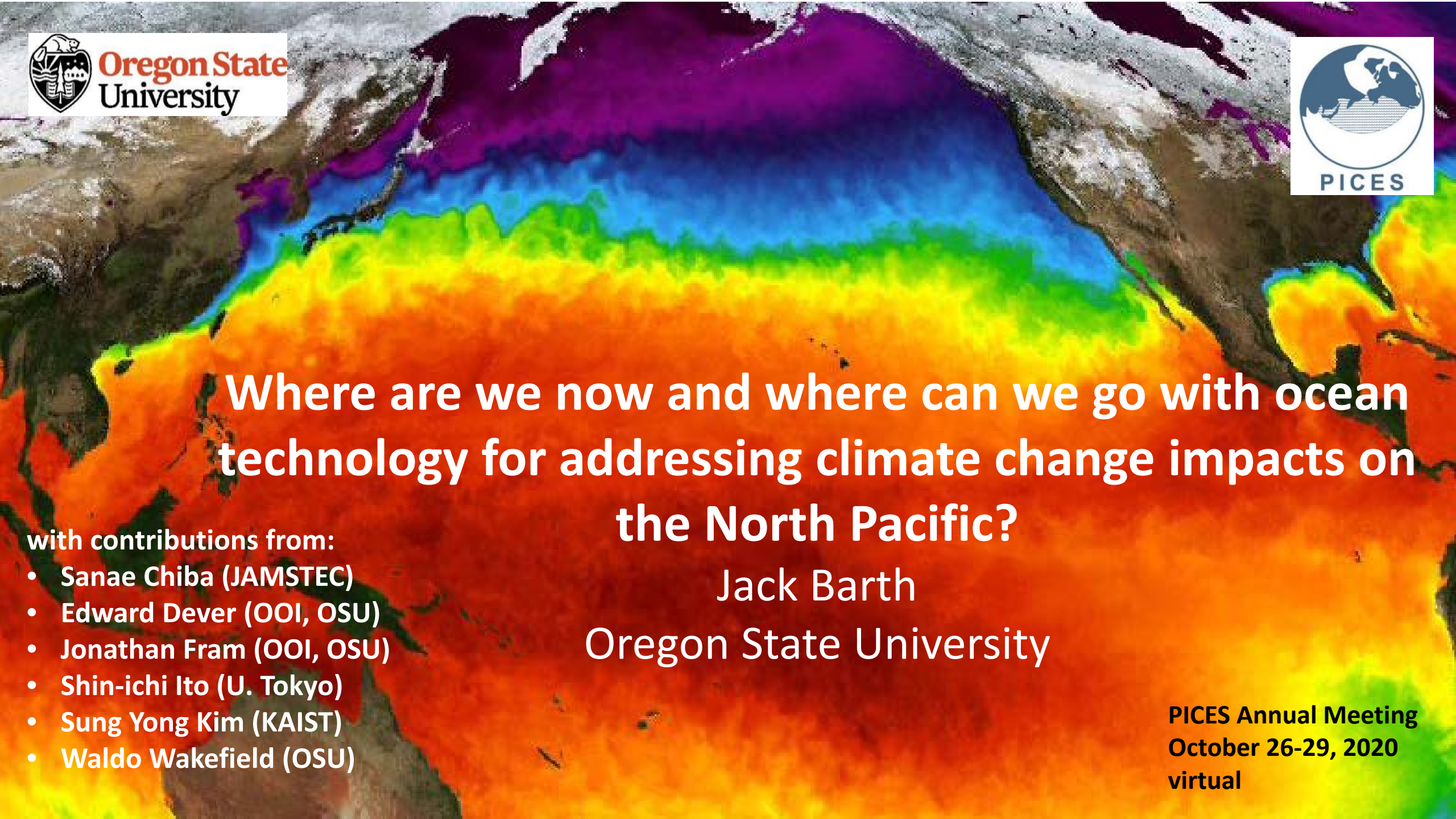


Where are we now and where can we go with ocean technology for addressing climate change impacts on the North Pacific?

Jack Barth

Oregon State University

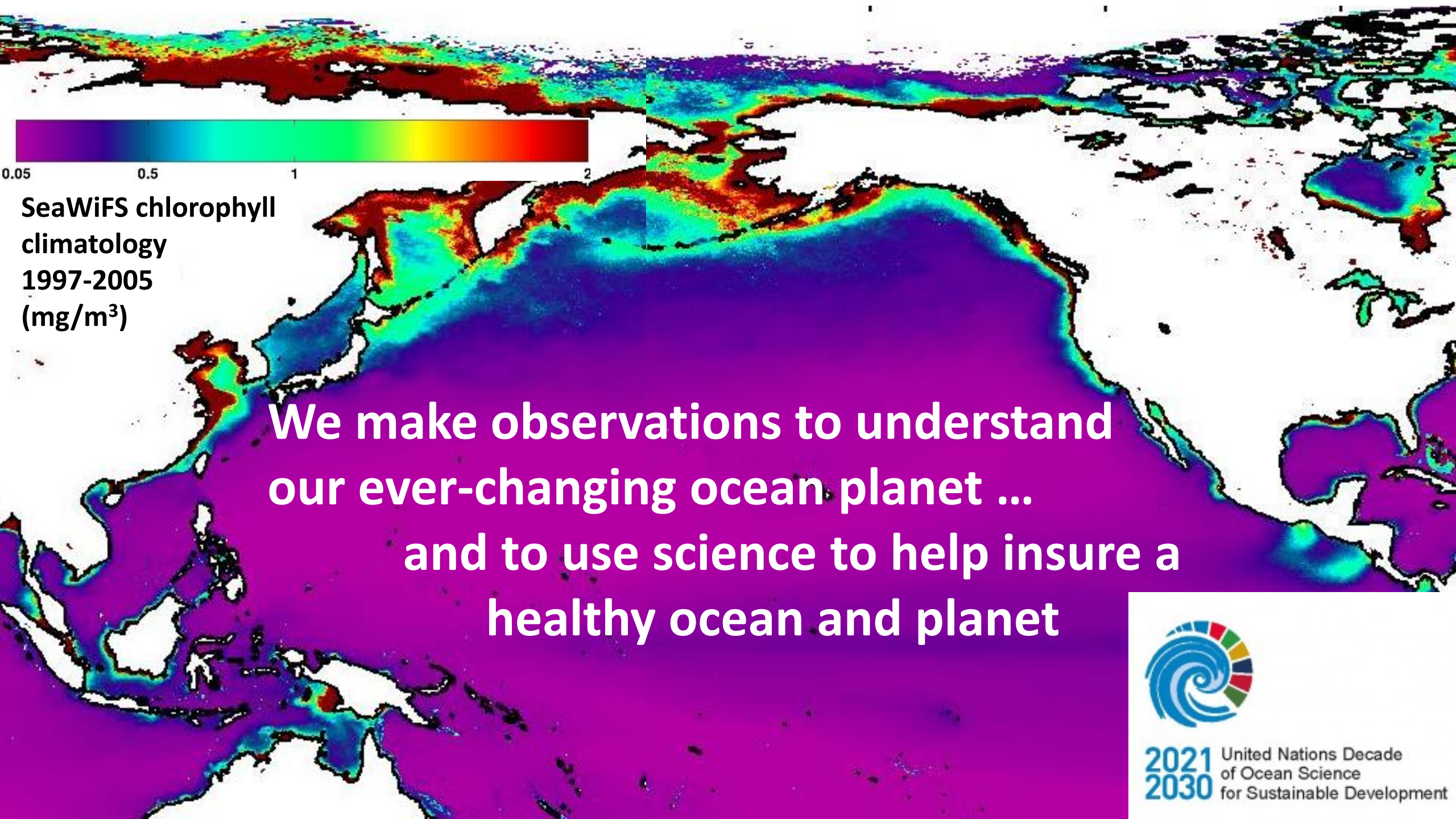
with contributions from:

- **Sanae Chiba (JAMSTEC)**
- **Edward Dever (OOI, OSU)**
- **Jonathan Fram (OOI, OSU)**
- **Shin-ichi Ito (U. Tokyo)**
- **Sung Yong Kim (KAIST)**
- **Waldo Wakefield (OSU)**

PICES Annual Meeting
October 26-29, 2020
virtual

Outline

- Why we make observations
- Essential Ocean Variables (EOVs)
- Data are FAIR (Findable, Accessible, Interoperable, Reuseable)
- Autonomous technology + new sensors
- Low-cost, small, easily deployed sensors
- We have the tools … what we need is the resolve and support of our community and our PICES nations



We make observations to understand our ever-changing ocean planet …

and to use science to help insure a healthy ocean and planet

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

ADVISORY REPORT

Fisheries & Ecosystem Responses

To Recent Regime Shifts in the North Pacific

PICES

North Pacific Marine Science Organization (PICES)

Working Group 30: Assessment of Marine Environmental Quality of Radiation around the North Pacific

アドリフト

太平洋の漂流物 (ADRIFT)

津波起因の海洋漂流物の影響を理解する

ADRIFT in the Pacific
Understanding the impacts of tsunami marine debris

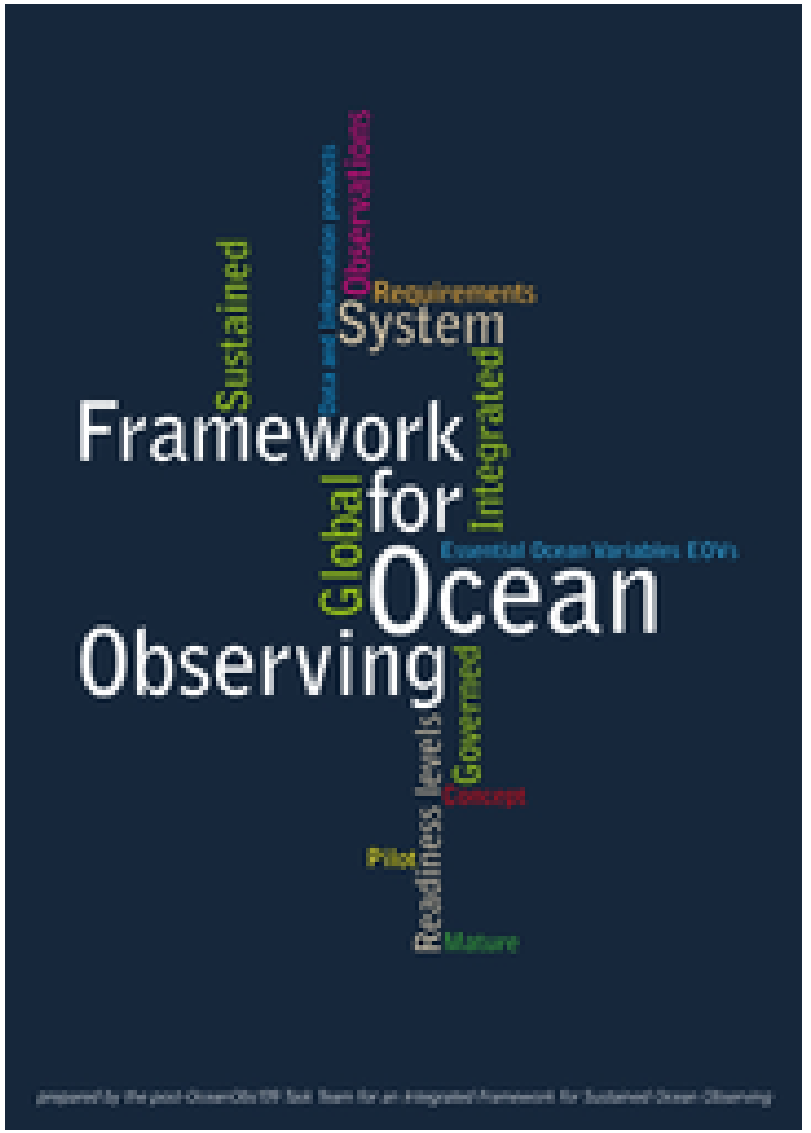
環境省
Ministry of the Environment

PICES

FOO = Framework for Ocean Observing
main output from OceanObs'09; Lindstrom et al. (2012)
http://www.oceanobs09.net/foo/FOO_Report.pdf

