Gaps and Recommendations (II)

(2) As far as marine data and information are concerned, there is no unified format for both data and metadata from different sources in China. It is necessary to define a unified data and metadata format which can be applied to all data from various sources. Moreover, there is no common data transfer protocol for all data facilities. That also needs to be defined clearly and quickly by learning from European expreinces.

Gaps and Recommendations (III)

(3) Very often in China and to a much lesser degree in Europe, the marine data and information provided by different platforms are overlapped with each other to some extent. In other words, data redundancy exists under many circumstances. More efforts should be made to ensure that marine data and information can be managed more efficiently and also more cost effectively.

Gaps and Recommendations (IV)

(4) Europe offers more types of data services, more data free of charge, and more data in near real-time. To achieve the goals of making marine data in China more easily accessible to and exploitable by various communities of interest, it is necessary to reduce the social barriers as well as the costs to data integration and sharing. One effective way to do so is to strengthen international cooperation in this regard.

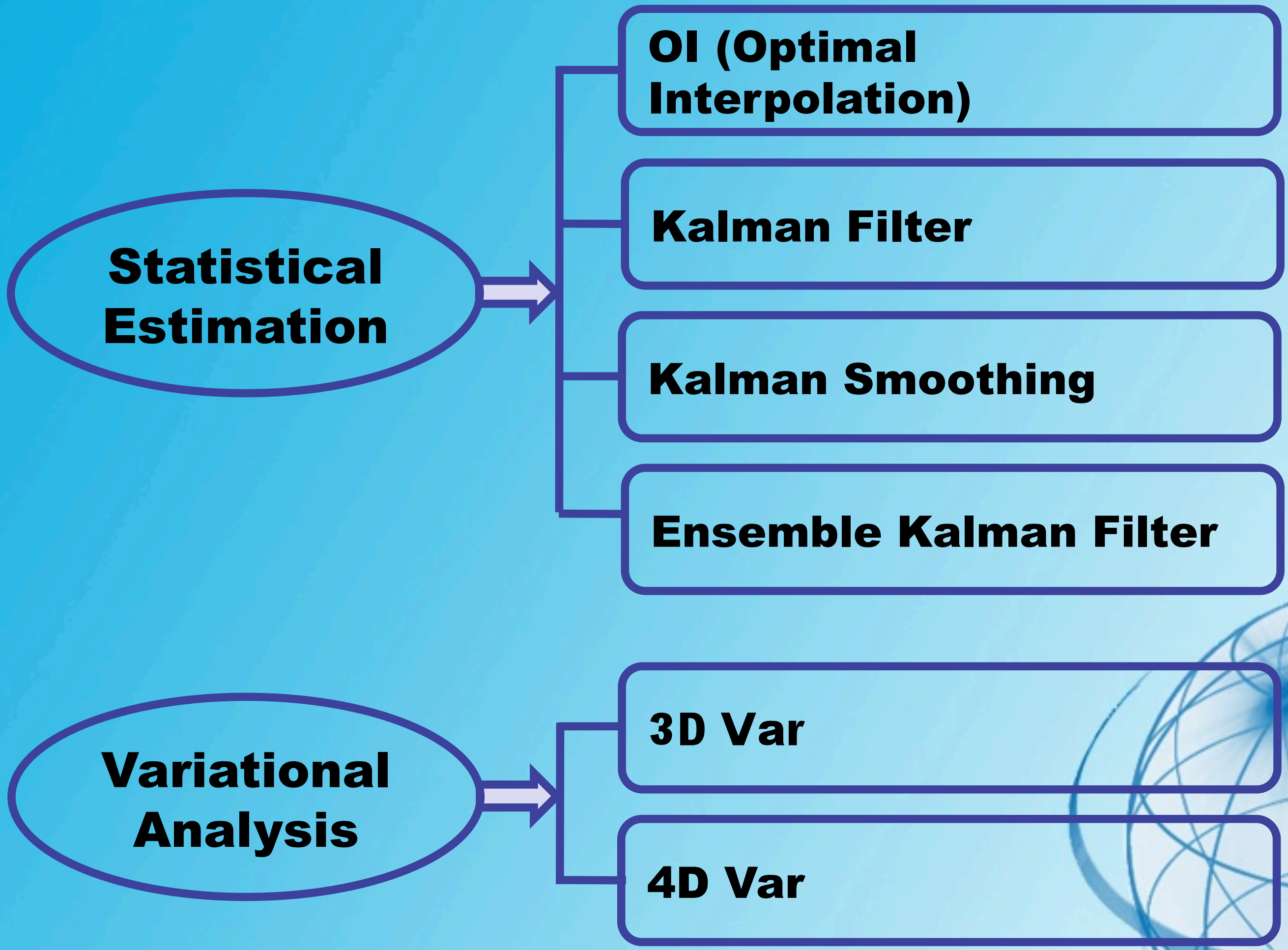
CONTENTS

- Description of Work
- Marine Data Policy
- Data Integration and Sharing
- Methods for Utilizing Data in Models

Ocean Data Assimilation

Ocean data assimilation is a mathematically rigorous process of combining ocean observations and ocean models to extract the most important information from relatively sparse and incomplete observations of time-varying ocean state. Ocean data assimilation has matured to the point that observations are now routinely combined with model forecasts to produce a variety of ocean products.

Data Assimilation Methods



Data Assimilation System

Ocean data assimilation systems are used to: (a) initialize ocean models using all available observations through sequential approaches for forecasting, and (b) synthesize observations with ocean models to obtain dynamically consistent estimates of changing ocean state.

A Selected List of Assimilation Projects/Systems

Country	The Representative Numerical Model of Assimilation Projects or Systems
China	GRAPES(Global and regional assimilation and prediction enhanced system)/ OVALS(Ocean variational analysis system)
Europe	MERSEA (Marine environment and security for the European area)/ ECMW F(European center for medium-range weather forecasts)/ ALADIN SYSTEM/ 3D-VAR
