Tuning and Validating HYCOM's KPP Mixed-Layer

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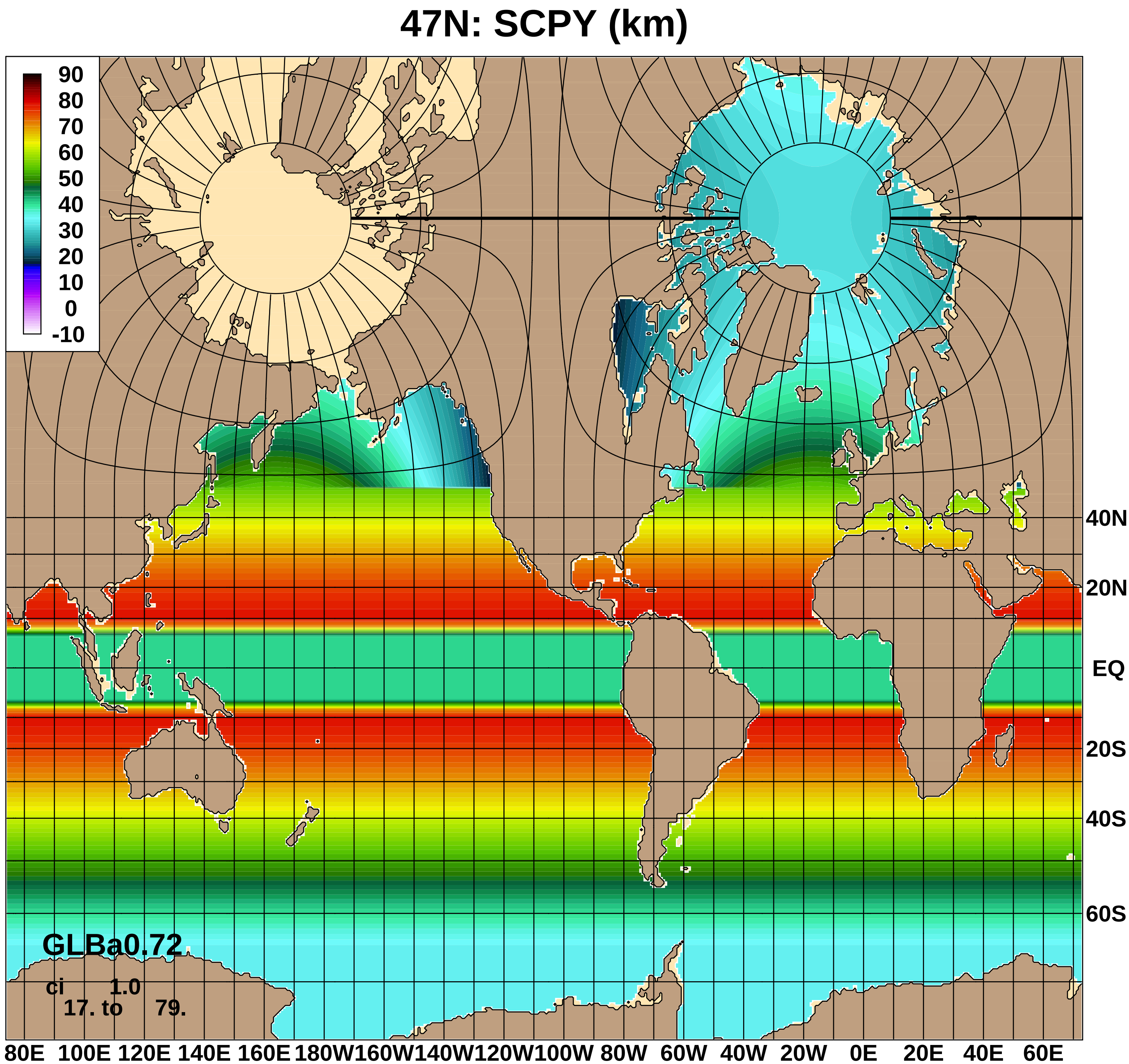
- Long-term Global HYCOM Objective
  - To depict and predict the 3D global ocean state at fine resolution (0.08° on the equator, $\sim$7 km at mid-latitudes)

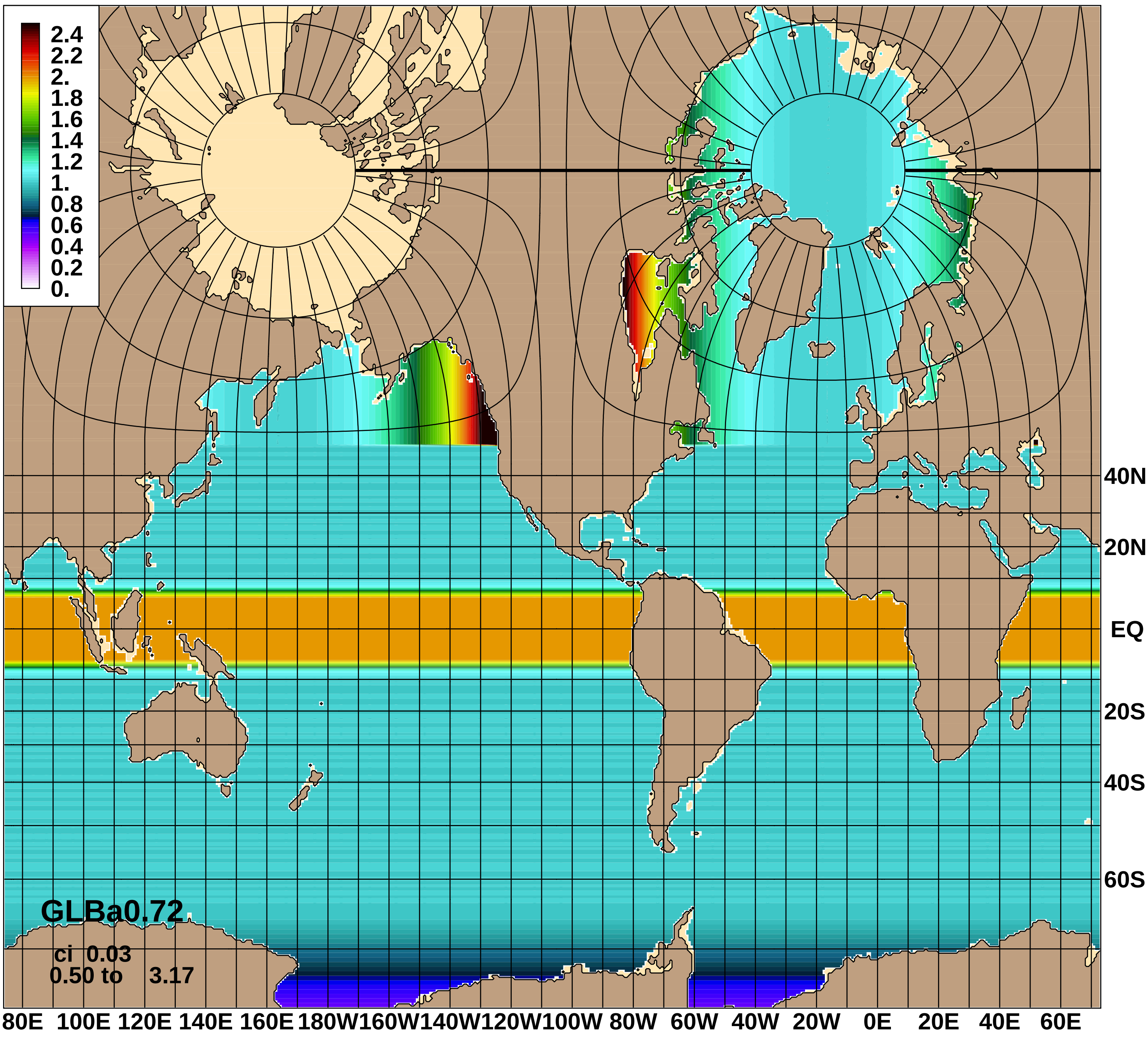
- Strategy
  - Begin with 0.72° resolution global HYCOM and optimize the KPP mixed layer performance (the subject of this presentation)
  - Before the end of FY03, start running and development of 0.24° global HYCOM
  - Submitted DoD HPC Challenge proposal (FY04-06) to continue development at 0.24° and start 0.08° model development

