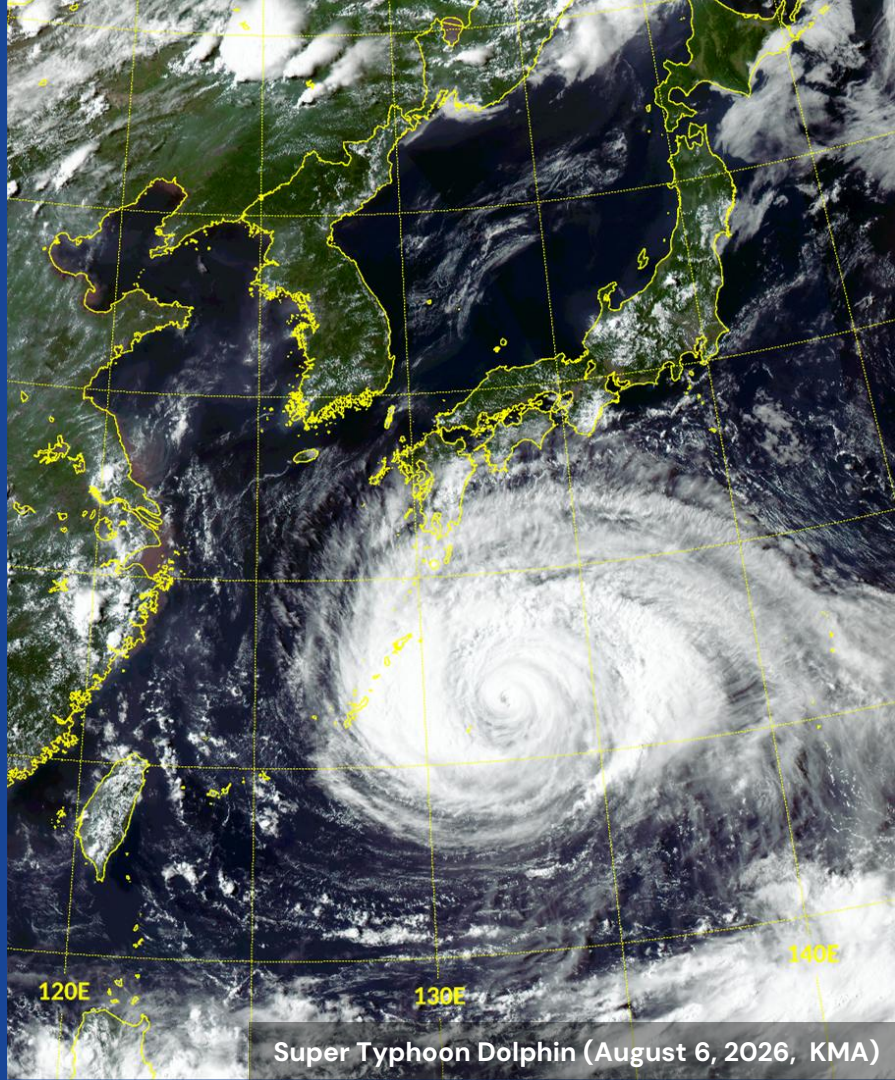
Ocean Observing Co-Design
by The Global Ocean Observing System

Co-Designing Ocean Observing Systems for Improving Tropical Cyclone Forecasts and Warnings

Cheyenne Stienbarger, NOAA Global Ocean Monitoring and Observing Program

Exemplar Steering Team:
Scott Glenn, Travis Miles, Hyun-Sook Kim, Matthieu Le Hènaff, Lev Looney, Hyoun-Woo Kang, Sok Kuh Kang, Kosuke Ito, Shoude Guan, I-I Lin, Bipendra Prakash, Pattabhi Rama Rao, Rémi Laxenaire



Super Typhoon Dolphin (August 6, 2026, KMA)

“Ocean Observing Co-Design will develop a more user-focused co-design process to create a truly integrated, responsive ocean observing system.

Ocean Observing Co-Design

by The Global Ocean Observing System

1.

— Provide national government funders the **information needed to target investment globally, regionally and locally**.

2.

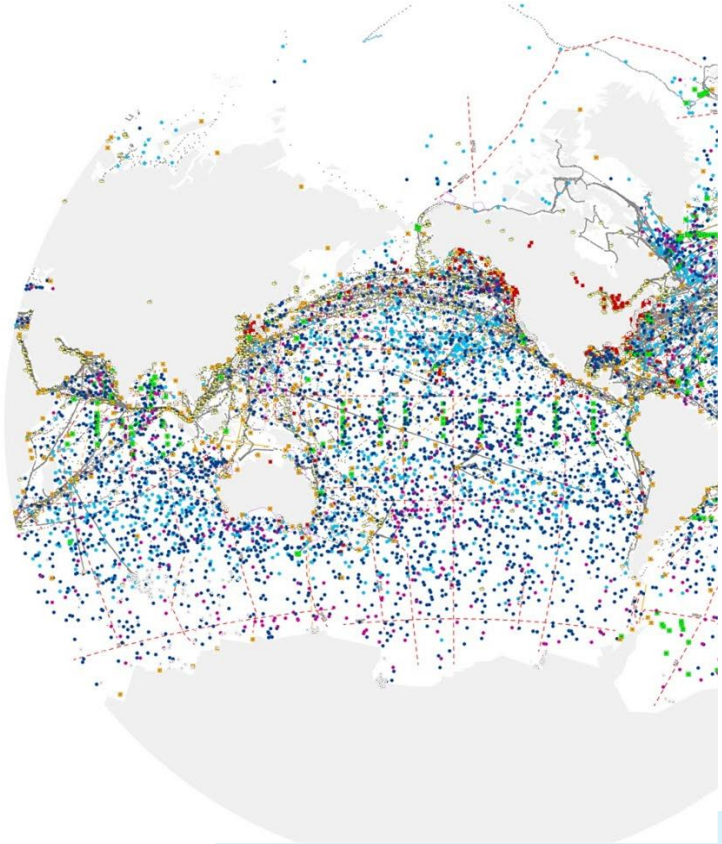
— Make ocean observing and forecasting outputs more **accessible and impactful for end-users**.

3.

— **Develop system diagnostics, tools and reporting capability** to better assess fitness-for-purpose across evolving requirements and use-inspired needs.

4.

— Establish international **capacity and infrastructure to co-design and regularly evaluate the observing system** at different scales.



