SOARS protégé Karl Clarke with his science mentors Kirsten Meymaris and Sandra Henderson. As his summer project, Karl developed a citizen science campaign to engage the public in collecting tree phenological data.
As RESESS completes five years and SOARS enters its 15th year, it is an excellent time to think about the meaning and impact of diversity. In Science, Technology, Engineering and Math, diversity is a common shorthand for the participation of people from historically under-represented groups, including Latinos, American Indians and Alaska Natives, and African-Americans. The National Science Foundation and others have invested heavily in SOARS and RESESS to increase participation of students from these groups in atmospheric and solid Earth geosciences. This investment is based, in part, on the idea that the new perspectives from a more diverse community of scientists will improve science. The abstracts in this volume provide direct evidence that this is true in the form of our protégés’ immediate contributions to their disciplines.

There is also a more subtle and long-term improvement. As newcomers, our protégés remind us that scientists, like all people, are animated by personal values and relationships. Introducing more diversity has introduced new values and new relationships to the atmospheric and solid Earth geosciences. For example, our protégés have helped our sciences reach out to new communities. UCAR’s recent research on climate change on tribal lands, for example, is a direct outgrowth of questions and suggestions from SOARS protégés. This last summer, our protégés voluntarily put together hands-on science activities for elementary-aged children in two low-income housing communities, and RESESS has added an outreach component to its newly funded five-year plan. In the same way that greater biodiversity enhances an ecosystem’s resilience, this increased diversity of relationships and values will enhance our sciences’ relevance and resilience.

The challenge of the next five years, for SOARS and RESESS, is to continue to learn, to expand our understanding of diversity, and to leverage diversity to improve our sciences and their connections to the increasingly diverse world. Given the evidence of the last few years, we are optimistic and excited. Read on, and you will be too…

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Fernando A. Martinez Torres
Tropical cyclones (TCs) can cause extensive damage due to strong winds, storm surge, and rainfall. These systems are capable of torrential downpours, producing flooding and forceful winds that damage buildings. Past studies and forecasts have focused on the immediate impacts surrounding the area of a TC; however, few studies have examined the effects that TCs have away from their immediate areas. The focus of this study is to examine the moisture properties of Hurricane Ike, the properties of the storm’s pre-existing conditions, and how Ike contributed to the intensification of precipitation poleward from itself. Version 3.1 of the Advanced Research version of the Weather Research and Forecasting model (WRF-ARW) was initialized to simulate Hurricane Ike on 13 September 2008 at 0000 UTC and on 12 September 2008 at 1200 UTC, with both ending on 16 September at 0000 UTC. The WRF-ARW model was able to replicate the occurrence of Hurricane Ike in the real atmosphere. Comparisons between both simulations and observations illustrated differences in reference to each other, but the general structure of the precipitation, water vapor, and temperature fields were similar. To test the sensitivity of rainfall accumulations to the presence of Ike, another simulation was run with Ike removed at the initialization of the second simulation. Initial analysis of the Ike removal scheme revealed a decrease in the moisture parameters; however, further study is needed to quantify Ike’s impact. This study offers insight into forecasting issues with areas poleward of tropical cyclones such as Hurricane Ike.

Figure 1
12-hour precipitation totals from 13 September 2008 at 1200 UTC. Observations on the left, first model simulation in the middle, second model simulation on the right. This image is used to compare the observations with the model simulations to determine which simulation best replicates the observations.
Modeling wildfires and analyzing emissions

The new atmospheric prediction model, the Weather Research and Forecasting Model version 3.1 (WRF) coupled with the empirical fire spread model was used to model wildfire behavior and analyze emissions. Modeling wildfires includes knowing the spread rate and where a fire will propagate based on environmental conditions. These play a key role in fire suppression efforts. The products and emissions of wildfires contribute to the weather and the air quality. WRF-Fire is a two-way coupled module. While providing feedback to the fire directing where it travels and controlling the spread rate, the fire module provides feedback to the atmosphere creating its own weather. Using the fire module WRF-Fire, we analyze the emissions from a standard model (the control) with a fuel category of short grass, fuel moisture level of 8 percent, wind speed of 2.5 m/s, and fuel loading of 0.166 kg/m² as shown in the figure. The fuel moisture, wind speed, fuel loading, and fuel category were changed, then the emissions were compared to the standard model. We found that heat flux is directly proportional to fuel moisture level and fuel loading. Fire spread rate is directly proportional to the wind speed. Using a new fire module we were able to reproduce the shape of naturally occurring fires and relate how they depend on environmental conditions. The results gained from this research can be used as verification data for future models.

Figure 1
Contours of heat flux (W/m²) from the surface fire in the standard model.
Decrease in the summer rainfall of the southern United States coast and the Caribbean due to climate change

Comparison and contrast of simulations from the North American Regional Climate Change Assessment Program (NARCCAP) Geophysical Fluid Dynamics Laboratory (GFDL) AM2.1 timeslice experiment were made for current climate (1971-2000) and future climate (2041-2070) to assess how May through October accumulated rainfall is responding to climate change along the southern United States coast and in the Caribbean under the Intergovernmental Panel on Climate Change (IPCC) A2 emissions scenario (a scenario of relatively high emissions increase). The simulations were done on a global domain at a horizontal resolution of roughly 50 km.

