Wind effect on the Hudson River plume

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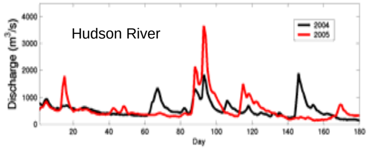
1. Introduction

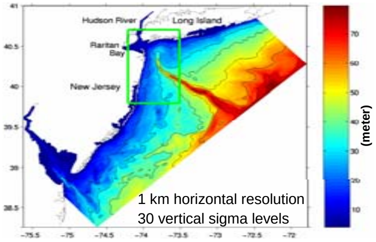
The Hudson River plume transports freshwater, nutrients, contaminants, sediments and momentum into the New York Bight and the inner New Jersey shelf region.



Background discharge
= 500 m^3/s.

One or two high discharge events in April and May:
Maximum discharge
= 1200 ~3500 m^3/s
Time scale = 20 days

Long term goal of this study is to answer two questions: (1) where does the freshwater from the Hudson River travel? (2) which forces are dominant in the momentum balance?

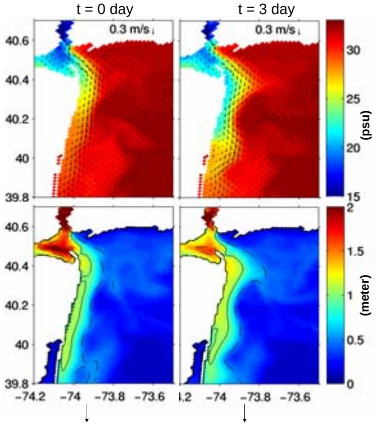


1 km horizontal resolution
30 vertical sigma levels

Regional Ocean Modeling System (ROMS) is used to investigate the Hudson River plume response to wind forcing. The model is setup with realistic coastlines and bottom topography. Tidal forcing is also included.

2. Unforced river plume

In order to study the influence of wind on the Hudson River plume, the model plume is spun up with constant river discharge (500 m^3/s) and daily mean winds from 1 January to 27 April 2004. After the spin-up, the freshwater from the Hudson River flows along the New Jersey coast (left panels). Without wind forcing, the plume front advances to the south and a coastally trapped current flows along the New Jersey coast at day 3 (right panels).



surface salinity at 1 m depth

Equivalent freshwater depth

It is defined as

$$\int_{-h}^{\eta} \frac{S_a - S}{S_a}\, dz$$

where S_a is the ambient salinity.

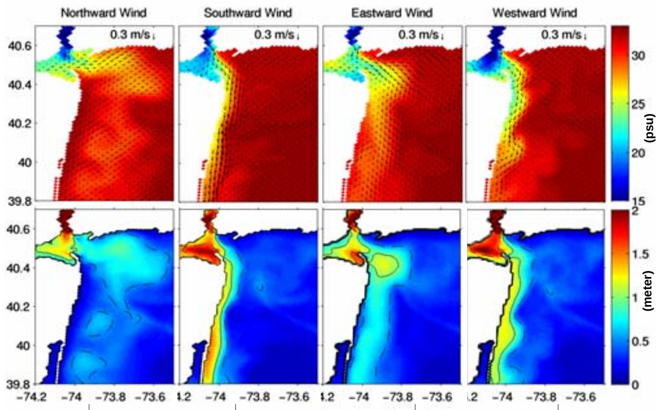
Freshwater flows from the Hudson River travels along the New Jersey coast.

Without wind forcing, the plume front advances to the south and freshwater flows along the New Jersey coast.

3. Constant Low Discharge (500 m^3/s)

3.1 sensitivity to wind direction

To examine response of the Hudson River plume to four different wind directions, 5 m/s speed of moderate winds are blown over the surface for three days in each direction. The winds are spatially uniform and the river discharge is constant of 500 m^3/s. Surface salinity distributions are in top panels; corresponding equivalent freshwater depths in bottom panels.



Surface current flows to the east along the Long Island and to the north along the New Jersey coast. Freshwater accumulates north of the Hudson Shelf Valley.

