# The Global High Frequency Radar Network

*Hugh Roarty*
*Rutgers University*
*Mid Atlantic Ocean Observing System*

The Global Ocean Observing System

# The State University of New Jersey


- 71,000 students
- $750 million in research grants and sponsored programs
- 24,000 faculty and staff
- 530,000 alumni

Presentation revised August 2021

# Rutgers University Center for Ocean Observing Leadership

Hurricane Science

Offshore Wind

Ocean Pollution

Polar Science

Ocean Acidification

Empower the Next Generation

Fisheries

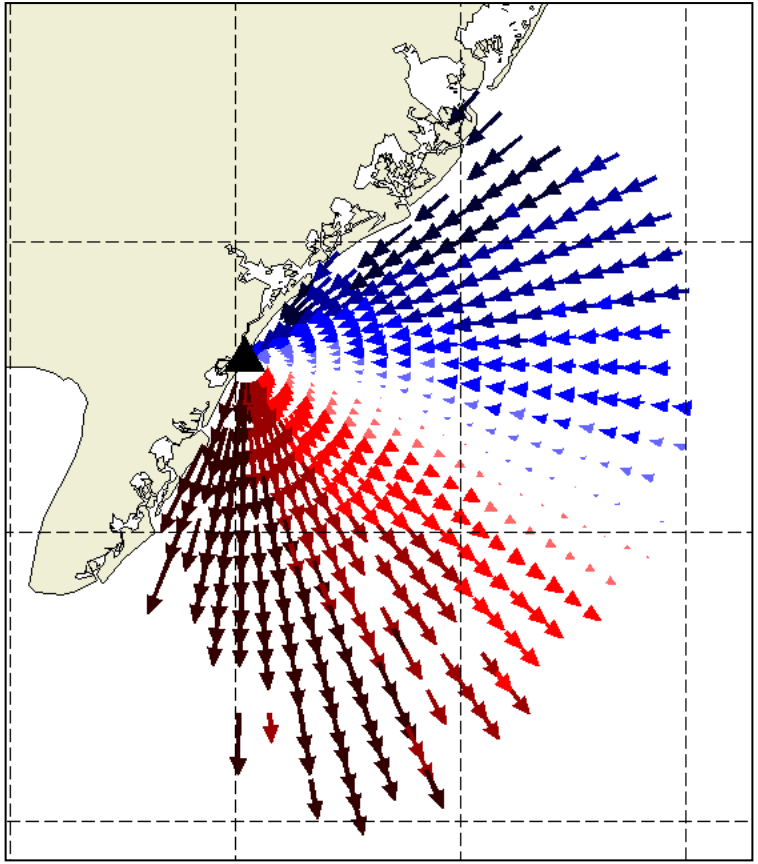
Integrated Technology

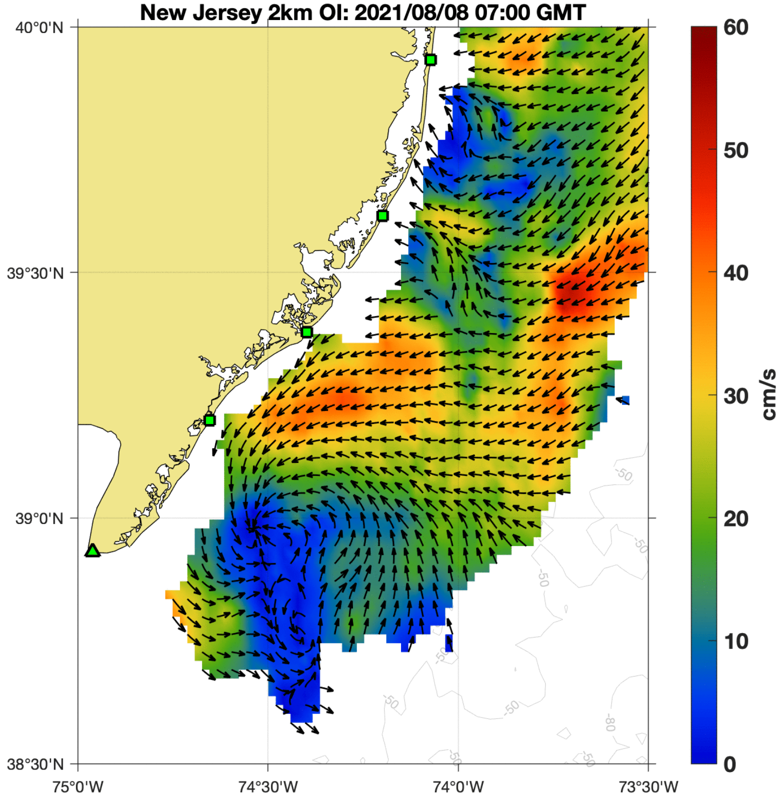
*RUCOOL is creating knowledge of our ocean planet by pushing the limits of science and new technologies while inspiring future generations of ocean explorers, within these core focus areas:*

# High Frequency Radar

CODAR Tx/Rx Antenna
Lewes Beach, DE USA

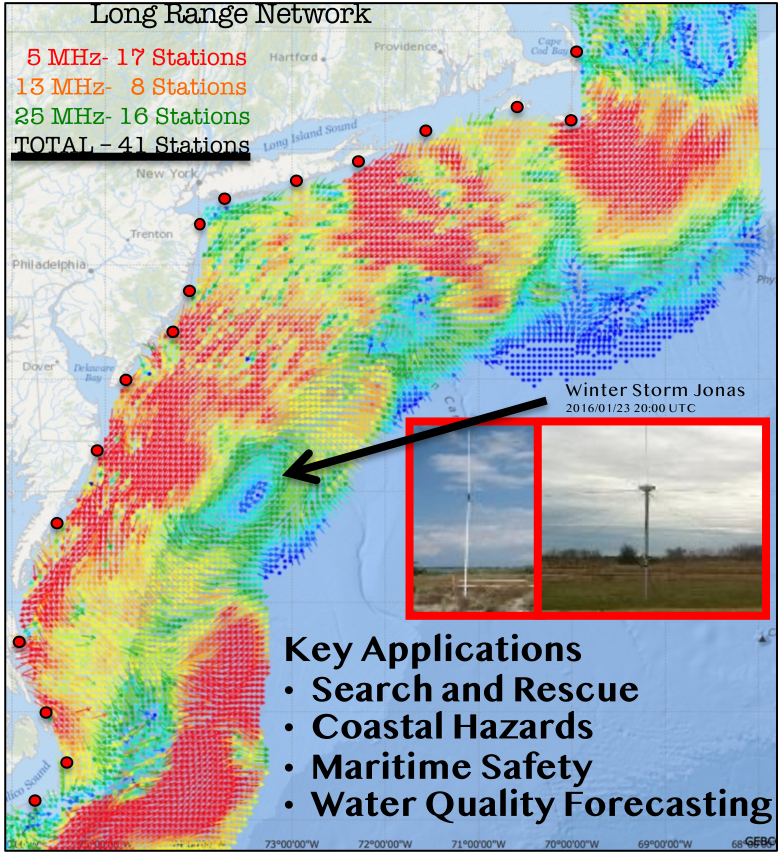
MARITIME SECURITY CENTER

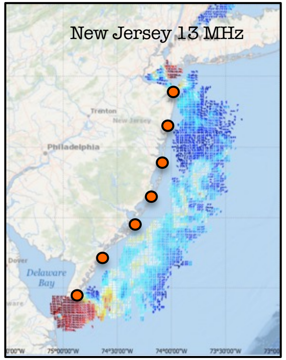


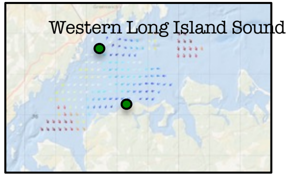


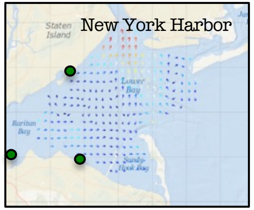

01/12/22 vector_plot_hourly_curly_13MHz_v2.m

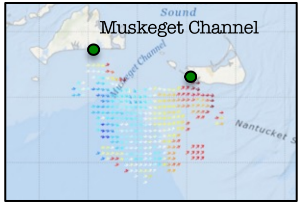
# High Frequency Radar Network – HF-Radar

