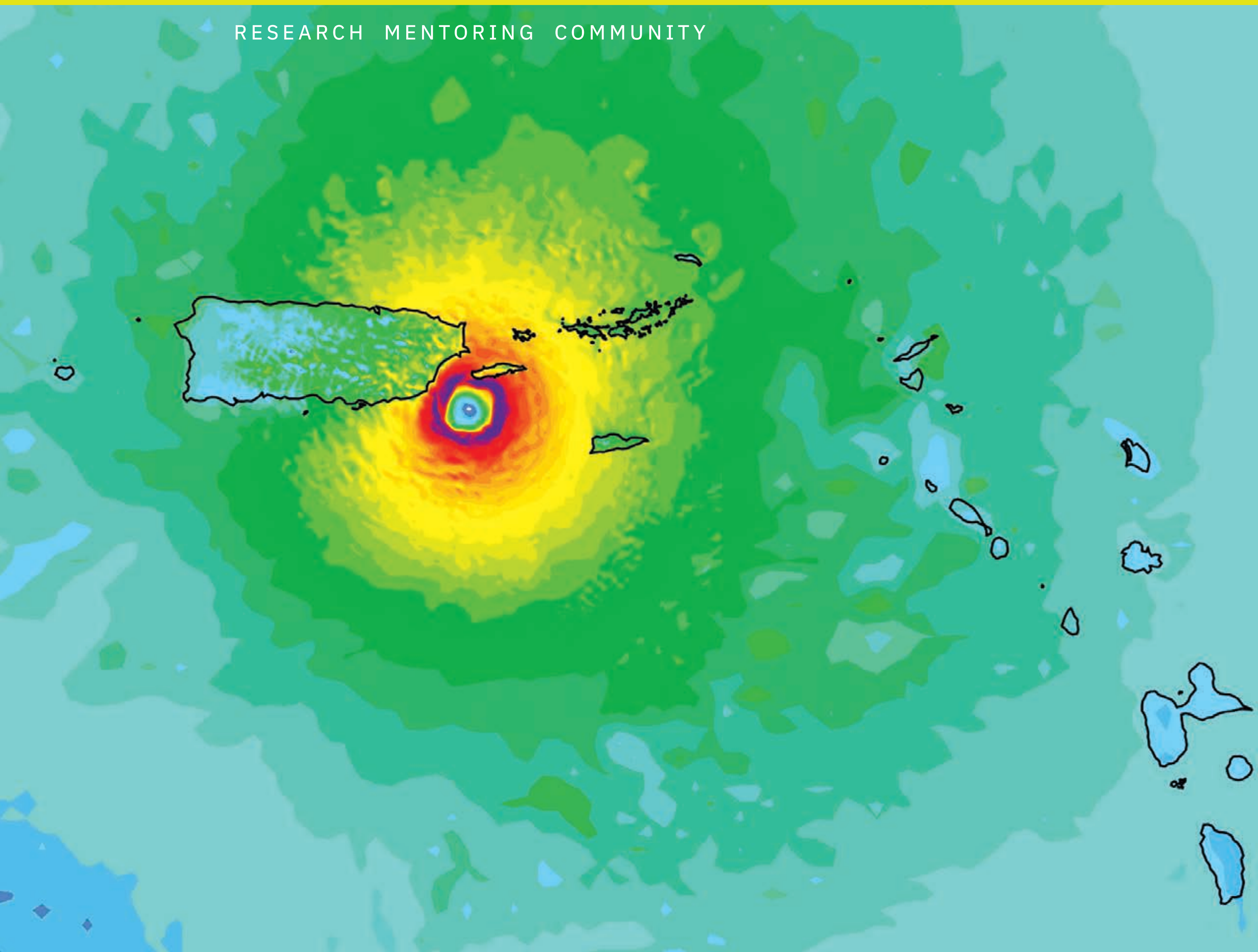
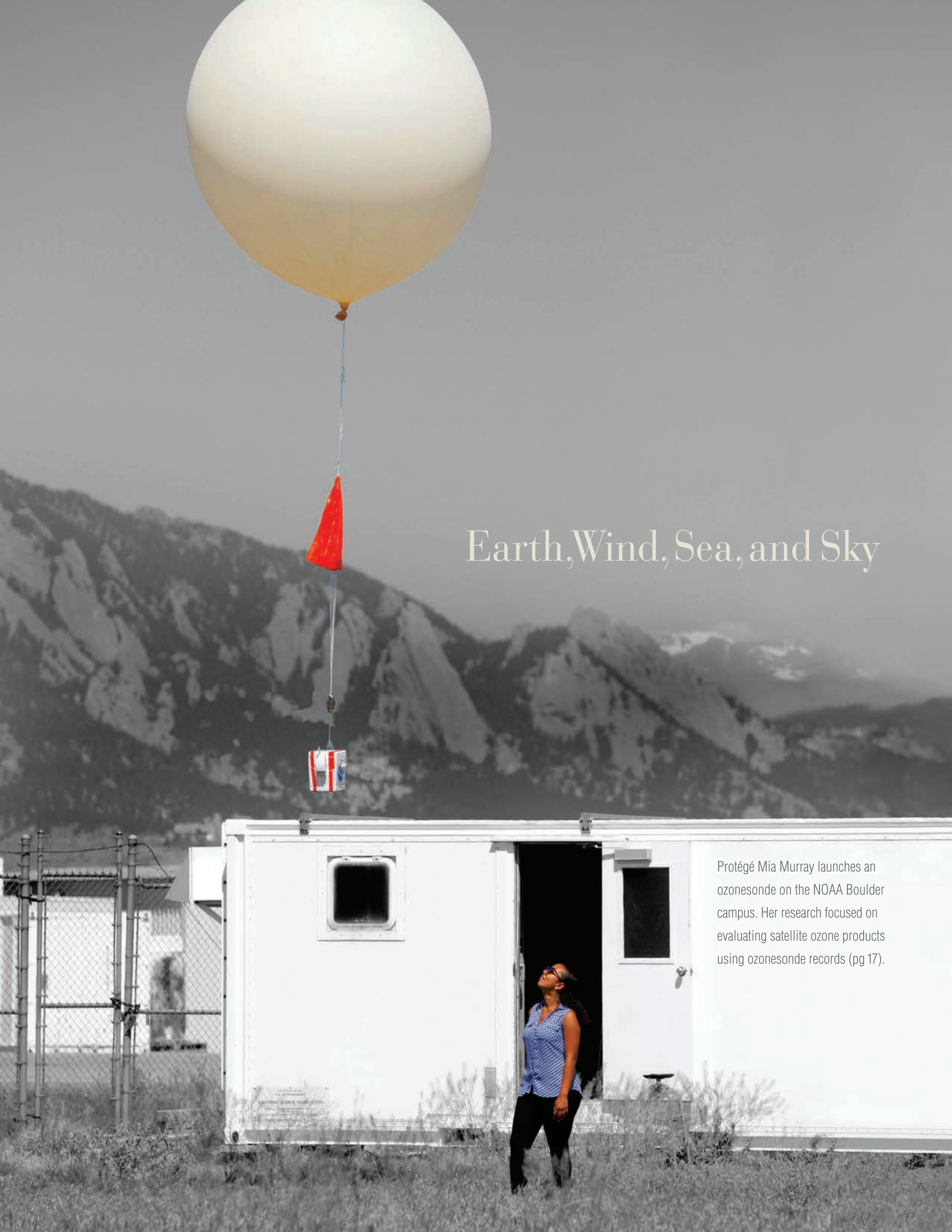
SOARS PROTÉGÉ ABSTRACTS 2018

Earth, Wind, Sea, and Sky

RESEARCH MENTORING COMMUNITY





Earth, Wind, Sea, and Sky

Protégé Mia Murray launches an ozonesonde on the NOAA Boulder campus. Her research focused on evaluating satellite ozone products using ozonesonde records (pg 17).

We are delighted to share this 2018 edition of Earth, Wind, Sea and Sky, showcasing the summer research of protégés from the Significant Opportunities in Atmospheric Research and Science (SOARS) program. Now in its 23rd year, SOARS remains true to its mission of increasing the diversity of the atmospheric and related sciences by engaging students from backgrounds traditionally under-represented in our field in genuine research. Their ability to do such excellent work in such a short period of time is a credit to their hard work and dedication, and to the exceptional training, care and attention of their mentors. We are so grateful for their commitment to the program.

While the hallmark SOARS mentoring structure, including up to five types of mentor and supportive learning community, continues to be the heart of the program and remains as relevant as it did when the program began, our field continues to evolve and our scientific challenges change. As such, SOARS continues to adapt and grow to meet the new needs of our community. Now in its third year, the SOARS scientific data and programming workshop recognizes the movement of geoscience literature toward sharing data and code, and prepares our protégés with tools to flourish in an open-access environment. We recognize that new careers in the atmospheric sciences are emerging that make use of weather and climate products, and that there is a need for scientists to translate these products for fields as diverse as insurance, agriculture, emergency management and policy. Our professional development program, highlighted inside, attempts to expose our protégés to the many opportunities available to them, and prepare them to succeed not only in graduate school, but in careers beyond.

Because of the 20+ year history and success of SOARS, we are now also able to tap into the strengths our alumni. This summer, Cindi-Ann Findley joined us from the new SOARS satellite at the University of Central Florida, bringing her work with alumna, co-PI, and professor Talea Mayo to NCAR and building a collaborative partnership with scientists here to better understand storm surge. Our alumni also served as mentors, panelists, and graduate-school selection advisors, and served on our steering and hiring committees. Beyond SOARS, our alumni are filling leadership roles in our national societies, government, industries and universities. Their perspective and leadership, along with that of our mentors, sponsors, and partners, helps SOARS to advance and remain a leader and valued partner in our field.

As the geosciences continue to evolve, and our planet and climate face rapid change, the need for diverse voices has never been greater, particularly those who can connect science, leadership, and community. SOARS has an ongoing role and responsibility in helping develop these voices. Our partnership with Biosphere 2, and revived partnership with Haskell Indian Nations University's Environmental Research Studies Program, continues to expand our community and expose our protégés to different experiences and indigenous ways of knowing. Our network of protégés, alumni, staff, partners, and past and current mentors continues to grow, and their voices and leadership are making vital contributions to the science and safety of our planet. We are grateful for your ongoing support, and are extremely proud to be part of this amazing community.

We hope you enjoy this edition of Earth, Wind, Sea and Sky. Please join us in congratulating the protégés of 2018!