International	GODAE(Global ocean data assimilation experiment)/GHRSST-PP (Global high-resolution sea surface temperature pilot project)

A Case of Chinese Data Assimilation System: AIPO Reanalysis System

- **AIPO Reanalysis System**

AIPO reanalysis system for the joining area of Asia and Indian-Pacific Ocean (AIPO) is developed by IAP and has been delivering reanalysis datasets for study on the air-sea interaction over AIPO and its climate impact over China at interannual timescales. This system consists of a nested ocean model forced by atmospheric reanalysis, an ensemble-based multivariate ocean data assimilation system and various ocean observations.

A Case of Chinese Data Assimilation System: AIPO Reanalysis System

➢ Input / Output of the AIPO Reanalysis System

System	Assimilated Data			Products
AIPO reanalysis system	In-situ data	Temperature and salinity profiles	Comprehensive data set ENSEMBLES (EN3 version 1d) includes WOD05, GTSPP, Argo and ASBO project.	Resolution: 3/4°x3/4 °/daily Variable: 3D-temperature, salinity, velocity and sea level Time range: 1992.01.01- 2006.12.31
	Remote sensing data	Sea level anomaly	1/3° x 1/3° Mercator grid from multi-altimeters produced by Ssalto/ Duacs.	
		Sea surface temperature	Daily high-resolution blended analyses for sea surface temperature by Reynolds et al.	

A Case of European Data Assimilation System: ECWMF

- ECWMF: European Center for Medium-Range Weather Forecasts

The European Center for Medium-Range Weather Forecasts (ECMWF) has produced operationally daily global ocean analyses to provide initial conditions for the seasonal forecasting system since 1997. It provides state-of-the-art weather forecast data and products to member states, as well as managing a supercomputer facility which provides resources for weather forecasting research and computer modeling of the global atmosphere and ocean.

A Case of European Data Assimilation System: ECWMF

Observations Assimilated by ECWMF
Ocean Data Assimilation Systems

Model	Product	Assimilated Data
HOPE/ OPA	Subsurface data	Subsurface temperature: TAO/TRITON and PIRATA, XBT Salinity data: ARGO and TRITON moorings
	Sea level data	Combining all satellites (Envisat, Jason, Topex/Poseidon, ERS-2, GFO)
	Sea surface temperature	Ship and buoys, AVHRR

A Case of International Data Assimilation System: GODAE

In 1997, the Global Ocean Data Assimilation Experiment (GODAE) was initiated to lead the way in establishing global operational oceanography. It aims to develop practical and robust operational activities for oceanography with great benefit for society. The systems are now producing ocean state estimates and ocean forecasts on a routine basis, some in near-real-time.

