HYCOM model development and validation

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6th HYCOM Consortium meeting

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HYCOM 2.1.03 (I)

- First public release of HYCOM 2.1
  - September, 2001
- Maintain all features of HYCOM 2.0
  - Requires Fortran 90
  - Can use HYCOM for pure ispoycnal cases
  - KPP or Kraus-Turner mixed layer
  - Energy-Loan (passive) ice model
  - High frequency atmospheric forcing
  - New I/O scheme (.a and .b files)
  - Scalability via OpenMP or MPI or both
    - Bit-for-bit multi-cpu reproducability

HYCOM 2.1.03 (II)

- Orthogonal curvilinear grids
- Fully global domains
  - Near-global mercator already in HYCOM 2.0
  - Pan-Am grid with closed Bering Strait
    - Open Bering Strait requires a special halo exchange
    - Available "soon"
- Multiple tracers
  - Passive
  - Simple biology (NPZ or NPZD)
    - Most of infrastructure in place
    - More work needed on biology and boundary conditions
- Rivers as bogused surface precipitation
  - Annual or monthly climatology

HYCOM 2.1.03 (III)

- Off-line one-way nesting
  - Similar to MICOM
    - Exact b.c. for depth averaged component
    - Relaxation for 3-D T/S/pressure/velocity
      - Based on relaxation to climatology
      - But with addition of velocity relaxation
  - Interpolate to target domain off-line
    - Source domain to target domain archive files
    - Nested model does not “know” about enclosing domain
  - Get boundary data from input archive files
    - Simplifies scalability
    - At the cost of more I/O and bigger files
- Must have same vertical structure
  - Can discard deep isopycnal layers
- Same resolution nesting unexpectedly useful
  - No need to rerun large domain
  - Change atmospheric forcing (e.g. use MM5)
  - Tracer studies (e.g. add biology)

HYCOM 2.1.03 (IV)

- More general fixed (sigma/Z) vertical coordinate
  - Emulate Z or Sigma or Sigma-Z models
    - Exact comparison to NCOM
  - HYCOM has partial cells
    - Emulate full cell Z models with the appropriate bathymetry
- Alternative mixed layer models
  - Mellor-Yamada 2.5
    - Exact comparison to NCOM
  - Price-Weller-Pinkel
- Explicit support for 1-D and 2-D domains
  - Tiling allows periodic domains
  - 1-D is 2x2 doubly periodic domain
    - Only read/write .b files
  - 2-D is Nx2 periodic domain
    - Infinate f-plane

HYCOM 2.1 (V)

- Region-independent setup and diagnostics
  - Dynamic memory allocation
  - Compile once for all domains
  - Actual model code still domain-dependent
- Restart processing
  - HYCOM from MICOM
  - HYCOM from archive file
  - HYCOM from coarser resolution HYCOM
  - Change land/sea boundary
- Archive processing
  - Add/subtract/merge layers
  - Mean and variability
  - Off-line sampling
    - Vertical profiles
    - Transport sections
  - To netCDF and other file formats
    - All x-y “hycomproc” fields
    - Interpolated to z-space

HYCOM FILE FORMAT

- MICOM's PAKK I/O not efficient or accurate
- HYCOM 2.1 reads/writes ".a and .b" files
  - ".a" is a raw IEEE REAL*4 array file (Fortran direct access)
  - ".b" is a plain-text header file (Fortran formatted)
- This I/O is simple and portable
- It can easily be parallelized
  - Have the N-th processor read/write every N-th 2-D array record
- Convert to netCDF off-line
  - Climate and Forecast (CF) conventions
    - Extension of COARDS conventions
      - Supports curvilinear grids
    - Most existing software is for COARDS only
  - Unlimited time dimension
    - Simplifies time concatination
  - Safest to have single field per file
    - Avoids all 2GB limits

DOMAIN DECOMPOSITION FOR MPI

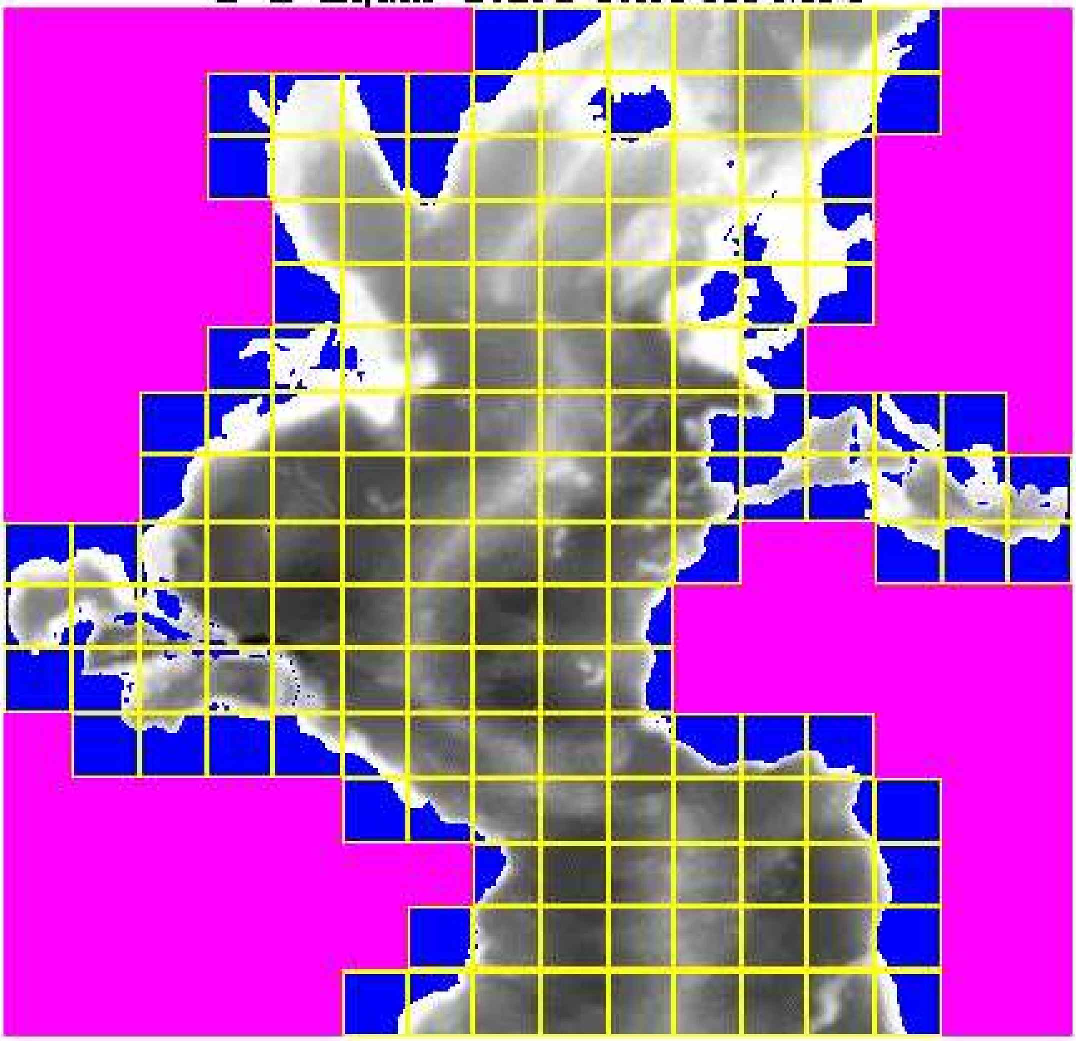
- Simplest domain decomposition is equal-sized rectangular tiles
  - Identical to data parallel block layout
  - Each tile has four nieghbors
    - Eight nieghbors including halo corners
  - Each row might exclusivly map to SMP nodes
- Overall speed controled by slowest tile
  - Probably have an "all ocean" tile
    - no advantage to avoiding land
- So, discard tiles that are entirely over land
  - Relatively simple to implement
  - Does not discard all land
  - Better for large tile counts
  - Ineffective on very small tile counts
  - Destroys any row to SMP node mapping
  - P-MICOM

EQUAL-OCEAN RECTANGULAR TILES

- Each rectangle contains the same amount of ocean
  - Near perfect load balance
    - Work per ocean point is approximately constant
    - Must skip all land calculations
  - More expensive halo exchange
    - Many North-South nieghbors
    - Variable tile size
- Some tiles require more memory than others
  - If they contain a lot of land
  - Can “shrinkwrap” tiles to reduce memory
  - Memory requirement may set minimum tile count
- Aspect ratio of rectangle can be large
  - Replace one N tile row with two N/2 tile rows
  - Can be coded as discarding N/2 tiles per row
- Equal-ocean code can easily handle equal-area tiles
  - Choose whichever is most appropriate
  - HYCOM 2.0 and 2.1

