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Modelling The Conveyor Belt Circulation using MICOM *

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The Project

- Oceans transport about half the heat from Tropics to Polar Regions
- Wind Driven ocean circulation is surface intensified and swift
- Buoyancy Driven (Thermohaline) circulation (THC) involves full depth and is slow
- Changes in THC are believed to control climate change
- Meridional Overturning Circulation (MOC) is one convenient measure of THC

- In CO_2 doubling scenarios N. Atlantic MOC seems to
  - slow down in level-based models (most of the models used)
  - be extraordinarily robust in layer-based models (only a couple)

- Aim of the project is to understand modeling artifacts and physical processes controlling MOC in layer-based models using Miami Isopycnal Coordinate Ocean Model

Characteristics of Setup

- MICOM
- Specified Monthly Climatalogy of Atmosphere
  - NCEP Reanalysis: Wind, Humidity, Temperature
  - ISSCP: Shortwave radiation, Cloud fraction
  - Fung et al.: Longwave radiation
  - MSU/Xie-Arkin: Precipitation
- Model SST + Bulk Forcing (Large et al.) $\Rightarrow$ Surface Flux of Heat and Freshwater

- NO RESTORING TO CLIMATOLOGY

- Precipitation adjustment

- Kraus-Turner Bulk Mixed Layer

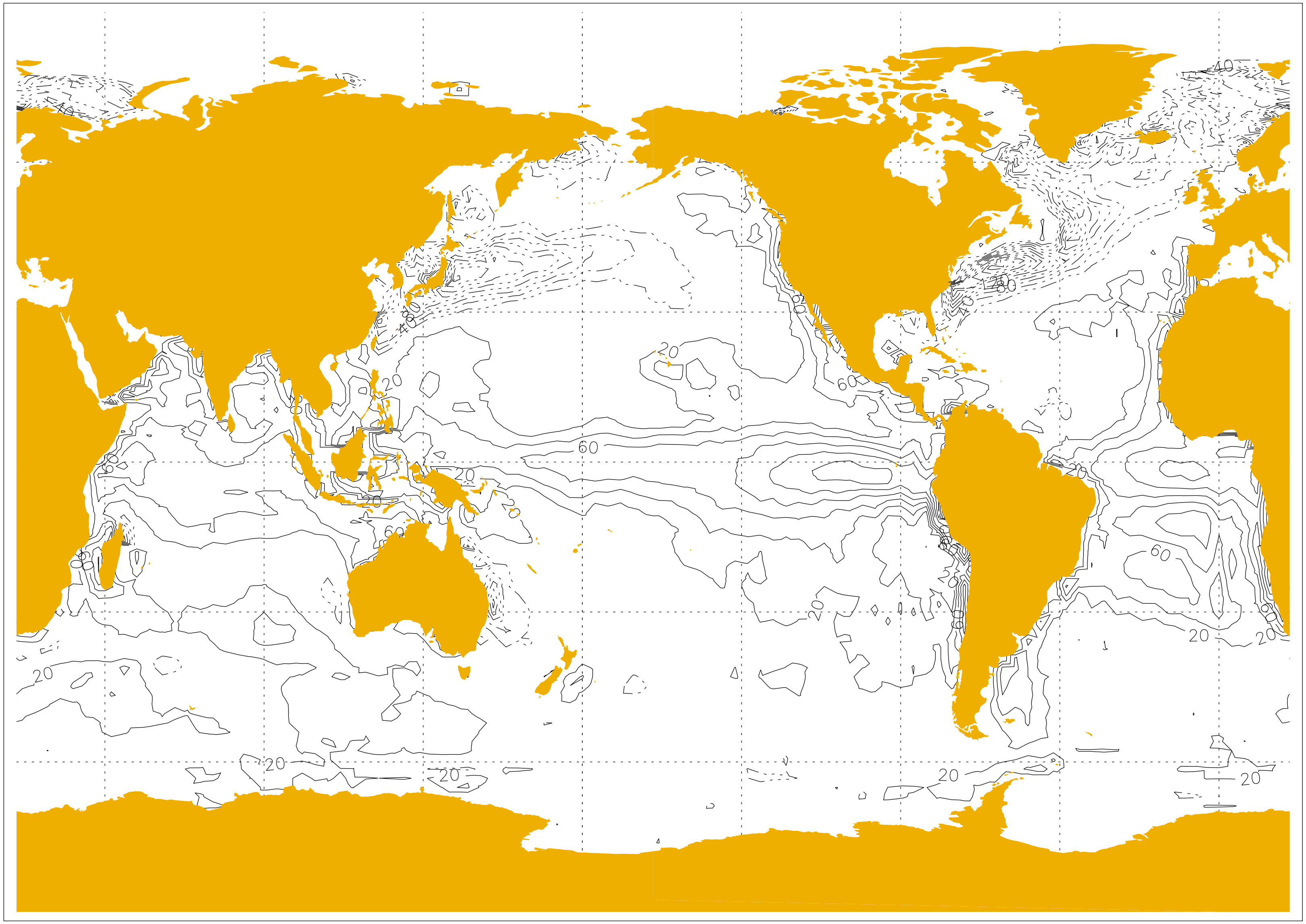
- Simple thermodynamic ice model with no brine rejection for first 3 years
  or
  Diagnosed ice (Shea-Trenberth-Reynolds SST climatology)

- 3^{o} displaced pole grid. 16 layers

- Topography derived from ETOPO5

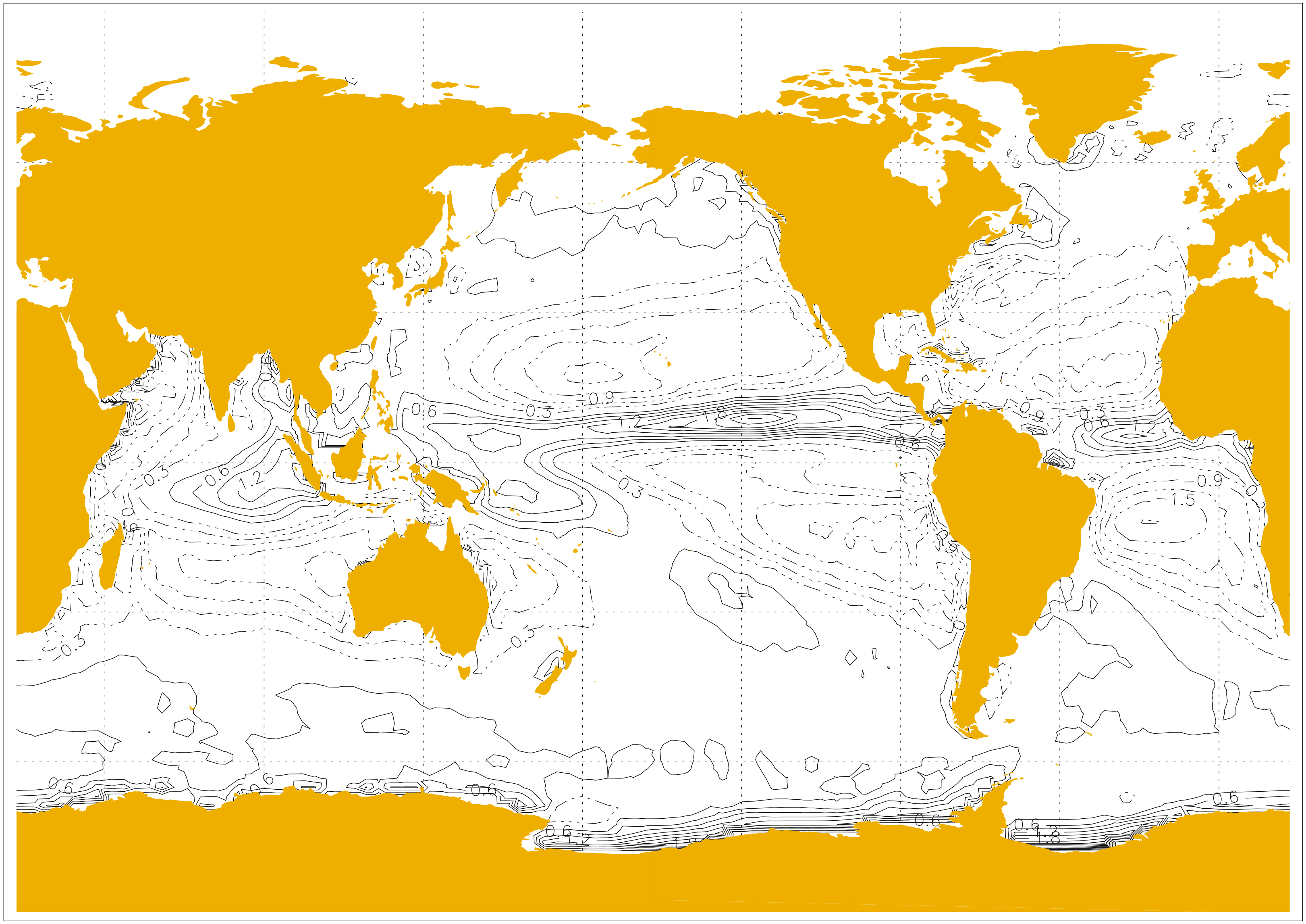
- Initial Condition based on Levitus '82

Surface Heat Flux −240, 160, 20



Climatological SST, Zero flux over ice, Net heating of 17 W/m^2

Surface Freshwater Flux–3.3, 2.7, 0.3



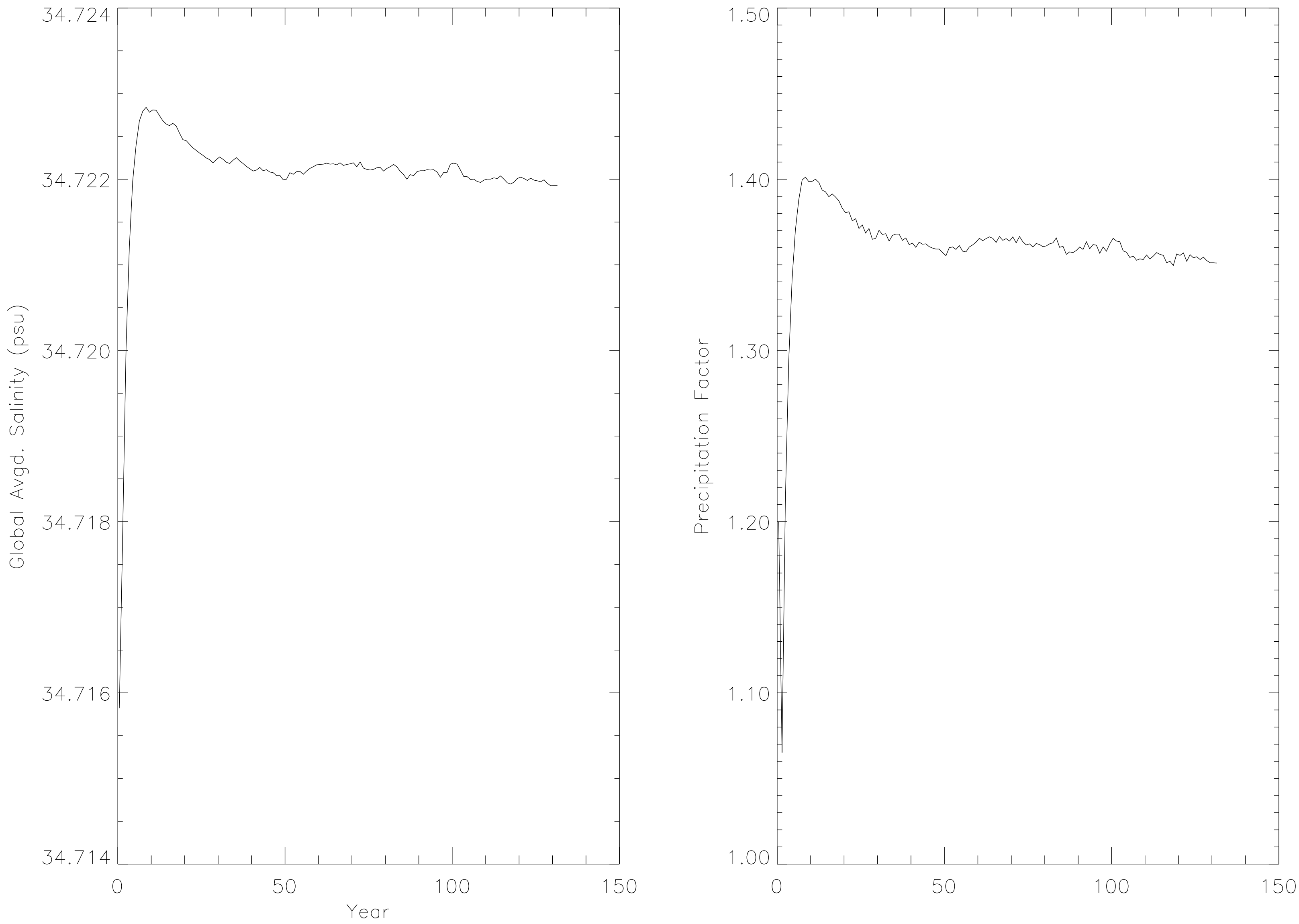
Climatological SST, Zero flux over ice, Net evap. of 0.16 m/yr

