Arctic MFC
marine.copernicus.eu

Offline NEMO-HYCOM nesting in TOPAZ system: Part I

**M. Bakhoday-Paskyabi, C. Yumruktepe, J. Xie,
A. Samuelsen, R. Raj, and L. Bertino**

Mostafa.Bakhoday@nersc.no

Outline

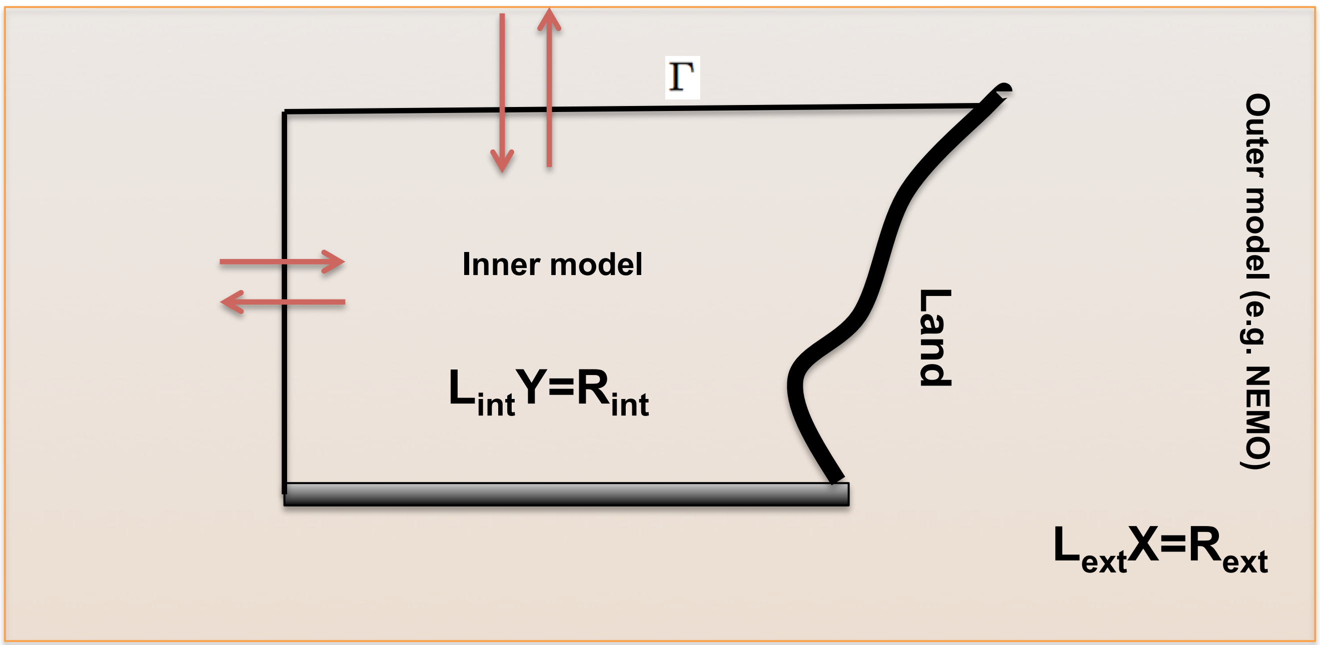
- Open Boundary Condition in HYCOM
- Offline nesting: preparation
- Offline nesting: input nesting files

Overview of nesting BC in HYCOM (OBC)

- **Key objective of using OBC:**

Supplying the external information required by the inner model at the boundaries, while information generated within the inner model is enbaled to freely exit through the boundaries with minimal artifacts onto the inner model solution.

