Earth, Wind, Sea, and Sky
2011 RESESS, SOARS, and HIRO Project Abstracts
Sharome Goode, a SOARS protege from the University of Central Oklahoma, collects data from particulate matter field samplers at the Boulder Atmospheric Observatory Tower in Erie, Colorado, along with his research mentor, Michael Hannigan, from the University of Colorado at Boulder. Sharome’s research focused on measuring the vertical distribution of coarse particulate matter as compared to the Community Multi-scale Air Quality model.
We are delighted to present the 2011 research abstracts of 56 diverse students from all over the United States, including Puerto Rico. These students, part of three integrated research intern programs (SOARS, RESESS and HIRO), represent the very best of promising scientists in the geosciences, and we are proud to be associated with them!

SOARS (Significant Opportunities in Atmospheric Research and Science), RESESS (Research Experience in Solid Earth Science for Students) and HIRO (High School Internship Research Opportunities) represent an exciting experiment in bringing together students from diverse backgrounds and ages to Boulder for a summer program of research, education, training and fun! The three research internship programs give students a wonderful opportunity to experience authentic research; to learn to communicate science through talks, posters and writing; and to develop long-lasting bonds with peers.

SOARS and RESESS are both undergraduate-to-graduate bridge programs: SOARS focuses on atmospheric and related sciences and RESESS focuses on geodesy and related earth sciences. HIRO is a high school internship program that encompasses a range of scientific and technical fields. Students work with scientists and engineers in UCAR, NCAR, NOAA, the University of Colorado, UNAVCO and the USGS. Students also join together throughout the summer to share experiences that enhance their total experience. To our knowledge, the breadth of backgrounds and the multidisciplinary research projects of the students, and the range of organizations participating in the three programs are unprecedented.

While the students get support from their peers and program staff, they also receive substantial guidance and encouragement from their science and writing mentors. These mentors are members of the scientific community who dedicate a tremendous amount of effort to their interns. In addition to helping the students shape their research project, mentors provide feedback and guidance on science, writing, and presentations which aid the student in their professional development and scientific thinking. We repeatedly hear from our interns how much they appreciate the efforts of their mentors and how much they feel that they have developed and matured in one summer. This feedback and the success of the interns after they leave our programs confirm that our mentors are successful in supporting, encouraging, and guiding future scientists who come from diverse backgrounds.

Though the benefits to the students of these programs may be obvious, there are also unheralded benefits to the mentors and organizations who work with the protégés. The students bring curiosity, enthusiasm, fresh ideas and new experiences. Students and mentors are engaged together in a process that encourages interaction between and within groups and organizations, fosters collaboration across disciplines, and broadens participation in and the relevance of the Earth sciences.

None of this would be possible without the careful attention and strong encouragement of our mentors. For that reason, we would like to dedicate this volume of abstracts to our mentors as a way of thanks, from us and the interns.

Rick Anthes President of UCAR

Meghan Miller President of UNAVCO
100 year record of glacier retreat in North America
Jordan Allen

The hydrologic impact of antecedent soil moisture and straw mulch on a burned area,
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  Sharome Goode

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HIRO Chaperon and Undergraduate Research

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RESESS, or Research Experience in the Solid Earth Science for Students, is a summer research internship program in the Earth sciences that supports underrepresented undergraduates on their path to graduate studies in the geosciences. It offers an intense and rich eleven-week experience in Boulder, Colorado. The summer interns worked four days a week with their science mentor at a local scientific institution or agency, and then joined the SOARS interns on the fifth day for a writing workshop.

The RESESS interns spent Friday afternoons on local geology field trips, in career development workshops, or at UNAVCO-based training on GPS or 3D Terrestrial Laser Scanning, all of which also served as bonding experiences. Many interns had the wonderful opportunity to work directly in the field such as at Great Sand Dunes National Park or at the recently discovered mastodon site near Snowmass, Colorado. By the end of the summer, all interns had presented talks at the RESESS colloquium and given a poster in a conference-like setting. Most of the 2011 interns submitted an abstract to a national meeting this fall. They are quite excited about what is, for most of them, their first conference presentation. We are proud to present here the 2011 RESESS abstracts, each of which represents a tremendous amount of work by the intern in conjunction with the mentors, peers, and RESESS staff. This program would not succeed without significant and generous efforts of our RESESS mentors, and we are extremely grateful.

Interns are pictured left to right:
Front Row: Christine Chesley, Theresa Carranza-Fulmer, Ashley Grijalva, Britton Mosley Jr.
Middle Row: Angel Torrens-Bonano, Breanna Skeets, Crystal Yelverton, Jenna Lente
Back Row: Calvin Johnson, Cristina Lugo-Centeno, Melissa Carnicle, Jordan Allen
Not pictured: Luis Montalvo-Lliteras
Glaciers grow and shrink in response to changes in snowfall and air temperature, two atmospheric phenomena strongly impacted by global warming. We hypothesize that glaciers decreased in length over the last 100 years across in western North America where the rate of warming is twice the rate at lower latitudes. Glacier length records were obtained by measuring and comparing the lengths of eight glaciers on maps made in 1957 with aerial photographs on Google Earth dating from 2005. Length measurements showed uncertainties of 50-200 m. We also analyzed time-series photographs of 46 North American glaciers from the U.S. Geological Survey, and the Glaciers of the American West Project to determine a change in glaciers prior to the monitoring interval that began in the 1950s. Repeat photography photos showed a change in glaciers between 1900-2005, notably revealing retreat prior to the monitoring interval. We conclude from the photo and length data that all glaciers examined are retreating across North America.

**Figure 1**

Measurements of changes in glacier length through time for four North American glaciers obtained from World Glaciological Survey.
The hydrologic impact of antecedent soil moisture and straw mulch on a burned area, Fourmile Canyon Wildfire near Boulder, Colorado

Mountainous watersheds often exhibit an increase in runoff and flash floods after a wildfire. In September 2010, the Four-mile Canyon wildfire burned in the foothills of the Rocky Mountains near Boulder, Colorado. In an effort to minimize the risk of flash floods in the canyon, Boulder County aerially applied straw mulch on high-risk areas selected primarily based on slope and burn severity. The purpose of this research is to investigate the effects of antecedent soil moisture and impact of straw mulch on the hydrologic response, specifically interception, soil moisture, and runoff of a burned area. Volumetric soil moisture and storm runoff were measured from two sets of bounded, paired plots (two control, and two experimental) calibrated for 35 days starting in June, 2011, in a basin burned by the Four-mile Canyon Fire. The calibration period allowed us to better determine the relation between antecedent soil moisture conditions and the resulting runoff measurements, before straw mulch was added. Straw (5 cm thick) was added to the two experimental plots on 19 July 2011 and to the funnels of two visual rain gages in order to measure the amount of rainfall absorbed by the straw. Results from the calibration period show that runoff was greater under conditions of lower antecedent soil moisture, as anticipated. Antecedent soil moisture levels varied considerably between plots that were 12 meters apart, which indicates that calibrating for soil moisture prior to straw placement was critical. In the next phase of research, it is anticipated that total runoff will be lower on plots with straw than those without straw.

Figure 1
Runoff coefficients, calculated by the percent of rainfall that runs off for a given storm, recorded as a time series (left). Black and grey bars indicate data recorded from two runoff plots within the same study site and only 12 m apart. T Runoff Coefficient 0.16% for plot 10239 shows trace amounts.

*Because runoff events were not distinguishable between two storms on 7/13, the runoff coefficient was calculated using the total rain and runoff during both storms and presented for the final storm. Higher antecedent soil water content resulted in lower amounts of runoff.

Figure 2
Soil water content (or soil moisture) was measured 2-3 times per week. High antecedent soil water content resulted in lower amounts of runoff.

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1st-year Intern
Junior
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Chemistry, Geology, Environmental Science

MENTORS
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Deborah Martin, USGS

WRITING & COMMUNICATION
Bob Meade, USGS, Scientist Emeritus
Carol Detesfeld, UNAVCO
Sharome Goode, SOARS

COACH
Bob Meade, USGS

PEER
Melissa Carnicle
An introduction to inner magnetosphere plasma composition changes during Solar Cycle 23

Over the course of one solar cycle, fluctuations in the amount of solar energy, in the form of charged particles, can cause dramatic changes in the plasmasphere’s mass density. Understanding the dynamics of plasmaspheric mass density is important for understanding energy flow through the magnetosphere that in turn is important for satellite communications on Earth. Solar cycle 23 began on May 1996 and ended on December 2008. It had an unusually long solar minimum and low maximum compared to the last four solar cycles. This particular solar cycle has been the topic of discussion within the solar and space physics community. Our goal is to constrain the changes in plasmaspheric mass density between a solar minimum and maximum in order to observe how the plasmasphere density changes during this unusual solar cycle. We attempted to use an automated method created by Berube et al. [2003] that combines the cross phase and power ratio method to determine resonant frequencies from magnetic field lines which are then used to calculate plasma mass density. We obtained our data from paired magnetometers from MEASURE array at L = 1.74 and L = 1.99 with a time resolution of one second. The time period of analysis for solar maximum 23 is the month of September in 2000 during the solar minimum and the month of February in 2005 during the solar maximum. We discovered that most of the syntax and methods in the original program have been deprecated. This project will next focus on the modification and update of the automated method, which will eventually enable further plasmaspheric research.

Figure 1
A comparison of the number of sunspot numbers (SSN) observed from the past four solar cycles starting with solar cycle 20 and ending with solar cycle 23.
Great Nankai Earthquake triggers Mt. Fuji eruption: Stress change model of the 1707 Hoei Earthquake as a scenario of eruption promotion

Studies in magma-tectonics point to a spatiotemporal correlation between earthquakes and volcanic eruptions. Here we examine the correlation between two great earthquakes, the 1703 Mw8.2 Genroku and the 1707 Mw>8.7 Hoei events in Japan, and Mt. Fuji’s explosive (VEI 5) Hoei eruption, 49 days after the 1707 earthquake. We modeled the static stress change and dilatational strain imparted on the Mt. Fuji magmatic system due to each earthquake to determine if these mechanisms enhanced the potential for eruption. Seismic and petrologic studies suggest that a basaltic magma chamber is located around 20 km depth and a dacitic chamber is at ~8 km depth. An andesitic chamber likely lies somewhere in between, as mixed andesite-dacite lavas were erupted in 1707. We modeled the magmatic system as a single, vertical dike that extended from the surface to 20 km depth so as to connect the magma chambers to each other and to the surface. Our modeling results show that both earthquakes compressed the magma chambers beneath Mt. Fuji and clamped the dike at 8 km. The 1703 earthquake, however, also clamped the dike at 20 km while the 1707 earthquake unclamped this segment of the dike. We hypothesize that the stress change and compressional strain generated by the 1707 earthquake triggered the eruption of Mt. Fuji by permitting the opening of the dike and the ascent of basaltic magma into the andesitic and dacitic magma chambers. The injection of basaltic magma into the more evolved magmatic system induced magma mixing and a Plinian eruption ensued.