There is an overall decrease of about 200 mm (30 percent) in May through October rainfall in the region of the southern United States coast and the Caribbean. The absolute decrease is larger in the regions that receive the most rain. Proportionally, however, the decrease is larger in the regions that receive the least rain. For the subregion of Florida, rainfall time series indicate a delay of the region’s late wet period in the future climate. This shift needs to be examined further to determine its significance and the underlying physical processes. Florida also received less rainfall in future climate, but the standard deviation of the early and late wet periods was found to be larger. This is in accord with the findings of the IPCC of an increase in global extremes as a result of climate change. In a future study, the time series for four other subregions will be analyzed.

Figure 1
GFDL AM2.1 percent changes in May through October accumulated rainfall between 1971-2000 and 2041-2070.
A citizen science campaign encouraging urban forest professionals to engage the public in the collection of tree phenological data

There are growing concerns among leading national and local organizations about American scientific literacy, fundamental understanding of science, and public appreciation for the value of scientific research. These organizations, including the University Corporation for Atmospheric Research, have been at the forefront in addressing these concerns. In an effort to improve scientific literacy, research conducted by Sam Droege, among others, suggested using citizen science and public participation as instrumental methods to engage the public. Urban Tree Phenology (UTP), a project of Project BudBurst and the USDA Forest Service, is one such citizen science program that sought to engage the public, including the professionals and amateurs among them, in collecting urban tree phenophase data. UTP participants monitored and reported the stages of phenological events, such as First Leaf and Leaf Fall, of 24 native and cultivated urban tree species, using the steps shown in Figure 1. Data collected will support the long-term research of plant ecology, climate change, public health, the effect of urban heat islands on tree physiology, and urban tree management. UTP, using the architectures of online learning, has developed two instructional tutorials to assist data collection (Phase 1). The instructional tutorials were published online, in print and PowerPoint formats, at www.UrbanTreePhenology.com. By completing these tutorials, participants will gain the skills necessary to provide urban tree phenological data to national research databases via the Internet. Phase 2 will test and review the instructional materials developed, and in Phase 3, the administrators of UTP will distribute promotional materials to national research organizations and to participants of the Project BudBurst national citizen science campaign.

Figure 1
An overview of the phenological investigation. By completing these steps required for data collection, UTP participants will gain the skills necessary to submit quality data to support long-term research of climate change, urban tree management, urban heat islands, and public health.
Orographic effects on rainfall induced by the passage of tropical cyclones over mountainous islands.
Part I: The effect of cloud microphysics

The passage of a tropical cyclone (TC) over a mesoscale mountainous island, such as Puerto Rico, often brings heavy rainfall that produces flooding and landslides. Factors that affect orographic rainfall in this region are not well understood. This study investigates the impact of microphysics (MP) schemes in TC simulations using the numerical mesoscale Advanced Research version of the Weather Research and Forecasting model (ARW) model, particularly for Hurricane Jeanne’s (2004) passage over the island. Sensitivity experiments using four different MP schemes were performed. Each experiment was represented by a single MP scheme, i.e., WSM 5-Class (EXP1), Eta Ferrier Microphysics (EXP2), WSM 6-Class (EXP3), and Thompson Graupel scheme (EXP4).

Results show strong consistency for cyclonic track among experiments, with landfall about four hours ahead of observations. Rainfall distribution was well represented, with maxima on the southeastern and higher mountain regions. EXP3 produced the best simulation in terms of rainfall distribution and high rainfall peak locations. However, there were sizeable differences between the model cyclone’s wind intensity and minimum sea-level pressure at landfall and those of the observed storm. EXP2 and EXP3 produced a more realistic sea-level pressure and sustained wind speed. In conclusion, the simulation using the WSM 6-Class scheme (EXP3) was strongly comparable with observations, and is the best choice for further investigations. Future study will examine some control parameters and common ingredients, such as Convective Available Potential Energy (CAPE), Precipitation Efficiency (E), and the impact of mountain height variations, to help understand the processes associated with orographic precipitation induced by the passage of TCs.

Figure 1
Hurricane Jeanne’s track for observations and model experiments. Tracks represent a 30-hour period starting on September 15th at 0000 Z.
Climate change is an increasing concern worldwide. In the Northern Hemisphere, sub-alpine ecosystems serve as a major carbon sink. Recent research has shown that these ecosystems are particularly vulnerable to changes in climate. Even small changes in water availability and temperature – despite longer growing season length – have been shown to cause significant reductions in the ecosystem’s ability to sequester carbon. In this study, sensors measuring photosynthetically active radiation, air temperature, relative humidity, sap flow, soil moisture, and soil temperature were deployed to a high-altitude sub-alpine forest ecosystem on Niwot Ridge near Nederland, Colorado, to collect data at a high spatial and temporal density. Using the data obtained from these sensors, preliminary observations were made concerning the effects of cloud cover on CO2 sequestration. Data from three representative days in July were analyzed to observe differences among sunny, cloudy, and partly cloudy days. The carbon uptake appeared to be greatest on the sunny day, less on the partly cloudy day, and even less on the overcast day. This is contrary to existing research, which suggests that cloudy and partly cloudy days should increase sequestration because light is distributed more evenly and temperatures keep exchange passages within the leaf open. These results may be due to a number of factors, such as the atypical rains that occurred this season and decreased temperatures overall. Reviewing additional data collected this summer and in past years, along with data collected this year, should further improve understanding of the effects of climate change in sub-alpine forests.
Reconsidering the role of Rossby waves in the Madden-Julian Oscillation (MJO)

