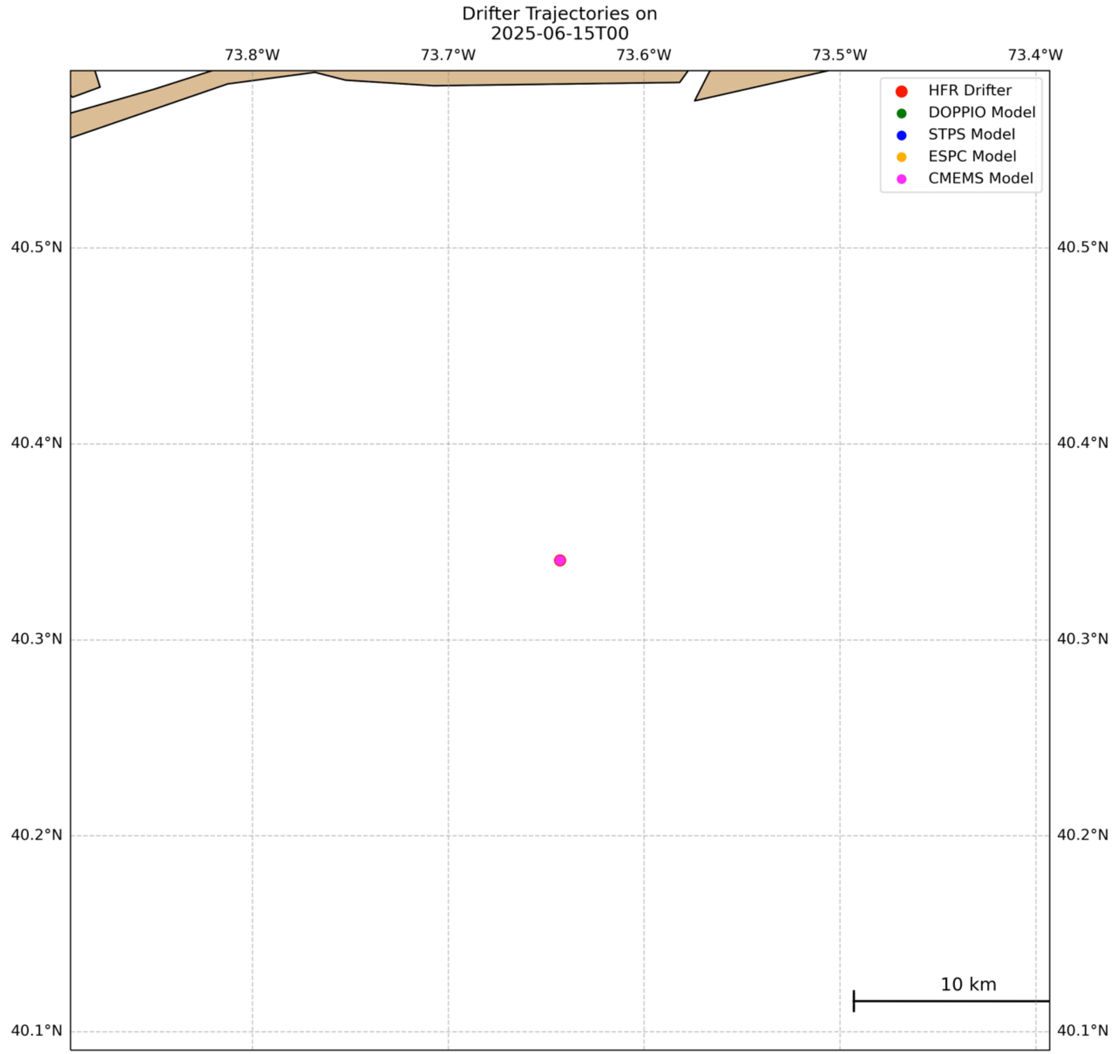
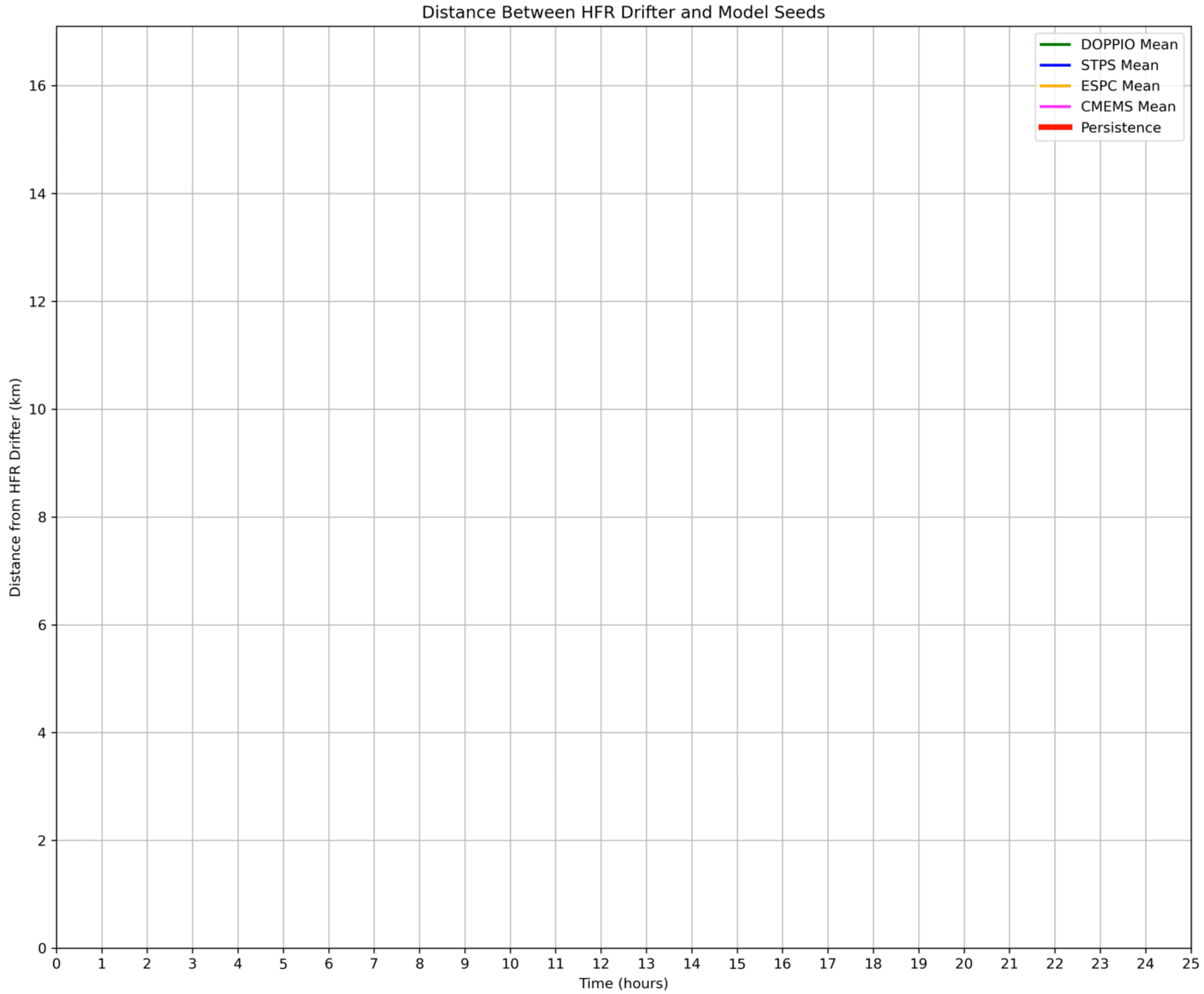
The History of Oceanographic High Frequency Radar at Rutgers University

Hugh Roarty
Josh Kohut
Tim Stolarz
Michael Smith
Jacquelyn Veatch
Ethan Handel
Scott Glenn

Generalitat de Catalunya
CODAR OCEAN SENSORS
qualitas remos
MARACOOS Ocean Information for a Changing World
IOOS Integrated Ocean Observing System
NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE



Distance Between HFR Drifter and Model Seeds



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Surface currents in operational oceanography: Key applications, mechanisms, and methods

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ABSTRACT
This paper reviews physical mechanisms, observation techniques and modelling approaches dealing with surface currents on short time scales (hours to days) relevant for operational oceanography. Key motivations for this article include fundamental difficulties in reliable measurements and the persistent lack of a widely held consensus on the definition of surface currents. These problems are augmented by the fact that various methods to observe and model ocean currents yield very different representations of a surface current. We distinguish between four applicable definitions for surface currents; (i) the interfacial surface current, (ii) the direct wind-driven surface current, (iii) the surface boundary layer current, and (iv) an effective drift current. Finally, we discuss challenges in synthesising various data sources of surface currents - i.e. observational and modelling – and take a view on the predictability of surface currents concluding with arguments that parts of the surface circulation exhibit predictability useful in an operational context.

ARTICLE HISTORY
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Accepted 28 February 2021

KEYWORDS
Surface currents; forecasting; upper ocean dynamics; ocean observation; ocean modelling

1. Introduction

Surface currents are a central subject in operational oceanography with rapidly growing observing and forecasting capabilities. We are entering an era where observations provide a sufficient level of detail, and numerical models the predictive skill, for applications to use surface current information to aid marine safety, value creation and environmental monitoring. Observation techniques now provide real-time surface current fields at the scale of kilometres (Isern-Fontanet et al. 2017), and high-resolution ocean models are on the verge of having predictive skill on short time scales (Jacobs et al. 2014b; Sandery and Sakov 2017; Christensen et al. 2018). In this context, we consider short time scales, i.e. time scales characterised by the inertial period (hours to a few days).

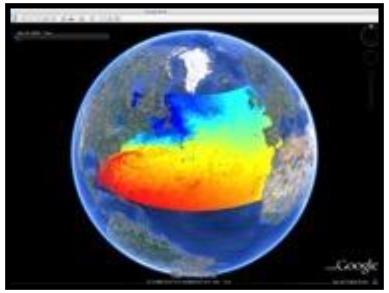
Rutgers University - Coastal Ocean Observation Lab

