Advancing Coastal Intelligence in the US Caribbean: Surface Currents

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LONG-TERM GOALS

Rutgers University Center for Ocean Observing Leadership (RUCOOL) is a global leader in High-Frequency radar (HFR) network implementation and management. Through this proposal, RUCOOL looks to assist CariCOOS in the expansion and operation of their HFR network. The US Coast Guard has identified the ocean surface current data from the four existing HFR stations as an important resource for their search and rescue activities. The real-time surface current information improves the decision-making capabilities during critical life saving search and rescue missions.

The HFR network is part of the observational sensor subsystem for CariCOOS. The other subsystem for CariCOOS is a modeling and forecast component. The subsystem is comprised of wave, storm surge, wind and ocean circulation models. The ocean circulation model is based upon the Regional Ocean Modeling System (ROMS). The goal of this proposal is to compare the surface current measurements of the HF radar network with the output of the circulation model and test the capability of the other models to assimilate the measured ocean surface current data.

MILESTONES / OBJECTIVES

1. Take inventory and assemble HF radar data in the region
2. Take inventory of the ocean models run in the region
3. Take inventory and assemble other in situ data for comparison (surface drifters, wind sensors, etc.)
4. Conduct kick off meeting in Puerto Rico

WORK COMPLETED

1. The HF radar data is comprised of radial and total vector data. The inception of radial data for each station is listed in Table 1. The data was inserted into a radial database at Rutgers and the inventory is shown in Figure 1. Totals are created on a 2 km and 6 km grid and the inception date for each data product is given in Table 2.

Table 1: Radial data inception dates for each of the stations in Puerto Rico.

Station	*Inception Date*
FURA	December 2009

CDDO	December 2009
FARO	February 2015
PYFC	February 2015
MABO	February 2016

Table 2: Total data inception dates for the three HF radar surface current products around Puerto Rico.

Total Product	*Inception Date*
2 km, Optimal Interpolation	November 2012
2 km, Unweighted Least Squares	January 2010
6 km, Unweighted Least Squares	January 2010

