Miriam Garcia joined researchers from the USA, Iceland, and Switzerland in August 2008 to install high-rate GPS stations in Iceland. This network will provide important data on the rate of deformation along the plate boundary in Iceland, as well as increase our understanding of volcanic and tectonic interaction.
As we go to press, our country’s 2008 U.S. Presidential campaign is in full swing. Differences in policy on energy, responses to climate change, educational priorities, and funding for science are among the topics in the nightly news. What a time to be a new student of geoscience!

This year 29 interns applied themselves for ten weeks to a broad array of geoscience research topics – air chemistry and geochemistry; statistical tools for extreme weather events and for very, very slow plate motion; variation in vegetation today and variation in animals 3.4-2.9 million years ago; space weather and thunderstorms – just to name a few. Two RESESS interns did research associated with projects funded by the International Polar Year. At least eight interns from both RESESS and SOARS studied topics associated with climate change. Three research projects involved new technology, and two used applied analytical mathematical techniques. You will find many of the summer research projects relevant to societal issues of today.

In 2008, RESESS and SOARS had an unusually large variety of institutions whose scientists and other mentors who worked with these students in 2008. You will find national agencies, a tribal nation, research institutions, research consortia, universities, and state and local agencies among the organizations which contribute to the success of RESESS and SOARS students. If we take the proverb “It takes a village to raise a child” as a metaphor for developing scientists, then these many organizations, people, and projects all contributed to welcoming these students to our scientific ‘village.’ We are proud to present Earth, Wind, Sea and Sky: Protégé Abstracts 2008. The emerging scientific abilities and diverse perspectives of these research interns contribute to our current knowledge, advance scientific understanding, and, hopefully, positively influence the decision-making of our leaders and fellow citizens.

To learn more about these students, their mentors, or the SOARS and RESESS programs, please visit both websites: www.soars.ucar.edu and www.resess.unavco.org

Sincerely,

SUSAN ERIKSSON  Director and Principal Investigator, RESESS, and Director of Education and Outreach, UNAVCO

RAJUL PANDYA  Director and Principal Investigator, SOARS, and Director of Community Building Program, UCAR
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Uplift, subsidence, or systematic error? Measuring elevation in the Longmont-Denver corridor

The Colorado Department of Transportation (CDOT) and National Geodetic Survey (NGS) conducted a 119 km leveling project that extended from Longmont to Denver International Airport. Up to 10 cm elevation differences were observed in the area of Denver International Airport, raising questions about data collection procedures and benchmark stability. A detailed examination of data was conducted to identify possible systematic error. Field notes and the field abstract (a report that summarized recorded observations) were examined to determine how observations were made. Observation times, progression of observation activities, and time lapses between observations were identified as the main sources of systematic error. Data analysis was performed using elevation differences, published values, and loop closures. These provided further evidence that elevation differences were the result of systematic error. This research concluded that systematic error was responsible for the overall observed elevation difference of approximately 10 cm and provided a basis for the National Geodetic Survey to finalize and publish elevation data for the benchmarks included in this leveling project. Future impacts of this research will include improvements in field crew training, revised data analysis procedures, and continued monitoring of possible uplift and subsidence through the National Geodetic Survey’s Height Modernization program.

Figure 1

It was found that sections were within allowable tolerance of .08 mm per 1 km. However, there were more negative than positive values, resulting in an overall cumulative shift of -96.6 mm over a length of 119 km and exceeding maximum tolerance of ±43.6 mm.
Modeling rainfall thresholds for landslide analysis

This research intends to successfully analyze landslide behavior by using a deterministic analysis of rainfall thresholds. An alternative approach for defining rainfall thresholds uses deterministic models for rainfall infiltration and slope stability testing. Deterministic modeling is believed to be less computationally costly than the empirical method. This project aims to define rainfall thresholds in Western Oregon by applying the deterministic modeling technique. The objectives are to use a computer model of landslide initiation and rainfall infiltration to define rainfall thresholds for certain sites in Western Oregon and to compare these thresholds with historically collected rainfall threshold and rainfall amounts data.