Global Average of E and P

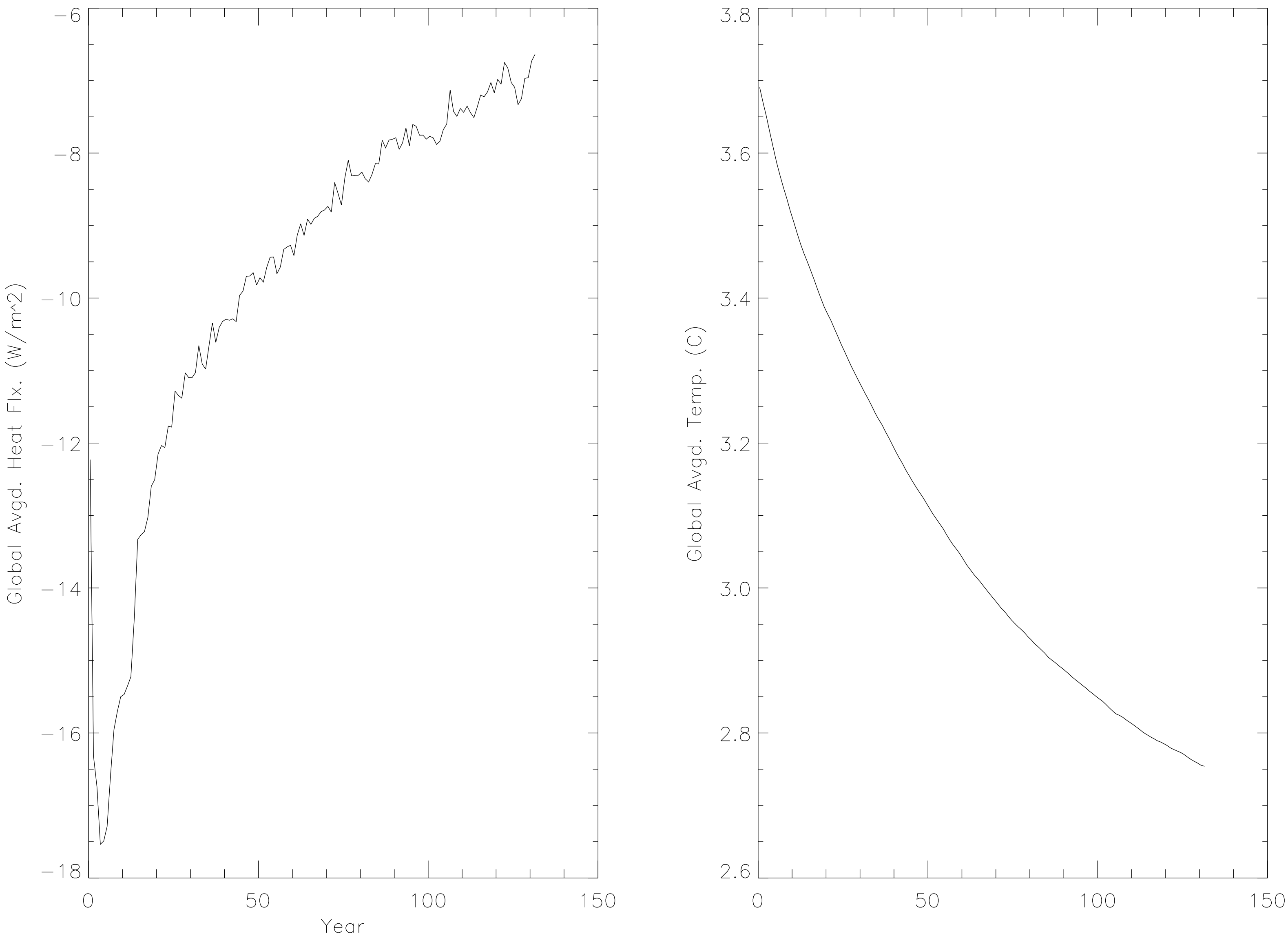
- Evaporation: 440 km^3/yr or 14 Sv or 1.24 m/yr
  (1.17 m/yr)

- Precipitation: 411 km^3/yr or 13.1 Sv or 1.16 m/yr
  (1.00 m/yr)

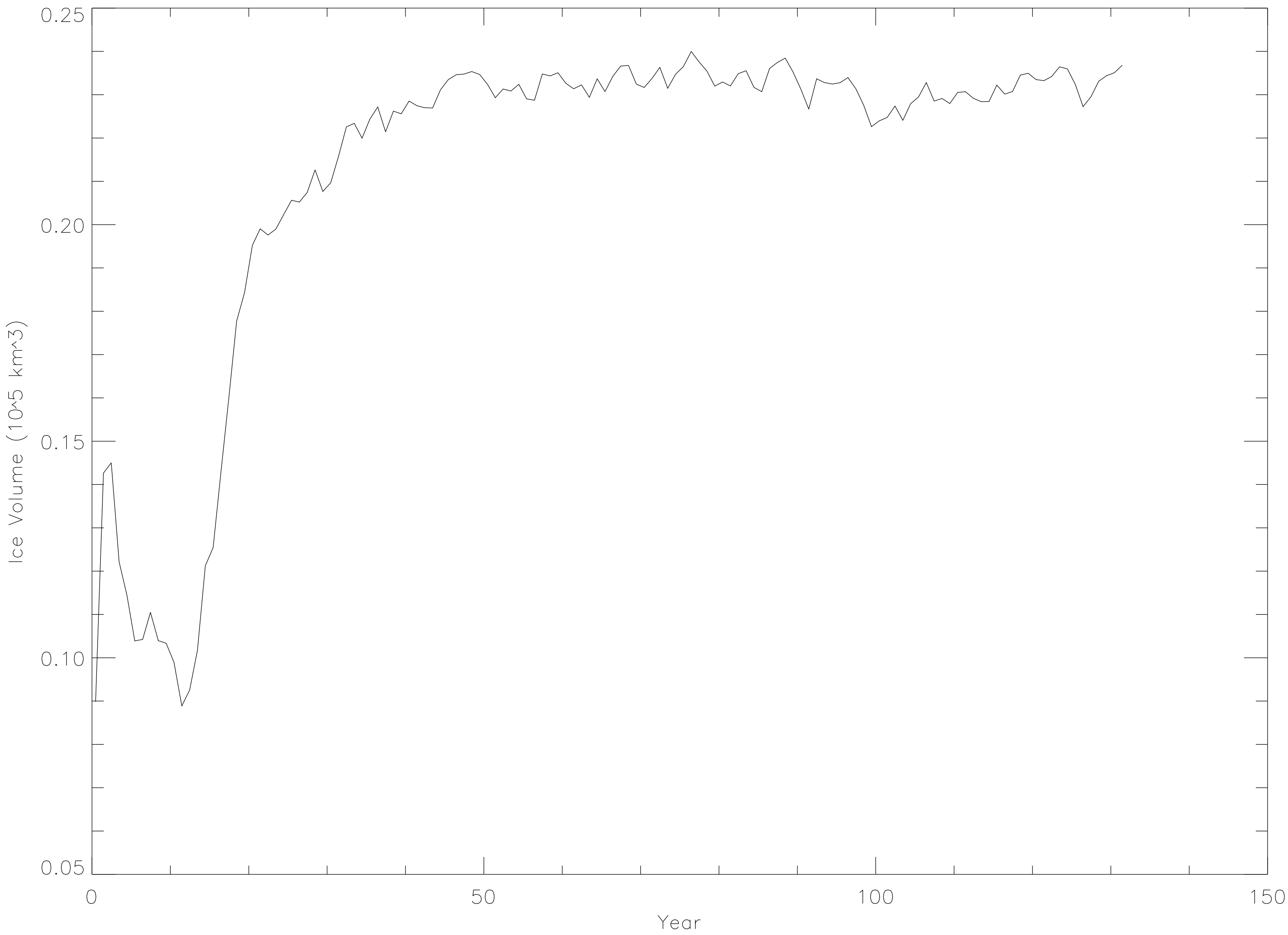
- River Runoff: 29 km^3/yr or 0.9 Sv or 0.08 m/yr



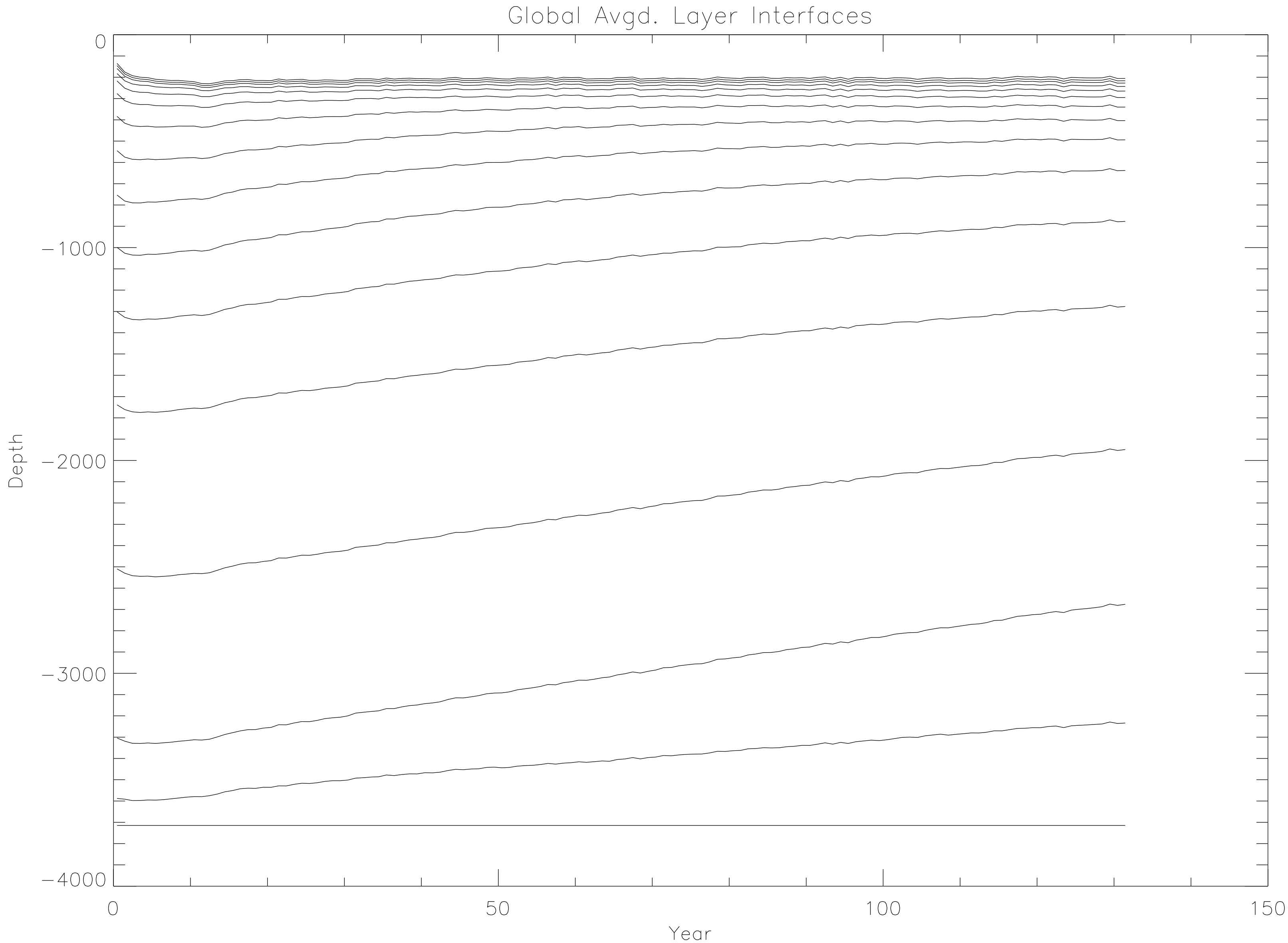
Precipitation adjusted annually with a 2 year timescale



