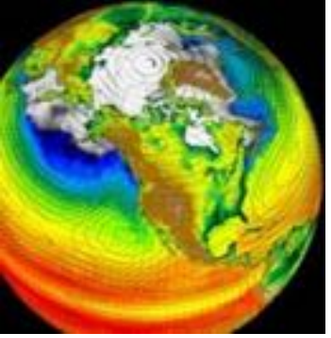
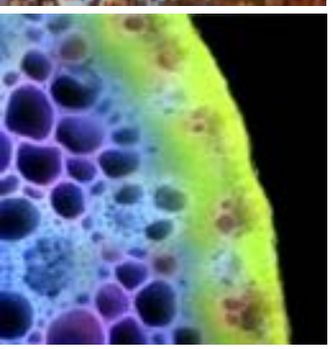
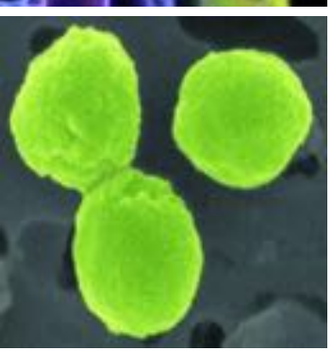


Department of Energy Modeling Interests and Activities in Predictability

ESPC S2S Metrics and V&V Workshop

Dorothy Koch & Renu Joseph
Earth and Environmental Systems Modeling

Department of Energy, Office of Science
Office of Biological and Environmental Research

February 28, 2018

DOE mission and Earth system prediction modeling

Energy security challenges:

- **Energy delivery** to consumers today and in future must be uninterrupted and affordable
- **Resilient designs** over lifetimes that extend 50-100 years into future
- **Extreme event aware** Energy facilities and processes are vulnerable to extreme events

Research foci, primarily for S2D statistical predictability

- Droughts (water for power plants)
- Storms and floods
- Extreme heat
- Sea-level rise and storm surge for coastal infrastructure

Outline

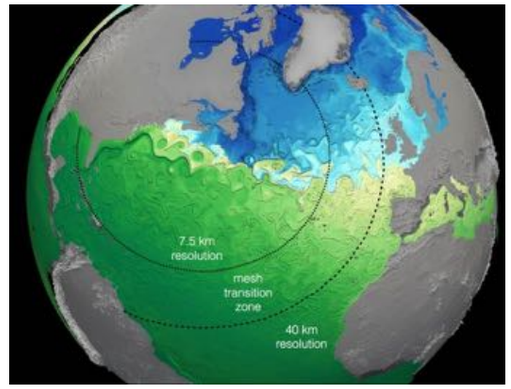
1. E3SM overview
2. E3SM current capabilities
3. E3SM metrics
4. Clouds: CAUSES, CAPT
5. CASCADE: Extremes diagnostics
6. WACCEM: Water cycle science
7. High-resolution model initialization workshop

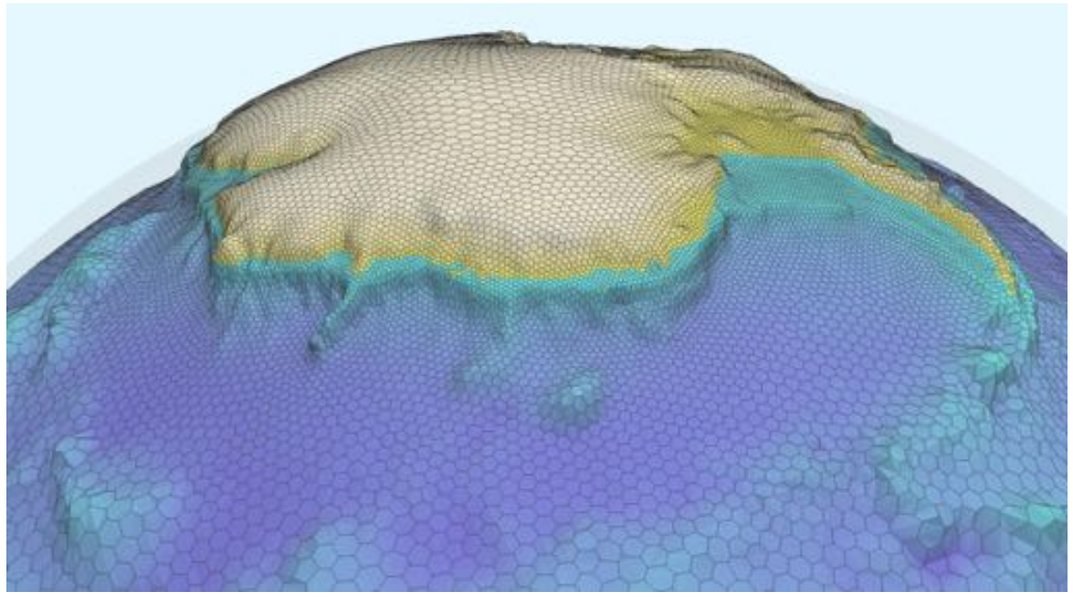
Energy Exascale Earth System Model Overview

