PICES-2016-Annual meeting, S11, Nov. 8, 2016

Ocean Mixing Processes (OMIX): Impact on biogeochemistry, climate and ecosystem

Grant-in-Aid for Scientific Research in Innovative Areas (MEXT) 2015-2019

Project representative:

Ichiro Yasuda

Atmosphere and Ocean Research Institute, University of Tokyo

PICES 25yr anniversary

- Congratulations!!
- Same as my daughter
- I have learned many from PICES
- In 1990-92, I worked at Tohoku National Fisheries Research Institute, and started research on NPIW and long-term ocean-fish variability

North Pacific Intermediate Water (NPIW) from Okhotsk Sea to east of Japan



Prof. Nagata Prof. Talley Prof. Suginohara

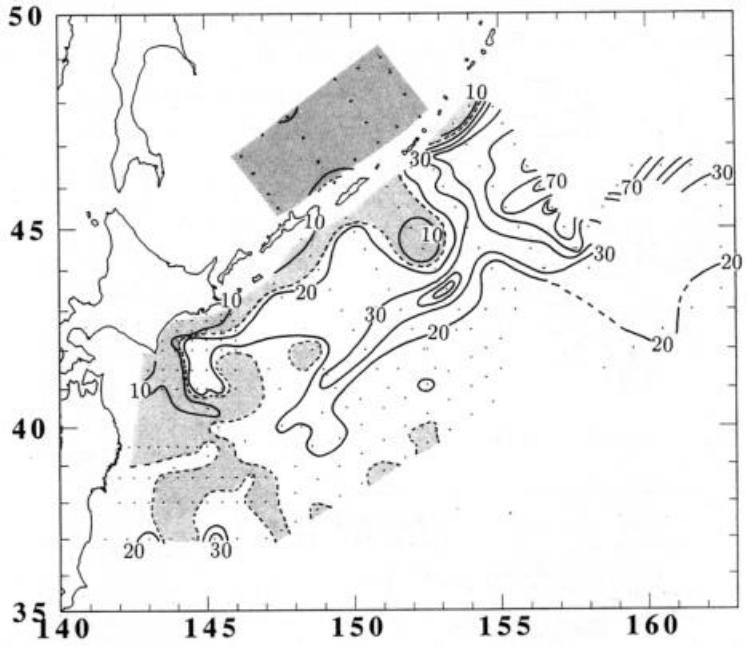
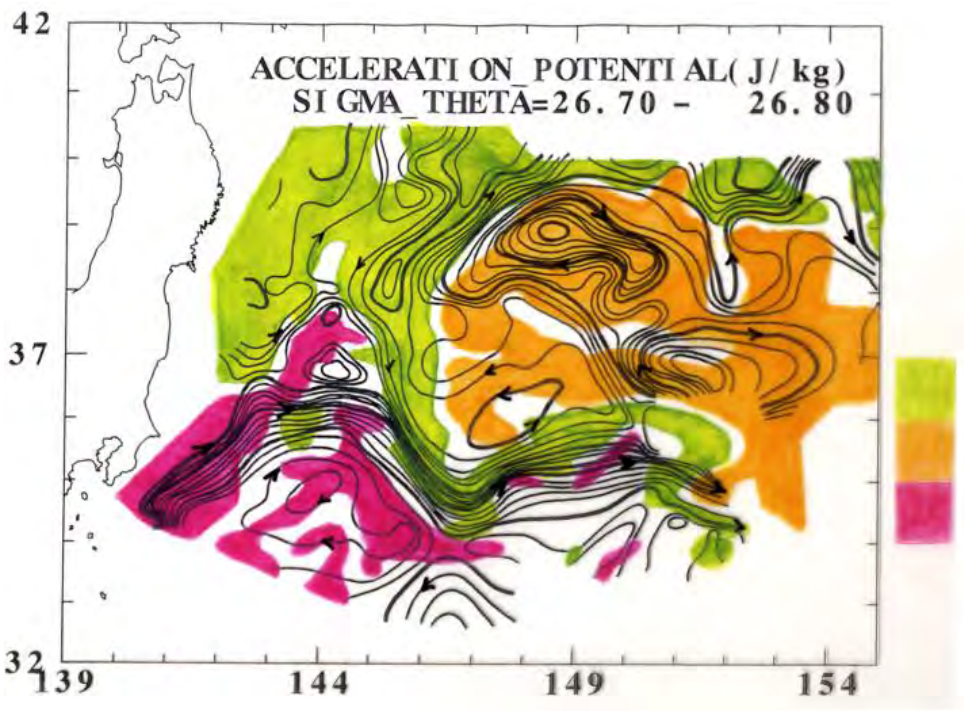


Figure 5. Isopycnal potential vorticity distribution, defined as $Q = (f/\rho)(\partial\rho/\partial z)$ (10^{-11} m^{-1} s^{-1}), along 26.7–26.8 σ_θ. Contour interval is 10×10^{-11} m^{-1} s^{-1}. Shaded regions denote low-Q water with $Q < 15$.

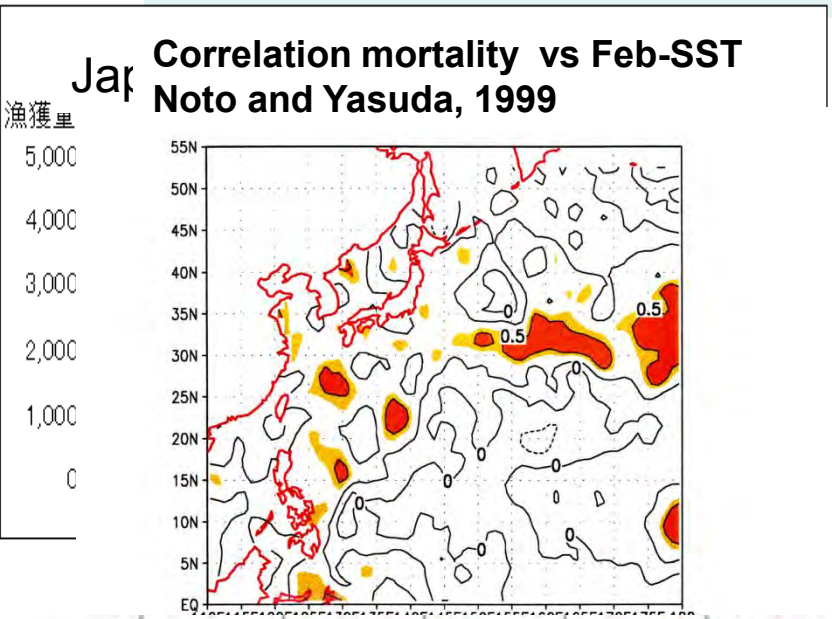


Cold, low salinity and thick low-PV Okhotsk water intrudes into the Kuroshio Extension and Mixes with Kuroshio water, to form new NPIW and salinity minimum.

