

The Impact of Increasing CO₂ Concentration on Ocean pH, Ocean Mixed Layer Depth, and the Sulfur Cycle Using the Community Earth System Model

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Acknowledgments

- SciDAC SEESM: A Scalable and Extensible Earth System Model for Climate Change Science
- OLCF (Oak Ridge Leadership Computing Facility) computational resources

Simulation Details

- Carbon dioxide increase for 2100 control designed to approximate the RCP 8.5

	1850	2000	2100
CO2_ppmv	284.7	367	936
CH4_ppmv	0.792	1.75	3.73
N2O_ppbv	275	308	435

- CESM version: ccsm4_0_beta35_CAM3.6.69
- LLNL Super Fast atmospheric chemistry
- LANL sulfur biogeochemistry (Elliott, 2009)

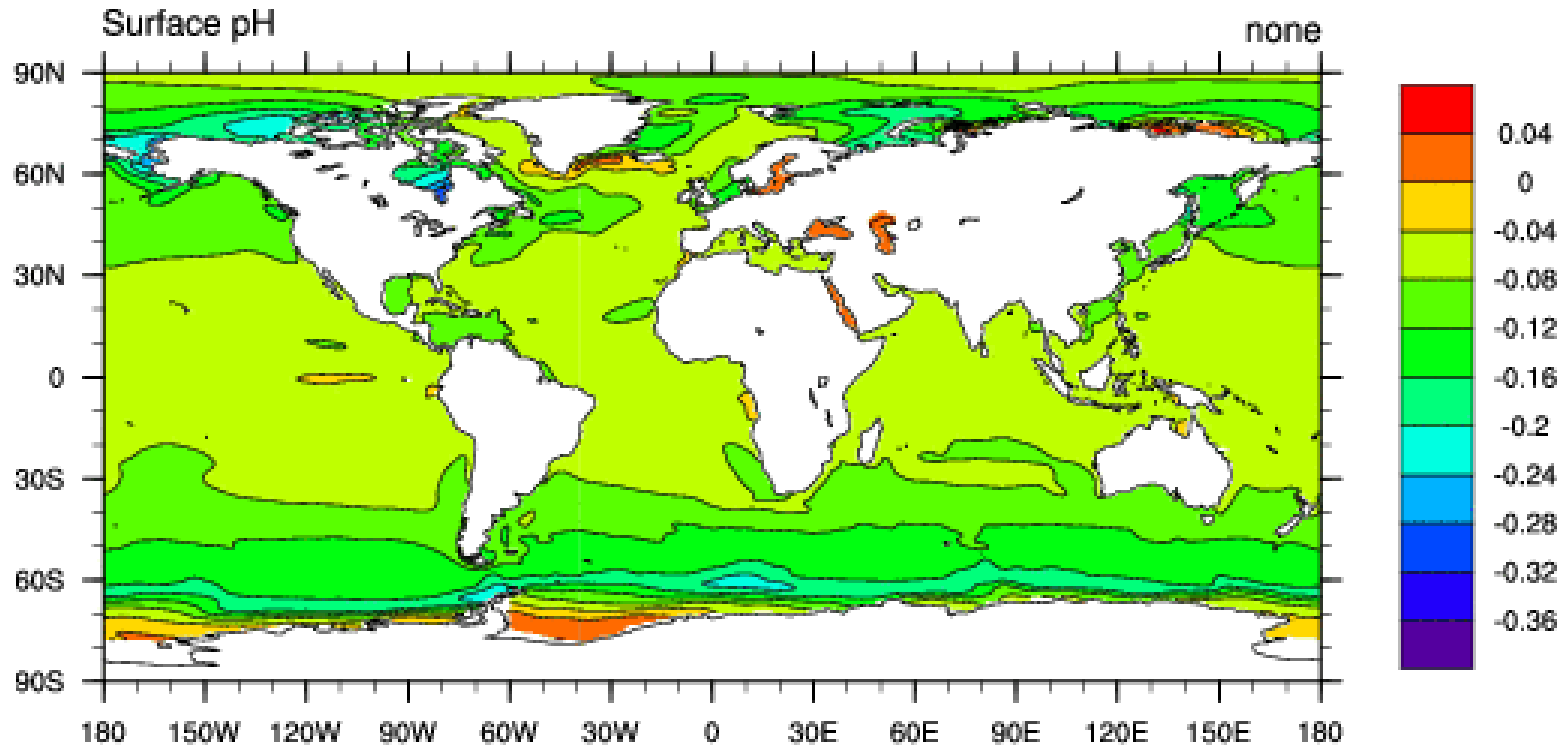
Simulation Details

- Length of runs

Control Run Year	With DMS coupling	Without DMS coupling
1850	30 years	13 years
2000	46 years	--
2100	46 years	--

- This analysis focuses on the 2000 and 2100 simulations with DMS coupling

Surface pH Difference 2100-2000

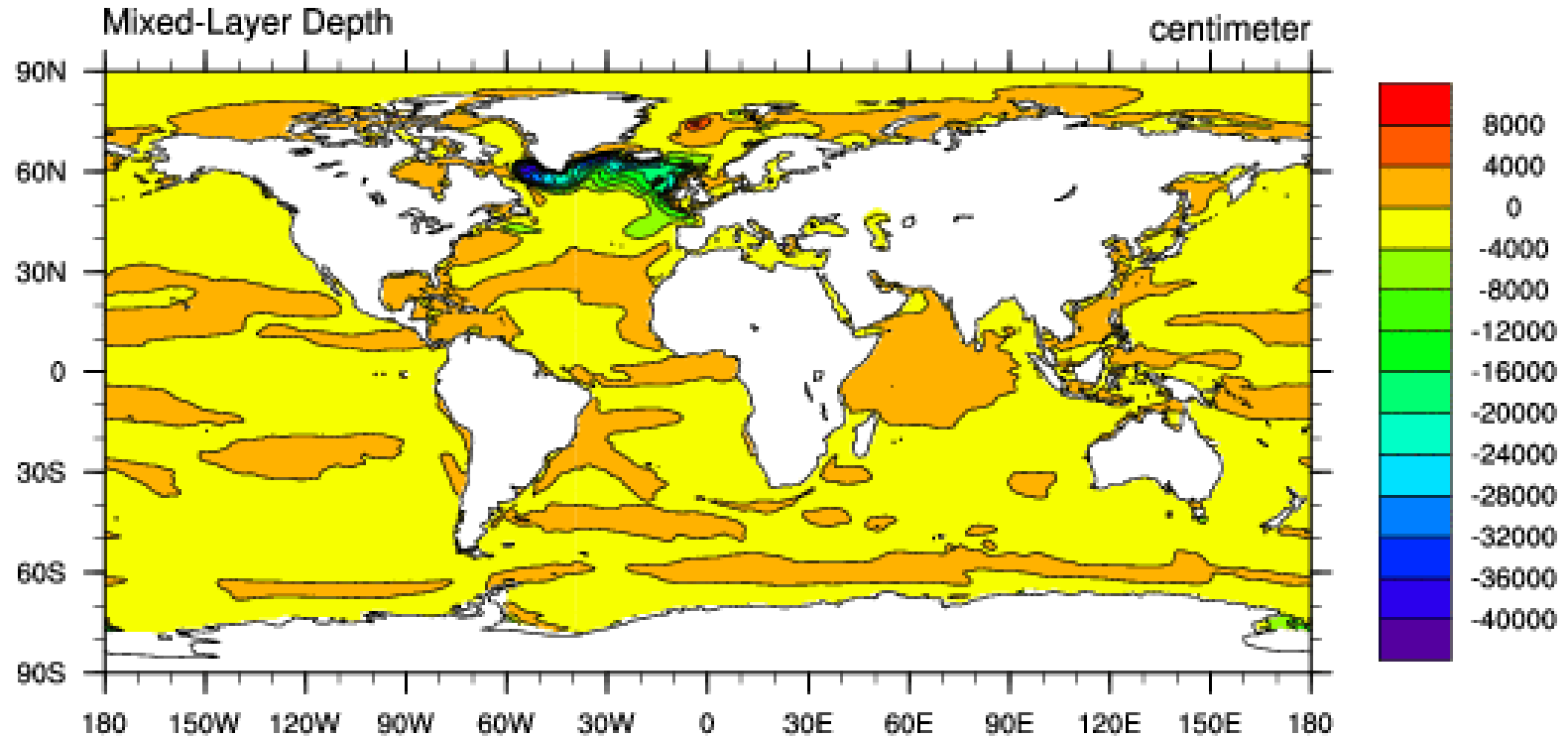


- Large regions of the ocean have been acidified 0.1 to 0.4 pH units
- Important to calcite based phytoplankton and ecosystem dynamics in general

