Simulating the tidal regime the coastal zone of the Red River Delta

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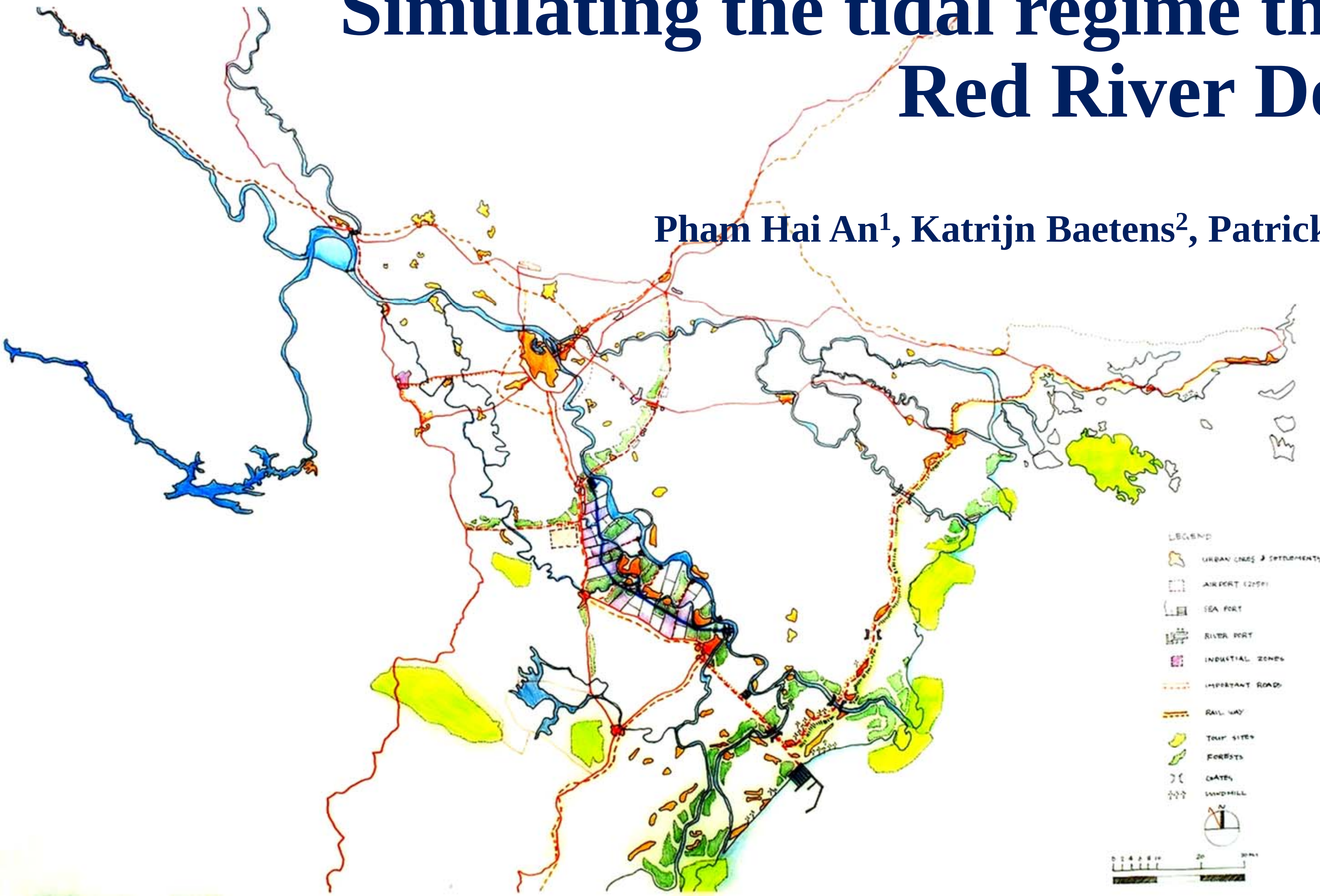

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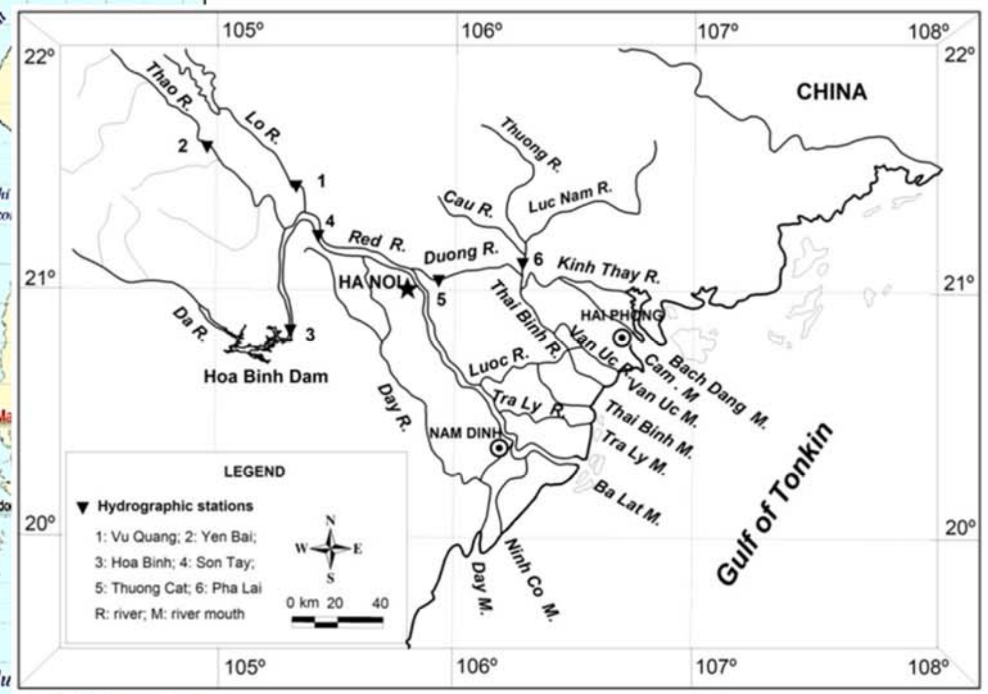
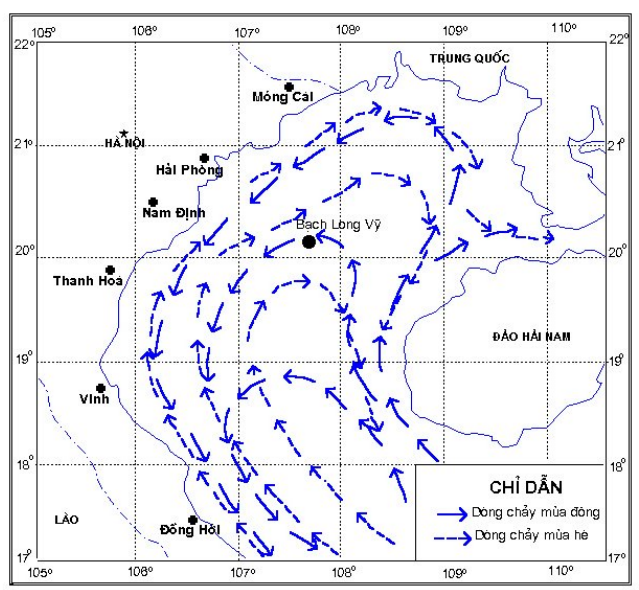
JONSMOD 2016

