2015 SOARS ABSTRACTS

Earth, Wind, Sea, and Sky

RESEARCH MENTORING COMMUNITY

Protege STANLEY EDWIN on board the National Science Foundation's National Ecological Observatory Network's (NEON) Twin Otter aircraft based at the Boulder airport. In the instrument rack in front of Stanley is the NEON imaging spectrometer, a hyperspectral imaging system used to measure vegetation.

We are very pleased to share with you the 2015 edition of Earth, Wind, Sea, and Sky, showcasing the summer research of students from our Significant Opportunities in Atmospheric Research and Science (SOARS) program. As we head into our 20th year, we are also using this publication as a chance to reflect on just how far we've come — to highlight our alumni who continue to serve as role-models and leaders; our partners who are spreading our mission beyond the atmospheric sciences; the opportunities SOARS has afforded our students; and especially, to celebrate the progress we've made towards an atmospheric science workforce that includes the talent of our diverse population.

The SOARS Program was founded in 1996 under the leadership of then UCAR President Richard Anthes and then NSF Director Neal Lane with the goal of addressing the lack of representation in the atmospheric sciences. Much has changed in the field since the program's early days and we are seeing some encouraging progress. Many of our alumni now hold leadership positions in academia, research and private industry. Still though, we face a discrepancy between the demographic makeup of the science workforce and the country as a whole, and the need for SOARS remains. We continue to strive towards a scientific workforce representative of the US population, especially including members of those groups who are already, and will continue to be, disproportionately impacted by current and future environmental change.

SOARS is known for encouraging students from groups that are historically under-represented to enter the atmospheric and related sciences, and has built a strong track record of exposing them to a range of opportunities in the field while preparing them to succeed in graduate school and the professional workplace. We engage students in real-world projects at world-class science facilities, pair them with scientists and engineers who are at the cutting edge of their fields, and build community to support these future STEM professionals. Our students get the opportunity to experience fieldwork and even do international work. This year alone we had protégés skiing on glaciers in Alaska, chasing nighttime storms across the Great Plains, sampling water on NOAA vessels in the waters off Cape Cod, Massachusetts, and working in rural communities in northern Ghana.

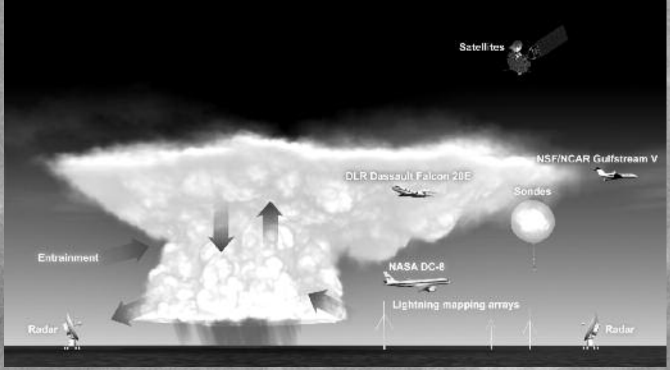
Beyond the program itself, we are actively building a network of programs and individuals who will create and support a culture of mentoring for all students to achieve their full potential. Many of our alumni are now in positions of leadership in academia, research and private industry and can carry our vision forward. Alumna like Talea Mayo, who is now faculty herself (see her profile on page 23), apply what they learned in SOARS to mentor the next generation of scientists. To build a community-wide culture of mentoring we are establishing collaborations with other laboratories and universities and helping to build programs modeled after SOARS. We highlight some of these partnerships on page 28.

We're very proud of every summer cohort and it's no different this year! The 2015 SOARS protégés did excellent research and formed a supportive cohort of peers who will be there for each other for years to come. Their success would not be possible without the support and dedication of a number of people and organizations. The biggest thank you goes to our funders, our many partnering laboratories, and of course to our mentors. Thank you for your careful guidance of the protégés, and for modeling what an exciting science or engineering career looks like! Without you these programs would not be possible. A special acknowledgement goes to Thomas Windham, SOARS director from its inception until 2004, and Rajul Pandya, who led the program until 2011. Their vision and dedication shaped the wonderful program it is today. We'd also like to thank our alumni, who continue to engage with each other, the program, and especially the current cohort of protégés. They serve as speakers on our panels, judges in our poster session, mentors and provide an unquestioning support for us all.

We hope that you will enjoy this edition of Earth, Wind, Sea and Sky. Thank you for your continuous support and please join us in congratulating our 2015 SOARS protégés!

Earth, Wind, Sea, and Sky

REBECCA HAACKER
SOARS Director



Satellites
NSF/NCAR Gulfstream V
DLR Dassault Falcon 20E
Sondes
Entrainment
NASA DC-8
Lightning mapping arrays
Radar
Radar

UCAR/NCAR

BIG BILL

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 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 our program.

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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 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.

research | mentoring | community

SOARS®

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.

Modification of a tropical storm tracking algorithm for extra-tropical cyclone detection

Ryan Adams

2nd-year Protégé
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Geography

MENTORS

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WRITING & COMMUNICATION
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COMPUTING
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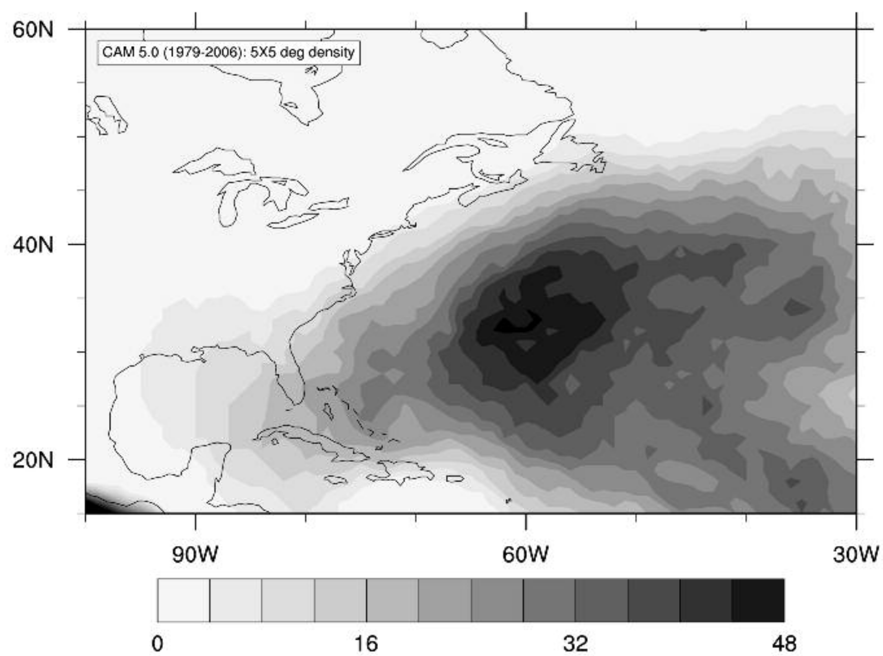
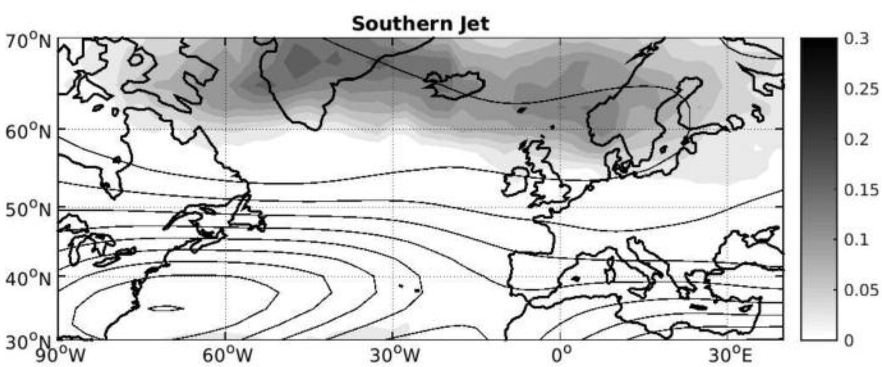
Extra-tropical cyclones are the main source of weekly weather variability across much of the middle latitudes and are often associated with damaging winds, coastal erosion, and significant snowfall. Under the right dynamic and thermodynamic conditions, these cyclones may rapidly intensify. This rapid intensification is called "bomb" cyclogenesis, and is particularly hazardous due to its low predictability and associated weather hazards. Using six-hourly Community Atmosphere Model (CAM 5.0) simulation output with a 0.25°×0.25° resolution for 1979-2006, an objective-based approach was implemented to modify a Geophysical Fluid Dynamics Laboratory (GFDL) tropical cyclone tracking algorithm to detect extra-tropical cyclones. The modification of the algorithm will be useful for future analyses based on extra-tropical cyclone climatology assessment. Systematically adjusting the algorithm thresholds reveal the sensitivities of tropical cyclone track density to each parameter in CAM 5.0 simulations. Increasing the radial distance threshold for a tropical cyclone at time t_0 to the same cyclone at time t_1 increases the Atlantic tropical cyclone storm count and deviates the Atlantic basin tropical storm track density. Additionally, decreasing the cyclone lifespan requirement from 3 days to 1 day increases tropical storm count globally and is more characteristic of storms traversing the North Atlantic in extra-tropical transition.



Atlantic tropical cyclone track density in Community Atmosphere Model (CAM 5.0) simulations for 1979-2006 with the default parameters in the GFDL tracking algorithm. The parameters reflect an 850 hPa vorticity maximum of 1.6×10^{-4} s^{-1}, 17 ms^{-1} wind velocity, and a lifespan of 3 days.

North Atlantic Oscillation, jet and blocking in CESM1 large ensemble simulations

Atmospheric blocking is a weather phenomenon that occurs when an upper-level anticyclone blocks the mid-latitude westerly flow causing it to divert to the north or south of the anticyclone. The associated anomalous circulation can often lead to severe weather events such as heat waves, cold spells and droughts. It has been shown that the winter North Atlantic Oscillation (NAO) is anticorrelated with the number of blockings near Greenland due to a southerly displacement of the jet. Climate models have been shown to underestimate the number of blockings near Greenland. In this study, the daily jet latitude index was constructed to quantify the origin of blocking bias in the 30 member ensemble simulations of the Community Earth System Model version 1 (CESM1). A previous study showed that the predecessor model of CESM1 exhibited a Gaussian distribution of the jet latitude at 850 hPa, while the reanalysis showed a trimodal distribution. In this work, we found the 20th century historical simulations of the CESM1 exhibited trimodal distributions of the jet latitude at 850 hPa, consistent with the reanalysis. However, the range of the jet latitude simulated in the CESM1 was still narrower compared to the reanalysis. A relationship between the jet location and blocking frequency from the reanalysis showed that a southern jet location causes the blocking near Greenland, as the central and northern jet locations have blocking on the south side of the jet. The CESM1, however, doesn't display this relationship as the southern jet doesn't move far enough south. These relationships were also examined for the 21st century.



The jet location (contoured every 5 m/s) is related to the location for the highest atmospheric blocking frequency (shading), such that a southern jet location is accompanied by the blocking north of the jet near Greenland.

