The State of the Art of Operational Ocean Predictions

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Brief Outline

- Potential for operational oceanography
- Present state of operational oceanography
- JCOPE - the state of the art prediction system developed at CPRV/FRCGC/JAMSTEC
- Introduction to the Forecast Ocean Partnership
- Areas of operations
- Future scopes

The advances in operational weather forecasting resulted in its present level of acceptance from a level of general curiosity, 20 years before. The operational oceanography has now entered a stage that was similar to operational meteorology a couple of decade ago. Improvement in satellite and in situ observations is a key to the success of operational oceanography

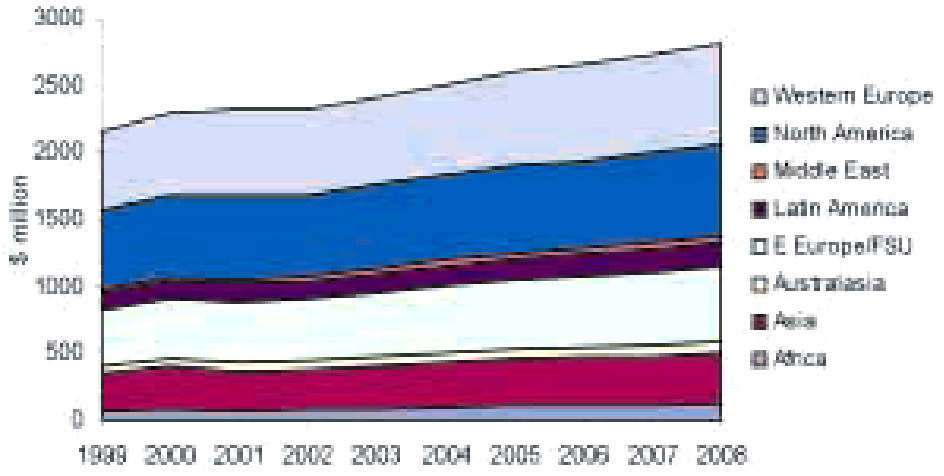
Potentials for operational oceanography

The potential for operational oceanography depends on several factors:

1. Reliable Models
2. **High performance computing system**
3. Good observational network
4. Effective communication system
5. And most importantly a sustainable market

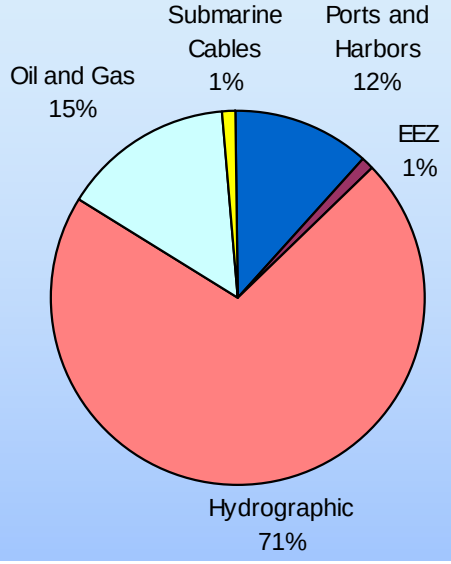
Present users of operational oceanography products are mostly government agencies and research centers.
There is a huge potential for operational oceanography products for improving safety of marine transports, offshore construction activities, and to provide warning and protection against marine and coastal hazards, floods, and coastal erosion.

Estimated trend in world market for ocean surveys



There is an increase in cargo transports and exploration for oil and natural gas. Exploration will be market driven based on the demand for those commodities.

US Gulf of Mexico. 830 wells, major companies continue to work the deep waters. 130 of 155 available rigs were under contract for 83.9% utilization, up from 71.8% a year ago. But only 24% of 68 platform-based rigs were contracted. The bulk of the US Gulf is the gas-prone shelf.



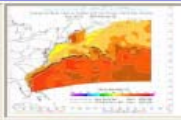
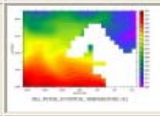
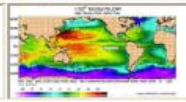
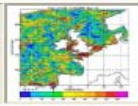
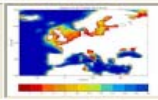
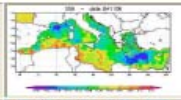
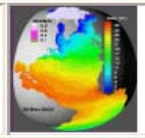
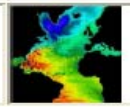
The estimated share of worlds' survey market

About 600 million dollars are used by private sector surveys – mostly for oil and natural gas

One day operational cost could be in excess of 500K

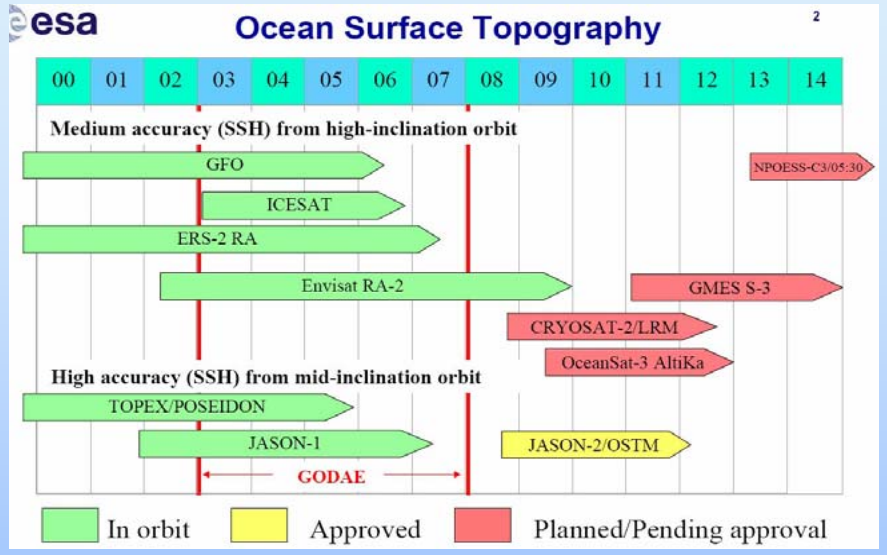
Westwood and Newman 2004

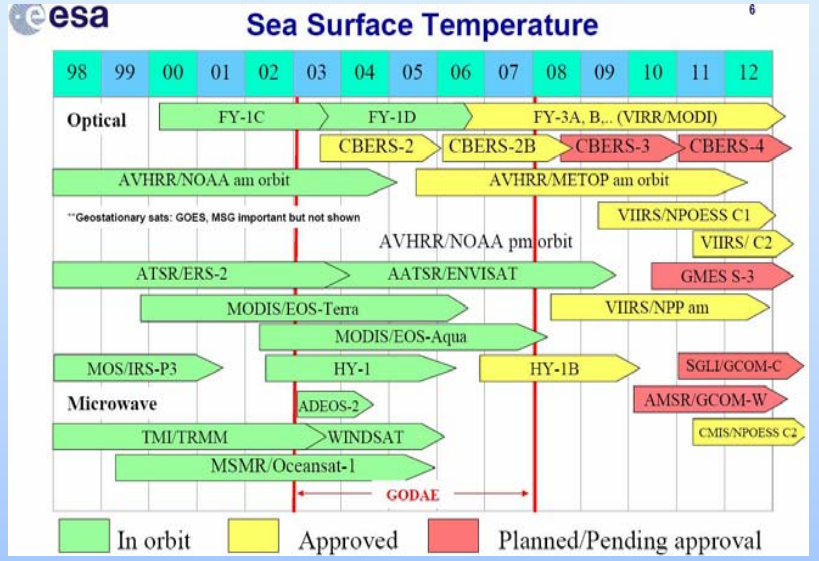
Some of the agencies and research centers engaged in operational oceanography

