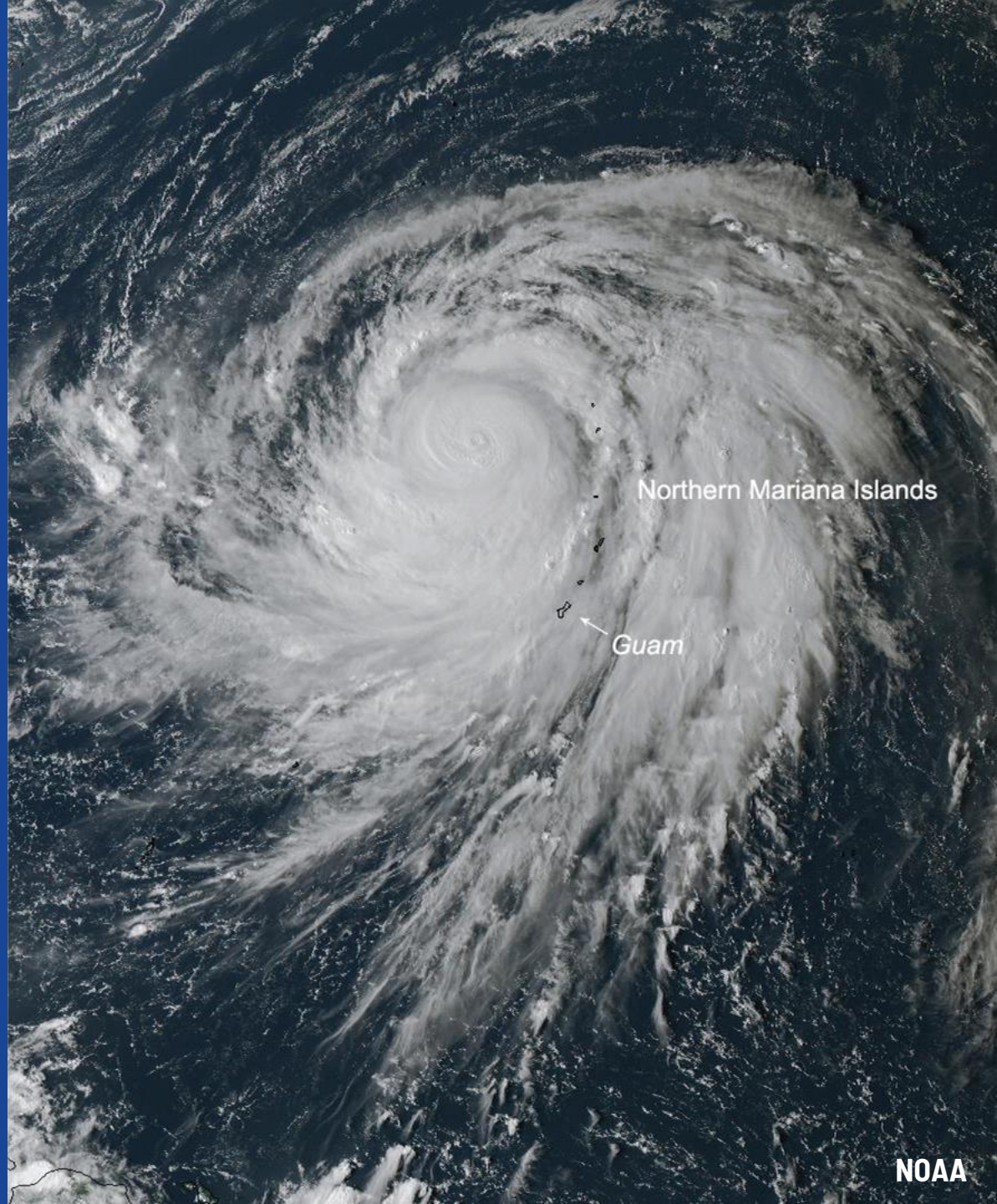
Ocean Observing Co-Design
by The Global Ocean Observing System

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

Presenter: Cheyenne Stienbarger

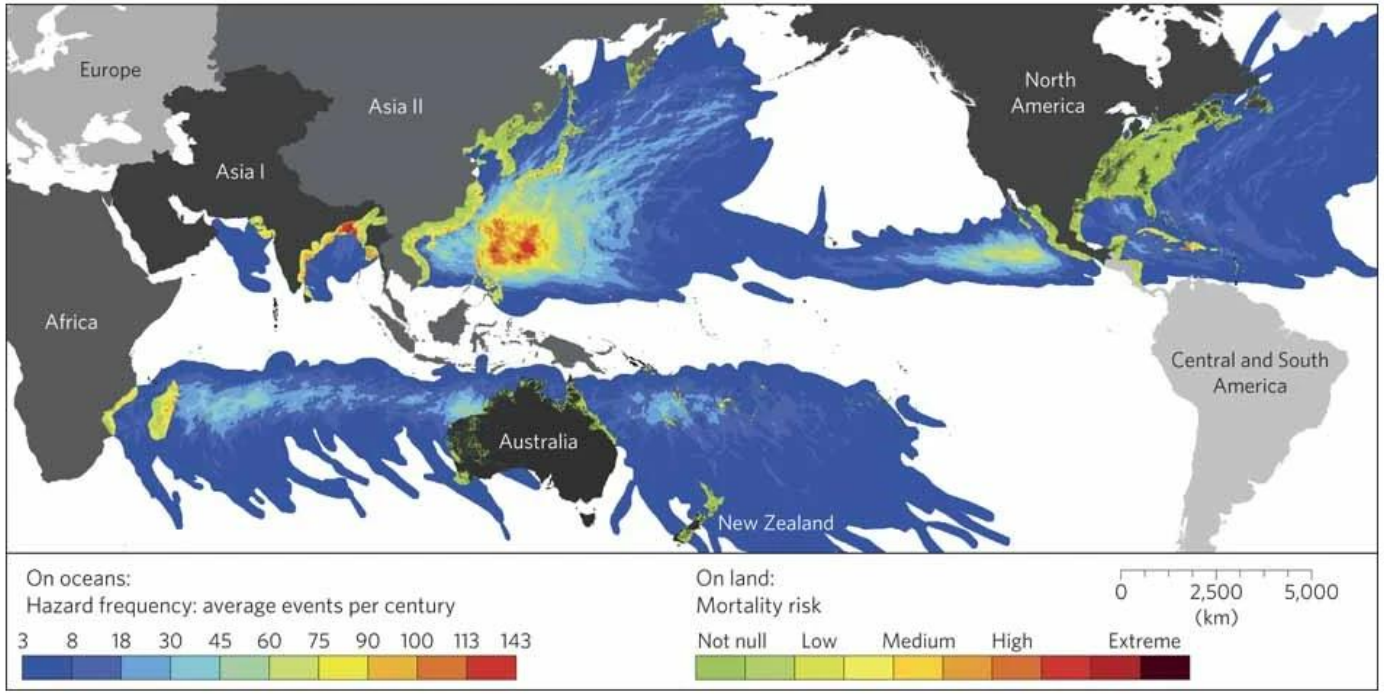
Exemplar Steering Team: Scott Glenn, Gustavo Goni, Sok Kuh Kang, Hyun-Sook Kim, Matthieu Le Henaff, Kosuke Ito, I-I Lin, Travis Miles, Shoude Guan



Motivation

Tropical Cyclones (TCs) are among the most **significant** weather & climate **disasters worldwide**

- Significant deaths, property damage & economic stress, challenge emergency responders and impact coastal ecosystems
- Climate change is expected to increase these negative impacts
- Increasing coastal populations and economic development further exacerbates these impacts
- Disproportionately impact less developed countries and small island developing states



Peduzzi et al. (2012) - Map showing distribution of hazard frequency and mortality risk from TCs for the year 2010.

Growing need for improved Tropical Cyclone forecasts to save lives & property, and to improve equity & resiliency.

