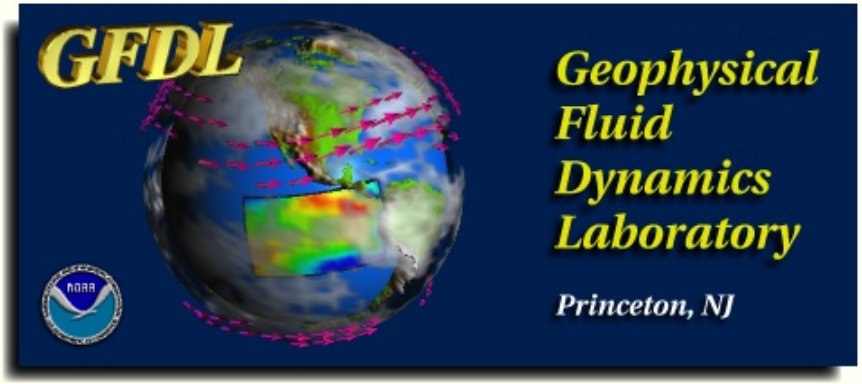
Sea Ice in the GFDL CM2 Coupled Atmosphere-Ice-Ocean Model



Tony Beesley and Michael Winton

14 June ‘04

GFDL Sea Ice Simulator

Thermodynamics

- Six ice-thickness partitions, including open water

- Ice properties resolved on two layers in ice, overlain by a single layer of snow. (Semtner 3-layer model.)

- Latent heat of fusion due to changes in brine content treated in an energy conserving manner following Bitz and Lipscomb (in upper layer); conductivity is constant.

- Ice formation by congelation, frazil growth, snow freezing

- Albedo: follows the NCAR CSIM scheme

Dynamics

- Viscous-Elastic-Plastic rheology of Hunke & Dukowitz (1997), with modifications

- Ice strength is a function of ice thickness (following Hibler), summed over ice thickness partitions

Transport and redistribution

- Upstream advection

- Ice thickness redistribution is based on realized divergence (not ice deformation)

GFDL CM2 Global Coupled Model

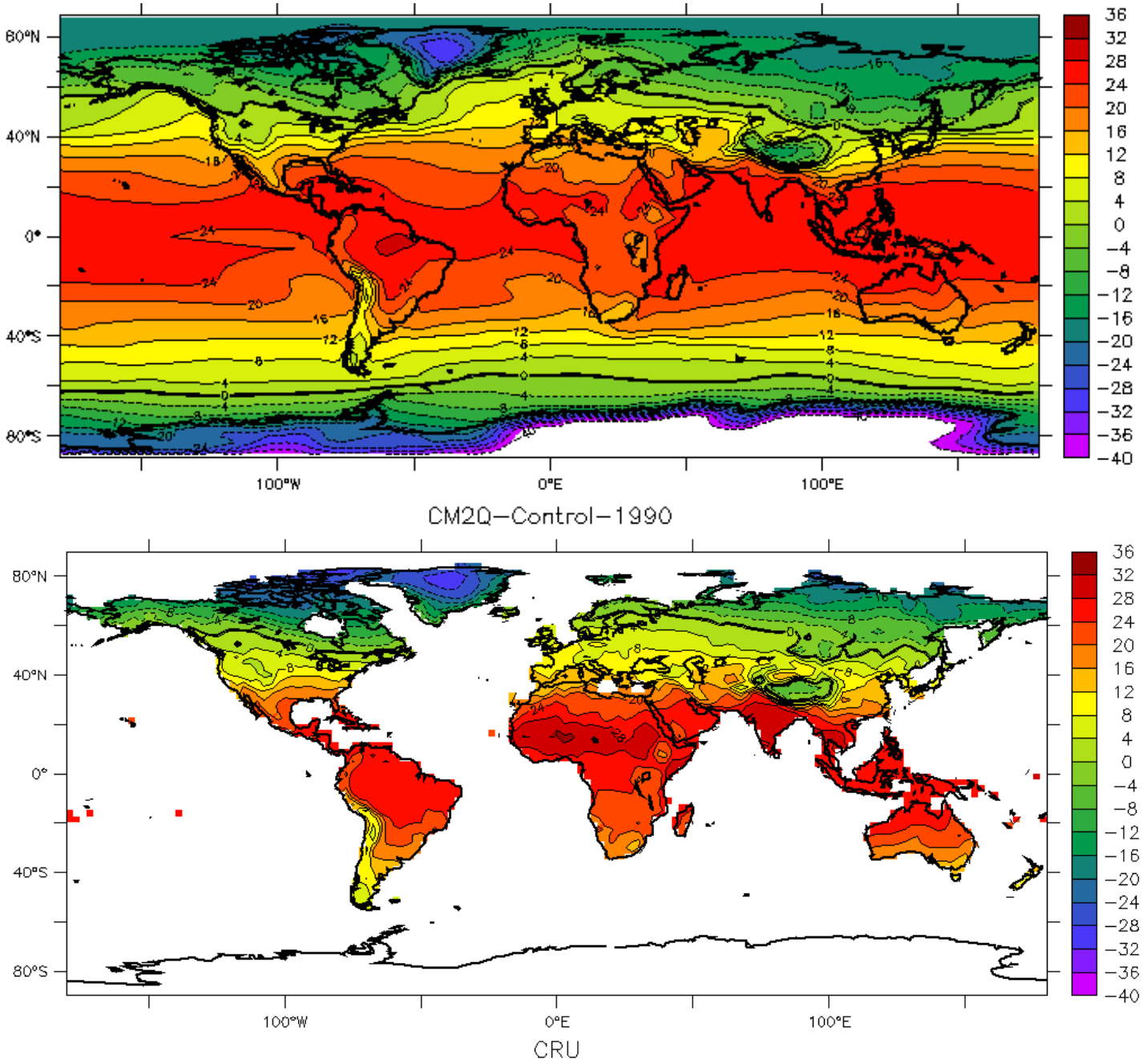
Atmosphere

- Advanced physical processes for global climate models
    - prognostic multi-phase stratiform clouds
    - relatively high resolution spectral resolution radiative transfer
    - etc.
- B-Grid dynamics (but moving to finite volume dynamic core)
- 2^{O} lat x 2.5^{O} lon spatial resolution on 24 vertical levels.