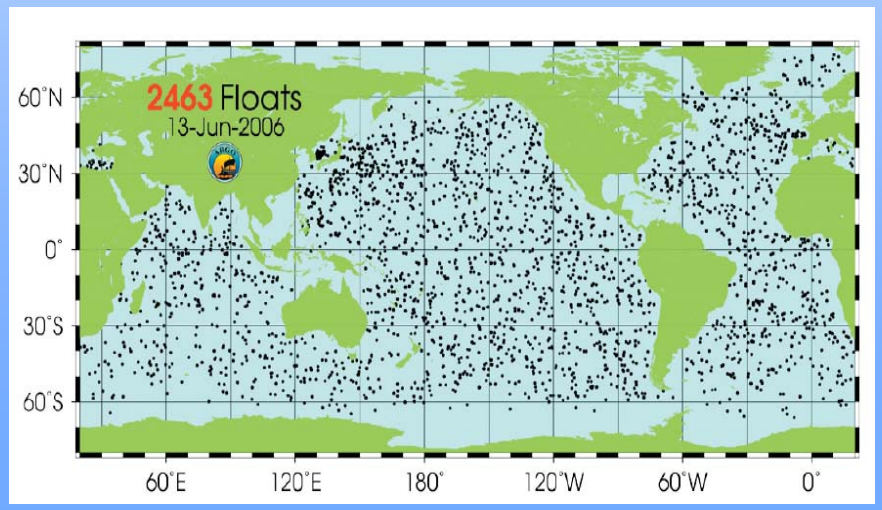
NCEP Marine Modeling and Analysis Branch Operational Products Wave Watch and regional forecasting system	
UK Forecasting Ocean Assimilation Model (FOAM)	
MERCATOR Atlantic prediction system	
US Navy Layered Ocean Model (NLOM) Many high resolution global ocean models. 1/8, 1/16, 1/32°	
UK Shelf-Seas Model	
UK Wave Models	
Mediterranean Forecasting System Toward Environmental Predictions (MFSTEP) INGV, Several other centers in Europe	
Blue Link, Australia	
Towards an Operational Prediction System for the North Atlantic European Coastal Zones (TOPAZ)	
Hybrid-Coordinate Ocean Model (HYCOM)	

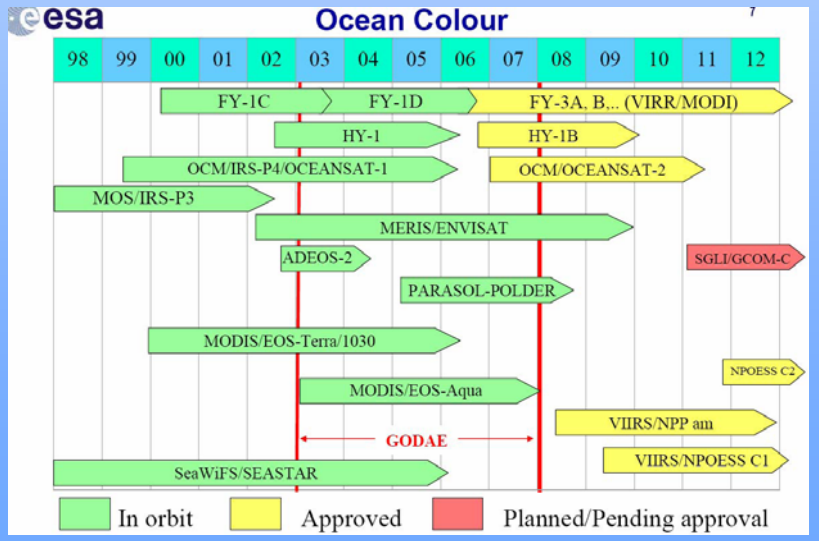
Eddy-resolving models are now in operation. Global models have been implemented. One just needs access to larger computing facilities to integrate global eddy-resolving models. The oceanic data assimilation is now adequately developed and most operational centers routinely use data assimilation. The re are international efforts, such as GODAE, for further developments in data assimilation.

Better Global Observation System





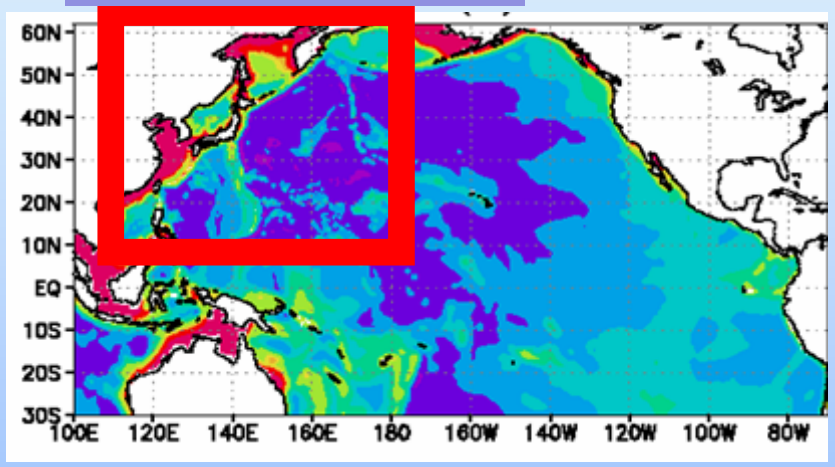




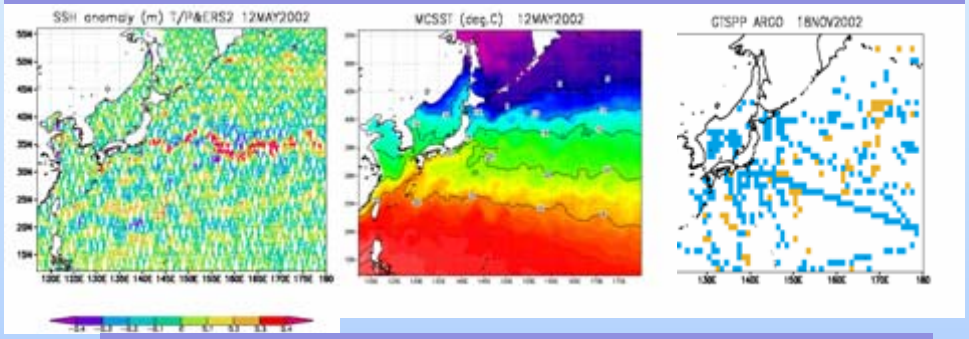
The JCOPE

Nested ocean model => Assimilation of observed data => Application of surface boundary forcings of available winds and heatfluxes => Predicted results

