Analysis of input climatologies for the development of a coastal ocean circulation model for the US Virgin Islands and Puerto Rico

Sonaljit Mukherjee[1] and Sennai Habtes[1] and Paul Jobsis[1]

[1]University of the Virgin Islands

Motivation

Ocean modeling is necessary to understand the impact of the ocean circulation on larval transport and coral reef resilience in the marine ecosystems surrounding the Virgin Islands and Puerto Rico.

An ocean model requires 3-dimensional ocean state properties as boundary conditions. Currently, available model frameworks that resolve the mesoscale flow around the islands are the following:

Global Ocean Forecast System (GOFS)

- Hybrid Coordinate Ocean Model (HYCOM)
- Navy Coupled Data Assimilation System (NCODA)
- Surface forcing from Navy Global Environmental Model (NAVGEM)
- 32 vertical level hybrid coordinates, (isopycnal in open ocean, terrain following in coastal ocean, z-level in mixed-layer)
- Orthogonal curvilinear horizontal coordinates, resolution 10 km

Relocatable Ocean Nowcast-Forecast System (RELO)

- Navy Community Ocean Model (NCOM)
- Navy Coupled Data Assimilation System (NCODA)
- Surface forcing from Navy COAMPS model
- 40 vertical levels, terrain-following σ coordinates near surface and z-level coordinates below
- Orthogonal curvilinear horizontal coordinates, resolution 3 km

System for Global Ocean Physical Analysis (PSY4)

- Nucleus for European Modeling of the Ocean (NEMO) model
- SAM2v1 (Kalman filter with SEEK formulation)
- Surface forcing from ECMWF
- 50 levels, decreasing resolution from 1 m at the surface to 450 m at bottom, 22 levels within upper 100 m
- Tripolar ORCA horizontal grid, resolution 10 km

Objective

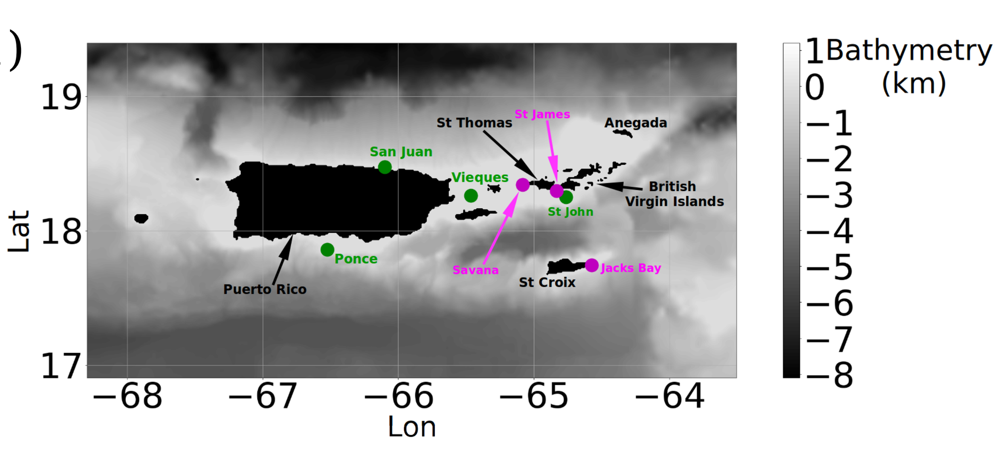
In this work, we compare the performance of existing model frameworks that resolve the mesoscale flow in the Caribbean Sea and the local flow surrounding Puerto Rico and the Virgin Islands.

Methods and Diagnostics

We conduct two separate comparisons for the open ocean and the nearshore flow. For the open ocean comparison, we use gridded data of Sea-Surface Height Anomaly (SSHA) from AVISO, surface current velocity data from OSCAR, and sea-surface temperature (SST) data from the G1SST. For nearshore comparison, we use in-situ time series data from the buoys operated by CariCOOS (Caribbean coastal ocean observing system).

