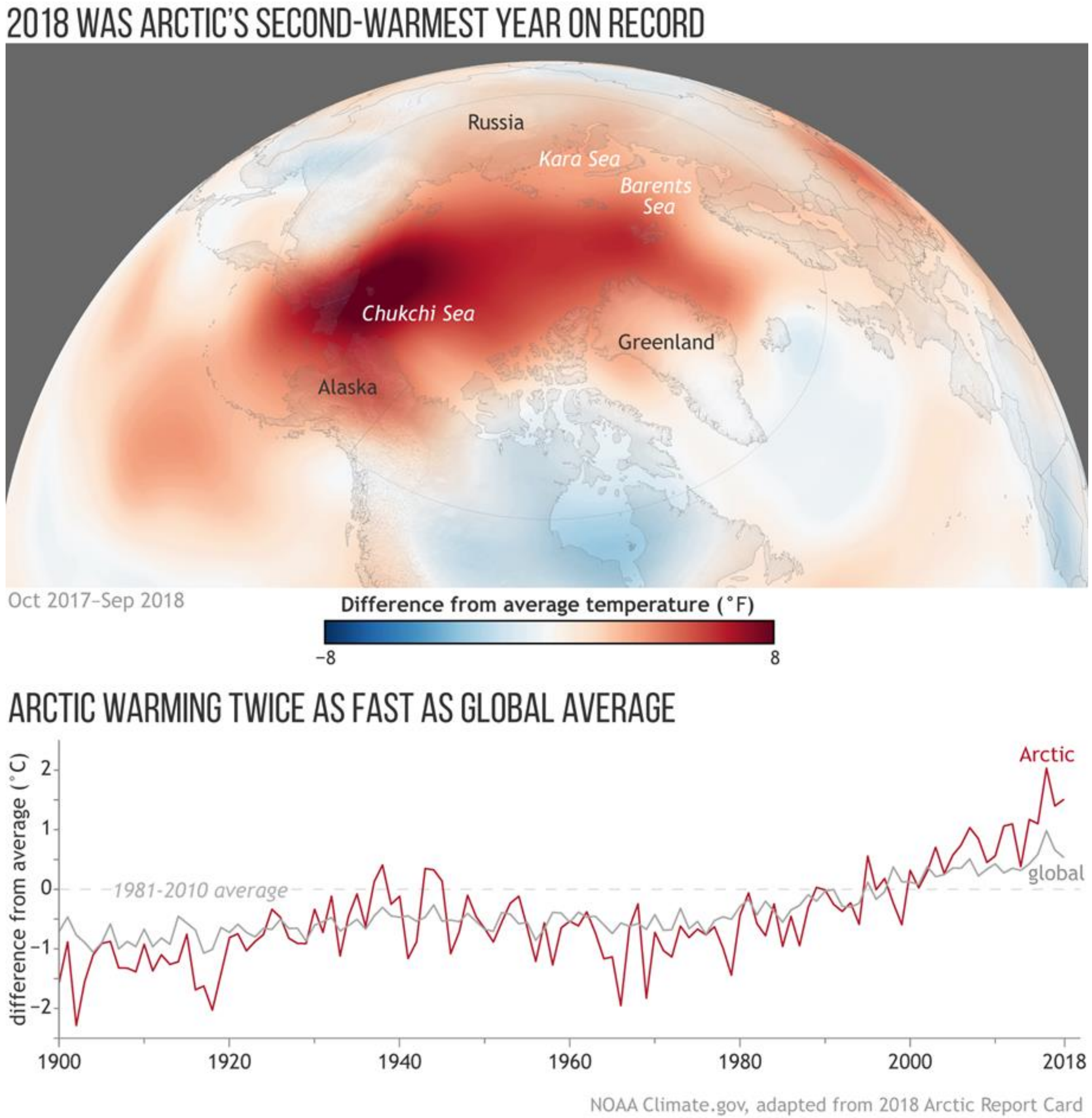
Climate and Environmental Sciences Division

