Earth and Environmental Systems Sciences Division

BERAC update

April 16, 2020

G. Geernaert

BER/EESSD

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.

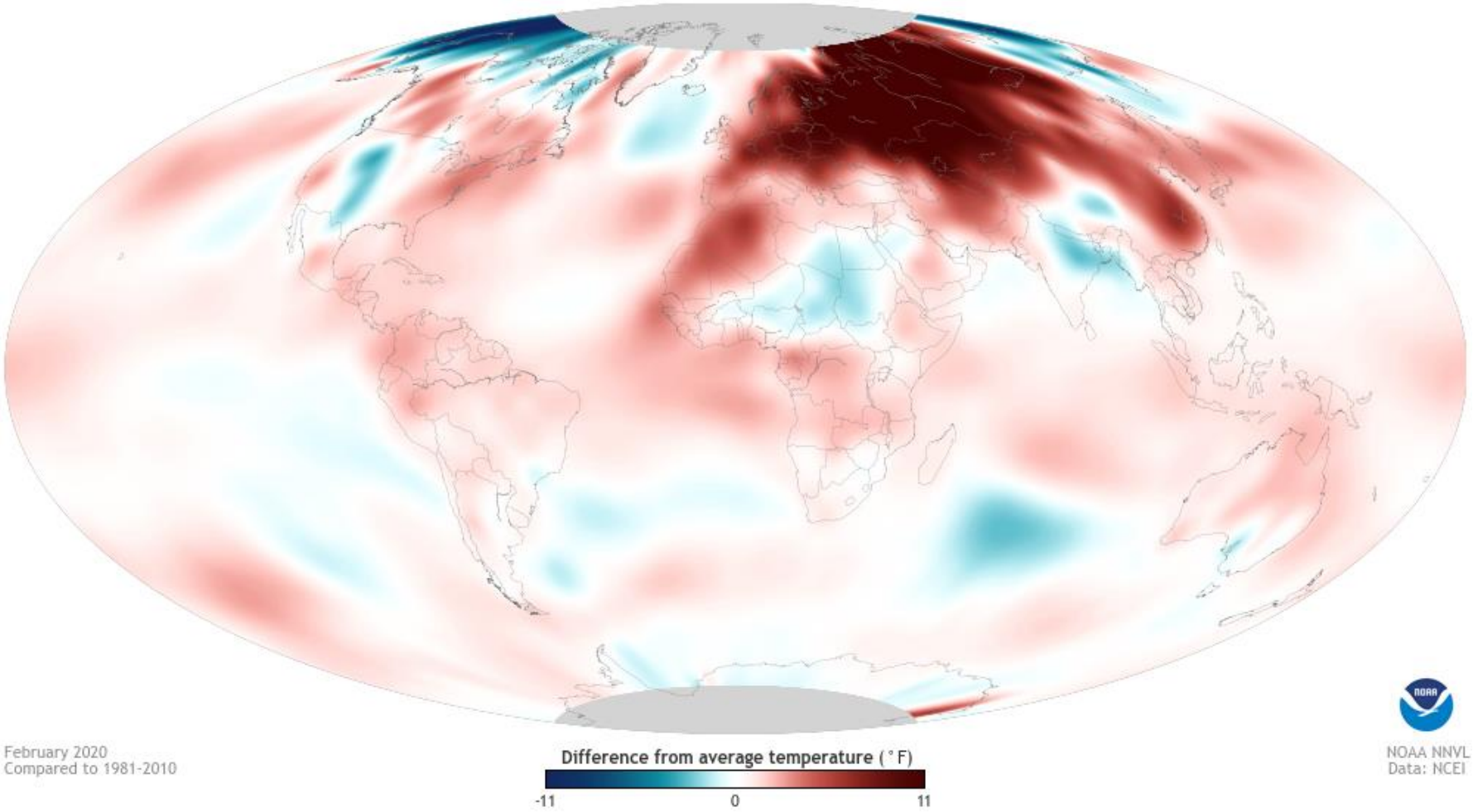
High level Grand Challenges

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

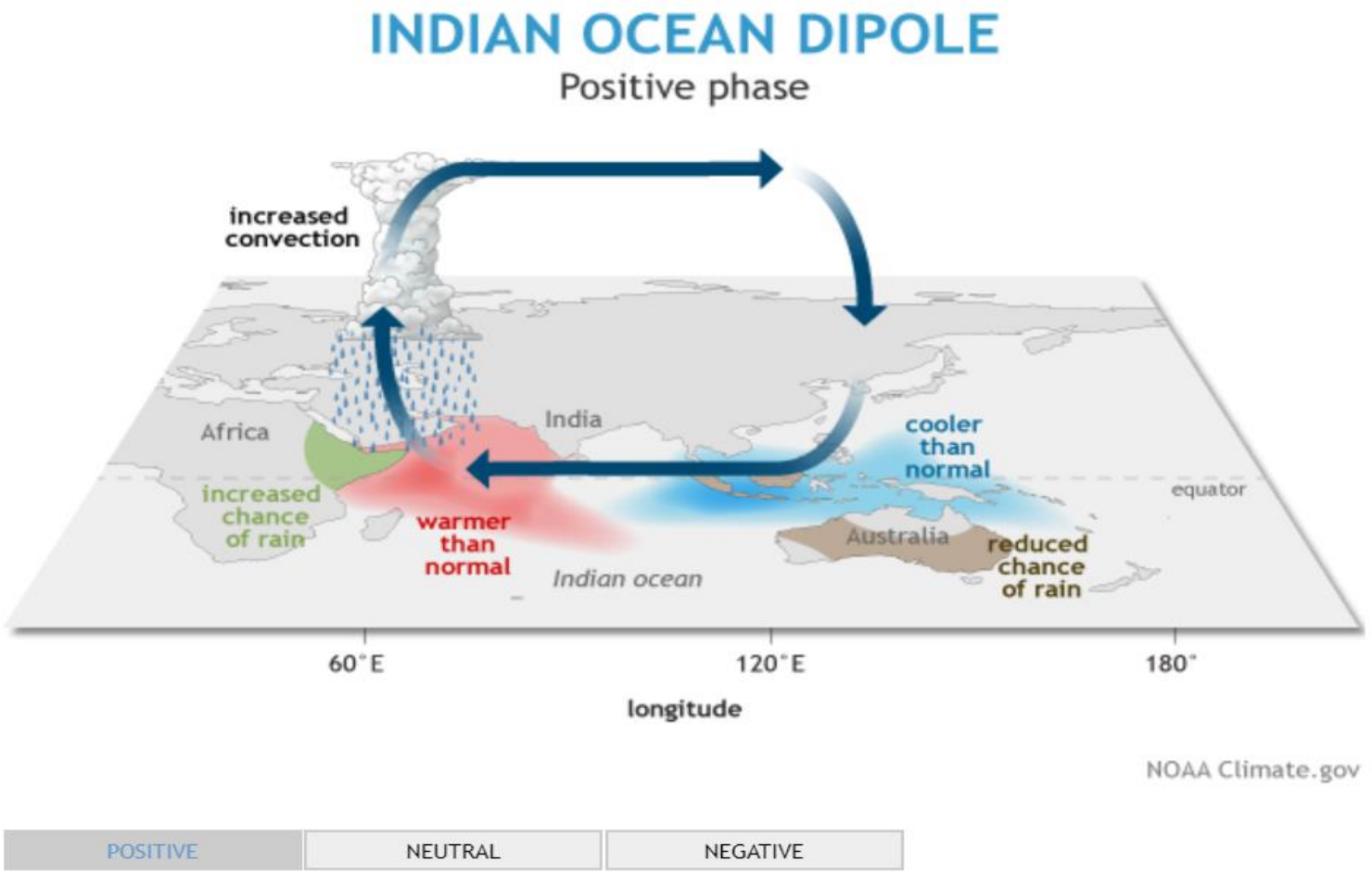
Execution involving integrative coastal research involving terrestrial/aquatic regions

- Timing: models at sufficiently high resolution to explore new science
- Collaborative opportunities: NOAA; USGS; NGA; NSF; NASA
- Topics: disturbance, initialization, data analytics (e.g., machine learning), software, advanced technologies, coastal, Terrestrial-Aquatic Interfaces, etc.

Anomaly for November 2019 through February 2020



Anomaly over Indian Ocean – East Africa and Australia



POSITIVE	NEUTRAL	NEGATIVE

Workshops set the stage for future EESSD priorities

Date	Topic	Venue
Sept 4-6, 2019	Integrated hydro-terrestrial models- development of a national prediction capability. (with NOAA, NSF, and USGS)	NSF, Alexandria
