EARTH, WIND, SEA, AND SKY

2019 SOARS PROTÉGÉS' ABSTRACTS

Protégés are pictured left to right:

Front row: Kylee Lewis, Mariama Feaster, Gabriela Cazares, Sung Min Kim, Angelie Nieves Jimenez, Nathalie Rivera-Torres, Ekaterina Lezine, Mia Murray, Jamin Rader

Back row: Marcel Corchado-Albelo, Jordan Benjamin, Ebone Smith, Malcolm Wilson, Kadidia Thiero, Pedro Brea, Ivy MacDaniel, Anthony Wilson, Tariq Walker, Nicolas Gordillo, Holly Olivarez, Amin Taziny

We are excited to share this 2019 edition of Earth, Wind, Sea and Sky; showcasing the summer research of the Protégés from the Significant Opportunities in Atmospheric Research and Science (SOARS) Program. SOARS began in 1996, and remains true to its mission of increasing the diversity of the atmospheric and related sciences, by engaging students from historically underrepresented communities in STEM, in genuine research. Their ability to do 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 guidance of their Mentors. We are ever so grateful for the Mentors' commitment to the Program.

The hallmark of the SOARS mentoring structure, which includes up to five (5) types of Mentors and a supportive learning community, continues to be the heart of the program and remains relevant. The Geoscience community continues to evolve and our scientific challenges change. As such, SOARS continues to adapt and grow, meeting the new needs of the field. Now in the fourth year, the SOARS scientific data and computation workshop recognizes the movement of geoscience literature toward sharing data and code; preparing Protégés with tools to flourish in an open-access environment. We recognize new careers in the atmospheric sciences are emerging that make use of weather and climate products; and there is a need for scientists to translate these products for fields as diverse as agriculture, emergency management, insurance, policy, and space weather, to name a few. Our professional development program, highlighted inside, exposes our Protégés to the many opportunities available to them, and prepares them to succeed not only in graduate school, but in careers beyond.

Because of the 23+ year history and success of SOARS, we are able to tap into the strengths of our Alumni. Our Alumni also serve as Mentors, panelists, graduate-school selection advisors, and on the SOARS 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, help SOARS to advance and remain a leader and valued partner in the community.

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. The network of Protégés, Alumni, staff, Mentors—current and former, and partners 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.

In recognition of the excellent and comprehensive mentoring that is the model of the SOARS Program, we were awarded the *2019 Diversity and Inclusion Program of the Year* by the US 2020, now Makers + Mentors organization in August.

We hope you enjoy this edition of **EARTH, WIND, SEA AND SKY**. Please join us in congratulating the 2019 Cohort of Protégés!

KADIDIA THIERO
SOARS Program Lead
UCAR Center for Science Education

EARTH, WIND, SEA, AND SKY

UCAR is a nonprofit consortium of more than 115 North American colleges and universities focused on research and training in the Earth system sciences. We are the experienced managers of the National Center for Atmospheric Research (NCAR) on behalf of the National Science Foundation. Founded in 1960 to fulfill this role, we are trusted administrators of the financial, human resources, facilities, and information technology functions that are essential to NCAR's success. Since our inception, collaborations between university researchers and our own scientists and engineers have helped push the boundaries of the Earth system sciences.

UCAR | NCAR

Activities in the UCAR Community Programs (UCP) include everything from training weather forecasters, firefighters, and emergency managers to supporting a constellation of atmosphere-observing satellites. We also develop internship programs and educational resources, provide real-time data and software analysis tools, and manage projects and staffing for scientific programs across the country and around the world. Our community programs provide a suite of innovative resources, tools, and services to researchers, educators, and practitioners in the Earth system science community.

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 the key to the success of SOARS.

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SOARS Protégés at 2019 Joint Poster Session— July 31, 2019 at Center Green Auditorium

Significant Opportunities in Atmospheric Research and Science

Since 1996, SOARS continues to provide authentic research experiences with world-class scientists and engineers for historically underrepresented communities in the atmospheric and related sciences. As an undergraduate-to-graduate bridge program, SOARS is designed to broaden participation in the geosciences. By supporting students from diverse backgrounds and experiences, SOARS guides participants to enter and succeed in graduate school; contribute to research, and become leaders in the geoscience community. SOARS complements academic institutions' mission in preparing students for career pathways in academia, research, and industry by combining summer research experiences with year-round mentoring, conference travel, and supportive community.

research | mentoring | community

SOARS®

During the summer, SOARS Protégés conduct research at the National Center for Atmospheric Research (NCAR), University Corporation for Atmospheric Sciences (UCAR), National Oceanic and Atmospheric Administration, the University of Colorado, Boulder, partnering laboratories, and universities to gain experience in the geosciences field. Topics of research span the disciplines of climate and weather, computing and engineering in support of atmospheric sciences, oceanography, and solar physics. Protégés are supported in their research by up to five (5) types of Mentors, including scientific, writing, computing, peer, and coach. In addition to this authentic research experience, which culminates in end-of-summer poster and oral presentations by the Protégés; the summer program incorporates a comprehensive, professional development schedule. After the summer, Protégés remain engaged through webinars, one-on-one career counseling, and participation at professional, national conferences.

Protégés may participate in SOARS for four (4) years, gaining additional independence in subsequent years to select, focus, and direct their research. By the time SOARS Protégés enter 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 national laboratories. It is also common for Protégés 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, encouraging connections with the wider community.

SOARS is proud of our Alumni, the vast majority of whom excel in graduate school; and move on to careers in atmospheric science and/or related STEM fields. Many are now faculty, and we are excited to partner with Alumni to spread SOARS' mission. Partnerships include the pilot SOARS Satellite programs at the University of Central Florida (UCF) and the University of Illinois–Urbana Champaign (UIUC). Wherever their careers take them, our Alumni remain 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 national STEM workforce.

Using Machine Learning Techniques to Forecast Solar Energetic Particles

Pedro Brea

3rd-year SOARS Protégé
Graduate Student
University of North Texas
Philosophy

MENTORS

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Hazel Bain, CIRES/NOAA

WRITING & COMMUNICATION
B.J. Smith, NCAR

Solar energetic particles (SEPs) endanger satellites, disrupt air traffic over the polar regions and high frequency radio communication. The capacity to predict SEP events on Earth ahead of time can lead to the preservation of important space and aeronautical assets, as well as protection for humans in space. Considering that the methods of acceleration and transport of these particles is still an area of active research and that physics-based models are, at the moment, slower than empirical models; forecasters at the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC) use the latter, combined with forecaster heuristics, to make real-time decisions. This project attempted to improve upon the results of the current statistical model in use at SWPC (Proton Prediction Model) by using machine learning classification techniques. Machine learning models learn and make decisions using an observational training set and are currently much quicker than numerical models for issuing a forecast. SEP forecasts are made based on physical parameters associated with solar flares and coronal mass ejections. Preliminary results showed that the logistic regression, Adaboost decision tree, and support vector machine algorithms showed an improvement in forecasting skill over the current SWPC Proton Prediction Model.
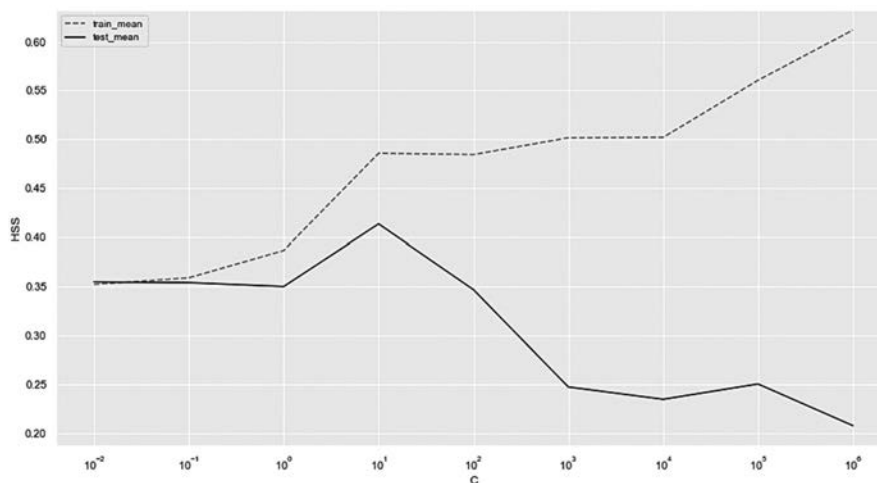
Comparison of average mean training and test set cross-validation scores for the support vector machine algorithm as a function of the penalty parameter 'C'.