Many studies attempt to gain insight into atmospheric and oceanic phenomena in the tropics using the Gill (1980) model because it simplifies the equatorial wave spectrum by making the “longwave approximation.” How can the equatorial wave spectrum be simplified to reproduce the waves important for the Madden-Julian Oscillation. The MJO is the main intraseasonal fluctuation in tropical weather, modulating precipitation, pressure and winds all year. Global Climate Models (GCMs) do not simulate the MJO well due in part to a lack of physical understanding. To improve physical understanding, the dynamical aspects of the MJO were investigated in a simple model framework. Steady-state anomalies of winds and geopotential heights, as well as momentum fluxes in both a “filtered” and “truncated” shallow-water model on the equatorial beta-plane were compared to those in a “complete” shallow-water model on the equatorial beta-plane that represented all waves. The “filtered” model produced all Rossby and Kelvin waves, and the “truncated” model produced all Kelvin waves and only long Rossby waves. Three scenarios of diabatic heating were analyzed. Winds, geopotential heights, and momentum fluxes were generally weaker, and maximum values were less concentrated in the “filtered” and “truncated” models. Therefore, short Rossby waves must be well represented in idealized models of the MJO, and inertia-gravity waves may also play an important role. Idealized models such as the one used here can help improve physical understanding of the MJO, and GCMs can be interpreted and revised so that the MJO is simulated with more accuracy.

Figure 1
The wind and geopotential height anomalies for the “truncated” model in the eastward propagating heating scenario. Winds are in vector form, with a minimum of 0.01 m/s and a maximum of 4.93 m/s. Geopotential heights are contoured, with a maximum of -11.12 m and a minimum of -166.2 m. The contour interval is 20 m. The diabatic heating is also contoured.
Comparison of ABL heights derived from COSMIC RO and the RUC Model

This study investigates two approaches for determining the height of the Atmospheric Boundary Layer (ABL): analyzing radio occultation (RO) observations and using NOAA’s Rapid Update Cycle (RUC) model. The first approach determines the ABL height by examining radio wave bending angle profiles from the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC). The second approach examines the vertical structure of meteorological parameters reproduced by the RUC model. This study compares the values of collocated ABL heights obtained by each approach over North America and adjacent oceans for both summer and winter months to determine seasonal variations. Significant differences in the ABL heights were found for the two approaches, as well as seasonal variations. High-precision comparisons were not produced between RUC and COSMIC ABL heights, because this ABL analysis did not include RUC model data for water vapor and turbulence. To perform a better comparison, the RUC ABL should be better characterized by accounting for water vapor and turbulent mixing.

Figure 1
This image shows bending angle profiles received from COSMIC.
A shows a profile with a sharp ABL top
B shows a smooth profile with no sharp top
C shows a profile that does not have a significantly sharp ABL top but has fluctuation which may be due to other factors such as multiple layers, convection, or noise.
Evaluating the effects of latent heating in tropical cyclone Sinlaku’s extratropical transition using ARW and energetics analysis

Of all the Tropical Cyclones (TC) that occur worldwide, 42% of the North Atlantic and 27% of the western North Pacific storms undergo Extratropical Transition (ET) into Extratropical Cyclones (EC). EC are asymmetric cold-core systems as opposed to their warm-core predecessors, and their radii of gale-force winds (17 ms⁻¹) may increase by a factor of two to three times their original radii. This expansion of the gale-force winds can cause a significant amount of damage. In addition, these ET can trigger and amplify upper atmospheric waves that indirectly lead to the generation of other powerful storms across the world, which makes it imperative to study the dynamics and energetics involved with the ET. The ET of TC Sinlaku (2008), with the aid of a 500-mb shortwave, was well observed through an international field campaign, THORPEX Pacific-Asian Regional Campaign (T-PARC). To understand the effects of latent heating when Sinlaku transitioned, this study followed techniques similar to Kuo et al. (1990). Two different sets of simulations using the Weather Research and Forecasting (WRF) model with the Advanced Research dynamical core were conducted, involving a full set of physics and fake dry physics (neglecting latent heating). This study examined the evolution of horizontal kinetic energy and its components to examine the impact of latent heating on the energetics of the ET processes. Results drawn from both simulations suggest that latent heating is crucial for the maintenance of the TC and the 500 mb trough, and for the ET process. This is clearly reflected by the significant differences in the kinetic energy of the two WRF-ARW simulations with and without latent heating.