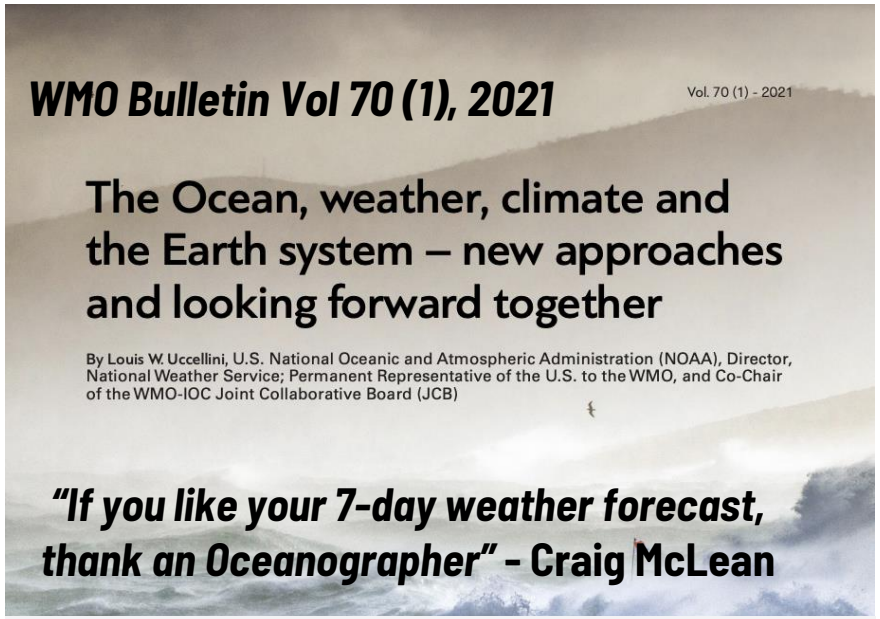
Earth System Modeling (ESM)

Forecasts of storm track, intensity, size, surge, wave height (sea state), & rainfall **require sufficient accuracy and lead time** to be actionable

- **Improved TC forecasts increasingly require an ESM approach** for model guidance, which then requires the observations to support the ESMs

Additional ESM requirements include:

- **Initial conditions** that include the **essential ocean features** and better resolution of the upper ocean that impact TC evolution
- ESMs must properly **represent essential ocean and air-sea interaction features and processes** that can vary rapidly in space and time during intense forcing

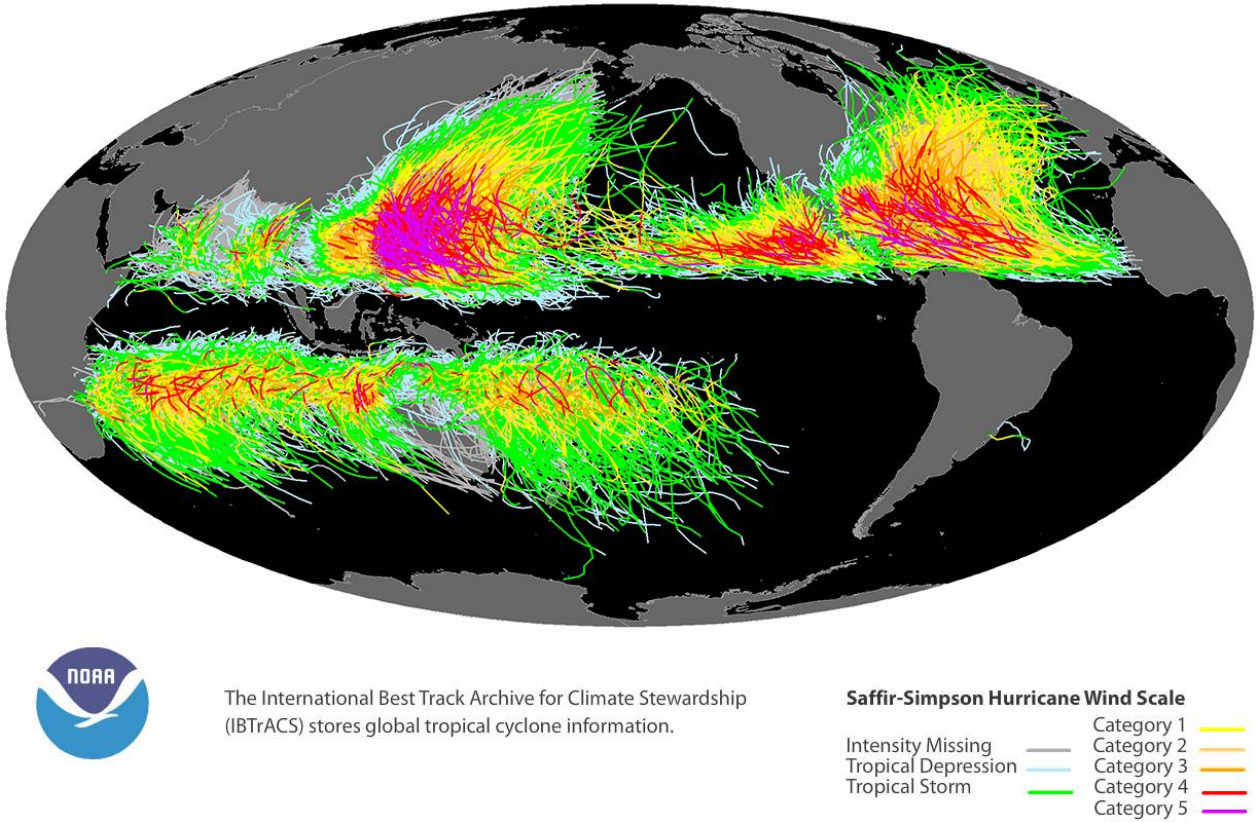


Earth System Model

Ocean Observing Challenges

Satellites provide critical global coverage of surface conditions, but **air-sea & subsurface conditions require in situ observations**

- Near real-time in situ observations assimilated into numerical forecast models are too sparse » **requires new sustained, spatially distributed, and collaborative observation programs**
- The intense forcing experienced during TCs limits observational approaches » **requires robust technologies**
- Some fundamental processes are still not well understood » **requires new scientific observations and research campaigns**



Some observing needs & responses are universal. Others are basin or region dependent. Capacity is unequally distributed.