GOOS = Global Ocean Observing System

EOV = Essential Ocean Variable
http://www.goosocean.org



OCEAN OBS'19

J. Barth & S. Y. Kim, co-chairs
September 2019

GOOS:

Essential Ocean Variables (EOVs)

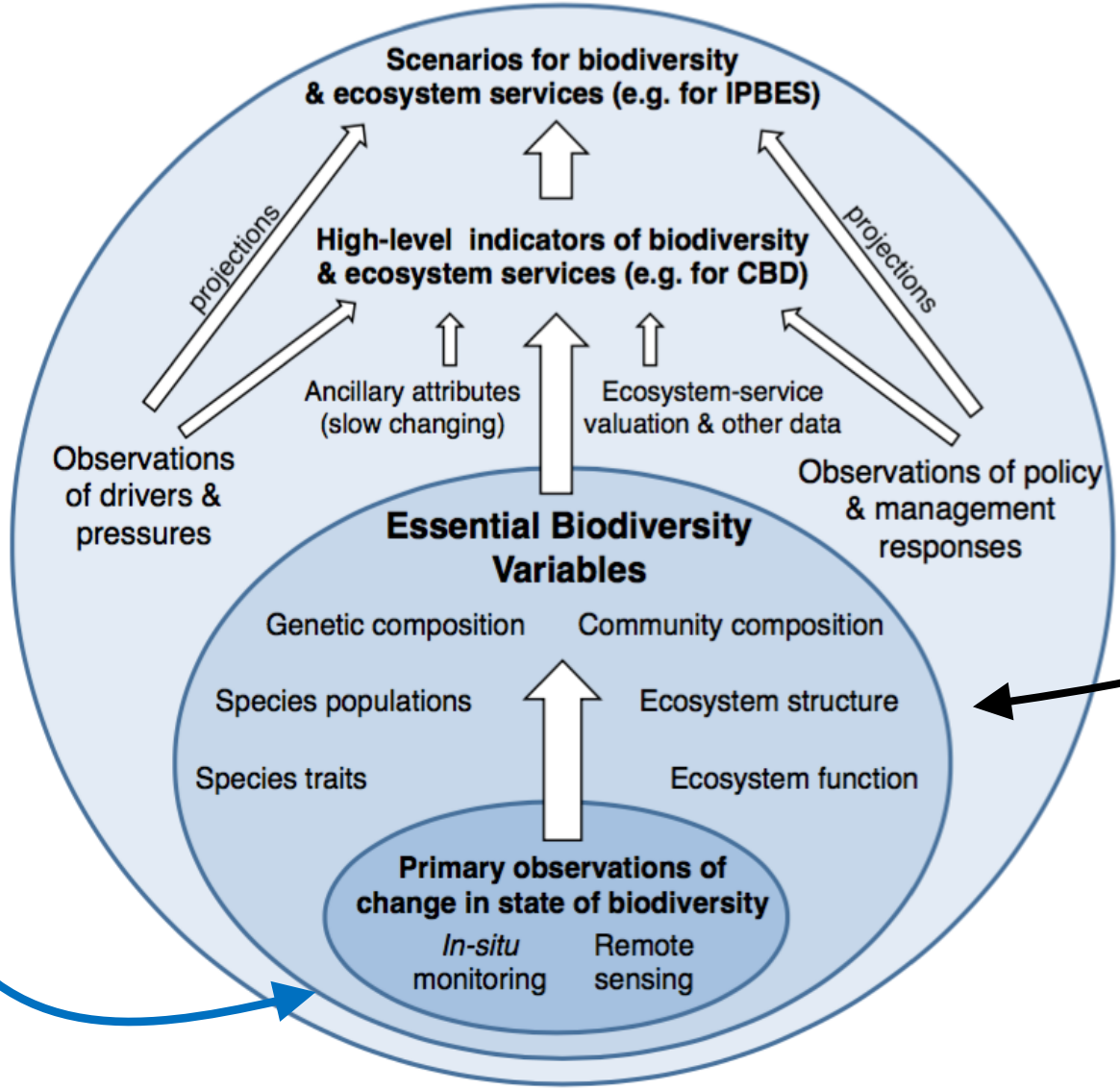
PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Particulate matter	Hard coral cover and composition
Subsurface temperature	Nitrous oxide	Seagrass cover and composition
Surface currents	Stable carbon isotopes	Macroalgal canopy cover and composition
Subsurface currents	Dissolved organic carbon	Mangrove cover and composition
Sea surface salinity		Microbe biomass and diversity (*emerging)
Subsurface salinity		Invertebrate abundance and distribution (*emerging)
Ocean surface heat flux		
CROSS-DISCIPLINARY		
Ocean colour	Ocean Sound	

GOOS Bio/Eco EOVs vs Group on Earth Observations (GEO) Biodiversity Observation Network (BON) Marine Essential Biodiversity Variables (EBVs)

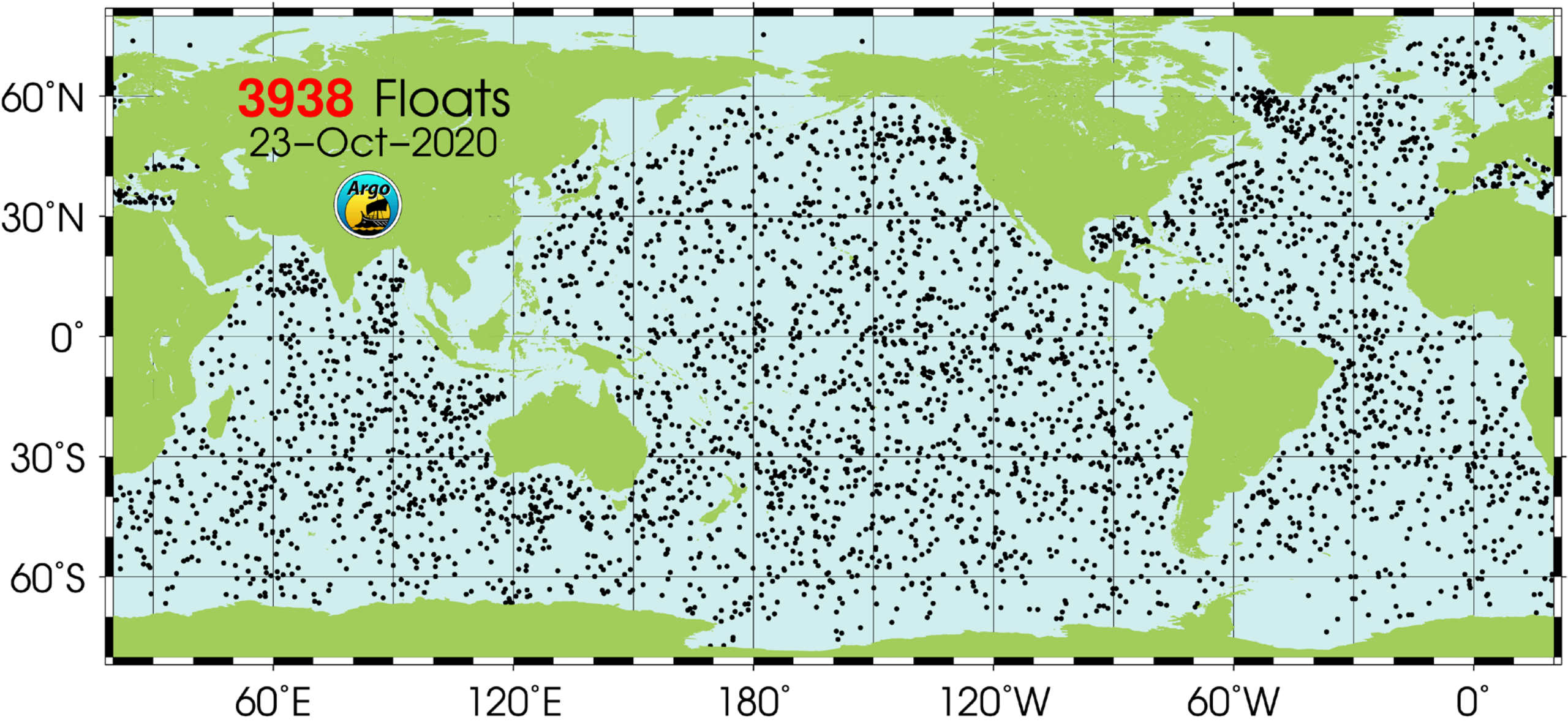
GEO BON

https://geobon.org/

I'm not going to talk about these … Contact Sanae Chiba and others if you're interested



(Pereira et al., Science, 2013)

