ISSUES IN PREDICTING SOLITARY WAVES IN STRAITS OF MESSINA AND LUZON

A. Warn-Varnas, P. Smolarkiewicz, J. Hawkins, S. Piacsek, S. Chin-Bing, D. King and J. Cazes.

SMOLARKIEWICZ 1997 NH MODEL IN MESSINA REGION

$$
\begin{aligned}
\frac{\mathcal{D}\mathbf{v}}{\mathcal{D}t} &= -\mathrm{Grad}\,(p') - \mathbf{g}\frac{\rho'}{\rho_0} - \mathbf{f}\times\mathbf{v}' \\
\frac{\mathcal{D}T}{\mathcal{D}t} &= 0 \quad , \\
\frac{\mathcal{D}S}{\mathcal{D}t} &= 0 \quad , \\
\mathrm{Div}\,(\mathbf{v}) &= 0 \quad .
\end{aligned}
$$

Initially temperature and salinity profiles are introduced into the model. The model is forced by applying a semidiurnal barotropic tidal forcing on the boundaries as :

$$u_{bc} = V_T \cos(\omega t + \phi)$$

Grid resolution is :

$$\Delta x = \Delta y = 50m$$

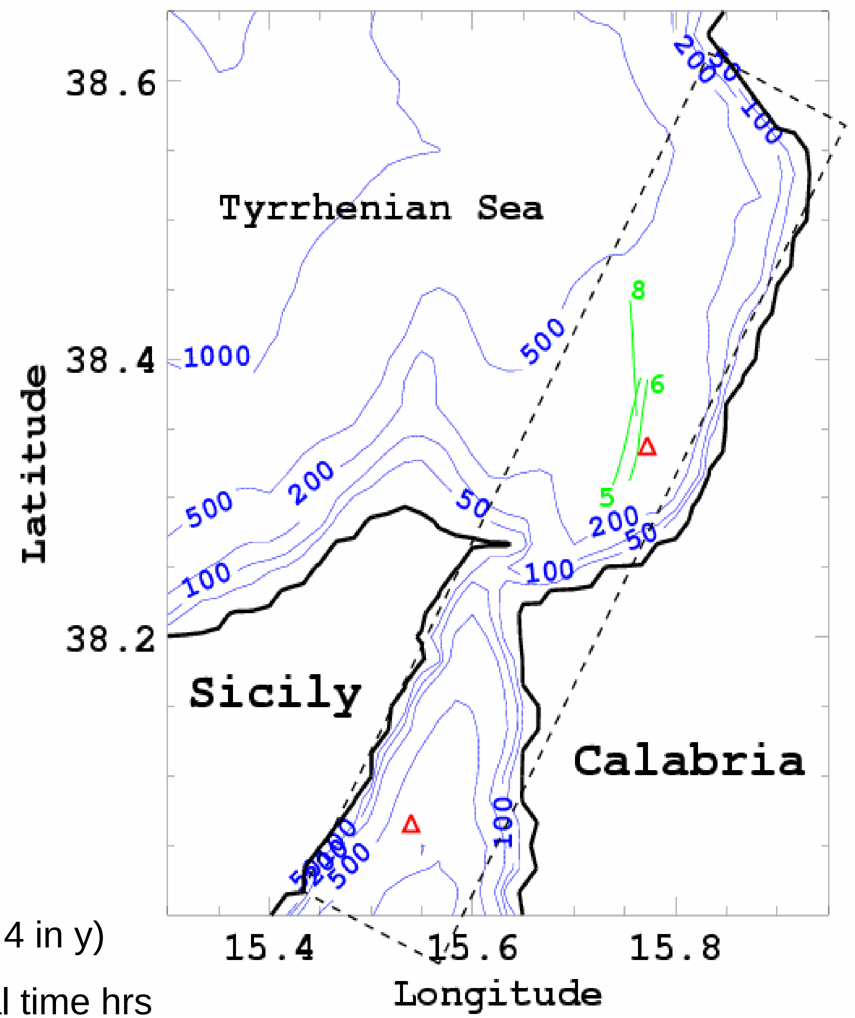
$$\Delta z = .8m \ to \ 4m$$

$$\Delta t = .75s$$

Computer usage:

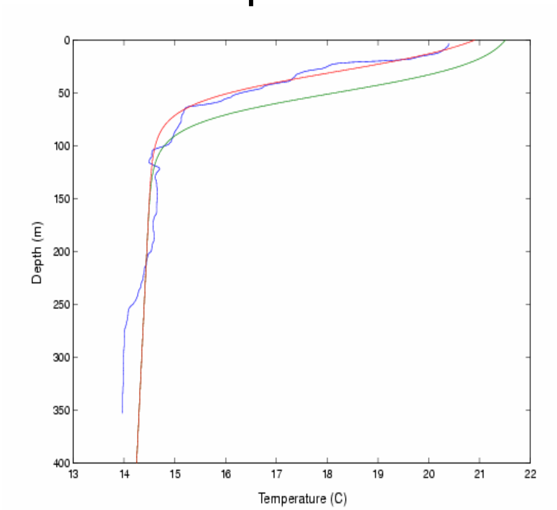
160 processors (40 in x, 4 in y)

12 hours of cpu for 2 real time hrs

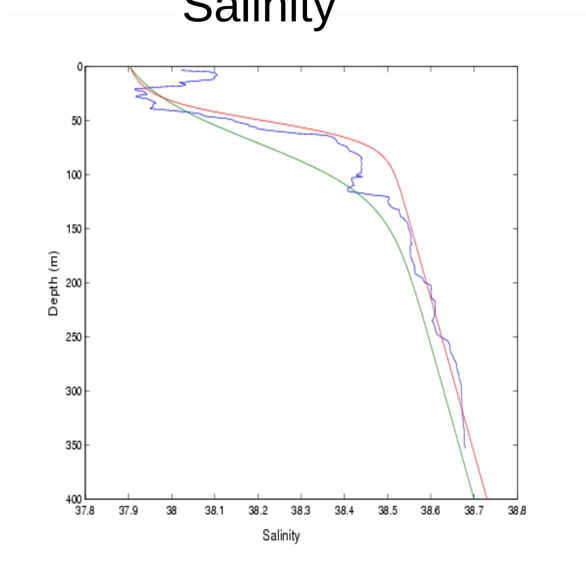


PARAMETER VARIATION STUDIES

Temperature



Salinity

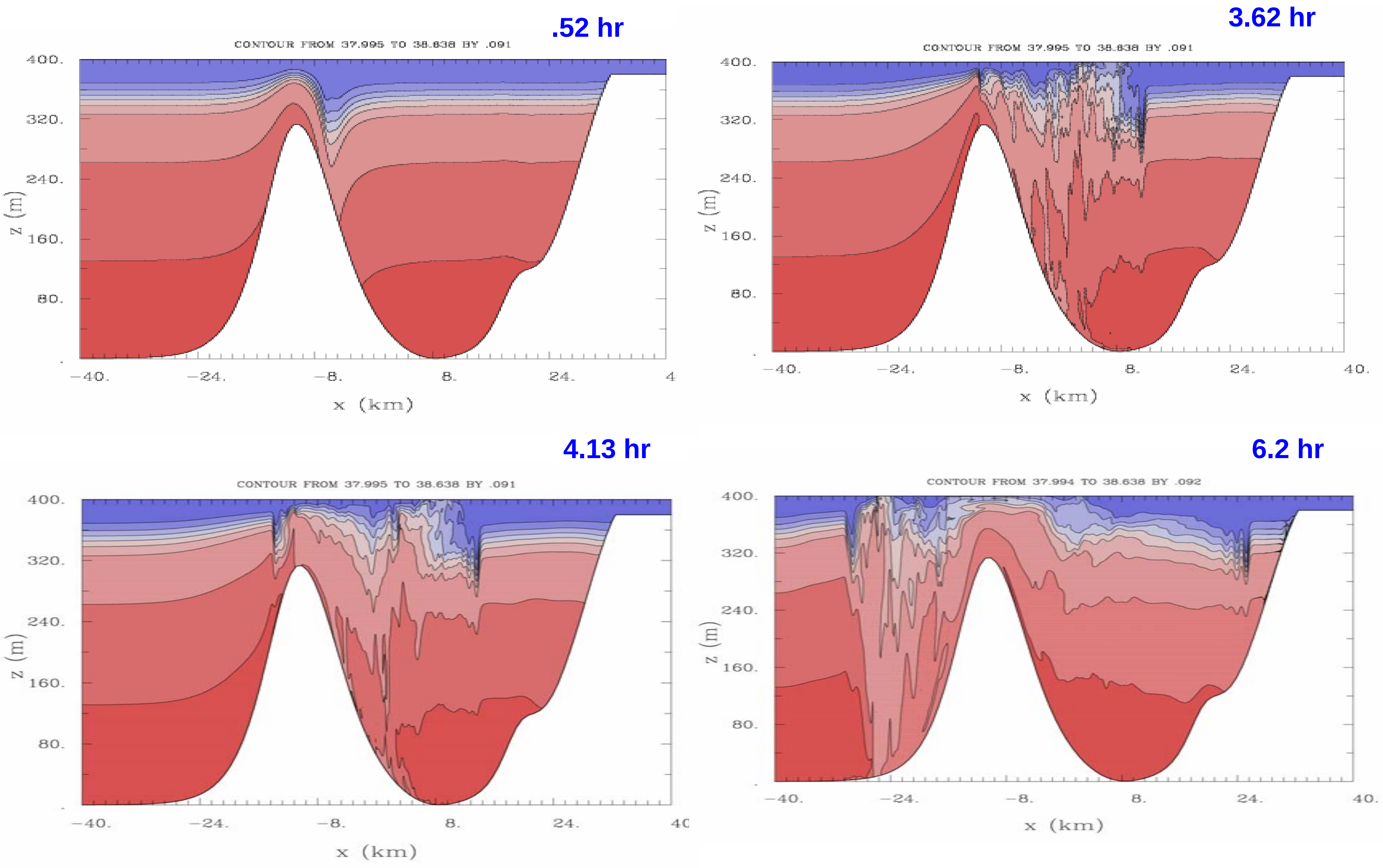


Case	$P_T(m)$	$P_S(m)$	$V_T(m/s)$
1	**40**	**50**	**.5**
2	**40**	**50**	**.25**
3	**60**	**70**	**.5**

Analytical fit for temperature and salinity:

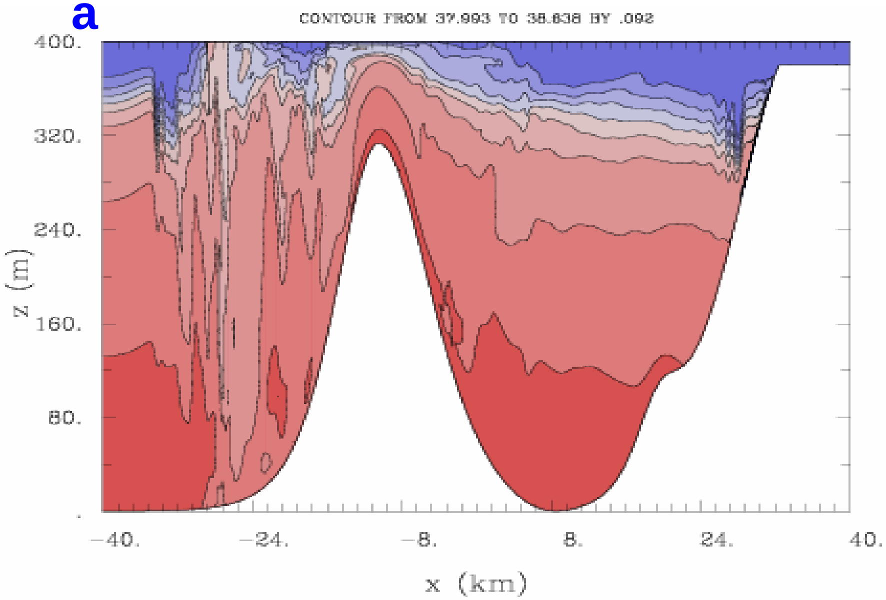
$$\varphi = a + b\,z + c(1 - \tanh\frac{z+d}{e})$$

GENERATION AND PROPAGATION

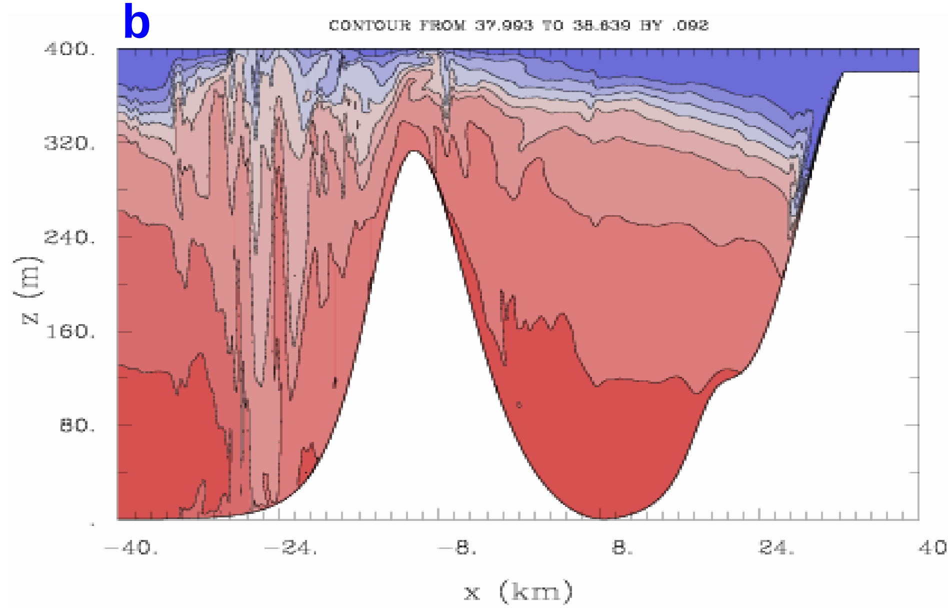


Shoaling in Gulf of Gioia

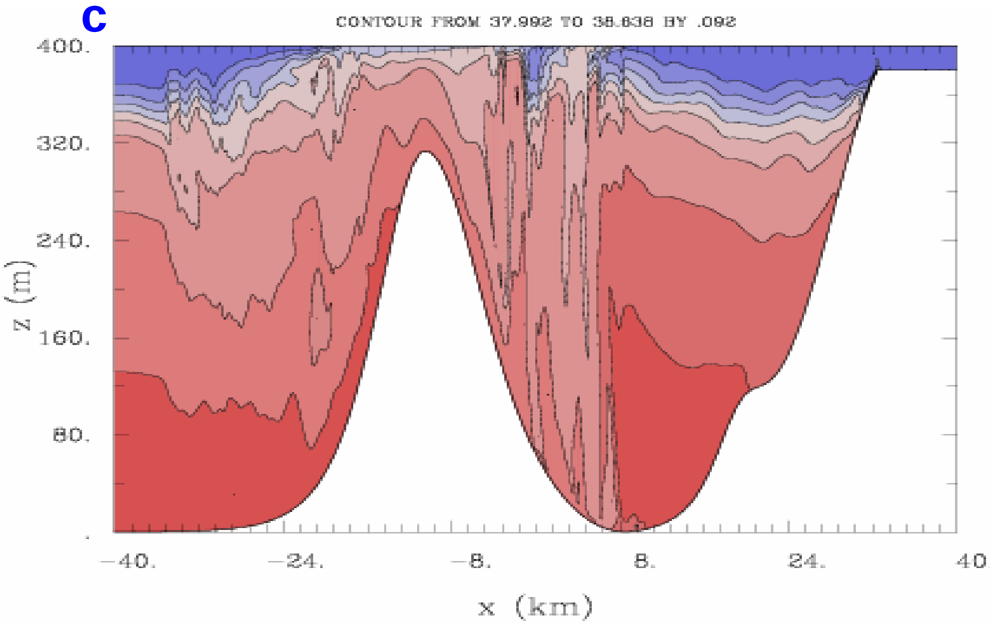
a



b

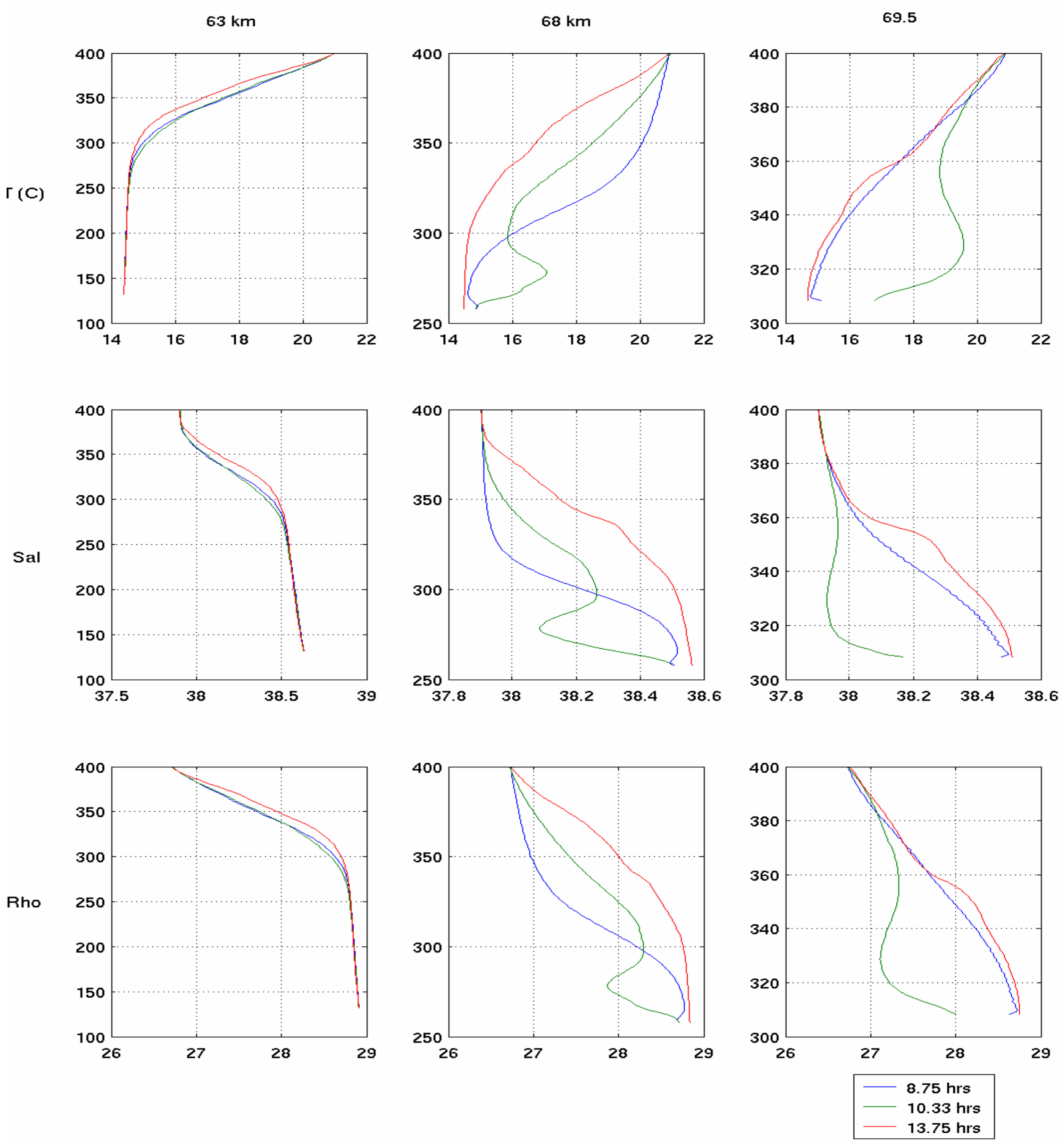


c

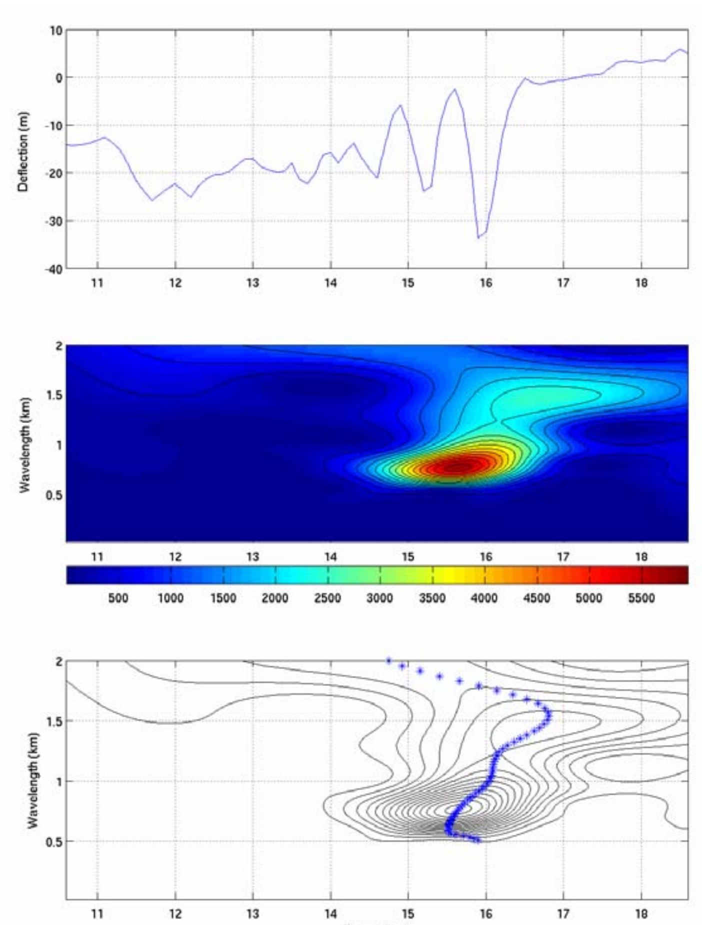


Results for a plane at j=51. Salinity contours range from 37.992 to 38.638 by .02. a) Isohalines at 8.78 hours, b) Isohalines at 10.33 hours and c) Isohalines at 13.95 hours.