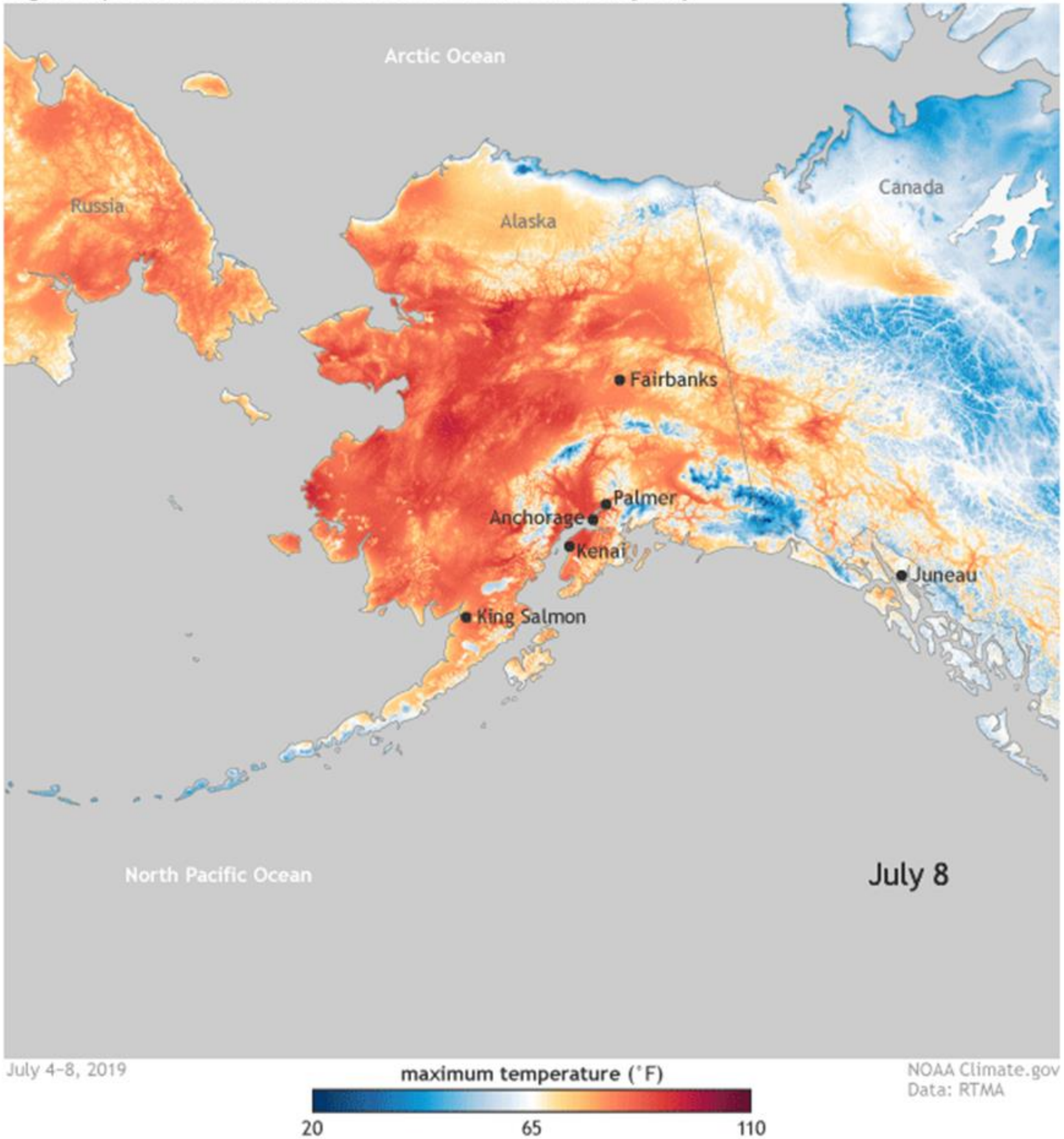
BERAC update

October 24, 2019

G. Geernaert
BER/CESD


2018 WAS ARCTIC'S SECOND-WARMEST YEAR ON RECORD
Russia
Kara Sea
Barents Sea
Chukchi Sea
Greenland
Alaska
Oct 2017–Sep 2018
Difference from average temperature (°F)
−8
8
ARCTIC WARMING TWICE AS FAST AS GLOBAL AVERAGE
difference from average (°C)
2
1
0
−1
−2
1981-2010 average
Arctic
global
1900
1920
1940
1960
1980
2000
2018
NOAA Climate.gov, adapted from 2018 Arctic Report Card

High temperatures smash all-time records in Alaska in early July



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
- Collaborative opportunities: NOAA; USGS; NGA; NSF
- Topics: disturbance, initialization, data analytics (e.g., machine learning), software, advanced technologies, coastal, Terrestrial-Aquatic Interfaces, etc.

Workshops set the stage for future CESD priorities

Date	Topic	Venue
Jan 28-30, 2019	Leveraging distributed research to understand watershed syst	Bethesda
Apr 3, 2019	Modes of variability workshop (w/NOAA, NASA, NSF)	Greenbelt
Apr 4, 2019	Climate Modeling Summit	Greenbelt
April 2019	Assessing simulation of precipitation in Earth system models	Wash DC
April 29, 2019	Cyberinfrastructure	Bolger
July 1-2, 2019	Precipitation metrics workshop	Wash DC
Sept 4-6, 2019	Integrated hydro-terrestrial models- development of a national prediction capability. (with NOAA, NSF, and USGS)	Wash DC
Winter 2020	Lessons learned from FACE, NGEE, and MODEX	Wash DC

Management updates – PI meetings: 2019-2020

Title	Program(s)	Location	Date
E3SM all hands mtg	**Modeling**	**Denver, CO**	**Mar 19-21, 2019**
ESS PI meeting	**TES, SBR**	**Bolger**	**April 30-May 1, 2019**
PCHES all hands	**Modeling**	**Penn State**	**May 15-16, 2019**
ARM/ASR PI meeting	**ARM, ASR**	**Bethesda Marr.**	**June 10-13, 2019**
SciDAC PI meeting	**SciDAC**	**Rockville Hilton**	**July 16-18, 2019**
ESS PI meeting	**TES, SBR**	**Hyatt Bethesda**	**May 18-22, 2020**
ARM/ASR PI meeting	**ARM, ASR**	**Rockville Hilton**	**Jun 22-26, 2020**

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

Management Update: solicitations

Funds	Program lead	Issued	Proposals	Panel	Selections
FY19	ASR	Dec 26, 2018	94	May 7-10, 2019	24 (27)
FY19	TES	Dec 27, 2018	90	May 13-16, 2019	7
FY19	SBR	Jan 7, 2019	92	May 20-23, 2019	5
FY20	ESS	Fall 2019			
FY20	ASR	Fall 2019			
FY20	Modeling	Fall 2019			

Management updates: Major reviews in 2019-2020

Lab	Program	Type	Review date	Decision	Date
PNNL	Model	SFA	Sept 10-11, 2018	Accept	Feb 15, 2019
Multi-	SBR	IDEAS proj.	Feb 22, 2019	Accept	Apr 13, 2019
ORNL	TES	NGEE-Arctic	April 1-2, 2019	Accept	May 6, 2019
Multi-	Data	Exashed	April 19, 2019	Accept	May 17, 2019
LBNL	SBR	SFA	May 2-3, 2019	Accept	Sep 30, 2019
UC Davis	Model	HYPERFACETS	May 12-13, 2019	Accept	May 30, 2019
ORNL	TES	SFA	June 3-5, 2019	Accept	July 2, 2019
LANL,…	Model	Coastal Arctic	July 29, 2019	Accept	Aug 15, 2019
PNNL,…	Model	Coastal Atlant	July 30, 2019	Accept	Aug 15, 2019
LBNL	Model	CASCADE SFA	Sep 23-24, 2019		
LBNL	TES	NGEE Tropics	Oct 16-18, 2019		
LLNL	Model	PCMDI/CI SFA	Oct. 29-30, 2019		

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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 – Apr 2020	Bart Geerts, U. Wyoming	AMF1
TRACER*	Houston	Apr 2021 – Mar 2022	Mike Jensen, BNL	AMF1

MOSAIC

- ARM 2nd Mobile Facility (AMF2) installed on R/V Polarstern – Sept 2019
- R/V Polarstern to be frozen in sea ice in the central Arctic for a full year – will provide unprecedented observations of the central Arctic atmosphere, sea ice, and ocean over an annual cycle
- ARM deploying ~50 instruments – the largest contributor to the atmospheric research theme
- ASR providing support to the lead PI – Matt Shupe (University of Colorado) and an early career PI – Jessie Creamean (CSU) who is conducting ice nucleation research
- DOE Early Career Award supporting aerosol observations by Kerri Pratt (U. Michigan)

Air-ARM Update

- ARM received full funding for a replacement research aircraft in FY2019
- Bombardier Challenger 850 aircraft procured May 2019
- RFP for aircraft modifications released June 2019; Contract expected to be awarded by end of Oct
- Aircraft modification contract will be ~18 months; then ARM will integrate research instrumentation onto aircraft and conduct flight testing
- Aircraft expected to be mission ready for first science campaign in 2022

Evaporation of drizzle decreases sub-cloud turbulence

Objective

- Marine stratocumulus cloud decks are important to the Earth's radiative balance because of their extensive coverage and brightness relative to the ocean surface.