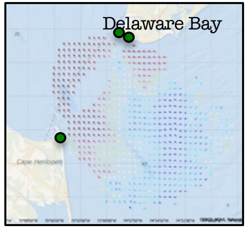


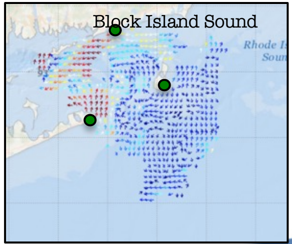



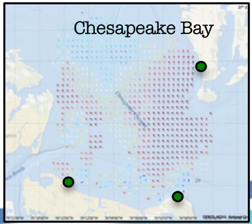



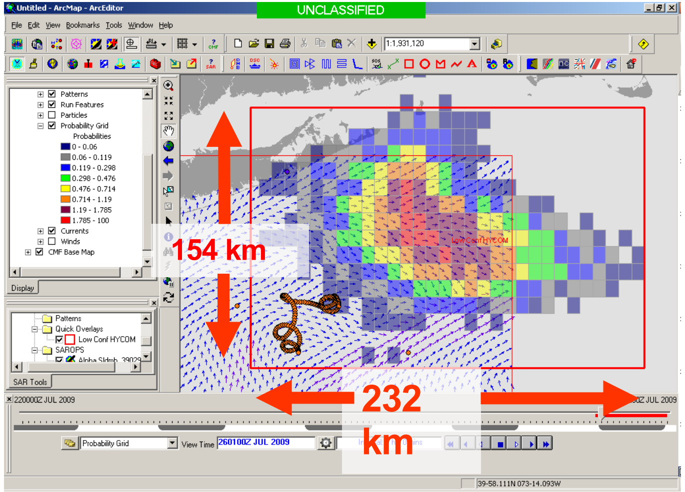



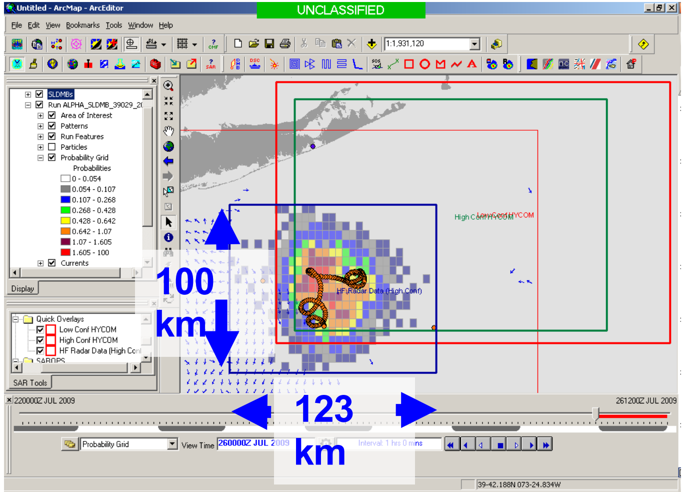
# Application: USCG Search and Rescue

Results of a 1-year blind validation study -
For every real drifter deployed at sea:

- 5000 Virtual Drifters Deployed in SAROPS
- Search Areas compared to real drifters every 12 hours




