Training program on Modelling: A *Case study – Hydro-dynamic Model of Zanzibar channel*

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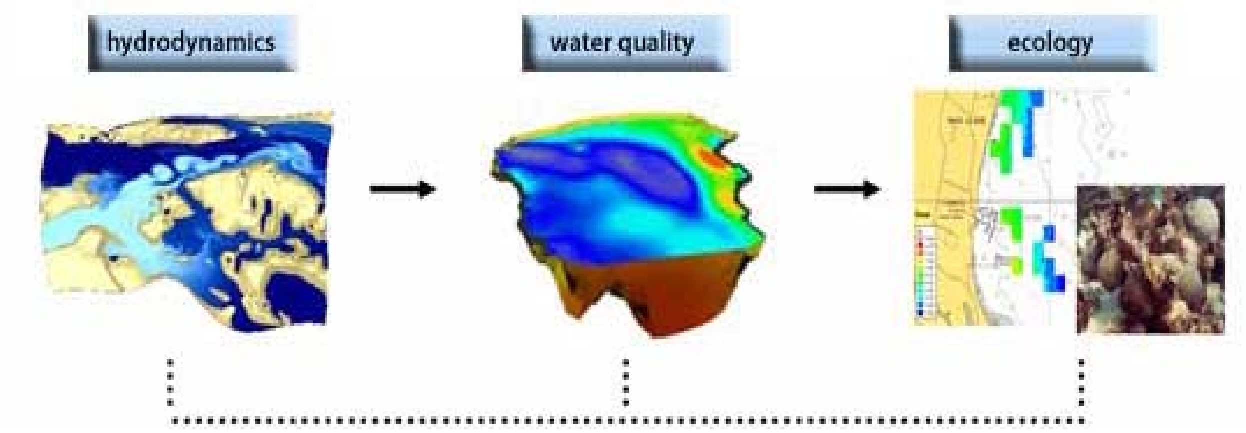
8 June 2007

INTRODUCTION

- Hydrodynamic Modeling

  – In understanding the marine and coastal environment the contribution of hydrodynamic numerical models become highly indispensable.

  – Water quality, sediment transport and ecology models all rely heavily on the results of the hydrodynamic simulations (water levels, horizontal & vertical velocities, salinity, temperature, density pattern etc).



  – At the same time feedback loops exist; the ecology influences the water quality and the hydrodynamics.

INTRODUCTION (Cont.)

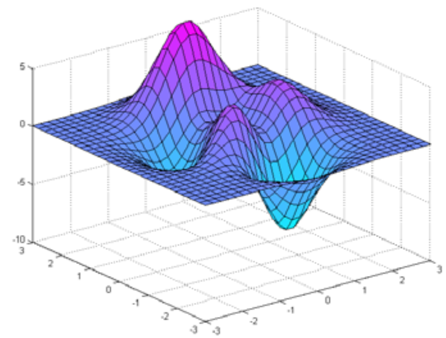
- The main goal of the hydrodynamic modeling is to provide the state of the art and accurate simulation for seeking the solutions for challenges present in marine and coastal environment.

Beneficiaries

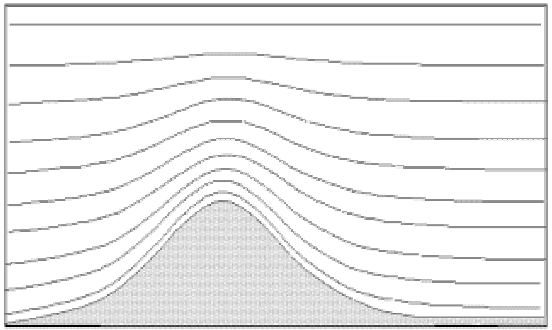
- Research institutions such as IMS, TAFIRI
- Commission of Tourism (for management of beaches and hotels along the coast)
- Port Authorities (Dsm & Zanzibar)
- Department of environment
- Department of fisheries (egg and larval transport)
- Municipal councils
- Department of lands
- Oil exploration (for rigs)
- Other scientist and stakeholders
- Local communities

What is ROMS?

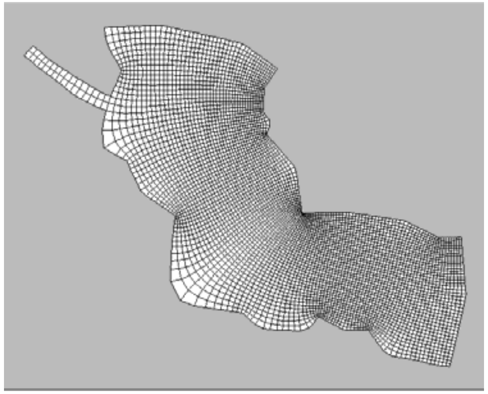
- The Regional Ocean Model System (ROMS) is a free-surface model that solves the hydrostatic primitive equations.



- It uses stretched, terrain-following coordinates in the vertical and orthogonal curvilinear coordinates in the horizontal.



- It was developed by Rutgers University and is broadly used in sciences worldwide.



Why ROMS?

- **It is free access software.**
- **It is more realistic than other models:**
  - It is a 3 dimensional model.
  - Includes complex ocean dynamics.
    - Coriolis effects
    - Friction
    - Heat fluxes
    - Vertical Mixing
  - Atmospheric and oceanographic features can be included:
    - Temperature and salinity fields
    - Winds
    - Tide
    - Mesoescale currents
    - Rainfall
    - River inputs
  - Biological systems and sediment transport dynamics can be coupled to the hydrodynamic model.

Why ROMS? (Cont.)

- **It allows you to assess the different physical processes that are going on in the ocean, individually.**

- **Results are quite accurate, and reproduces the most important features of ocean circulation and hydrodynamics of the study area even using a semi-idealized application.**

The difficult of using ROMS

- It is as complex as the ocean itself…

  – It runs in Linux operating system.
  – It doesn't have a graphical user inter-phase.
  – It can not be used as a black box or a plug and play model.
  – A deep understanding of ocean dynamics and modeling is needed to configure the model.
  – Knowledge about the local oceanographic features affecting the area of study are also required.
  – It doesn't work with default values. Real data is required.
  – Format of input and output files. NetCDF (binary files).
  – Skills in different software are needed for data treatment and results analysis (matlab, Linux, fortran, etc).

