

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

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)

Jack Barth

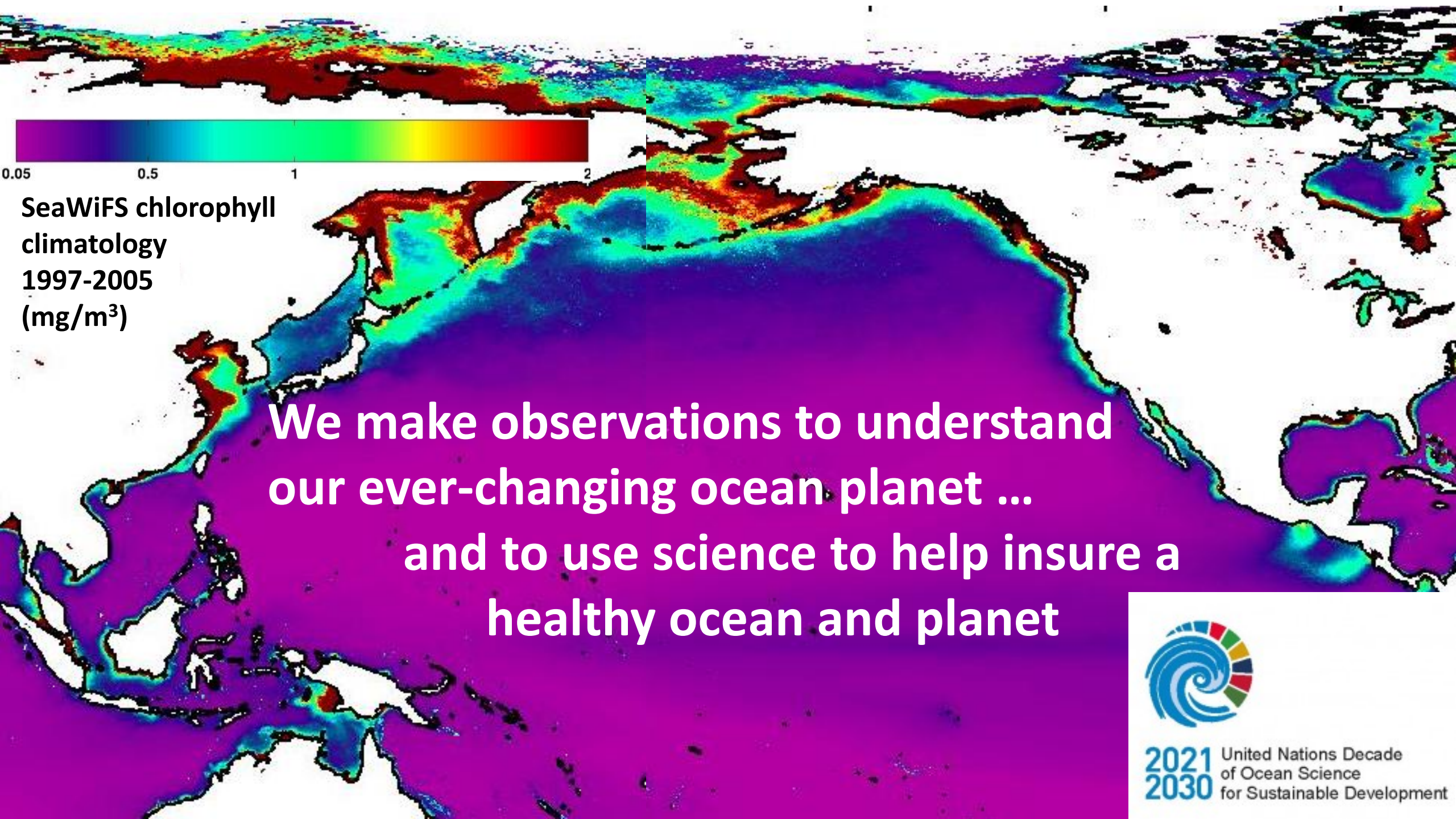
Oregon State University

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





SeaWiFS chlorophyll
climatology
1997-2005
(mg/m³)

**We make observations to understand
our ever-changing ocean planet ...
and to use science to help insure a
healthy ocean and planet**



2021 United Nations Decade
2030 of Ocean Science
for Sustainable Development



ADVISORY REPORT

Fisheries & Ecosystem Responses

To Recent Regime Shifts in the North Pacific



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



OceanObs'09

Ocean information for society:
sustaining the benefits,
realizing the potential

21-25 September 2009, Venice, Italy

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>



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

GOOS:

Essential Ocean Variables (EOVs)

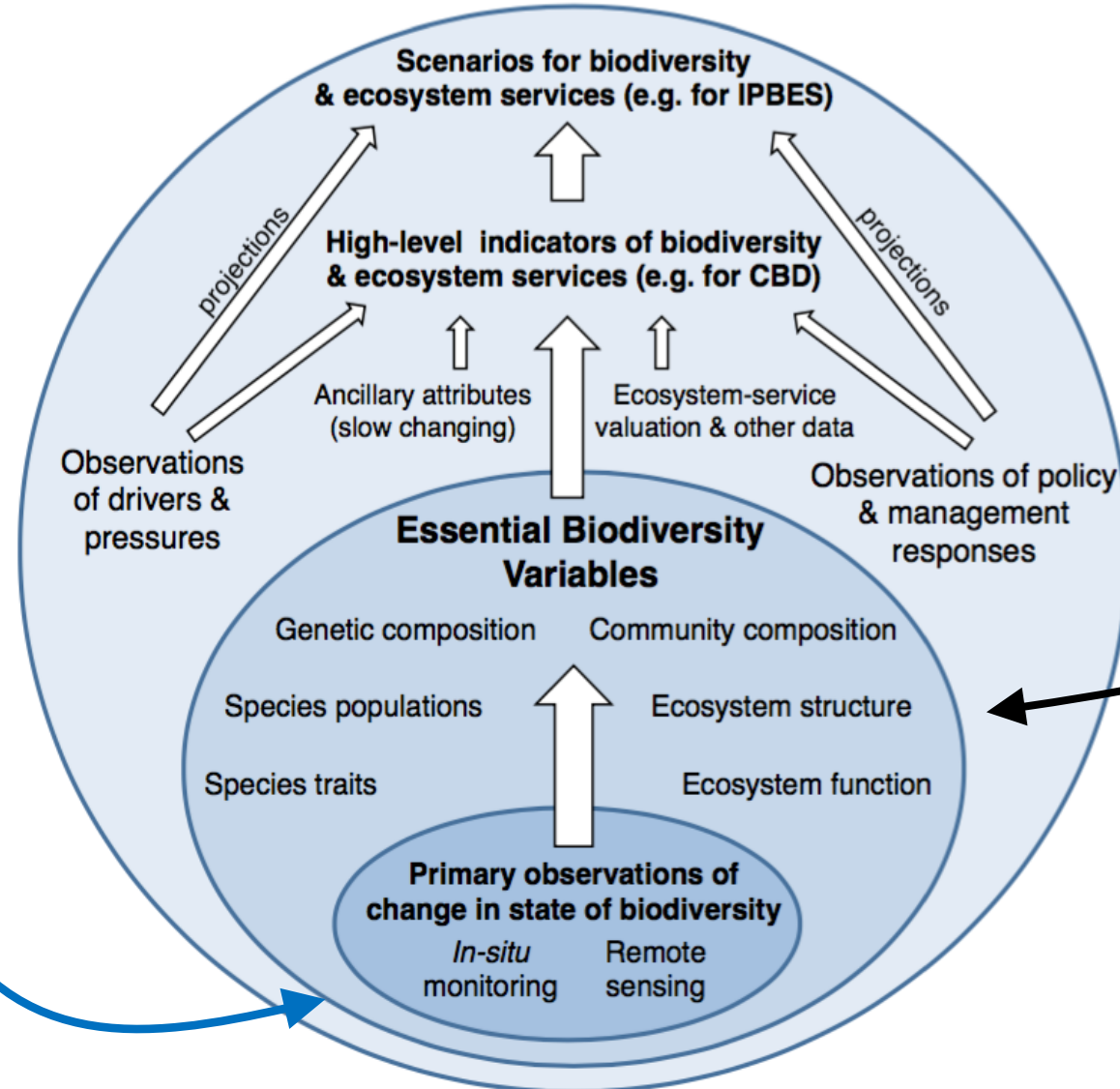
PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and 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)

