Construction of WRF/CAM two-way coupling system and preliminary results

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Introduction-Objectives

- Created a WRF/CAM two-way inline coupling system within CCSM4 framework .
- The CAM along with other CCSM4's components drives WRF.
- The WRF feeds back by exporting state variables, heat and moisture fluxes at fine scale to the CAM.
- The essential WRF Processing System (WPS) and REAL program are integrated in WRF components
- New conservative and noise data resistant method is employed to improve the remapping precision.
- WRF has ability to perform nesting domain and separated multiple geophysical domain simulations.

Model Design
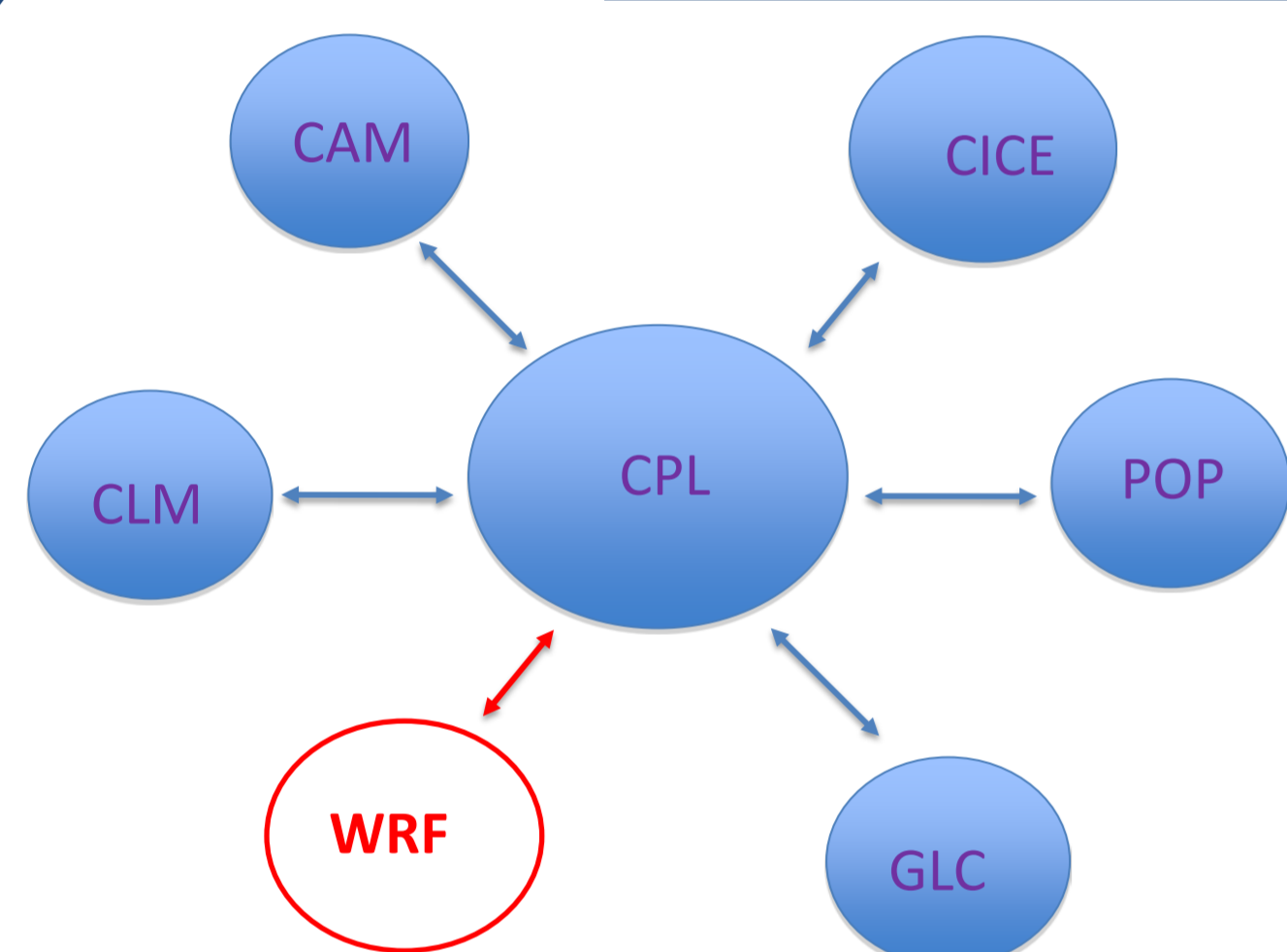
- WRF, based on ARW v3.2, becomes a component of CCSM4.
- WRF can have a two-way interaction in line with CAM/CLM/POP/CICE