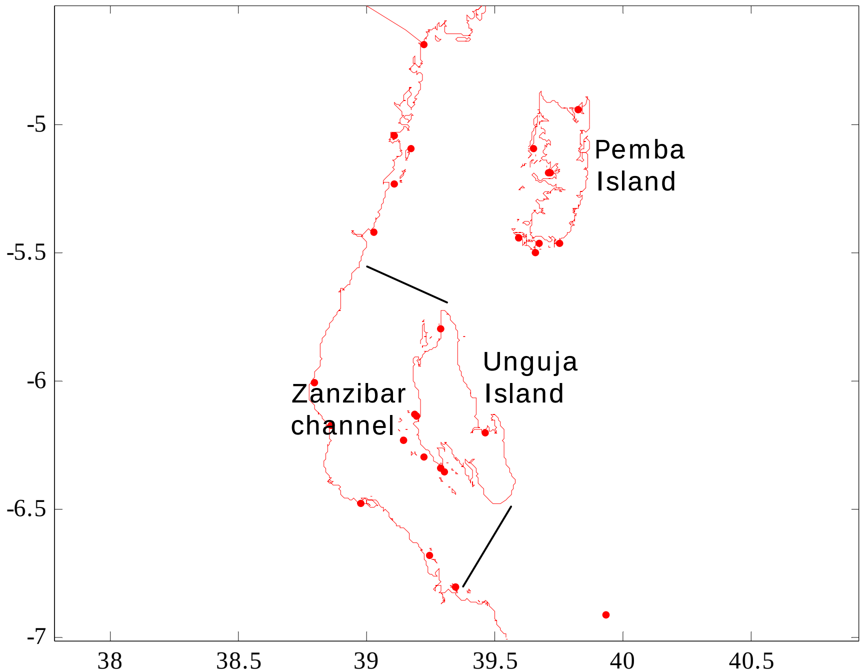
Objectives

- To build capacity of modeling team at IMS.
- To develop a Local Semi-idealized Model of Zanzibar Channel.

Case of study

- Zanzibar channel located between longitude 38.8ºE – 39.6ºE and latitude 5.5ºS – 6.8ºS. (the coasts of Tanzania mainland and that of Unguja Island)

- The length of the channel is about 120Km and 35 – 40Km wide



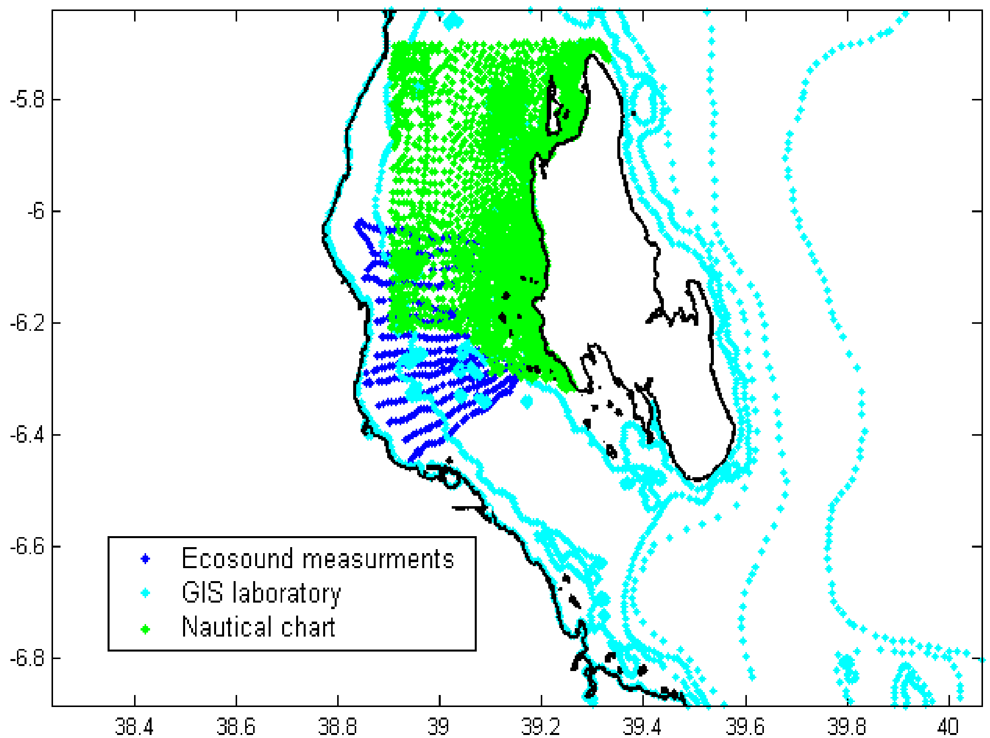
Zanzibar channel

Methodology

- Data collection:
  - Bathymetry and coast line data from global data bases.
  - Local bathymetry data
  - Wind
  - Tides
  - Oceanographic parameters
  - Current (for validation of the model).
- Data analysis and processing.
- Preparation of input files
- Configuration ROMS for the Zanzibar Channel.
- Analysis of the results and validation of the results.

