Newly Compiled and Gridded Seasonal Sea Surface T and S for the Atlantic Ocean at the Last Glacial Maximum

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Purpose:

Compile a *new* global, seasonal, and consistent SST and SSS data set for the last glacial, 23–18 ky BP

Data base:

Numerous SST reconstructions and oxygen isotope measurements from deep-sea sediment cores

Methods:

Variogram analysis and kriging, paleo-T-S-δ^{18}O Relations

Application:

Forcing and assessing numerical ocean and atmosphere models

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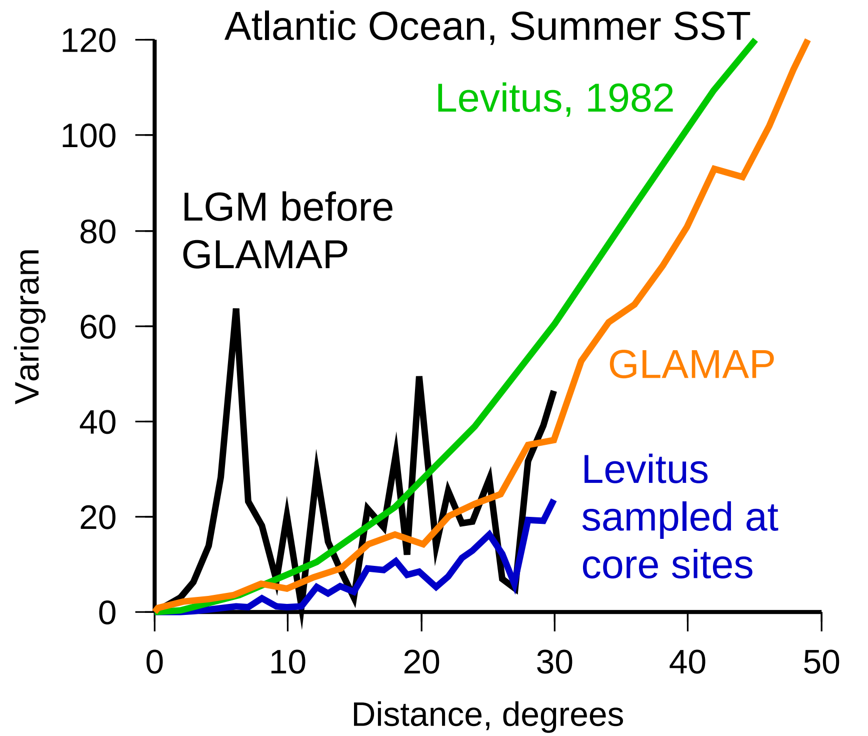
Motivation

Understand glacial climate — on its own and as a prerequisite for deglaciation

20 years after CLIMAP, the new GLAMAP (Glacial Atlantic Mapping and Prediction) effort provides considerably improved data sets:

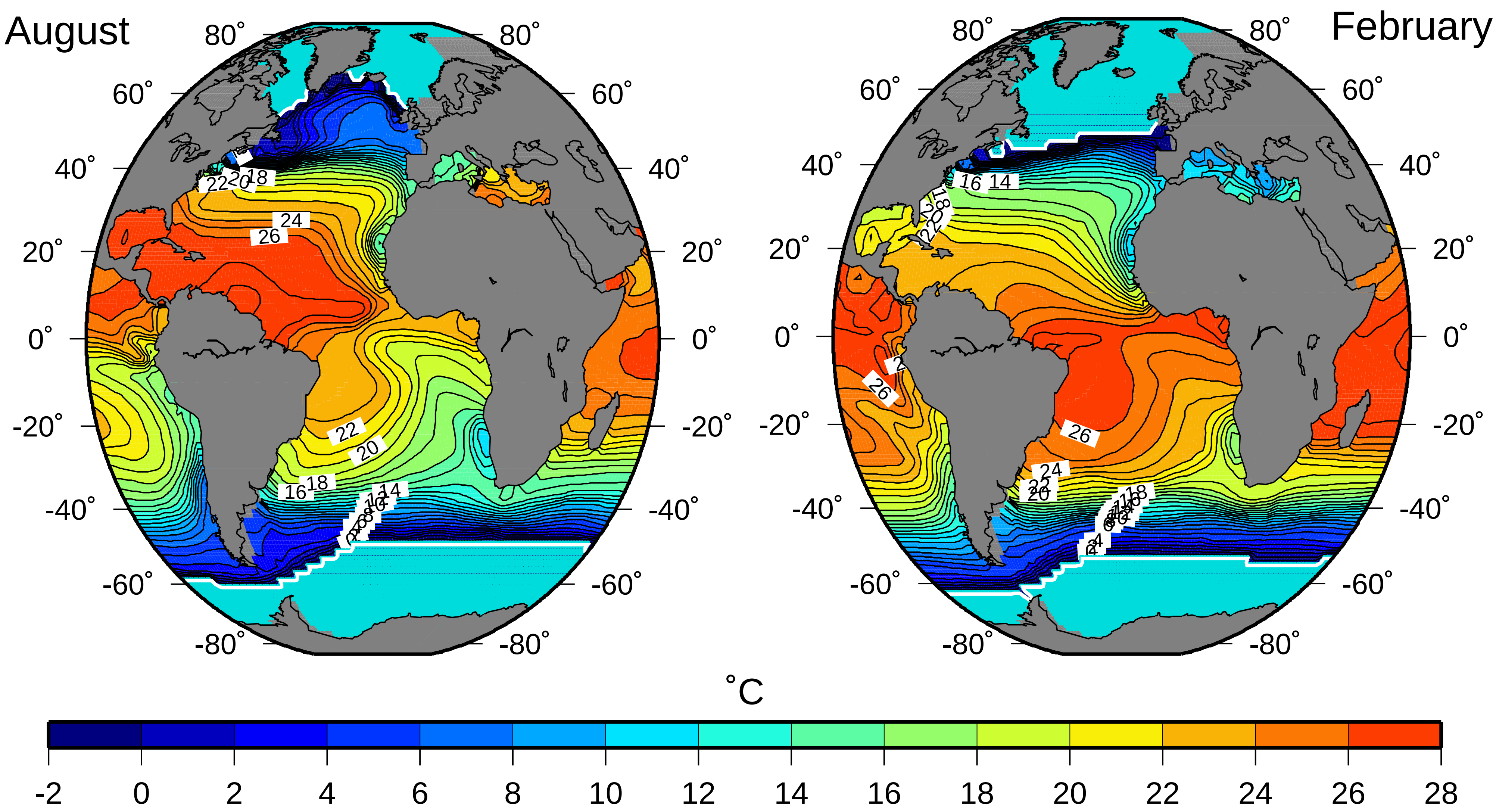


- unique time slice definition employed by contributing institutes
- new or refined seasonal SST estimates for the entire Atlantic Ocean
- increased sampling density
- supplemental information on seasonal ice covers in both hemispheres