- WRF can initialize and reinitialize inline in the WRF/CAM coupling system
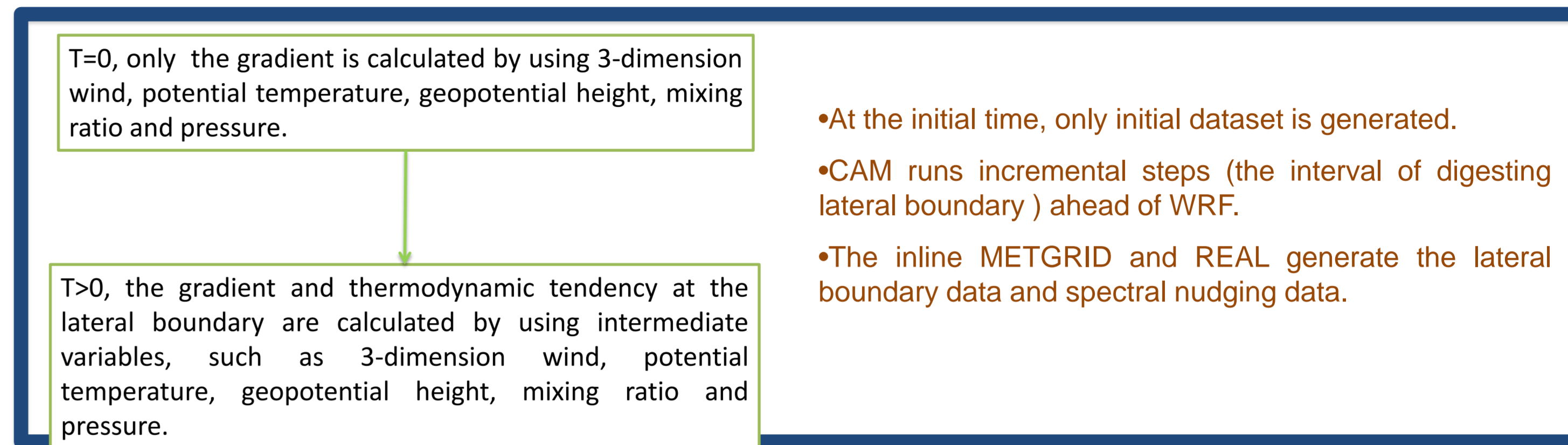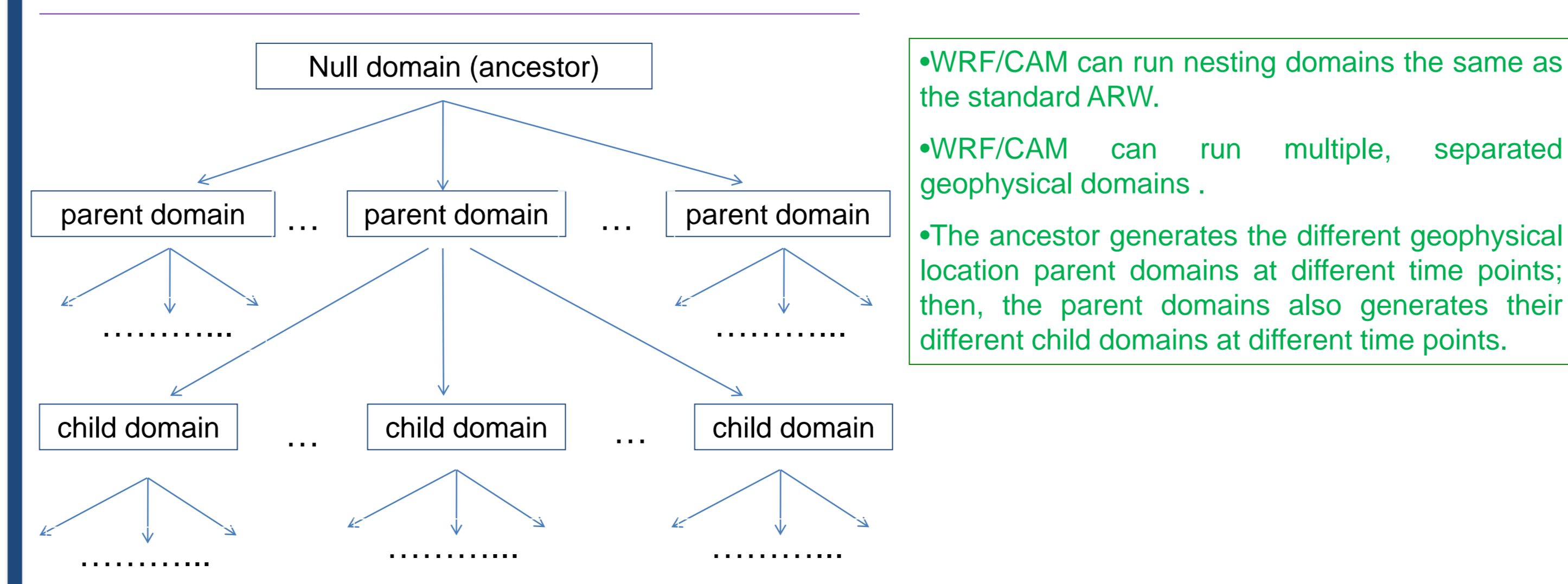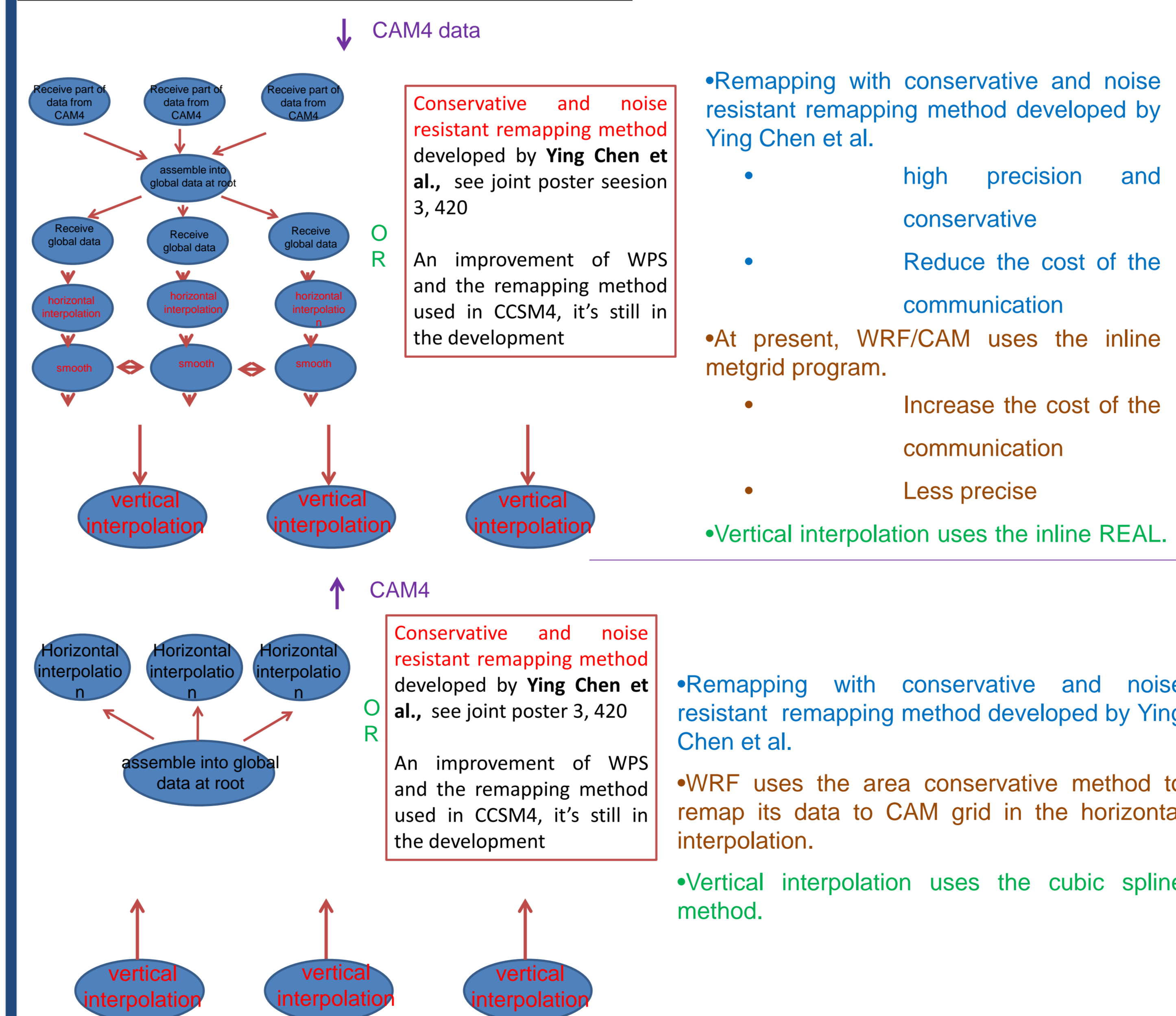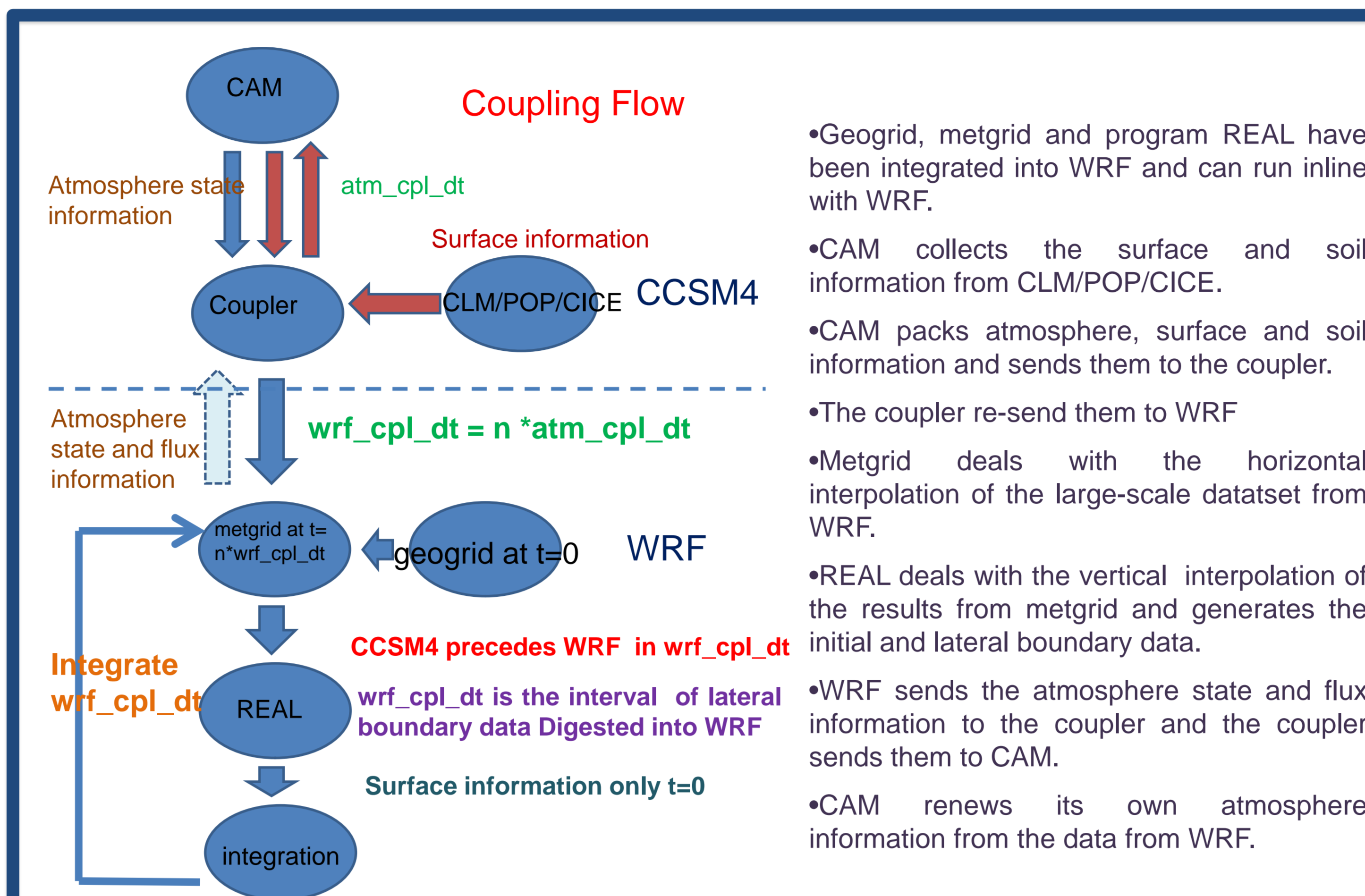- WRF can have a separated multiple domain simulation in the WRF/CAM coupling system