Global Values

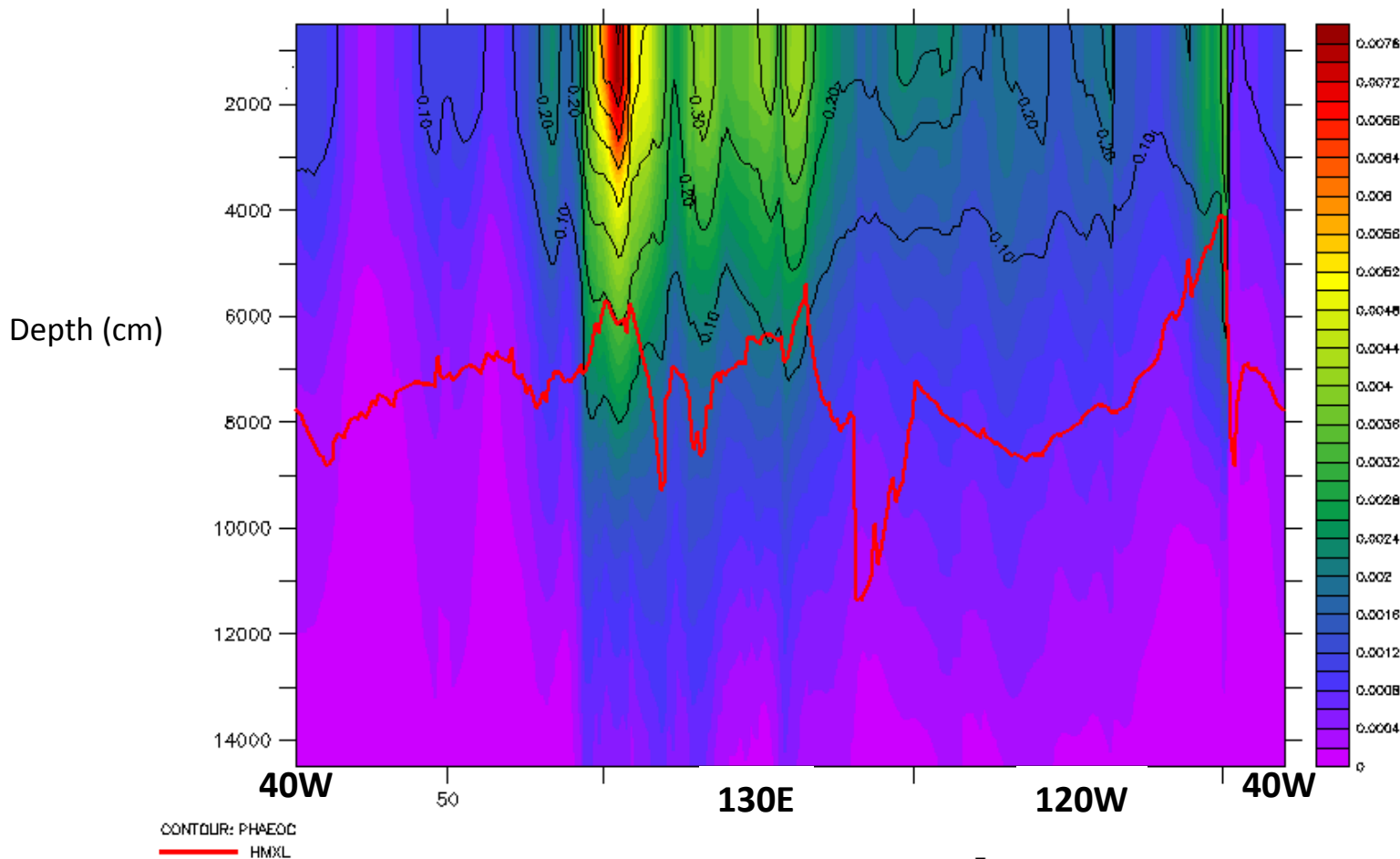
	2000	2100	units
DMS	4.703 E -5	4.303 E -5	mmol/m ³
<i>Phaeocystis</i> concentration	5.411 E -4	4.260 E -4	mmol/m ³
Diatom Carbon	0.009596	0.01058	mmol/m ³
Diatom Chlorophyll	0.002255	0.002004	mg/m ³
Mixed Layer Depth	6634	6088	cm
Max Mixed Layer Depth	8077	7297	cm
Min Mixed Layer Depth	4773	4574	cm

Mixed-Layer Depth Difference 2100-2000



- Significant decreases in mixed layer depth in Arctic regions on the order of 5-20 meters
- Antarctic regions also show mixed layer depth decrease

2000 Vertical Slice of Southern Ocean DMS, *Phaeocystis*, Mixed Layer Depth



DiMethyl Sulfide (mmol/m³)