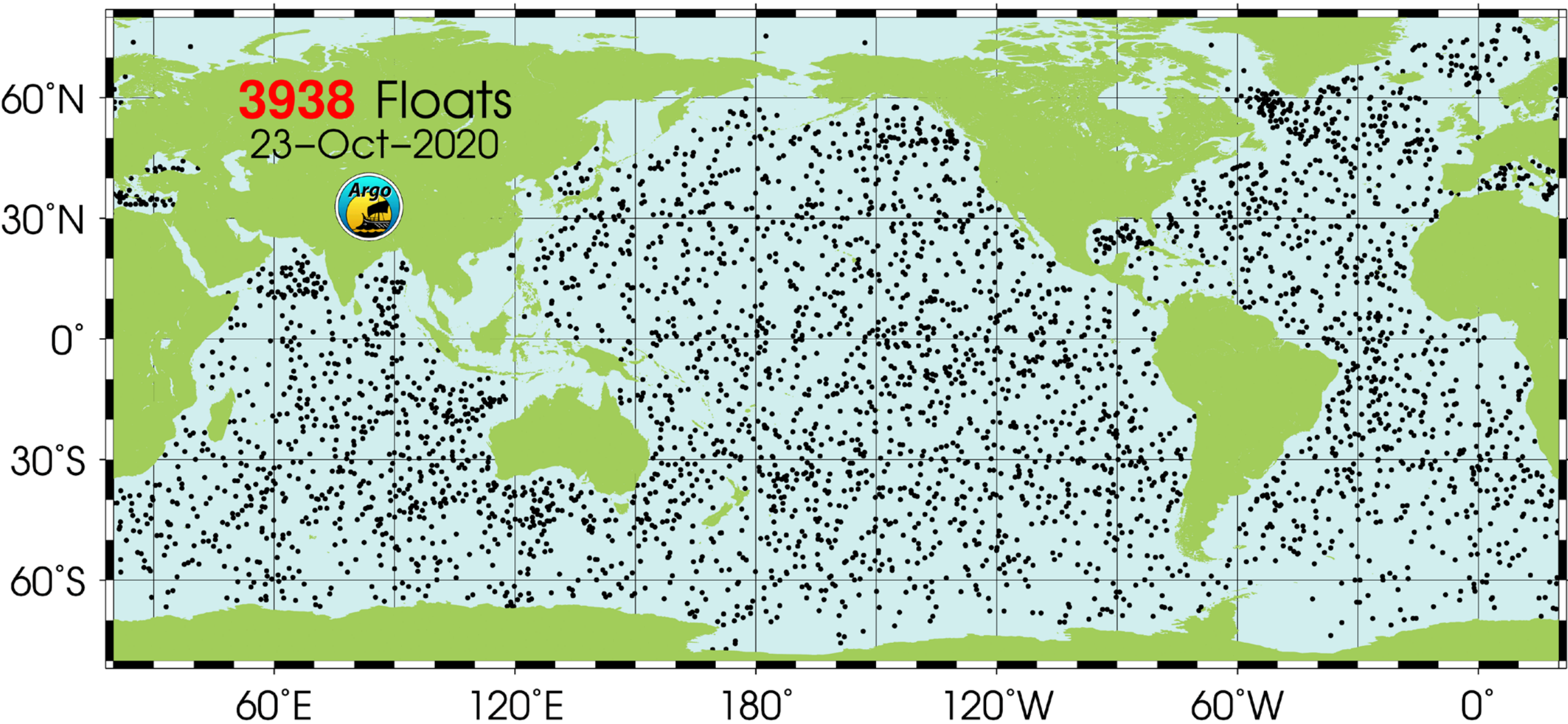


<https://geobon.org/>

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



(Pereira et al., Science, 2013)

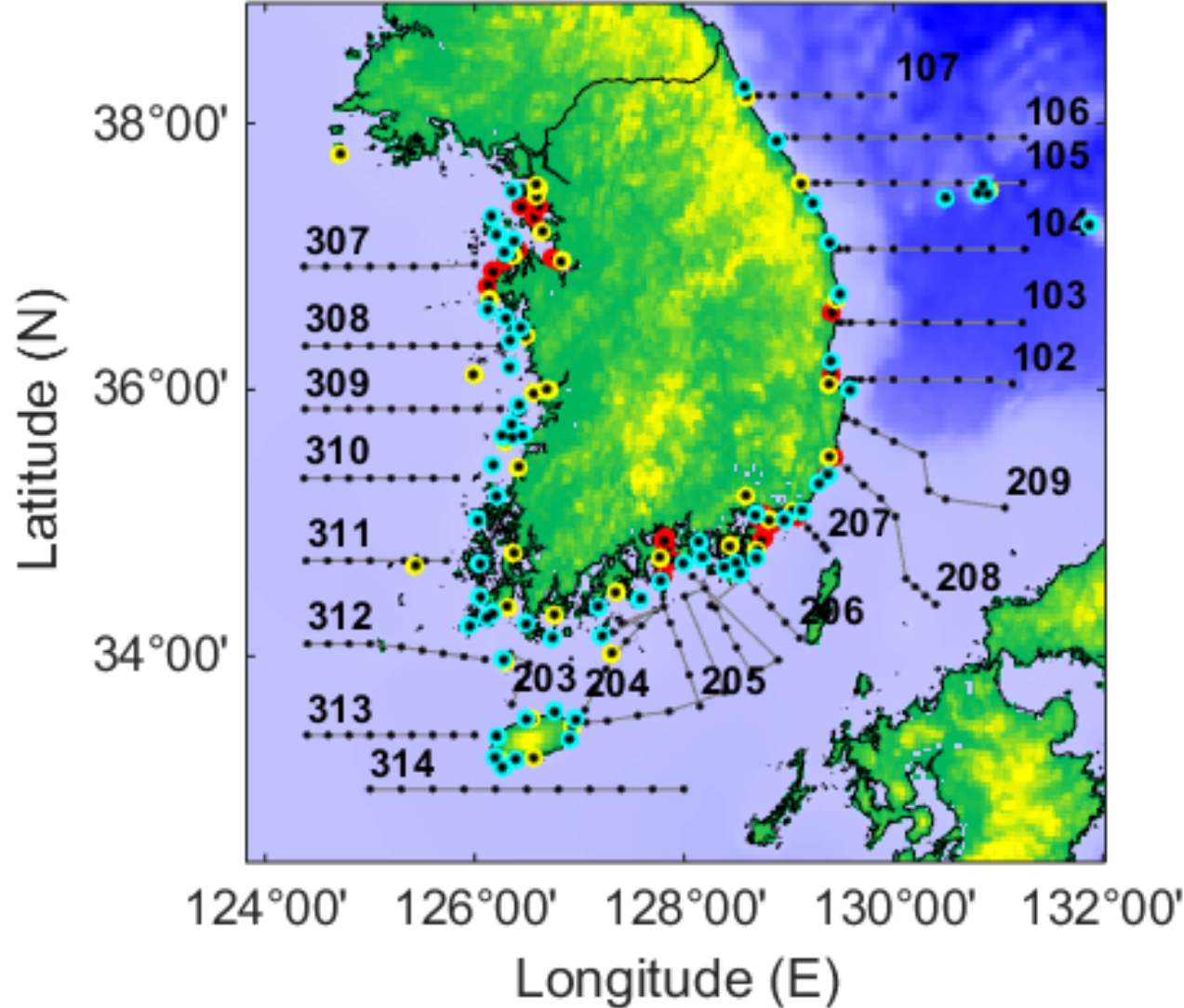


physical EOVs: surface and subsurface
Temperature, Salinity and currents

<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)