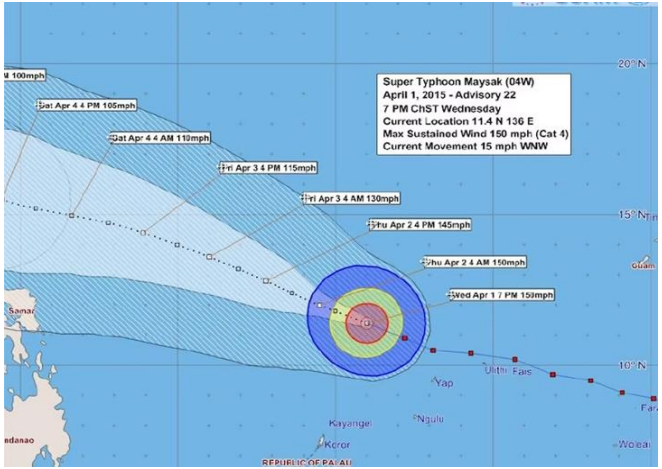
Ocean Observing Co-Design

by The Global Ocean Observing System

Tropical cyclones are among the most destructive natural disasters

Regions face economic damage and numerous deaths from tropical cyclones; equivalent to **$78 million in damages & 43 deaths every day**[1]

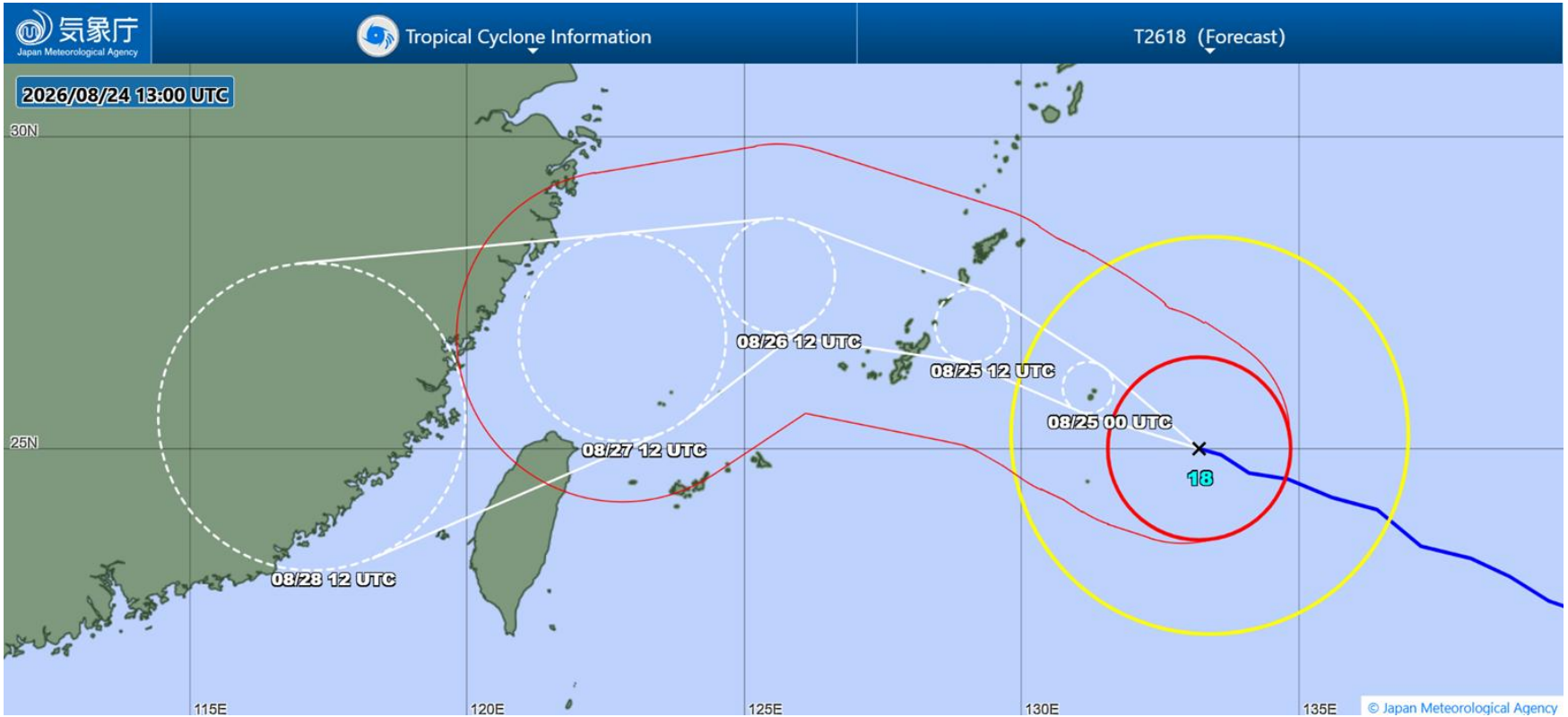
- **$1.4 trillion** — the staggering cost of tropical cyclones over the past 50 years
- Impacts felt **disproportionally**, especially across vulnerable populations
- **Countries need increased capacity for accurate forecasts and timely warnings**




Typhoon Maysak (2020, ABC)

