Study on the identification of mesoscale eddies by taking 4D-VAR method in the South China Sea region

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Abstract

A 4-Dimensional Variation Data Assimilation (4D-VAR) experimental system was designed for the South China Sea (SCS) region. It was taken to study the identification problem of mesoscale eddies in SCS region by assimilating sea level anomaly (SLA) observation. An auto-detective vortex identification algorithm based on SLA was adopted in this study. The data assimilation (DA) experiment shows that the vortex identifying result derived from the posterior field has a better performance than that derived from the prior field. Furthermore, it displays a potential strength for identifying mesoscale eddies by combining DA method. As in conventional vortex identification method, only observation SLA was adopted and it usually has a lower spatial resolution than model settings. And a higher spatial resolution strength owed by the model confirms a more accurate structures for mesoscale eddies, which will lead to a better vortex identification result.

Main Question

- How to assimilate SLA data into **DA** system
- How to identify mesoscale eddy from analysis field
- What's the impact of **DA** on vortex identification

Data and Method

The SLA (**S**ea **L**evel **A**nomaly) data used are derived from AVISO, with spatial resolution $0.25° \times 0.25°$. A statistical MDT (**M**ean **D**ynamic **T**opography) was applied to form the model variable ζ with SLA together.

$$\zeta = SLA + MDT \tag{1}$$

The **DA** method used was I4DVAR method. The corresponding algorithm was showed in Figure1[2].

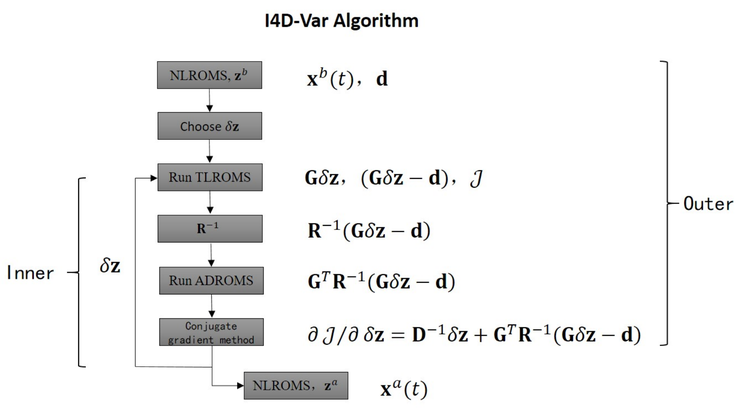

Figure 1: I4DVAR Algorithm

A hybrid vortex identification method was adopted in this experiment[1], an eddy is identified based as following criteria:

1. The eddy is a simple connected pixel set.
2. Only *one* SLA extremum exists in the set.
3. The amplitude of the eddy is larger than the data error (e.g. 3cm).
4. The SLA values of the eddy are above (below) a given SLA threshold for anticyclonic(cyclonic) eddies.

Experiment and Result

We take a set of control experiments to investigate the impact of assimilating SLA on eddy identification in the South China Sea Region. The model we adopted is ROMS and the model resolution was set to be $1/12°$ on horizontal and 32 levels on vertical. The assimilation window was set to be 24 hours.

Assimilation Result

The observation file is depicted as Figure2.

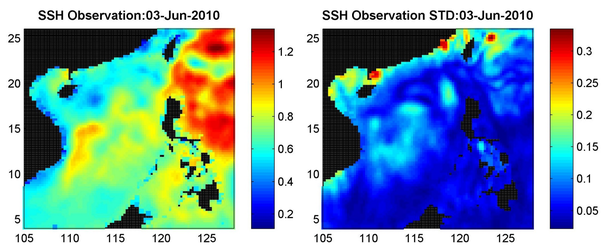

Figure 2: Observation (SLA+MDT)

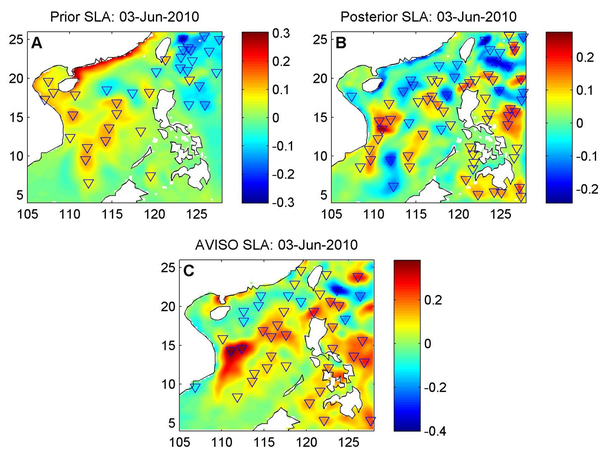

Figure 3: SLA Contrast

Taking I4DVAR as assimilation method, subtracting model variable ζ with MDT, a posterior field for SLA is obtained and showed in Figure3, also with a prior field and corresponding observation field as comparison (∇ denotes the vortex extremum location).

