

Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009



Clouds and Global Atmospheric Model Development

Presented by
Leo J. Donner

Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009



Clouds and Global Atmospheric Model Development

AM3, the atmospheric component of GFDL'S coupled model CM3, has been developed to address emerging science questions:

- What are the roles of aerosol-cloud interactions in climate and climate change?
- How will land and ocean carbon cycles interact with climate change?
- To what extent is decadal prediction possible?
- What are the dominant chemistry-climate feedbacks?



Answering Emerging Science Questions

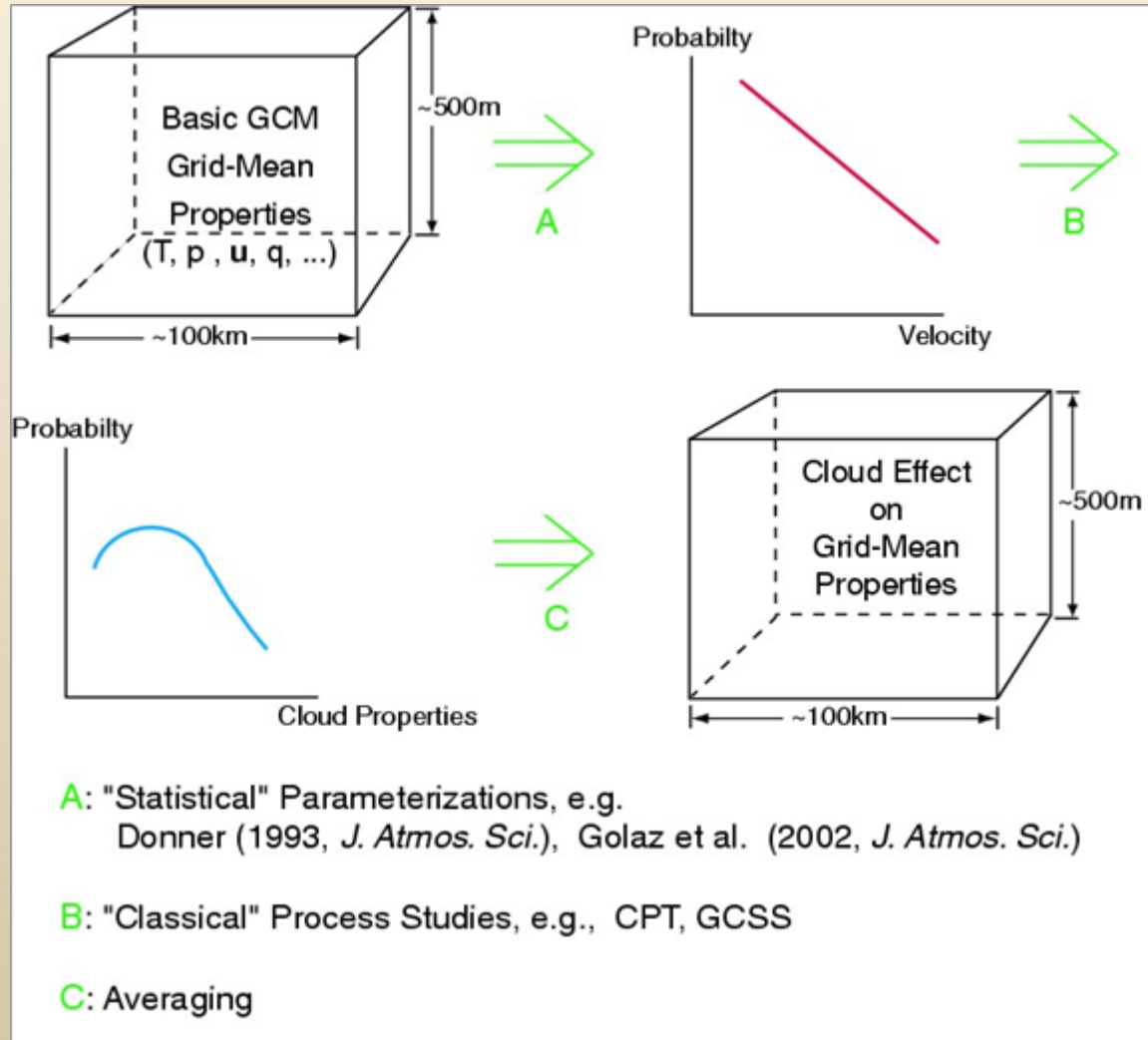
What is NEW in AM3?

