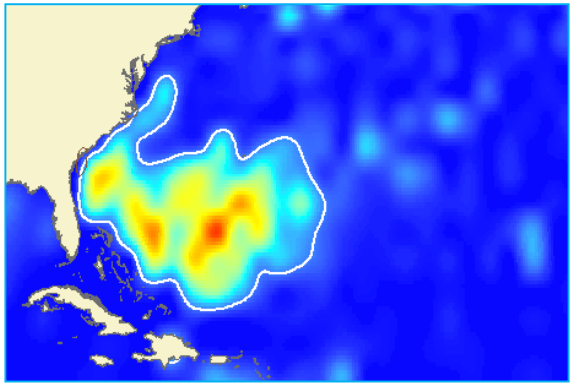
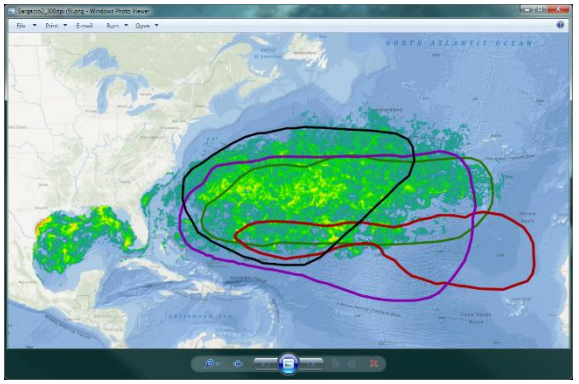
Mapping the Sargasso Sea

Sargasso Sea Commission Meeting 31 March 2016





Marine Geospatial Ecology Lab
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Jason Roberts

Pat Halpin

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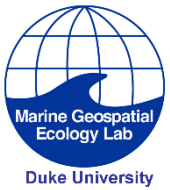
The Sargasso Sea

- What and where is it? (2011-2012)
  - Approach 1: map the *Sargassum*
  - Approach 2: map circulation patterns

MCI
Jeff Ardron
Russ Moffitt
Sharon Gulick

MGEL
Pat Halpin
Jason Roberts
Ben Donnelly
Jesse Cleary



- New data developments (2012-2015)

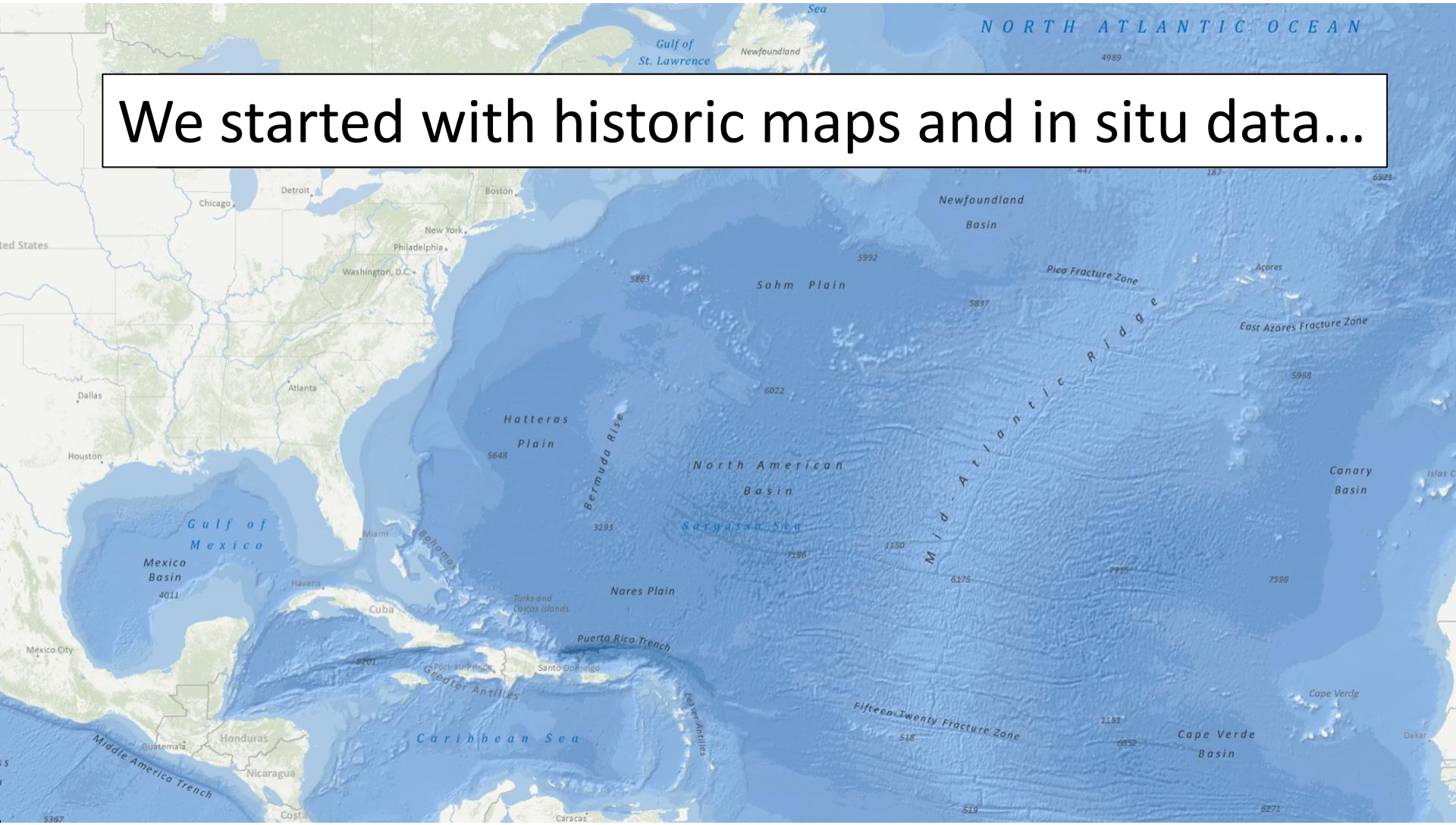
Mapping the *Sargassum*

Multiple approaches:

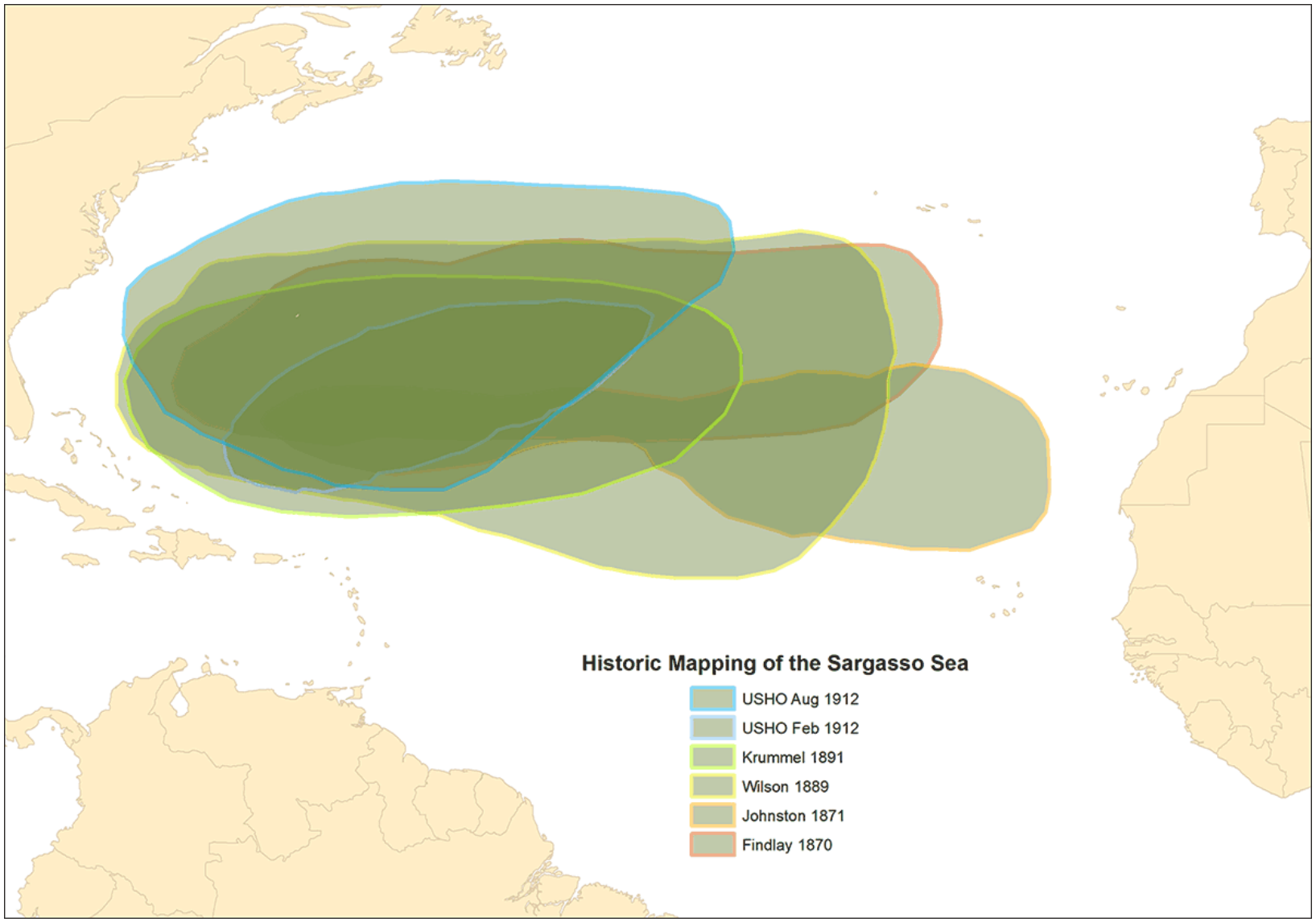
- Historic studies
- In situ observations
- Remote sensing
- Hydrodynamic simulation

How do they compare?

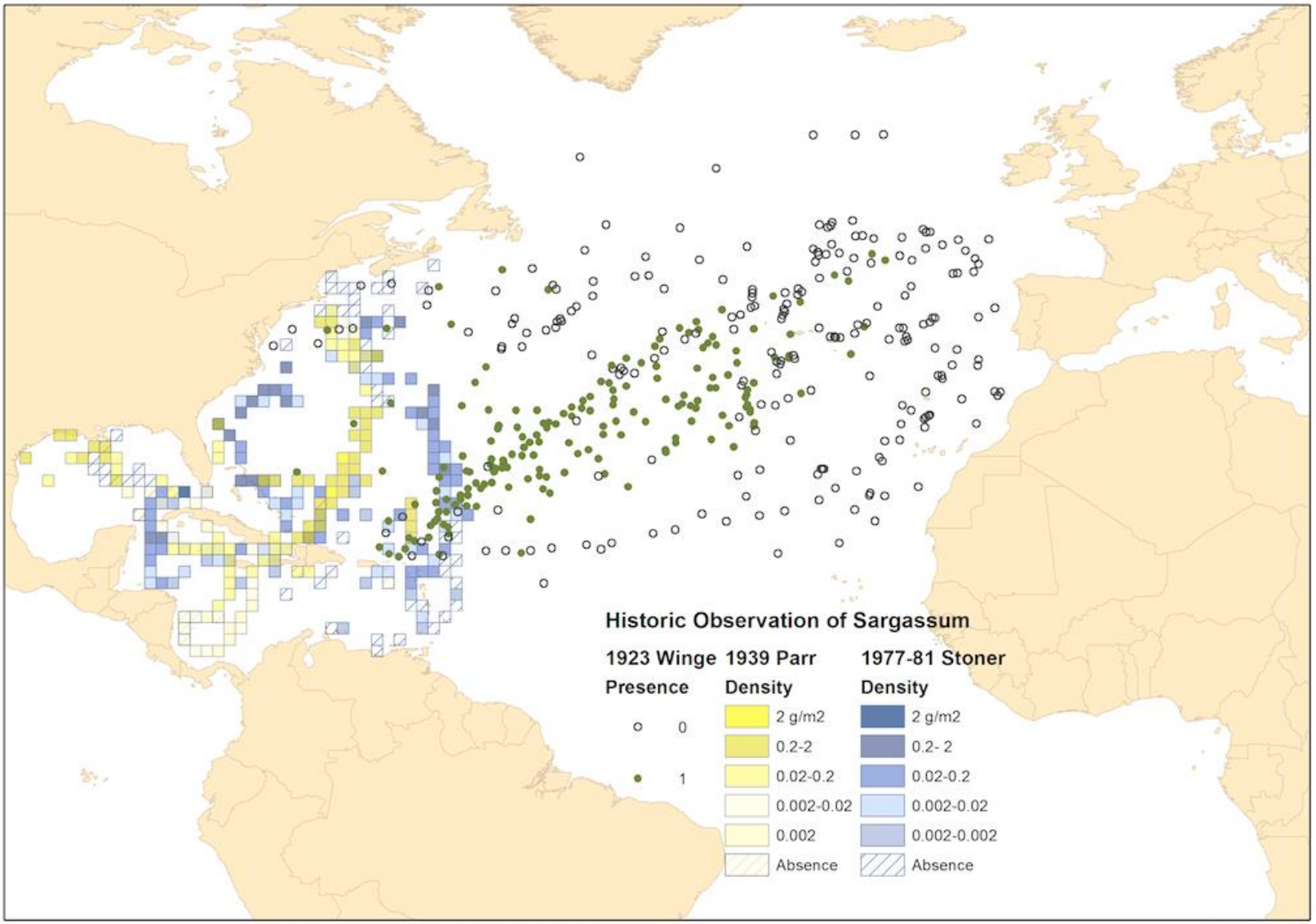
National Geographic 1976


We started with historic maps and in situ data…
NORTH ATLANTIC OCEAN
Gulf of St. Lawrence
Newfoundland
Sea
Newfoundland Basin
Sohm Plain
Pico Fracture Zone
Acores
East Azores Fracture Zone
Mid-Atlantic Ridge
Hatteras Plain
Bermuda Rise
North American Basin
Sargasso Sea
Canary Basin
Nares Plain
Puerto Rico Trench
Fifteen Twenty Fracture Zone
Cape Verde Basin
Cape Verde
Gulf of Mexico
Mexico Basin
Caribbean Sea
Greater Antilles
Lesser Antilles
Middle America Trench
Bahamas
Turks and Caicos islands
Detroit
Chicago
Boston
New York
Philadelphia
Washington, D.C.
Atlanta
Dallas
Houston
Miami
Havana
Cuba
Mexico City
Guatemala
Honduras
Nicaragua
Costa
Caracas
Port-au-Prince
Santo Domingo
Dakar
Islas C
5992
5863
5837
6022
5968
5648
3293
7196
1150
6175
7598
4989
6521
4011
8201
1181
6852
519
8271
5367
518