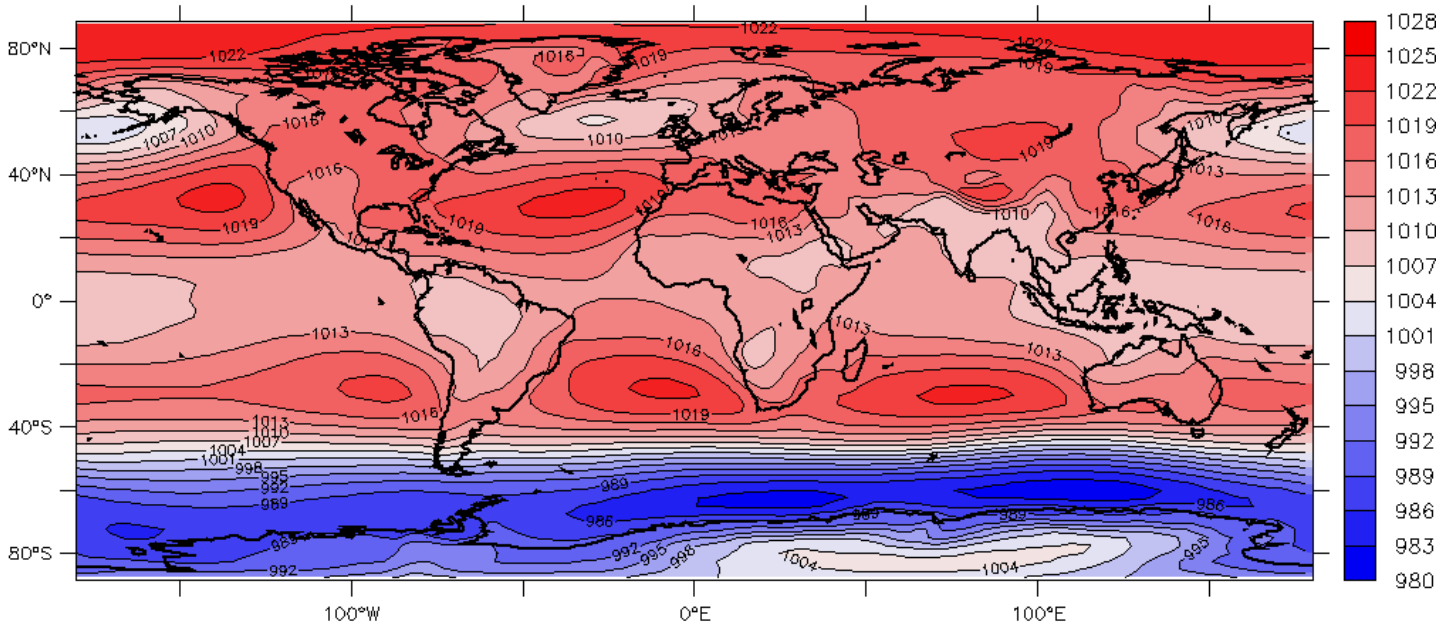
Ocean (Modular Ocean Model)

- Based on Bryan-Cox model with tri-polar grid
- Resolution: horizontal ~< 100 km (better in Arctic)
  vertical 50 levels, 10 m down to 2 km