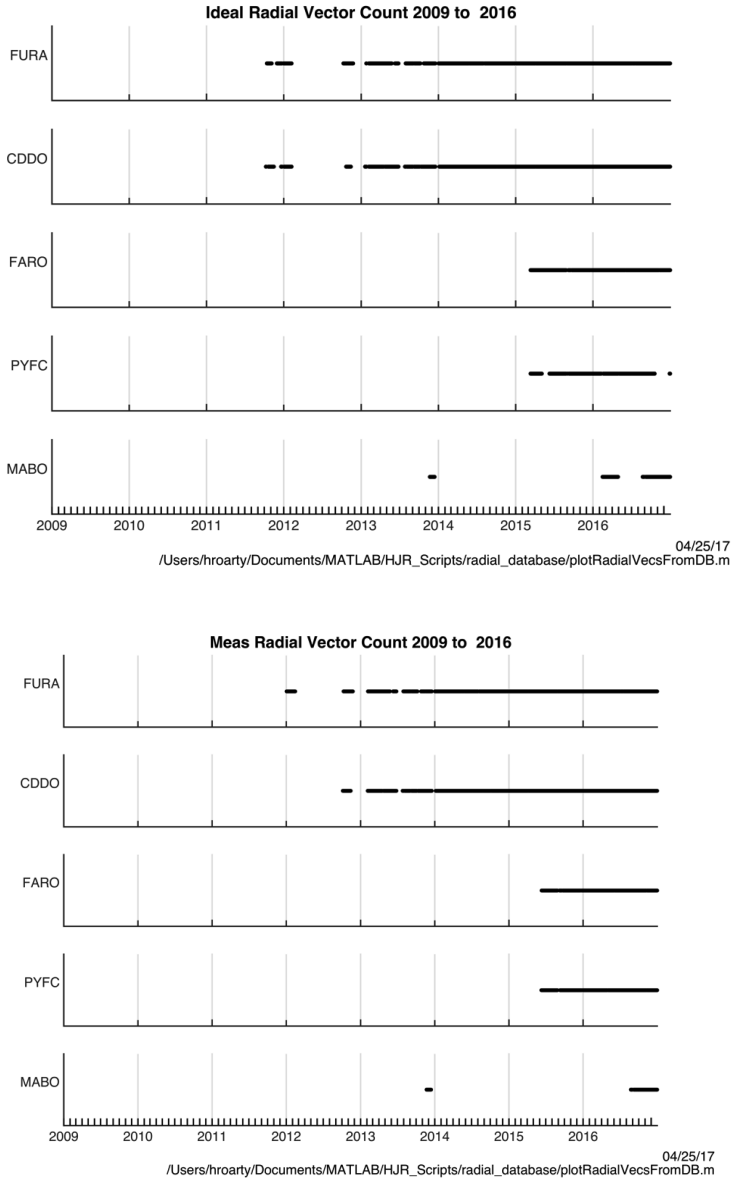

Figure 1: Ideal (top) and measured (bottom) radial data availability on the Rutgers servers.

2. The inventory of the ocean models in the area are:

Model	*Spatial Resolution*	*Temporal Resolution*	*Time Range*
HYCOM	1/12 degree	3 hours	April 18, 2016 to present
AMSEAS	1/30 degree	3 hours	April 5, 2013 to present
MERCATOR	1/12 degree	3 hours	January 1, 2013
OSCAR	1/3 degree lon or lat	5 days	October 12, 1992 to present

HYCOM[1], The **HY**brid **C**oordinate **O**cean **M**odel is global with 1/12 degrre horizontal resolution [Chassignet et al., 2009]. The real-time system is operated by the U.S. Navy NAVOCEANO center and uses the NCODA (Navy Coupled Ocean Data Assimilation) [Cummings, 2005] mul- tivariate optimal interpolation (MVOI) scheme to assimilate satellite sea surface height (SSH) and SST, and temperature and salinity profiles from Argo floats and ships of opportunity. Surface meteorological forcing is from the U.S. Navy Operational Global Atmospheric Prediction System (NOGAPS) [Rosmond et al., 2002]. Tides are not simulated. River inflows are from a climatological monthly global database [Vörösmarty et al., 1996]. Vertical coordinates are a hybrid of isopycnal layers in deep water and a mixture of pressure and terrain following on continental shelves [Chassignet et al., 2006]. There are 32 layers in total.

[1] Text from Wlikin and Hunter (2013)