Figure 1
Schematic of the proposed triggering mechanism of the 1707 Hoei eruption:
a) Mt. Fuji magmatic system prior to the 1707 Hoei earthquake. The dacitic (light gray), andesitic (medium gray), and basaltic (dark gray) magma chambers are shown at their approximate depths. The dike connects the chambers to the surface;
b) Static stress changes from the 1707 Hoei earthquake undamp the dike at 20 km and clamp the dike at 8 km, allowing basaltic magma to intrude into the andesitic and dacitic magma chambers. Magma mixing is stimulated;
c) Mt. Fuji erupts.
Slip rate of the northern San Jacinto and southern San Andreas Faults from GPS measurements

Slip rate is the key determinant of the repeat time of earthquakes rupturing a fault and a critical input into assessments of seismic hazard. To determine slip rates, both geologic and geodetic methods are used. Geologic methods measure historical slip and include the use of LiDAR data or field mapping to measure offsets, and radiocarbon dating to determine the ages of those offsets. Geodetic methods can give accurate estimates of current slip rates by measuring crustal strain accumulation at various distances from a fault. In southern California, there is a discrepancy in slip rates between the two methods; the geologic slip rate estimate for the San Andreas Fault in Cajon Pass is 25 mm/year while the geodetic estimate is 5 mm/year. We constructed time series to obtain velocities for our sites. We then conducted two-dimensional elastic modeling to find the ranges of fault slip rates that are consistent with our GPS velocities. The best-fitting model had slip rates of 8 mm/yr for the San Andreas and 14 mm/yr for the San Jacinto fault. These results are consistent with prior geodetic studies, which suggest a low rate for the San Andreas Fault. However, from the combinations that produce relatively well-fitting lines, the San Andreas Fault slip rate could be anywhere between 0-24 mm/yr and the San Jacinto Fault slip rate could also be anywhere between 0-24 mm/yr. Nonetheless, our results showed that the SJF-SAF system must have a total slip of 20-24 mm/yr on the two faults combined. The best-fitting rate for all faults in the Eastern California Shear Zone combined was 15 mm/yr. The models we tested were that showed the best-fitting line ranged from 0-10 mm/yr. For the faults west of the SJF system, the combined best-fitting rate was 8 mm/yr.

Figure 1

The magnitude of the fault-parallel velocity component of each benchmark surveyed is plotted as a function of distance from the SJF (San Jacinto Fault) which is the vertical line at x=0. Our best-fitting model (curved line) shows the SJF to have a slip rate of 14 mm/yr and the SAF to have a slip rate of 8 mm/yr. The Geologic estimate represented by the dashed line shows the SJF to have a slip rate of 12 mm/yr and 24 mm/yr for the SAF.
Delineation of aquifer heterogeneities using transient electromagnetic soundings in the Great Sand Dunes National Park

During the Pleistocene epoch a laterally extensive aquitard composed of clay was deposited in the bed of Lake Alamosa throughout San Luis Valley (SLV), southern Colorado, including what is now Great Sand Dunes National Park and Preserve. Despite the lateral continuity of the “blue clay,” as it is colloquially known, hydrological and geophysical evidence suggests that there are heterogeneities in the depth and thickness of the clay within the siliciclastic aquifer system. These heterogeneities can cause variations in the confining pressure affecting groundwater flow and complicating the monitoring of groundwater resources. Transient electromagnetic (TEM) soundings were used to delineate the continuity of the blue clay near Antelope Springs. TEM data were collected along profiles by inducing electrical currents into the ground. Resistivities of lithological features were modeled using mathematical inversion and were used to develop a cross section of the subsurface. In the interpreted cross section, the top of the blue clay unit has a 50 m decrease in depth over a distance of approximately 1400 m along the profile and then terminates at the interpreted shoreline of the ancient Lake Alamosa. Preliminary analysis suggests that subsurface elevation of the top of the blue clay unit exhibits an anomalous decrease to the west, and post-depositional faulting is unlikely because of the shallow and gradual slope. Additional data acquisition and analysis are needed to further investigate whether the heterogeneity in the blue clay is related to pre-depositional faulting, sedimentary processes, or both.

Figure 1
Interpreted cross section showing the surface elevations of each sedimentary layer as constructed from TEM sounding data and modeling results. Shades of gray show differences of resistivity that identify each layer in the cross section. The darkened data points from approximately 4 – 6 km represent this study’s profile, and the other points are from previous investigations.
Measurements of possible seiches in Lake Yellowstone

On July 12th 2009, a large and persistent signal was detected on a borehole strainmeter in Grant Village in Lake Yellowstone. A significant wind event and fluctuations in the discharge rate at the Yellowstone River outlet occurring concurrently suggest that the signal was caused by a seiche (a harmonic wave in an enclosed water body). Using Merian’s formula and the dimensions of the West Thumb Basin, the waves’ period was calculated to be 11.2-13.0 minutes. This correlation indicates a concurrent event is occurring in the lake and the river outlet, but it cannot verify a seiche. Some information suggested that the signal wasn’t a seiche. Crustal strain modeling, with a static non-gravitational model, indicates that to create strain such as what was observed at Grant Village, the amplitude of the seiche would have to be 1-5 meters. That is the amplitude of a tsunami, not a common seiche. Also, the wave continued for an uncharacteristically long time for a seiche—up to hundreds of cycles indicating a high Q factor (a dimensionless quantity describing loss of energy compared to stored energy). Normal seiches only oscillate for about 5-6 cycles; exhibiting a low Q factor. Because wind is a typical seiche forcing mechanism, wind data was analyzed and compared with strain data for June 2011. Data from the Yellowstone river outlet was also plotted searching for fluctuations at the same time there is a “seiche” signal detected on strainmeters. To verify a seiche, water level fluctuations were measured using a pressure sensor in mid-August 2011. Preliminary measurements of water levels indicate a 2 cm wave with a period of 11.0 minutes. This correlation between water levels, wind speed, river discharge, and the strain strongly support a seiche as the primary source of the strain signal.

Figure 1
Correlating the wind data with the strain data, it is clear that near constant wind throughout the week could have forced enough water to one side of the lake to create a seiche around June 23rd continuing strongly through the 26th and continuing slightly through the end of the week. Wind speeds of 0 MPH do not necessarily mean a seiche is impossible, because the water could still be sloshing back and forth from previous winds.
The Snowmastodon Site: 
Investigation of the Yellow Brick Road

In October 2010, bones of a juvenile Columbian mammoth were found during the excavation of a small reservoir near the town of Snowmass Village, Colorado. Subsequent excavation efforts led by the Denver Museum of Nature and Science recovered more than 4800 bones from at least 26 different Pleistocene taxa, including mammoths, mastodons, ground sloths, bison, camel, and horse, as well as smaller mammals, reptiles, and birds. At this site, informally called the “Snowmastodon Site,” a yellow-banded silt unit delineates the approximate transition between mastodons (below) and mammoths (above). The unique yellow color suggests that chemical and mineralogical differences between this and adjacent units that are likely related to changes in depositional environments. During the summer of 2011, we collected multiple samples from the yellow-banded silt and adjacent units to physically and chemically characterize the sediments and their depositional context. X-Ray diffraction analysis was performed to examine the mineralogical composition of the samples, energy-dispersive x-ray fluorescence was done to quantify elemental concentrations, and grain size analysis was conducted. Results did not reveal significant differences between the yellow-banded silt and adjacent units. However, the yellowish color of the banded silt suggests that the iron (and possibly manganese) species are oxidized, which implies that its deposition occurred during a period of particularly shallow water depths. Faunal remains, including abundant tiger salamanders, snakes, and rodents, also suggest water depths were especially shallow at this time. Work is ongoing to constrain the age, identify possible sediment sources, and further improve our understanding of these depositional environments.

Figure 1

Percentage of abundance of chemical elements in the samples of the yellow-banded silt (ZR-10-1, ZR-10-6, ZR-10-8) and the adjacent units (ZR-9, ZR-11). Based on our data, the concentration of Fe in the yellow-banded silt is similar to the concentration of the adjacent unit.
Evaluation of drilling events in the Haynesville and Bossier Shale, Magnolia, NW Louisiana

The Magnolia field in NW Louisiana has been a potential target for the drilling of gas wells by Shell Exploration and Production and Encana since 2007. Data taken from drilling reports and mudlogs was used to create geohazard maps for the Haynesville and Bossier shales in the Magnolia AMI (area of mutual interest). Three types of drilling events were identified: gas shows (circles in figure), circulation loss (crosses in figure) and failed Formation Integrity Test (LOT) (crosses in figure). An evaluation was done using reports and mudlogs to explain the genesis of each of these events in two categories: lithology related or fracture related events (includes faults). Using the software, Schlumberger Petrel 2009.2, well sections were used to plot the stratigraphic location of these events, and geohazard maps were generated to analyze their aerial distributions. Correlation of events was possible in some areas and three hazard zones were found in the Lower Bossier stratigraphic layer. The Lower Bossier is the stratigraphic interval with the largest amount of gas shows due to a slight change in permeability making it easier to expel gas while drilling. This is consistent with the estimated amount of generated gas found on the Lower Bossier by other studies. The Upper Bossier is the depth at which the larger amount of circulation losses was detected. Fewer events where found at the Haynesville, which is the present target for gas production. Geohazard maps were developed and compared with data for Estimated Ultimate Recoveries (EUR) to correlate drilling events with the production of Shell and Encana wells. No correlation is found because gas shows are happening on nonproducing intervals and the amount of gas shows can be affected by drilling parameters.

Figure 1
Map of the NW Louisiana Haynesville gas play showing the distribution of drilling events taken from drilling reports and mudlogs. Drilling events represented in the map are: gas shows (circles in map), circulation losses (crosses in map) and failed formation integrity tests (crosses in map).
Factors controlling infiltration rates in a semi-arid landscape

Agricultural landscapes in semi-arid regions are often prone to gully erosion. Understanding rates and patterns of gully erosion requires documenting the driving hydrology, and in particular quantifying the capacity of soils to generate runoff during summer convective storms. Here we report measurements of soil infiltration capacity at a study site, known as the West Bijou Creek escarpment, 40 miles southeast of Denver. Rapid gully network propagation at this site appears to be driven mainly by head cut retreat during flash floods. Using a double-ring infiltrometer, measurements of infiltration rate were collected across a variety of soil and vegetation types to determine the degree to which factors such as vegetation, slope steepness, soil porosity and permeability influence soil infiltration capacity. We measured infiltration capacity in 15 different locations and observed infiltration rates ranging from 40 to 400 mm/hr. In general, the hillslopes were less permeable than valley floors. Hillslope infiltration capacity was in the range of 40 to 70 mm/hr. Valley floors on the landscape show greater variability in the saturated infiltration capacity, with rates ranging from 70 to 320 mm/hr. Surprisingly, areas that are underlain by sandstone and shale show similar infiltration rates. At the study site, rainstorms with a 10-minute peak intensity above 60 mm/hr are capable of producing overland flow; such storms typically occur several times a year. The data suggest a conceptual model in which most runoff is generated on hillslopes, and the resulting flow routed through valley networks drives rapid erosion, sediment transport, and head cut retreat.