Projecting Extremes in
California Current Acidification

With the substantial use of fossil fuels as a source of energy, the concentration of carbon dioxide in the atmosphere has increased significantly. Much of this anthropogenic carbon has been absorbed into the ocean, forcing a chemical reaction with water that culminates in the acidification of the ocean. The acidification of the ocean causes the decrease in carbonate ion concentration, creating an undersaturated system that increases susceptibility to shell dissolution. Modeling studies of the California Current system have projected drastic and rising acidification levels in this region of the ocean within the following century, implying a stressful future for all members of the system's food web and the fishing industry. Using the Community Earth System Model – Large Ensemble (CESM-LE) projected changes in the frequency of acidification events were analyzed on a monthly basis from 1920 through 2100 in the California Current system. Additionally, seasonal trends were calculated using saturation depth data in order to gain insight on mechanisms of acidification events. Furthermore, a case study of the CCE1 and CCE2 buoys was used for future validations of the CESM-LE projections. Results demonstrated how the frequency of acidification events is expected to rise more quickly than hypothesized, and how undersaturated water levels are rising to depths higher than ever recorded in history.
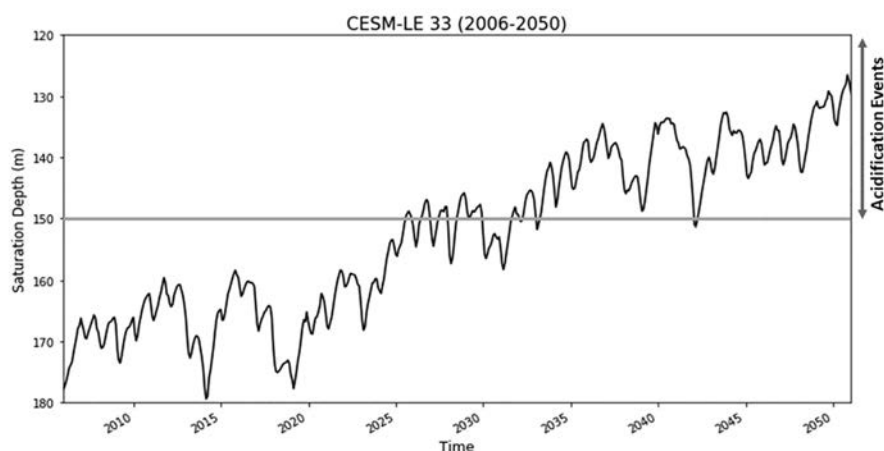
This figure shows the change in depth of the acidity horizon as depicted by ensemble member 33 from the year 2006 through the year 2050, averaged over the entire California Current. When this horizon line is found above 150m in depth, it is considered an acidification event.

Gabriela Cazares

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Eleanor Middlemas, CU

COMPUTING
Riley Brady, CU

COACH
Shay Gilpin, CU

PEER
Jamin Rader, Malcolm Wilson

Identifying Flux Ropes in the Corona

Marcel Corchado-Albelo

3rd-year SOARS Protégé
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University of Puerto Rico
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MENTORS

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Anna Malanushenko, NCAR

WRITING & COMMUNICATION
Kate Musgrave, CSU

Observations of the magnetic surface flux in the Earth-facing side of the Photosphere are regular but lack a global perspective. As we extend farther out into the Corona, measurements of the magnetic field have recently become available, although with a narrow field of view. Therefore, we rely on models of the global solar exterior. While current models can extrapolate the magnetic field from surface flux observations assuming a current-free Corona; other techniques are used to simulate the current-carrying field via flux transportation methods and inserting current-carrying fields, like twisted flux ropes into the Corona. These current-carrying fields are of interest for studying solar energetic events like coronal mass ejections and flares because they provide the energy reservoir needed to drive these events. Previous studies suggest that ground-based polarimetric measurements correlate with the energy of the current-carrying field. In this study we generated synthetic polarimetric observations from a fully-resolved magnetohydrodynamics model of the August 21, 2017 eclipse. The synthetic observations were used as input to a diagnostic we developed to identify regions where the modeling team inserted twisted flux ropes. The diagnostic evaluated linearly and circularly polarized synthetic observations of the Corona as a means to identify the current-carrying magnetic energy density. The findings indicated that the diagnostic does identify the distribution of flux ropes in the Corona. Thus, the findings motivate the implementation of polarimetric measurements to identify "hot spots" in which flux ropes can be inserted, and a degree of how twisted/sheared the current-carrying field should be.
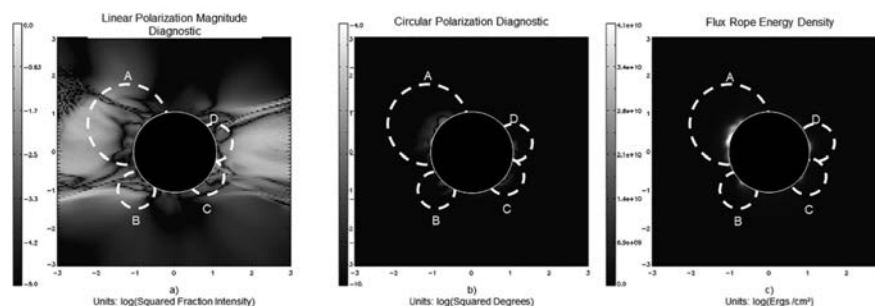
Diagnostic of current-carrying energy in the Corona from synthetic polarimetric observations:

a) linearly-polarized light magnitude diagnostic
b) circularly-polarized light diagnostic and
c) model magnetic flux rope energy density.

The thin solid line represents the limb view of the Photosphere. Each of the flux ropes are identified with letters from A-D counterclockwise starting from northeast limb (upper left side), and are circled in dashed white lines.

Using WRF to Determine the Effects of Natural Sensitivities on Orographic Precipitation

Orographic precipitation is an important source of water for parts of the world. However, many factors affecting orographic precipitation are not well understood. This study used modeling to investigate natural sensitivities of orographic precipitation in producing snow and in its spatial distribution. Based on observations from the Seeded and Natural Orographic Wintertime (SNOWIE) clouds: The Idaho Experiment SNOWIE, several variations of a 2-D idealized hill case were run using the Weather, Research, and Forecasting (WRF) model V4.1 in order to investigate snow precipitation. The idealized case used a simple terrain and an idealized temperature profile based on SNOWIE observations as realistic set-up for orographic precipitation. A series of wind and temperature profile variations were run to study the sensitivity of the spatial and temporal distribution of orographic snow. We found that the model was very sensitive to small changes in wind and temperature, with the largest amounts of snow being generated using the initial temperature profile. Increases in wind speed increased the amount of windward generated snow. Temperature increases and decreases of up to 3 K reduced both the windward and the leeward snowfall. Temperature has a large effect on cloud liquid water and ice content needed for producing snowfall in the model.

2-D Hill Snow Accumulation, Hour 10

Legend:
- ...... +3 T Celsius
- --- +2 T Celsius
- --.-- +1 T Celsius
- —— Initial Temperature
- -.-.- -1 T Celsius
- - - - -2 T Celsius
- ...... -3 T Celsius
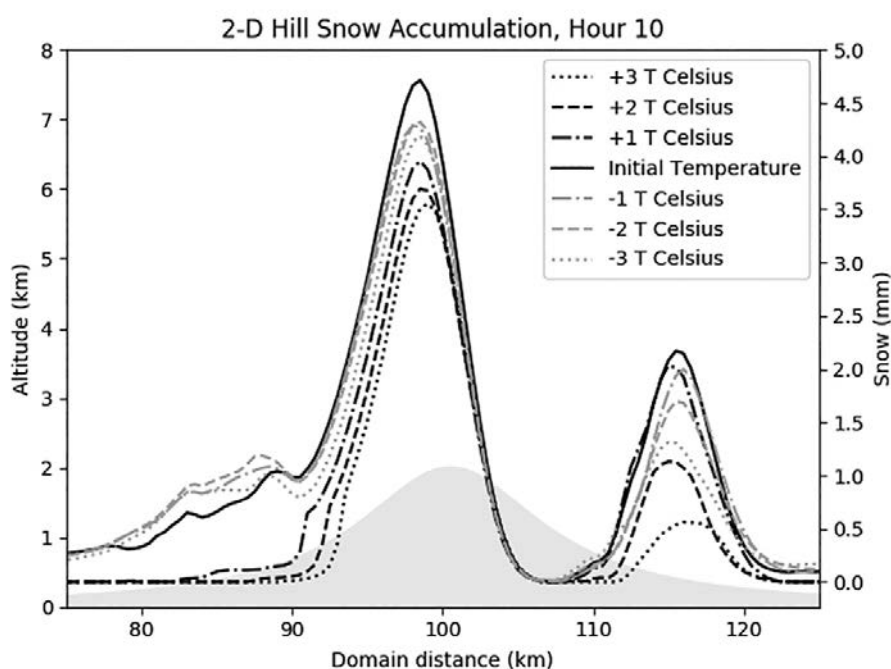
Accumulation amounts of orographic snowfall from different temperature profiles after a 10-hour run. All runs except the initial were one (1) degree shifts up or down of the entire temperature profile while keeping the humidity the same.