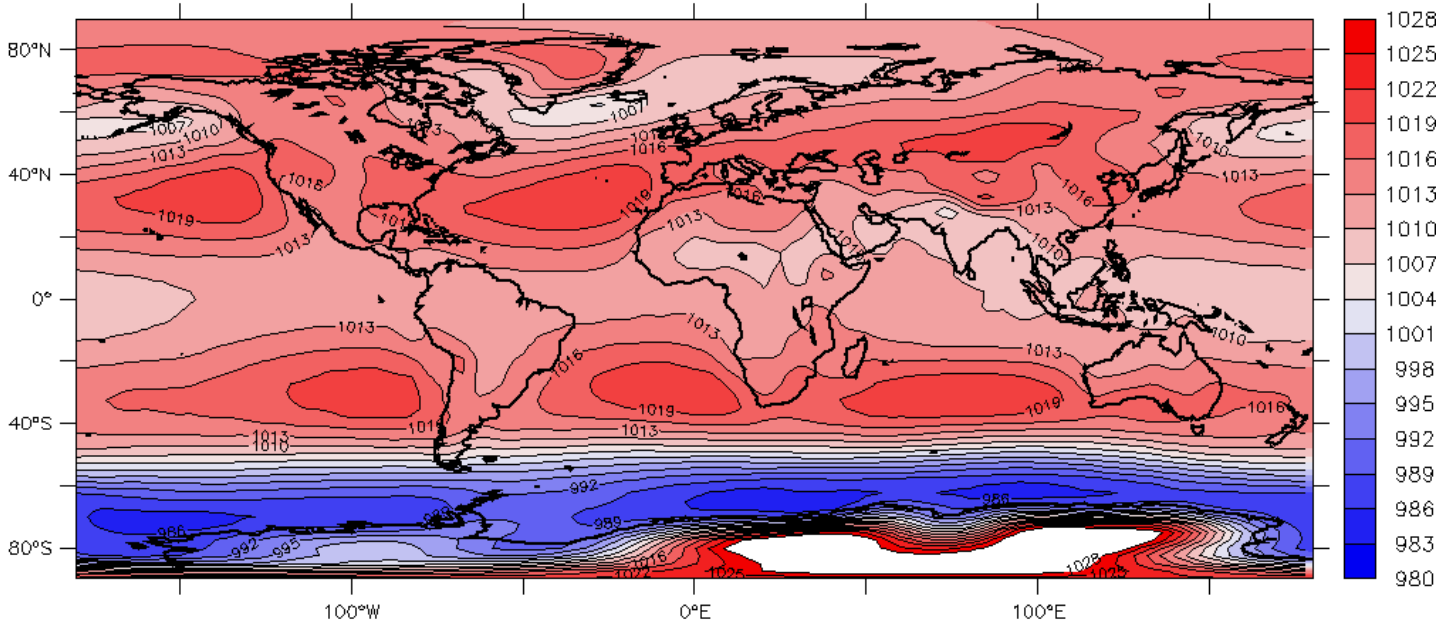
CM2 Annual Mean 2-M Air Temperature



CM2 Annual Mean Sea Level Pressure

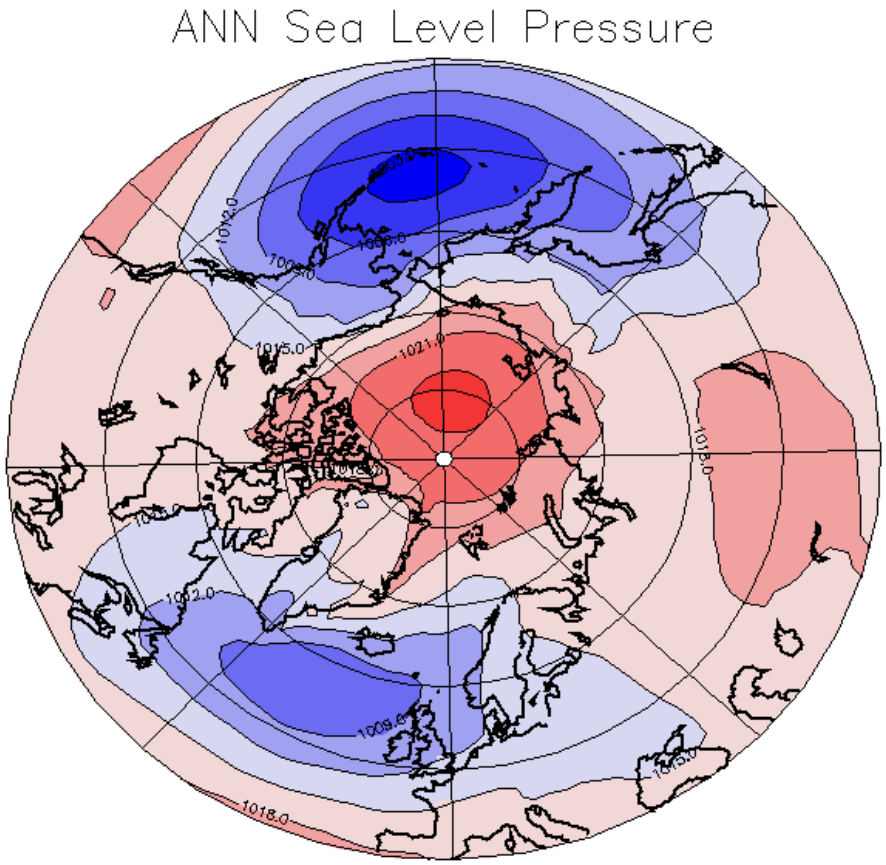


CM2Q–Control–1990

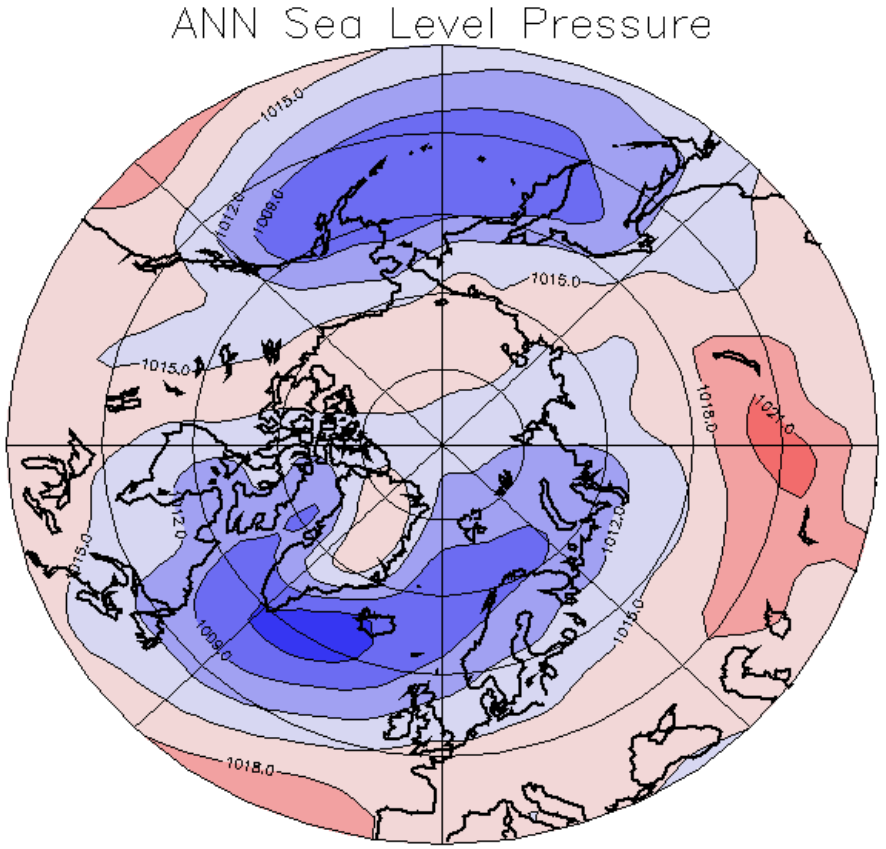


NCEP–Reanal

CM2 “forcing”
Average Polar Sea Level Pressure



CM2Q–Control–1990



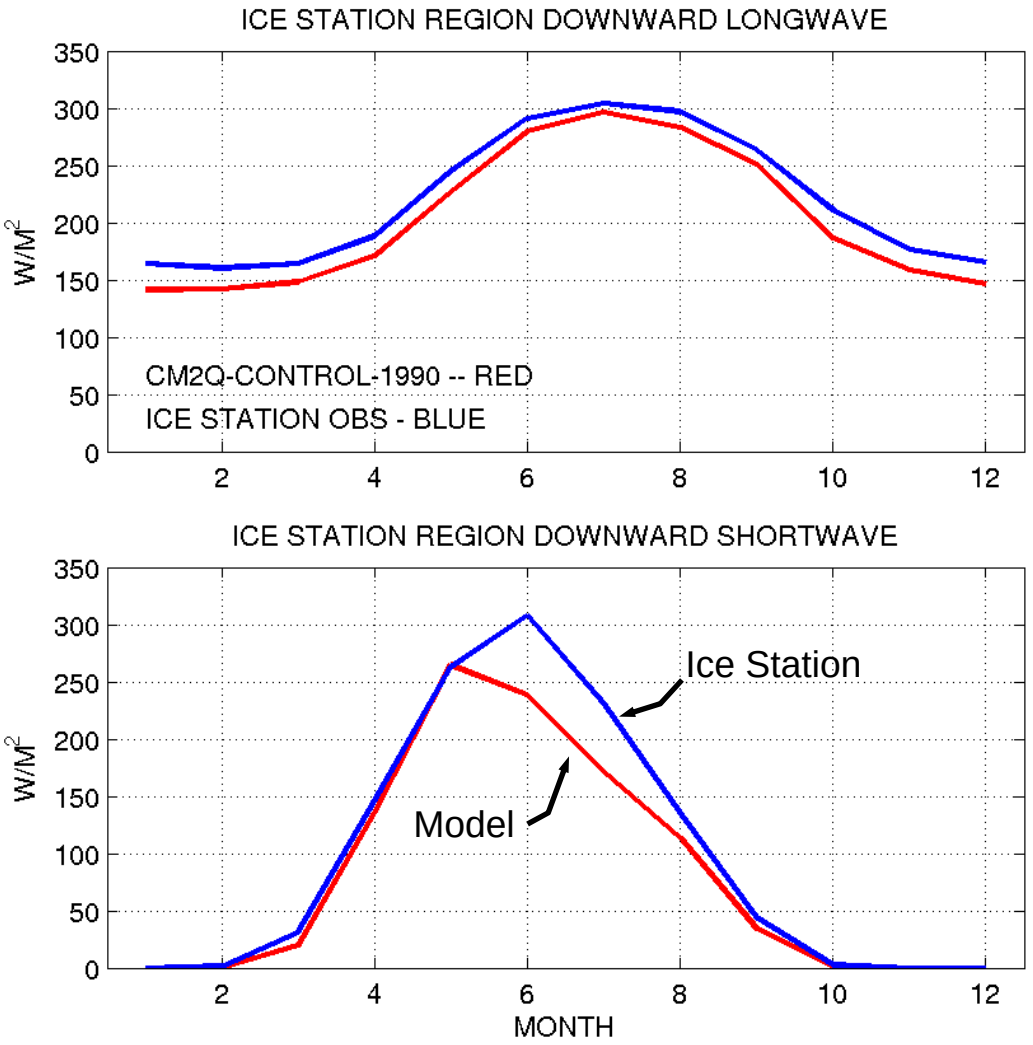
