Using SCHISM

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Primer

- Online manual and wiki resource: www.schism.wiki
    - There are beta_notes, sample files etc in each source code bundle
- It helps if you know a few programming/scripting languages: python, matlab, FORTRAN etc for pre- and post-processing needs
- ‘Bare minimum’: mandatory inputs
    - Generate a hgrid.gr3 with simplest possible b.c. (e.g., no open bnd)
    - Run SCHISM in 2D config: manning.gr3, param.nml, bctides.in, vgrid.in (2 levels)
    - Pre-processing with ipre=1 first (with 1 CPU) to catch grid and other issues
    - Then proceed to more complex set-ups
    - **Establish a good work flow and be willing to revise the grid**

Sample run directory

- /sciclone/home10/yinglong/vims20/schism_verification_tests/Test_CORIE/TMP% ls -L

```
albedo.gr3          CORIE_TMP.o3660379  drag.gr3     fort.11     hotstart.nc  postpros.pl              run_bora              show_schism_nc.m  tmp.xyuv      watertype.gr3
bctides.in          coriolis.out        err2.out     fort.17     mirror.out   pschism_WHIRLWIND_Intel_VL  run_whirlwind_openmpi  sidecenters.gr3  total.dat
 windrot_geo2proj.gr3     bnd.xy        date.in          estuary.gr3  fort.33  SAL_nudge.gr3        TEM_1.th          total_TR.dat
centers.gr3         diffmax.gr3         flux.dat     hgrid.gr3  outputs/      read.in                  SAL_nu.nc           TEM_nudge.gr3     tvd.prop
CORIE_TMP.e3660379  diffmin.gr3         flux.th      hgrid.ll   param.nml     README                   sflux/              TEM_nu.nc         vgrid.in
```

- /sciclone/home10/yinglong/vims20/schism_verification_tests/Test_CORIE/TMP% ls -L *.gr3 *.ll *.ic

```
albedo.gr3   diffmax.gr3  drag.gr3     hgrid.gr3  SAL_nudge.gr3    TEM_nudge.gr3  windrot_geo2proj.gr3
centers.gr3  diffmin.gr3  estuary.gr3  hgrid.ll   sidecenters.gr3  watertype.gr3
```

- /sciclone/home10/yinglong/vims20/schism_verification_tests/Test_CORIE/TMP% ls -L *.in *.nml

```
bctides.in param.nml  vgrid.in
```

- /sciclone/home10/yinglong/vims20/schism_verification_tests/Test_CORIE/TMP% ls -L *.th*

```
flux.th  TEM_1.th      <- ASCII
```

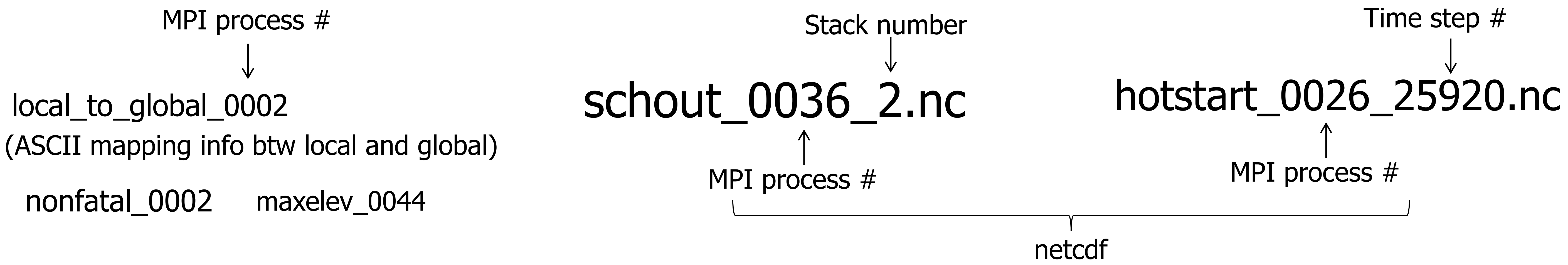
- /sciclone/home10/yinglong/vims20/schism_verification_tests/Test_CORIE/TMP% ls -L *.nc

```
hotstart.nc  SAL_nu.nc  TEM_nu.nc
```

Sample output directory

```
/sciclone/home10/yinglong/vims20/schism_verification_tests/Test_CORIE/TMP% ls outputs/
hotstart_0013_14400.nc  hotstart_0026_20160.nc  hotstart_0039_26880.nc  maxelev_0041        schout_0010_5.nc   schout_0023_27.nc  schout_0036_21.nc
hotstart_0013_15360.nc  hotstart_0026_21120.nc  hotstart_0039_2880.nc   maxelev_0042        schout_0010_6.nc   schout_0023_28.nc  schout_0036_22.nc
global_to_local.prop    hotstart_0013_16320.nc  hotstart_0026_22080.nc  hotstart_0039_3840.nc  maxelev_0043        schout_0010_7.nc   schout_0023_29.nc  schout_0036_23.nc
hotstart_0000_10560.nc  hotstart_0013_17280.nc  hotstart_0026_23040.nc  hotstart_0039_4800.nc  maxelev_0044        schout_0010_8.nc   schout_0023_2.nc   schout_0036_24.nc
hotstart_0000_11520.nc  hotstart_0013_18240.nc  hotstart_0026_24000.nc  hotstart_0039_5760.nc  maxelev_0045        schout_0010_9.nc   schout_0023_3.nc   schout_0036_25.nc
hotstart_0000_12480.nc  hotstart_0013_19200.nc  hotstart_0026_24960.nc  hotstart_0039_6720.nc  maxelev_0046        schout_0011_10.nc  schout_0023_4.nc   schout_0036_26.nc
hotstart_0000_13440.nc  hotstart_0013_1920.nc   hotstart_0026_25920.nc  hotstart_0039_7680.nc  maxelev_0047        schout_0011_11.nc  schout_0023_5.nc   schout_0036_27.nc
hotstart_0000_14400.nc  hotstart_0013_20160.nc  hotstart_0026_26880.nc  hotstart_0039_8640.nc  nonfatal_0000       schout_0011_12.nc  schout_0023_6.nc   schout_0036_28.nc
hotstart_0000_15360.nc  hotstart_0013_21120.nc  hotstart_0026_2880.nc   hotstart_0039_9600.nc  nonfatal_0001       schout_0011_13.nc  schout_0023_7.nc   schout_0036_29.nc
hotstart_0000_16320.nc  hotstart_0013_22080.nc  hotstart_0026_3840.nc   hotstart_0039_960.nc   nonfatal_0002       schout_0011_14.nc  schout_0023_8.nc   schout_0036_2.nc
hotstart_0000_17280.nc  hotstart_0013_23040.nc  hotstart_0026_4800.nc   hotstart_0040_10560.nc nonfatal_0003       schout_0011_15.nc  schout_0023_9.nc   schout_0036_3.nc
hotstart_0000_18240.nc  hotstart_0013_24000.nc  hotstart_0026_5760.nc   hotstart_0040_11520.nc nonfatal_0004       schout_0011_16.nc  schout_0024_10.nc  schout_0036_4.nc
local_to_global_0000 ….
```

- SCHISM code generally outputs results per MPI rank (not per openMP thread)
  - Exception: station outputs
- Post-proc scripts are used to 'gather' all ranks into a 'global' output (either ASCII or netcdf4)
  - V5.5.0 needs netcdf 4.4* and newer



Pre- and post-combined outputs

- Netcdf outputs

schout_0000_2.nc schout_0001_2.nc …………………. schout_0399_2.nc

combine_output11.f90

schout_2.nc (global output)

Similarly for hotstart

- ASCII

maxelev_0000 maxelev_0001 …………… maxelev_0399

combine_gr3.f90

maxelev.gr3 (max elevation over all time steps)

Main diagnostic output (mirror.out, by rank 0)

```
Run begins at 20171026, 082037.556
 You are using baroclinic model
 # of tracers in each module:           1           1           0           0
           0           0           0           0           0           0
           0
 Total # of tracers=           2
 Index ranges of each module:           1           1           2           2
           3           2           3           2           3           2
           3           2           3           2           3           2
           3           2           3           2           3           2
 # of global outputs=          29
 done reading param.nml; s2_mxnbt in param.nml =   3.00000000000000
 lhas_quad= F
 mnei, mnei_p =          10          11
 lhas_quad= F

Global Grid Size (ne,np,ns,nvrt):     38960     20641     59615        54

**********Augmented Subdomain Sizes**********
 rank     nea      ne     neg     nea2    neg2     npa      np     npg     npa2    npg2     nsa      ns     nsg    nsa2    nsg2
    0    1071     821     250     1071       0     634     521     113     634       0    1701    1345     356    1701       0
    1    1055     828     227     1055       0     611     514      97     611       0    1664    1349     315    1664       0
    2     981     794     187      981       0     588     500      88     588       0    1566    1293     273    1566       0
……………………
```

```
heat budge model completes...
 time stepping begins...           1       26880
 heat budge model completes...
 done adjusting wind stress ...
 done flow b.c.
 done MYG-UB...
 done hvis...
 done backtracking
 done 1st preparation
 done 2nd preparation
 done solver; etatot=  0.939833361180156      ; average |eta|= 4.553235604767967E-005
 done solving momentum eq...
 done solving w
 done tracer transport...
 done solving transport equation
 done recomputing levels...
 done density and flux calculation...
TIME STEP=            1;  TIME=          90.000000
 heat budge model completes...
 done adjusting wind stress ...
 done flow b.c.
```

Sample netcdf output file (pre-combine)

```
netcdf schout_0011_4 {
dimensions:
        nSCHISM_hgrid_node = 516 ;
        nSCHISM_hgrid_face = 813 ;
        nSCHISM_hgrid_edge = 1326 ;
        nMaxSCHISM_hgrid_face_nodes = 4 ;
        nSCHISM_vgrid_layers = 54 ;
        one = 1 ;
        two = 2 ;
        time = UNLIMITED ; // (96 currently)
variables:
        float time(time) ;
                time:i23d = 0 ;
        float wetdry_elem(time, nSCHISM_hgrid_face) ;
                wetdry_elem:i23d = 4 ;
                wetdry_elem:ivs = 1 ;
        float zcor(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers) ;
                zcor:i23d = 2 ;
                zcor:ivs = 1 ;
        float elev(time, nSCHISM_hgrid_node) ;
                elev:i23d = 1 ;
                elev:ivs = 1 ;
        float wind_speed(time, nSCHISM_hgrid_node, two) ;
                wind_speed:i23d = 1 ;
                wind_speed:ivs = 2 ;
        float vertical_velocity(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers) ;
                vertical_velocity:i23d = 2 ;
                vertical_velocity:ivs = 1 ;
        float temp(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers) ;
                temp:i23d = 2 ;
                temp:ivs = 1 ;
        float salt(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers) ;
                salt:i23d = 2 ;
                salt:ivs = 1 ;
        float diffusivity(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers) ;
                diffusivity:i23d = 2 ;
                diffusivity:ivs = 1 ;
        float hvel(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers, two) ;
                hvel:i23d = 2 ;
                hvel:ivs = 2 ;
data:

 time = 260100, 261000, 261900, 262800, 263700, 264600, 265500, 266400,
    267300, 268200, 269100, 270000, 270900, 271800, 272700, 273600, 274500,
    275400, 276300, 277200, 278100, 279000, 279900, 280800, 281700, 282600,
    283500, 284400, 285300, 286200, 287100, 288000, 288900, 289800, 290700,
    291600, 292500, 293400, 294300, 295200, 296100, 297000, 297900, 298800,
    299700, 300600, 301500, 302400, 303300, 304200, 305100, 306000, 306900,
    307800, 308700, 309600, 310500, 311400, 312300, 313200, 314100, 315000,
```

Connectivity table is found in local_to_global_*

Sample netcdf output file (post-combine)

```
netcdf schout_3 {
dimensions:
        nSCHISM_hgrid_node = 20641 ;
        nSCHISM_hgrid_face = 38960 ;
        nSCHISM_hgrid_edge = 59615 ;
        nMaxSCHISM_hgrid_face_nodes = 4 ;
        nSCHISM_vgrid_layers = 54 ;
        one = 1 ;
        two = 2 ;
        sigma = 37 ;
        nz = 17 ;
        time = UNLIMITED ; // (96 currently)
variables:
        double time(time) ;
                time:long_name = "Time" ;
                time:units = "seconds since 2002-30-04  00:00:00 PST" ;
                time:base_date = "04/30/2002 00:00:00 PST" ;
                time:standard_name = "time" ;
        int SCHISM_hgrid(one) ;
                SCHISM_hgrid:long_name = "Topology data of 2d unstructured mesh" ;
                SCHISM_hgrid:topology_dimension = 2 ;
                SCHISM_hgrid:cf_role = "mesh_topology" ;
                SCHISM_hgrid:node_coordinates = "SCHISM_hgrid_node_x
SCHISM_hgrid_node_y" ;
                SCHISM_hgrid:face_node_connectivity = "SCHISM_hgrid_face_nodes" ;
                SCHISM_hgrid:edge_coordinates = "SCHISM_hgrid_edge_x
SCHISM_hgrid_edge_y" ;
                SCHISM_hgrid:face_coordinates = "SCHISM_hgrid_face_x
SCHISM_hgrid_face_y" ;
                SCHISM_hgrid:edge_node_connectivity = "SCHISM_hgrid_edge_nodes" ;
        int Mesh3D(one) ;
```

Connectivity table

```
        int SCHISM_hgrid_face_nodes(nSCHISM_hgrid_face,
nMaxSCHISM_hgrid_face_nodes) ;
                SCHISM_hgrid_face_nodes:long_name = "Horizontal Element Table" ;
                SCHISM_hgrid_face_nodes:units = "non-dimensional" ;
                SCHISM_hgrid_face_nodes:cf_role = "face_node_connectivity" ;
                SCHISM_hgrid_face_nodes:start_index = 1 ;
                SCHISM_hgrid_face_nodes:_FillValue = -99999 ;
        int SCHISM_hgrid_edge_nodes(nSCHISM_hgrid_edge, two) ;
                SCHISM_hgrid_edge_nodes:long_name = "Map every edge to the two
nodes that it connects" ;
                SCHISM_hgrid_edge_nodes:units = "non-dimensional" ;
                SCHISM_hgrid_edge_nodes:cf_role = "edge_node_connectivity" ;
                SCHISM_hgrid_edge_nodes:start_index = 1 ;
        float SCHISM_hgrid_node_x(nSCHISM_hgrid_node) ;
                SCHISM_hgrid_node_x:long_name = "node x-coordinate" ;
                SCHISM_hgrid_node_x:standard_name = "projection_x_coordinate" ;
                SCHISM_hgrid_node_x:units = "m or degrees" ;
                SCHISM_hgrid_node_x:mesh = "SCHISM_hgrid" ;
        float SCHISM_hgrid_node_y(nSCHISM_hgrid_node) ;
                SCHISM_hgrid_node_y:long_name = "node y-coordinate" ;
                SCHISM_hgrid_node_y:standard_name = "projection_y_coordinate" ;
                SCHISM_hgrid_node_y:units = "m or degrees" ;
                SCHISM_hgrid_node_y:mesh = "SCHISM_hgrid" ;
```

