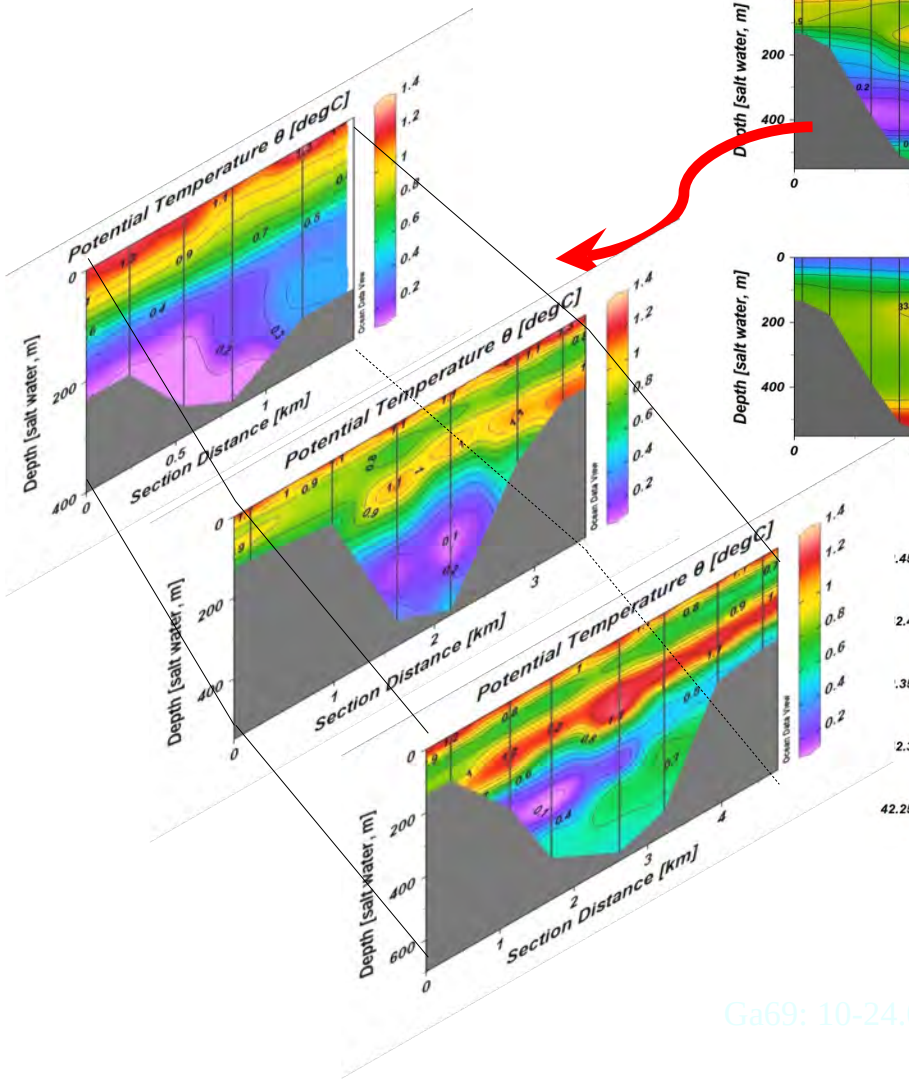
CTD section across a cascading plume, 12-13.01.2015

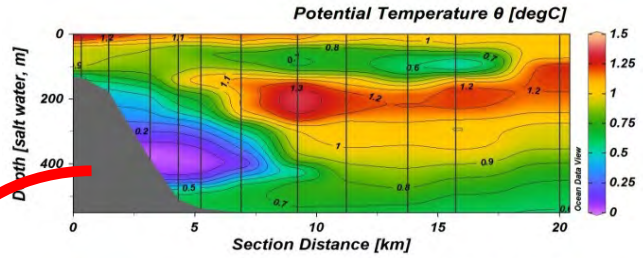


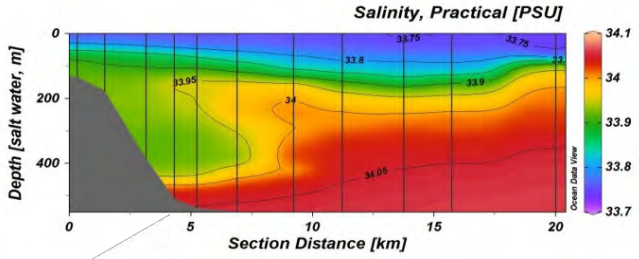
Cascading plume over the slope between 350 and 700 m

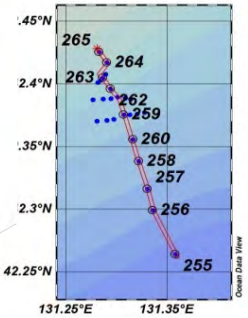
Ga64: 12-13.01.2015

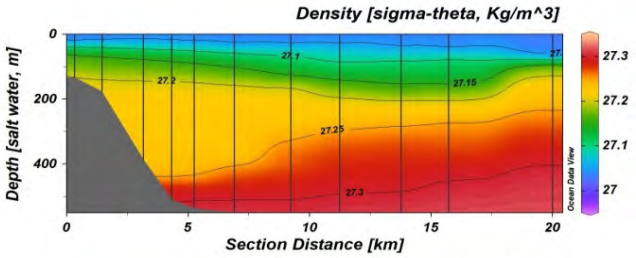
3D Structure of Cascading plume at Gamov Canyon, 17.03.2016

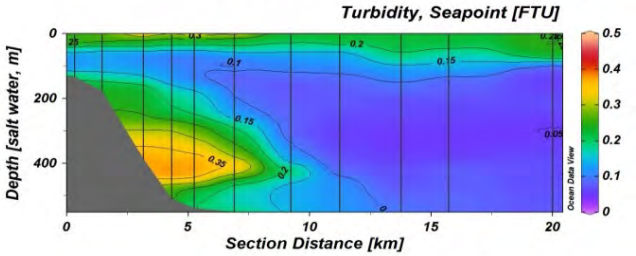


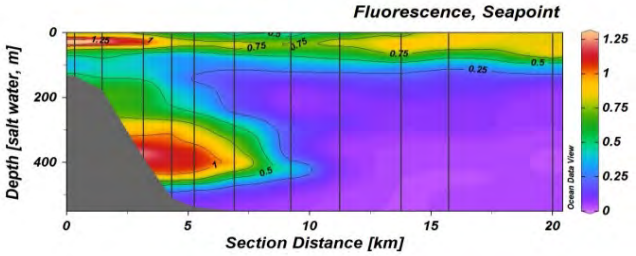










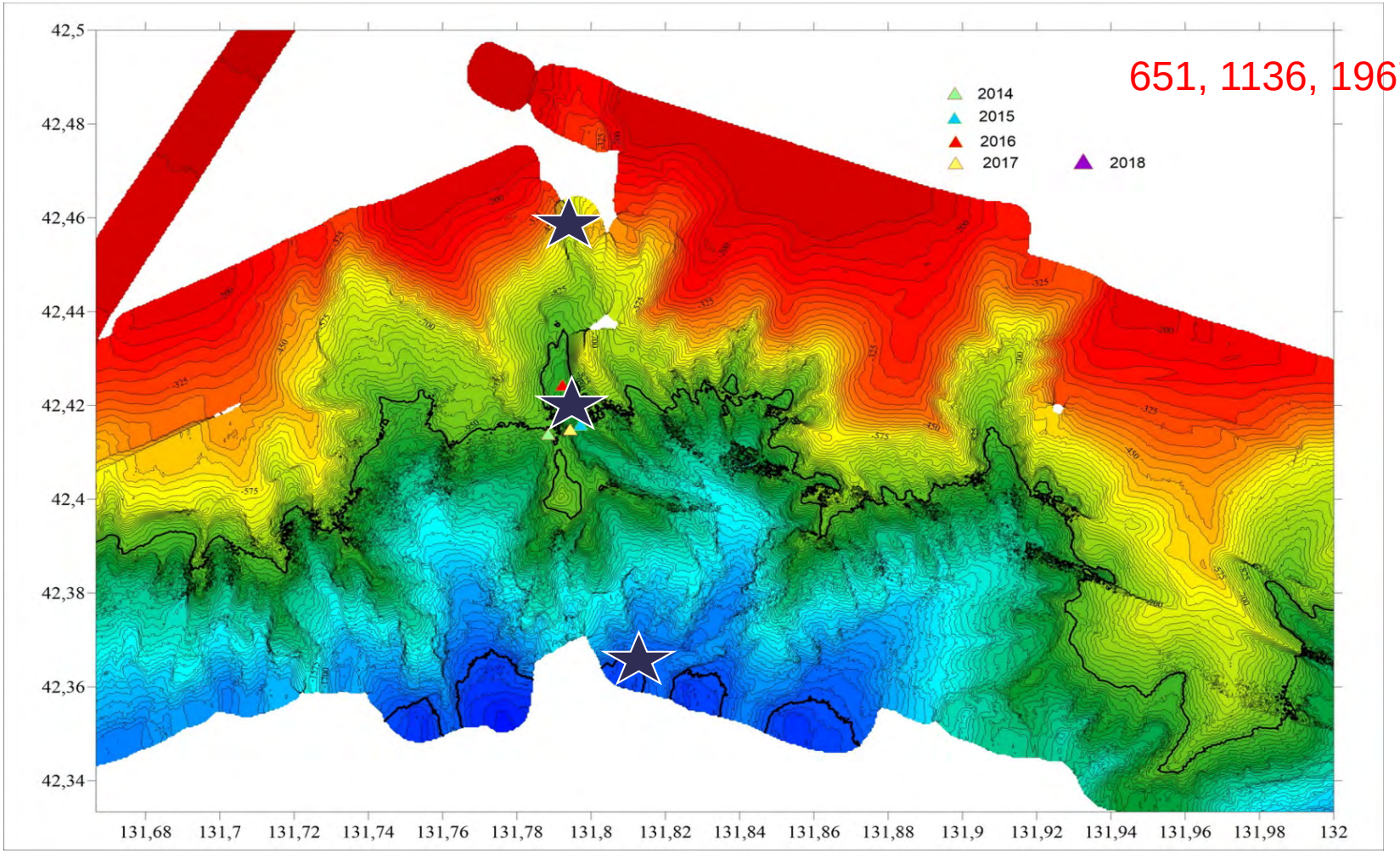


Shelf water intrusions at 200-600 m

H= 200 m L= 5-12 km

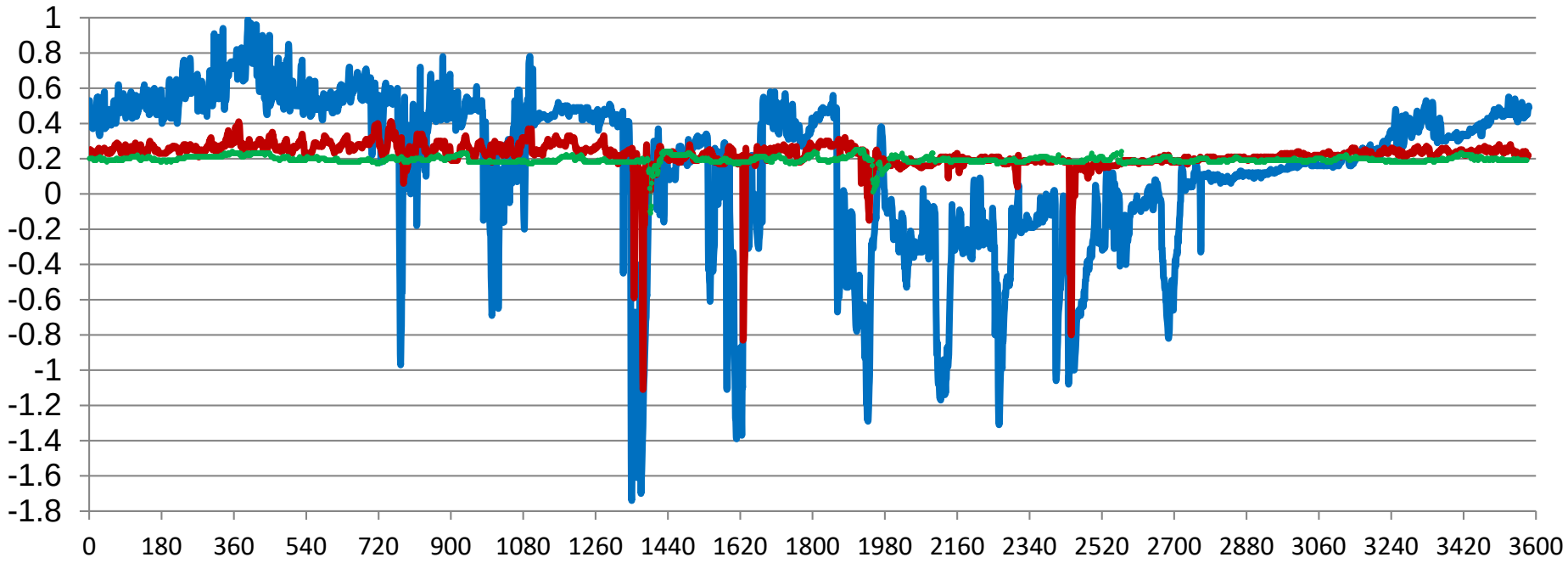
Ga69: 10-24.03.2016

Cascading at the Peter the Great Bay (2017-2018)



Bottom moorings at the slope of Peter the Great Bay at 651, 1136 and 1967 m during 1.12.2017- 29.04.2018

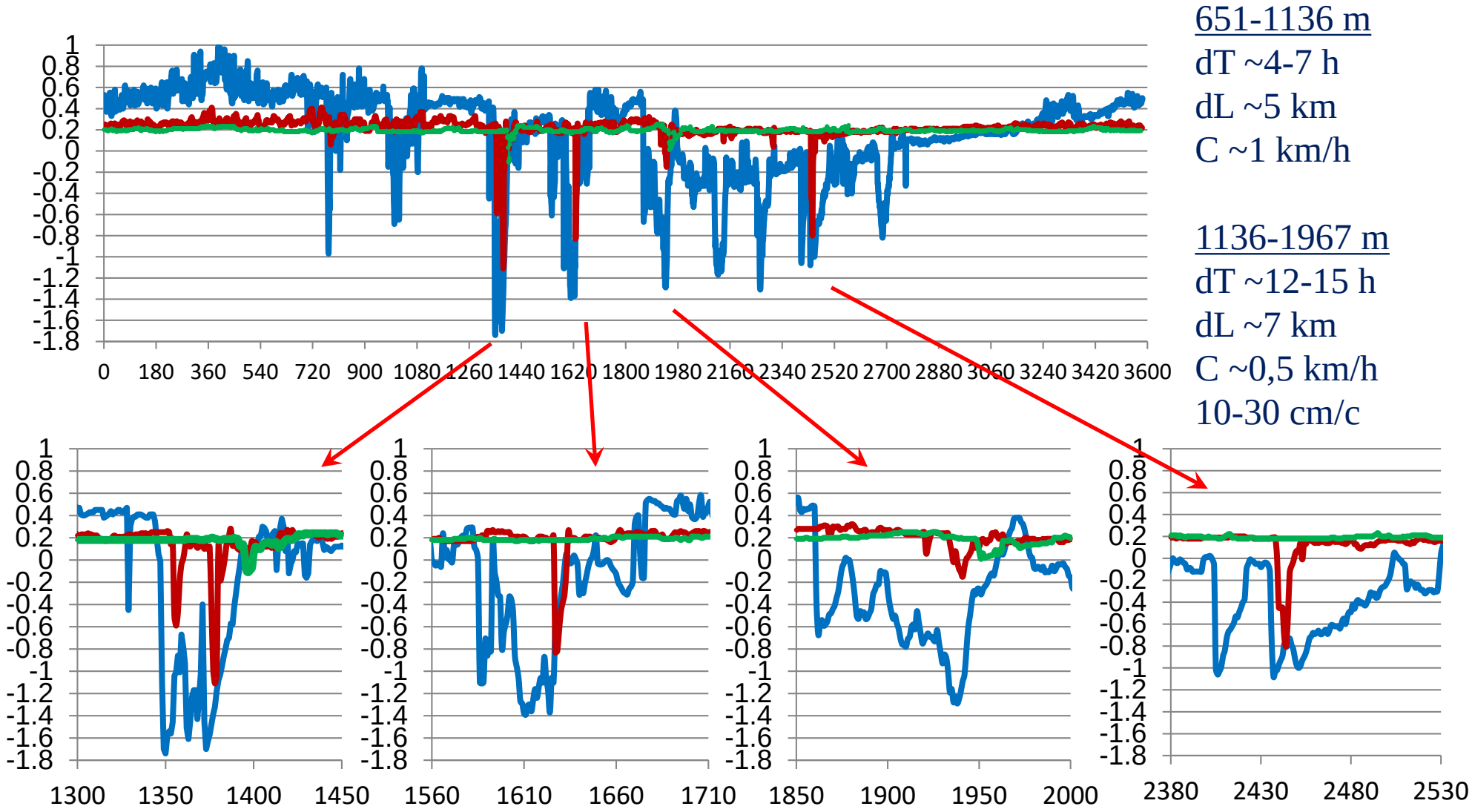
Cascading at the Peter the Great Bay (2017-2018)



Variations of T at 651 m (blue), 1136 m (red) and 1967 m (green) during 1.12.2017- 29.04.2018 AquaDopp .

10 events at 651 m, **7** events at 1136 m and **2** events at 1967 m

Cascading at the Peter the Great Bay (2017-2018)

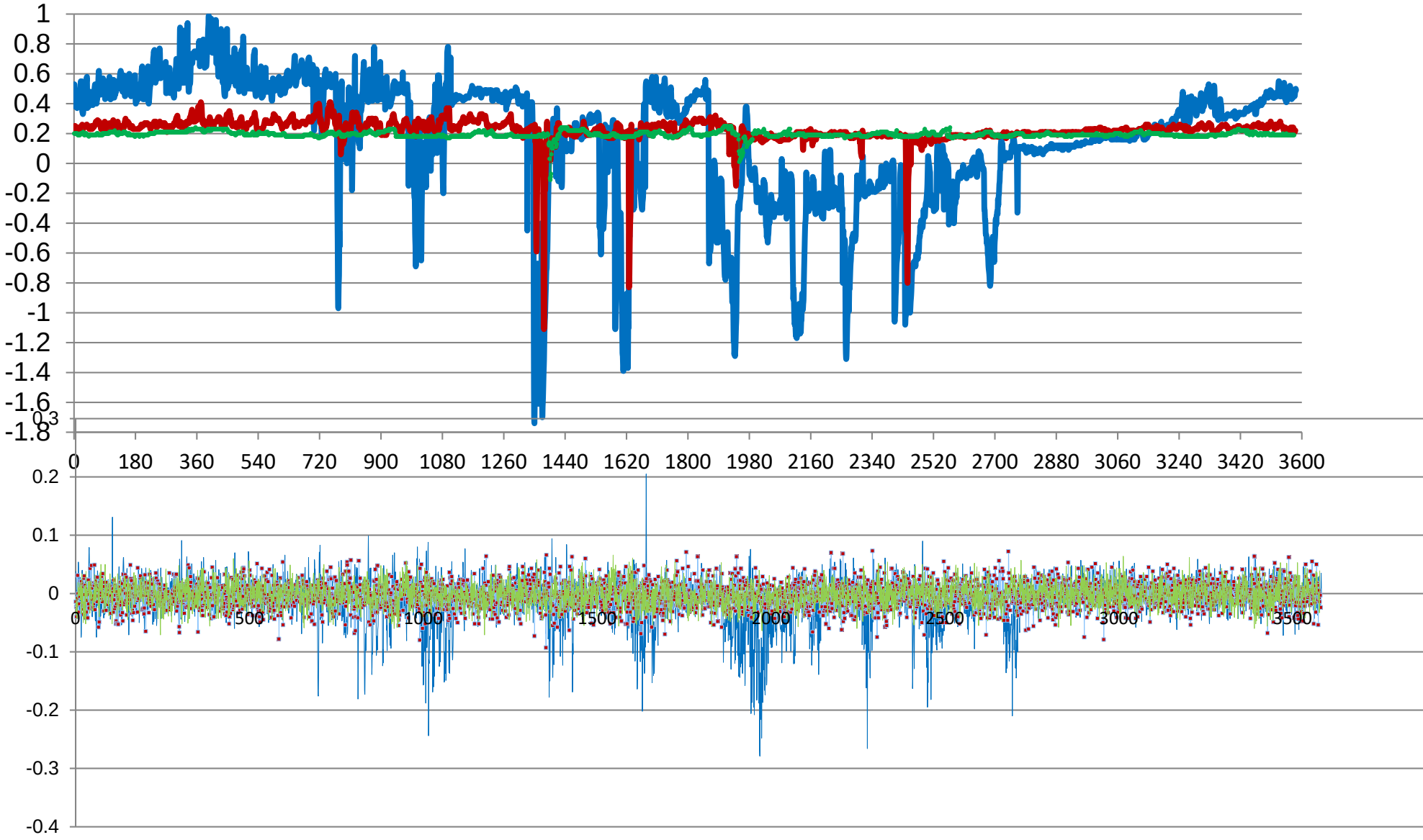


651-1136 m
dT ~4-7 h
dL ~5 km
C ~1 km/h

1136-1967 m
dT ~12-15 h
dL ~7 km
C ~0,5 km/h
10-30 cm/c

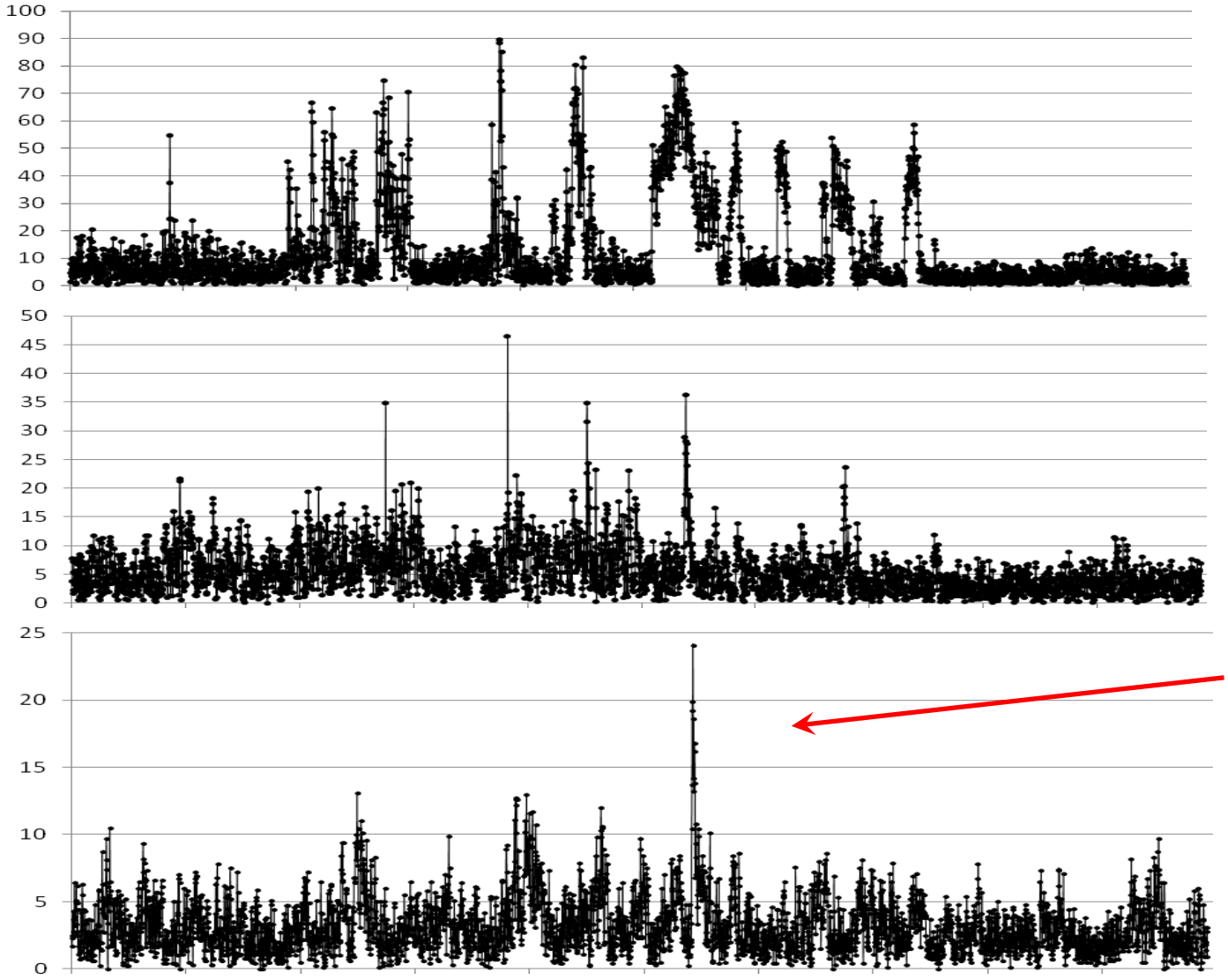
Penetration with depth ~ 10-30 cm/s

Cascading at the Peter the Great Bay (2017-2018)