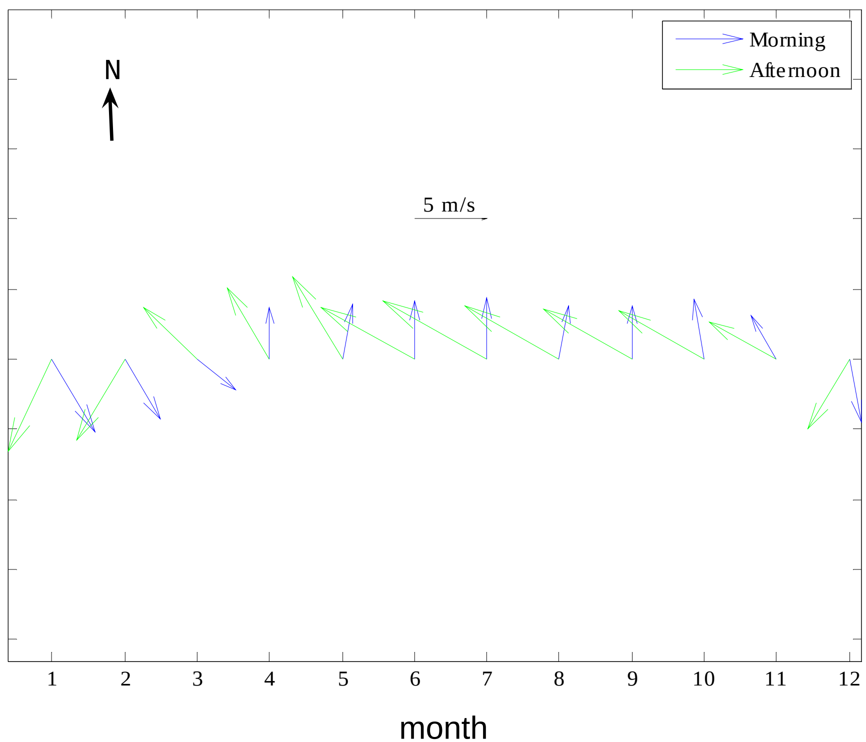
Data analysis and processing

- Local bathymetry data.
  - Direct measurement (Dr. Shagude)
  - GIS laboratory data base (Kombo)
  - Digitize from nautical charts (Dr. Dubi)



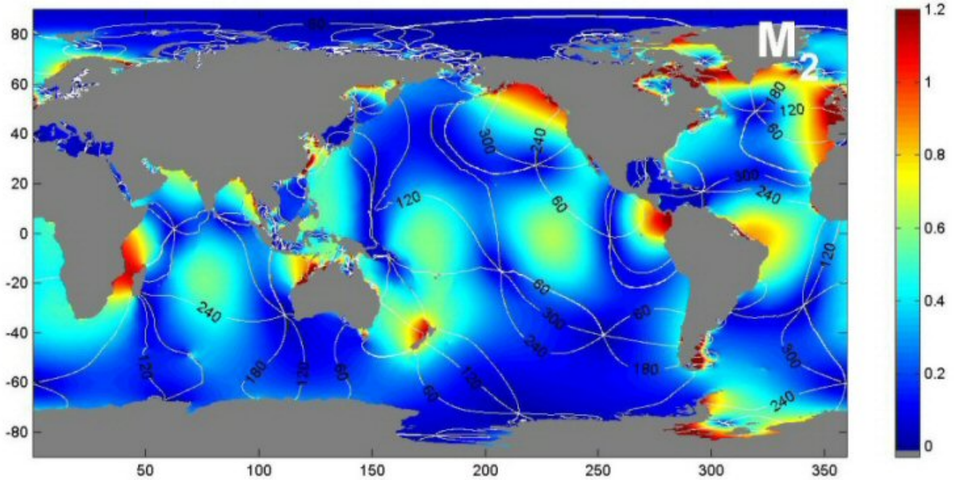
Data analysis and processing (cont.)

- Winds
  - Monthly averages of wind data (speed and direction) for 10 years (1996-2005) from Zanzibar airport meteorological station.

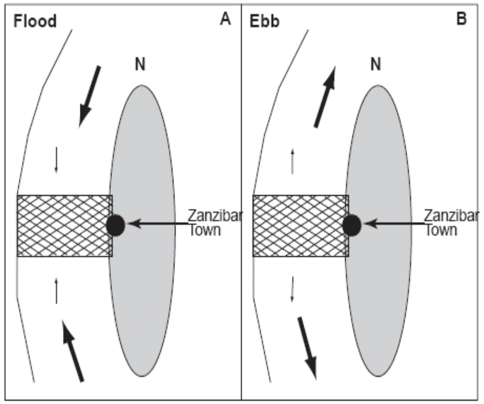


Data analysis and processing (cont.)

- Tide
  - Topex/Poseidon global co-tidal map for the component M2 shows that the tide is coming in through the southern mouth of the channel.

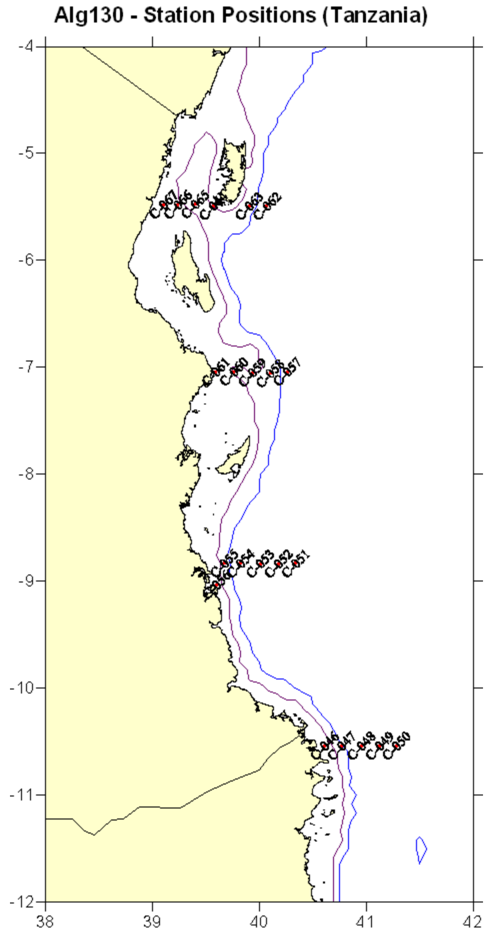


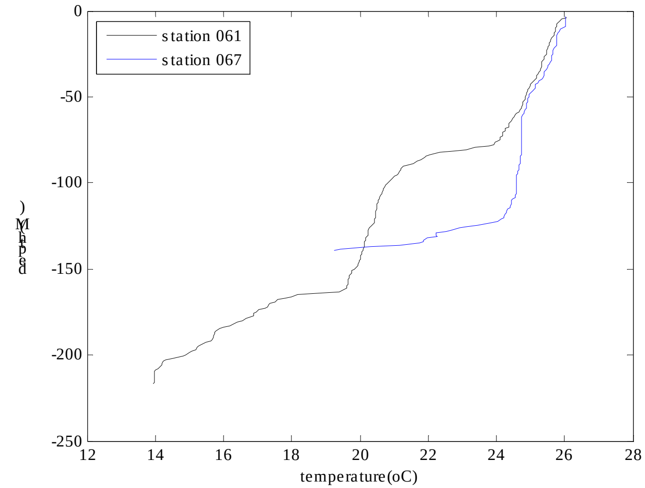
  - There is information of more complex local tide dynamics (Shaghude et al, 2002).

