Climate and Environmental Sciences Division

BERAC update

April 26, 2018

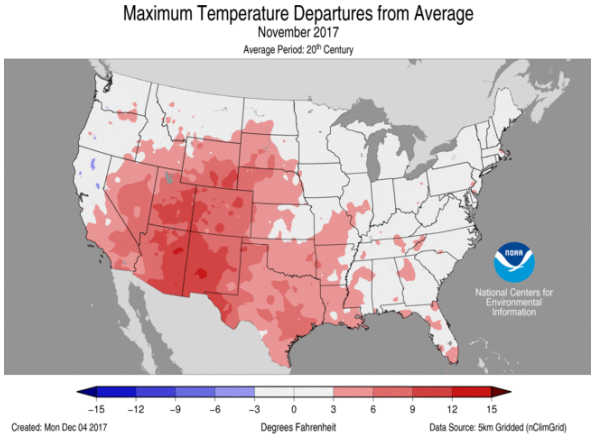
G. Geernaert

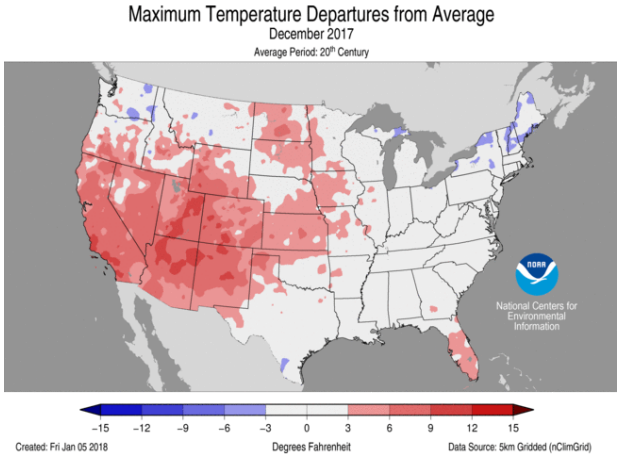
BER/CESD

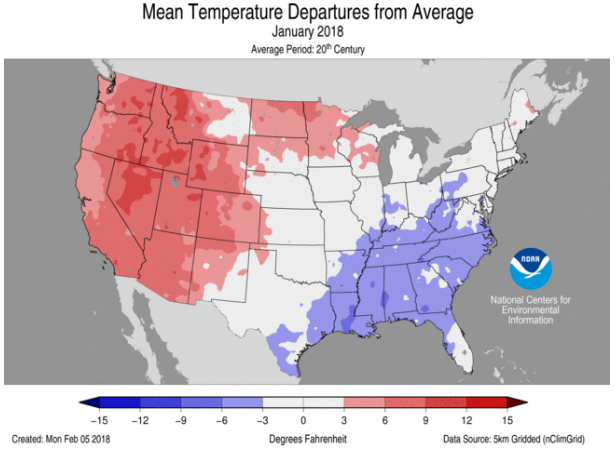
Outline

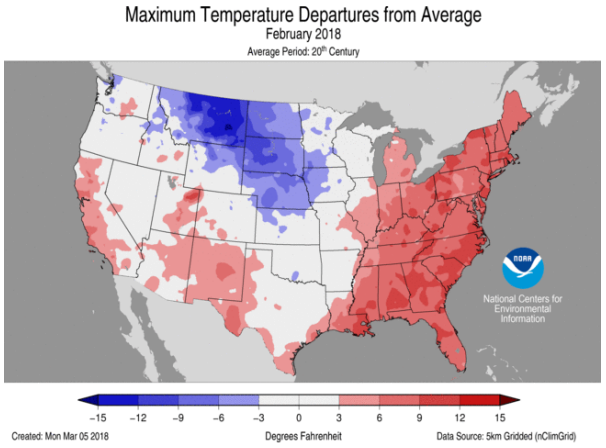
- Recent extreme events
- Strategic science challenges
- Administrative
- Scientific highlights