NCEP Reanalysis

CM2 “forcing”
Downward Radiative Fluxes in Central Arctic

Significant deficit in downward radiative fluxes.

20 W/m^2 in LW

Up to 70 W/m^2 in SW



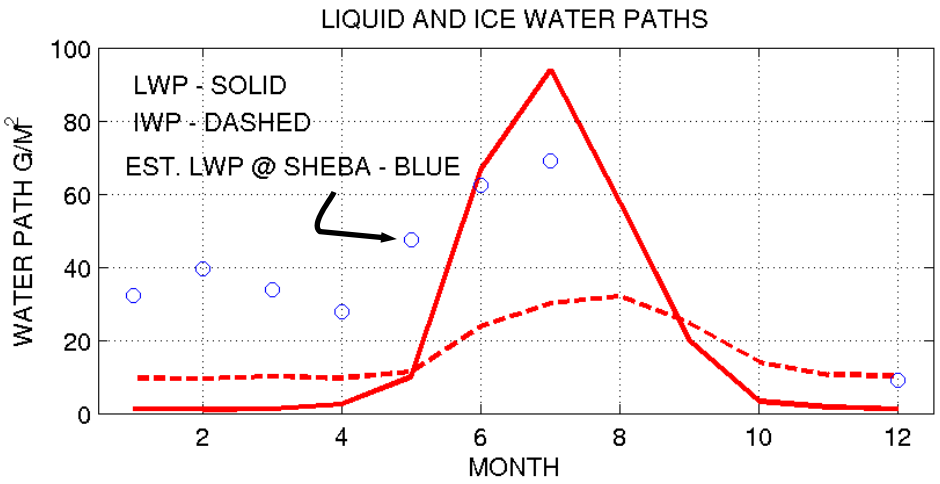
Why too little downward radiation?

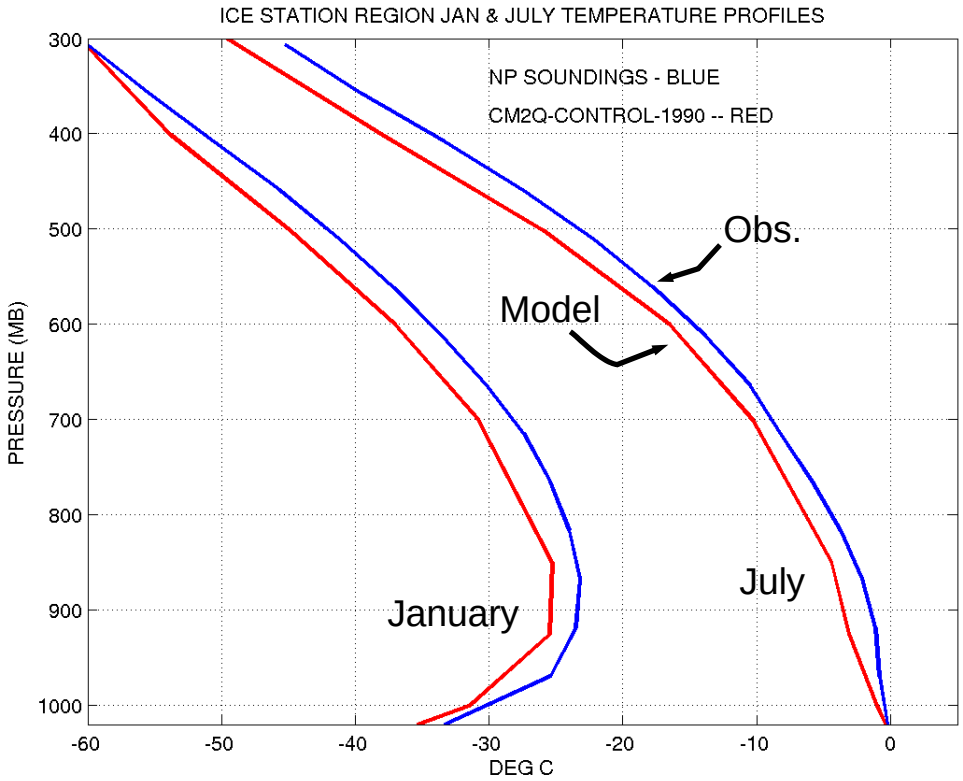
Shortwave is blocked by clouds.