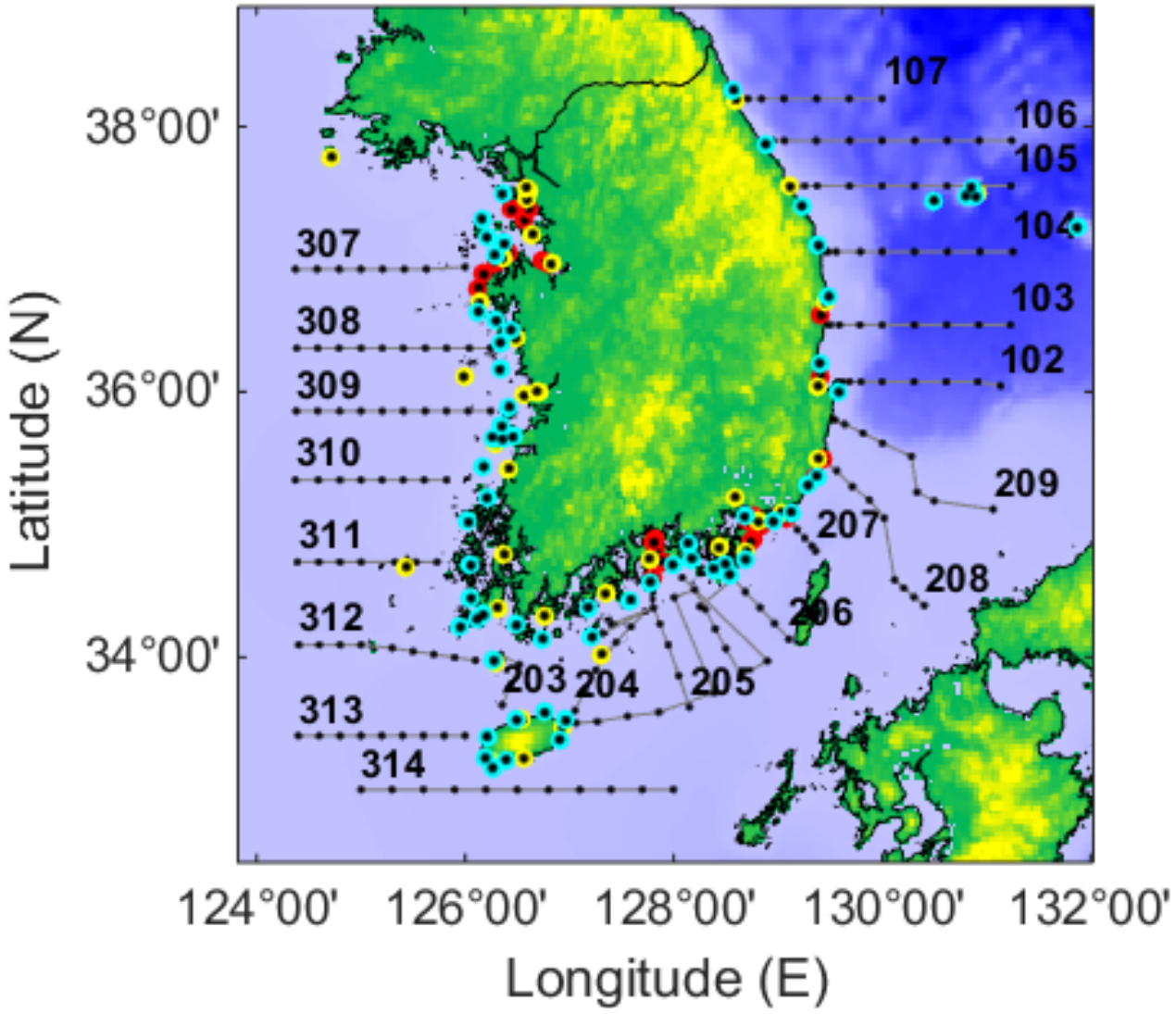


physical EOVs: surface and subsurface
Temperature, Salinity and currents

https://argo.ucsd.edu/

EOV/EBV observations through COOS in Korea

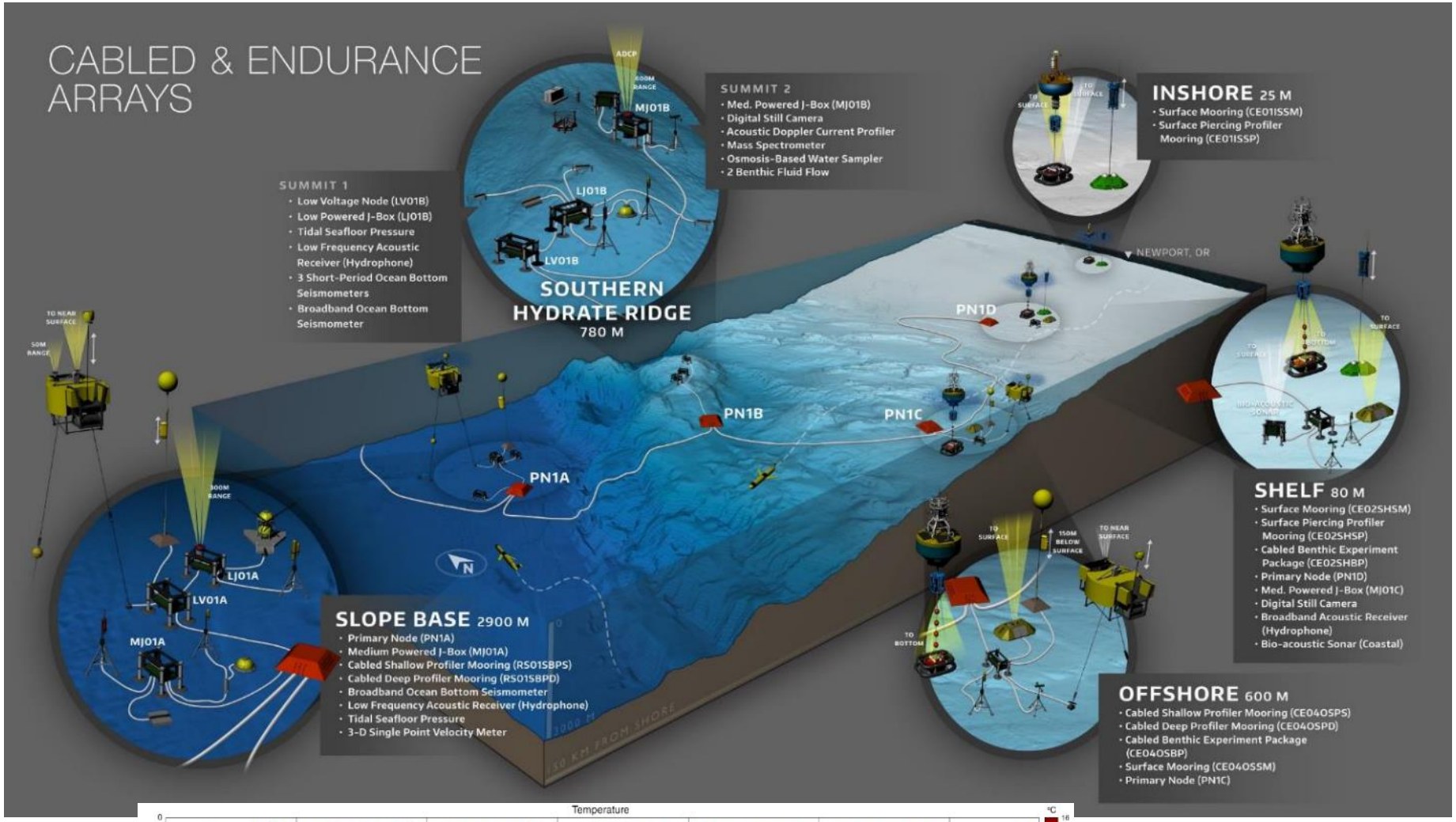
(Coastal Ocean Observing System)



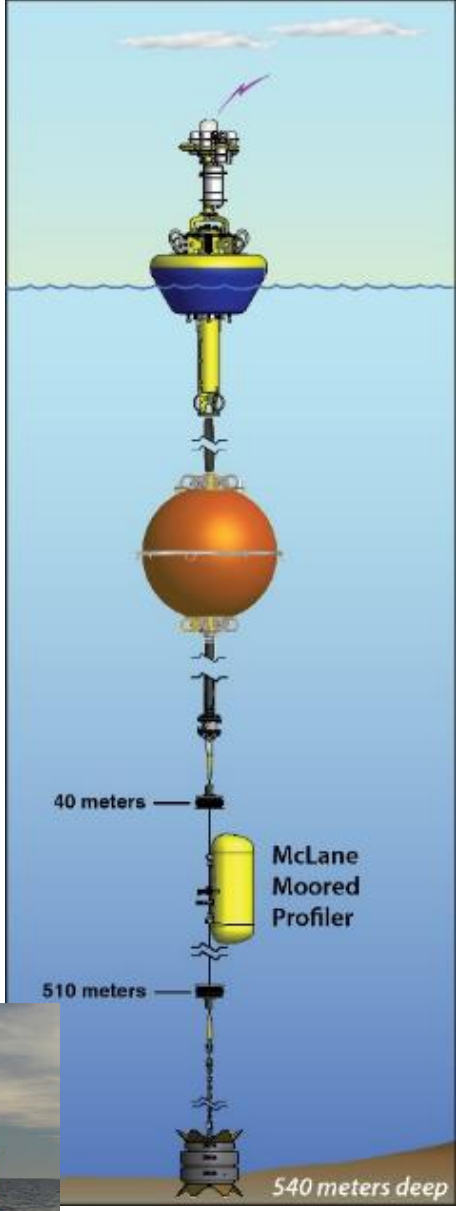
- SSHs (Tide gauges)
- Surface currents (High-freq. radars)
- Profiles of T/S, Oxygen, Phosphate, Nitrate, Silicate, PH, and Chl-a (Long-term hydrographic surveys)
- Significant wave heights, direction and period (Wave buoys)

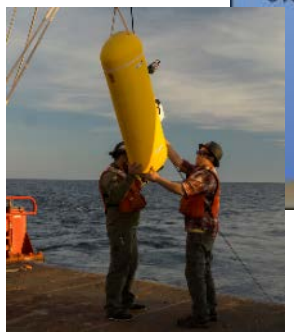
Courtesy of Sung Yong Kim (KAIST, Korea)

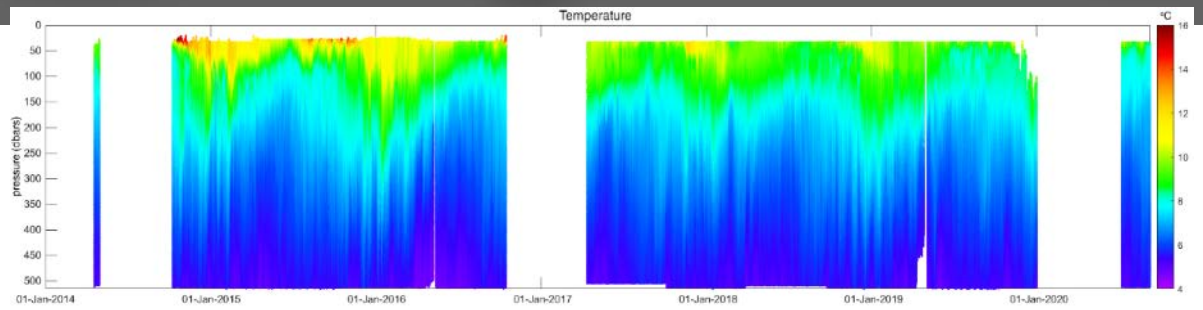
Cabled Ocean Observatories (real time, interactive)



Temperature
Salinity
Dissolved Oxygen
Chlorophyll *a*
PAR
Light backscatter
CDOM
Point velocity







2014

> 12,500 profiles!

2020

https://oceanobservatories.org

Ocean Observing System Report Card 2019

Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organization (WMO) and UNESCO's Intergovernmental Oceanographic Commission (IOC)

www.jcommops.org/reportcard2019

IN SITU AND SATELLITE OBSERVING SYSTEM STATUS

In 2018, extreme weather and climate events affected about 62 million people with many parts of the globe impacted by climate change. The current increase of carbon dioxide levels in the atmosphere is having a significant impact on temperatures, with 2015-2018 having been confirmed as the four warmest years on record and with an unprecedented increase in ocean acidity which is impacting a number of commercial fisheries.

efficiency for extreme events. They are also crucial for providing scientific assessments to enable environmental prediction and adaptation to climate change, as well as leading to more effective protection of ecosystems. To better meet expanding societal needs, the global ocean observing system is introducing new technologies and improved capabilities. These advancements will provide more observational information in real-time and long duration high-quality data needed for detection of ocean

2018: ocean observations

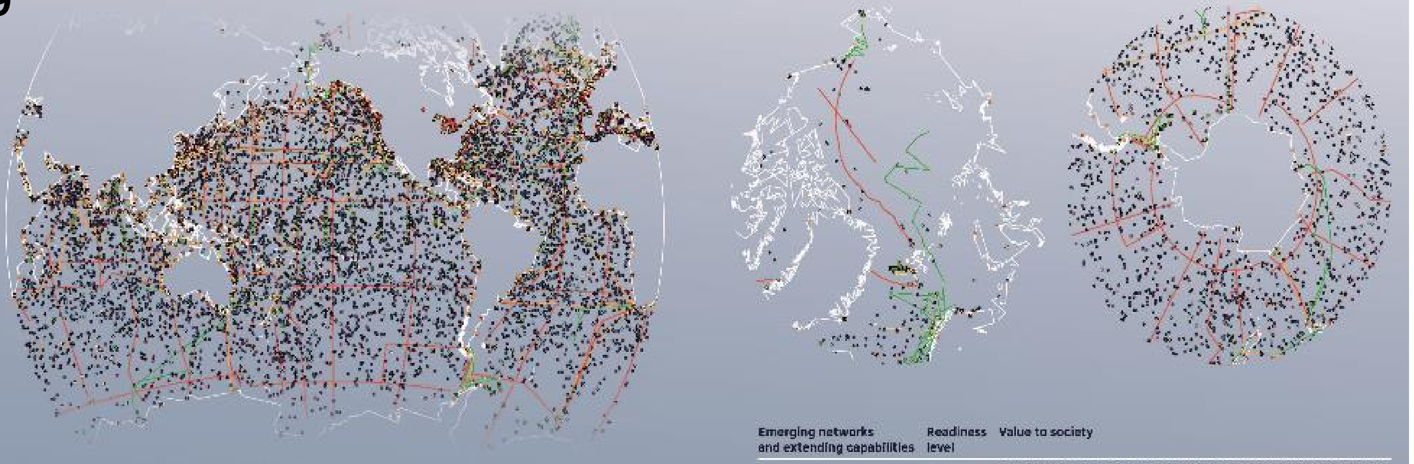
86 countries involved in ocean observations

8,933 *in situ* ocean observing platforms and...

