State of CESM

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CESM Chief Scientist
Atmospheric Chemistry Division and
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NCAR

Twitter: #CESM19

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CESM Project

Based on 20+ Years of Model development and application

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

Most working groups have winter/spring meetings. Annual meeting in June.

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

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Societal Dimensions Working Group

Allison Thomson (PNNL)
Bill Gutowski (Iowa State University)
Brian O'Neill (NCAR)
Lawrence Buja (NCAR)

SDWG broadening beyond initial Water and IAM focus:

- Area of research and practice includes the use of CESM in studies of climate change impacts, adaptation and mitigation.
- Diagnosis of CESM performance from an applications perspective, with an eye toward model improvement.
- Participants come from the fields of integrated assessment modeling, climate impacts modeling, adaptation and vulnerability research, social sciences and climate modeling. Participants also include practitioners involved in resource management or policy analysis relevant to these areas of research.

CESM COMMUNITY

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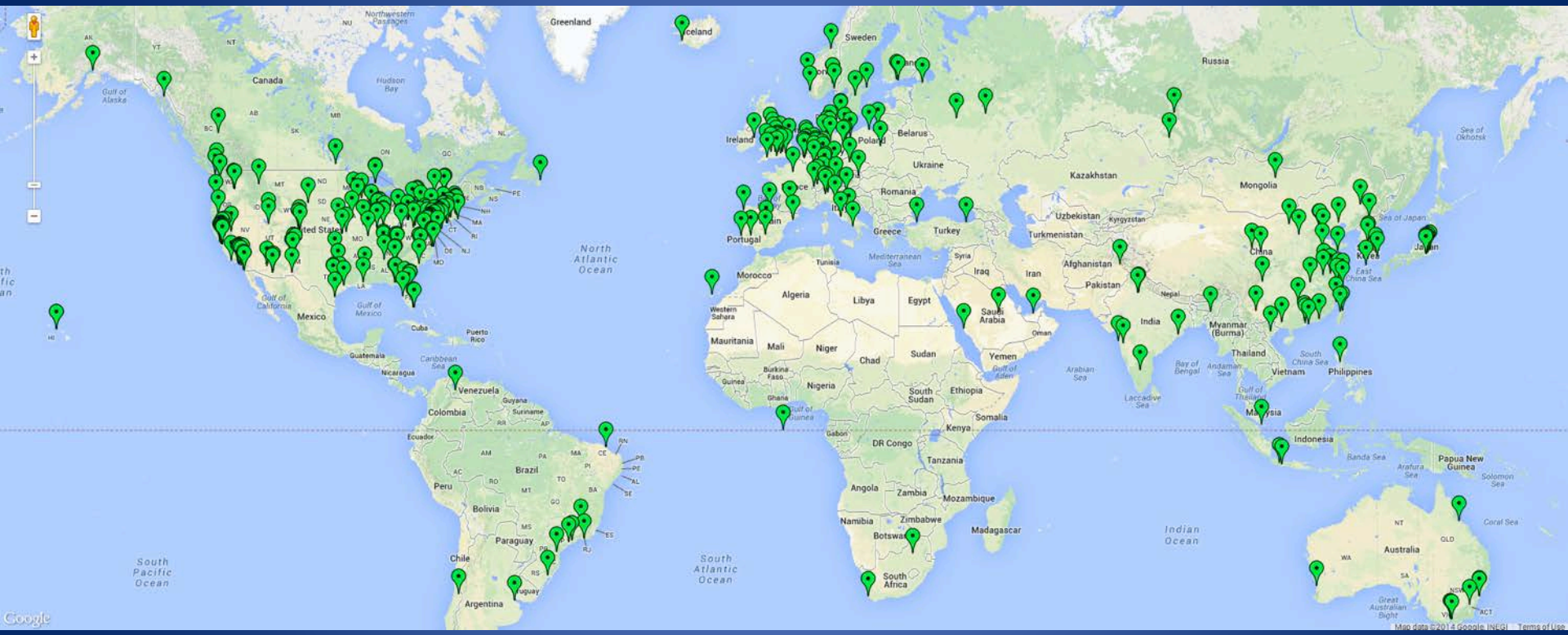
A truly global community



Download of release version since 2010

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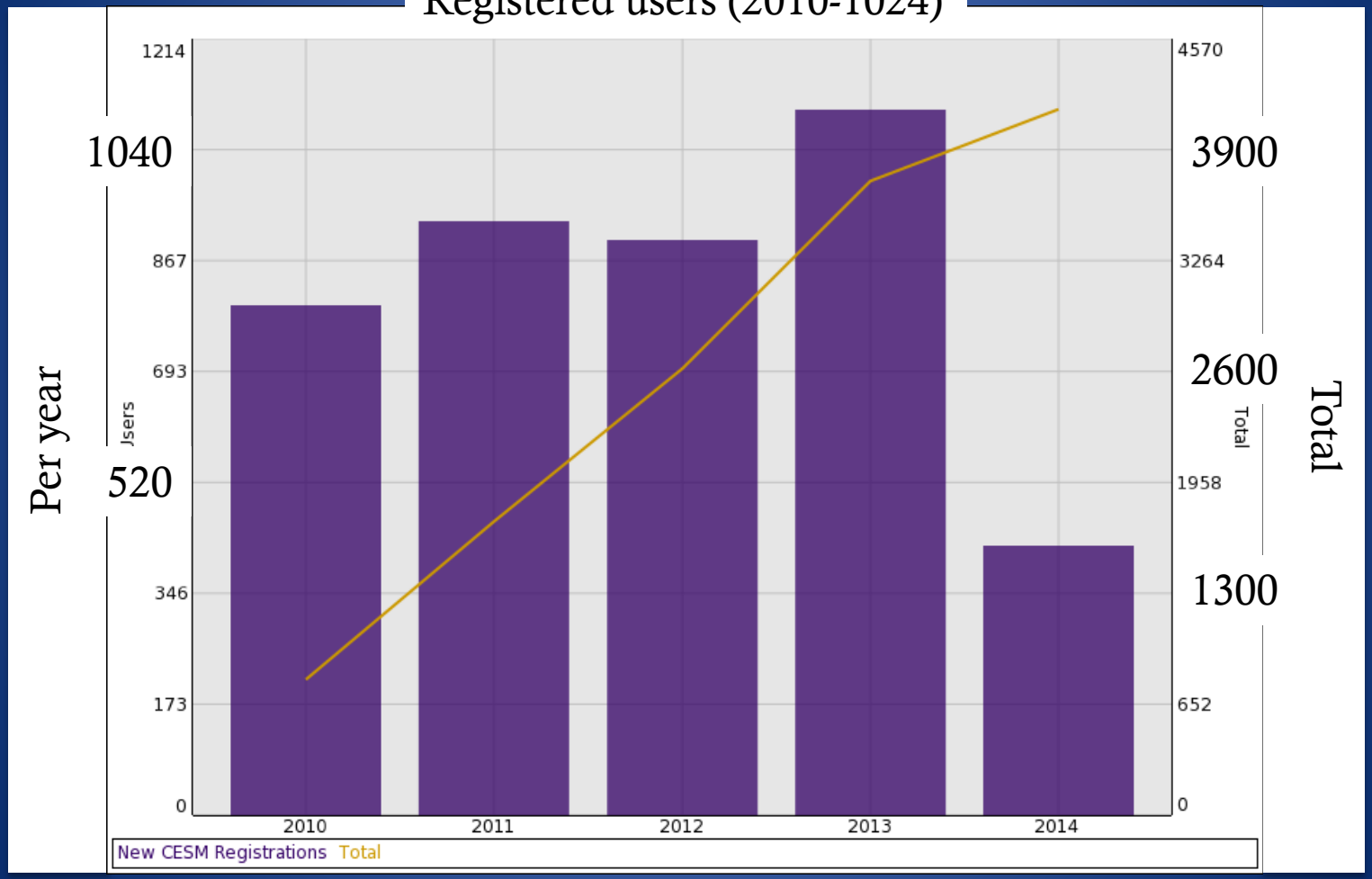
And growing!



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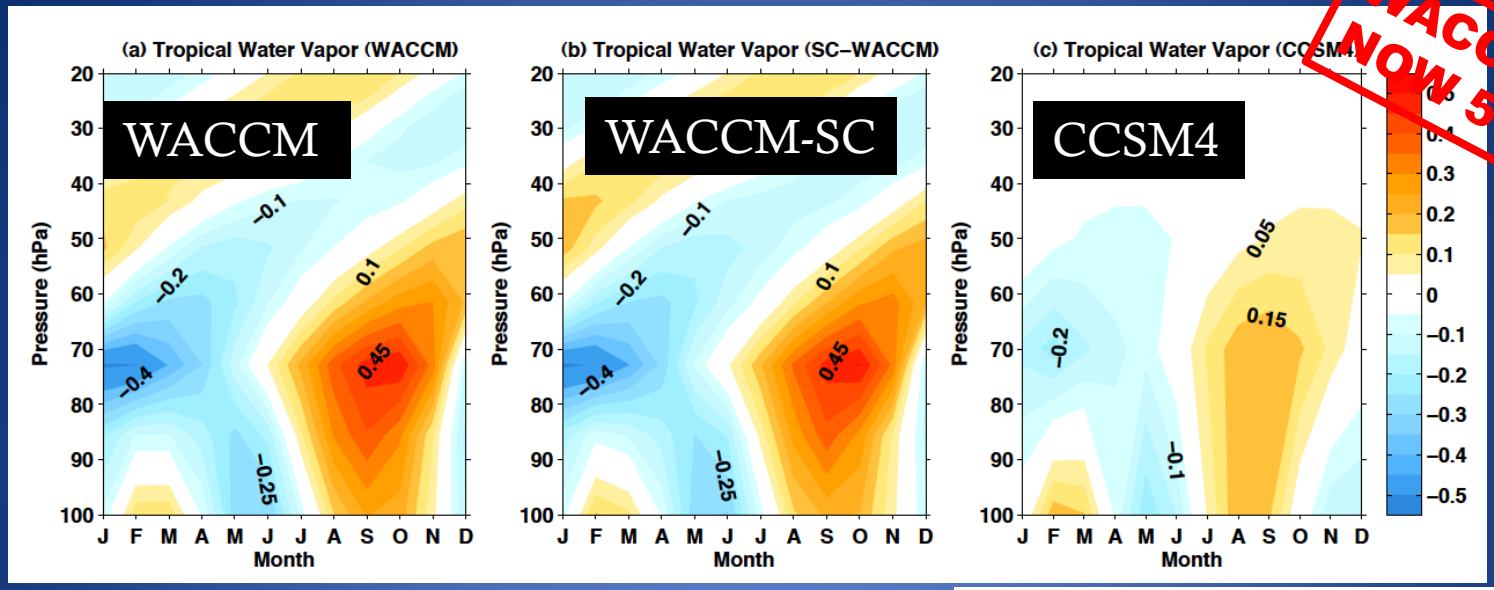
CESM 1.0.6 and 1.2.2 releases

- 1.0.6. May 2 2014
- 1.2.2. June 11 2014
- Release notes for more information

  http://www.cesm.ucar.edu/models/cesm1.2/tags/index.html

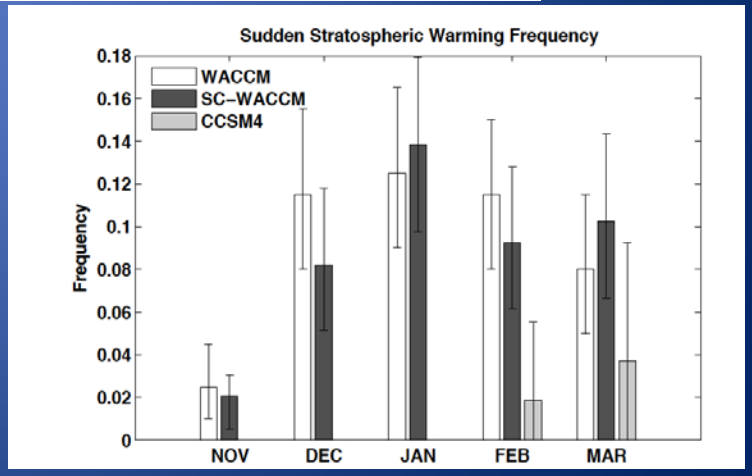
WACCM4-SC in CESM1.0.6 & 1.2.2

"Stratospheric Dynamics for ½ the price"



Above: WACCM-SC Tropical Stratospheric H2O looks like WACCM (good), not CCSM4 (bad)

Right: WACCM4-SC also gets Sudden Stratospheric Warmings (SSWs)



Smith et al., 2014, in review

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Communication within CESM Community

- Working group liaisons: several liaison (software and/or science) positions at NCAR have been lost over the last few years. Main funding agencies are aware of the issue and are working to remediate it.
- Bulletin board:

DiscussCESM Forums Bulletin Board

http://bb.cgd.ucar.edu

- 1793 Total Registered users
- 14 Top level forums with 77 sub-forums

Bulletin Board

- 2004-2013: 1861 posts
- March 2013-Jan 2014: 650 new posts
- Since Jan 2014: 800 posts
- Considerable community response to threads
- Will be the central place for users to report bugs:
  - New bug workflow being devised (separate from developer bugzilla)
  - This is for bugs!