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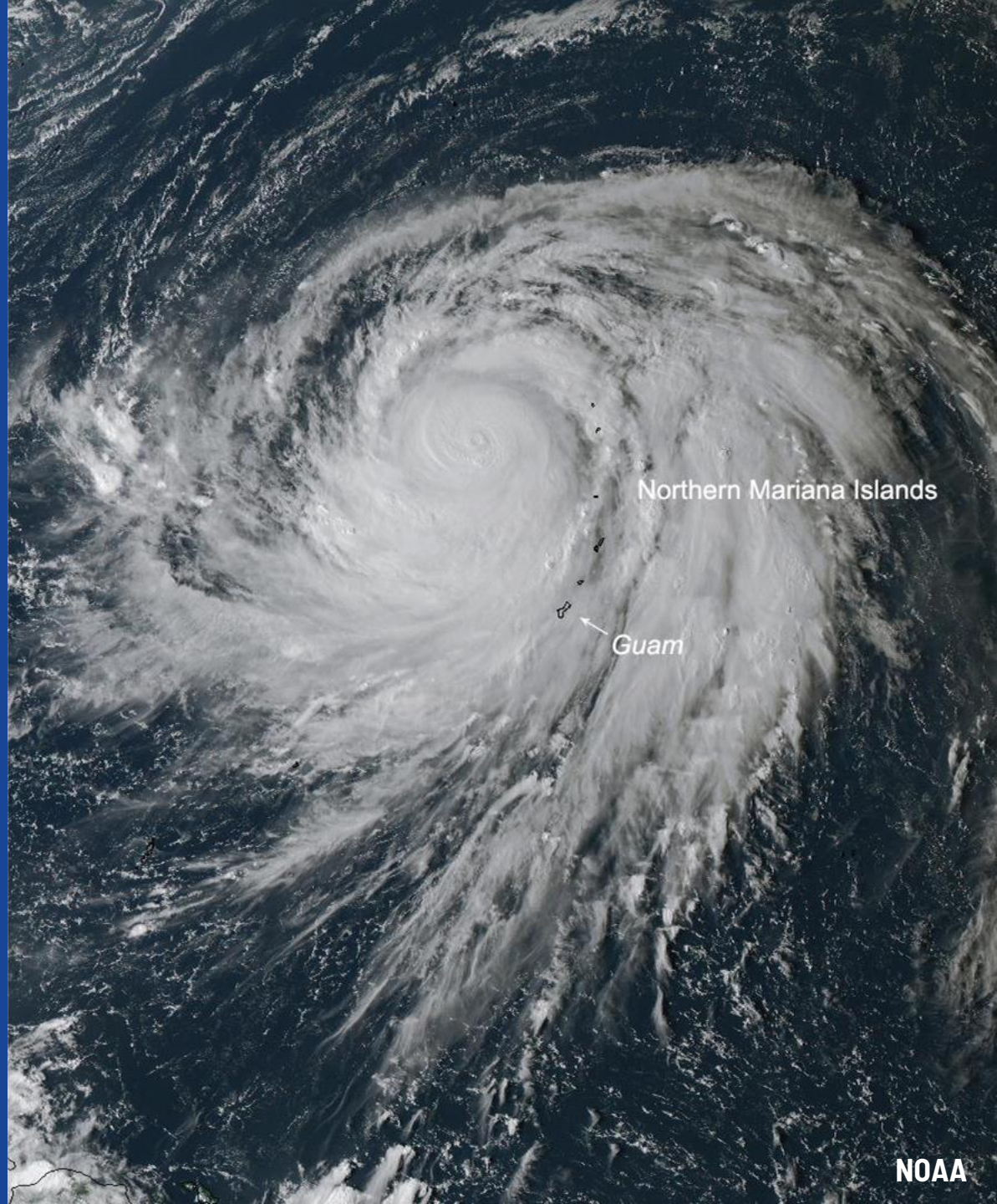
OBSERVING CO-DESIGN: TROPICAL CYCLONE EXEMPLAR



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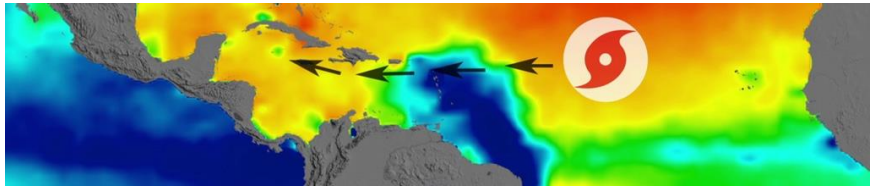
Observing Co-Design – TC Exemplar – Benefits & Deliverables

BENEFITS

- **Improve prediction** of tropical cyclones, particularly those that rapidly intensify
- **Advance ocean observing** technologies, process studies, & data impact studies - regionally & globally
- **Increase connectivity of stakeholders** along the value chain to support predictions and services

