Indian Ocean Modeling: Opportunities and Challenges for Data Assimilation

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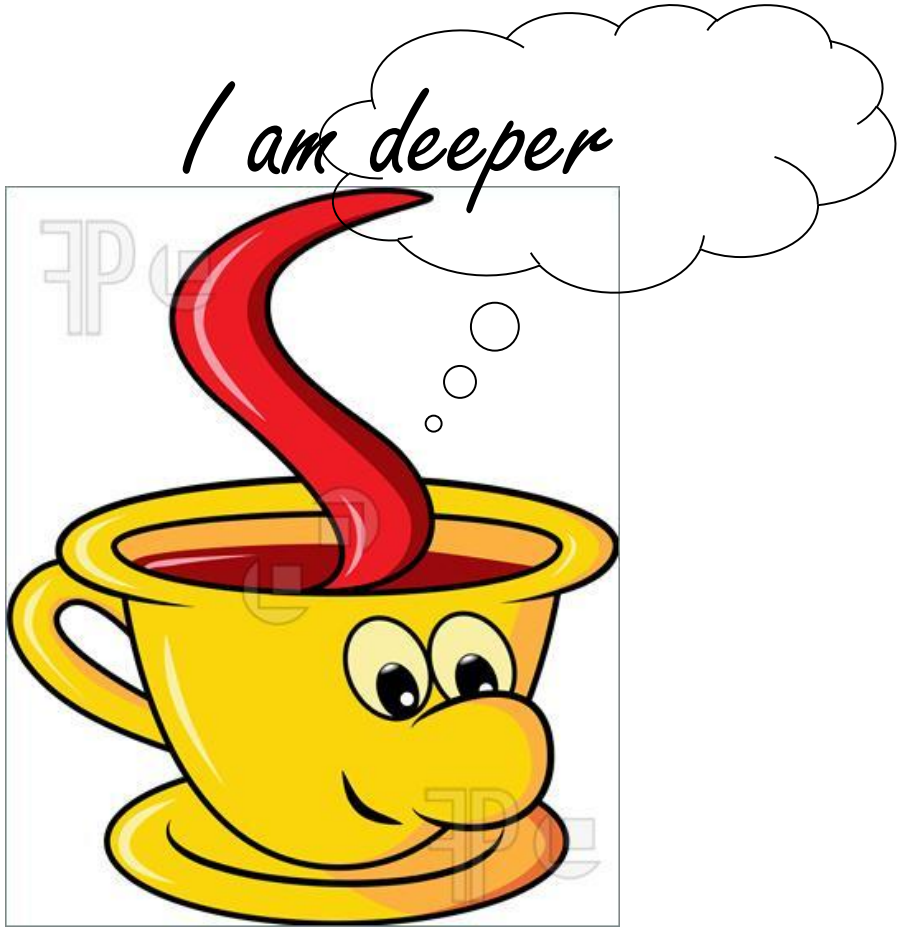
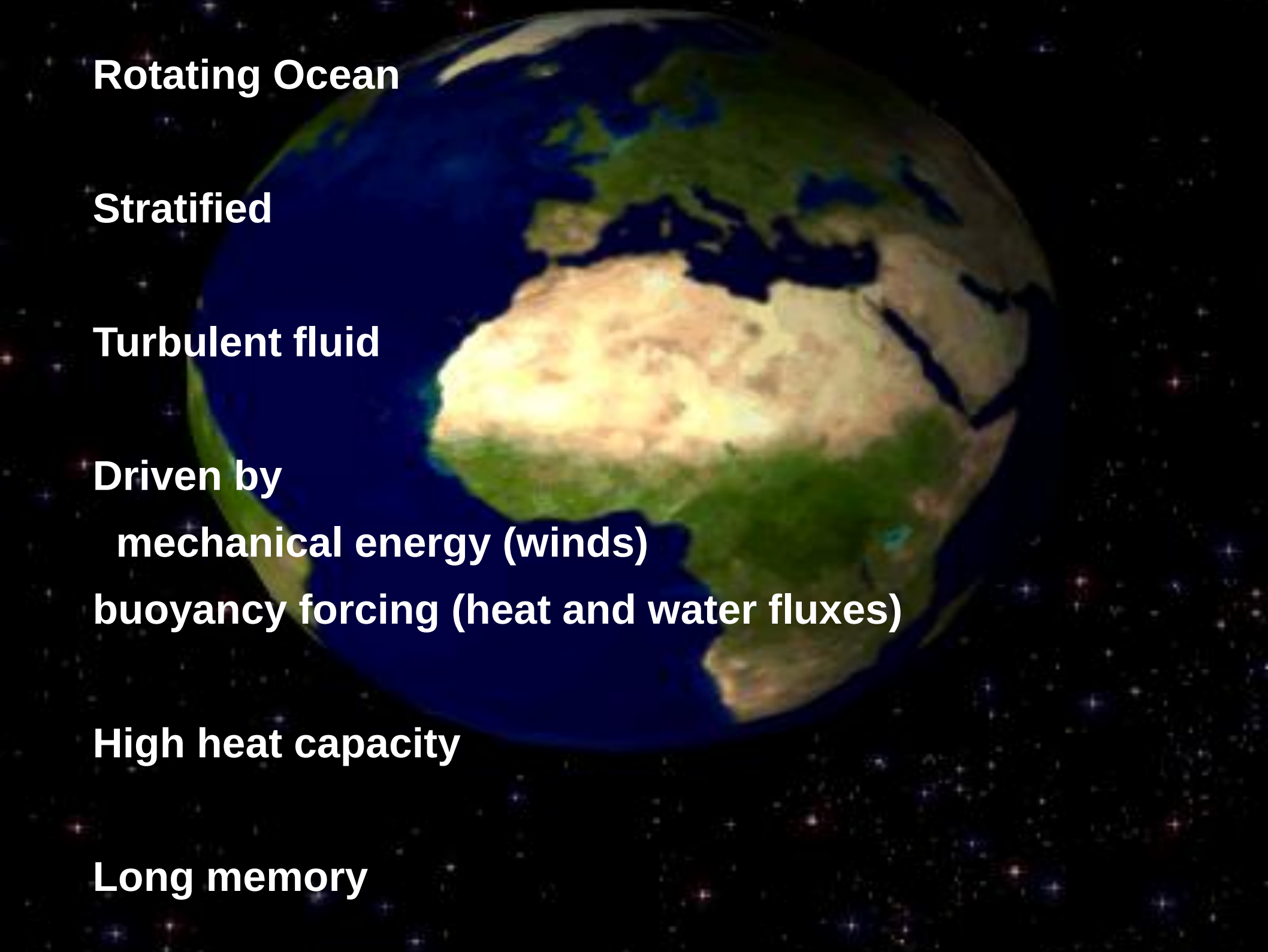
Ocean Modelling



Length / Depth = O(1000km) / O(1000m) << 1



Rotating Ocean

Stratified

Turbulent fluid

Driven by

mechanical energy (winds)

buoyancy forcing (heat and water fluxes)

High heat capacity

Long memory

Rotating Ocean

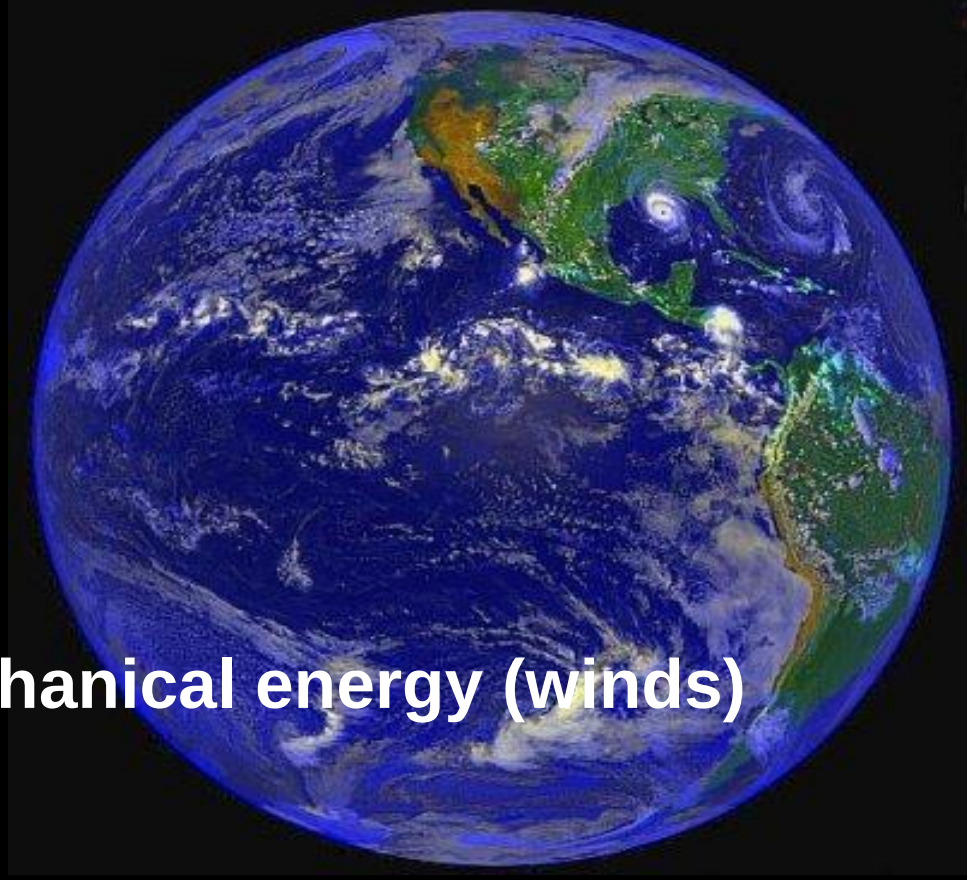
Stratified

Turbulent fluid driving by mechanical energy (winds)

Buoyancy forcing (heat and water fluxes)