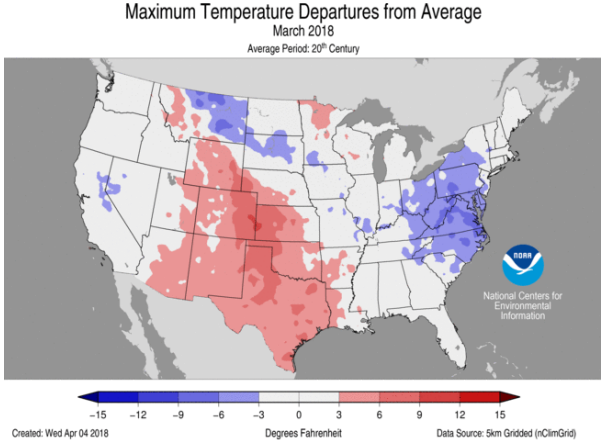
Month by month since last BERAC meeting

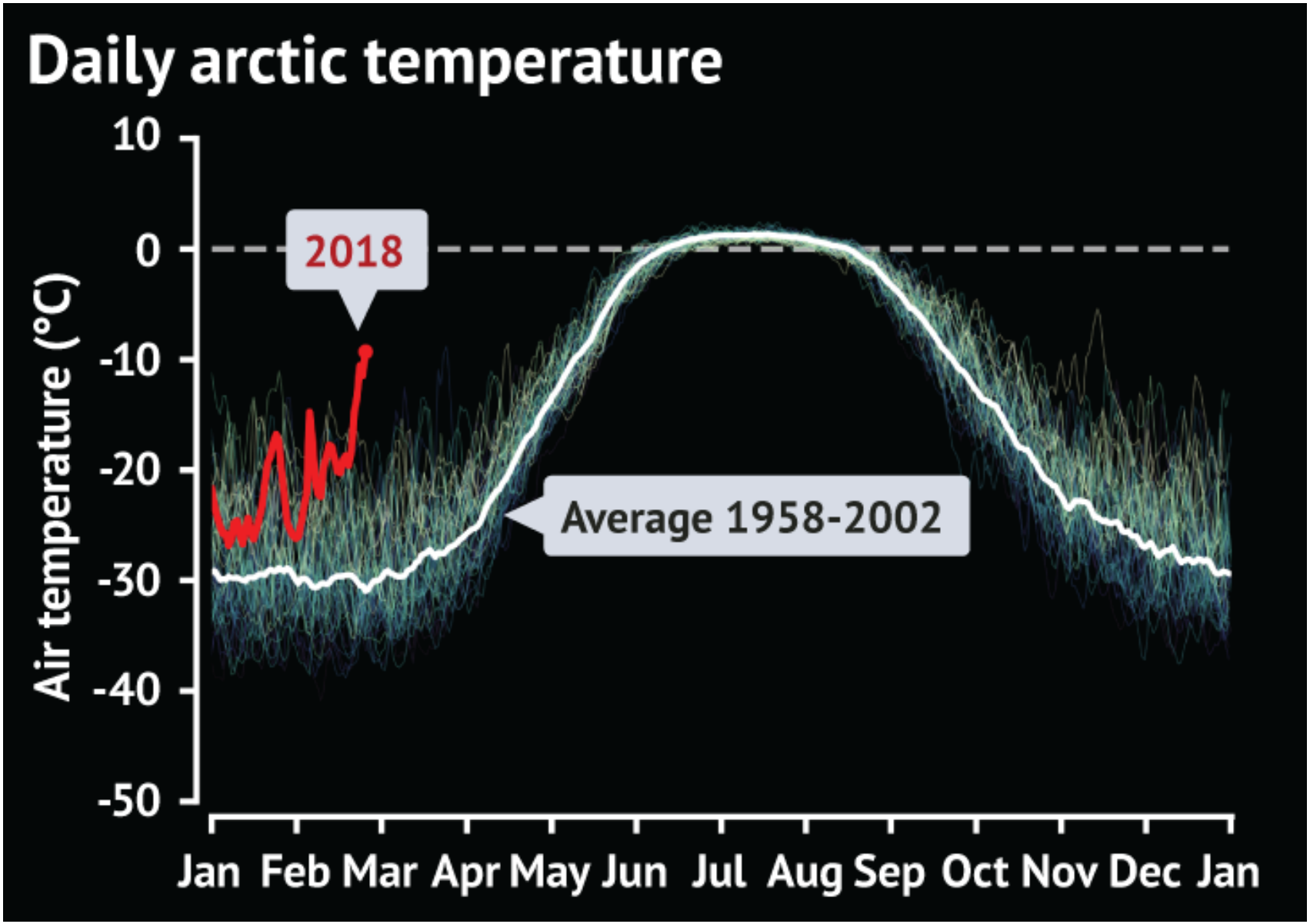


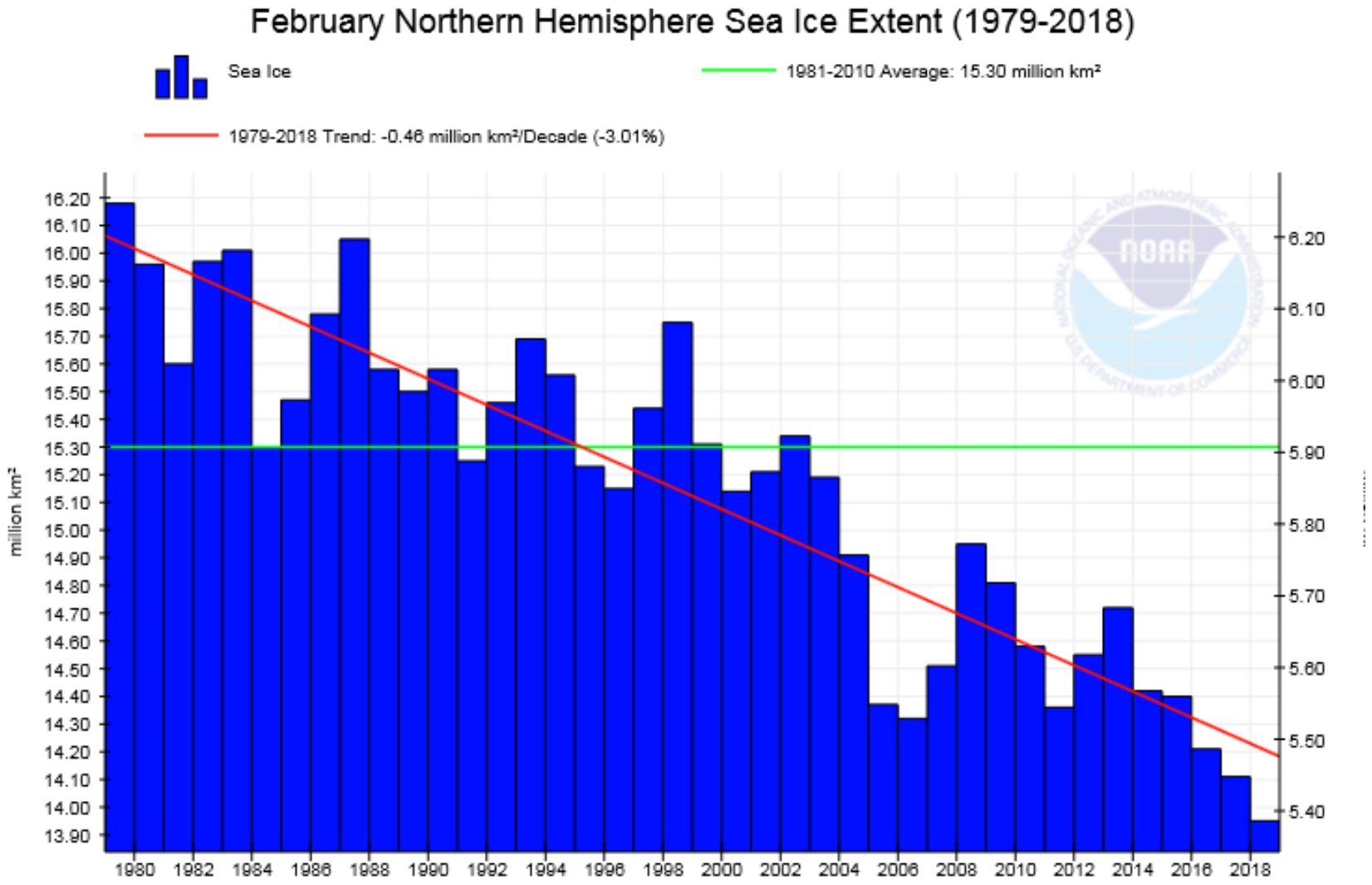









Daily arctic temperature
10
0
-10
-20
-30
-40
-50
Air temperature (°C)
2018
Average 1958-2002
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


