Operational and Verification
---A coupled forecasting system for the seas off China

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Outline

1. Introduction of the coupled forecast system for the seas off China
2. Applications of this forecast system
3. Verification
4. Conclusion
Introduction

- The circulation part is the improved POM adding the wave-induced mixing coefficient
- The wave part is MASNUM -WAV model
- The tidal current is included
- The Model is parallelized using MPI method
- The meteorological model is MM5 for regional and NCEP products for the global
3 nested layers
One way
55km-13km-3.5km

Global model:
0°E~0°W
78°S~65°N
(1/2)°×(1/2)°

Northwest pacific model:
99°E~150°E
0°N~50°N
(1/8)°×(1/8)°

Focused section
China Seas Model:
105°E~135°E,
15°N~41°N
(1/24)°×(1/24)° fine
SST is assimilated in mixing layer using Nudging method:

\[
\frac{\partial T}{\partial t} + \frac{\partial T}{\partial x} + \frac{\partial T}{\partial y} + \frac{\partial T}{\partial \sigma} = \frac{\partial}{\partial \sigma} \left( K_H \frac{\partial T}{\partial \sigma} \right) + F_T - \frac{\partial R}{\partial \sigma} + \frac{T_{obs} - T}{\tau}
\]

Where T is forecast SST, Tobs is observed SST, \( \tau \) is relaxation time scale.

The advantage of Nudging is less simple, affective and low time costing.

The observed SST is obtained from the NEAR-GOOS real time regional ocean data base under Japanese meteorological society web site: http://goos.kishou.go.jp
Operational forecast system

Atmospheric Model
- Wind, Heat Flux

Sub-Models
- Tide
- Wave

Real-Time Observing system
- Winds, SST, Sea Level
- NDBC, NCEP, NOS

Forecast section
- Wave height
- Tide current
- Tide height
- Current
- Temperature
- Salinity
- Sea level

POM

Verification system
- Forcing
- Verification
- Data assimilation (sst)

Release Website
http://172.16.3 2.155/rts

Archives
Providing validation report per month
Installed in National Marine Environment Forecast Center (NMEFC) located in 2007

Running in the forecast center of the East China Branch, SOA in Shanghai and Xiamen since Mar. 1, 2008
Validation for this coupled forecast system

Verification is an indispensable part of ocean research and operational forecasting activities.
Verification the differences between observation data and the forecast products (sea surface temperature, subsurface temperature and mixed layer depth, wind) of 24 hour, 48 hour and 72 hour.
The statistical metrics

Mean error (ME) = \[ \frac{1}{N} \sum_{i=1}^{N} (O_i - F_i) \]

Mean absolute error (MAE) = \[ \frac{1}{N} \sum_{i=1}^{N} |O_i - F_i| \]

Root mean absolute error (RMSE) = \[ \sqrt{ \frac{1}{N} \sum_{i=1}^{N} (O_i - F_i)^2 } \]

Correlation coefficient (R) = \[ \frac{\sum_{i=1}^{N} (F_i - \overline{F})(O_i - \overline{O})}{\sqrt{\sum_{i=1}^{N} (F_i - \overline{F})^2} \sqrt{\sum_{i=1}^{N} (O_i - \overline{O})^2}} \]
Observation data

Buoy data: Operational observation program

SST Web site: ftp.discover-earth.org

Verification of SST with Buoy data

SST time series obtained from buoy and 24 hour forecast product since Apr 20. 2008

<table>
<thead>
<tr>
<th>Buoy</th>
<th>ME</th>
<th>MAE</th>
<th>RMSE</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>QF201</td>
<td>0.60</td>
<td>0.70</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Qf202</td>
<td>0.80</td>
<td>0.95</td>
<td>1.2</td>
<td>0.95</td>
</tr>
</tbody>
</table>

QF202 31.3N 123.5E
1680 records

QF201 29.5N 124E
2530 records
Verification of SST with satellite data

MAE > 0.6 °C

Low forecast skill
Forecast barrier?
Why? Jan-Feb-Mar

MAE for all records:
1 Day 0.61
2 Day 0.64
3 Day 0.67

May be wind forecast??

b. Variation of MAE with time, All statistic results are obtained with respect to daily-averaged satellite data and model data
Variation of RMSE, MAE and ME for SST with time. All statistic results are obtained with respect to daily-averaged satellite data and model data.
In shallow domain (green), Mean Error > zero, worse forecast skill, So forecast system undervalue SST.