April 4 (now thru month of April)	Cloud-aerosol interactions and modeling (now as 4 mini-workshops during April and May). w/NASA, NOAA, and NSF	Virtual, delayed and distributed as 4 webinars
April 2020	Cyberinfrastructure Workshop	Virtual webinars
June 30 – July 1	Climate Modeling Summit	Wash DC
Spring 2021	Lessons learned from FACE, NGEE, and MODEX	Wash DC

Management Update: solicitations

Funds	Program lead	Issued	Proposals	Panel	Selections
FY20	Early Career (model/coastal)	Nov 21, 2019	28	Apr 30 - May 1, 2020	
FY20	ESS	Nov 7, 2019	116	May 4-8, 2020	
FY20	ASR	Nov 20, 2019	87	May 11-15, 2020	
FY20	Modeling	Dec 17, 2019	70 preapps	May 28-29, 2020	

Management updates - PI meetings: 2019-2020

Title	Program(s)	Location	Date in 2020
GCAM annual meeting	Modeling	PNNL/UMD	Nov 5-6, 2020
E3SM all-hands	Modeling	Arlington, VA	Nov 19-21
NGEE Arctic/Tropics	TES	San Francisco	Dec 15, 21
ESS PI meeting	TES, SBR	Hyatt Bethesda	May 19-20. Now virtual as 90 min webinars each day. Full PI mtg moved to 2021
PCHES PI meeting	Modeling	Penn State	Postponed to fall
ARM/ASR PI meeting	ARM, ASR	Rockville Hilton	Jun 22-26, 2020
Modeling PI meeting	ESM, RGMA, MSD	TBD	Mid FY2021