DMS concentration (mmol/m³) in color contours

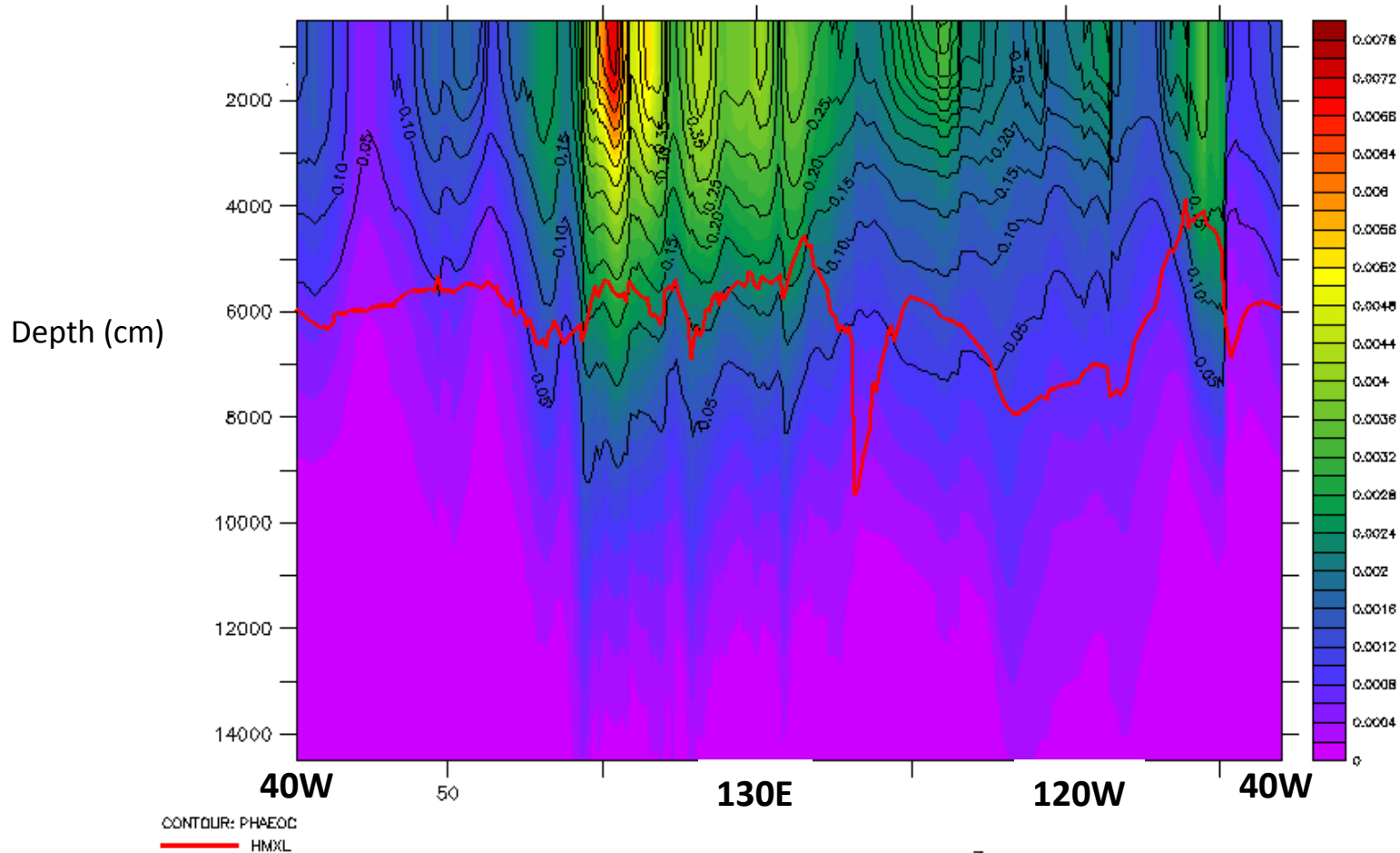
Phaeocystis conc. (mmol/m³) in black contour lines

Mixed layer depth (cm) red line

Longitudinal slice with the
lowest 30 latitude bands averaged

2100 Vertical Slice of Southern Ocean

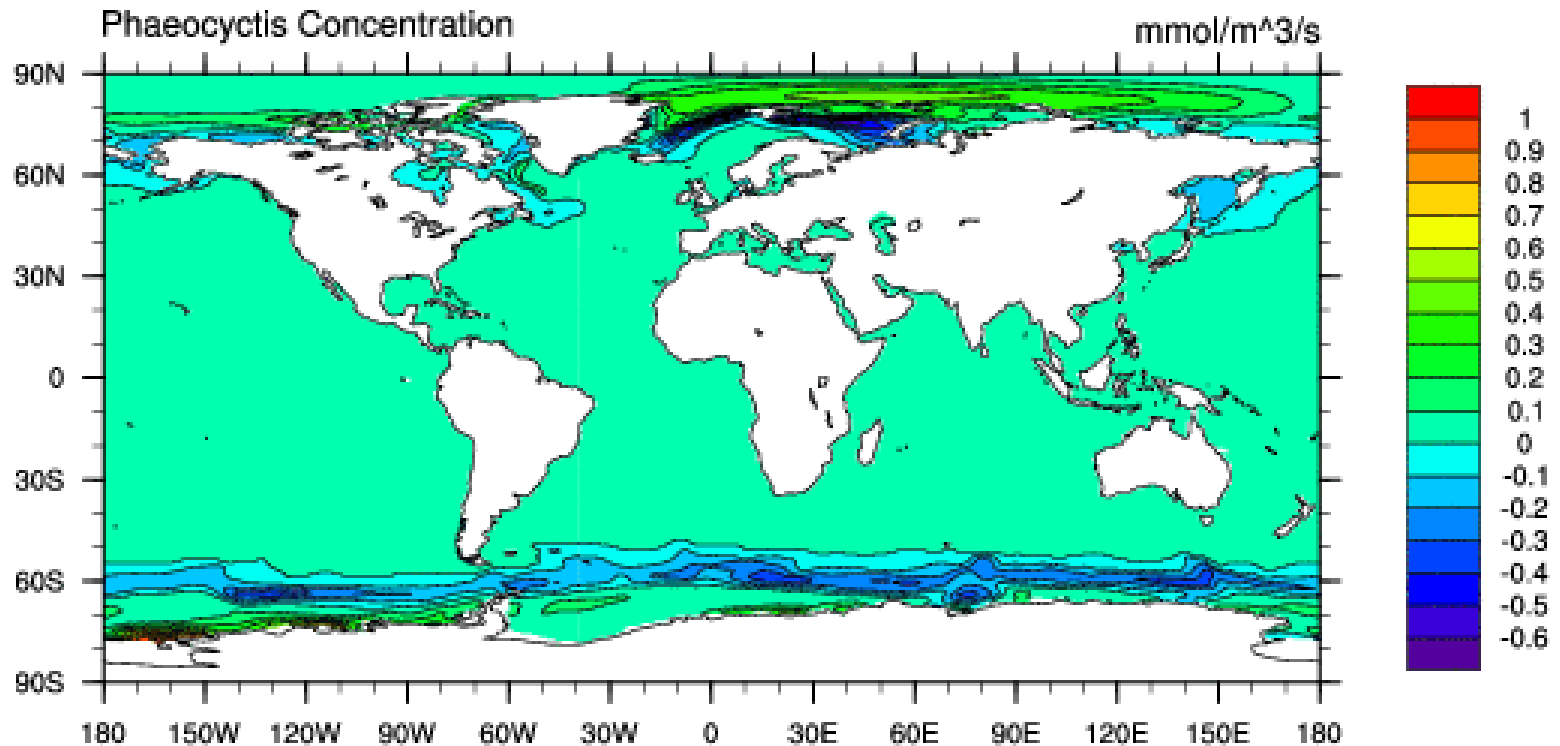
DMS, *Phaeocystis*, Mixed Layer Depth



DMS concentration (mmol/m³) in color contours
Phaeocystis conc. (mmol/m³) in black contour lines
Mixed layer depth (cm) red line