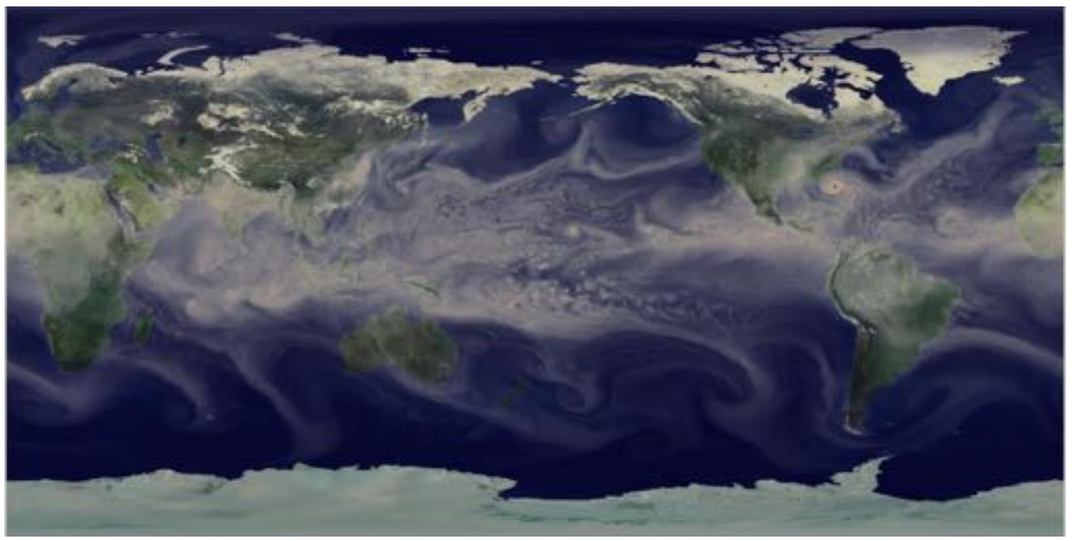
E3SM is a DOE-Office of Science model project and model

Unique features:

- major effort to use DOE supercomputers and advanced software practice
- Focus is on high-resolution configuration (25km) and the coupled system
- DOE science and mission are central to the development priorities
- Variable-resolution-mesh capabilities included in all components (up to 10km atmos, 6km ocean, 500m ice-sheet)







Science Goals

- "Water cycle": What factors govern precipitation and water cycle (land-atmosphere-ocean) now and in the future? How will freshwater supplies change?
- "Cryosphere-ocean": What is likelihood of Antarctic-ice-sheet destabilization, regional sea-level changes and storm-surge?
- "Biogeochemistry": What are the effects of nutrients and land-use on soil carbon reservoirs?

Model Release

- Version 1 "v1" model release in April, 2018
- Initial release will be water cycle configuration