High heat capacity

Long memory



Governing Equations

u-momentum

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} - fv = -\frac{1}{\rho}\frac{\partial p}{\partial x} + A_H\frac{\partial^2 u}{\partial x^2} + A_H\frac{\partial^2 u}{\partial y^2} + A_v\frac{\partial^2 u}{\partial z^2}$$

v-momentum

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + fu = -\frac{1}{\rho}\frac{\partial p}{\partial y} + A_H\frac{\partial^2 v}{\partial x^2} + A_H\frac{\partial^2 v}{\partial y^2} + A_v\frac{\partial^2 v}{\partial z^2}$$

hydrostatic

$$\frac{\partial p}{\partial z} = -\rho g$$

continuity

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

temperature

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = K_H\frac{\partial^2 T}{\partial x^2} + K_H\frac{\partial^2 T}{\partial y^2} + K_v\frac{\partial^2 T}{\partial z^2}$$

salinity

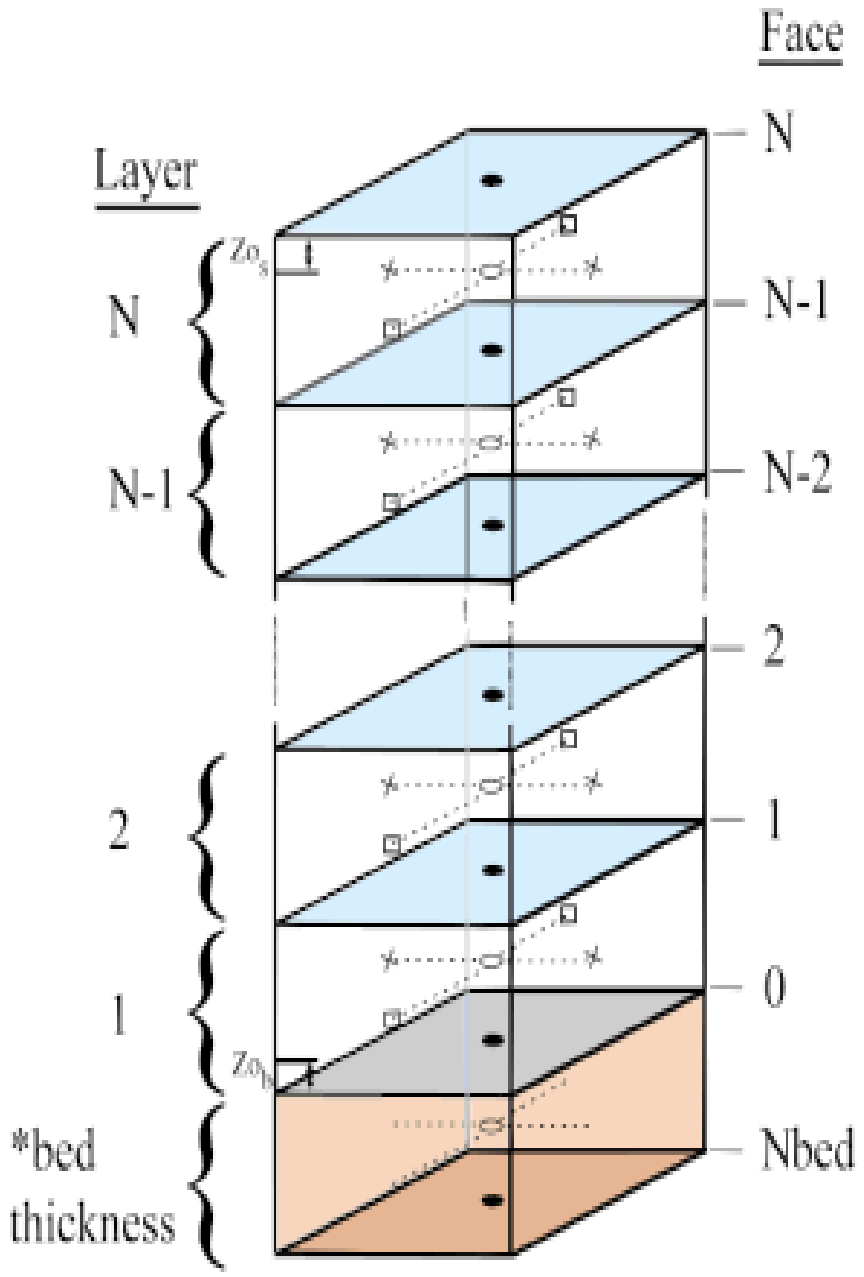
$$\frac{\partial S}{\partial t} + u\frac{\partial S}{\partial x} + v\frac{\partial S}{\partial y} + w\frac{\partial S}{\partial z} = K_H\frac{\partial^2 S}{\partial x^2} + K_H\frac{\partial^2 S}{\partial y^2} + K_v\frac{\partial^2 S}{\partial z^2}$$