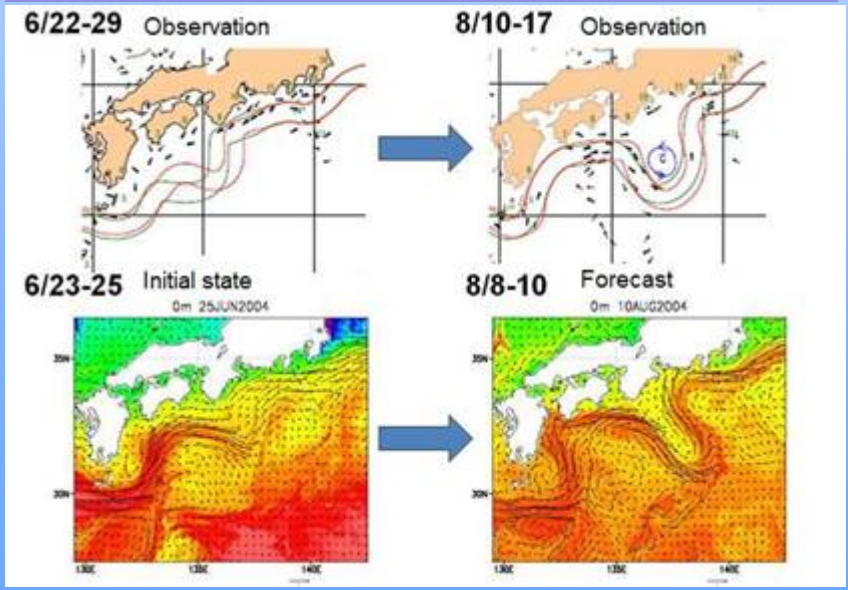
Nested ocean model



Observations



Successful prediction of the large meander formation in 2004



(Kagimoto et al., Springer, 2007)

3D variational assimilation

$$
\begin{aligned}
&(X - X^f)^T B^{-1}(X - X^f) \\
&+(y_T^o - H_T X)^T R_T^{-1}(y_T^o - H_T X) + (y_S^o - H_S X)^T R_S^{-1}(y_S^o - H_S X) \\
&+(y_\eta^o - H_\eta(X))^T R_\eta^{-1}(y_\eta^o - H_\eta(X)) \\
&+(y_{T_s}^o - H_{T_s} X)^T R_{T_s}^{-1}(y_{T_s}^o - H_{T_s} X)
\end{aligned}
$$

An established model for Kuroshio predictions

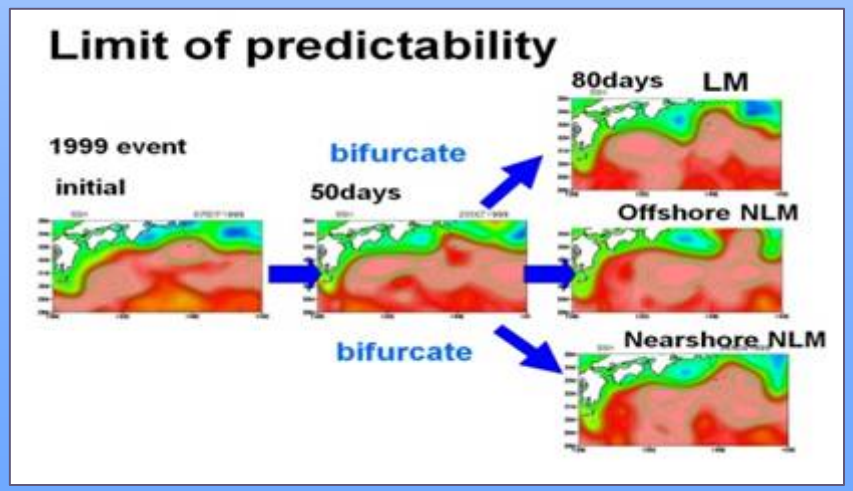
Roles of JEBAR in Kuroshio in ECS
(Guo et al., JPO, 2003)

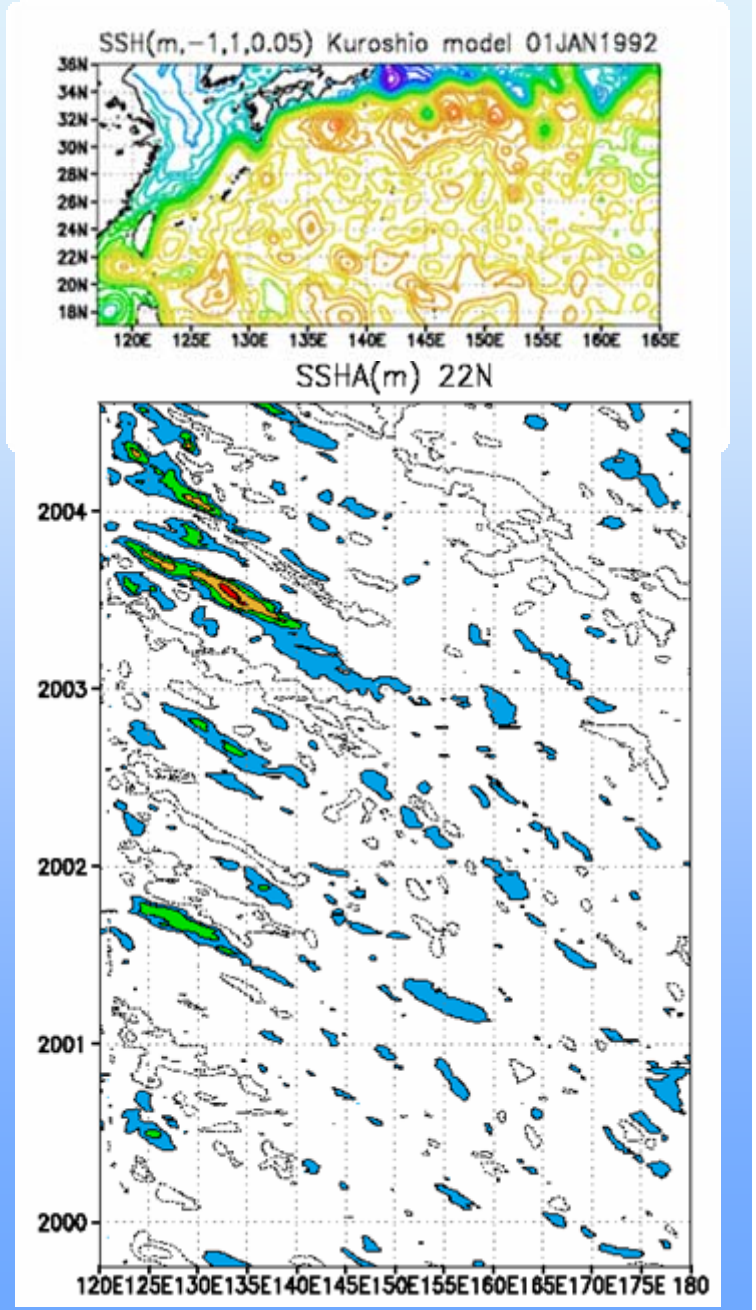
Roles of meso-scale eddies in the Kuroshio path
(Miyazawa et al., JPO, 2004)