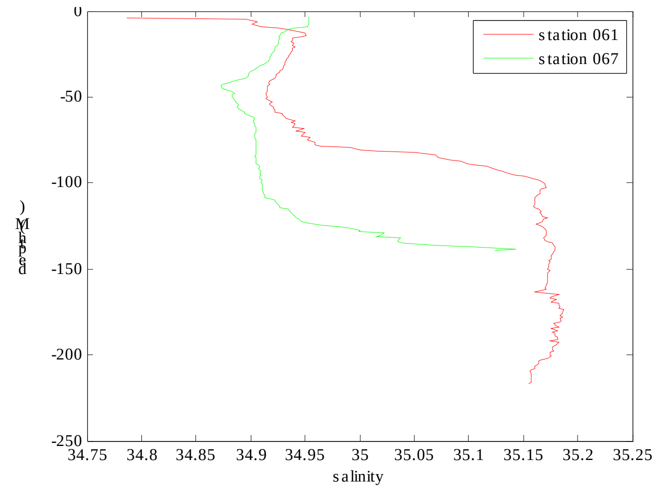


Data analysis and processing (cont.)

- Oceanographic parameters
  - CTD casts near the Zanzibar Channel from a Western Indean Ocean Oceanographic Cruiser (Dr. Shaghude).

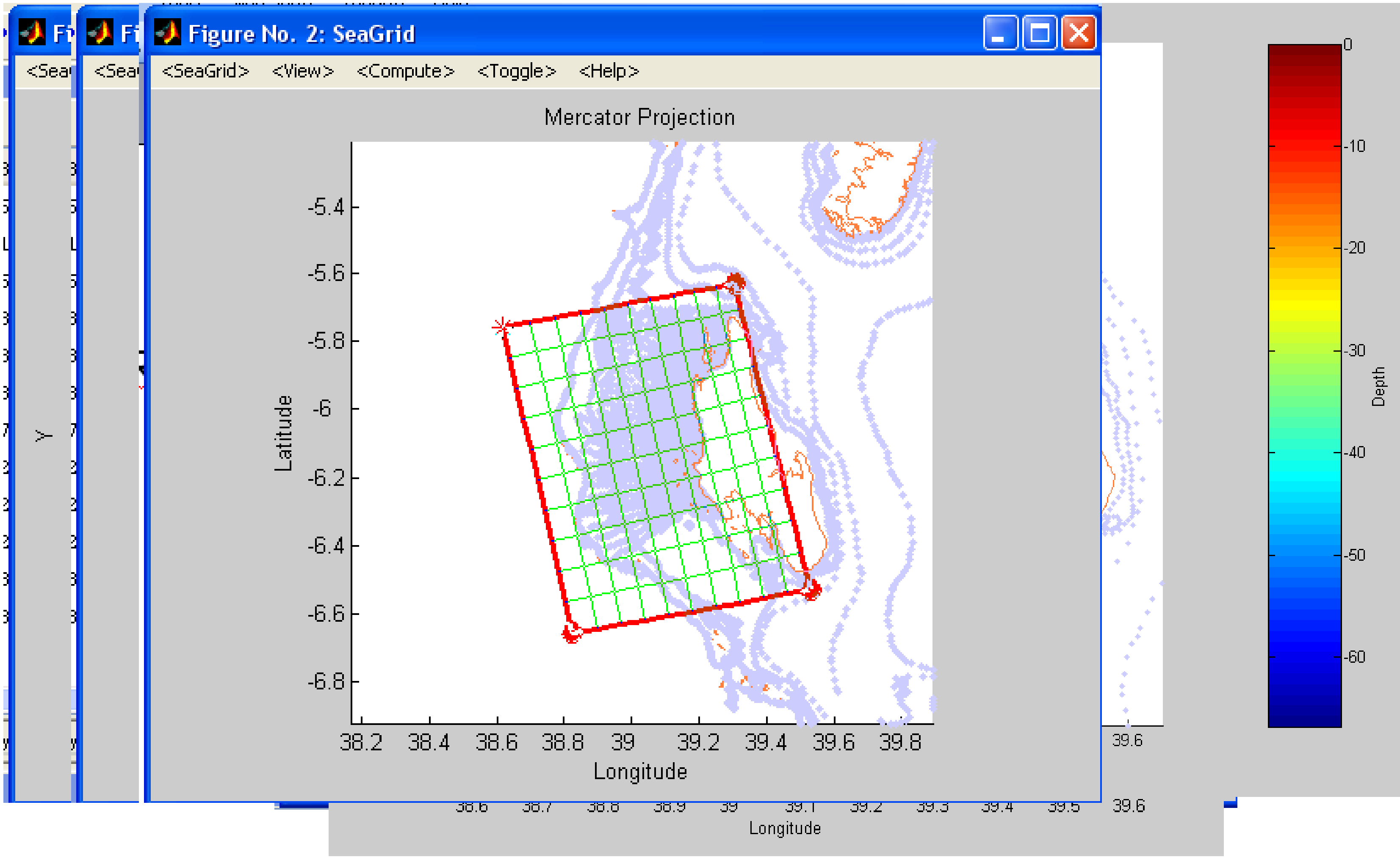






Preparation of input files

- Creation of grid file



Preparation of input files (cont.)

