

New Features of HYCOM

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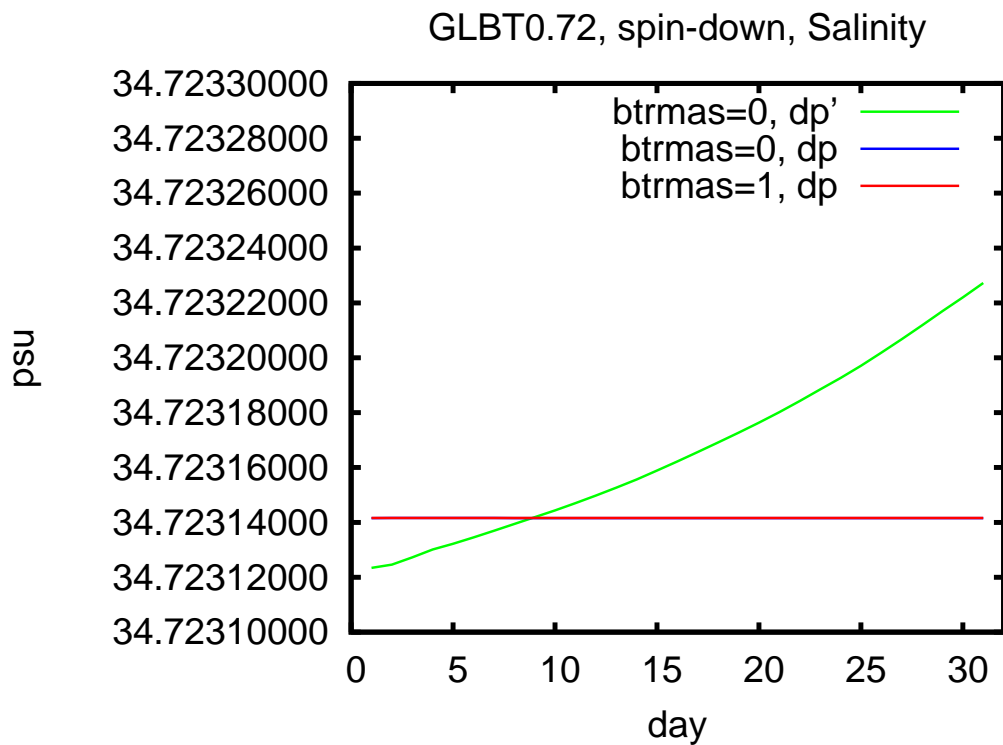
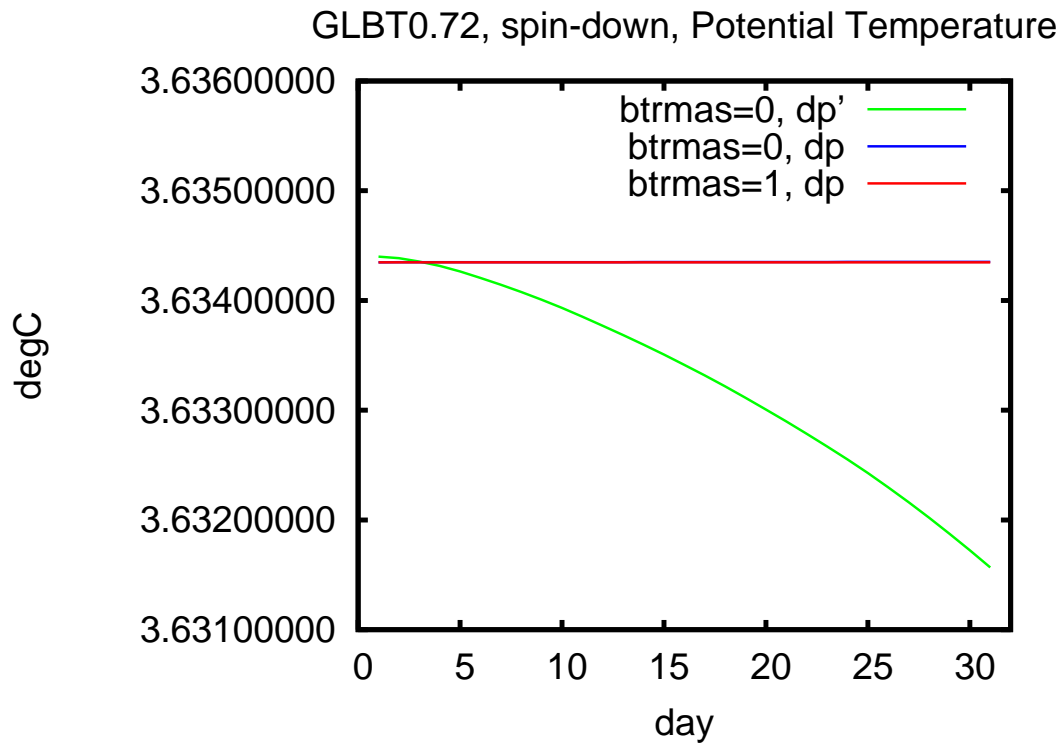
Mass Conservation - I