Figure 1
Infiltration measurements recorded on soil derived from a sandstone formation at Bijou Creek. The line represents a best fit line. It shows the pattern of high rate of infiltration followed by a rapid decrease and leveling off to a base rate of infiltration.
Transpiration source water and geomorphological potential of root growth in the Boulder Creek CZO, Colorado

The influence of vegetation on the hydrological cycle and the possible effect of roots in geomorphological processes are poorly understood. Gordon Gulch watershed in the Front Range of the Rocky Mountains, Colorado, is a montane climate ecosystem in the Boulder Creek Critical Zone Observatory (CZO) whose study adds to the understanding of ecohydrology in different climates. This work sought to identify the sources of water used by different tree species and to determine how trees growing in rock outcrops may contribute to the fracturing and weathering of rock. Stable isotopes ($^{18}$O and $^2$H) were analyzed from water extracted from soil and xylem samples from trees. We found that *Pinus ponderosa* trees on the south-facing slope consume water from deeper depths during dry periods and use water from soils saturated by rainfall events. *Pinus contorta* trees on the north-facing slope show a similar, expected response in water consumption, before and after rain.

Two trees (*Pinus ponderosa*) growing within rock outcrops demonstrate water use from cracks replenished by new rains. An underexplored question in geomorphology is whether tree roots growing in rock outcrops contribute to long-term geomorphological processes by physically deteriorating the bedrock. The dominant roots of measured trees contributed approximately 30-80% of total water use, seen especially after rainfall events. Preliminary analysis of root growth rings indicates that root growth is capable of expanding rock outcrop fractures at an approximate rate of 0.6 – 1.0 mm per year. These results demonstrate that tree roots play a significant role in a tree’s physiological processes and in bedrock fracturing.

**Figure 1**

Isotopic samples from soils and trees plotted against the Global Meteoric Water Line (GMWL)(A) North-facing slope with closely spaced *Pinus contorta* demonstrating a strong isotopic signature of evaporated water in soils. The first period, June 13–15, was dry with little rain shown by tree water uptake from the evaporative zone. June 21st samples indicate that the trees consumed water from recent rainfall, as shown by similar isotopic signatures of the xylem and the soil samples. Water sources for the trees on June 29 are below 20 cm, as noted by a less evaporated isotopic signature.

(B) Xylem fluids from more widely spaced *Pinus ponderosa* growing in soil on the south-facing slope show that the trees tapped into deeper water sources during the dry period of June 13–15. On June 21, the soil isotopic signature was more negative in response to recent rain; however, the trees’ isotopic signature was similar to that of the first period. Samples from June 29th show that the trees used shallow water near recorded soil depths.

(C) Rock outcrop samples demonstrate that the trees used the water that’s not in soil, but presumably from fractures. In the first period (dry), trees used deeper water sources, rather than surface soil water. During the second (wetter) period, recent rainwater was the trees’ source. On June 29th, the trees were not using surface soil water, which suggests a deeper water source.
GPS site velocities in the San Bernardino Mountains

The southern part of the San Andreas Fault (SAF) has been locked for almost two centuries now, but because of the elastic behavior of the Earth’s crust, the surroundings are moving, and thus accumulating strain along the fault. To know how much strain has been accumulated on the San Bernardino Strand (SBS) of the SAF, a Global Positioning System (GPS) campaign was conducted in mid July 2011 collecting data from 25 different benchmarks to measure sites positions in and around the San Bernardino Mountains. Combining these positions with positions measured in previous years, we created time series to determine each site’s rate and direction of motion. The east and north velocities were combined to obtain a horizontal velocity for each site. All of the sites are moving toward northwest, at rates ranging from 11.6 to 35.1 mm/yr. As expected, stations farther to the west are moving faster (relative to the North American plate) than those to the east. In the companion project (Grijalva), these site velocities are use to describe the crustal deformation within a transect area across the SAF and other parallel faults to find the combinations of fault slip rates that fit the site velocities well.

Figure 1
Time series plot for GPS site NORC in the North direction

y = 0.0244x - 42.85
r² = 0.99656
Is climate change affecting tropical cyclone activity?

Determining the consequences of a warmer climate is a highly important issue in today’s society. This study attempted to determine whether tropical cyclone activity has increased in frequency and intensity due to a warming climate. We developed the null hypothesis that there would not be a detectable increase in tropical cyclone activity due to an increase in sea surface temperature. To test our null hypothesis, we examined sea surface temperatures (SST), storm count (HURdat) data, sediment core grain size data from a tropical lagoon, and category 2, 3, 4, and 5 hurricanes, covering time periods over the past 30 to 150 years. A t-test was used to identify significant trends in the regression lines of the five data sets. The SST data and Category 4 and 5 hurricane data exhibited significant increases over time at the 95% confidence level. In the category 2 and 3 storms, HURdat, and grain size data, we could not reject the null hypothesis of no significant change. We examined a direct correlation between annual SST and annual number of storms per year in the North Atlantic, over more than 100 years. Although this correlation suggested a positive trend, a t-test showed that the correlation coefficient $r^2$ was low, less than 0.2. Our analysis confirmed that tropical Atlantic SST only increased by 0.4°C over a 100-year period, perhaps not enough warming to cause a clear increase in tropical cyclone activity.

![Graph showing correlation between SST and number of storms per year.](image)

**Figure 1**

A correlation between North Atlantic SST data (from Brohan et al. 2006) and the adjusted North Atlantic storm count data of Landsea (2009) for the time period 1878 to 2008. Although the data show a hint of a positive correlation, suggesting that as SST increases, storm count increases as well, the correlation coefficient, $r^2$, was 0.12, not significant at the 95% confidence level.
SOARS is a multi-year undergraduate-to-graduate bridge program designed to broaden participation in the atmospheric and related sciences. It focuses on three strategies: building a strong and supportive learning community, offering students multiple mentors, and providing hands-on experience in research. SOARS invites students from many disciplines—including meteorology, chemistry, physics, engineering, mathematics, ecology, and the social sciences—to apply their expertise to understanding the Earth’s atmosphere.

The SOARS experience centers on ten-week summer research internships that also include a weekly communication workshop and culminate in end-of-summer research presentations by protégés. During the summer, each protégé is supported by mentors at UCAR, NCAR and partnering labs who focus on research, communication and computing; SOARS staff and returning protégés provide career and life-choice mentoring throughout the year. SOARS protégés also receive need-based tuition support, GRE and graduate-school training, and financial and logistical support to present their research at scientific meetings.

In the 15 years since SOARS’ founding, 147 students have participated in the program. Of those participants, nine are still enrolled as undergraduates, and 113 have gone on to pursue graduate school in STEM. Overall, this represents a success rate of 75% for STEM, or 89% if we include students who earn graduate degrees in non-STEM fields. Fifteen SOARS participants have already earned their PhD, and additional 23 are currently in PhD programs.

Protégés are pictured left to right:

Front Row: Theresa Aquilar, Manuel Hernandez, Jr., Daniel Pollak, Jenny Evac, Javier Lujan
Back Row: Diamilet Perez-Botanotchur, Graylen Boone, André Perkins, Sharome Goode, Karl Clarke, Vanessa Almata, Raymond Dettwiler
Gust front vs. non-gust front thunderstorms: An investigation into storm characteristics and environmental conditions

The development and propagation of a gust front is shown to be an integral part of a thunderstorm’s life cycle in conceptual models and schematics. This outflow boundary has the potential to initiate new storms as well as inhibit or enhance existing storms. However, not every thunderstorm produces a gust front, and the reasons are not well understood. This deficit in knowledge leads to a lack of criteria for forecasting which storms will produce gust fronts that may generate new storms. This study examined four ordinary thunderstorms — two gust front (GF) storms and two non-gust front (NGF) storms — during the 2002 International H2O Project (IHOP). The objective was to determine if GF and NGF storms exhibit differences in terms of storm characteristics and environmental conditions. The S-band Dual Polarization (S-Pol) Doppler radar provided measurements of reflectivity (Z), differential reflectivity (Zdr), and specific differential phase (Kdp) to describe each storm’s characteristics (microphysics). Standard parameters that characterized the environment were derived from soundings at different sites within S-Pol’s range. Preliminary analyses indicate some similarities and differences between GF and NGF storms — more in storm characteristics (e.g., growth rate of Z, descent of 0 Zdr, strong gradient change in Kdp) than in environment (e.g., nearly similar profiles). However, more storms need to be investigated to substantiate these preliminary findings, which can help improve our understanding of GF production and forecasting.

Figure 1
Comparison of storm characteristics and environmental profiles for a GF and a NGF storm.
A) Time-height plot of the mean reflectivity (Z) overlaid with the mean differential reflectivity (Zdr) for the GF storm.
B) Corresponding environmental profiles from a Skew-T Log-P diagram.
C) Same data as A), but for the NGF storm.
D) Same data as B), but for the NGF storm. The GF storm underwent two cycles of growth, whereas the NGF storm only had only one cycle. As indicated by Zdr, the GF storm produced a prominent descent of spherical precipitation (e.g., graupel) prior to the time the GF appeared on radar (black arrow); such an event is not clearly evident in the NGF storm. The environmental profiles show the mid-atmosphere (500-200 mb) to be very dry with a nearly uniform wind profile for the GF storm, while the NGF storm showed a slightly moister environment with strong low-level shear.
Precipitable water vapor in and around tropical cyclones in the Caribbean: 2007-2010

This study analyzes precipitable water vapor (PWV) in and around tropical cyclones (TC) over the Caribbean region. PWV is highly variable in time and space, and it is a potential energy source for tropical cyclone development. To characterize the PWV profile in and around TCs, observations of PWV are compared to PWV from an operational weather forecasting model for the years 2007-2010. PWV observations were gathered from the Suomi Network of ground-based Global Positioning System (GB-GPS) stations within a 1,000 km radius of a TC’s center and categorized by storm strength. Maximum wind speeds and coordinates of storm centers were obtained from the North Atlantic Basin Hurricane Dataset. The Global Forecast System (GFS) model initializations of PWV were then linearly interpolated to the GB-GPS at a 6-hourly time resolution for comparison. The statistical analysis of PWV from the GPS and the GFS revealed a consistent overestimation of PWV in the GFS. This overestimation ranged from 2-4 mm at distances beyond 200 km from the storms’ centers. However, at distances within 100 km from the storms’ centers, the average PWV was underestimated by the GFS in the tropical storm category. The GFS model error was greatest at approximately 200 km from storm centers. Statistics correlating PWV and storm strengths of Category 3 and higher were inconclusive due to lack of observations. This study thus provides adequate analysis of PWV for TC strengths below Category 3, and this can be useful for improving tropical cyclone forecasts.