New opportunity to construct consistent monthly SST and SSS maps for:

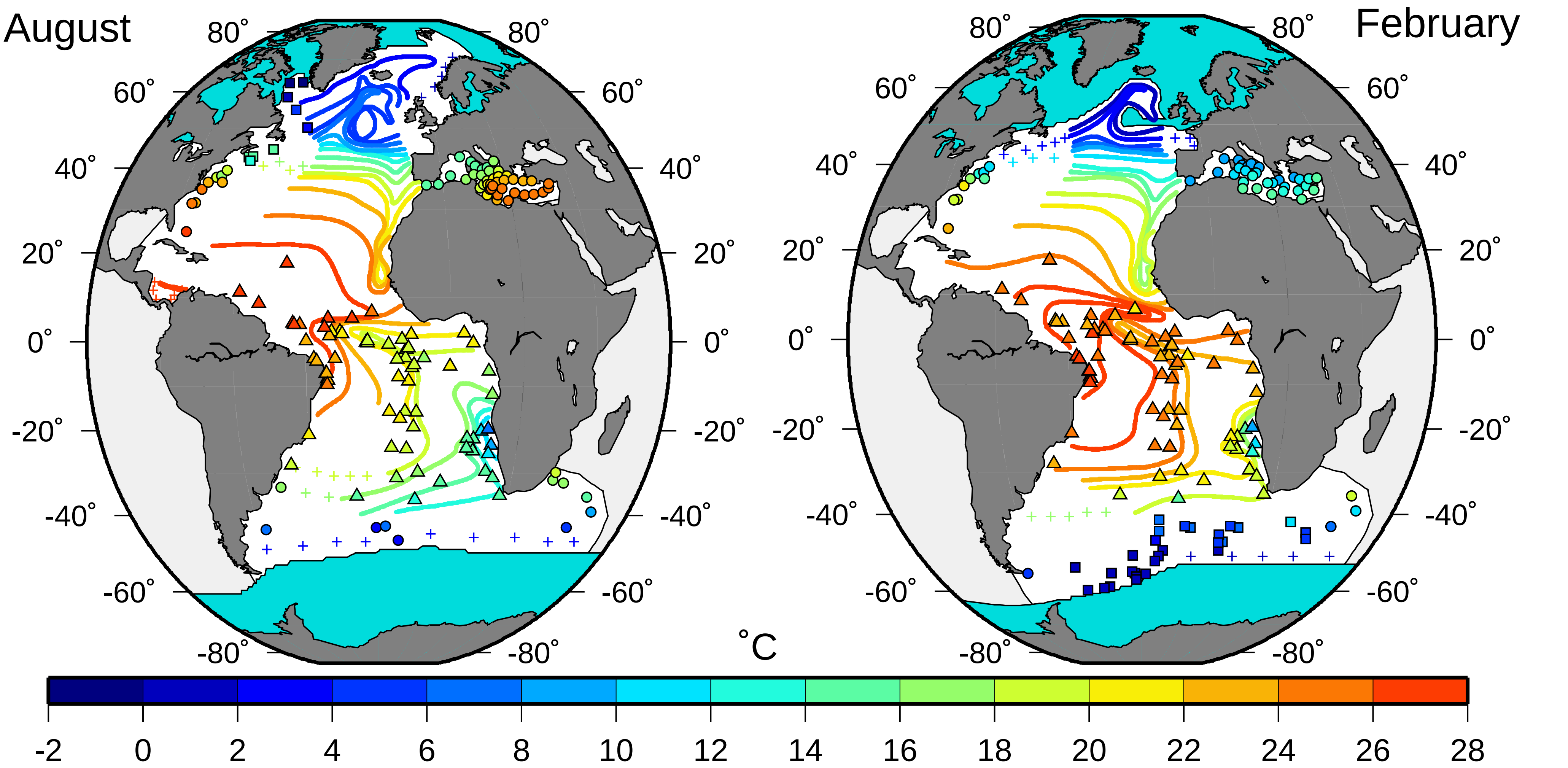
- driving ocean and atmosphere circulation models
- validating coupled models