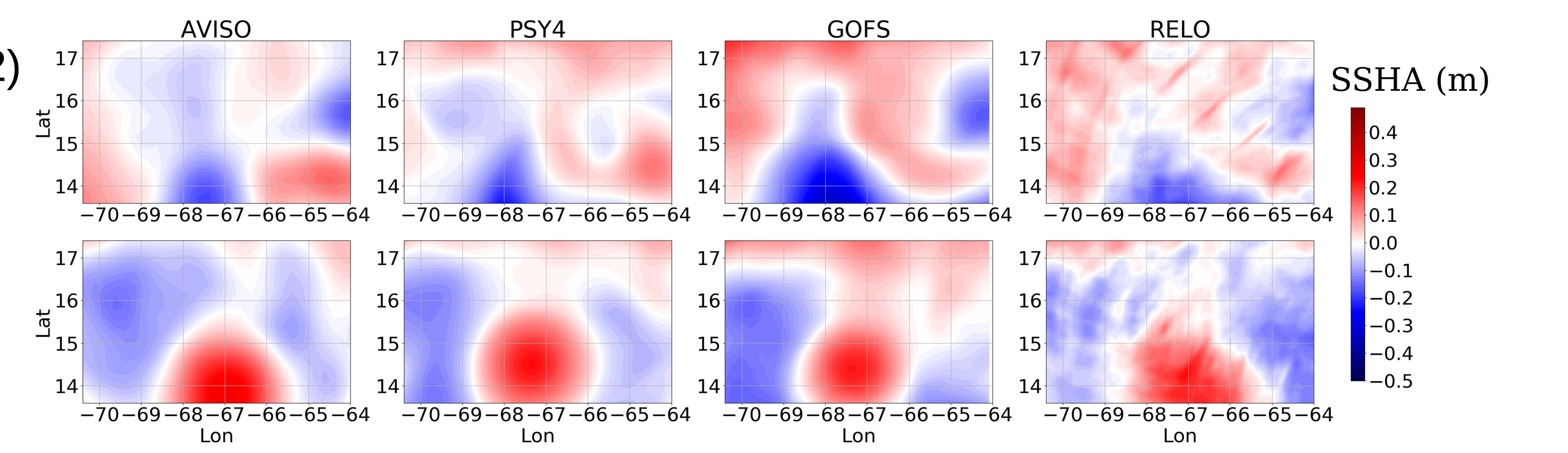
We analyze the surface mesoscale variability using snapshots of SSHA and the Okubo-Weiss parameter in the Caribbean Sea, and temporal variability in SSHA within the Anegada passage (fig. 2, 4).

For each surface ocean property (SSHA, SST, current velocities), we compare the standard deviation, RMSD and cross-correlation of each model output with respect to observed data using Taylor diagrams (fig. 3,6,7,8,9).

1)


Results

SSHA, Caribbean Sea

2)


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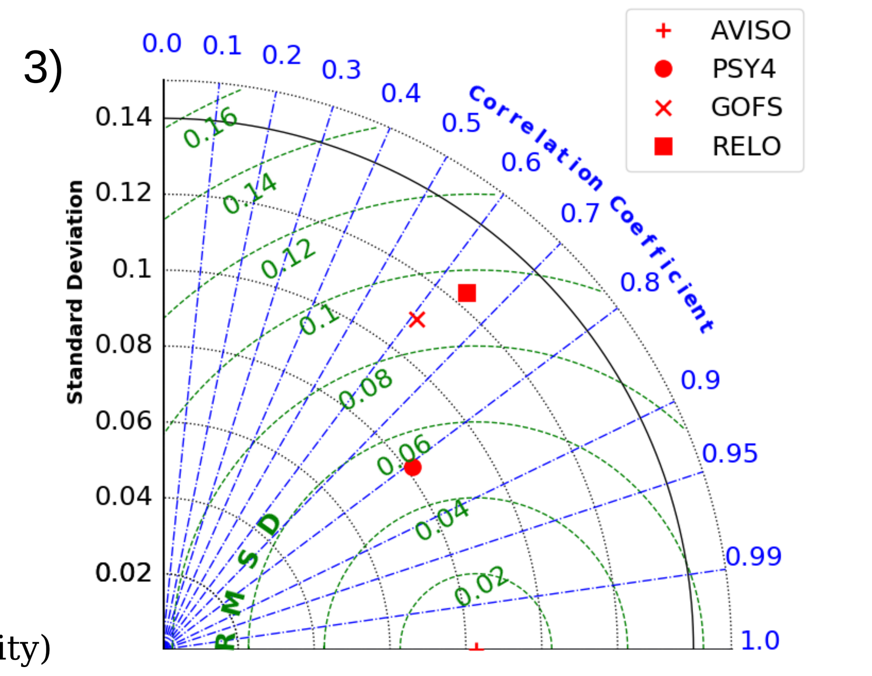