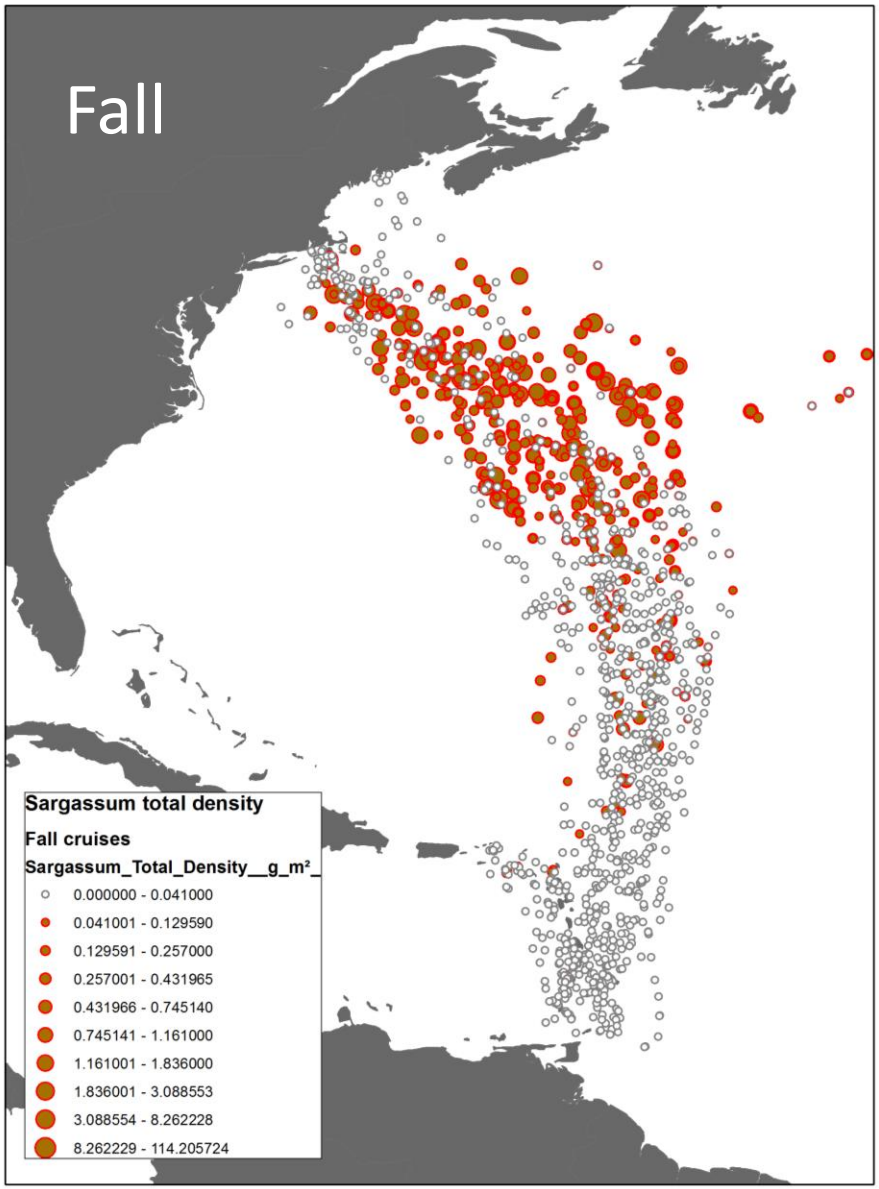
Historic mapping: 1870 - 1912

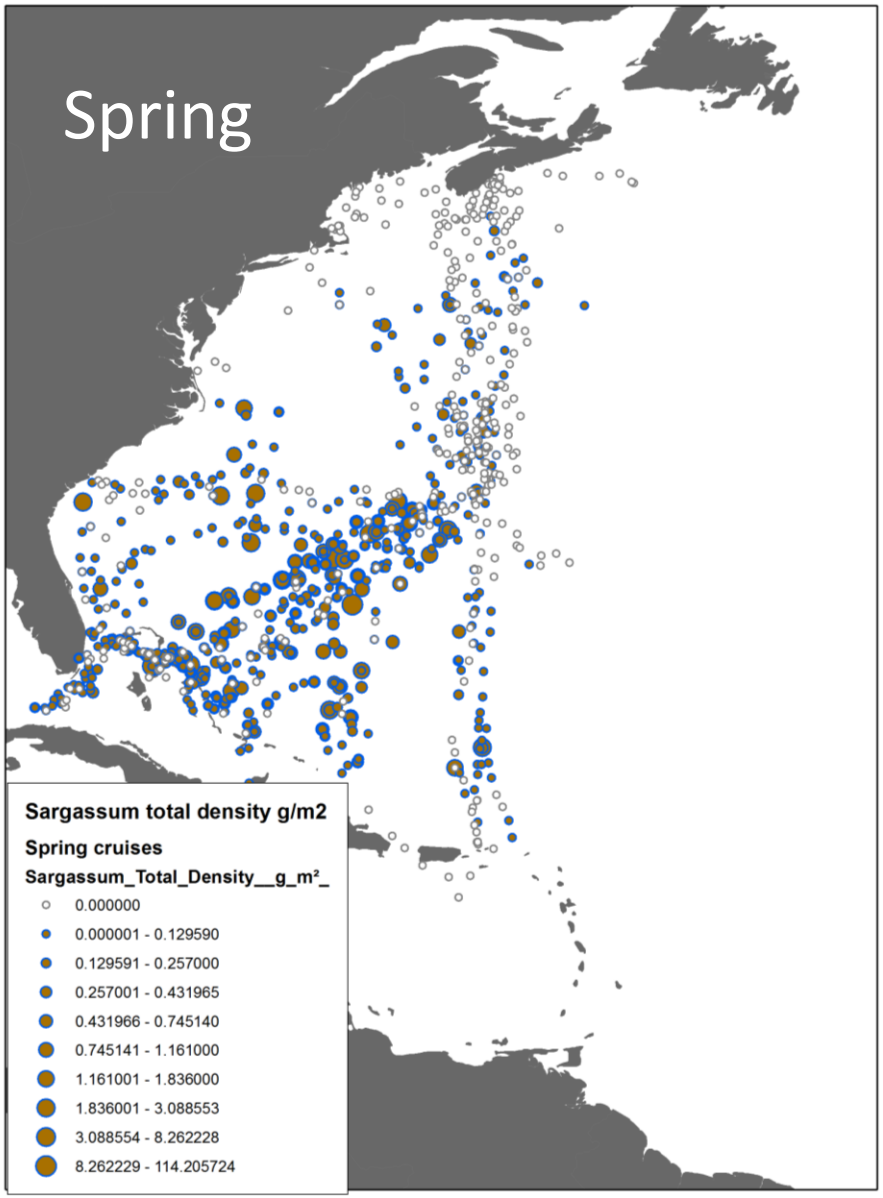


In situ observations: 1923-1981

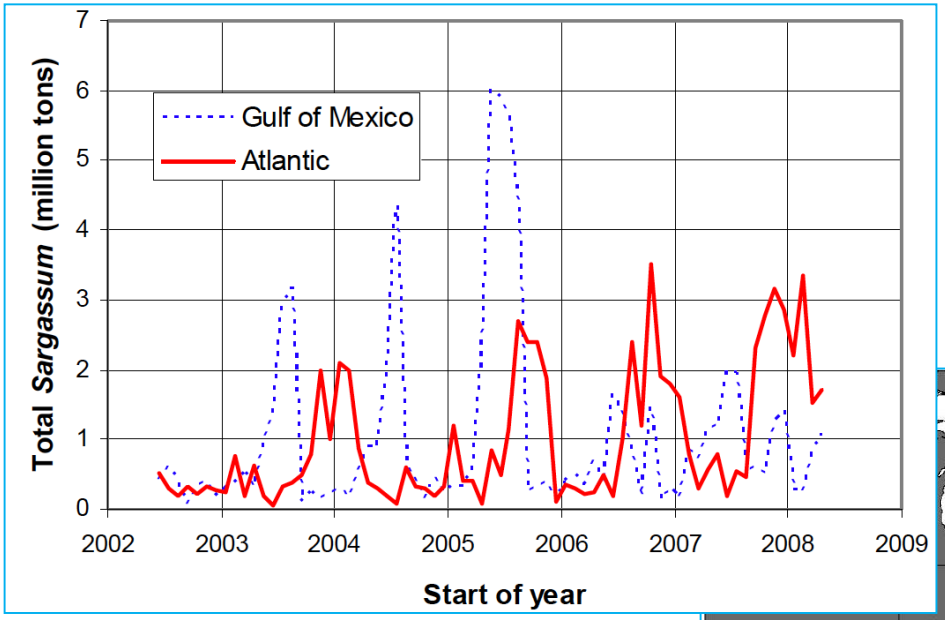


In situ observations: SEA surveys 1977 - 2010

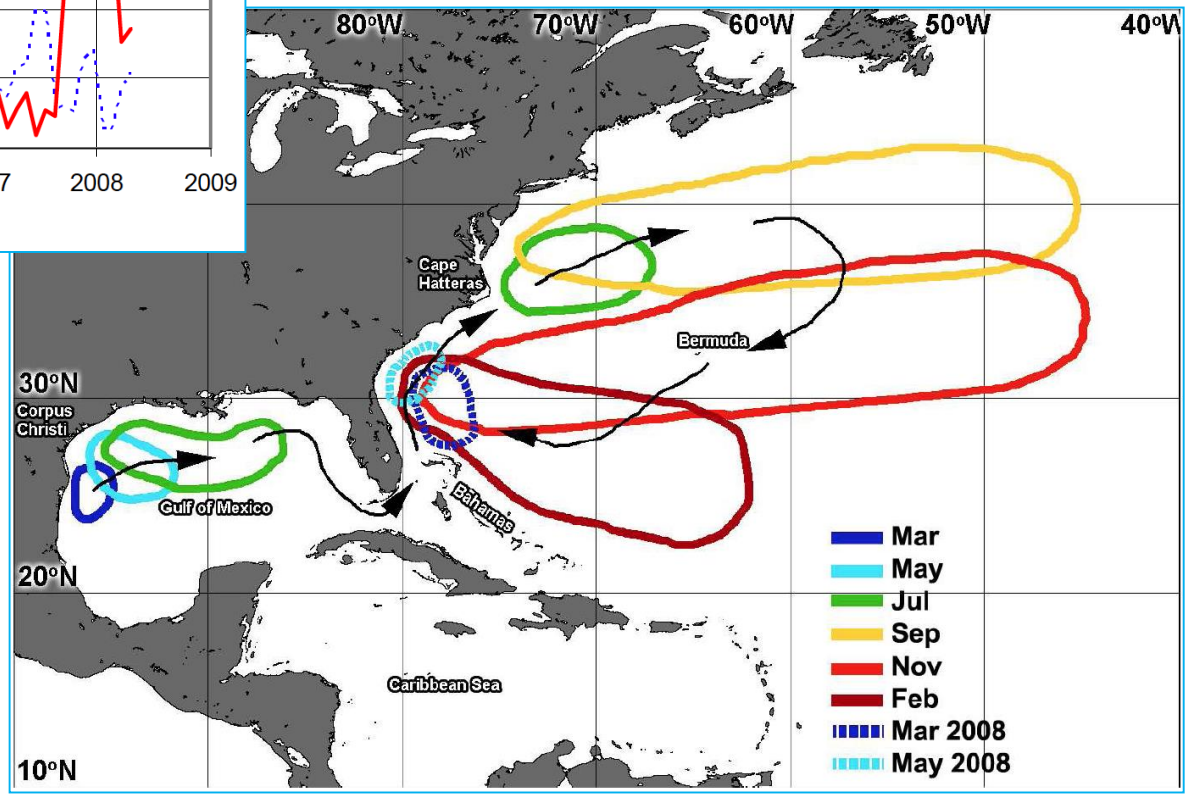




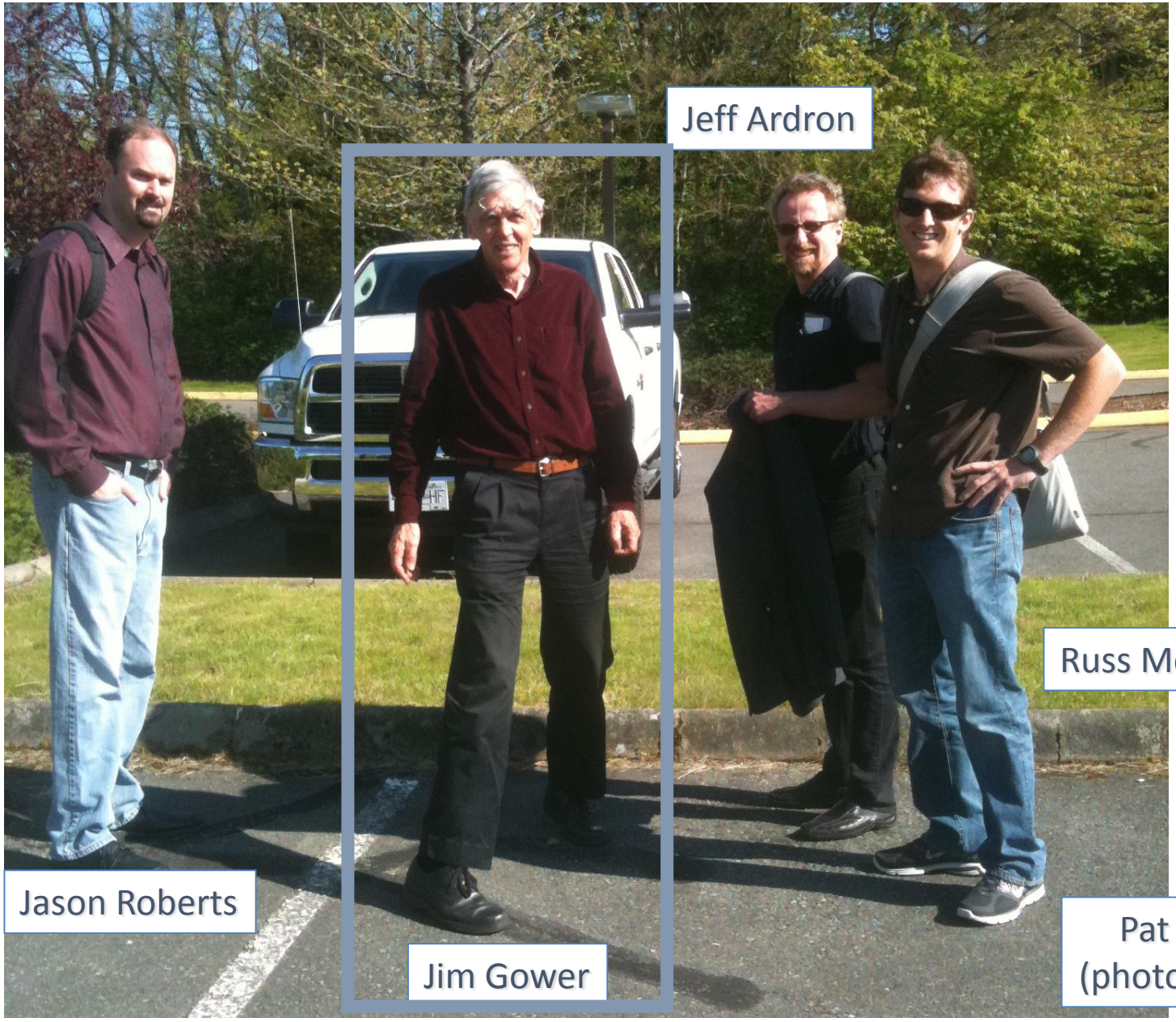
Remote Sensing: Gower et al. with MERIS



From Gower and King 2008, 2011



Sydney, BC (2011)



Gower et al. Approach

European Space Agency (ESA)
Medium Resolution Imaging Spectrometer (**MERIS**)

MERIS is a sensitive detector "shifted red-edge" characteristic of marine and floating vegetation (Gower et al., 2006, 2008, 2011).

Maximum Chlorophyll Index: MCI index measures the local peak in water-leaving radiance near 705 nm, measured for each pixel of the satellite image data to show excess radiance at 709 nm, above a baseline defined by linear interpolation between the neighboring spectral bands at 681 and 754nm

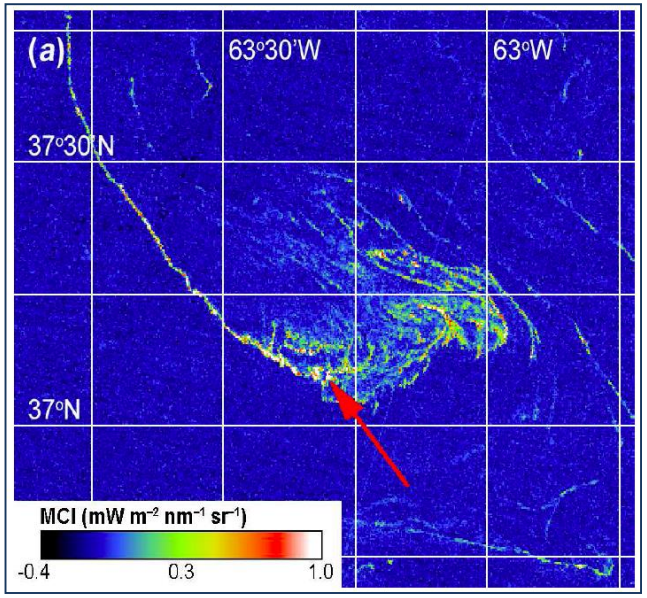
$$L_{709} - L_{681} - (709 - 681)(L_{754} - L_{681})/(754 - 681)$$

Gower et al. Approach

The monthly composites of MCI signal at 5 km spatial resolution are analyzed by computing the frequency distribution (histogram) of MCI values in each one-degree square.

MERIS Count: the number of MCI values above threshold, multiplied by the amount by which MCI exceeds its background value (in mW m^{-2} nm^{-1} sr^{-1})

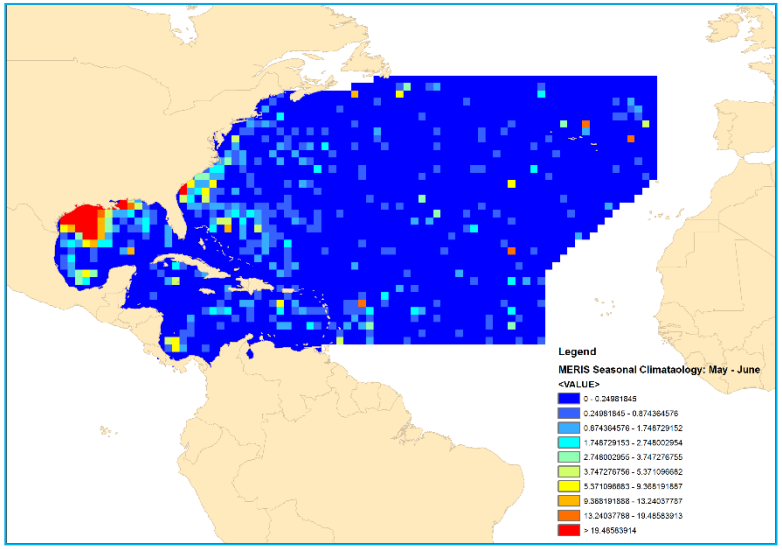
$$\text{MERIS count} = \sum_{m=b+t}^{m=\infty} (m-b)n(m)$$



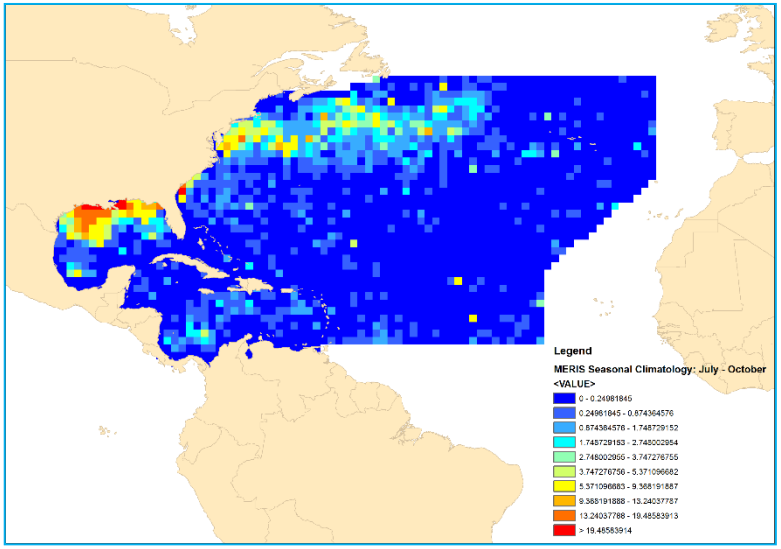
Detectibility: To be detected with 1200m-resolution data (aggregated to 5000m), *Sargassum therefore has to* be dense enough, and to cover a large enough area, to affect the average colour (visible surface spectral reflectance) of an area of ocean surface 1200m across.