- Interactive chemistry to link emissions to aerosol composition
- Sub-grid vertical velocity PDFs for convective and stratiform clouds => Supersaturation at cloud scale for aerosol activation
- Stratospheric model for chemistry and possible links to troposphere on multi-year time scales (e.g., Southern Hemisphere Annular Mode)
- More realistic land precipitation for land carbon and nitrogen models

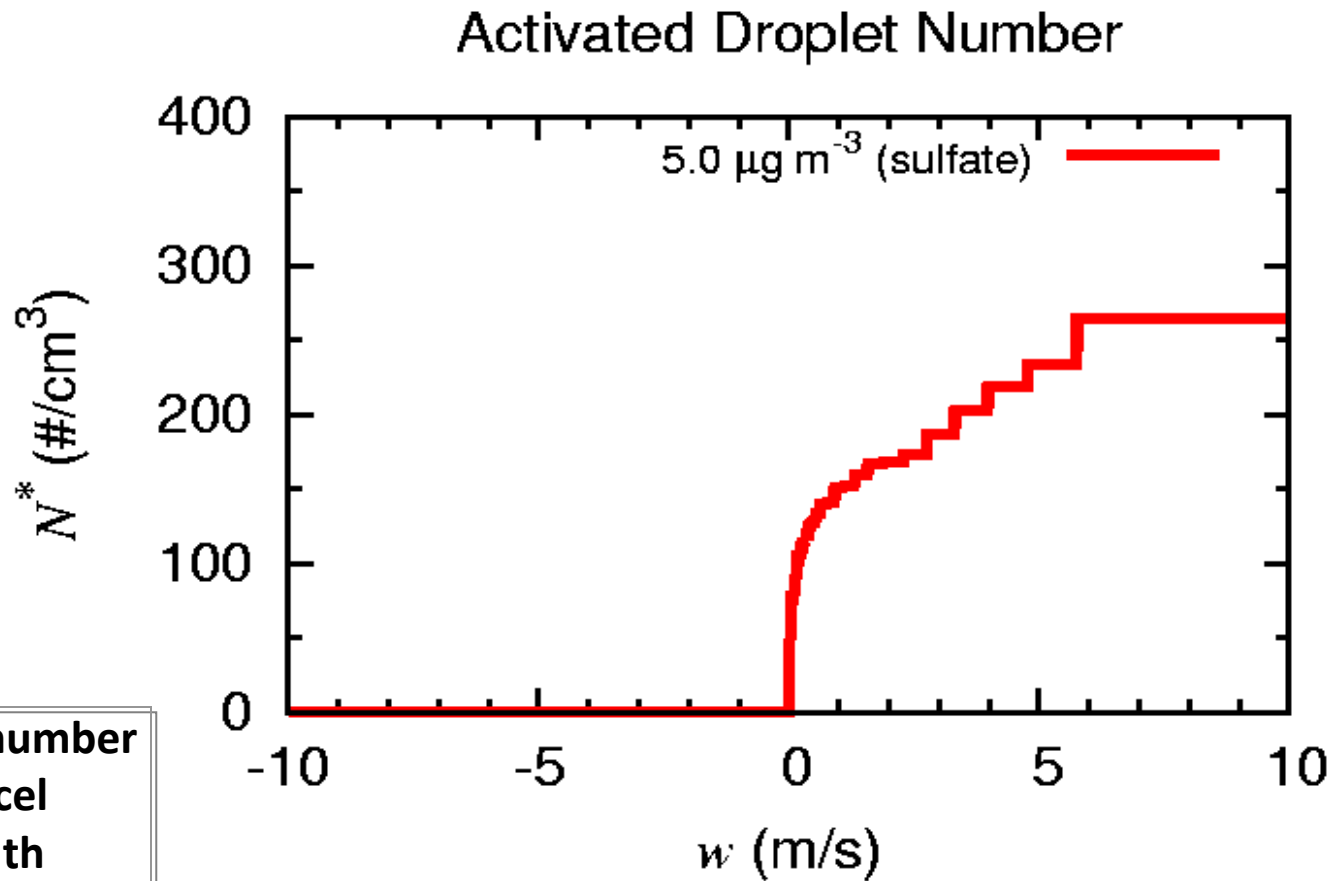


Cloud-aerosol-microphysics interactions depend on vertical velocity variations much smaller than the GCM grid

