An ensemble based approach to simulate the uncertainty in the BP oil spill using a high resolution mesoscale ocean model

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Objectives:

Quantify the pathways of transport of oil and its uncertainty during the BP oil spill in the Gulf of Mexico (GoM) using an ensemble based appoach.

Experimental Setup and discussion:

- ROMS model with 9 km resolution and 50 levels in GoM domain (Figure 1).
- Initial conditions and lateral boundary conditions from HYCOM.
- Surface forcing from COREII climatology.
- Ensemble size = 12

ROMS is initialized every 7 days starting from 1 March 2010 using the HYCOM analysis. This is termed the control forecast. The control is the backbone of the bred vector method (Figure 2). The random perturbations introduced on 1 March decay initially, but start growing on 8 March (Figure 3). It appears that the growth is linear till about 19 April. Temperature perturbation give rise to perturbations in u, v, SSH and salinity. Figure 4 shows that the perturbation in velocity grows with time.

Lagrangian floats are used to track transport trajectories. A float is released at every 50 km in the surface level of GoM on 12 April. These floats are advected by the control run and also the ensemble. The results of this advection over one month are analysed. Figure 5a shows that the transport can range from a few km to more than 500km. The floats at locations with dark red color tend to move with the gulf stream and eventually pass out of GoM. In the oil spill region (Figure 5b) the transport is over a distance of about 100 km.

The uncertainty in this distance is quantified by calculating the spread in the end points of ensemble trajectories (Figure 6a and b). The largest spreads (>50km) are in the loop current region (north of the Yucatan channel). This region corresponds to the region of largest perturbation in surface current (Figure 4).

The uncertainty near the spill location is typically about 10 to 30 km. Some locations have larger spreads but this is mainly because of outlier ensemble members. For example, one of the ensemble members for float 1058 deviates considerably from the rest of the ensemble giving rise to a large spread.

The ensemble tracks the control float (1016) at the spill location well only for a few days but later deviates from the control. On the other hand the control float 1056 is tracked quite well by the ensemble througout the month.

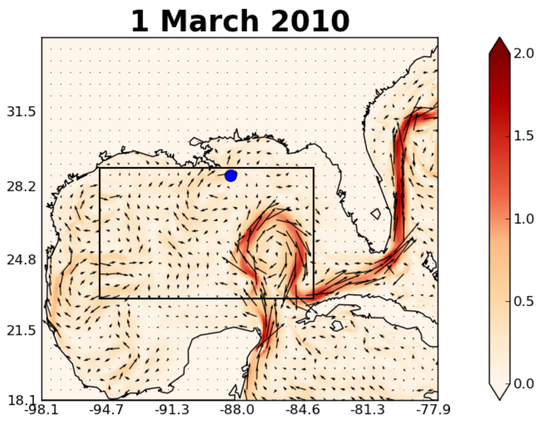


Figure 1 : The surface current in GoM on 1 March. The magnitude of current is shown in color. The blue dot shows the location of the BP oil spill that occurred on 15 April 2010.

Figure 2 : Illustration of the bred vector method. The control is initialized every week starting on 1 March. A forecast of 7 days is launched from each of these control initalizations. A 12 member ensemble is generated by randomly perturbing the initial temperature at all grid points on 1 March. These perturbations are of the order of 0.1% of the initial temperature. This ensemble is integrated for 7 days. The 7 day ensemble forecast is subtracted from the 7 day control forecast to produce perturbations in the u, v, T, salinity and SSH fields. The perturbations so obtained are added to the control initial condition on 8 March. This ensemble (and the control) is integrated till 15 March. The perturbations are generated by subtraction and the process is repeated. This process is carried out from 1 March to 31 May. Each breeding cycle is of 7 days and there are a total of 12 breeding cycles in this experiment.

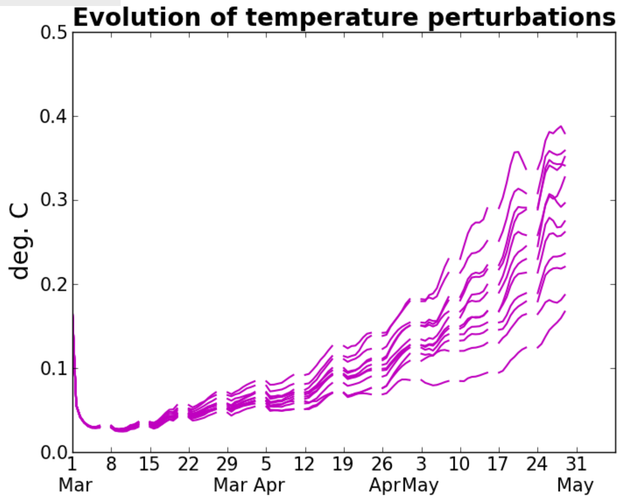


Figure 3 : Each curve is an ensemble (magnitude of) perturbation member averaged over the box shown in Figure 1 and depth of 500m.

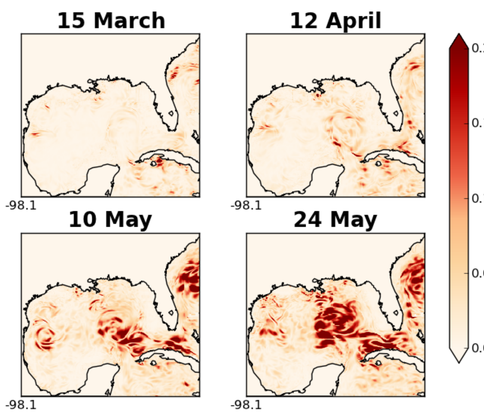


Figure 4 : The magnitude of perturbations (m/s) in the u component of the surface current averaged over the 12 ensemble members is shown on four different dates.