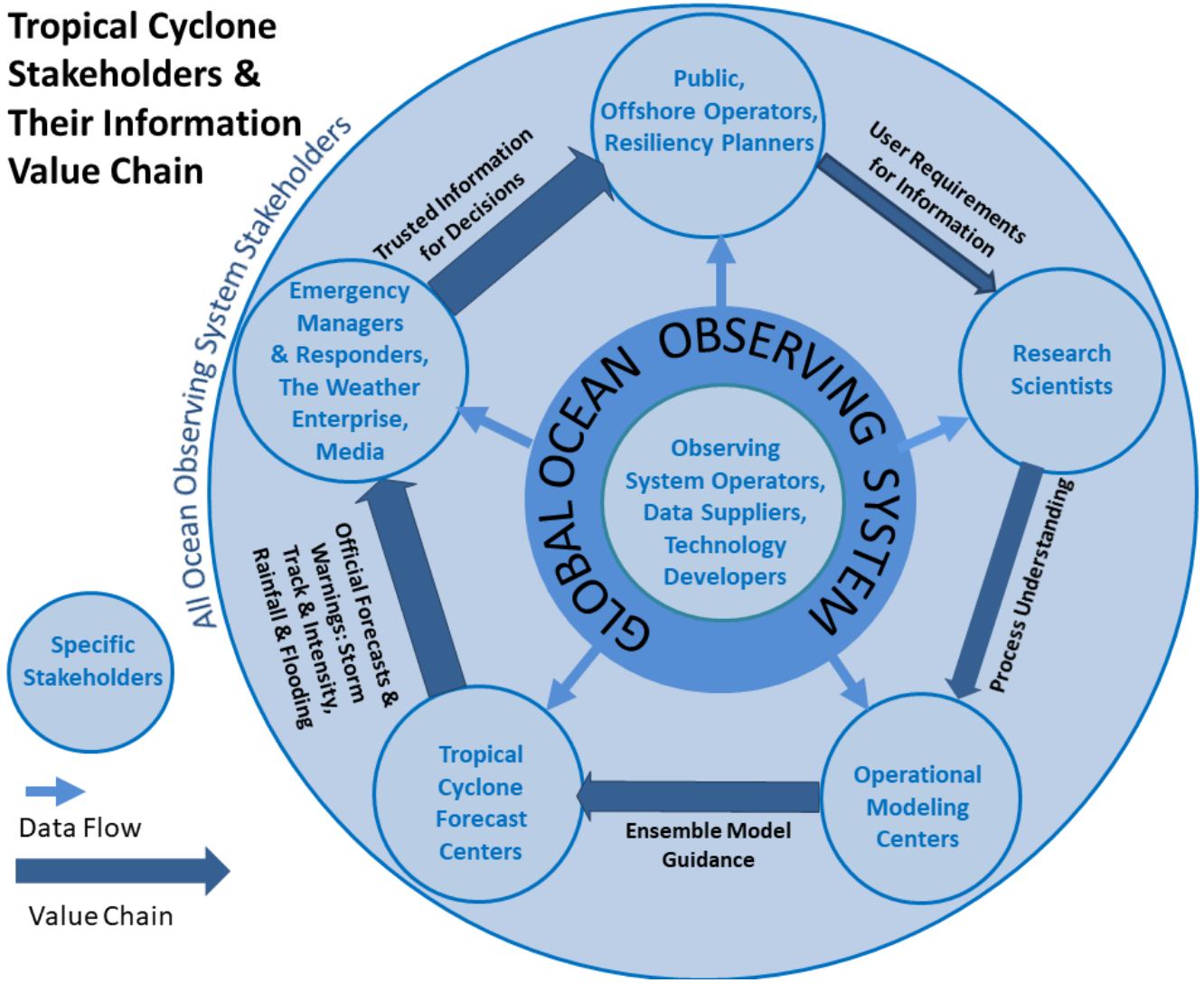


DELIVERABLES

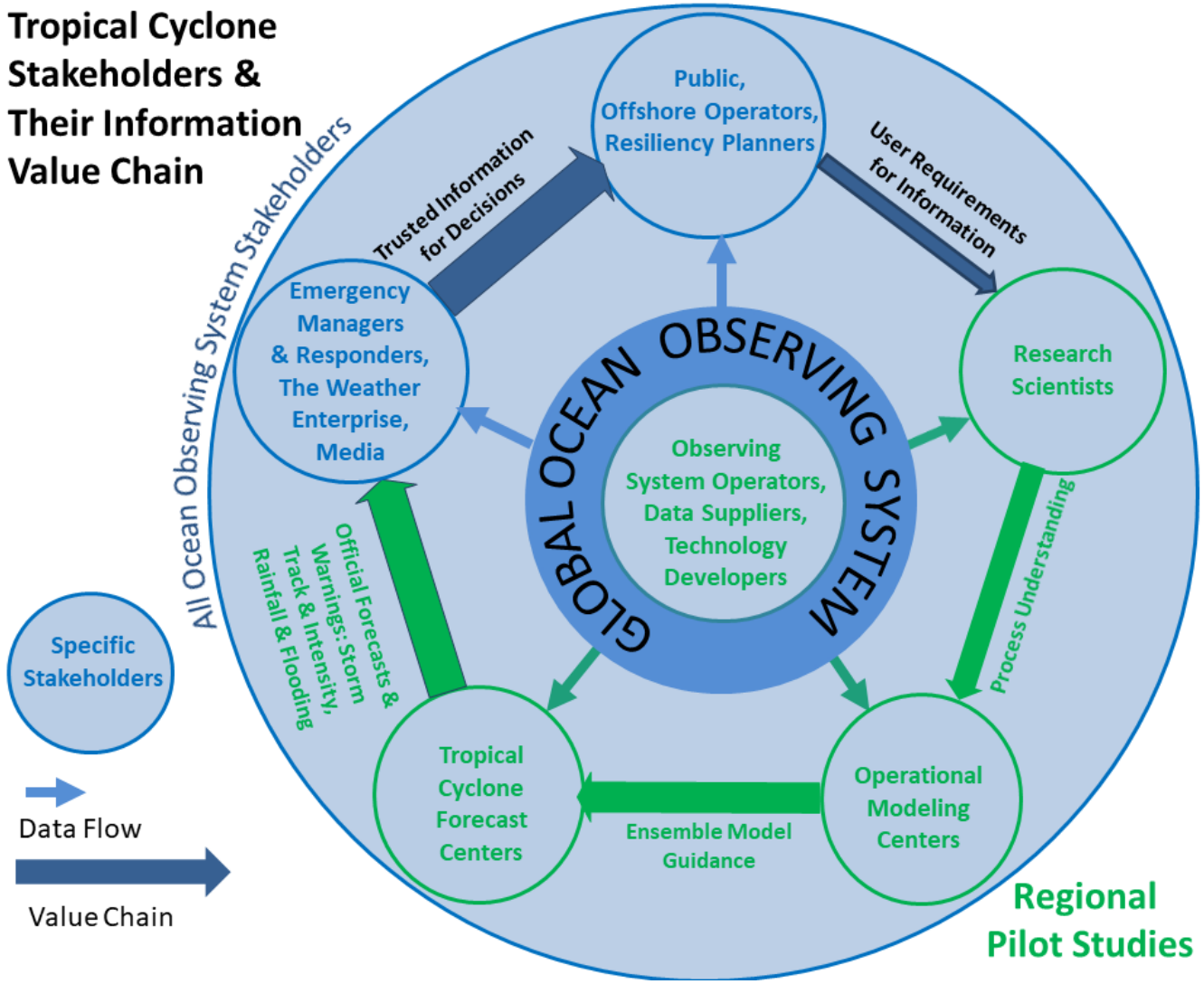
- **Co-designed**, regionally distributed ocean observing **pilot studies** - *to develop collaborative capacity and demonstrate mutual value*
- **Increased coverage and delivery** of ocean data to forecasting centers and scientists - *to expand critical observations across international borders*
- **More accurate characterization and understanding** of essential ocean-atmosphere features and processes - *to improve Earth System Models and tropical cyclone forecasts*

Recognized the Circular Nature of the Information Value Chain

Tropical Cyclone Stakeholders & Their Information Value Chain



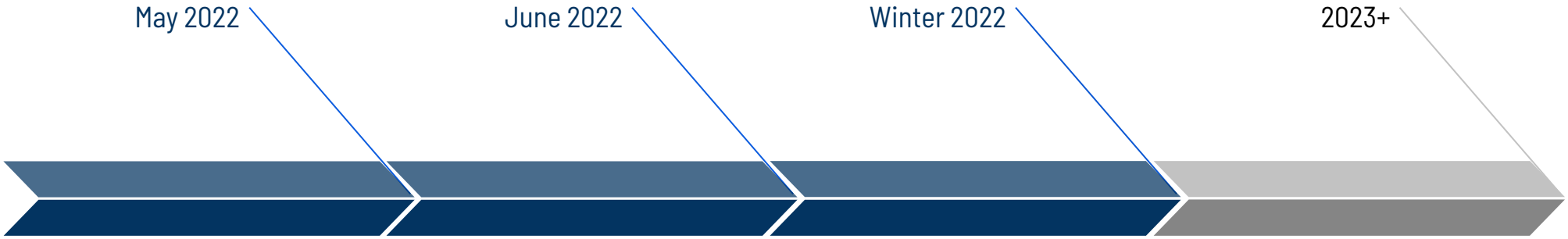
Recognized the Circular Nature of the Information Value Chain



The proposed regional pilot studies have particular emphasis on these nodes of the value chain:

- **Research scientists** that improve understanding
- **Operational modeling centers** that produce the ensemble of model forecasts
- **TC Forecast centers** that produce the official forecasts and warning

Progress & Timeline



Community Co-Design Meeting

Met with members of tropical cyclone ocean observing community to understand current status and gaps regionally & globally

GOOS Co-Design Workshop

Solidified Tropical Cyclone Exemplar within GOOS Observing Co-Design Programme; set priorities

Stakeholder Engagement Meetings

Engaging various levels of ocean observing stakeholders, improving connectivity along value chain, etc.

Future Plans

Re-engage community; develop concepts for pilot studies and potential funding opportunities

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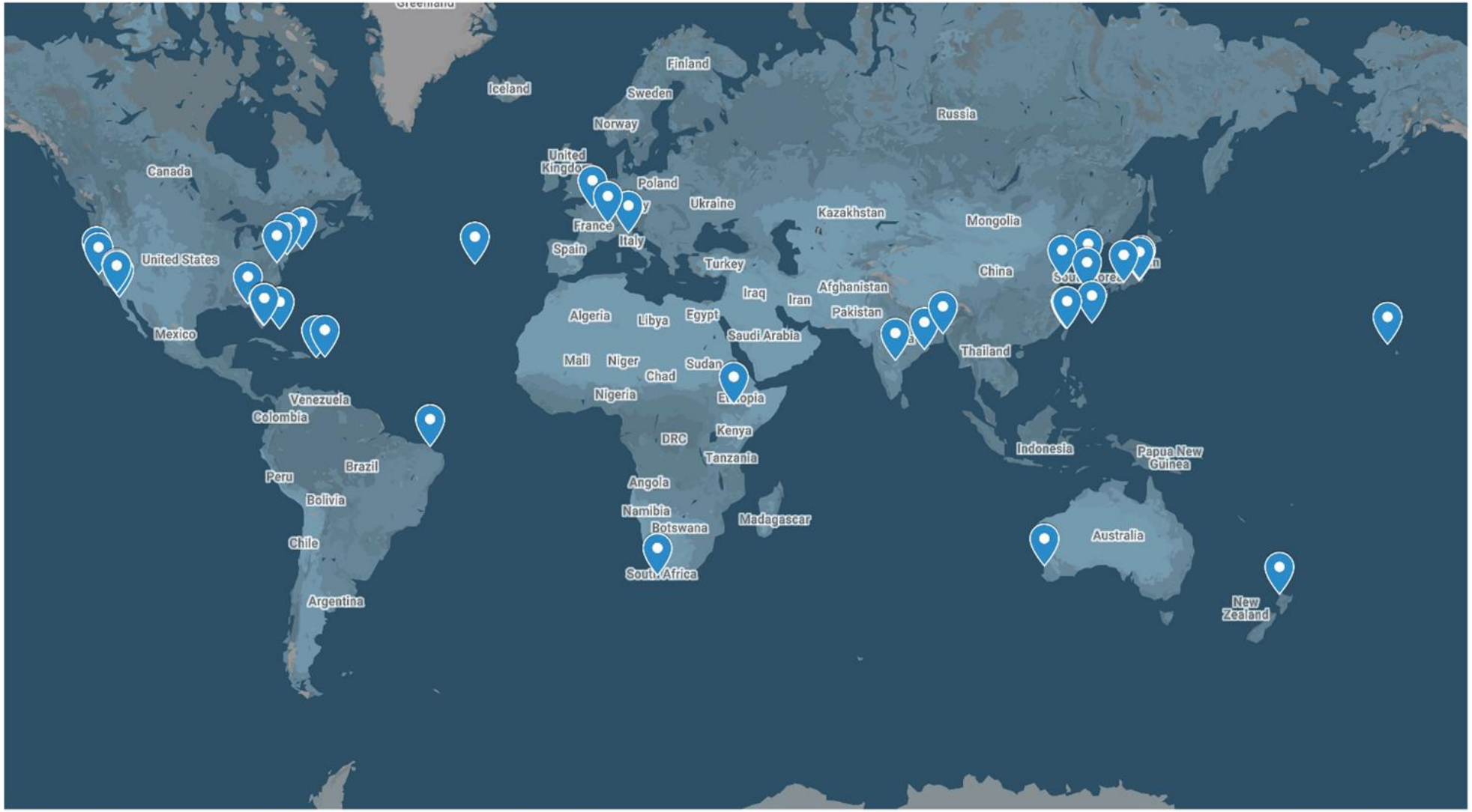
ORGANIZERS