MICOM 2–D DOMAIN DECOMPOSITION

2–D Equal–Sized Tiles for MPI



Each Tile has 4 neighbors

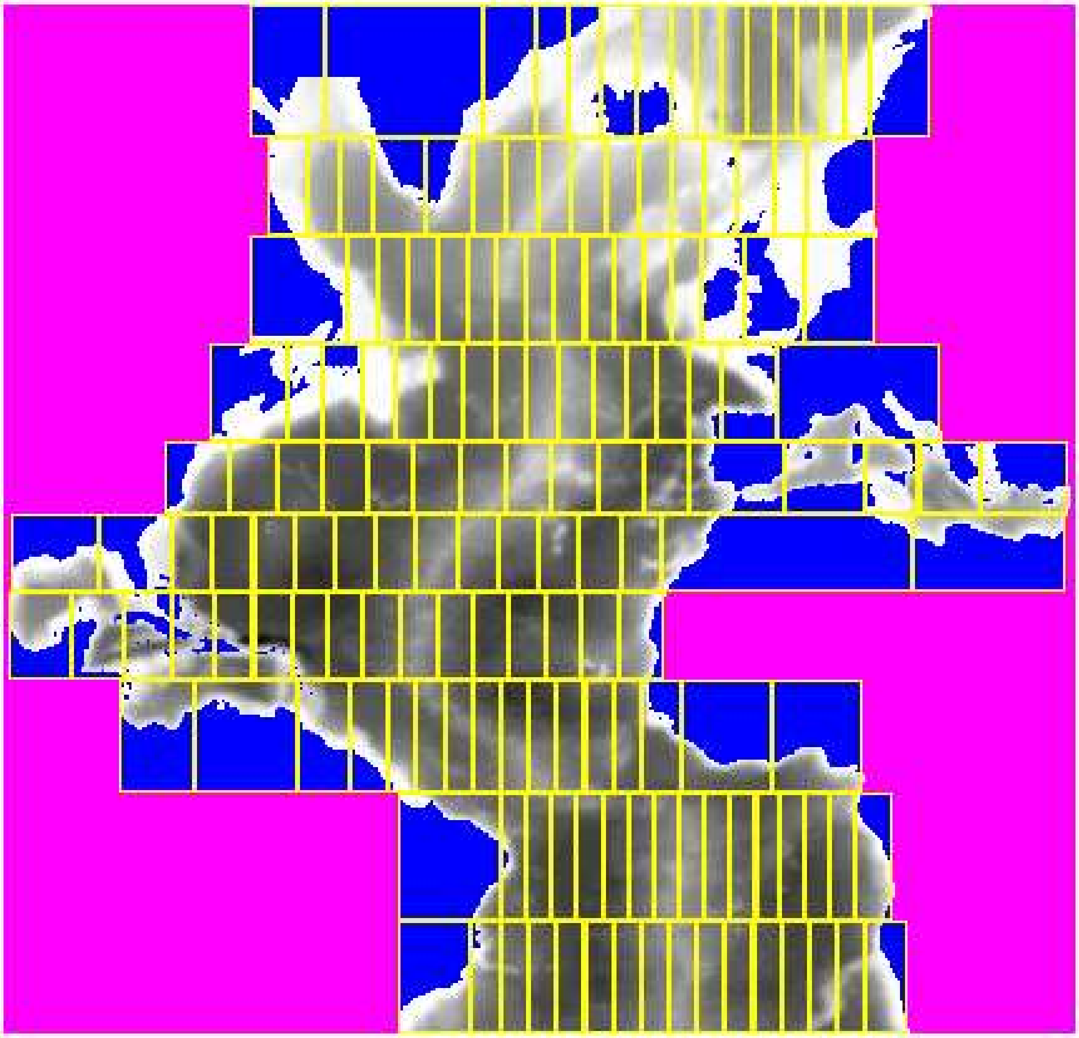
Discard "All–Land" Tiles

16x16 = 256 Tiles but only 161 active

Still have significant load imbalance

HYCOM 2-D DOMAIN DECOMPOSITION

2-D "Equal Ocean" Tiles for MPI



Each tile has 2 E-W neighbors, but many N-S neighbors

Compared to 16 x 16 "equal - size" decomposition:

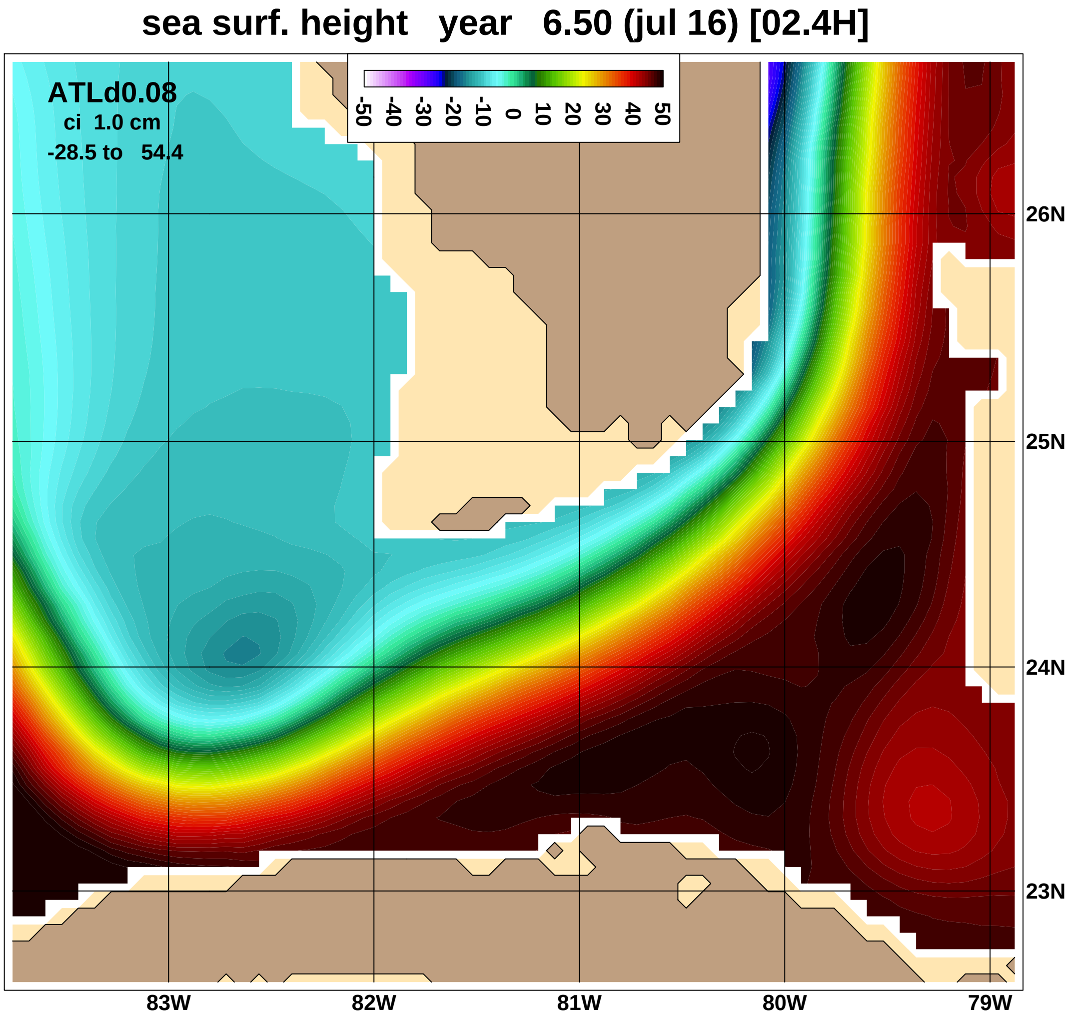
30% less work on "worst" tile

larger memory requirement

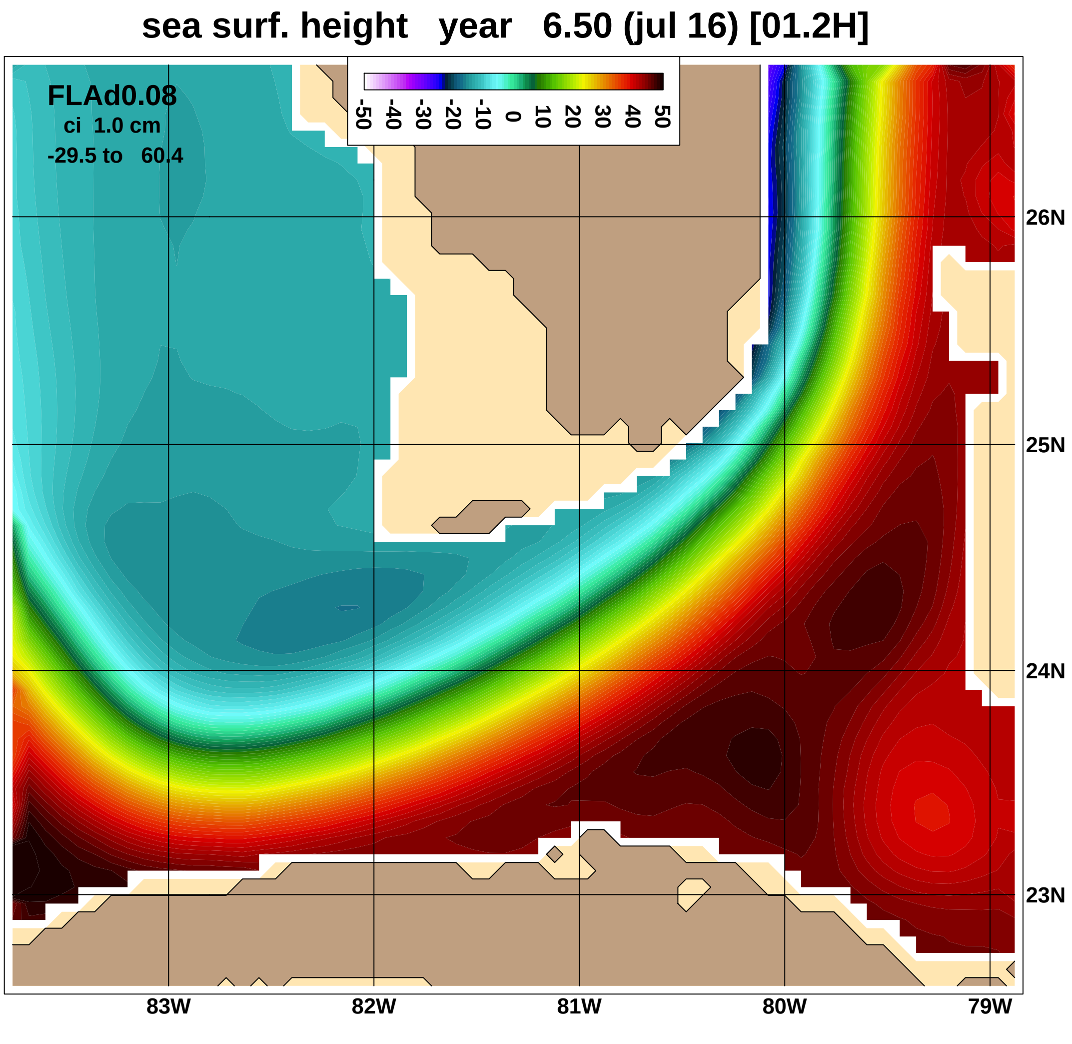
NESTING EXAMPLE

- Extract very small piece of 1/12 degree Altantic
  - Florida Straits only
  - 1.8 m/s surface intensified flow
  - about 30 Sv total transport
- Same grid resolution
  - Can run on a workstation
  - Intent is to add biological tracers
- Based on previous test cases, started with
  - 1-day depth averaged Atlantic sampling
  - 6-day 3-D Atlantic sampling
  - T/S/p relaxation, with 1-day e-folding
- 1-day e-folding increased 10x
- Added u/v/T/S/p relaxation
- Probably need 1-day 3-D sampling

