EWSS

Earth, Wind, Sea, and Sky

2016 SOARS & PRECIP ABSTRACTS

Long before I was appointed the new president of the University Corporation for Atmospheric Research (UCAR), and years before I served on UCAR´s Board of Trustees, I saw firsthand the powerful impact the Significant Opportunities in Atmospheric Research and Science (SOARS) program can have on a young scientist´s life.

As a professor at the University of Maryland, one of my doctoral students, Ernesto Muñoz, came to work with me after having been a SOARS protégé. At that point in time the SOARS program was only a few years old but already had an excellent reputation for nurturing students from diverse and under-represented backgrounds into the atmospheric and related sciences.

ANTONIO J BUSALACCHI
PRESIDENT UCAR

Ernesto went on to be one of the 38 SOARS protégés who have earned a Ph.D. in the program´s 20 years of existence. In this time, SOARS protégés have also earned 117 master´s degrees. Thirty-seven protégés are currently on track to complete graduate degrees in the near future.

While these numbers clearly demonstrate the SOARS program´s resounding success, much is still left to do. Only 8 percent of doctoral degrees awarded in atmospheric, oceanic, and earth sciences in 2014 were awarded to under-represented minorities, according to the National Science Foundation. This is why, as SOARS celebrates its 20th anniversary, the program is more important than ever.

Throughout my career as a scientist studying the Earth system, I have seen how essential it is to study this coupled system from the perspective of the atmosphere, ocean, and land surface. Similarly, over the years I have come to appreciate the importance of diverse viewpoints, backgrounds, and inputs to moving the state of our science forward.

As the president of UCAR, I see increasing the diversity of our scientific community as a critical part of our mission. I look forward to joining with the funders, partnering laboratories, and mentors – whose continuing support has been fundamental to the SOARS program´s success – to ensure that SOARS remains a vital and effective community resource for many more years to come.

Earth, Wind, Sea, and Sky

The University Corporation for Atmospheric Research (UCAR) serves as a national hub for research, education, and advanced technology development for the atmospheric and related Earth sciences. On behalf of the National Science Foundation (NSF) and the university community, UCAR manages the National Center for Atmospheric Research (NCAR) and the UCAR Community Programs (UCP), the organizational home of the SOARS program. UCAR's mission is to support, enhance and extend the capabilities of the university community, nationally and internationally; understand the behavior of the atmosphere and related systems and the global environment; and foster the transfer of knowledge and technology for the betterment of life on Earth. There are currently over 100 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 is a federally funded research and development center, conducting a wide range of weather, climate, and solar science and related applications research. At the heart of this work is improving predictions about our atmosphere how it behaves from moment to moment, day to day, and decade to decade, and the risks and

UCAR/NCAR
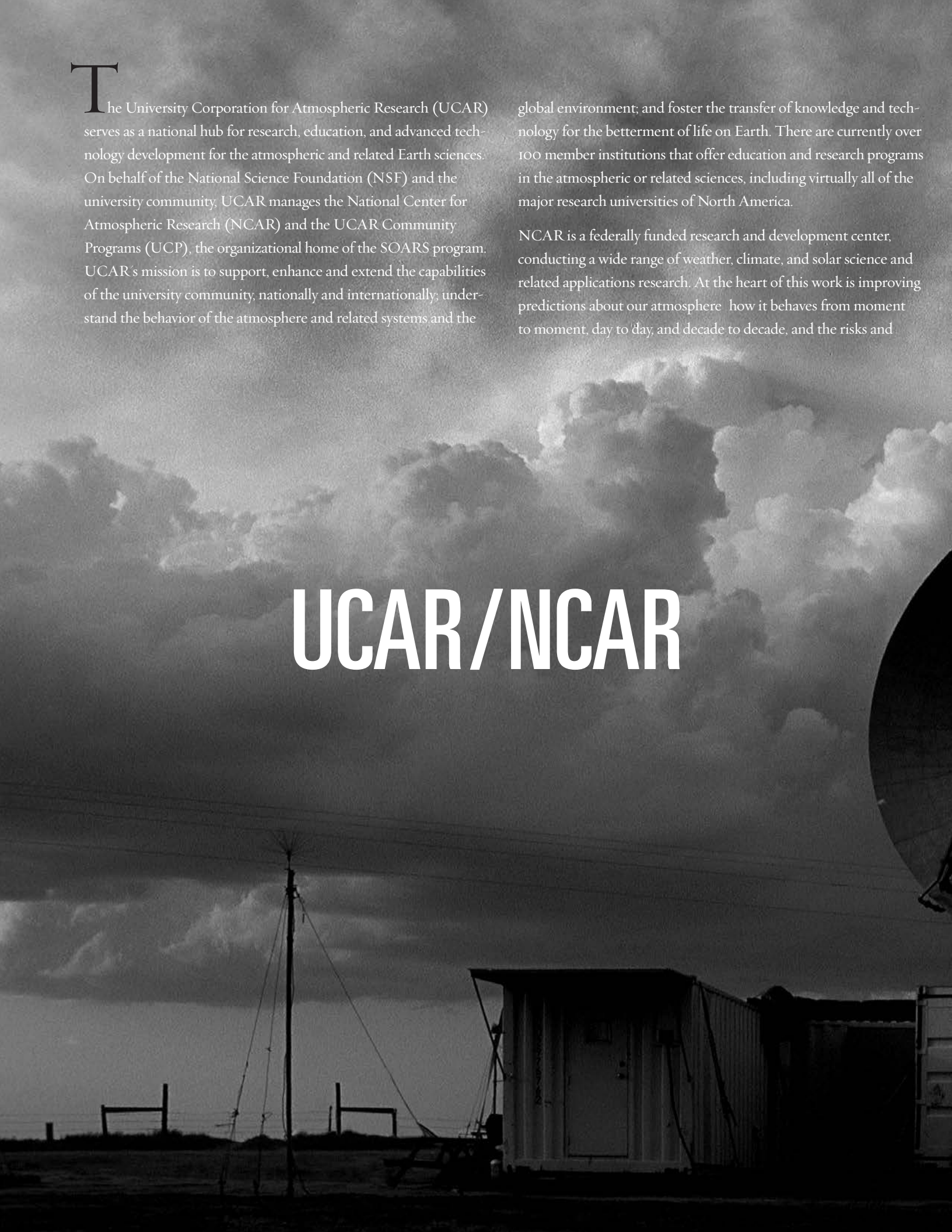
opportunities associated with these changes. Each year, hundreds of people from universities, labs, and the weather enterprise collaborate with NCAR staff, and rely on NCAR resources, in order to carry out vital research and applications.

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 these programs.
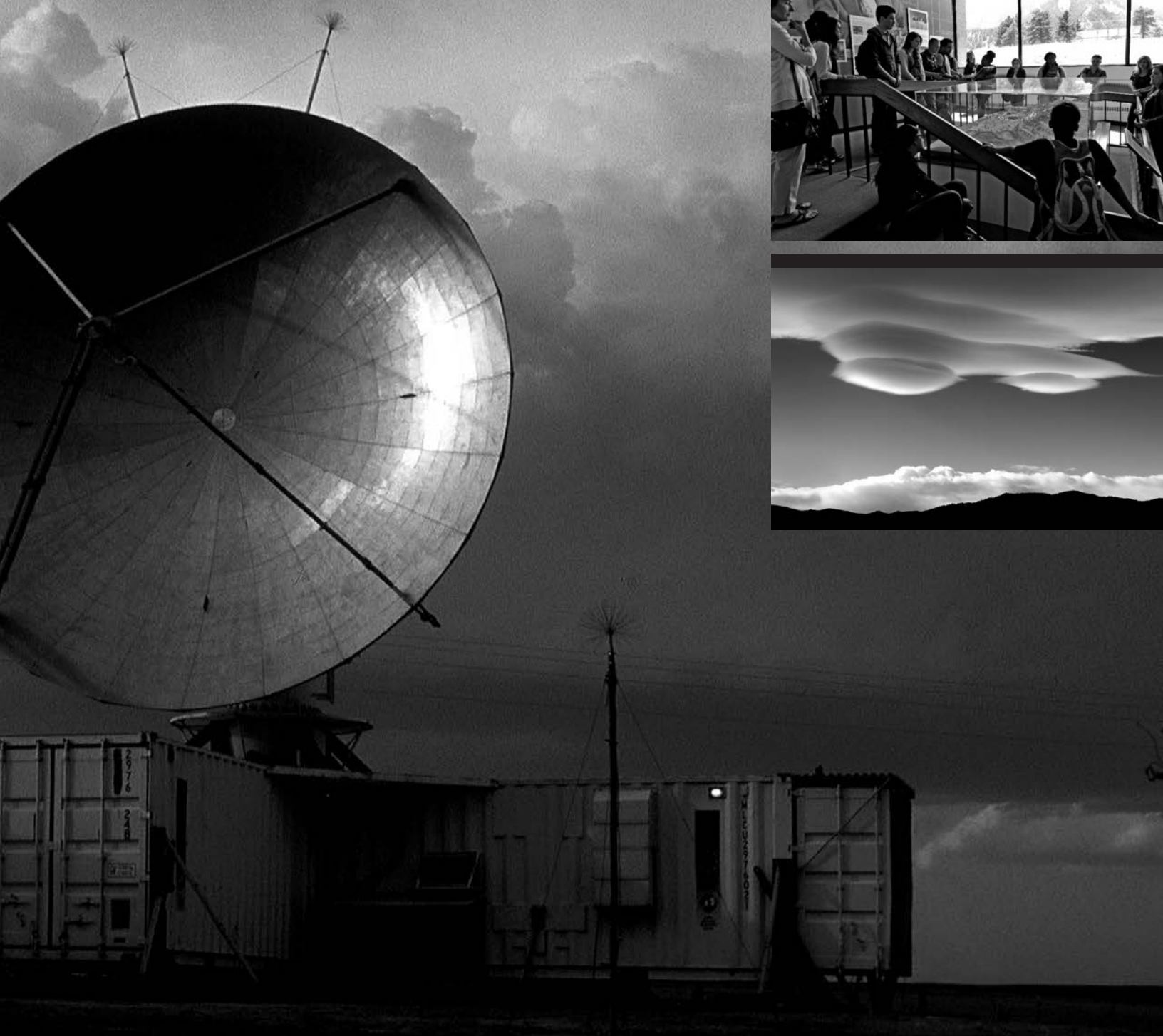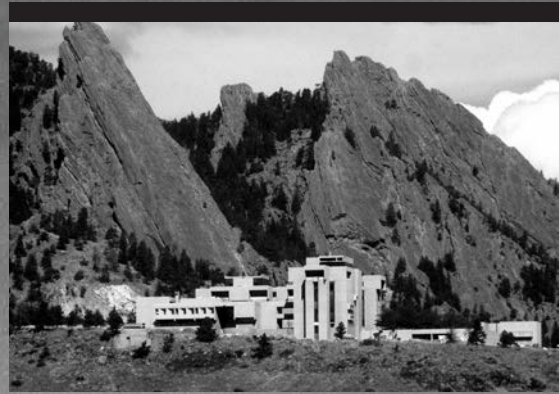
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Significant Opportunities in Atmospheric Research and Science

SOARS is an undergraduate-to-graduate bridge program designed to broaden participation in the atmospheric and related sciences. 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 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. In addition to this authentic research experience, guided by scientific mentors, the summer program includes a weekly communication workshop, seminars about graduate school and career choices, and end-of-summer poster and oral presentations by the students. Topics of research span the broad field of climate and weather, including computing and engineering in support of the atmospheric sciences. After the summer, protégés stay engaged through webinars, one-on-one career counseling, and conference travel.

