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 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
  - Cheaper calculations at small scales

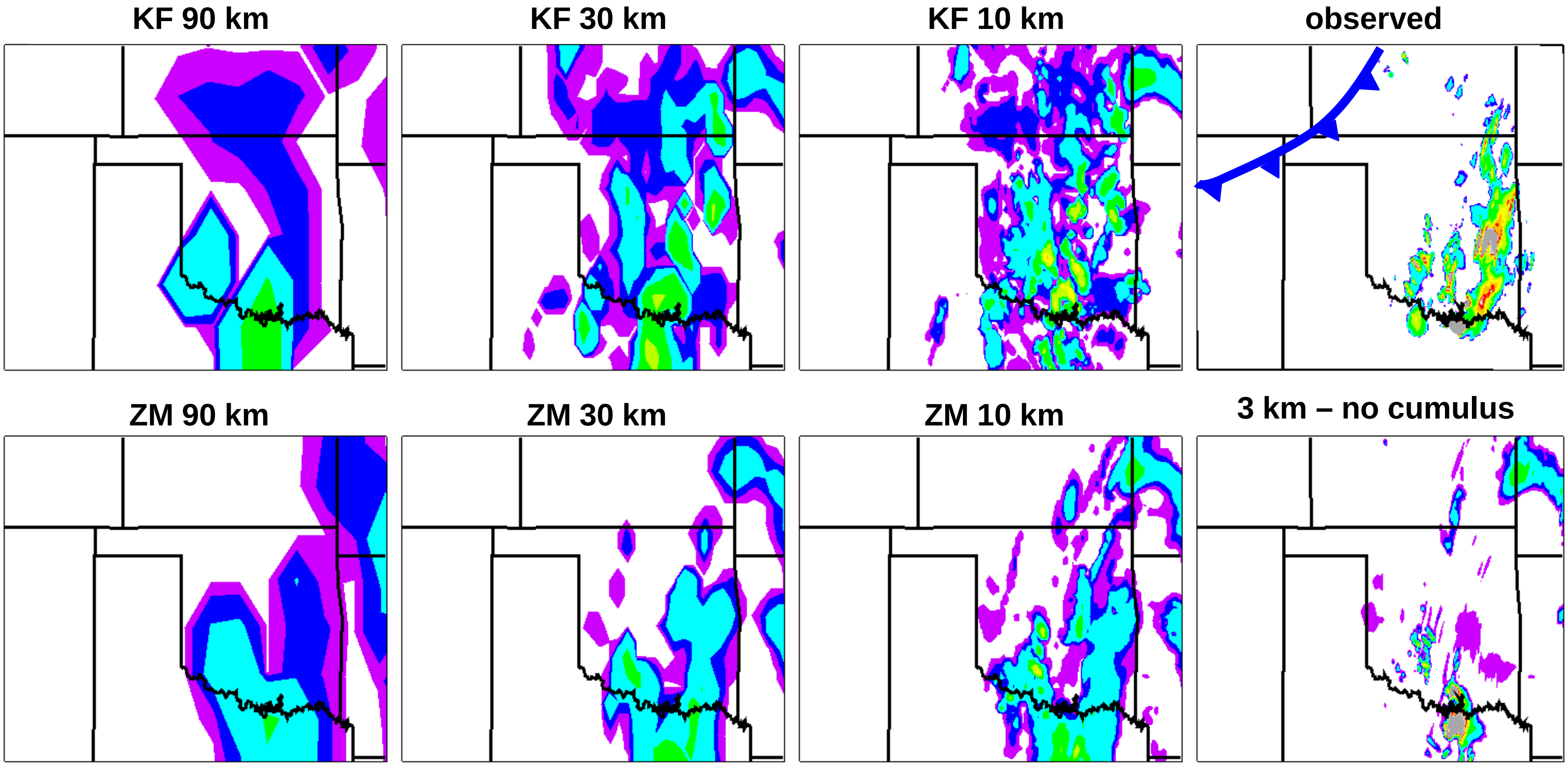
Goal and Objectives

- 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 compatibile 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

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
- **Testbed Case:**
  - WRF domain and simulation period set up to test ported code
- **Interaction with NCAR:**
  - Meeting and conference calls - NCAR also interested in coupling CAM to WRF so that CAM provides boundary conditions to WRF
- **New Hire to speed progress**

Example Differences: Hourly Precipitation 12 UTC June 18



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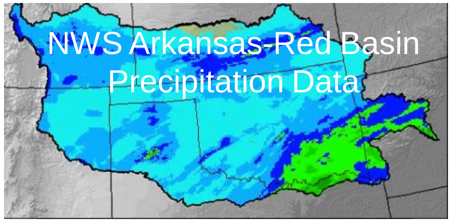


Other Parameterizations

To be implemented next this summer:

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

Activities by other groups:

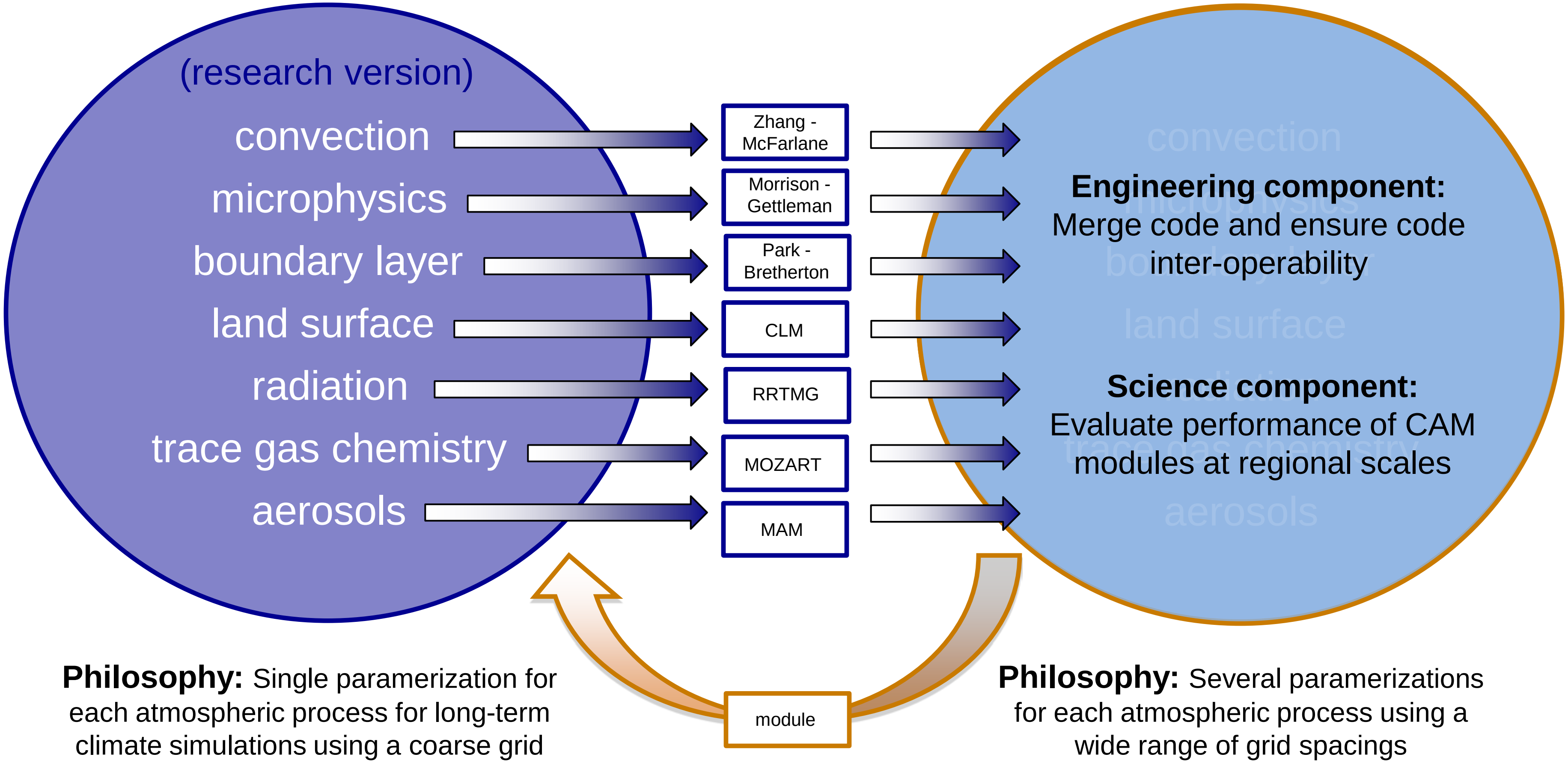
- **Radiation:**
  - RRTMG already implemented in WRF by AER Inc.
  - Need to assess whether code is latest CAM5 version
- **Gas-Phase Chemistry:**
  - Full MOZART already implemented in WRF by NCAR, but …
  - Limited MOZART from CAM5 needs to be ported (NCAR ?)
- **Land-Surface:**
  - Several groups 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, so is it useful to port to WRF ?

Extra Slides

Approach



Community Atmosphere Model (CAM)

Weather Research & Forecasting (WRF)

(research version)

- convection → Zhang - McFarlane
- microphysics → Morrison - Gettleman
- boundary layer → Park - Bretherton
- land surface → CLM
- radiation → RRTMG
- trace gas chemistry → MOZART
- aerosols → MAM

module

Engineering component: Merge code and ensure code inter-operability

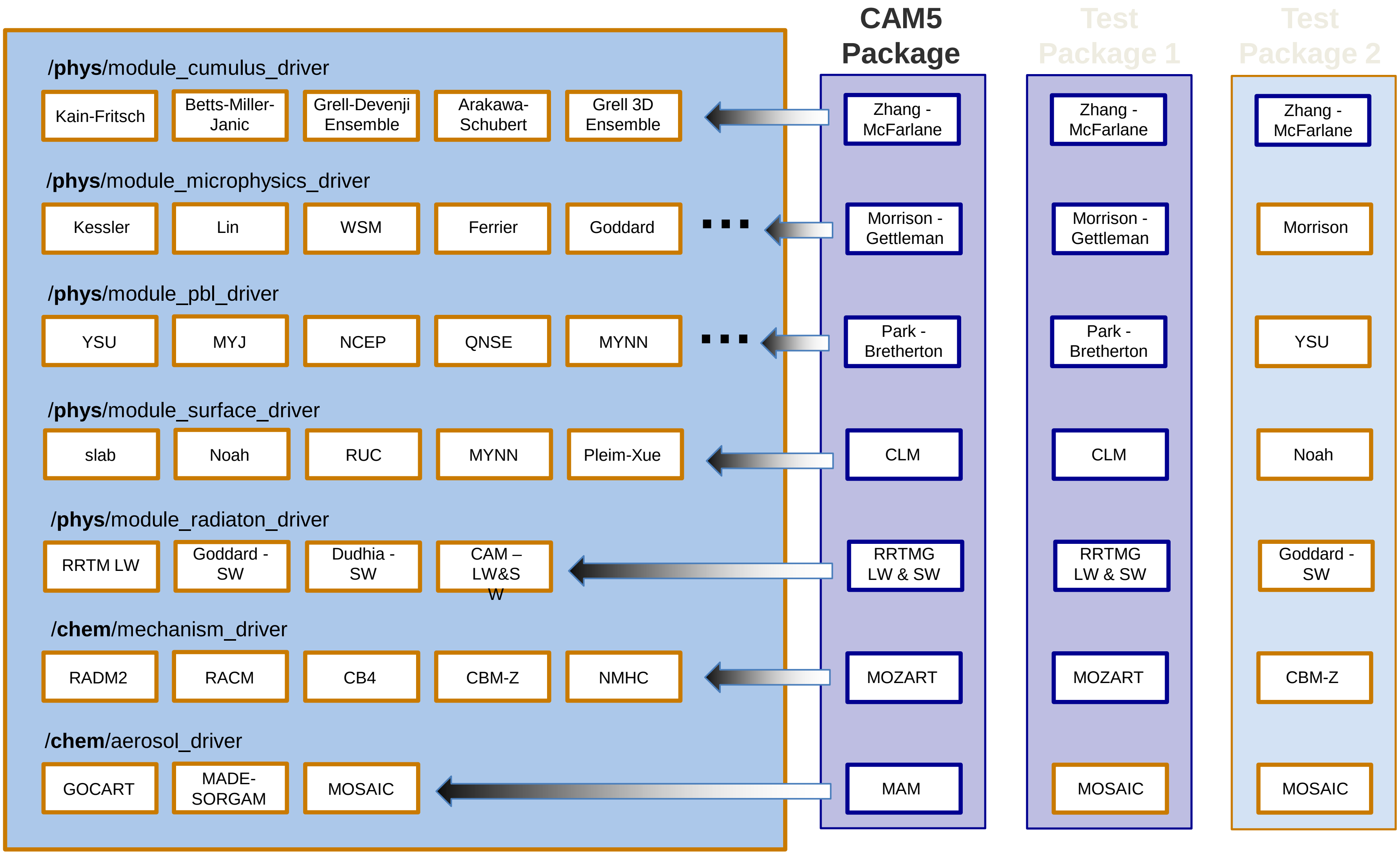
Science component: Evaluate performance of CAM modules at regional scales