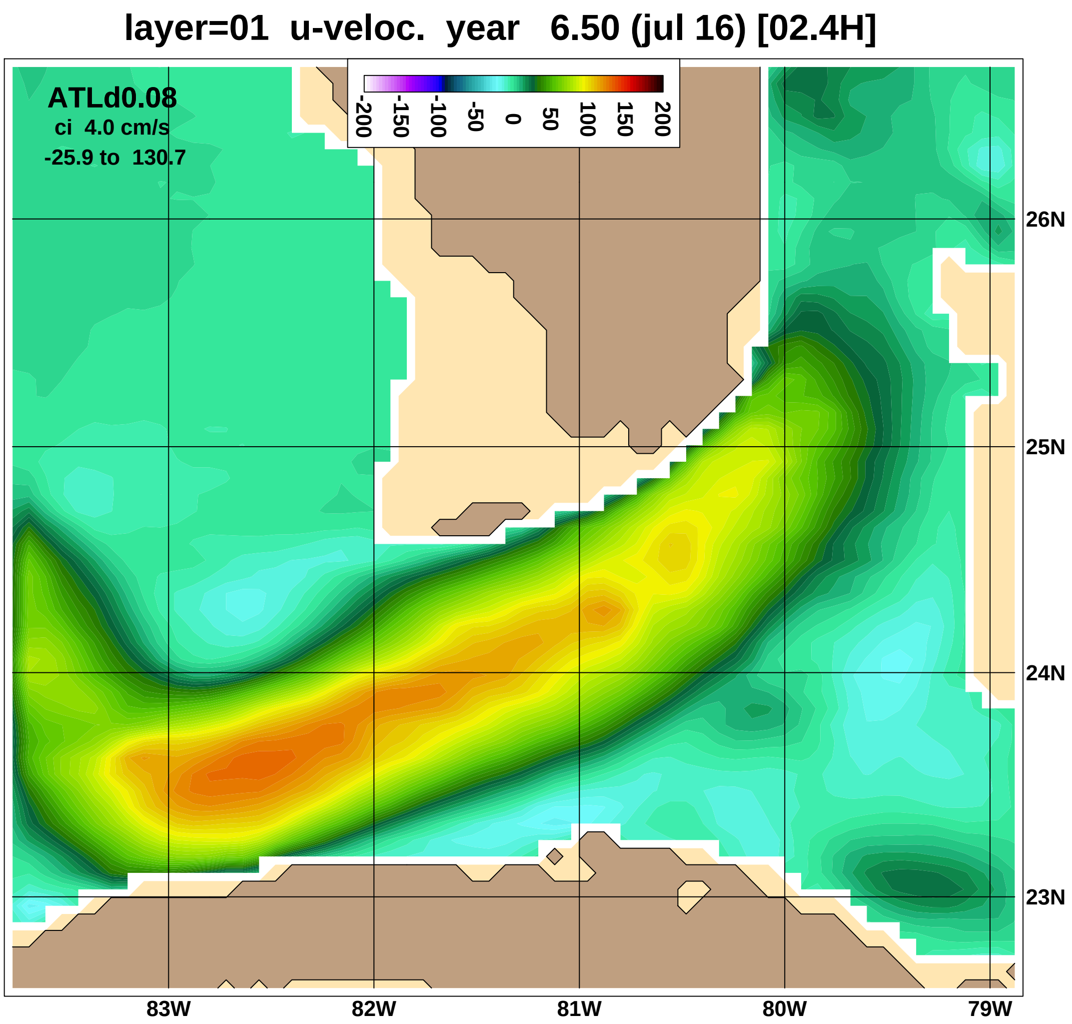
ORIGINAL FSD AFTER 180 DAYS



NESTED FSD AFTER 180 DAYS
0.1-DAY E-FOLD T-S-p-u-v RELAX



ORIGINAL U-VELOCITY AFTER 180 DAYS



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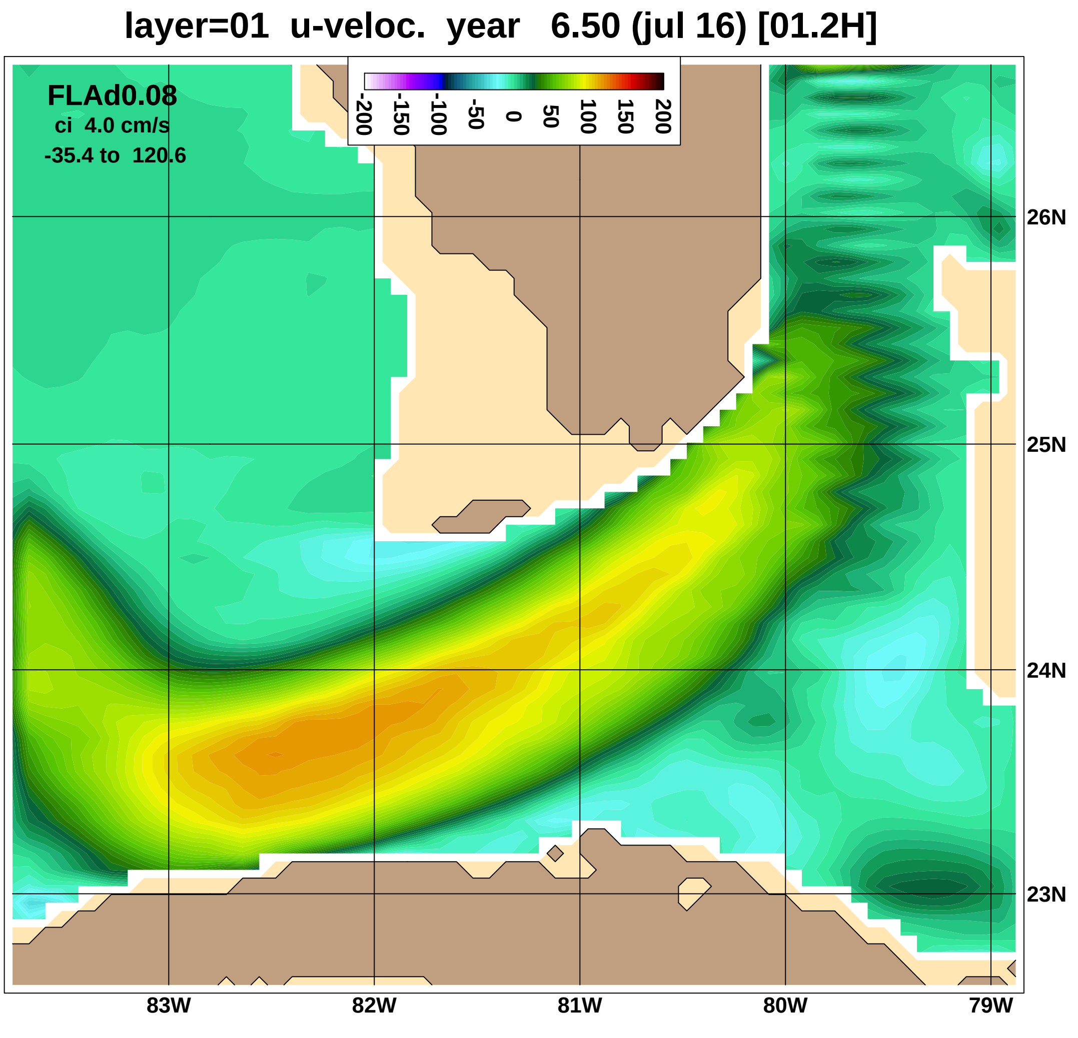
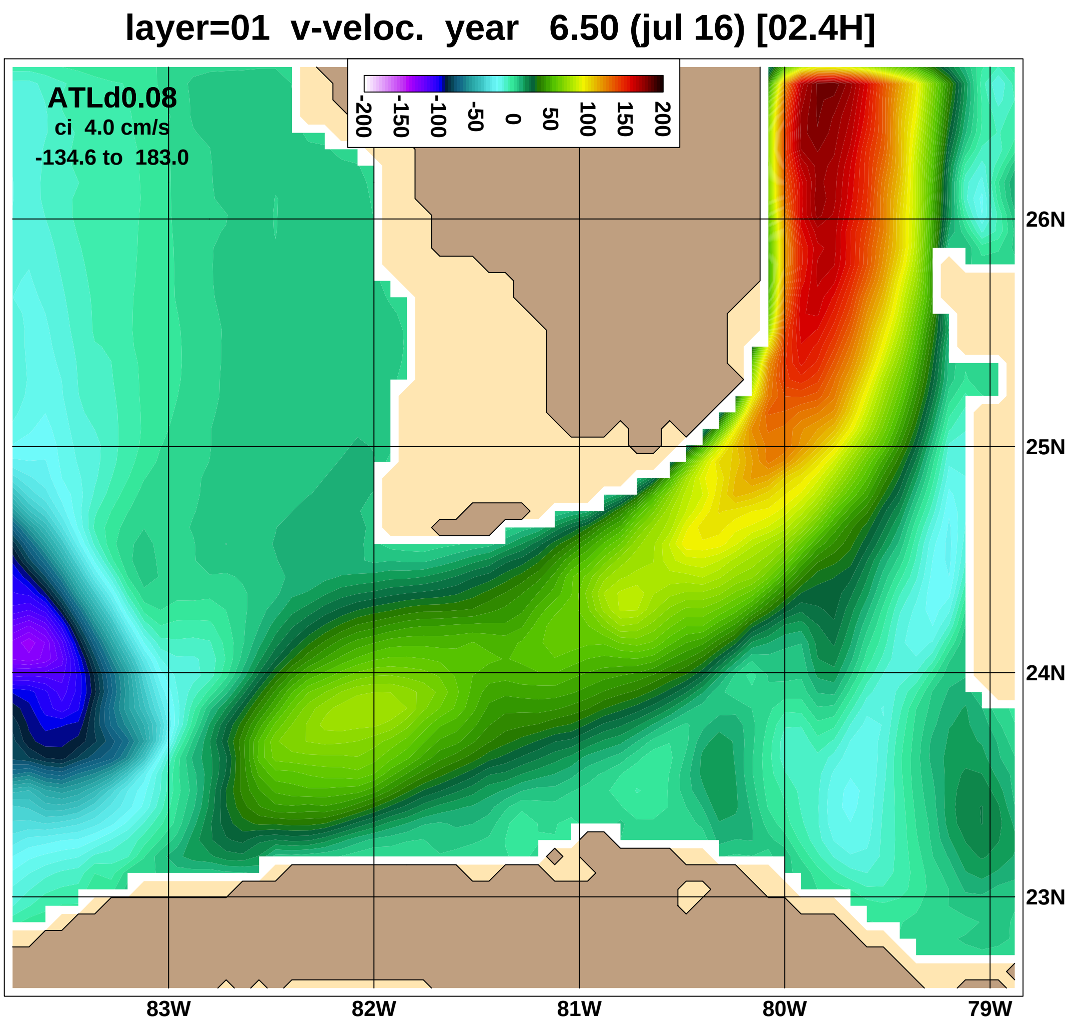
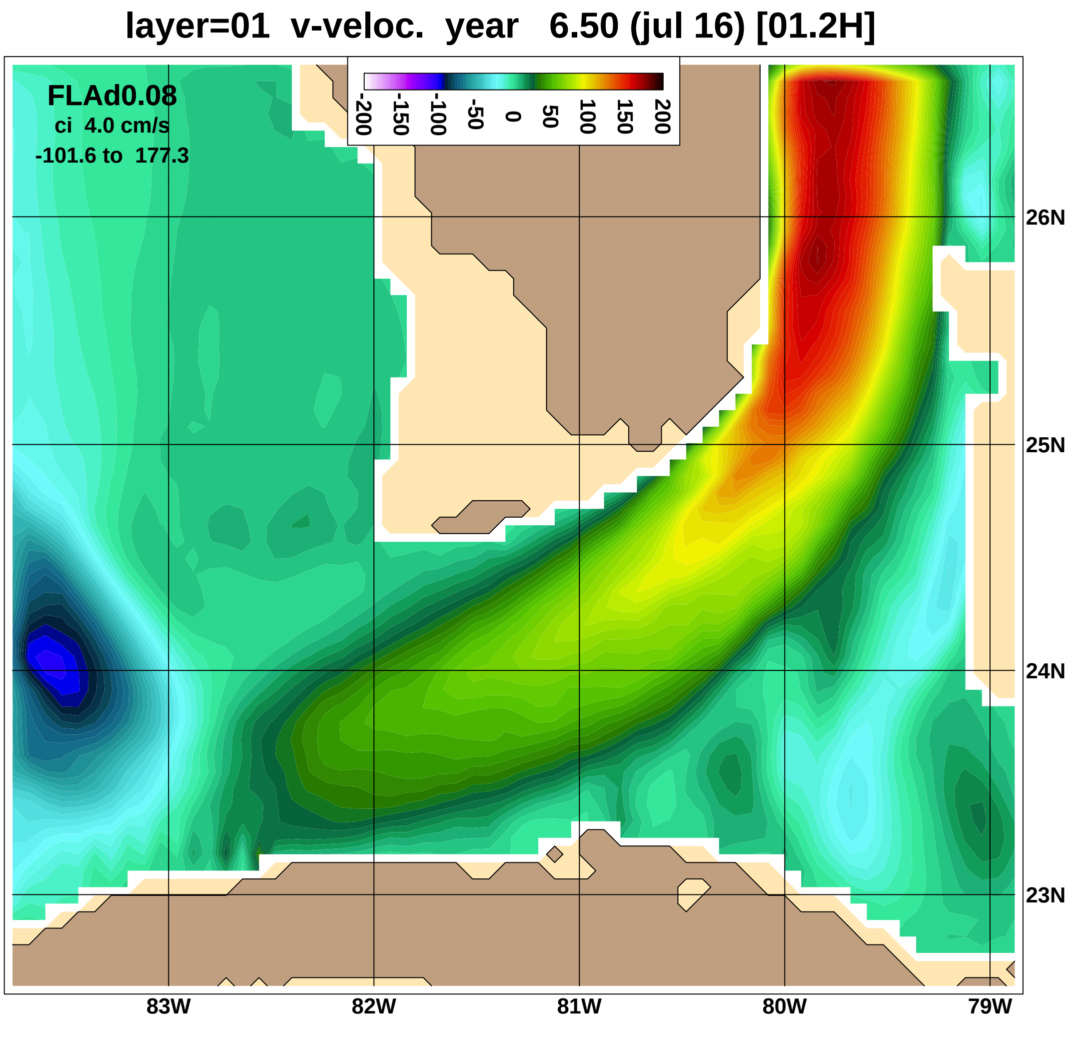