- Mass conservation is important for climate studies
 - It is a powerfull debugging tool even for shorter time scales
- Many ocean models are Bousinessq
 - Density differences are neglected except in terms multiplied by g
 - Implies conservation of volume, not mass
 - ◇ Still want, and can get, tracer conservation
- HYCOM is not Bousinessq, so it should conserve mass
 - Except that it assumes the non-steric SSH is a small fraction of the total depth
 - ◇ Includes steric effects, such as mean SSH rise due to thermal expansion, but does not exactly conserve either mass or volume
 - ◇ Not satisfactory for coastal domains
 - Replaces dp with dp' nearly everywhere

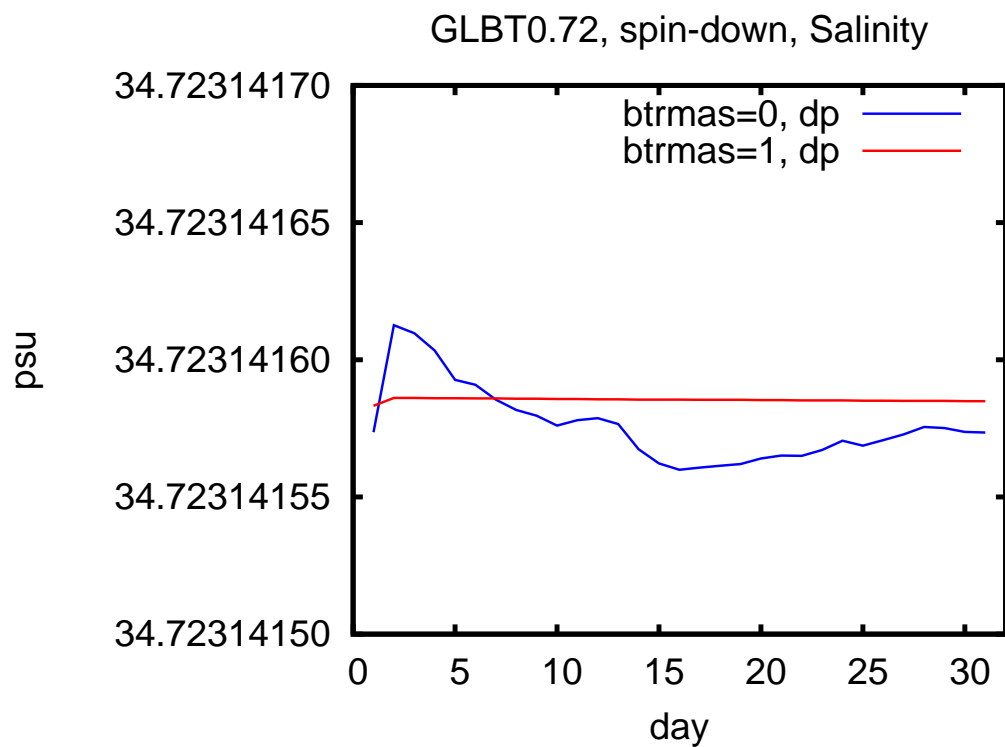
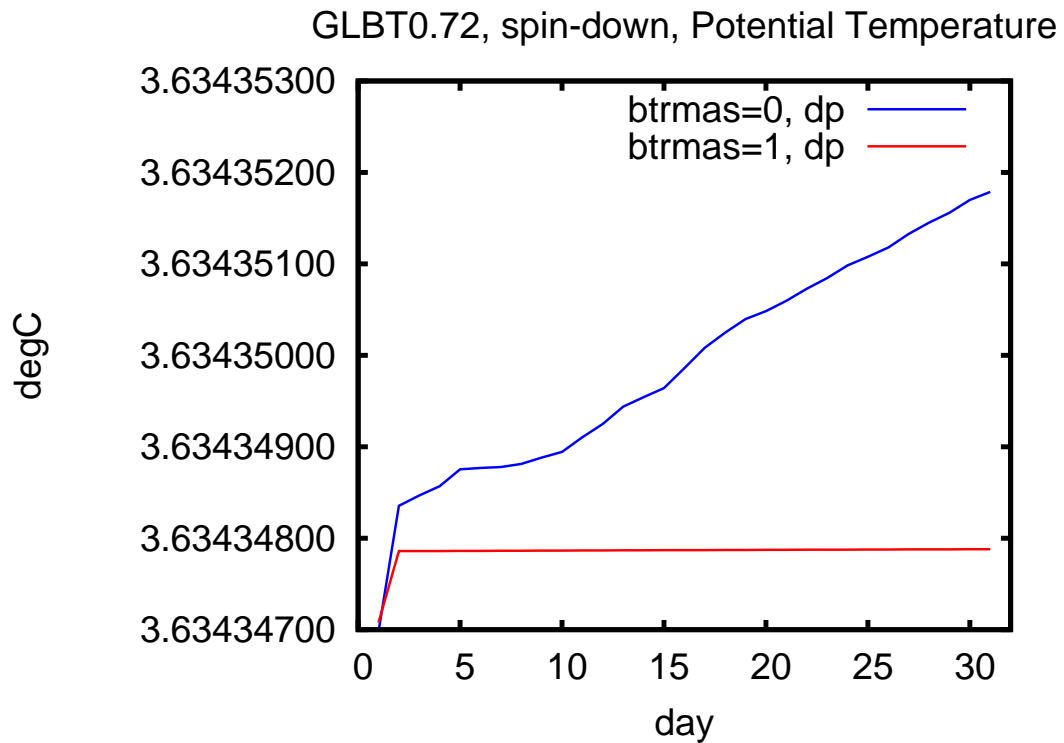
Mass Conservation - II

- HYCOM's reputation for non-conservation is partially due to using dp' in mean calculations
 - Much better conservation properties when correctly using dp in region-wide means
 - HYCOM source code uses dp' for means, i.e. this is a long standing “bug”
- New option, $btrmas=1$, for exact mass conservation
 - From Remy Baraille at SHOM
 - Removes the dp' “equals” dp approximation
 - Note that dp' is still the prognostic variable
 - ◇ Still dp' in restart and archive files
 - Currently, $btrmas=1$ is less stable than $btrmas=0$
 - ◇ Still working on making it more stable
- As a test, 0.72° Global HYCOM was spun-up for 5 years with typical atmospheric forcing and then all forcing was removed
 - During “spin down” there should be no change to the total heat and salt, i.e. to the mean T and S