Nicolas Gordillo

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MENTORS

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COACH
Terra Ladwig, NOAA

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Investigating the Characteristics of Future North American Monsoon Temperature and Precipitation

Sung Min Kim

2nd-year SOARS Protégé
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MENTORS

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WRITING & COMMUNICATION
Nan Rosenbloom, NCAR
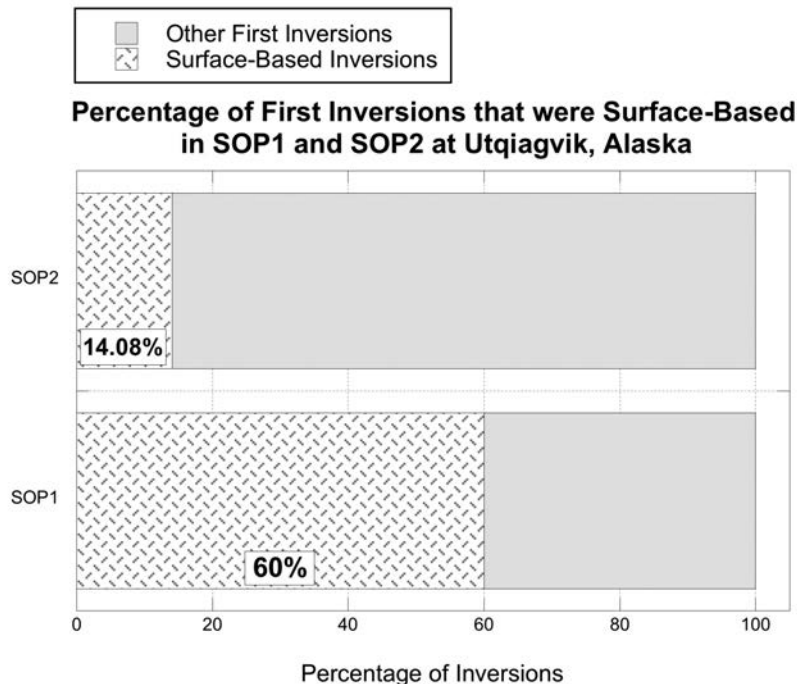
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The North American Monsoon (NAM) extends over the South Western US during summertime and its magnitude, extent, and intermittency are critical for ecosystems, water resources, agriculture, and human hazards. It is characterized by a seasonal increase in precipitation, but the combination of extreme precipitation events and significant year-to-year variability dictates the balance of positive and negative impacts. Our objective was to determine how robust climate models are in predicting future NAM precipitation changes in order to reliably inform the response to climate variability changes. This study used a subset of the Community Earth System Model (CESM1) Large Ensemble (LENS). With 10-member sets of both historical (1920-2005) and RCP8.5 future (2006-2080, 2081-2100) climate projections; we examined the future changes in precipitation characteristics. Global temperature is projected to increase by around 4K by 2100. This is accompanied by a significant predictable increase. During summertime, the NAM region is projected to warm by 28.9% greater than the globe. However, the NAM region experiences no significant increase in precipitation, a fact compounded by the very large internal variability of precipitation typical of NAM. Contrast this with a different climate regime such as the Pacific Northwest, where its surface temperature increases by 5.4K compared to 6K in the NAM region. However, this region experiences a 10% increase in precipitation during the winter and a 29.8% decrease in the summer. Although there is little trend in the mean NAM precipitation, the results do not conclude that other characteristics of the monsoon stay the same.
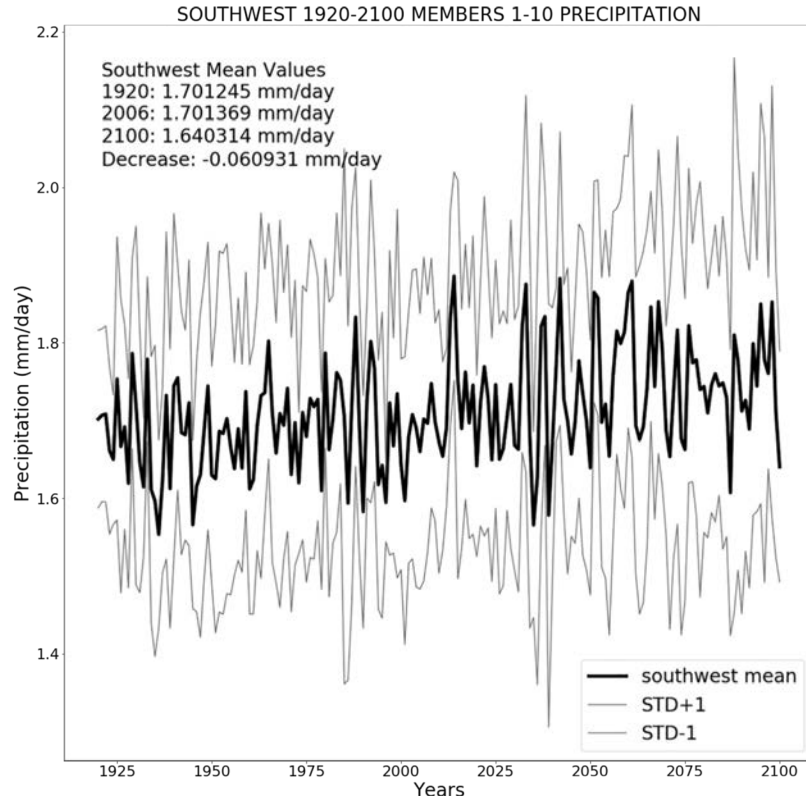
Precipitation trends for the Southwest for 10-member subset during 1920-2100.

Low-level Temperature Inversions over Alaska's North Slope: Results from Radiosondes in 2018 Special Observing Periods

The Year of Polar Prediction (YOPP) was created to improve weather prediction models and thus make weather forecasts more accurate. Ensuring that people have accurate and timely information about upcoming weather events is critical to ensuring human health and safety. Although YOPP focuses specifically on the polar regions, improving weather forecasts in the Arctic will lead to better forecasts across the world. The focus of this research was understanding low-level temperature inversions, which can reflect and affect larger-scale weather events. Understanding more about them will foster further knowledge of other aspects of the atmosphere, such as Arctic haze. Radiosonde profiles from Utqiaġvik, Alaska collected during YOPP Special Observing Periods (SOPs), throughout which more data was gathered than is standard, were analyzed in this research. These data were analyzed using computer algorithms, statistical tests, and visual analyses. Results included plots of low-level inversions and statistics covering their depth, temperature gradient, and other factors. Examples of how inversion characteristics vary throughout the day and year were also shown. Winter months have more inversions and on average stronger inversions than summer months due to the lack of solar heating. Surface-based inversions are most likely to occur at 12:00 UTC during the summer months, when sunlight is minimal. The results from this research will be shared with scientists on the YOPP Supersite Model Intercomparison Project (YOPPsiteMIP), who will compare their weather forecasts with the observations to ensure forecasts are as accurate as possible.

Bar chart showing the percentages of the first inversions in the soundings from the two Special Observing Periods (SOPs) in 2018 that were surface-based.

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Environmental Sustainability

MENTORS

RESEARCH
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WRITING & COMMUNICATION
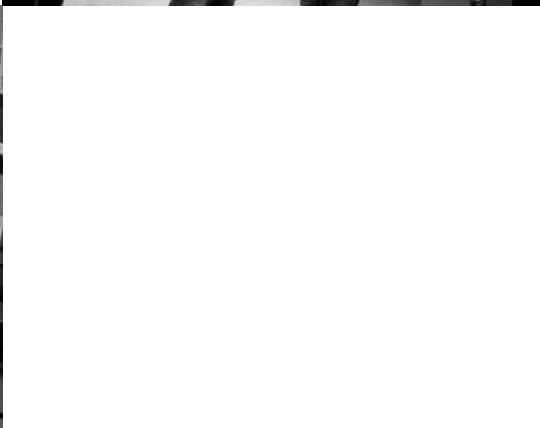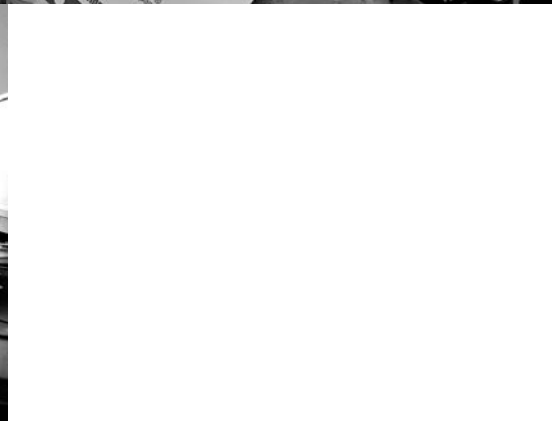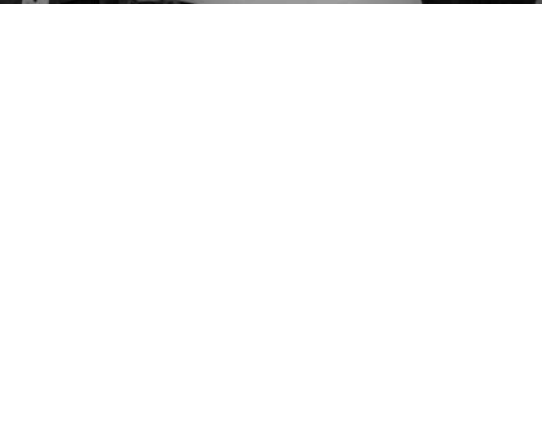Lesley Smith, CIRES/NOAA

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Katy Putsavage, UCAR

PEER
Jordan Benjamin

2019

EXPLORING

LEARNING

FRIENDS

AND FUN!

