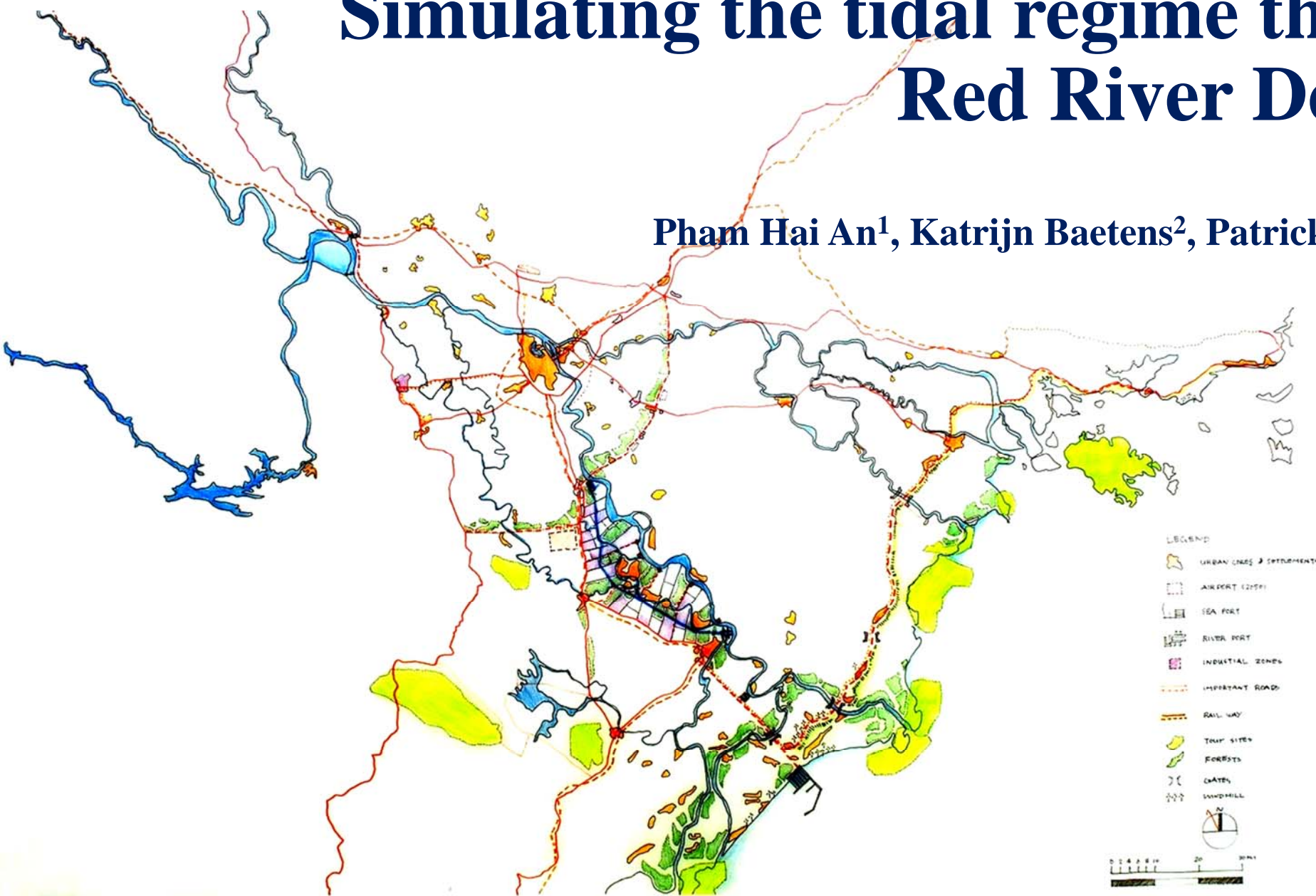


Simulating the tidal regime the coastal zone of the Red River Delta

Pham Hai An¹, Katrijn Baetens², Patrick Luyten², Vu Duy Vinh¹

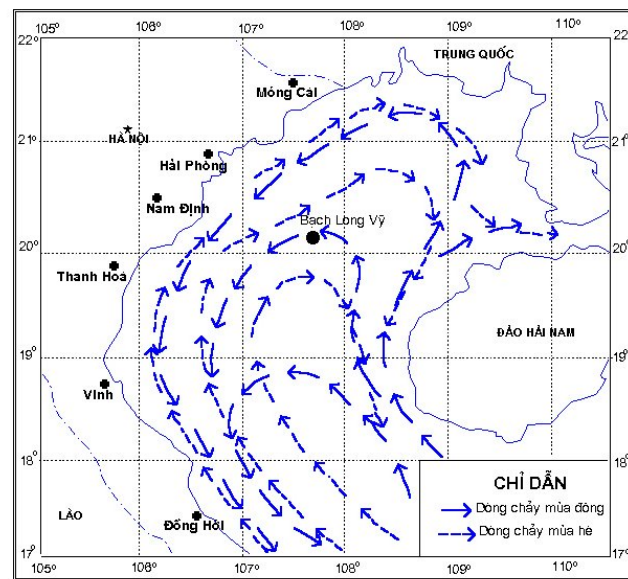
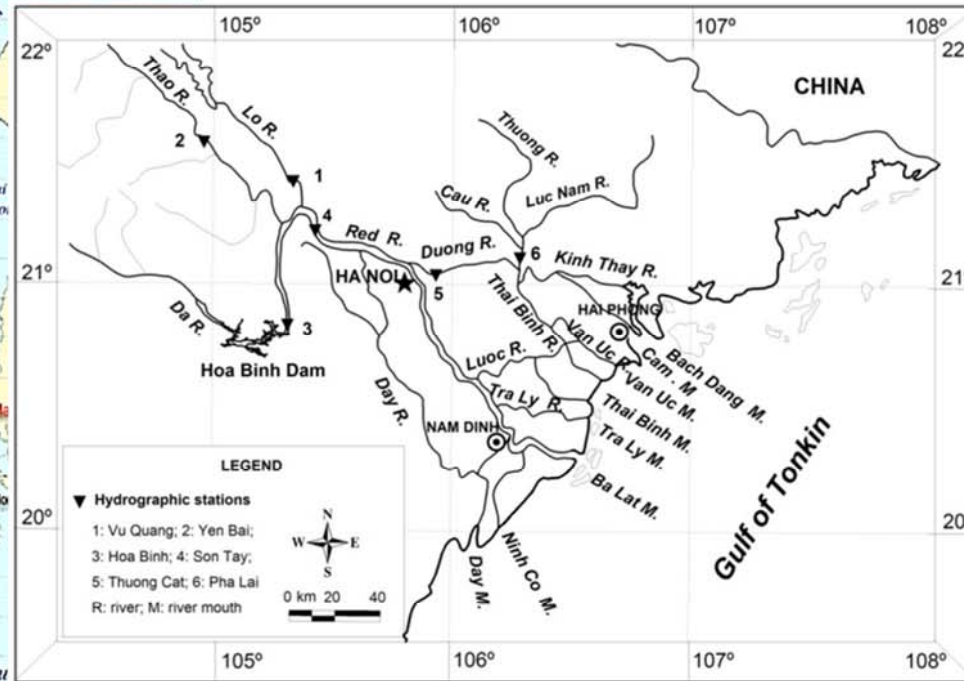


¹ Institute of Marine Environment and Resources, VAST, 246 Danang Street, Haiphong City, Vietnam