STEERING TEAM

PRESENTERS



CO-DESIGN MEETING PARTICIPANTS

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PROPOSED PILOT REGIONS

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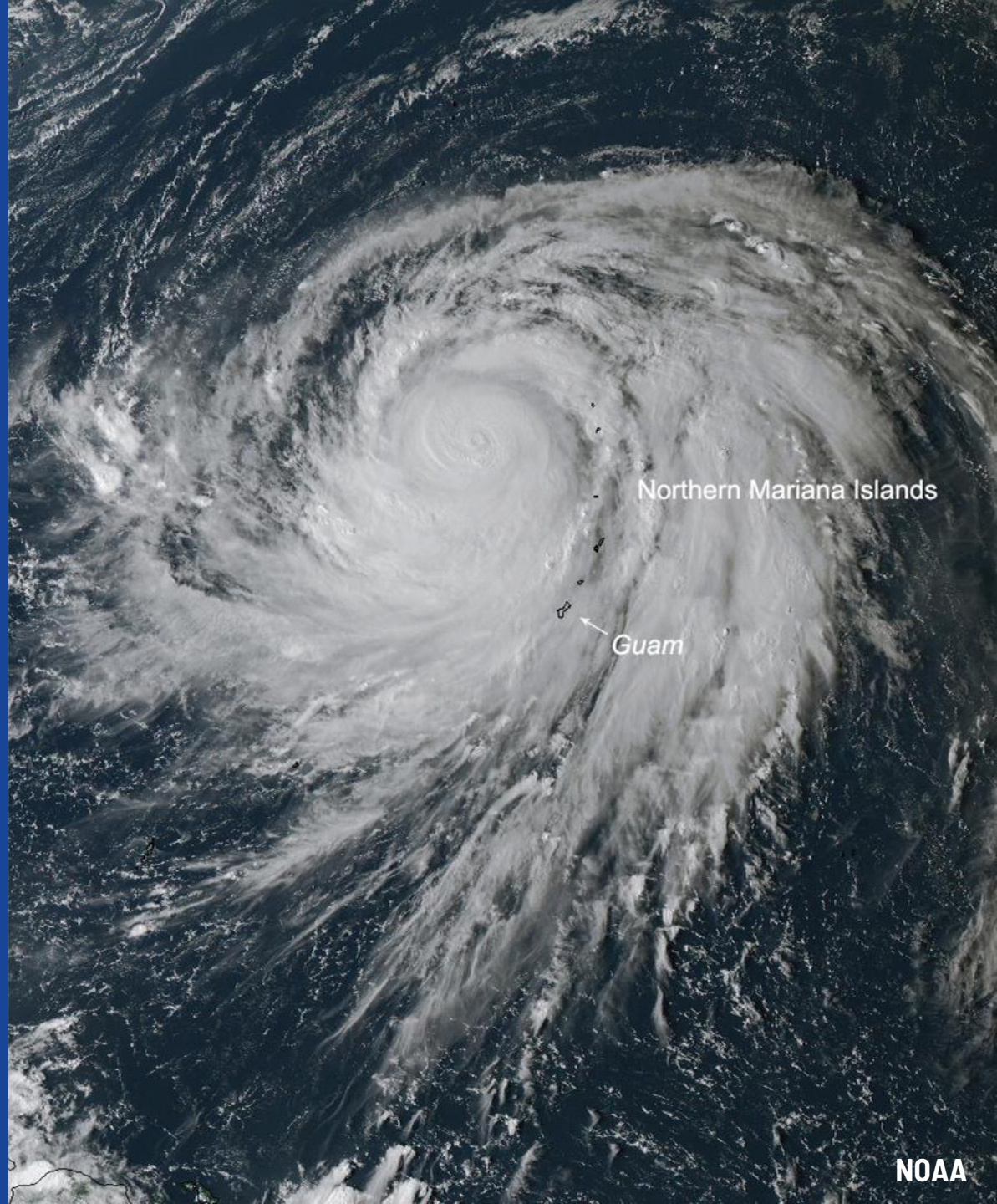


OVERVIEW

- Tropical Atlantic - Caribbean Sea
- Indian Ocean - Bay of Bengal
- North Pacific Ocean and Marginal Seas (NPOMS)

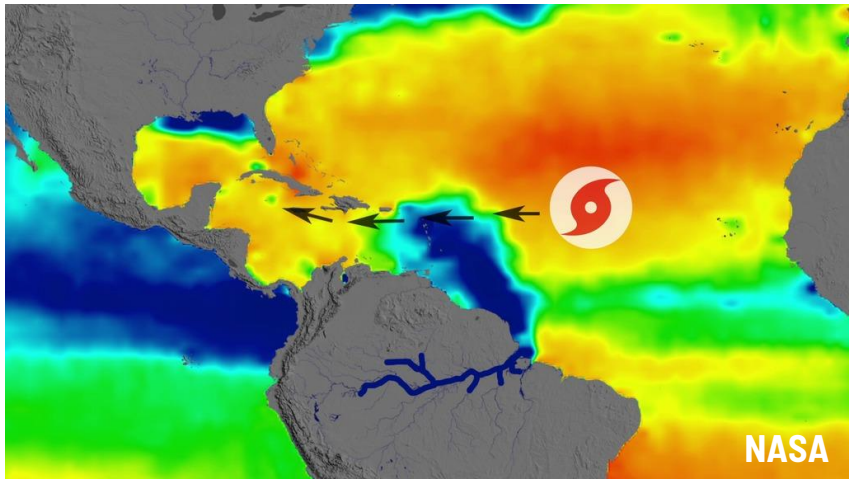
Caribbean Sea: Characteristics

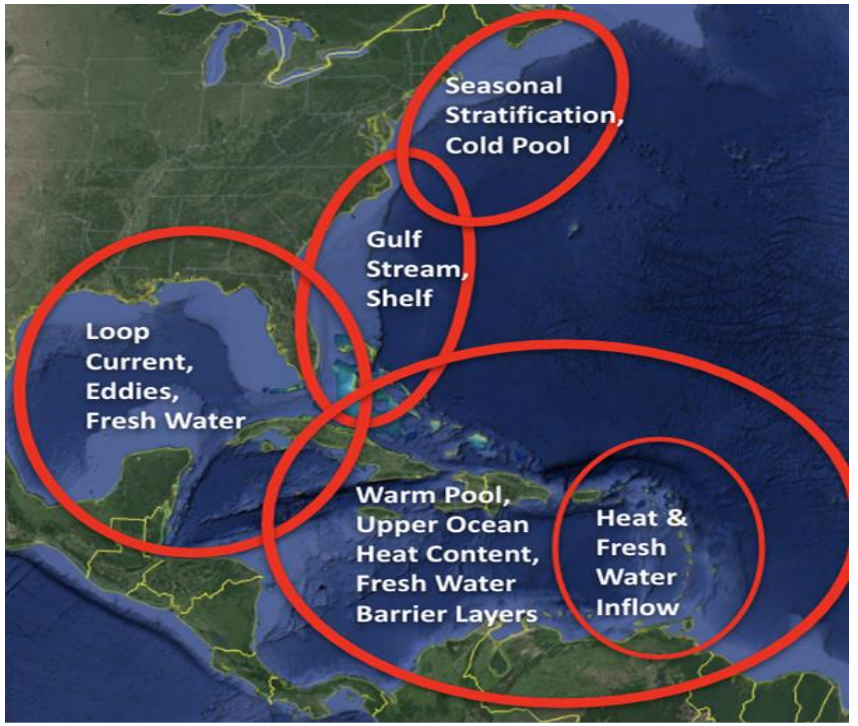
Region: Tropical Atlantic - Caribbean Sea