Sample netcdf output file (post-combine)

```
int node_bottom_index(nSCHISM_hgrid_node) ;
        node_bottom_index:long_name = "bottom level index at each node" ;
        node_bottom_index:units = "non-dimensional" ;
        node_bottom_index:mesh = "SCHISM_hgrid" ;
        node_bottom_index:location = "node" ;
        node_bottom_index:start_index = 1 ;
float SCHISM_hgrid_face_x(nSCHISM_hgrid_face) ;
        SCHISM_hgrid_face_x:long_name = "x_coordinate of 2D mesh face" ;
        SCHISM_hgrid_face_x:standard_name = 391266304 ;
        SCHISM_hgrid_face_x:units = "m" ;
        SCHISM_hgrid_face_x:mesh = "SCHISM_hgrid" ;
float SCHISM_hgrid_face_y(nSCHISM_hgrid_face) ;
        SCHISM_hgrid_face_y:long_name = "y_coordinate of 2D mesh face" ;
        SCHISM_hgrid_face_y:standard_name = "projection_y_coordinate" ;
        SCHISM_hgrid_face_y:units = "m" ;
        SCHISM_hgrid_face_y:mesh = "SCHISM_hgrid" ;
int ele_bottom_index(nSCHISM_hgrid_face) ;
        ele_bottom_index:long_name = "bottom level index at each element" ;
        ele_bottom_index:units = "non-dimensional" ;
        ele_bottom_index:mesh = "SCHISM_hgrid" ;
        ele_bottom_index:location = "elem" ;
        ele_bottom_index:start_index = 1 ;
float SCHISM_hgrid_edge_x(nSCHISM_hgrid_edge) ;
        SCHISM_hgrid_edge_x:long_name = "x_coordinate of 2D mesh edge" ;
        SCHISM_hgrid_edge_x:standard_name = "projection_x_coordinate" ;
        SCHISM_hgrid_edge_x:units = "m" ;
        SCHISM_hgrid_edge_x:mesh = "SCHISM_hgrid" ;
```

```
float SCHISM_hgrid_edge_y(nSCHISM_hgrid_edge) ;
        SCHISM_hgrid_edge_y:long_name = "y_coordinate of 2D mesh edge" ;
        SCHISM_hgrid_edge_y:standard_name = "projection_y_coordinate" ;
        SCHISM_hgrid_edge_y:units = "m" ;
        SCHISM_hgrid_edge_y:mesh = "SCHISM_hgrid" ;
int edge_bottom_index(nSCHISM_hgrid_edge) ;
        edge_bottom_index:long_name = "bottom level index at each edge" ;
        edge_bottom_index:units = "non-dimensional" ;
        edge_bottom_index:mesh = "SCHISM_hgrid" ;
        edge_bottom_index:location = "edge" ;
        edge_bottom_index:start_index = 1 ;
float depth(nSCHISM_hgrid_node) ;
        depth:long_name = "Bathymetry" ;
        depth:units = "meters" ;
        depth:positive = "down" ;
        depth:mesh = "SCHISM_hgrid" ;
        depth:location = "node" ;
float sigma(sigma) ;
        sigma:long_name = "S coordinates at whole levels" ;
        sigma:units = "1" ;
        sigma:standard_name = "ocean_s_coordinate" ;
        sigma:positive = "up" ;
```

* All of these arrays are static

Sample netcdf output file (post-combine)

```
        int coordinate_system_flag(one) ;
        float minimum_depth(one) ;
        float sigma_h_c(one) ;
                sigma_h_c:long_name = "ocean_s_coordinate h_c constant" ;
                sigma_h_c:units = "meters" ;
                sigma_h_c:positive = "down" ;
        float sigma_theta_b(one) ;
                sigma_theta_b:long_name = "ocean_s_coordinate theta_b
constant" ;
        float sigma_theta_f(one) ;
                sigma_theta_f:long_name = "ocean_s_coordinate theta_f
constant" ;
        float sigma_maxdepth(one) ;
                sigma_maxdepth:long_name = "ocean_s_coordinate
maximum depth cutoff (mixed s over z boundary)" ;
                sigma_maxdepth:units = "meters" ;
                sigma_maxdepth:positive = "down" ;
        float Cs(sigma) ;
                Cs:long_name = "Function C(s) at whole levels" ;
                Cs:units = "non-dimensional" ;
                Cs:positive = "up" ;
        float z(nz) ;
                z:long_name = "Z coordinates at whole levels" ;
                z:units = "meters" ;
                z:positive = "up" ;
```

```
float wetdry_elem(time, nSCHISM_hgrid_face) ;
        wetdry_elem:missing_value = 9.96921e+36f ;
        wetdry_elem:mesh = "SCHISM_hgrid" ;
        wetdry_elem:data_horizontal_center = "elem" ;
        wetdry_elem:data_vertical_center = "full" ;
        wetdry_elem:i23d = 4 ;
        wetdry_elem:ivs = 1 ;
float zcor(time, nSCHISM_hgrid_node, nSCHISM_vgrid_layers) ;
        zcor:missing_value = 9.96921e+36f ;
        zcor:mesh = "SCHISM_hgrid" ;
        zcor:data_horizontal_center = "node" ;
        zcor:data_vertical_center = "full" ;
        zcor:i23d = 2 ;
        zcor:ivs = 1 ;
float elev(time, nSCHISM_hgrid_node) ;
        elev:missing_value = 9.96921e+36f ;
        elev:mesh = "SCHISM_hgrid" ;
        elev:data_horizontal_center = "node" ;
        elev:data_vertical_center = "full" ;
        elev:i23d = 1 ;
        elev:ivs = 1 ;
float wind_speed(time, nSCHISM_hgrid_node, two) ;
```

$\uparrow$

Time series

*zcor: z-coordinates at nodes and each time step; junk values if below bottom. Also used to infer wetting and drying

Pre- & post-processing and visualization

- Combine binary outputs (MPI): FORTRAN & perl script in Utility/Combining_Scripts/)
- Visualization
  - xmgredit5: for inputs; can handle mixed grids
  - python: for in/outputs; see DWR tools
  - VisIT: the best & most comprehensive tool for visualizing outputs; up to date and can viz shaved cells. Beware visual of wetting/drying
  - matlab: for in/outputs; not as efficient as VisIT but easier to see the wetting/drying representation
  - GIS and google earth based: specialty tools; needs some customization
- Extracting time series: vertical profiles, horizontal slabs, transects
  - station outputs (easiest): be careful not to abuse; only 'online'
  - FORTRAN scripts: works on either pre- and post-combined netcdf ('offline')
  - Linear interpolation in 3D (and time for some)
  - calculation of *z*-coordinates consistent with SCHISM code
  - beware wet/dry interpolation
- Residuals, harmonics analysis

SCHISM input types: glossary

- *.gr3: grid-like files (node centered): only hgrid.gr3 has b.c. info at the end
- hgrid.ll: lon/lat form of horizontal grid (.gr3 format)
- *.th*: time history (b.c.); ASCII or nc
- *.ic: initial condition for elev, tracers (ASCII; most of them actually of .gr3 format)
- *.prop: element centered property (ASCII)
- sflux/: atmos. Forcings (netcdf)
- *.in: vgrid.in (vertical grid); bctides.in (b.c.) [ASCII]
- param.nml: parameters
- *.nc: hotstart; tracer nudging inputs; b.c. time history inputs (type '±4' or '5')
- Modules: gotmturb.inp, wwminput.nml, ice.nml ….
- Bare minimum (mandatory) for pre-processing (ipre=1)
  - hgrid.gr3 (and hgrid.ll if you are using some modules): no need to have correct bathymetry & boundaries yet
  - vgrid.in (1 layer for 2D for simplicity)
  - param.nml
  - bctides.in (easiest is to use no open bnd)
  - drag.gr3/rough.gr3/manning.gr3 (to specify bottom friction, depending on the *bfric* specified in param.nml)
- Pre-processing
  - Prepare the mandatory input files, and set ipre=1 in param.nml
  - Run SCHISM with 1 CPU only
  - Check fatal.error and system error logs for fatal errors (e.g. grid issues)
  - Rectify grid/inputs errors and repeat until pre-processing is successful

Details of model setup

.gr3 and .ll files

```
Your comments
 44343  24025
```

nodes

```
    1       -90.4293       30.1689      0.30
    2       -90.4313       30.1625      0.30
    3       -90.4327       30.1559      0.20
    4       -90.4320       30.1498      0.20
    ...........................................
```

Except in hgrid.gr3 and hgrid.ll, only depth info is used

elements

```
    1       3      1     2     3
    2       3      2     4     5
    3       3      15943    16197    15942
     ...........................................
```

Boundary info (hgrid.gr3 only)

```
     2 = Number of open boundaries
     69 = Total number of open boundary nodes
     4 = Number of nodes for open boundary 1
     1
     2
     3
     4
     ........................................
     12 = number of land boundaries
     1756 = Total number of land boundary nodes
     737 0 = Number of nodes for land boundary 1
     29368
     29421
     29420
     29467
     ...........................................
```

*There is a simple perl converter between .2dm and .gr3

.bp format

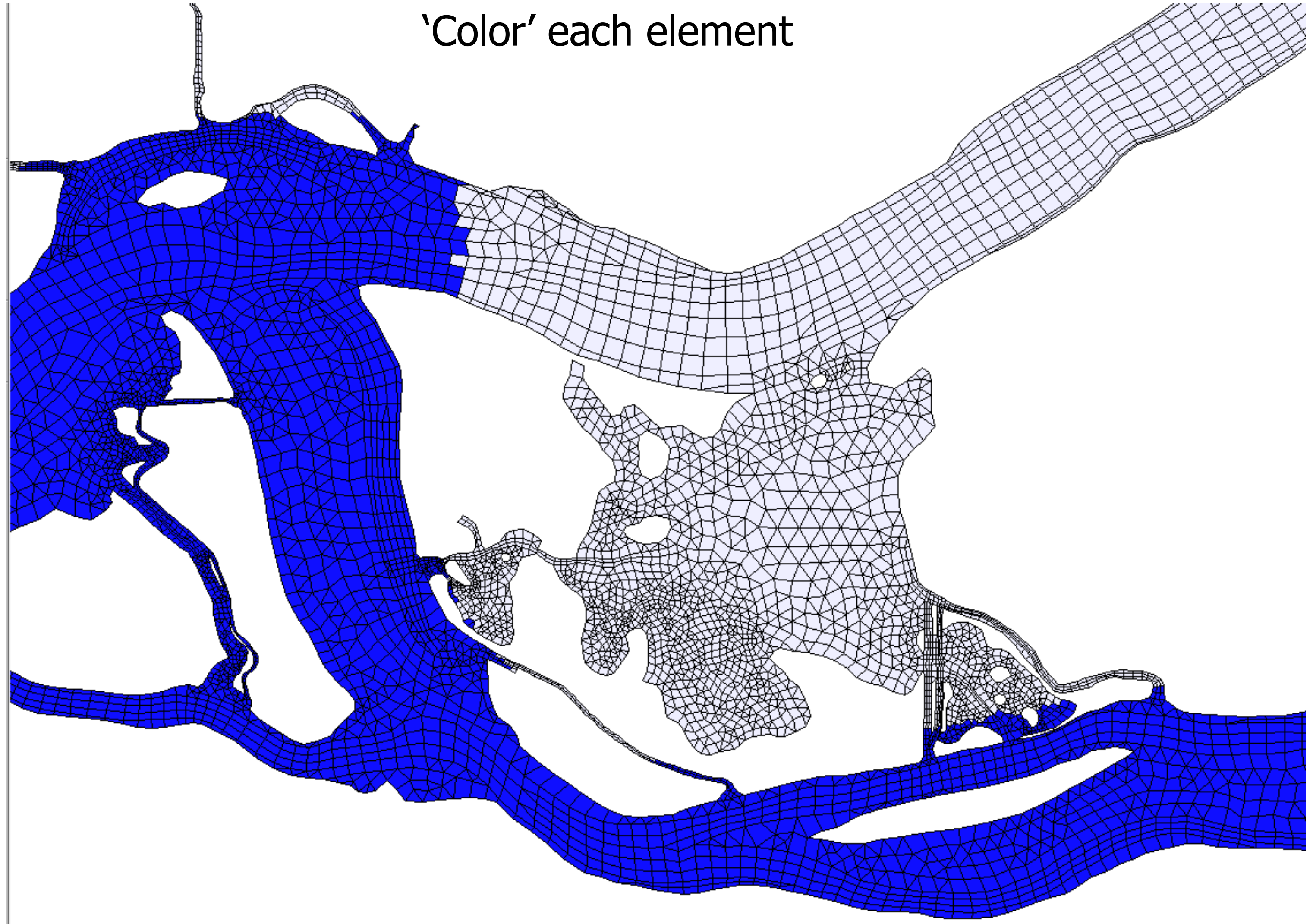
- Not used in SCHISM per se, but used in some scripts
- Basically a .gr3 file without connectivity
- Alternative: .sta

```
                                 Your comments
# of nodes or points  ------->   24025
                                     1       -90.4293      30.1689     0.30
                                     2       -90.4313      30.1625     0.30
                        points {     3       -90.4327      30.1559     0.20
                                     4       -90.4320      30.1498     0.20
                                     ..........................................
                                     24025  -89.01           35.71       10.5
```

.prop format

```
1  0.0000000E+00
2  0.0000000E+00
3  0.0000000E+00
4  0.0000000E+00
5  0.0000000E+00
6  0.0000000E+00
7  0.0000000E+00
8  0.0000000E+00
9  1.0000000E+00
10  1.0000000E+00
11  0.0000000E+00
12  0.0000000E+00
13  0.0000000E+00
14  0.0000000E+00
15  0.0000000E+00
16  0.0000000E+00
17  0.0000000E+00
18  0.0000000E+00
19  1.0000000E+00
20  0.0000000E+00
21  0.0000000E+00
22  1.0000000E+00
23  0.0000000E+00
……………………..
```

‘Color’ each element



vgrid.in (1): SZ

2 ivcor

28 18 100. !h_s

Z levels

1 -5000. $\longleftarrow$ Bottom z

……..