Vertical velocity up to ~ 0.28 cm/s

Cascading at the Peter the Great Bay (2017-2018)



Vel max

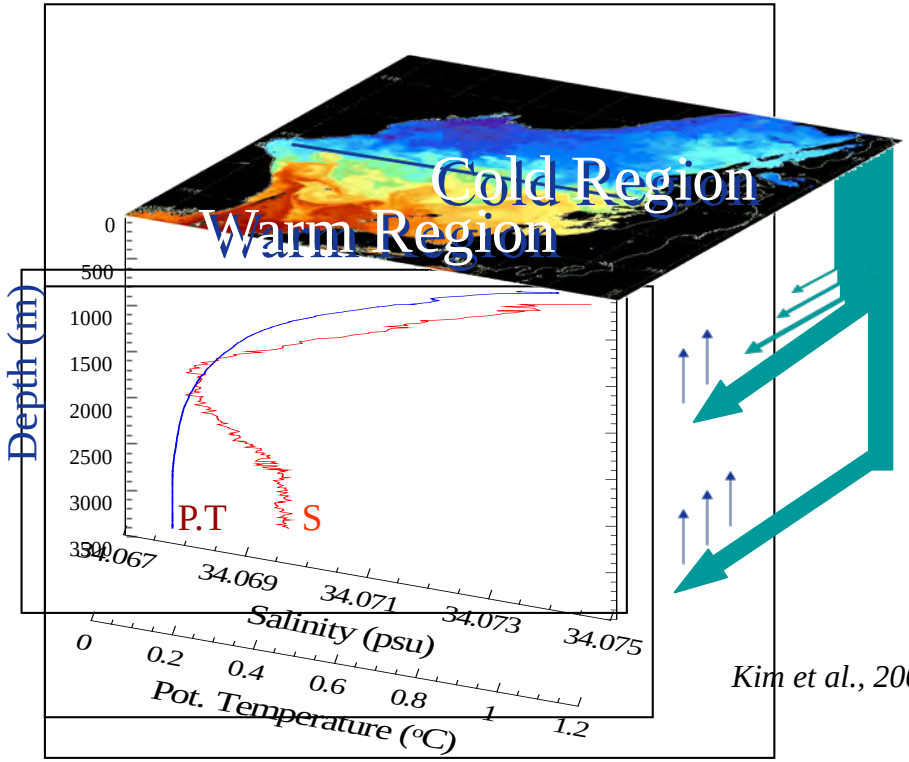
651 m ~ 90 cm/c

1136 m ~ 46 cm/c

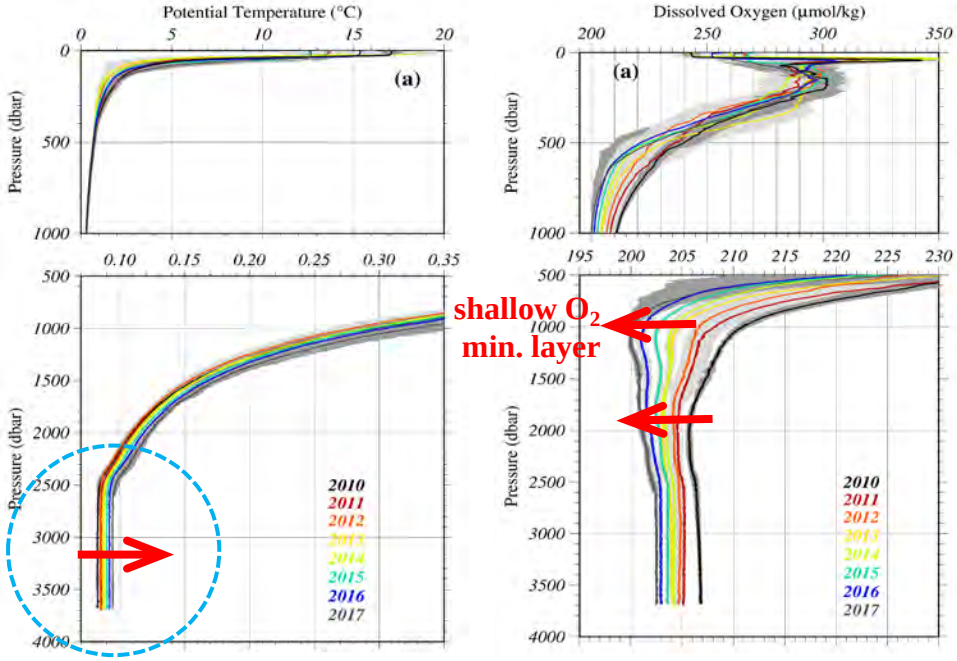
1967 m ~ 10-12 (24) cm/c

Strong event – 19.02.2018

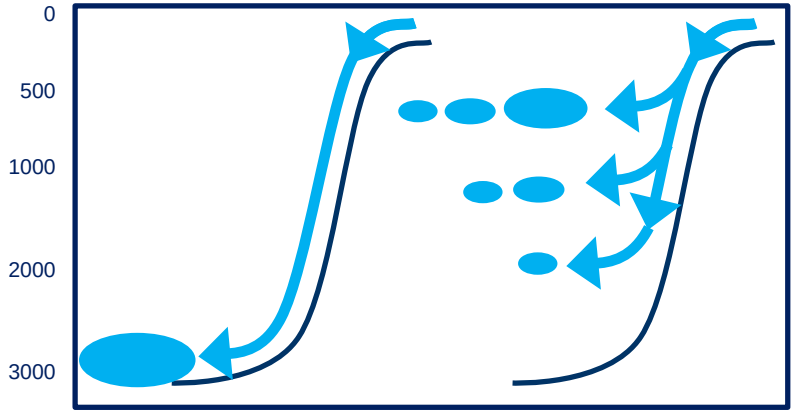
Changes of ventilation regime and vertical structure of water masses, warming of bottom water

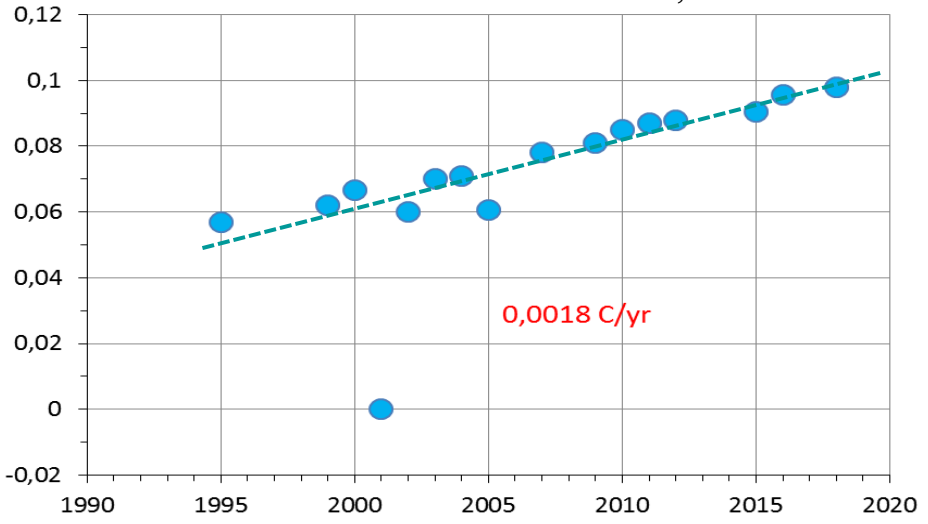


Kim et al., 2005

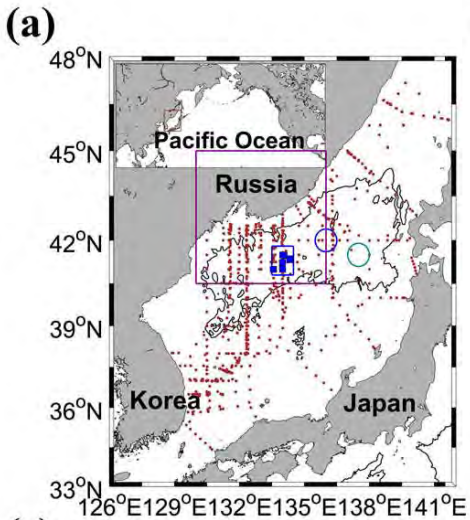


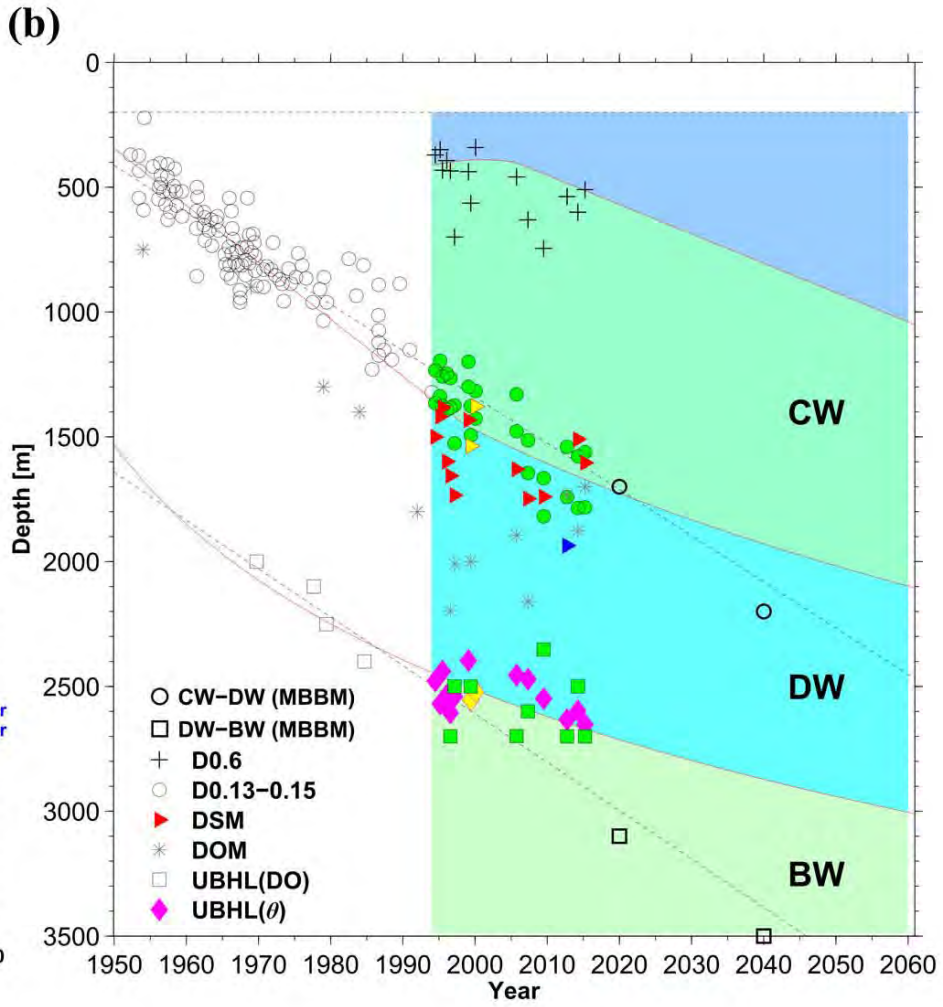
Nakano et al., 2019

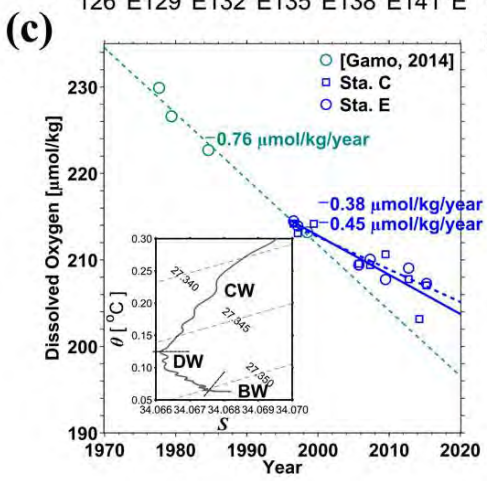


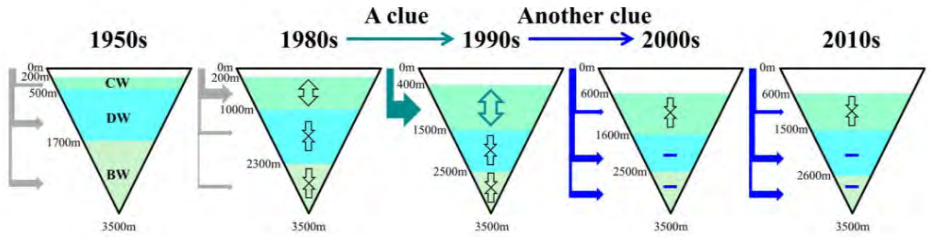


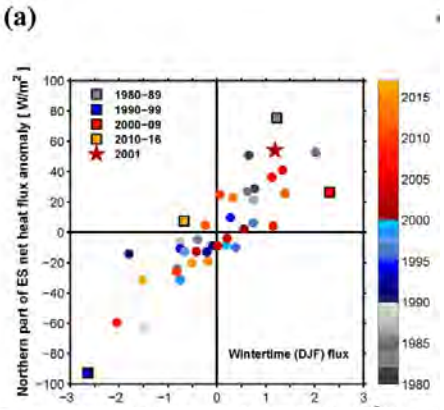
Continuing warming of deep and bottom waters

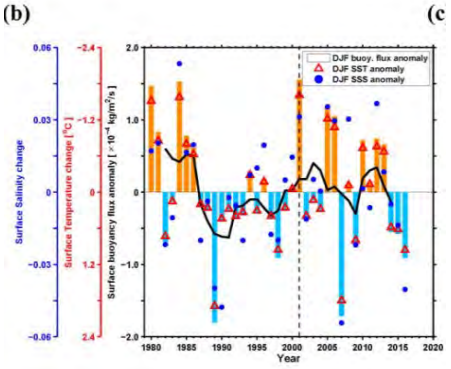


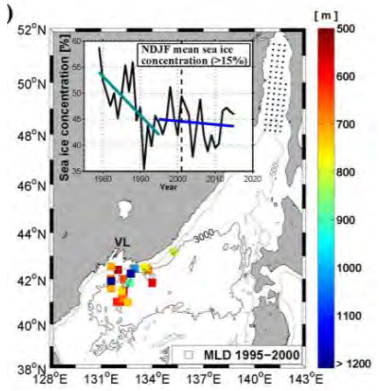












Yoon et al., Nature Scientific Reports, 2018

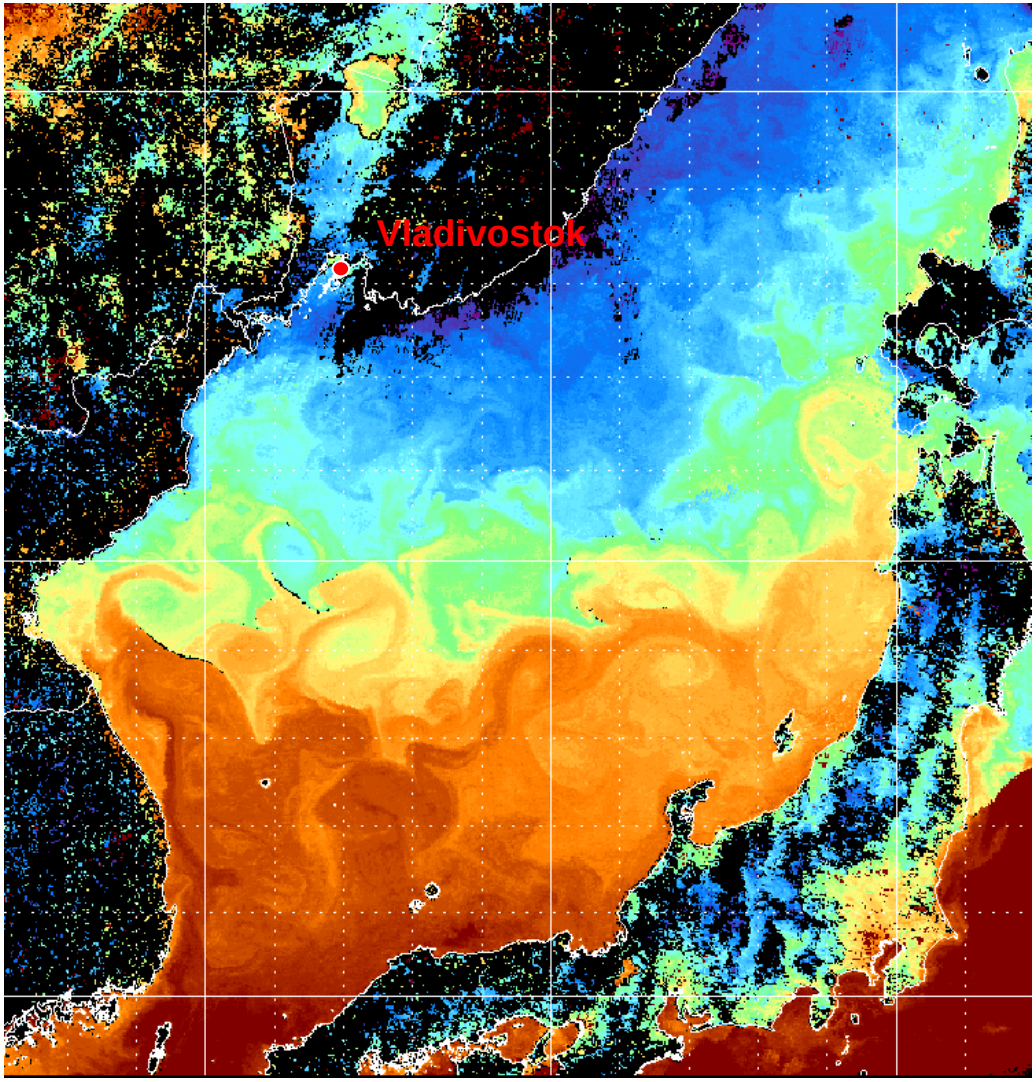
Outline

1. Brief history of AP-CREAMS
2. Main results in the EAST-I

   - Mechanisms and changes in the deep ventilation system

   - **Mesoscale water dynamics (eddies, upwellings)**
3. Further development – CREAMS 3.0

Mesoscale eddies over the entire sea



Mesoscale eddies are important component of the Japan Sea water dynamics *(e.g. Ichiye and Takano, 1988)*

Ichiye, T., and K. Takano, 1988: Mesoscale eddies in the Sea of Japan. *La Mer,* **26,** 69–79.

Strong anticyclonic eddies in the southern area *(Isoda et al., 1992; Isoda and Saitoh, 1993; Isoda, 1994; An et.al.,1994; …Gordon et al., 2002)*

Eddies north of the subarctic front *(e.g. Sugimoto and Tameishi, 1992; Danchenkov et al., 1997; Lobanov et al., 1998)*

Hydrographic structure (CTD and moorings) *(Takematsu et al., 1999; Lobanov et al., 2001, 2007)*

Mesoscale dymanic phenomena of the northwestern JES

Moonsoon climate

(winds, SST, SSH)