Observatory Operations, Data Fusion & Training Center

L-Band & X-Band Satellite Receivers

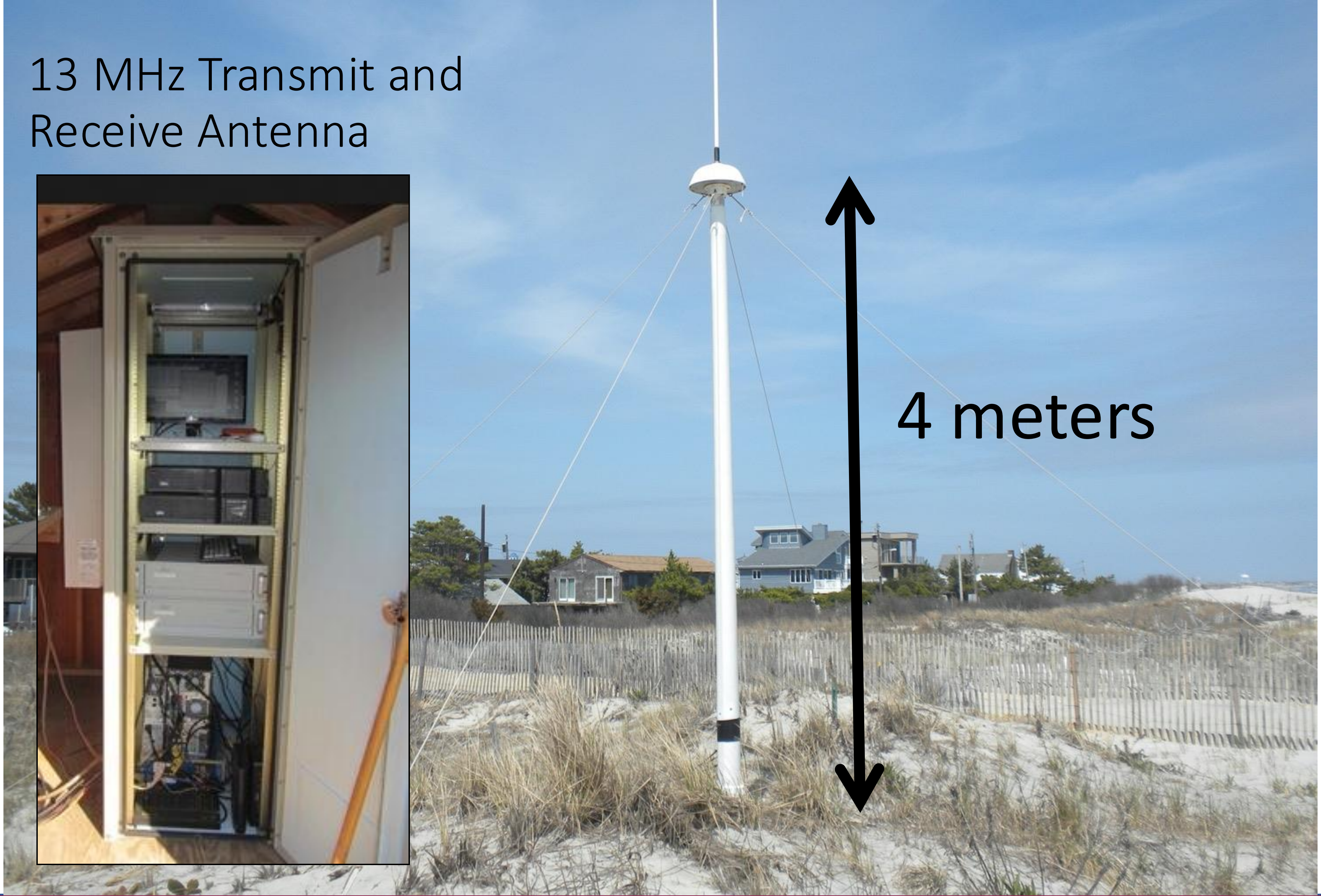
CODAR Network

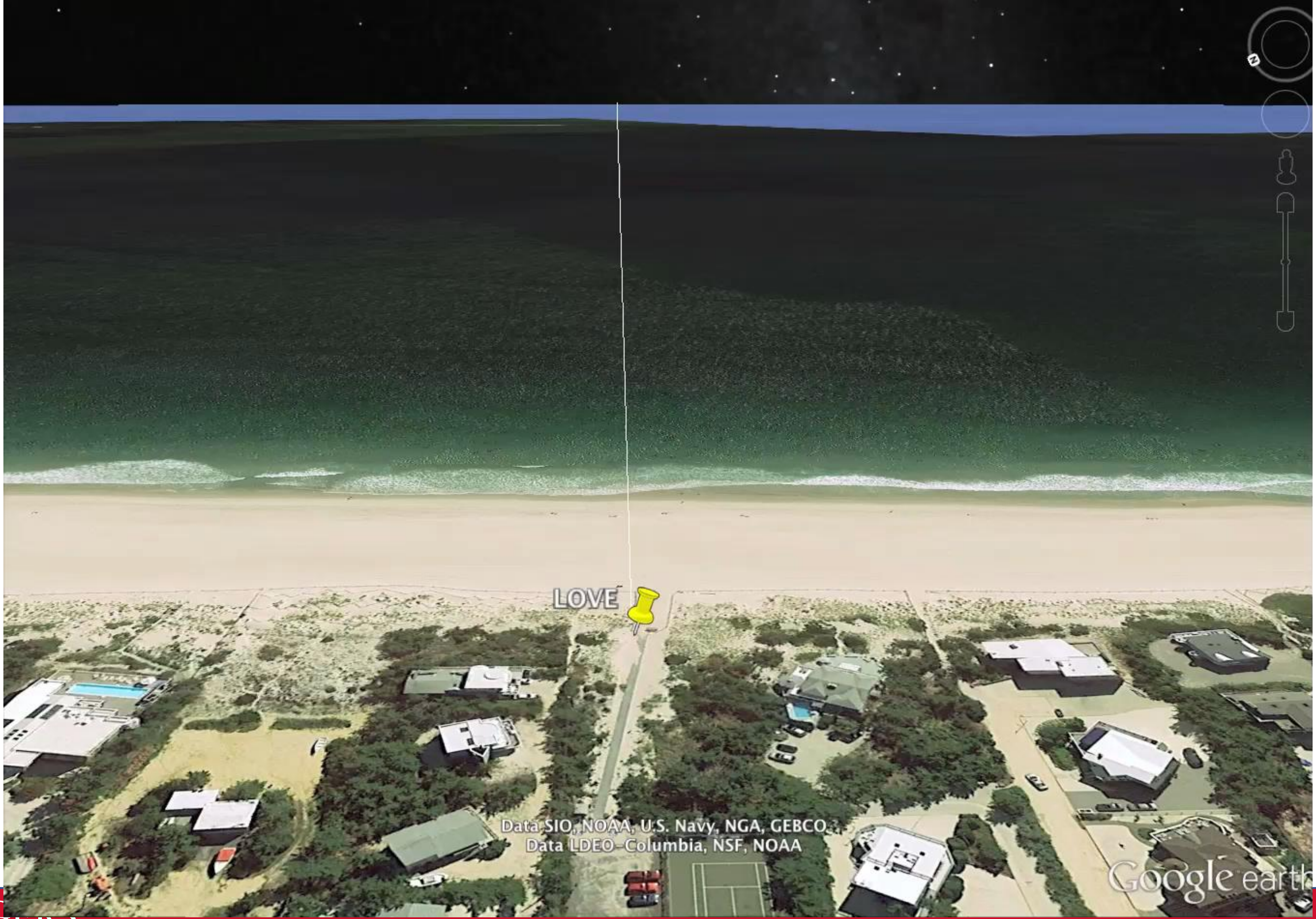
Glider Fleet



3-D Nowcasts & Forecasts

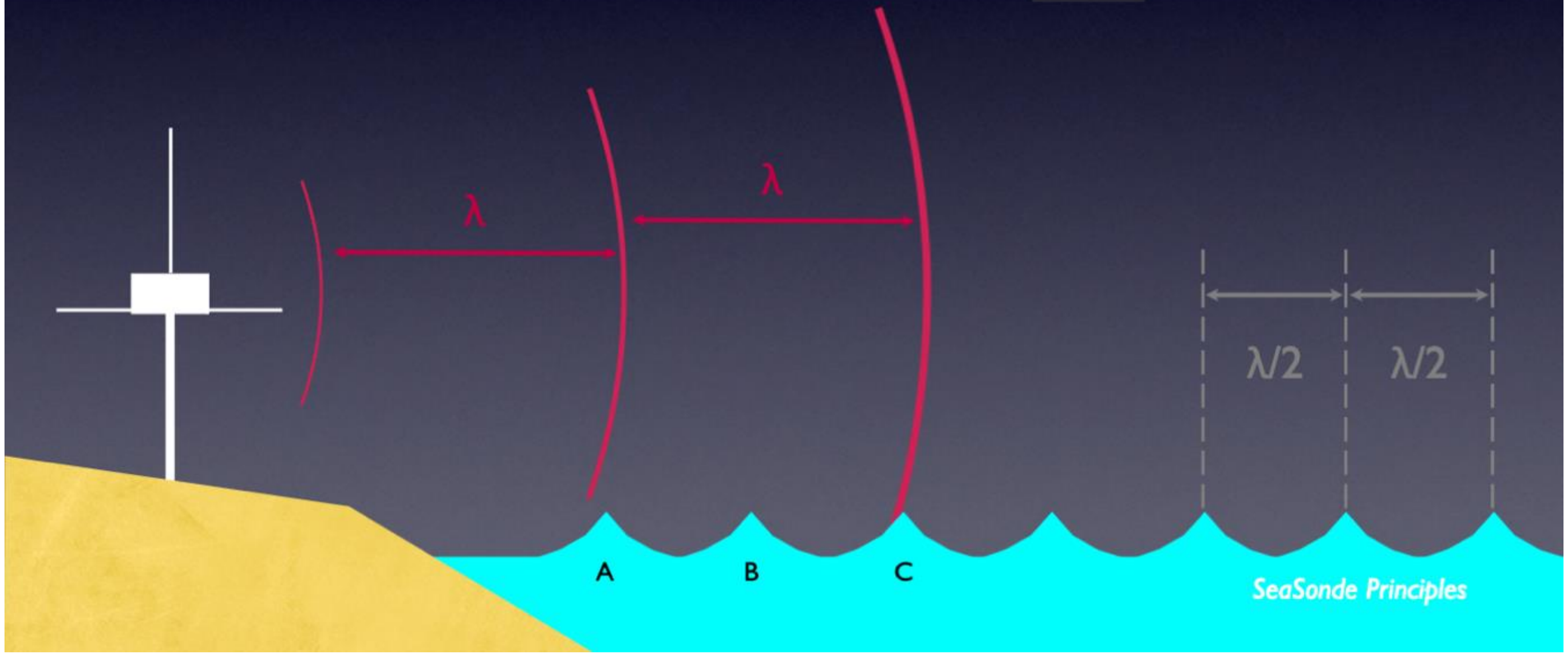
13 MHz Transmit and Receive Antenna




LOVE
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data LDEO-Columbia, NSF, NOAA
Google earth

Bragg Sea Echo

Freq mhz	λ meters	λ/2 meters	T seconds
5	60	30.0	4.4
13	23	11.5	2.7
25	12	6.0	2.0
42	7	3.6	1.5



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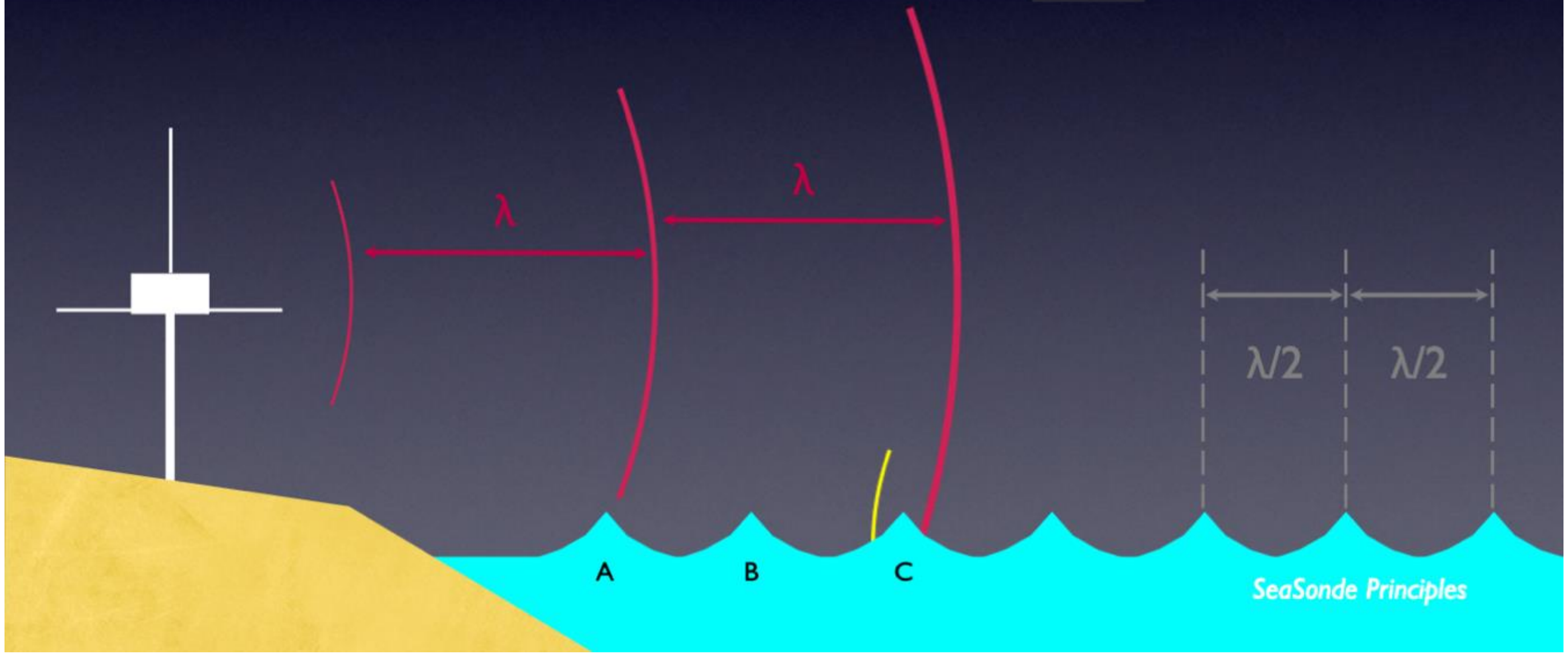

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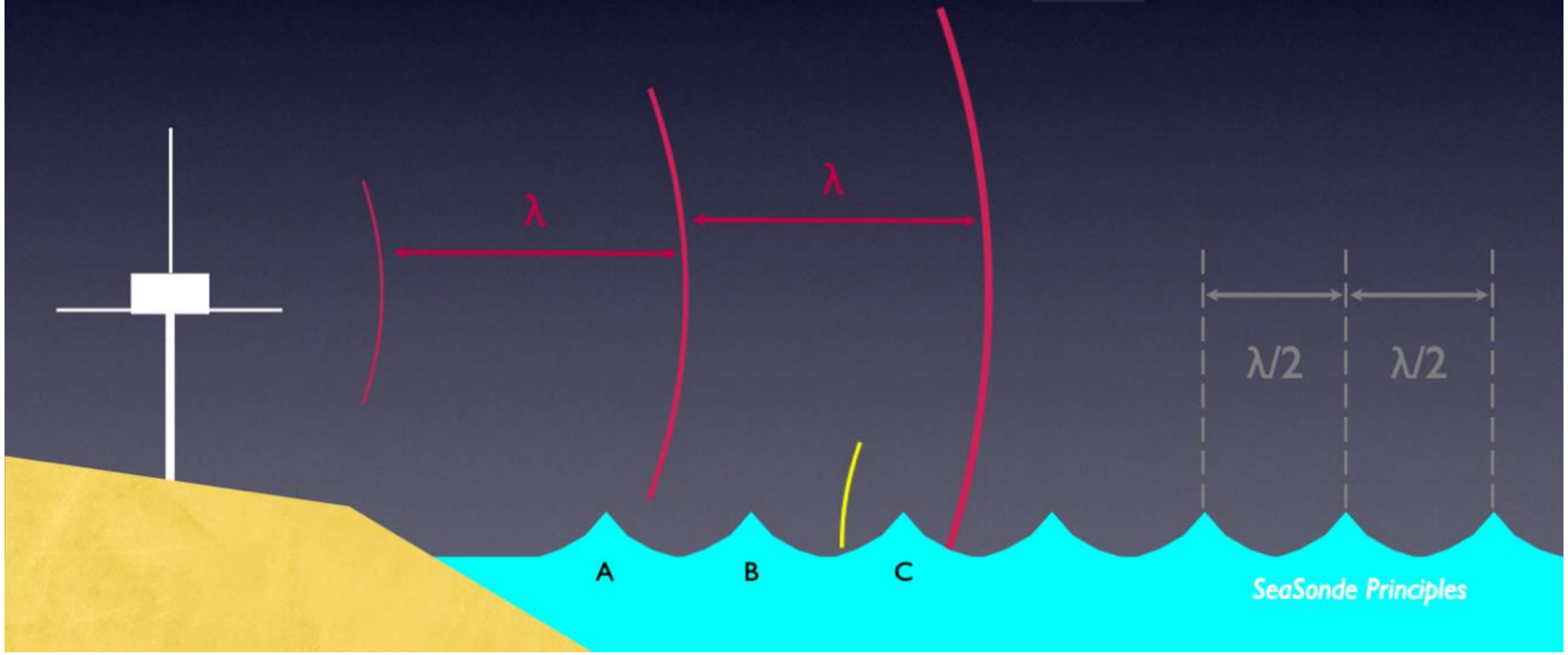

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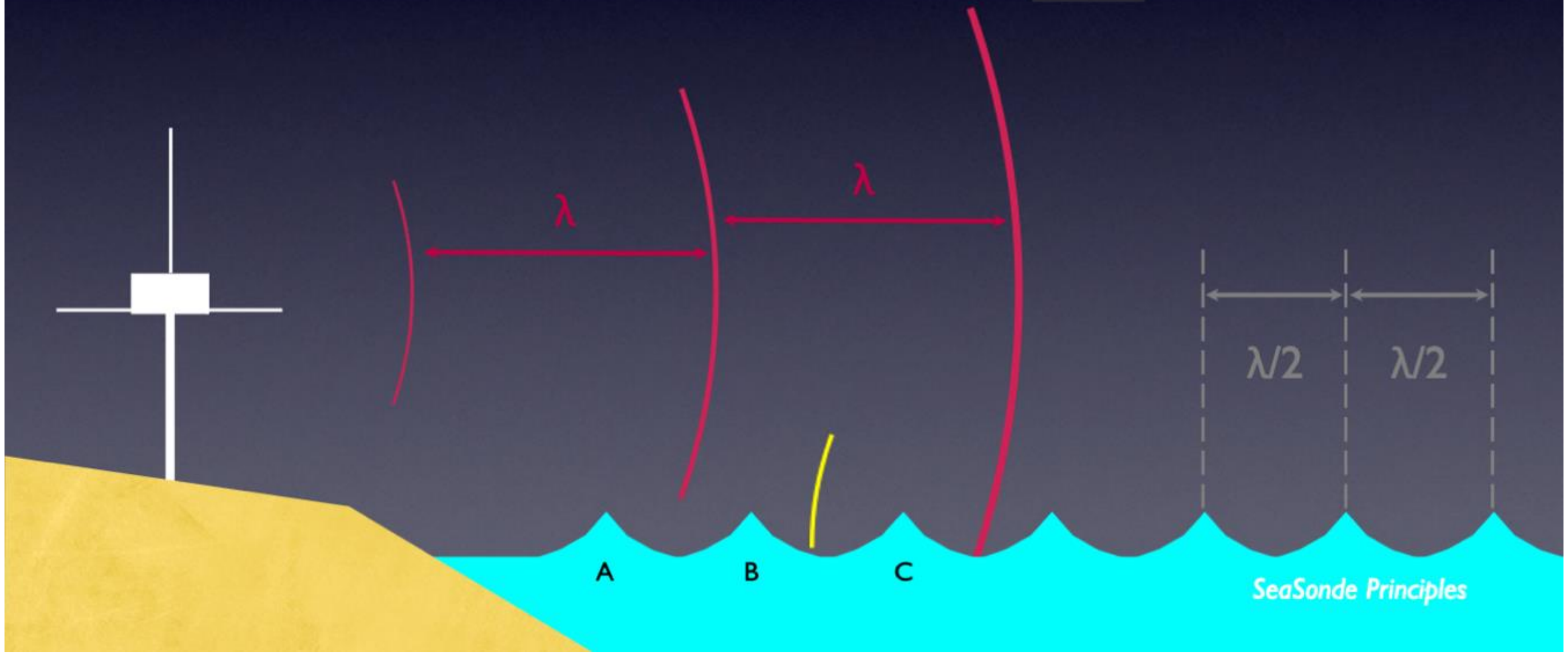