Temperature: CLIMAP 1981



CLIMAP temperature source: NOAA Paleoclimatology Program / World Data Center

Temperature: Data Sources for 23–19 ky BP

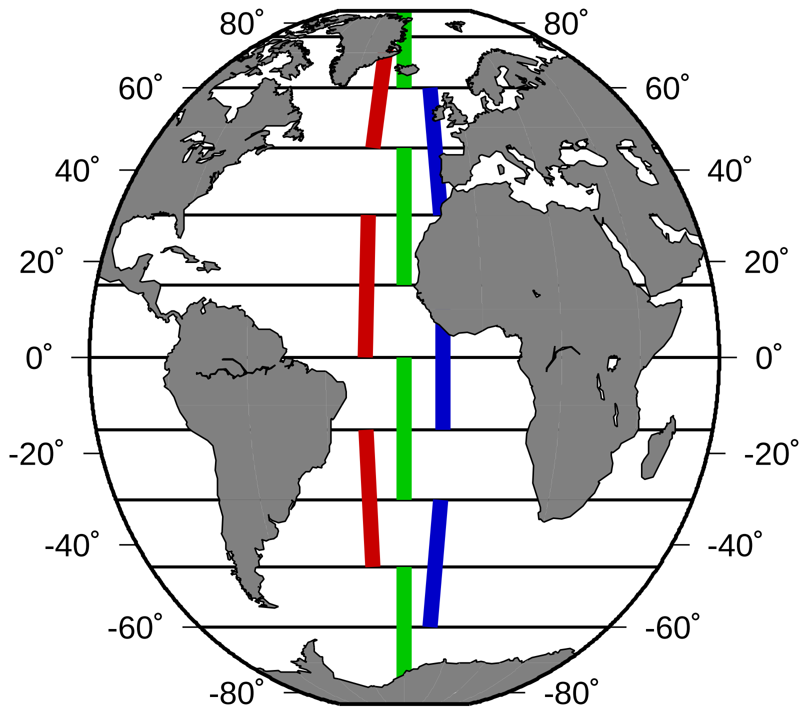


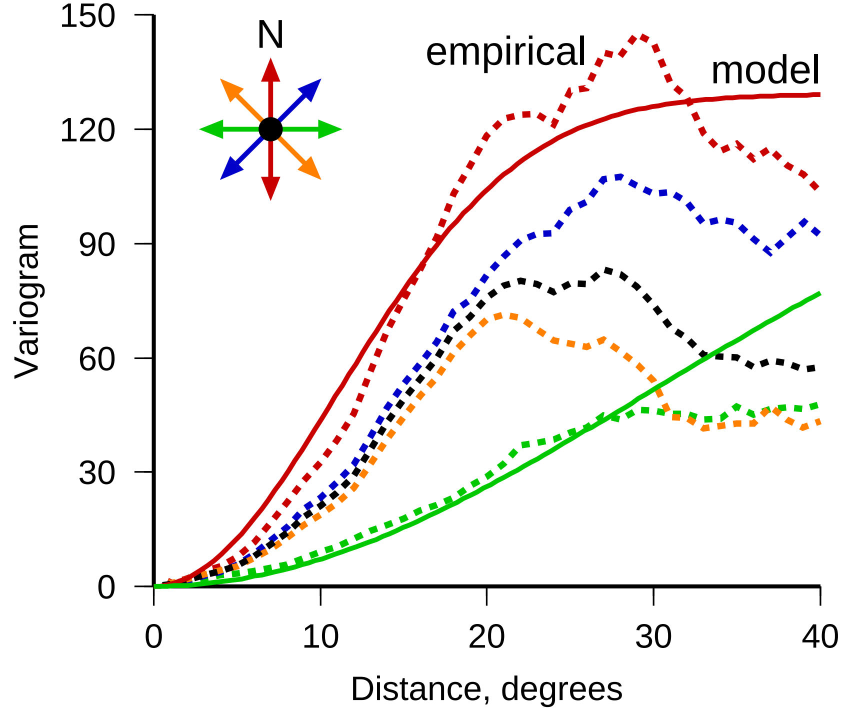
Isolines: Pflaumann et al. 2002. △: Niebler et al. 2002. □: De Vernal et al. 2000 (August), Gersonde et al. 2002 (February). ○: Prell 1985 (Atlantic), Bigg 1994 (Mediterranean). Ice cover: Pflaumann et al. 2002; De Vernal et al. 2000; Gersonde and Zielinski 2000. Grey shade: SST data taken from CLIMAP (1981). +: artificial tie points.

Temperature: Gridding Procedure

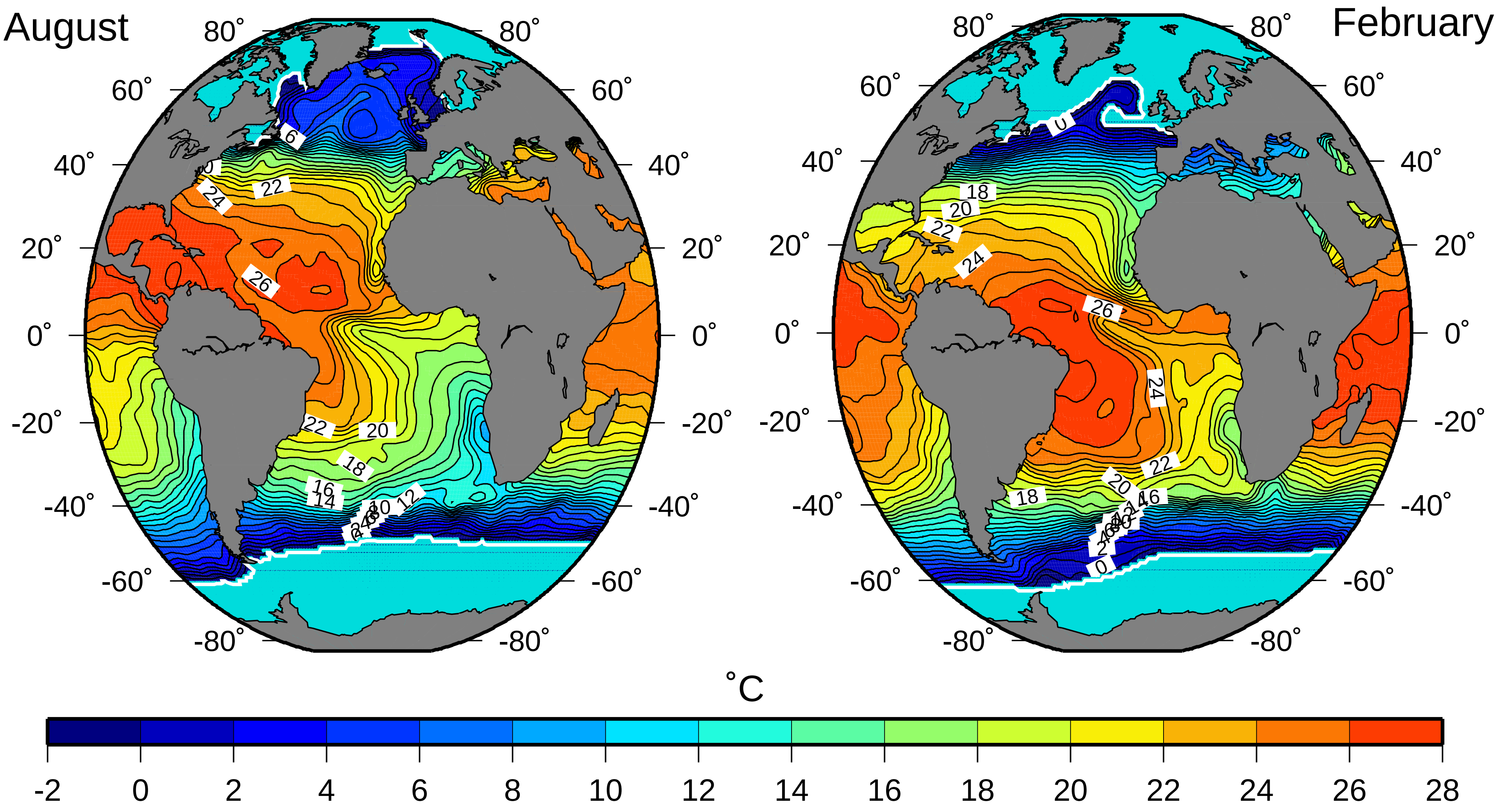
For each season. . .