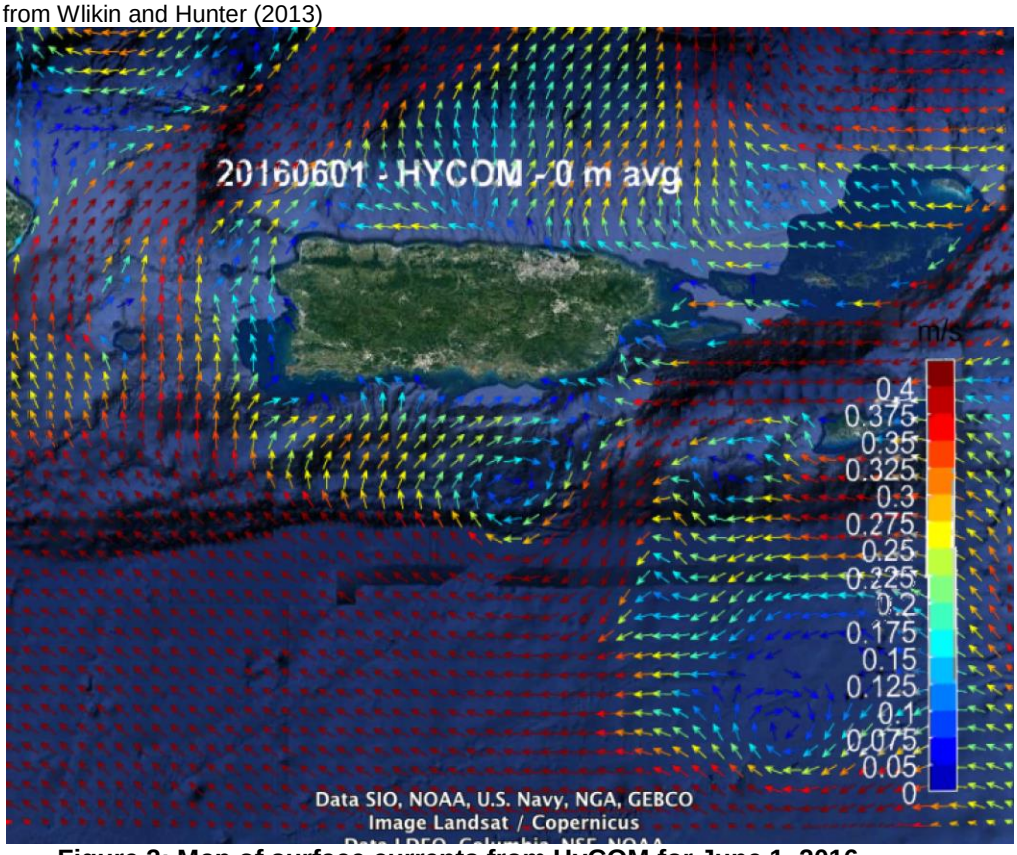

Figure 2: Map of surface currents from HyCOM for June 1, 2016.

AMSEAS[2], The Naval Oceanographic Office (NAVOCEANO) operates regional ocean prediction systems based on the Navy Coastal Ocean Model (NCOM). The AMSEAS domain covers the Americas Seas region including the Gulf of Mexico and Caribbean Sea. The regional NCOMs produce 4-day forecasts at 3-hour time steps, updated at 00Z daily. NAVOCEANO interpolates the output onto a regular grid with 1/30 degree (~3km) resolution in the horizontal and 40 levels in the vertical; prior to April 5, 2013, the resolution was roughly 1/36 degree. The NetCDF files contain ocean temperature, salinity, eastward and northward currents, and elevation, along with the atmospheric forcing fields provided over the model domain by a 15 km application of the Navy's COAMPS model. The regional NCOM ocean prediction systems assimilate all quality-controlled observations in the region including satellite sea surface temperature and altimetry, as well as surface and profile temperature and salinity data using the Navy Coupled Ocean Data Assimilation (NCODA) system. Boundary conditions are applied from the NAVOCEANO operational 1/12 degree Global HYCOM. Prior to April 2013, boundary conditions were applied from the Navy operational Global NCOM.

2 Text from https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/navoceano-ncom-reg

MERCATOR[3], is based on the NEMO ocean model [Madec, 2012] and uses a z level coordinate system with partial cells to represent sloping bathymetry. The daily av- erage output analyzed here is from the 1/12 degree resolution operational Atlantic Ocean model with 43 vertical levels. Output for 2010–2011 assimilated SSH, SST and profile data using a reduced Kalman filter approach [Brasseur et al., 2005]. MERCATOR is forced with surface meteorology from the European Centre for Medium-range Weather Forecasts (ECMWF). Tides are not modeled. River inflows are Dai and Trenberth [2002] monthly climatology.

[3] Text from Wlikin and Hunter (2013)

OSCAR[4], Ocean Surface Current Analses Real-Time contains near-surface ocean current estimates, derived using quasi-linear and steady flow momentum equations. The horizontal velocity is directly estimated from sea surface height, surface vector wind and sea surface temperature. These data were collected from the various satellites and in situ instruments. The model formulation combines geostrophic, Ekman and Stommel shear dynamics, and a complementary term from the surface buoyancy gradient.

