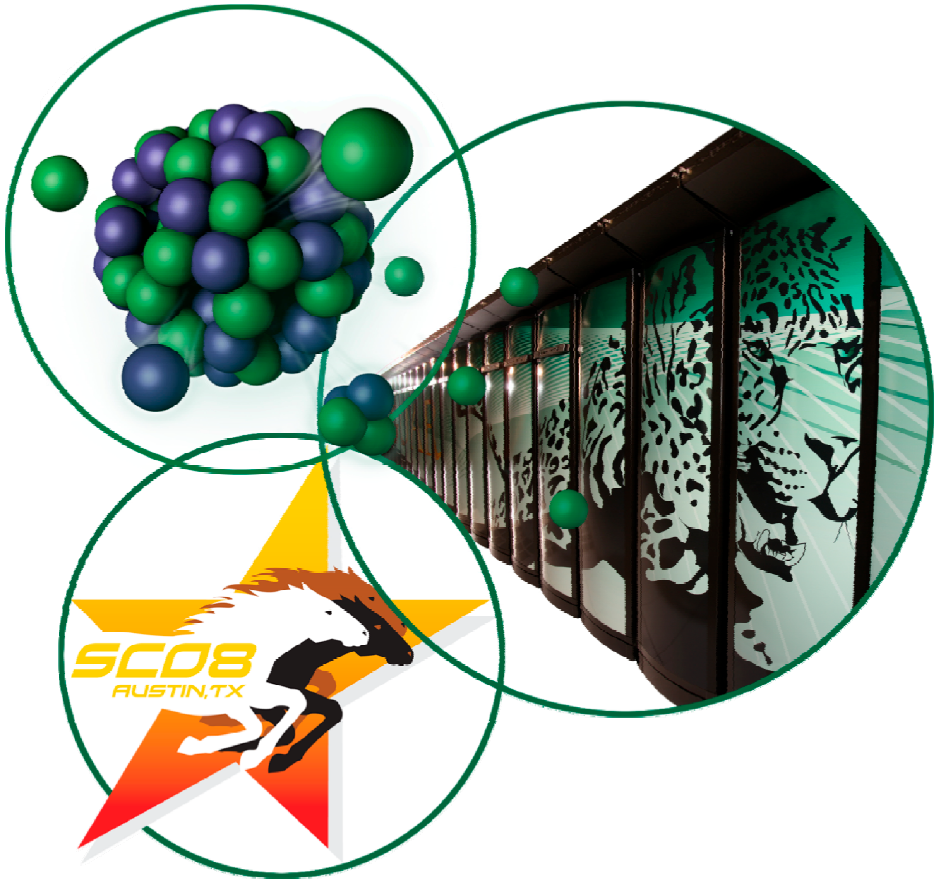
The SciDAC CCSM Consortium Project



Presented by

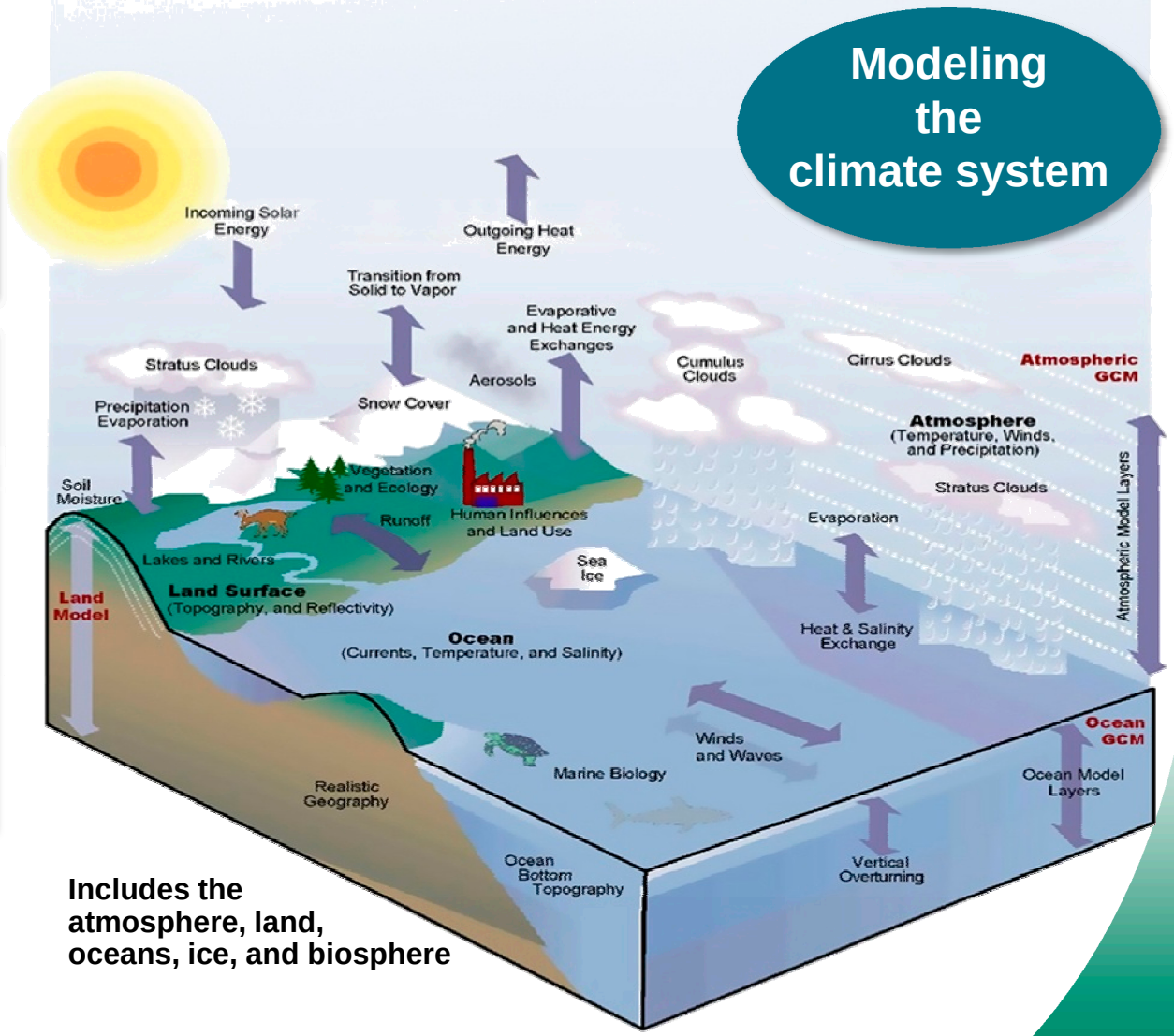
John B. Drake

Computational Earth Sciences Group
Computer Science and Mathematics Division

The Earth climate system

The Grand Challenge problem

- **To predict future climates based on scenarios of anthropogenic emissions and changes resulting from options in energy policy**

