Ocean and Climate Prediction Services for the Society

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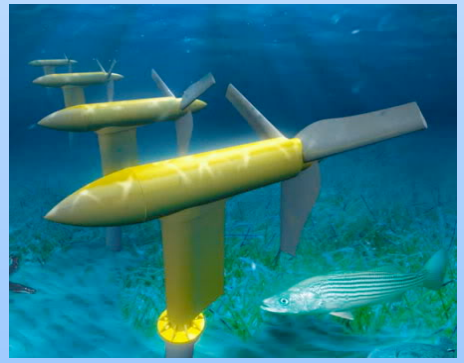
Operational Ocean Forecasts for a Sustainable World

Shipping, Fishery, Recreation….

- Ships consume at least 2 billion barrels of oil a year.
- International Maritime Organization estimated about1.12 billion metric tons of carbon dioxide release by ships in 2007 (about 3.5% of the planet's total emissions), This may increase 30% by 2020.
- Maritime shipping, which transports more than 90% of global trade goods, generates a trillion dollars in annual revenue.

Renewable Energy

- Ocean mechanical and thermal energies have potential for marketing.
- Exploration of potential ocean energy sites
- Operational efficiency



Resource Management

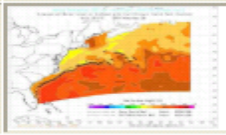
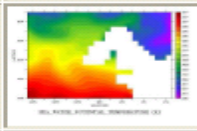
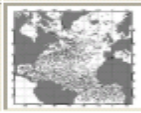
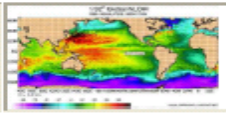
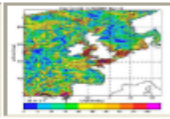
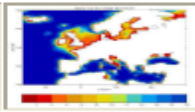
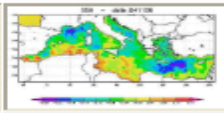
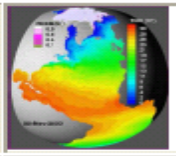
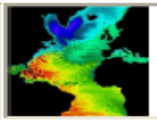
- Management of marine-eco system.
- Management of near-shore installations
- Management of off-shore installations
- Near-shore and open sea explorations.

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**

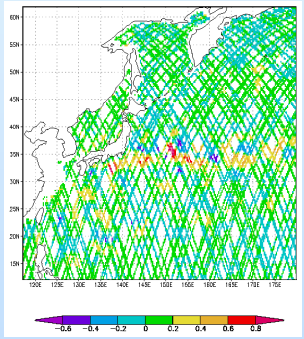
Present users of operational oceanography products are mostly government agencies and research centers.
There is a huge potential for operational oceanography products for improving safety of marine transports, offshore construction activities, and to provide warning and protection against marine and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

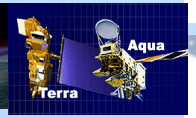
Some of the agencies and research centers engaged in operational oceanography

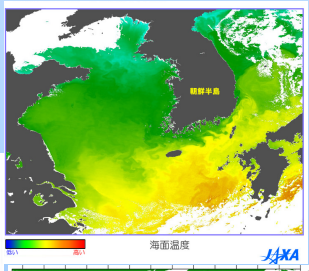
Name of agencies	
NCEP Marine Modeling and Analysis Branch Operational Products Wave Watch and regional forecasting system	
UK Forecasting Ocean Assimilation Model (FOAM)	
MERCATOR Atlantic prediction system	
US Navy Layered Ocean Model (NLOM) Many high resolution global ocean models. 1/8, 1/16, 1/32°	
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)	

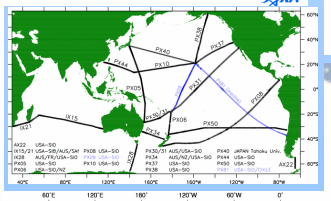
Eddy-resolving models are now in operation. Global models have been implemented. One just needs access to larger computing facilities to integrate global eddy-resolving models. The oceanic data assimilation is now adequately developed and most operational centers routinely use data assimilation. The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

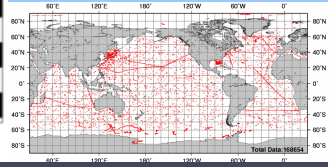
Better Global Ocean Observation System

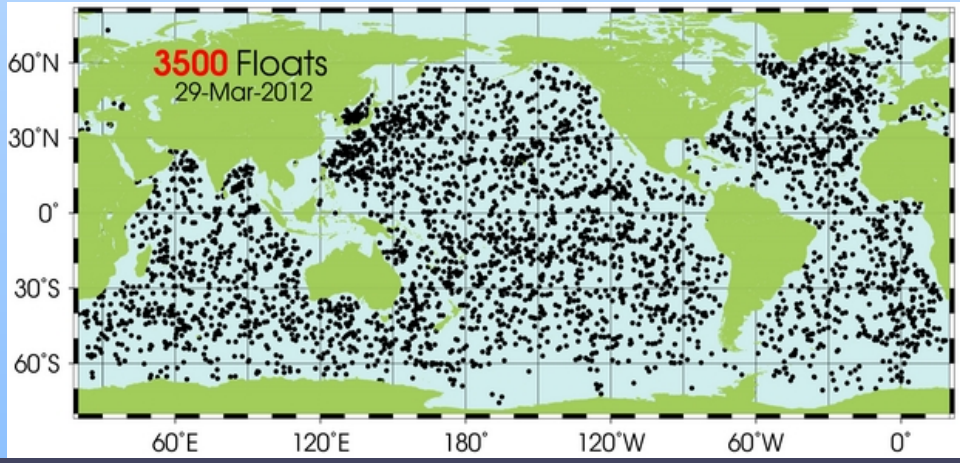


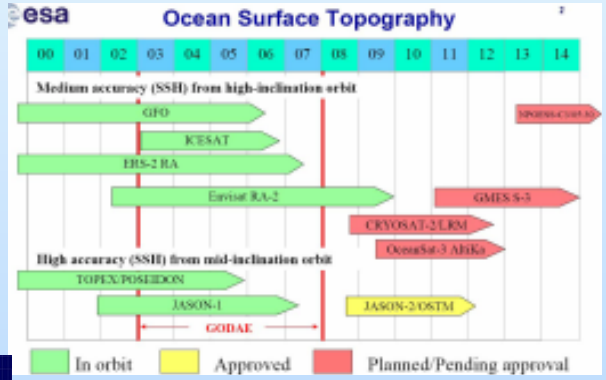


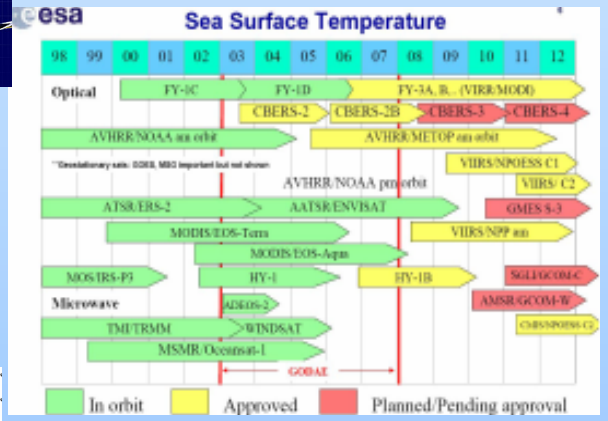


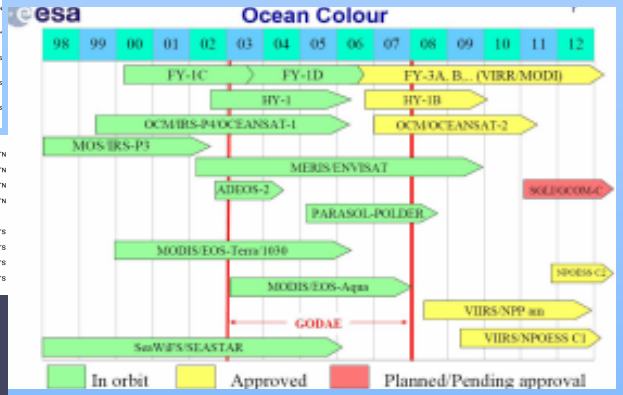










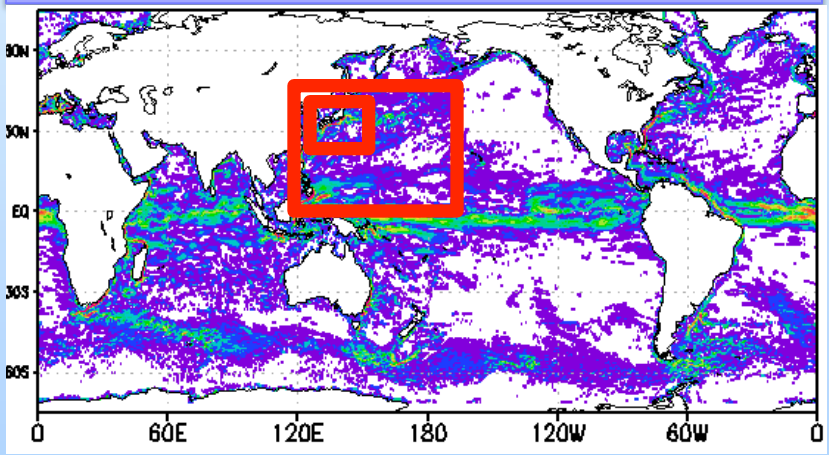


Numerical ocean model needs observation for oceanic state forecasts and in turn it can provide optimum design for effective observation.

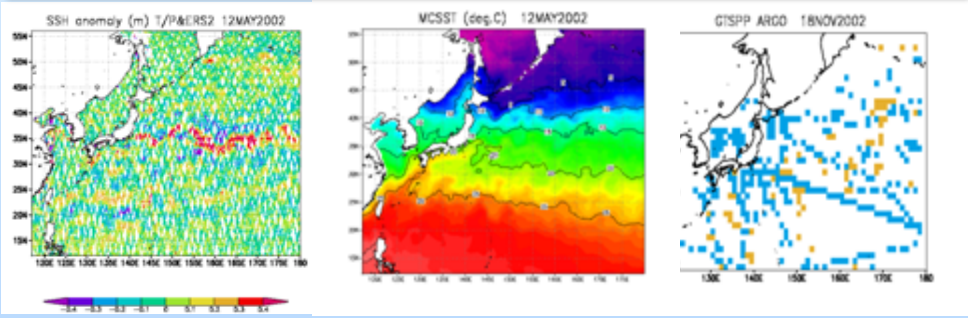
JAMSTEC's Japan Coastal Ocean Predictability Experiment (JCOPE)

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

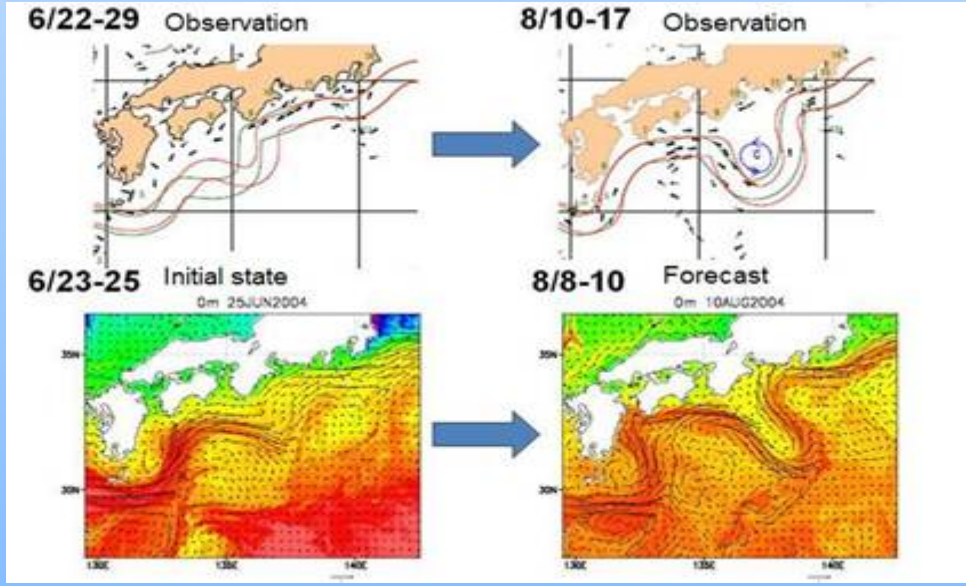
Nested ocean model



Observations



Successful prediction of the large meander formation in 2004



3D variational assimilation

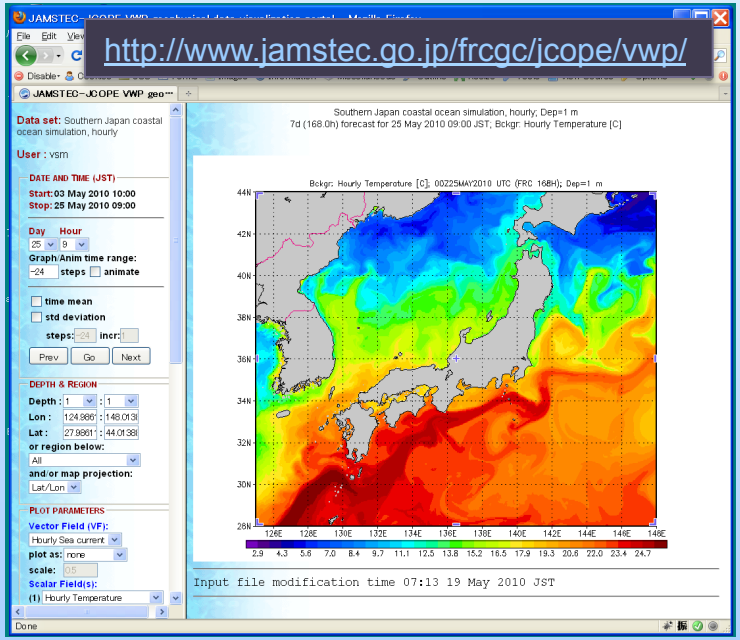
$$(X - X^f)^T B^{-1}(X - X^f)$$
$$+(y_T^o - H_T X)^T R_T^{-1}(y_T^o - H_T X) + (y_S^o - H_S X)^T R_S^{-1}(y_S^o - H_S X)$$
$$+(y_\eta^o - H_\eta(X))^T R_\eta^{-1}(y_\eta^o - H_\eta(X))$$
$$+(y_{T_s}^o - H_{T_s} X)^T R_{T_s}^{-1}(y_{T_s}^o - H_{T_s} X)$$

