The Community Earth System Model
State of the CESM

June, 2012

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Outline

- Project Updates
- Science Highlights
  - Projected climate from different CESM configurations
- New Developments and Directions

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Project Updates

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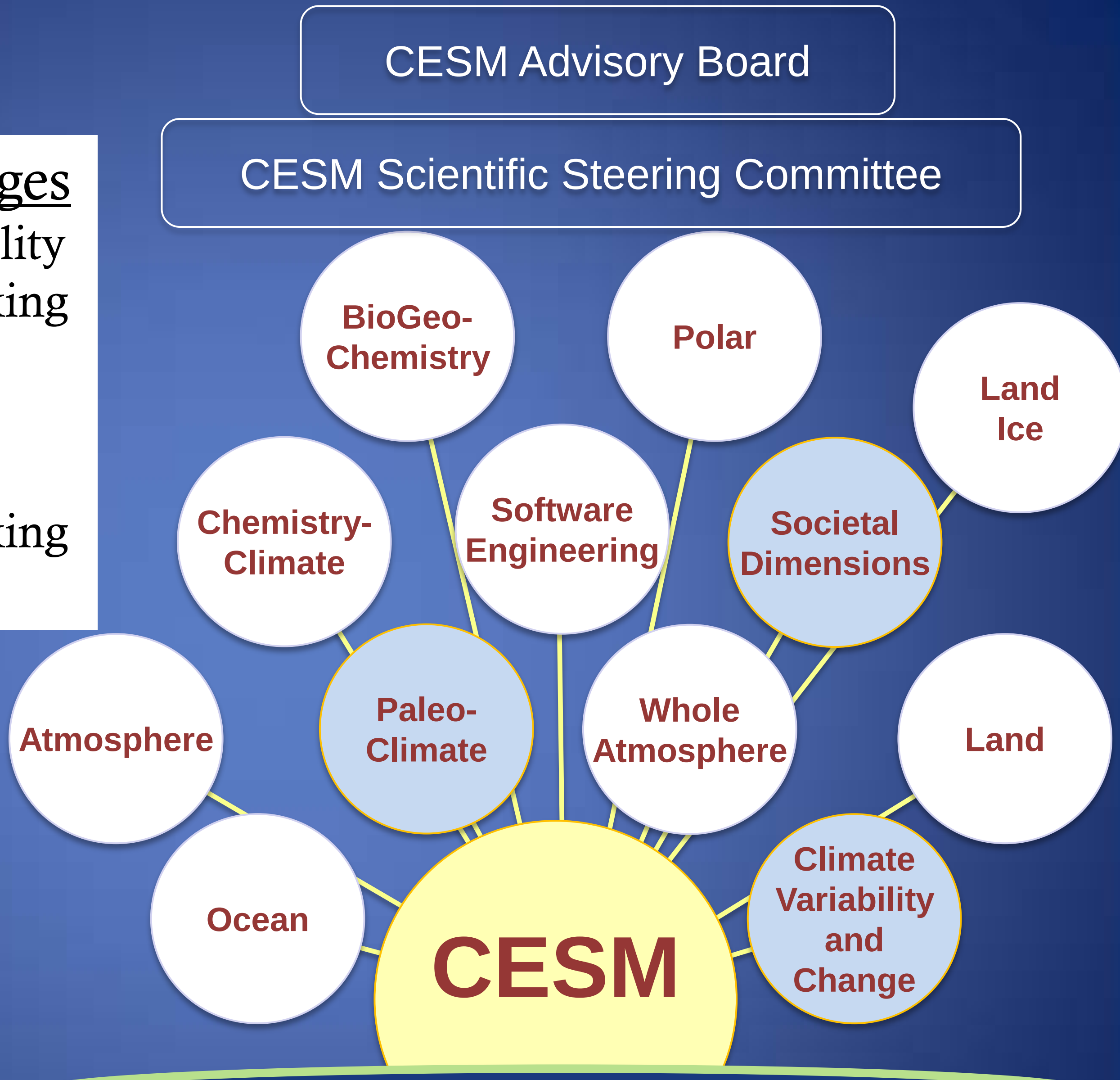
CESM Management

Working Group Changes

Merger of Climate Variability and Climate Change Working Groups

Formation of Societal Dimensions Working Group



http://www.cesm.ucar.edu/management

CESM is primarily sponsored by the National Science Foundation and the Department of Energy

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Working Group Changes

Societal Dimensions Working Group

Co-chairs: Lawrence Buja (NCAR), Bill Collins (LBNL), Bill Gutowski (Iowa State), Brian O'Neill (NCAR)

CESM

- How to interface water/ESMs
  - Scale issues, precip biases, etc.
- Pilot project on national-level water management

- How to interface IAMs/ESMs
- Initial pilot project on Land Use linkages

WATER

IA

Held 1st working group meeting 27 Feb-2 March jointly with SD, Land, Chemistry and BGC

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CESM Tutorial

Providing lectures describing component models and applications and practical sessions that give hands-on experience in running and modifying the model

- 2nd Annual Tutorial was held 1-5 August, 2011
- 3rd Annual Tutorial planned for 30 July – 3 Aug, 2012
- About 80 Participants
- Tutorial materials on-line, including practical session walk-throughs

Thanks to NSF and DOE for co-sponsoring student participation!

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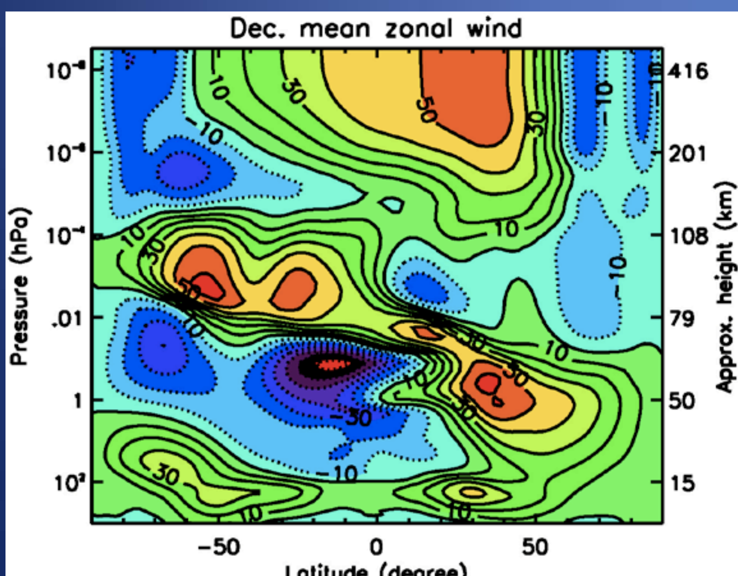
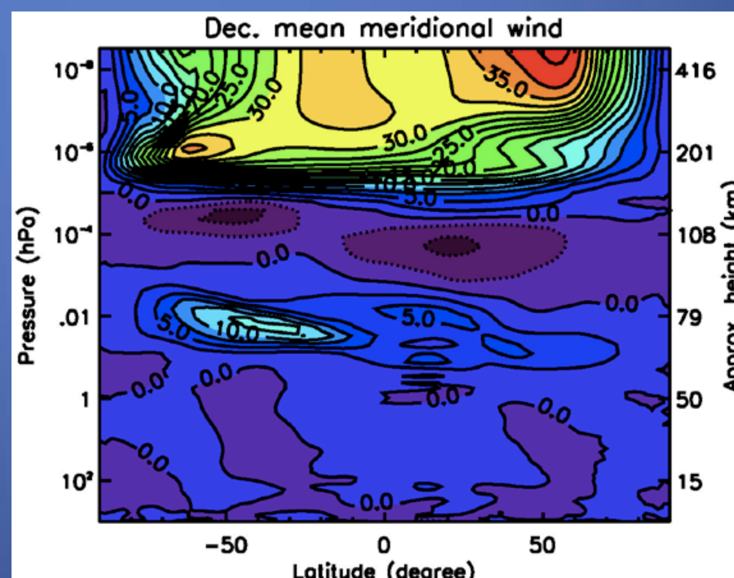
Model Release

CESM 1.0.4

- Released February, 2012
- Capability for Interannual Forcing for data atmosphere model
- WACCMX capability (vertical extension of WACCM through thermosphere/ionosphere ~500km)





Figures courtesy of Han-Li Liu

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Improved Diagnostic Tools

New parallel versions of AMWG and OMWG diagnostics

- Using task-parallelism to speed up execution of scripts.
- 2 – 3 times faster depending on available resources. Same output.
- AMWG parallel version included in version 5.3 (Jan, 2012).
- OMWG parallel version just released.
  - Also includes conversion to all-NCL graphics and analysis!
- Tutorial on new parallel scripts: 6pm Tuesday.
- All work done under the ParVis project sponsored by DOE.

parVis

Slide courtesy of Rob Jacob

U.S. DEPARTMENT OF ENERGY | Office of Science

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CESM CMIP5 Output

CCSM4 History Files available through ESG since May, 2011
Currently ~550 TB available

CESM CMIP5 ESG Publishing Status:

- CCSM4_LT Simulations ~65%
- CCSM4_DP (Decadal Prediction) Simulations ~65%
- CESM1-FASTCHEM Simulations 100%
- CESM1-BGC Simulations ~35%
- CESM1-CAM5 Simulations ~80%
- CESM1-WACCM Simulations 100%

Largest outstanding datasets – CFMIP output, Ocean BGC output

Many new fields have become available in last month – Thanks to CISL for their contributions
Target of mid-July for publishing remaining data

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Science Highlights

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CCSM4/CESM J. Climate Special Collections

- 33 Papers available via AMS early-online release
- Additional papers in various stages of review and preparation
- Document major model components and numerous aspects of simulated variability and change

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All Publications > CCSM4/CESM1 | Advanced Search

CCSM4 Special Collection

Theme Description:

This collection consists of papers analyzing results from the recently completed and released Community Climate System Model, version 4; see http://www.cesm.ucar.edu/models/ccsm4.0/. The coupled simulations range from runs of past paleoclimates, a long preindustrial control forced by 1850 conditions, an ensemble of 20th century runs, and four ensembles of the future climate using different Representative Concentration Pathways.

CESM1 Special Collection

Theme Description:

The second part of this collection has papers analyzing results from the recently completed and released Community Earth System Model, version 1; see http://www.cesm.ucar.edu/models/cesm1.0/. The new components that are available which turn it into an Earth System Model are: carbon cycle modules in the land, ocean, and atmosphere components; an interactive chemistry component in the atmosphere; a version of the atmosphere that reaches into the upper stratosphere, called WACCM; and a completely new land ice component. In addition, an updated version of the atmosphere component, CAM5, is available, which uses several new parameterizations, and can simulate the indirect effects of aerosols.

The CCSM4/CESM1 Special Collection organizers are:

Peter Gent, Past Chairman of the CCSM Project SSC (gent@ucar.edu)
Jim Hurrell, Chairman of the CCSM Project SSC (jhurrell@ucar.edu)

Abstracts for all AMS articles are available to everyone, as is the full text of Bulletin articles. Access to full-text HTML and PDF articles in the technical journals is limited to paid subscribers.

denotes open access content.