[4] Text from https://podaac.jpl.nasa.gov/dataset/OSCAR_L4_OC_third-deg

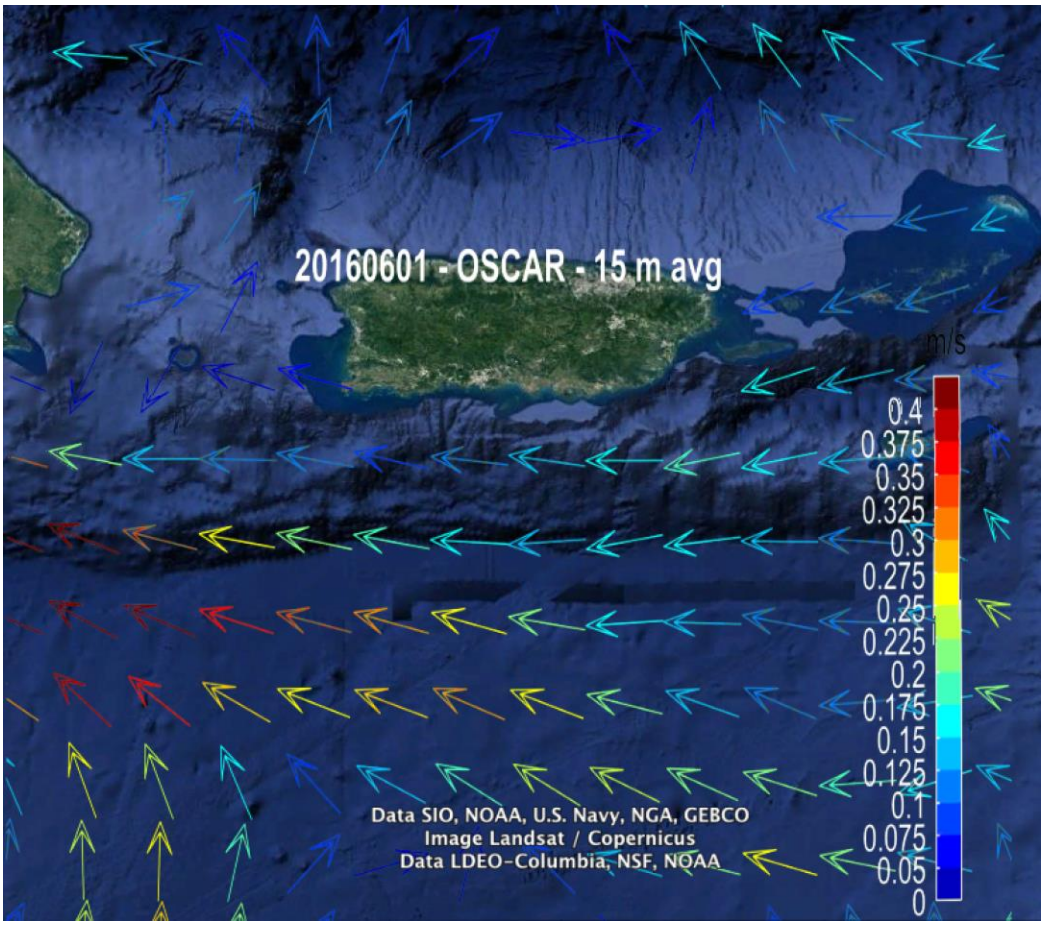

Figure 3: Map of surface currents from OSCAR for June 1, 2016.

3. We have identified a surface drifter set for CARICOOS. We are in the process of assembling that data. Surface current data is also available from the CARICOOS buoys.
4. Attended the CARICOOS General Assembly to conduct kickoff meeting.

MAJOR OUTCOMES

The major outcome was the operation of the five HF radars in Puerto Rico. The systems performed exceptionally well during this progress period with high data coverage as noted in Table 1. Monthly average maps are presented in Figure 4 . Note that the average maps have not been quality controlled. The maps show a large pulse of water flowign throught he Mona Passage from December 2016 to March 2017. There was an anticyclonic eddy south of Puerto Rico for January 2017. The deficiency of the PYFC site degrades the maps in December 2016 and May 2017. Antenna patterns were conducted at three of the stations this progress period.

Table 3: Data coverage and range for the five stations in Puerto Rico.

