Climate Sensitivity

Presented by

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Introduction

- Transient Climate Response (TCR) benchmarks global temperature response to doubled CO_2. CMIP5 TCRs range by more than a factor of two.
- Reducing TCR uncertainty will allow better mitigation/adaptation decision making
- Goal is to develop observational constraints on sensitivity and make models that satisfy them for improved predictions/projections
- Focus is on the ocean's role. We separate out equilibrium climate sensitivity uncertainty using equilibration ratio: $TCR = (TCR/ECS) \cdot ECS$

GFDL models TCRs

- Ten GFDL climate models have a broad range of TCRs (1.3-2.1 K) encompassing 25 of the 30 CMIP5 models
- Equilibration also ranges broadly from 0.36 (ESM2G) to 0.65 (CM2.6)
- The suite tests the influence of ocean model formulation (ESM2M/ESM2G), ocean model resolution (FLOR/CM2.6), control climate ocean temperature biases (CM2.5/CM2.6) and Atlantic meridional overturning circulation (AMOC) decline.

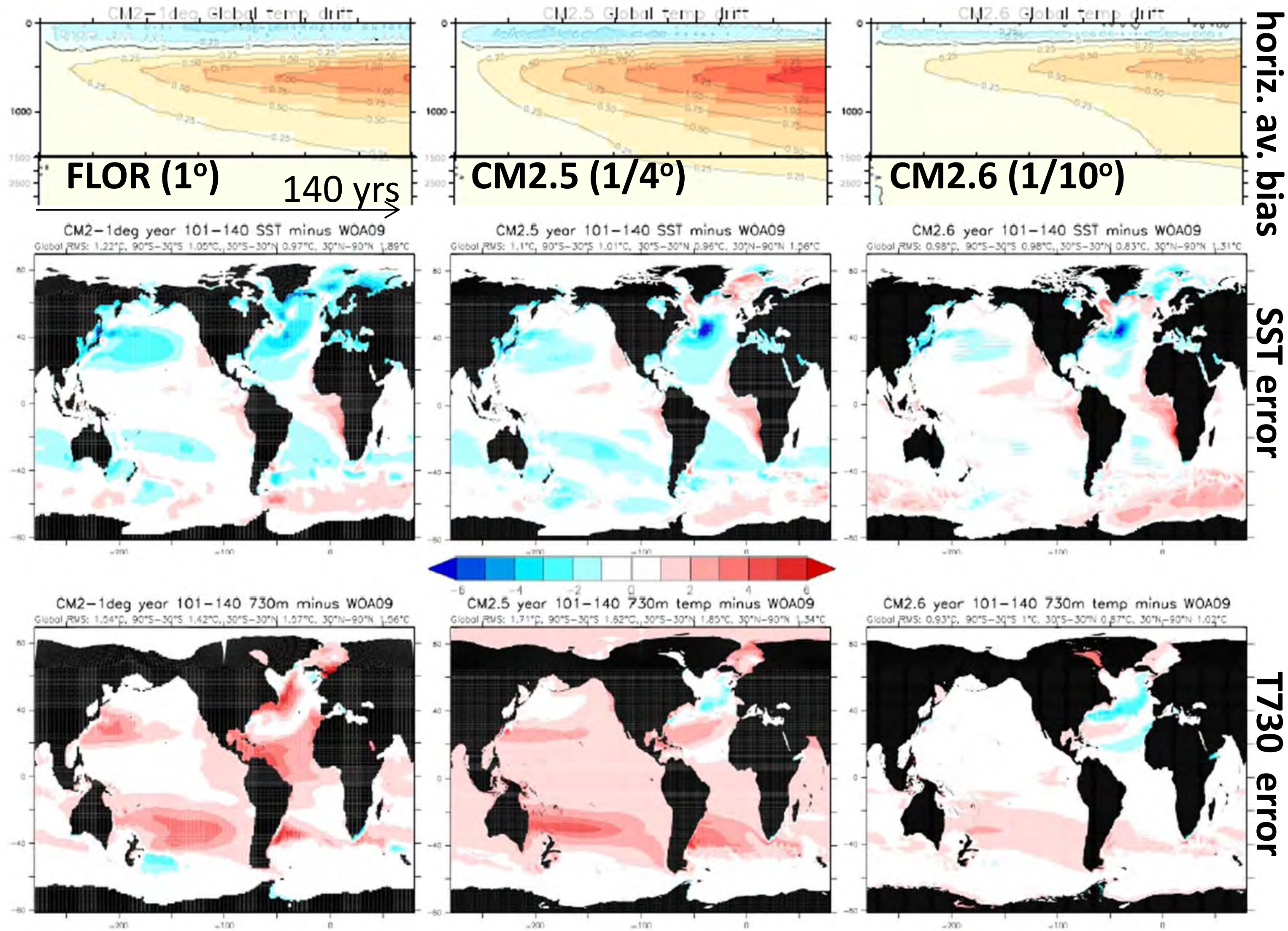
1.5 K **CM2.1**

1.5 K	1.8 K	2.0 K	2.1 K	1.5 K	1.3 K
FLOR	**CM2.5**	**CM2.6**	**CM3**	**ESM2M**	**ESM2G**

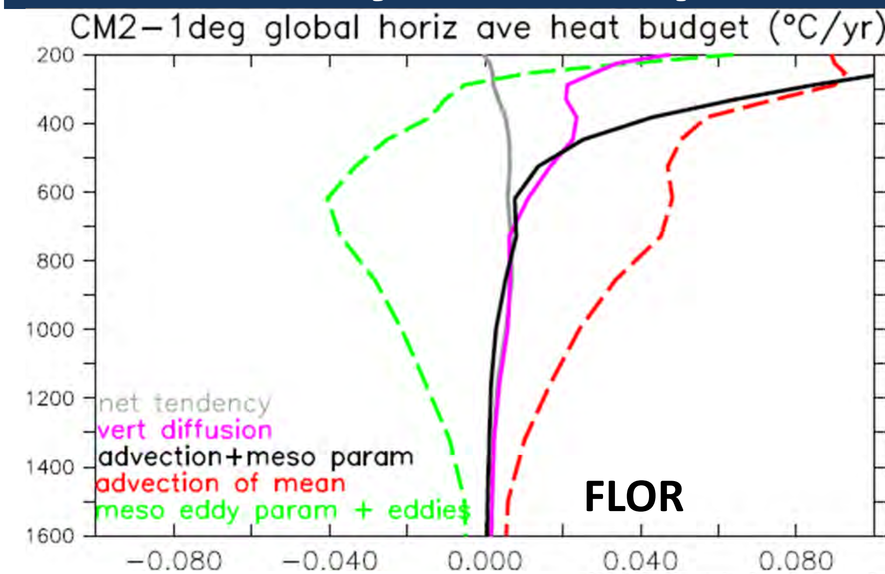
Also: CM2.0: 1.6 K; FLORa6: 1.9 K; ESM2preG: 1.6 K