Figure 1
Statistical analysis of precipitable water vapor (PWV) distribution at 50 km intervals with respect to distance away from the tropical cyclone’s (TC) center, storm center being zero. These were obtained from 45 storms between the years 2007-2010 that traveled within 1,000 km from one or more of the 310 ground-based GPS stations.

a) The average PWV GPS-GFS difference calculated from the values along the circumference of concentric circles. The left y-axis shows the average PWV difference (points) of GPS and GFS in millimeters, with the standard deviation (whiskers).
b) Average percent difference between GPS and GFS relative to GPS PWV observations. The left y-axis indicates the absolute percent difference (solid line) of GPS and GFS. The right y-axis indicates the number of PWV observations (grey dashed line).
Evaluation of the new crop option in the CLM4CN/CAM4 using Midwestern United States site observations

As greenhouse gases, particularly carbon dioxide, become more prevalent in land-climate interaction studies, models that accurately represent vegetation are critically important since plants store and emit large amounts of CO₂. Recent studies note that climate models fail to reproduce observed phenological data. Comparing models with observations helps identify needs and approaches for model improvement. The focus of this study is to evaluate the performance of the new crop option in the Community Land Model v.4 Carbon Nitrogen Model/Community Atmosphere Model v.4 (CLM4CN/CAM4) by comparing two sensitivities of the coupled simulation to observed data gathered from the AmeriFlux Network website. In the Late-planting simulation, crops are planted as late as the conditions in the simulation allow, while in the Crop simulation, crops are planted whenever the conditions allow during the planting period. The selected locations, Bondville, Illinois (US-Bo1), Ponca City, Oklahoma (US-Pon), and Fermi, Illinois (US-IB1) revealed better accuracy using the Late-planting simulation. US-Bo1 revealed that Leaf Area Index (LAI) heavily influenced net ecosystem exchange (NEE) and sensible (H) and latent (L) heat fluxes. Increasing LAI results in an increase in L through more transpiration from leaves. As a result, less of the net radiation goes toward H. The timing of maximum LAI also influences carbon uptake and, therefore, the NEE. US-Pon exhibited the model’s inability to accurately represent winter wheat, while US-IB1 showed small influences from crops due to very small crop coverage in the grid cell. Further research at additional locations will help determine the accuracy of model representation of crop vegetation on land-climate interactions.

Figure 1
Monthly averages for observed and model-simulated Leaf Area Index (LAI) and square meter of leaves per square meter of ground for site locations US-IB1 (top), US-Pon (middle), and US-Bo1 (bottom). The Crop simulation is represented by the dotted line, the Late-Planting simulation is represented by the dashed line, and the observed data is represented by the solid line.
Climatology of stability indices for Cincinnati, Ohio

Three of the top five worst tornado outbreaks in U.S. history occurred between January and May 2011. Some may make the hypothesis that this is due to climate change. To explore methods for testing this theory, the changes in decadal averages of numbers of severe thunderstorm days in the metropolitan area of Cincinnati were examined. This area was chosen due to its high population and its location near the jet stream and Tornado Alley. Three stability indices were chosen from all 0 Z soundings during the last 30 years: the Lifted Index, the K-Index and Convective Available Potential Energy (CAPE). The decadal and 30-year averages of monthly, seasonal, and annual percentages of possible severe thunderstorm days were first derived. Afterward, an examination of the decadal averages revealed some trends. The results showed the month of July having the highest number of possible severe weather days. The frequency of possible severe thunderstorm days increased during the summer, while the winter had hardly any severe weather. The spring, summer, and fall averages for the decade of 2001-2010 were always higher than their 30-year climate normals. These findings are consistent with an increase in the frequency of severe thunderstorms over the past few decades, but more study is needed.

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Figure 1
Decadal and 30-year averages of the seasonal percentage of days with Unstable CAPE.
Program coordinators’ perceptions of effective national citizen science programs and their impacts: An exploratory study

The increasing desire to engage the public in science and research has advanced citizen science as a valuable and popular means to this end. Citizen science, a process by which concerned individuals, agencies, industries or community groups collaborate to monitor, track, and respond to issues of common community concerns, has evolved and grown over the past decade. Much of the citizen science research thus far has primarily focused on the public participants (citizen scientists) and/or organizations themselves. This study looks instead at the people, the coordinators, implementing or coordinating citizen science programs and activities, specifically in the Community Collaborative Rain, Hail & Snow Network (CoCoRaHS), and their perceptions for program effectiveness. CoCoRaHS is a national program in which citizens monitor, record, and report precipitation conditions from backyard observations. Semi-structured interviews and an online survey completed by the program’s coordinators in the state of Colorado found that the effectiveness of CoCoRaHS depends less on the interactions of the coordinators with each other or funding impacts on program activities, but rather on the interactions between coordinators and citizen scientists. The effectiveness of CoCoRaHS was perceived to depend more significantly on the connections coordinators have with the community of program users and citizen scientists, and a supportive culture within the program. The next step, therefore, is to explore these interactions between the coordinators and citizen scientists to develop a better understanding of their nature of participation in the citizen science program, and to describe the characteristics of all participants.

Figure 1

This chart shows the frequency of response for concepts that program coordinators believed to be important for the effectiveness of national citizen science programs.
Satellite observations of NO$_2$ and CO

Data were obtained from the Global Ozone Monitoring Experiment (GOME) instrument on the European Remote Sensing 2 (ERS-2) satellite and from the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) on the European Space Agency’s Environmental Satellite (ENVISAT) to construct a time series of nitrogen dioxide (NO$_2$) column measurements over the Eastern U.S., Western Europe, Japan, Eastern China, and India for the period 1996-2010. Data from the Measurement of Pollution in the Troposphere (MOPITT) instrument aboard the NASA Earth Observing System (EOS) platform were obtained to construct a time series of both column and surface carbon monoxide (CO) over the same areas for the period 2002-2010. A decrease in NO$_2$ was found over the Eastern U.S. and Western Europe. The values from Western Europe and Japan remained almost constant, and the values from China showed a rapid increase. CO trends were expected to be similar since the two pollutants share many common sources, but in fact both the column and surface CO observations trended downward for each of the regions. The decreasing trend was especially pronounced over Eastern China, which was also the only area that exhibited a concurrent increase in NO$_2$ emissions. It was found that changing fuel use in the residential sector may be the principal driver behind the observed drop in CO emissions.

Figure 1
Trends in NO$_2$ columns from GOME and SCIAMACHY measurements over Eastern China, Western Europe, Eastern U.S.A., Japan, and India.
Monoterpenes (C_{10}H_{16}) are volatile organic compounds (VOCs) naturally emitted into the atmosphere from vegetation, especially flowering plants and conifers. VOCs play a role in controlling atmospheric chemistry and they participate in the formation of air pollutants, such as ozone. Monoterpene emissions from vegetation are species-specific and strongly dependent on temperature. There have been no detailed studies that correlate monoterpene emissions into the atmosphere with monoterpenes found in storage reservoirs in plant foliage nor are there detailed studies that describe the variability of monoterpene composition within individual plants and between plants of the same species. Using a gas chromatograph equipped with a mass spectrometer and flame ionization detector, this study surveyed the variation in concentration and composition of monoterpenes in Pinus ponderosa and Pinus nigra needles to determine (1) whether variation occurs between needle orientation (e.g., north-, east-, west-, south-facing) or age within individual trees (new, one-, and two-year-old needles); (2) whether variation of oil composition exists among different trees of the same species, and (3) whether differences occur between monoterpene composition stored within needles and emissions. Results show that compositions and concentrations did not differ in samples taken from different positions within a tree, but they do differ between age groups in Ponderosa pine. Additionally, sabinene and myrcene were found in emission samples in the presence of light, but not in monoterpene pools of Austrian pine needles, suggesting that they are produced and emitted immediately and not stored. Future study will develop a numerical model for emissions incorporating temperature and concentrations.
Simulating magnetosphere-ionosphere coupling in the TIEGCM

At high latitudes there is a strong coupling between the magnetosphere and ionosphere. Modeling the full coupling can require extensive computing resources since a magnetosphere model has to be coupled to an ionosphere model. Therefore, most general circulation models (GCMs) approximate this high-latitude coupling by using empirical models that specify the high-latitude convection pattern for different geospace conditions. This research aims not only to show the viability of the NCAR Thermosphere-Ionosphere Electrodynamics GCM (NCAR-TIEGCM) in its ability to model the magnetosphere-ionosphere coupling using a prescribed electrical potential from the empirical model, but also to show that it can accurately represent the coupling using field-aligned current (FAC) consistent with the prescribed electric potential. Using FAC to drive the high latitudes has the advantage that the neutral wind effects can be considered everywhere instead of using a prescribed empirical electric-potential pattern. In addition, with new data from the AMPERE satellite, the TIEGCM has the option to be driven by a more realistic spatial and temporal distribution of the energy input. This study compared the effects of forcing the model with a prescribed electric potential to forcing the model with a consistent FAC. The results indicate that convection is stronger when the model is forced by FAC because of the neutral wind effect. We further examine the difference in total energy input and its effects on the thermosphere temperature. The electrical potential is affected by the FAC and neutral winds, also the Joule heating is affected by the ion density and conductivity, temperature by all. This study found that the FAC represents a more dynamic coupling between the magnetosphere and ionosphere. Further studies would be using satellite data for the TIEGCM FAC input.

Figure 1
Vertical distribution of coarse particulate matter

Studies of air quality and health effects from airborne particulate matter (PM) have traditionally focused on particles <10 µm in diameter (PM10), or particulates <2.5 µm in diameter (PM2.5). The coarse fraction of PM10 (particulates >2.5 µm) has only been studied recently. This study investigates the vertical distribution of coarse PM at the Boulder Atmospheric Observatory Tower located in Erie, Colorado. There were five measurement levels selected on the tower at 2, 22, 50, 100, and 300 meters. Two devices were used for collecting coarse PM: a PM10 field sampler and a PM2.5 field sampler. The concentrations of PM10 and PM2.5 were calculated, then the coarse particulate (CP) concentration was obtained by subtracting the concentration of PM2.5 from PM10. These measurements of the vertical distribution of coarse PM were compared to the Community Multi-scale Air Quality (CMAQ) model, which assumes all particulate matter is uniformly distributed vertically in the Atmospheric Boundary Layer (ABL). These results indicate that the concentration of CP decreases with altitude. Further research is needed to refine the CMAQ modeling system assumption and more accurately predict future air quality.

| Height | Pump | Date | Total Time | Pump Flow | Mass Conc. | Coarse Conc.
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**Figure 1**

Data from the third sample collection of PM10 mass, concentration, and coarse concentration.
Analysis of present-day and future precipitation in the Southwestern United States

The southwestern U.S. is one of many regions susceptible to the effects of our changing climate system. Numerous climate phenomena, such as the North American Monsoon and Madden-Julian Oscillation, are known to correlate with precipitation and temperature variations in the Southwest. These processes can be linked to sea surface temperatures (SST) in the tropical Pacific Ocean which also influence global climate. This study explored the relationship between SST in the Pacific and temperature and precipitation changes in the southwestern U.S. by comparing observational data in an Intensive Observation Period (IOP) of the Southern Great Plains to the Community Atmosphere Model (CAM 4.0) and the Community Climate System Model (CCSM 4.0). This comparison was used to verify that these model data accurately depicted the present climate and could be used to capture a reasonable prediction for our future climate. Our analysis showed a correlation between tropical Pacific SST and variations in temperature and precipitation in the southwestern U.S. that creates an El Niño effect in part because of an increase in greenhouse gases. Our statistical analysis yielded large values for this correlation, confirming our hypothesis that our changing climate system is affecting weather patterns in the southwestern U.S. through increased tropical Pacific sea surface temperatures.