density

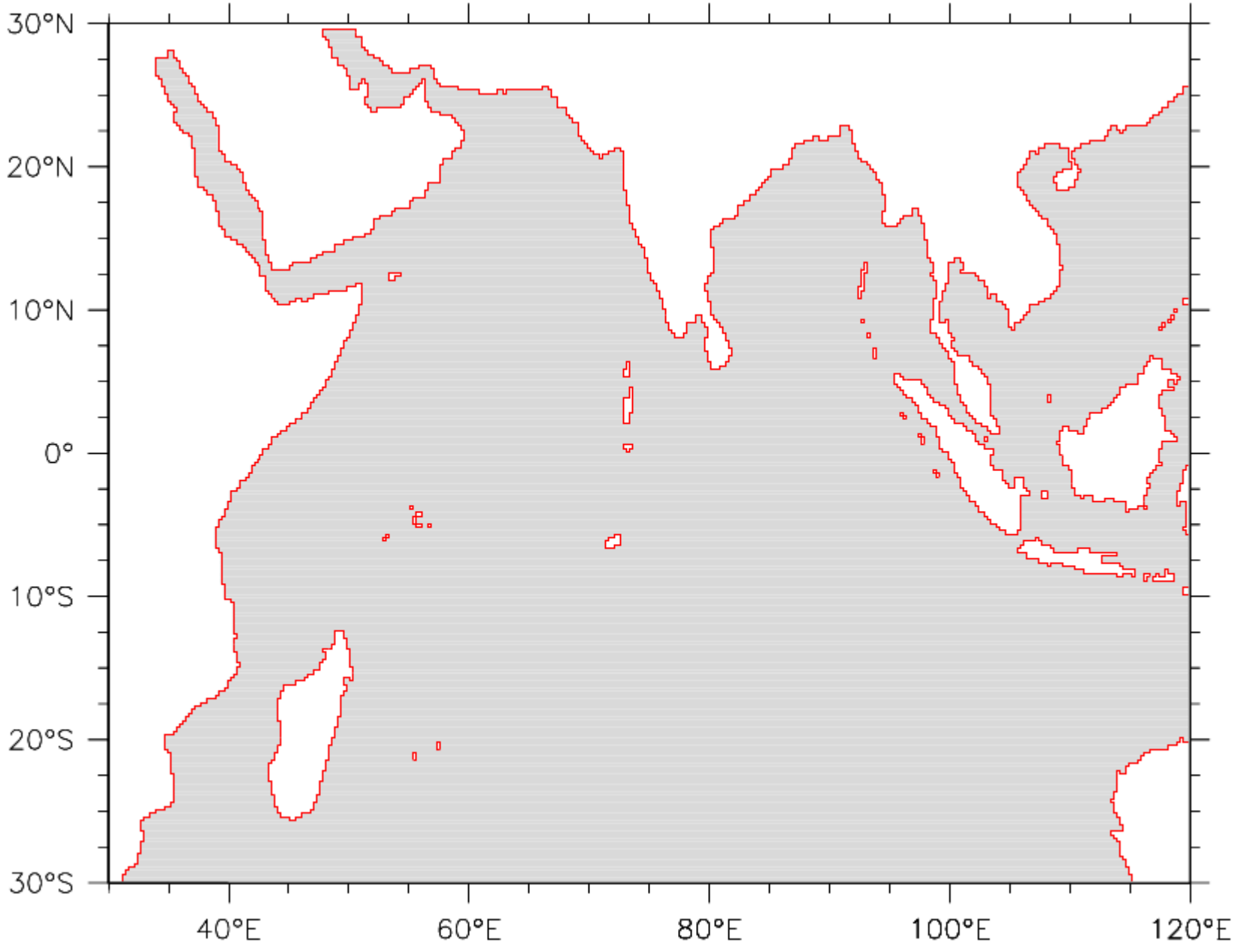
$$\rho = \rho(S, T, p)$$

Spherical co-ordinates

Grids



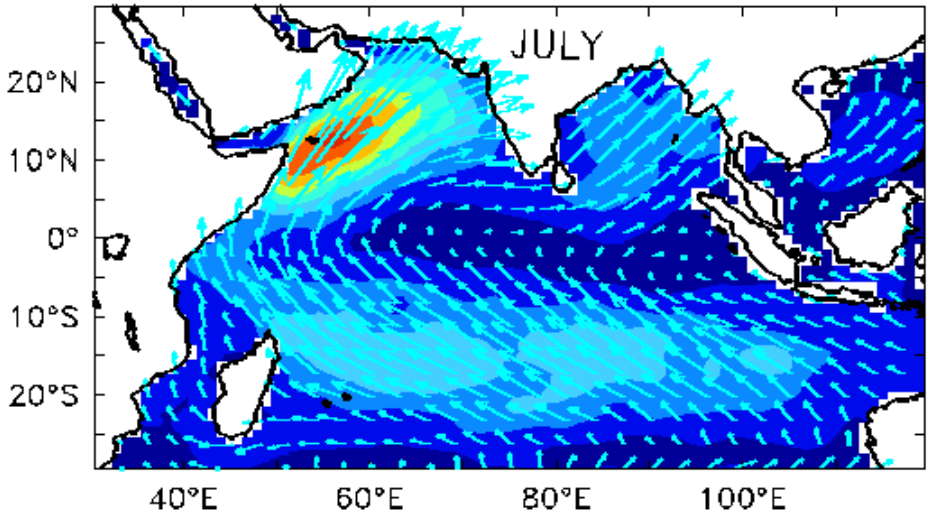
Indian Ocean Model Domain

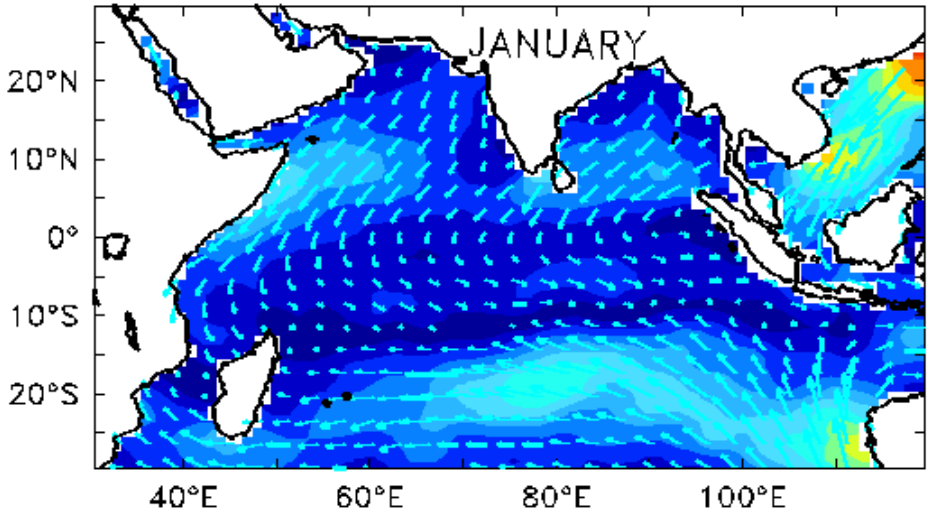


- **Base code GFDL MOM4, 30S-30N; 30E – 120E**
- **Horizontal resolution: 0.25º X 0.25º**
- **40 Vertical Levels, 5m resolution in the top 60m**
- **Horizontal mixing: Chassignet and Garaffo (2001)**
- **Vertical mixing: KPP (Large et al., 1994)**
- **Forced by daily data**
  - **Wind stress**
  - **Wind speed, air temperature, humidity**
  - **Incoming shortwave and longwave radiation**
  - **Rainfall and river discharge**

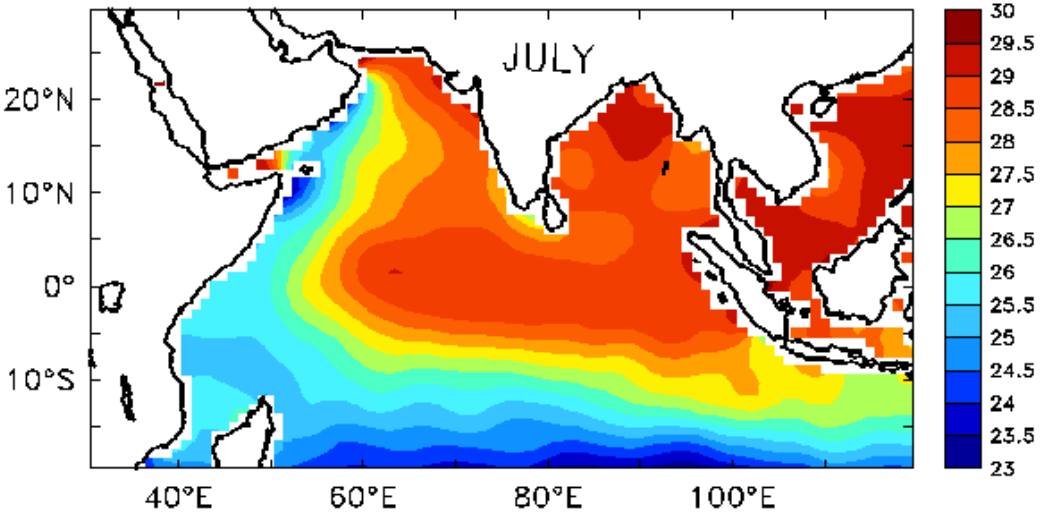
J. Kurian, Ph.D. Thesis, IISc, 2007
Kurian and Vinayachandran, J. Geophys. Res., 2007
Kurian and Vinayachandran, Geophys. Res. Lett., 2007