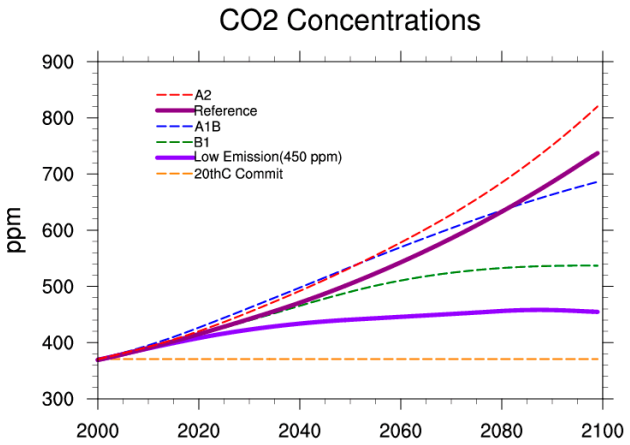


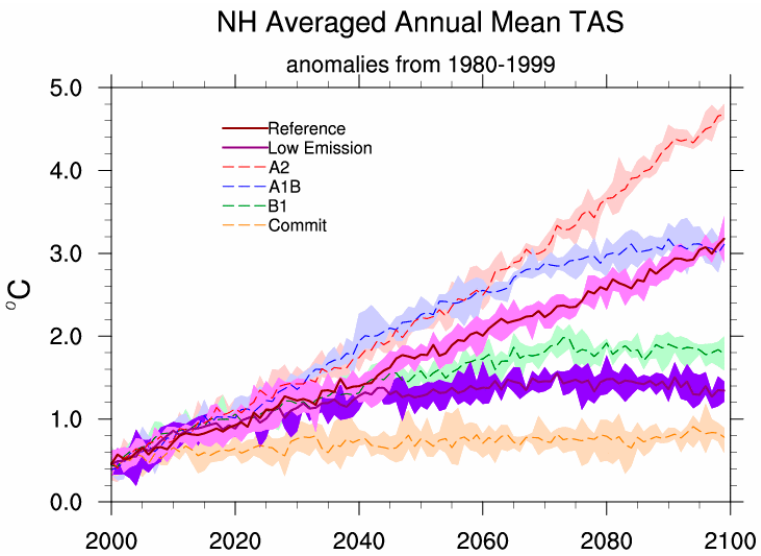
Includes the atmosphere, land, oceans, ice, and biosphere

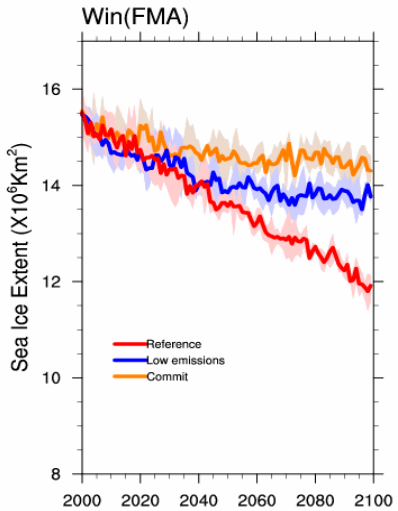
Climate change (Warren Washington)

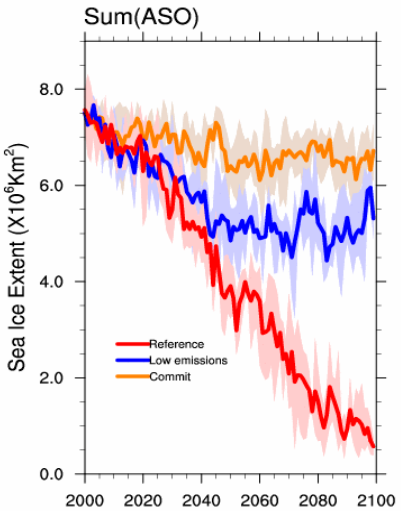
CCSM Climate Change Working Group: Critical science development and applications in support of climate-informed decision making