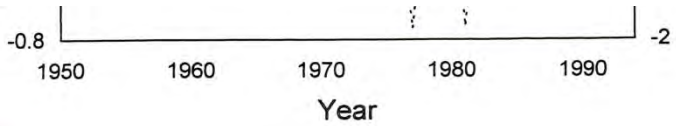
Yasuda, Okuda & Shimizu 1996 JPO, Yasuda 1997 JGR, Okuda et al.2001JC

Japanese sardine and ocean/climate inter-decadal variability

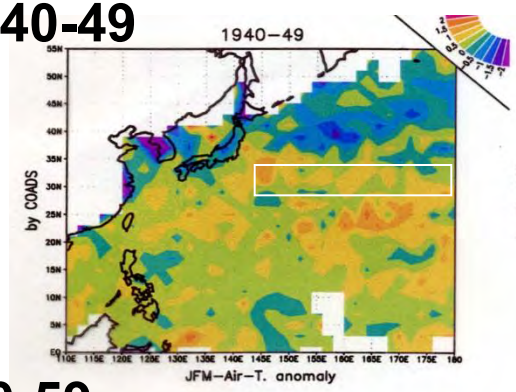
Correlation mortality vs Feb-SST
Noto and Yasuda, 1999



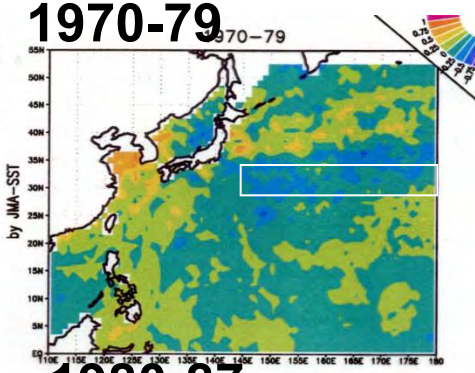
Correlation (MLD vs survival rate)
Nishikawa et al. 2010



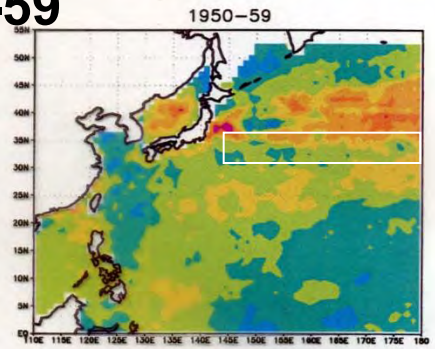
1940-49



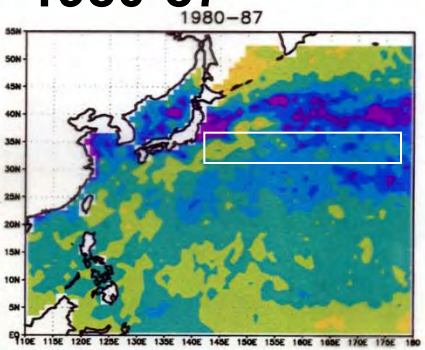
1970-79



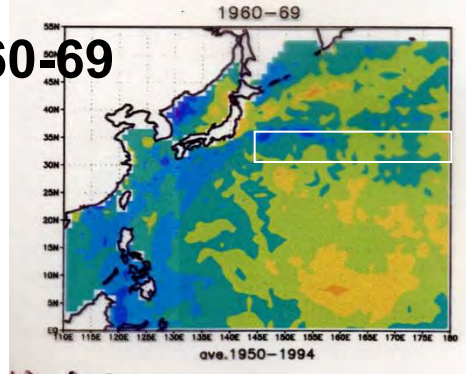
950-59



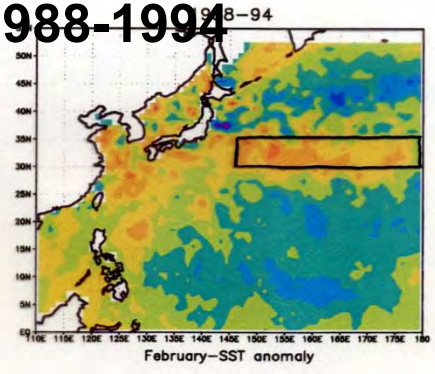
1980-87



960-69



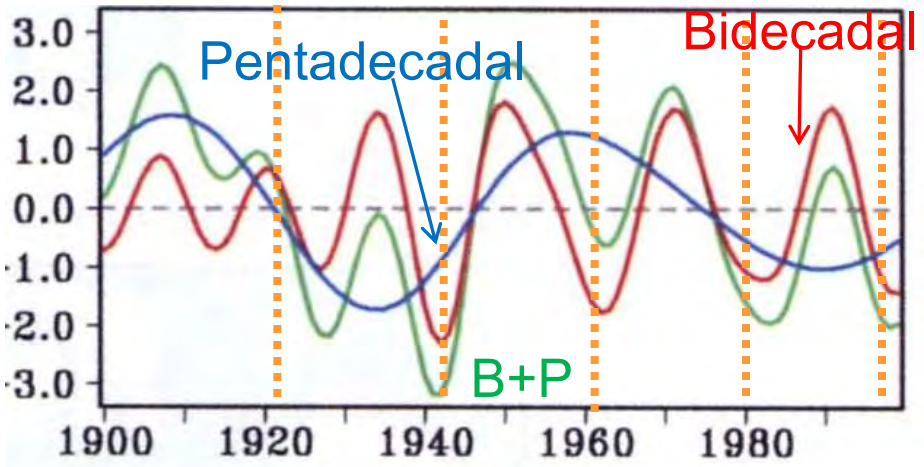
1988-1994



2002 LaPaz, Mexico "North Pacific Transitional Areas"
Bi-decadal variations of Oxygen in Oyashio Intermediate Water and 18.6-year tidal cycle