February Northern Hemisphere Sea Ice Extent (1979-2018)
Sea Ice
1981-2010 Average: 15.30 million km²
1979-2018 Trend: -0.46 million km²/Decade (-3.01%)
million km²
16.20
16.10
16.00
15.90
15.80
15.70
15.60
15.50
15.40
15.30
15.20
15.10
15.00
14.90
14.80
14.70
14.60
14.50
14.40
14.30
14.20
14.10
14.00
13.90
6.20
6.10
6.00
5.90
5.80
5.70
5.60
5.50
5.40
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

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.

Scope: Integration of atmospheric, oceanic, terrestrial, ecological, hydrological, and human components, and inclusion of system level uncertainty quantification

High level Grand Challenges:

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

What's new?

- Water cycle and hydrology
- High latitude instead of just Arctic
- Greater emphasis on E3SM as development and analysis tool
- Extremes, disturbance, gradients, etc.,…

Workshops set the stage for future CESD priorities

Date: 2018	Topic	Venue
March 15-16	Disturbance and vegetation dynamics in ESMs	Gaithersburg
April 4	Land extremes modeling Workshop	College Park
April 5	Climate Modeling Summit (USGCRP)	College Park
April 9-10	Initialization of high resolution models workshop (w/NOAA)	Rockville
April 23-24	ARTMIP workshop (with NOAA)	Washington DC
April 30	Cyberinfrastructure workshop	Bolger
June 18-21	CESM Annual Workshop (UCAR)	Boulder
July 16-19	Energy Modeling Forum (Stanford)	Snowmass
Fall 2018	ARM Mobile Facility workshop	Greater DC

Workshops in the pipeline include, e.g., Machine learning

Management Update: solicitations

Funds	Program lead	Issued	Proposals	Panel	Selected
FY18	ESM and Analysis	Nov 28, 2017	92	May 22-24, 2018	
FY18	ASR	Nov 16, 2017	70	April 17-19, 2018	
FY18	TES	Nov 16, 2017	129	May 7-11, 2018	

Management updates: Major reviews in 2017-2018

Lab	Program	Type	Review date	Decision	Decision-date
ORNL	NGEE-Arctic	Project	Sep 18, 2017	Approved	Oct 3, 2017
UCAR	RGCM	CA	Sep 19-20, 2017	Approved	Oct 24, 2017
ORNL	RGCM	SFA	Sep 25-26, 2017	Approved	Nov 1, 2017
PNNL	**EMSL**	**Facility**	**Nov 29-30, 2017**	**Positive**	**Feb 9, 2018**
LBNL	**TES**	**SFA**	**May 3, 2018**		
ORNL	**SBR**	**SFA**	**May 3-4, 2018**		
E3SM	**ESM**	**SFA**	**May 15-16, 2018**		
PIAMDDI	**IAR**	**CA**	**May 21-22, 2018**		
ANL	**SBR**	**SFA**	**June 11, 2018**		
LLNL	**SBR**	**SFA**	**June 15, 2018**		
LANL	**RGCM**	**SFA**	**Late summer**		
PNNL	**RGCM**	**SFA**	**Late summer**		

Management updates - PI meetings: 2017-2018

Title	Program(s)	Location	Date in 2018
NGEE Arctic	TES	New Orleans	Dec 16-17, 2017
NGEE Tropics	TES	Virtual	Feb 12-14, 2018
ARM/ASR PI meeting	ARM, ASR	Tysons	March 19-23, 2018
ESS PI meeting	TES, SBR	Bolger	May 1-2, 2018
Modeling PI meeting	Modeling		Fall/winter 2018-19

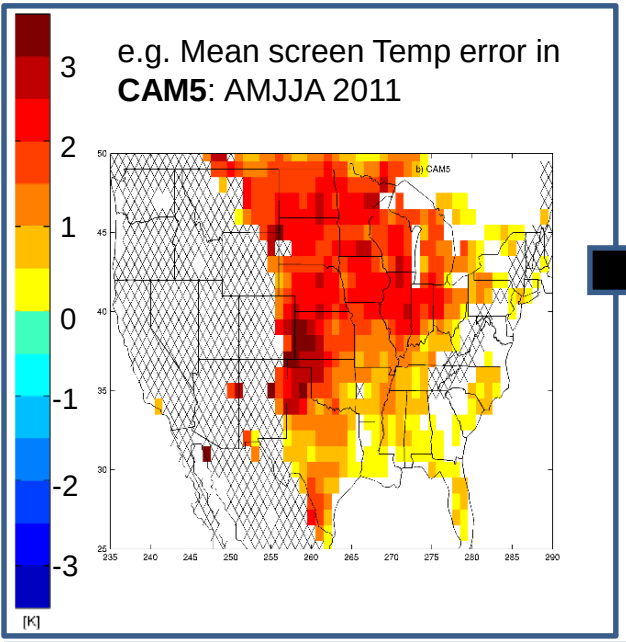
Science Highlights

Storyline is that modes of variability plus better representation of small scale processes will improve system level predictability.