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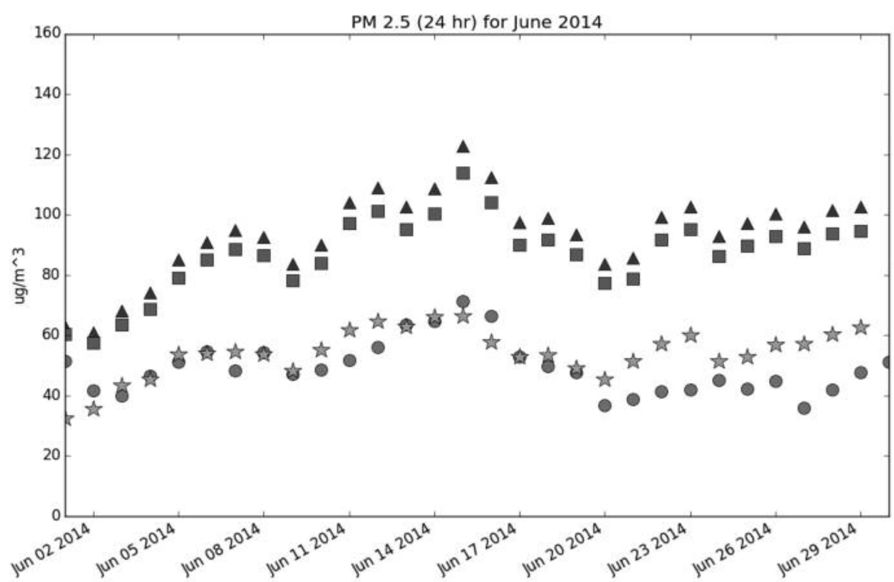
Assessing air quality sensitivity to residential emissions using WRF-Chem model simulations and observational data in China

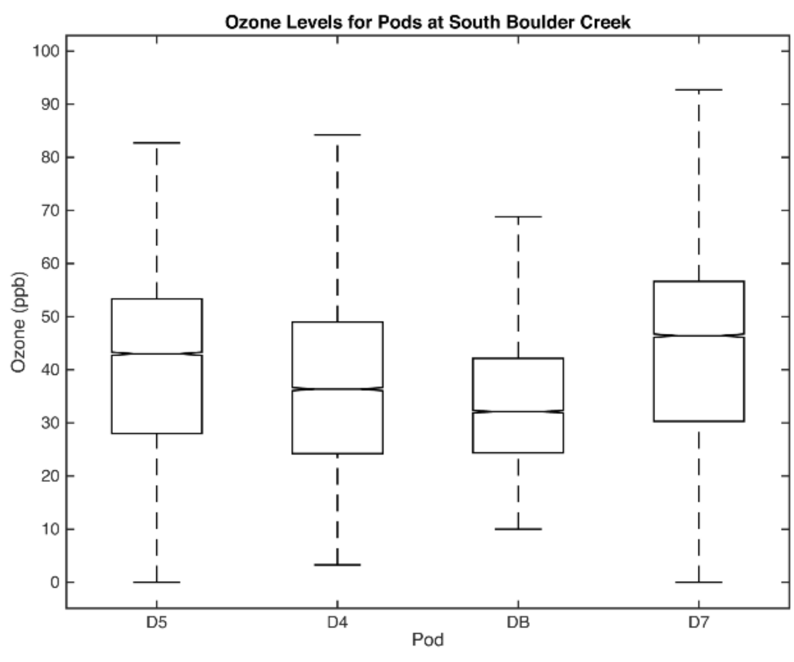
Poor air quality negatively affects respiratory health in humans and is a major killer in developing countries. Approximately 2.8 billion people burn solid fuels that introduce toxic gases and particles into the atmosphere. These residential emissions emit large quantities of particulate matter; particulate matter below 2.5 µm in diameter ($PM_{2.5}$) is strongly correlated to respiratory illnesses and diseases. Globally, exposure to residential emissions caused approximately 3.5 million premature deaths in 2010. China is currently facing an air quality crisis. Residential sources of $PM_{2.5}$ in China accounted for 34% of total emissions in 2005. Reducing particulate emissions from solid-fuel cook stoves has the potential to significantly improve China's air quality. This research project poses the following questions: can the Weather Research and Forecasting model with Chemistry (WRF-Chem) be used to accurately predict air pollutant concentrations over China, and what contribution do residential emissions have to the air quality in China? To investigate the question, model simulations are compared with an observational dataset of 945 measurements. The observational data are of chemical atmospheric gases and aerosols with measurements taken hourly throughout the day. There is a bias towards overestimating the aerosol loadings, with the All Emissions scenario showing an average difference of 44.49 $\mu g/m^3$ in June and 41.98 $\mu g/m^3$ in December. This bias is not so strong when using the MOZCART chemical-aerosol scheme. However, the model captured seasonal trends well when compared with data. There is an average difference of 6.68 $\mu g/m^3$ in June 2014 and 20.94 $\mu g/m^3$ in December 2014 between the model simulations of All Emissions and No Residential Emissions scenarios, showing that residential emissions contribute a large component of the $PM_{2.5}$ pollution in China.



June 2014 measurements of $PM_{2.5}$ from observed data (circles) with WRF-Chem model simulations. The emissions scenarios are: All Emissions (triangles) and No Residential Emissions (squares). The WRF-Chem simulation with the MOZCART chemistry-aerosol scheme and all emissions is indicated by the stars.

Small-scale spatial variability of ozone in Boulder, Colorado

Surface ozone (O_3) is detrimental and can pose several health problems to humans, such as increased and more intense asthma attacks. Considering this, it is important that these ozone levels be monitored. While municipal air quality monitors are present in cities like Boulder, Colorado, these monitors often only consider regional analysis, neglecting the variability of compounds, such as ozone or carbon monoxide, over smaller distances. Small-scale (approximately 1 kilometer) spatial variability in ozone is important because humans experience these small scales on a daily basis. Using low-cost, next-generation air quality monitors ("pods") developed at the University of Colorado at Boulder, the small-scale spatial variability of surface ozone in Boulder, Colorado was assessed. This was done by placing clusters of 4-5 pods within approximately 1 kilometer of each other at specific sites in the city of Boulder. Pods were left in their positions for one to two weeks allowing for observation of ozone trends. Data collected by the pods allowed for better understanding of small-scale spatial variability of surface ozone. As expected, higher ozone levels were detected during the afternoon hours, probably due to increased sunlight during this time. Also, the pod located closest to the roadway had the largest range of ozone data, which is plausible when considering its location. Finally, after statistical analysis, it was determined that the differences in the pods' ozone levels at South Boulder Creek were statistically significant. This implies that ozone levels can be different over small spatial scales and should be monitored.



Ozone levels detected by pods at South Boulder Creek from June 29 - July 11, 2015. Pods furthest to the left were located furthest from the roadway. The differences in the location of the notches between pods indicate statistically significant differences in the ozone levels detected by the pods.

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Links between oxygen minimum zones and the Hadley circulation

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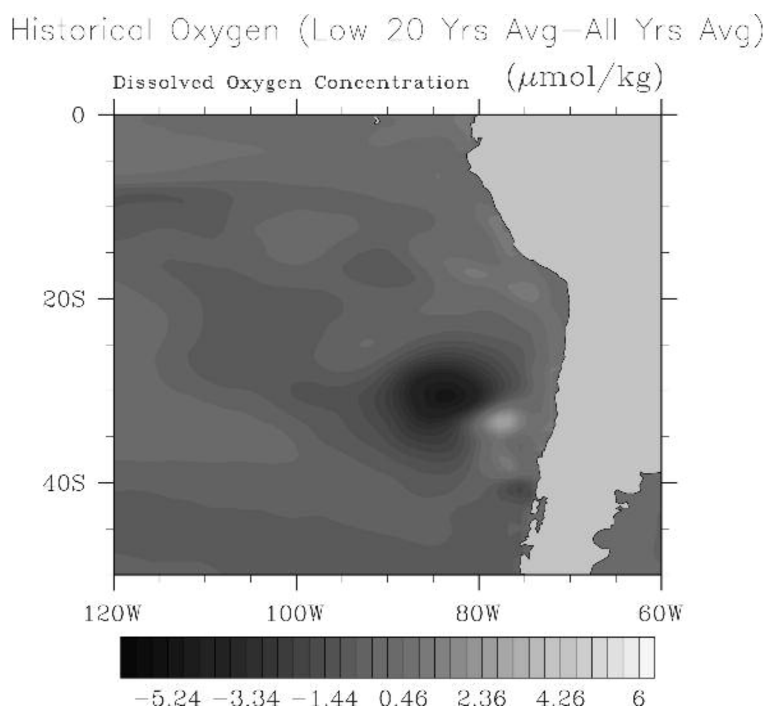
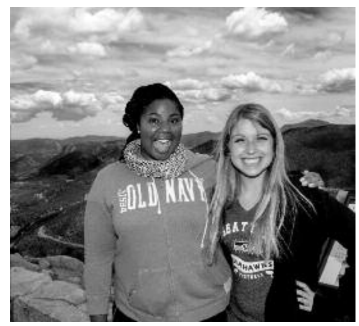
SOARS

This research aimed to find links between the projected changes in oceanic oxygen minimum zones (OMZs) and the Hadley Circulation (HC). OMZs are regions of very low oxygen concentration. Latitudinal ocean oxygen slices place the OMZs in the eastern edges of ocean basins. Recent research suggests that the HC is composed of three regional cells instead of the two globe-encircling cells previously thought to be the case. These three cells are co-located with OMZs along the eastern edges of ocean basins. The HC and OMZs are expected to expand in concert with global warming, which will have many consequences. The National Center for Atmospheric Research (NCAR) Community Earth System Model 1.0 (CESM1), Representative Concentration Pathways 8.5 experiment with a resolution of 0.9 by 1.25 degrees was used for this analysis. It was run via the Coupled Model Intercomparison Project phase 5 (CMIP5), and the data was retrieved from the Woods Hole Oceanographic Institution (WHOI) community storage server. Meridional winds and oceanic oxygen concentrations were the primarily analyzed variables, along with sea surface temperature and upward ocean mass transport. Meridional winds overlaid with oxygen concentration were suggestive of links between the surface Hadleywise flow and OMZs. Area-averaged time series spanning historical through RCP8.5 to 2100 indicate that future changes in OMZs and the HC may be connected. Establishing relationships between the secondary and primary variables may increase our understanding of the responsible mechanisms.



Average of the 20 years of lowest oxygen concentrations minus the average of all oxygen concentrations, 1850-2005, for the top 2000 m of the water column off the west coast of South America. The darker colors indicate a decrease in oxygen concentrations, and the lighter colors indicate the opposite. An oxygen minimum zone can be seen quite clearly around 30S, 85W.