CESM Tutorial

- Last year (S. Bates)
  - ➢ 81 participants
    - – 70 U.S.
    - – 11 International (Europe, Asia, South America, Canada)
  - ➢ Funded by NSF and DOE
- This year: 11-15 August 2014 (A. Phillips)

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First CLM Tutorial, Feb. 18-21
www2.cesm.ucar.edu/events/tutorials/clm/2014

40 students, 15 lectures (incl. 5 by NCAR/CGD postdocs), 5 practical sessions
all materials available online

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CESM WORKSHOP 2014

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CESM Workshop

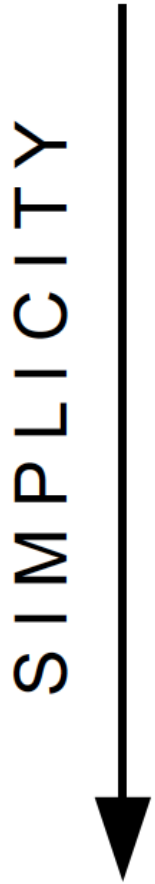
- Two invited speakers
  - Peter Clark (OSU)
  - John Fyfe (Env. Canada)
- Cross-WG sessions (in addition to tutorial)
  - Simpler models (L. Polvani and R. Neale)
  - BGC/chemistry couplings (L. Emmons and K. Lindsay)
  - Model testing tools (Jay Shollenberger)
  - Coupled model-up spinup and tuning (C. Hannay and C. Jackson)
  - Isotopes (B. Otto-Bliesner and C. Koven)

simplER models within CESM...?

amy clement & lorenzo polvani

- why we need a hierarchy of models
- what the university colleagues think
- what a hierarchy might look like
- questions & discussion

an example CESM model hierarchy



+ a fully coupled CMIP-class atmos-ocean-land-sea-ice model
+ an atmosphere only model (w/ slab ocean or spec'd SSTs)
+ an aquaplanet atmosphere w/ slab ocean (Lee et al. 2008)
+ a dry dynamical core (see Held & Suarez 1994)
+ a shallow water model on the sphere
+ a single-column model

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COMMUNITY PROJECTS

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Large Ensemble

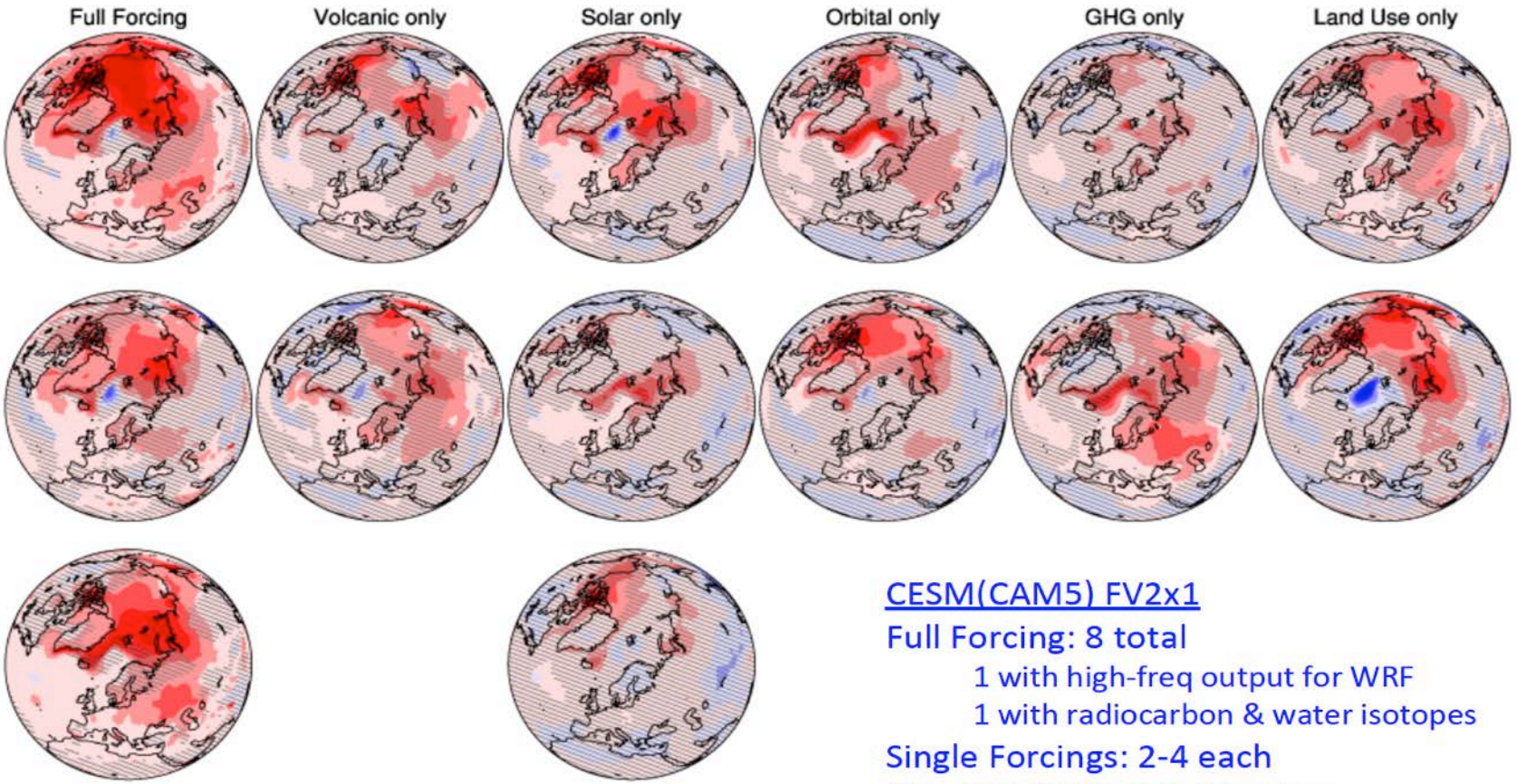
- CESM1-CAM5-BGC 1 degree
- Long control simulation (1500+ years)
- One member 1850-2080
- 29 members 1920-2080 (20 extended to 2100)
- 7-10 additional members being run in Toronto (Paul Kushner's group)
- BAMS paper submitted
- Data publicly available this week on ESG

LE Data Access

- CESM-LE website = where you can learn about the experiment, see diagnostics etc. http://www2.cesm.ucar.edu/models/experiments/LENS/
- ESG = where you can get all data https://www.earthsystemgrid.org
- Also: /glade/p/cesm0005 partition for users with yellowstone access

Last Millennium Ensemble Project

Surface Temperature Change: Medieval Climate Anomaly – Little Ice Age
(950-1250 CE) (1400-1700 CE)



CESM(CAM5) FV2x1

Full Forcing: 8 total

- 1 with high-freq output for WRF
- 1 with radiocarbon & water isotopes

Single Forcings: 2-4 each

Also WACCM5: 1 full forcing

CESM Paleoclimate Working Group

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HIGHLIGHTS AND UPDATES

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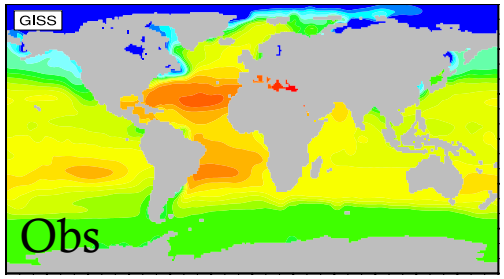
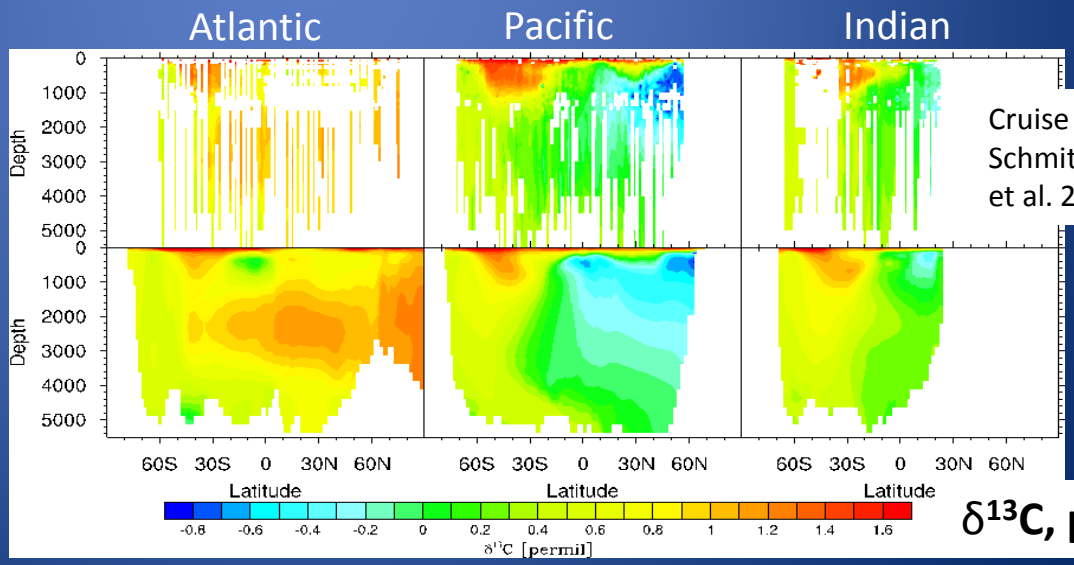
Results from the isotope enabled CESM

Surface water isotope ($\delta^{18}O$, per mil) distribution



Zonal carbon isotope ($\delta^{13}C$) distribution



Cruise data; Schmittner et al. 2013

$\delta^{13}C$, per mil

Slide courtesy of A. Jahn, E. Brady
The iCESM project is funded by DOE, Office of Science