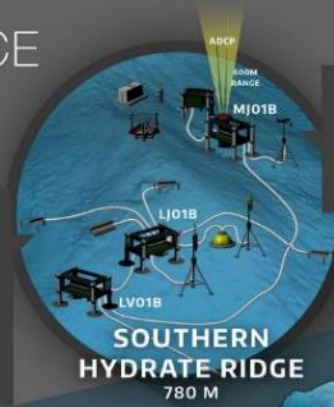
Courtesy of Sung Yong Kim (KAIST, Korea)

Cabled Ocean Observatories (real time, interactive)

CABLED & ENDURANCE ARRAYS

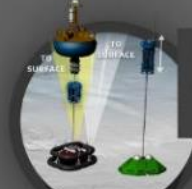
SUMMIT 1

- Low Voltage Node (LV01B)
- Low Powered J-Box (LJ01B)
- Tidal Seafloor Pressure
- Low Frequency Acoustic Receiver (Hydrophone)
- 3 Short-Period Ocean Bottom Seismometers
- Broadband Ocean Bottom Seismometer



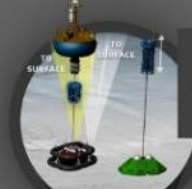
SUMMIT 2

- Med. Powered J-Box (MJ01B)
- Digital Still Camera
- Acoustic Doppler Current Profiler
- Mass Spectrometer
- Osmosis-Based Water Sampler
- 2 Benthic Fluid Flow



INSHORE 25 M

- Surface Mooring (CE01SSM)
- Surface Piercing Profiler Mooring (CE01SSP)



SOUTHERN HYDRATE RIDGE 780 M

PN1D

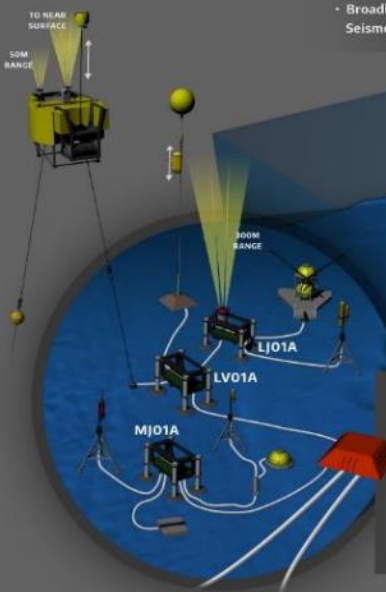
PN1C

PN1B

PN1A

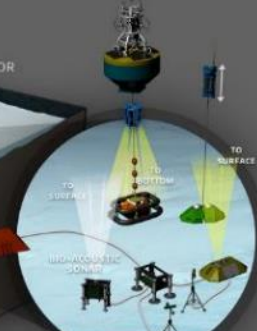
SLOPE BASE 2900 M

- Primary Node (PN1A)
- Medium Powered J-Box (MJ01A)
- Cabled Shallow Profiler Mooring (RS01SBPS)
- Cabled Deep Profiler Mooring (RS01SBPD)
- Broadband Ocean Bottom Seismometer
- Low Frequency Acoustic Receiver (Hydrophone)
- Tidal Seafloor Pressure
- 3-D Single Point Velocity Meter



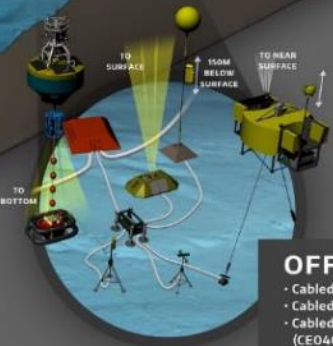
SHELF 80 M

- Surface Mooring (CE02SHSM)
- Surface Piercing Profiler Mooring (CE02SHSP)
- Cabled Benthic Experiment Package (CE02SHBP)
- Primary Node (PN1D)
- Med. Powered J-Box (MJ01C)
- Digital Still Camera
- Broadband Acoustic Receiver (Hydrophone)
- Bio-acoustic Sonar (Coastal)

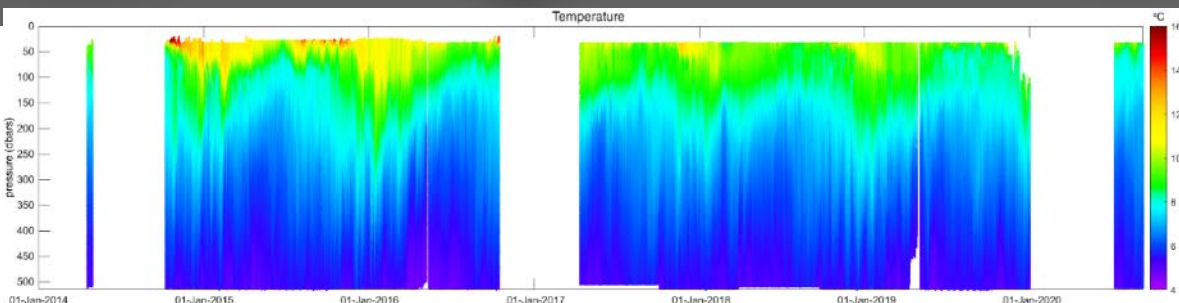
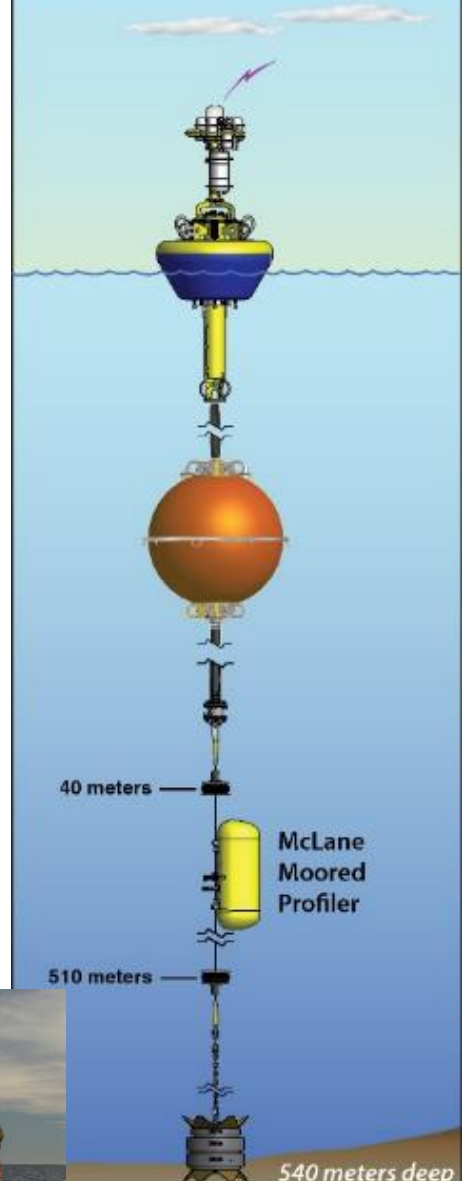


OFFSHORE 600 M

- Cabled Shallow Profiler Mooring (CE04OSPS)
- Cabled Deep Profiler Mooring (CE04OSPD)
- Cabled Benthic Experiment Package (CE04OSBP)
- Surface Mooring (CE04OSSM)
- Primary Node (PN1C)



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



2014

2020

> 12,500 profiles!