Protégés are pictured left to right:

Front Row Jenine McKoy, Alan Gorchov Negron, Alicia Camacho, Breanna Zavadoff, Rosa Vargas Martes, Lauren Deanes, Nkosi Muse, Meghan Mitchell
Back Row Anthony Torres, Ryan Adams, Awolou Sossa, Steven Naegele, William Evonosky, Erin Dougherty, Stanley Edwin
Not Pictured Eugene Cody, Gabriela De La Cruz Tello, Zoraida Pérez Delgado, Arianna Varuolo-Clarke

Precipitation characteristics of warm-season nocturnal convection in the Great Plains as determined by ground-based measurements during the PECAN field campaign

Erin Dougherty

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MENTORS

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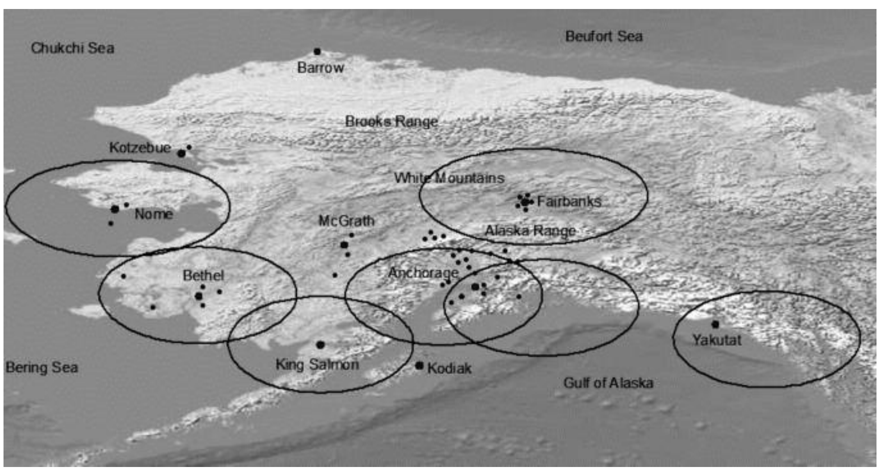
During the summer in the Great Plains, some of the heaviest precipitation falls from large thunderstorm complexes known as Mesoscale Convective Systems (MCSs). These frequently occurring MCSs are often nocturnal in nature, so the dynamics associated with these systems are more elusive than those in the daytime. The Plains Elevated Convection at Night (PECAN) field campaign was launched over a 7-week period with the goal to better understand nocturnal MCSs occurring in the Great Plains. PECAN featured a dense array of ground-based and airborne instruments to observe nocturnal MCS, including dual-polarization radars at multiple frequencies, mobile mesonets, and sounding units. Our role in PECAN involved deploying Parsivel disdrometers to gain information on drop size distribution (DSD) and fall speeds. Analysis of disdrometer data in conjunction with radar data, contour frequency by altitude diagrams, and radiosonde data allowed for a horizontal and vertical structural comparison of two severe, nocturnal MCSs – an MCS in South Dakota with a leading-line trailing-stratiform configuration and an MCS in Missouri with a less-classic configuration. These two cases were examined to better understand the environmental conditions supporting upscale growth into a robust nocturnal MCS with a large stratiform region compared to conditions that inhibit the growth of stratiform precipitation. Understanding the environmental conditions that resulted in different nocturnal MCS configurations is useful for gaining insight into precipitation distributions and potential flooding hazards in the Great Plains.

Lightning from a nocturnal mesoscale convective system illuminates a field site in Goodnight, TX, featuring a disdrometer (left) measuring the rain drop-size and fall speed and a mobile pod (right) collecting basic weather data. Similar set-ups like the one depicted were deployed across the Great Plains as part of the PECAN field campaign.

Characteristics and forcing mechanisms of funnel clouds in Alaska

There are no forecasting systems for funnel clouds in Alaska. This is problematic because funnel clouds can pose a threat to aviation, which serves as Alaska's main form of transportation. Motivated by the lack of understanding of the formation of funnel clouds, this research investigated characteristics of funnel clouds and the atmospheric conditions under which they form using operational Doppler weather radar and soundings as well as synoptic weather maps. Funnel clouds usually occur during the summer months of May to September, with a maximum of occurrence in July, and during the day at around 1500 UTC. The observed funnel clouds are usually not associated with severe thunderstorms and do not occur with strong synoptic forcing. As such, it can be hypothesized that local effects from sea breeze fronts and orographic circulations might be the main forcing. Operational soundings indicate that some, but not all, funnel cloud events occurred under conditions of large convective available potential energy and strong low-level wind shear. Funnel clouds were difficult to identify in Doppler weather radar because these clouds display small cross-sectional area compared to the radar resolution.



Funnel cloud sightings throughout Alaska, from 1955 to present. The smaller dots represent the funnel cloud sightings, while the larger dots represent NWS sounding sites. The circles illustrate the maximum observation range obtained from the Nexrad WSR88D weather radar.

Stanley Edwin

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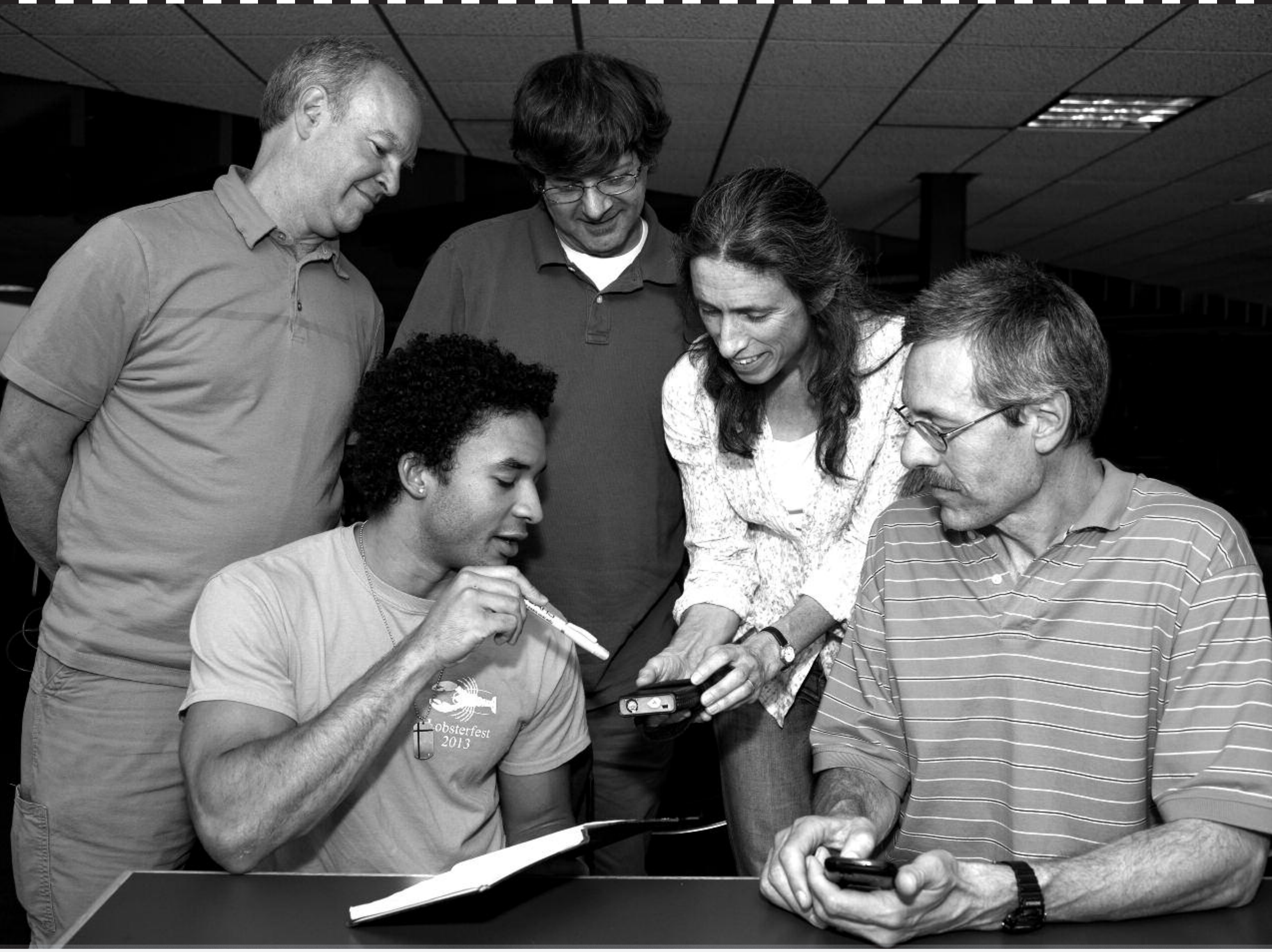
WRITING & COMMUNICATION
Vu Nguyen, CU



MENTORING IS AT THE HEART OF SOARS

SOARS combines multi-year summer research experiences with intensive mentoring and a supportive learning community to help undergraduate students gain research experience, complete college and make successful transitions into graduate school and careers. A unique and important aspect of SOARS is its strong, formal mentoring structure. Mentors provide relevant resources, transfer necessary skills, advice about career options, introduce protégés professionally, assist in career placement, and provide inspiration and personal support.

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. This provides the student with a broad sense of support and multiple opportunities to make a meaningful personal connection, while also leveraging the time and knowledge of the many people who contribute to SOARS as mentors. These formalized mentoring relationships are focused on the summer internship part of the program, while a strong peer cohort and support from staff runs year-round and, to a lesser degree, over many years.

In any given year, more than 50 scientists, engineers, programmers and other staff spanning a number of organizations serve as mentors. Many of these are now SOARS alumni, who are committed to the program and want to give back. A large number serve as mentors year after year. Their reasons for mentoring range from wanting to work with talented students to a commitment to diversity—or just because they enjoy it!

Leslie Smith (CIRES, NOAA, formerly at NCAR)

has mentored many SOARS students in scientific writing and giving presentations over the last 15 years. She says ***"I always find SOARS fun. Interacting with mentors and protégés is fun. I enjoy meeting other professionals across the organization. I also always learn science stuff. For example, [my protégé] Nkosi taught me about NWS shapefiles which I've used since the summer in my own research. I talked to several protégés at the poster session and was amazed at all the awesome research I discovered. It makes me optimistic for our future!"***

Vu Nguyen (CU)

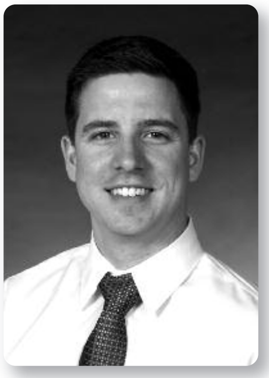
a graduate student at CU-Boulder, has served as a writing mentor for SOARS for the past two summers. He says ***"SOARS has showed me that having people from diverse backgrounds greatly enhances the range of perspectives and skills of the science workforce. My protégé, for example, comes from a unique background as an older student living in rural Alaska and as a result, he has a different way of explaining things and approaching problems. These non-traditional ways of thinking, which may not exist without diversification, are essential in making further progress in science."***

Brian McDonald (NOAA)

is a new research mentor. He guided a SOARS protégé scientifically for the first time in 2015. He says that working with SOARS ***"started research in a new area which would not have occurred without the help of [his protégé] Alan."*** He describes his protégé as ***"exemplary in his work, so much so that he is continuing on with his project and is planning to write a peer-reviewed publication and present at the AGU Fall meeting."***

Many thanks to our wonderful mentors. We couldn´t do this program without you!

