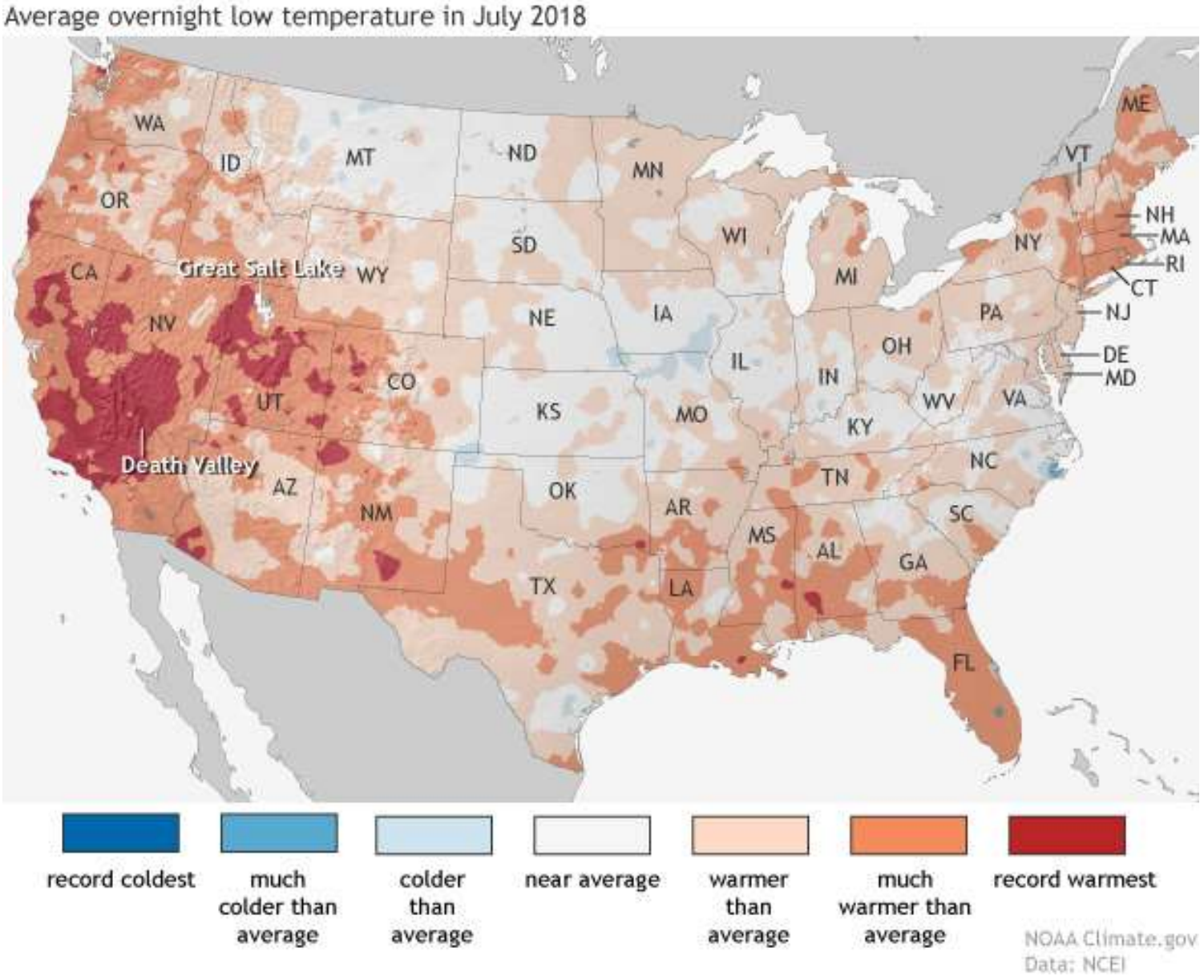
Climate and Environmental Sciences Division