Figure 1
A comparison of tracks for TC Sinlaku’s best track (circles), full physics simulation (diamonds), and adiabatic simulation (triangles).
Eliassen-Palm fluxes of the diurnal tides from the Whole Atmosphere Community Climate Model-Extended (WACCM-X)

Through perturbation interactions with the zonal mean flow, the migrating diurnal tide and the diurnal eastward 3 (DE3) tide are fundamental to a holistic understanding of the atmospheric dynamics at the altitudes of the mesosphere and lower thermosphere (MLT) and the ionosphere. Previous tidal studies have noted the semiannual variability associated with the migrating diurnal tide and the DE3 tide, which maximize around equinox and minimize around solstice. Seasonally varying source and dissipation regions and/or wind structures are believed to cause the differences in the maximum amplitudes experienced between the two equinoxes. Using monthly averaged output from the Whole Atmosphere Community Climate Model-Extended (WACCM-X), this study is among the first to apply this model to a diagnostic examination of the sources and sinks of tidal momentum and document the associated seasonal variability. From the averaged amplitudes obtained during March and September, the WACCM-X replicates the observed seasonal variability associated with the migrating diurnal tide and the DE3 tide. Calculating the divergence of the Eliassen-Palm Flux (EP Flux) for the migrating diurnal tide revealed robust seasonal variation that may be linked to differential solar heating of ozone in the stratosphere. Seasonal variation in the tropospheric sources of the DE3 tidal momentum alone does not appear to explain the semiannual variability observed in the tidal amplitudes. This study provides a better understanding of the seasonal variation in the generation and dissipation mechanisms of the migrating diurnal tide and the DE3 tide.

Figure 1
The migrating diurnal tide reconstructed U-Wind Field from March 21 at 0° longitude and 0 local time, with wind contours at 5 m/s.
Weather and climate models require both efficient and accurate numerical methods to simulate tracer (e.g., moisture, salinity) advection. The distribution of the tracer used in transport equations is approximated by a Taylor expansion. A method was developed that builds on a simpler, second-order convergent method named Miura’s Scheme. This original method describes tracer distributions with a first-order Taylor expansion, while the Extended Scheme uses a second-order expansion to describe the distribution. The original method is conservative and defines a simple departure region, but it violates monotonicity preservation. Due to its simplicity, Miura’s Scheme is not very accurate with more complex tracer and velocity flow configurations. The Extended Scheme required three specific modifications: Green’s Theorem was used to calculate these next-order terms and minimize the computational stencil, Gauss Quadrature was employed to calculate the tracer advected in a departure region, and the cell-averaged value was re-normalized to correct for the addition of these higher-order terms. Two tests were run on a planar, perfect hexagonal grid: a solid body rotation case and a time-dependent deformational-flow case. The extension of the tracer distribution function shows marked improvements over the original method, and this extended scheme is third-order convergent for the solid-body rotation case. The improvements, however, are not as obvious in the deformational-flow test. Nonetheless, the results indicate that the Extended Scheme warrants further testing. The successful application of a flux limiter shows that the method can be prepared further for possible implementation in weather and climate models.

Figure 1
Final results for $nx=169$ of (a) Miura’s Scheme and (b) the Extended Scheme for solid body rotation, and (c) Miura’s Scheme and (d) the Extended Scheme for a time-dependent deformational-flow case. The exact solution, outlined in the thick dashed line, is overlaid over the numerical solution.
Climatology of precipitation in West Africa through observational studies

The occurrence of precipitation in the Sahelian belt is highly variable and unpredictable. Incessant droughts and sporadic flash floods cause residents to experience crop failures and subsequent famine. These unfortunate occurrences served as the motivation for this study. This research used the Thunderstorm Identification, Tracking, Analysis, and Nowcasting (TITAN) tool to detect and evaluate storms, summarize the precipitation regime of Mali, West Africa, and compare storm statistics of observed squall lines and Mesoscale Convective Systems (MCS) for the study period of 2006-2008. The results of this research are promising for the future of precipitation occurrence in the Sahelian region. Time series and storm distribution analysis showed that the region experienced atypical rainy seasons for the last three years, with storms in 2008 being the most intense and producing the most precipitation. The comparison of MCS and squall line statistics allowed for the preliminary designation of storm characteristics. Results showed that compared to chosen MCS cases, squall lines tend to be more intense, produce more precipitation, last longer, and have higher storm heights. Future work includes scrutinizing additional storms and storm statistics and performing model verification.