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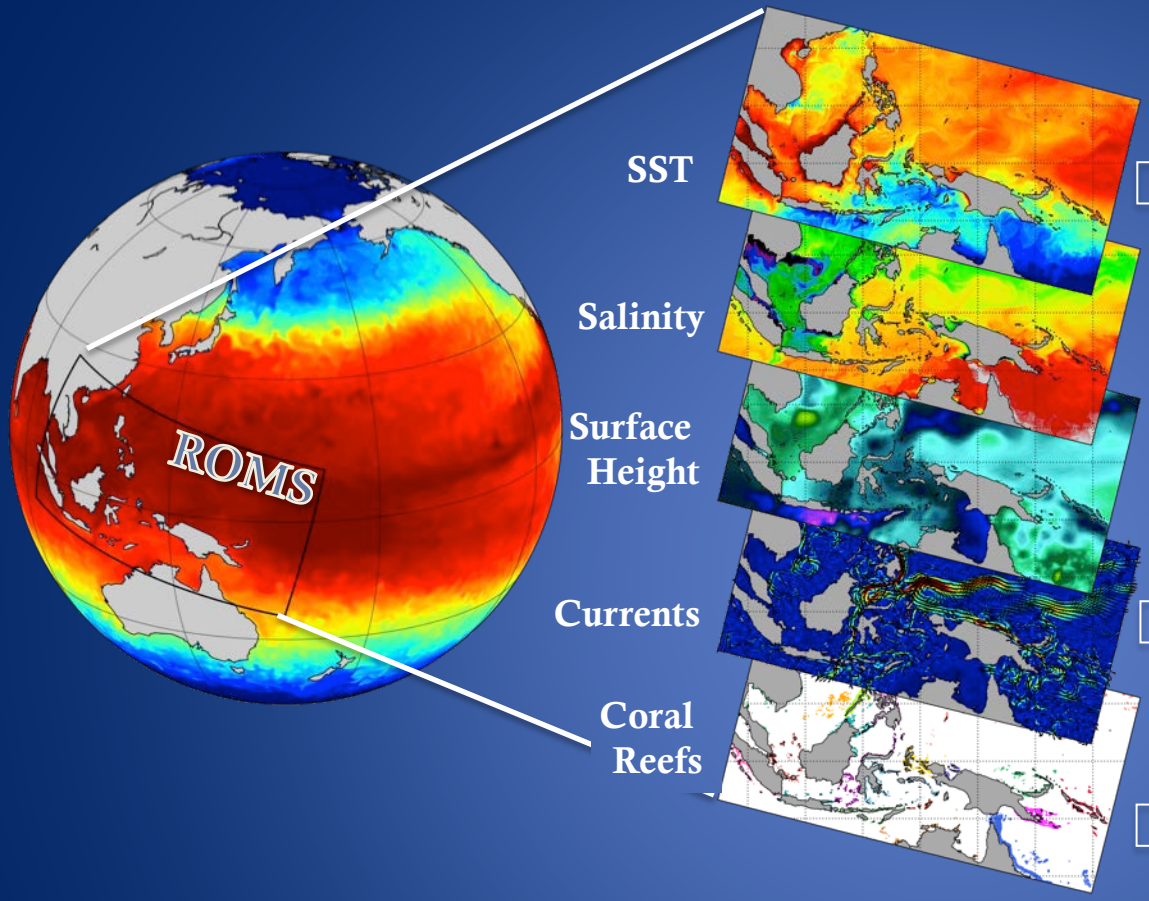
Community Ocean Vertical Mixing (CVMix) Project

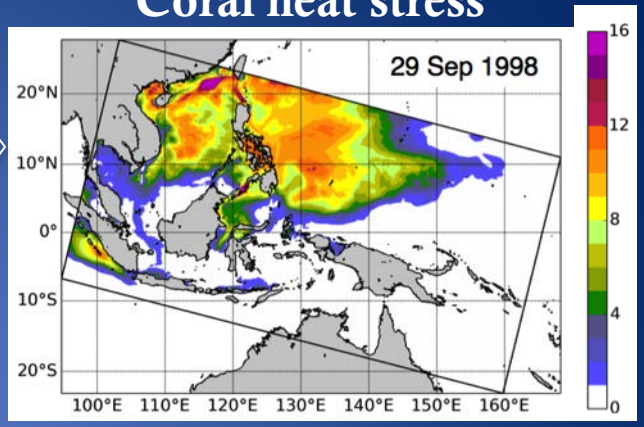
- CVMix is a software package that aims to provide transparent, robust, flexible, well documented, and shared Fortran source codes for use in parameterizing vertical mixing processes in numerical ocean models.
- The project is focused on developing software for a consensus of first-order closures that return a vertical diffusivity, viscosity, and possibly a non-local transport, with each variable dependent on prognostic model fields.
- CVMix modules are written as kernels designed for use in a stand-alone manner or in a variety of Fortran ocean model codes such as MPAS-O, MOM, and POP.

NCAR: Michael Levy, Gokhan Danabasoglu, Bill Large
LANL: Todd Ringler, Doug Jacobsen
GFDL: Stephen Griffies, Alistair Adcroft, Robert Hallberg

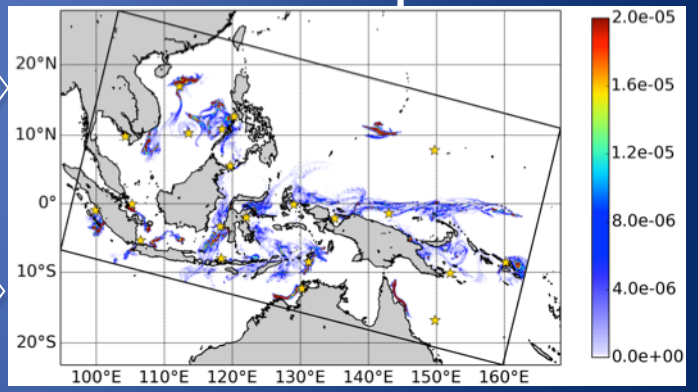
Using CESM output in marine ecosystem research



Coral heat stress



Larval transport



Goal: How will climate change affect marine ecosystems in the western tropical Pacific?

Method: Dynamical downscaling of CESM using a 5-km Regional Ocean Model System (ROMS)

Results: Identify regions for conservation: low heat stress, important sources/sinks of larvae

Coral Triangle Project: J. Kleypas, F. Castruccio, D. Thompson, E. Curchitser (Rutgers), and The Nature Conservancy. *See the posters by Castruccio and Thompson.*

Sponsors: NSF, Rutgers Univ., and NCAR ISP and ASP programs

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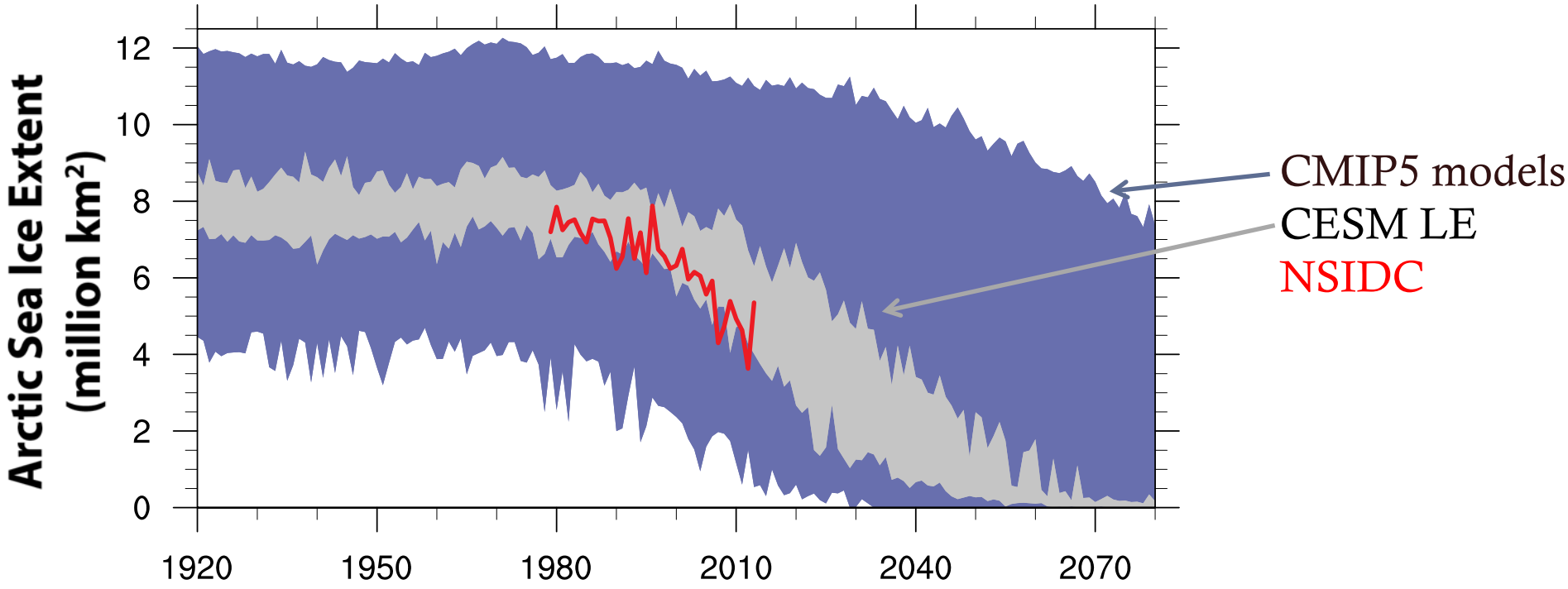
September sea ice extent



Slide courtesy of A. Jahn
CMIP5 data courtesy of A. Barrett and J. Stroeve (NSIDC)

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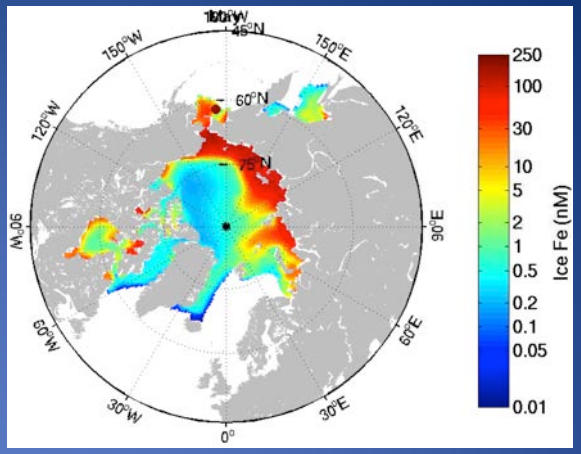
Impact of Sea Ice on the Marine Iron Cycle and Ecosystems

Motivation

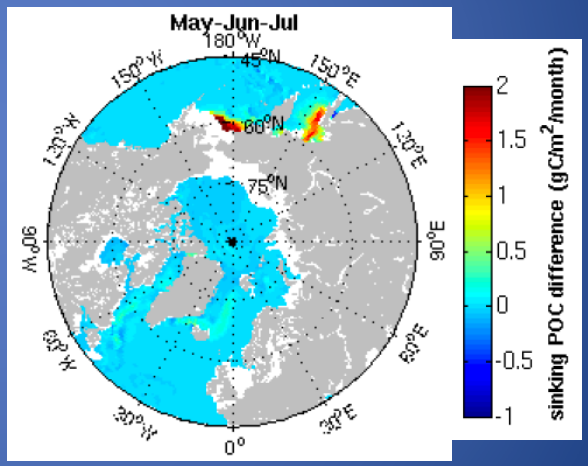
- **Iron is a key nutrient for phytoplankton growth in the surface ocean**. At high latitudes, the iron cycle is closely related to the dynamics of sea ice. Iron sequestration in ice needs to be considered in simulations of the iron cycle and marine ecosystems.

Approach

- Iron is incorporated in CICE4 as a passive tracer.
- **Iron cycles between seawater and ice.**
- Three sources of iron are considered for iron accumulation in sea ice: atmospheric deposition, seawater iron, and suspended sediments in shallow regions.