Shoaling at 3 sites in Gulf of Gioia



WAVELET ANALYSIS



a) Isopycnal contour at a time of 617.95 hours (labeling from top to bottom). b) Intensity as function of wavelength and range. c) Black line is the spine that tracks the maximum intensity for each wavelength. Background shows the contours of part b) that extend from 371.08 to 5566.3 and span 11.76 db.

Wavelet transform

$$T_g(b,a) = \frac{1}{\sqrt{a}} \int g\left(\frac{x-b}{a}\right) f(x)dx$$

$$g_{ba}(x) = \frac{g}{\sqrt{a}}\left(\frac{x-b}{a}\right)$$

discrete form

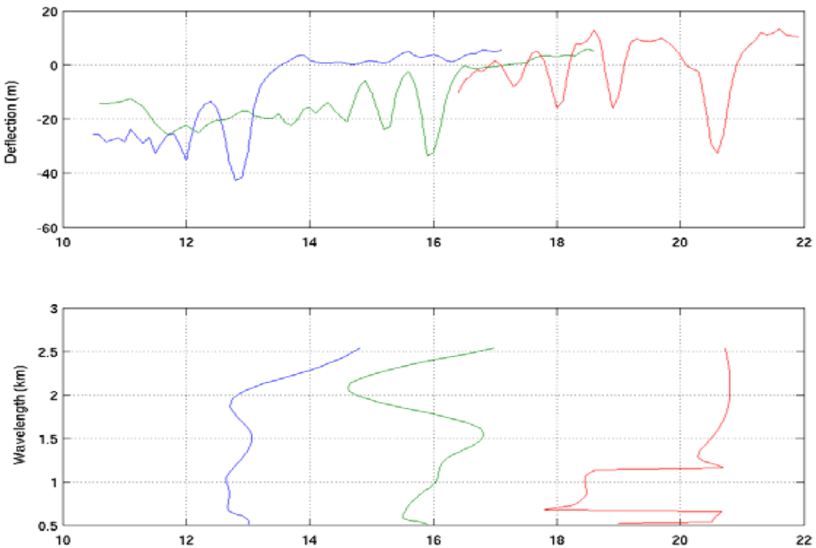
$$T_n(b) = \sum_{k=0}^{N-1} \hat{f}_k \hat{g}^*(b\omega_k) \exp\left(i\omega_k n\delta x\right)$$

$$\hat{f}_k = \frac{1}{N}\sum_{n=0}^{N-1} f_n \exp\left(-2\pi i k n/N\right)$$

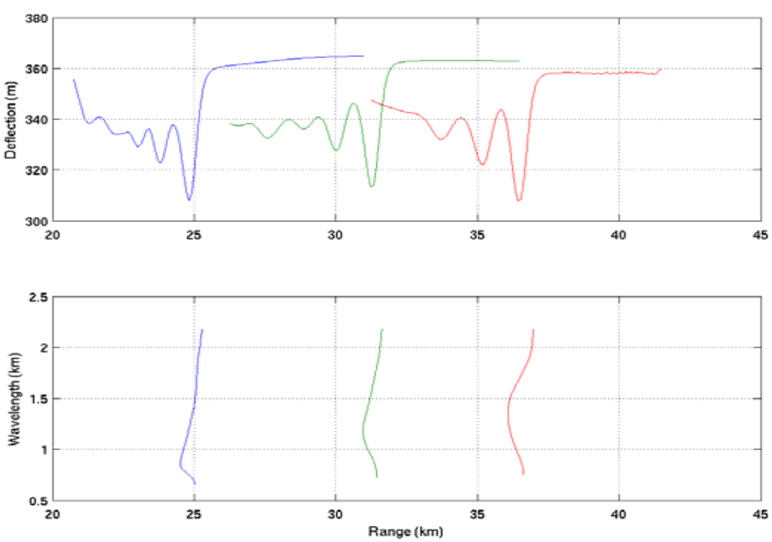
$$g_0(x) = \pi^{-1/4} \exp\left(i\omega_0 x\right) \exp\left(-x^2/2\right)$$

WAVELET ANALYSIS

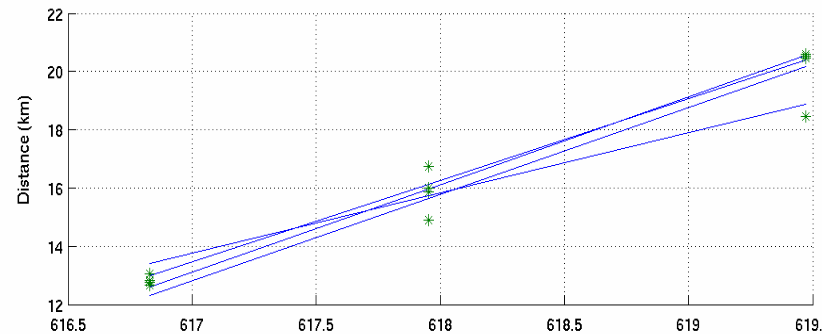
Data

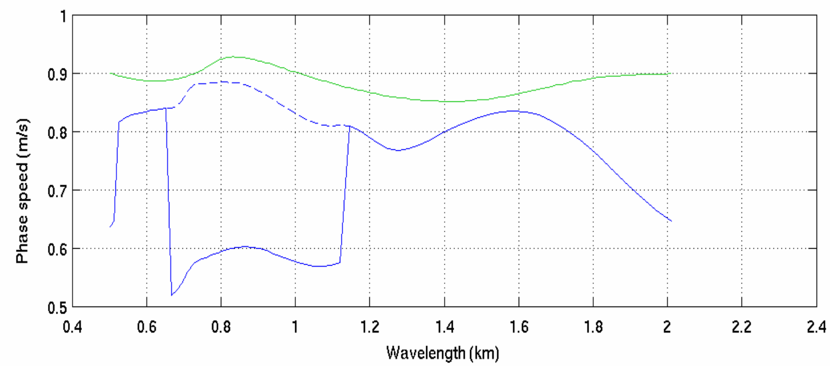


Model



Data and model phase speeds



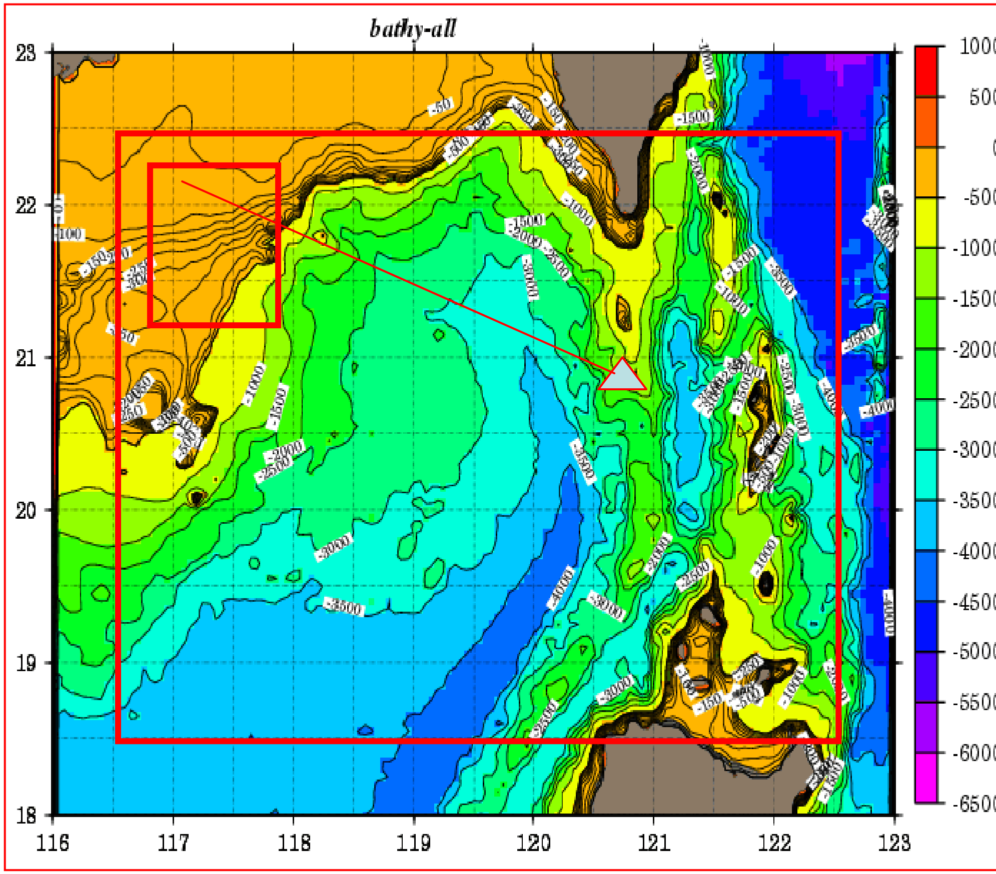


a) The measured wavelengths tracked by the spines in range are plotted at the times of 616.83 hours, 617.95 hours, and 619.47 hours (top panel). b) Phase speeds calculated from the slopes as a function wavelength (lower panel). Green curve is derived from model predictions and blue curves from measurements.

SMOLARKIEWICZ 1997 NH MODEL IN SOUTH CHINA SEA

$$
\begin{aligned}
\frac{\mathcal{D}\mathbf{v}}{\mathcal{D}t} &= -\mathrm{Grad}\,(p') - \mathbf{g}\frac{\rho'}{\rho_0} - \mathbf{f}\times\mathbf{v}' \quad ,\\
\frac{\mathcal{D}T}{\mathcal{D}t} &= 0 \quad ,\\
\frac{\mathcal{D}S}{\mathcal{D}t} &= 0 \quad ,\\
\mathrm{Div}\,(\mathbf{v}) &= 0 \quad .
\end{aligned}
$$

Strait of Luzon & South China Sea



Initially temperature and salinity profiles are introduced into the model. The model is forced by applying barotropic tidal forcing on the boundaries or over the region or analytical tidal functions.