Figure 1
Comparison of temperature histograms for:
- a) Observations
- b) CAM 4.0
- c) CCSM 4.0

Figure 2
Correlation of precipitation with Tropical Pacific sea surface temperatures with a lag of one season.
Understanding wind profiler observations of the stratocumulus-topped marine boundary layer

Clouds directly affect Earth’s energy budget by changing the planet’s albedo and the balance of incoming and outgoing radiation. Of particular interest are marine stratocumulus (Sc), which typically play the important role of cooling the planet. To fully understand Sc and their effects, and to improve modeling, their thickness needs to be more precisely determined. While cloud bottoms can be measured effectively by ceilometers, the tops are more difficult. Wind profiler data are often suggested as an aid in identifying the top of the marine boundary layer (MBL), which coincides with the top of Sc, but the interpretation of the data is often difficult. This project focuses on analyzing and understanding profiler data acquired over the eastern Pacific Ocean, with the assistance of both ceilometer and radiosonde data. Data were acquired during a Pan American Climate Study research cruise in fall 2004. The ship sailed through the eastern Pacific Ocean just off the west coast of South America. Monthly averages from the International Satellite Cloud Climatology Project were used to identify days when the ship was likely under Sc. On those days, the wind profiler data showed a high reflectivity layer. The ceilometer measured cloud base heights that never surpassed the reflectivity layer’s height. The sonde measurements of relative humidity decreased sharply across the layer, indicating the presence of the inversion that caps the MBL. This project determined that the height of the MBL top was at the height of the inversion shown by the radiosonde.

Figure 1
Ceilometer cloud base measurements plotted over the wind profiler reflectivity.
Bottom: Relative humidity measurements from radiosondes deployed the same day.
Improvement of hurricane risk perceptions: Re-analysis of a hurricane damage index and development of spatial damage assessments

Implementation of potential damage assessment tools in hurricane-prone areas is an essential aspect of communicating accurate hurricane risk information. Several indices currently exist (e.g., Saffir-Simpson Hurricane Wind Scale) that effectively communicate storm strength; however, they are unable to quantify potential damage. The recently developed Maina Hurricane Index (MHI) addressed this deficiency and used a hurricane’s central minimum pressure and radius of hurricane-force winds to create damage forecasts. The MHI was developed by analyzing data from 13 historical storms – a small sample size limited by the availability of storm size data. This work revisited the MHI using a larger data set, and results showed that central pressure is the best indicator of potential damage. By creating a single damage value per storm, the MHI aids in the decision-making of government and private agencies such as emergency managers, yet it does not convey storm impacts on individuals within a community. In response, this study also developed a methodology to generate spatial damage assessments that illustrate the relative damage distribution across a storm’s path. A swath of maximum winds was first generated using a parametric wind field model, then translated to damage using a function based on wind speed and a measure of the directional change in wind. Through the ability to forecast both net damage of land falling storms and the distribution of damage across the storm’s path, individual perceptions of hurricane risk can be unified to make way for safer preparation and evacuation decisions.

Figure 1
Developed by translating the modeled swath of maximum winds (a) to relative damage for several case storms, the spatial damage assessment map (b) indicates the degree of potential damage on a scale from 0 to 1, where 1 indicates the maximum amount of sustainable damage.
Semi-empirical functions describing the response of short-lived radicals to their driving forces in the WRF/Chem model

Short-lived radicals play a key role in the chemistry of the lower atmosphere. Short-lived radicals oxidize pollutants, e.g., carbon monoxide (CO) and methane (CH₄), making them more soluble and therefore easier to remove by wet or dry deposition. Without these radicals, tropospheric pollution would accumulate to much higher levels and have a stronger negative effect on our climate and health. To understand short-lived radicals, i.e., hydroxyl radical (OH), they were evaluated against the environmental and chemical driving factors that, theoretically, should control them. A semi-empirical function (SEF) that is linear in log space, and whose slopes represent the “normalized sensitivity coefficients was used in this evaluation.” These coefficients describe how sensitive a radical is with respect to changes in the individual driver, e.g., \( J(\text{NO}_2) \), \( H_2O \), VOCs, NOx. Using the output from the WRF/Chem model and the coefficients calculated from the NCAR Master Mechanism box model, the chemical concentrations were evaluated with respect to the SEF. A reasonably linear relation with a reduction in scatter compared to the correlations with each individual driver was found. However, multiple correlation lines were identified, and their origins were traced to WRF/Chem’s use of different chemical mechanisms over land, ocean, and near the domain boundaries. Therefore, these correlations may provide a powerful technique for comparing models with one another and with measurements, specifically with field campaign observations (like those of MIRAGE) for evaluating the representation of fast radical photochemistry in three-dimensional chemistry-transport models (such as WRF/Chem).

Figure 1
Correlation of OH concentration predicted by the WRF/Chem three-dimensional regional model simulation for the 2006 MIRAGE field campaign and the SEF for OH. The figure clearly contains two lines of data points that “fork” away from each other. The correlation coefficient is \( R = 0.73 \).
Detection of mesoscale vortices and their role in subsequent convection

Mid-level mesoscale vortices impact warm-season precipitation by initiating and focusing deep convection. Given their significance to forecasting, it is important to understand mesoscale vortices, their frequency, and their impact on subsequent convection in greater detail. This research was a pilot study to identify such vortices using two separate techniques. Vortices were identified through a subjective visual identification technique that relied mostly on composite radar reflectivity and satellite imagery, as well as through an objective algorithm applied to hourly 20-km Rapid Update Cycle model analyses. Vortices arising within organized convection, called mesoscale convective vortices (MCVs), as well as ones forming in the absence of convection (dry vortices) were identified over the central United States during an active period from 1-10 June 2009. Additionally, MCVs were identified that were responsible for triggering subsequent convection. The results from the subjective and objective methods were compared, and vortex characteristics such as duration were analyzed. The objective algorithm detected more vortices than expected, as well as an approximately equal distribution of dry and convective vortices. Approximately two-thirds of the MCVs detected by the algorithm were also detectable by the subjective, visual method. MCVs that triggered new convection accounted for less than half of all cases, while in general MCVs lasted longer than dry vortices. While extension of this research is necessary in order to apply to a more broad range of MCVs, these results demonstrate the potential of the methodology in identifying these vortices, which will potentially lead to a greater understanding of such systems.
Rapid intensification of Hurricane Earl in Advanced Hurricane WRF model simulations

Rapid intensification (RI) is a form of tropical cyclone (TC) intensification that is particularly challenging to predict. Understanding RI is essential for improving hurricane intensity forecast skill and hurricane preparedness. However, the physical processes that lead to RI are not well understood. Hurricane Earl, the second-strongest TC of the 2010 North Atlantic basin season, underwent RI on August 29, in its first day as a hurricane. The Advanced Hurricane Weather Research and Forecasting (AHW) model produced a simulation of Earl that was unsuccessful in predicting intensification, followed closely by a simulation successfully forecasting RI. The purpose of this study is to investigate the environmental and storm structure characteristics that led to Earl’s simulated RI. The unsuccessful and successful simulations were first compared in terms of the environmental vertical wind shear, because this parameter is often negatively correlated with TC intensification. Area averages of the deep-layer and mid-layer vertical wind shear over the storm suggest that this parameter did not influence the intensification of the successful simulation. Initially, the successful simulation featured greater relative humidity throughout the troposphere within the storm’s circulation. This led to a greater upward mass flux throughout the troposphere and a rapid intensification of circulation in the middle troposphere before any significant change occurred at the surface. After this deep vortex had been established, the mass flux (and lower-tropospheric convergence) continued to increase, leading to RI. These results provide a basis for further research to better understand and predict the development of RI.

Figure 1
The AHW simulation starting on August 27 (dark gray curve) was unsuccessful in predicting Hurricane Earl’s intensification, while the simulation starting on August 28 (light gray curve) was successful in forecasting Earl’s RI, as recorded by the National Hurricane Center (black curve). This study addresses the question of why these simulations differed.
Deciduous-broadleaf forest simulation accuracy in the Community Land Model v4.0

Seasonal changes in leaf area index (LAI) are an important factor in determining radiative transfers, and ecosystem exchanges between the land and atmosphere components of the Community Land Model (CLM). Thus, striving for more accurate vegetation simulations will yield more realistic results from the CLM. A recent study showed a possible problem with the spring green-up in the vegetation simulation of a deciduous-broadleaf forest. This study was conducted using an older version of the CLM with an early prototype of the carbon-nitrogen (CN) biogeochemical model. The result of that study prompted an investigation into the current behavior of deciduous-broadleaf forests in the CLM v4.0. To investigate current behavior, we employed a multi-grid-cell, multi-year, monthly average of a prognostic and prescribed vegetation simulations, and also used averages of observed data from AmeriFlux tower sites. LAI values between the two simulations and observations were compared, and then effects on latent heat flux (LH), sensible heat flux (SH), gross primary production (GPP), and the net ecosystem exchange (NEE) were assessed. Comparisons show that although there has been an improvement in the seasonal behavior of LAI, the LAI for the simulated vegetation is biased high. The high LAI causes increases of GPP and LH, and a decrease in SH. The NEE is underestimated during summer and overestimated during winter, but this does not appear to be caused by the high LAI values. These biases highlight the need for further study and improvement of CN model, and CLM accuracy.

Figure 1

Monthly average LAI for two CLM simulations: one uses the CN biogeochemical model, and the other uses the satellite prescription mode. Both simulations are compared to the monthly average observations from Morgan Monroe State Forest.
Comparison of microphysical cloud properties from the FSSP and the CDP during the CAMPS field campaign

Understanding and accurately sampling microphysical cloud properties for orographic-forced mixed-phase clouds is of crucial importance for an enhanced representation of mixed-phase clouds in global climate models. The Forward Scattering Spectrometer Probe (FSSP) has been the most widely used instrument to measure cloud microphysical characteristics for over three decades. The Cloud Droplet Probe (CDP) is a new instrument that was introduced to address mechanical issues the FSSP experienced (e.g. ice shattering). In current work, in-situ cloud data from 9 January 2011 of the Colorado Airborne Multi-Phase Cloud Study (CAMPS) field campaign were used to compare measurements by the FSSP and CDP. For all cloud penetrations considered, the FSSP measured a mean cloud droplet concentration of 131.66 cm$^{-3}$ while the CDP measured a mean concentration of 110.89 cm$^{-3}$. From calibration data, the CDP showed to undersize cloud particles. Results show concentrations measured by the FSSP and CDP, in general, do not agree in clouds comprised mostly of ice. In conclusion, on the considered day, data from the FSSP were significantly affected by ice particle shattering while the CDP undersized particles by 2-3.5 µm.