Aggregating Gower's Results

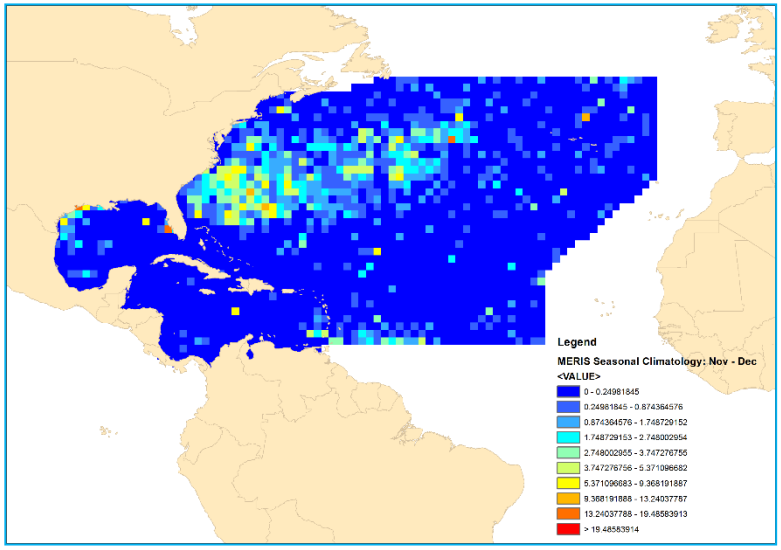
May – June: GoMEX bloom



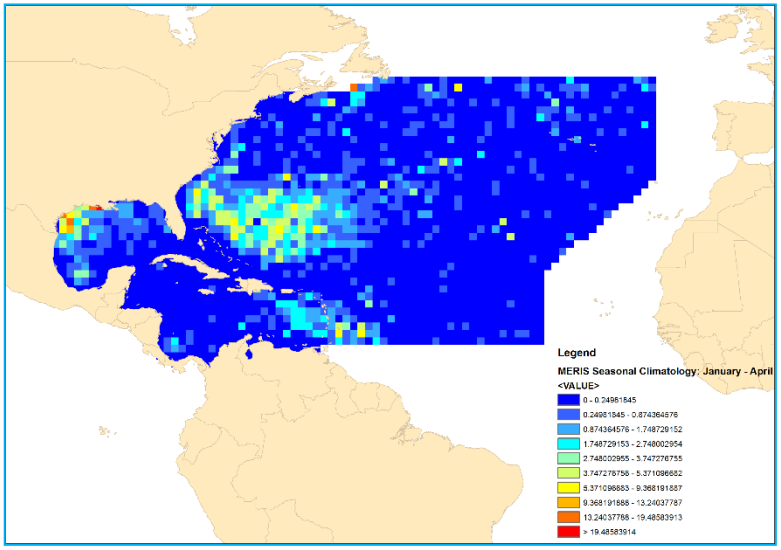
July - October: Gulf Stream transport



November - December: transition

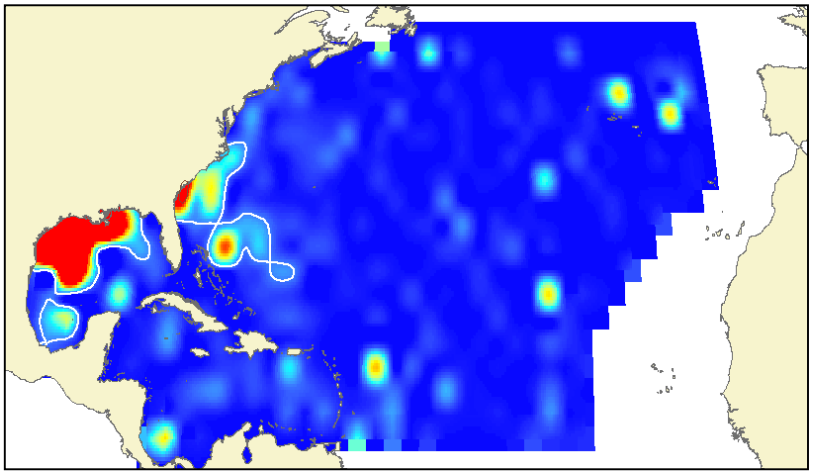


January – April: aggregation

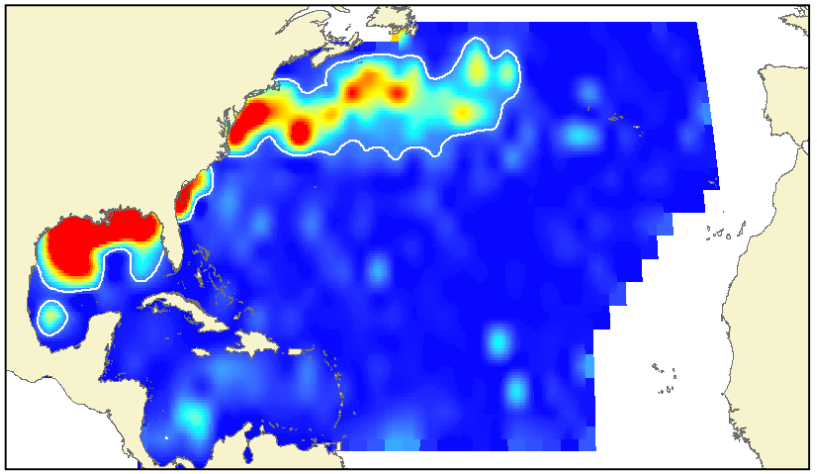


Smoothing and contouring

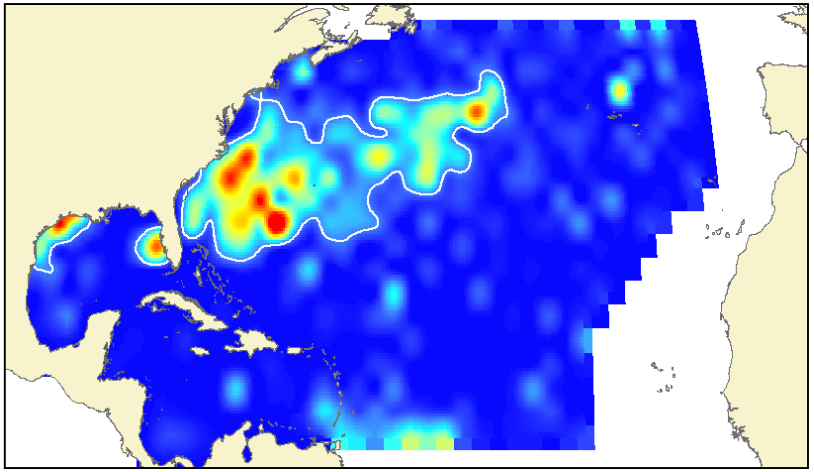
May – June: GoMEX bloom



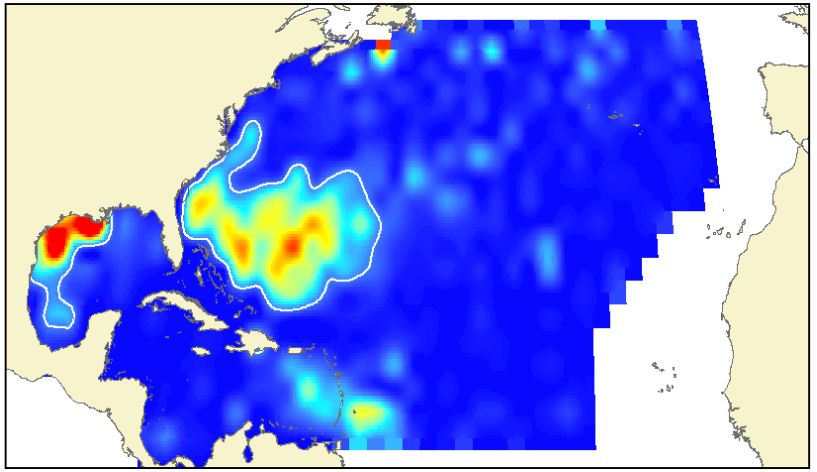
July - October: Gulf Stream transport



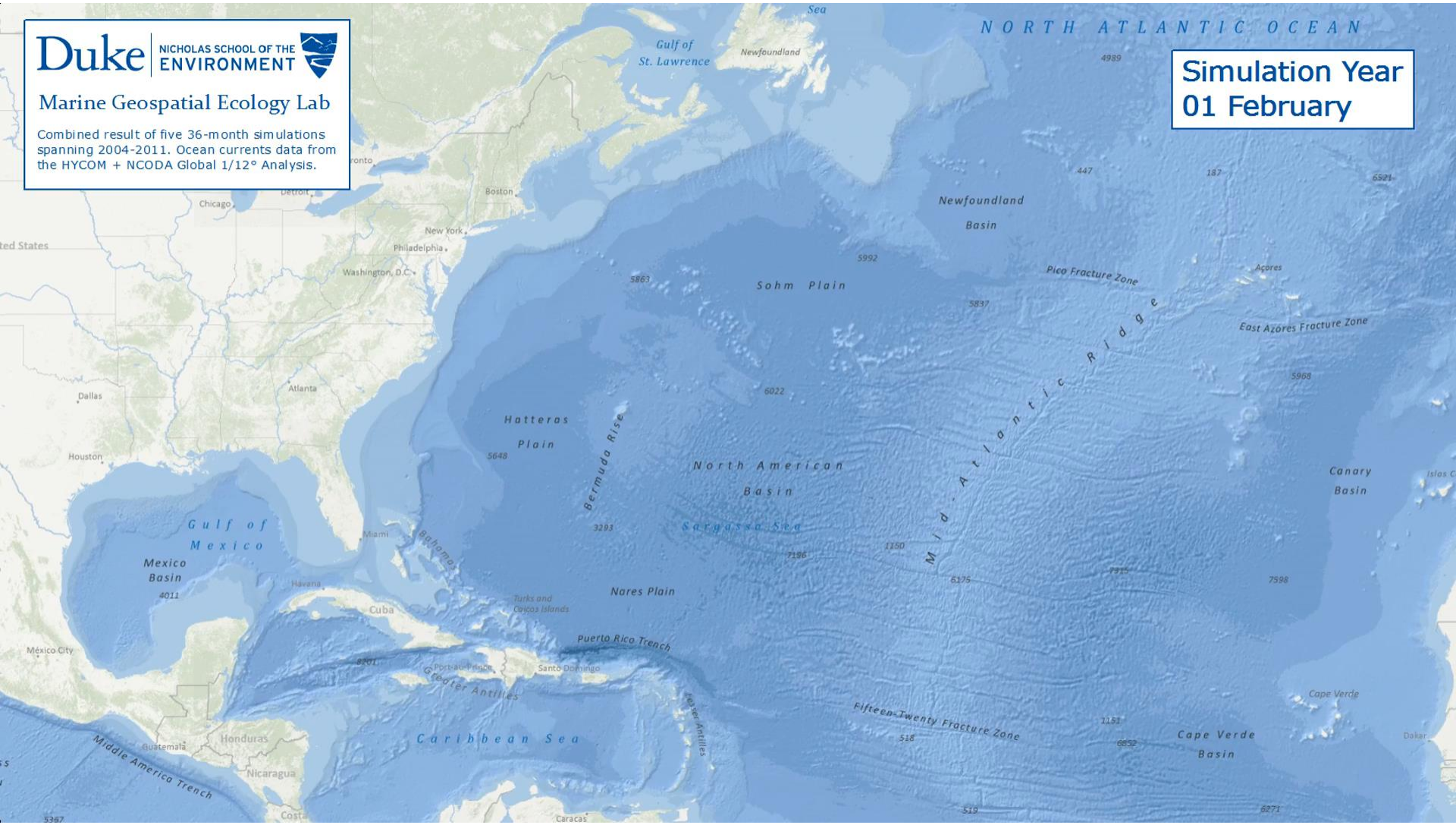
November - December: transition



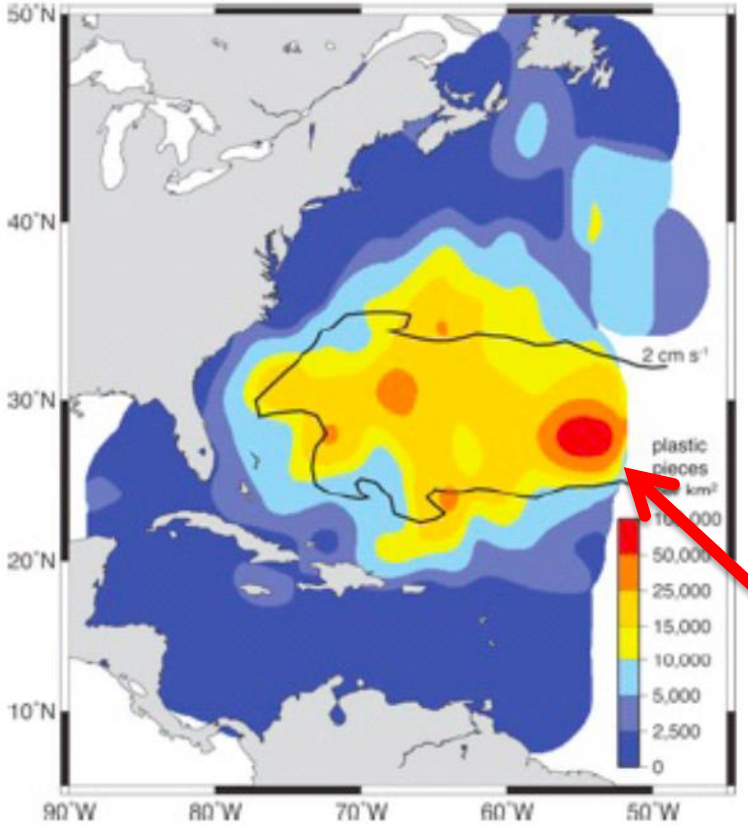
January – April: aggregation



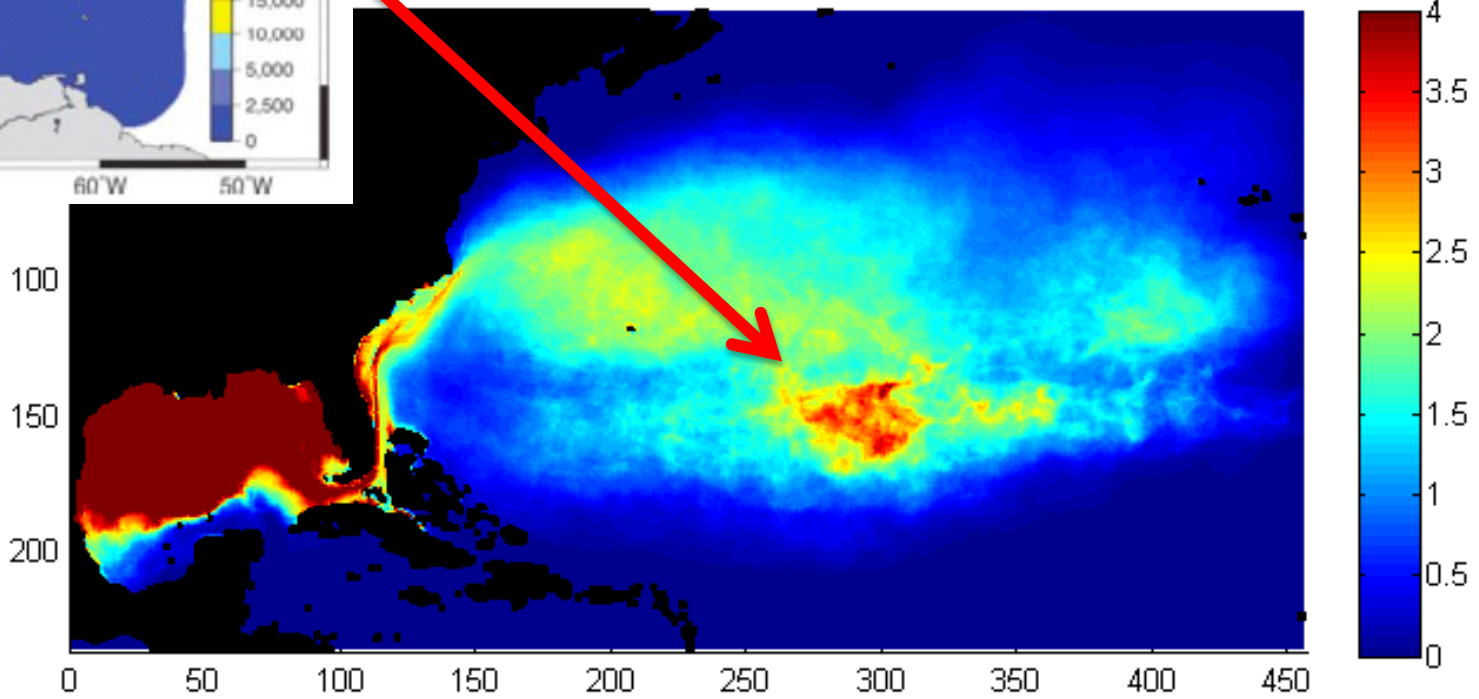
Hydrodynamic dispersal simulations



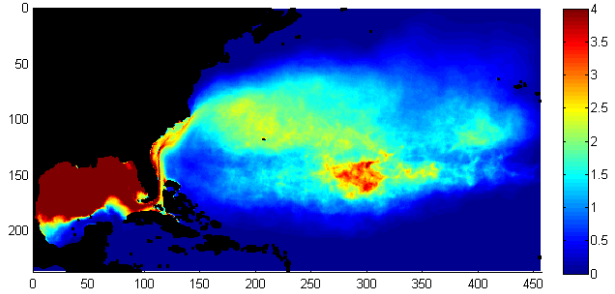
Plastics vs. *Sargassum* Dispersal Simulations



Lew et al. 2010



Sargassum is not plastic; it does not live forever…



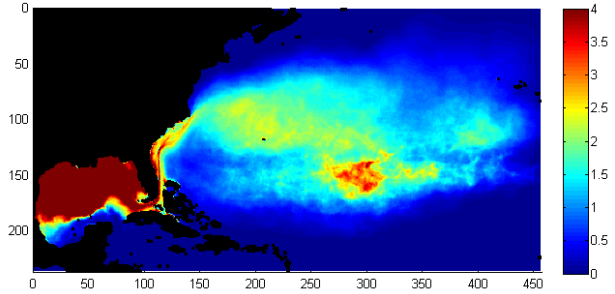
Mortality Model 0: In this model, sargassum grows in February and lives for one year. After the end of the 12th month (January of the following year), it is all killed in a single event.

Mortality Model 1: Sargassum lives for 1 year with no mortality. Then, over the next 12 months, 1/12 dies each month, such that after 24 months, it is all dead.

Mortality Model 2: Feb-Nov: no mortality, Dec-Feb: 1/6 of stock killed off per month, for each of these three months, leaving 1/2 the stock alive, Mar-Nov: no mortality, Dec-Feb: 1/6 stock killed off per month, killing off the remaining 1/2 stock

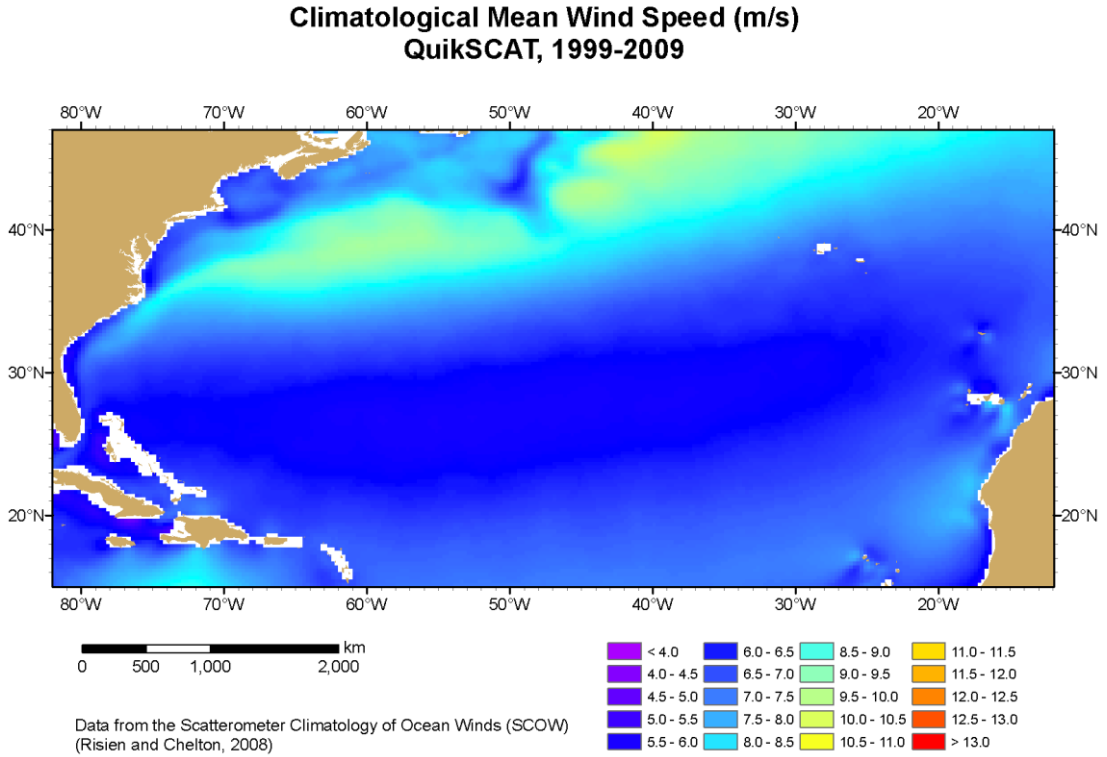
Mortality Model 3: Feb-Nov: no mortality, Dec-Feb: 1/9 of stock killed off per month, for each of these three months, leaving 2/3 the stock alive, Mar-Nov: no mortality, Dec-Feb: 1/9 of stock killed off per month, for each of these three months, leaving 1/3 the stock alive, Mar-Nov: no mortality, Dec-Feb: 1/9 of stock killed off per month, for each of these three months, leaving none alive

Sargassum may also interact with surface winds…

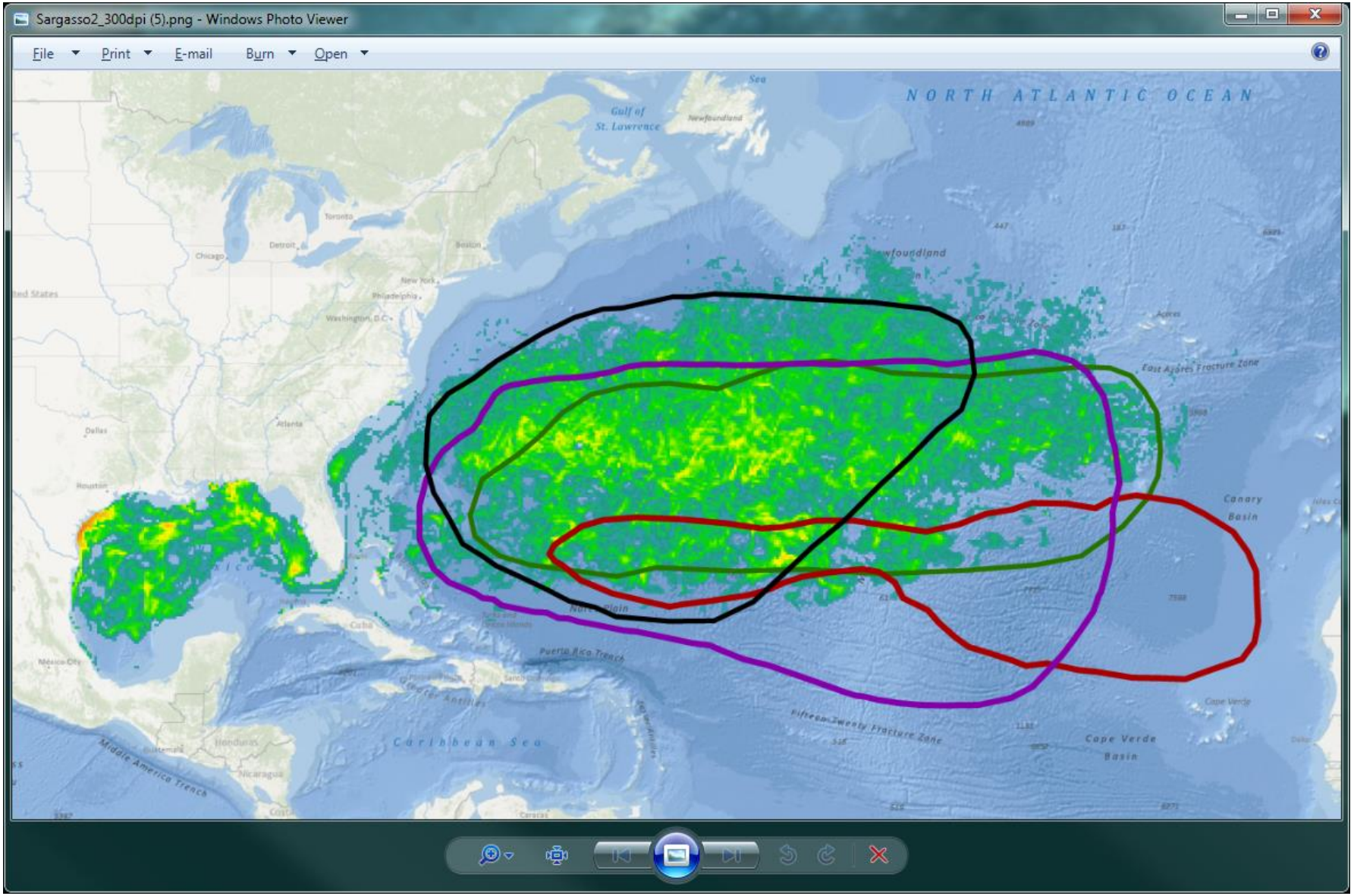


1. Advect Sargassum via Stokes drift.

2. Permanently sink sargassum as wind speed increases, via Langmuir circulation



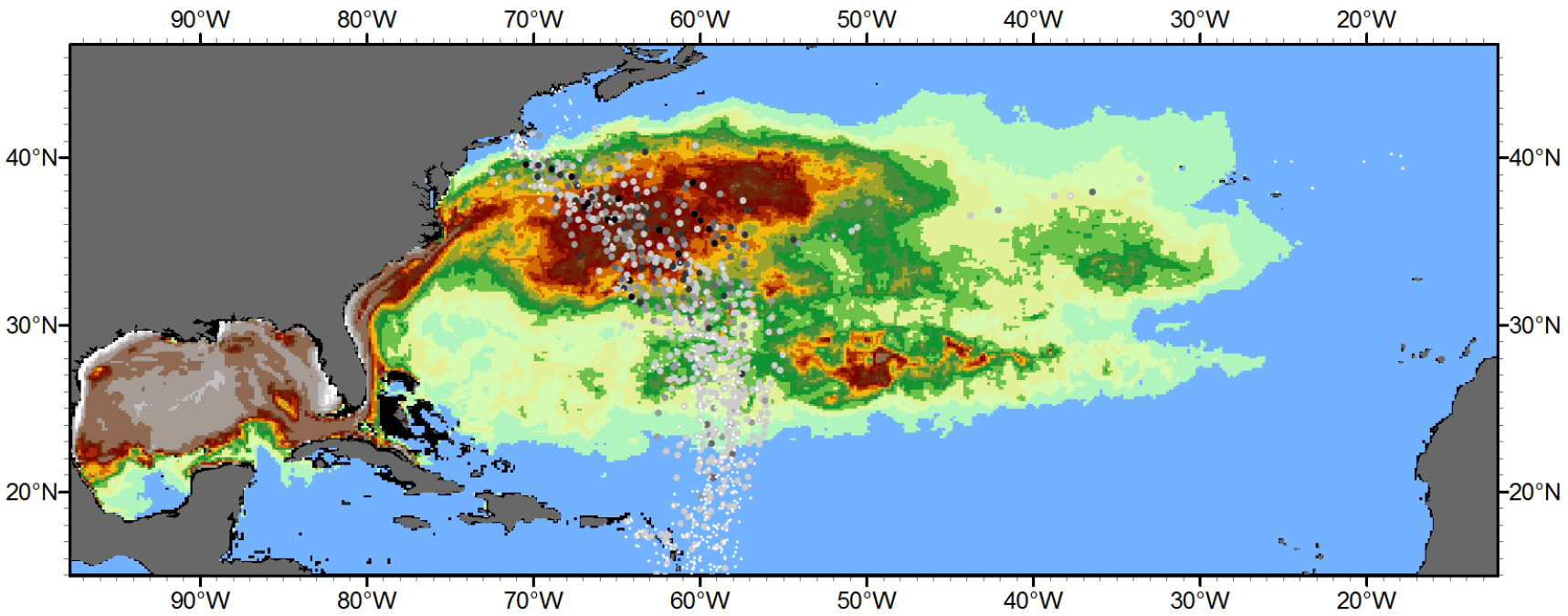
Successive refinements showed some promise…