Grid resolution is :

$67m \le \Delta x \le 500m$

$1km \le \Delta y \le 21km$

$2.5m \le \Delta z \le 40m$

$1s \le \Delta t \le 5s$

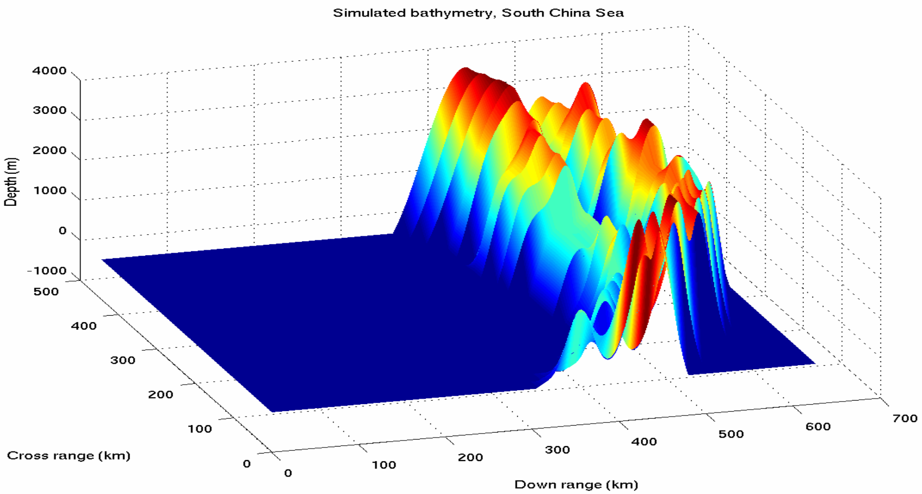
Computer usage:

32 processors (32 in x, 1 in y)

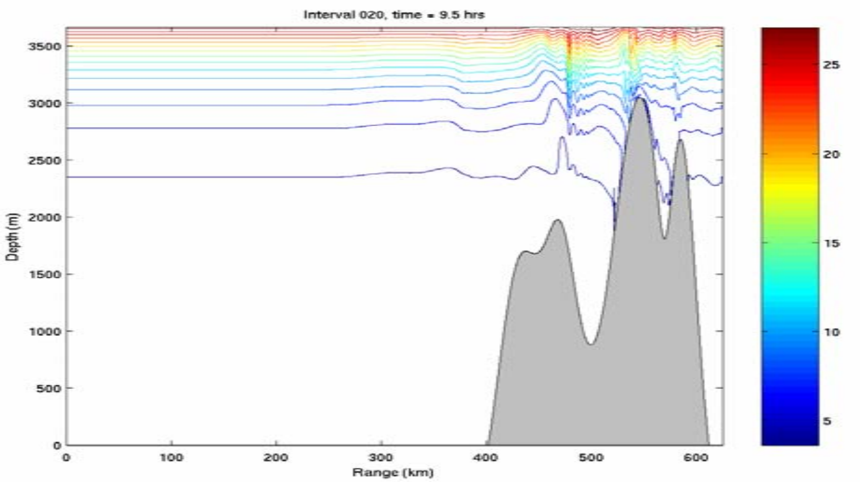
4.5 hr cpu for 16 hr real time for dx=100m, dy=20km

Generation in Strait of Luzon by M2 tidal component

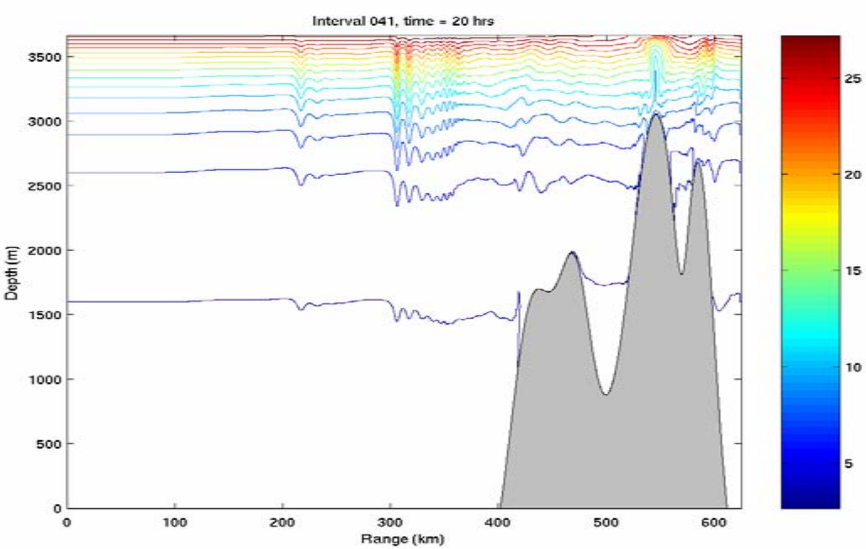
3D Luzon bathymetry



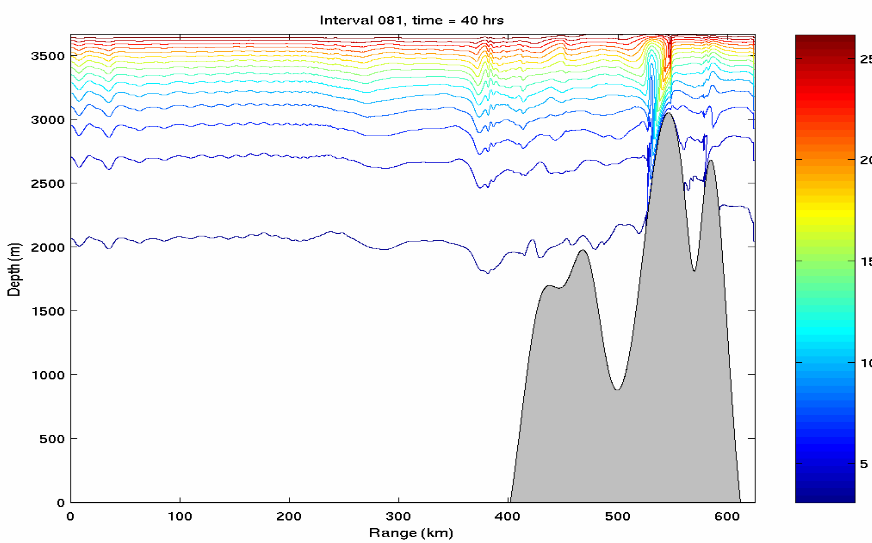
T in mid plane at 9.5 hours



T in mid plane at 20 hours

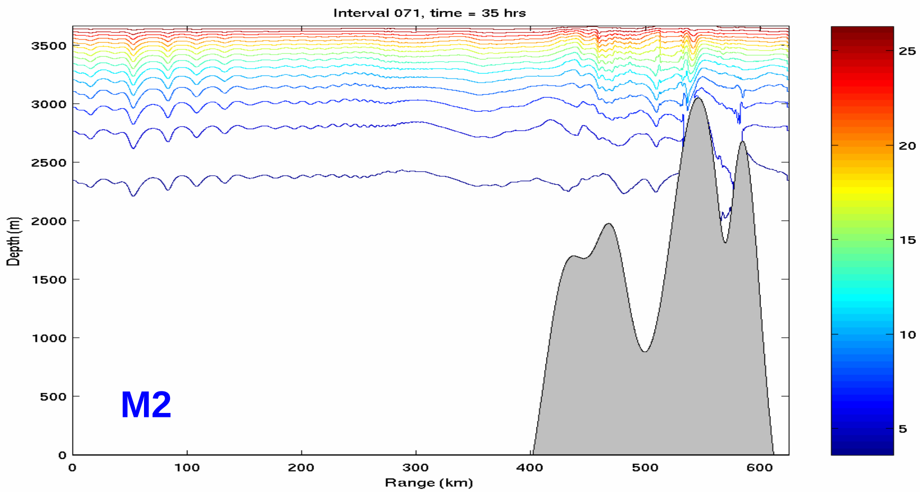


T in mid plane at 40.25 hours

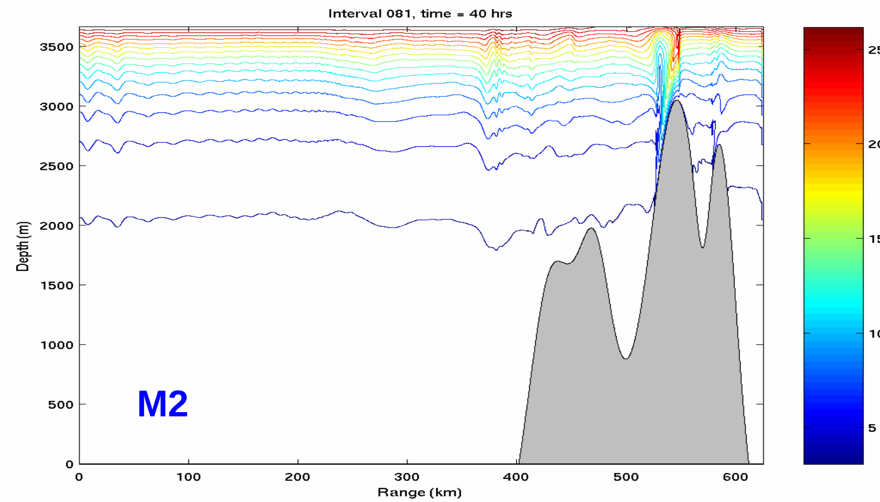


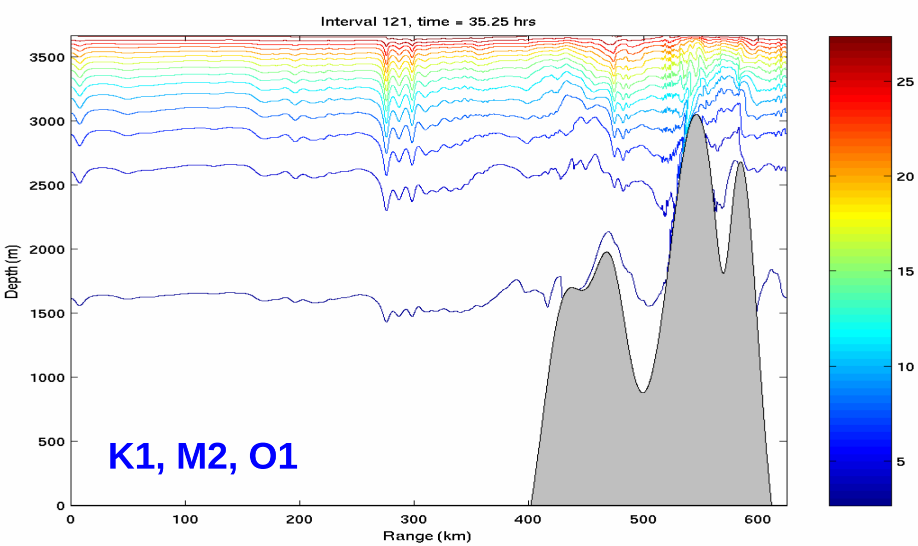
Comparison of generation by K1, M2, and O1 tidal components with M2 only