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 onto 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 their protégés and alumni, helping them stay connected with the wider community.

SOARS is proud of their 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. They 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 diverseness of the STEM workforce.

Western North Atlantic explosive cyclones in relation to Arctic ice and atmospheric blocking

Ryan Adams

3rd-year Protégé
Graduate student
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Geography

MENTORS

RESEARCH
Scott Sheridan, KSU

SOARS

Extratropical cyclones that undergo 'bomb' cyclogenesis (pressure drop ≥ 24mb per 24hrs) remain an under-predicted phenomenon in operational weather forecasts. This research aims to explore the climatology of bombs in the western North Atlantic, their relationship with North Atlantic blocking, and the teleconnective influence of Arctic sea ice and Siberian snow cover on each.

Sea level pressure data from the NCEP-NCAR Reanalysis (1948-2016) was used to create a bomb cyclone dataset of the western North Atlantic basin that retained genesis locations and the magnitude of pressure decrease at 24hr time intervals along the storm's trajectory. Geopotential height at the 500hPa pressure level was used to compute monthly and seasonal blocking indices with central bounds of 40° and 80° north latitudes across the North Atlantic basin. Implementing a circulation to environment approach, we classified 500hPa geopotential height, relative humidity, and sea-level pressure patterns by season across the western North Atlantic using self-organizing maps (SOMs). Blocking indices and monthly Arctic sea ice and Siberian snow extent data from the Special Sensor Microwave Imager and Special Sensor Microwave Imager Sounder (SSMI-SSMIS) were mapped with their respective SOM patterns. The months of March-May exhibited the highest frequency of 5-day blocking across the entire North Atlantic. Furthermore, initial results of the SOMs contain atmospheric patterns characteristic of bomb environments that include relatively low sea level pressure in the mid-Atlantic region of the United States with large amplitude, downstream ridging.

5-day Blocking Frequencies (TM90 Index) by Season
North Atlantic (1948-2016)
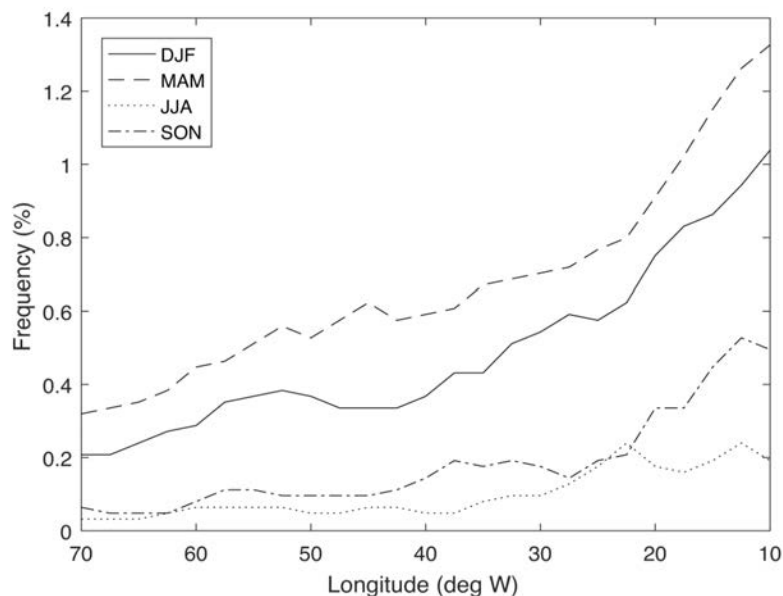
Seasonal frequencies for 5-day duration blocking events in the North Atlantic. The blocks were identified using the Tibaldi and Molteni (TM90) algorithm using the 500hPa geopotential height gradient in NCEP-NCAR Reanalysis between 40° and 80° North for each 2.5° longitude increment between 10° and 70° West.

Sensitivity of model verification results to object identification parameters using Method for Object-based Diagnostic Evaluation – Time Domain

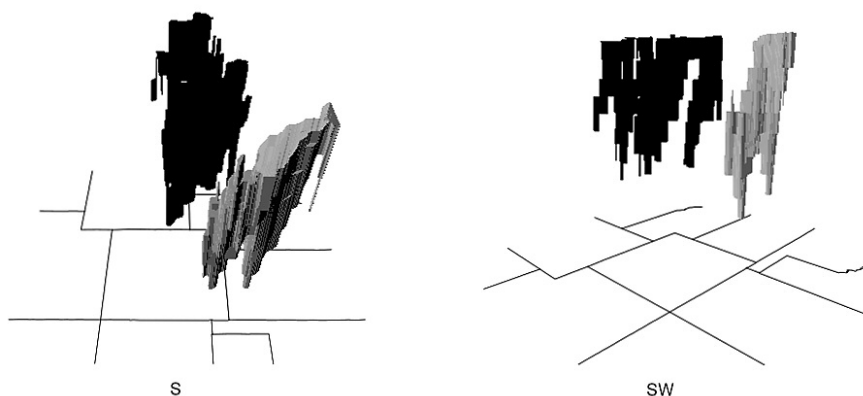Spatial verification methods for feature- or object-based approaches are becoming more prevalent due to increases in both model resolution and the demand for identification of specific features in storms. Yet further investigation is needed to determine which spatial verification methods and specific configurations work best for certain forecast parameters, storm types, or regions of interest. This study investigated the use of Method for Object-based Diagnostic Evaluation – Time Domain (MODE-TD) configurations to identify objects for the purpose of evaluating both mesoscale convective systems (MCSs) and smaller, localized storms through verification of precipitation areas. Unlike other statistical evaluation tools, MODE-TD has two horizontal spatial dimensions and time extending into the vertical spatial dimension which creates a 3D image, producing a more complete spatial view of the data. Weather Research and Forecasting (WRF) model forecasts for two cases were run with a variety of configurations of MODE-TD for analysis, and were then compared against Multi-Radar Multi-Sensor observations of precipitation. With an increase in convolution radius (hereafter R) and threshold (hereafter T), fewer objects were identified – especially for coarser and smaller objects – and they tended to initiate later in time. For MCSs, a medium R-medium T combination is recommended whereas a medium R-small T combination is suggested for local storms. The results of this study will be applied in a verification study of the 2015 Short Term Explicit Prediction program forecast experiment to evaluate model performance related to predicting heavy rainfall as well as storm propagation and evolution.

ShaoWen (Amy) Chen

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COACH
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William Evonosky
Steven Naegele

S

SW

Two objects identified by MODE-TD on July 15, 2015 MCSs over the central Rockies using a convolution radius of 3 and convolution threshold of 3 viewed from the south and southwest.

From DOS to LabVIEW Real-Time: Modernizing a carbon monoxide instrument for user-friendly data acquisition

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Rosa Vargas-Martes

Carbon monoxide (CO) is best known for its toxicity to humans, but as a trace gas it is also vital in understanding the concentrations and potential effects on climate of strong greenhouse gases in the atmosphere. Carbon monoxide can be easily transported across continents and oceans in as little as a few days by wind and circulation patterns and it has a short lifetime of only two months, so is not evenly distributed around the globe. This pollutant must be continually monitored because sources of carbon monoxide emissions such as motor vehicle exhaust and forest fires, along with wind patterns, rapidly change its concentrations. There are a large number of instruments that measure concentrations of CO, including the Ultra-Fast Carbon Monoxide Analyser used in the National Center for Atmospheric Research aircraft. In the case of this instrument, CO concentrations are acquired using an outdated DOS-based operating system. The instrument is functional, with both precise and accurate measurements, but it is also non-intuitive, difficult to navigate, and limited in its capabilities. This decreases both the efficiency and effectiveness of the instrument operator. Modernizing the instrument with two different versions of the LabVIEW graphical programming language provides a means to facilitate user-friendly interactions between the instrument and operator. The different software options also provide insight into the most effective way to boost the productivity of CO measurements.
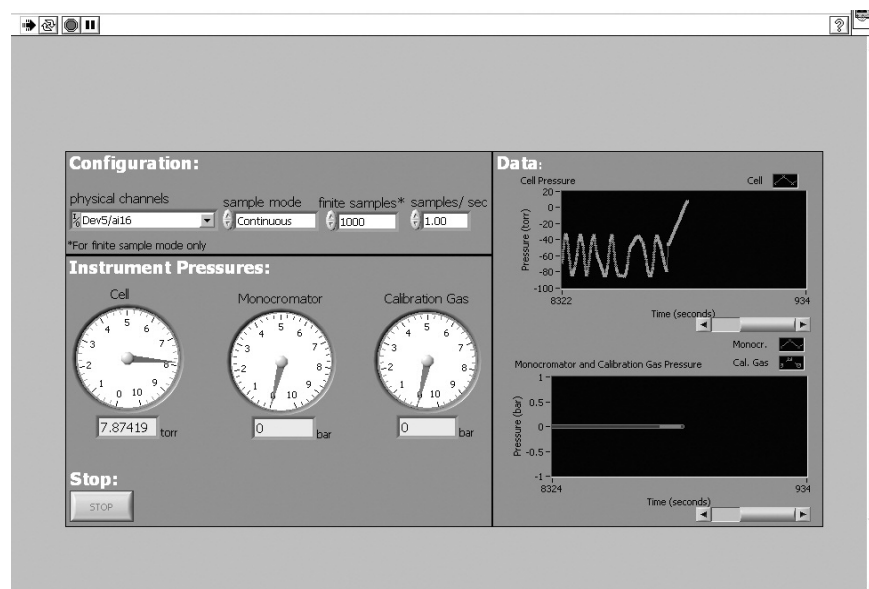
The preliminary interface for the pressure subsystem of the carbon monoxide instrument created using non-FPGA LabVIEW. Data is being collected from an RTD wired to the instrument.