shelf of the Peter the Great Bay

Narrow shelf of Primorye

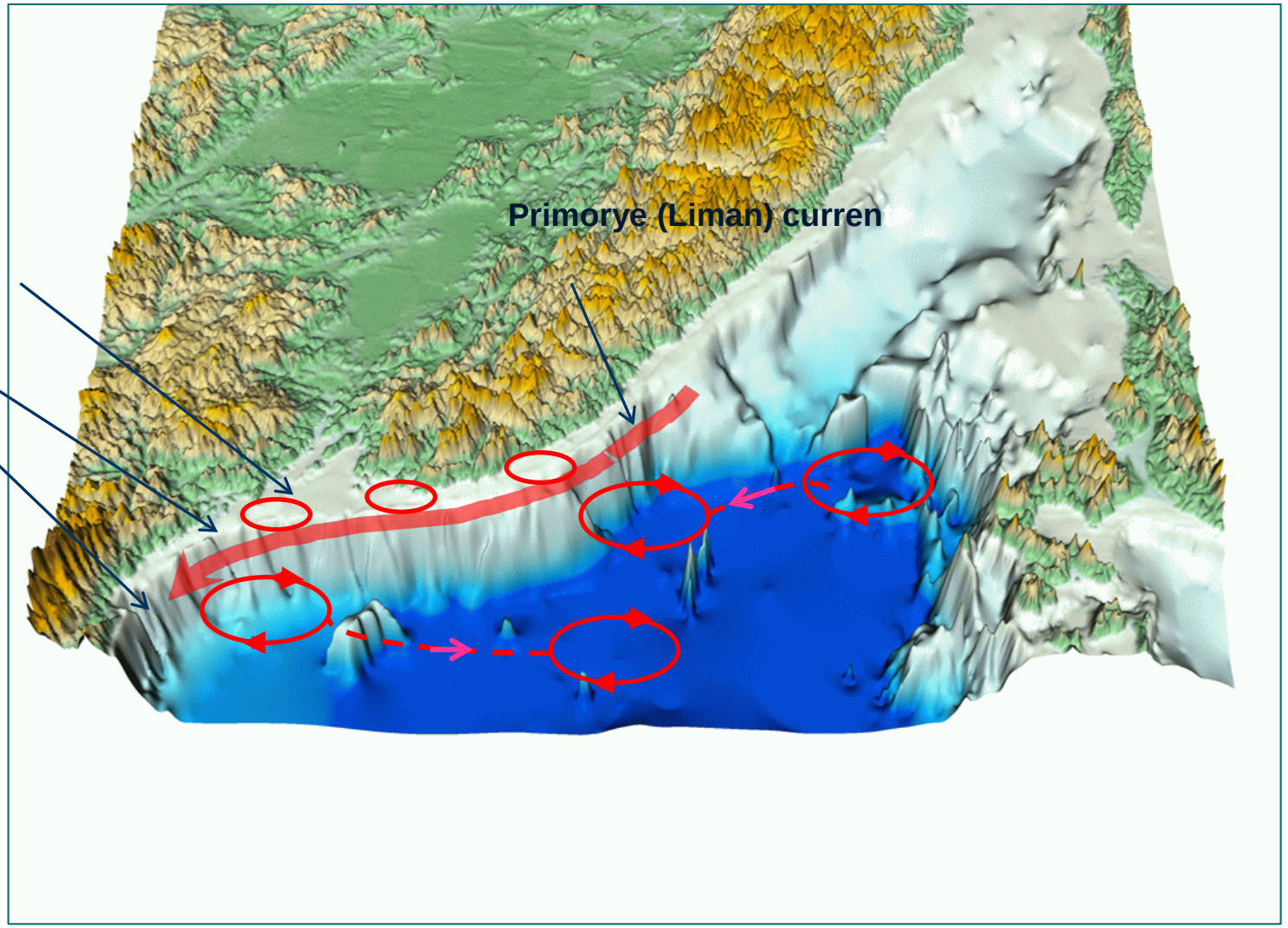
Steep continental slope

Primorye (Liman) Current

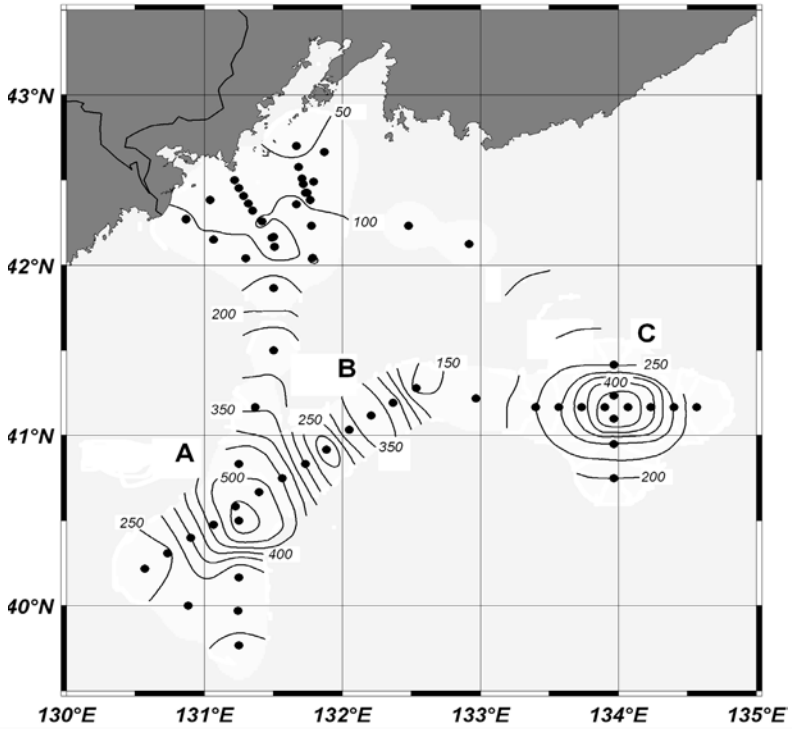
Shelf-slope eddies

NW anticyclonic eddies

NE anticyclonic eddies

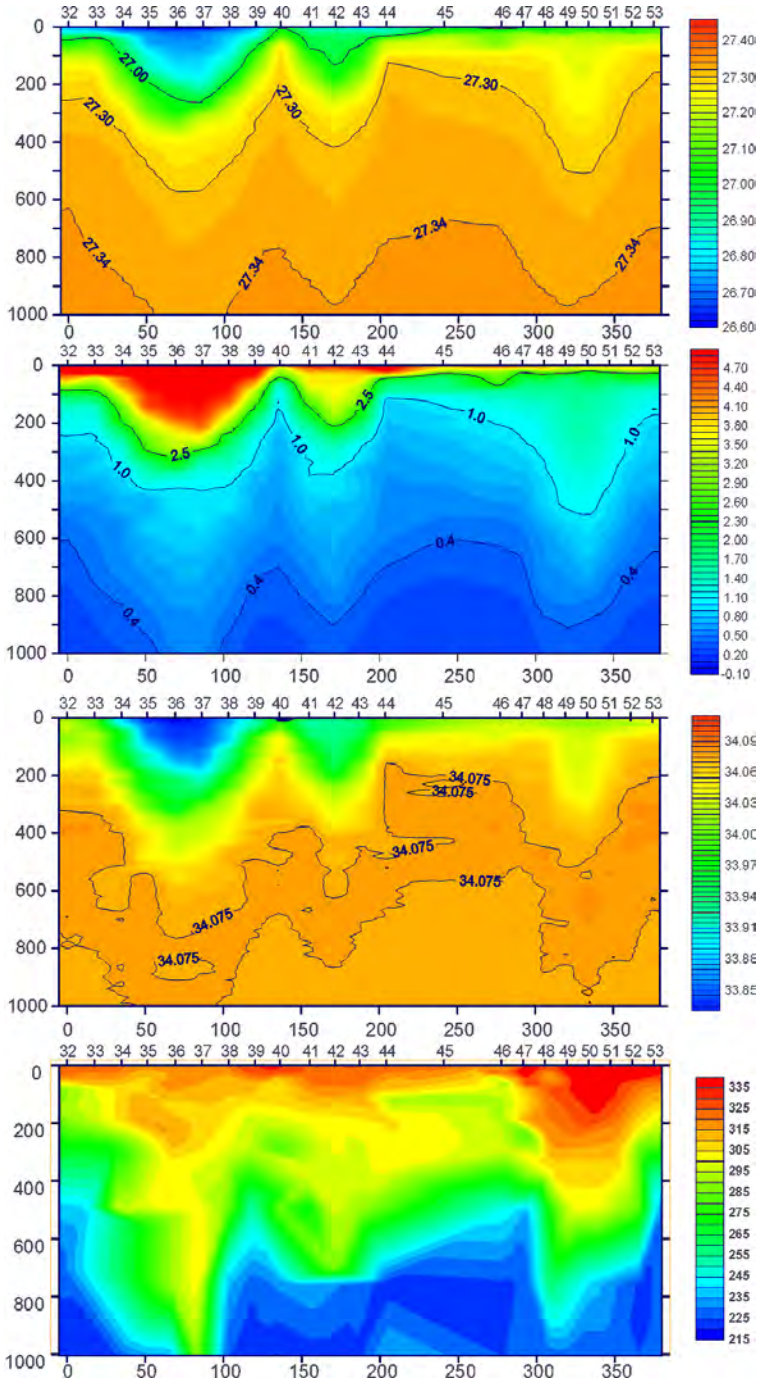


Eddies in the NW Japan Sea: vertical structure

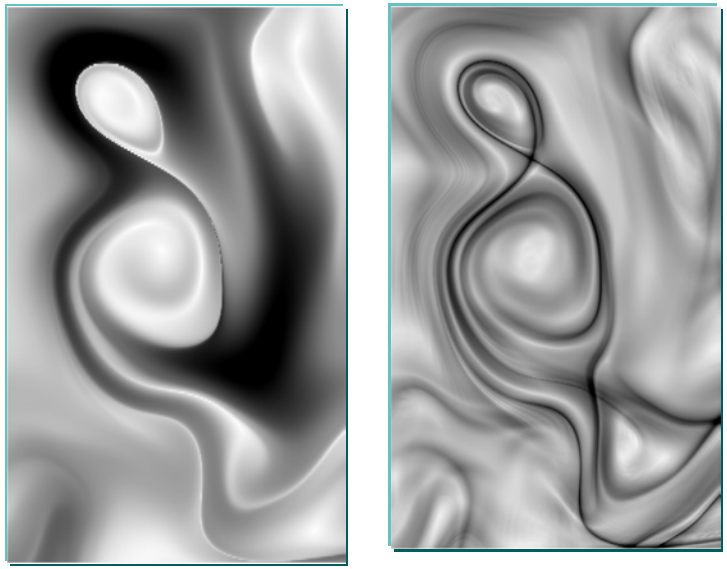


Geostr. Vel.

- **warm, lower salinity core; strong dynamic features,**
- **deep penetration**

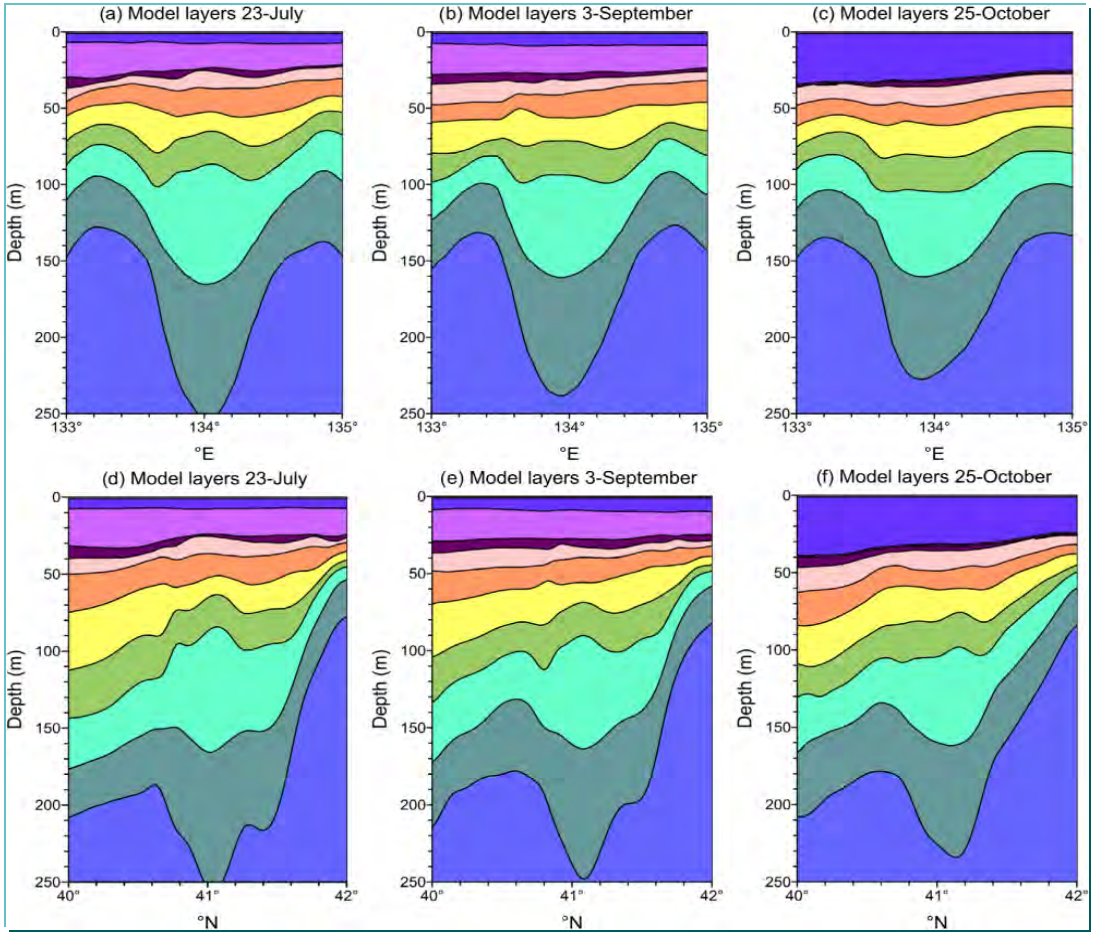


Modeled vertical structure of the eddy

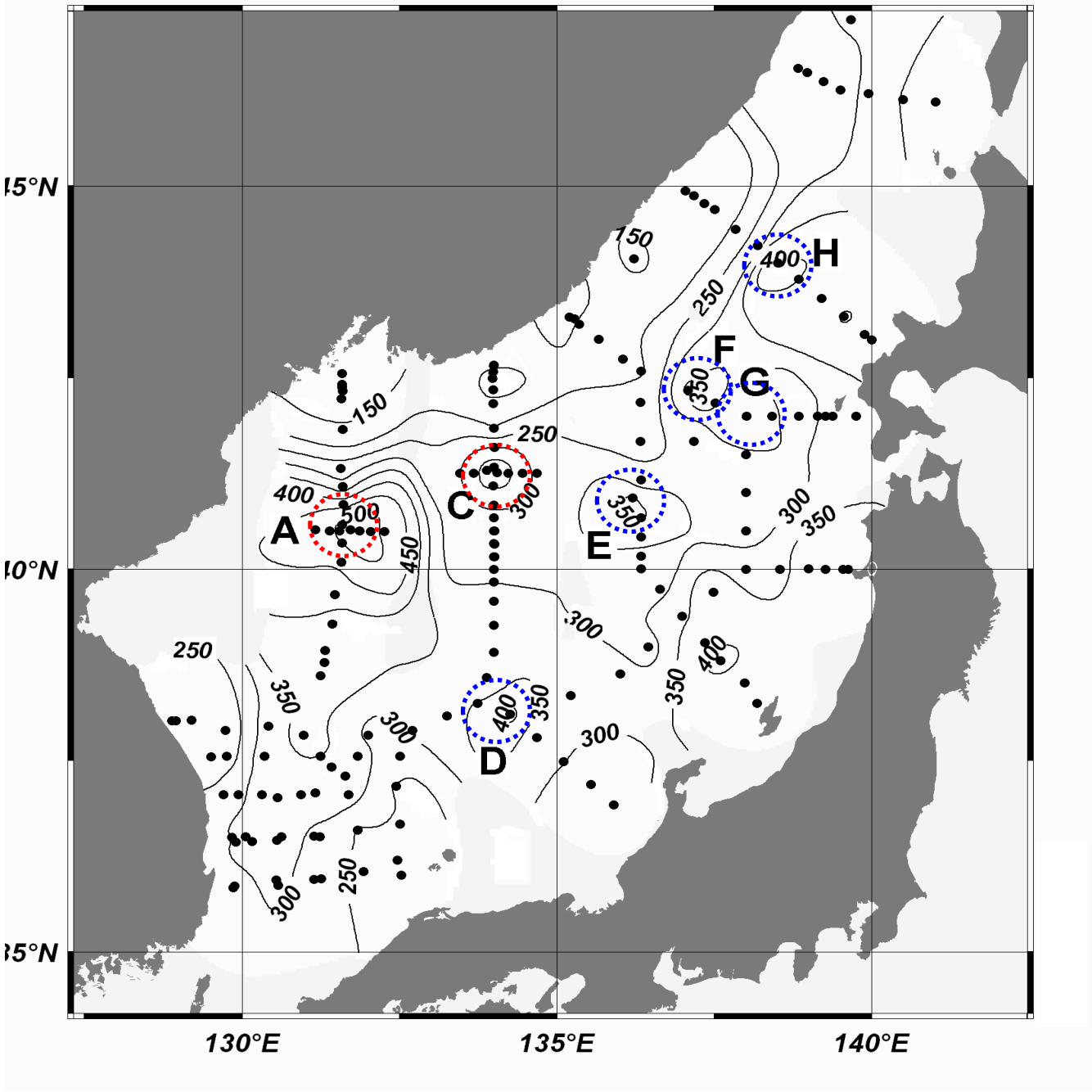


Manifestations of modeled eddies on 23 July in the ninth layer on (a) the drift map (D in km) and (b) the combined Lyapunov map of forward (Кю) and backward-intime (K) FTLE with the velocity field imposed. K is in days1. ‘‘Instantaneous’’ elliptic and hyperbolic points, to be present in the area on 23 July, are indicated by circles and crosses, respectively.

Prants et al., OM, 2015



6. Zonal (along 41N, the upper row) and meridional (along 134E, the lower row) sections of the interfaces between modeled eddy layers on 23 July, 3 September and 25 October. Each quasi-isopycnal layer is shown by its own color



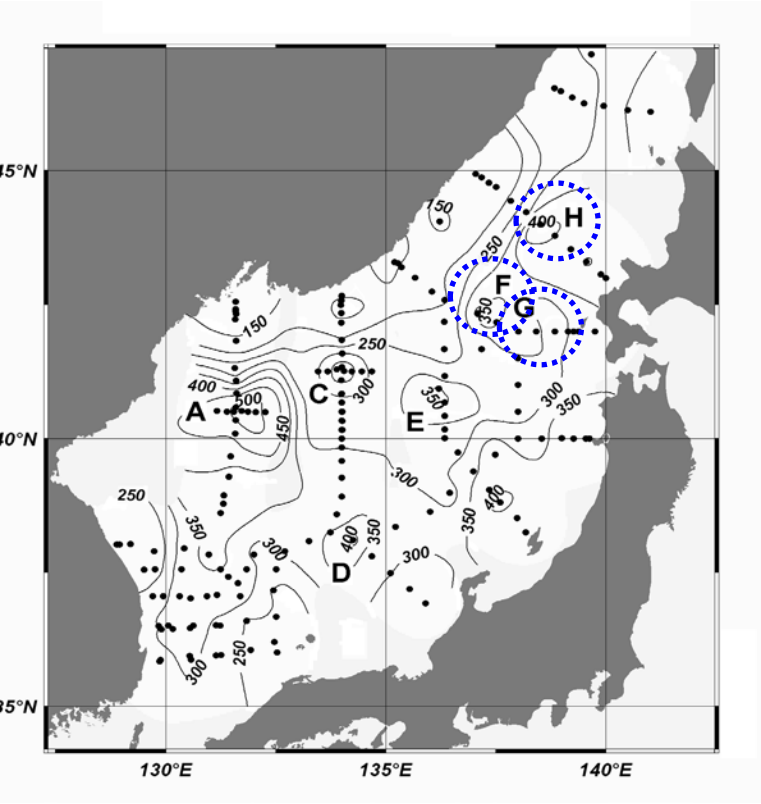
Basin scale survey
Jun-Aug 1999

CREAMS-II program
r/v Professor Khromov and Roger Revell

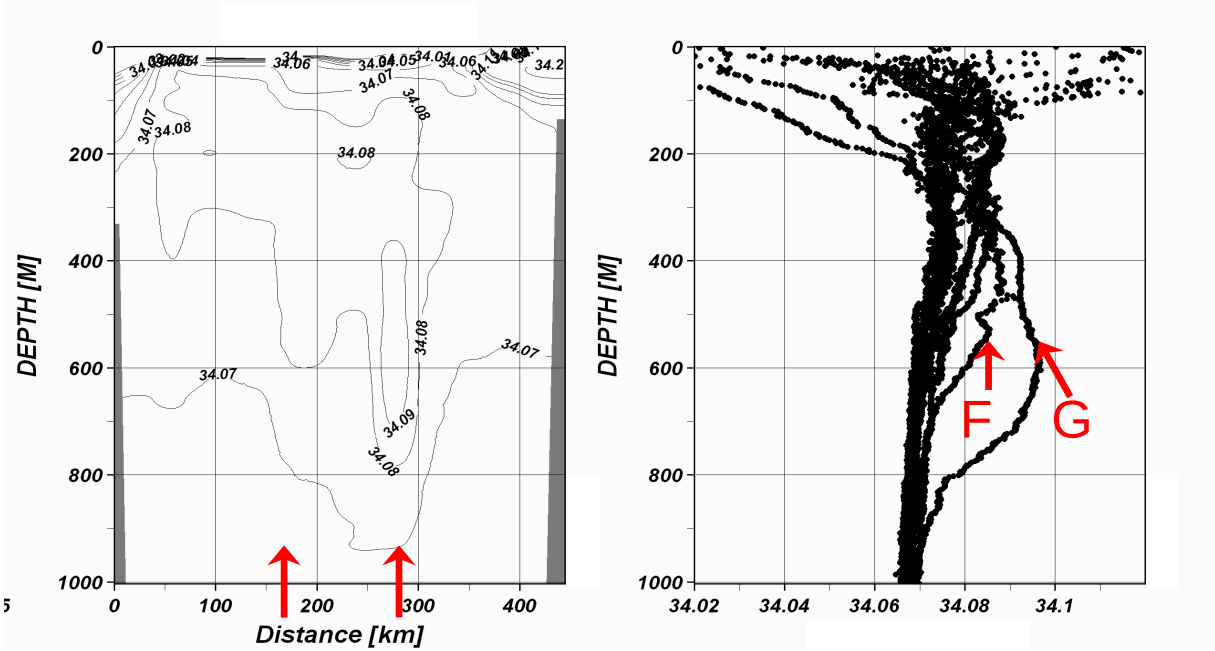
Planned sampling of
Eddies A and C
and
occasional sampling of
D, E, F, G, H