Characterizing Spatial and Temporal Sampling Uncertainty in the SWOOSH Database

Ekaterina Lezine

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SOARS

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. Although SWOOSH provides rough uncertainty estimates, it does not currently provide comprehensive estimates of uncertainty resulting from non-uniform spatial and temporal sampling within monthly latitudinal grid boxes. These uncertainty estimates could be critical in interpreting the long-term SWOOSH record. To quantify such uncertainties, a climate model was sampled using the viewing geometries and overpass times of the SWOOSH instruments. The sampled climate model was compared to the true monthly zonal mean from the climate model, resulting in an uncertainty estimate. The results of the model sampling suggested that sampling uncertainties are substantial in the early record (1984-2004) and small in the later period, with the onset of the Aura MLS satellite (2004-on) provided significant improvements in coverage. In the early record, ozone sampling error is particularly high towards the poles (Figure 1). Though sampling uncertainties decreased during the Aura MLS era, they remained high towards the poles, reflecting poor satellite sampling at high latitudes.
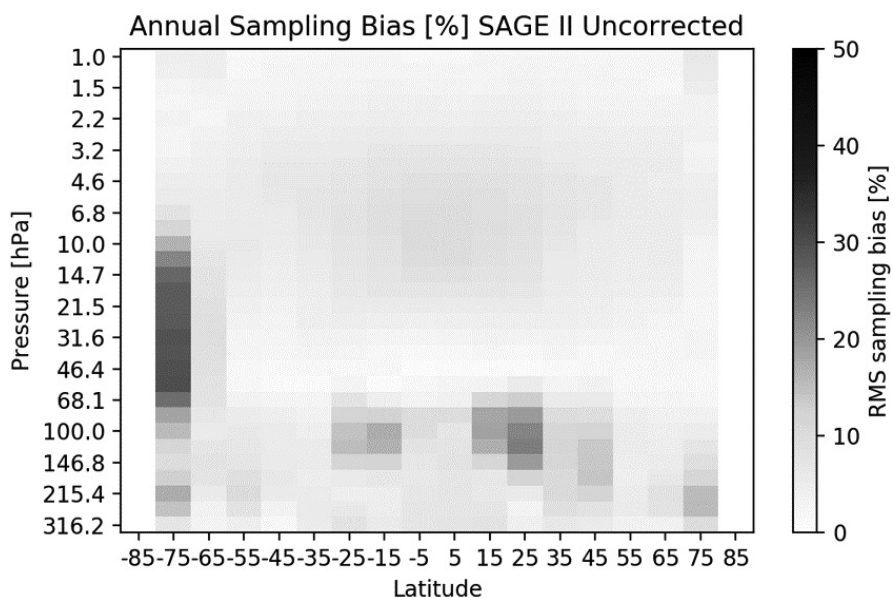

The average O3 RMS sampling bias from 1984-2004 for the SAGE II satellite at all pressure levels and latitudes. The sampling bias was computed by comparing the average O3 SAGE II sampled O3 values to the model truth values.

2019 SOARS Abstracts Significant Opportunities in Atmospheric Research and Science

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Comparing statistics of precipitation variations during the American Monsoon in CESM1

Detecting rapid intensification (RI) in tropical cyclones was a difficult task for models despite advances in technology; models still struggled to predict RI, defined here as an increase of at least 30 knots over the next 24 hours period. A new logistic regression model was developed to predict the probability that a storm will undergo RI. The model is driven by multiple predictors derived from the 2018-configuration of the Hurricane Weather Research and Forecasting (HWRF) model. HWRF reforecasts from 2015 to 2017 were used to train the model to select the best predictors. The resulting model is called the HWRF Logistic Regression Model, or HLOG. Preliminary Brier Skill Scores (BSS) of 0.30158 for Atlantic and 0.3644 for East Pacific were obtained for the 2015-2017 retrospective test. For 2018 data, the BSS were 0.2427 and 0.1264 for Atlantic and East Pacific, respectively. Compared to the operational SHIPS-RII model, HLOG performed significantly better in the Atlantic, but worse in the Eastern Pacific in 2018. Also, HLOG's predicted probabilities correlated well with RI episodes. One of the best examples was Hurricane Florence, a Category 4 Atlantic storm that underwent two separate RIs. In the past, Florence was well-known for previously unforecasted first RI, but HLOG gave a 22% probability of RI when Florence underwent first RI and upwards of 63% during second RI. Similar patterns were also observed in other notable hurricanes that underwent RI. HLOG's probabilities were much lower for tropical cyclones which did not undergo RI.

Wind Intensity and Probability of RI for Hurricane Florence
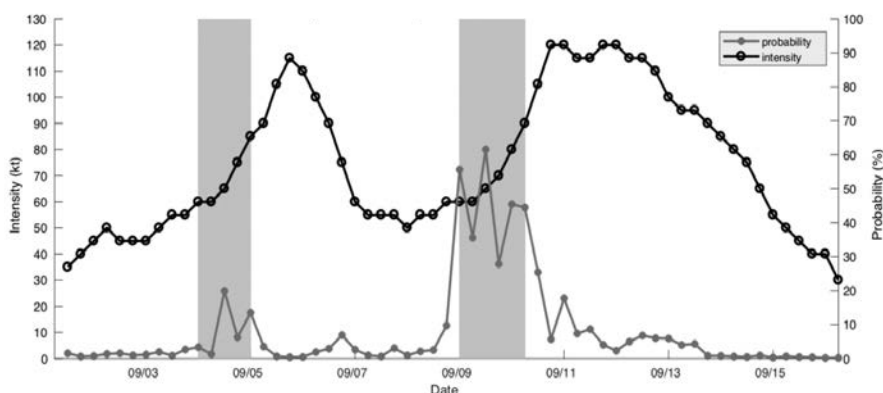
Wind intensity and probability of rapid intensification of Hurricane Florence with observed rapid intensification marked in gray bars.

Ivy MacDaniel

1st-year Protégé
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Physics

MENTORS

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PEER
Nathalie Rivera Torres

Evaluation of Snow Cover Over the Tuolumne River Basin: A Comparison of the National Water Model with Remote Sensing

Mia Murray

2nd-year SOARS Protégé
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Geography

MENTORS

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Snowpack collected in mountain watersheds is vital to the water resources and water supplies across the globe. Snow accumulates in the winter months to form snowpack that melts during the spring and early summer, filling rivers and lakes. Considerable efforts are being made to measure accumulating snowpack so that water managers can plan for the high demand summer seasons. The National Oceanic and Atmospheric Administration (NOAA) National Water Model (NWM) is an operational, continental scale hydrologic forecasting model that is intended to provide flood forecast guidance to promote resilience to water risks. A primary component of NWM is modeling snowpack—volume and timing—for accurate depiction of hydrologic states and stream flow in the mountainous regions of the U.S. The data from the NWM is used to understand snowpack accumulation, its water content, and melt rate. This study aimed to evaluate estimates of snow cover over the Tuolumne river basin between the NWM and Moderate Resolution Imaging Spectrometer (MODIS). The Tuolumne basin is a primary location for this evaluation, as it is a highly-gauged headwaters basin in the Sierra Nevada mountains; and provides an essential water source for multiple demands including irrigation and hydroelectric supply. Expected outcomes of this project are to identify the biases between the NWM and MODIS estimates of snow cover and compare these products with point observations from Snow Telemetry (SNOTEL) and stations in the Tuolumne basin.
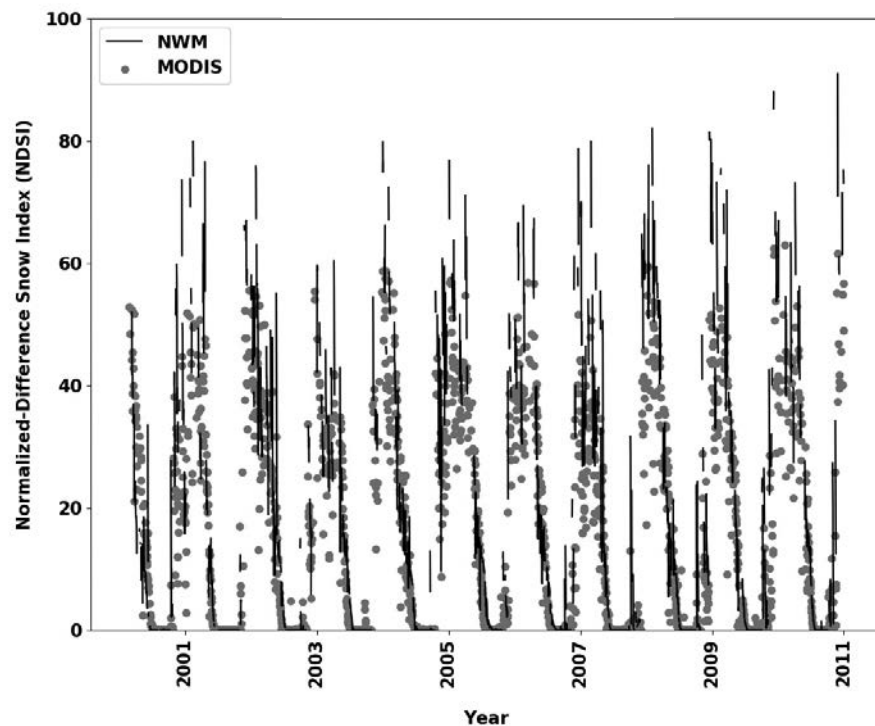
National Water Model (NWM) vs. Moderate Resolution Imaging Spectroradiometer (MODIS) time series for the Tuolumne watershed (2000 to 2010).