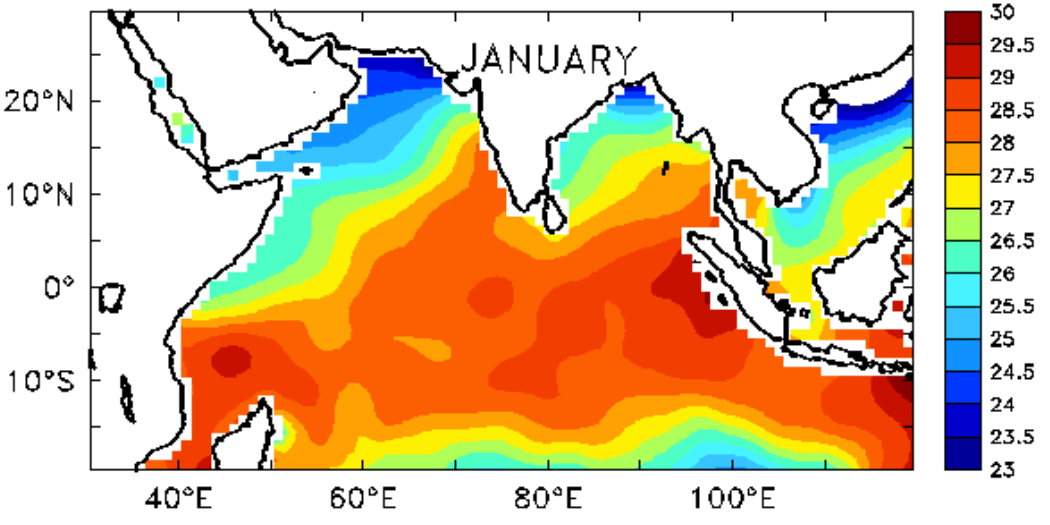
Winds



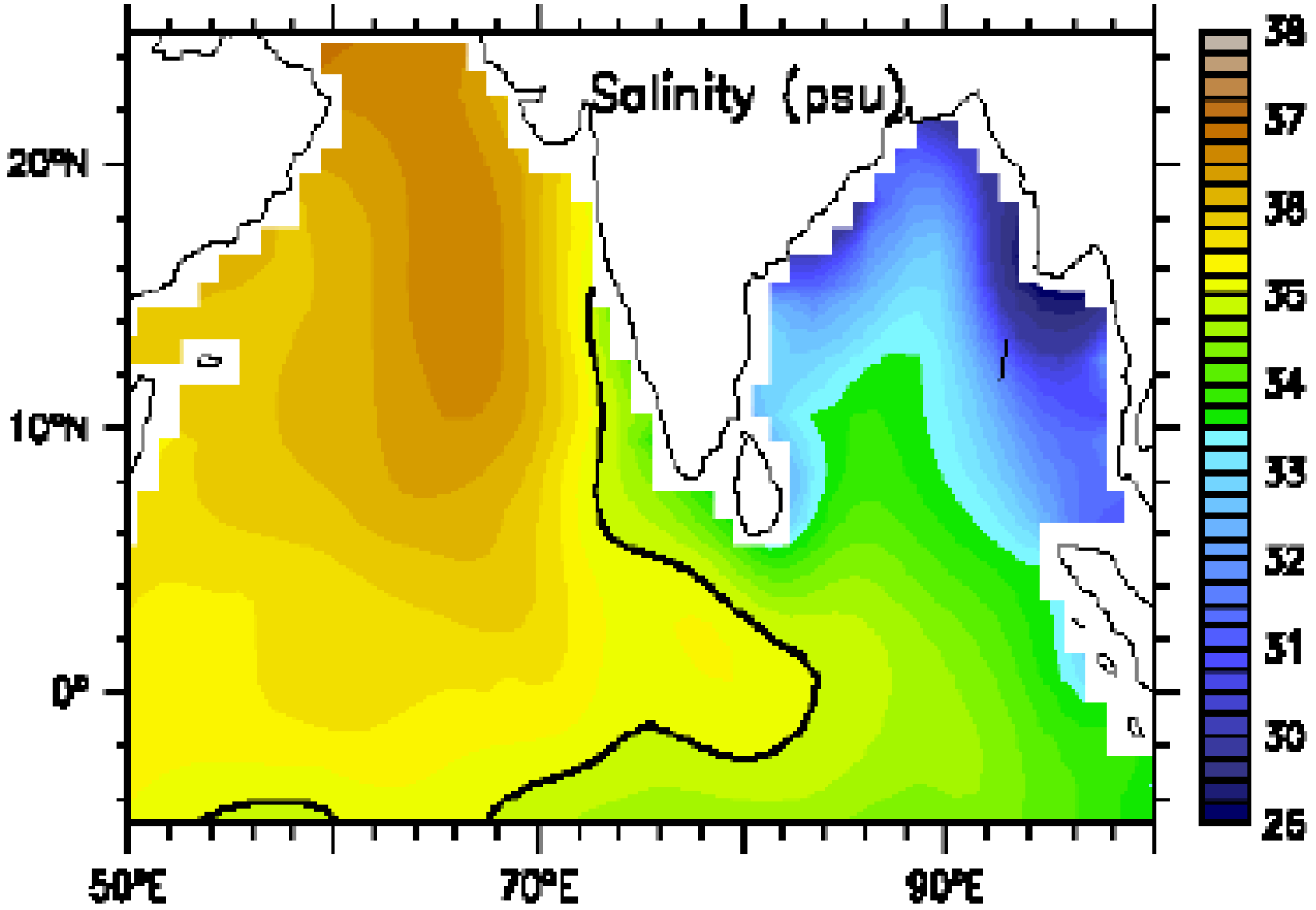


Temperature

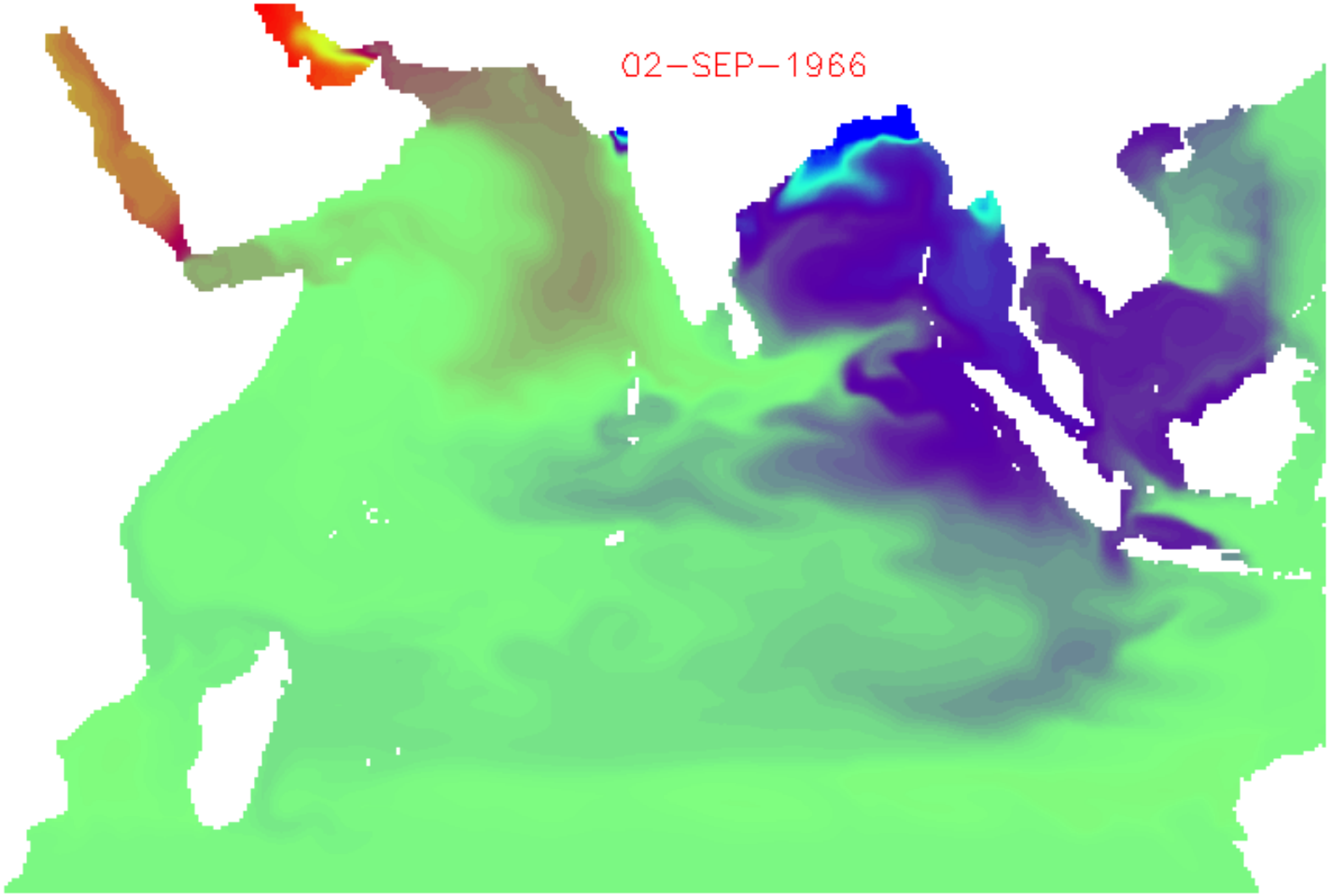




Salinity, December

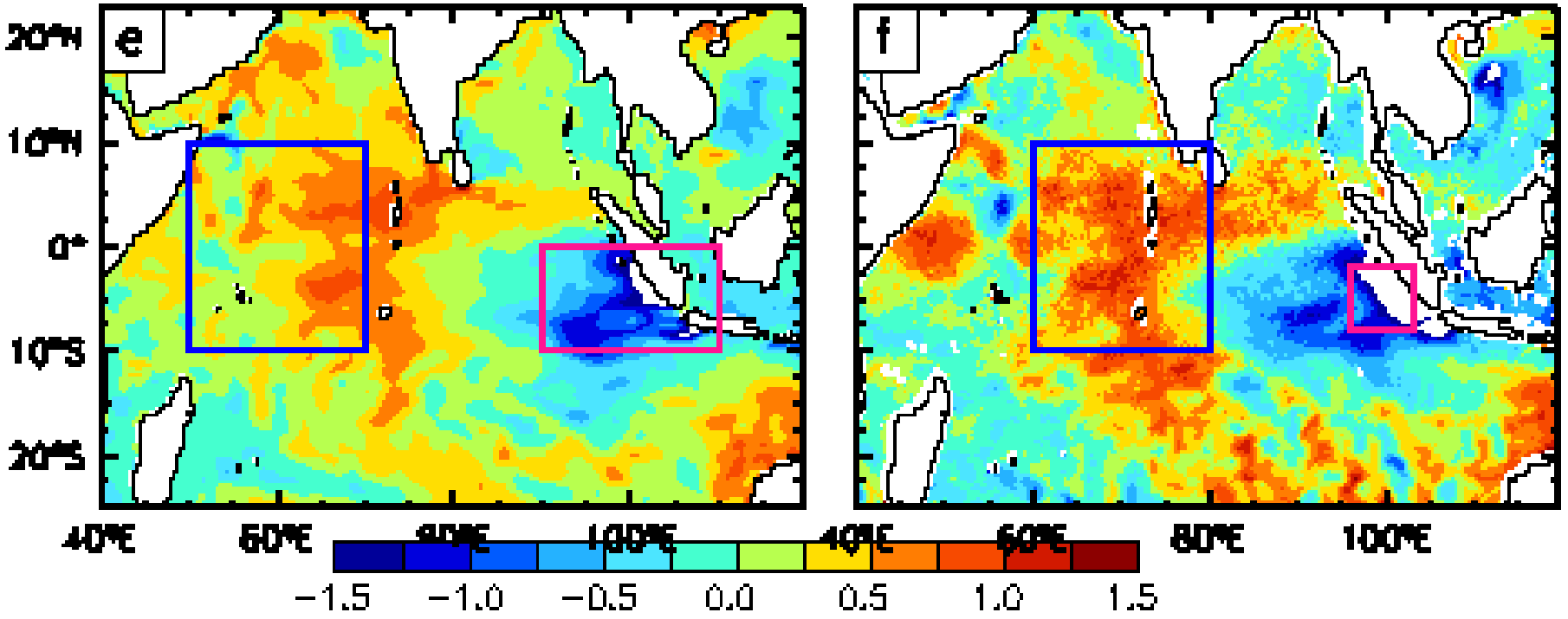


Simulation of Bay of Bengal River Plumes



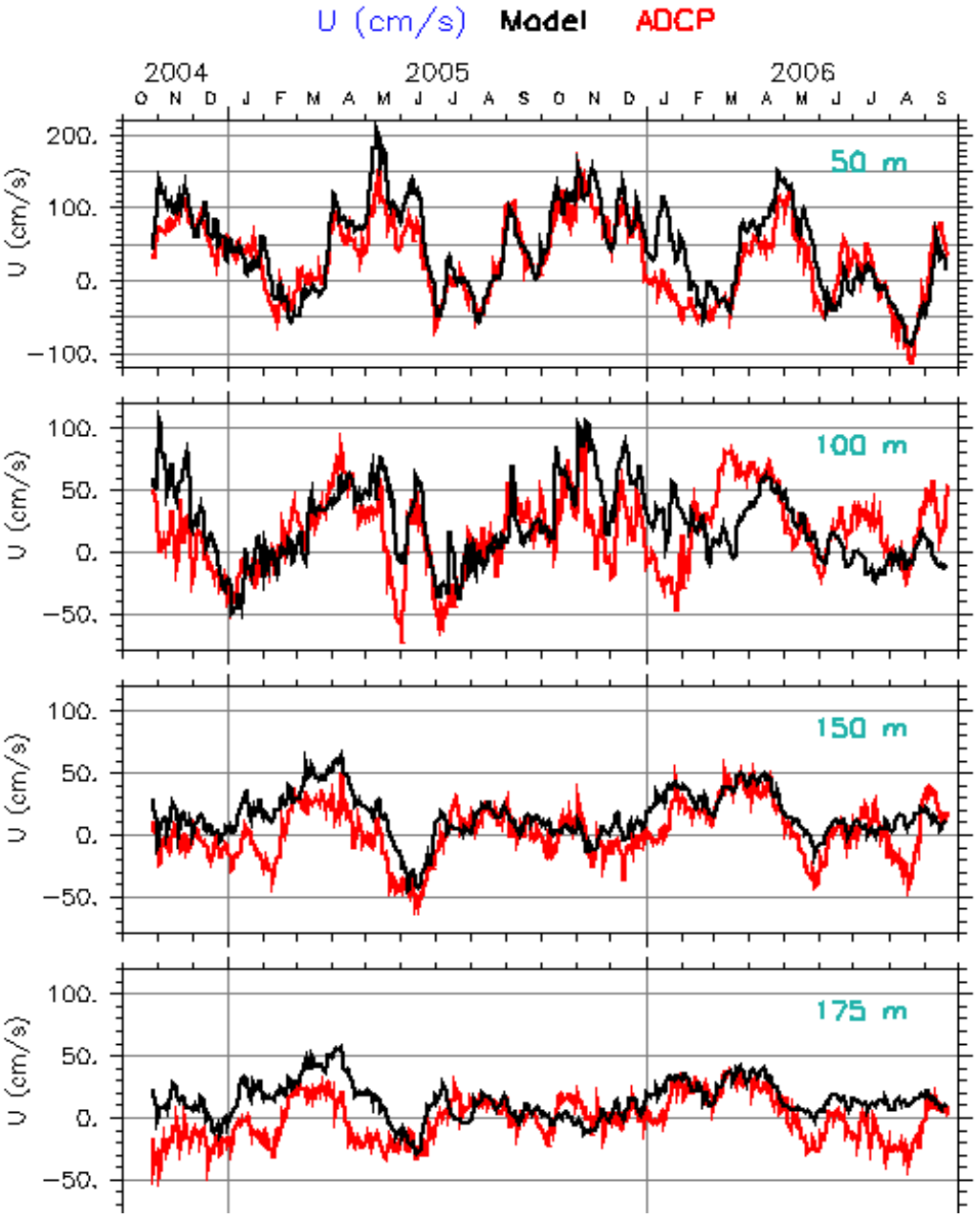
Vinayachandran and Kurian, Deep Sea Research, 2007

