Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009

Atmospheric Physics and Chemistry Introduction and Overview

Presented by

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Introduction

Atmospheric Physics and Chemistry at GFDL Encompasses :

- Atmospheric long- and short-wave radiation
- Stratospheric dynamics, transport and chemistry
- Tropospheric chemistry and transport
- Atmospheric aerosols
- Convective and stable clouds
- Aerosol – cloud interactions

and their impacts on global air quality, climate change and climate sensitivity

Understanding is based on a synthesis of model simulations and observations

Key Research Questions

Current

- What roles do short-lived species (not just anthropogenic), aerosol-cloud interactions and cloud microphysics play in the Earth's climate system?

- What are the nature, size and sensitivity of Air Quality–Climate interactions and feedbacks?

Prospective

- How will model physics and chemistry be advanced and how would the resulting interactions be enhanced as GFDL proceeds to higher model resolution? Will this more accurately simulate regional climate forcing and change and regional air quality?

Upcoming Talks in this Session

Next Generation Physical Climate Model:

Leo Donner: Latest global atmospheric model (AM3) development for CM3

Atmospheric Chemistry and Aerosols:

Larry Horowitz: Modeling of atmospheric chemistry

Paul Ginoux: Aerosol modeling and evaluation

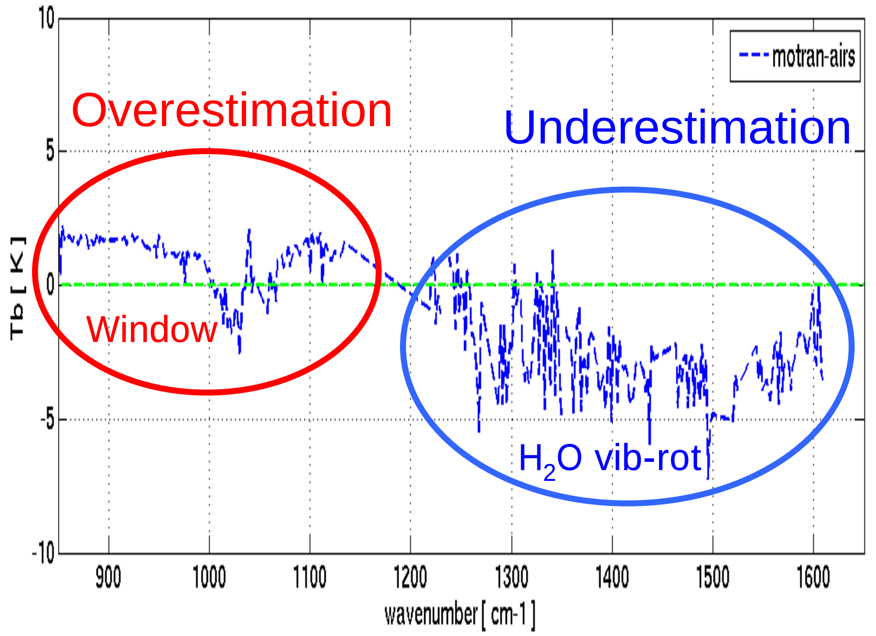
Yi Ming: Aerosol-cloud-climate interactions

Arlene Fiore: Climate and air quality

Other key contributors: John Austin, Songmiao Fan, Stuart Freidenreich, Chris Golaz, Rick Hemler, Bud Moxim, V. Ramaswamy, Dan Schwarzkopf, Charles Seman, Georgiy Stenchikov, John Wilson, and many post-docs and students.