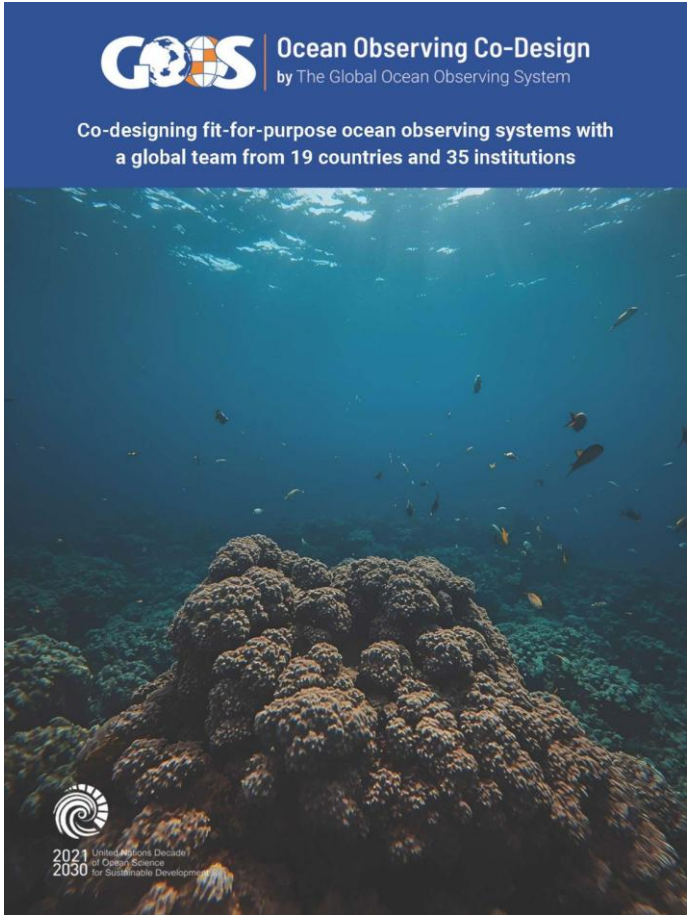
[1] World Meteorological Organization

Currently: Typhoon Saudel



Tropical Cyclone Exemplar Goals

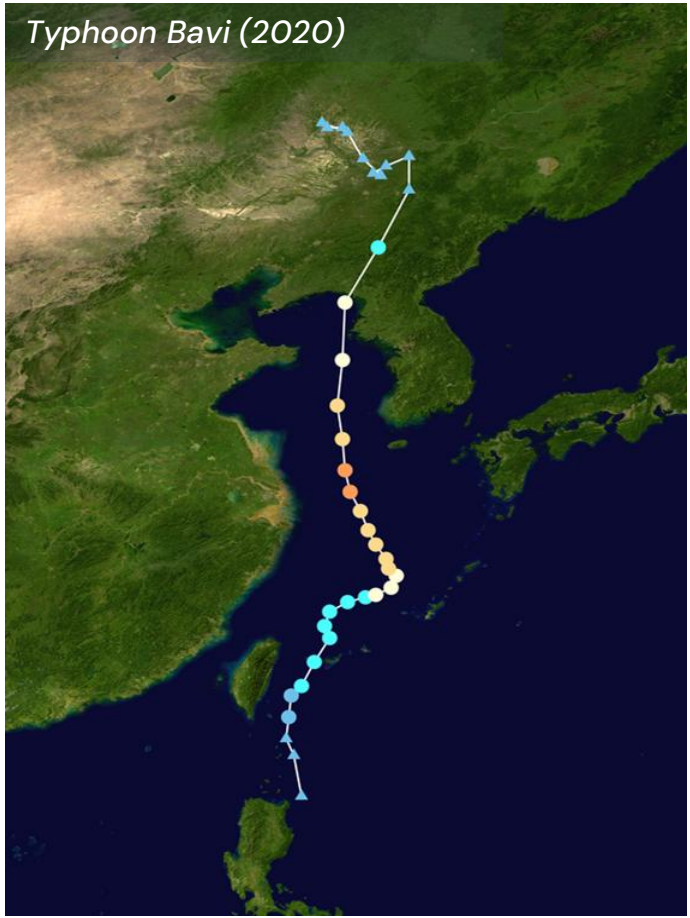
1. **Co-designed**, regionally distributed ocean observing **pilot studies** - *to develop collaborative capacity and demonstrate mutual value*



Tropical Cyclone Exemplar Goals

1. **Co-designed**, regionally distributed ocean observing **pilot studies** - *to develop collaborative capacity and demonstrate mutual value*

2. **Increased coverage and delivery** of ocean data to forecasting centers and scientists - *to expand critical observations across international borders*

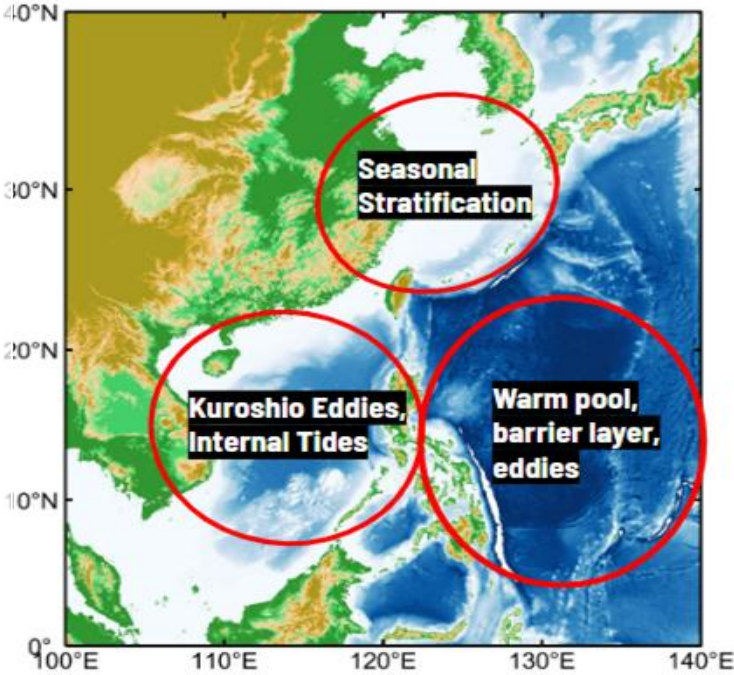


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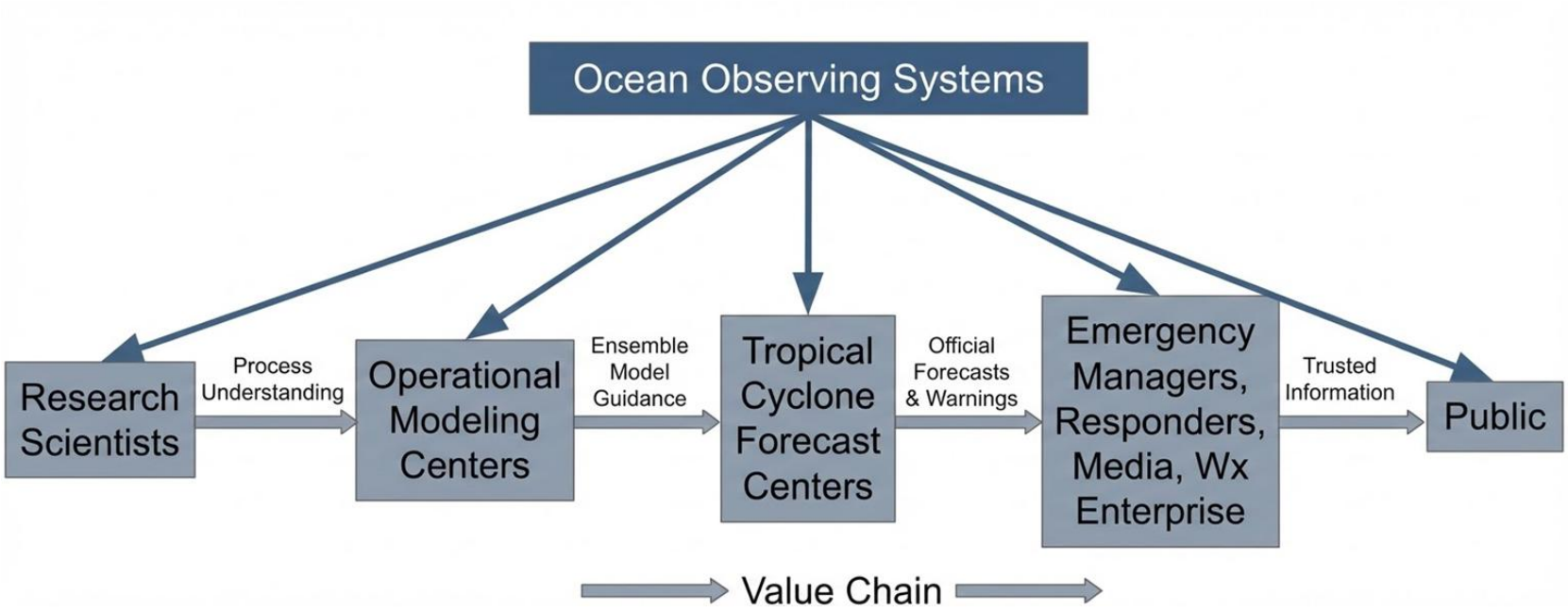
2. **Increased coverage and delivery** of ocean data to forecasting centers and scientists - *to expand critical observations across international borders*

3. **More accurate characterization & understanding** of essential ocean features & air-sea processes - *to improve Earth System Models & tropical cyclone forecasts*



Credit: Dr. Shoude Guan

Connecting stakeholders along the value chain – regionally & globally



Phase I: Engagement & Design

At the inception of the program in June 2022, we hosted an **open community meeting** and asked global experts to share their **capabilities, challenges, and pressing needs for TC-ocean observing**.