Horizontal resolution for global ocean is 1/10 degree, for northwestern Pacific is 1/12 degree, for Japan coastal ocean is 1/36 degree

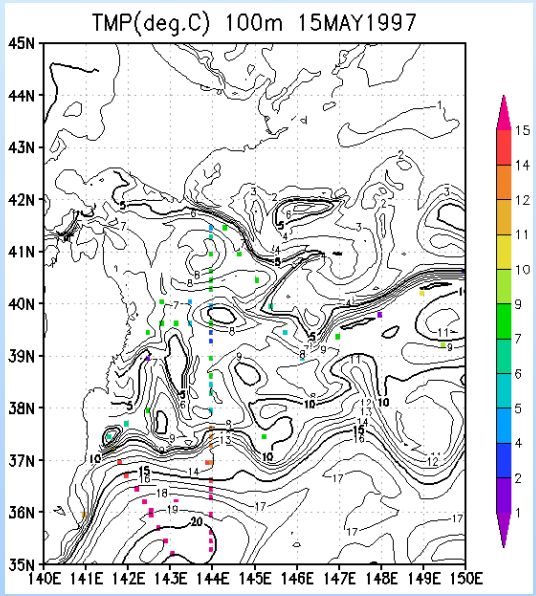
Miyazawa et al. 2009, JO

Web portal for JCOPE2-FRA re-analysis (free access) and JCOPE real-time products :

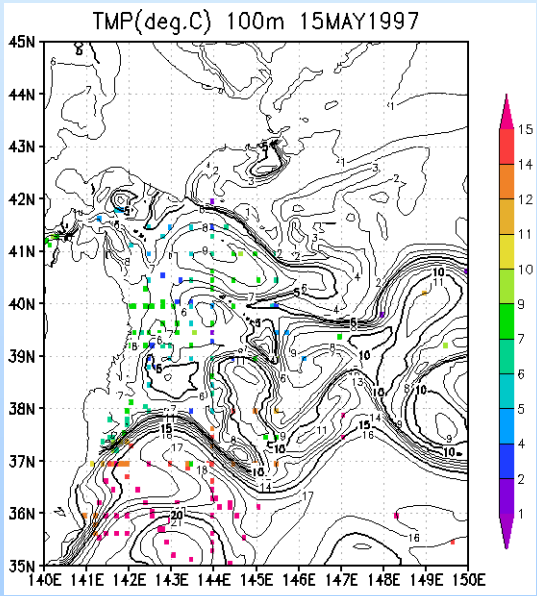
Contact: Dr. Miyazawa (miyazawa@jamstec.go.jp)



JCOPE2

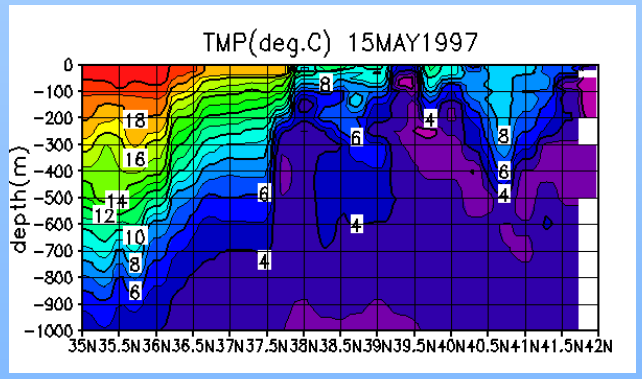


FRA-JCOPE2

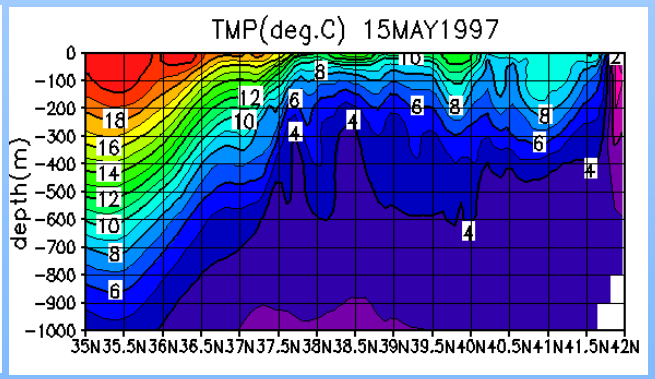


144E line: MAY 1997

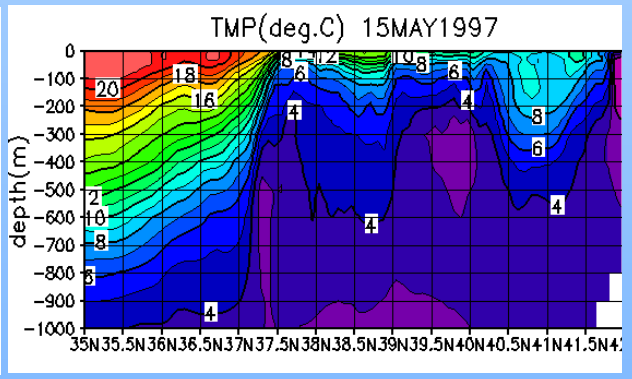
In-situ observation



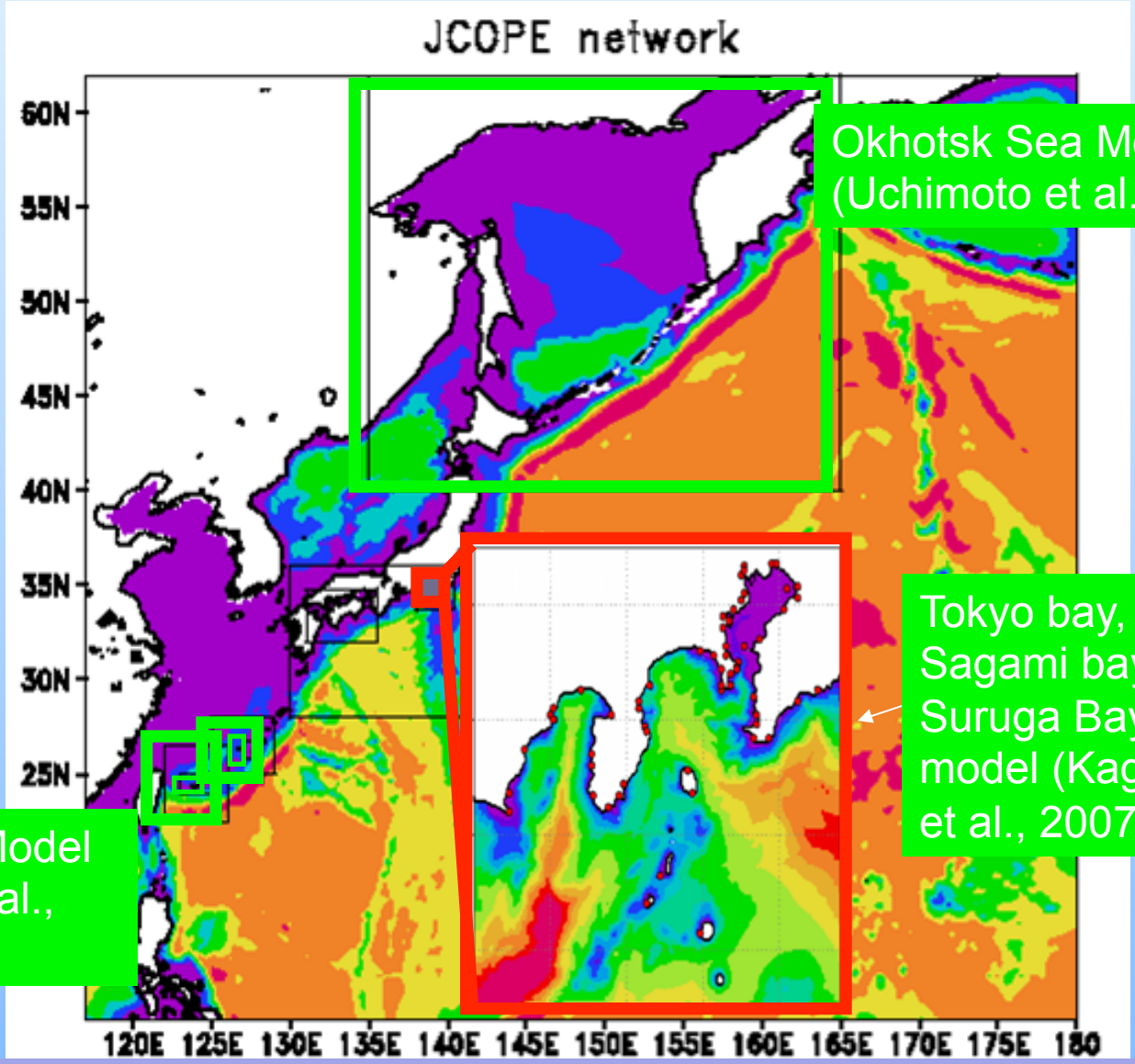
JCOPE2



FRA-JCOPE2

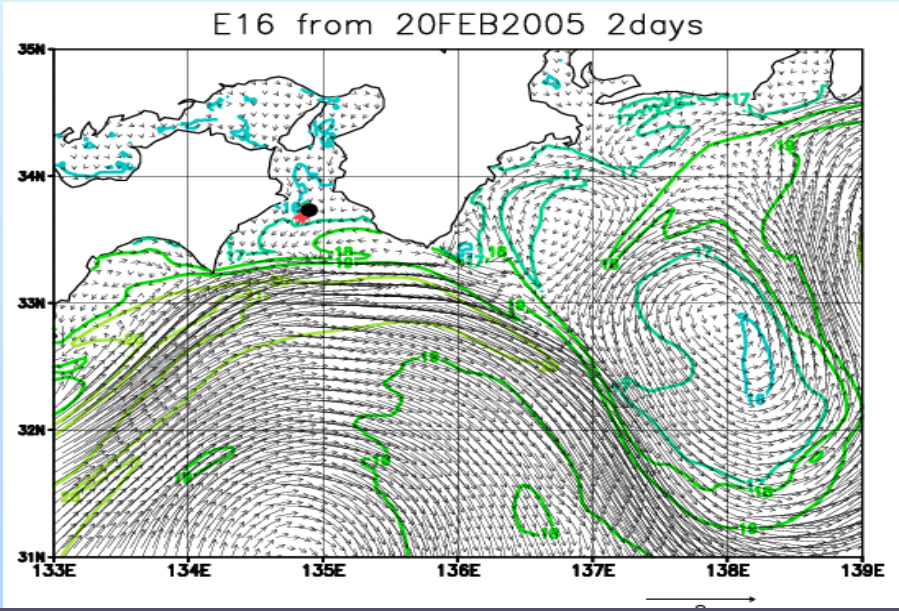


Applications Studies Using Regional Models

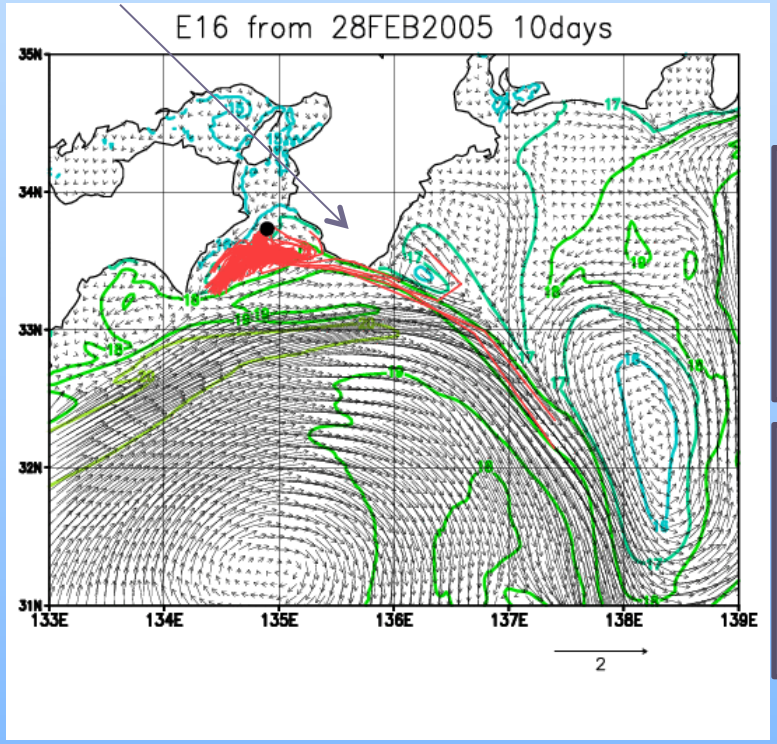


The JCOPE model provides the lateral boundary conditions for regional modeling use.

Applications: Predictions of Japanese Anchovy Distribution



Wakayama prefecture

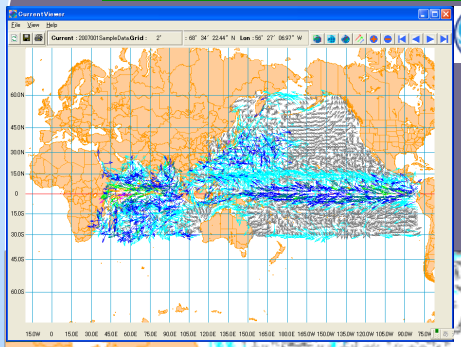


To predict drifted Japanese Anchovy distribution south of Japan , we are conducting a cooperative study with Wakayama Fishery Research Agency.

If we can get information of anchovy eggs catch at the start points, this kind of information will be quite useful information for fishery people of Wakayama.