SSTA September 2006: Model – TMI Comparison



Vinayachandran et al., Geophys. Res. Lett., 2007

Current Meter Comparison



Three major reasons for the departure between simulation and observation

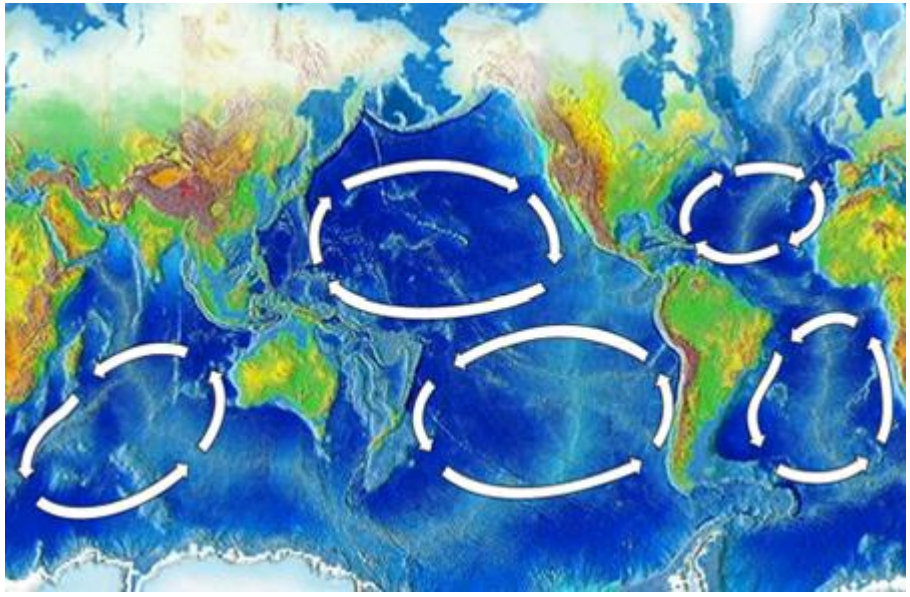
Unresolved physics

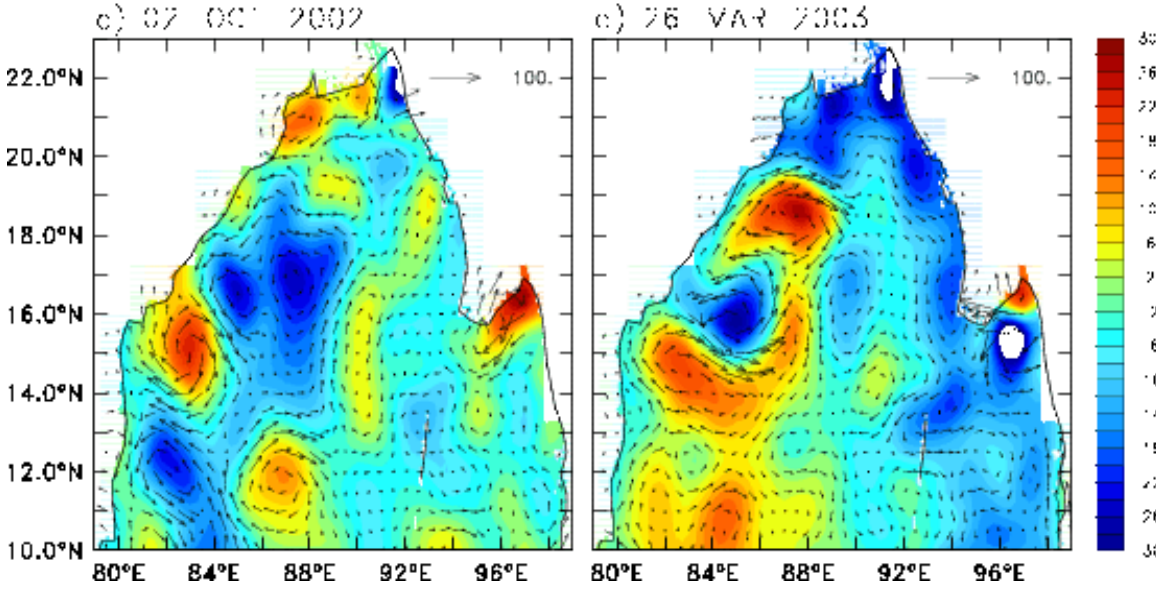
Unresolved length scales, horizontal & vertical

Defficiency of forcing fields

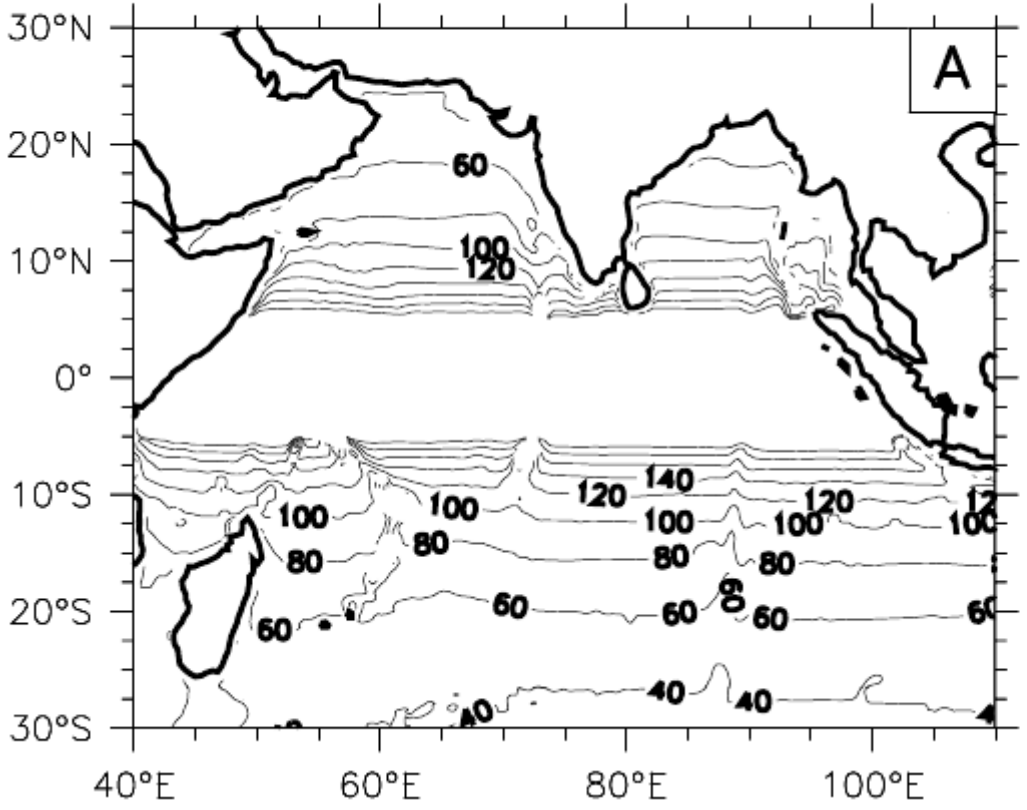
Length scales in the Ocean

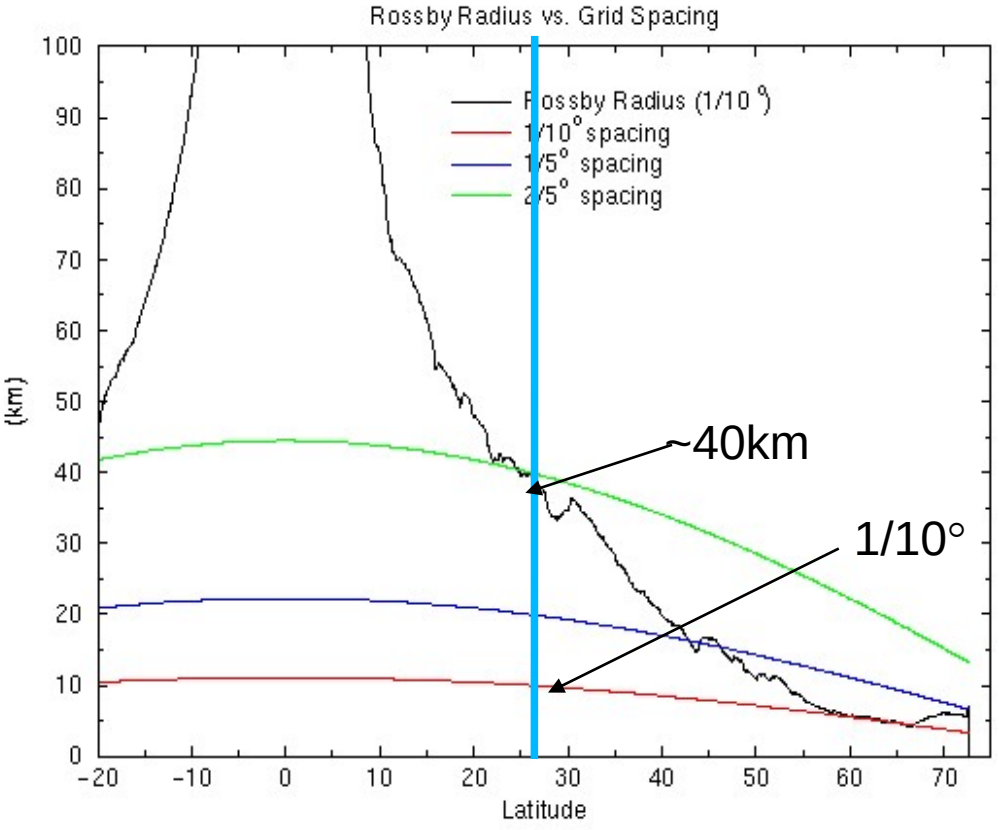
Ocean basins	$\sim$ 5000 to 10000 km
Horizontal gyres	basin scale
Western boundary currents	$\sim$ 100 km
Eddies	tens to hundreds of km
Depth of the ocean	$\sim$ 4 to 5 km, in the mid-ocean
Depth of surface currents	hundreds of metres