Phase I: Engagement & Design



Ms. Cheyenne Stienbarger, co-chair
NOAA Global Ocean Monitoring & Observing Program



Dr. Scott Glenn, co-chair
Rutgers University

A **steering team** was created to guide the pilot region activities, **promote regional leadership**, and **share regional lessons learned globally**.

Phase I: Engagement & Design



Dr. Hyoun-Woo Kang
KIOST (Korea Institute of Ocean Science & Technology)



Dr. Lev Looney
NOAA Atlantic Oceanographic & Meteorological Laboratory



Dr. I-I Lin
National Taiwan University

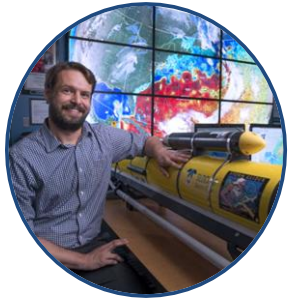


Dr. Kosuke Ito
Kyoto University

Phase I: Engagement & Design



Dr. Hyun-Sook Kim
NOAA Atlantic Oceanographic & Meteorological Laboratory



Dr. Travis Miles
Rutgers University

Dr. Shoude Guan
Ocean University of China



Dr. Sok Kuh Kang
Seoul National University

Phase I: Engagement & Design



Dr. Matthieu Le Hènaff
NOAA Atlantic Oceanographic & Meteorological Laboratory



Mr. Pattabhi Rama Rao
INCOIS (Indian National Centre for Ocean Information Services)

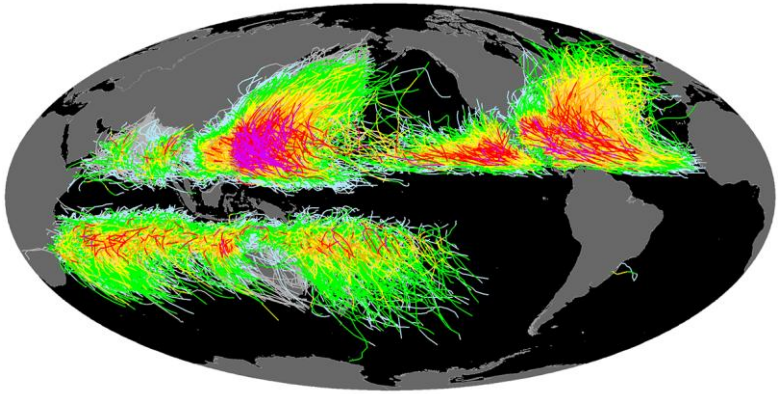


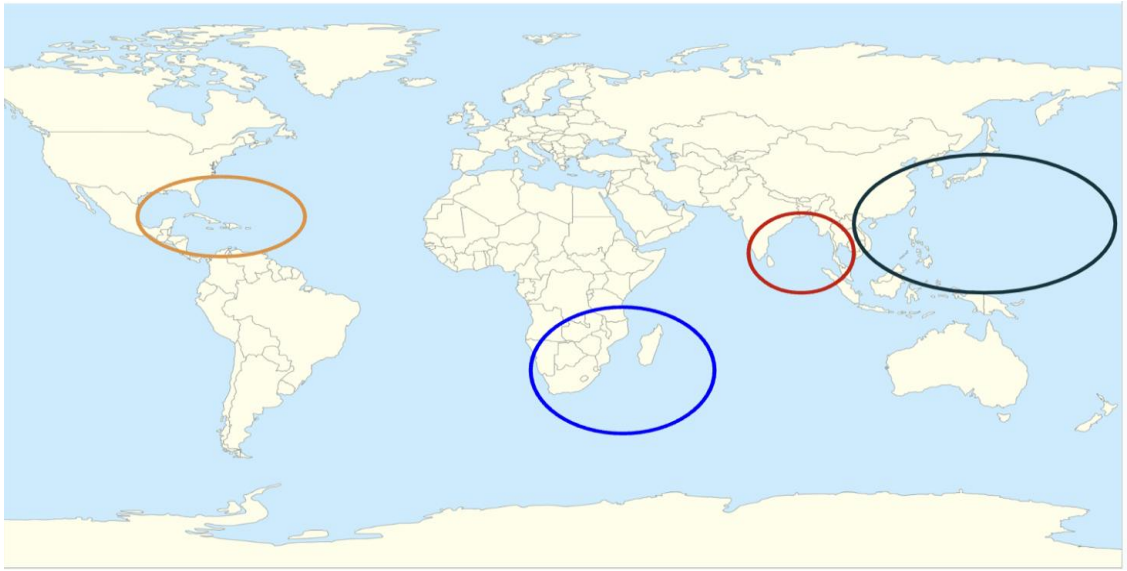
Mr. Bipendra Prakash
The Pacific Community
PI-GOOS



Dr. Rémi Laxenaire
LACy - Laboratoire de l'Atmosphère et des Cyclones (Chercheur Météo-France, Reunion Island)

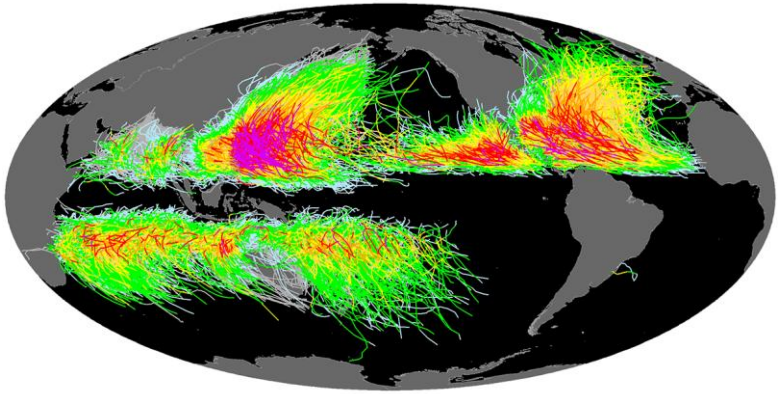
Phase I: Engagement & Design





Each pilot area has **different regional needs** for ocean observing, **different capacities for implementation**, and **significant contributions to the global program**.

