Porting the CAM5 Physics Suite into WRF

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Problem Statement / Motivation

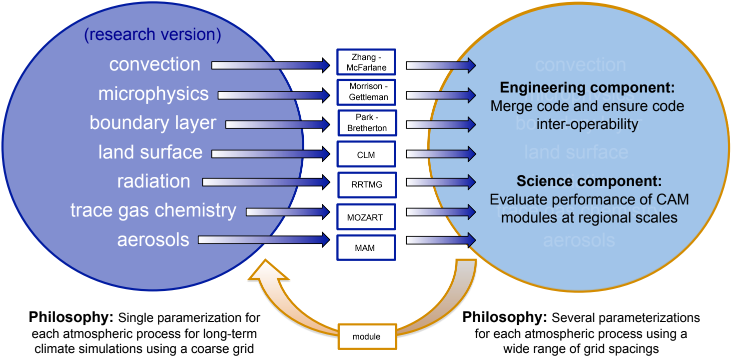
- There has been relatively *little interaction* between the WRF (cloud-resolving and mesoscale) and CCSM/CAM (global scale) communities
  - Models have been optimized for different purposes
  - Lessons learned on parameterizations are not necessarily shared
- CAM will be run at higher spatial resolution (10 – 20 km) in the future (5 – 10 years from now), but the *performance of the current suite of physics modules at those scales are not known*
- Rapid development and evaluation of the next generation suite for CAM requires
  - Ability to isolate processes
  - Ability to easily test parameterizations across a range of scales

Goal and Objectives

- Incorporate the **parameterization suite from CAM5 into WRF**
- Use the **Aerosol Modeling Testbed** to evaluate the parameterization suite from CAM5
  - Evaluate CAM5 physics suite at higher spatial resolution more compatible with data
  - Compare CAM5 physics against more complex and expensive representations using systematic and consistent methodology
  - Use performance metrics to identify more desirable parameterization choices for both models
- **Increase communication** between WRF (cloud-resolving and mesoscale) and CCSM/CAM (global scale) modeling communities

Approach

Community Atmosphere Model (CAM)　　　　Weather Research & Forecasting (WRF)



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

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

Coding Philosophy: Both emphasize modularity and have scheme independence, interface subroutines / layers

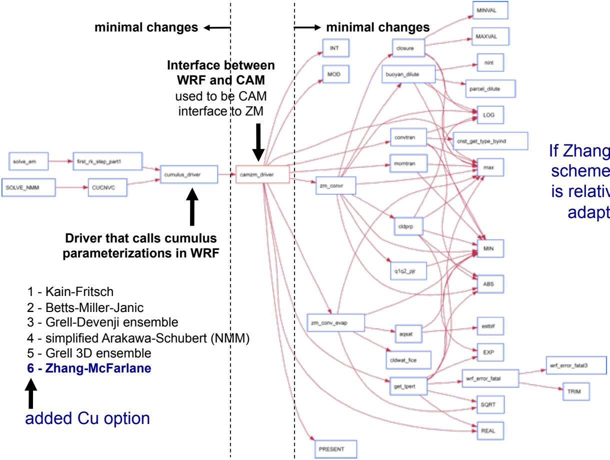
Coding Philosophy

- **Top priority:** ease code maintenance for long-term sustainability

- **Methodology**
  - Use Subversion with vendor branches for WRF and CCSM
  - Implement CAM physics via intermediary driver subroutines
  - Minimize code changes outside of driver
  - When possible, make schemes interoperable