Approach

- Use multiple ARM datasets from Azores site to investigate the process interactions that are important to lifetime and properties of marine stratocumulus clouds.

ARM Azores (Eastern North Atlantic) site

Impact

- ARM observations show frequent drizzle from these cloud systems that evaporates almost entirely before reaching the surface.
- The evaporating drizzle cools and moistens the sub-cloud layer and decreases below-cloud turbulence.
- Earth system models need to accurately represent these processes to improve simulation of marine stratocumulus.

Ghate V and M Cadeddu. 2019. "Drizzle and Turbulence Below Closed Cellular Marine Stratocumulus Clouds." *Journal of Geophysical Research: Atmospheres*, 124(11), 10.1029/2018JD030141.

Tarballs form through chemical transformation of wildfire emissions

Background: Recent studies have shown biomass burning (BB) aerosols emitted from wildfires include significant amounts small spherical particles called tarballs that differ chemically and optically from soot.

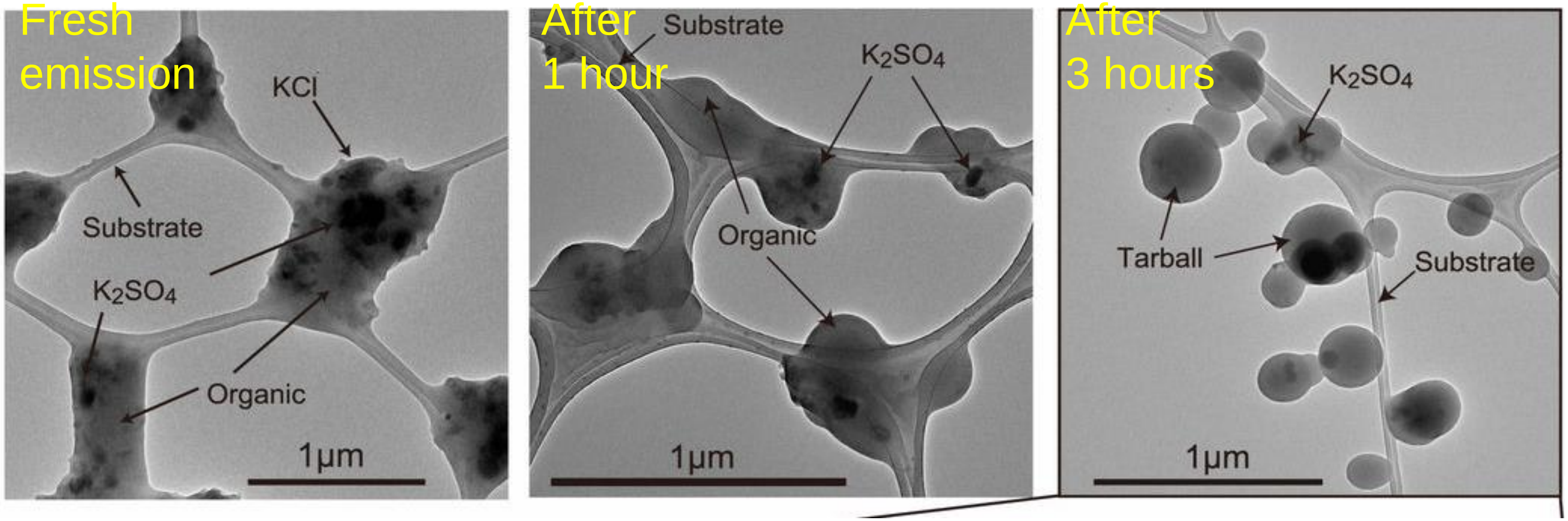
Objective: Test atmospheric tarball formation hypothesis

Approach

- Analyze samples collected during 2013 ARM BBOP campaign using sophisticated microscopy and analysis techniques (TEM, STXM, EDS), and compare N to O ratios relative to K during aging

Impact

- Chemical processing within the first few hours leads to increased surface tension and viscosity, forming tarballs
- Test results will lead to better modeling of BB aerosol types, aging, properties, and radiative



K. Adachi, A. J. Sedlacek III, L. Kleinman, S. R. Springston, J. Wang, D. Chand, J. M. Hubbe, J. E. Shilling, T. B. Onasch, T. Kinase, K. Sakata, Y. Takahashi, and P. R. Buseck, "Formation of tarballs through the aging of liquid organic particles from biomass burning." *Proc. Nat. Acad. Sci.,* **116**, 39 (2019) [doi:10.1073/pnas.1900129116].

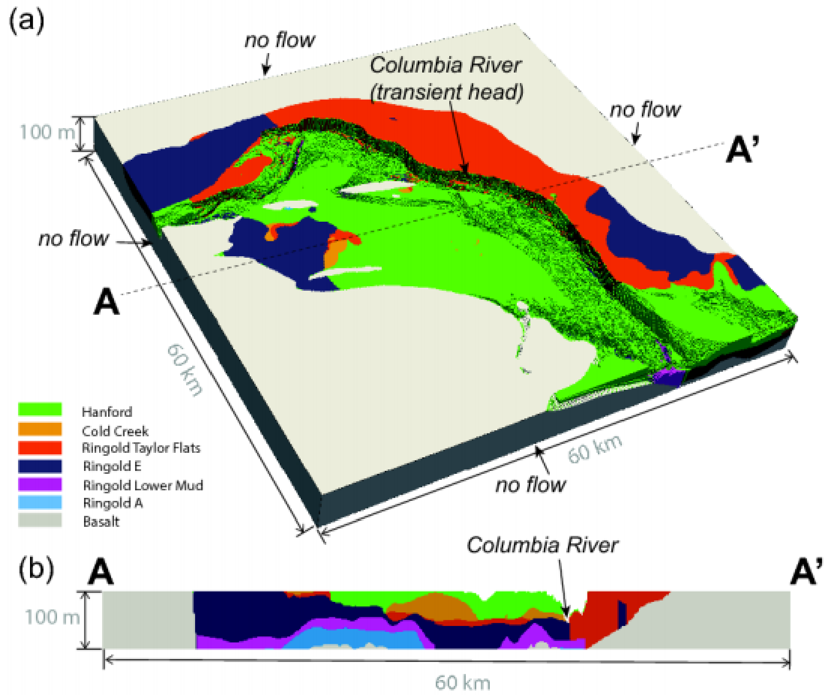
First 3-D Model of Hydrologic Exchange at River Reach-Scale

Objective

Understand the dominant factors controlling signatures of hydrological exchange flows (HEFs) along a dam-regulated river reach.