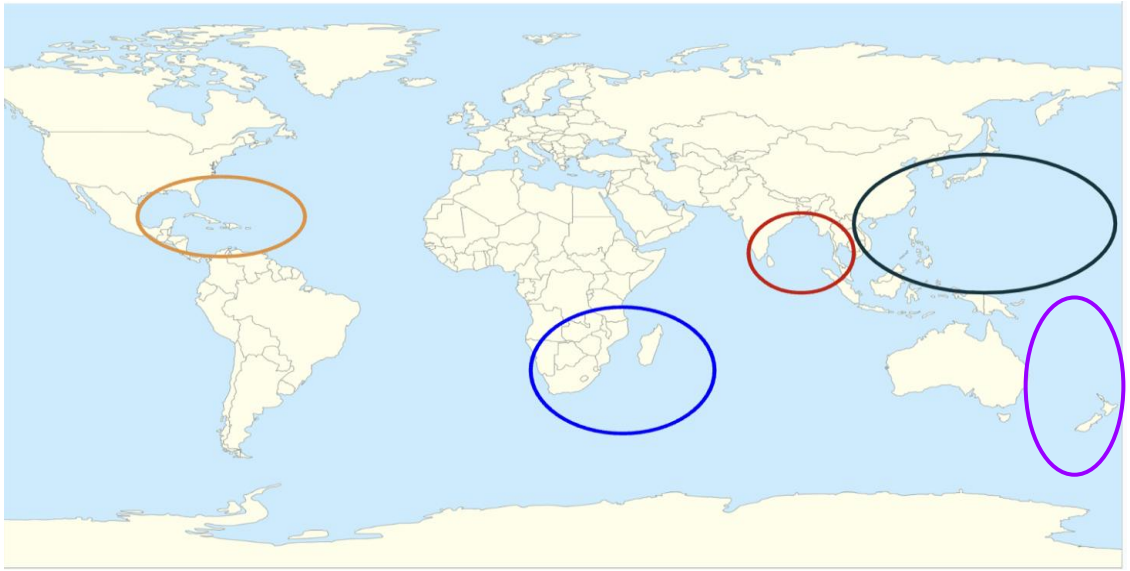
Phase I: Engagement & Design



The International Best Track Archive for Climate Stewardship (IBTrACS) stores global tropical cyclone information.

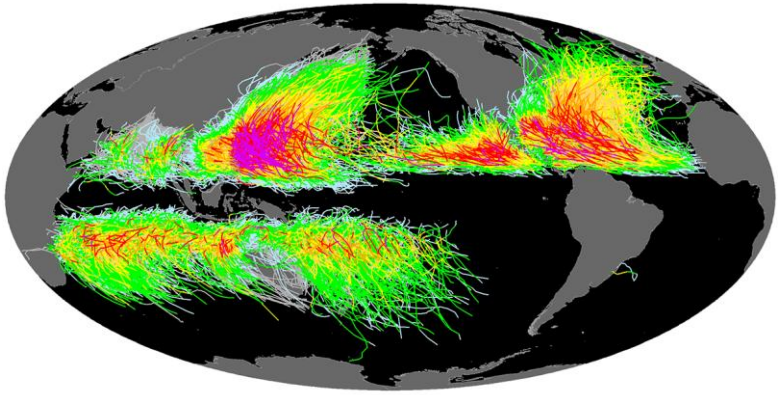
Saffir-Simpson Hurricane Wind Scale

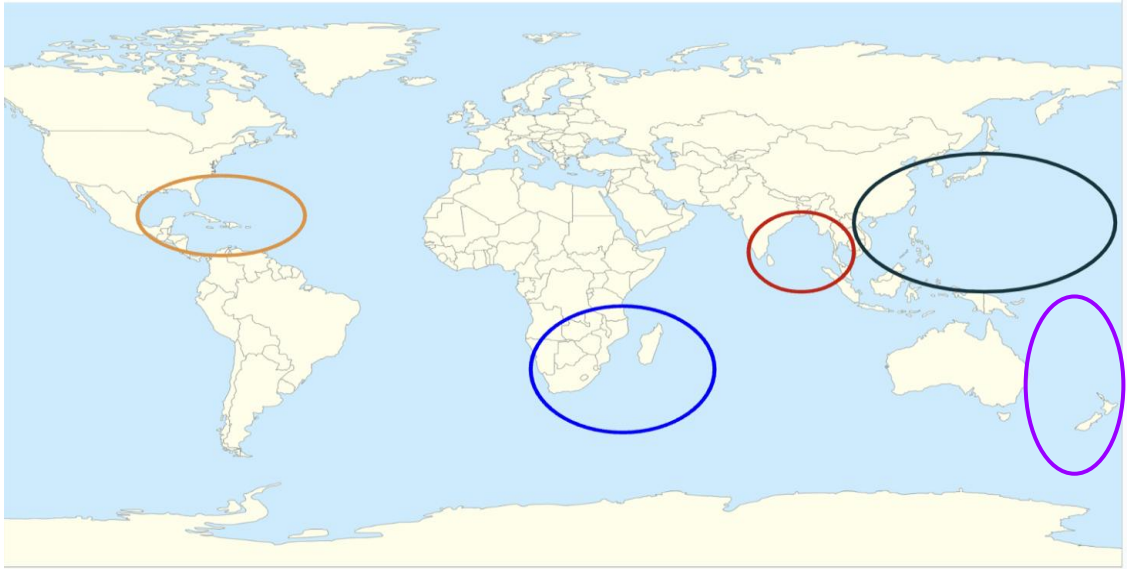
Intensity Missing	Category 1
Tropical Depression	Category 2
Tropical Storm	Category 3
	Category 4
	Category 5



Each pilot area has **different regional needs** for ocean observing, **different capacities for implementation**, and **significant contributions to the global program**.

Phase I: Engagement & Design





Key Outcomes: Refined regional priorities and confirmed key stakeholders along the value chain to ensure pilot activities respond to operational requirements.