Evaluation of High Resolution Rapid Refresh-Smoke (HRRR-Smoke) model products using $PM_{2.5}$ observations

Wildfires are increasing in number and size in the western United States as climate change contributes to warmer and drier conditions in this region. Because these fires contribute to poor air quality and diminished visibility, it is crucial to accurately predict smoke transport and the impact of wildfires on air quality. The High Resolution Rapid Refresh-Smoke modeling system (HRRR-Smoke) is designed to simulate fire emissions and smoke transport with high resolution. HRRR-Smoke is used in experimental smoke forecasts at the National Oceanic and Atmospheric Administration Earth System Research Laboratory for the contiguous United States (CONUS) and Alaska domains. The model is based on the Weather Research and Forecasting model, coupled with chemistry (WRF-Chem) and uses fire detection data from the Visible Infrared and Imaging Radiometer Suite (VIIRS) satellite instrument to simulate wildfire emissions and their plume rise. Model improvements have the potential to advance wildfire air quality forecasting efforts. To evaluate HRRR-Smoke, we compared its gridded output to hourly $PM_{2.5}$ observations from multiple air quality monitoring sites in Washington state, focusing on a case study of August 17-31, 2015, during one of the worst wildfire seasons on record. We found that HRRR-Smoke captures large peaks in observed $PM_{2.5}$ concentrations due to wild-fires, with some underestimation.

$PM_{2.5}$ Comparisons at Spokane, WA: August 17-31, 2015
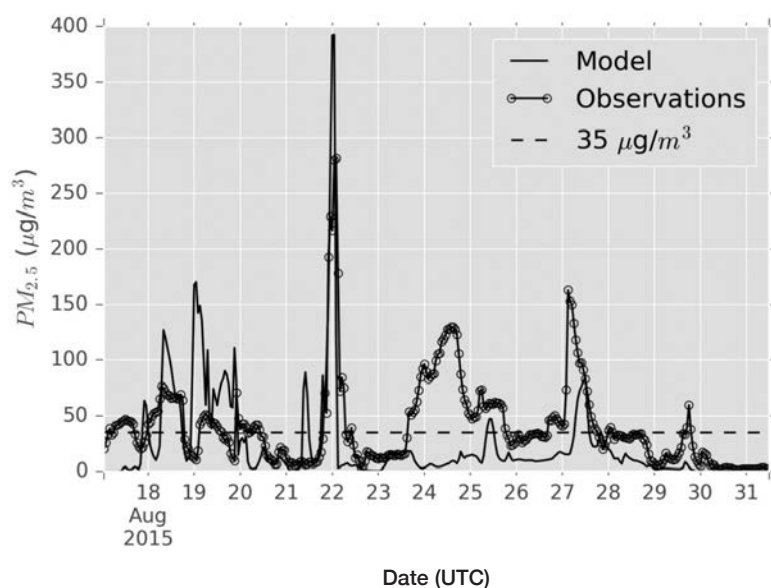
Spokane, Washington experienced very high $PM_{2.5}$ levels because of fires in the state during August 2015. The model captures the large $PM_{2.5}$ peak on August 21. 35 ug/m^3 is the EPA air quality standard for daily averaged $PM_{2.5}$.

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PEER
Amber Liggett

SOARS®

Modeling molecular hydrogen emission in M-dwarf exoplanetary systems

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2nd-year Protégé
Senior
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SOARS

Exoplanets orbiting low-mass stars are prime candidates for atmospheric characterization due to their sheer abundance and short orbital periods. These planets orbit stars which are much more active than main sequence solar-type stars. They are exposed to differing levels of ultraviolet radiation which can cause traditional "biosignature" gases to be generated abiotically, potentially causing false-positive identifications of life. We examined the recently discovered molecular hydrogen emission from these stars by modeling the ultraviolet environment (1350 – 1650 Å) of their surfaces and upper atmospheres. The model was compared with observed hydrogen emission from the "Measurements of the Ultraviolet Spectral Characteristics of Low-mass Exoplanet host Stars" (MUSCLES) survey by conducting a grid search and implementing a chi-squared minimization routine. We considered only progressions from the [1, 4] and [1, 7] first excited levels. Our modeling procedure varied the atomic hydrogen column density (in the chromosphere) as well as the photo-spheric molecular hydrogen column density and temperature. The model required as an input a reconstructed intrinsic Lyman alpha profile which served as the pumping radiation for the molecular hydrogen. We found that an atomic hydrogen column density of around $10^{14.2}$ cm^{-2} represents a breaking point above which there is not enough Lyman alpha flux available to excite a significant molecular hydrogen population into the [1, 7] state. We also present H_2 temperatures which may suggest that star spots on low mass stars persist longer, and encompass more area than star spots on solar-type stars.
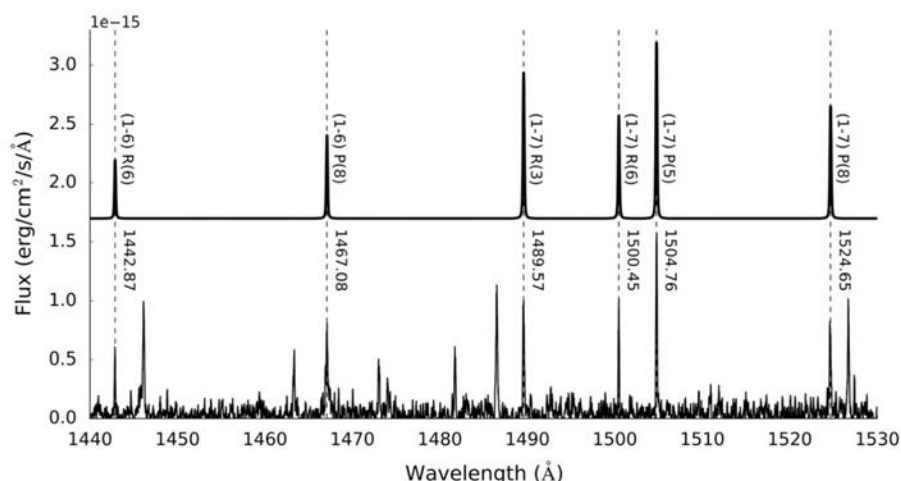
Selection of the total observed spectrum (bottom line) for GJ 876 and the modeled H2 fluorescence (top line). The modeled line is offset by a set factor of 1.7 x 10^{-15} erg/cm^2/s/Å to make comparisons easier. Each H_2 line is identified with a vertical dashed line and its line label and corresponding wavelength. The (1-6) P(5) line at 1446.12 Å is an H_2 line however was not modeled due to contamination with other spectral features.

Behind the rapid intensification of Hurricane Patricia, the strongest recorded hurricane in history

In October of 2015, Hurricane Patricia stormed through the eastern Pacific to become the strongest recorded hurricane in history. Within a twenty-four hour period, Patricia's maximum wind speed increased by 105 kt, while the sea level pressure decreased by 95 hPa. At its greatest intensity, the storm reached an estimated maximum wind speed of 185 kt and a minimum sea level pressure of 872 hPa. Operational weather prediction models failed to accurately forecast Patricia's intensity evolution, provoking questions about the factors behind this unparalleled case of hurricane rapid intensification. In this study, a high resolution numerical weather prediction model (WRF) was employed to simulate Hurricane Patricia to shed light on the environmental conditions during its rapid intensification. An analysis of the WRF model fields demonstrated that environmental variables such as vertical wind shear, sea surface temperature, and relative humidity were extremely favorable for intensification (e.g., the shear briefly dropped to < 1 m/s). The environmental conditions during Patricia's rapid intensification were compared with the corresponding quantities from a 30+ year climatology of hurricanes in the Eastern Pacific, revealing that sea surface temperature and relative humidity values fell into the 99th percentile. This indicates that the storm environment played a substantial role in Patricia becoming the strongest hurricane on record. It additionally suggests that potential future cases of extreme rapid intensification can be predicted if the models are able to capture the environmental conditions.
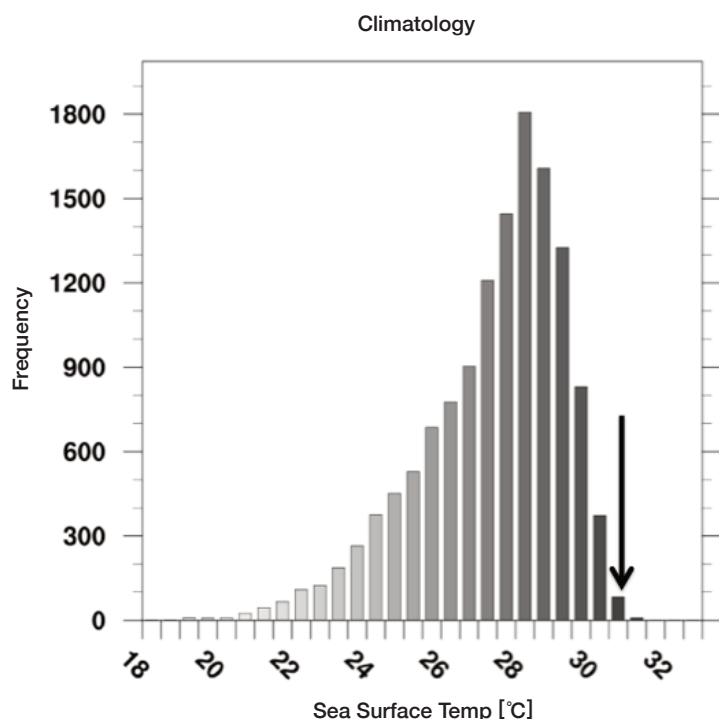
Climatology

Frequency distribution of 30+ year climatology of sea surface temperatures (SSTs) for Eastern Pacific hurricanes. The black arrow is placed at the average SST in the WRF model output, which falls in the top 1 percentile (Hurricane Patricia, 2015).