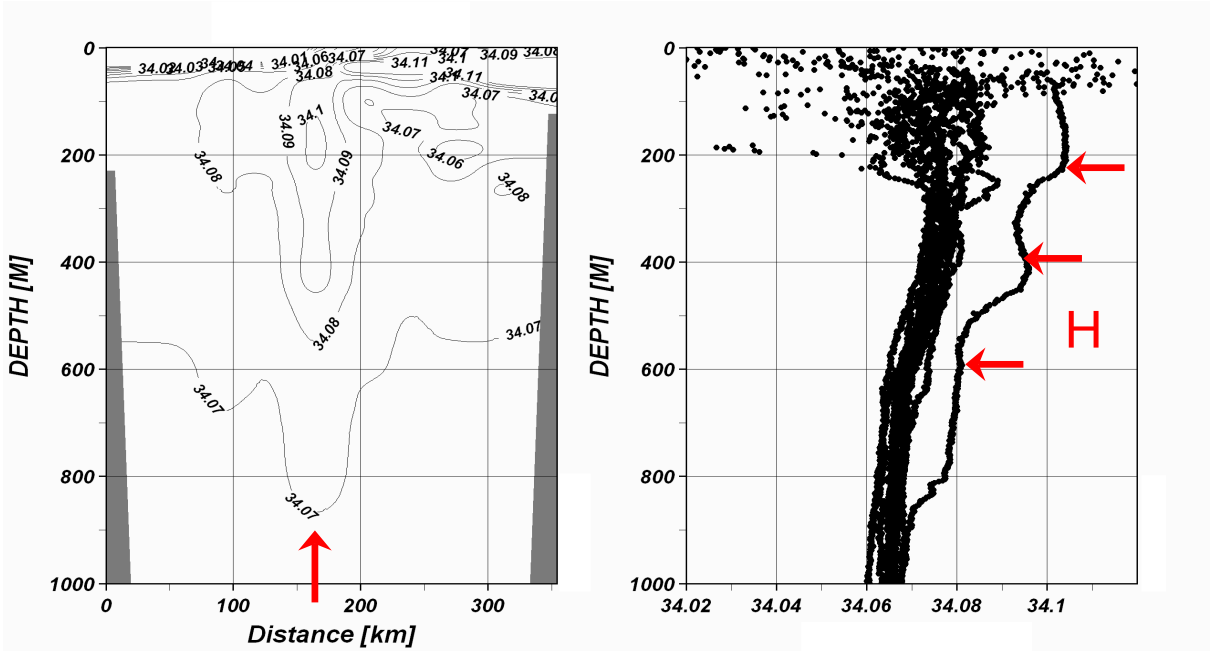
Depth of 27,3 sigma theta

Jun-Aug 1999

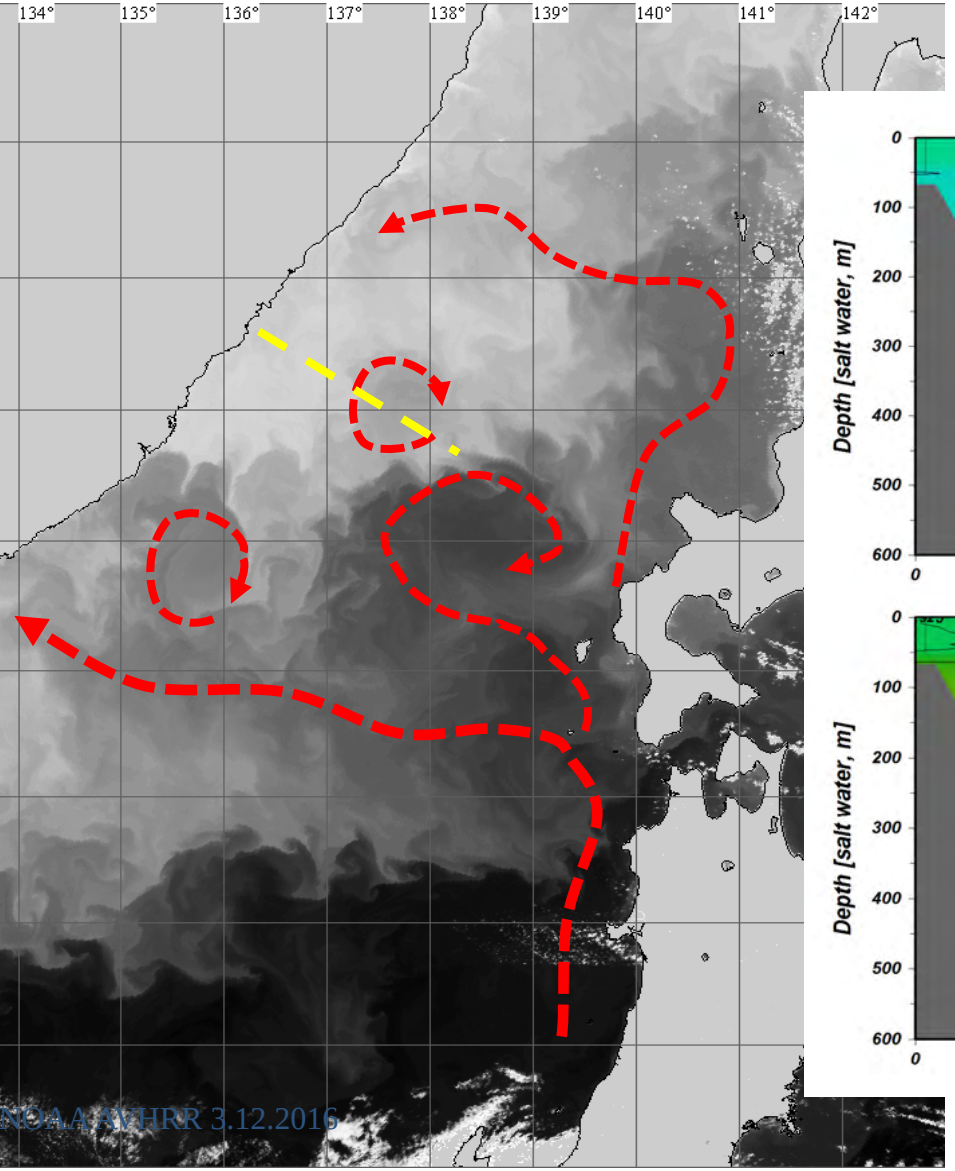


Eddies G, F and H vertical section of salinity

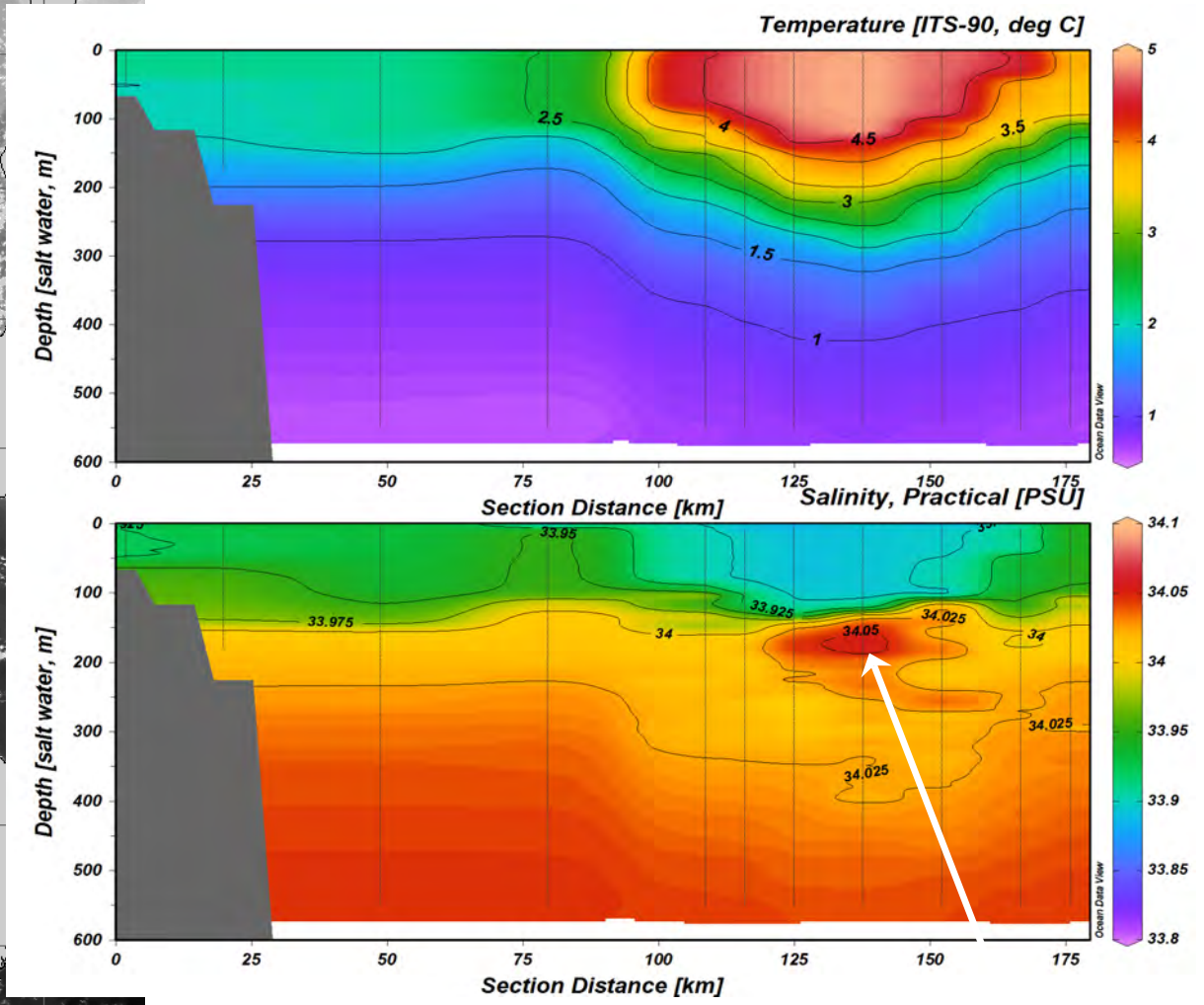




Eddies of the NW branch of Tsushima Current



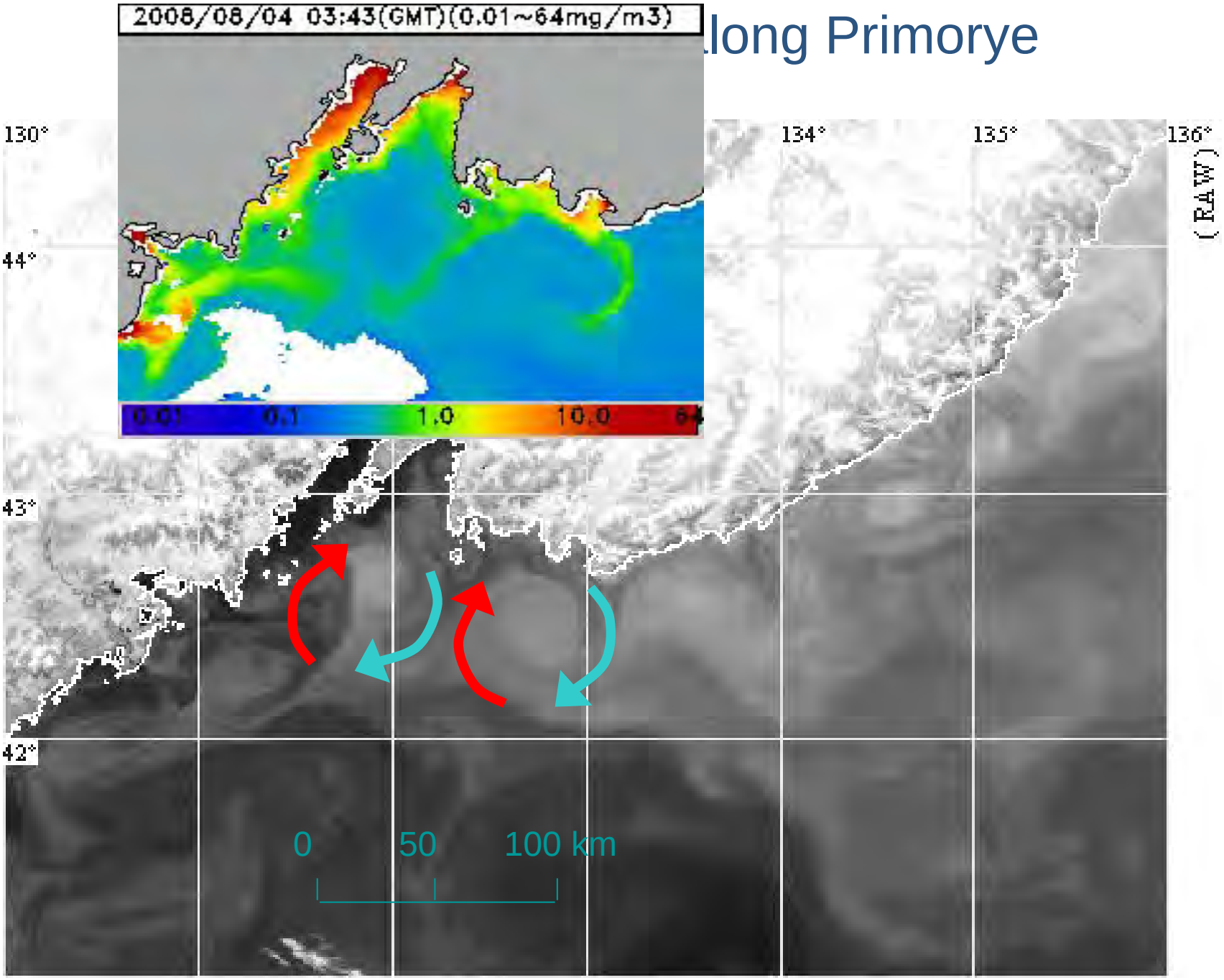
La79, Dec 2016



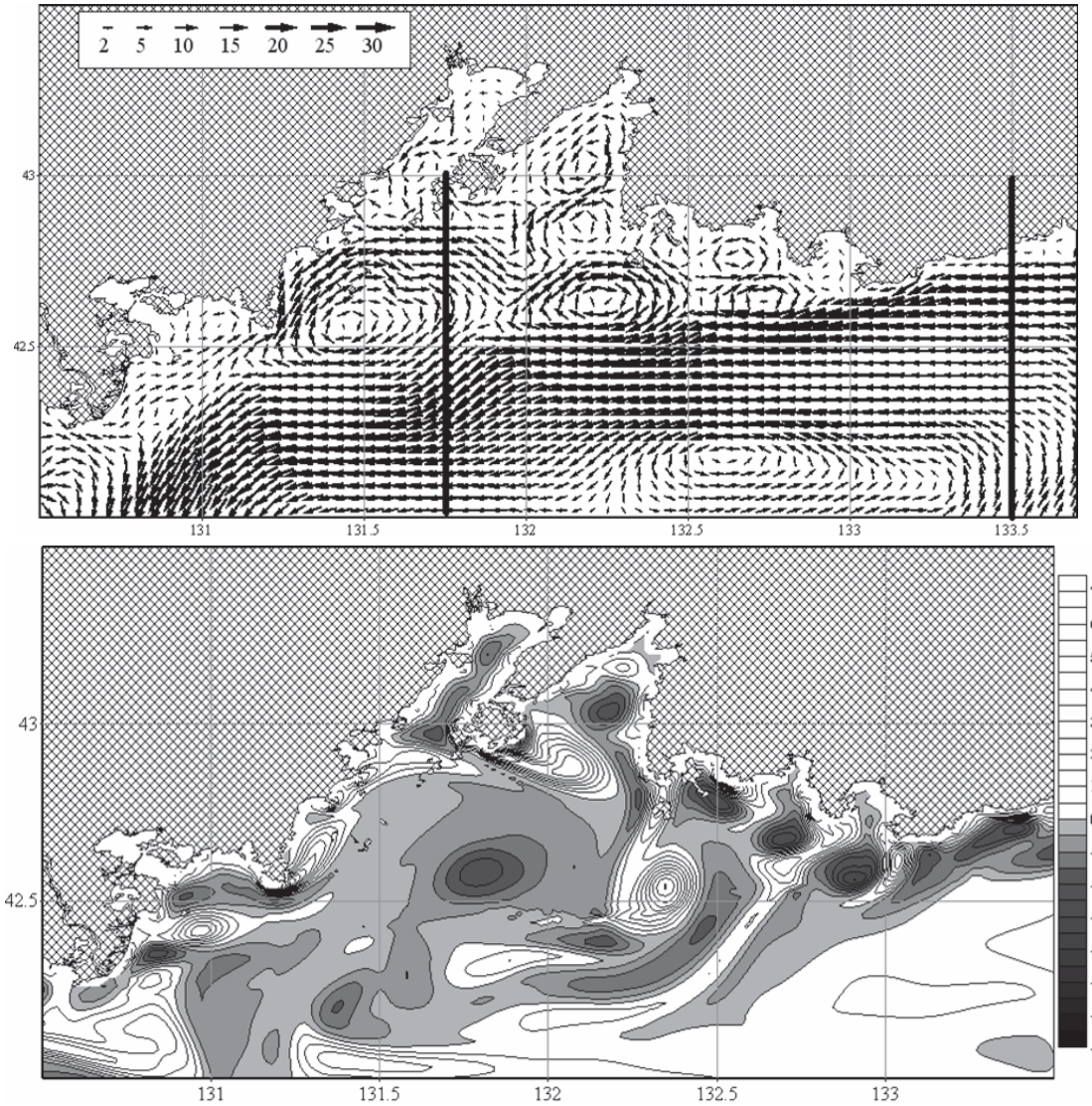
High Salinity Core

ПП «Дальний Восток» 15-I-1-047, Грант РФФИ 16-55-50071 яф-а

long Primorye

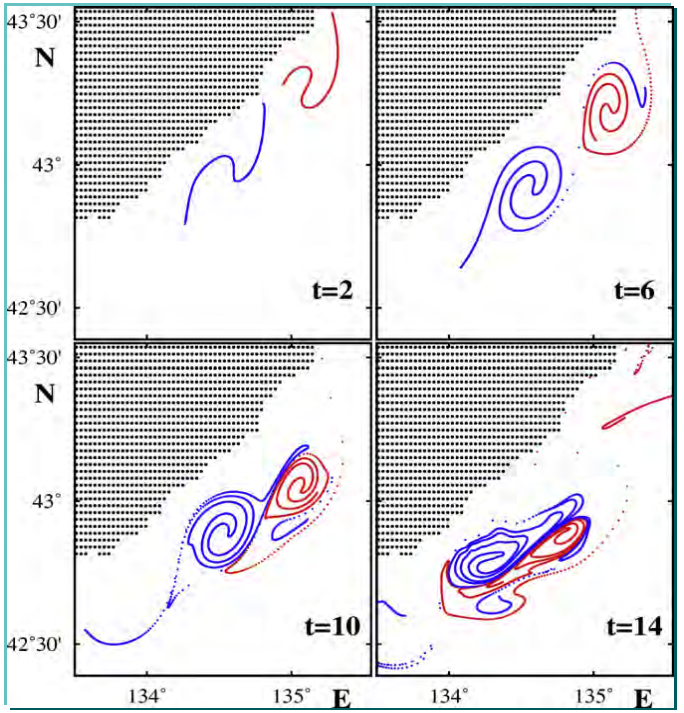


Modelled Primorye Slope Eddies



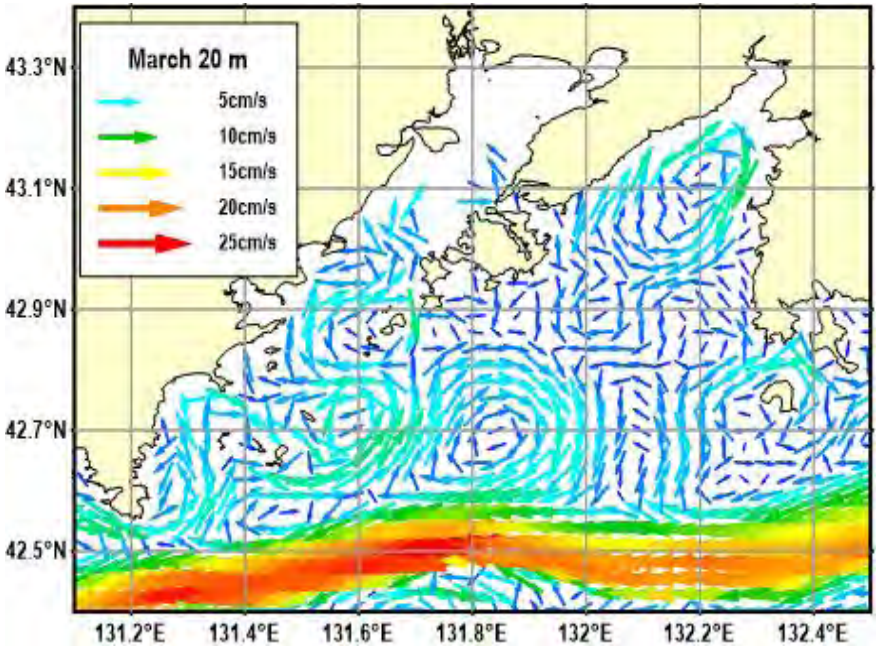
Current velocity (top) and vorticity (bottom) in the upper mixed layer by quasi-isopycnal layered model in z-coordinate system (Shapiro and Mikhailova, 2001) 2,5 km, 10 layers

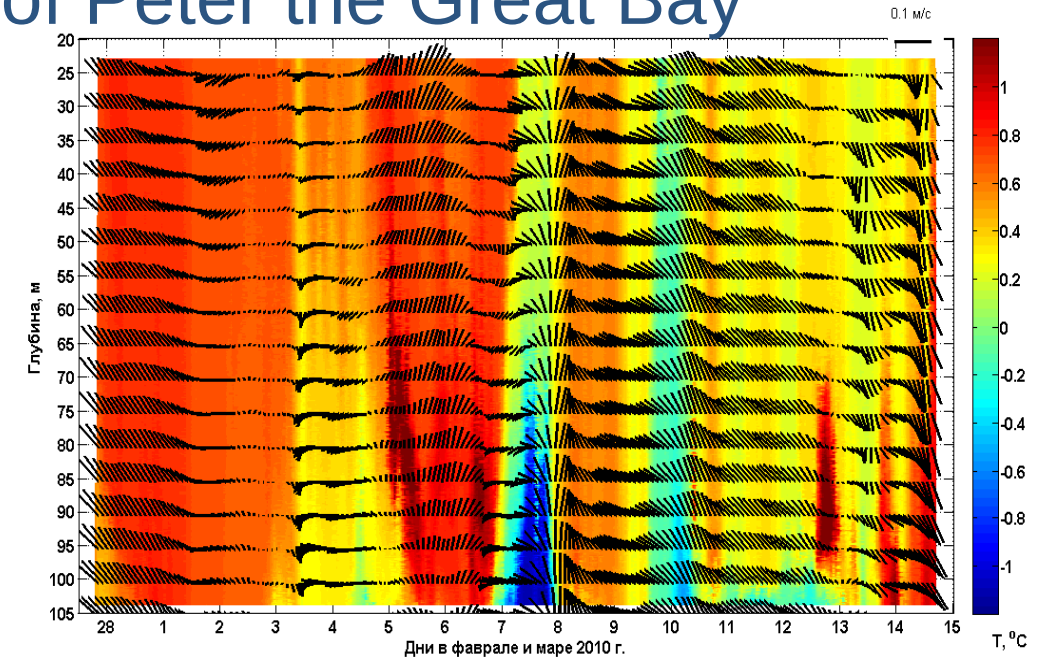
Ponomarev et al., 2011

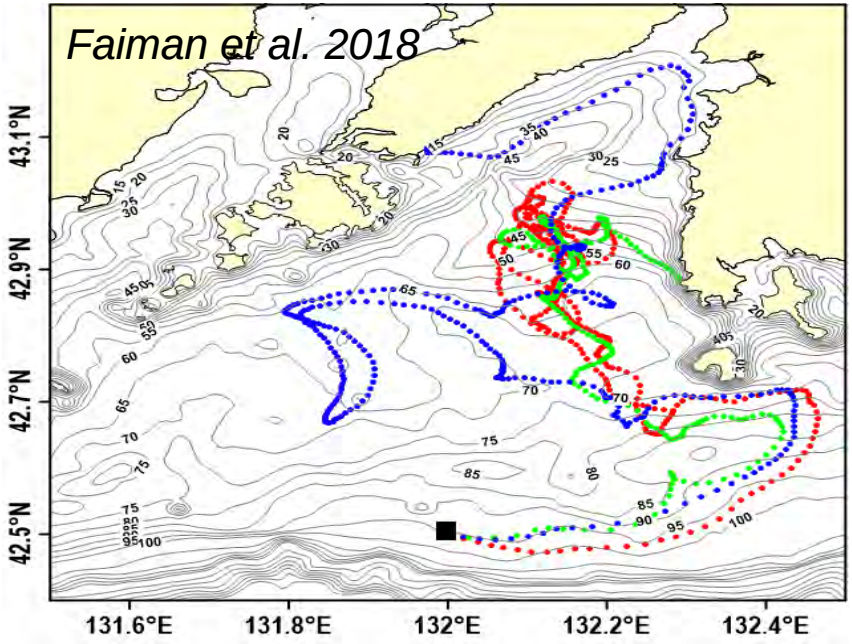


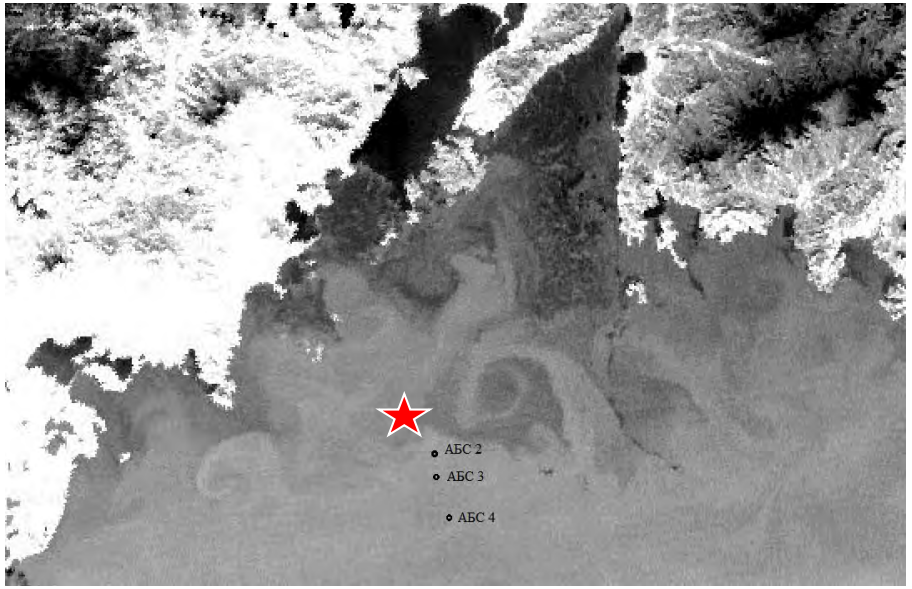
Lagrangian simulations, Prants et al. 2011

Eddies over the shelf of Peter the Great Bay









Outline

1. Brief history of AP-CREAMS
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   -Mechanisms and changes in the deep ventilation system

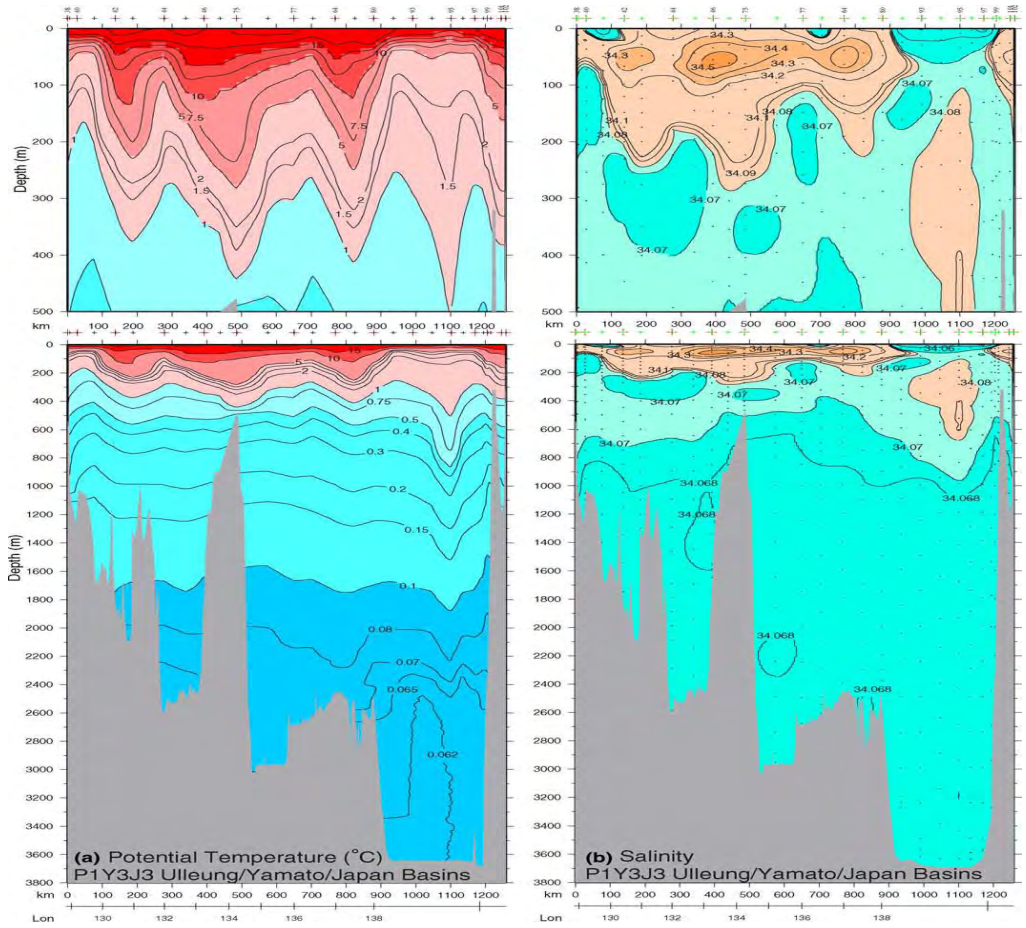
   -Mesoscale water dynamics (upwelling, eddies)