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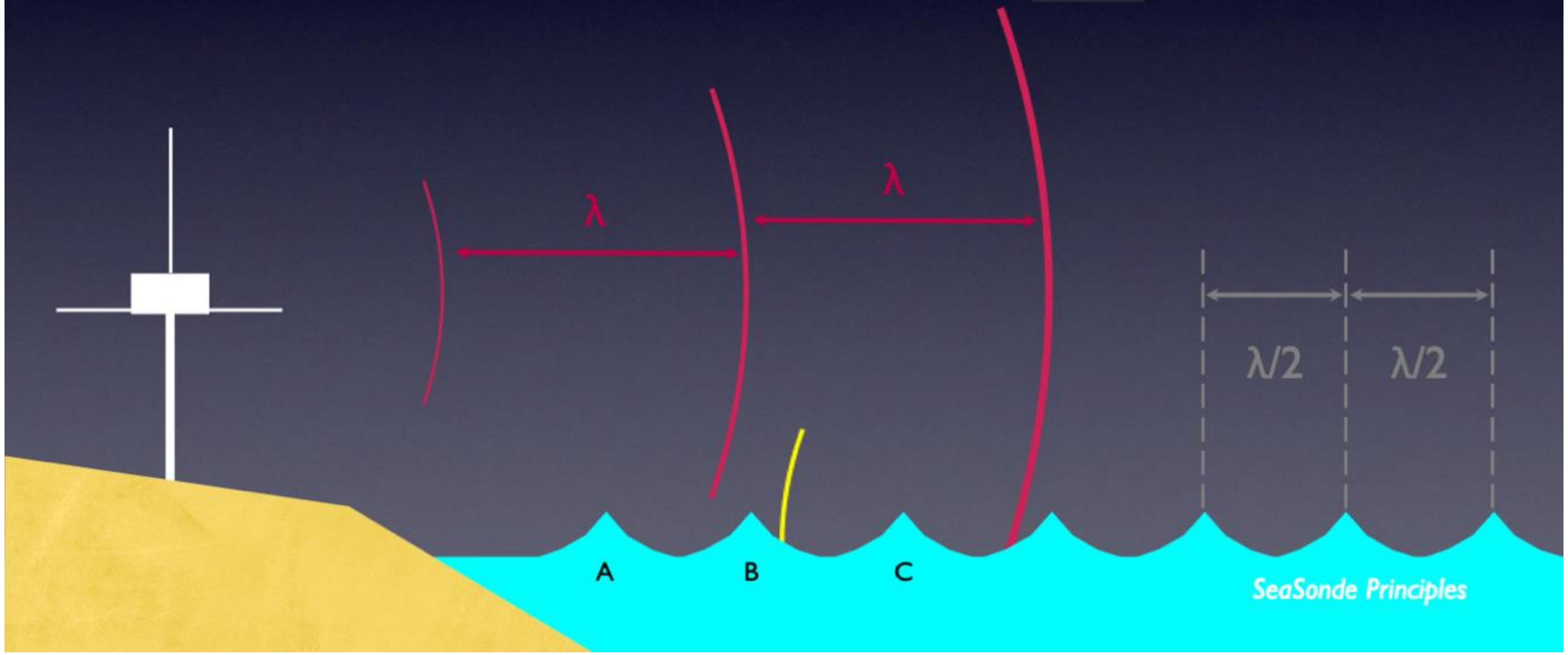

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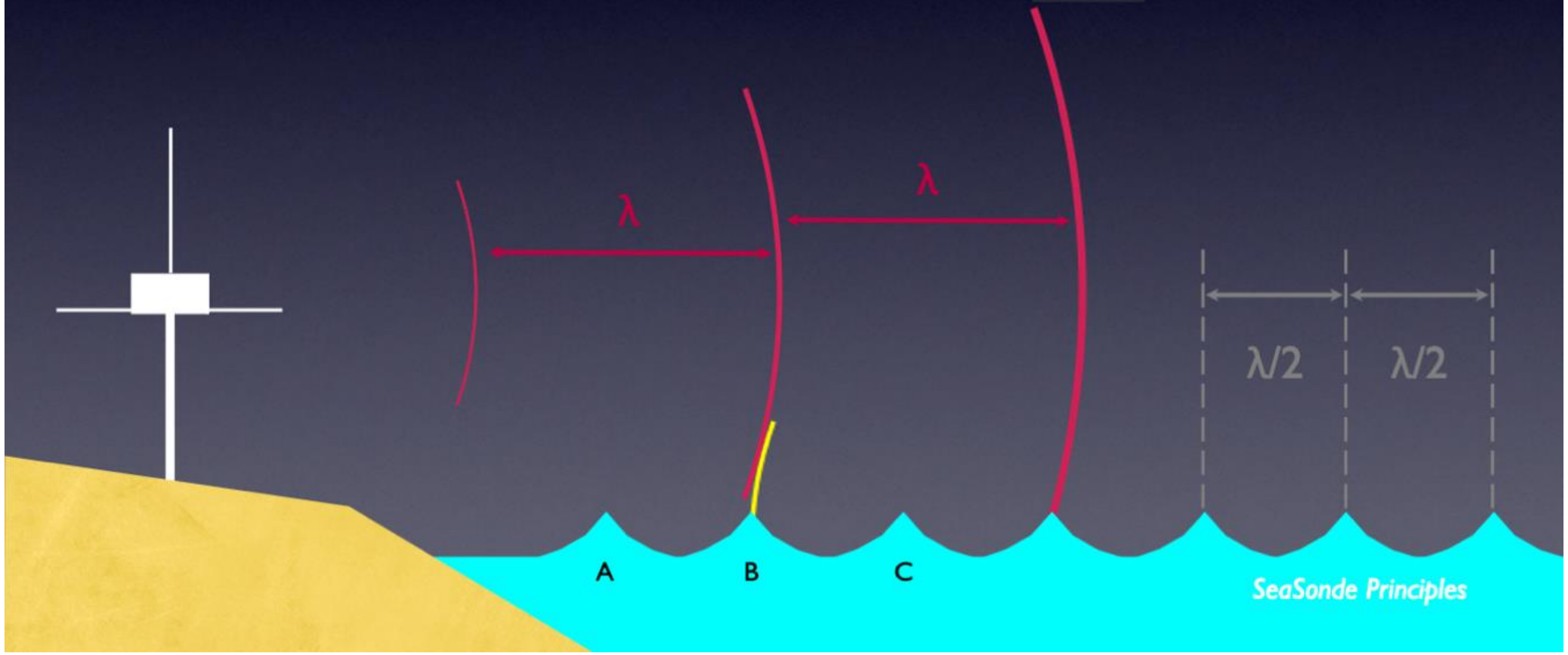

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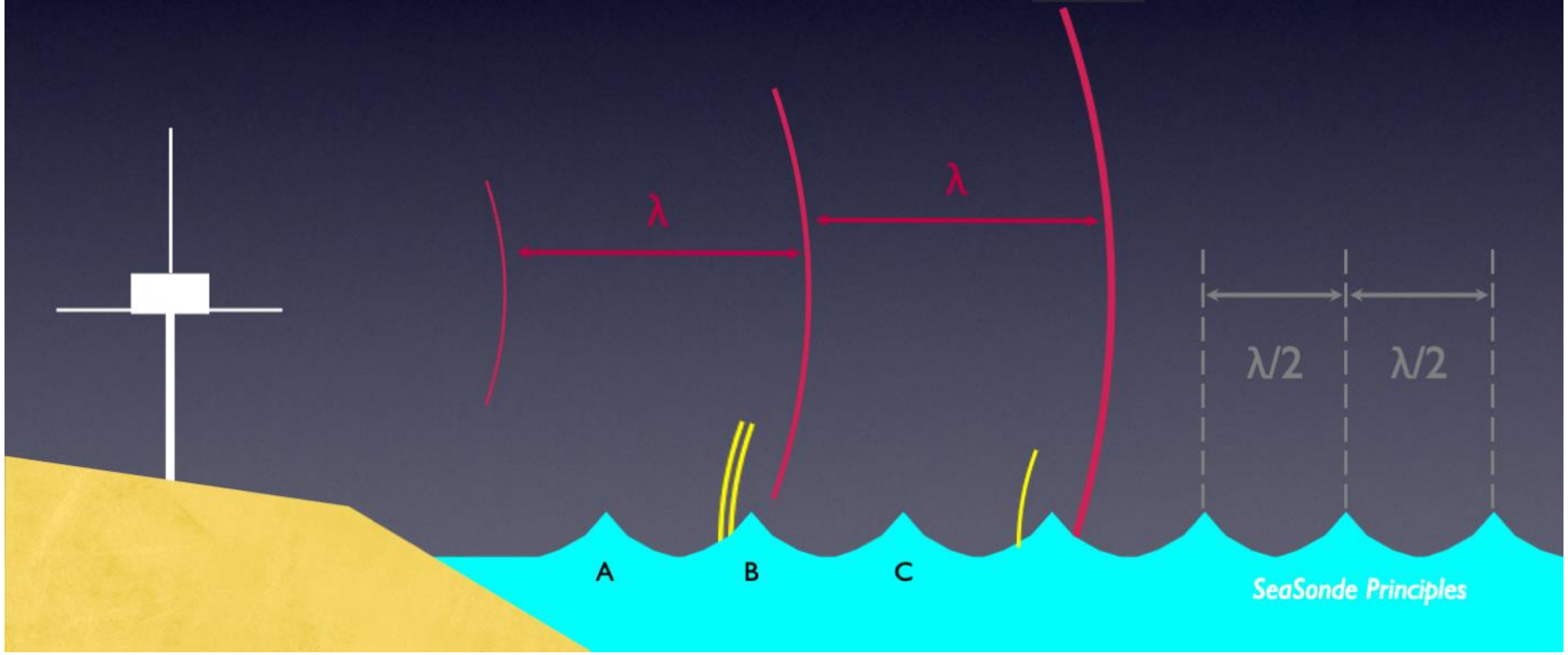
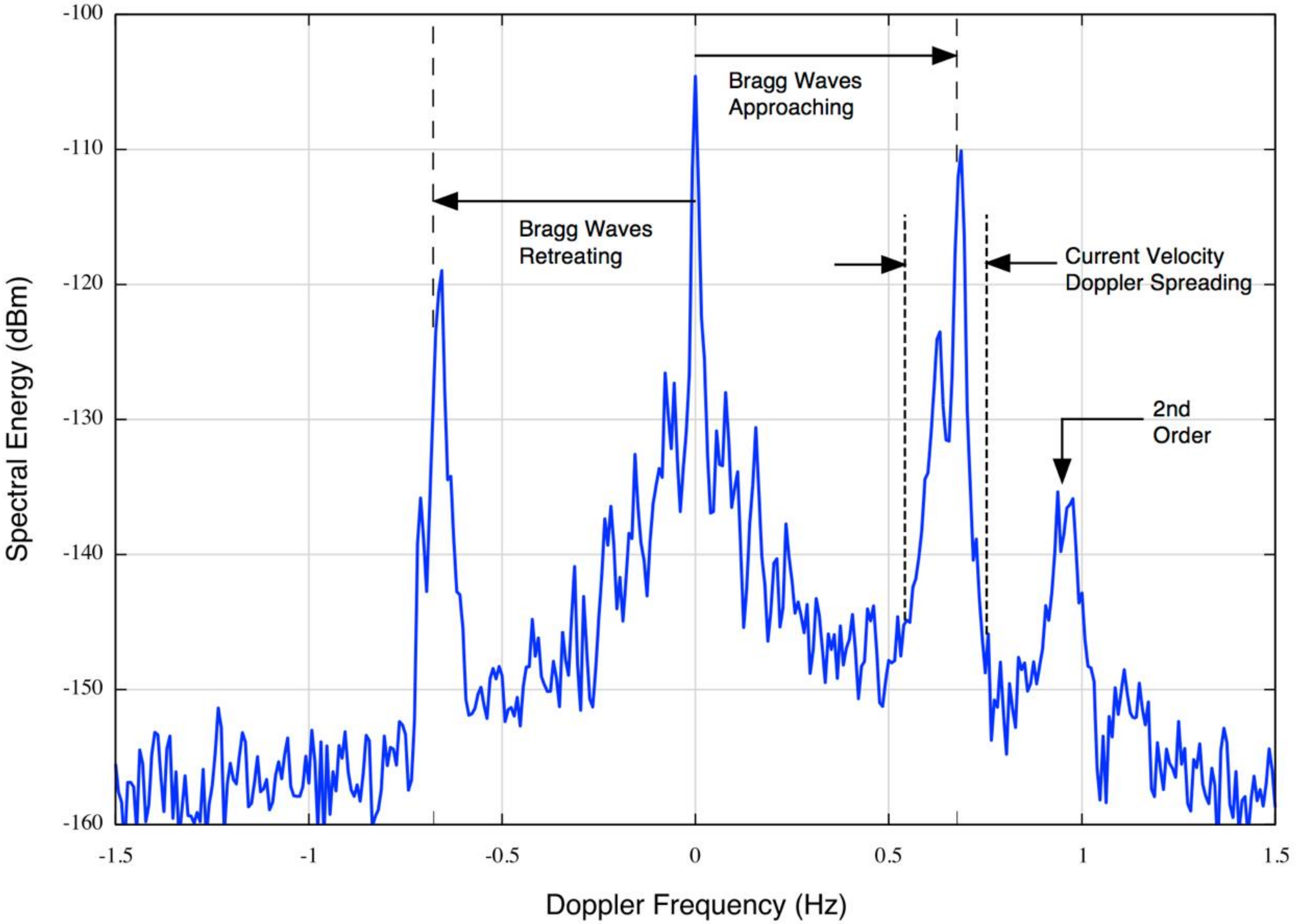
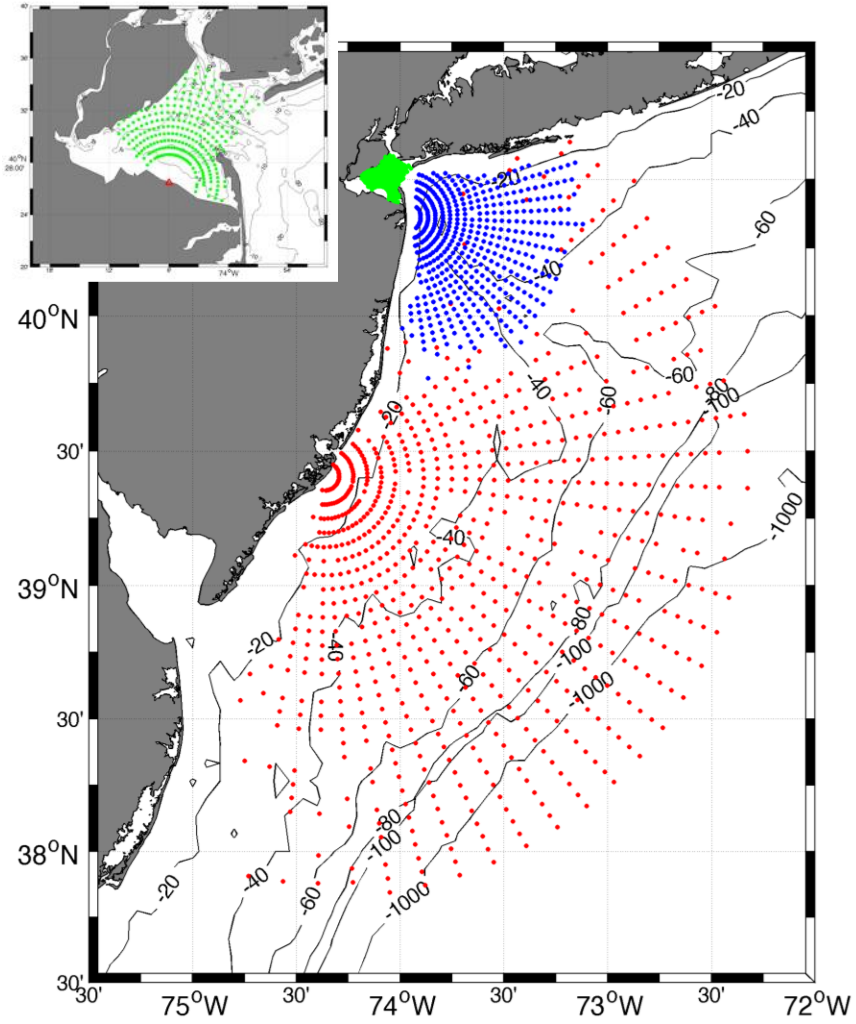