- digitize isolines
- split complete set of core and isoline data into overlapping zonal belts 30° wide
- for each belt. . .
  - compute empirical directional variograms in spherical coordinates
  - fit variogram models
  - interpolate core and isoline data to a regular $1^\circ \times 1^\circ$ grid by kriging in spherical coordinates
- join belts to a new Atlantic-wide grid
- smoothly incorporate Atlantic data into the global CLIMAP SST fields

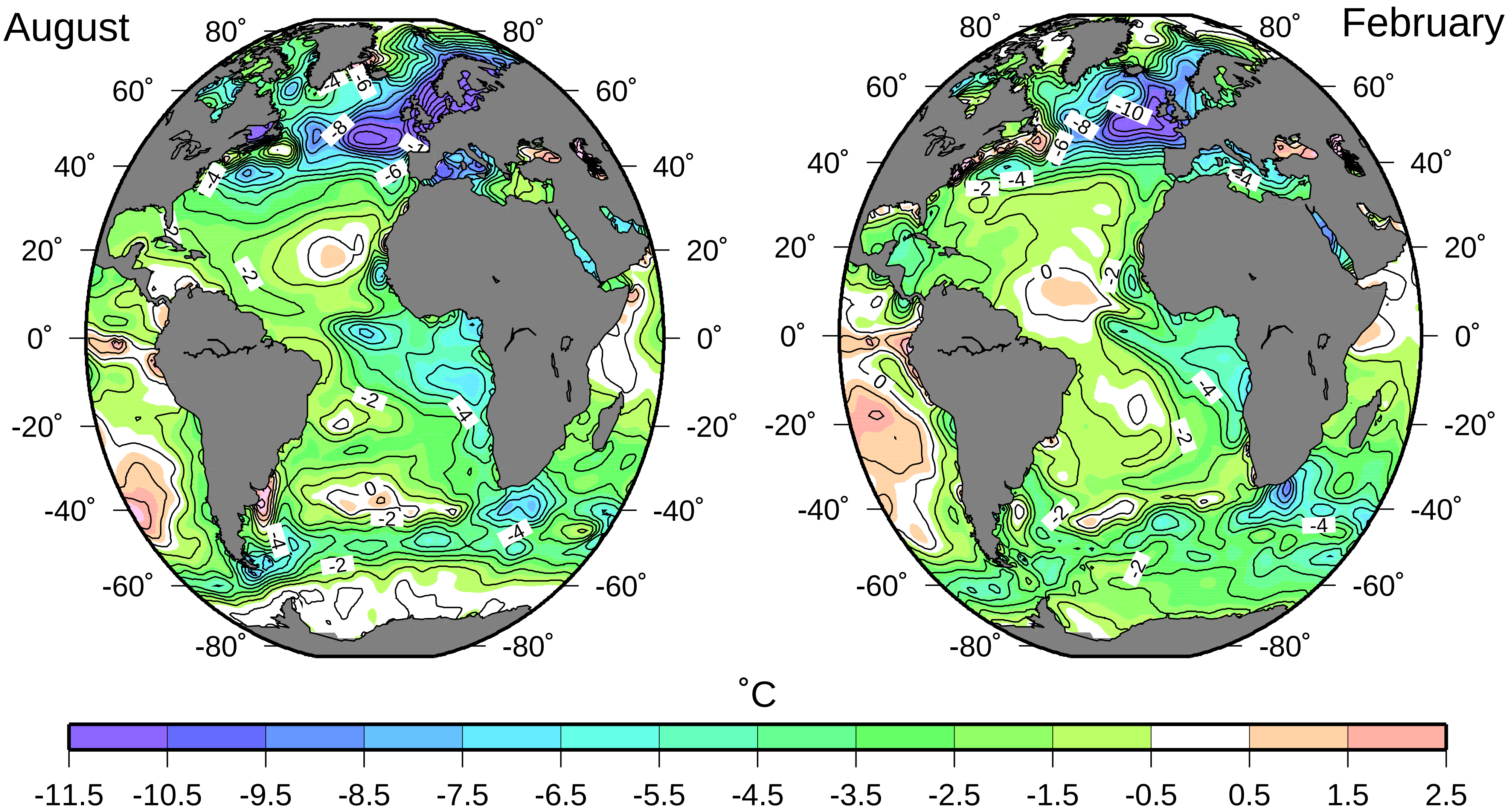




Temperature: Gridded Fields



Temperature: GLAMAP–Modern Anomaly

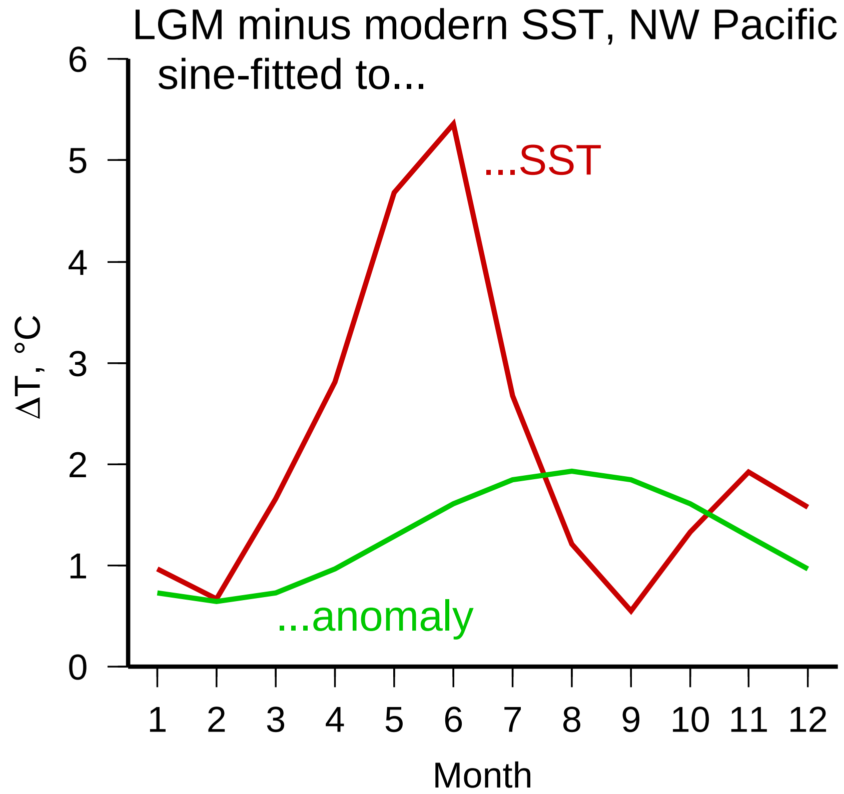


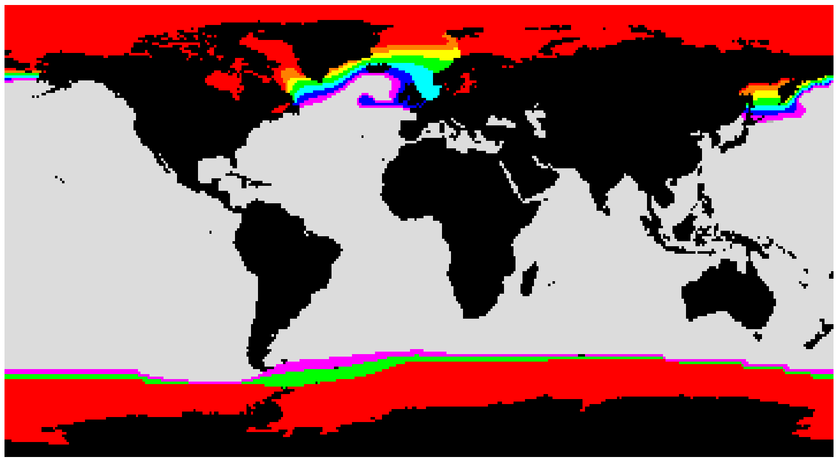
Modern temperature source: World Ocean Atlas 1998, 10 m depth.

Temperature: Seasonal Cycle

Directly sine-interpolating between the reconstructed February and August fields leads to local overshoots. Therefore, use the PMIP approach...

- compute August and January LGM minus modern anomalies
- construct monthly anomalies by sine-interpolation
- add monthly modern SSTs to obtain monthly glacial SSTs

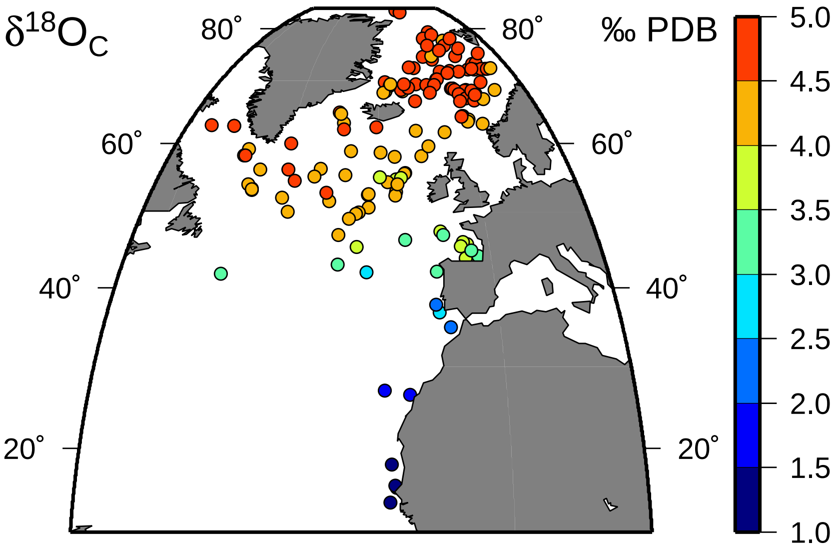




To complete...