0.72 degree Global Domain

- Pan-Am Global Grid
  - 0.72 degree equatorial Mercator 78S-47N
  - Arctic bi-polar patch above 47N
    - Low resolution global had patch at 59N
    - Can’t include Hudson Bay
  - Double latitudinal resolution near the equator
  - Halve latitudinal resolution in Antarctic
- Coastline at 50m isobath
  - Closed Bering Strait
  - No Sigma (terrain-following) vertical coordinate
- Same 26-layers as 0.08 degree Atlantic
- First Z-level 3 m, increases 1.125x up to 12 m


47N: SCPY (km)
90
80
70
60
50
40
30
20
10
0
-10
40N
20N
EQ
20S
40S
60S
GLBa0.72
ci 1.0
17. to 79.
80E
100E
120E
140E
160E
180W
160W
140W
120W
100W
80W
60W
40W
20W
0E
20E
40E
60E

47N: Grid Aspect Ratio (SCPX/SCPY)



0.72 degree Global Standard Configuration

- KPP mixed layer
- Energy-Loan ice model
- Sigma-theta (some Sigma-2 runs, not discussed here)
- Horizontal diffusion chosen to suppress eddies
- Initialize from Levitus
- ECMWF Reanalysis monthly mean forcing
    - Plus 6-hrly wind anomalies from sep94-sep95
- Annual mean of 10 largest rivers via precip bogus
- Strong relaxation to monthly Levitus SSS
    - Necessary to prevent SSS drift
- Weak relaxation to monthly Levitus SST
    - Parameterizes SST’s effect on longwave radiation