Phase II: Regional Pilot Activities

Tropical Americas & Caribbean

- Collaborating with **regional leaders** (e.g., Caribbean Institute for Meteorology & Hydrology) to:
  - Establish glider deployment port in Barbados
  - Advance international partnerships in the context of expanding EEZ permissions for uncrewed systems



Regional Leads: USA (NOAA, Rutgers), Barbados (CIMH), IOCARIBE-GOOS

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  - First glider deployment out of Barbados (2025)
  - Stronger connection to IOCARIBE
  - Increased technical capacity
  - Student engagement and public awareness



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- CIMH is now pursuing investment funds to **procure and deploy their own gliders** and **expand their observational footprint** in the region

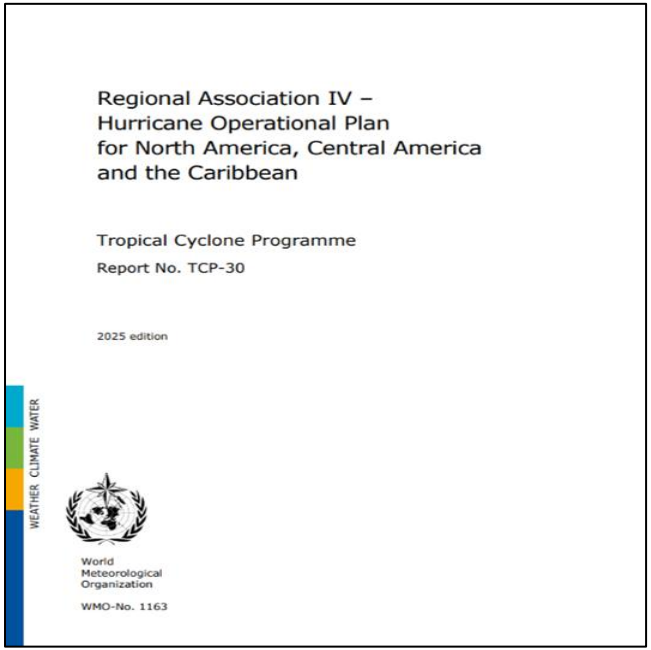


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Phase II: Regional Pilot Activities

Tropical Americas & Caribbean

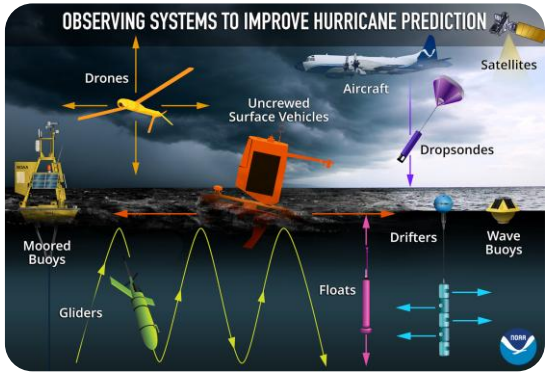
- Building and enhancing regional connections via **IOCARIBE-GOOS** and **WMO RA-IV Hurricane Committee**
  - Promote coordination and collaboration within and across member states and platforms
  - Inform operational requirements
  - Major success: advocate for the formal recognition of ocean observations in the WMO RA-IV Hurricane Operations Plan

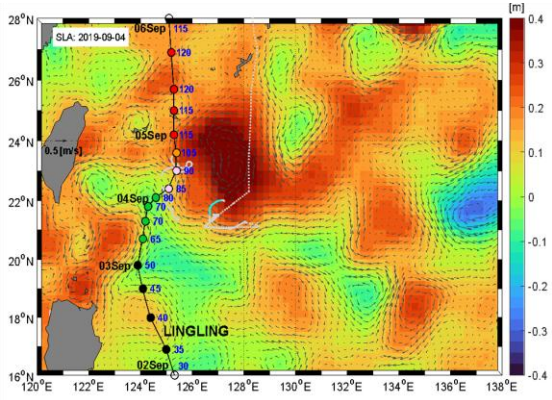


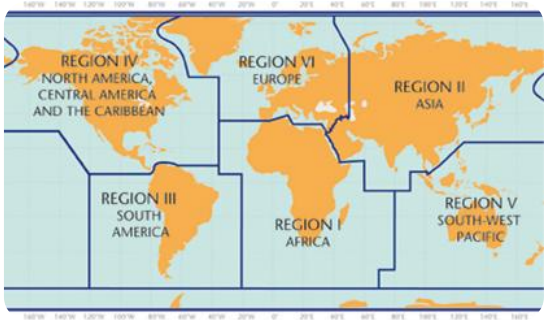
Regional Leads: USA (NOAA)

Phase II: Regional Pilot Activities

North Pacific Ocean and Marginal Seas (NPOMS)







Air-sea Interactions

Prioritize research focusing on air-sea interactions, observational campaigns, uncrewed systems, etc. for rapidly intensifying typhoons

Regional Leadership

Encourage continued national support, investment, and leadership
across the region

Stakeholder Connectivity

Advance connectivity with operational centers (e.g., KMA, RSMC Tokyo)

Regional Leads: Korea (KIOST, KMA), Japan (JMA, Kyoto University), Taiwan (National Taiwan University), China (Ocean University of China)

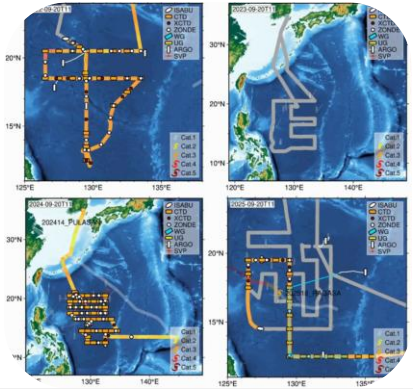
Phase II: Regional Pilot Activities

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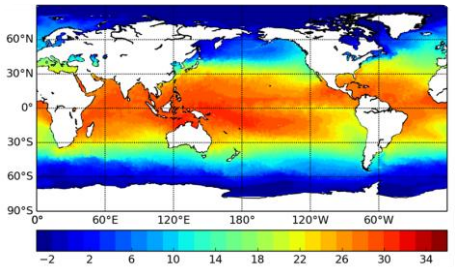
JMA-MRI Campaigns

Intensive observational campaigns to better understand air-sea interactions, enhance marine observations, and introduce new observing instruments.



KIOST Campaigns

TC-ocean field campaigns (2022~2025) utilizing different observing platforms to understand of ocean conditions between pre/post-typhoon.



KMA Data Assimilation

National Institute of Meteorological Sciences will establish an implementation framework for developing ocean glider data assimilation techniques.

Regional Leads: Korea (KIOST, KMA), Japan (JMA, Kyoto University), Taiwan (National Taiwan University), China (Ocean University of China)

Phase II: Regional Pilot Activities

Observing Technologies & Strategies

- Cost-effective, autonomous systems and advanced uncrewed platforms (USVs, gliders) pre-deployed in areas of interest
- Adaptive sampling strategies to better capture TCs & upper-ocean responses
- Higher sampling rates under extreme TC/high-wind conditions
- Co-located, simultaneous observations spanning the ocean, atmosphere, waves, and sea spray across all TC quadrants

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Addressing Geographic & Parameter Gaps

- Better coverage of coastal regions, marginal seas, and deep ocean
- Direct, in-situ ocean measurements captured directly during typhoon passages
- More mooring locations with expanded parameters (e.g., flow velocity) and enhanced coastal atmospheric observations
- Sustained measurements of salinity, oxygen, carbon

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Unlocking Restricted Data & Customizing Products

- Access to restricted institutional campaign datasets (e.g., establish more collaboration frameworks, agreements)
- Access to various commercial and maritime industry datasets
- Tailored, user-friendly data products designed specifically for operational end-users