Applications in Ship Route Predictions

Green Innovations: Efficient ship routing to save fuel (and cut CO_2 emission) by use of our ocean current forecast



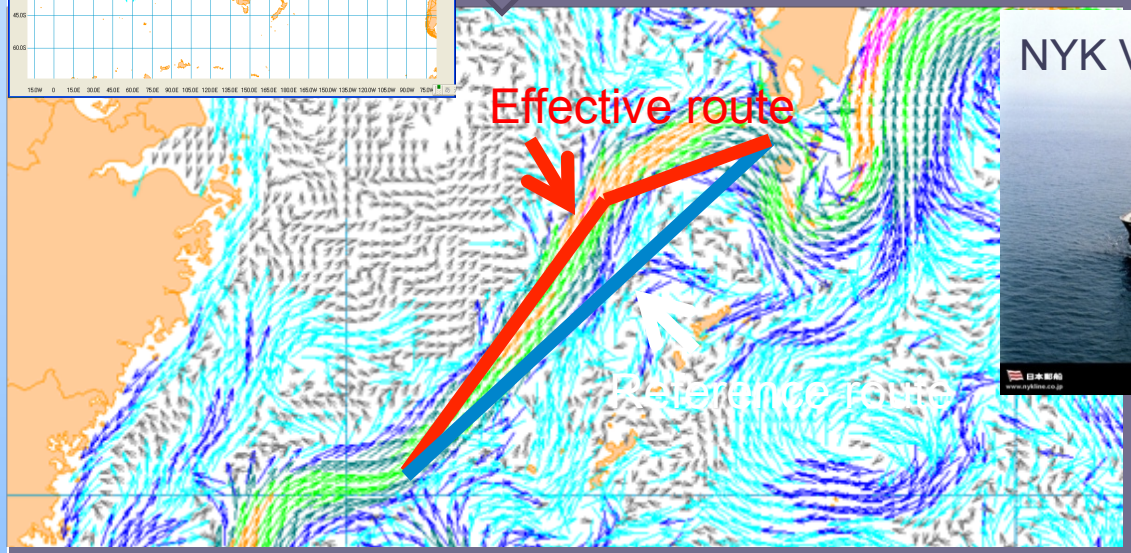
JAMSTEC JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

NYK LINE

Monohakobi Technology Institute

A big ship company, Nippon Yusen Kabushiki Kaisha (NYK) has demonstrated reduction in fuel consumption and CO_2 emission by use of our ocean current forecast.

Newspaper (Nikkei) 2008.03.14



9% fuel efficient

日本郵船の原油タンカー

潮流つかみ省エネ運航

消費燃料、最大9%減

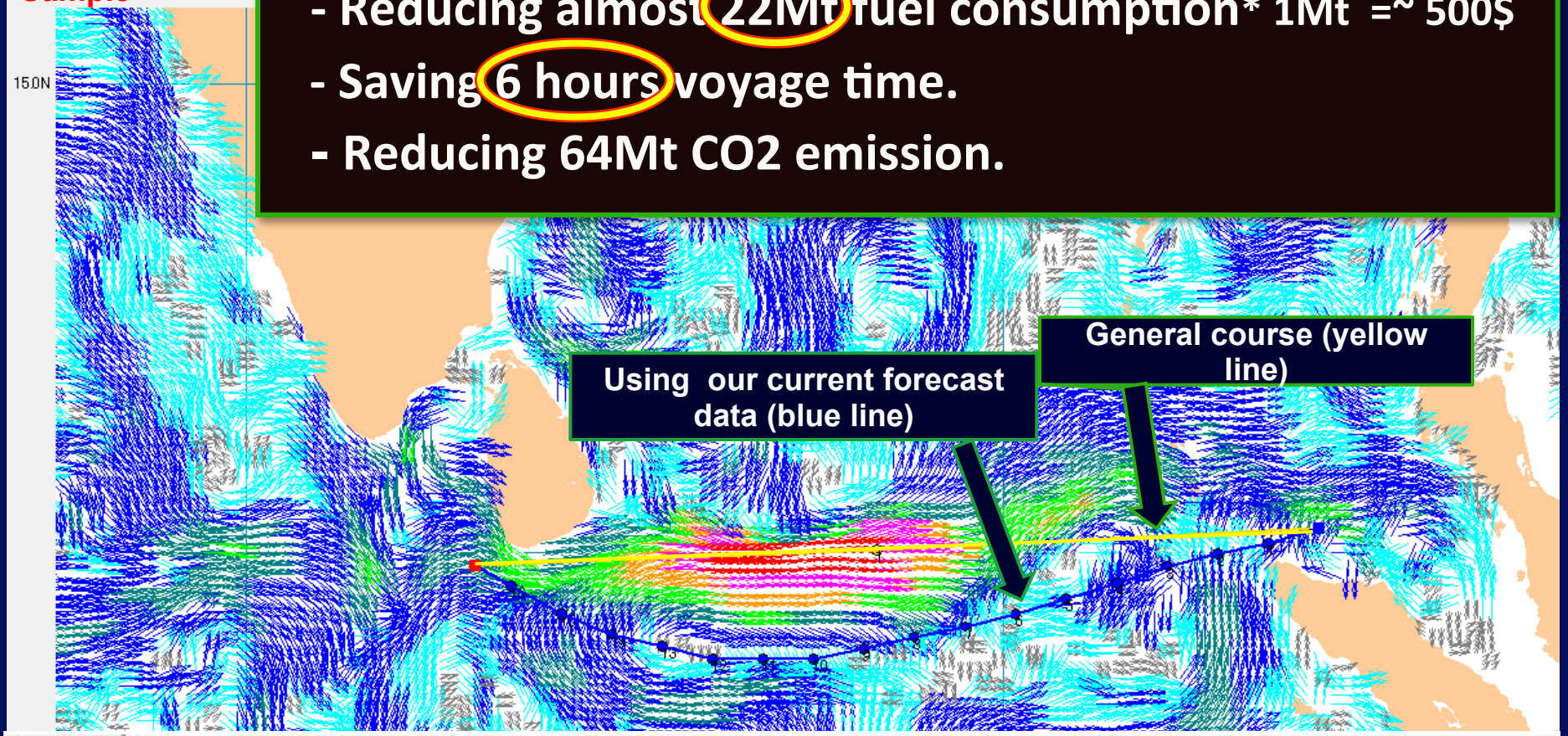
Big oil tankers (VLCC) has actually taken its ship route along the Kuroshio near the Okinawa Islands and confirmed **9% of fuel reduction** in the way from Okinawa to Kyushu, corresponding to 40-ton of oil.

NYK Press Release, 2008

Estimation of the cost effectiveness in the Indian Ocean

Sample

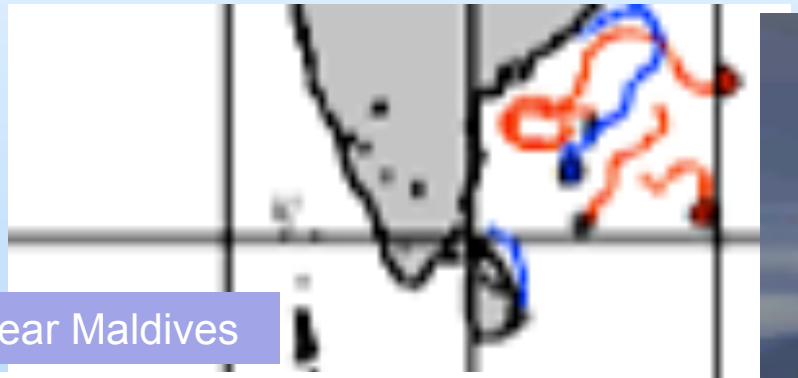
- Reducing almost 22Mt fuel consumption* 1Mt =~ 500$
- Saving 6 hours voyage time.
- Reducing 64Mt CO2 emission.



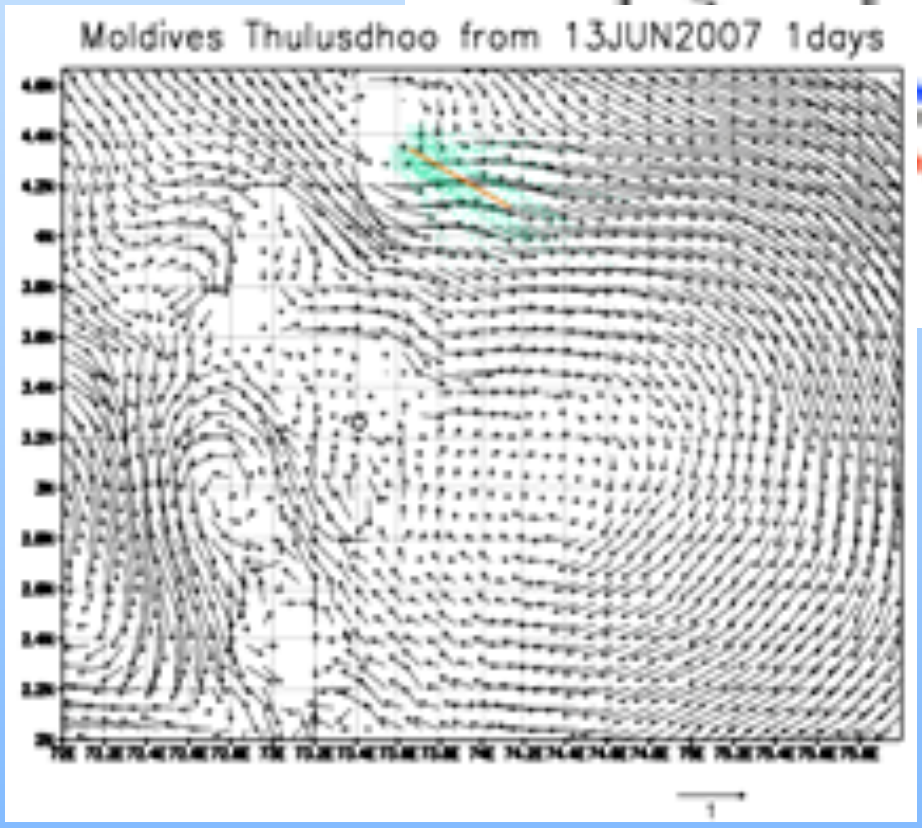
Route	Time[hours]	Diff_Time[hours]	Distance[nm]	Diff_Distance[nm]	Fuel[Mton]	Diff_Fuel[Mton]
*Optimum Route(OR)	71.20		1049.54		261.05	
Rumb Line(RL)	77.21	6.019	1004.81	-44.727	283.12	22.069

※VLCC class (estimated engine speed 14.8kts)

Applications in Marine Safety and Rescue Operations



Rescue operation near Maldives



Multi-Model Ensemble Prediction Experiment for Indian Ocean Operations

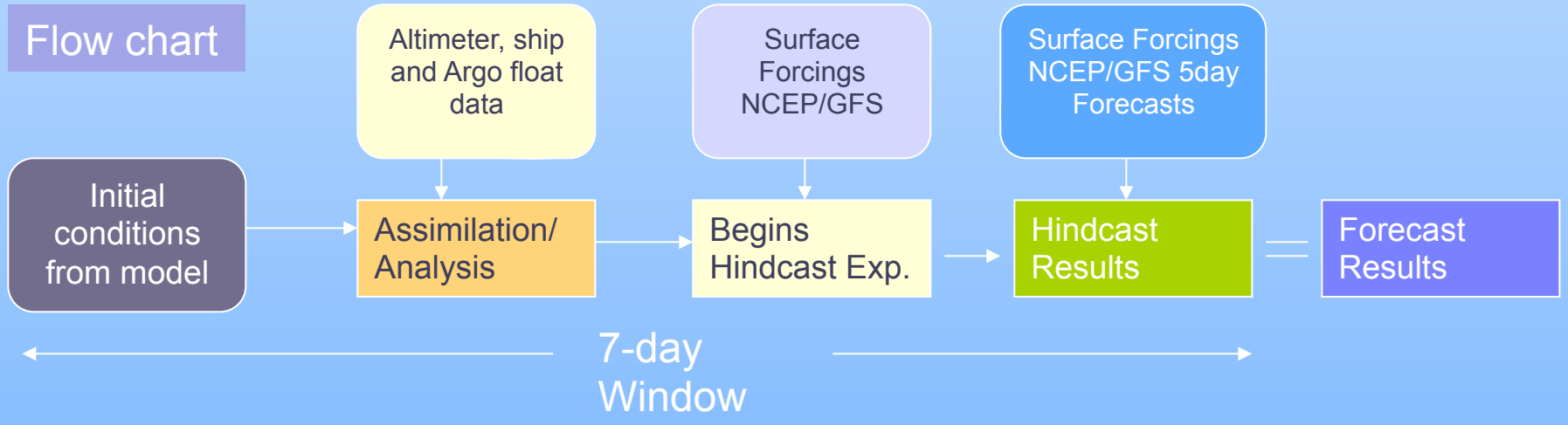
Indian Ocean operational forecasts are used by oil exploration companies through JAMSTEC's venture **Forecast Ocean Plus** (http://forecastsocean.com)

MOM Based Model:
1/3 x1/3 degree horizontal resolution, 26 levels
6 hourly forcings