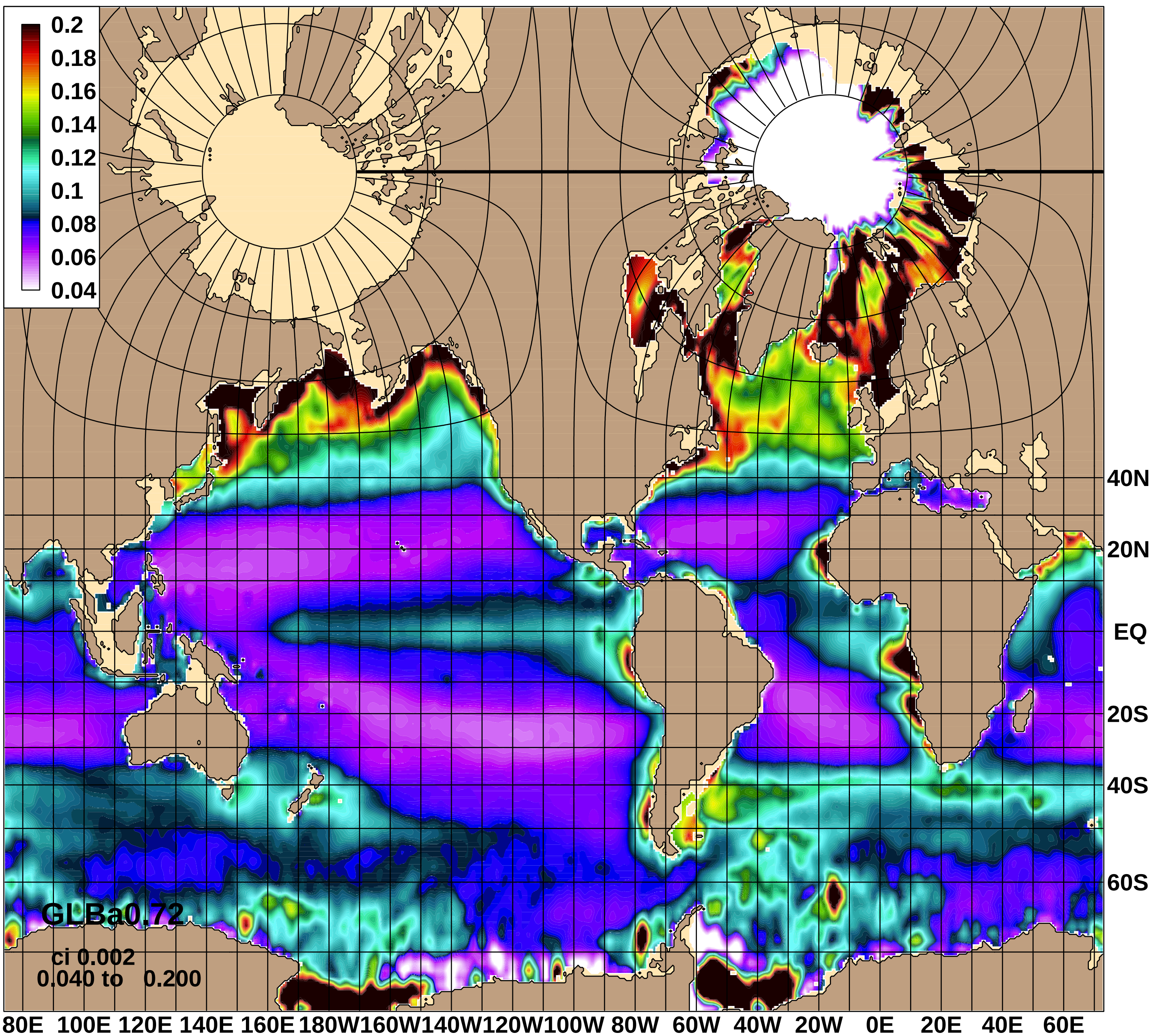
Longwave Radiation and SST

- Longwave Radiation is sum of:
  - Upward blackbody longwave radiation
    - $Q_{bb} = -0.98\,(5.67 \times 10^{-8})\,(T_s + 273.16)^4$
  - Downward atmospheric longwave flux
    - Highly dependent on cloudiness
    - Unknown dependence on SST (assume independent)
- If longwave was calculated using a SST of T_{so}:
  - $Q_{lw}(T_s) = Q_{lw}(T_{so}) + Q_{bb}(T_s) - Q_{bb}(T_{so})$
  - $Q_{lw}(T_s) = Q_{lw}(T_{so}) + Q'_{bb}\,(T_s - T_{so})$
  - $Q'_{bb} = -0.98\,(5.67 \times 10^{-8})\,4\,(T_s + 273.16)^3$
- Or, approximately (in W/m^2):
  - $Q'_{bb} = -4.506 - 0.0554\,T_s$
- So, $-5.3W/m^2/degC$ is a good longwave correction
  - Equivalent to 3.5 m reference thickness and 30 day e-folding SST relaxation
  - 10x weaker than typically SSS relaxation
- Ocean Model Intercomparison Project includes $(Q_{bb}(T_s) - Q_{bb}(T_{so}))$ as a longwave correction

Variable Turbidity

- Penetrating solar (shortwave) radiation is important for accurate SST
- HYCOM parameterizes turbidity via a “two band” version of Jerlov water types
  - One of 5 classes, red and blue bands
  - Same everywhere in time and space
- NLOM used “single band” kPAR turbidity
  - Photosynthetically Available Radiation
  - kPAR from SeaWIFS k490
  - monthly climatological fields
- Single band approach only OK for bulk mixed layer
- Added two band Jerlov-like kPAR scheme
  - kPAR isn’t a good fit to Jerlov
  - Much better than single class everywhere
- Need a better scheme:
  - 3-band based on chlorophyll (Morel & Antoine, 1994)?
  - Jerlov-like based on k490?

Annual SeaWiFS KPAR



SST Metrics I

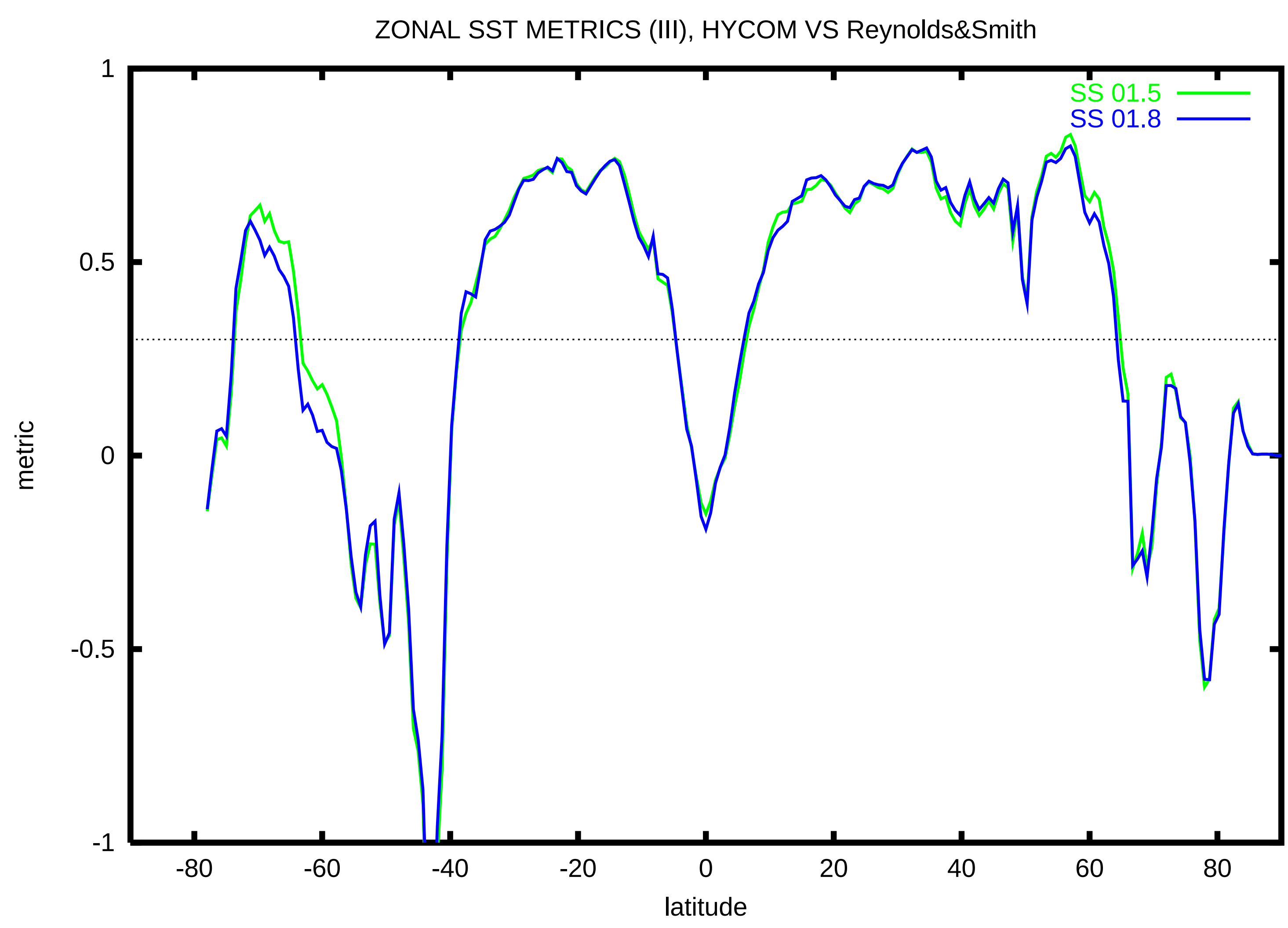
- Run for 5 years and form monthly means
  - May not be long enough
  - Length of run vs confidence in results
  - Takes two days on 64 IBM POWER4 cpus
- Compare monthly SST to Reynolds and Smith (R&S) climatology
  - Monthly anomalies
  - Annual mean difference
  - RMS difference
  - Correlation Coefficient
  - Skill Score
    - Correlation squared - Unconditional Bias - Conditional Bias
    - Maximum is 1, but minium is -infinity
    - Measure of error w.r.t. seasonal cycle (i.e. w.r.t. standard deviation)
    - Use a minimum of 1 degC for standard deviation
      - Still get poor skill scores near equator

