Atmospheric Dynamics - Introduction and Overview

Presented by
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Can we improve regional climate change projections?
Development of high resolution atmospheric models to date is very encouraging.

Can our models provide useful projections of changes in extreme weather events?
We are making rapid progress on the effects of warming on tropical cyclones.

How does research into atmospheric dynamics interface with our model development process?
Several examples illustrate the importance of these connections.
A variety of high resolution atmospheric models are under development

M180 AM2.1/LM2 (NARCCAP)  =>  C90 and C180 AM2.1/LM3

HIRAM2.1

Cn => cubed-sphere grid with n x n points in each face of cube

- C90/100km
- C180/50km
- C360/25km
- C720/13km
- C2000/5km

Alternative sub-grid closures being actively pursued to optimize model at different resolutions

Lin, Zhao, Wyman, Held, Lau, ...

hydrostatic

non-hydrostatic
Ongoing tropical cyclone/global warming modeling at GFDL

- Zetac regional model of Atlantic hurricane season
- Rotating radiative-convective equilibrium
- C90 global model
- C180 global model
- C360/720 track/intensity forecasts

Downscaled with GFDL hurricane prediction system (coupled, multiple mesh)
A sampling of ongoing research on atmospheric dynamics with a spectrum of models

- Are there useful idealized geometries in which to study hurricane genesis and intensity?
- How sensitive is tropical precipitation to extratropical thermal forcing (aerosols, ice sheets)?
- What determines the position of the midlatitude surface westerlies?
Tropical storm models in idealized geometries provide important insights into tropical cyclogenesis.

These two models are identical, except that:
one has realistic geometry and boundary conditions;
the other is homogeneous and doubly periodic on an f-plane.

Zhao, Held, Lin, Vecchi, in review

Surface wind speed
20,000 X 20,000km
f = 10N

Surface pressure

Precipitation

Held and Zhao, JAS, 2008
The response of tropical rainfall to high latitude heating/cooling is very sensitive to cloud feedbacks

*(Important for response to aerosols, ice age ice sheets, variations in Atlantic overturning)*

When the atmosphere is cooled in high latitudes in one hemisphere and warmed in the other, in an idealized “slab-ocean, aqua-planet” version of AM2:

the ITCZ moves to the warmed hemisphere, but the size of the movement is sensitive to cloud feedbacks *(Kang, Zhang, Held, Frierson)*.
Stormtracks/droughts are linked to the latitude of surface westerlies; idealized models isolate factors that can alter this latitude.

“Roaring 40’s” are moving polewards

Ozone hole or global warming?

Surface westerlies move polewards as surface friction is reduced (Chen, Held, Robinson, 2007). Research suggests that, surprisingly, the same dynamics may be at play in both cases.
Morris Bender
The GFDL Hurricane Prediction System

Gabriel Lau
Some applications of high resolution atmospheric modeling

Ming Zhao
Global simulations of hurricane climatology/variability/change

Shian-Jiann Lin
Dynamical cores and seamless global/regional model development

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