Doppler Spectra From the Radar



Surface Current Mapping Capability



25 MHz

Radar λ: 12 m   Ocean λ: 6 m

Range: 30 km   Resolution: 1 km

13 MHz

Radar λ: 23 m Ocean λ: 12 m

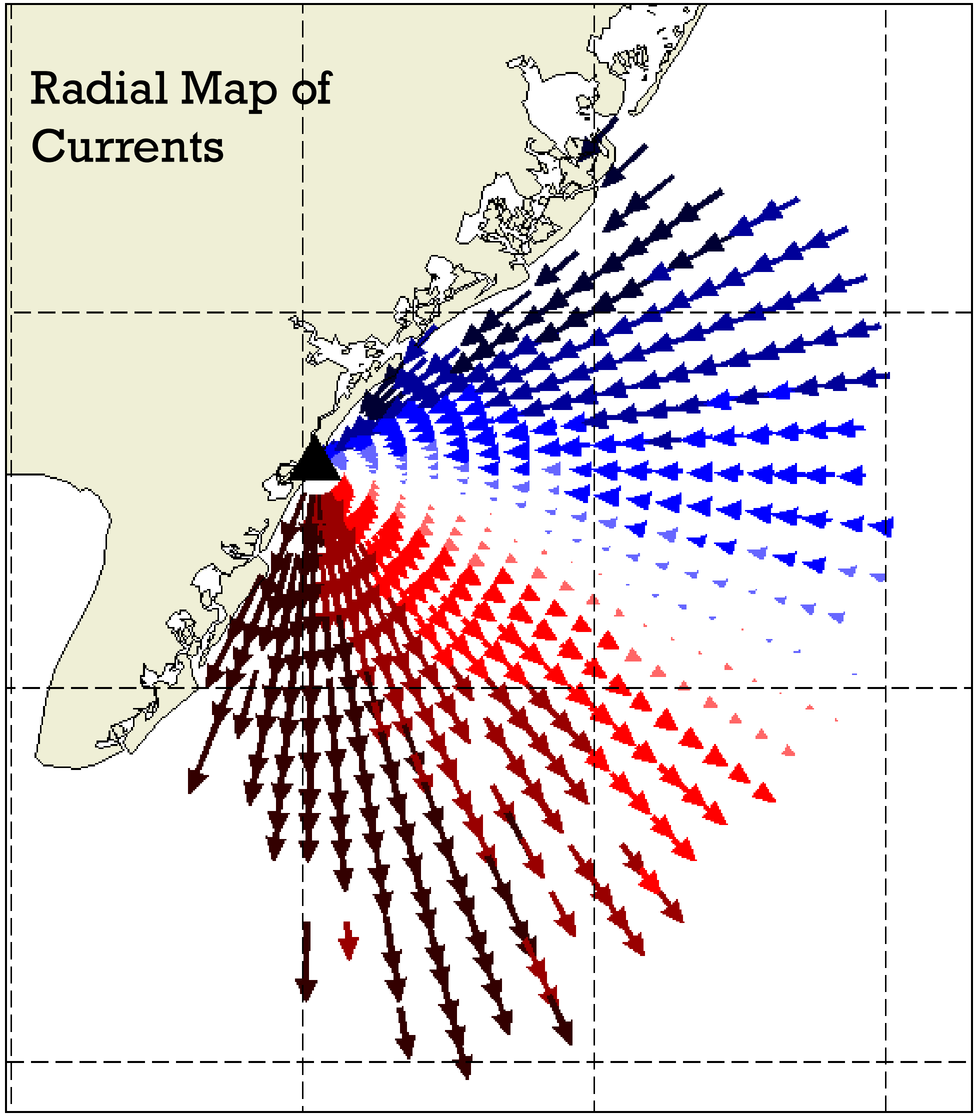
Range: 80 km   Resolution: 3 km

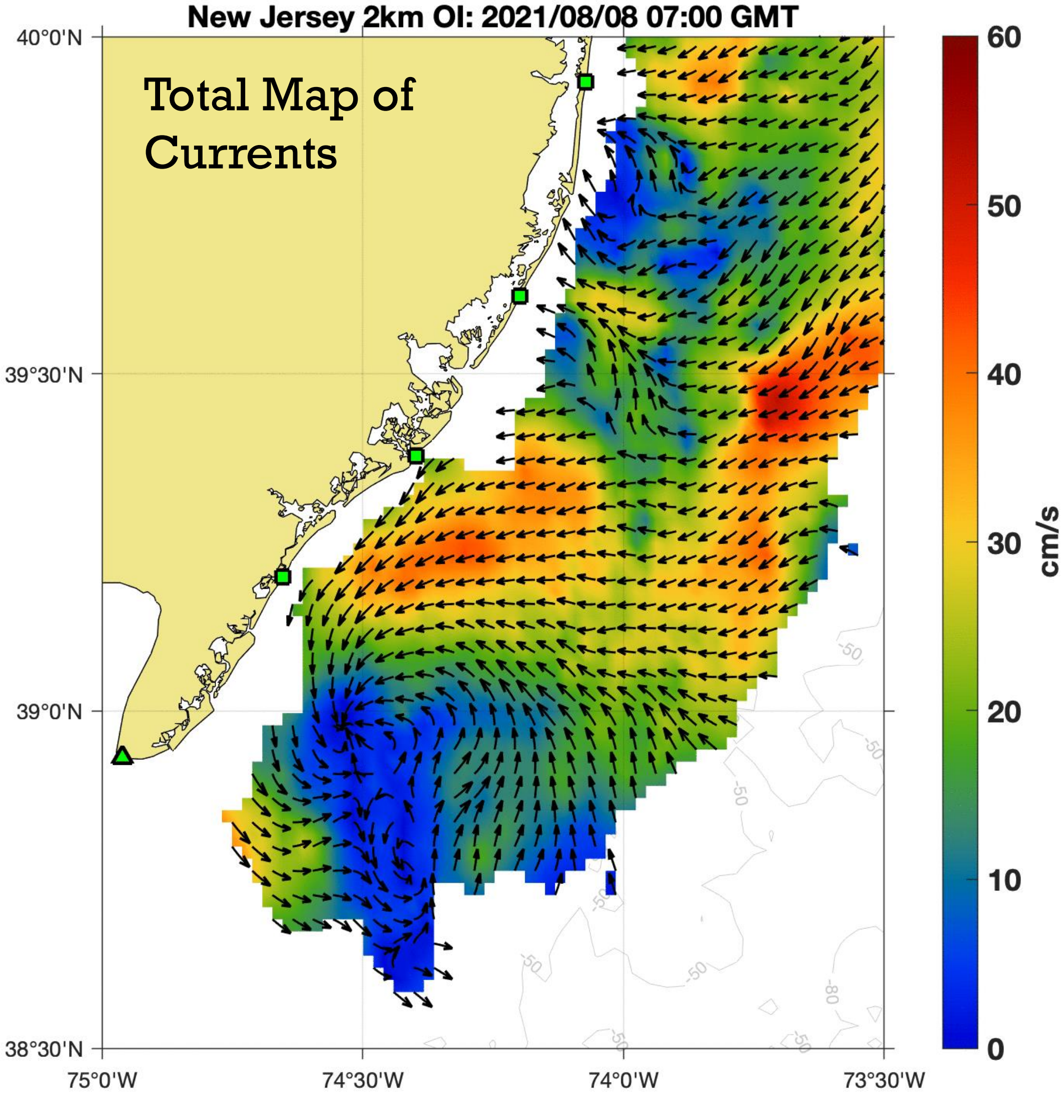
05 MHz

Radar λ: 60m   Ocean λ: 30 m

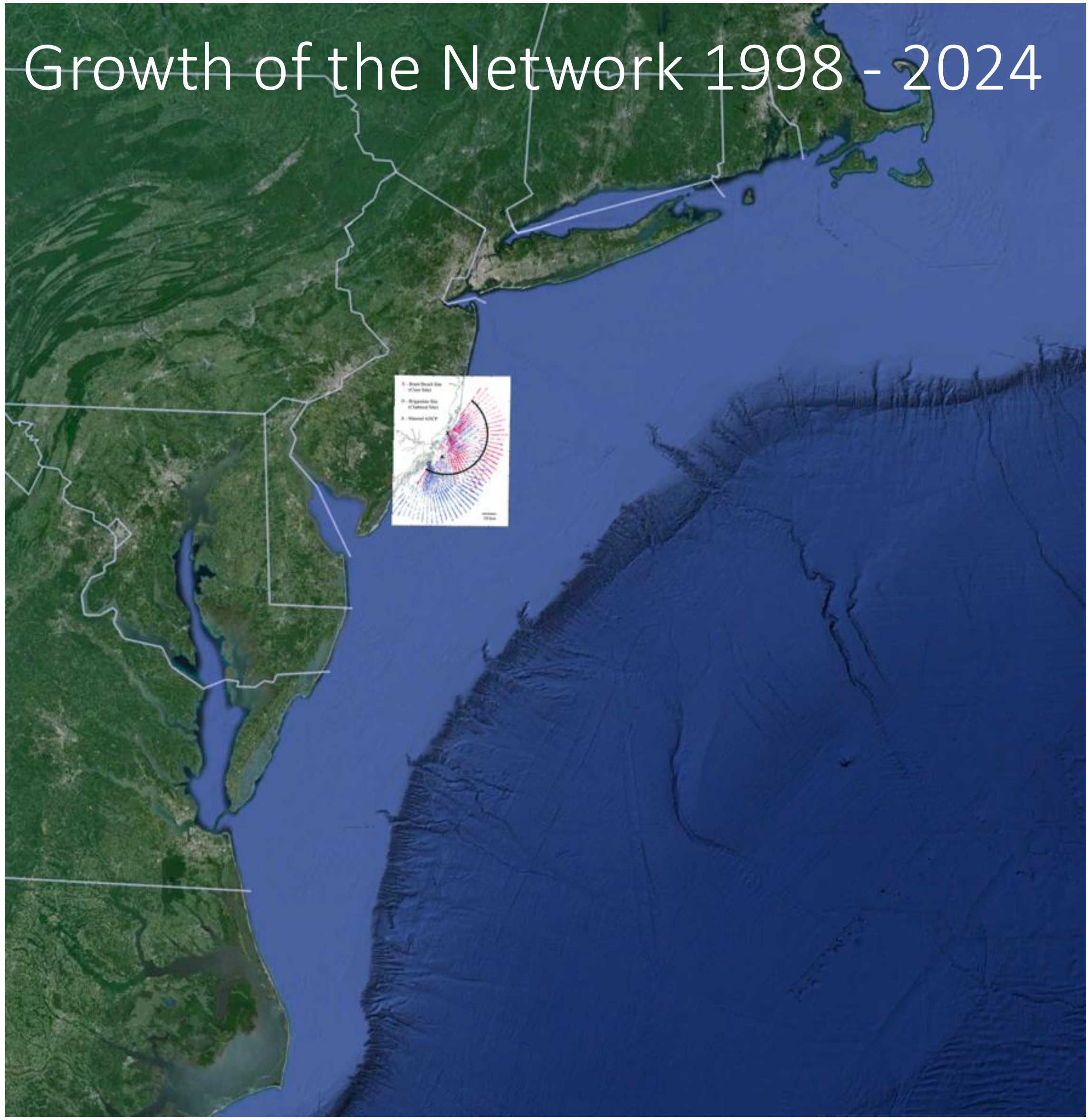
Range: 180 km   Resolution: 6 km

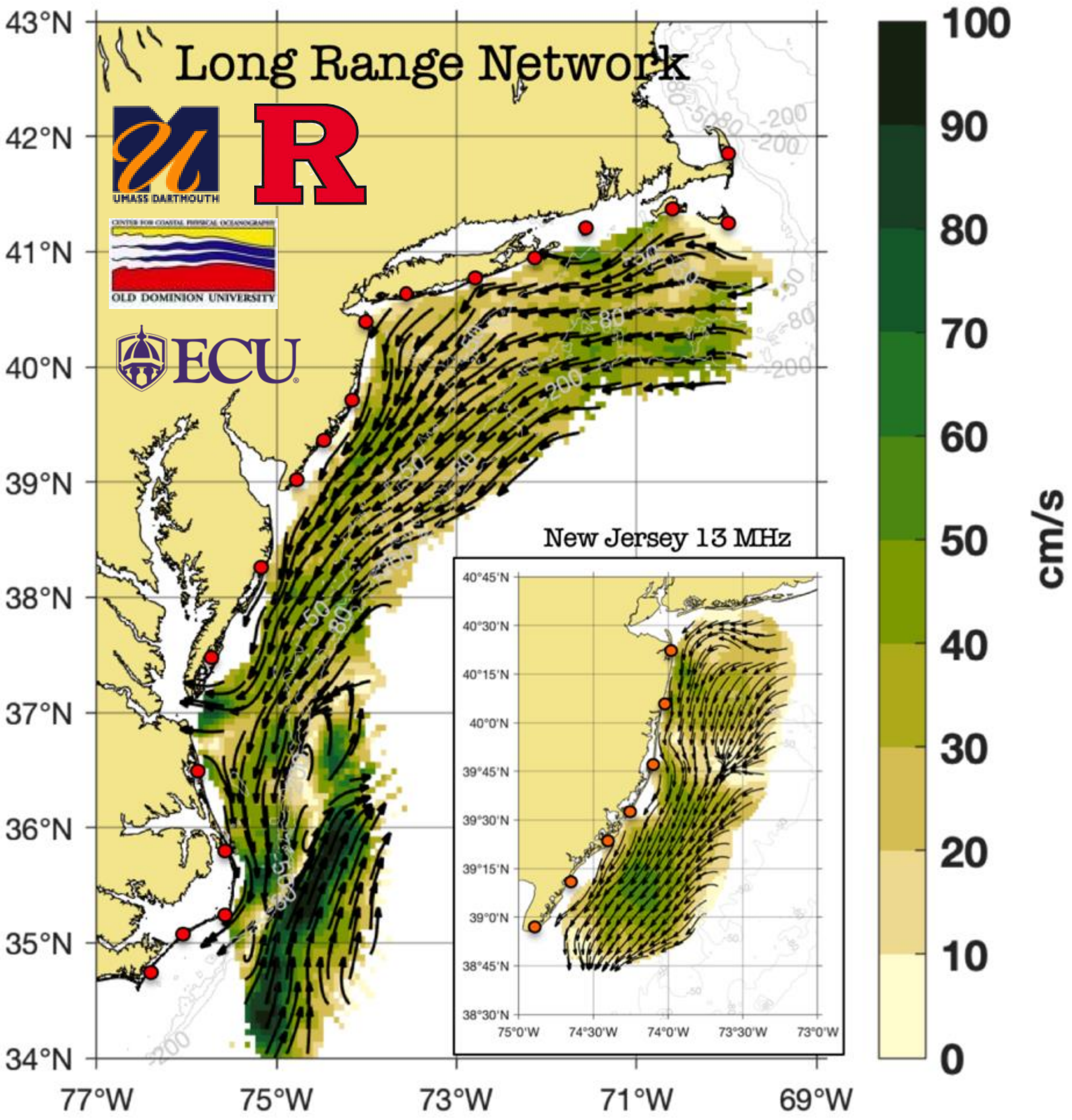
Surface Currents from SeaSonde HF Radar



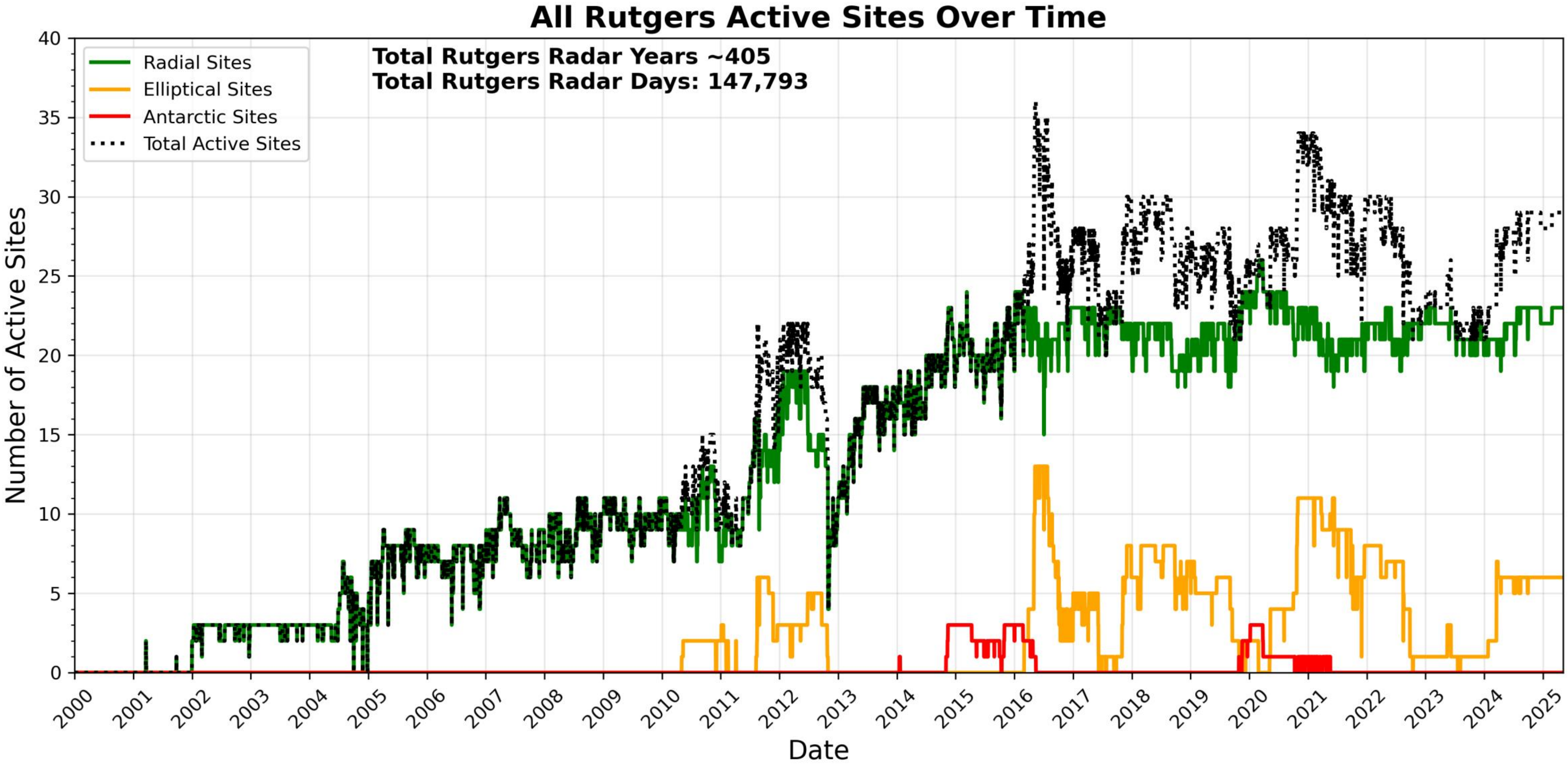


Growth of the Network 1998 - 2024

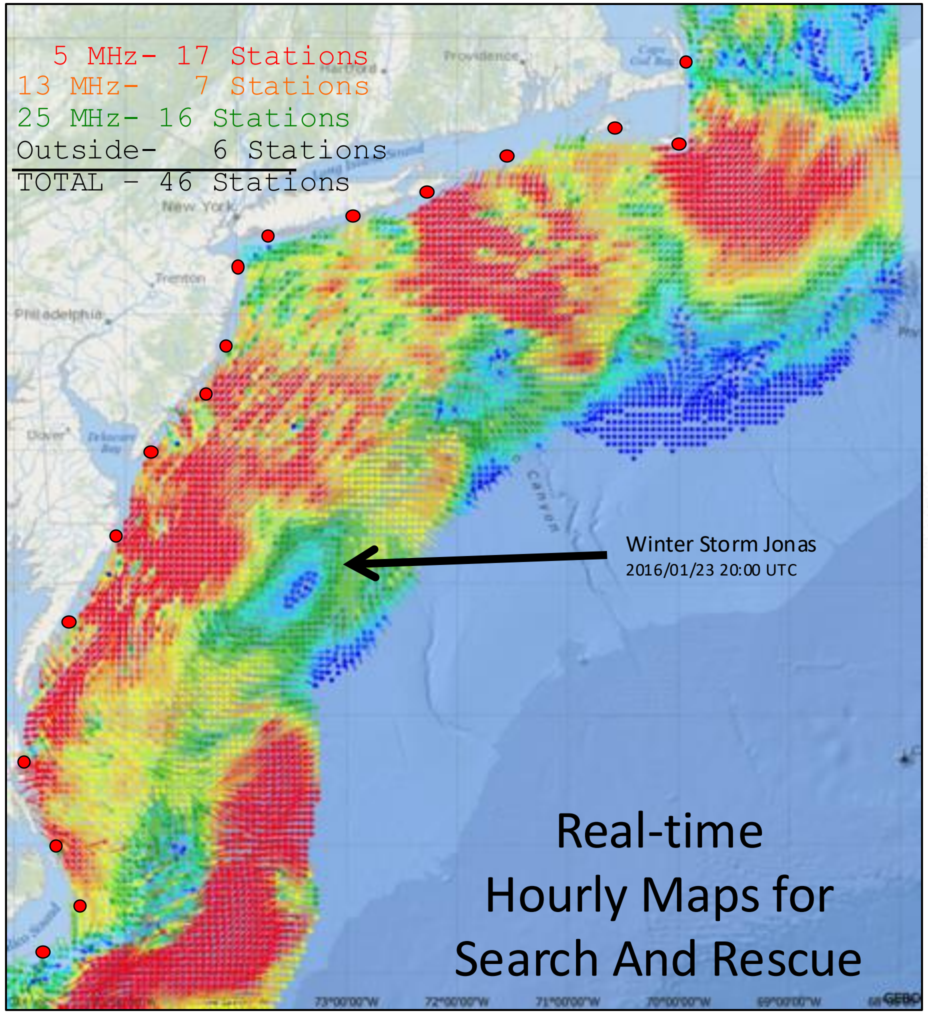