Parameterization Strategy



Aerosol activation is highly nonlinear – requires upward motion

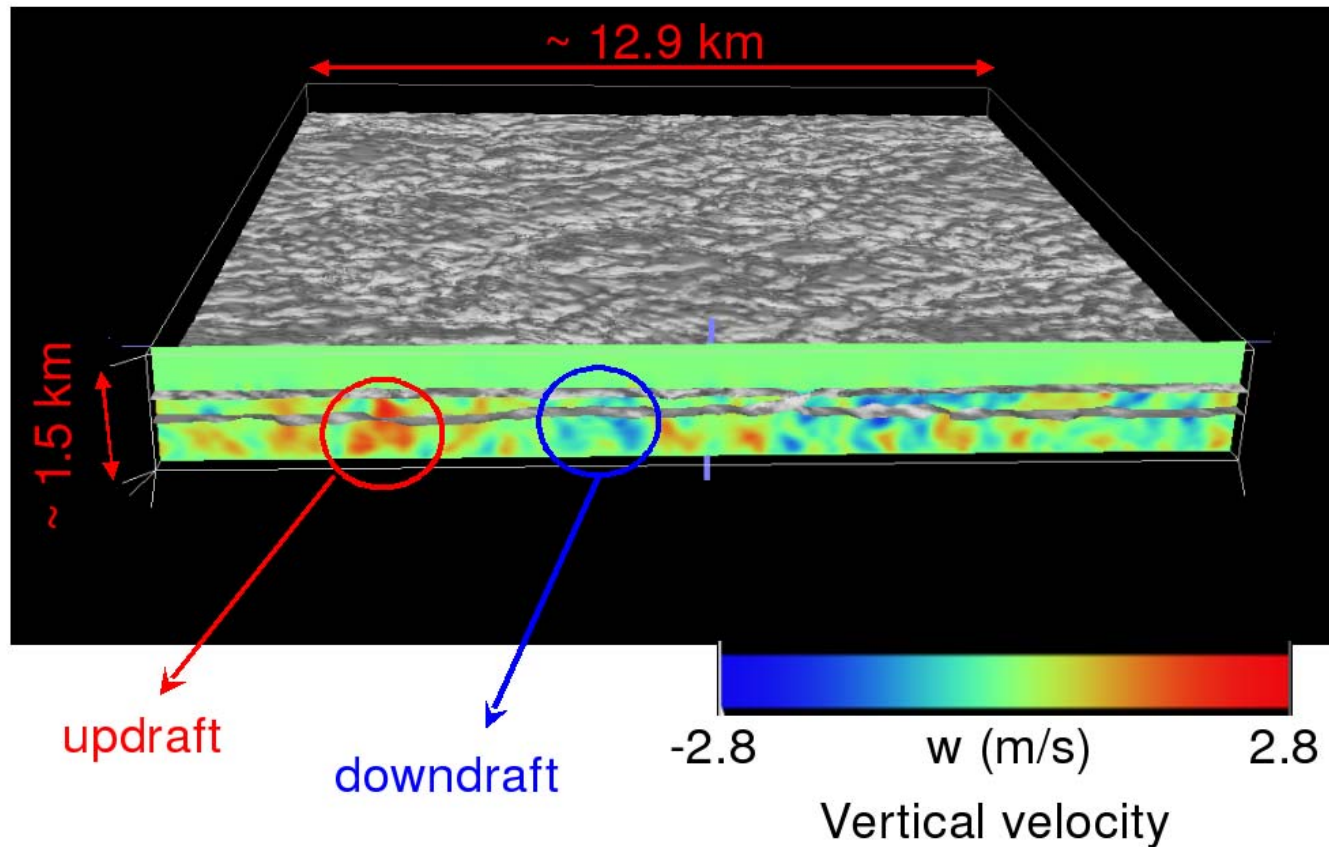


Droplet number
from parcel
model with
Köhler theory

(Ming et al., 2006)

Activation occurs in updrafts at small scales

Large-eddy simulation of a stratocumulus cloud



(cf., Golaz et al., 2005)

Parameterize by integrating over dynamics PDF

Layer-averaged activation:

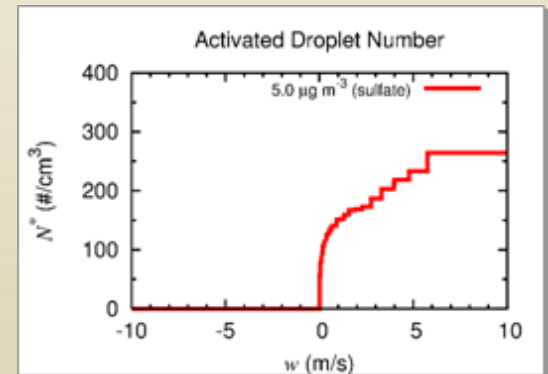
$$\overline{N}_{\text{activation}} = \int N^*(w, p, T) dx dy$$

Because N^* is non-linear

$$\overline{N}_{\text{activation}} \neq N^*(\overline{w}, \overline{p}, \overline{T})$$

However,

$$\overline{N}_{\text{activation}} \approx \int N^*(w, \overline{p}, \overline{T}) pdf(w) dw$$