Rebecca (Bec) Batchelor – SOARS Director

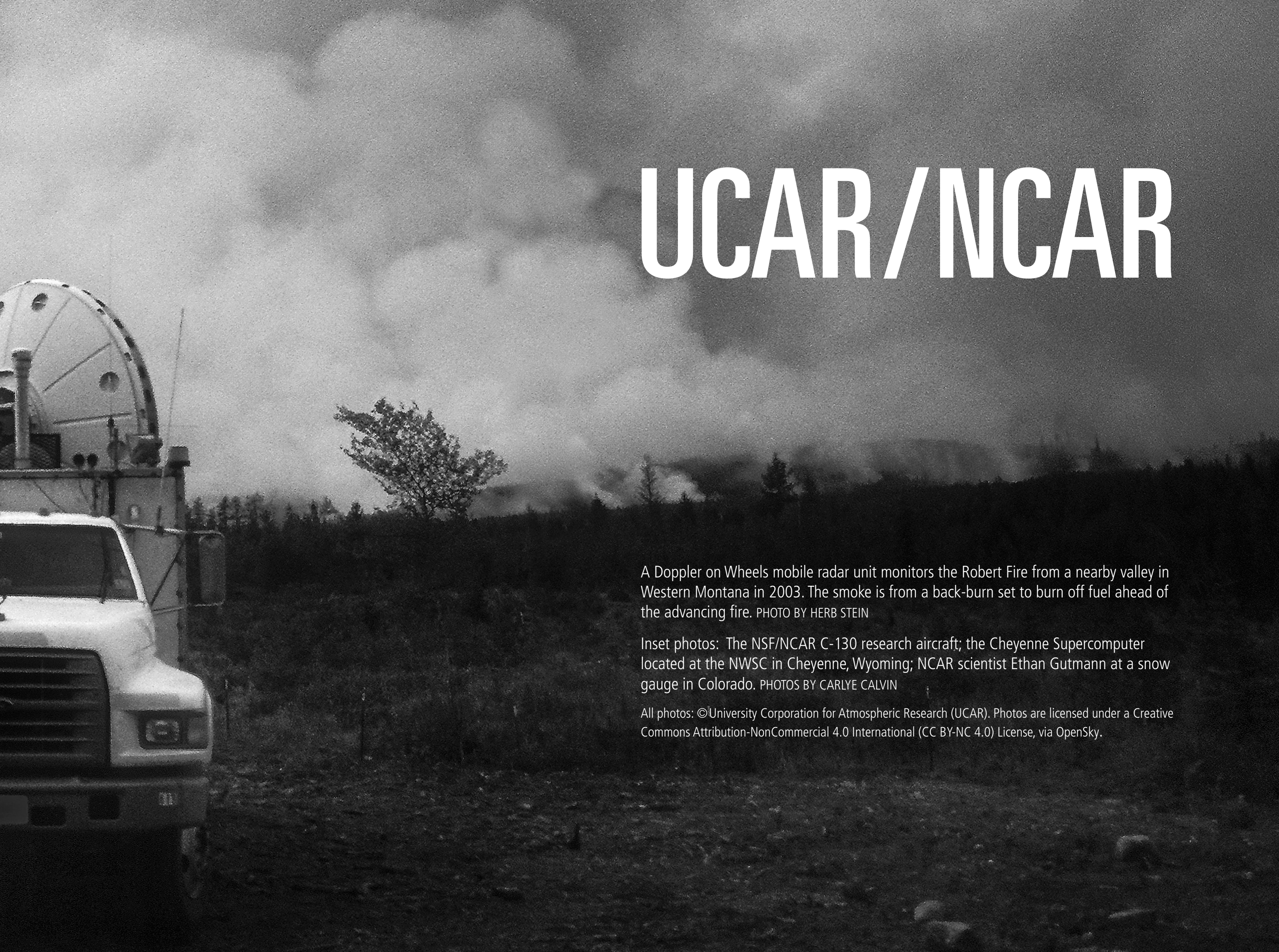
The University Corporation for Atmospheric Research (UCAR) is a national hub for research, education, and advanced technology development for Earth system science. On behalf of the National Science Foundation (NSF) and the university community, UCAR manages the National Center for Atmospheric Research (NCAR), a federally funded research and development center. UCAR Community Programs (UCP) is the organizational home of the SOARS program. UCAR seeks to empower their university member institutions and NCAR by promoting research excellence, developing fruitful collaborations, managing unique resources, creating novel capabilities, building critical applications, expanding educational opportunities and engaging in effective advocacy. UCAR is comprised of over 115 member institutions that offer education and research programs in the atmospheric or related sciences, including virtually all of the major research universities of North America.

NCAR was established by the National Science Foundation in 1960 to provide the university community with world-class facilities and services that were beyond the reach of any individual institution. NCAR provides the atmospheric and related Earth system science community with state-of-the-art resources, including supercomputers,

research aircraft, sophisticated computer models, and extensive data sets. Each year, hundreds of people from universities, labs, and the weather enterprise collaborate with NCAR staff, and rely on NCAR resources, in order to carry out vital research and applications.

NCAR and UCAR have been supporting the SOARS Program since its inception in 1996. Institutional support and the mentoring of their scientists, engineers and staff have been a key to the success of SOARS.

UCAR/NCAR



A Doppler on Wheels mobile radar unit monitors the Robert Fire from a nearby valley in Western Montana in 2003. The smoke is from a back-burn set to burn off fuel ahead of the advancing fire. PHOTO BY HERB STEIN

Inset photos: The NSF/NCAR C-130 research aircraft; the Cheyenne Supercomputer located at the NWSC in Cheyenne, Wyoming; NCAR scientist Ethan Gutmann at a snow gauge in Colorado. PHOTOS BY CARLYE CALVIN

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Protégé Ekaterina Lezine (right) with mentors Sean Davis (left, NOAA/CIRES) and Karen Rosenlof (NOAA) discussing results at NOAA's Boulder campus.


THE
WORLD
POLITICAL
AguaClara
carolinagreen

Significant Opportunities in Atmospheric Research and Science

For the past 23 years, SOARS has provided authentic research experiences with world-class scientists and engineers for students from backgrounds traditionally underrepresented in the atmospheric and related sciences. As an undergraduate-to-graduate bridge program, SOARS is designed to broaden participation by supporting students from many diverse backgrounds and experiences to enter and succeed in graduate school, make contributions to research and become leaders in the geoscience community. SOARS complements our partnering academic institutions' efforts in preparing students for careers in academia, research and industry by combining a summer internship with year-round mentoring, conference travel, a supportive community and career support. During the summer, SOARS protégés work at the National Center for Atmospheric Research (NCAR), partnering laboratories and universities to gain experience with what a career in atmospheric sciences could look like for them. Topics of research span the broad field of climate and weather, including computing and engineering in support of the atmospheric sciences, oceanography and solar physics. Protégés are supported in their research by up to five types of mentor, including scientific, writing, computing, peer and coach. In addition to this authentic research experience, culminating in end-of-summer poster and oral presentations by the students, the summer program includes a comprehensive professional development program. After the summer, protégés stay engaged through webinars, one-on-one career counseling, and participation at professional conferences.

Protégés are able to participate in SOARS for up to four years, gaining additional independence in subsequent years to select, focus, and direct their research. By the time SOARS protégés move on to graduate school, they are well prepared to succeed in independent research. Many use SOARS as an opportunity to expand their research through contacts and facilities available at a national laboratory, and it is common for students and their advisors to collaborate and publish with mentors beyond their SOARS research experiences. In addition, SOARS provides publishing and grant-writing support to our protégés and alumni, helping them stay connected with the wider community.

SOARS is proud of our alumni, the vast majority of whom go on to excel in graduate school and move on to careers in atmospheric science or related STEM fields. Many are now faculty, and we are excited to partner with them to spread SOARS mission, including through the new SOARS satellite programs at the University of Central Florida and the University of Illinois – Urbana Champaign. Wherever their careers take them, our alumni stay connected to the SOARS community, committed to the SOARS mission of increasing diversity in the sciences, and play an important role in increasing the strength and diversity of the STEM workforce.

Using machine learning techniques to forecast solar energetic particle events

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Solar energetic particles (SEPs) endanger satellites and astronauts in orbit, and can disrupt air traffic and spaceflight communication, among other effects. Therefore, the ability to forecast these events in advance is vital, both economically and for the safety of air and space faring passengers. Considering that the method of acceleration and transport of these particles is still an area of active research and that physics-based models are currently relatively slow compared to statistical empirical models, forecasters at the Space Weather Prediction Center make use of the latter to make real-time decisions. The motivation behind this project was to create a model that improves upon the results of the statistical model currently in use at the NOAA Space Weather Prediction Center. Machine learning models learn and make decisions based on empirical data and are currently much more efficient in providing timely insight for the generation of forecasts than numerical models. For this project, logistic regression and boosted decision trees were used to make a binary classification, i.e. whether or not there will be an SEP event based on the physical parameters associated with solar flares and coronal mass ejections. Results were analyzed against the performance of the Space Weather Prediction Center's existing model. Additional observational features were added in an attempt to improve the model's accuracy and performance.

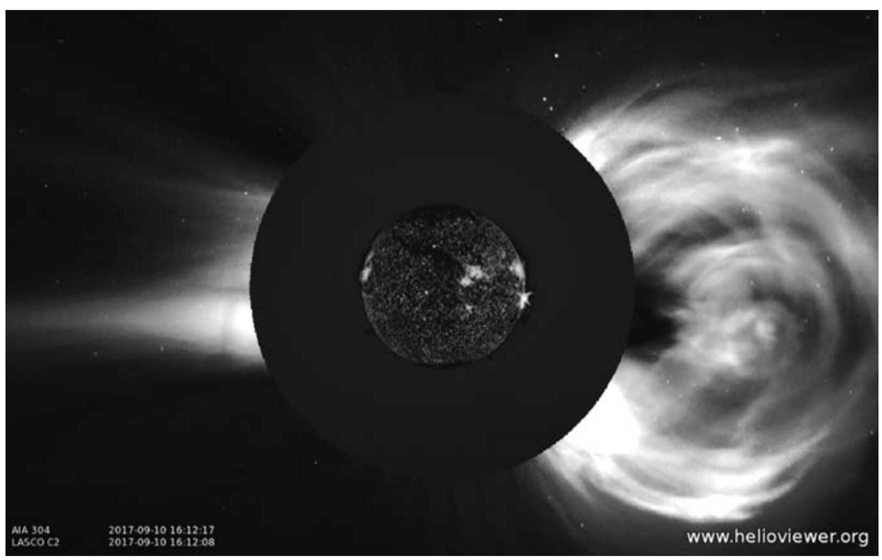
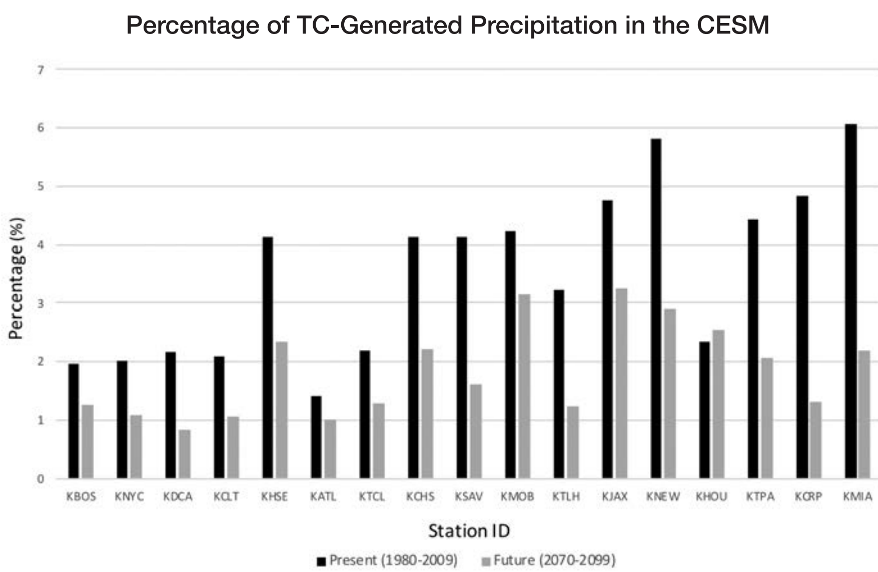


Image of a coronal mass ejection from September 10, 2017 from the ESA/NASA SOHO observatory LASCO instrument overlaid by AIA images from the NASA SDO observatory.

Present and future impacts of tropical cyclones on U.S. metropolitan hydroclimatology in a high-resolution climate model

Tropical cyclones (TCs) of varying intensities have historically impacted the eastern United States. One of the resulting effects of TCs is often extreme precipitation, which was defined in this project as more than 20 mm of precipitation per 6-hour period. Extreme precipitation events can lead to devastating impacts such as flooding, mudslides, and numerous human fatalities. Emergency managers, stakeholders, and the general public rely on impact-based information and guidance to prepare for impacts of TCs on human life, property, businesses, and the environment in the present and for the future. A three member ensemble of high-resolution (∼25 km) of the Community Earth System Model (CESM) version 1 from present and future scenarios was used to investigate impacts on U.S. cities relevant to the aforementioned populations. Point-wise data from 17 eastern U.S. cities historically impacted by TCs were used to explore seasonality, regionality, and future changes in the proportion of TC-generated precipitation and how extreme precipitation events change over time. The analyses showed that for most cities, the proportion of precipitation generated from tropical cyclones decreased in the future, but when filtering the data for extreme events, some cities saw increases in TC-generated precipitation for large rainfall rates. Looking at the data on a regional scale, it was found that the ratio of high-intensity TC-generated precipitation in inland cities increased in the future, whereas in coastal cities it decreased.



Percentage of tropical cyclone-generated precipitation for each station, arranged by latitude (from highest latitudes on the left to lowest latitudes on the right). The data were obtained from three ensemble members of CESM output for two time periods: present (1980 to 2009) and future (2070 to 2099).

