State of CESM

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NCAR
Twitter: #CESM19
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
Societal Dimensions Working Group

Allison Thomson (PNNL)  Brian O’Neill (NCAR)
Bill Gutowski (Iowa State University)  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
A truly global community

Download of release version since 2010
And growing!

Registered users (2010-1024)
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
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)
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
CESM Workshop

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

Full Forcing Volcanic only Solar only Orbital only GHG only Land Use only

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
HIGHLIGHTS AND UPDATES
Results from the isotope enabled CESM

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

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

Cruise data; Schmittner et al. 2013

The iCESM project is funded by DOE, Office of Science
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

**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
September sea ice extent

Arctic Sea Ice Extent (million km²)

1920 1950 1980 2010 2040 2070

CMIP5 models
CESM LE
NSIDC

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

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.**

Slide courtesy of S. Wang (LANL)
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)
Ice-sheet coupling with dynamic landunits

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

Year 1  Year 2  Year 3  Year 4  Year 5

Vegetation area (1.0 – glacier area)

% of grid cell

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
4-mode version of Modal Aerosol Module (MAM4)

- Aitken number
- Accumulation number
- Coarse number

- sulfate
- secondary OM
- number
- sulfate
- secondary OM
- number
- primary OM
- number
- soil dust
- sea salt
- sea salt

- 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\(^{-2}\)

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

Liu et al., in prep, (2014)
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
WACCM5-High Res (ne120: ≈25km)
Meridional Wind at ~110km:
Space Weather Driven by Tropospheric Weather

V [m/s], 05Feb 1 00:00

WACCM-X: WAWG Liu Talk
Climate variability: La Nina composites (3°S-3°N)
• 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

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’.

Accounting for hitherto neglected sources of uncertainty will invariably mean impact assessments will portray increased uncertainty — same as the IPCC experience.
Reduced biases in CLM4.5

ANN Latent Heat bias (obs: FLUXNET MTE)

CLM4.5BGC

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

CLM4CN

<table>
<thead>
<tr>
<th></th>
<th>CLM4</th>
<th>CLM4.5</th>
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<tbody>
<tr>
<td>LH (W m^{-2})</td>
<td>8.9</td>
<td>5.9</td>
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<tr>
<td>GPP (gC m^{-2} d^{-1})</td>
<td>0.41</td>
<td>0.07</td>
</tr>
<tr>
<td>Albedo (%)</td>
<td>-0.41</td>
<td>-0.52</td>
</tr>
</tbody>
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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
Probability of US Heat Waves Affected by a Subseasonal Planetary Wave Pattern

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

- 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).

CMIP6 AND CESM2
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
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
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
CSL PROPOSAL
Proposal

• Large request for development/production/community projects
• Last proposal (18 months):
    – 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
Questions? Comments?

Purple: precipitation

Slide courtesy of R. Knutti and O. Stebler
2014 CESM Distinguished Achievement Award
“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“