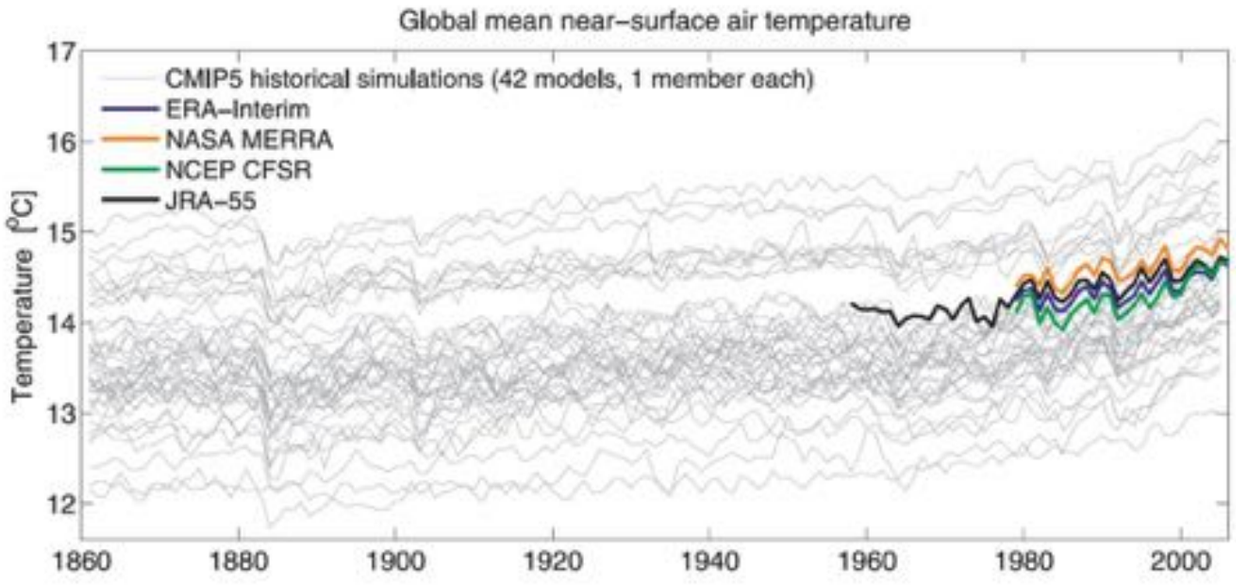
E3SM capabilities

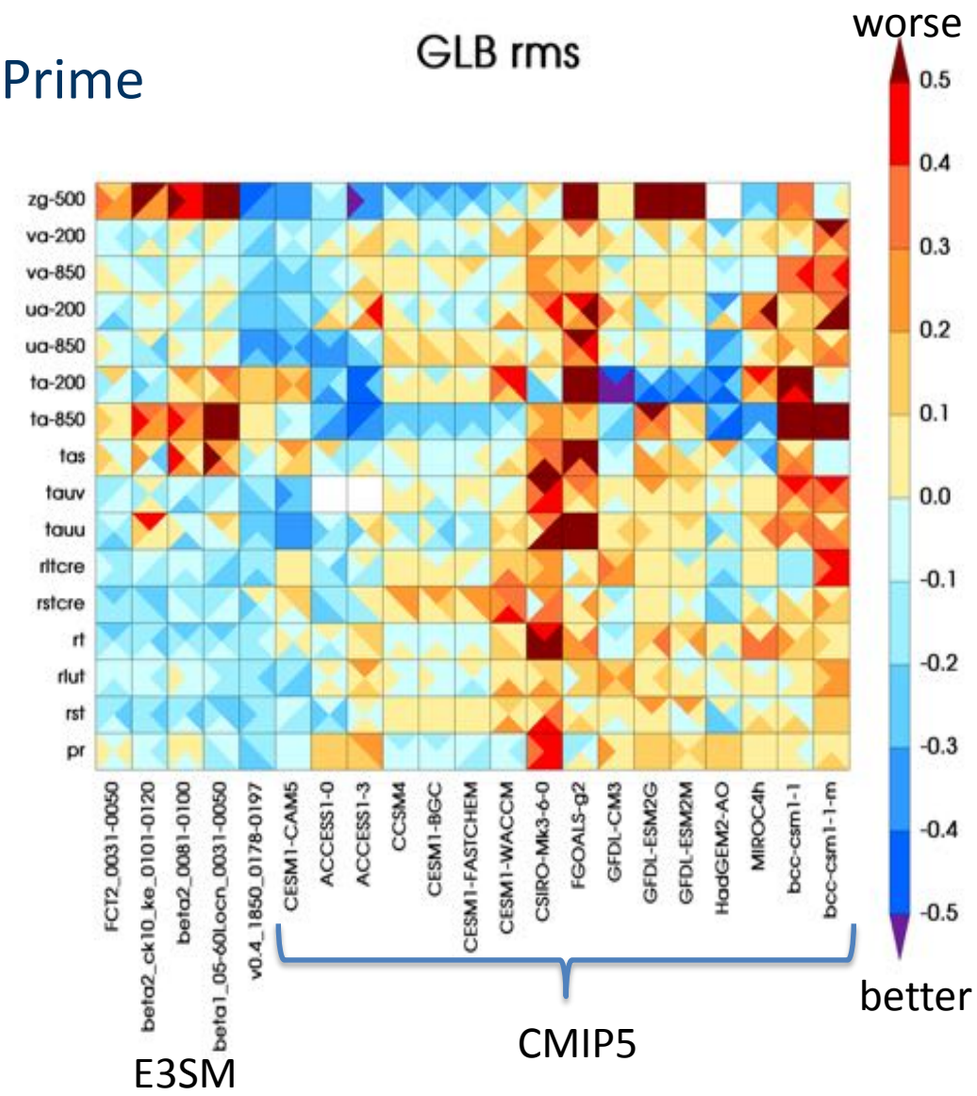
Components and softwares in v1:

- New MPAS ocean, MPAS sea-ice, MPAS land-ice (FELIX)
- ELM - land: P-N-C BGC, VSFM 1-D hydrology, water management, new crop developments, MOSART rivers, flooding-inundation, FATES – ecosystem demography
- EAM - atmosphere: 72levels, cube-sphere “HOMME” dycore, MAM4 aerosols, CLUBB for shallow convection, Z-M for deep

Softwares (released, in v1 release or very soon to be released)

- Whole code: iESM (couples GCAM and CESM)
- Infrastructure: MPAS, CIME, LIVVkit, CEDS, NCO, MCT, A-Prime
- Ocean: CVMix, LIGHT, MARBL
- Ice: CICE, IcePack, BiSICLES
- Land: FATES, MOSART, BeTR, MPP/VSFM
- Atmosphere: SCM, HOMME, MAM, CLUBB, RRTMGP