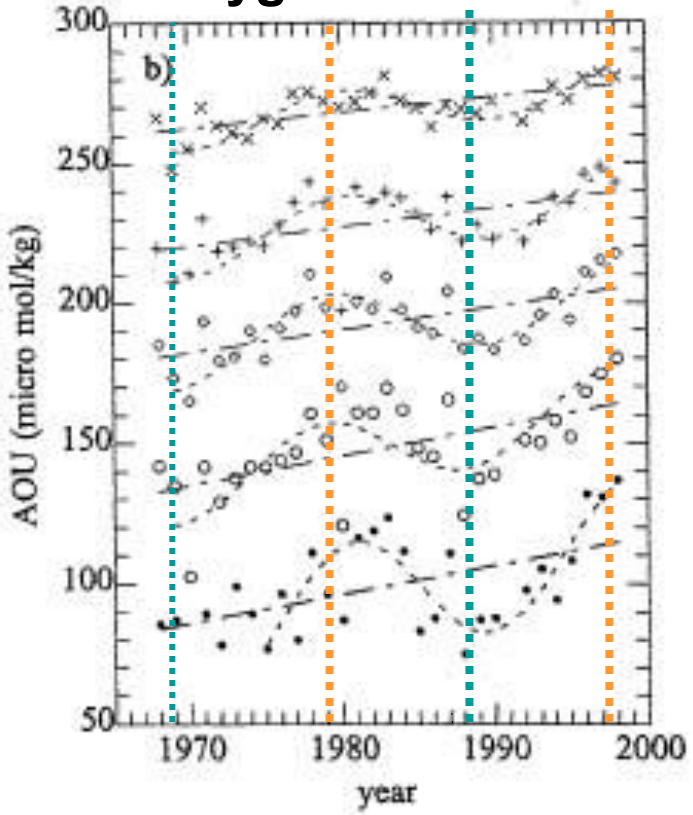
Skip McKinnell

Winter-NPI Minobe (2000 PiO)



In the period of weak diurnal tide, Aleutian Low is strong and Oyashio oxygen is low even in intermediate depths at which atmospheric effect does not reach. Many other bidecadal variability in the subarctic north Pacific waters have been detected (Yasuda etal.2006GRL;Mckinnel Crawford 2007JGR;Osafune & Yasuda 2006; 2010 JGR; Tadokoro et al. 2009; Yasuda 2009)

Oyashio oxygen Ono et al. 2001 GRL



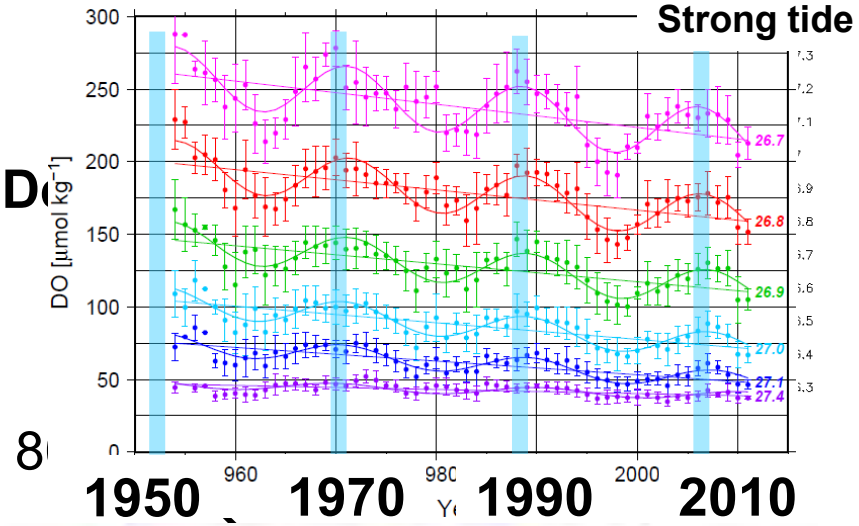
Weak-K1,O1 strong-M2
Weak vertical mixing

strong-K1,O1 weak-M2
Strong vertical mixing

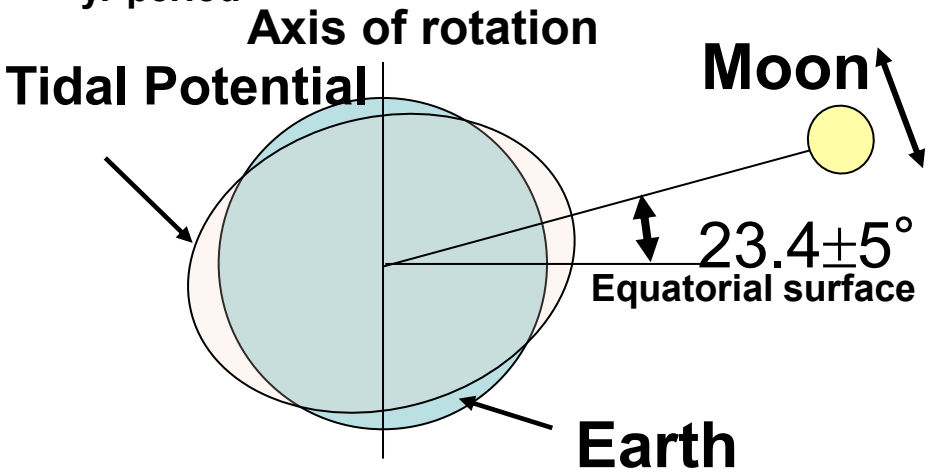
Hypothesis: Bi-decadal variability of climate/fisheries

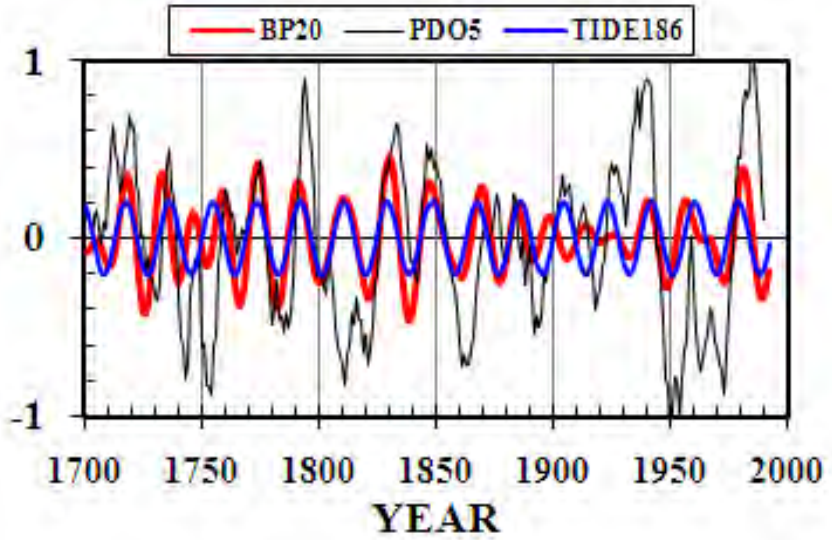
Hypothesis: 18.6-yr period tide-induced mixing variability (Loder and Garrett 1978; Royer 1993; Yasuda et al. 2006; McKinnel & Crawford 2007)