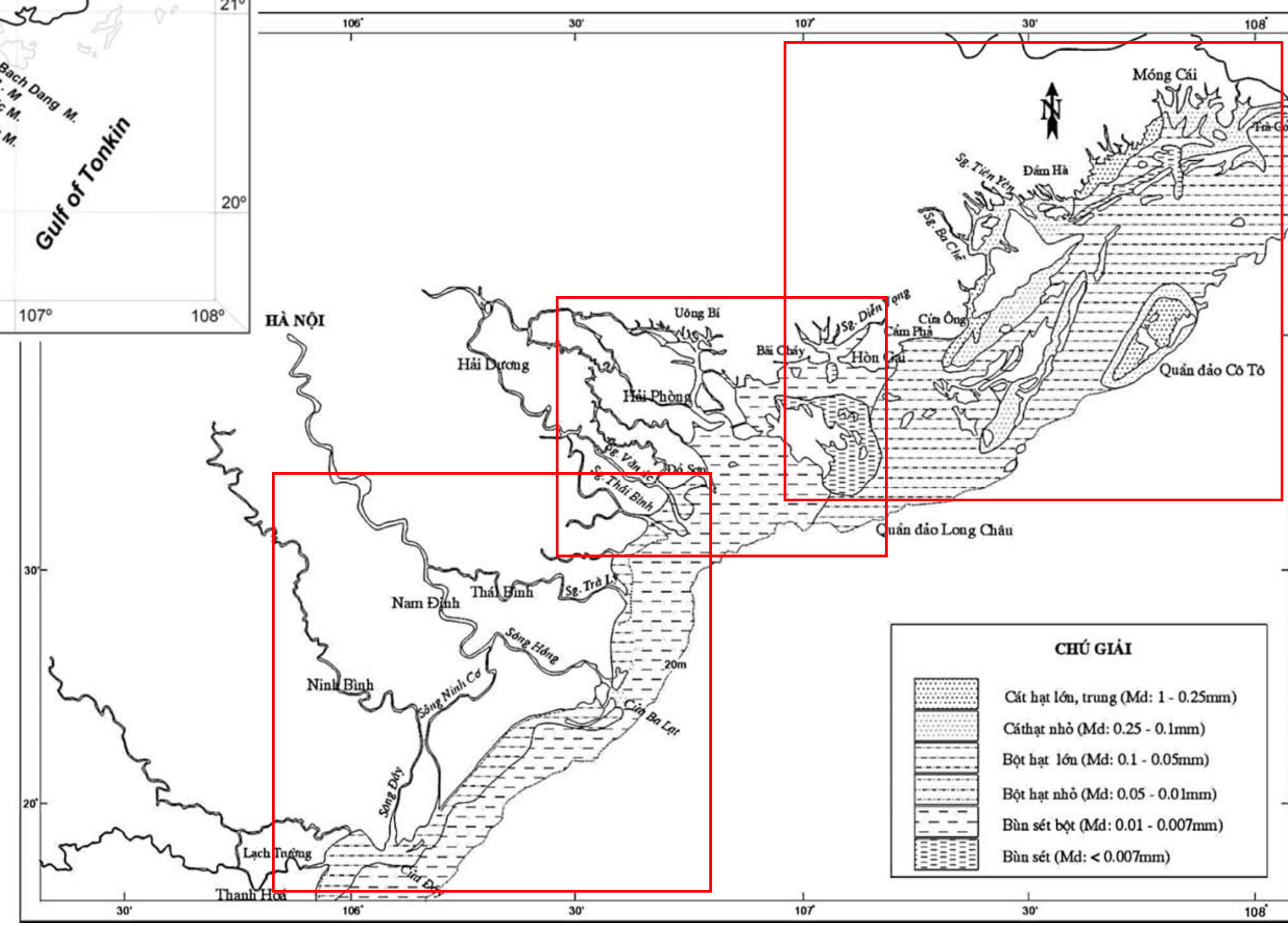
Oslo, Norway, May 10-12, 2016

The problem – Red River Delta (RRD)





Dòng chảy tầng mặt ở vịnh Bắc Bộ trong mùa đông và mùa hè



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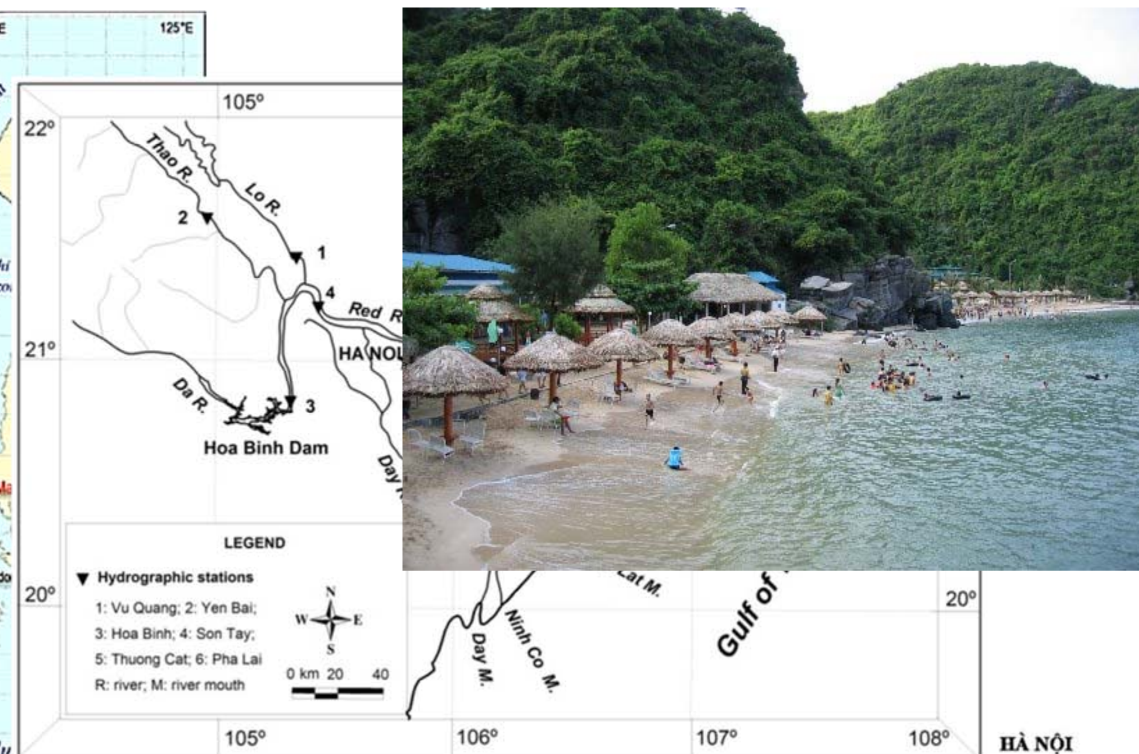