Semyon A. Grodsky, James A. Carton, Sumant Nigam, Yuko M. Okumura, **Tropical Atlantic Biases in CCSM4.** *Journal of Climate*, early online release.
Abstract . PDF (1250 KB)

Gerald A. Meehl, Warren M. Washington, Julie M. Arblaster, Aixue Hu, Haiyan Teng, Claudia Tebaldi, Ben Sanderson, Jean-Francois Lamarque, Andrew Conley, Warren G. Strand, James B. White III. **Climate system response to external forcings and climate change projections in CCSM4.** *Journal of Climate*, early online release.
Abstract . PDF (9088 KB)

C. M. Bitz, K. M. Shell, P. R. Gent, D. Bailey, G. Danabasoglu, K. C. Armour, M. M. Holland, J. T. Kiehl, **Climate Sensitivity of the Community Climate System Model Version 4.** *Journal of Climate*, early online release.
Abstract . PDF (2920 KB)

Keith Oleson, **Contrasts between urban and rural climate in CCSM4 CMIP5 climate change scenarios.** *Journal of Climate*, early online release.
Abstract . PDF (4067 KB)

Alexandra Jahn, Kara Sterling, Marika M. Holland, Jennifer E. Kay, James A. Maslanik, Cecilia M. Bitz, David A. Bailey, Julienne Stroeve, Elizabeth C. Hunke, William H. Lipscomb, Daniel A.

http://journals.ametsoc.org/page/CCSM4/CESM1

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Science Highlights: Climate Change and Feedbacks

21 Century CMIP5 Runs for:
CCSM4
CESM1-CAM5
CESM1-CISM
CESM1-BGC
CCSM4-DP

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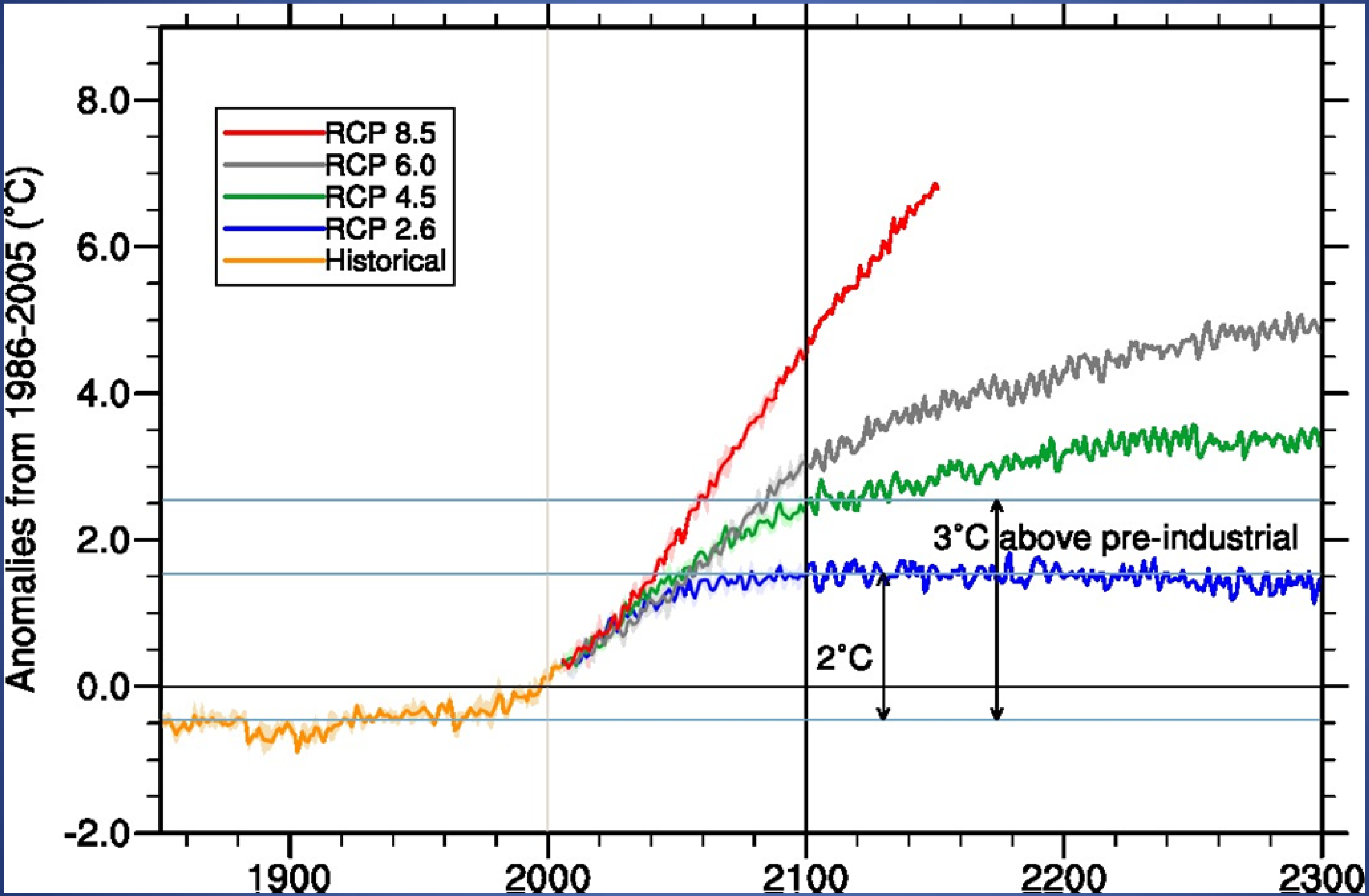
Global Surface Air Temperature Change

CESM1-CAM5

CCSM4



(Meehl, G.A., W.M. Washington, J.M. Arblaster, A. Hu, H. Teng, C. Tebaldi, B. Sanderson, J.F. Lamarque, A. Conley, and W.G. Strand, 2012: Climate change projections in CESM1/CAM5. *J. Climate*, in preparation).

Meehl et al. 2012

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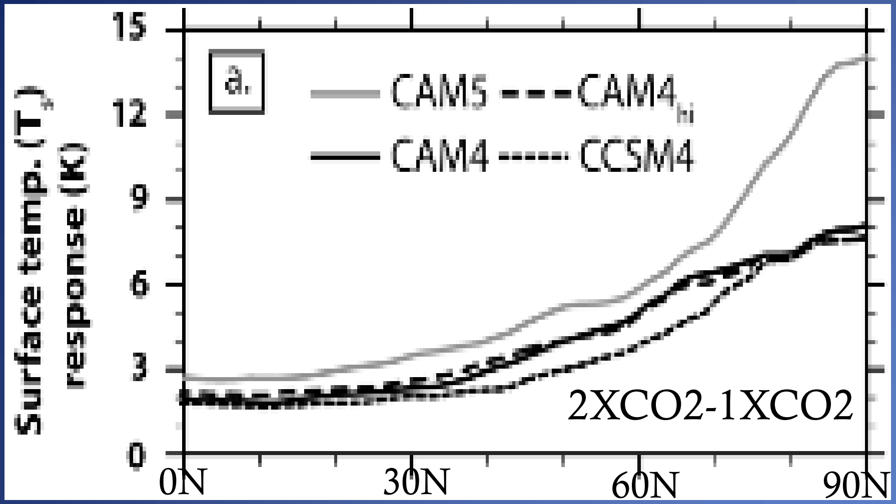
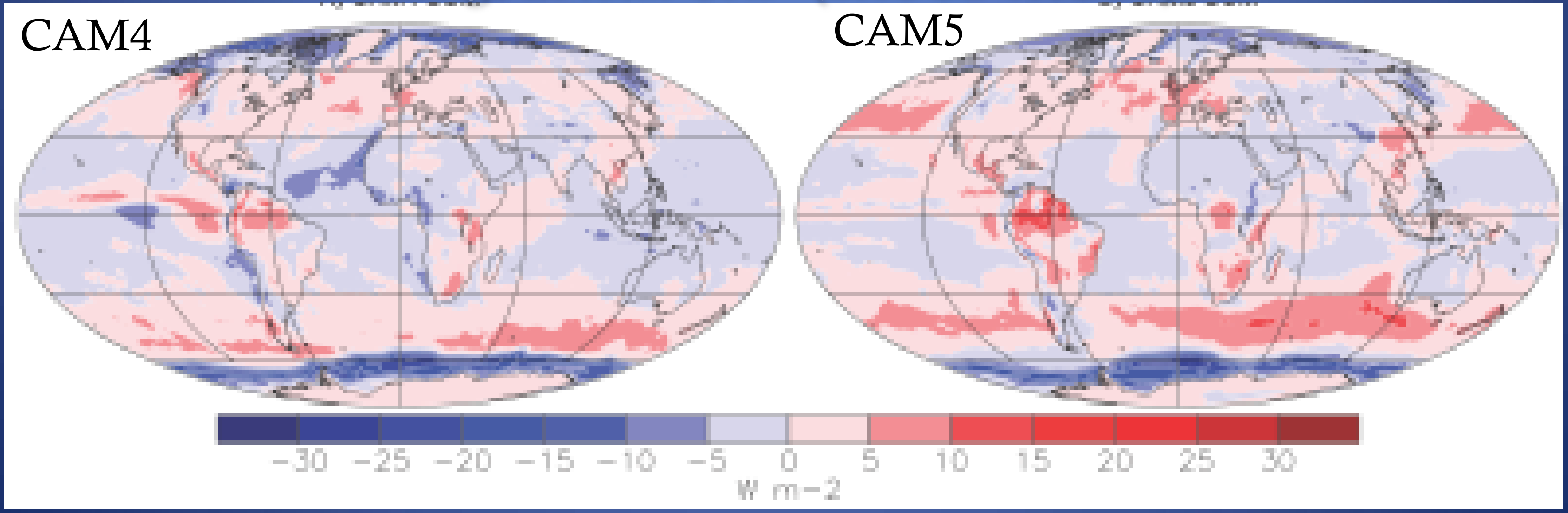
Climate Sensitivity



Surface Temperature Change
3.2K in CAM4
4.0K in CAM5

Feedback analysis (Gettleman et al, 2012) suggests considerably different cloud feedbacks – particularly in mid-latitudes – are largely responsible

Change in total CRF (2XCO2-1XCO2)



Bitz et al., 2012; Gettelman et al., 2012; Kay et al., 2012

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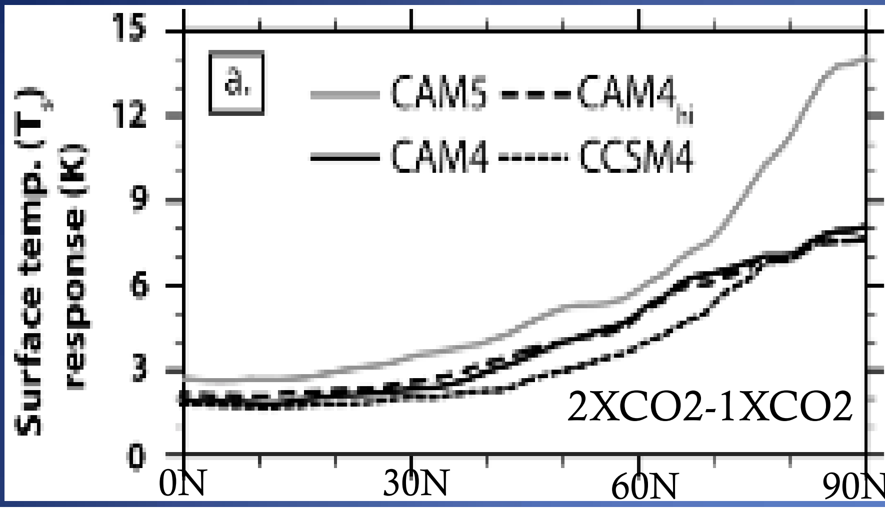
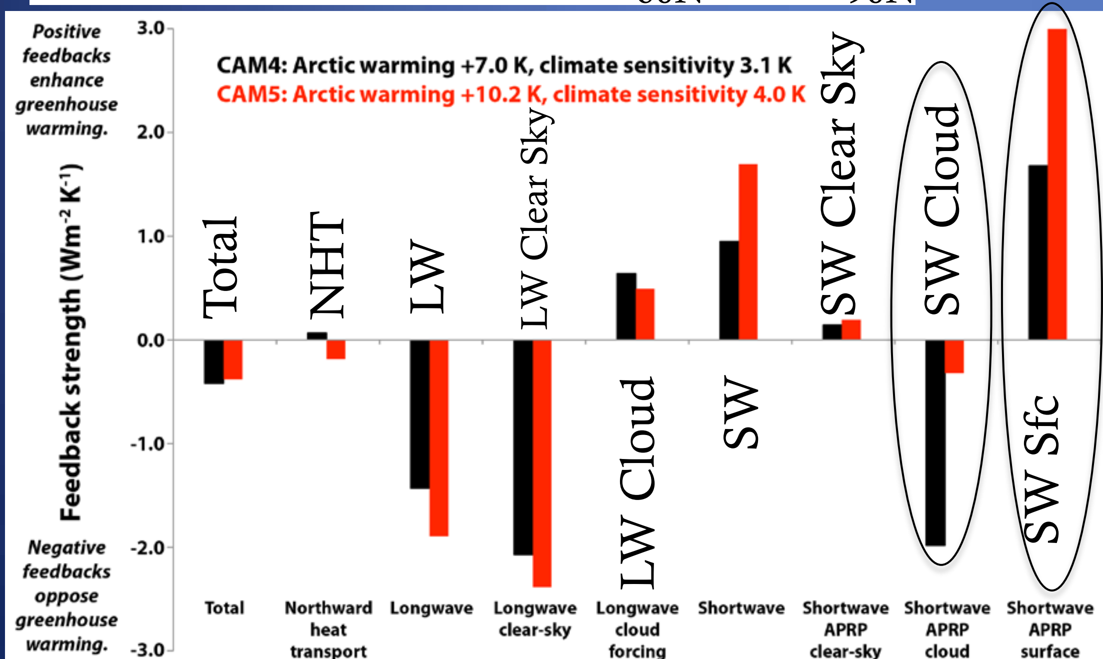
Climate Sensitivity