HYCOM 96 hour Search Area
36,000 km$^2$

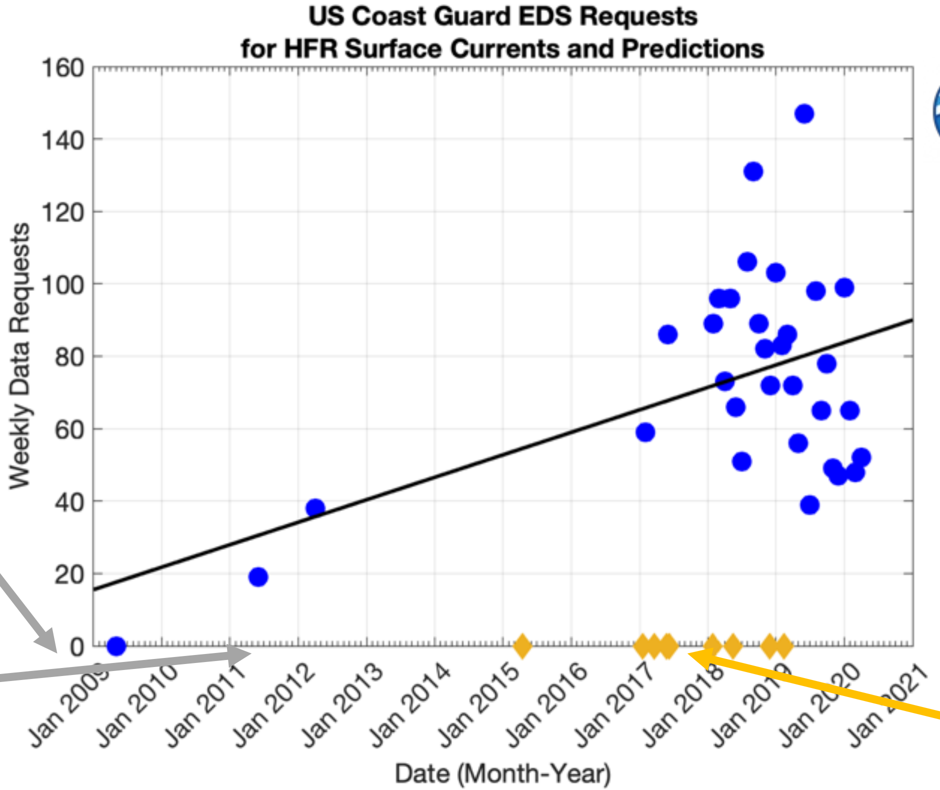



HF Radar 96 hour Search Area
12,000 km$^2$

# WEEKLY HFR DATA REQUESTS BY USCG

MARACOOS surface currents operational with USCG May 4, 2009

US IOOS surface currents operational with USCG March 2011




MARACOOS engagement events with USCG

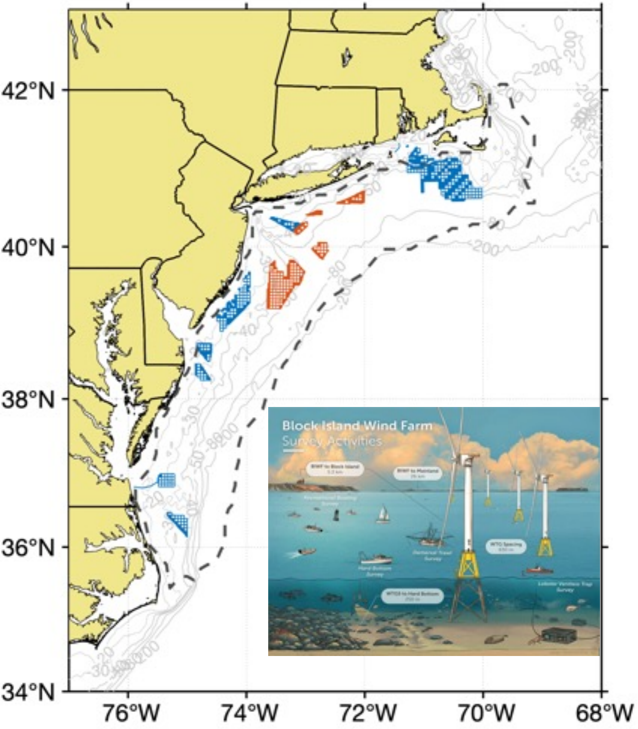
MARITIME SECURITY CENTER

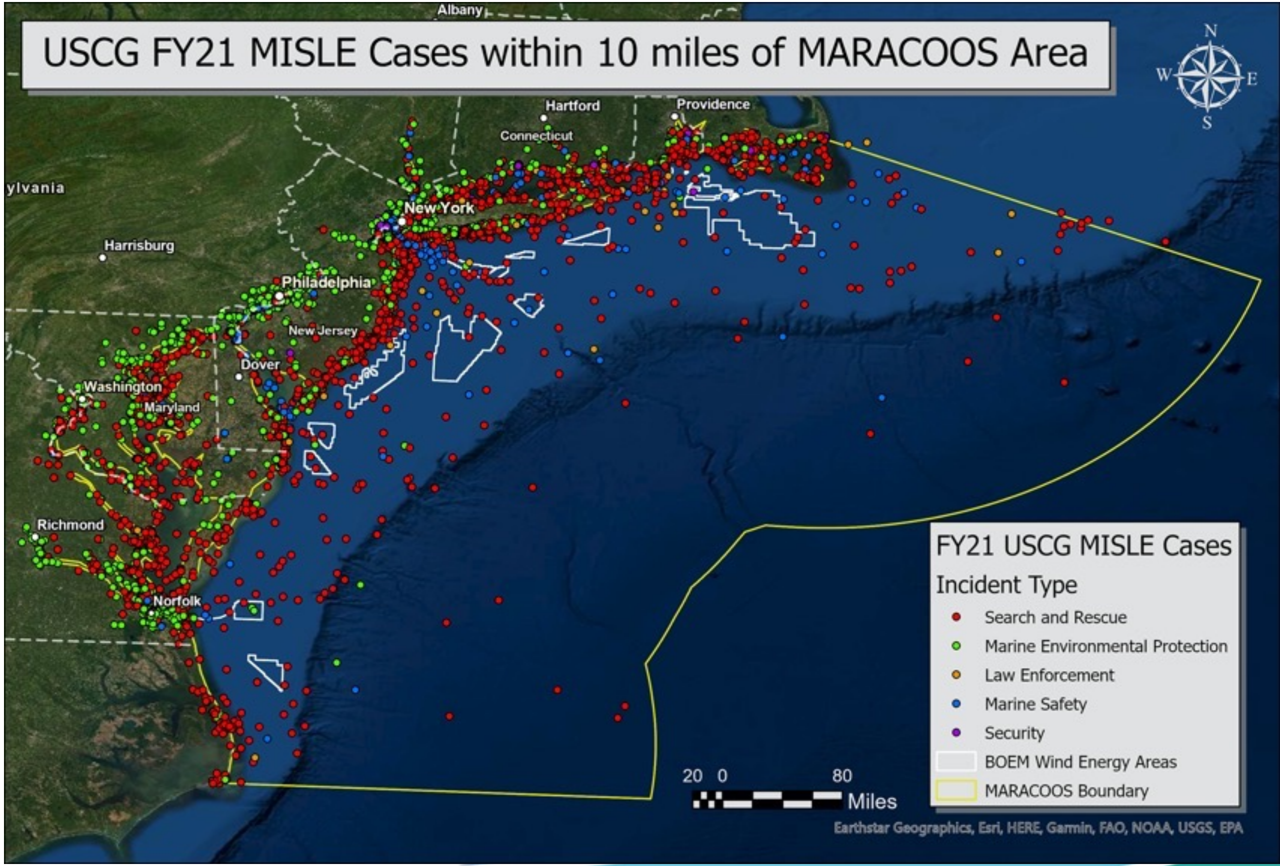
MARACOOS Ocean Information for a Changing World

IOOS Integrated Ocean Observing System

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

# Offshore Wind
## 30,000 MW by 2030

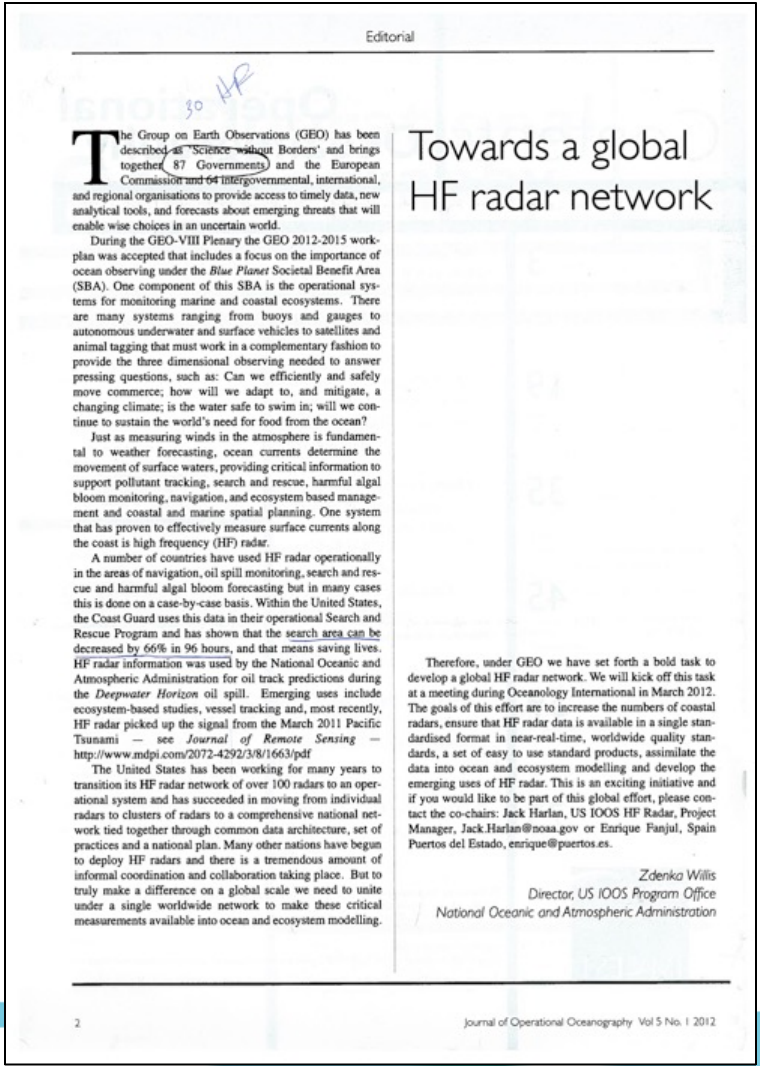


# The Global HF Radar Network

# GLOBAL HF RADAR NETWORK

- Established in March 2012
- Journal of Operational Oceanography Vol. 5 No. 1



Editorial

## Towards a global HF radar network

The Group on Earth Observations (GEO) has been described as 'Science without Borders' and brings together 87 Governments and the European Commission and 64 intergovernmental, international, and regional organisations to provide access to timely data, new analytical tools, and forecasts about emerging threats that will enable wise choices in an uncertain world.