Simulated iron concentration in sea ice in Arctic spring



Impact of sea ice iron on biological carbon export

Slide courtesy of S. Wang (LANL)

Results

- Sea ice shifts the timing and location of iron supplied to high latitude surface waters.
- Simulated surface iron distributions are improved in the Arctic.
- **Iron released from melting ice increases phytoplankton production in spring and summer.**

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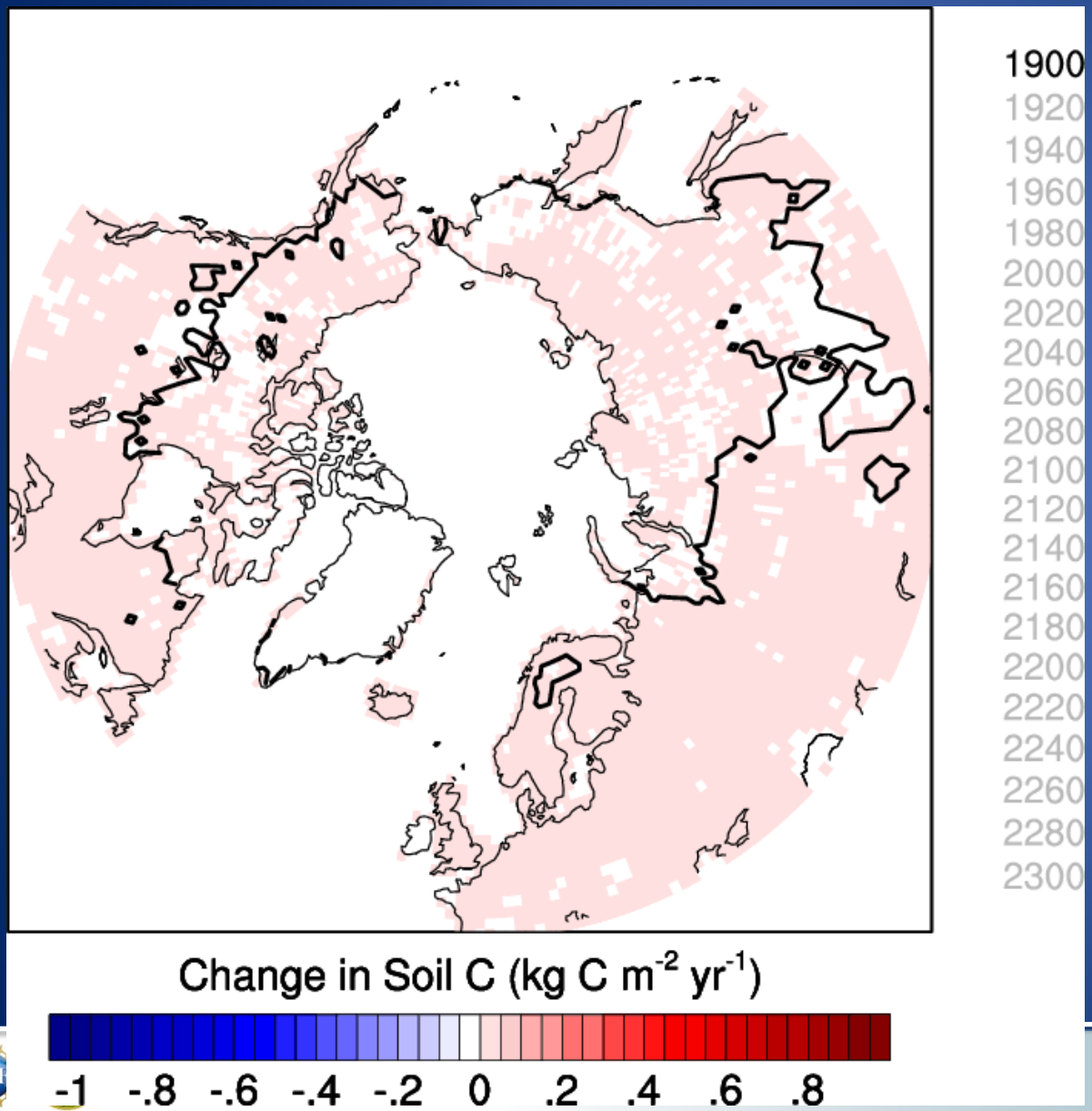
Projected soil C emissions follow retreating permafrost boundary (black line) and persist long after permafrost has thawed



CLM4.5BGC forced with RCP8.5 climate projections

- 17 – 42 Pg of 'deep' C lost by 2100
- 103 – 252 PgC by 2300
- Many potentially important processes still not included or poorly understood

Koven et al., 2014 (submitted)

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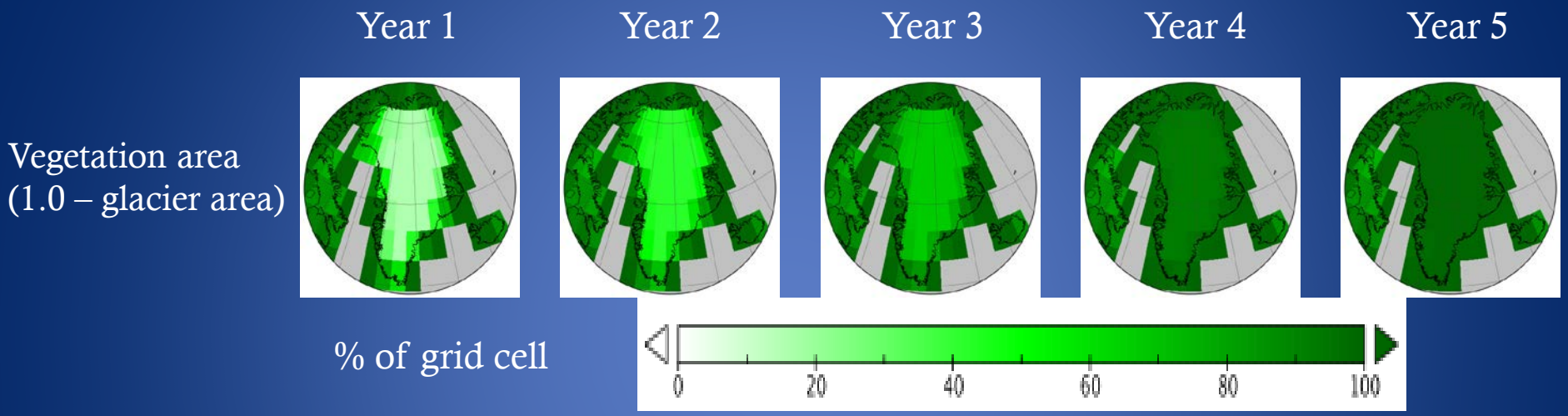
Ice-sheet coupling with dynamic landunits

Fast deglaciation experiment: 100% to 0% in 5 years



Ice sheets can now be coupled interactively in CESM:

- CISM sends ice-sheet extent and elevation to CLM via coupler
- Dynamic landunits in CLM: As ice sheets retreat, glaciated regions are replaced by vegetation
- CAM lower surface responds to evolving ice topography
- This will allow multi-century deglaciation experiments

Slide courtesy of B. Sacks and J. Fyke

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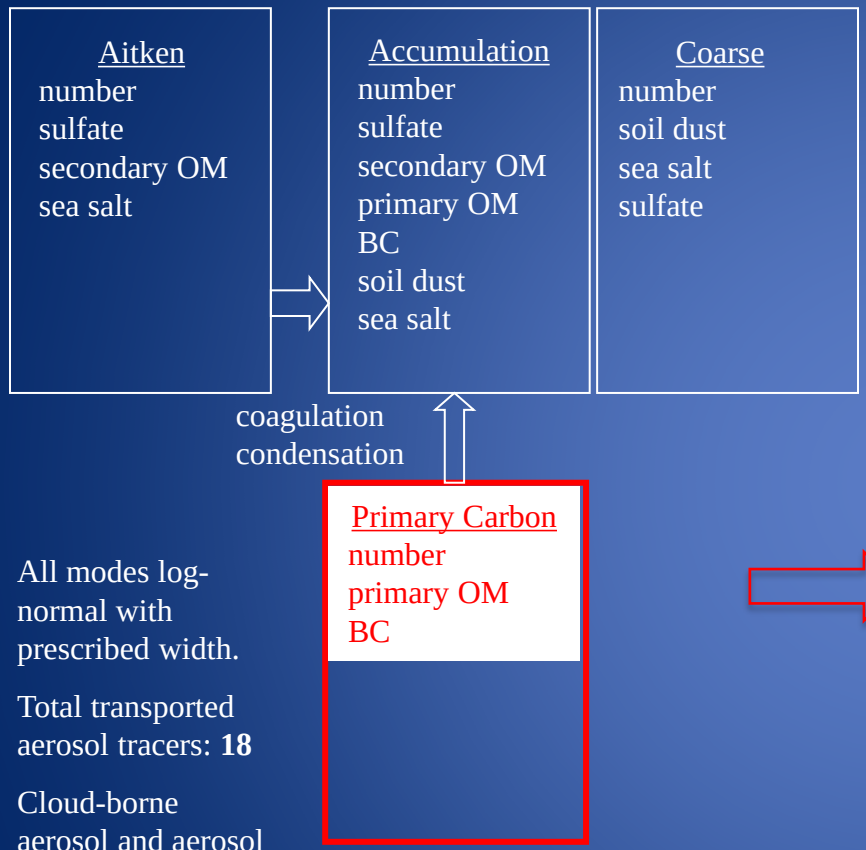
4-mode version of Modal Aerosol Module (MAM4)



All modes log-normal with prescribed width.

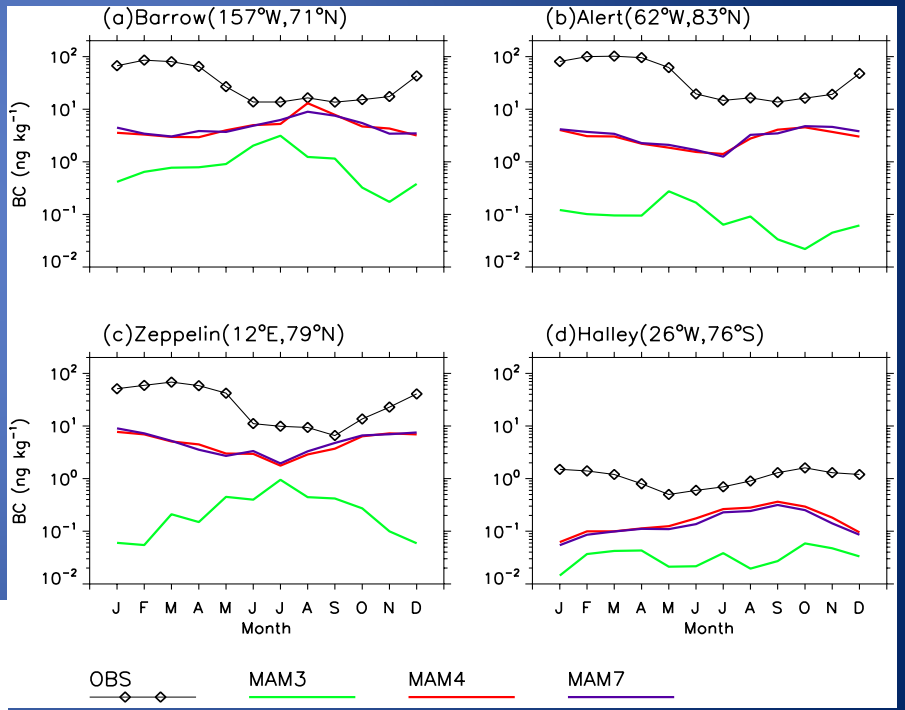
Total transported aerosol tracers: **18**

Cloud-borne aerosol and aerosol water predicted but not transported.

Adding the primary carbon mode to MAM3 increases run time ~10%.
RESTOM change: 0.06 W m^{-2}

Liu et al., in prep, (2014)

MAM4 significantly increases (and improves) BC concentration in Arctic compared to MAM3 (and agrees with MAM7). The remaining underestimation of BC concentration in Arctic in MAM4 is very likely due to wet scavenging by precipitation and/or emissions.