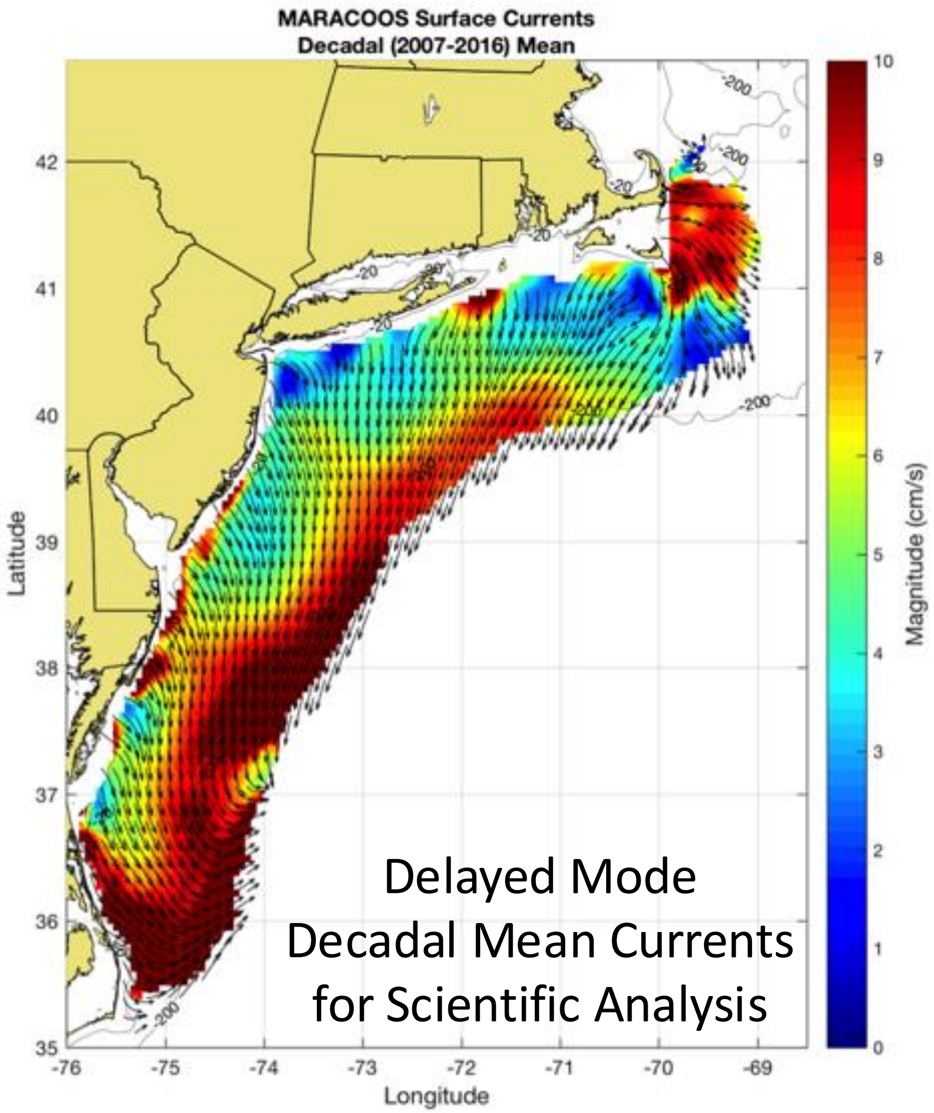


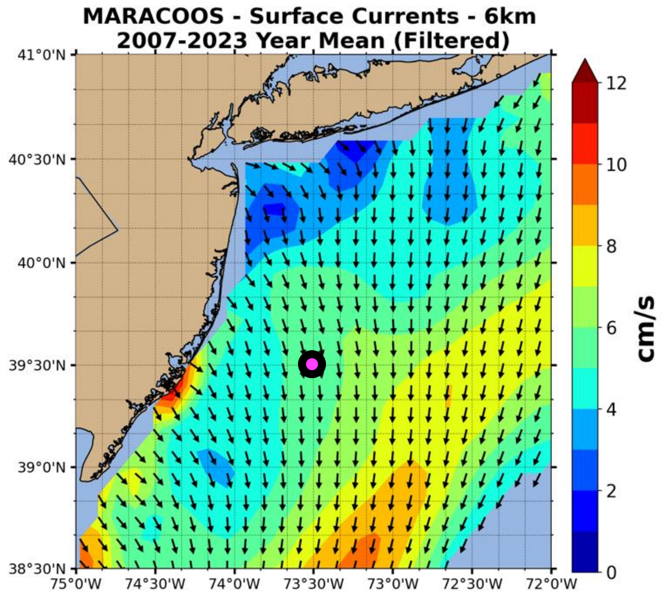
Data Coverage 2000 - Present

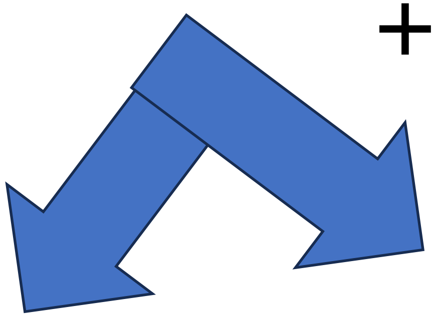


Generate Surface Current Maps Every Hour for a Decade



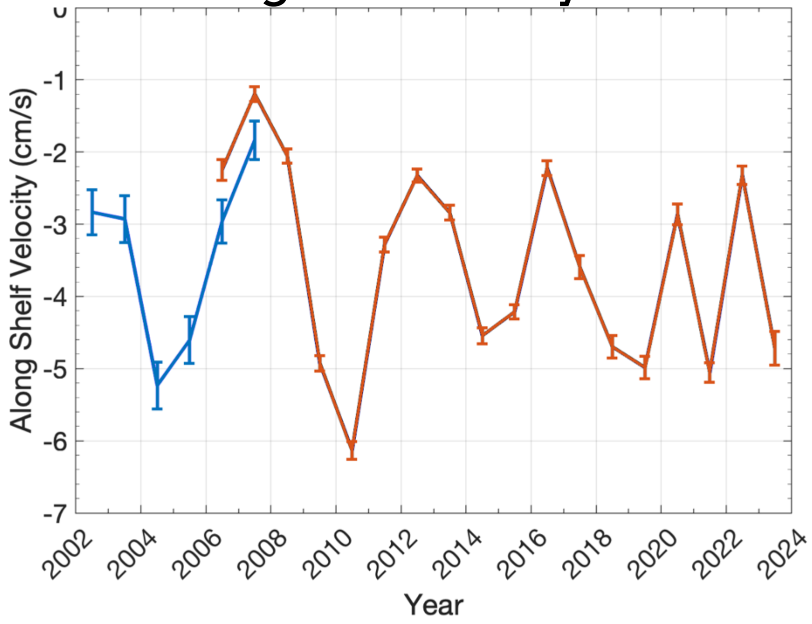


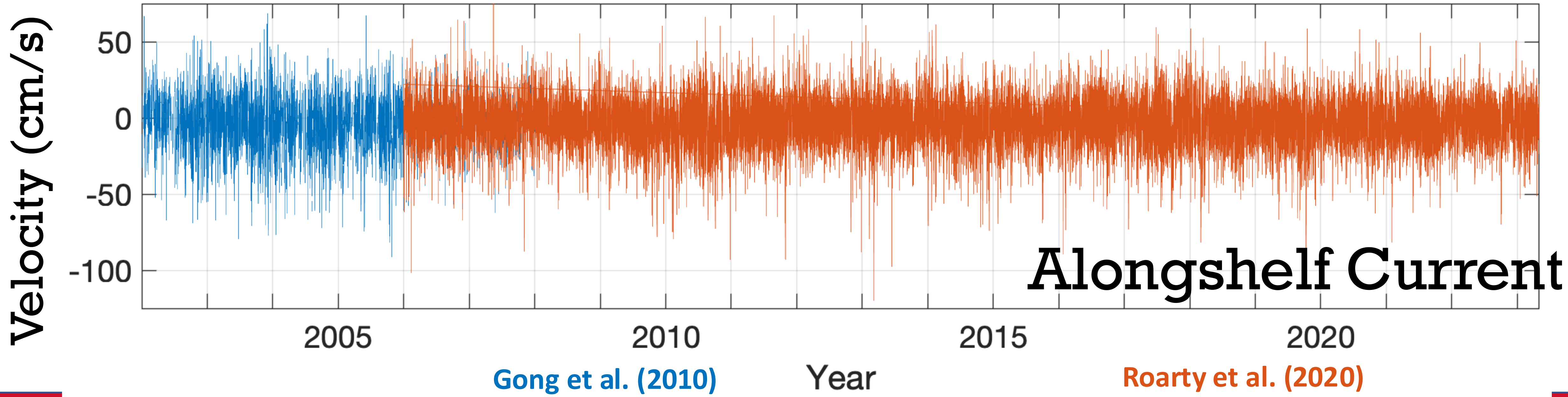




+ Cross Shelf

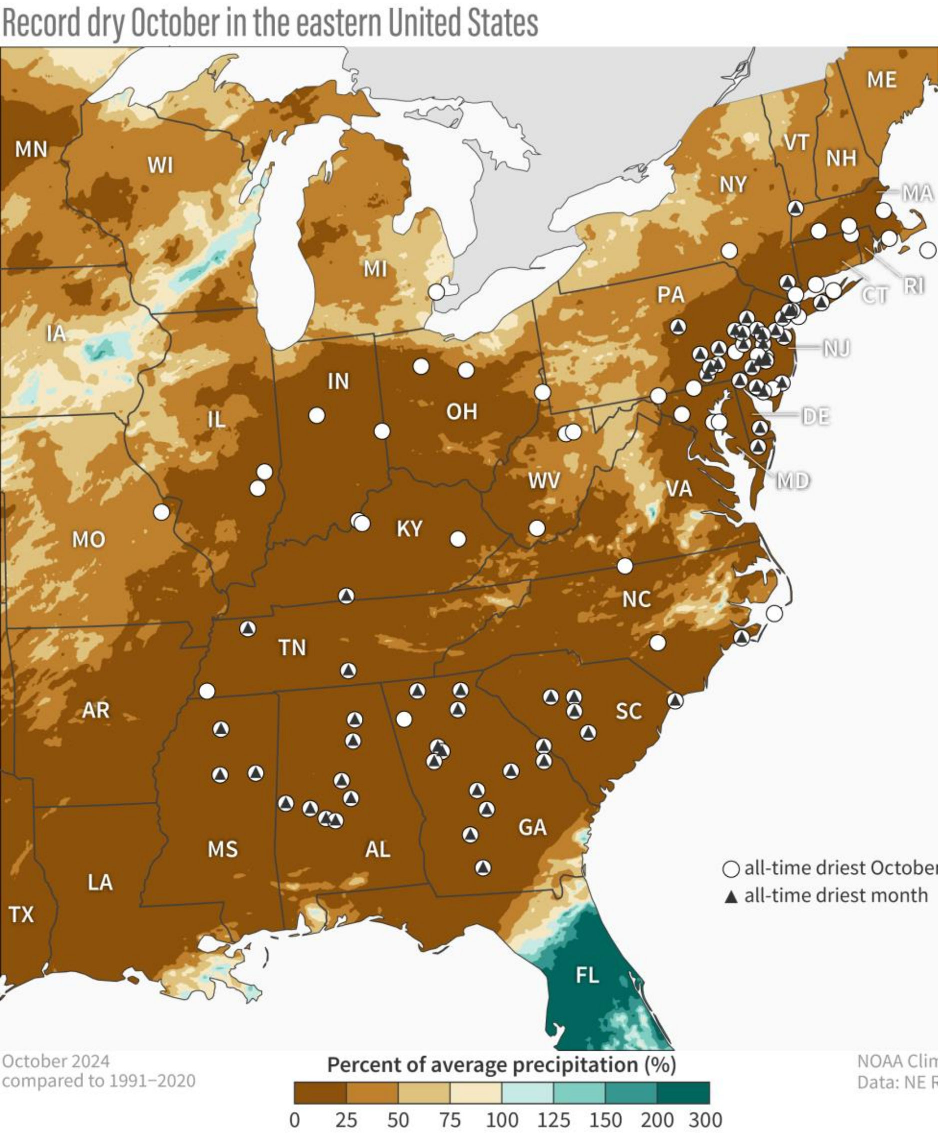
+ Alongshelf

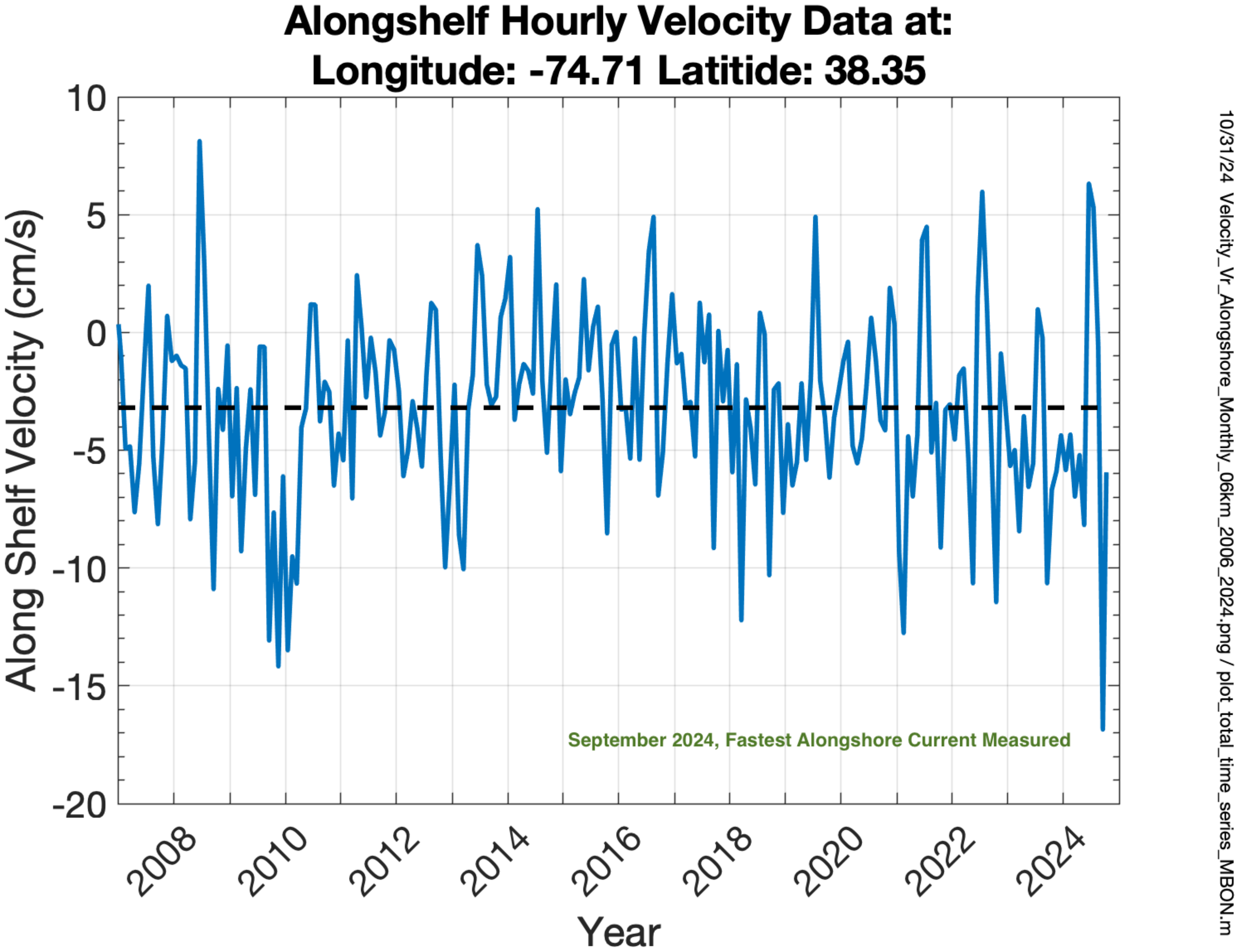




Gong et al. (2010)

Roarty et al. (2020)





https://www.climate.gov/news-features/event-tracker/drought-expands-east-following-exceptionally-dry-october

HF Radar - Antarctica

NSF

physical mechanisms driving food web focusing