18 Ocean and **9** Atmosphere Essential Climate Variables (ECVs)[1] observed

170 satellites continuously monitor the global ocean and atmosphere

2 million Temperature and Salinity profiles acquired in 20 years by the Argo program - a historical record!



In situ observations

In situ observing instruments continuously monitor the global ocean, from the sea surface to the sea floor, in near real-time. They measure many environmental parameters, providing essential calibration and validation data for satellite observations of the sea surface. These *in situ* observational platforms also measure surface marine meteorological variables and sample the water column, that cannot be measured by satellites.

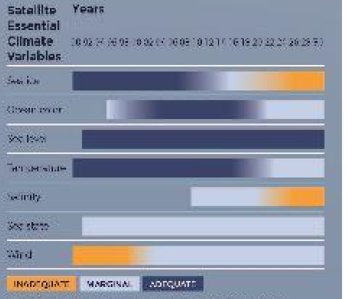
JCOMM *in situ* networks	Implementation: Status	Data & metadata: Real-time	Data & metadata: Archived high quality	Data & metadata: Metadata	Value to society
Ship based meteorological measurements - SOT/VOS	★★	★★	★★★	★★	[illegible]
Ship based aerological measurements - SOT/ASAP	★★	★★		★	[illegible]
Ship based oceanographic measurements - SOT/SOOP	★★★	★★★	★★	★★	[illegible]
Sea level gauges - GLOSS	★★★	★★	★★★	★★	[illegible]
Drifting and polar buoys - DBCP	★★	★★★	★★	★★	[illegible]
Moored buoys - DBCP	★★	★★★	★	★★	[illegible]
Interdisciplinary moorings - OceanSITES	★★★	★	★★★	★★	[illegible]
Profiling floats - Argo	★★★	★★★	★★★	★★★	[illegible]
Repeated transects - GO-SHIP	★★★	★★★	★★★	★★	[illegible]

Emerging networks and extending capabilities	Readiness level	Value to society
OceanGliders	PILOT to MATURE	[illegible]
HF radars	MATURE regionally PILOT globally	[illegible]
Surface based measurements CO2 - SOCONET	PILOT	[illegible]
Biogeochemistry & Deep floats - Argo	PILOT	[illegible]
Animal borne sensors	PILOT to MATURE	[illegible]

Satellite-based observations

The satellite network provides repeated global sampling of key ocean surface variables. These remotely-sensed variables are complementary to *in situ* observations, in that they fill in the gaps in *in situ* coverage, both in time and space, while *in situ* measurements provide critical ground-truthing information for satellite sensors. Together they provide foundational knowledge about the ocean environment and enable a wide range of forecasts and services.

For this reason, it is essential to ensure the continuity of satellite missions in the future. It is also imperative to keep improving the accuracy, coverage, spatial and temporal resolution provided by these satellite missions.



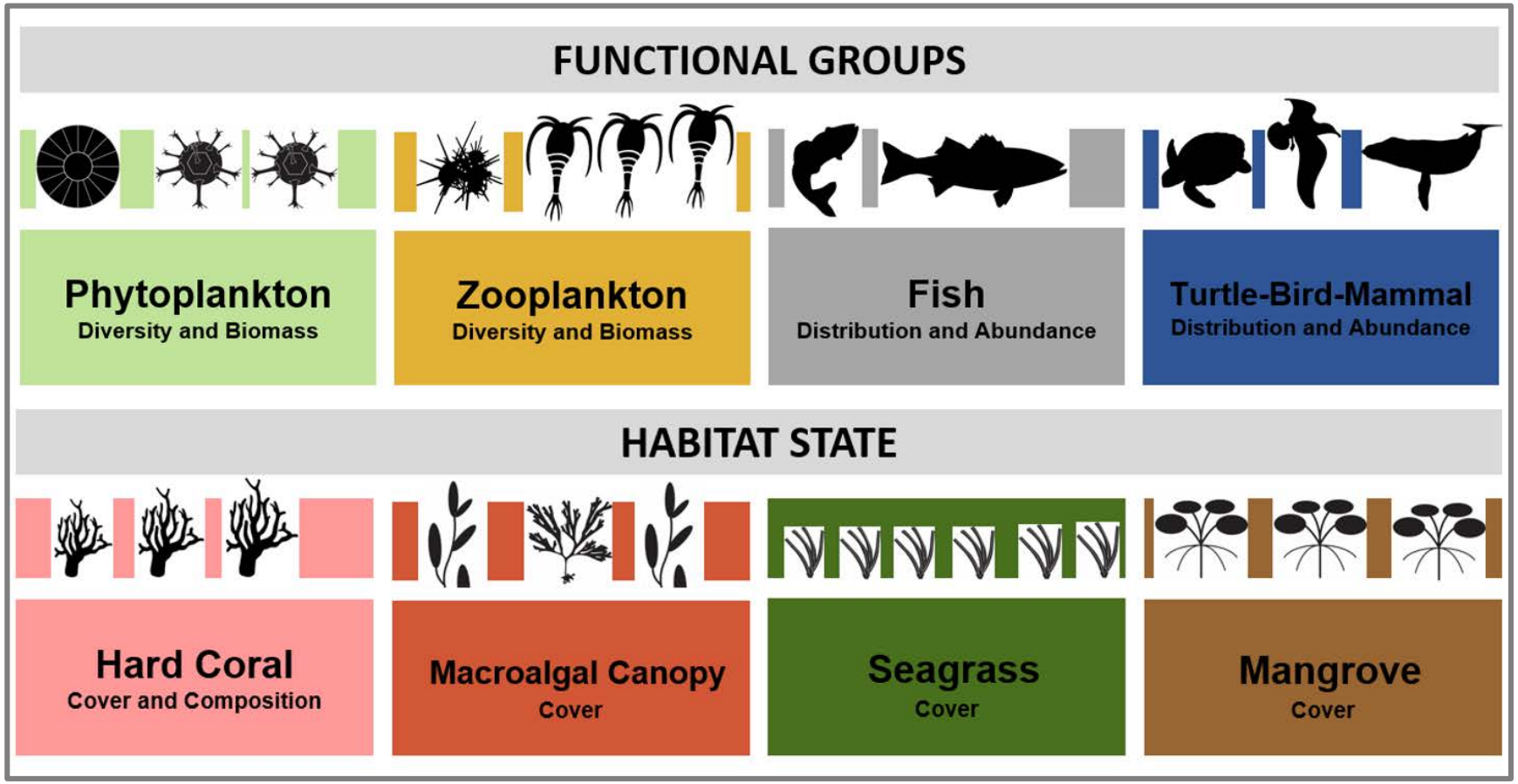
JCOMM in situ networks

- ✔ Ship based meteorological measurements - SOT/VOS
- ✔ Ship based aerological measurements - SOT/ASAP
- ✔ Ship based oceanographic measurements - SOT/SOOP
- ✔ Sea level gauges - GLOSS
- ✔ Drifting and polar buoys - DBCP
- ✔ Moored buoys - DBCP
- ✔ Interdisciplinary moorings - OceanSITES
- ✔ Profiling floats - Argo
- ✔ Repeated transects - GO-SHIP

Emerging networks and extending capabilities

- ✔ OceanGliders
- ✔ HF radars
- ✔ Surface based measurements CO2 - SOCONET
- ✔ Biogeochemistry & Deep floats - Argo
- ✔ Animal borne sensors

Essential Ocean Variables (EOVs) for Biology and Ecosystem

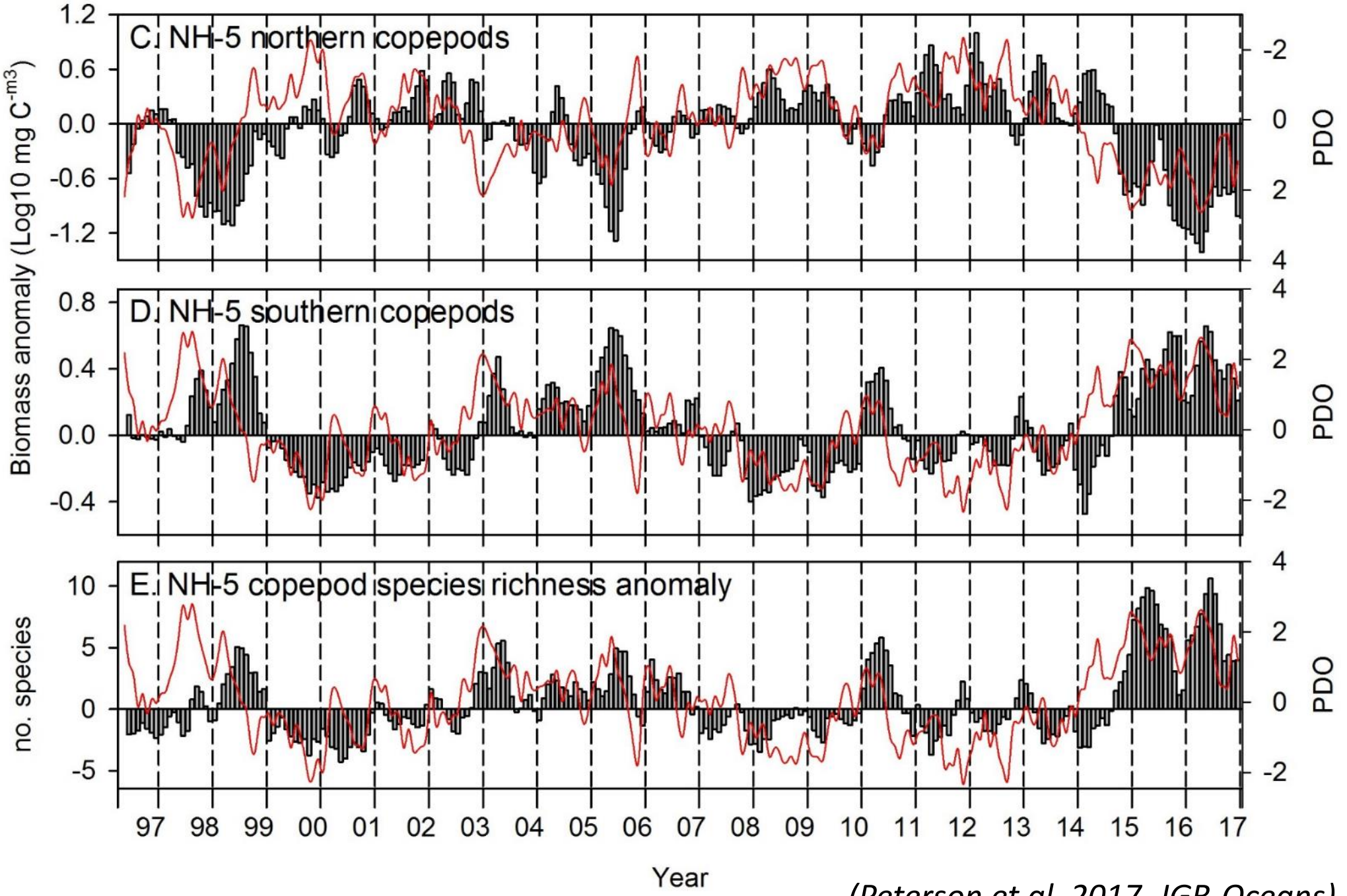


(Miloslavich et al. 2018, GCB)