Title		Location	Date in 2019
Committee of Visitors	CESD	Germantown	July 8-10, 2019

Management updates: Major reviews in 2019-2020

Lab	Program	Type	Review date	Decision	Date
LBNL	Model	CASCADE SFA	Sep 23-24, 2019	Accept	Jan 9, 2020
LBNL	TES	NGEE Tropics	Oct 16-18, 2019	Accept	Nov 26, 2019
LLNL	Model/ASR	PCMDI SFA	Oct. 29-30, 2019	Modified	Feb 7, 2020
PNNL	Model	IM3	Mar 25, 2020		
PNNL	Model	IHESD	Mar 26, 2020		
PNNL	ESS	SBR	May 21, 2020		
ANL	ESS	TES	June 2, 2020		
SLAC	ESS	SBR	June 17, 2020		
LBNL	ESS	Ameriflux mgmt	June (mail in)		
LBNL	Data	ESS-DIVE	July 19-20, 2020		
LLNL	Data	Exashed	Late summer		
LLNL	Data	ESGF	Late summer		
PNNL	ASR	ICLASS	Aug 9-12, 2020		
PNNL	Division	Coastal	Sept 2020		
PNNL, …	ARM	Facility	Sep 21-25, 2020		
BNL/ANL	ASR	ASR	Nov 3-5, 2020		

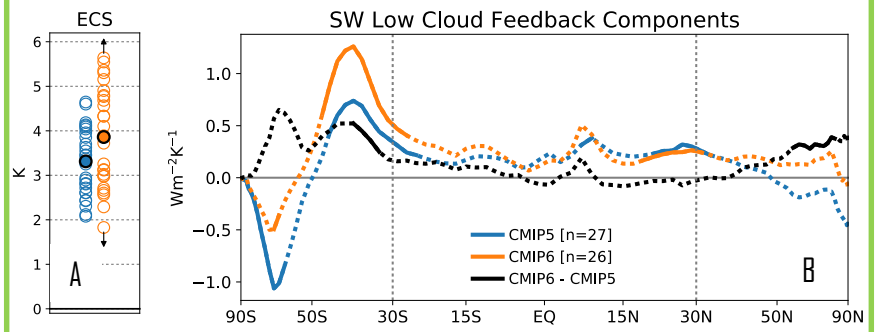
Why Is Climate More Sensitive in the Latest Earth System Models?

Objective: Determine why CMIP6 models produce much higher (~0.5°C) climate sensitivity than the earlier CMIP5 models

Approach: The LLNL team computed radiative forcing, feedbacks, and climate sensitivity across 27 CMIP6 and 28 CMIP5 models

Results:

- Analyses show stronger amplifying cloud feedbacks from decreases in extratropical low cloud amount and reflectivity, due to water content and coverage of low-level clouds decreasing more strongly with warming, This leads to enhanced planetary absorption of sunlight that ultimately results in more warming.
- Differences in the physical representation of clouds in models were shown to drive this enhanced sensitivity.



(A) Estimates of effective climate sensitivity (ECS) for individual (blue) CMIP5 and (orange) CMIP6 models. Multi-model averages are shown with filled markers.
(B) Zonally averaged multi-model average shortwave low cloud feedbacks.
CMIP6-CMIP5 differences are shown in black lines, which are solid where differences are significant at 95% confidence.

Significance

- These results suggest cloud-aerosol feedbacks are introducing far more significant biases in long term projections.
- it will be crucial to establish whether their predictions of greater future warming are also more realistic.

Zelinka, M.D., T. A. Myers, D. T. McCoy, S. Po-Chedley, P. M. Caldwell, P. Ceppi, S. A. Klein, & K. E. Taylor, 2019: Causes of higher climate sensitivity in CMIP6 models, *Geophys. Res. Lett.*, doi:10.1029/2019GL085782.

Flood Generation Mechanisms and Their Recent Trends

Objective

- Improve ability of global earth system models to represent floods, which are important to both ecological processes and infrastructure planning
- Study flood generation mechanisms and their recent trends in global major river basins

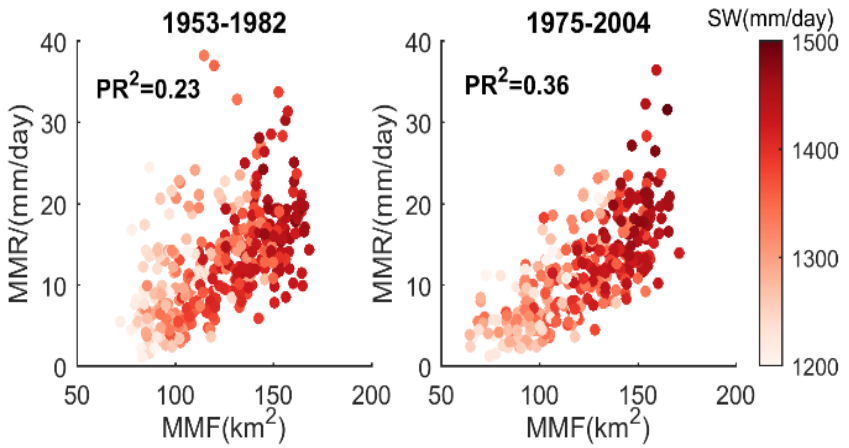
Approach

- Calibrate and evaluate a physically-based floodplain inundation model coupled with the land and river models of Energy Exascale Earth System Model (E3SM) using observed streamflow and inundation
- Perform and analyze global simulations of flood inundation area to understand flood generation mechanisms and their trends in 1953-2004