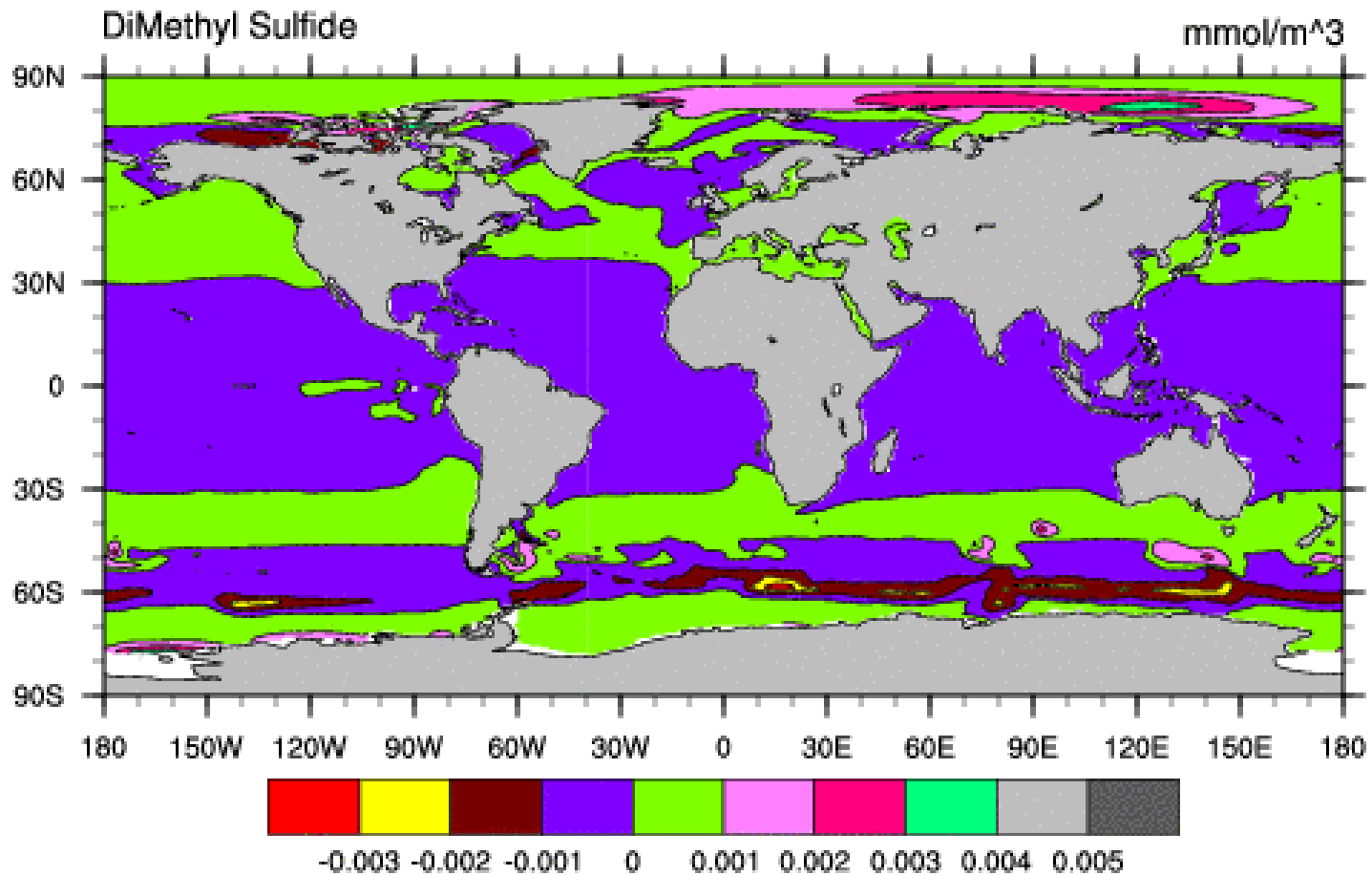
Longitudinal slice with the
lowest 30 latitude bands averaged

Phaeocystis Difference 2100-2000



- Changes have implications within the context of the sulfur emission to the atmosphere (Cameron-Smith et al., 2011)