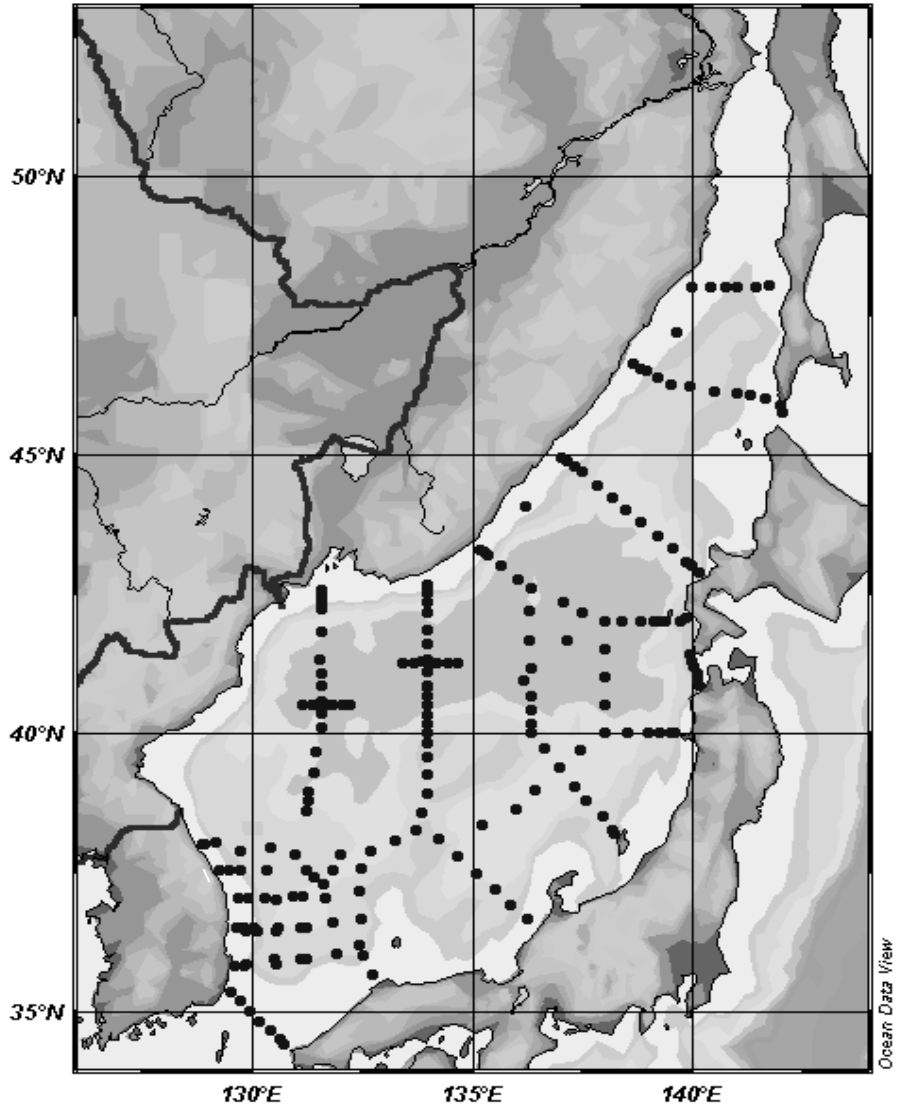
3. **Further development – CREAMS 3.0**

CREAMS 3.0: international cooperative experiments

CREAMS

- Synchronous basin scale survey (repeat of 1999-2000)



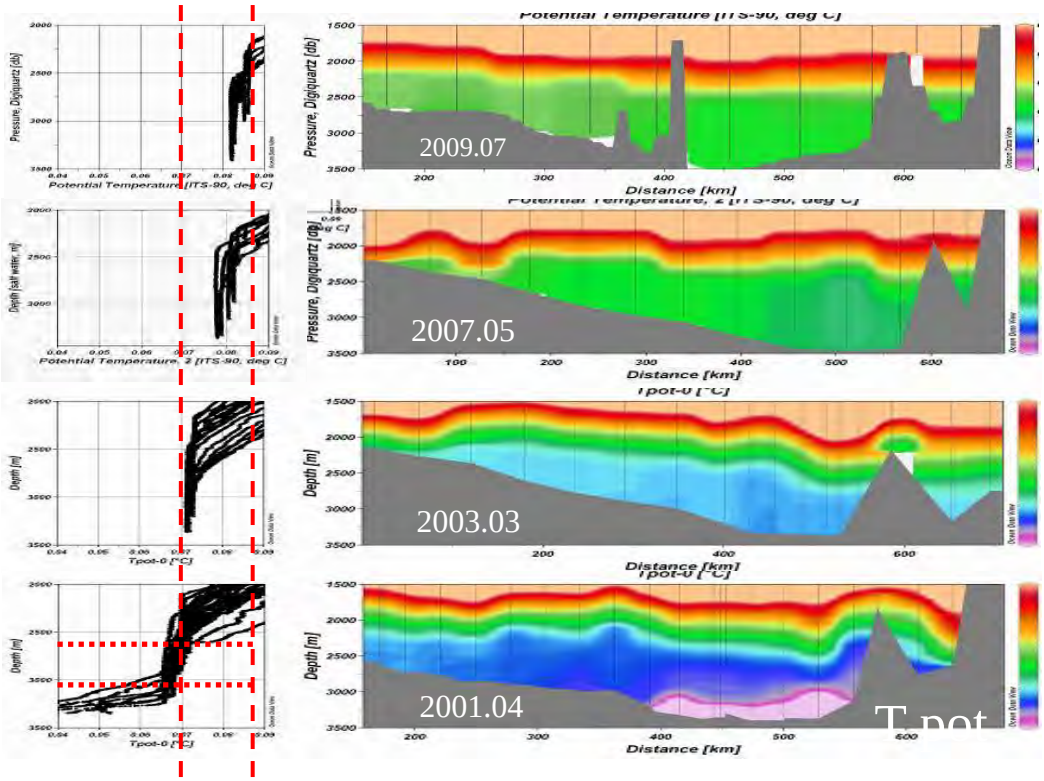


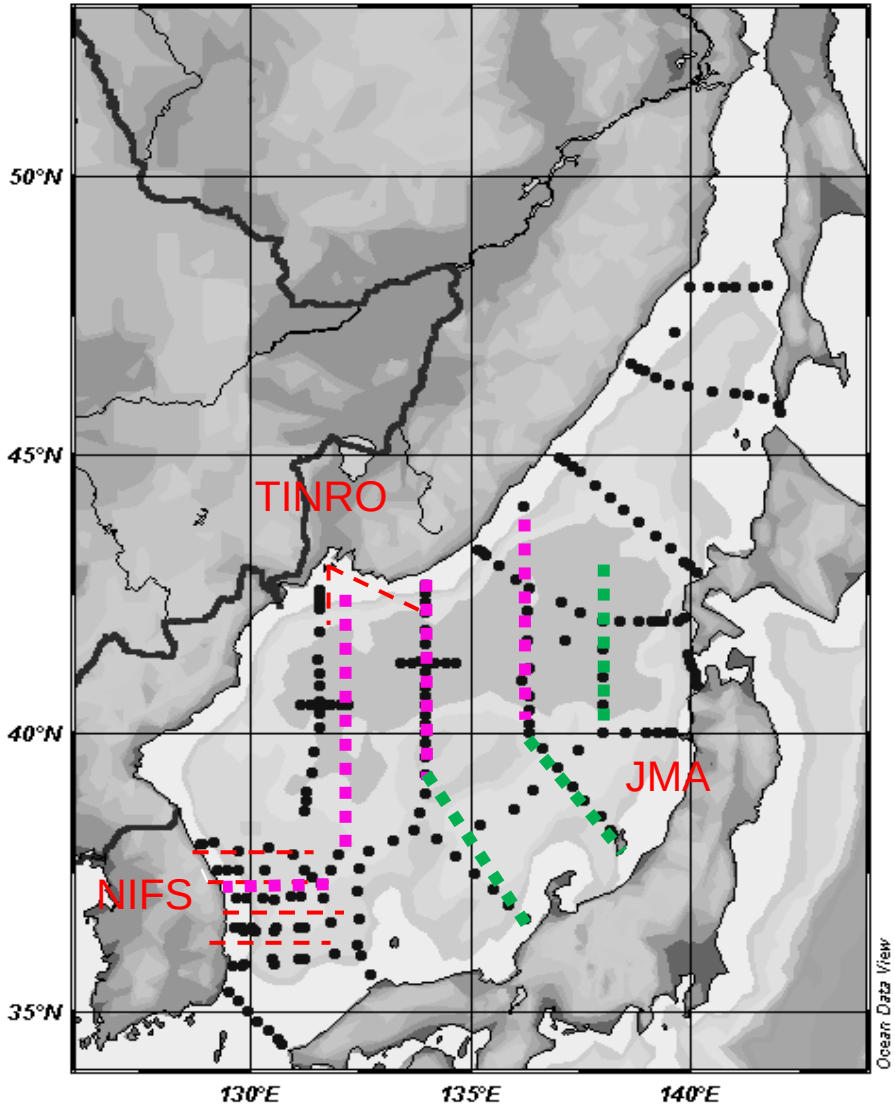
CREAMS 3.0: international cooperative experiments

CREAMS

- Synchronous basin scale survey (repeat of 1999-2000)

- Climate monitoring sections (CREAMS, NEAR-GOOS), national agencies





CREAMS 3.0: international cooperative experiments

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- Synchronous basin scale survey (repeat of 1999-2000)
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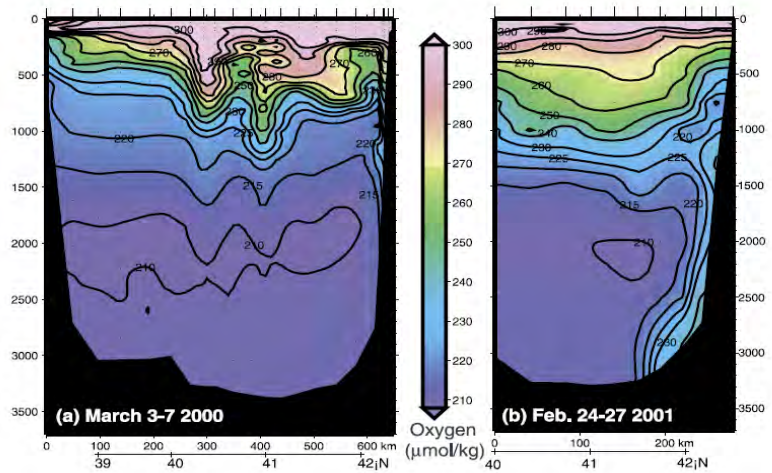
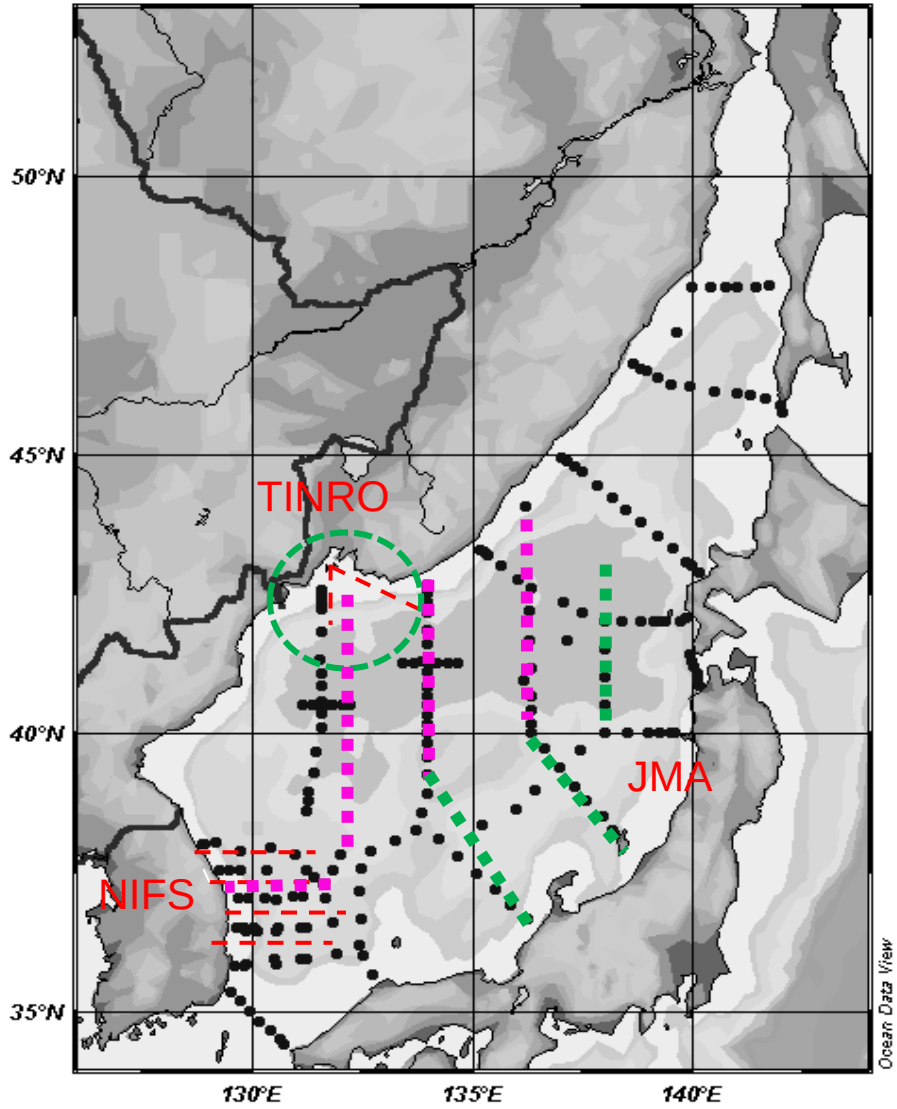
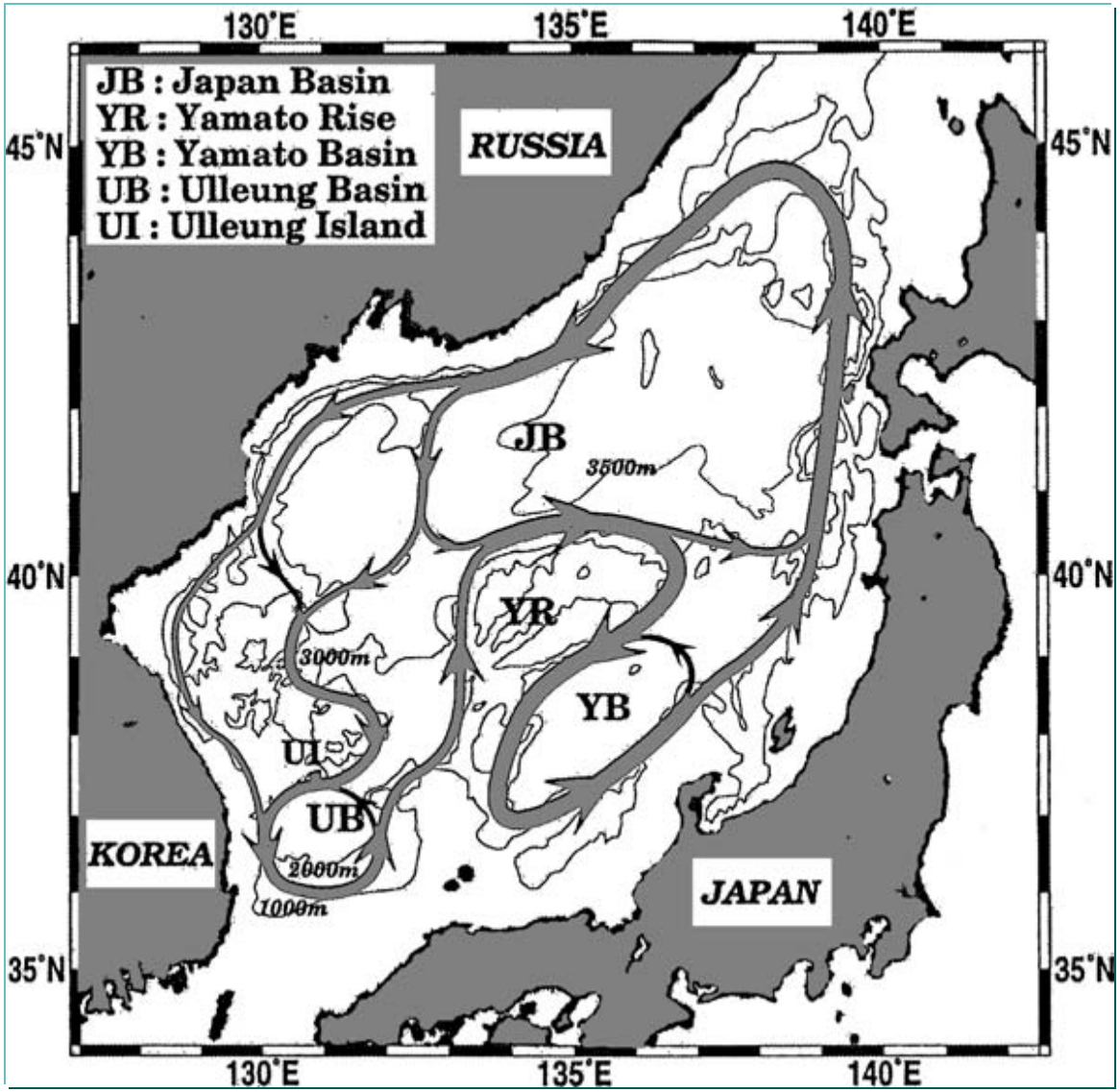


Figure 4. Oxygen (μmol/kg) along 131°30′E: (a) March 3–7, 2000 and (b) Feb. 24–27, 2001. Sections in Figure 1.

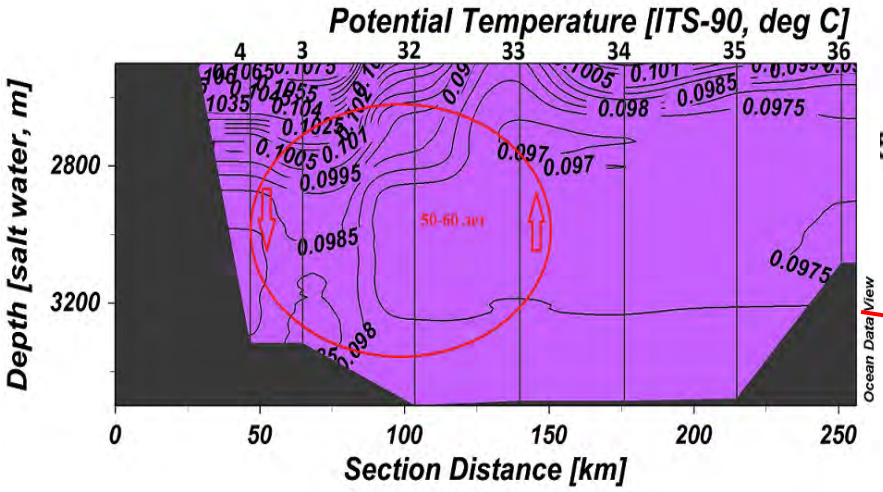


Do we know basin scale abyssal circulation?

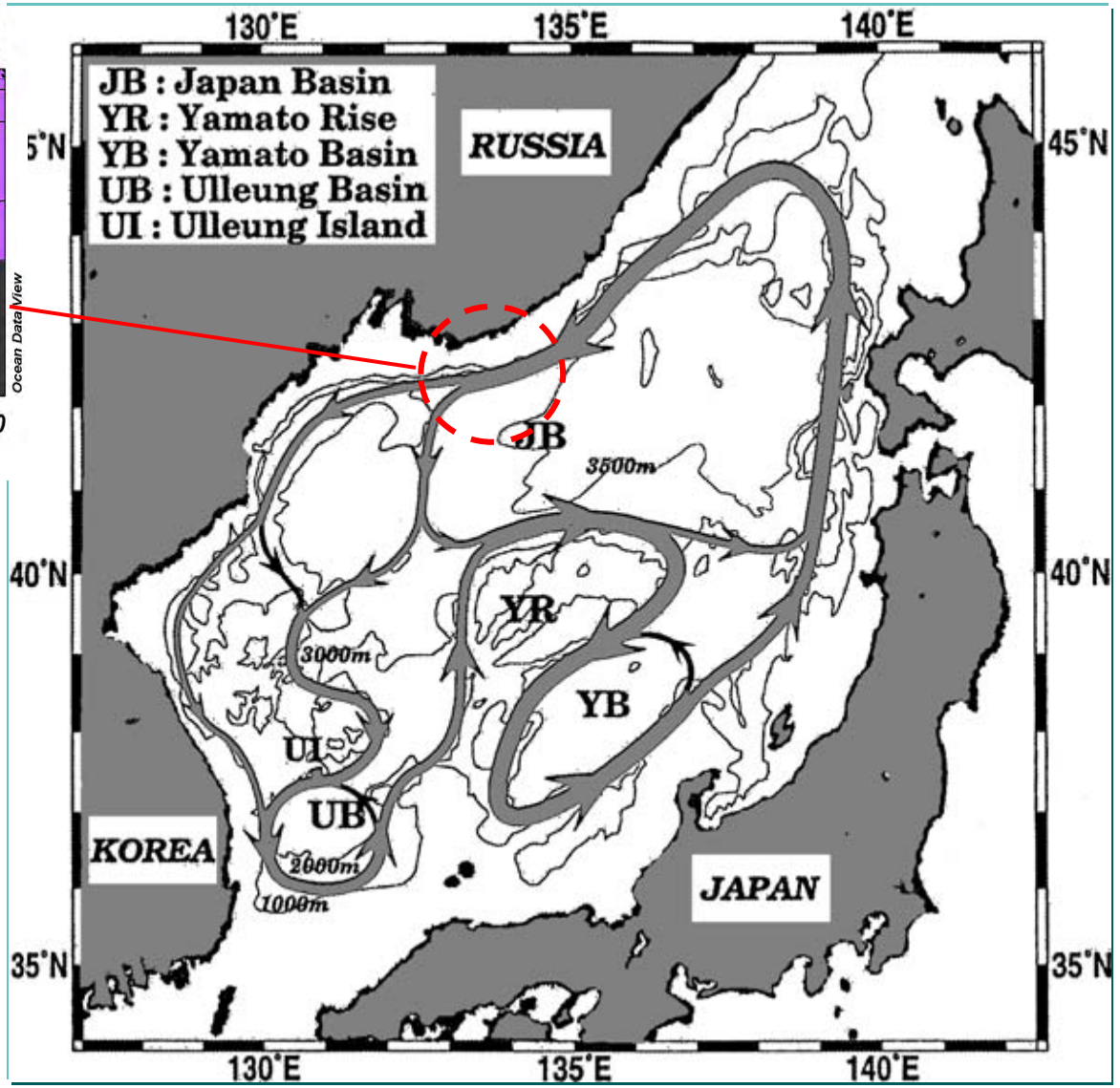


Senjyu, 2005

Do we know basin scale abyssal circulation?