Comparison of model results (MAM3, MAM4, MAM7) with seasonal BC observations at surface in high latitudes

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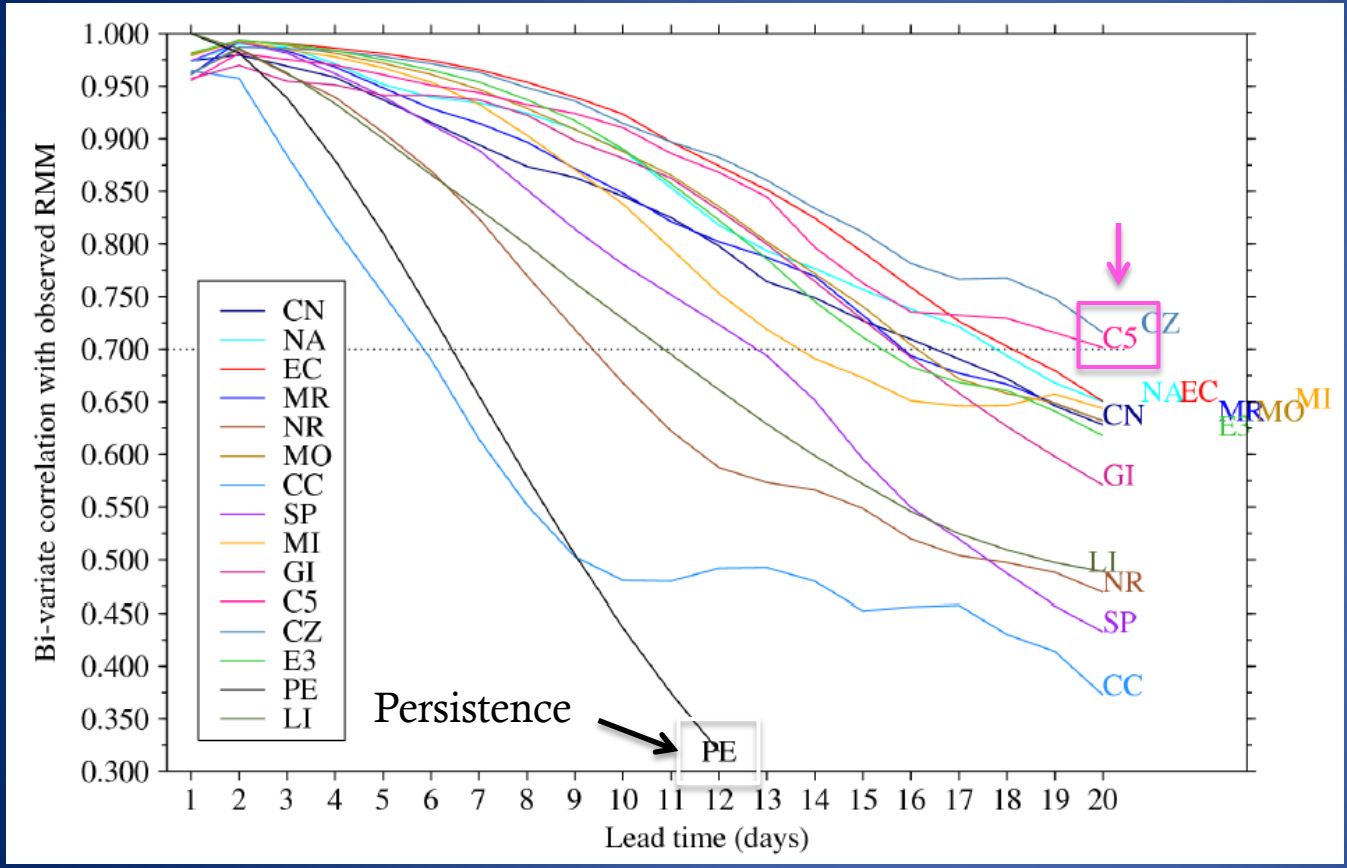
Madden Julian Oscillation (MJO) Hindcasts



Initial forecast mode (CAPT)

During MJO-DYNAMO Campaign

Combined bivariate mode of MJO variability

CAM5 only model to retain skill out to 20 days.

Top performer among participating CMIP5 models.

Courtesy: Nick Klingaman, U. Reading, UK

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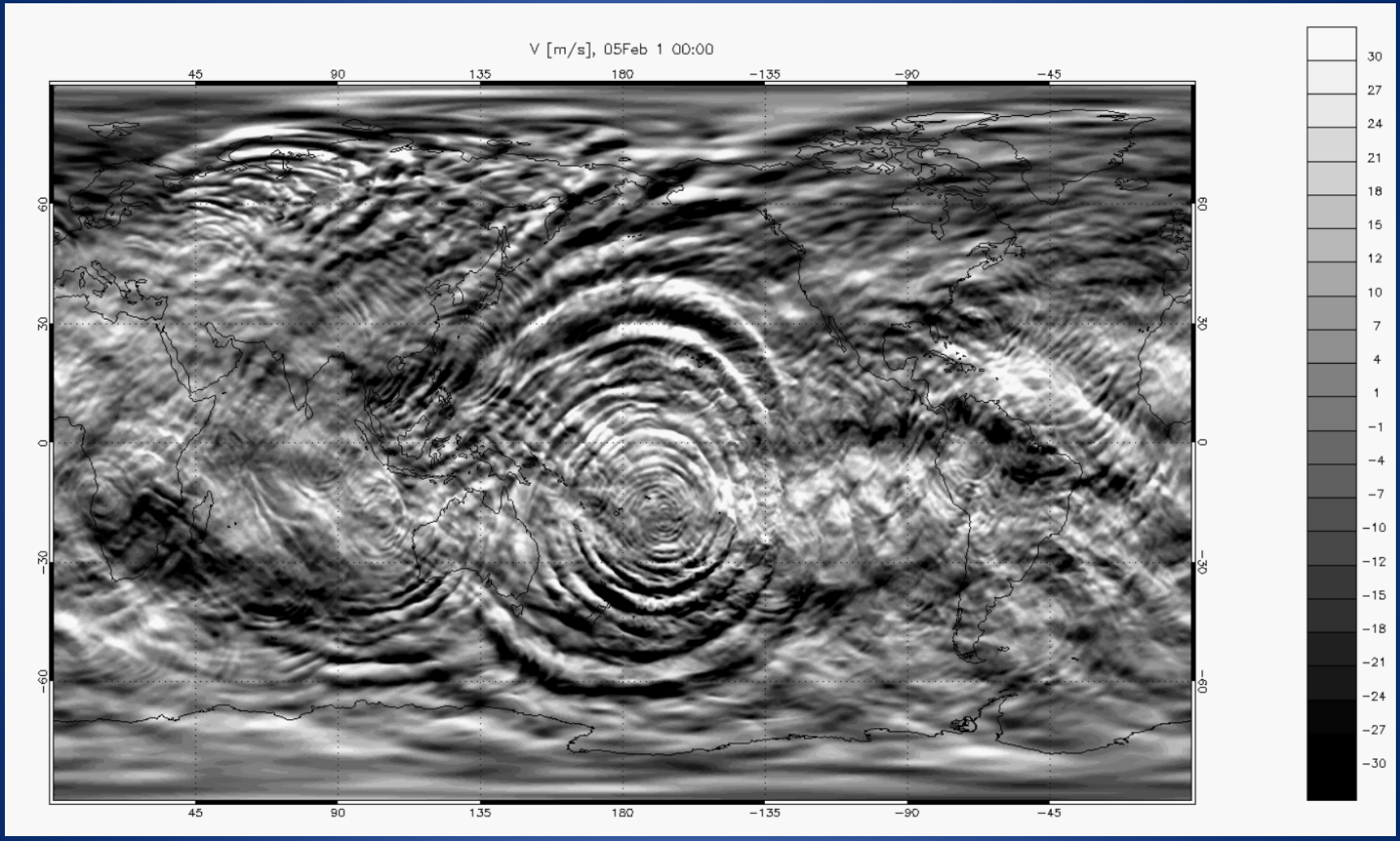
WACCM5-High Res (ne120: ≈25km)
Meridional Wind at ~110km:
Space Weather Driven by Tropospheric Weather



WACCM-X: WAWG Liu Talk

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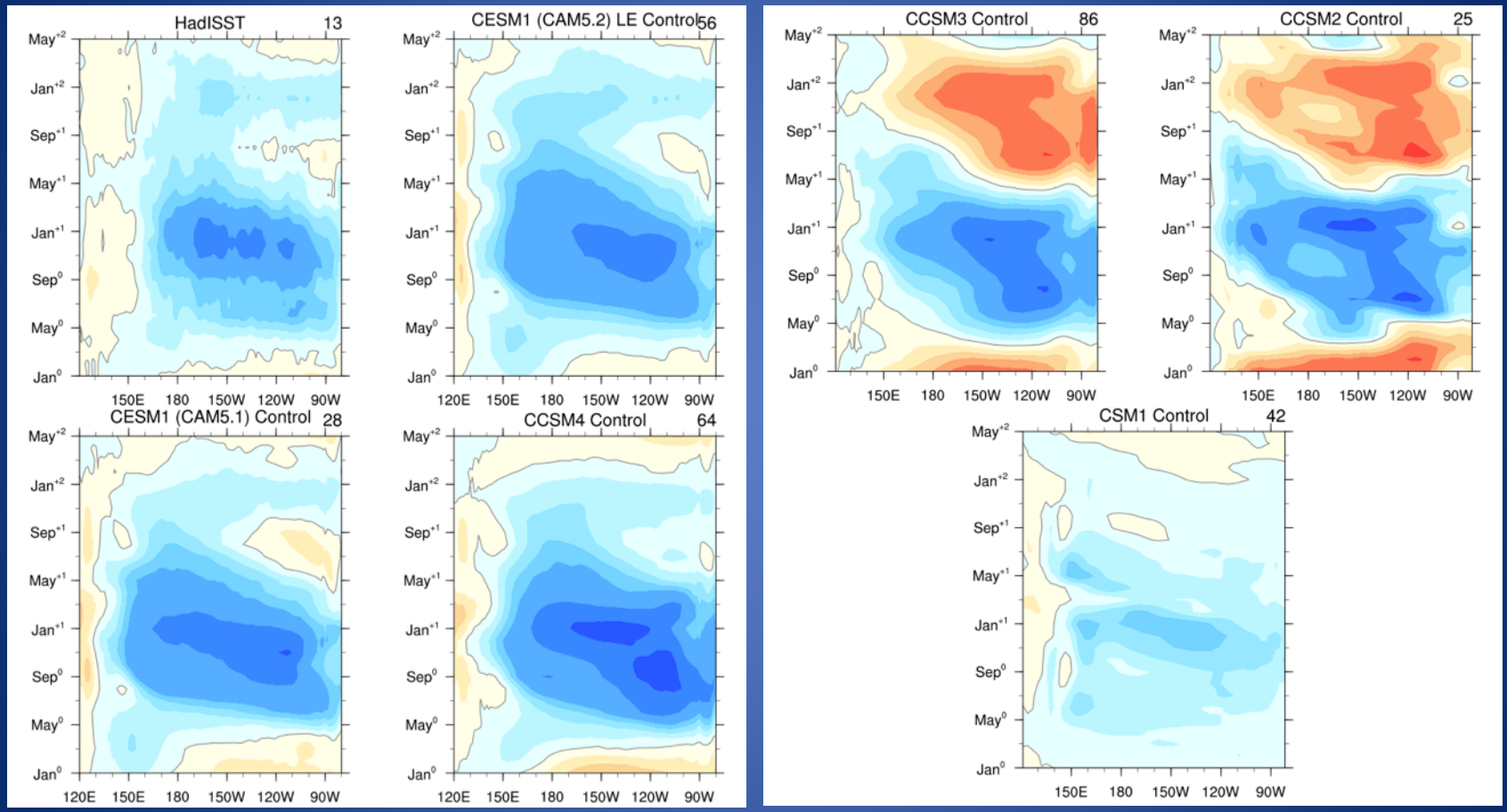
Climate variability: La Nina composites (3°S-3°N)



