Simulating the Transport, Dispersal and Connectivity of Red Hind Eggs and Early Larvae from MPAs in the USVI and Eastern Puerto Rico Shelf Using an Advanced 3D Numerical Model

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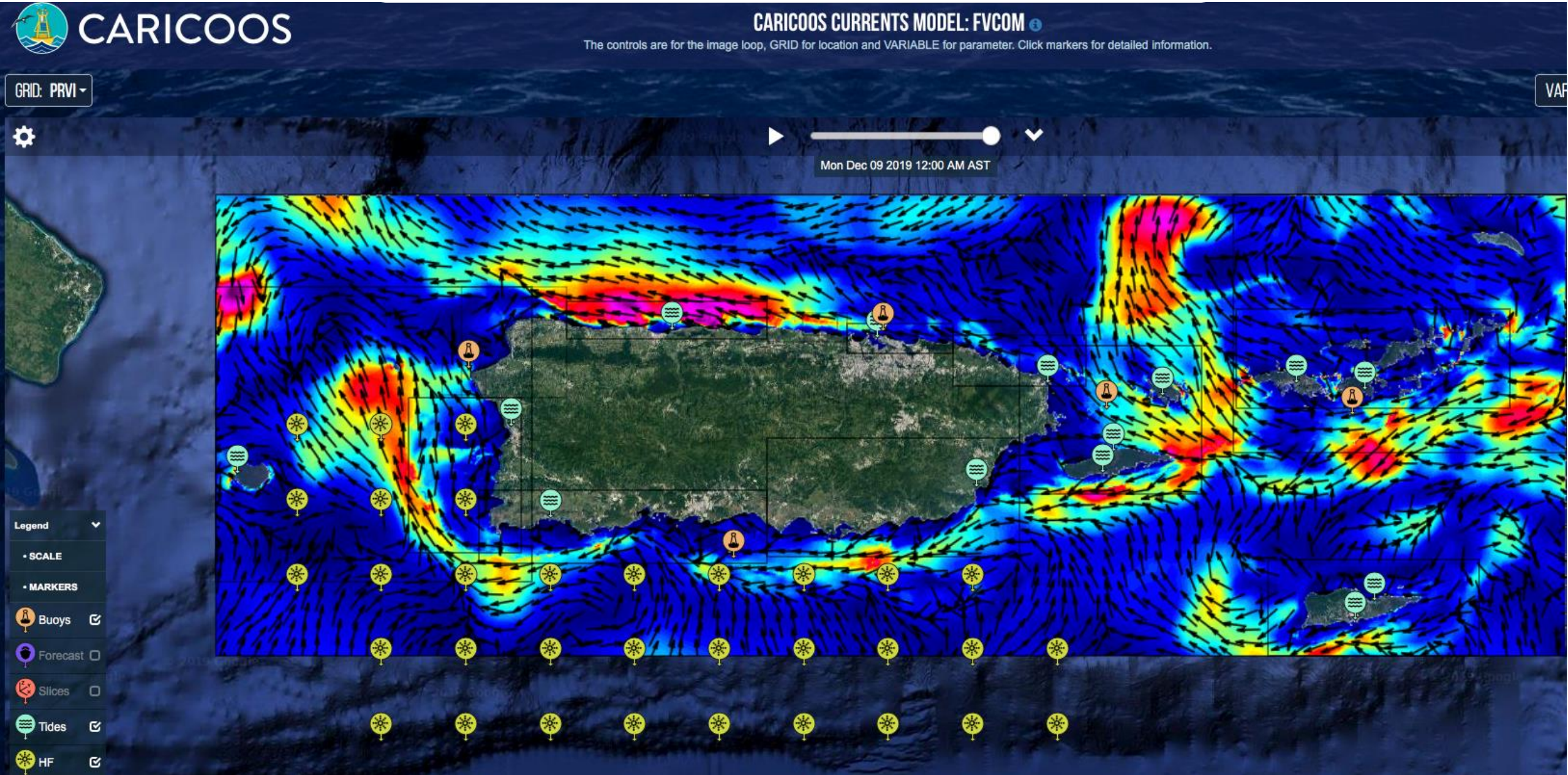
UPRM CENTER FOR APPLIED OCEAN SCIENCE & ENGINEERING

How do we do this?

1. Develop and implement a circulation model
2. Deploy sensors and validate / calibrate the numerical model
3. Obtain fish egg & larvae data on size / buoyancy / behavior and spawning dates / times / locations
4. Implement egg & larval tracking model, simulate many egg releases, do ensemble averaging (*similar to hurricane spaghetti plots*)
5. Compute connectivity matrix between spawning locations and recruitment sites
6. FUTURE: Validate connectivity estimates using genetics / biology

The circulation model



Model calibration with CARICOOS assets

- Efficient design minimizing observing assets that meet stakeholder needs for coastal information
- Strategic buoy placement to capture dominant wave directions

SEAGLIDER 2 (variable location)

AGUADILLA Meteo Station

SAN JUAN Meteo Station

SAN JUAN Data Buoy

RINCON Meteo Station

RINCON Wave Buoy

AÑASCO HFR Antenna

GURABO Meteo Station

FAJARDO Meteo Station

VIEQUES Data Buoy

CROWN MOUNTAIN Meteo Station

SAVANAH ISLAND Meteo Station

TWO BROTHERS Meteo Station

ST THOMAS Data Buoy

ST JOHN Data Buoy

RUPERTS ROCK Meteo Station

BUCK ISLAND Meteo Station

NORTH CABO ROJO Meteo Station

NORTH CABO ROJO HFR Antenna

SOUTH CABO ROJO Meteo Station

SOUTH CABO ROJO HFR Antenna

LA PARGUERA MapCO2 Buoy

ISLA MAGUEYES Meteo Station

PONCE HFR Antenna

PONCE Data Buoy

LAS MAREAS Meteo Station

MAUNABO HFR Antenna

YABUCOA Meteo Station

SANDY POINT Meteo Station

SEAGLIDER 1 (variable location)

CARICOOS

CARICOOS

CAOSE

Model calibration at Grammanik Bank

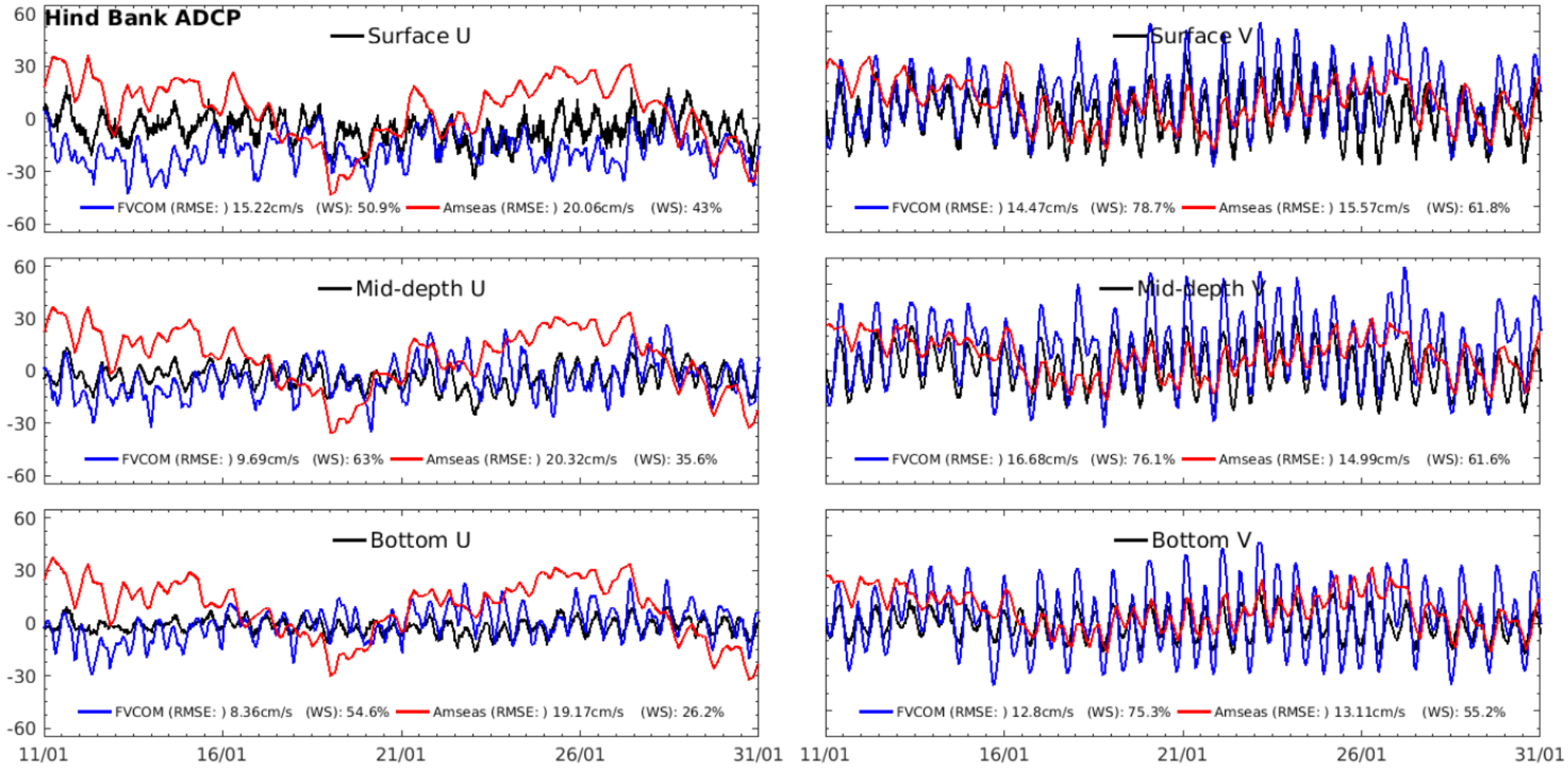
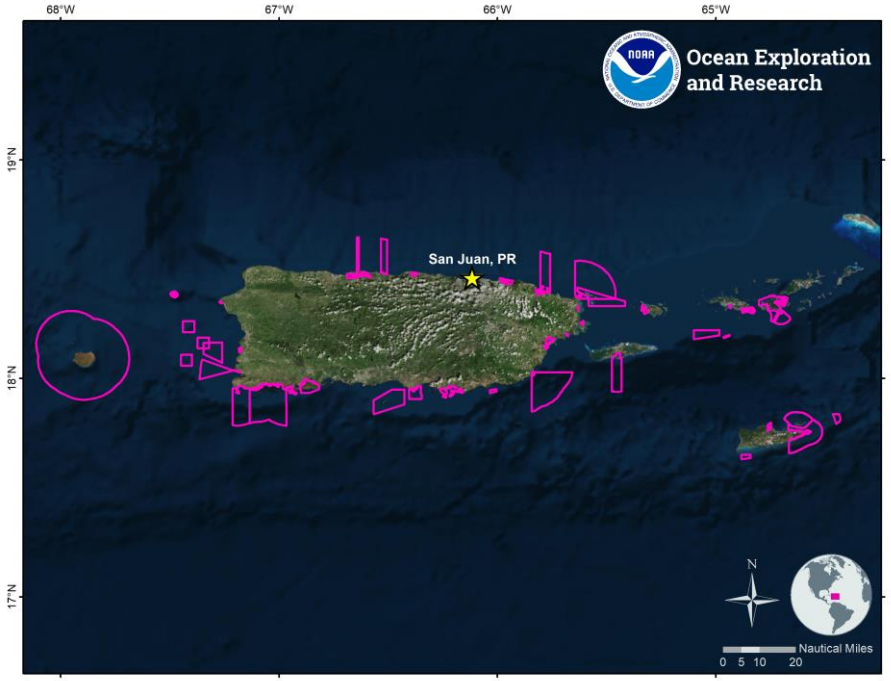