CAM5 also has considerably higher Arctic amplification

Feedback Analysis (Kay et al) suggests this results from:

- Less negative SW Cloud Feedbacks
- More positive surface albedo feedback

Gettelman et al., 2012; Kay et al., 2012

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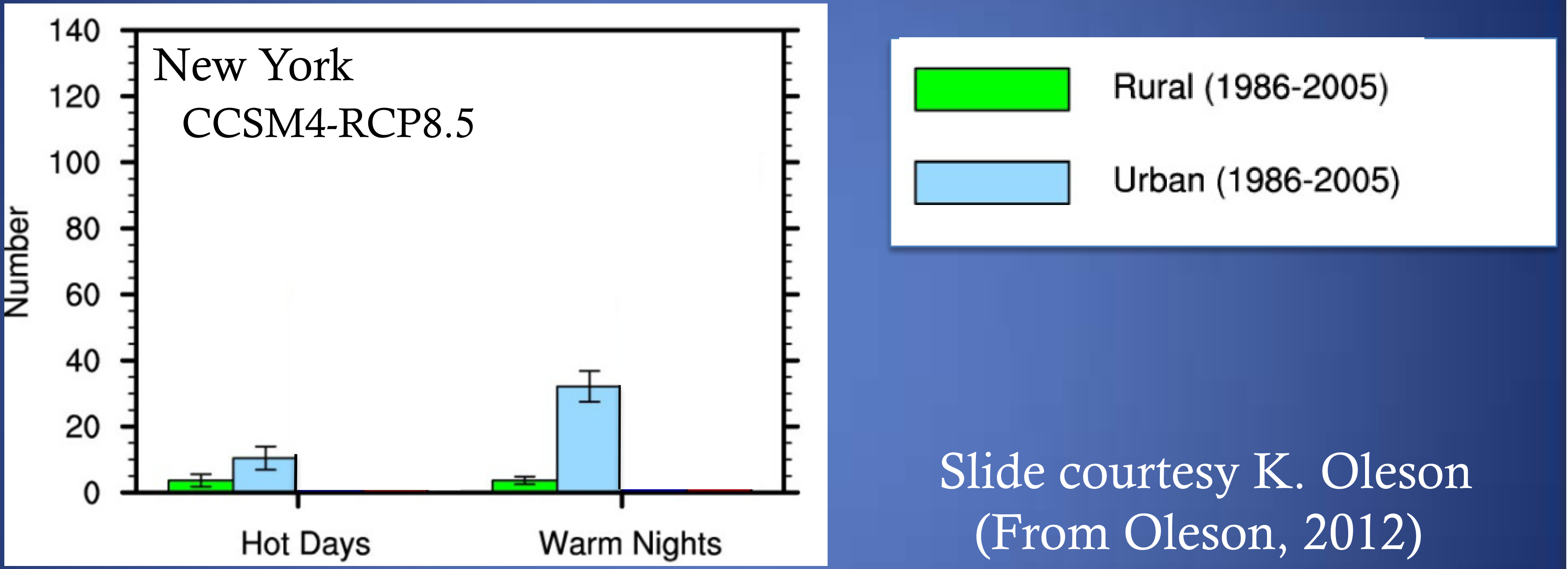
Changing Extremes:
Changes in hot days and warm nights

Hot days (warm nights) – Number of days per year that daily TMAX (TMIN) exceeds 99th percentile of present day Rural daily TMAX (TMIN)



Slide courtesy K. Oleson (From Oleson, 2012)

Present-day climate

Cities have more hot days and warm nights than rural land

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Changing Extremes:
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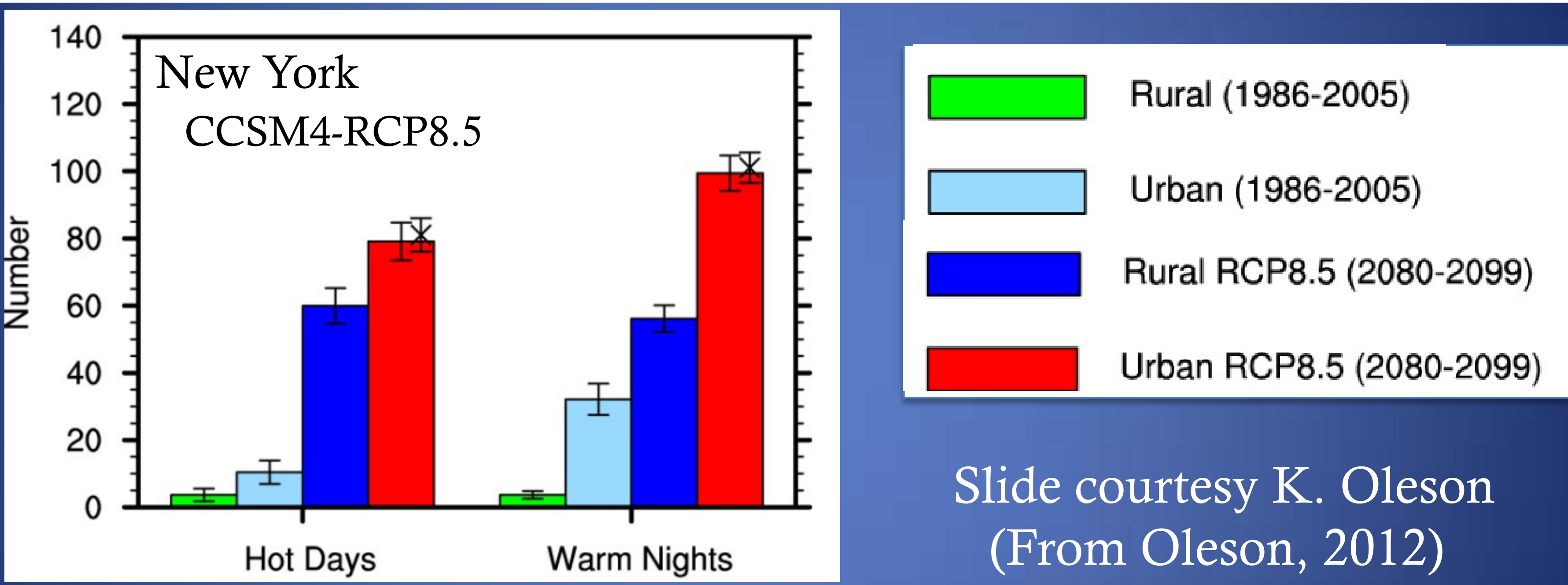

Slide courtesy K. Oleson (From Oleson, 2012)

Present-day climate

Cities have more hot days and warm nights than rural land

21st century climate change

Cities increase more in hot days and warm nights than does rural land

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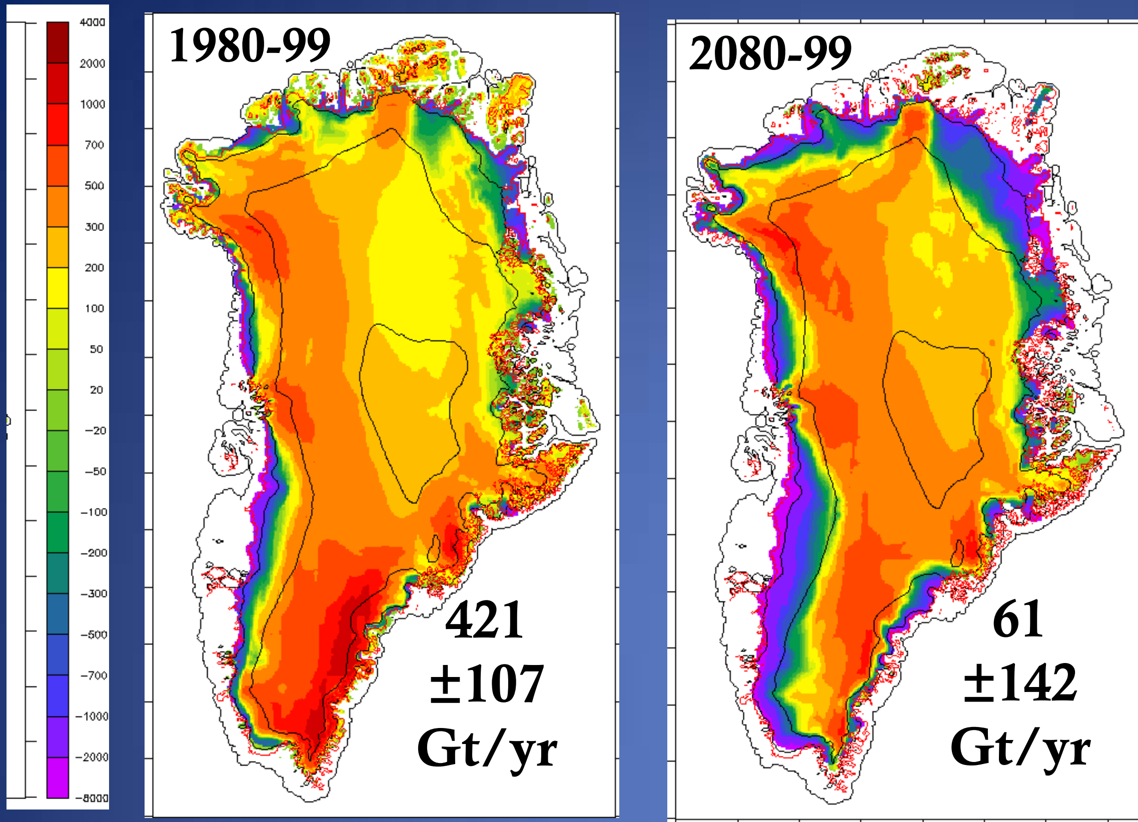

CESM1-CISM

Changing Ice Sheet Conditions

Community Ice Sheet Model (CISM)

Simulated Greenland surface mass balance (red = net growth purple = net melting)

- Fully coupled CMIP5 simulations (preindustrial, 20th century, RCP8.5) with Greenland ice sheet model are completed
  - 20th century surface mass balance (SMB) agrees well with regional models
  - SMB approaches zero by late 21st century, implying long-term instability
- Ran 100-member spin-up ensemble to optimize Greenland ice sheet parameters for modern climate

Slide courtesy of Bill Lipscomb

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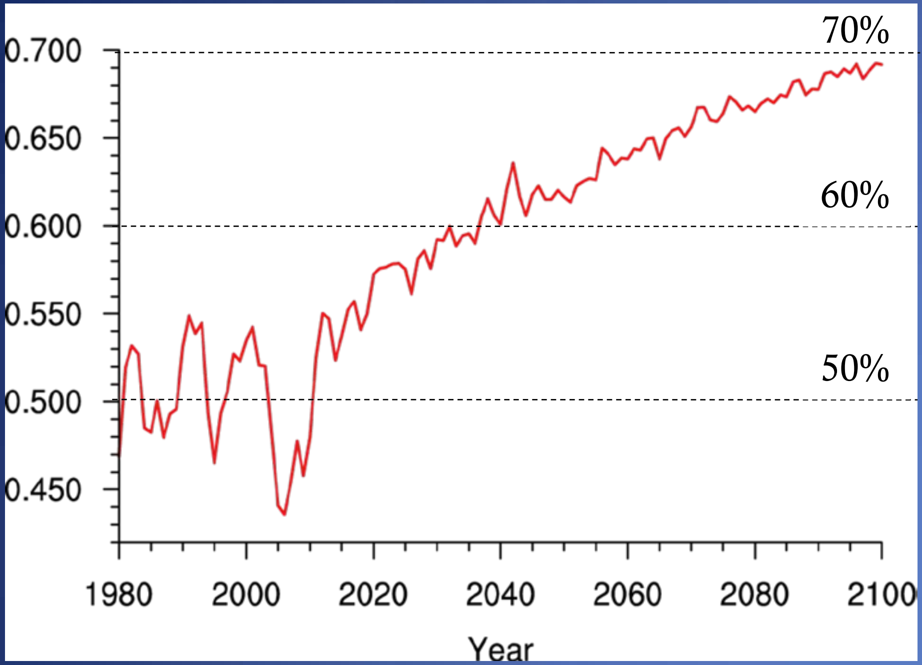
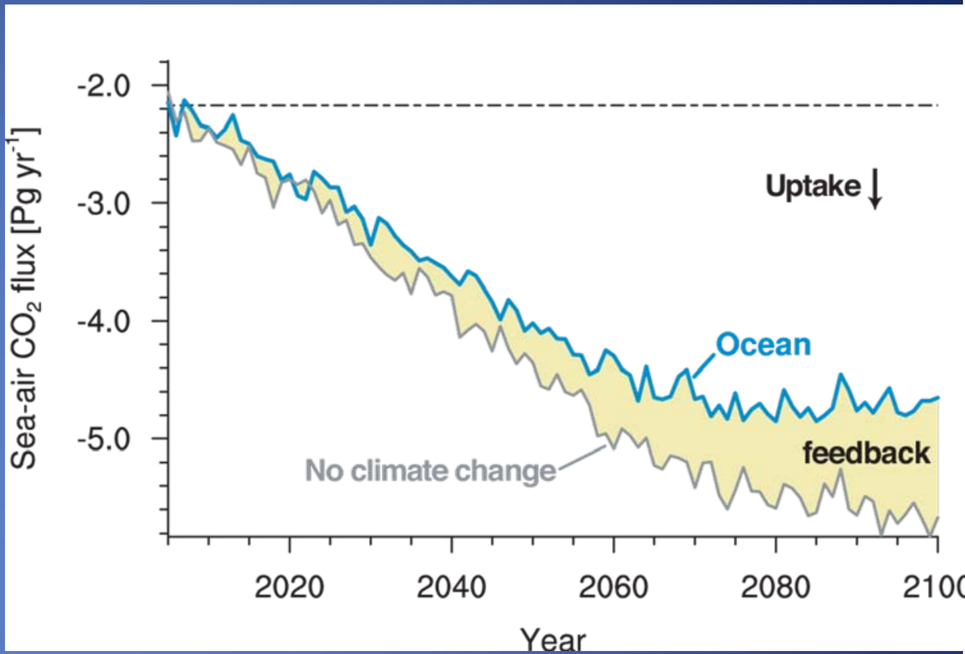
CESM1-BGC: 21st Century carbon cycle