Goal: expand and advance ocean observing capabilities to Caribbean islands that are disproportionately impacted by TCs

This region has known **essential ocean features and ocean processes** in need of capacity building to address critical observing and modeling gaps:

- Surface transport of **freshwater river plumes**
- Subsurface transport of high salinity **SubTropical UnderWater**
- Spread of **freshwater surface barrier layers** by **mesoscale eddies**
- Unsampled **warm pool** in the W. Caribbean





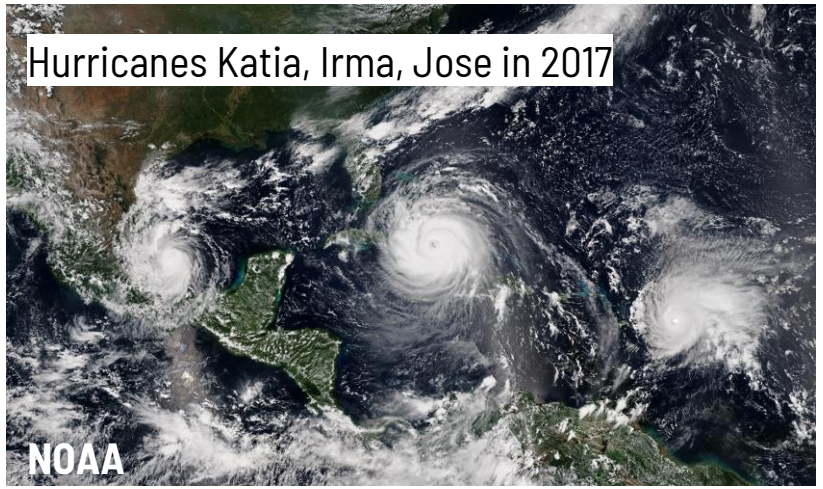
Caribbean Sea: Pilot Study Approach

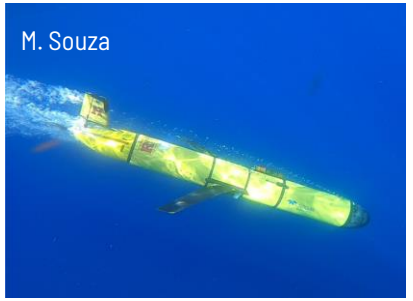
Leverage Existing Efforts

- Numerous demonstration and pre-operational projects in the U.S. territories of Puerto Rico & U.S. Virgin Islands
- Need increased capabilities in non-U.S. territories for islands with fewer resources

Co-Design and Build Capacity

- Engage local communities through educational training and active participation in observing activities
- Expand the ocean observations across multiple EEZs
  - in the Eastern Caribbean to improve the inflow of heat and fresh/salty water, and
  - in the Western Caribbean basin to characterize its warm pool.





NPOMS: Characteristics

Region: North Pacific Ocean and Marginal Seas (NPOMS)

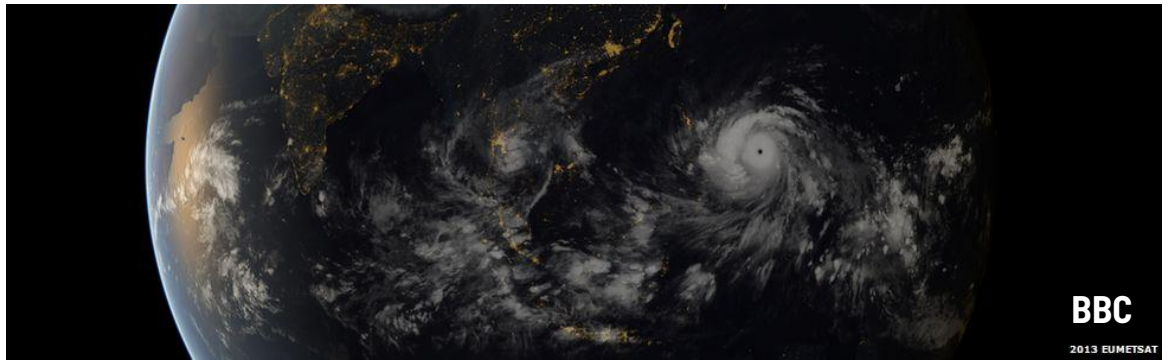
- This region is the largest TC basin on earth where the **highest number** and **most intense TCs occur**

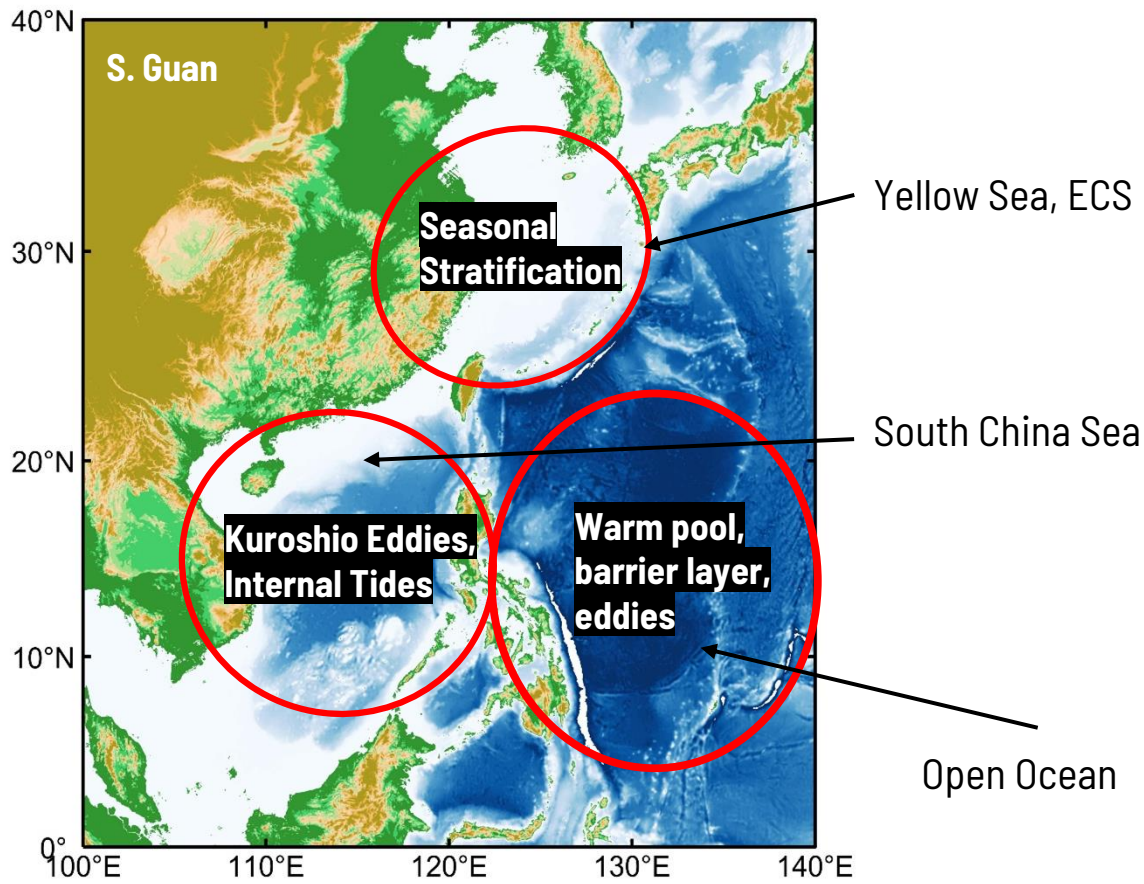
Goal: collaboratively increase understanding of key **ocean processes** in the **most extreme storm environments** through targeted field campaigns & experiments