BERAC update

October 18, 2018

G. Geernaert
BER/CESD


Average overnight low temperature in July 2018
WA
OR
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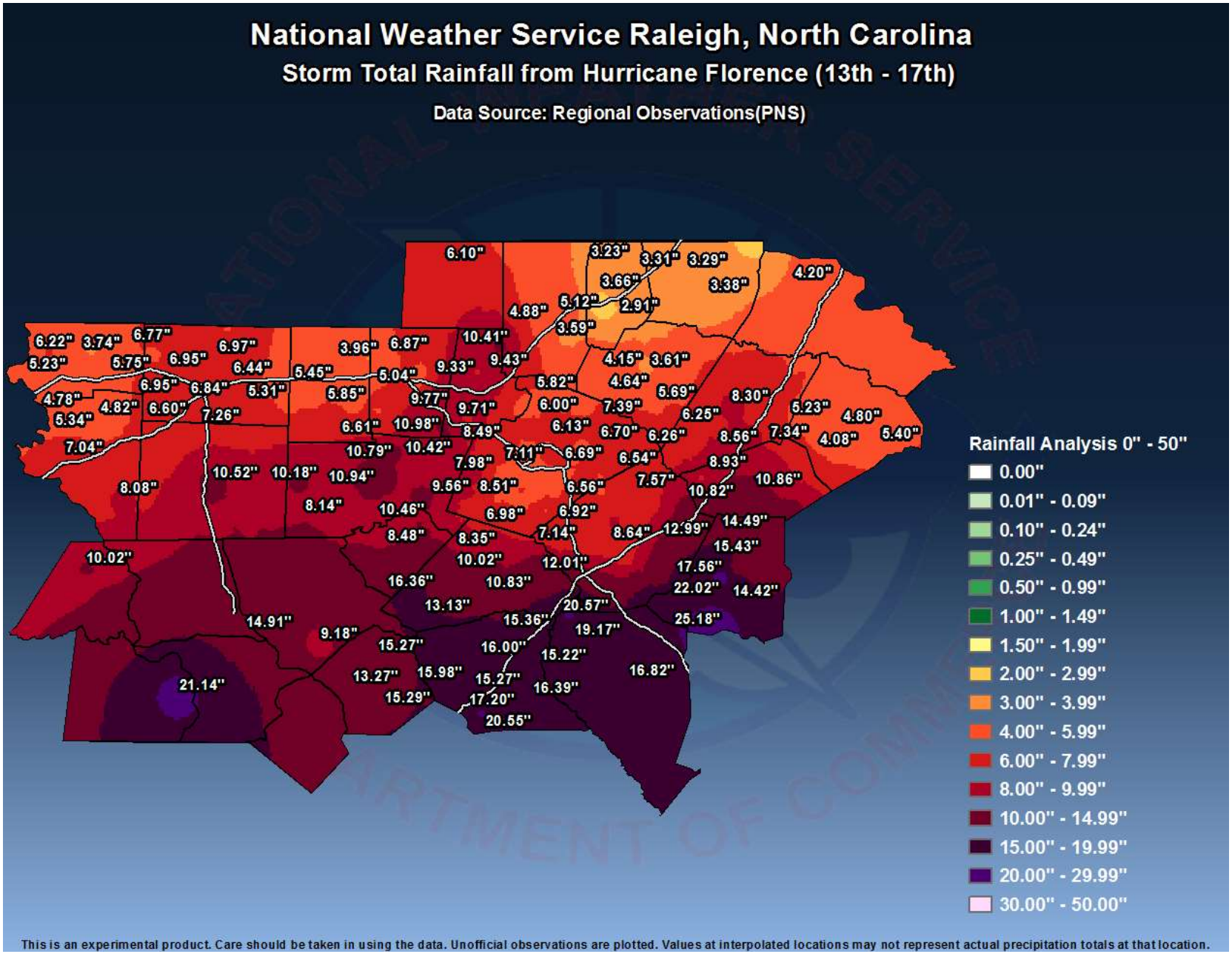
Great Salt Lake
Death Valley
record coldest
much colder than average
colder than average
near average
warmer than average
much warmer than average
record warmest
NOAA Climate.gov
Data: NCEI


National Weather Service Raleigh, North Carolina
Storm Total Rainfall from Hurricane Florence (13th - 17th)
Data Source: Regional Observations(PNS)
6.10"
3.23"
3.31"
3.29"
4.20"
3.66"
3.38"
4.88"
5.12"
2.91"
3.59"
6.22"
3.74"
6.77"
10.41"
5.23"
5.75"
6.95"
6.97"
3.96"
6.87"
9.33"
9.43"
4.15"
3.61"
6.44"
5.45"
5.04"
5.82"
4.64"
6.95"
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5.31"
5.85"
9.77"
9.71"
6.00"
7.39"
5.69"
8.30"
4.78"
4.82"
6.60"
7.26"
6.25"
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4.80"
5.34"
6.61"
10.98"
8.49"
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6.70"
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7.34"
4.08"
5.40"
7.04"
10.79"
10.42"
7.11"
6.69"
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10.18"
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9.56"
8.51"
6.56"
7.57"
10.82"
10.86"
8.08"
8.14"
10.46"
6.98"
6.92"
14.49"
8.48"
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7.14"
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12.99"
15.43"
10.02"
10.02"
12.01"
17.56"
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25.18"
9.18"
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16.00"
15.22"
16.82"
13.27"
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21.14"
16.39"
15.29"
17.20"
20.55"
Rainfall Analysis 0" - 50"
0.00"
0.01" - 0.09"
0.10" - 0.24"
0.25" - 0.49"
0.50" - 0.99"
1.00" - 1.49"
1.50" - 1.99"
2.00" - 2.99"
3.00" - 3.99"
4.00" - 5.99"
6.00" - 7.99"
8.00" - 9.99"
10.00" - 14.99"
15.00" - 19.99"
20.00" - 29.99"
30.00" - 50.00"
This is an experimental product. Care should be taken in using the data. Unofficial observations are plotted. Values at interpolated locations may not represent actual precipitation totals at that location.