Ω_{ext}

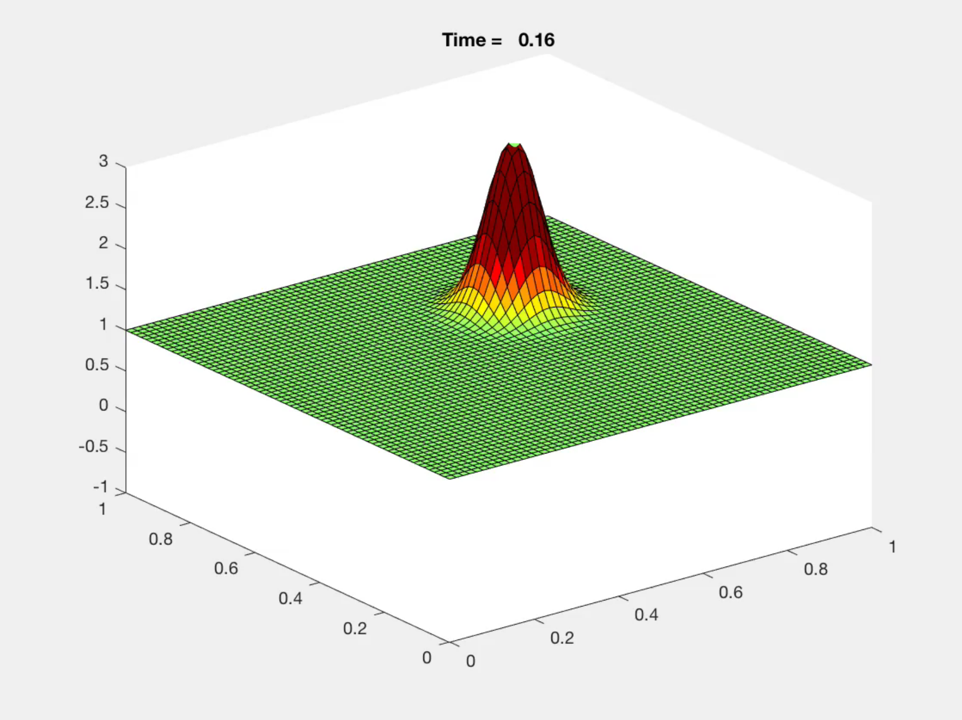


Minimize

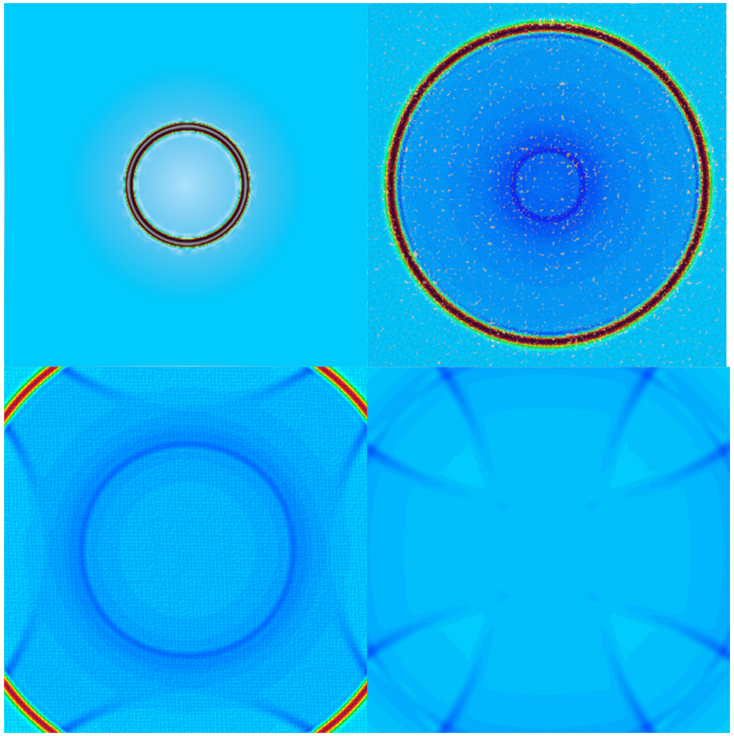
$$\|L_{int}X_{int} - Y_{int}\|^2_{\Omega_{int]\times[0,T}} + \mathcal{E}\|X_{int} - X_{ext}\|^2_{\Gamma\times[0,T]}$$

OBC: difficulties

Reflective boundary condition



OBC: modified Flater



Mason et al 2010

Boundary conditions in HYCOM

Relaxation in sponge layer

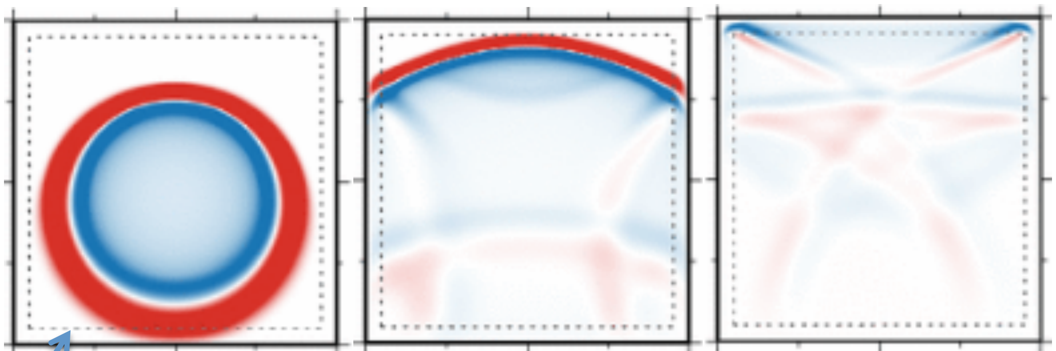
Full OBC

For sponge boundary zones (relaxation zone), temperature, salinity, and vertical coordinate pressure are specified as

$$T_{t+1}^{k} = T_{t}^{k} + \Delta t \mu \left(\hat{T}_{t}^{k} - T_{t}^{k} \right)$$

$$S_{t+1}^{k} = S_{t}^{k} + \Delta t \mu \left(\hat{S}_{t}^{k} - S_{t}^{k} \right)$$

$$p_{t+1}^{k} = p_{t}^{k} + \Delta t \mu \left(\hat{p}_{t}^{k} - p_{t}^{k} \right),$$



Area of sponge layer

Maeda et al 2016

Boundary conditions in HYCOM

OBC (for normal baroclinic velocity, Browning and Kreiss 1982,1986**)**

$$u_t + U_0 u_x + g h_x = 0$$
$$h_t + U_0 h_x + H u_x = 0.$$

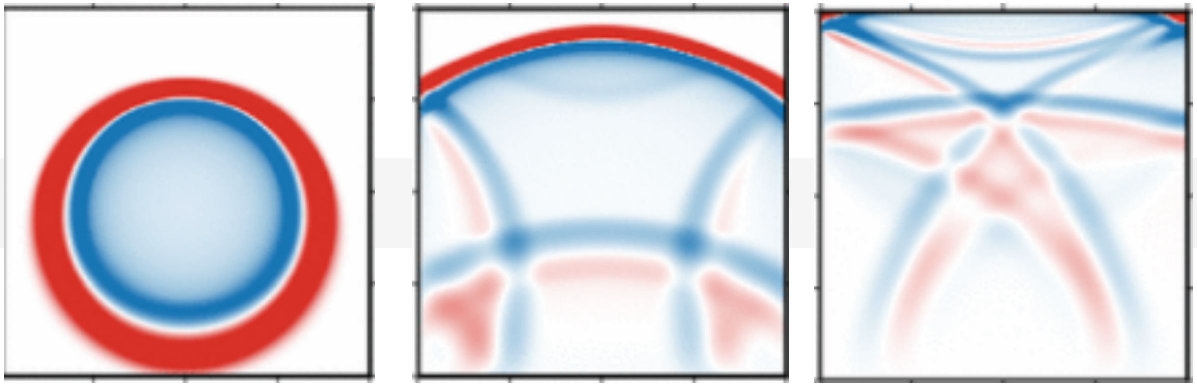
$$\frac{\partial \phi}{\partial t} + F(\phi) = 0$$

$$\left(\frac{\partial x}{\partial t}\right)_{char} = U_0 \pm c,$$

$$u* = \frac{1}{2}\left[u^o + u^i + c_1\left(h^o - h^i\right)\right]$$
$$h* = \frac{1}{2}\left[h^o + h^i + c_1^{-1}\left(u^o - u^i\right)\right].$$

WAllcrAft eta all 2009

Boundary conditions in HYCOM



$$u^* = \frac{1}{2}\left[u^o + u^i + c_1\left(h^o - h^i\right)\right]$$

$$h^* = \frac{1}{2}\left[h^o + h^i + c_1^{-1}\left(u^o - u^i\right)\right].$$

$$\phi_{new} = (1-w)\phi + w\phi_b.$$

Value at a grid-point

Weights (i.e. *w*) are used in a finite-width sponge zone (see port script)

Baroclinic tangential velocity components are nudged toward given values

For the baroclinic mode, other boundary conditions (for interface pressure nudging, damping of the tendency term in the continuity equation, and enhanced viscosity in the momentum equations) are applied in a finite-width "sponge" zone.