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Designing a new coronal magnetic energy diagnostic

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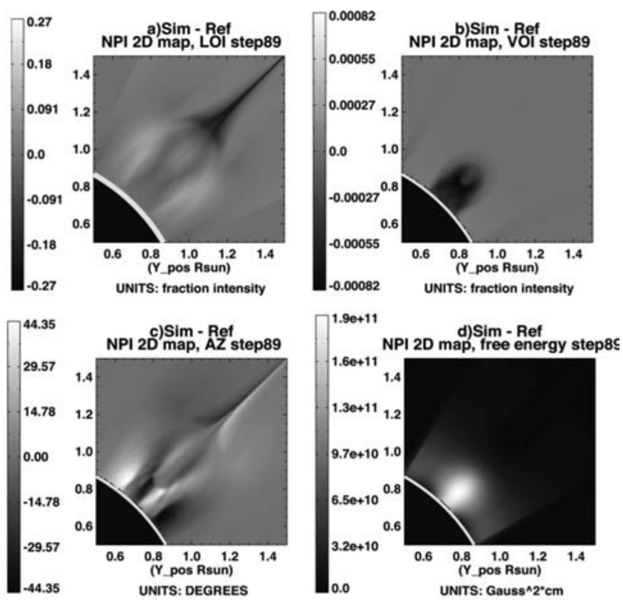
Since there are no direct magnetic measurements, spectropolarimetry has been used as an indirect measurement of magnetic field strength, structure, and interactions, allowing modeling to recreate observations and reconstruct the magnetic field. In the sun's corona, excess in magnetic energy (free energy) over a minimum potential field drives events such as Coronal Mass Ejections (CMEs). However, polarimetric measurements of the corona are particularly challenging because the corona is not as bright as the surface of the sun. Only recently have coronal polarimetric observations been possible using instruments such as NCAR's Coronal Multi Channel Polarimeter (CoMP). By using a model (magnetic field and plasma environment) of the solar corona that has been energized relative to a potential field model, we created synthetic observables resembling those of CoMP. We also created synthetic observables from a potential field magnetic model using two distinct plasma density models. A diagnostic of non-potentiality (free energy) was created by direct subtraction of the synthetic observables generated by the potential models from the ones generated by the energized model. Also, we calculated a single-valued Non-Potentiality Index (NPI) as a sum of squared differences between the energized and potential synthetic observables. We found that the NPI calculated from the circular polarization observable showed a strong correlation with free energy, and that although the NPI linear polarization observable showed correlation to free energy, it was more sensitive to changes in the density models. Our work thus demonstrates the capabilities of polarization measurements for diagnosing non-potentiality in the corona.

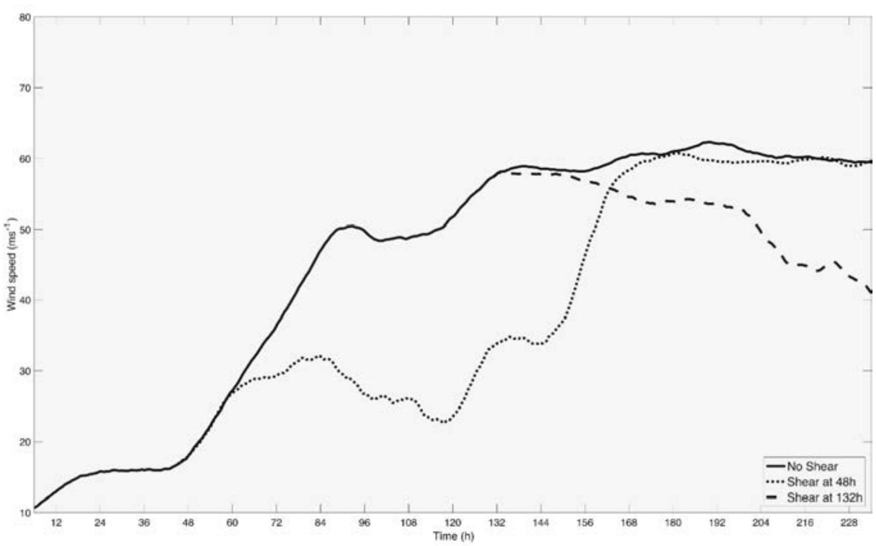


Non-potentiality spatial distributions of different polarimetric synthetic measurements corresponding to an emerged flux rope stage compared to the difference in magnetic energy: a) linearly polarized light; b) circularly polarized light; c) azimuth; d) difference in magnetic energy. There is a stronger correlation between the figures b) and d).

Physical mechanisms of tropical cyclone intensification in environments with temporally varying vertical wind shear

Accurate forecasts for tropical cyclones (TCs) are essential for the mitigation of loss of life and property. Track forecasts have substantially improved in the last couple of decades, but intensity forecasts have lagged behind in skill. Intensity forecasts are particularly challenging when a TC interacts with vertical wind shear (VWS) that is neither too strong nor too weak. Although VWS often results in a weakening of the TC, sometimes TCs intensify in spite of VWS magnitudes between 5–10 m/s. These issues have inspired many idealized studies to better understand TC-VWS interactions; however, idealized simulations typically prescribe VWS that does not vary with time. Observed VWS changes substantially on time scales of 1–2 days, thus motivating the use of a time-varying shear to study TC intensity changes due to VWS. A series of experiments using the non-hydrostatic Cloud Model 1 (CM1) were performed to analyze the response of a simulated TC's intensity in an idealized environment with time-varying VWS. The simulations showed that the introduction of moderate VWS in the early stages of the TC's life cycle delays development, but ultimately does not significantly limit the intensity. Conversely, VWS added to the environment of a TC, near the time of maximum intensity, produced a weakened storm that does not recover. Understanding how the intensity of a TC is affected by VWS is important for progress in intensity forecast improvements.

Simulated Maximum Wind Speed



Time series of 12-hour running mean of the maximum horizontal 10-m wind speed for idealized simulations without shear (solid black), with shear introduced at 48h (dotted black), and with shear introduced at 132h (dashed black).

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Investigating hurricane storm surge predictability using ADCIRC and SLOSH

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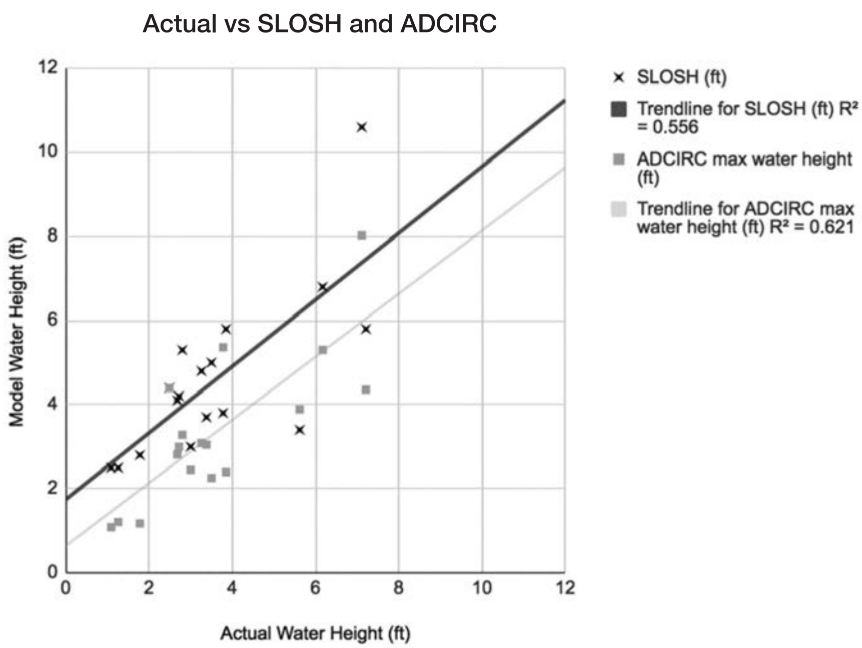
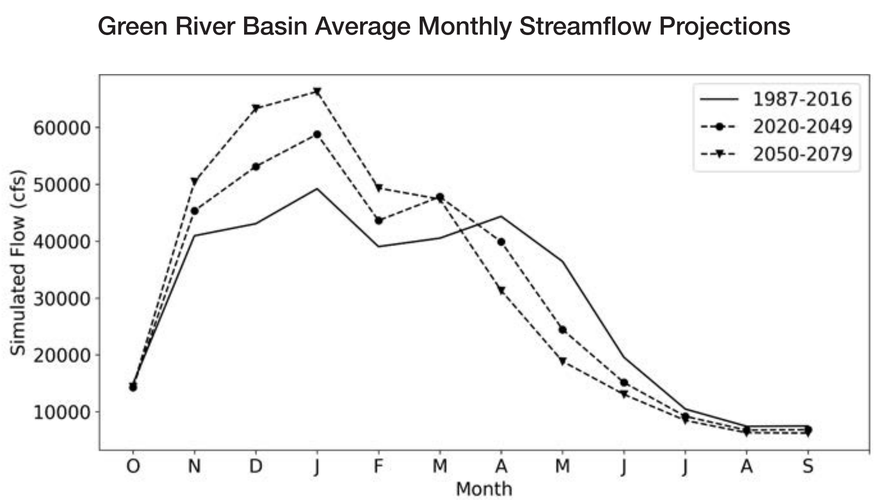
Storm surge is the excess water above the normal tide caused by hurricanes and extratropical cyclones. It is also the deadliest, most destructive part of these storms. Current models can predict storm surge up to 48 hours prior to landfall. This is not enough time for emergency management to establish an evacuation decision. To better analyze this phenomena, this study modeled hurricane Irma's storm surge with the operational model used by the National Weather Service, the Sea, Land, and Overland Surges from Hurricanes (SLOSH) model, and compared the results to those of a more detailed model, the Advanced Circulation (ADCIRC) model, and actual observations. To model Irma's surge, best track data was obtained from the National Hurricane Center's FTP site and converted into a track file for SLOSH, using Python. Storm surge is sensitive to changes in storm characteristics such as storm size (radius of maximum winds or RMW), speed, and location. To test the surge's response, the SLOSH track file was manipulated with Python to change these characteristics. After verifying that the changes in storm characteristics affected the surge as expected, the track file based on Irma's best track data was used in SLOSH and the results were compared to those of ADCIRC and actual observations. Preliminary results showed that, for this case, ADCIRC had a better correlation with the observations and less root mean squared error than SLOSH. Future work would explore whether these results were unique to this case or applicable to other storms and basins.



Scatter plot of actual water height vs. model water height. The trendlines are the best linear fit to the data. The darker color represents SLOSH and the lighter color represents ADCIRC. ADCIRC has a higher correlation coefficient than SLOSH (0.62 vs. 0.56).

Predicting streamflow and snowpack sensitivities to climate change in the Pacific Northwest's Green River Basin

Climate change will have significant impacts on Pacific Northwest hydrology. For water and environmental resource managers, an improved understanding of climate impacts at the watershed scale is critical for regional mitigation and adaptation. The Pacific Northwest's Green River Basin is a valuable water supply, major flood risk, and provides habitat to cold-water aquatic species. Streamflow in the basin is seasonally regulated for flood prevention and flow modulation for ecosystem health. This study investigated the implications of climate change on streamflow and snowpack in the Green River Basin. Climate sensitivity analysis and future climate change impacts were simulated using the Snow17/Sacramento Soil Moisture Accounting model (Snow17/Sac) implemented with two elevation zones. Future climate change impacts on basin hydrology were assessed using an ensemble of statistically downscaled climate projections from Global Climate Models (GCMs) run as part of the Intergovernmental Program on Climate Change 5th Assessment Report. The application of two future emission scenarios (RCP 4.5 and 8.5) led to moderate increases in streamflow volume and 49.9% to 84.0% reductions in snowpack by the year 2079. Center timing of streamflow is projected to shift towards earlier timing indicating that the basin is predicted to evolve from a transient to rain-dominated watershed. This shift in the annual hydrologic cycle could lead to heightened demands on seasonal water needs and changes in the frequency of extremes (flood and drought). Future planning and reassessment of how water is managed in the Green River Basin may be necessary to maintain operations that suffice to meet the region's water needs.