Executing our Strategic Plan 2018-2023

Vision: Improve a systems level understanding and predictability of the earth system in support of DOE's mission, through integrative theory, modeling, and experiment, over a variety of spatial and temporal scales.

High level Grand Challenges

- Integrated water cycle
- Biogeochemistry
- High latitudes
- Drivers and responses
- Data-model integration

Execution

- Influence strategic planning in NSTC subcommittes, e.g., USGCRP, SWAQ, etc.
- Coastal (TAI) as an integrative example that packages grand challenges and collaborations
- Future: disturbance, initialization, data analytics (e.g., machine learning), software, advanced technologies

Energy Exascale Earth System Model

Programmatics:

- Phase 2 of the project was reviewed May 14-16, 2018
- Reviewers urged ultra-high resolution simulation on exascale machines

Simulation progress (v1):

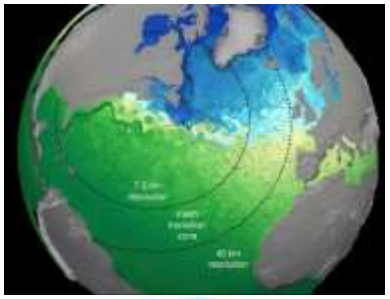
- High-resolution (25km atmos; 16-8km equator-pole ocean/ice) coupled simulation has completed 30 years. Polar temperatures are too high.
- Low-resolution (100km) sensitivity and ensemble simulations are in progress
- BGC coupled (low resolution) single-component simulations are nearly equilibrated, then the fully coupled system will be initiated
- Ocean-sea-ice simulations are studying the effects of resolution, heat and salinity to optimize the coupled system configuration

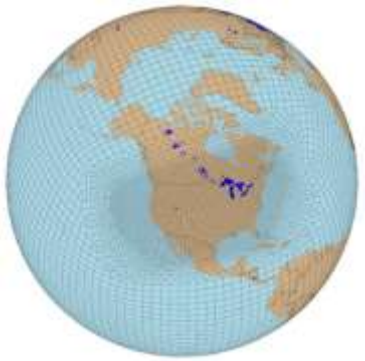
Phase 2 plans (v2-v3-v4)

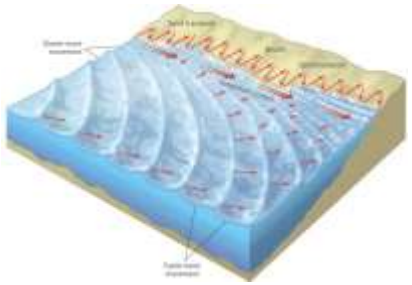
- Regional refinement over North America, focus on Energy-relevant science (e.g. water management, land-use, crops)
- V3-v4 will ultimately target very high-resolution (3km) atmospheric version with simpler physics and strong scaling on DOE computers
- Ongoing work, with variable mesh around Antarctica, to determine AIS instabilities and sea-level change
- Coastal work includes adding waves and inundation

Community engagement

- Several new University and DOE-Laboratory projects, including SciDAC projects, will use E3SM. On-line training provided this fall.
- E3SM Town Halls at AGU and AMS







Workshops set the stage for future CESD priorities

Date: 2018	Topic	Venue
March 15-16, 2018	Disturbance and vegetation dynamics	Gaithersburg
April 9-10, 2018	Initialization and DA in ESMs	Rockville
April 23-24, 2018	ARTMIP workshop	Wash DC
April 30, 2018	Cyberinfrastructure workshop	Bolger
May 29-31, 2018	Lab Day	Fairbanks
June 18-21, 2018	CESM Annual Workshop (UCAR)	Boulder
July 16-19, 2018	Energy Modeling Forum (Stanford)	Snowmass
August 15-17, 2018	ARM Mobile Facility workshop	Gaithersburg
Jan 28-30, 2019	Leveraging distributed research to understand watershed syst	Bethesda
Late Winter 2019	Computer and mathematical science for initializing high-resolution Earth system models	Wash DC
April 2019	Climate Modeling Summit	Wash DC
April 2019	Assessing simulation of precipitation in Earth system models	Wash DC
April 29, 2019	Cyberinfrastructure	Bolger
Spring/summer 2019	Integrated hydro-terrestrial models- development of a national prediction capability. (with NOAA, NSF, and USGS)	Wash DC
Summer 2019	Next generation data-work environments	Wash DC
Fall 2019	Lessons learned from FACE, NGEE, and MODEX	Wash DC