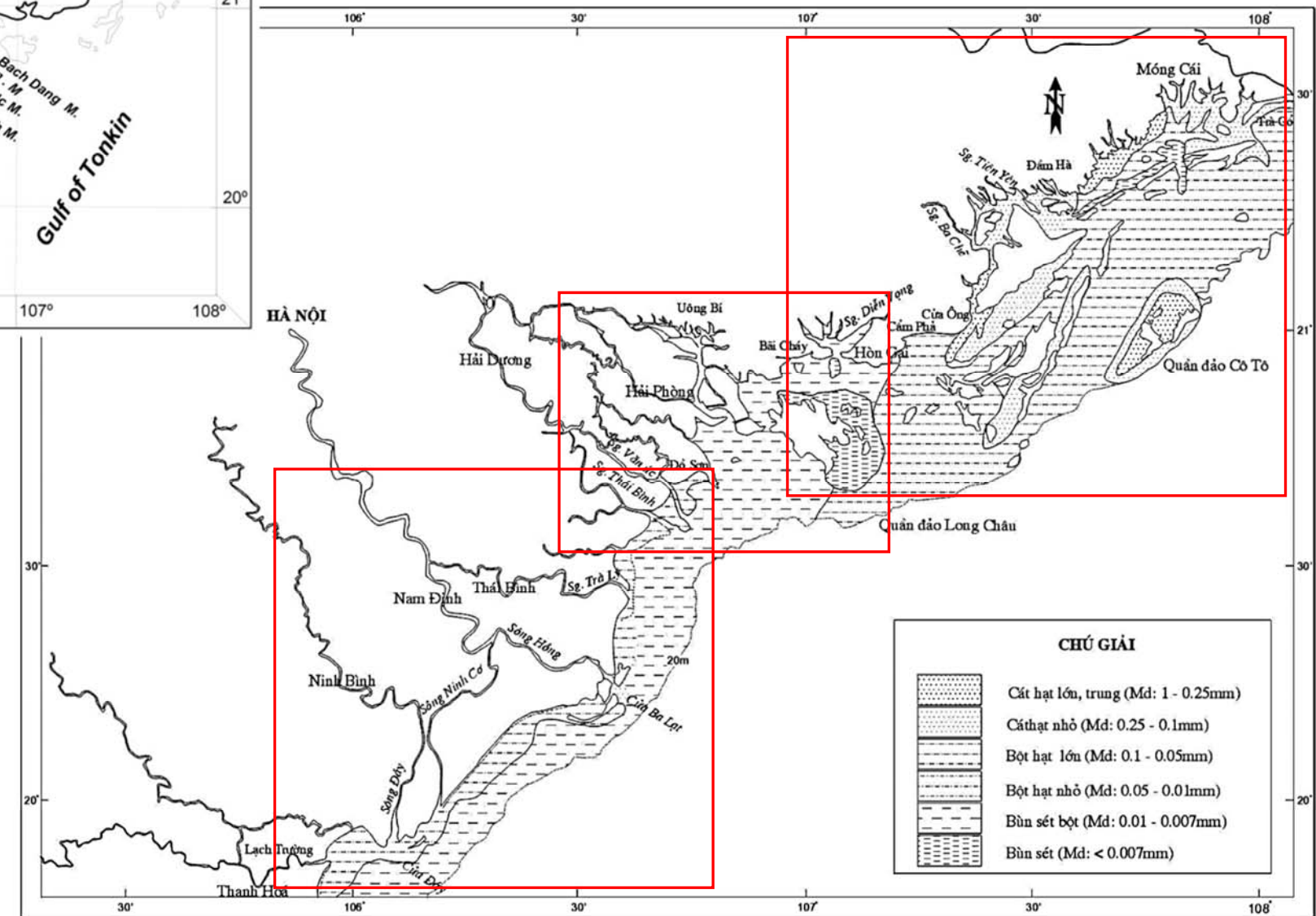
² Operational Directorate Natural Environment (OD Nature), RBINS, Gulledele 100 B-1200 Brussels, Belgium

JONSMOD 2016
Oslo, Norway, May 10-12, 2016

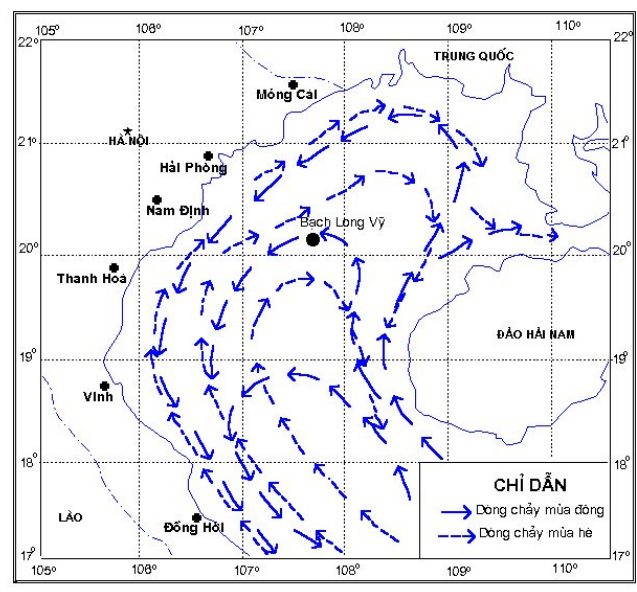
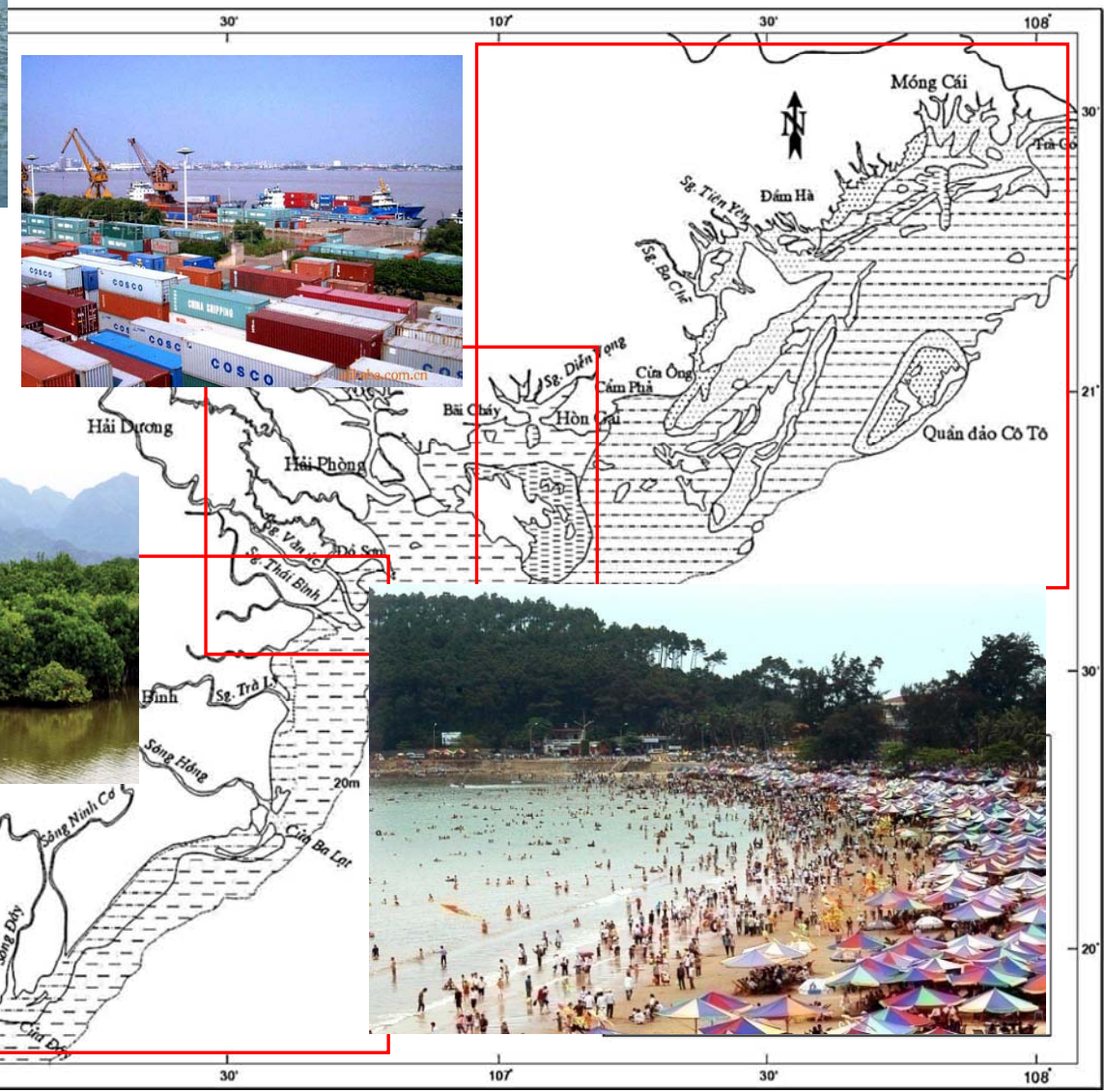
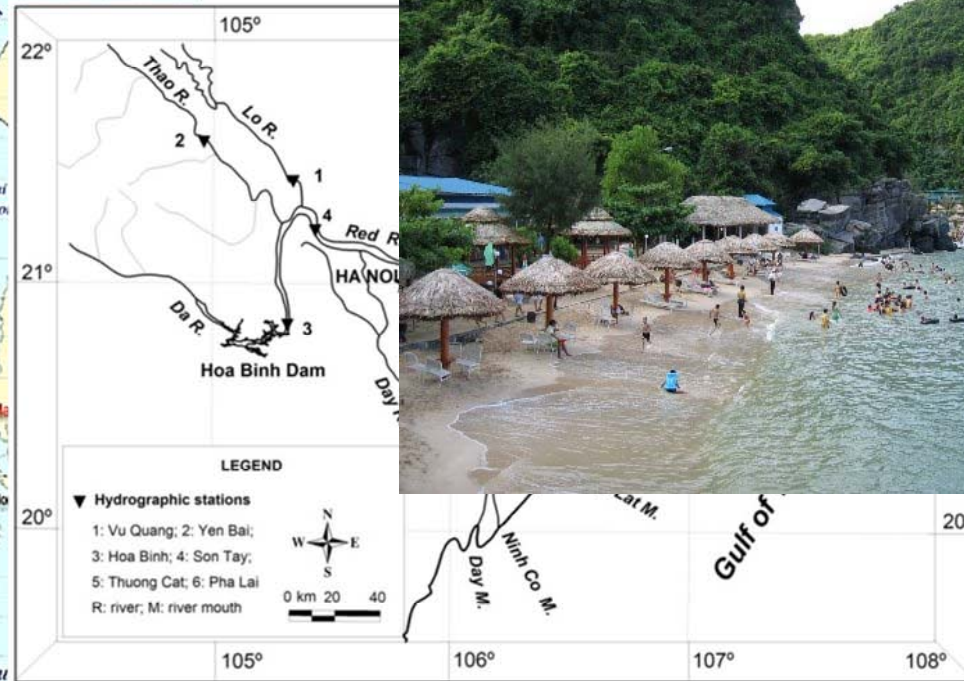
The problem – Red River Delta (RRD)