Slide courtesy of A. Phillips

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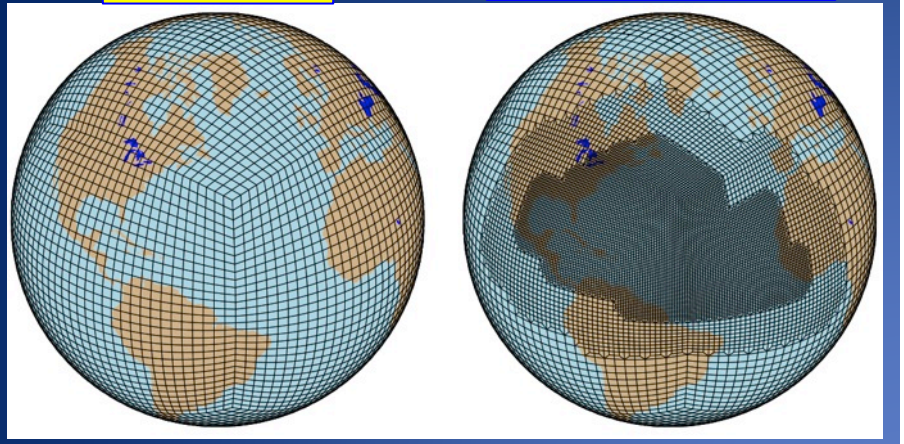
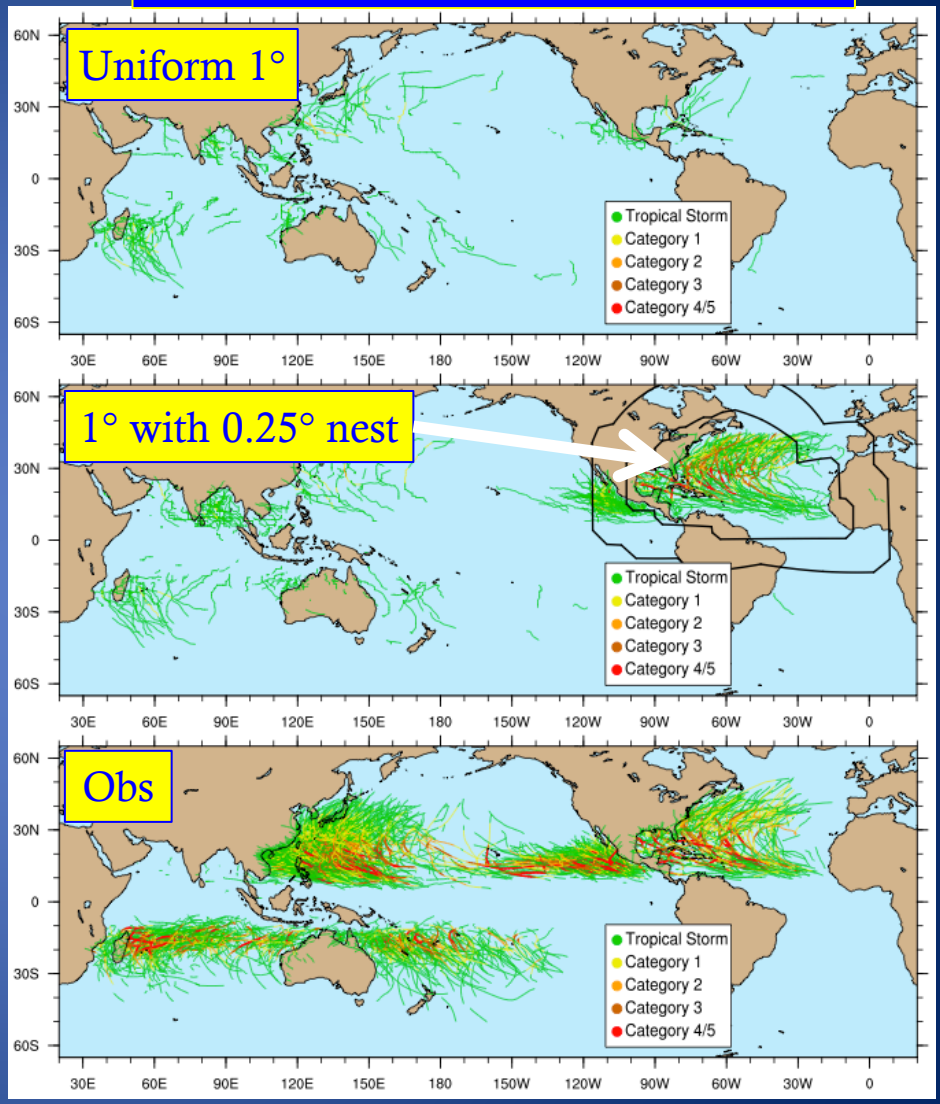
Uniform 1°

1° with 0.25° nest



Tropical cyclone tracks, 1980-2002



- Variable-resolution CAM-SE (CAM5) simulations -> dramatically improved tropical cyclone representation at regional scale
- 0.25° nest produces realistic storm counts/intensities in North Atlantic at 1/6th compute cost of globally-uniform 0.25° mesh

Courtesy: Colin Zarzycki, U. Mich.

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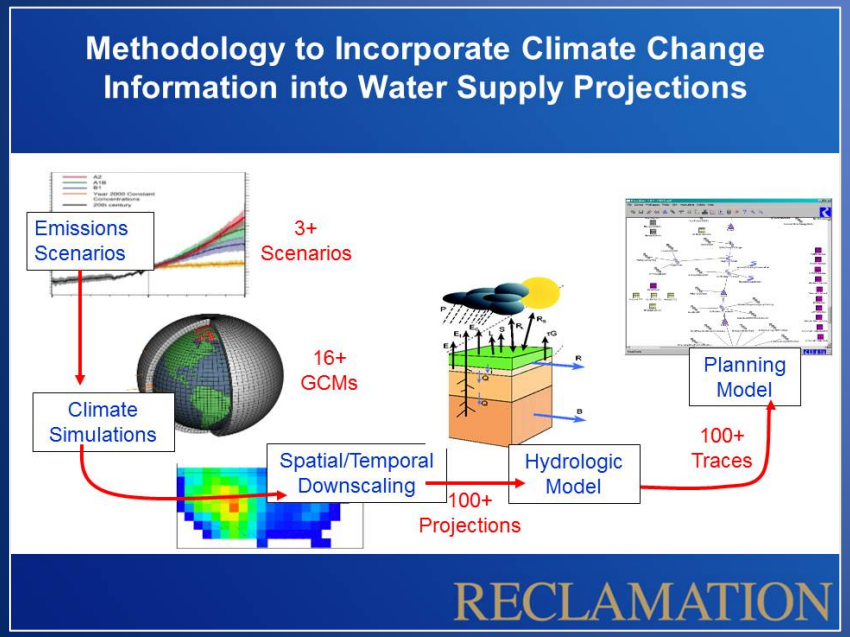
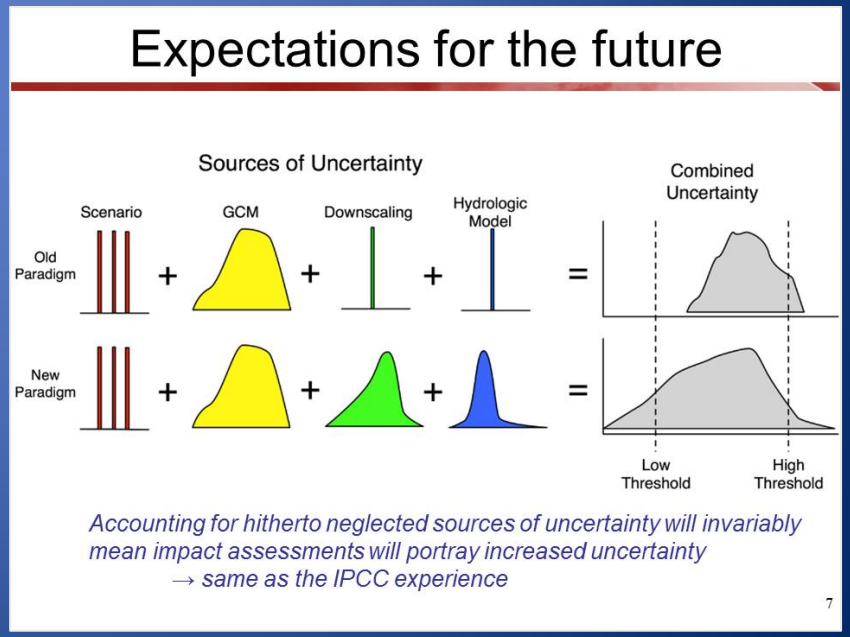
SDWG: How does our portrayal of climate change impacts depend on methodological choices?

Martyn Clark[1], Ethan Gutmann[1], Naoki Mizukami[1], Pablo Mendoza[4],Roy Rasmussen[1], Kyoko Ikeda[1], Andy Wood[1], Balaji Rajagolapan[4],Tom Pruitt[2], Levi Brekke[2], and Jeff Arnold[3]
1. NCAR, 2. Bureau of Reclamation, 3. US Army Corps of Engineers, 4. CU

Projected outcomes on water resources depend significantly on subjective decisions made in calibrating hydrologic models, such as the choice of forcing data, the choice of calibration scheme, and the choice of objective function

The state of the practice does not fully recognize these uncertainties – many studies are likely 'overconfident'





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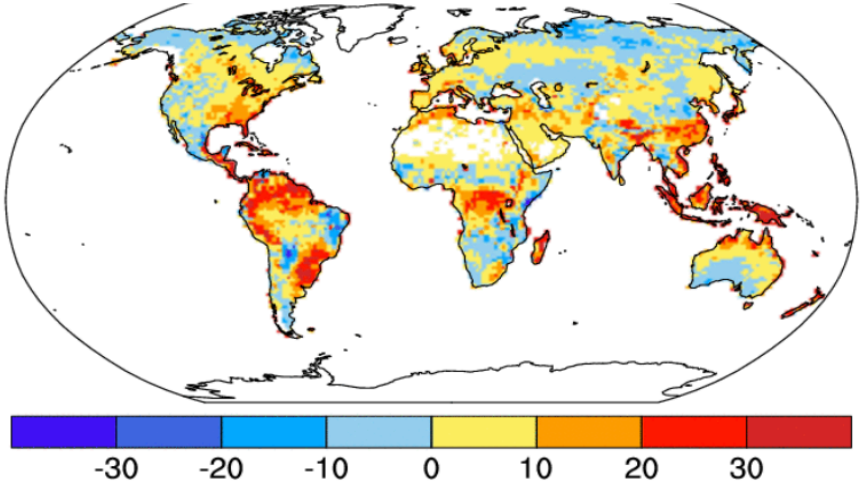
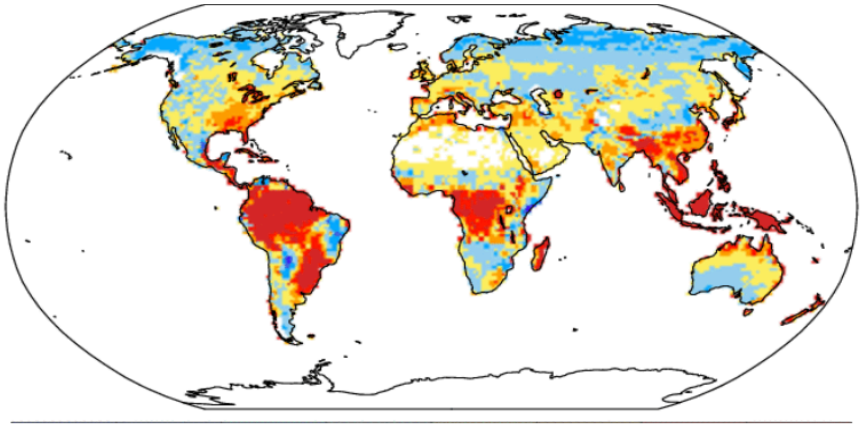
Reduced biases in CLM4.5

ANN Latent Heat bias (obs: FLUXNET MTE)

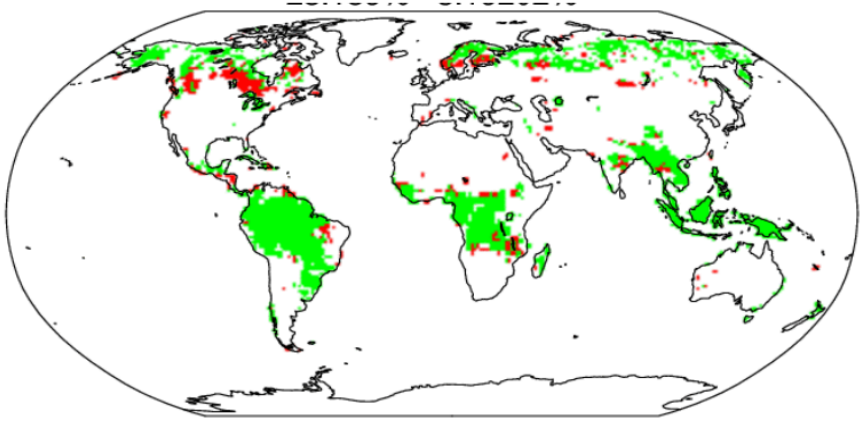
CLM4.5BGC



CLM4CN



Green: Improved in CLM4.5
Red: Degraded in CLM4.5



	CLM4	CLM4.5
LH (W m^{-2})	8.9	5.9
GPP (gC m^{-2} d^{-1})	0.41	0.07
Albedo (%)	-0.41	-0.52