K. Ryder Fox

1st-year Protégé
Junior
New Mexico Institute of Mining
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Physics (Atmospheric Focus)

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SOARS

Investigating the sources of inaccuracy in a Geonor precipitation gauge

KEON GIBSON

1st-year Protégé
Junior
Jackson State University
Meteorology

MENTORS

RESEARCH
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Justin Lentz, NCAR

COACH
Eileen Carpenter, UCP

PEER
Nkosi Muse

SOARS

This study describes various techniques for correcting the data output from the Geonor T-200B Precipitation Gauge, which utilizes vibrating wire technology to measure the accumulating mass of precipitation. In some instances, data recorded by the gauge is unusually noisy. This study aimed to isolate the source of the noise in the vibrating wires' frequency data by isolating variables that may be causing the problem. The goal was to recommend ways to modify the instrument to produce more accurate precipitation data. To study the vibrating wires, a 326-gram weight was placed on the wires in a test enclosure to see how they performed with a static load in isolation. This test showed that wire two was noisier than the others. During the day, changes in the wire frequencies were associated with the changing ambient temperatures. Plots showed a strong correlation between ambient temperature and the data being recorded by the precipitation gauge. There are additional sources of noise, one of which was revealed after a power outage occurred during this test; the noise on wire two diminished, wire three began producing more noise, and the output from wire one did not change. This showed that many factors may be contributing to the inaccuracy of the frequency outputs the gauges produce. Engineers and other researchers can use this information to further improve the accuracy of this instrument.
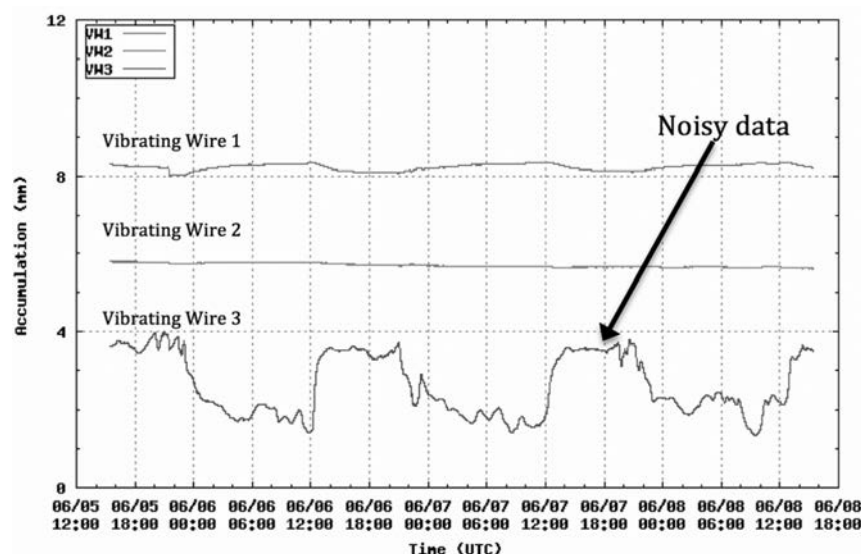
The accumulation values from each of the three vibrating wires in the test enclosure from 5-8 June 2016, which highlights the noisy data from vibrating wire 3.

Protégés are pictured left to right:

Front Row Rosa Vargas-Martes, Lauren Deanes, Meghan Mitchell, Arianna Varuolo-Clarke, Nkosi Muse

Back Row Briah' Davis, Ryder Fox, Amber Liggett, Shay Gilpin, Steven Naegele, Jenine McKoy, Ryan Adams, William Evonosky, Keon Gibson, Shao Wen (Amy) Chen, Tony Hurt, Jesse Villalobos

PHOTO BY J. LA PLANTE PHOTO

Weather balloons to satellites: A mathematical comparison of radio occultation and radiosonde refractivities over Guam

Shay Gilpin

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Senior
University of California Santa
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Pure Mathematics

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SOARS

Radio occultation (RO) uses GPS and low-Earth orbit satellites to obtain vertical profiles of refractivities from which temperature and water vapor pressure can be derived and used in various meteorological and climatological applications. Comparing RO with other types of atmospheric observations, such as radiosondes (RS), is crucial in understanding the properties and quality of RO observations. However, comparing RO and RS is difficult due to spatial and temporal sampling differences, which can result in large sampling errors. Previous studies have compared RO and RS observations separated by a constant distance, i.e. within circles centered at the RS location. This study hypothesizes that sampling errors will be reduced by comparing observations within ellipses oriented along the direction of wind flow rather than circles. Refractivities within ellipses parallel and perpendicular to the flow, and two circles of 6° and 2.6° latitude radii, were compared to reference refractivities at five pressure levels and two locations in the Tropical West Pacific during 2007. European Centre for Medium-Range Weather Forecasts Interim Reanalysis (ERA Interim) refractivity fields indicated a strong correlation of refractivity and wind flow in this region. RMS differences in model refractivities, model and RO observations, and RO and RS observations were significantly less in the parallel ellipses compared to the perpendicular ellipses and larger circle, indicating less refractivity variability along the direction of wind flow. As expected, we found that that wind speed at the reference location strongly influences the effectiveness of the parallel ellipse in reducing sampling errors.

**RO Observations ±6hrs Reference Location (RS): (13.5° N, 144.8° E) All 2007**
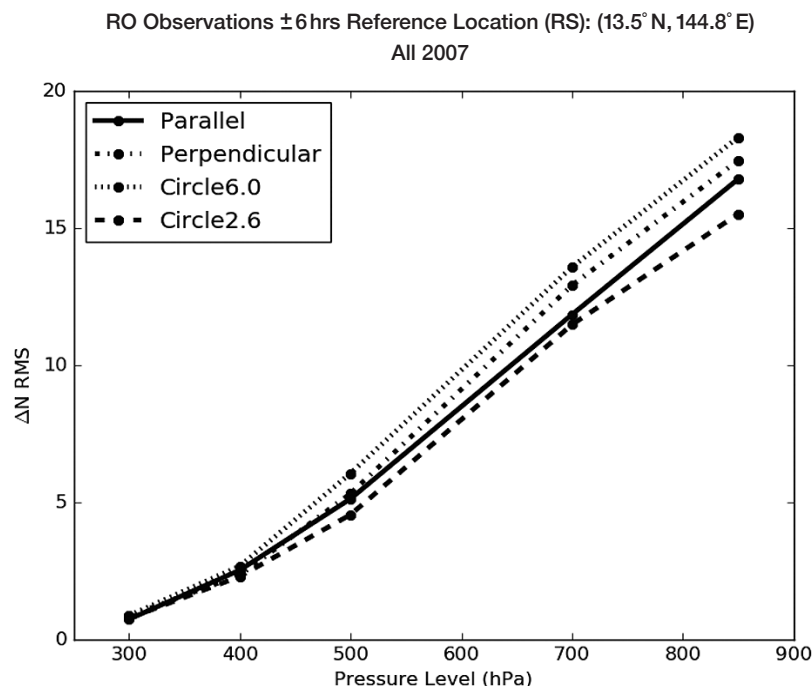
Differences in refractivity (N) between RO observations and RS observations RMS values vs. pressure (hPa) during 2007 at Guam. Ellipses and circles are centered at the Guam radiosonde. Circles have radius of 6° and 2.6,° respectively, and ellipses have 6° semi-major axis oriented parallel and perpendicular to the wind direction at the RS.

Examining the variability of the diurnal cycle of rainfall over the Pacific basin associated with El Niño

Accurately reproducing the diurnal cycle of rainfall for atmospheric modeling represents a potential challenge for improving the reliability of weather and climate forecasting. Scientific advances such as the Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Measurement (GPM) have provided invaluable rainfall data for detailed research. Moreover, large-scale decadal- to multi-decadal climate variations such as El Niño create significant deviations in atmospheric conditions and rainfall, particularly within the tropics. El Niño and its counterpart La Niña represent the respective warm and cool phase of the global-scale phenomenon known as El Niño – Southern Oscillation (ENSO), and distinct variations in the diurnal cycle of rainfall are associated with each phase.

This research focuses on the December through February (DJF) period of each ENSO phase, when it has historically been strongest. Daily mean rainfall, diurnal amplitude and phase values from 1998-2016 were compared to observations during individual and averaged ENSO events. Probability distributions were calculated for statistical analysis of diurnal amplitude and phase, and results indicated a statistically significant relationship between ENSO phase and the diurnal cycle. Amplitude was enhanced and suppressed, respectively, with El Niño and La Niña events. Phase maximum and minimum probability during La Niña occurred in the mid-morning and mid-afternoon hours, respectively, while El Niño closely mirrored climatology, with a much smaller spread in probability and a distinct secondary maximum during the afternoon.

Diurnal Cycle Amplitude
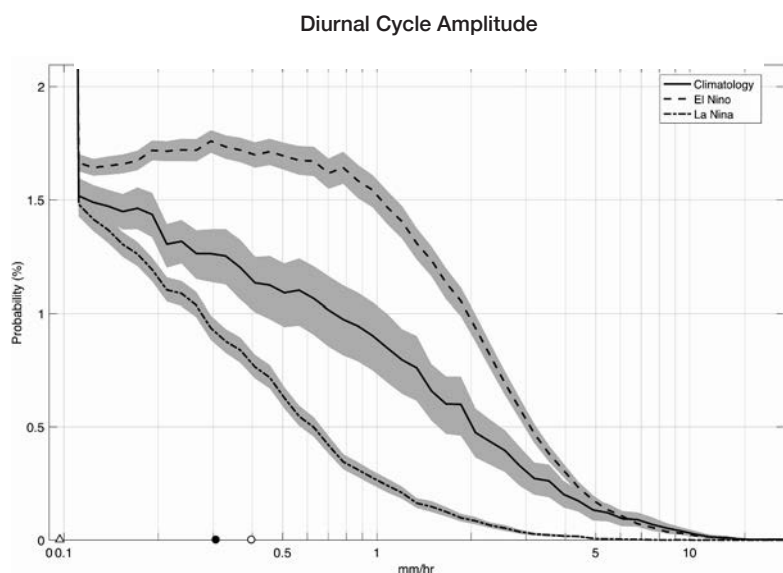
Probability distribution with confidence interval of amplitude for diurnal cycle of TRMM 3B42 rainfall over Niño 3.4 region from 1998 to 2016. Mean for climatology, El Niño, and La Niña is represented with a shaded circle, unshaded circle, and triangle, respectively.

Tony O. Hurt, Jr.

1st-year Protégé
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PEER
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SOARS
research | mentoring | community

The SOARS Mentoring Model
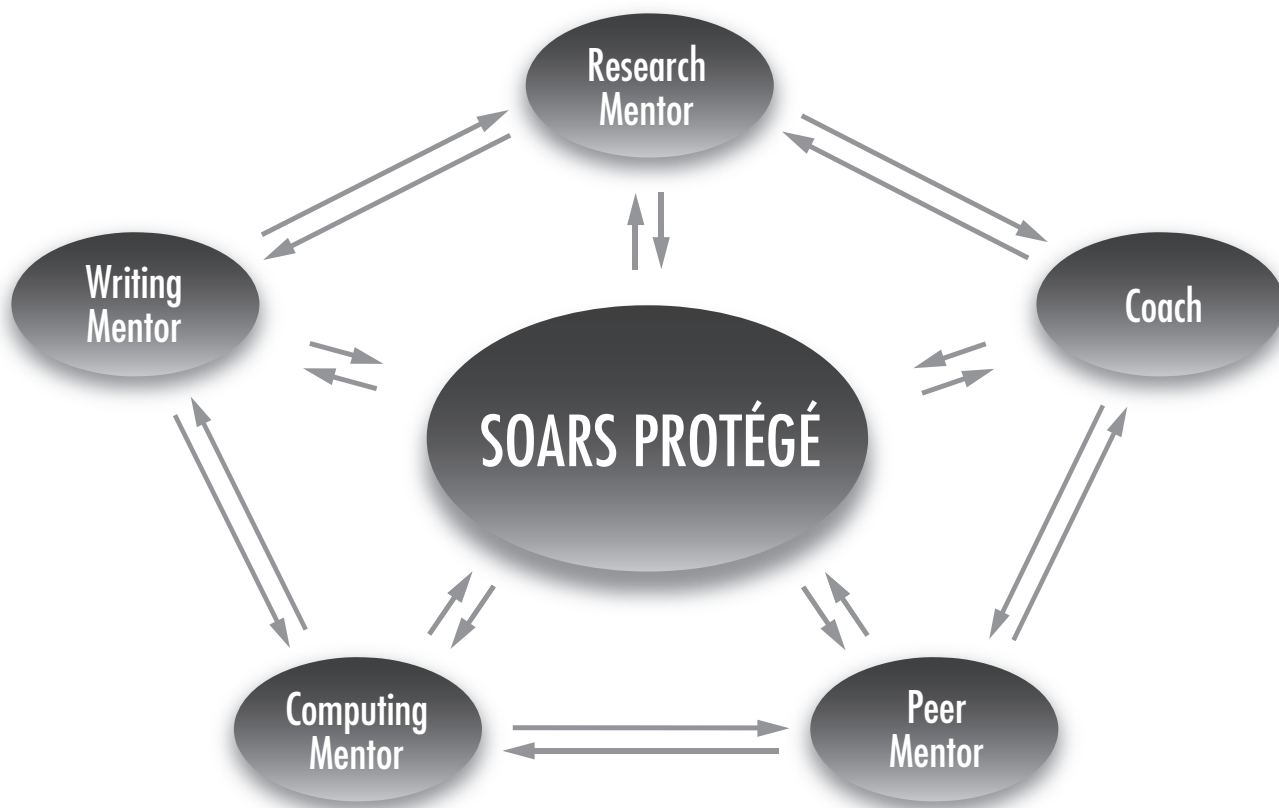
Adapted from Thomas L. Windham, Amy J. Stevermer, and Richard A. Anthes, 2004: SOARS®: An Overview of the Program and Its First 8 Years. *Bull. Amer. Meteor. Soc.*, **85**, 42–47