Historic and future streamflow projections in the Green River Basin for the RCP 8.5 scenario. By 2079, the loss of the springtime peak indicates the basin is projected to become rain-dominant.

Jane Harrell

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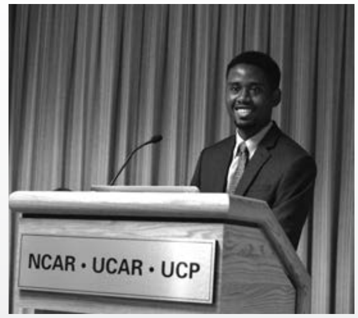
IT WAS A GREAT SUMMER!


A Seat at the Table
Women
Women make up 50.8% of the US population
50.0% of Undergraduate STEM Degrees (BS)
46.0% of STEM Graduate Degrees (MS)
41.6% of STEM Graduate Degrees (PhD)
28.4% of STEM Careers
33.5% of Ranked Professors
Black/African Americans
Black people make up 12.4% of the US population
8.3% of Undergraduate STEM Degrees (BS)
7.8% of STEM Graduate Degrees (MS)
3.5% of STEM Graduate Degrees (PhD)
4.8% of STEM Careers
3.6% of Ranked Professors

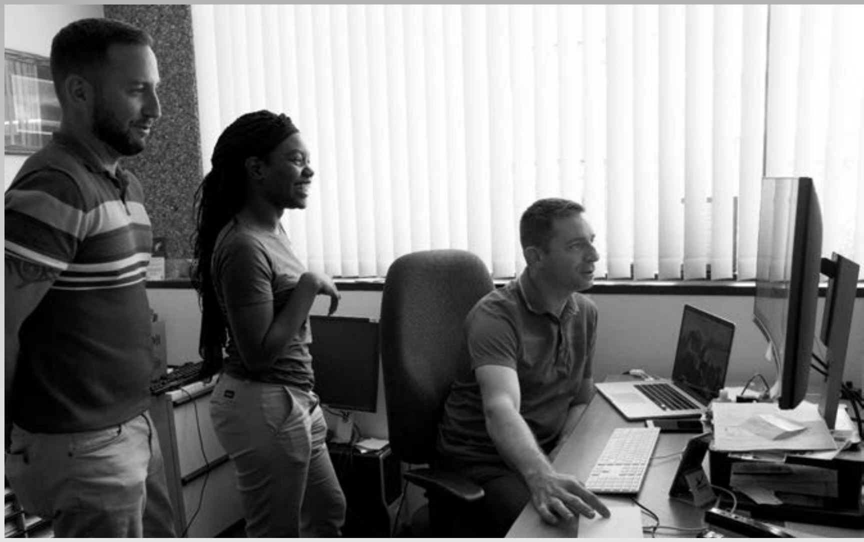
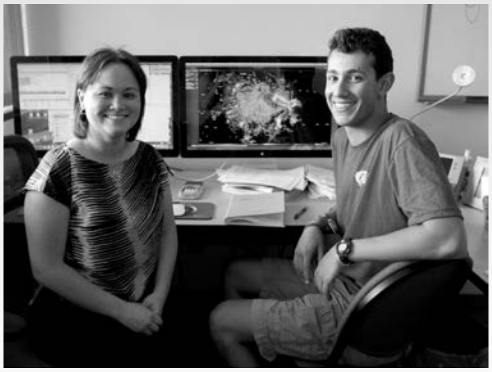

NCAR · UCAR · UCP


Amber


Intro/context

2018




Exploring the relationship between liquid water equivalent and ice accretion rates

Jaylond Harvey

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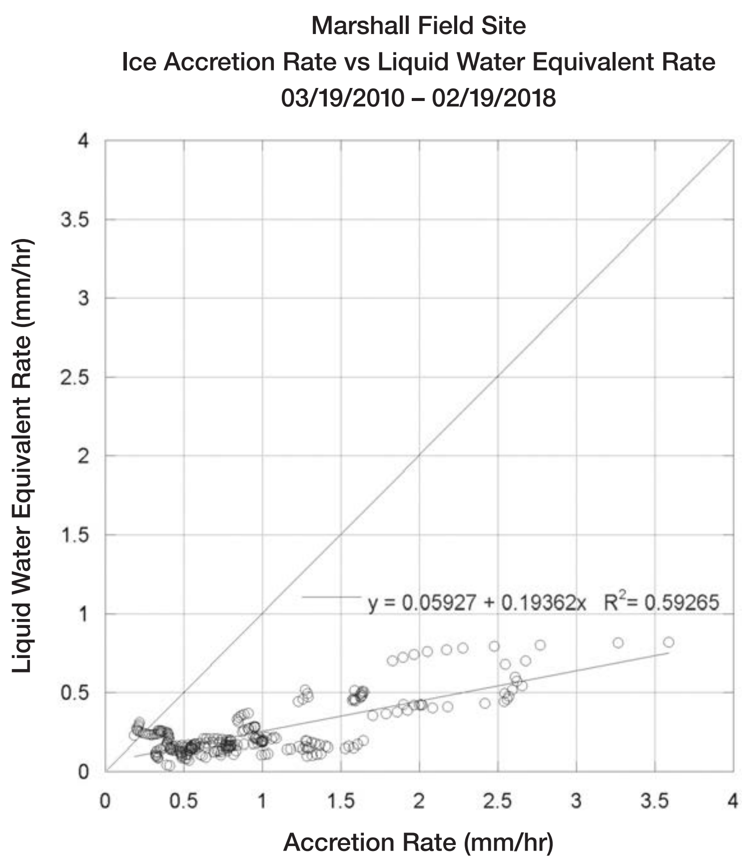
Aircraft face potential danger due to Supercooled Liquid Water (SLW) coming into contact with the aircraft surface, resulting in Ice Accretion (IA). When exposed to SLW conditions, such as freezing rain and freezing drizzle, aircraft run the risk of ice accretion developing on the surface of the plane. IA occurs over a period of time, causing ice to accumulate and build up on various parts of aircraft, including critical surfaces such as the wings and tail. One way to measure IA at the surface is to measure the Liquid Water Equivalent (LWE) of the falling precipitation. LWE is the real-time measurement of the falling precipitation and is a measure of the water content in the precipitation. This is important because various organizations, such as the Federal Aviation Administration (FAA), assume that the LWE rate is the same as the IA rate. For this study, data from a B.F. Goodrich Ice Detection Sensor and a GEONOR precipitation gauge were analyzed. The sensors were located at the Marshall Field Site, south of Boulder, CO, and the dataset spans 8 years, from March 2010 to May 2018. A Vaisala PWD22 was used to identify periods of freezing rain and freezing drizzle events. LWE and IA rates were derived from each of the sensor datasets during periods of freezing precipitation and the rates were compared against each other. The comparison showed that the two rates were not the same and that IA rates were, on average, four times higher than the LWE rates.

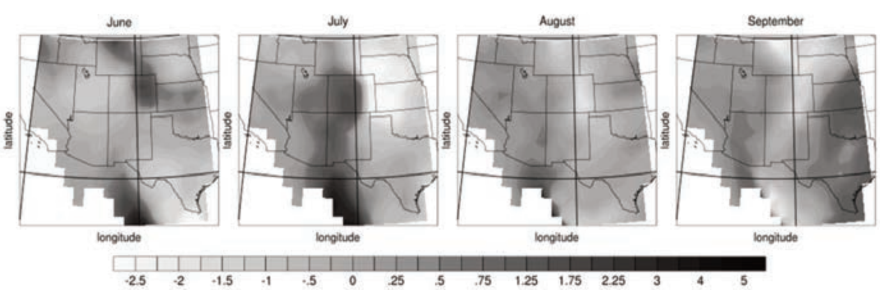


Marshall Field Site ice accretion rate vs. liquid water equivalent rate shows weak correlation.

Comparing statistics of precipitation variations during the American Monsoon in CESM1

The summer-time American Monsoon region experiences large variations in precipitation, leading to significant impacts on hydrology. These fluctuations are poorly represented in climate models, making it challenging for predicting future changes and enforcing countermeasures. This project analyzed the National Center for Atmospheric Research (NCAR)'s Community Earth System Model 1 (CESM1) large-ensemble to determine how robust and reliable the model is at predicting the monsoon on seasonal and daily timescales. It examined the precipitation over the US, focusing on the Southwest summer-time monsoon, how it is simulated and how it might change in the future. Examination of pre-industrial, present day and future CESM1 simulations revealed that the monsoon simulation is somewhat deficient compared to observations. Rather than a localized maximum centered over the Arizona and New Mexico regions, there is a westward extension of the spurious north-south elongated precipitation feature positioned along the Eastern Rocky Mountains. Furthermore, the seasonality of the monsoon exhibited a shift of about a month, with the onset moving closer to August and significant rains still seen in September. These simulation shortcomings could call into question the reliability of future projections. The dominant climate change simulated showed an increase in monsoon rainfall and humidity, consistent with the inevitable surface temperature rise. The location of these increases are, however, distant from the observed and are co-located with the model's main precipitation bias. An analysis of the daily precipitation PDF revealed that the model does not predict a significant change in extreme events and reflected the same regional biases.

Average Precipitation (mm/day) – Future and Present Day Difference



Panel of the summer-time monsoon focused on the Southwest region. The maps present the difference between future and present day average precipitation simulations of CESM1, showing a significant increase in precipitation during July but an overall decrease in precipitation throughout the region.

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Characterizing spatial and temporal sampling uncertainty in the SWOOSH database

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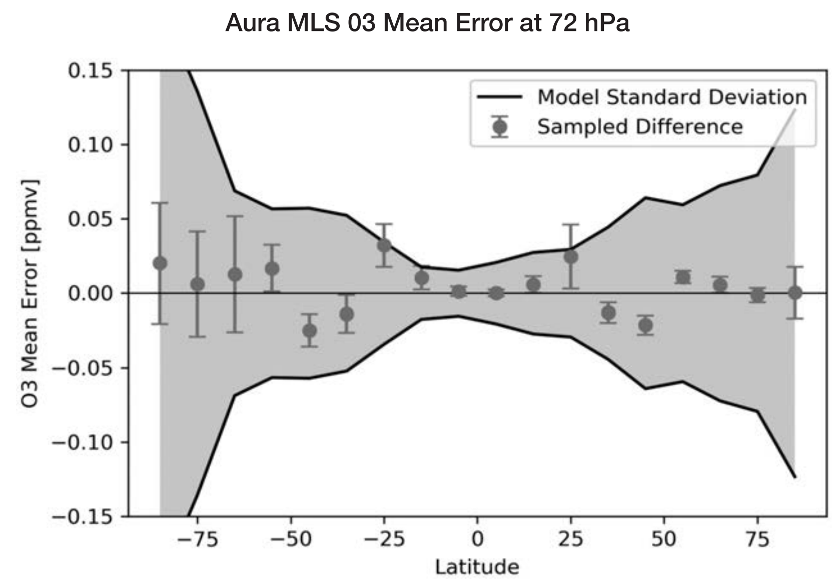
Pedro Brea

The Stratospheric Water Vapor and OzOne Satellite Homogenized (SWOOSH) data set merges data from five different satellites to create a continuous record of stratospheric ozone and water vapor from 1984 to the present. This record can be used to understand how water vapor and ozone may have changed over time or to validate model results. Currently, SWOOSH does not provide comprehensive estimates of uncertainty resulting from non-uniform spatial and temporal sampling within monthly latitudinal grid boxes. Three methods to characterize such uncertainties were undertaken, including a climatological gradient, interpolation, and sampling a model with the sampling patterns of the SWOOSH satellites for the entirety of the period. All three methods suggest that sampling errors are substantial in the early record (1984-2004) and smaller in the later period, with the onset of the Aura MLS satellite (2004-on). In the early record, ozone sampling error is particularly high towards the poles at low pressure, while water vapor sampling error is higher around the equator and mid-latitudes at high pressure. Though sampling errors decrease during the Aura MLS era, they remain high towards the south pole and midlatitudes. Future work will involve testing methods of error correction for the SWOOSH database using a sampled model.



The difference between the model ozone (O_3) mean for 2004-2006 and the sampled Aura MLS mean at 72 hPa for each 10° latitude bin. The error bars are the standard deviation of the sampled difference. The standard deviation of the model values is also shown for each latitude bin.