- Summer cloudcover is 95% in model versus ~85% observed.
- Liquid water path is too large (clouds are too thick).

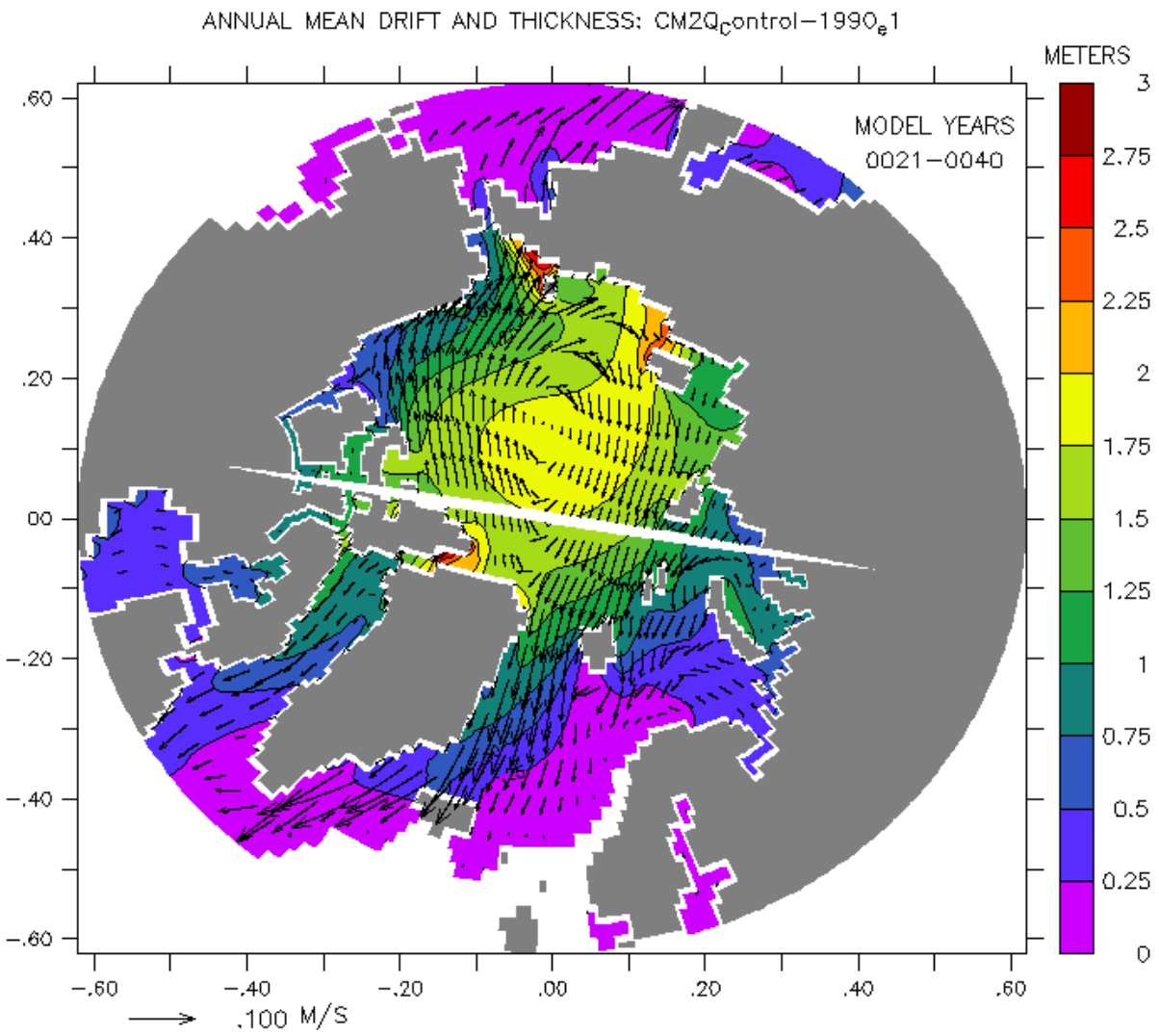
Atmosphere is too cool, resulting in too little downward longwave.

Probably attributable to storm activity not bringing enough energy into the Arctic.