SST Metrics II

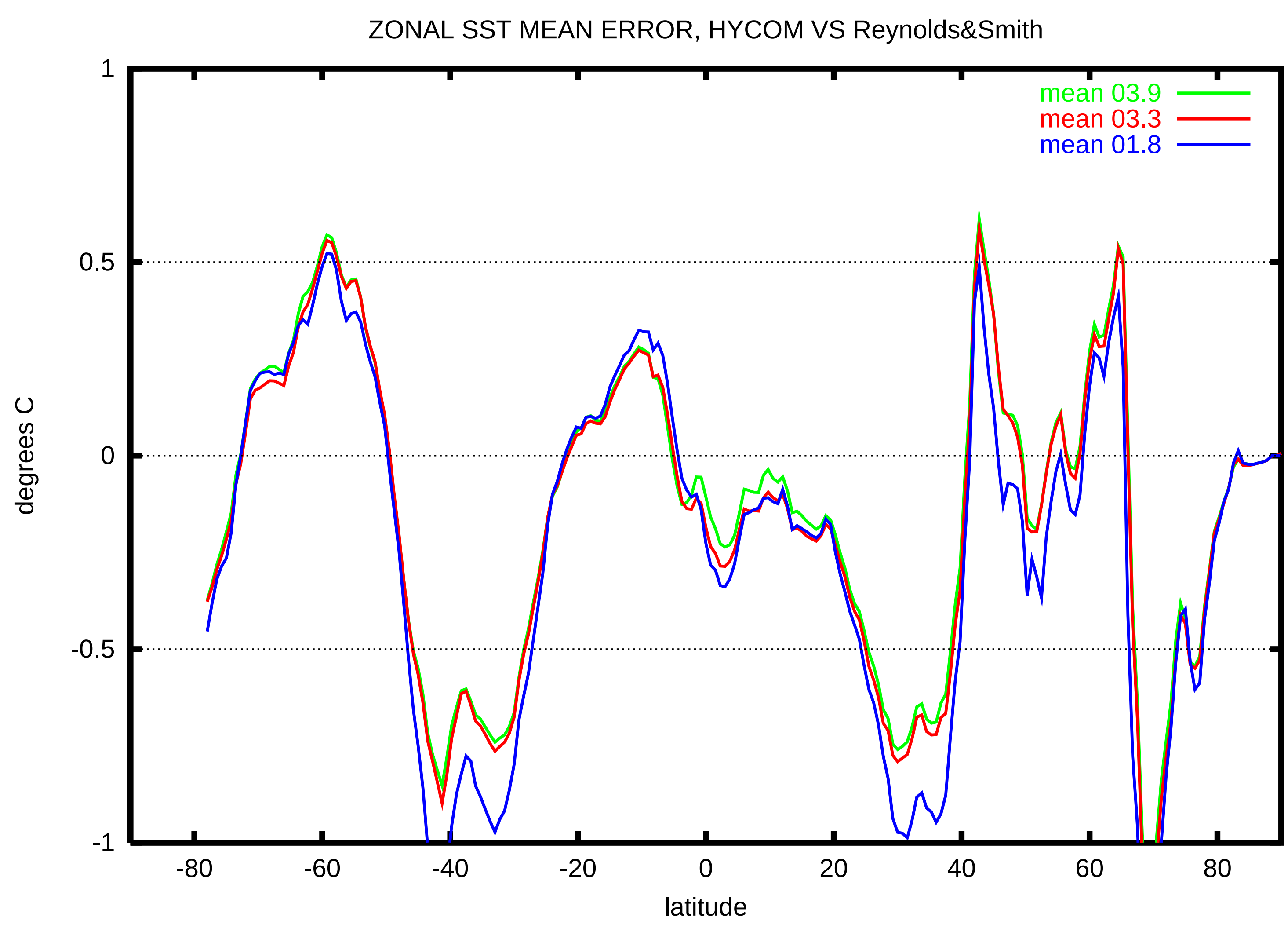
- Purpose of comparison is to find “good enough” configuration
  - Assume that “skill” on climatological forcing is maintained on interannual forcing
  - Is monthly thermal climatological forcing enough?
  - NLOM experience suggests that this is OK, but can’t be certain until we run interannually with HYCOM
- Targets:
  - Annual mean error < 0.5 degC
  - Correlation Coefficient > 0.6
  - Skill Score > 0.3
- Use zonal averages to reduce amount of data
  - Average not necessarily best statistic
    - A few large negative skill scores can dominate the average
  - Same targets as for full field