Weather-Ready Nation: Care model development for Ambassadors

The National Oceanic and Atmospheric Administration's (NOAA) nationwide Weather-Ready Nation (WRN) Ambassador™ initiative affords each individual National Weather Service (NWS) Weather Forecast Office (WFO) the ability to recruit and work closely with WRN Ambassadors in their local County Warning Area (CWA). This project developed the Denver/Boulder Care Model (DBCM), a protocol for WFO Denver/Boulder that encompasses Ambassador recruitment and marketing plans and decision support services. DBCM is a scalable model that supports Ambassadors with education, outreach, and other weather, water, and climate-related decision-making materials, encourages open dialogue and collaboration, builds trust, promotes transparency, and welcomes suggestions from Ambassadors. The goal of the DBCM is to help prepare WFO Denver/Boulder partners for high-impact severe weather, water, and climate-related events, help mitigate the loss of life and property through partner education, and enable efficient use of staff during Blue Sky (fair weather) days. DBCM allows WFO Denver/Boulder to develop strong working partnerships before hazardous weather threatens so that both the WFO and decision-makers are well-equipped to work together during impactful events. Qualitative surveys were disseminated to current and potential Ambassadors of WFO Denver/Boulder. Content for DBCM was developed by evaluating survey responses, thorough discussion with the Meteorologist In Charge (MIC) and Warning Coordination Meteorologist (WCM), and collaboration with other WFOs. DBCM contains a compilation of administrative, recruitment, outreach, and partner support materials. Survey results specifically influenced partner support, outreach, and recruitment content development.

The primary categories of the Denver/Boulder Care Model, along with the supporting materials.

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Evaluating satellite detected tropospheric ozone trends above Europe with ozonesondes

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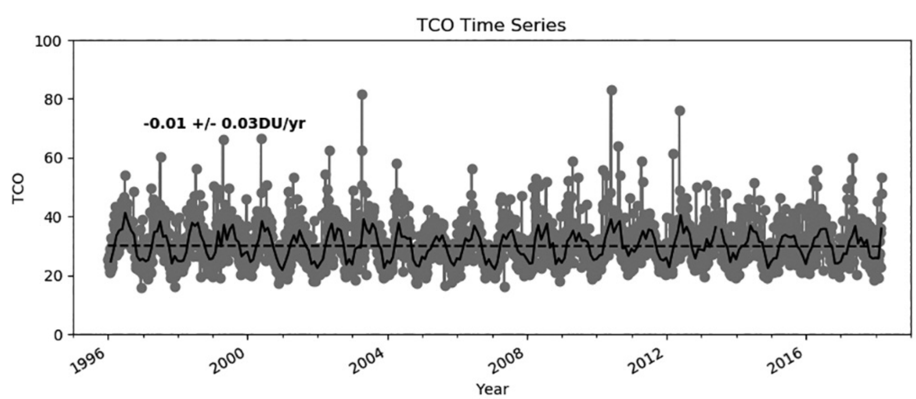
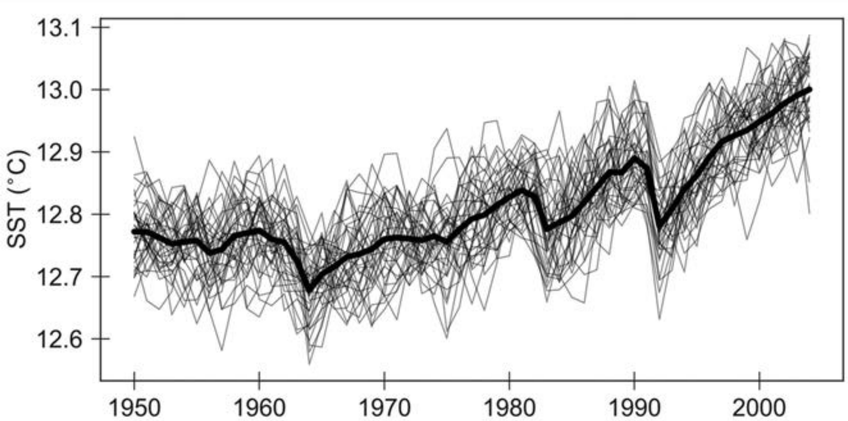
Tropospheric ozone is of significant concern due to its detrimental impact on human health, crops and climate. Assessment of the global tropospheric ozone burden and its trend requires global observations of tropospheric column ozone. Satellite observations are the only source of this important information. There are a total of five satellite products available for the community but they disagree regarding tropospheric column ozone trends. Continual monitoring of ozone profiles from in situ observations such as ozonesondes at different locations around the world provide data necessary for evaluating satellite-detected ozone variability and trends. This study quantified the trends of tropospheric column ozone as measured by ozonesondes over Hohenpeissenberg, Germany. While ozonesondes are flown with a frequency of once a week or less at most stations around the world, Hohenpeissenberg has on average 3-4 launches per week. The tropospheric column ozone was maximum in spring/summer in agreement with other mid-latitude sites. The analysis of tropospheric column ozone trends over Hohenpeissenberg showed no change during the 1996-2018 period. However, the regression analysis of seasonal ozone indicated a statistically significant negative trend during the summer months and a small positive trend during the winter, with no trend during the other seasons. We will use this robust data set to evaluate satellite-detected ozone trends above Europe and will report findings from three publicly available satellite products. This analysis is just the first step in a global-scale intercomparison of newly developed satellite products.



Time series of the tropospheric column ozone measured by ozonesondes above Hohenpeissenberg, Germany from 1996 to 2018.

The impact of volcanic eruptions on ocean pH

Volcanic eruptions can have a major influence on the Earth system. Aerosols, gas molecules, and fine ash particles from large explosive eruptions can remain in the stratosphere for months to years, decreasing incoming solar radiation and causing Earth's surface to cool. Eruption records reflect temperature decreases significant enough to disrupt the water cycle and reduce atmospheric carbon dioxide concentrations. The impact of volcanic eruptions on ocean biogeochemistry has not been well studied, yet there is a pressing need to explore this topic because volcanic eruptions are analogous to radiation management geoengineering schemes and to the climate effects of a potential nuclear conflict. Understanding these effects may also help us understand the effects of past asteroid collisions with the Earth. Using output from the Community Earth System Model Large Ensemble (CESM-LE), which includes atmospheric and biogeochemistry components, we investigated the effects of three major volcanic eruptions in the past (Agung 1963, El Chichón 1982, Mount Pinatubo 1991) on the modeled ocean potential hydrogen (pH). Ocean pH is a measure of ocean acidity that is closely tied to temperature, salinity, and carbon dioxide solubility in seawater. We show that sea surface temperatures decrease following a volcanic eruption and global ocean pH rises in the next two to three years. We further show this effect is amplified in the equatorial Pacific as a result of slower upwelling of corrosive water during an El Niño-like event, which supports current scientific discussion regarding El Niño-like responses following a volcanic eruption.



Community Earth System Model Large Ensemble (CESM-LE) 1950-2005: global mean sea surface temperatures (SST). Each thin line represents annual means of one of 36 ensemble members; bold line represents mean of all ensemble members. All three volcanic eruptions are seen as sea surface temperatures drop in 1963 (Agung), 1982 (El Chichón), and 1991 (Mount Pinatubo).

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Protégés are pictured left to right: **Front Row** Jamin Rader, Marcel Corchado Albelo, Pedro Brea, Jaylond Harvey, Starlette Williams
Middle Row Kimberly Brothers, Brittany Welch, Cindi-Ann Findley, Ekaterina Lezine, Nathalie Rivera Torres, Jane Harrell, Sung Min Kim, Michaela Serpas, Holly Olivarez, Mia Murray
Back Row Malcolm Wilson, Amin Taziny, Jeremiah Piersante, Keenan Eure, Amber Liggett

PHOTO BY CARLYE CALVIN


NCAR · UCAR · UCP

Understanding subtropical MCSs in Argentina using WRF

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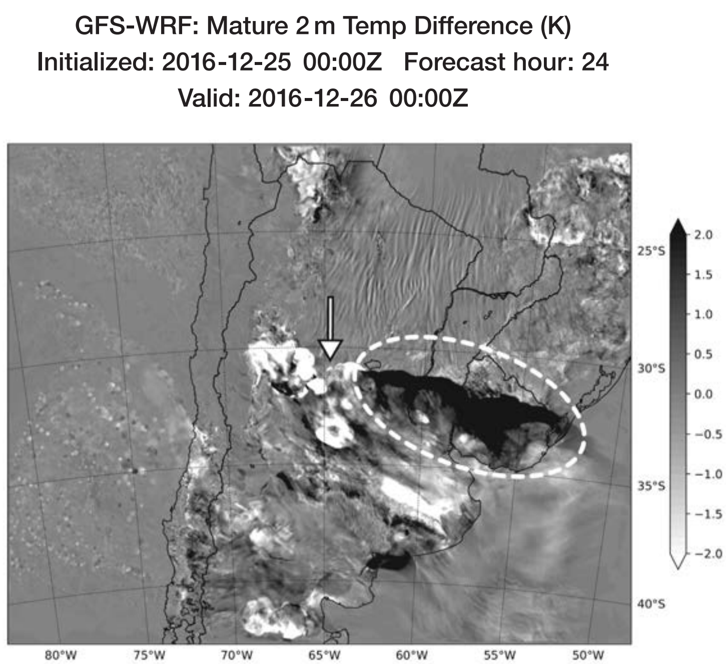
Subtropical South America is home to some of the world's most intense convection, particularly near the Andes and Sierras de Córdoba mountain ranges of Argentina. Convective cells typically initiate along the foothills due to the combined influence of complex topography, the South American low-level jet, large-scale support, and the diurnal cycle. As storms mature and propagate eastward, they grow upscale to much larger horizontal dimensions and frequently develop into mesoscale convective systems (MCSs). These MCSs have substantial socioeconomic impacts on the region's cities and agriculture due to damaging hail, winds, and rainfall often associated with various stages of an MCS. The distinguishing factor of these MCSs relative to those in other more studied locations is their tendency to "backbuild," or remain convectively tied to the eastern edge of the foothills terrain as they grow and propagate eastward. To investigate this unique characteristic, the Weather Research and Forecasting (WRF) model is used to perform simulations of a long-lasting, backbuilding MCS in Argentina testing different microphysics schemes: Morrison, Thompson, and NSSL. Analysis shows that all three simulations featured backbuilding convection tied to the Sierras de Córdoba and depicted three waves of convection, two of which likely were related to the diurnal cycle. The simulation with Morrison microphysics featured the broadest areal extent of moderate to intense rainfall, while the Thompson simulation produced the broadest extent of forecast hail. Morrison sustained the most robust cold pool and convection east of the Sierras de Córdoba throughout the simulation.

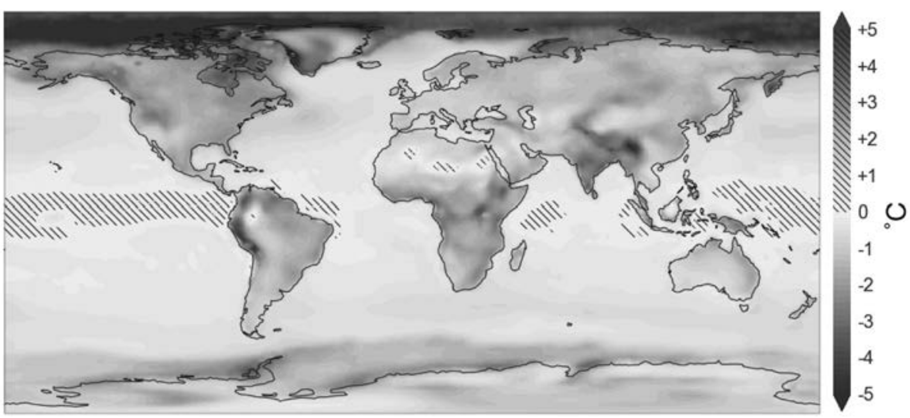


Difference in 2 m above ground level temperature (K) between Thompson and Morrison simulations during backbuilding convection. The white arrow indicates the approximate location of the Sierras de Córdoba and the white dashed circle outlines the location of persistent backbuilding convection. Black (white) regions indicate where Thompson predicted warmer (cooler) surface temperatures. Here it is evident that at the location of the backbuilding convection, Morrison predicted cooler surface temperatures.