The project can be divided into subcategories: define landslide provinces based on similar climate, terrain, and geology; compile a database of relevant geotechnical parameters for selected provinces; model rainfall infiltration and slope stability for representative rainfall intensities and durations, geotechnical parameters, soil thicknesses, and slope angles for selected provinces; define thresholds based on model results; and compare rainfall thresholds defined by computer modeling with published empirically defined thresholds and actual landslide events. Two areas of major research are discussed: the rainfall threshold analysis methods, and how they can be used by the TRIGRS (Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability Analysis) program to compute a factor of safety.

Figure 1

These graphs show factor of safety (y axis) versus slope angle (x axis) for the study region.
Terrestrial laser scanning study of gully erosion at West Bijou Creek, Arapahoe County, Colorado: An investigation on field acquisition and data processing

Terrestrial laser scanning (TLS) or ground-based LiDAR (light detection and ranging) is a relatively new technology that digitally maps geological outcrops at centimeter-to-millimeter resolutions. This paper reports the results of a trial TLS project that has two main aims: collecting scans for monitoring gully erosion, and conducting a survey to connect field methods of TLS with geomorphology. The site of this TLS survey was located in Arapahoe County, Colorado, and data collection consisted of a three-day campaign. This project focused on a new approach to analyzing and measuring deformation and erosion in gully-dominated landscapes. Our approach to the survey consisted of going to the field with an Optech scanner to acquire the data, searching for different field acquisition strategies, practicing with data processing, and making a web page of the project for the scientific community. A preliminary terrain model was made in Polyworks software using only 20 percent of the scans; this provided insight into how the landscape model can look in the future. The long-term goal of this research is to keep track of the changes in the morphology of the gullies located at West Bijou Creek in Colorado using Real Time Kinematic GPS (RTK-GPS) and Terrestrial Laser Scanning (TLS). Because applications of TLS in geology and geophysics are evolving rapidly, in this project a web page including a forum is provided to the scientific community with a summary of current field acquisition practices for sharing ideas and discoveries.

Figure 1
3D point cloud mesh of the four scans from the first scanner position.

Figure 2
3D preliminary model of West Bijou Creek Gully Network with four scans.
Reassessing spatial, temporal, and compositional trends in western North American magmatism using NAVDAT

Plate tectonic setting and magmatic activity are intimately related, as evidenced by the fact that 95% of all magma generation (by volume) occurs along active continental margins. However, in Cenozoic western North America, magmatism occurred more than 1,000 km from the active continental margin, even after corrections for Basin and Range extension. Previous research suggests that these magmas may be the product of changing plate configurations between the Farallon and North American plate and subduction-related processes.

These hypotheses were re-examined using MATLAB-generated animations and visualizations of data in the North American Volcanic and Intrusive Rock Database (NAVDAT, navdat.kgs.ku.edu). Continental basaltic rocks (ages: 80 m.y.-present, SiO₂ wt.-%: 40-52%, 7,987 samples) and volcanic rocks from four mid-Tertiary volcanic fields (ages: 50 m.y.-20 m.y., SiO₂ wt.-%: 0-100%, 3,639 samples) were examined for the presence of a subduction-related geochemical signature.

Animations of the temporal and spatial changes in the Na/K ratio of basaltic rocks showed an increase in the prevalence of sodic magmatism through time, as well as a general concentration of more potassic rocks toward the interior of the continent. Also notable was the observation that potassic volcanism in the Sierra Nevadas (~3.5 m.y.) thought to be related to the lithospheric delamination, was the only location of potassic volcanism in the entire western United States province during that time period.

Harker variation diagrams of various major and trace element abundances in the mid-Tertiary volcanic fields revealed that the Trans-Pecos volcanic field had a consistently distinct chemical composition, characterized by low Ba/Nb, Th/Nb, and Sr/Ta ratios, low wt.% CaO and wt.% MgO, and high wt.% TiO₂. Differences between the Challis/Absaroka, Mogollon-Datil, and San Juan volcanic fields were subtle but still evident. Taken together, these observations suggest that (1) spatial variations in the intensity of metasomatism of the mantle might have existed at the time, and that (2) magmas in the Trans-Pecos volcanic field may have been generated in a back-arc basin environment.