During the GEO-VIII Plenary the GEO 2012-2015 work-plan was accepted that includes a focus on the importance of ocean observing under the *Blue Planet* Societal Benefit Area (SBA). One component of this SBA is the operational systems for monitoring marine and coastal ecosystems. There are many systems ranging from buoys and gauges to autonomous underwater and surface vehicles to satellites and animal tagging that must work in a complementary fashion to provide the three dimensional observing needed to answer pressing questions, such as: Can we efficiently and safely move commerce; how will we adapt to, and mitigate, a changing climate; is the water safe to swim in; will we continue to sustain the world's need for food from the ocean?

Just as measuring winds in the atmosphere is fundamental to weather forecasting, ocean currents determine the movement of surface waters, providing critical information to support pollutant tracking, search and rescue, harmful algal bloom monitoring, navigation, and ecosystem based management and coastal and marine spatial planning. One system that has proven to effectively measure surface currents along the coast is high frequency (HF) radar.

A number of countries have used HF radar operationally in the areas of navigation, oil spill monitoring, search and rescue and harmful algal bloom forecasting but in many cases this is done on a case-by-case basis. Within the United States, the Coast Guard uses this data in their operational Search and Rescue Program and has shown that the search area can be decreased by 66% in 96 hours, and that means saving lives. HF radar information was used by the National Oceanic and Atmospheric Administration for oil track predictions during the *Deepwater Horizon* oil spill. Emerging uses include ecosystem-based studies, vessel tracking and, most recently, HF radar picked up the signal from the March 2011 Pacific Tsunami — see *Journal of Remote Sensing* — http://www.mdpi.com/2072-4292/3/8/1663/pdf

The United States has been working for many years to transition its HF radar network of over 100 radars to an operational system and has succeeded in moving from individual radars to clusters of radars to a comprehensive national network tied together through common data architecture, set of practices and a national plan. Many other nations have begun to deploy HF radars and there is a tremendous amount of informal coordination and collaboration taking place. But to truly make a difference on a global scale we need to unite under a single worldwide network to make these critical measurements available into ocean and ecosystem modelling.

Therefore, under GEO we have set forth a bold task to develop a global HF radar network. We will kick off this task at a meeting during Oceanology International in March 2012. The goals of this effort are to increase the numbers of coastal radars, ensure that HF radar data is available in a single standardised format in near-real-time, worldwide quality standards, a set of easy to use standard products, assimilate the data into ocean and ecosystem modelling and develop the emerging uses of HF radar. This is an exciting initiative and if you would like to be part of this global effort, please contact the co-chairs: Jack Harlan, US IOOS HF Radar, Project Manager, Jack.Harlan@noaa.gov or Enrique Fanjul, Spain Puertos del Estado, enrique@puertos.es.

*Zdenka Willis*
*Director, US IOOS Program Office*
*National Oceanic and Atmospheric Administration*

# GOALS FOR GLOBAL HF RADAR NETWORK

1) Increase the number of coastal radars
2) Ensure HFR data is available in a single standardized format in near-real-time,
3) Assimilate data into ocean and ecosystem models
4) A set of easy to use standard products
5) Worldwide Quality Standards
6) Develop emerging uses of HF radar

# GLOBAL HF RADAR NETWORK

- Co Chairs 2012–2015
  - **Jack Harlan (USA)**
  - **Lucy Wyatt (Australia)**
  - **Enrique Alvarez-Fanjul (Spain)**

# Global HF Radar Network

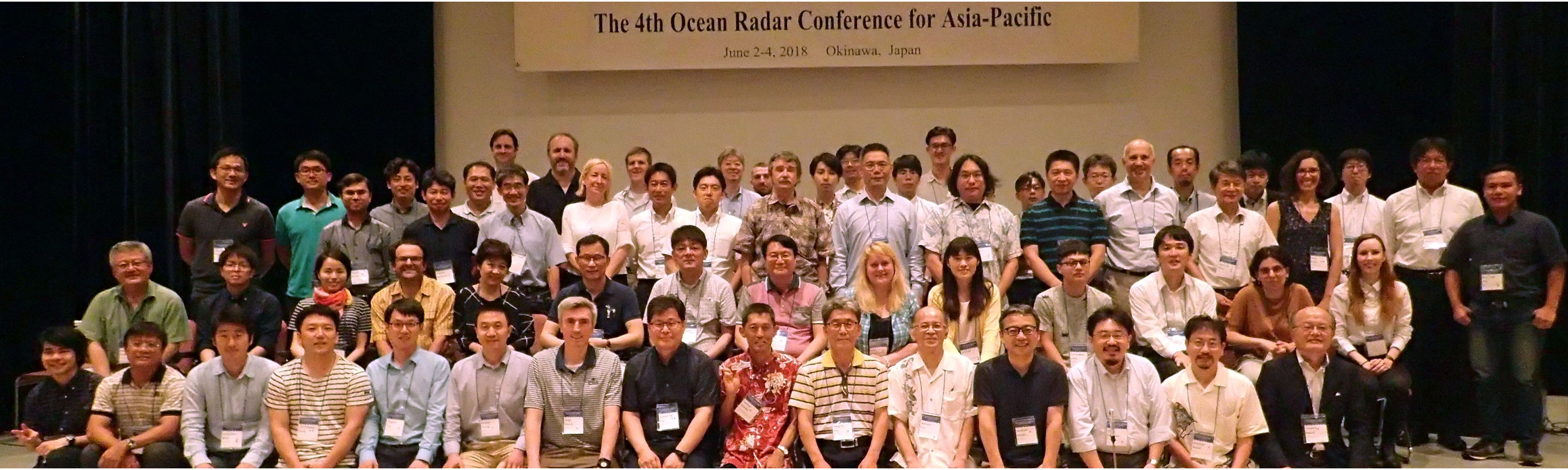
- Co Chairs Present
  - **Hugh Roarty (USA)**
  - **Lisa Hazard (USA)**
  - **Lucy Wyatt (UK)**
  - **Julien Mader(Spain)**
  - **Simone Cosoli (Australia)**
  - **Naoto Ebuchi (Japan)**