SWARM
in Antarctic biological hotspots

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and Biological Sciences

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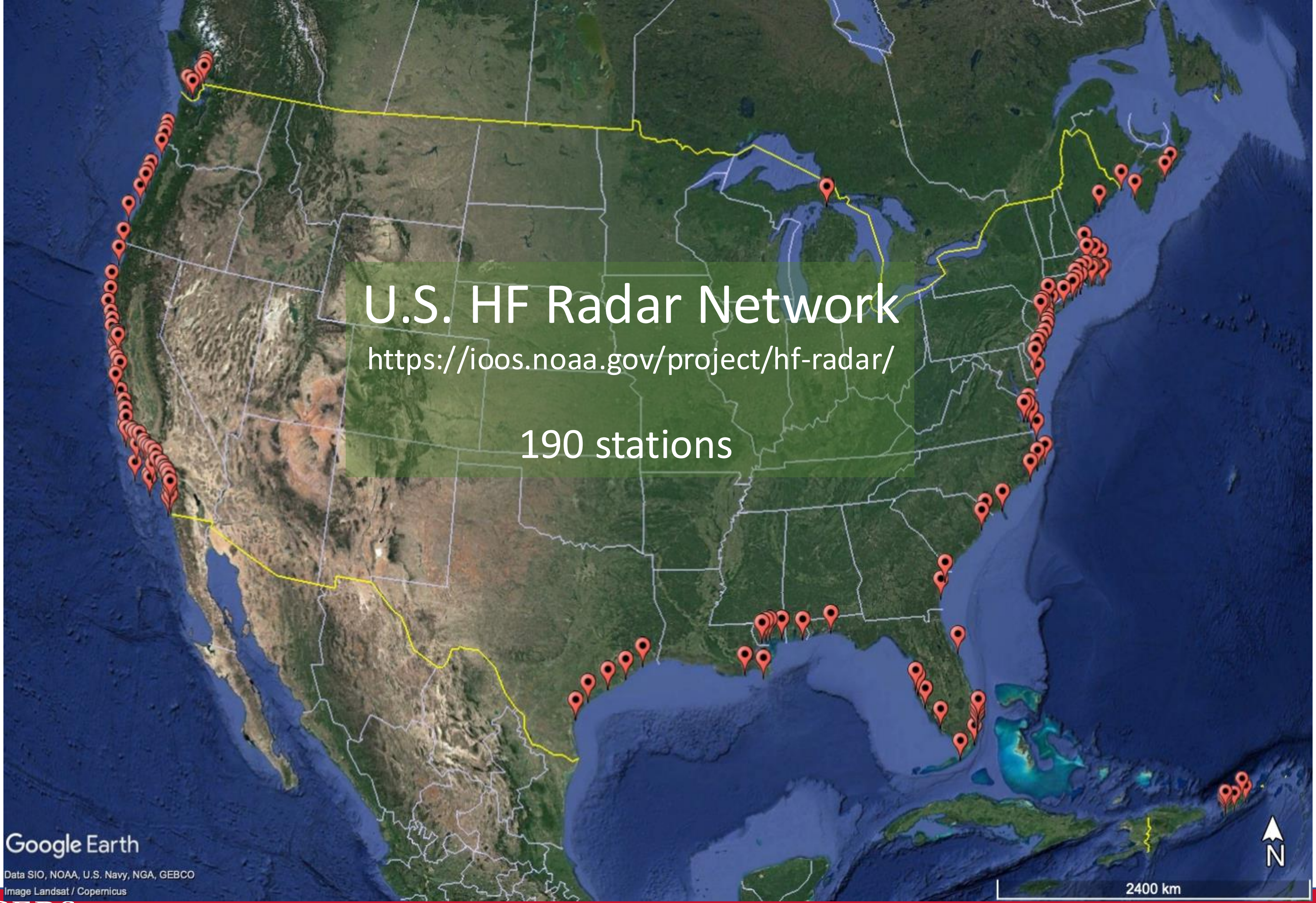
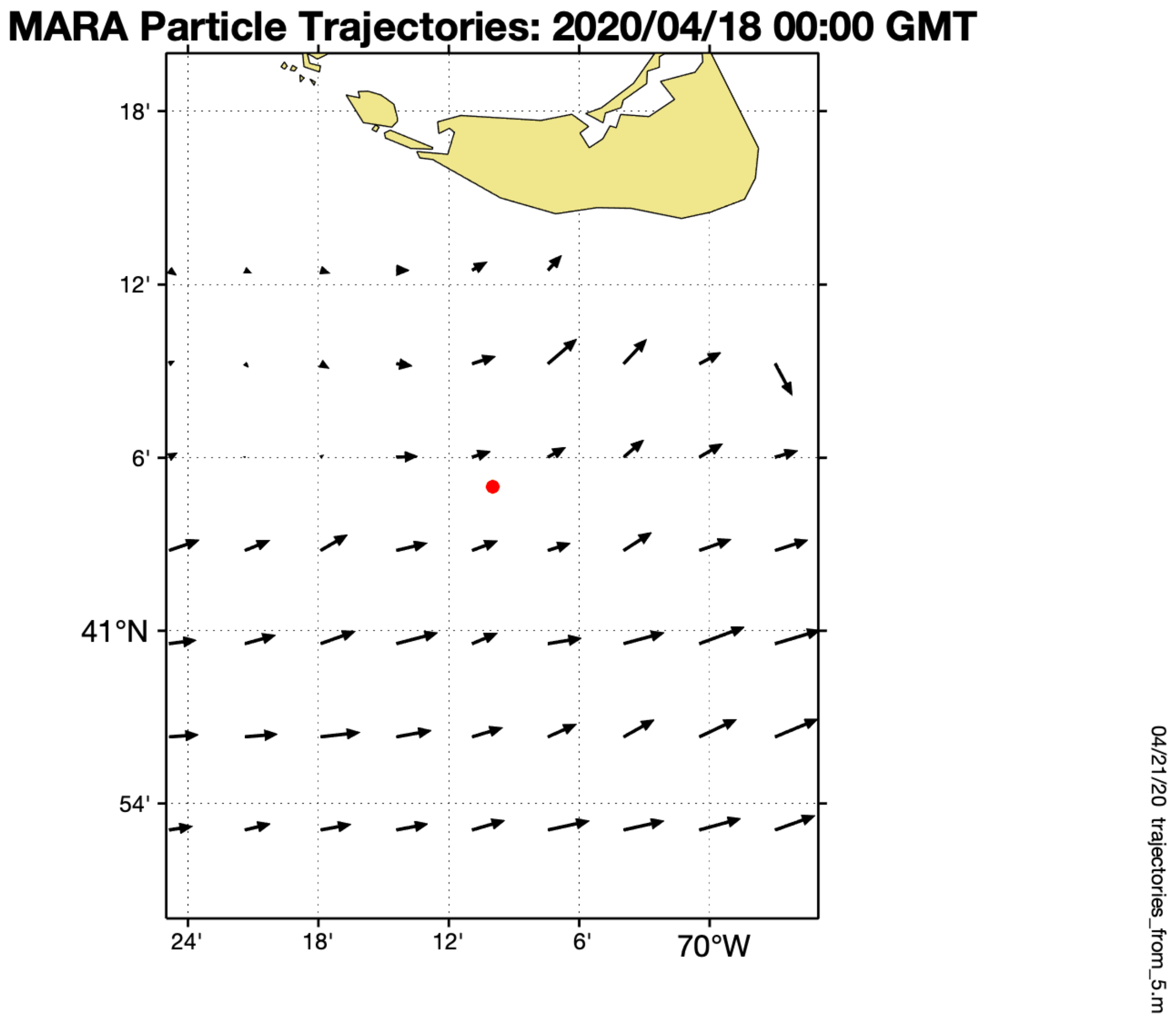
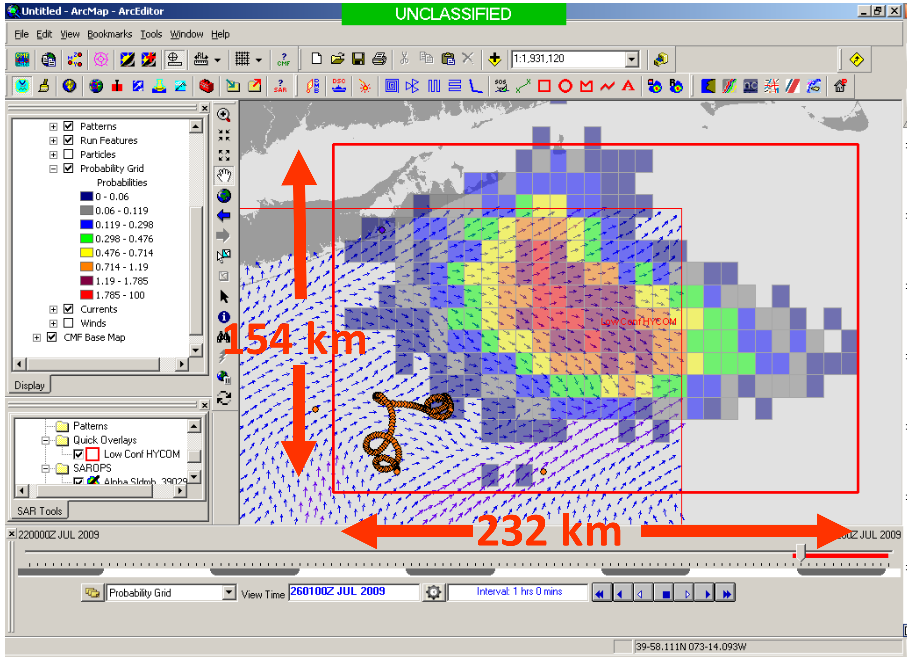


U.S. HF Radar Network
https://ioos.noaa.gov/project/hf-radar/
190 stations
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
N
2400 km

Surface Particle Trajectories

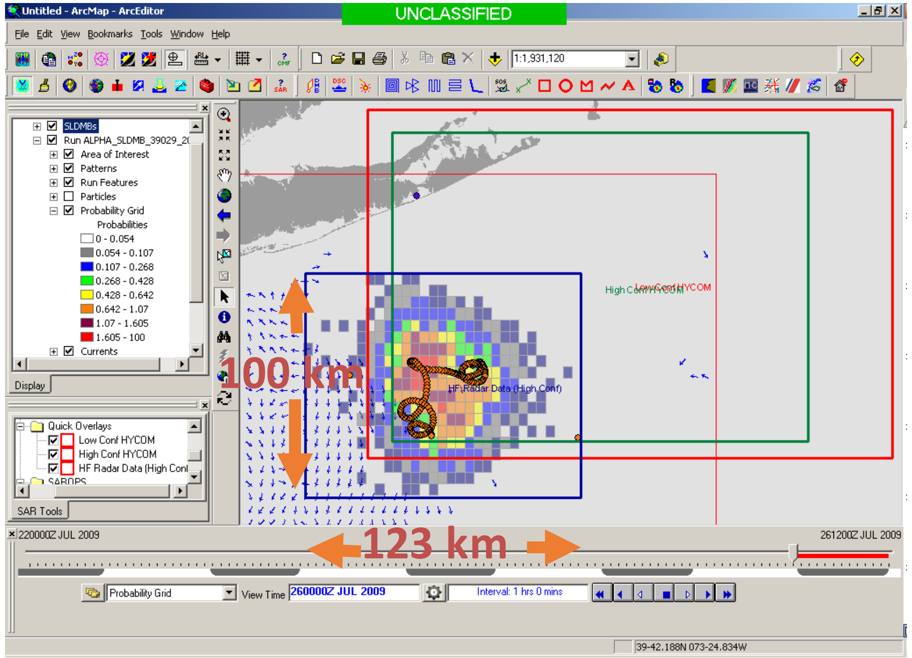


USCG Evaluation Process - 5000 Virtual Drifters & 1 Real Drifter: Compare Search Areas after X Hours