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

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

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

CAM5 Physics Package in WRF



/**phys**/module_cumulus_driver

Kain-Fritsch | Betts-Miller-Janic | Grell-Devenji Ensemble | Arakawa-Schubert | Grell 3D Ensemble

/**phys**/module_microphysics_driver

Kessler | Lin | WSM | Ferrier | Goddard ...

/**phys**/module_pbl_driver

YSU | MYJ | NCEP | QNSE | MYNN ...

/**phys**/module_surface_driver

slab | Noah | RUC | MYNN | Pleim-Xue

/**phys**/module_radiaton_driver

RRTM LW | Goddard - SW | Dudhia - SW | CAM – LW&SW

/**chem**/mechanism_driver

RADM2 | RACM | CB4 | CBM-Z | NMHC

/**chem**/aerosol_driver

GOCART | MADE-SORGAM | MOSAIC

CAM5 Package	Test Package 1	Test Package 2
Zhang - McFarlane	Zhang - McFarlane	Zhang - McFarlane
Morrison - Gettleman	Morrison - Gettleman	Morrison
Park - Bretherton	Park - Bretherton	YSU
CLM	CLM	Noah
RRTMG LW & SW	RRTMG LW & SW	Goddard - SW
MOZART	MOZART	CBM-Z
MAM	MOSAIC	MOSAIC

ensure interoperability: permit combination of WRF and CAM modules

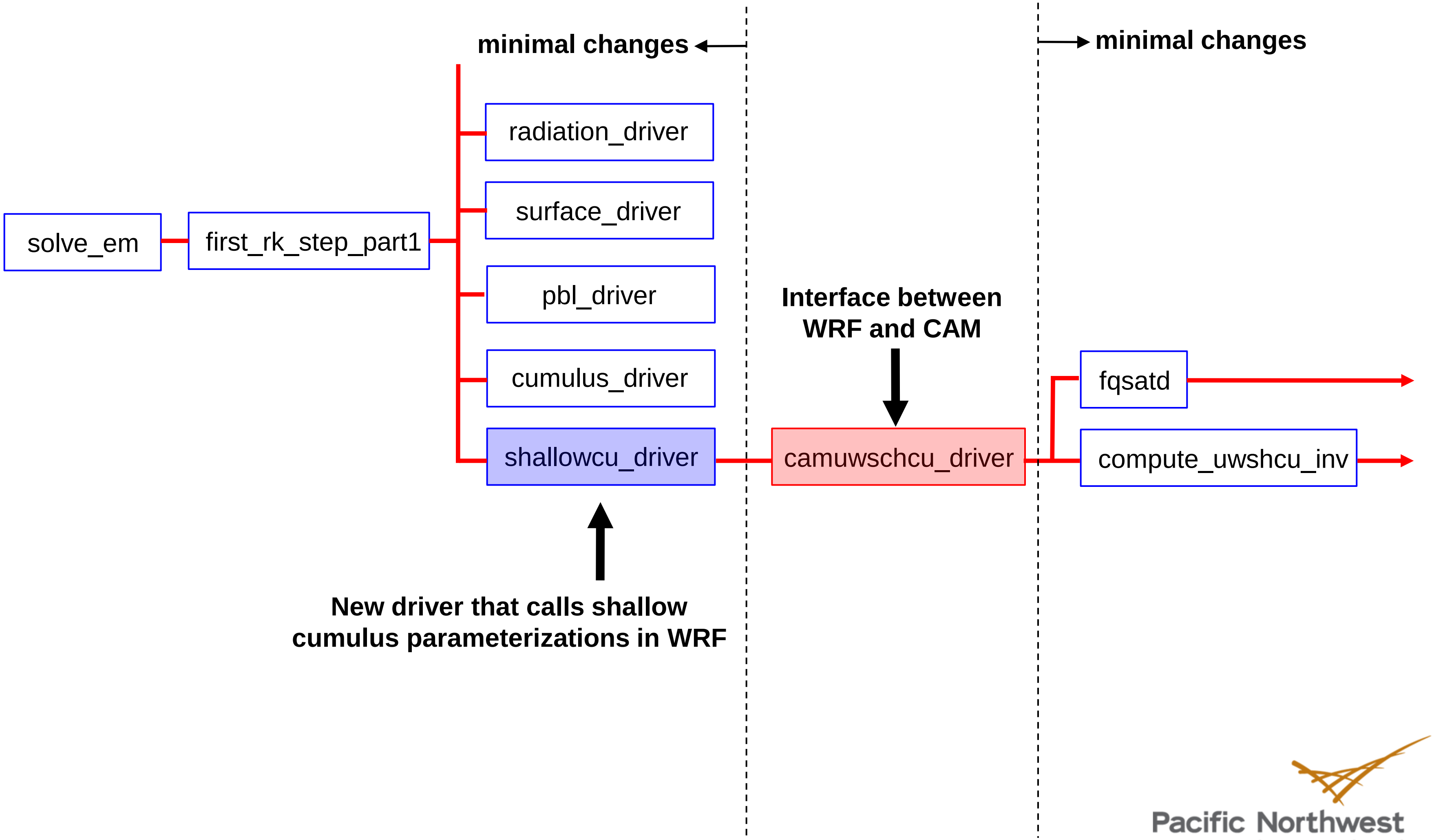
Coding Philosophy

- **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 (lower priority)