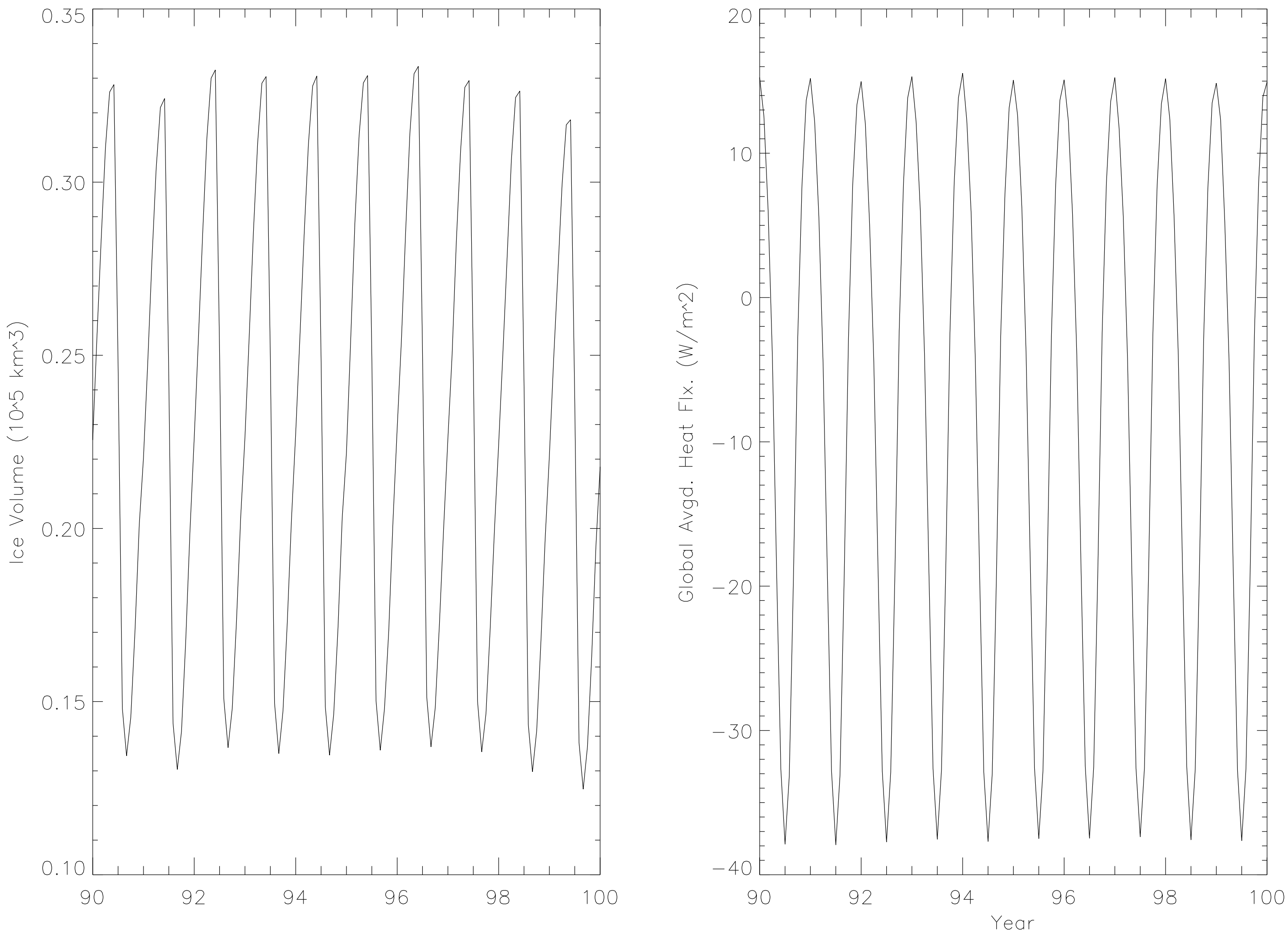
Ocean losing too much heat



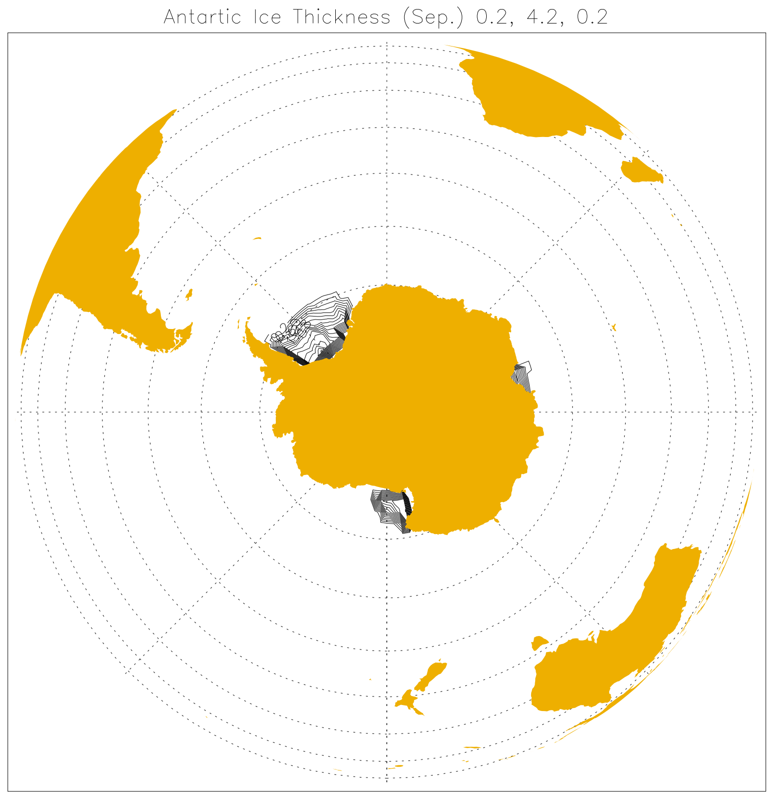
Slightly low, but reasonable ice volume

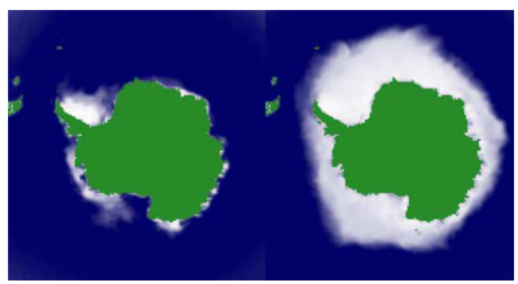


Evolution of avgd. layer thknss. consistent with cooling

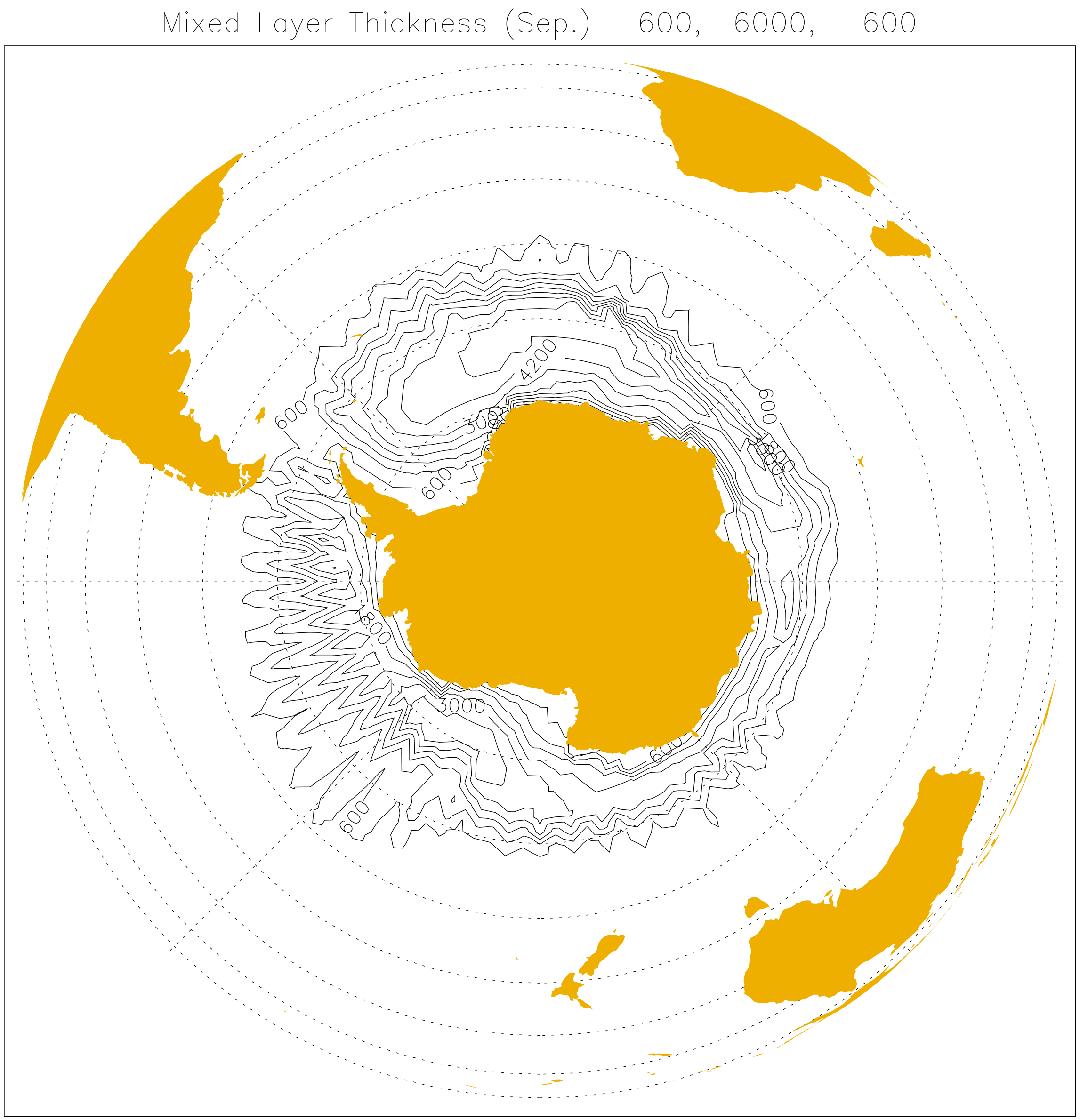


Too little ice in Antarctic; Larger heat loss in Ant. winter (Too much?)