- draw monthly ice edges from the reconstructed extremes
- set monthly SSTs to freezing point in the ice-covered regions

Salinity: $\delta^{18}O_C$, Planktic Foraminiferal Oxygen Isotope Data Base

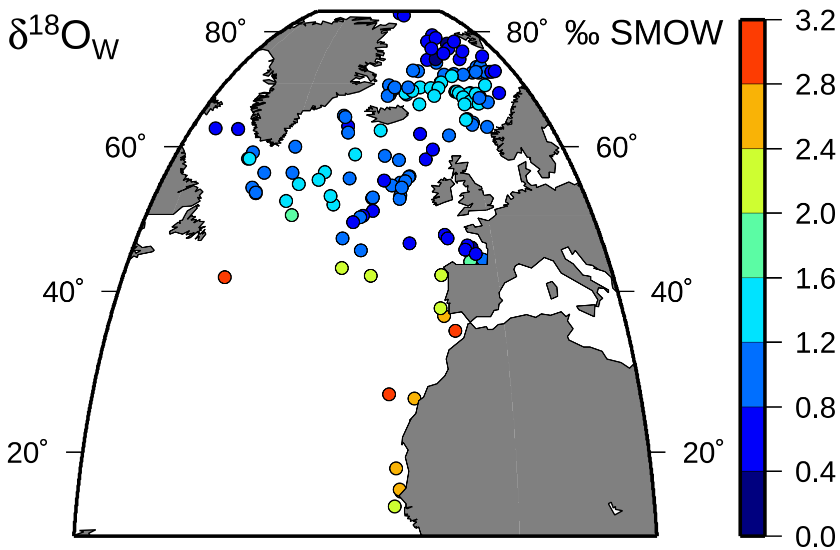


$\delta^{18}O_C$ Sources:

Bard et al. 1987
Duplessy et al. 1991, 1992
Jansen and Erlenkeuser 1985
Jansen and Veum 1990
Jones and Keigwin 1989
Jünger 1993
Keigwin and Boyle 1989
Kellogg et al. 1978
Köhler 1991
Lackschewitz 1991
Morris 1988
Ruddiman and Mcintyre 1981
Sarnthein et al. 1995
Veum et al. 1992
Vogelsang 1990
Weinelt 1993
Weinelt et al. 1996
Zahn et al. 1985

Compute $\delta^{18}O_W$, the water oxygen isotope ratio, from $\delta^{18}O_C$ and the sampled August SST using

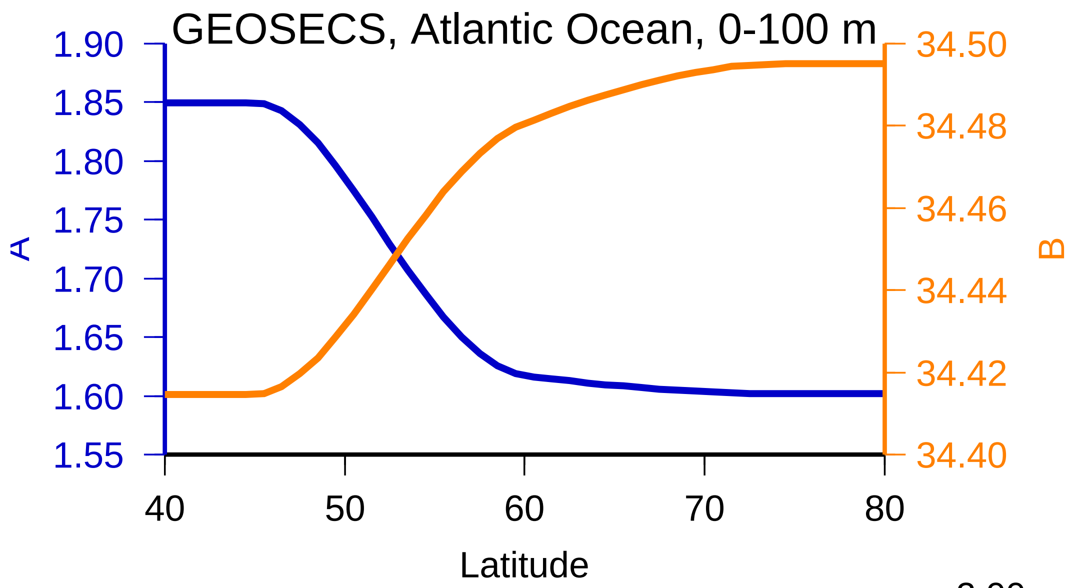
- the Epstein et al. (1953) paleotemperature equation:
  $$\delta^{18}O_W = \delta^{18}O_C - 21.63 + \sqrt{310.61 + 10T_C}$$
- species-dependent temperature corrections:
  N. pachyderma sin. (Weinelt 1993)
  $$T_C = SST - 2.5 \quad \text{if } SST < 4.5^\circ C$$
  $$T_C = 0.42\,SST + 0.39 \quad \text{if } SST > 4.5^\circ C$$
  G. bulloides (Duplessy et al. 1991)
  $$T_C = SST - 1$$