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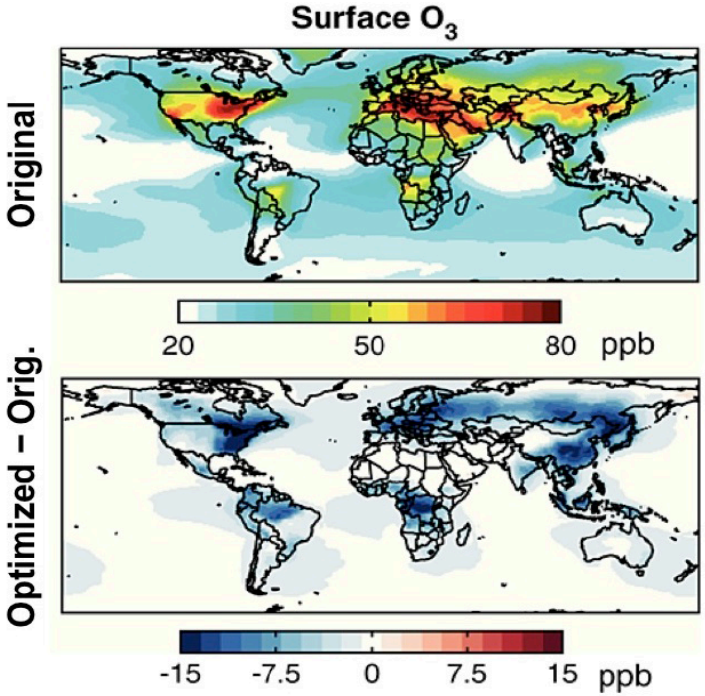
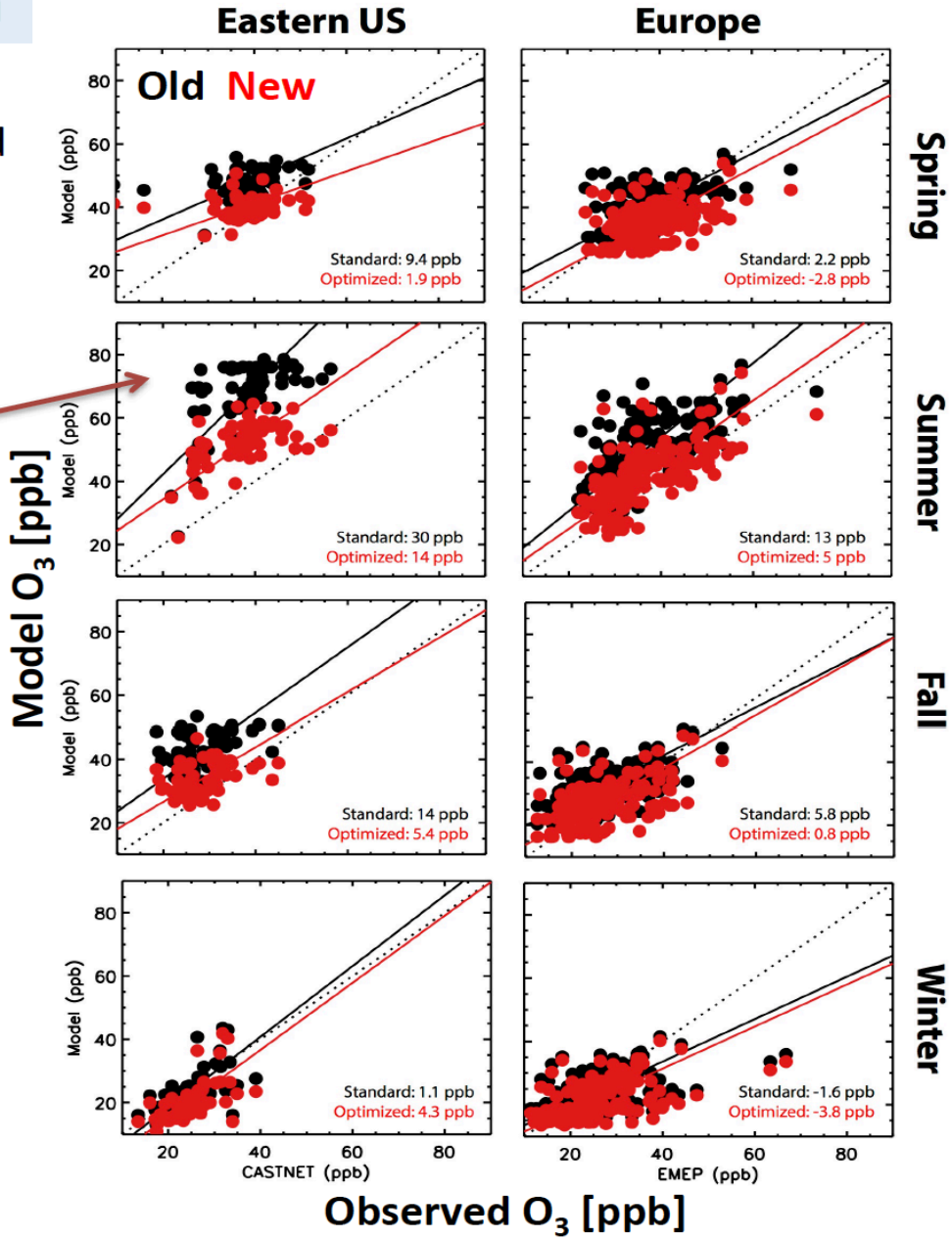
Ozone Dry Deposition Correction

Dry deposition parameterization in MOZART and CAM-chem lacked coupling of leaf and stomatal vegetation resistances to LAI

Correcting this and optimizing to observations improves model surface ozone

Summer U.S. bias reduced (30 to 14 ppb)





M. Val Martin, et al., GRL, 2014

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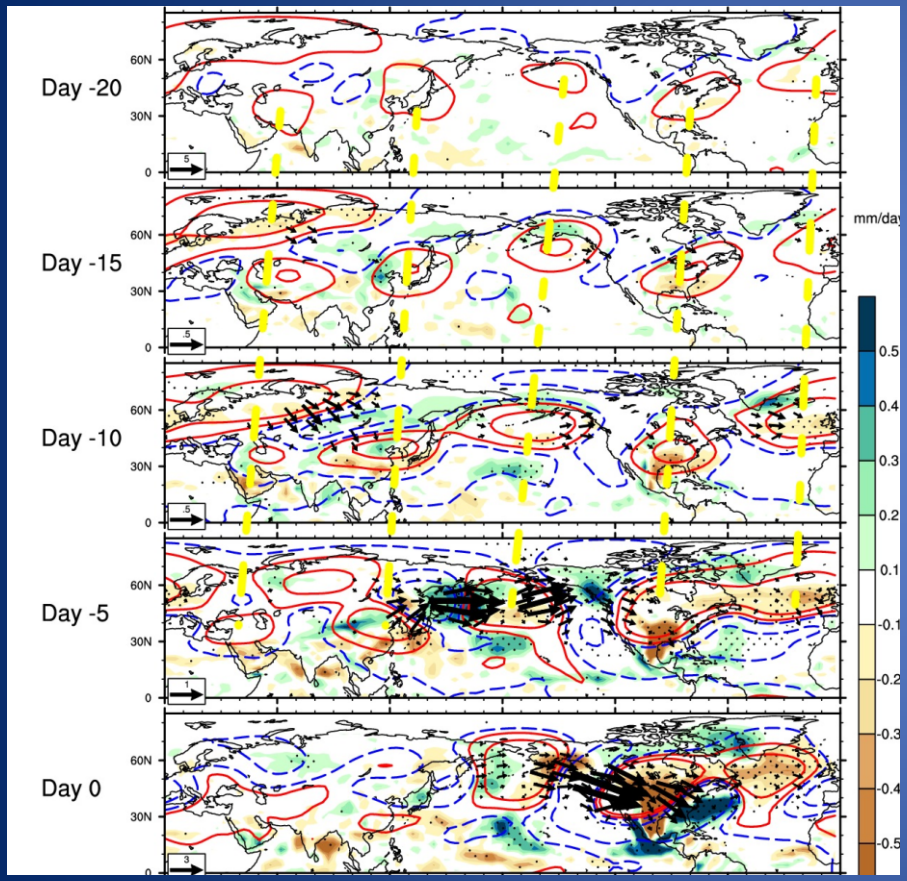
Probability of US Heat Waves Affected by a Subseasonal Planetary Wave Pattern

Haiyan Teng, Grant Branstator, Hailan Wang, Gerald A Meehl, Warren Washington



Contours: 300hPa streamfunction. Shading: precipitation. Arrows: Plumb vectors indicating energy propagation

- Based on a 12,000-year integration of an atmospheric general circulation model CAM3, we identified a striking zonal wavenumber-5 Rossby wave pattern that is responsible for many US heat waves.
- This pattern can improve probability forecasts of US heat waves 15 days in advance in the model – a one or two standard deviation wave5 event makes a future heat wave twice or four times as likely to happen.
- This pattern resembles the leading pattern of subseasonal variability in nature. It has been associated with some historical droughts that lasted longer than subseasonal time scales (e.g. the 1952-1954 , 1988 droughts).

Teng, H., G. Branstator, H.Wang, G.A.Meehl, W.M.Washington, 2013: Probability of US heat waves affected by a subseasonal planetary wave pattern. Nature Geoscience, **6**, *1056-1061.*

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CMIP6 AND CESM2

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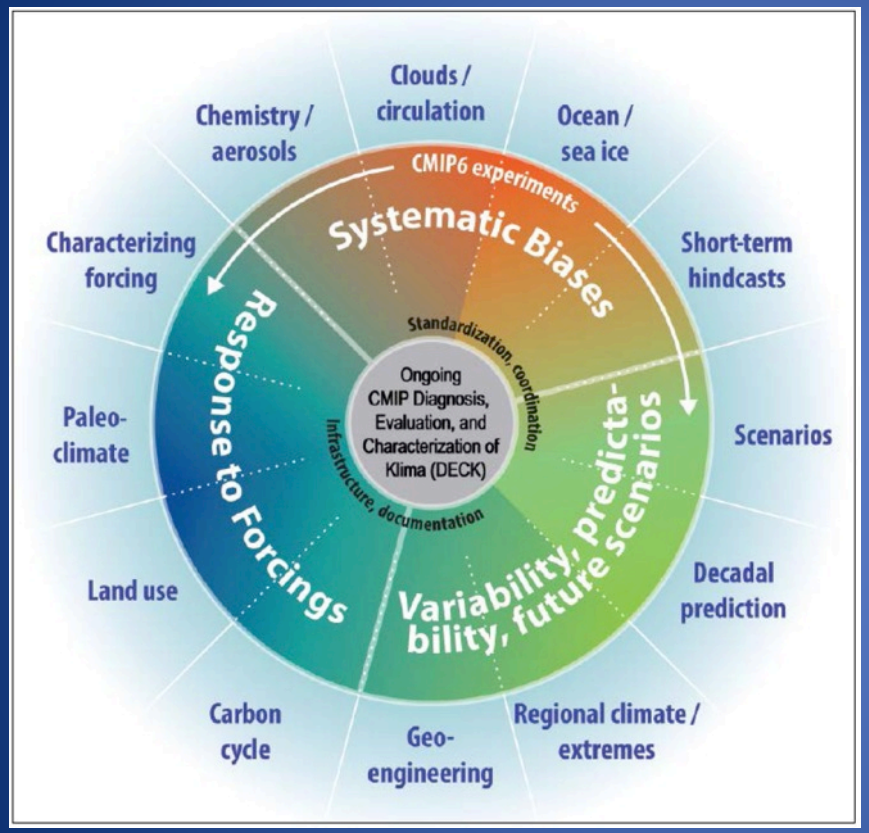
CMIP6 organization and schedule



Proposed experiments to be discussed in October 2014

This is an important opportunity to provide input to what interesting science questions this community is interested in tackling