Data Assimilation Methods Used by GODAE System

System Name	Country	Data Assimilation Method	Reference
BODAS	Australia	Ensemble optimal interpolation	Oke et al., 2008
ECCO-JPL	USA	Kalman filter and smoother	Fukumori, 2002
FOAM	UK	Analysis correction	Martin et al., 2007
Mercator	France	Static SEEK filter	Brasseur et al., 2005
MOVE/MRICOM	Japan	Multivariate 3DVAR	Fujii and Kamachi, 2003
NVODA	USA	Multivariate optimal interpolation	Cummings, 2005
NEMOVAR	European Union	Multivariate incremental 3DVAR	Weaver et al., 2005
TOPAZ	Norway	Ensemble Kalman filter	Evensen, 2006

A Case of International Data Assimilation System: GODAE

Observations Assimilated by Each of the GODAE Systems

System	Sea Level	Subsurface Temperature and Salinity	Surface Temperature	Sea Ice
BODAS	Along-track data from satellite altimeters, coastal tide gauges	Argo, CTD, XBT, and moorings	Satellite data	—
ECCO-JPL	Along-track data from TOPEX/ Poseidon and Jasion-1	Argo, CTD, XBT, and moorings	Reynolds SST analysis	—
FOAM	Along-track data from satellite altimeters	Argo, CTD, XBT, and moorings	In situ and satellite data	OSI-SAR sea ice analysis
Mercator	Along-track data from satellite altimeters	Argo, CTD, XBT, and moorings	NOAA RTG SST analysis	—
MOVE/ MRICOM	Along-track data from all satellite altimeters	Argo, CTD, XBT, and moorings	MGDSST SST analysis	MGDSST sea ice analysis
NVODA	Along-track data from satellite altimeters	Argo, CTD, XBT, and moorings	In situ and satellite data	SSM/I and SSMIS sea ice concentration
NEMOVA R	Along-track data from satellite altimeters	Argo, CTD, XBT, moorings, buoys, and gliders	In situ and satellite data	—
TOPAZ	Gridded sea level anomaly maps	Argo	Reynolds SST analysis	AMSR sea ice concentration and sea ice drift products from CERSAT

Assimilation Example: Altimeter Data

- Title:
  - ✓ Assimilation of TOPEX/Poseidon data into a Global Ocean Model
- Authors:
  - ✓ Juan Liu et al.
- Institutions:
  - ✓ Institute of Atmospheric Physics
  - ✓ Chinese Academy of Sciences, etc.