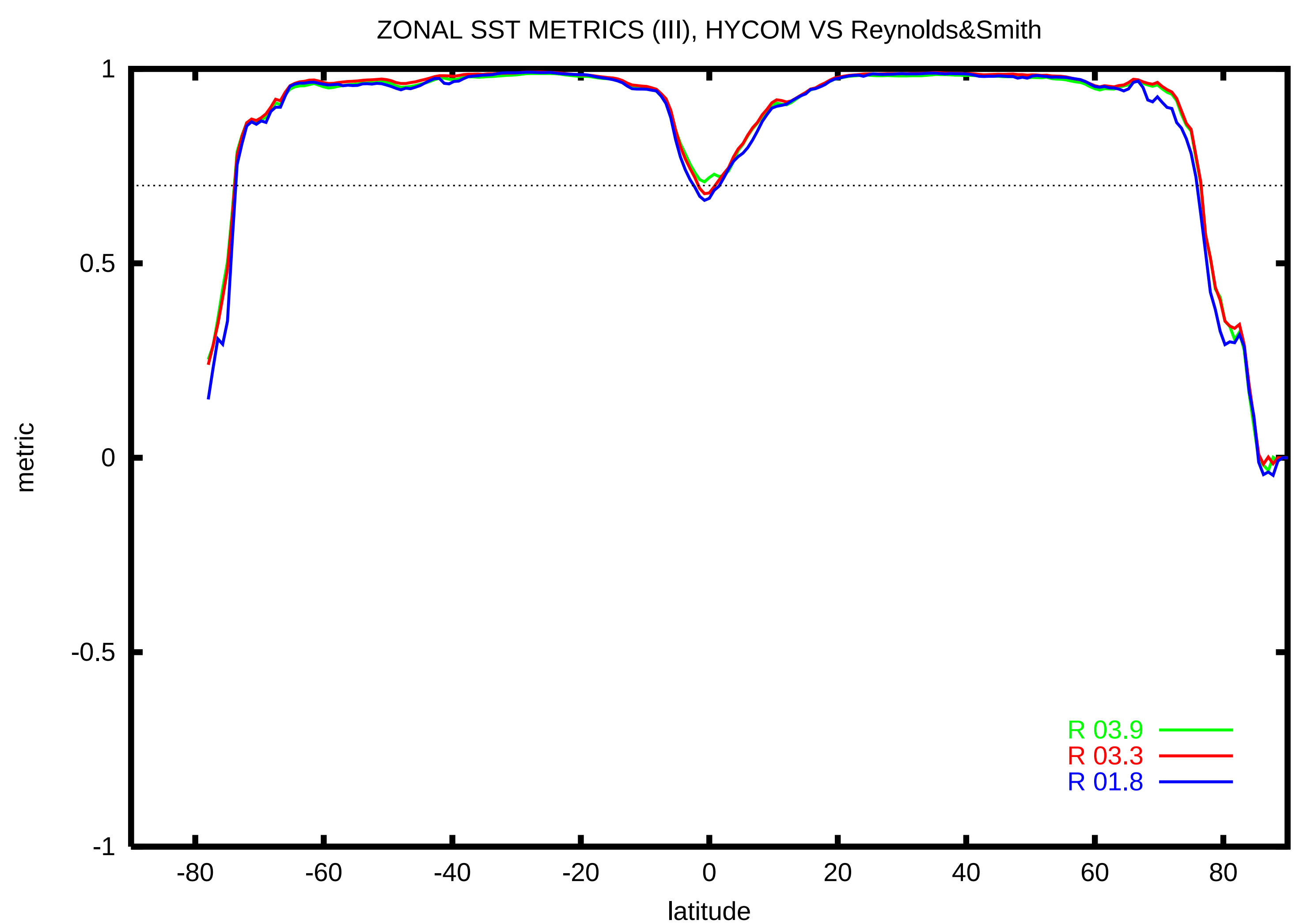
Simulation History

- Expt 1.5:
  - Standard KPP
  - Jerlov Ia everywhere
  - No rivers
  - No SST relaxation
- Expt 1.8:
  - Monthly kPAR turbidity
  - Annual rivers
- Expt 3.3:
  - “Longwave” SST relaxation
- Expt 3.9:
  - Modified KPP shear instability
- Expt 4.2:
  - Twin of 3.3 (same winds)
  - FNMOC thermal forcing (average 98-01)

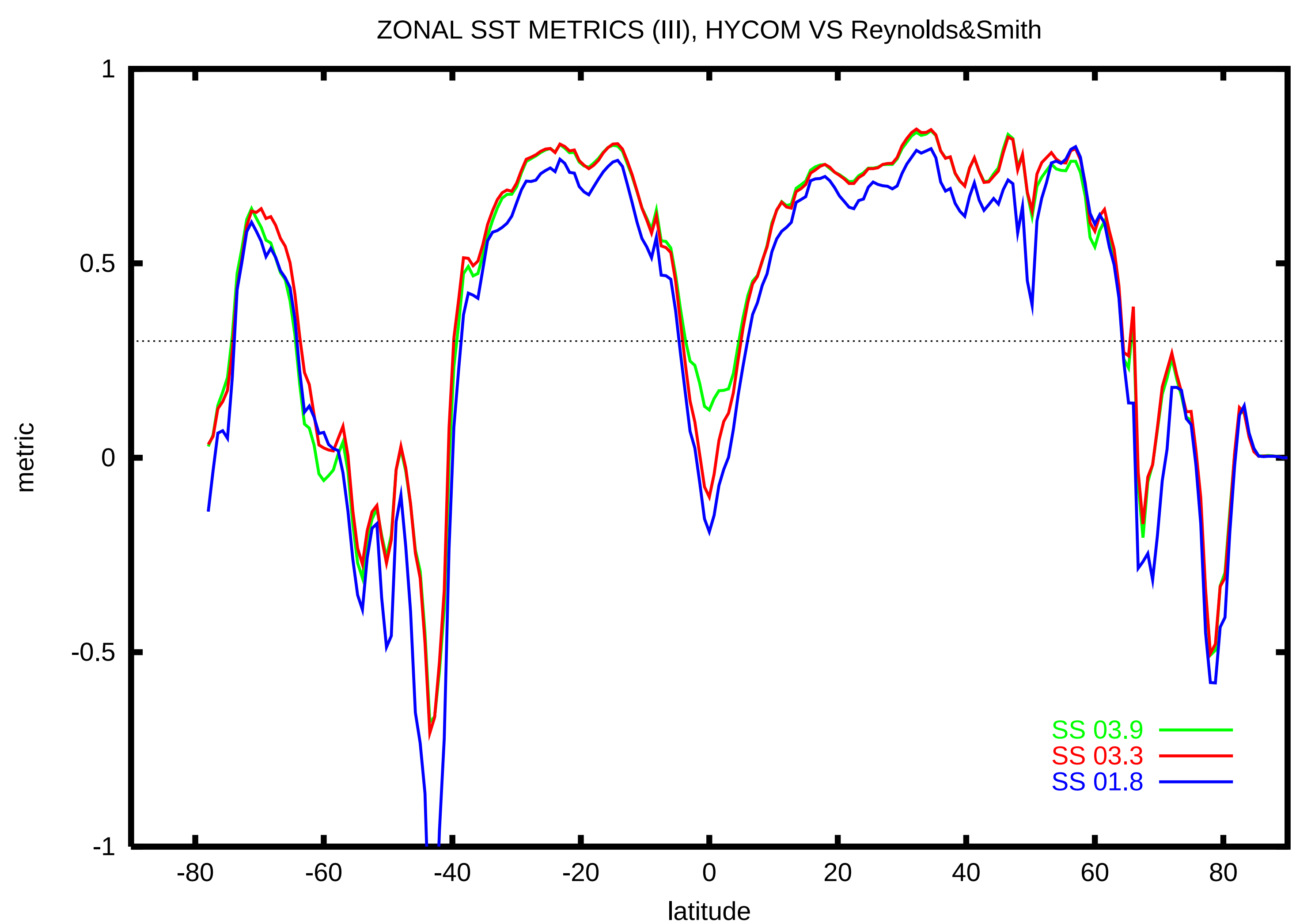


ZONAL SST METRICS (III), HYCOM VS Reynolds&Smith
SS 01.5
SS 01.8
metric
1
0.5
0
-0.5
-1
-80
-60
-40
-20
0
20
40
60
80
latitude