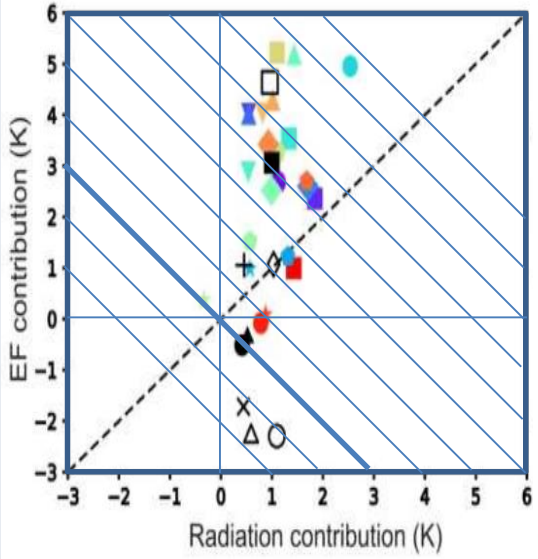
The causes of US Midwest surface temperature errors in climate models

Detailed diagnostics developed in the CAUSES project provide the tools necessary for model builders to use ARM observations to improve their models.

e.g. Mean screen Temp error in **CAM5**: AMJJA 2011

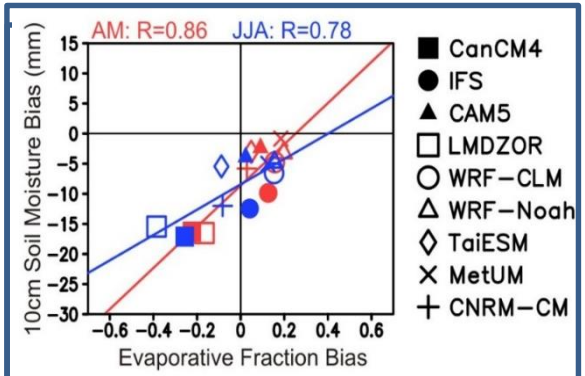


Theoretical analysis: relative contribution of error from evaporative fraction & from radiation in **hindcast** & **CMIP5** models.



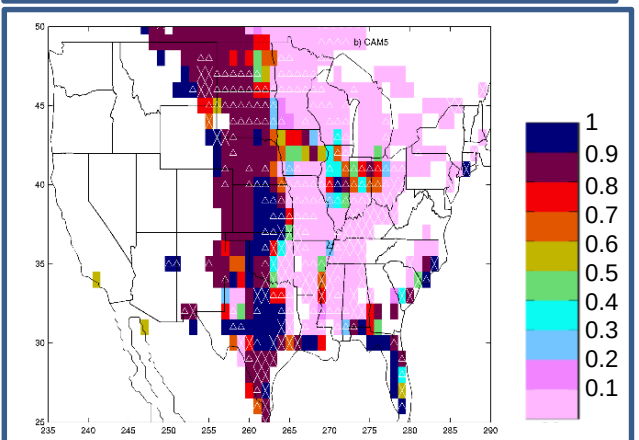
Evap fraction error explains 0-5 K of error, and most of error, when error is large.

Radiation error explain 0-2 K of the error.



Link between **evap fraction** error and soil moisture error.

Is what we learn at SGP representative of what is happening elsewhere?



Large correlation of temp error over Midwest with temp error at SGP.

Morcrette C. et al. 2018. "Introduction to CAUSES: Description of Weather and Climate Models and Their Near-Surface Temperature Errors in 5 day Hindcasts Near the Southern Great Plains." Journal of Geophysical Research: Atmospheres, , doi:10.1002/2017JD027199. ONLINE.

GASS GEWEX WCRP Global Atmospheric System Studies | ASR Atmospheric System Research | Met Office | PCMDI | RGCM

Small Particles Play Large Role in Thunderstorms

Objective

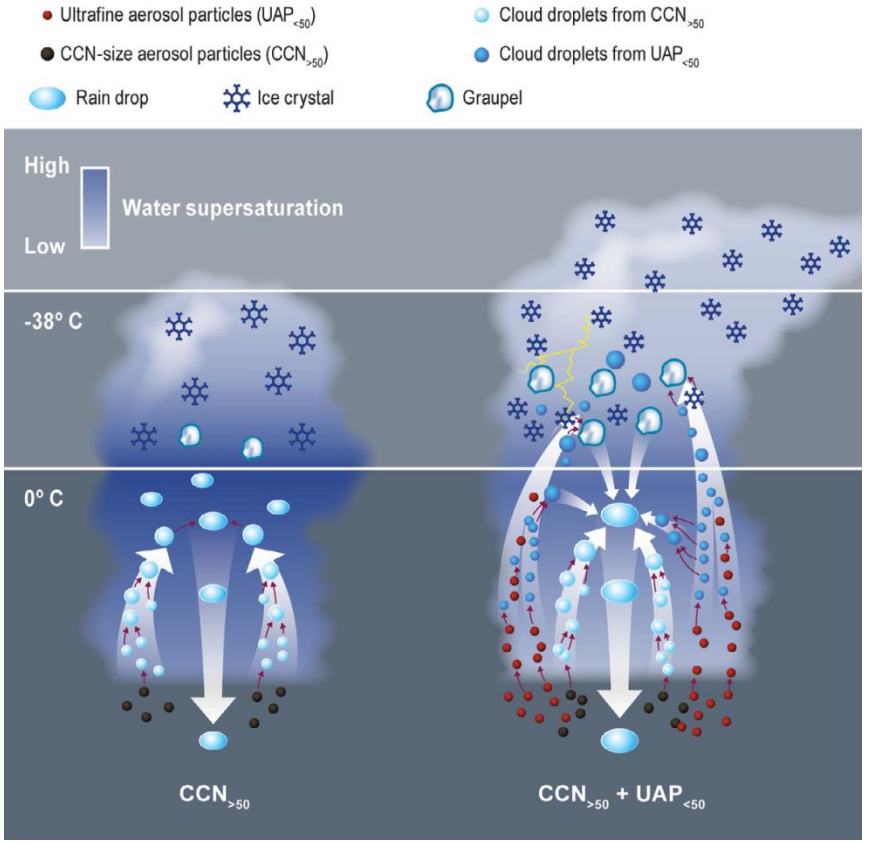
- Study how aerosols affect the development of thunderstorms to reduce uncertainty in modeling of aerosol-cloud interactions

Approach

- Analyzed the unique ARM GOAmazon observations and discovered that ultrafine aerosol particles can impact convective intensity & precipitation
- Used detailed numerical modeling to understand the physical processes and mechanisms responsible for this observed intensification of convection