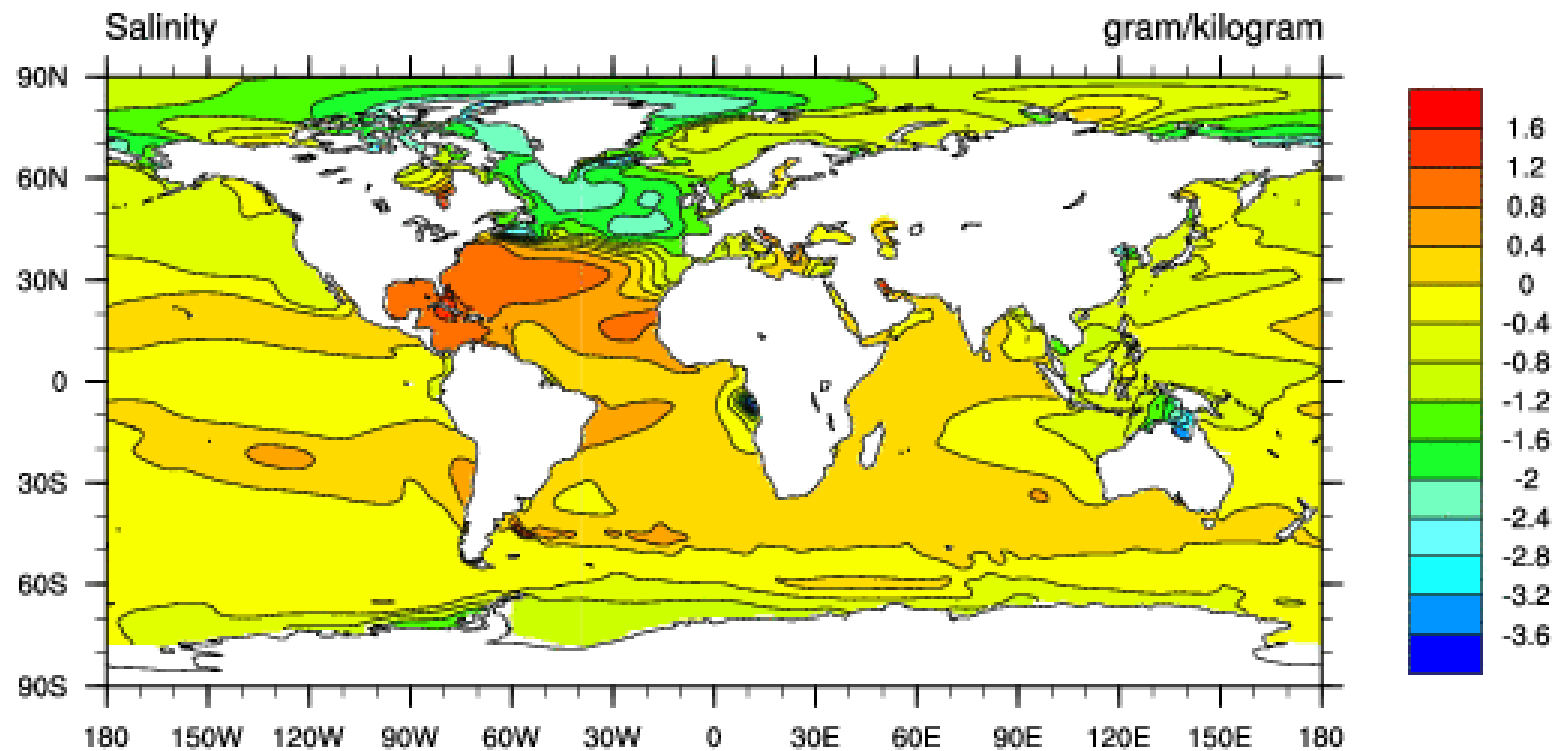
DiMethyl Sulfide Difference 2100-2000



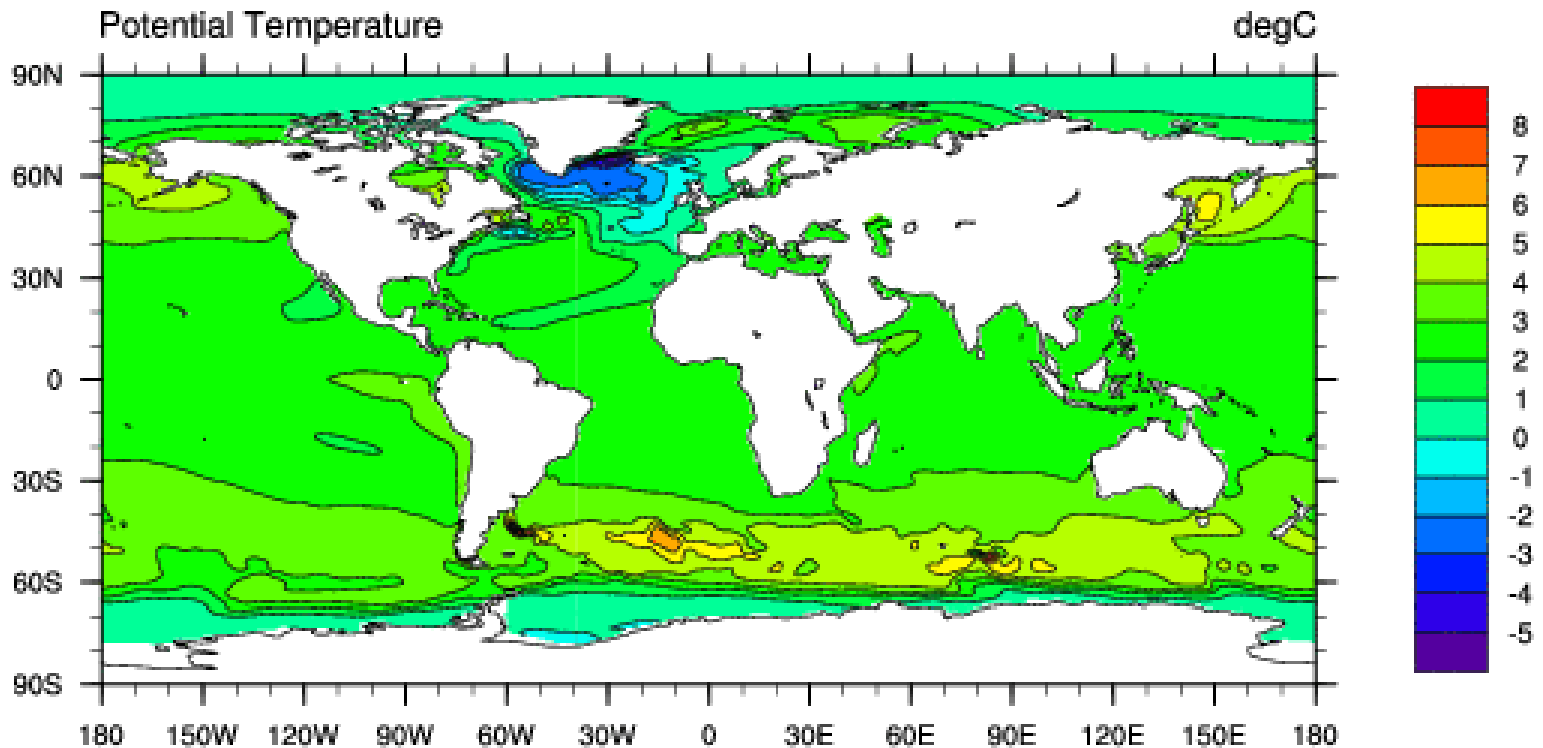
Conclusions

- Results from the 2100 simulation showed considerable ocean acidification .
- There was an increase in dimethyl sulfide in the polar regions, which could have implications for the sulfur cycle in the atmosphere.
- There were significant decreases in mixed layer depth in the Arctic and Antarctic regions.
- *Phaeocystis* increased in the same regions.