Influence of Environmental Wind on Land-Sea Breeze Afternoon Thunderstorms over Puerto Rico

Land and sea breeze circulations are induced by large temperature contrasts along coastlines. In Puerto Rico, a relatively small Caribbean island with a prolonged mountain range and completely surrounded by water, sea breezes are often present. This phenomenon—along with terrain and other factors—affects thunderstorm formation on the island. This study focused on the direct consequence of the confluence of the land-sea breeze phenomenon and the upstream winds on thunderstorm location and intensity over the western side of the island. The research aimed to improve the prediction and understanding of these convective storms, which still remains a challenge. The data used for analyzing upstream winds were gathered from the San Juan National Weather Service soundings, and the ones used to determine sea breeze days were obtained from the Mayagüez Harbor Station. A climatological wind analysis determined winds predominantly came from the east, in addition to some southeasterlies and northeasterlies, and their direction depended on the subtropical high location and intensity during the sea breeze days. Radar data and numerical simulations with the Weather Research and Forecasting (WRF) model were examined to test the hypothesis that upstream wind conditions affect the location and intensity of thunderstorms associated with sea breeze. The results concluded that our hypotheses on rainfall location were correct at the time the convection started, but as time passed, thunderstorms moved and expanded due to the sea breeze duration and intensity, among other factors.

Angelie Nieves Jiménez

1st-year SOARS Protégé
Senior
University of Puerto Rico
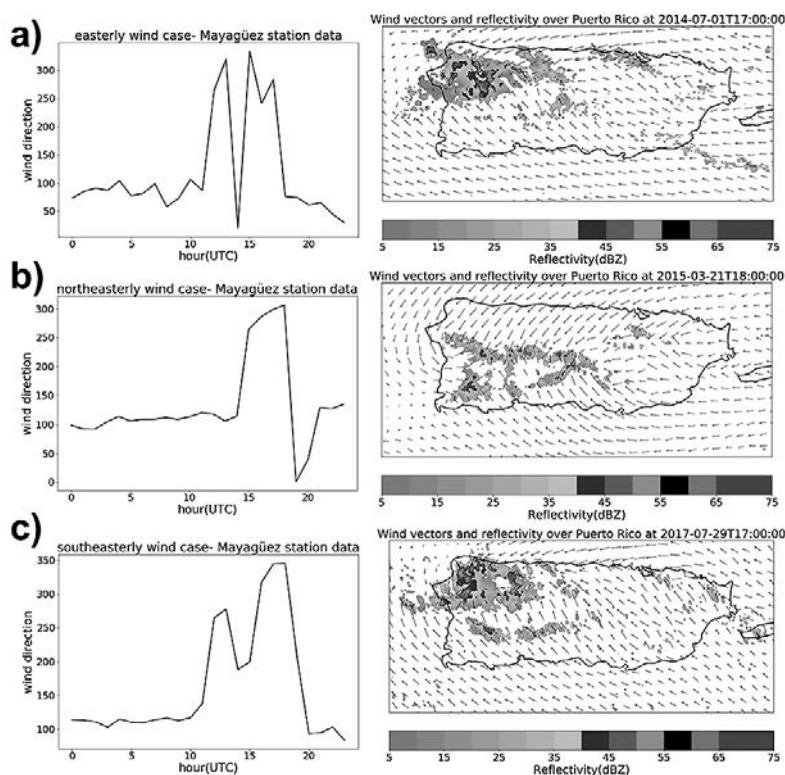at Mayagüez
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Kelly Werner, NCAR

WRITING & COMMUNICATION
David Ahijevych, NCAR

COMPUTING
Keith Maull, NCAR

COACH
Christopher Williams, NCAR

PEER
Ekaterina Lezine

(Left) Time series of wind direction at Mayagüez and (Right) maps of simulated radar reflectivity (shading, every 5 dBZ) and winds (vectors) for case studies with (a) easterly winds, (b) northeasterly winds, and (c) southeasterly winds. Noticeable wind direction changes demonstrate that a sea breeze has occurred.

CREATING INSPIRED

By Thomas Windham, PhD and Kadidia Thiero

The leadership training theme for the 2019 Cohort focused on organizational and personal excellence. As such, the activities, seminars, and workshops incorporated the theme of excellence, enhancing the research experience. During the summer experience on May 31st, one of the sessions for Professional Development, was led by Thomas 'Tom' Windham, PhD. Tom is currently the Senior Advisor to the SOARS Program, and the Inaugural Director of SOARS.®

The seminar was focused on *"Creating Inspired Performance"* using strategies and tools to better understand and grasp how to build inspired perform-ance. How to assess when one is in the Flow State/Growth/Risk Zone for optimal learning? What being in the Comfort Zone, Anxiety Zone, and Boredom Zone means? And how to navigate amongst them? The Protégés also received an overview of the various influences that shaped Tom's trajectory from Harlem and the South Bronx to Boulder; and the events that continue to influence his work, especially the Civil Rights Movement in the US.

Each zone in the graphic (above) represents an individual or group state. The goals and outcomes of SOARS Program complement the Flow State/Growth/and Risk Zone as this represents growth, learning, and challenges that improve performance. The Comfort Zone represents accomplishments and experience gained through one's academic trajectory and life experiences. It is when one is taking risks by mov-ing beyond one's comfort zone in research and working collaboratively; that growth and learning are accelerated. Challenges that significantly exceed one's skill level tend to result in anxiety overload, while challenges significantly below one's skill level tend to contribute to boredom. Neither zone is optimal for learning, nor contributes to creating inspired performance.

Understanding and knowing how to appraise and navigate performance within the param-eters of *"Creating Inspired Performance"* has been especially helpful for many Protégés and mentors engaged in the prac-tice of mentoring. Protégés and mentors have reported this strategy has helped maximize learning and increase skill-building, by providing a diagnostic that is easily understood, while serving as a motivational tool. This diagnostic tool has guided Protégés and mentors to work collaboratively, identifying zones of performance and inspiring excellence.

PERFORMANCE

Knowledge

the vision
strategic skills

planning

organizational skills

the current state

judgment

Trust
People Skills

the building block

trustworthiness

competence   character

An Observational Large Ensemble for Air-Sea CO$_2$ Flux

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Variations in the fluxes of carbon dioxide between the ocean and the atmosphere are an important contributor to the atmospheric CO$_2$ growth rate, the evolving global carbon budget, and the climate system. It is important to both quantify and understand the causes of these air-sea CO$_2$ flux variations, so as to make better near-term predictions and long-term projections of the future climate system. Measurements suggested substantial past variations in the air-sea CO$_2$ flux on interannual to decadal timescales. We explored whether the observation-based variability in air-sea CO$_2$ flux is of internal (i.e., associated with climate models such as ENSO or SAM) or external (i.e., driven by anthropogenic/volcanic emissions) origin.

The externally-forced and internal components of variability in air-sea CO$_2$ flux can be easily separated within large initial condition ensembles of Earth system model simulations. In these ensembles, the ensemble-mean described the externally forced variability, while the departures from the ensemble mean represented the internal component of variability. But how can one tease apart the contributions of internal and external processes to variability in real-world observations, for which we have only one realization or ensemble member?

We statistically resampled the observational record in order to generate a synthetic ensemble of air-sea CO$_2$ flux. In the resulting observational large ensemble, each ensemble member had a unique sequence of internal variability, statistical properties that are identical to the observational record, and identical external forcing. We used this observational large ensemble to explore the origin of variability in the observation-based air-sea CO$_2$ flux.

## Observational Large Ensemble for Air-Sea CO$_2$ Flux
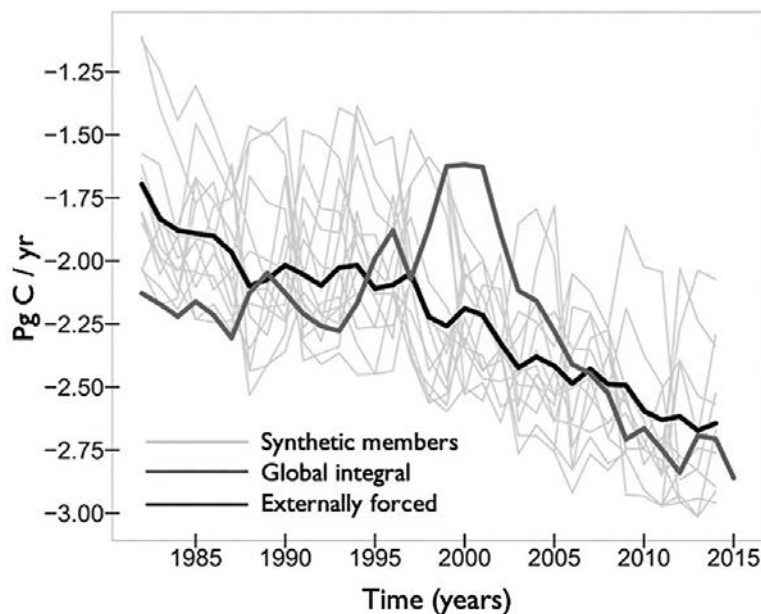
Synthetic ensemble members (light gray), temporal evolution of globally-integrated air-sea CO$_2$ flux (dark gray), and externally forced trend from IPSL-LR ensemble (black). Units are in Pg C yr-1.