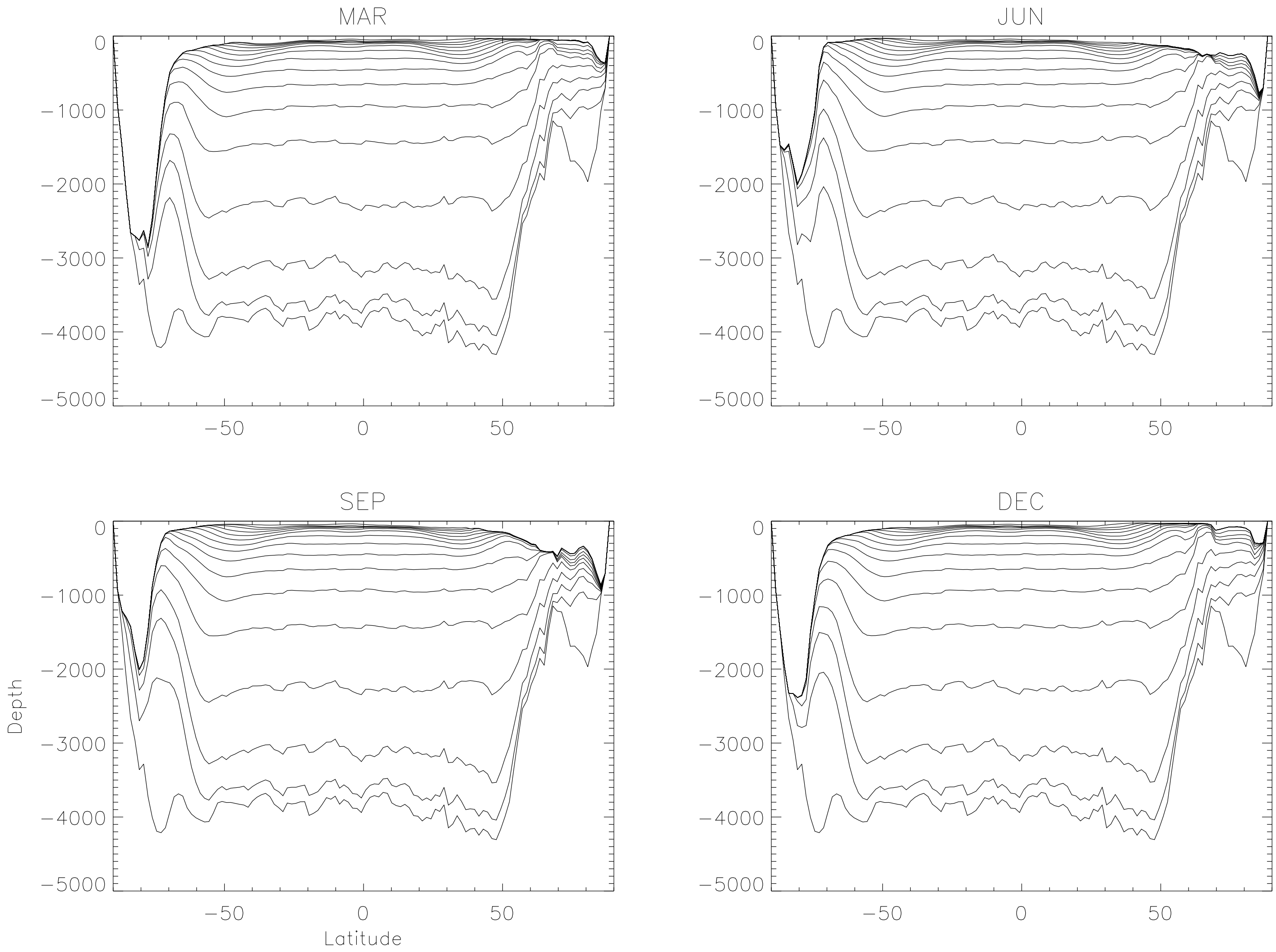




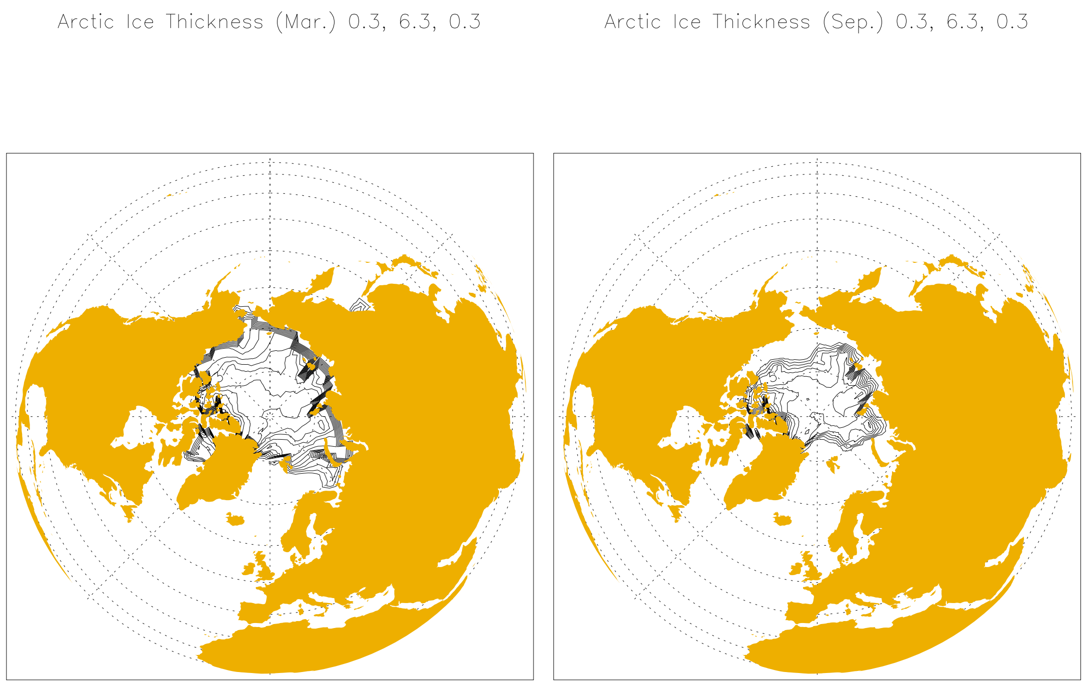
Too little Antarctic ice

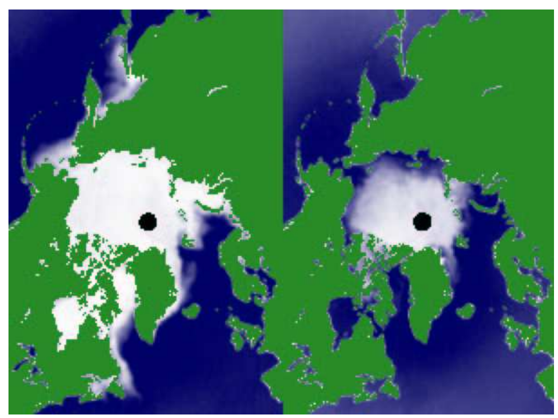


Too deep mixed layer? Grid scale oscillations.



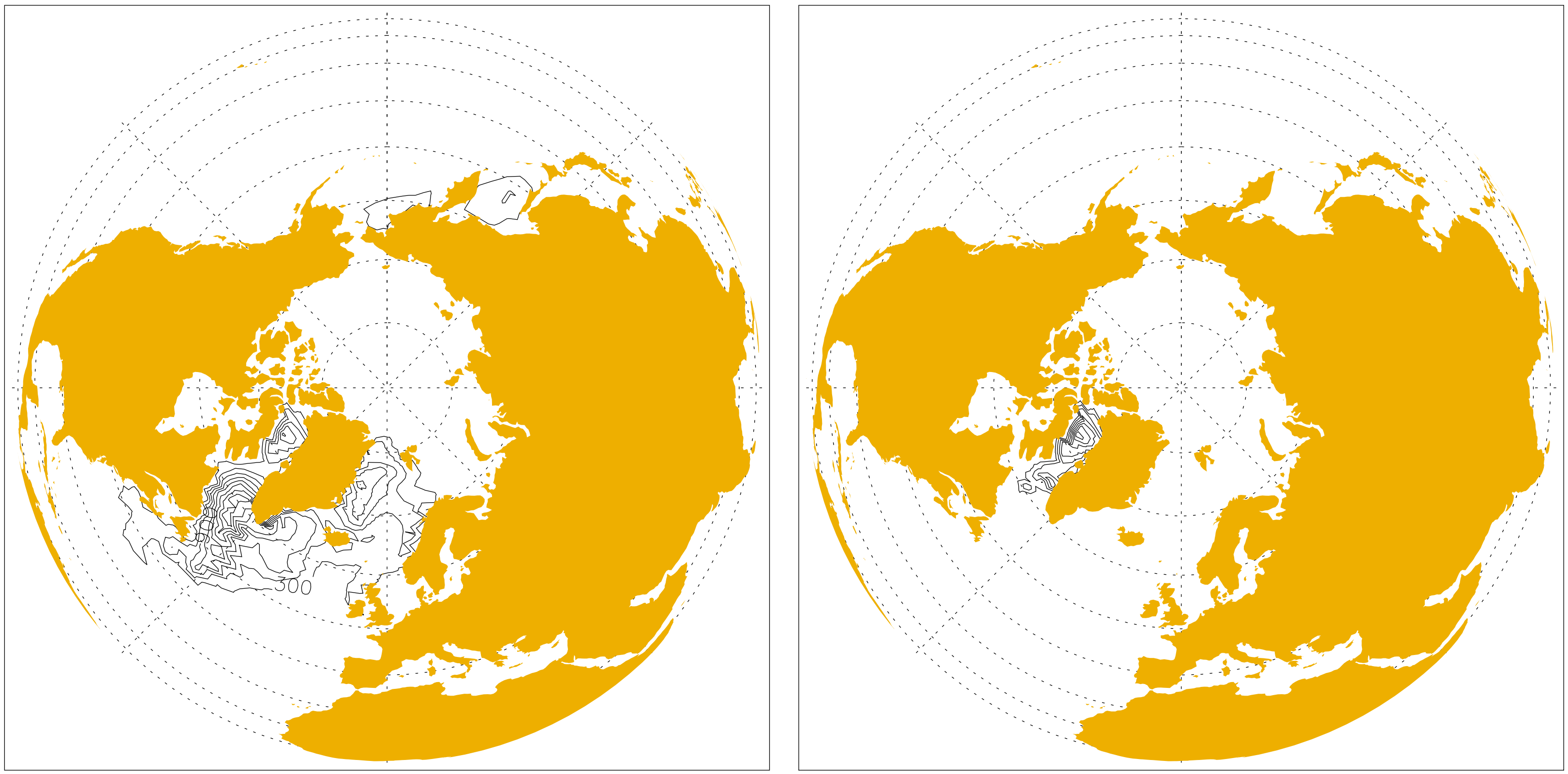
Zonally Avgd. Layer Interfaces: Year round deep ML in Ant.
No spring-summer restratification in Antarctic!





Reasonable Arctic ice

Mixed Layer Thickness (Mar.) 300, 3000, 300 Mixed Layer Thickness (Sep.) 200, 2000, 200



Arctic Mixed Layer Thickness

Antarctic vs. Arctic

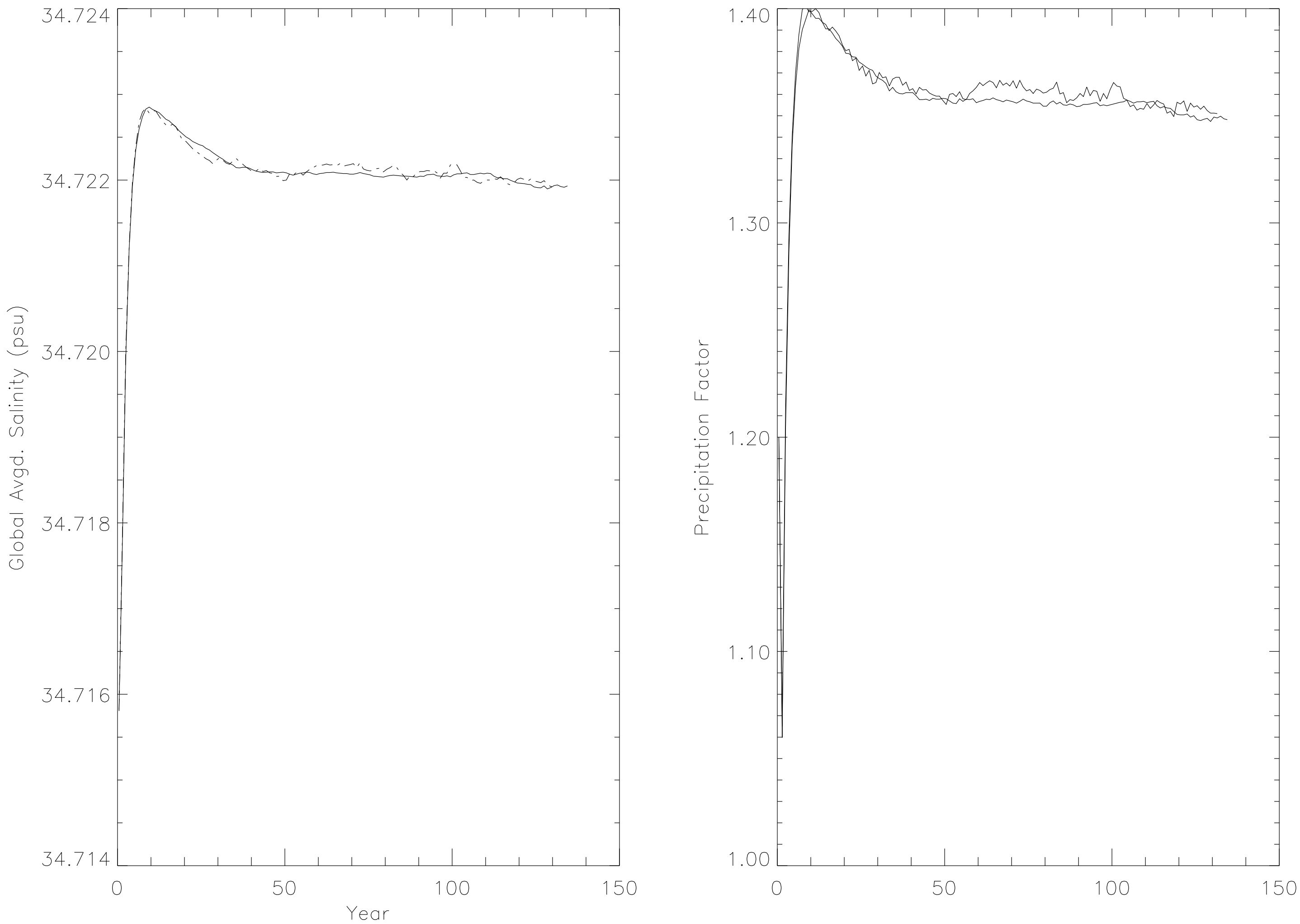
- Antarctic has thinner seasonal sea ice cover compared to Arctic

- Winter air-ice-ocean heat flux much larger in Antarctic (25-40 W/m^2) compared to Arctic (≤ 1 W/m^2)