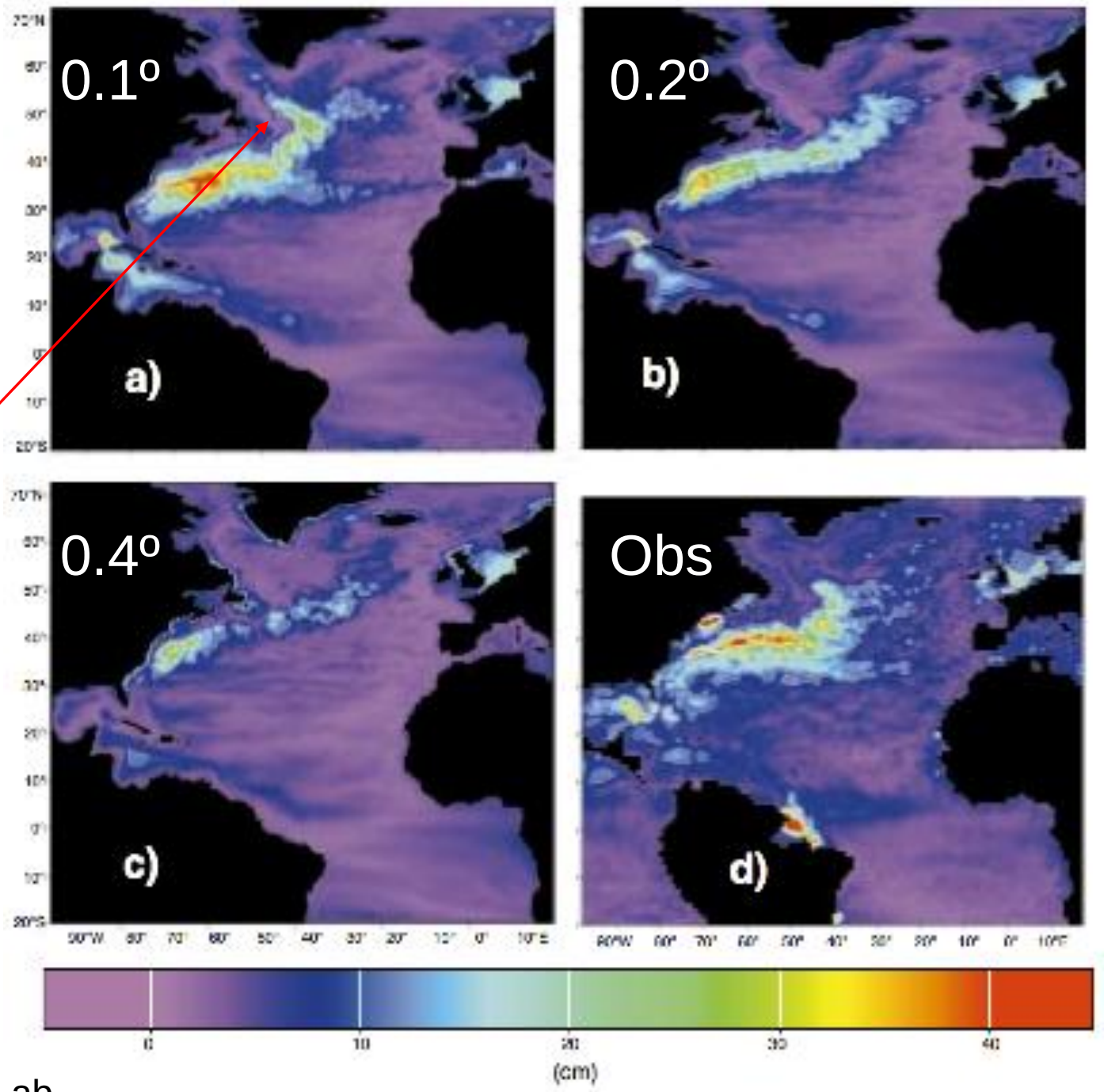


Horizontal grid spacing should resolve the length scale (Rossby Radius)