Need to better understand and observe key features that contribute to **TC intensification**:

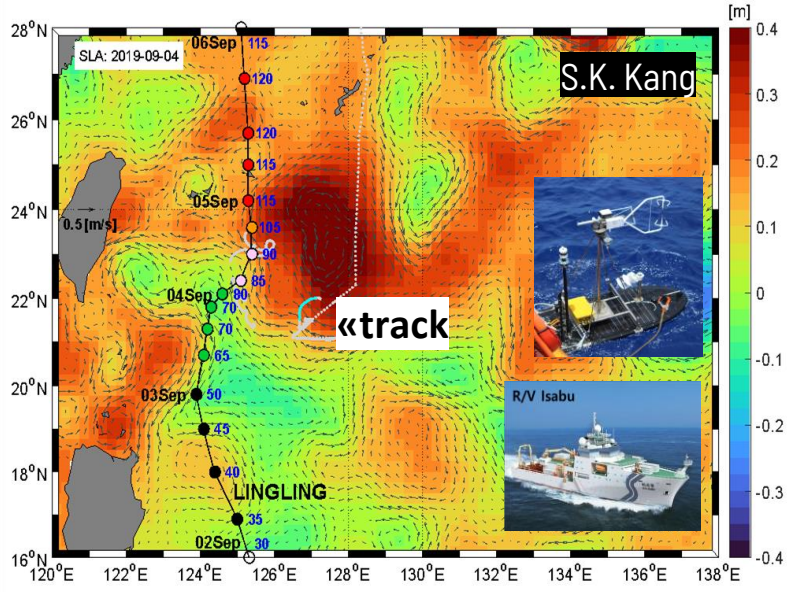
- Kuroshio Warm Current
- North Equatorial Current
- 2 eddy-rich zones
- Seasonal stratification
- Barrier layers

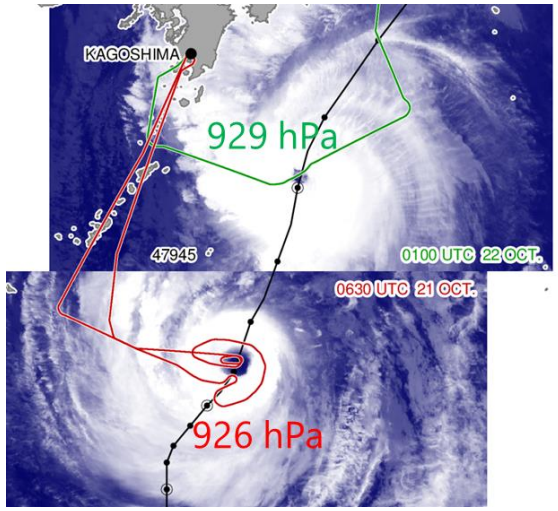
60% of all Category 5 TCs are from the NPOMS region



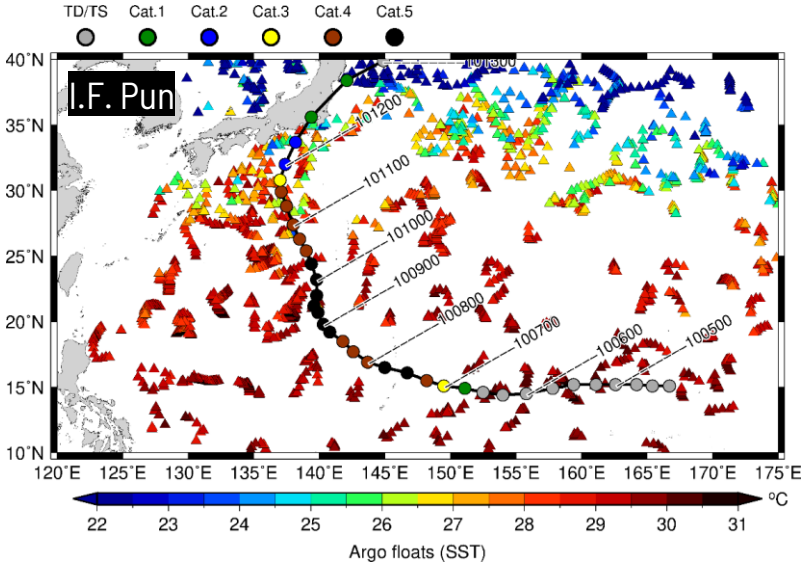


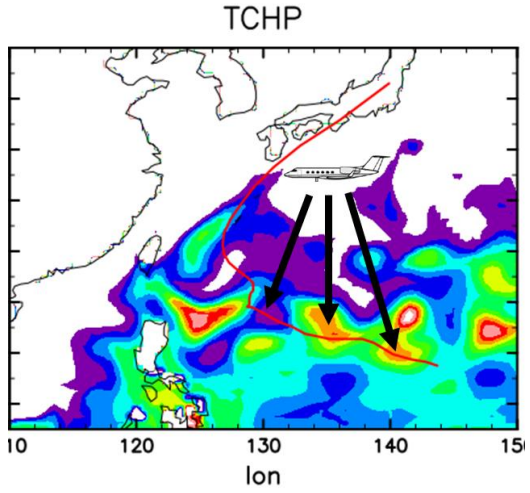
NPOMS: Pilot Study Approach





K. Ito et al.





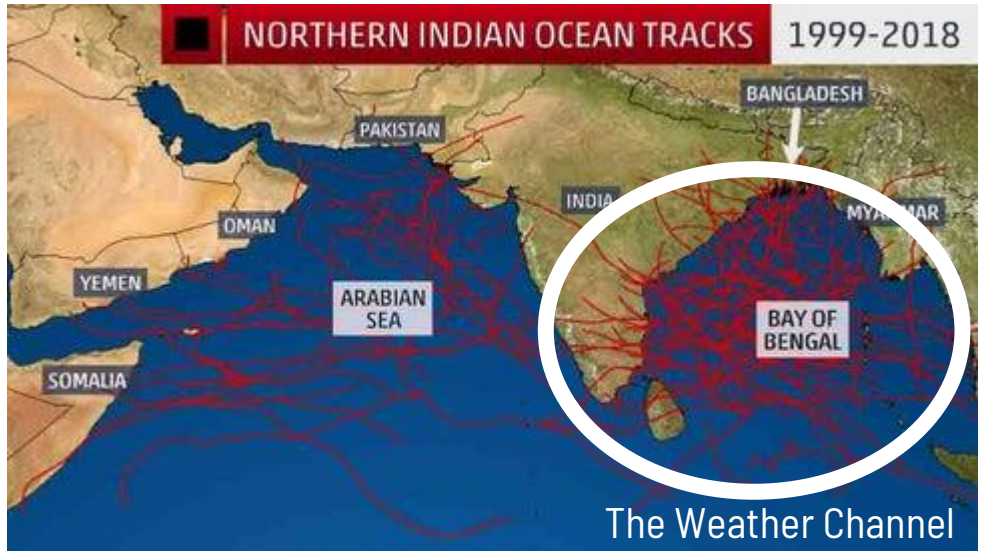
Advances in Monitoring of Ocean Processes & Modeling/Data Assimilation