Diurnal temperature variability: An observations-climate model intercomparison

Surface temperature measurements since the mid-20th century have revealed a diurnally asymmetrical global warming trend, with nighttime minimum temperatures increasing faster than daily maxima. The result is an overall decrease in the diurnal temperature range (DTR), which has implications for agriculture, streamflow, winter sports, as well as the overall magnitude of global warming. Through linear regression of DTR on specific humidity, an empirical model was derived for predicting DTR variability with respect to changes in future water vapor concentrations. This model projects end-of-century decreases in DTR globally as surface temperatures, and consequently water vapor concentrations, rise. This is consistent with a continued asymmetrical warming trend. This finding contrasts with explicitly simulated end-of-century DTR by global climate models (GCMs), which do not reproduce asymmetrical warming on a global scale. This prompted further assessment of the fidelity of GCM-simulated DTR baseline estimates between 2007 and 2016 through comparison with similar calculations applied to modern atmospheric reanalysis data. The significant deviations between observed and GCM-simulated DTR are proposed to be associated with inaccuracies in GCM-simulated water vapor concentrations. This may be symptomatic of limitations in the physical parameterizations of cloud and precipitation processes, warranting further investigation to increase the reliability of global warming projections.

2090-2099 Regression-based Change in Diurnal Temperature Range



The predicted change in DTR by 2090-2099 relative to 2007-2016 based on the linear regression of DTR on specific humidity and observed mean specific humidity projections from CNRM-CM5, GFDL-CM3, INM-CM5, and MIROC5.

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The impact of high-resolution terrain data in WRF simulations of Hurricane María (2017)

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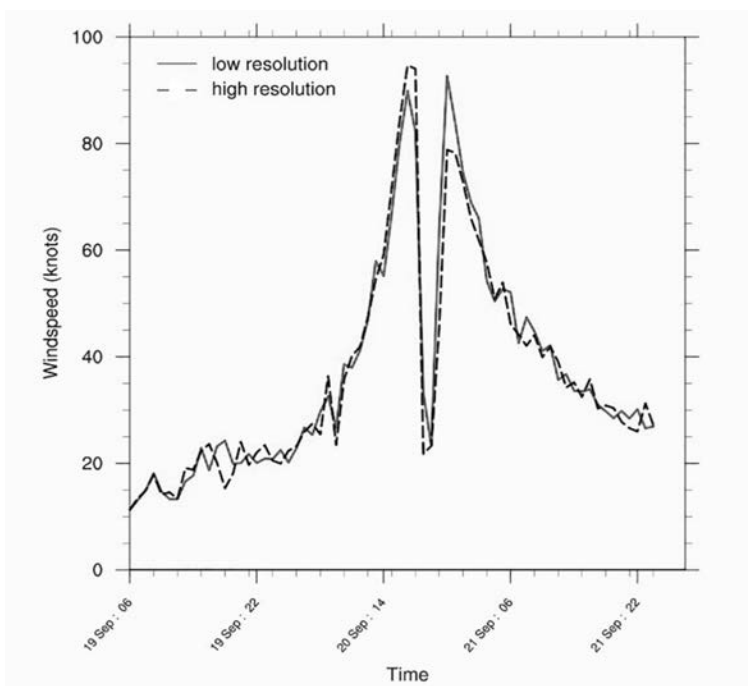
Brittany Welch

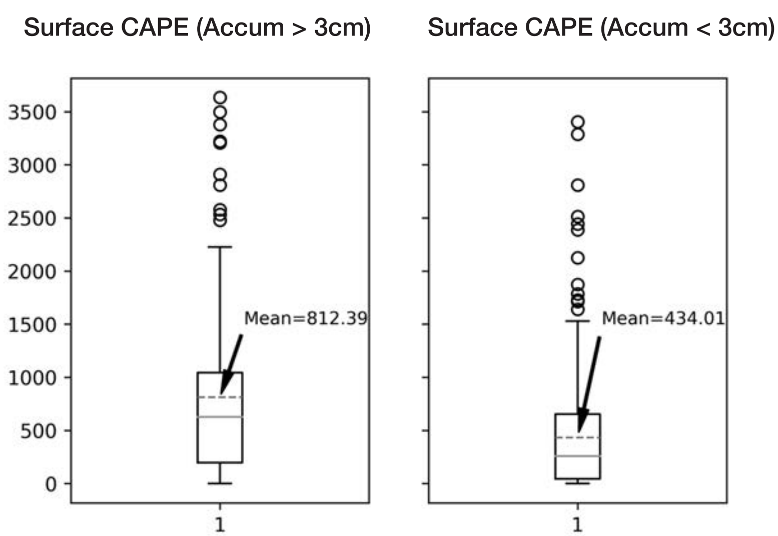
The atmospheric processes involved in a tropical cyclone are affected by topographical factors during and after landfall. Interactions with land are capable of changing the tropical cyclone's structure, behavior, and impact on the landmass. However, one of today's forecasting problems is that computer models cannot interpret many of the factors that influence surface weather over complex terrain, forecasting the tropical cyclone's behavior that would be expected if it was moving over a smooth landmass. This research project investigated the impact of high-resolution terrain data in Weather Research and Forecasting (WRF) model simulations of Hurricane María, focusing on its path over Puerto Rico. Two WRF simulations were compared to see the impact of the model's terrain resolution. One of the simulations used a default terrain dataset that considers Puerto Rico a smooth surface and the other used a high-resolution terrain data set that accurately represents the island's mountainous topography. Time series plots, horizontal maps, and swaths of atmospheric variables such as wind and rain at specific locations, were used to show differences between the two simulations, demonstrating the impact of high-resolution terrain data on WRF tropical cyclone simulations. First, the high-resolution simulation showed higher rainfall, and second, the simulated wind speed was higher before the hurricane crossed the island, but it decayed after the interaction with landmass. It is concluded that high-resolution land data has the potential to lead to more accurate forecasts of wind and rain in cases when tropical cyclones interact with a landmass.



Time series of Hurricane María wind speed over the highest point in Puerto Rico, Cerro de Punta, from 19 September 2017 at 6:00:00 UTC to 22 September 2017 at 00:00:00 UTC. The graph compares the high and low resolution terrain data wind speed in the WRF model.

Characteristics of hail accumulation events around Denver

The Colorado Front Range lies in Hail Alley, the area that receives the greatest frequency of large hail in North America. Thunderstorms in this region can produce hail accumulations up to 60 cm deep, affecting people's safety. Since hail reports and hail research have mainly focused on hail size, deep hail accumulations have been understudied and reports about hail depth are sparse. To combat this, the Colorado Hail Accumulations from Thunderstorms (CHAT) project began in 2016 and focused on developing a data archive of hail accumulations. Previous research within the project led to the development of a radar-based hail accumulation algorithm which uses radar reflectivity and dual-polarization data to calculate hail depth in real time. Using hail accumulation maps based on operational weather radar in Denver, frequency, spatial and temporal distributions of these events were generated. The frequency of deep hail events was found to be associated with certain months, years, and large-scale locations rather than small-scale locations. While shallow accumulations (< 3 cm) are more frequent, deep hail events occur at least 15 times per year. Environmental conditions leading to deep hail accumulations have also been analyzed. The preliminary analysis showed that CAPE levels are approximately double on hail accumulation days than on days with little to no hail. Since deep hail is so frequent in the Front Range, these statistics guide city meteorologists, drivers, and residents to be aware of hail's unpredictability. Hail can occur anywhere in the Front Range and even small accumulations affect local wellbeing.



Boxplots of CAPE measured in the Colorado Front Range, from 2013-2017, for days with little to no hail accumulation and days with hail accumulation greater than 3 cm.

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PREPARING TOMORROW'S SCIENTISTS

Successful scientists do more than just "research." They work individually and in teams. They spend hours writing code. They prepare, practice, and present talks and posters. They write scientific papers and grant proposals. They reach outside of the institutional walls and volunteer their knowledge to school groups and the general public. Some of them spend their careers at universities and national labs, but many work in industry, in government or in non-profits, using their knowledge, research skills and critical thinking to shape policy, protect lives and property, develop creative solutions and solve today's most challenging problems. As part of preparing the next generation of scientists, SOARS aims to equip our protégés with these skills and expose them to a wide range of career paths. Professional development occurs throughout the SOARS summer. During the first week, protégés engage in formal **leadership training** to prepare them to be successful teammates, communicators and leaders, and they practice these skills throughout the summer. Our weekly **scientific communication workshop** guides the protégés toward their SOARS deliverables of a scientific paper, a poster and a talk, using active learning strategies to build confidence in team work and in presenting to an audience. Students participate in our four week **scientific data and computing workshop** that introduces computational thinking, programming in Python and provides tools for sharing and co-creating code, in preparation for the next generation of science papers that share data and code as well as writing and graphs. Each year, we also

offer individual **career counseling**, a **GRE preparation** course, a **career panel**, training in **preparing graduate school and fellowship applications**, **outreach**, opportunities to **interact with alumni, other students, and scientists** in various capacities, and **field trips** to graduate schools and scientific institutions. We also offer new and varied opportunities each summer: this year our career panel focused on **careers in policy and societal impact**, we visited the **Denver Museum of Nature and Science**, hosted a **financial planning** seminar, and engaged in **shared events with visiting student groups**. At the end of the program, after nine weeks of research, protégés **present talks and posters** at the SOARS colloquium and SOARS joint internship poster session, an opportune time to celebrate their accomplishments and share their research with the broader community. Through the fall and winter, SOARS continues to support protégés in **applying to graduate school and fellowships, attending and presenting at national conferences**, and offers **financial assistance** in the form of scholarships. Combined, these activities not only prepare protégés to succeed in graduate school and beyond, but help bring them together as a cohort and build the long-term support network and commitment to the program that SOARS is known for.

Left: Protégés **Jaylond Harvey**, **Amber Liggett**, and **Mia Murray** during a scientific communication workshop.

Top: Protégés volunteer at WeatherFest at Colorado State University, with the UCAR Center for Science Education. PHOTO BY TIFFANY FOURMENT

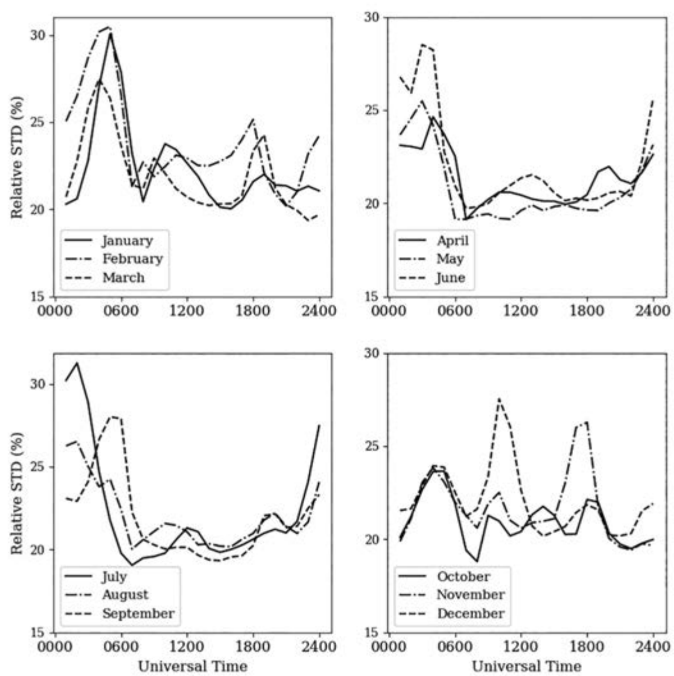
Second: “What does a scientist look like?” Group discussion during orientation.

Third: Colorado State University field trip and graduate school discussion.

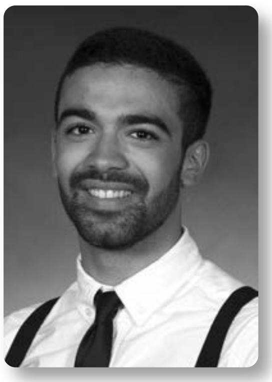
Bottom: Protégés check out specimens during a “behind the scenes” tour and career discussion at the Denver Museum of Nature and Science.