- DOE CCSP SAP2.1A "Low Emissions Scenarios"
- Coupled ice sheet runs
- Near-term high-resolution climate prediction
- Climate change 2100 and beyond
- Prognostic carbon aerosol experiments





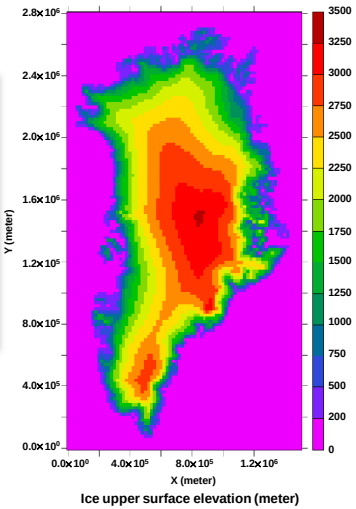




Ice sheet model (William Lipscomb)

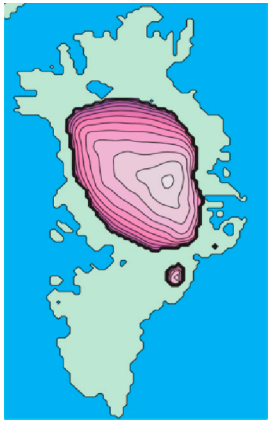
- GLIMMER has been added to CCSM, with wrapper code for exchanging fields between GLC and the coupler
- The Community Land Model (CLM) has been modified to compute the ice sheet surface mass balance in glaciated columns and pass the mass balance to GLC via the coupler
- CLM allows multiple vertical columns for each land unit in each grid cell. Work is under way to compute the mass balance for ~10 elevation classes (i.e., columns) in each glacier land unit

Greenland topography in GLIMMER

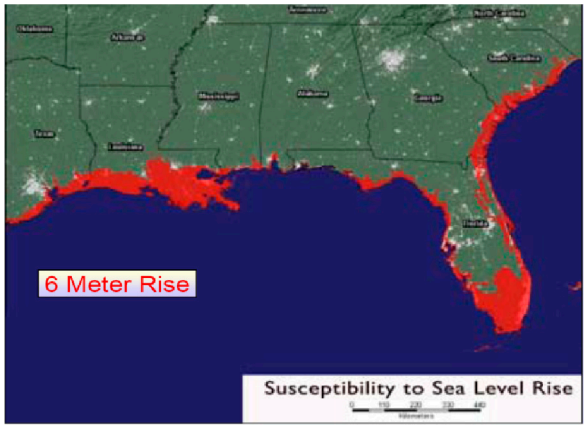


We will soon begin coupled climate experiments with a dynamic Greenland ice sheet. The model will be tuned as needed to produce a realistic control ice sheet and then applied to standard IPCC forcing scenarios. The model also will be used for paleoclimate studies of the Eemian interglacial (~125 ka), when the GIS was smaller and sea level was several meters higher. We will do climate change experiments with the Antarctic and Laurentide ice sheets when a more realistic ice sheet model is available

- The rate of 21st century ice sheet melting and sea level rise is extremely uncertain and is now recognized as a high priority for climate models
- We have coupled the GLIMMER model to CCSM and will soon begin climate experiments with a dynamic Greenland ice sheet
- We will devote substantial resources (2–3 FTEs) to improving the ice sheet model during the next several years
- We aim to make a useful contribution to IPCC AR5 (~2013), but time is limited Models must be frozen by 2009 or 2010