Interactive ion-neutral dynamics in the low latitude evening ionosphere



William Evonosky

1st-year Protégé
Senior
University of South Florida
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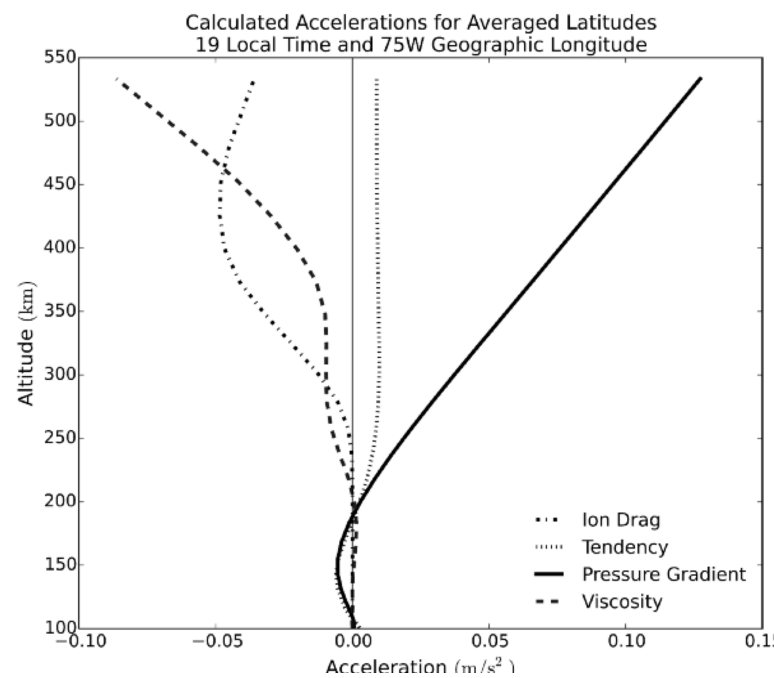
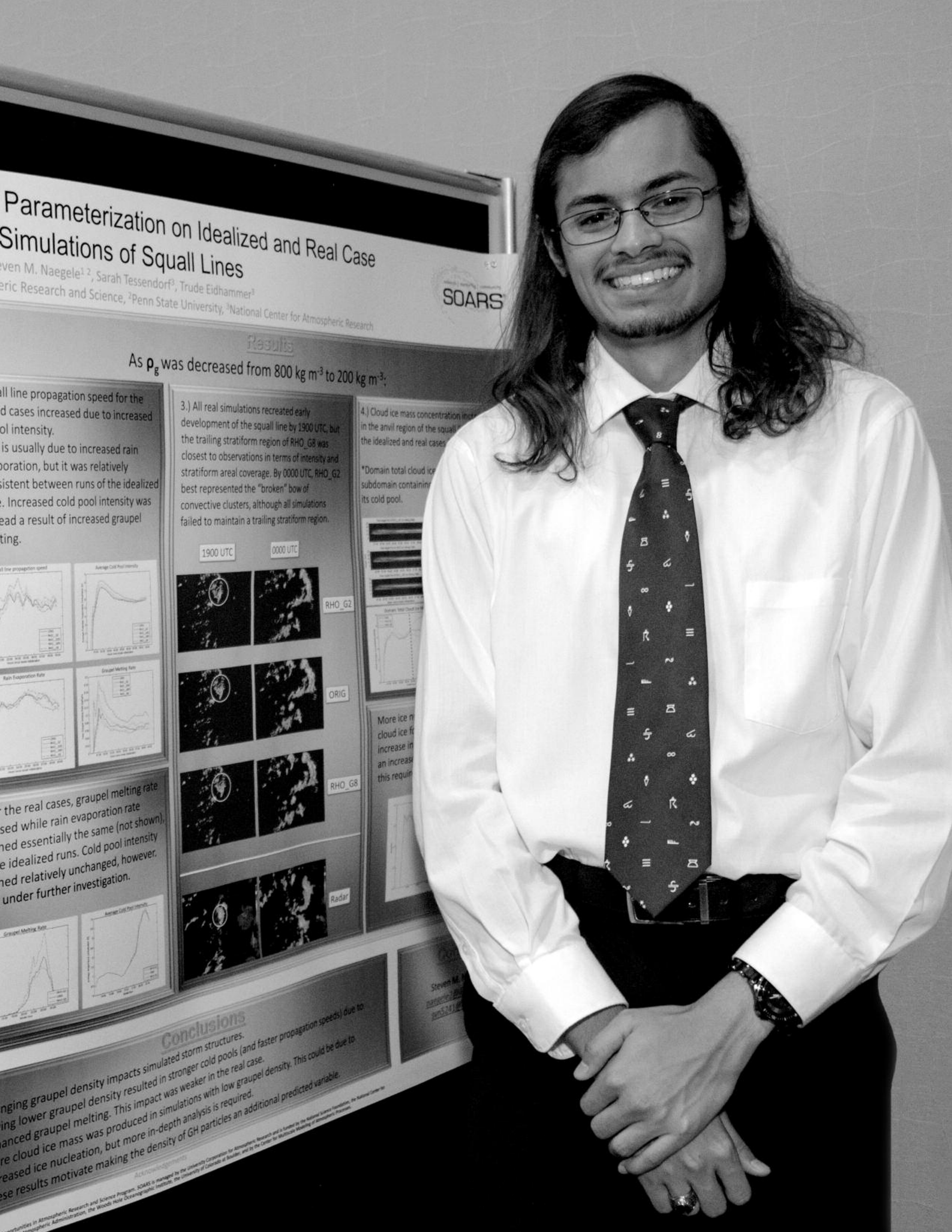
COMPUTING
Bill Anderson, NCAR

COACH
John Ristvey, UCP

This study examined the relationship between accelerations acting on neutral winds in the ionosphere and the formation of a vertical shear of these winds in low latitudes (between ±30° magnetic) and early evening local times (16-22 LT). Accelerations were calculated using variables output by the thermosphere ionosphere electrodynamics general circulation model under different solar activity and night time ionization initial conditions and visualized both spatially and temporally. In general, with acceleration values averaged along magnetic latitudes between ±30° degrees (inclusive) and only considering medium solar activity conditions, we found that the ionosphere exhibits distinct layering defined by the dominant accelerations in each layer. The pressure gradient dominates the net acceleration below ~200 km while it tends to be offset by ion drag above ~300 km and viscosity in between. We also found hints that during different night-time ionization levels, ion drag acceleration tends to remain constant while ion and neutral velocities change to conserve the difference between them. When considering specific latitudes and initial conditions, previously unreported phenomena appear which involve interactions between the ion drag and viscous forces. One such phenomenon (found in minimum solar activity conditions and from 0° to +30° magnetic latitude) is the viscosity acceleration becoming dominant in balancing the pressure gradient acceleration for all altitudes above 200 km with the ion-drag acceleration remaining significantly smaller in magnitude. Another interesting feature was the damping of neutral velocities by 10-25 m/s in medium and higher solar activity conditions above ±15 magnetic latitude.



The ionosphere exhibits layering characterized by the dominant accelerations in each layer. Below 200 km the pressure gradient drives the neutral tendency and above 300 km the ion drag dominates in balancing the pressure gradient with viscosity playing the larger role in between. The result is a net eastward acceleration of the neutral winds in the early evening.


Parameterization on Idealized and Real Case
Simulations of Squall Lines
Sarah Tessendorf, Trude Eidhammer
Penn State University, National Center for Atmospheric Research
SOARS
Results
As ρg was decreased from 800 kg m-3 to 200 kg m-3:
3.) All real simulations recreated early development of the squall line by 1900 UTC, but the trailing stratiform region of RHO_G8 was closest to observations in terms of intensity and stratiform areal coverage. By 0000 UTC, RHO_G2 best represented the "broken" bow of convective clusters, although all simulations failed to maintain a trailing stratiform region.
1900 UTC
0000 UTC
RHO_G2
ORIG
RHO_G8
Radar
Rain Evaporation Rate
Graupel Melting Rate
Average Cold Pool Intensity
Conclusions
Acknowledgements

A spatially resolved fuel-based inventory of U.S. oil and natural gas emissions

Alan Gorchov Negron

1st-year Protégé
Junior
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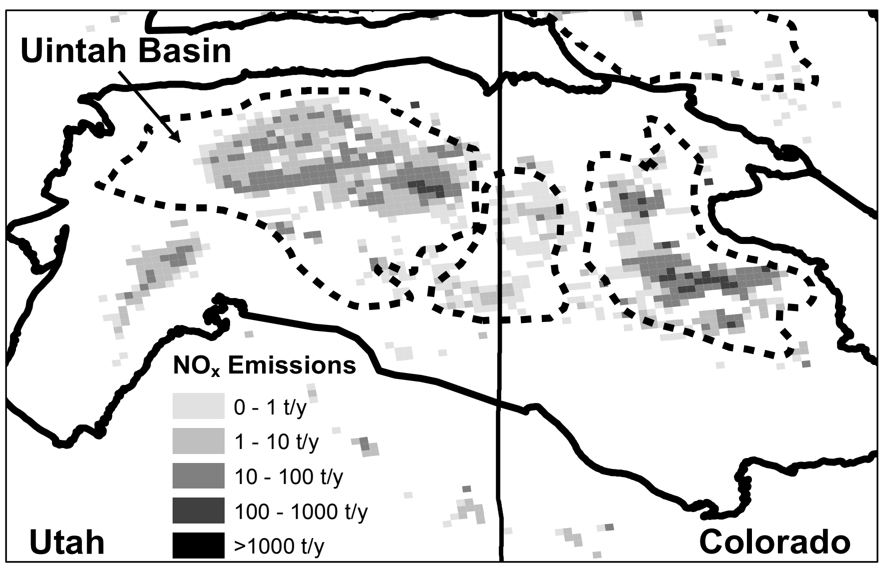
COACH
Amy Solomon, NOAA & CIRES

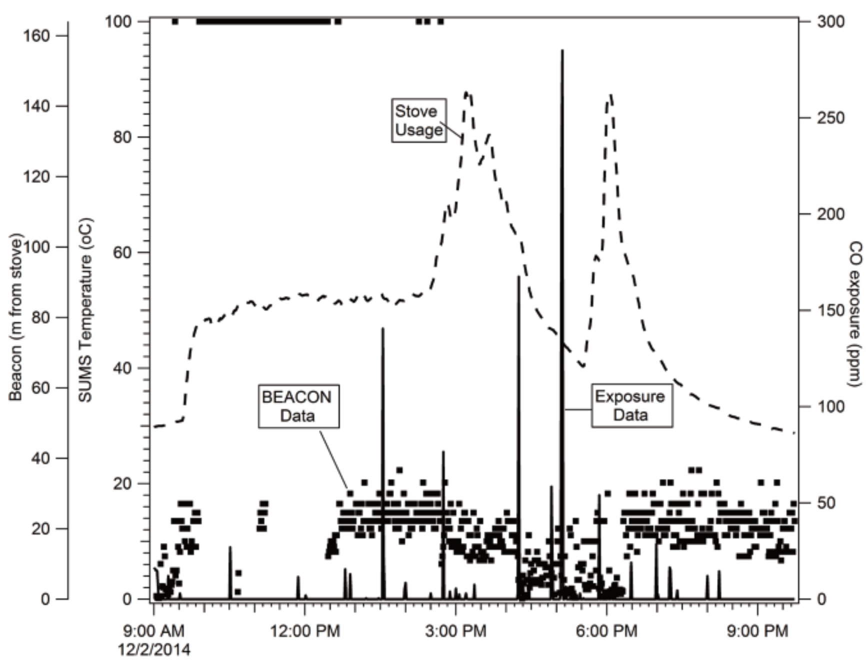
The recent rise in US production of natural gas and crude oil has intensified the need to quantify emissions from the exploration, production, and processing of hydrocarbons in shale basins because they pose consequences for air quality and climate change. However, it is difficult to estimate emissions due to large uncertainties in oil and gas engine activity and emission factors, which are continuously evolving. A fuel based approach is presented that utilizes state-level fuel surveys on oil and gas activity, well-level production data, and emission factors. CO_2 and NO_x emissions are mapped on a 4 km x 4 km horizontal grid for 2013-14 in Utah and Colorado. Emission sources include combustion from exploration (e.g., drilling), production (e.g., heaters, dehydrators, and compressor engines), and natural gas processing plants, which comprise much of the local combustion activity in shale basins. Fuel-based emissions factors of NO_x are from the U.S. Environmental Protection Agency, and applied to maps of CO_2 emissions. NO_x emissions from this study for the Uintah Basin, UT, are consistent with top-down estimates derived from measurements, ~5324 versus ~4158 metric tons per day, respectively. We intend to expand our fuel-based approach to map emissions in other basins across the US and compare with observational datasets.