Shallow Convective Parameterization

Flow Chart for UW Scheme implemented in WRF



minimal changes

minimal changes

solve_em

first_rk_step_part1

radiation_driver

surface_driver

pbl_driver

cumulus_driver

shallowcu_driver

Interface between WRF and CAM

camuwschcu_driver

fqsatd

compute_uwshcu_inv

New driver that calls shallow cumulus parameterizations in WRF

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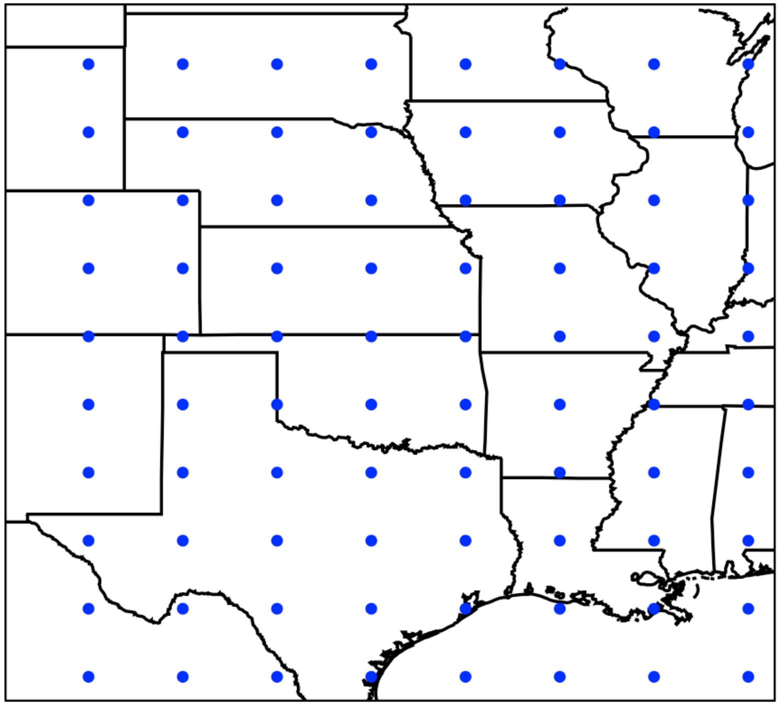
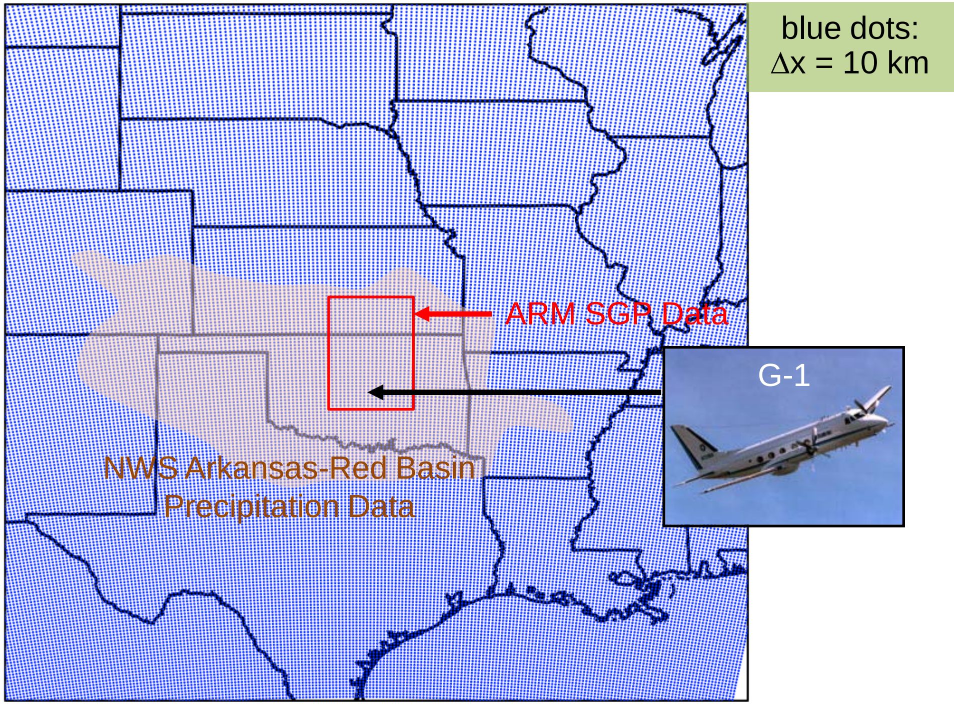
Testbed Case: CHAPS Field Campaign