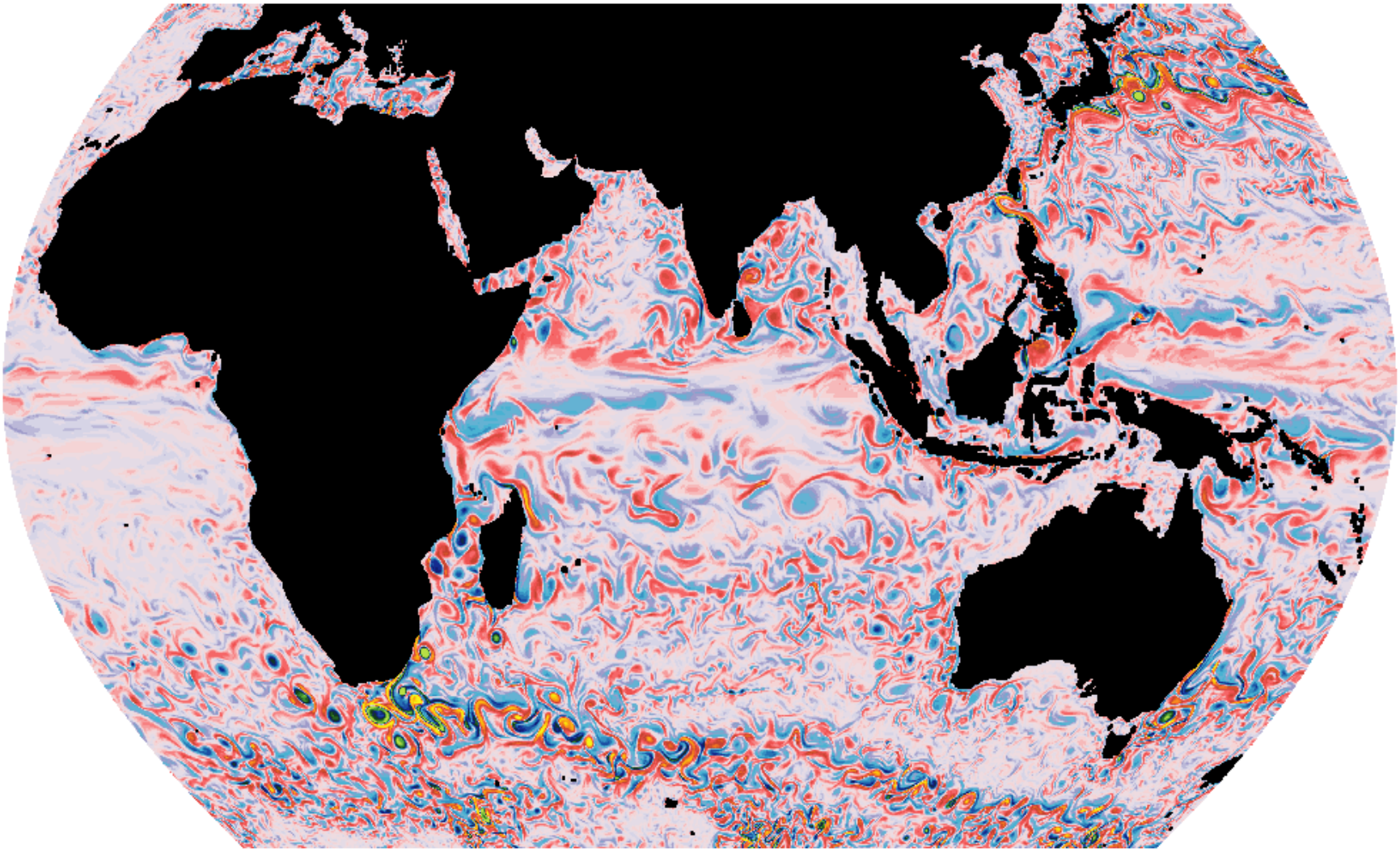




Note also that the North Atlantic Current formed at 0.1º

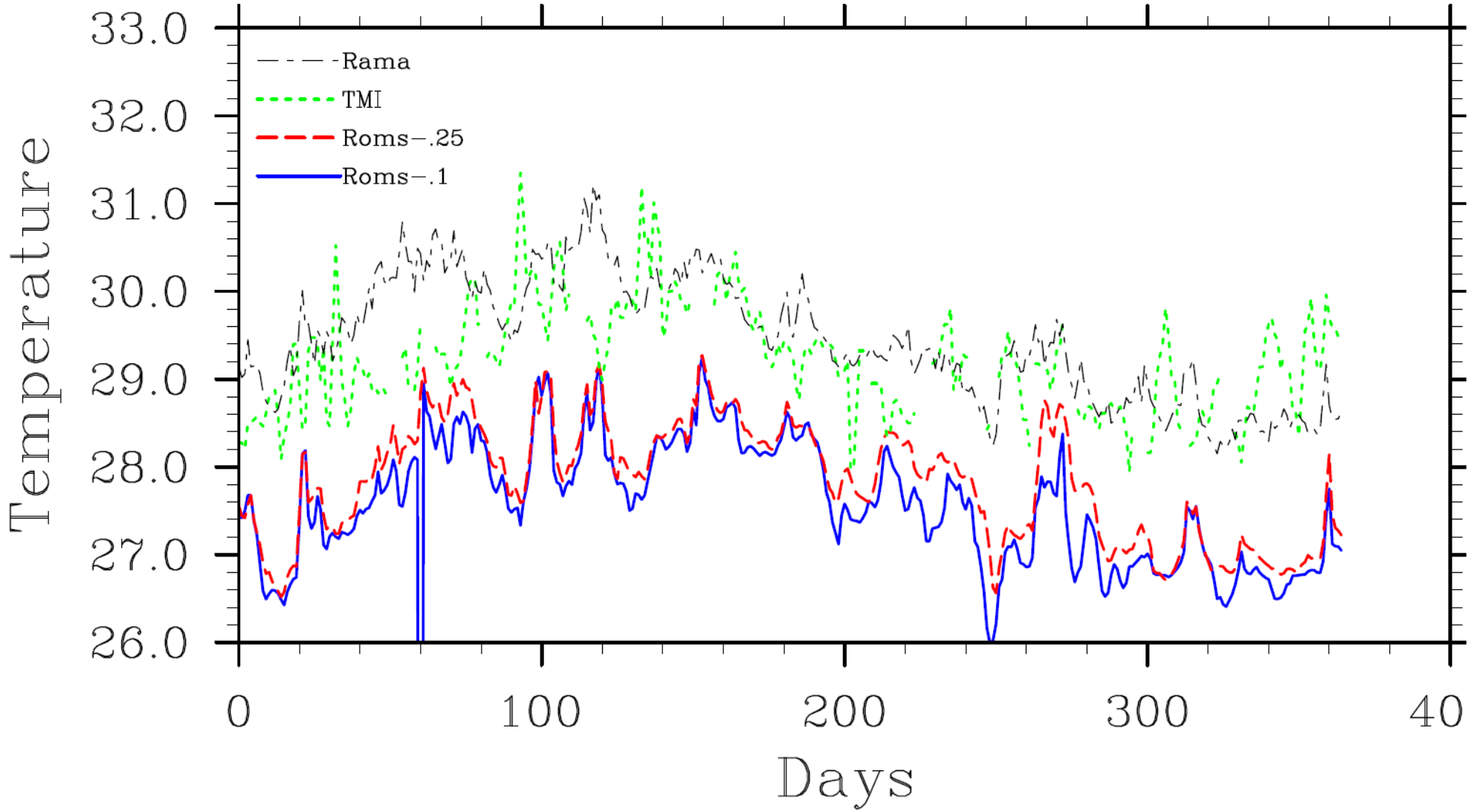


Oakridge National Lab.



snapshot of relative vorticity at 15m depth from 0.1 tripole

Oakridge National Lab.


Rama
TMI
Roms−.25
Roms−.1
Temperature
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
0
100
200
300
40
Days

Forcing: Impact of Diurnal Cycle

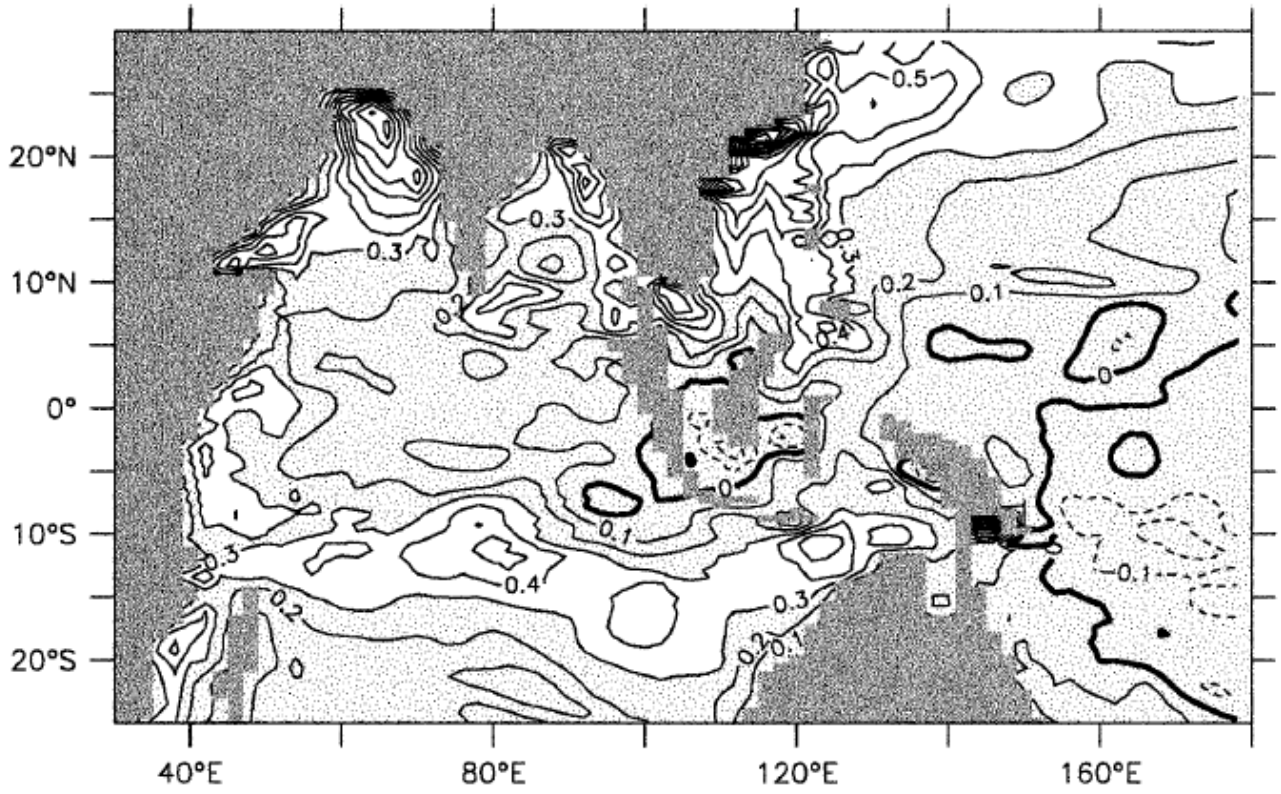


FIG. 11. Mean boreal spring–summer 1992 SST difference for model experiments with and without diurnal cycle in solar shortwave radiation. Contour interval is 0.1°C. Shaded areas denote regions with $-0.3 \leq \Delta SST \leq 0.3$°C.

Schiller & Godfrey, J. Climate, 2003

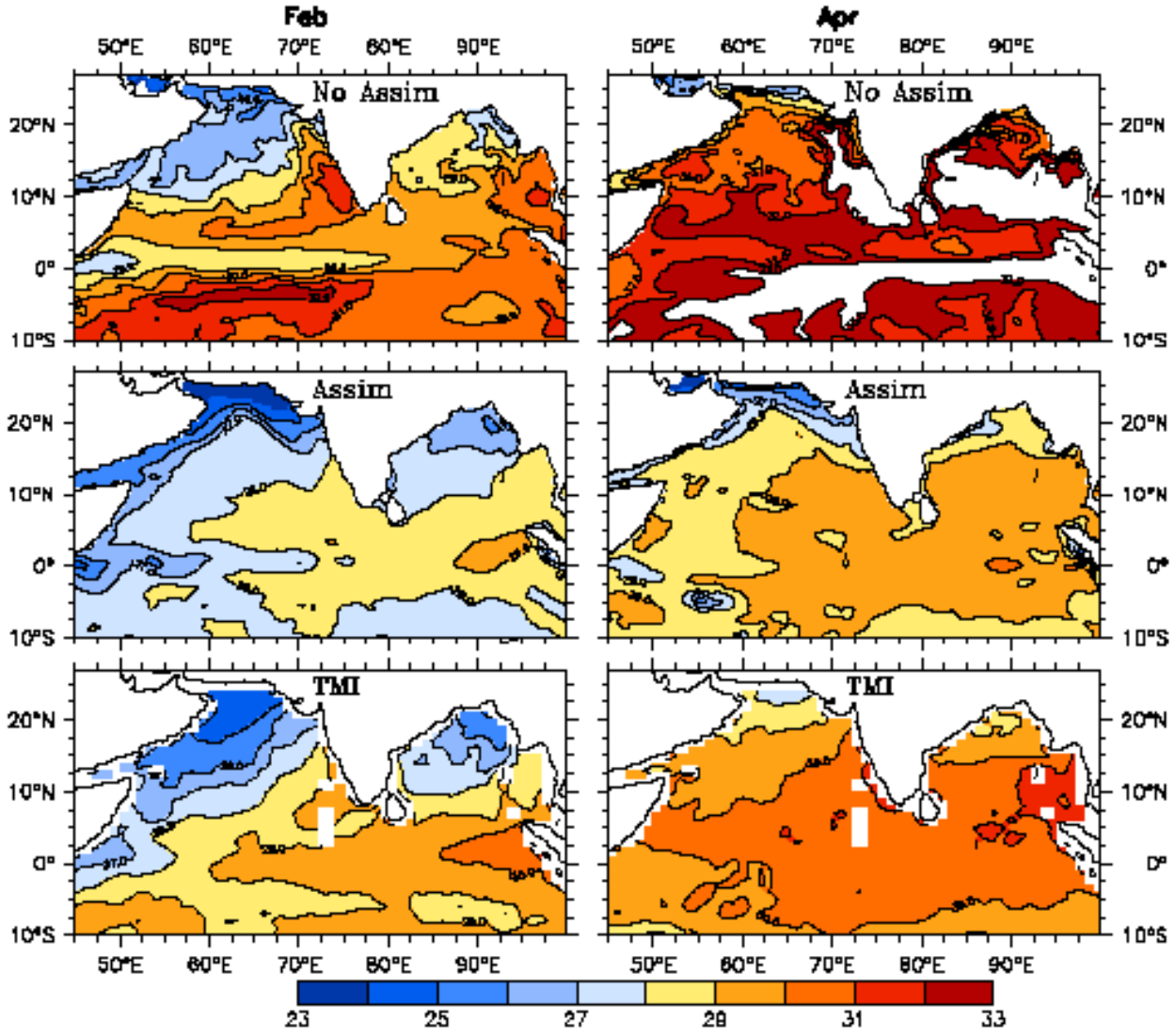
Data Assimilation Experiments using an Indian Ocean General Circulation Model

Aneesh C. S.