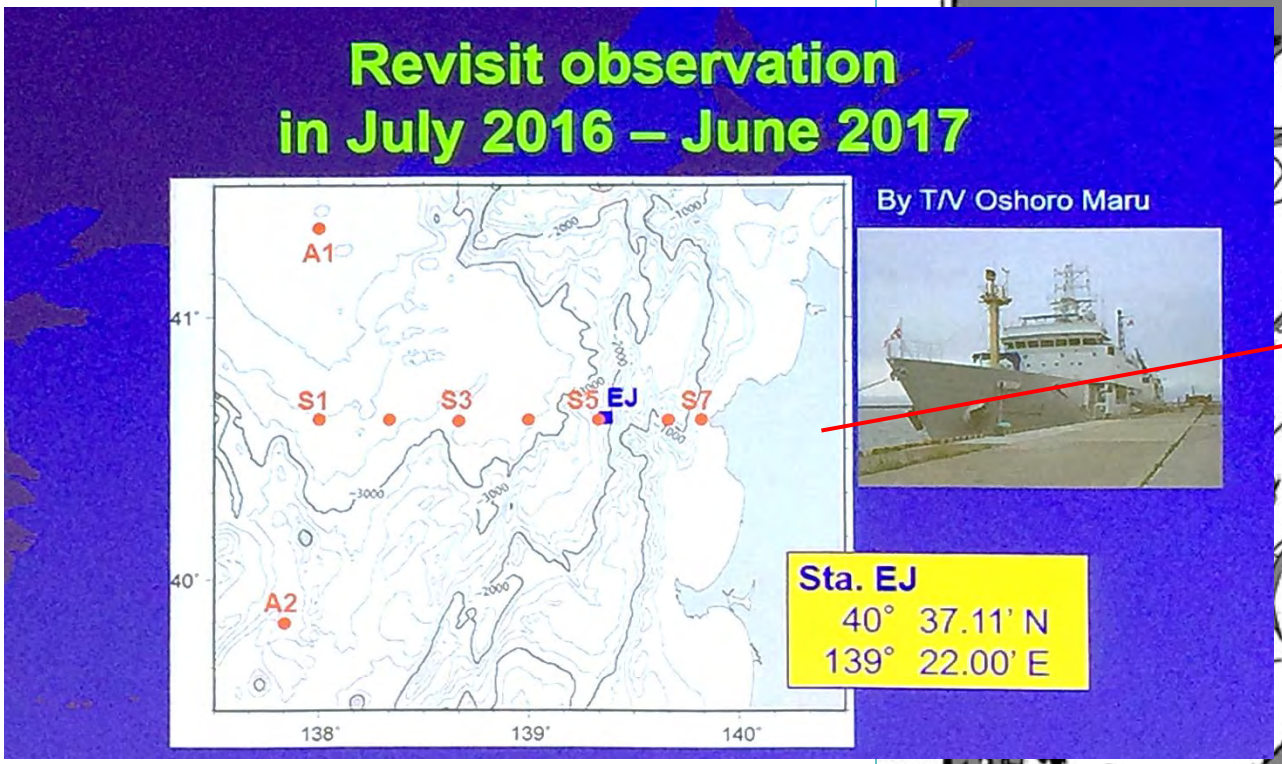
Abyssal front at continental slope, current shear, mixing



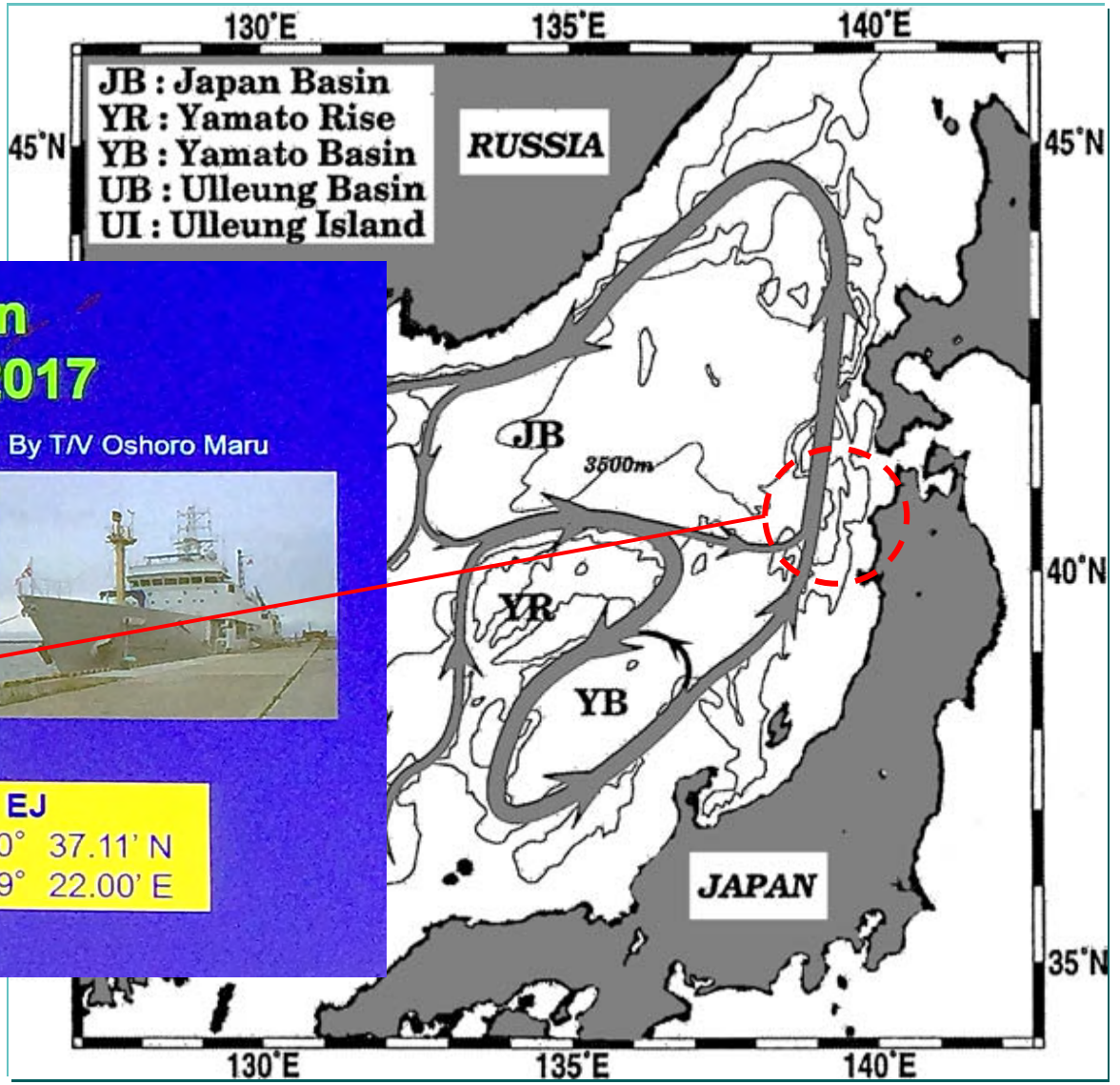
Senjyu, 2005

Do we know basin scale abyssal circulation?

Weakening of thermohaline circulation since 1994-95?



Senjyu, 2019



Senjyu, 2005

CREAMS 3.0: international cooperative experiments

- Synchronous basin scale survey (repeat of 1999-2000)
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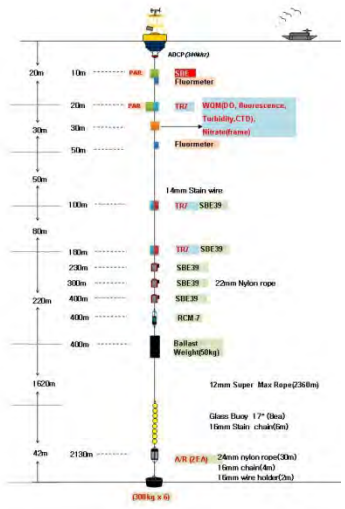
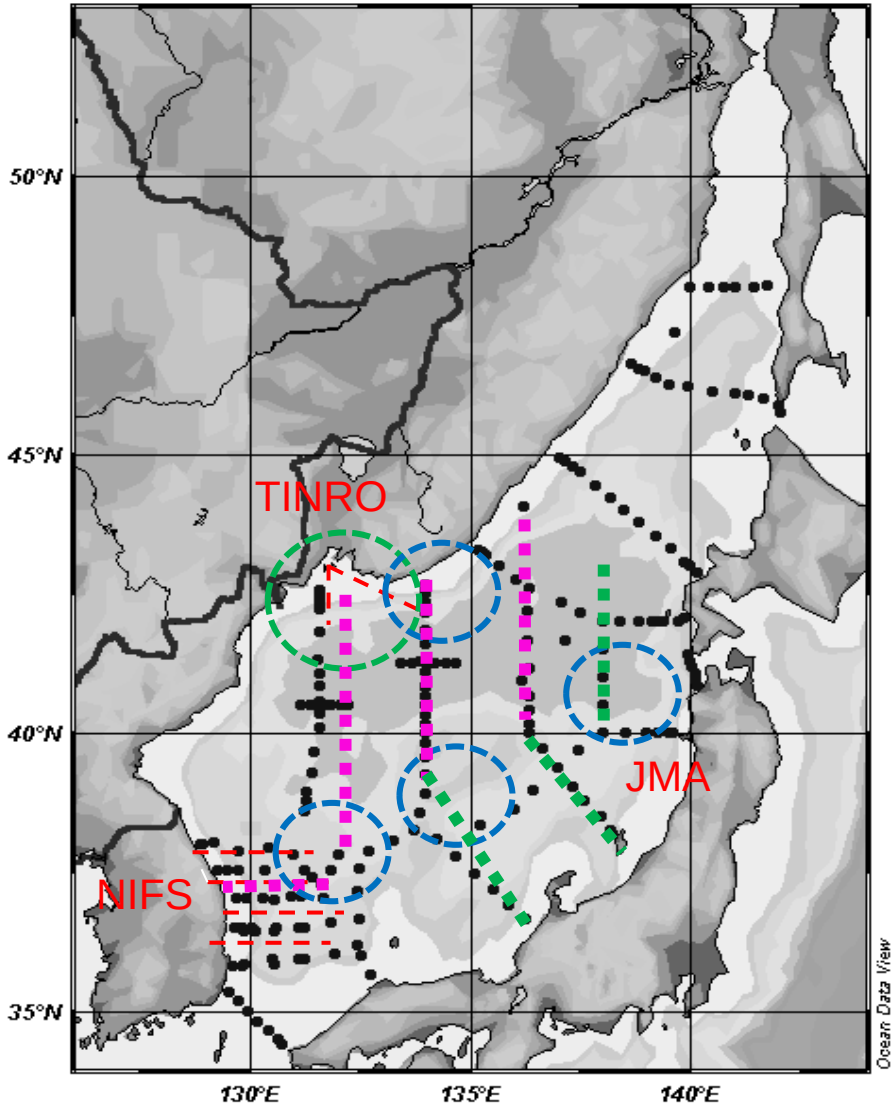
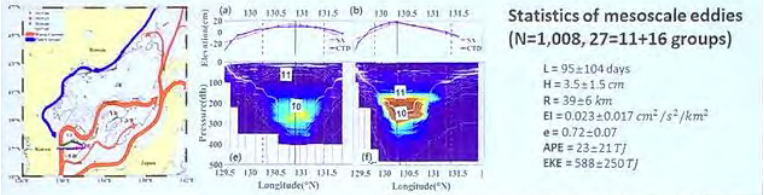




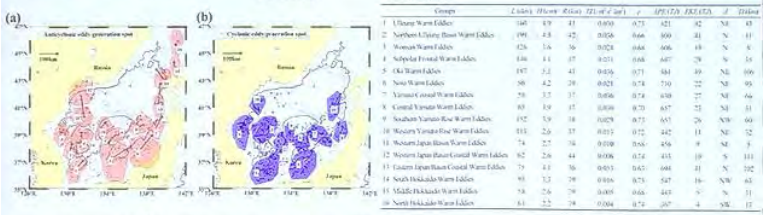
A role of mesoscale water dynamics? (mixing, water mass formation and transport, biogeochemical cycles, ecosystem)

MSJRK science publication 2. Meso-Eddies



Statistics of mesoscale eddies
(N=1,008, 27=11+16 groups)

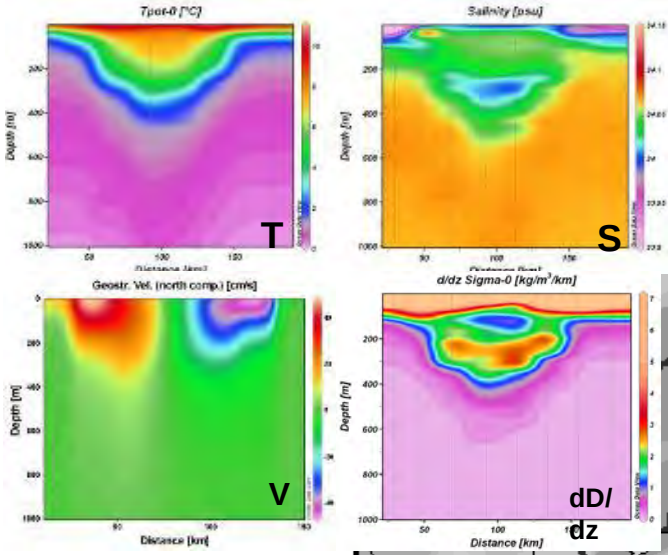
L = 95±104 days
H = 3.5±1.5 *cm*
R = 39±6 *km*
EI = 0.023±0.017 $cm^2/s^2/km^2$
e = 0.72±0.07
APE = 23±21 *TJ*
EKE = 588±250 *TJ*

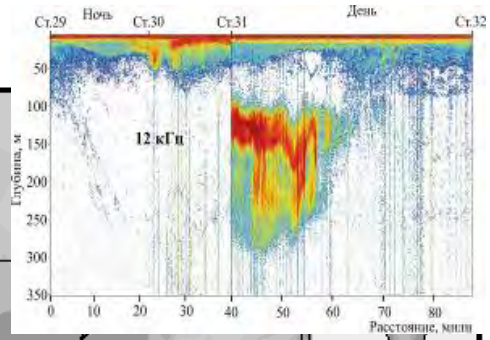


$$EKE(J) = \int_J \int_0^h \frac{1}{2}\rho_0 \sqrt{u'^2 + v'^2}\, dz\, dA, \qquad EI = \frac{EKE}{A}\Big/\frac{EKE}{hA^2}, \qquad APE(J) = \int_J \int_0^h \frac{\eta^2 \rho'^2}{2\rho_0 N^2} dz\, dA$$

Lee, K. J., S. H. Nam*, and Y. -G. Kim (2019), Statistical characteristics of East Sea mesoscale eddies detected, tracked, and grouped using satellite altimeter data from 1993 to 2017, *Journal of the Korean Society of Oceanography (Bada)*, 24 (2), in print. doi:10.7850/jkso.2019.24.2.000 (in Korean with English abstract)

S-H Nam, 2019

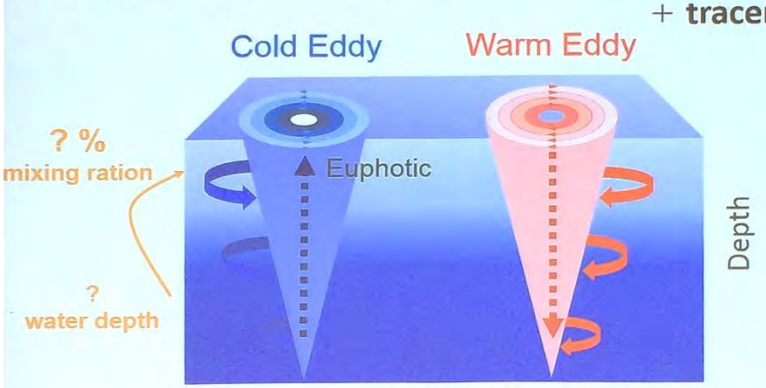




Motivation

Synergy study: **eddy/upwelling/downwelling**

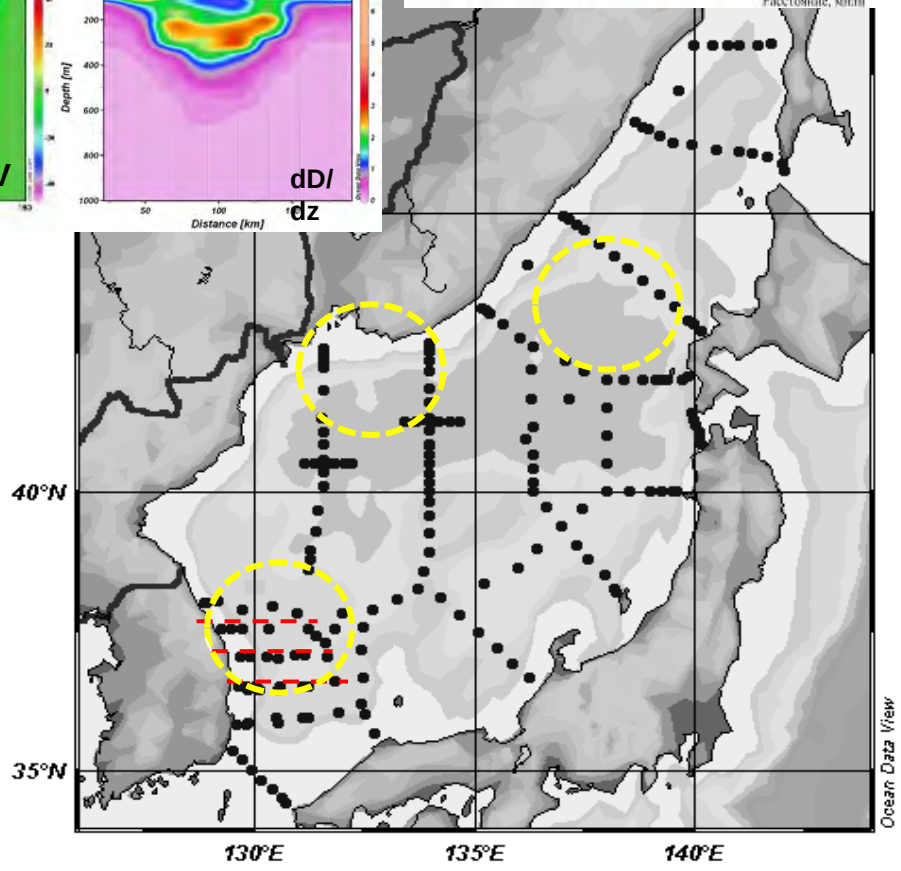
+ tracers



to identify the origin & estimate contribution

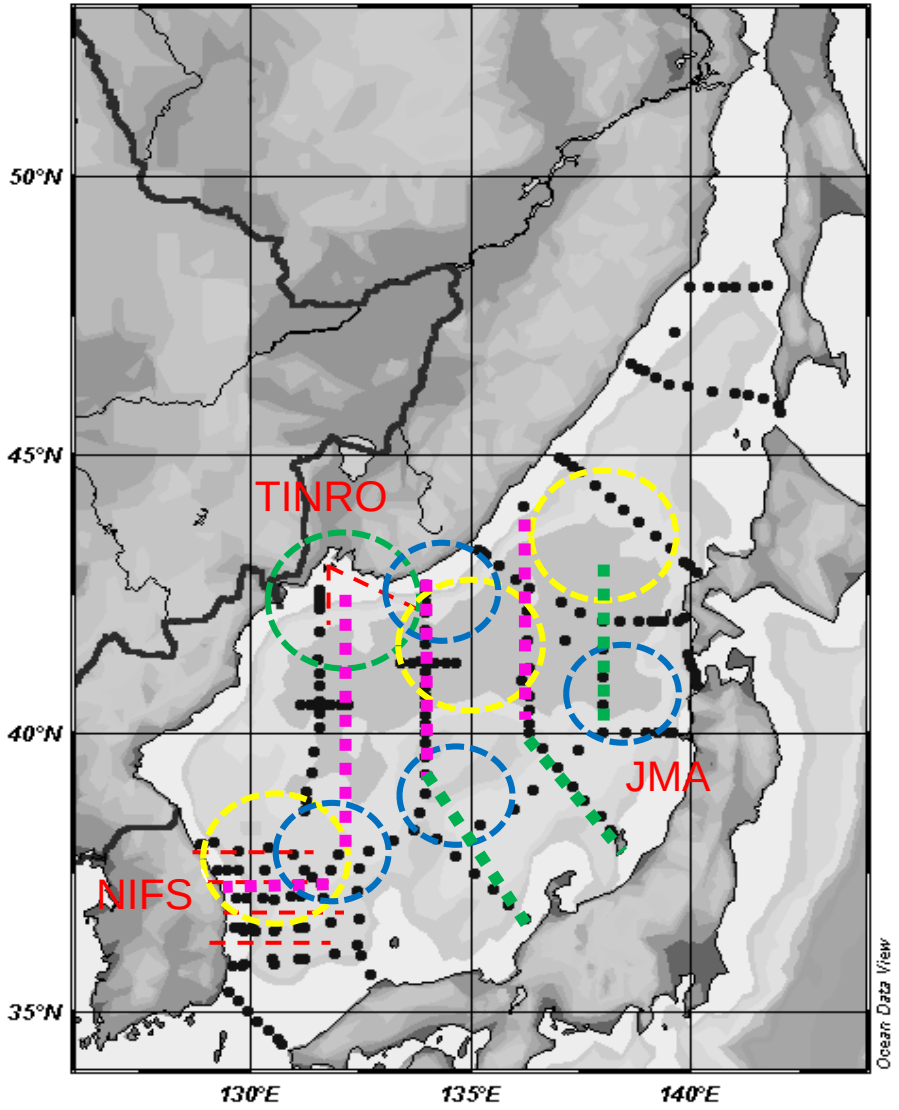
Isopycnaly? diapycnally ??