New Developments in Atmospheric Radiation

A *New* Long-wave Verification Tool



units: W m^{-2}	OLR	Window band
	Total sky	Total sky
CERES	**241.73**	**66.94**
AM2	**240.63**	**73.99**
AM2 -CERES	**-1.10**	**+7.05**

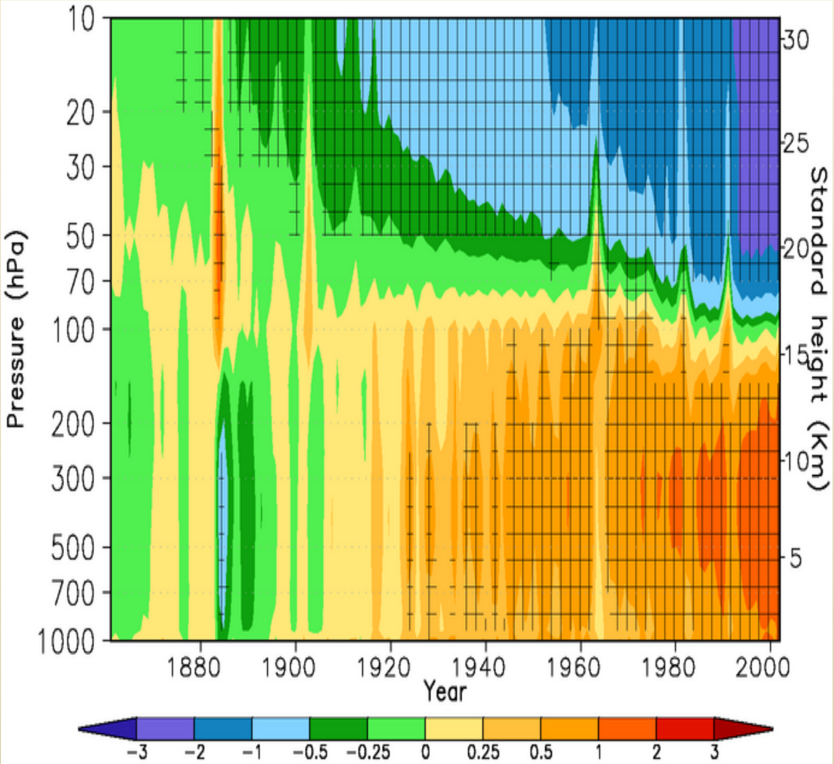
Comparison of GFDL-AM2 and AIRS satellite "all-sky" spectral brightness temperature

Model has the "right" TOA broadband flux.
BUT, bias "offset" occurs due to 'window' and 'vibration-rotation' bands.

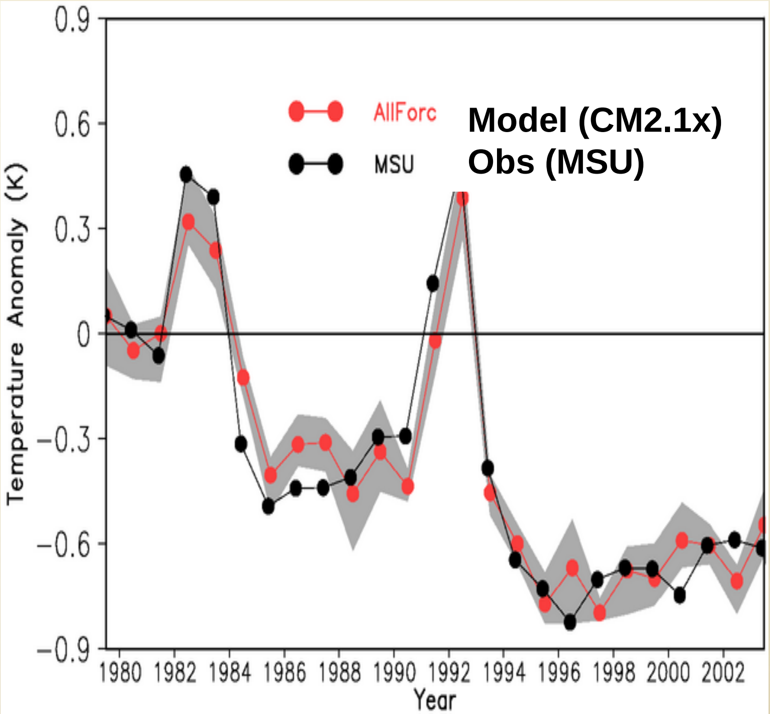
Huang et al., GRL, 2007

Simulation of Stratospheric Temperature Changes

Modeled Global Temperature Change



Lower Stratospheric Temperature Change (1979-2003)