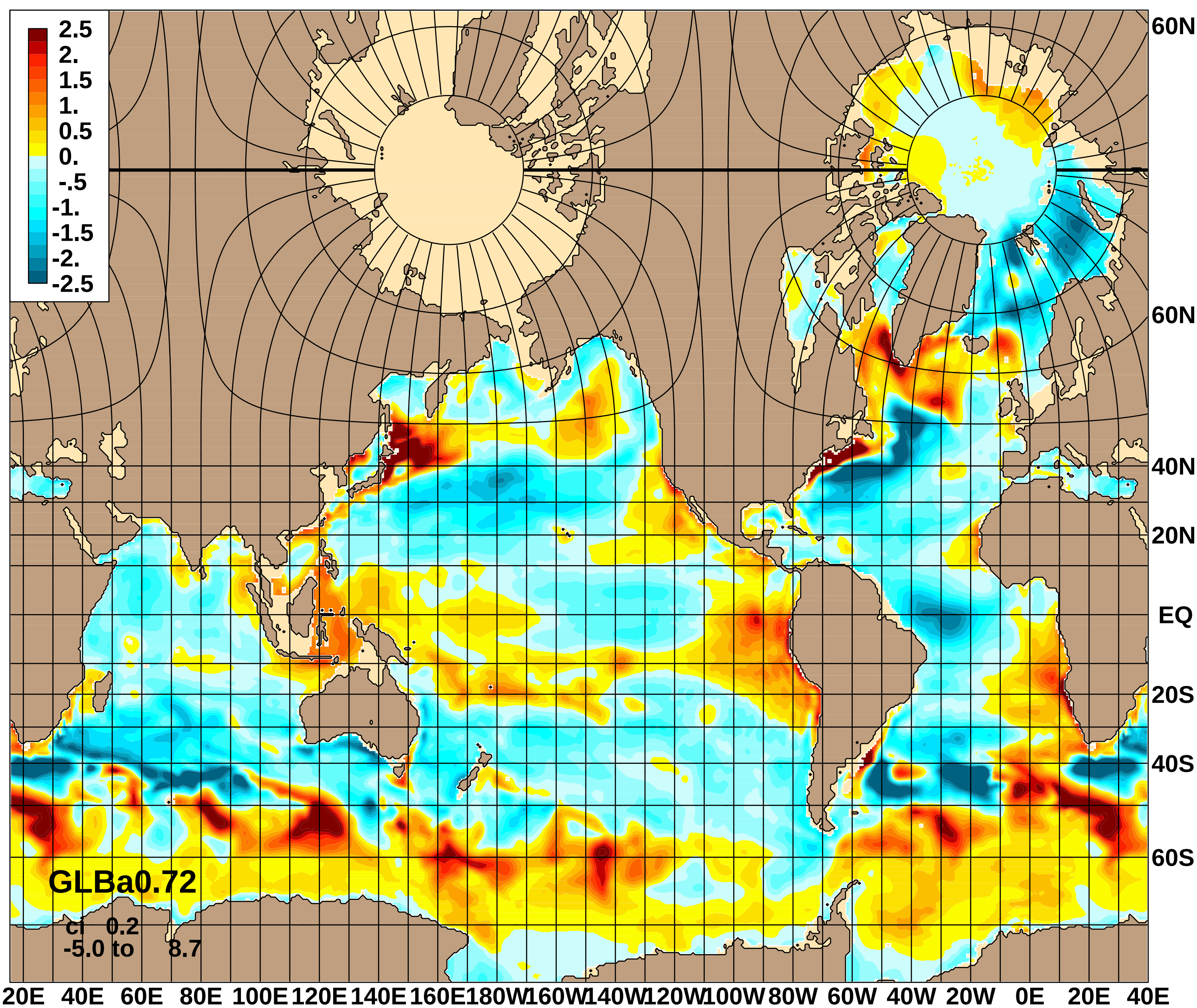

ZONAL SST MEAN ERROR, HYCOM VS Reynolds&Smith
mean 03.9
mean 03.3
mean 01.8
degrees C
1
0.5
0
-0.5
-1
-80
-60
-40
-20
0
20
40
60
80
latitude



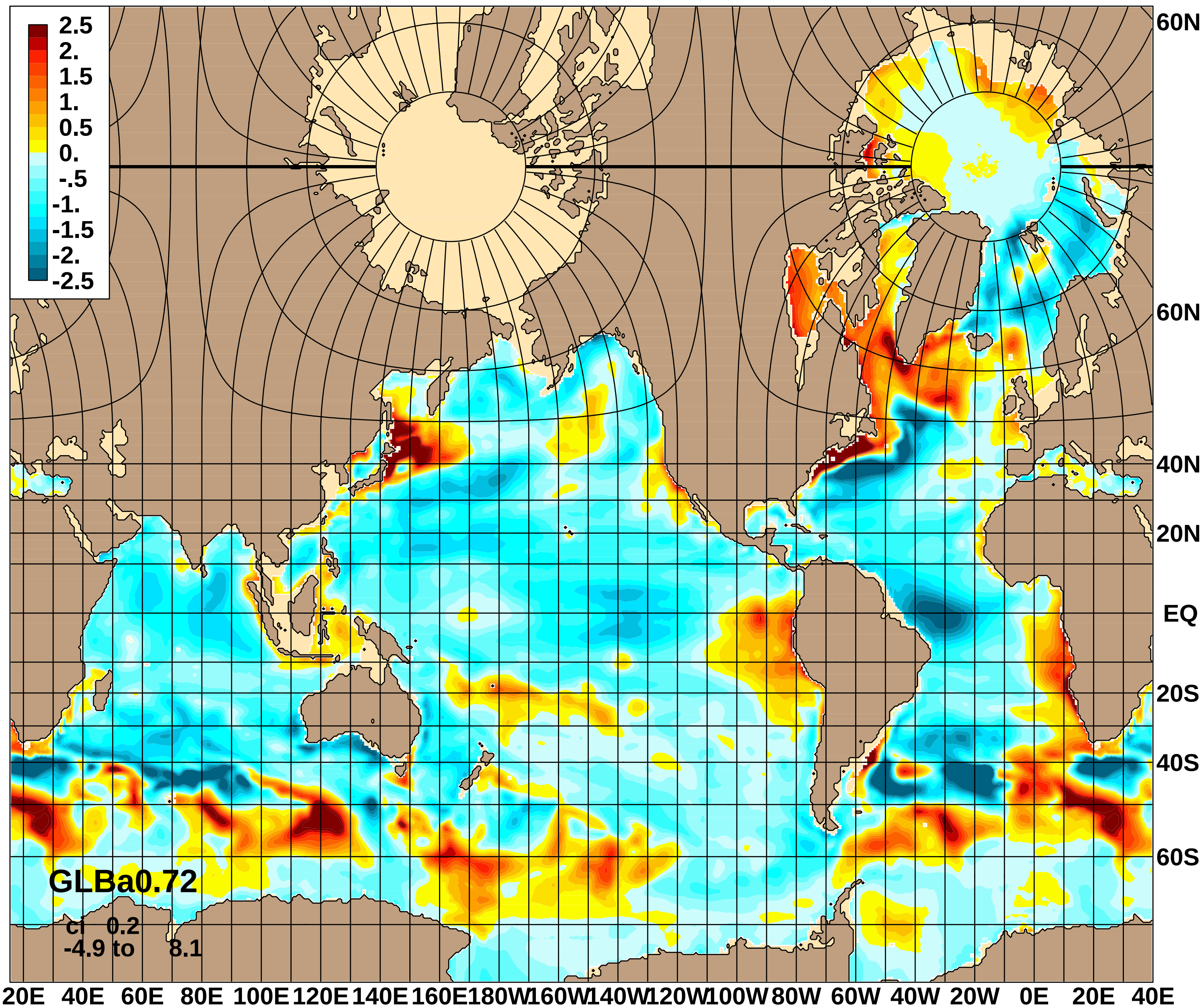
ZONAL SST METRICS (III), HYCOM VS Reynolds&Smith
metric
latitude
1
0.5
0
-0.5
-1
-80
-60
-40
-20
0
20
40
60
80
R 03.9
R 03.3
R 01.8