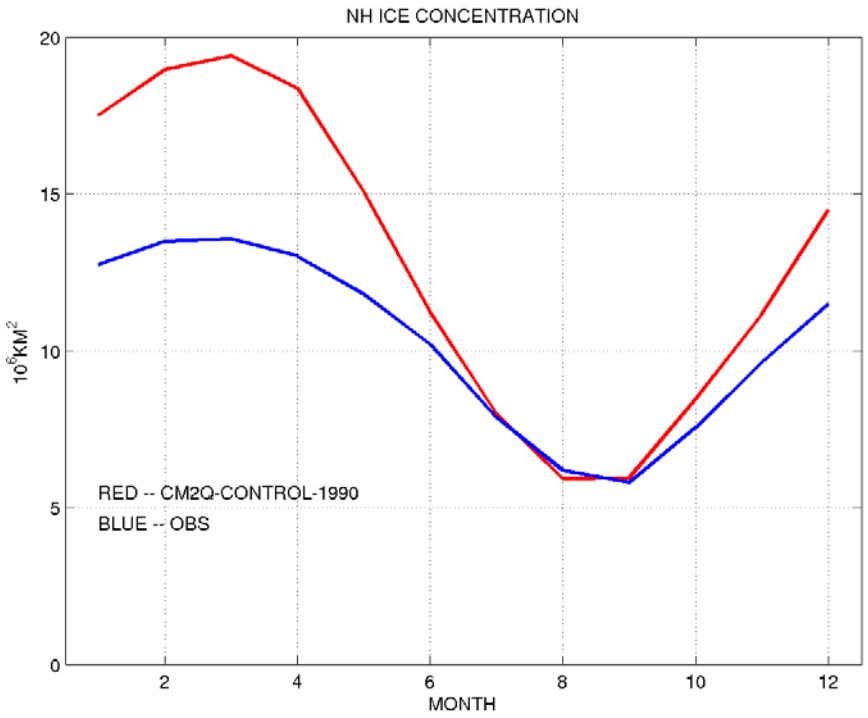


Average Ice Drift and Thickness

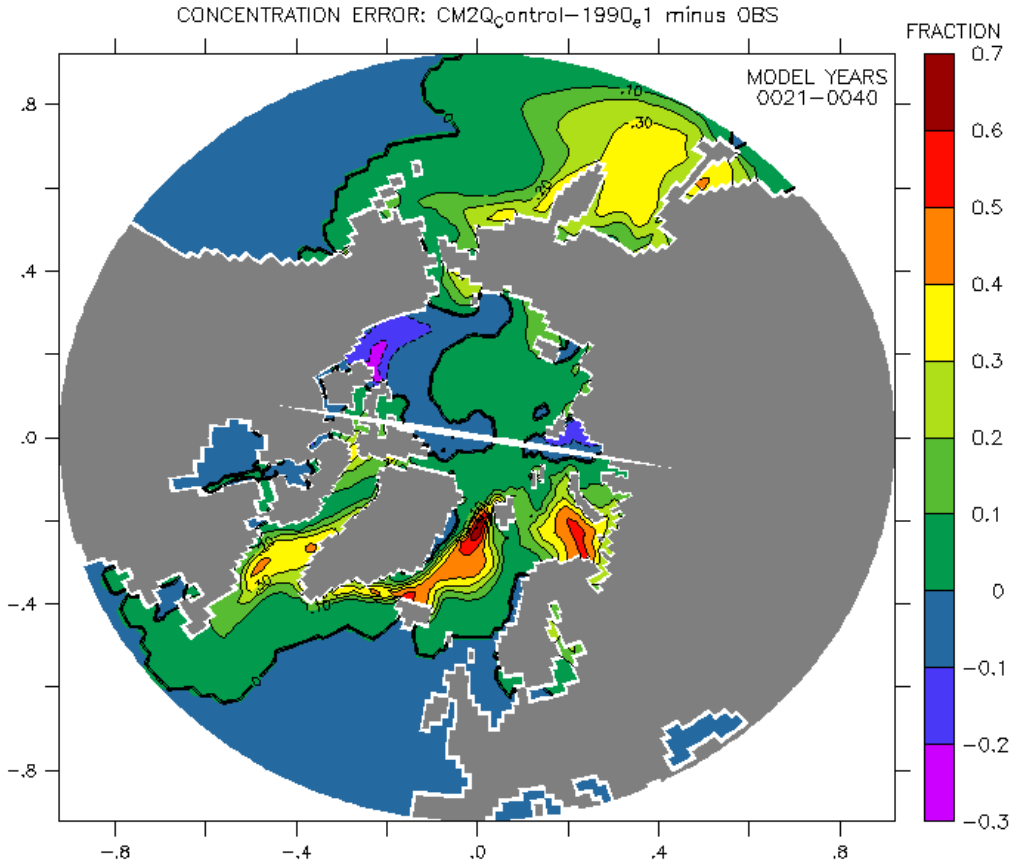


Sea Ice Area

Annual Cycle in NH Ice Area

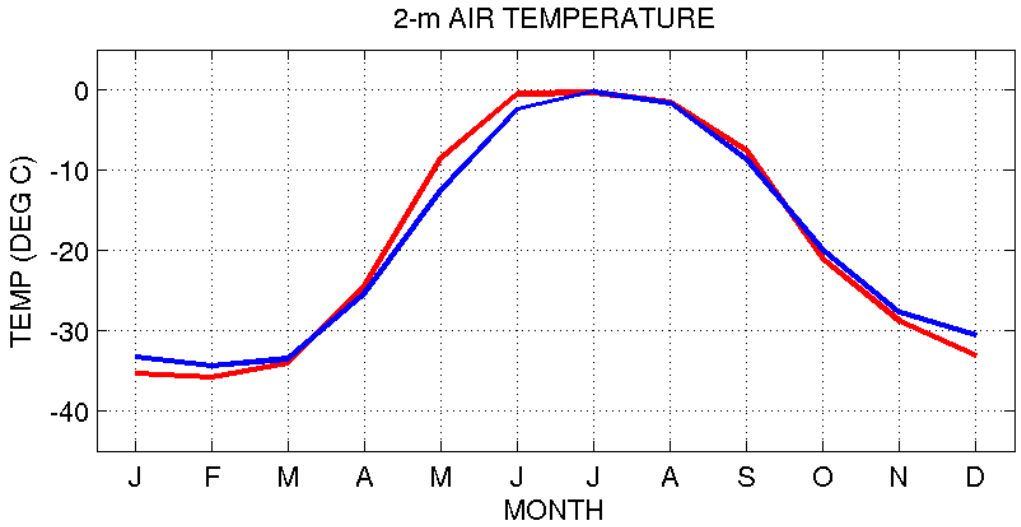


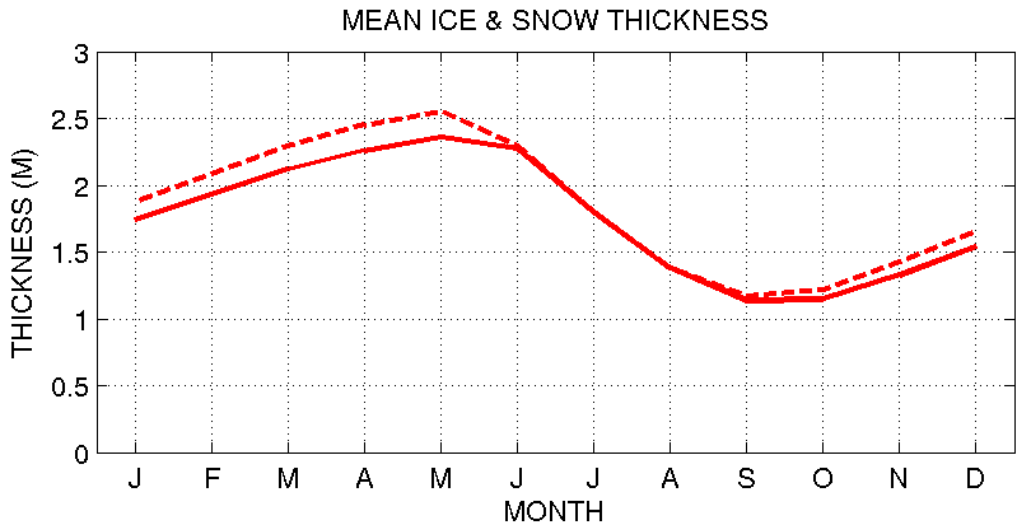
Average Error in Ice Concentration



Related problem: Northern Pacific and Atlantic are too cool.