Jing Zhang, 2019

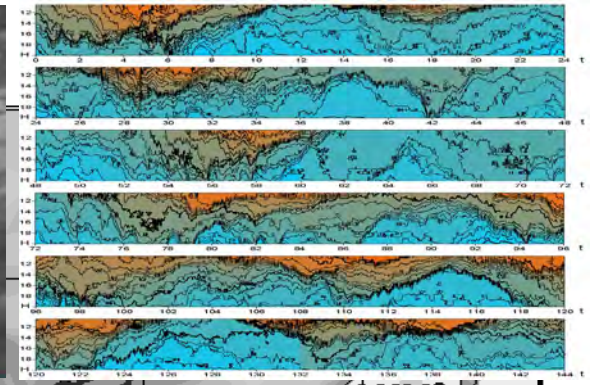


CREAMS 3.0: international cooperative experiments

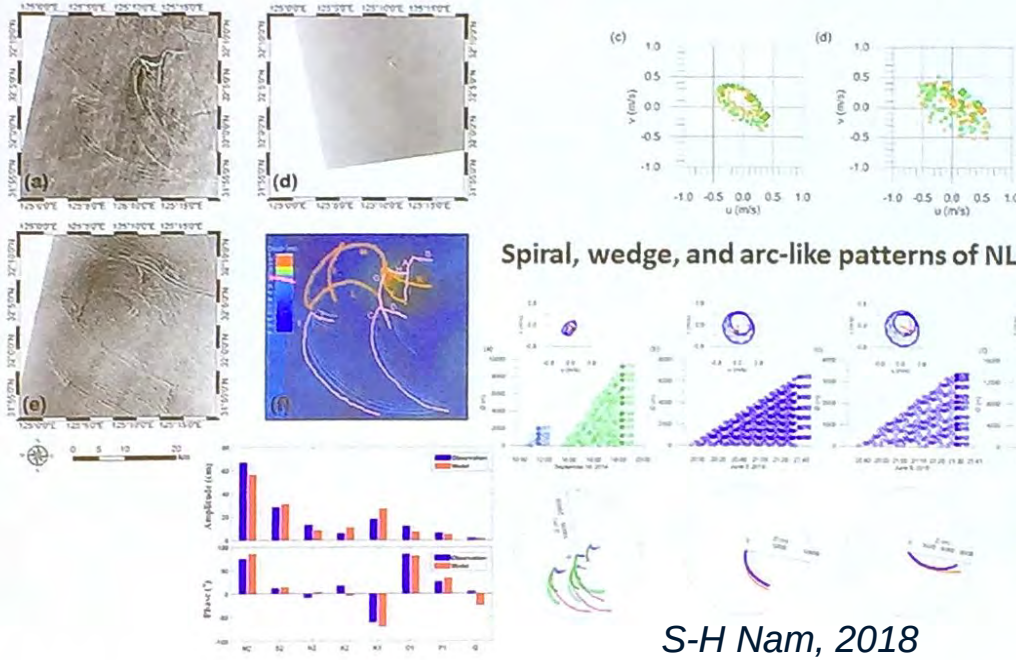
- Synchronous basin scale survey (repeat of 1999-2000)
- Climate monitoring sections (CREAMS, NEAR-GOOS), national agencies
- Convection study experiment, ventilation of the sea interior
- Deep sea circulation study and monitoring
- Mesoscale water dynamics



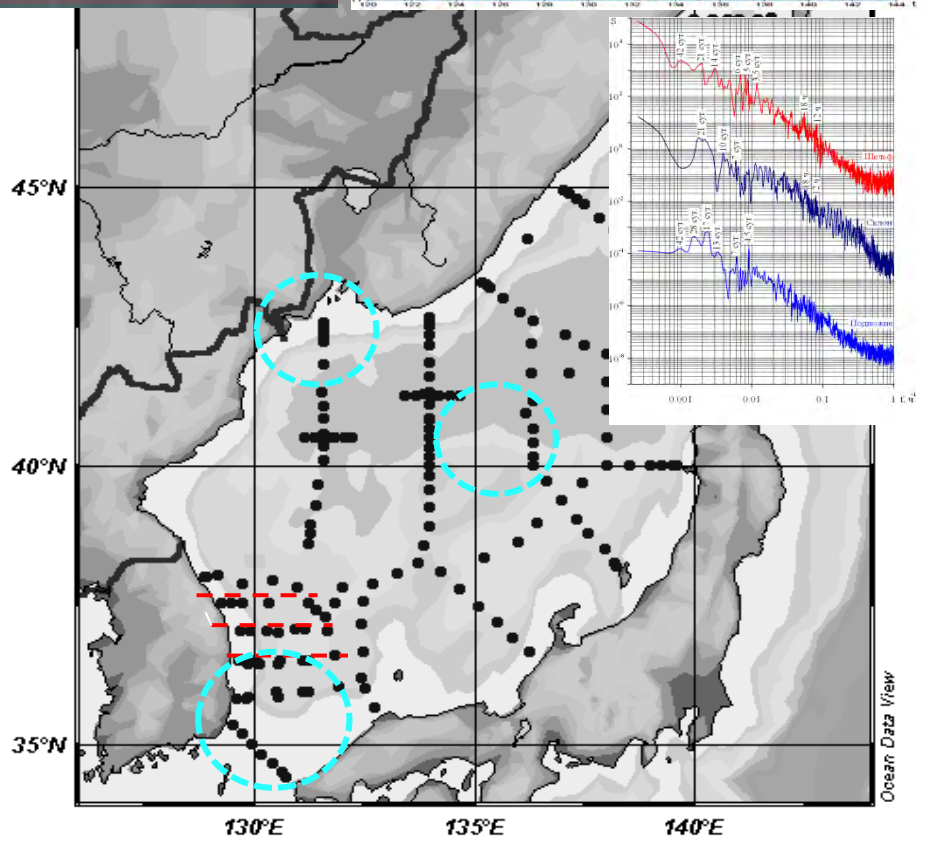
Small-scale water dynamics (internal waves, turbulence, coastal mixing)



ECS science publication 2. Nonlinear IW



S-H Nam, 2018



Nam, S. H., D. -J. Kim*, S. -W. Lee, B. -K. Kim, K. -M. Kang, and Y. -K. Cho (2018), Nonlinear interna spirals in the northern East China Sea, *Scientific Reports*, 8, 3473, doi:10.1038/s41598-018-21461 http://doi.org/10.1038/s41598-018-21461-3

CREAMS 3.0: international cooperative experiments

CREAMS

- Synchronous basin scale survey (repeat of 1999-2000)
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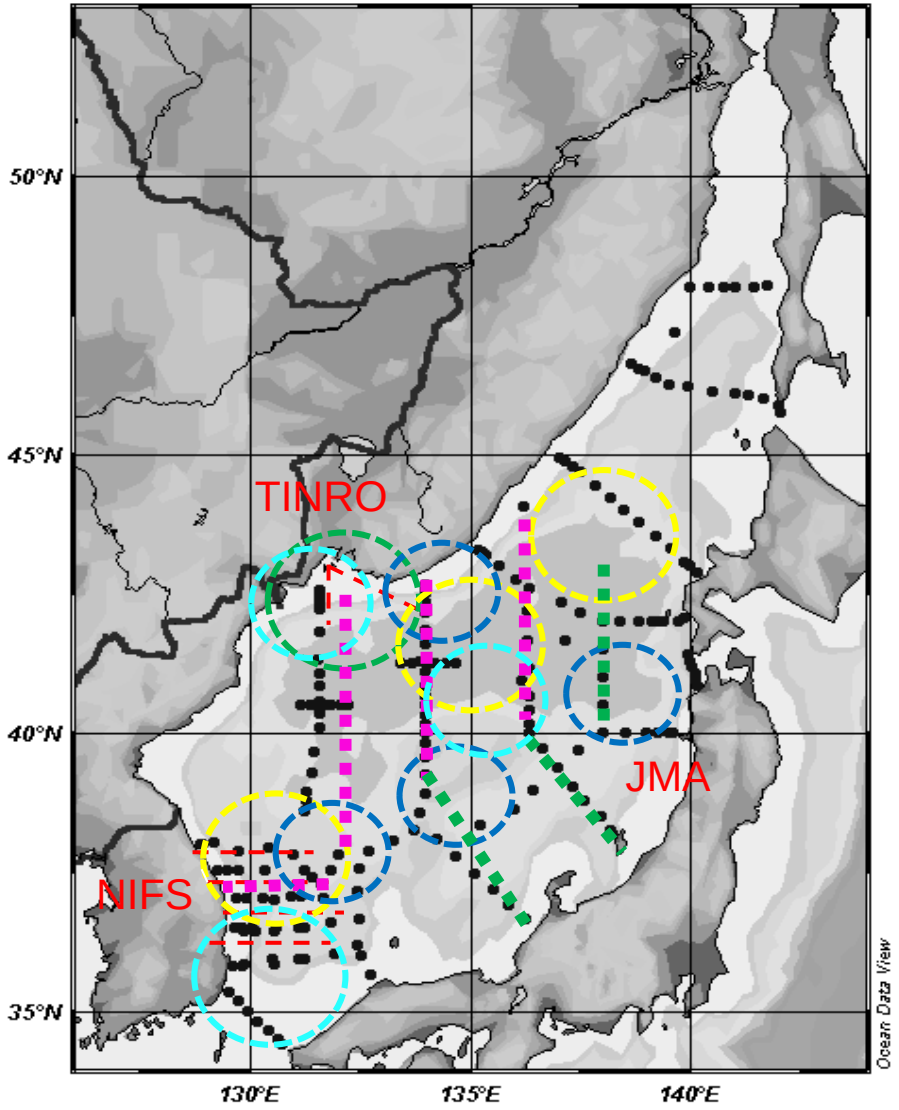
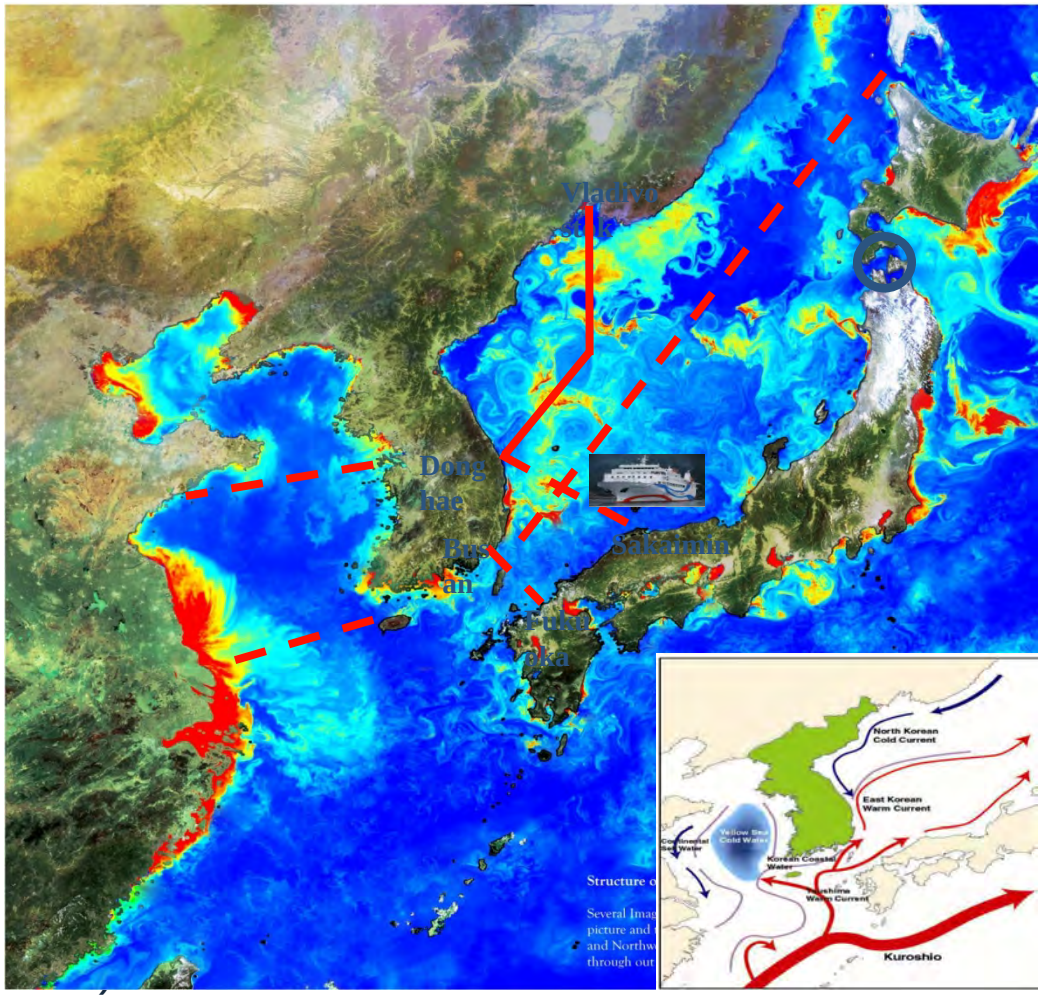
- Convection study experiment, ventilation of the sea interior
- Deep sea circulation study and monitoring
- Mesoscale water dynamics
- Internal waves, turbulence, mixing (with NRL)



CREAMS 3.0: international cooperative experiments

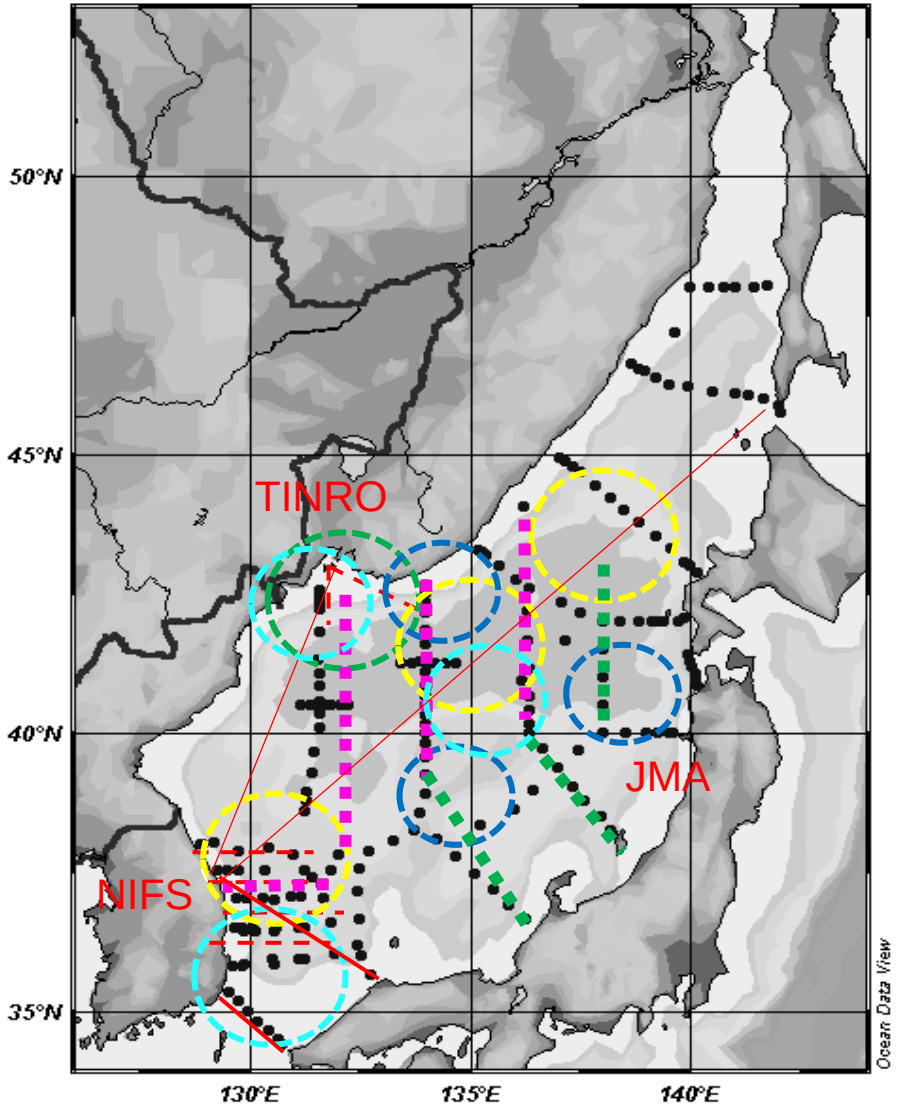


- Ferry-based monitoring lines
- (H-D Jeong, NIFS)

CREAMS 3.0: international cooperative experiments

CREAMS

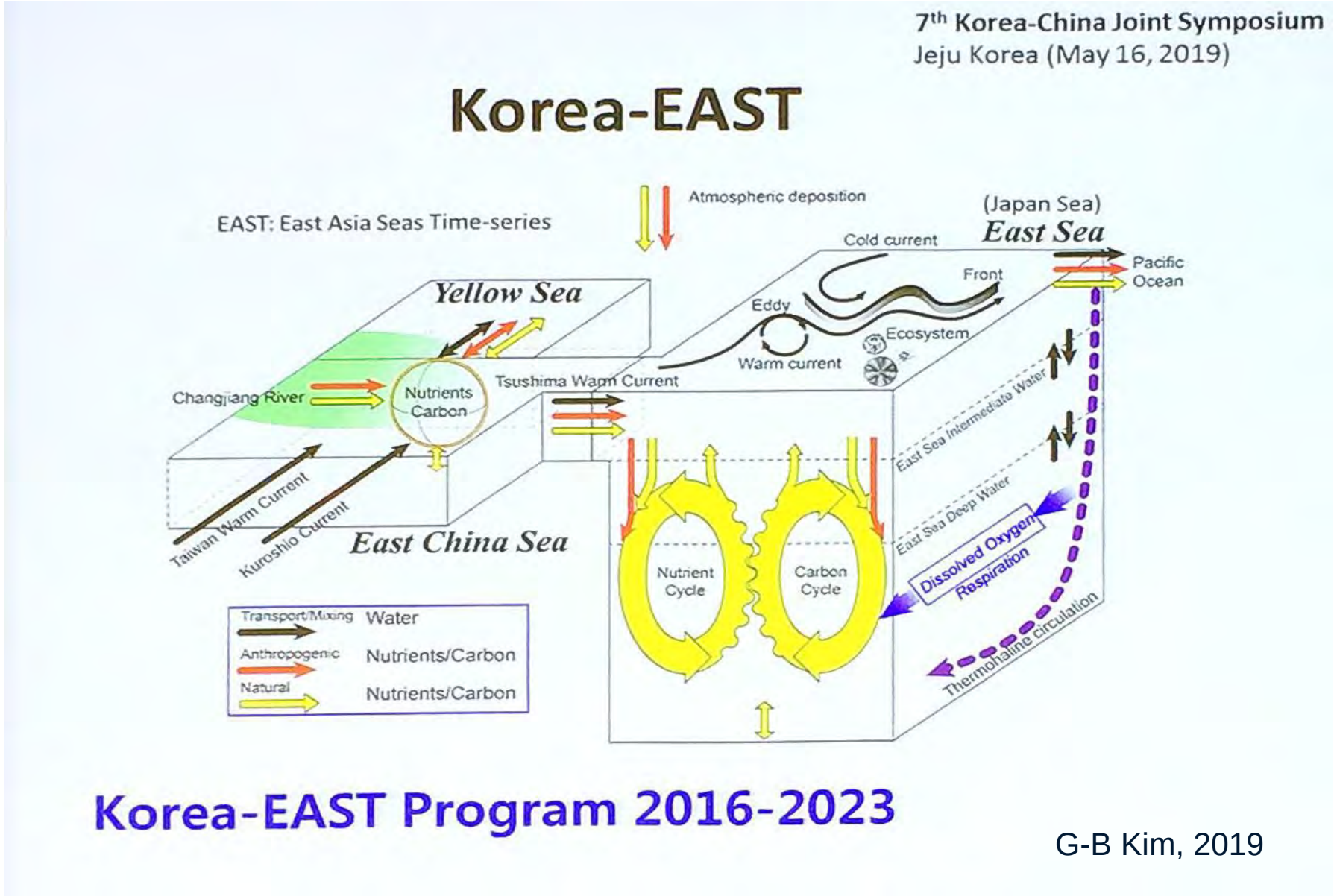
- Synchronous basin scale survey (repeat of 1999-2000)
- Climate monitoring sections (CREAMS, NEAR-GOOS), national agencies
- Convection study experiment, ventilation of the sea interior
- Deep sea circulation study and monitoring
- Mesoscale water dynamics
- Internal waves, turbulence, mixing (with NRL)
- Ferry-based monitoring lines
- .....



CREAMS 3.0: multidisciplinary approach

CREAMS

7th Korea-China Joint Symposium
Jeju Korea (May 16, 2019)

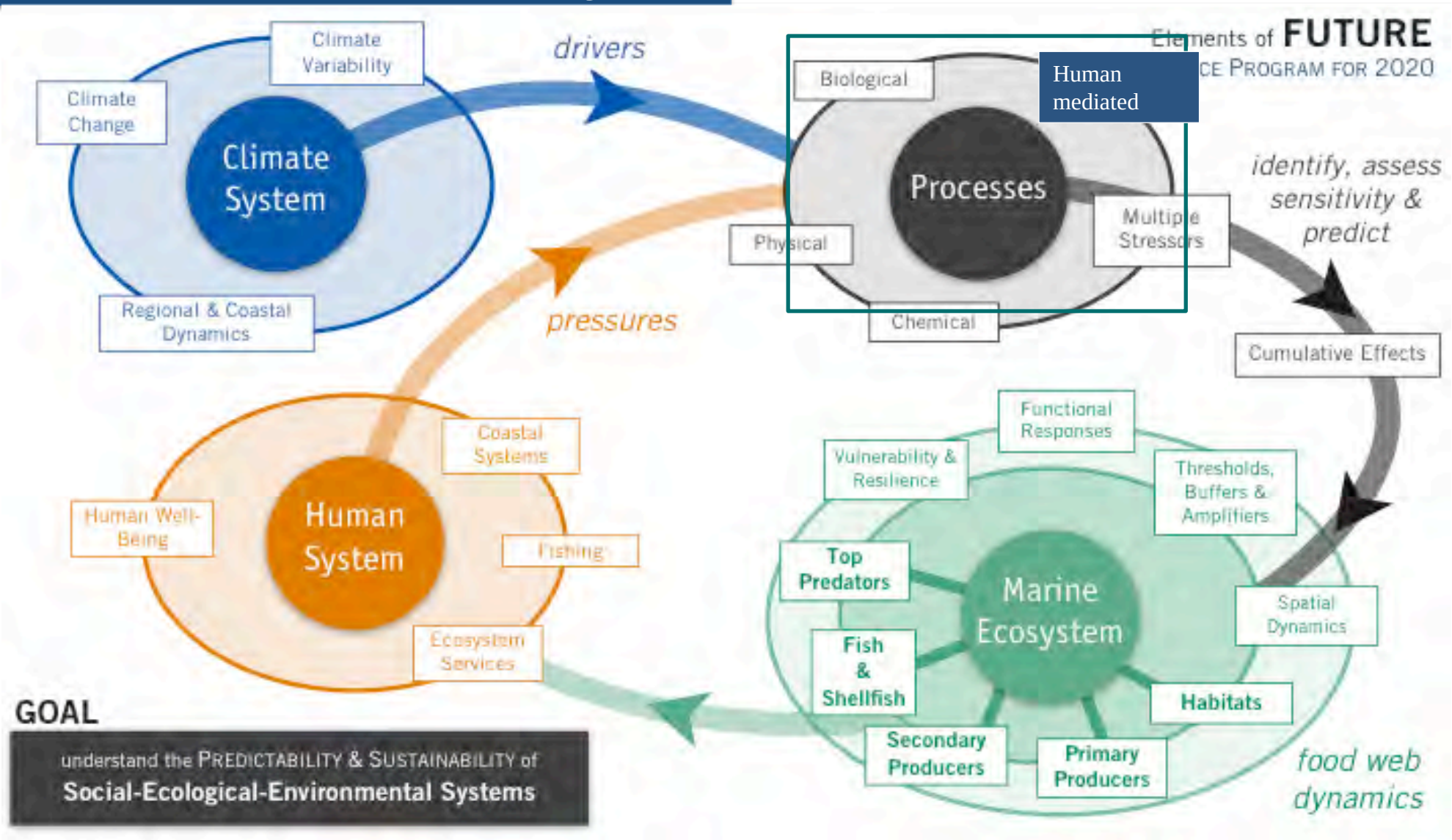


Korea-EAST Program 2016-2023

G-B Kim, 2019

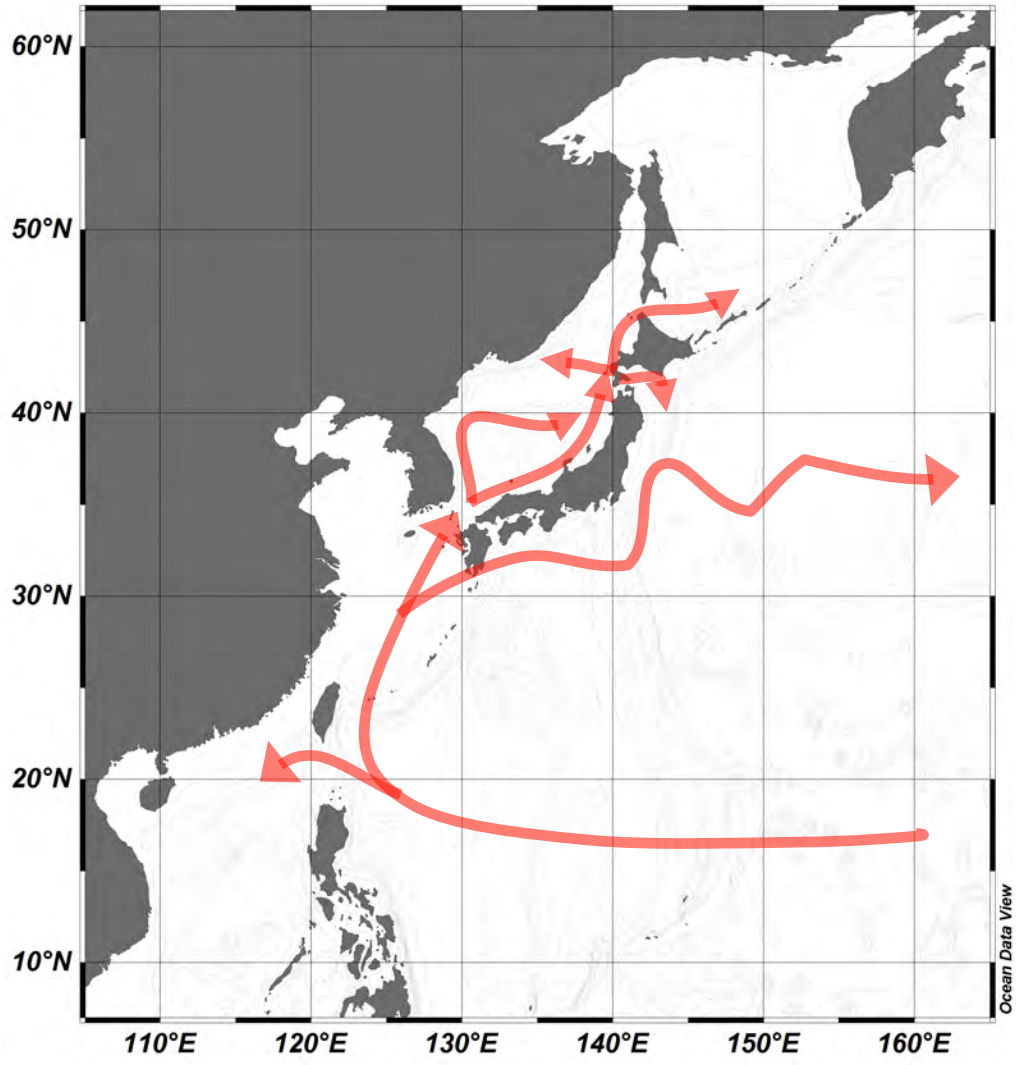
CREAMS 3.0: on social-ecological-environmental system