New Science

- HEFs are largely controlled by channel morphology and subsurface hydrogeology, along with the magnitude and timing of river stage fluctuations.
- First study to simulate a 3-D hydrologic exchange, at reach-scale.



Significance

- Improves understanding of the biogeochemical processes occurring in large rivers that experience dam-induced flow variations.
- Demonstrates the influences of river water intrusion on the migration of groundwater contaminant plumes.

Participants:
Pacific Northwest National Laboratory
Sandia National Laboratory

Shuai, P., X. Chen, X. Song, G.E. Hammond, J. Zachara, P. Royer, H. Ren, W.A. Perkins, M.C. Richmond, and M. Huang. "Dam Operations and Subsurface Hydrogeology Control Dynamics of Hydrologic Exchange Flows in a Regulated River Reach." 2019. *Water Resources Research*. doi: 10.1029/2018WR024193.

Examining the effects of ice and permafrost on Arctic deltas

Objective

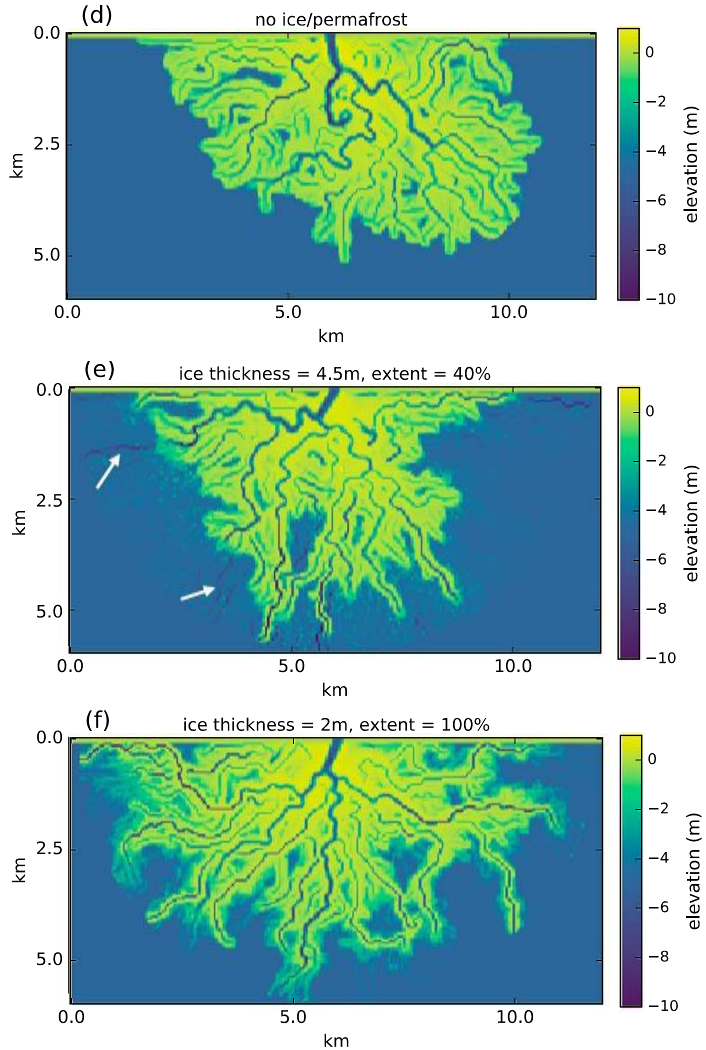
- Determine how ice cover and permafrost affect delta morphology and channel dynamics

Research

- Use a reduced complexity numerical model with representations of shorefast ice and permafrost
- Quantify changes to channel mobility, delta morphology, and distribution of sediment onshore and offshore

Impact

- First study of long-term delta dynamics under the influence of ice and permafrost
- Ice and permafrost reduce channel mobility, suggesting Arctic warming will increase channel mobility and delivery of sediment and carbon to the coastal ocean
- Ice cover encourages flooding that aids in vertical delta growth to help keep up with sea level rise, such that reduced ice cover from warming may make Arctic deltas more vulnerable to sea level rise



Elevation maps for different model runs showing the effects of ice thickness and extent on delta morphology. Top image has no ice or permafrost. Middle has 4.5m thick ice over 40% of the delta. Bottom has 2m thick ice over the entire delta. Arrows in middle image highlight channels that extend offshore that develop under thick ice.

Lauzon, R., Piliouras, A., & Rowland, J. C. (2019). Ice and permafrost effects on delta morphology and channel dynamics. *Geophysical Research Letters*, 46. https://doi.org/10.1029/2019GL082792