Impact

- Demonstrated the ability of E3SM for global modeling of floodplain inundation
- Identified the flood generation mechanisms in major river basins around the world
- Revealed significant trends in the contributions of extreme rainfall and snowmelt to floods in major basins and the processes responsible for the trends
- Future work will implement land-river-ocean coupling in E3SM to improve simulations of coastal flooding

Amazon Basin



Top: Monthly maximum rainfall (MMR) explains a larger fraction of variance in monthly maximum flood (MMF) in 1975-2004 than 1953-1982. Soil wetness (SW) is high when MMR is also high in the later period.

Mao, Y., T. Zhou, L.R. Leung, T.K. Tesfa, H.-Y. Li, K. Wang, Z. Tan, and A. Getirana. 2019. "Flood Inundation Generation Mechanisms and Their Changes from 1953 to 2004 in Global Major River Basins." J. Geophys. Res., doi:10.1029/2019JD031381.

Irrigation Practices affect Monsoon Precipitation

Objective

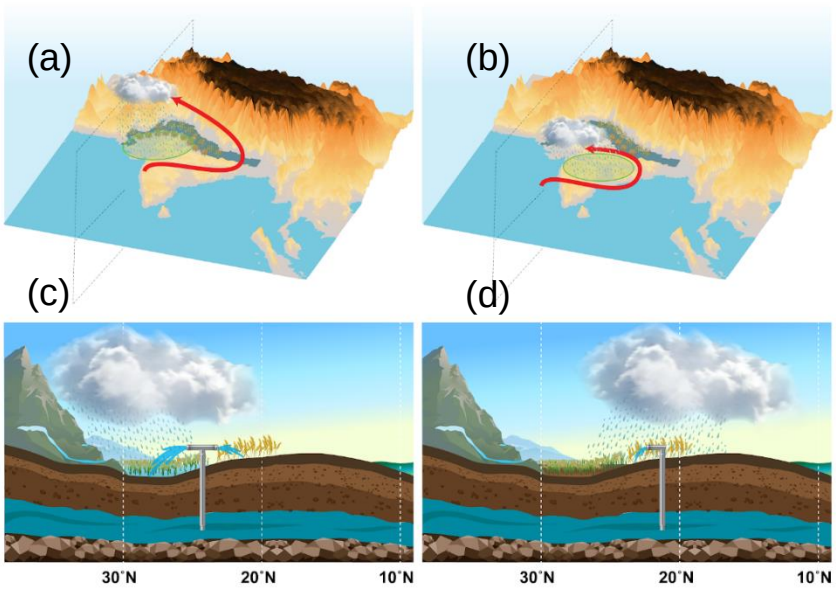
- Understand the effects of land and water management practices on monsoon circulation and extreme rainfall.

Approach

- Implement modules into Weather Research and Forecasting model coupled to the Community Land Model version 4 (WRF-CLM4) to represent irrigation, groundwater pumping, and the bio-geophysical effects of flooded paddy fields.
- Employ the enhanced WRF-CLM4 to simulate the impact of agricultural water management practices using numerical experiments.

Impact

- Confirmed through modeling that excess irrigation over northern India causes a northwestward shift in monsoon rainfall and intensifies widespread extreme precipitation over Central India, consistent with observations.
- Demonstrated that it is important to represent land management and irrigation practices accurately in Earth system and weather models.



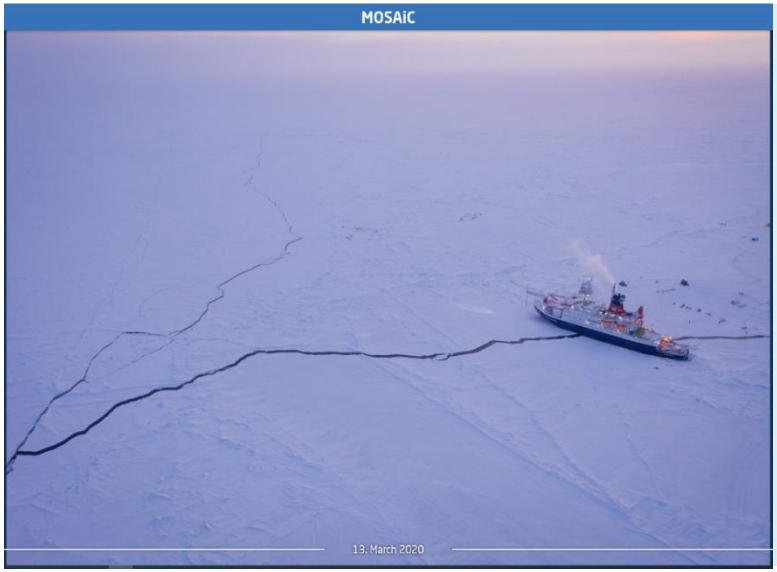
Experiments with realistic representation of unmanaged irrigation and paddy cultivation over north-northwest India exhibit an increase in the late season terrestrial monsoon precipitation and intensification of widespread extreme events over Central India (panels a and c), compared to the case in which irrigation is managed based on crop water demand (panels b and d). This finding is consistent with changes in observations.