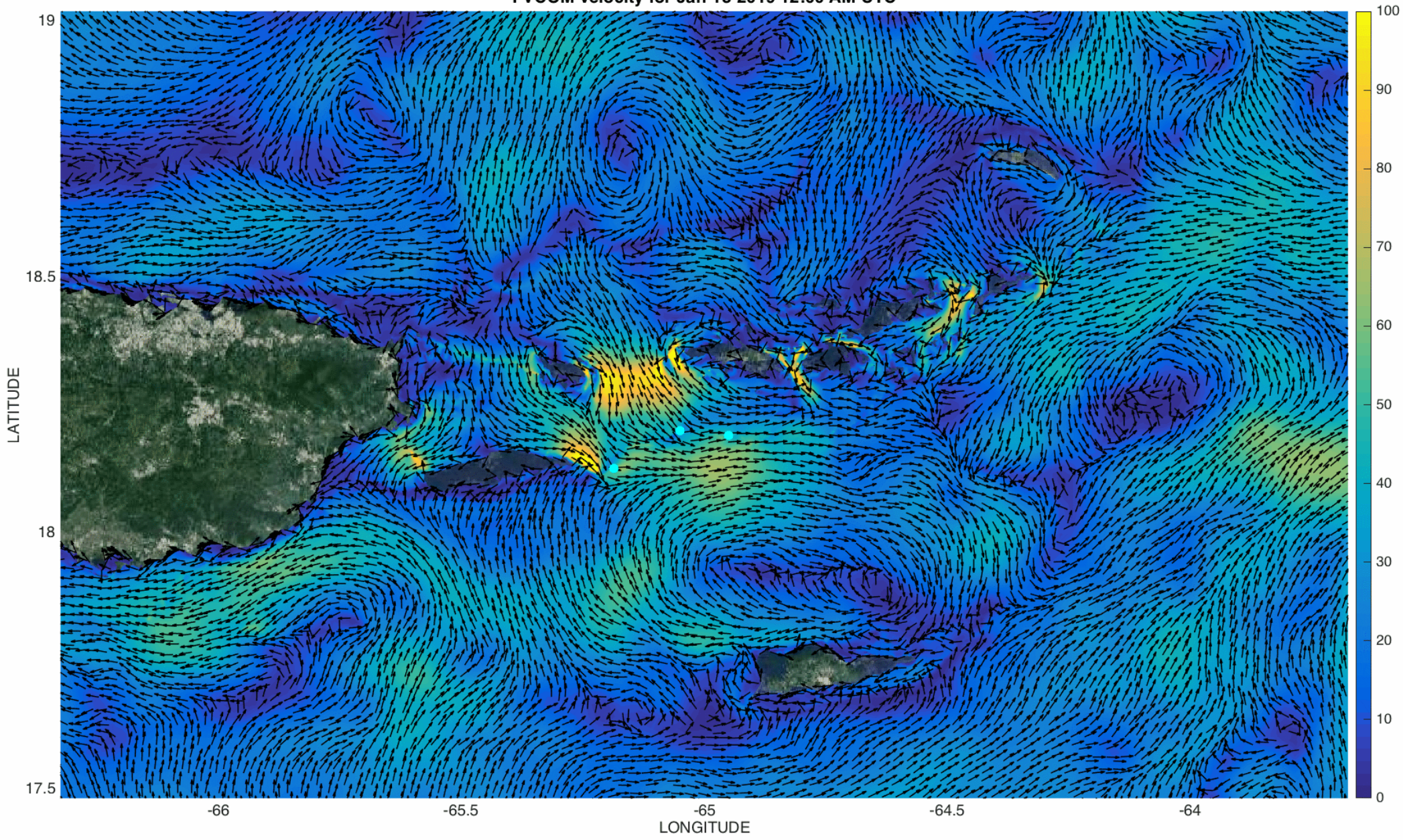
Fig. 5. Comparisons of the current profiles recorded by ADCP at Hind Bank (black) and modeled currents by AmSeas (red) and PRVI-FVCOM (blue) at the surface, middle, and bottom layers. The eastward (U) velocities are shown in the left column and the northward (V) components in the right column. The y-axis denotes velocity magnitude in cm/s.

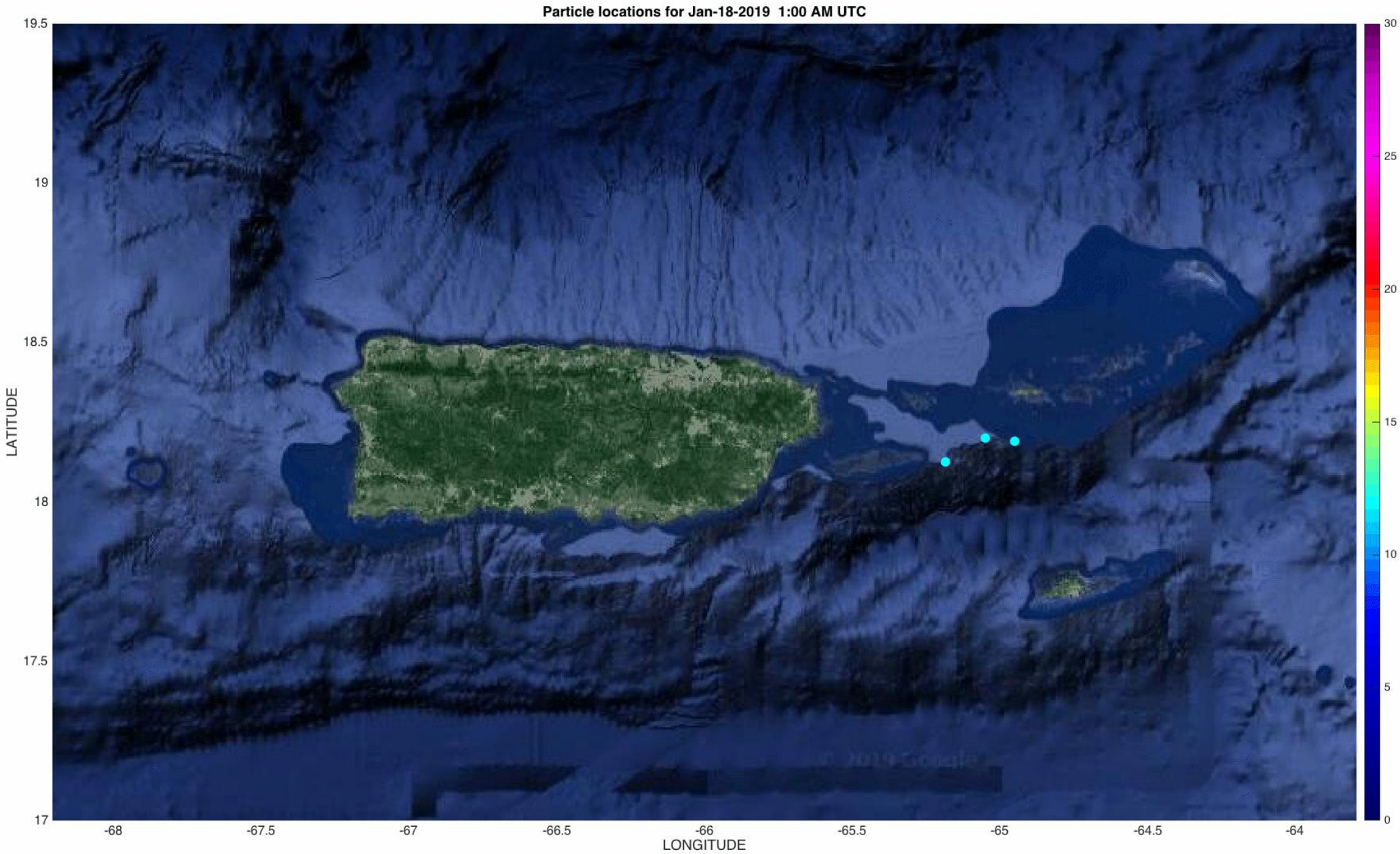
Simulation details for January (same applies for Dec & Feb)

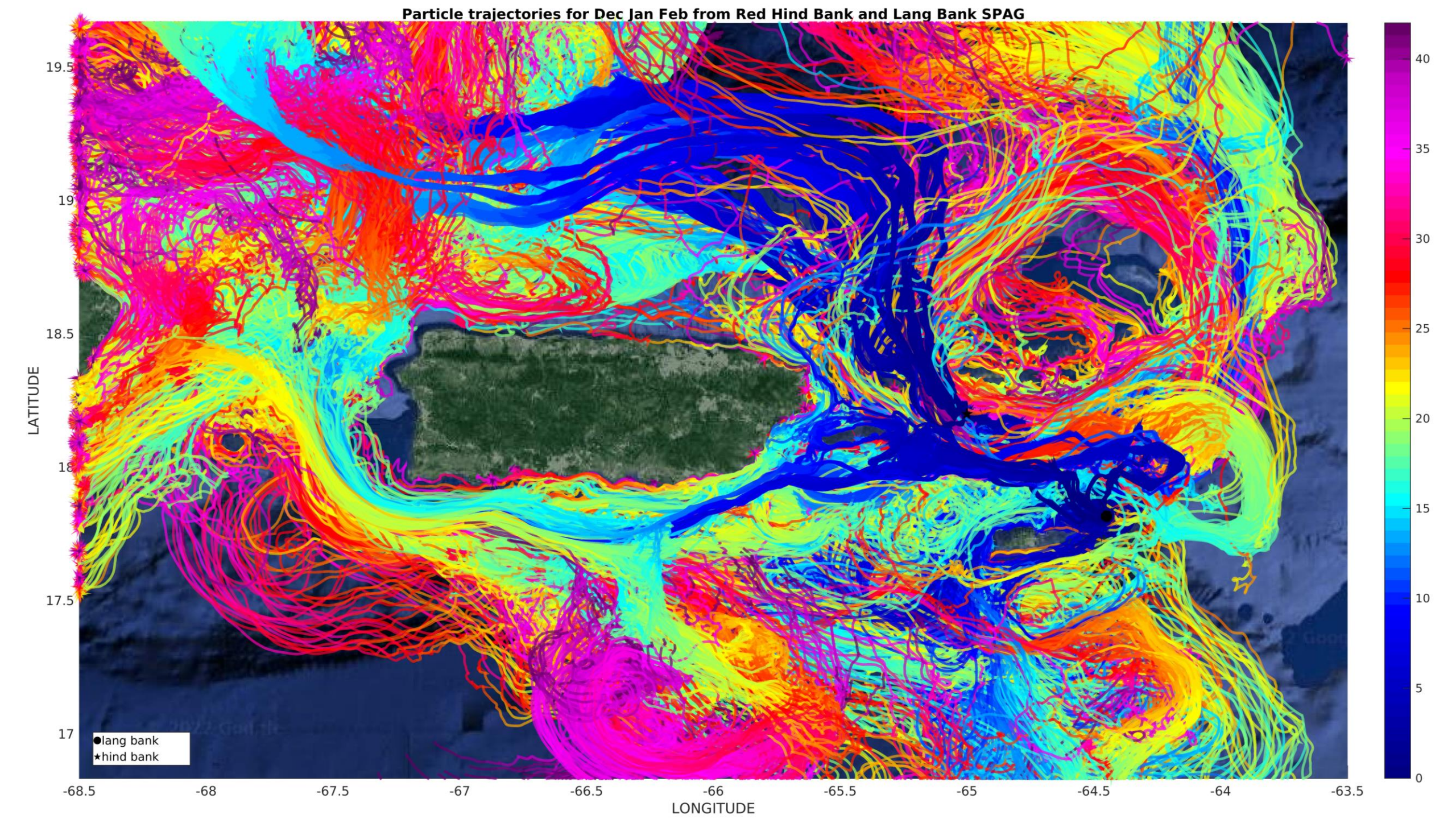
Date	Jan19	Jan20	Jan21	Jan22	Jan23
Time	5 PM		6 PM		7 PM
Release sites	Hind Bank		Lang Bank		
Release numbers	100		100		
Scenarios	Vertical distribution probability matrix + egg buoyancy dynamics				
Duration	42 days				