WAllcrAft eta all 2009

Maeda et al 2016

Offline nesting in HYCOM-CICE

1) MERCATOR data (downloading)

2) Outer model coordinate and mapping matrix (bathymtry & grid [ab] files)

3) Bathymetry merging

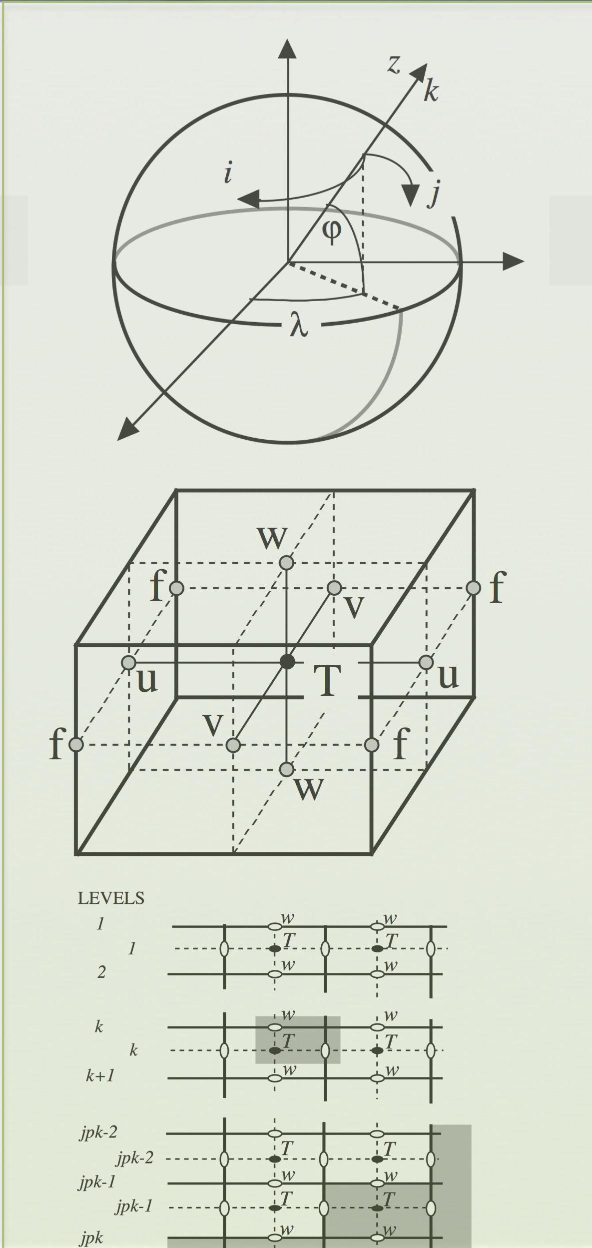
4) Create MERCATOR [ab] files

5) Horizontal interpolation from NEMO grid to TOPAZ5 grid in z-level

6) Vertical interpolation from TOPAZ5 archives in z-level into the isopycnal coordinate

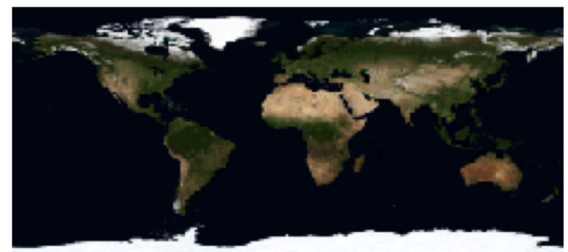
I. Preparation (done only once)

MERCATOR data

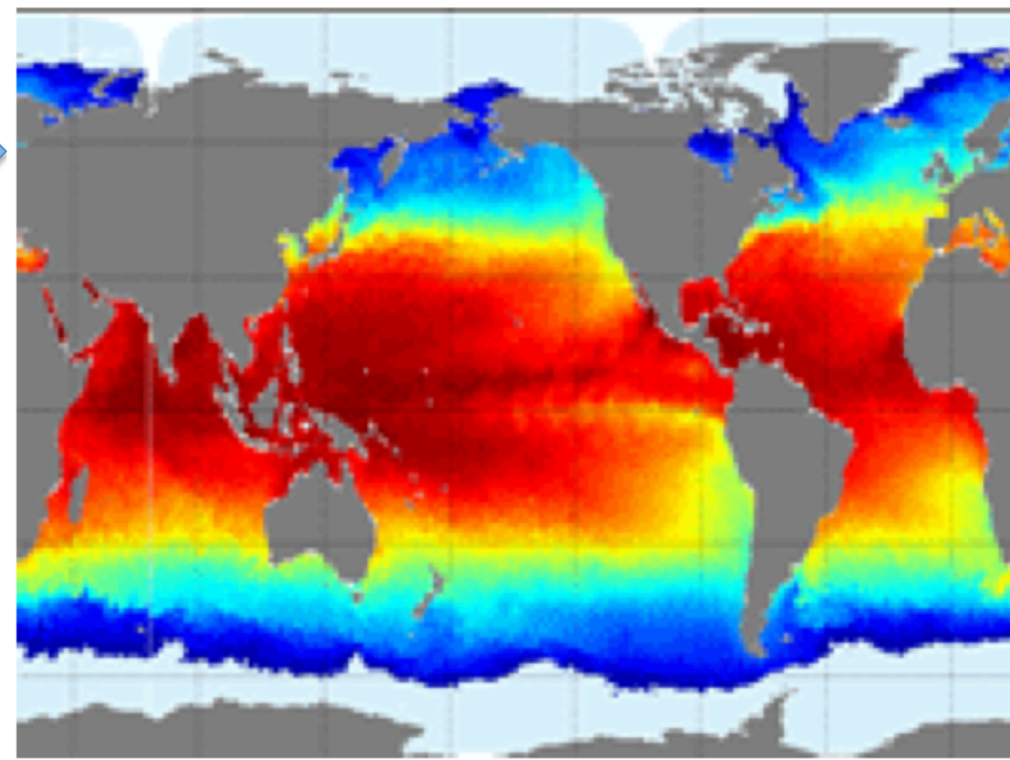


GLOBAL_ANALYSIS_FORECAST_PHY_001_024

Areas
global



Arakawa C-grid architecture
Non-native



MERCATOR data

sea_water_salinity (S)
eastward_sea_ice_velocity (SIUV)
ocean_mixed_layer_thickness_defined_by_sigma_theta (MLD)
sea_ice_thickness (SIT)
sea_surface_height_above_geoid (SSH)
eastward_sea_water_velocity (3DUV)
sea_water_potential_temperature_at_sea_floor (bottomT)
sea_ice_area_fraction (SIC)
northward_sea_water_velocity (3DUV)
northward_sea_ice_velocity (SIUV)
sea_water_potential_temperature (T)
cell_thickness ()
model_level_number_at_sea_floor ()
sea_floor_depth_below_geoid ()