- WRF keeps its own parallel mechanism
- WRF has its communication subgroup in CCSM4.
- WRF associated with CPL has a shared communication subgroup in CCSM4.
- WRF can use all processors or part of processors to make a parallel run according to the parallel strategy of CCSM4.

Re-design of WRF infrastructure and modification to CCSM4

- The new module wrf_comp_mct reshapes the WRF top layer and controls the integration flow of WRF and the communication between WRF and other components.
- The geogrid, metgrid and REAL is integrated into WRF and can run inline with the main WRF program.
- Conservative and noise resistant remapping method is being added into WRF.
- CAM is modified to import and export data from WRF, and to relax/nudge the data from WRF.
- The coupler is modified to import and export the 3-dimensional data exchange between WRF and CCSM4.
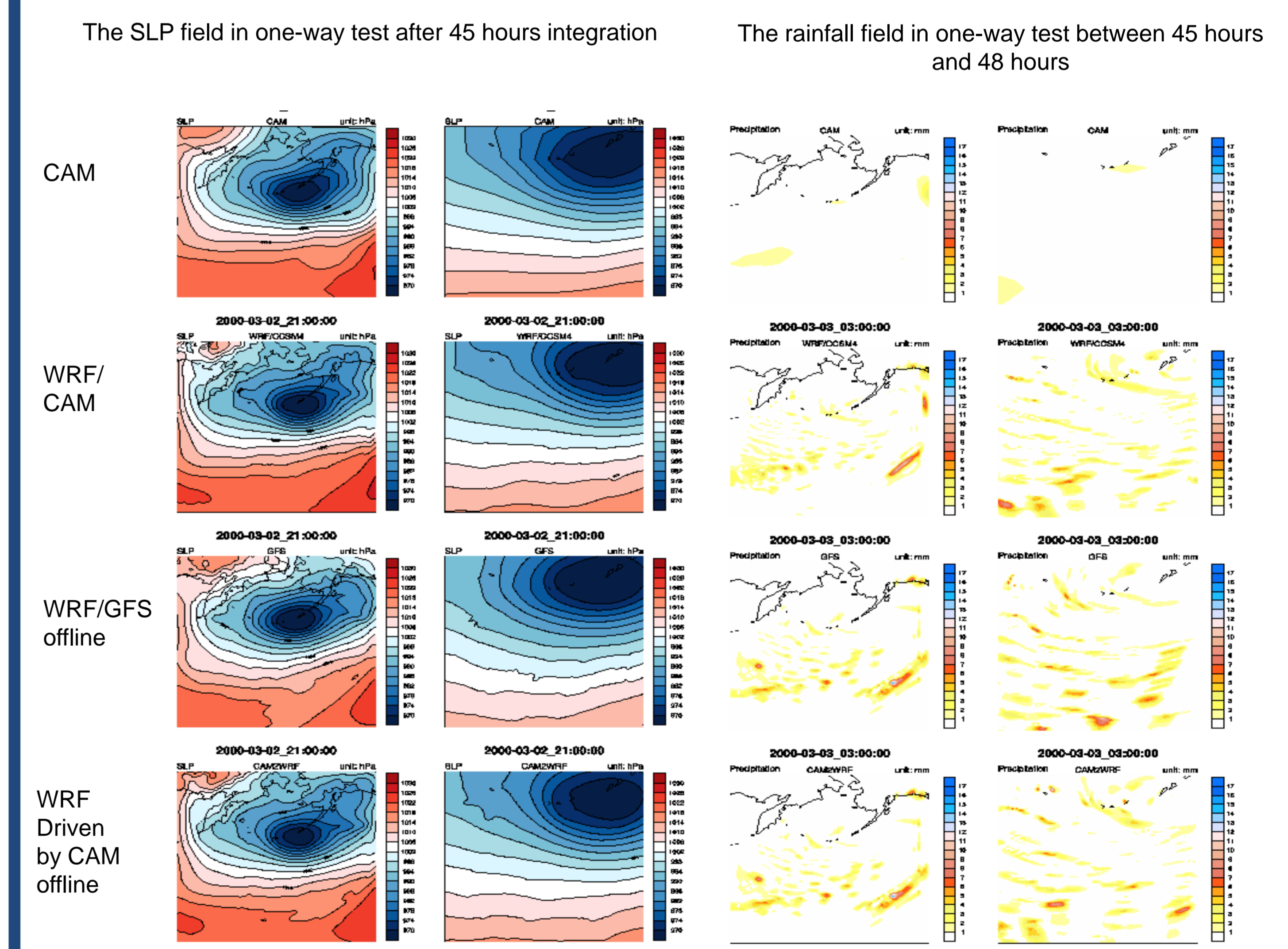- The driver routine of CCSM4 is modified to couple WRF with other components.

Data exchange between WRF and CCSM4

- Realize the 3-dimension transfer and remapping in the coupler
- State variables from WRF can be relaxed/nudged into CAM and flux variables from WRF can be injected be into CAM.
- Input variables of WRF include the surface pressure, 3-dimensional wind, temperature, specific humidity, pressure, geopotential height; SST, TSK, sea ice, snow, soil temperature, soil moisture, soil layer, latitude and longitude of CAM.
- Export variables of WRF include surface pressure, 3-dimensional wind, temperature, specific humidity; 3-dimensional thermodynamic tendency from radiation, PBL, land surface and microphysics, moisture flux trend from PBL and land surface, momentum flux trend from PBL.

Coupling Flow

Atmosphere state information — atm_cpl_dt

Surface information

CLM/POP/CICE — CCSM4

Atmosphere state and flux information

wrf_cpl_dt = n *atm_cpl_dt

geogrid at t=0 — WRF

CCSM4 precedes WRF in wrf_cpl_dt

wrf_cpl_dt is the interval of lateral boundary data Digested into WRF

Surface information only t=0

- Geogrid, metgrid and program REAL have been integrated into WRF and can run inline with WRF.
- CAM collects the surface and soil information from CLM/POP/CICE.
- CAM packs atmosphere, surface and soil information and sends them to the coupler.
- The coupler re-send them to WRF
- Metgrid deals with the horizontal interpolation of the large-scale datatset from WRF.
- REAL deals with the vertical interpolation of the results from metgrid and generates the initial and lateral boundary data.
- WRF sends the atmosphere state and flux information to the coupler and the coupler sends them to CAM.
- CAM renews its own atmosphere information from the data from WRF.