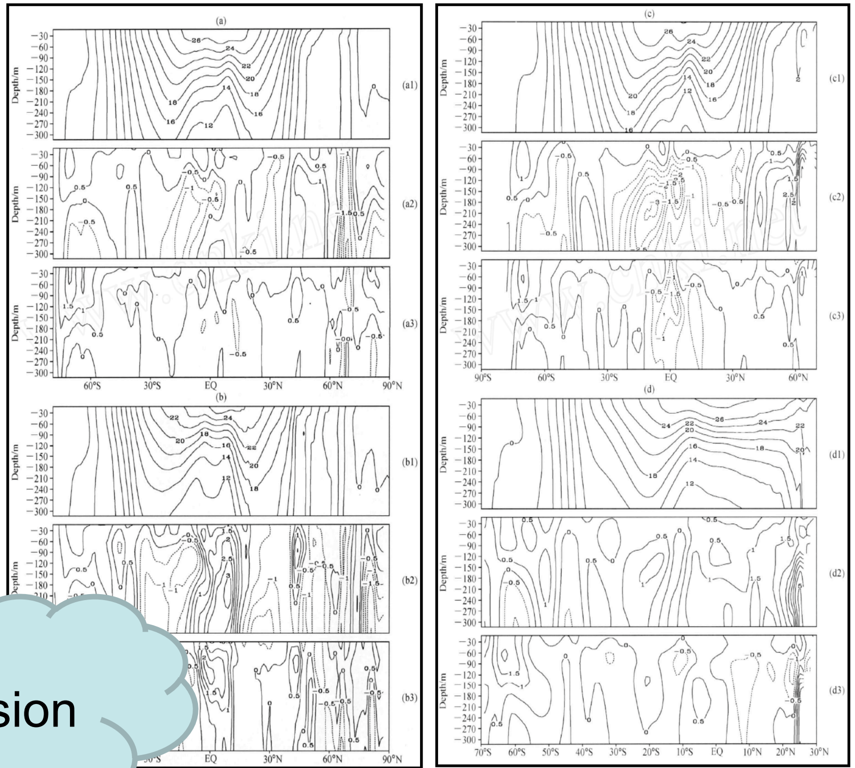
Assimilation Example: Altimeter Data

- Model:
  - ✓ LICOM110 (LASG/ IAP Climate Ocean Model, Version 1.0)
  - ✓ Resolution: 1^{o} x 1^{o}
  - ✓ Scope: 90^{o}N～79^{o} S
  - ✓ Vertical layers: 30 layers with varying distance
- Assimilation system: LICOM-3DVM
  - ✓ Institute of Atmospheric Physics
  - ✓ Chinese Academy of Sciences, etc.
  - ✓ Basis: 4D-Var of LICOM 1.0 in LASG/ IAP
  - ✓ Assimilation method: 3DVM (3-dimensional variational data assimilation of mapped observation)
  - ✓ Window: 5d
  - ✓ Optimal analysis value at the end of the window Ta

Assimilation Example: Altimeter Data

- Model data:
  - ✓ Wind stress: NCEP/DOE Reanalysis 2 monthly data
  - ✓ Net shortwave radiation, non-shortwave heat flux, couple coefficients: monthly forcing field of OMIP from MPI
  - ✓ Monthly SST and sea surface salinity: WOA98 from NODC
- Assimilation data: TOPEX/Poseidon altimetry data
  - ✓ Spatial resolution: 1º x 1º
  - ✓ Temporal resolution: 5d
- Comparison data: SODA, WOA01, HadISST
- Experiment design:
  - ✓ CTRL: Control experiment with no altimetry data
  - ✓ ASSM: Assimilation experiment with altimetry data

Assimilation Example: Altimeter Data



The zonal averaged temperature profile in (a) the whole ocean, (b) the Atlantic ocean, (c) the Pacific Ocean and (d) the Indian Ocean.

The contour interval is 0.5°C. (a1), (b1), (c1), (d1): WOA01; (a2), (b2), (c2), (d2): CTRL-WOA01; (a3), (b3), (c3), (d3): ASSM-WOA01.