18 -100.00 $\longleftarrow$ Last z = $-h_s$

S levels

30. 0.9 3. h_c, θ_b, θ_f

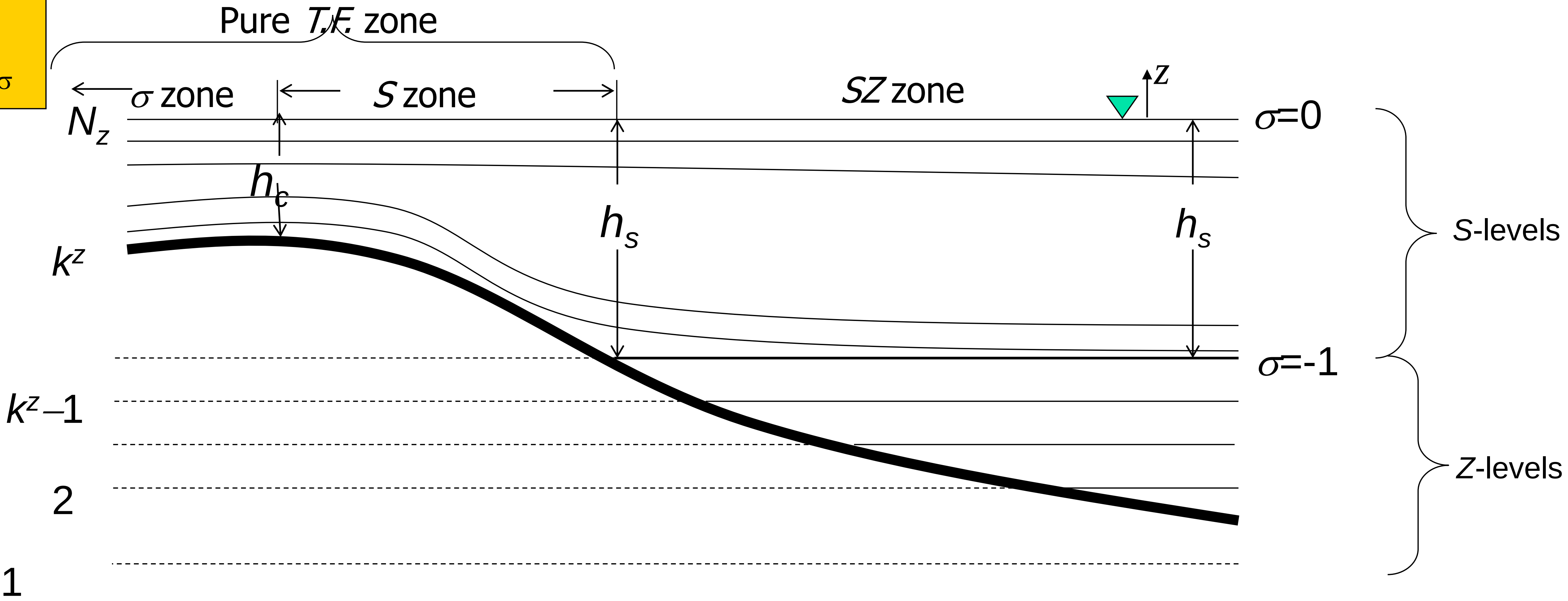
18 -1 $\longleftarrow$ 1st σ

19 -0.9

……..

28 0. $\longleftarrow$ Surface σ

$$\begin{tikzcd}\text{Bottom} \arrow[d] \\ \text{surface}\end{tikzcd}$$

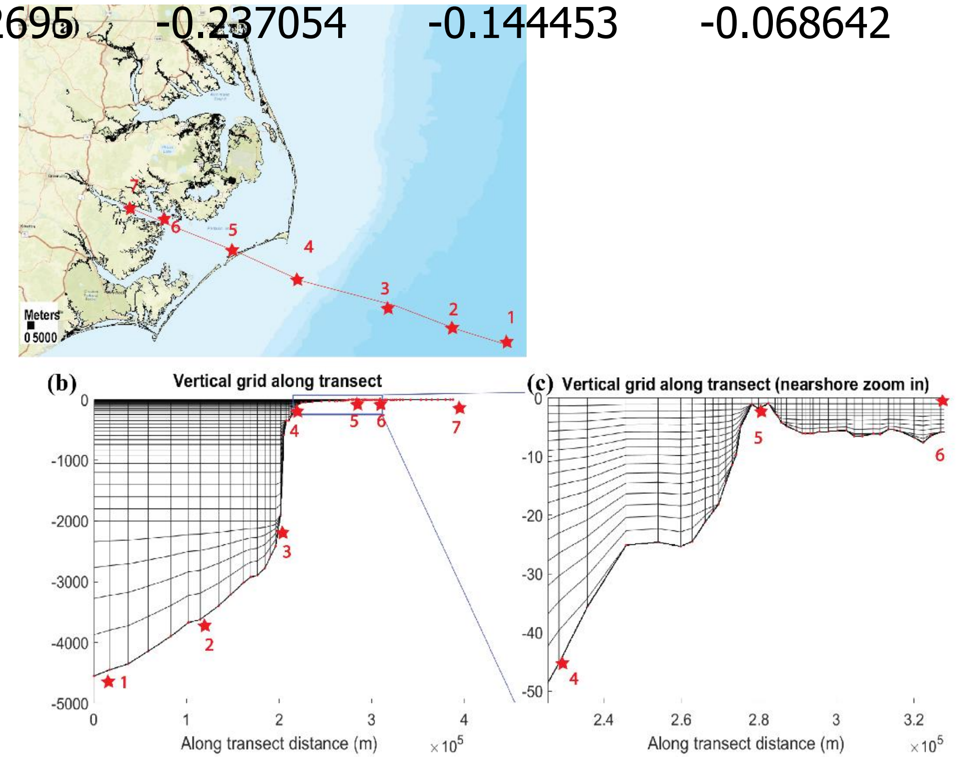


vgrid.in (2): LSC^2

- Needs pre-proc script to generate (e.g. gen_vqs*.f90 in Utility)
- *Always visualize a few transects using plot_vqs.m*

```
 1 ivcor
42 nvrt
      1      37    -1.000000    -0.703456    -0.665960    -0.369236    -0.167103     0.000000
      2      37    -1.000000    -0.703456    -0.665960    -0.369236    -0.167103     0.000000
    ..............................

    233      37    -1.000000    -0.703456    -0.665960    -0.369236    -0.167103     0.000000
    234      37    -1.000000    -0.703456    -0.665960    -0.369236    -0.167103     0.000000
    235      37    -1.000000    -0.703456    -0.665960    -0.369236    -0.167103     0.000000
    236      34    -1.000000    -0.749747    -0.562022    -0.419538    -0.309461    -0.222147    -0.136640    -0.065220     0.000000
    237      34    -1.000000    -0.754543    -0.570416    -0.430663    -0.322695    -0.237054    -0.144453    -0.068642     0.000000
..................................
```

Node # **Bottom index** **Bottom σ** **Surface σ**



bctides.in: a simple example

```
04/30/2002 00:00:00 PST
0 40. ntip
0  nbfr
0  nope*
```

*Note that there is no open boundary here. This is convenient for ipre=1

bctides.in: more examples

A simpler example

```
12/01/2013 00:00:00 GMT
0 50. ntip
0  nbfr
2 nope
1190 4 4 4 4 3 Pacific
5.e-1
5.e-1
1.
139 4 4 4 4 3 South China Sea
5.e-1
5.e-1
1.
```

Relaxation constants for each tracer module

b.c. flags for **enabled** tracer modules (SED in this case)

A more complex example

```
04/15/2004 00:00:00 PST
0 40. ntip
2  nbfr
Z0
 0. 1. 0.
O1
 6.759775e-05  1.15343 118.92151
4 nope
3 3 0 4 0  Georgia
 Z0
  0.1299680       0.000000E+00
  0.1299680       0.000000E+00
  0.1299680       0.000000E+00
O1
  0.361010246  281.862898
  0.36065857  281.918305
  0.360767938  281.968364
1.e-3 T relaxation
88 3 0 0 0 ocean
 Z0
   8.892417E-02   0.000000E+00
   8.631096E-02   0.000000E+00
........................
O1
........................
```

Extra b.c. flags for tracer models if invoked

Phases don't matter for Z0

- Use bi-section method if you really cannot find the cause for crash….
- B.C. flags drives additional b.c. inputs .th*
- Order of tracer modules: T, S, GEN, AGE, SED3D, EcoSim, ICM, CoSINE, Feco, TIMOR, FABM

Lateral b.c. and nudging

bctides.in $\underbrace{\hspace{10em}}$ (Type 1 – Type -4, -5) param.nml

Variable	Type 1 (*.th)	Type 2:	Type 3	Type 4 (*[23]D.th)	Type 5	Type -1	Type -4, -5 (uv3D.th); nudging	Nudging/sponge layer near boundary
η	**elev.th**: Time history; uniform along bnd	constant	Tidal amp/phases	**elev2D.th.nc**: time- and space-varying along bnd	**elev2D.th.nc:** combination of 3&4	Must =0	N/A	inu_elev
S&T, tracers	**[MOD]_?.th** : relax to time history (uniform along bnd) for inflow	Relax to constant for inflow	Relax to i.c. for inflow	**[MOD]_3D.th.nc**: relax to time- and space-varying values along bnd during inflow	N/A	N/A	N/A	inu_[MOD]
u,v	**flux.th**: via discharge **(<0 for inflow!)**	Via discharge **(<0 for inflow!)**	Tidal amp/phases	**uv3D.th.nc**: time- and space-varying along bnd (in lon/lat for ics=2)	**uv3D.th.nc:** combination of 3&4	Flather ('0' for η)	Relax to **uv3D.th.nc** (2 separate relaxations for in & outflow)	inu_uv

param.nml

- FORTRAN namelist format
- Format rules:
    - Lines beginning with “!" are comments; blank lines are ignored;
    - one line for each parameter in the format: keywords= value;
    keywords are case insensitive; spaces allowed between keywords and "=" and value; comments starting with “!" allowed after value;
    - value is an integer, double, or 2-char string; for double, any of the format is acceptable: 40 40. 4.e1; use of decimal point in integers is discouraged
    - Order of parameters not important
- Three major sections
    - CORE: mandatory parameters. If not specified, the code will crash
    - OPT: optional parameters with code defaults (often a good starting point but…)
    - SCHOUT: optional parameters that control outputs

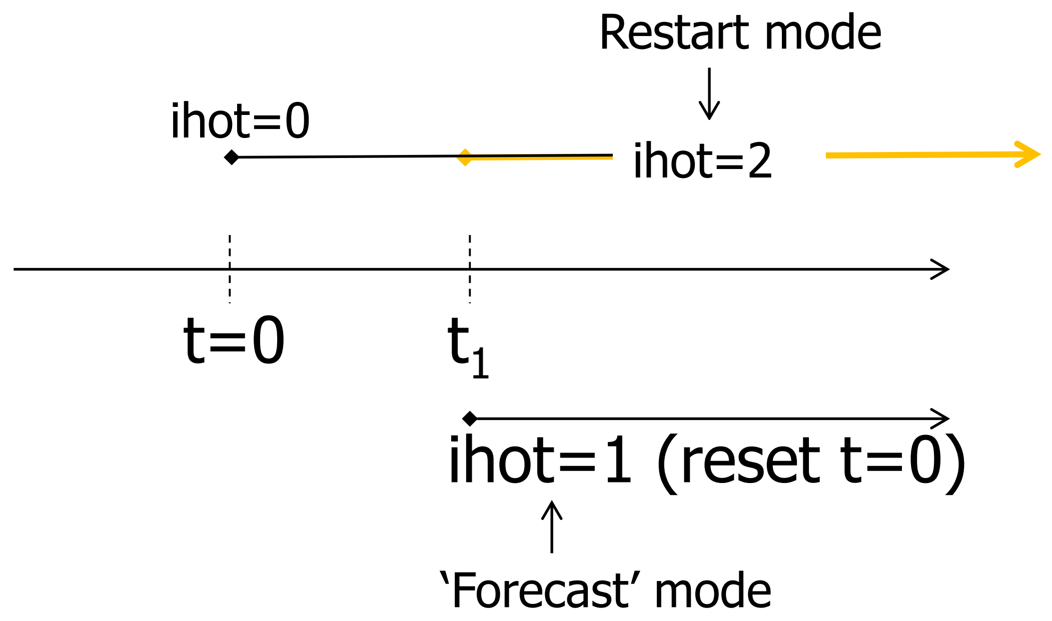
param.nml

```
&CORE
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Core (mandatory) parameters; no defaults
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Pre-processing option. Useful for checking grid errors etc. Can only use 1 CPU if ipre=1
  ipre = 0 !Pre-processor flag (1: on; 0: off)

! Baroclinic/barotropic option. If ibc=0 (baroclinic model), ibtp is not used.
  ibc = 0 !Baroclinic option
  ibtp = 1

  rnday = 30 !total run time in days
  dt = 100. !Time step in sec

! Grid for WWM (USE_WWM)
  msc2 = 24     !same as msc in .nml ... for consitency check between SCHISM and WWM
  mdc2 = 30     !same as mdc in .nml

! Define # of tracers in tracer modules (if enabled)
  ntracer_gen = 2 !user defined module (USE_GEN)
  ntracer_age = 4 !age calculation (USE_AGE). Must be =2*N where N is # of age tracers
  sed_class = 5 !SED3D (USE_SED)
  eco_class = 27 !EcoSim (USE_ECO): must be between [25,60]

! Global output controls
  nspool = 36 !output step spool
  ihfskip = 864 !stack spool; every ihfskip steps will be put into 1_*, 2_*, etc...
/
```

OPT section

```
&OPT
!-----------------------------------------------------------------------
! Coordinate option: 1: Cartesian; 2: lon/lat (hgrid.gr3=hgrid.ll in this case,
! and orientation of triangles is outward of earth)
!-----------------------------------------------------------------------
  ics = 2 !Coordinate option
  cpp_lon = -124  !CPP projection centers: lon; not used if ics=2
  cpp_lat = 46.25 !CPP projection centers: lat

!-----------------------------------------------------------------------
! Hotstart option. 0: cold start; 1: hotstart with time reset to 0; 2:
! continue from the step in hotstart.in
!-----------------------------------------------------------------------
  ihot = 0

!-----------------------------------------------------------------------
! Hydraulic model option. If ihydraulics/=0, hydraulics.in
! is required. This option cannot be used with non-hydrostatic model.
!-----------------------------------------------------------------------
  ihydraulics = 0

!-----------------------------------------------------------------------
! Point sources/sinks option (0: no; 1: on). If =1, needs source_sink.in,
! vsource,th, vsink.th, and msource.th
! If =-1, all info is in source.nc
! and each type of volume/mass source/sink can have its own time step and
! # of records.
!-----------------------------------------------------------------------
  if_source = 0
  nramp_ss = 1 !needed if if_source=1; ramp-up flag for source/sinks
  dramp_ss = 2 !needed if if_source=1; ramp-up period in days
```

You can use lon/lat even for high-resolution inundation study!