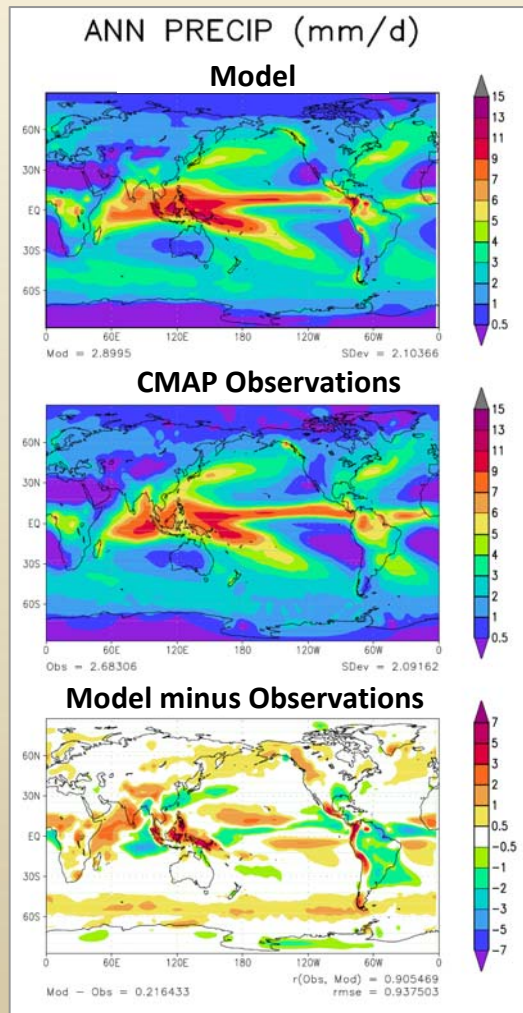


Parameterizations based on sub-grid PDFs of vertical velocity have been implemented in AM3

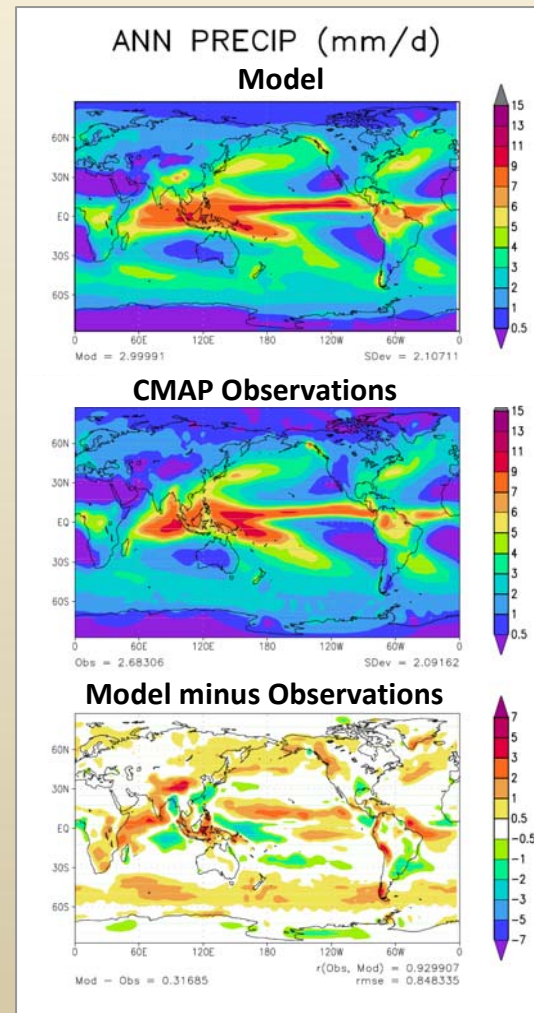
- **Deep convection:** Donner *et al.* (2001, *J. Climate*), Wilcox and Donner (2007, *J. Climate*)
- **Shallow convection:** Bretherton *et al.* (2004, *Mon. Wea. Rev.*) implemented by Ming Zhao
- **Stratiform:** modification of Tiedtke (1993, *Mon. Wea. Rev.*) by Chris Golaz, to include w PDF for activation only

Amazon precipitation bias reduced in AM3

AM2



AM3



AM3: The Next-Generation Atmospheric Component of Coupled Model CM3

- **Capability for new research on cloud-aerosol interactions, atmospheric chemistry, and stratosphere-troposphere interactions**
- **New parameterizations for cloud-droplet activation, deep and shallow cumulus convection, and sub-grid vertical velocity variability in stratiform clouds**
- **New cubed-sphere formulation of the finite-volume dynamical core**
- **Interactive tropospheric and stratospheric chemistry**
- **More realistic Amazon precipitation, sea surface temperatures, and aerosol properties**



Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009