Surface Ocean Salinity Difference 2100-2000

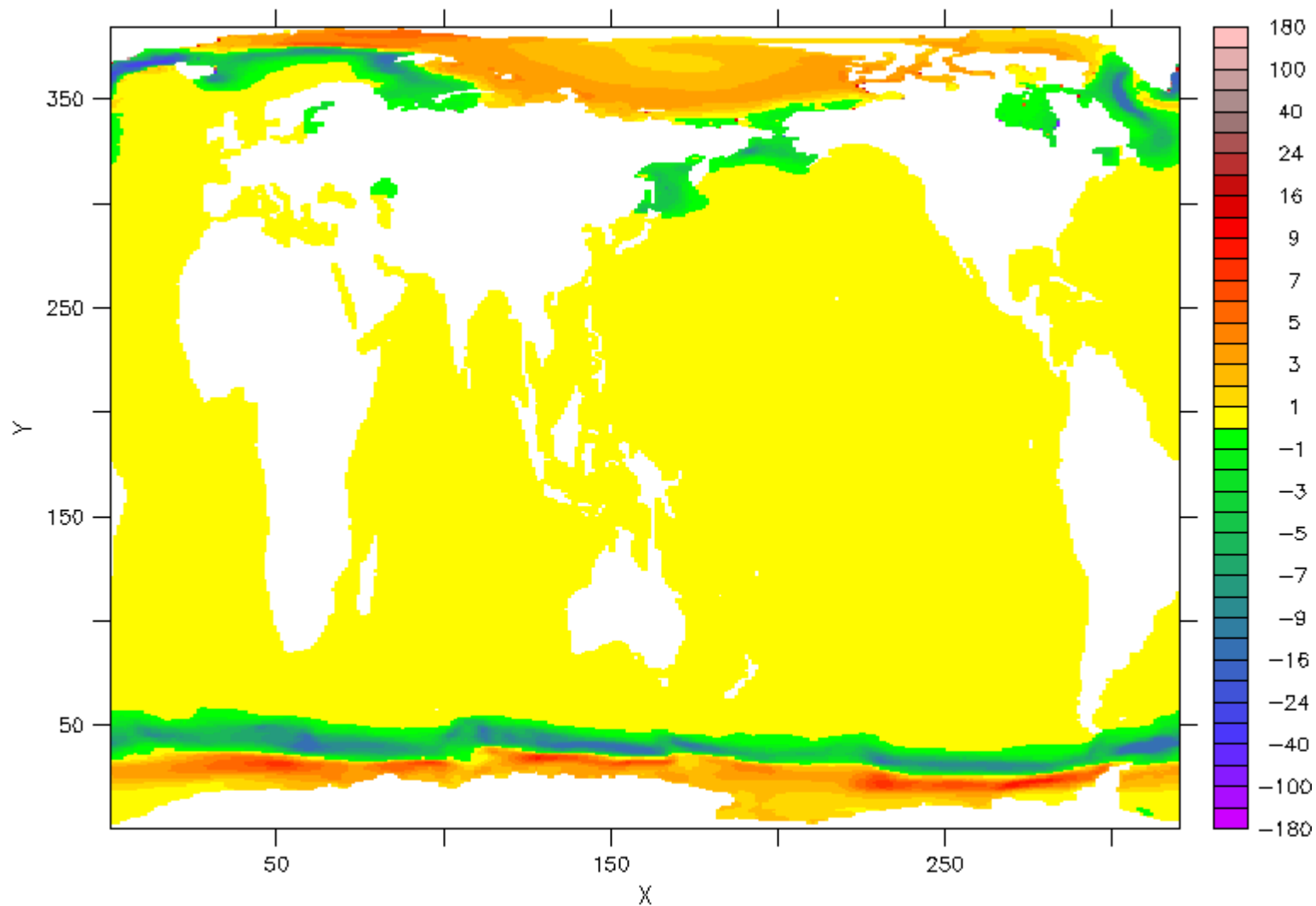


Surface Ocean Temperature Difference 2100-2000

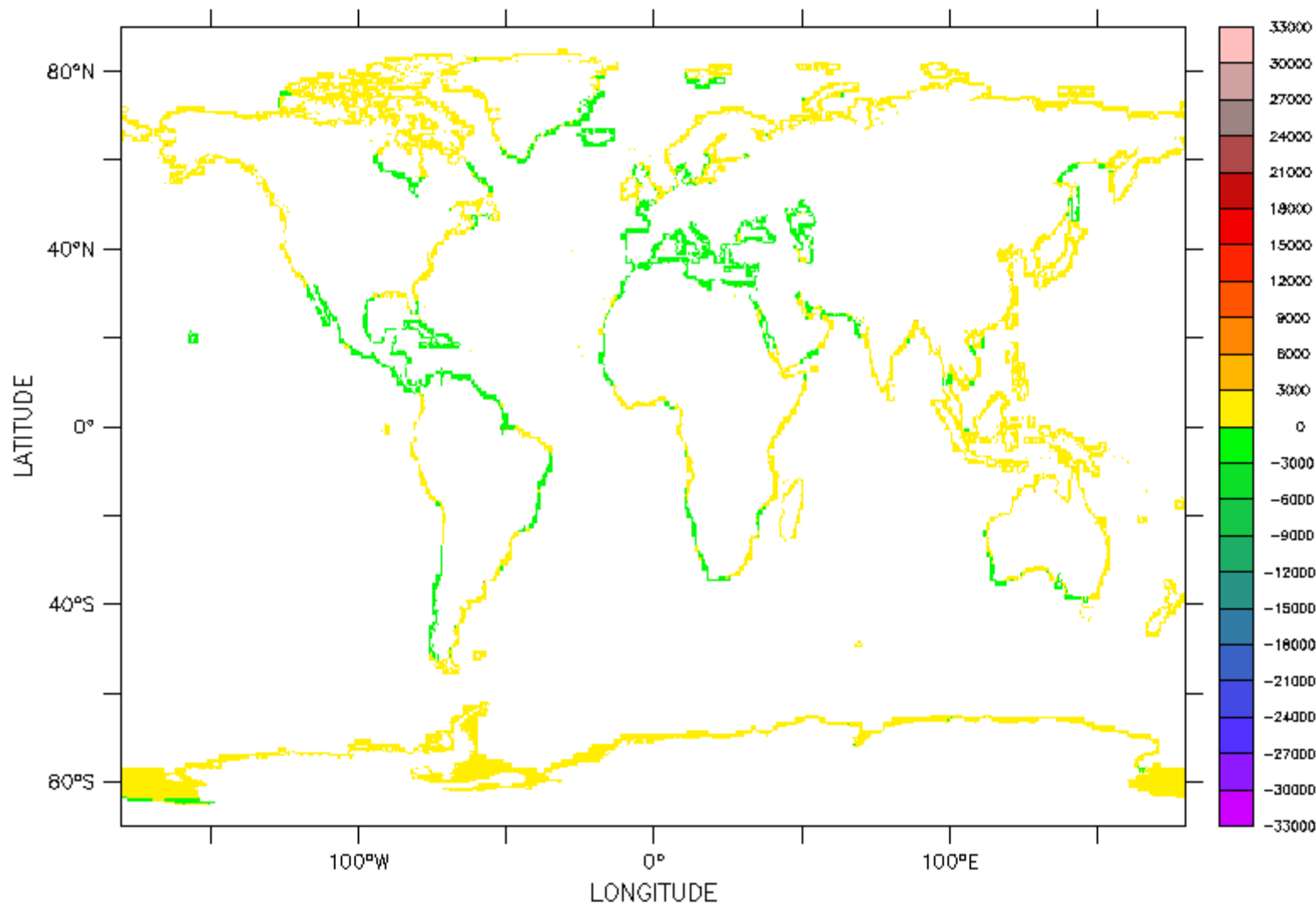


Other slides

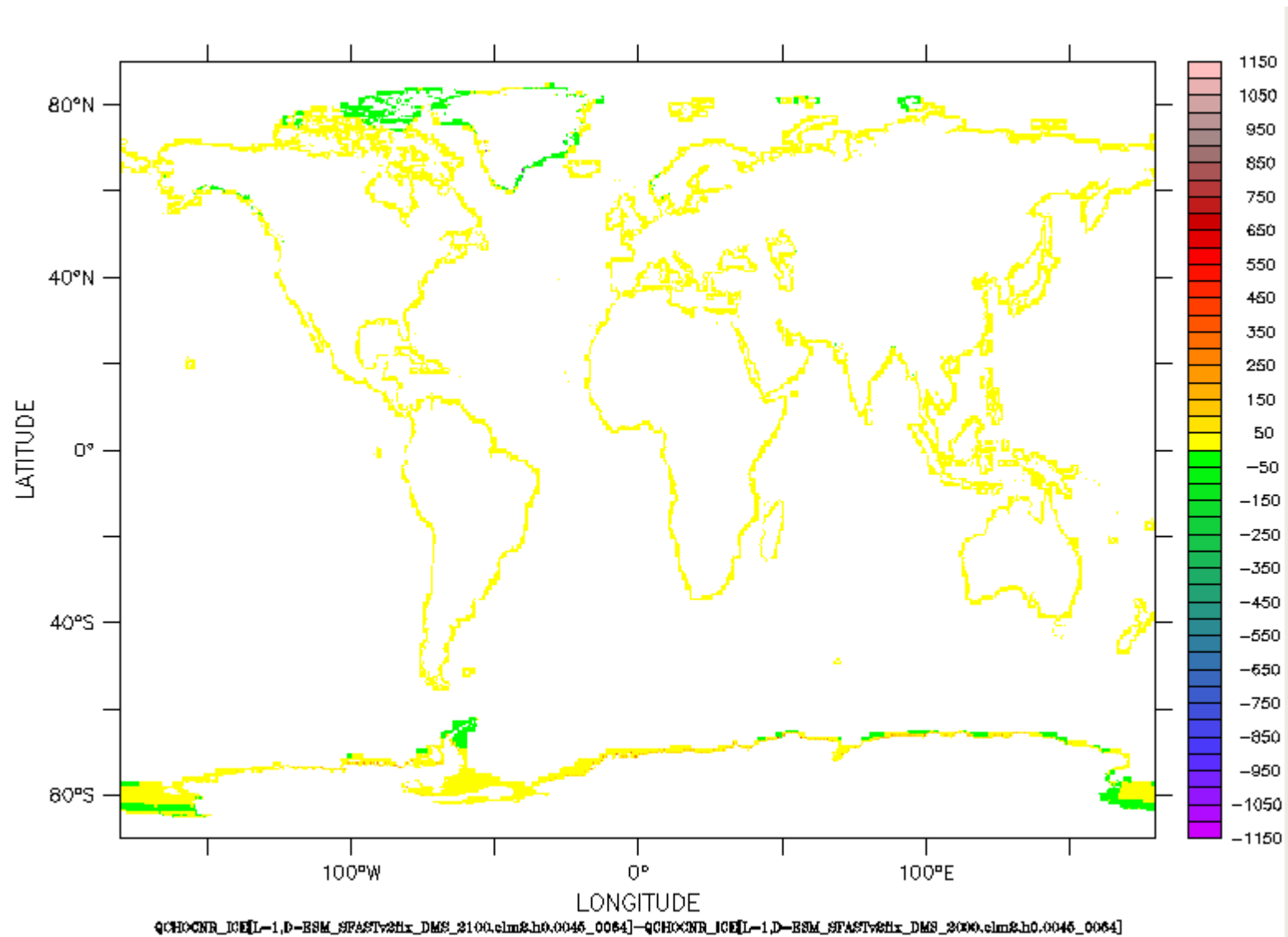
- Freshwater changes
 - From sea ice
 - From liquid continental runoff
 - From ice continental runoff
- Depth profiles
 - Temperature
 - salinity