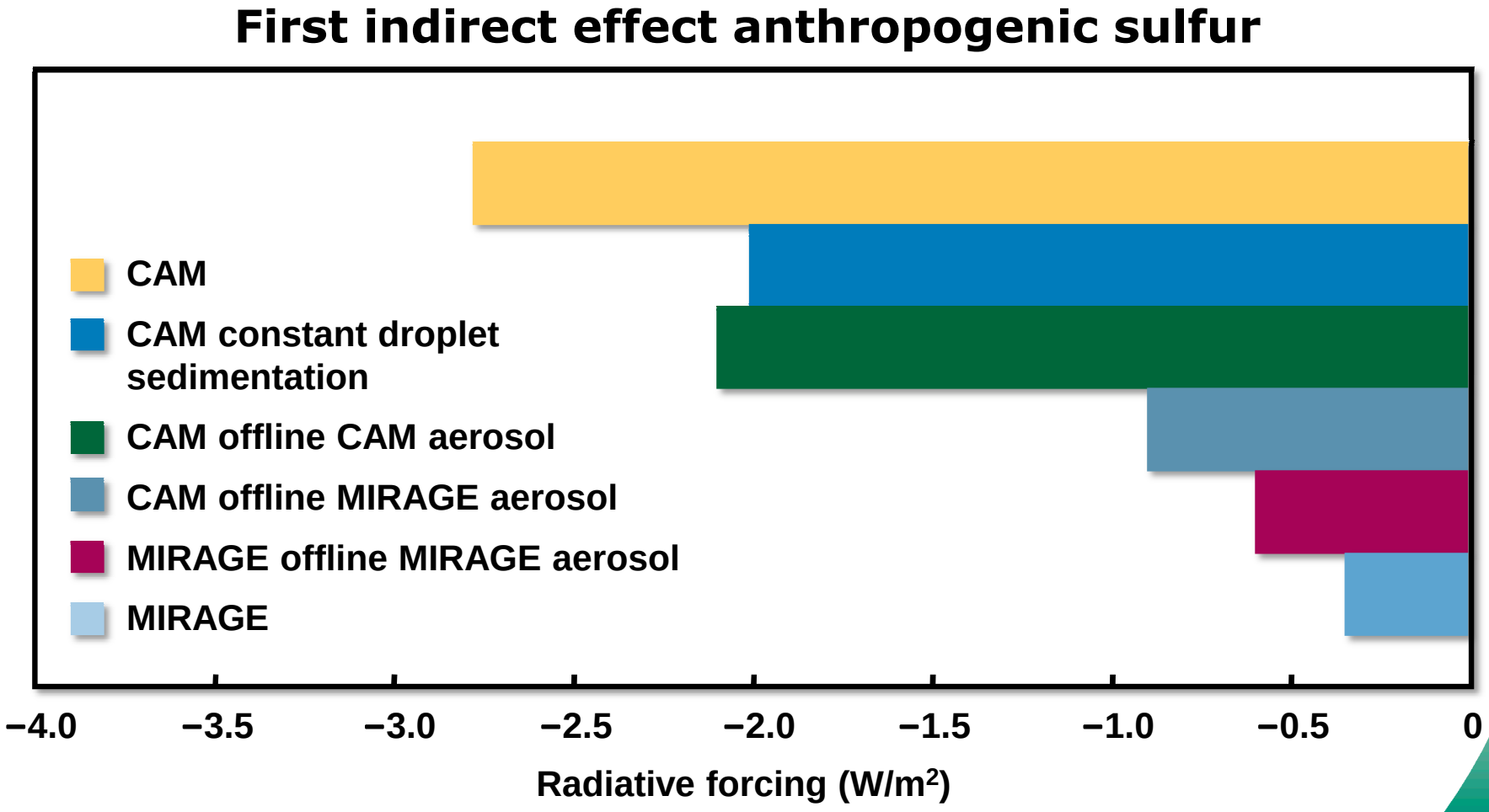
Reconstructed GIS from the last interglacial (Cuffey and Marshall, 2000), when sea level was about 6 m higher than today



Effect of a 6 m sea level rise on the southeast United States (Weiss and Overpeck, University of Arizona)

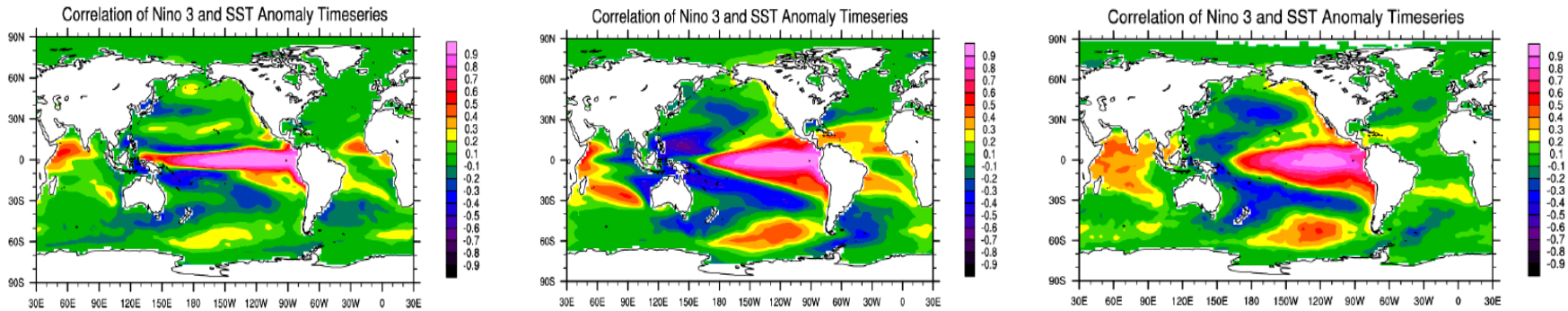
Indirect effect

Steve Ghan (PNNL)

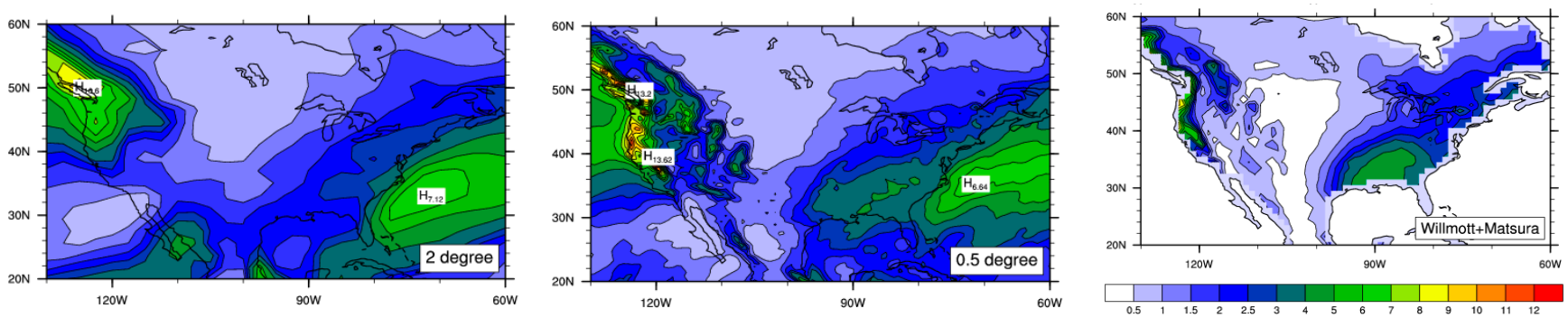


CCSM4 model development
(Peter Gent)