Analysis of short-term ionospheric variability using WACCM-X

The ionosphere is the region embedded in Earth's upper atmosphere that presents a high concentration of electrons and ionized atoms. This ionospheric plasma scales more than 1000 km in altitude and is highly variable (spatially and temporally) from solar ionizing flux, space weather conditions, and lower atmospheric processes such as vertically propagating gravity waves, planetary waves, etc. Within this study, output from the Whole Atmosphere Community Climate Model with thermosphere and ionosphere extension (WACCM-X), a general circulation model spanning from Earth's surface to the upper thermosphere, was studied to quantify short-term variability of the ionosphere total electron content (TEC). The short-term variability is quantified based on the standard deviation within a given month, allowing us to determine how the short-term variability depends on season, location, and solar local time. Mid-latitude longitudinal dependence at local noon was determined to quantify the spatial distribution of TEC. These values were then compared with model output of fixed solar and geomagnetic activity to determine the amount of ionospheric variability that can be contributed to the lower atmosphere. A significant amount of this variability was found and can most likely be attributed to meteorological influences originating in the lower atmosphere. Additionally, the WACCM-X simulations were compared with previous works using ionosonde observations to both help validate model output and quantify seasonal TEC data. The results of this study help to improve quantitative understanding and predictability of upper atmosphere variability.



Diurnal variability of total electron content (TEC) from WACCM-X over Slough, UK during 2009. Graphs show relative standard deviation with respect to mean TEC by season and month.



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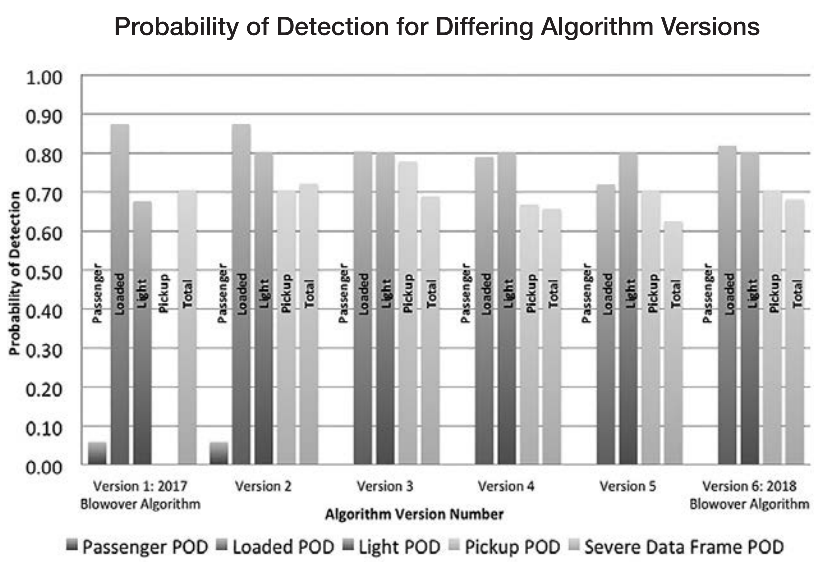
Updates to the truck blowover algorithm for the Pikalert® system

Various weather phenomena impact the safety of vehicles on the roadway by way of sudden changes in crash risk and vehicle operation. This causes weather-related crashes to account for 22 percent of all U.S crashes. These incidents occur frequently along Wyoming's 402-mile long Interstate 80 (I-80) corridor. Here, severe winds occur year-round and preferentially affect freight traffic, resulting in 1000 blowovers a year. Severe winds impact roadway safety, road closure frequency, and economic stability, making it vital to warn drivers of blowover risks. To help mitigate the impact of severe winds, a blowover algorithm was developed for the Wyoming Department of Transportation's (WYDOT) Pikalert® system.

The algorithm underwent verification testing during the 2017 to 2018 winter season. The results determined that the algorithm needed further tuning by way of a missed crash analysis. As a result of this analysis, a fourth vehicle category for vehicles hauling trailers was added, allowing other functions to be refined. A sensitivity analysis was performed on the algorithm's weights and functions to assess values that fit the dataset. These updates will aid in increasing the accuracy of the algorithm.

This version of the algorithm will provide effective aid in route planning and issuing driver advisories or restrictions seeking to reduce the number of blowovers. The algorithm will also help with advisory issuance and road closures along I-80. Updates to this algorithm will be available to the community as part of the open source code developed for the WYDOT Connected Vehicle Pilot Deployment (CVP).



Analysis of the Probability Of Detection (POD): "Hit" to "Total Event Occurrence" ratio to determine the blowover detection probability, for all vehicle classes for each algorithm version.

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Quantifying snow/ice albedo feedback in the Arctic based on reanalysis data

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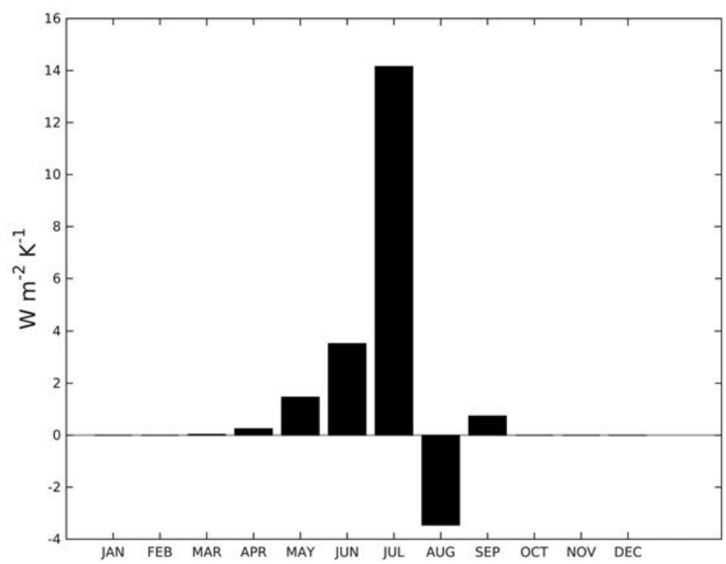
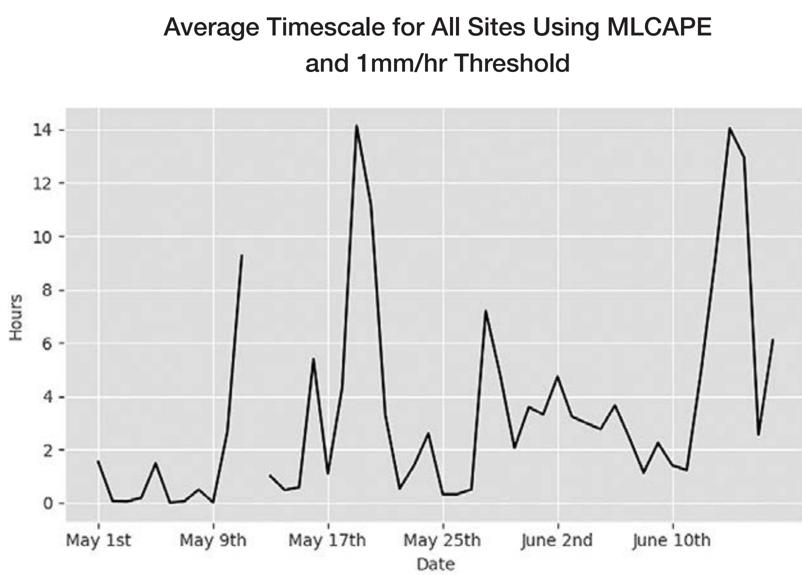
Snow/ice is a key climate element in the Earth system which significantly affects surface energy and water balance through a strong snow/ice albedo feedback (SAF). Over the past decade, substantial progress has been made on improving the understanding of SAF over the Northern Hemisphere, particularly under climate change scenarios. However, minimal attention has been paid to quantifying the SAF over the Arctic, a region that is extremely sensitive to global warming. SAF is also an important component of the Arctic amplification. Quantifying the SAF strength in the Arctic allows for a comparable representation of modeled and measured warming responses in the region especially under the effects of climate change. In this study, SAF was decomposed into the product of two terms, one representing the dependence of net incoming solar radiation on surface albedo and the other representing the change in surface albedo induced by a unit temperature change. The reanalysis data from the Modern-Era Retrospective analysis for Research and Applications (MERRA-2) from the NASA Global Modeling and Assimilation Office provided observational constraints for the calculations. Surface albedo radiative kernels from four widely-used global climate models (GCMs) were also utilized to quantify the first term. Model results were compared with the MERRA-2 analysis in order to investigate GCM ability to reproduce the Arctic SAF strength. SAF was analyzed over the different surface types within the Arctic, including ocean with sea ice and land snow/ice/glacier, to quantify their relative contributions.



Multi-year (1980-2017) mean seasonal variation of snow albedo feedback strength averaged over the Arctic (60-90°N), based on MERRA-2 reanalysis data.

A potential diagnostic to characterize different weather-regime forcings of convective precipitation events

The ability of numerical weather prediction models to forecast convective precipitation varies under different convective forcing regimes. Past research indicates that models have better performance forecasting convective precipitation under synoptically-forced scenarios than under a mesoscale-forcing regime. To efficiently test models under different weather-regime forcings, a diagnostic that differentiates the regimes is needed. This research focused on analyzing the Convective-Adjustment Timescale, a diagnostic that can potentially differentiate convective precipitation regimes using Convective Available Potential Energy (CAPE) and precipitation rate. Previous research has demonstrated that this diagnostic timescale is effective based on model output for events in Europe. In this paper, we instead use radar-based observations and sounding data over the United States during the spring of 2017 to calculate the timescale, and then verified its effectiveness using surface pressure analyses from the Weather Prediction Center. This research also analyzed the sensitivity of the timescale to the parameters used in calculating the diagnostic. The parameters include the CAPE definition, the precipitation rate threshold, and the observed radius around the focused radiosonde sounding sites. Results indicated that the timescale magnitude strongly depends on the precipitation threshold, but its behavior in differentiating the regimes is similar despite using different precipitation thresholds and CAPEs. This gives crucial insight that the precipitation threshold is critical in calculating the timescale and that the convective-adjustment timescale could potentially serve as a useful diagnostic in the field of model development.



Mean Convective-Adjustment Timescale for all sounding sites within observed region between May 1st and June 17th, 2017.

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MANY VOICES

SOARS is a proud partner in the NSF INCLUDES project **“Collaborative Research: Integrating Indigenous and Western Knowledge to Transform Learning and Discovery in the Geosciences.”** We recognize the value of bringing diverse voices and indigenous science to NCAR, and have long worked to support Native American and Alaska Native students in SOARS.

As part of this collaborative effort between Haskell Indian Nations University, SOARS, NCAR's Rising Voices, GLOBE, the University of Michigan and Biosphere 2 at the University of Arizona, we have been able to support Native American students through SOARS. Our part of this grant also supports citizen science in tribal communities and provides opportunities for our protégés to engage with tribal voices.

Top: Participants at the Rising Voices workshop, Duluth, Minnesota, April 2018. PHOTO BY HEATHER LAZARUS, NCAR
Bottom Left and Bottom Right: HERS interns share their community-based research posters with SOARS proteges.
Bottom Center: SOARS, HERS, and Biosphere2/SOARS interns together at the Denver Museum of Nature and Science.

In last year's EWSS, we highlighted the partnership we had built with the Research Experience for Undergraduate (REU) program at Biosphere 2 through this grant, whereby two indigenous students became joint fellows, participating in the Biosphere 2 REU and being provided with ongoing support through SOARS. Both fellows went on to present work at national conferences, and one of these protégés, Mychal Thompson, spent part of this summer collecting data and stories in her community on the Navajo nation through the citizen science part of the grant. She also participated in the annual **Rising Voices: Climate Resilience through Indigenous and Earth Sciences** workshop. Rising Voices is a unique collaboration with the community that brings social and physical scientists together with tribal community members and, following cultural protocols, aims to understand Native community needs and priorities. This enables research collaborations to be pursued that would not be possible by physical scientists, social scientists, or communities working in isolation. Like SOARS, Rising Voices has an emphasis on engaging indigenous students and early career scientists to help address the underrepresentation of Indigenous populations in the atmospheric sciences, and has been a natural connection for SOARS' Native American protégés since its inception.