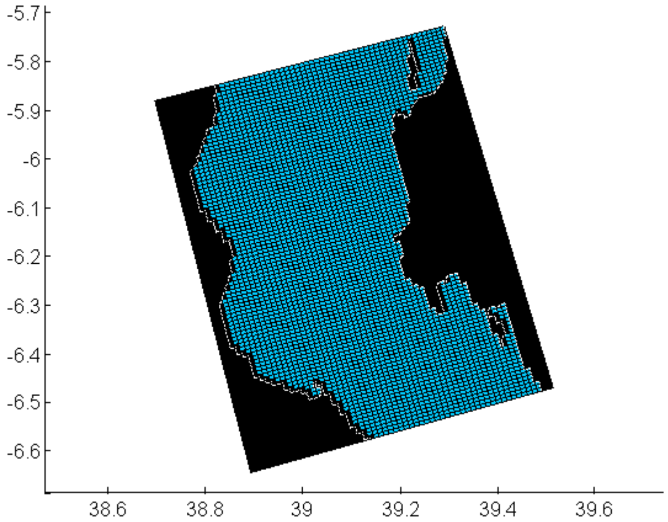
roms_grd.nc

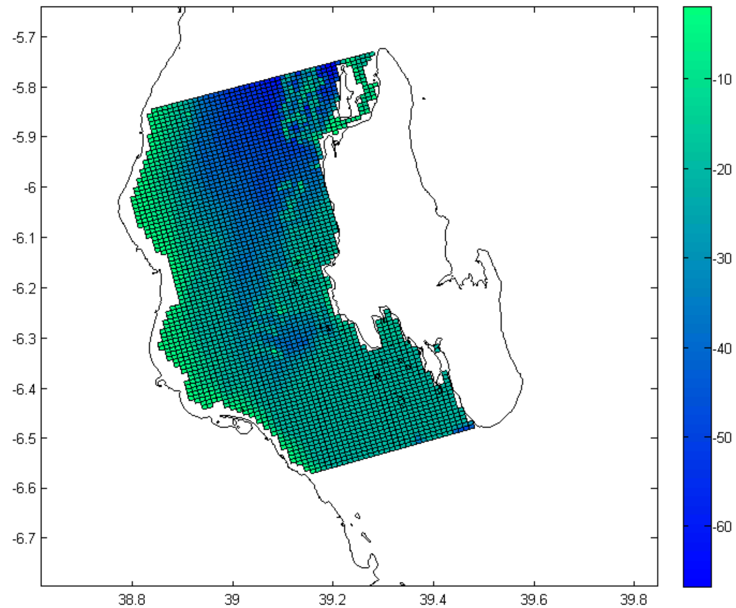
Position of the grid points

Size of the grid cells

Bottom topography

Land mask





Bathymetry distribution along the Zanzibar channel

Configuration of ROMS for the Zanzibar Channel.

- 60 x 100 cells covering 72.4 x 88.4 km
- 16 levels in the vertical.
- Resolution ~ 1km2
- Minimum depth 2 m.
- Maximum depth 66 m
- Time step 100 sec.
- North and South boundaries open.
- Oceanographic parameters
  - Salinity 34.9 **$^{oo}/_{o}$**
  - Temperature 26 ^{o}C
  - Density 1023 Kg/m3

Configuration of ROMS for the Zanzibar Channel (cont.)

- Analytical Forcing

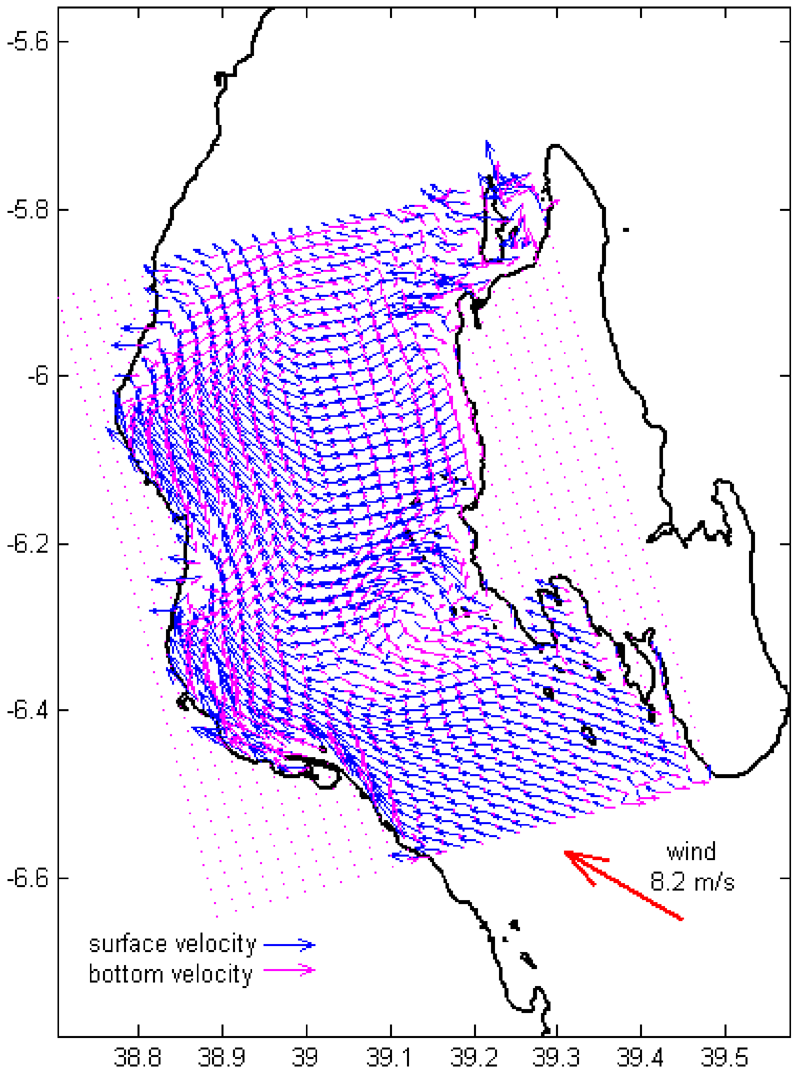
- Wind
  - It was establish as a surface momentum flux uniform over all the domain.
  - The wind stress was calculated based on the magnitude of the wind velocity components.
  - A linear ramp was use to increase wind magnitude from zero to its maximum during the first 2 days modeled, after this wind remain constant over time.
  - The two more common wind condition in the zone were reproduced SE and NE winds.
- Tide
  - Was establish as a sea level perturbation at the South open boundary, with the frequency of the M2 component (12.42 hrs), and an amplitude of 1 m. The model it self propagate the perturbation Northward along the domain.