Devanand A, M Huang, M Ashfaq, B Barik, S Ghosh. 2019. "Choice of Irrigation Water Management Practice affects Indian Summer Monsoon Rainfall and its Extremes." *Geophysical Research Letters,* 46 (15): 9126-9135, *https://doi.org/10.1029/2019GL083875* .

ARM Major Field Campaigns

Title	Location	Time	Principal Investigator	Major Facility
AWARE	Antarctica	Nov 2015 – Jan 2017	Dan Lubin, Scripps	AMF-2
HI-SCALE	Southern Great Plains	Apr – Sep 2016	Jerome Fast, PNNL	G-1, SGP
LASIC	Ascension Island, S. Atlantic	June 2016 – Oct 2017	Paquita Zuidema, U. Miami	AMF-1
ACE-ENA	Azores	June-July 2017; Jan-Feb 2018	Jian Wang, BNL	G-1
MARCUS	Southern Ocean	Oct 2017 – Apr 2018	Greg McFarquhar, U. Illinois	AMF-2
CACTI	Argentina	Oct 2018 – Apr 2019	Adam Varble, U. Utah/PNNL	AMF-1, G-1
MOSAIC	Arctic Ocean	Sep 2019 – Oct 2020	Matt Shupe, U. Colorado/NOAA	AMF2
COMBLE*	Norway	Jan 2020 – May 2020	Bart Geerts, U. Wyoming	AMF1
TRACER*	Houston	Apr 2021 – Mar 2022	Mike Jensen, BNL	AMF1
SAIL*	Crested Butte	Sept 2021-June 2023	Dan Feldman, LBNL	AMF2

ARM Update



MOSAIC

- **3 ARM staff onboard Polarstern operating ARM Mobile Facility**
- **Challenges due to ice conditions and COVID-19 travel restrictions – however there is no coronavirus on the ship**
- **Instrumentation on ice had to be moved after large lead opened up near ship; still issues with power to the "Met City" instruments**
- **Polarstern has followed expected drift path, but ice has moved south faster than expected; currently at position expected to reach in August**
- **Planned aircraft resupply/crew change in April cancelled; current tentative plan is for resupply with an ice breaker in June**

ARM sites responsive to COVID19:

- **Sites closed to guest users, only site operations staff on site**
- **All sites have implemented social distancing guidelines and are limiting number of operational staff on site at a time**
- **No travel by ARM instrument mentors to sites; many instrument repairs postponed**
- **SGP site recently moved to limited operations - no staff on site and no daily instrument maintenance; some instruments shut down, others being monitored remotely**
- **Oliktok site likely to move to reduced operations, staff only on site 1-2 times/week**

An explanation for black carbon absorption enhancement discrepancies

Motivation

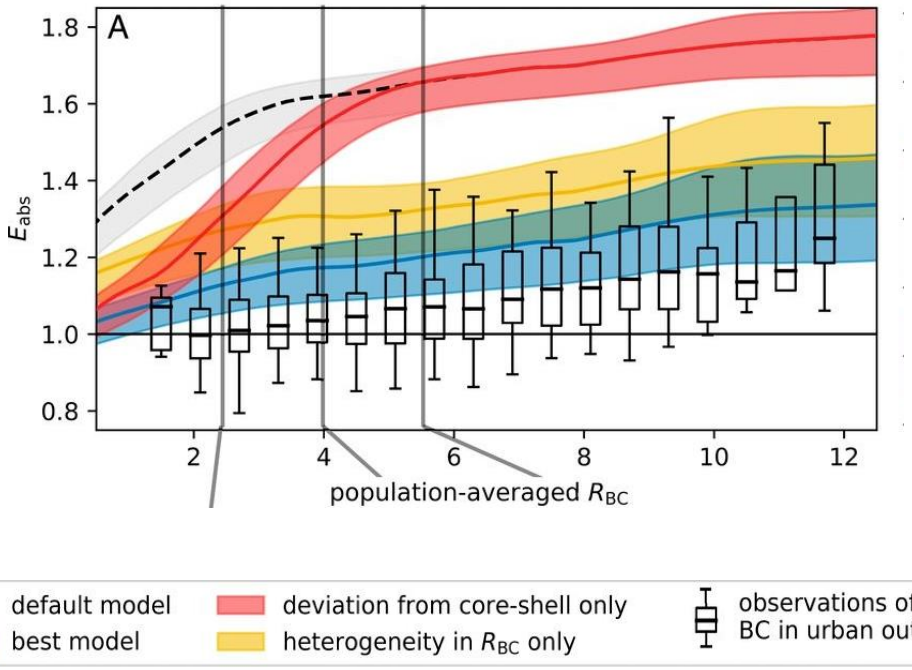
- Black carbon, formed through incomplete combustion, is the second most important climate warming agent after CO2
- Large discrepancies between standard model predictions and regionally specific observations exist. Atmospheric observations of absorption are often much lower than expected based on models and lab experiments. These discrepancies add to uncertainty the global climate impacts of black carbon.