# TAIWAN 2014

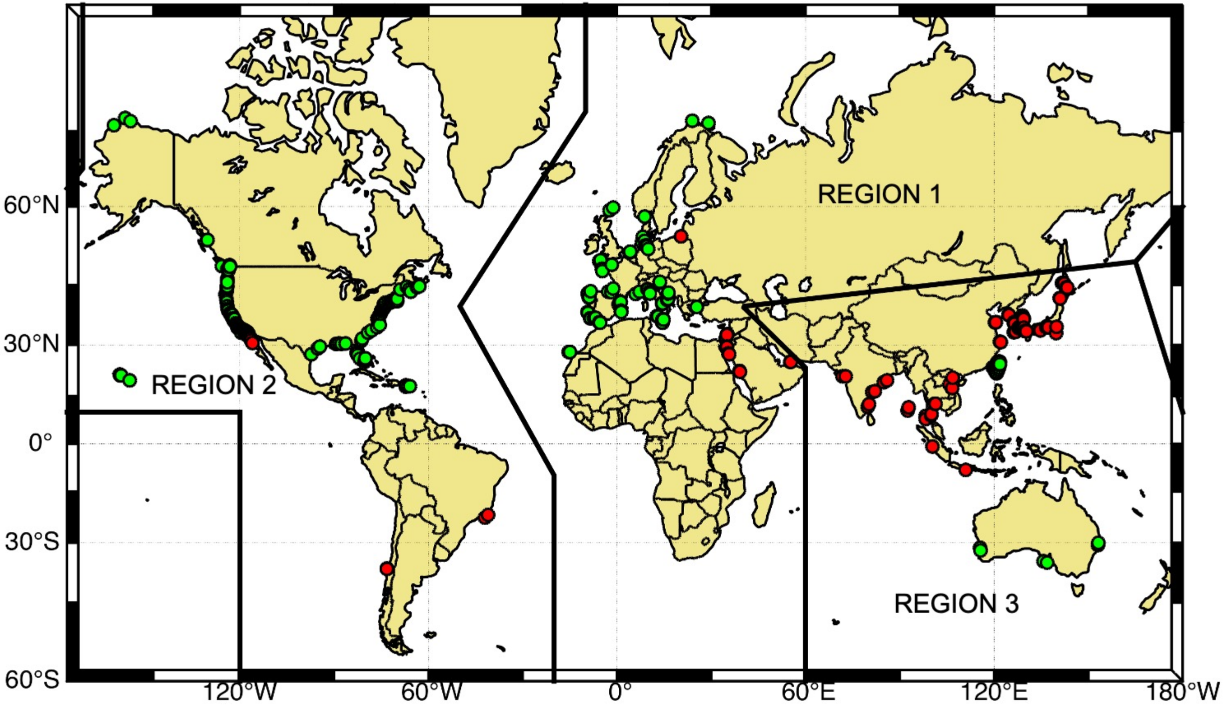

April 2-4 2014, Kaohsiung, Taiwan
The 2nd Ocean Radar Conference for Asia Pacific (ORCA)
ORCA '14
NAR Labs
IOOS


The 3rd Ocean Radar Conference for Asia-Pacific
第三届亚太地区海洋雷达研讨会
Wuhan China 2016.4.15

# JAPAN 2018


The 4th Ocean Radar Conference for Asia-Pacific
June 2-4, 2018 Okinawa, Japan

4. Global distribution of HFR stations organized within the three ITU regions. Green dots indicate stations that are sharing their data from ten countries and 17 organizations.




## REGION 1

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

National Research Council of Italy
OGS

UNIVERSITY OF MALTA
L-Università ta' Malta

Puertos del Estado
euskalmet
SOCIB Balearic Islands Coastal Observing and Forecasting System
intecmar
UCA Universidad de Cádiz
UNIVERSIDADE DE VIGO

INSTITUT ZA OCEANOGRAFIJU I RIBARSTVO SPLIT

## REGION 2

IOOS Integrated Ocean Observing System

OCOMEX Observatorio de Corrientes Oceánicas MEXicanas

## REGION 3

TORI
台灣海洋科技研究中心
Taiwan Ocean Research Institute

IMOS
Integrated Marine Observing System

http://global-hfradar.org

frontiers in Marine Science

TECHNOLOGY REPORT
published: 14 May 2019
doi: 10.3389/fmars.2019.00164

# The Global High Frequency Radar Network

*Hugh Roarty[1]*, Thomas Cook[2], Lisa Hazard[2], Doug George[3], Jack Harlan[4], Simone Cosoli[5], Lucy Wyatt[6], Enrique Alvarez Fanjul[7], Eric Terrill[2], Mark Otero[2], John Largier[3], Scott Glenn[1], Naoto Ebuchi[8], Brian Whitehouse[9], Kevin Bartlett[10], Julien Mader[11], Anna Rubio[11], Lorenzo Corgnati[12], Carlo Mantovani[12], Annalisa Griffa[12], Emma Reyes[13], Pablo Lorente[7], Xavier Flores-Vidal[14], Kelly Johanna Saavedra-Matta[14], Peter Rogowski[2], Siriluk Prukpitikul[15], Sang-Ho Lee[16], Jian-Wu Lai[17], Charles-Antoine Guerin[18], Jorge Sanchez[19], Birgit Hansen[20] and Stephan Grilli[21]*

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Academic, government, and private organizations from around the globe have established High Frequency radar (hereinafter, HFR) networks at regional or national levels. Partnerships have been established to coordinate and collaborate on a single global HFR network (http://global-hfradar.org/). These partnerships were established in 2012 as part of the Group on Earth Observations (GEO) to promote HFR technology and increase data sharing among operators and users. The main product of HFR networks are continuous maps of ocean surface currents within 200 km of the coast at high spatial (1–6 km) and temporal resolution (hourly or higher). Cutting-edge remote sensing technologies are becoming a standard component for ocean observing systems, contributing to the paradigm shift toward ocean monitoring. In 2017 the Global HFR Network was recognized by the Joint Technical WMO-IOC Commission for Oceanography and Marine Meteorology (JCOMM) as an observing network of the Global Ocean Observing System (GOOS). In this paper we will discuss the development of the network as well as establishing goals for the future. The U.S. High Frequency Radar Network (HFRNet) has been in operation for over 13 years, with radar data being ingested from 31 organizations including measurements from Canada and Mexico. HFRNet currently holds a collection from over 150 radar installations totaling millions of records of surface ocean velocity measurements. During the past 10 years in Europe,