SPATIAL RESOLUTION	0.083degree x 0.083degree
VERTICAL COVERAGE (m)	from -5500.0 to 0.0 (50 levels)
UPDATE FREQUENCY	daily

MERCATOR data: downloading

0) Download GLOBAL_ANALYSIS_FORECAST_PHY_001_024 data using get_mercator.py

```
DownloadString=''
VarString=''
for i in range(1,len(Flags)+1,1):
    if Flags[i-1]==True:
        VarString = VarString + ' -v %s  ' % VarNames[i-1]

VarString = ' -z '+str(depth[0])+' -Z '+str(depth[1])+VarString
reg=' -x '+str(region[0])+' -X '+str(region[2])+' -y '+str(region[1])+' -Y '+str(region[3])

DownloadString = motu_client_name+ ' -u '+usr+' -p '+password+' -m '+mercator_motu+' -s '+http_address+' -d '+
    product_name+reg


def extract_data(DownloadString,VarString,StartDate,StopDate,SaveFileName):
    print 'python '+DownloadString+' -t "'+StartDate+' 12:00:00" -T "'+StopDate+ ' 12:00:00" '+VarString+' -o ./ -
        f '+SaveFileName
    extract_data = 'python '+DownloadString+' -t "'+StartDate+' 12:00:00" -T "'+StopDate+ ' 12:00:00" '+VarString+
        ' -o ./ -f '+SaveFileName
    return extract_data
```

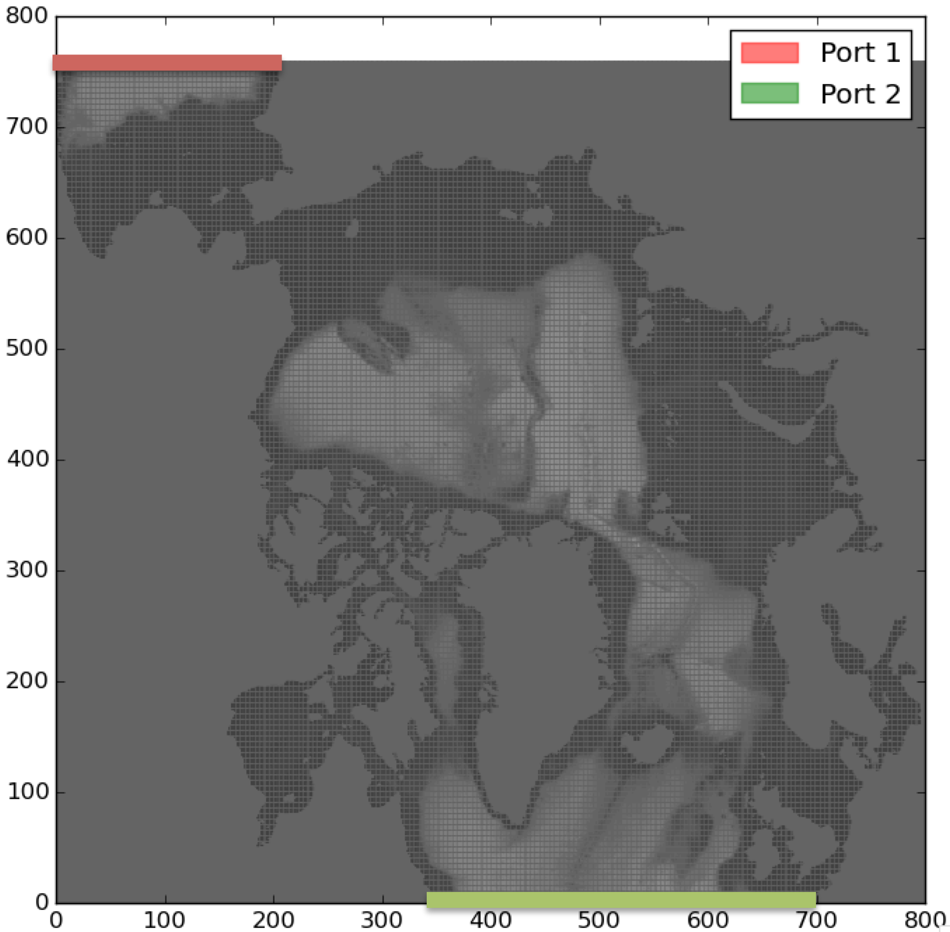
Outer model coordinate and mapping matrix

1) A netcdf file containing all required data for nesting is provided using the MERCATOR available coordinate files (MERCATOR-PHY-24-COORD.nc)

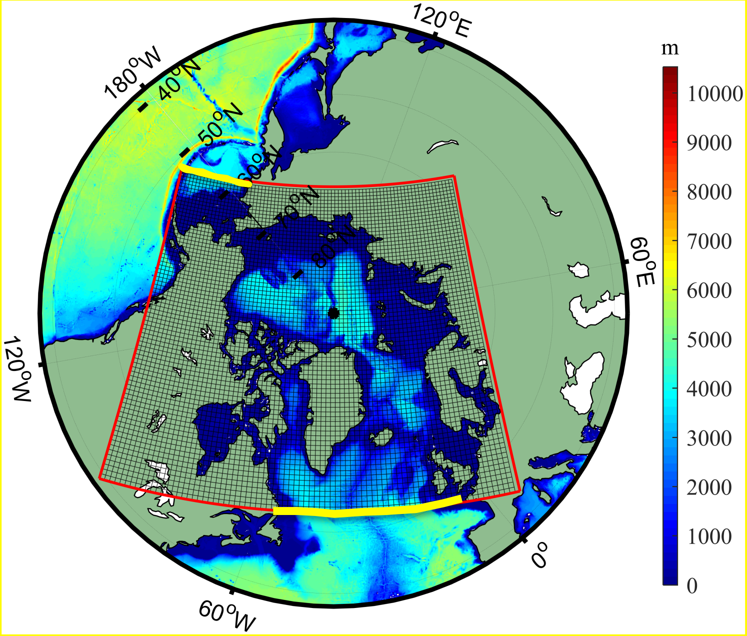
2) Grid (regional.grid.[ab]) files and topography file are calculated and given using MERCATOR-PHY-24-COORD.nc (are done once)