O_2 in Oyashio (From Dr. Sasano, JMA)



18.6-yr tidal oscillation: Moon orbit changes the inclination with the mean 23.4 deg and the amplitude 5 deg and the 18.6-yr period



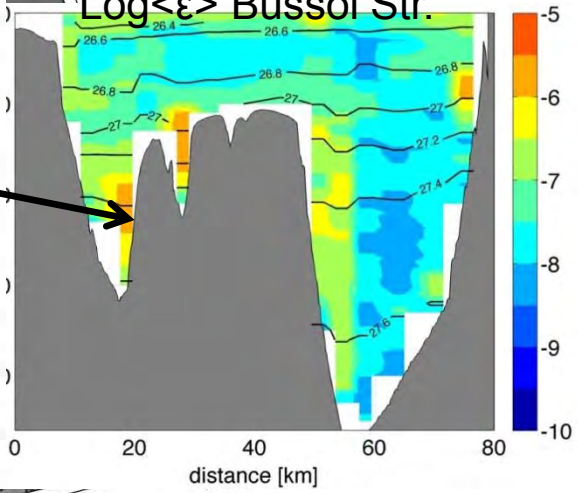


Diurnal tidal amplitude changes up to 20%

20% variability of strong tidal mixing could lead to big impacts. Indeed, in the Oyashio Water DO downstream of Kuril Straits and PDO demonstrate 18.6-yr period variability. Climate model experiments with better tidal mixing is being constructed. (2 models: Hasumi et al. 2008GRL; Tanaka et al. 2012JC)

Direct turbulence observations using microstructure profilers with Japanese and Russian vessels (2006-2010)

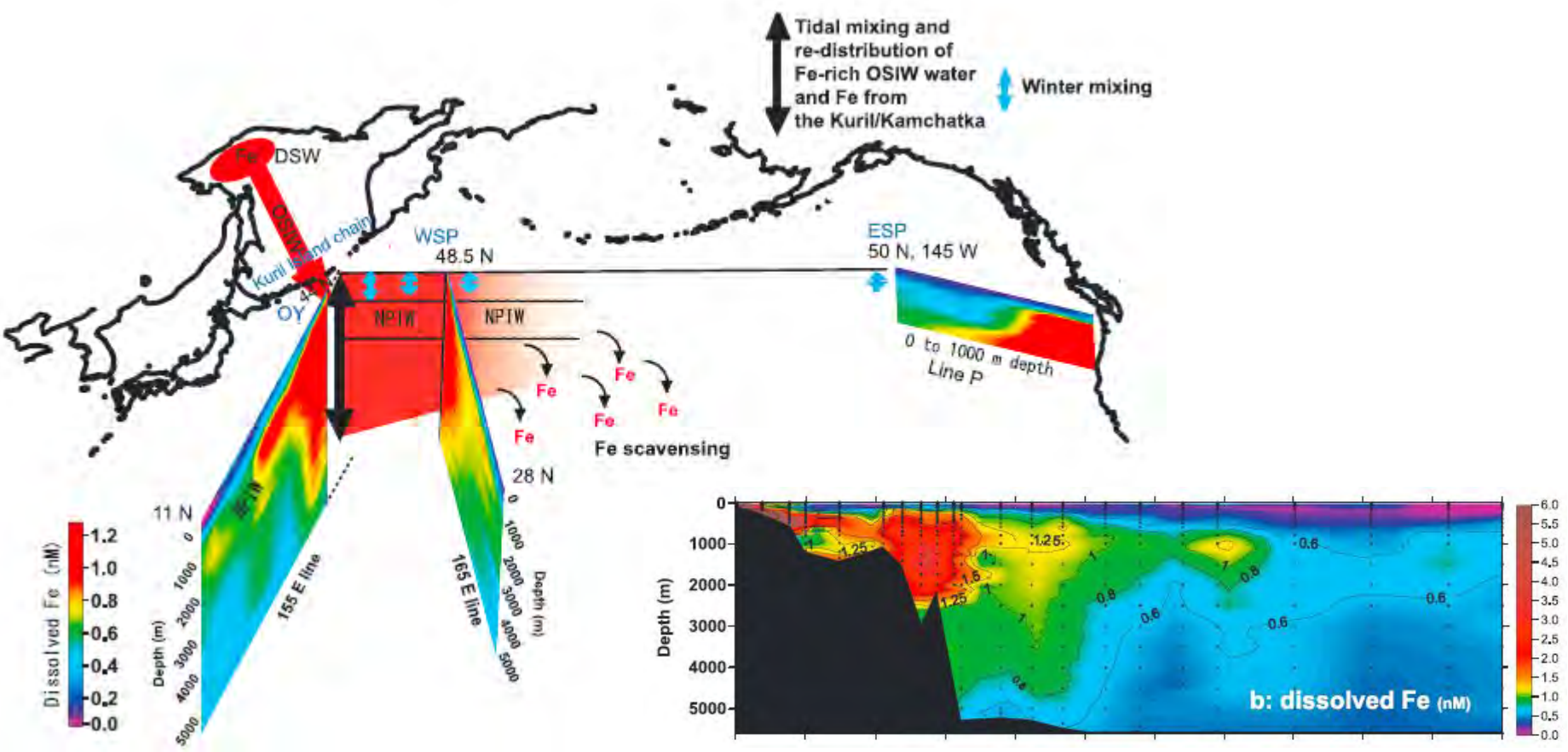
Log<ε> Bussol Str.



Khromov 2006 2007 2010
Hakuho-maru KH08-2
KH09-4 Aleutian-Bering
Tansei-maru 2007-2010 Kuroshio

Hypothesis for: Why is NWP productive?