2008 Storm Precipitation Flux

Precipitation Flux (m³/s)

Time

Figure 1
Daily averaged precipitation flux estimated from TITAN storm cells observed during the 2008 field season in Mali.
The effects of convective clouds on vertical scalar transport using a numerically simulated flow field

In the planetary boundary layer (PBL), pollutants travel shorter distances and have shorter residence times relative to those in the upper troposphere. Without clouds, pollutants released near the surface are likely to stay within the PBL or deposit onto the ground if there is no deep convection to carry them upward. The objective of this study was to understand how deep convective cloud systems influence the transport of insoluble species to the upper troposphere using a Lagrangian approach. We used velocity field data from a synthetic flow field numerically generated from a 3-D large eddy simulation (LES) model of a deep convection system. The domain was large, consisting of 2048 x 2048 x 256 (or 10^9) grid points, so this LES is also known as a giga-LES. The results showed three interesting features. First, a peak in the particle concentration occurred around 8-9 km at 3, 6, and 12 hours after their release. Possible mechanisms explaining this include water loading and a larger areal coverage of downward motion than upward motion at that height. Second, approximately 25% of particles remained near the surface, the lowest level used for the particles. This is probably due to neglecting the subgrid-scale (SGS) motion in our Lagrangian approach. Finally, within the PBL, we found a sharp drop in pollutants. Possible explanations include (1) neglecting the SGS effect and (2) the use of a large time interval (15 minutes) for the velocity field. Our future work will include the SGS effect, and will use a five-minute time interval for the flow field.
Lightning activity in Atlantic tropical cyclones: Using the Long-range Lightning Detection Network (LLDN)

Mitigating potential disasters from land-falling tropical cyclones requires accurate forecasts of trajectory and intensity. In the last 20 years, trajectory forecasting has improved 50%, while intensity forecasts have improved little or not at all. This lack of any major advances can be partly explained by poor understanding of the physical processes behind intensity changes. Recent studies suggest that monitoring lightning activity in tropical cyclones could help improve understanding of these processes and also help predict intensification. We studied lightning in six Atlantic tropical cyclones using the Long-Range Lightning Detection Network, which reaches 2,000 kilometers offshore from the continental U.S. With the exception of tropical cyclones intensifying close to continental landfall, lightning frequency didn’t show a consistent peak before the time of maximum sustained winds. On the other hand, the outer rainband-to-eyewall lightning ratio shows a clear peak 24 hours before maximum sustained winds in all of the storms. A better understanding of the physics behind the temporal behavior of this ratio is needed. Preliminary assessment of these results suggests that some lightning changes could be related to the eyewall replacement cycle. Interaction of tropical cyclones with continents could increase lightning activity, and the use of a ratio is not needed to see a clear peak in lightning before maximum sustained winds. A more detailed approach to studying the interactions between the outer rainband and eyewall lightning activity should be conducted. Lightning in the eyewall should be compared with radar and airplane observations to observe its relationship to the eyewall replacement cycles.

Figure 1
Location of lightning activity inside Hurricane Gustav during maximum sustained winds.
Comparison of the VORTRAC retrieved structure of Hurricane Danny (1997) to prior analyses

Tropical cyclone (TC) intensity forecasts continue to be one of the most challenging aspects of hurricane prediction. However, through an innovative new tracking and analysis tool, a high resolution, real-time analysis and greater understanding of the complex dynamics of TCs is possible; both lead to better forecasting skill. The validity of this tool was analyzed in this research.

Through the ground-based Velocity Track Display (GBVTD) technique, a single ground-based Doppler radar can be used to retrieve the three-dimensional (3-D) kinematic structure of a TC. The GBVTD technique and GBVTD-simplex center-finding algorithm is used within the Vortex Objective Radar Tracking and Circulation (VORTRAC) software package for this purpose. VORTRAC is capable of automatic center tracking and retrieval of storm-scale circulation, structure, and central pressure tendency of a TC, for use in real-time forecasting and research. VORTRAC was used to analyze Hurricane Danny (1997). This analysis was then compared to the National Hurricane Center (NHC) best track (considered to be the “ground truth”) and the manual GBVTD analysis previously performed on Danny. Additionally, the VORTRAC runs from two separate radars were compared.

The VORTRAC software package was shown to be a viable tool for the retrieval of the detailed 3-D structure of a TC. VORTRAC was shown to agree well with observations and with manual GBVTD analyses, while efficiently processing data at a high temporal resolution. This promises to be a useful tool for both forecasting and research.

Figure 1

VORTRAC retrieved 60-minute averaged central pressure (solid line) of Hurricane Danny from the KLIX radar and the six hour National Hurricane Center best track central pressure (dashed line).
Different ways of knowing: exploring traditional ecological knowledge and climate modeling for the Turtle Mountains, North Dakota

Different ways of understanding climate change are pertinent to its study. To better understand the full scope of the impacts brought about by a changing climate, observations and perspectives from indigenous and local peoples, in combination with scientific climate data, are important to include in discussions and considerations of regional climate change. This study explores impacts of climate change on plants, and therefore culture, in the Turtle Mountain Reservation (North Dakota) community as seen through the eyes of an Anishinabe tribal elder who is the community’s medicine man. The analysis of CCSM3 coupled climate model projections for north central North Dakota revealed potential increases of 0.5 – 3.0°C in regional monthly temperatures by 2020. Precipitation is projected to increase in spring months and decrease in summer and fall. Through a semi-structured interview, the elder reported unpredictable regional weather conditions over the last 10 – 12 years. Observations included changes in winter temperatures and precipitation, unstable weather patterns during the transition from winter to spring, and dry summer conditions. The elder stated he is indirectly impacted when the harvest of culturally significant plants is compromised by changing environmental conditions. The ecosystem’s plant, insect, and wildlife species are shifting. By way of exploring Traditional Ecological Knowledge and climate modeling, we understand projected changes in temperature and precipitation are already underway in the Turtle Mountains. The breadth of knowledge and understanding of the region's environment exposes the changing weather’s impacts on not only the ecosystem, but on a community’s cultural practice.