MAE of SST went down with ocean depth increasing. MAE became larger at open boundary (red). Ocean terrain have negative impact on MAE (yellow). WHY? Maybe vertical layer.
There have been the same phenomena along 30N and 123E
Probability of distribution of MAE for SST

Forecast error rise with forecast time
The probability of MAE(>=0.8) is up to 21% in 72 forecast
Profile number: 8036

The distribution of Argo Profile used in verification between Apr 20. 2008 to Apr 30. 2010
Average Variations of ME, MAE, R and RMSE with depth from surface to 500m below the sea surface last 2 years.

In the layer between 100m to 150m: maximum MAE(>2°C)
minimum correlation coefficient
maximum RMSE
Mixed Layer Depth

The depth, where the temperature has changed by a variable value (0.5°C) from the temperature at a reference depth of 10 m.

<table>
<thead>
<tr>
<th>Time</th>
<th>ME</th>
<th>R</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day</td>
<td>11.8</td>
<td>0.54</td>
<td>21.6</td>
<td>32.3</td>
</tr>
<tr>
<td>2 Day</td>
<td>12.1</td>
<td>0.54</td>
<td>21.6</td>
<td>32.4</td>
</tr>
<tr>
<td>3 Day</td>
<td>12.3</td>
<td>0.52</td>
<td>21.7</td>
<td>33.1</td>
</tr>
</tbody>
</table>

Mixed layer depth was underestimated. ME value is about 12m for forecast vs Argo. Table data show that the forecast skill was reduced with time.
### Mixed Layer Depth

#### Distribution of ME for MLD

<table>
<thead>
<tr>
<th>Time</th>
<th>&lt;15M</th>
<th>15-40M</th>
<th>&gt;40M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day</td>
<td>50.3%</td>
<td>34.4%</td>
<td>15.3%</td>
</tr>
<tr>
<td>2 Day</td>
<td>50.4%</td>
<td>34.2%</td>
<td>15.4%</td>
</tr>
<tr>
<td>3 Day</td>
<td>50.4%</td>
<td>34.1%</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

#### Probability of forecast accuracy for MLD

<table>
<thead>
<tr>
<th>Forecast Accuracy</th>
<th>1 Day</th>
<th>2 Day</th>
<th>3 Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-ABS(Obs.-Fcast)/Obs</td>
<td>43.3%</td>
<td>43.1%</td>
<td>43.2%</td>
</tr>
<tr>
<td>Time</td>
<td>acc.</td>
<td>&gt;70%</td>
<td>50%–70%</td>
</tr>
<tr>
<td>1 Day</td>
<td>43.3%</td>
<td>27.6%</td>
<td>29.1%</td>
</tr>
<tr>
<td>2 Day</td>
<td>43.1%</td>
<td>27.7%</td>
<td>29.2%</td>
</tr>
<tr>
<td>3 Day</td>
<td>43.2%</td>
<td>27.5%</td>
<td>29.3%</td>
</tr>
</tbody>
</table>
Conclusion

1. Skill in predicting SST, MLD is expected to be improved. However, this will tend to increase the shallow bias in MLD
2. Forecast skill goes down with forecast time
3. Open boundary and ocean terrain have an important impact on forecast skill
4. In a period of time (Jan-Feb-Mar), forecast skill is lost. There might be a forecast barrier.

Overall, the forecast shows reasonable accuracy over a series of studies designed to test ability to represent upper ocean conditions.
I can always make you smile.

Thanks!