Phase II: Regional Pilot Activities

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Compute, Infrastructure, & Collaboration

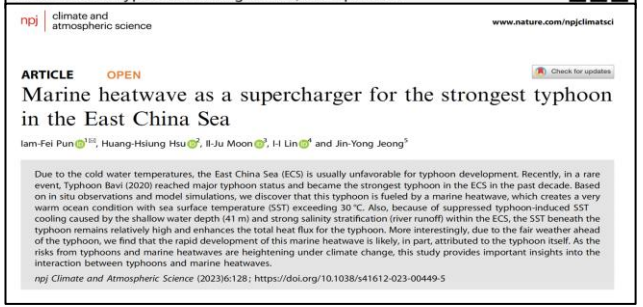
- Address high-performance computing needs to run advanced numerical models and data assimilation
- Dedicated financing for co-design organizational work
- Funding for technical support personnel and platform procurement
- Practical resource sharing, including ships of opportunity, observational infrastructure, and researcher exchanges

Phase II: Regional Pilot Activities

North Pacific Ocean and Marginal Seas

- Many typhoons **impact multiple EEZs** and territories
- Increasing interactions between **marine heatwaves and tropical cyclones**
- **Significant national investment** in ocean observing but challenges remain regarding information sharing, stakeholder connectivity, and multi-national coordination
- We had a very productive meeting this morning about advancing the TC Exemplar NPOMS Pilot Activity and look forward to sharing more as this continues to develop!




npj climate and atmospheric science

www.nature.com/npjclimatsci

ARTICLE OPEN

Marine heatwave as a supercharger for the strongest typhoon in the East China Sea

Iam-Fei Pun[1✉], Huang-Hsiung Hsu[2], Il-Ju Moon[3], I-I Lin[4] and Jin-Yong Jeong[5]

Due to the cold water temperatures, the East China Sea (ECS) is usually unfavorable for typhoon development. Recently, in a rare event, Typhoon Bavi (2020) reached major typhoon status and became the strongest typhoon in the ECS in the past decade. Based on in situ observations and model simulations, we discover that this typhoon is fueled by a marine heatwave, which creates a very warm ocean condition with sea surface temperature (SST) exceeding 30 °C. Also, because of suppressed typhoon-induced SST cooling caused by the shallow water depth (41 m) and strong salinity stratification (river runoff) within the ECS, the SST beneath the typhoon remains relatively high and enhances the total heat flux for the typhoon. More interestingly, due to the fair weather ahead of the typhoon, we find that the rapid development of this marine heatwave is likely, in part, attributed to the typhoon itself. As the risks from typhoons and marine heatwaves are heightening under climate change, this study provides important insights into the interaction between typhoons and marine heatwaves.

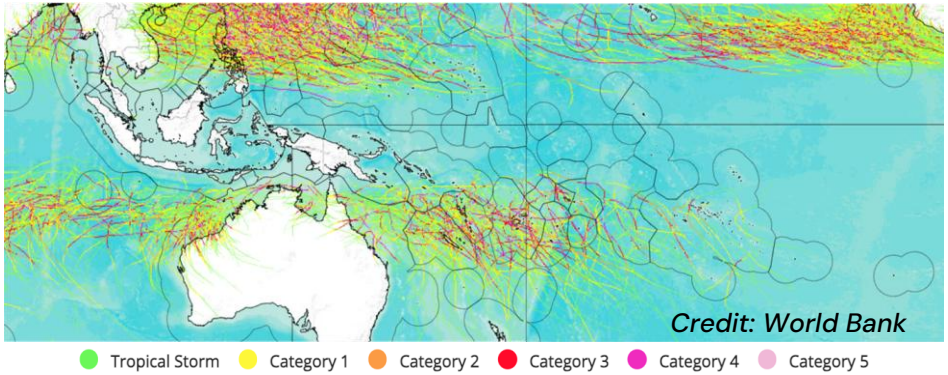
npj Climate and Atmospheric Science (2023)6:128 ; https://doi.org/10.1038/s41612-023-00449-5

Regional Leads: Korea (KIOST, KMA), Japan (JMA, Kyoto University), Taiwan (National Taiwan University), China (Ocean University of China)

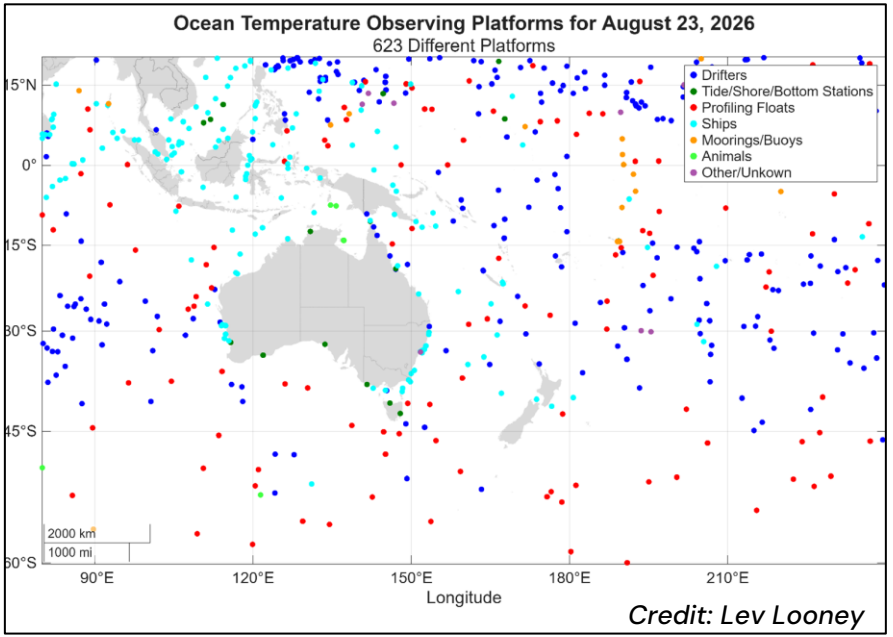
Phase II: Regional Pilot Activities

South Pacific Islands

TC Tracks (1980 – 2023) with EEZ Boundaries



"Pacific island tropical cyclones are more frequent and globally relevant, yet less studied" (Marler, 2014)

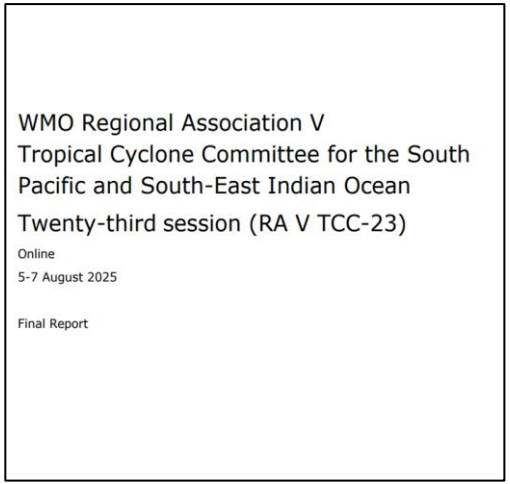


Regional Lead: The Pacific Community (SPC)