Station	*Data Coverage (%)*	*Average Range (km)*	*Antenna Pattern Date*
FURA	94	98	March 10, 2017
CDDO	99	113	May 30, 2017
FARO	98	200	
PYFC	99	183	January 23, 2017
MABO	100	237	

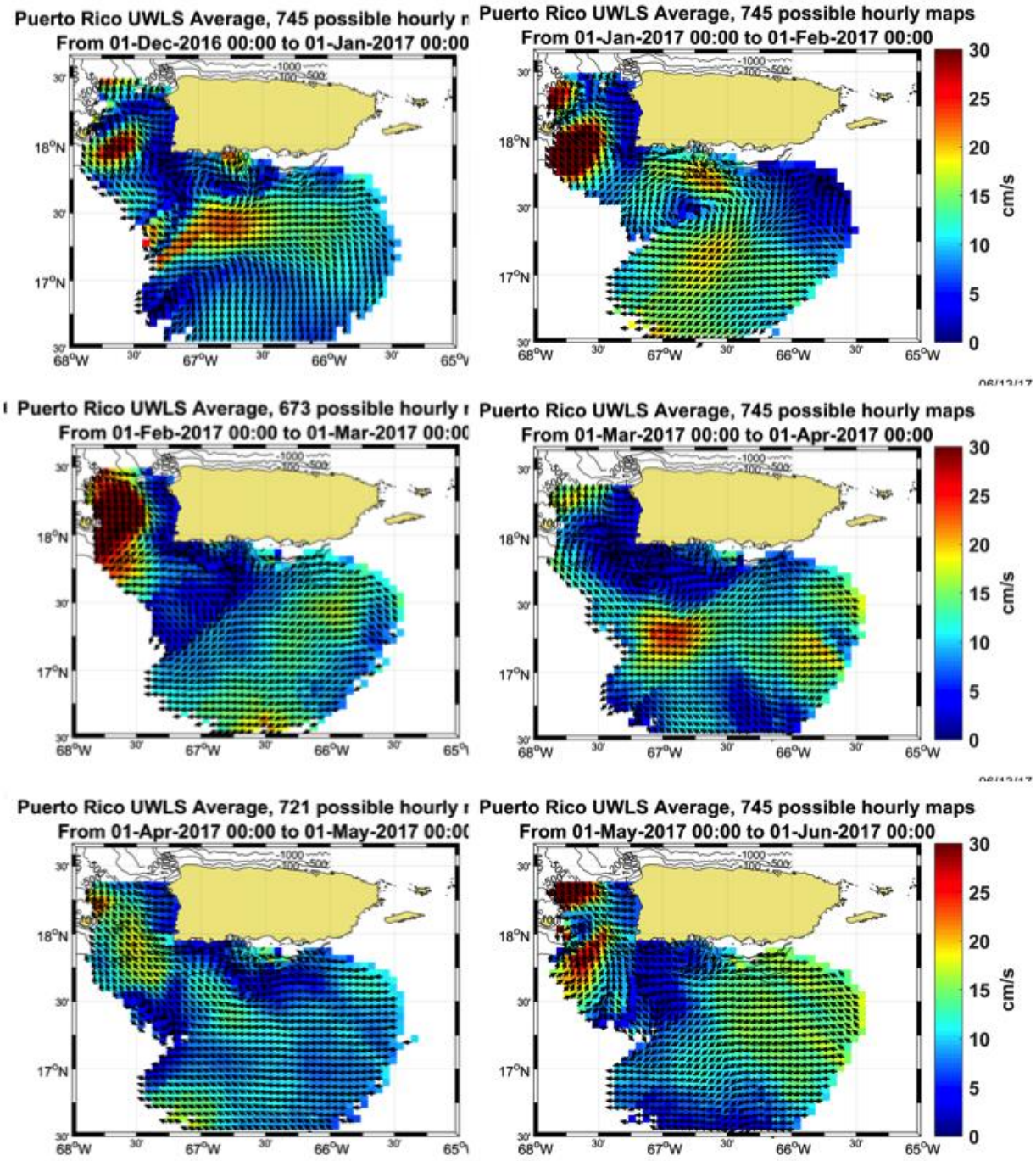

Figure 4: Monthly mean surface current measurements on the 6 km grid from December 2016 (upper left) to May 2017 (lower right). The colorbar indicates speed from 0-30 cm/s and the arrow on the map indicates direction the current is towards.

