New Features of HYCOM

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HYCOM 2.2 (I)

- Maintain all features of HYCOM 2.1
    - Orthogonal curvilinear grids
    - Can emulate Z or Sigma or Sigma-Z models
        - It is "Arbitrary Lagrangian-Eulerian", see: Adcroft and Hallberg, O. Modelling 11 224-233.
    - Explicit support for 1-D and 2-D domains
    - KPP or Kraus-Turner or Mellor-Yamada 2.5 or Price-Weller-Pinkel
    - Rivers as bogused surface precipitation
    - Multiple tracers
    - Off-line one-way nesting
    - Scalability via OpenMP or MPI or both
        - Bit-for-bit multi-cpu reproducibility

HYCOM 2.2 (IIa)

- Alternative scalar advection techniques

  - Provided by Mohamed Iskandarani
  - Donor Cell, FCT (2nd and 4th order), MPDATA
  - FCT2 replaces MPDATA as standard scheme

- Vertical coordinate changes

  - Vertical remapping uses PLM for fixed coordinate layers
  - Thin deep iso-pycnal layers
  - Stability from locally referenced potential density
  - Spatially varying layer target densities
   - Different isopycnal layers in semi-enclosed seas

HYCOM 2.2 (IIb)

- Equation of state that is quadratic in salinity

    - HYCOM must "invert" the equation of state
        - tofsig(r,s) and sofsig(r,t)
    - Traditional version is cubic in T and linear in S
        - Finding the root of a cubic is expensive, but exact
        - Linear in S is not accurate at low salinity
    - Optional version is cubic in T and quadratic in S
        - Coefficients provided by Shan Sun
        - More accurate at low salinity
            - Rivers, Black Sea, Caspian Sea
        - Not much more expensive

- Pade equation of state

    - Optional Pade version: P_{22}/Q_{11}
        - P_{22} is quadratic in T and S
        - Q_{11} is linear in T and S
    - Developed at NCEP
        - Only Sigma0 at present
    - More accurate at low salinity

HYCOM 2.2 (IIc)

- Special halo exchange for tripole global grid

    ○ Arctic dipole patch on standard Mercator globe
    ○ Logically rectangular domain
        ◇ Two halves of top edge "fold" together
        ◇ V-velocity changes sign across the fold

- Improved thermobaricity

    ○ No single reference state is appropriate
      for the global ocean
        ◇ Hallberg, Ocean Modelling, 8, 279-300
    ○ Use a linear combination of pressure gradients
      from two out of three reference states
        ◇ Atlantic   (3°C, 35.0 psu)
        ◇ Arctic/Antarctic   (0°C, 34.5 psu)
        ◇ Mediterranean (13°C, 38.5 psu)
    ○ Most locations use just one reference state
        ◇ Linear combinations allow smooth transition
          between states
            · Do this in shallow water if possible
    ○ In deep water, constrain the T&S used for
      thermobaricity to be close to the reference state

1/12° GLOBAL THERMOBARIC REFERENCE STATE

TBARIC MAP (1=Arctic,2=Atlantic,3=Med.)