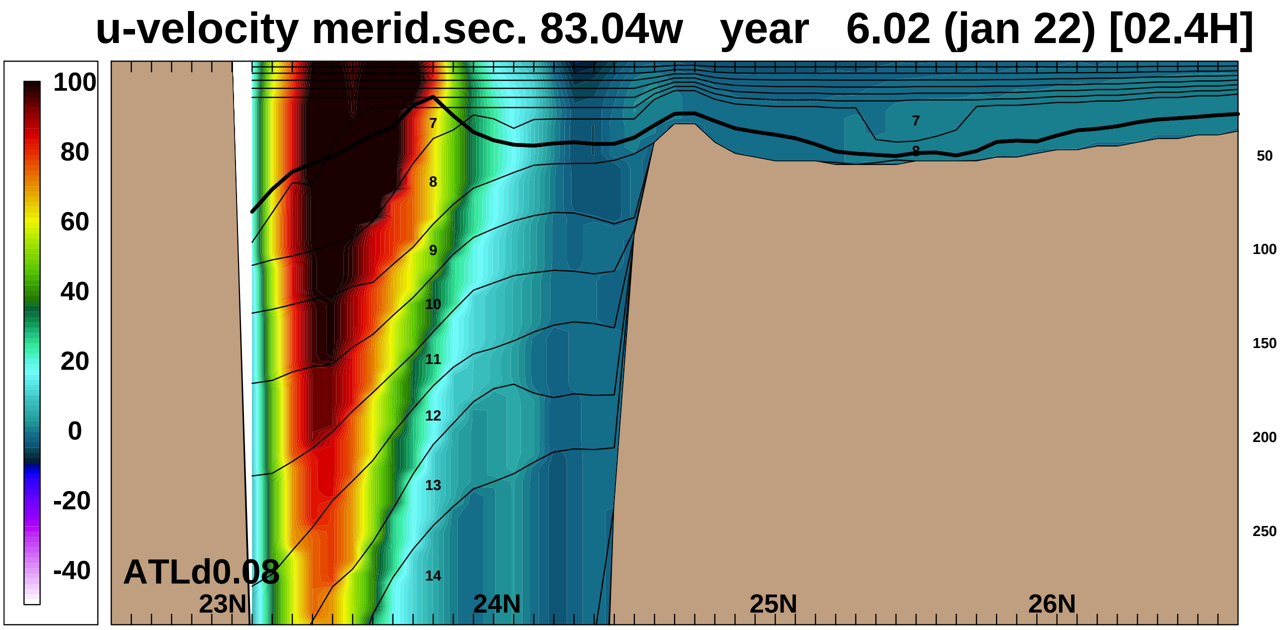
ORIGINAL V-VELOCITY AFTER 180 DAYS

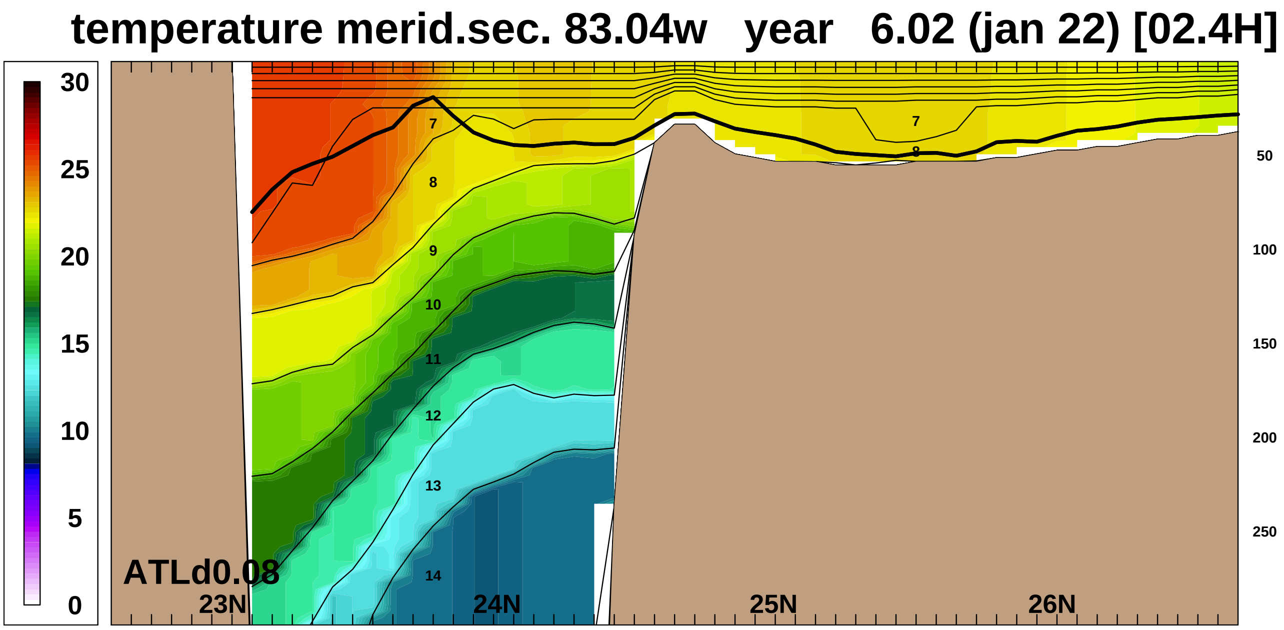


NESTED V-VELOCITY AFTER 180 DAYS
0.1-DAY E-FOLD T-S-p-u-v RELAX

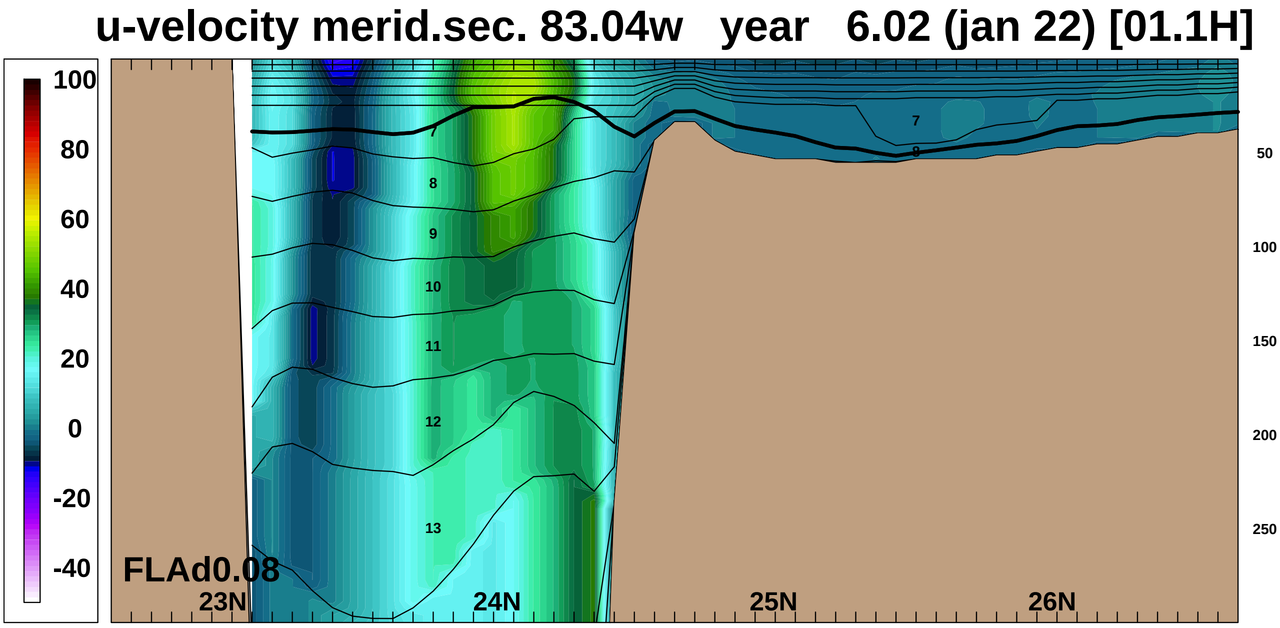


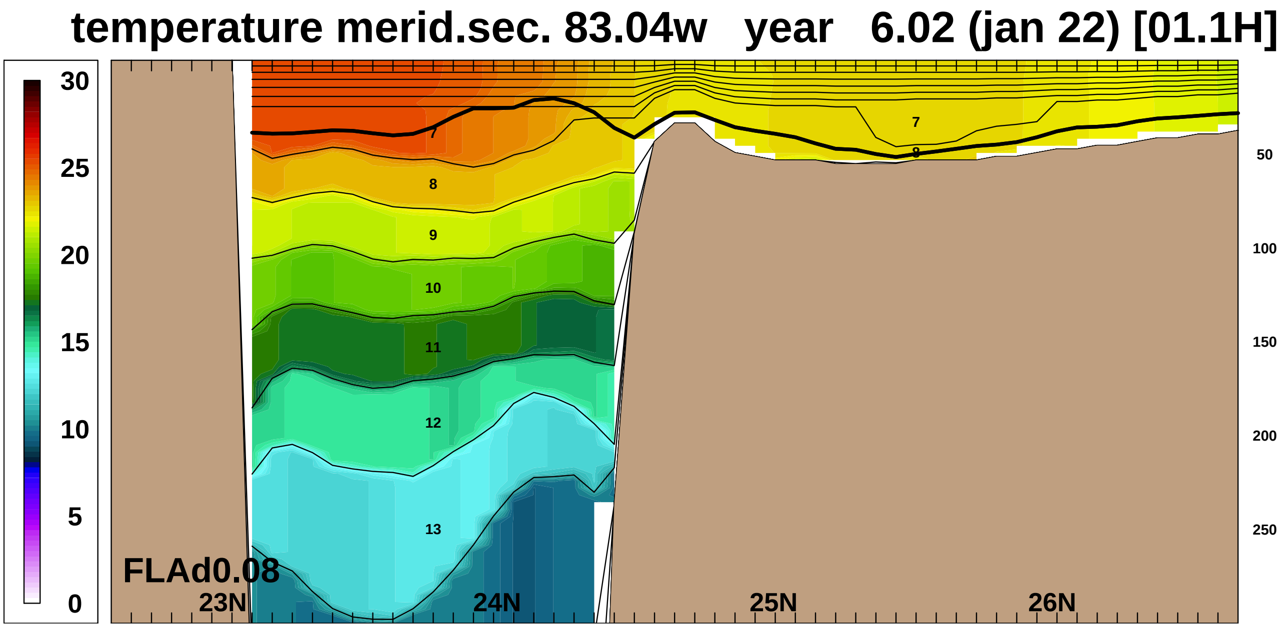
ORIGINAL SECTION AFTER 6 DAYS