Prognostic global carbon budget

Airborne CO2 Fraction



Ocean sink: climate-carbon feedback



- Emissions specified, atmospheric CO_2 is modeled as a function of surface fluxes;
- Ocean carbon sink stabilizes late-21st century—in part a result of climate-carbon feedback;
- Airborne fraction increases.

Slides courtesy of Matt Long

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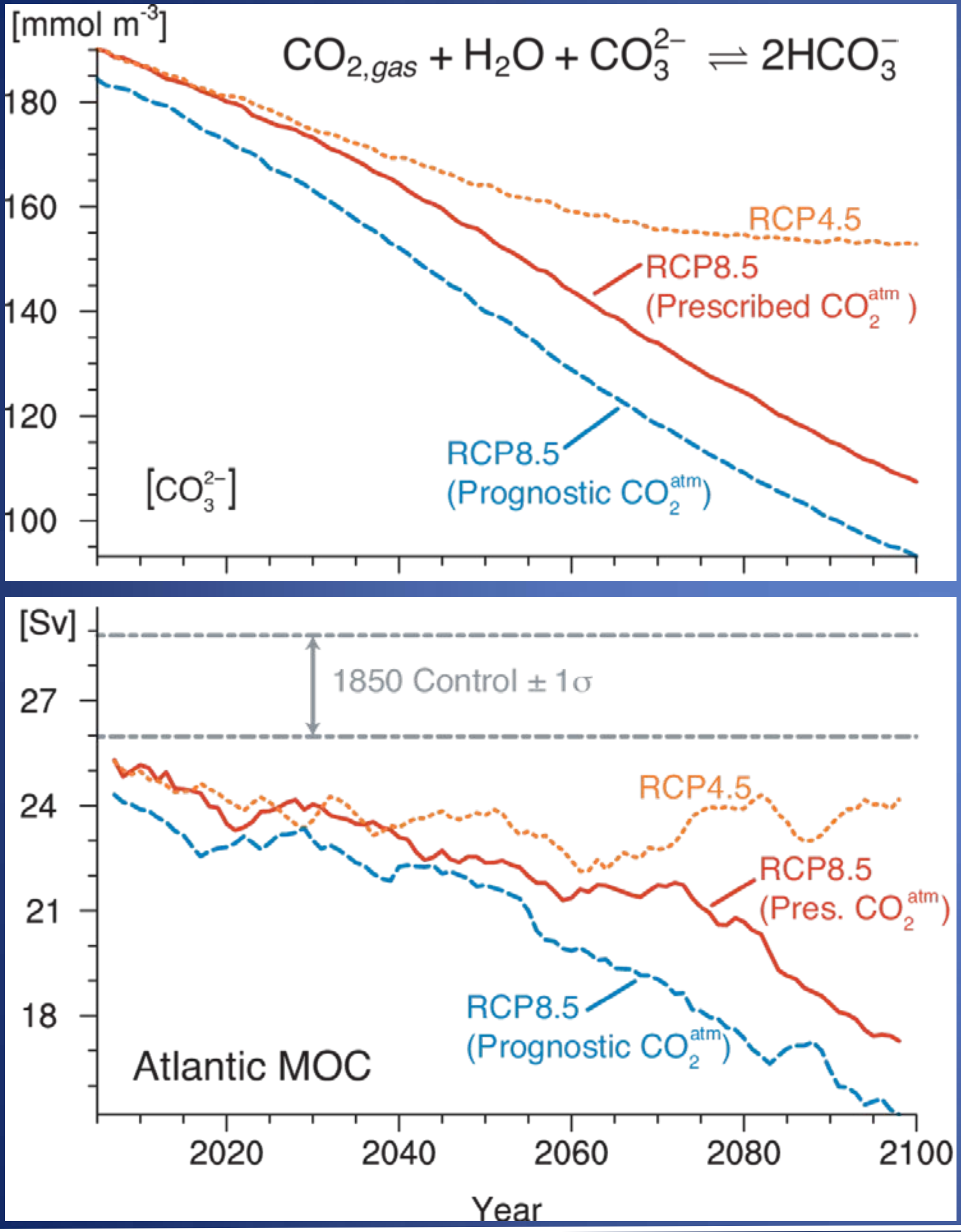
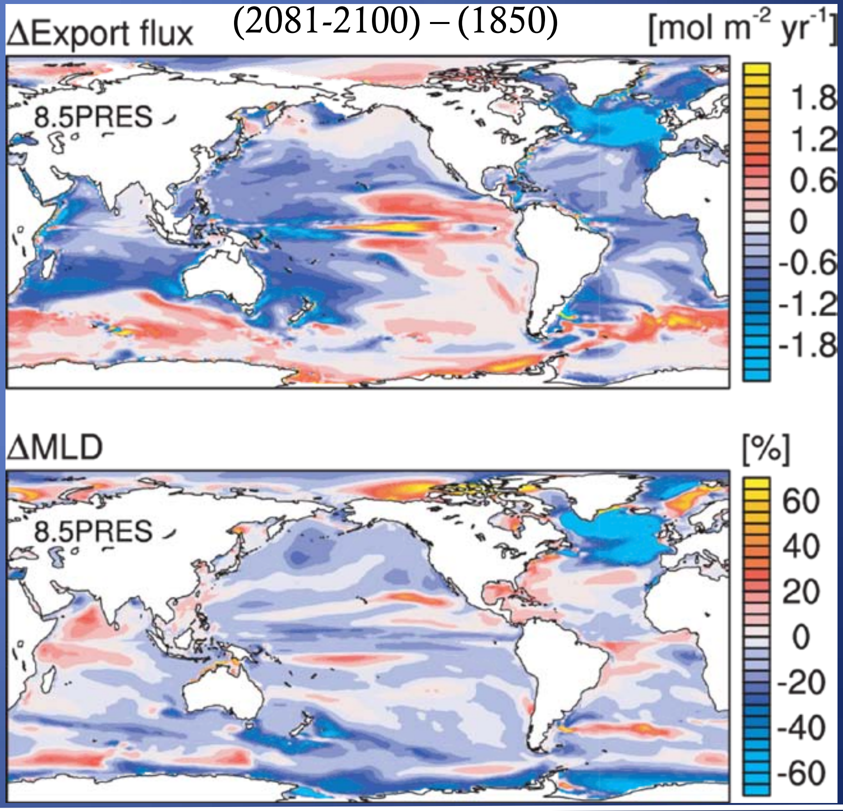
CESM1-BGC: 21st Century Ocean carbon sink stabilization



- Ocean Chemistry - Consumption of carbonate ion reduces buffer capacity;
- Ocean Circulation - MOC slow down and stratification inhibit ventilation;
- Ocean Biology - Nutrient limitation drives reductions in biological export



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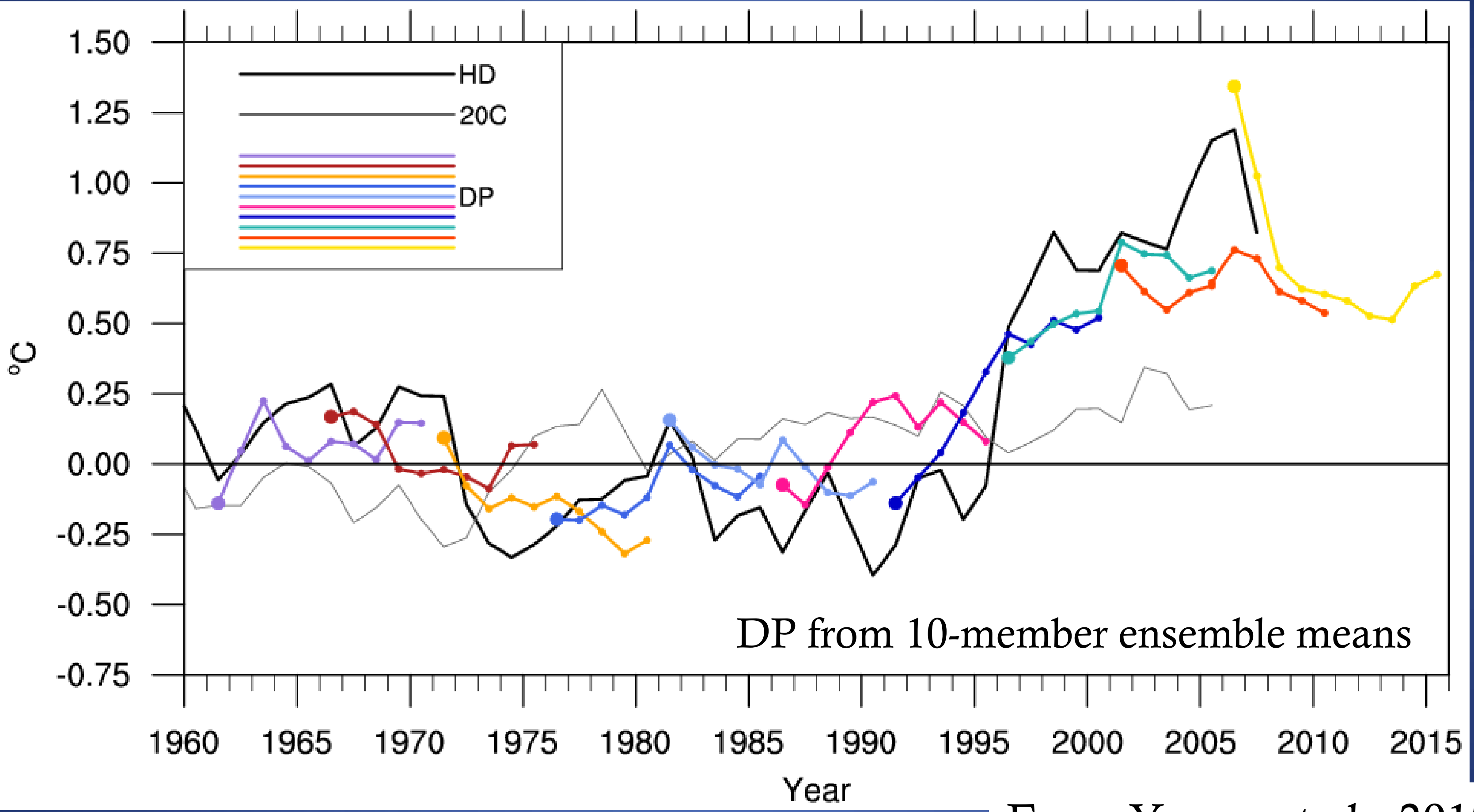
Decadal Prediction