3) An index remapping matrix between the coarse grid (i.e. 2) and the inner (TOPAZ5) fine pre-existing grid files using **isuba_gmapi.sh (is done once for a given region)**

Port file and inner model bathymetry using MERCATOR bathymetry file

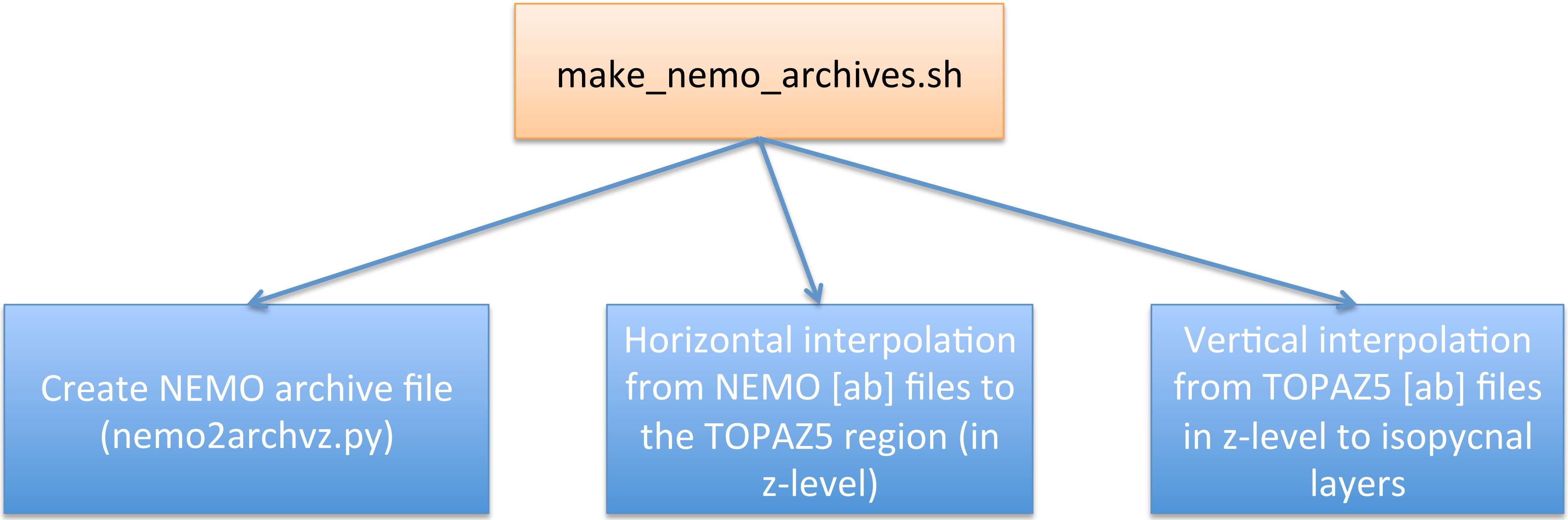


4) Create a ports.input file using **nest_setup_port.sh (is done once for a given region)**



5) Based on the outer model grid of topography, the topography in the inner model are smoothed, especially along the common boundary for nesting stability.

II. Generate nesting archive files



II. Generate nesting archive files

```
# --- 'flnm_i' = name of source archive file
# --- 'flnm_o' = name of target  archive file
# --- 'NZ ' = Number of vertical z levels (for MERCATOR sets to 50)
# --- 'flnm_z' = text file containing the vertical grids in z-level
# --- 'flag_t   ' flag to activate temperature for vertical interpolation
# --- 'flag_s   ' flag to activate salinity for vertical interpolation
# --- 'flag_th   ' flag to activate thickness for vertical interpolation
# --- 'flag_u   ' flag to activate u-componen of current for vertical interpolation
# --- 'flag_v   ' flag to activate v-component of current for vertical interpolation
#
${prog_nemo}  <<EOF
${N}/${target_archv}${L}.a
${NEST}/${target_archv}.a
50
${N}/ZL50.txt
T
T
T
T
T
EOF
```

Old version

Run fortran code

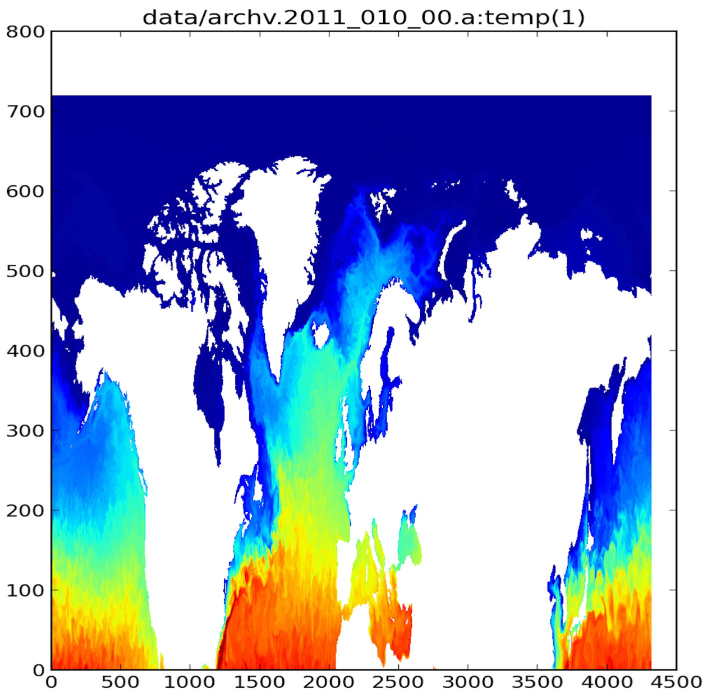
```
      CALL READ_ARCHIVE(K,KZ,KDM,IDM,JDM,NREC,COORD,
     +   tlevel1,ARCHVFILE,cfld,ISOPYC,SIGVER,
     +   ZLEV,DEPTH,SIG3D,MSK,TZ,SZ,RZ)
```