- Most parts of the code do not use the calendar time
  - Exceptions: heat exchange, WWM etc
- The code basically starts from t=0 and marches thru time

OPT: Initial condition flags

```
!-----------------------------------------------------------------------
! Elevation initial condition flag for cold start only. If ic_elev=1, elev.ic
! (in *.gr3 format) is needed
! to specify the initial elevations; otherwise elevation is
! initialized to 0 everywhere
!-----------------------------------------------------------------------
  ic_elev = 1

!-----------------------------------------------------------------------
! Elevation boundary condition ramp-up flag. =0: ramp up from 0;
! =1: ramp up from
! elev. values read in from elev.ic or hotstart.nc - if neither is
! present, from 0.
! This flag is mainly used to start the simulation from non-zero elev.
! The ramp-up period is same as 'dramp' below.
!-----------------------------------------------------------------------
  nramp_elev = 0
```

```
!-----------------------------------------------------------------------
! Initial condition for T,S. This value only matters for ihot=0 (cold start).
! If ic_*=1, the initial T,S field is read in from temp.ic and salt.ic (horizontally varying).
! If ic_*=2, the initial T,S field is read in from ts.ic (vertical varying).
! If ihot=0 && ic_*=2 || ibcc_mean=1, ts.ic is used for removing mean density profile.
!-----------------------------------------------------------------------
  ic_TEM = 1
  ic_SAL = 1 !must be same as ic_TEM

! initial conditions for other tracers.
! 1: needs inputs [MOD]_hvar_[1,2,...].ic ('1...' is tracer id); format of each file is similar
to salt.ic;
!    i.e. horizontally varying i.c. is used for each tracer.
! 2: needs [MOD]_vvar_[1,2,...].ic. Format of each file (for each tracer in tis MOD) is
similar to ts.ic
!    (i.e. level #, z-coord., tracer value). Verically varying i.c. is used for each tracer.
! 0: model sets own i.c. (EcoSim; TIMOR)
  ic_GEN = 1 !user defined module
  ic_AGE = 1 !Age
  ic_SED = 1 !SED3D
  ic_ECO = 1 !EcoSim
  ic_ICM = 1 !ICM
  ic_COS = 1 !CoSINE
  ic_FIB = 1 !FIB
```

OPT: control of dissipation in momentum

```
!-----------------------------------------------------------------------
! Methods for computing velocity at nodes.
! If indvel=0, conformal linear shape function is used; if indvel=1, averaging method is used.
! For indvel=0, a stabilization method is needed (see below).
!-----------------------------------------------------------------------
  indvel = 0

!-----------------------------------------------------------------------
! 2 stabilization methods, mostly for indvel=0.
! (1) Horizontal viscosity option. ihorcon=0: no viscosity is used; =1: Lapacian;
! =2: bi-harmonic. If ihorcon=1, horizontal viscosity _coefficient_ (<=1/8, related
! to diffusion number) is given in hvis_coef0, and the diffusion #
! is problem dependent; [0.001-1/8] seems to work well.
! If ihorcon=2, diffusion number is given by hvis_coef0 (<=0.025).
! If indvel=1, no horizontal viscosity is needed.
! (2) Shapiro filter (see below)
!
! For non-eddying regime applications (nearshore, estuary, river), two easiest options are:
! (1) indvel=1, ishapiro=ihorcon=0, and any choices of inter_mom;
! (2) indvel=0, ishapiro=1 (shapiro=0.5), ihorcon=inter_mom=0.
! For applications that include eddying regime, refer to the manual.
!-----------------------------------------------------------------------
  ihorcon = 0
  hvis_coef0 = 0.025 !const. diffusion # if ihorcon/=0; <=0.025 for ihorcon=2, <=0.125 for ihorcon=1
!  cdh = 0.01 !needed only if ihorcon/=0; land friction coefficient - not active yet

!-----------------------------------------------------------------------
! 2nd stabilization method via Shapiro filter. This should normally be used
! if indvel=ihorcon=0. To transition between eddying/non-eddying regimes, use
! indvel=0, ihorcon/=0, and ishapiro=-1 (shapiro.gr3).
!-----------------------------------------------------------------------
  ishapiro = 1 !on/off flag
  shapiro = 0.5 !Shapiro filter strength, needed only if ishapiro=1; max is 0.5

!-----------------------------------------------------------------------
! Horizontal diffusivity option. if ihdif=1, horizontal diffusivity is given in hdif.gr3
!-----------------------------------------------------------------------
  ihdif = 0
```

- Eddying or regime or cross scale: indvel=0, ihorcon=2, hvis_coef0 = 0.025 ishapiro=0 or
  - We are working on combined bi-harmonic and Laplacian viscosity (to replace ishapiro=-1)
- indvel=1, ishapiro=ihorcon=0 occasionally useful for b-tropic applications

OPT

```
!-----------------------------------------------------------------------
! Bottom friction.
!           nchi=0: drag coefficients specified in drag.gr3; nchi=-1: Manning's
!           formulation (even for 3D prisms) with n specified in manning.gr3.
!           nchi=1: bottom roughness (in meters) specified in rough.gr3 (and in this case, negative
!           or 0 depths in rough.gr3 indicate time-independent Cd, not roughness!).
!           Cd is calculated using the log law, when dzb>=dzb_min; when dzb<dzb_min,
!           Cd=Cdmax*exp[dzb_decay*(1-dzb/dzb_min)], where Cdmax=Cd(dzb=dzb_min),
!           and dzb_decay (<=0) is a decay const specified below. We recommend dzb_decay=0
!           and may remove this constant in the future.
!           If iwbl/=0, nchi must =1.
!-----------------------------------------------------------------------
  nchi = -1
  !dzb_min = 0.5 !needed if nchi=1; min. bottom boundary layer thickness [m].
  !dzb_decay = 0. !needed if nchi=1; a decay const. [-]. should =0
  hmin_man = 1. !needed if nchi=-1: min. depth in Manning's formulation [m]
!-----------------------------------------------------------------------
! Coriolis. If ncor=-1, specify "latitude" (in degrees); if ncor=0,
! specify Coriolis parameter in "coriolis"; if ncor=1, model uses
! lat/lon in hgrid.ll for beta-plane approximation if ics=1, and in this case,
! the latitude specified in CPP projection ('cpp_lat') is used. If ncor=1 and ics=2,
! Coriolis is calculated from local latitude, and 'cpp_lat' is not used.
!-----------------------------------------------------------------------
  ncor = 1 !must be 1 if ics=2
  !latitude = 46 !if ncor=-1
  !coriolis = 1.e-4 !if ncor=0
```

If bfric=1

We always use dzb_decay=0, so Cd<=Cdmax

OPT

```
!-----------------------------------------------------------------------
! Wetting and drying. If ihhat=1, \hat{H} is made non-negative to enhance
! robustness near wetting and drying; if ihhat=0, no retriction is imposed for
! this quantity.
! inunfl=0 is used for normal cases and inunfl=1 (not available yet) is used for more accurate wetting
! and drying if grid resolution is sufficiently fine.
!-----------------------------------------------------------------------
  ihhat = 1 !not used for 2D model
  inunfl = 0
  h0 = 0.01 !min. water depth for wetting/drying

!-----------------------------------------------------------------------
! Implicitness factor (0.5<thetai<=1).
!-----------------------------------------------------------------------
```

$\theta \longrightarrow$ thetai = 1

```
!-----------------------------------------------------------------------
! ramp option
!-----------------------------------------------------------------------
  nramp = 1 !ramp-up option (1: on; 0: off)
  dramp = 2. !needed if nramp=1; ramp-up period in days


!-----------------------------------------------------------------------
! Solver option. JCG is used presently.
!-----------------------------------------------------------------------
  slvr_output_spool = 50 !output spool for solver info (fort.33)
  mxitn = 1000 !max. iteration allowed
  tolerance = 1.e-12 !error tolerance
```

OPT

```
!-----------------------------------------------------------------------
! Advection (ELM) option. If nadv=1, backtracking is done using Euler method;
! nadv=2, using 2nd order Runge-Kutta; if nadv=0, advection in momentum
! is turned off/on in adv.gr3 (the depths=0,1, or 2 also control methods
! in backtracking as above). dtb_max/min are the max/min steps allowed -
! actual step is calculated adaptively based on local flow gradient.
!-----------------------------------------------------------------------
  nadv = 1
  dtb_max = 50. !in sec
  dtb_min = 15.


!-----------------------------------------------------------------------
! If inter_mom=0, linear interpolation is used for velocity at foot of char. line.
! If inter_mom=1 or -1, Kriging is used, and the choice of covariance function is
! specified in 'kr_co'. If inter_mom=1, Kriging is applied to whole domain;
! if inter_mom=-1, the regions where Kriging is used is specified in krvel.gr3
! (depth=0: no kriging; depth=1: with kriging).
! For velocity, additional controls are available in 'blend_internal' and 'blend_bnd',
! two parameters specifying how continuous and discontinuous velocities are blended
! for internal and boundary sides. If indvel=1, code resets blend_internal=blend_bnd=0.
!-----------------------------------------------------------------------
  inter_mom = 0
  kr_co = 1 !not used if inter_mom=0 (-h, h^2log(h), h^3, -h^5)
```

Choice of inter_mom depends on *indvel.* If indvel=0, inter_mom=1, then kr_co should be 1 (otherwise dispersion is too strong)

OPT: Transport solver

```
!-----------------------------------------------------------------------
! Transport method.
! If itr_met=1, upwind method is used. If itr_met>=2, TVD or WENO method is used
! on an element/prism if the total depth (at all nodes of the elem.)>=h_tvd and the flag in
! tvd.prop = 1 for the elem. (tvd.prop is required in this case);
! otherwise upwind is used for efficiency.
! itr_met=3 (horizontal TVD) or 4 (horizontal WENO): implicit TVD in the vertical dimension.
! Also if itr_met==3 and h_tvd>=1.e5, some parts of the code are bypassed for efficiency
! Controls for WENO are not yet in place
!-----------------------------------------------------------------------
  itr_met = 1
  h_tvd = 5. !used only if itr_met>=2; cut-off depth (m)
  !If itr_met=3 or 4, need the following 2 tolerances of convergence. The convergence
  !is achieved when sqrt[\sum_i(T_i^s+1-T_i^s)^2]<=eps1_tvd_imp*sqrt[\sum_i(T_i^s)^2]+eps2_tvd_imp
  eps1_tvd_imp = 1.e-4 !suggested value is 1.e-4, but for large suspended load, need to use a smaller value (e.g. 1.e-9)
  eps2_tvd_imp = 1.e-14

  !if itr_met = 4, the following parameters are needed
  !if itr_met=4 and ipre=1, diagnostic outputs are generated for weno accuracy and stencil quality,
  !  see subroutine weno_diag in src/Hydro/misc_subs.F90 for details
  ip_weno = 2   !order of accuracy: 0- upwind; 1- linear polynomial, 2nd order; 2- quadratic polynomial, 3rd order
  courant_weno=0.5 !Courant number for weno transport
  epsilon1 = 1.e-8   !coefficient for 2nd order weno smoother
  epsilon2 = 1.e-10  !1st coefficient for 3rd order weno smoother
  epsilon3 = 1.e-25  !2nd coefficient for 3rd order weno smoother (not used)
  !Elad filter has not been implemented yet; preliminary tests showed it might not be necessary
  ielad_weno = 0      !ielad, if ielad=1, use ELAD method to suppress dispersion
  small_elad = 1.e-4  !small
```

- Use itr_met=3 or 4 for most b-clinic applications

OPT: Atmospheric forcing

```
!-----------------------------------------------------------------------
! Atmos. option. If nws=0, no atmos. forcing is applied. If nws=1, atmos.
! variables are read in from wind.th. If nws=2, atmos. variables are
! read in from sflux_ files.
! If nws=4, ascii format is used for wind and atmos. pressure at each node (see source code).
! If nws>0, 'iwindoff' can be used to scale wind speed (with windfactor.gr3).
!
! Stress calculation:
! If nws=1 or >=4, or nws=2 and ihconsv=0, or nws=2 and iwind_form=-1,
! the stress is calculated from Pond & Pichard formulation
! If nws=2, ihconsv=1 and iwind_form=0, the stress is calculated from heat exchange
! routine;
! If WWM is enabled and icou_elfe_wwm>0 and iwind_form=-2, stress is calculated by WWM;
! otherwise the formulations above are used.
!-----------------------------------------------------------------------
  nws = 2
  wtiminc = 150. !time step for atmos. forcing
  nrampwind = 1 !ramp-up option for atmos. forcing
  drampwind = 2. !needed if nrampwind/=0; ramp-up period in days
  iwindoff = 0 !needed only if nws/=0; '1': needs windfactor.gr3
  iwind_form = -1

!-----------------------------------------------------------------------
! Heat and salt exchange. isconsv=1 needs ihconsv=1; ihconsv=1 needs nws=2.
! If isconsv=1, need to compile with precip/evap module turned on.
!-----------------------------------------------------------------------
  ihconsv = 0 !heat exchange option
  isconsv = 0 !evaporation/precipitation model
```

nws=2 is recommended. There are matlab scripts to help you

OPT: Turbulence closure

```
!-----------------------------------------------------------------------
! Turbulence closure.
!-----------------------------------------------------------------------
  itur = 0
  dfv0 = 1.e-6 !needed if itur=0
  dfh0 = 1.e-6 !needed if itur=0
!  turb_met = KE !needed if itur=3,5. Use KE if itur=5
!  turb_stab = KC !needed if itur=3 or 5. Use 'GA' if turb_met='MY'; otherwise use 'KC'.
!  xlsc0 = 0.1 !needed if itur=3 or 5. Scale for surface & bottom mixing length (>0)
```

3 or 4: needs diffmax.gr3,diffmin.gr3

OPT

```
!-----------------------------------------------------------------------
! Dimensioning parameters for inter-subdomain btrack.
! If error occurs like 'bktrk_subs: overflow' or 'MAIN: nbtrk > mxnbt'
! gradually increasing these will solve the problem
!-----------------------------------------------------------------------
  s1_mxnbt = 0.5
  s2_mxnbt = 3.5
```

No effects on accuracy; only affect memory consumption

```
!-----------------------------------------------------------------------
! Conservation check option. If consv_check=1, some fluxes are
computed
! in regions specified in fluxflag.prop (regional number from -1 to
an arbitrary !integer).
!-----------------------------------------------------------------------
  iflux = 0
```