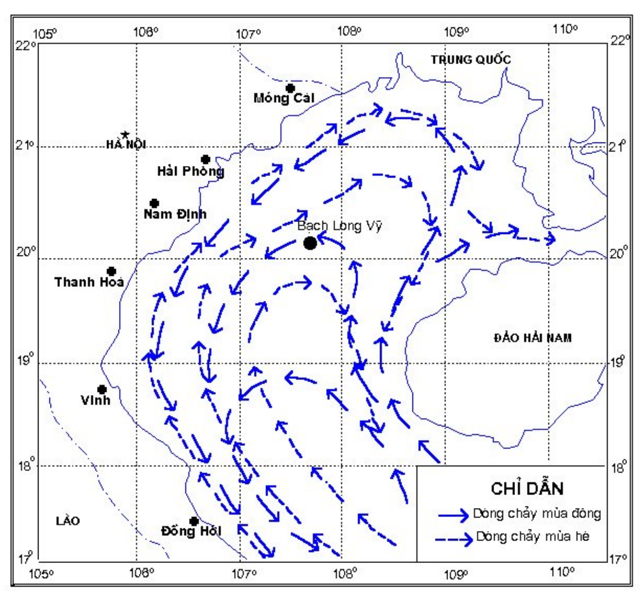

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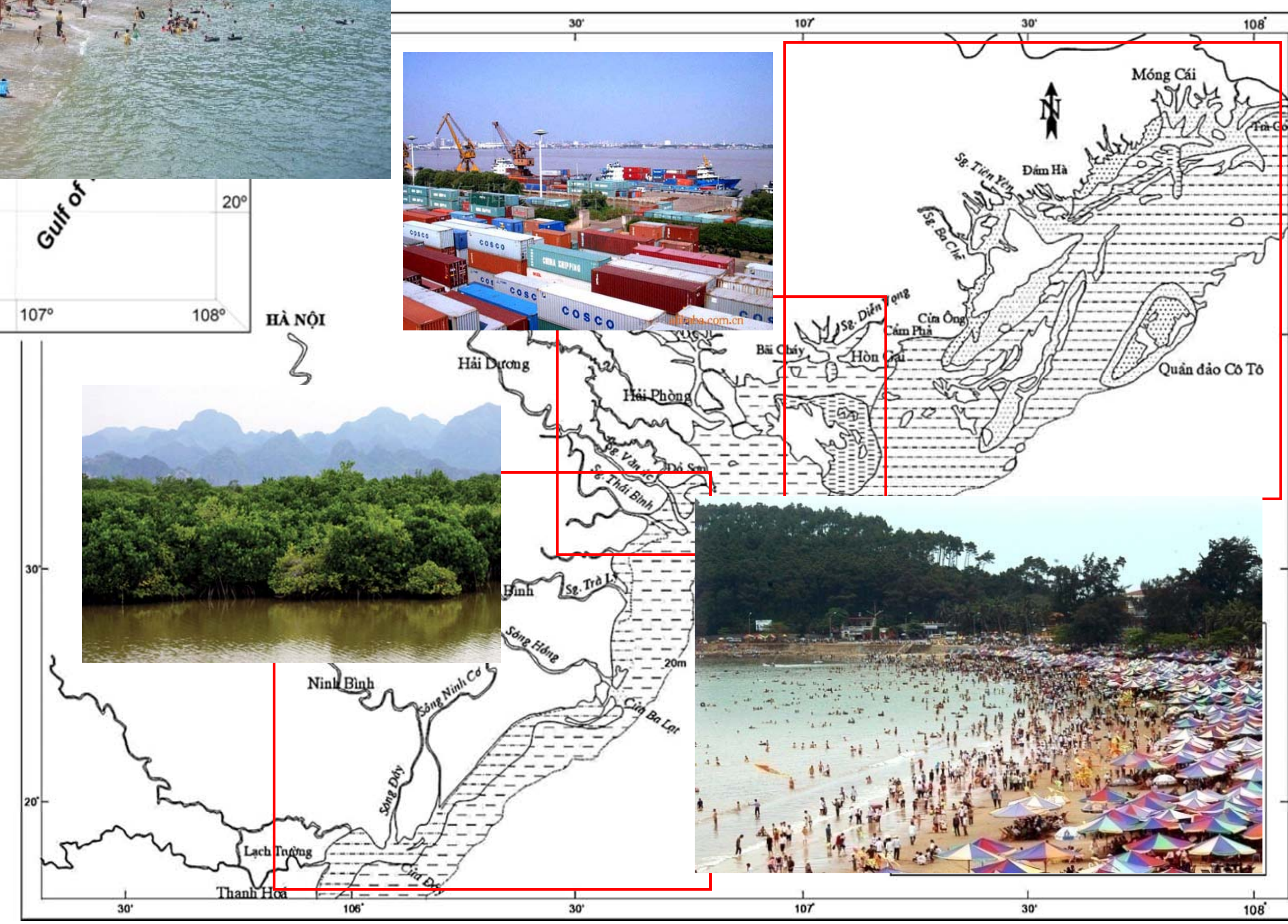
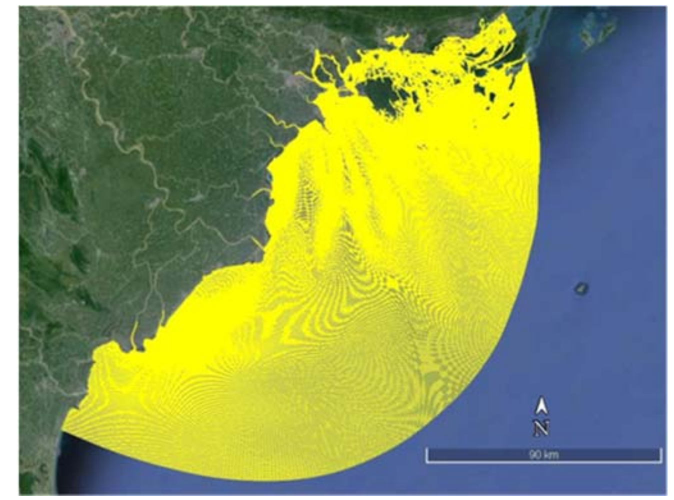
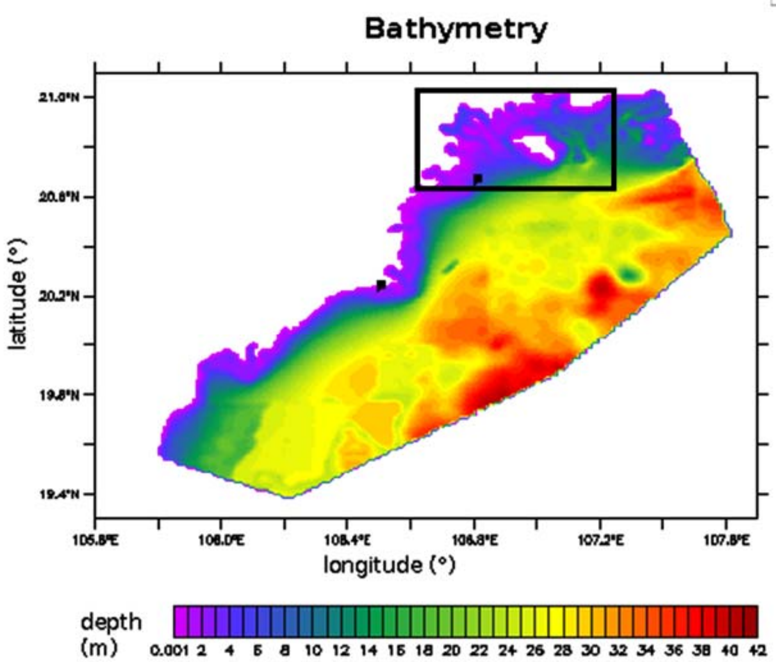