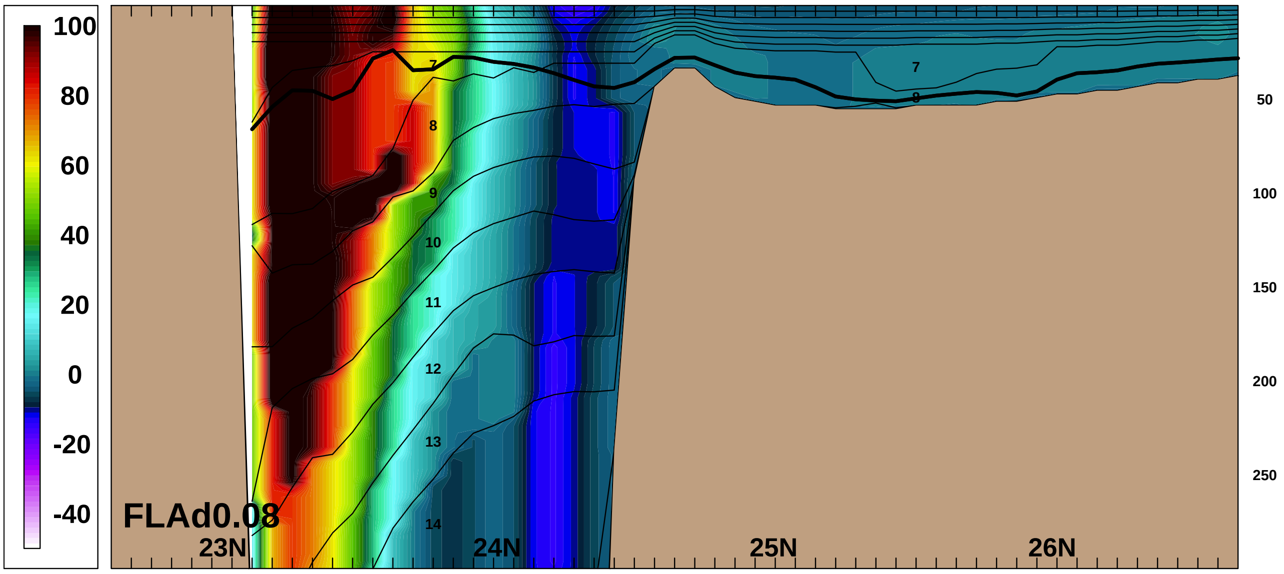
NESTED SECTION AFTER 6 DAYS:
1-DAY E-FOLD T-S-p RELAX



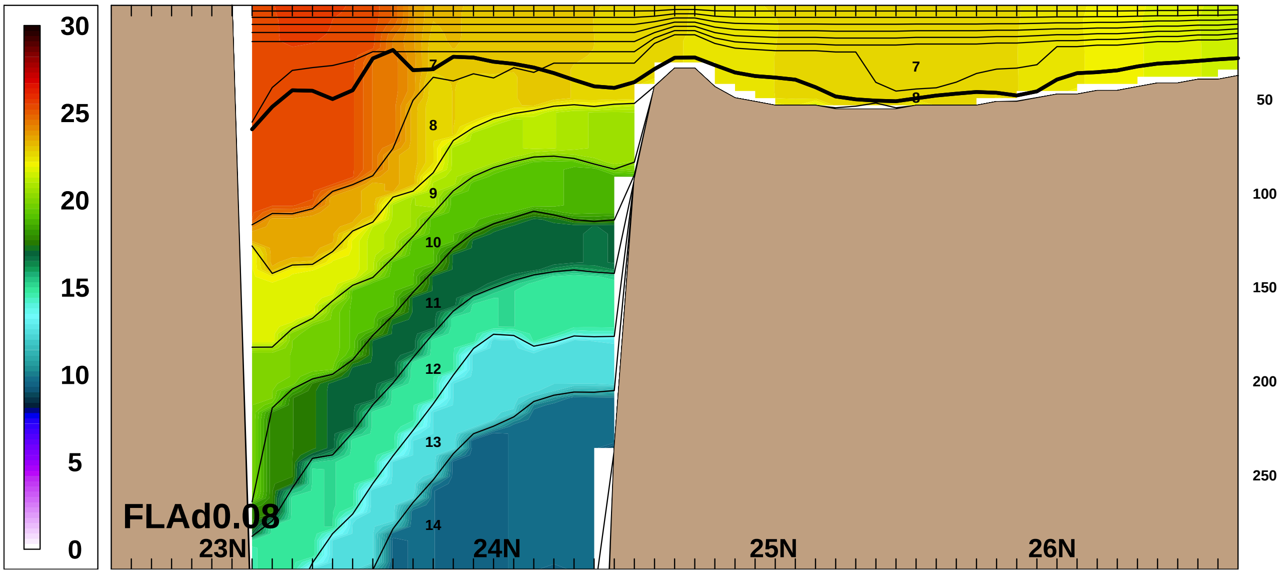


NESTED SECTION AFTER 6 DAYS:
0.1-DAY E-FOLD T-S-p RELAX

u-velocity merid.sec. 83.04w year 6.02 (jan 22) [01.3H]



temperature merid.sec. 83.04w year 6.02 (jan 22) [01.3H]