	Red Hind Grouper
Fertilized Egg diameters	Fertilized 0.95mm; After 21hr 1.2mm; after 24hr hatched 1.54mm; after 30hr 1.91mm (positive buoyancy); after 50hr 2.28mm (swim up and down) (Edgardo. PhD thesis, 2002)
Egg density / buoyancy (approx..)	Positively buoyant ~50 hrs. (Edgardo. PhD thesis, 2002), ascent rate of 110mm min-' in seawater of 36ppt. eggs released at depths of 20-30 m should reach the surface within three to five hours of spawning.
Pelagic larval duration (PLD)	30-45 days (Colin et al., 1987). Average PLD is 41.6 days. (Cherubin et al., 2011)
Settlement behavior / habitats	Fish in pre-settlement stages are strong swimmers can synchronize their active behavior and sustain speed from 0.1 to 0.4 m/s.
Timing of hatching and flexion	Hatching occurs in 27 h at 26.5 degree and about 31 h at 25.5 degree (Burnett-Herkes, 1975; Colin et al., 1987; Luckhurst, 1998; Nemeth et al., 2007). Red Hind reaches flexion ~12 day after fertilization. ~18 days after fertilization to complete post-flexion (Cherubin et al., 2011)


FVCOM velocity for Jan-18-2019 12:00 AM UTC
19
18.5
18
17.5
LATITUDE
-66
-65.5
-65
-64.5
-64
LONGITUDE
100
90
80
70
60
50
40
30
20
10
0

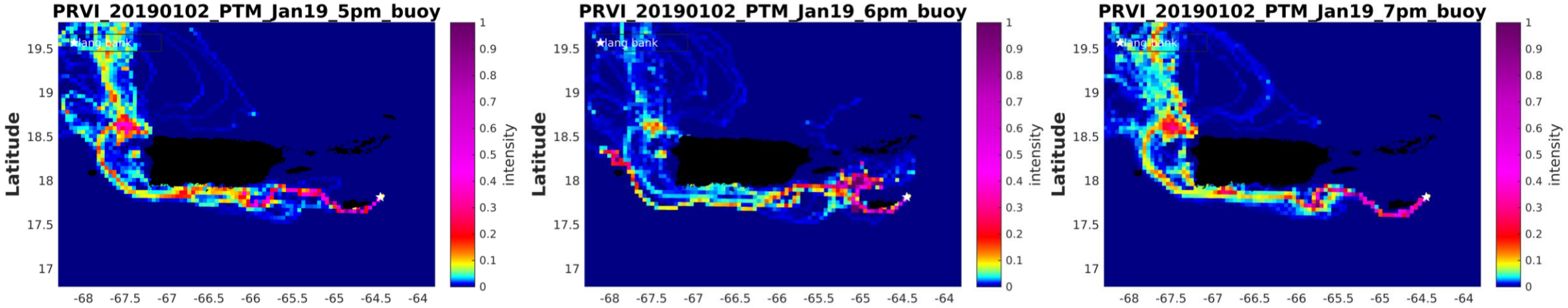

Particle locations for Jan-18-2019 1:00 AM UTC
19.5
19
18.5
18
17.5
17
LATITUDE
-68
-67.5
-67
-66.5
-66
-65.5
-65
-64.5
-64
LONGITUDE
30
25
20
15
10
5
0


Particle trajectories for Dec Jan Feb from Red Hind Bank and Lang Bank SPAG
LATITUDE
LONGITUDE
19.5
19
18.5
18
17.5
17
-68.5
-68
-67.5
-67
-66.5
-66
-65.5
-65
-64.5
-64
-63.5
lang bank
hind bank
40
35
30
25
20
15
10
5
0

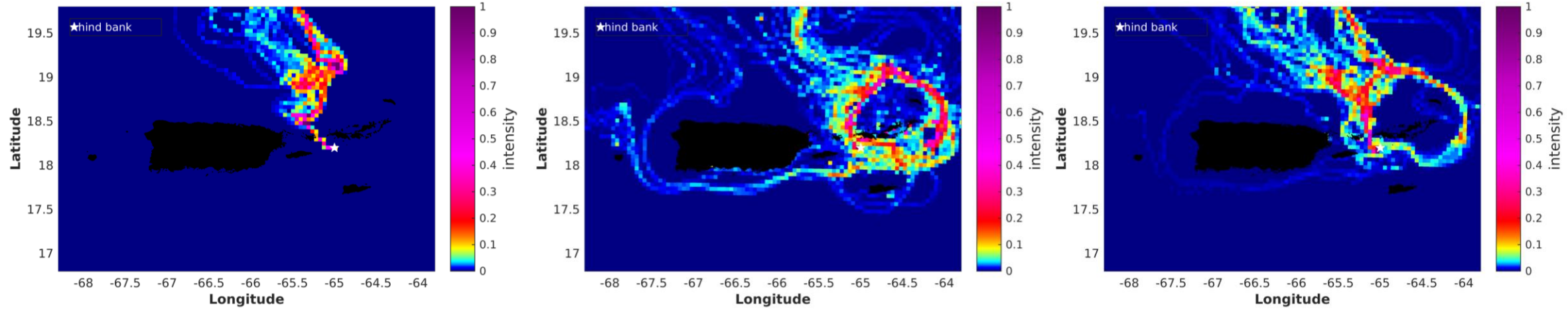
Sensitivity to release time:

Released on the same day with 1 hour difference

Lang Bank



Hind Bank

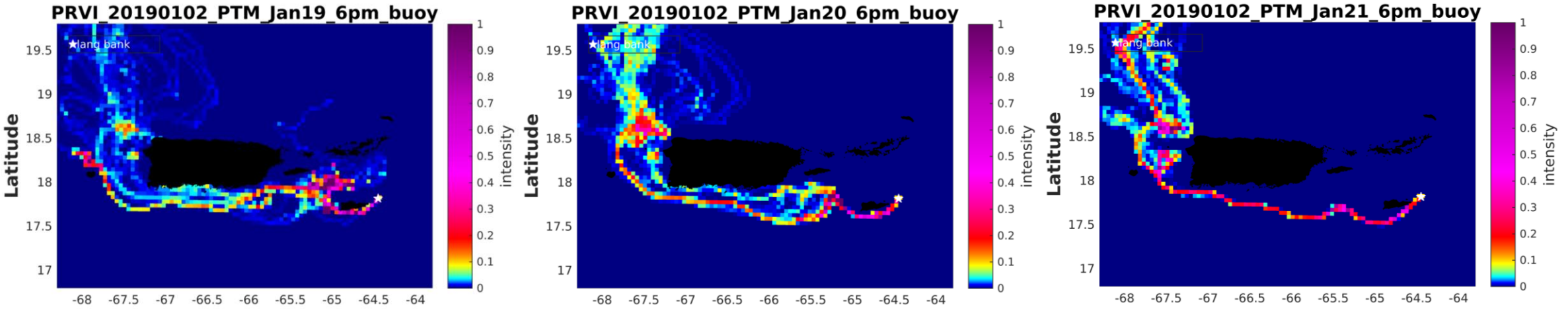


Sensitivity to release date:

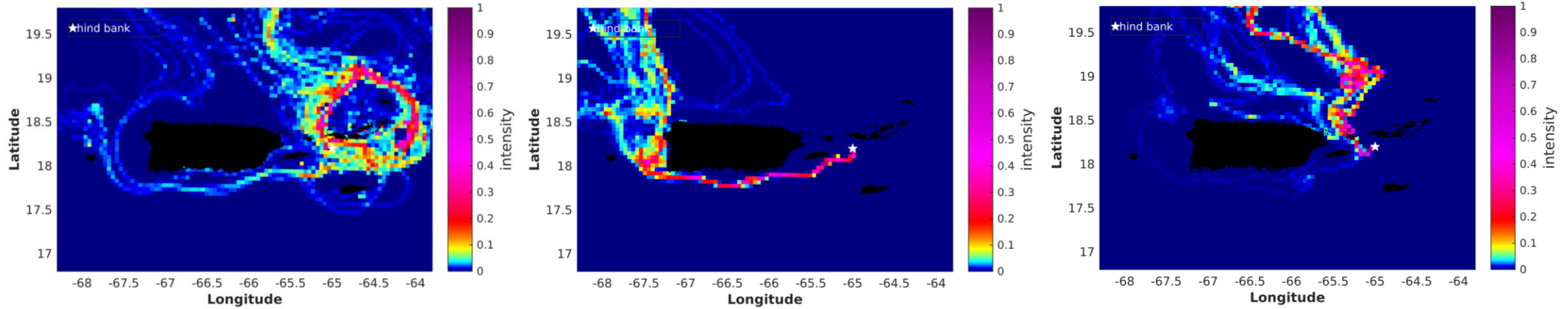
Released at the same time with 1 day difference