Convective Parameterization

Flow Chart for Zhang-McFarlane Scheme implemented in WRF



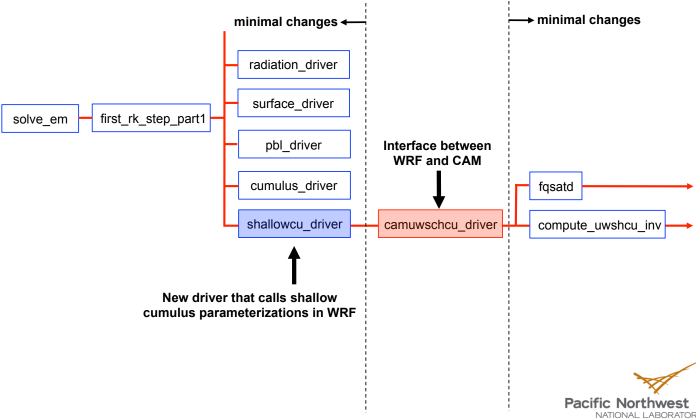
1 - Kain-Fritsch
2 - Betts-Miller-Janic
3 - Grell-Devenji ensemble
4 - simplified Arakawa-Schubert (NMM)
5 - Grell 3D ensemble
6 - Zhang-McFarlane

added Cu option

If Zhang-McFarlane scheme updated, it is relatively easy to adapt for WRF

Shallow Convective Parameterization

Flow Chart for UW Scheme implemented in WRF



Progress So Far…

- **Convective Parameterization:**
  - Zhang-McFarlane scheme ported from CAM5 to WRF
  - Tested ZM in comparison with other parameterizations in WRF
- **Shallow Convective Parameterization:**
  - UW scheme ported from CAM5 to WRF
  - New driver for shallow convection added to WRF, with flexibility to handle other schemes such as Larry Berg's CuP
  - Added separate tendency arrays for shallow to supplement Cu and MP
- **Testbed Case:**
  - WRF domain and simulation period set up to test ported code
- **New Hire to speed progress:**
  - Hired programmer to help with code development issues; starting "any day now"

Other Parameterizations

To be implemented next this summer:

- **Boundary Layer**: Park - Bretherton TKE scheme similar to those in WRF
- **Aerosols:** Modal Aerosol Model (MAM) developed by Liu, Easter, and Ghan
- **Microphysics:** Morrison - Gettleman

Activities by other groups to consider:

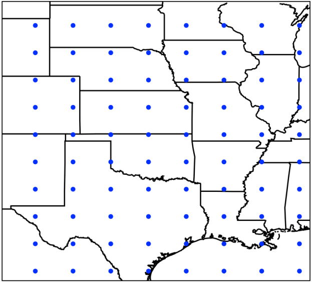
- **Radiation:**
  - RRTMG already implemented in WRF by AER Inc.
  - Need to assess whether code is latest CAM5 version
- **Gas-Phase Chemistry:**
  - Full MOZART already implemented in WRF by NCAR, but …
  - Limited MOZART from CAM5 needs to be ported (NCAR ?)
- **Land-Surface:**
  - Several groups coupling CLM to WRF, either hard-coded or via flux coupler

Implement interfaces consistent with our efforts ?

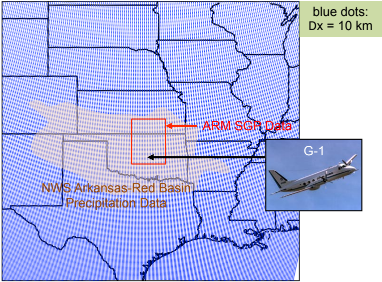
- **Macrophysics:**
  - Designed for large spatial and temporal scales—a foreign concept to many WRF modelers

Testbed Case: 2007 CHAPS Field Campaign

Typical CAM grid: **2.5° x 1.9°**



WRF grid: **90, 30, 10, 3 km**

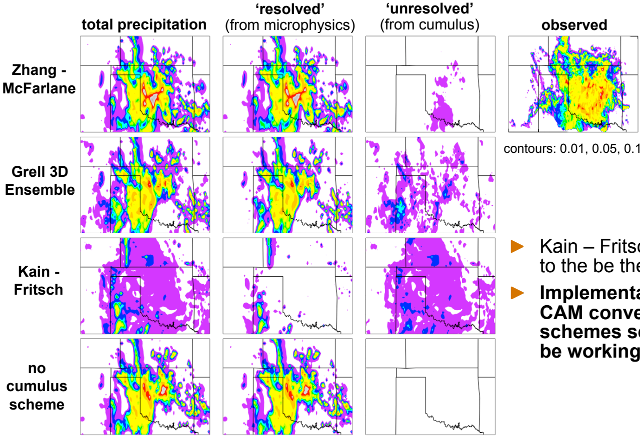


- Evaluate convective parameterizations using different Dx
- Two sets of simulations performed: Convection parameterization is either Zhang-McFarlane (from CAM) or Kain-Fritsch (from WRF); all runs use same microphysics, boundary layer, and surface layer parameterizations
- Initially looking to confirm Zhang-McFarlane is implemented correctly