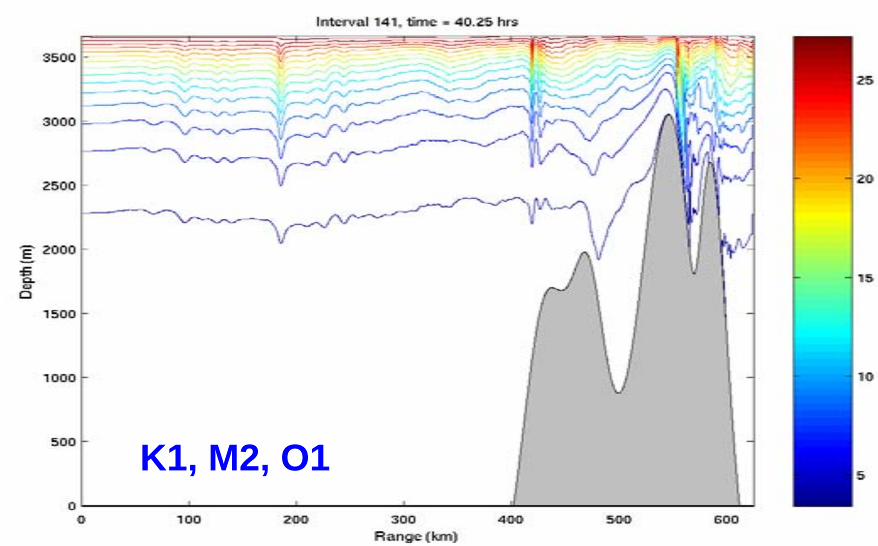
T in mid plane at 35 hours



T in mid plane at 40.25 hours

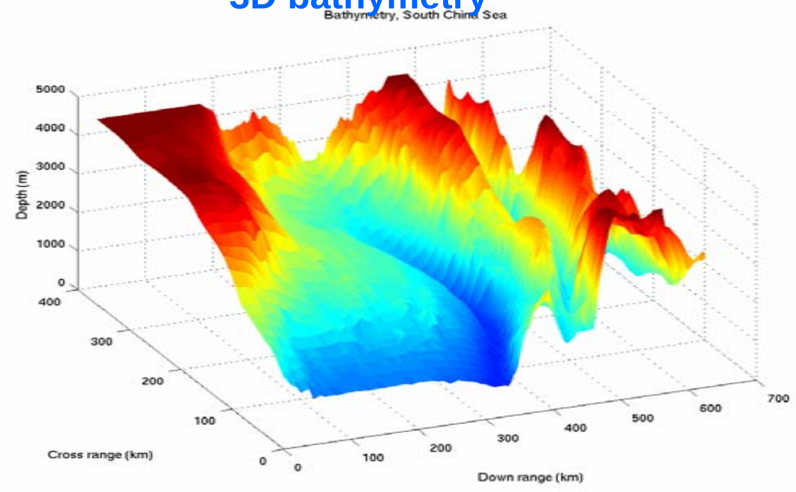




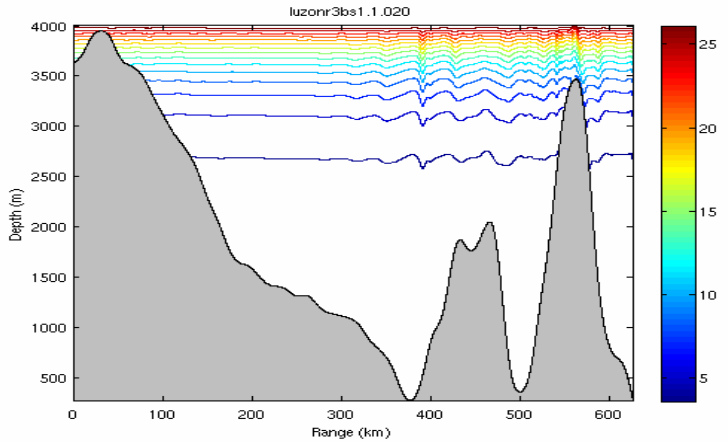


GENERATION & PROPAGATION IN LUZON STRAIT & SOUTH CHINA SEA (dx=100m,dy=20km,dz~2.5m-40m)