- Antarctic is much less stably stratified compared to Arctic

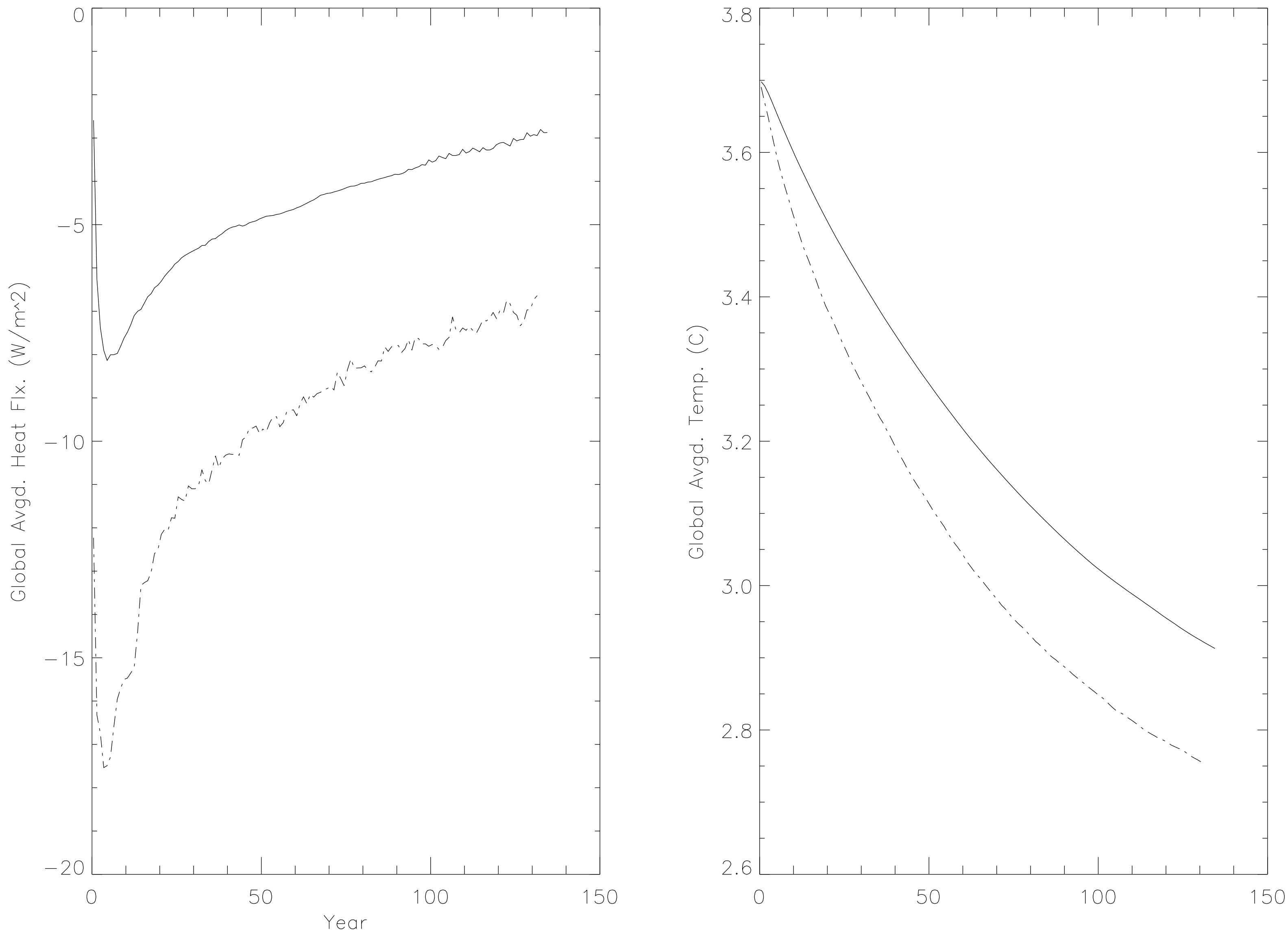
- Arctic tends to have a Cold Halocline Layer (CHL) separating the surface layer from the warmer interior
  Antarctic doesn't

- Nonlinear equation of state

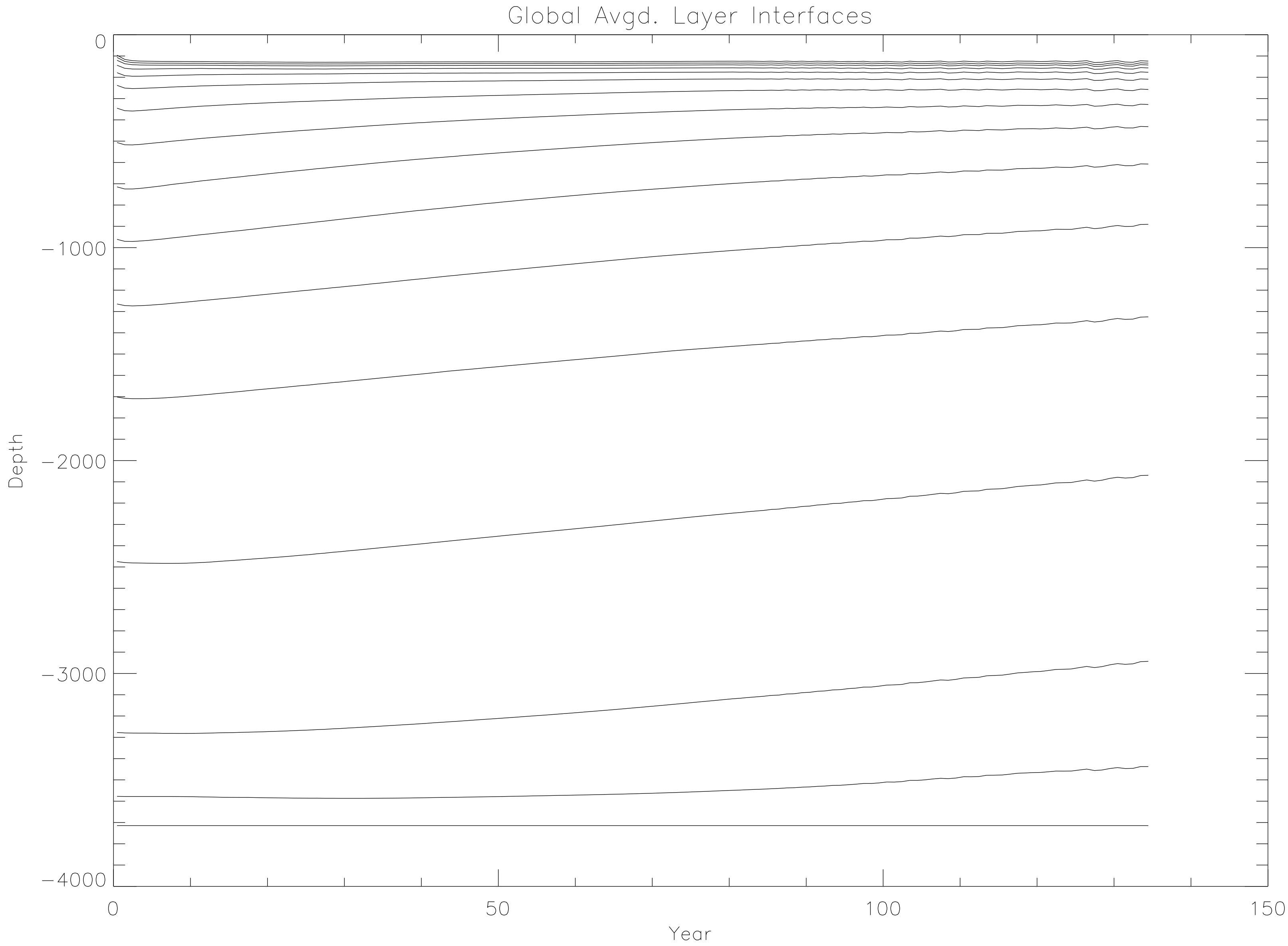


Precipitation adjustment behaves similarly

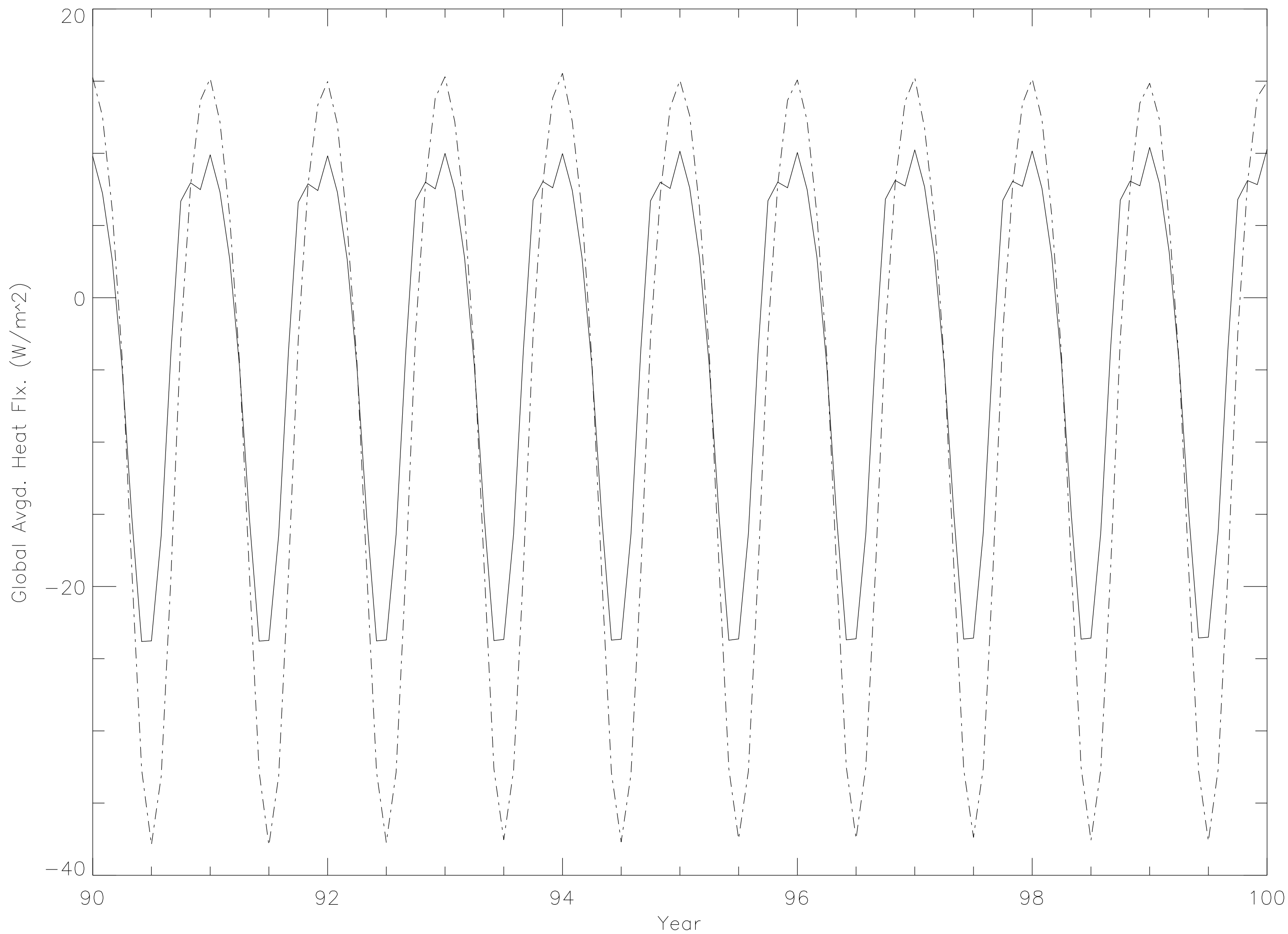
Climatological Ice. Fluxes over ice set to 0



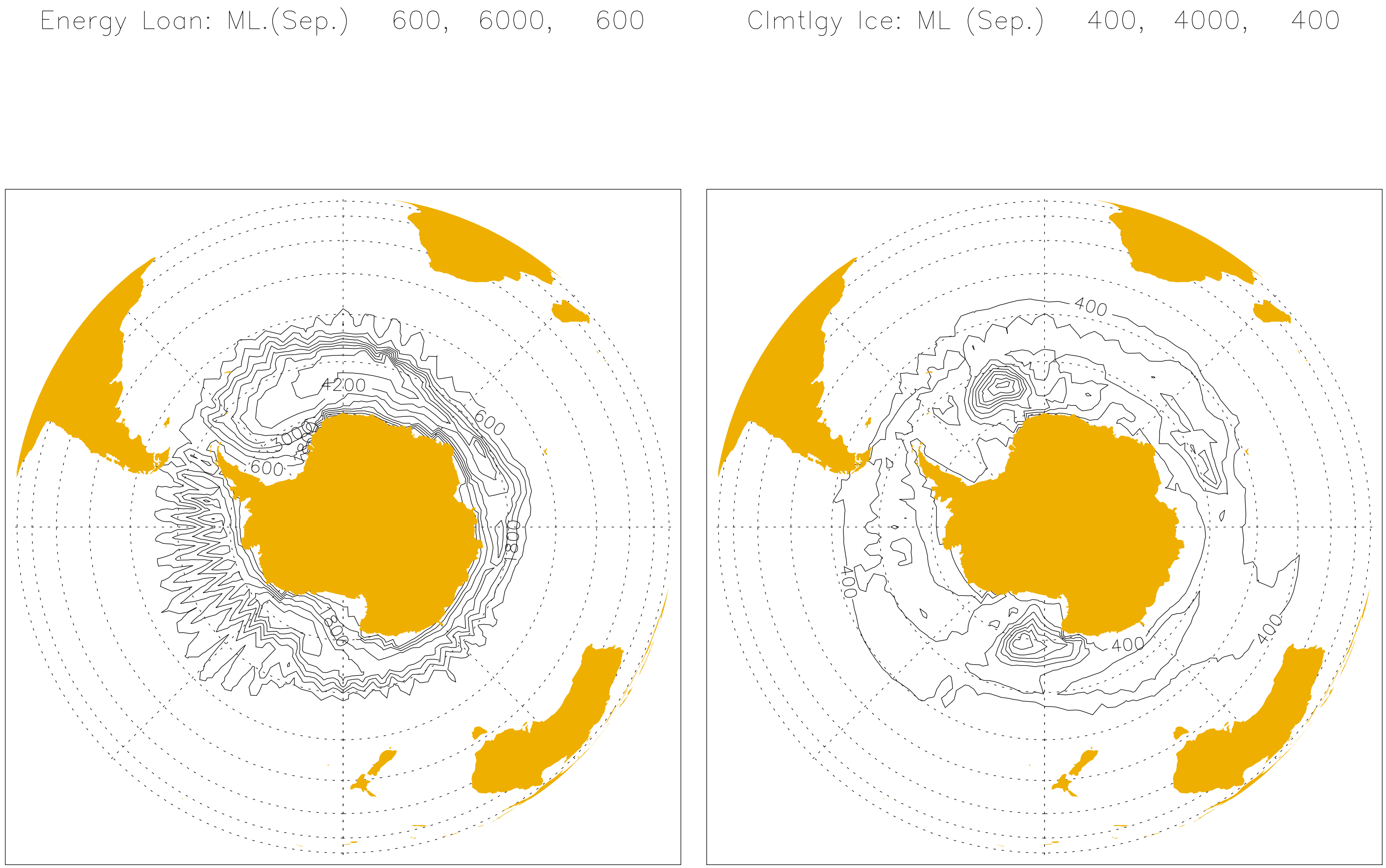
Heat loss lesser, but ocean still losing too much heat