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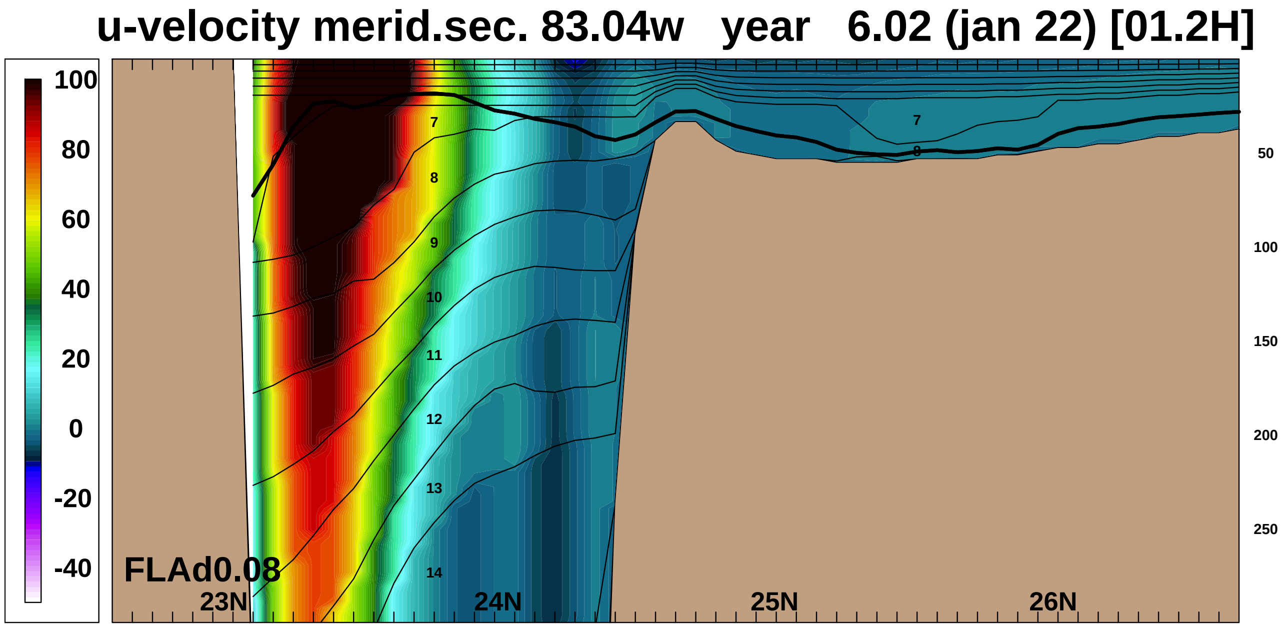
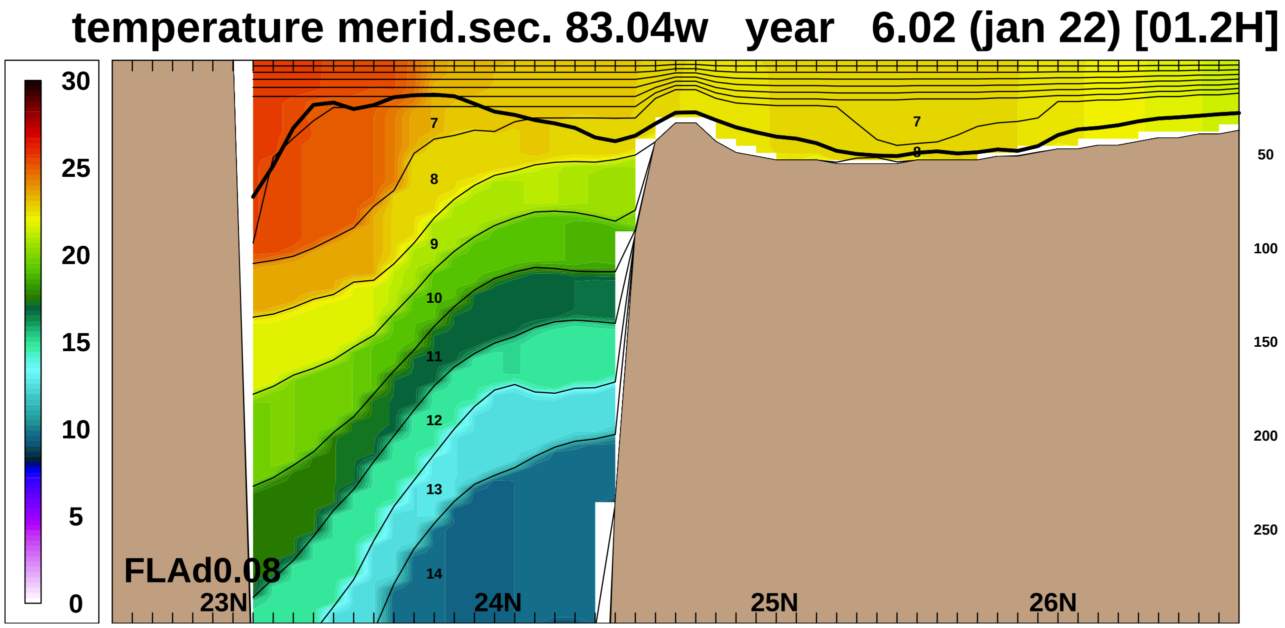
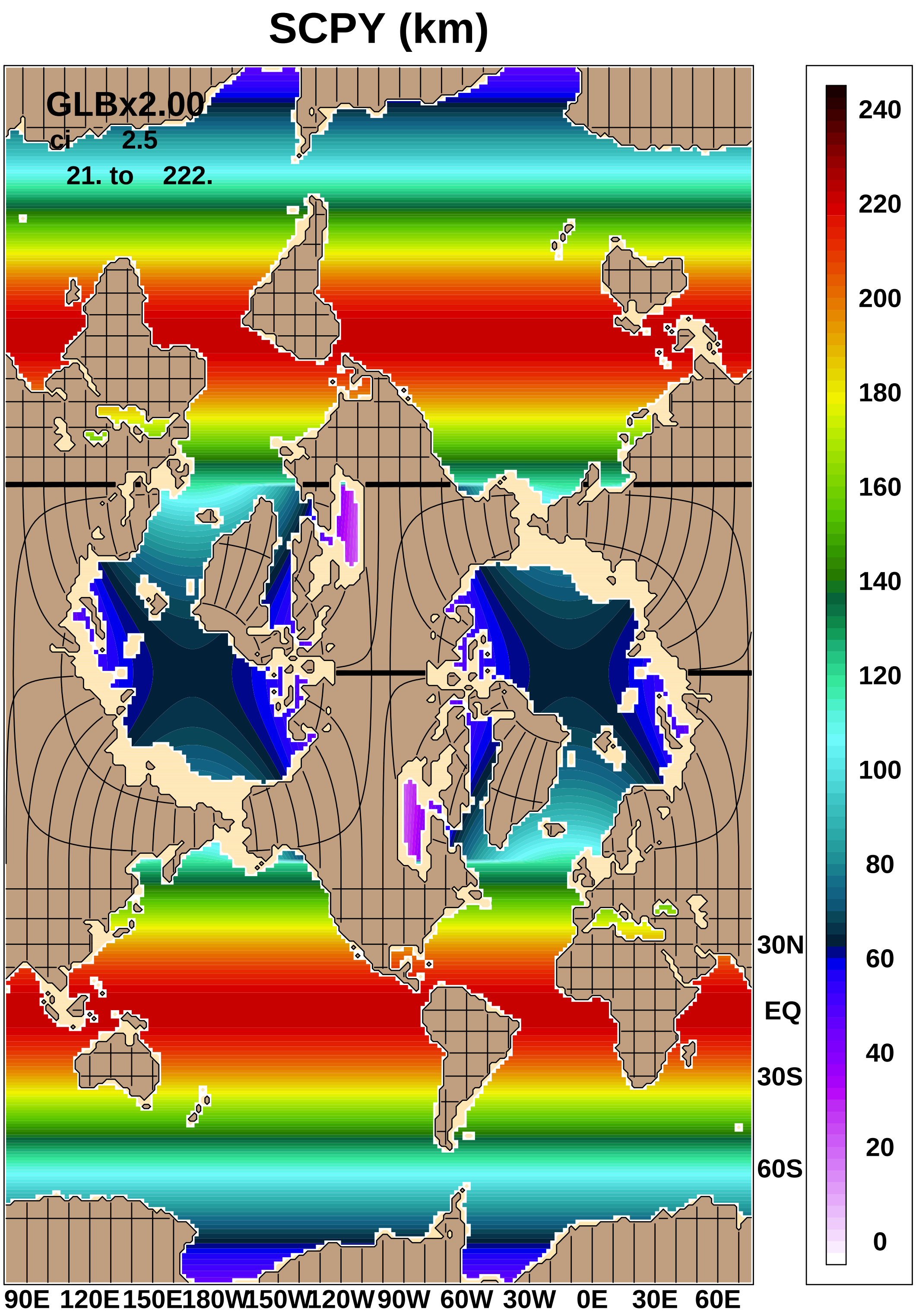




FULL PAN-AM GRID

- Full Pan-Am Grid contains all locations twice
- Use a subregion with each location at least once
- Original version had Bering Strait closed
  - Includes some of the Arctic twice
  - Sets the Arctic over the Pacific to land
- Three possibilities for an open Bering Strait
  - Original with a Bering Strait halo exchange
    - Small, but very non-standard, halo exchange
    - Arrays and files larger than necessary
  - Minimum array with an Arctic halo exchange
    - Used by global NCOM
    - One line of double valued points
  - Minimum array with an Atlantic to Pacific halo exchange
    - Simplest halo exchange
    - Separates ”Altantic” and ”Pacific”
- All three equivalent for diagnostics
  - e.g. can plot any subdomain, even if it wraps


SCPY (km)
GLBx2.00
ci 2.5
21. to 222.
240
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90E 120E 150E 180W 150W 120W 90W 60W 30W 0E 30E 60E

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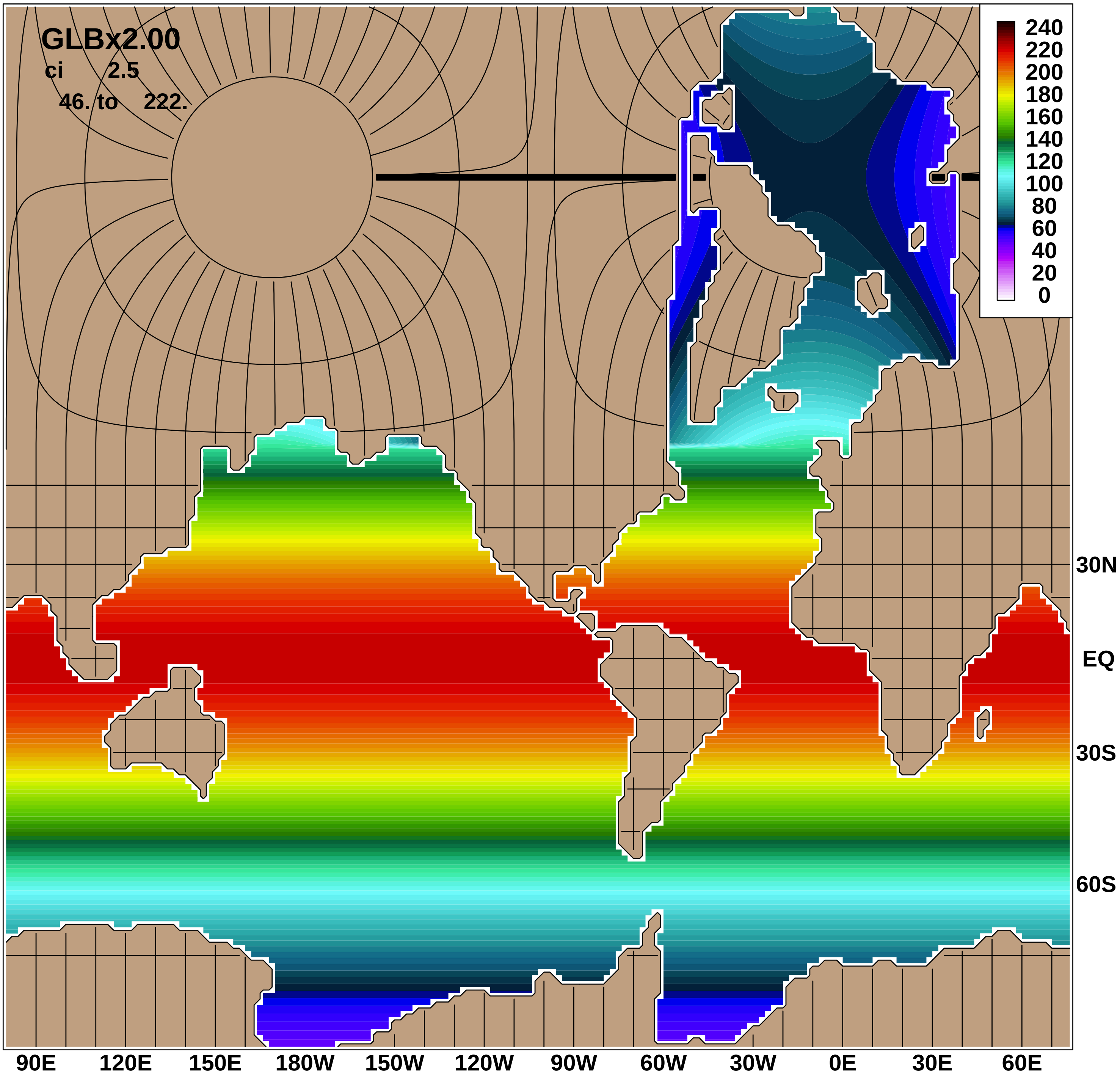