Relating Zonal Variability in Sea Surface Temperature to the Structure of North Pacific Anticyclones

Traditional Hadley Cell theory explains the presence of subsidence in the subtropical troposphere (20°-40° N/S) but does little to elucidate the zonally asymmetric distribution of the resultant high-pressure centers over the oceans. Persistent regions of high pressures over the subtropical oceans are focused into distinct anti-cyclonic cells that strongly lean eastward against the coastlines, especially in the summer months. Identifying various dynamical processes behind the eastward-leaning anticyclones will offer insight into what shapes the subtropics and inform studies of North American climate impacts and variability. This study used a global atmospheric general circulation model (AGCM) to investigate geographic variability in the North Pacific sub-tropical anticyclone through experiments with three different prescribed sea surface temperature (SST) fields: increasing, constant, and decreasing SSTs from west to east in the subtropical latitudes. In these experiments, the high moved to the west in the spring and fall months when SST was warmed in the East Pacific and cooled in the West Pacific. Changes in the summer and winter months were negligible. These results high-lighted that the relationship between SST and the position of the subtropical high is significant during the spring and fall months when land-sea temperature contrasts are minimal. This suggested that as SST changes with our warming climate, so will the structure of North Pacific anticyclones. This has profound implications for North American weather and climate, which will observe changes to freshwater distribution and drought frequency with shifting North Pacific storm tracks.

MAM Mean Sea Level Pressure
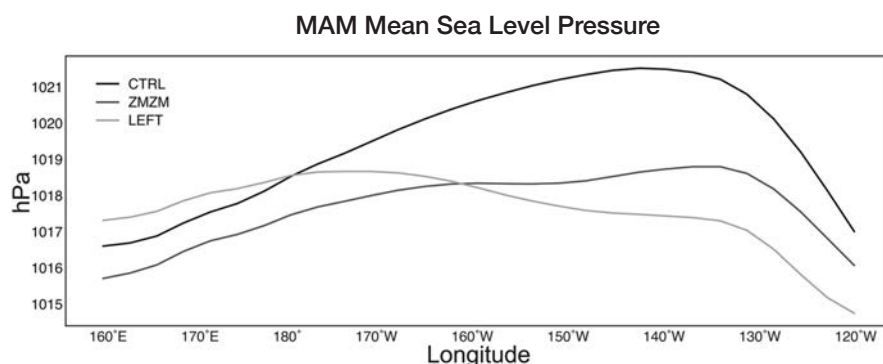
Zonal mean sea-level pressure for March, April, and May across the subtropical North Pacific Ocean (26°N – 46°N). In the control case with decreasing SSTs from west to east (CTRL), the highest sea-level pressures lean to the east where a strong persistent anticyclone is present. In the zonal mean case with constant SSTs from west to east (ZMZM), the highest sea-level pressures lean to the east where a weaker anticyclone persists. In the "left-leaning" SST case where SSTs increase from west to east (LEFT), the persistent anticyclone sets up in the west-central Pacific.

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SOARS

A Numerical Study on the Landfall of Hurricane Maria in Puerto Rico

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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 and behavior, and, ultimately, its impact on the landmass. However, one of today's forecasting challenges is that computer models cannot resolve many of the factors that influence surface weather, resulting in a forecast that predicts the expected behavior of a tropical cyclone moving over a smooth landmass. Therefore, these models do not accurately represent the impact at landfall of these systems in regions that are characterized by having a complex terrain and multiple mountain ranges. This research project investigated how the terrain resolution affected the landfall and behavior of tropical cyclones focused on the landfall of Hurricane Maria in Puerto Rico in 2017. The project incorporated a set of simulations produced by the Weather Research and Forecasting (WRF) model, where one of the simulations used the default terrain resolution and the other used high-resolution terrain data. It was shown that the magnitude of the wind speed, vertical velocity, and precipitation was higher in the mountainous interior of the island when incorporating the terrain roughness. In addition, ensemble forecasts demonstrated that high-resolution terrain data in hurricane simulations produced more realistic results in terms of the hurricane structure and behavior. It was concluded that high-resolution land data led to more accurate forecasts in cases when tropical cyclones interact with a landmass.
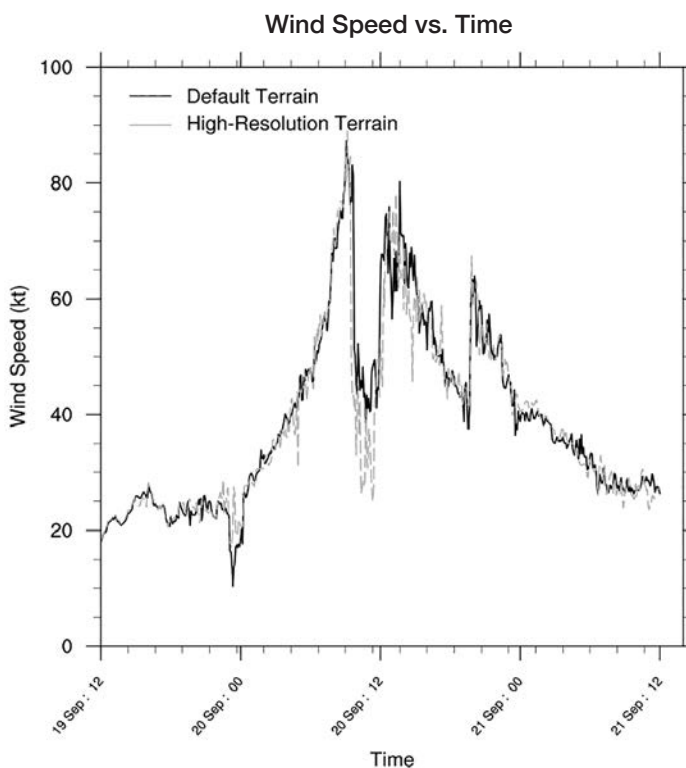
Time series of Hurricane Maria wind speed from 19 September 2017 at 12:00:00 UTC to 21 September 2017 at 12:00:00 UTC. The graph compares the high-resolution and default terrain data wind speed in the WRF Model.

An Ignition Point Sensitivity Study of the WRF-Fire Model: An Analysis of Wildfire Area and Location

In 2015, the population in Colorado's wildland urban interface (WUI) had nearly doubled since the 2000's, and wildfire seasons lengthened due to changes in climate, which threatens Colorado's millions of acres of forestland. As the annual amount of Colorado land being burned by wildfires increased, the state-funded development of the Colorado Fire Prediction System (CO-FPS), a system that integrates the Weather and Research Forecasting (WRF) model's wildland fire behavior module (WRF-Fire) into a decision-support framework. In this study, an analysis of how varying ignition point location influenced fire size and location of the 2018 Indian Valley wildfire was conducted to increase understanding of the model's output uncertainty due to delayed and inaccurate reported starting locations. Sixteen simulated ignition points were inputted into the model: eight were distanced 100 meters away from the reported ignition location and eight were distanced 200 meters away. Both distances were calculated in each of the cardinal (N, S, E, W) and intercardinal (NE, SE, NW, SW) directions. The resulting fire spread forecasts were compared against each other and the observed fire spread to determine the sensitivity of the WRF-Fire model to small changes in ignition location. The results from the sensitivity study revealed that on average ignition points south of the reported ignition point forecasted poorly, whereas ignition points north of the reported ignition point had stronger probabilities of detection and success ratios. Results also concluded that ranges of uncertainty increased as distance from the reported ignition point increased.

100-200 m Ignition Point Performance Diagram
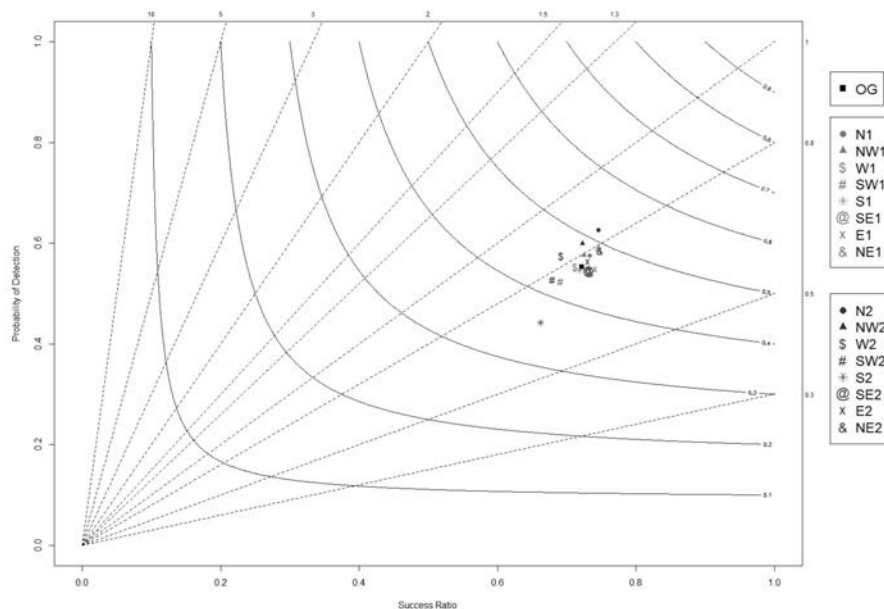
A performance diagram of the 17 simulated ignition points based on probability of detection (POD) and success ratio (SR).

