A Framework for Evaluating the CAM5 Physics Suite at High Spatial Resolution in WRF

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**Motivation**

Representing Clouds and Aerosols in Global Climate Models

- **Computationally inexpensive globally**
- **Computationally expensive to run routinely globally**

Global climate models, such as CAM, will be run at higher spatial resolution in the future.

Performance of current suite of physics parameterizations at these scales is not known.

- CAM: Global modeling community
- WRF: Mesoscale modeling community

- Relatively little interaction
  - Optimized for different purposes
  - Lessons learned not shared

Development of the next generation suite for CAM requires the ability to **isolate processes and test parameterizations** across a range of scales.
Objectives

- Use WRF’s framework to **test the scale dependency of the CAM5 parameterization suite** and develop improved parameterizations for both models

- Use the **Aerosol Modeling Testbed** to evaluate performance of the CAM5 parameterization suite
  - Evaluate physics suite at spatial resolution more compatible with data
  - Compare simple and complex representations
  - Identify more desirable parameterization choices

- **Increase communication** between WRF (cloud-resolving / mesoscale) and CAM (global scale) modeling communities
Overall Approach

Community Atmosphere Model (CAM5)
- deep convection
- shallow convection
- microphysics
- boundary layer
- aerosols
- trace gas chemistry
- radiation
- land surface

Philosophy: Single parameterization for each atmospheric process for long-term climate simulations using a coarse grid

Weather Research & Forecasting (WRF)
- deep convection v3.3
- shallow convection v3.3
- microphysics
- boundary layer v3.3
- aerosols
- trace gas chemistry
- radiation
- land surface

Philosophy: Several parameterizations for each atmospheric process using a wide range of grid spacings

Engineering Component: Merge code and ensure code inter-operability

Science Component: Evaluate performance of CAM modules at regional scales

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Interfaces in /phys Directory

- Can now compare CAM5 parameterizations with many alternative methods
- With the “interfaces”, updates to CAM5 code can be easily added to WRF
Interfaces in /chem Directory

- Can now compare MAM with other aerosol treatments
- 3-mode and 7-mode version of MAM implemented

CBM-Z provides oxidants for MAM

MAM species passed to optical property module

red = new modules

4 options

Minimal changes

To radiation_driver

emissions_driver

optical_driver

photolysis_driver

dry_dep_driver

grelldrvct

mechanism_driver

cloudchem_driver

aerosols_driver

wetscav_driver

minimal changes

interface between WRF and CAM

CAM support modules

primary subroutines

WRF

optical_averaging

optical_prep_mam

cam_mam_drydep_driver

cbam_z_driver

cam_mam_addemiss

cam_mam_aerchem_driver

CAM5

CBM-Z provides oxidants for MAM

red = new modules

MAM species passed to optical property module

4 options
Aerosols: Comparing with Other Models

- **AMT methodology**: identical emissions, meteorology (aerosol-radiation-cloud feedbacks turned off), chemistry, dry deposition, boundary conditions

**MAM (from CAM5)**
- modal – 3 modes, 18 species
- 'simple'
- total CPU time = 1

**MADE/SORGAM**
- modal – 3 modes, 38 species
- 9 times more species
- 1.14

**MOSAIC**
- sectional – 4 bins, 164 species
- ‘complex’
- 2.85

Differences due to secondary aerosols (SO₄, NO₃, NH₄, organics)

Treatment of organics:
- **MAM**: POA - non-volatile, SOA – simple yields
- **MADE/SORGAM**: POA - non-volatile, SOA - 2-product approach
- **MOSAIC**: volatility basis set, non-volatile POA & SOA
Aerosols: Comparing with Other Models

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**fine aerosol water (< 2.5 μm) ~200 m AGL**

- Differences in secondary aerosols and thermodynamic modules leads to large variations in uptake of water on aerosols
- These differences will influence aerosol direct effect
Aerosols: Impact on Radiation