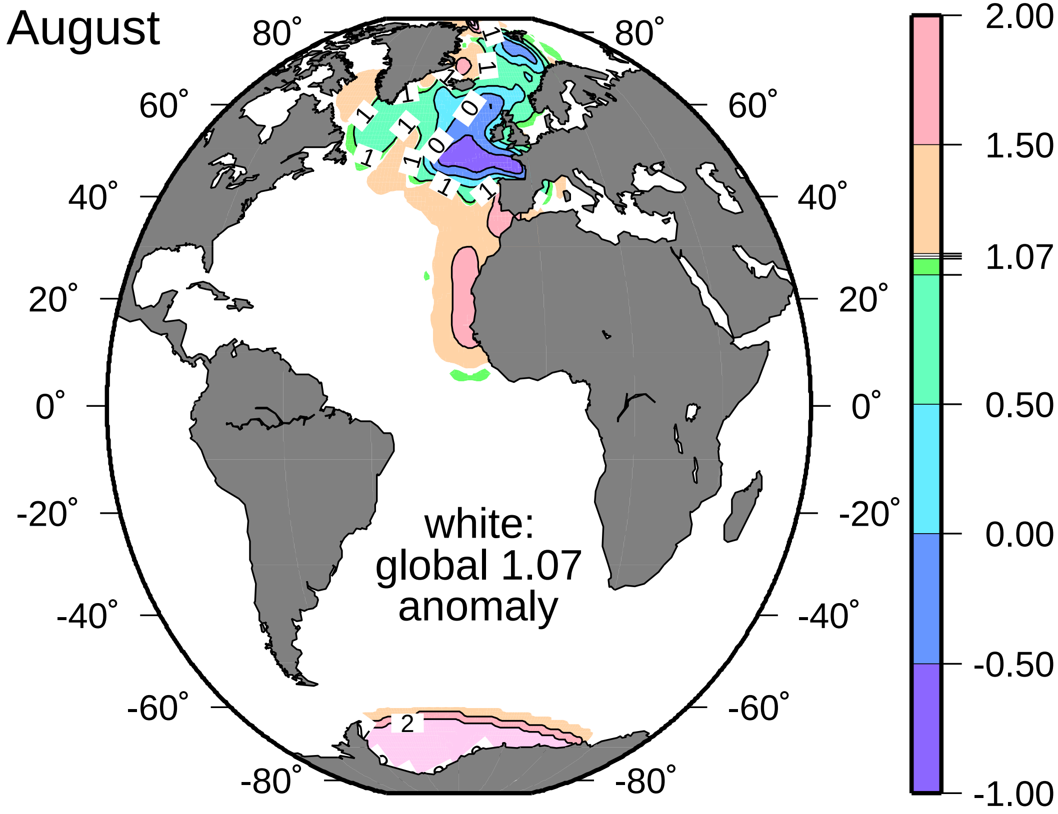


Salinity: LGM–Modern Anomaly

To estimate sea surface salinity...

- assume the modern S-$\delta^{18}O_W$ relation:
  $S = A \cdot \delta^{18}O_W + B$
- compute August salinity at the core locations from the glacial relation:
  $SSS = A \cdot (\delta^{18}O_W - \Delta_{ice}) + B + \Delta S_{\Delta h}$
  with $\Delta_{ice} = 1.2‰$ and $\Delta S_{\Delta h} = 1.07$
- from the World Ocean Atlas 1998 10 m salinity, compute the glacial minus modern anomaly, set to 1.07 over unsampled regions
- grid
- include the 0.5-1.0 Weddell Sea anomaly (Duplessy et al. 1996; Melles 1991)