Impact

- Ultrafine aerosol particles (< 50 nm) were assumed to have small impacts on clouds
- In a warm & humid environment, ultrafine particles can invigorate thunderstorms in a much more powerful way than their larger counterparts through an enhanced condensation mechanism
- Incorporating these results in earth system models will improve their representation of deep convective processes



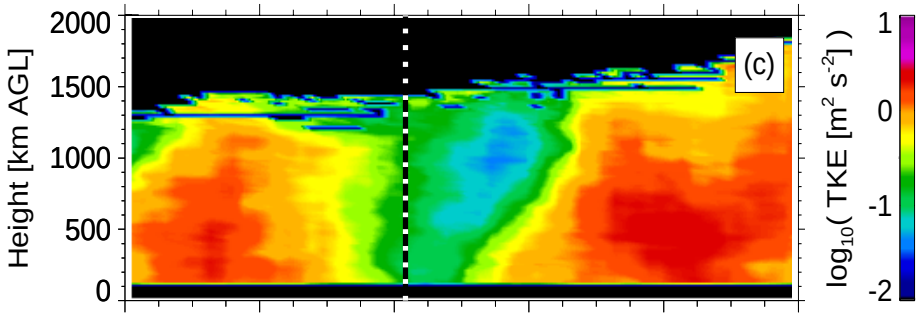
Using data from GOAMAZON and numerical modeling, ASR scientists found that small particles play a larger role in tropical storm clouds than bigger particles, primarily due to enhanced condensation.

Fan J, D Rosenfeld, Y Zhang, SE Giangrande, Z Li, LAT Machado, ST Martin, Y Yang, J Wang, P Artaxo, HMJ Barbosa, RC Braga, JM Comstock, Z Feng, W Gao, HB Gomes, F Mei, C Pöhlker, ML Pöhlker, U Pöschl, and RAF de Souza. 2018. "Substantial Convection and Precipitation Enhancements by Ultrafine Aerosol Particles." *Science,* 359(6374), 10.1126/science.aan8461.

Solar eclipse helps scientists study boundary layer

Objective

- The 2017 Land-Atmosphere Feedback Experiment (LAFE) at ARM Southern Great Plains site in Oklahoma was designed to study land-atmosphere interactions with state of the art scanning lidars
- Solar eclipse provided a unique opportunity to study boundary layer transitions during an analogue to a rapid sunset/sunrise



Response of the turbulent kinetic energy profile to the solar eclipse. Time of full eclipse indicated by dashed line.

Approach

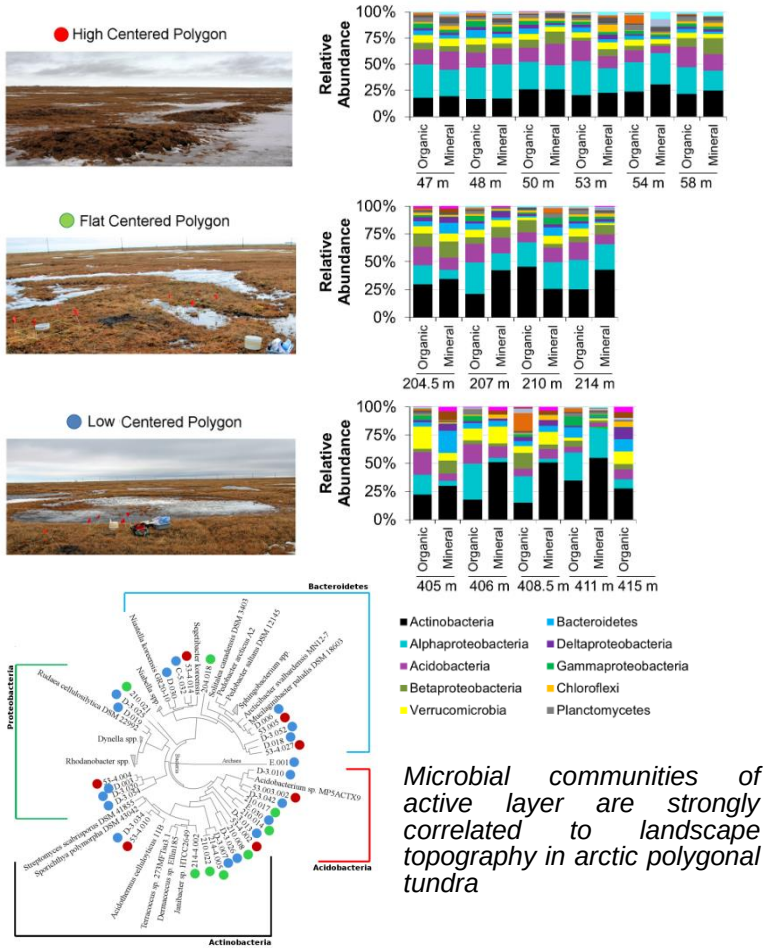
- Used ARM and other observations to study the response of the land surface and the atmospheric boundary layer during and after the eclipse
- Comparisons of this rapid event to normal sunset/sunrise events will enable separation of quick and slow processes associated with evolution of surface properties and boundary layer during transitions

Impact

- After the collapse of the convective boundary layer during the peak of the eclipse, a nocturnal boundary layer developed that included both a dramatic decrease in the turbulent kinetic energy and the development of a low-level jet.
- When the sun reemerged from behind the moon, a new convective boundary layer rapidly developed.
- The observations during the solar eclipse provide a unique opportunity to evaluate how models handle these transitions.

Turner D, V Wulfmeyer, A Behrendt, T Bonin, A Choukulkar, R Newsom, W Brewer, and D Cook. 2018. "Response of the Land-Atmosphere System Over North-Central Oklahoma During the 2017 Eclipse." Geophysical Research Letters, 45(3), 10.1002/2017GL076908.