Solving the problem for tidal regime the coastal zone of the RRD



For this simulation tidal scenario

- *data is updated (2014)*
- *computed with coordinate curvilinear system*



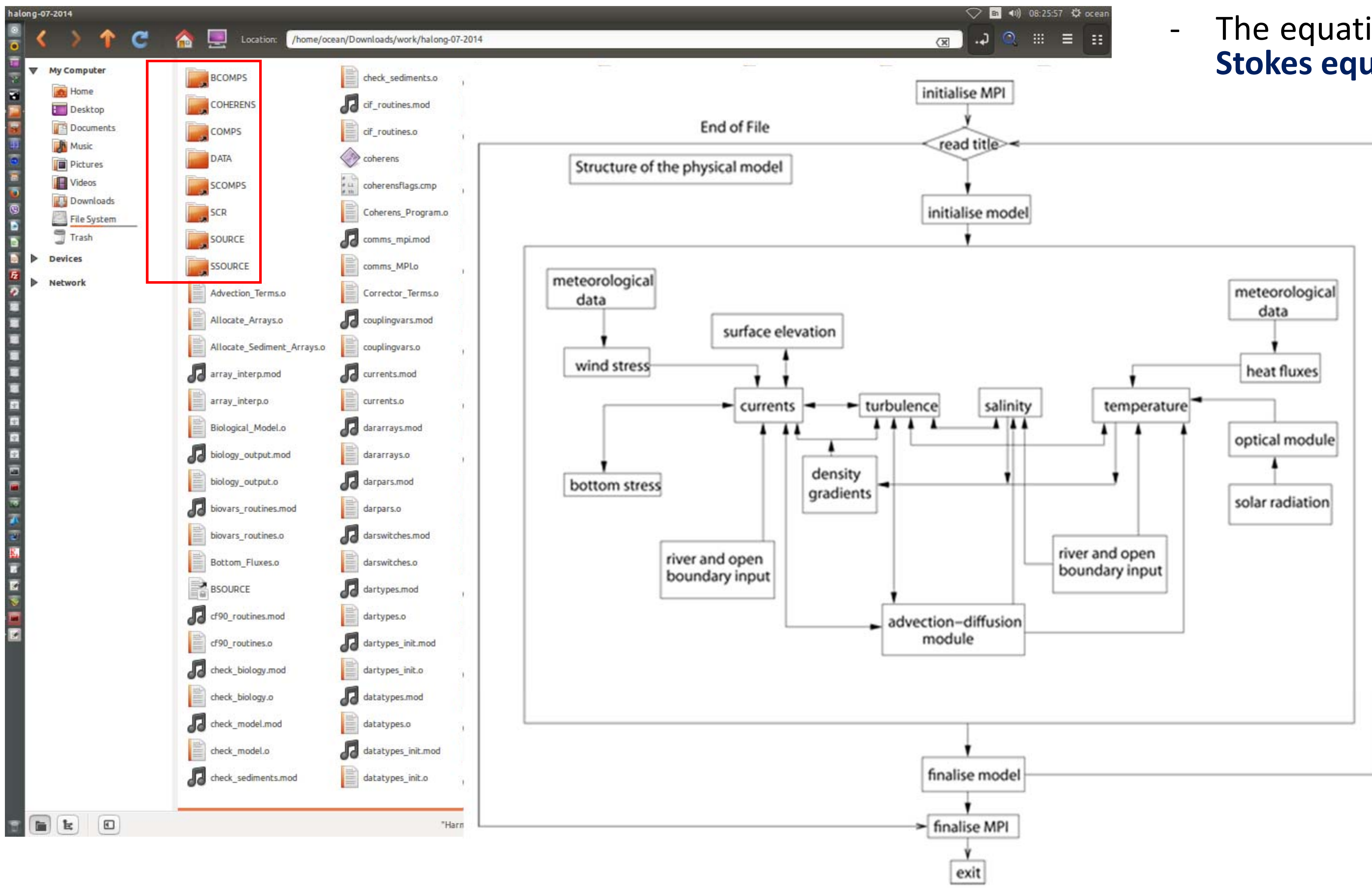
Contents

- New version of **COHERENS V2.9**
- **Coupled Hydrodynamical - Ecological Model for Regional and Shelf Seas** model to simulation tidal regime study along the coastline of the Red River estuary.
- Setup modelling for RRD coastal area
- Results
- Future

- Support from the CEBioS programme of the Royal Belgian Institute of Natural Sciences (RBINS), Belgium (2015-2017)
- Development of a physical-ecological model system for the study of CLImate change and MAnagement of marine Resources in Vietnamese COastal waters (CLIMARCO) in Cooperation Programme on Science and Technology between VIETNAM AND BELGIUM (2013)

Model COHERENS V2.9

Fluid dynamics is based on: **the equations for the conservation of mass, momentum and energy**



- The equation system of the three conservation laws - known as the **Navier Stokes equations**
  - **Turbulence**: as superimposed fluctuations of the flow on the mean or averaged flow
  - *Vertical travel of acoustic waves is filtered out from the vertical momentum equations (hydrostatic model)*
  - **Arakawa C grid** for space discretization
  - **Finite difference method**
  - The COHERENS file structure looks like this:

    Code

    COHERENS_License

    Data

    install_test

    install_utils

    Scr

    Setups

    utils

open source model for coastal and shelf seas, estuaries, ect, development by researchers at RBINS in collaboration with worldwide scientists

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Model COHERENS V2.9

- The equation system of the three conservation laws - known as the **Navier-Stokes equations**
- Turbulence can be regarded as superimposed fluctuations of the flow on the mean or averaged flow
- The vertical travel of acoustic waves is filtered out from the vertical momentum equations (i.o.w. it is a hydrostatic model)
- COHERENS uses the well known **Arakawa C grid** for space discretization
- COHERENS is based on the popular **finite difference method**. This method is based on the Taylor expansion and on the straightforward application of the definition of the derivatives

* **The text in blue denotes folders**, the one in green are executable programs and the black text denotes a text file.
* The program consists of several file directories, some executable files and the file that contains the license under which COHERENS operates.
* The file directory **code** contains the Fortran files and the files necessary to compile the code. The files that execute COHERENS are store in **scr**.
* The directory **setups** contains a number of test cases that demonstrate how to implement several features (a river, salinity, temperature, …)
* The directory **data** contains the data files necessary to run the test files.
* **Install_test** is an executable file that links the working directory with the program.
* The directory **Utils** and the executable **install_utils** are used in the official developing circuit of the code and are of no interes to the external user

Model COHERENS V2.9

-> Install_test

- Executable file to install COHERENS in your working directory or to install a predefined test case.
- Executing this file does two things.
- It creates the symbolic links needed to operate the program from your working directory. The links are referring to the fortran code (**SOURCE**, **BSOURCE** and **SSOURCE**), to compilation directories (**COMPS**, **BCOMPS** and **SCOMPS**) and to the program executable files (**SCR**).
- It copies the executable files (**Makefile**, **Run**,**Run_hpd_par**,**Run_hpd_ser** and**Run_vic**) and the file used to define the compilation details (coherensflags.cmp) to the local working directory.

-> Code

- This directory contains the following subdirectory trees:
- **biology physics sediment**
- You see that all these directories contain a COMPS and a SOURCE sub directory.
- The **comps** directory contains:
- coherensflags.cmpdependencies.cmpobjects_bio.cmp
- compilers.cmpdependencies_sed.cmpobjects.cmp
- dependencies_bio.cmpMakefileobjects_sed.cmp

Multi-grid scheme in COHERENS

- **Multi-grid scheme**

  - algorithm for solving differential equations with a heirarchy of discretizations

- **Explicit time stepping**

  - slow

  - cfl condition (to keep the error buonded)

- **Imlpicit time stepping**

  - unconditionally stable

  - large time steps can be handled

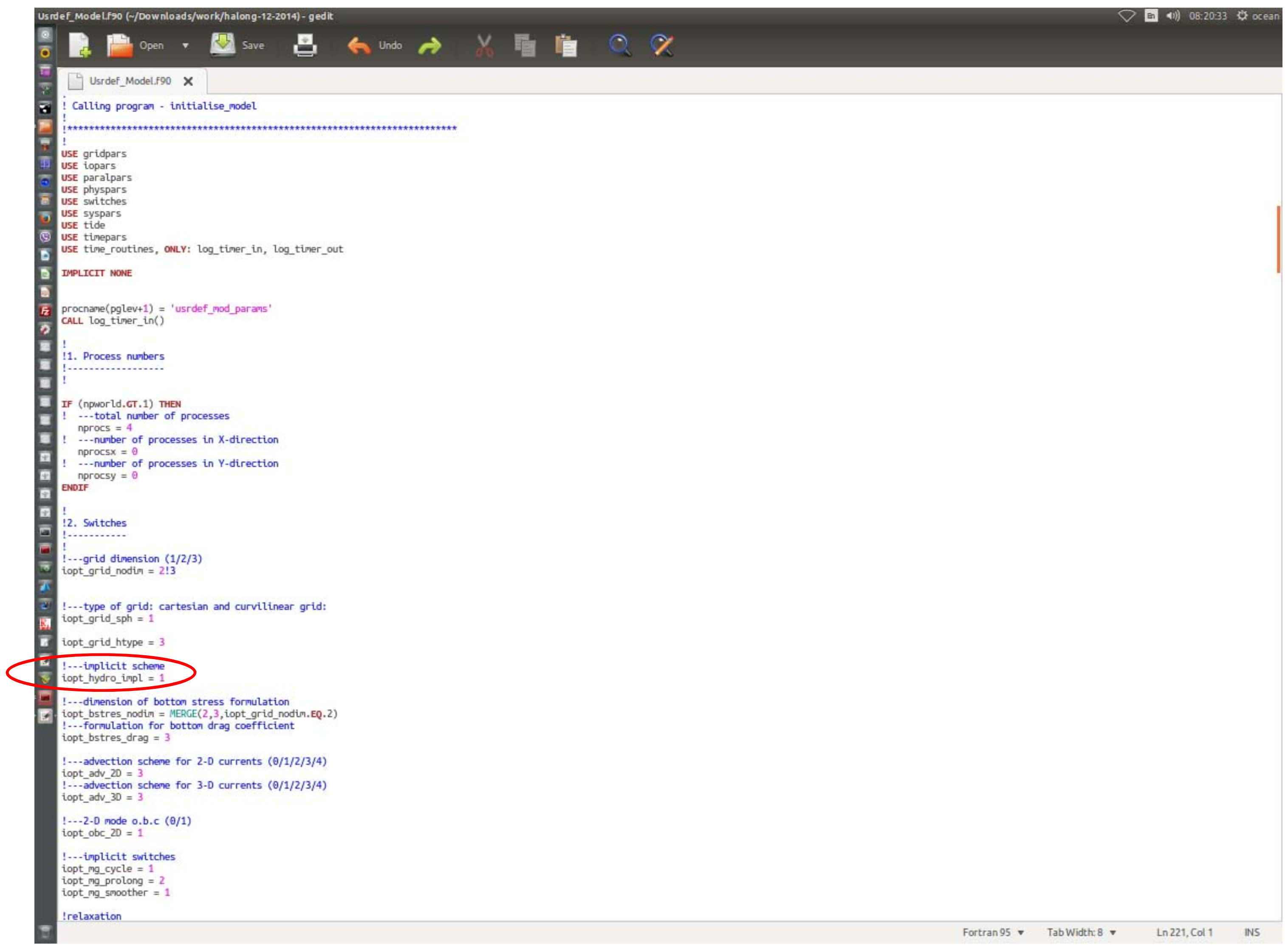
- **Using a multi-grid implicit scheme**