HASKELL INDIAN NATIONS UNIVERSITY

This summer, we were proud to once more support joint fellowships with Biosphere 2, welcoming **Violet Eagle** and **Shawna Greyeyes** into our SOARS community and hosting them for a 3-day visit to Boulder. Their research abstracts follow. We were also glad to welcome the Haskell Indian Nations University's Environmental Research Studies (HERS) interns back to Boulder, after a multi- year funding hiatus. These talented students shared their summer research with SOARS protégés through a dinner and poster session, participated in a week-long program with NCAR Education & Outreach, and joined SOARS, Violet, and Shawna in a field trip to the Denver Museum of Nature and Science to learn about sharing science with the public and careers in the geosciences. Connecting across programs has proven to be both fun and a powerful way of sharing diverse experiences and knowledge, learning about the research of different communities, and most importantly, building and expanding the community of diverse voices that will be our next generation of geoscientists.

SOARS/Biosphere 2 visit, left to right: **Bec Batchelor** (SOARS), **Katie Morgan** (Biosphere 2), **Shawna Greyeyes** and **Violet Eagle** (SOARS/Biosphere 2 fellows).

Community level physiologic profile: Microbial responses to experimental warming in semi-arid soils

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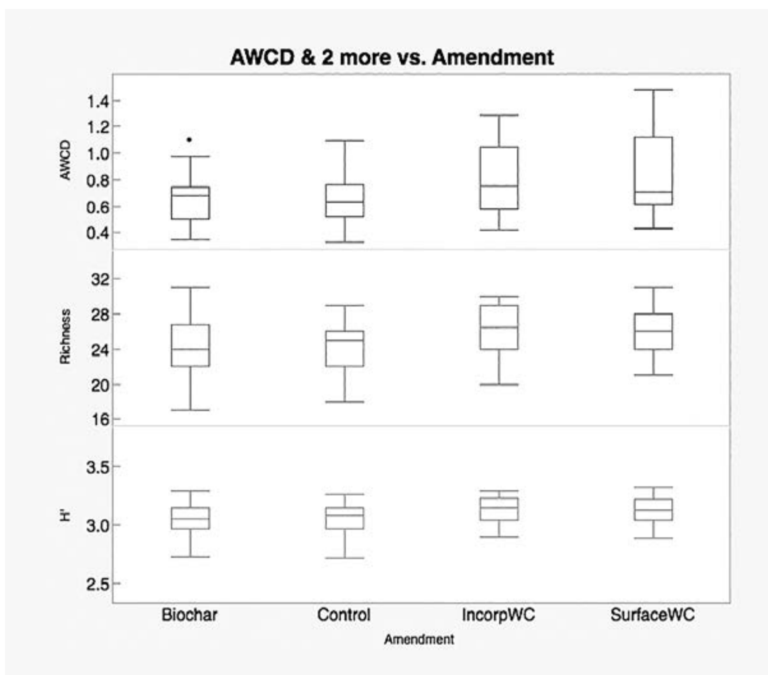
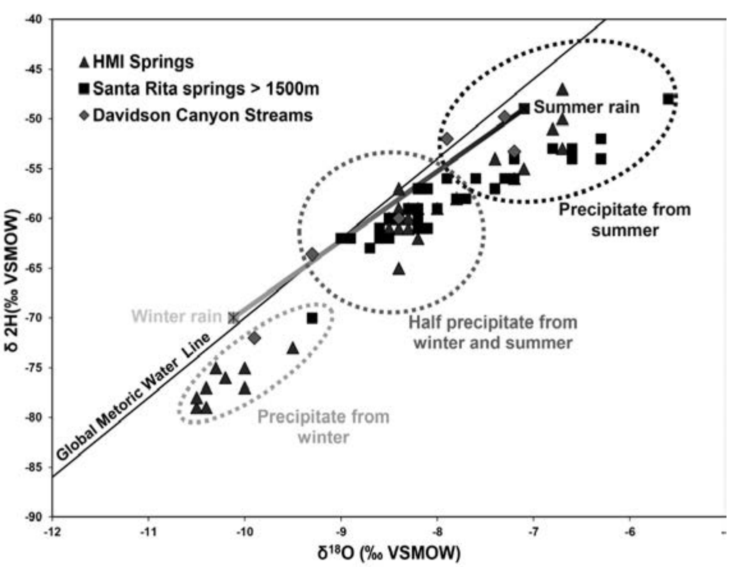
Semiarid grasslands worldwide are facing woody plant encroachment, a process that dramatically alters carbon and nutrient cycling. This change in plant types can influence the function of soil microbial communities with unknown consequences for soil carbon cycling and storage. We used soils collected from a five-year passive warming experiment in Southern, AZ to test the effects of warming and substrate availability on microbial carbon use. We hypothesized that substrate addition would increase the diversity of microbial substrate use, and that substrate additions and warming would increase carbon acquisition, creating a positive feedback on carbon mineralization. Community Level Physiological Profiling (CLPP) of microbial activity was conducted using Biolog EcoPlateTM assays from soils collected in July 2018, one week after the start of monsoon rains. Two soil types common to Southern AZ were amended with one of four treatments (surface juniper wood chips, juniper wood chips incorporated into the soil, surface biochar, or a no-amendment control) and were randomly assigned to a warmed or ambient temperature treatment. We found that surface wood chips resulted in the highest richness and diversity of carbon substrate use with control soils yielding the lowest. Substrate use was positively correlated with the total organic carbon but not with warming.



Average Well Color Development (AWCD), Richness (R), and Shannon-Weaver (H') measure of diversity of carbon substrates used were calculated to analyze the effect of amendment and soil type. ANOVA with Tukey HSD showed that Hathaway soil with Surface WC (Wood Chips) yielded the highest AWCD (F=4.30, $p<0.05$), R(F4.04, $p<0.05$), and H' (F=3.63, $p<0.05$) with the lowest values in the control non amended soils.

Examining the source of water to springs and streams in the Santa Rita Mountains: SE Arizona

The Santa Rita Mountains are essential to the biodiversity of 300 native species of plants and animals, including seven threatened and endangered species. The mountain range is designated as an Important Bird Area by the Coronado National Forest and is a part of the Las Cienegas National Conservation Area. The Rosemont Copper Mine is a proposed open pit mine located in Barrel Canyon within the Santa Rita Mountains. Barrel Canyon drains to Davidson Canyon, which is designated an Outstanding Arizona Water by the Arizona Department of Environmental Quality. Hydrogeochemistry approaches were used to understand the source of water to Davidson Canyon. Stable water isotopes, deuterium and oxygen-18, were used to investigate the seasonality and elevation of recharge for springs, groundwater, and surface water. Radioactive isotopes, tritium and radiocarbon, were used to analyze water residence time. Solute chemistry, including calcium, magnesium, sodium, and alkalinity concentrations, were used to understand water-rock reactions affecting water type, such as gypsum dissolution, carbonate dissolution, and cation exchange. Results suggest a mixture of winter and summer precipitation are the dominant source of recharge for springs in the Santa Rita Mountains. Ephemeral flows in Davidson Canyon have a similar chemical and isotopic composition, and age (<~10 years old), to multiple springs in the Mountains. The analysis of springs, streams, and wells at various locations and elevations in the Santa Rita Mountains and Barrel Canyon suggests Davidson Canyon is supported by shallow groundwater, rather than by direct precipitation events or deeper (older) groundwater.



Davidson Canyon ephemeral flows primarily come from summer precipitation.

Shawna Greyeyes

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Cover: Hurricane Maria about to make landfall in Puerto Rico, from a high-resolution simulation produced with the Weather Research and Forecasting Model (WRF). Colors indicate wind speed at 10-m height (in miles per hour). The figure shows Maria's entire wind field including the "eyewall," the ring of destructive winds (>140 mph) and torrential rain that surrounds the calm eye. IMAGE BY NATHALIE RIVERA-TORRES AND FALKO JUDT

Rear Cover: NASA composite image of Hurricane Maria making landfall in Puerto Rico on September 20, 2017. https://earthobservatory.nasa.gov/images/91004

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CIRES	Cooperative Institute for Research in Environmental Sciences
CU	University of Colorado at Boulder
CSU	Colorado State University
IRAP	Institut de Recherche en Astrophysique et Planétologie, France
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NWSC	NCAR–Wyoming Supercomputing Center
SOARS	Significant Opportunities in Atmospheric Research and Science
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WN	Weather Nation

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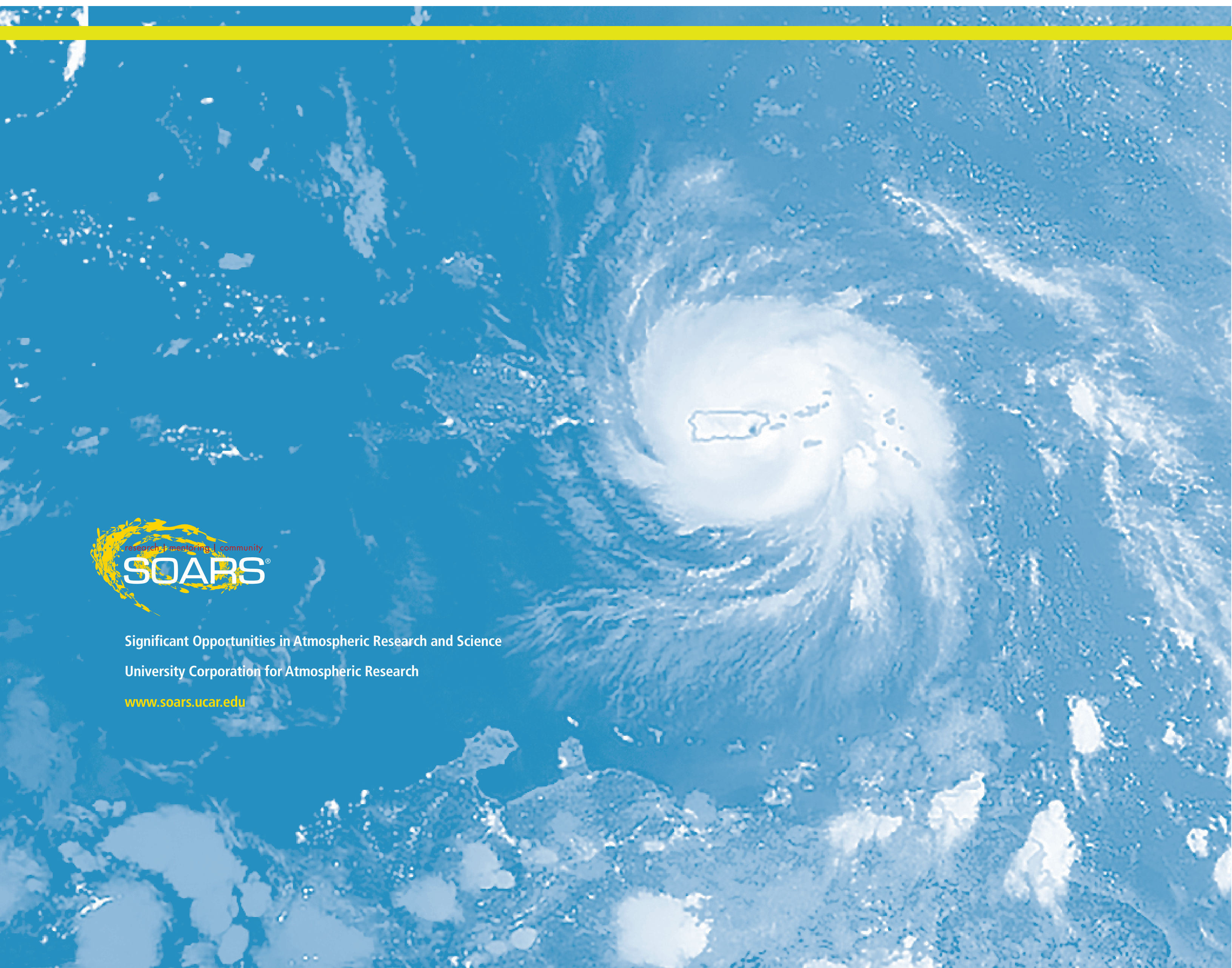
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