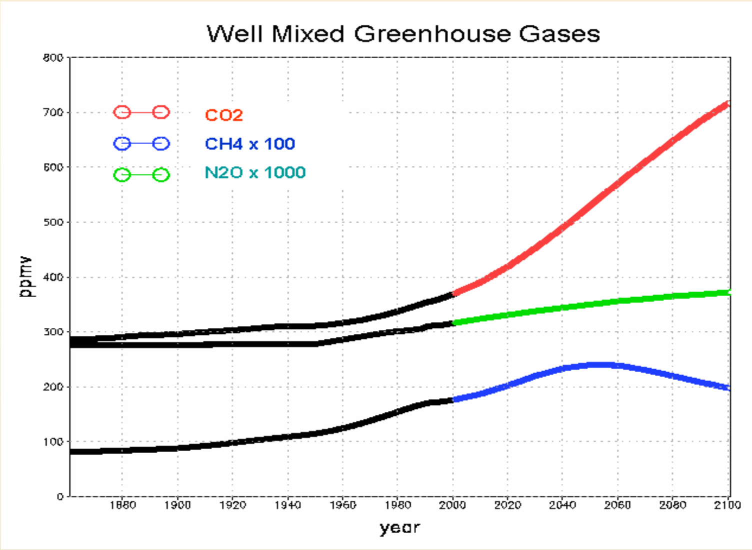
Key Points:

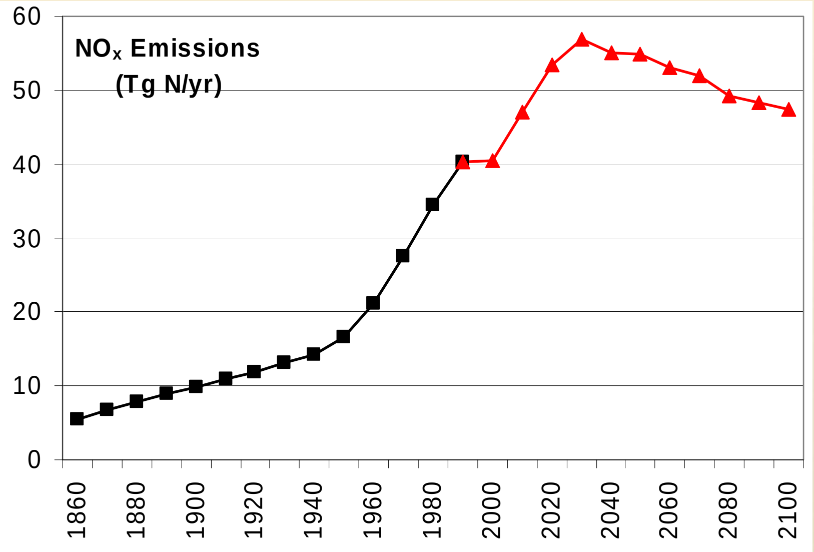
1. Modelled “significant” stratospheric cooling shows first by early 20th century
2. 3-member ensemble captures **observed** recent lower stratosphere cooling