Running the model

- We run the model until it gets to stable state. The intermediate states skipped “spin up” that considered to be not valid results.
  - 10 days of simulation for wind = 1hr and 35 min computing time
  - 5 days of simulation for tide = 20 min computing time

Results

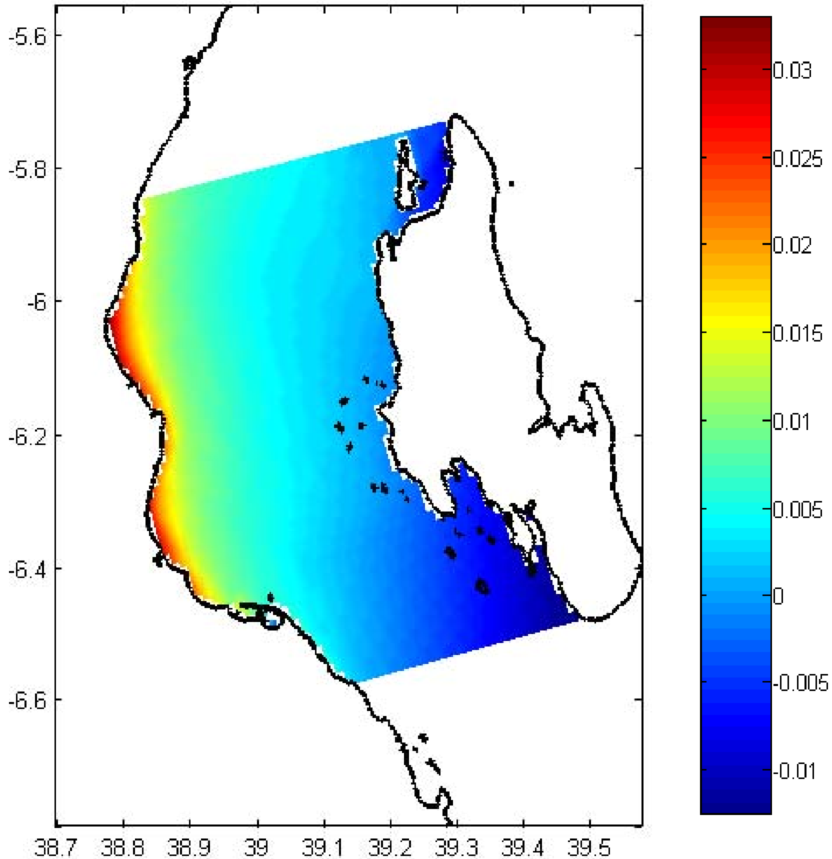
- SE wind (July)



- In the south part of the Island the surface velocity vectors follow the wind direction.
- Minimal velocities are found a bit southern than Zanzibar town, due to deflection caused by the tip of Fumba peninsula.
- From there to the north tip of the island the current have a predominant westward component.
- The stronger surface (27cm/s) and bottom (16cm/s) velocities are found around Tumbatu island and along the coast of mainland, where the vectors align following the shape of the coast showing a northward current.
- Bottom velocity vectors follow the shape of the coast in both sides of the channel but point southward along the coast of Zanzibar island and northward along mainland coast.

Results

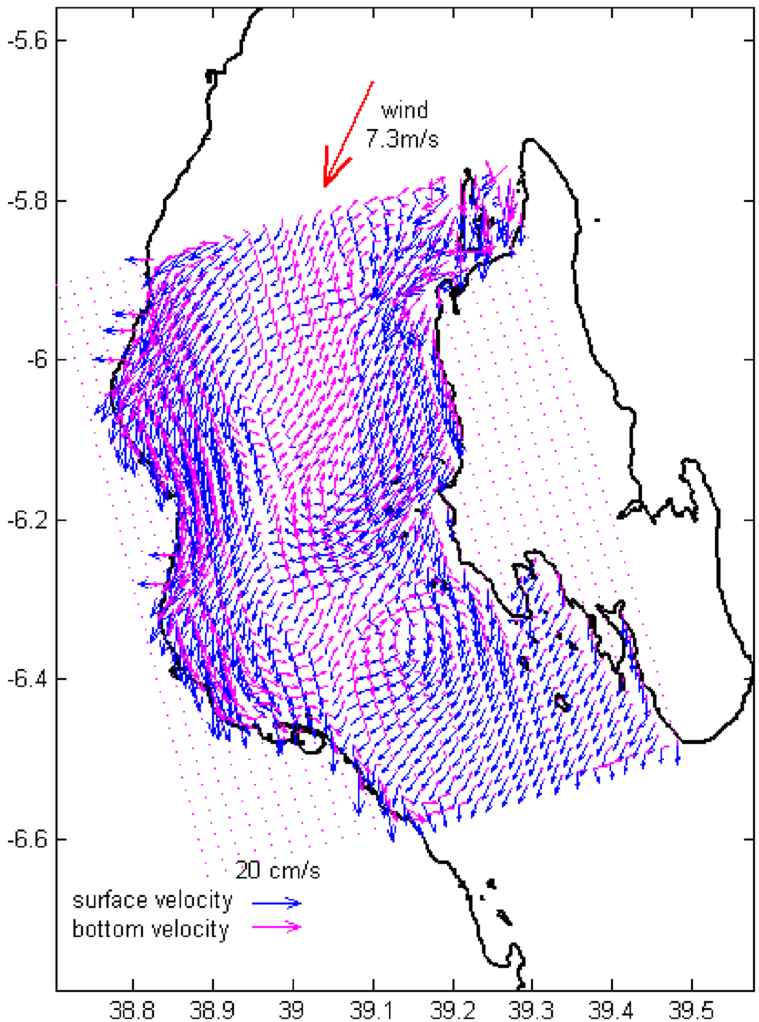
- SE wind (July)



- The sea surface elevation shows a longitudinal gradient towards the coast of mainland of 5 cm.
- The water is piling up towards the coast of mainland due to the sum of the wind effort in the “x axes” and coriolis effect.
- Upwelling conditions can be expected along the coast of Zanzibar Island under this wind condition.