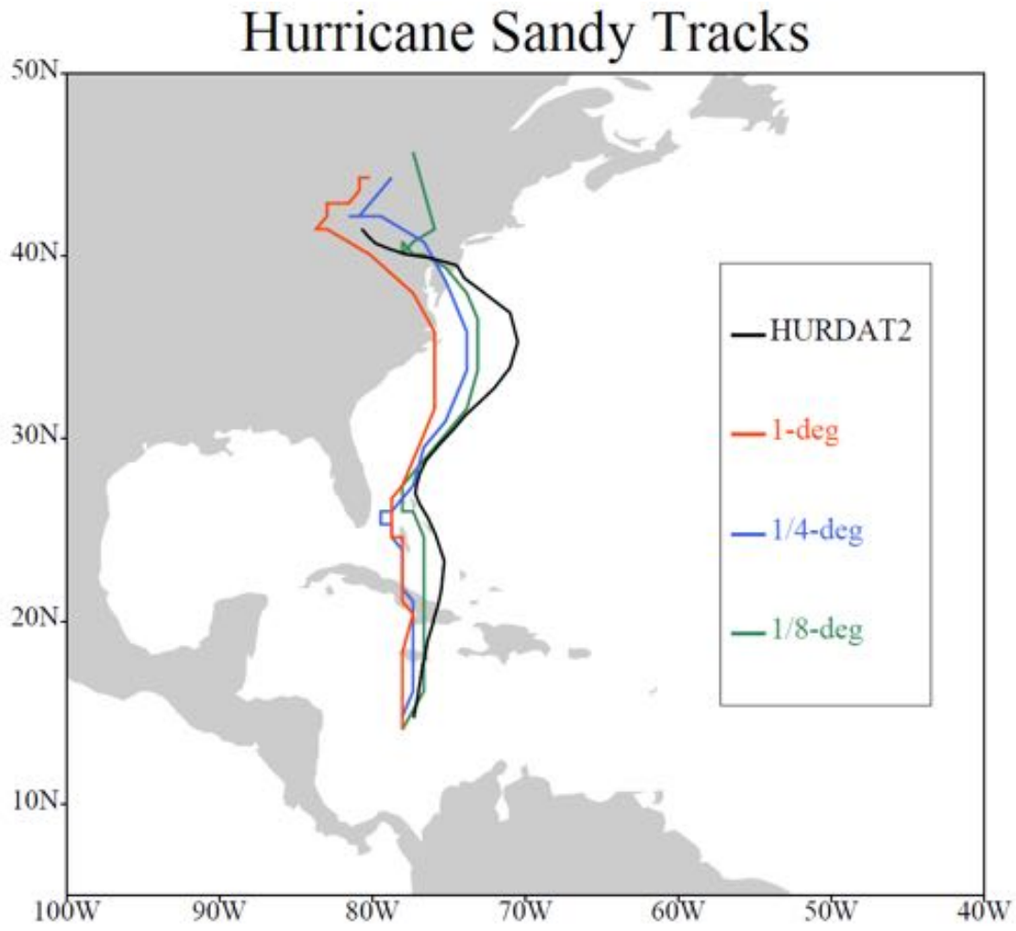


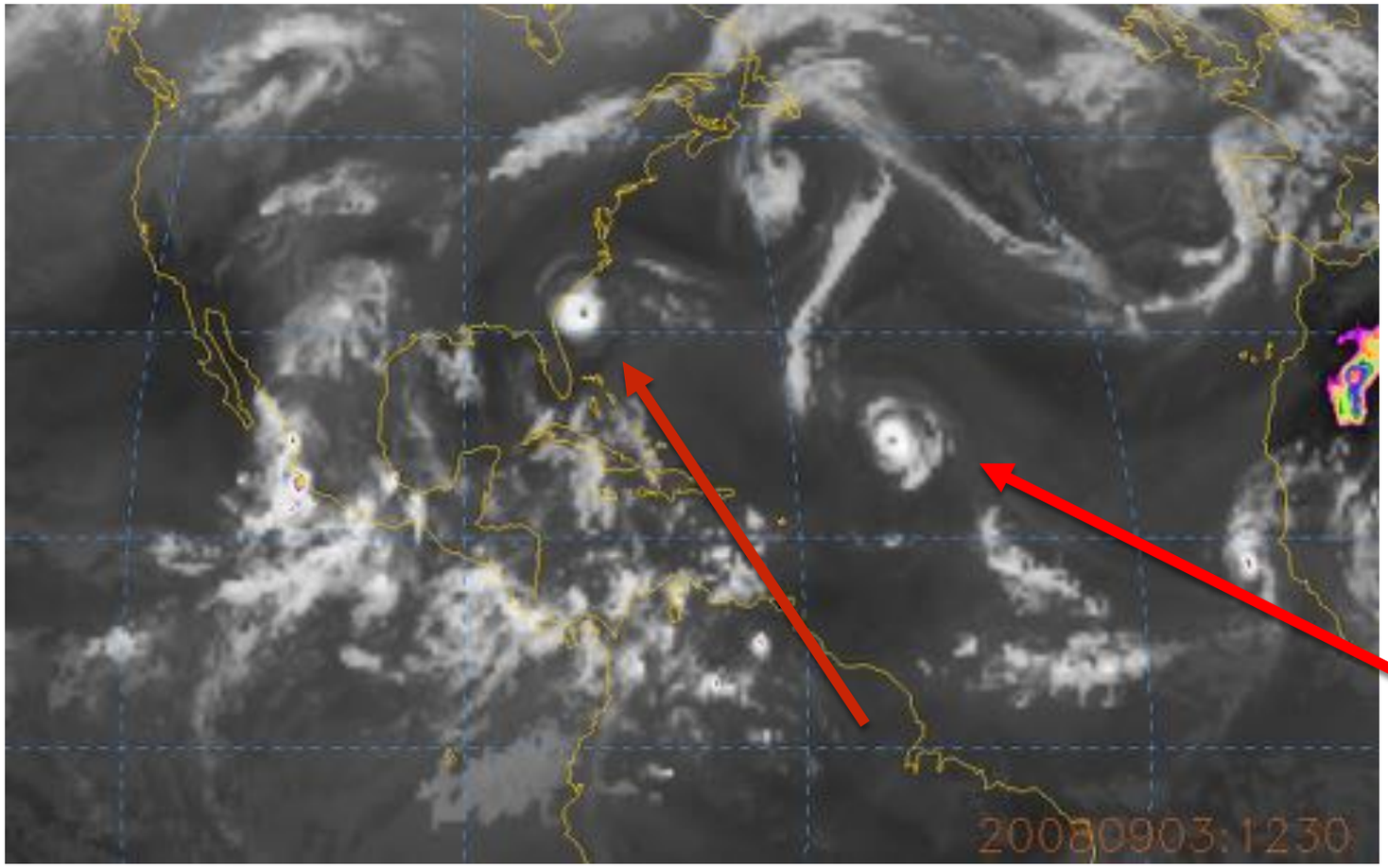


E3SM high resolution model capabilities

Atmosphere-only simulations

Hurricane Sandy tracks
1 week lead-time,
Skill increases with resolution

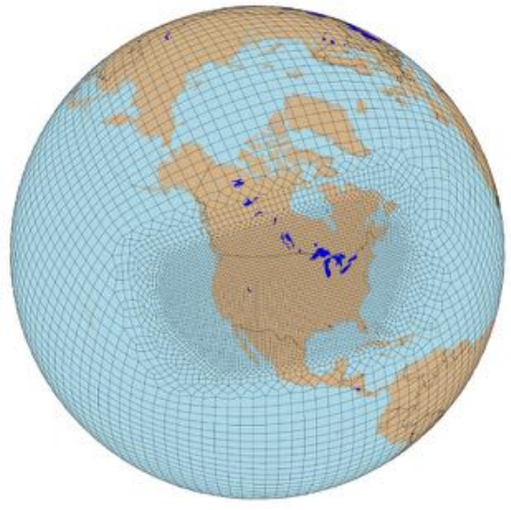




Late-Aug, Early-Sep 2008
2 Atlantic hurricanes
1/8 degree simulation

E3SM predictability and metrics

E3SM requires S2D projections and predictability for energy needs (e.g. temperature conditions), availability (e.g. water for power) and planning (e.g. infrastructure)
E3SM focus will be on high-resolution and regionally refined simulations



Current metrics for "water cycle" and "cryospheric" simulation campaigns:

"Standard diagnostics"

Hydrological – atmosphere, land

- **Precipitation, river flow, and water storage.**
- Monthly histograms of **instantaneous and daily precipitation** (by phase)
- **Diurnal cycle of precipitation**; the 10th and 90th percentile precipitation rates;
- Return times for precipitation below and above thresholds to characterize **floods and droughts**;
- **Surface water balance** statistics, e.g. runoff and streamflow, soil moisture, snowpack, evapotranspiration
- **Large-scale circulation features** such as atmospheric rivers, jet stream, storm tracks, monsoon circulation, and modes of variability,
- **Tropical cyclone** frequency, intensity, and tracks, atmospheric vs oceanic influences

Ocean and sea ice:

- **Ocean:** sea-surface temperature and salinity, mixed-layer depth, ocean heat content and trend, meridional-heat transport and overturning circulation, ocean temperature and salinity at depth, and sea ice area and volume.