POM Based 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

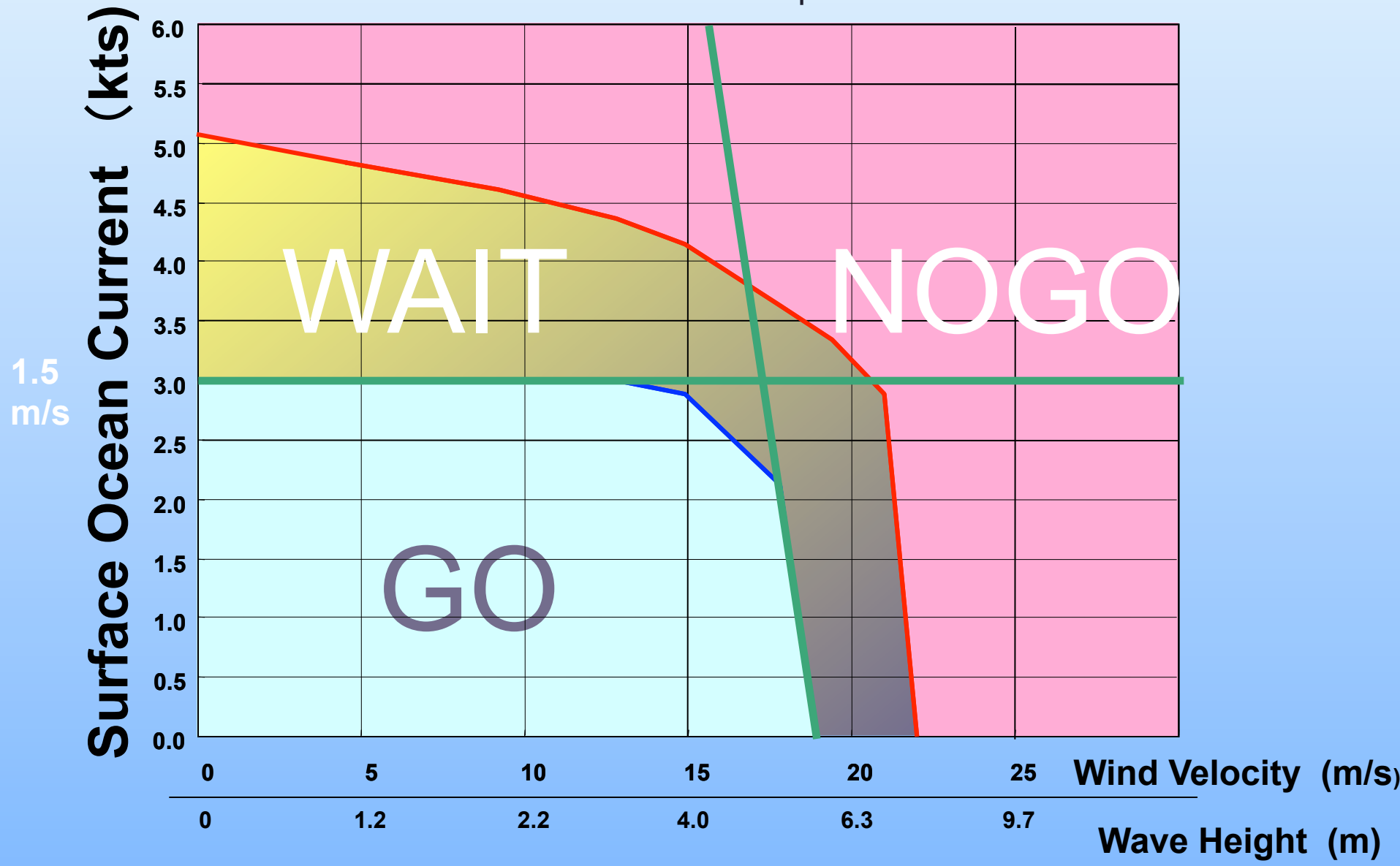
Reduced Gravity Model:
Data Assimilation
6 hourly Surface Forcings

Flow chart



Applications in Deep Sea Drilling

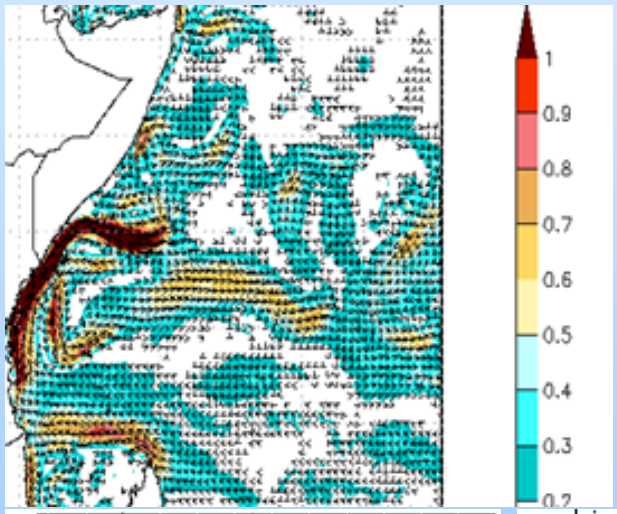
http://forecastsocean.com



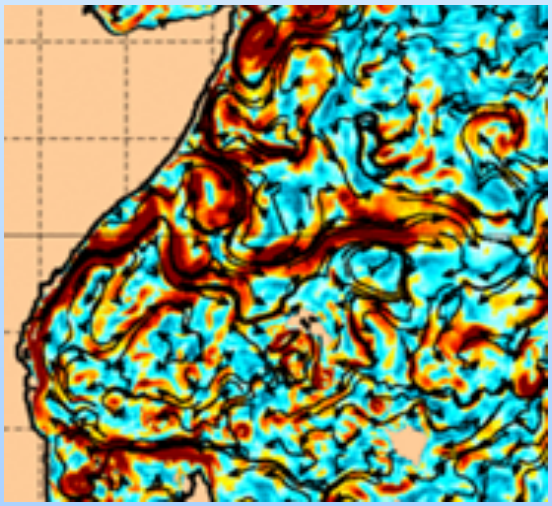
Validation

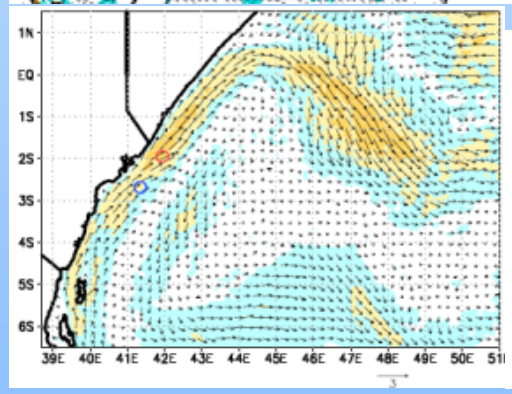
Indian Ocean operational forecasts are used by oil exploration companies through JAMSTEC's venture **Forecast Ocean Plus** (http://forecastsocean.com)

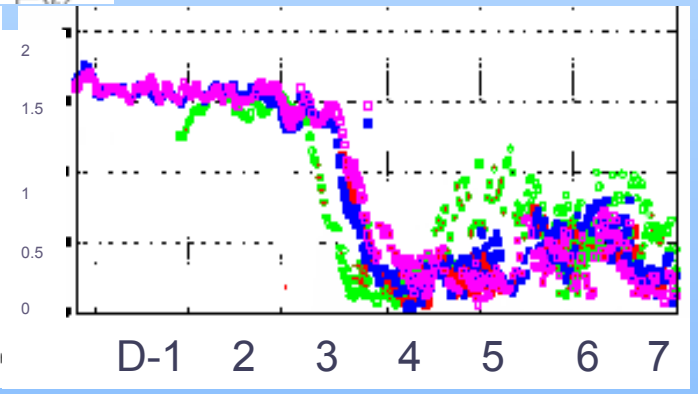
Forecast-Ocean Predictions



1/32 Global NLOM

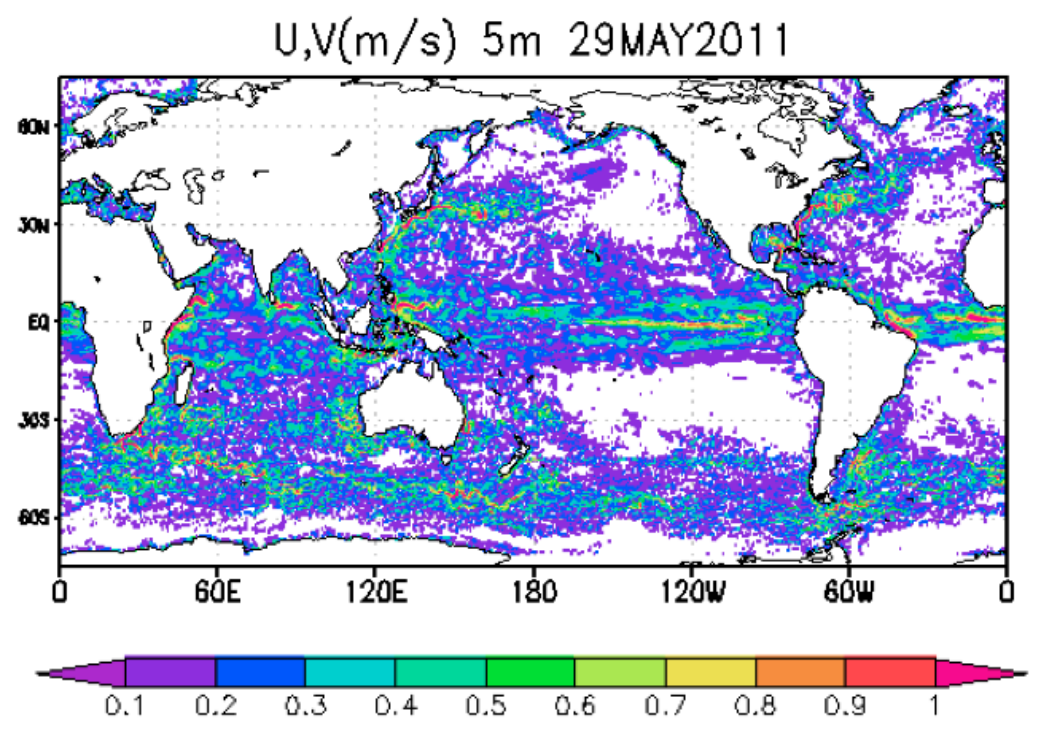




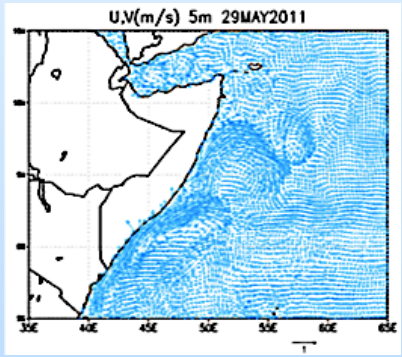


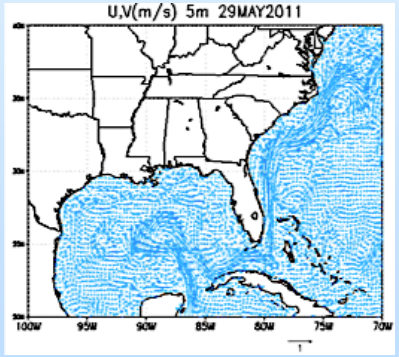
1. ***Dynamic positioning** of the rig or drill ship*
2. ***Optimized operational planning***
3. ***Enhanced safety for maintenance on site***
4. ***ROV, cable & pipe laying, drilling operations***
5. ***To predict currents higher than a threshold that will damage the operation***

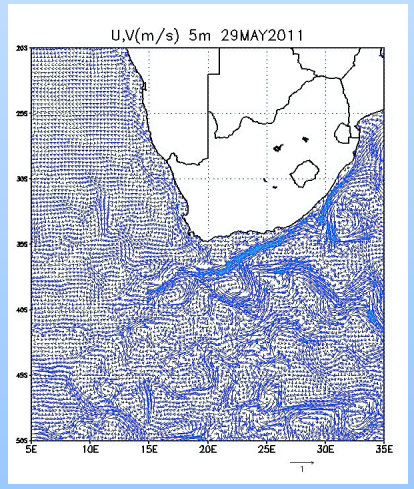
JCOPE semi-global prediction system: 1/10 Deg.