Development of the fourth version of the CCSM; one of the biggest improvements is the simulation of ENSO



Use of the CCSM to produce short-term climate forecasts to 2030; higher atmosphere resolution (0.5º) produces better rainfall in southeastern United States

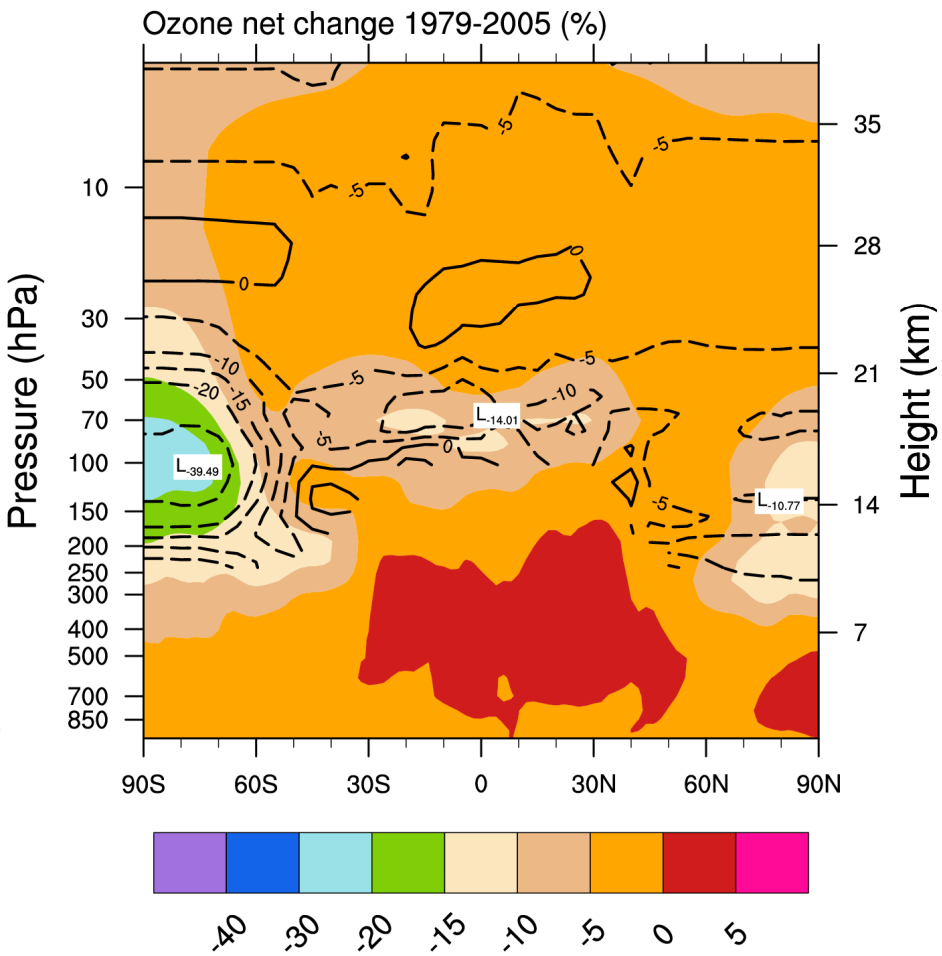


Note improved southeastern United States rainfall

CAM3: Tropospheric and stratospheric chemistry

J. F. Lamarque (NCAR)

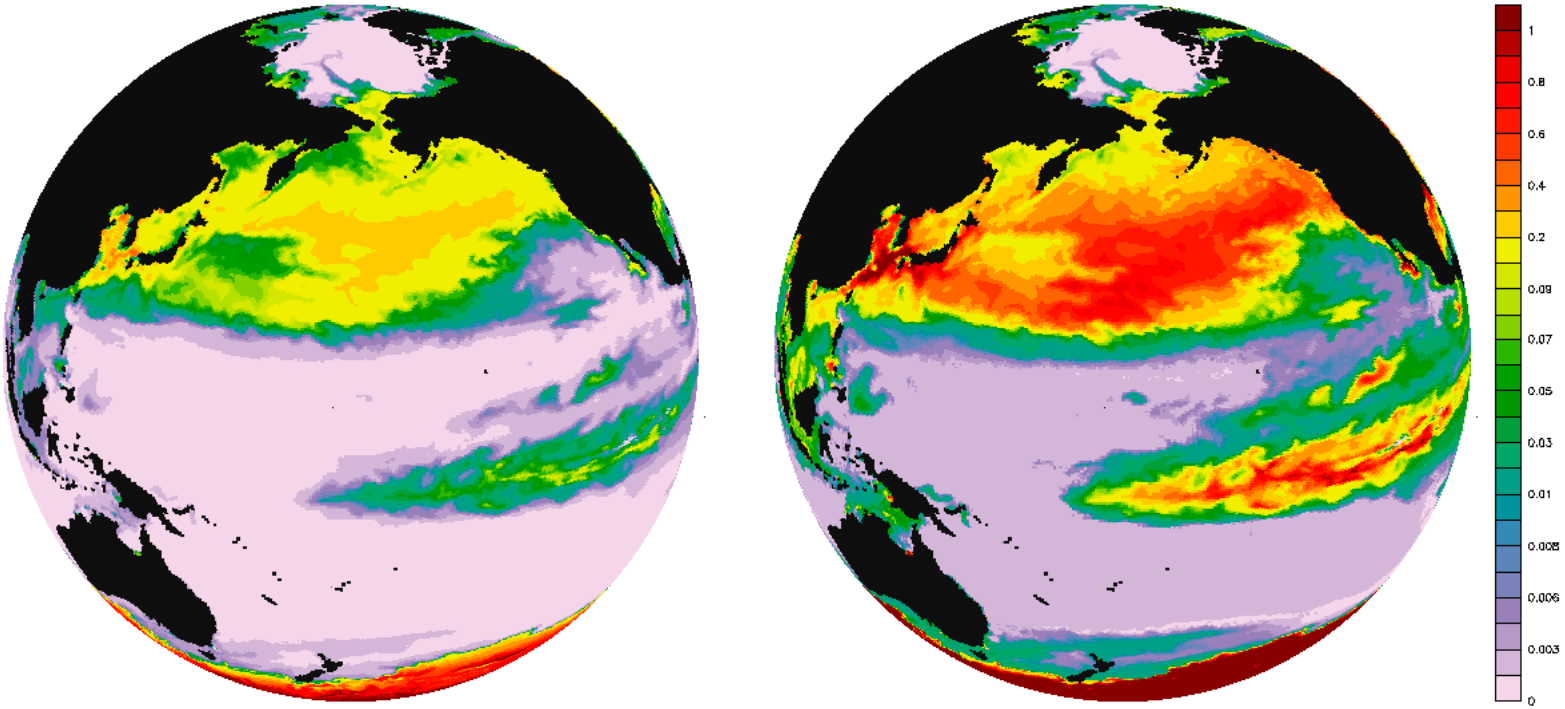