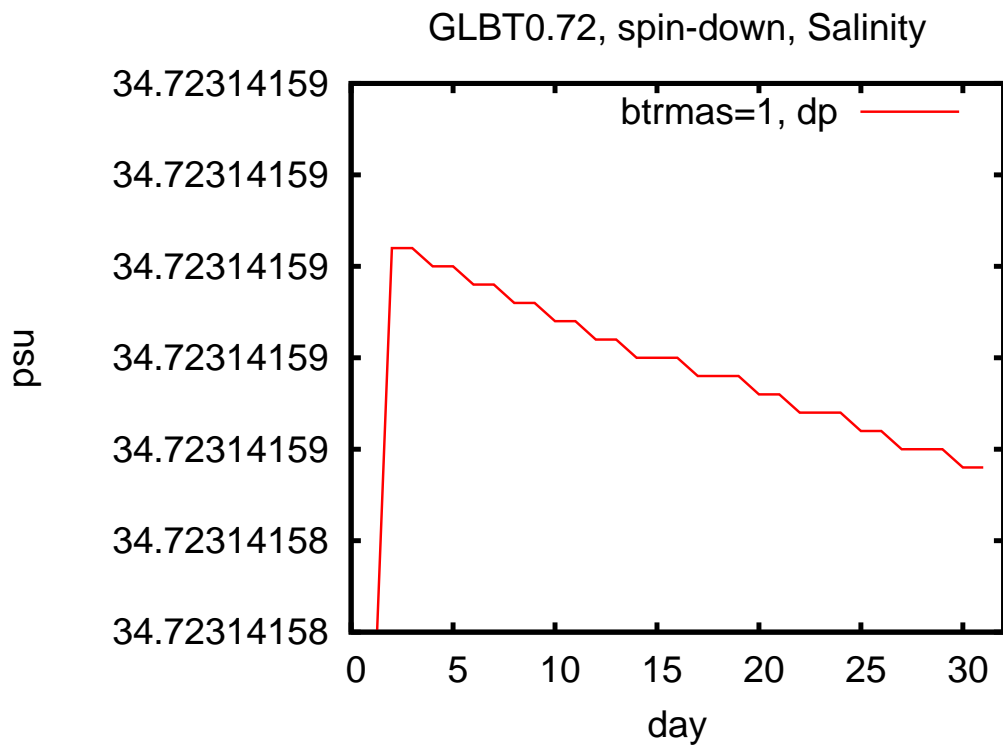
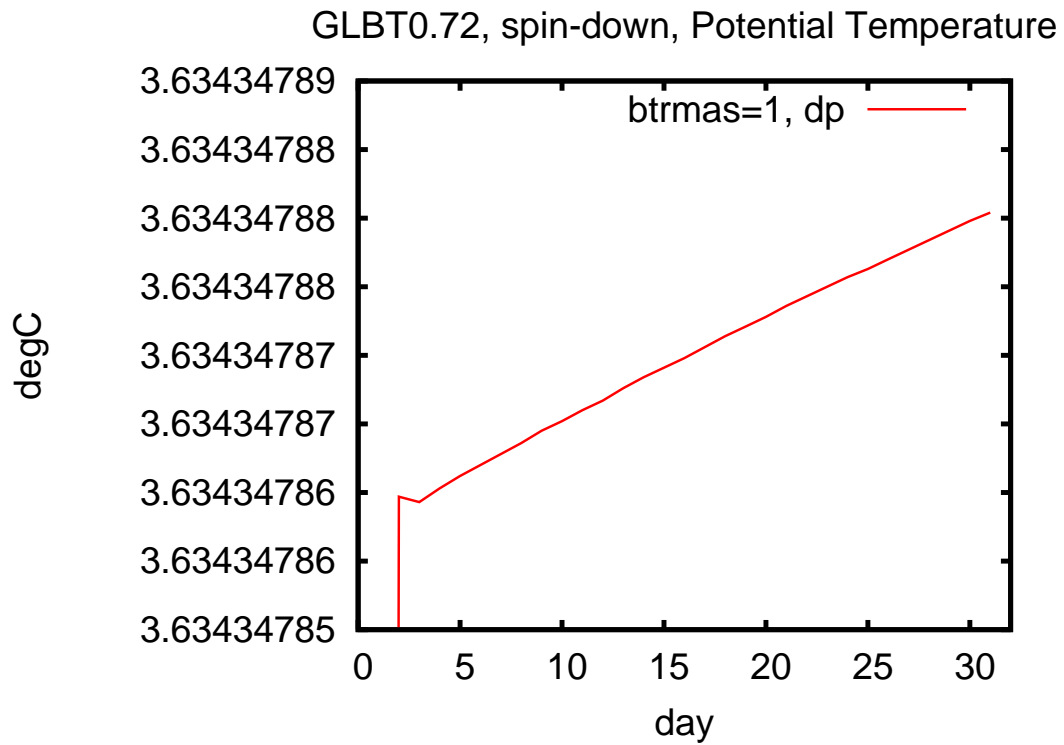
Spin Down Test of Conservation - I