Landscape Topography Structures the Soil Microbiome in Arctic Polygonal Tundra



Microbial communities of active layer are strongly correlated to landscape topography in arctic polygonal tundra

- Environmental factors governing microbial degradation of soil carbon in active layer and permafrost are poorly understood. Determined the functional potential of soil microbiomes horizontally and vertically across a cryoperturbed polygonal landscape in Barrow.
- Demonstrated that microbial communities and ecosystem function vary across fine-scale topography in an arctic polygonal tundra.
- With comparative metagenomics, genome binning of novel microbes, and gas flux measurements, microbial greenhouse gas production strongly correlates to topography.
- Microbial functions such as fermentation and methanogenesis were dominant in wetter polygons, in drier polygons genes for C mineralization and CH_4 oxidation were abundant.

Reference: Taş et al.(2018),Landscape topography structures the soil microbiome in arctic polygonal tundra, *Nature Communications*, doi:10.1038/s41467-018-03089-z

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NGEE-Arctic Next-Generation Ecosystem Experiments | EARTH & ENVIRONMENTAL SCIENCES

BERKELEY LAB

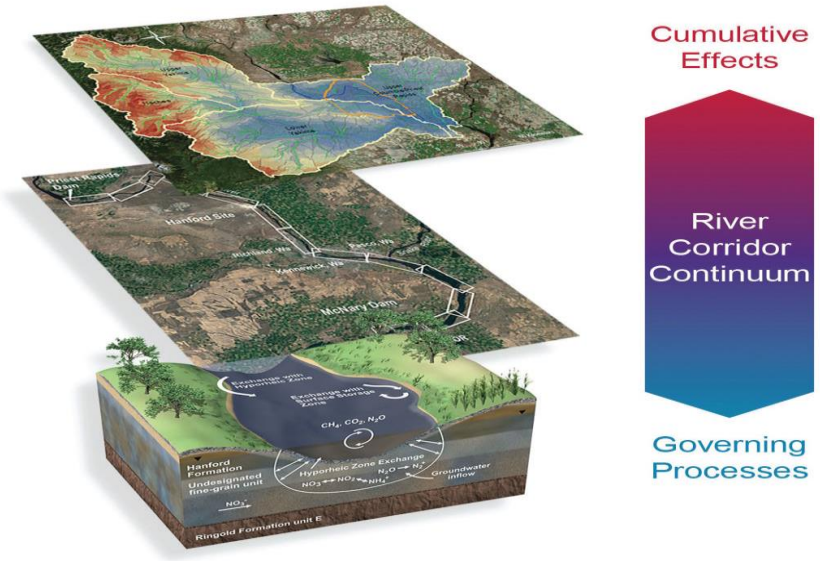
New Conceptual Model of BGC Mixing in the Hyporheic Zone

Objective

- To determine if biogeochemical activity in the hyporheic zone can be described by thermodynamic mechanisms.

New Science

- A four-part thermodynamic mechanism, distinct from classical paradigms, governs the biogeochemical impacts of groundwater-river water mixing.
- This mechanism leads to nonlinearities through space and time in the concentration of dissolved organic carbon throughout the larger-scale hyporheic corridor.
- The ecology of microbes within the zone of stimulated activity is tied to biochemical processes distinct from those occurring in other parts of the system.



Significance

- Reveals novel mechanisms that must be accounted for within predictive hydro-biogeochemical models
- Demonstrates the larger scale consequences of small-scale processes, providing a point of reference for moving process knowledge across scales
- Indicates important feedbacks among organic carbon thermodynamics, biochemical mechanisms, microbial ecology, and dynamic hydrology

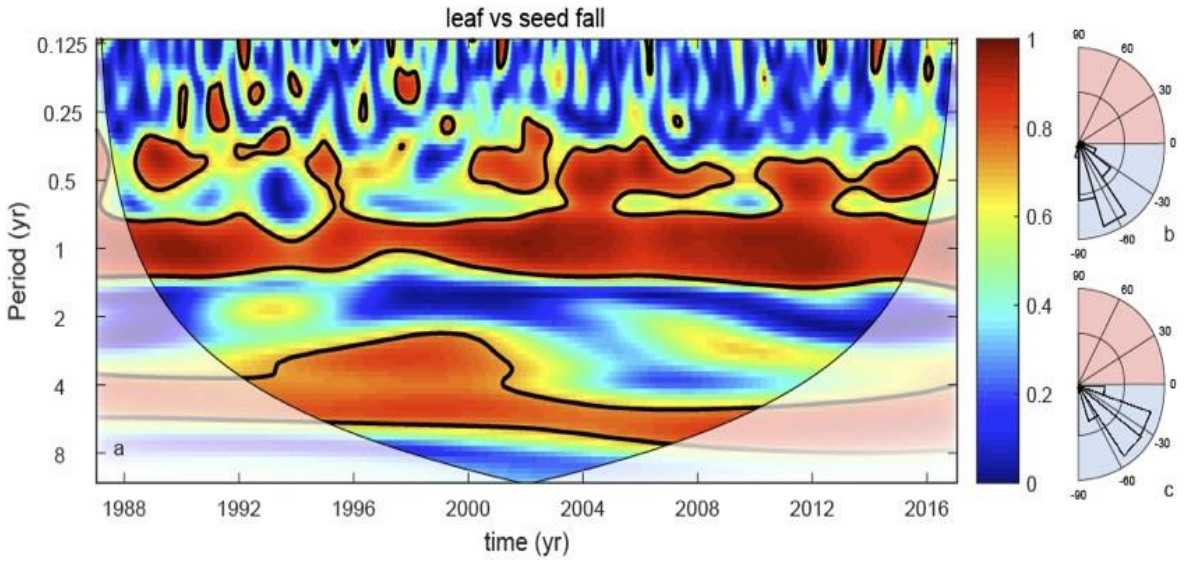
J.C. Stegen, et al., “Influences of organic carbon speciation on hyporheic corridor biogeochemistry and microbial ecology.” *Nature Communications* 585 (2018). DOI: 10.1038/s41467-018-02922-9

Resource Acquisition & Reproductive Strategies of Tropical Forest in Response to the El Niño–Southern Oscillation

Objective:
Determine how tropical systems respond to ENSO variability

Approach:
Analyze weekly samples of tropical forest fruit and leaf fall at Barro Colorado Island, Panama over 30 years

Correlate with phase of ENSO



Results: (**a)** strong coordination at both seasonal and ENSO cycles (red regions); (**b)** Phase-angle histogram for leaf fall and seed fall for the seasonal cycle; and (c) for periods of 2–7 years, corresponding to the ENSO cycle. Phase angles were calculated for areas inside the cone of influence and for coherence >0.5 in (a). Negative angles (blue area) indicate that leaf fall leads seed fall.