Results comparison

Simulated Mean Sargassum Density vs. SEA Fall Sargassum Tows
Mortality Model 3 - November (All Years Combined)

Averaged from five 3-year hydrodynamic dispersal simulations:
2004-2006, 2005-2007, 2006-2008, 2007-2009, 2008-2010



km
0 500 1,000 2,000

Density From Tows (g/m^2)

- 0 (tiny white dots)
- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

Simulated Density (abitrary units)

0.0 - 0.2	1.0 - 1.2	2.0 - 2.2	3 - 5
0.2 - 0.4	1.2 - 1.4	2.2 - 2.4	5 - 10
0.4 - 0.6	1.4 - 1.6	2.4 - 2.6	10 - 15
0.6 - 0.8	1.6 - 1.8	2.6 - 2.8	15 - 20
0.8 - 1.0	1.8 - 2.0	2.8 - 3.0	> 20

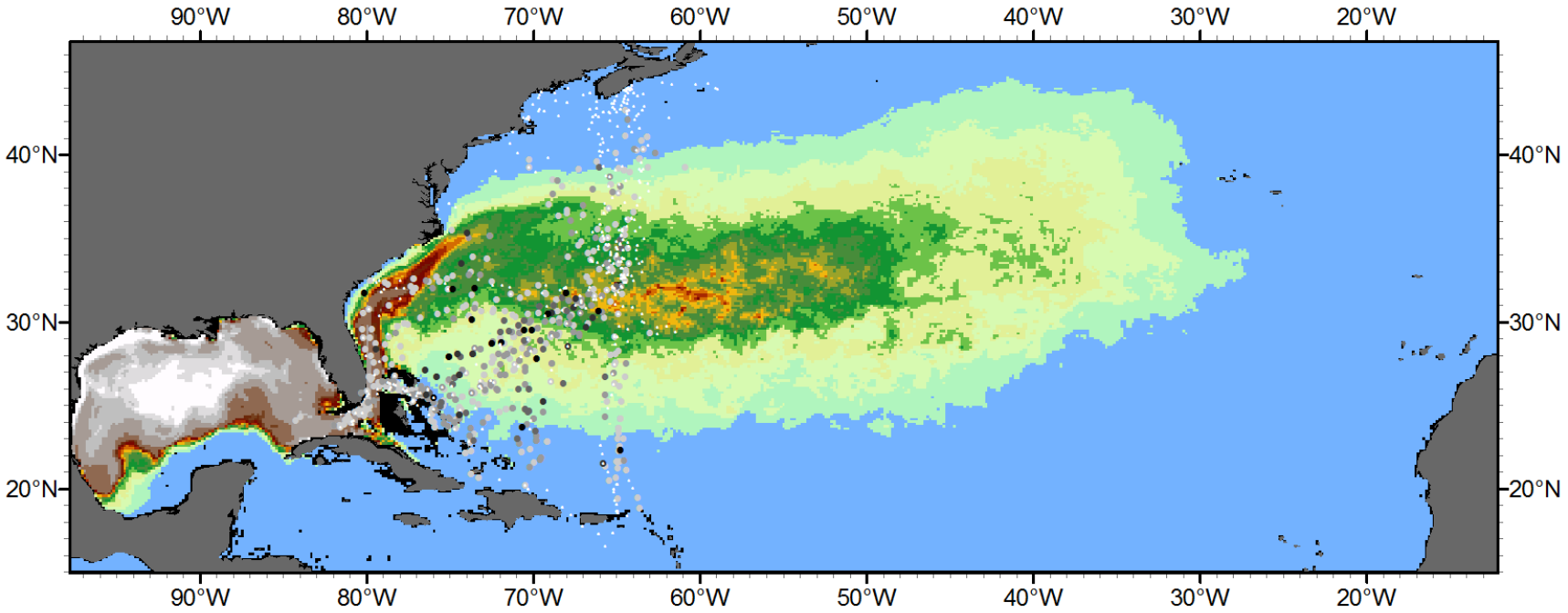
These are arbitrary units of Sargassum per grid cell (80 km^2). When the simulation starts, 48 units / cell / day are released from 1 February through 7 February into 192 cells in the northwestern Gulf of Mexico. On 8 February and every day thereafter, 64512 units in total are in circulation.

Black areas around land are waters not modelled by HYCOM. Sargassum is prevented from entering these areas.

Results comparison

Simulated Mean Sargassum Density vs. SEA Fall Sargassum Tows
Mortality Model 3 - May (All Years Combined)

Averaged from five 3-year hydrodynamic dispersal simulations:
2004-2006, 2005-2007, 2006-2008, 2007-2009, 2008-2010



km
0 500 1,000 2,000

Density From Tows (g/m^2)

- 0 (tiny white dots)
- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

Simulated Density (abitrary units)

0.0 - 0.2	1.0 - 1.2	2.0 - 2.2	3 - 5
0.2 - 0.4	1.2 - 1.4	2.2 - 2.4	5 - 10
0.4 - 0.6	1.4 - 1.6	2.4 - 2.6	10 - 15
0.6 - 0.8	1.6 - 1.8	2.6 - 2.8	15 - 20
0.8 - 1.0	1.8 - 2.0	2.8 - 3.0	> 20

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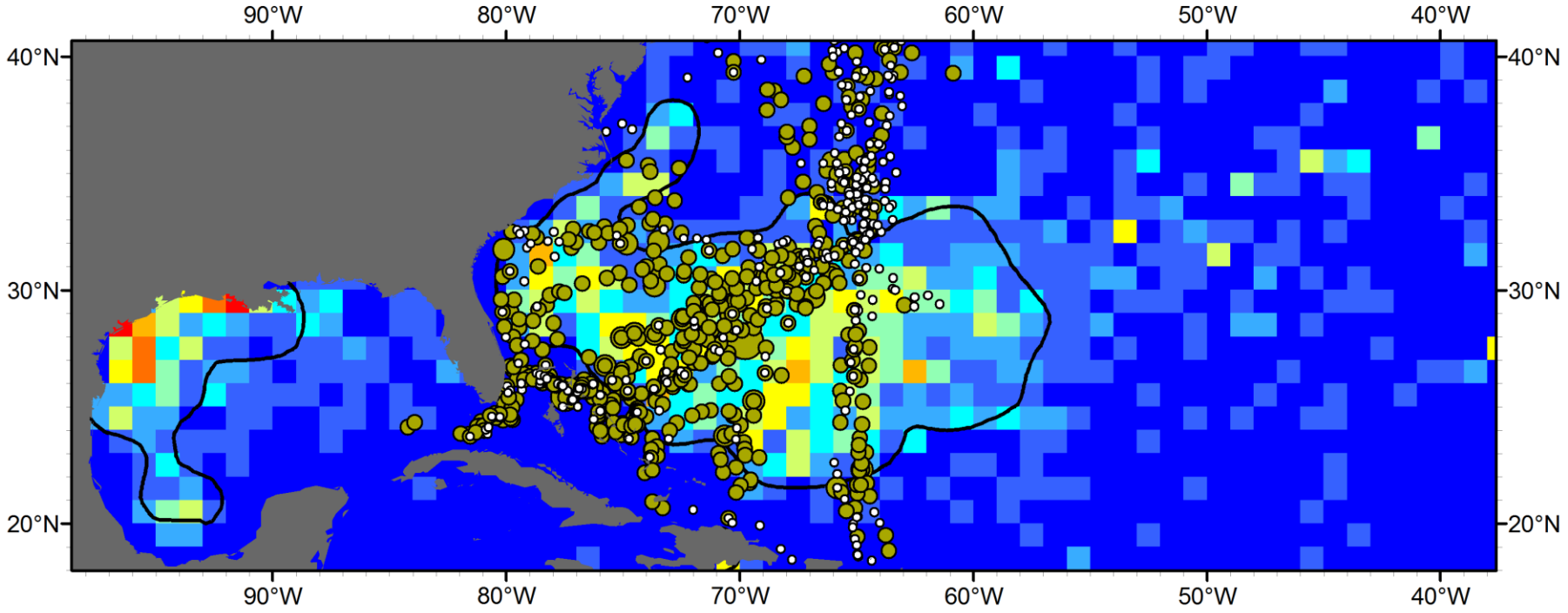
Black areas around land are waters not modelled by HYCOM. Sargassum is prevented from entering these areas.

Results comparison

SEA spring observations & MERIS spring density contour



SEA Observer Data

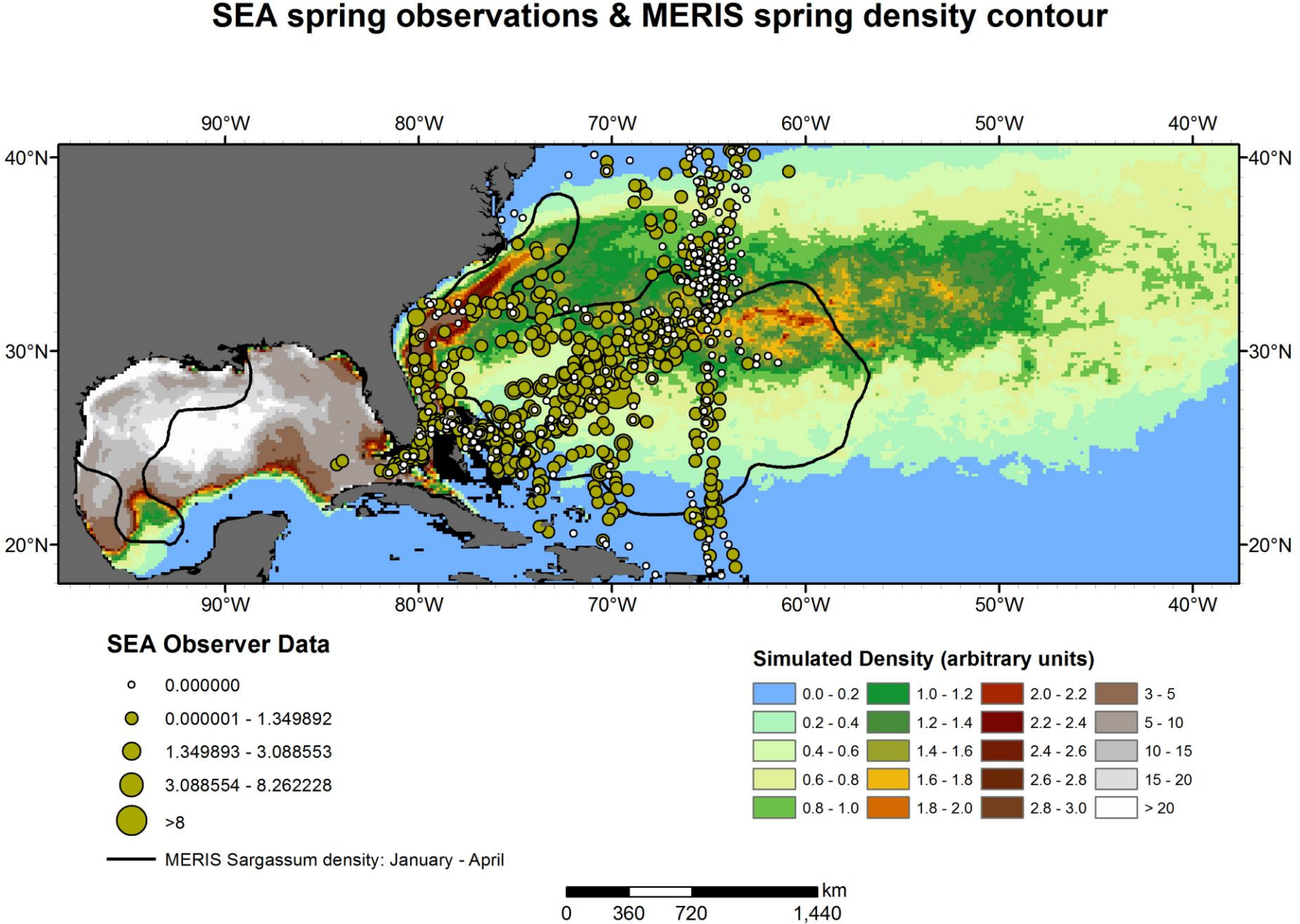
- 0.000000
- 0.000001 - 1.349892
- 1.349893 - 3.088553
- 3.088554 - 8.262228
- >8
- MERIS Sargassum density: January - April

MERIS Count Density: January - April

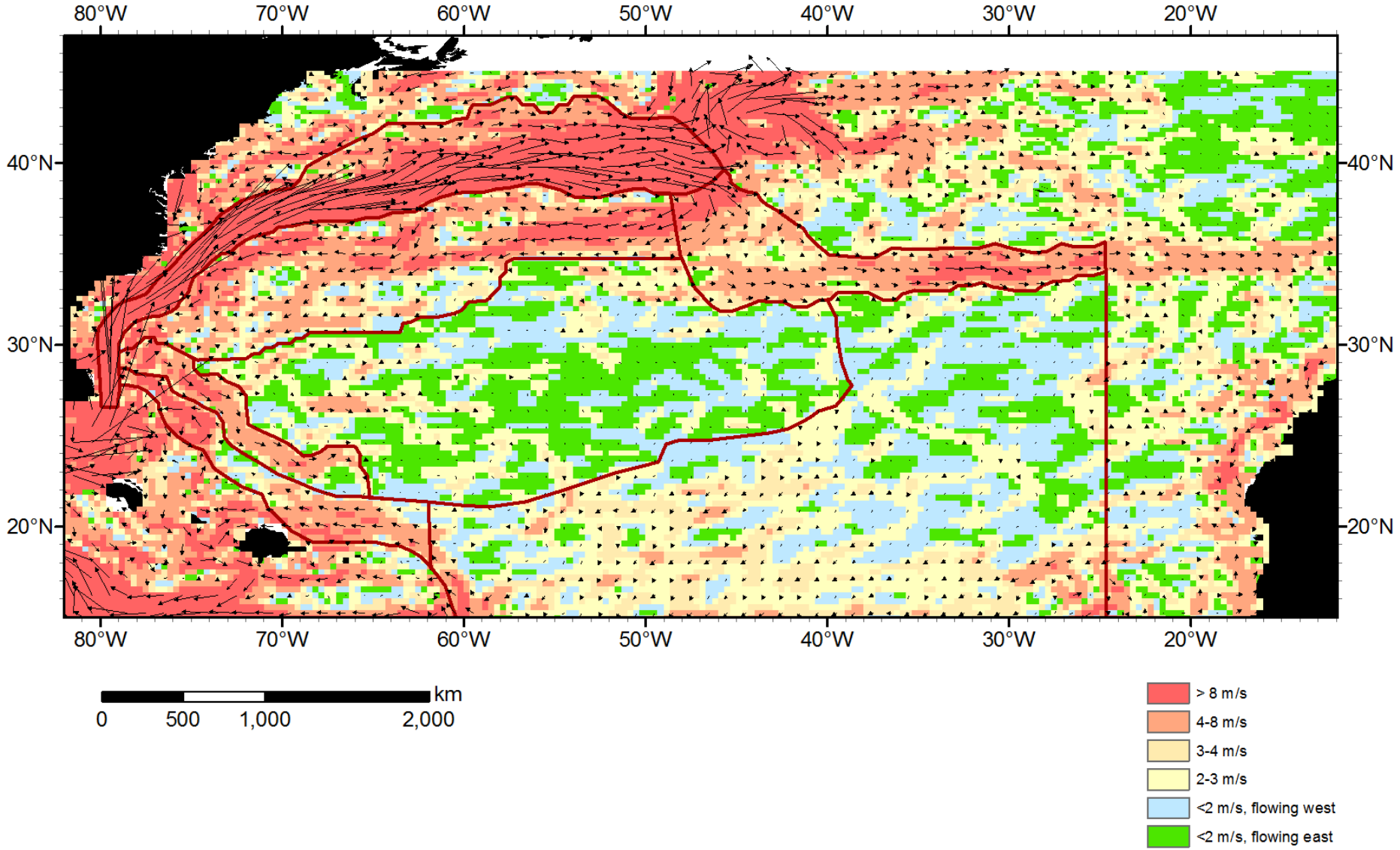
0 - 0.130283221	3.126797307 - 4.299346296
0.130283221 - 0.781699327	4.299346297 - 5.732461727
0.781699327 - 1.563398653	5.732461728 - 9.380391918
1.563398654 - 2.345097979	9.380391919 - 16.93681874
2.34509798 - 3.126797306	16.93681875 - 33.22222137