Figure 1
The CCSM3 projected change in temperature from end of the 20th century to 2020 for north central North Dakota.
Flash floods: A spatial and temporal analysis. A case study of the March 2008 flash floods in southwestern Missouri

Floods are the leading cause of weather-related fatalities in the United States and the second most common cause of weather-related death worldwide. Of all floods, flash floods are found to be the most deadly with an average global mortality rate of 3.62%. This study performed a spatial and temporal analysis of flash flood risk using Geographic Information Systems (GIS) to analyze an event that occurred in southwestern Missouri in March 2008. The goals of the study were to identify different impacts of the disaster as indicated by flood reports, examine the social and natural factors that account for the spatial and temporal distribution and severity of the impacts, and compare the results with a previous study of a flash flood event in France. In the Missouri case, the analysis confirmed that small catchments react faster than large catchments, and they react to smaller amounts of rainfall. Seventy-seven percent of incidents (water rescues, fatalities, flooded homes, and flooded roads) occurred in catchments smaller than 200 km². The study also showed that a majority of the severe impacts (water rescues, fatalities, and flooded homes) occurred after the rainfall had tapered off, perhaps indicating that people erroneously believe that the danger has passed after the rain stops. When looking at water rescues and fatalities, this study found that fewer incidents occurred in medium-sized catchments (50-450 km²) than in either large (>450 km²) or small catchments (<50 km²). This is similar to the French study which found that no fatalities occurred in medium-sized catchments. Using GIS to examine flash flood risk will take strides forward in comparing human vulnerability with catchment size.

Figure 1

Time series displaying the circumstances surrounding the flood report incident in catchment 5. The time series was created by performing a temporal analysis.
The relationship between sea breezes and rainfall along western Mexico during the North American Monsoon

The North American Monsoon (NAM) is an annual phenomenon that influences the southwestern United States and northwest Mexico during the summer months. Atmospheric general circulation models have had difficulty forecasting precipitation events during the NAM season. The cause of this predicament has been linked to models’ insufficiency in simulating the daily cycle of winds within this region. Previous studies examined the daily cycle of winds measured by a 915-MHz wind profiler stationed at Estación Obispo (ETO), Mexico in an attempt to characterize the sea breeze events during the 2005 NAM season. This research extends that work by investigating the relationship between variations in the sea breezes over ETO and variations in the precipitation that fell on the western slopes of the Sierra Madre Occidental (SMO) in Mexico during the 2005 NAM season. Examination of the mid-afternoon (14-17 Local Time) wind directions at ETO revealed that onshore flow was present from a broad range of directions but within the south to west sector. Sea breezes occurred almost every day at ETO, more frequently than previous studies indicated. Daily rainfall from the North American Monsoon Experiment Event Rain Gauge Network (NERN) showed high variability throughout the season as well as between NERN stations. There was no significant association between the mid-afternoon wind direction along the west coast of Mexico and the daily rainfall on the SMO. These results may guide NAM scientists as they seek better methods to relate onshore flow with convective activity across the SMO.

Figure 1
Two polar plots of the daily rainfall at one NERN station versus the mid-afternoon wind direction at Estación Obispo, Mexico. NERN Station 79 (left) shows high variability in its summer rainfall amounts, and most of the rain fell on days with a general southwest wind direction. The precipitation amounts for NERN station 67 (right) were not as variable and tended to be concentrated in small amounts. Again, the majority of its rainfall events occurred on days with a southwest wind direction.
Re-examination of Northeast United States drought trends and characteristics

Drought or dry periods can have devastating societal and environmental impacts. For the northeastern United States, increases in dry periods could negatively impact the 54 million people who live in the region and depend upon the regional water resources. Because of climate change and the fluctuating precipitation patterns, drought/dry periods are expected to increase in the northeastern United States.

In this study we use Principle Component Analysis (PCA), Extreme Value Theory (EVT), and other statistical techniques to diagnose trends, characteristics, and possible causality of summer drought/dry periods for this region. The Palmer Drought Severity Index (PDSI), a widely employed and popular drought index, is used for the first part of the study. An independently developed dry period index, based on evaporation estimates and precipitation data, is used for the second part of the study.

Early results from the PCA performed on the PDSI data show a drying trend, spatially and temporally, for the northeastern United States, with the most intense drying visible over Pennsylvania. Results also show that there may be significant antecedent and seasonal correlations between the PDSI dataset and global weather and climate indices, such as land and sea surface temperatures and global surface wind fields.

This analysis is an important step in understanding the seasonal and sub-seasonal drought/dry period occurrences in the Northeast. It also provides insight into how these events are related to climate change and climate indices, and it improves the assessment and understanding of changes in drought/dry periods in this region.