Full moon

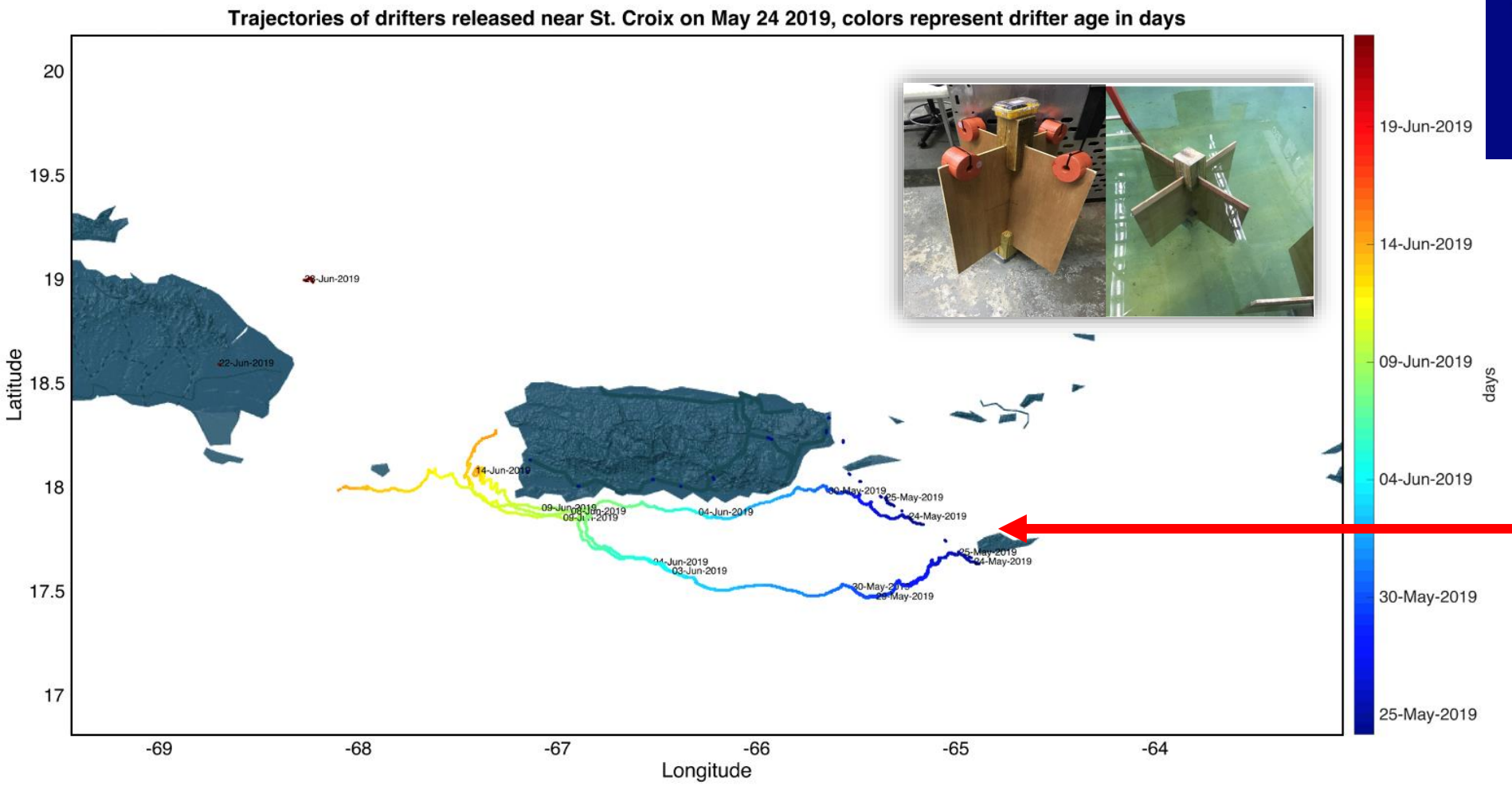
Lang Bank

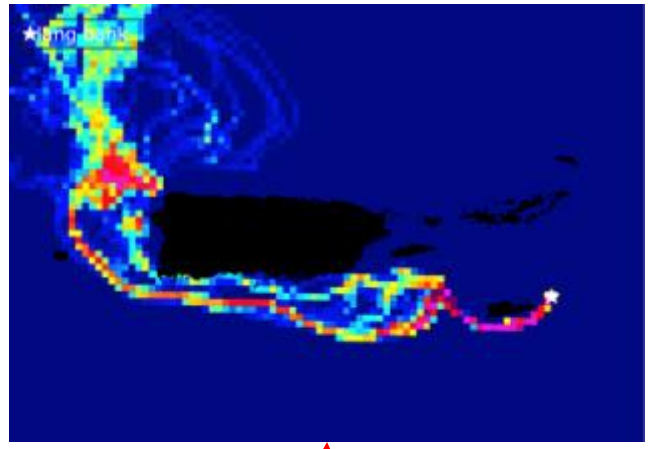


Hind Bank



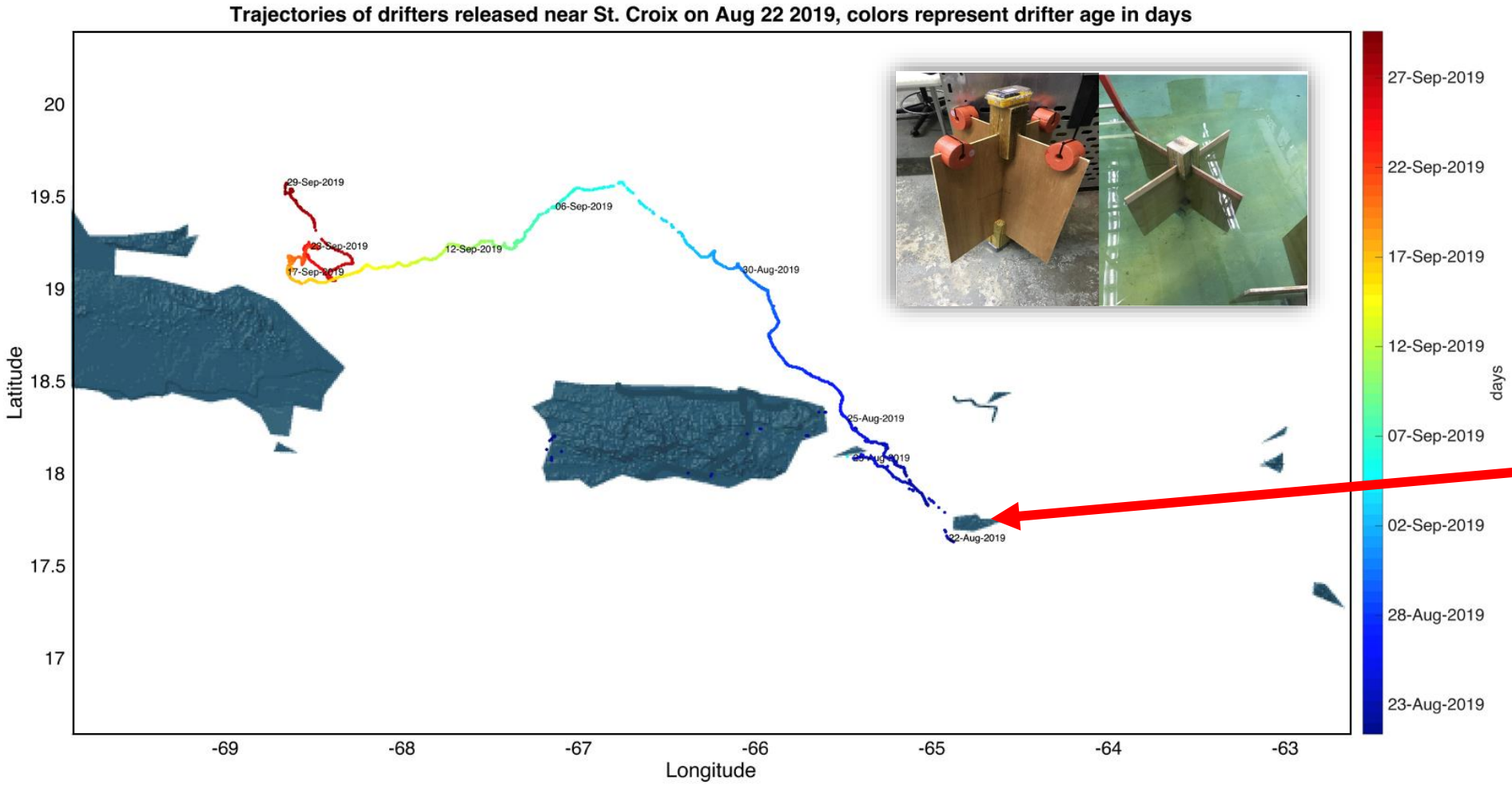
Are these trajectories realistic?

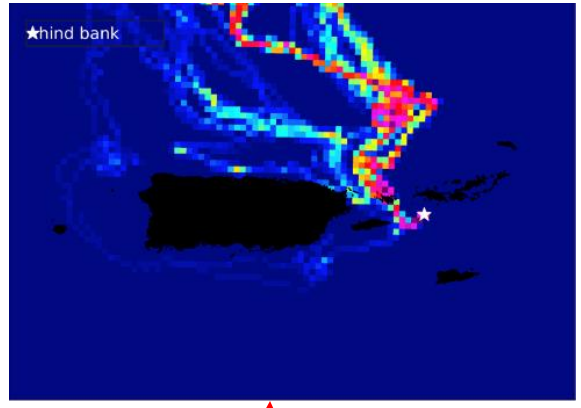




Trajectories of surface drifters released around St. Croix match with the density distribution of particles started from Lang Bank.

Are these trajectories realistic?



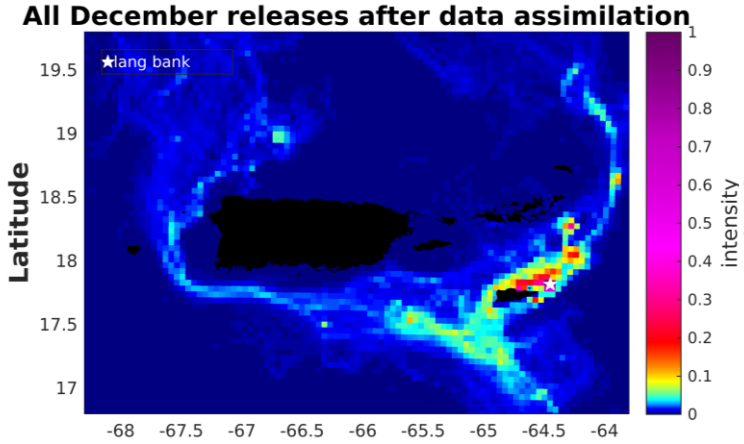


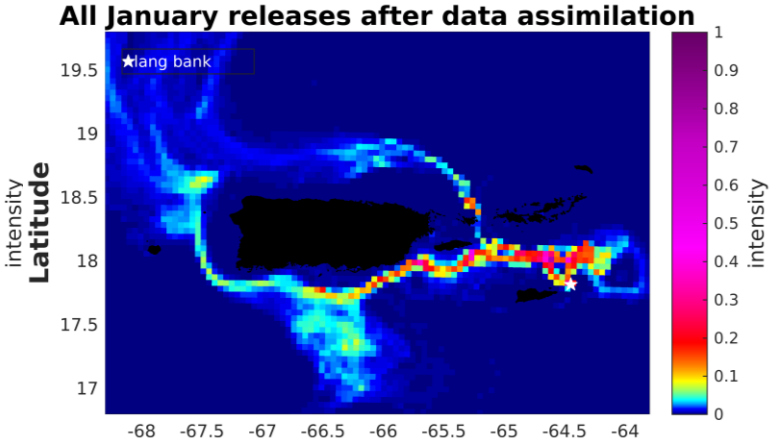
Trajectories of surface drifters sucked into the Vieques / Culebra Passage.