Emissions of nitrogen oxides from oil and gas exploration, production, and natural gas processing plants during 2013-2014. Tight gas basins are outlined by solid lines and tight gas plays are outlined by dashed lines.

Risky exposure: Methodologies for examining air pollution in northern Ghana

In developing nations, the majority of the population burns biofuels to cook and heat their homes. Over time, emissions generated from open fires have impacted regional and global climate, air quality, environment and health. The REACCTING (Research of the Emission, Air Quality, Climate and Cooking Technologies in Northern Ghana) Project uses a 200 household cookstove intervention to understand cooking behaviors in Navrongo, Ghana. The REACCTING Project also includes the implementation of a microscale and macroscale measurement campaign within the region. Evaluation of the health and environmental impacts of cooking activities in the study region depends heavily on the quantification of three factors: pollutant emissions from stoves, participants' exposures to cookstove emissions, and participant proximity to stoves relative to other pollutant sources. Over the course of the REACCTING study, stove usage, personal carbon monoxide, and personal range measurements have been collected and compiled. In this study, we developed a database that was used to identify cooking and exposure events at particular study households. The classification of co-located data resulting from examination of the database enables a more complete assessment of personal exposures to cookstove smoke relative to other pollutant sources. This study also highlights the challenges and uncertainties associated with emissions and exposure studies in developing countries.



Co-located stove usage (SUMs), exposure (personal CO) and range measurements (beacon data) used to identify cooking and exposure relationships at household NBC59 on December 2, 2014.

Jenine N. McKoy

3rd-year Protégé
Senior
University of Michigan
Environmental Engineering

MENTORS

RESEARCH
Michael Hannigan, CU
Ricardo Piedrahita, CU
Christine Wiedinmyer, NCAR

WRITING & COMMUNICATION
Julie Malmberg, UCP

COMPUTING
Keith Maull, NCAR

SOARS

SOARS IN THE FIELD

FIELD WORK is a unique and important part of the geosciences. The close quarters, long hours, instrumental pressures and changing demands of a field campaign are an experience unto themselves. Not every scientist enjoys field work and giving students an opportunity to try it out before they decide on their graduate research direction has a significant benefit for the student. And even if they decide that field work is not for them, having a better grasp of the field process, the uncertainties inherent in data collection and a respect for the scientists, engineers and technicians making measurements helps build a better scientist and collaborator. For the mentor, having enthusiastic extra hands can be a great advantage on a field campaign. As such, SOARS is committed to helping our students get in the field where they can. In 2015 there were a number of students involved in field work:

Erin Dougherty and **Anthony Torres** participated, with their mentors, in Plains Elevated Convection At Night (PECAN); a large multi-organizational field campaign aimed at better understanding nocturnal mesoscale convective systems. **Arianna Varuolo-Clarke** was supported,in partnership with Elizabeth City State University, in joining the Juneau Icefield Research Program where she spent six weeks on a glacier digging snow pits and living with 50 other upcoming polar scientists. And **Jenine McCoy** joined her research team collecting data in Ghana—a process she says gave her a whole new respect for the challenges and difficulties in conducting multi-disciplinary and social research. Closer to home, **Lauren Deanes** used a new instrument, developed by her mentors at the University of Colorado at Boulder, to measure ozone around the city—learning along the way the challenges of instrument development, calibration and deployment. Despite the long hours and the intense environments, these students came back excited about their research and experiences, and felt better prepared for entering graduate school.

Validating the WRF-Chem model for wind energy applications using High Resolution Doppler Lidar data from a Utah 2012 field campaign

Models are important tools for assessing the potential of wind energy sites, but the accuracy of these projections has not been properly validated. In this study, High Resolution Doppler Lidar (HRDL) data obtained with high temporal and spatial resolution at heights of modern turbine rotors were compared to output from the WRF-Chem model in order to help improve the performance of the model in producing accurate wind forecasts for the industry. HRDL data were collected from January 23 - March 1, 2012 during the Uintah Basin Winter Ozone Study (UBWOS) field campaign. The model validation method was based on the qualitative comparison of the wind field images, time-series analysis and statistical analysis of the observed and modeled wind speed and direction, both for case studies and for the whole experiment. To compare the WRF-Chem model output to the HRDL observations, the model heights and forecast times were interpolated to match the observed times and heights. Then, time-height cross-sections of the HRDL and WRF-Chem wind speed and directions were plotted to select case studies. Cross-sections of the differences between the observed and forecasted wind speed and direction were also plotted to visually analyze the model performance in different wind flow conditions. A statistical analysis included the calculation of vertical profiles and time series of bias, correlation coefficient, root mean squared error, and coefficient of determination between the two datasets. The results from this analysis revealed where and when the model typically struggled in forecasting winds at heights of modern turbine rotors so that in the future the model can be improved for the industry.

MEGHAN MITCHELL

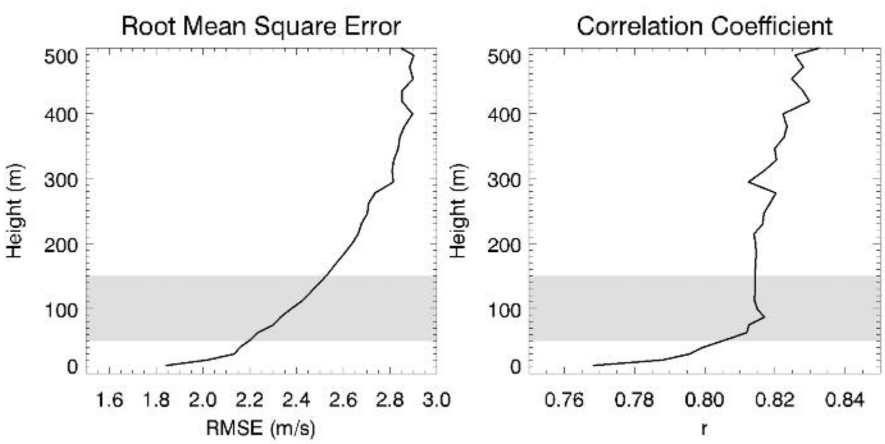
3rd-year Protégé
Graduate Student
Texas Tech University
Atmospheric Science

MENTORS

RESEARCH
Robert Banta, NOAA
Yelena Pichugina, NOAA & CIRES

WRITING & COMMUNICATION
Imke Durre, NOAA

COMPUTING
Dustin Swales, NOAA



Left: The root mean squared error (RMSE) between the observations and the model for wind speed.
Right: the correlation coefficient (r) between the observations and the model for wind speed.
The shaded region indicates the turbine rotor layer, defined as 50 - 150 m.

Ingesting geospatial data into Hazard Services' database for National Weather Service flood alerts

Nkosi Muse

1st-year Protégé
Junior
University of North Carolina
at Charlotte
Meteorology

MENTORS

RESEARCH
Tracy Hansen, NOAA
Kevin Manross, NOAA & CIRA
Joseph Wakefield, NOAA

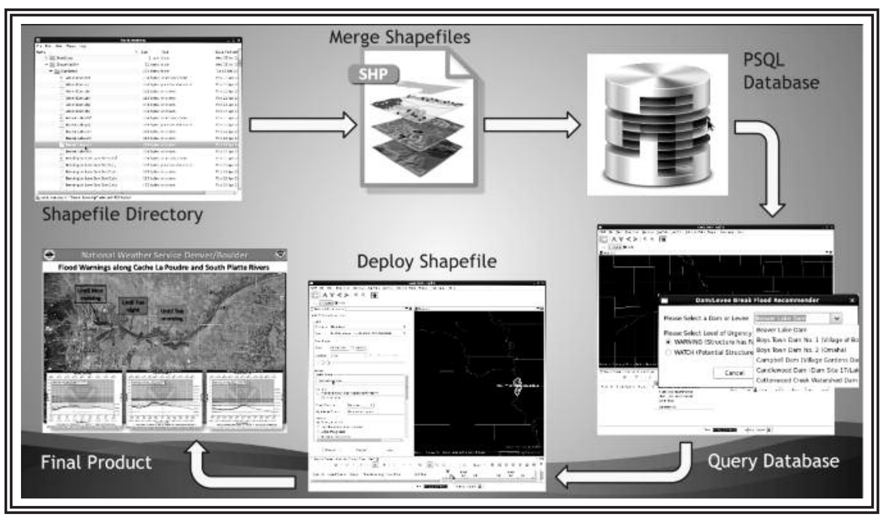
WRITING & COMMUNICATION
Lesley Smith, NOAA & CIRES

COMPUTING
Ryan May, UCP
Sean Arms, UCP

COACH
Jeff Weber, UCP

PEER
Meghan Mitchell

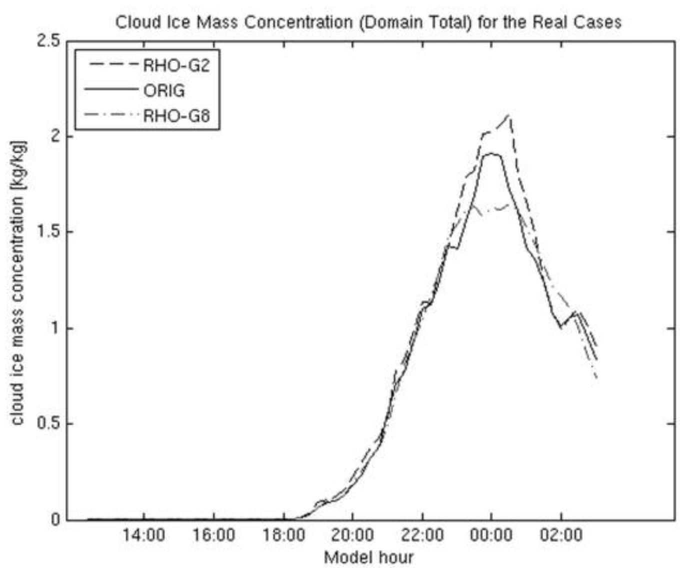
Statistically, flooding is the most devastating natural disaster not only in the US, but in the world. Of the many different severe and normal weather events, floods typically cause the most casualties and damage. Within Hazard Services of the National Oceanic and Atmospheric Administration, software is being developed and improved for use by the National Weather Service to help minimize the catastrophic effects associated with these disasters. Because flooding is a worldwide event, the new program produced by this Hazard Services project was created with the intention of being used anywhere for the safety of the public. Time is of the essence in a flooding event and forecasters need to have all relevant information readily available. This project's work provides a script that gives forecasters the tools to issue quick and efficient warnings by creating a catalog of flood prone areas, customized for the regions that each forecast office covers. By ingesting unique dam, river, and burn scar geospatial data all at once into a relational database in the form of merged file, forecasters can simply choose and deploy within the Advanced Weather Interactive Processing System (AWIPS) software. Having access to pre-set outlines of dam-break outflow, burn scars, and river inundation is much more efficient than the freehand shape drawing of an area that is expected to flood. Thus, not only does the new program allow faster issuance of alerts, but it has left less room for error and more room for geospatially accurate alerts.



A brief, visual description of the overall process this project undergoes. Steps 1 to 3 involve the new program, and steps 4 through 6 are within the Advanced Weather Interactive Processing System (AWIPS).