<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)

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

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



See in situ and emerging networks table for more legend. Symbol size is not to scale. In the maps lines are exaggerated for a view of hundreds to miles for readability.

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 Archival high quality	Data & metadata Metadata	Value to society
Ship based meteorological measurements - SOT/VOS	***	***	***	***	Observations on the quality of weather forecasts and numerical weather prediction for the safety of life and sailing with improved understanding of global climate.
Ship based aerological measurements - SOT/ASAP	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.
Ship based oceanographic measurements - SOT/SOOP	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.
Sea level gauges - GLOSS	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.
Drifting and polar buoys - DBCP	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.
Moored buoys - DBCP	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.
Interdisciplinary moorings - OceanSITES	***	***	***	***	Climate research long-term reference time-series observations for marine biogeochemistry, biogeochemistry, and biogeochemistry. Assessing inter-oceanic climate change, and ocean data on ocean circulation, carbon fluxes, deep ocean warming, etc.
Profiling floats - Argo	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.
Repeated transects GO-SHIP	***	***	***	***	Key for research on sea level change and ocean circulation, ocean protection during storm surges and sea level rise, and monitoring business risks linked to sea level rise, sea level rise, and sea level rise.

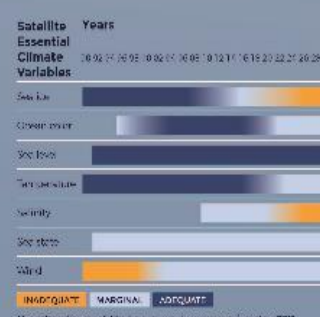


Emerging networks and extending capabilities	Readiness level	Value to society
OceanGliders	PLC to V/L/UL	Sustained observations from the open ocean to the poles for regional climate studies and storm prediction and ocean health assessment, with a direct impact on fisheries assessment, transportation, climate prediction and ocean food security management.
HF radars	W/L/UL to V/L/UL globally	Speed and direction of ocean surface currents in near real-time for coast guard search and rescue of and hazardous material spills, water quality monitoring and for site specific operations.
Surface based measurements CO2 - SOCONET	PLC to V/L/UL	Reference surface CO2 data for ocean acidification and to quantify global atmospheric CO2 fluxes.
Biogeochemistry & Deep floats - Argo	PLC to V/L/UL	Characterization of biogeochemical processes globally under natural ocean conditions, the past and present, and to provide conditions for the future and to provide salinity and density as well as the marine ecosystem health, deep ocean variability.
Animal borne sensors	PLC to V/L/UL	Unique source of real-time ocean and climate data in remote, data-poor, polar regions.

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.



2018: ocean observations

86 countries involved in ocean observations

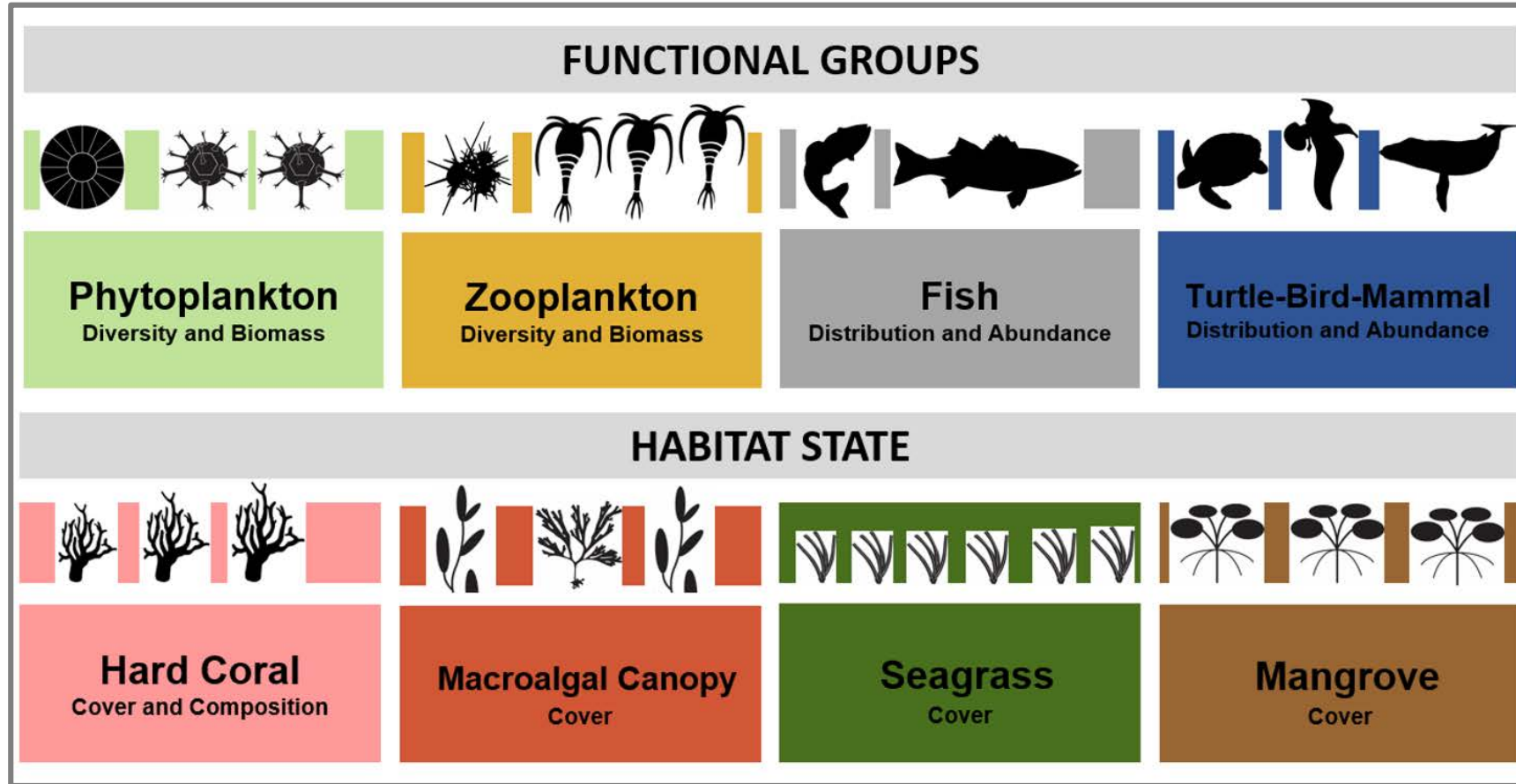
8,933 *in situ* ocean observing platforms and...