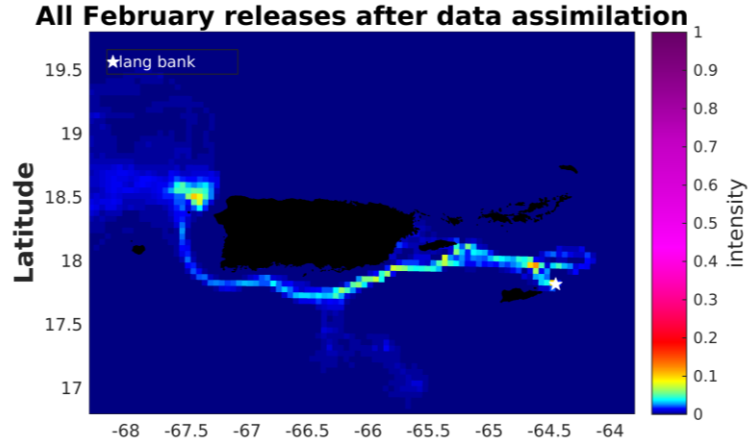
Egg / larval density maps for Dec ‘18 / Jan ‘19 / Feb ‘19

Released at every 5pm, 6pm, 7pm on five days (two days before the full moon to two days past the full moon)

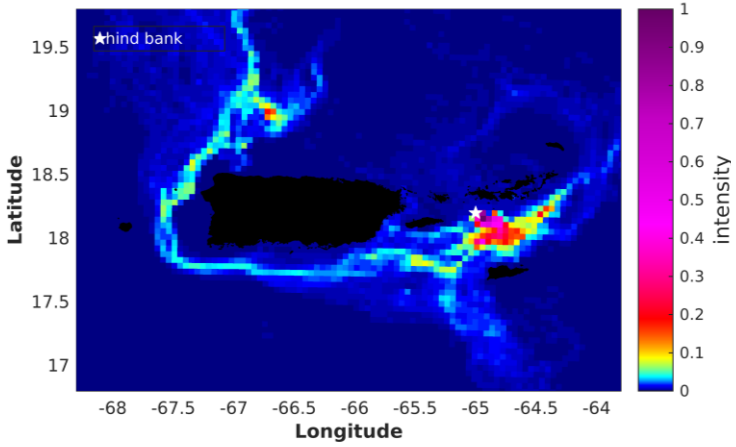
Lang Bank

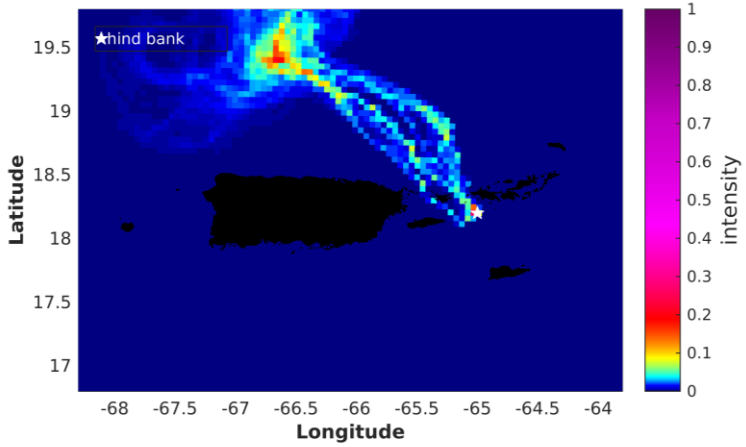


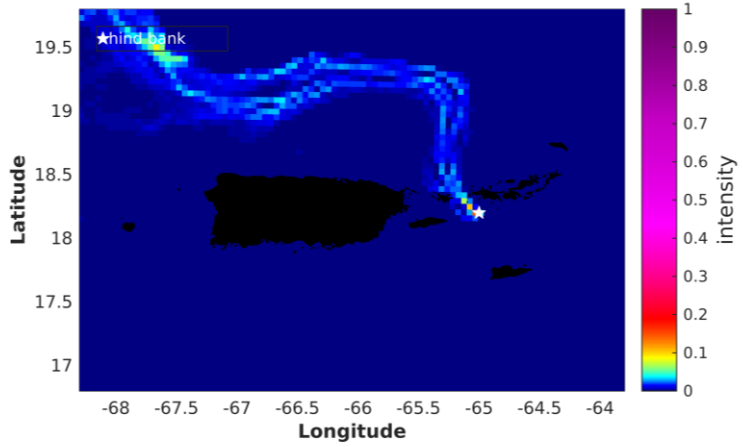




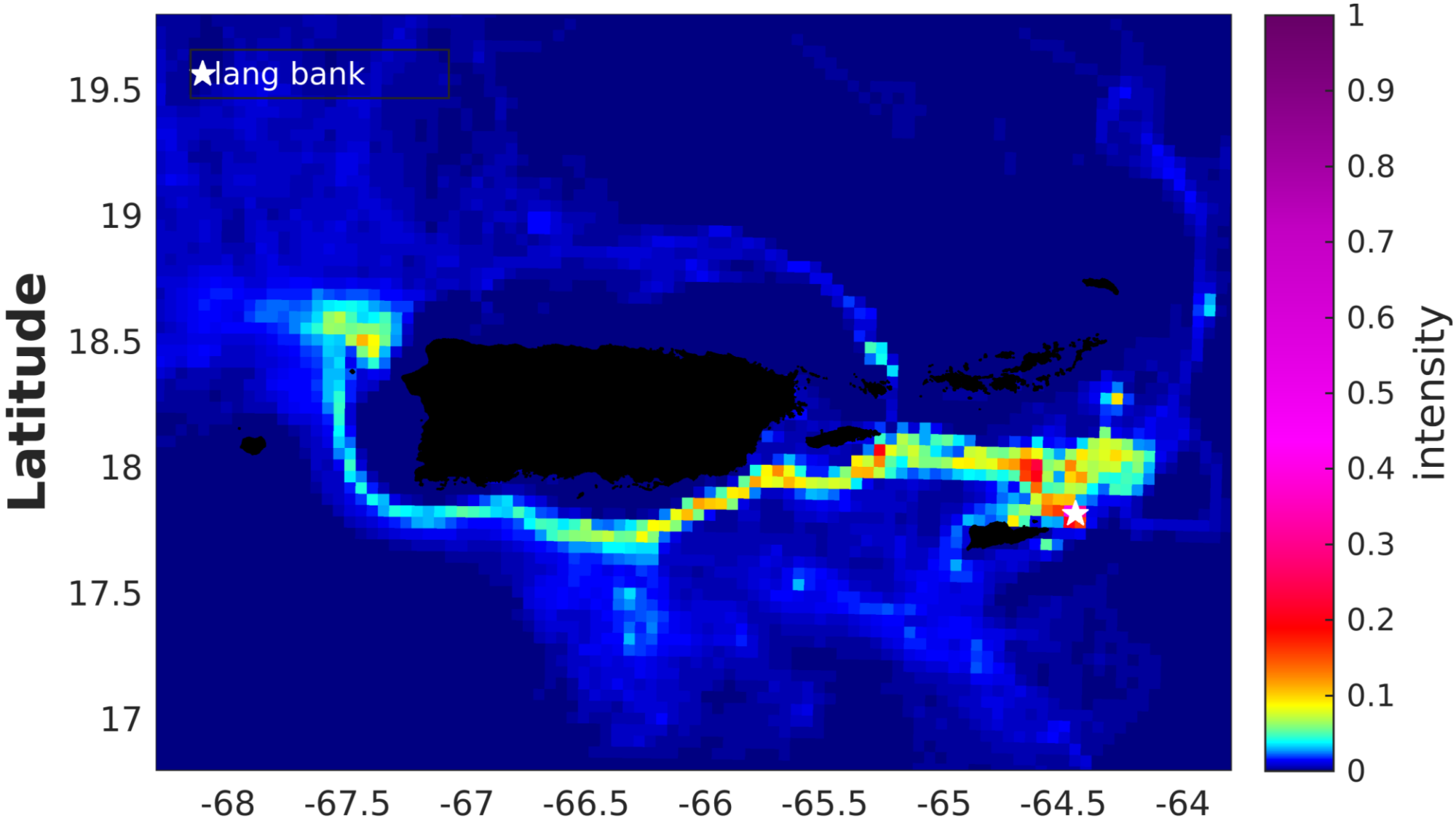
Hind Bank



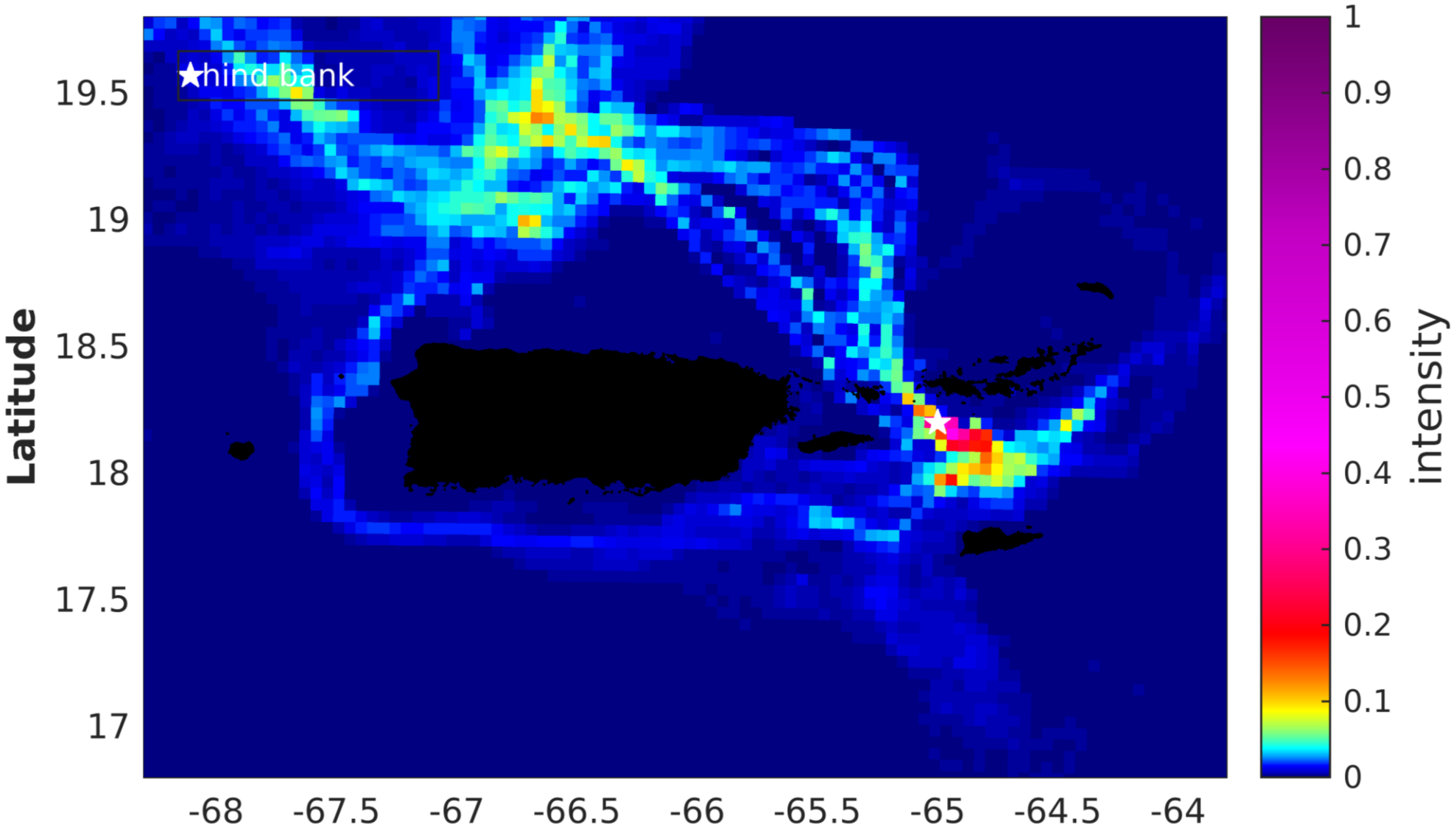




All releases for December, January & February from Lang Bank



All releases for December, January & February at Lang Bank



What's left to do?