- A new **ocean particle tracking** capability in E3SM (LIGHT) will be used to better quantify Southern Ocean water mass transformation ocean (through monitoring of source and destination waters) and ocean mixing of heat and other trace constituents.

Ice-sheets and ocean

- **Sub-ice shelf melt rates** - spatial maps (seasonal and annual) and time series for any of ~70 Antarctic ice shelves.
- Quasi-equilibrium **basal melt rates** compared to satellite-derived observations
- **Freshwater fluxes influences** on water masses and currents below the ice shelves
- **Southern Ocean wind change influences** on the strength and position of the Antarctic slope front, circulation within ice shelf cavities, and sub-ice shelf melt rates and water mass formation

Clouds Process Research @ LLNL

CAUSES

Hsi-Yen Ma and Chengzhu Zhang with Steve Klein (LLNL)
Cyril Morcrette and Kwinten Van Weverberg with Jon Petch (UKMO)

Ma et al. (2014)

- CAUSES is a multi-model inter-comparison project aiming to understand the contributors to the robust warm-bias in modeled summertime surface air temperature over the Central U. S.
- Participating models: Hindcasts from 9 global models, (2 NWP, 8 climate) and 1 regional model (2 versions), supplemented by an analysis of AMIP integrations from 23 CMIP5 models
- **Future work @LLNL**: testing land-surface parameterization controls on evaporative fraction in CAM

Diagnosing the Causes of Sea Surface Temperature Biases with Initialized Coupled Models ("Coupled CAPT")