275-m HEAT CONTENT ANOMALY IN SPG BOX



From Yeager et al., 2012

After drift correction, there is skill in reproducing historical changes in the SPG

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Where We Are Heading

Higher Resolutions with New Science Applications

New Model Capabilities

Improved Earth System Processes

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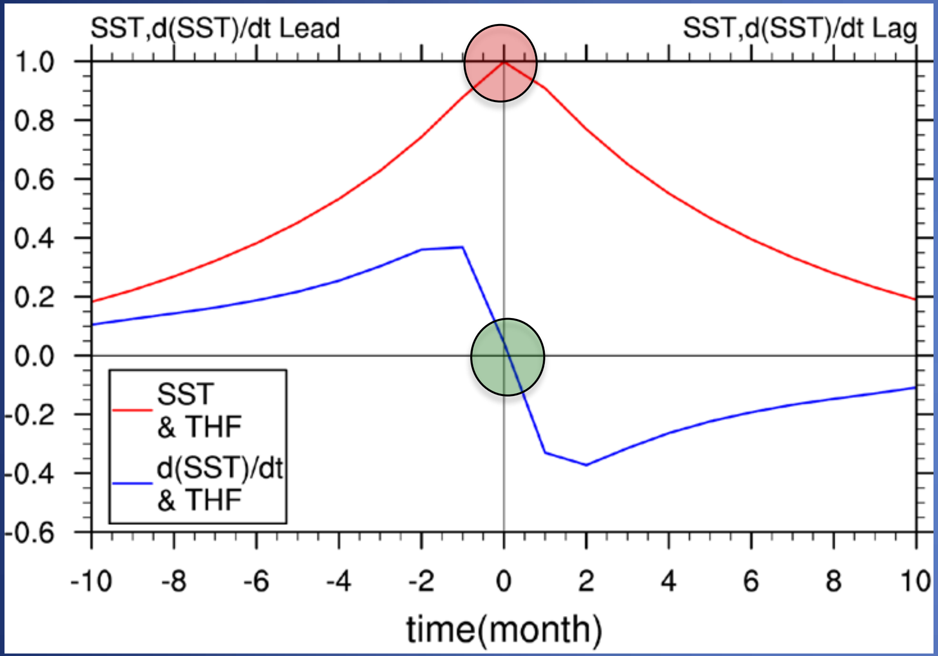
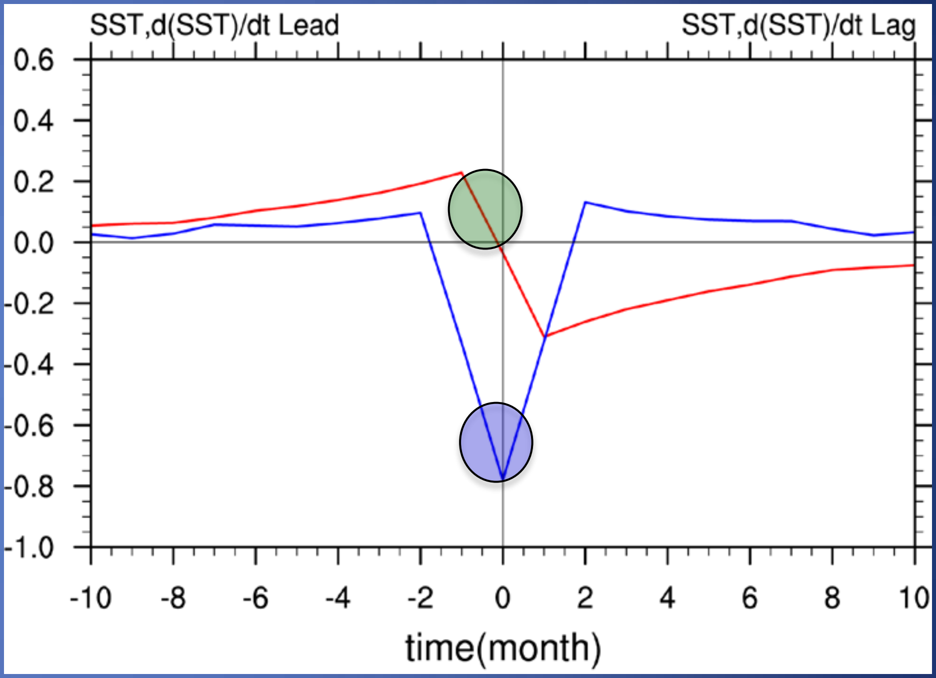
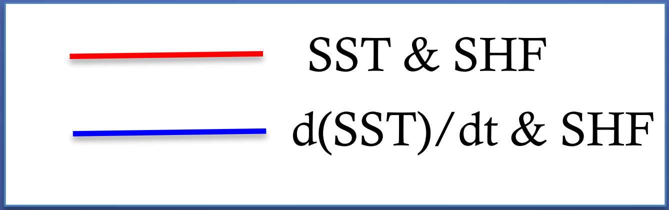
Higher Resolution Simulations Enabling Studies on Ocean-Atmosphere Scale Interactions

Ocean Weather



Atmosphere Weather





Courtesy of Frank Bryan

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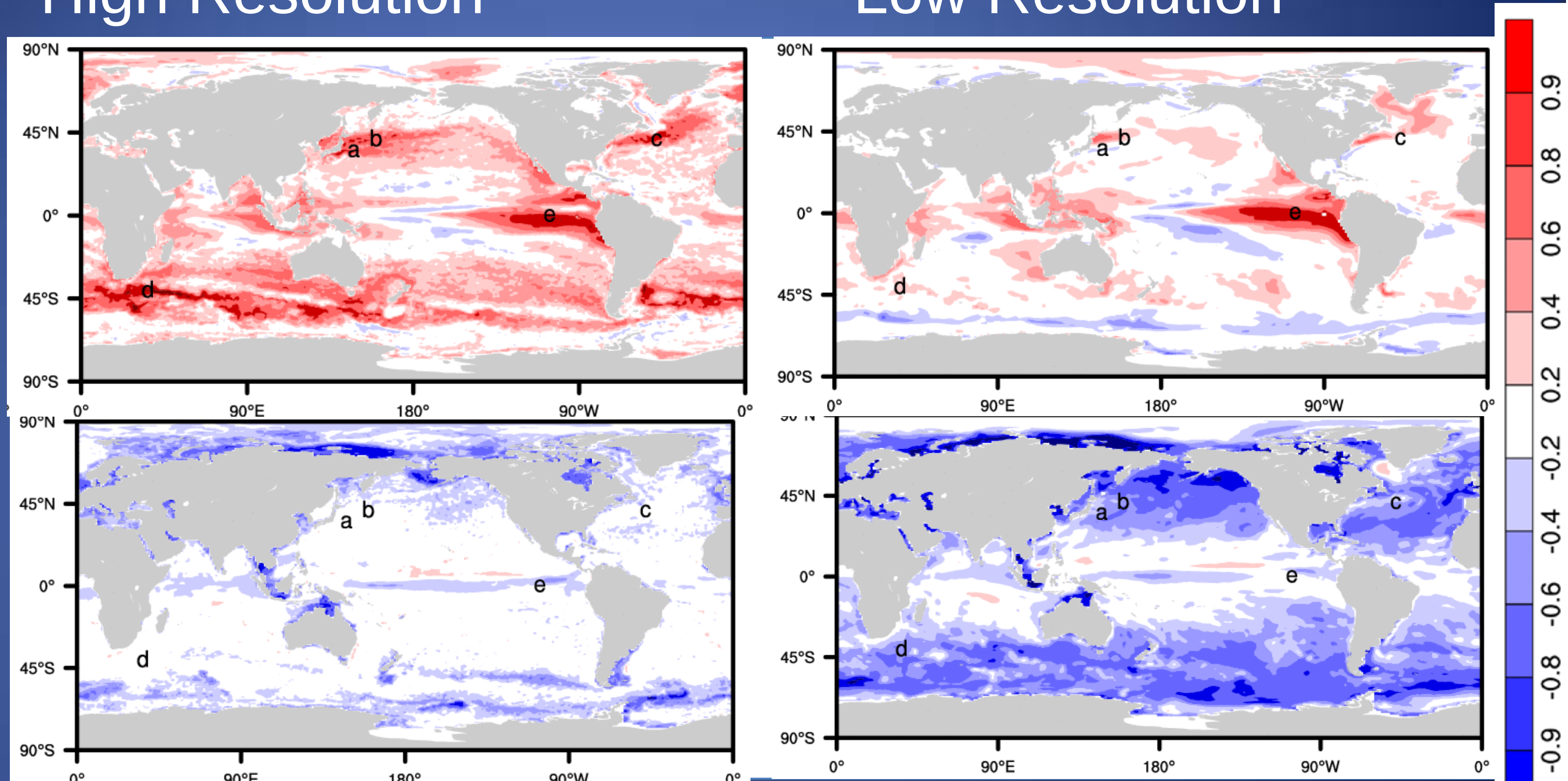
Ocean-Atmosphere Scale Interactions

Correlation

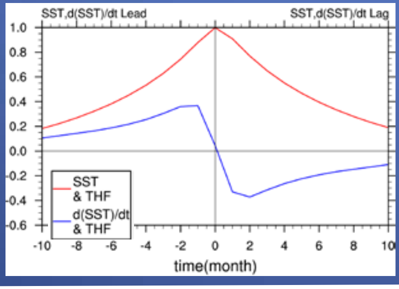
High Resolution | Low Resolution

SST & SHF

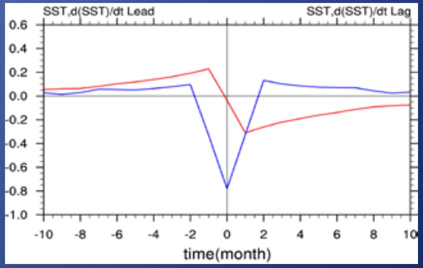
d(SST)/dt & SHF



Ocean Weather



Atm Weather



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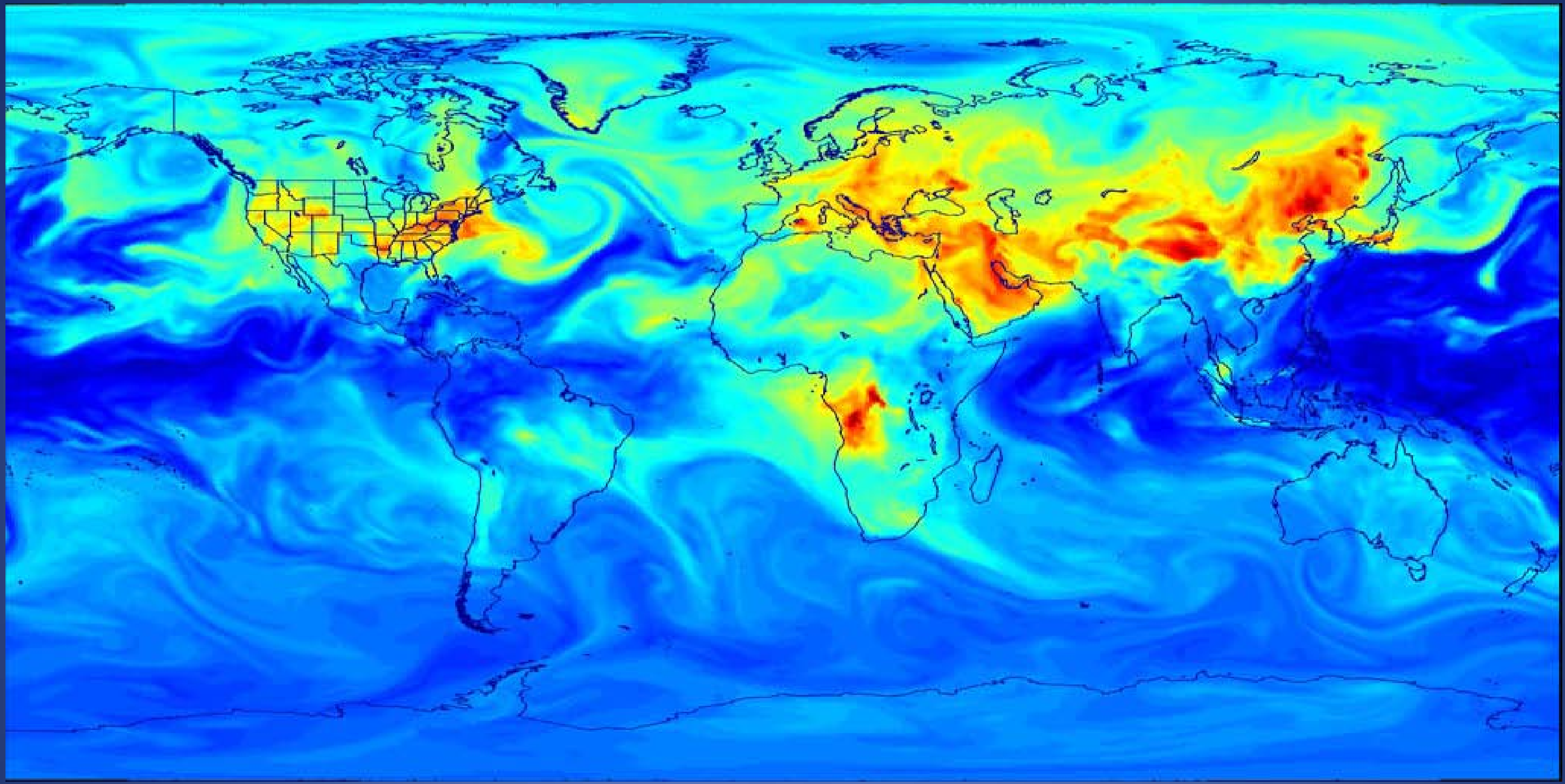
Atmospheric Chemistry