Phase II: Regional Pilot Activities

South Pacific Islands

- Invited to attend **WMO Tropical Cyclone Committee (RA-V) and co-present with PI-GOOS**
  - Proposed options for TC Exemplar pilot activities and formally requested input from the Committee
  - Returned to the Committee in 2026 to further engage national representatives (forecasters) about potential ocean observing requirements


WMO Regional Association V
Tropical Cyclone Committee for the South Pacific and South-East Indian Ocean

Twenty-third session (RA V TCC-23)

Online

5-7 August 2025

Final Report

Regional Lead: The Pacific Community (SPC)

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  - Returned to the Committee in 2026 to further engage national representatives (forecasters) about potential ocean observing requirements
- **PI-GOOS identified FVON (Fishing Vessel Observing Network) as a priority collaboration**
  - Utilizing existing observations that are relevant to the South Pacific
  - Working together to trace impact of FVON data on ocean models and co-design new products to maximize these observations



Regional Lead: The Pacific Community (SPC)

Phase III: Implementation

Scaling Co-Design & Regional Cooperation

01 Value Chain Connection

Connecting stakeholders along the value chain, from research scientists to operational end-users (e.g., forecasters).

02 GOOS Landscape & Regional Alliances

Working across the GOOS landscape with regional alliances and networks.

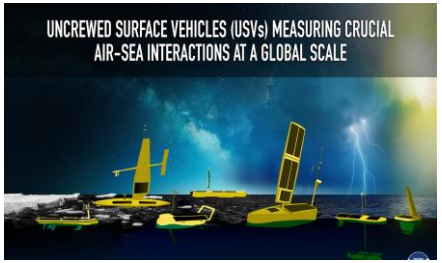
03 WMO Collaboration

Fostering significant collaboration across multiple regions to inform observing network requirements (e.g., RBON) and align observing efforts with forecasting needs.









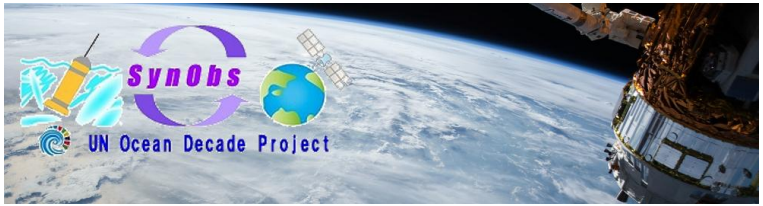
Next Steps

- Bolster **regional leadership** to advance pilot region activities
- **Incorporate feedback** from recent surveys (e.g., NPOMS, Pacific Islands) to address observing gaps, value chain gaps, etc.
- Continue to **enhance partnerships and stakeholder connectivity** by ensuring end-users have access to and are able to **utilize available ocean data**
- Continue **advancing ocean observing requirements** with the WMO
- More formally **document the co-design process** region-by-region and **share lessons learned globally**

Thank You

Meteorological Research Institute
Japan Meteorological Agency

Ocean Observing Co-Design
by The Global Ocean Observing System



NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

KIOST
KOREA INSTITUTE OF
OCEAN SCIENCE & TECHNOLOGY

KUSCO
KOREA - U.S. SCIENCE COOPERATION CENTER

National Institute of
Meteorological Sciences

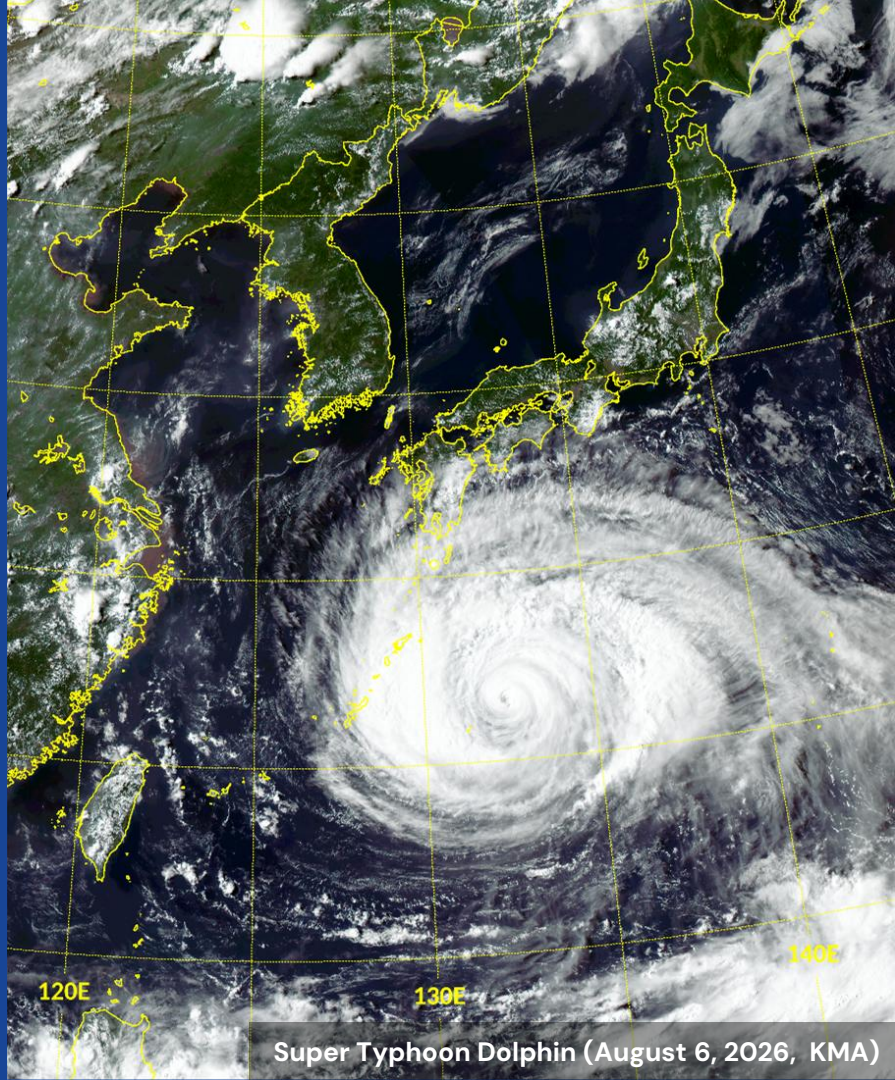
Ocean Observing Co-Design
by The Global Ocean Observing System

THANK YOU!

CONTACT:

cheyenne.stienbarger@noaa.gov
glenn@marine.rutgers.edu

2021 2030 United Nations Decade of Ocean Science for Sustainable Development



Super Typhoon Dolphin (August 6, 2026, KMA)