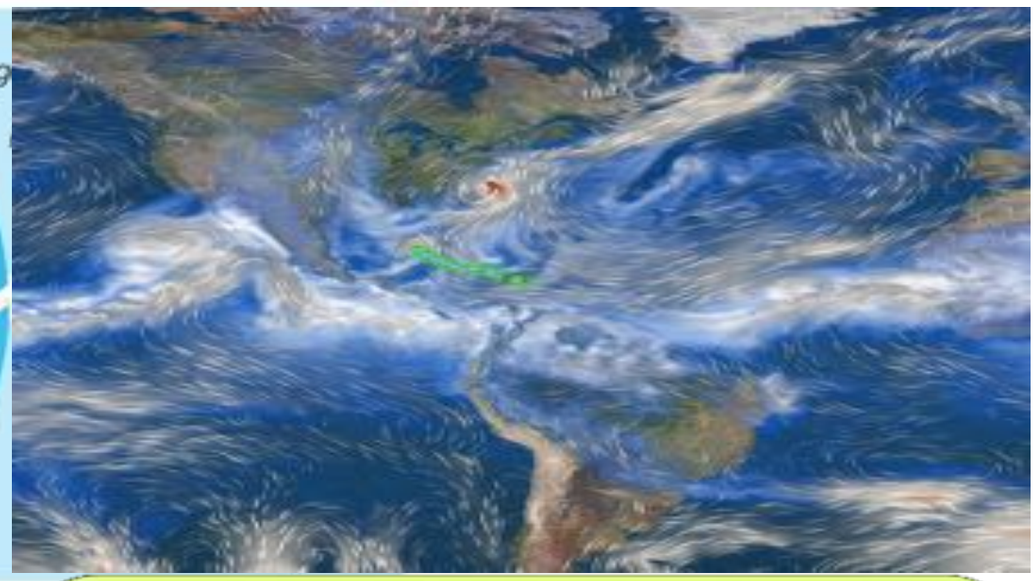
- Experiments with CESM show that SST errors after only 6 months of integration started from an observed state resemble climatological SST errors
- This is also true for other models we have studied (CanCM3/4, CCSM4)
- **Future work:** Conduct model sensitivity experiments to identify the role of errors in wind stress in SST bias, and the identify the cause of the wind stress bias

Calibrated And Systematic Characterization, Attribution and Detection of Extremes (CASCADE) : S2S Connections - @LBNL

- Tools for characterizing extremes in the obs. record: climextRemes, fastKDE, TECA
- Participation in ARTMIP
- Studies documenting changes in extremes

BERKELEY LAB

- Studies on drivers of tropical cyclone variability
- Focus on compound extremes: droughts and heatwaves
- Approach uses observations and simulation hierarchies



- Leadership of C20C+ interaction w/ WRAF: seasonal attribution forecasts
- Studies attributing changes in extremes

- First-ever perturbed parameter ensemble for D&A: a public dataset
- Studies on effect of ocean variability on attributability

CASCADE Ongoing and Future Activities Relevant to ESPC

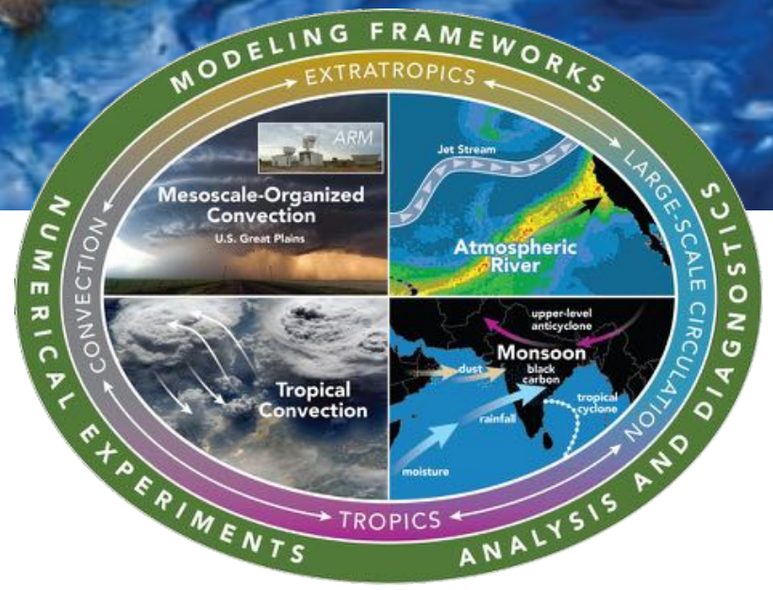
- Development of machine-learning methods for detecting weather events
- New statistical methods for gridding data on extremes from stations

- Hierarchy of frameworks for relating convective aggregation to intensity, duration and frequency
- Participation in HighResMIP

- Convection-permitting studies of tropical cyclones for event attribution
- High-resolution, global contributions to the C20C+ D&A project

- Development of emulators for extreme precipitation
- Pioneering work on an experimental design to falsify D&A statements

Water Cycle and Climate Extremes Modeling (WACCEM) (FY19-21)



- Element 1: Large-scale circulation
  - 1a: Monsoon-ITCZ from an energetic perspective
  - 1b: Baroclinic annular mode (BAM) and precipitation variability
- Element 2: Convection
  - 2a: Characteristics of MCSs from the global tropics to the extratropics
  - 2b: Changing characteristics of MCS induced flooding in the U.S.
- Element 3: Multiscale interactions between convection and large-scale circulation
  - 3a: Role of shallow, deep, and organized convection in the tropical overturning circulation and precipitation
  - 3b: Subseasonal variability of convection and influence on large-scale circulation and extreme events