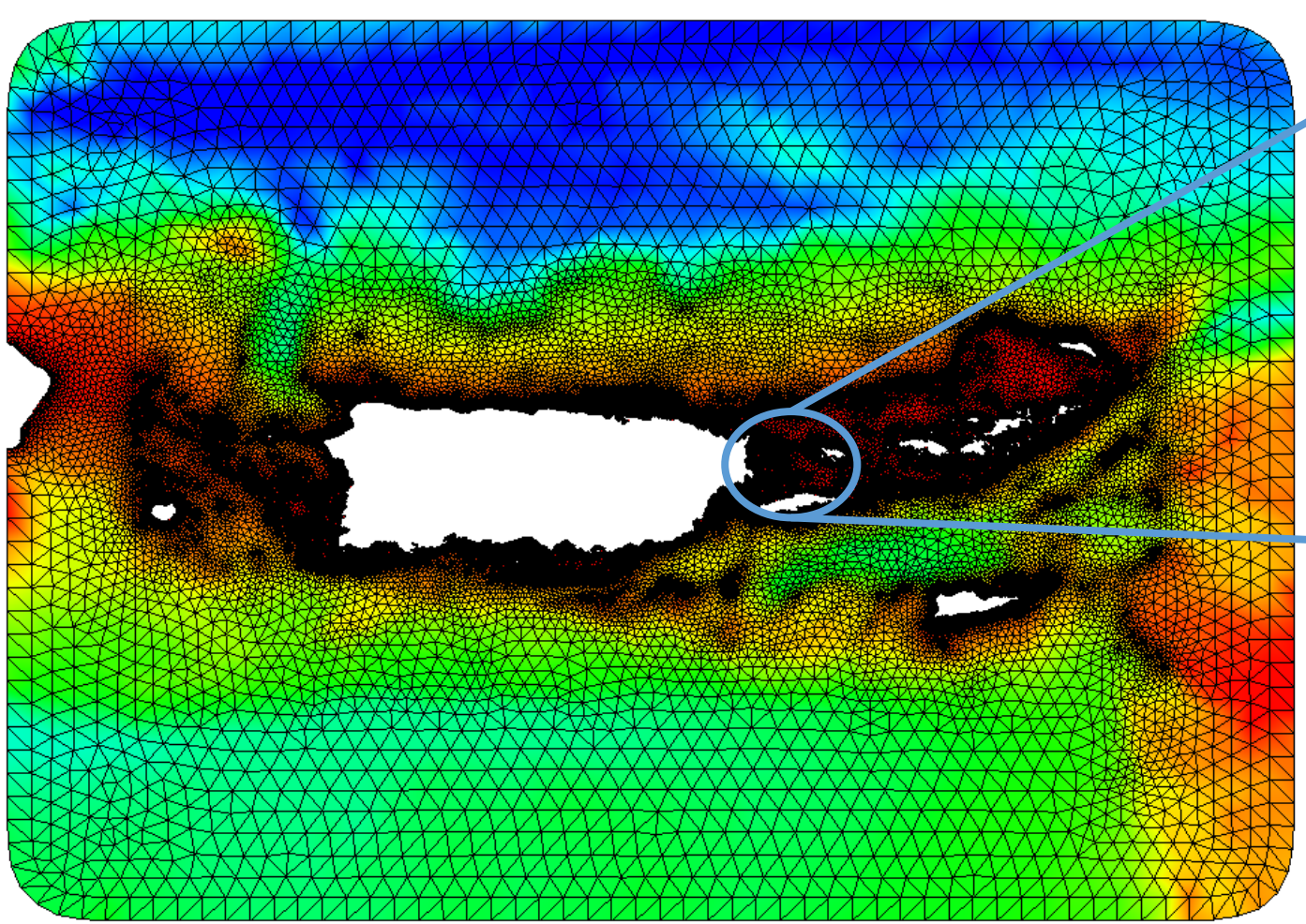
- [x] 1. Develop and implement a circulation model
- [x] 2. Deploy sensors and validate / calibrate the numerical model
- [x] 3. Obtain fish egg & larvae data on size / buoyancy / behavior and spawning dates / times / locations
- [x] 4. Implement egg & larval tracking model, simulate many egg releases, do ensemble averaging (*similar to hurricane spaghetti plots*)
- [x] 5. Compute connectivity matrix between spawning locations and recruitment sites
- [ ] **6. FUTURE: Validate connectivity estimates using genetics / biology**

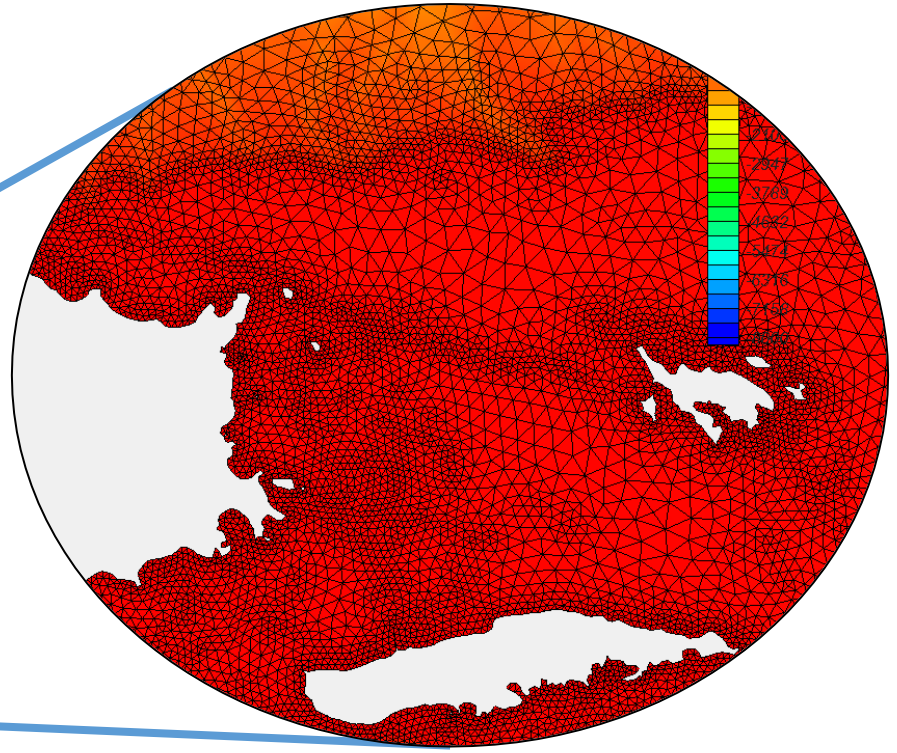
Questions?

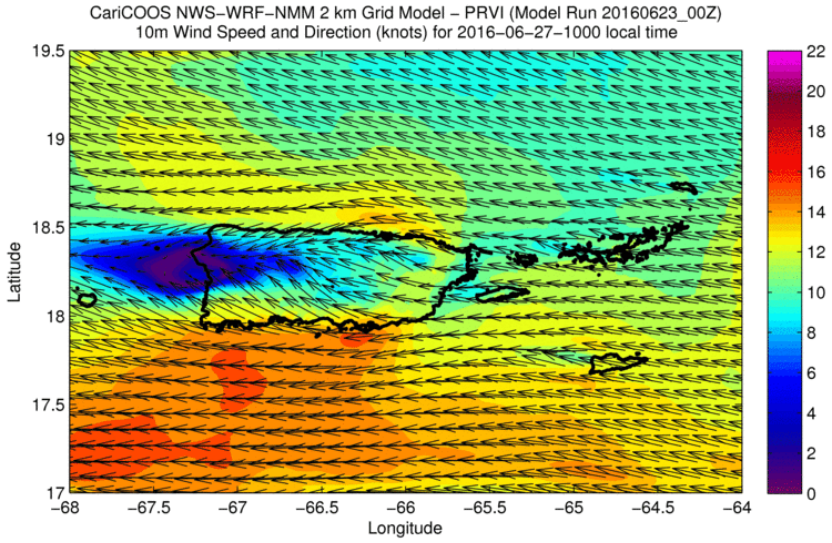
- Miguel Canals (miguelf.canals@upr.edu)
- www.caricoos.org

CARICOOS

CARICOOS FVCOM Model Setup



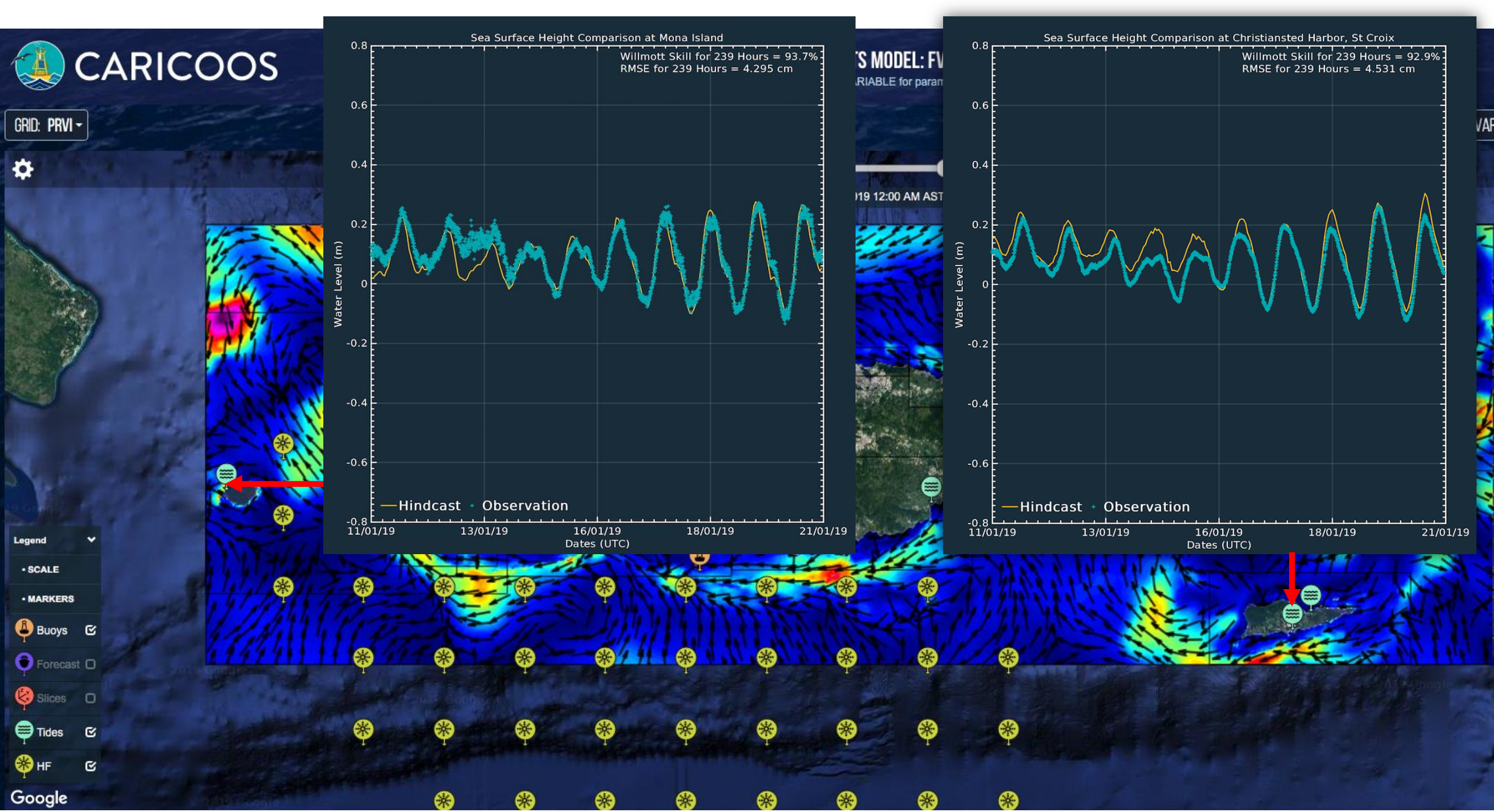




Mesh: Max. depth 5000 m, 175616 elements, 91221 nodes, 41 Hybrid sigma levels

Boundary forcing: Tides (TMD), Wind (CARICOOS WRF 2km), Baroclinic Structure (Amseas).