- Change in CONHERENS with switch: iopt_hydro_impt

  - 0: explicit time discretization (more splitting techique)

  - 1: implicit time discretization with multi-grid scheme

- **Scenario simulations**



Stephanie Ponsar and Patrick Luyten (MUSEUM)

Multi-grid scheme in COHERENS

-> Using a multi-grid implicit scheme

- It solves an equation involving both the current state of the system and the later one
- It better than explicit scheme (the state of the system at a later time computed from the system state at the current time)
- Time step 20 sec (explicit) , 300 sec (multigrid)

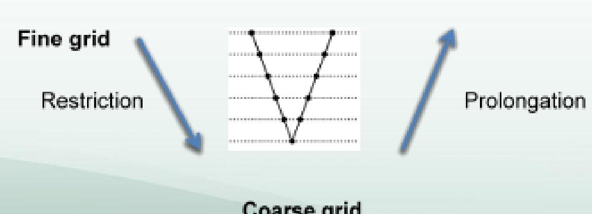
- What you wish:
  - To solve T(u) = f
  - Solution: u
- Error: $e_m = u_m - u$
- Residual: $r_m = T_m(u_m) - f_m$

How does a multi-grid scheme work

CFL (Courant Friedrichs Lewy condition)

- Error:
  - high frequencies: removed in a few iterations
  - low frequencies: reduced very slowly
  - multi-grid idea: to change to a coarser grid where low frequencies act like higher frequencies

- Three stages:
  - A restriction matrix: transfers vectors from the fine grid to the coarse grid
  - Iteration methods: on the coarser grid
  - A prolongation (interpolation) matrix: to return from the coarse to the fine grid:
  - Fine-coarse-fine loop: cycle

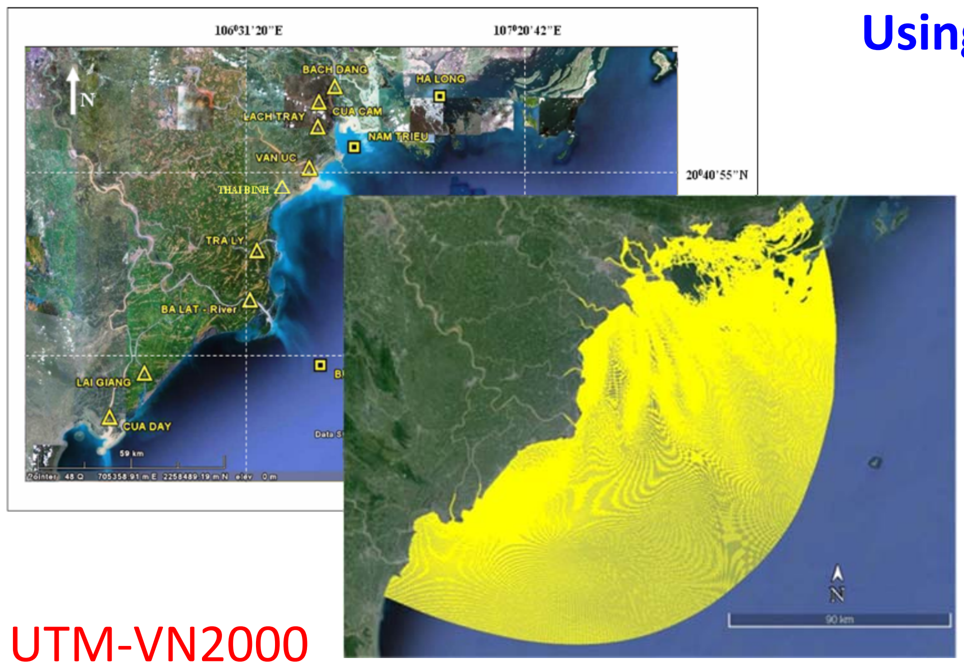


- Algorithm:
  - Solve $T_m(u_m) = f_m$ on the fine grid
  - Compute residual on the fine grid: $r_m = T_m(u_m) - f_m$
  - Restrict the residual from the fine grid to the coarse grid
  - Cycle γ times (iteration) to minimize the residual on the coarse grid
  - Apply the coarse grid correction
  - Prolongate from the coarse grid to the fine grid

Setup modelling - Coastline and Bathymetry

Preparing source data

- Topography map (1 : 50000) - near coast & General Bathymetric Chart of the Ocean – offshore GEBCO -1/8