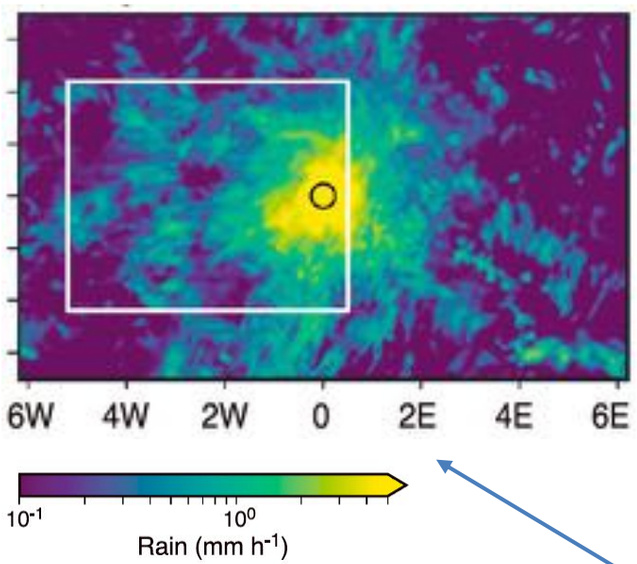
2b: Mesoscale convective systems and flooding

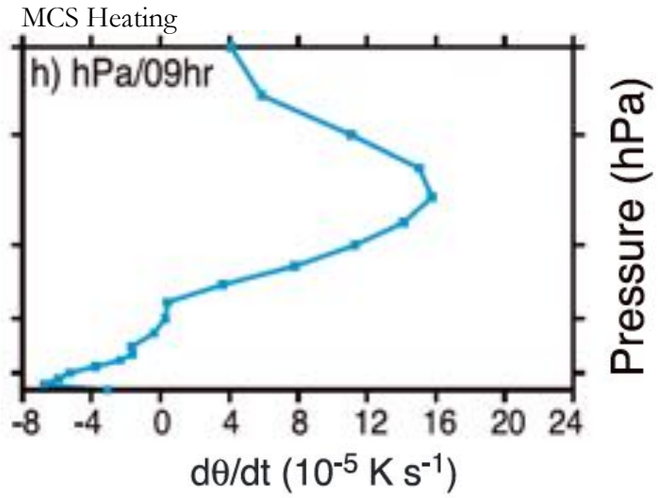
- MCS properties including lifetime, size, propagation speed, and rainrate all have important control on flooding
- MCSs are strongly influenced by the large-scale environment, but they also provide important feedback to the environment that alters their longevity and total rainfall
- S2S prediction of the large-scale environment conducive to MCSs has important implications for precipitation and flood forecast

(Yang et al. 2017 *JGR*)

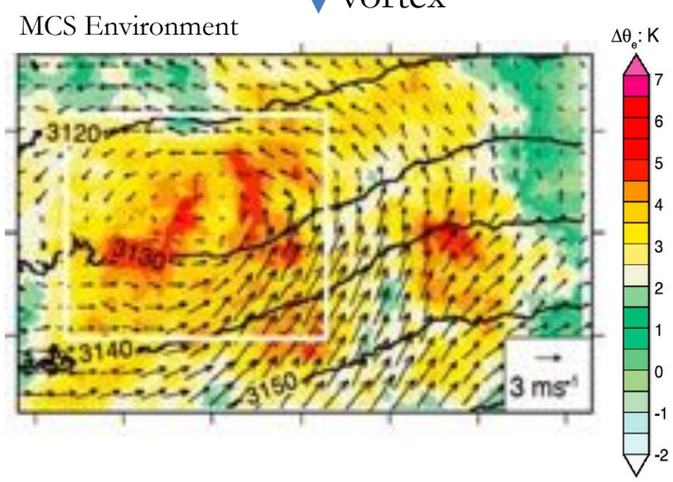
Interactions between MCSs and their large-scale environment

MCS precipitation generates top-heavy heating profile





Top-heavy heating strengthens the mesoscale vortex



Mesoscale vortex feeds dry, cooler air that enhances evaporative cooling and prolongs the lifetime of MCS

Workshop: Initialization of high-resolution Earth System Models, April 9-10, Hilton Rockville, sponsored by DOE-NOAA