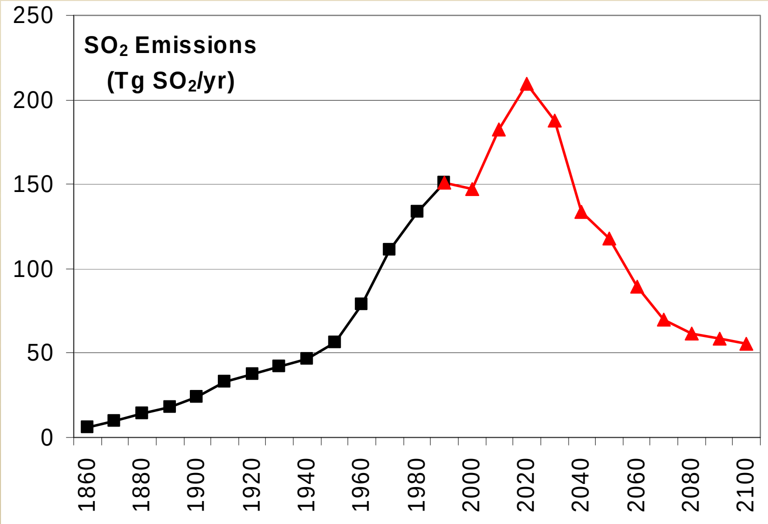
Schwarzkopf et al., 2008; Ramaswamy et al., 2006