TRAINING THE NEXT GENERATION OF MENTORS

ASP postdoctoral fellow and mentor Falko Judt (left) with SOARS protégé Ryder Fox.

One of the key ingredients of the SOARS model is its strong commitment to mentoring. More than 50 scientists, engineers and administrators serve as mentors each summer, and the program would not exist without their commitment and talent. Each SOARS protégé is paired not only with a **research mentor**, but also with mentors covering other aspects of being a scientist, including a **writing mentor** (writing and public speaking), and **computing mentor** (programming and computing skills). Perhaps most importantly, each new student works with a returning protégé who serves as a formal **peer mentor** and a **coach** to handle stress and help with life choices.

A strong mentoring relationship is an acknowledged success strategy in the sciences, particularly for underrepresented students. An important take-away for SOARS protégés and our mentors is an understanding of what constitutes a good mentor. As such, we look at mentoring as an opportunity for our early career scientists to gain skills working with students and developing expertise in mentoring that they can take into their future careers.

This summer, as part of a new partnership with NCAR′s Advanced Study Program (ASP), we encouraged postdocs to volunteer as SOARS mentors. Postdocs make great mentors – they′re in touch with the current status of the field, remember the challenges of completing a degree and tend to be very approachable. Adding SOARS training, a team of mentors working together, and a structured program helps them make the most of the experience. While most postdocs this year served as writing mentors, several also served as research mentors. ASP postdoctoral fellow **Falko Judt** mentored SOARS protégé **Ryder Fox**. He says he chose to mentor because *"my ultimate goal is to pass my own passion for science, i.e. discovering how the world works, on to others..."* He strongly agreed that mentoring was rewarding, and that *"motivating and inspiring the student to continue doing research"* was one of the most valuable aspects of the experience. He says he also *"got some ideas for possible future science projects."* Ryder said of Falko, he was *"so generous with time and knowledge, so passionate, both about the work and the SOARS program overall. If I got stuck I was quickly able to ask a question and get back to work."*

SOARS alum **Annareli Morales** also rose to the mentoring challenge. Currently a PhD. student at the University of Michigan, Annareli was visiting NCAR through the ASP graduate visitor program and volunteered to mentor PRECIP student **Christine Soh**.

She hoped this opportunity would help prepare her for mentoring in a future faculty role, and gave her practice at identifying and supporting student research. She found the experience very gratifying and inspiring as Christine successfully navigated and presented her research, and also provided results that supported Annareli′s own research. She says *"the mentoring I received during SOARS was critical for helping me balance Christine′s independence and support, and I used many of the tools my own mentors had shared with me."*

By training early career scientists, whether SOARS alumni, future faculty, or the protégés themselves to be great mentors, we hope that mentoring becomes a part of their future efforts – one that helps support and retain the next generation of diverse atmospheric scientists.

Thank you to all our mentors!

SOARS alum Annareli Morales (left) with her mentee, PRECIP intern Christine Soh during the end-of-summer poster session.

Developing a quantitative measure of convective forcing to evaluate High Resolution Rapid Refresh Ensemble (HRRRE) variance

Amber Liggett

1st-year Protégé
Junior
Millersville University
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David Dowell, NOAA
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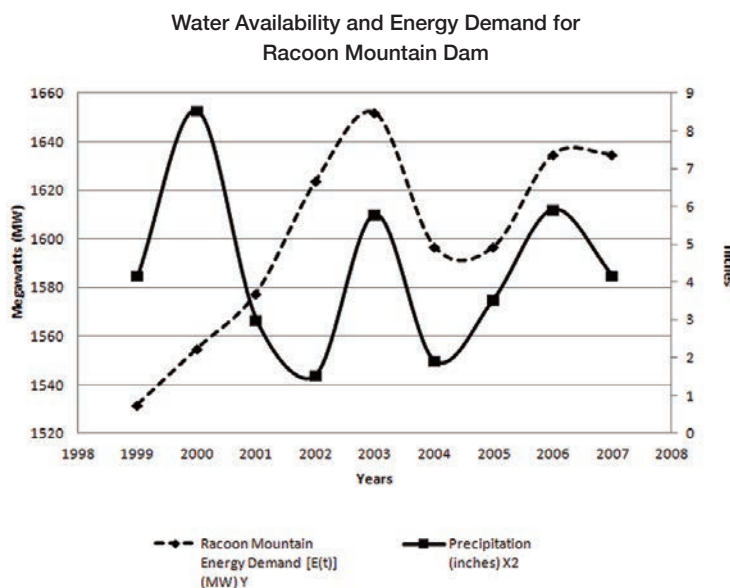
COACH
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PEER
Lauren Deanes

Hazardous weather events have the greatest impact when they are not accurately forecasted. The quest for advanced lead times of accurate forecasts has motivated the improvement of numerical weather prediction models. Stemming from successful hourly updated forecasting by the High Resolution Rapid Refresh model, the High Resolution Rapid Refresh Ensemble (HRRRE) utilizes ensemble data assimilation for improved convective scale forecasts. HRRRE and other Convective Allowing Model (CAM) guidance skill can vary widely in different weather regimes. Convective forcing is hypothesized to influence forecast skill and CAM ensemble variance. Understanding the correlation between forcing and ensemble skill/variance can potentially enhance the future HRRRE ensemble design. To analyze this relationship, this study developed an objective measure of convective forcing. The Reflectivity Convective Forcing Categorization (RCFC) is a quantitative method to categorize convective forcing using Multi-Radar Multi-Sensor (MRMS) composite reflectivity observations. Both reflectivity coverage and rate of change of reflectivity were examined for the months of May and June 2016 utilizing RCFC. Measuring forcing based on MRMS radar observations allowed the classification to be independent from model analyses and forecasts, implying less error in the objective measure. Several events exemplifying strong and weak forcing regimes were qualitatively analyzed using Storm Prediction Center mesoscale/surface analyses and upper air maps, to verify the RCFC method. Findings include strongly forced days having a greater reflectivity rate of change and coverage than weakly forced days. The RCFC results enable the correlation between convective forcing and HRRRE ensemble variance/skill to be examined in the future, facilitating HRRRE improvements.

Correlation between Reflectivity Coverage and Rate of Change (35dBZ)
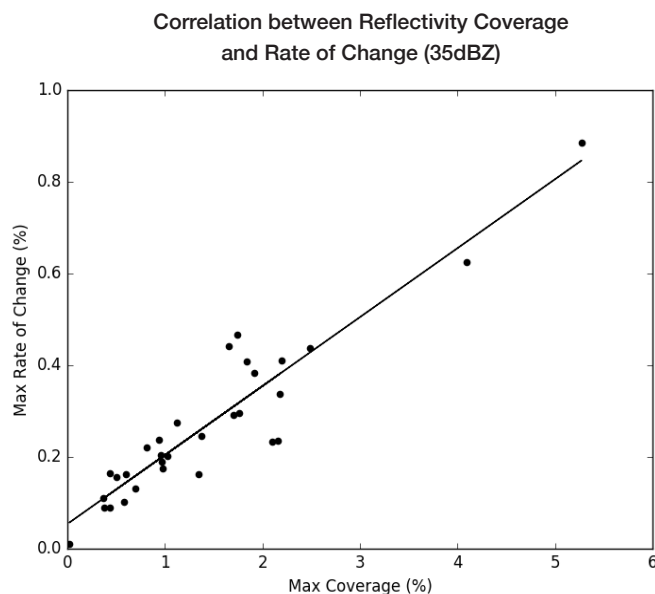
The correlation between reflectivity coverage and rate of change based on the 35 dBZ RCFC method for all cases chronologically from May through June 2016. Days with large (small) reflectivity coverage and rate of change had strong (weak) convective forcing.

Sustainable waterways: Modeling the impact of interdependent relationships within the water-energy nexus

One of the most significant interdependent systems is the relationship between water and energy. In the United States, a significant quantity of water is required for energy generation and in turn energy is needed for the transmission of water for industrial and municipal use. The interlinked relationship between water, climate and energy is known as the water-energy nexus. Unfortunately, climate change variability factors, such as temperature, precipitation, and increasing demands, threaten to affect the stability of the water-energy nexus. As this stability continues to be threatened, it has become vital to have the ability to predict the future condition of the nexus. In this study, we have developed a model to predict the future conditions of four interdependent relationships within the water-energy nexus for the city of Chattanooga, TN from 2016 to 2050. The interdependent relationships considered in the model include the following: natural freshwater availability, energy availability, energy demand, and water demand. These interdependent relationships consider how factors such as population growth, temperature, and precipitation affect past and future water and energy availability. This study modeled the statistical significance of the factors within each relationship via linear regression to determine the most impactful factor that will shape future water and energy availability. As a result, the study was able to highlight the most strained interdependent relationship to ultimately inform future local and state water and energy policies.

Jenine N. McKoy

4th-year Protégé
Senior
University of Michigan
Environmental Engineering

MENTORS

RESEARCH
Hiba Baroud, VU

WRITING & COMMUNICATION
Carolyn Brinkworth, NCAR

COMPUTING
Keith Maull, NCAR

The energy demand and precipitation for a high capacity hydropower plant, Raccoon Mountain Dam in Chattanooga, TN, for the month of April, from 1999 to 2007. This shows the intersection and interdependency between water availability and energy demand.