Results

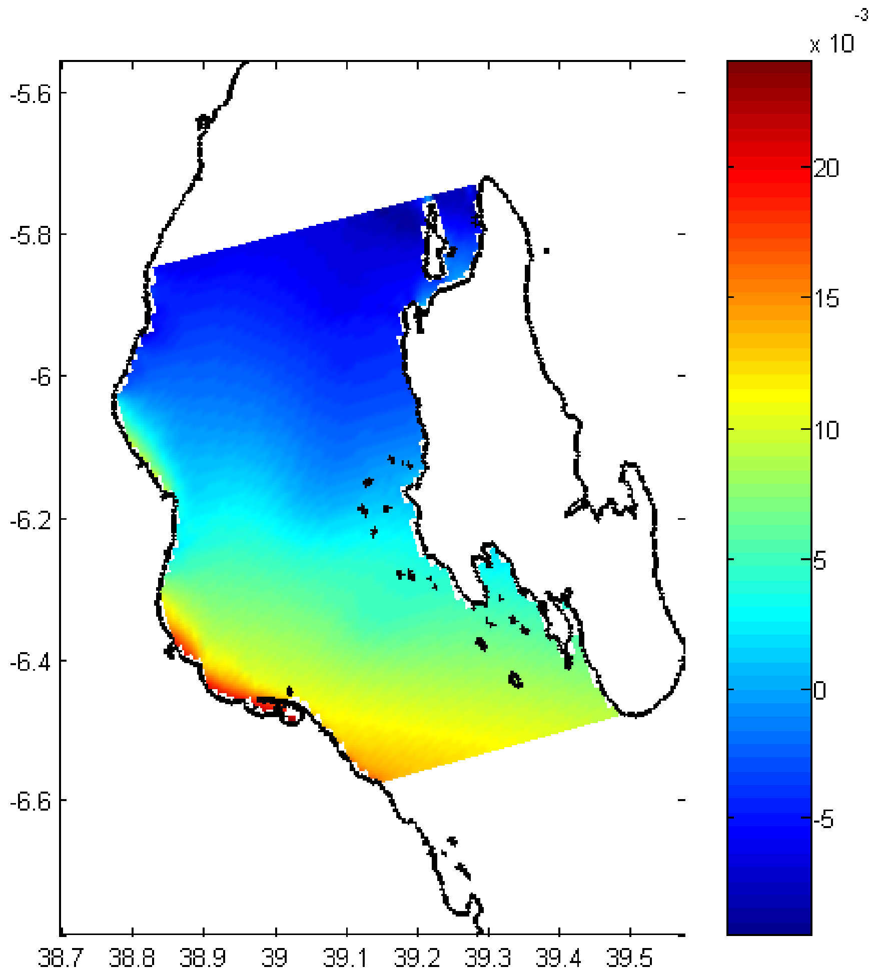
- NE wind (January)



- North East wind generates southward surface currents (30 cm/s) along both coasts of the channel.
- Slower velocities are found in the central part of the Channel and in front of Zanzibar Town where the southward surface current is deviated to the west due to the morphology of the coast and the presence of shallow reef patch's and small islands.
- Bottom current flow southward along both coasts of the Channel and northward in the center of it.
- Topography has a strong effect over the bottom current, generating two eddies turning clockwise, that meet in front of Zanzibar town.

Results

- NE wind (January)

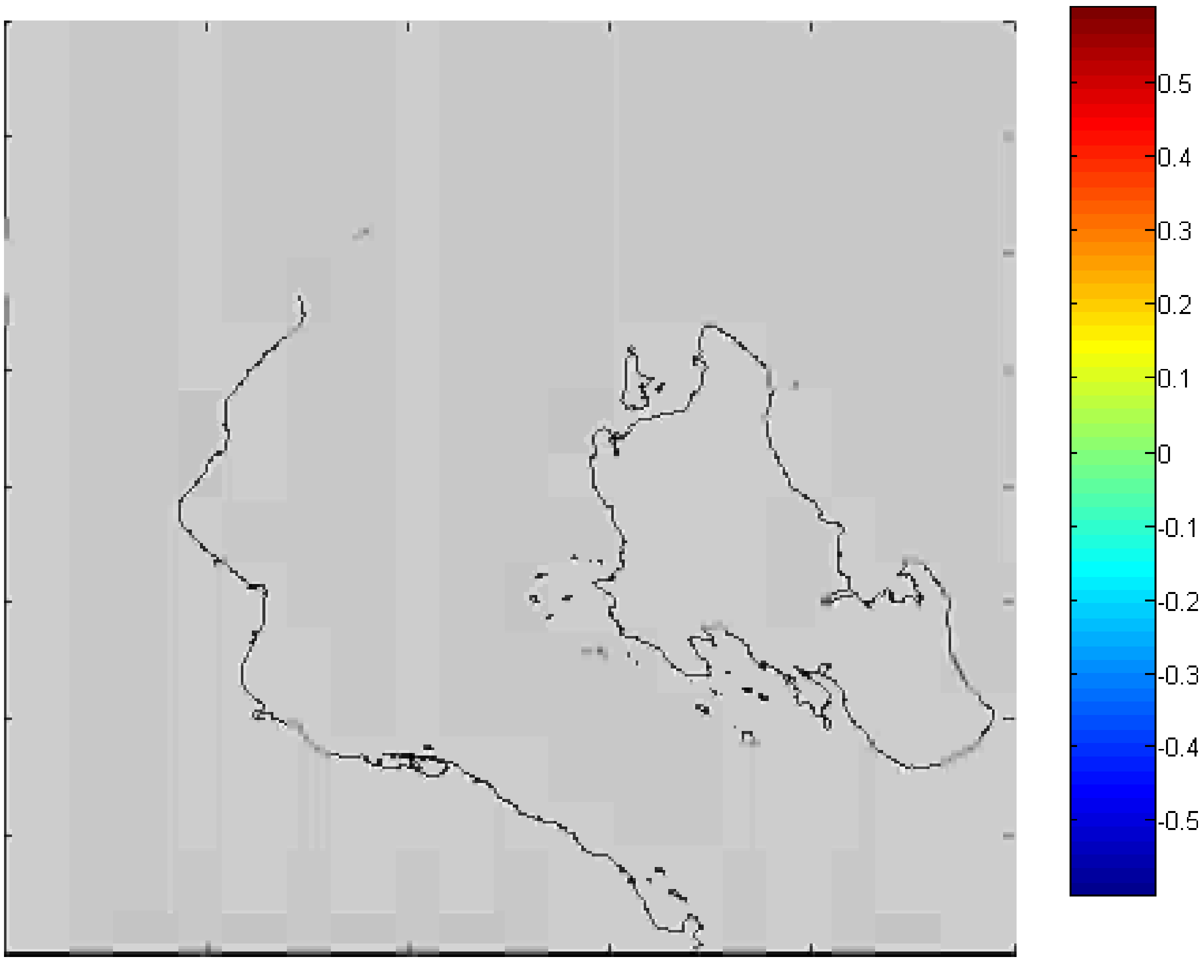


- Sea surface elevation shows a variation of 1.5 cm, water accumulates towards the south mouth of the channel and the west coast.