Figure 1

The figure shows lognormalized size distributions of two separate cloud penetrations with different characteristics. Because of a known ice-particle shattering problem with the FSSP, a bimodal distribution from the FSSP is an indicator of ice during a penetration; a unimodal distribution suggests mostly supercooled liquid water. In the two lower plots, the CDP size distribution is shifted to the right by two bin sizes (≈2-3.5µm).
Characterizing wind turbine inflow and wakes through comparison of sodar and meteorological tower observations – A part of TWICS: The Turbine Wake Inflow Characterization Study

Wind offers an inexhaustible domestic energy source with minimal greenhouse gas emissions. To maximize energy generation from wind turbines, it is essential to understand the influences of inflow conditions and wakes on wind turbine energy production. In accordance with this goal, the TWICS field campaign was conducted in April and May 2011 at the National Renewable Energy Lab’s (NREL) National Wind Technology Center (NWTC) in the complex terrain downwind of Colorado’s Front Range mountains. TWICS employed meteorological monitoring towers and remote sensing systems to provide a three-dimensional spatio-temporal illustration of the inflow to, and wake from, a 2.3 MW turbine with a 100-meter rotor diameter. An important step in analyzing the TWICS data was quantifying the performance of the different measurement devices that were used. This research compares simultaneous measurements taken during TWICS by a Second Wind Triton sodar and from the NREL M2 80-meter meteorological tower, which were located one kilometer apart. During the TWICS campaign, strong linear correlations were found between wind speed measurements at 50 and 80 meters from the sodar and the tower. The high correlation suggests that flow is usually homogenous across the NWTC at time scales of ten minutes, but that there are also occasional periods of inhomogeneous flow. Wind speed correlations were also found to vary with time of day. This diurnal variation could represent different conditions at the sodar and tower sites because of localized heating and turbulent mixing, but it may also be due to changes in sodar performance as atmospheric stability changes during the course of the day. Results from this research will support future analysis of data collected during TWICS and may help improve our understanding of turbine performance in the atmospheric boundary layer.

Figure 1
The National Renewable Energy Laboratory’s National Wind Technology Center is located downwind of Colorado’s Front Range near Boulder. The magnified cross-section of the site (top left) shows the location of a Triton sodar and an 80-meter M2 meteorological tower relative to a 2.3 MW wind turbine. Correlations between the sodar and the tower (top right) over 37 days in 2011 were $R > 0.93$ at both 50- and 80-meter elevations. Correlations and data returns show a slight diurnal variation (top center, 50-m elevation represented by dotted line and light bars; 80-m elevation represented by solid line and dark bars).

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Quantifying the role of tropospheric relative humidity on the development of tropical cyclones

The sensitivity of tropical cyclone (TC) development to environmental moisture was studied using a two-dimensional, axisymmetric model. The model was initialized with tropospheric relative humidities (RH) ranging from 0% to 100%. Generally, initial environments with more moisture required less time for a TC to develop. Moistening of the full troposphere in the TC inner core was a key ingredient for genesis to occur. Downdraft activity slowed TC development by transporting drier, cooler air into the boundary layer. To quantify the effects of the initial environmental moisture on the spin up process, the precipitation efficiency, conversion of available potential energy efficiency, and normalized gross moist stability (NGMS) were calculated. Precipitation efficiency in the inner core increased with time, albeit more slowly if the initial condition was drier, which reflected a gradual moistening of the troposphere and increasing net latent heating. In the drier simulations, available potential energy was used to moisten the troposphere rather than spin up TC winds. Only when the inner core was nearly saturated did the conversion of available potential energy to kinetic energy become more efficient. Initially negative values of the NGMS in the drier simulations indicated bottom-heavy convection and a shallow overturning circulation. Comparison with three-dimensional forecasts from a high-resolution, full-physics model having various moisture environments (RH ranging from approximately 45-65%) showed that TC development occurred on a different time scale than in the two-dimensional simulations. Additionally, it was hypothesized that rainbands moisten the outer region and protect the inner core from entrainment of dry air.

Figure 1

The maximum surface wind speed as a function of time for a set of two-dimensional, idealized tropical cyclone simulations. The numbers indicate the initial tropospheric relative humidity for each case. In general, it takes longer for the drier cases to develop.
Analysis of moisture transport and its impact on mid-latitude precipitation by tropical storm Hermine (2010) using WRF simulations

Recent research has shown that predecessor rain events (PREs), regions of heavy rainfall that occur well in advance of recurving tropical cyclones (TCs), can enhance mid-latitude precipitation. Since numerical weather prediction serves as a key component in developing precipitation forecasts, it is important to assess its performance with these high-impact rain events. Understanding the meteorological factors responsible for the influence TC-PREs have on mid-latitude precipitation will help forecasters recognize model limitations. This study investigated 1) the difficulties of simulating mesoscale processes and 2) the synoptic-scale interactions that contributed to the heavy precipitation associated with one TC-PRE event over the Southern Plains region of the U.S. on 6-9 September 2010. Model output of Tropical Storm Hermine was retrieved from version 3.3 of the Advanced Research Weather Research and Forecasting (WRF-ARW) numerical weather model and compared with surface precipitation observations. Discrepancies were observed in the simulation, such as the under-estimated magnitude, western bias, spread, and structure characteristics of the precipitation. Very high moisture content was indicated by the high precipitable water values that accompanied Hermine as it moved further inland. Southerly winds associated with Hermine’s circulation helped advect this rich moisture northward into Oklahoma and Arkansas. An approaching frontal boundary from the northwest served as a lifting mechanism to precipitate the moisture, and led to the development of the PRE. These observations emphasize the role TC moisture plays in producing PRE events, and how being able to quantify that effect will improve practices for effective TC-PRE precipitation forecasts.

Figure 1
A comparison of the 6-hour precipitation totals from 7 September 2010 at 1800 UTC between the WRF-ARW model simulation (left) and surface observations (right). The simulation shows the lack of a northward spread in Hermine’s precipitation shield as it moved inland. While the model did capture the initiation of the Hermine-PRE event near the observed location, it lacked the spread of PRE-precipitation in Oklahoma and Arkansas.
An analysis of the sensitivity of pavement temperature to the makeup of the road surface

Each year, adverse weather along roadways results in over 7,000 fatalities, 673,000 injuries, nearly $9.5 billion in congestion delays, and costs shipping companies $3.5 billion. Currently, decision support systems recommend road surface treatments for snow removal operations by incorporating output from pavement temperature models. However, current pavement temperature models issue point forecasts that fail to describe the conditions between the points. A forecast from a gridded pavement model is a possible solution to this problem. To produce this forecast, the sensitivity of the pavement temperature when stratified by different materials (i.e., concrete and asphalt) and their thicknesses must be assessed. This analysis used eight Road Weather Information System (RWIS) stations in the greater Denver metropolitan area and four RWIS sites at Denver International Airport. Uniform radiation was assumed using a cross-referencing method between five-minute daily weather observations and satellite-surface composite maps. Sixteen total case studies were selected for day and night with diverse weather conditions. Concrete roads generally averaged 3.2°C warmer than asphalt roads and therefore will have to be modeled separately. Elevated (e.g., overpass) and non-elevated surfaces were also compared, and elevated roads tended to be 3.3°C cooler than non-elevated; therefore, a condition protocol for the elevated site will subtract 3°C from the standard forecast. This work lays the foundation for additional analyses with a more robust data set to confirm initial results observed from these data, the results of which may be used to develop and tune gridded pavement model forecasts.

Figure 1
January 7, 2011, a clear-day case comparison between a concrete roadway (Interstate-25 at Colorado Route 470) and an asphalt roadway approximately 10 km away (E470 Tollway at Smokey Hill Road).
Examining ionization parameterizations for energetic electrons in the ionosphere using TIME-GCM simulations

Energetic electrons in the upper atmosphere influence atmospheric dynamics and ionize chemical species; these processes ultimately affect the atmosphere’s chemical composition. Two important chemical constituents affected by electron ionization are HOx and NOx, whose presence and mechanisms contribute to ozone destruction. Therefore, energetic particles have an important influence on dynamical and chemical processes in the upper atmosphere. The Thermosphere-Ionosphere-Mesosphere Electrodynamics General Circulation Model (TIME-GCM) has been developed at the National Center for Atmospheric Research (NCAR) to study the upper atmosphere at altitudes between 30 and 500 km. Currently, TIME-GCM only includes effects from lower-energy auroral electrons (those with energies less than 30 keV). The purpose of this study is to incorporate higher-energy electrons (those having energies between 30 keV and 1 MeV) into TIME-GCM then study their effects. To represent these higher-energy electrons, two parameterization codes have been tested in TIME-GCM. The first parameterization code applies a Maxwellian distribution, while the second uses in-situ measurements of electron distribution to calculate ionization rates. The runs were then compared with base runs that did not contain either parameterization and also with satellite measurements. The second parameterization produced higher ionization rates, and electron densities at lower altitudes. It also generated neutral temperatures and NO values that are in better agreement with satellite observations, making it a more accurate depiction of this region. Model improvements such as these are crucial to better simulate the upper atmosphere and to improve our understanding of atmospheric physics.

Figure 1

NOx difference plot for energetic electron parameterizations run in TIME-GCM. Values from the TIME-GCM run, including the Maxwellian distribution parameterization, were subtracted from the parameterization using calculated ionization rates. The solid contour lines indicate increasing (positive difference) values. Differences are mapped onto global latitude (in degrees) on the x-axis and altitude on the y-axis.
UCAR’s HIRO (pronounced hero) program is designed to provide talented high school students with a snapshot view of careers in science, computing and engineering. Students are paired with a scientist at NCAR or NOAA in order to give them an authentic summer research experience and one-on-one mentoring. They are part of a community of students with similar interests. Now in its second full year, HIRO grew to 20 students, the majority from the Denver metro area. Six students from Puerto Rico joined HIRO through a partnership with the Ana Méndez University System’s Pre-College Summer Research Internship Program. While 18 students were new to HIRO, two returned for their second summer and were able to serve as informal peer mentors for the group. For six weeks, HIRO students worked with top scientists and engineers in the field and tackled research topics as varied as ozone transport, gust front thunderstorms, wind turbines, Arctic sea ice and HIAPER aircraft observations. Weekly writing workshops taught students how to create posters that highlighted the results of their research and which they shared with others at a formal poster session at the conclusion of the summer program. A key component of the HIRO program is mentoring: in addition to a research mentor, each student was assigned a peer mentor from either NOAA or the SOARS program. Students participated in seminars on scientific topics and science careers, were offered individual counseling on colleges and careers, and enjoyed visits to local colleges.
Engineering challenges associated with installing surface-based weather instrumentation in remote, mountainous terrain

Climate change can have a significant impact on winter precipitation processes, particularly in mountainous regions. Changes to the snowpack and runoff can have serious consequences to the communities downstream that rely on them for their water supply. Climate models are being used to simulate the effects of climate change on the snowpack and runoff over the Rocky Mountain region in western Colorado, but verification of those models is required before results can be trusted. To verify the models, accurate surface measurements of temperature, wind speed and direction, pressure, solar radiation, and liquid-equivalent precipitation must be taken at various points within the model domain. This research project focused on the construction of three instrumentation setups using ETI precipitation gauges (referred to as ETI19, ETI20, and ETI21). The setup included mechanical and electrical engineering tasks as well as programming required for each instrument component. Each setup was tested at NCAR and will ultimately be moved to the Fraser Experimental Forest where they will be used for model verification. This paper provides a detailed description of the setup and a discussion of the engineering challenges of preparing each instrument for installation in mountainous terrain.