Snapshot of Simulated Ozone Concentration in Lowest 2km

High-resolution (~0.5 degree) simulations driven by GEOS-5 meteorology

Slide courtesy of Jean-Francois Lamarque
Simulation by Louisa Emmons

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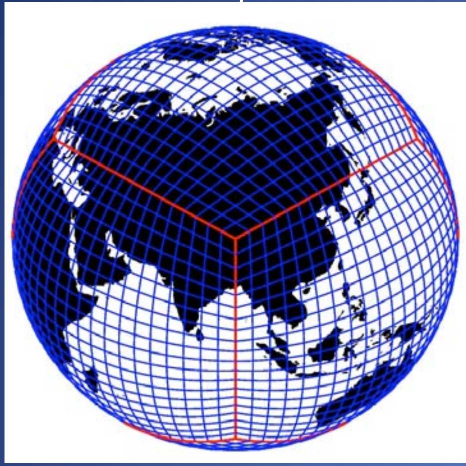
High Resolution: New Dynamical Cores

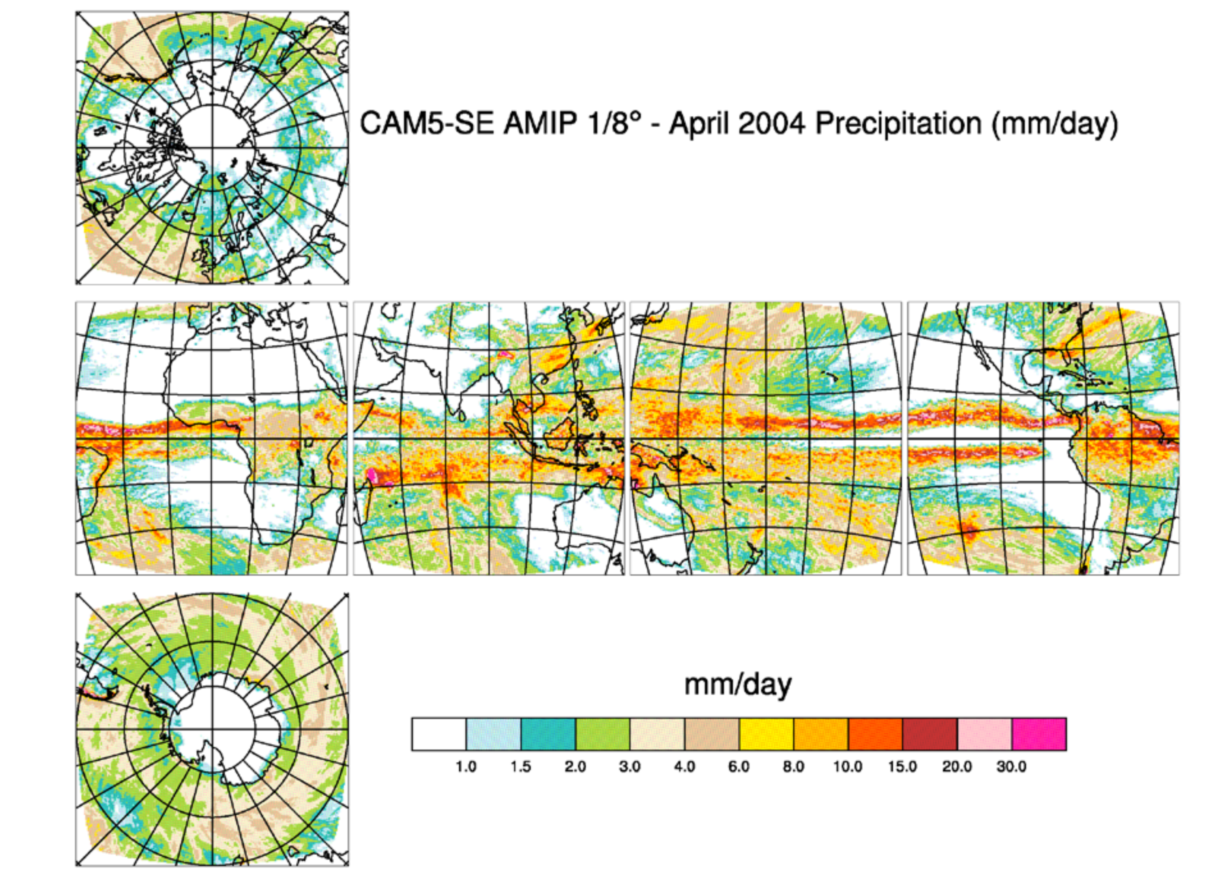
CAM5-Spectral Element on Cubed Sphere Grid

Cubed Sphere



Regular lat-lon

SE Dynamical Core – More conservative and less diffusive than FV. Scales efficiently to many processors.



Slide courtesy of Rich Neale

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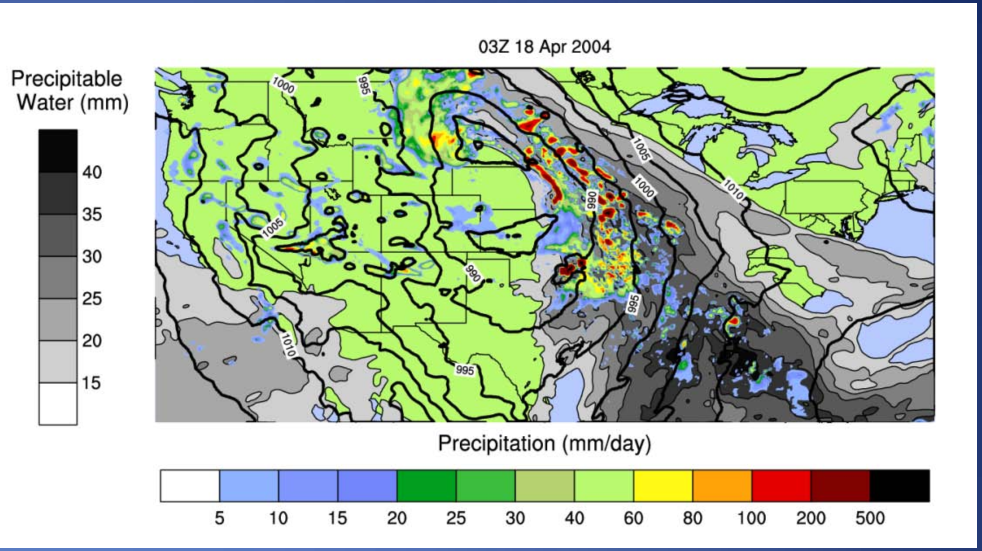
High Resolution: New Dynamical Cores

CAM5-Spectral Element on Cubed Sphere Grid

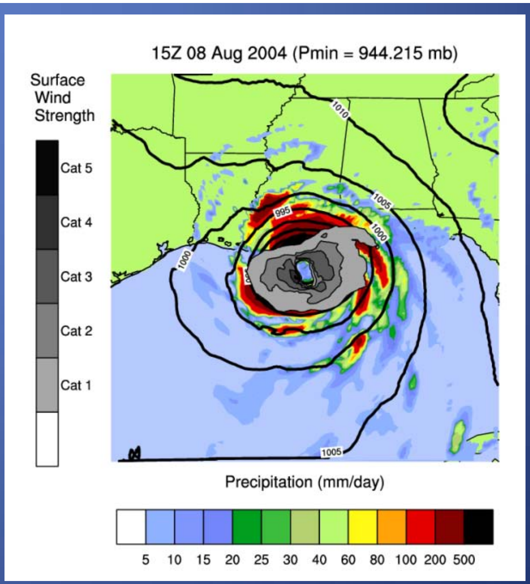
Cubed Sphere

Regular lat-lon

Mid-west Spring time propagating systems



Tropical Cyclones



12-km CAM-SE Run

Slide courtesy of Rich Neale

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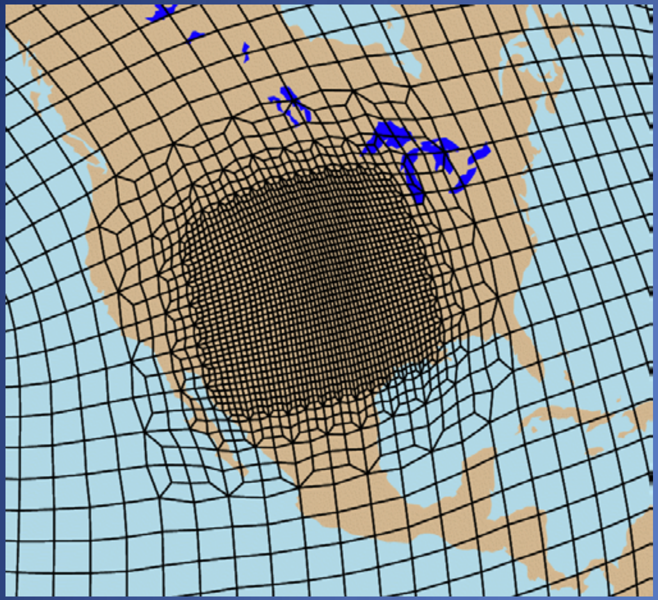
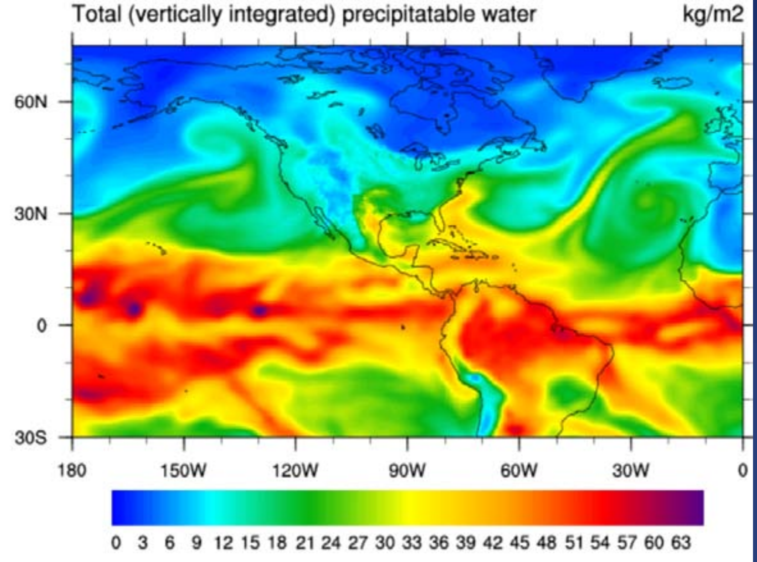
CESM1(CAM5-SE): Regional Refinement

