CAM5 – Opening Remarks

- Phil
- CAM5 Model Development Team.

Prior Model Development Teams…

"We are like dwarfs standing [or sitting] upon the shoulders of giants, and so able to see more and see farther than the ancients." *Bernard of Chartres, ca1130*

"If I have not seen as far as others, it is because giants were standing on my shoulders". *Hal Abelson, recently*

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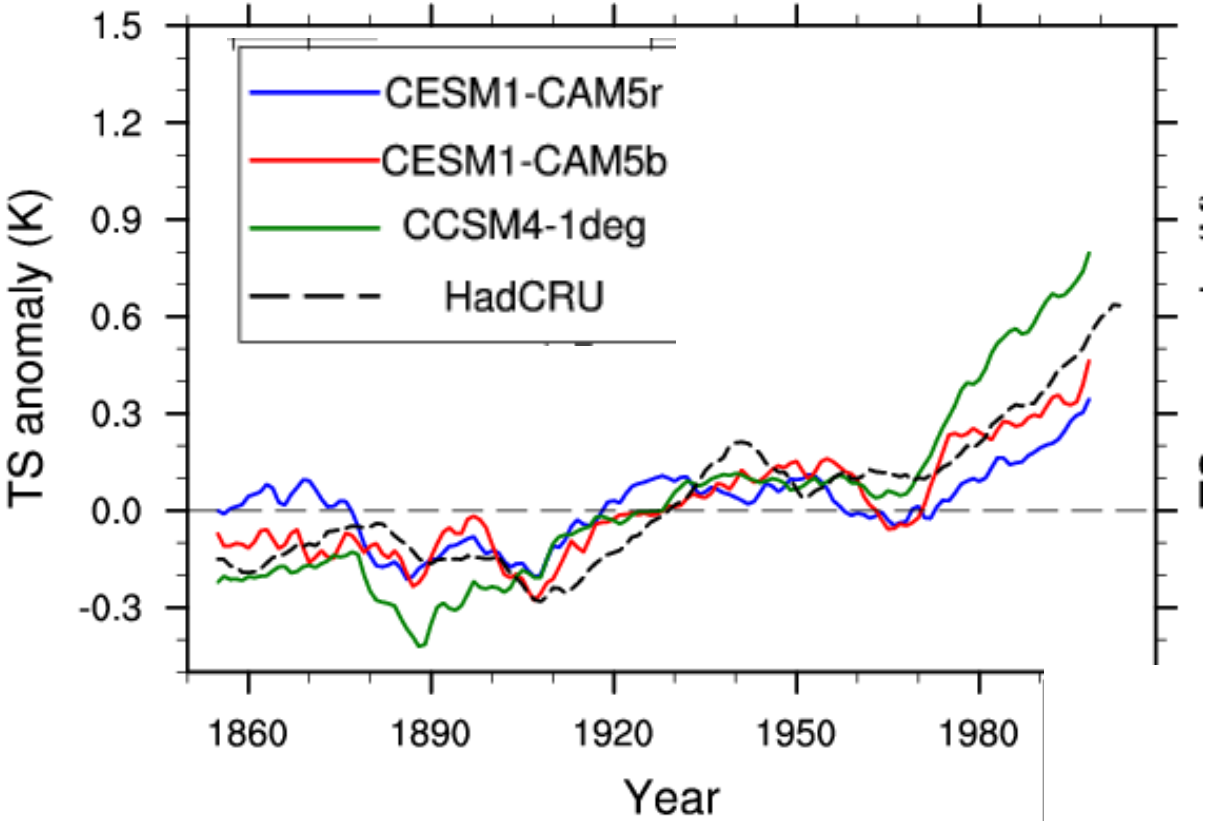
20th Century Surface temperature



CAM - the Atmospheric Component of CCSM/CESM

Model	CCSM3 (2004)	CCSM3.5 (2007)	CCSM4 (Apr 2010)	CESM1 (Jun 2010)
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4 (L26)	CAM5 (L30)
Boundary Layer Turbulence	Holtslag-Boville (93) Dry Turbulence	Holtslag-Boville	Holtslag-Boville	Bretherton-Park (09) Moist Turbulence
Shallow Convection	Hack (94)	Hack	Hack	Park-Bretherton (09) Shallow Convection
Deep Convection	Zhang-McFarlane (95)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)
Cloud Macrophysics	Zhang et al. (03)	Zhang et al. with Park & Vavrus' mods.	Zhang et al. with Park & Vavrus' mods.	Park-Bretherton-Rasch (10) Cloud Macrophysics
Stratiform Microphysics	Rasch-Kristjansson (98) *Single Moment*	RK *Single Moment*	RK *Single Moment*	Morrison and Gettelman (08) *Double Moment*
Radiation / Optics	CAMRT (01)	CAMRT	CAMRT	RRTMG Iacono et al.(08) / Mitchell (08)
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Liu & Ghan (2009)
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume	Finite Volume
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2 - *BGC*	POP2.2
Land	CLM3	CLM3.5	CLM4 - *CN*	CLM4
Sea Ice	CSIM4	CSIM4	CICE	CICE