GLBa0.08
ci 0.10
1.0 to 3.0
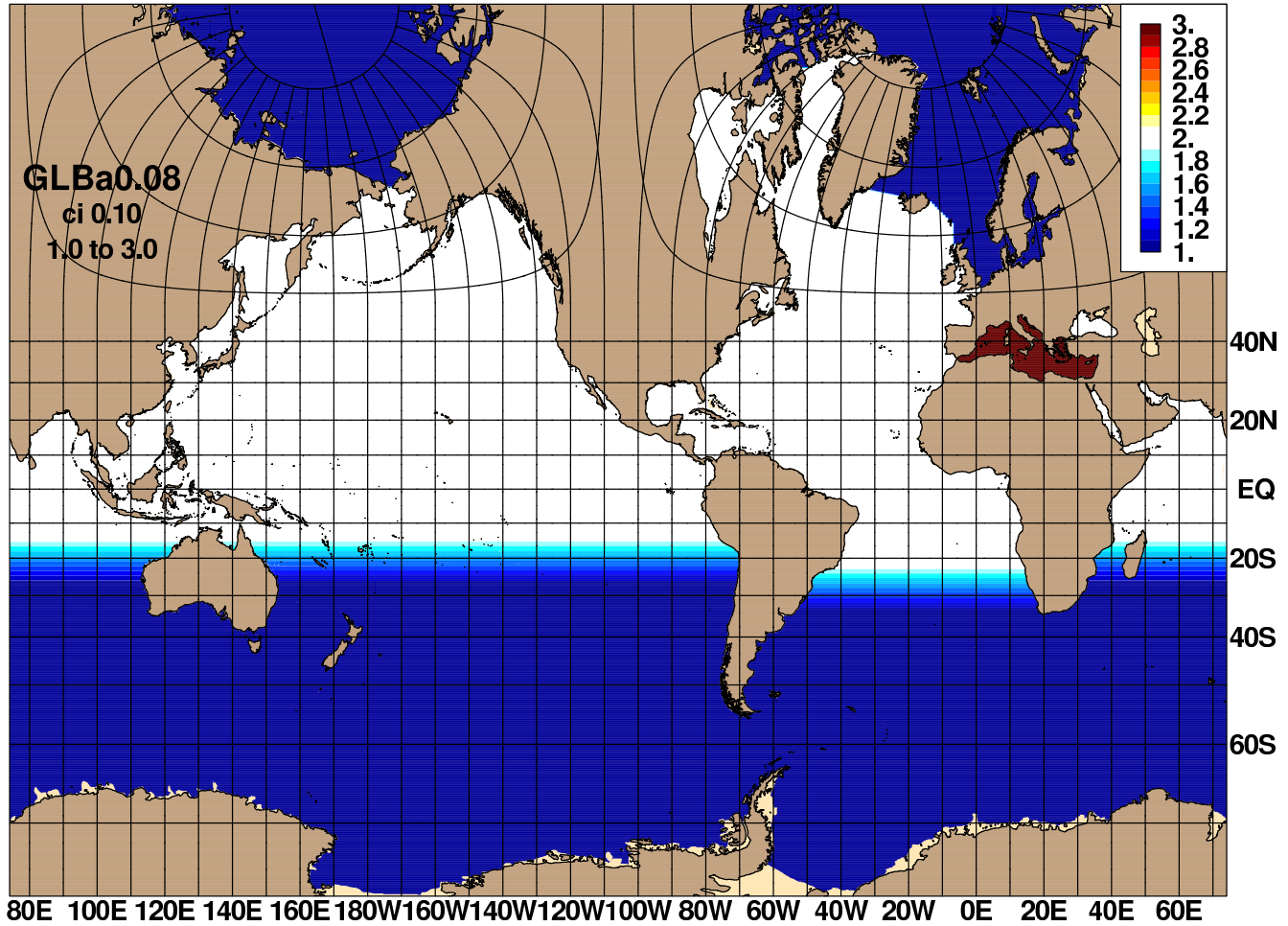
HYCOM 2.2 (IIIa)

- Mixed layer changes

  - GISS mixed layer model
    - ◇ Provided by Armando Howard
  - KPP bottom boundary layer
    - ◇ Provided by George Halliwell
  - KPP tuning

- Atmospheric forcing changes

  - Option to input ustar fields
    - ◇ Best option for monthly forcing
    - ◇ Otherwise calculated from wind stress or speed
  - Can relax to observed SST fields
  - Improved COARE 3.0 bulk exchange coefficients
  - Black-body correction to longwave flux
  - Climatological heat flux offset, $\overline{Q}_c$
    $$Q = (Q_{sw} - Q_{lw}) + (Q_l + Q_s) + \overline{Q}_c$$
    - ◇ $\overline{Q}_c$ is constant in time
      - · Typically based on the model's climatological SST error, times (say) -45 $Wm^{-2}/{}^\circ C$

HYCOM 2.2 (IIIb)