- **Vertical distribution of the zonal–mean ozone change (1979–2005)**
- **Color contours are for the model results (average of 2 simulations) and line contours are from TOMS/SBUV**



Jean-François Lamarque, D. E. Kinnison, P. G. Hess, and F. M. Vitt, "Simulated lower stratospheric trends between 1970 and 2005: Identifying the role of climate and composition changes," *JGR*, **113**, (2008)

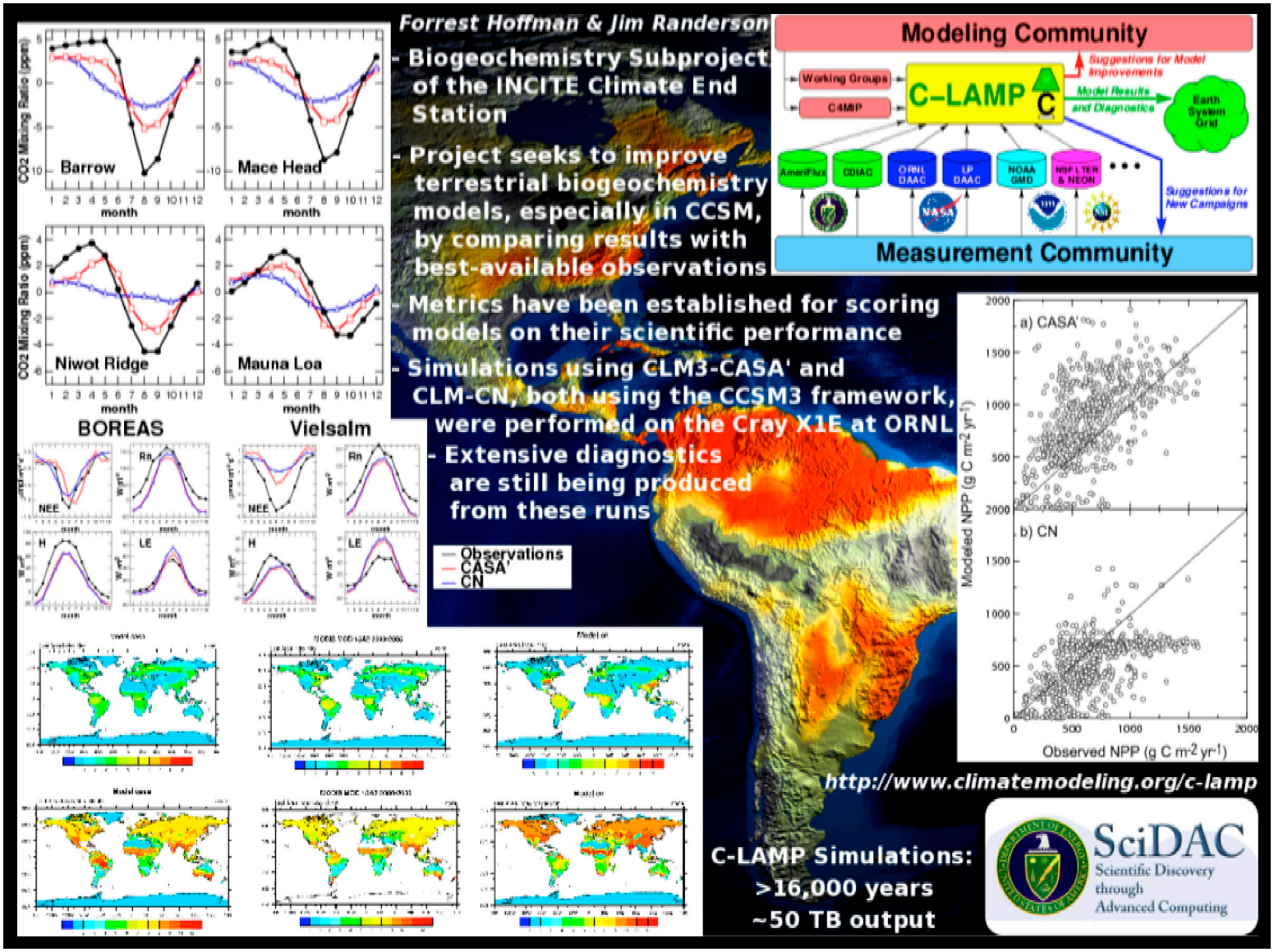
Toward an Earth System Model: Ocean biogeochemistry feeding atmospheric chemistry