First principle component (PC) time series from the Principle Component Analysis performed on the Palmer Drought Severity Index data for the northeastern United States. Positive PC values correspond to moist conditions and negative PC values correspond to dry conditions. This time series, which explains close to 50% of the variance of the original PDSI dataset, shows an overall drying trend for the Northeast.
Model analysis of 27-day solar-induced variability of chemical dynamics in the equatorial upper and middle atmosphere

The effect of solar variability on the atmosphere remains poorly understood. This study explored the impact of 27-day rotation of sunspots on the equatorial upper and middle atmospheric photochemistry from Whole Atmosphere Community Climate Model 3 (WACCM3) output. WACCM3 was driven with observed solar and greenhouse gas forcing for a period during the last solar maximum which included 1999, 2000, and 2001. Fourier and wavelet analysis were applied to determine the magnitude and phase responses to the solar-induced forcing on ozone (O3), temperature, hydrogen species (OH, HO2, H), molecular oxygen (O(3P)), water vapor (H2O), and shortwave heating. Wavelet analysis demonstrated that the response of these atmospheric constituents to the 27-day forcing is largely intermittent and depends on the magnitude of solar forcing. Fourier and phase analysis demonstrated that the largest responses of ozone occurred around 80 and 40 km. The former is attributed to increased production of odd hydrogen (HOX) from photolysis of water vapor at Lyman-α, while the latter is attributed to increased O3 production in the stratopause from increased UV. The analysis also demonstrated that the largest responses of temperature occurred around 70 km and 40 km. They are attributed to increased UV at those altitudes. The figure illustrates these responses. The amplitude of these responses compared well with data from models and observations. Phase difference, on the other hand, did not. Internal modes of variability close to 27 days and the realistic forcing mechanisms used to drive the model may contribute to this.

Figure 1
Profiles of temperature (dotted) and O3 (solid) for a zonally averaged latitudinal band, 20S to 20N, during a period of increased 27-day solar forcing during the 1999-2001 solar maximum.
Understanding past conditions of early Earth using trace metals in sulfide minerals

It is widely believed that drastic changes in Earth’s biosphere led to the great oxidation event (GOE), a sudden increase in atmospheric oxygen approximately 2.5-2.4 Ga. Nickel is an essential nutrient for methanogens, and there was a decrease in nickel production during this time due to Earth’s cooling. The emergence of cyanobacteria and the declining population of methanogens resulted. Cyanobacteria are photosynthetic bacteria that supplied an appreciable amount of oxygen to the atmosphere by first oxygenating the ocean surface. This created an iron oxide which settled to the bottom of the ocean floor as sediments in layered deposits called banded-iron formations (BIF). Once iron was nearly depleted, the release of oxygen from the oceans filled the atmosphere. BIF store geochemical signatures from early Earth that contain sulfide minerals with various amounts of trace metals in each sulfide mineral. By studying the abundance of trace metals (Ni, Zn, Cu, Co, Mo) before and after GOE, we can better understand the catalytic processes that were influential. Through use of an electron microprobe, new lines of evidence can be obtained to support the theory of the rise of atmospheric oxygen. Analysis of Ni/Fe ratios coincides with the nickel famine theory. During the GOE, there was a decrease in Co/Fe ratios. The other trace metals noted above are under further investigation.

Graph 1: Results (Graph 1) suggest decreasing ratios of Ni/Fe from 3.87-1.87 Ga. In comparison to K. Konhauser’s data (Graph 2), our results reveal similar trends of decreasing Ni/Fe ratios before and after the great oxidation event.

Cobalt analysis (Graph 3) yielded results of decreasing Co/Fe ratios suggesting possible decrease in cobalt after the great oxidation event.
Geochemical evidence for flat-slab subduction in Cenozoic western North America

Voluminous intermediate to silicic composition magmatism occurred in the Cenozoic throughout much of western North America and is generally attributed to melting in the upper mantle triggered by shallowing and resteeplening of oceanic lithosphere subducting along the western continental margin during this time. If so, then not only should there be systematic variations in the position of the magmatic activity through time, but these magmas should also carry geochemical signatures characteristic of arc magmatism, including enrichments in the abundances of large-ion lithophiles (LIL) relative to high-field-strength elements. With this issue in mind, a re-examination of space-time-composition patterns of Cenozoic magmatism in the western United States and northern Mexico is presented here, using igneous rock data compiled in the on-line western North American Volcanic and Intrusive Rock Database (NAVDAT).

An investigation of 5,625 volcanic rocks from the Rocky Mountain region in the western United States revealed latitudinal variations in the age of the mid-Tertiary magmatic pulse, and longitudinal variations in chemical composition, with alkalic character increasing to the east, and the highest Sr/Nb concentrations found in the central Rocky Mountain region. Isotopically, there was little to no variation in initial $\beta^{87}$Sr/$\beta^{86}$Sr ratios, while there were marked differences in initial $\varepsilon$Nd values, with values increasing to both the east and west of the central Rockies. Space-time patterns from 6,788 volcanic and plutonic rock samples from northern Mexico indicate that while there is evidence for periods of magmatic migration from 120 Mya to the present, these migrations are confined to the northernmost latitudes (36° N–28° N).