SCHOUT

```
&SCHOUT
!-----------------------------------------------------------------------
!Option for hotstart outputs (use combine_hotstart7.f90 to combine)
!-----------------------------------------------------------------------
  nhot = 1 !1: output *_hotstart every 'hotout_write' steps
  nhot_write = 4032 !divisible by ihfskip
!-----------------------------------------------------------------------
!Global output options (node centered)
!-----------------------------------------------------------------------
  iof_hydro(1) = 1 !0: off; 1: on - elev. [m]  {elev}
  iof_hydro(2) = 0 !air pressure [Pa]  {air_pressure}
  iof_hydro(3) = 0 !air temperature [C] {air_temperature}
  iof_hydro(4) = 0 !Specific humidity [-] {specific_humidity}
  iof_hydro(5) = 0 !Net downward solar (shortwave) radiation after albedo [W/m/m]
{solar_radiation}
  iof_hydro(6) = 0 !sensible flux (positive upward) [W/m/m]  {sensible_flux}
  iof_hydro(7) = 0 !latent heat flux (positive upward) [W/m/m] {latent_heat}
  iof_hydro(8) = 0 !upward longwave radiation (positive upward) [W/m/m] {upward_longwave}
  iof_hydro(9) = 0 !downward longwave radiation (positive downward) [W/m/m]
{downward_longwave}
  iof_hydro(10) = 0 !total flux=-flsu-fllu-(radu-radd) [W/m/m] {total_heat_flux}
  iof_hydro(11) = 0 !evaporation rate [kg/m/m/s] {evaporation}
  iof_hydro(12) = 0 !precipitation rate [kg/m/m/s] {precipitation}
  iof_hydro(13) = 0 !Bottom stress vector [kg/m/s^2(Pa)] {bottom_stress}
  iof_hydro(14) = 0 !wind velocity vector [m/s] {wind_speed}
  iof_hydro(15) = 0 !wind stress vector [m^2/s/s] {wind_stress}
  iof_hydro(16) = 0 !depth-averaged vel vector [m/s] {dahv}
  iof_hydro(17) = 0 !vertical velocity [m/s] {vertical_velocity}
  iof_hydro(18) = 0 !water temperature [C] {temp}
  iof_hydro(19) = 0 !water salinity [PSU] {salt}
  iof_hydro(20) = 0 !water density [kg/m^3] {water_density}
  iof_hydro(21) = 0 !eddy diffusivity [m^2/s] {diffusivity}
  iof_hydro(22) = 0 !eddy viscosity [m^2/s] {viscosity}
  iof_hydro(23) = 0 !turbulent kinetic energy {TKE}
  iof_hydro(24) = 0 !turbulent mixing length [m] {mixing_length}
  iof_hydro(25) = 1 !horizontal vel vector [m/s] {hvel}
```

```
!-----------------------------------------------------------------------
!Non-node centered outputs
!-----------------------------------------------------------------------
  iof_hydro(26) = 0 !horizontal vel vector defined @side [m/s] {hvel_side}
  iof_hydro(27) = 0 !vertical vel. @elem [m/s] {wvel_elem}
  iof_hydro(28) = 0 !T @prism centers [C] {temp_elem}
  iof_hydro(29) = 0 !S @prism centers [PSU] {salt_elem}
  iof_hydro(30) = 0 !Barotropic pressure gradient force vector (m.s-2) @side centers
{pressure_gradient}
```

SCHOUT

```
!-----------------------------------------------------------------------
 !Station output option. If iout_sta/=0, need output skip (nspool_sta) and
 !a station.in. If ics=2, the cordinates in station.in must be in lon., lat,
 !and z (measured from datum; not used for 2D variables).
!-----------------------------------------------------------------------
  iout_sta = 0
  nspool_sta = 10 !needed if iout_sta/=0

!-----------------------------------------------------------------------
! Flag for harmonic analysis for elevation. If used , need to turn on USE_HA
! in Makefile, and input harm.in. Otherwise set it to 0. Hotstart ihot=2 is not working with HA
! Outputs are harme_* and use combine_outHA to combine.
!-----------------------------------------------------------------------
  iharind = 0
```

Most important parameters are…

- Momentum dissipation: indvel, ihorcon, ishapiro, inter_mom
    - Appropriate combination of these can be used for different applications (dispersion vs diffusion)
    - May start with: indvel= ihorcon=inter_mom=0, ishapiro=1 ('MB-LI' scheme)
    - If dissipation is still too high, use indvel= inter_mom=ishapiro=0, ihorcon=2, hvis_coef0=0.025 (or smaller) – the 'eddying' option. If oscillation is found in non-eddying part, use ishapiro=-1 and set the filter strength in shapiro.gr3 (eventually we will replace this with a new option of using both Laplacian and bi-harmonic viscosities)
    - indvel=1, ihorcon=ishapiro=inter_mom=0 is the most diffusive option ('MA-LI' scheme), but might be useful for 2D runs etc
- dt: appropriate time step
    - Another way to control dispersion/diffusion
    - Reducing dt will increase diffusion and decrease dispersion
- nws: use '2' as much as possible (and there are scripts for generating sflux*.nc)
- itr_met: use 3 or 4
    - Use 'h_tvd' and tvd.prop to control efficiency
    - 'Upwind' zone: upstream river where there is no stratification

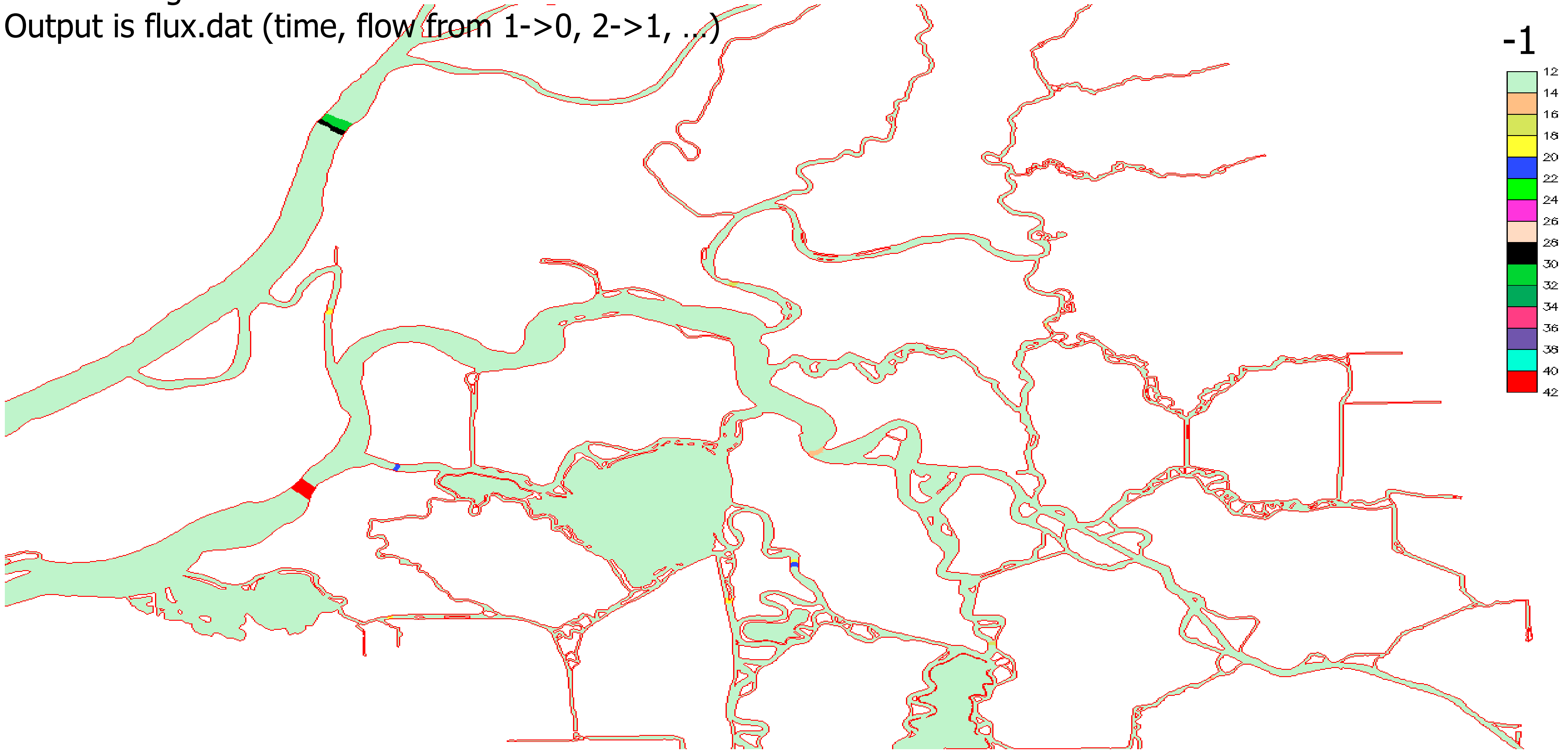
Station.in

```
1 1 1 1 1 1 1 1 1 !on (1)|off(0) flags for elev, air pressure, windx, windy, T, S, u, v, w
4        !# of stations
1 6.5833 54.0000 0     !Format: station #,x,y,z; z is z-coord.
2 7.1583 55.195 -1.       !Fino3
3 6.35  54.1667 -5.       !Ems
4 8.4514 54.7942 0     !PHoern
```

- If ics=2, x,y are degrees in lon/lat.
- z is z-coordinates, not distance from surface! So z<0 is below the datum
- If you want to extract series at multiple depths, use multiple stations
- For 3D variables, code will extrapolate above surface/below bottom if necessary

Fluxflag.prop

- Invoked by iflux=1
- Compute various fluxes (from ‘high’ to ‘low’), if the difference of flags=1 and neither are -1
- Otherwise ignored
- Output is flux.dat (time, flow from 1->0, 2->1, …)



Hotstart and nuding inputs

```
netcdf hotstart {
dimensions:
        node = 20641 ;
        elem = 38960 ;
        side = 59615 ;
        nVert = 54 ;
        ntracers = 2 ;
        one = 1 ;
        three = 3 ;
variables:
        double time(one) ;
        int iths(one) ;
        int ifile(one) ;
        int idry_e(elem) ;
        int idry_s(side) ;
        int idry(node) ;
        double eta2(node) ;
        double we(elem, nVert) ;
        double tr_el(elem, nVert, ntracers) ;
        double su2(side, nVert) ;
        double sv2(side, nVert) ;
        double tr_nd(node, nVert, ntracers) ;
        double tr_nd0(node, nVert, ntracers) ;
        double q2(node, nVert) ;
        double xl(node, nVert) ;
        double dfv(node, nVert) ;
        double dfh(node, nVert) ;
        double dfq1(node, nVert) ;
        double dfq2(node, nVert) ;
data:

 time = 0 ;

 iths = 0 ;

 ifile = 1 ;

 idry_e = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
```

```
netcdf SAL_nu {
dimensions:
        node = 20641 ;
        nVert = 54 ;
        ntracers = 1 ;
        time = UNLIMITED ; // (29 currently)
variables:
        double time(time) ;
                time:long_name = "simulation time in days" ;
        float tracer_concentration(time, node, nVert, ntracers) ;
data:

 time = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
    20, 21, 22, 23, 24, 25, 26, 27, 28 ;

 tracer_concentration =
  34.63076,
  34.62345,
  34.57667,
  34.50737,
  34.4041,
  34.30476,
  34.17599,
  34.11315,
  34.06581,
  34.03587,
  33.99743,
```

*.th: ASCII

flux.th (**negative for inflow**), TEM_1.th, SAL_1.th, elev.th, wind.th

- Corresponds to b.c. flag=1
- Easy to plot with xmgr5

```
Time (sec)      value 1 (1st bnd)      value 2 (2nd bnd)      .............           value N (Nth bnd)

→0.      -0.084950529 0. -0.283168435 -0.226534754 -3.19980335 -16.367136
86400 -0.084950529 0. -0.283168435 -0.226534754 -3.19980335 -16.367136
172800 -0.084950529 0. -0.283168435 -0.226534754 -0.906139016 -22.2853565
259200 -0.084950529 0. -0.25485158 -0.226534754 -0.764554799 -16.367136
345600 -0.084950529 0. -0.25485158 -0.226534754 -0.764554799 -16.367136
432000 -0.084950529 0. -0.25485158 -0.226534754 -0.877822161 -16.367136
518400 -0.084950529 0. -0.25485158 -0.226534754 -3.17148638 -16.367136
604800 -0.084950529 0. -0.25485158 -0.226534754 -0.906139016 -16.367136
.......................................................................................................
```

- ■ Time steps ≥ main time step in param.nml; record must start from 0
- ■ Time step in wind.th specified in param.nml (*wtiminc*)

*[23]D.th.nc

elev2D.th.nc, TEM_3D.th.nc, SAL_3D.th.nc, [tracer]_3D.th.nc, uv3D.th.nc (not discharge)

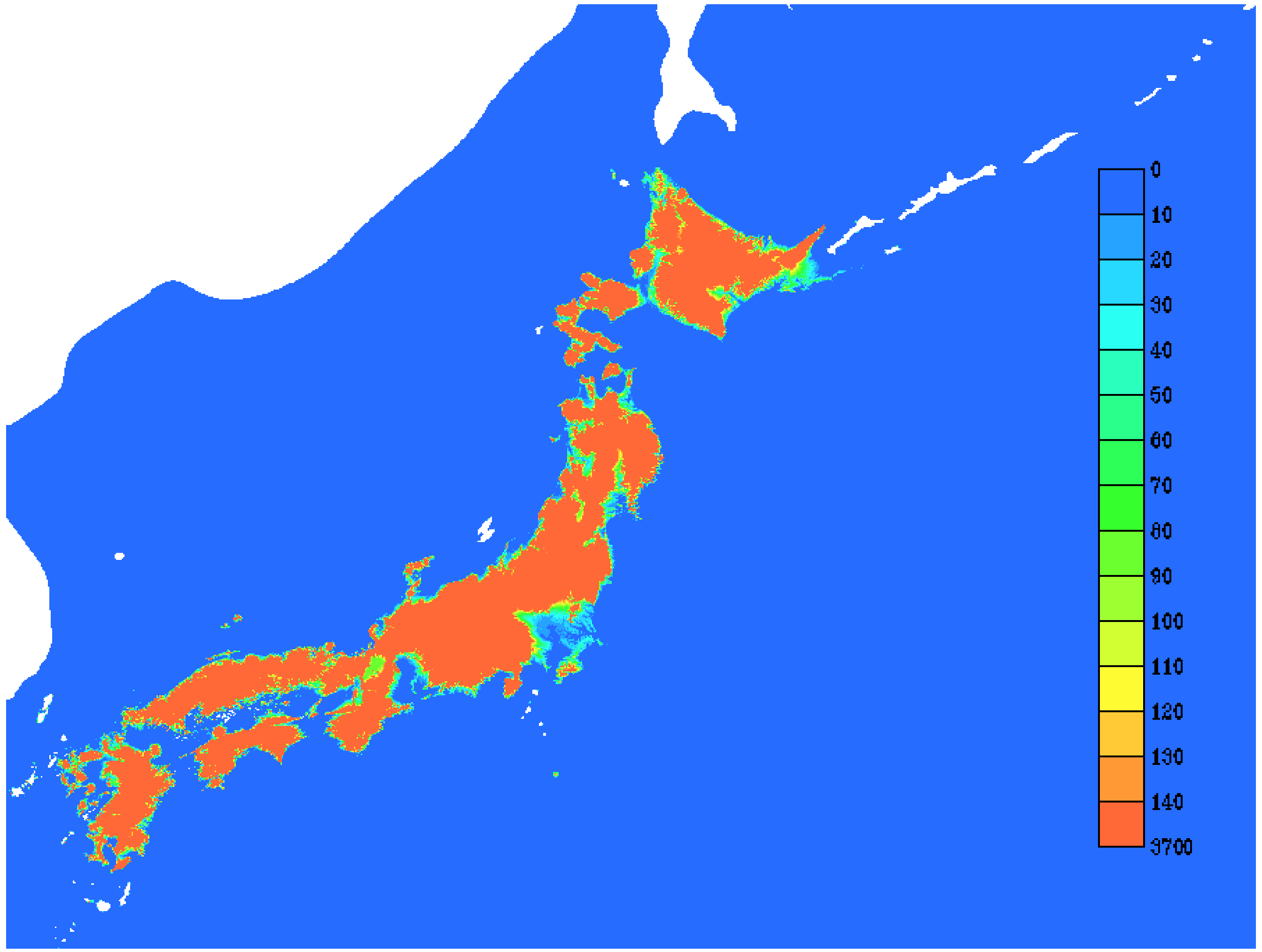
- Corresponds to b.c. flag=±4 or 5
- Make sure you check values after creation