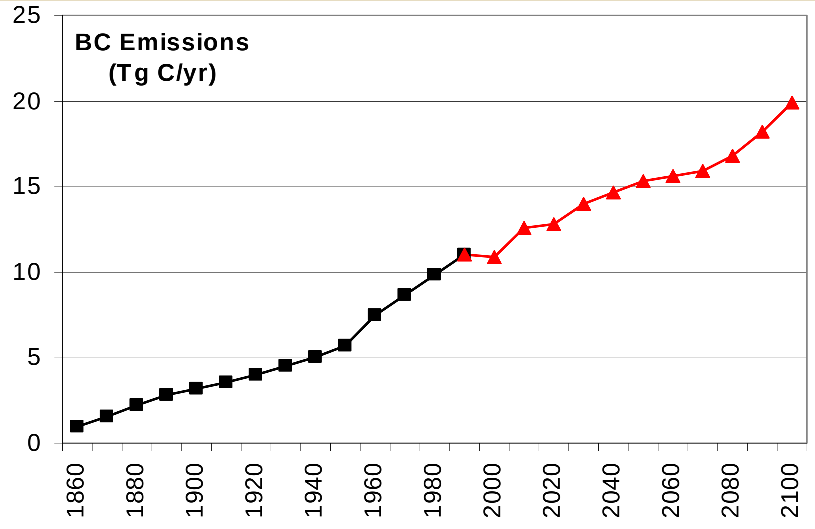
Aerosols and Climate circa AR4

The A1B "marker" Scenario

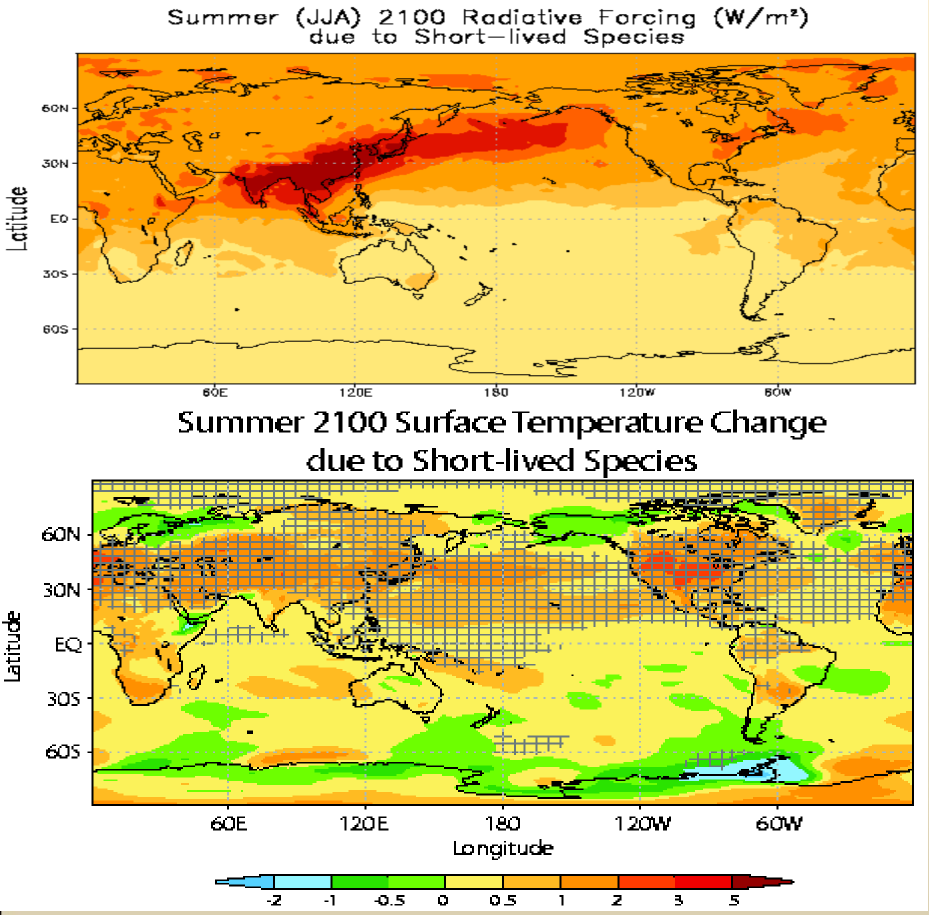








Impact of Future Aerosol Levels on Climate
(CM2.1)



Three Main Points:

1. Summertime central US is very sensitive to climate change.

2. Radiative forcing and climate response are not spatially correlated *(global pattern-correlation coefficient of -0.172)*

3. Asian emission controls may significantly impact US summertime warming

Levy et al., JGR, 2008