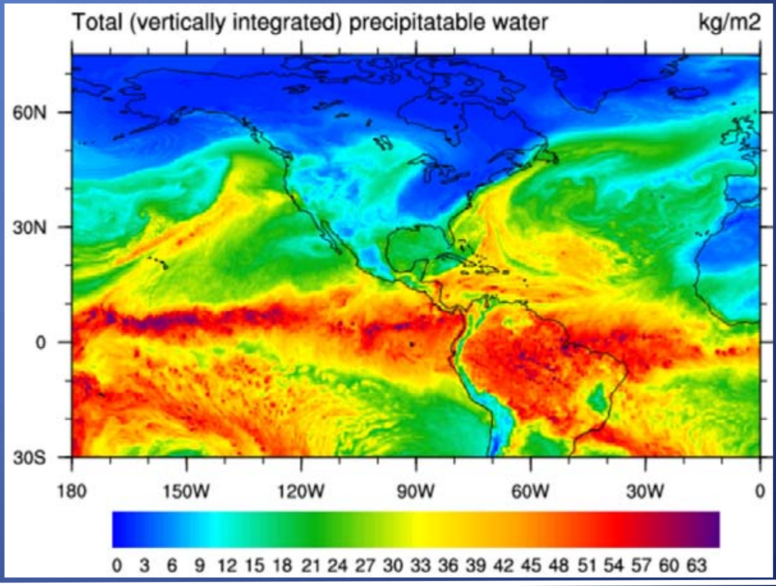
Avoiding Downscaling BUT Implications for resolution dependence



1° to 1/8°
Over USA



Global 1/8°



- ✓ 3 levels (steps) of refinement
- ✓ CAM5-SE AMIP simulations
- ✓ Regional refinement should reproduce statistics of global high-res equivalent
- ✓ Land can run on same grid
- ✓ Calibration testbed

Slide courtesy of Mark Taylor

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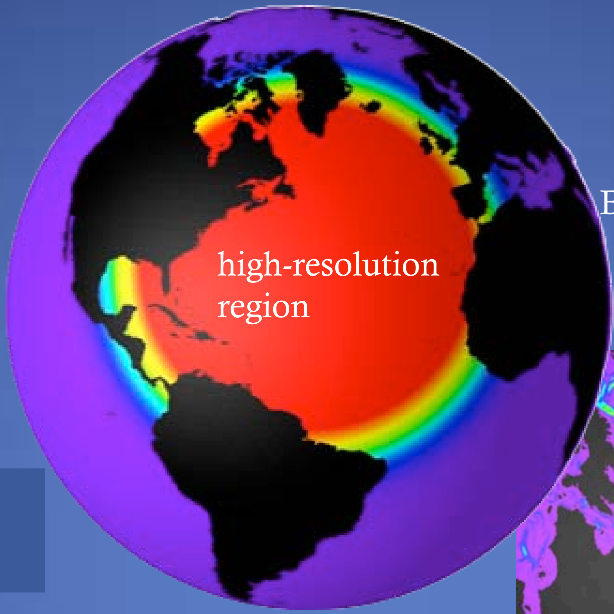
Building a Global, Multi-Scale Ocean Model

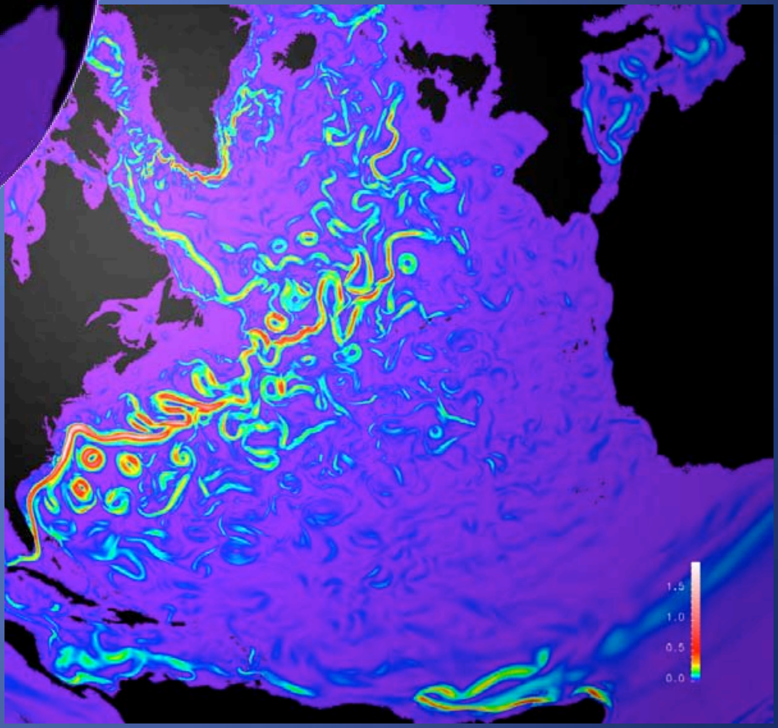
MPAS supports both quasi-uniform and variable resolution meshing of the sphere.

MPAS development is a partnership between NCAR and LANL.

The MPAS ocean (MPAS-O) model will be coupled into the CESM over the next year.



Below: Snapshot of kinetic energy from a global ocean simulation with 7.5 km resolution in the North Atlantic. The rest of the global ocean is resolved with a 38 km mesh.



Slide courtesy of Todd Ringler

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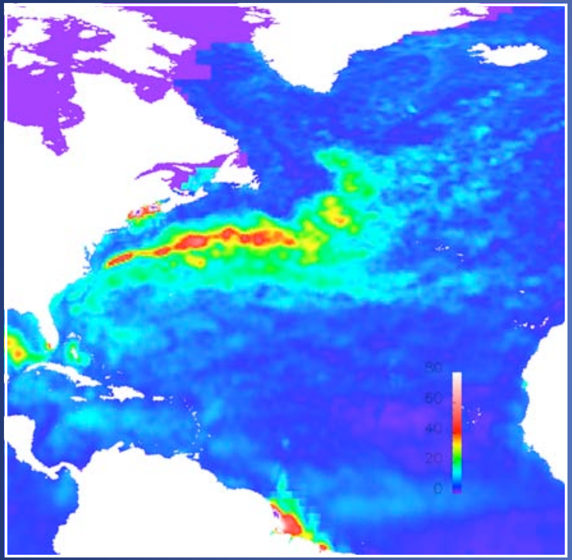
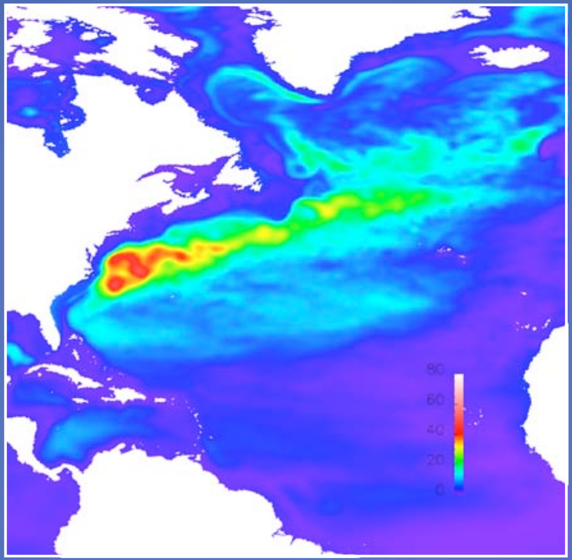
Simulating Mesoscale Eddies on a Variable Resolution Mesh.

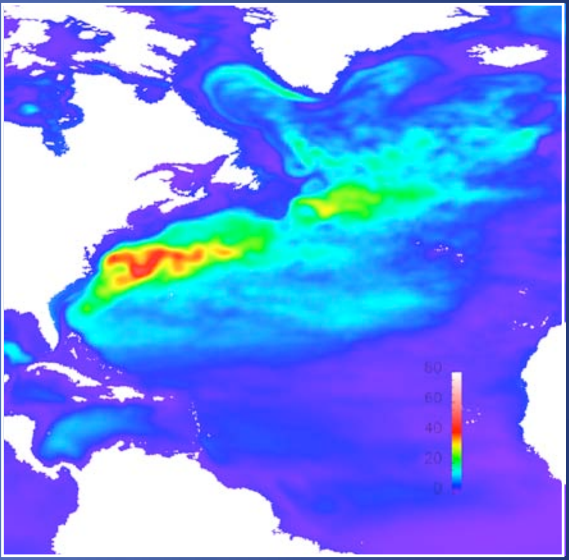
Observations: AVISO



Traditional Approach:
Global, quasi-uniform mesh
15 km resolution everywhere



New Approach:
Global, variable-resolution mesh
15 km in North Atlantic, 75 km elsewhere



Figures show sea-surface height RMS which is a proxy for the amplitude of mesoscale ocean eddies.

The mesoscale eddies in the North Atlantic are simulated as well on the variable resolution mesh as on the uniform-resolution mesh, but at only 15% the cost.

Slide courtesy of Todd Ringler

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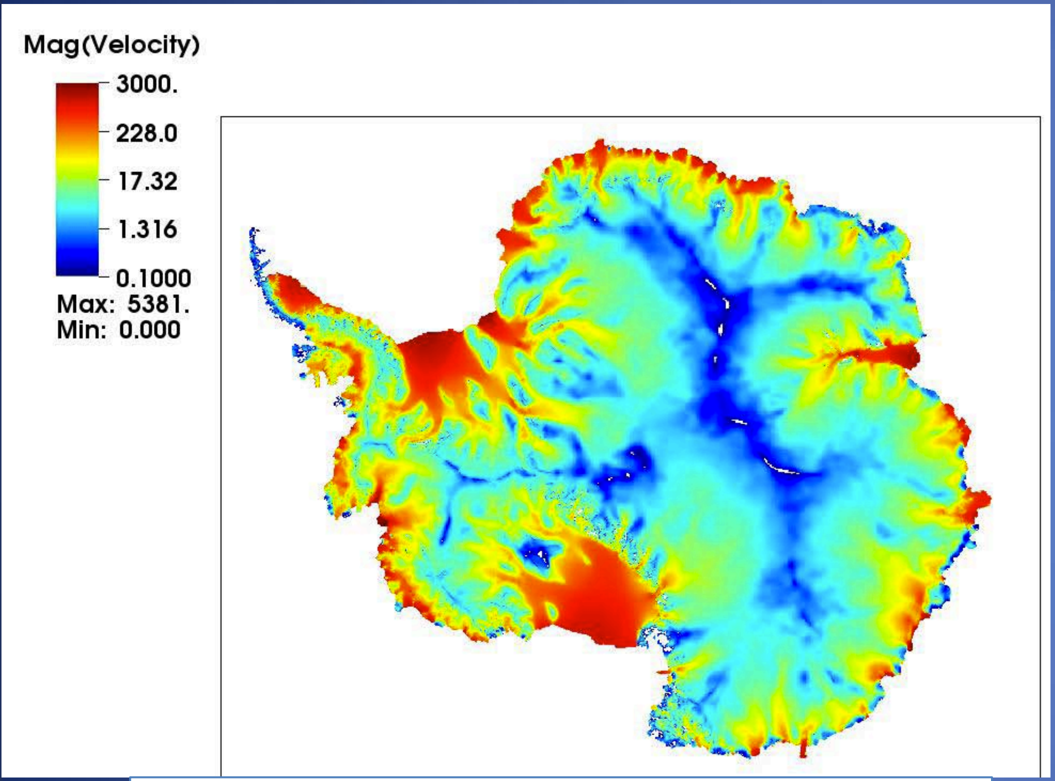
Community Ice Sheet Model (CISM)



Antarctic ice speed, BISICLES model (red = fast flow)

- Now testing scalable dynamical cores with higher-order ice flow
  - –SEACISM dycore with Trilinos solvers
  - –BISICLES dycore with adaptive mesh refinement
  - –To be included in CISM 2.0, CESM 1.1

Slide courtesy of Bill Lipscomb

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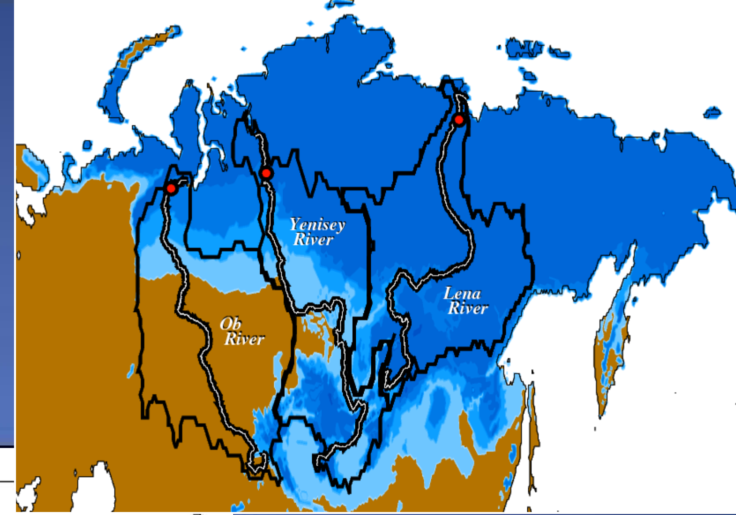
Cold region hydrology

Results: Good hydrographs for both permafrost basins and non-permafrost basins; better active layer hydrology and veg?