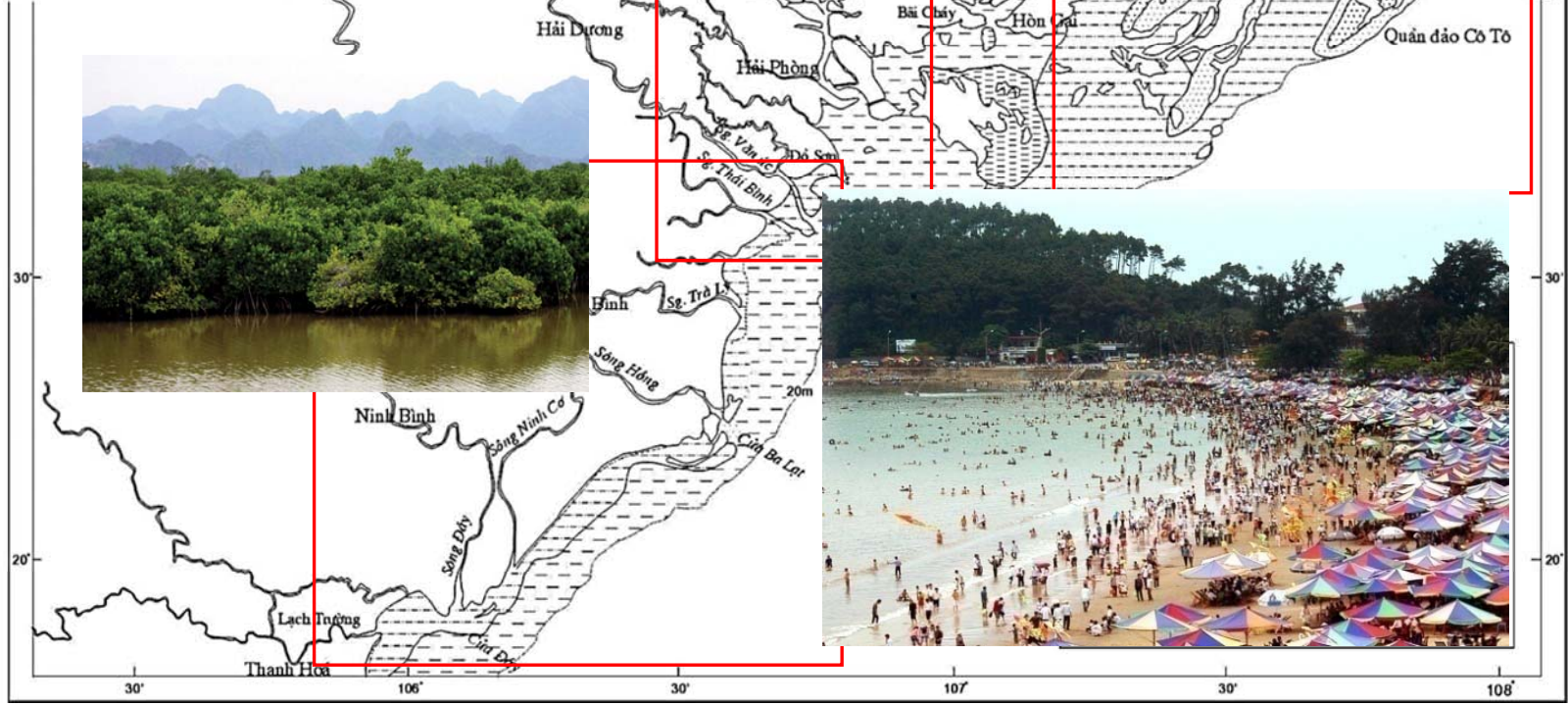
Dòng chảy tầng mặt ở vịnh Bắc Bộ trong mùa đông và mùa hè



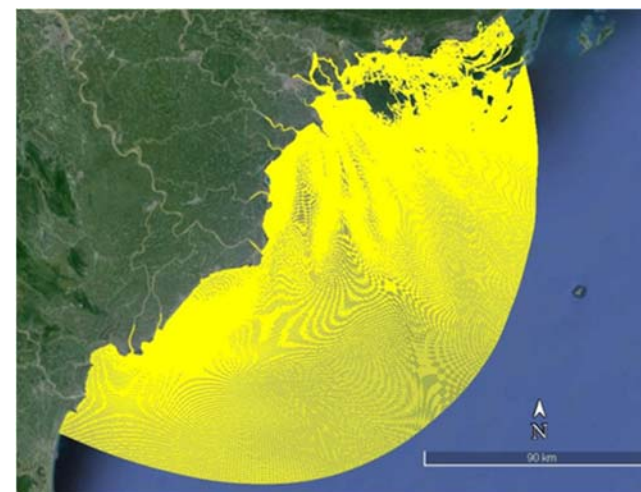
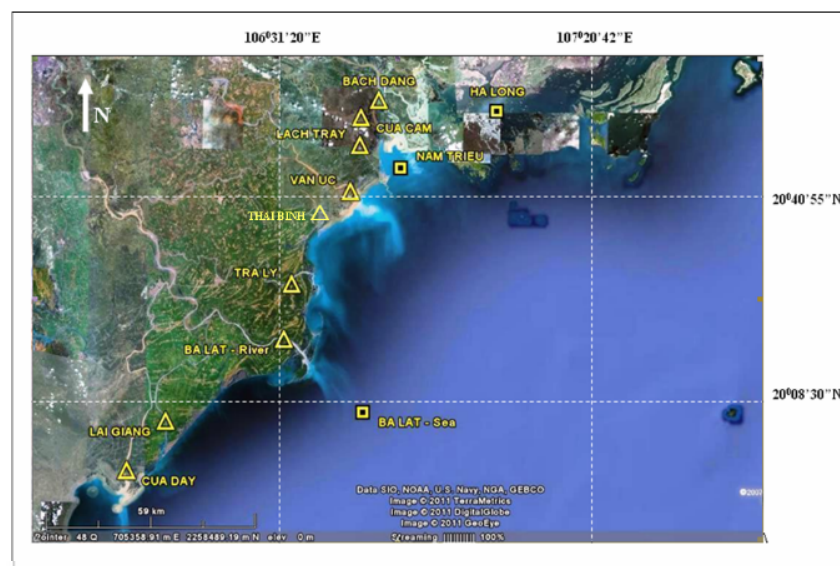
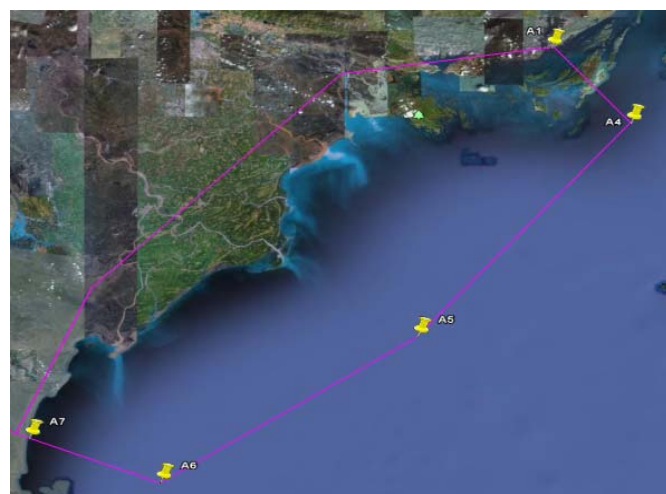
The problem – Red River Delta (RRD)