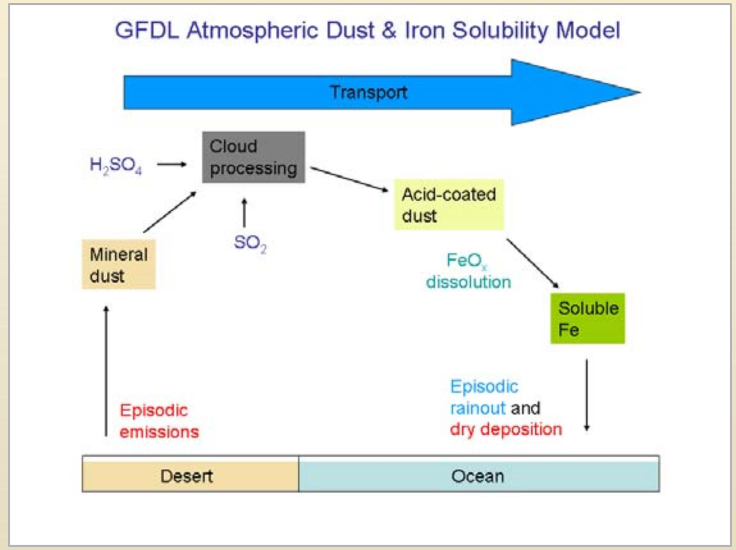
Nature's Iron Fertilization

- Besides its role in radiation, dust also supplies nutrients to the ocean
- Along with gas-phase and heterogeneous chemistry, iron dissolution on dust involves aerosol surface chemistry
- Dust deposition of bioavailable iron to the ocean is an important source of a critical micronutrient and links atmospheric physics and chemistry to ocean biogeochemistry

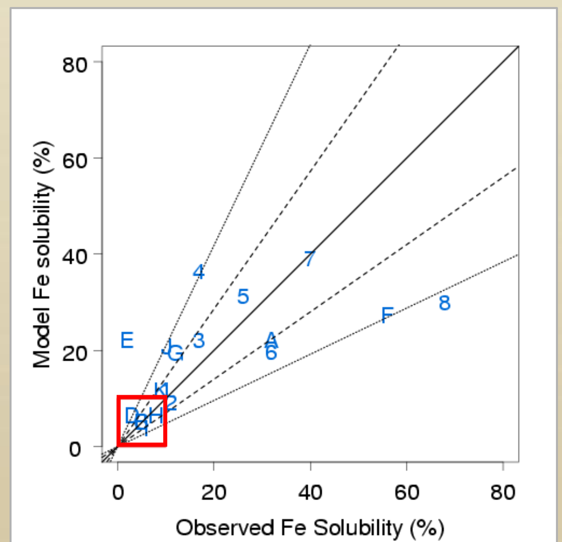
A Two-step Mechanism for Dust Deposition of Soluble Iron to the Oceans