18 Ocean and 9 Atmosphere Essential Climate Variables (ECVs) 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!

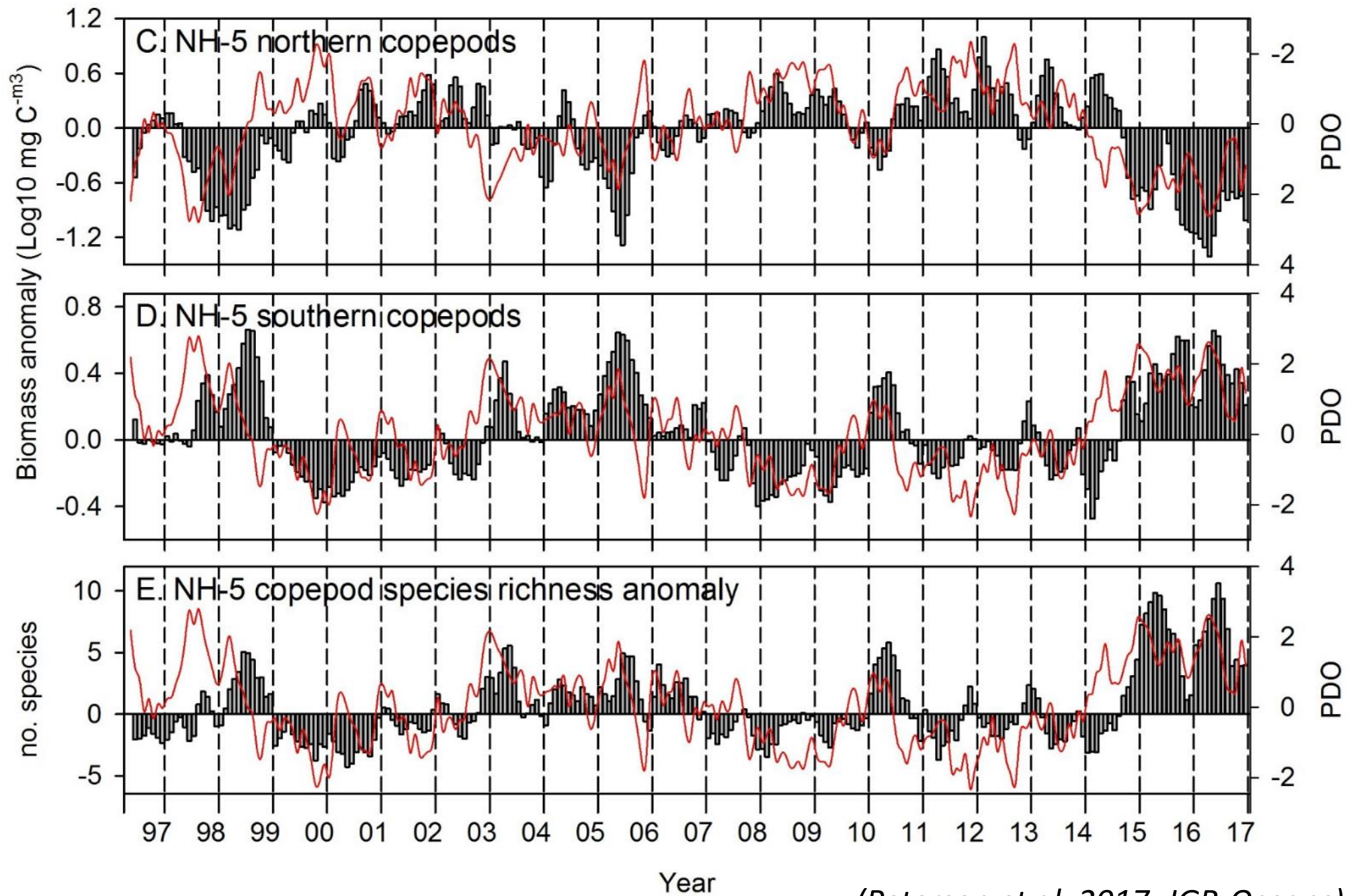
Essential Ocean Variables (EOVs) for Biology and Ecosystem



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

(Miloslavich et al. 2018, GCB)

Newport, Oregon Hydro- graphic Line



(Peterson et al. 2017, JGR-Oceans)

FAIR Data Services

Findable, Accessible, Interoperable, Reusable

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

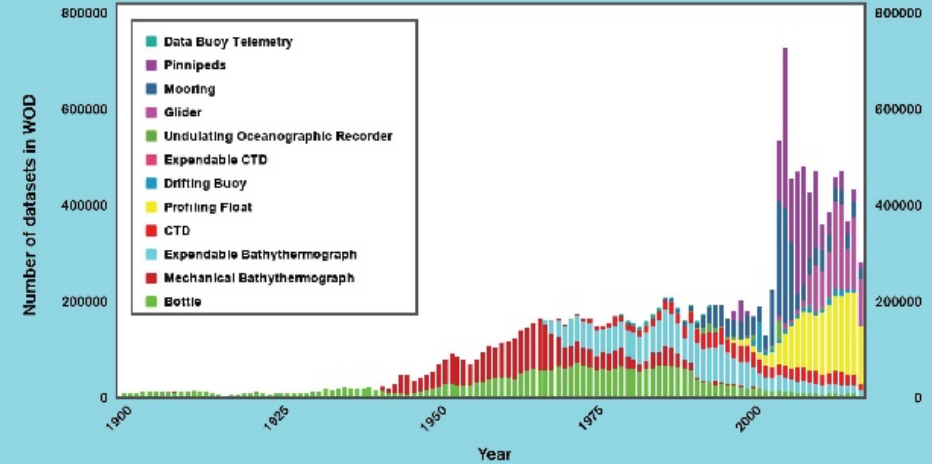
Ocean Best Practices

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.)

Data flows to WOD



Recommendations for the Data System

The integrated data system

Not a new system !

- Enhance Network Data Systems
- Integrate existing data systems
- Enhance systems to ingest and deliver more in-situ data
- Enhance services to serve users better in a harmonized way
- Upgrade existing integrators to serve networks and users better

Minimum set of agreed recommendations

A data exchange backbone to ease discovery, viewing and downloading by users

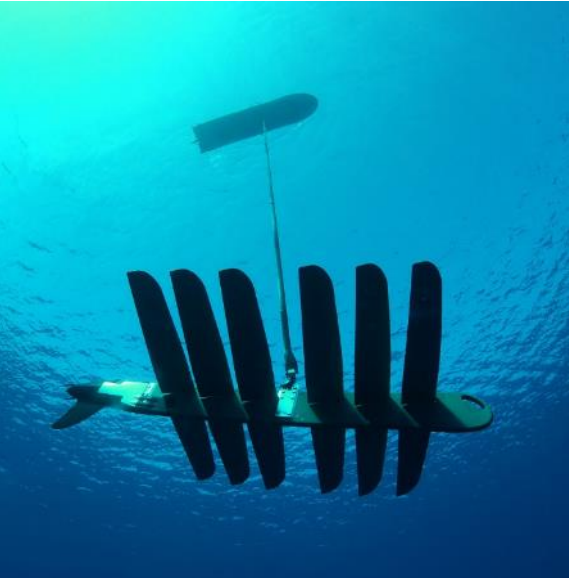
Autonomous drifters and surface vehicles



CODE and WOCE surface Drifters



Saildrone



Wave glider – Liquid Robotics



Sea Hunter - Vigor



This one goes underwater too!