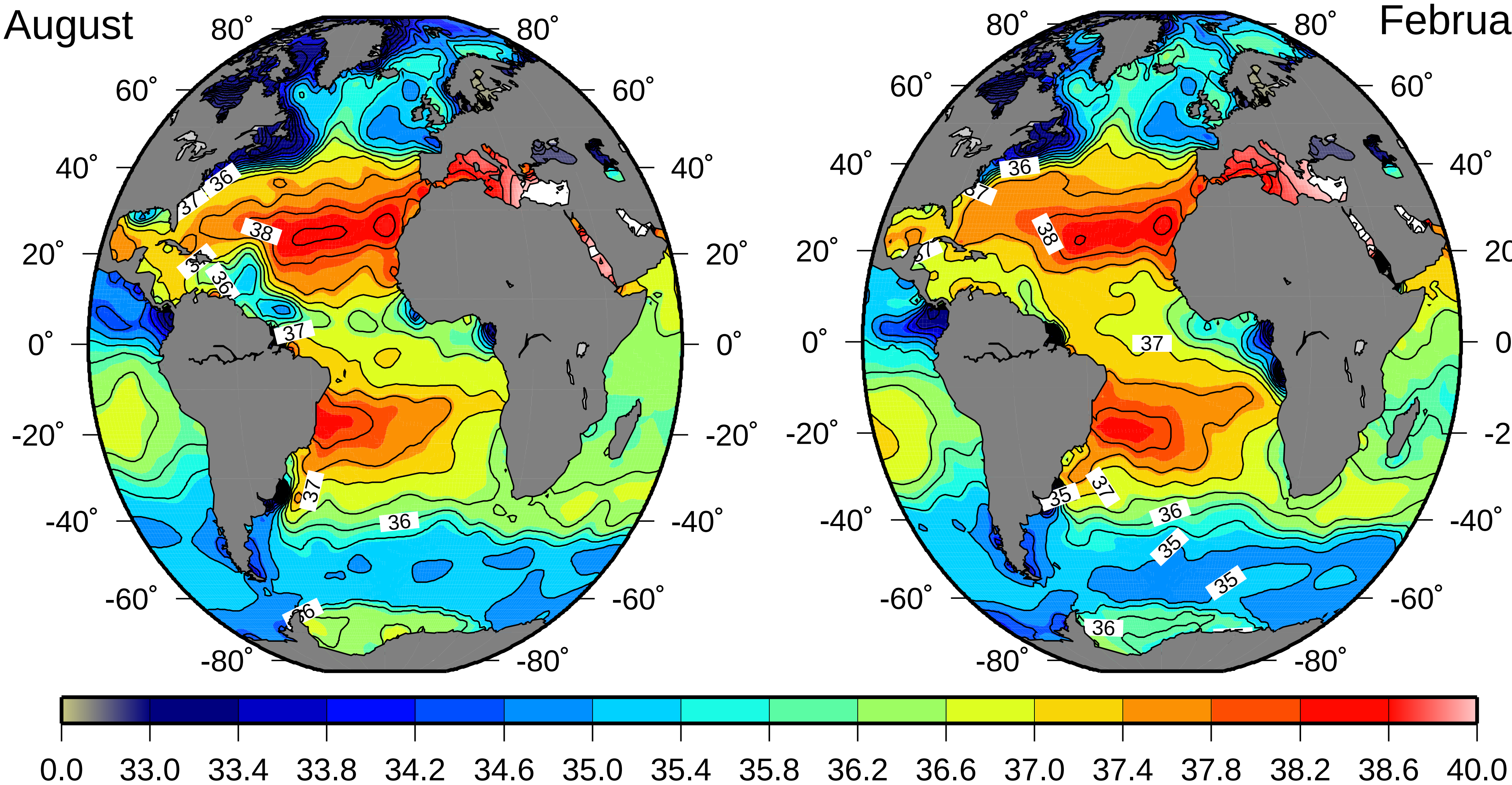




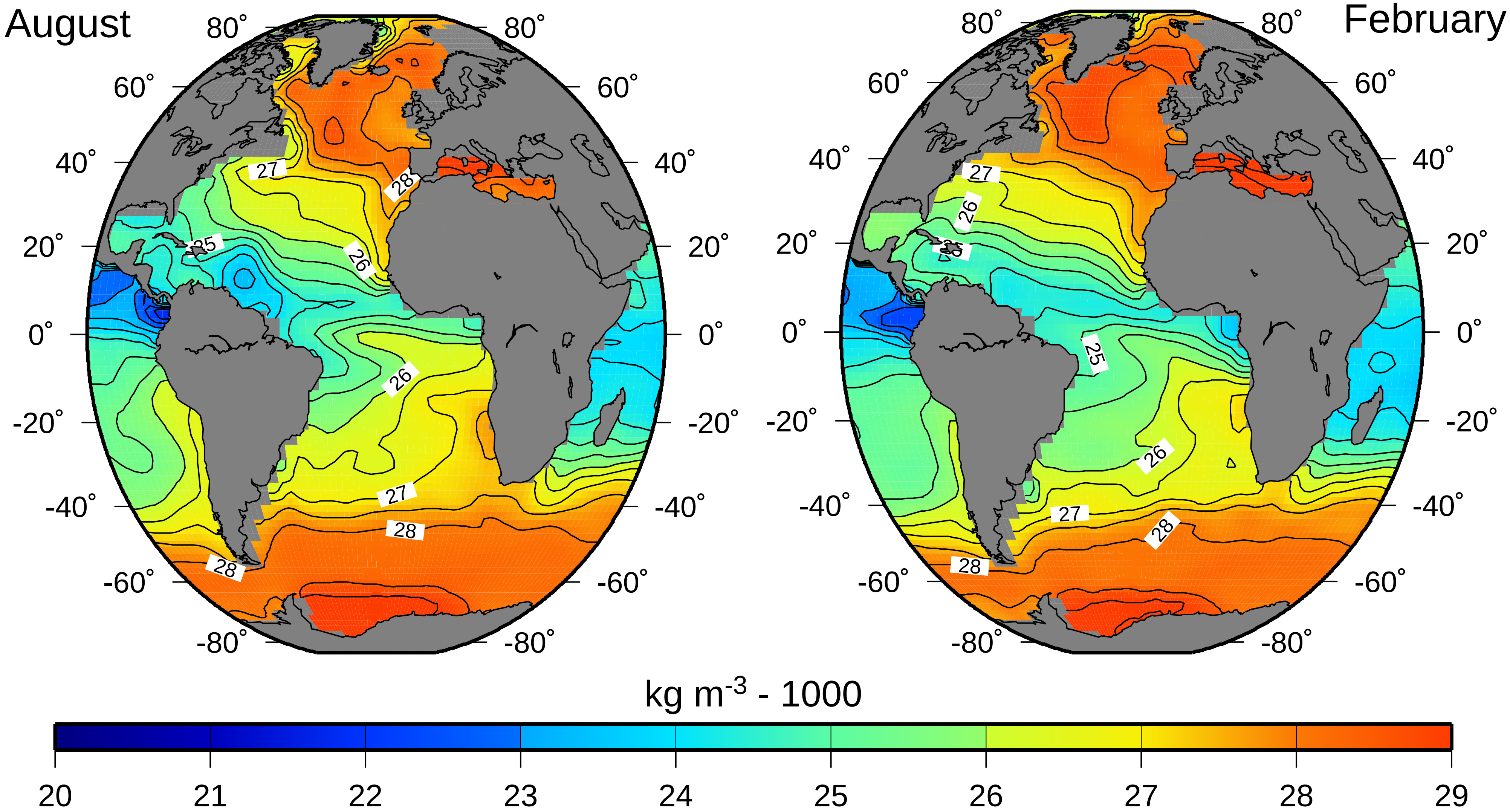
Salinity: Gridded Fields and Seasonal Cycle

To compute monthly glacial salinity...

- interpret the August salinity anomaly as representative for the entire year
- add the gridded anomaly to the modern 10 m salinity fields (World Ocean Atlas 1998)



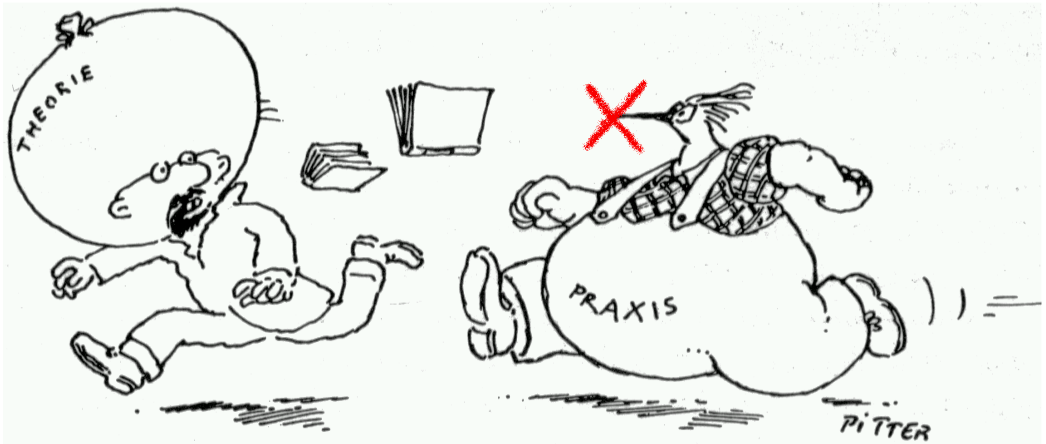
Density: What Drives the Model



Diagnosed from an OGCM run under T/S restoring

And Finally...

- The new GLAMAP data are much more consistent than any older reconstruction
- Spatial coverage of the Atlantic Ocean has been greatly improved
- This enables a compilation of inherently consistent seasonal glacial sea surface T and S maps suitable for driving and validating numerical models
- The newly gridded SST and SSS fields will be made available online at www.pangaea.de



- First model application: glacial-to-modern contrasts of
  - north-south density gradients and meridional overturning
  - deep and bottom water mass formation and characteristics
  - southwest African upwelling
- Stay tuned for the more detailed information provided in the following talk...