Step 1: acid coating through heterogeneous and cloud chemistry

Step 2: acid-catalyzed mineral dissolution



Iron solubility increases with time from <1% near desert to >10% in remote regions



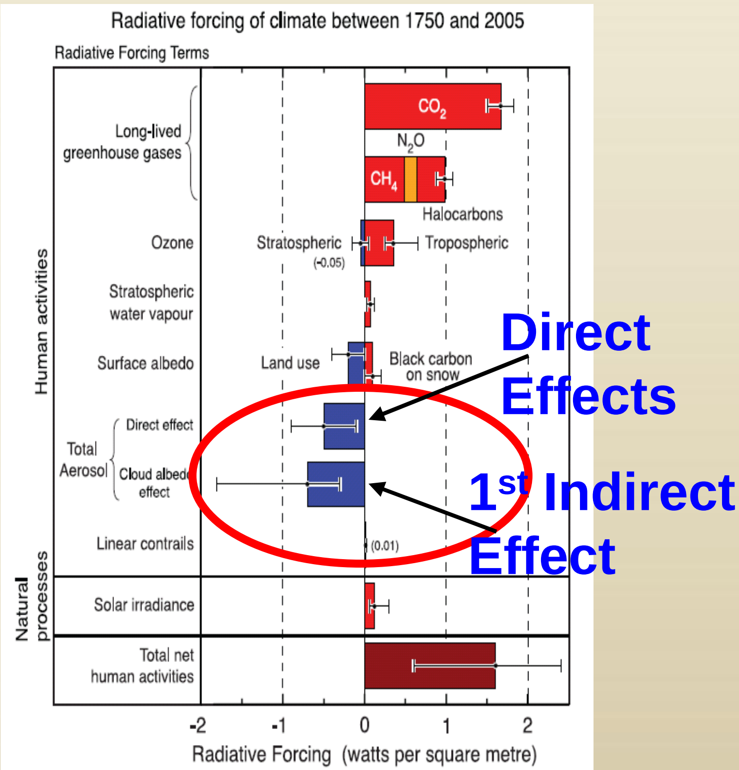
Fan et al., 2006

The Next Generation

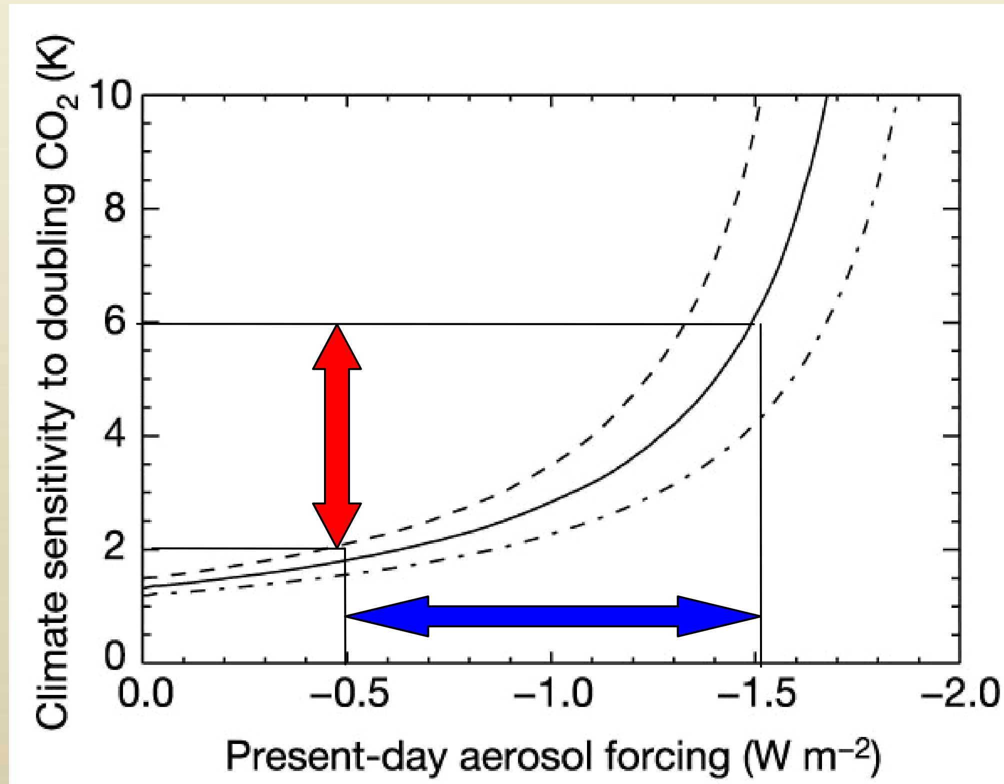
- GFDL wide discussions in early 2006 led to a proposed next generation physical climate model to be called CM3.
- Aerosol-cloud interactions, interactive stratospheric and tropospheric chemistry, dynamic vegetation and comprehensive hydrology were the focus.
- Lab wide collaboration was enabled through the global atmosphere model development team.
- Interactions with external groups and institutions (e.g. ESRL, PMEL, ARM, NASA Science Teams, Climate Process Teams, GCSS, AeroCom, CCMVal, ...) aided observational evaluation of model components.

Aerosol Forcing and Climate Sensitivity

Large uncertainty in present-day aerosol forcing precludes constraining climate sensitivity



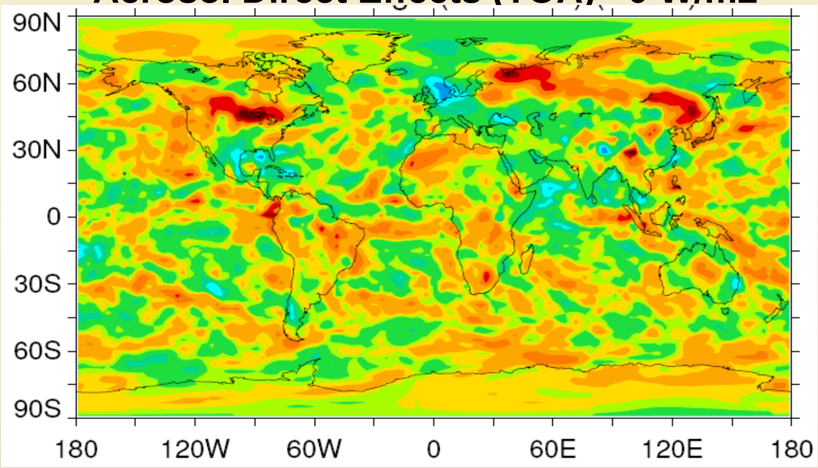
Foster et al. (2007)