Central Arctic Surface Air Temperature and Ice Thickness





Too thin by ~ 1m

Discussion

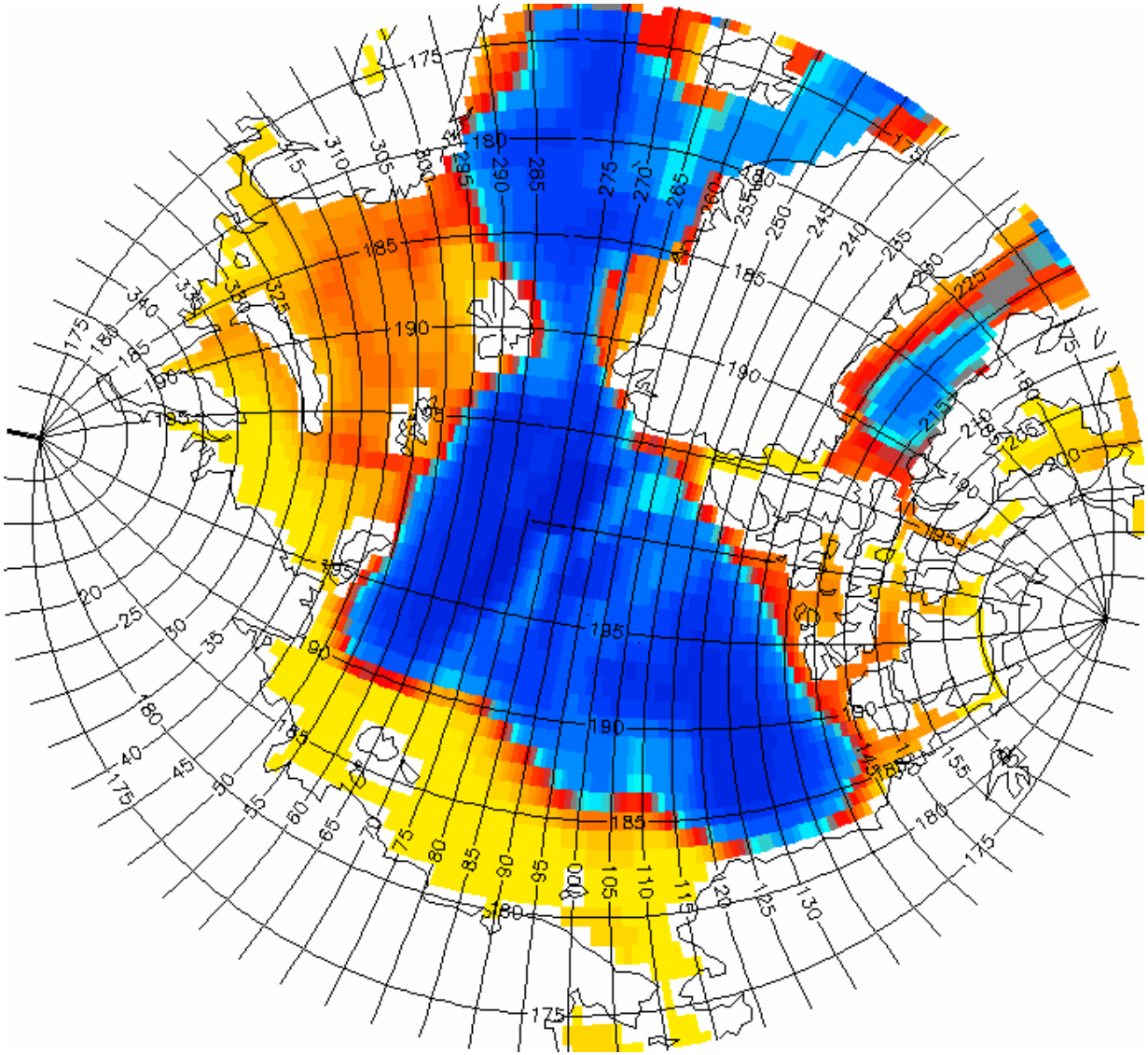
- When forced with incoming solar radiation at the top of the atmosphere and prescribed atmospheric constituents from 1990, the CM2 captures most essential features of sea ice in the Arctic.
- Problems:

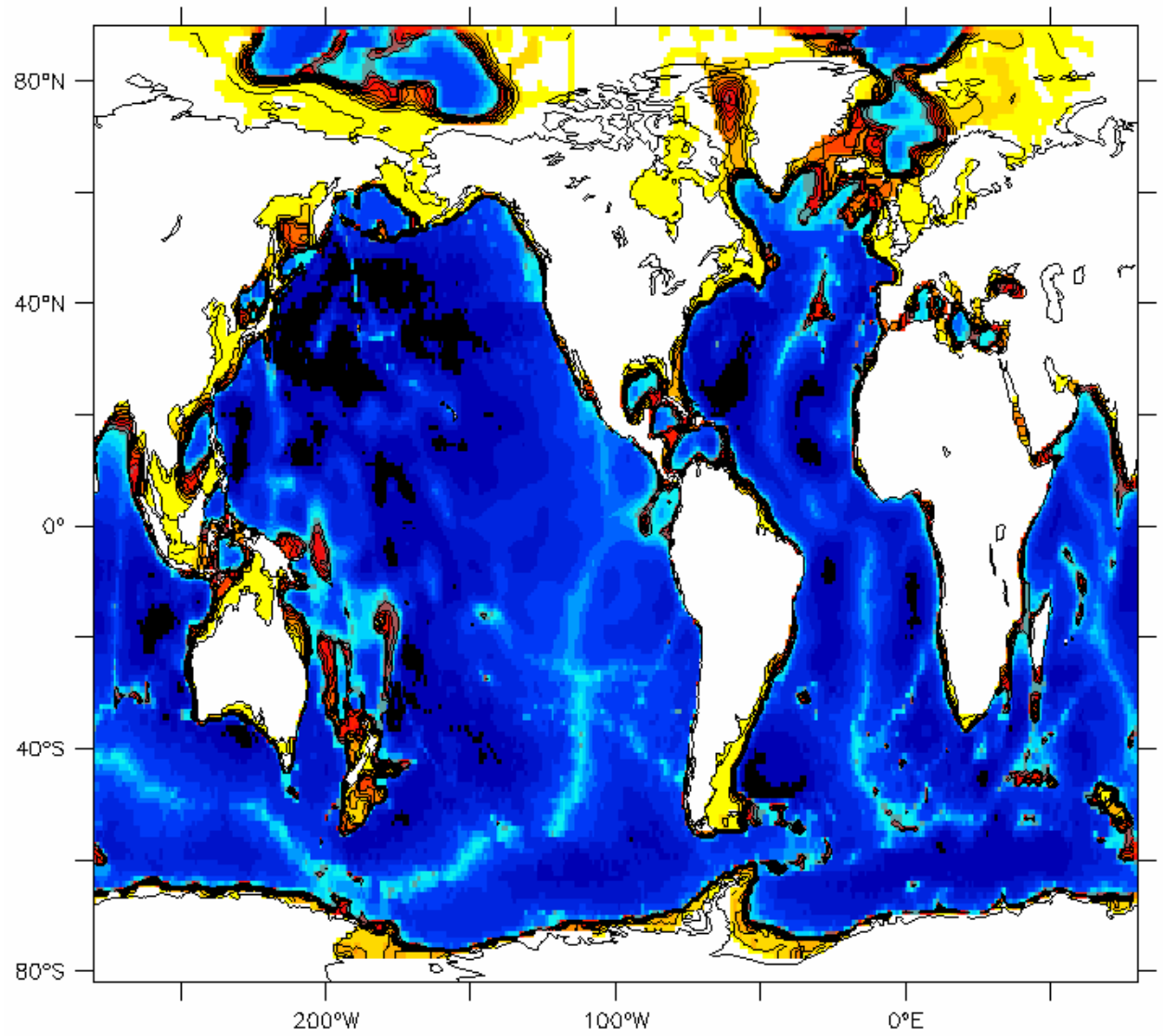
  - Central Arctic ice is about a meter too thin despite downward radiative forcing being 20+ W/m^2 too low.