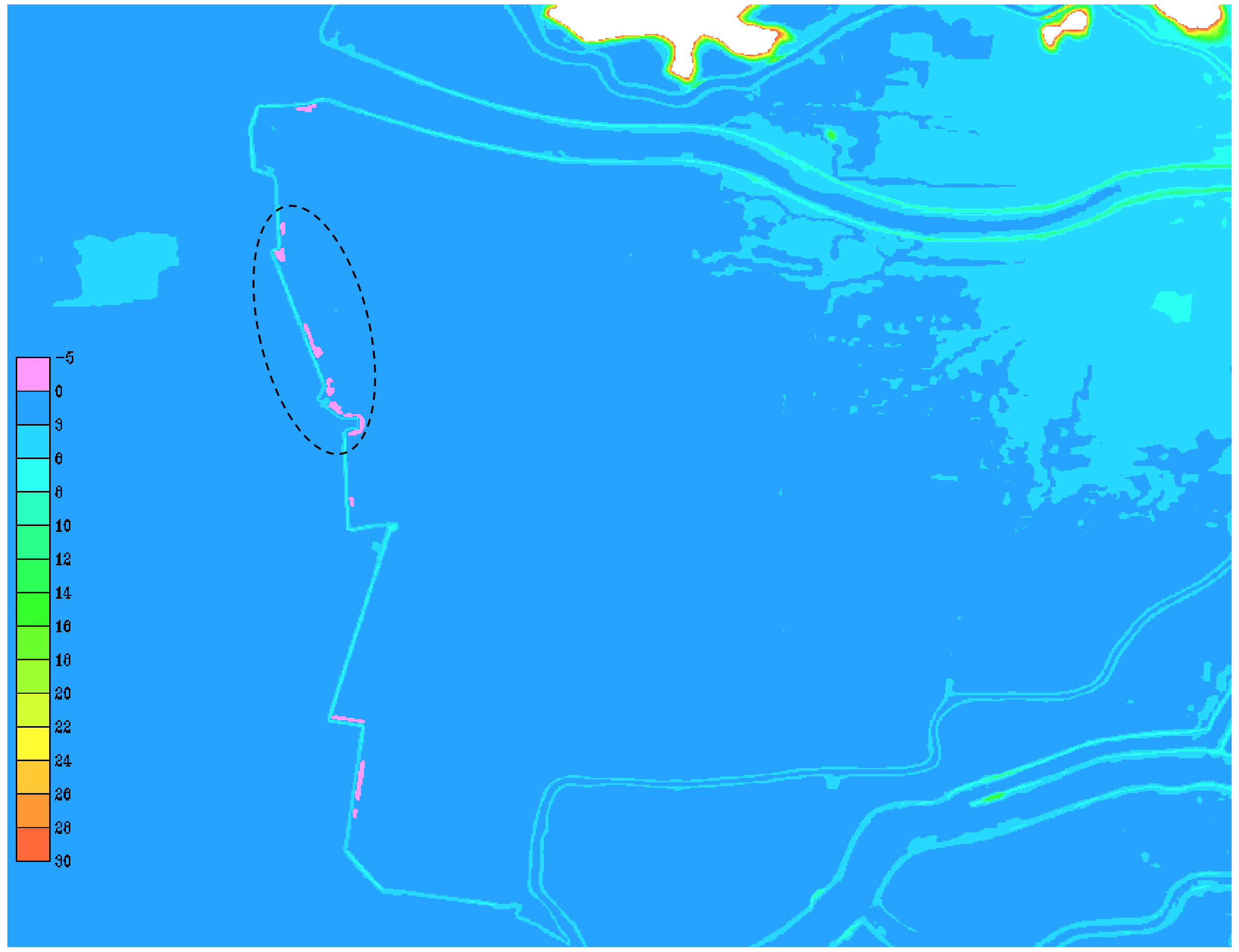
```
netcdf uv3D.th {
dimensions:
        nOpenBndNodes = 1329 ;
        nLevels = 48 ;
        nComponents = 2 ;
        one = 1 ;
        time = UNLIMITED ; // (2881 currently)
variables:
        float time_step(one) ;
                time_step:long_name = "time step in seconds" ;
        double time(time) ;
                time:long_name = "simulation time in seconds" ;
        float time_series(time, nOpenBndNodes, nLevels, nComponents) ;

// global attributes:
                :_NCProperties = "version=1|netcdflibversion=4.4.1.1|hdf5libversion=1.8.18" ;
data:

 time_step = 3600 ;

 time = 0, 3600, 7200, 10800, 14400, 18000, 21600, 25200, 28800, 32400,
    36000, 39600, 43200, 46800, 50400, 54000, 57600, 61200, 64800, 68400,
    72000, 75600, 79200, 82800, 86400, 90000, 93600, 97200, 100800, 104400,
    108000, 111600, 115200, 118800, 122400, 126000, 129600, 133200, 136800,
    140400, 144000, 147600, 151200, 154800, 158400, 162000, 165600, 169200,
```

Time steps may be different from each other and ≥ dt in param.nml; record must start from t=0

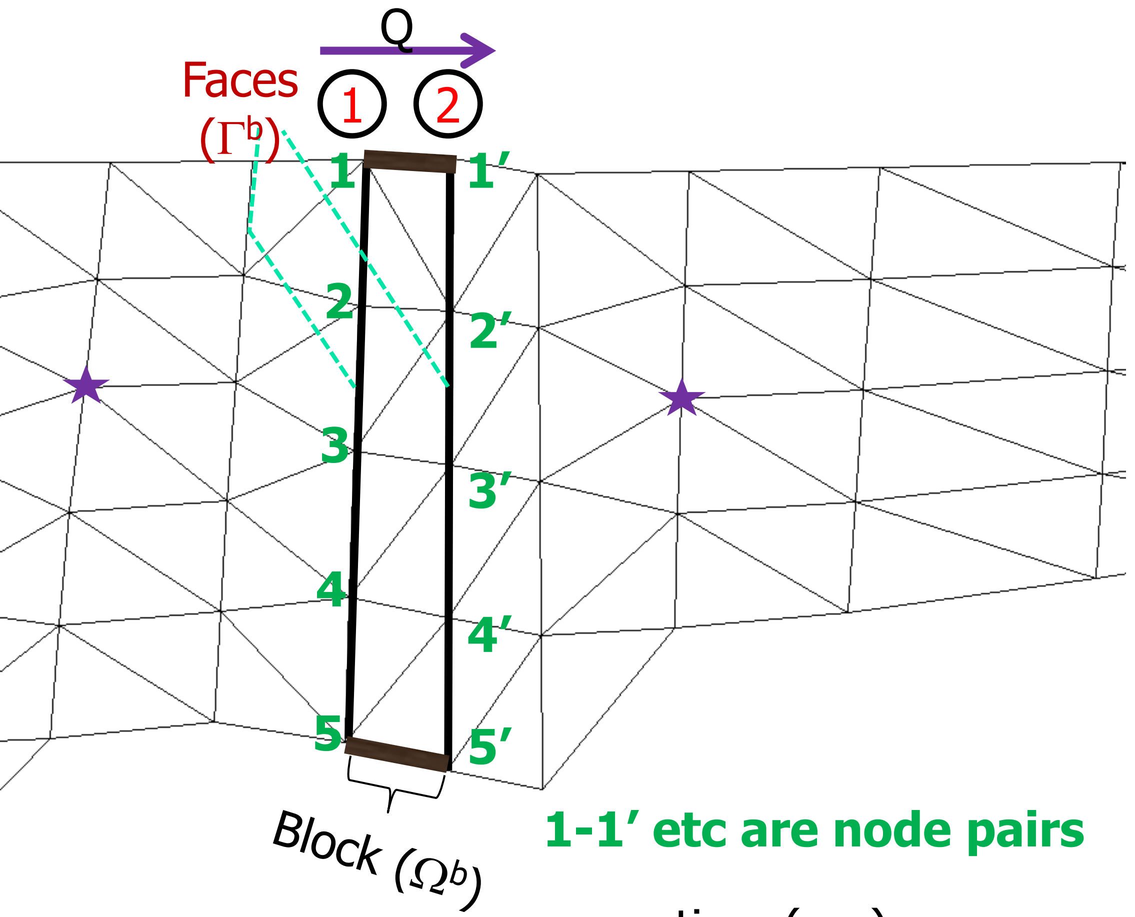
elev.ic: initial condition for elev

- .gr3 format
- For compound flooding studies, we typically set the initial condition of elev=0 in 'wet' zone, and just below bottom in 'dry' zone (watershed)
- In xmgredit5, depth=max(0,-depth-ε), where is a small positive depth e.g. ε=0.01mm
- Can further edit elev.ic to make certain wet areas dry (e.g. behind coastal levees in Kumamoto City)





Hydraulics.in



1-1′ etc are node pairs

```
14 # of structures
0.1  Nudging factor
1 delta_cross_channel
3 48402 48977    # of node-pairs, 2 ref. nodes (global indices) for 2 faces
48403 48589 node pair
48591 48782
48783 48978
radial  struct type
2  n_duplicates
-3.420000 18.290000 10.000000  elevation, width, height or radius
1.000000 1.000000 1.000000  coef, op_downstream, op_upstream
1  time series enabled
2 ccfb_gate
3 163413 163248    # of node-pairs, 2 ref.nodes (global indices) for 2 faces
```

delta_cross_channel.th

time (sec) op_up elevation, width, height

```
-315420.0       1     2     1     1     -3.42   18.29   0
17748180.0      1     2     1     1     -3.42   18.29   10
28290600.0      1     2     1     1     -3.42   18.29   0
28297800.0      1     2     1     1     -3.42   18.29   10
```

install nduplicates op_down

Consult hydraulics manual for more details

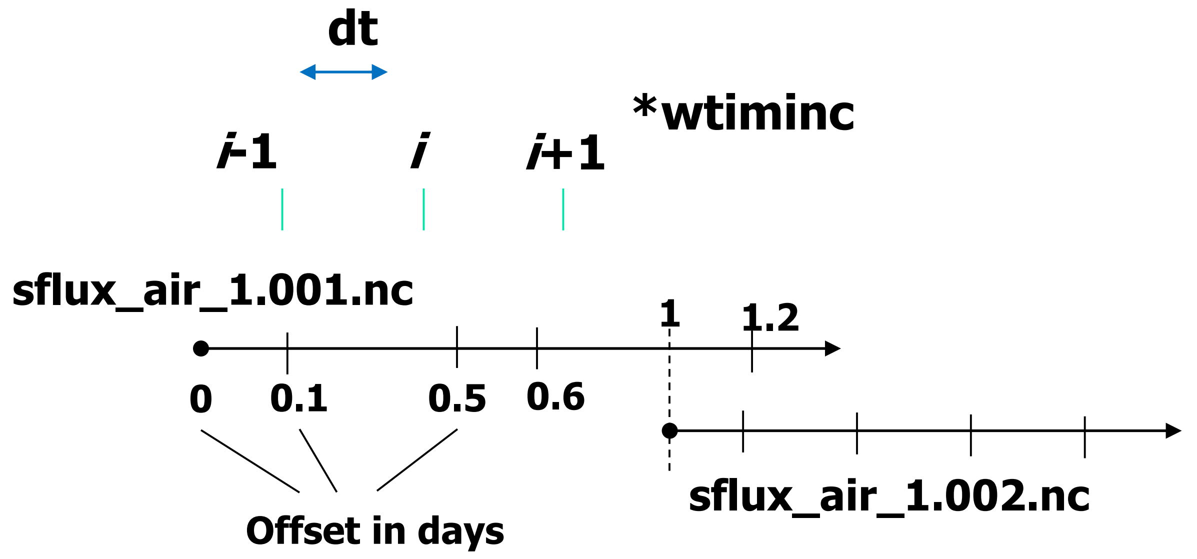
sflux/ (nws=2)

- Requires hgrid.ll for interpolation
- netcdf files (CF-1.0) reformatted from CFSR, NARR, NAM, WRF, MM5… (structured grid)
- Three types
  - sflux_air_[12]_*.nc: wind speed (u,v) (10m above MSL), air pressure (MSL), surface air T (2m above MSL), and *specific* humidity (2m above MSL)
  - sflux_rad_[12]_*.nc: *downward* long (infrared) and short (solar) wave radiation fluxes – used in heat exchange only (ihconsv=1)
  - sflux_prc_[12]_*.nc: surface precipitation rate (kg/m^2/s) – used in salt exchange only (isconsv=1)
- Sample files: NARR (we have 1979-present on Sciclone)
  - Download NARR files for your application period. Each NARR file covers ~ 1 day (e.g., narr_air.1981_01_28.nc is for Jan. 28, 1981).
  - In your run directory, mkdir sflux and inside it, create symbolic links to the NARR files. e.g., if you run starts from June 10, 2004 and ends June 20, 2004, then

```
ln –s   narr_air.2004_06_10.nc    sflux_air_1.001.nc (OR: earlier date to account for time zone)
ln –s   narr_air.2004_06_11.nc    sflux_air_1.002.nc
…
ln –s   narr_air.2004_06_21.nc    sflux_air_1.012.nc (extra day to account for time zone difference)
```