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



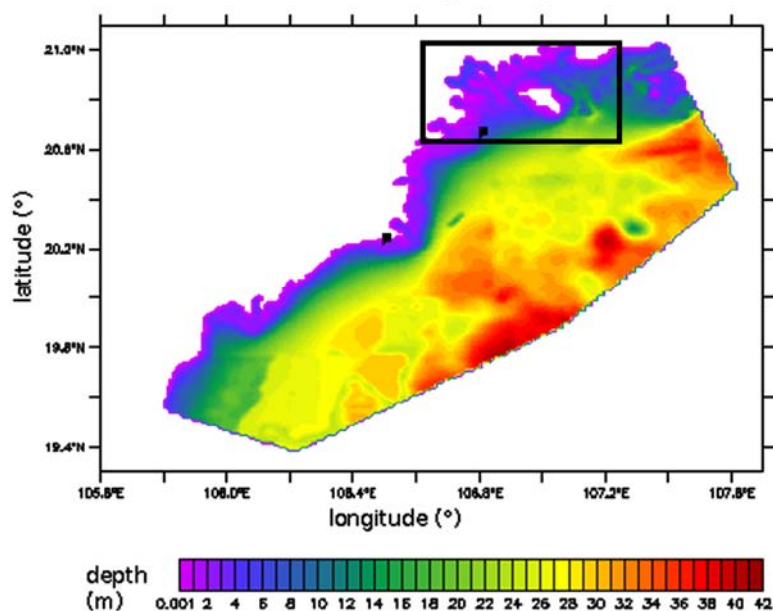
Solving the problem for tidal regime the coastal zone of the RRD



For this simulation tidal scenario

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

Bathymetry



Contents

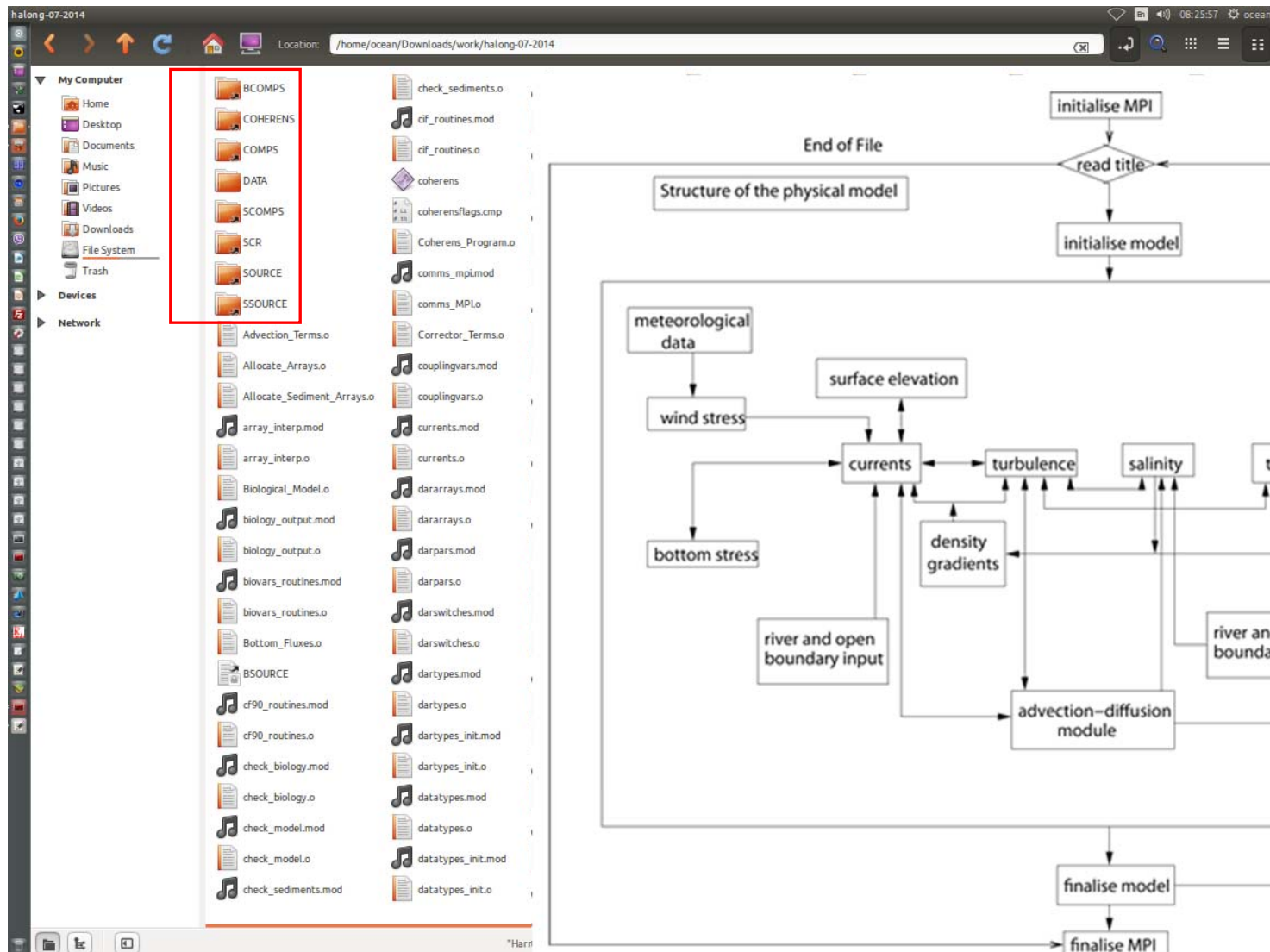
- New version of **COHERENS V2.9**
- **Coupled Hydrodynamical - Ecological Model for Regional and Shelf Seas** model to simulation tidal regime study along the coastline of the Red River estuary.
- Setup modelling for RRD coastal area
- Results
- Future

- Support from the CEBioS programme of the Royal Belgian Institute of Natural Sciences (RBINS), Belgium (2015-2017)

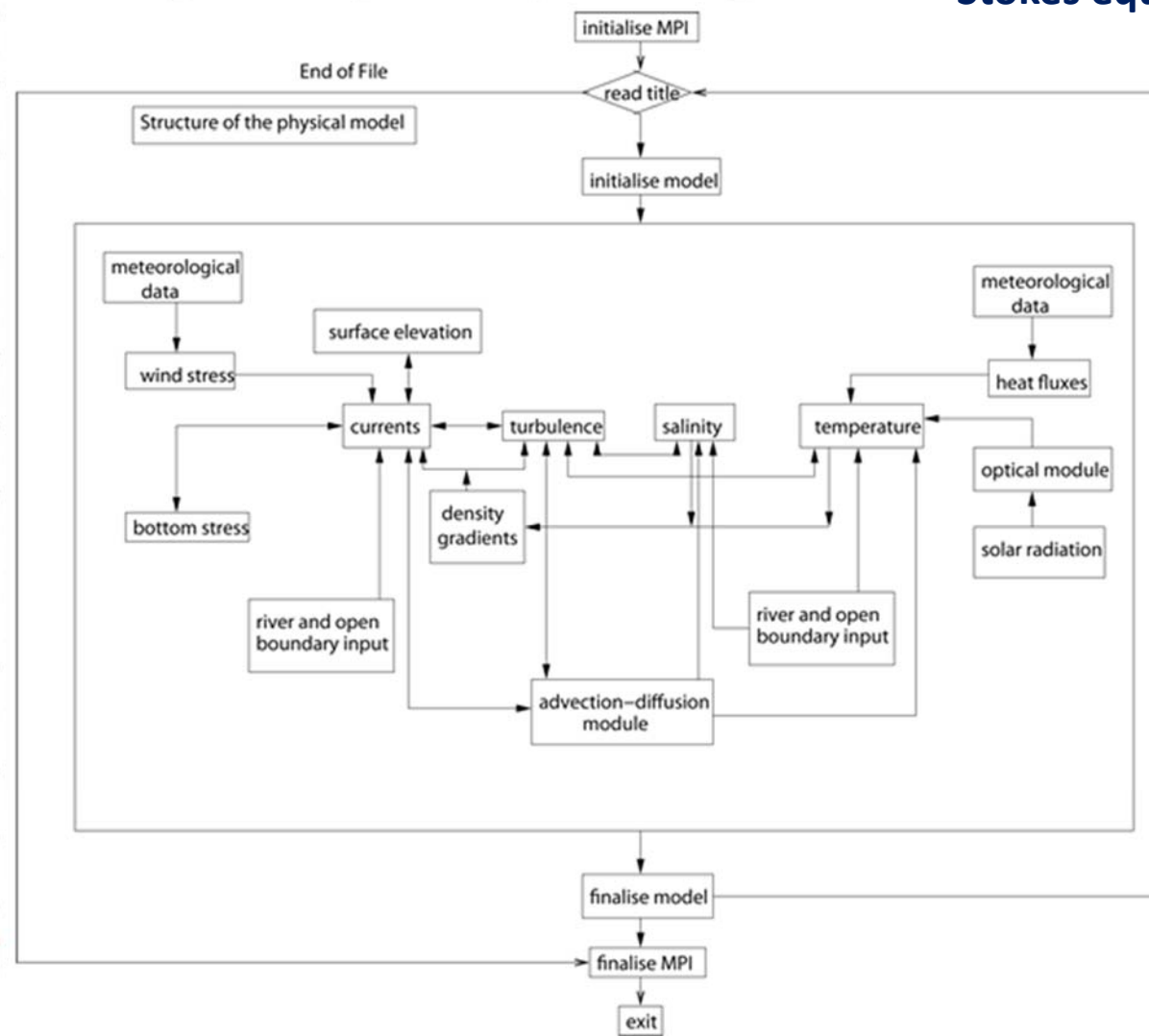
- Development of a physical-ecological model system for the study of **CL**imate change and **MA**nagement of marine **R**esources in Vietnamese **CO**astal waters (**CLIMARCO**) in **Co**operation Programme on Science and Technology between **VIETNAM AND BELGIUM** (2013)