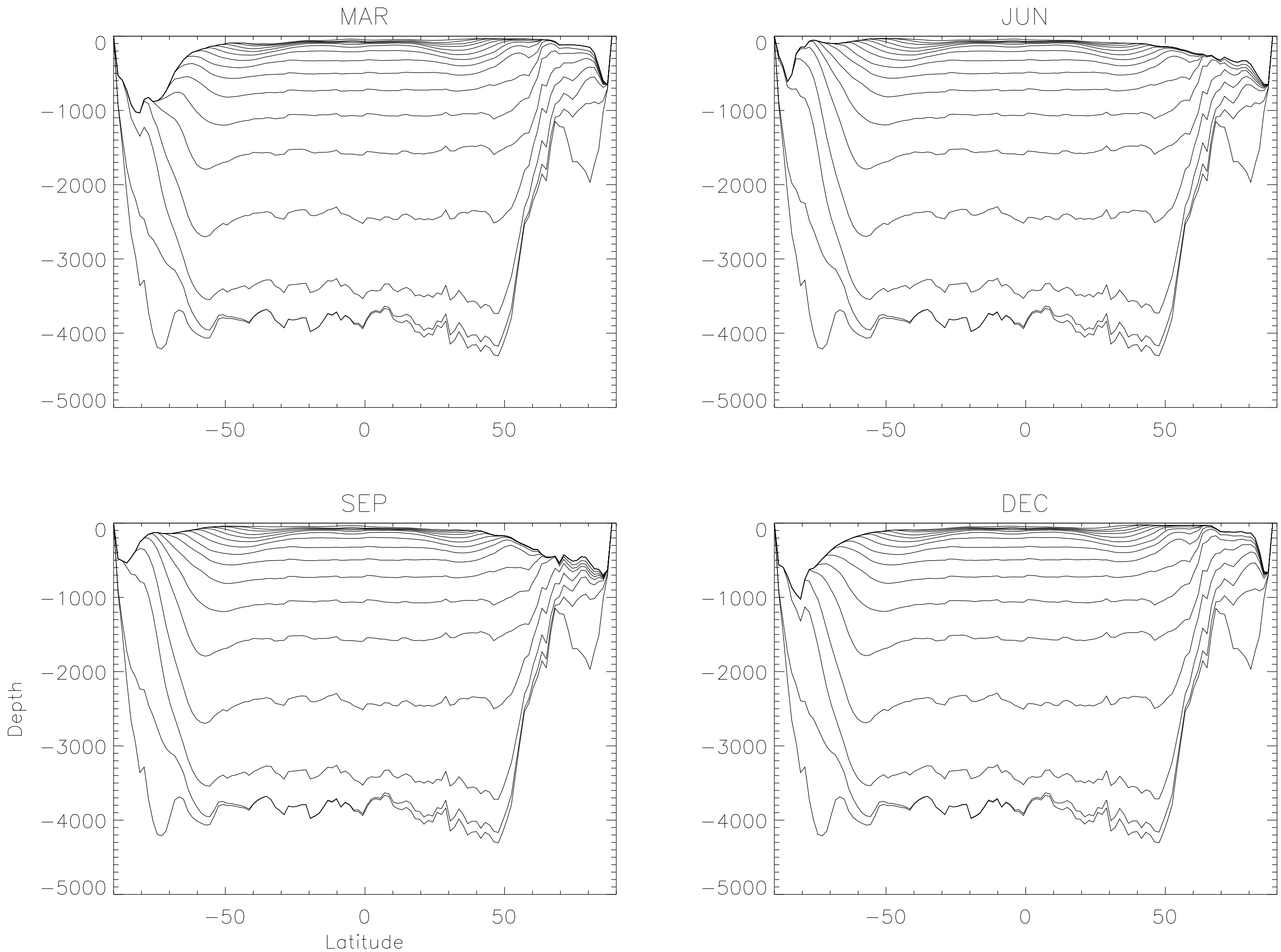
Evolution of avgd. layer thknss. consistent with cooling



Large heat loss in Antarctic winter ameliorated
(Too much?)

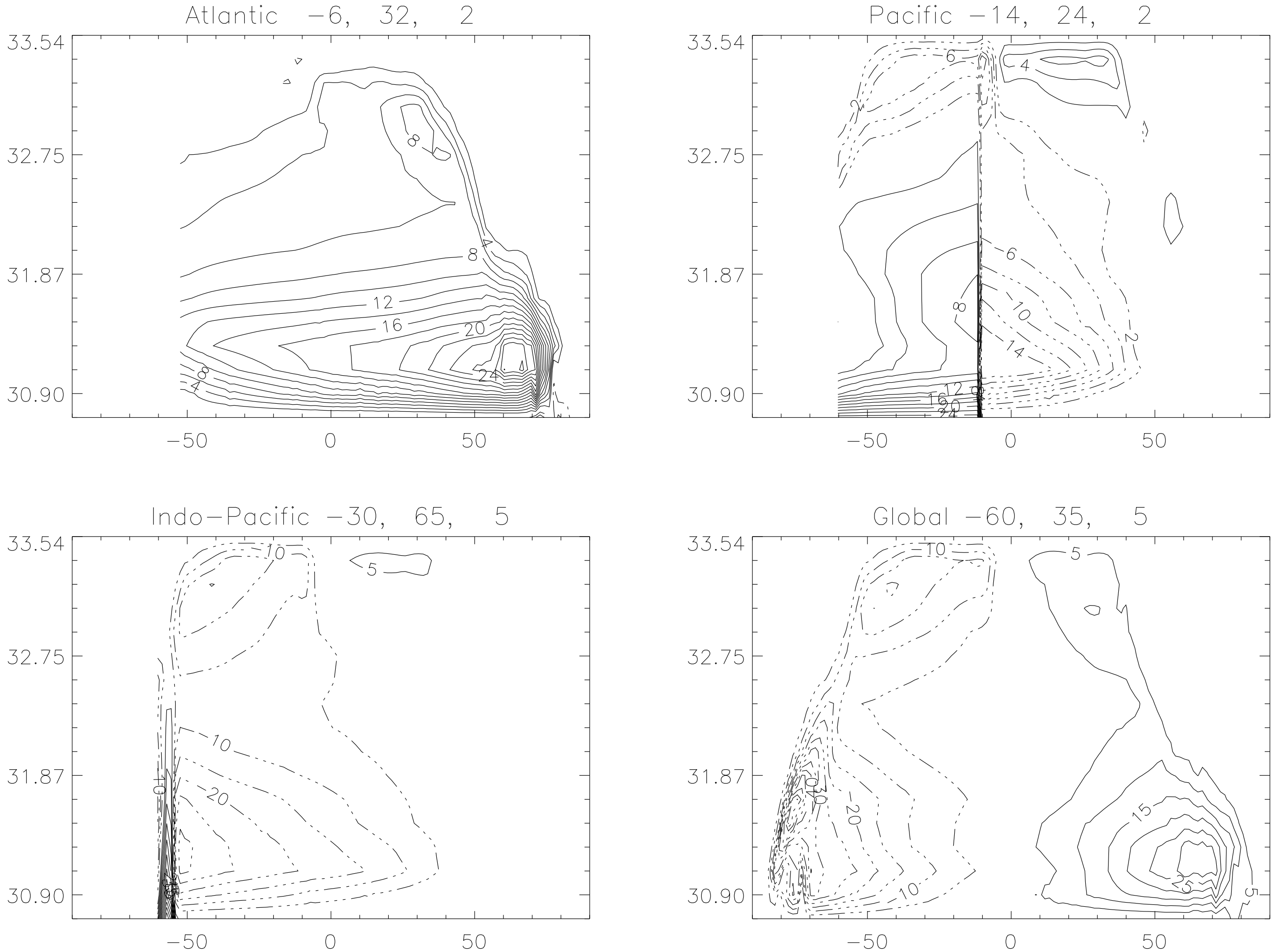


Grid scale oscillations persistent, but shallower ML.



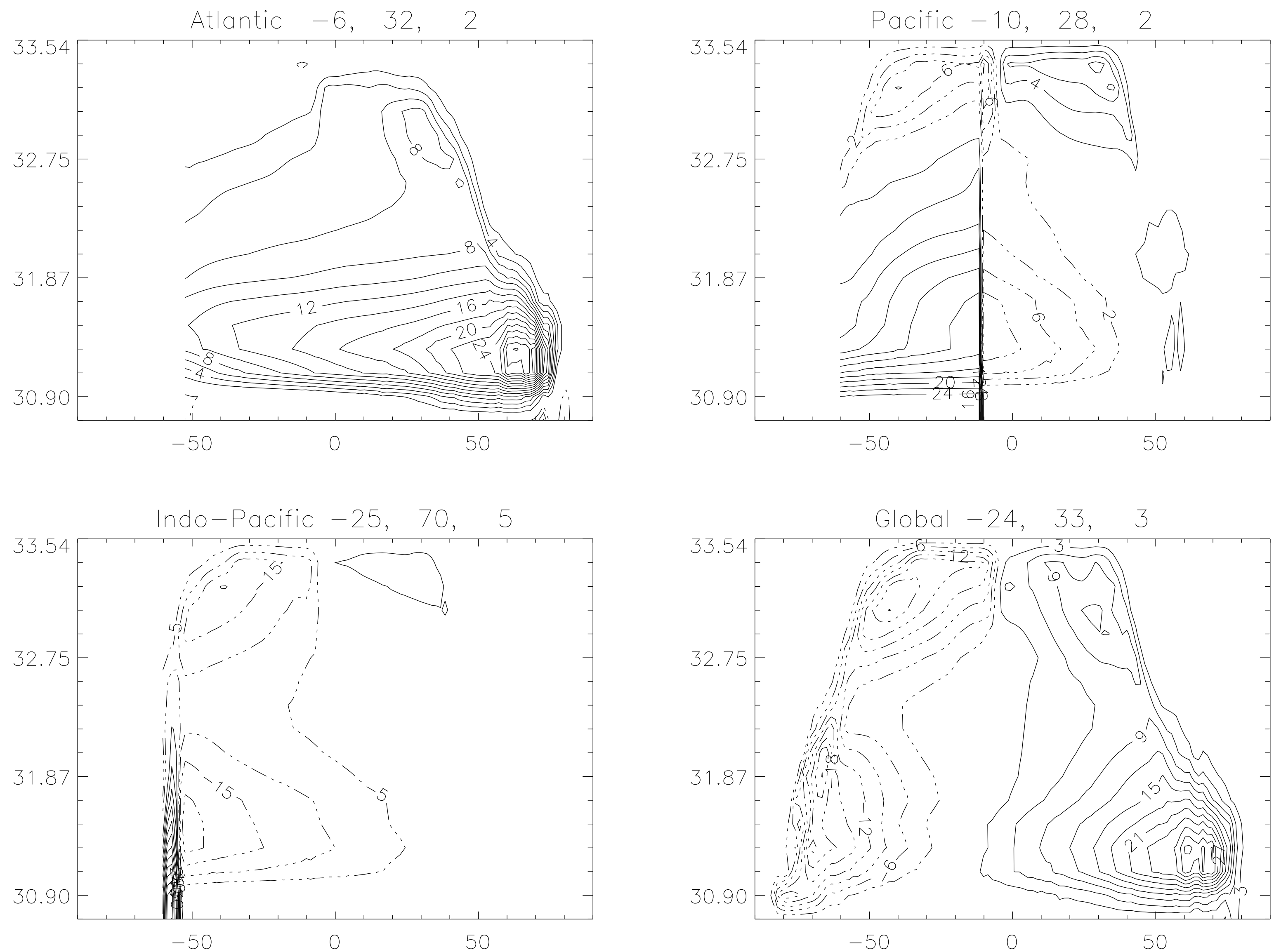
Zonally Avgd. Layer Interfaces: Shallower ML in Ant.

But, still no strong restratification in Antarctic!