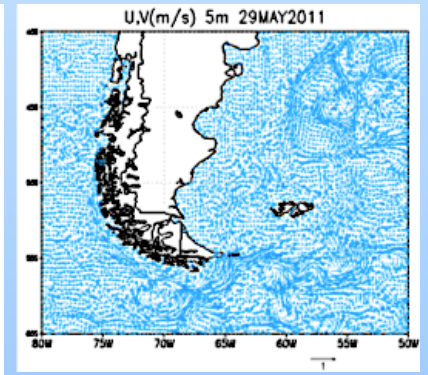


Miyazawa and Waseda 2010

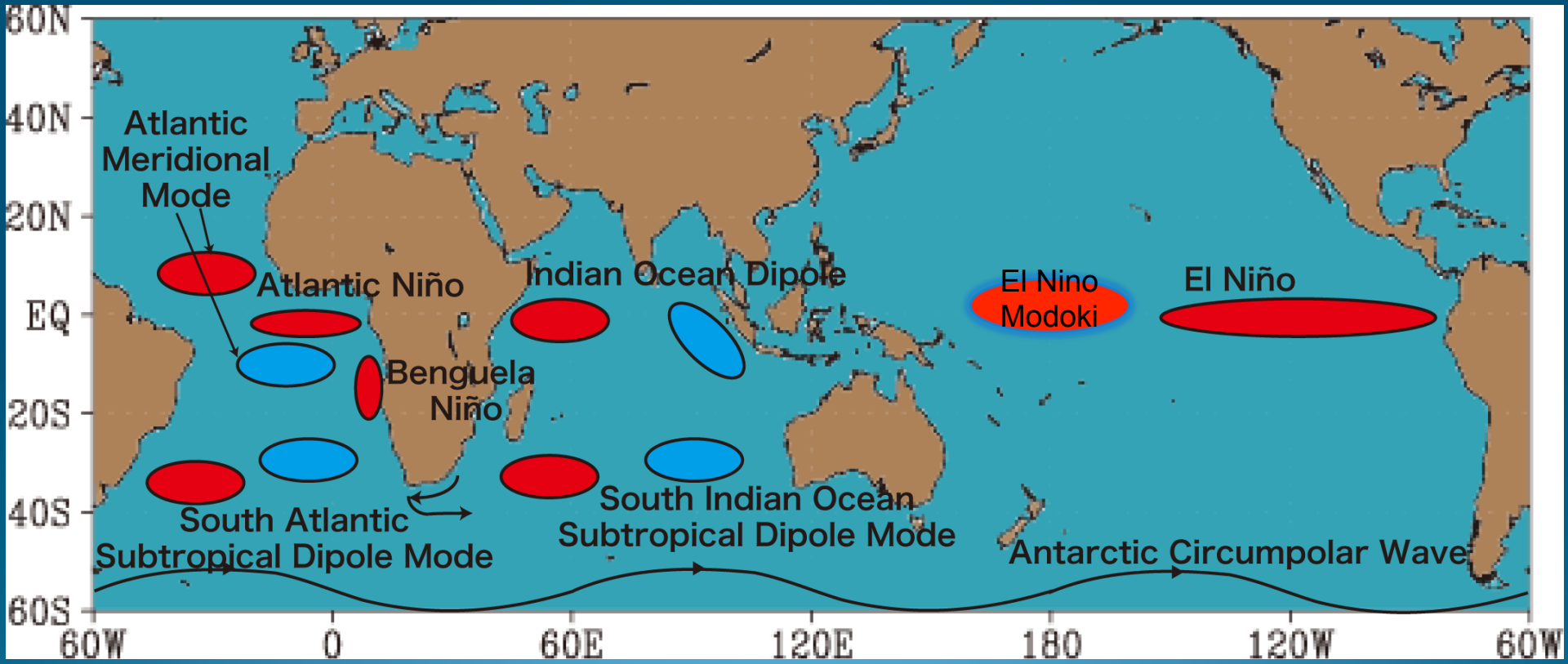




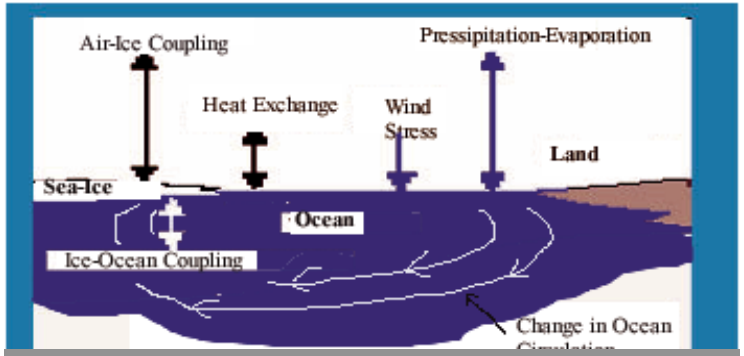




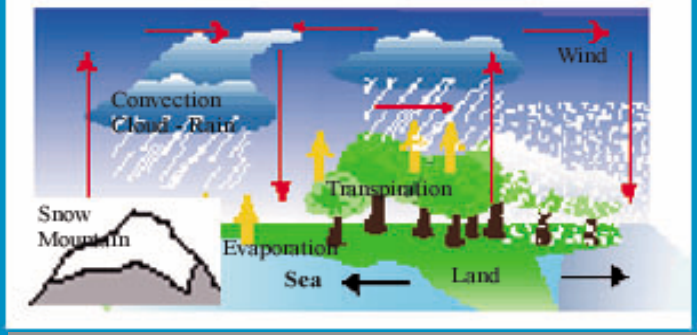
Climate Predictions using SINTEX-F



Schematic of the SINTEX-F1 CGCM



OCEAN: OPA8.2 ORCAR2 Grid
2^0X1.5^0 Eq-0.5 Level 31



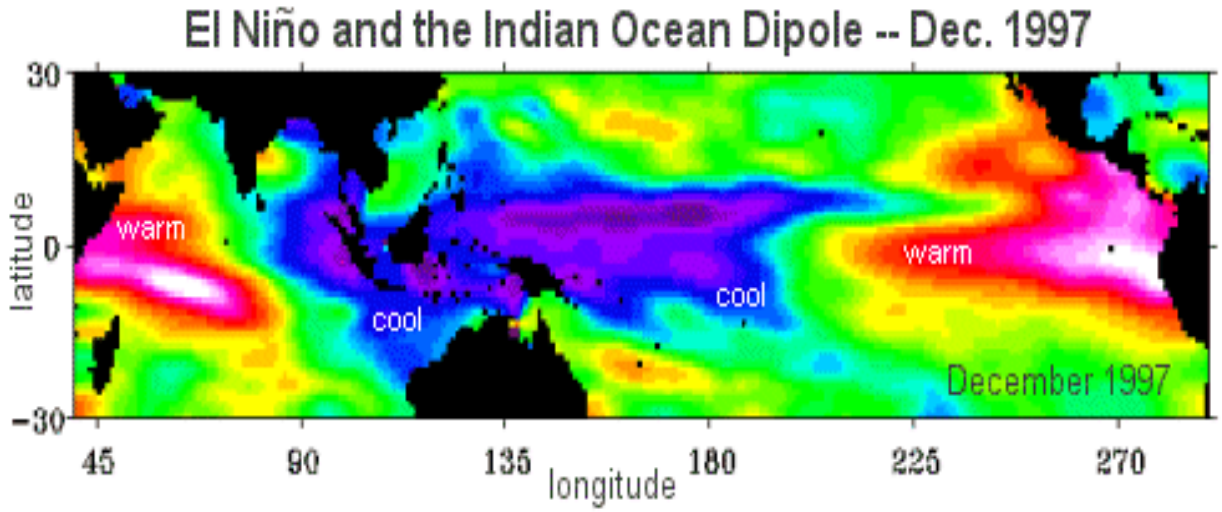
ATMOSPHERE: ECHAM4
T106 L19

Non-flux adjustment

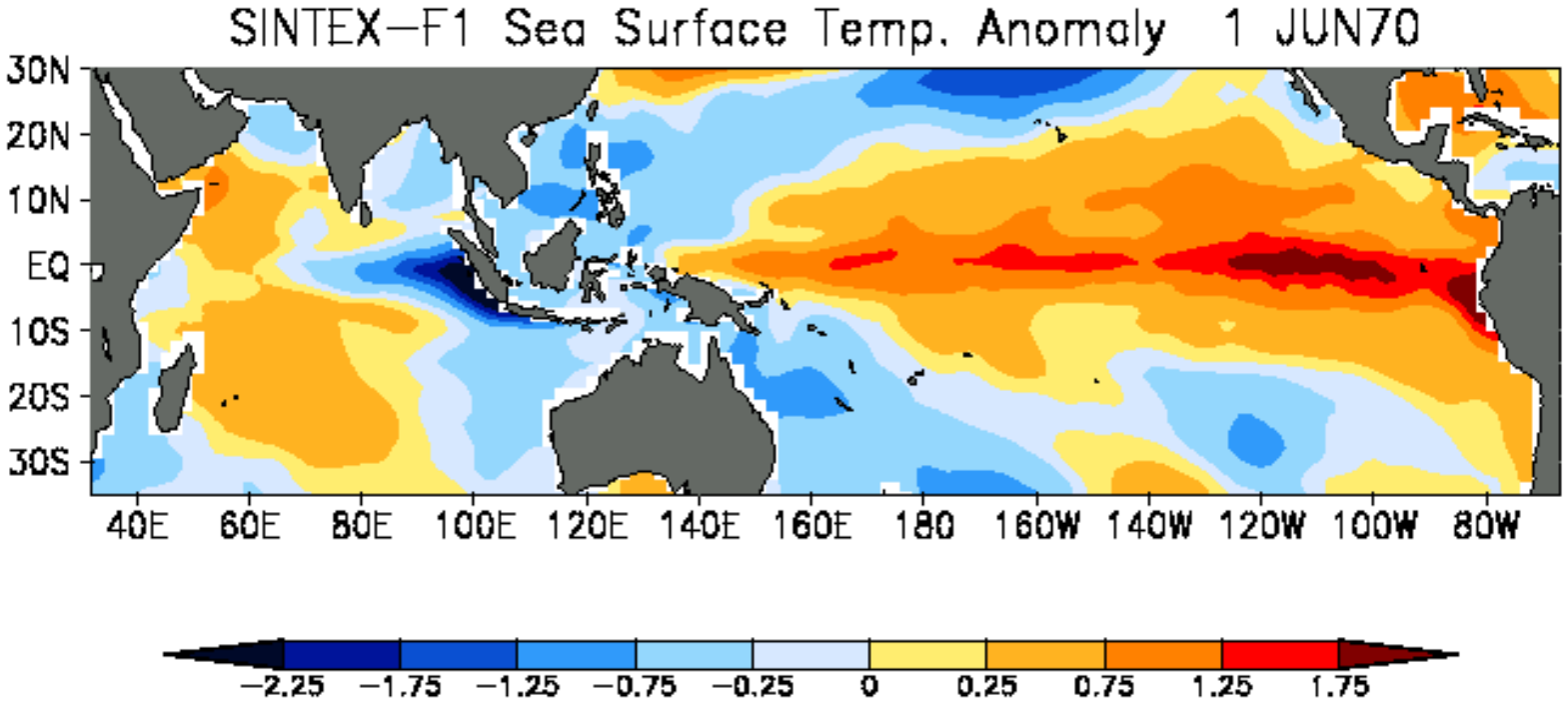
Every 2 hrs
Coupler-
OASIS 2

The Earth Simulator

Observation



SINTEX-F CGCM simulated IOD concurrent with El Nino



JAMSTEC's Semi-multi-model Ensemble Prediction System

1. Three models with different coupling physics:

(Each model has realistic ENSO & IOD simulations, Luo et al. 2005a)

m1: Ocean surface is solid to atmosphere.

(|**U**a| **U**a for Tau & heat flux)

m2: Ocean surface current momentum is passed to atmosphere.

(|**U**a-**U**o| (**U**a-**U**o) for Tau & heat flux)

m3: Ocean surface is solid to atmosphere, but

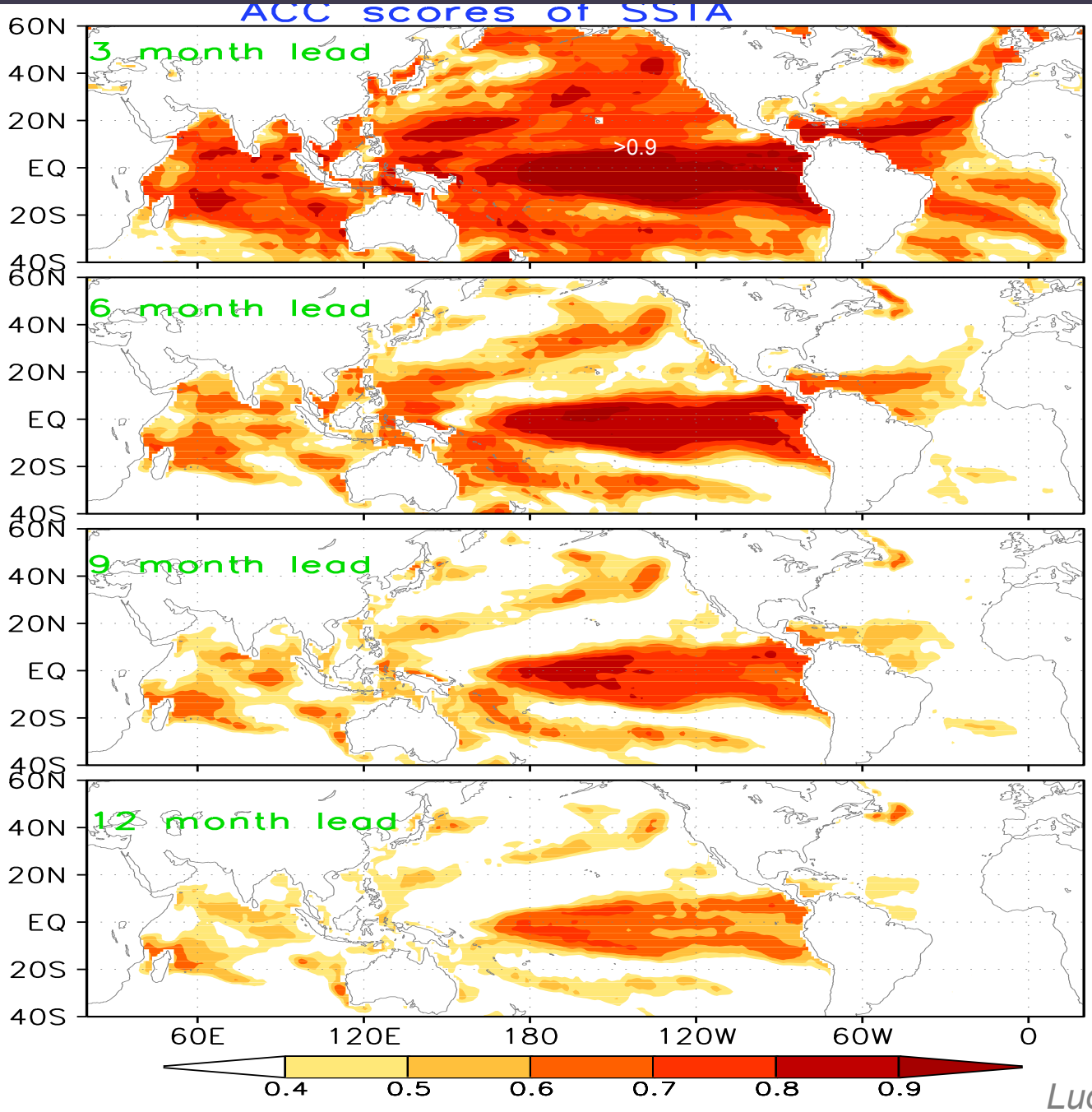
(|**U**a-**U**o| (**U**a-**U**o) for Tau)

2. Three initial conditions for each model:

- Model spin-up (1971-1981)
- A simple coupled SST-nudging initialization scheme
- 1day, 2 days, 3 days (weekly NCEP Reynolds data)

Retrospective forecast: 12 months from 1st day of every month for 1982-present.