Ensemble forecast of the Kuroshio path
(Miyazawa et al., JGR, 2005)

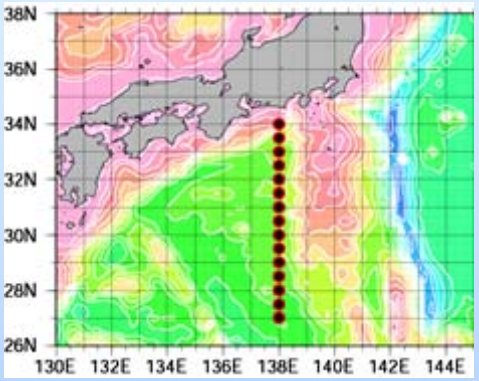
Origin of the Tsushima warm current
(Guo et al., JPO, 2006)

Generation mechanism of
the Kuroshio large meander in 2004
(Miyazawa et al., submitted, 2007)





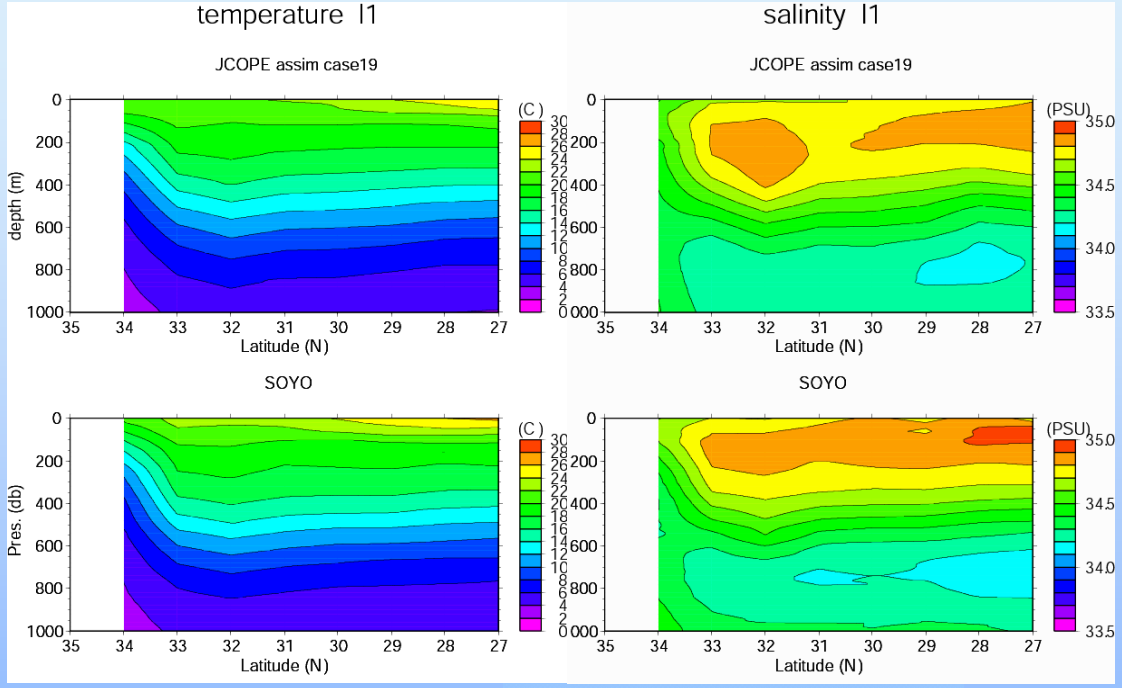
Validation

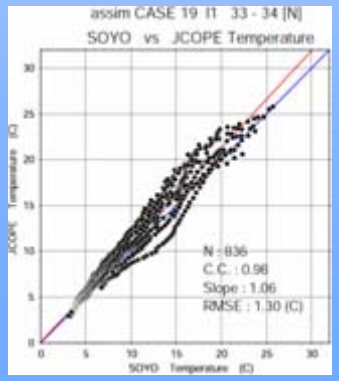


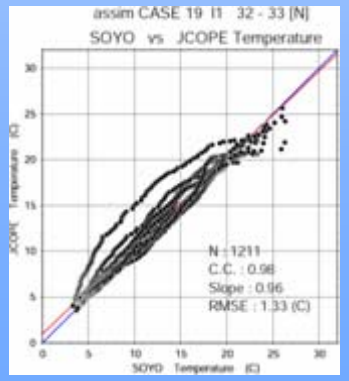
Model

6 cruises

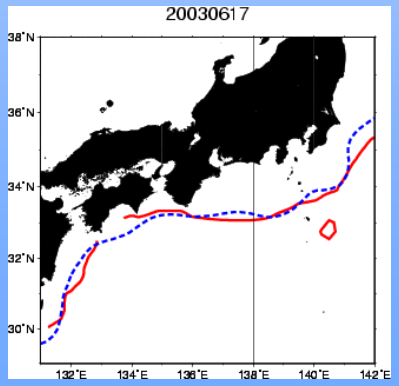
Observation

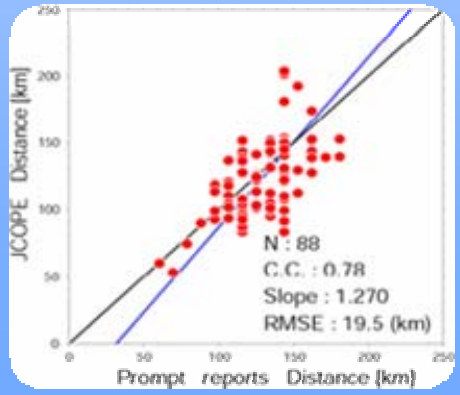




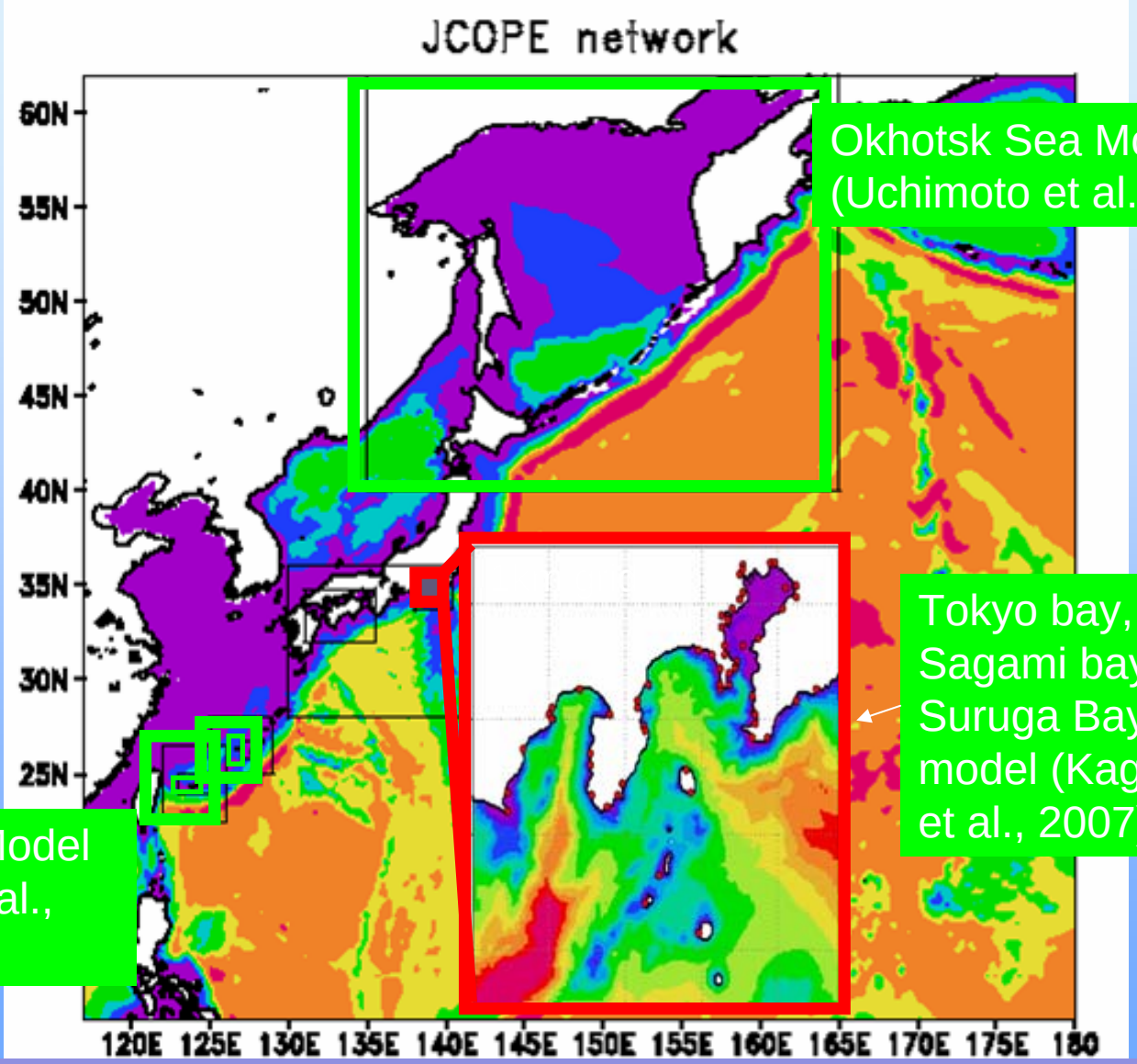


(Setou et al., 2005)





Applications Studies Using Regional Models



Okhotsk Sea Model (Uchimoto et al., 2007)

Tokyo bay, Sagami bay, Suruga Bay model (Kagimoto et al., 2007)

Okinawa Model (Suzuki et al., 2005)

The JCOPE model provides the lateral boundary conditions for regional modeling use.

Applications

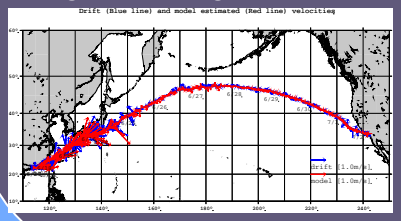
Cooperative study for optimum ship routing

JAMSTEC

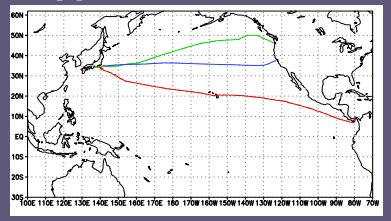
NYK LINE

Mitsubishi Heavy Industries Technology Institute

Designated route of a container ship from Hong-Kong to Los Angelis



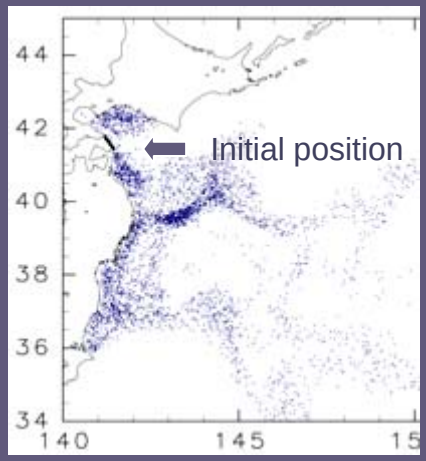