Typical CAM grid: **2.5^{o} x 1.9^{o}**

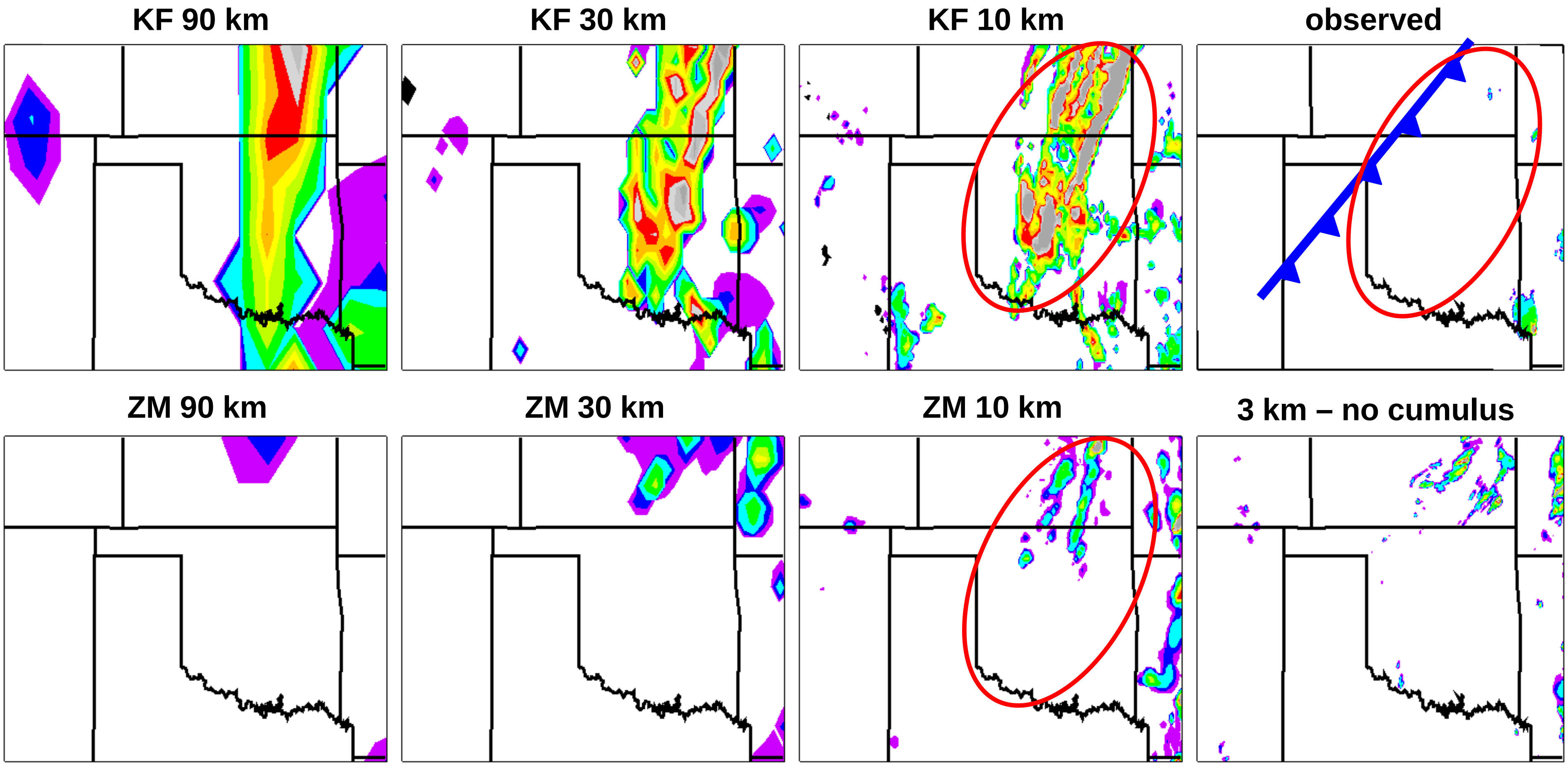


WRF grid: **90, 30, 10, 3 km**



- Evaluate convective parameterizations using different Δx
- 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