Biology and Ecosystems Panel

Sanae Chiba (JAMSTEC)
GOOS-Bio/Eco Panel member

Newport, Oregon Hydro-graphic Line

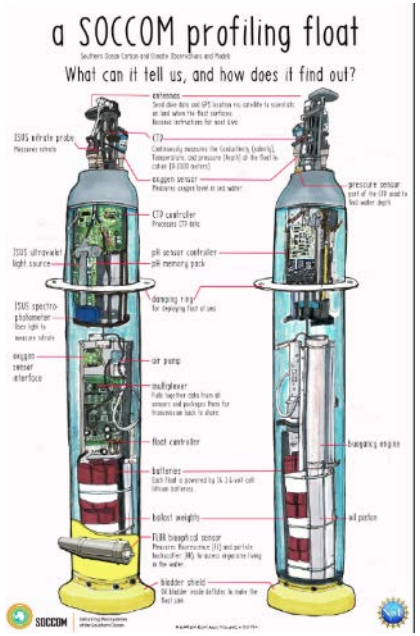


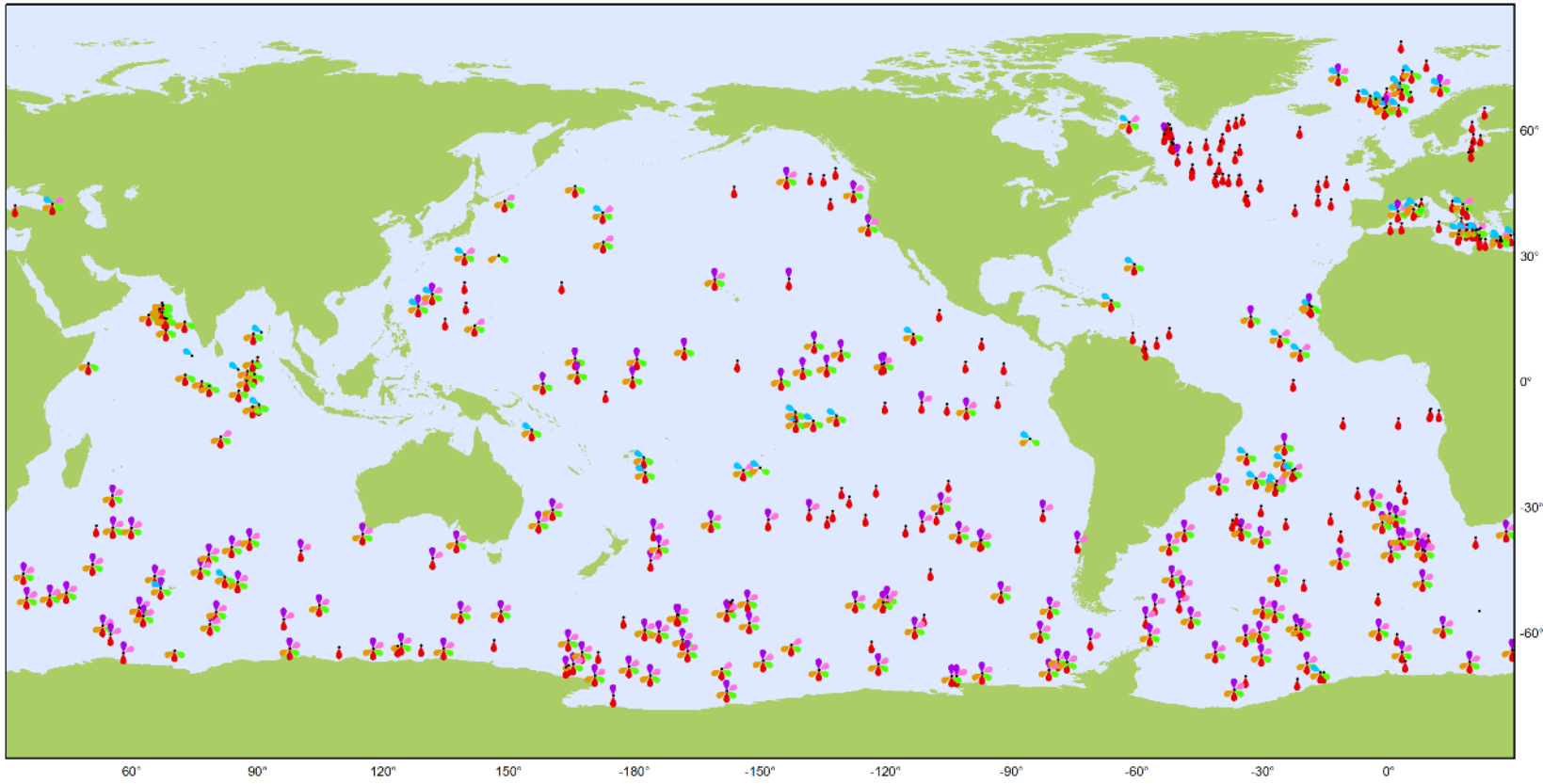
(Peterson et al. 2017, JGR-Oceans)

Biogeochemical Argo floats

Can measure more EOVs:

- **dissolve oxygen**
- **Nitrate**
- pH
- Chlorophyll a
- **Suspended particles**
- **Downwelling irradiance**





Biogeochemical Argo — **Sensor Types** — **September 2020**

Latest location of operational floats (data distributed within the last 30 days)

Operational Floats (380)
Suspended particles (205)
Downwelling irradiance (55)
pH (156)
Nitrate (158)
Chlorophyll a (204)
Oxygen (365)

Generated by www.jcommops.org, 01/10/2020

FAIR Data Services

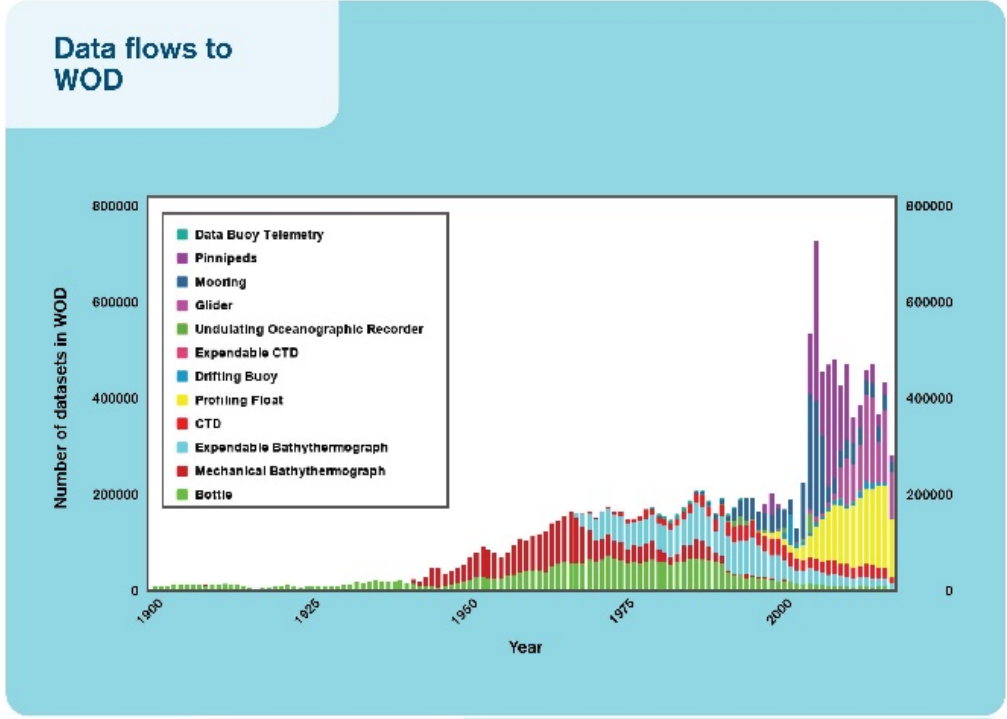
Findable, **A**ccessible, **I**nteroperable, **R**eusable

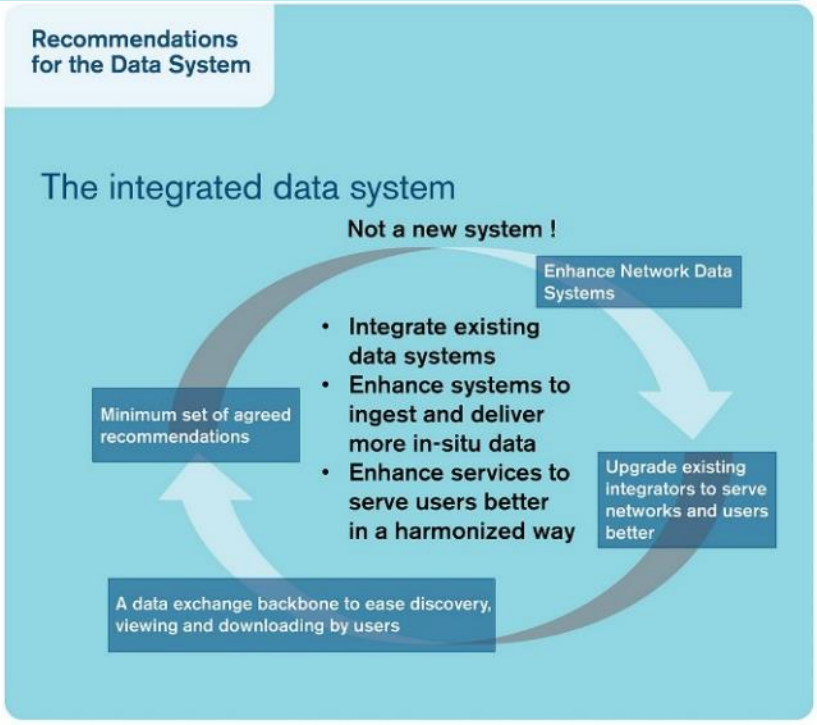
Tanhua et al., 2019 (Front. Mar. Sci.)

Ocean Best Practices

The Ocean Best Practice System (OBPS)
"agreed and broadly adopted methods for every activity in ocean observing from research to operations to applications."

Pearlman et al., 2019 (Front. Mar. Sci.)