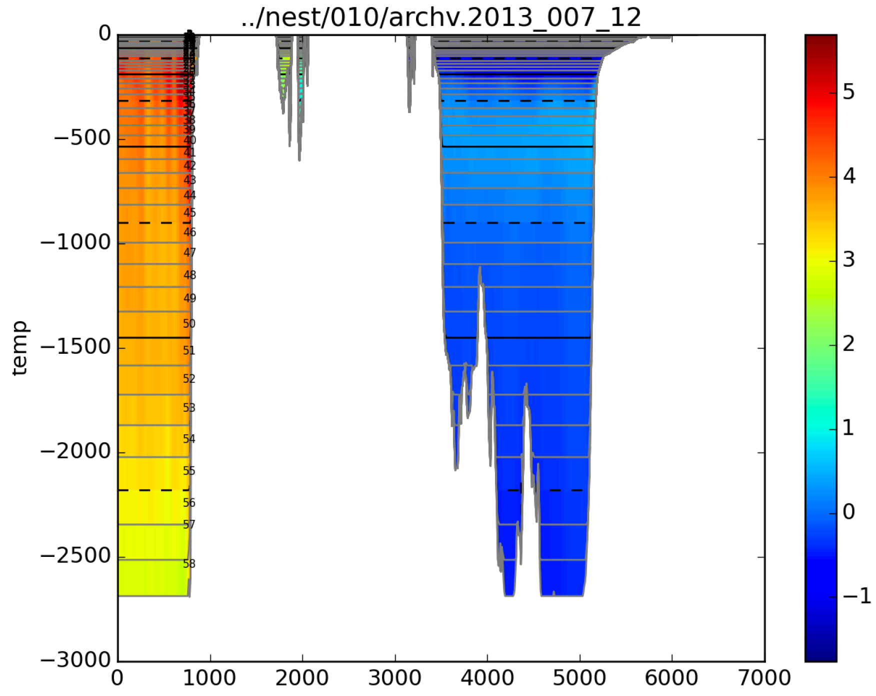
```
      call RMPM_02(i,j,K,KDM,KZ,NSIGMA,SIG3D_TMP,RM(I,J),
     +     PM(I,J),RZ(:,I,J),DEPTH(I,J),DSCK,DPCK,ISOTOP,
     +     ISOPYC,PKM1(I,J),PZBOT(I,J),PZTOP(I,J),RKM1(I,J),
     +     ZL,PMIX(I,J),PCM0(I,J),PCM1(I,J),PCM2(I,J),
     +     PKM2(I,J),DP0K,DP00I,DS0K,flag_t,flag_s,
     +     flag_u,flag_v,itest,jtest,SM(I,J),TM(I,J),
     +     PU(I,J),PV(I,J),UV(:,I,J),VV(:,I,J),
     +     ldebug,sigver,TZ(:,I,J),SZ(:,I,J))
```

Carry out first-order flux transport remapping and interpolation

(1) Generate NEMO archive files

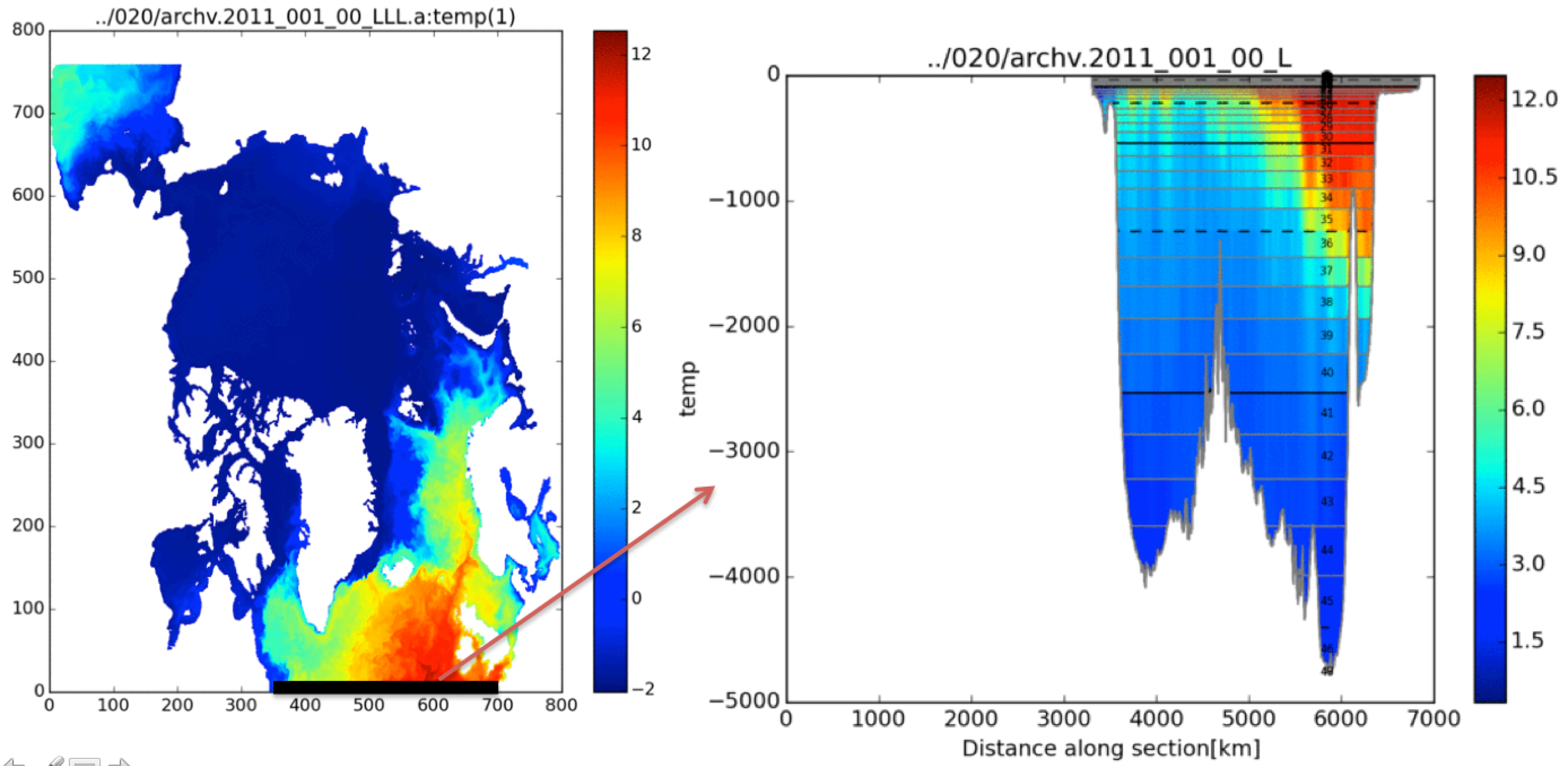
Create NEMO archive file (nemo2archvz.py) two netcdf files as input: (i) the coordinate (mesh) file; and (ii) GLOBAL_ANALYSIS_FORECAST_PHY_001_024 physical/biochemical data.