0 360 720 1,440 km

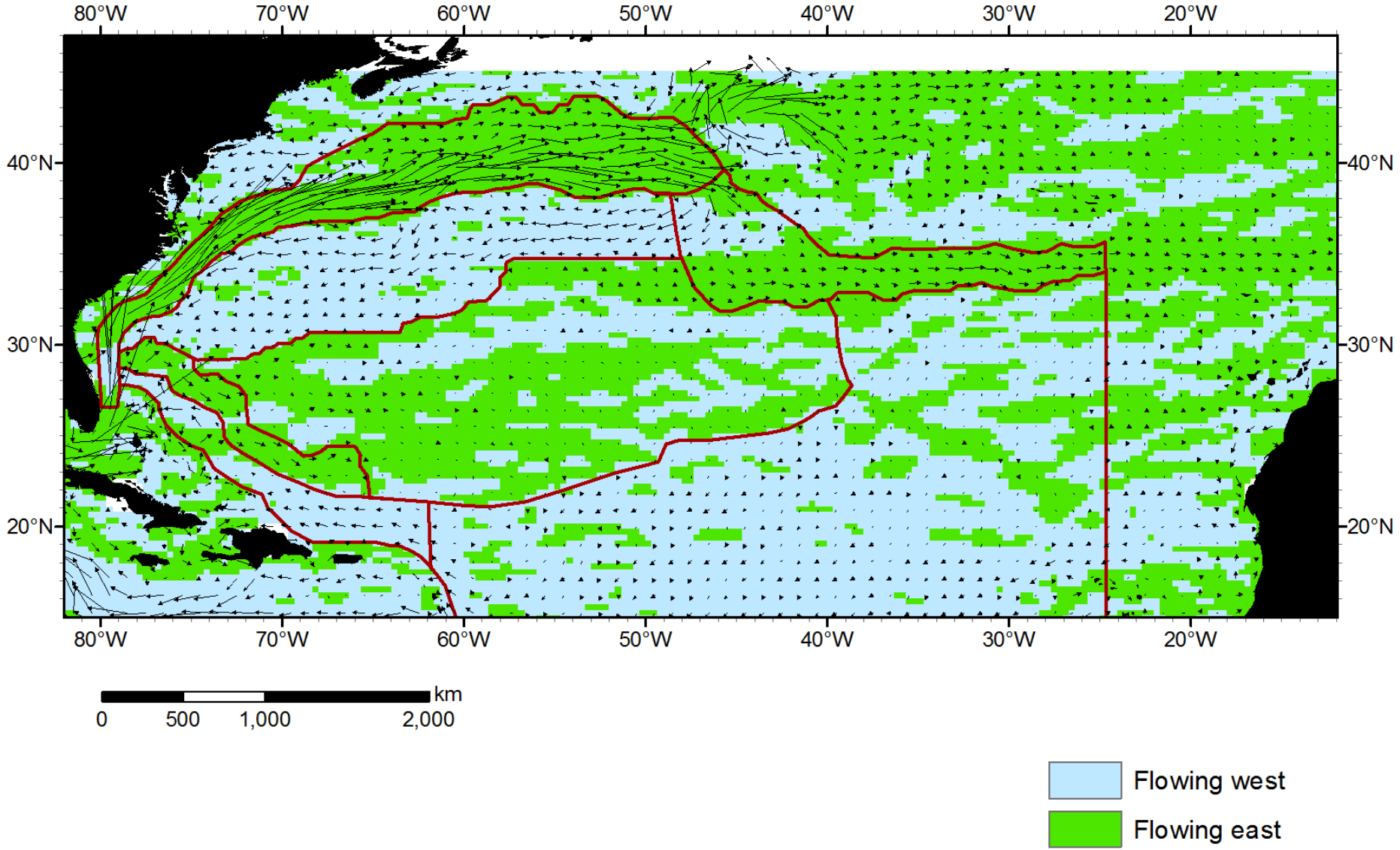
Results comparison



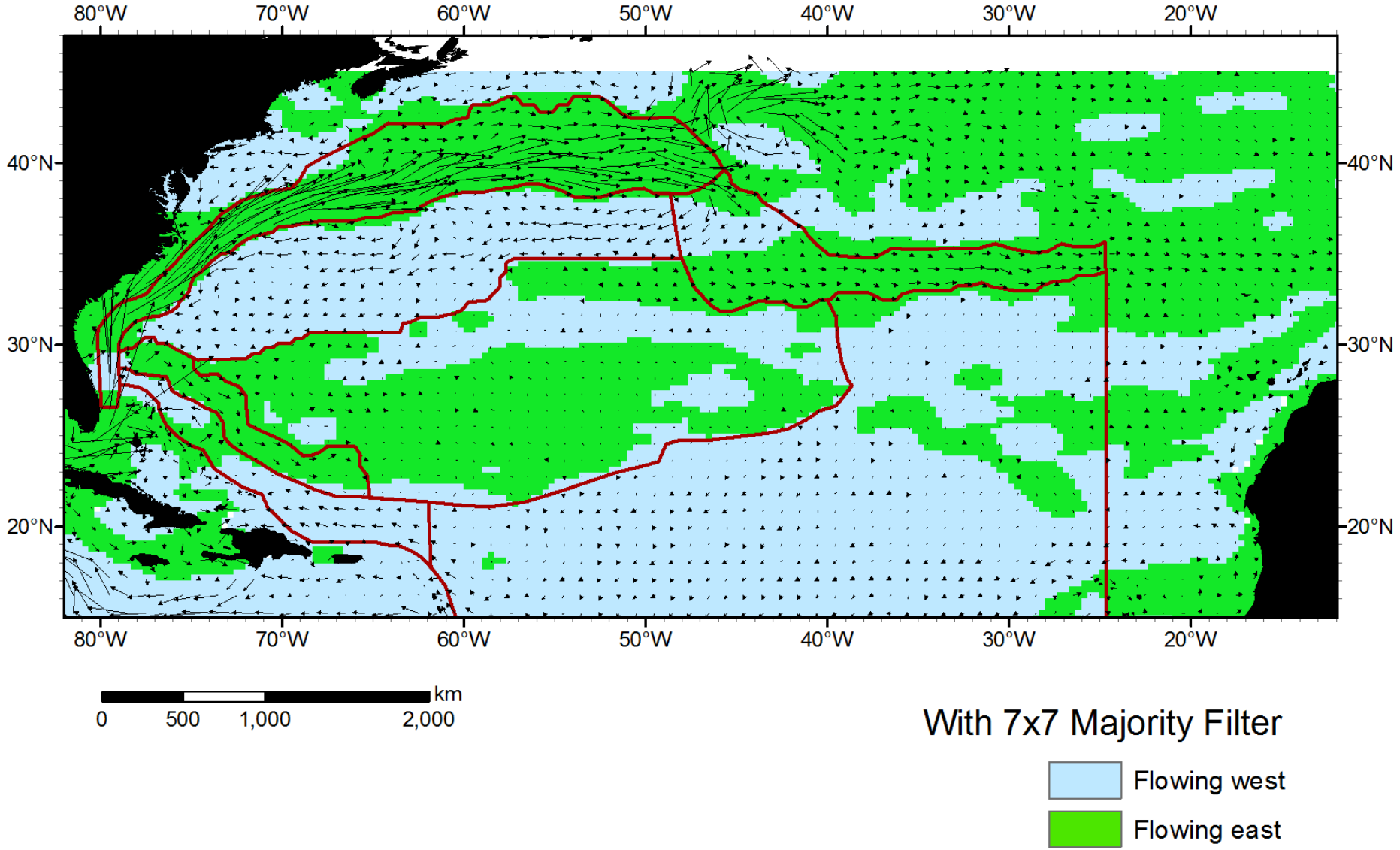
Another approach: circulation features



Another approach: circulation features



Another approach: circulation features



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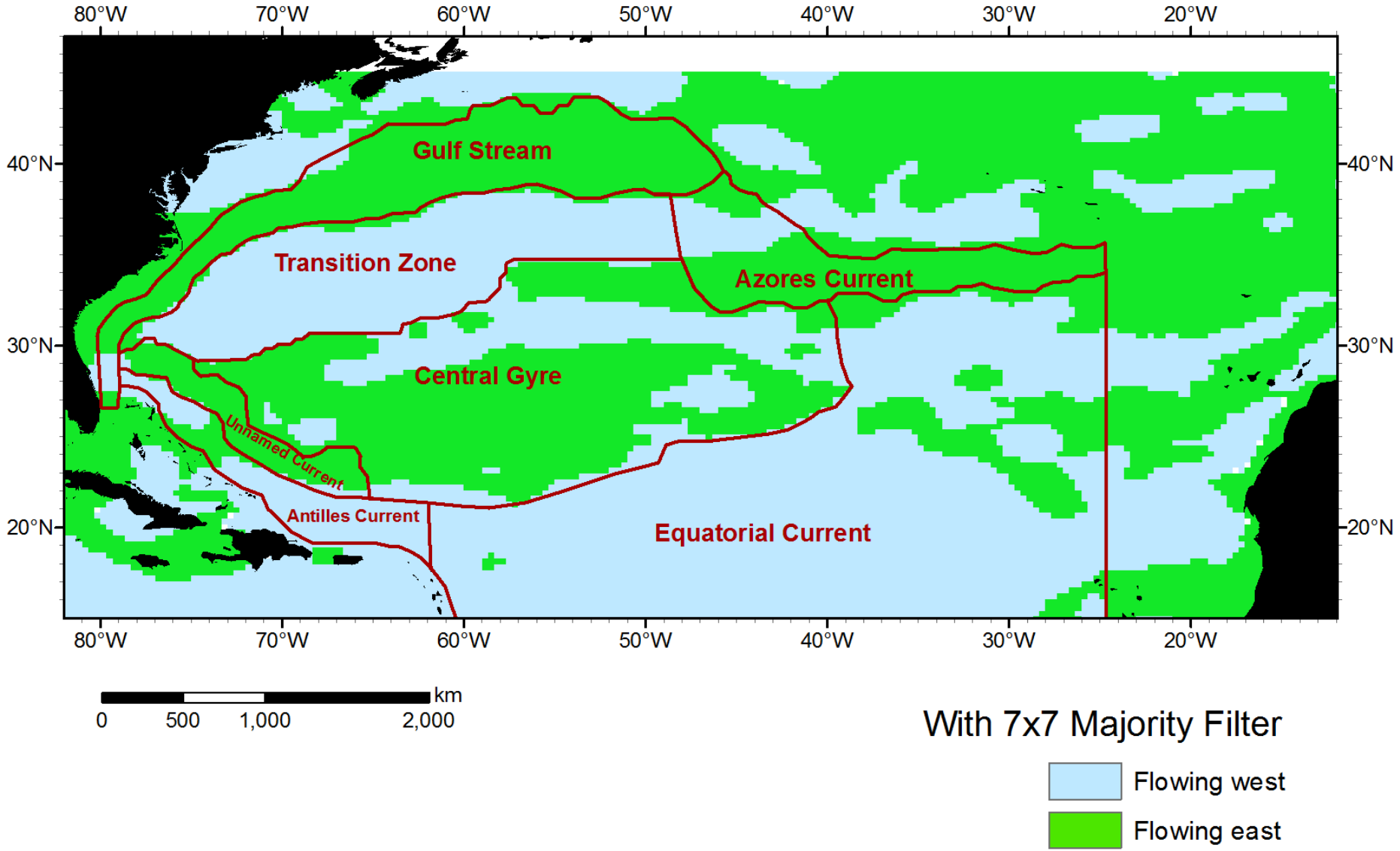
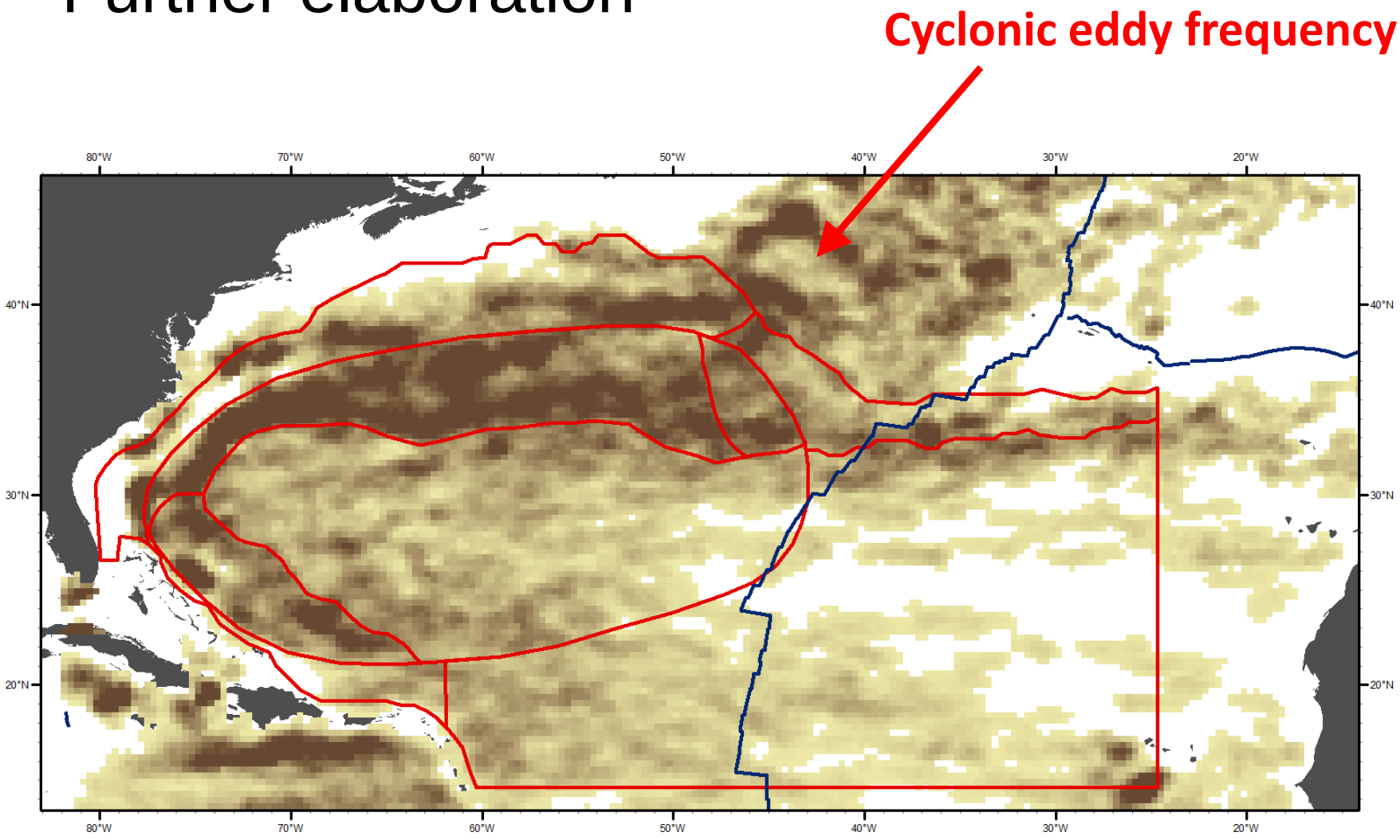
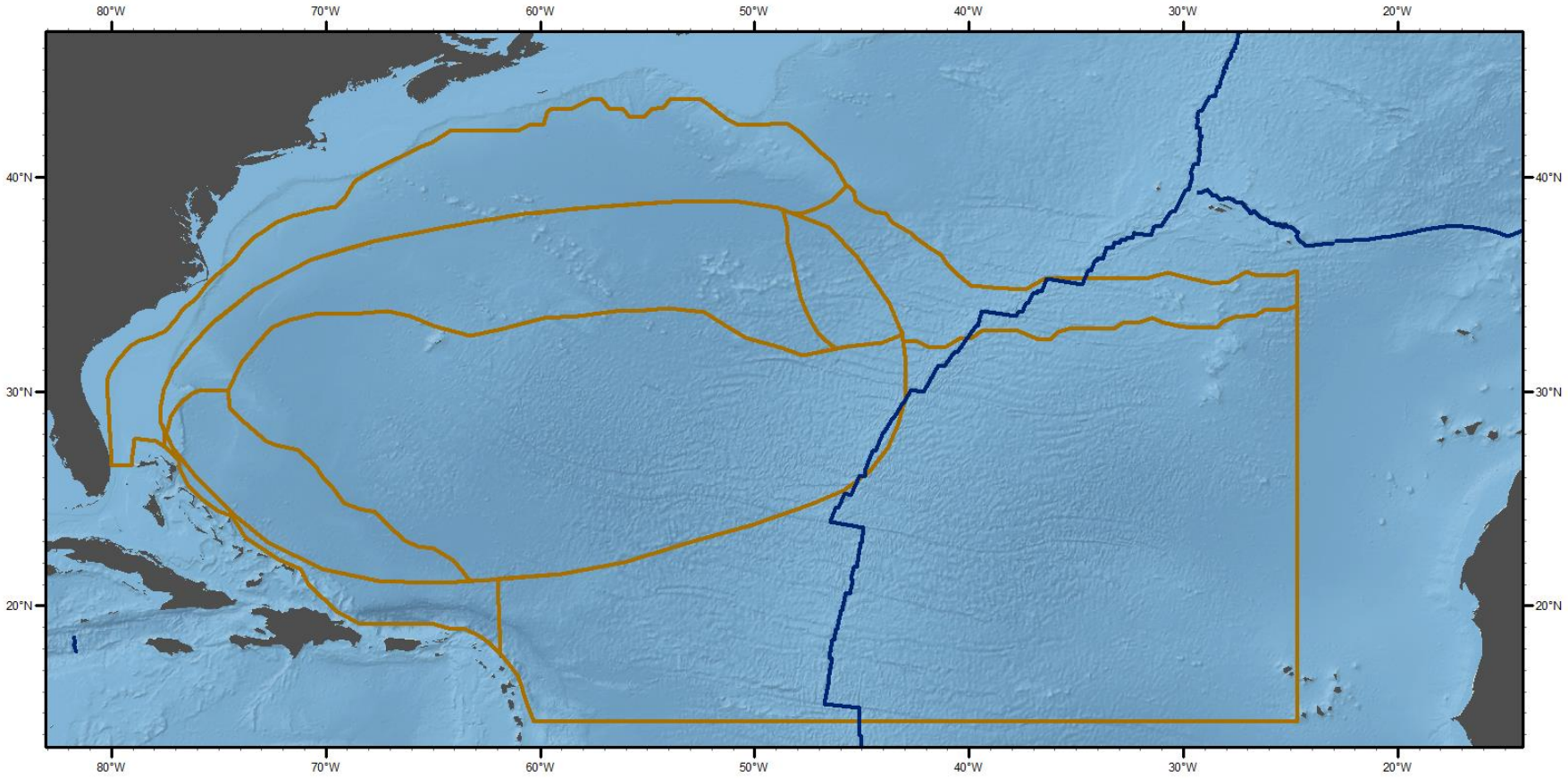