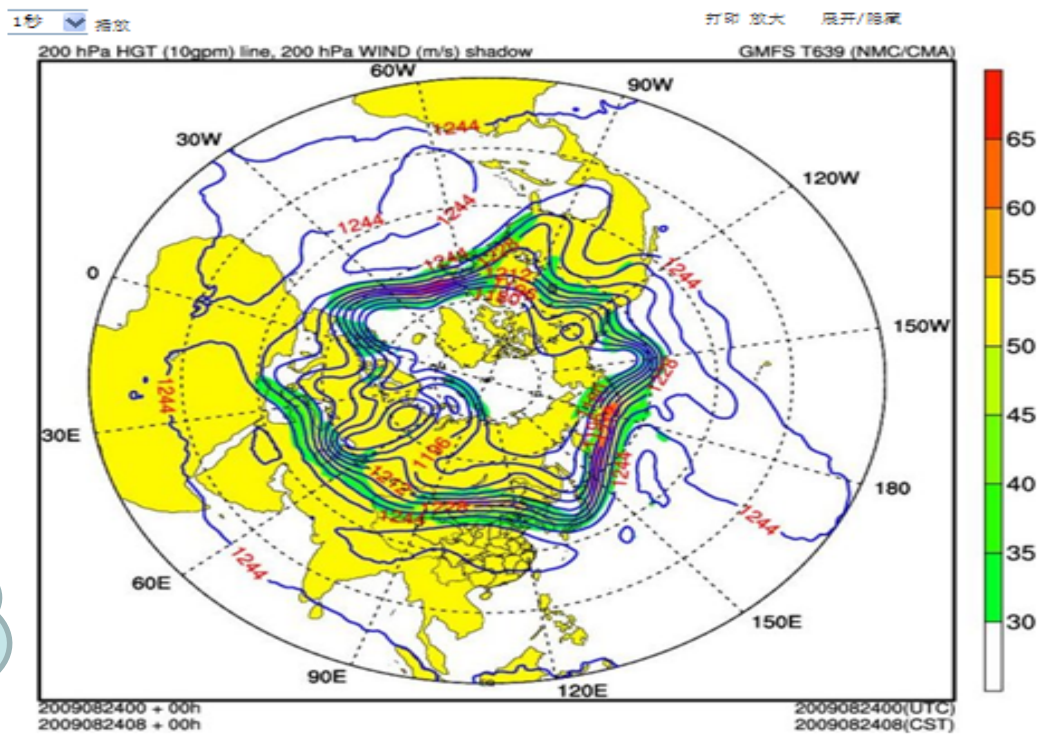
Conclusion

The results of assimilation using altimeter data is better than otherwise for all three oceans. The error is reduced from 2.5°C to 0.5°C in the area below the depth of 180m of Atlantic equator, and from 6.5°C to 4°C around 20~30°N in the Indian Ocean.

Assimilation Example: Radiometer Data

- Title: Assimilation of NOAA-ATOVS Data Into a Global Weather Forecast Model
- Model: TL639
- Institution: National Meteorological Center
- Model data:
  - ✓ GTS ship reports temperature data
  - ✓ Coastal station observation data
  - ✓ Buoy data
- Assimilation data:
  - ✓ ATOVS data from NOAA-15/16/17

Assimilation Example: Radiometer Data



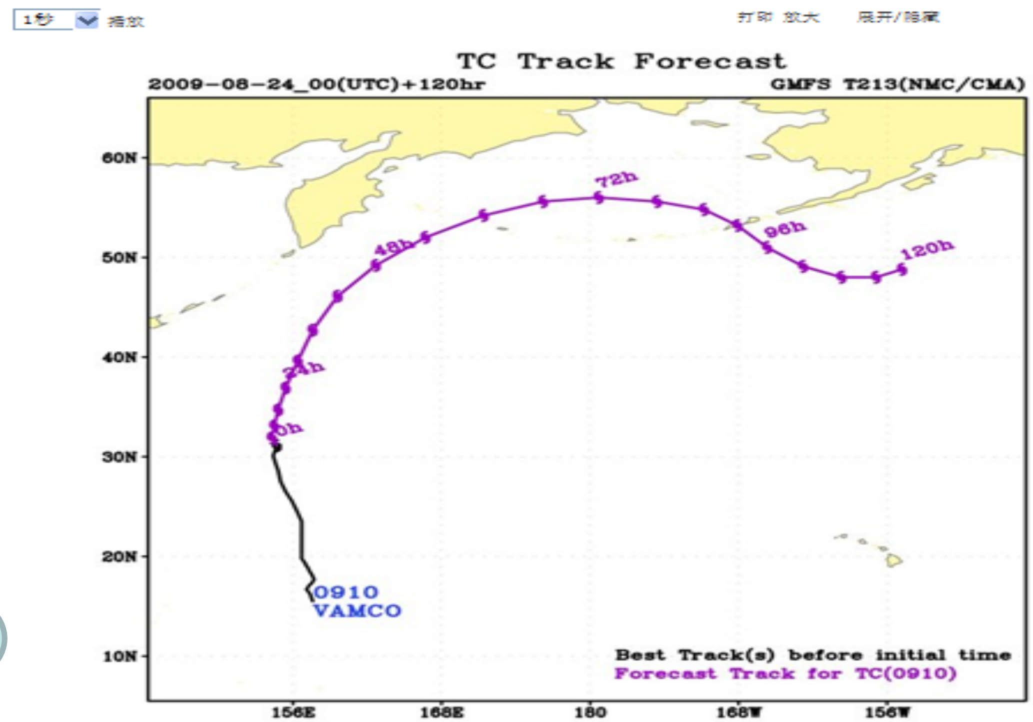
Conclusion

The assimilated 30% of satellite data not only significantly improved the forecast quality but also increased the spatial resolution up to 0.28125º ×0.28125º .