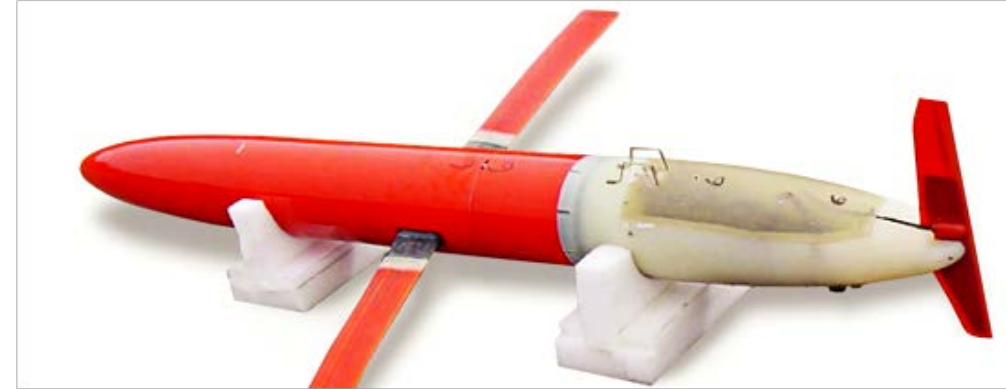
Submaran S10 – Ocean Aero

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

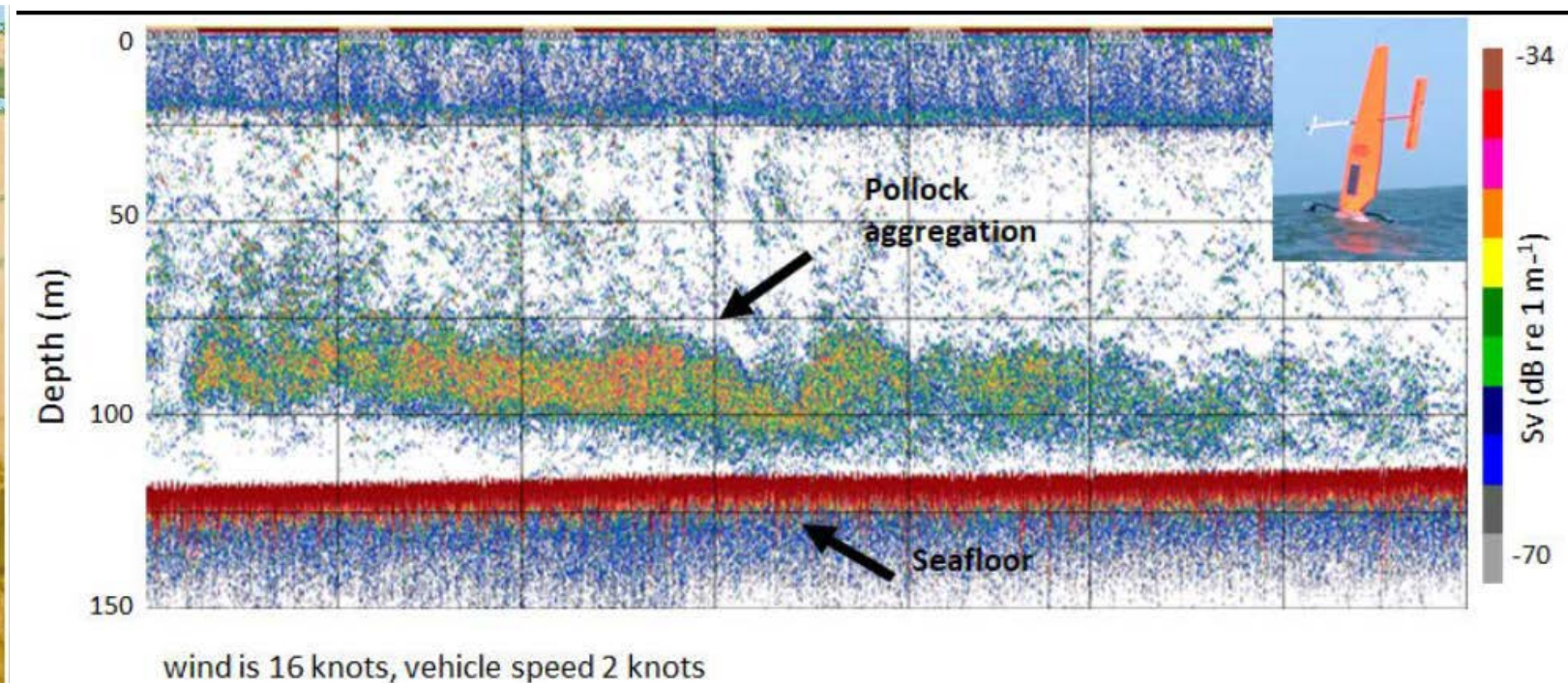
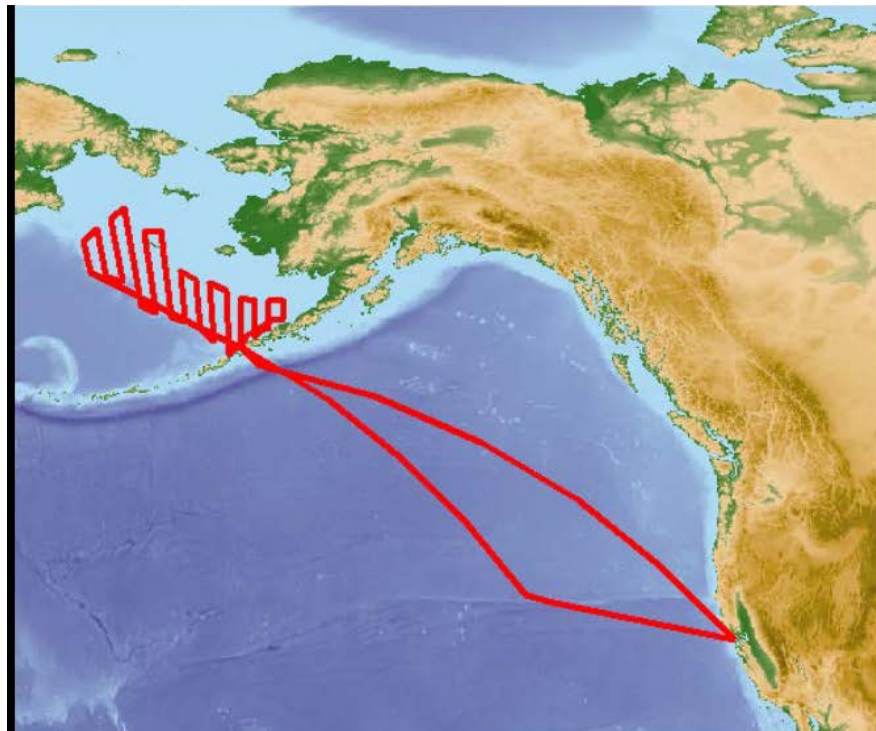


2020 Sailability Pollock Acoustic Survey

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

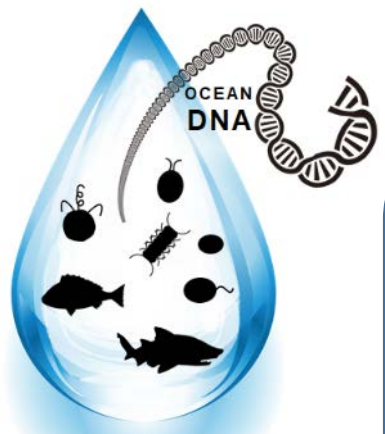
(Contact Alex De Robertis, NOAA AFSC, for details – via Lisa Eisner, PICES MONITOR)

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)

さらなる展開へ：自動化技術の開発と実用化・展開

Autoanalyzer on deck

Continuous analyzer

Continuous analyzer

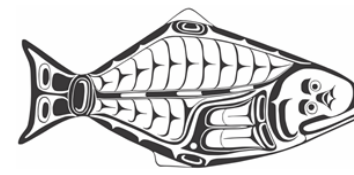
Time-series buoy

AUVs

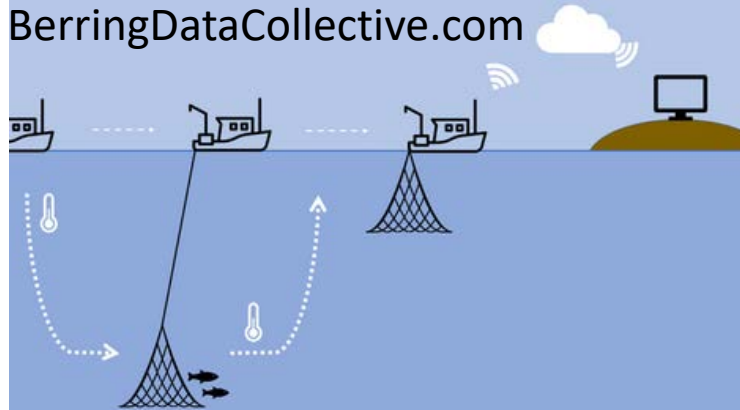
生物遺伝子情報の遠隔・高速通信とAIによる解析
→赤潮藻類や外来生物由来遺伝子検出
→海洋資源、生態系の監視、アラートシステム

文部科学省海洋情報把握技術開発プログラム
「海洋生物遺伝子情報の自動取得に向けた基盤技術の開発と実用化」
(研究代表者：東京大学大気海洋研究所・濱崎恒二)