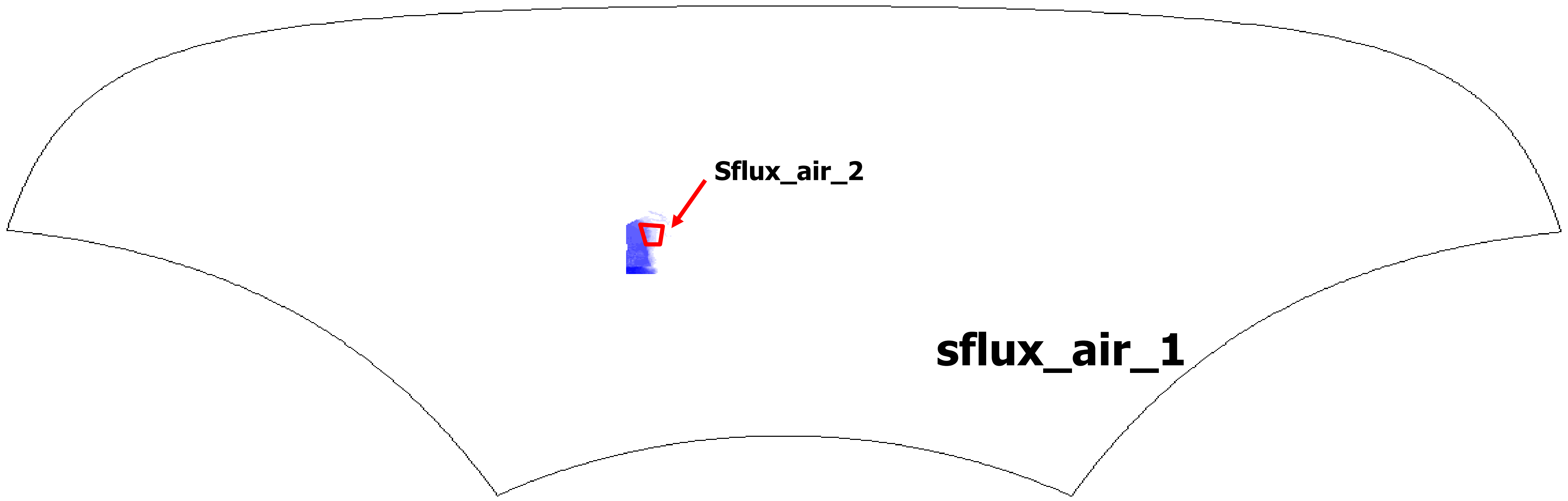
  - Similarly for sflux_rad_*.nc and sflux_prc_*.nc. The number "1" or "2" after "air_" denotes data set used
  - In sflux, copy the file *sflux_inputs.txt* and edit it to reflect the start time (time origin). The field "**utc_start**" is hours *behind* UTC (for application in eastern hemisphere, you may need to add an extra stack to cover *t*=0)
  - The time records in *.nc can be in irregular time steps. **The code will first dovetail all time records (giving preference to later deck e.g. hindcast)**
  - The time interval at which the main routine interpolates the atmos. info from *.nc is specified as *wtiminc* in param.nml
  - Make sure the dovetailed time records from all .nc cover the entire simulation period

```
netcdf sflux_air_1.001 {
dimensions:
        nx_grid = 349 ;
        ny_grid = 277 ;
        time = UNLIMITED ; // (8 currently)
variables:
        float time(time) ;
                time:long_name = "Time" ;
                time:standard_name = "time" ;
                time:units = "days since 2001-01-01" ;
                time:base_date = 2001, 1, 1, 0 ;
        float lon(ny_grid, nx_grid) ;
                lon:long_name = "Longitude" ;
                lon:standard_name = "longitude" ;
                lon:units = "degrees_east" ;
        float lat(ny_grid, nx_grid) ;
                lat:long_name = "Latitude" ;
                lat:standard_name = "latitude" ;
                lat:units = "degrees_north" ;
        float uwind(time, ny_grid, nx_grid) ;
                uwind:long_name = "Surface Eastward Air Velocity (10m AGL)" ;
                uwind:standard_name = "eastward_wind" ;
                uwind:units = "m/s" ;
        float vwind(time, ny_grid, nx_grid) ;
                vwind:long_name = "Surface Northward Air Velocity (10m AGL)"
;

                vwind:standard_name = "northward_wind" ;
                vwind:units = "m/s" ;
        float prmsl(time, ny_grid, nx_grid) ;
                prmsl:long_name = "Pressure reduced to MSL" ;
                prmsl:standard_name = "air_pressure_at_sea_level" ;
                prmsl:units = "Pa" ;
        float stmp(time, ny_grid, nx_grid) ;
                stmp:long_name = "Surface Air Temperature (2m AGL)" ;
                stmp:standard_name = "air_temperature" ;
                stmp:units = "K" ;
```



- The code will dovetail time records from all .nc
- What happens if you choose a large wtiminc?
- Actually we almost always set wtiminc=dt for nws=2

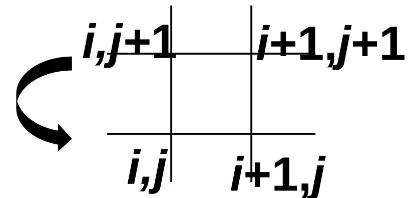
Details: interpolation



- In case of 2 sources/grids for a variable, use "1" as larger grid (i.e. encompassing hgrid.ll) and "2" as smaller grid
- Both grids must start from stack 1 and have same # of stacks for each variable. However, within each nc file # of time steps may vary
- In the overlapping area btw the 2 grids, the blending ratio is specified by *relative_weight* in netcdf_io of sflux_9c.F90 (default 1:99) to smooth out the transition
- The code will calculate interpolation weights associated with the 2 grids, and if some nodes in hgrid.ll fall outside grid "2" the interpolation will be done on grid "1" only (see combine_sflux_data, in particular, bad_node_2 based on area coordinates outside [0,1])

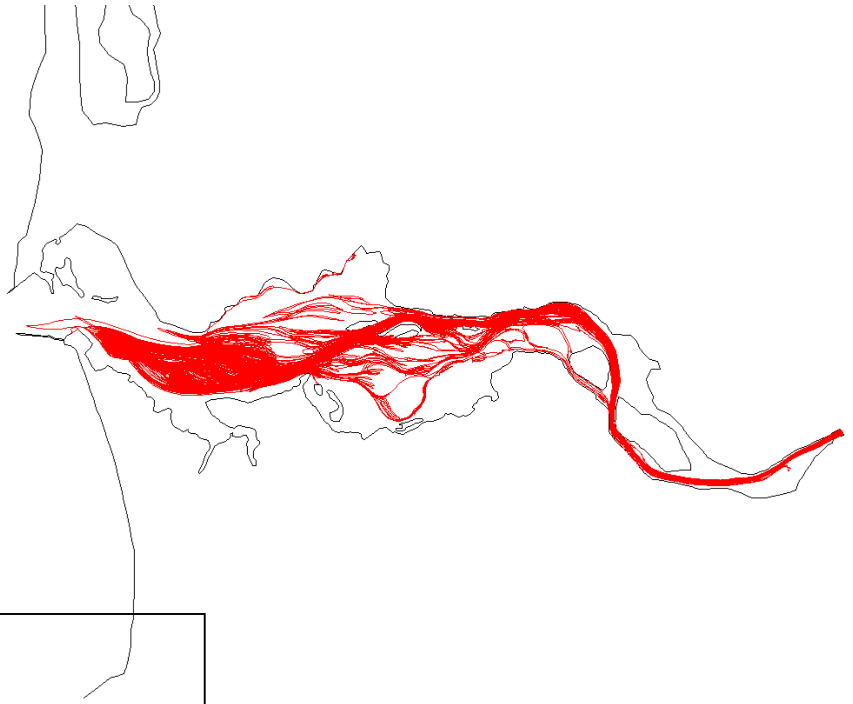
Creating your own sflux/

- Sample m-lab scripts: readnc*.m
- The grids used in atmospheric forcings are structured grids, but atmos grid "1" must encompass hgrid.ll for successful interpolation, which is done in SCHISM at run time (both in space and in time)
  - The collective time window from all .nc files MUST cover the simulation period
- Of all attributes in nc file, only 'base_date' is required (hour is not used)
- Grids for air, rad and prc can be different (but must be the same within each type and each source).
  - Additional requirements for the structured grid in .nc: [lon,lat](nx,ny) give x,y coord. (nx is # of pts in lon). Suppose a node in the grid is given by (i,j) (1<=i<=nx), then the quad (i,j), (i+1,j), (i+1,j+1,i,j+1) must be along **counter-clockwise** direction (check signs in .m scripts)
  - Beware the m-lab function meshgrid when you transform the 1D lon/lat arrays to 2D.
- Some constants are hard-wired in sflux_9c.F90
  - The maximum numbers of input files and time records are set in the module netcdf_io as *max_files* and *max_times*. If your application requires larger values simply increase them in the module
  - **_[12]_max_window_hours* are set in netcdf_io to define the max. time stamp (offset from start time in each file) within each nc file. Also, *max_file_times* (max. # of time records in each nc file) in routine get_times_etc() may be adjusted as well
- Be careful if you use a huge *wtiminc*



Particle tracking

- 3D tracking on unstructured grid
- Adapted from backtracking portion of SCHISM (currently only Euler)
  - Can do both forward and backward tracking
  - Oil spill option supports only forward tracking
- Inputs: hgrid.gr3, vgrid.in, particle.bp, schout_*.nc (need to contain elev, hvel, vertical_velocity; also wind and diffusivity for oil spill)
- Output: particle.pth (drogue format that can be viz'ed with xmvis6)



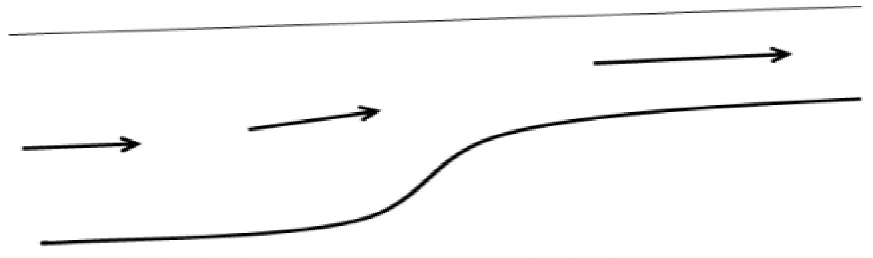
particle.bp

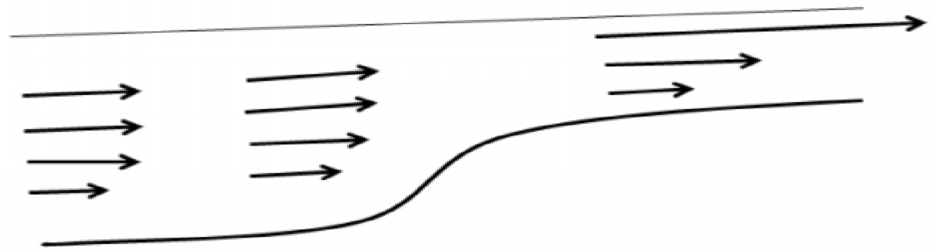
```
Input for ptrack
1 nscreen
0 mod_part (0: passive; 1: oil spill)
1 ibf (forward (=1) or backward (=-1) tracking)
1 istiff (1: from F.S.)
1 -124 46.25  ics slam0 sfea0 (ics=2 still uses CPP)
0.1 8. 90. 10 960 9 h0,rnday,dtm,nspool,ihfskip,ndeltp (same as param.nml except for the last one, which is # of divisions)
16 nparticle
1 84600.      385000  510000 -5.    particle id, start time (s), starting x,y, and z relative to the instant f.s. (<=0)
2 84600.      300000  450000 -5.
3 84600.      200000  450000 -5.
4 84600.      120000  450000 -5.
5 84600.      380000  292500 -5.
6 84600.      360000  290000 -5.
7 84600.      320000  290000 -5.
…….
[Oil spill parameters]
```

Advanced topics

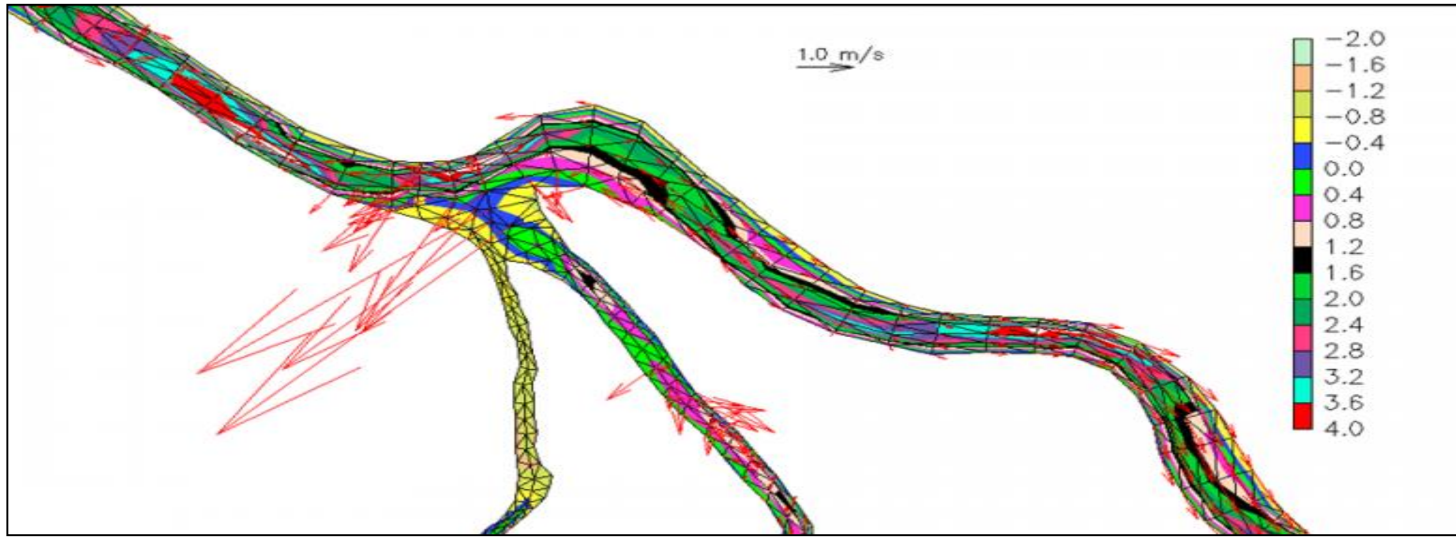
Wet/dry in shallow region (3D model)

- In 3D, the roughness formulation leads to large Cd in shallow area
- Limiting Cd in the shallow helps: 3D model prefers smaller Cd in shallows
- Locally 2D configuration helps


(a) 2D model velocity


(b) 3D model velocity

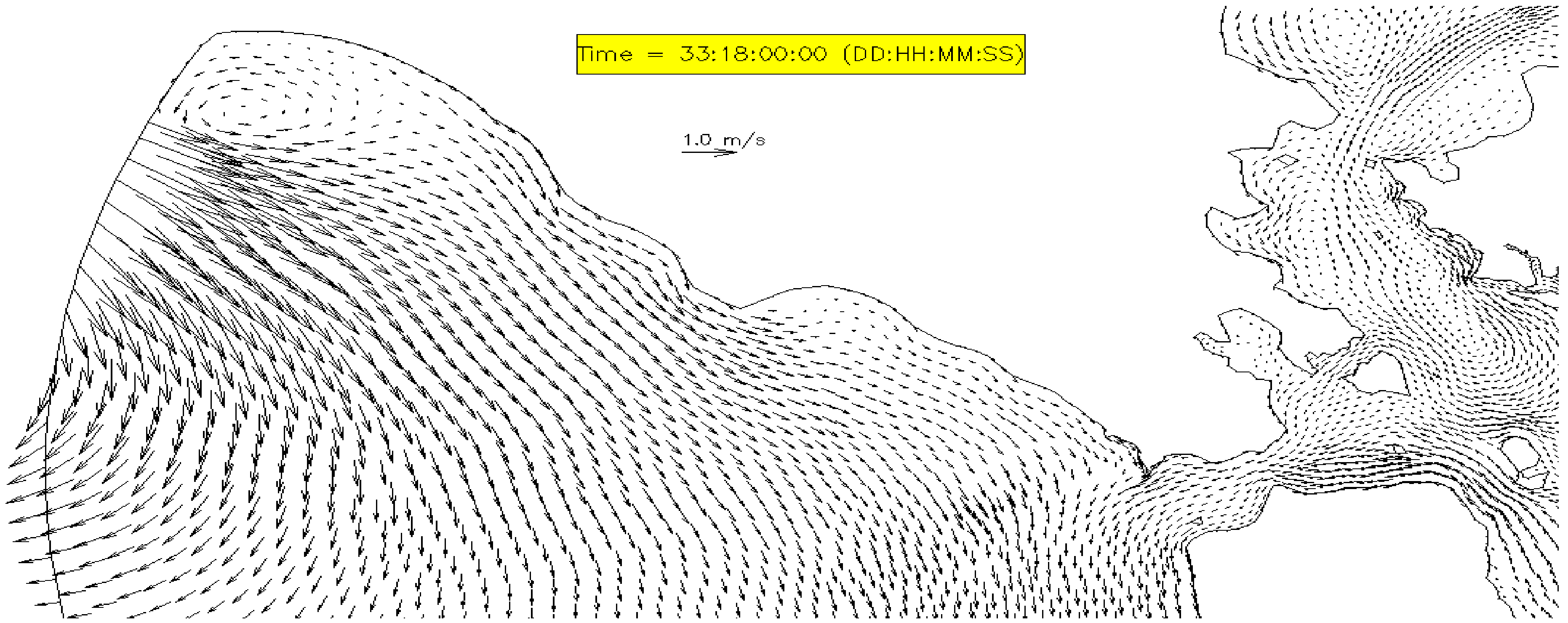
Make sure that channels are not 'blocked' by using at least 1 row of *always-wet* elements