Assimilation: ssh sst. Simulation years: 2018Dec -2019Dec.


CARICOOS
GRID: PRVI
Legend
• SCALE
• MARKERS
Buoys
Forecast
Slices
Tides
HF
Google
Sea Surface Height Comparison at Mona Island
Willmott Skill for 239 Hours = 93.7%
RMSE for 239 Hours = 4.295 cm
Water Level (m)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Hindcast
Observation
11/01/19
13/01/19
16/01/19
18/01/19
21/01/19
Dates (UTC)
Sea Surface Height Comparison at Christiansted Harbor, St Croix
Willmott Skill for 239 Hours = 92.9%
RMSE for 239 Hours = 4.531 cm
Water Level (m)
Hindcast
Observation
Dates (UTC)

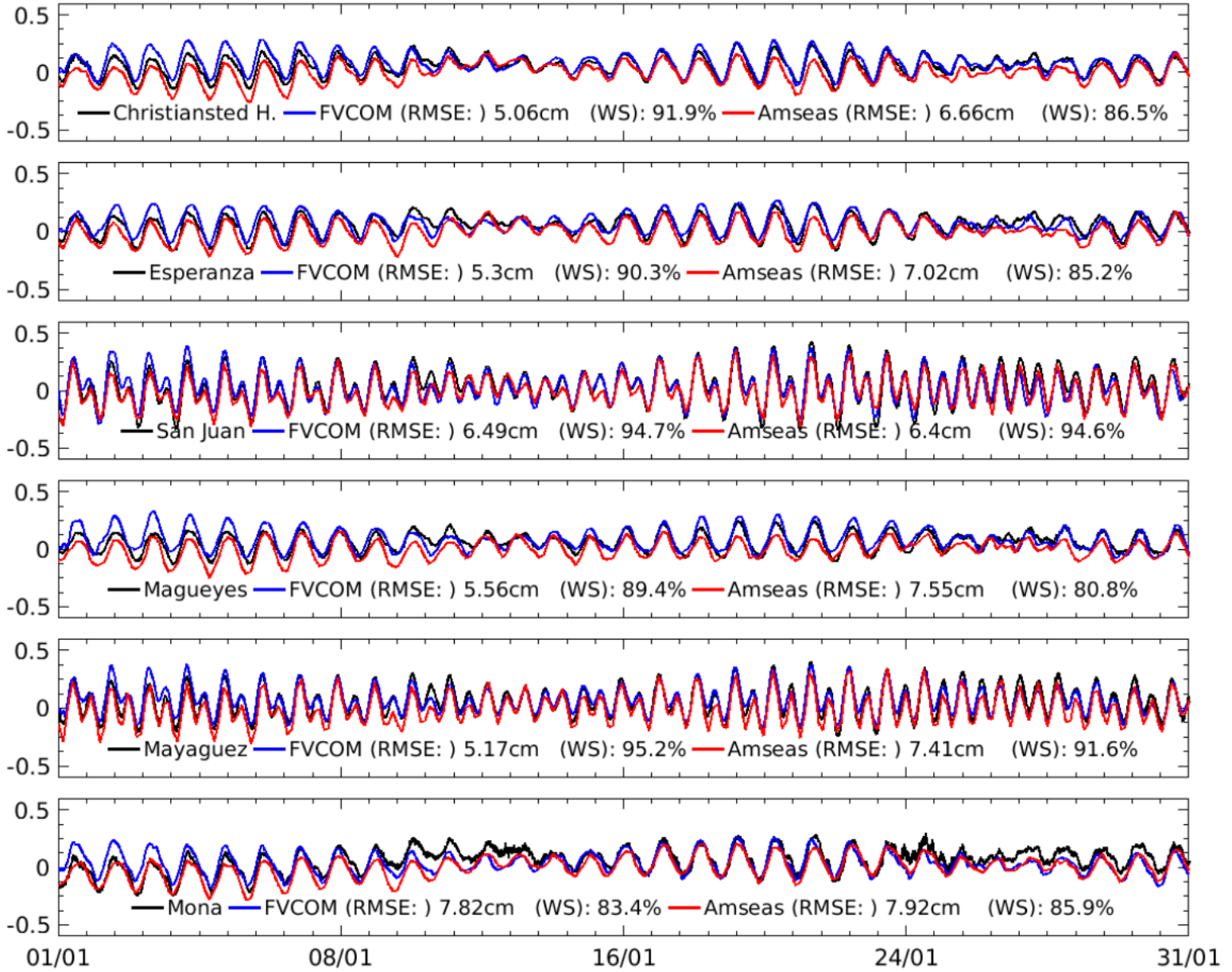


Fig. 3. Comparisons of the observed (black) and modeled water level by AmSeas (red) and PRVI-FVCOM (blue). The NOAA tide locations from top to bottom are: Christiansted Harbor (ID: 9751364), Esperanza (ID: 9752695), San Juan (ID: 9755371), Magueyes (ID: 9759110), Mayaguez (ID: 9759394) and Mona (ID: 9759938) as plotted in Fig. 1. The y-axis denotes SSH in m.

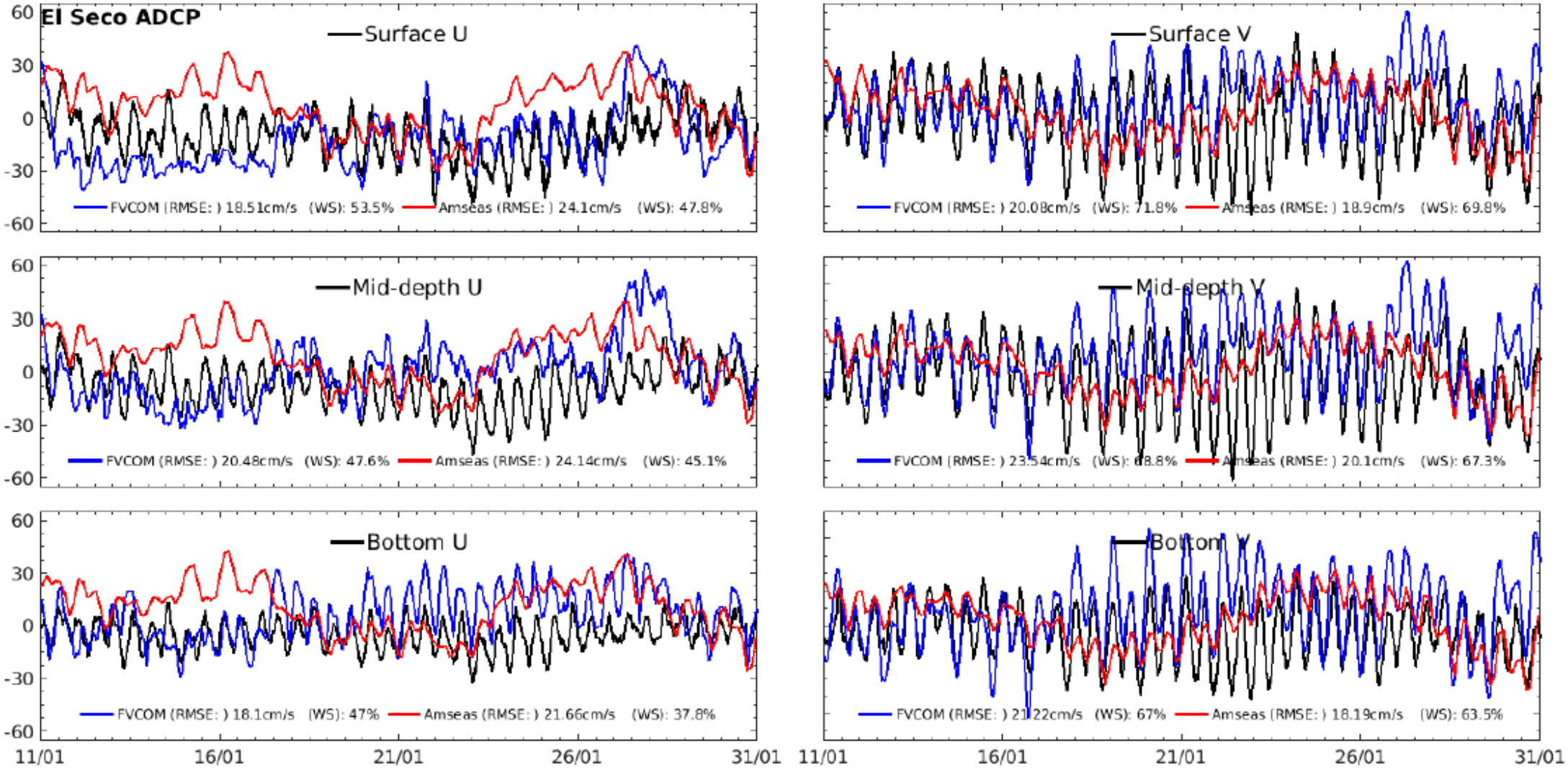


Fig. 4. Comparisons of the current profiles recorded by ADCP at El Seco (black) and modeled currents by AmSeas (red) and PRVI-FVCOM (blue) at the surface, middle, and bottom layers. The eastward (U) velocities are shown in the left column and the northward (V) components in the right column. The y-axis denotes velocity magnitude in cm/s.