Figure 1
These four charts show measurements recorded by the instruments ETI19, ETI20, and ETI21 as a) temperature and humidity, b) wind speed and direction, c) precipitation and d) solar radiation.
A tornado climatology: 
Is climate change causing a shift in tornado occurrences and intensities?

Tornadoes have always posed a threat to the United States, not only because of their potentially destructive power, but also because of their tendency to appear, at least some of the time, without warning. Tornadoes strike the U.S. more than any other part of the world, and they tend to be concentrated around the central U.S. in a region called “Tornado Alley.” Learning how their occurrences may be shifting in the U.S. can provide a big advantage to forecasters. The main aspect of this project is to develop a climatology of tornado occurrences using a NOAA database. Of interest will be the determination of any shifts in latitude or the number of tornadoes over the past 60 years, organized according to F-scale ratings. Histograms were constructed for comparison and analysis of tornadoes from 1950 to 2010. Though no trends were found for shifts in latitude, the number of tornadoes increased or decreased depending on F-scale rating.

Forecasting the location of convective air 
12-48 hours after being lofted

The Deep Convective Cloud and Chemistry (DC3) 2012 field campaign will study the chemical changes of the Upper Troposphere (UT) as impacted by convective storms. To guide the design of the campaign, the location of the convective outflow must be found 12-48 hours after the air is lofted by deep convection to resample the composition of the air in order to determine the chemical production of ozone. We used weather and tracer forecasts, which were conducted during and after the DC3 test flights period of 1-15 May for three regions to predict the location of convective outflow in the UT 12-48 hours after the air was lofted. The results from these forecasts were used to answer questions such as the latitude and longitude of the convection, the location of the convective outflow 12-48 hours after being lofted, the total condensed water in the convective outflow air, and whether or not the air was near a site of active convection or precipitation. Preliminary results show that the boundary layer tracer can be followed from their lofting point in northeastern Colorado as they travel northeast over 48 hours. Convective outflow from storms in the central Oklahoma and northern Alabama regions were more difficult to track as they often remained close to their original lofting point or lacked a tracer altogether.
Changes in regional background ozone transported to Houston, Texas, over the past decade

Ground-level ozone produced by the photochemical reactions of hydrocarbons (HC) and nitrogen oxides (NOx) from cars and refineries can cause significant respiratory problems. The Houston region is subject to background ozone being transported there from multiple sources causing local ozone levels to increase. Transported ozone levels may increase to approach or exceed the legally regulated air quality standard concentration when combined with Houston’s local ozone production. Determining if there was a systematic change in the background ozone from 2000-2009 can help establish more effective air quality control strategies in Houston. Multiple air monitors were set up throughout Houston by the Texas Commission on Environmental Quality to measure ozone concentration. A principal components analysis of the data was used to determine the background ozone levels and allow examination of any systematic changes. This analysis found that the background ozone levels have decreased over the past decade, information which will be useful when determining future air quality standards for Houston.

Gust front versus non-gust front thunderstorms: An investigation of storm characteristics

During the course of its lifetime, a thunderstorm may or may not produce a gust front (a boundary between the cool air falling from a storm and the surrounding air). Since gust fronts can act as mechanisms for lifting more warm air to fuel a thunderstorm, they can significantly increase a storm’s lifetime and intensity. However, not all storms produce gust fronts, and since we do not completely understand what differentiates gust front storms from non-gust front storms, these phenomena are difficult to accurately forecast. This work analyzed and compared the characteristics of gust front and non-gust front storms using data collected during the 2002 International H2O Project. Time-height plots were created for four thunderstorms (two gust front and two non-gust front) based on multiple parameters measured by NCAR’s S-Band Dual-Polarization Radar, including reflectivity and polarimetric fields such as differential reflectivity and specific differential phase. These plots helped establish the intensity and microphysics of each storm. Although additional case studies and more accurate precipitation identification methods need to be incorporated into this avenue of research, some possible trends emerged from preliminary analyses, including faster growth rates and greater variation in precipitation types for gust front storms. Future work will establish more definite characteristics associated with gust front production, which in the future could make gust fronts easier to forecast.
The viability of using a wind turbine and photovoltaic cells to power meteorological instrumentation

Burning fossil fuels to produce energy has long been used as a reliable source of power. However, we are rapidly depleting these fuels, and the gases created by their burning contribute to climate change. Cleaner renewable energy sources will reduce humanity’s burden on the Earth System. Two major alternative energies are wind and solar power, which not only are cleaner, but also do not have to be connected to a traditional power grid. This research investigates the possibility of using these two sources to power weather equipment. A wind turbine and two solar panels were installed to charge the batteries that power two ETI NOAH II precipitation gauges and an anemometer. The solar panels were successful through the testing stages, but the turbine hasn’t been proven because of insufficient wind during the test period. However, it should work because it is rated at 400 watts, and the instruments draw very little power. Using a combination of solar panels and wind turbines allows for power sources despite different weather conditions. This system will be set up at NCAR’s Marshall Field Site for further testing. This technology will allow more remote weather monitoring sites to be powered by clean alternate energy sources in the future, thus lessening our fossil fuel dependence.

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The effect of composite and 1-kilometer reflectivity on the accuracy of severe weather forecasting models

Current forecasting of severe weather events relies primarily on numerical weather prediction, in which mathematical models are used to predict future weather based on current conditions. The reflectivity of water vapor in the atmosphere present at a 1 kilometer elevation (1-km reflectivity) is often used in these models. However, composite reflectivity (the maximum reflectivity at any elevation) might provide for a more accurate forecast of severe weather. A possible difference in performance between composite reflectivity and 1-km reflectivity forecasts was investigated to determine whether one level of reflectivity is markedly better at producing accurate forecasts of severe weather events. NOAA’s Spring 2011 Hazardous Weather Testbed provided a set of forecasts with both composite reflectivity and 1-km reflectivity that allowed comparison of forecast accuracy using the different reflectivity levels. To quantify the relative accuracies of the forecasts, we analyzed the data using the Model Evaluation Tools verification packet to obtain validation statistics for the accuracy of the forecasts. These statistics were aggregated by forecast lead time, with a reflectivity threshold of 30 dBZ. This study determined that composite reflectivity provided a more accurate forecast of the reflectivity. This indicates that it may be a better choice to use composite reflectivity in forecast models, particularly for severe weather prediction.

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**Processing images to understand the impact of Arctic ice changes on ice seal populations**

Arctic sea ice has been changing in recent decades, both in extent and in the types of ice present. To understand the impacts of these changes on Arctic ice seal populations, tens of thousands of images were collected from altitudes between 300 and 500 feet above the ice surface by a Boeing unmanned aircraft in spring 2009. Processing these images involves evaluating both the ratio of ice to water and the ratio of ice edge to ice area, as well as identifying seals. Automation of the process is essential to obtaining meaningful results. An open-source image processing software tool called Opticks (created by Ball Aerospace) was evaluated to determine if it could achieve these objectives. Implementation of a Python coding extension allowed for successful automation of importing JPEG images and outputting pixel count values for an ice-to-water comparison. The program was used to identify a unique color signature histogram for seals. This work provides the groundwork to evaluate the images collected by aircraft in 2009. Software and code developments will allow the images to be analyzed with a batch program requiring minimal user interaction. This will speed data analysis and improve data accessibility.

**Organization of current weather data into easily manageable bundles for major U.S. cities**

Weather data can be discovered and viewed with the Integrated Data Viewer, a Java® application created by Unidata; however, these data are distributed amongst UCAR servers. In contrast, weather sites are on a larger scale and do not show localized weather. This research focused on making specific types of weather data uniformly available by organizing bundles of weather data that would update to the last five hours. These bundles include many different types of measurements: satellite images, which show the cloud cover during the day and are updated half-hourly; radar, which can be used to show precipitation and cloud cover based on reflectivity and are updated every five to six minutes; ground observations, including wind velocity, direction, dewpoint, and air temperature, which are updated every hour; and webcam images, which show the sky every few minutes. When these four are combined in two viewing modes, either specific to type, or stacked on each other, they allow one to view general weather patterns across the continental U.S. using the IDV data analysis and visualization framework. These datasets are now available for registered users to more easily obtain this information.
CarbonTracker smartphone application

Our daily life involves tasks that require a great quantity of energy. In this modern world, the use of technological devices like computers and cars is essential to perform these tasks. The vast majority of the energy we use for our activities comes from burning fossil fuels. This burning releases large amounts of greenhouse gases, mostly carbon dioxide, into the atmosphere. CarbonTracker visualizes the amount of carbon dioxide in the atmosphere and helps us appreciate its rapid increase; it was developed by the National Oceanic and Atmospheric Administration (NOAA). The major consequence of this increase is global warming, which is likely to affect worldwide food production, quality of life, and more. Despite accessibility via the internet and even cell phones, many people are unaware of these CO2 data. The purpose of this research is to create awareness among people about this information by developing an application for iPhones and iPods, called CO2 Tracker. Built using xCode and programmed in Objective-C, the CO2 Tracker application includes general information about CarbonTracker, animations of the concentrations of CO2 in the world, the points of air sample collection, detailed graphics showing CO2 increases over different time ranges, videos, and more. All the content is well organized in a user-friendly interface for easy access.

Hail climatology and the effects of climate change on latitude measurements of hail events in the United States

The formation of hailstones in thunderstorms has long been studied by scientists. Strong updrafts lift and support the hail as it grows larger and heavier. When hail falls to the ground, it can cause painful, costly, and devastating damage to people, possessions, and crops. Large hail in particular must be further researched as its potential for damage is greater. Learning more about predicting where hail will fall would allow for more precautions to be taken. As part of research on large hailstones, storm data were compiled from a NOAA database to create a hail climatology from 1955 to 2004 for hail of at least two inches in diameter. The research consisted of analyzing the latitude of each hailstone’s location to determine whether there was a progressive shift over time in where large hail fall was most concentrated. Microsoft Excel spreadsheets and charts were used to evaluate the data, which was graphed in 10-year increments. Preliminary results suggest no latitudinal shifts, and future work will examine potential longitudinal shifts.
Comparing predictions of icing conditions by the WRF model with aircraft pilot reports

Aircraft icing occurs when a plane flies through a cloud composed of supercooled liquid water, or water drops that are below 0 degrees Celsius. Pilots have little way of knowing whether a cloud will contain water drops that represent an icing threat versus a cloud with only ice and snow crystals, which do not accumulate on wings. Aircraft icing remains a significant cause of accidents and incidents, especially for general aviation in contrast to commercial flights. The goal of this project was to determine if the model predicted the existence of icing conditions as well as clear sky conditions using pilot reports by analyzing 8.25 years of the Weather Research and Forecasting (WRF) model output. It was also confirmed that WRF predicts physically reasonable values of liquid water content and median volume diameter by validating the model output against the Federal Aviation Administration’s standard table of these values, Appendix C to Part 25: Airworthiness Standards – Transport Category Airplanes. The WRF model was determined to predict correctly the existence of icing conditions 54 percent of the time and was able to predict clear sky conditions with an accuracy of approximately 80 percent.