Spin Down Test of Conservation - II



Spin Down Test of Conservation - III



Robert-Asselin Time Filter

- One potential source of non-conservation is the RA filter used to stabilize the leapfrog time step scheme
 - Williams (2009) proposed a modified filter that is more conservative and more accurate
 - ◇ However, it is not applicable to models with time varying layers than must filter h and hC consistently while maintaining non-negative fields
- Leclair and Madec (2009) showed that RA is:
 - Conservative without surface forcing
 - ◇ As demonstrated numerically by spin-down case
 - Can be made conservative if surface forcing terms are calculated at half time steps
 - ◇ Implies no time splitting from forcing
 - ◇ Explicitly remove forcing from RA filter
- HYCOM is not currently conservative with surface forcing
 - Started testing Leclair's approach

Bit-for-Bit Multi-CPU Reproducibility

- Repeating a single processor run:
 - Produces identical results
- Repeating a multi-processor run:
 - Produces different results
 - ◇ Using either OpenMP or MPI
 - ◇ e.g. fastest global sum is non-reproducible
 - Unless programmer explicitly avoids non-reproducible operations
 - ◇ May need to avoid some compiler options
- Two levels of reproducibility
 - On the same number of processors
 - ◇ Some scalable libraries provide this
 - On any number of processors
 - ◇ Only “safe” option for code maintenance
 - Always requires careful programming
 - Can be slower
 - ◇ Should be required for operational ocean prediction models
 - Is implemented by HYCOM

Are Two HYCOM Runs Identical? - I

- The only way to confirm bit-for-bit identity is to compare binary fields
- Could compare binary archive and/or restart files
 - But these don't tell you where any differences came from
- P-MICOM used “named pipes” to compare arrays between MASTER and SLAVE model runs while they were in progress
 - A named pipe is a special Unix file providing a FIFO capability via a shared memory buffer
 - Can read and write to it just like a normal file
- SLAVE writes an array to the pipe, MASTER reads the array and compares it to its own version
 - Usually MASTER runs on one processor and SLAVE on multiple processors
 - Only limitation is that MASTER and SLAVE must be running under the same Unix image
 - ◇ May be difficult to arrange for MPI on a cluster

Are Two HYCOM Runs Identical? - II

- HYCOM includes a named pipe based comparator
 - Similar to P-MICOM, but easier to use
 - Calls to compare or compareall in source code:
 - ◇ Can trigger a comparison of arrays at run time, between two HYCOMs via the named pipe
 - ◇ Can invoke other run-time debugging options
- A new option is to compile with the OCEANS2 macro
 - Runs two instances of HYCOM in the same executable
 - ◇ Each on a different number of MPI tasks
 - Calls to compare or compareall in source code:
 - ◇ Will trigger a comparison of arrays at run time via MPI send/recv
 - Easier to use than named pipes and only requires MPI
 - ◇ Works for OpenMP with MPI, but same number of threads used by both HYCOMs
 - ◇ Does not currently work in coupled models