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

p.luyten@mumm.ac.be, k.baetens@mumm.ac.be

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**

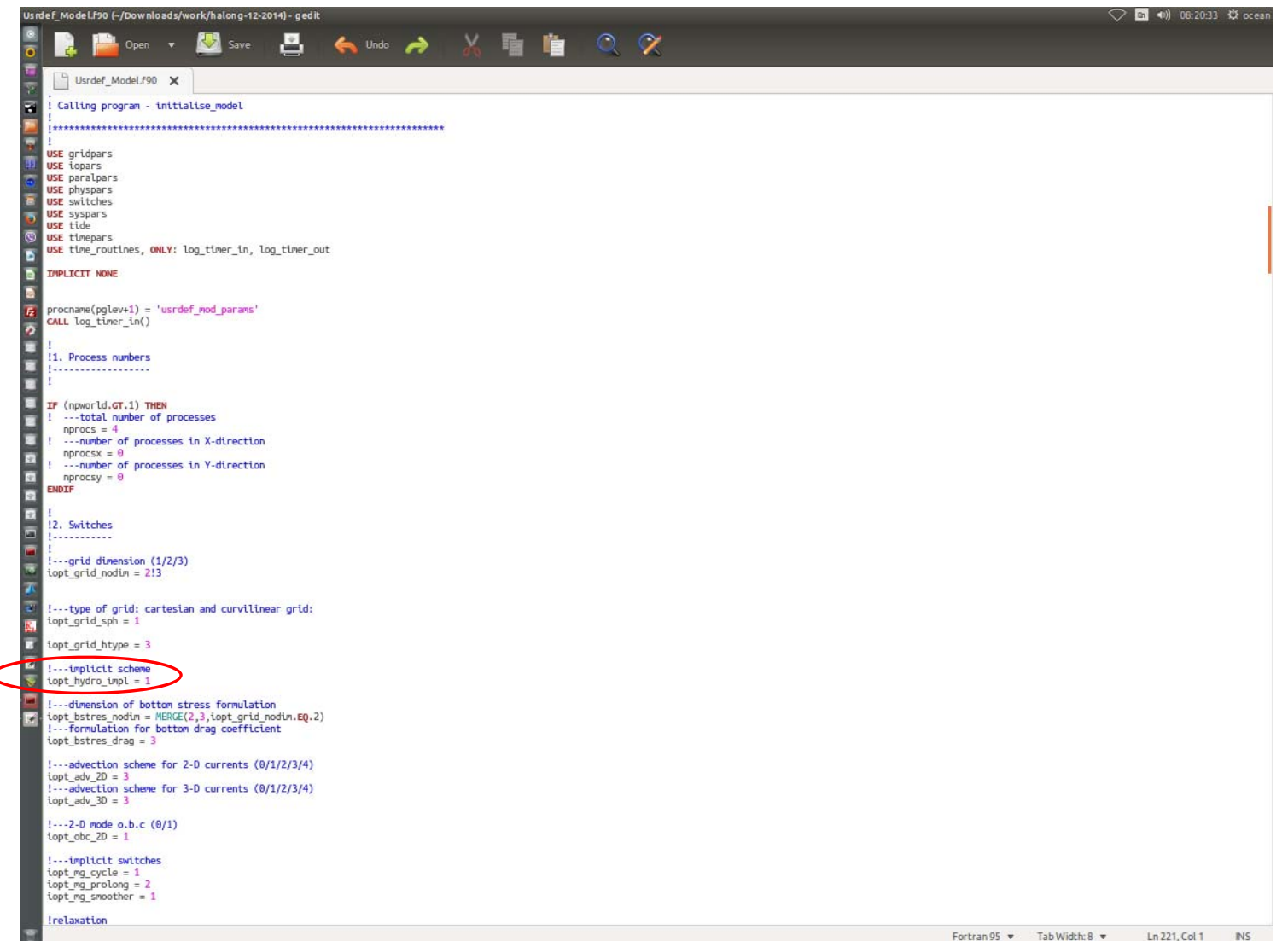
- Executable file to install COHERENS in your working directory or to install a predefined test case.
- Executing this file does two things.
- It creates the symbolic links needed to operate the program from your working directory. The links are referring to the fortran code (**SOURCE**, **BSOURCE** 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 hierarchy of discretizations
- **Explicit time stepping**
 - slow
 - cfl condition (to keep the error bounded)
- **Implicit time stepping**
 - unconditionally stable
 - large time steps can be handled
- **Using a multi-grid implicit scheme**
- Change in COHERENS with switch: `iopt_hydro_impt`
 - 0: explicit time discretization (more splitting technique)
 - 1: implicit time discretization with multi-grid scheme
- **Scenario simulations**



```
! Calling program - initialise_model
!
!-----
!
! USE gridpars
! USE lopars
! USE paralpars
! USE physpars
! USE switches
! USE syspars
! USE tide
! USE timepars
! USE time_routines, ONLY: log_timer_in, log_timer_out
!
! IMPLICIT NONE
!
! procname(pglev+1) = 'usrdef_mod_params'
! CALL log_timer_in()
!
! 1. Process numbers
! -----
!
! IF (npworld.GT.1) THEN
! ---total number of processes
! nprocs = 4
! ---number of processes in X-direction
! nprocsx = 0
! ---number of processes in Y-direction
! nprocsy = 0
! ENDOF
!
! 2. Switches
! -----
!
! ---grid dimension (1/2/3)
! iopt_grid_nodim = 213
!
! ---type of grid: cartesian and curvilinear grid:
! iopt_grid_sph = 1
!
! iopt_grid_htype = 3
!
! ---implicit scheme
! iopt_hydro_impl = 1
!
! ---dimension of bottom stress formulation
! iopt_bstres_nodim = MERGE(2,3,iopt_grid_nodim,2)
! ---formulation for bottom drag coefficient
! iopt_bstres_drag = 3
!
! ---advection scheme for 2-D currents (0/1/2/3/4)
! iopt_adv_2D = 3
! ---advection scheme for 3-D currents (0/1/2/3/4)
! iopt_adv_3D = 3
!
! ---2-D mode o.b.c (0/1)
! iopt_obc_2D = 1
!
! ---implicit switches
! iopt_ng_cycle = 1
! iopt_ng_prolong = 2
! iopt_ng_smoother = 1
!
!relaxation
```