Impacts of graupel parameterization on idealized and real case simulations of squall lines

To better simulate storms and associated precipitation within atmospheric models, accurate representation of atmospheric processes is needed. In the Thompson microphysics parameterization, graupel and hail are represented by a single hydrometeor category that only predicts mass mixing ratio and therefore sets particle density to a constant value. This is not realistic given that the densities of graupel and hail are known to vary greatly between and within storms. This study assessed the sensitivity of two simulated squall lines to the prescription of graupel density using the Weather Research and Forecasting model. One case was an idealized simulation, while the other was simulated to represent an observed squall line. The range of graupel density was varied from 200 kg m^{-3} to 800 kg m^{-3}, representing particles more characteristic of graupel to those of hail, respectively. As the density of graupel/hail particles was decreased from being hail-like to graupel-like, the idealized simulation showed a faster squall line with less graupel and more cloud ice. In particular, the lower density case had a notable increase in the graupel melting rate, which resulted in more latent cooling and therefore a more intense cold pool and a faster storm propagation speed. The "real" case exhibited similar trends, but its sensitivity to graupel density was not as strong. Overall, a clear sensitivity of these simulated storms to the prescription of graupel density was found. These results provide motivation to make graupel/hail density a predicted variable in the Thompson microphysics scheme.



Time series plot of total ice mass content in the "real" squall line for the low (RHO_G2 = 200 kg m^{-3}), default (ORIG = 500 kg m^{-3}), and high (RHO_G8 = 800 kg m^{-3}) density cases, showing that the low density case results in the most ice mass. A similar trend was found in the idealized simulations.

Steven M. Naegele

2nd-year Protégé
Graduate Student
The Pennsylvania State University
Meteorology

MENTORS

RESEARCH
Sarah Tessendorf, NCAR
Trude Eidhammer, NCAR

WRITING & COMMUNICATION
Jamie Wolff, NCAR

Ana Ortiz (SOARS 2012)

completed her BS degree in atmospheric science at the University of Illinois Urbana-Champaign and a Master of Professional Science (M.P.S.) in Meteorology and Physical Oceanography at the University of Miami. Today she is a forecaster for private weather company UBIMET. After completing SOARS, Ana found she wanted to apply her meteorology training outside of academia. She says ***"What I like best about working in industry is that you don't just focus on one specific forecast area like the NWS or broadcast meteorologists do. I forecast for all of North America and can be forecasting severe thunderstorms in one part of the country and snow in another part."*** In her new position she forecasts and monitors the weather for clients, issues alerts for severe weather, and creates forecasts for special events as well as creating forecast verification methods and finding the best approaches to communicating risks to her clients. Ana reflects, ***"Although I enjoy research, it is often very specialized and you focus on one topic, such as tornadoes. But industry jobs focus on anything that has a major impact on the public. Most industry jobs allow you to communicate with clients and you get to make unique connections with people outside the meteorology field. You are also given a lot of freedom in industry jobs. For example, you are encouraged to seek out new ideas and products to make the experience for your clients even better."***

WE ARE PROUD OF OUR ALUMNI, MANY OF WHOM ARE NOW MOVING INTO POSITIONS OF LEADERSHIP IN ACADEMIA, RESEARCH AND PRIVATE INDUSTRY. THEY CARRY OUR VISION FORWARD NOT ONLY IN THEIR CAREERS BUT IN THEIR COMMITMENT TO MENTORING AND DIVERSITY. WE ARE EXCITED TO SHARE WITH YOU JUST A FEW EXAMPLES OF OUR TALENTED ALUMNI.

SOARS

THE NEXT GENERATION OF LEADERS

Christopher Williams (SOARS 2007, 2008)

completed his BS in Earth and Atmospheric Sciences from the Georgia Institute of Technology in 2008 and has been working as an associate scientist in the Joint Numerical Testbed in the Research Applications Laboratory here at NCAR since 2009, a position that grew out of his SOARS research. He assists with data collection and visualization as well as doing extensive model evaluation. He says ***"I enjoy working in a research facility because I am a curious individual. I get to think about and engage in addressing a steady stream of challenges and problems, often near the frontiers of science. Working at NCAR in particular affords the opportunity to collaborate with many talented and multi-disciplinary researchers from universities, federal laboratories, and the private sector. Additionally, my work is only made more meaningful with the Research Applications Laboratory's mission to promote the "Science in Service to Society" mantra of NCAR's founder, Dr. Walter Orr Roberts."*** In addition to his research, Christopher remains very committed to SOARS. He has served as a writing mentor (2010) and coach (2012–2015). When asked why he mentors he says, ***"I like to give. Someone said we don't lose anything by lighting someone else's candle. In fact, seems like our collective path gets brighter and clearer the more candles we light."***

Talea Mayo (SOARS 2006, 2008)

started this year as an Assistant Professor in the Department of Civil, Environmental, and Construction Engineering at the University of Central Florida. She specializes in coastal ocean modeling, with special interests in hurricane storm surge modeling, risk analysis, and statistical data assimilation methods for state and parameter estimation. Of her new position, Talea says ***"I love the challenge of "doing it all." UCF is a research university, and so faculty are expected to teach well, conduct state of the art research, and serve the university. Like most things, I find the key to be balancing it all. It is difficult, but I am excited to be taking on the challenge. I also really love teaching. My class is "small" (for UCF), and I have a great group, so I love that I get to interact with my students. Working with young adults is a major job perk."***

Talea completed her BS in mathematics at Grambling State University (LA), her MS and PhD degrees in computational and applied mathematics at The University of Texas at Austin, and a postdoctoral research appointment in the Civil and Environmental Engineering department at Princeton University. Committed to outreach, in addition to her science role, Talea has been involved in teaching extracurricular mathematics to girls, underserved students and even prisoners (through Princeton's Prison Teaching Initiative). She says ***"The absence of brown faces was particularly isolating at the beginning of my graduate studies, and has been the primary factor in my decision to enter academia. It is my hope that my presence and position at a university can serve as a silent reminder to young, black science students that they should be there too."***

Satellite and model analysis of coral reefs in the Western Indian Ocean: 2001 to 2007

ZORAIDA P.
PÉREZ DELGADO

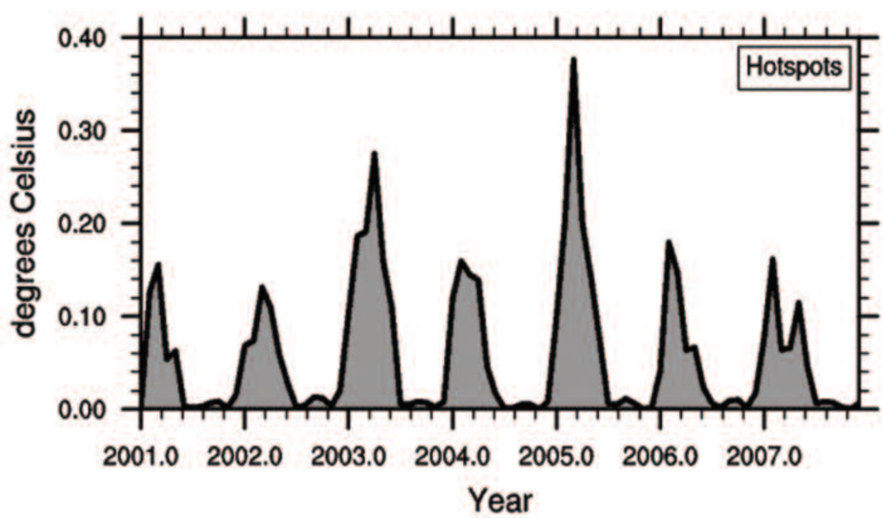
2nd-year Protégé
Senior
Universidad Metropolitana
Environmental Science

MENTORS

RESEARCH
Caroline Ummenhofer, WHOI

COMPUTER
Dustin Swales, NOAA

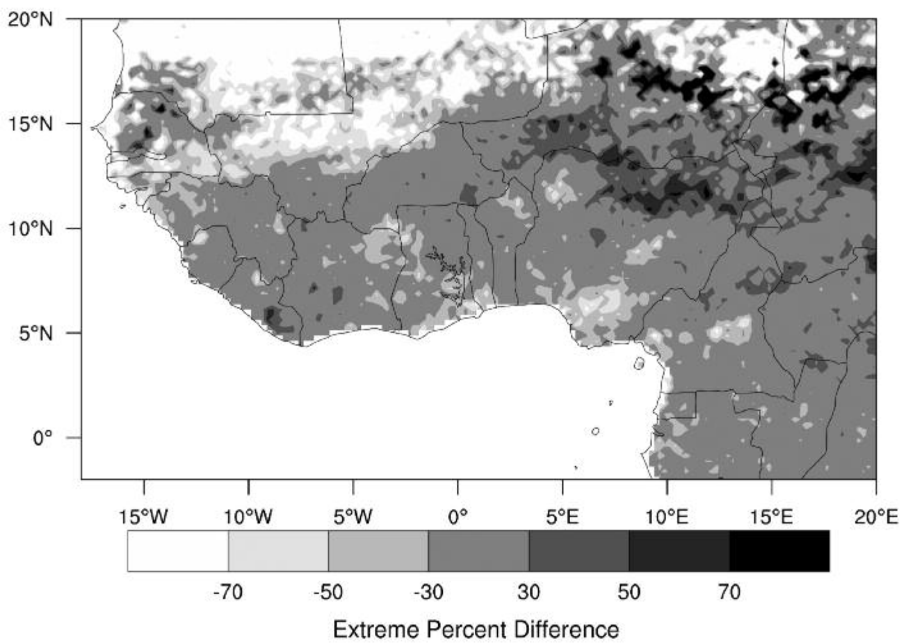
Corals are thought to be one of the smallest yet most productive ecosystems in the world. They have great economic and ecological value, but are increasingly affected by anthropogenic, biological and physical threats, such as a rise in sea surface temperature (SST) and ocean acidification due to an increase in CO_2 in the atmosphere, among other factors. Here, we investigate specific events that likely exerted significant stress on corals, focusing particularly on unusual climatic conditions in the Western Indian Ocean during the 2001 to 2007 period as reflected by anomalies in degree heating weeks, hotspots and SST. We also examine anomalous conditions in subsurface temperatures and mixed layer depth across the Indian Ocean region. We do this by using monthly, year-to-date, and annual composites of twice-weekly 50-km satellite coral bleaching monitoring products from the NOAA Coral Reef Watch and complementing it with output from a high-resolution global ocean model hindcast (1948-2007) forced with observed atmospheric forcing. Two years stand out in our analysis for the satellite data and model output: 2003 and 2005 exhibit strong warming in the Western Indian Ocean and cooling in the East. Further analysis will be made to establish a better connection between the satellite and model output and the physical mechanisms giving rise to the unusual conditions in 2003 and 2005.



Time series analysis of the Western Indian Ocean for hotspots. Two years stand out/exhibit anomalous conditions: 2003 and 2005.

The influence of the Madden-Julian Oscillation on large daily precipitation events in West Africa

The Madden-Julian Oscillation (MJO) is a global-scale disturbance that originates over the Indian Ocean and propagates eastward, occasionally circumnavigating the Equator. Although it is known to modulate weather and extreme events throughout the tropics, relatively little attention has been paid to the MJO's implications in West Africa, perhaps because it is nearing the end of its life cycle by the time it arrives there. In Sub-Saharan Africa, especially near the Guinean coast, variations in short-term extreme rainfall events are more important than variations in total seasonal precipitation, because they cause flooding that damages crops and infrastructure. This study focuses on the modulation of West African precipitation by the MJO. Using composites based on various thresholds of daily precipitation amounts, variations associated with the MJO's phase are presented. In general, precipitation and extreme events are enhanced during the phase in which composites show upward motion over western Africa, and suppressed when composites indicate downward motion. Some extremes (e.g., those above the 90th percentile of all events) are doubled in one phase compared to another. The differences in the number of extreme events between MJO phases are shown to be statistically significant.