  - Too much ice in the northern Pacific Ocean.

Outline

- Ice Model Description
- CM2 description
- CM2 (IPCC 1990) mean climate:
  - Global T_ref , SLP (overall good, mention strong internal variablilty ENSO
- CM2 “Forcing” for Arctic
  - Arctic SLP (mention location of high, weak storm track)
  - NP downward LW,SW
  - Why? NP temperature profiles, clouds
- Sea ice in CM2 Control
  - Drift/thick (polar cap)
  - Concentration bias (polar cap)
  - Annual cycle of of ice area
  - NP Region
  - Ts, Hi, Hs
  - Albedo, SH, LH
- Discussion of biases
- Summary




80°N
40°N
0°
40°S
80°S
200°W
100°W
0°E

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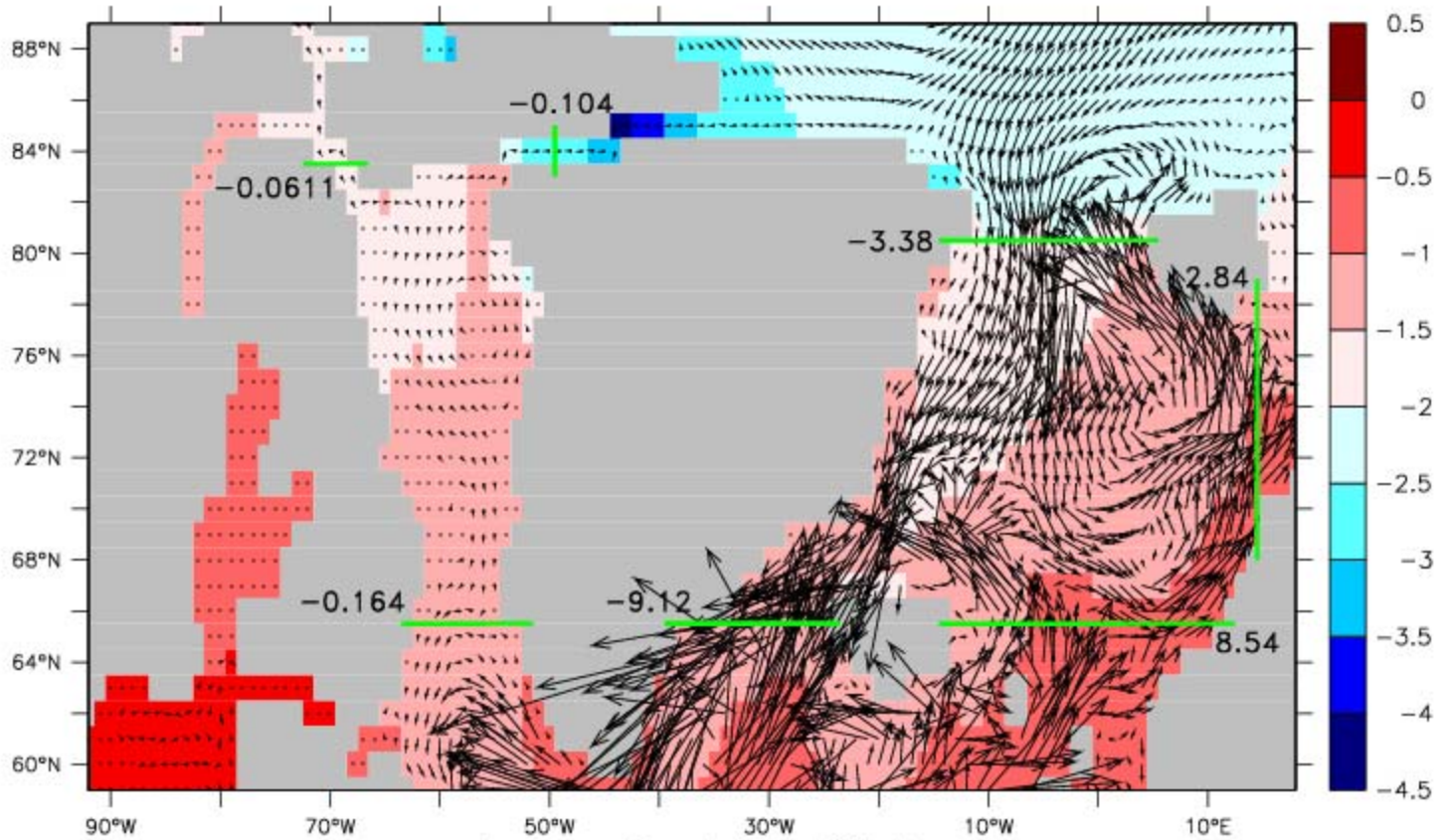

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