Improved Quasi-biennial Oscillation (QBO) in E3SMv1

Motivation

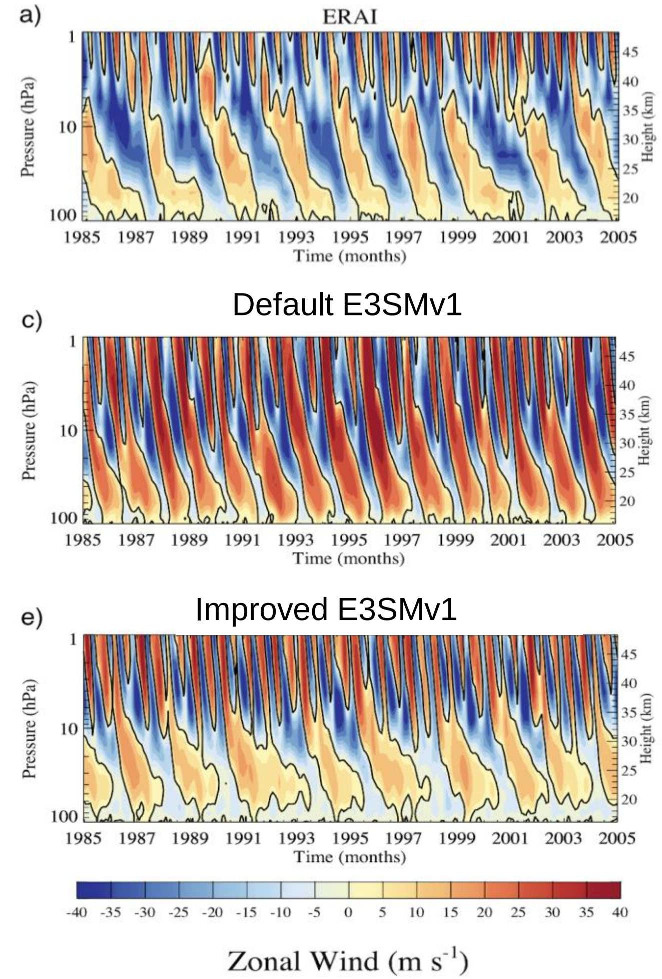
- The QBO is feature of the tropical lower stratosphere, influencing stratospheric and tropospheric variability.
- Although observed for many decades, the QBO is difficult to accurately capture in Earth System Models.

Approach

- The free parameters of E3SM's parameterization of convective gravity waves were modified to improve agreement with observations.

Impact

- The QBO influences the polar vortex variability, tropical convection, the North Atlantic Oscillation (NAO), storm tracks and the Madden Julian Oscillation (MJO).
- Improvement of the representation of the QBO will allow E3SM to more realistically simulate these important climate features.



Monthly mean zonal mean zonal wind averaged between 5°S and 5°N as a function of pressure and time for a) ERAI, c) default E3SMv1, e) improved E3SMv1. ERAI and simulations are shown for years 1985 to 2005.

Y. Richter, Chih-Chieh Chen, Qi Tang, Shaocheng Xie, Philip Rasch, 2019. "Improved Simulation of the QBO in E3SMv1." *JAMES*, 10.1029/2019MS001763.

Toward Improving the Diurnal Cycle of Precipitation in E3SM

Motivation

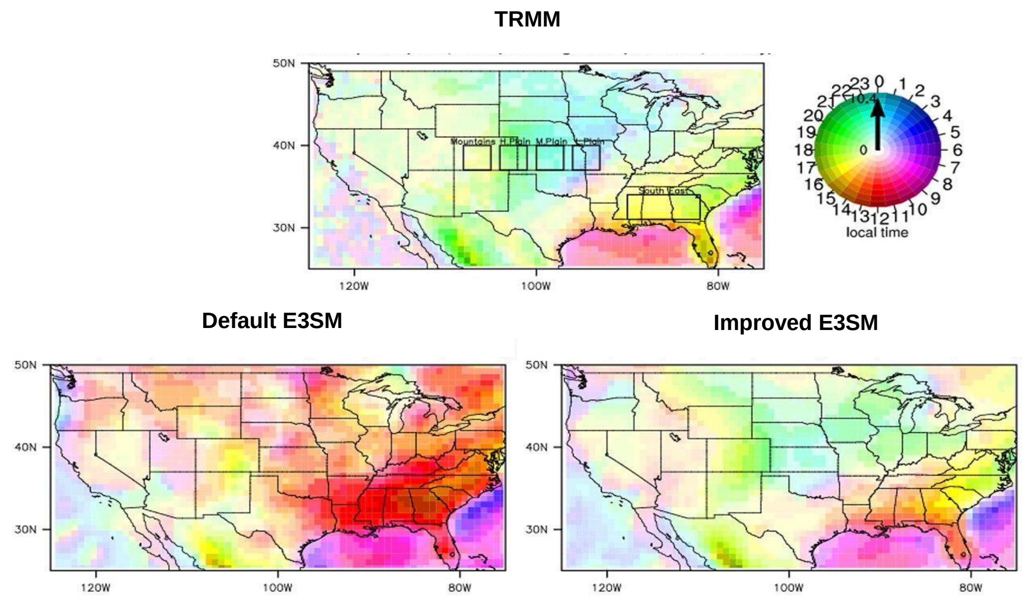
- Earth System Models continue to have difficulty in accurately capturing the diurnal cycle of precipitation, particularly over land.
    - Rain too early during the day and fail to capture nocturnal elevated convection
    - Rain ”too frequent, too weak”
    - No propagation of meso-scale convective systems

Approach

- Two-part revision to E3SM that focuses on the processes that trigger convection.
    - Added a new constraint that limits how easily and frequently precipitation occurs
    - Captured atmospheric instability above the boundary layer, which may be key in predicting high-altitude nocturnal convection systems.

Impact

- E3SM shows dramatic improvements in capturing the timing of rainfall events, especially in its ability to accurately capture the diurnal cycle. E3SM is one of a very few models that can capture the nocturnal elevated convection.



Timing phase (color) and amplitude (color intensity) of summertime precipitation over the Contiguous U.S.. Note the improvement to the diurnal phase across the U.S.

Xie, S., Wang, Y.-C., Lin, W., et al. (2019). Improved diurnal cycle of precipitation in E3SM with a revised convective triggering function. *JAMES*, 11. https://doi.org/10.1029/2019MS001702.

Impacts of Atmospheric Rivers on Surface Hydrological Processes in Western U.S. Watersheds