UTM-VN2000

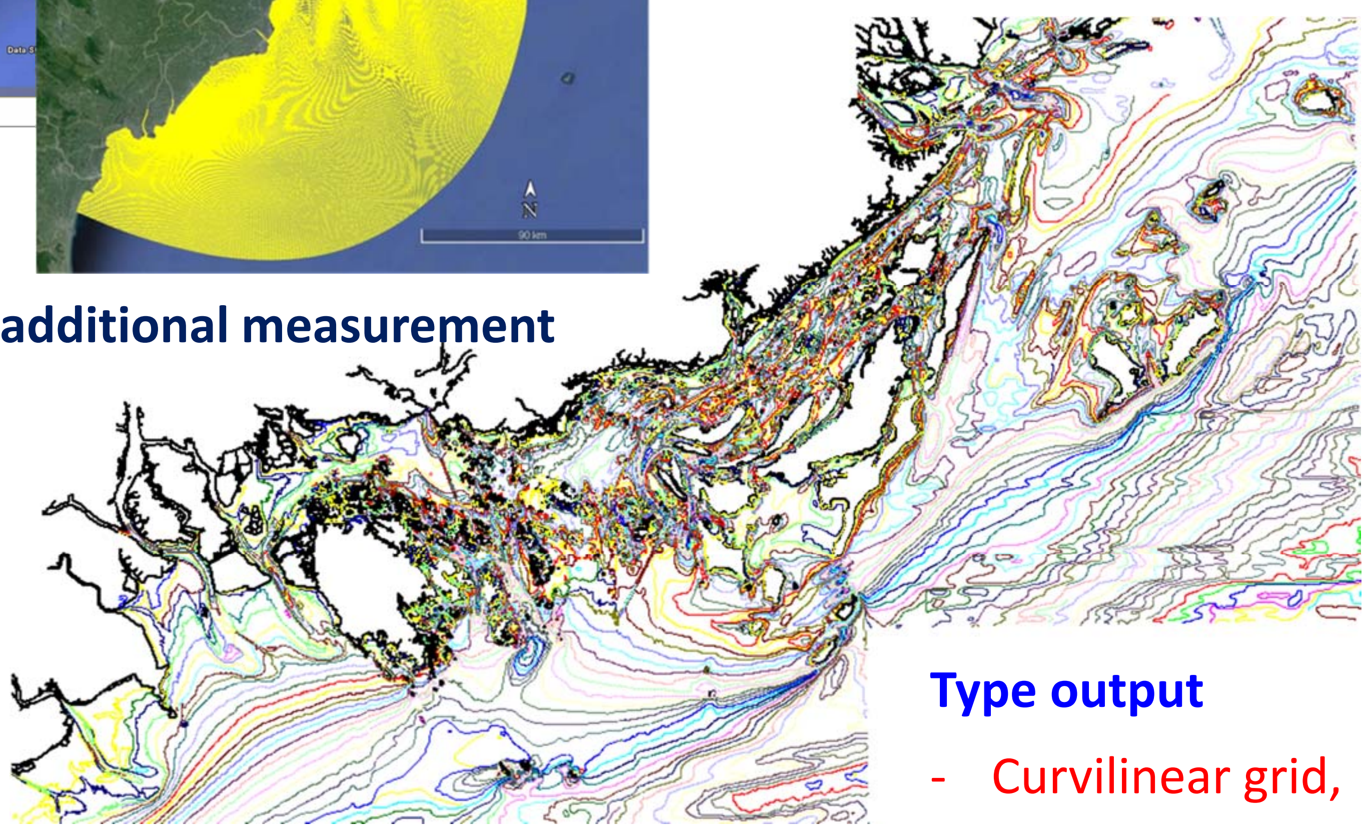
(digital map) additional measurement

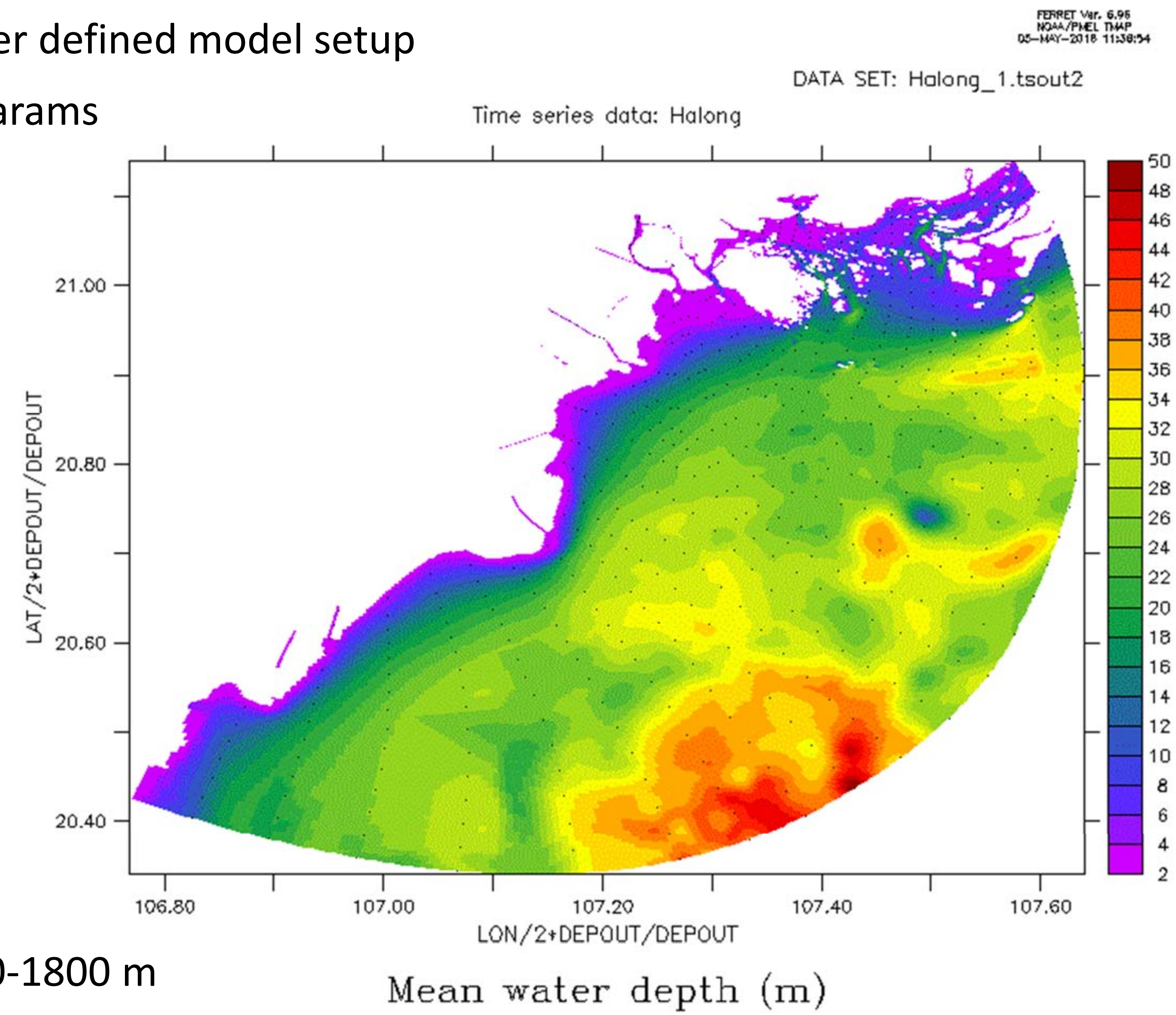
Using methods Usrdef_Model.f90 - User defined model setup

… / SUBROUTINE usrdef_mod_params

… / SUBROUTINE usrdef_grid

Ferret graphic (Linux)





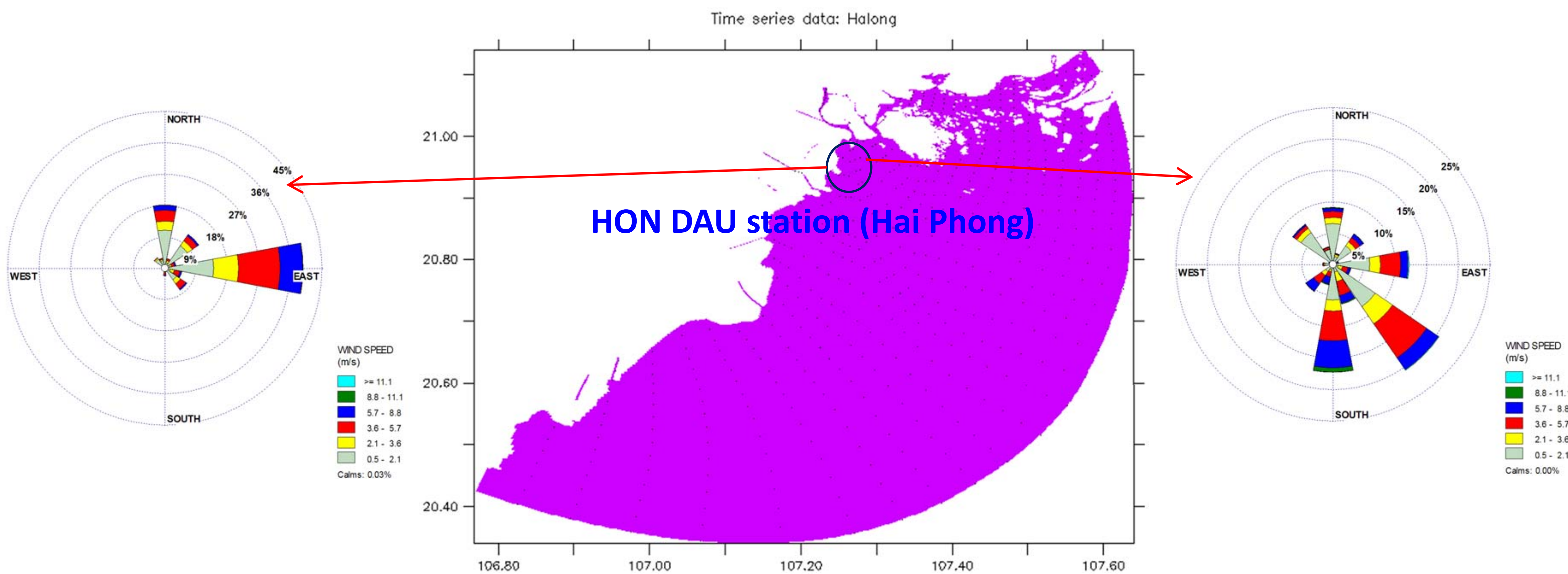
Type output

- Curvilinear grid, 10-1800 m
- With 607x502 grid cells and bathymetry file

Setup modelling - Wind data

Parameters

- wind velocity, measured interval: frequency **6 hours/obs**
- data time: **dry season – December and wet season – July**