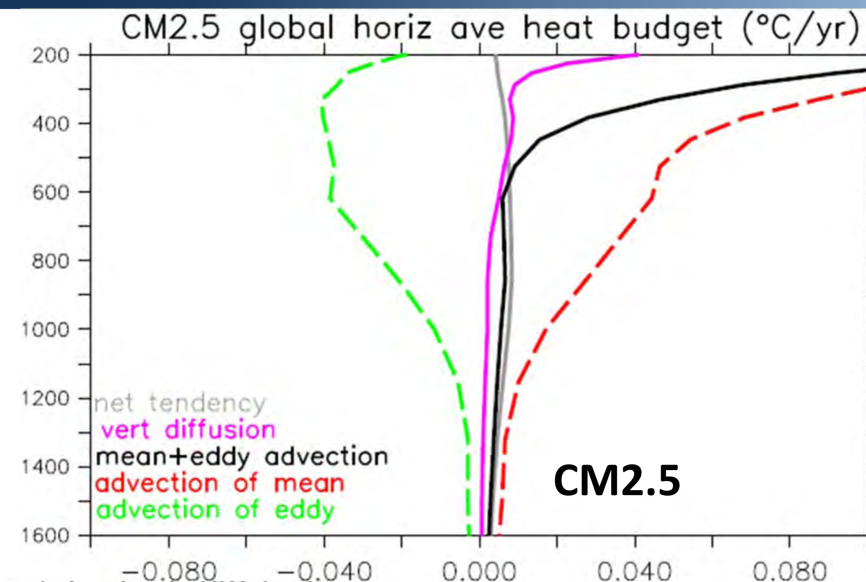
Ocean resolution and temp. drift

Griffies et al, submitted
Also Delworth et al 2012

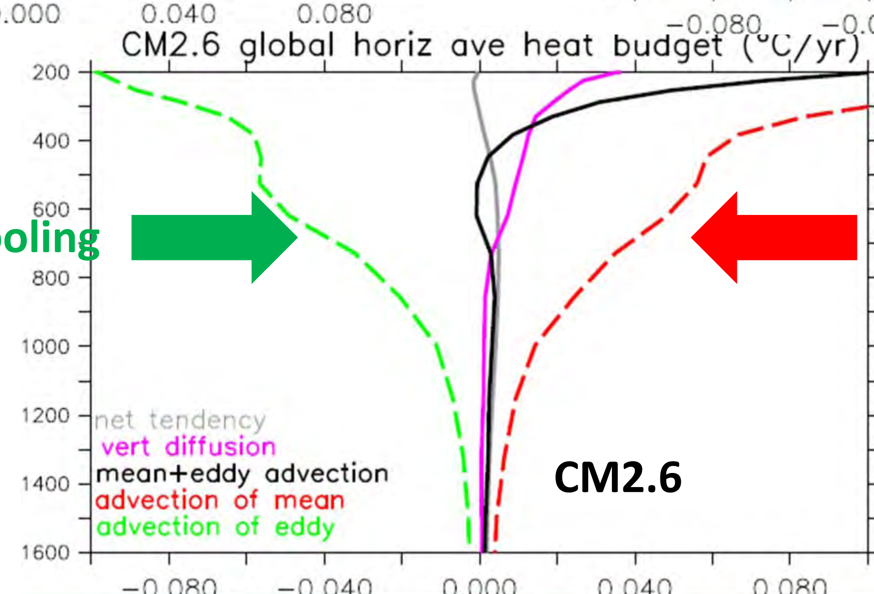


Eddy compensation reduces drift





Eddy cooling



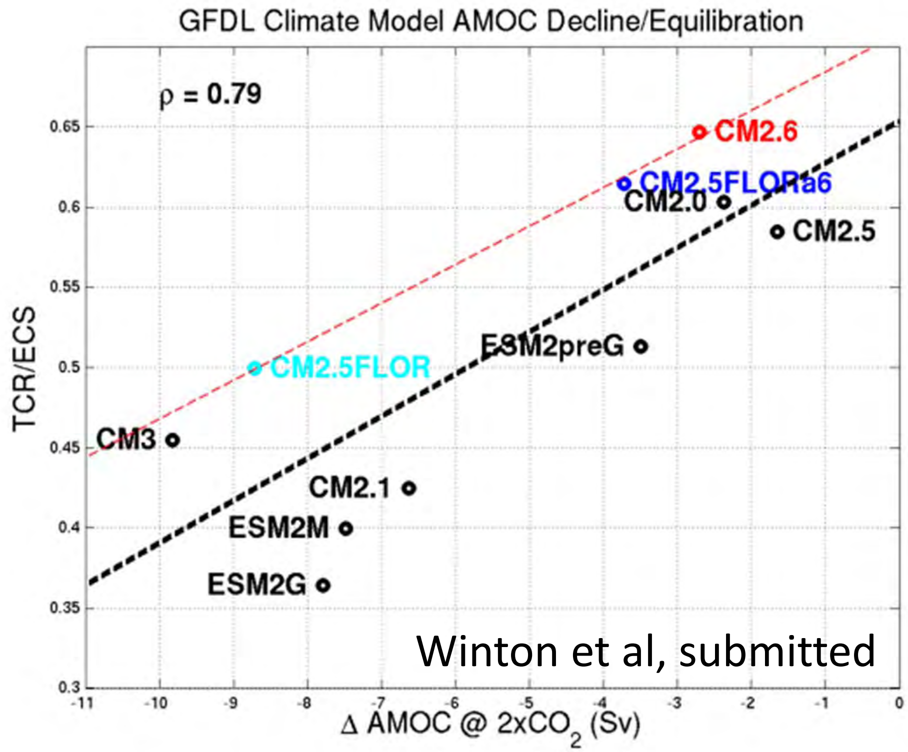
Mean flow warming

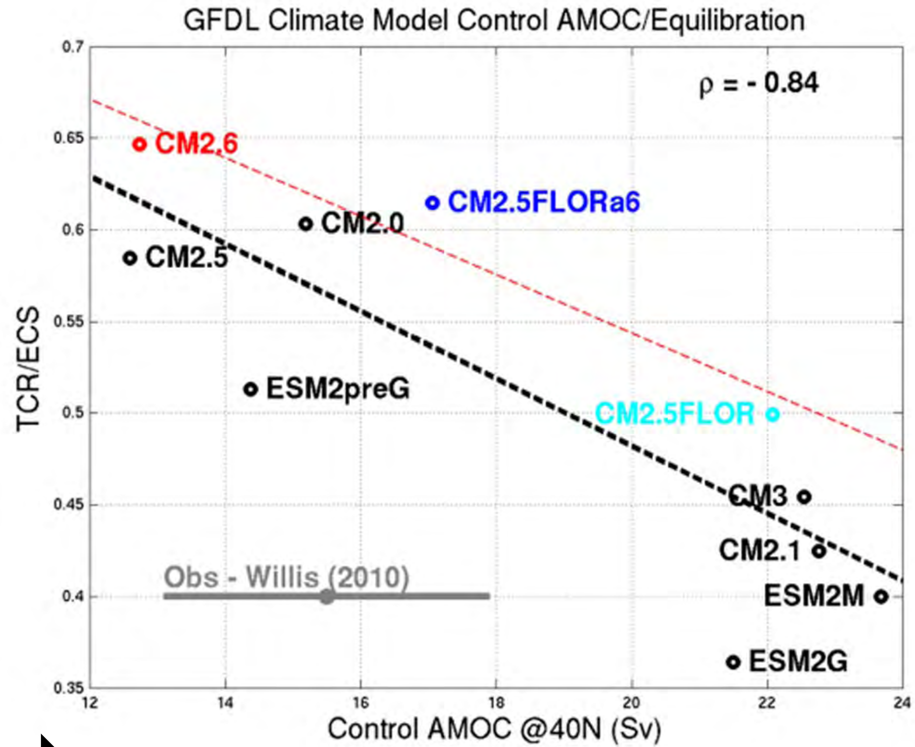
Griffies et al, submitted
Also Delworth et al 2012

Ocean circulation change & TCR

- Idealized studies:
  - Winton 2003: Arbitrarily increasing (decreasing) current speeds warmed (cooled) global climate; Also: atmosphere-slab ocean models with modified “ocean heat transport”
  - Winton et al 2013: Disallowing ocean circulation changes in 1%/yr CO_2 increase experiment increased global warming by 35%
- Rugenstein et al 2013: Heat budget analysis shows AMOC weakening reduces warming at high northern latitudes in GFDL models with z* and isopycnal ocean components