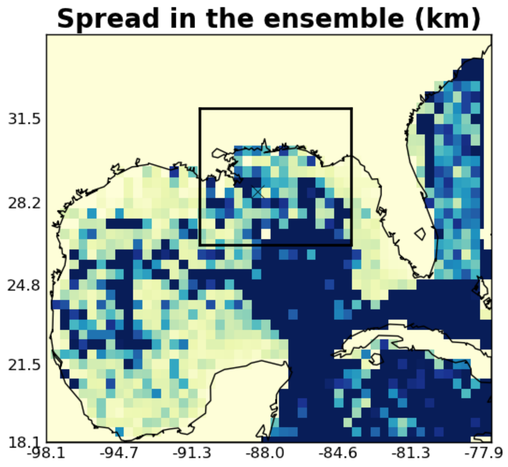


Figure 6a : The spread quantifies the uncertainty in the transport distance shown in figures 5a and 5b.

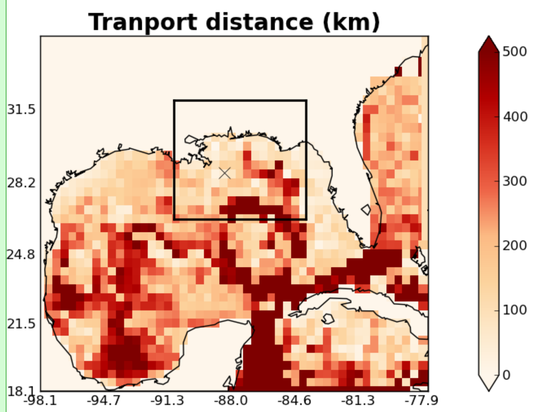
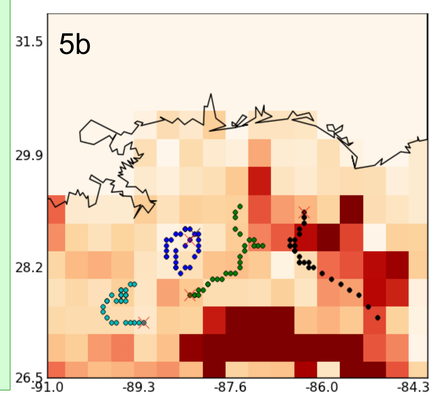


Figure 5a: The color shows the distance travelled by the control float in one month.

Figure 5b: The rectangular region in figure 5a is magnified. The trajectories of a few floats are shown. The blue trajectory corresponds to the float at the oil spill site.



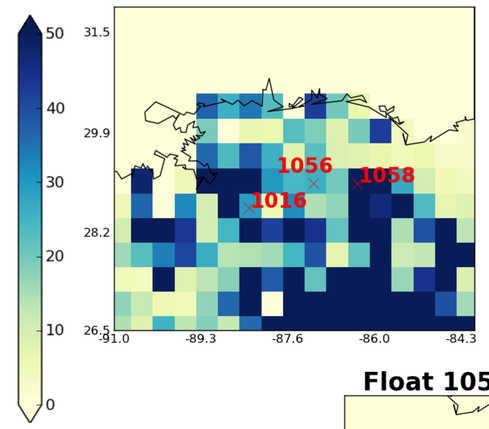
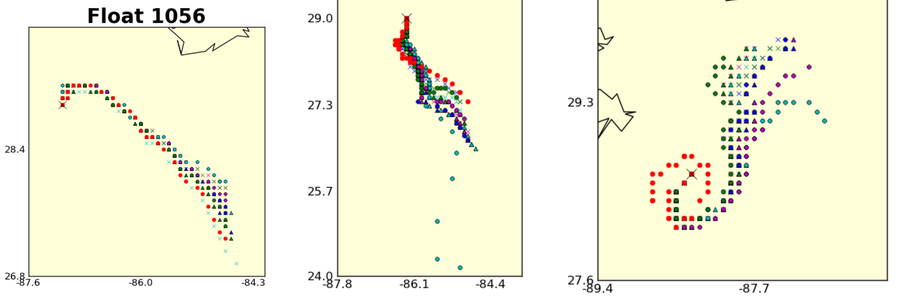


Figure 6b : The magnification of box shown in figure 6a. The initial locations of four different floats are marked by numbers. Float 1016 corresponds to the spill location. The control and ensemble float trajectories for each of these floats is shown in panels below the figure. In each of these panels the red circles show the control float trajectory. The other markers show the trajectories of the 12 ensemble floats. In each of the panels the initial location of the float is marked by black 'x'.



Conclusions :

- The temperature perturbations grow at a rate of about 0.03 deg. C. / week (Figure 3).
- In the vicinity of the oil spill the floats are advected about 100 to 200 km towards the south, over a period of 1 month (Figures 5b).
- The uncertainty in the advection near the spill location is about 10 to 30 km. (Figure 6b).

Further work:

- Rescale the bred vectors.
- Use a more realistic surface forcing.
- Use a coupled model.

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References:

Toth, Z. and Kalnay, E. (1993) : Ensemble forecasting at NMC : The generation of perturbations. Bull. Amer. Met. Soc., **74 (12)**, 2317-2330.
Yin, X. –Q. and Oey, L.-Y. (2007) : Bred-ensemble ocean forecast of loop current and rings. Ocean Modeling , **17**, 300-326.