Source: Measured by Vietnam National Hydro-meteorological Service

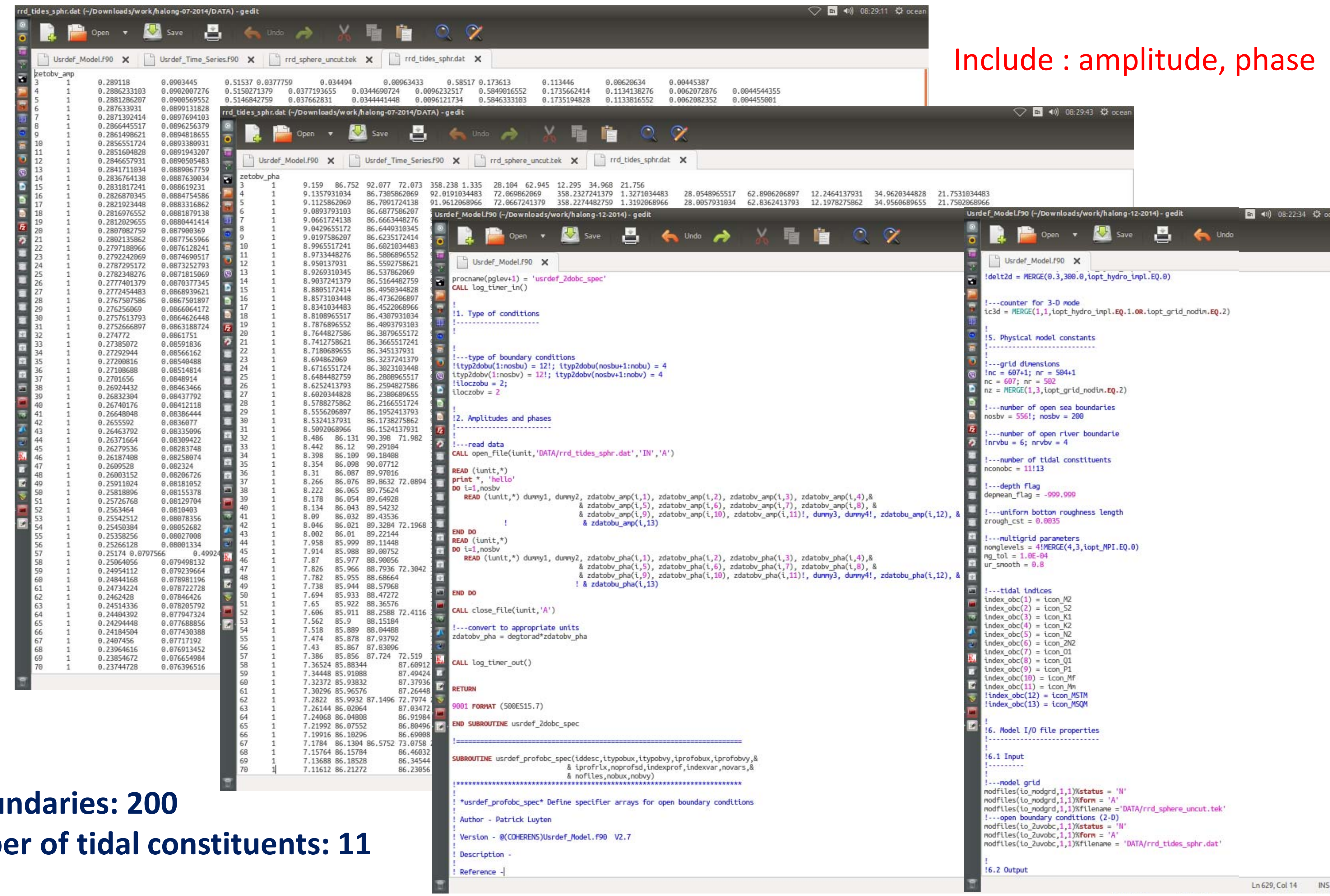
Dry season / during the winter monsoon, the wind blows from the northeast generating a southward, southwest flow, the average speed 5m/s (sometimes appear wind speed with value 9m/s)

Compared with winter, during summer monsoon, reverse current direction, the average speed 4m/s (8m/s)

Setup modelling – Tide data

Forcing for sea boundary : the open sea boundaries condition include effect of 11 tidal constituents

Include : amplitude, phase



- **From on FES2004 database of LEGOS**

  Laboratoire d'Etude en Géophysique et Océanographie Spatiales - offshore

- **Tidal harmonic constant of**

  M2, S2, K1, K2

  N2, 2N2, O1, Q1, P1

  Mf, Mm

  (K1, O1, M2, S2)

- **From observed data**:

  Sea level (analyzed) near shore by Vietnam National Hydro meteorological Service

- **Hon Dau station**:

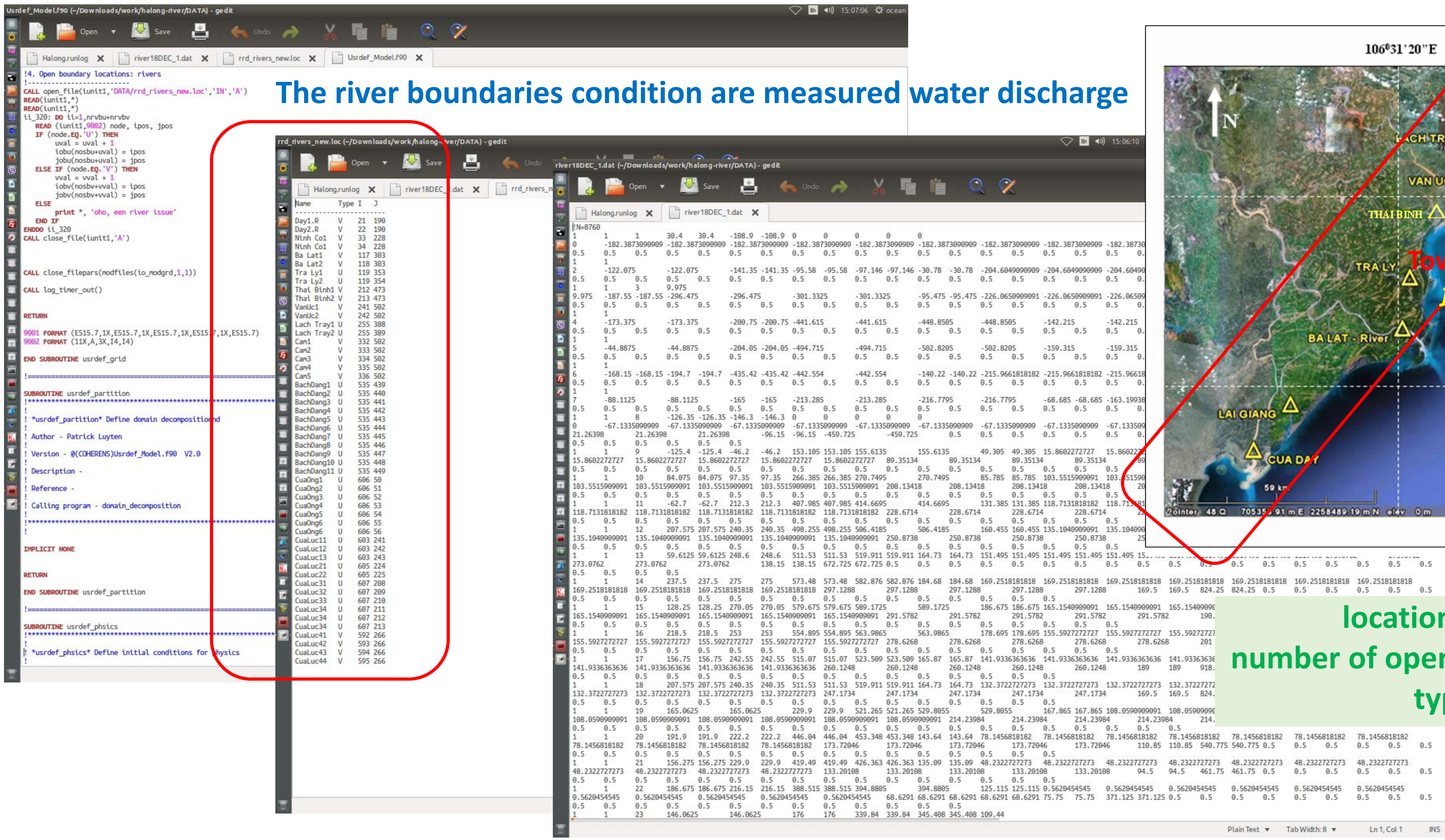
  frequency 1h/obs for dry and wet season