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: $r_m = T_m(u_m) - f_m$

• 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

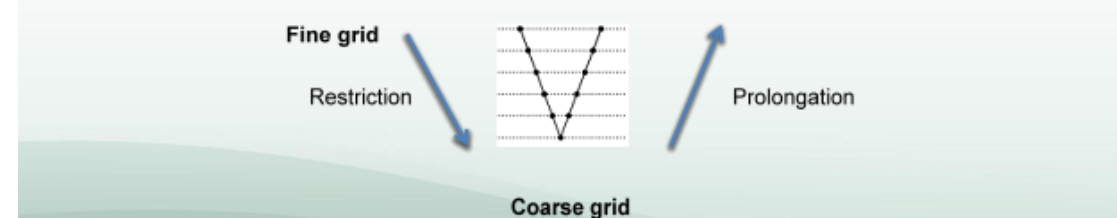


How does a multi-grid scheme work

CFL (Courant Friedrichs Lewy condition)

• 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



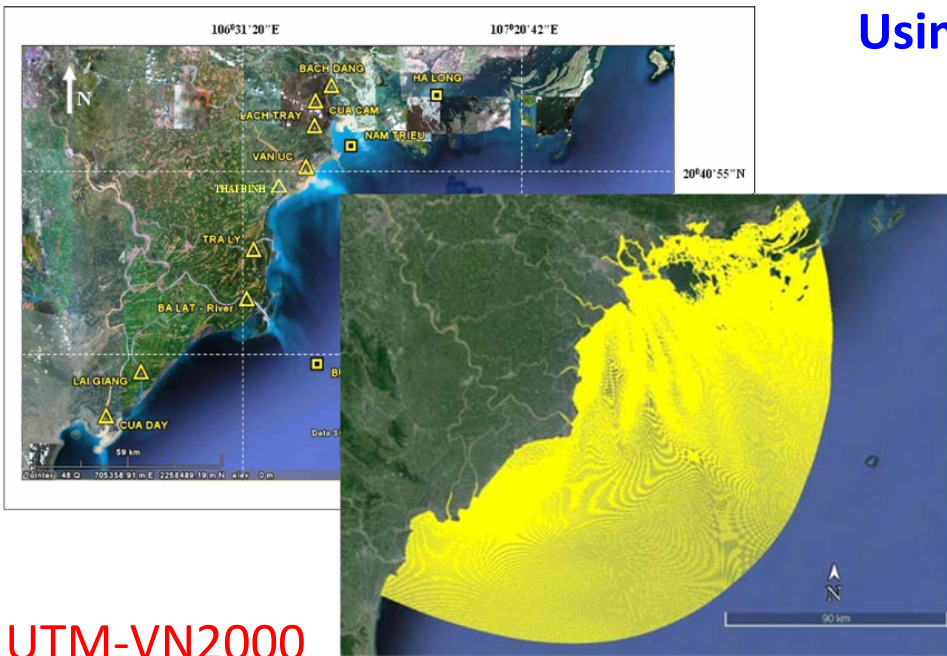
• Algorithm:

- 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

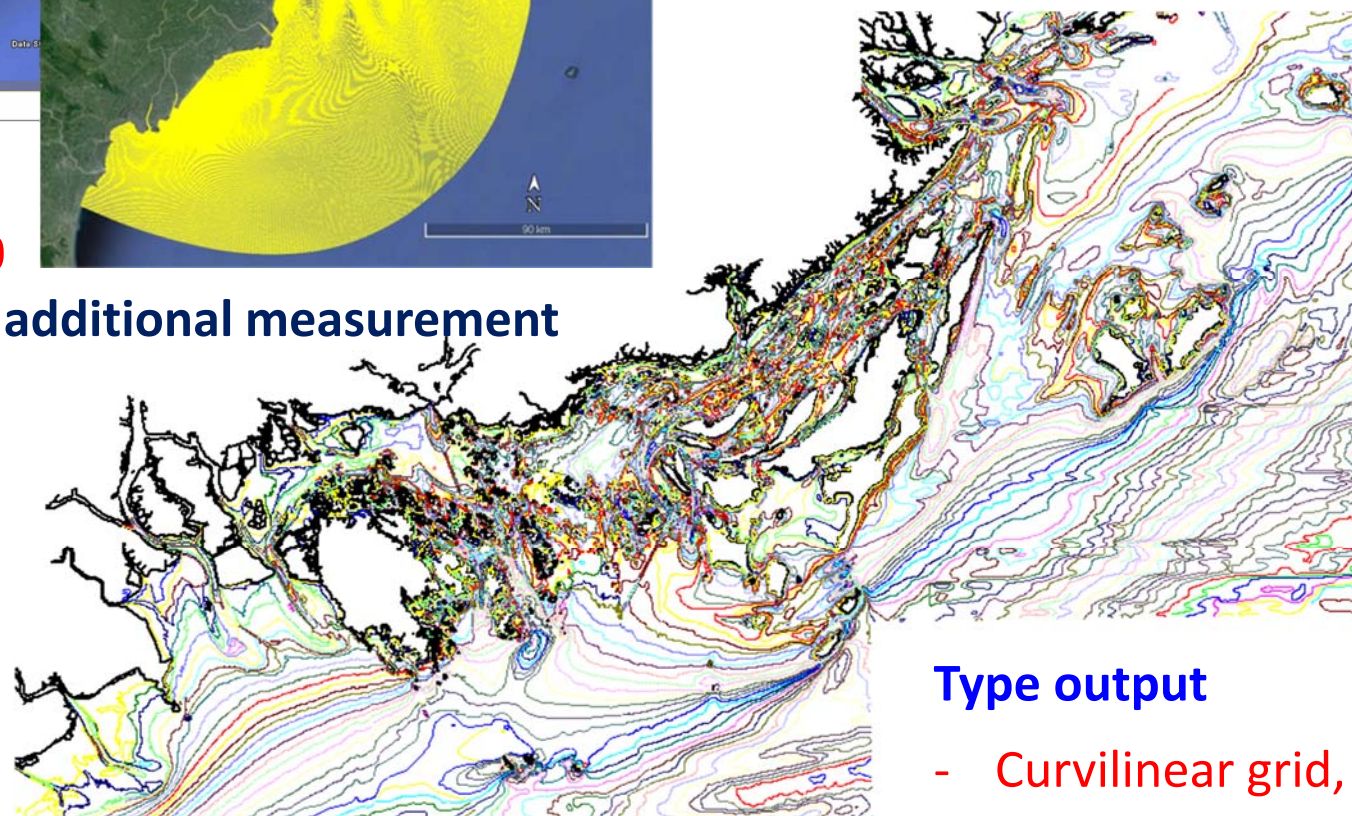
- Topography map (1 : 50000) - near coast & General Bathymetric Chart of the Ocean – offshore GEBCO -1/8



UTM-VN2000
(digital map) additional measurement

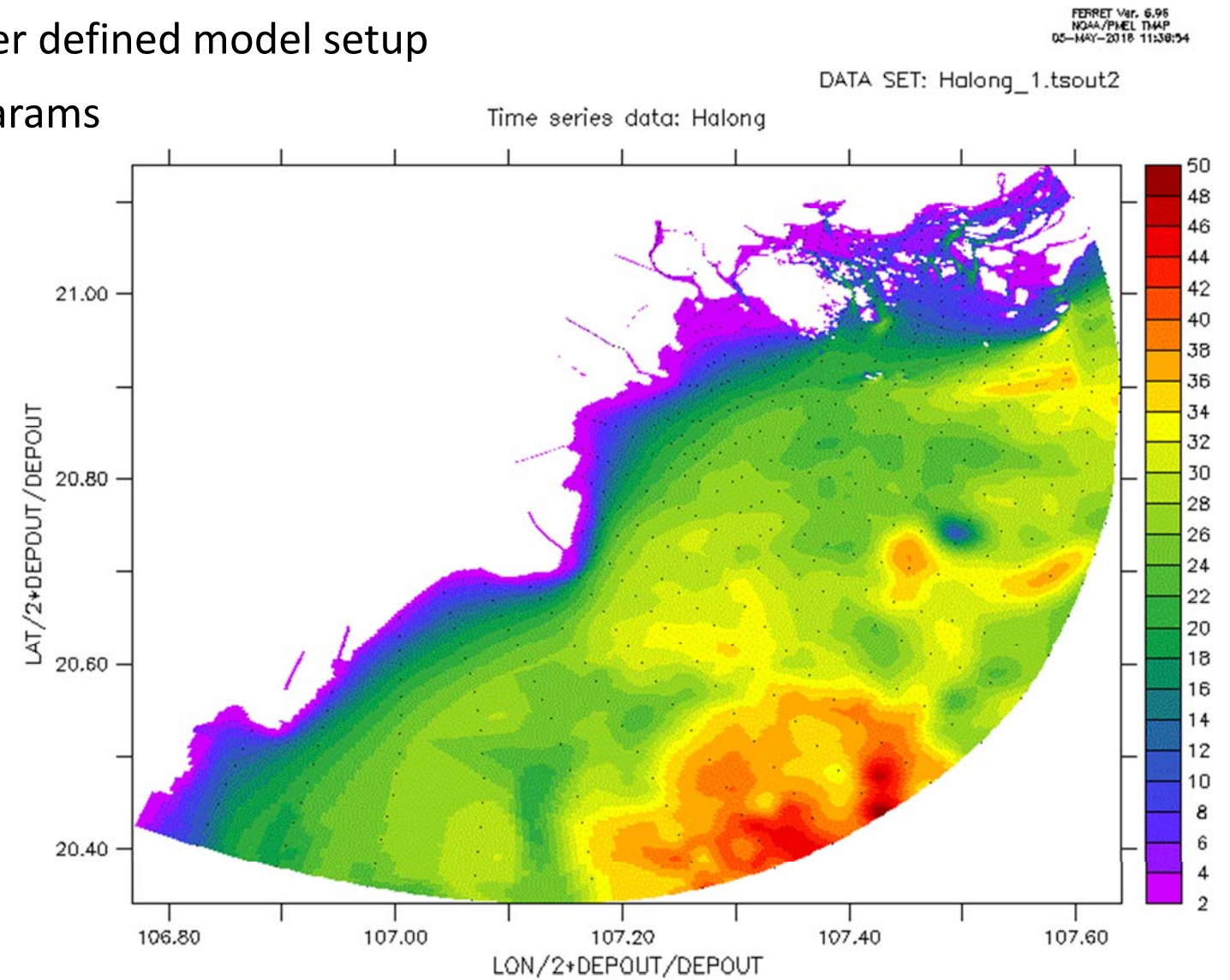
Using methods `Usrdef_Model.f90` - User defined model setup

```
... / SUBROUTINE usrdef_mod_params  
... / SUBROUTINE usrdef_grid  
Ferret graphic (Linux)
```