Management Update: solicitations

Funds	Program lead	Issued	Proposals	Panel	Selected
FY18	ESM and Analysis	Nov 28, 2017	99	May 22-24, 2018	13
FY18	ASR	Nov 16, 2017	74	April 17-19, 2018	18
FY18	TES	Nov 16, 2017	129	May 7-11, 2018	7
FY18	SBR	Dec 30, 2016	130	May 15-17, 2017	13
FY18	RGCM	Mar 6, 2017		May 18-19, 2017	13
FY18	SciDAC	Jan 17, 2017	91	May 3-4, 2017	10

Management updates: Major reviews in 2017-2018

Lab	Program	Type	Review date	Decision	Date
LBNL	TES	SFA	May 3, 2018	Accept	Jun 22, 2018
ORNL	SBR	SFA	May 3-4, 2018	Acc w/rev	Aug 30, 2018
E3SM	ESM	SFA	May 15-16, 2018	Accept	Jun 25, 2018
ANL	SBR	SFA	June 11, 2018	Accept	Jul 13, 2018
LLNL	SBR	SFA	June 15, 2018	Acc w/rev	Oct 12, 2018
LANL	RGCM	SFA	Aug 21-22, 2018		
PNNL	RGCM	SFA	Sept 10-11, 2018		
Multi-	SBR	IDEAS proj.	Jan 2019		
ORNL	TES	NGEE-Arctic	April 1-2, 2019		
ORNL	TES	SFA	May 2-3, 2019		
LBNL	SBR	SFA	May 2-3, 2019		
LBNL	TES	NGEE Tropics	Summer 2019		
LBNL	Modeling	CASCADE SFA	Aug 2019		
LLNL	Modeling	PCMDI/Cl SFA	Sept 2019		

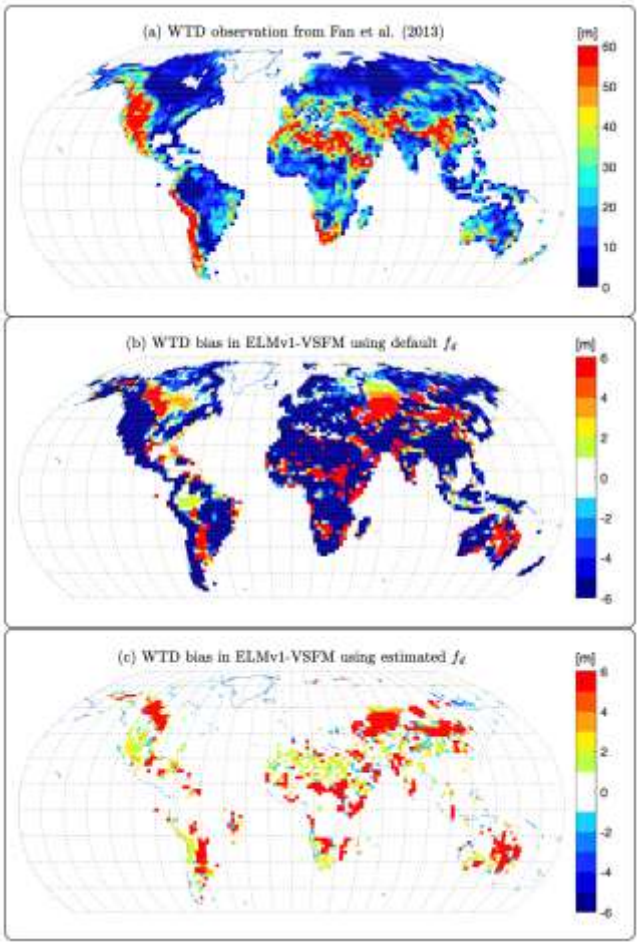
Management updates - PI meetings: 2017-2018

Title	Program(s)	Location	Date in 2018
Modeling PI meeting	EESM	Bolger	Nov 5-8, 2018
NGEE Tropics all hands	TES	Washington DC	Dec 7-8, 2018
NGEE Arctic all hands	TES	Washington DC	Dec 8-9, 2018
ARM/ASR PI meeting	ARM, ASR	Tysons	March 19-23, 2018
ESS PI meeting	TES, SBR	Bolger	April 30-May 1, 2019
PCHES all hands	Modeling	Penn State	May 2019
AMR/ASR PI meeting	ASR, ARM	Bethesda Marriott	June 9-14, 2019

Science Highlights

Integrated water cycle
Biogeochemistry
High latitudes
Drivers and responses
Data-model fusion

Unified treatment of hydrologic processes in unsaturated and saturated zones in the E3SM Land Model



Objective: develop a unified physics formulation to unify the treatment of soil hydrologic processes in the unsaturated and saturated zones

Approach: Use of calibrated drainage parameter, f_d, significantly improved model prediction of deep water table depth (WTD) when compared against an observationally-constrained spatially-explicit global WTD product.