Identification Result

Using vortex identification algorithm mentioned before, the identification result is concluded in Figure3, Figure4 and Table1.

Field	Count	Mean-amplitude(m)	Mean-area	Total-area
Prior	36	-0.006	4.04	145.6
Posterior	69	0.036	2.98	205.6
Observation	43	0.076	5.03	216.2

Table 1: Vortex Identification Result

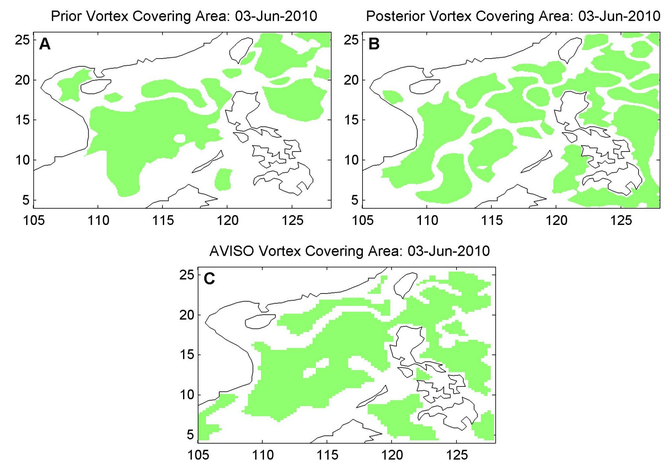

Figure 4: Vortex Region Contrast

Considering a specific case in the north part of Philippine Islands, a illustration is obtained as Figure5.

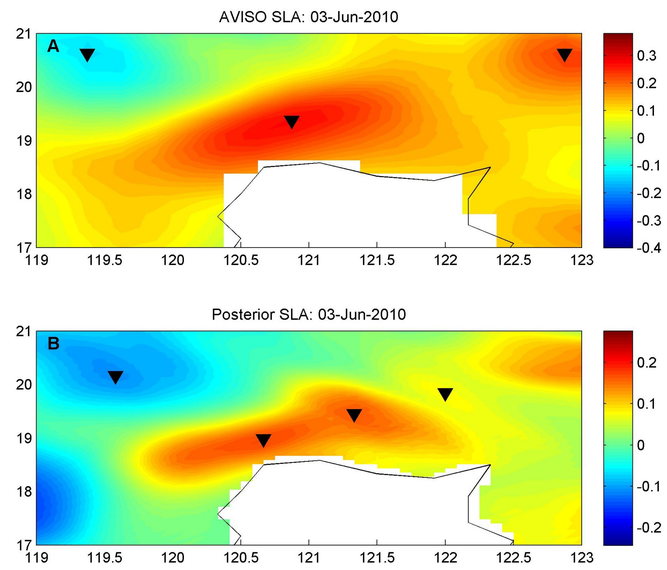

Figure 5: Posterior VS Observation

As we can see in Figure5, the posterior field reveals more details than direct observation, which may approach a bit more to the real condition (because the model owns a higher resolution).

Conclusions

- The model resolution owns a more flexible and higher resolution than direct observation, **DA** method will depict a more accurate picture to real ocean environment.
- Combining vortex identification with **DA** method can not only improve the identification quality but also provide a novel way to examine **DA** performance quantitatively.

Shortage and Forthcoming Research

1. The MDT should be counted with a longer simulation result.
2. The identification result should be also compared with an objective data set result those have a better resolution than the SLA observation (e.g. HYCOM Reanalysis Field).

References

[1] Qiu Yang Li, Liang Sun, Shan Shan Liu, Tao Xian, and You Fang Yan. A new mononuclear eddy identification method with simple splitting strategies. *Remote Sensing Letters*, 5(1):65–72, 2014.

[2] Andrew M. Moore, Hernan G. Arango, Gregoire Broquet, Brian S. Powell, Anthony T. Weaver, and Javier Zavala-Garay. The regional ocean modeling system (roms) 4-dimensional variational data assimilation systems: Part i system overview and formulation. *Progress in Oceanography*, 91(1):34 – 49, 2011.

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