Influences on photon flux density in a high-elevation subalpine forest

Increased CO₂ in the atmosphere causes greenhouse effects such as increased temperature and changes in cloud cover, water availability, and weather patterns. Terrestrially, trees can offset the effects of greenhouse gases through photosynthesis. However, scientists have limited knowledge of how to model light in areas where the light regime is complicated by tree structures that block and scatter light in unpredictable ways. By determining what factors influence Photon Flux Density in a high-elevation subalpine forest, for example, scientists can build a light model to use in conjunction with a water usage model to predict how trees will respond to greenhouse gases in the future. During the 2008 and 2009 growing seasons, NCAR scientists deployed a series of sensors to investigate light in conifer forests. Nine trees, three pines, four spruces, and two firs were chosen for this experiment. As part of this study, they also included sap flow and weather sensors to determine the effects of light relative to water availability and climate. This research examined that project’s data and determined that the tree species relative to the canopy structure offered clues about how to model light in a conifer forest. We found that light models should include sun angle information, cloudiness effects and tree species.
Sensitivity of a lidar instrument to different types of atmospheric aerosols

Aerosols are solid particles or liquid droplets suspended in a gas. Examples include smoke, cloud droplets, dust, soot, ashes, and nanoparticles. Lidar is an optical remote sensing technology that can detect these particles and also investigate the distance and properties of targets such as land, ice, vegetation, clouds, and even single molecules. This research project assesses lidar AR sensitivity to various types of aerosols by computing the aerosol backscatter cross section using the Mie theory of light scattering on spherical particles. This research has the potential to improve our ability to study aerosol properties with the Tunable Optical Profiler for Aerosol and Ozone (TOPAZ). The TOPAZ lidar used in this research emits ultraviolet laser light and detects air molecules and atmospheric aerosols through their light scattering properties. The Mie calculations were performed with a computer program written in the IDL computer language. Based on our Mie calculations combined with aerosol size and number density data taken from previous studies, we found that the TOPAZ lidar is insensitive to aerosol particles with a diameter smaller than 0.03 µm. The lidar is most sensitive to particles in the size range of 0.10 µm to 0.50 µm (accumulation mode). If particle number density is about 1 cm⁻³ or larger, coarse particles larger than 1.00 µm can be detected by the TOPAZ lidar even though its emitted wavelength is 0.30 µm. This research supports that the TOPAZ lidar is accurate and sensitive enough to be used for aerosol detection.

Validation of the surface energy budget in reanalysis near the North Pole in summertime

This project intends to validate the summertime surface energy budget near the North Pole in three different reanalysis models using observations taken during the Arctic Summer Cloud Ocean Study (ASCOS). The ASCOS campaign took measurements from the Swedish icebreaker Oden from 1 August 2008 to 9 September 2008. This study focuses on the dates 16 August 2008 through 30 August 2008 and compares the longwave and shortwave radiation from the reanalysis models with the observations. The reanalysis models used in this study are the ERA-INTERIM (Interim European Centre for Medium-range Weather Forecasts Reanalysis), JRA25 (Japanese 25-year Reanalysis Project), and NCEP/DOE Reanalysis (National Centers for Environmental Prediction/NCAR Reanalysis). We identify how systematic errors in the modeled clouds affect the different components of the surface radiation, and what the net effect is on the sea ice. Because available observations are very limited, we can verify them using reanalysis models, which provide more data through time and space. This research determined that none of the reanalysis models accurately simulate the measurements taken by ASCOS.
The relationship between meningitis and relative humidity in northern Ghana

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Group A meningococcal meningitis affects thousands of people each year in the African meningitis belt. Enabling more accurate forecasting of meningitis outbreaks in this area could help health partners facilitate vaccination and preparation measures with greater effectiveness. One factor that has been shown to be related to meningitis outbreaks is relative humidity, which is thought to have a negative correlation to meningitis cases: as relative humidity decreases, the frequency of meningitis cases increases. To better understand the relationship between humidity and meningitis cases, this study focused on the Navrongo region of northern Ghana and analyzed the correlation between the number of cases per 100,000 people and the distance of such cases from the Tono Dam Reservoir. A Geographic Information System (GIS) was employed to map buffer zones surrounding the reservoir and to normalize these zones by population. By correlating relative humidity data collected in the area to distance from the reservoir, we tested the assumption that as the distance from a body of water increases, relative humidity decreases. Preliminary results show a trend of an increasing frequency of meningitis cases as the distance from the reservoir increases within the bounds of approximately 7 km. However, our results are speculative rather than conclusive, and more work is necessary to obtain greater statistical significance.

Comparison between lightning detection systems and their application to severe weather prediction

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Previous studies have shown a positive correlation between the upward trend of a storm’s total lightning flash rate and the occurrence of severe weather. This research evaluates a new national lightning detection network called the Weatherbug Total Lightning Network (WTLN). WTLN claimed to detect approximately 50% of the total lightning produced by a storm (on average), which could provide additional data for meteorologists to use in their decision-making process for issuing severe storm warnings. This project compared WTLN data to data collected by a total Lightning Mapping Array (LMA) and the National Lightning Detection Network (NLDN) in 73 storms in the Tennessee Valley. Results indicated that the WTLN detected 51% of the amount of lightning the LMA detected within the first 50 km from the LMA center, 83.5% in the next 50-100 km range, and 118.7% in the 100-150 km range. WTLN data were also used to analyze lightning trends in five tornadic storms on 27 April 2011 that occurred outside the LMA coverage. These trends displayed rapid increases in total lightning before tornadic development. Based on these results, the WTLN could prove to be a viable tool in forecasting severe weather on a national scale, however, more research must be done with a larger set of thunderstorms in other regions of the country.
Effects on solar radiation transmittance of pine forest canopy deterioration due to mountain pine beetles

The current mountain pine beetle outbreak spanning Colorado and southern Wyoming has spread to 4 million acres since 1996, making it the largest recorded epidemic in these areas. Canopy loss within stands of affected pine trees is a symptom of this epidemic. Part of the loss occurs during the “red phase,” wherein the trees still retain red needles, and the remaining loss occurs during the “gray phase,” wherein the trees have shed all of their needles and some small branches. The stands of dead trees should allow more solar radiation to reach the surface through their deteriorated canopies, and this may affect snowpack accumulation and ablation. To quantify and compare the levels of solar radiation transmittance in healthy pine stands with transmittance levels in stands affected by pine beetles, pyranometer data was analyzed from both sites at Niwot Ridge, Colorado, an area unaffected by the beetle, and Chimney Park, Wyoming, a red phase site. This study found that, compared to nearby open sites (forest clearings), the average ratio of solar radiation recorded by sensors under the canopy was closer to unity at the Chimney Park site, while the ratio was reduced at the healthy site near Niwot Ridge. This implies that more solar radiation was transmitted through the red phase canopy; however, additional sites need to be analyzed to more firmly establish these results.

HIAPER pole-to-pole observations of greenhouse gases and black carbon

In a society where people are not always aware of the environmental effects of their activities, it is important to research the consequences of using fossil fuels for energy. Studying greenhouse gases and black carbon and examining their patterns of climate forcing is essential for understanding our future environment. The HIAPER Pole-to-Pole Observations (HIPPO) mission is designed to evaluate the dynamics of CO₂, N₂O, O₃, H₂O, and other greenhouse gases over all four seasons and relate them to climate change. During HIPPO flights, the aircraft is equipped with a laser spectrometer, gas chromatographs, air samplers, and oxygen sensors to monitor variations in the gases. Greenhouse gases were evaluated and compared against the stable tracer N₂O. Google Earth and EOL Flight Data [BB1] were used to monitor the location of the aircraft and real-time chemical data [BB2], and Fetch and Igor Pro were used to manage the research [BB3] data obtained from the flights. Results showed that when O₃ and H₂O are compared using N₂O, they do not have obvious seasonal cycles or annual increases as CO₂ does.
Using the student T-test to evaluate the significance of the differences between forecast RMSE from determinate and ensemble data analysis schemes

Weather forecasts are predictions that enable the public to react in advance to adverse weather and minimize economic losses from weather-related events. However, the accuracy of weather forecasts may depend on the analysis schemes used to prepare the initial conditions. In earlier work, we used a single forecast model and applied different ensemble analysis schemes to determine whether the ensemble schemes improved forecasts compared to the more conventional determinate scheme. We found that the ensemble schemes had lower Root-Mean Square Error (RMSE) scores compared to the determinate scheme. This project used statistics to study whether the RMSE differences between the determinate and ensemble analysis schemes were statistically significant. To do so, we used the Student t-Test to evaluate RMSE difference for the wind components, temperature, and specific humidity. With a 95% confidence level, we found a significant difference between the determinate and all ensemble analysis schemes for specific humidity. We concluded that the ensemble method provided greater forecast skill than the determinate method.

Evaluating the Belfort Aerovane 140A prototype anemometer

Weather patterns and wind variations affect Earth’s atmosphere in variable and unpredictable ways. Dynamics within the troposphere are studied as indicators of local weather and storm systems and to improve meteorological forecasts. Anemometers provide data valuable for studying the troposphere. The Belfort 140A Aerovane is a fairly large windmill-style anemometer that measures wind speed and direction using both a propeller and a tail. This research investigated whether “bigger is better” in regard to customary sized anemometers, and whether anemometer size compromises its accuracy, reliability, or durability. By assembling, programming, and testing the prototype aerovane, which was later installed at NCAR’s Marshall Field Site, this project determined that the Belfort Aerovane 140A needed minimal wind speeds to start, was large enough to reduce small wind anomalies and take large air samples, and was reliable in gathering data. Prototype meteorological sensors help researchers interpret data and refine the basis for comparing the accuracy of their instruments.
### Key to Mentors’ Affiliations

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<tr>
<th>Acronym</th>
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<tbody>
<tr>
<td>CIRES</td>
<td>Cooperative Institute for Research in Environmental Sciences</td>
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<tr>
<td>COMET</td>
<td>Cooperative Program for Operational Meteorology, Education and Training</td>
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<tr>
<td>COSMIC</td>
<td>Constellation Observing System for Meteorology Ionosphere &amp; Climate</td>
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<td>Desert Research Institute</td>
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<td>GLOBE</td>
<td>Global Learning and Observations to Benefit the Environment</td>
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