Hypothesis: Strong vertical mixing around the Kuril Straits supply iron to Oyashio ecosystem (**e.g. Nishioka et al. 2013GBC**)

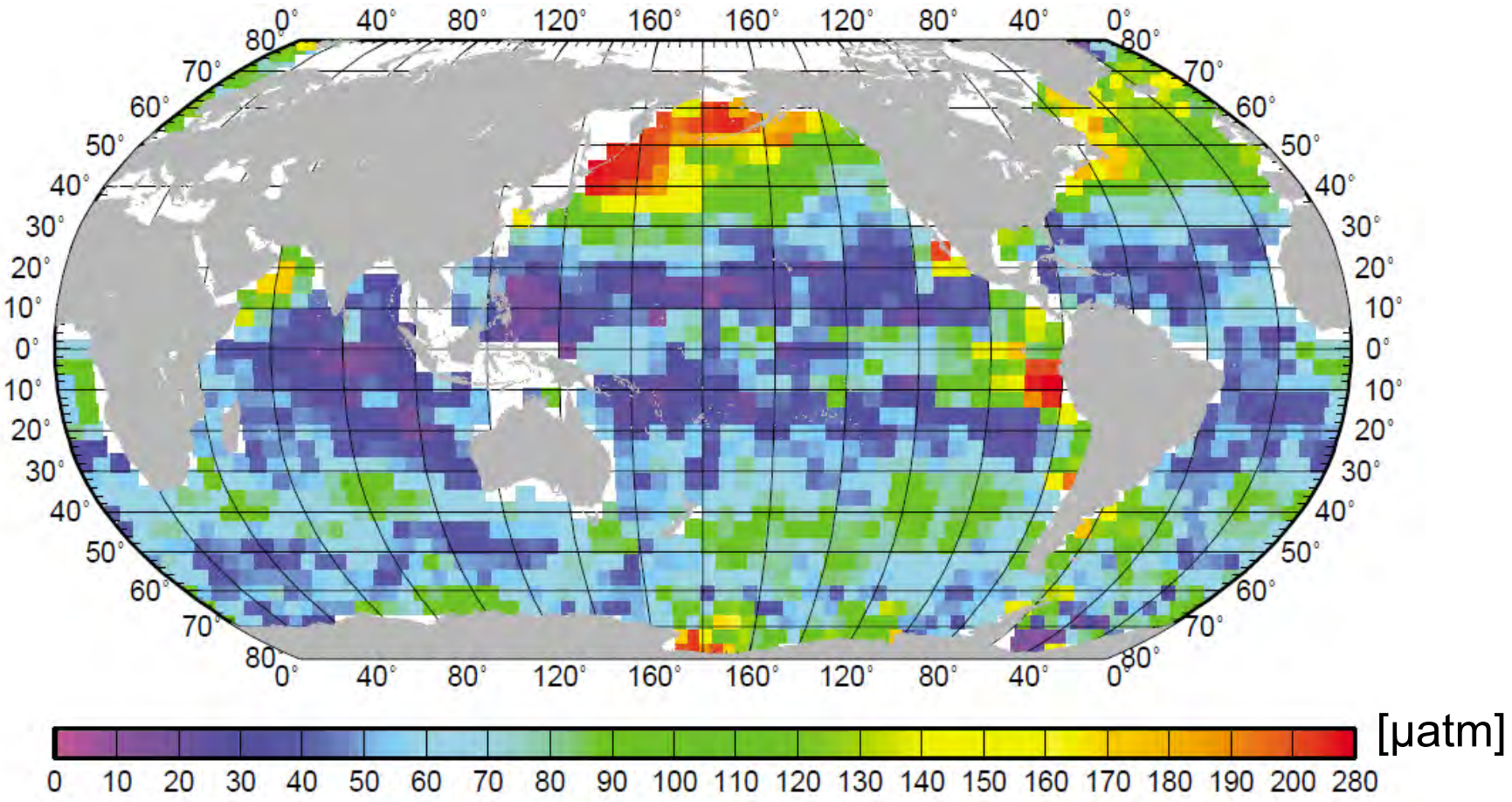


Strong vertical mixing due to diurnal tides could supply iron to the Oyashio ecosystem, and its 18.6-yr period variability may lead to cause the 18.6-yr period climate and fisheries variability.

Hypothesis:

Why is so productive in the western North Pacific? World highest biological CO_2 absorption, 26% fisheries catch in 6% sea-surface area

Distribution of biological CO2 drawdown (Takahashi et al. 2002)



Iron supply through mixing in the Kuril and western Bering Sea may explain the high biological productivity and the CO2 drawdown distribution

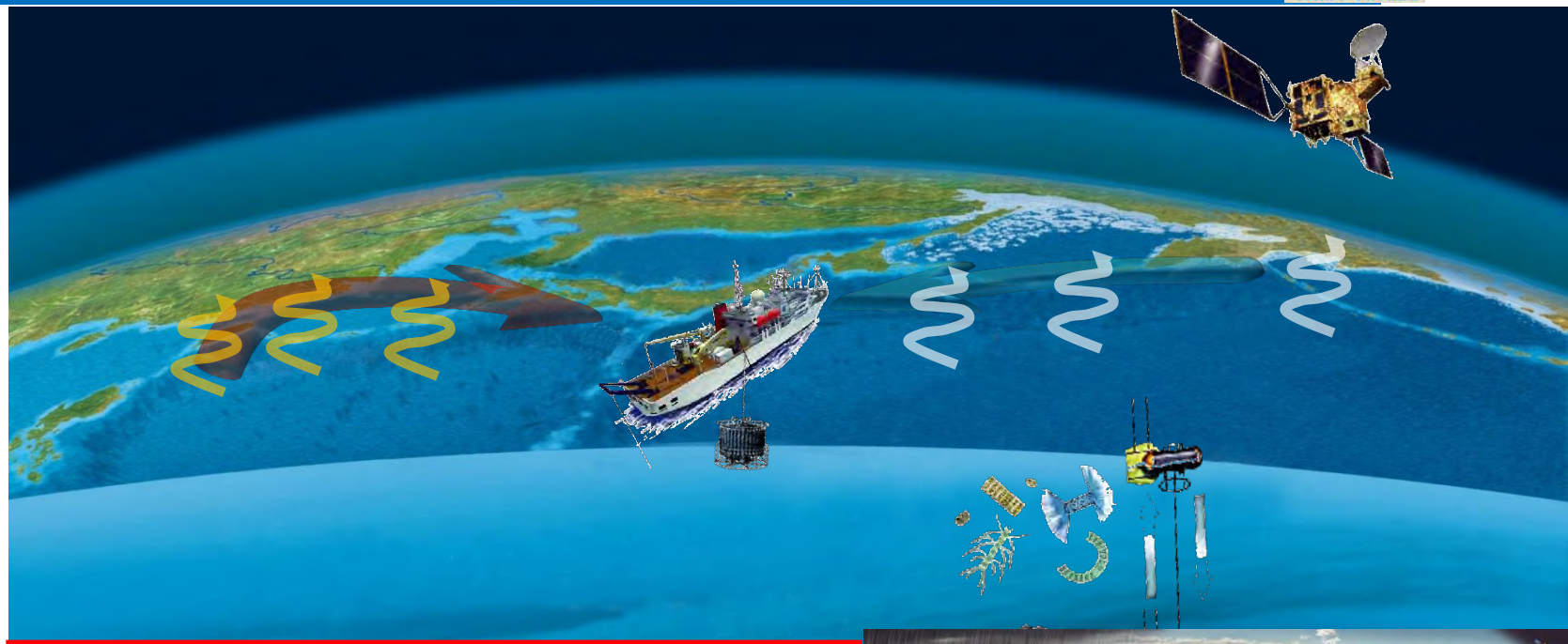
Motivation for expanding research and observations/models on mixing