Differences using MAM, Feedback – No Feedback on Radiation, using RRTMG

With Feedback on Radiation using RRTMG

Behavior of MAM and MADE/SORGAM somewhat different, especially for SSA, due to size distribution assumptions
Aerosols: Downscaling

What’s different from previous coupling of models? Answer: **Consistent physics from global to regional scale**

Differences in predictions between the models due to resolving atmospheric processes, and not the physics parameterizations.
Aerosols: MILAGRO Test

PM2.5 at 700 hPa, 18 UTC 19 March 2006

- CAM5 + IPCC AR5 emissions
  - SW ambient winds
  - $\Delta x = (2.5 \times 1.9^\circ)$

- WRF + CAM5 Physics + (IPCC AR5) emissions
  - $\Delta x = 12$ km
- WRF + CAM5 Physics + local emissions

- CAM5 + IPCC AR5 emissions
- WRF + CAM5 Physics + (IPCC AR5) emissions
- WRF + CAM5 Physics + local emissions

- Differences mostly due to online dust calculations
- Magnitude similar, but small grid spacing add details
Aerosols: Summary

- With our new tool, we now have opportunities to:
  - Examine performance of MAM at local to regional scales, and
  - Explore alternative treatments of organics for the next version of MAM
  - See [poster P80](#) for more details on MAM and its evaluation

- Next, provide examples boundary layer and microphysics schemes

![Diagram showing aerosol transformation, cloud chemistry, boundary layer processes.](image)
Boundary Layer: Central U.S. Test

- **CAM5 – Bretherton & Park Scheme (TKE variant)**
  - PBL depths from CAM5 scheme qualitatively similar to MYJ scheme
- **MYJ Scheme (TKE variant)**
  - PBL from YSU scheme > MYJ (consistent with previous testing)
- **YSU Scheme (non-local closure)**
  - Choice of PBL scheme led to somewhat different cloud distributions

PBL Depth
March 24
21 UTC 2007

*clouds*
Boundary Layer: MILAGRO Test

Using AMT to Evaluate PBL Implementation (all other modules identical)

observed at T1 site CAM5 MYJ YSU (used by default in AMT)

As with central U.S. test, CAM5 scheme more similar to MYJ scheme
PBL depths from CAM5 too low during afternoon
Performance likely to vary from location to location
Microphysics: ISDAC Test

- Observations from ARSCL over Barrow, Alaska
- M&G scheme working correctly
- Coarse spatial resolution likely explains missing clouds in CAM5

WRF ($\Delta x = 5$ km)

- Morrison

WRF ($\Delta x = 5$ km)

- Morrison & Gettelman

CAM5 ($\Delta x = 2.5 \times 1.9^\circ$)

- Morrison & Gettelman
Microphysics: ISDAC Test

Using AMT to Evaluate Microphysics Implementation

Convair Flight, April 4 - 5, 2008
observed
Morrison & Gettelman

percentiles percentiles percentiles percentiles

bias   -1.4    -1.4
r  0.95  0.95

bias    6.3     5.7
r  0.57  0.60

Cloud Distribution
00 UTC. April 5

statistics from all aircraft flights

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Summary

► Most of the CAM5 physics suite is now functional in WRF
  ■ 3 schemes made available in v3.3, others in next release?
  ■ Users should be aware there may still be bugs
► Behavior of CAM5 parameterizations similar to other parameterizations
  ■ MAM performs as well as other aerosol models in many respects, but the AMT suggests there areas of improvement
  ■ Computational efficiency of 3-mode version could be attractive to other applications besides its use for climate applications
► Tested functionality of downscaling CAM5 to WRF using same physics

Remaining Tasks (to be completed this summer):
► Couple MAM aerosols with cloud-aerosol interactions in Morrison & Gettelman scheme and add wet removal
► Couple MAM with MOZART and “fast” MOZART
► Perform final simulations and publish results
Next Steps

- Assess performance of CAM5 physics suite at low and high spatial resolution for simulations aerosols and clouds in the Arctic.

Move CAM5 physics into Model for Prediction Across Scales?