Objective

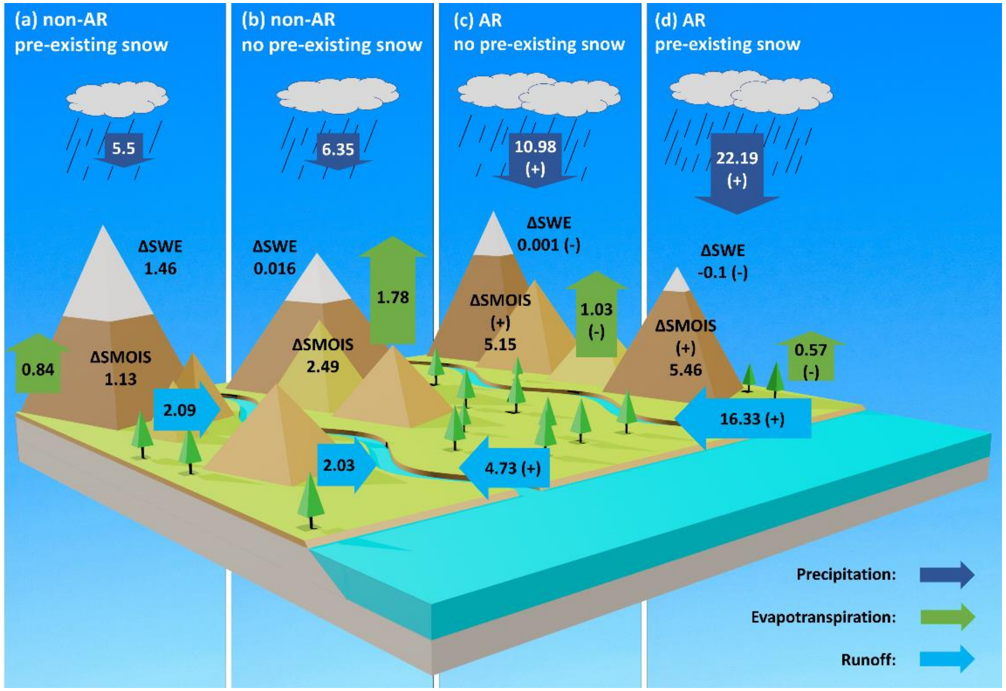
- Quantify the impact of atmospheric rivers (ARs) on the surface hydrological processes and water resources in the western U.S.

Approach

- Perform and analyze a multi-decade high-resolution regional hydroclimate simulation
- Analyze the relationship between ARs and a suite of land surface processes at inter- and intra-annual scales

Impact

- Identified the intensified snowmelt during ARs as a key reason for the contrasting hydrological response during AR and non-AR events
- Revealed the high correlation between AR occurrence and water resource availability at annual scale along the coastal watersheds



The average land surface hydrological responses during precipitation events across the western U.S. Precipitation events are classified into four categories (a) – (d) depending on whether precipitation is associated with ARs and whether there is pre-existing snowpack on the ground. All the numbers are in mm/day. Notation: SWE: snow water equivalent; SMOIS: soil moisture.

Chen, X., L. R. Leung, M. Wigmosta, and M. Richmond (2019), Impact of Atmospheric Rivers on Surface Hydrological Processes in Western U.S. Watersheds, *Journal of Geophysical Research*, 124. DOI: 10.1029/2019JD030468

Global Agricultural Green and Blue Water Consumption Under Future Climate and Land Use Conditions

Objective

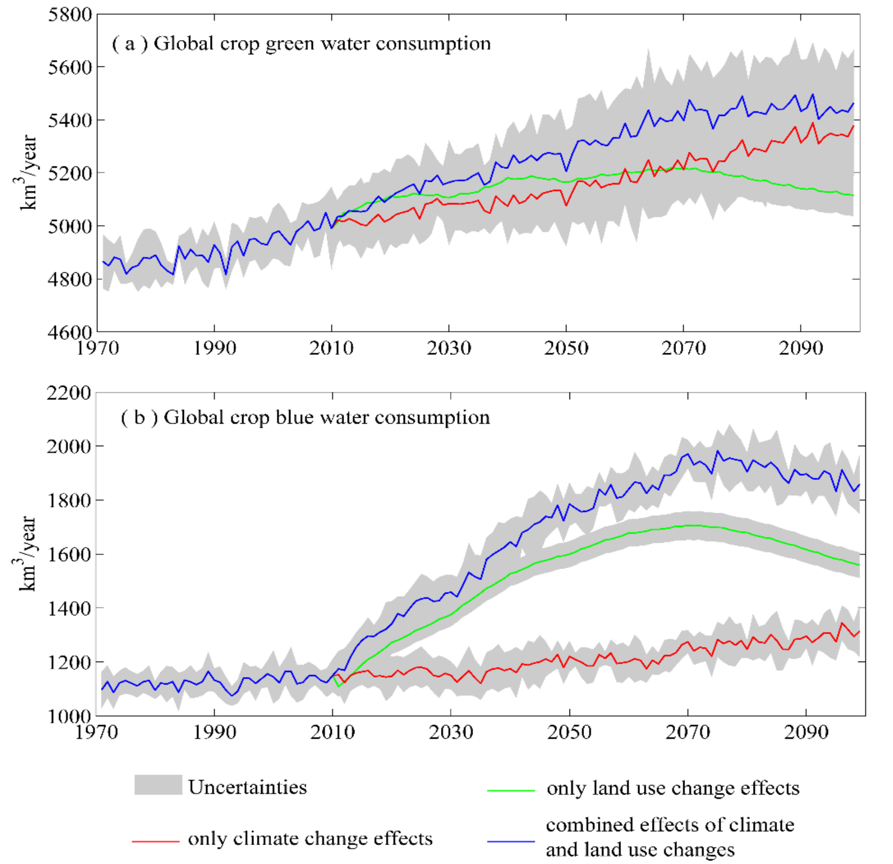
- Estimate global crop consumption of green water (precipitation) and blue water (irrigation) during the 21st century
- Determine effects of future climate and land use conditions on crop water consumption

Approach

- Incorporate a crop-water use module into Global Change Assessment Model (GCAM) system
- Design three control experiments to separate effects of climate and land use on future crop water consumption

Impact

- Global crop green and blue water consumption are projected to increase by about 12% and 70%, respectively, by the 2090s
- Shifts in crop green and blue water consumption are mainly driven by climate and land use, respectively
- Study improved understanding of how future climate and land use conditions can affect global agricultural water consumption, which is critical to devise effective adaptation strategies for securing future food and water needs sustainably



A time series for the period 1971–2099 shows individual and combined effects of climate and land use changes on future global crop green and blue water consumption.

Huang Z, M Hejazi, Q Tang, CR Vernon, Y Liu, M Chen, and KV Calvin. 2019. "Global agricultural green and blue water consumption under future climate and land use changes." *Journal of Hydrology* 574:242–256, https://doi.org/10.1016/j.jhydrol.2019.04.046.