Sensitivity to Convective Parameterization

24-h Accumulated Precipitation (12 UTC June 19 – 20, 2007)

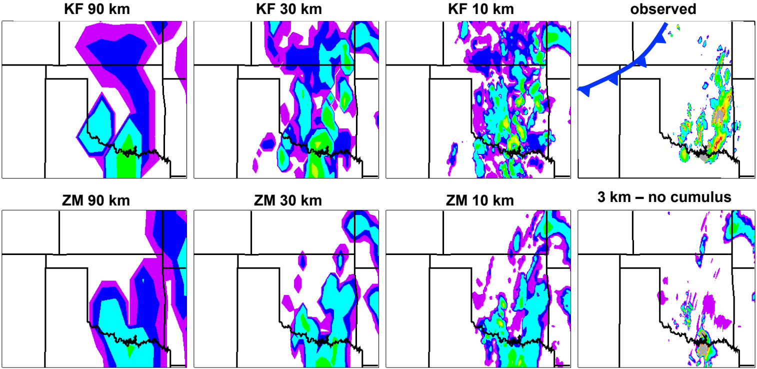
Using Morrison Microphysics and Dx = 12 km



contours: 0.01, 0.05, 0.1, 0.5, 1, 2 … mm

- Kain – Fritsch appears to the be the outlier
- **Implementation of CAM convection schemes seems to be working okay**

Example Differences: Hourly Precipitation 12 UTC June 18, 2007



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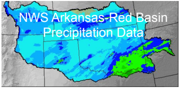
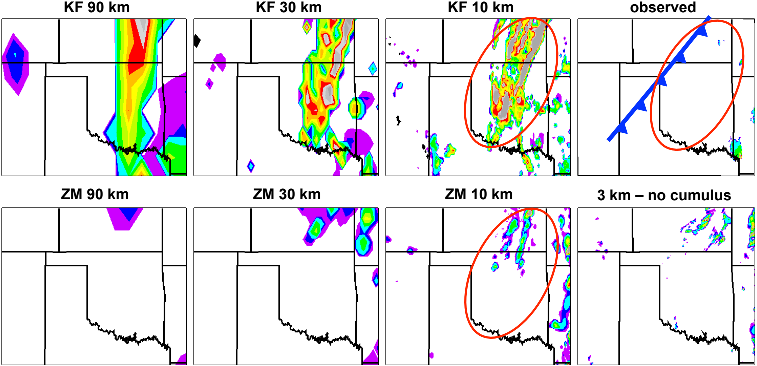


Example Differences: Hourly Precipitation 00 UTC June 19, 2007



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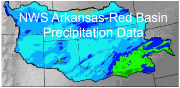
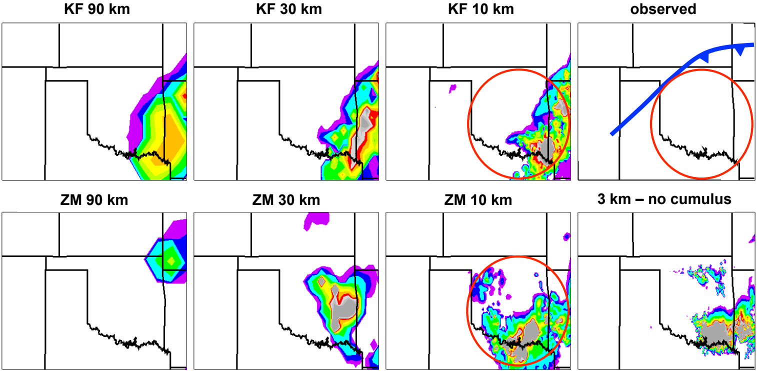