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W eather observation has been a human activity for millennia. Indeed, weather has shaped the activities of humans since the beginning—the conditions of the outdoors have governed our pursuit of food, shelter, commerce, and even war. Yet, the observation of weather has been *qualitative* for the vast majority of human existence. Quantitative measurement requires precise instruments and scientific models, and such measurements have been possible only within the past four (4) centuries. By 1900 in the US, broad networks of human weather observers had been created [@fiebrich] to collect and record weather observations all across the country. It was recognized, then as now, that weather monitoring is a crucial tool for decision making in agriculture, transportation, commerce, and meteorological prediction and research.

WEATHER

A new era for continuous, advanced, automated weather observation is underway. Weather monitoring with Do-It-Yourself weather stations, built atop 3D-printed technology, low-cost, microcontrollers, and high precision digital sensors, supported by *open source* software and hardware, are spawning globally connected citizen science observation and research networks. During the summer **Agbeli Ameko**, CISL; and **Keith Maull**, NCAR Library; provided insight into the design and technology behind these new technological marvels.

The 90-minute professional development workshop for SOARS Protégés demonstrated the technology created here at UCAR: the **3D-PAWS** platform, a 3D-Printed Automated Weather Station conceived nearly five (5) years ago by UCAR/COMET scientists **Martin Steinson** and **Paul Kucera** [@kucera]. Originally designed to address meteorological capacity building in rural areas such as central and west African countries, stations have now been deployed around the world from the Barbados to Berlin, Saudi Arabia to Hawaii. The design is built around the low-cost, wallet sized Raspberry Pi B+ computer [@pi] running the open-source Raspian operating system, a variant of the Linux operating system. It is connected to an instrument platform consisting of six (6) primary measurements: temperature, humidity, pressure, wind (speed and direction), rain, and one secondary UV intensity measurement. The uniqueness of the 3D-PAWS, however, is not it's measurements or low-cost electronics, but rather the open source 3D-printed parts which are easily replaceable when necessary. To date, fewer than 75 3D-PAWS stations have produced, *hundreds of millions of measurements* that are available publicly for curious enthusiasts, citizen scientists and researchers alike.

In the workshop, Keith and Agbeli presented the background of the 3D-PAWS stations along with some new innovations they have been developing to re-conceptualize the architecture of the station as an IoT (Internet of Things) instrument [@ameko] that can be deployed by non-experts more quickly and with a broader array of sensors. The workshop demonstrated how everyone is *empowered* to become innovators and creators of the next generation of measurement technologies and observation data, especially at a time of increasing uncertainty of the impacts of climate change. Technologies like these, the data they produce and the networks formed around them, will be an important force in understanding, planning, predicting and responding to the weather events of our rapidly changing future.

OBSERVATION

By Keith E. Maull
& Agbeli Ameko
October 1st, 2019

WITH AUTOMATED 3D-PRINTED WEATHER STATIONS
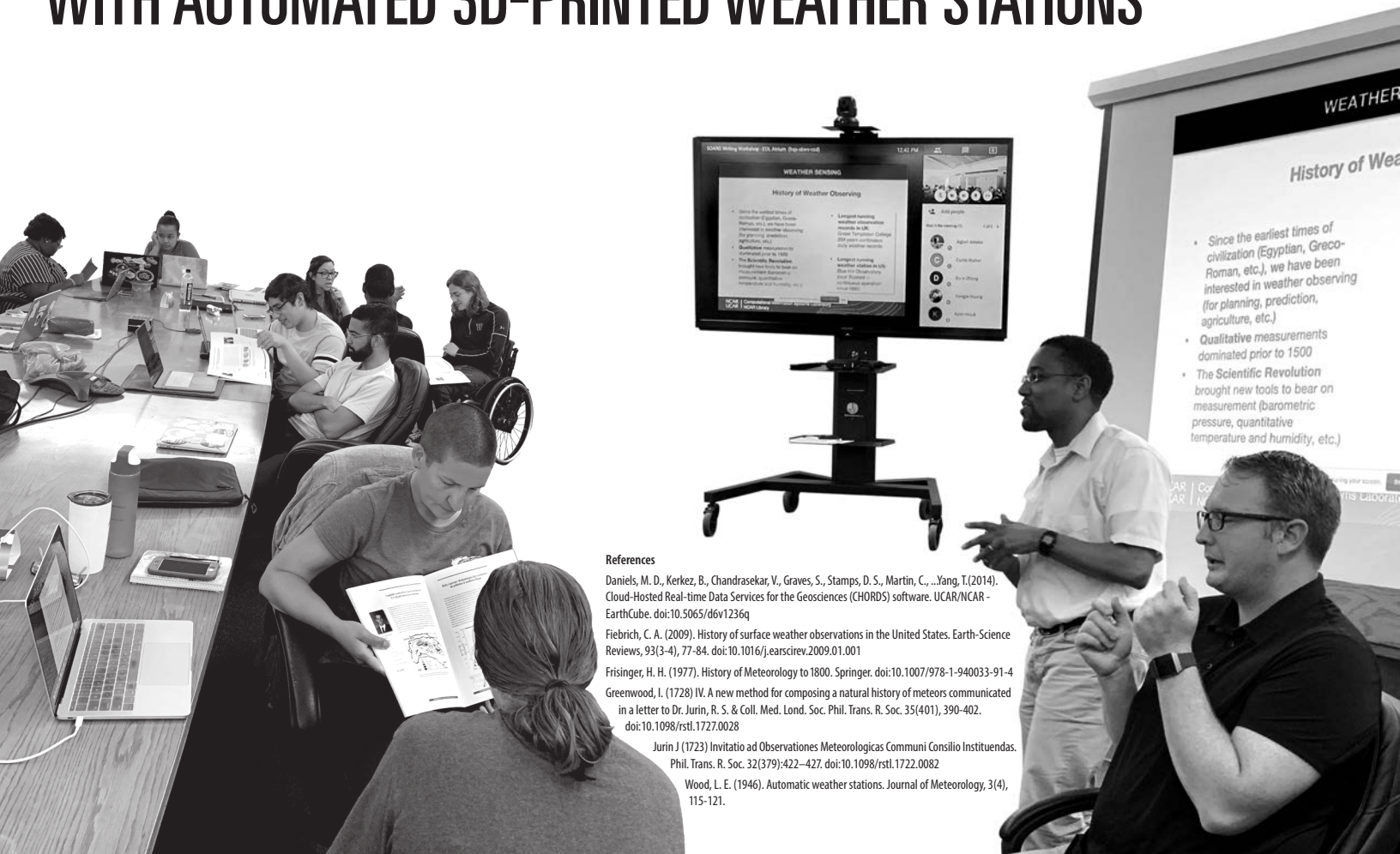
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Nowcasting of Auroral Electron Precipitation Using an Artificial Neural Network

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The impact of space weather phenomena on human society continues to grow as more technology is developed that is exposed to the space environment. As a result of modern data-driven sciences, we are now able to complement our physics understanding of the effect of the Sun's variability on Earth with advanced machine learning techniques. A model applying the artificial neural network (ANN) methodology for predicting auroral electron energy flux in the atmosphere was used for this project.

The ANN was developed using high-resolution solar wind, magnetic field, and plasma data from spacecraft orbiting the 1st Lagrangian point, in addition to several ground-based magnetometers, and observations from the Defense Meteorological Satellite Program (DMSP). Different combinations of inputs were tested to find the optimal set of parameters.

The model was then trained and validated using the Adam optimization method over a complete solar cycle. The resulting validation root-mean-square error after training was 0.12, and the Pearson correlation coefficient equaled to 0.93. Trained ANN output was then compared with OVATION Prime, which is the operational model running at the NOAA Space Weather Prediction Center, for multiple geomagnetic storm events. The resulting network in combination with other statistical models may provide further accuracy in short-term auroral forecasting.
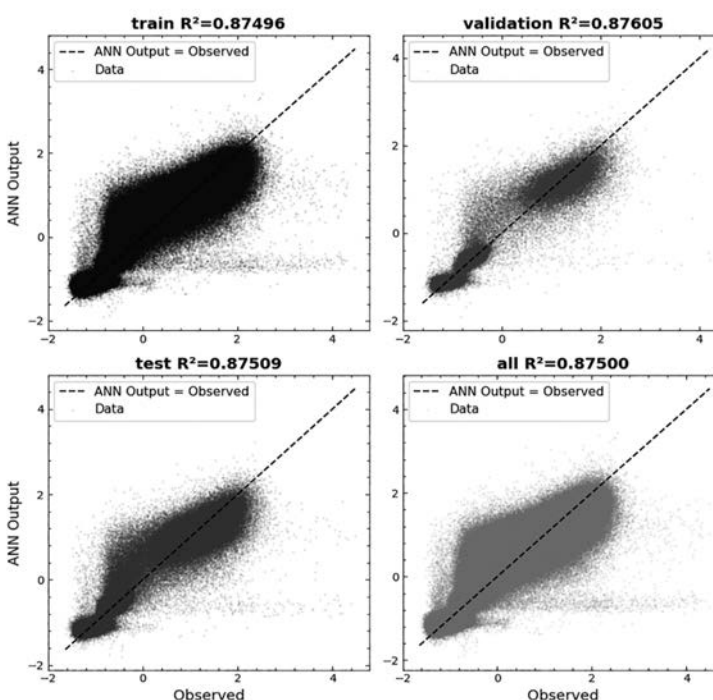
Regression results of the artificial neural network. The top left, top right, bottom left, and bottom right represent the data points in the training set, validation set, test set, and all data set, respectively. The horizontal axis represents the observational Defense Meteorological Satellite Program data, and the vertical axis represents the output of the artificial neural network model.