- Common problems for physical, chemical, biological and fisheries oceanography through nutrient diffusive supply
- Still scarce turbulence observations in intermediate –deep oceans below 500m
- We need much more studies and data by developing new observations and models with realistic mixing distributions to reproduce impacts of mixing and its 18.6-yr variability

MEXT KAKENHI INNOVATIVE STUDY Ocean Mixing Processes (OMIX): Impact on Biogeochemistry, climate and ecosystem (2015-2019) Vertical mixing and physical- chemical-biological-integrated observations and ocean-climate-biogeochemistry ecosystem modelling in the northwestern Pacific especially in the Kuroshio and Oyashio regions

Please visit web-site http:/www.omix.aori.u-tokyo.ac.jp/en/

8 main groups and 14 specific themes, total over 70 scientists



Overarching Goals

By exploring vertical mixing in western North Pacific & impacts on circulation, biogeochemistry, climate and ecosystem:

Deep Circulation in the N.P.

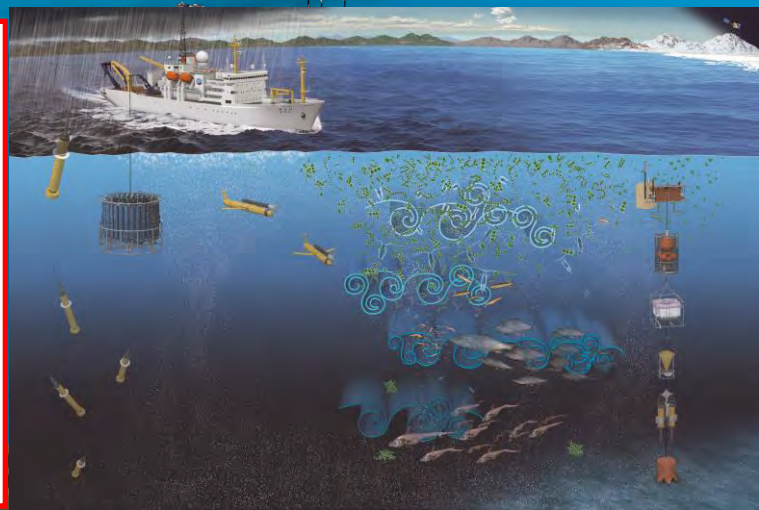
(quantify upwelling through vertical mixing)

Processes to sustain ocean ecosystem

(quantify transport of nutrients to ecosystem)

Long-period variability and forecast of ocean/climate/fisheries

(develop models to reproduce 18.6yr and related period variability and pursue their mechanisms)



Developing microstructure observation system:

Glider with microstructure-ADCP, deep-Ninja float with turbulence sensors, CTD-attached fast-thermistors, and data-assimilation