- Improved support for rivers

  - Still bogused surface precipitation
  - High frequency inter-annual river flow allowed
    - Add it to atmospheric precip, off-line
    - Instead of monthly climatology,
      or in-addition to it (flow anomalies)
  - Better control of low salinity profiles
  - Option for mass (vs salinity) flux
  - Equation of state that is quadratic in salinity

- Tidal forcing

  - Provided by NCEP
  - Body forcing and open boundary forcing
  - Boundary forcing currently for "Flather" ports
    - Extend it to Browning-Kreiss ports and nesting
  - Tidal drag based on bottom roughness
    - Presently applied to total near-bottom velocity
      · Can we apply this to tidal signal only?

HYCOM 2.2 (IIIc)

- New diagnostics within HYCOM

  - Time-averaged fields (in archive files)
    - ◇ Identical to off-line mean archives
    - ◇ No on-line capability to capture variability
    - ◇ Instantaneous archives still available
  - Synthetic instrumentation
    - ◇ Provided by George Halliwell
    - ◇ 3-D particle tracking
    - ◇ surface and constant depth drifters
    - ◇ isopycnic drifters
    - ◇ fixed instruments and moorings

HYCOM 2.2 (IIId)

- Finer control over energy loan ice model

  ○ Melting point can be linear in salinity

  ○ Set ice minimum and maximum thickness

  ○ Set ice vertical temperature gradient

    ◇ Or get ice surface temperature from T_a

  ○ Made compatible with coupled sea-ice approach

- Two-way coupling to LANL's CICE sea ice model

  ○ HYCOM exports:

    ◇ SST, SSS, SSH

    ◇ Surface Currents

    ◇ Available Freeze/Melt Heat Flux

  ○ CICE exports:

    ◇ Ice Concentration

    ◇ Ice-Ocean Stress

    ◇ Actual Freeze/Melt Heat/Salt/Mass Flux

    ◇ Solar Radiation at Ice Base

  ○ Coupling via the Earth System Modeling Framework

HYCOM AND ESMF

- Earth System Modeling Framework
  http://www.esmf.ucar.edu/

  ○ Superstructure couples components
    ◇ Air/Ocean/Ice/Land
    ◇ Asynchronous I/O component
      · Run "concurrent" with model components
  ○ Infrastructure provides data structures
    and utilities for building scalable models

- Added a superstructure "cap" to HYCOM

  ○ Simplifies coupled systems
    ◇ HYCOM coupled to LANL CICE sea-ice
    ◇ Convert atmospheric field processing and the
      energy-loan ice model into ESMF components
  ○ Use ESMF for (user-level asynchronous) I/O
  ○ Inter-operate with other ESMF compliant ocean
    models (e.g. Poseidon, MITgcm, MOM4)

- This initial ESMF support is optional

  ○ TYPE=esmf instead of TYPE=mpi

- ESMF will eventually required to run HYCOM

  ○ HYCOM version 3.0

HYCOM AND CCSM

- Community Climate System Model
  http://www.ccsm.ucar.edu/

  - Fully-coupled, global climate model
  - Sea-Ice: CICE
  - Ocean: POP

- HYCOM can be used in place of POP in CCSM3

  - Only tested at NCAR on an IBM p575+ (blueice), for the gx1v3 domain with ocean as the only active component

- Uses the standard HYCOM source code

- Subdirectory CCSM3 used to hold and build the CCSM3 version

  - Some source code files are specific to CCSM3
  - HYCOM ".f" files are renamed ".F" to simplify CCMS3 integration
 - Macro USE_CCSM3 for CCSM3-specific code

HYCOM 2.2 (IV)

- Climatological nesting now allowed

  - Start from monthly mean outer model archive files
  - Allows nested runs longer than the outer run
    - But with less accurate boundary state
  - Probably only suitable for regional nests

- Nesting no longer requires co-located grids

  - General archive to archive horizontal interpolation (curvilinear)

- Hybrid to fixed vertical grid remapper

  - Allows fixed-coordinate nests inside hybrid coordinate outer domains
   - HYCOM to (fixed-grid) HYCOM
    - HYCOM to NCOM