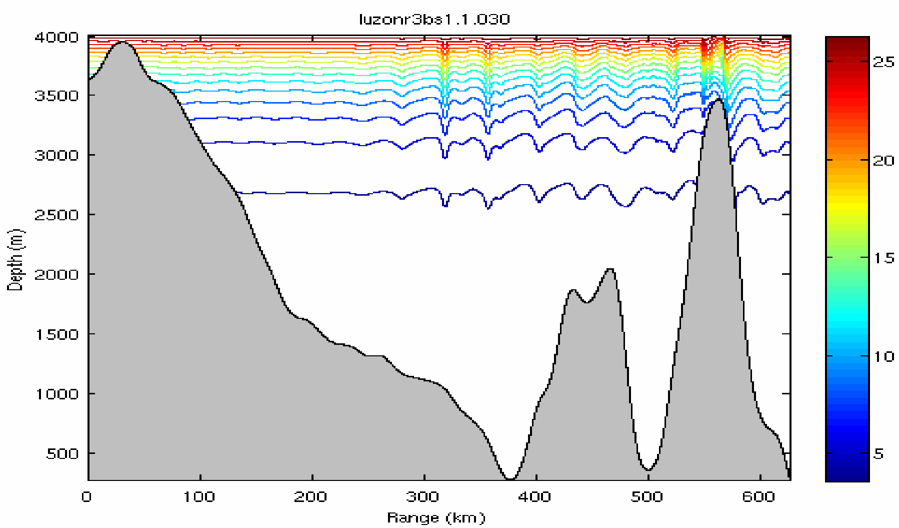
3D bathymetry



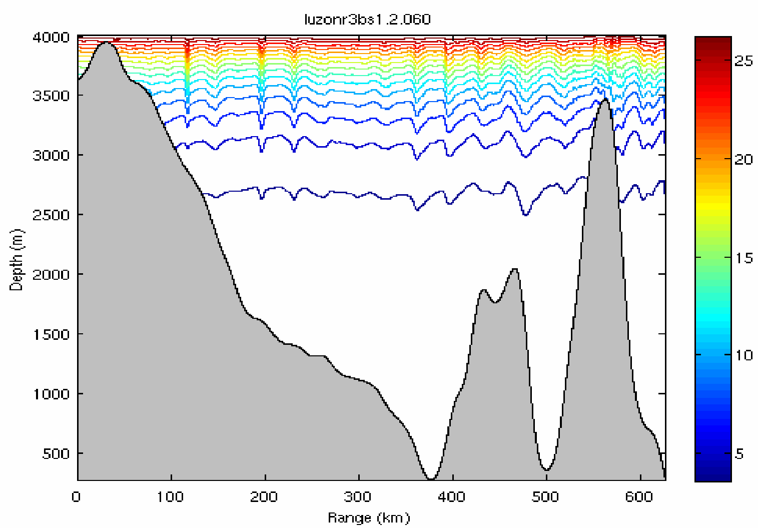
J=13 & t=10 hr



J=13 & t=15 hr



J=13 & t=30 hr



CROSS RANGE RESOLUTION ISSUES

I = 6251 J = 23 K = 41

625 km 444 km 4000 m

nprocx = 32 nprocy = 1

dx = 100 m dy = 20 km

5 m < dz < 100m

CPU time 8:36 h for 10 h similation

I = 3840 J = 111 K = 41

625 km 444 km 4000 m

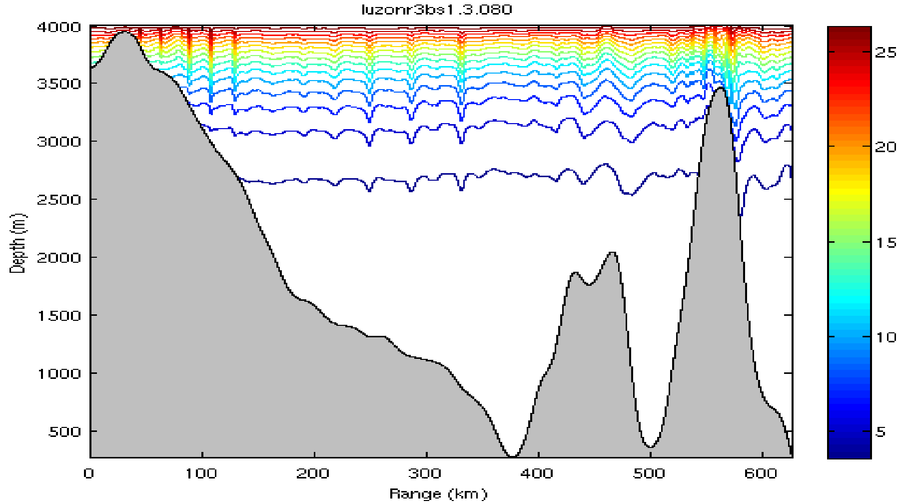
dx=163 m dy = 4 km

5 m < dz < 100 m

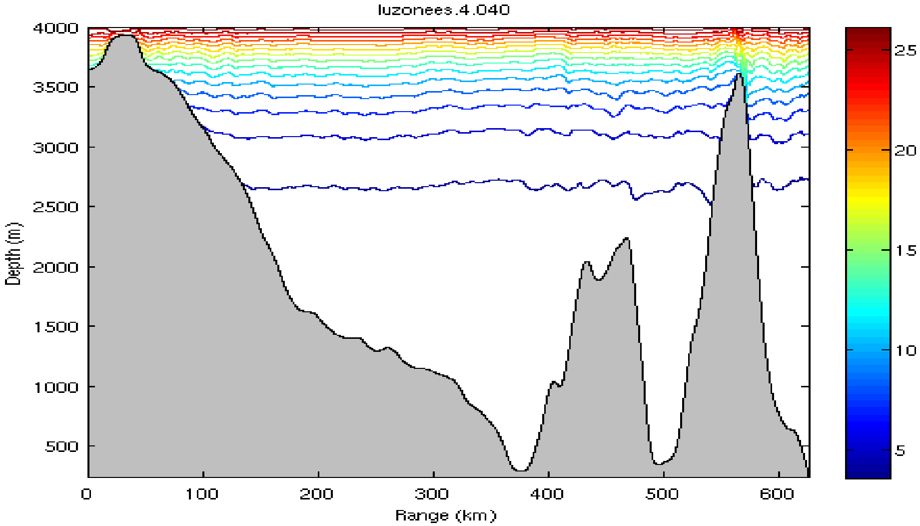
nprocx = 32 nprocy = 1

CPU time 4:06 h for 16 h similation

J=13 & t=40 hr



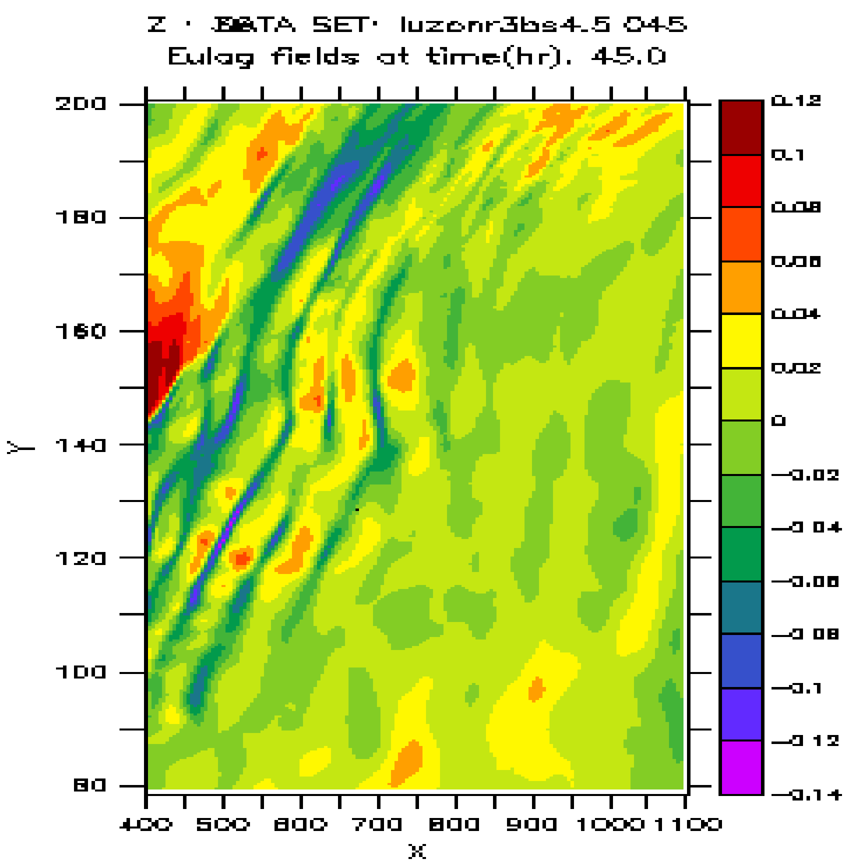
J=62 & t=40 hr



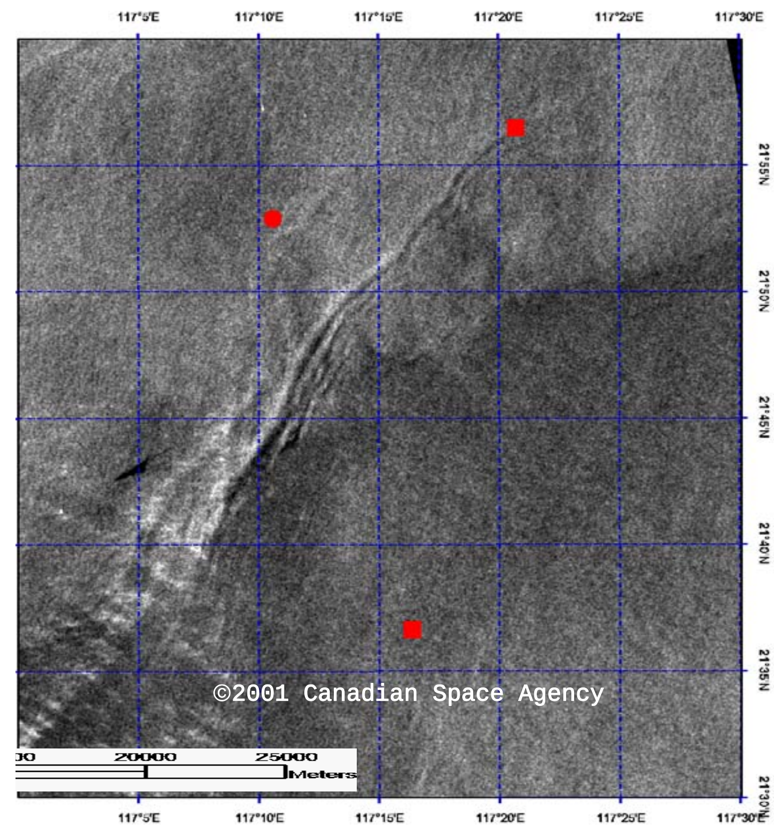
Surface Manifestations of Internal Wave Packet Propagation at the ASIAX Site

(a) 3-D Eulag model result

(b) Satellite

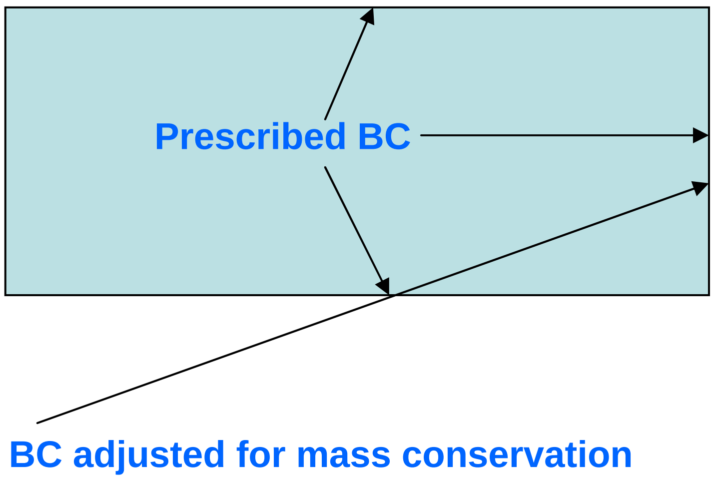


(a)



(b)

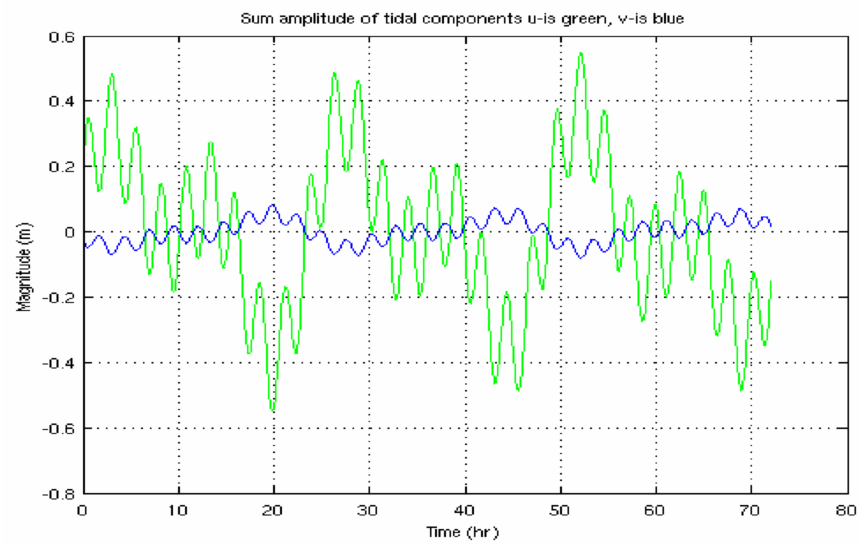
Fine Resolution (dx~100m,dy~1.2km,dz~2.5m-40m)



U component of tidal forcing

$$u(t)_e = A_{K1}\sin(\omega_{K1}t+\phi_{K1}) + A_{M2}\sin(\omega_{M2}t+\phi_{M2}) + A_{O1}\sin(\omega_{O1}t+\phi_{O1})$$

Tidal forcing functions



I = 6016 J = 180 K = 41
625 km 216 km 4000 m
nprocx = 128 nprocy = 4
dx = 99.13 m dy = 1.19 km
5 m < dz < 100m
CPU time 1.03 h for 5 h simulation

Summary

- **Topography, tidal magnitude and hydrography control the generation of internal bores and solitons in the Straits of Messina and Luzon.**
- **In Strait of Messina 3D simulations with a horizontal resolution of 50 m and .8m to 4m in the vertical are performed. Acoustical calculations in cross range vertical planes exhibit different ray patterns.**
- **In Luzon Strait and South China Sea, The application of barotropic tidal forcing in the region and on the boundaries is an ongoing issue.**
- **In Luzon Strait and South China Sea, mesh size is a issue both in the principal propagation direction (E-W,x) or perpendicular to it (N-S,y).**
- **At 300 m depth in Luzon Strait the predicted temperatures, salinities, and vertical velocities, using dx=167m and dy=2km, exhibit structures and curvatures similar to satellite observations.**
- **The predicted sound speed in presence of solitary waves is used in 3D acoustical intensity calculations. In analogous studies, acoustical intensity dependence on frequency is pursued.**