SINTEX-F Prediction Skills

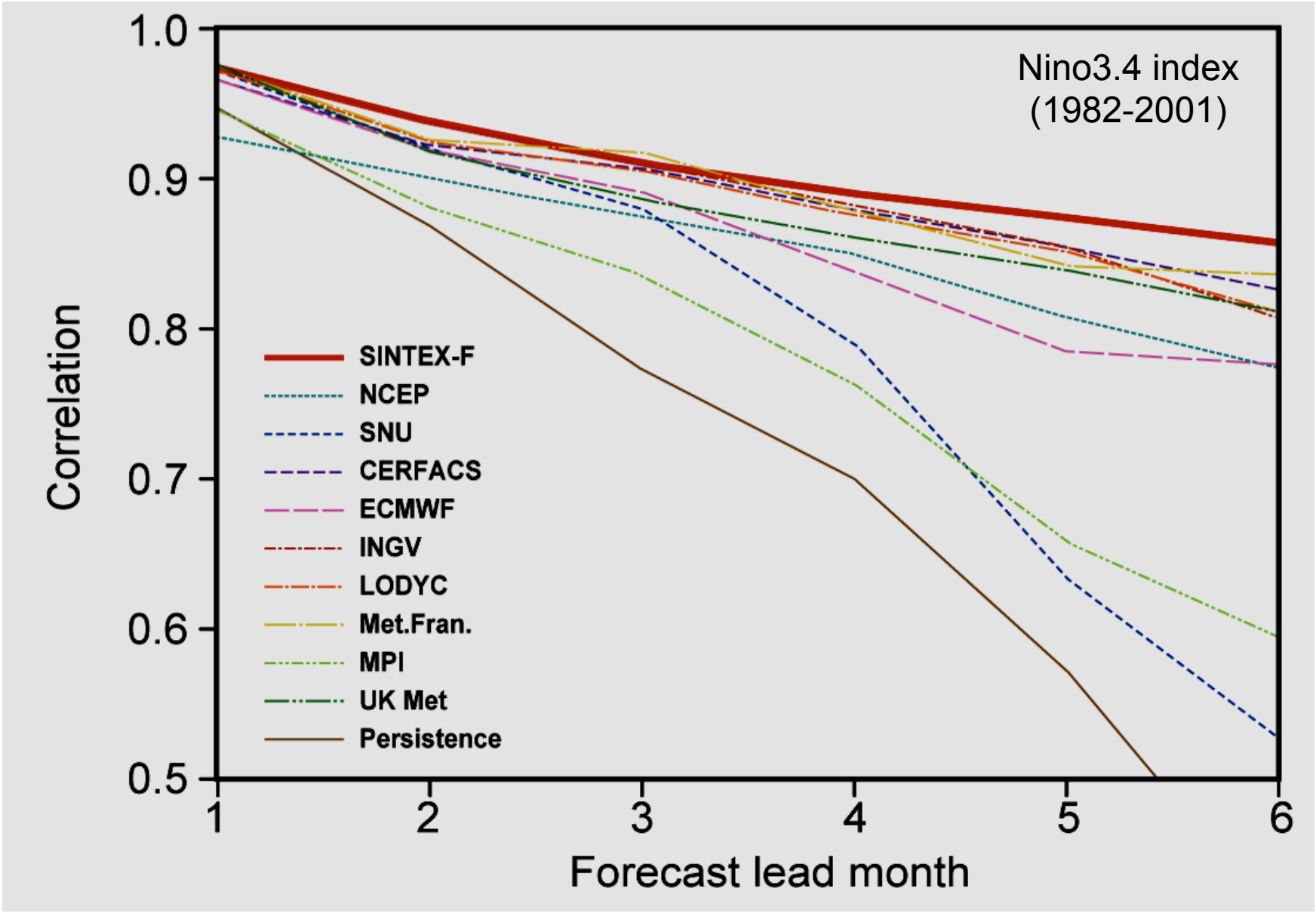


9-member mean (1982-2004)

based on a semi-multimodel ensemble prediction system

Luo et al., J. Climate, 2005b.

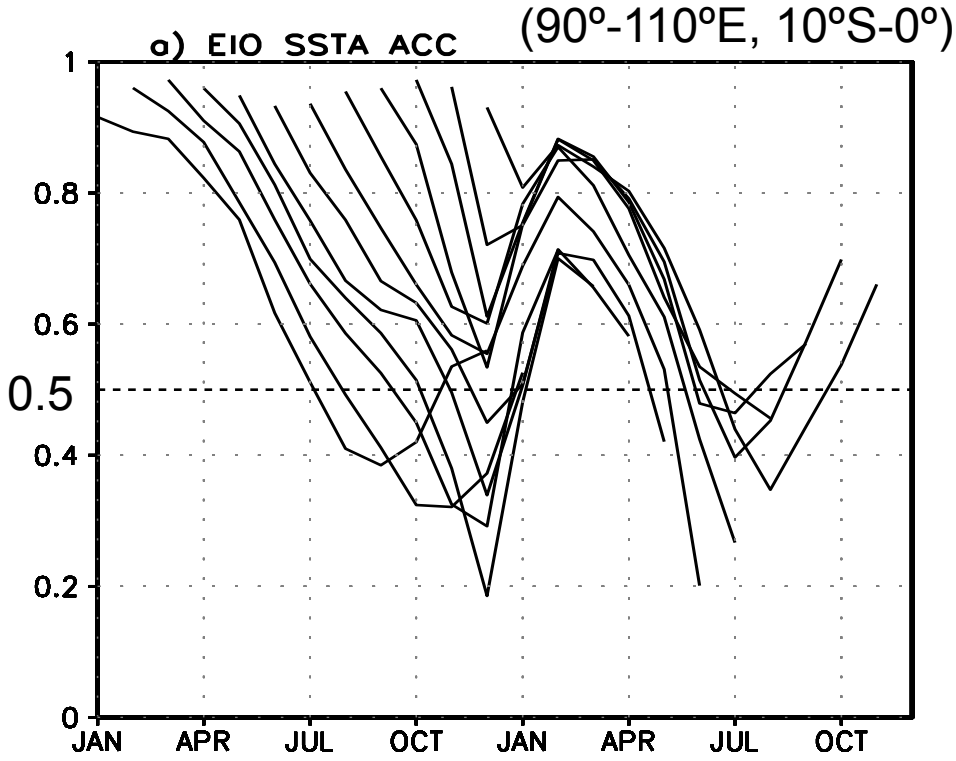
ENSO prediction skills in 10 coupled GCMs



Adapted from Jin et al. 2008, APCC CliPAS

Indian Ocean Dipole Predictability

Both winter and spring barrier exist



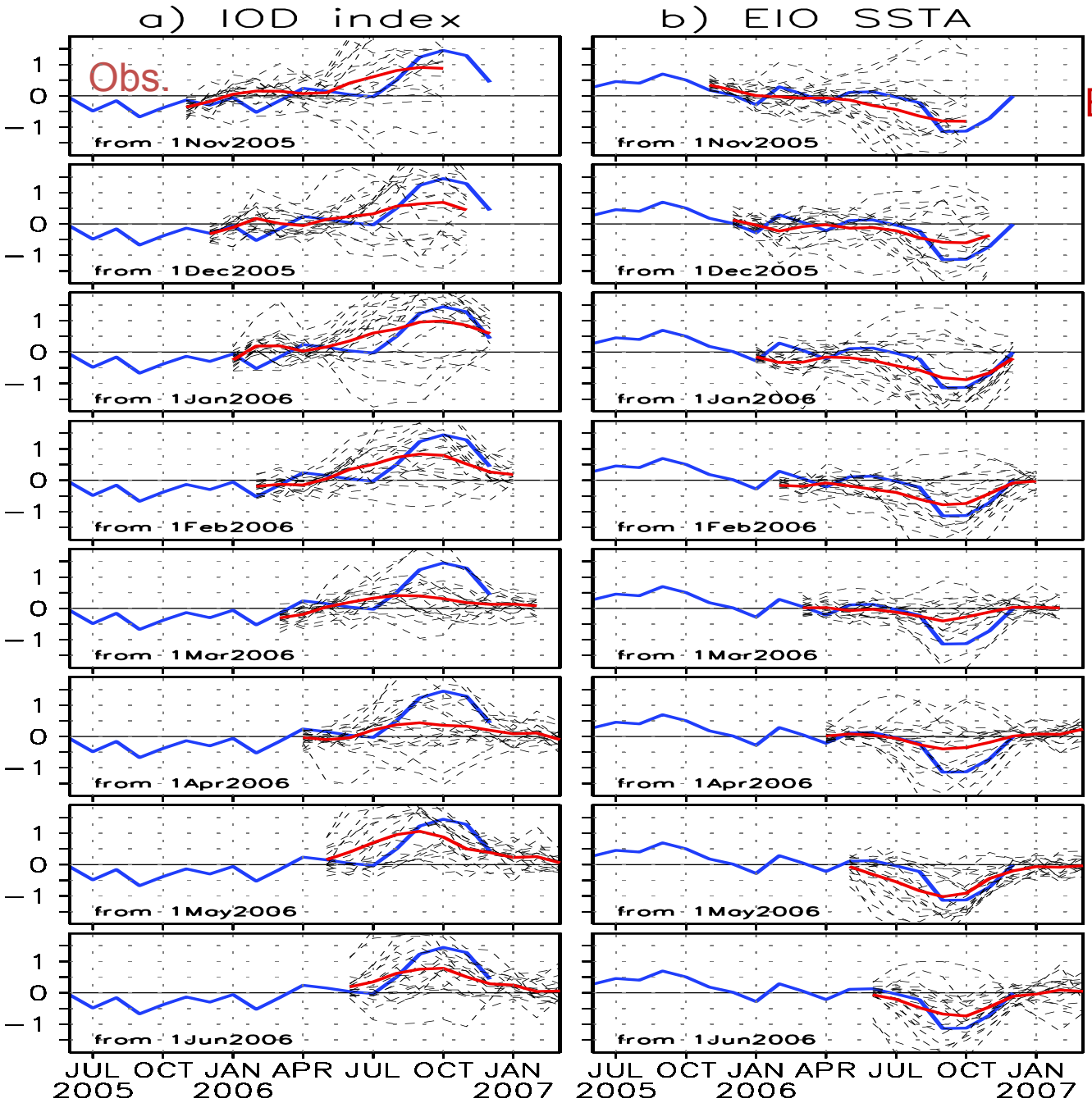
9-member ensemble hindcasts (1982-2004)

Difficulties

- Large deficiencies of current coupled GCMs in simulating Indian Ocean climate
- Sparse subsurface observations in the Indian Ocean
- Chaotic and active ISOs *(initial conditions & predictions)*
- Strong monsoon influence *(seasonal & interannual)*
- ENSO influence *(require correct ENSO onset prediction)*

Predictable up to ~2 seasons ahead.

Luo et al., J. Climate, 2007, 2178-2190.



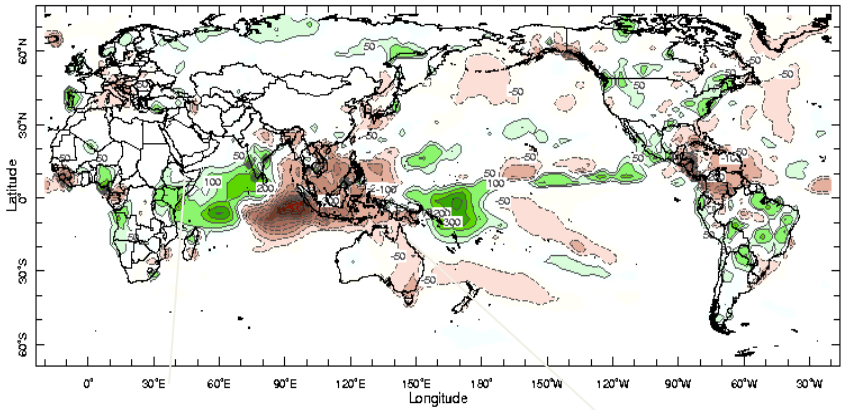
Ensemble mean

IOD forecasts in 2006 (18-member)

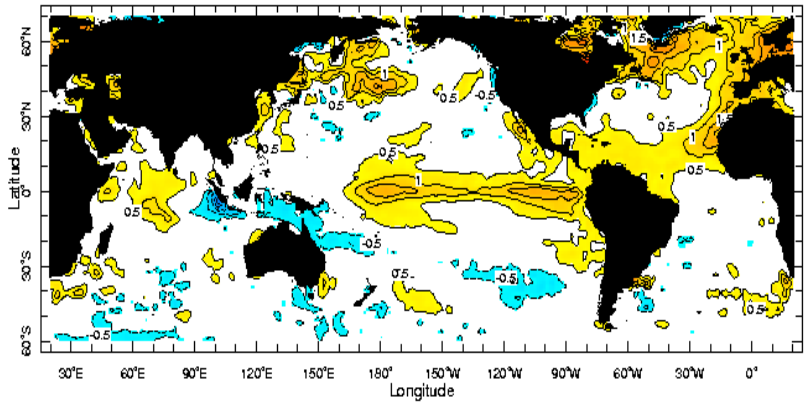
http://www.jamstec.go.jp/frcgc/research/d1/iod/index.html

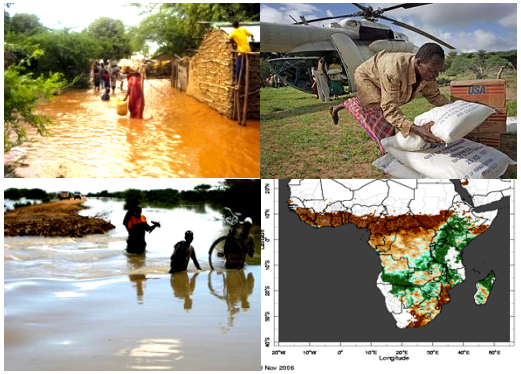
IOD Impacts in 2006 Boreal Fall

Rainfall Anomalies Sep-Nov 2006

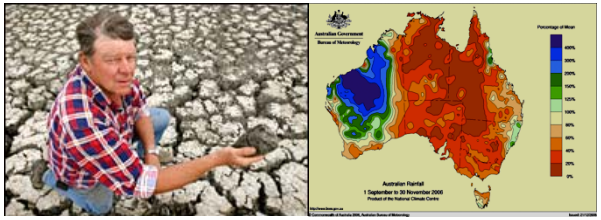


Corresponding SST Anomalies



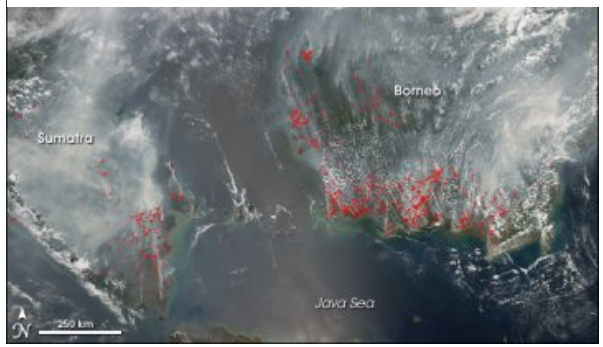


More than 1 million people in Kenya, Somalia and neighboring countries were affected by the flooding.



Severe drought devastated farmers in eastern Australia, estimated loss of 8 billion AUD.

2006 fires in Borneo and Sumatra



Early drought warning kept quiet

Signal failure

24 Oct 2007, The Weekly Times

EXCLUSIVE

By XAVIER DUFF

AUSTRALIAN scientists were warned as early as March that Australia could be heading back into drought.

But the warning was kept under wraps for fear that it would lead to increased suicides in rural communities.

"I would warn against rushing to a public announcement," one weather scientist said in an email to colleagues in June. "Seasonal predictions can be very upsetting to the public who live in areas of risk."

Yet the secrecy came as grain growers across southern Australia — hopeful of a bumper season — entered hedge contracts that have since plunged the industry into $1 billion in debt.

The first warning that drought may be returning was made by a Japanese scientist during a meeting of international weather experts in March. At the time, Australian weather authorities were predicting a wet La Nina year.

However, the Japanese scientist's warning that a warmer Indian Ocean would knock out the La Nina winter and spring rain has come true.