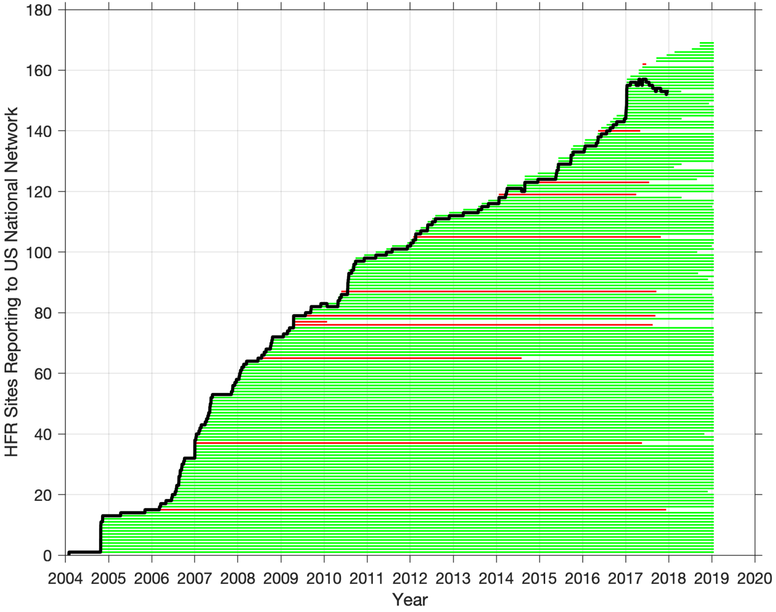
OCEAN OBS'19

AN OCEAN OF OPPORTUNITY

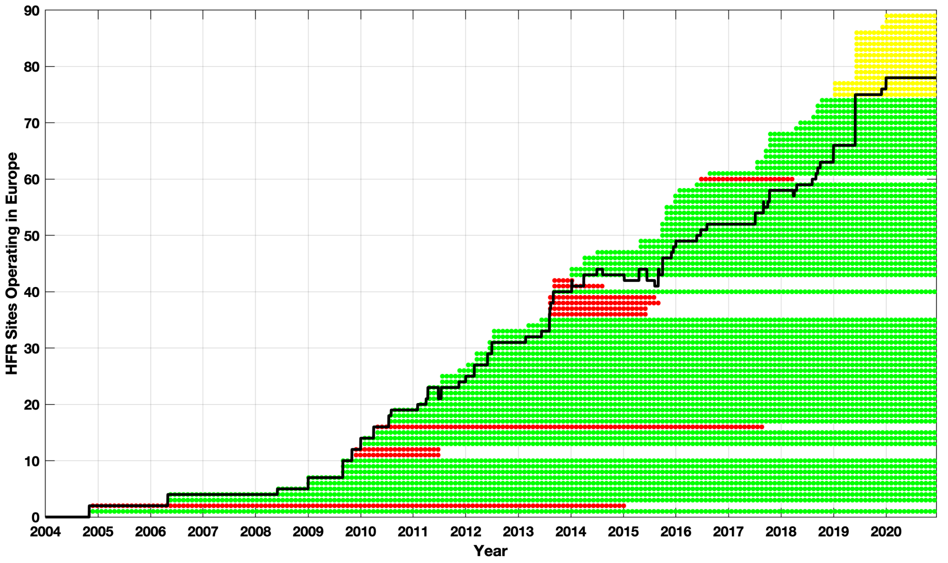
September 16-20, 2019

# Growth of HFR Stations

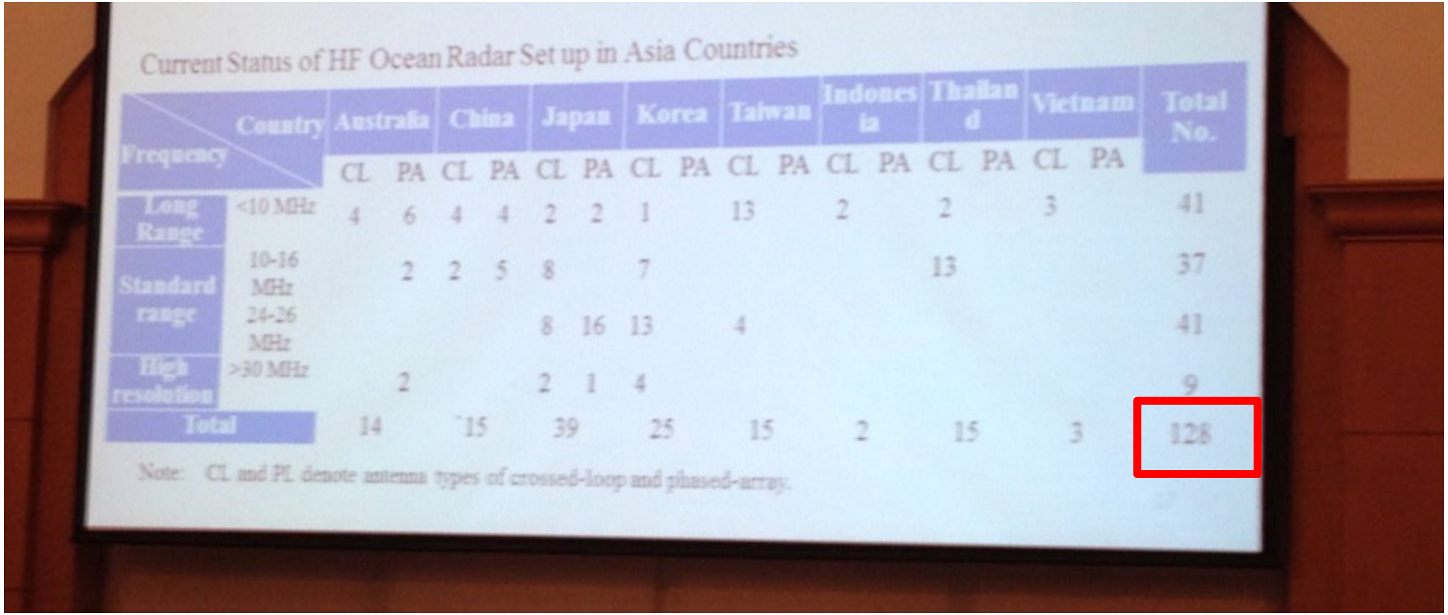
### *North America*




### *Europe*



# ORCA 2014 MEETING INVENTORY

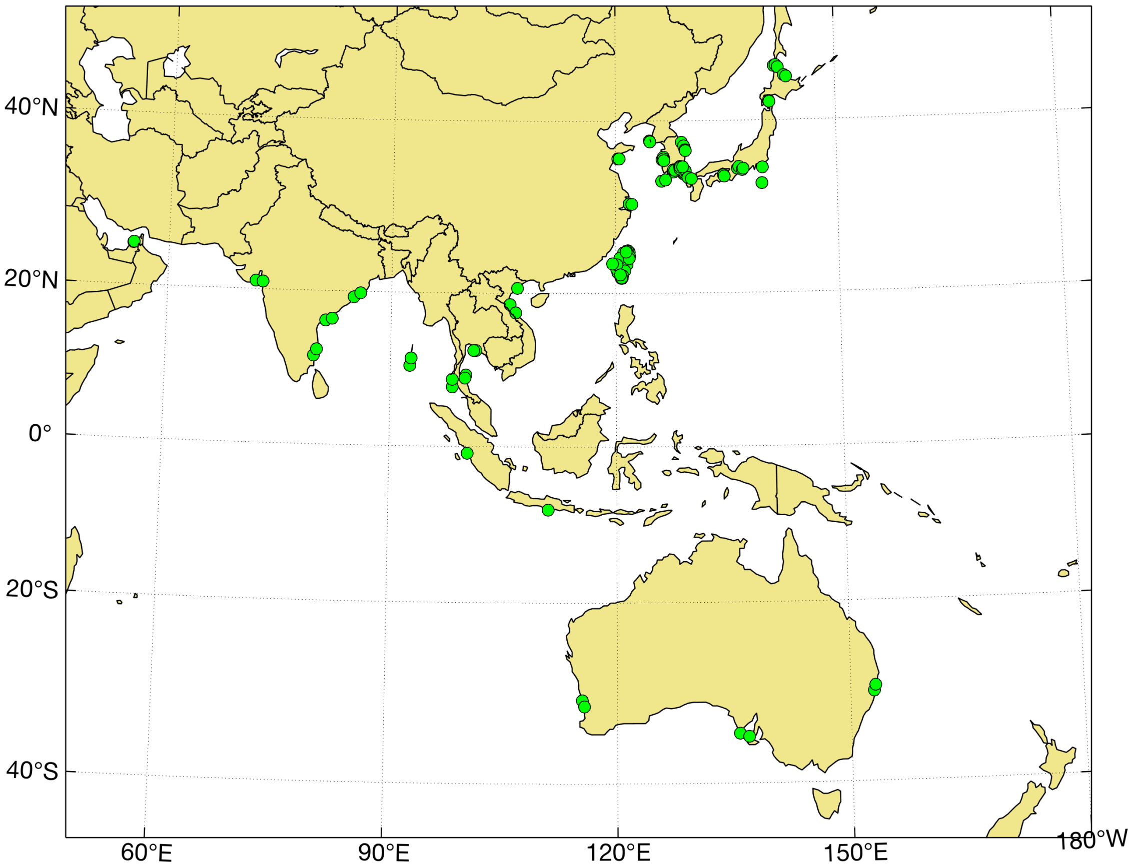


Current Status of HF Ocean Radar Set up in Asia Countries

| Frequency / Country | | Australia | | China | | Japan | | Korea | | Taiwan | | Indonesia | | Thailand | | Vietnam | | Total No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CL | PA | CL | PA | CL | PA | CL | PA | CL | PA | CL | PA | CL | PA | CL | PA | |
| Long Range | <10 MHz | 4 | 6 | 4 | 4 | 2 | 2 | 1 | | 13 | | 2 | | 2 | | 3 | | 41 |
| Standard range | 10-16 MHz | | 2 | 2 | 5 | 8 | | 7 | | | | | | 13 | | | | 37 |
| | 24-26 MHz | | | | | 8 | 16 | 13 | | 4 | | | | | | | | 41 |
| High resolution | >30 MHz | | 2 | | | 2 | 1 | 4 | | | | | | | | | | 9 |
| Total | | 14 | | 15 | | 39 | | 25 | | 15 | | 2 | | 15 | | 3 | | 128 |

Note: CL and PL denote antenna types of crossed-loop and phased-array.

# EXISTING INVENTORY




87 radars in database

# The Global Ocean Observing System

# What is GOOS?

The **Global Ocean Observing System** (GOOS) is a permanent global system for observations, modeling, and analysis of marine and ocean data that aims to contribute to its highest capacity towards building an integrated and responsive global system.

## Delivery across 3 target application areas

*Climate*

*mitigation and adaptation, seasonal forecasts*

*Forecasts and warnings*

*supporting the marine economy and reducing risk*

*Ocean health*

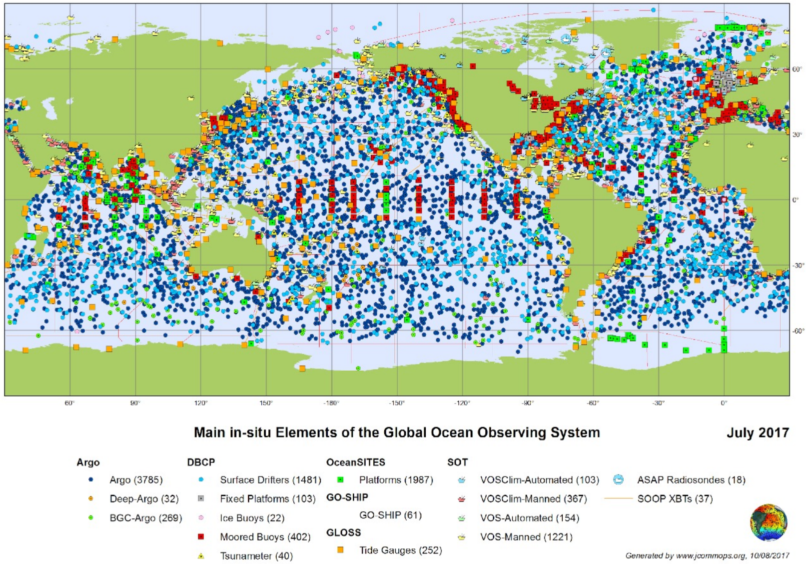
*sustainability of ocean ecosystem services*

# The role of OCG

The Observation Coordination Group (OCG) works to **efficiently operate, maintain, coordinate** and **integrate** a comprehensive *in-situ* global ocean observing system