Ensuring Climate Simulation Reproducibility in the Exascale Era

Motivation

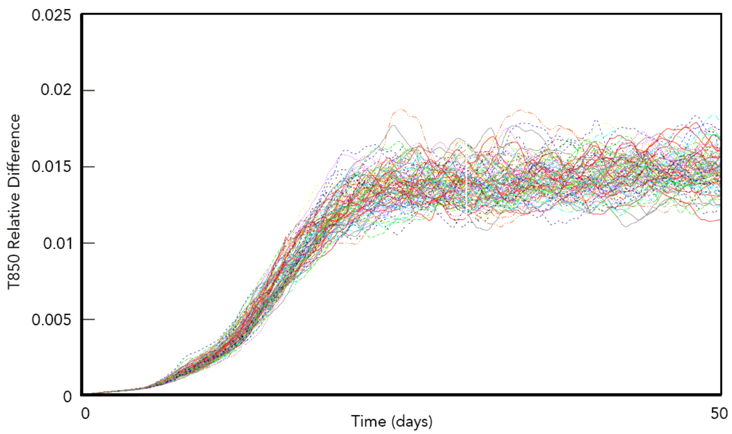
- Exact numerical reproducibility is the requirement that two simulations configured the same way give identical results that match to the last digit
- Maintaining exact reproducibility when new optional features are added, code is modified for computational performance, or code is moved to new computer architectures safeguards against unintended changes in the model simulation

Approach

- Developed three methods for evaluating whether changes in the simulation results affect model climate.
- All of these methods use ensembles of simulations from both the original and modified codes to compute the statistical probability that two versions of the code are the same.

Impact

- Ability to test and statistically-rigorous way is an advance for E3SM
- Climate reproducibility tests allow E3SM developers to perform production runs spread across multiple machines
- Improves confidence in E3SM simulations



Growth of differences in 850 mb temperature (in Kelvin, using the L1 norm) between each pair of simulations in a 100-member ensemble. Adapted from Mahajan et al.. Because atmospheric motions are inherently chaotic, tiny differences will grow quickly.

Mahajan, S., K. J. Evans, Joe Kennedy, M. L. Branstetter, M. Xu, M. Norman (2019): Ongoing solution reproducibility of earth system models as they progress toward exascale computing, High Performance Computing Applications (in press) https://doi.org/10.1177/1094342019837341

Simulating Coastal Wave Dynamics within E3SM

Motivation

- Subgrid scale wind wave processes are not represented by the E3SM ocean model.
- Wave, ocean, and sea ice interactions are needed to properly simulate waves in high-latitudes, storm surge flooding, erosional fluxes, and cryosphere contributions to global and regional sea level rise.

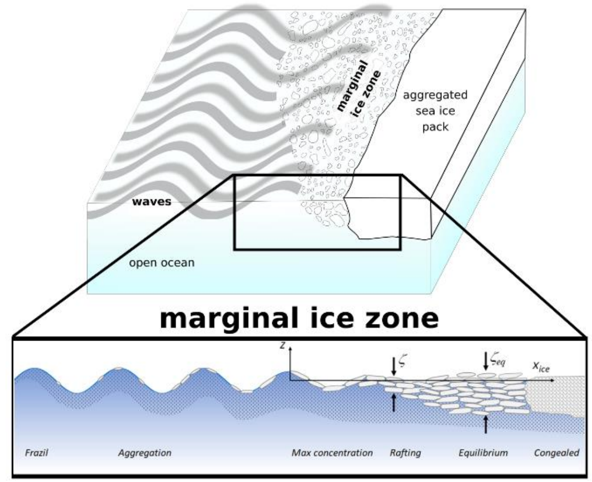


Figure: Wave and sea ice interactions in the marginal ice zone. Waves contribute to the dynamics, growth, and melt within the pack, impacting established sea ice and ice shelves.

Approach

- WAVEWATCH III® is being introduced into E3SM to advance coastal processes within E3SM.
- Directly simulate ocean waves and their cross-component interactions.

Movie: Significant wave height across the North Atlantic. Notice Hurricane Katrina impacting the Gulf Coast.

E3SM
Energy Exascale
Earth System Model

Impact

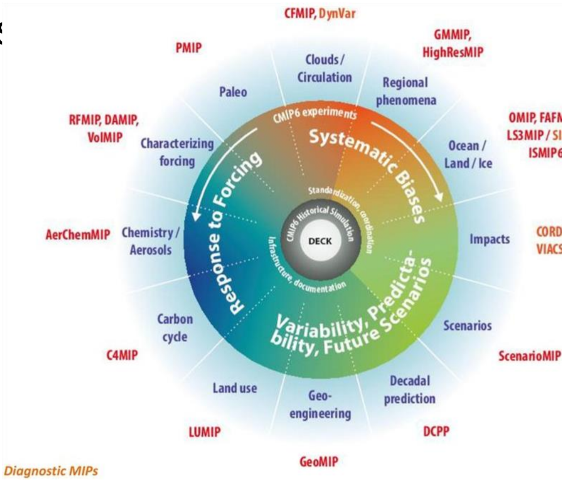
- These developments are essential to understanding how coastal processes will evolve and affect critical human infrastructure, including energy networks.

RGMA CMIP6 Analysis and Hackathon

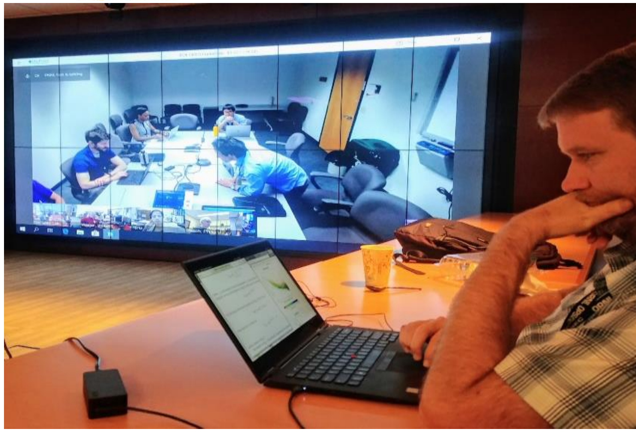
- To support RGMA scientists doing multi-model research and benchmarking, **RGMA** & **Data Programs** are coordinating & sponsoring
  - Downloading & staging **CMIP6 output from ESGF** plus **reanalysis** & **observations**
  - Series of **tutorials** on CMIP6 organization, Jupyter notebooks, and (V)CDAT
  - **RGMA CMIP6 Hackathon** via videoconferencing at multiple hubs

- **NERSC** is providing **>2 PB disk storage** and **computing resources**

/global/cscratch1/sd/cmip6



- **RGMA CMIP6 Hackathon**, July 31–August 6, 2019
  - RGMA researchers are encouraged to participate at one of the hubs at LANL, LBNL, ORNL, U. Washington, and PNNL
  - Tutorials will build capabilities among RGMA researchers
  - Pre-loaded data will allow scientists to focus on analysis
  - Event will foster cross-institution/project collaboration
  - **Impact of analysis papers will be a measure of success**
  - Final report on lessons learned from CMIP6 and format



New Jupyter lab and VCDAT 2.0 Released

ESGF Earth System Grid Federation

Objective

VCDAT 2.0 improves upon VCDAT 1.0 by allowing users the option to work directly with their code using Jupyter Notebooks, while retaining the ease of use offered by an intuitive user interface (UI).