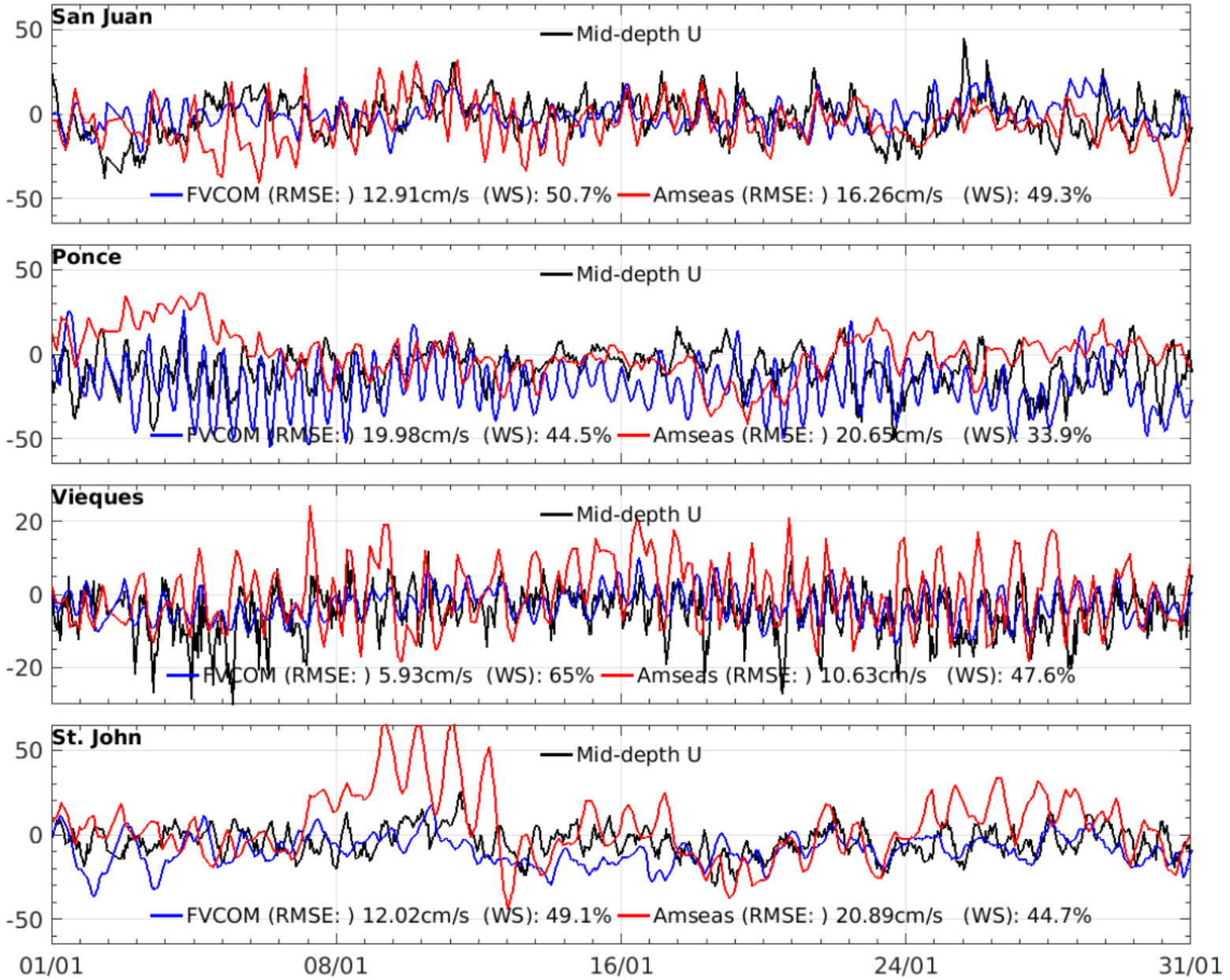


Fig. 6. Comparisons of the mid-depth observed (black) and modeled zonal (V) velocities by AmSeas (red) and PRVI-FVCOM (blue). The buoy stations from top to bottom are San Juan, Ponce, Vieques, and St. John. The y-axis denotes velocity magnitude in cm/s.

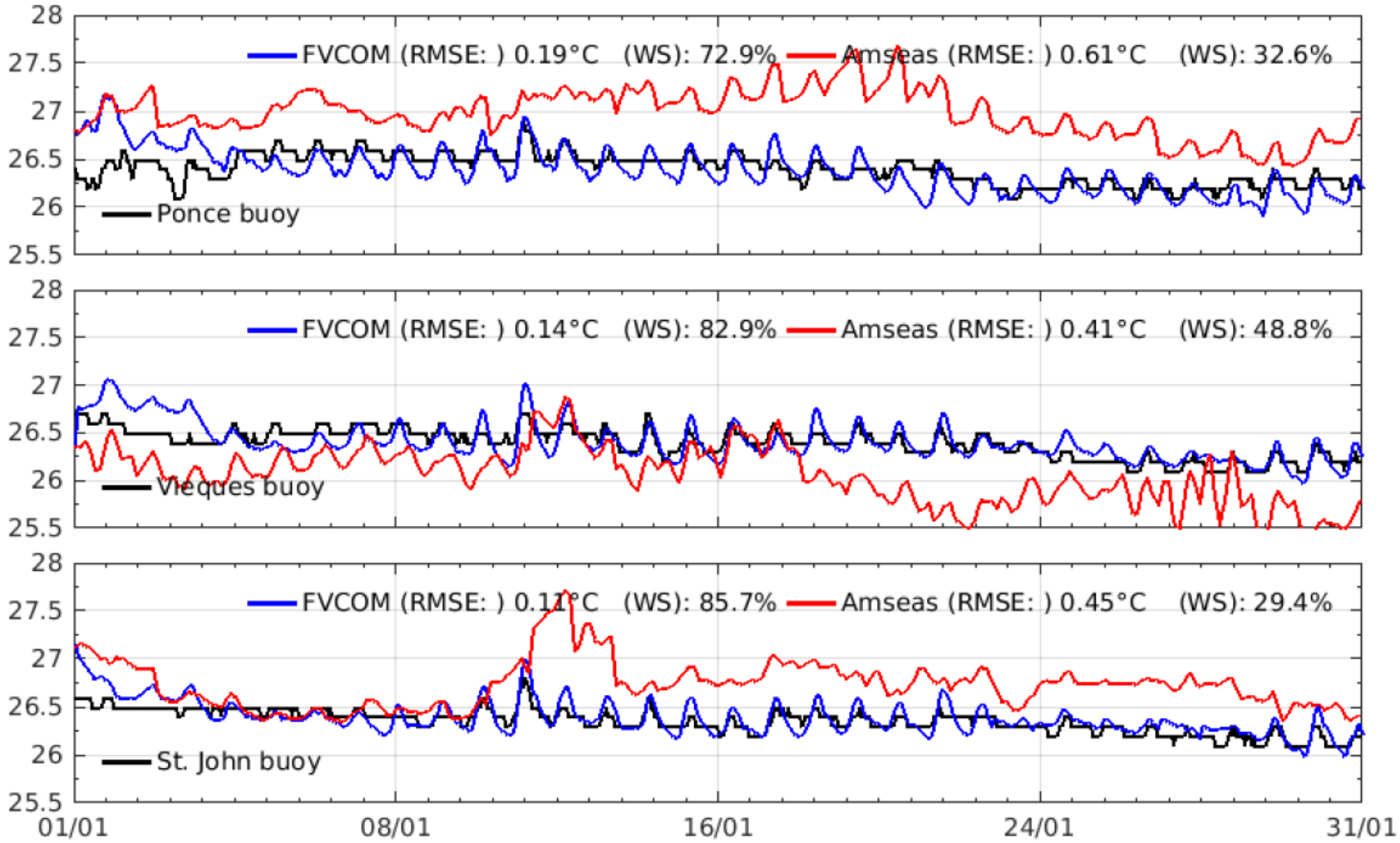


Fig. 10. Comparisons of the observed (black) and modeled sea surface temperatures by AmSeas (red) and PRVI-FVCOM (blue). The buoy locations from top to bottom are Ponce, Vieques and St. John. The y-axis denotes temperatures in °C.

Ongoing work

- Construct the connectivity network among the defined MPAs and potential settlement sites based on the result of this study.
- Other species (such as mutton snapper) will be analyzed if time allows (The project has been extended to 2022)

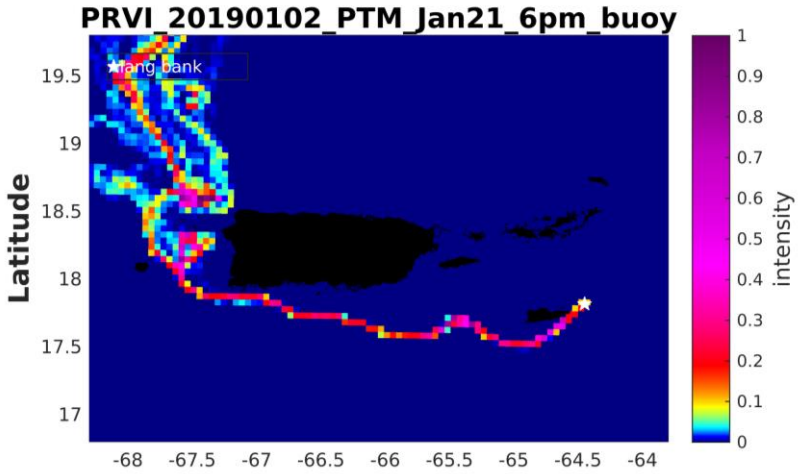
Sensitivity to release scenarios

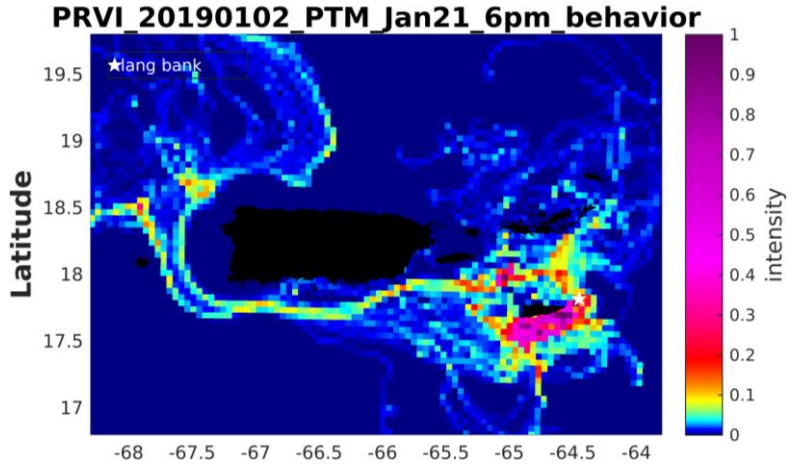
Release at the same hour, same day, different scenarios.

Positive buoyancy

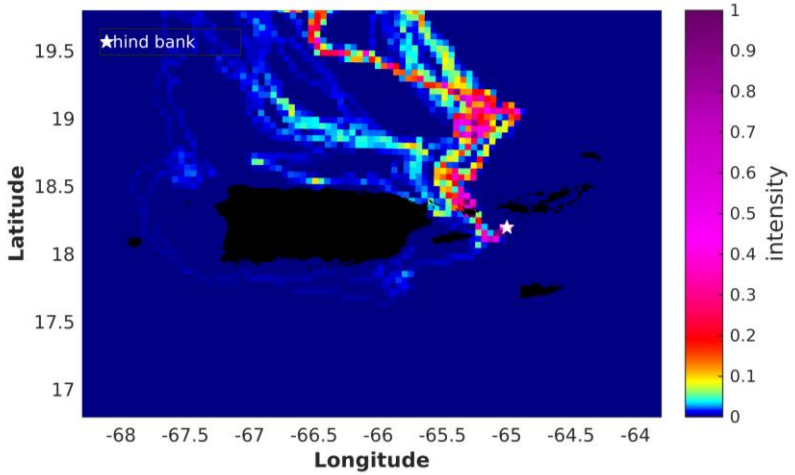
vertical distribution probabilistic matrix

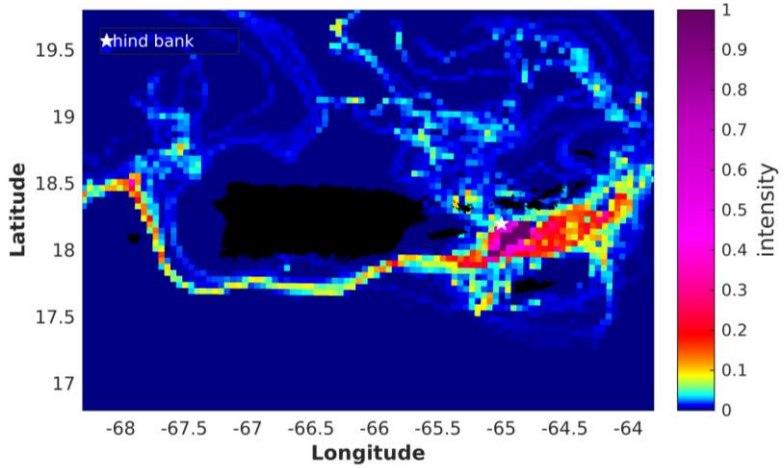
Lang Bank





Hind Bank





Project goals

- Explore main oceanographic pathways leading to the dispersal patterns of eggs and early larvae from marine protected areas (MPAs) in the US Virgin Islands and off the Eastern Puerto Rico shelf
- Quantify the hydrodynamic connectivity between eggs & larvae spawned from these MPAs and PR/USVI coastal locations, with a special focus on an commercially important fish species: **red hind (*Epinephelus guttatus).***