**OCG now targets 8 foci:**

1. Requirements
2. Observing Advances
3. Standards and Best Practices
4. Data Management
5. OceanOPS
6. Metrics
7. Environmental Stewardship
8. Capacity Development



# The 12 global Ocean Observing Networks

**Argo**
A window into the ocean, a 20-year-old ocean observing network of autonomous/robotic profiling floats that has revolutionized the way scientists learn about the ocean.

**Data Buoy Cooperation Panel (DBCP)**

Coordinates autonomous data buoys to observe atmospheric and oceanographic conditions over ocean areas where few other measurements are taken.

**Ship Observations Team (SOT)**
Consists of several very successful and enduring data collection programmes involving voluntary observing ships and ships of opportunity.

**Global Sea Level Observing System (GLOSS)**
A well-designed, high-quality sea level observing network supporting a broad research and operational user base.

# The 12 global Ocean Observing Networks

**Animal-Borne Ocean Sensors (AniBOS)**
A network deploying instruments on seals and other marine animals to provide salinity and temperature profiles and behavioural data.

**The Global Ocean Ship-Based Hydrographic Investigations Programme (GO-SHIP)**
Research vessels serving scientists interested in physical oceanography, the carbon cycle, marine biogeochemistry and ecosystems, and other data users and collectors.

**OceanSITES**
A worldwide system of long-term, deepwater moored reference stations measuring many variables and monitoring the full depth of the ocean.

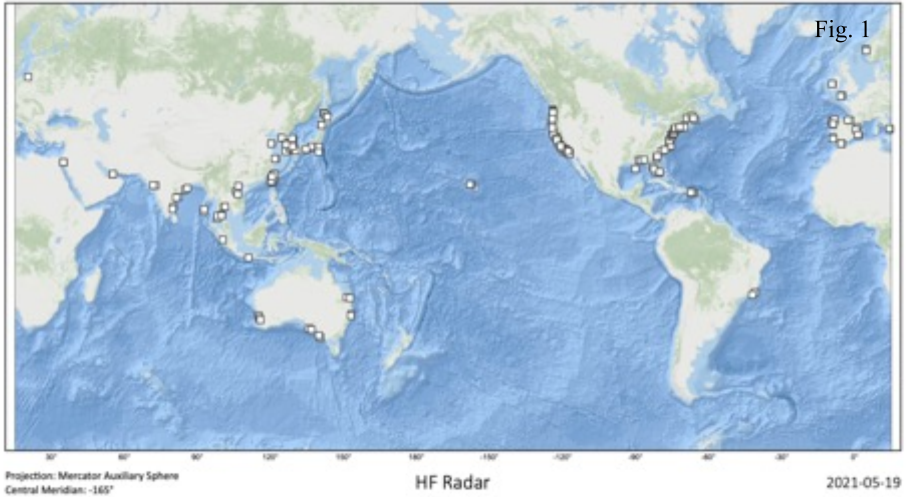
**The Global High Frequency Radar Network**
A vision for a global operational system measuring coastal surface currents to support monitoring of marine and coastal ecosystems.