Approach

- Lower-than-expected enhancements in ambient measurements relative to laboratory and modeling studies result from a combination of two factors: particle-to-particle compositional heterogeneity and deviation from the core-shell approximation.
- When both factors are accounted for, model results compare much better to ambient atmospheric observations.
- ARM photometer in field observations

Impact

- This work provides a consistent model framework that explains disparate observations and that can be used to improve estimates of black carbon's impact on climate.



Fierce, L., T. B. Onasch, C. Cappa, C. Mazzoleni, S. China, J. Bhandari, P. Davidovits, D. A. Fischer, T. Helgestad, A. Lambe, A. J. Sedlacek III, G. D. Smith, and L. Wolff, Radiative absorption enhancements by black carbon controlled by particle-to-particle heterogeneity in composition, *Proc.Nat. Acad. Sci.,* 117 (10) 5196-5203; DOI: 10.1073/pnas.1919723117

Earlier Leaf-Out Warms Air in the North.

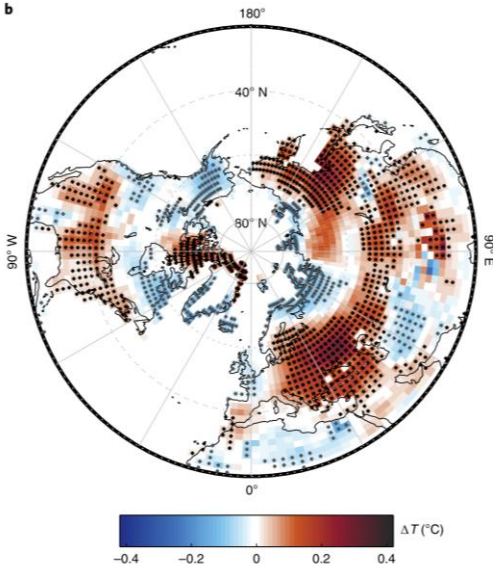


Figure. Temperature response to imposed 12-day earlier spring leaf out throughout the northern hemisphere.

Scientific Achievement

The timing of leaf growth in the spring is sensitive to climate, and has shifted earlier in recent decades. Earth System Model experiments show that earlier spring greenup can affect atmospheric circulation and radiative balance, and thereby further warm the climate.

Significance & Impact

The extra warming due to increased water vapor and clouds in the atmosphere that results from earlier leaf-out, is sufficiently large that it can amplify the climate response.

Research Details

- Warming due to atmospheric water vapor larger than the direct surface energy balance effects of earlier leaf greenup
- Spring leaf phenology has been observed to shift, and its representation in climate models is not well constrained.
- Because the warming that results from these phenological shifts is large, our results emphasize the importance of better representing phenology in climate models.

RUBISCO

BERKELEY LAB

Xu, X., Riley, W. J., Koven, C. D., Jia, G., Zhang, X. (2020). Earlier leaf-out warms air in the north. Nature Climate Change, doi:10.1038/s41558-020-0713-4.

From the Arctic to the Tropics: Multi-Biome Prediction of Leaf Mass Per Area Using Leaf Reflectance

Objective

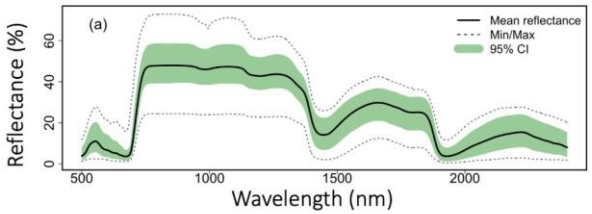
Leaf-mass-per-area (LMA) is a key plant trait, reflecting fundamental tradeoffs in resource investments to leaf photosynthesis, longevity, and structure. As such, capturing spatial and temporal variability in LMA is a goal of ecological research and is an essential component for advancing Earth system models.

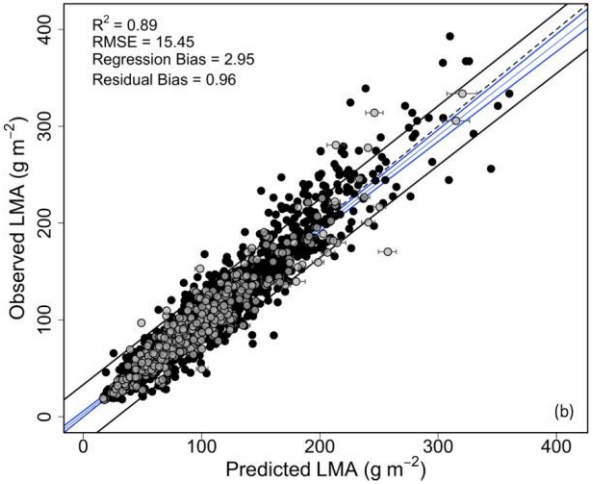
New Science

- Traditional approaches for measuring LMA are laborious while existing approaches utilizing remote sensing have focused on small geographic areas
- We assembled a large dataset of combined LMA and leaf reflectance spectra measurements across a broad range of species and growth environments
- For the first time, we demonstrate the capacity to rapidly, accurately, and non-destructively estimate LMA across multiple biomes and a diverse range of plant species using only leaf spectral reflectance.