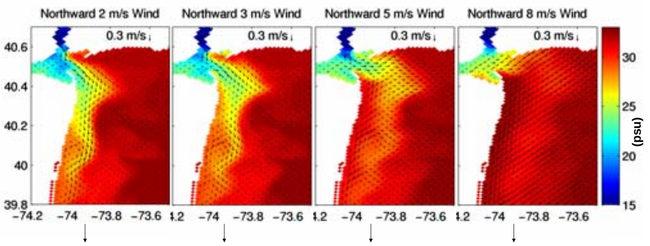
A relatively strong and coastally trapped current flows to the south along the New Jersey coast. Freshwater accumulates in Raritan Bay and flows along the New Jersey coast.

Surface current flows to the southeast from the mouth of Raritan Bay. Freshwater accumulates at the northern tip of the Hudson Shelf Valley and forms a circular bulge.

Surface current flows to the south along the New Jersey coast. Freshwater accumulates in Raritan Bay and along the New Jersey coast.

3.2 sensitivity to wind speed

To examine response of the Hudson River plume to different strength of surface wind stress, northward winds are blown with speed of 2, 3, 5 and 8 m/s for two days. The winds are spatially uniform and the river discharge is constant of 500 m^3/s.



Freshwater flows out of Raritan Bay and travels along the New Jersey coast. Tail of the plume front moves offshore in the south of 40.2°N.

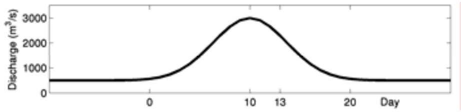
Surface current flows to the southeast from the mouth of Raritan Bay. The plume along the New Jersey coast is detached from the coast.

Surface current flows eastward near the mouth of Raritan Bay. Subsuface saline water upwells and flows northward along the New Jersey coast .

The plume flows eastward along the Long Island. A relatively strong and 15 km wide northward current develops along the New Jersey coast.

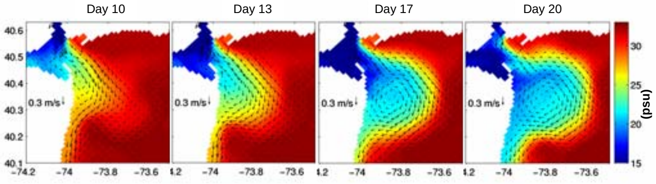
4. High Discharge Event (max=3000m^3/s)

A Gaussian shape of river discharge time series is assumed in this experiment: an idealized discharge function starts from 500 m^3/s, increases to 3000 m^3/s during the first period of 10 days and decreases to 500 m^3/s during the second period of 10 days.



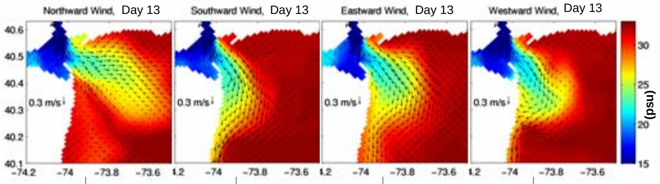
4.1 unforced high discharge event

Without wind forcing, a bulge forms at the south of Raritan Bay mouth. Eventually, the north-south elongated bulge grows and becomes a circular bulge after 16 days later of the high discharge event.



4.2 sensitivity to wind direction during high discharge event

Wind forcing is not given until the river discharge reaches its maximum value at day 10. Winds are blown for three days from day 10 to day 13. Four different wind directions are tested while the wind speed is fixed as 5 m/s.



The plume moves to the north of Hudson Shelf Valley toward Long Island.

The plume water forms a broad southward flow and drains to the south.

Freshwater moves to the northern tip of the Hudson Shelf Valley and accumulates.

Freshwater accumulates in Raritan Bay and is arrested at the south of Raritan Bay mouth.

5. Summary and future work

For a constant low discharge case, (1) unforced plume flows along the New Jersey coast as a coastally trapped buoyancy-driven current. (2) Northward and eastward winds move freshwater out of Raritan Bay and away from the New Jersey coast while southward and westward winds accumulate freshwater in those locations. Especially, eastward wind forms a relatively small bulge near the mouth of Raritan Bay. During high discharge event, (3) the river plume forms a growing freshwater bulge without wind forcing . (4) Northward wind directs freshwater to the east while southward wind drains freshwater to the south. Eastward and westward winds arrest the plume near the mouth of Raritan Bay. (5) We are working on the modeled momentum balance and freshwater flux for dynamical interpretation of the numerical simulation results.

References

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