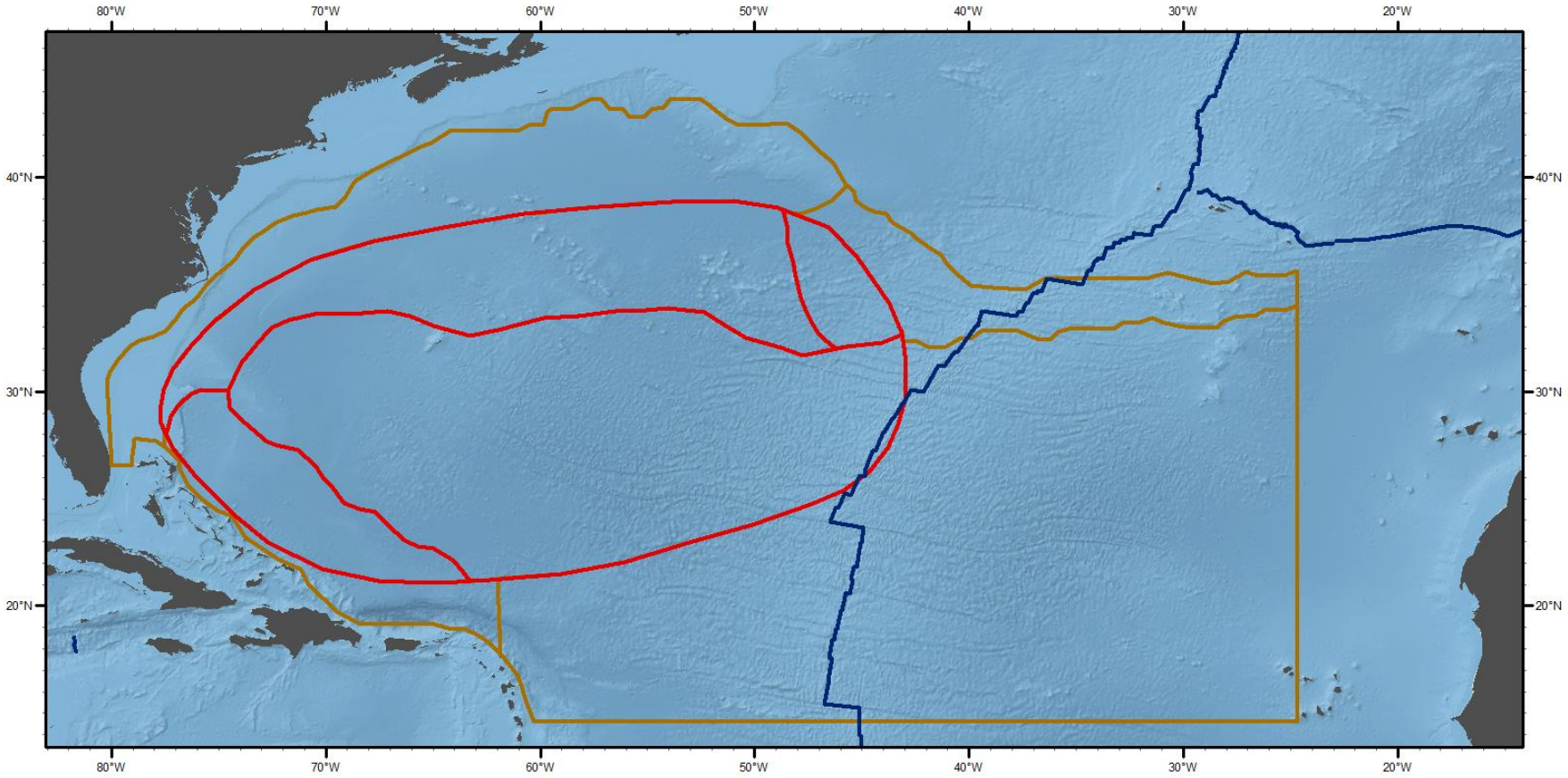
Further elaboration



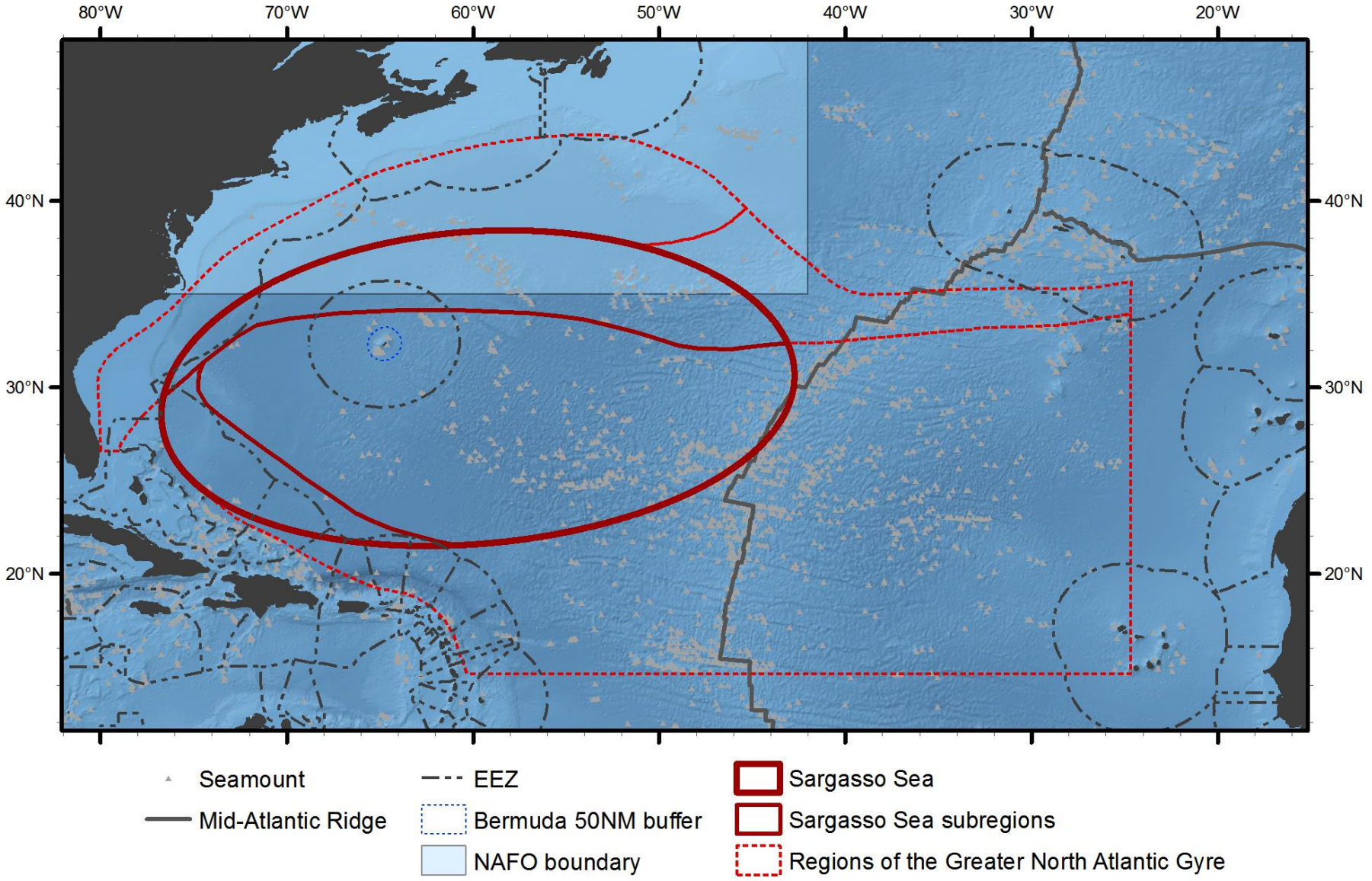
Further elaboration



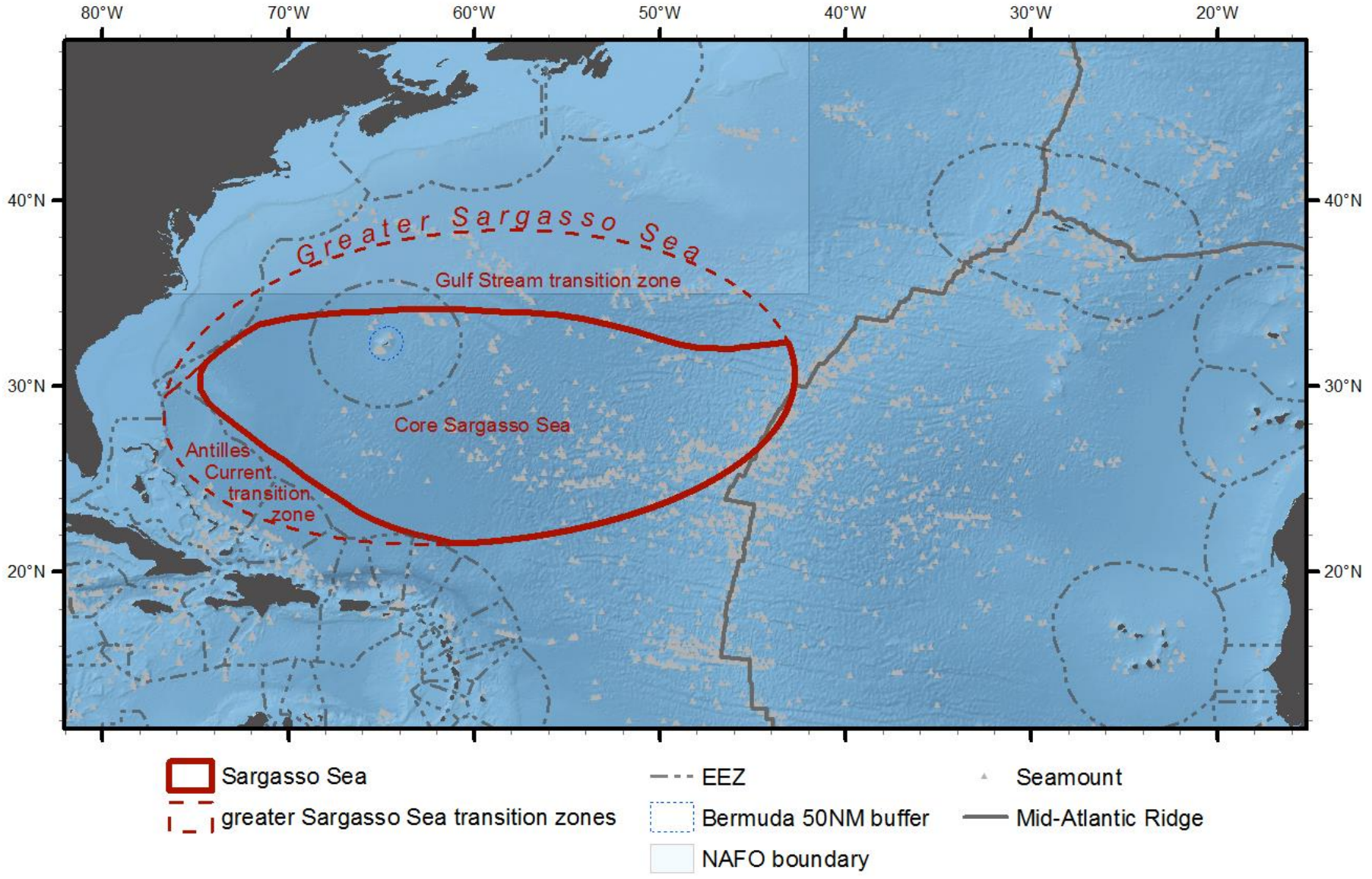
Further elaboration



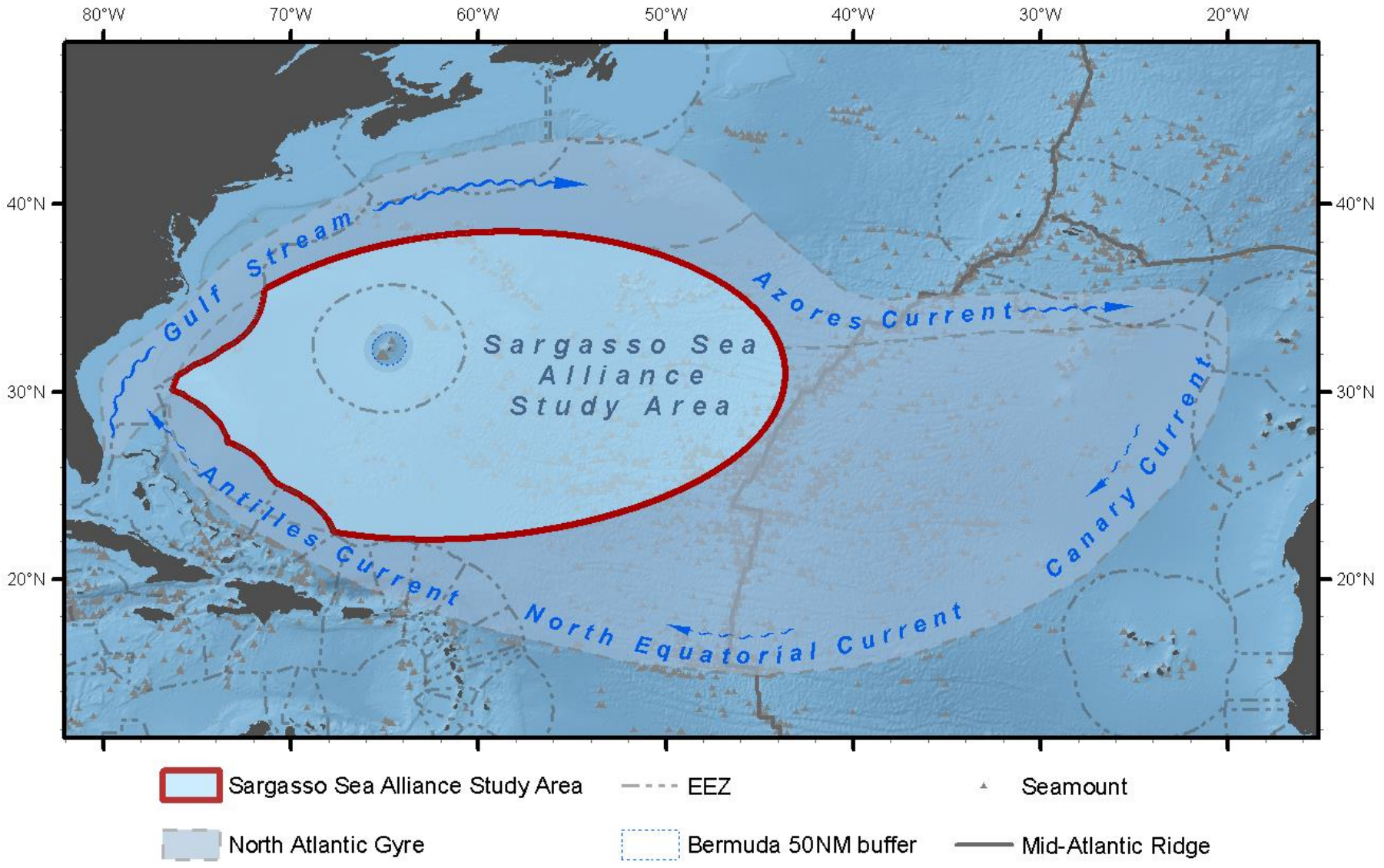
Proposed Sargasso Sea area



Proposed Sargasso Sea area

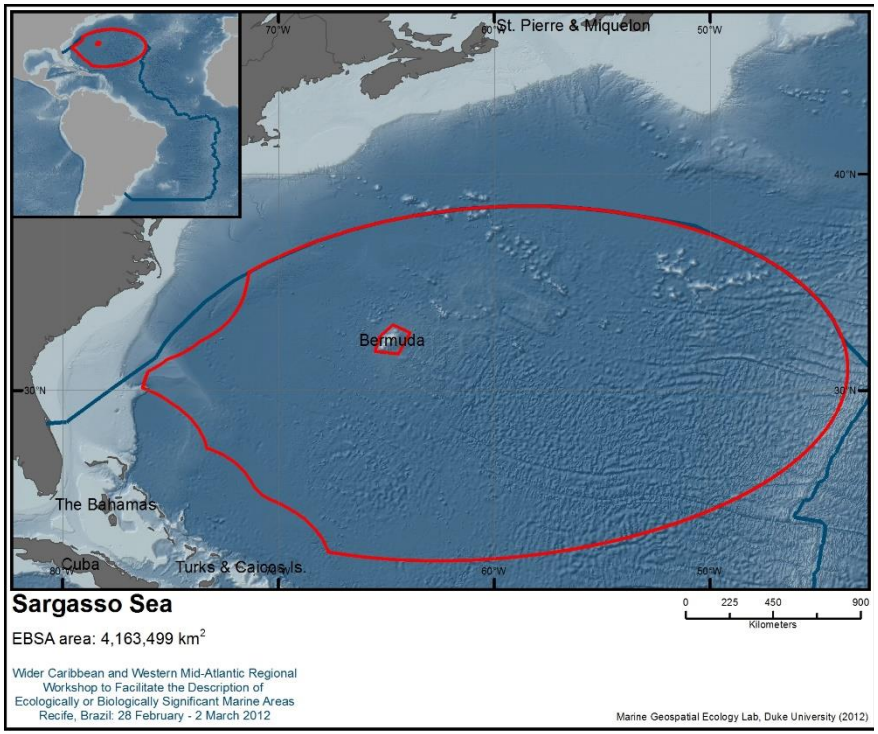


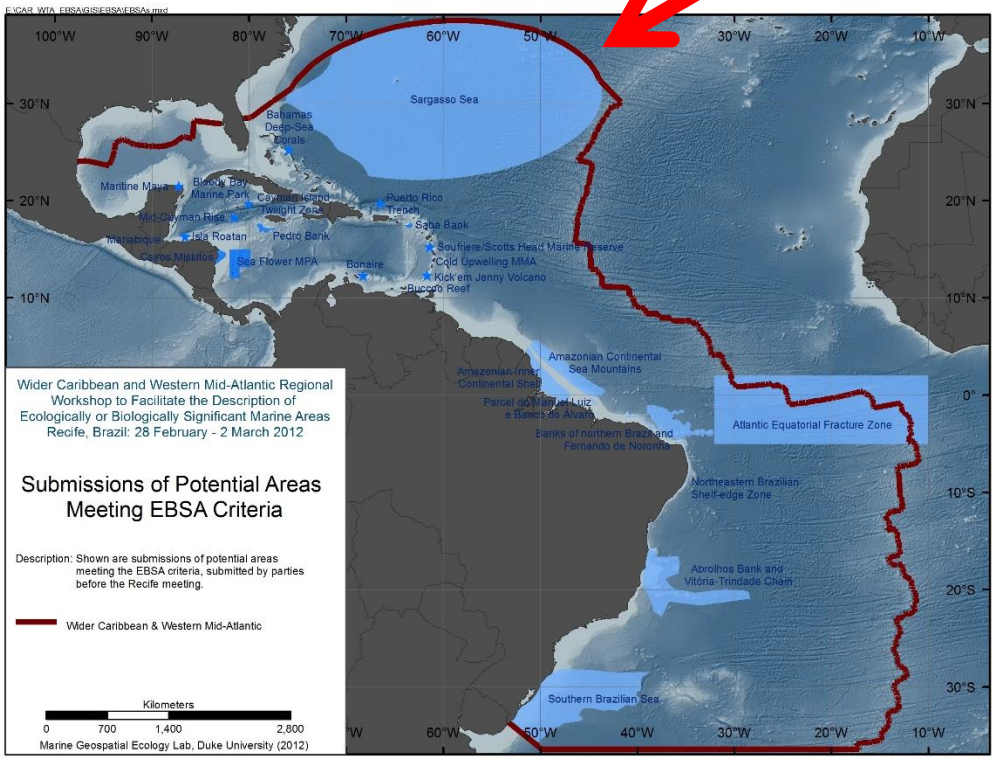
Proposed Sargasso Sea area



Proposed Sargasso Sea area

The Sargasso Sea was formally submitted as a candidate Ecologically or Biologically Significant Area (EBSA) to the UN Convention on Biological Diversity in February 2012





New data developments

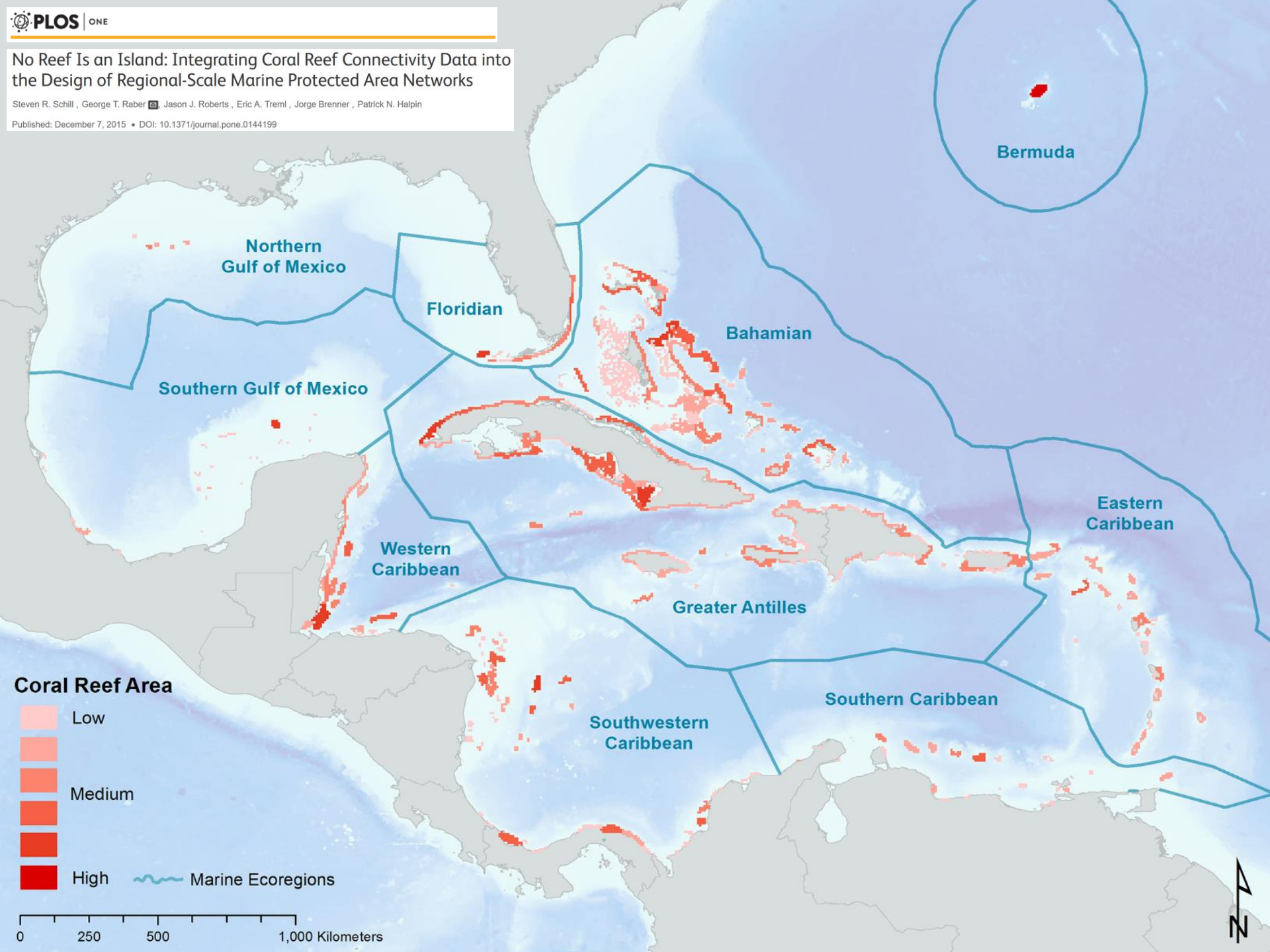
- Coral larval dispersal and connectivity models
- Cetacean density models
- Data product aggregation and synthesis in support of efforts to delineate ecologically and biologically significant areas