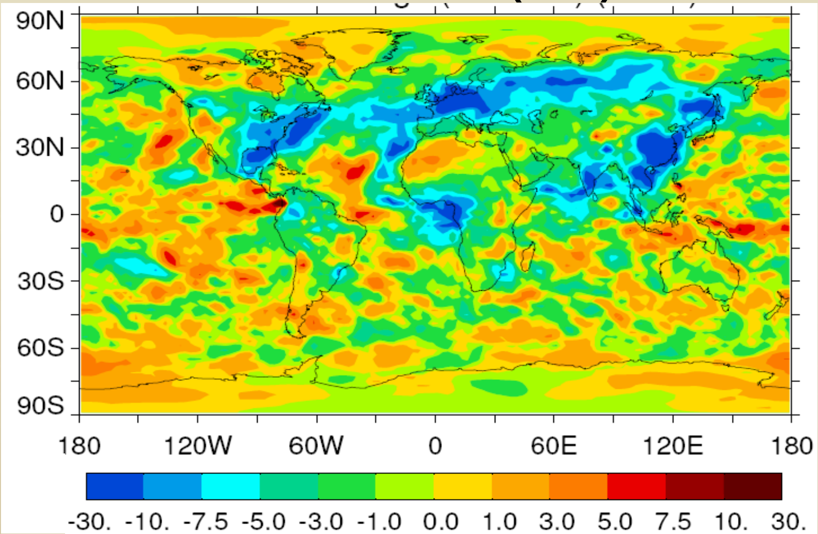
Andreae et al. (2005)

A Key Advance for CM3: Aerosol Indirect Effects

Aerosol Direct Effects (TOA) ~0 W/m2

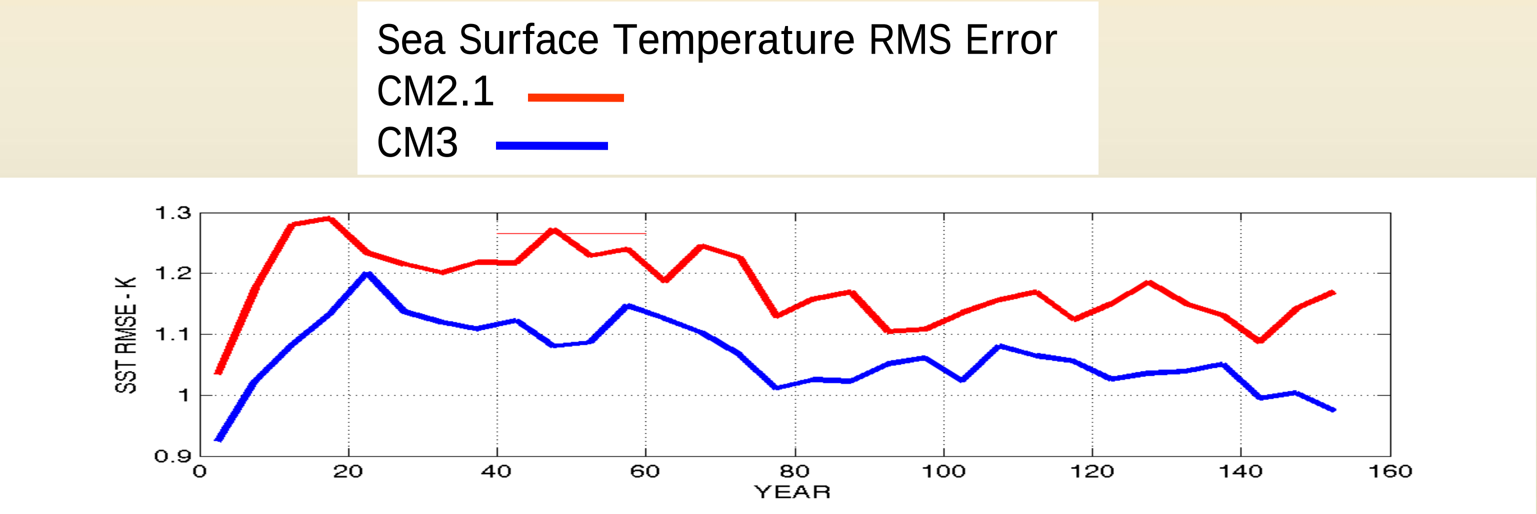


Aerosol Indirect effects (TOA) ~ -1.3 W/m2



- **TOA direct aerosol effect reduced to ~ 0 using internal mixtures**
- **Strong cooling due to aerosol interactions with clouds**

GFDL's Newest Coupled Climate Model (CM3)



Mike Winton will talk about CM3 performance tomorrow

Leo Donner will speak next on the development of the atmospheric component (AM3)

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