Results and model features

- An open-source variably saturated flow model (VSFM) was developed in ELMv1

- PETSc library was used to provide numerically solution of nonlinear discretized equations VSFM

- Optimal spatially-explicit f_d values were obtained for 79% of gridcells at $1.9^0 \times 2.5^0$ spatial resolution

- Model evaluation using the ILAMB package showed that improvements in WTD predictions did not degrade model skill for any other metric

Bisht, G., Riley, W. J., Hammond, G. E., and Lorenzetti, D. M.: Development and evaluation of a variably saturated flow model in the global E3SM Land Model (ELM) Version 1.0, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-44, accepted, 2018

U.S. DEPARTMENT OF ENERGY | Office of Science | E3SM Energy Exascale Earth System Model | EARTH & ENVIRONMENTAL SCIENCES | BERKELEY LAB

Warmer Temperatures Lengthen Growing Season, Increase Plants' Vulnerability to Frost

Richardson, A.D., K. Hufkens, T. Milliman, D.M. Aubrecht, M.E. Furze, B. Seyednasrollah, M.B. Krassovski, J.M. Latimer, W.R. Nettles, R.R. Heiderman, J.M. Warren and P.J. Hanson. "Ecosystem warming extends vegetation activity but heightens vulnerability to cold temperatures." *Nature* **560**, 368-371 [DOI: 10.1038/s41586-018-0399-1]

- The SPRUCE experiment is applying warming (0 to +9°C above ambient) and CO_2 (ambient and elevated) treatments to intact communities of mature vegetation in a Boreal black-spruce sphagnum bog in the upper Midwest USA
- Warming treatments linearly extended the period of vegetation activity in both spring and autumn; there was little evidence that photoperiod limited the phenological shifts. The observed shifts can be extrapolated to a 3-6 week extension of the growing season by the end of the current century.
- In spring 2016, unusually warm weather in March was followed by extreme cold in early April. Vegetation in the warmest chambers (+6.75, +9.0 °C) suffered severe frost damage as the temperature dropped to -3 °C, indicating a premature loss of frost hardiness. By comparison, vegetation in the cooler chambers (0, +2.25, +4.5 °C) was undamaged, despite experiencing dramatically colder temperatures (up to -15 °C).
- Because phenological transitions—including loss of frost hardiness—appear to be temperature-driven, rather than cued by photoperiod, vegetation may be exposed to greater risk of frost damage in a warmer world.

This research is based upon work supported by the US Department of Energy (DOE), Office of Science, Office of Biological and Environmental Research. Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for DOE under contract DE-AC05-00OR22725. Support for PhenoCam has come from the National Science Foundation (EF-1065029, EF-1702697).

Microbial Types May Prove Key to Gas Releases from Thawing Permafrost

Challenge

- Knowing how much carbon dioxide and methane is released by microbial communities in thawing permafrost is stymied by community diversity and complexity.

Approach and Results

- An international team sampled thawing permafrost and studied communities there at the genomic level.
- They expanded the number of genomes recovered by two orders of magnitude and identified key types that may be responsible for most gas releases.

Significance and Impact

- The work lays a powerful foundation for future research at rapidly changing sites across the Arctic.
- Scientists can now better predict how much carbon will be released from thawing permafrost, which makes up roughly 24 percent of the land surface in the Northern Hemisphere.

An international team tracked the genomic composition of microbes in thawing permafrost to determine which had the most impact on releases of carbon dioxide and methane to the atmosphere.