ZONAL SST METRICS (III), HYCOM VS Reynolds&Smith
metric
1
0.5
0
-0.5
-1
-80
-60
-40
-20
0
20
40
60
80
latitude
SS 03.9
SS 03.3
SS 01.8

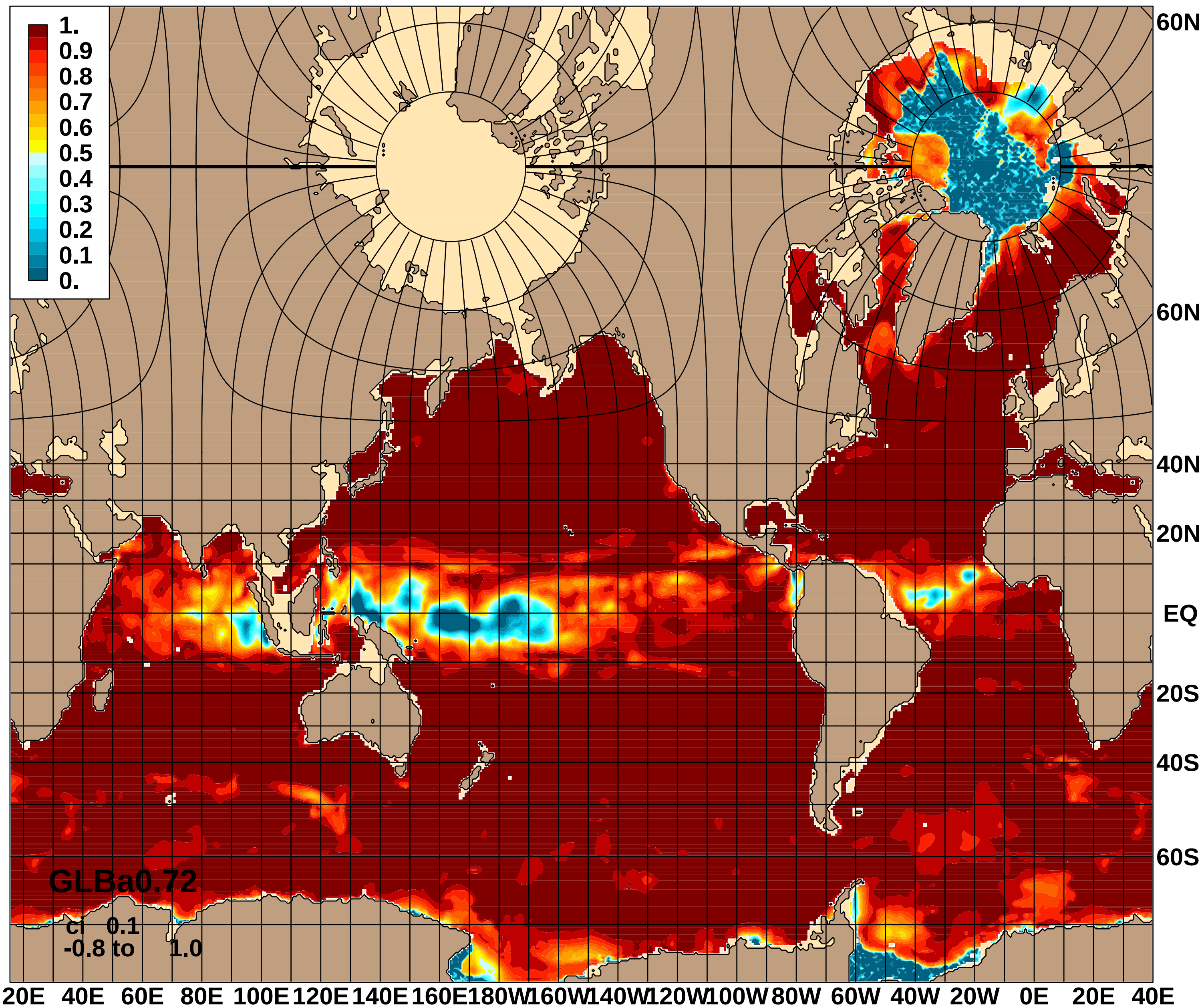
03.3 vs R&S SST: Mean Error



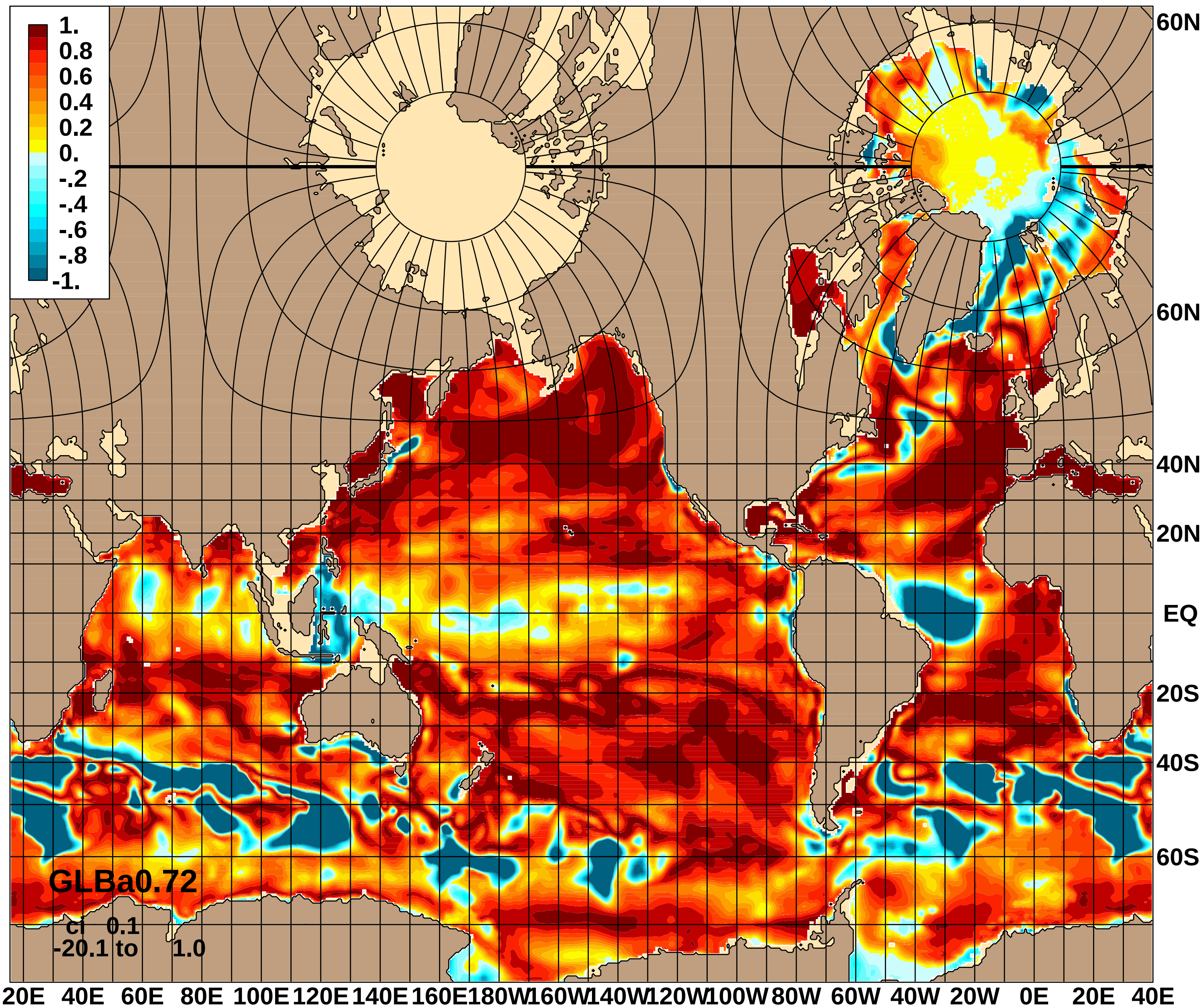
04.2 vs R&S SST: Mean Error



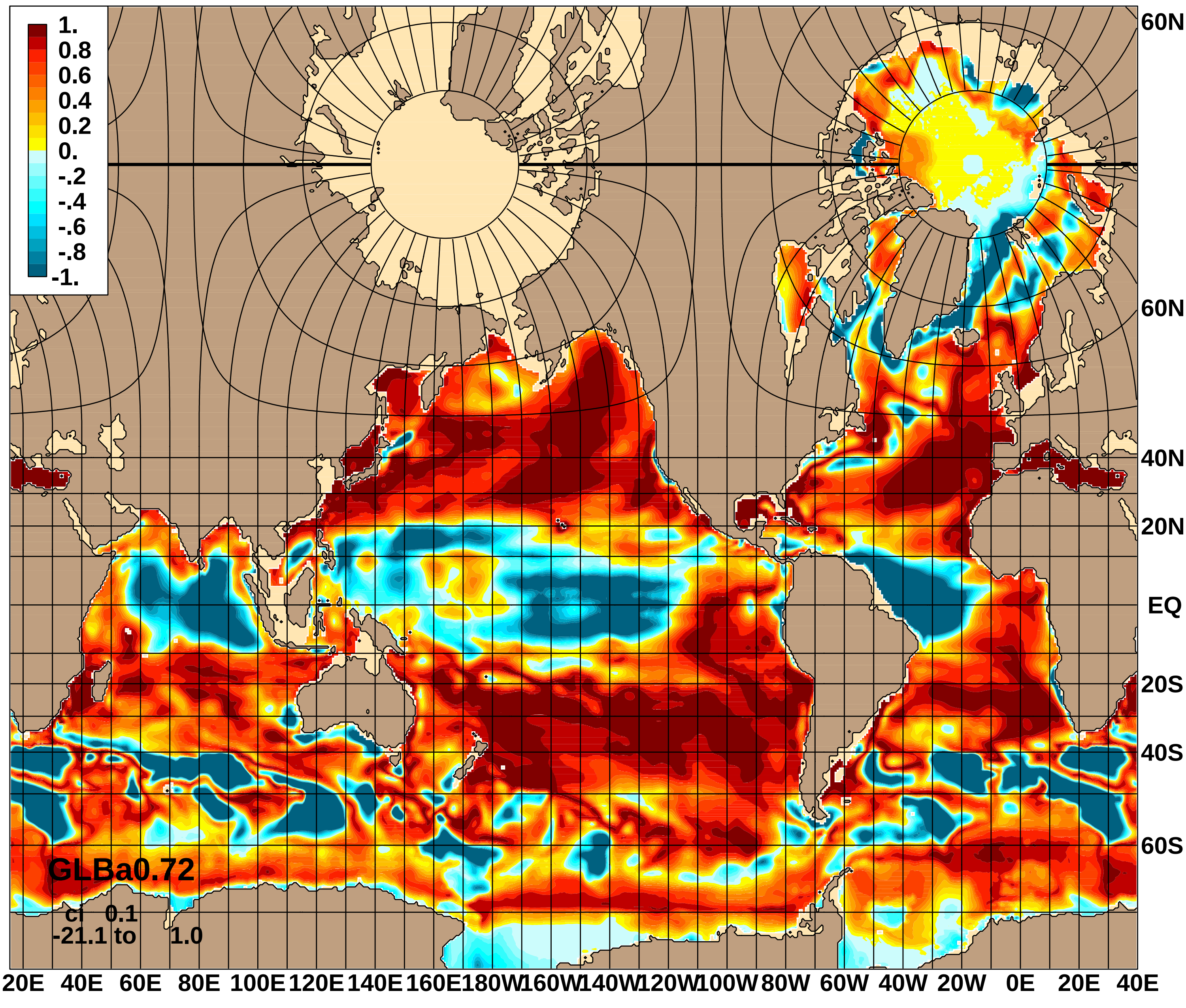
03.3 vs R&S SST: Correlation



03.3 vs R&S SST: Skill Score



04.2 vs R&S SST: Skill Score



Conclusions

- KPP is performing well in HYCOM
- Western Equatorial Atlantic a major trouble spot
  - Modifying KPP shear instability helps
  - More needs to be done
- In general, most of the SST error is in the annual mean
- Not yet clear how much is due to forcing and how much due to KPP