Assimilation Example: Scatterometer Data

- Title:
  - ✓ Assimilation of Quikscat data into a wind field forecast model in the presence of typhoon
- Model: MM5
- Institutions: National Marine Environment Forecasting Center
- Model data:
  - ✓ GTS ship reports temperature data
  - ✓ Coastal station observation data
  - ✓ Buoy data
- Assimilation data:
  - ✓ Quikscat data

Assimilation Example: Scatterometer Data



Conclusion

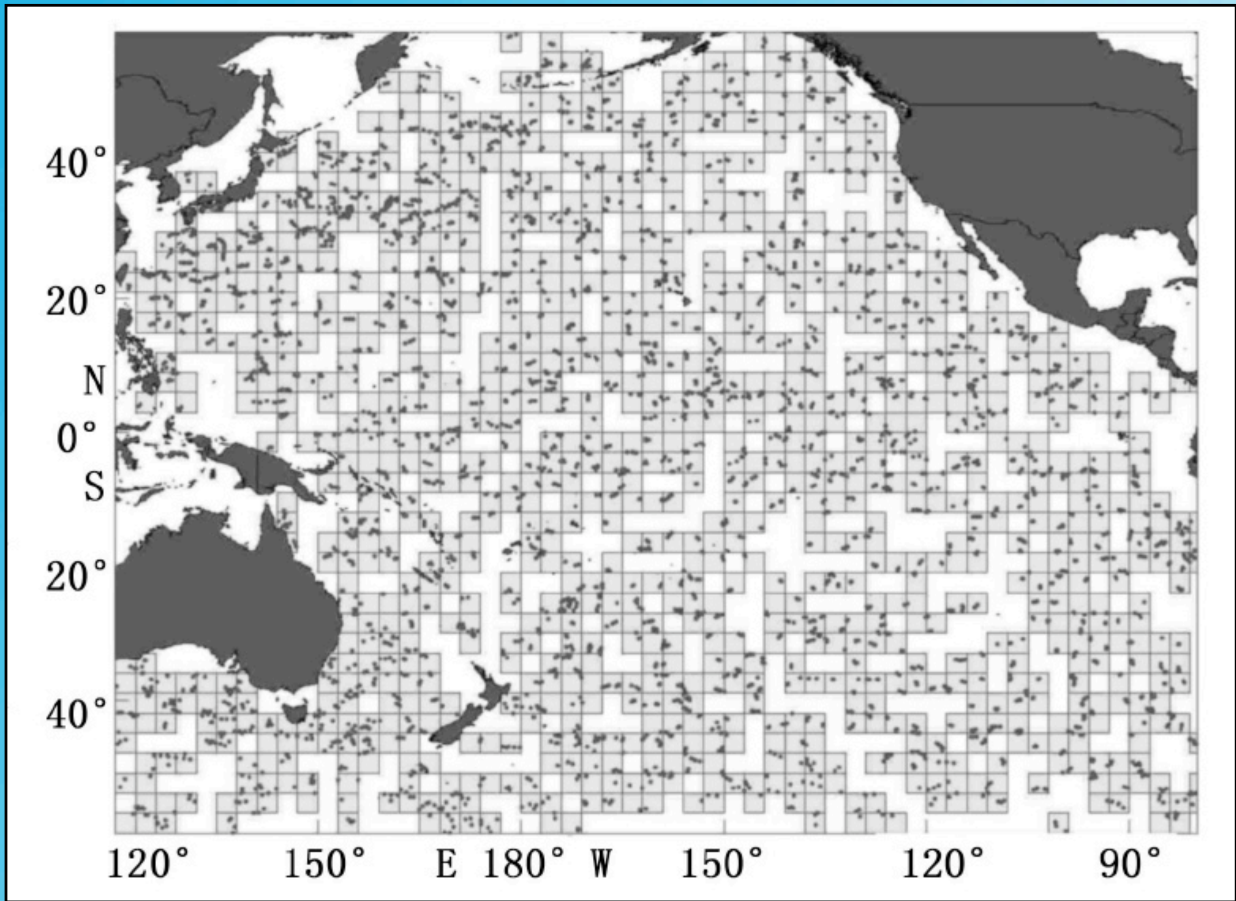
The assimilation of scatterometer data into MM5 model can significantly improve the forecast accuracy of the path and intensity of a typhoon.

Assimilation Example: Argo Data

- Title:
  - Reconstruction of Pacific temperature arena with Argo data based on the Kriging methods
- Authors: Sheng-long Yang et al.
- Institutions:
  - Key and Open Laboratory of Remote Sensing Information Technology in Fisheries Resources
  - East China Sea
  - Fisheries Research Institute
  - Chinese Academy of Fishery Sciences

Assimilation Example: Argo Data

- **Data—Argo Data in the Pacific from January to December 2007**



The distribution of Argo data in 3º ×3º grid.