Example Differences: Hourly Precipitation 00 UTC June 19



KF 90 km

KF 30 km

KF 10 km

observed

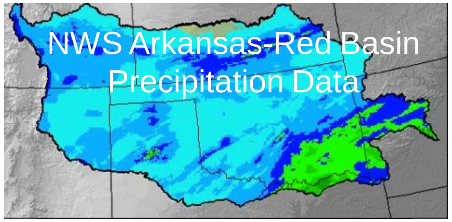
ZM 90 km

ZM 30 km

ZM 10 km

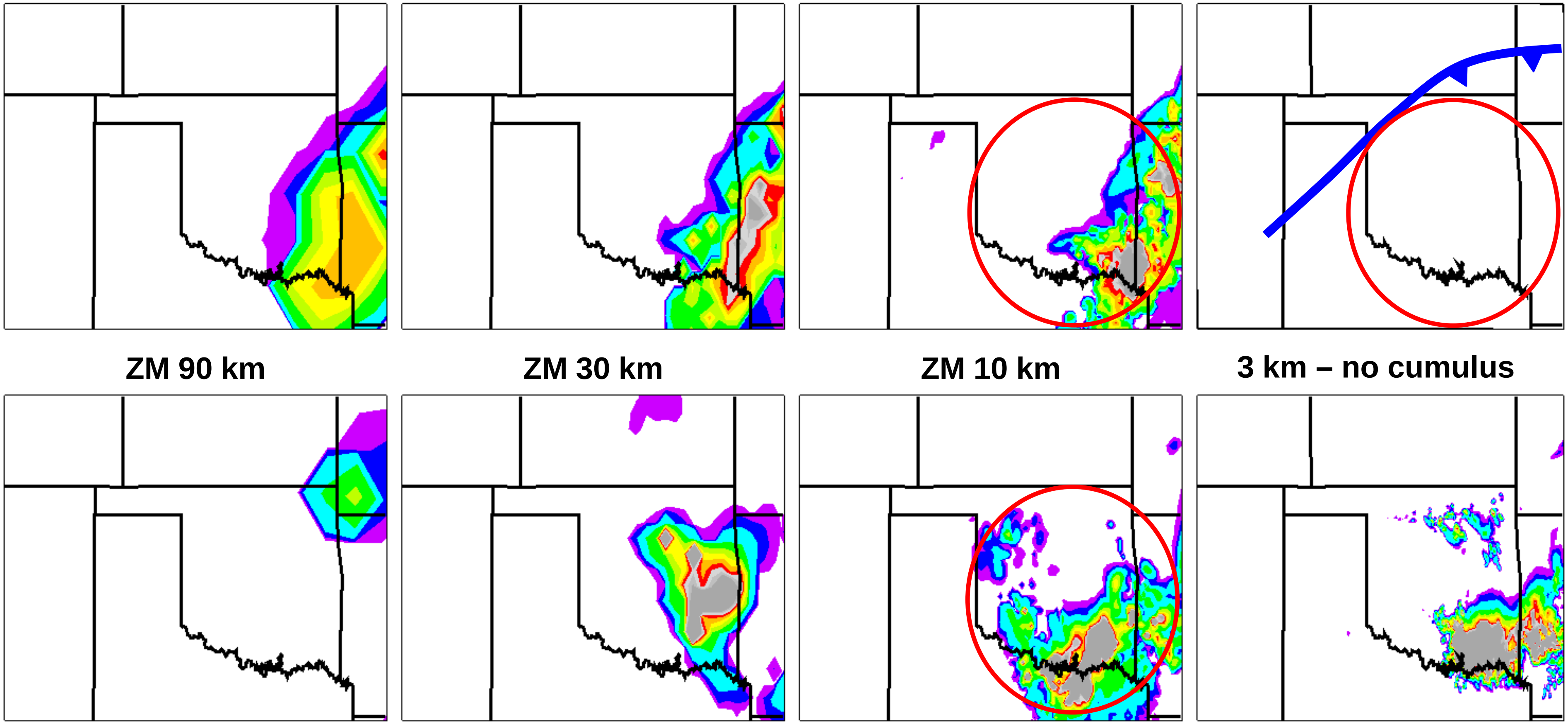
3 km – no cumulus

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



NWS Arkansas-Red Basin Precipitation Data

Example Differences: Hourly Precipitation 12 UTC June 19



KF 90 km

KF 30 km

KF 10 km

observed

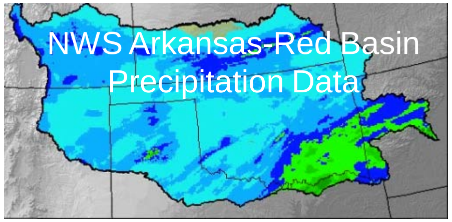
ZM 90 km

ZM 30 km

ZM 10 km

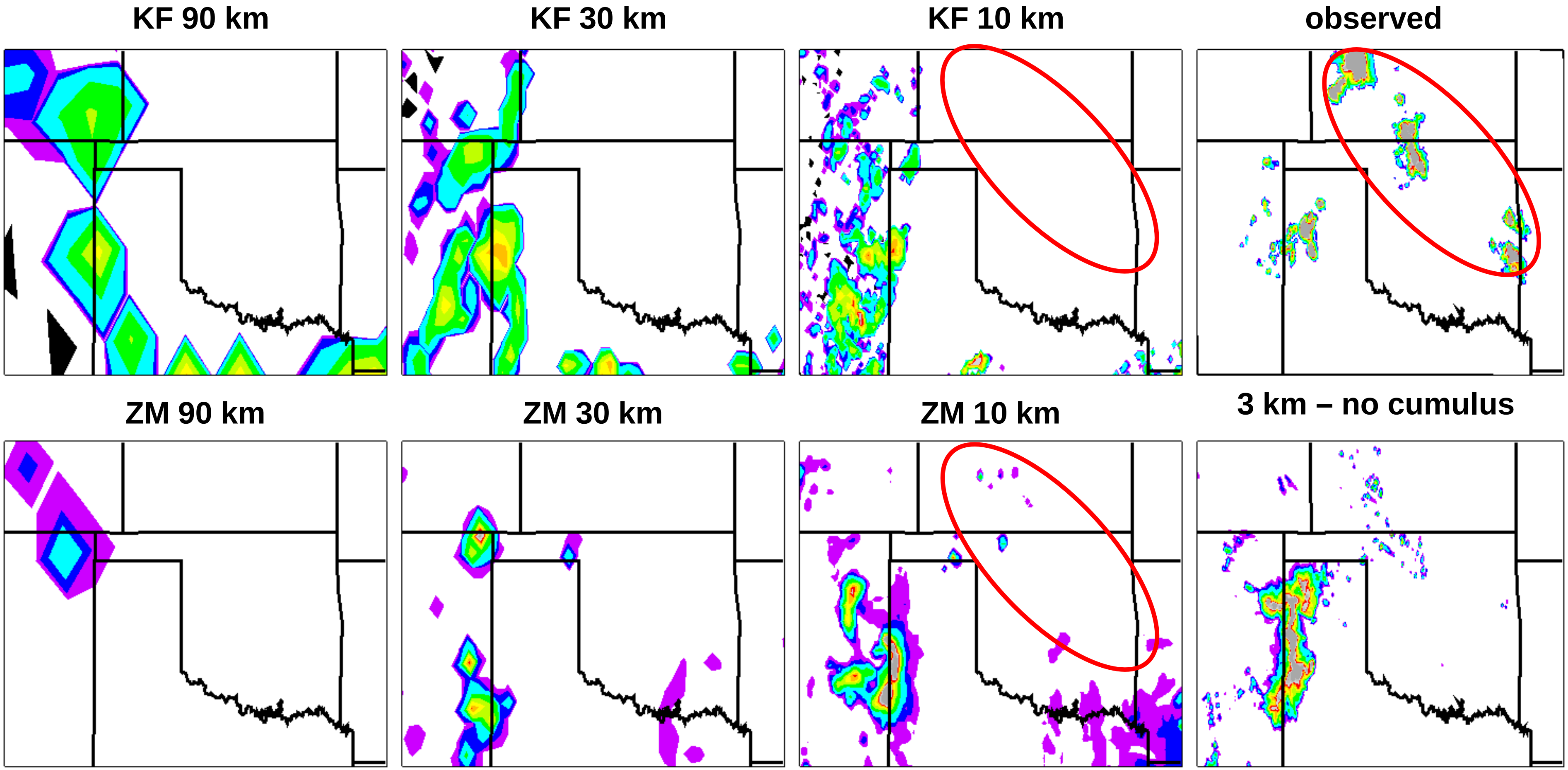
3 km – no cumulus

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



NWS Arkansas-Red Basin Precipitation Data