Tides in HYCOM - I

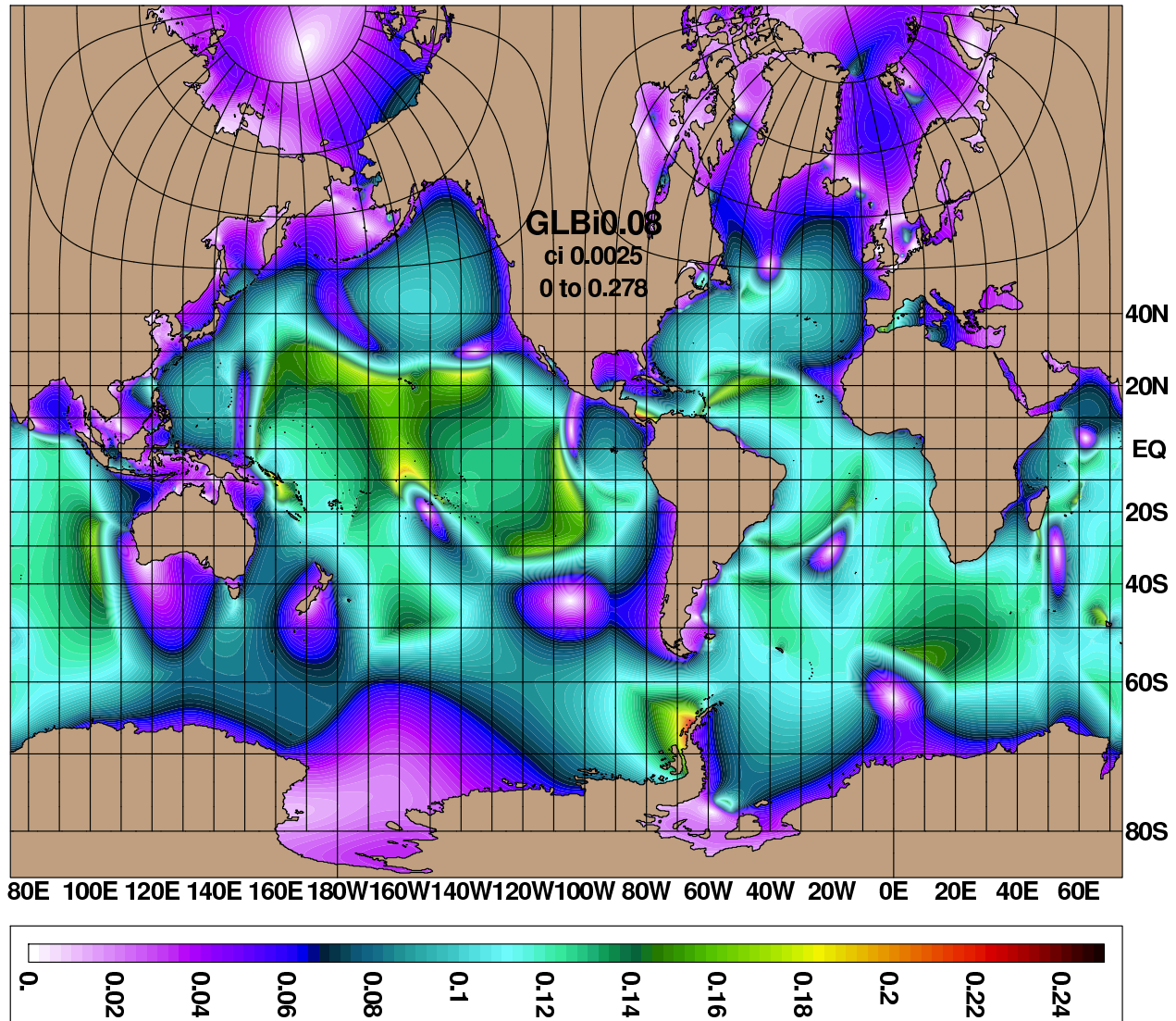
- Body forcing for 8 largest components
 - With (optional) nodal corrections
 - Implemented in HYCOM by NCEP
- Boundary forcing for Flather or Browning-Kreiss ports
 - Implemented by various groups in local versions of HYCOM
 - Now in standard version
 - ◇ 8 largest components specified as complex amplitudes at each boundary point using unmodified extract_HC program from OSU's OTPSnc or OTPS2 package
 - ◇ Allows for curvilinear grid
 - ◇ With (optional) nodal corrections
 - Tidal forcing under floating ice shelves requires 1147 ports for Global 1/12° domain
 - ◇ Port implementation updated to allocate memory at run time and to make many fewer MPI calls for better MPI performance