AMOC decline influences TCR/ECS



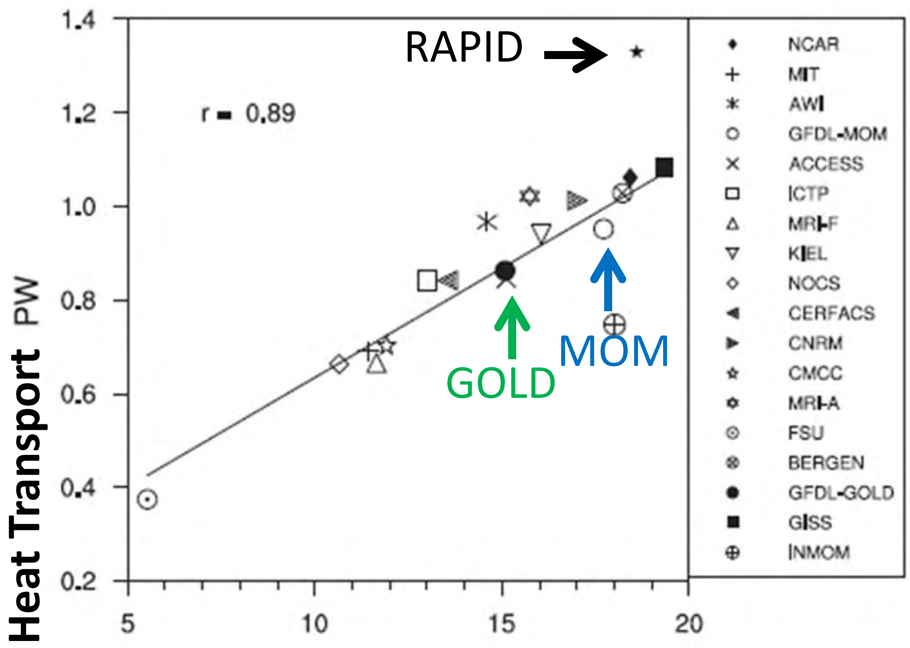


ΔAMOC → AMOC

ρ(ΔAMOC,AMOC)=-.93

bigger AMOC -> bigger AMOC decline

CORE ocean-ice model comparison



Danabasoglu et al 2014

Fig. 7. Scatter plot of the maximum AMOC transport against meridional heat transport (MHT), both evaluated at 26.5°N. The model data are for the time-mean. The solid star denotes the observational AMOC and MHT estimates from the RAPID data. The regression line and correlation coefficient are also shown.