1% decrease of ship time by following our suggested route



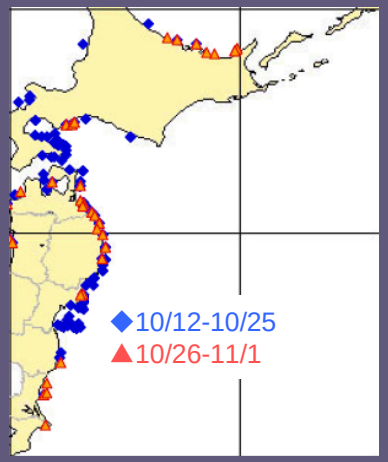
Prediction of jellyfish distributions

JAMSTEC

Incorporated Administrative Agency Fisheries Research Agency



Predicted distribution on Oct. 30, 2005 from the initial position on Sep. 4, 2005



Observed distribution of the jellyfish in Oct. and Nov., 2005

The FOP

Toshio Yamagata

President, FOP

While JCOPE established a reliable system for ocean state predictions and possible applications, sometimes the day-to-day operational needs are not easy to handle by the research group. This demanded a need to establish an outreach program.
Researchers of CVRP and MIRI started a venture (LLP) named Forecast Ocean Partnership (FOP) on May 24, 2006 for promoting utilization of the ocean current forecast. FOP has been supported by JAMSTEC* through the JAMSTEC venture framework since June 1, 2006.

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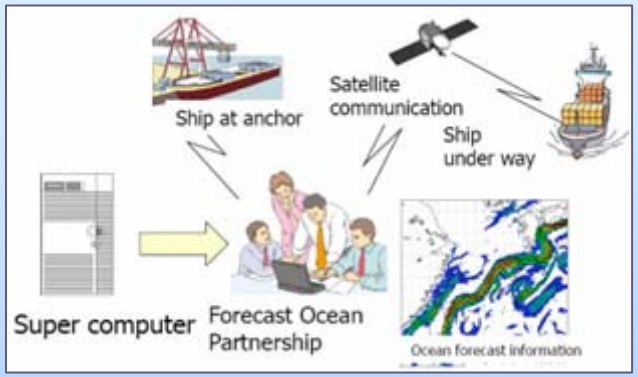
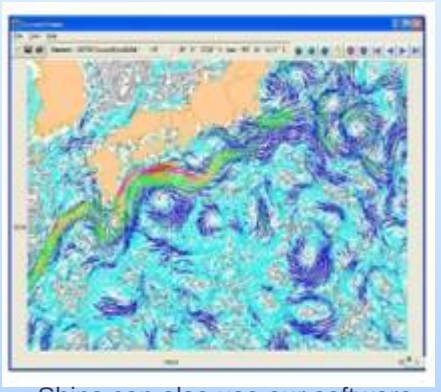




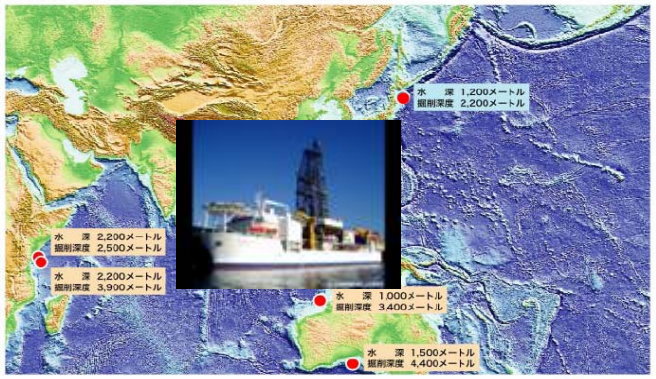
Ships can also use our software developed in FOP to view currents and decide a route.