CAM4 data

Conservative and noise resistant remapping method developed by Ying Chen et al., see joint poster seesion 3, 420

An improvement of WPS and the remapping method used in CCSM4, it's still in the development

- Remapping with conservative and noise resistant remapping method developed by Ying Chen et al.
  - high precision and conservative
  - Reduce the cost of the communication
- At present, WRF/CAM uses the inline metgrid program.
  - Increase the cost of the communication
  - Less precise
- Vertical interpolation uses the inline REAL.

Conservative and noise resistant remapping method developed by Ying Chen et al., see joint poster 3, 420

An improvement of WPS and the remapping method used in CCSM4, it's still in the development

- Remapping with conservative and noise resistant remapping method developed by Ying Chen et al.
- WRF uses the area conservative method to remap its data to CAM grid in the horizontal interpolation.
- Vertical interpolation uses the cubic spline method.

- WRF/CAM can run nesting domains the same as the standard ARW.
- WRF/CAM can run multiple, separated geophysical domains .
- The ancestor generates the different geophysical location parent domains at different time points; then, the parent domains also generates their different child domains at different time points.

- T=0, only the gradient is calculated by using 3-dimension wind, potential temperature, geopotential height, mixing ratio and pressure.
- T>0, the gradient and thermodynamic tendency at the lateral boundary are calculated by using intermediate variables, such as 3-dimension wind, potential temperature, geopotential height, mixing ratio and pressure.

- At the initial time, only initial dataset is generated.
- CAM runs incremental steps (the interval of digesting lateral boundary) ahead of WRF.
- The inline METGRID and REAL generate the lateral boundary data and spectral nudging data.

Preliminary results and summary

- Begin at March 1, 2000, integrate 5 days
- The configuration of CAM/CLM4/CICE/DOCN is F_2000 case. The Qian atmosphere input dataset for 2000 is used to spin up CLM4 for 100 years in T42 resolution.
- CAM drives inline WRF based on WRF/CAM coupling system for a one-way test and WRF feeds back to CAM for two-way test.
- WRF offline simulation is performed by using the offline CAM and CLM dataset and 1x1 GFS analysis dataset.
- All WRF simulations have two domains with the size of 80x80x41, 102x102x41, with the same center located at (47N,-177E), and the ratio of grid distance and time step between the two domains is 3:1. The outside domain is with 60 kilometer resolution and 180 seconds time step. WRF physical parameterizations use CAM long wave and short wave radiation scheme, Monin-Obkuhov scheme, YSU PBL scheme, Kain-Fristch scheme, and WSM 3-class scheme. The inner domain turns off the cumulus scheme.
- Summary: Preliminary tests verify the inline one-way simulation and the feasibility of two-way coupling

The SLP field in one-way test after 45 hours integration | The rainfall field in one-way test between 45 hours and 48 hours

CAM

WRF/CAM

WRF/GFS offline

WRF Driven by CAM offline

- The SLP and rainfall field are similar to each other.
- There are still differences between WRF/CAM simulation and WRF offline simulation driven by CAM due to the different vertical interpolation methods to remap the CAM dataset onto the vertical level of WRF.
- The preliminary tests validate the feasibility and stability of WRF/CAM coupling system, but further refinement and development are needed to complete the coupled system.

Reference
Ying Chen, X. Jiao, W. Lin, M. H. Zhang, and J. He, 2011: Conservative and Noise Resistant Data Remapping for Coupling WRF and CAM. 91st American Meteorological Society Annual Meeting, Joint Poster Seesion 3, 420.