See also Msadek et al 2013

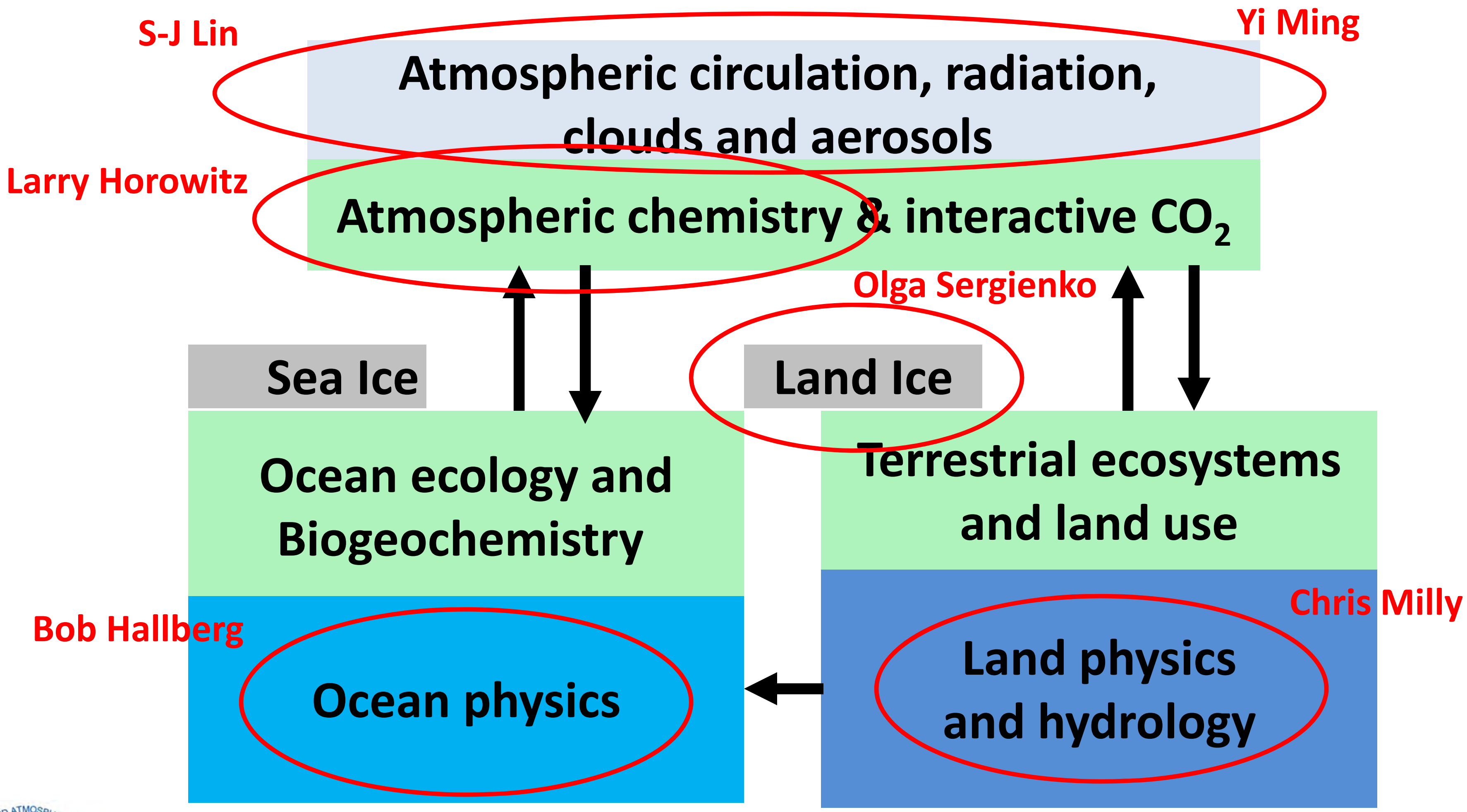
- International comparison of "reanalysis-forced" ocean-ice models
- GFDL leadership role: Steve Griffies
- Suite of ~10 papers using 15-20 ocean-ice climate models on: sea level, ocean basin simulations

Even with observed forcing ocean models simulate too little ocean heat transport per Sv AMOC

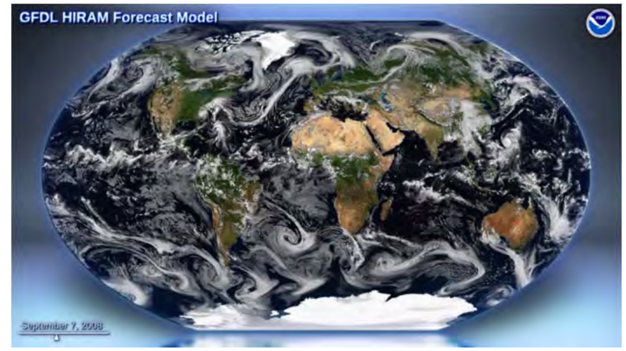
Summary

- Comparison of a 10-member suite of GFDL climate models demonstrates some robustness of TCR to ocean formulation, resolution and temperature drift. AMOC representation emerges as an opportunity for placing an observational constraint on TCR.
- Comparison of 3-member ocean-resolution suite suggests eddy parameterization as a promising pathway to reduced drift