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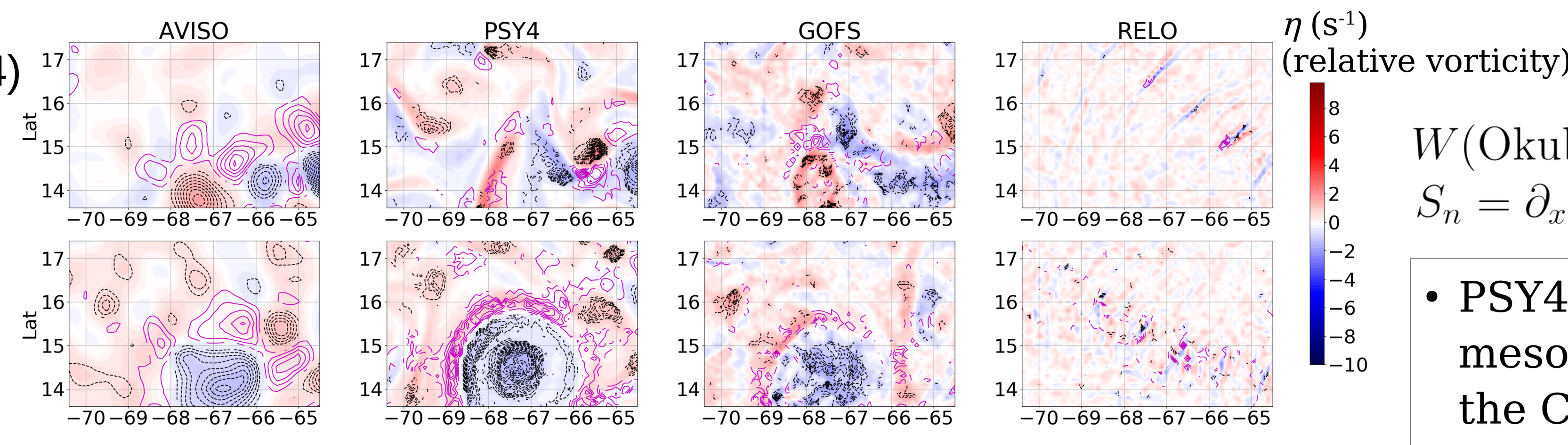
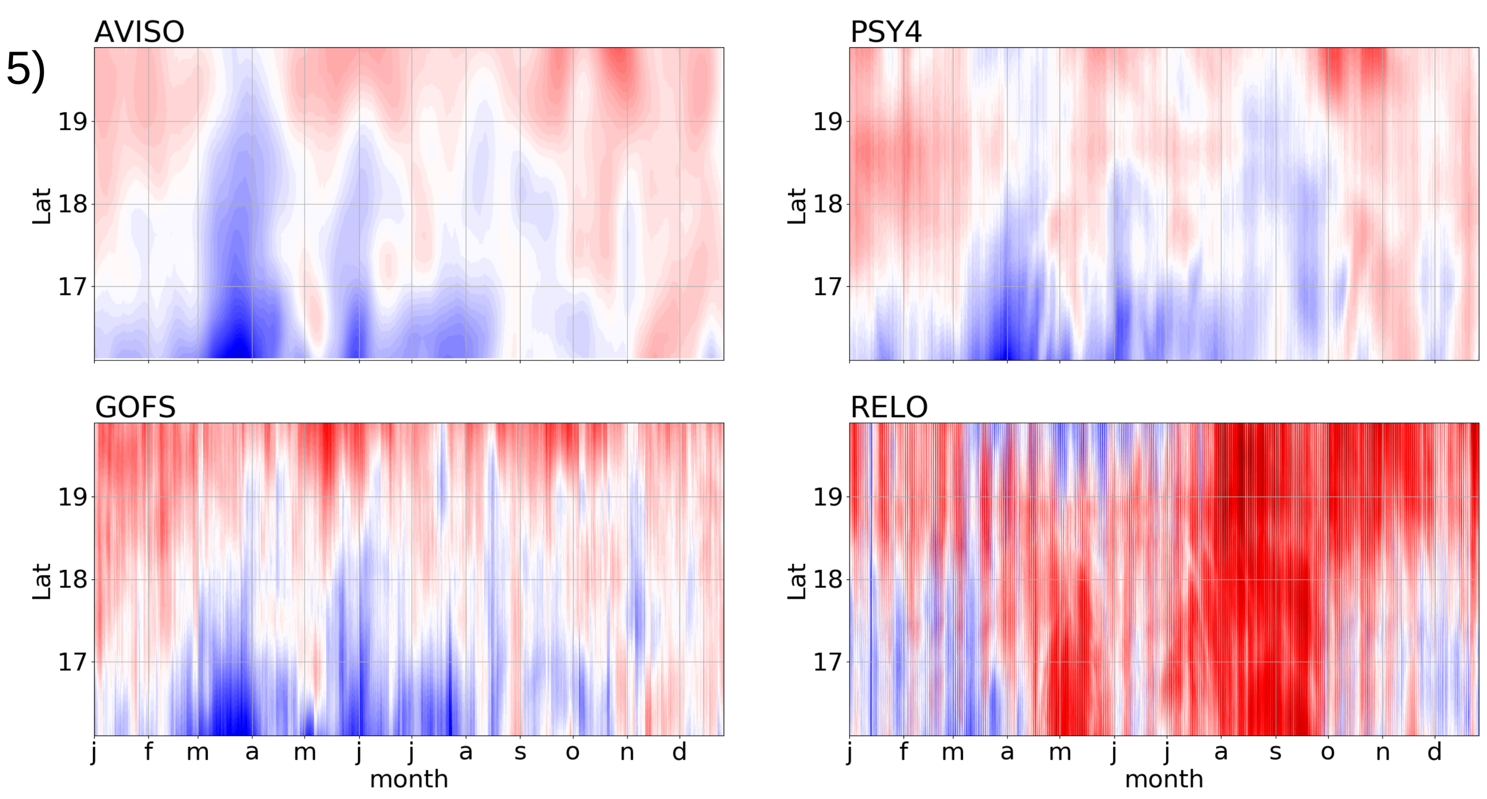