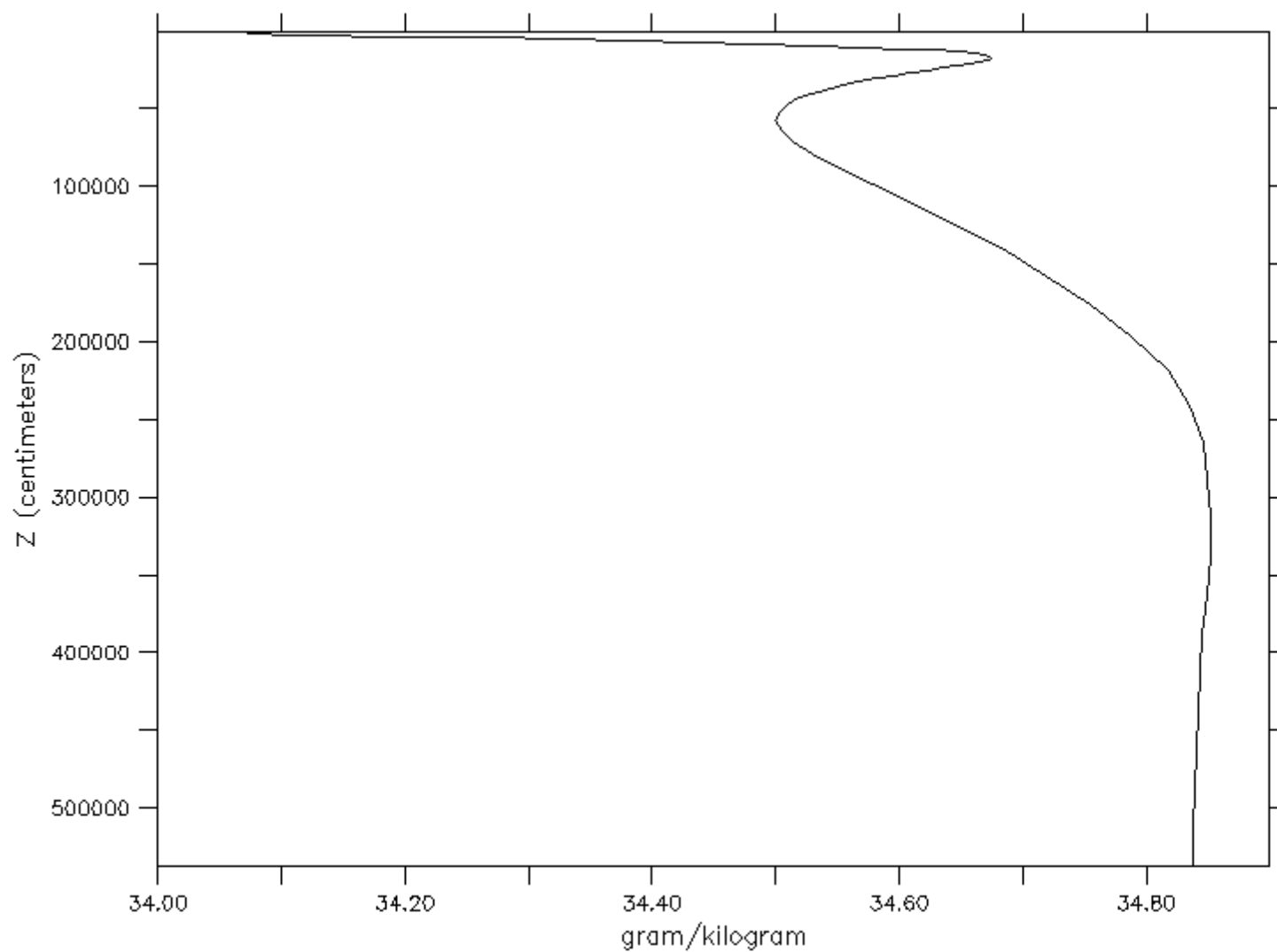
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QCHOCNR[L=1,D=BEM_FASTv8fx_DMS_2100.clm2.h0.0045_0064]-QCHOCNR[L=1,D=BEM_FASTv8fx_DMS_2000.clm2.h0.0045_0064]