HYCOM @ 96 Hours

Search Area = 36,000 km^2



CODAR @ 96 Hours

Search Area = 12,000 km^2

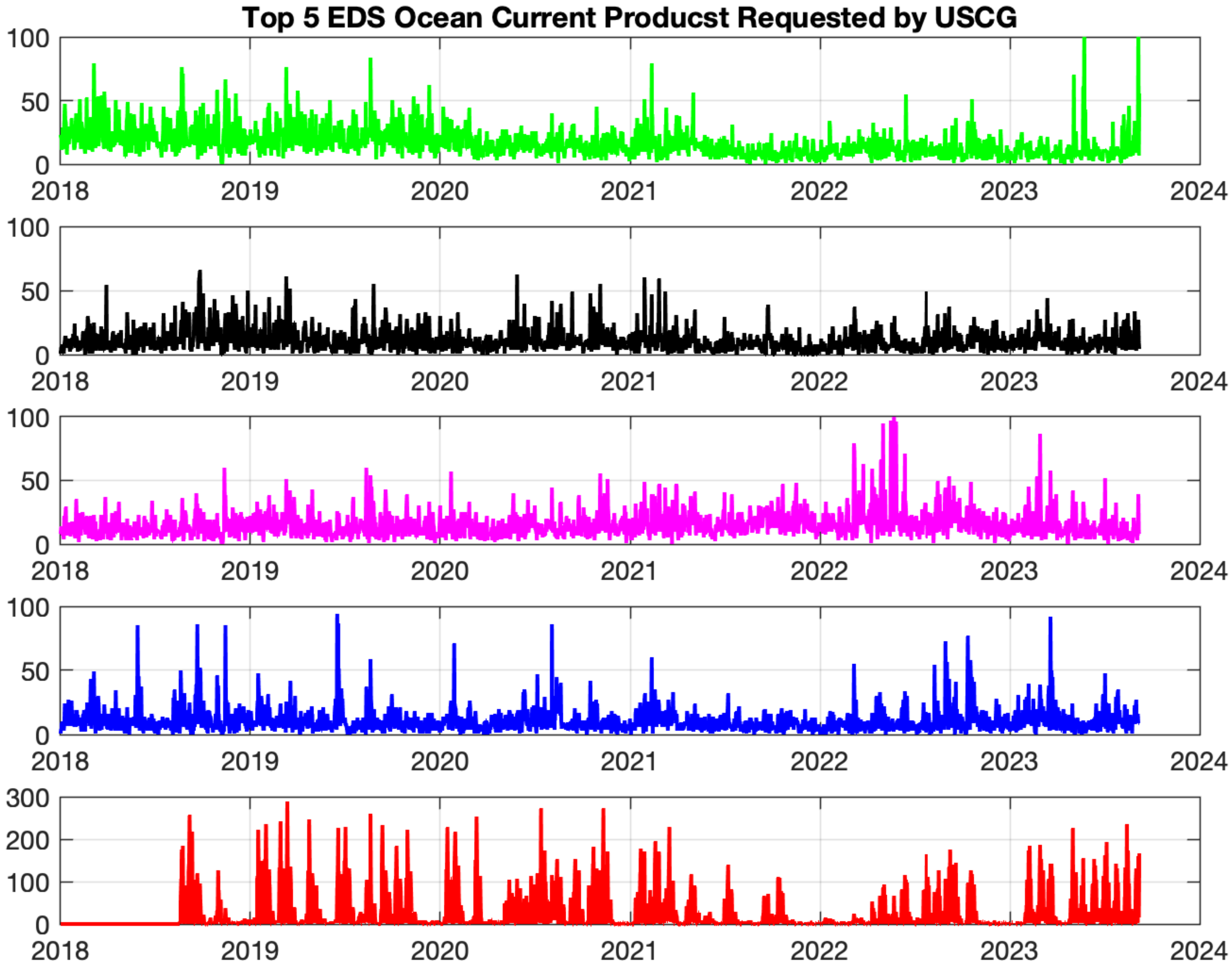
ADCIRC

HYCOM Navy

HYCOM NCEP

HFR STPS

DOPPIO



Average Daily Requests

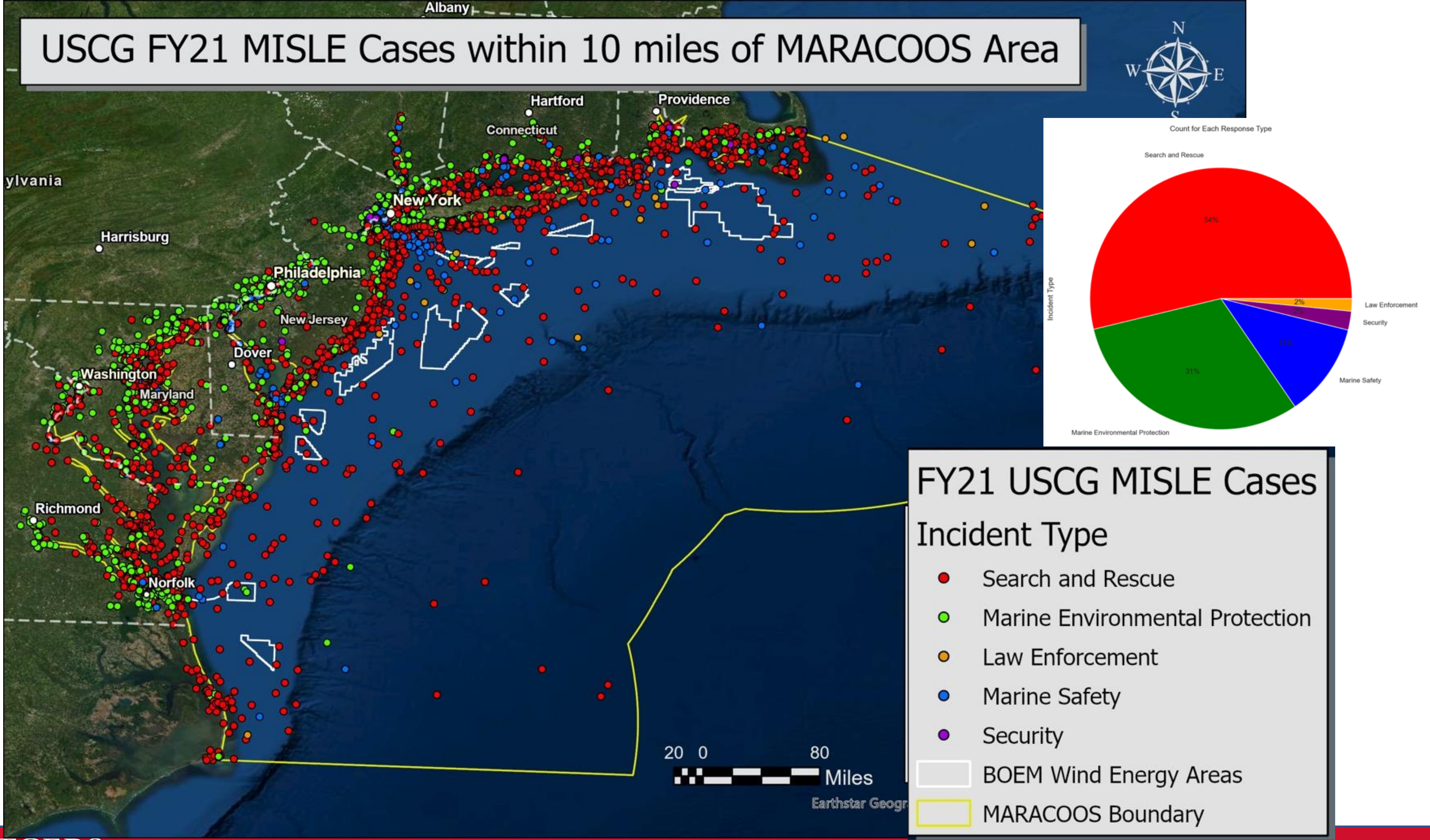
16

10

14

11

26


USCG FY21 MISLE Cases within 10 miles of MARACOOS Area
Albany
Hartford
Providence
Connecticut
ylvania
New York
Harrisburg
Philadelphia
New Jersey
Dover
Washington
Maryland
Richmond
Norfolk
N
W
E
20 0 80
Miles
FY21 USCG MISLE Cases
Incident Type
Search and Rescue
Marine Environmental Protection
Law Enforcement
Marine Safety
Security
BOEM Wind Energy Areas
MARACOOS Boundary
Count for Each Response Type
Search and Rescue
54%
Incident Type
2%
Law Enforcement
2%
Security
12%
Marine Safety
31%
Marine Environmental Protection

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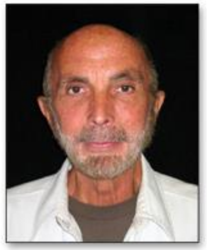
High Frequency Radar



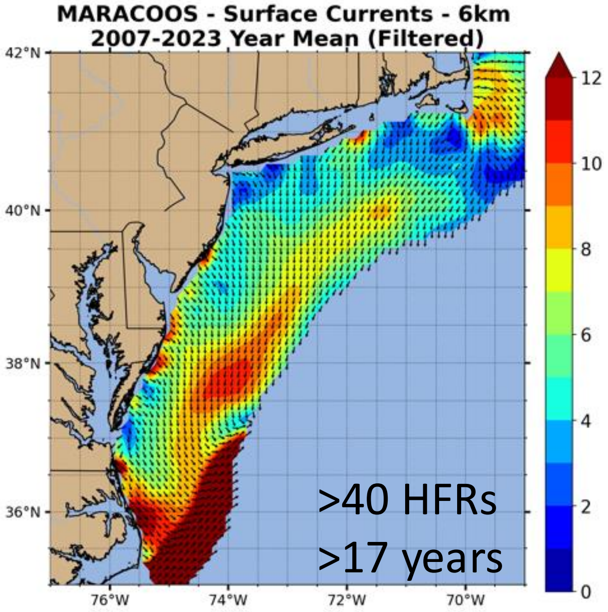
CODAR OCEAN SENSORS

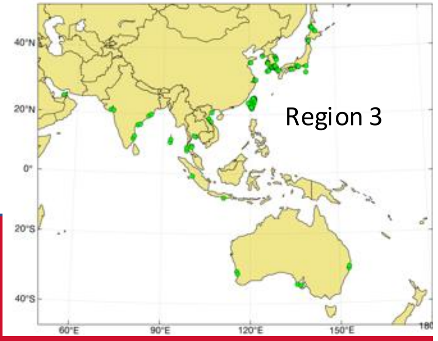
Innovation

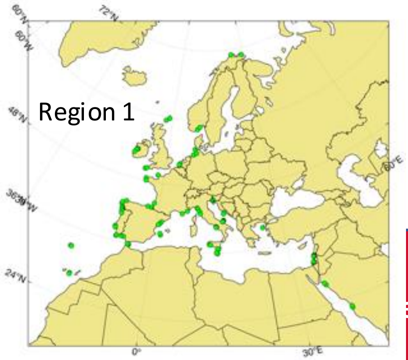
- AIS APM
- AutoAPM
- Bistatic Buoy
- Dual Transmitter
- GPS Timing
- Lightning Protection
- Low Power
- RiverSonde
- SuperDirective Antenna
- Tx/Rx Single Antenna
- Wave Powered Buoy
- Multistatic Network
- QARTOD
- Vessel Det./Assoc./Track
- Windfarm Mitigation

- Coast Guard SAR
- Network KPIs
- ROWG
- Hurricane Science
- Lag. Coherent Structures
- Tidal Maps
- HFR Waves
- Tsunami Detection
- Remote Locations – Puerto Rico, Antarctica, Yucatan
- Global HFR Network

Expansion





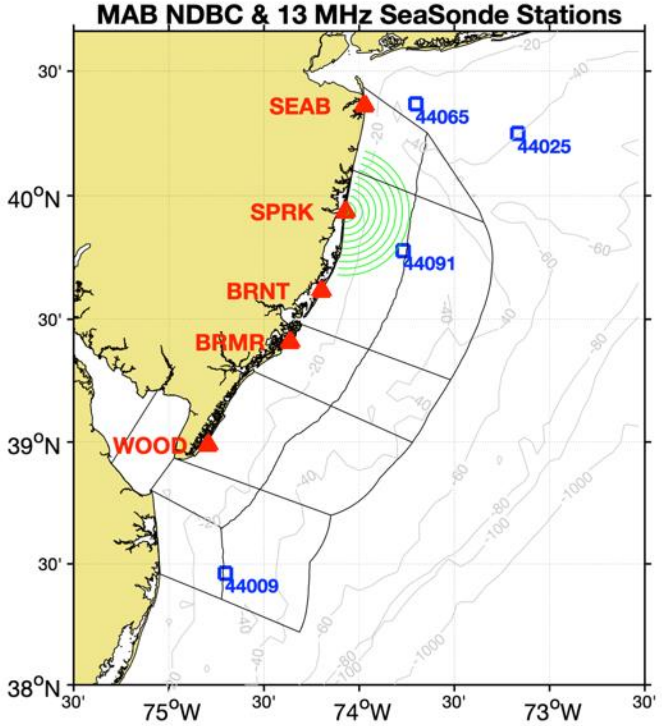


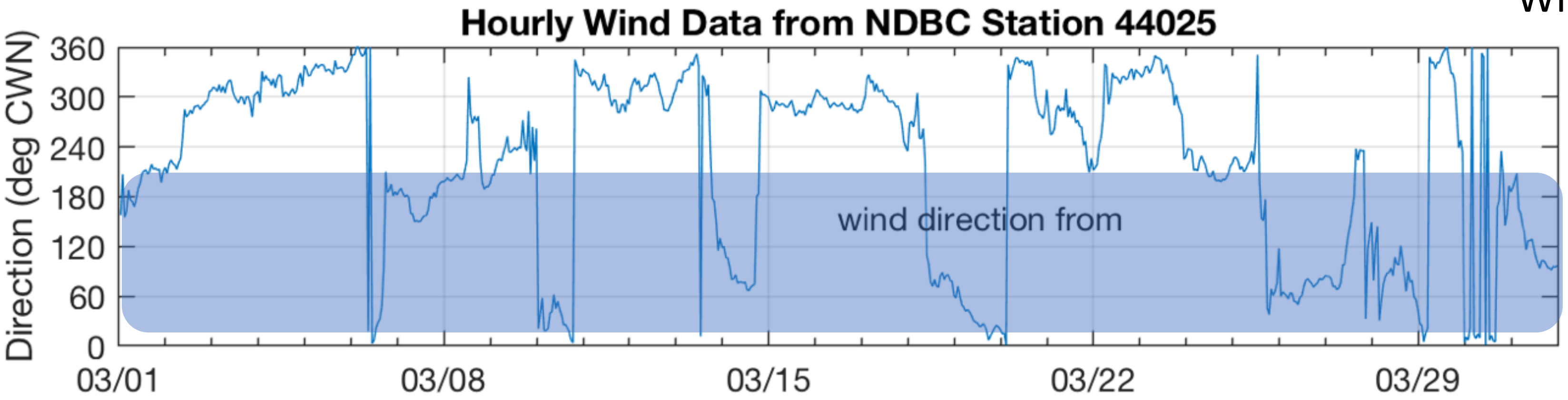
Timeline

1996 OSCR radar site
1998 SeaSonde 25 MHz
2000 SeaSonde 05 MHz
2003 Surf. Current Mapping Init.
2005 SeaSonde 13 MHz
2007 MARACOOS HFR
2009 USCG Operational
2010 Gulf Oil Spill
2010 National HFR Steering Team
2010 Global HFR Network
2016 GOOS Emerging Network
2022 GOOS Mature Network

Region Number	Geographic Coverage	Number of Stations
1	Europe, Africa, Middle East	72
2	North and South America	195
3	Asia and Oceania	140