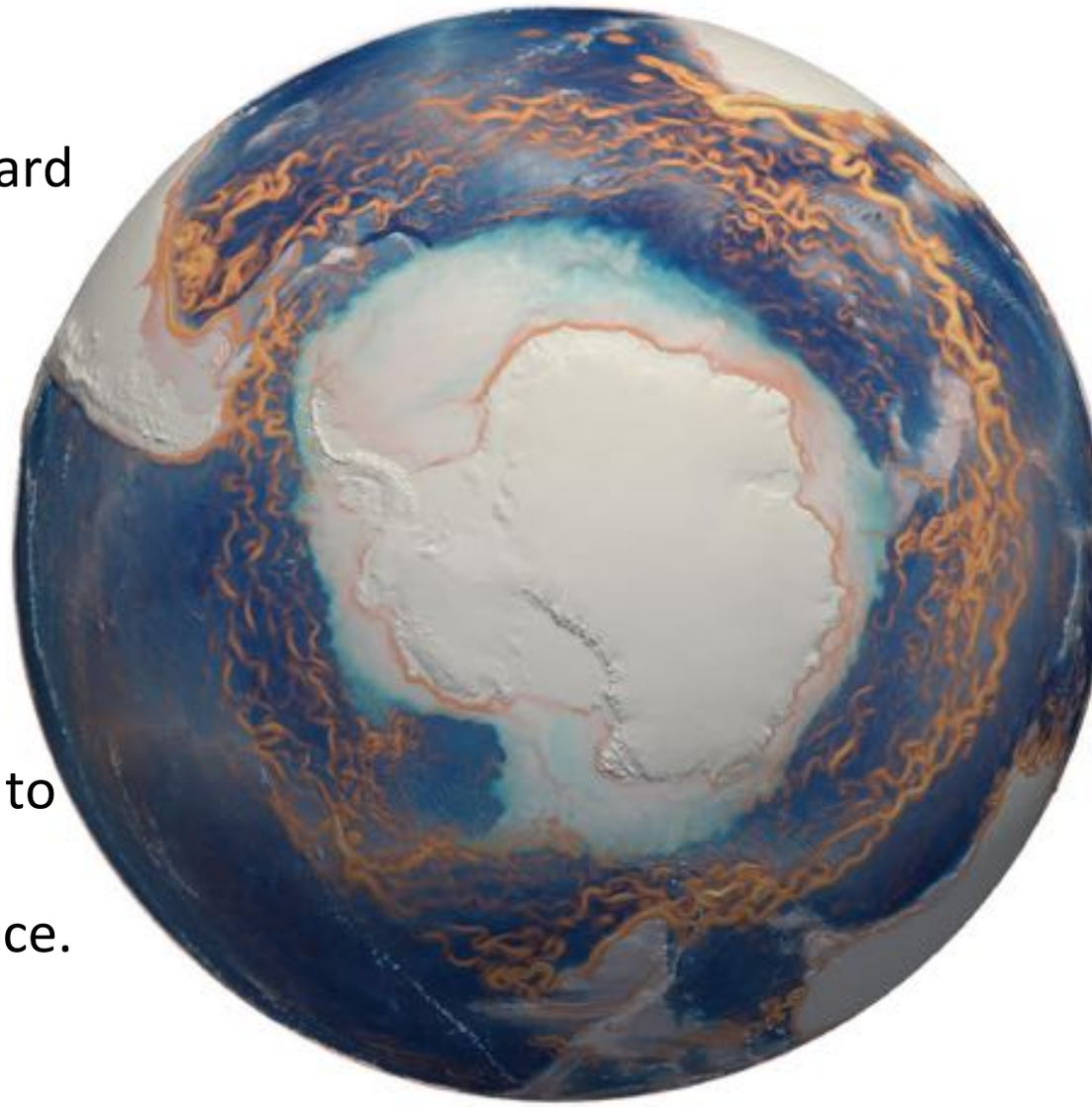
Initialization of high-resolution Earth System Models remains an outstanding challenge for both the weather prediction and climate science communities.

The weather prediction community is starting to look toward Earth System Models to improve seasonal to sub seasonal forecasting.
Climate science is starting to apply Earth System

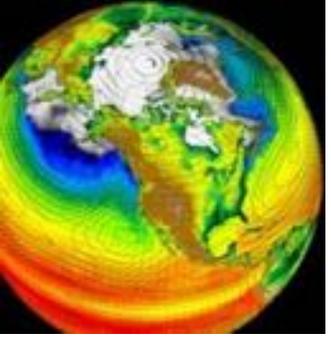
Models for prediction at decadal time scales. However traditional approaches for long pre-industrial spin-up is prohibitively expensive

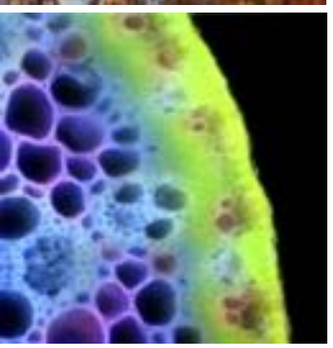
This workshop will bring these two communities together to discuss the use of shared coupled data assimilation approaches for both weather prediction and climate science.

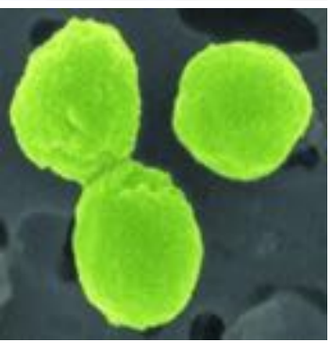
Include comparison of methods, exploration of more computationally efficient algorithms and approaches



Co-chairs:
Todd Ringler (DOE-LANL) Todd.Ringler@science.doe.gov
Steve Penny (NOAA-U-MD) Steve.Penny@noaa.gov







Thank you!

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BER Modeling activities
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E3SM
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