Earth System Model Components

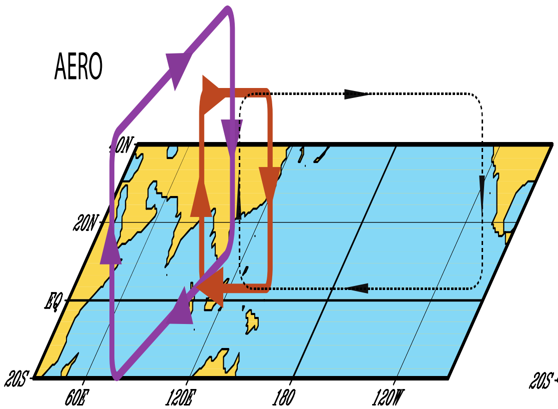


Session recap



Atmospheric Dynamical Core/Seamless Weather-Climate - SJ Lin

- *Million-core-capable SuperHiRAM: weather & climate*
- *Non-hydrostatic is advantageous for climate too*
- *Quality weather increases climate model credibility*

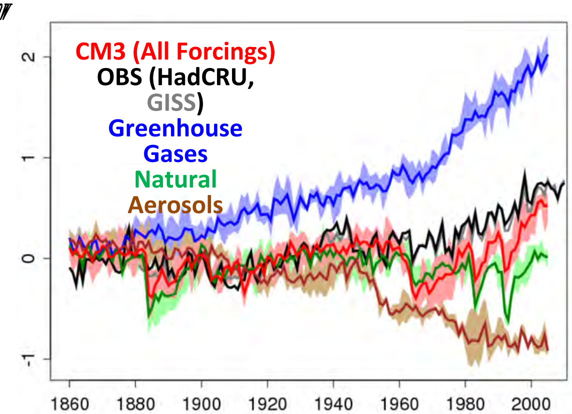


Atmospheric Physics - Yi Ming

- *CM3 aerosol simulation compares well with obs*
- *Convective detrainment affects cloud feedback*
- *Aerosols influence precipitation patterns and tropical cyclones*

Atmospheric Chemistry - Larry Horowitz

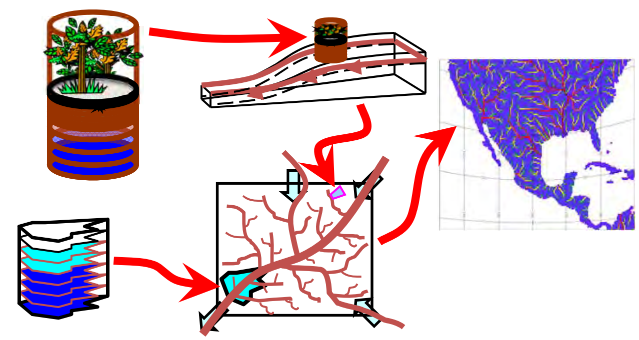
- *Aerosol cooling in CM3*
- *Stratospheric influence on surface ozone*
- *Response to volcanic eruptions*

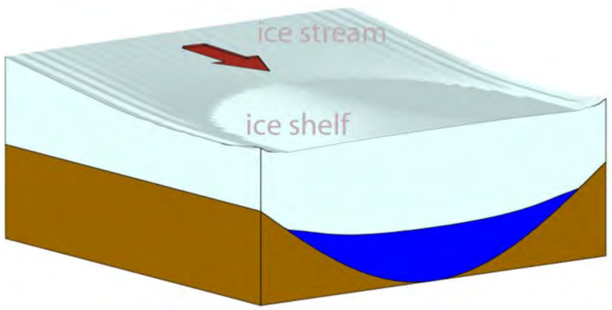


Session recap

Hydrology - Chris Milly

- *LM3 brings impact-relevant variables into GFDL's models*
- *PET usage confounds many hydrologic impact studies.*





Ocean and Ice-sheet Modeling and Sea Level Rise - Bob Hallberg /Olga Sergienko

- *GFDL ocean models are converging on MOM6*
- *Sea level rise is sensitive to ocean mixing and ice sheets*
- *GFDL is developing coupled ocean/ice sheet models that move the grounding line*

Intro to GFDL Earth System Models/Climate Sensitivity - Mike Winton

- *GFDL ESM suite represents an optimization of computer resource toward addressing NOAA goals*
- *Analysis of these related models gives insight into their emergent properties (e.g. TCR)*