Development of statistical post-processing techniques for improved low-level wind speed forecasts in West Texas

Meghan Mitchell

4th-year Protégé
Graduate student
Texas Tech University
Atmospheric Science

M E N T O R S
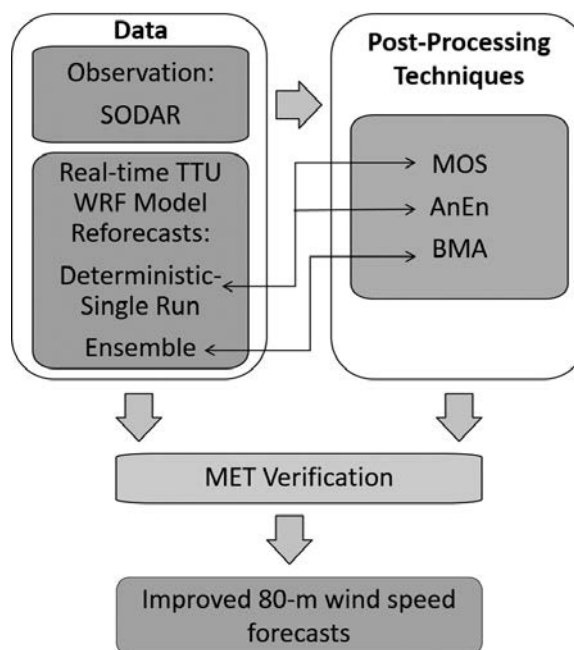
RESEARCH
Luca Delle Monache, NCAR
Sue Haupt, NCAR
Jared Lee, NCAR

WRITING & COMMUNICATION
Michael Lawler, NCAR

COMPUTING
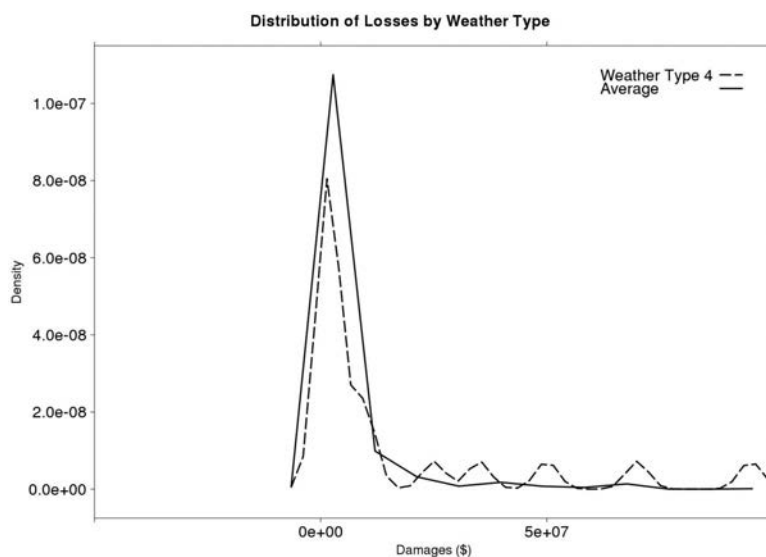Ryan Sobash, NCAR

PEER
Ryder Fox

The wind energy industry needs accurate forecasts of wind speeds at hub height and in the rotor layer in order to accurately project expected power output from a wind farm. These forecasts aid the industry in deciding if there will be enough power to meet the energy need or if back up power sources will be necessary, and to site future wind farms. Current numerical weather prediction (NWP) models struggle to accurately predict low level winds such as those at hub height, partially because of systematic biases within the models. These systematic errors were corrected through this study with statistical post-processing techniques such as Model Output Statistics (MOS). Additionally, ensemble-based statistical techniques were developed to take advantage of the spread of solutions produced by the ensemble members. These techniques include Bayesian Model Averaging, Ensemble MOS, and Analog Ensemble. This study used reforecasts from Weather Research and Forecasting (WRF-ARW) model version 3.5.1 and observations from SODAR instruments for the training data set to examine the skill added to corrected forecasts when testing aspects of deterministic MOS (e.g. model resolution, number of predictors, training set length). Both deterministic MOS and each of the ensemble post-processing techniques were developed for 80 m (hub height) wind speed forecasts and applied to the raw forecast model output. Results of this study presented the degree of improvement each technique provided to the raw forecasts. Each of these applied post-processing techniques translated directly into improved low-level wind speed prediction within the real-time Texas Tech University prediction system.

In situ Sonic Detection and Ranging (SODAR) wind speed data provided by the West Texas Mesonet and Texas Tech University Weather Research and Forecasting (TTU WRF) model outputs will be inputs for post-processing techniques (MOS: Model Output Statistics, AnEn: Analog Ensemble, and BMA: Bayesian Model Averaging) aimed at improving 80-m wind speed forecasts. The results will be verified using the National Center for Atmospheric Research (NCAR) Developmental Testbed Center's (DTC) Model Evaluation Tools (MET).

Understanding and communicating future flood losses using weather typing

As the science of meteorology progresses, meteorologists are given new tools to aid in the weather forecasting process. One of these tools is known as "weather typing," which allows for the bypassing of complex processes such as numerical weather models which can produce rainfall amount and location uncertainty. By assigning a potential flood damage or loss value to a specific weather type, meteorologists, emergency managers and other professionals are able to infer the flood threat a certain weather type brings. Flood damage by weather type was derived using historical data. Daily weather maps were assigned one of twelve weather types, defined using mid-level winds, sea level pressure, and precipitable water. Combined with property damage data dating back to 1996, flood damage amounts for a number of states along the east coast were sorted by weather type. The likelihood of flood damage and large flood events was found to substantially vary by weather type. The results of this study have broader and immediate impacts on real time weather forecasting—allowing for earlier and easier weather prediction, and even climate change projections as we can see the evolution of weather types over time.

Nkosi Muse

2nd-year Protégé
Senior
University of North Carolina at
    Charlotte
Meteorology

MENTORS

RESEARCH
James Done, NCAR

WRITING & COMMUNICATION
Lesley Smith, NOAA/CIRES

PEER
Keon Gibson

SOARS

Distribution of Losses by Weather Type

Distribution of the average flood damage of all weather types and the distribution of flood damages by Weather Type 4. Total area under the curves is equal to 1. While Weather Type 4 is less likely than average to cause smaller amounts of damage, it is generally more likely to trigger flood events with higher amount of damages.

SOARS
20 YEAR
SYMPOSIUM

Over the weekend of June 24-26, 2016, sixty-five protégés and alumni from across the country reconnected in celebration of SOARS 20th anniversary. The weekend began with a reception celebration at the NCAR Mesa Lab, where attendees were joined by current and past mentors from NCAR, UCP, NOAA-ESRL, and the university community, funders, and past and present SOARS directors. In addition to cake and celebratory speeches, including those by UCP director **William Kuo**, UCAR interim president **Michael Thompson** and SOARS director **Rebecca Haacker**, there were hugs, joyful reunions and many, many memories and stories.

On Saturday the attention moved to strengthening the inter-decadal connections, sharing career advice and reinspiring leadership for the SOARS mission. Talks by past directors **Thomas Windham** and **Raj Pandya** charged attendees to this mission, and formal leadership training got people laughing and connecting before moving on to breakout groups focused on careers in research, government, industry and education. A career panel on *"Careers outside the Ivory Tower"* followed, with SOARS alumni **Maribel Martinez** (Emergency Management, CNS Pantex), **Marcus Walter** (Broadcast Meteorologist, RNN-TV/Verizon FiOS 1 News), **Fabiola Navarro** (Senior Cybersecurity Engineer, La Jolla Logic), and **Melanie Zauscher** (Air Pollution Specialist, California Air Resources Board) sharing their career and life journeys. The day was rounded out with a poster session, with posters spanning scientific research to career journeys to memories of SOARS, before a shared working dinner focused on balancing career and family.

Sunday moved the weekend´s discussion to diversity, the future, and SOARS´ role in supporting the next generation of diverse leaders in the atmospheric and related sciences. We discussed minority challenges, our role as leaders, and where SOARS might head as we move into our next twenty years. Many ideas were raised and there was a strong commitment by both alumni and current protégés to staying connected and moving SOARS into the future. The love and the joy for being part of the SOARS family was an overarching theme of the weekend, clearly demonstrating the power of this program to positively influence lives.

Celebrating
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20 years
1996-2016

Riming parameterization impacts on the microphysical evolution of a northeast winter cyclone and the associated snowbands

STEVEN M. NAEGELE

3rd-year Protégé
Graduate student
Pennsylvania State University
Meteorology

MENTORS

RESEARCH
Trude Eidhammer, NCAR

WRITING & COMMUNICATION
Ben Gaubert, NCAR

PEER
Jesse Villalobos
Amy Chen

Many northeast winter cyclones ("nor'easters") can produce large amounts of snow that have the potential to economically cripple entire cities. However, incorrect forecasts of nor'easter snowbands can cause cities to waste resources preparing for an extreme snow event that never happens. One uncertainty in snowband forecasting is how the riming of ice crystals is represented within the microphysical parameterization schemes of numerical models. Simulations of the nor'easter of 26-27 January 2015 and its associated snowbands were performed using the Weather Research and Forecasting (WRF) model to compare accumulated snowfall and other microphysical variables when riming efficiency thresholds were altered in the Thompson microphysics scheme. When the riming parameterization was altered to produce graupel more frequently (THO_new), more snow accumulated over the western and eastern ends of Long Island, New York by the end of the nor'easter event, even though observed snowfall was primarily in eastern Long Island. Also unlike observations, the original riming parameterization (THO_old) produced maxima in accumulated snowfall in central Long Island, as well as approximately 100 km east of Long Island over the Atlantic Ocean. The change in simulated snow accumulation indicated that the parameterization of riming in Thompson microphysics, as well as other microphysical schemes, can affect where heavy snowfall occurs within the domains of numerical models, thus affecting forecast accuracy of the snowbands associated with nor'easters.