Example Differences: Hourly Precipitation 00 UTC June 20



KF 90 km

KF 30 km

KF 10 km

observed

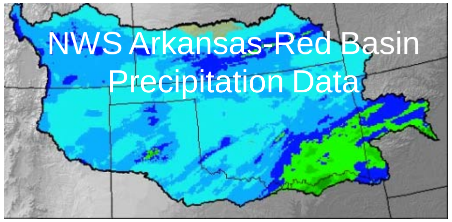
ZM 90 km

ZM 30 km

ZM 10 km

3 km – no cumulus

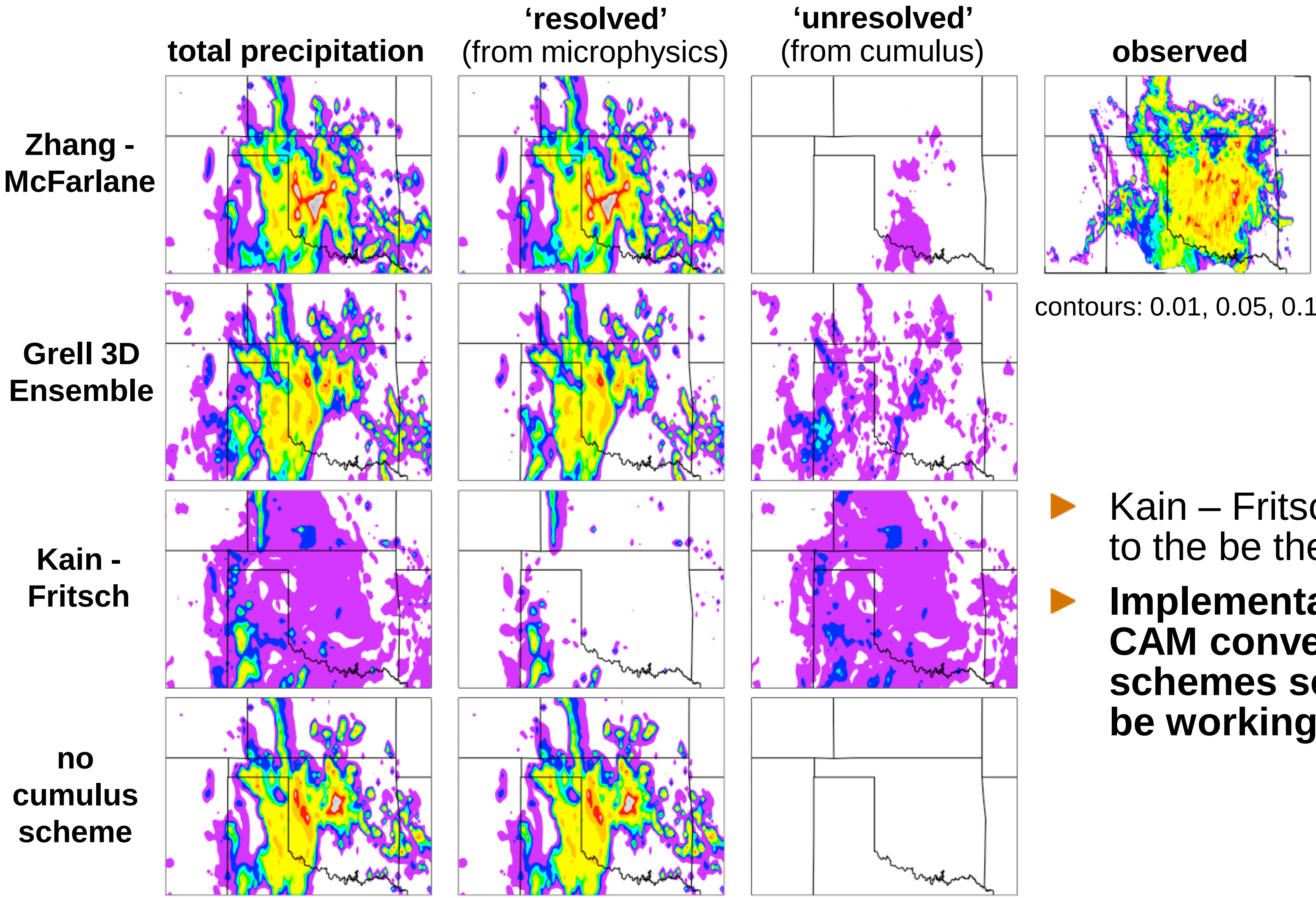
contours: 0.01, 0.05, 0.1, 0.5, 1, 2 … mm/hr



Sensitivity to Convective Parameterization

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

Using Morrison Microphysics and Δx = 12 km



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

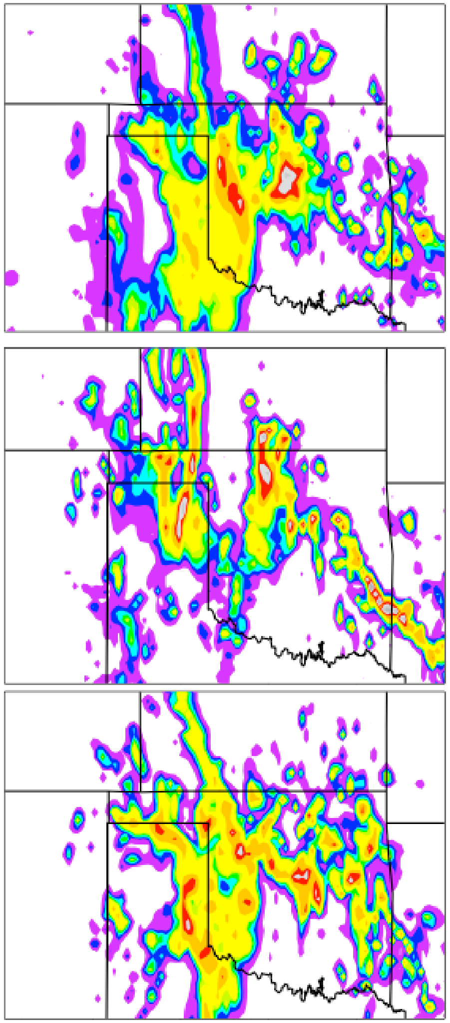
- Kain – Fritsch appears to the be the outlier
- **Implementation of CAM convection schemes seems to be working okay**