Approach + Results

- VCDAT 2.0 works within the JupyterLab platform as an extension. Because it is a Jupyter extension, it benefits from the full range of features and continuous improvement inherent within the JupyterLab platform, while offering functionality specific to CDAT.
- The new UI interface requires almost no learning curve for visualizing data, yet allows the user to see and modify the CDAT code that produced the results.
- Provides provenance for a notebook so that others can replicate the results.
- For more details see this article: https://e3sm.org/vcdat-2-0-available

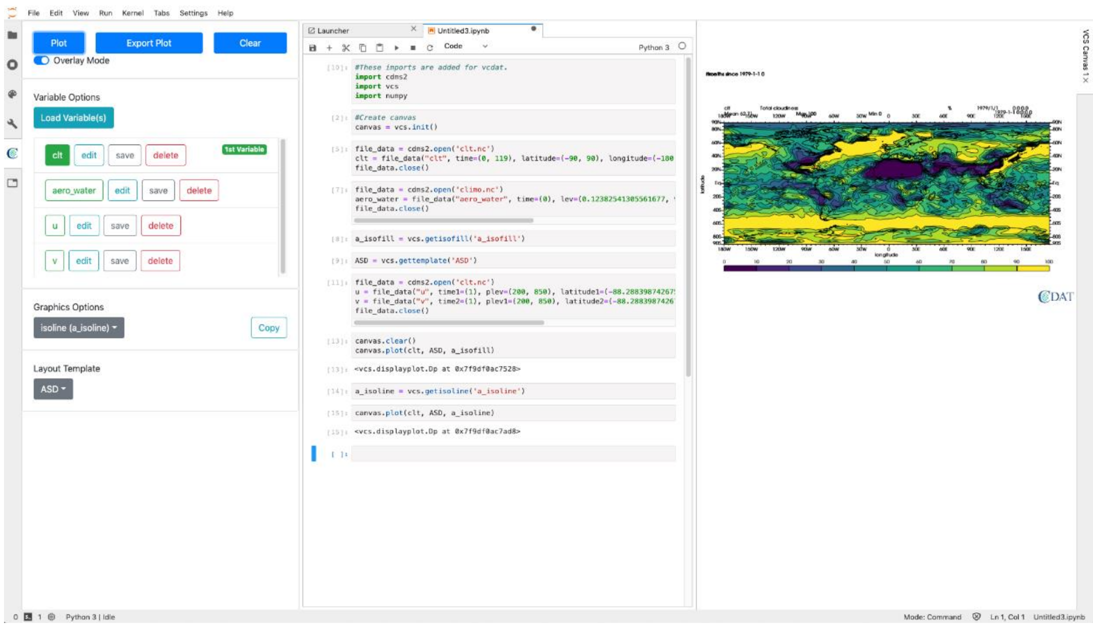


Figure: VCDAT 2.0 is used within the JupyterLab environment.

Impact

- VCDAT 2.0 makes CDAT available to the wide community of researchers and students who use Jupyter tools for data exploration and running code.
- The tool facilitates increased collaboration between users via JupyterHub and the sharing of Notebooks.
- Users who prefer to work with python code benefit from VCDAT's UI features while still having access to the code.

Code: https://github.com/CDAT/jupyter-vcdat **Documentation: https://github.com/cdat/jupyter-vcdat/wiki**

New ESGF YouTube Tutorials Channel

ESGF
Earth System Grid Federation

Objective

Create a unified video presence on the web for ESGF tutorials and other ESGF video content.

Approach + Results

- The ESGF team recently created two tutorial videos on how to download data from ESGF using Globus.
- In order to share these videos as well as other relevant content, staff created the official ESGF YouTube Channel located at: https://www.youtube.com/channel/UCRTfkCkF-W8TSXO4-hrVFXQ.
- The channel includes video content from other ESGF partners as well as LLNL created content.

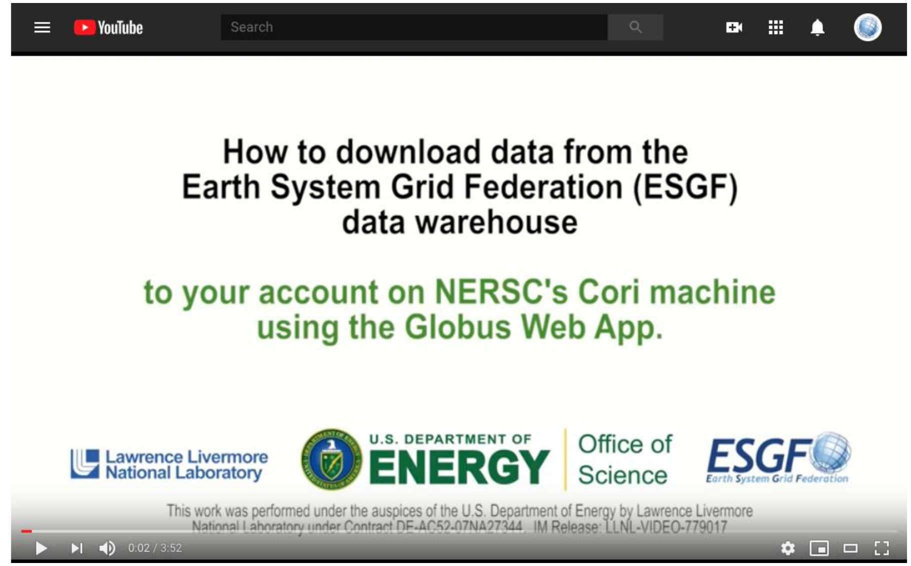


Figure: Screenshot of one tutorial on the ESGF YouTube Channel.

Impact

- Providing a single location for the official ESGF video content will make it easier for users to find relevant tutorials quickly and easily.
- Using YouTube will improve ESGF's web presence and increase the visibility of the ESGF project.

Channel address: https://www.youtube.com/channel/UCRTfkCkF-W8TSXO4-hrVFXQ

THANK YOU!