Detail information and daily forecasts can be found at the FOP website;

http://forecast-ocean.com

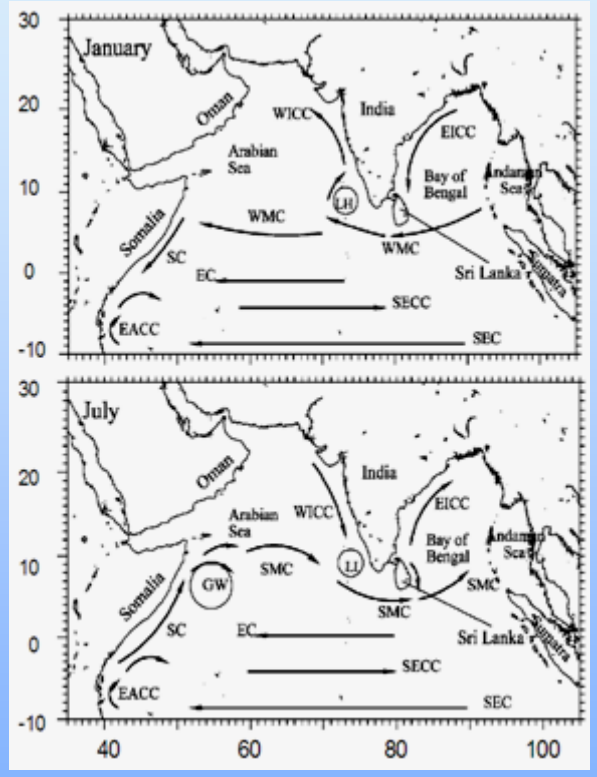
* ・JAMSTEC researchers and MIRI invested their moneys to establish FOP.
・FOP has been supported by JAMSTEC through permissions to use software, patent , and management office room.

Applications in the Indian Ocean

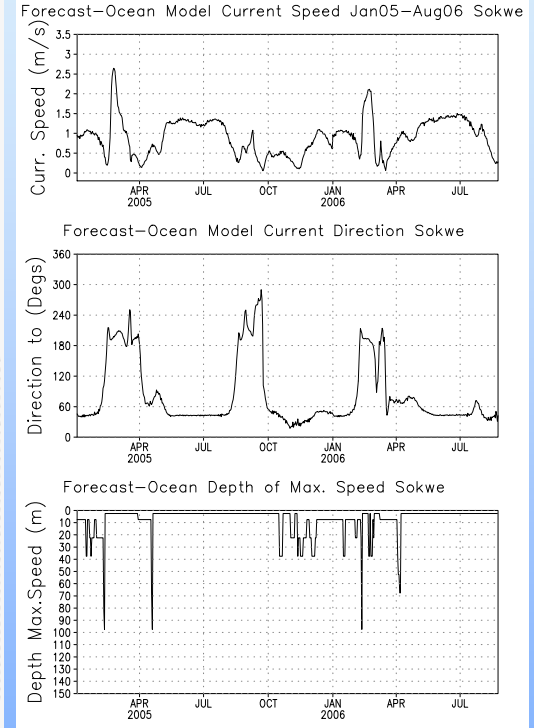


掘削試験の予定海域と水深、掘削深度

Surface current predictions for Woodside Energy – Seadril and JAMSTEC joint operation off Kenya in a deep sea exploration.



Seasonal surface currents



The current speed (in upper 150 m) and direction from model hindcast experiments at one operational site.

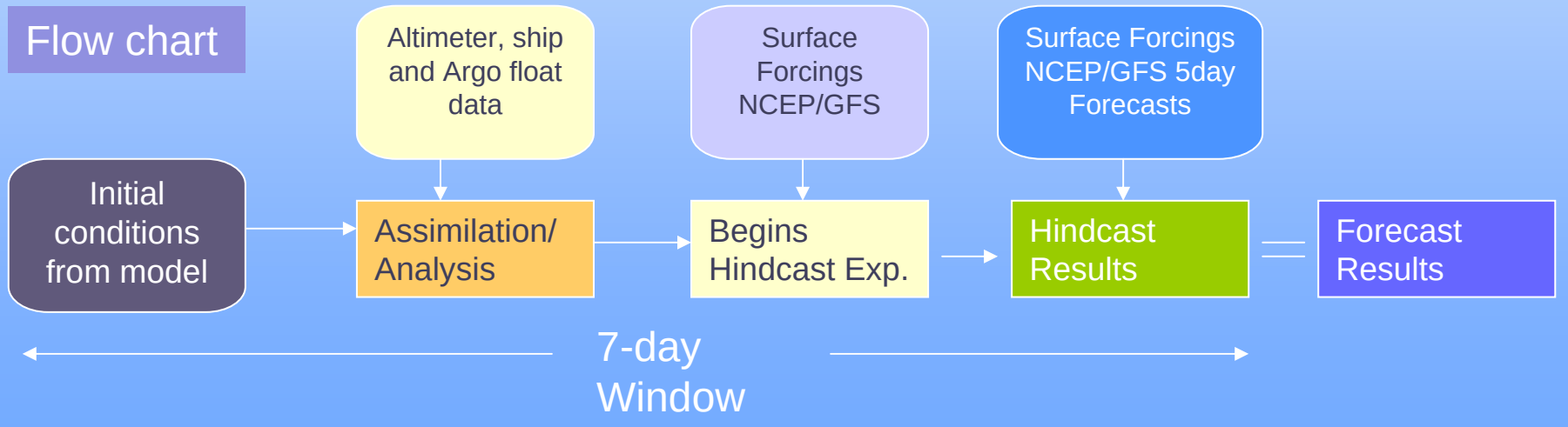
Multi-Model Ensemble Prediction Experiment

MOM Model:
1/3 x1/3 degree horizontal resolution, 26 levels
6 hourly Surface Forcings
1.5 Layer Reduced Gravity Model:
Data Assimilation

POM Model:
The Indian Ocean model has 1/12 x 1/12 degree horizontal resolution
45 Vertical Levels
Based on POMgcs with simple sigma coordinate
35E-120E, 30S-25N
Open boundaries (east, south, west sides)
Realistic topography
Data Assimilation
6 hourly Surface Forcings