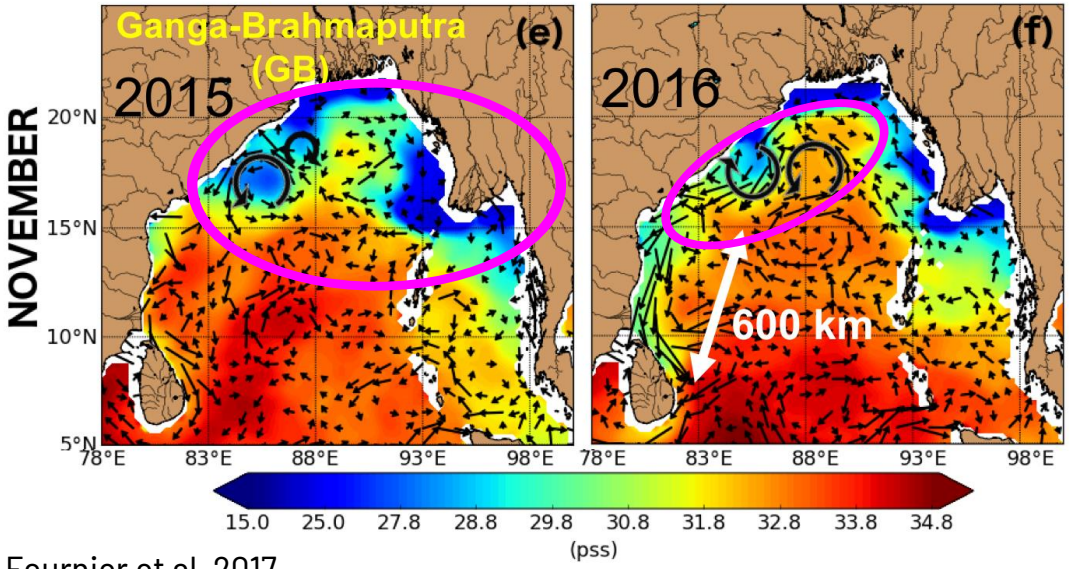
- Increase observational coverage with various real-time/near real-time observations, especially in shallow coastal waters
- Use data input from modern technologies, such as autonomous ocean surface vehicles and profiling gliders, drifters, Argo/Arvo profiling floats, vessel-based observations, aircraft observations, satellite altimetry, etc.

Targeted Air-Sea Process Field Campaign(s)

- Emphasis on air-sea processes in eddy-rich zones, western boundary current, and lower salinity coastal regions
- Significant regional expertise!

Bay of Bengal: Characteristics





Fournier et al. 2017

Region: Indian Ocean - Bay of Bengal

- Historically the region with the largest number of TC casualties due to high populations in low-lying, less-developed coastal areas

Goal: demonstrate value of ocean observations to motivate further national interest and investments in ocean observing

Essential ocean features and processes likely contributing to TC intensification in this region:

- **Low salinity waters** from the discharge of the Ganges, Brahmaputra, and Irrawaddy Rivers
- **Barrier layers** and **temperature inversion**
- Ocean vertical structure is modulated by mesoscale **eddies**
- Sea surface temperature anomalies modulated by the Madden-Julian Oscillation (**MJO**)

Bay of Bengal: Pilot Study Approach

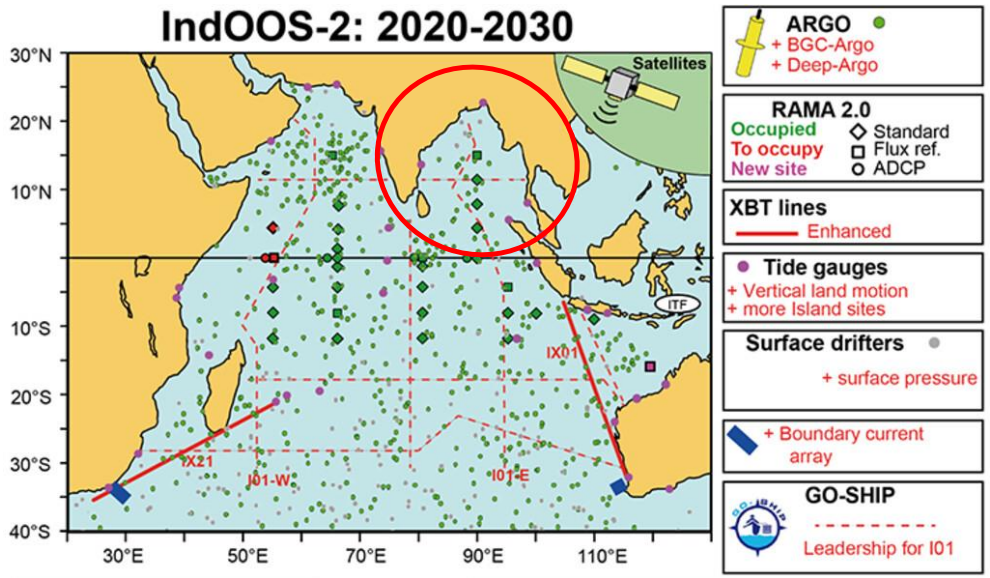
Leverage National Capacity & Expertise

- Wide range of expertise from India, Sri Lanka, Indonesia, Australia, and more
- Varying degrees of government interest and support

Address Critical Gaps through International Collaborations

- Aid in collaborative approaches to building out the national infrastructures
- Identified critical needs:
  - » High resolution met-ocean parameters for cyclone studies
  - » OSEs to determine regional impacts
  - » Cyclone track and intensity resolving models with improved lead times and accuracy

Beal et al. 2020



Need more sustained observations.
Enhanced resolution of upper-ocean measurements, in addition to those from existing and expanded measurement platforms, would improve the situation.

Conclusions

Stakeholder engagement within the tropical cyclone ocean observing communities is critical to:

- Raise awareness and secure funding to establish pilot studies
- Enhance connectivity along the value chain, particular emphasis on working with forecasters and modeling centers

Continue **prioritizing community engagement** for **co-designing** pilot studies and improving regional information & products

Solidify the **role of the ocean for improving forecasts** to protect lives and property

- More success story headlines like TC Fani in India

The New York Times

How Do You Save a Million People From a Cyclone? Ask a Poor State in India

By Hari Kumar, Jeffrey Gettleman and Sameer Yasir

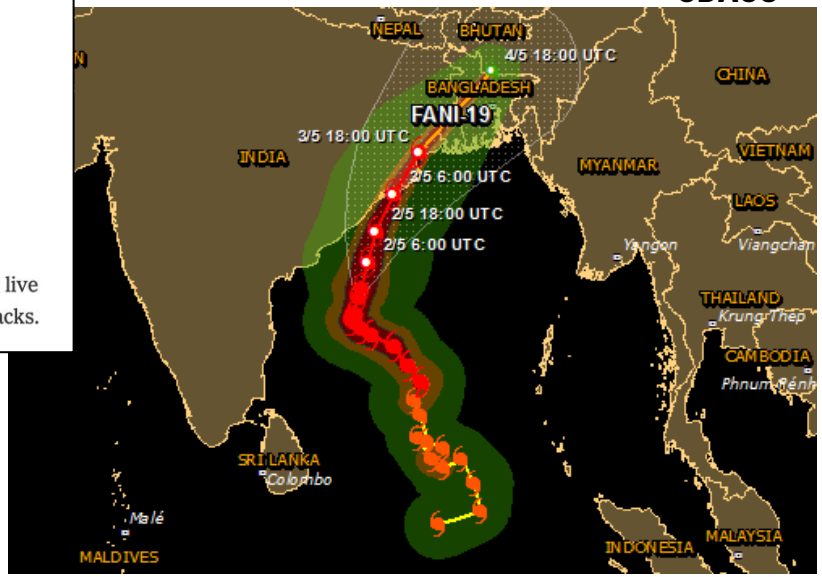
May 3, 2019

BHUBANESWAR, India — Flights were canceled.

Train service was out.

And one of the biggest storms in years was bearing down on Odisha, one of India's poorest states, where millions of people live cheek by jowl in a low-lying coastal area in mud-and-stick shacks.

Track of Tropical Cyclone Fani, 2019



"The vital role of the ocean in the genesis and the intensification highlights the need to efficiently incorporate ocean initial conditions and ocean-atmosphere coupling in the operational cyclone forecasting framework." (Singh et al. *Nature*, 2021)

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