The temporal lags between phenology and soil water availability indicates higher leaf fall before a dry warm phase and higher fruiting following such phase.

This is the first time that ENSO scale mode of variability is discovered to drive phenophases of tropical plants. This interaction mirrors the dynamics between dry and wet season, suggesting adaptive strategies to optimize reproduction and resource acquisition in response to environmental conditions

Detto, M., Wright, S. J., Calderón, O. & Muller-landau, H. C. (2018) Resource acquisition and reproductive strategies of tropical forest in response to the El Niño- Southern Oscillation. *Nature Communication*. 9, 1–8.

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NGEE-Tropics Next-Generation Ecosystem Experiments

PRINCETON UNIVERSITY Smithsonian

Earth system models can successfully simulate a major mode of decadal variability, the Interdecadal Pacific Oscillation (IPO)

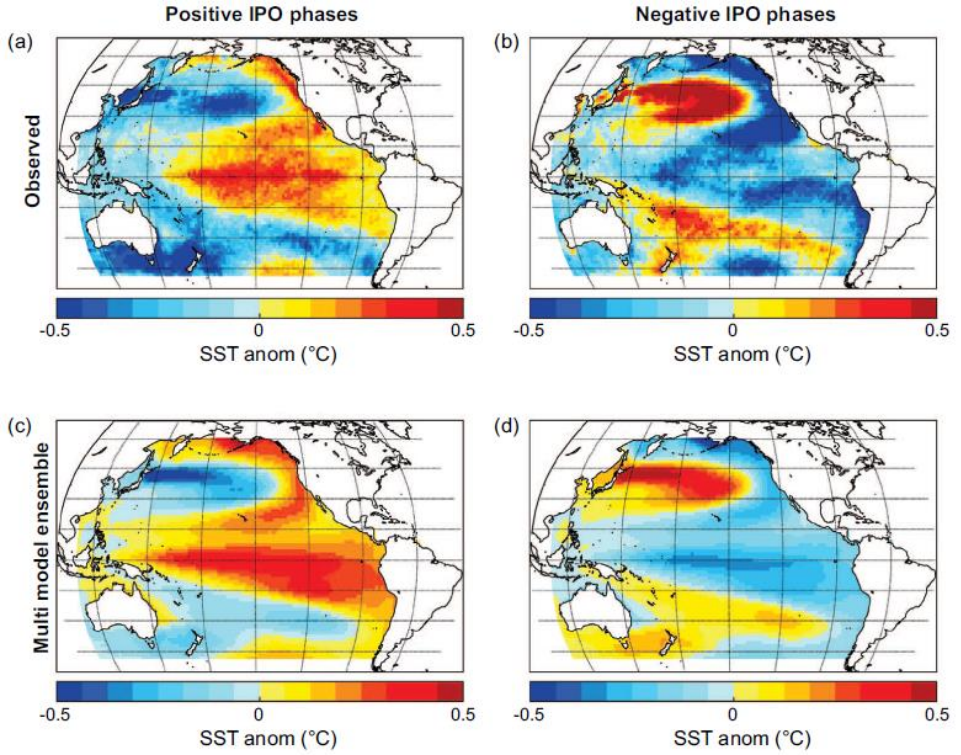
Significance: The IPO is a long-term oscillation of sea-surface temperatures in the Pacific Ocean that can last from 20 to 30 years. Its positive and negative phases affect the strength and frequency of El Niño and La Niña.

Objective: Explore how well current Earth System Models simulate a major mode of internally generated, naturally-occurring decadal earth system variability, the Interdecadal Pacific Oscillation (IPO).

Research:

- Analyze the CMIP5 multi-model ensemble to document the models' capability to simulate the IPO
- Compare model results to observations, and quantify agreement

Results: A systematic evaluation of the simulation of the IPO in the suite of Coupled Model Intercomparison Project 5 (CMIP5) models shows that the Pacific basin-wide spatial pattern of positive and negative phases of the IPO are simulated reasonably well, thus building confidence in initialized decadal climate simulations that include the IPO



Spatial IPO patterns show good agreement between models and observations. Observed IPO spatial patterns in (a) IPO positive and (b) IPO negative phases; Multi-model pre-industrial control mean spatial patterns of IPO in (c) IPO positive and (d) IPO negative

Henley, B.J., **G.A. Meehl**, S.B. Power, C.K. Folland, A.D. King, J.N. Brown, D.J. Karoly, F. Delage, A.J.E. Gallant, M. Freund, and R. Neukom, 2017: Spatial and temporal agreement in climate model simulations of the Interdecadal Pacific Oscillation, *Env. Res. Lett.,* 12, 044011.

NCAR

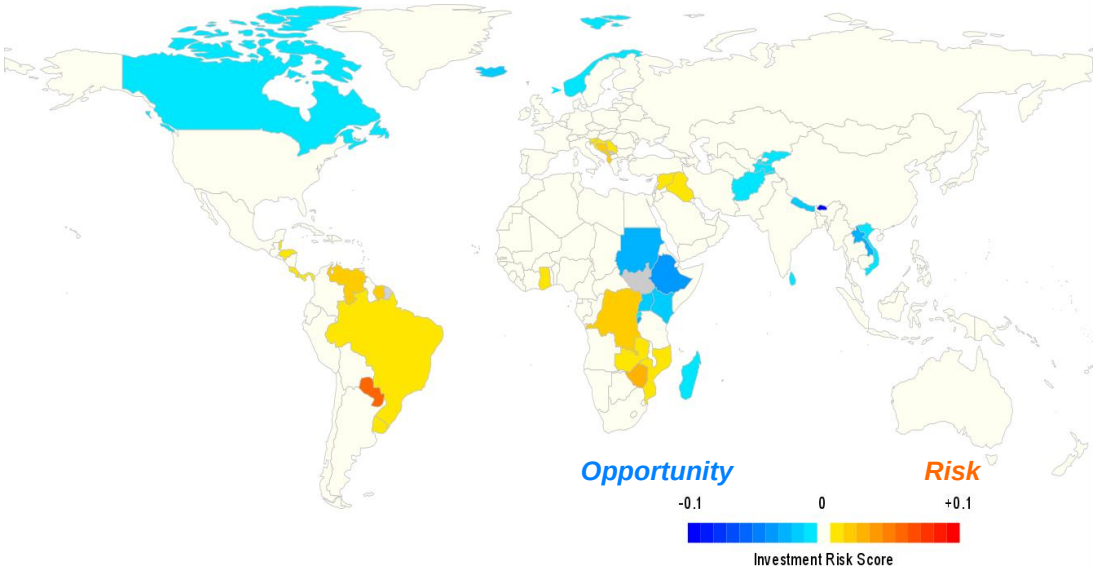
Future Hydropower Generation and Consequences for Global Electricity Supply