Slocum glider with microRider and ADCP

Sea Explorer with turbulence and ADCP

Data assimilation
for estimate mixing, circulation
And water mass distribution

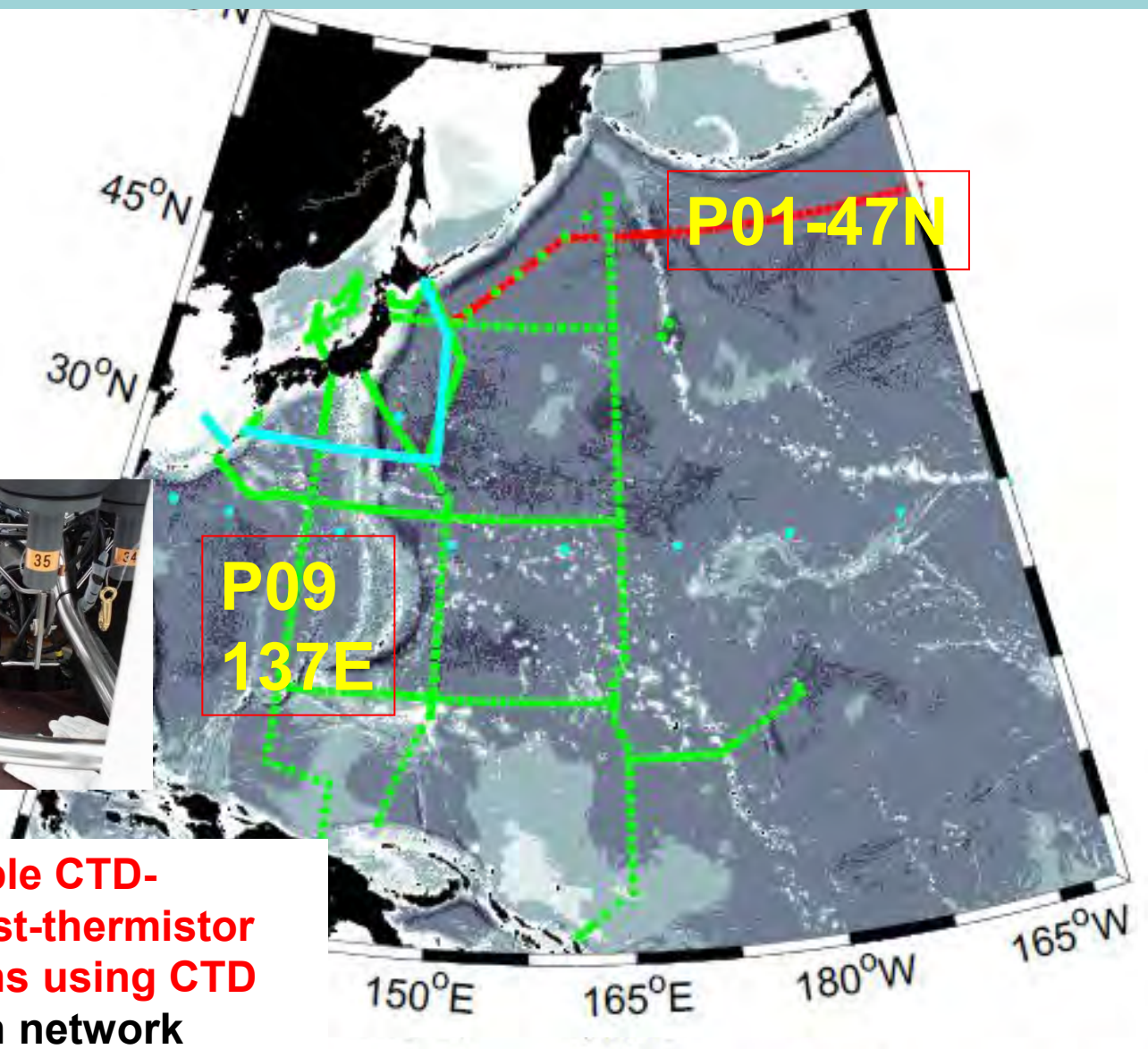
CTD-attached AFP07

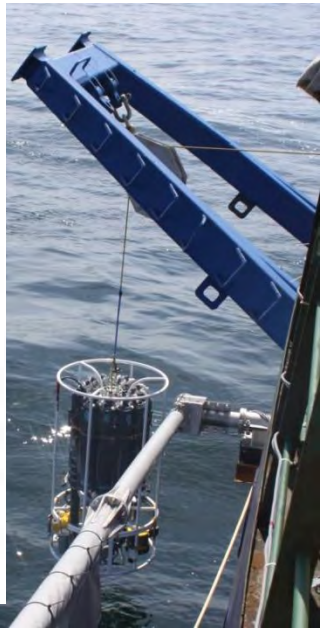
Deep Ninja float (4000m)
with turbulence sensor
Tsurumi/RSI/AORI

EM-Apex with
FP07 (UW/APL)

Motivation-1 : NWP turbulence distribution?

New observation system of vertical mixing and observations using CTD observational networks

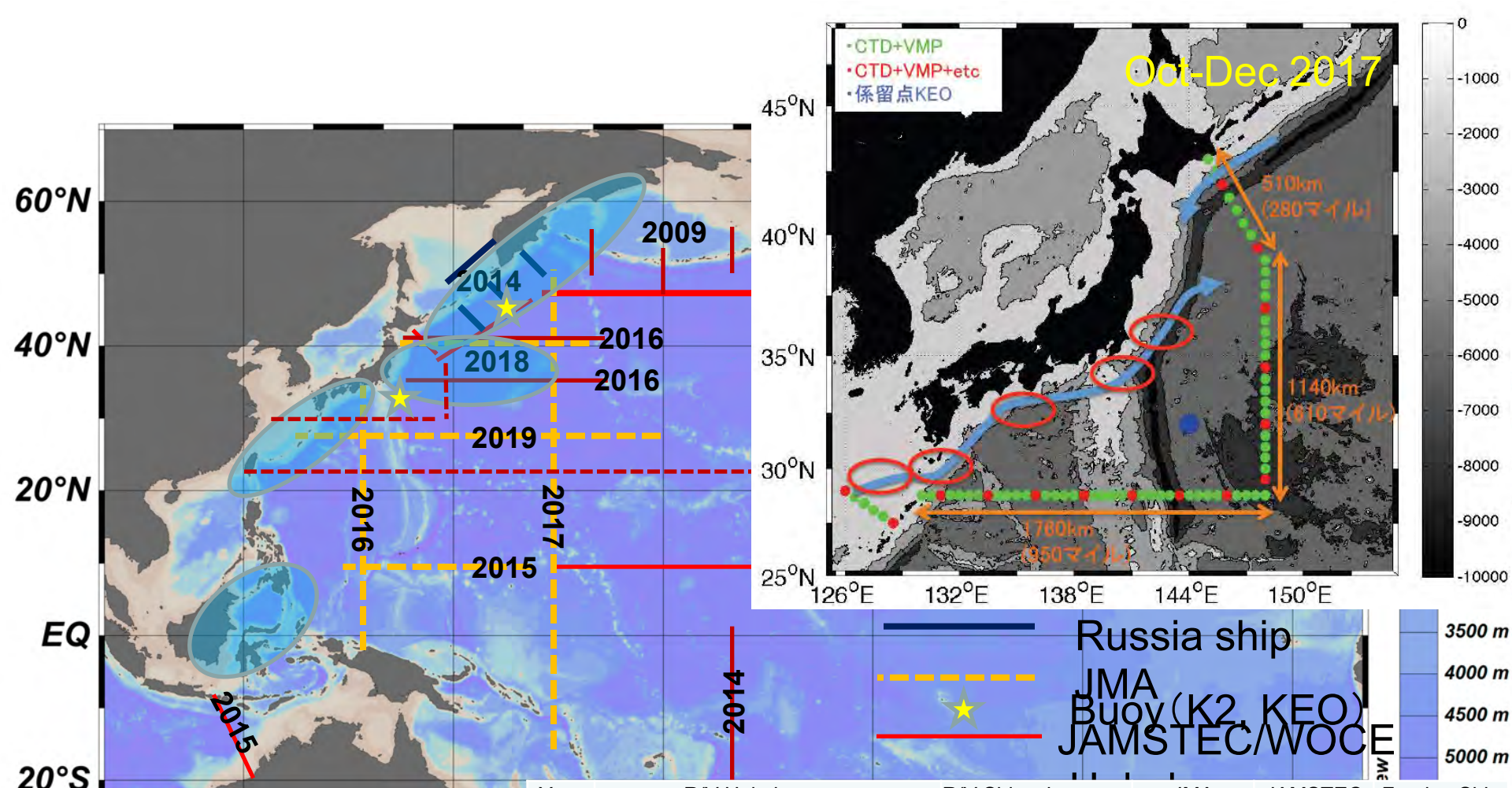




Make feasible CTD-attached fast-thermistor observations using CTD observation network

Why the Kuroshio/Oyashio current system feed abundant ecosystems?

Intensive and integrated observations in mixing hotspots to confirm diffusive nutrient supply hypothesis in the Kuroshio and Oyashio and their originating regions



Year	R/V Hakuho-maru	R/V Shinsei-maru	JMA	JAMSTEC	Foreign Ship
2015	Oyashio (March、20d) ECS/Kuroshio（Oct-Nov,40d）	Tokara Pacific (Jun 11d)	P04W(10N)	I10	
2016	41N/37.5N 170E (Jun 30d) Kerama/23N (Dec. 21d)	Izu/Kuroshio (9d) Tohoku (12d)	P09(137E)	Southern Ocean	
2017	TransP 47N/22N(Jun-Sept、70d) 149E/28.5N/Luzon.(Oct-Dec,60d)	Proposal	P13(165E)	Arctic Bering	Indonesia (20d)
2018		Proposal	40N		Russia (Jul-Aug 60d)
2019	Indian Ocean (Jan-Feb 60d) Indonesia (Feb. 20d)	proposal	P03(24N)		

Overview of the project：synthesis of observations and modelling

Developing next-generation models with vertical mixing

Integrated dataset production with data assimilation models

Impact of realistic vertical mixing and its 18.6yr-varibaility on ocean, climate and ecosystem with high resolution models

In-situ Obs.