Tides in HYCOM - II

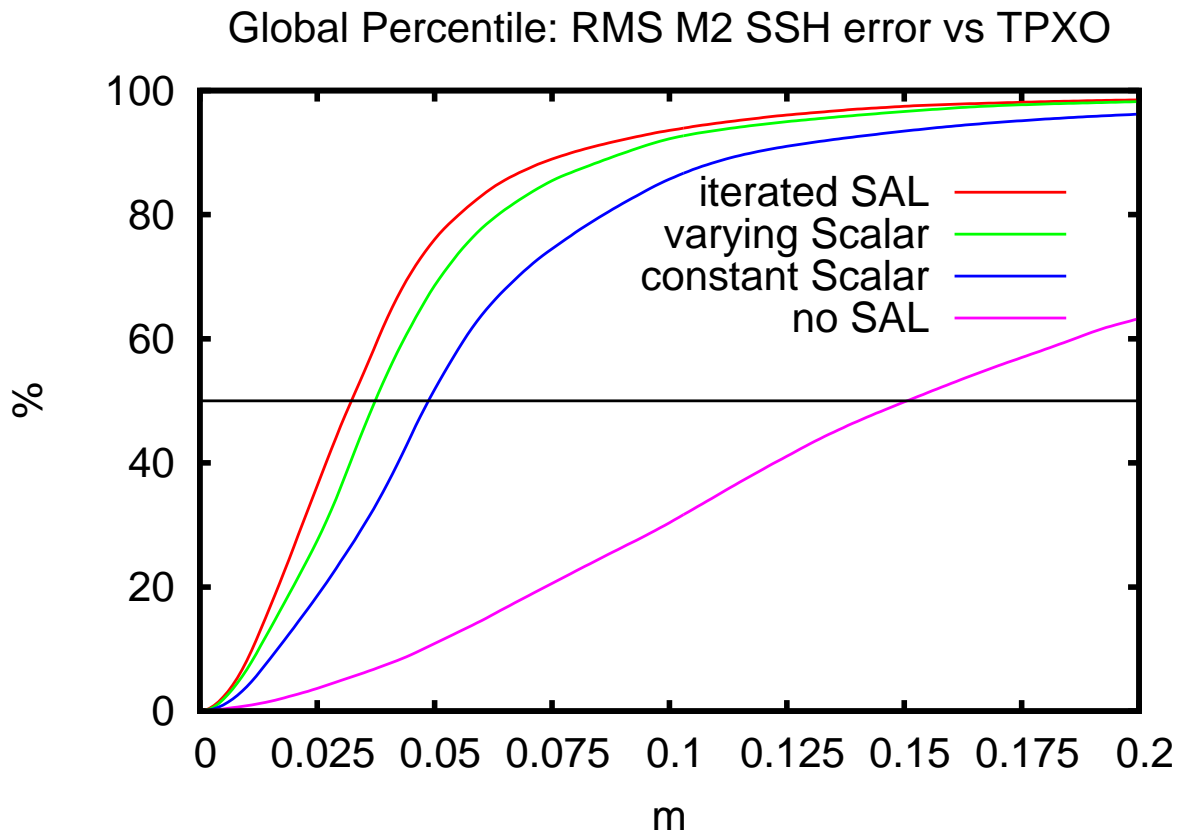
- Linear tidal drag based on bottom roughness
 - Applied to near-bottom tidal velocity or to depth averaged tidal velocity
 - ◇ Tensor drag for depth averaged case only
 - Use a lagged 49-hour filter as the non-tidal velocity
 - ◇ Convolution of a 21 hour Savitzky-Golay smoother and a 24.842 hour boxcar filter
 - ◇ Passes 0.02% of semi-diurnal and 3.2% of diurnal (1.2% of total) tides
 - Replaces a lagged 25-hour average
 - Better band pass and better diurnal phase
 - Limit drag's e-folding time for stability
- Self Attraction and Loading
 - “Scalar” approximation:
 - ◇ SAL treated as a fraction of non-steric SSH
 - Constant, or spacially varying, fraction
 - Input SAL complex amplitude fields from a file
 - ◇ With or without a “scalar” SAL
 - ◇ Iterate SAL to convergence