Prof Toshio Yamagata, from the Japan Agency of Marine Earth Science and Technology, predicted a positive Indian Ocean Dipole, the Indian Ocean equivalent of the drought-inducing El Nino.

In an email to international colleagues on June 24, Prof Yamagata again warned that the eastern Indian Ocean near Australia remained cold, mirroring conditions of 1967.

That year, Victoria experienced a severe drought and Melbourne had its lowest rainfall on record.

"I think we had better go ahead about cautioning regional societies about possible floods/drought/hot conditions," Prof Yamagata wrote.

A member of Prof Yamagata's research team, Dr Swadhin Behera, also suggested that the information should be made public even if it was not definite, so that people could make their own judgments.

He drew on the experience of last year as an example.

"Last year (2006), because of the debate early on during the development of IOD, we delayed the press release until August," Dr Behera wrote in an email to colleagues.

- **Continued Page 4**
- **Rule's View, Page 15**
- **Editorial, Page 16**

Signal failure as drought warning kept quiet

• From Page 1

"But probably because of the delay, the announcement could not be utilised by people who were most affected by the 2006 IOD.

"Some of the farmers who kept calling us almost on a daily basis told us they could have benefited had the information about the IODs been passed on to them based on our model predictions."

But Australian scientist Prof Gary Meyers, from the University of Tasmania, who plays a key role in monitoring international weather patterns, wrote back, arguing more evidence was needed before rushing to an announcement.

"I would caution against rushing to a public announcement," he said. "Seasonal predictions can be very upsetting to the public who live in areas of risk."

Prof Yamagata then agreed, saying the release of such a forecast might trigger suicides among Australian farmers.

But grain growers said any hint of another dry year could have prevented some of the huge losses they now faced.

Prof Meyers told *The Weekly Times* that Prof Yamagata's computer model had predicted a positive IOD as early as March but two other computer models did not agree.

It was only in July that all the models agreed and the warnings of adverse Indian ocean temperatures were given to the Bureau of Meteorology for its seasonal forecasts.

Prof Meyers told *The Weekly Times* this week that while it turned out the Japanese model was correct and it appeared to be a good model, it was still in its early stages of development and its reliability was uncertain.

Releasing what could be a wrong forecast could cause as many problems as not releasing it, Prof Meyers said.

Monitoring and research into the Indian Ocean dipole was still in its infancy and much more data was needed for scientists to predict weather patterns with it, he said.

David Jones, from the Bureau of Meteorology's National Climate Centre, said the bureau factored in a range of Indian Ocean data into their seasonal outlooks.

"You could not rely on just one model," he said.

But he said most of the bureau's seasonal outlooks this year had forecast below-average rains.

Victorian Farmers Federation grains group president Geoff Nalder said even with the uncertainty of the models, farmers should have been told of Prof Yamagata's forecast, so they could make their own judgments.

Many growers had forward sold their crops in expectation of at least an average year and many had believed the predictions of a La Nina developing and good rains with it.

"I'm very disappointed that information was not widely circulated," Mr Nalder said.

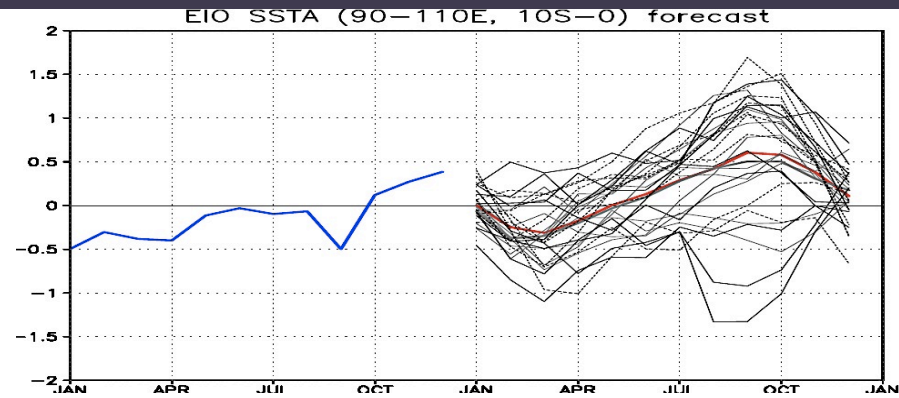
"To have had a contrary view to the one that we were in for a bumper year would have slowed the momentum to forward positions and could have saved many farmers hundreds of thousands of dollars in washing out contracts."

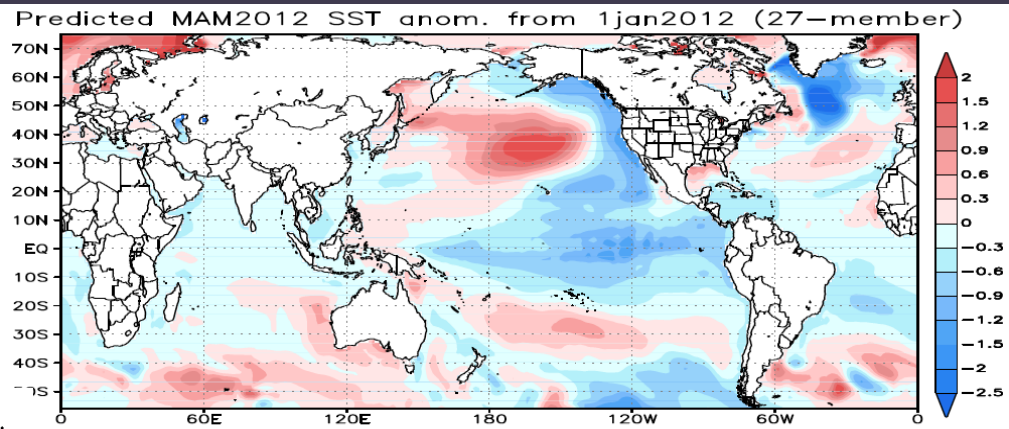
Birchip farmer Leigh Weir, one of those unable to deliver enough grain against forward contracts, said knowing the Japanese prediction would definitely have helped.

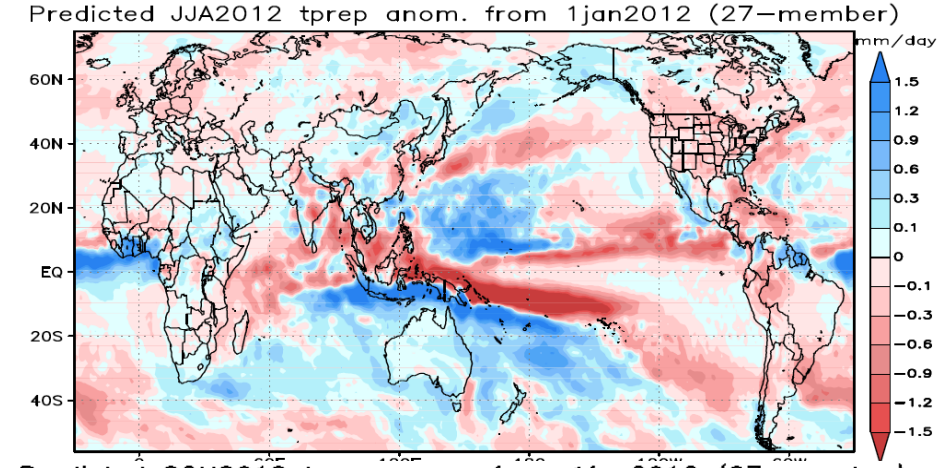
"If there were doubts about the season, we would like to have known and we would have definitely reduced the amount we sold forward and washed out contracts much earlier than we did," Mr Weir said.

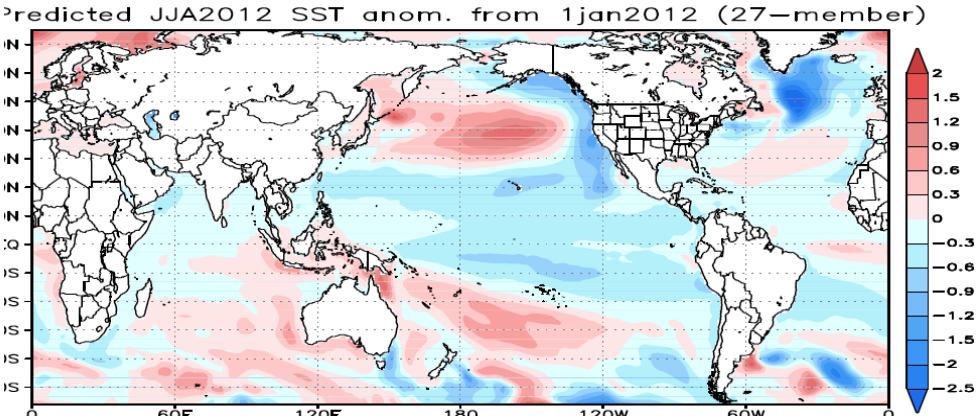
Societal impacts of IOD forecasts

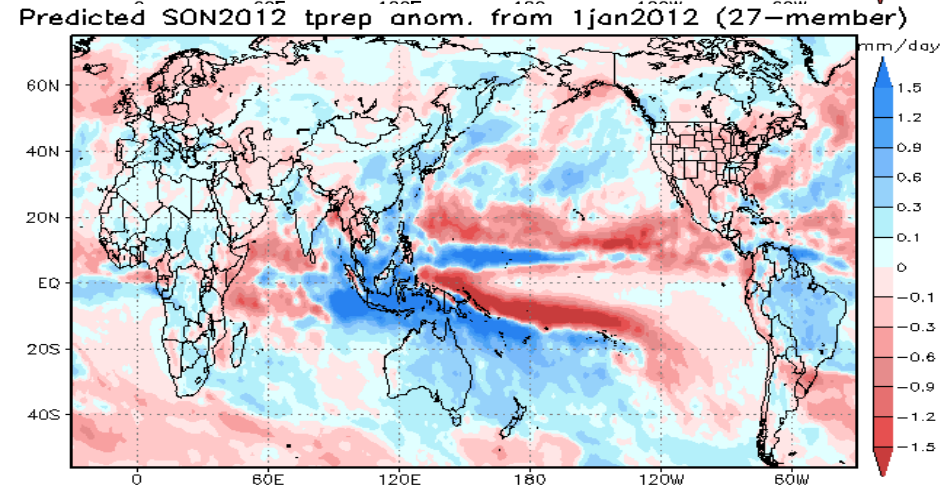
Latest SINTEX-F Seasonal Predictions from 1 Jan 2012

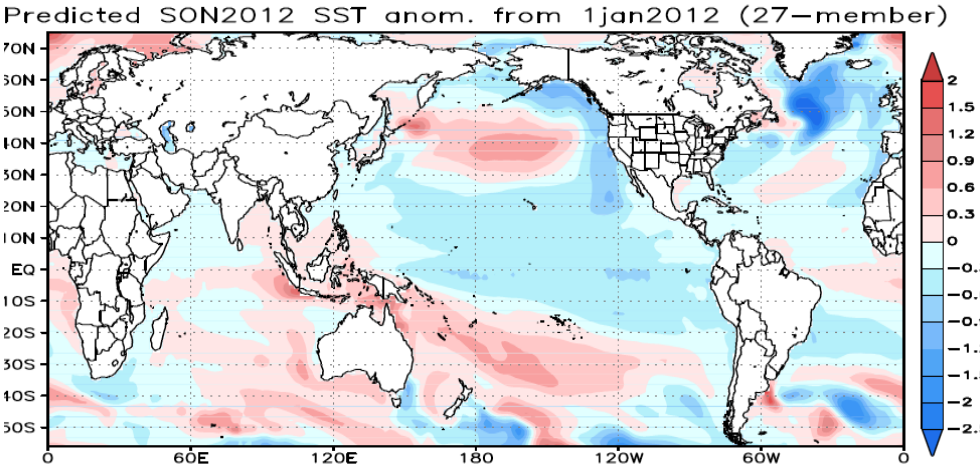












The Hindu Business-line

Japanese expert warns of deficit monsoon for India

Vinson Kurian

Thiruvananthapuram, Feb. 1

A widely respected Japanese researcher-cum-scientist has warned that India might be faced with a deficit monsoon this year.

The warning comes from Prof (Dr) Toshio Yamagata, Dean of University of Tokyo Graduate School of Science, and Head of the Application Laboratory of Japan Agency for Marine-Earth Science and Technology (Jamstec).

DEFICIT IN NORTHWEST

It is not yet known from the forecast, since made available to *Business Line*, the likely extent of deficit.

It was as high as 23 per cent during the latest lean monsoon year of 2009. That was also the worst monsoon deficit to be recorded in more than three decades.

Dr Yamagata's latest forecast indicates deficit in north-west India, adjoining parts of central India and east-central India during the crucial June to August this year.

State-wise, deficits are indicated for almost entire Rajasthan, Haryana-Delhi-west Uttar Pradesh, Andhra Pradesh and adjoining east Maharashtra.

NORMAL FOR SOUTH

Monsoon rains are indicated to be normal to excess for Jammu and Kashmir, Himachal Pradesh and Uttarakhand in the rest of the northwest; Bihar, Gangetic West Bengal and Orissa in the east; Gujarat in the west; and most of southern peninsula.

North-west India, except possibly Uttar Pradesh, will get its share of rains in the September to November period, the forecast says. Deficit is indicated for adjoining east and central India during this period.

Once again, southern peninsula is forecast to receive normal to excess rainfall during this latter three-month period.

IOD EXPLAINED

Dr Yamagata blamed 'an unexpected developing' Indian Ocean Dipole (IOD) for the likely poor performance of the Indian monsoon this year.

The Indian Ocean event mimics the El Nino-La Nina phenomena, its mega-sized cousin in the east equatorial Pacific, but has a more immediate impact for Indian monsoon.

The IOD has positive and negative phases. During a positive phase, sea-surface temperatures are comparably high to the west of the Indian Ocean. It has a benign influence on the concurrent Indian monsoon.

The situation is exactly reversed in the case of a negative event, when the temperature anomaly shifts to the east and with it associated convection and cloudiness.

MOISTURE ROBBED

This robs the approaching monsoon current from south-west and west Indian Ocean of the moisture needed to rain down over land.

It would also translate into above normal winter rains over Indonesia and Australia, which are currently proving the forecast true.