Difference in the count of extreme events during March-May between MJO phase 2 and phase 8, expressed as a percentage of the mean of those two phases. Negative values indicate more events during phase 8. "Extreme" is defined as daily precipitation events that exceed the 90th percentile of all days of the season. There are no values over the ocean.

Awolou S. Sossa

1st-year Protégé
Junior
The City College of New York
Civil Engineering

MENTORS

RESEARCH
Brant Liebmann, NOAA & CIRES

WRITING & COMMUNICATION
Tanya Peevey, NOAA & CIRES

COACH
Christopher Williams, NCAR

PEER
Ryan Adams

Comparison of ground- and space-based radar observations with disdrometer measurements during the PECAN field campaign

Anthony D. Torres

2nd-year Protégé
Graduate Student
University of Michigan
Atmospheric Science

MENTORS

RESEARCH
David Bodine, NCAR
Kristen Rasmussen, NCAR

WRITING & COMMUNICATION
Andrea Smith, UCP

Plains Elevated Convection At Night (PECAN) was a large field campaign that studied nocturnal mesoscale convective systems (MCSs), convective initiation, bores, and low-level jets across the central plains in the United States. MCSs are responsible for over half of the warm-season precipitation across the central U.S. plains. The rainfall from deep convection of these systems over land has been observed to be underestimated by satellite radar rainfall-retrieval algorithms by as much as 40 percent. These algorithms have a strong dependence on the generally unmeasured rain drop-size distribution (DSD).

During the campaign, our group measured rainfall DSDs, precipitation fall velocities, and total precipitation in the convective and stratiform regions of MCSs using Ott Parsivel optical laser disdrometers. The disdrometers were co-located with mobile pod units that measured temperature, wind, and relative humidity for quality control purposes. There were also several ground-based mobile radar facilities that used different wavelengths and dual-polarization located 5 to 40 km from the disdrometers. Additionally, data from operational radars and space-based radar measurements from the Global Precipitation Measurement satellite overpasses were used.

The focus of this study was to compare DSD measurements from the disdrometers to radars in an effort to reduce errors in existing rainfall-retrieval algorithms. The error analysis consisted of substituting measured DSDs into existing quantitative precipitation estimation techniques (e.g. Z-R relationships) and comparing these estimates to ground measurements of total precipitation. The results from this study will improve climatological estimates of total precipitation in tropical and subtropical regions that are used in hydrological studies, climate models, and other applications.

The deployment of an Ott Parsivel optical laser disdrometer in a field ahead of an MCS in northeastern Kansas.

Exploring the synoptic evolution of MJO events identified by multiple algorithms

Rosa M. Vargas Martes

1st-year Protégé
Junior
University of Puerto Rico
at Mayagüez
Physics

MENTORS

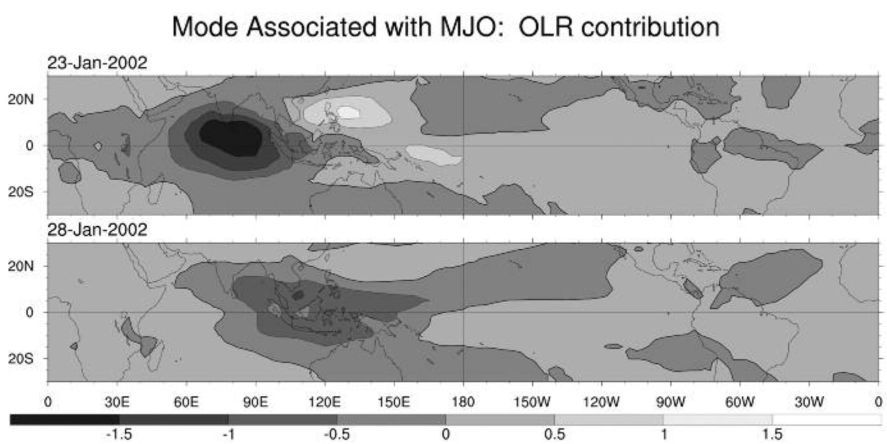
RESEARCH
Leslie M. Hartten, NOAA & CIRES

WRITING & COMMUNICATION
Brian Bevirt, NCAR

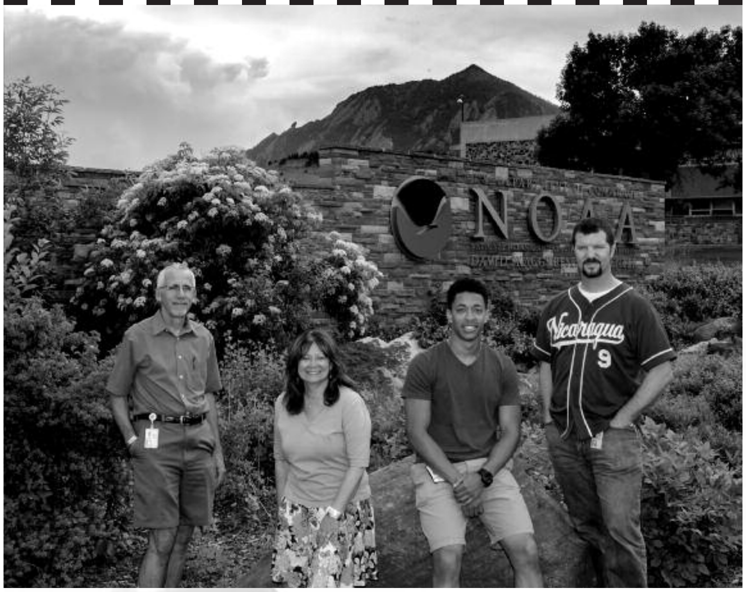
COACH
Eileen Carpenter, UCP

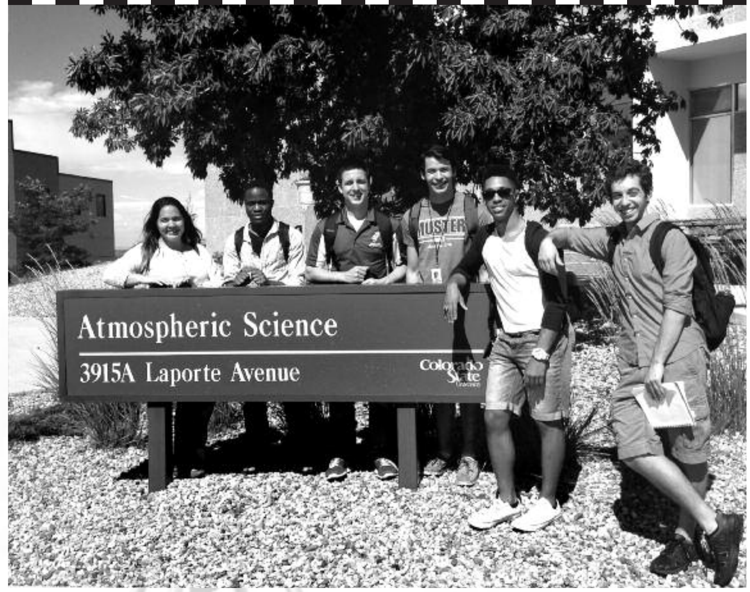
PEER
Eugene Cody

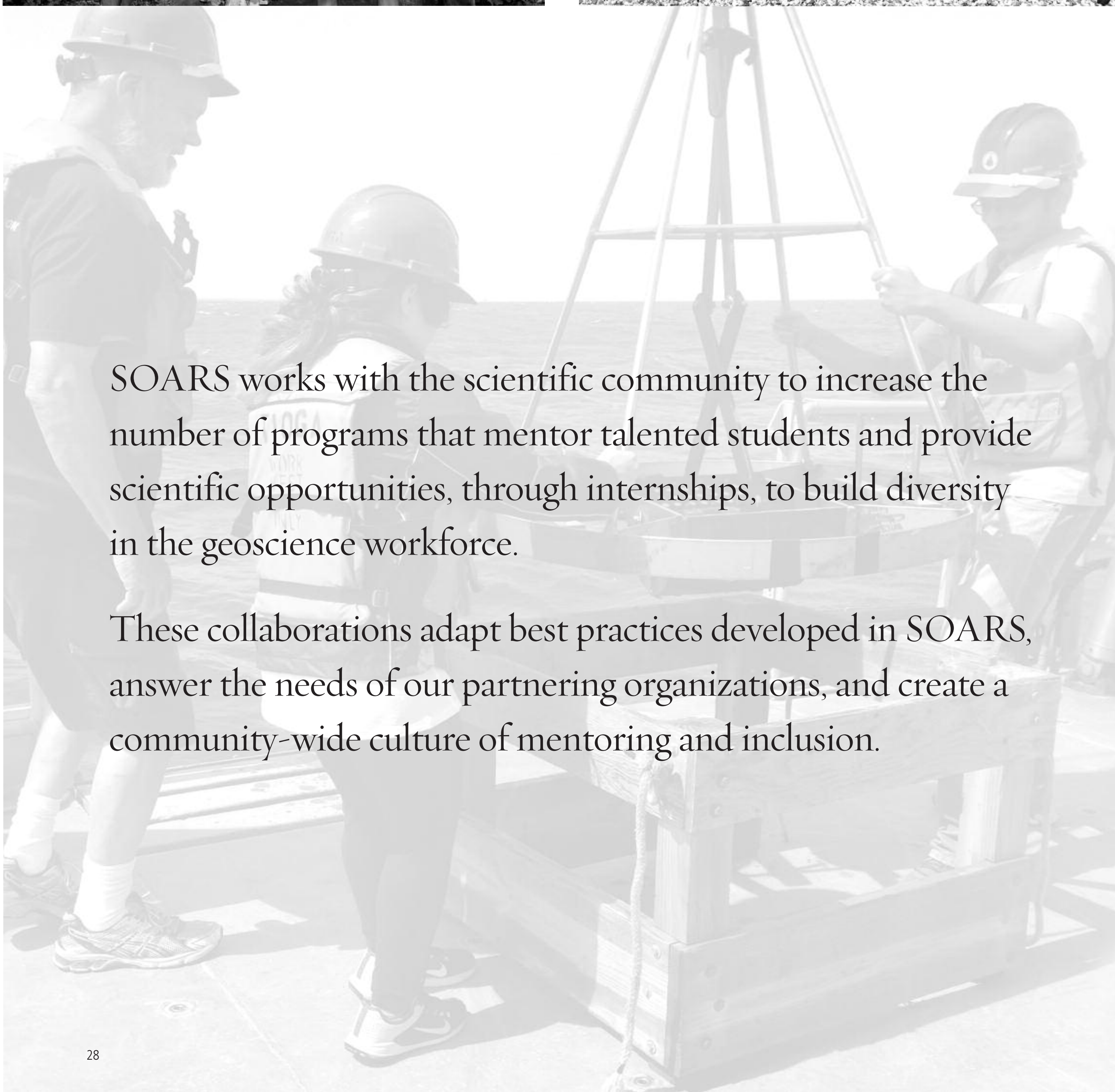
The Madden-Julian Oscillation (MJO) is a tropical phenomenon that develops over the Indian Ocean. This intraseasonal oscillation consists of an extensive area of convection, about 1000 km across, that releases latent heat in the mid-troposphere. The latent heating forces planetary-scale waves to travel through the upper troposphere. These waves can affect weather and climate in the extratropical regions. Since our computational models do not simulate the MJO correctly, international efforts are underway to improve our understanding of the processes involved, especially during the MJO's early stages. This study examines and compares MJO initiation events and types (primary, intensifying, non-MJO) identified by researchers using four methods during 1998-2009 boreal winters. Two methods focused on the precipitation aspect of the oscillation, and the others focused on circulation. Five variables were selected for analysis: temperature at 400-hPa, outgoing long-wave radiation (OLR), sea level pressure (SLP), and zonal winds at 200- and 850-hPa. Of the twelve selected MJO events, four were analyzed. The variables' contributions to each event were mapped using the MJO-like mode recently identified by other scientists from unfiltered five-day mean gridded data. These visualizations show consistent behaviors in OLR, temperature, and SLP. Positive OLR anomalies occurred in the Indian Ocean before MJO convection began, supporting another research group's idea of an MJO "dry dynamic mode." The maps also serve to validate the MJO-like mode, demonstrating that it identifies both MJO and non-MJO convection.