Objective

- Assess how impaired or enhanced hydropower generation due to changes in future precipitation and temperature could affect power sector technology deployment and associated investment needs across the globe

Approach

- Simulate power generation at ~1,600 large hydropower dams throughout the world
- Implement resulting regional hydropower generation trajectories in the Global Change Assessment Model to simulate technology deployment in the 21st century
- Assess risk and opportunity for individual countries



Changes in future precipitation and temperature present both opportunities and risks for hydropower generation around the globe.

Impact

- Hydro-dependent countries in drying regions likely to need substantial investments (about $1 trillion in the 21st century) to address impaired power production
- Canada, Norway, and a selection of South Asian countries could avoid substantial investments as increased precipitation raises output

Turner SWD, M Hejazi, SH Kim, L Clarke, and J Edmonds. 2017. “Climate Impacts on Hydropower and Consequences for Global Electricity Supply Investment Needs.” *Energy* 141:2081-2090. DOI: 10.1016/j.energy.2017.11.089

The Earth System Grid Federation: Outreach, engagement, and contributions to the community

Challenge

Framework for and relationships among distributed, federated data products and services to support powerful, flexible, and advanced computational virtual environments and data analytics.

Approach and Results

- Federated, web-based, application programming interface (API) software and data infrastructure that are easy to use and secure.
- A flexible infrastructure that allows participating data projects to customize parameters to address their specific requirements.
- High-performance search, analysis, and visualization tools that make data accessible and useful to the climate research community.
- Access to a broad set of data and tools for comparative and exploratory analysis.
- A virtual collaborative environment for diverse research and analysis tasks that demand large and varied data sets.

ESGF won the 2017 R&D 100 Award for Software and sustained community services.

Significance and Impact

- Currently serving more than 25,000 users.
- The ESGF archive supports more than 700,000 data sets and over 6 petabytes of data.
- The ESGF archive manages over 6 petabytes of Earth system science data sets from more than 25 projects, including multiple model intercomparison projects (MIPs) such as the Coupled Model Intercomparison Project (CMIP).

Participants: LLNL (lead), DKRZ, IPSL, NASA, NOAA, NCI, CRIM, CEDA, NSF

Reference: Justin Hnilo and Dean N. Williams. “ESGF Brochure / White Paper”, https://esgf.llnl.gov/brochures.html.

ESS-DIVE: A New Data Archive for Earth and Environmental Science Data

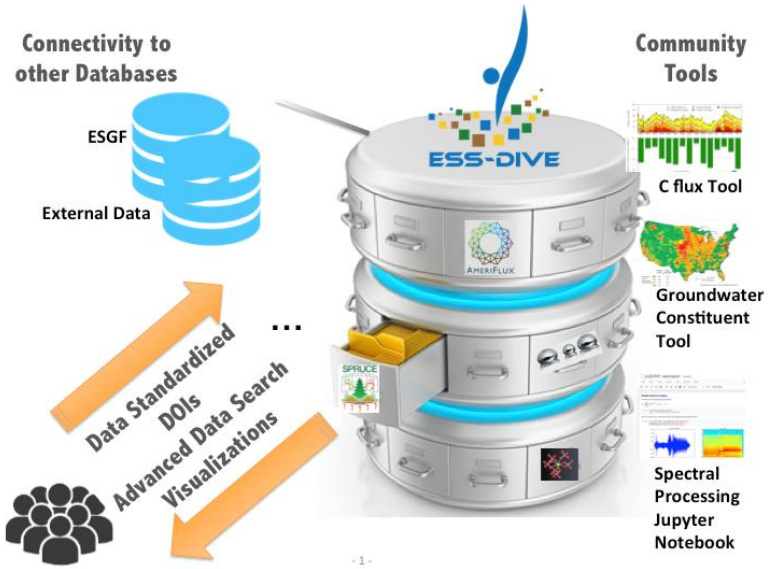
Challenge

Preserve, expand access to, and improve usability of critical data generated through DOE-sponsored research of terrestrial and subsurface ecosystems

http://ess-dive.lbl.gov

Approach and Results

- Environmental System Science - Data Infrastructure for a Virtual Ecosystem (ESS-DIVE) available for archiving of data as of April 2018
- Leverage emerging digital library technologies and data standards
- Data citation using Digital Object Identifiers (DOI)
- Engage the community in the design of the archive
- Incentivize data providers to contribute well-structured, high-quality data
- Transition legacy DOE data into the new archive



Significance and Impact

- Enables the scientific community to archive and publish critical environmental science data
- Users will be able to find and obtain data generated by ESS researchers in usable formats

Participants:

- Lawrence Berkeley National Laboratory (LBNL)
- National Energy Research Scientific Computing Center (NERSC)
- National Center for Ecological Analysis and Synthesis (NCEAS)

Reference: D. Agarwal, C. Varadharajan, et al., IN12B-06 Environmental System Science Data Infrastructure for a Virtual Ecosystem (ESS-DIVE) - A New U.S. DOE Data Archive, Presented at American Geophysical Union Fall Meeting 2017.

THANK YOU!