Type output

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

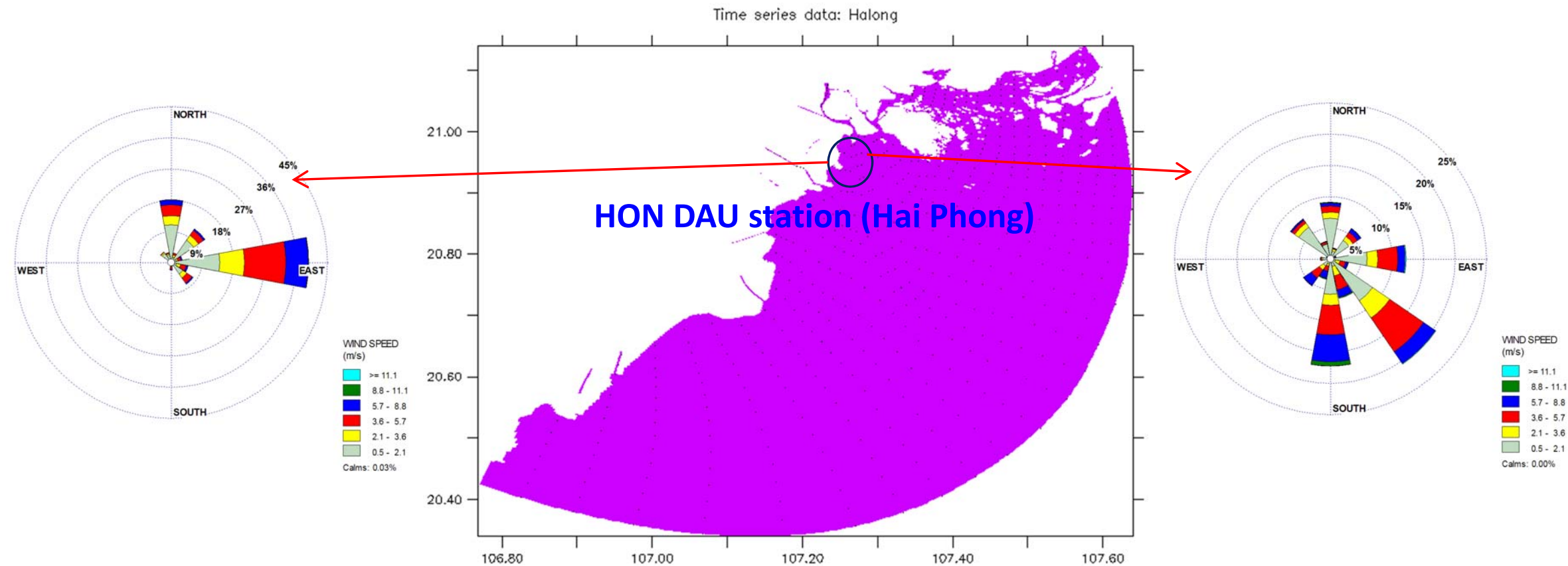


Mean water depth (m)

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

The screenshot shows a code editor with two windows. The top window, titled 'zdtobv_pha', contains a table of tidal constituent data. The bottom window, titled 'usrdef_profbc_spec', contains Fortran code defining boundary conditions for open sea boundaries, including tidal constituents.

Constituent	Amplitude	Phase
1	0.289118	0.0903445
2	0.2886233103	0.0902007276
3	0.2881286207	0.0900560552
4	0.287633931	0.0899131828
5	0.2871392414	0.0897694103
6	0.2866445517	0.0896256379
7	0.2861498621	0.0894818655
8	0.2856551724	0.0893380931
9	0.2851604828	0.0891943207
10	0.2846657931	0.0890505483
11	0.2841711034	0.0889067759
12	0.2836764138	0.0887630034
13	0.2831817241	0.088619231
14	0.2826870345	0.0884754586
15	0.2821923448	0.0883316862
16	0.2816976552	0.0881879138
17	0.2812029655	0.0880441414
18	0.2807082759	0.087900369
19	0.2802135862	0.0877565966
20	0.2797188966	0.0876128241
21	0.2792242069	0.0874690517
22	0.2787295172	0.0873252793
23	0.2782348276	0.0871815069
24	0.2777401379	0.0870377345
25	0.2772454483	0.0868939621
26	0.2767507586	0.0867501897
27	0.276256069	0.0866064172
28	0.2757613793	0.0864626448
29	0.2752666897	0.0863188724
30	0.274772	0.0861751
31	0.2742773072	0.0860313298
32	0.2737826175	0.0858875074
33	0.2732879278	0.0857436850
34	0.2727932381	0.0855998626
35	0.2722985484	0.0854560402
36	0.2718038587	0.0853122178
37	0.271309169	0.0851683954
38	0.2708144793	0.0850245730
39	0.2703197896	0.0848807506
40	0.2698250999	0.0847369282
41	0.2693304102	0.0845931058
42	0.2688357205	0.0844492834
43	0.2683410308	0.0843054610
44	0.2678463411	0.0841616386
45	0.2673516514	0.0840178162
46	0.2668569617	0.0838739938
47	0.266362272	0.0837301714
48	0.2658675825	0.0835863490
49	0.2653728928	0.0834425266
50	0.2648782031	0.0832987042
51	0.2643835134	0.0831548818
52	0.2638888237	0.0830110594
53	0.263394134	0.0828672370
54	0.2628994443	0.0827234146
55	0.2624047546	0.0825795922
56	0.2619100649	0.0824357698
57	0.2614153752	0.0822919474
58	0.2609206855	0.0821481250
59	0.2604259958	0.0820043026
60	0.2599313061	0.0818604802
61	0.2594366164	0.0817166578
62	0.2589419267	0.0815728354
63	0.258447237	0.0814290130
64	0.2579525473	0.0812851906
65	0.2574578576	0.0811413682
66	0.2569631679	0.0810000000
67	0.2564684782	0.0808586318
68	0.2559737885	0.0807172636
69	0.2554790988	0.0805758954
70	0.2549844091	0.0804345272