$$W(\text{Okubo}-\text{Weiss parameter}) = S_n^2 + S_s^2 - \eta^2$$
$$S_n = \partial_x u - \partial_y v,\ \ S_s = \partial_x v + \partial_y u,\ \ \eta = \partial_x v - \partial_y u$$

SSHA, Anegada passage

5)


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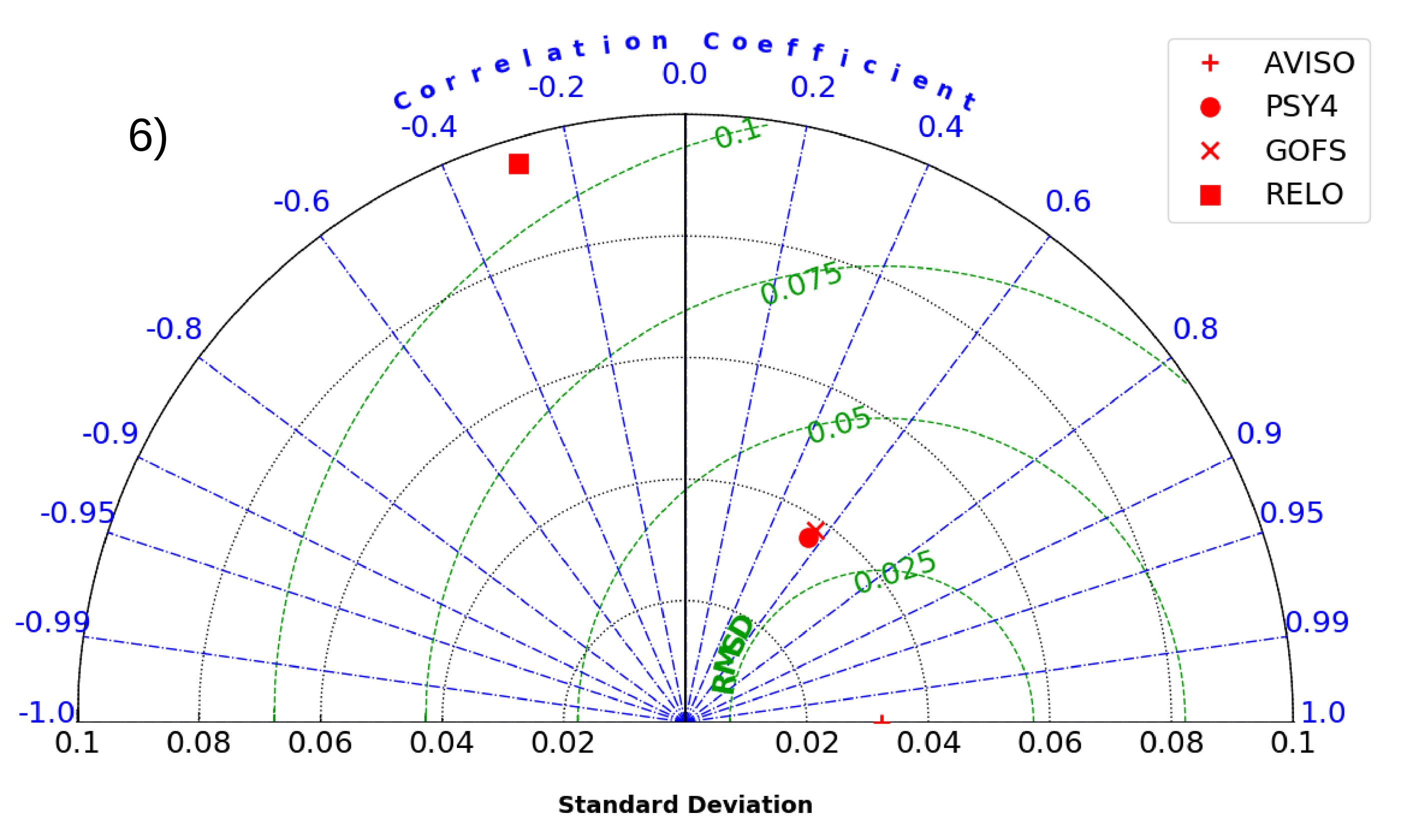
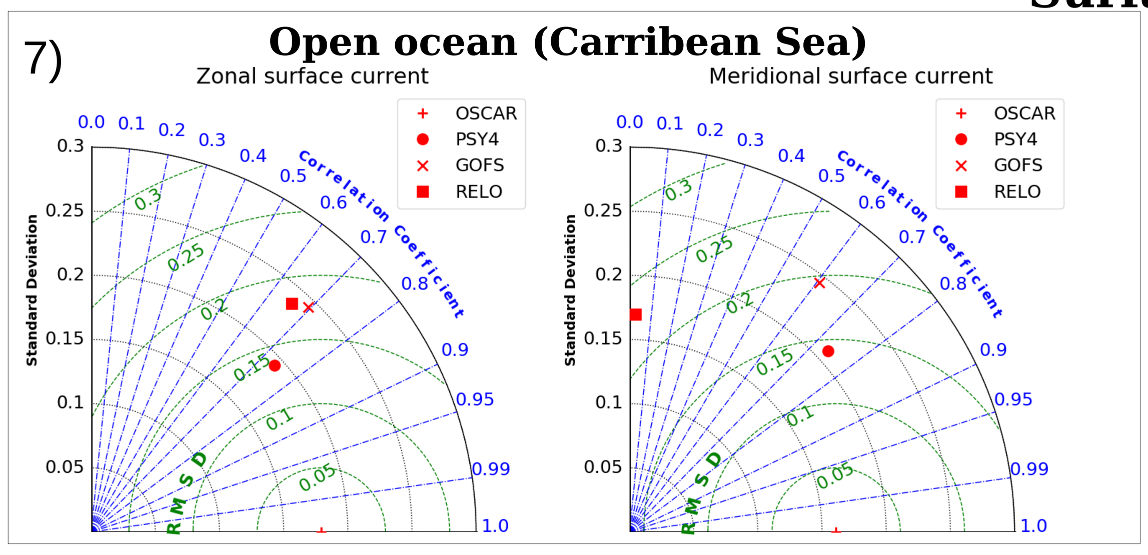