END

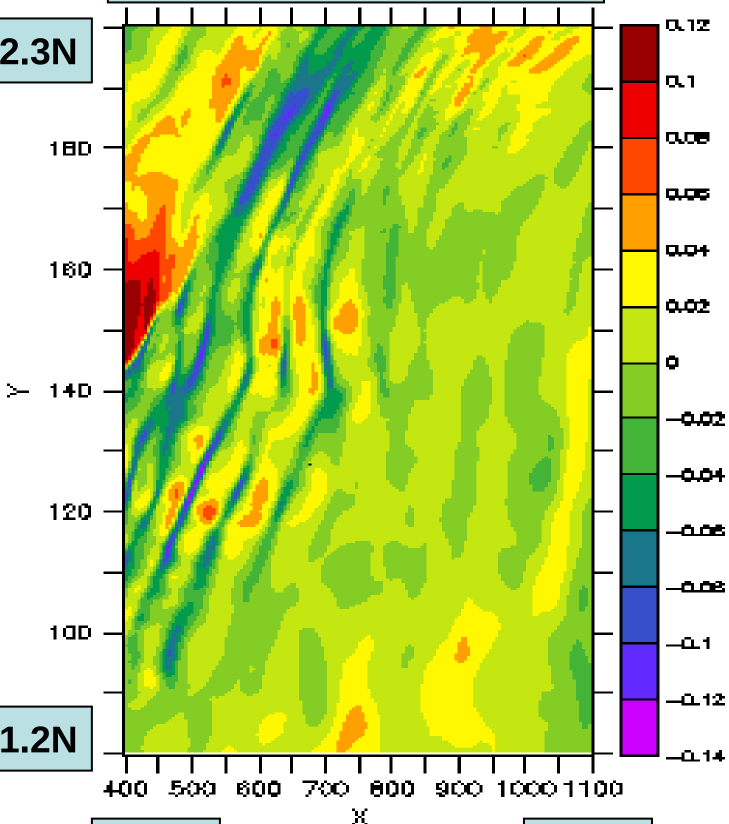
3D EULAG PREDICTIONS IN ASIAEX REGION

Effects of grid resolution on perturbation salinity field

Simulation time = 45 hours

DX=167m, DY=2 km

22.3N

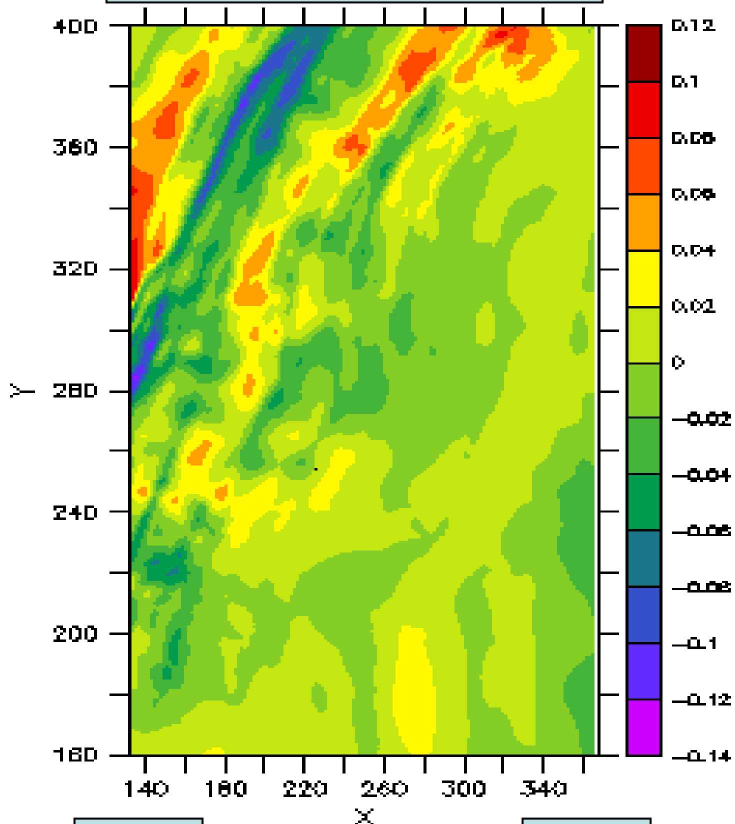


21.2N

116.8E

118.2E

DX=500m, DY=1 km

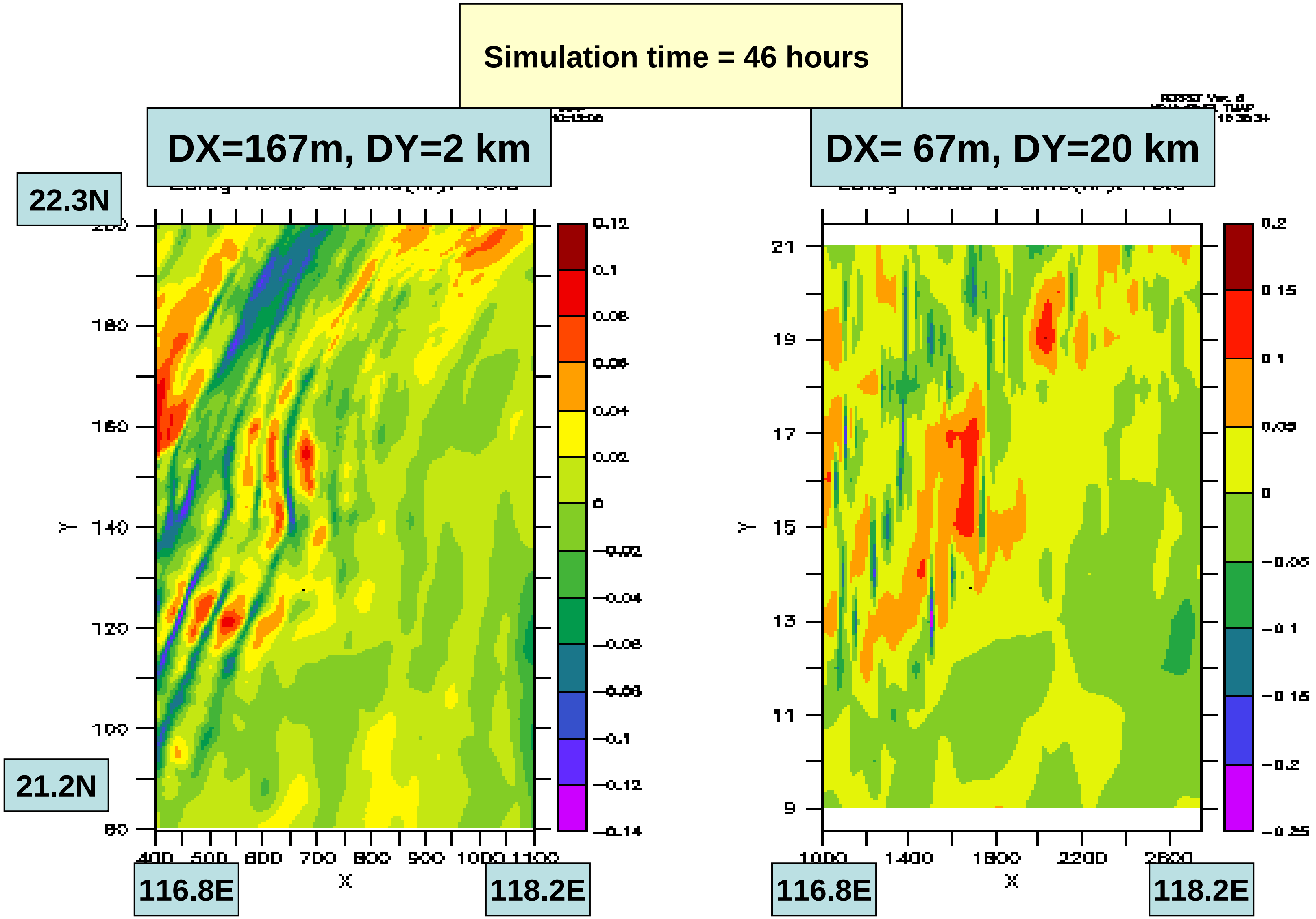


116.8E

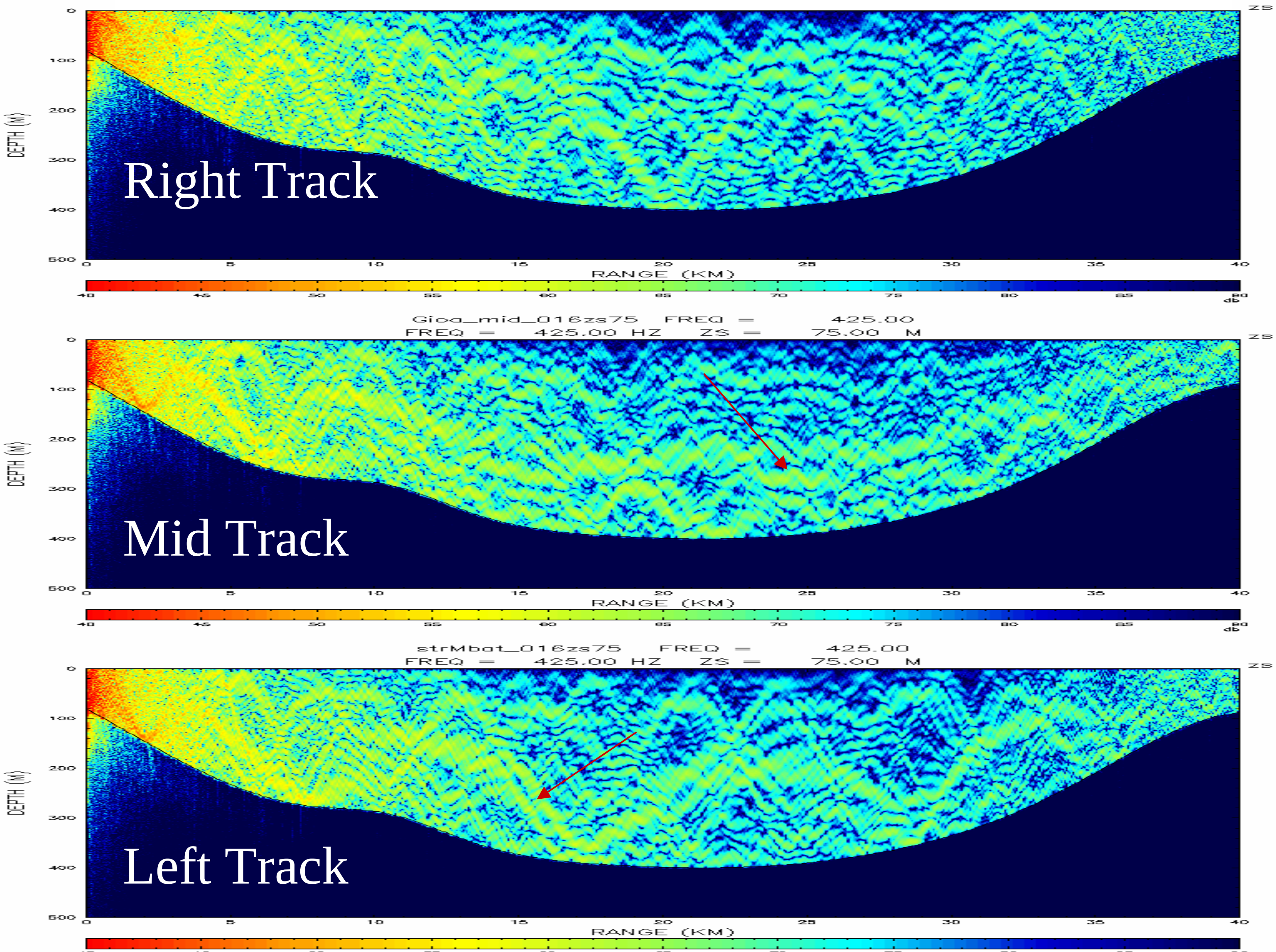
118.2E

3D EULAG PREDICTIONS IN ASIAEX REGION

Effects of grid resolution on perturbation salinity field



Time Step 016 - ZS = 75 m; freq 425 Hz



REGIONS OF FULL OCEAN-ACOUSTIC INTERNAL SOLITON WAVE PREDICTION AND STUDIES

Luzon Strait & South China S.