Five-day (pentad) mean contributions of anomalous OLR to the MJO-like mode during the January 2002 event. Negative OLR anomalies are a proxy for enhanced convection that starts up on the 18th, intensifies on the 23rd and then decays as it moves eastward across the Maritime Continent and western Pacific Ocean.







SOARS works with the scientific community to increase the number of programs that mentor talented students and provide scientific opportunities, through internships, to build diversity in the geoscience workforce.

These collaborations adapt best practices developed in SOARS, answer the needs of our partnering organizations, and create a community-wide culture of mentoring and inclusion.

SOARS PARTNERS FOR DIVERSITY

Over the years, we have supported several laboratories in building their own internship programs. These include the Research Experiences in Solid Earth System Science at UNAVCO and the Research Experiences for Community College Students in Critical Zone Science at the University of Colorado at Boulder. Both programs have been very successful in attracting and supporting underrepresented students into the sciences. SOARS also helped build the Internship Program at the National Ecological Observatory Network. Its director, Liz Goehring, describes the biggest benefit of this collaboration as ***"[...] the opportunity it affords for students to get to know other undergraduates from across the country, from a wide variety of backgrounds and experiences, all brought together because of their passion for science and discovery. It's exciting to see ideas exchange and new friendships develop, even beyond our own program. Thanks, SOARS, for making that happen!"***

In addition to building new programs, we have partners who generously fund students to participate in SOARS and host students at their institutions. SOARS protègès receive excellent scientific mentoring at these partnering organizations, and their staff are exposed to working with highly talented and enthusiastic students from diverse backgrounds—a win-win situation. Examples of these partners include the Center for Multi-Scale Modeling of Atmospheric Processes at Colorado State University (CMMAP), the National Oceanic and Atmospheric Administration, the Woods Hole Oceanographic Institution (WHOI) and the University of Colorado at Boulder. Jim Yoder, Vice President for Academic Programs and Dean at WHOI, says ***"WHOI appreciates the excellent SOARS students that join our summer program and contribute so much to our scientists' research programs. I believe it also helps SOARS students to have research experience in both atmospheric and oceanographic sciences."*** Similarly, Melissa Burt, Education and Diversity manager at CMMAP, states that ***"Our collaboration with the SOARS program has been an extremely valuable and rewarding two-way partnership. We are very thankful to have the opportunity to sponsor and support 16 protègès—many of whom we've had the opportunity see prosper as early-career scientists in our graduate program at Colorado State University."***

In 2014, SOARS went a step further in supporting the geoscience community, leading the NSF-funded GEO-REU network. This network offers workshops, resources, mentoring and community for faculty who run Research Experiences for Undergraduates across the geosciences. Melissa Burt points out that ***"Over the years the SOARS program and staff have provided insight and served as a model for the development of our research experiences for undergraduates (REU) program."*** Currently, over 70 PIs of REUs have joined the network and use it to discuss best practices in student recruitment, support and retention. Our hope is that one day we'll have enough programs to offer all talented and motivated students an opportunity to try out geoscience research while providing excellent mentoring and career guidance.

Juneau Icefield Research Program: Mass balance of Taku and Lemon Creek Glaciers

Arianna Varuolo-Clarke

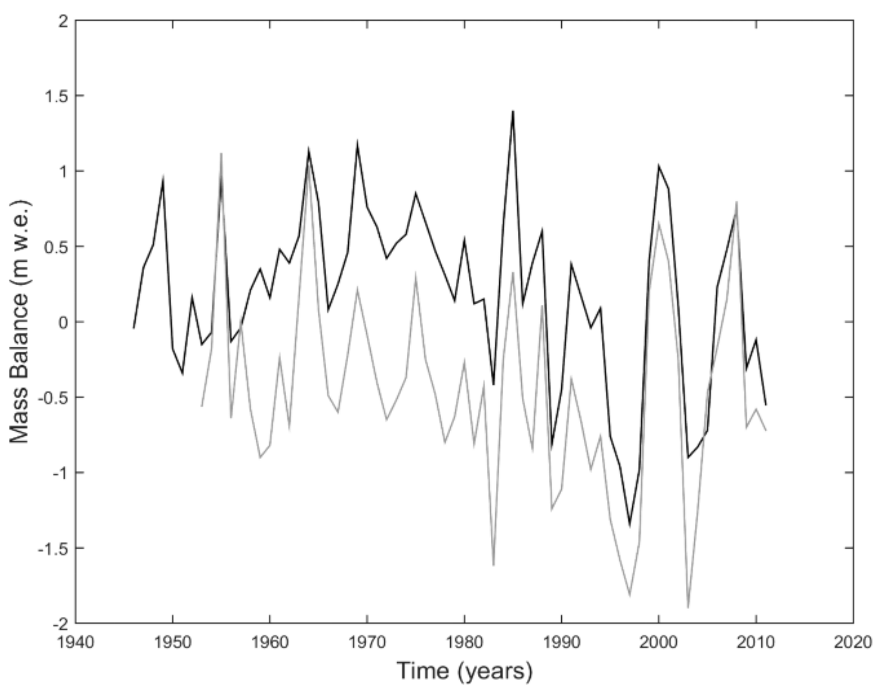
2nd-year Protégé
Senior
Lyndon State College
Atmospheric Sciences

MENTORS

RESEARCH
Matthew Beedle, JIRP
Shad O'Neel, JIRP
Lindsey Nicholson, JIRP

SOARS

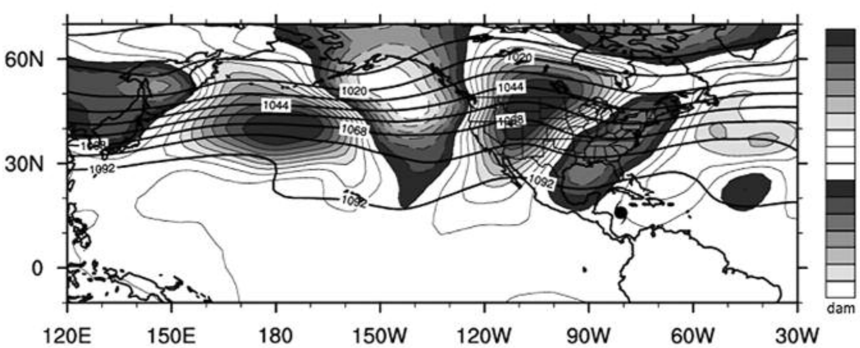
The Juneau Icefield Research Program (JIRP), founded in 1946, studies several glaciers on the Juneau Icefield. JIRP also trains young scientists to conduct expeditionary research in the field of glaciology. The original focus of JIRP was to measure the mass balance of the Taku and Lemon Creek Glaciers. This is now one of the longest mass balance records in the world. Mass balance is the measurement of mass the glacier has lost or gained over one year, where mass gain is the measurement of snow accumulation over the accumulation season and mass loss is the amount of ablation or melt that occurs during the melt season. The accumulation season is a function of precipitation, whereas the ablation season is a function of temperature. As the climate changes, so will glaciers, which poses problems for communities that depend on glaciers for water supply, fisheries, and tourism. For these reasons, and others, there are many efforts throughout the geosciences community to understand and simulate glacier change. JIRP participants contribute to this effort by annually measuring the mass balance of the glaciers by digging snow pits and recording accumulation. Snow pits are dug through the entire annual snow pack and 0.5 meters into the previous annual snow pack. Density measurements are taken vertically every 10 cm down a wall of the snow pit and are used later to calculate the mass balance. This research uses JIRP measurements to investigate the relationship between temperature, precipitation, and mass balance of the Taku and Lemon Creek Glaciers.



Annual mass balance of the Taku (black line) and Lemon Creek (grey line) Glaciers on the Juneau Icefield. This data was collected by JIRP participants.

Examining tropical cyclone development in the southwest Caribbean Sea

Tropical cyclones (TCs) that develop in the southwest Caribbean Sea commonly make landfall due to their relatively close proximity to land masses, bringing flooding rains, high winds, and destructive storm surge to the impacted areas. Despite the dangers posed by southwest Caribbean TCs, there are relatively few studies in the refereed literature that examine the TC genesis climatology and pre-TC development synoptic-scale flow environment in this region. The aim of this study was to use the National Hurricane Center best track database and gridded atmospheric reanalysis data to construct a climatology of TC formation, determine the origin of the low-level precursor disturbance, and diagnose the synoptic-scale flow pattern in which TC genesis occurs in the southwest Caribbean Sea from 1990-2014. Results are presented from the synoptic climatology, composite, and case study perspectives. The results show that TC formation in the southwest Caribbean Sea occurs preferentially in October and November, later in the season compared to the North Atlantic basin as a whole. Of the 45 TCs identified, 28 occurred in a baroclinic environment on the south-east flank of an upper-tropospheric trough. The upper-level trough results most frequently from downstream energy propagation via a Rossby wave train initiated in the western North Pacific. Preliminary findings suggest that the upper-level trough and attendant baroclinicity provide a focus for enhanced synoptic-scale ascent, which aids in moistening, destabilization, and maintenance of convection. Results from this study may provide aid in medium-range forecasting of southwest Caribbean TCs through awareness of synoptic precursors and their effects.



250-hPa geopotential height mean (thick contours, dam) and anomaly (shaded, dam) composite at Day -1 for all southwest Caribbean TCs that developed near an upper-tropospheric trough (*N=28*) from 1990-2014. Thin solid (dashed) contours and progressively darker (lighter) shading are used for positive (negative) height anomalies. The TC symbol denotes the general area of development for southwest Caribbean TCs.

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2015 SPONSORS AND ACKNOWLEDGEMENTS

SOARS

National Science Foundation,
Directorate for Geosciences, Atmospheric Sciences

National Oceanographic and Atmospheric Administration

National Center for Atmospheric Research

Center for Multi-scale Modeling of Atmospheric Processes at Colorado State University

University of Colorado at Boulder

University Corporation for Atmospheric Research

Woods Hole Oceanographic Institute

Center of Excellence in Remote Sensing Education and Research at Elizabeth City State University

The material is based upon work supported by the National Science Foundation under Grants No. AGS-1120459 (SOARS).

This publication has been printed on recycled-content paper by an environmentally-friendly printer.

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Authors: SOARS students and staff

Editors: SOARS mentors and staff

Photography: UCAR

Design: Eugene Malowany, Malowany Associates

Printing: B&B Printers

Earth, Wind, Sea, and Sky is a publication of UCAR.

On the cover: SOARS protégé Erin Dougherty took this photo of mammatus clouds illuminated by the sunset near Buffalo, Missouri while en route to a deployment for the PECAN field campaign.

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