Wave Measurements from HFR

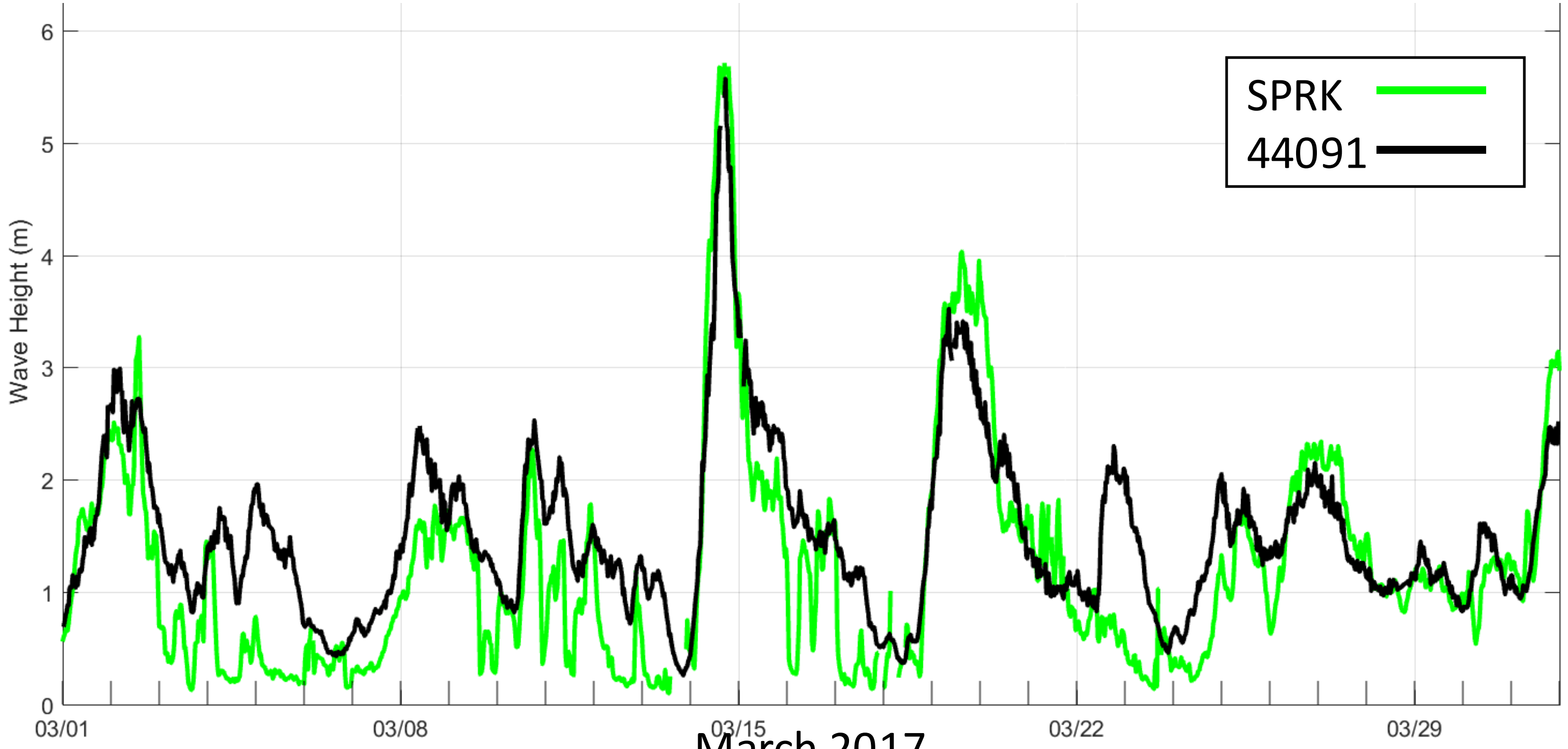




Wind from

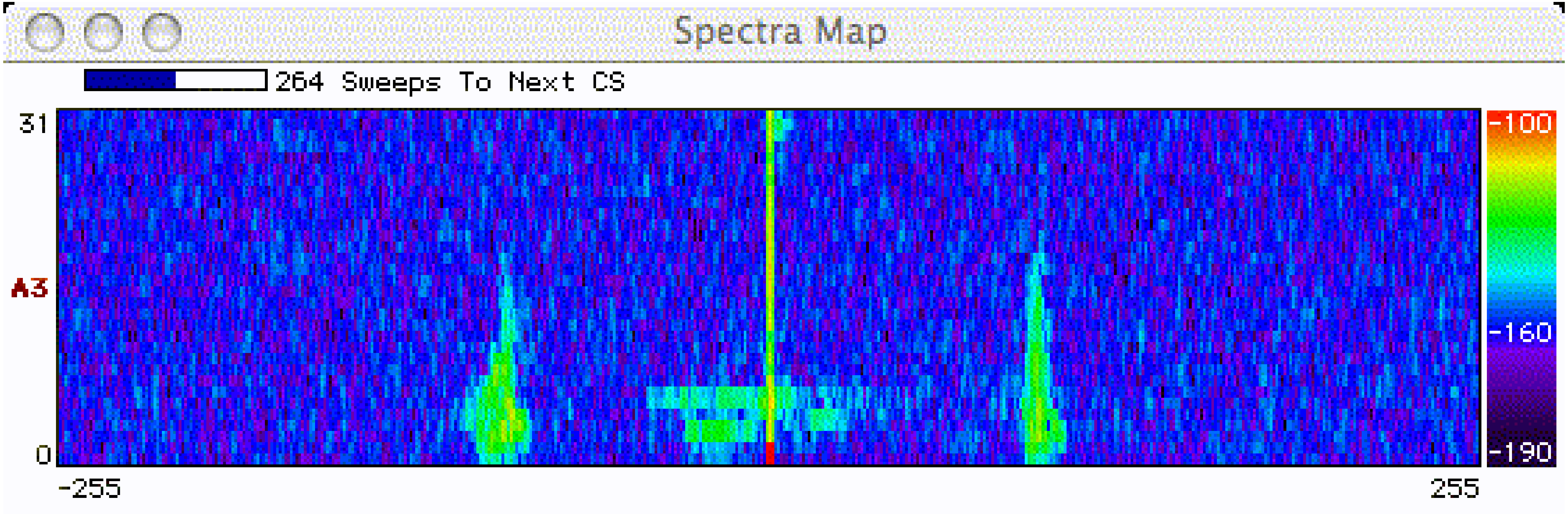
Land

Ocean

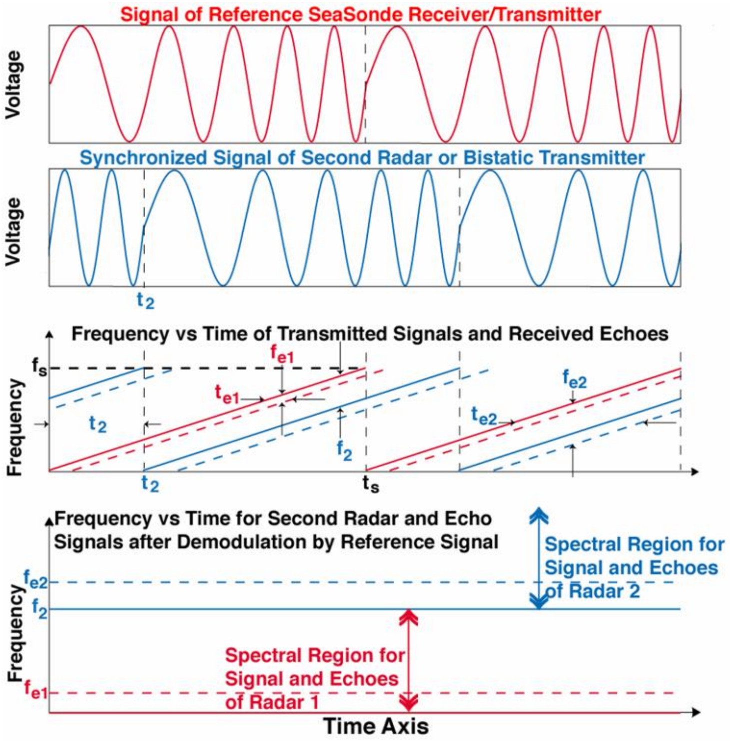


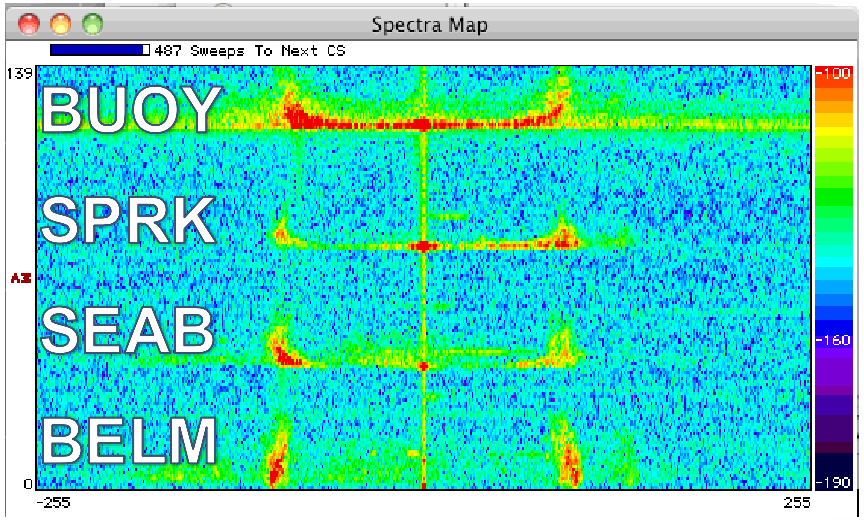
March 2017

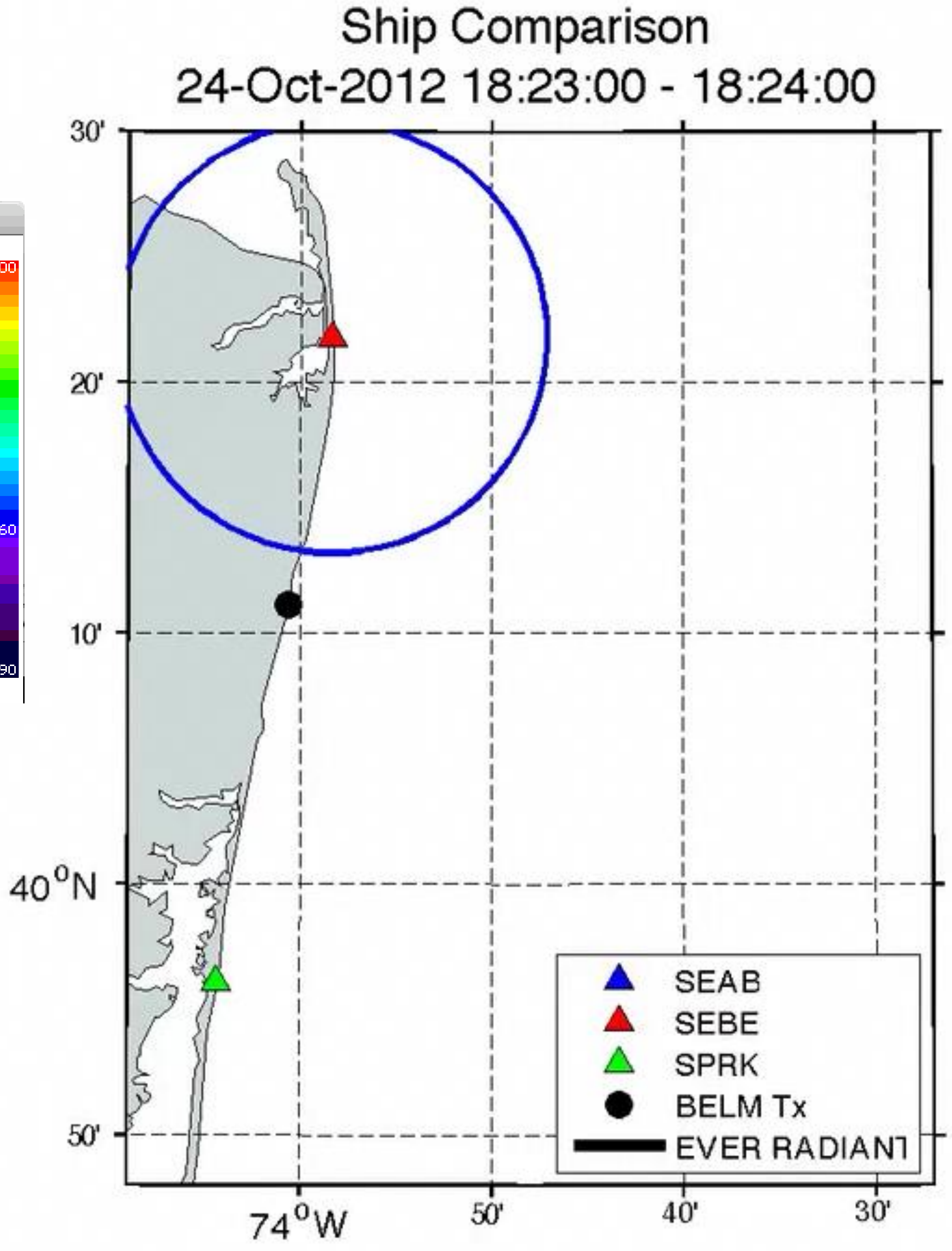
Vessels in the Spectra



Multistatic Vessel Detections

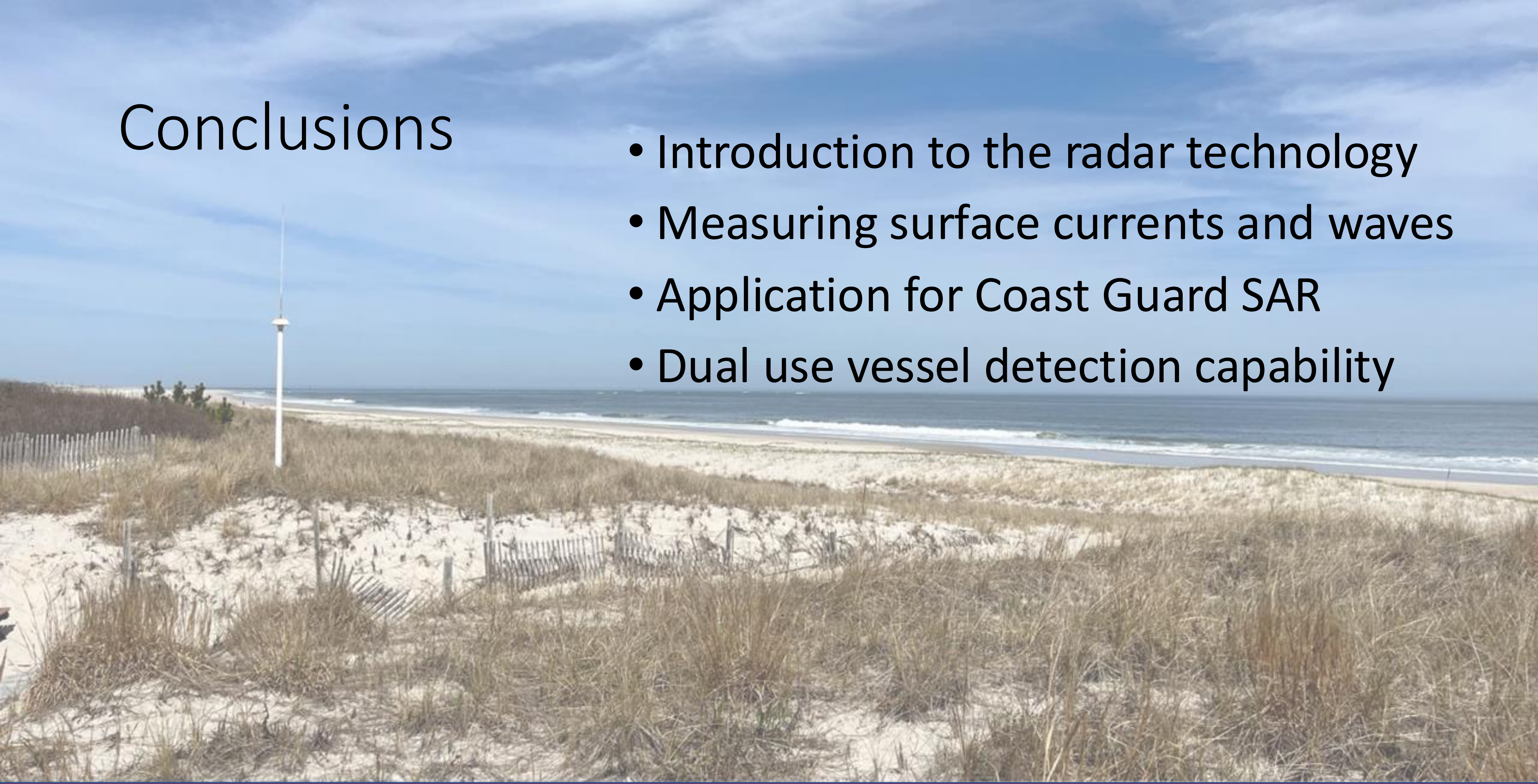






Conclusions

- Introduction to the radar technology
- Measuring surface currents and waves
- Application for Coast Guard SAR
- Dual use vessel detection capability



The History of Oceanographic High Frequency Radar at Rutgers University

Thanks

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