Solar Panel Fabrication Techniques for CubeSats

Total Solar Irradiance (TSI) is the measurement of solar energy reaching the earth and is critical for understanding the Earth's radiation budget. Measuring TSI accurately is best done from space, but space borne platforms are expensive, short lived, and difficult to calibrate. To alleviate some of these challenges, the High Altitude Observatory (HAO) proposed development of a CubeSat named the Distributed Irradiance Monitoring Systems (DIMS) that is a fraction of the cost, but has the same capabilities. To help lower the potential cost of a DIMS CubeSat, HAO has a project to develop low cost solar panels for DIMS. This began by researching commercially available options that best fit the interests to assemble our panel. By weighing cost with efficiency, voltage, and current outputs, SpectroLab XTJ solar cells were ultimately selected. HAO's instrumentation team paired up with CU student Andrew Dahir to continue development on low cost solar panels. The construction of the solar panel from individual cells using Kapton tape and silver epoxy are described in detail. Once constructed, the solar panel was tested outside, and the data collected were analyzed and compared to theoretical efficiency curves. We measured across two pairs of solar panels and found the maximum voltage and current characteristics with varying resistance. We could not replicate the manufacturers IV curve, but were close. This is likely due to indirect pointing to the sun, having each pair in series, and each value varied due to the sun's movement during a set amount of time.
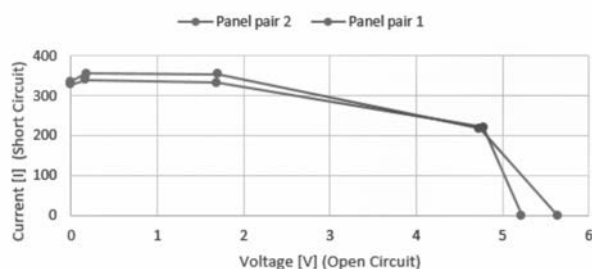
The figure above shows the final solar panel prototype and the Current vs Voltage chart based off the panel's performance.

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Investigating CESM1 Ability to Predict Extreme Temperature Events

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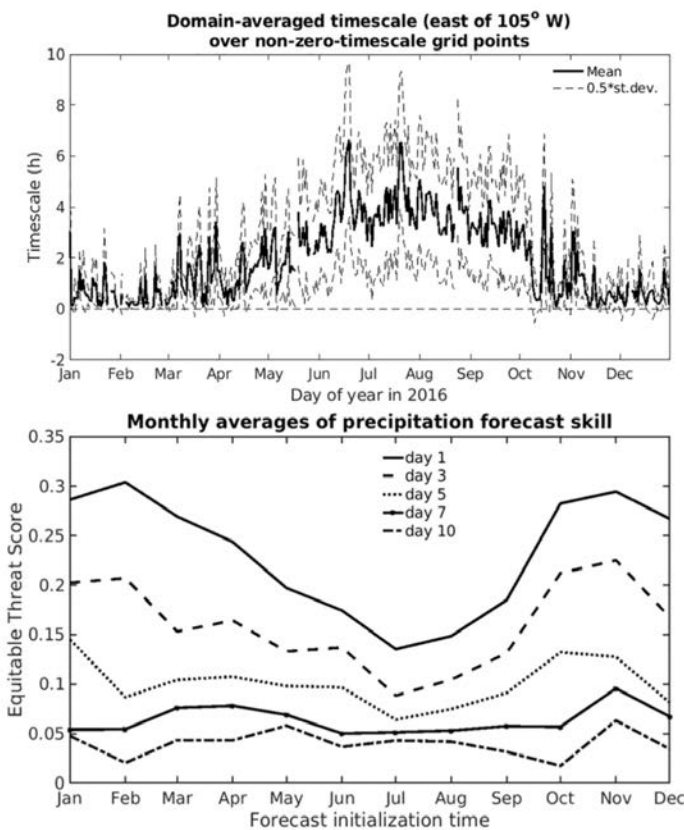Climate change influences the frequency and intensity of heat waves. This project investigated heat waves using data from observations and the Community Earth System Model, version 1 (CESM1). The observational data set contained daily minimum and maximum temperatures from weather stations, that have been combined using a 0.5° latitude-longitude grid. The CESM1 dataset has been re-gridded to the same 0.5° grid as the observations. From this data we derived the ninetieth percentile of the daily temperatures for each day of the year. This threshold was defined as "extreme temperature" at every location across the globe. Events were then defined as consecutive days that were "extreme," and such events were compiled as statistics of duration, frequency, and amplitude. Case studies were created, including the Atlanta Heatwave in 1984, and the European Heatwave in 2003. These demonstrated daily maximums matched with observational data on these events. The same approach applied for both the observations and the model, and compared them to evaluate the model's ability to produce realistic heat wave statistics. The model generally produced realistic statistics of where heat waves occurred and the amplitude. The difference between the model and observational data is the duration of the heat wave. Future work will analyze daily minimum temperature, providing a more complete view of extreme temperature events. A better understanding of CESM's ability to predict extreme temperature events will enable the use of model projections in adaptation decision making.
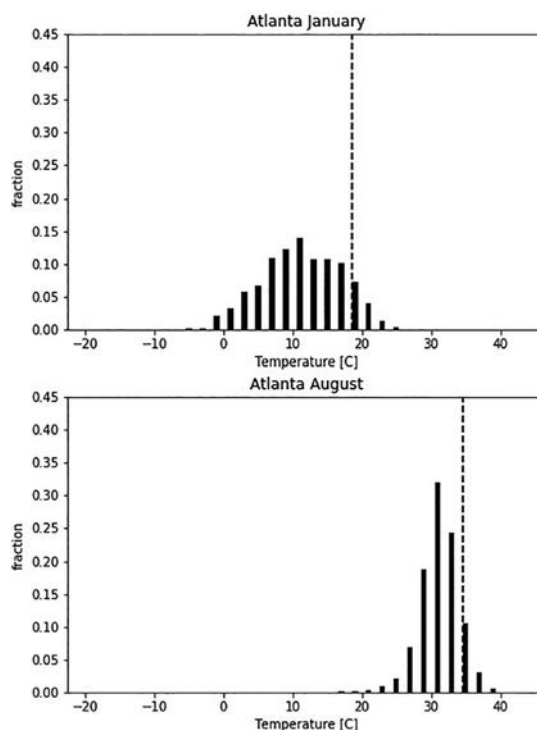
Top: Histogram of Tmax NOAA/NCEP Climate Prediction Center Global Daily Temperature data set in Atlanta in January with the dashed line being the 90pp Tmax at this location. Bottom: Histogram of Tmax NOAA/NCEP Climate Prediction Center Global Daily Temperature data set in Atlanta in August with the dashed line being the 90pp Tmax at this location. The plots show that percentile thresholds vary from month to month at every location, therefore it accurately represents extreme temperature events.

Analyzing Weather-Regime-Dependence of GFS Extended Precipitation Forecast Skill-Based on the Convective Adjustment Timescale

Numerical weather prediction (NWP) models have been shown to have varying precipitation forecasting skill depending on the dominant weather regime. Specifically, NWP precipitation forecasts are generally more accurate under the equilibrium (synoptic) regime compared to the non-equilibrium (mesoscale) regime, where the former is typically better resolved by current NWP models. Limitations of NWP models, such as model resolution and model error due to physical parameterizations, lead to the discrepancy of forecast skill between the weather regimes. This research evaluated the skill of the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) extended precipitation forecasts up to 10 days under different weather regimes. The forecast skill was analyzed for the conterminous United States during 2016. Spatial and temporal characteristics of the dominant weather regime were diagnosed based on the convective-adjustment timescale. As expected, forecast skill generally degraded with increasing lead time under both regimes. Various skill scores based on a contingency table indicated that warm-season precipitation forecasts had lower skill relative to the cold season, consistent with results from past studies. The warm season, using the convective-adjustment timescale, can be characterized to be dominantly under the non-equilibrium regime, indicating that precipitation forecasting is more difficult under this regime as compared to the equilibrium regime.

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(Top) The domain-mean and error of the timescale over non-zero grid points for the conterminous United States east of 105°W for 2016. (Bottom) Equitable Threat Score (ETS) of GFS precipitation forecast for multiple lead times over the same region and time. Note the inverse relationship between timescale and ETS.

research | mentoring | community

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Key to Mentors' Affiliations

ATOC	CU Department of Atmospheric and Oceanic Sciences	**NOAA**	National Oceanic and Atmospheric Administration
CIRES	Cooperative Institute for Research in Environmental Sciences	**NSCP**	NOAA Science Collaboration Program
CU	University of Colorado at Boulder	**SOARS**	Significant Opportunities in Atmospheric Research and Science
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NCAR	National Center for Atmospheric Research	**UCP**	UCAR Community Programs

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