- PSY4 and GOFS captures most of the mesoscale features in SSHA observed in the Caribbean Sea and Anegada passage. The RELO SSHA shows prominent small-scale features due to finer resolution and lower viscosity, but cannot realistically produce the mesoscale features (fig. 2,4,5).
- PSY4 shows the highest correlation and lowest RMSD of SSHA with respect to AVISO. The RELO shows a correlation of 0.7 in the Caribbean Sea, but in the Anegada passage it correlates negatively (fig. 3,6).
- The open-ocean surface currents from PSY4 show the highest correlation and lowest RMSD with respect to the OSCAR. The RELO shows a correlation of 0.65 for the zonal currents, but nearly 0 correlation for the meridional currents (fig. 7).
- Nearshore Taylor diagram shows that all model outputs correlate very weakly with in-situ data. This is because the nearshore buoy data from the CariCOOS buoys are not assimilated in these models (fig. 8).

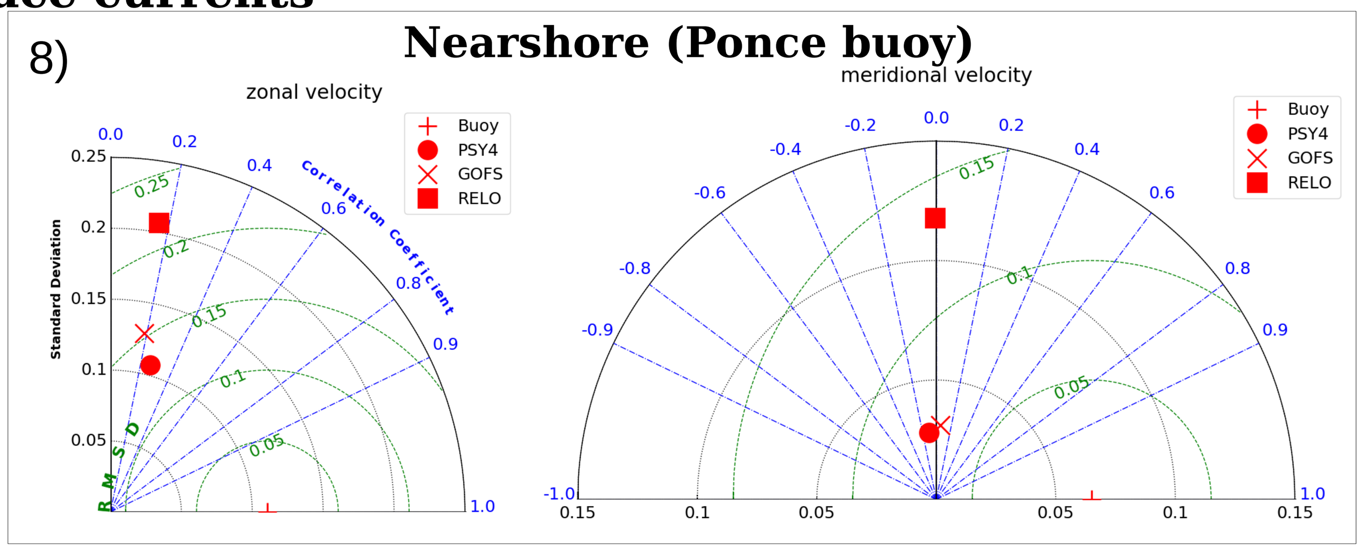
Inference: PSY4 and GOFS are best suited models for simulating SSHA and surface currents in the Caribbean Sea open ocean, whereas the RELO is not well suited. The PSY4 is slightly better than the GOFS, although this assessment of model performance is limited to the resolution of the observed data.