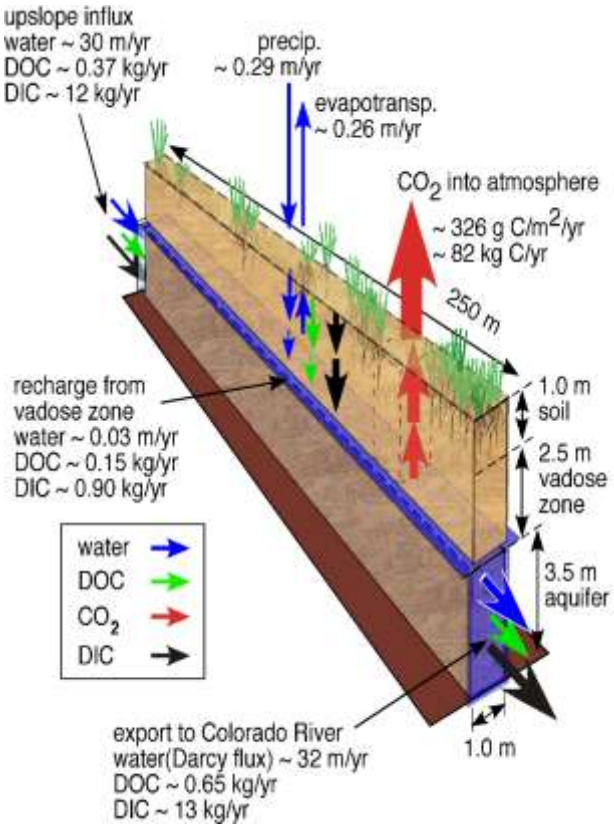
Participants:
University of Queensland, The Ohio State University, Rochester Institute of Technology, Florida State University, PNNL, University of New Hampshire, Stockholm University, University of Arizona

Reference: B.J. Woodcroft, C.M. Singleton, J.A. Boyd, P.N. Evans, J.B. Emerson, A.AF. Zayed, R.D. Hoelzle, T.O. Lamberton, C. K. McCalley, S.B. Hodgkins, R.M. Wilson, S.O. Purvine, C.D. Nicora, C. Li, S. Frolking, J.P. Chanton, P.M. Crill, S.R. Saleska, V.I. Rich, and G.W. Tyson. "Genome-centric view of carbon processing in thawing permafrost." *Nature* (2018). DOI:10.1038/s41586-018-0338-1.

FICUS Facilities Integrating Collaborations for User Science

EMSL

Unexpected High Carbon Fluxes from the Deep Unsaturated Zone in a Semi-Arid Region



Estimated carbon fluxes and balance along the measurement transect, showing 30% of annual CO_2 emissions from deeper than 1.0 m, contrary to predictions of < 1% by the Earth System Models.

Scientific Achievement

Understanding of terrestrial carbon cycling has relied primarily on studies of top soils that are typically characterized to depths shallower than 0.5m. We found and quantified 30% of CO_2 annual efflux to atmosphere (60% in winter) originates from below 1m, contrary to prediction of <1% by the ESM land models.

Significance and Impact

The findings indicate the importance of ESM land models incorporating deeper soil processes to improve CO_2 flux predictions in semi-arid climate regions.

Research Details

The seasonal DOC influx and favorable temperatures, moisture and oxygen availability in deeper unsaturated zone sustain the respiration of deeper microbial communities and roots. These conditions are common characteristics of many subsurface environments.

Wan, J., Tokunaga, T.K., Dong, W., Williams, K.H., Kim, Y., Conrad, M.E., Bill, M., Riley, W.J., Susan S.H., Deep unsaturated zone contributions to carbon cycling in semiarid environments. Journal of Geophysical Research: Biogeosciences, 123. https://doi.org/10.1029/2018JG004669.

Re-examining the Tropics' Bulging Waistline

Objective

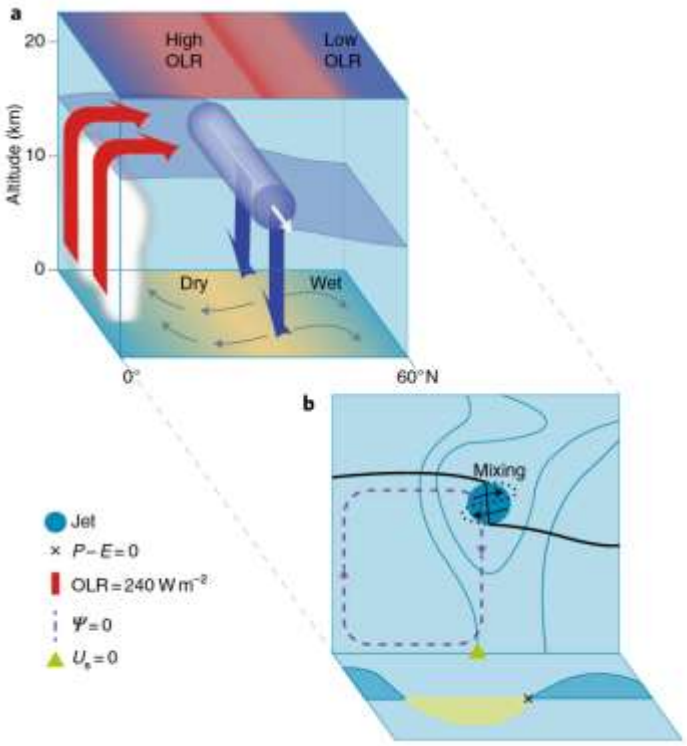
- Provide an authoritative update on the state of science regarding the expansion of the tropics, as invited by the editor of *Nature Climate Change*