Taken together, these observations suggest that (1) variations in the mantle source region and the intensity of metasomatism existed during the mid-Tertiary in the western United States, and (2) flat-slab subduction did not extend into the southernmost latitudes (28° N–16° N) of northern Mexico.

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**Figure 1**
Comparison of Sr/Nb, initial $\beta^{87}$Sr/$\beta^{86}$Sr, and initial $\varepsilon$Nd values versus longitude in mid-Tertiary volcanic rocks in the Rocky Mountain Region, western United States.

Samples were restricted to ≤55 wt.% SiO$_2$ for $\beta^{87}$Sr/$\beta^{86}$Sr and $\varepsilon$Nd plots.
Shear wave splitting analysis from newly-installed seismic stations in Antarctica

The tectonic fabric of the upper mantle is inferred using SKS and SKKS splitting analysis of data from 15 newly-installed broadband seismic stations in West and East Antarctica. Data collected between December 2007 and December 2008 from 5 stations from the Polar Earth Observing Network (POLENET experiment) and 10 stations from the Gamburtsev Antarctic Mountains Seismic Experiment (GAMSEIS experiment) are used to perform an SKS and SKKS anisotropy analysis of the regions. In West Antarctica, POLENET stations straddle the West Antarctic Rift System (WARS) while in East Antarctica GAMSEIS stations are centered on and around the Gamburtsev Subglacial Mountains (GSM). POLENET stations show splitting times ranging from .85s to 1.25s and fast axes in cursory agreement with the inferred direction of WARS extension. For the larger focus of our study, GAMSEIS stations show a wider range of delay times (.65s to 1.55s) and fast splitting directions that may indicate the existence of 2 distinct tectonic regimes.

Figure 1
A  Normalized overlaid radial (solid) and transverse (dashed) broadband recordings of a teleseismic SKS wave. Note the non-trivial amplitude of the transverse component SKS energy.
B  Uncorrected elliptical particle motion for the SKS energy of figure A.
C, D  Reconstructed versions of A, B. Linearized particle motion in D indicates we have correctly modeled the best-fit splitting parameters characterizing the anisotropy beneath our station.
A study of gully erosion dynamics and processes at Bijou Creek, Colorado, using laser scanning and aerial photography

The process of gully erosion is not completely understood by geologists due to insufficient data. We use various techniques including 3-D laser scanning (terrestrial and airborne), real-time kinematic-GPS and aerial photography to acquire new data from a study site at Bijou Creek, Colorado, to help improve our understanding of this process. Analysis of the data shows that the average rate of erosion in the head cut of this specific gully is 0.5 meters per year with the rate of movement every year to be generally very constant. We also analyzed the rate of erosion of other gullies in Bijou Creek and found that their rates of erosion vary depending on the location of the landscape. The aerial photographs confirm the rate of erosion for the general head cut of the gully, but with TLS, we can analyze the locations of the gully being eroded the quickest and how much each area has been eroded. By comparing TLS scans from 2008 and 2009, we observed that the main erosion is in the head cut of the gully; everything else in the scan area was seen to move at a slower rate (or showed no movement over the this period).

Figure 1
Point Cloud of 2008 imposed over 2009 data, colors indicate the difference in meters from one year to the next. To view this figure in color, visit http://resess.unavco.org/past2009.html.
RESESS combines structured mentoring, ongoing research internships, and a supported learning community for undergraduate students from underrepresented groups in order to increase diversity within geology and geophysics.

RESESS participants share the SOARS organizational, structural, and social environment, centered on a series of 10-week summer internships in Boulder, Colorado. The internships include a research project in collaboration with a solid earth scientist who is trained as a mentor, an experience of living and working with other students from underrepresented populations in science, and multidimensional mentoring from writing and communication, community, and peer mentors.

Students who enter the program after their sophomore or junior year can participate in the program for up to four years. This continuity provides a bridge to graduate school with some financial support during their master’s program.

www.resess.unavco.org

Key to Mentors’ Affiliations

- CIRES
- COMET
- COSMIC
- NCAR
- NOAA
- UCAR
- UCAR E&O

CRES: Cooperative Institute for Research in Environmental Sciences

COMET: Cooperative Program for Operational Meteorology, Education and Training

COSMIC: Constellation Observing System for Meteorology Ionosphere & Climate

NCAR: National Center for Atmospheric Research

NOAA: National Oceanic and Atmospheric Administration

UCAR: University Corporation for Atmospheric Research

UCAR E&O: UCAR’s Office of Education & Outreach
Kneeling (L to R): Raymond Detweiler, Nicole Ngo, Vanessa Vincente, Daniel Pollak, Alex Gonzalez

Front Row (L to R): Roque Céspedes, Michael Hernandez, Fernando Martinez Torres, Katherine Fornash, John Braswell, Imani Morris, Marques Cameron, Matthew Paulus, Dana Pauzauskie, Ian Pagán-Colón


Not pictured: Stephen Hernandez, Lumari Pardo-Rodriguez, and Anastasia Yanchalina