Surface currents

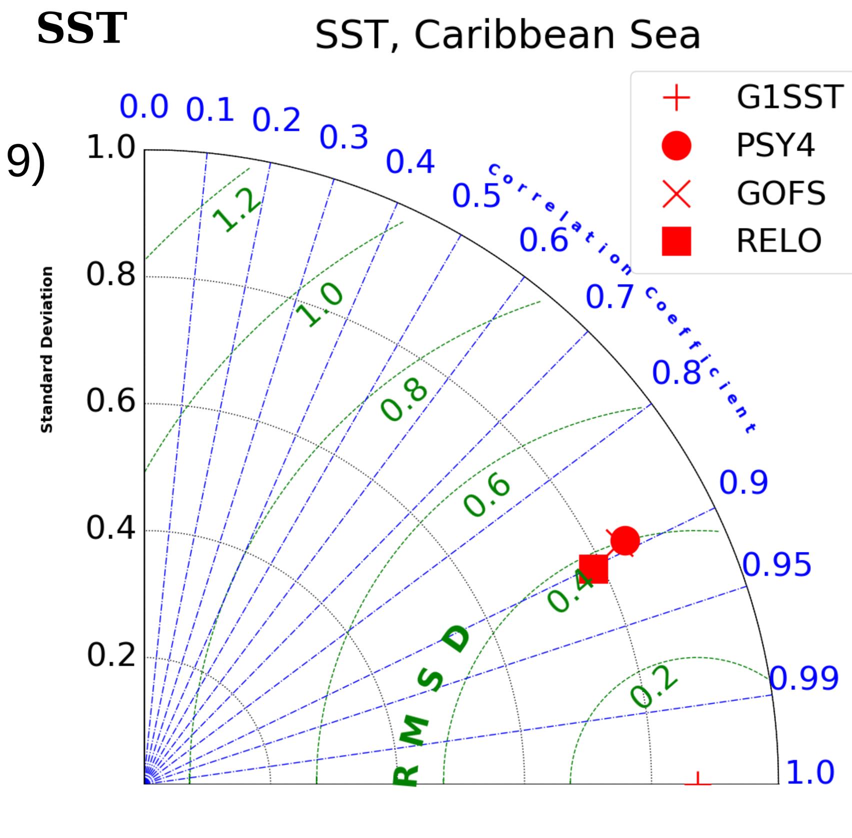
7) **Open ocean (Carribean Sea)**



8) **Nearshore (Ponce buoy)**

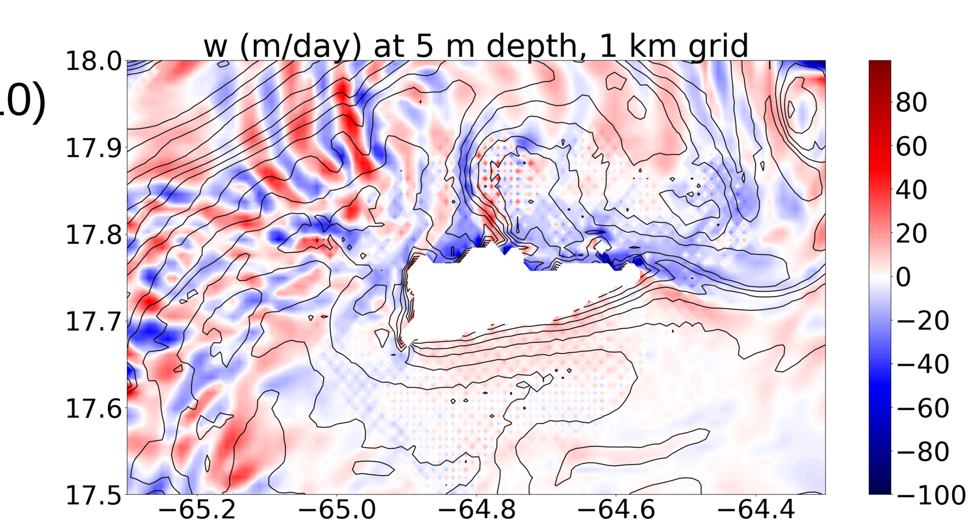


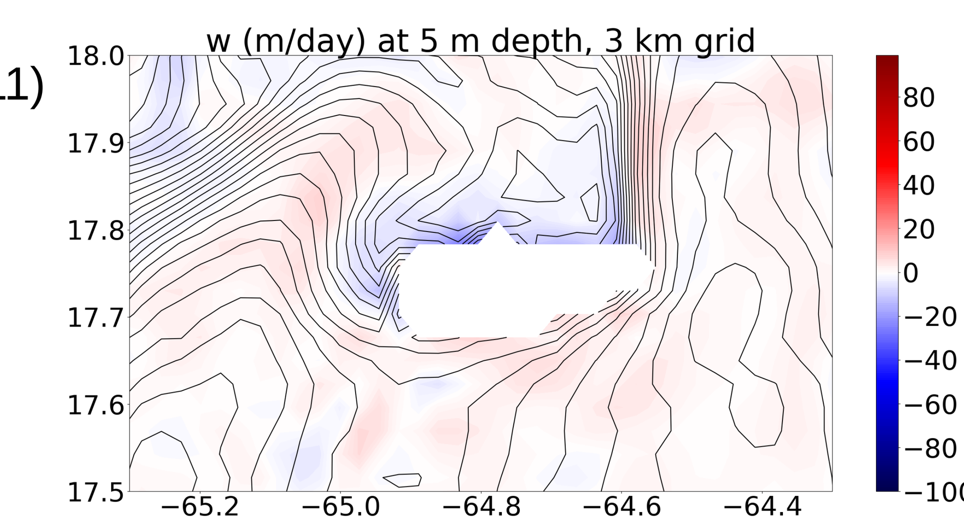
SST

9)


SST from all model outputs show strong correlations of 0.9. This indicates that all the models can produce the seasonal variability of SST in the observed data.

Preliminary ROMS results

10)


11)


We configured the ROMS model with climatology data from PSY4, and forced with MERRA 2 surface fluxes.

Preliminary results show small-scale processes of O(1-10 km) diameter, along with vertical velocity of O(100 m/day) indicating the presence of submesoscale dynamics at the wake regions of St Croix.

We plan to conduct further analysis on the flow pattern.

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