Significance

We provide a generalizable approach which paves the way for remote sensing technology to predict the diversity of LMA in ecosystems across global biomes





BROOKHAVEN NATIONAL LABORATORY

OAK RIDGE National Laboratory

Serbin, S.P., Wu, J., Ely, K.S., Kruger, E.L., Townsend, P.A., Meng, R., Wolfe, Brett T., Chlus, A., Wand, Z., and A. Rogers (2019). *New Phytologist*. 224 (4), 1557- 1568. doi: 10.1111/nph.16123

Roots Play a Direct Role in How Declining Snowpack Affects Soil Microbes and Nitrogen Cycling

Challenge

- To understand whether lower volumes of winter snowpack will affect the diversity of abundance of soil bacterial and fungal communities, and whether there will be a particular impact on soil nitrogen cycling.

Approach and Results

- Root ingrowth and exclusion cores (216 total) were incubated *in situ* for 29 months at Hubbard Brook Experimental Forest, a northern hardwood forest, which has experienced winter snowpack decline over the past 50 years.
- Both the declining winter snowpack and its effect on plant roots had direct effects on the diversity and abundance of the soil microbial communities, and these effects interacted to reduce rates of soil N cycling.

Significance

- Little work to date has focused on the role that roots play in enhancing or moderating nutrient cycling in soils by bacteria and fungi.
- Results are broadly relevant to other temperate ecosystems that are experiencing long-term snowpack loss.

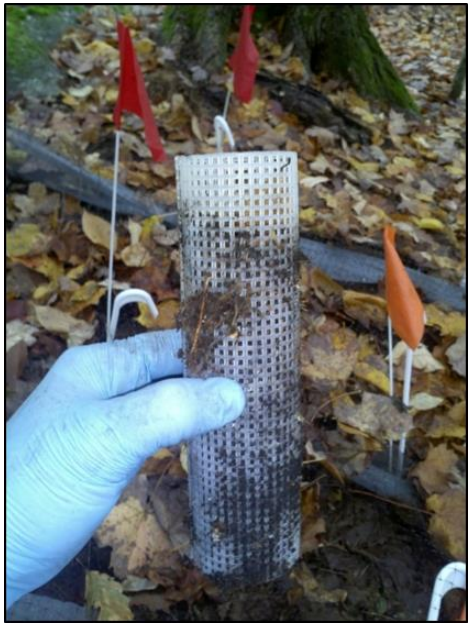
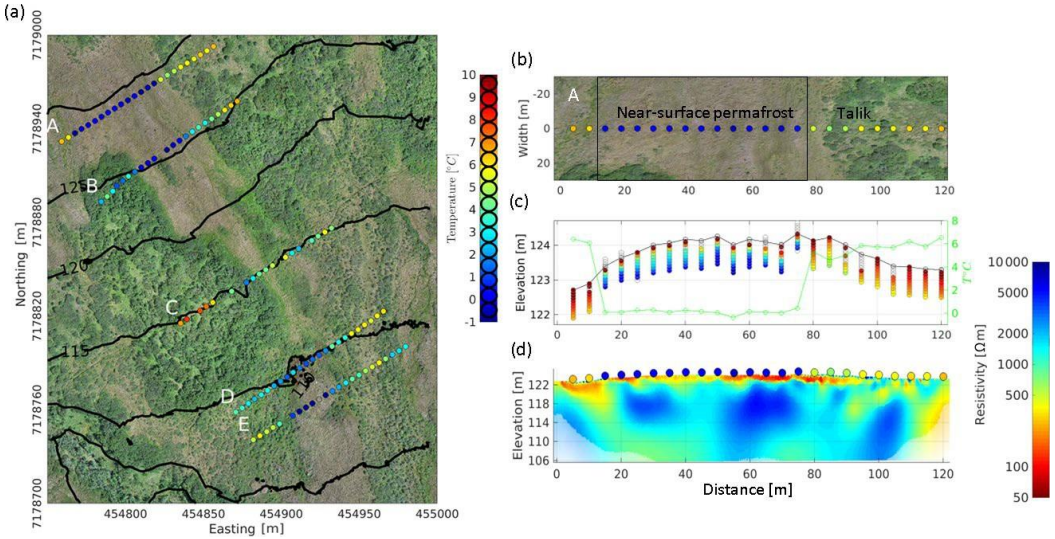


Photo: Root ingrowth cores were made out of nylon mesh (2-mm mesh size) which allowed roots to grow into and colonize the soil core. Root exclusion cores were made out of finer-sized nylon mesh (50-µm mesh size) that prevented root colonization.

Subsurface Biogeochemical Research

Sorensen PO, Bhatnagar JM, Christenson L, Duran J, Fahey T, Fisk MC, Finzi AC, Groffman PM, Morse JL and Templer PH (2019) Roots Mediate the Effects of Snowpack Decline on Soil Bacteria, Fungi, and Nitrogen Cycling in a Northern Hardwood Forest. *Front. Microbiol.* 10:926. doi: 10.3389/fmicb.2019.00926

A Distributed Temperature Profiling (DTP) Method for Assessing Spatial Variability in Ground Temperatures in a Discontinuous Permafrost Region of Alaska



(a) Plan view map of soil temperature at 0.8 m depth measured using a DTP system; (b) closer look along Transect A, where (c) the vertically resolved profiles of soil temperature and (d) soil electrical resistivity both suggest the presence of near-surface permafrost and talik areas along the transect. Transitions from near surface permafrost to talik areas along the transect are collocated with changes in vegetation type and topography.