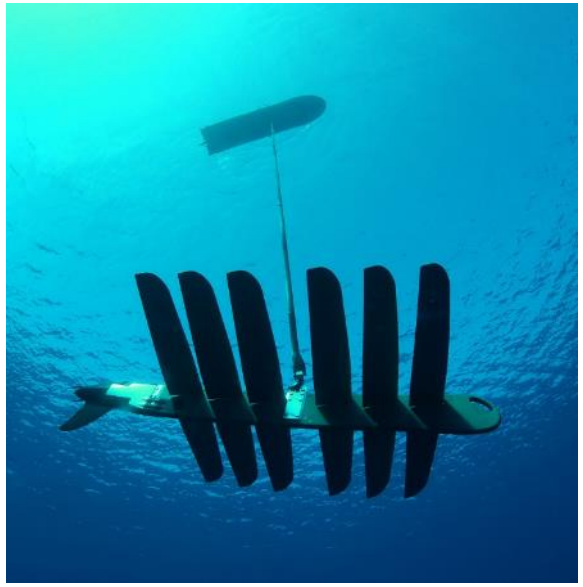




Autonomous drifters and surface vehicles

CODE and WOCE surface Drifters

Saildrone



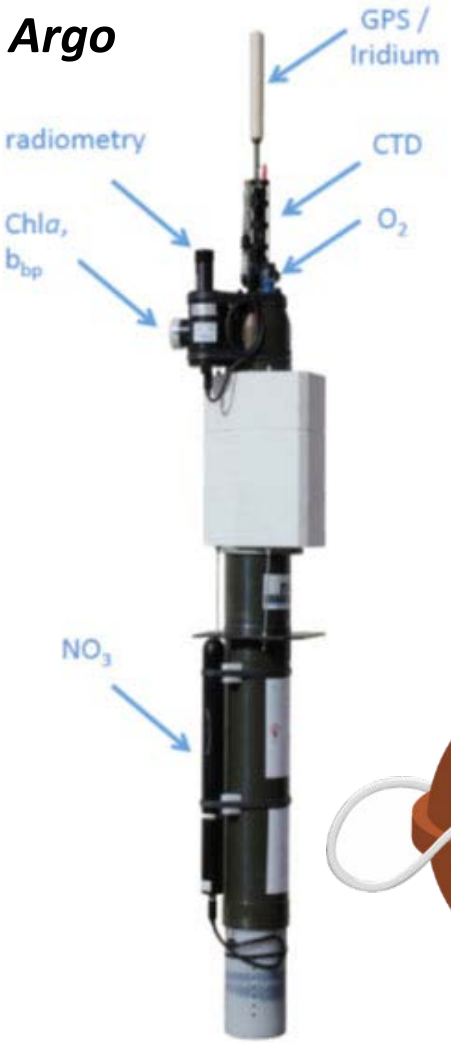
Wave glider – Liquid Robotics

Sea Hunter - Vigor

Submaran S10 – Ocean Aero

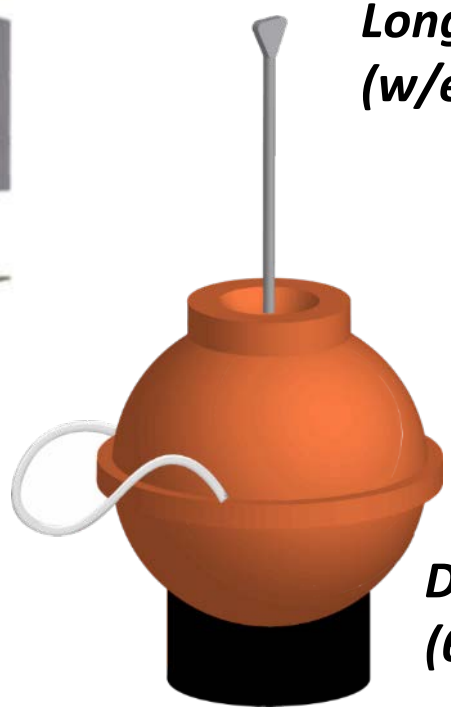
Autonomous floats and vehicles

Biogeochemical Argo

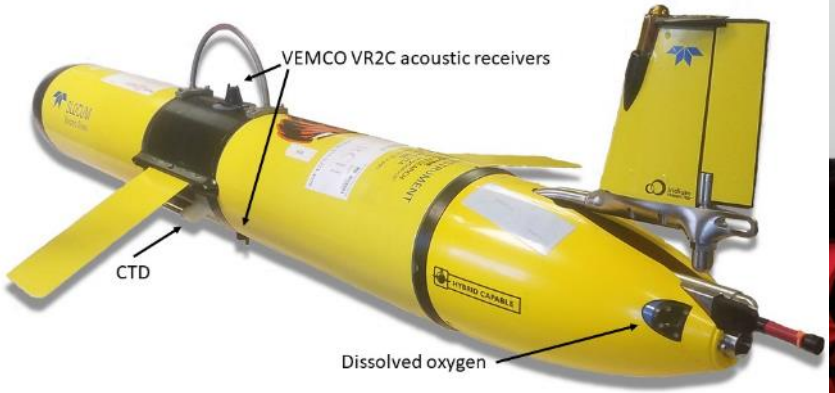


Long-Range AUV Tethys – MBARI (w/eDNA now!)

Underwater gliders (w/lots of sensors!)



Deep Argo (6000 m)



into popular culture …

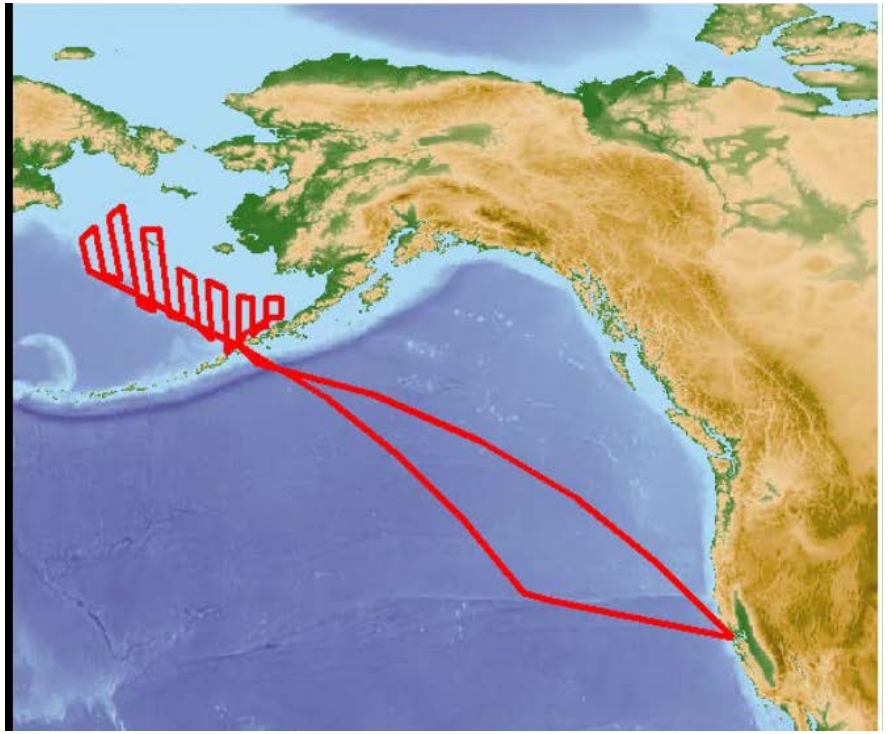
Sherman's Lagoon by Jim Toomey

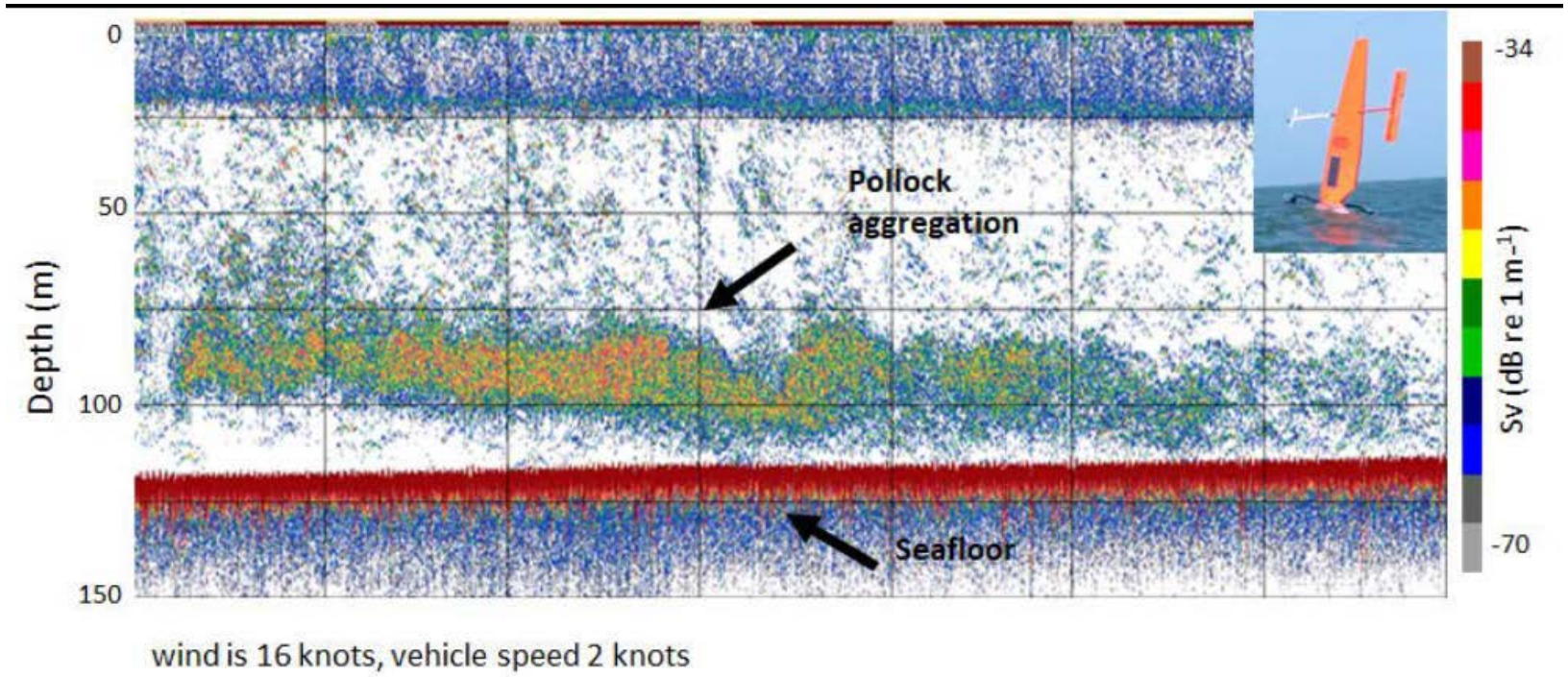
2020 Saildrone Pollock Acoustic Survey

NOAA Alaska Fisheries Science Center

4 July to 20 August 2020

In response to lack of ship survey due to COVID-19





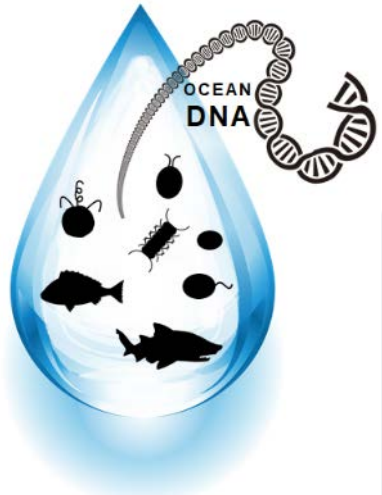
38/200 kHz echosounder, oceanographic and meteorological measurements

(Contact Alex De Robertis, NOAA AFSC, for details – via Lisa Eisner, PICES MONITOR)

Big knowledge gap: Dynamic distribution of species (species overlap)