Example Differences: Hourly Precipitation 12 UTC June 19, 2007



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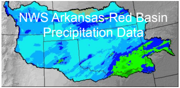
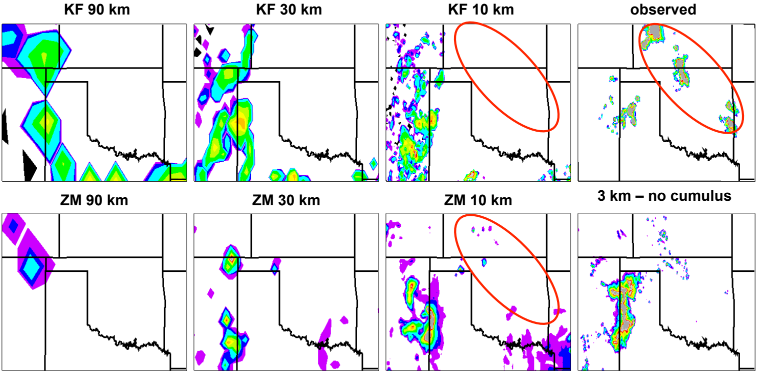


Example Differences: Hourly Precipitation 00 UTC June 20, 2007



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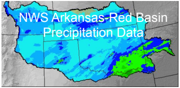

The Completed Product

- The ability to run CAM physics package in WRF at higher spatial resolution that is more compatible with cloud and aerosol data
- Simplified framework for parameterization development
  - Easily compare behavior across a range of grid spacings
  - Interoperability enables comparisons with different param. combinations
- A regional atmospheric model with self consistent physics between global and regional domains for downscaling CAM climate simulations

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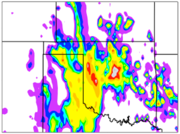
Sensitivity to Microphysics

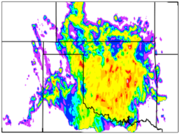
24-h Accumulated Precipitation (12 UTC June 19 – 20, 2007)

No Convective Parameterization and Dx = 12 km

total precipitation | **observed precipitation**

Morrison





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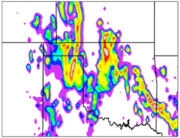
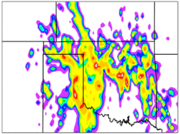
Thompson



Lin



- Thompson produced the least amount of precipitation
- Spatial pattern of Morrison and Lin scheme similar
- How will Morrison – Gettleman scheme perform?

CAM5 Physics Package in WRF

WRF module	Options	CAM5 Package	Test Package 1	Test Package 2
/**phys**/module_cumulus_driver	Kain-Fritsch, Betts-Miller-Janic, Grell-Devenji Ensemble, Arakawa-Schubert, Grell 3D Ensemble	Zhang - McFarlane	Zhang - McFarlane	Zhang - McFarlane
/**phys**/module_microphysics_driver	Kessler, Lin, WSM, Ferrier, Goddard ...	Morrison - Gettleman	Morrison - Gettleman	Morrison
/**phys**/module_pbl_driver	YSU, MYJ, NCEP, QNSE, MYNN ...	Park - Bretherton	Park - Bretherton	YSU
/**phys**/module_surface_driver	slab, Noah, RUC, MYNN, Pleim-Xue	CLM	CLM	Noah
/**phys**/module_radiaton_driver	RRTM LW, Goddard - SW, Dudhia - SW, CAM – LW&SW	RRTMG LW & SW	RRTMG LW & SW	Goddard - SW
/**chem**/mechanism_driver	RADM2, RACM, CB4, CBM-Z, NMHC	MOZART	MOZART	CBM-Z
/**chem**/aerosol_driver	GOCART, MADE-SORGAM, MOSAIC	MAM	MOSAIC	MOSAIC

ensure interoperability: permit combination of WRF and CAM modules