RELATED PROJECTS

None

WORK PLAN FOR UPCOMING PERFORMANCE PERIOD (June 1 2017 – Nov 30 2017)

Some radial processing and hardware issues were identified and should be resolved in the upcoming progress period.

1. The number of range cells processed at CDDO, FARO and MABO can be increased.
2. The reflected power at PYFC is trending upward. Identify a fix for this.
3. CDDO, the temperature dropped from 40 C to 30 C around May 18, 2017. Identify if a change at the site brought about this temperature change or if this is sensor related.
4. MABO, transmit power fluctuated from December 1, 2017 till March 13, 2017 then ceased. Determine what caused this fluctuation.
5. MABO, the reflected power spiked to 20 watts on March 27, 2017. Determine the cause of this occurrence.
6. PYFC, the AWG module temperature is consistent near 50 C, this should be reduced. There was also a step increase in the temperature of the station on March 27, 2017. Determine the cause of this occurrence.
7. The coverage gap directly offshore of PYFC is of concern (Figure 5). It has persisted for some time. The gap is present in the ideal and measured overage maps. It should be investigated. This is the only station in Puerto Rico that displays this pattern.

Also here are some analysis work we will perform:

1. Discuss with Univerity of Connecticut and Coast Guard Search and Rescue about implementing STPS for the Puerto Rico area.
2. Identify weather events where the use of surface current data may impact wave, circulation and surge models
3. Develop validation metrics for the comparison of the HFR data with the models
4. Measure observation impact and skill on the suite of models
5. Test different assimilation schemes for the surface current data

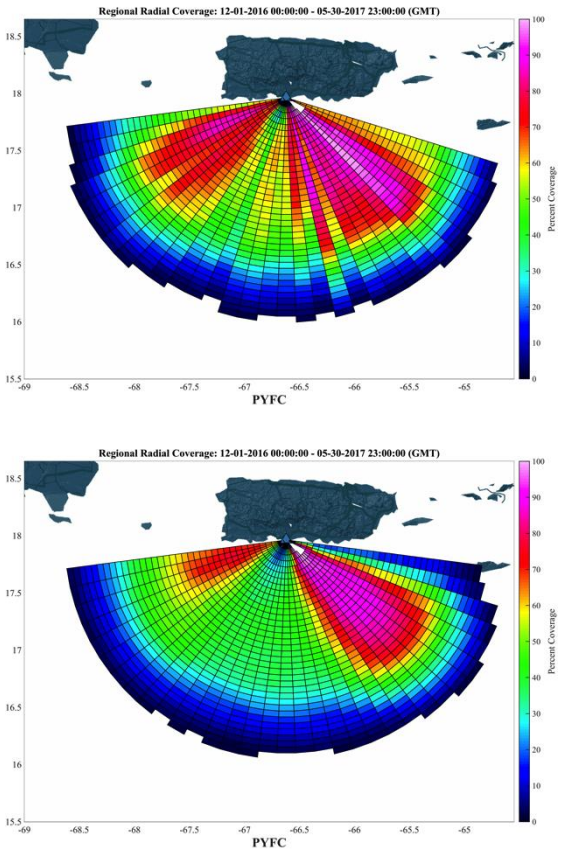

Figure 5: Measured (top) and ideal (bottom) radial data coverage map from December 1, 2016 to June 1, 2017 for station PYFC.

PUBLICATIONS & PRODUCTS

1. Prakash, Evans, Roarty (2017) "Observations of the Surface Circulation Around Puerto Rico" CARICOOS 2017 General Assembly, Anasco, Puerto Rico, April 28, 2017