**Ocean Gliders**
Monitors global glider activity, shares the requirements, efforts and scientific knowledge needed for glider data collection and supports sharing glider data.

Global HF Radar Network

# Global HF Radar

Fig. 1




HFR in Japan

Fig. 2

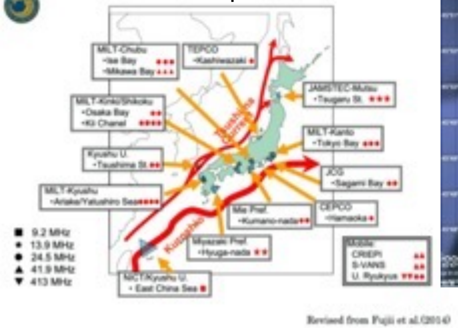
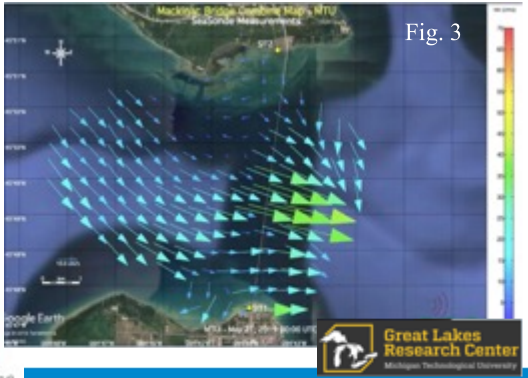



Fig. 3




### Status (March 2022)

- 72 stations In Region 1 (Europe, Africa, Middle East) reporting data in real-time.
- 182 stations reporting in Region 2 (North and South America)
- 140 radars operating in Region 3 (Asia and Oceania)

### Recent achievements

- A governance structure for the HFR community has been proposed (EUROSEA D3.4)
- New release of the Copernicus Marine Service delayed-mode product dedicated to in-situ observations of water velocity with historical data reporting
- The first US operational freshwater HF radar system went fully active on October 18, 2022 (Fig. 3)
- MARACOOS HFR wave data was used operationally by the National Weather Service on October 6, 2021 during the passage of Hurricane Sam.
- The annual meeting of HFR user communities in Japan was held in December 2021 in Fukuoka.
- Taiwan, Province of China plans to increase radar coverage from 19 stations to 65 stations by 2024 (42 HFR and 23 microwave radars)

### Foci for the Year 2021

- Finish work with for OceanOPS to integrate Global HFR Network in their monitoring network.

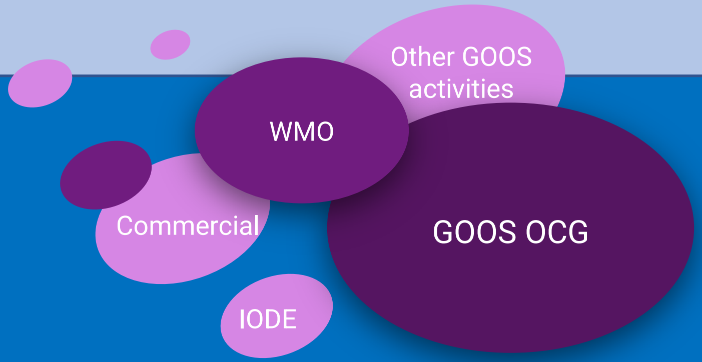
# Who is OCG?

Global Ocean Observing Networks

Emerging global observing networks

Observation Coordination Group Executive

Chair, Vice Chairs WMO/Technical, Standards and Best Practice, Data Management, Developing Community representative



# Ocean Observing Report Card 2020 - status of the global observing networks

| GOOS *in situ* networks[1] | Implementation | Data & metadata | | | Best practices[6] | GOOS delivery areas[7] | | |
|---|---|---|---|---|---|---|---|---|
| | Status[2] | Real time[3] | Archived high quality[4] | Meta-data[5] | | Opera-tional services | Climate | Ocean health |
| 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 | ★★★ | ★☆☆ | ★★★ | ★★☆ | ★★★ | | ✓ | ✓ |
| OceanGliders | ★☆☆ Emerging | ★★☆ | ★☆☆ | ★★☆ | ★☆☆ | ✓ | ✓ | ✓ |
| HF radars | Emerging | ★★★ | ★★★ | ★☆☆ | ★★★ | ✓ | ✓ | ✓ |
| Biogeochemistry & Deep floats - Argo | ★☆☆ Emerging | ★★★ | ★☆☆ | ★★★ | ★★☆ | ✓ | ✓ | ✓ |
| Animal borne ocean sensors - AniBOS | Emerging | ★★★ | ★☆☆ | ★☆☆ | ★★☆ | ✓ | ✓ | ✓ |

The Global Ocean Observing System

Спасибо

Thank you

Gracias

Merci

谢谢

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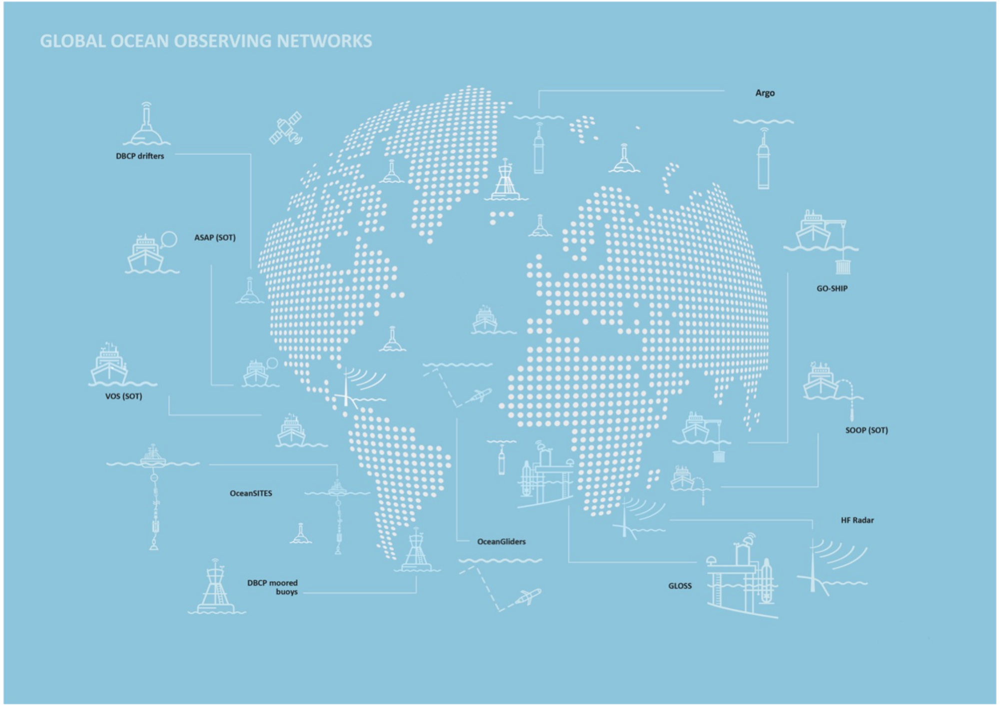
# The Global High Frequency Radar Network




United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

WORLD METEOROLOGICAL ORGANIZATION

UN environment United Nations Environment Programme

International Science Council