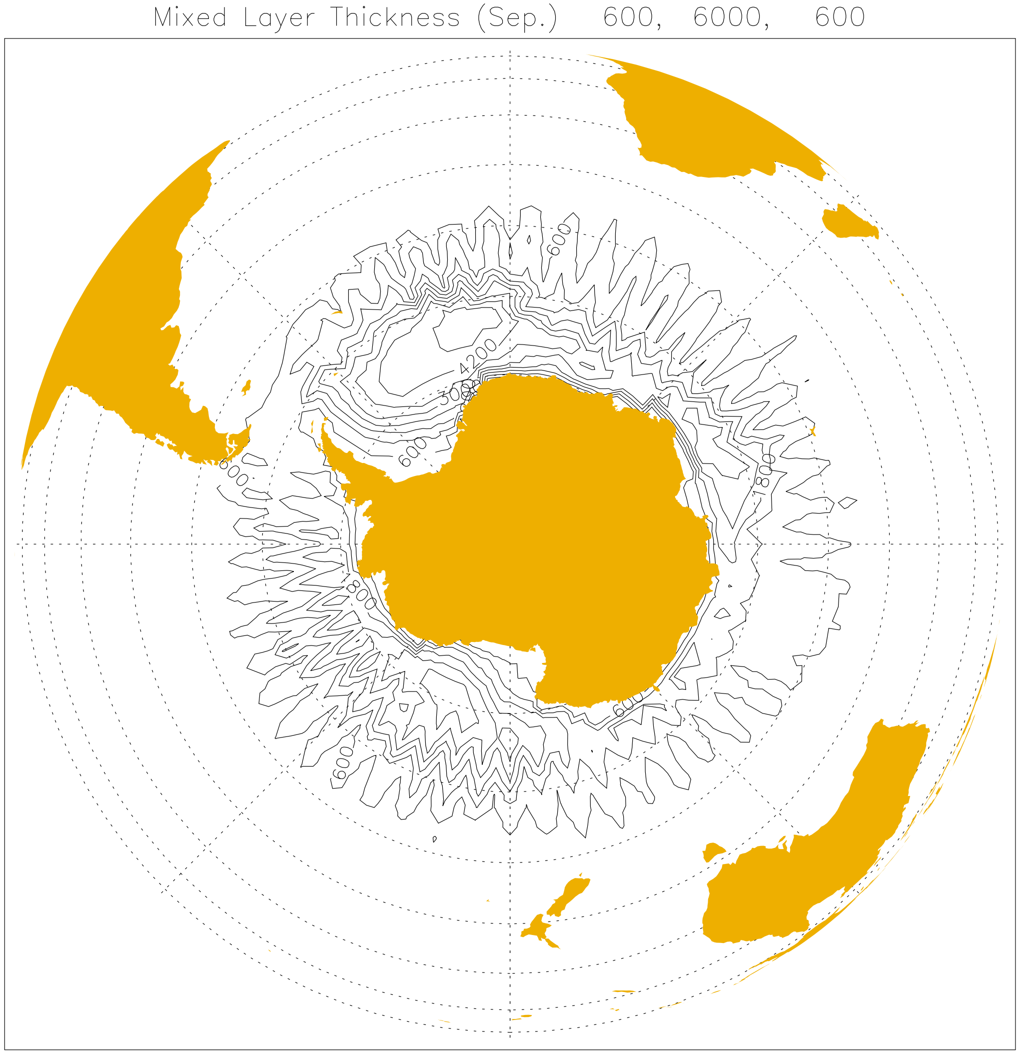


Ice Model: Meridional Overturning Streamfunction (Yrs 90-100)

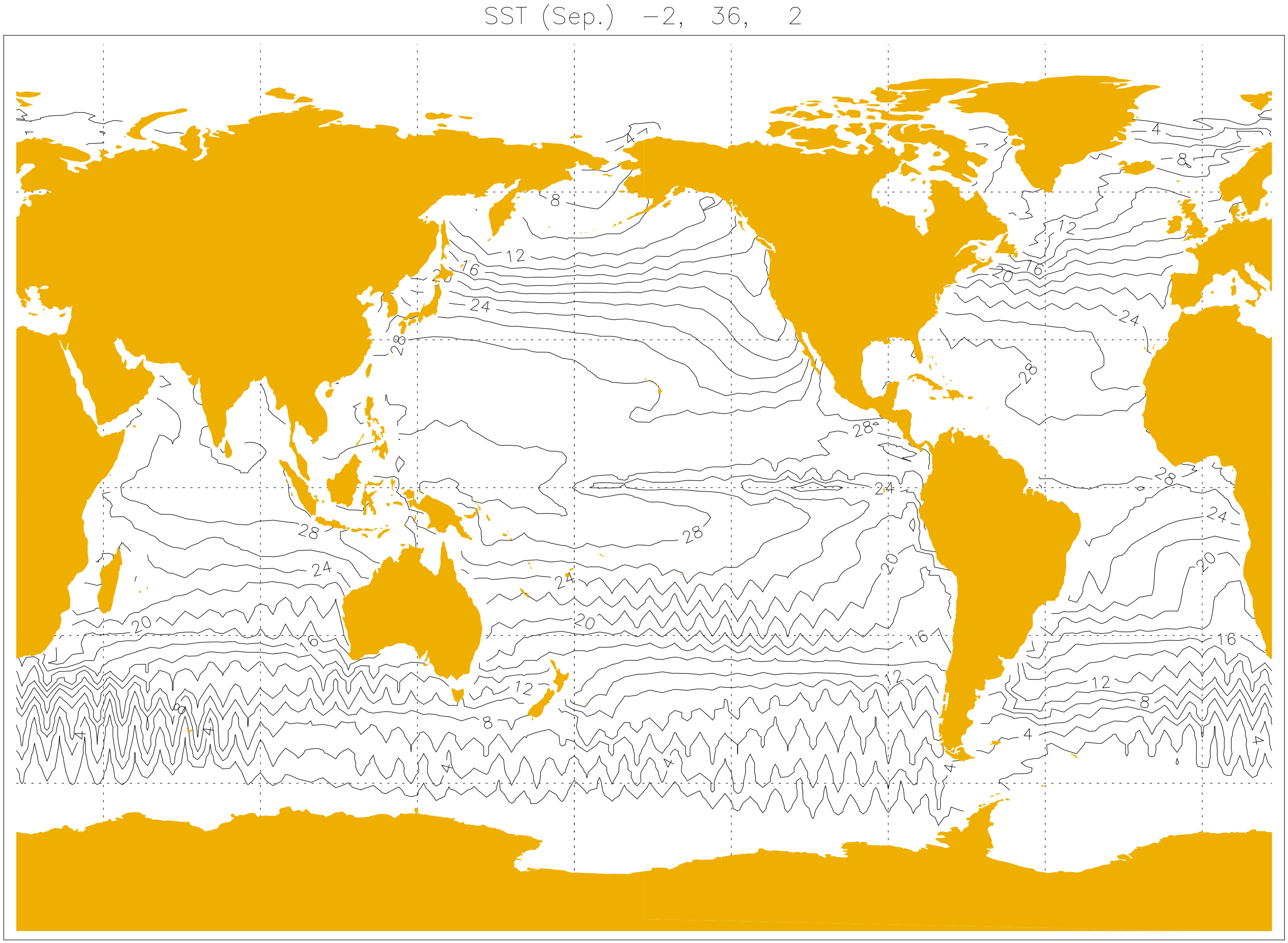
Too much ventilation ⇒ Strong MOC



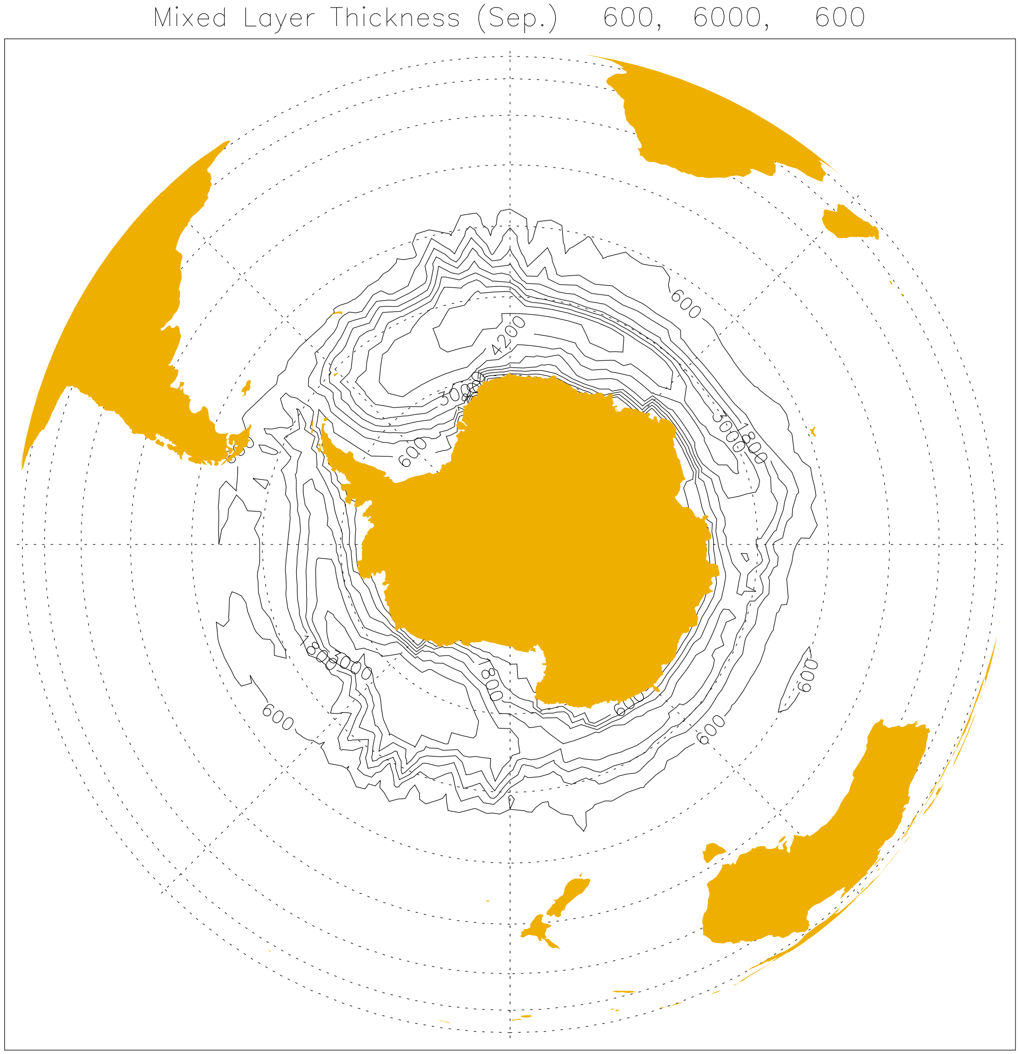
Diagnosed Ice: Reduced ventilation in Antarctic



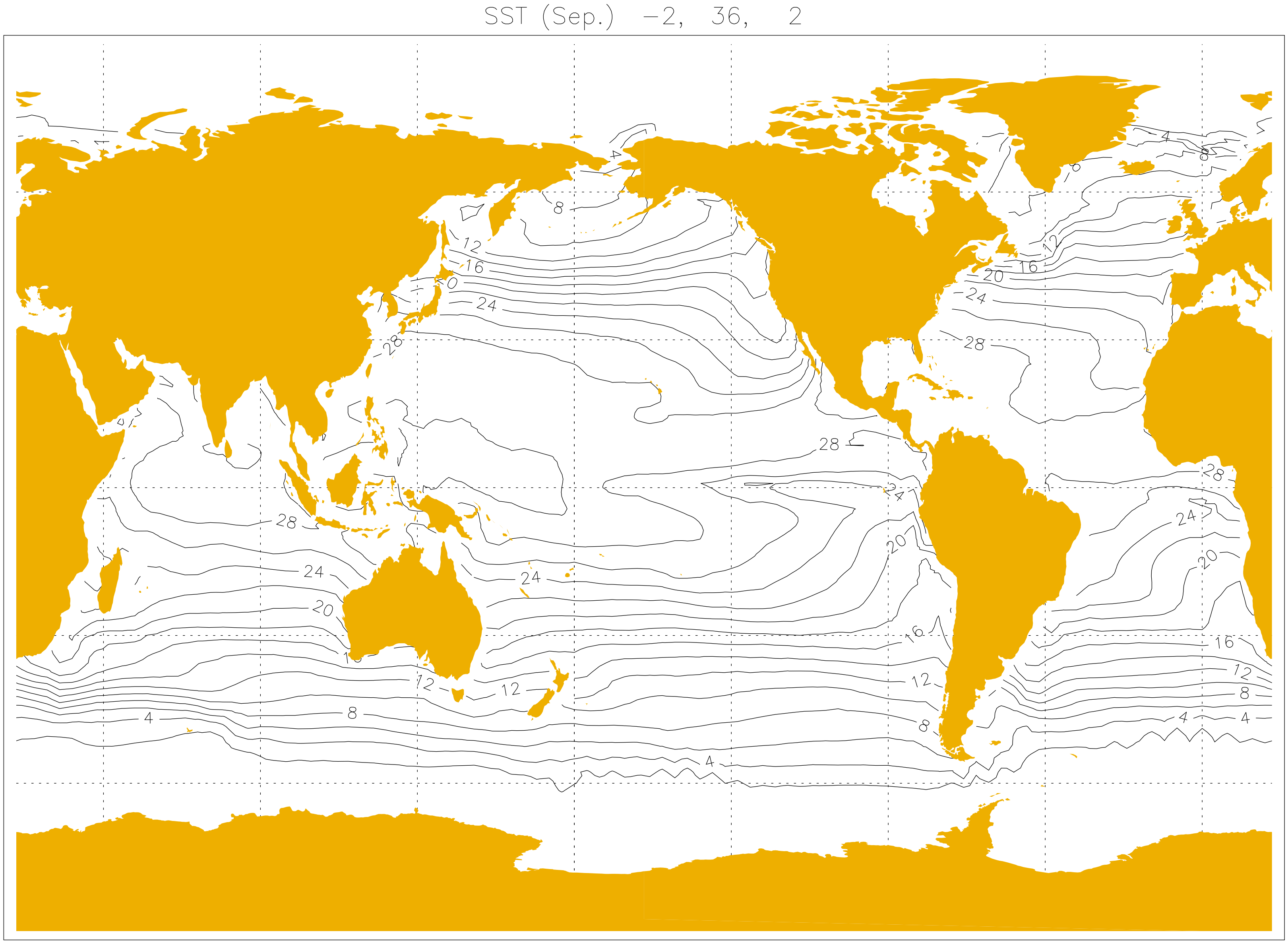
Top layer depth (veldff=2cm/s; t=1350 days)
Noise is largely due to non-resolution of viscous BL scale