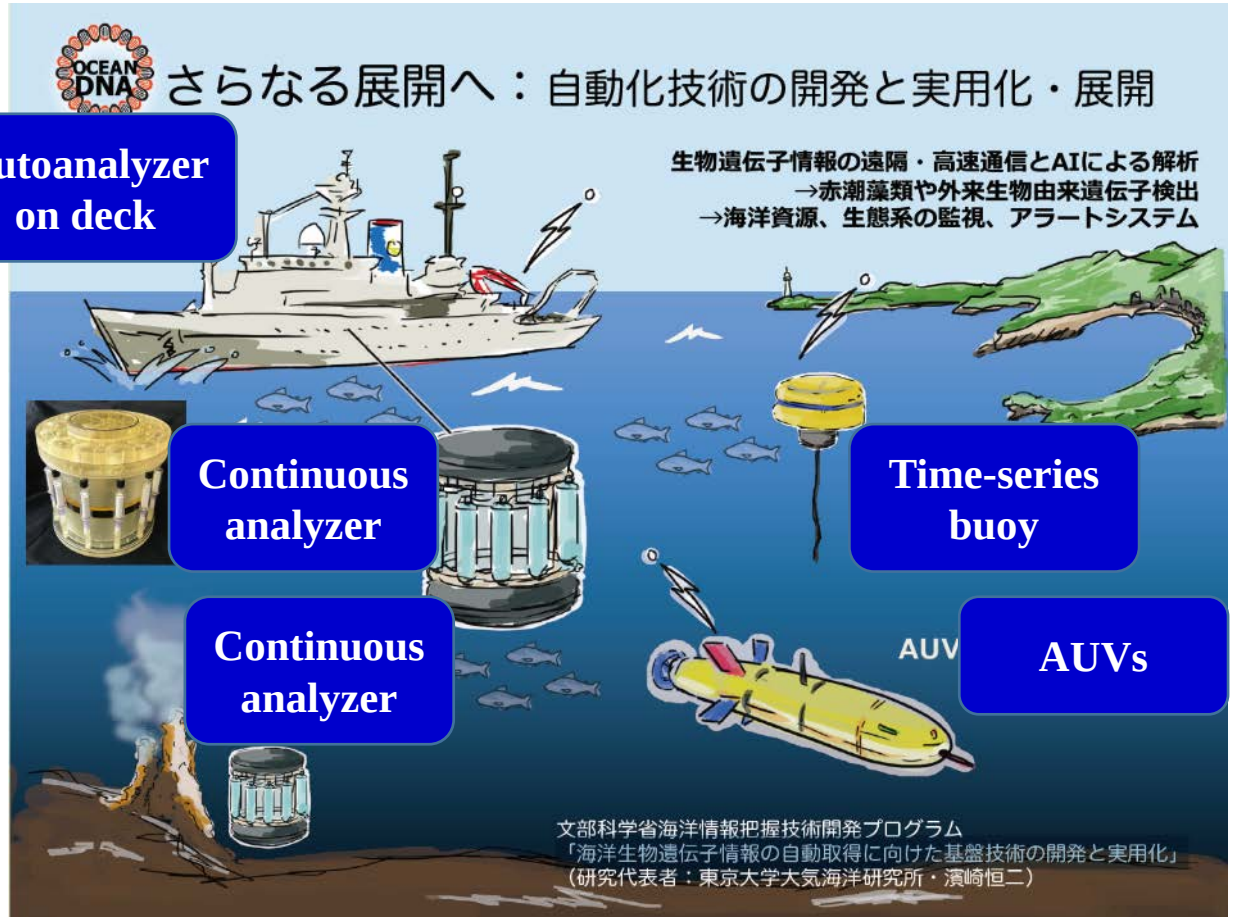
In the Ocean, 91% of species have been still underdetermined (Mora et al., 2001).
We have a big knowledge gap in dynamical variation of species distribution.
Dynamical variation of species distribution is a key to understand the ecosystem functioning.

OceanDNA Project in AORI Univ. Tokyo



- **AORI has been developing "Mitochondrial Genome Database of Fish (MitoFish)".**
- **AORI lunched OceanDNA Project which extends environmental DNA observation techniques to open oceans.**
- **Further developing auto-analyzer of OceanDNA which potentially applied to AUVs in future.**

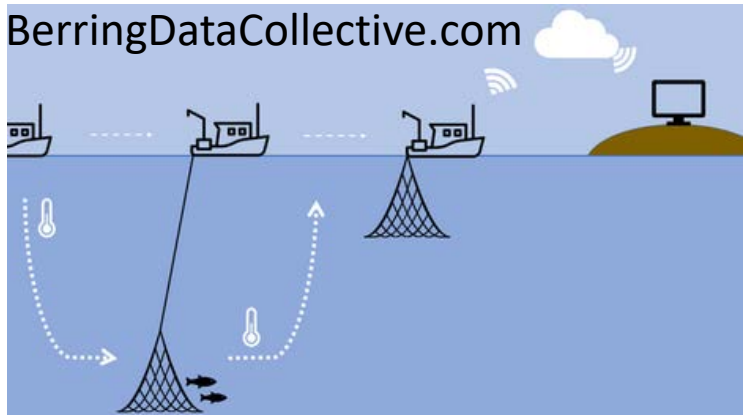
→ See PICES 2020 Session VS3

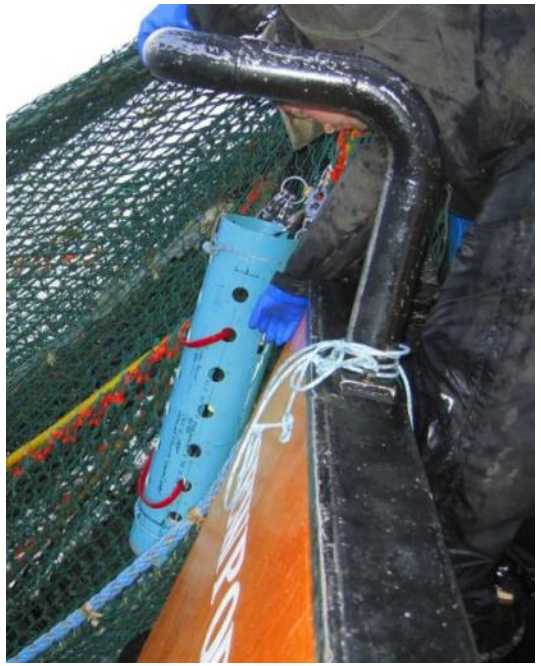


(courtesy of S-i. Ito)

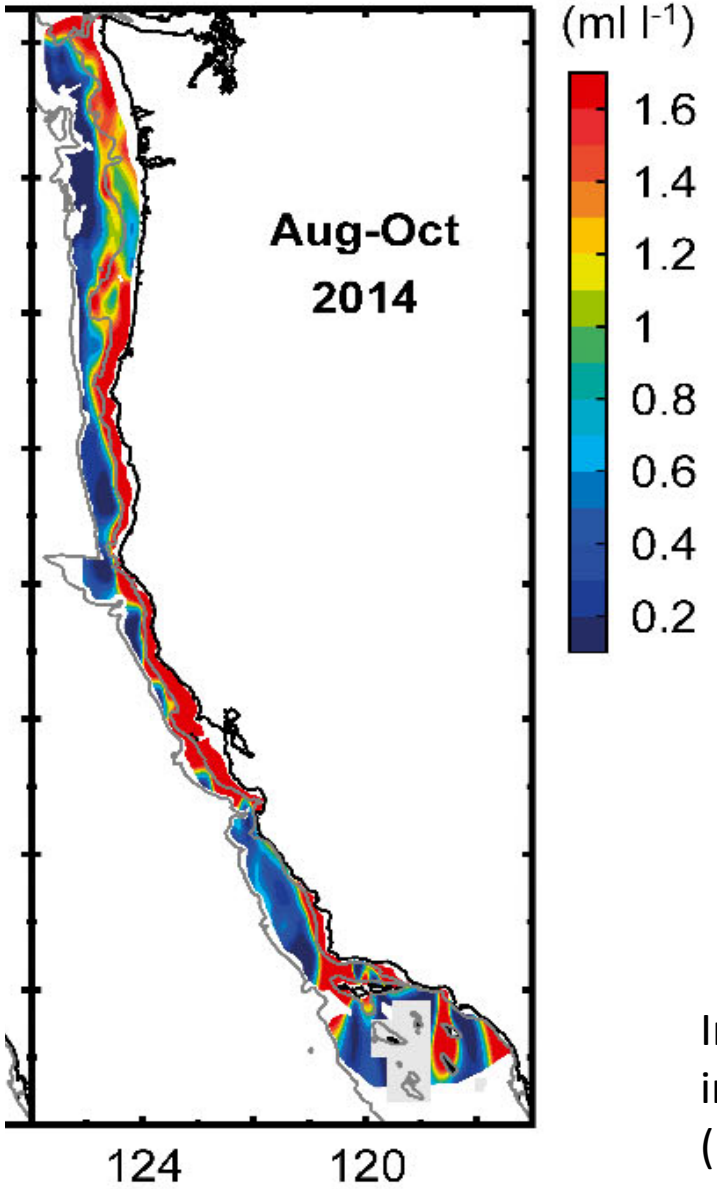
http://ecosystem.aori.u-tokyo.ac.jp/microbiology-wp/projects/
by Prof. Koji Hamasaki

Instrumenting fishing vessels

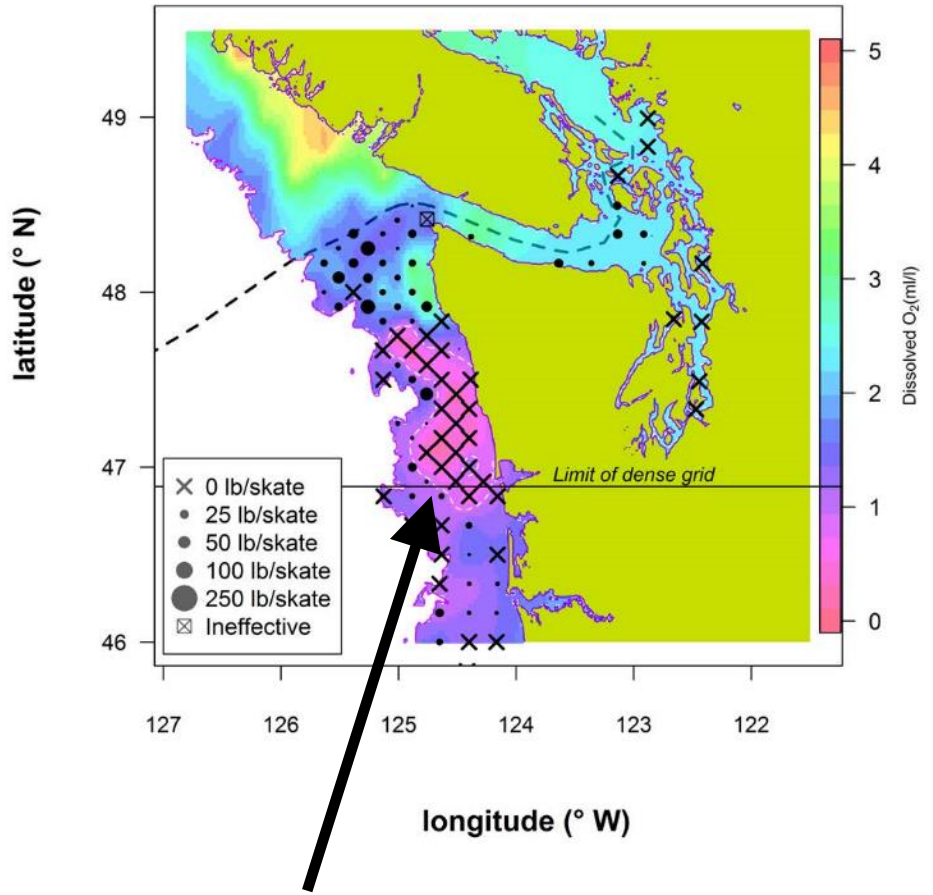




(Keller et al. 2017, MEPS)