Assimilation Example: Argo Data

NO.	Lon/ Degree	Lat/ Degree	In Situ Data/ Degree	Interpolate Data/ Degree	Error/ Temperature	Relative Error/ Percent
1	124.59	- 48	9.1	9.1	0	0
2	128.36	27.43	28.2	27.8	0.4	1.41844
3	132.11	17.81	28.5	28	0.5	1.754386
4	137.16	- 55	3.4	3	0.4	11.76471
5	137.67	- 55.2	3.4	2.9	0.5	14.70588
6	137.78	28.38	26.5	27.1	- 0.6	- 2.26415
7	141.61	28.74	28.1	27.5	0.6	2.135231
[illegible]	[illegible]30	34.6	26.1	26	0.1	0.38142
[illegible]	[illegible]5	-14.9	27.4	27.3	0.1	0.364964
[illegible]	[illegible]4.69	- 17.8	26.7	26.6	0.1	0.374532

Conclusion

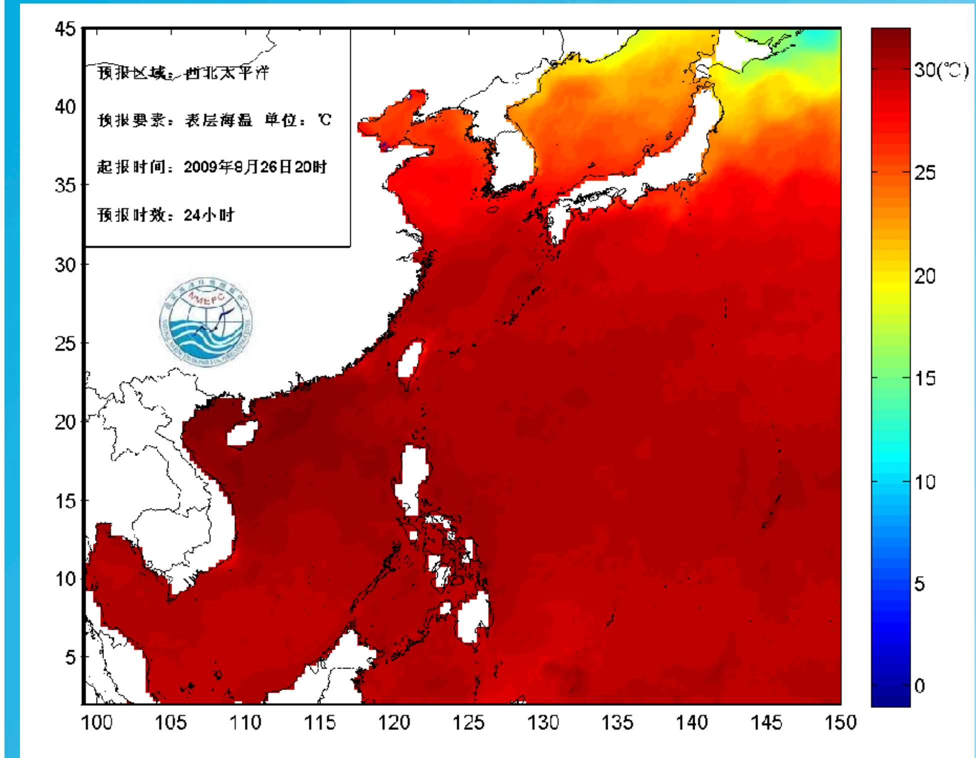
Compared with interpolated data and actual measurements of same period, the assimilation results are significantly improved. It shows that the maximum error is 0.7°C, the mean bias is 0.3°C, the mean relative error is 0.7%, the standard error is 0.06°C.