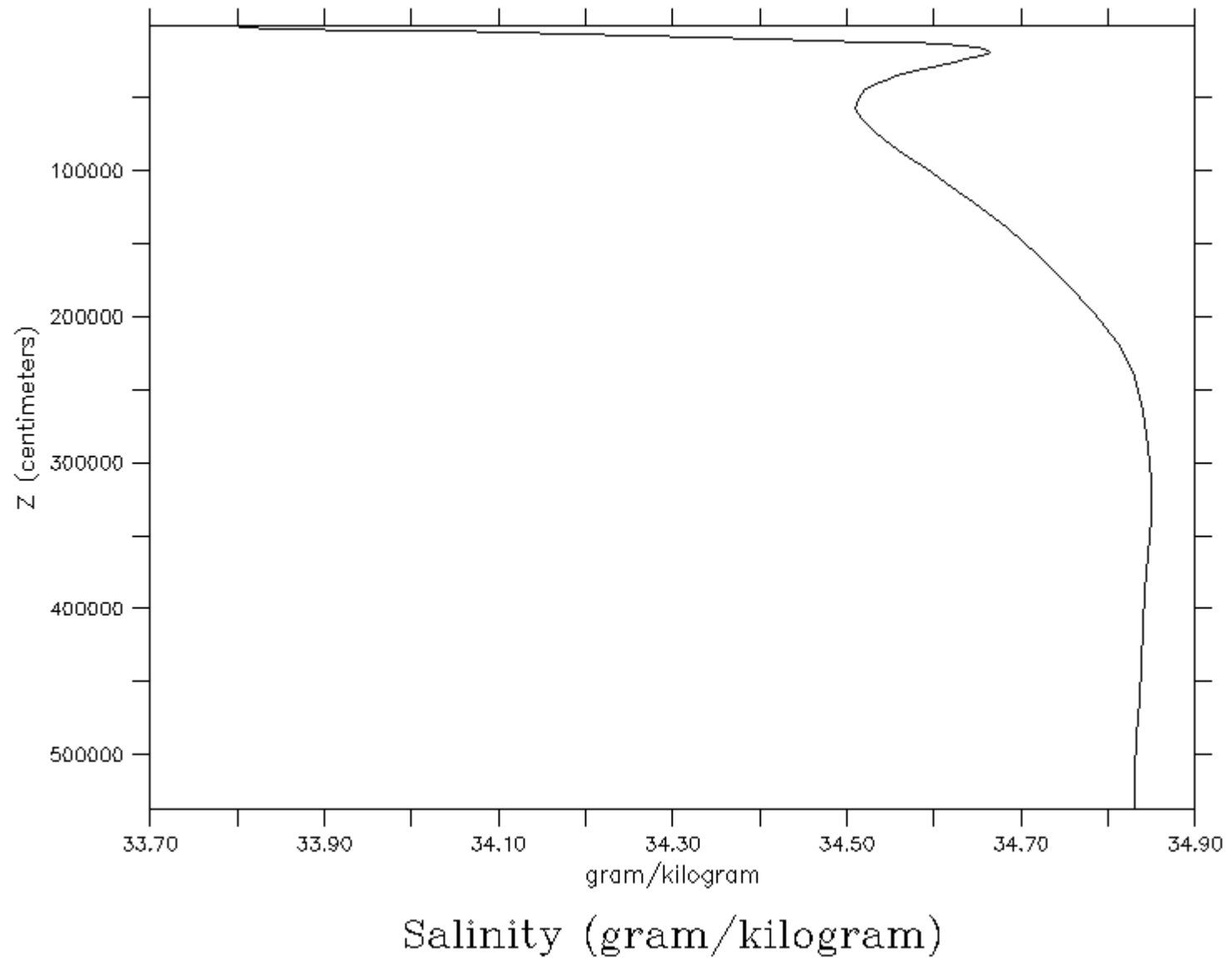


2000

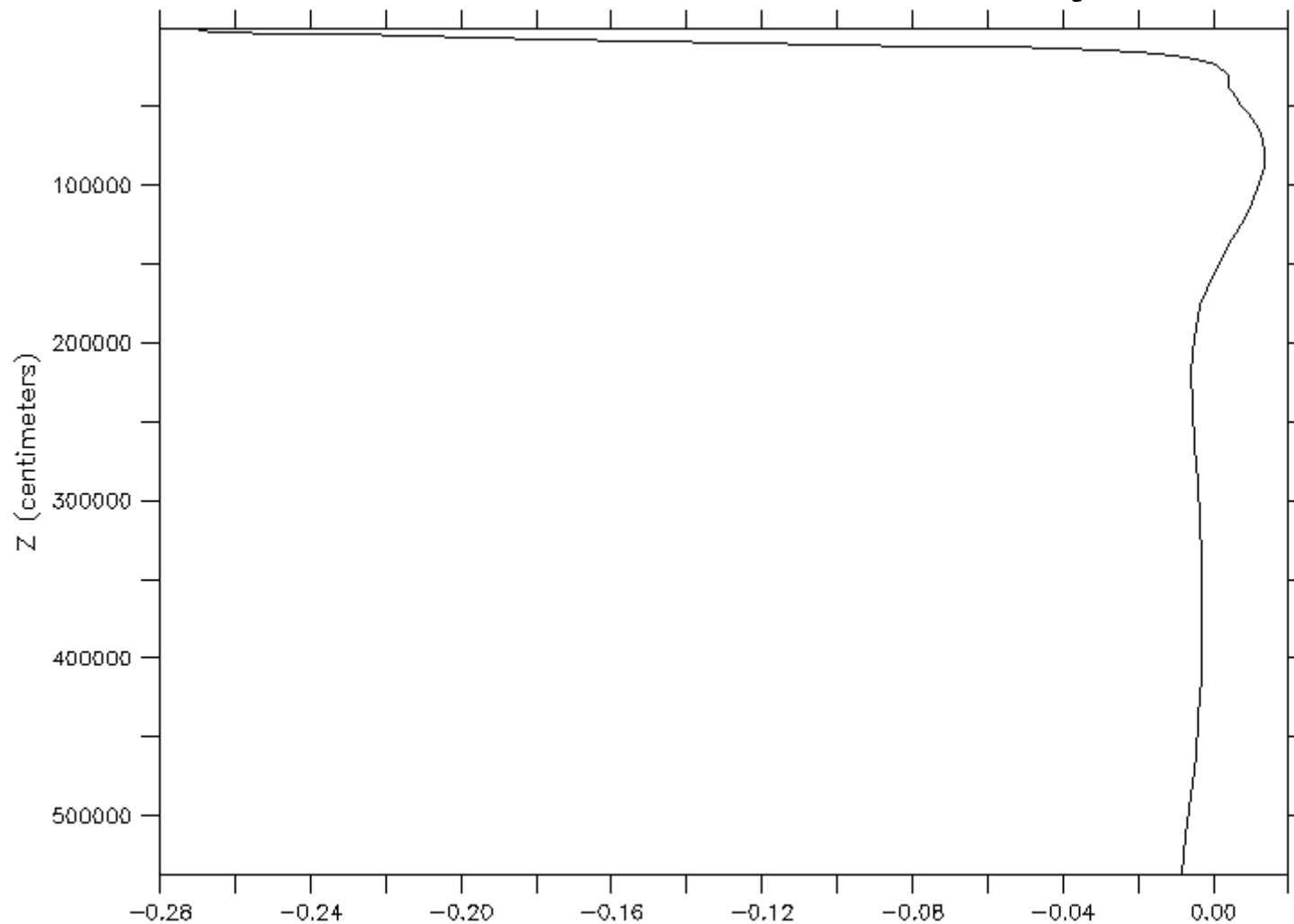


Salinity (gram/kilogram)

2100

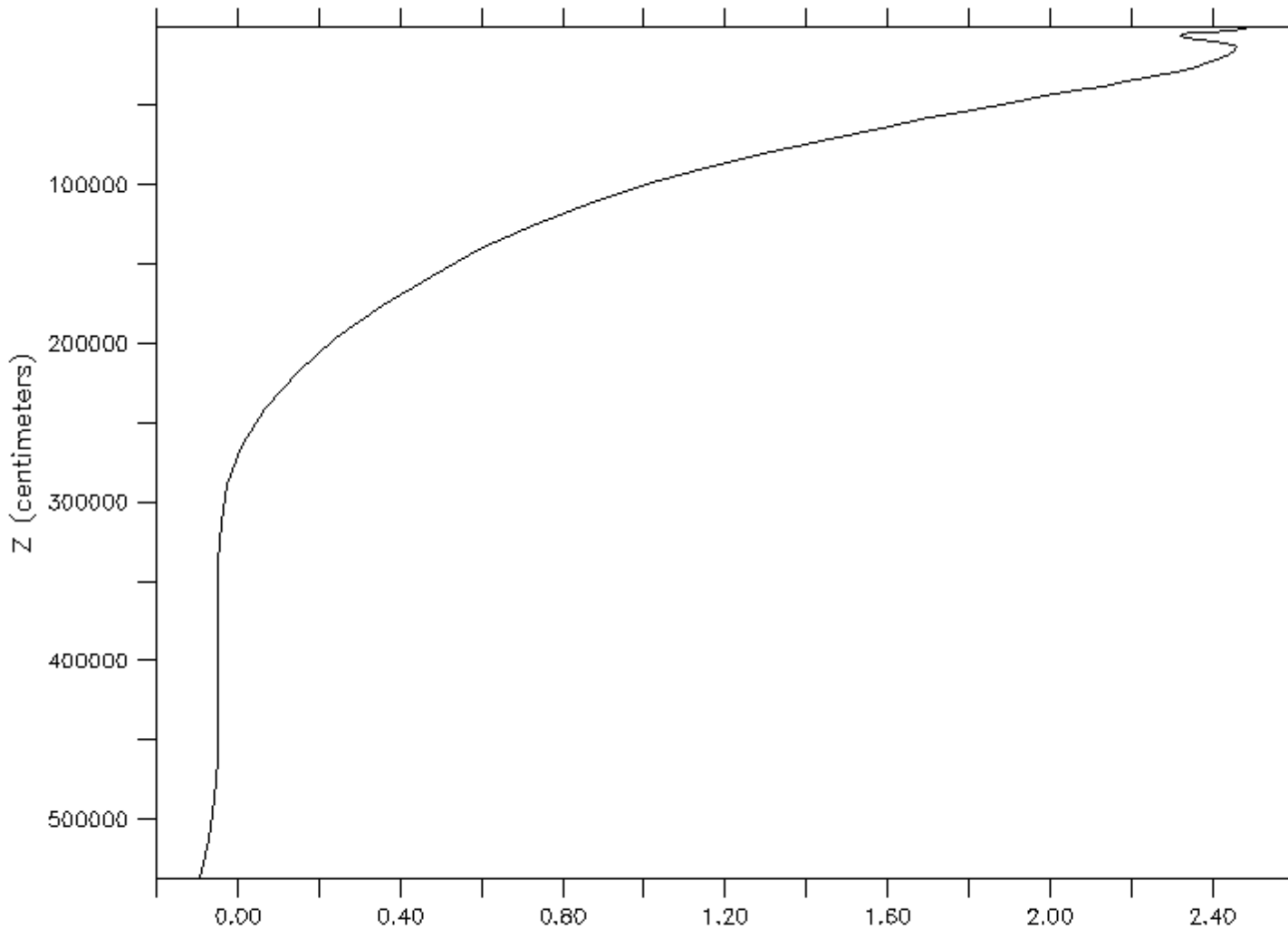


2100-2000 Salinity



`SALT[D-ESM_SFASTv2fix_DMS_2100.pop.h.0045_0064]-SALT[D-ESM_SFASTv2fix_DMS_2000.pop.h.0045_0064]`

2100-2000 Temperature



TEMP[D=ESM_SFASTv2fix_DMS_2100.pop h 0045_0064]-TEMP[D=ESM_SFASTv2fix_DMS_2000.pop h 0045_0064]