P. Cameron-Smith, C. Chuang, D. Bergmann (LLNL), S. Elliott (LANL)



The figure shows ammonia (NH_3) in the marine boundary layer (picomoles) on the right, and its dissolved form, ammonium (NH^+_4, in the ocean mixed-layer in micromoles on the left

Carbon-Land Model intercomparison
(Forrest Hoffman)



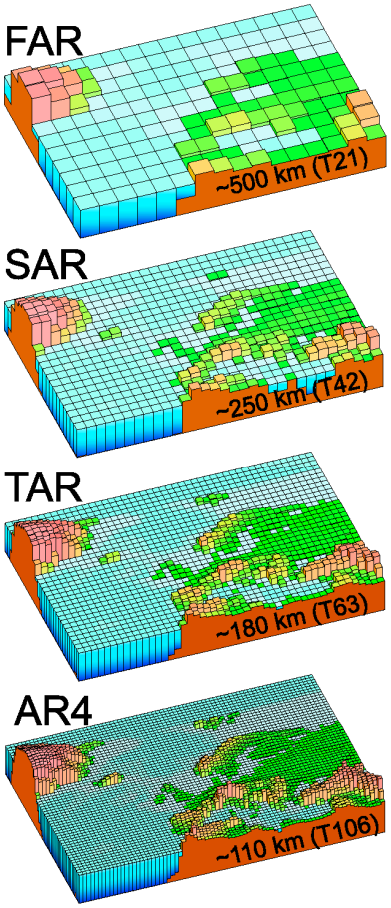
Correcting transport errors during numerical transport of correlated moment sequences

R. McGraw, BNL/SUNY-SB Science Application Partnership: "Statistical approaches to aerosol dynamics for climate simulation"

PROBLEM: Nonlinear transport algorithms, designed to reduce numerical diffusion over coarse model grids, can destroy consistency within a sequence of aerosol size/composition moments transported as independent "chemical" tracers

Until now this has been the most serious impediment to the widespread use of moment methods for aerosol simulation in climate models

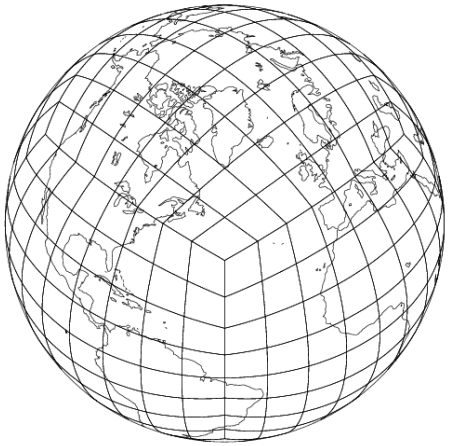
SOLUTION: We present a new approach based on non-negative least squares that finally eliminates this consistency problem—with the added bonus of providing a much more accurate scheme for source apportionment and transport of aerosol mixtures.
It should work with any transport scheme



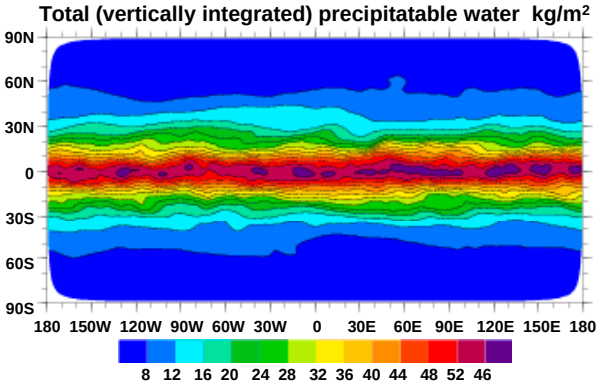
IPCC model resolutions 1990–2007

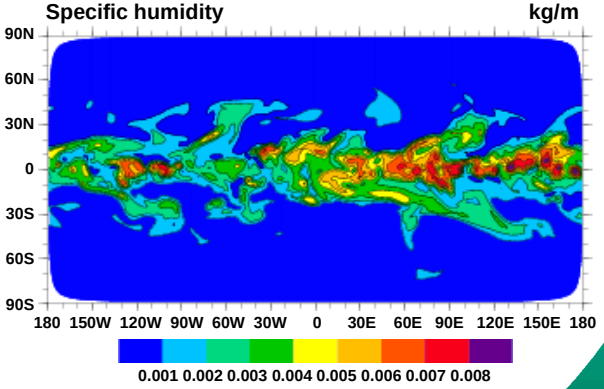
CAM scalable dycore integration and evaluation