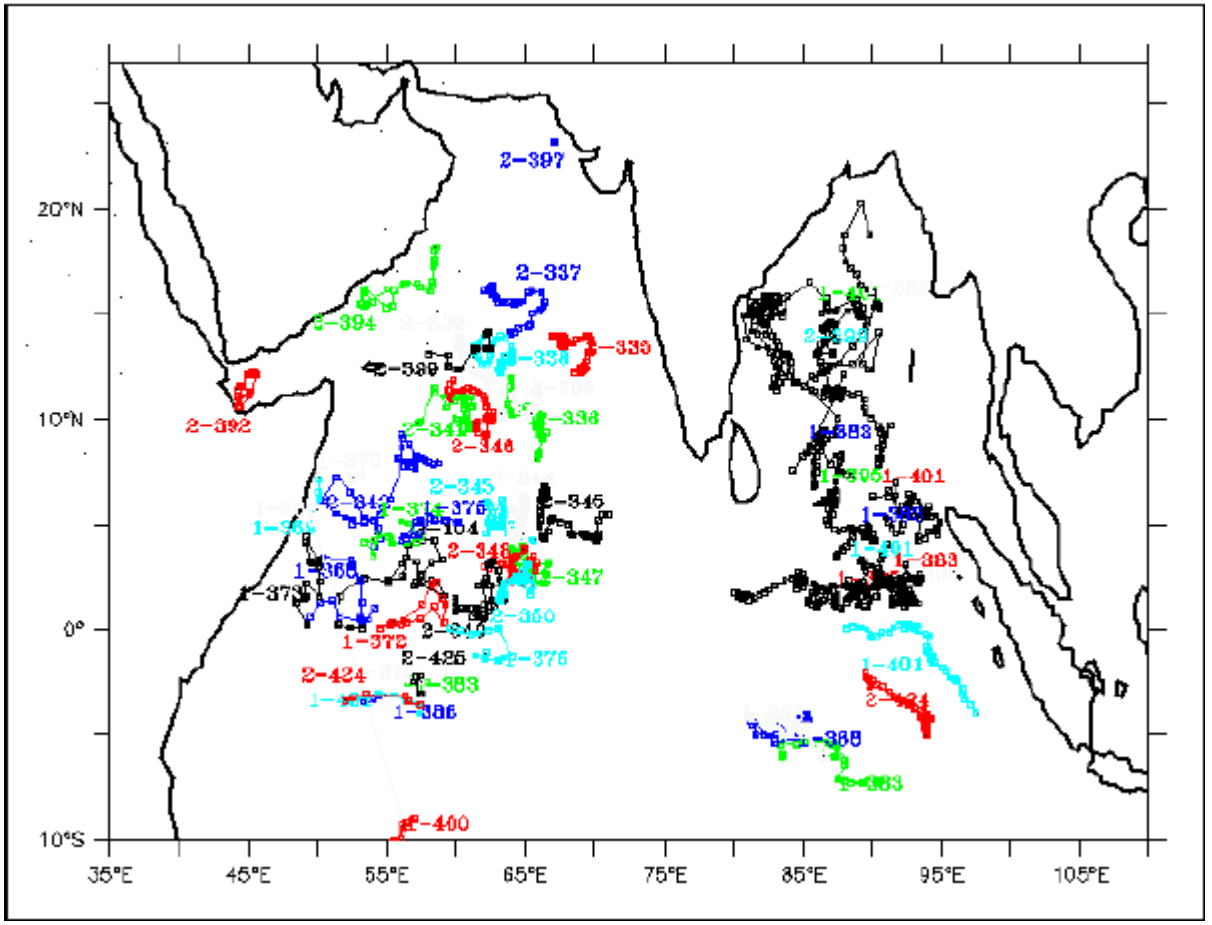
M. Sc. (Engg.) Thesis

CAOS, IISc

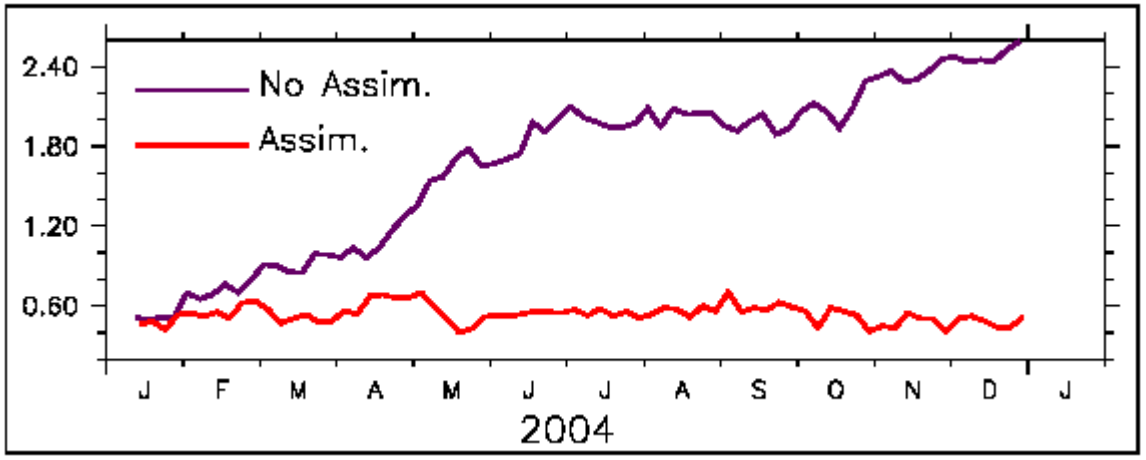
August 2006


Feb
Apr
No Assim
No Assim
Assim
Assim
TMI
TMI
50°E
60°E
70°E
80°E
90°E
20°N
10°N
0°
10°S
23
25
27
29
31
33

Argo Trajectories in the Indian Ocean -2004

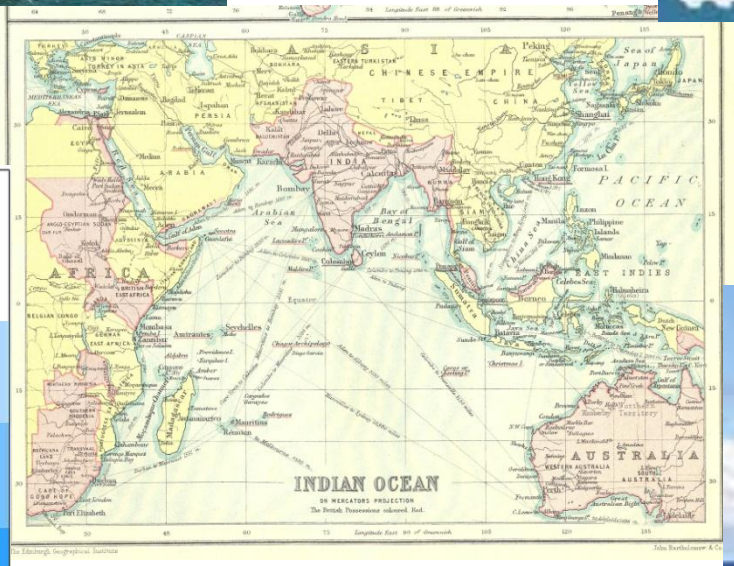


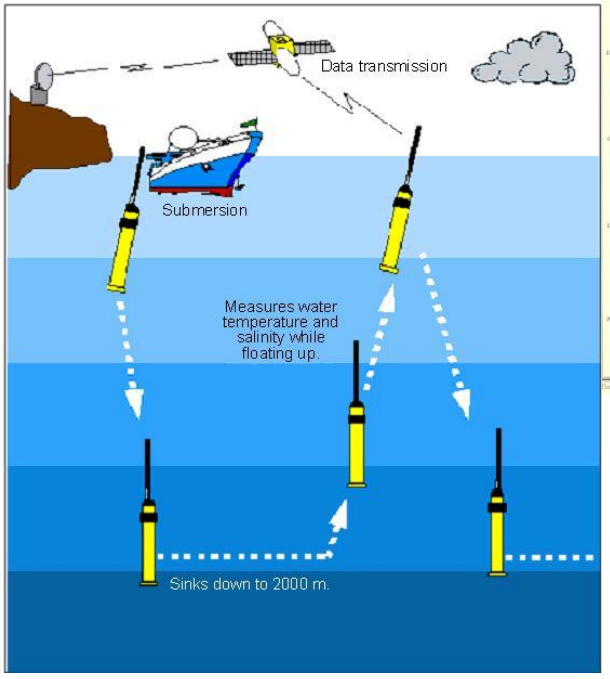
RMSE between model SST (with and without Assimilation) and TMI SST data



Challenges


भारत
INDIA
3.00
ओशनसैट-1 OCEANSAT-1


INDIAN OCEAN
PACIFIC OCEAN
AUSTRALIA
AFRICA
EAST INDIES
CHINESE EMPIRE


Data transmission
Submersion
Measures water temperature and salinity while floating up.
Sinks down to 2000 m.

Ocean Modeling At CAOS

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Prof. Amit Apte (TIFR)
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Thank you