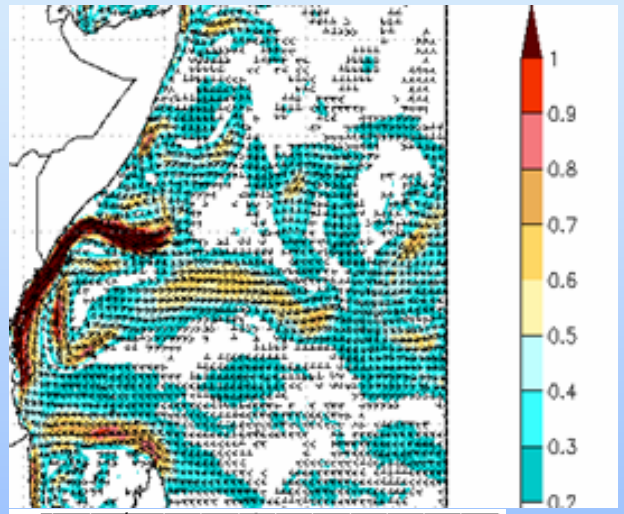
1.5 Layer Reduced Gravity Model:
Data Assimilation
6 hourly Surface Forcings

Flow chart

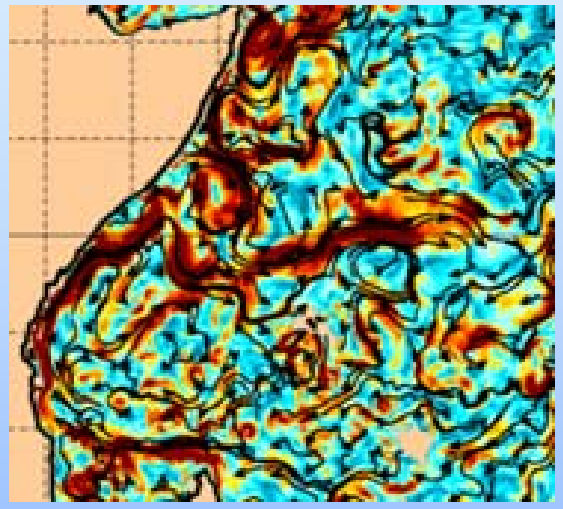


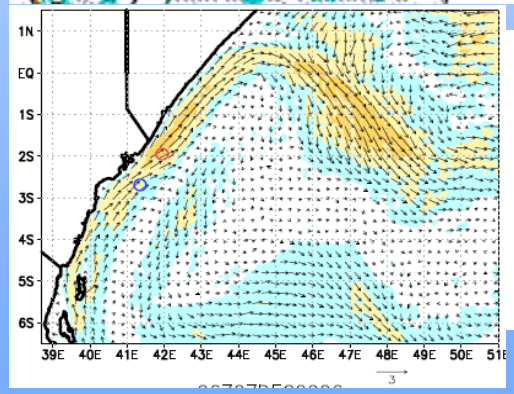
Validation

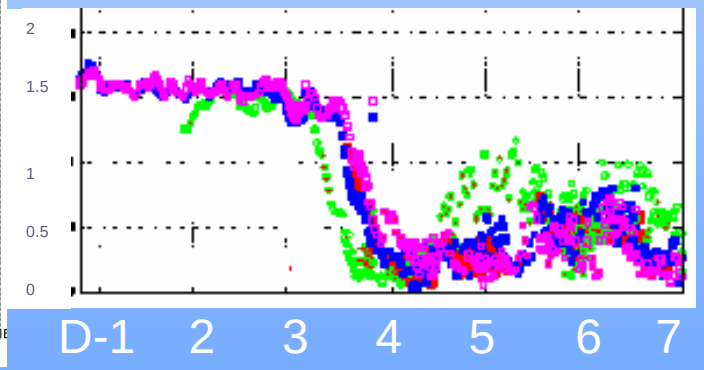
Forecast-Ocean Predictions



1/32 Global NLOM

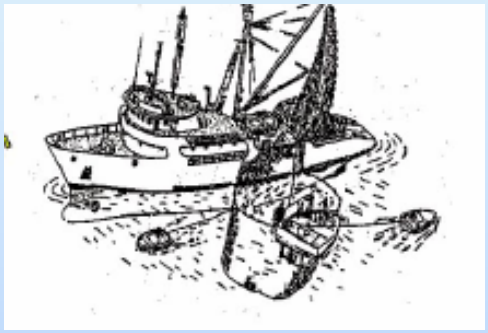


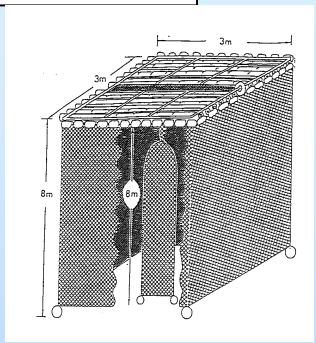




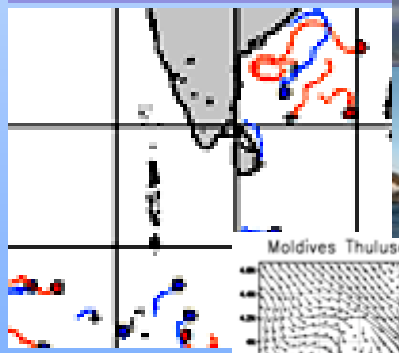
1. ***Dynamic positioning** of the rig or drill ship*
2. ***Optimized operational planning***
3. ***Enhanced safety for maintenance on site***
4. ***ROV, cable & pipe laying, drilling operations***
5. ***To predict currents higher than a threshold that will damage the operation***