A Non-Assimilation Example

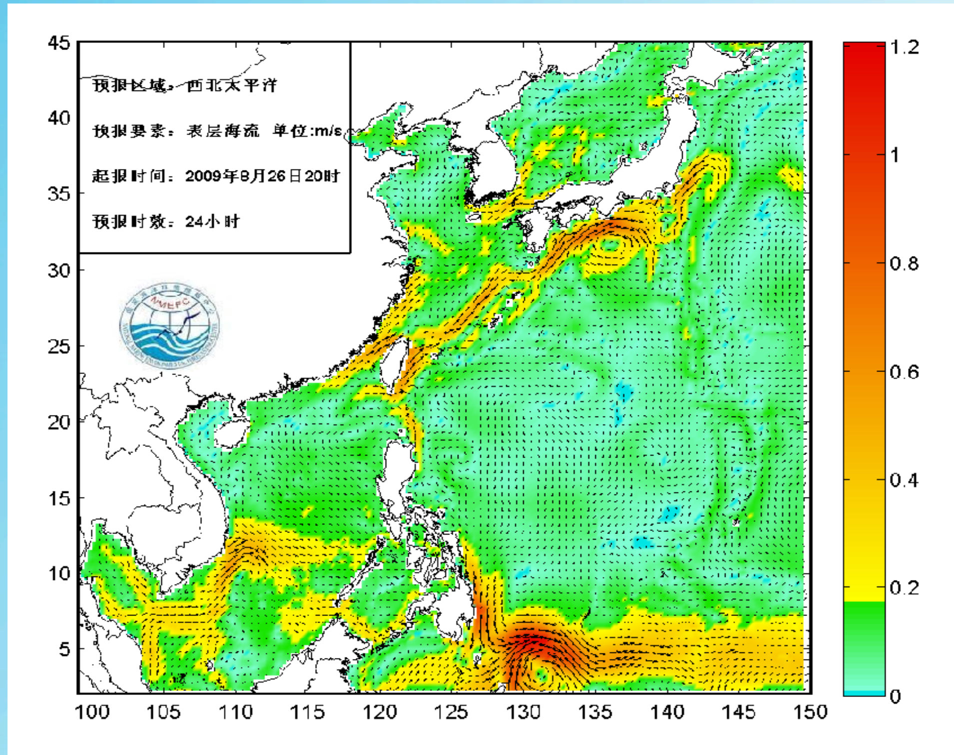
- Title:
  - ✓ Operational Forecast of 3-D Sea Temperature and Ocean Current
- Model: MM5
- Institutions: National Marine Environment Forecasting Center
- Model data:
  - ✓ Coastal station observation data
  - ✓ Buoy data

A Non-Assimilation Example

- Temperature



- Current



Evaluation of Data Assimilation into Models

- **A majority of oceanic and atmospheric models use station and ship data as input in China.**

- **Satellite data from altimeters, scatterometers and radiometers as well as buoy data from ARGO are also assimilated into numerical models with a percentage of 0-30%.**

- **All assimilated satellite data are from abroad. Chinese remote sensing data are rarely used in this context.**

Evaluation of Data Assimilation into Models

- **The assimilation of satellite data are found to improve the quality of model output in terms of accuracy and resolution.**

- **The exact impact of different observation types depends on how those observations are assimilated, what errors are prescribed to them and how well the model is initialized.**

- **The current status of real time availability and continuity of satellite data has prevented most of them from being used operationally.**

Major Gaps between China and Europe in Data Assimilation

- **Assimilation methods♪**

Various assimilation schemes have been used in European systems such as OI, KFs, SEEK, 3D, 4D, etc. But in China, less kinds of methods with less advanced implementation skills are adopted. The most popular method used in China is 3D-Var.

- **Data used in the assimilation**

➢ Both in situ and satellite data have been assimilated into most of the European operational systems. In China, in situ data are assimilated in a lesser degree, while little satellite data have been assimilated into forecasting models.

➢ Collaborations among European countries are fairly good to ensure that all available data can be used for the sake of advanced operational systems. In China, relatively low level of data sharing and distribution has, to a certain degree, hampered the assimilation efforts.

Major Gaps between China and Europe in Data Assimilation

- **The assimilation product**

  - European simulation systems have relatively high resolution for basin and global scale forecasts. But the regions of Chinese assimilations are mostly limited to the China Seas. In addition, the time length of European forecast is usually longer than that of China's.

  - In Europe, most of the observation, forecast and diagnostic data and product can be conveniently accessed from the MyOcean website free of charge. In China, however, almost no website can completely reach that level.

Major Gaps between China and Europe in Data Assimilation

- Recommendation

Although China has achieved good results in many ocean data assimilation experiments, it should improve its work in operational assimilation through enhancing the level of near-real-time data distribution and sharing in order to bridge the gap with Europe.

Thank you !