Horizontal b.c. for velocity: uv3D.th.nc

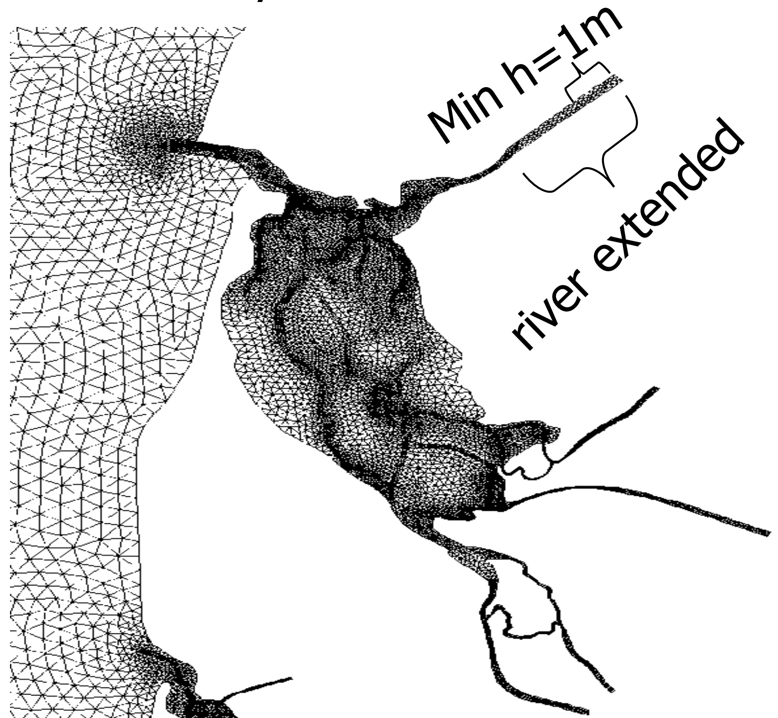
What's wrong with my open boundary ?

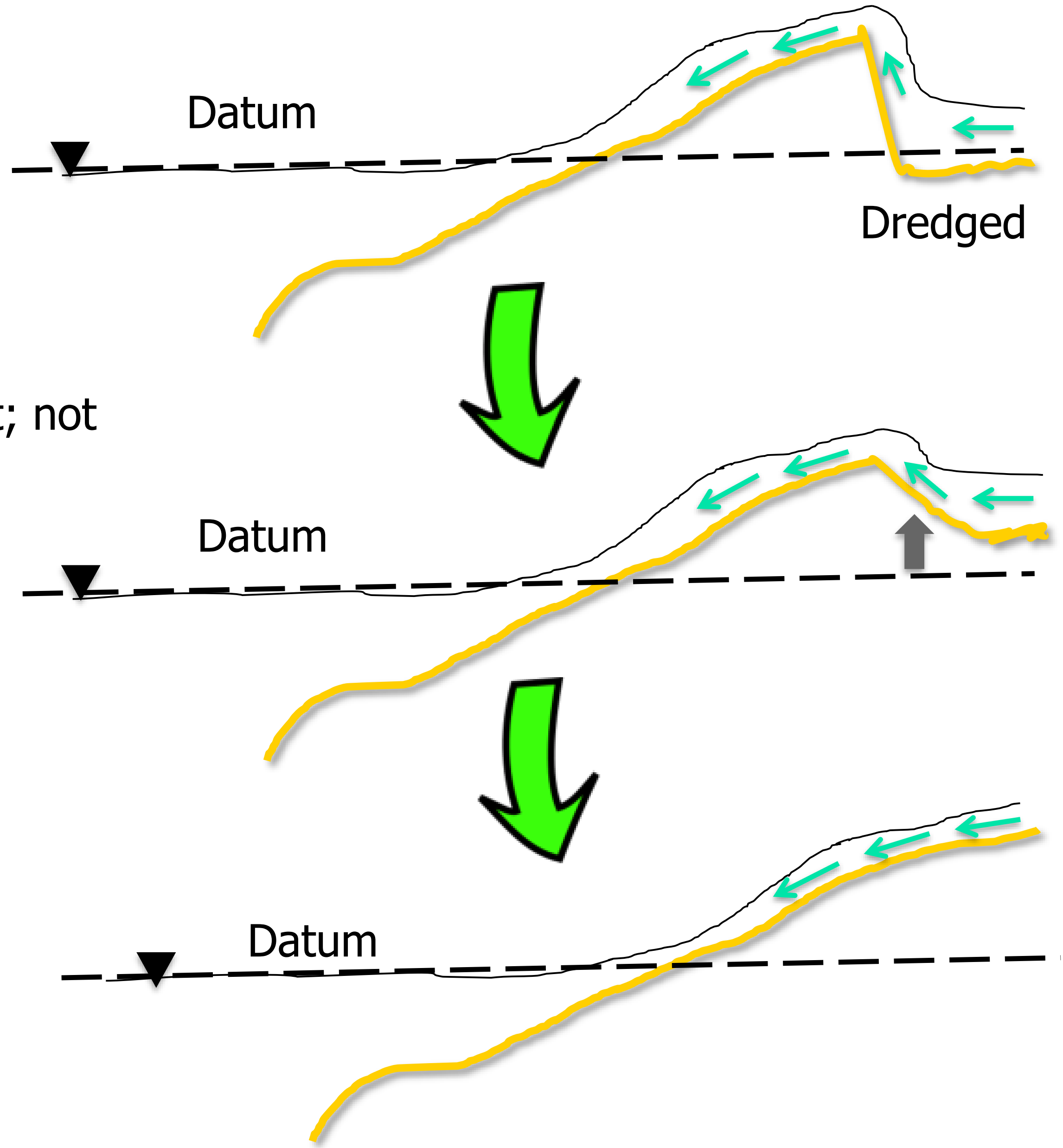
- Incoming velocity is required but sometimes unavailable
- Use 1-way nesting to generate uv3D.th.nc
    - Can be combined with a non-tidal model (e.g. HYCOM)
- Use 2D model for the 'larger-domain', with most dissipative settings
    - θ=1
    - Large Manning's *n* near bnd
    - indvel=1; inunfl=0
    - Often you can 'cheat' by using the same grid for 'large domain' and 'small domain' if you don't care too much about accuracy near the boundary



River boundary

- To prevent drying near the river boundary, impose a min depth in ~2 rows of elements
- Datum issue in upstream rivers is severe
  - Flow b.c. alone should suffice
  - Initially "dry" river
    - Option 1: dredged inflow boundary
    - Option 2: elev.ic (with nramp_elev=1)
    - Option 3: bed deformation module
    - Option 4: point sources (combined with elev.ic)
  - Implicitness factor: θ=1 stabilizes for channel flooding
  - Damping of tides near river end: depth, friction
  - elev+flow b.c.: over-specification to get stages right; must be consistent; not usually recommended as essential b.c. overwrites Neumann b.c.



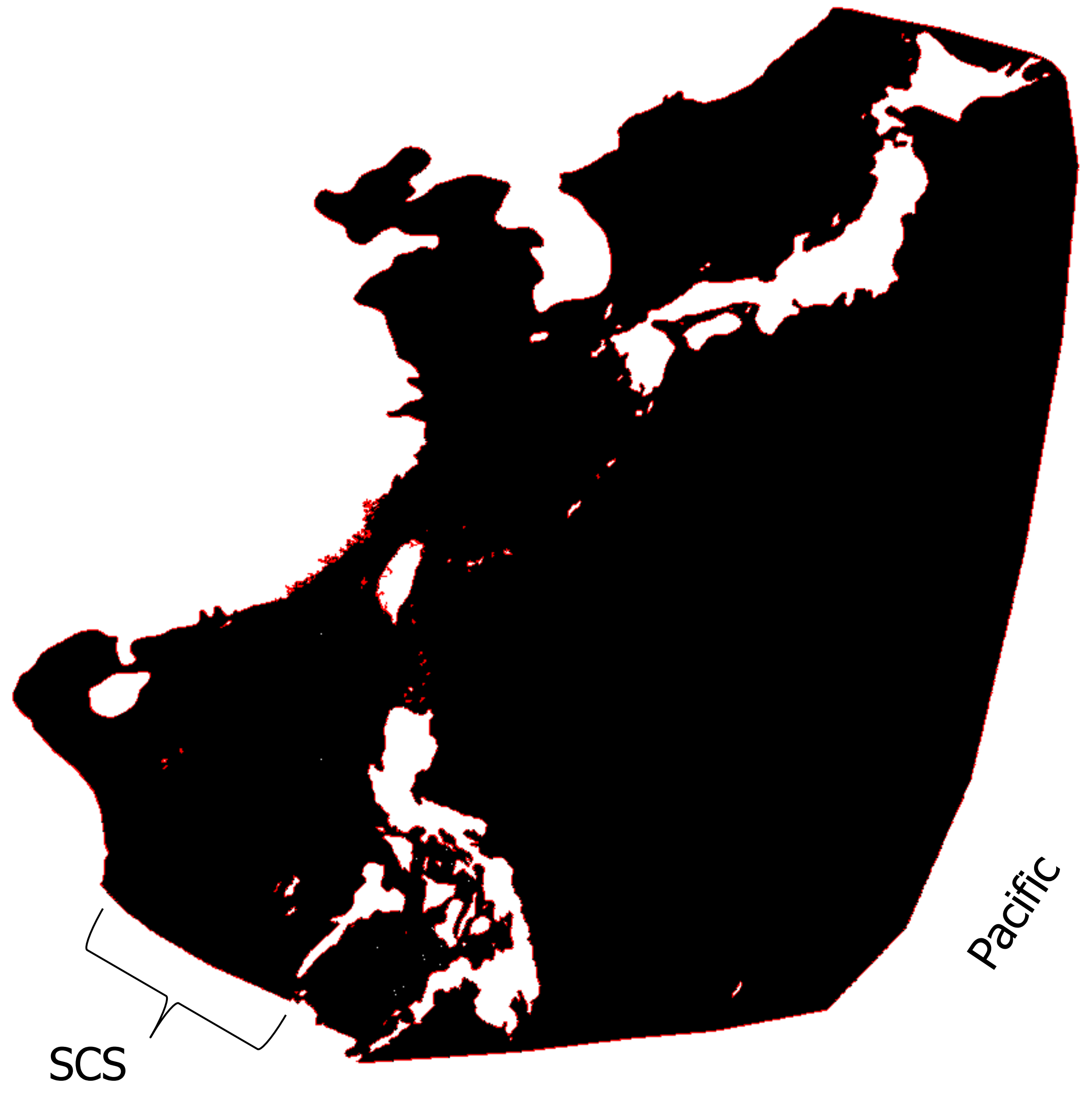


Add tides

- HYCOM does not have tides (actually it may be better to explicitly filter out any high-frequency signals in it)
- Tidal signals are added into HYCOM SSH and u,v at the boundary
    - Tidal potential should be added in the interior of the domain
- Add tidal elevation
    - Use iettype=5: tidal amplitudes/phases are specified in bctides.in, whereas non-tidal HYCOM is in elev2D.th.nc
- Add tidal velocity
    - Use ifltype=5: tidal amplitudes/phases are specified in bctides.in, whereas non-tidal HYCOM is in uv3D.th.nc
- Since the velocity is never perfect at the boundary, the tracer concentration needs to be nudged in a zone near the ocean boundary
    - The incoming vel is more important, especially for indvel=0 which has lower dissipation and thus requires more stabilization

Case study: Kuroshio

- Step 1: mesh generation for both 2D b-tropic and 3D b-clinic models
    - Start from a moderate resolution in eddying regime and refine as needed
    - Smooth transition from deep ocean to shelf break
    - Add nearshore features (channels, rivers, jetties); non-smooth grids are fine
- Step 2: do 2D b-tropic model
    - Get tidal amplitudes and phases from a global model (e.g. FES2012)
    - Make sure to output elev, hvel, at a tide-resolving frequency (e.g. hourly)



Recap...

SCHISM model …

- Is an implicit model without mode splitting
- Uses Galerkin FEM
- uses Eulerian-Lagrangian Method for advection
- Numerical diffusion and dispersion are balanced and can be adjusted in different regimes

Therefore….

- Sufficiently large CFL(>0.4) is required for accuracy and convergence
- No grid orthogonality is necessary – skew elements and sharp transition of resolution are tolerated, at least in non-eddying regime

When generating a mesh for SCHISM…

- Make sure major channels are resolved with at least 1 row of ‘always wet’ elements – do not block channel flow
- Always keep the SMS map file and DEM sources and be willing to edit the mesh, as often the model results (and sometimes performance) depend on the mesh
- First estimate the smallest Δt you’d use, and then estimate the coarsest Δx at sample depths to make sure CFL>0.4
- Resolving features is much easier with SCHISM – be game! Bathymetry smoothing is not necessary
- Implicit TVD^2 transport is very efficient, but horizontal transport is still explicit (and is the main bottleneck). Therefore beware of mesh resolution in critical regions to avoid excessive sub-cycling
    - use upwind or even ELM in areas of no interest (e.g. stratification)

When setting up a model…

- Always check the mesh first with a simple 2D model with ipre=1
  - The model is very adept at checking integrity of inputs
- Start from simple and then build up complexity
- Examine surface velocity in animation mode to find potential issues
- Avoid large C_D in very shallow areas in 3D regions
- Make sure open boundaries do not become completely dry (partial dry is fine)
- Negative river flow for inflow

When calibrating SCHISM…

- Remember the mesh is the single most important factor for accuracy – here lies the greatest strength and challenge of unstructured grids
- Control the balance between numerical diffusion and dispersion (indvel, ihorcon…)
- Transport solver performance may require some experience
- LSC^2 grid requires some learning, but is a very powerful tool (resembling unstructured grid in the vertical)

User support

1. Online manual
2. Test suite on svn
3. Register on schism.wiki and send a ticket to user mailing list