number of open sea boundaries: 200

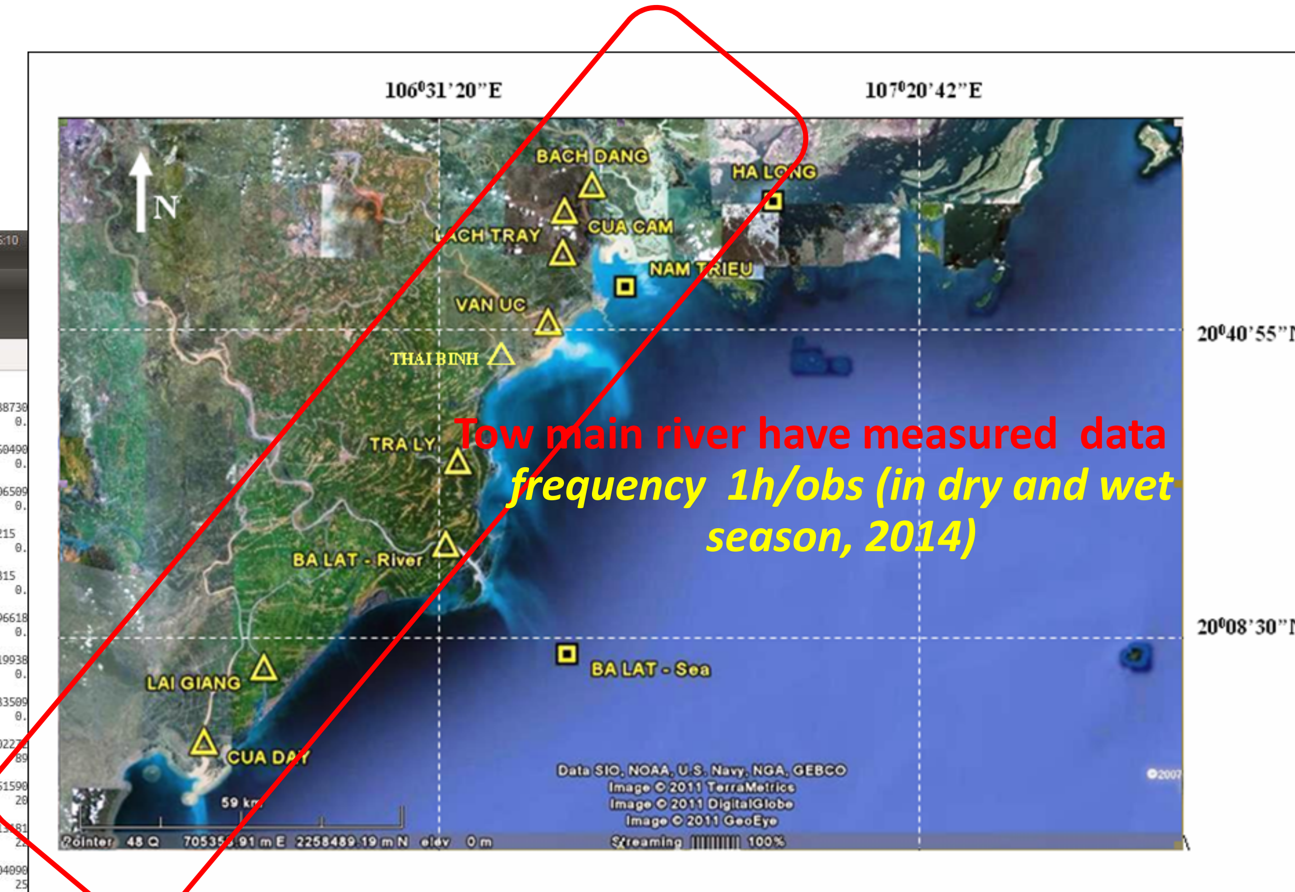
number of tidal constituents: 11

Setup modelling – River data

River discharges for 9 rivers mouth



The river boundaries condition are measured water discharge



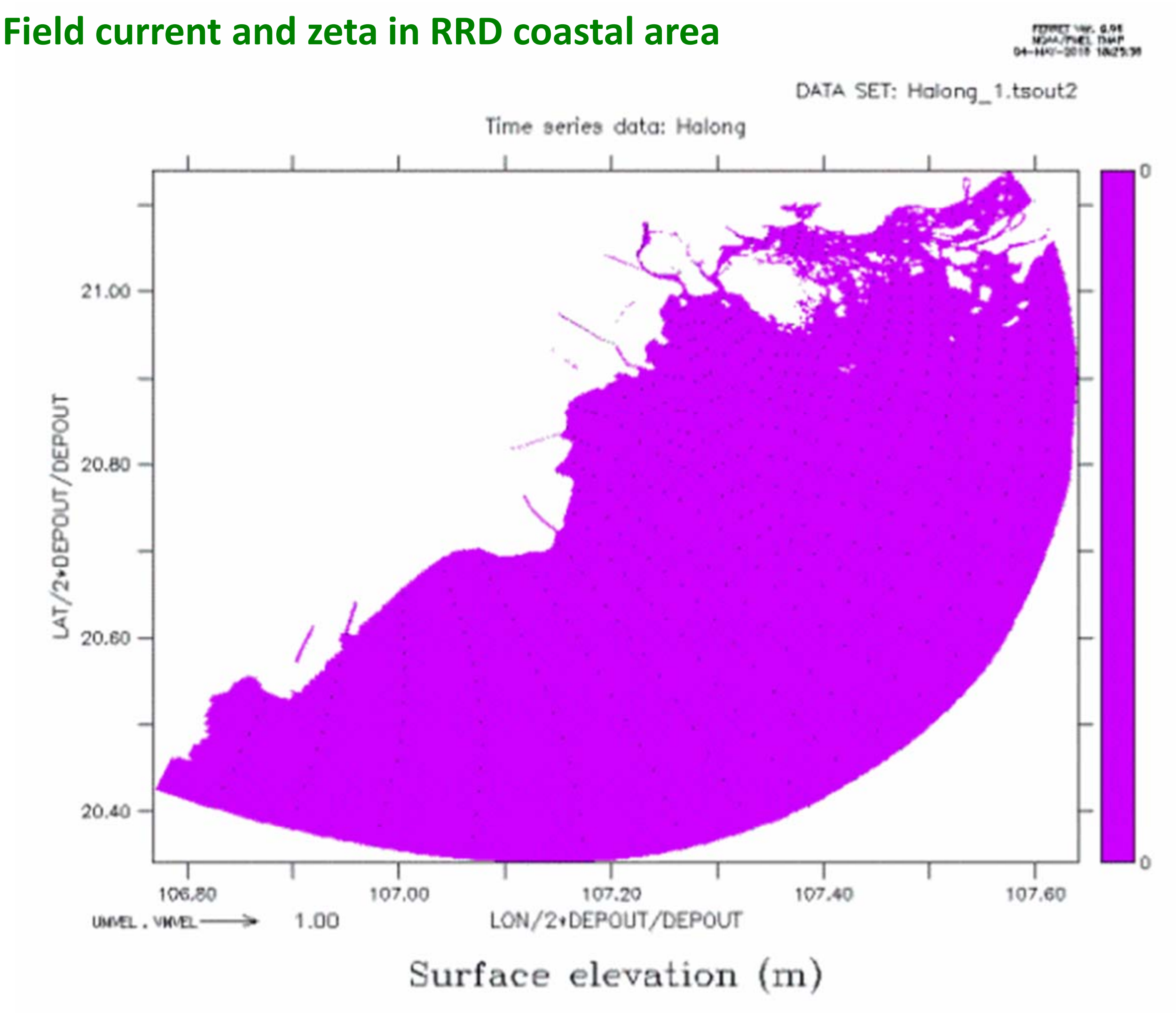
Tow main river have measured data frequency 1h/obs (in dry and wet season, 2014)

location of open boundary (i,j)
number of open river boundaries: 52, 33u, 19v
type data: discharge

- **Discharge data in different river is calculated correlation analysis from history data and survey data with short preiod**

Results

Field current and zeta in RRD coastal area



The initial simulation results show that along the coast the tidal regime is conform to commonly known rule:

- **diurnal waves (O1, K1) have maximum tidal amplitude**
- **semi-diurnal waves (M2, S2) have a minimum amplitude**
- **the amplitude of tidal diurnal waves decrease gradually from North to South**
- **on the contrary, the tidal semi-diurnal waves increase from North to South**

Future

Continue

- **Tide**
- **Scenarios base on Climate change and Human activities**
- **Climate change simulation scenarios for modelling area** based on the Climate change scenarios for Vietnam of Ministry of natural resources and environment (2009)
- Focus on: temperature and sea level rise, change of wind and extreme typhoon therefore

Update and use

- Total discharge at the estuary
- Observation data
- Temperature - Salinity data from WOA2009 (World Ocean Atlas 2009)
- Forcing fields, heat and freshwater fluxes, are based on monthly climatology of the COADS -Comprehensive Ocean Atmosphere Data Set
- Wind forcing is interpolated from climatology of QuikSCAT satellite scatterometer

Thanks for your attention !

Thank to Dr. Katrijn Baetens, Patrick Luyten for guide us about

Training for Hydrodynamics Model in during time December, 2015