PLOS | ONE

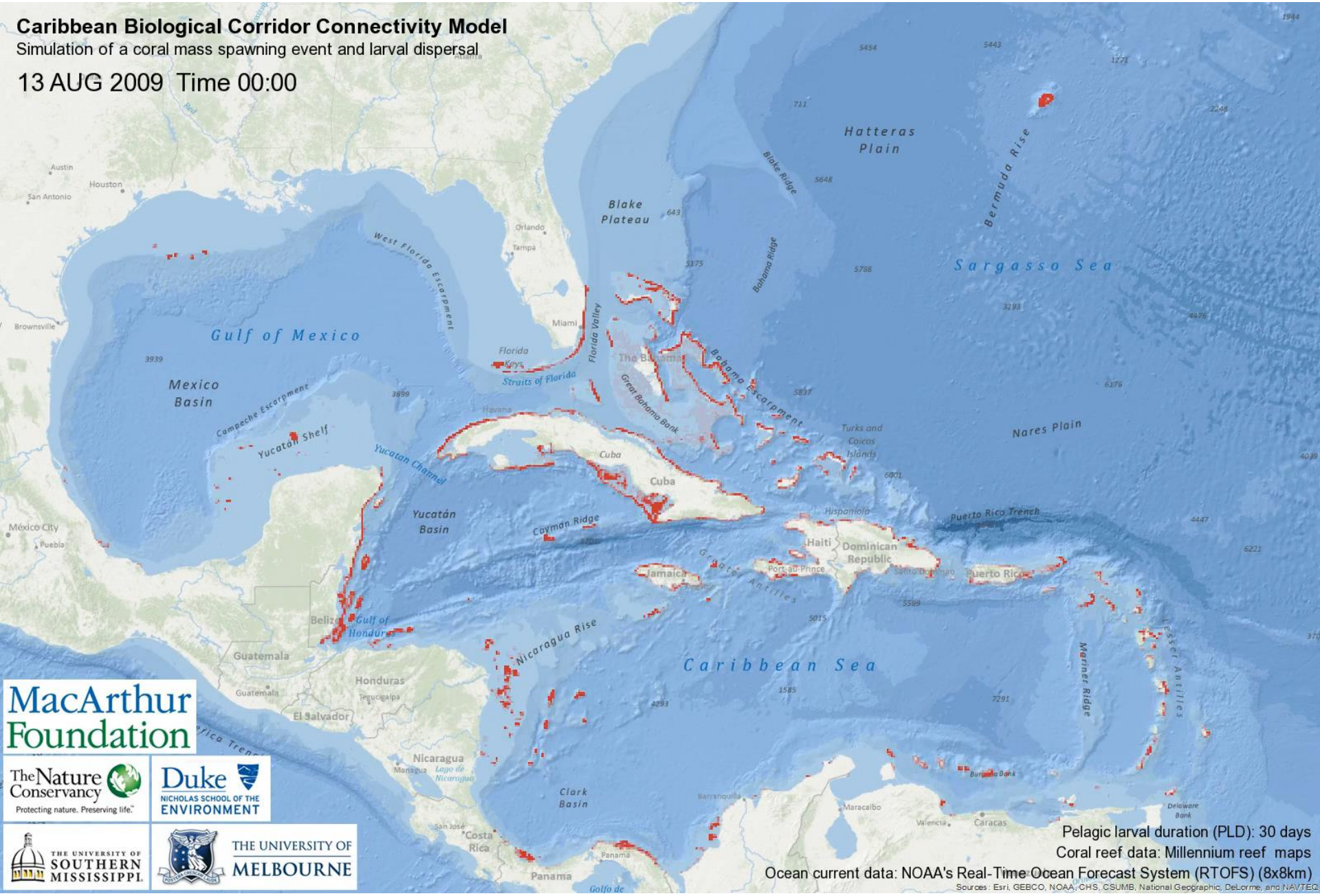
No Reef Is an Island: Integrating Coral Reef Connectivity Data into the Design of Regional-Scale Marine Protected Area Networks

Steven R. Schill , George T. Raber , Jason J. Roberts , Eric A. Treml , Jorge Brenner , Patrick N. Halpin

Published: December 7, 2015 • DOI: 10.1371/journal.pone.0144199



Dispersal driven by RTOFS model



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THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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Larval Connections

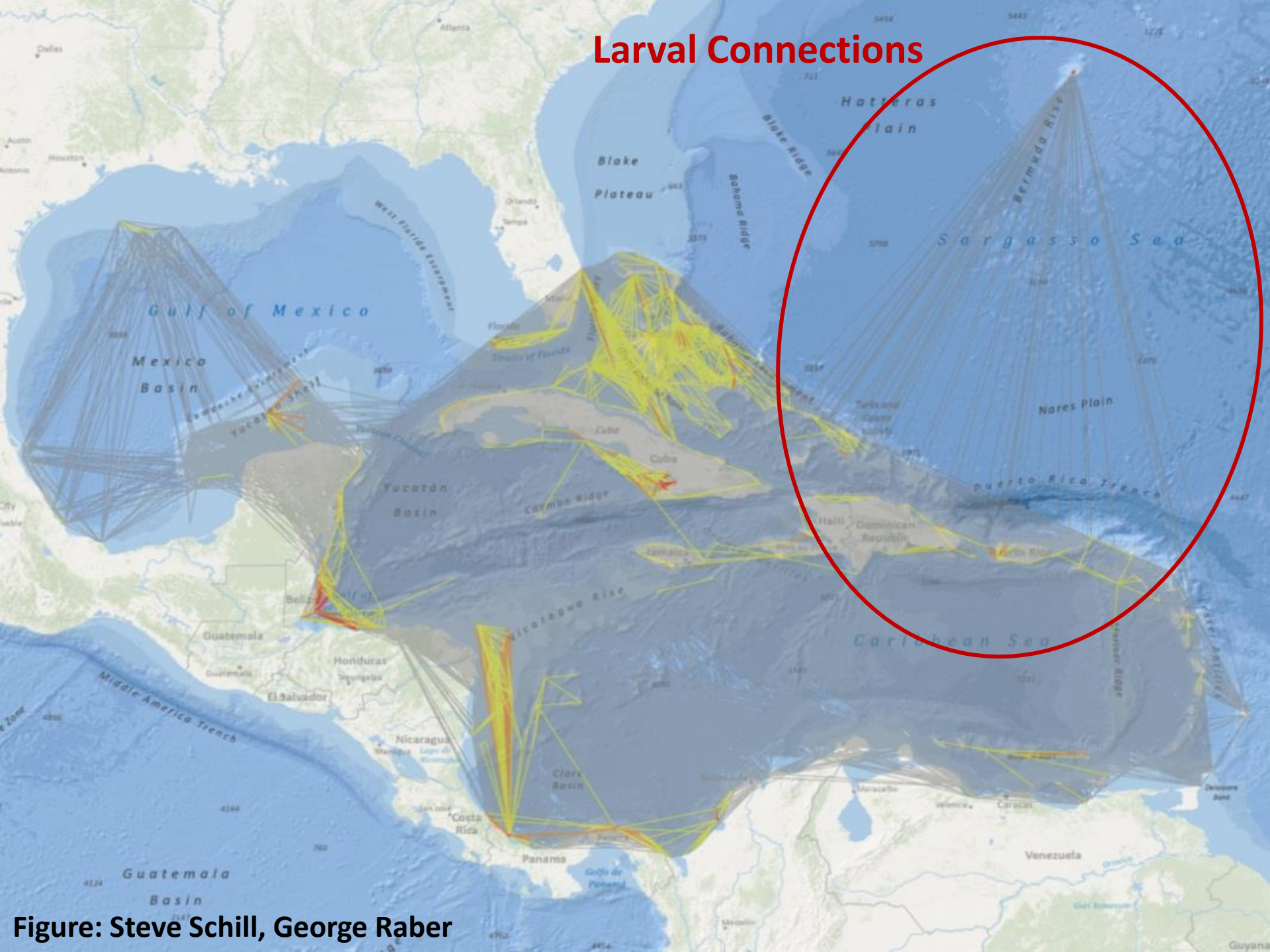

Figure: Steve Schill, George Raber

SCIENTIFIC REPORTS

OPEN

Habitat-based cetacean density models for the U.S. Atlantic and Gulf of Mexico

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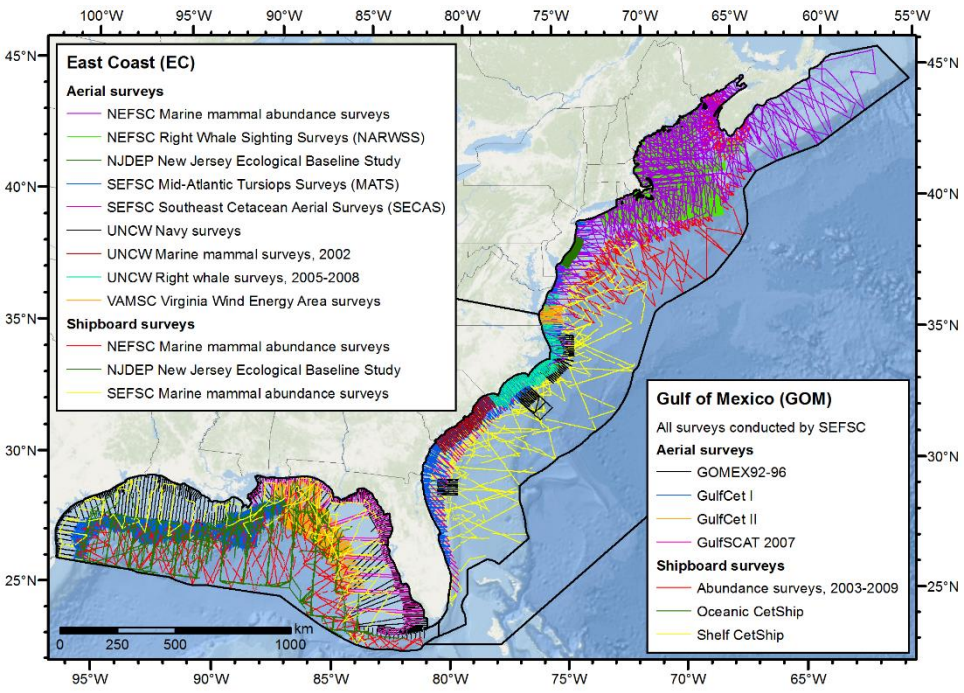
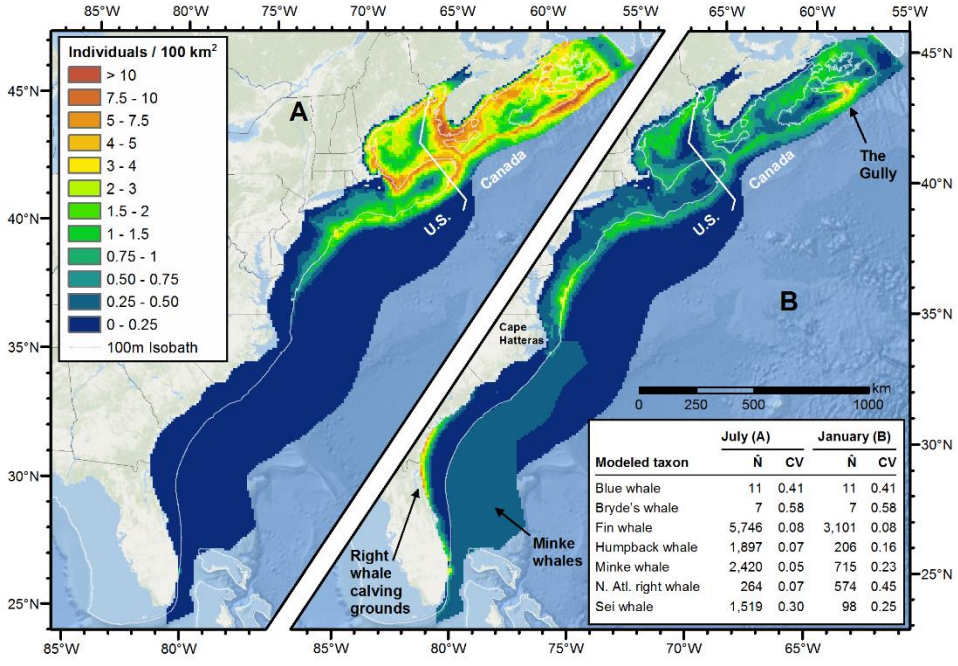
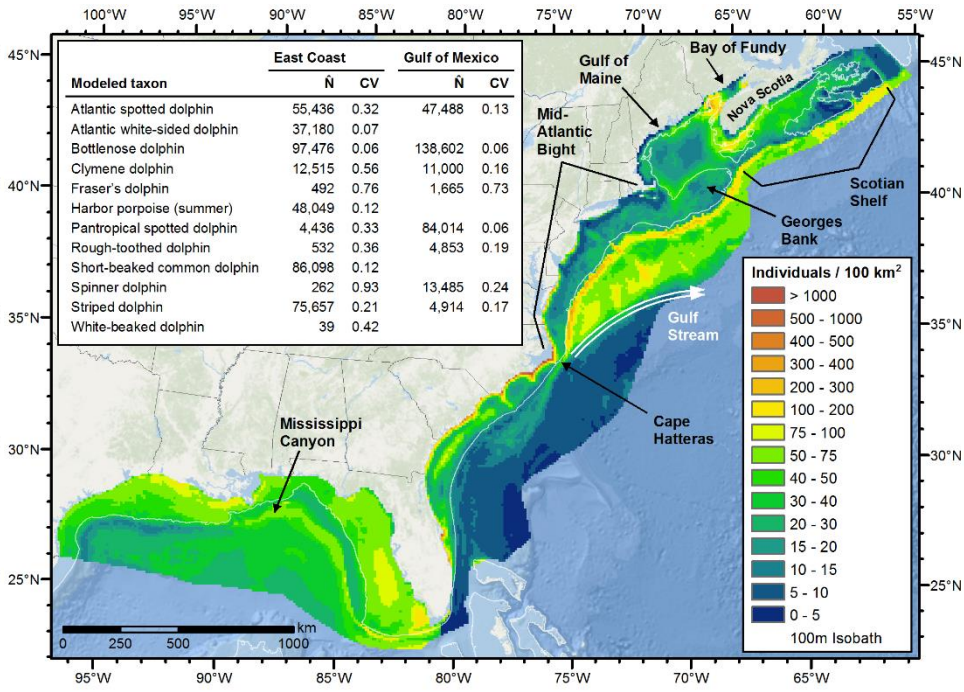
Jason J. Roberts[1], Benjamin D. Best[1,2], Laura Mannocci[1], Ei Fujioka[1], Patrick N. Halpin[1], Debra L. Palka[3], Lance P. Garrison[4], Keith D. Mullin[5], Timothy V. N. Cole[3], Christin B. Khan[3], William A. McLellan[6], D. Ann Pabst[6] & Gwen G. Lockhart[7]

http://www.nature.com/articles/srep22615



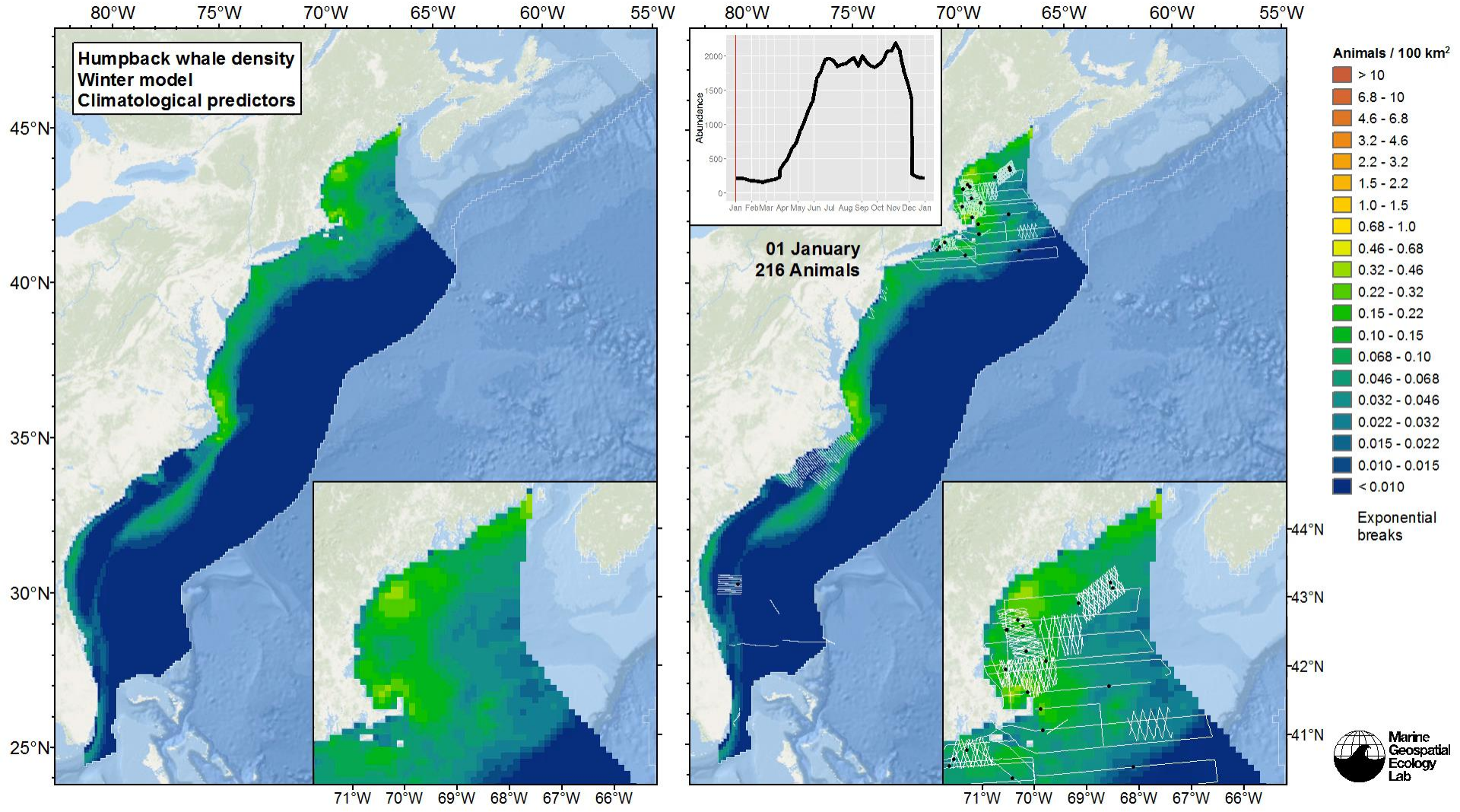


Modeled taxon	July (A) Ñ	July (A) CV	January (B) Ñ	January (B) CV
Blue whale	11	0.41	11	0.41
Bryde's whale	7	0.58	7	0.58
Fin whale	5,746	0.08	3,101	0.08
Humpback whale	1,897	0.07	206	0.16
Minke whale	2,420	0.05	715	0.23
N. Atl. right whale	264	0.07	574	0.45
Sei whale	1,519	0.30	98	0.25