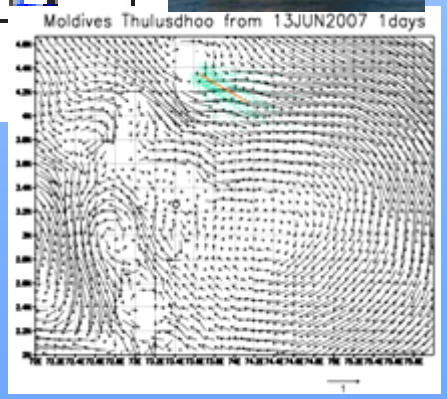
インド洋まき網漁業における海流予測



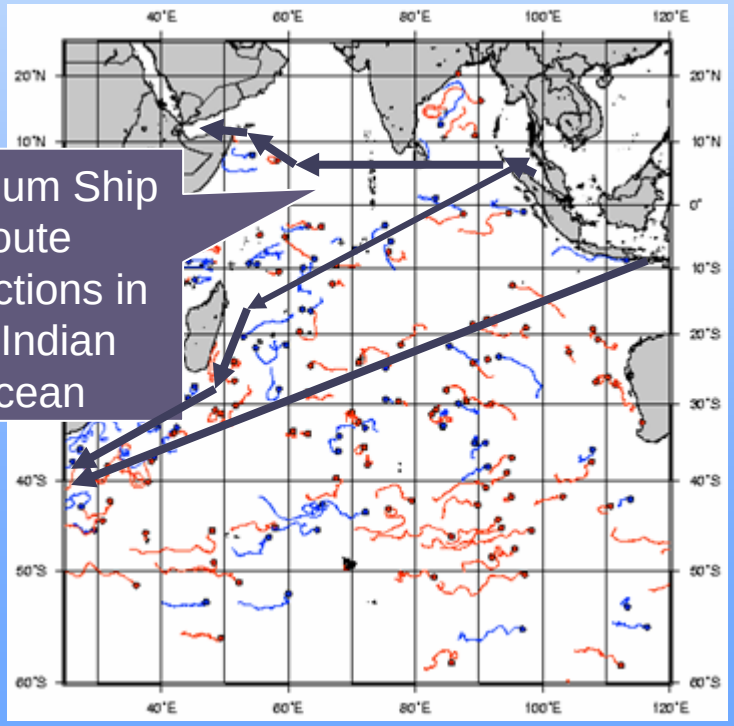


Rescue operation near Maldives

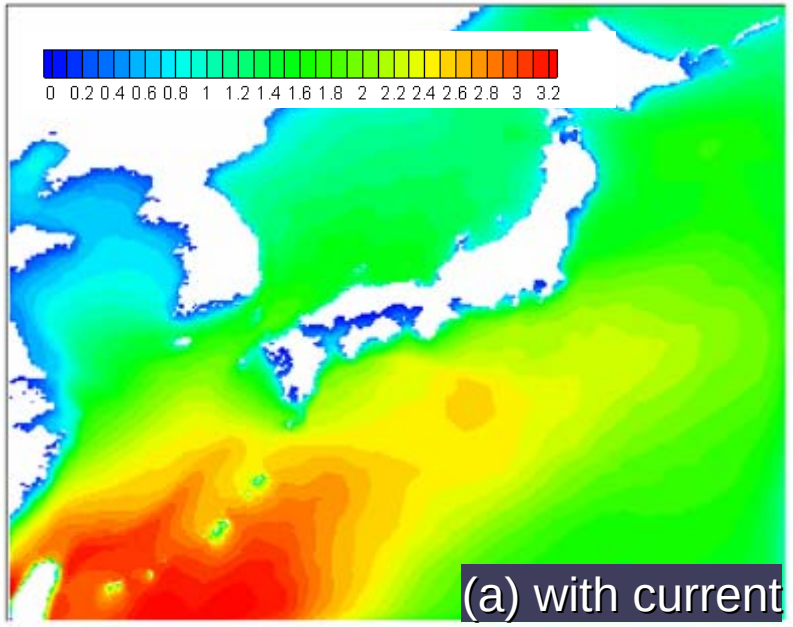


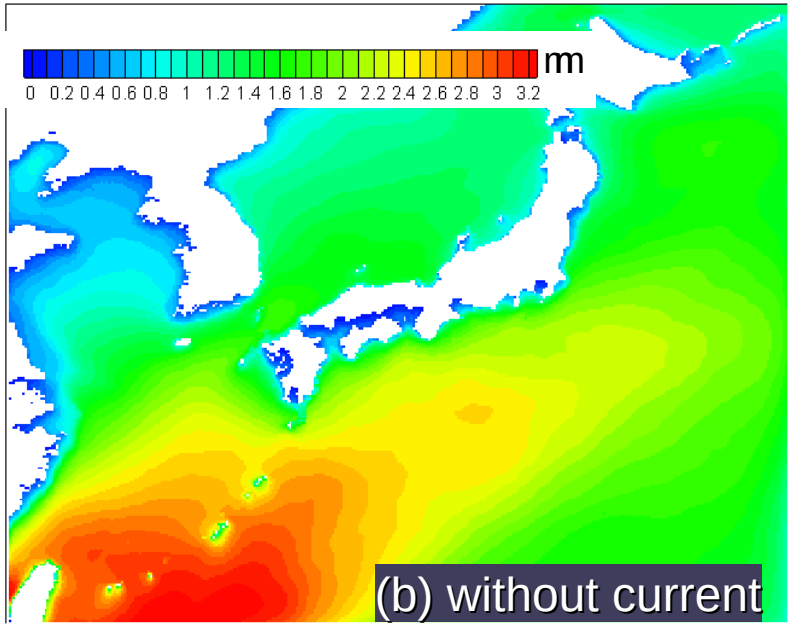


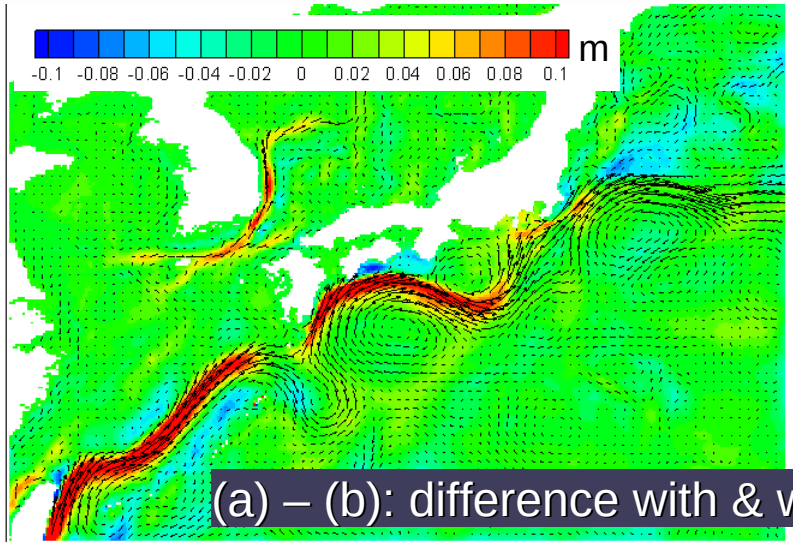
Optimum Ship route predictions in the Indian Ocean



Future Scopes: Wave-current modeling







Monthly averaged wave height (Oct. 2004)

The difference of the wave height over the Kuroshio is quite eminent.

(Tamura et al., 2006)

Future Scopes

Unconventional energy

For example, model results can be used to tap wave power. The market for Wave Energy Converters has been estimated to be worth up to $500bn. Thermal energy conversion is another potential target.

Combined ocean state and wind forecast for better ship routing

Development of high resolution regional coupled models will help to resolve wind forcing better. In addition, wind forecasts from these models can be utilized for better ship routing.

Better warning system for maritime search and rescue operations

Development of effective communication systems and model forecasts validations will help to improve maritime search and rescue operations. The inclusion of wave and tides models will also help in improving the predictions of freak waves to help ship navigations.

Summary

- **Development of the ocean forecast system in Japan coastal ocean (JCOPE) in CVRP is a model case of possible connection between research and real-world oceanographic application.**
- **Our outreach experience suggests there is huge potential for application of reliable and timely operational oceanography products. Comprehensive information of ocean—wave— atmosphere will be very attractive for various users.**
- **We will start new research for ocean-wave-atmosphere couple modeling, which is also attractive for scientific interest.**