M. Taylor (Sandia)



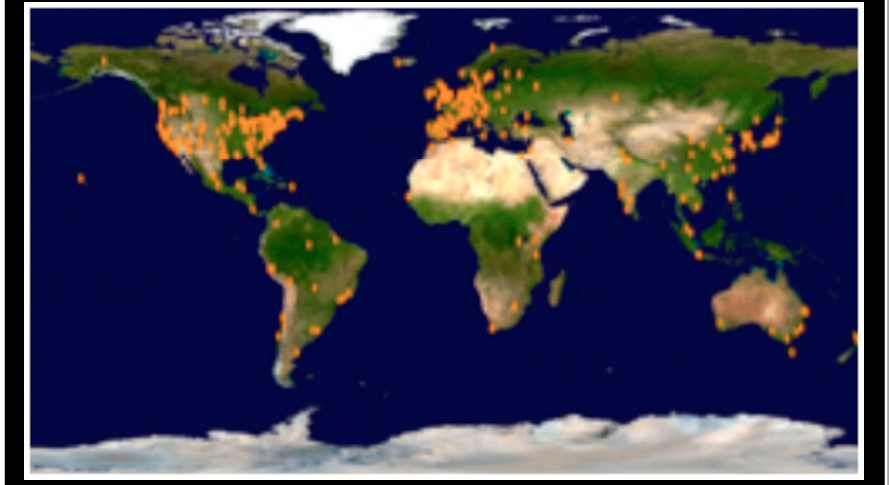
- Cubed-sphere dycores in CAM (with J. Edwards IBM/NCAR)
  - Motivation: more scalable dycores
  - Using NCAR's HOMME with Spectral Elements
  - Process split model with full dynamics subcycling
  - Next steps: evaluation of AMIP results
- New and notable
  - Developed conservative formulation of spectral elements based on compatibility. First dycore in CAM to locally conserve both mass and energy
  - Developed efficient hyper-viscosity to replace element based filtering. The filter was causing bad grid imprinting in moisture and other fields
  - Scaled to 80K processors on BG/L
  - Correctly simulated multiscale dynamic turbulence transition





Earth System Grid—International distribution of simulation results

- International central site: Earth System Grid
  - Sponsored by DOE SciDAC project. Integrates major centers for supercomputing and analysis coordinated internationally through PCMDI
  - IPCC AR4: 12 experiments, 24 models, 17 climate centers, 13 nations
  - C-LAMP experiments
- Archive status and activity
  - 6000 registered users
  - Downloaded: 250 terabytes in 2007
  - Current contents: 100,000 simulated years of data
  - Data sets: 1M files, 180 terabytes
  - New portals: ORNL, NCAR
- Access point: https://www.earthsystemgrid.org/



ESG usage worldwide

Contact

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Schedule of Key Simulations

CCWG/CCP Research 2008-2013
June 5 2008

2008
- 1000 year CCSM4
- BGC Control Run

- NCAR: Analysis of climate variability: Forced vs unforced decadal variablity, extremes, water cycle, Arctic & North Atlantic Oscillation, Large Ensembles
- NCAR: Analysis of specified hurricane simulations
- NERSC: 1000 Year CCSM4 Biogeochemistry Control Run: C & N cycles + dynamic vegetation w/ BGCWG
- NERSC: Low emissions scenarios
- NERSC: Aerosol indirect forcing
- ORNL: Climate Change 2100 & beyond
- ORNL: Prognostic carbon aerosol forcing
- ORNL: Fully coupled ice sheet runs
- ORNL: Near-term High-res climate predictions (1980-2030)
- ORNL: Special DOE US energy strategy scenarios

2009
- CCSM4 Release
- AR5 preparation

- NCAR: Analysis of climate variability: NSF Climate change detection/attribution
- NCAR: Signal-to-noise detection in forced simulations
- NCAR: Analysis of specified hurricane simulations
- NERSC: CCSM4 AR5 sensitivity/test runs: Equilibrium climate sensitivity
- ORNL: Ultrahigh-res 1870 control: 0.2'Atm x 0.1'Ocn
- ORNL: High-resolution near-term climate predictions (1980-2030)
- ORNL: Special DOE Scenarios for US energy strategies
- ANL: ESM and IAM integration testing

2010
- IPCC AR5 runs

- ALL: IPCC AR5 Simulations
- NCAR: Analysis of climate variability: Monsoons & monsoon breakdown threshold: Role of aerosols
- NCAR: Analysis of climate variability: Climate change detection and attribution including regional effects of urbanization.
- NCAR: IPCC AR5: Adaptation and Mitigation Scenarios
- NERSC: IPCC AR5: Long-term stabilization Scenarios
- NERSC: Geographic representations of probabilistic climate change
- ORNL: IPCC AR5: Short-term, high-resolution
- ORNL: Ultrahigh-res historical simulations: 0.2'Atm x 0.1'POP
- ORNL: Special DOE Scenarios for future US energy strategies
- ANL: IPCC AR5 simulations
- ANL: ESM and IAM integration testing

2011-2013
- Very high Resolution

- NCAR: Climate change with cloud-system and cloud resolving (1-10km) ESMs
- NERSC: Very High-resolution Decadal Prediction of climate
- ORNL: Very High-resolution stabilization experiments, near-term and century time-scales
- ANL: ESM simulations