Approach

- Examine the historical and latest literature on the quantification and attribution of the observed expansion rate of the tropics
- Analyze the width of the tropics using more robust metrics based on four modern retrospective reanalyses

Impact

- The expansion of the tropics exerts profound impacts on the subtropical climate, in terms of drought, heat waves, wildfires, and even marine ecosystems
- Climate models with the best estimate of the climate forcings, including sea surface temperature trends, can capture the bulk part of the tropical expansion
- Although human influences have contributed to tropical expansion since the late 1970s, much of it is likely due to natural multi-decadal swings of the climate system



These schematics summarize the metrics for the width of the tropics: (a) a three-dimensional depiction of the circulation, radiation, and hydrological features for the width of the tropics; (b) height-latitude transect shows Hadley cell overturning, mixing across the jet and the tropopause at the edge of the tropics, and subtropical zero-crossing of P − E.

Staten P, J Lu, K Grise, S Davis, and T Birner. 2018. "Re-examining tropical expansion." *Nature Climate Change*, 11:768-774.
DOI: 10.1038/s41558-018-0246-2

Storm System Longevity over United States Depends on Cloud Microphysical Processes

Objective

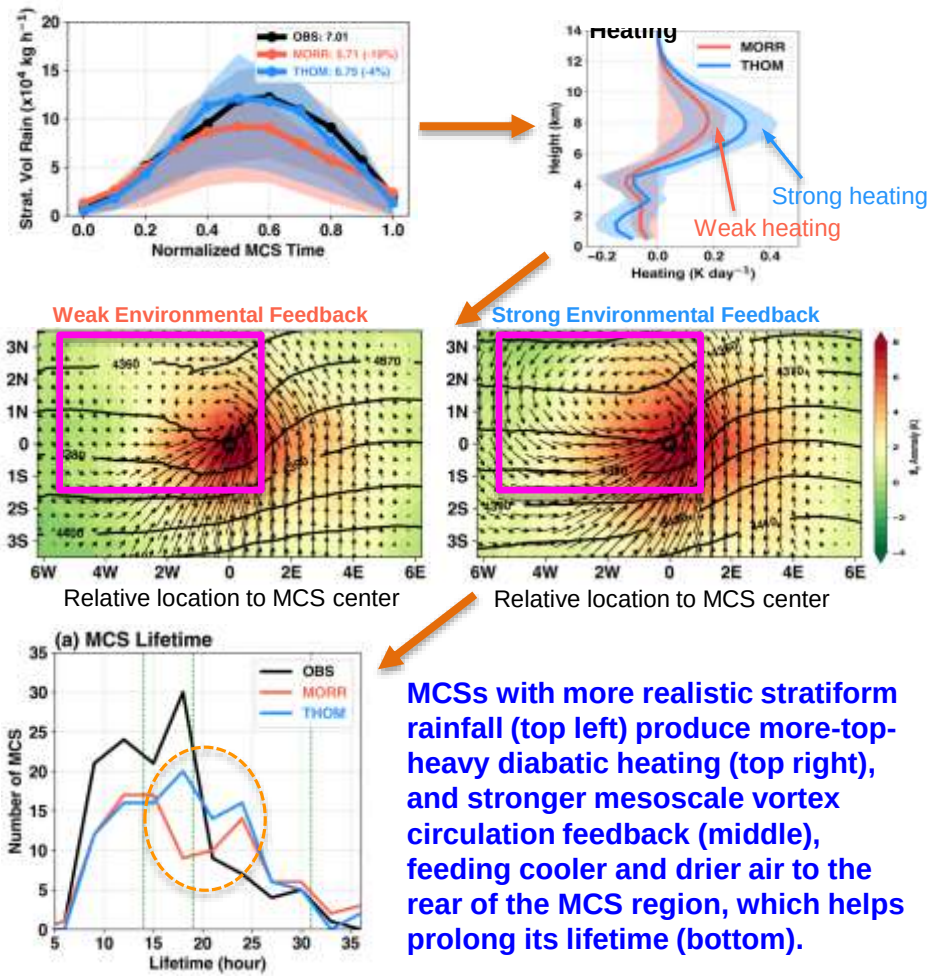
- Evaluate sensitivity of mesoscale convective system (MCS) properties to model representation of cloud microphysical processes

Approach

- Perform convection-permitting regional climate simulations using the Weather Research and Forecasting model over the United States with two different microphysics parameterizations
- Track MCSs in both simulations, and evaluate against satellite and 3-D radar observations
- Compare composite MCS diabatic heating and synoptic (large)-scale environment anomalies to clarify upscale-feedback processes from cloud microphysics