PICES/FUTURE Science Program



CREAMS 3.0: wider geography – whole system of NE Asian marginal seas

- - Expand area to cover both seas (EAST-I and II), or even a whole system of NE Asia seas
- - Transport of subtropical water (branches of Kuroshio current)



CREAMS 3.0: wider geography – whole system of NE Asian marginal seas

- - Expand area to cover both seas (EAST-I and II), or even a whole system of NE Asia seas
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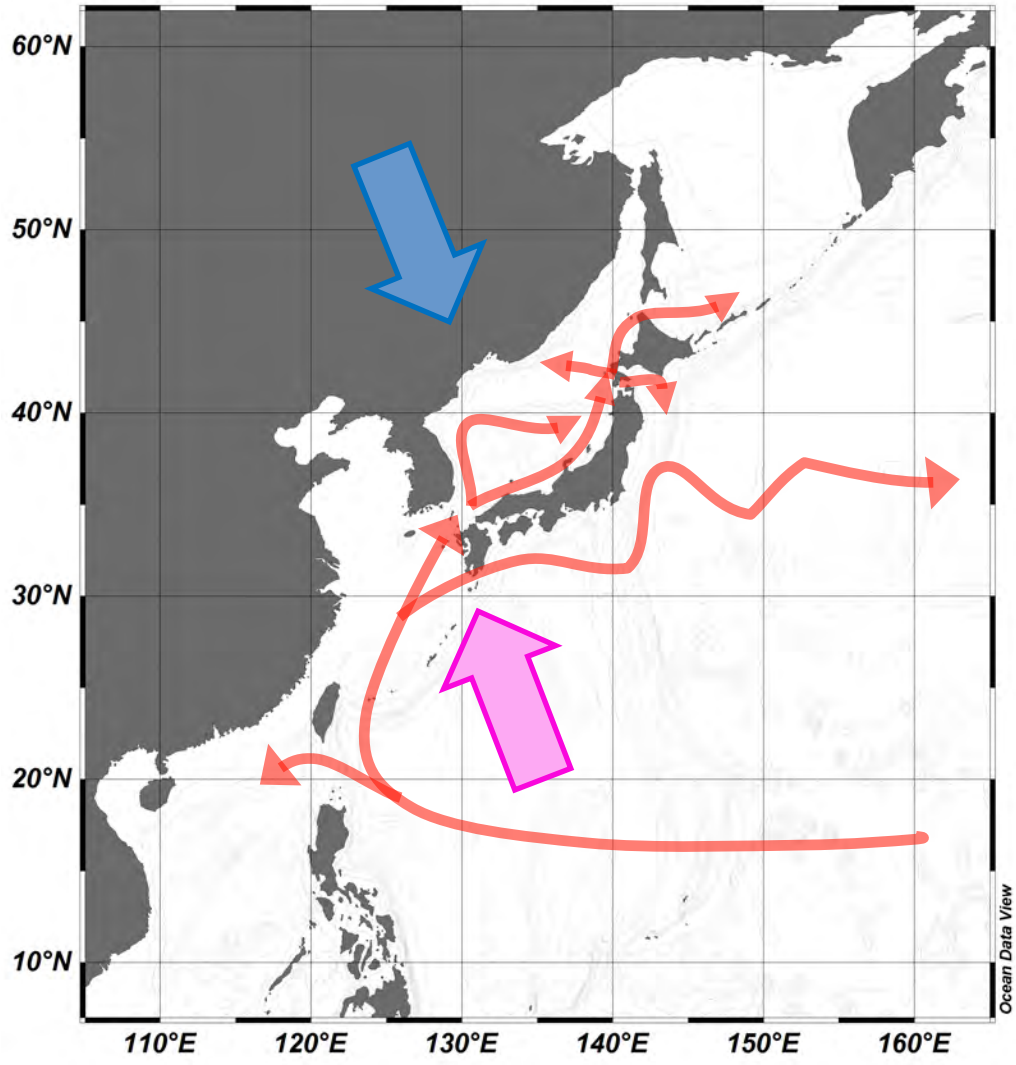
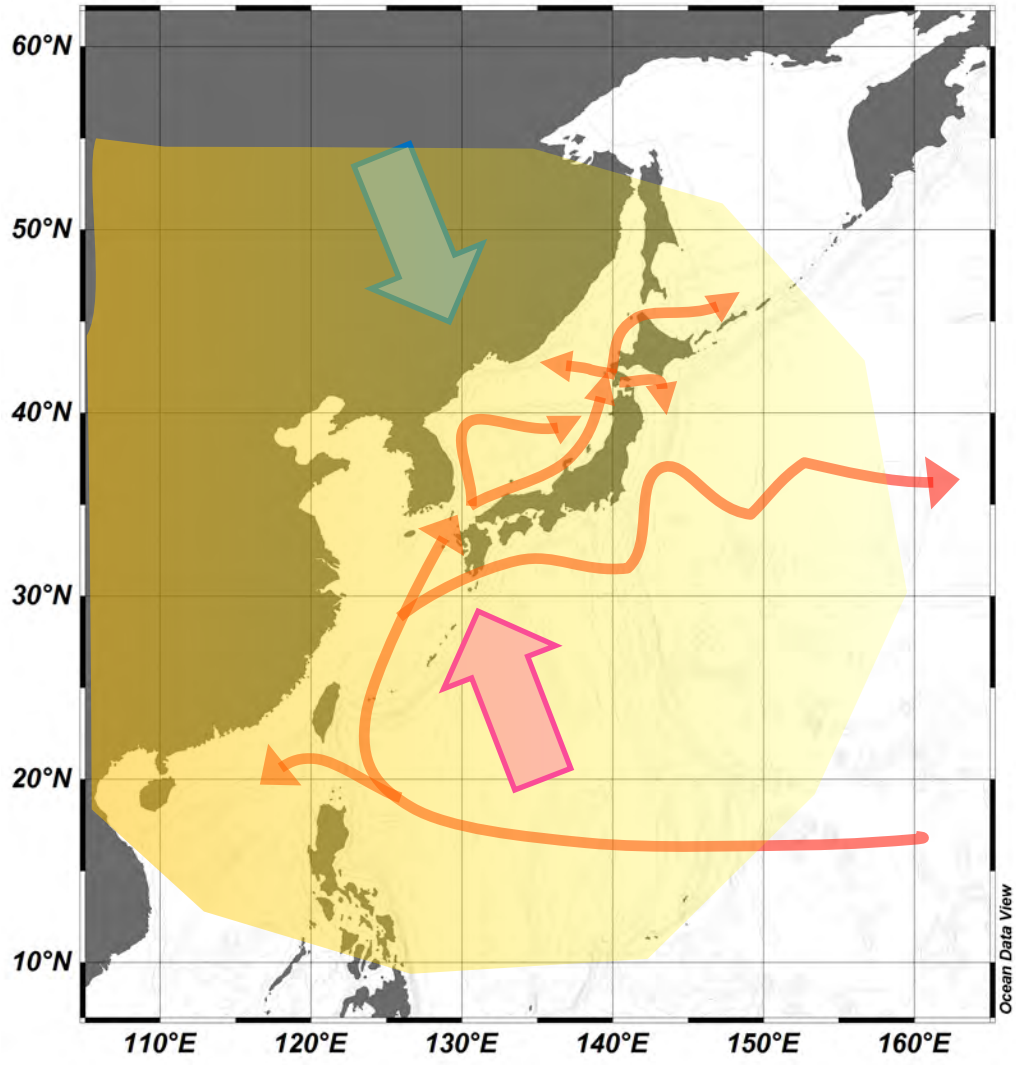
- - Asian monsoon



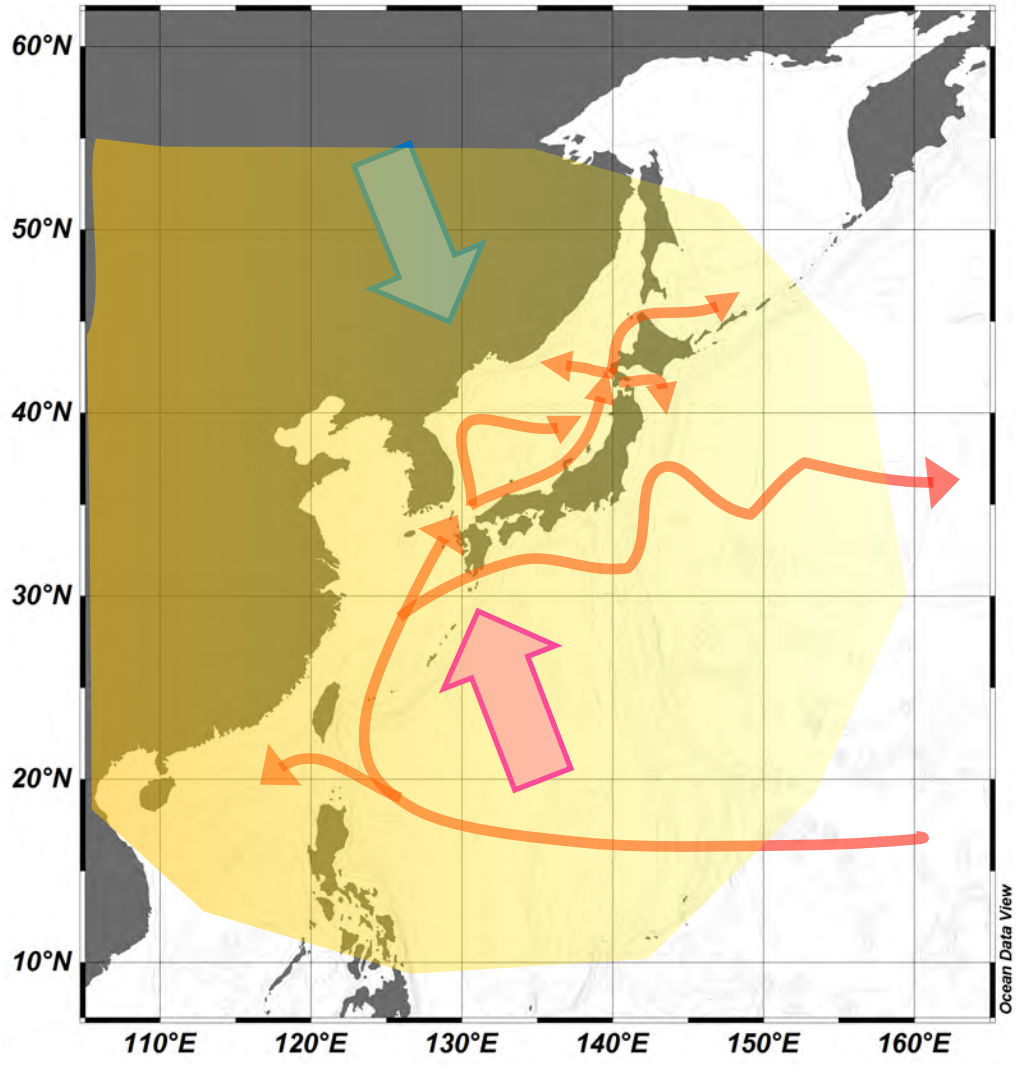
CREAMS 3.0: wider geography – whole system of NE Asian marginal seas

- - Expand area to cover both seas (EAST-I and II), or even a whole system of NE Asia seas
- - Transport of subtropical water (branches of Kuroshio current)
- - Asian monsoon
- - Anthropogenic impacts from the continent (atmosphere, microplastic, etc.)



CREAMS 3.0: cooperation with other programs

- WESTPAC- NEAR-GOOS
- WESTPAC- WG06 – Marginal seas
- WESTPAC- CSK-II
- UNEP/NOWPAP
- GEOTRACES
- PEACE
- PAMS



United Nations Educational, Scientific and Cultural Organization

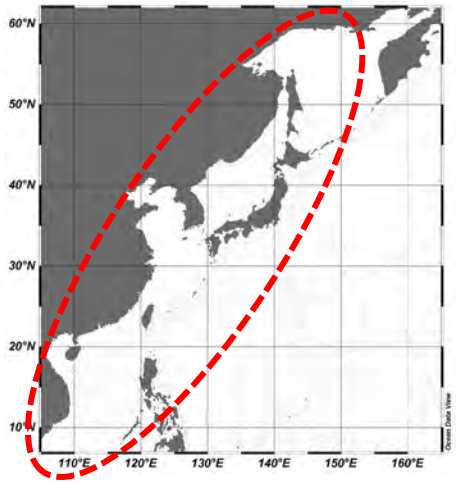
Intergovernmental Oceanographic Commission

WESTPAC WG06 on “A framework for Cooperative Studies in the Western Pacific Marginal Seas: Energy and materials exchange between land and open ocean”

Workplan May 2019 - April 2021

Expected outputs and/or outcome

- Start and progress some cooperative projects under international cooperative research grants.
- Coordinate and organize workshops by early career scientists.
- Correspond to urgent issues in marine environments such as hypoxic water, acidification, micro-plastic, and so on, which support SDG14.1~7, and UN Decade of Ocean Science for Sustainable Development .
- Strengthen the collaborations between natural and social sciences to contribute to SDG14.a,c.
- Objective 4 : enhance ocean observing networks and data systems.
- Objective 6 : enhance cooperation, coordination, and communication between stakeholders in ocean sciences

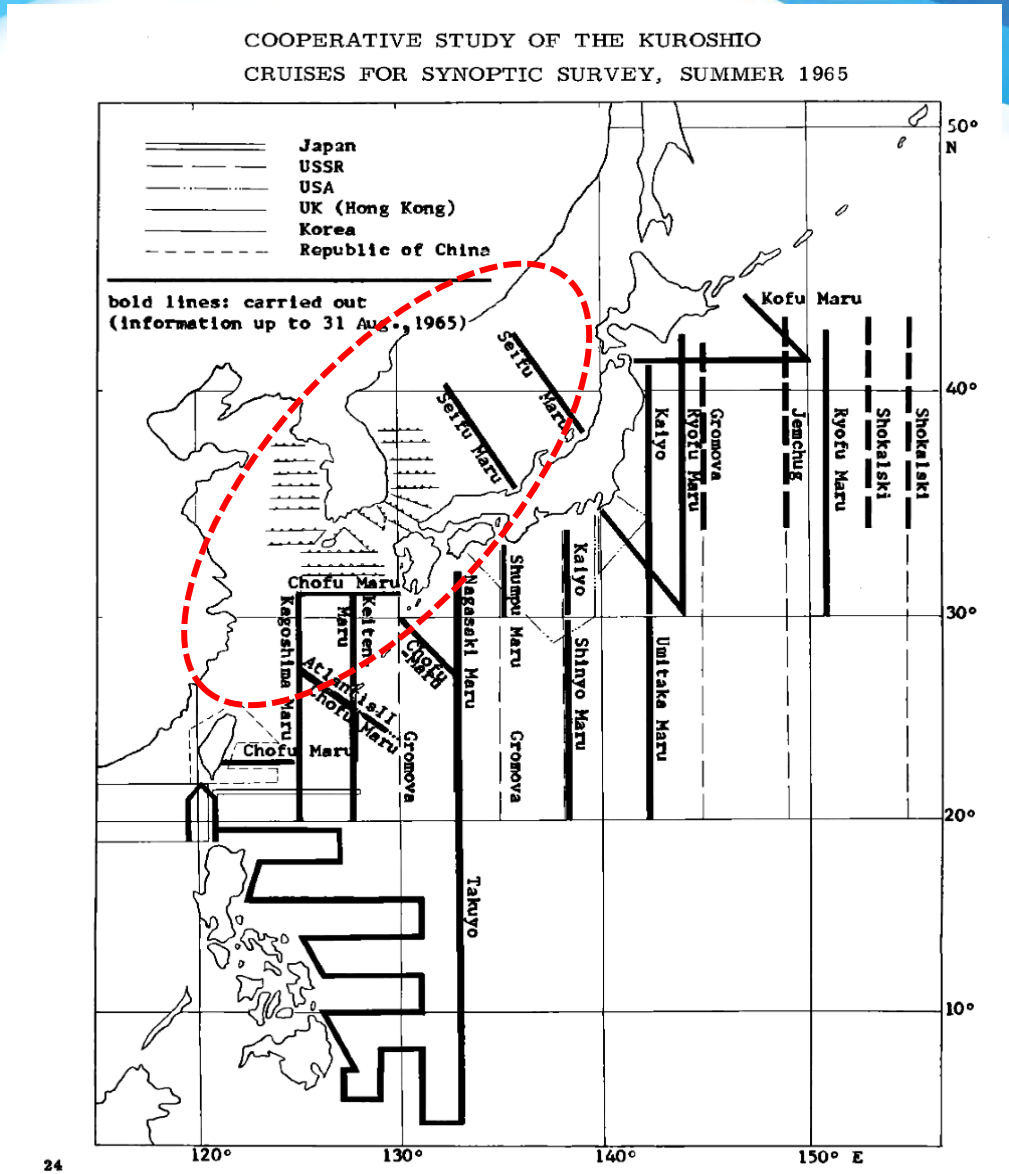


Jing Zhang, 2019

Co-operative Study of Kuroshio –II (s. 2021?) (CSK-I, 1965-1979)

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission



Phase-1:1965-1970
Focusing on Kuroshio region

-Understand origin of Kuroshio, its seasonal variations
-Understand its relation to ecosystem
-Understand sub-tropical mode water, North Equatorial current.

Phase-2:1970-1979
Focusing on its adjusting regions

- Understand the South China Sea circulation and its impact

JODC was the data center of CSK (KDC), and most of CSK data is compiled as “Guide to CSK data (1981)”

CREAMS 3.0: cooperation with other programs

- WESTPAC- NEAR-GOOS
- WESTPAC- WG06 – Marginal seas
- WESTPAC- CSK-II
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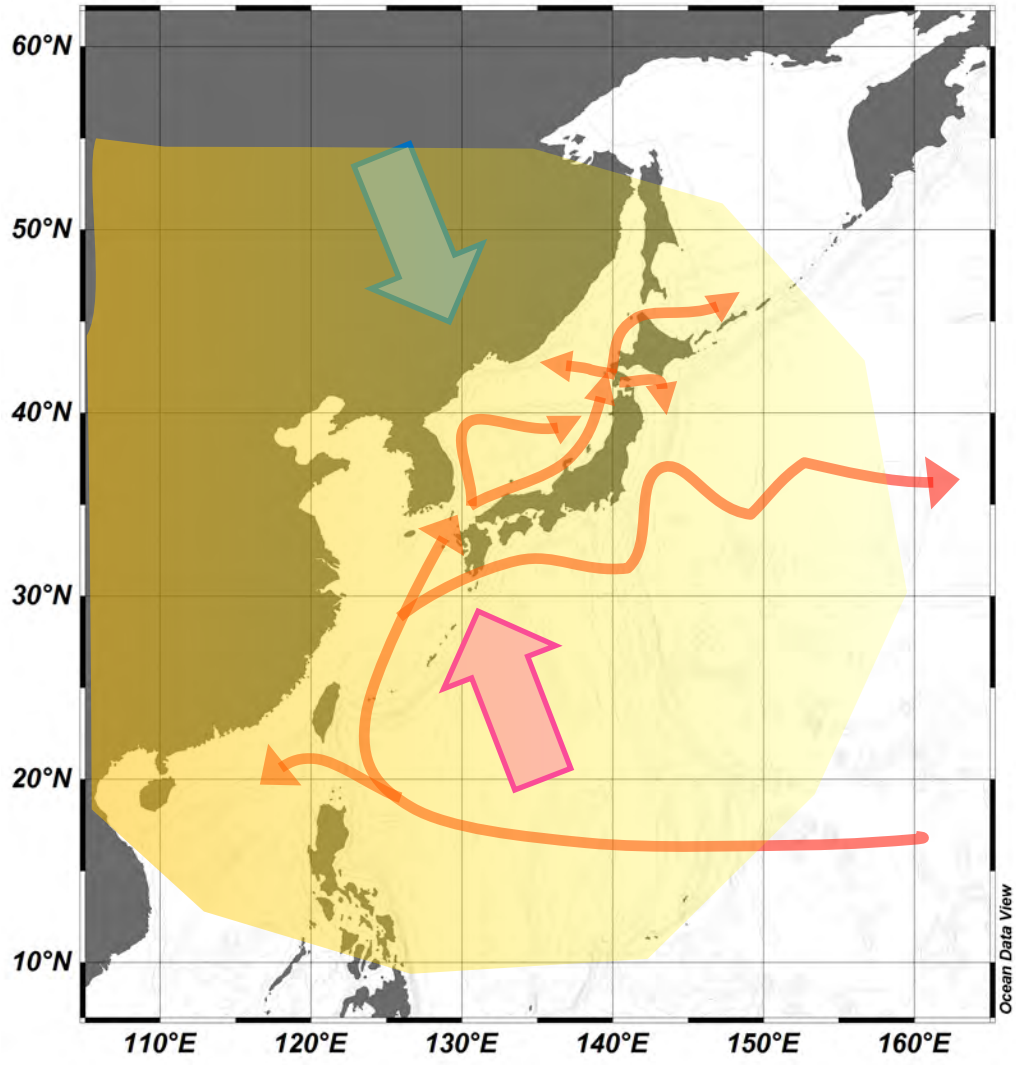

Conclusion

1. PICES has supported long life of the CREAMS program
2. Among many findings I would mentioned:

   - ventilation processes of bottom and deep waters;

   - mesoscale water dynamics (eddies, upwelling, cascading);

   - biogeochemical issues (ODZ, denitrification, acidification etc., *not mentioned in this presentation*)

4. Further development (CREAMS 3.0) should be:

   - focused on multi-scale water dynamics and its impact on biogeochemical processes and ecosystem;
   - long-term changes associated with climate and anthropogenic forcing;
   - multidisciplinary, focused on social-ecological-environmental system;
   - covering wider area: EAST-I and EAST-II or even a whole NE Asian seas;
   - in close collaboration with other international organizations and programs.


Thank you for attention!