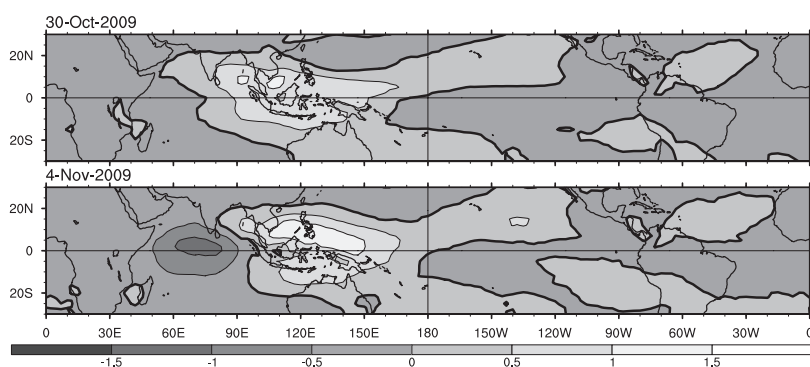Thompson pre-v3.8 vs v3.8 snow-graupel conversion efficiency
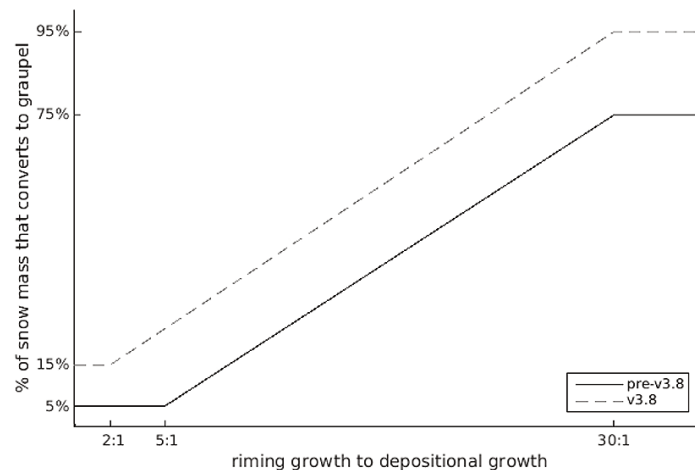
A graphical representation of the differences in the riming parameterization for the Thompson microphysics scheme for versions of WRF before WRFv3.8 (THO_old) and WRFv3.8 (THO_new).

Further exploration of MJO initiation events and precursors as revealed by an MJO-like dynamical mode

The Madden Julian Oscillation (MJO) is a tropical phenomenon that develops over the Indian Ocean as a large area of convection approximately 1000km across. This intraseasonal oscillation affects both weather and climate in extratropical regions, where most of the world's population resides. However, computational models do not represent the MJO adequately, and the scientific community has turned its attention to the MJO's initial stages. This research studies Primary MJO events (those arising in the absence of a pre-existing MJO signal) identified by four methods developed by previous researchers. Two of the methods focus mainly on precipitation while the other two focus on circulation. A multivariate MJO-like dynamical mode, obtained from unfiltered five-day-mean gridded data, was used to visualize the events during the 1998-2009 boreal winters. The contributions of the following variables to the MJO were analyzed: outgoing long-wave radiation (OLR), sea level pressure (SLP), mid-tropospheric temperature (T400), and upper- and lower-level zonal winds (u200hPa and u850hPa). The mode was able to depict typical eastward-propagating events, and it was also able to show westward-propagating and non-propagating events seen by other researchers. In addition, the mode depicts extratropical interactions and the areas of suppressed convection preceding events, as noted by previous studies. However, the mode was not able to represent all of the selected events. The study shows that the multivariate MJO-like dynamical mode was able to capture the complexity of MJO events, making it a useful tool for future MJO studies.

Rosa M. Vargas-Martes

2nd-year Protégé
Senior
University of Puerto Rico
    at Mayagüez
Theoretical Physics

MENTORS

RESEARCH
Leslie M. Hartten, NOAA/CIRES

WRITING & COMMUNICATION
Katherine McCaffrey, NOAA

PEER
Briah' Davis
Tony Hurt

Mode Associated with MJO: OLR contribution

Contribution of anomalous five-day-mean OLR to the MJO-like mode during an event in November 2009. Positive OLR anomalies (suppressed convection, in lighter colors) appear on 30-Oct-2009 over the Maritime Continent, preceding MJO convection. Negative anomalies (enhanced convection, in darker colors) appear on 4-Nov-2009 over the Indian Ocean.

Northeast Pacific stratocumulus to cumulus transition in the Community Earth System Model

ARIANNA VARUOLO-CLARKE

3rd-year Protégé
Graduate student
Stony Brook University
Atmospheric Science

MENTORS

RESEARCH
Brian Medeiros, NCAR

WRITING & COMMUNICATION
Karen McKinnon, NCAR

COMPUTER
Gary Strand, NCAR

PEER
Shay Gilpin

SOARS

This project investigates the transition from stratocumulus to cumulus clouds along a northeast Pacific transect from the southern coast of California past Hawaii toward the Equator. The quasi-permanent stratocumulus cloud decks transition to trade wind cumulus clouds along this transect. Since the albedo of stratocumulus and trade wind cumulus are very different, representing the transition between these regimes in present and future climate simulations is important for understanding cloud feedbacks and therefore making credible climate projections. Toward that end, cloud cover and other meteorological variables are analyzed along the transect. Observed meteorological conditions are approximated using reanalysis products, while cloud cover and radiative fluxes are obtained from satellites products. These observations are compared to model simulations from the Community Earth System Model (CESM). The CESM Large Ensemble is used to describe the transition and quantify its variability. Simulations using high-resolution and fixed sea-surface temperature are used to determine whether horizontal resolution or air-sea interactions impact the location and character of the transition. Initial results suggest the CESM's transition occurs near 31°N, 227°E, which we suggest is too far to the northeast compared to observations. These results suggest the need for deeper diagnosis of the model's errors, for example by comparing the surface energy balance along the transect. Such analyses could provide a physical understanding of the transition and inform model development activities.
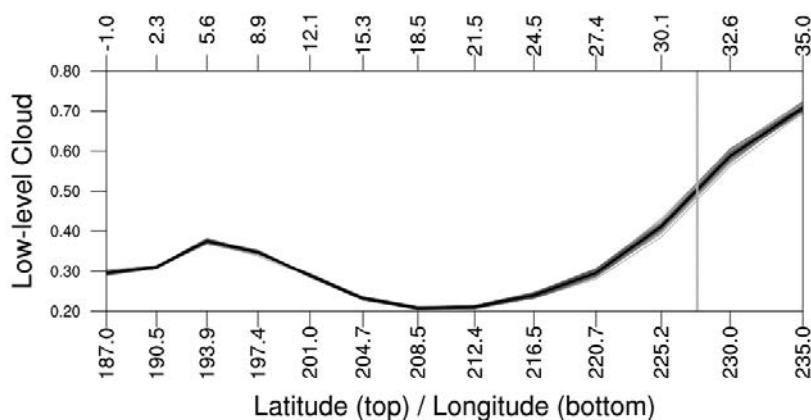
Climatology of low cloud cover (fraction) along northeast Pacific transect during meteorological summer (JJA) for each of the 41 ensemble members (light, gray) and the ensemble mean (thick, black). The vertical thick, gray line marks the beginning of the southwestward "transition"; where cloud fraction is above 50% to the right (unbroken stratocumulus) and below 50% to the left (broken stratocumulus).

Confirming the improved precision and accuracy of a modified airborne carbon monoxide (CO) analyzer for measurement in the upper troposphere

Analyzing carbon monoxide (CO) and ozone (O_3) concentrations in the lower troposphere is of great importance to the atmospheric science community. Elevated concentrations of these gases mainly result from urban anthropogenic sources but then travel throughout the atmosphere. CO gas from combustion serves to track the export of pollutants from the earth's surface. No previous studies have been conducted to verify whether ozone interferes in a CO analyzer commonly flown in research aircraft, the Aerolaser AL5002. This analyzer implements a vacuum ultraviolet (VUV) resonance fluorescence technique. Since plumes of carbon monoxide and ozone are frequently found in the same air parcels, this study was conducted to verify if ozone interferes with the detection of CO. Using two analyzers with identical performance specifications this study also investigated whether a new design flow cell for the instrument would substantially improve the detection of CO. The new cell was designed to increase the signal-to-noise ratio and to reduce the pressure drop across the flow system. Once data had been compared from both instruments over a range of ambient ozone, one of the Aerolaser CO instruments was modified to incorporate the new flow cell. Data was acquired from both instruments over a range of ozone mixing ratios. Results demonstrate that the new flow cell design creates a lower signal-to-noise ratio and that ozone is not a factor in interference. Recommendations for further research in improving CO in-situ instruments implementing the VUV resonance fluorescence technique are also presented.

CO measurements from both analyzers vs. O_3 concentration

Shown are the relative difference in CO concentration from both Aerolaser 5002 analyzers. An unmodified AL5002 (=) and one modified with a new flow cell (◊) are compared to a reference AL5002 under conditions of varying ozone concentration.

Jesse Villalobos

1st-year Protégé
Junior
University of California, Irvine
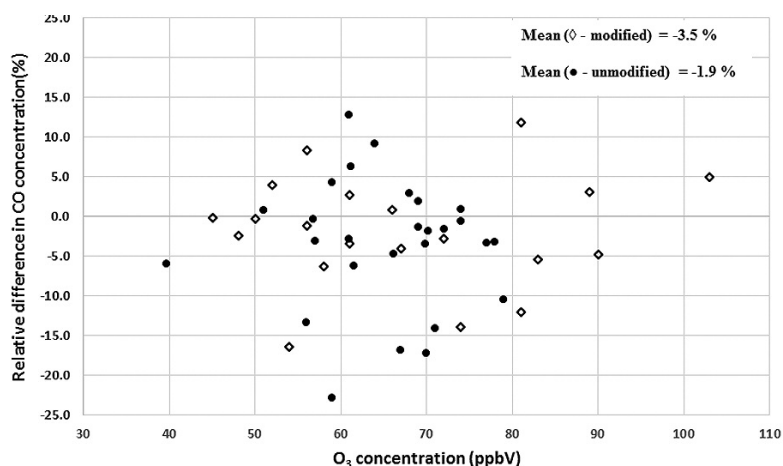Mechanical Engineering