- There is no evidence of upwelling condition along the mainland coast. The influence of the morphology of the coast is stronger than the coriolis effect under this wind conditions.

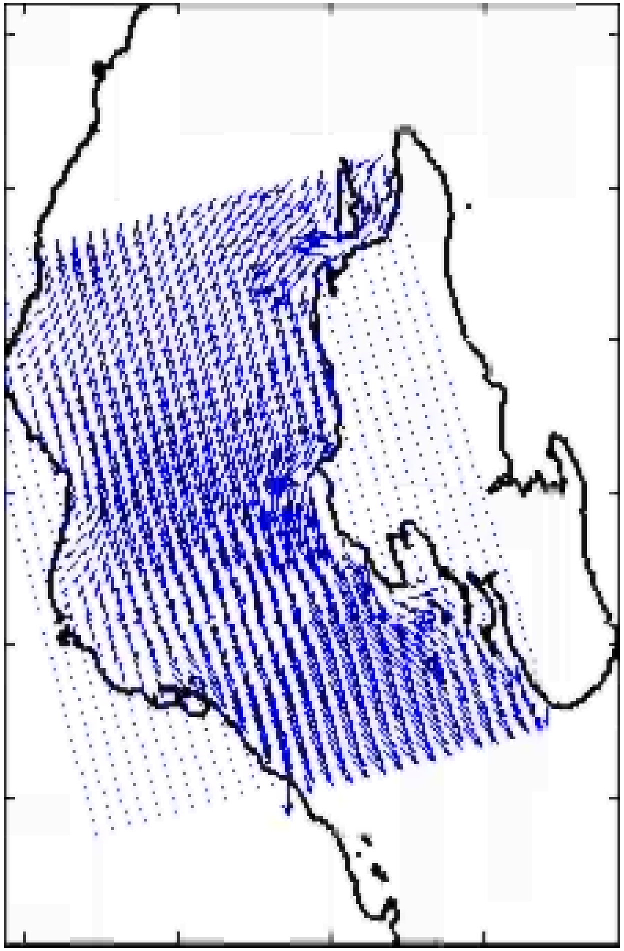
Results

- Semi-diurnal (M2) tide coming in through the southern mouth. Sea surface elevation.



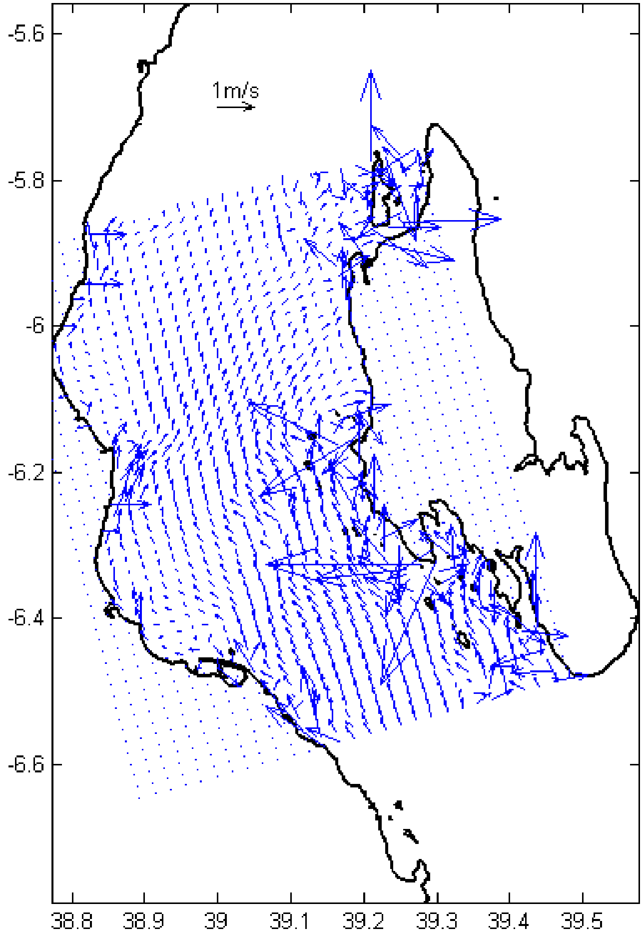
Results

• Semi-diurnal (M2) tide coming in through the southern mouth. Velocity vectors.



Results

• Semi-diurnal (M2) tide coming in through the southern mouth. Residual vertically integrated velocities.



- An overall northward flux all along the channel is observed.
- High speed velocities up to ~4 m/s are observed in punctual locations along the coast of Zanzibar due to reflection caused by morphological features of the coast line.
- Tidal forcing generates stronger current velocities (~60 cm/s) than wind forcing (~30cm/s).

Further steps…

- Putting all together wind, tide, stratification, and running for long time.
- Including more local data if available.
- Validating the results.
- Developing a mesoescale model with global data to get more realistic forcing fields for the free surface and open boundary conditions.
- Nest the local model to the mesoescale one.

Conclusion

- We have
  - A team that is doing well and a building capacity of modeling at IMS will be achieved
  - Developed a hydrodynamic model of Zanzibar channel. It revealed a number of observations

- To make a useful model for the stakeholders for use in making decisions
  - We need to incorporate local measured data of the channel (salinity, temperature, current, etc).
  - Global data on the Zanzibar channel is not available.
  - The model should be run for long time.
  - We also need to *validate* the model.
  - The model is very potential and it can be very useful for management, planning and decision making

Thank you