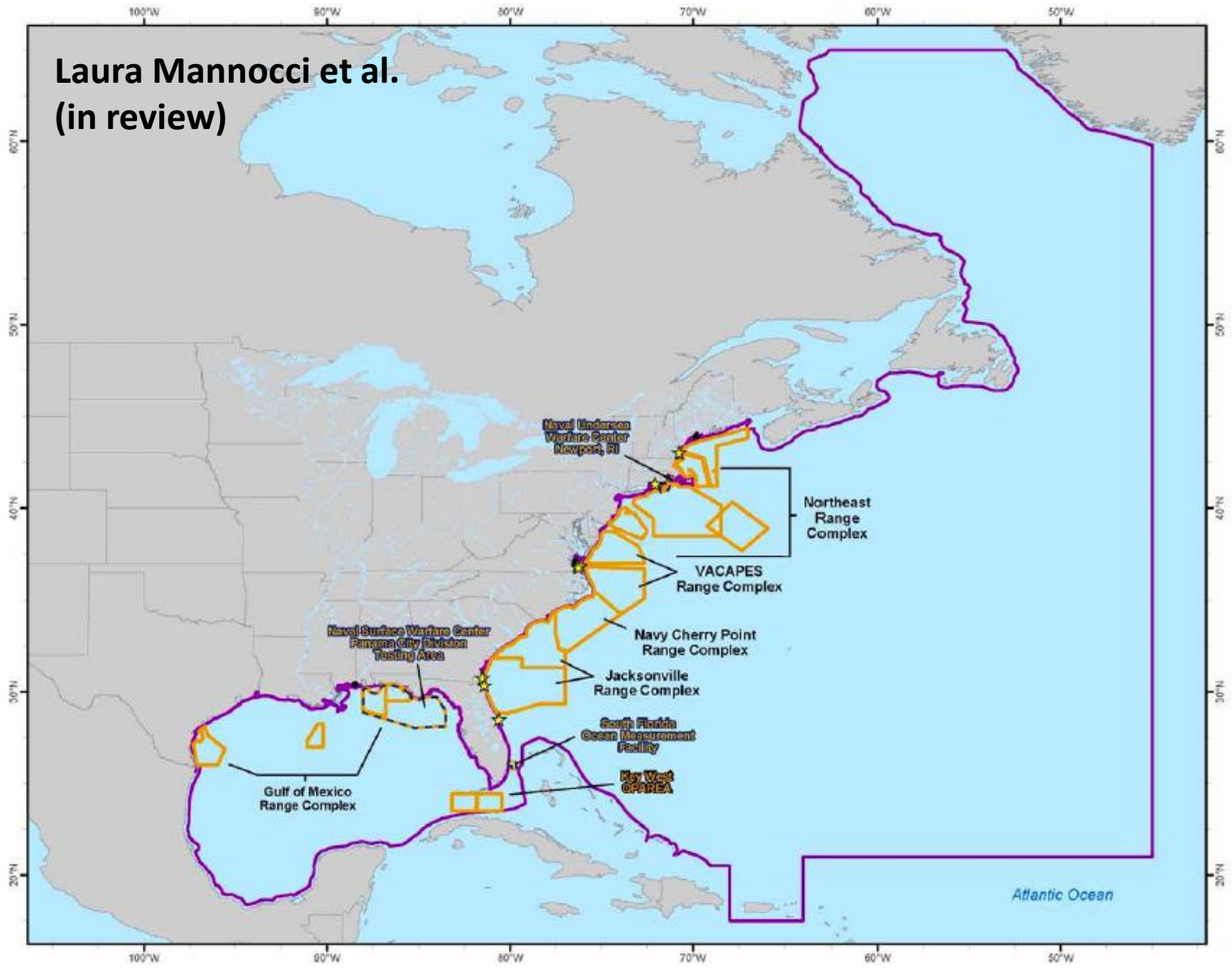


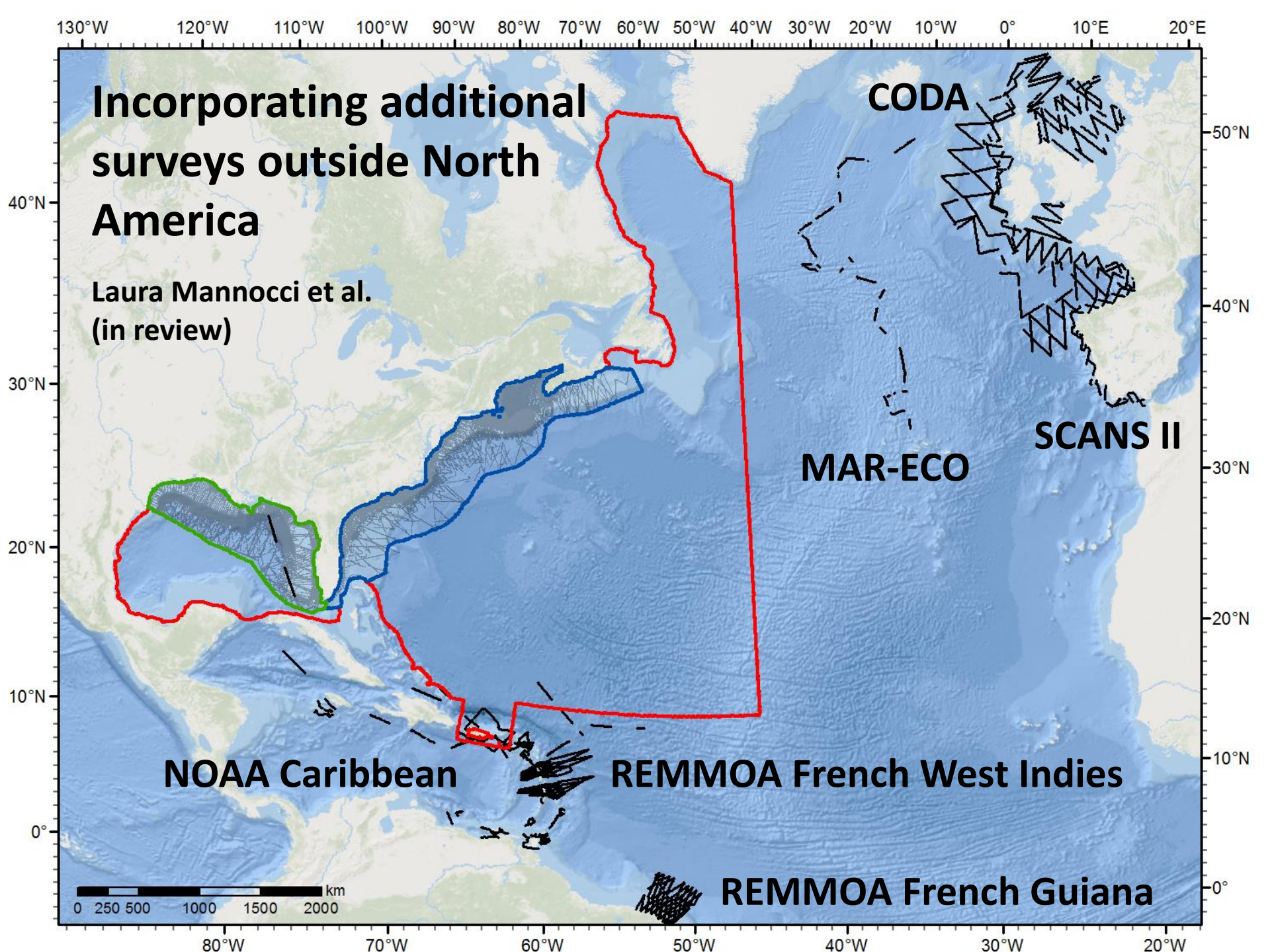
Modeled taxon	East Coast Ñ	East Coast CV	Gulf of Mexico Ñ	Gulf of Mexico CV
Atlantic spotted dolphin	55,436	0.32	47,488	0.13
Atlantic white-sided dolphin	37,180	0.07		
Bottlenose dolphin	97,476	0.06	138,602	0.06
Clymene dolphin	12,515	0.56	11,000	0.16
Fraser's dolphin	492	0.76	1,665	0.73
Harbor porpoise (summer)	48,049	0.12		
Pantropical spotted dolphin	4,436	0.33	84,014	0.06
Rough-toothed dolphin	532	0.36	4,853	0.19
Short-beaked common dolphin	86,098	0.12		
Spinner dolphin	262	0.93	13,485	0.24
Striped dolphin	75,657	0.21	4,914	0.17
White-beaked dolphin	39	0.42		

Humpback whales

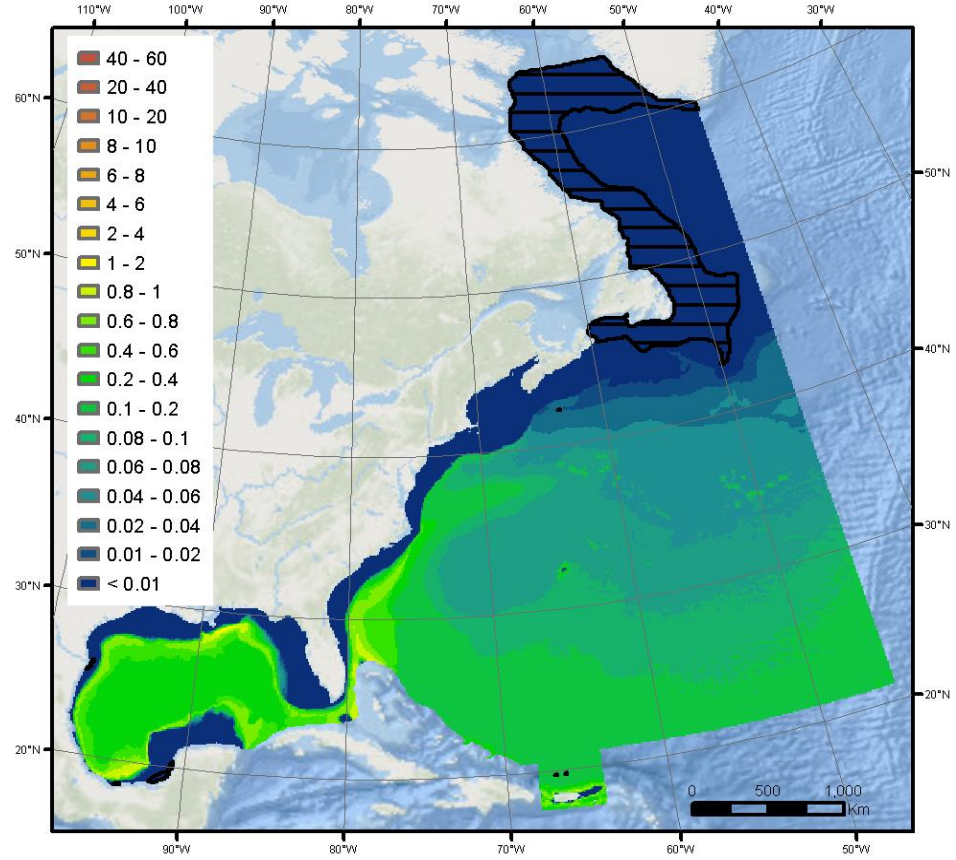


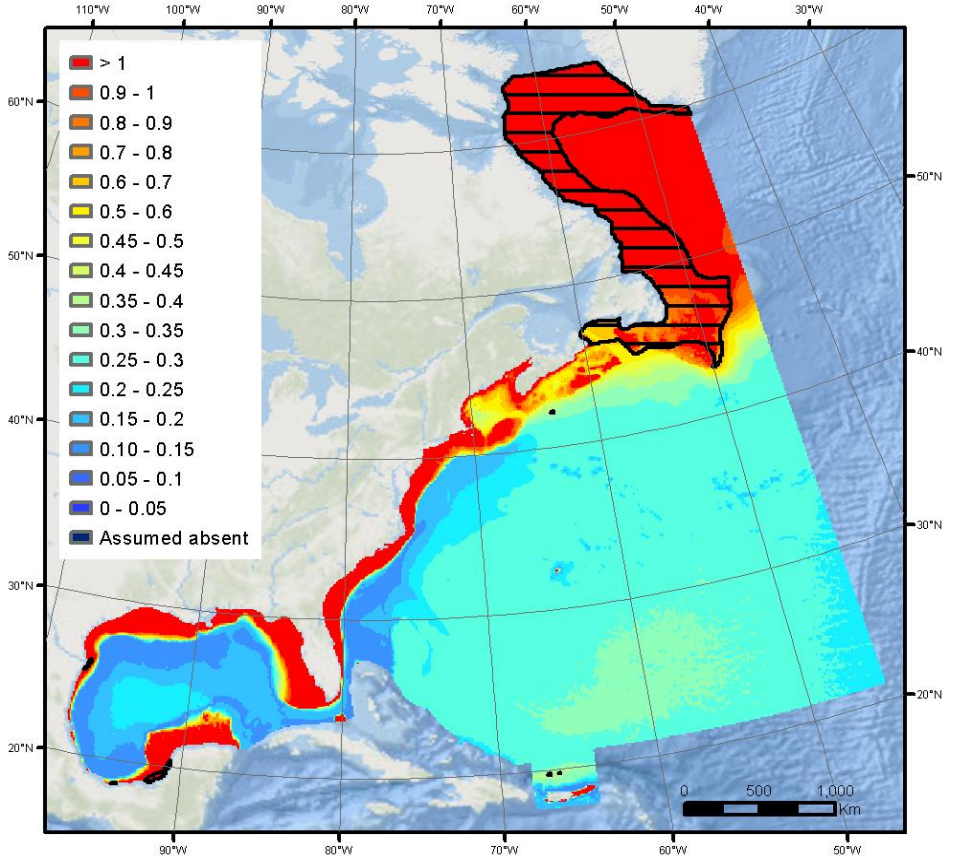
Cetacean densities beyond the U.S. EEZ:
The U.S. Navy Atlantic Fleet Testing & Training (AFTT) Area




Incorporating additional surveys outside North America
Laura Mannocci et al.
(in review)
CODA
SCANS II
MAR-ECO
NOAA Caribbean
REMMOA French West Indies
REMMOA French Guiana
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
50°W
40°W
30°W
20°W
10°W
0°
10°E
20°E
50°N
40°N
30°N
20°N
10°N
0°
km
0 250 500 1000 1500 2000

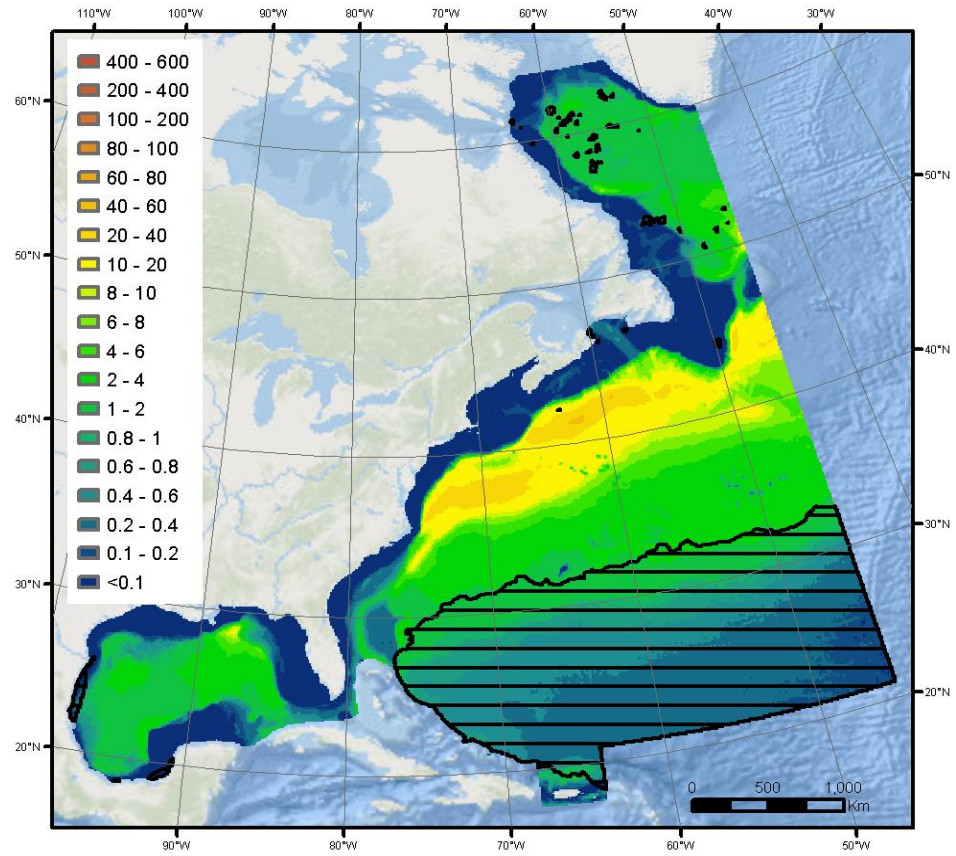
Results: *Kogia* spp. (dwarf and pygmy sperm whales)

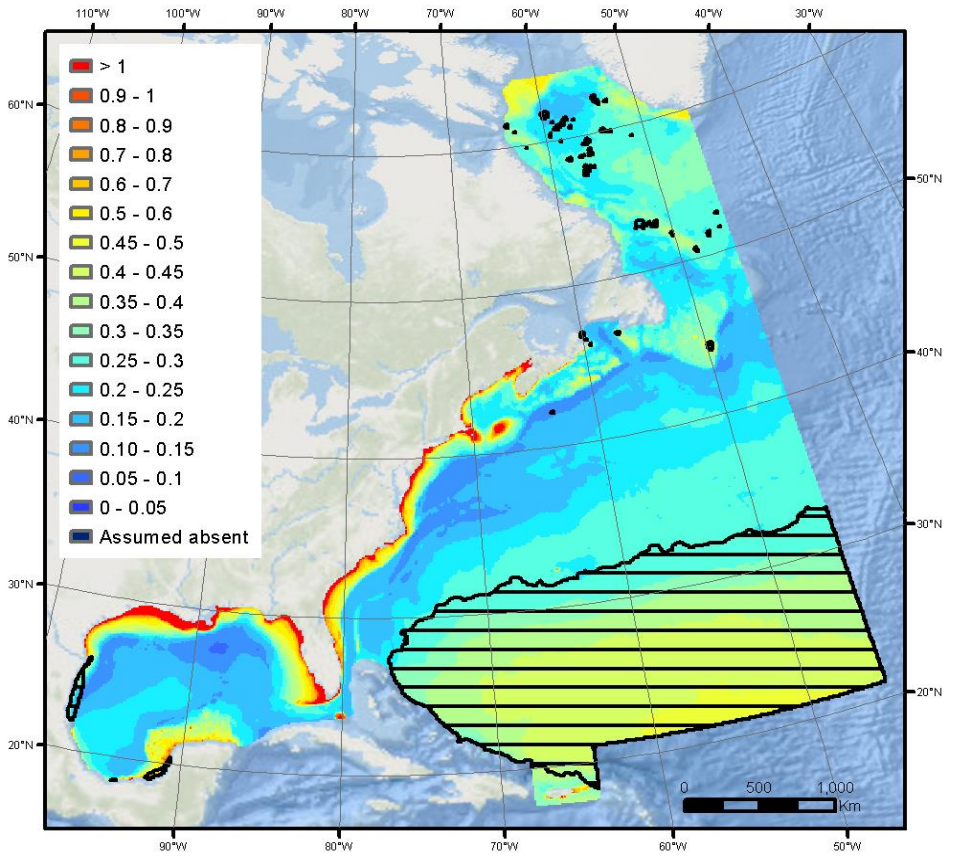




Laura Mannocci et al. (in review)

Results: Striped dolphin

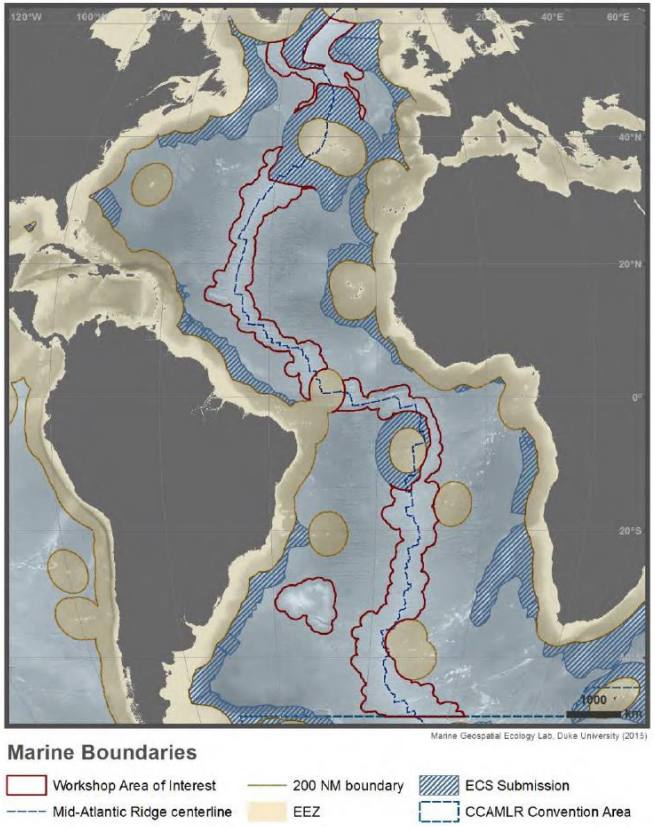




Laura Mannocci et al. (in review)

Data report: Towards development of a Strategic Environmental Management Plan for deep seabed mineral exploitation in the Atlantic basin

Pre-Workshop Data Report



1-3 June 2015, Horta, Azores, Portugal

Telmo Morato, Jesse Cleary, Gerald H. Taranto, Frederic Vandeperre, Christopher K. Pham, Daniel C. Dunn, Ana Colaço, Patrick N. Halpin

Last update: 12th June 2015; 16:30 Azores time

Data report to inform the workshop Towards development of a strategic Environmental Management Plan for deep seabed mineral exploitation in the Atlantic basin, prepared by IMAR Instituto do Mar and the Marine Geospatial Ecology Lab, Duke University.

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Cover image:	Jesse Cleary, MGEL, Duke University

Many, many data products…

Table of Figures