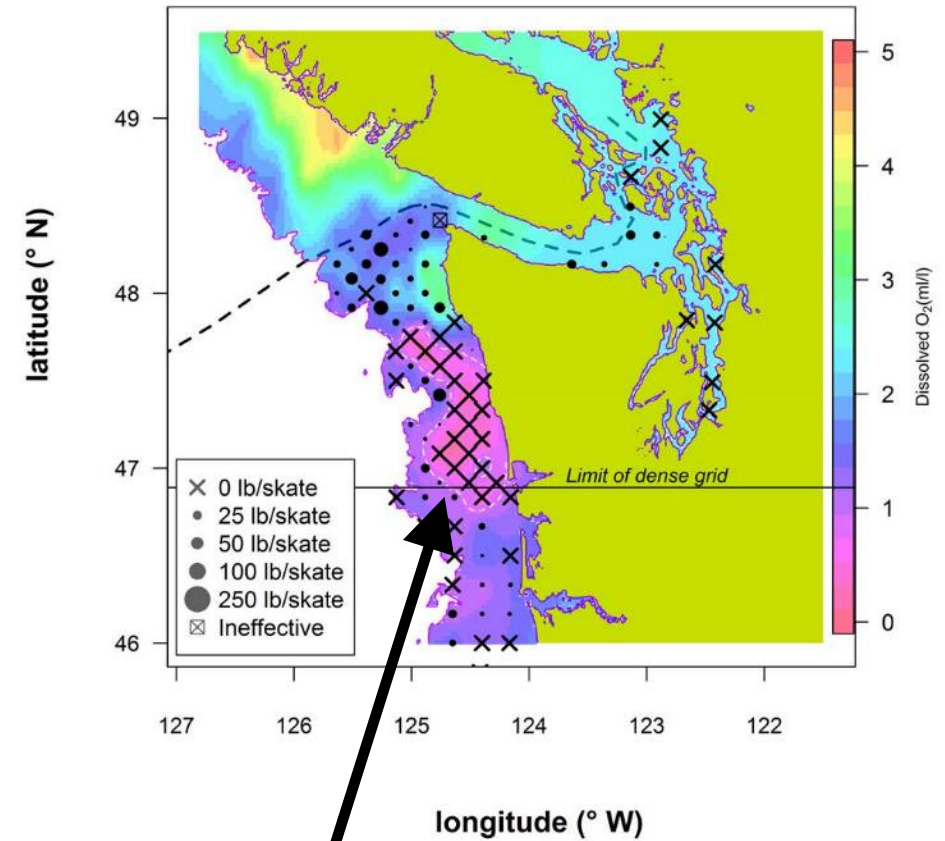
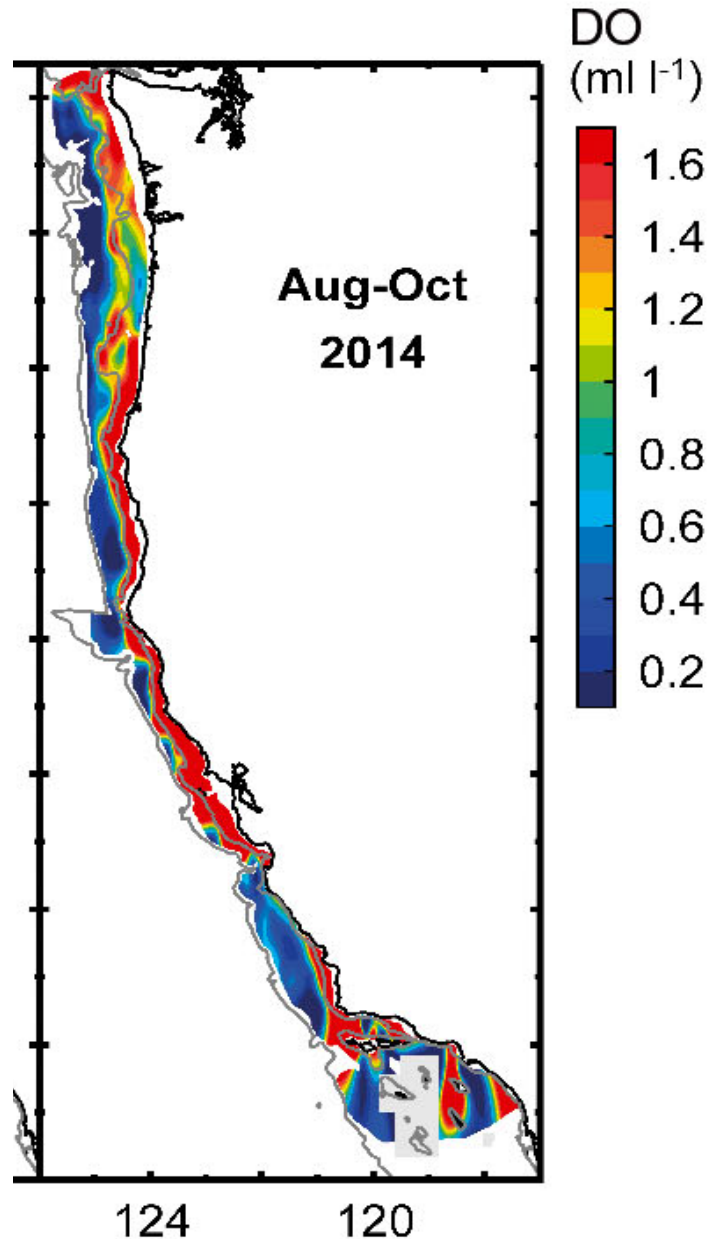
Instrumenting fishing vessels



INTERNATIONAL PACIFIC
HALIBUT COMMISSION



(Keller et al. 2017, MEPS)



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

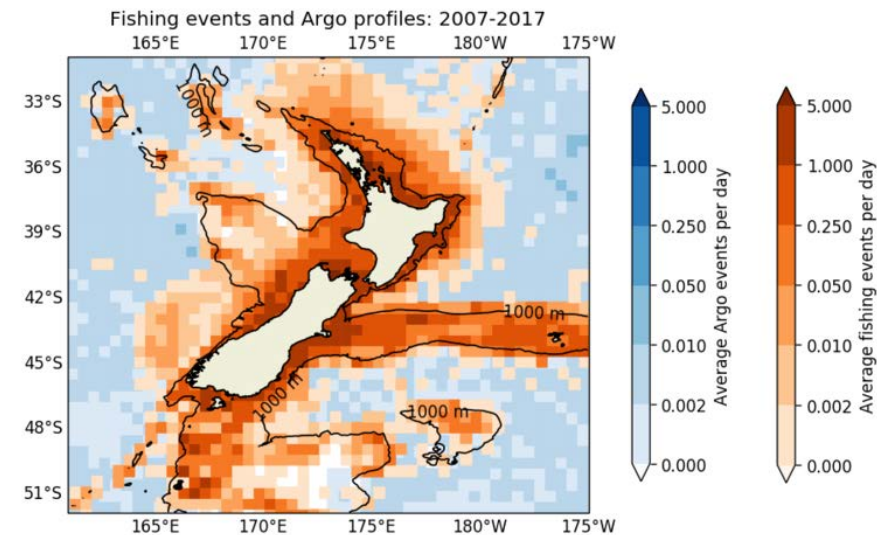
Available to many ocean observers
(equity)