(2) Horizontal interpolation from NEMO archive files to TOPA5 grid

Create archive file interpolated (bilinear interpolation with masked land points) using the NEMO [ab] fils isuba_region.sh) using the created index-map matrix.



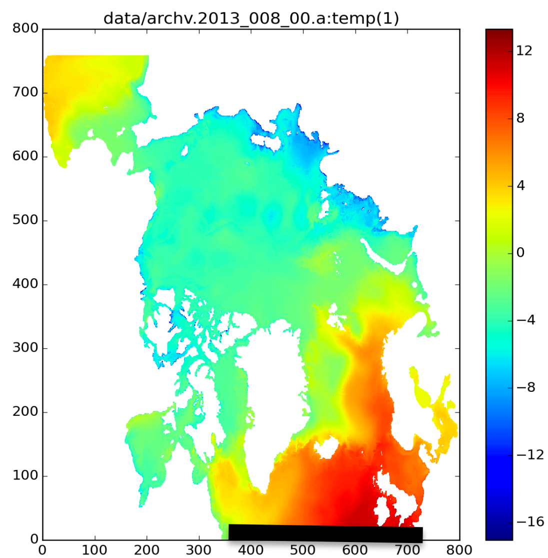
(3) Vertical interpolation

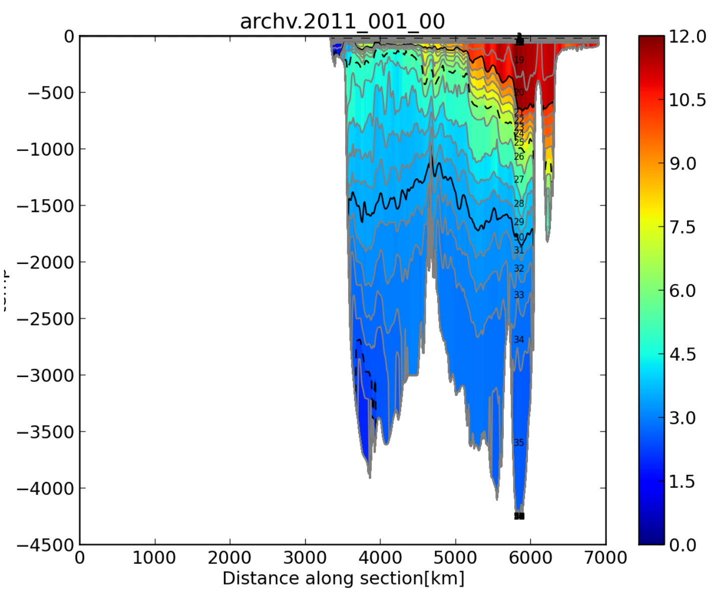
The original remapper in HYCOM assumed that each field was constant in the vertical within each layer (best for nearly isopycnal layers).

For layers far away from the isopycnal, the method is diffusive.

The method here, however, allows the profile vary linearly with a layer which is away from being isopycnal (will reduce diffusion).

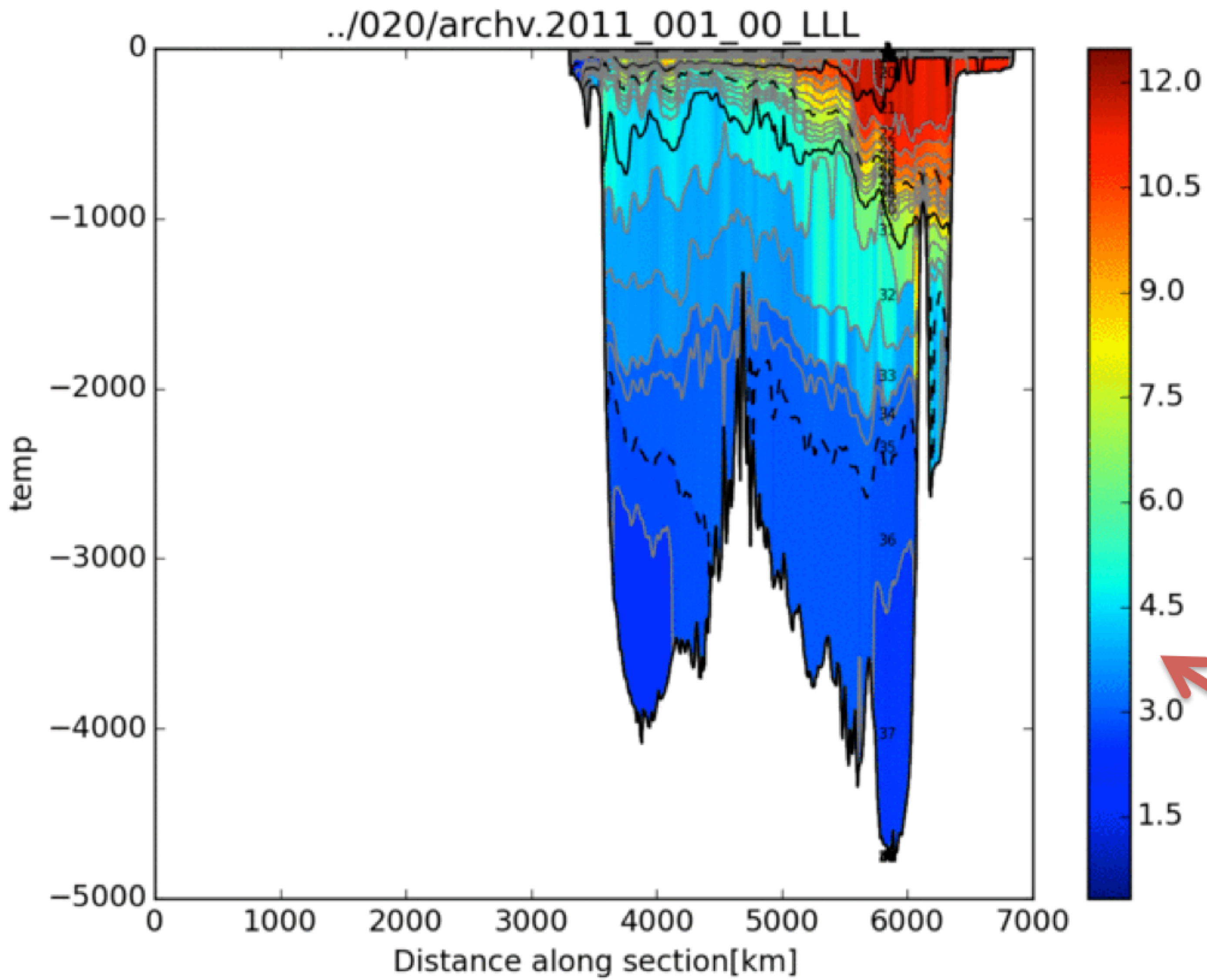
Remapping is treated like finite volume vertical advection coupled with peicewise linear interpolation.