Sensitivity to Microphysics

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

No Convective Parameterization and Δx = 12 km

total precipitation

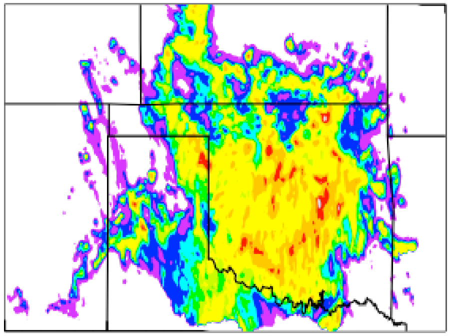


Morrison

Thompson

Lin

observed precipitation

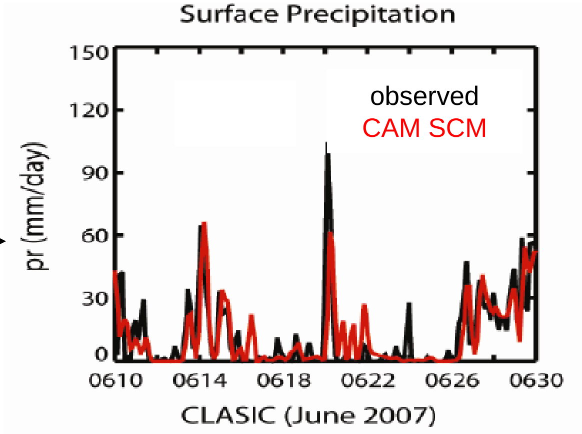


contours: 0.01, 0.05, 0.1, 0.5, 1, 2 … mm

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

Next Steps

- Utilize **Aerosol Modeling Testbed** to obtain statistics on model performance, rather than just qualitative comparisons so far
  - Profiles of wind, temperature, moisture, and cloud properties using ARM SGP data, spatial distribution of clouds from satellite data
  - Longer simulation period (entire month) to fairly evaluate CAM's convective cloud parameterizations in relation to those from WRF
- WRF **Single Column Model**
  - When testing convective and microphysics parameterizations
  - Use forcing data derived from Shaocheng Xie (LLNL) →
  - Compare observed, simulated, CAM single column model precipitation



- **Porting** boundary layer, aerosol, and microphysics parameterizations

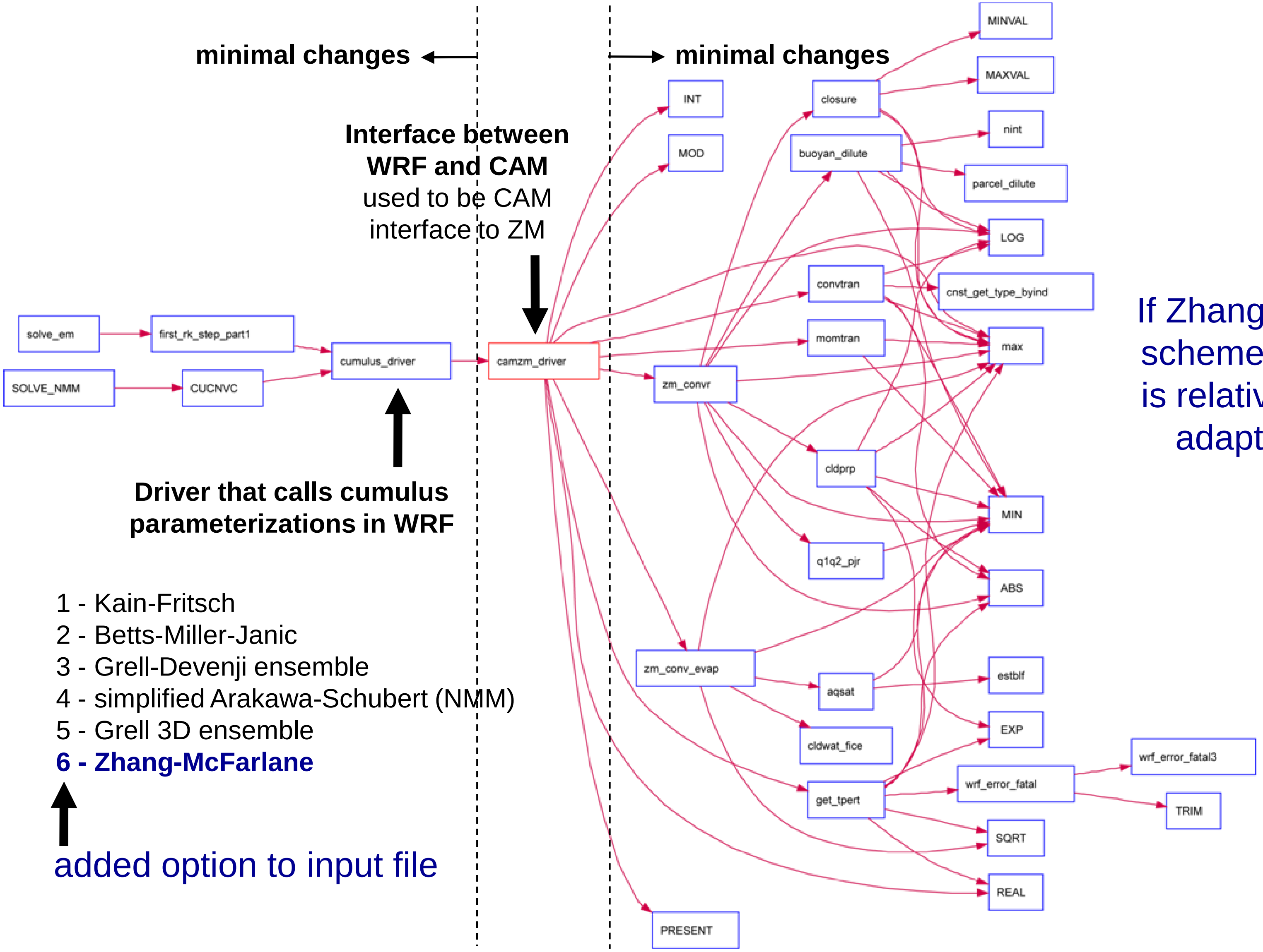
The Completed Product

- The ability to run CAM physics package in WRF at higher spatial resolution 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

Acknowledgements: Funding provided by the Aerosol Climate Initiative LDRD program of the Pacific Northwest National Laboratory

Convective Parameterization

Flow Chart for Zhang-McFarlane Scheme implemented in WRF



minimal changes ← | → **minimal changes**

Interface between WRF and CAM
used to be CAM interface to ZM

Driver that calls cumulus parameterizations 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 option to input file

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