How is CAM5 different from CAM4? (part 1)

- Every parameterization that was replaced contains demonstrable improvements in physical formulation
  - Sometimes removing errors increased climate biases
  - Prognostic aerosols in CAM4 would need work if they were to be used
- Most of the parameterizations had an extremely active contribution from “outside NCAR”. This represents a much more “open” process than we were able to do in earlier CAM.
  - Those parameterizations developed outside NCAR could not have been integrated correctly without NCAR expertise. *NCAR was the lynchpin*
  - Most of the parameterizations were developed with DOE support

How is CAM5 different from CAM4? (part 2)

- There is a coherence and level of integration between parameterizations that has never existed in the model before, e.g.
  - The same cloud particle size, number, and particle distribution is felt by radiation, cloud microphysics, sedimentation, etc.
  - Explicit assumptions about cloud fractions (ice, liquid, and overlap, stratiform vs convective), explicit assumptions about “precipitation fractions” are done consistently across macrophysics, aerosol scavenging, evaporation, etc.
  - Aerosol/cloud/radiation interactions are now treated explicitly, and consistently

What are the new capabilities in CAM5?

- Aerosols treated as internal mixtures, mass and number are explicit, more processes are represented explicitly.
- Cloud microphysics is more comprehensive: Drop & Crystal # is predicted, size distributions are explicit. More processes are included in the formulation, and previous treatments are handled more accurately
- condensate is treated consistently across radiation and microphysics
- Much more flexible (& accurate) treatment of optically active trace constituents in radiation
- The aerosol indirect effect is calculated
- The improvement in consistency and connections between processes has opened up opportunities for new science. Many of these are outlined in the “strategic plan”. Talk to Rich & Andrew G about these.

The consequences of internal consistency & complexity of parameterizations in CAM5

- Pros
  - Internal physical consistency throughout the parameterizations

- Cons
  - Internal physical consistency throughout the parameterizations, For example,
    - if one changes the assumed size distribution of precipitation, it now effects radiative transfer, scavenging of aerosols and gases.
    - Changing assumptions about “autoconversion” in deep convection, has consequences in radiation, stratiform clouds, aerosol scavenging, etc
  - Many more “tunable parameters”
  - Many more dependencies on poorly measured atmospheric quantities (e.g. “the size of primary particles emitted from fossil fuel sources)
  - Cost

Performance on a fast 16 node Linux Cluster

120 CPUS, PGI compiler, CESM1_0_beta03
32 day simulation, with SOM writing restart files
CAM4 26 layers *PRESCRIBED AEROSOLS*
CAM5 30 layers *PROGNOSTIC AEROSOLS*

Component	CAM4	CAM5	Comment
Total Atmos	150s (22 SYPD)	700s (8.4SYPD)	
Dynamics+Adv	61	115	
Diff/Chem/DryDep	5 (5/0/0)	120 (20/60/40)	
Radiation + Aer Opt	45	150	
Deep Conv	15	15	
Shallow Conv	2	55	
Macrophysics	10	85	
Microphysics	5	60	
Wet Aer Phys	1	50	
Unaccounted for	10	170	

What is not yet working in CAM5?

- CAM allows simultaneous treatment of predicted and archived trace species. These trace species could in principle be used equivalently in various model calculations. E.g.
  - One might use an archived value of aerosol properties for the radiation calculation, but the predicted aerosols for doing cloud microphysics.
  - One might use archived aerosol properties for the radiation and microphysics calculation and turn off the predictive calculation to save time.
  - One might do two radiative transfer calculations, one with aerosol combination “A”, and the other with “B” to contrast the radiative forcing
- These capabilities have not been completed for aerosols

Short term next steps in CAM

- Scientific papers and documentation
- The philosophy was always “lets get the physics working reasonably well, then we can go back and clean up the code, making it faster and better”.
  - Opportunity for the software engineers to look at these codes now
  - Higher level code and infrastructure much better than CAM3 (same as CAM4)
  - There may still be opportunities to speed up the parameterizations through both scientific insight and better coding
- There are great opportunities for CAM5 science now that we have some time, and many new eyes looking at the simulations
  - Using and understanding the Model and Atmosphere
  - Moving forward with the “Strategic Plan”
  - CSSEF “Next Generation + 1” model development activities