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



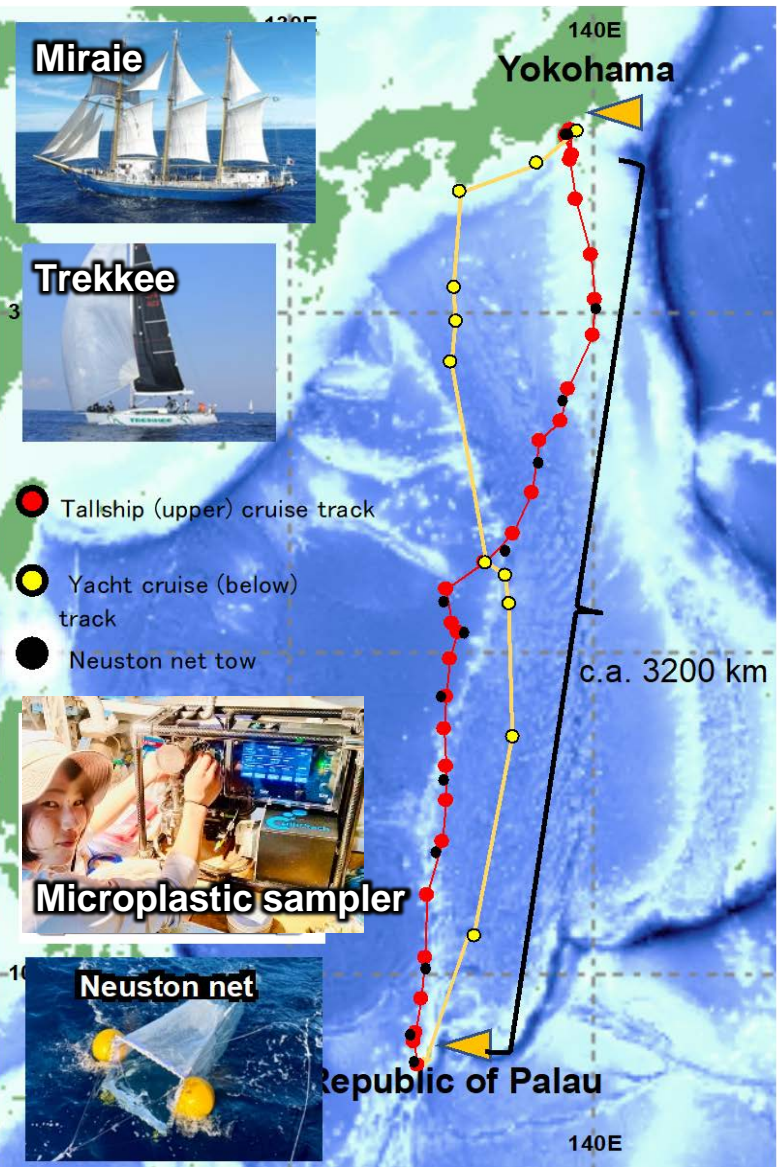
Onset Tidbit, salinity
<https://www.onsetcomp.com/>



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

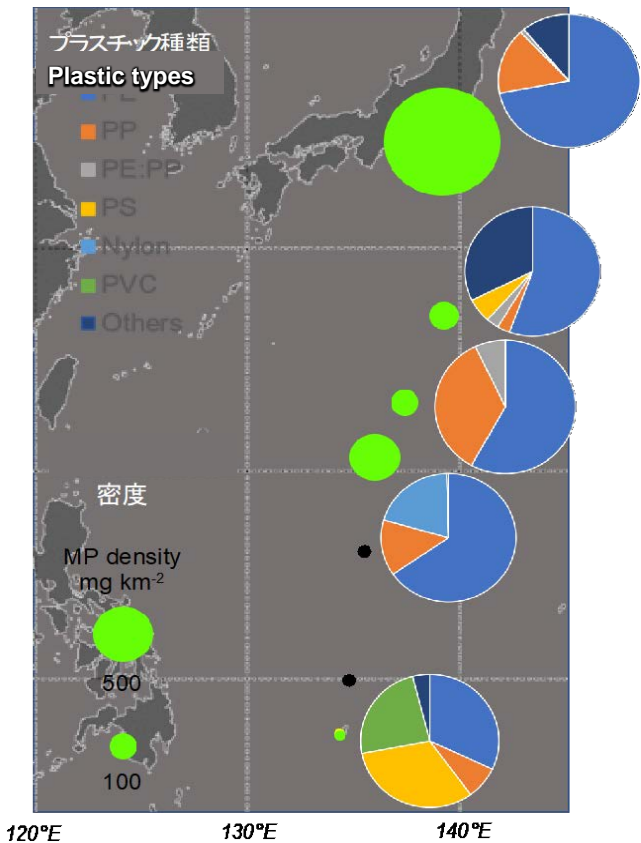


Microplastic survey & promotion of ocean literacy in collaboration with sailing community



Microplastic Survey

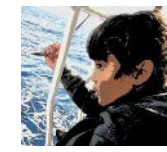
The survey was conducted during the Japan-Palau Goodwill Yacht Race (Dec 2019 – Jan 2020) in collaboration with the Republic of Palau, Japanese government, the yacht race organizer, UNEP-WCMC and private sectors.



Ocean Literacy Program on the Tall ship MIRAIE

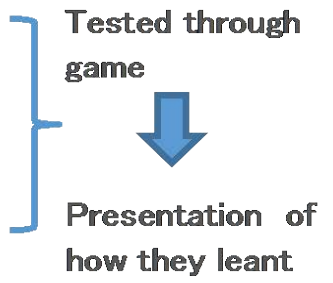


Palau youth



Lecture series
Learning how to survey marine plastics

Mini independent project



Daily report on SNS media



Lecture on the ship deck

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

PICES Ocean Observing and data access

MONITOR

CPR Survey

TCODE

AP-NPCOOS

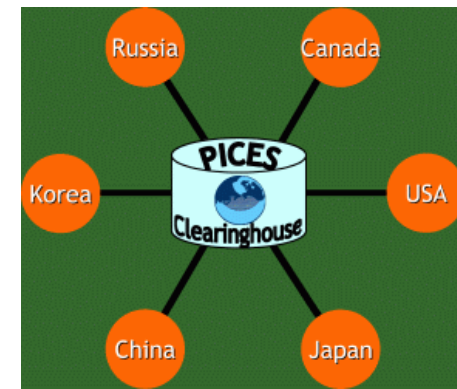
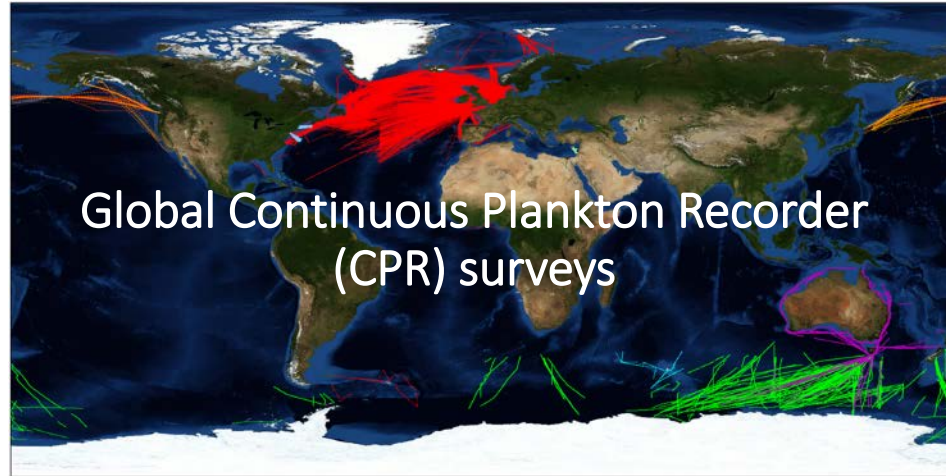
FishGIS - Building capacity for coastal monitoring
by local small-scale fishers

NPESR

PICES Metadata Federation

POMA - PICES Ocean Monitoring Service Award winners

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



PICES SPECIAL PUBLICATION 4
Marine Ecosystems of the
North Pacific Ocean 2003-2008



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



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for Sustainable Development