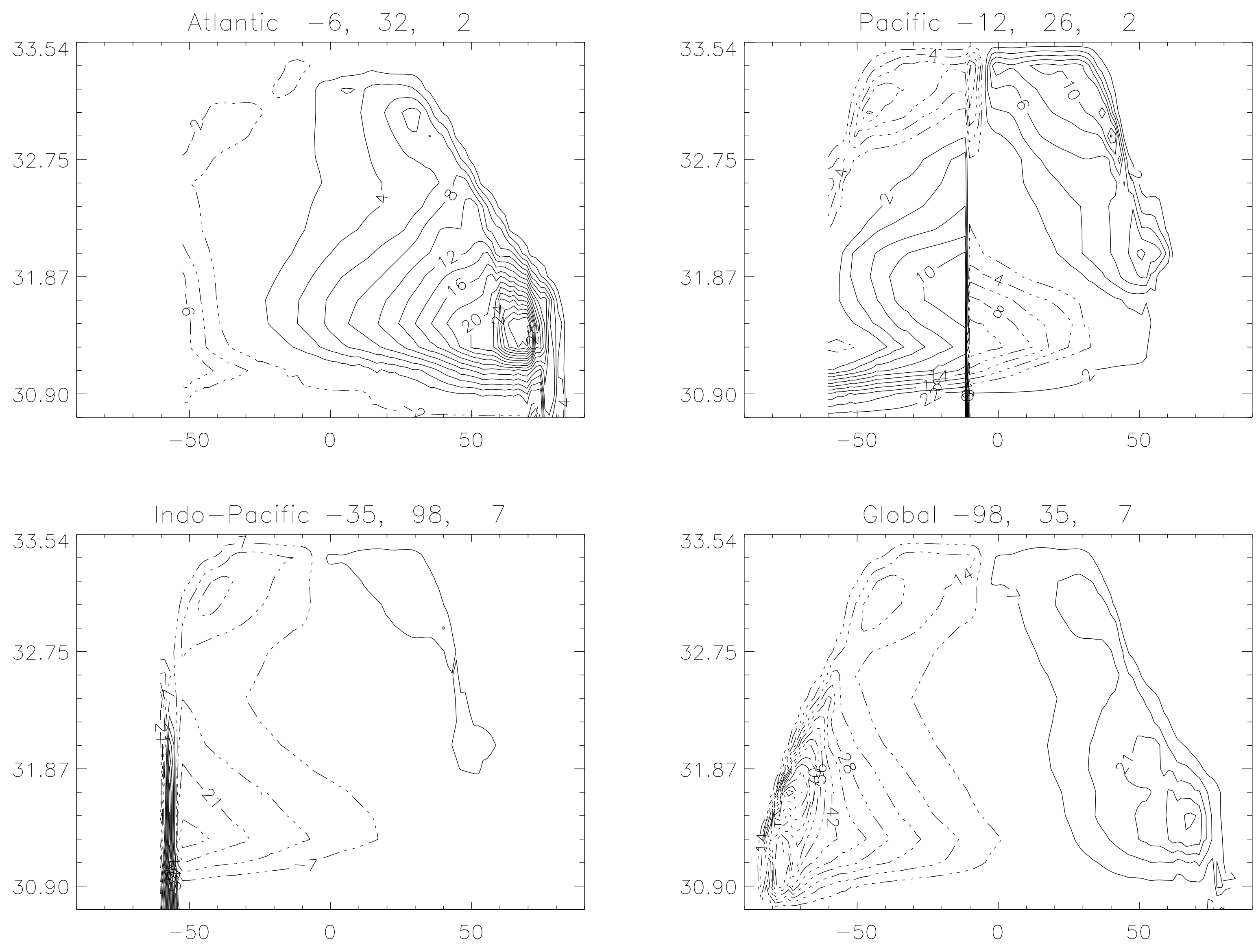
SST (veldff=2cm/s; t=1350 days)



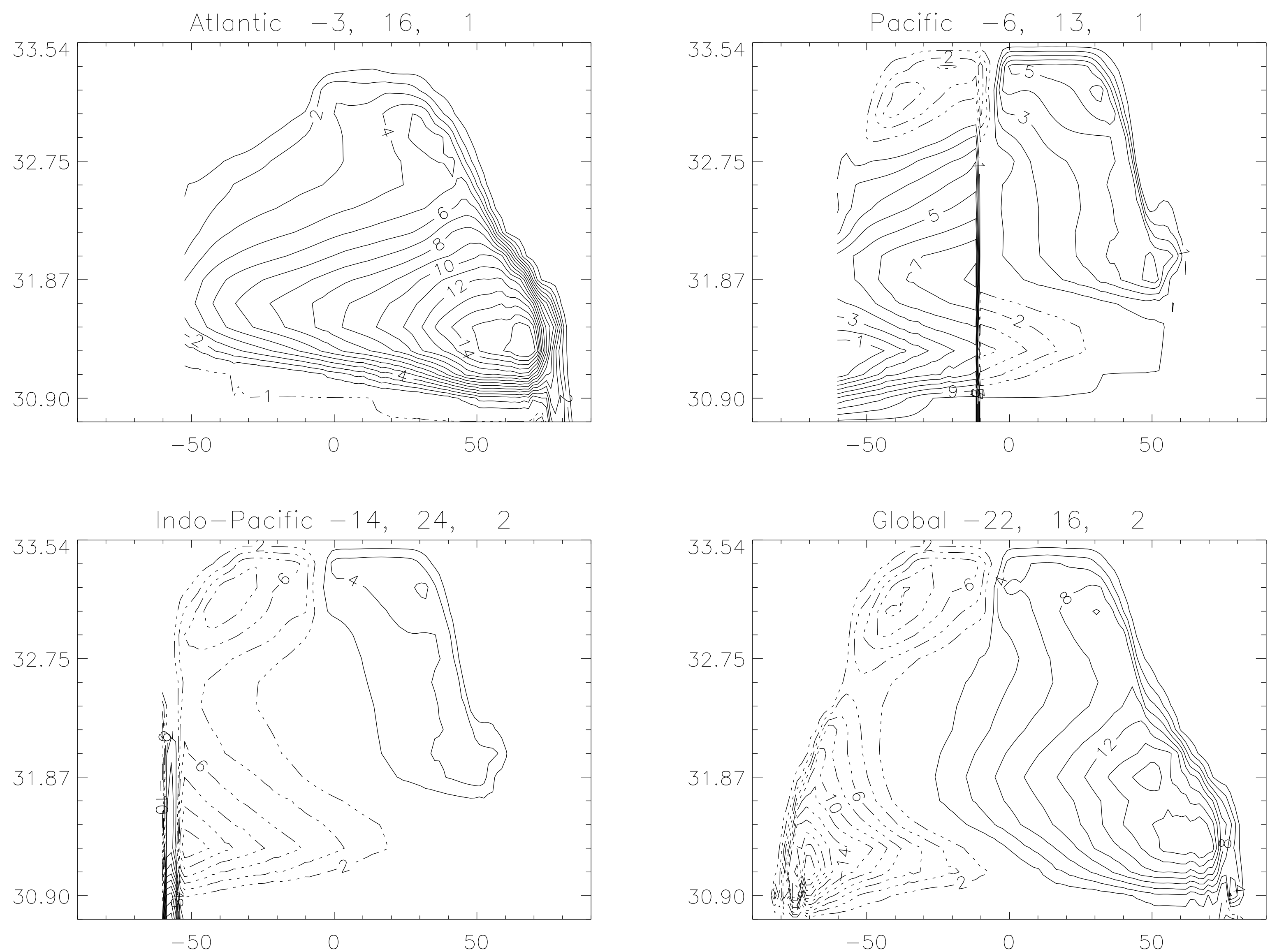
Top layer depth (veldff=80cm/s; t=450 days)



SST: Reduced grid scale noise (veldff=80cm/s; t=450 days)



veldff=2 cm/s. Significantly Noisy fields. Large MOC



veldff=80 cm/s. MOC magnitude reduced

Summary

- Work in progress

- Too much ventilation in Antarctic

  - Entrainment heat flux too high
    Ocean loses too much heat

  - Consequently too strong an MOC

- Inability to restratify deep ML in Antarctic
  due to bulk treament of ML

- Such problems not apparent in Arctic

- Unable to capture halocline because of unmixing strategy?

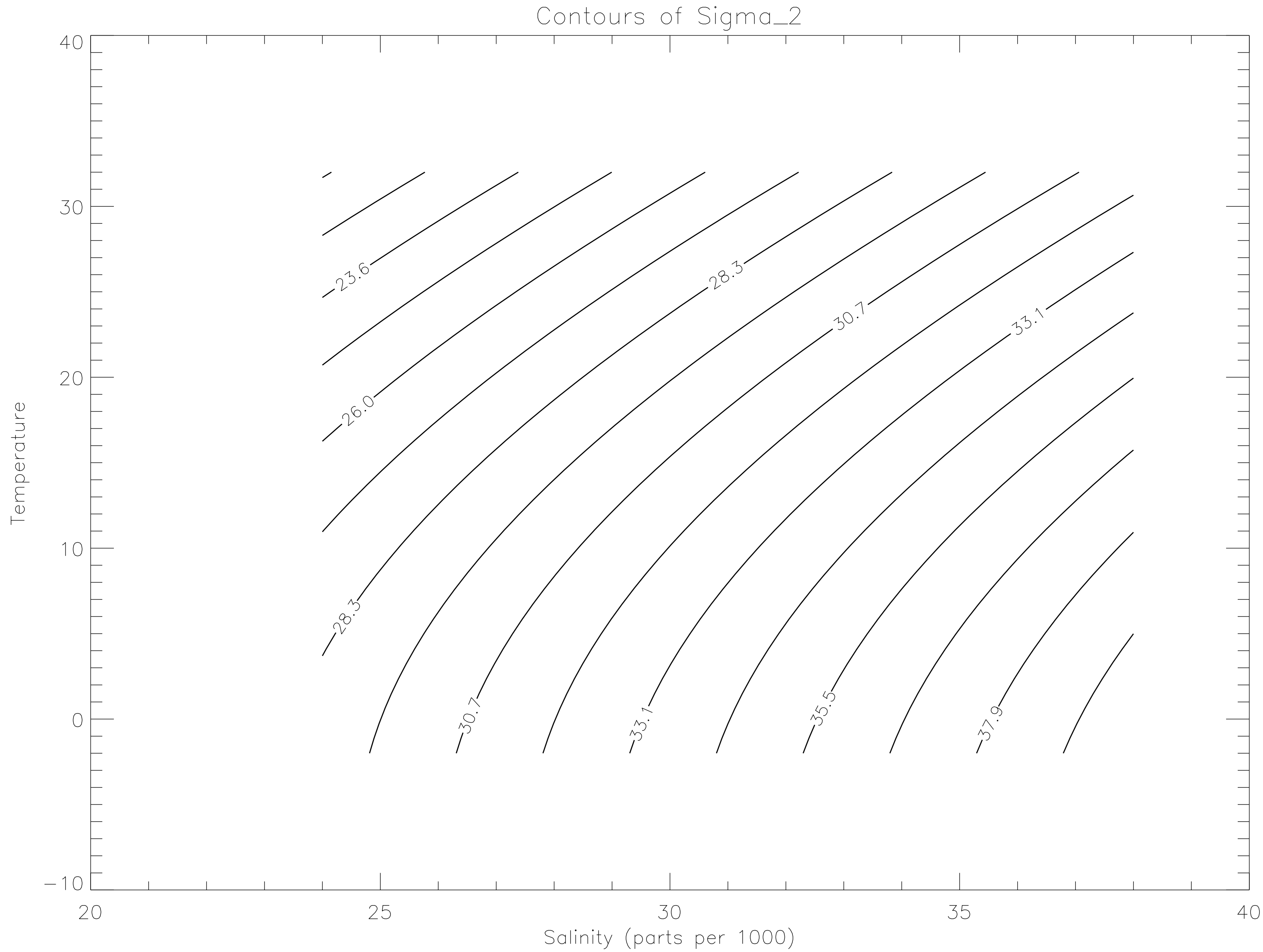
- Perhaps dynamics of ice is important?

- Nonlinearity (a la Whitehead)

  formation rate of dense salty water may be quite limited for small cooling rates, but one strong cooling event can trigger intense formation rates that may persist vigorously for the rest of the winter.

- Traditionally MICOM has not cared to resolve BLs (Uses too low viscosities)

- This non-resolution has definite implications on the strength of the MOC it produces



Nonlinearity of Equation of State