HYCOM 2.2 (V)

- Enhanced hycomproc and fieldproc

  - NCAR-graphics based
  - Many more color palette options
    - ◇ Can read in an arbitrary palette
  - Mark locations, and draw tracks, on plot
  - Plot diffusion coefficients and tracers (hycomproc)
  - Overlay vector and line-contours (fieldproc)

- Added fieldcell

  - Like fieldproc, but for cell-array (vs contouring)
    - ◇ Mark locations and draw tracks
    - ◇ Overlay line-contours
  - Uses NCAR's map projections
  - Typically much faster than fieldproc, but can leave unfilled cells
  - Option to increase resolution of input (bi-linear interpolation)

ERA-15 SST: Feb

GLBa0.72
ci 0.35
-1.7 to 29.8

SSS (hour 0)

GLBa0.72
ci 0.040
32.47 to 36.99
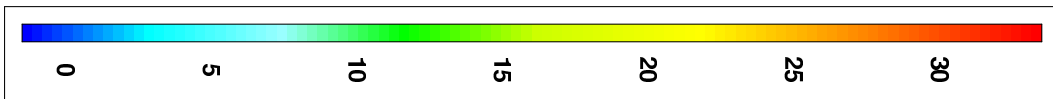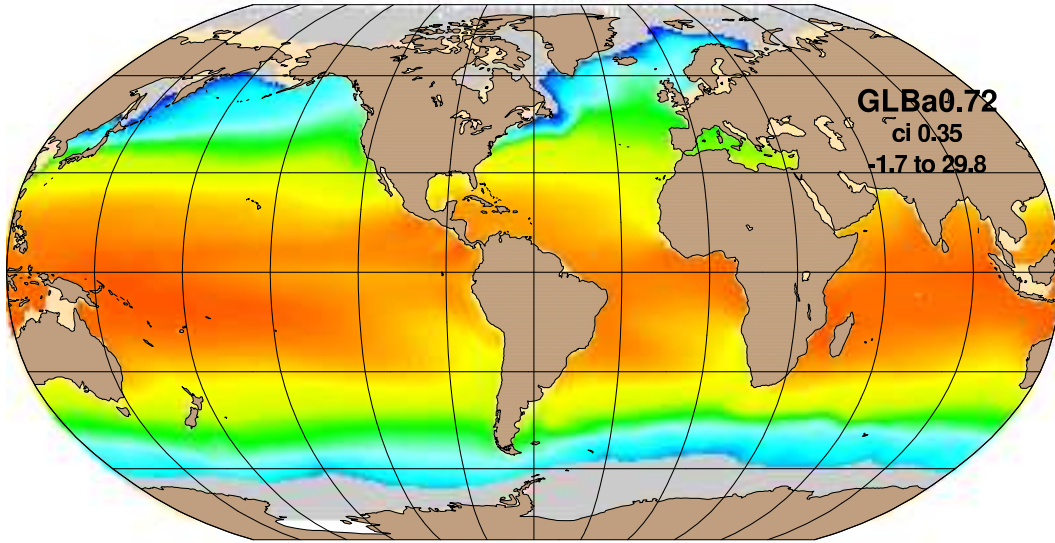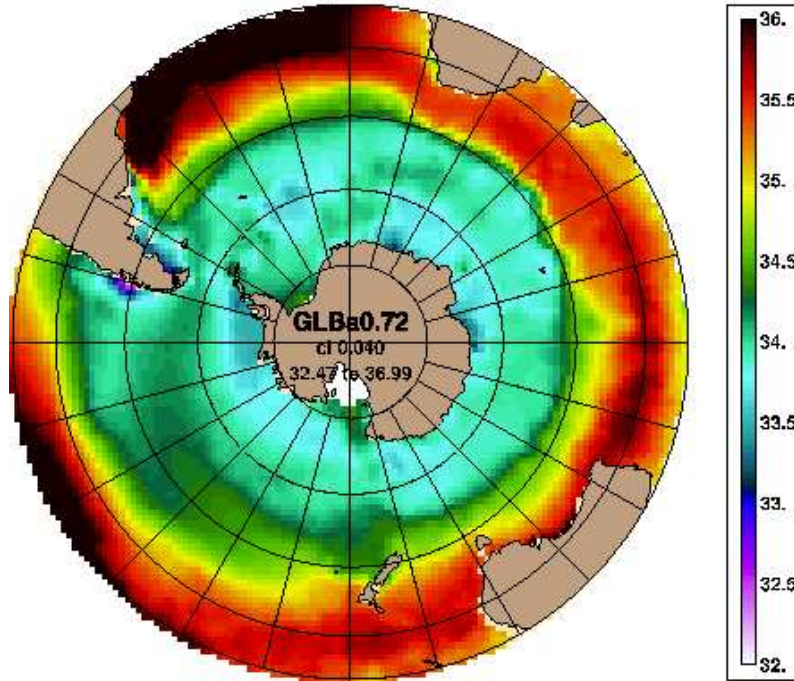
HYCOM 2.2 (VI)