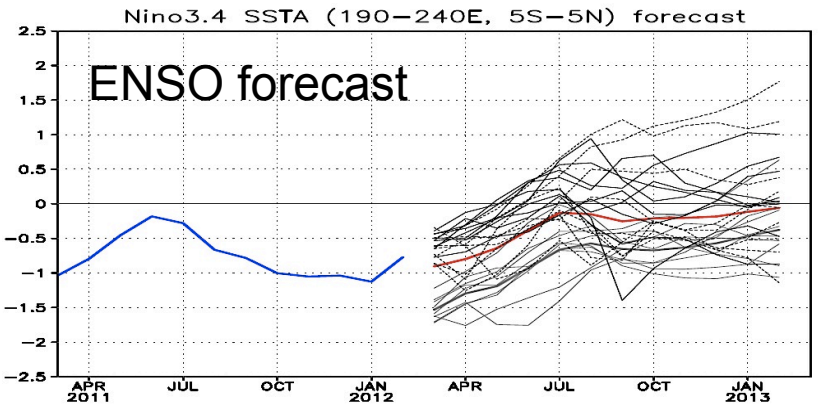
Dr Yamagata said that the ongoing La Nina condition would start decaying from the ensuing summer of 2012. It was this La Nina that helped turn out a successful Indian monsoon last year.

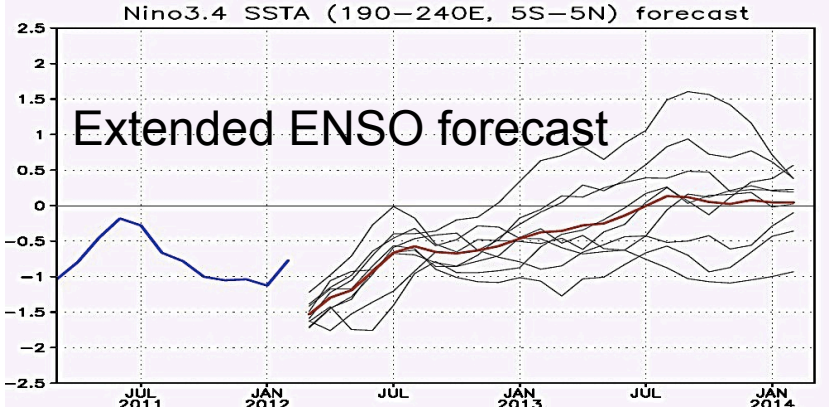
The La Nina would also sustain the colder-than-normal condition over many parts of the world in following seasons. Northern Eurasia and the US will experience warmer-than-normal climate in the spring.

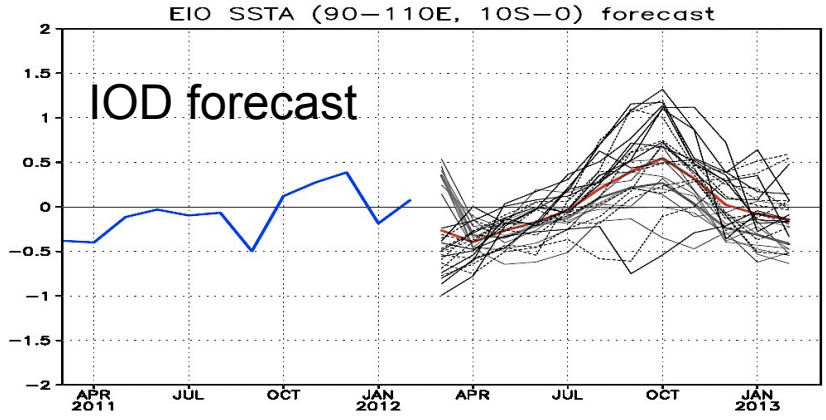
Vinson@thehindu.co.in

http://www.thehindubusinessline.com/opinion/editorial/article2938910.ece
http://articles.economictimes.indiatimes.com/2012-02-08/news/31037700_1_monsoon-rains-bp-yadav-india-meteorological-department
http://oryza.com/Rice-News/14229.html

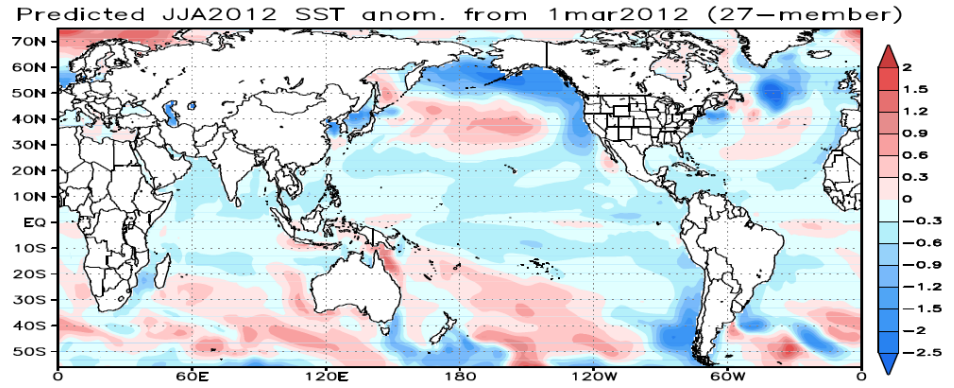
SINTEX-F Latest Seasonal Predictions

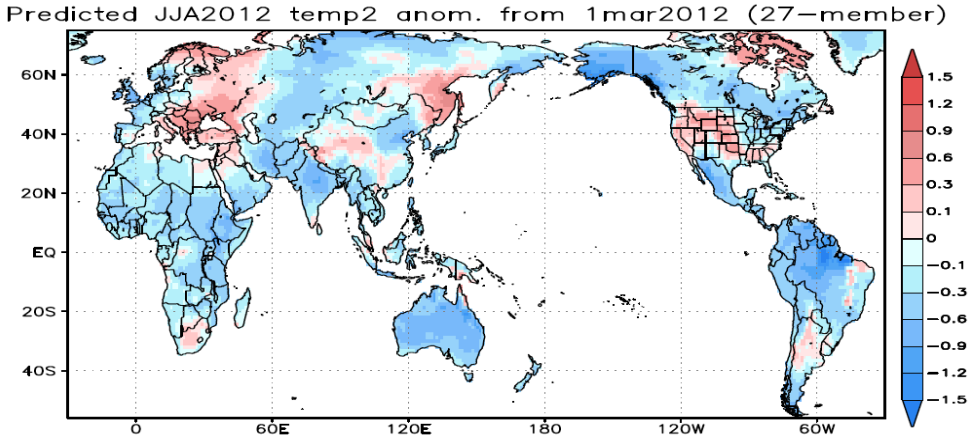


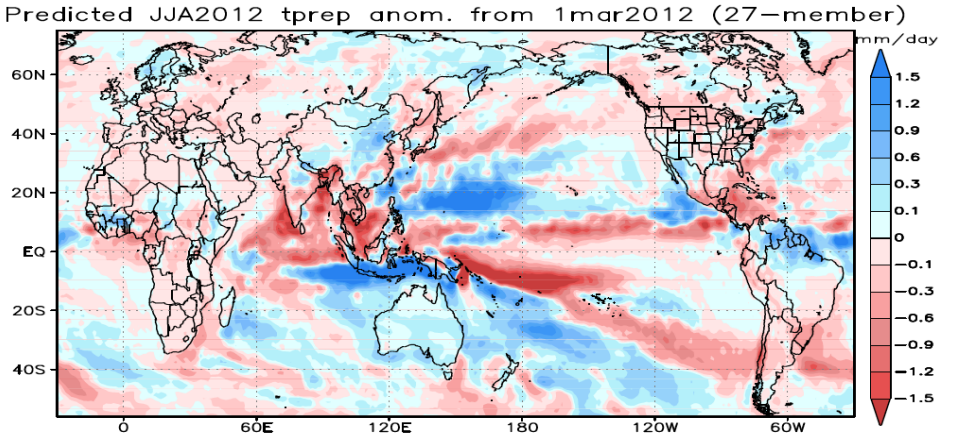




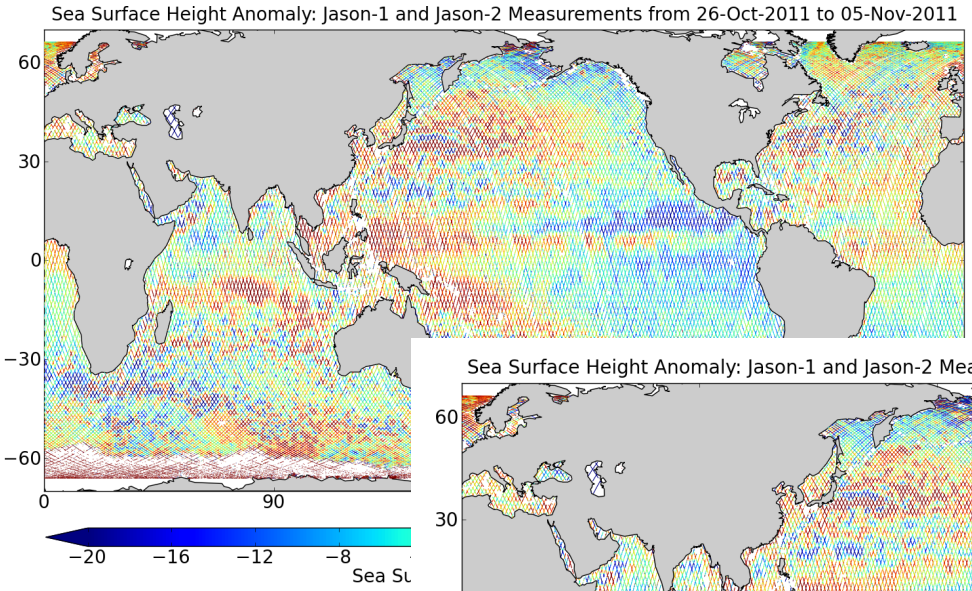
Predicted SST, SAT, PRECIP Anomalies for Jun-Aug from 01Mar2012

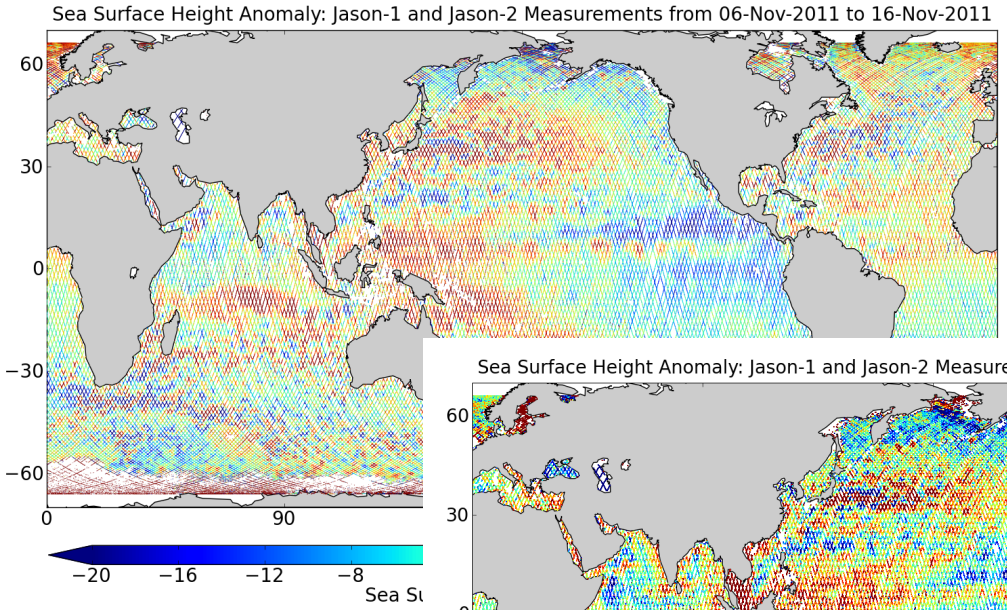


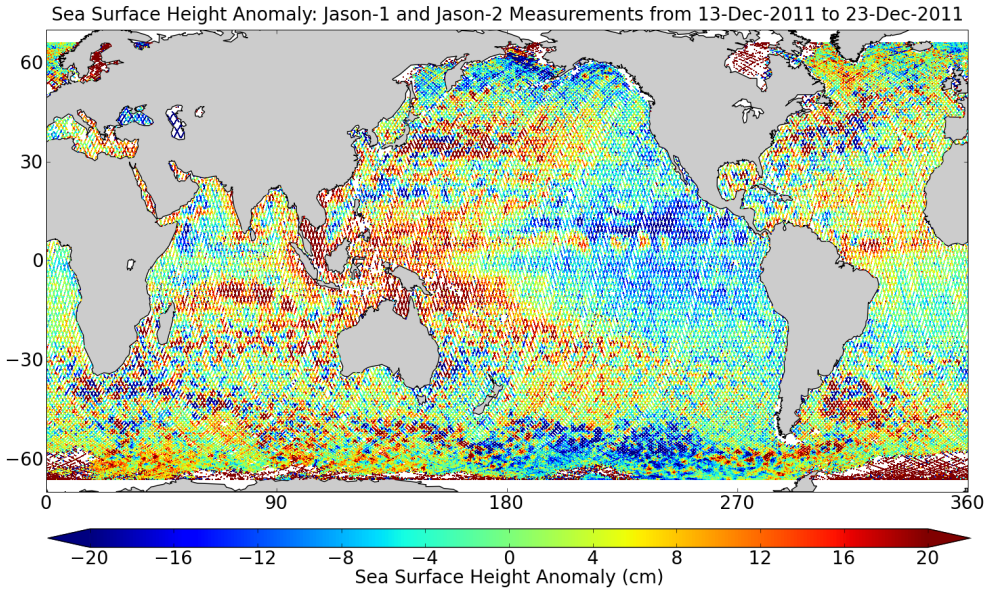




SSH Anomalies Oct-Dec 2011







Summary

- The present generation of ocean and climate forecast systems are benefited by a good network of observations and high-performance computational system.
- These predictions can be used in various societal operations for the sustainable management of the marine and continental environment.
- The Japan Coastal Ocean Predictability Experiment (JCOPE) project in JAMSTEC provided a scope to develop connection between research and real-world oceanographic applications.
- Ocean observations are vital for the sustenance of these ocean and climate prediction systems. Therefore, the existing observational network need to be maintained and enhanced together with remote sensing observations.