Impact

- With the microphysics parameterization that produces more realistic (stratiform) rainfall, diabatic heating produces stronger mesoscale vortices prolonging MCS lifetime and more rain
- Cloud microphysics plays a substantial role in the evolution of an MCS, so evaluating and improving its representation in weather and climate models is critical for understanding and modeling MCSs and their hydrological effects



MCSs with more realistic stratiform rainfall (top left) produce more-top-heavy diabatic heating (top right), and stronger mesoscale vortex circulation feedback (middle), feeding cooler and drier air to the rear of the MCS region, which helps prolong its lifetime (bottom).

Z Feng, LR Leung, RA Houze, S Hagos, J Hardin, Q Yang, B Han, and J Fan. 2018. "Structure and Evolution of Mesoscale Convective Systems: Sensitivity to Cloud Microphysics in Convection-Permitting Simulations over the U.S," *Journal of Advances in Modeling Earth Systems* 10:1470-1494. https://doi.org/ 10.1029/2018ms001305.

New approach allows detailed 4D observations of clouds

Objective

- Shallow cumulus clouds – the cotton-ball clouds that drift overhead on partly cloudy days – are hard to observe and, therefore, hard to model and predict.

Approach

- LBNL scientists proposed a new observational approach for shallow clouds using stereo photogrammetry, which has now been implemented at the ARM facility.
- Six digital cameras are situated in pairs at a distance of 6 km from the central facility of the ARM Oklahoma site.
- These pairs of cameras provide stereoscopic views of shallow clouds from all sides; allowing for a complete stereo reconstruction.

Impact

- The resulting Clouds Optically Gridded by Stereo (COGS) product is a gridded cloud field with a 50-m spatial resolution and a 20-s temporal resolution.
- These unprecedented observations will allow scientists to test theories and improve model parameterizations of shallow cloud formation, vertical velocity, entrainment, and dissipation.

D.M. Romps and R. Oktem, "Observing clouds in 4D with multi-view stereo photogrammetry," Bulletin of the American Meteorological Society, in press, 2018, DOI: 10.1175/BAMS-D-18-0029.1

ARM: CACTI Campaign in Argentina (Cloud, Aerosol, and Complex Terrain Interactions)

- Goal: Improve understanding of convective cloud lifecycle and organization in relation to environmental conditions in order to improve model parameterizations
- Earth system models have difficulty representing organized convective systems, with resulting biases in precipitation, temperature, and radiation budgets
- CACTI region experiences frequent orographic convection that often organizes into mesoscale systems; convection in this region is among the deepest, largest, and longest-lived in the world
- ARM Mobile Facility deployed to Sierra de Cordobas mountains in north-central Argentina
  - Oct 2018 – Apr 2019
  - G-1 aircraft deployed for 6 weeks in Nov-Dec 2018
- Strong coordination with NSF RELAMPAGO campaign & Argentinian weather service
- PI: Adam Varble, PNNL

What Plants in Space Can Tell Us

Challenge

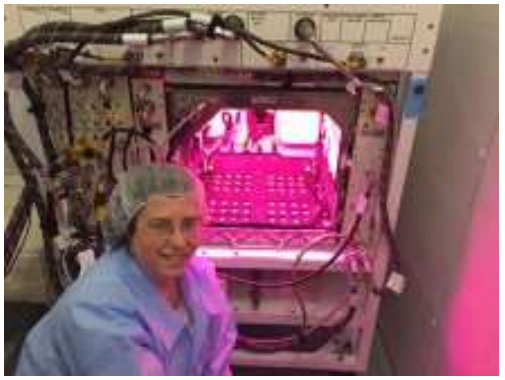
- Astronauts need plants that will grow in space for food and oxygen on long-range missions, but it is not clear how plants will react to the microgravity of space.

Approach and Results

- Scientists developed a unique strain of plant and sent the seeds to grow on the International Space Station, and they planted comparable seeds at the Kennedy Space Center in Florida.
- The team will compare cellular and metabolic products from each group of plants to look at differences in DNA, proteins, metabolites, and the ability to conduct photosynthesis to determine how the plants respond to microgravity.

Significance and Impact

- Understanding how plants respond will help scientists develop plants that can support long-term missions or be grown on distant worlds.
- The results will also help scientists develop hardier plants that can survive harsh environments on Earth.



A team of scientists including Mary Lipton of EMSL will compare plants grown on the International Space Station with counterparts at the Kennedy Space Center to determine how plants respond to the microgravity of space.

Participants:
Washington State University, University of New Mexico, Los Alamos National Laboratory, EMSL

EMSL

THANK YOU!