Topic of Thursday 12pm wrap-up

Meehl et al., EOS, 2014

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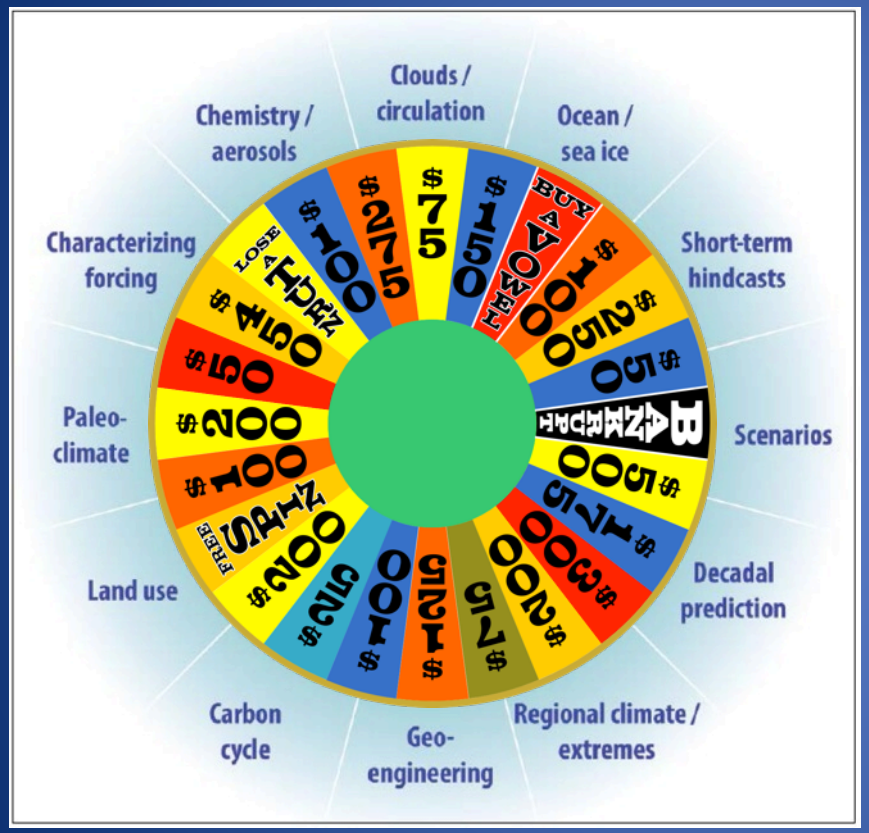
CMIP6 organization and schedule



Proposed experiments to be discussed in October 2014

Simulation phase: 2015-2020

Limiting factors in performing simulations:

- People
- Computing time
- Data volume

Meehl et al., EOS, 2014

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CESM2 targets and timeline

- CESM2 release June 2016
- 2 main target configurations for CMIP6
  - 1-degree CAM5.5 (FV or SE)
    - ⟹ for BGC/Chemistry/WACCM/Paleo/…
  - ¼-degree CAM6-SE
- CAM5.5 to be finalized by winter AMWG and released by June 2015 to allow for testing and development of other components

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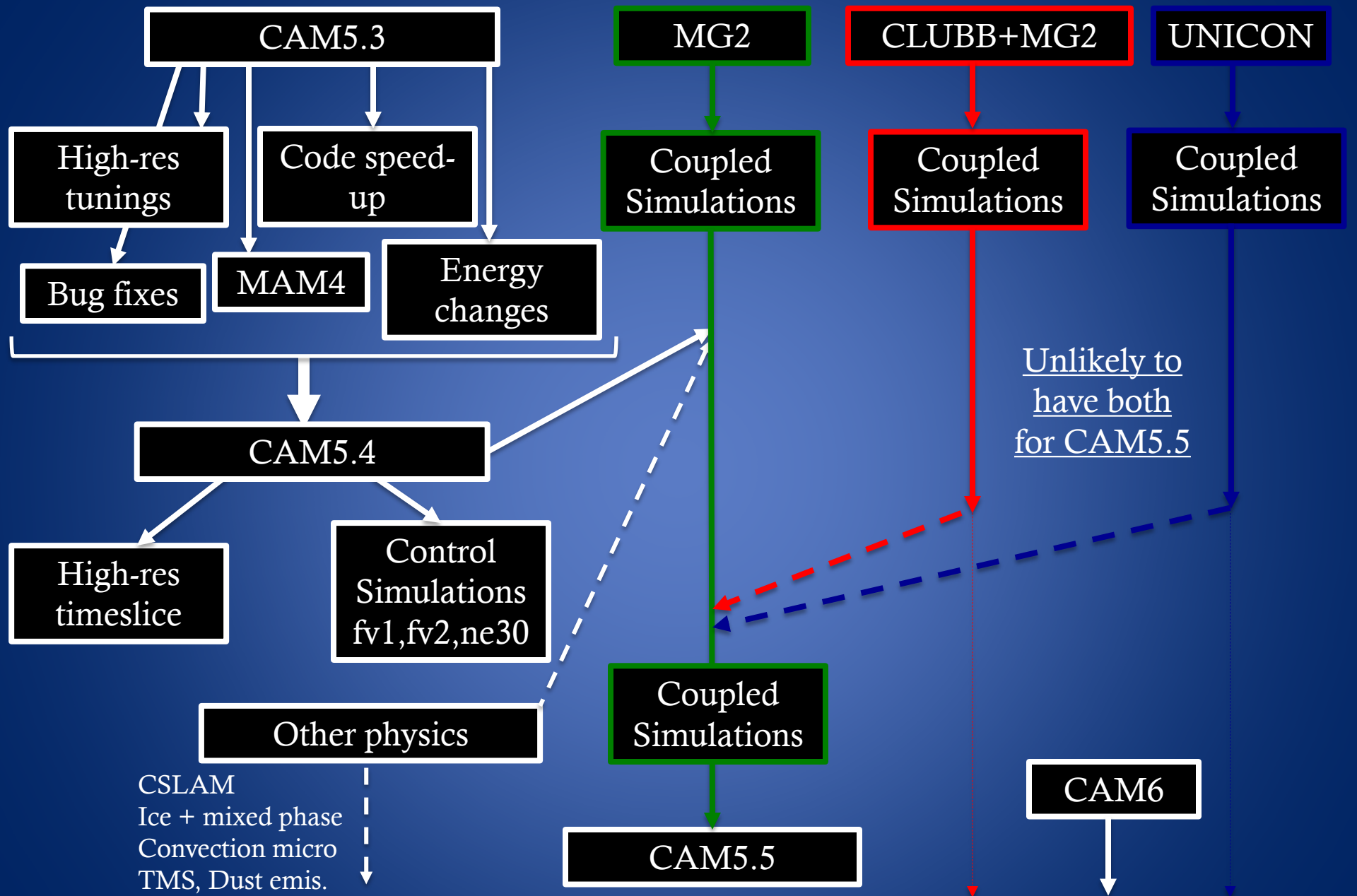

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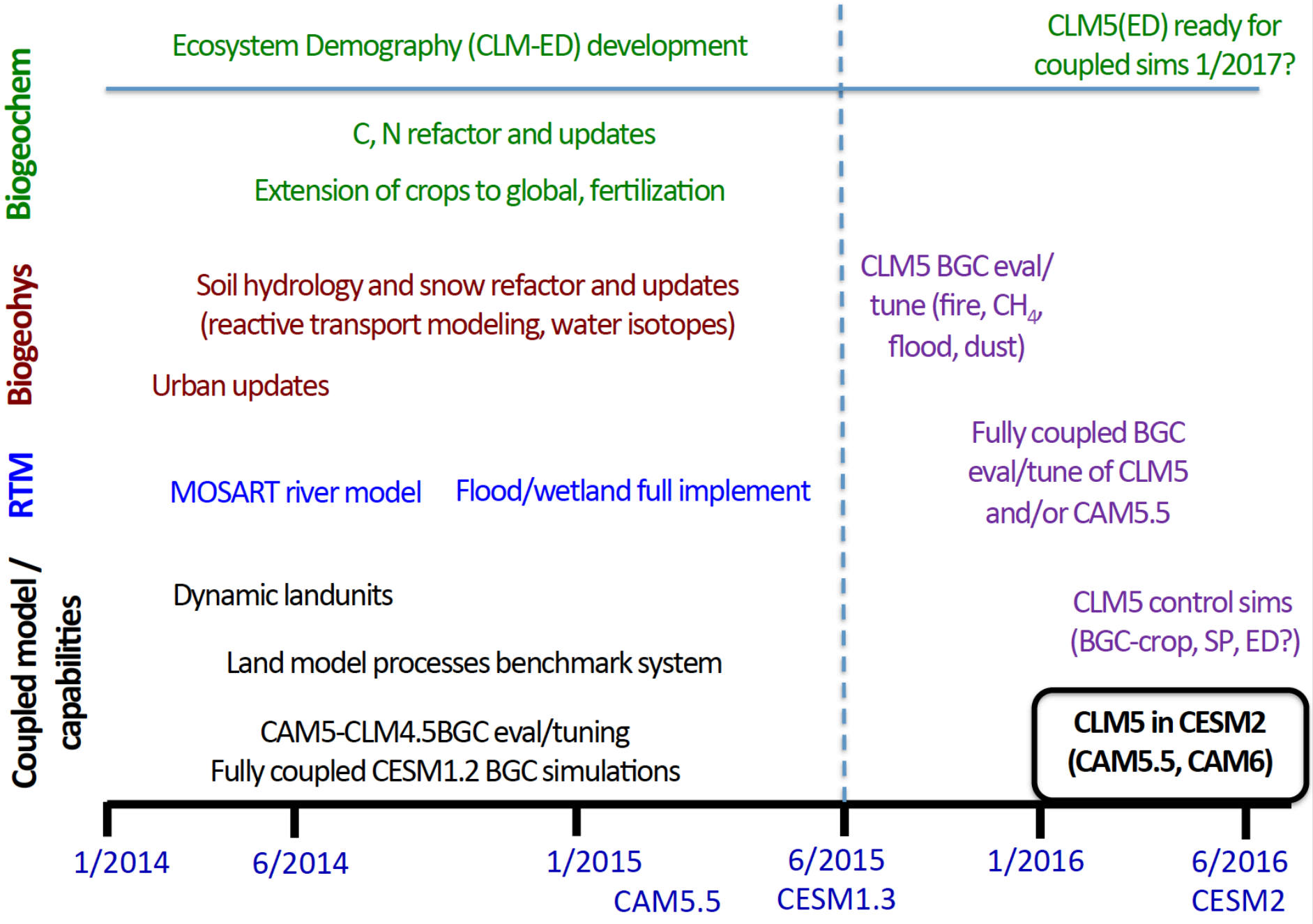
CLM Development Timelines: *The path towards CLM5/CESM2*



CSL PROPOSAL

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Proposal

- Large request for development/production/community projects
- Last proposal (18 months): http://www.cesm.ucar.edu/management/CSL/CSL12-14ProposalCESMFinal.pdf
  - Production/Community requested: 115M core-hours
  - Development requested: 61M core-hours
  - ~ 80% funded
- Plan for 2 years (CESM2 development), but split between years 1 and 2
- Science driven
- Prioritization A/B/C
- Proposal by each WG needed by mid-August 2014
- Timings (will be updated): http://www.cesm.ucar.edu/models/cesm1.2/timing/

In summary:

- CESM is a flexible, extensible and well supported community tool
- Moving towards CESM2 and CMIP6
- CSL proposals due mid-August

NCAR is sponsored by the National Science Foundation

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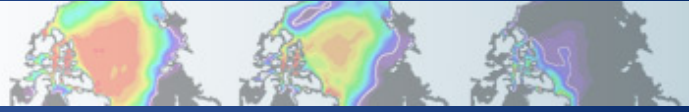

Questions? Comments?

Purple: precipitation

Slide courtesy of R. Knutti and O. Stebler

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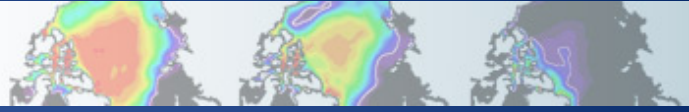

2014 CESM Distinguished Achievement Award

Jean-François Lamarque
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Marika Holland (NCAR)

"Marika embodies the community ethos of CESM by collaborating willingly and widely with other polar scientists within the PGWG and beyond, in addition to interacting with the broader world of climate modelers and climate-change researchers"

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