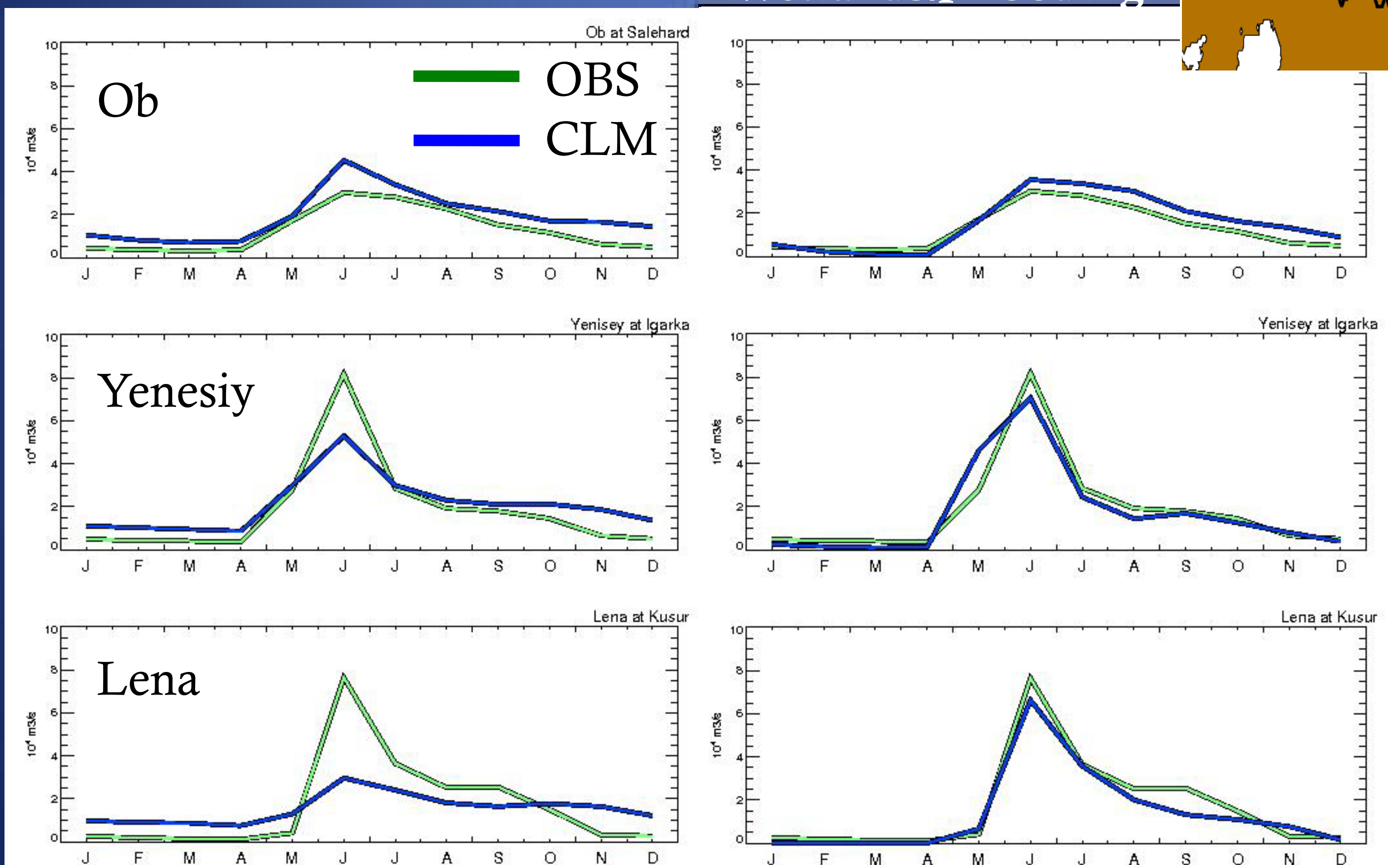
In Control, water permeates icy soils too easily causing poorly simulated discharge in permafrost basins



Control

Ice Impedance + Wetlands/Flooding

Ice Impedance



Swenson and Lawrence, in prep

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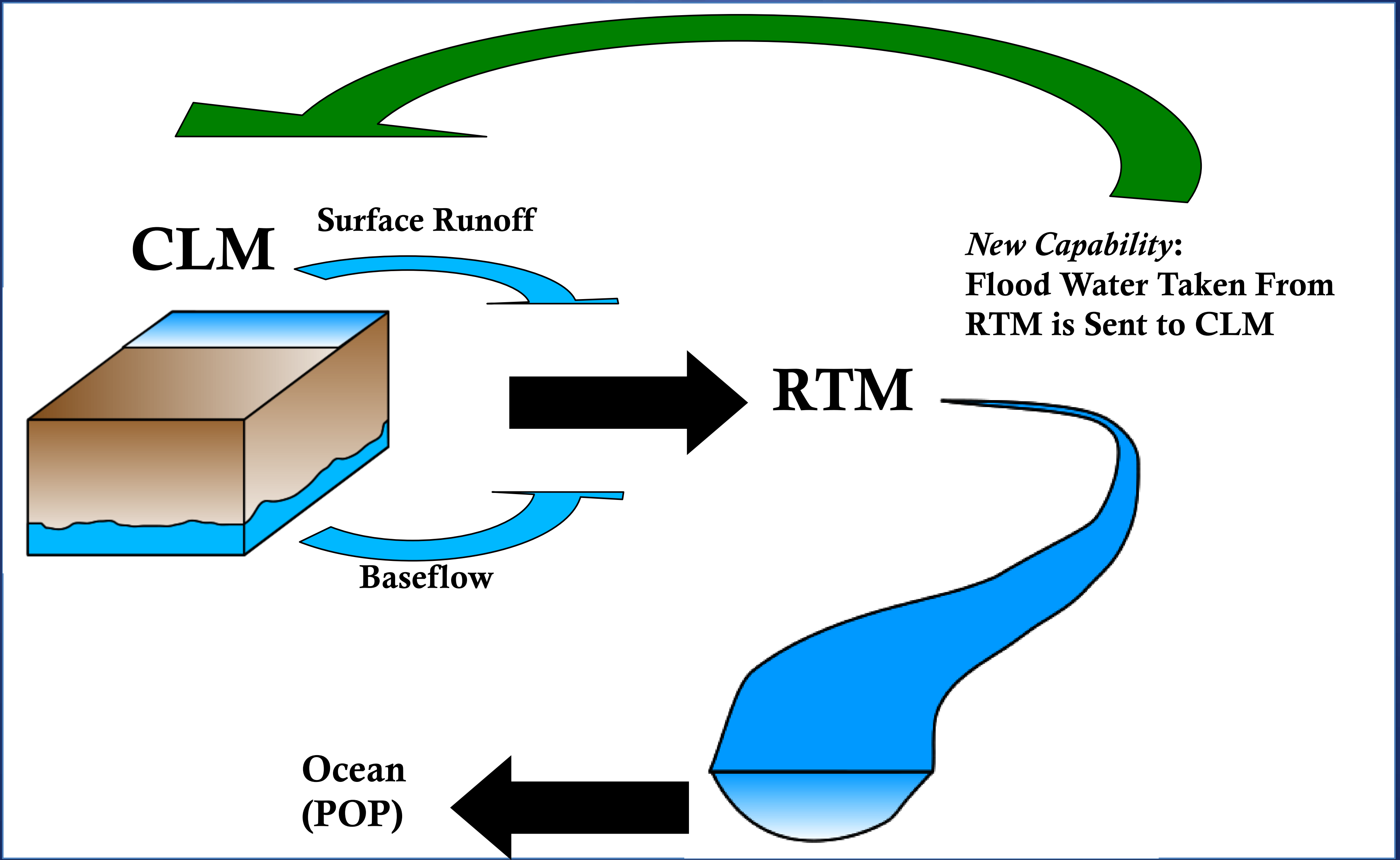
Adding Flooding Capability / 2-way CLM-RTM interactions



Slide courtesy of Dave Lawrence

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Development of an Isotope-Enabled CESM

Simulating Stable Water Isotopes in the Climate System

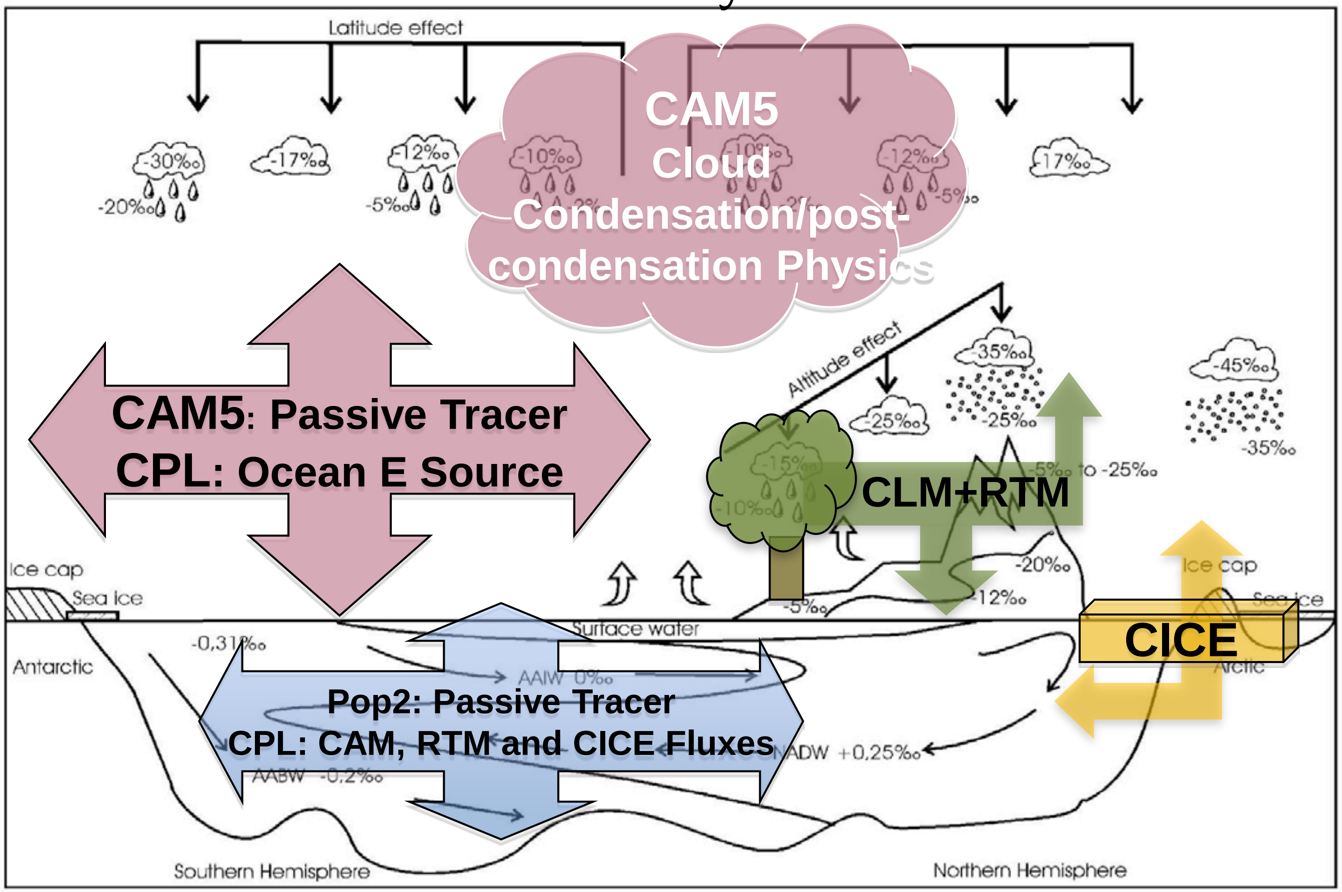

Figure adapted from Paul, A. et al. 1999: Simulation of Water Isotopes in a Global Ocean Model, in *Use of Proxies in Paleoclimatology: Examples from the So. Atlantic,* Fischer G. and W. Wefer, eds., Springer-Verlag, 655-686.

Community effort partnering NCAR, U. Wisc, U. CO, U. Bern, DOE LBL

Slide courtesy of B. Otto-Bliesner

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And More…

All component models incorporating improved parameterizations and processes

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In summary:

- Community aspects of the project generally remain strong
- CESM applications continue to increase
- Model developments and improvements are ongoing

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Questions?

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