INTERNATIONAL PACIFIC HALIBUT COMMISSION



no halibut ←→ low oxygen

International Pacific Halibut Commission fishery-independent survey → stock assessment. (IPHC-2018-RAB19-06)

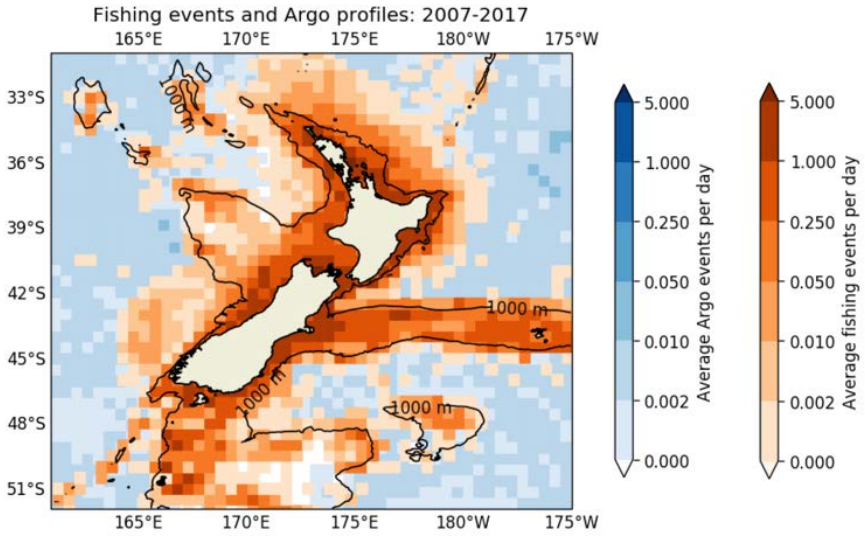
Small, simple, inexpensive sensors

More observations from many platforms

Citizen science

Available to many ocean observers (equity)

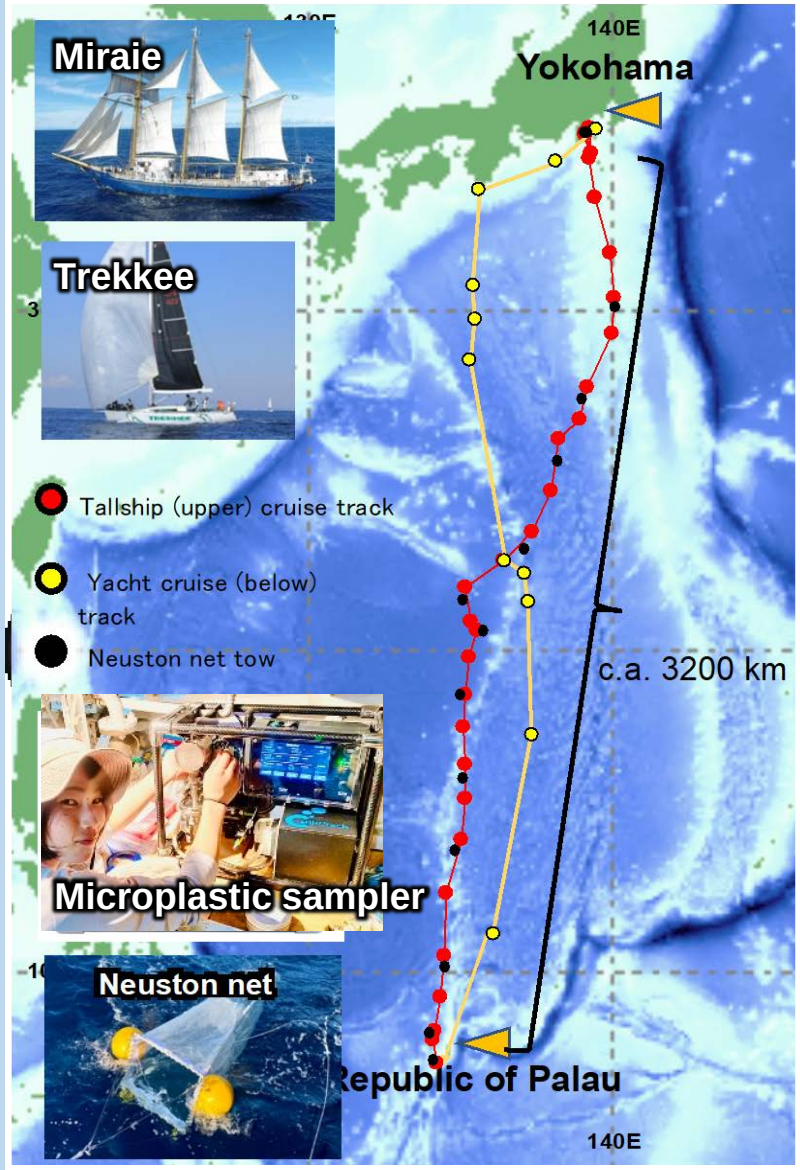
Onset Tidbit, salinity
https://www.onsetcomp.com/



Tiro Moana temperature-pressure
https://www.moanaproject.org/

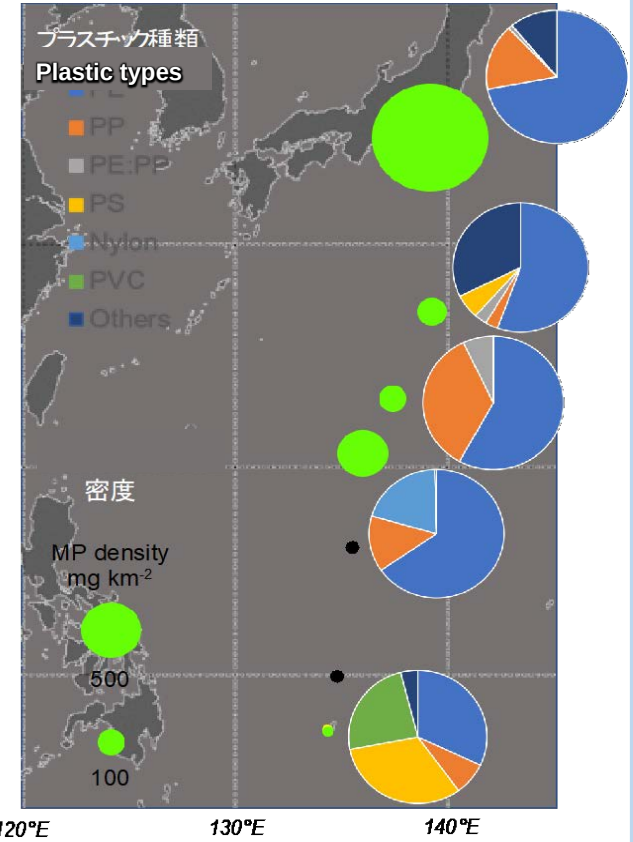
Temperature, dissolved oxygen
(Courtesy of L. Stoltz & F. Chan Oregon State University)

Microplastic survey & promotion of ocean literacy in collaboration with sailing community



Microplastic Survey

The survey was conducted during the Japan-Palau Goodwill Yacht Race (Dec 2019 – Jan 2020) in collaboration with the Republic of Palau, Japanese government, the yacht race organizer, UNEP-WCMC and private sectors.



Ocean Literacy Program on the Tall ship MIRAIE

JNEP WCMC

Palau youth






Lecture series

Leaning how to survey marine plastics

Mini independent project

Tested through game

Presentation of how they leant

YouTube

Daily report on SNS media

Chiba et al (2020) , Griffin & Chiba (2020)

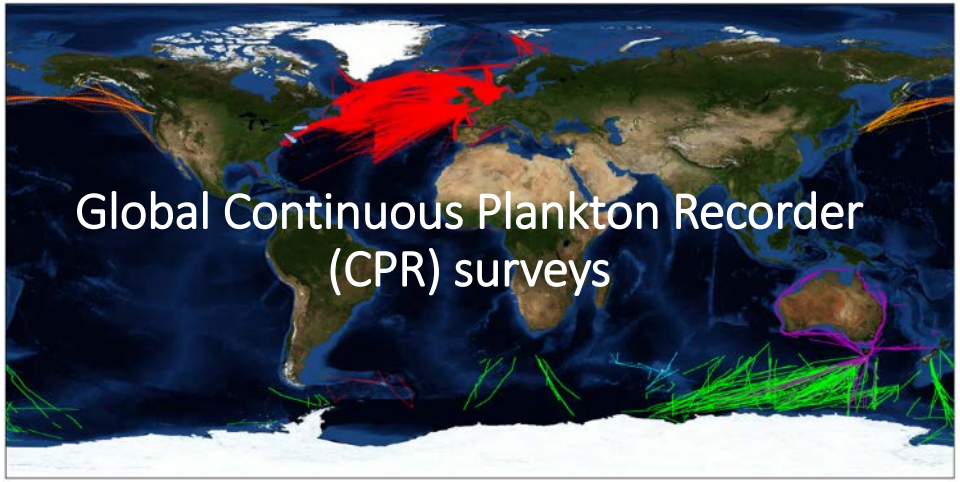
PICES Ocean Observing and data access

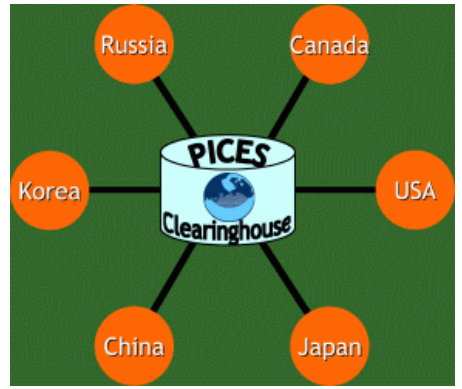
MONITOR

CPR Survey

TCODE

AP-NPCOOS





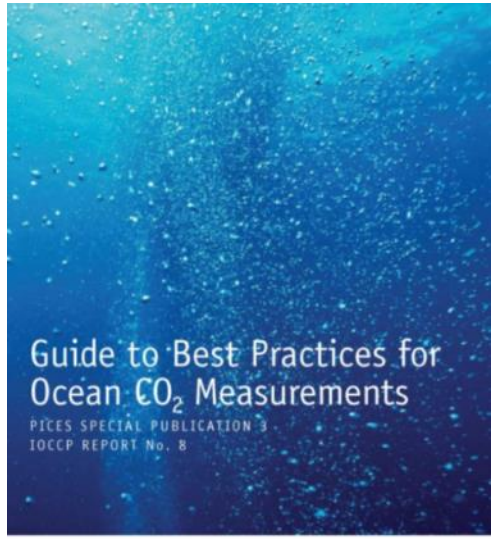
FishGIS - Building capacity for coastal monitoring by local small-scale fishers

NPESR

PICES Metadata Federation

POMA - PICES Ocean Monitoring Service Award winners

Special Publications, e.g., "Guide to Best Practices for Ocean CO2 Measurements"



Into the UN Decade of Ocean Science for Sustainable Development

- An ever-increasing set of tools …
  - Autonomous technology + new sensors
  - Low-cost, small, easily deployed sensors
- Let's make our data FAIR
  - Findable, Accessible, Interoperable, Reusable
- We need the resolve and support of our community and our PICES nations

2021 2030 United Nations Decade of Ocean Science for Sustainable Development