Spacially Varying Self Attraction and Loading

TPXO8atlas M2 Amplitude: SAL/TIDE



Self Attraction and Loading Comparison



- Barotropic Global $1/12^\circ$ M2-only simulations
 - Twin cases that differ only in Self Attraction and Loading
- The percentage of the globe (Y) where model - TPXO8atlas SSH RMS is less than X m
 - Note the long tail with the median (50%), for the with-SAL cases, between 3 cm and 5 cm
 - ◇ Median is typically a more robust statistic than mean or global RMS

Tides in HYCOM - III

- Several tide-specific diagnostic programs:
 - hycom_tidal_foreman
 - ◇ Foreman tidal analysis on HYCOM .a file
 - ◇ HYCOM's 4096-word blocking allows strip-mined transpose from (x,y,t) to (t,x,y)
 - hycom_calcSAL
 - ◇ Calculate SAL on uniform cylindrical global grid
 - hycom_tidal_rms
 - ◇ RMS difference between two sets of tides
 - hycom_tidal_ap2ri and hycom_tidal_ri2ap
 - ◇ Amp,Phase to/from Real,Imaginary tidal components
- Tidal analysis enabling output:
 - HYCOM SSH has mass and steric anomalies
 - Steric SSH can optionally be output
 - ◇ Steric anomaly plus long term SSH mean
 - ◇ Explicitly “filters” external tides
 - ◇ Get internal tides from Foreman tidal analysis
 - Non-steric SSH from difference
 - ◇ Largely external tides

HYCOM and Sea Ice

- Two-way coupling to LANL's CICE sea ice model, regional and global domains
 - 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
 - ◇ ESMF version 4.0.0rp2
 - ◇ Plan to migrate to NUOPC Layer on top of ESMF version 6.X.0r
- Coupled to CICE version 4.0
 - Version 4.1 was released in May, 2010
 - Plan to skip 4.1 and implement the “next release”, due later this year

Coming Soon

- Wave forcing
 - Stokes Drift Current (SDC)
 - Wave-to-Ocean Momentum Flux (WOMF)
 - Bottom Orbital Wave Current (OWC)
- Wetting and Drying
 - Made possible by mass conservation option
 - Code from Remy Baraille at SHOM is already in HYCOM but needs more testing
- Fully region-independent
 - Compile once, run on any region and any number of processors
 - ◇ Run-time memory allocation, less memory used
 - ◇ Reduces performance
 - Compilers make fewer optimizations
 - Prototype is 5% slower
 - Needed for full ESMF compliance
 - ◇ Single executable, multiple components each running on separate cpus
 - ◇ HYCOM arrays currently on all cpus