Setup modelling – River data

River discharges for 9 rivers mouth

The river boundaries condition are measured water discharge

```

!4. Open boundary locations: rtrvers
CALL open_file(lunit1,'DATA/rrd_rivers_new.loc','IN','A')
READ(lunit1,*)
!i_320: DO ii=1,nrvb+nrvbv
  READ (lunit1,9902) node, ipos, jpos
  IF (node.EQ.'U') THEN
    uval = uval + 1
    lobv(nosbv+uval) = ipos
    jobv(nosbv+uval) = jpos
  ELSE IF (node.EQ.'V') THEN
    vval = vval + 1
    lobv(nosbv+vval) = ipos
    jobv(nosbv+vval) = jpos
  ELSE
    print *, 'oho, een river issue'
  END IF
ENDDO ii_320
CALL close_file(lunit1,'A')

CALL close_filepars(modfiles(io_nodgrd,1,1))
CALL log_timer_out()

RETURN

9901 FORMAT (E15.7,1X,E15.7,1X,E15.7,1X,E15.7,1X,E15.7)
9902 FORMAT (1X,A,3X,I4,I4)

END SUBROUTINE usrdef_grd

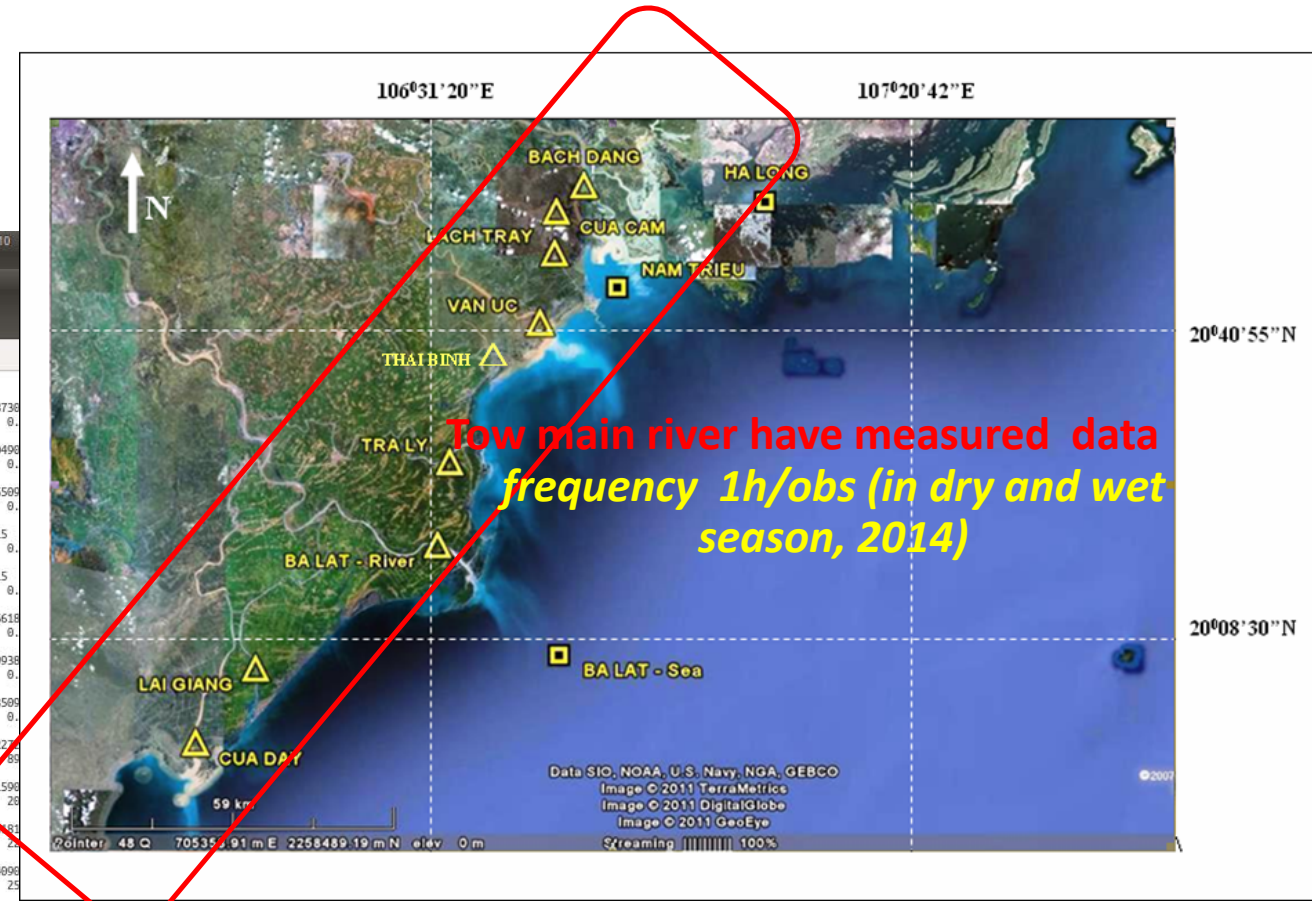
SUBROUTINE usrdef_partition
! Author - Patrick Luyten
! Version - @((COHERENS)usrdef_Model1.f90 V2.0)
! Description -
! Reference -
! Calling program - domain_decomposition

IMPLICIT NONE

RETURN

END SUBROUTINE usrdef_partition

SUBROUTINE usrdef_physics
!usrdef_physics* Define initial conditions for physics
  
```



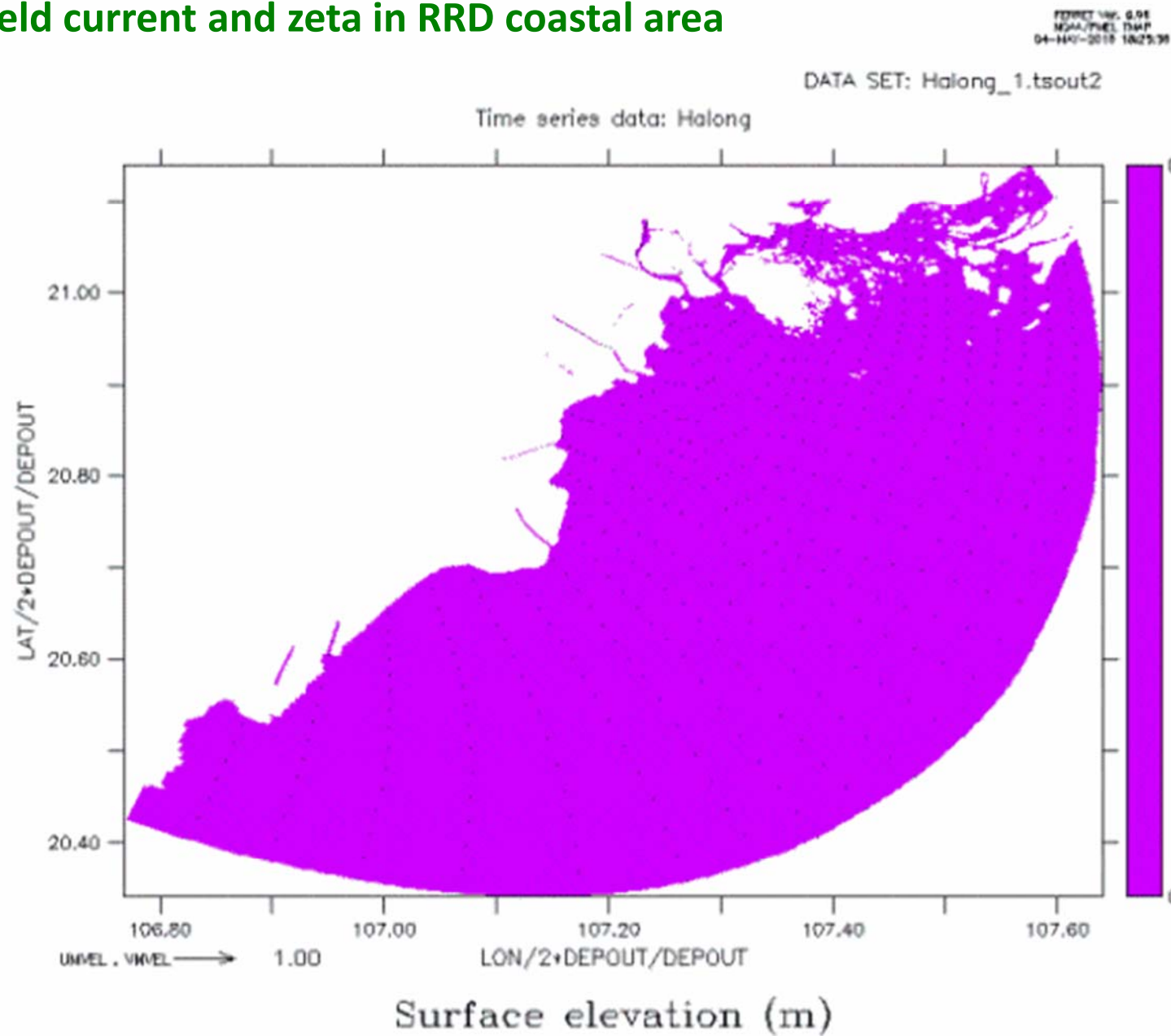
Tow main river have measured data frequency 1h/obs (in dry and wet season, 2014)

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*