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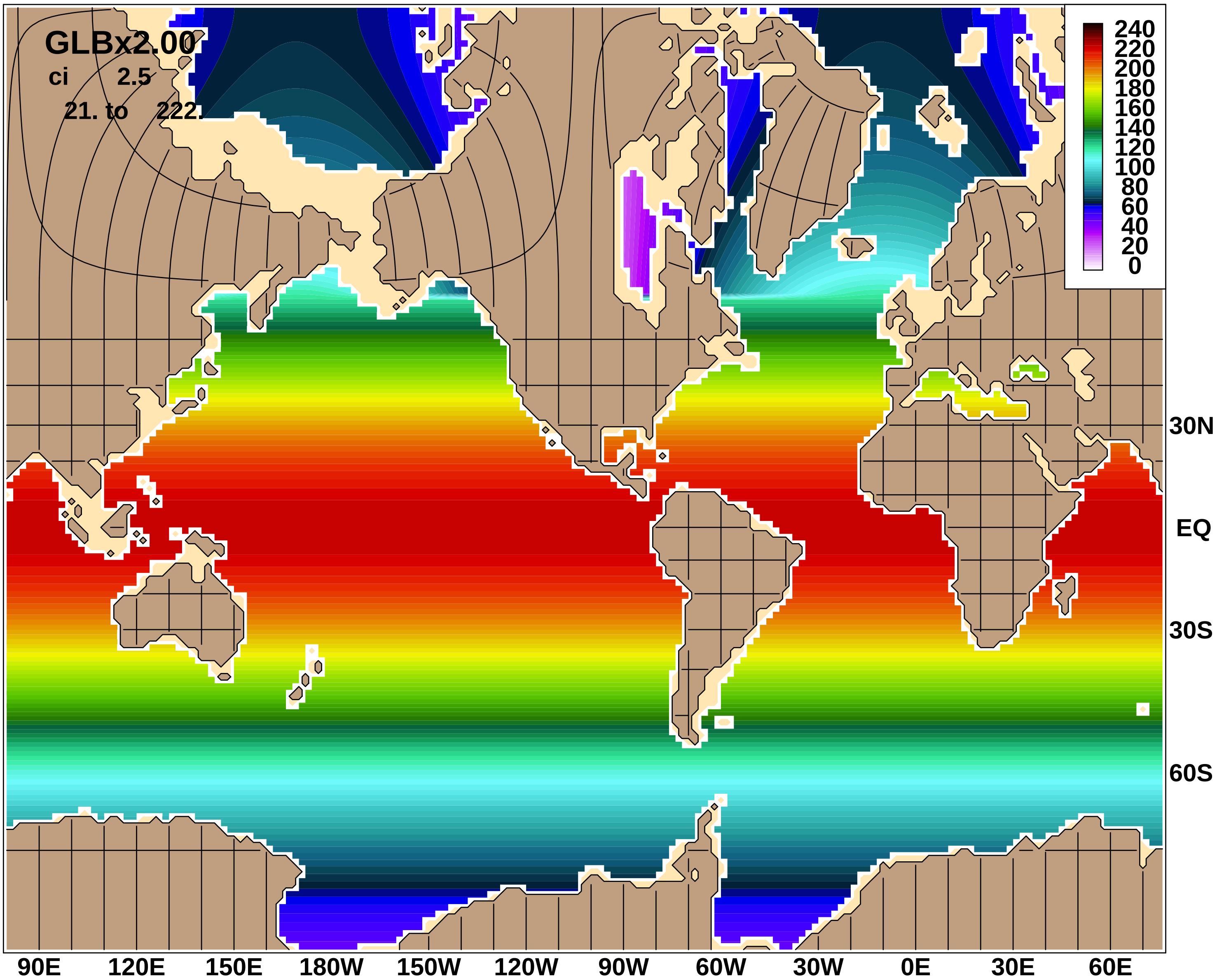
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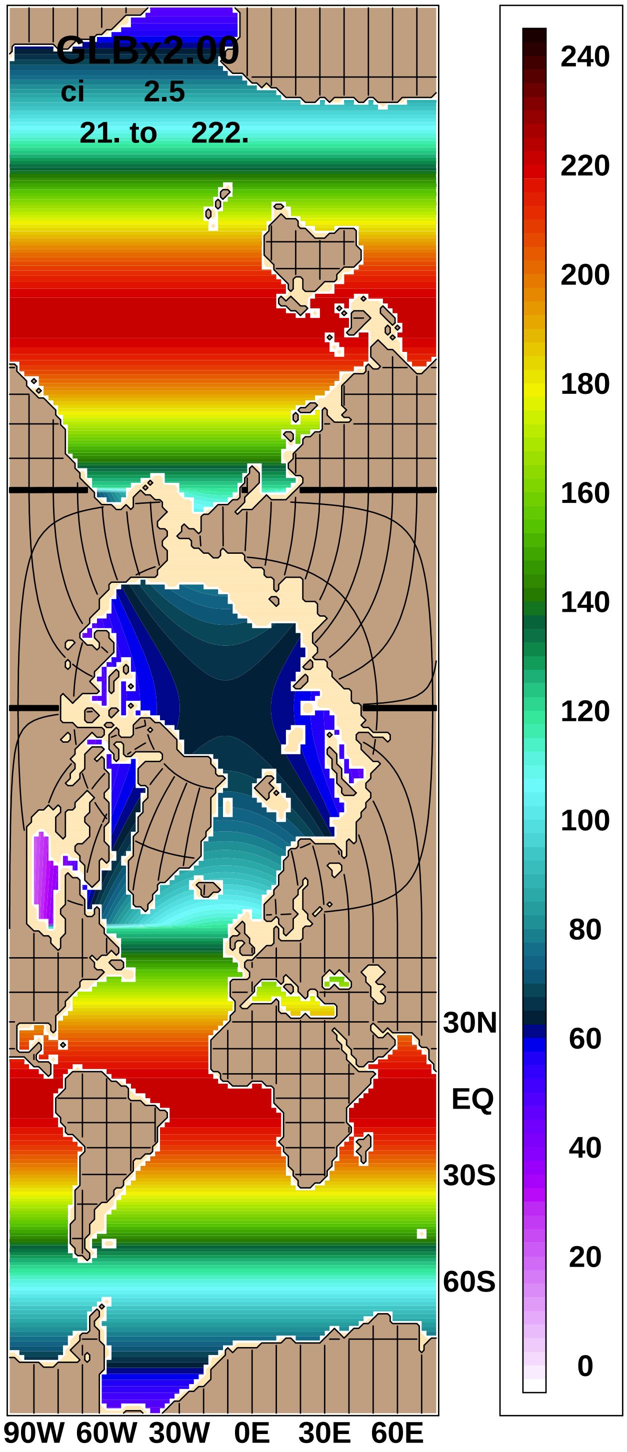
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90W 60W 30W 0E 30E 60E

WISHLIST FOR HYCOM (I)

- Fully region-independent
  - Compile once, run on any region and any number of processors
- Spatially varying iso-pycnal layer target densities
- Alternative Mixed Layer models (GISS, ...)
- Support for data assimilation
- Within HYCOM:
  - Drifters
  - Moored buoy sampling
  - Transport section sampling
- Comprehensive tracer support
  - Within HYCOM and off-line
  - In z-space?
- Coupler support
  - Alternative ice models (PIPS3, ...)
  - Coupled air-ocean-ice
  - Bio-geochemical/ecosystem model
  - Asynchronous I/O
  - Which coupler(s)?

WISHLIST FOR HYCOM (II)

- Archive to archive conversion
  - for diagnostics and for nesting
    - general horizonal re-mapping
    - general vertical re-mapping
- Bathymetry generation and editing
- Grid generation and editing
- Improved wind plotting/diagnostics
- Finalize
  - User’s Manual (the algorithms and code)
  - User’s Guide (how to run HYCOM)

WISHLIST FOR HYCOM (III)

- Improved/Alternative hybrid remapping (hybgen)?
- Improved/Alternative advection (tsadvc)?
- Alternative free surface formulation?
  - Currently assume free surface is a small fraction of the total depth
    - Does this work for coastal domains?
- Bottom boundary layer in KPP?
- Atmospheric pressure forcing?
- Tidal forcing?
- Rivers (and surface E-P) as mass exchange?