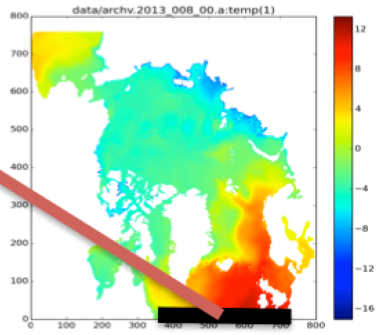
Bleck 2002, WAllcrAft
Eta all 2009

(3) Vertical interpolation

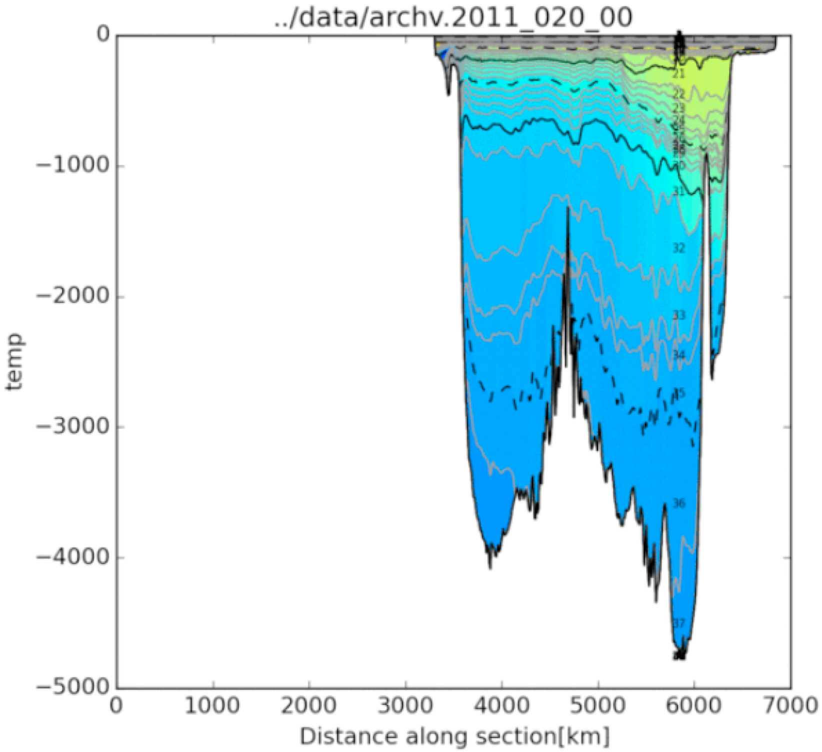


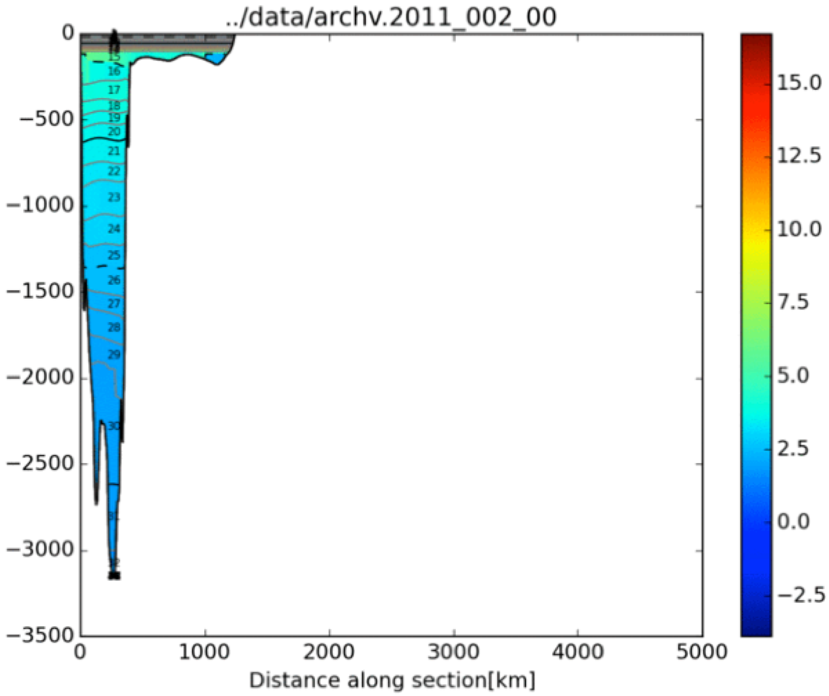
Note that the vertical remapping is controlled by the reference isopycnals (also by the minimum accepted thickness)

remapping shows less pronounced response to the weak diapycnal diffusivity.



A short-term run on Sisu





Delivery plan

Moving all scripts and codes to the HPC, and carrying out all required checks to provide the near to optimum run configuration.

The first version for all partners will be available sometimes end of December?.

Thanks