MENTORS

RESEARCH
Teresa Campos, NCAR

WRITING & COMMUNICATION
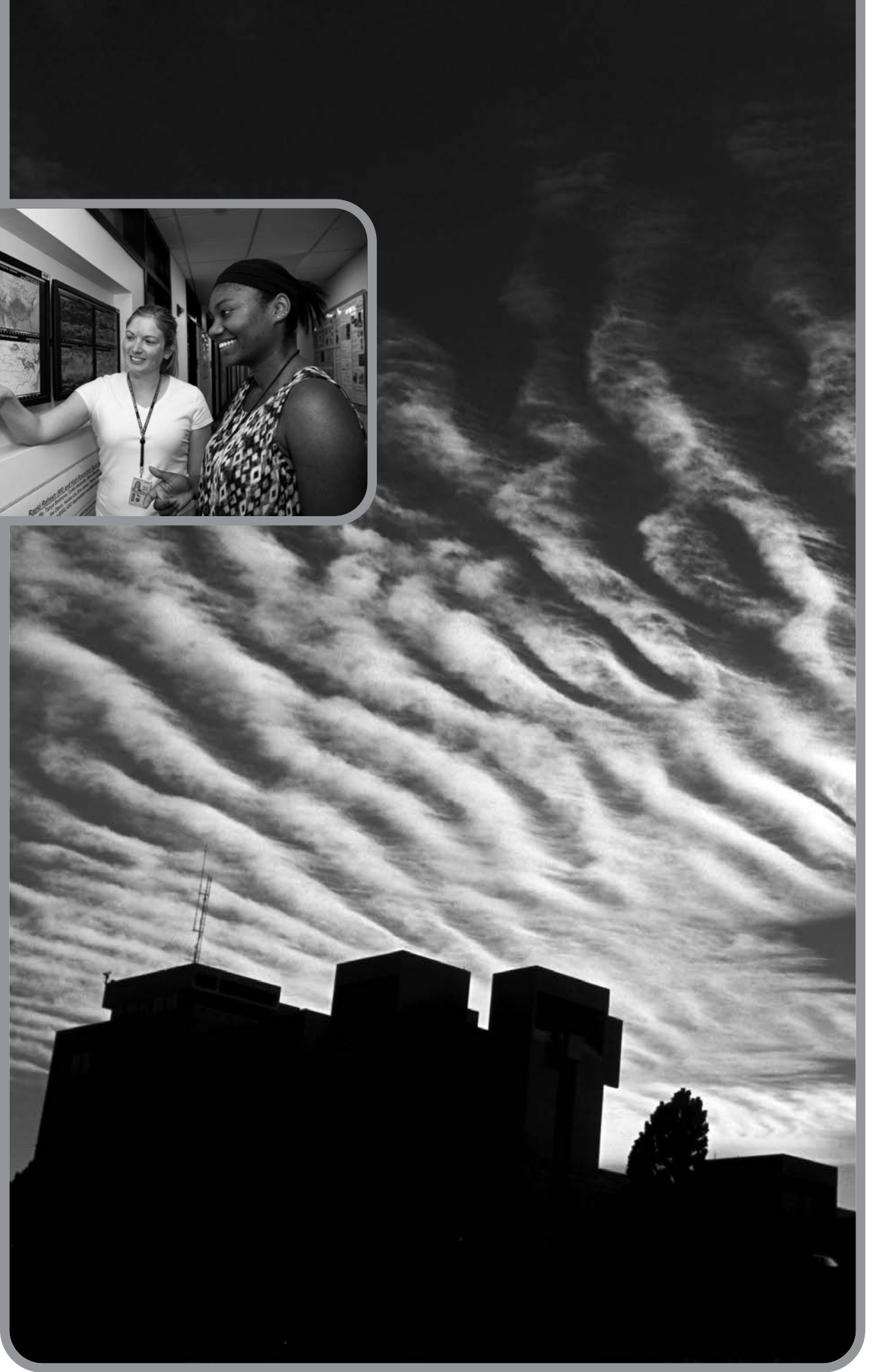Andrea Smith, UCP

COACH
Vanessa Vincente, UCP

PEER
Steven Naegele

SOARS

PRECIP

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

PRE-College Internship Program at NCAR

The NCAR/RAL PRECIP program, now in its seventh year, is designed to provide high school students with an opportunity to gain experience with real-world scientific research and engineering projects and to engage them in STEM-related fields. Six students from local Colorado high schools participated in the program. For eight weeks, the students worked closely with engineers and scientists on projects ranging from precipitation measurements to radar measurements of hailstorms, and the effect of cloud droplet number on orographic rainfall. Students participated in professional development workshops to help them with scientific writing and poster creation skills. They presented posters on their research at the conclusion of the summer program at the joint intern poster session, in conjunction with SOARS and a number of our other partner programs. The PRECIP program is proud of this year´s students and our past students, almost all of whom have gone on to pursue college degrees in STEM-related fields.

Interns are pictured left to right:

Front Row Jessie Bolger, Courtney Delong,* Christine Soh, Emily Markowitz*
Back Row Hisham Haddad, Aakash Venkatesan, Nathan Biesterfeld, Kiernan McClish

*NON-PRECIP HIGH-SCHOOL INTERNS

Diurnal distribution of freezing precipitation in the United States

Nathan Biesterfeld

Fairview High School

MENTORS

RESEARCH
Andrew Schwartz, NCAR

Freezing precipitation conditions can cause aircraft icing when super cooled water freezes upon contact with airplane surfaces. A study was conducted on the climatologies of freezing drizzle, freezing rain, and ice pellet events in order to better understand when occurrences of freezing precipitation are occurring. This study separates previously attained human observations of freezing precipitation by region and then by hour in order to identify the times of day it is most likely for airplane icing to occur in different areas of the United States. This information can be used to make deicing procedures in airports far more efficient. It was found that 1) freezing drizzle is most likely to occur just after sunrise and just after sunset; 2) ice pellets are most likely to occur just after mid-day; 3) freezing rain is most likely to occur around midnight; 4) All the regions had peaks and minimums at similar times across every type of freezing precipitation; 5) Freezing precipitation is much more frequent in Central and Eastern America than in the West; 6) Even though different types of freezing precipitation had peaks and minimums at different times, it is most important to examine the peaks and minimums for freezing rain with respect to airplane icing because it occurs far more frequently than freezing drizzle or ice pellets.

Radar examination of severe hailstorms near Mendoza, Argentina

Jessie Bolger

Fairview High School

MENTORS

RESEARCH
Rita Roberts, NCAR

The agricultural region of Mendoza, Argentina is susceptible to extreme thunderstorms, which sometimes produce hail. Since the damage resulting from these hailstorms devastates acres of crops, three radars have been collecting data for a hail suppression operation in Mendoza. This research examines the formation, frequency, and severity of thunderstorms near Mendoza. An analysis of radar data from three different Argentina radars from December 2010 to February 2012, identifying storm systems' severity and formation, can provide key information for potential preventative measures. This analysis studied fifteen storms with identifiable storm cells and reflectivities above 50 dBZ, indicating high volumes of precipitation. 53.3% of these storms had reflectivities above 65 dBZ, which suggests a high probability of hail. The complete statistical analysis revealed that the majority of the identified hailstorms occurred on the San Martin plains during the night, originating from the Andes in the evening. Based on the storms' times of occurrence and locations of origin, these severe hailstorms are most likely all secondary thunderstorms resulting from the Andes' convection driven storm systems. These conclusions will assist RELÁMPAGO, an upcoming study examining the initial conditions of Mendoza's intense convection-related weather.

An analysis of error sources in a Geonor precipitation algorithm

The Geonor T-200B precipitation gauges at the National Center for Atmospheric Research (NCAR)'s Marshall Field Site reliably measure precipitation, but are susceptible to errors specific to their design. While a post-processing algorithm can correct some errors, others remain in the data. Analysis of these errors was conducted in an effort to aid in optimizing the algorithm and improving the accuracy of the gauge data. It was found that the algorithm was primarily inaccurate at the beginning and end of precipitation events and when there was little accumulation, and recommendations were made for improvements to the algorithm and Geonor data.

Hisham Haddad

Fairview High School

MENTORS

RESEARCH
Megan Lerman, STAR

Variations in snowfall over a vast area

Airports today operate and rely on point observations for determining snowfall rates over the area of the terminal. With only one sensor active, the airport can only accurately observe weather for one small piece of land, rather than the whole terminal, causing problems in the calculations used to determine anti-icing, de-icing, and holdover times. Examination of variation of snowfall rates at scales equivalent to airport terminal areas was needed to aid in accurate holdover times. Data were collected from six Geonor T-200B All Weather Precipitation Accumulation Gauges (AWPAGs) during the 2015/2016 winter, with the distance between each gauge ranging from 0.12 to 9.97km apart. Using a statistical analysis method known as the Coefficient of Variation, snowfall cases were studied for one-minute rate differences over an approximately 10 km area.
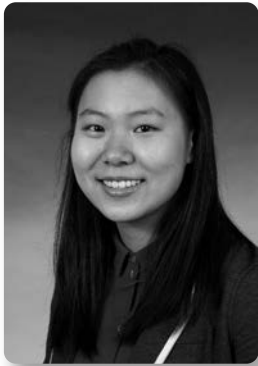
Kiernan McClish

Nederland Middle/Senior High School

MENTORS

RESEARCH
Andrew Schwartz, NCAR

The effect of cloud droplet number concentration on orographic precipitation

Christine Soh

Fairview High School

MENTORS

RESEARCH
Annareli Morales, UM/ASP

Orographic precipitation runoff provides 75% of the water supply to the Western United States. Increased concentrations of aerosols from pollution, acting as cloud condensation nuclei (CCN), have been found to have both a suppressing and delaying effect on precipitation in the life cycle of a cloud. In some micro-physics parameterizations, the concentration of CCN is directly associated with the cloud droplet number concentration (CDNC), which can impact precipitation development. Thus, this study assesses the effect of the CDNC on orographic precipitation using the CM1 model. Idealized quasi-2D simulations of the 13 November 2015 OLYMPEX event were performed with CDNC varied from 50 to 750 cm^{-3}. Results showed that varying CDNC did not have much effect on the dynamics and the cloud structure. An increase in CDNC exhibited both the delaying and suppressing effect on surface precipitation. Additionally, higher CDNC led to a decrease in the spatial distribution of rain upslope of the mountain as well as an increase in the spatial distribution of frozen hydrometeors downstream. As an overall trend, larger changes in precipitation between the lower three CDNC values in this project compared to the changes between the higher three CDNC values suggest the presence of a threshold or an exponentially decreasing effect of increasing CDNC.

Meso-gamma and meso-beta spatial variability for freezing drizzle

Aakash Venkatesan

Fairview High School

MENTORS

RESEARCH
Reid Hansen, NCAR

Freezing drizzle (FZDZ) can have harmful effects on many industries such as energy, transportation and agriculture, and also commonly causes icing on airplanes, which can lead to hazardous flying conditions. A study was conducted in order to determine the spatial variability of freezing drizzle to enhance nowcasting and forecasting capabilities in the United States. To determine spatial variability, data was collected from 21 Automated Surface Observation Stations (ASOS) in five states over an eleven-year period from 2005 to 2016. The data was processed and analyzed utilizing a statistical method known as the Coefficient of Variation. It was found that variation of FZDZ rates during events were smaller when sites were closer in proximity to each other. Stations with closer proximities had lower average coefficients of variation and, therefore, were better correlated during events.

research | mentoring | community

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Key to Mentors' Affiliations

ASP	NCAR Advanced Study Program
CIRA	Cooperative Institute for Research in the Atmosphere
CIRES	Cooperative Institute for Research in Environmental Sciences
CU	University of Colorado at Boulder
KSU	Kent State University
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
SOARS	Significant Opportunities in Atmospheric Research and Sciences
STAR	STEM Teacher And Researcher Fellow
UCAR	University Corporation for Atmospheric Research
UCP	UCAR Community Programs
UM	University of Michigan
VU	Vanderbilt University

Significant Opportunities in Atmospheric Research and Science
University Corporation for Atmospheric Research (UCAR)
www.soars.ucar.edu

PRECIP NCAR

Pre-College Internship Program
www.ral.ucar.edu/projects/pre-college-internship-program-precip

RESEARCH   MENTORING   COMMUNITY