- Oceanographic and acoustical data April/May 2001
- Oceanographic data May-July 1998
- WISE 05-06 data

Strait of Messina

- October 1995 CTD chain survey
- 2007 - 2008 surveys
- Coach_06 survey (Oct-Nov 06)

Models:

- K. Lamb 2.5 D NH model
- P. Smolarkiewicz 3D NH EULAG model
- NCOM with tides
- PE acoustical model

Issues addressed

*Loss of acoustical signal due to soliton packets

*Soliton simulation capabilities of hydrostatic and nonhydrostatic models

*Relation of soliton packet wavelengths to acoustical modes

*Shoaling of soliton packets

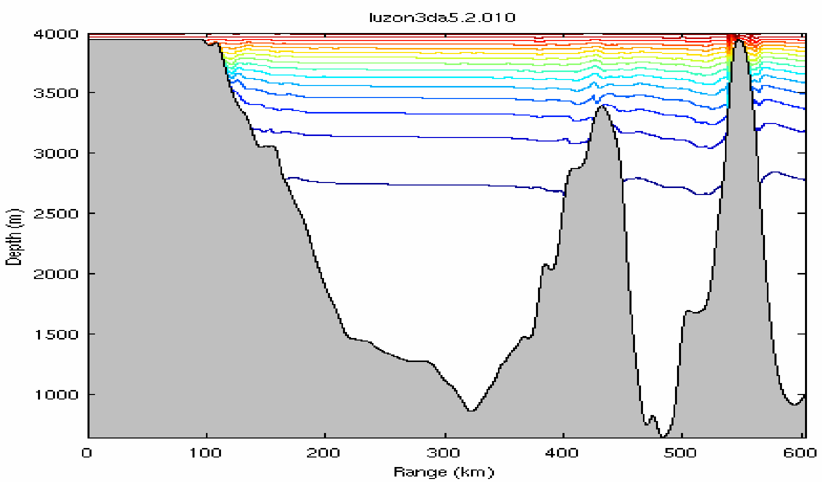
*Initial parameter variations (density, tidal forcing, topography)

*3 dimensionality of problem

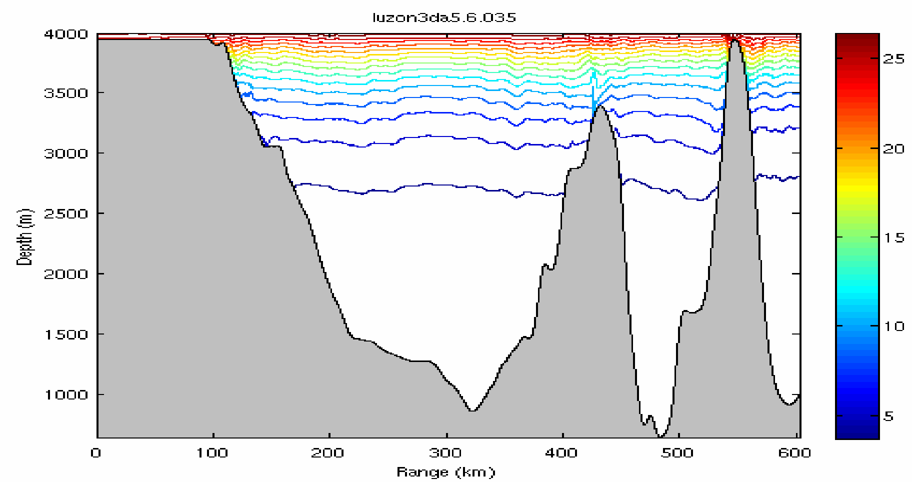
*Mesh size sensitivity for soliton simulations

Fine Resolution (dx~100m,dy~1.2km,dz~2.5m-40m)

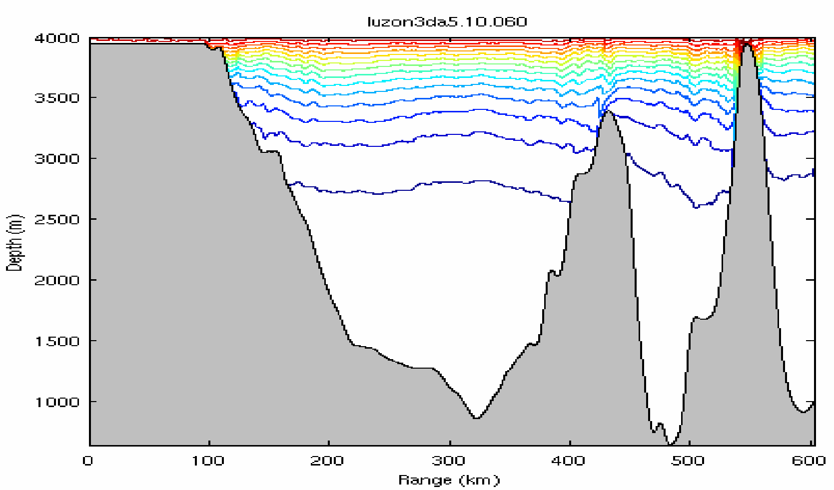
T at 5 hours for J=150



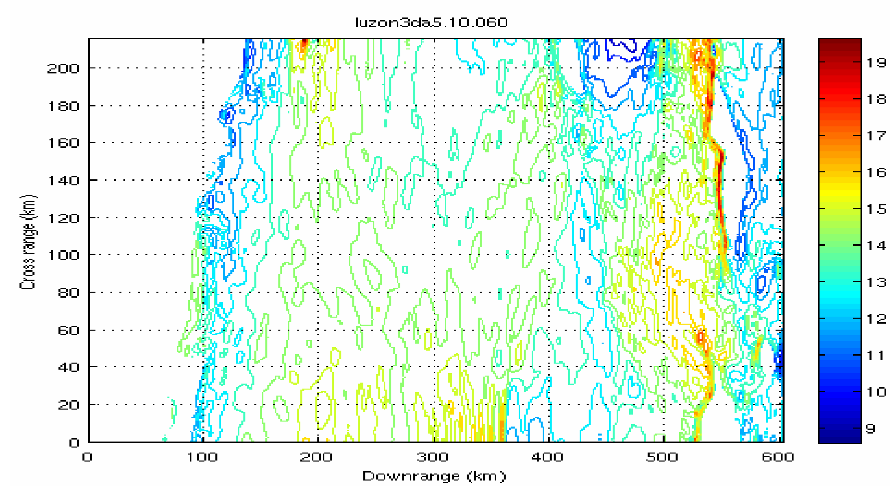
T at 17.5 hours for J=150



T at 30 hours for J=150

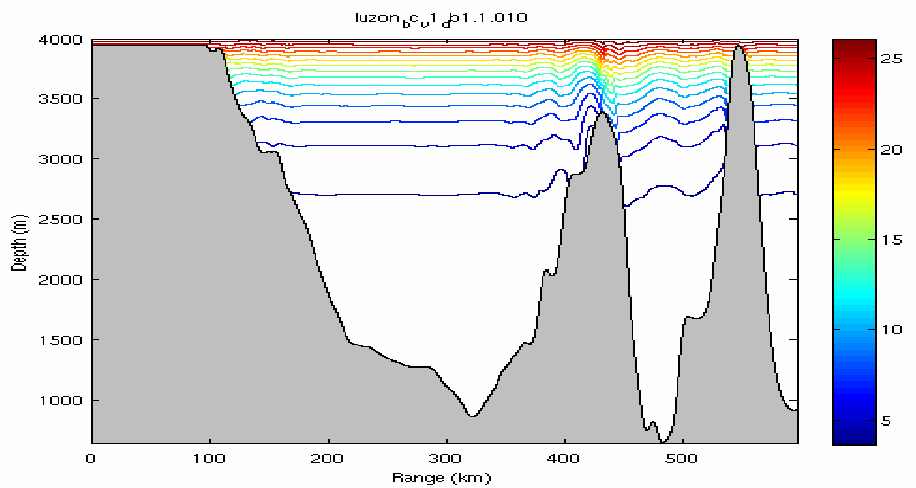


T at 30 hours for 300m depth

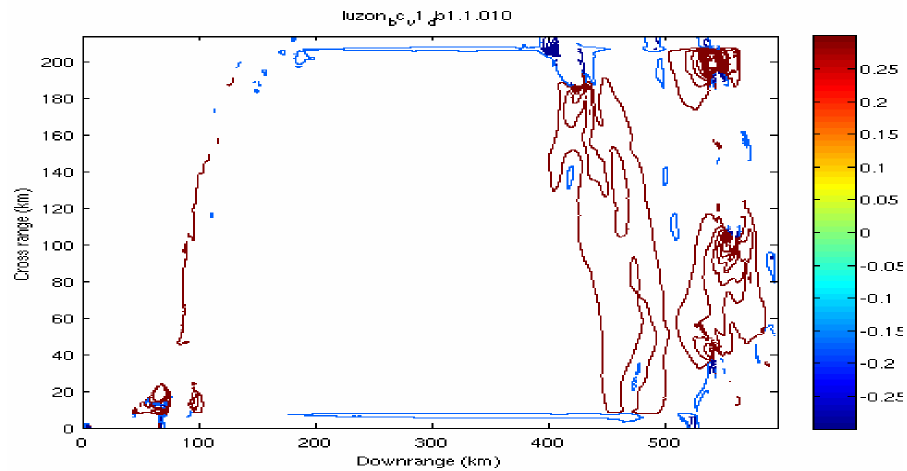


Fine resolution results at 5 h

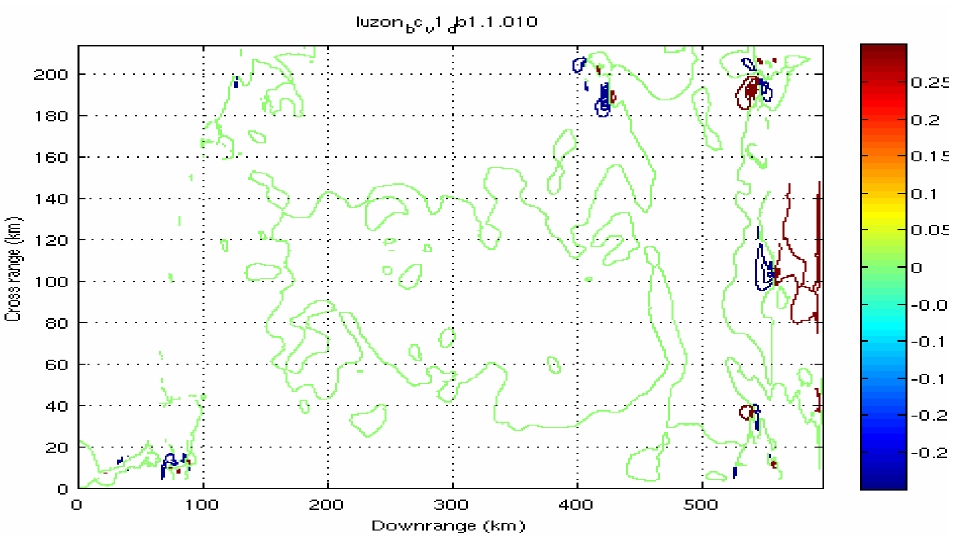
Temperature for j=150



Horizontal u velocity at 300m depth



Zonal velocity v at 300m depth



Vertical velocity w at 300m depth