Scientific Achievement

A novel autonomous DTP system provides new insights about soil thermal regimes and correspondence with above ground properties.

Significance and Impact

The low cost, portability, and ease of deploying the DTP system render it efficient for investigating the heterogeneity and complexity of soil-permafrost thermal and hydrological regimes.

Research Details

The DTP system provides unprecedented spatial resolution in soil temperature. The data were used to delineate near-surface permafrost bodies from surrounding zones with no permafrost or deep permafrost table locations overlain by a perennially thawed layer. We found that near-surface permafrost is primarily collocated under topographic highs and/or under areas covered with graminoids.

Léger, E., Dafflon, B., Robert, Y., Ulrich, C., Peterson, J. E., Biraud, S. C., Romanovsky, V. E., and Hubbard, S. S. A distributed temperature profiling method for assessing spatial variability in ground temperatures in a discontinuous permafrost region of Alaska, The Cryosphere, 13, 2853-2867, 2019.

The Inner Workings of the Rhizosphere

EMSL

Challenge

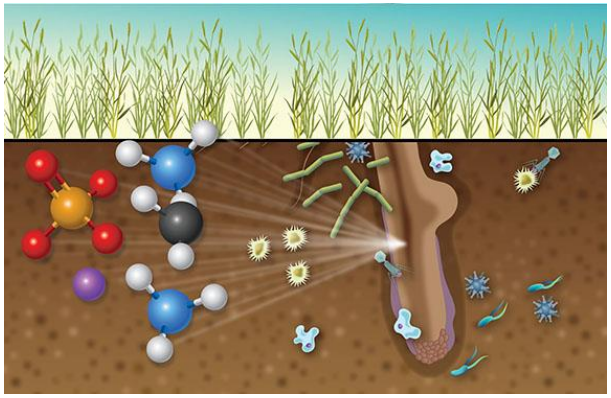
- Bacteria in the rhizosphere perform a host of beneficial functions that could be harnessed to improve agriculture, but the interactions between plants and bacteria remain a puzzle.

Approach and Results

- Scientists developed an innovative approach that allowed imaging of these interactions at the molecular level.
- Results suggest that these interactions are confined to a few specific locations along the plant root.

Significance and Impacts

- If scientists could understand, predict, and control interactions between plants and bacteria in the rhizosphere, they could design ways to increase or restore plant productivity, develop natural fertilizers, and even create carbon-storage ecosystems to combat climate change.
- The results of the new study build the foundation to better understand these interactions.



For the first time, scientists were able to view the interactions between bacteria and plants at the molecular level, offering insights for improving agriculture. Illustration by Nathan Johnson, PNNL Creative Services.

Participants:
Environmental Molecular Sciences Laboratory
China University of Geosciences
Pacific Northwest National Laboratory

W. Liu, L. Huang, R. Komorek, P.P. Handakumbura, Y. Zhou, D. Hu, M. H. Engelhard, H. Jiang, X.-Y. Yu, C. Jansson, and Z. Zhu, “Correlative surface imaging reveals chemical signatures for bacterial hotspots on plant roots.” *Analyst*, (2020). DOI: 10.1039/c9an01954e. Inner Cover.

Environmental Molecular Sciences Laboratory

EMSL

Accelerating scientific discovery and pioneering new capabilities to understand biological and environmental processes across temporal and spatial scales

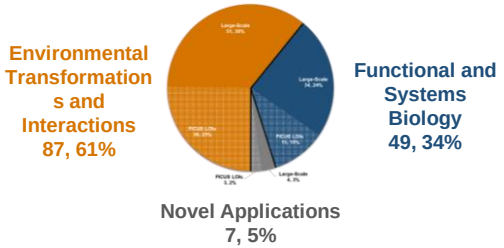
COVID-19

- Limited to COVID-19 research and irreproducible/irrecoverable samples
- C Fall (March 12, 2020) Letter – seeking ideas to use capabilities at EMSL and other user facilities for research

Proposal Opportunities

- 2020 Large-Scale EMSL Research – 89 proposals
- 2020 FICUS call – 54 Letters of Intent

FICUS Facilities Integrating Collaborations for User Science



Thermo Scientific Krios G3i cryo-EM

Scientific Leadership

- Krios G3i Cryo-EM – available to users July 2020
- Mixed architecture (CPU/GPU) supercomputer, July 2020 – “Tahoma”

Outreach and User Activities

- Special Issue – ACS Earth and Space Chemistry – Chemical Interactions in the Plant-Soil-Atmosphere System (outcome from the 2019 Integration Meeting)
- 2020 Multiscale Microbial Dynamics Modeling Summer School – July 6-10
- 2020 Integration Meeting – Visualizing the Proteome – Oct. 6-8

ACS EARTH AND SPACE CHEMISTRY

THANK YOU!