True but sparse

Vert.Mixing
(current structure)

Process and Prameterize

Bio-Chemistry

Fish-history

Data-assimilation
Dataset with interporation

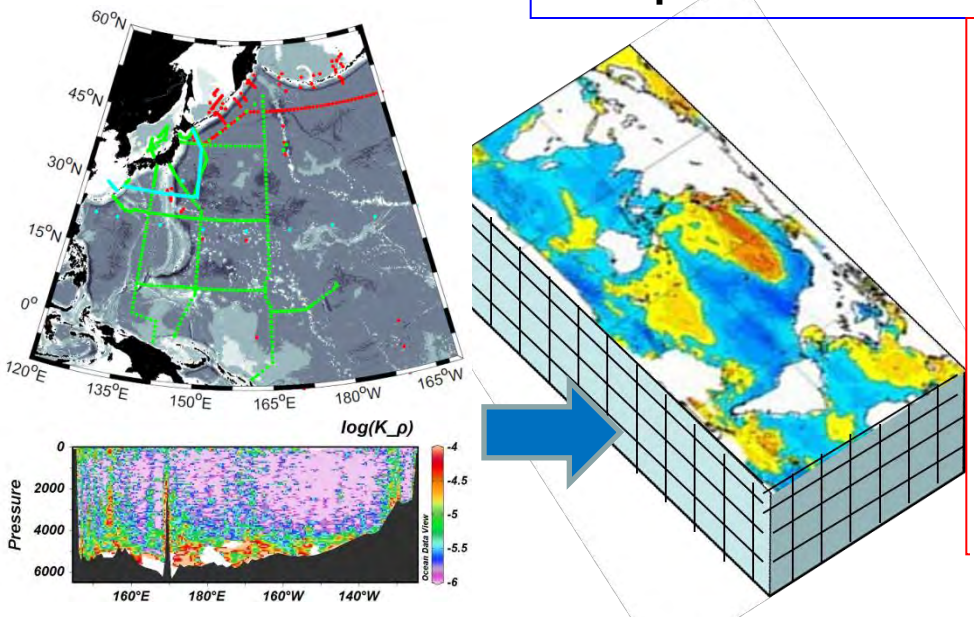
Mixing distribution

Quantfy diffusivity,
Upwelling and nutreint transports

Prognostic and predictive Modelling with vertical mixing and its 18.6-yr period variability

Climate/Ocean/ecosystem Modelling

Fish models with response to environment



Overarching Goals

Vertical mixing in western North Pacific

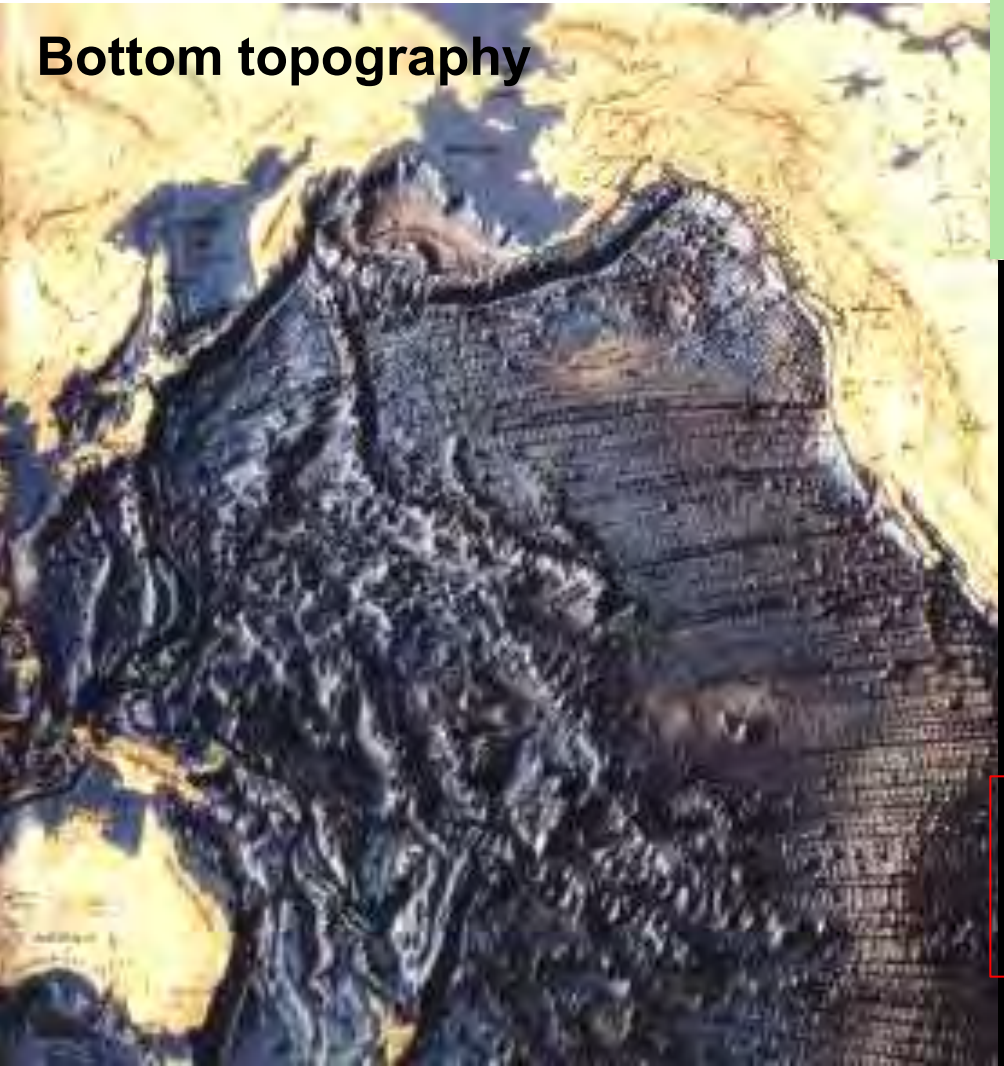
Deep Circulation in the N.P.
（quantify upwelling through vertical mixing）

Processes to sustain ocean blessings
（quantify transport of nutrients to ecosystem）

Long-period variability and forecast of ocean/climate/fisheries
（Reproduce bi-decadal and related period variability And their mechanisms）

Thank you for attention

"Tides from moon and bottom roughness produces vertical mixing and changes ocean circulation, sustain biological production and produces long-period variability of ocean and climate" will be confirmed by this project→Ocean Mixing Study



Welcome international collaboration