- Diagnostic fields to netCDF and other file formats
    - Archive fields in layer space
        - On p-grid (interpolated velocity)
    - 3-D archive fields interpolated to z-space
        - On p-grid, or
        - Sampled at stations or along arbitrary tracks
    - 3-D archive fields sampled on iso-therms
    - Meridional stream-function from (mean) 3-D archive
        - In logical array space (rectilinear grids)
        - Binned to latitude bands (curvilinear grids)
    - Atmospheric forcing input fields
        - Time axis depends on ".b" file format
        - Any ".a" file with the right ".b" file structure can be converted to netCDF
    - Fields binned into lon-lat cells

HYCOM CURVILINEAR GRIDS and NetCDF

- Most basin-scale cases use a Mercator grid

  - 1-D lat & lon axes (rectilinear)
  - Handled well by many netCDF packages

- Global HYCOM's tripole grid is curvilinear

- HYCOM netCDF use the CF-1.0 conventions, which support curvilinear grids

  - If latitude and longitude are 2-D grids
    - 1-D axes are array indexes
    - Longitude and latitude arrays are also in the file and identified as alternative coordinates
    - Velocity rotated to eastwards and northwards
      - Optionally output native x_velocity & y_velocity

- Most netCDF packages are not CF-1.0 aware

  - Bin into uniform lon-lat cells off-line
  - Interpolate to a 1-D latitude and longitude grid off-line
    - General archive (field) to archive (field) horizontal interpolation

- Archive to archive remapper can also be used to support standard (non-native) grids, e.g. MERSEA

WETTING AND DRYING

- Current free surface formulation

  - Assumes the free surface is
    a small fraction of the total depth

    - ◇ Includes steric effects, but does not
      exactly conserve either mass or volume
    - ◇ Not satisfactory for coastal domains

  - Replaces dp with dp' nearly everywhere

    - ◇ Simplifies split-explicit time step

- Mass conserving formulation

  - Remove the dp' "equals" dp approximation
  - Could still archive dp' (for compatibility)
  - Allows wetting and drying

    - ◇ Almost for "free", given HYCOM's existing
      numerics

  - Already implemented in SHOM variant of HYCOM
  - Will be in HYCOM 2.3

- Mass conservation also allows:

  - E-P and rivers as a mass flux

    - ◇ Already approximately available via
      "epmass" option

OTHER CANDIDATE FEATURES FOR HYCOM 2.3

- Stable-code vs new features

  - Released code-base has to be tested and stable
  - New features can be a significant improvement
  - Will add interim releases to web page
    - Features may be removed in next released code

- Fully region-independent

  - Compile once, run on any region and any number of processors
    - Run-time memory allocation
    - Might reduce performance (fewer compiler optimizations available)
  - Needed for full ESMF compliance

- Enhanced support for ESMF

- Diurnal heat flux cycle

  - Already in CCSM3 version

- Wind drag coefficient based on model SST