Figure 1
Static time slice of the spatial variation in the Na/K ratio at ~3.5 m.y. The potassic pulse of magmatism in the southern Sierra Nevadas is indicated by the darker dots.
Miriam E. Garcia

Mogi model application on Grímsvötn Volcano, Iceland: continuous GPS data (2004-2008)

Grímsvötn is a subglacial volcano in Iceland with the highest eruption frequency of any of Iceland’s 30 volcanic systems during the past 800 years. It is located below the Vatnajökull ice cap and above the Iceland mantle plume. This study focused on the analysis of Grímsvötn’s recent deformation that will allow a better understanding of its behavior. This insight might also be applicable to the assessment of the risk of volcanic hazards, such as glacial floods (jökulhlaups), that affect the local population. The 2004-2008 time series data from the continuous GPS station (GFUM) was divided into five events. A Mogi model for each event was used to find characteristics of an equivalent point source that results in the same 3-D displacements displayed by GFUM. The Mogi code consists of four parameters: source geometry, observation point, and the Poisson’s ratio and shear modulus of the surrounding crust. Three values are output by the code: displacements, strains, and stresses in the east, north, and up directions. All five recent volcanic events at Grímsvötn were fitted to a volume change at a specific depth using the displacement output. The November 2004 eruption (event 2) resulted in a volume decrease of 23.5E-3 km³ at a depth of 2.55 km. All events had similar model results with the exception of event 4, which had a deep source, 15.2 km. There were several aspects of the modeling process that contributed to errors in the results: 1) a non-spherical magma source, 2) an inhomogeneous crust, 3) lack of continuous GPS data at GFUM.

Figure 1
Mogi model for 1 of 5 events. The graph represents a constant depth. The “+” signs represent different volume changes. Areas in brackets show the possible range of appropriate fits.
Lineament analysis for the McMurdo Dry Valleys region, Antarctica

Light Detection and Ranging (LIDAR) data were collected for regions spanning approximately 4,000 km$^2$ in the McMurdo Dry Valleys region of Antarctica. We assess the efficacy of using digital elevation models (DEMs) derived from these data for geomorphic mapping applications in the Dry Valleys. Using the ArcGIS Geographic Information Systems (GIS) software suite, we determine optimal image processing techniques to enhance visibility of geologically and geomorphically significant lineaments including faults, dikes, paleoshorelines, and other rift and glacial features. Optimized filters, shadowing parameters, and the determination of positive and negative relief are applied to regions of interest. Results highlight features that can be used to constrain long-term glacial isostatic adjustment and neotectonic processes related to the West Antarctic Rift System (WARS).

PRELIMINARY RESULTS

A Denton Hills DEM with digitized lineaments outlined in white
B Symmetric polar histogram of azimuths in 5-degree bins, uncorrected for lineament lengths
C Same as B, with bins weighted according to lineament lengths
Drilling Induced Fracture (DIF) characterization and stress pattern analysis of the Southern McMurdo Sound (SMS) Core, Victoria Land Basin, Antarctica

There is a significant lack of data about present-day stress fields in Antarctica. Stresses provide valuable information about the forces acting on tectonic plates. In Antarctica, stresses may be related to ridge forces such as rifting and/or uplifting, to ice loading/unloading-related processes, or both. This project studies drilling induced fractures from core recovered in the Victoria Land rift basin of Antarctica. Drilling induced fractures form ahead of the drill bit during drilling from stress imbalances due to the removal of excess weight pressure around the rock. Because horizontal stresses strike parallel to the planes made by drilling induced fractures, they can be used to measure modern-day stress fields. Whole core images obtained during core logging by digitally scanning the outside of the core are stitched into longer intact intervals. Drilling induced fractures in the core are ‘picked’ to obtain their azimuth. Magnetically oriented acoustic images of the inside of the drill hole are then compared side by side with the stitched whole core images and visually scanned for matching features. Once the same set of fractures is found in the core and the borehole, it is then possible to rotate core images to match the orientation of the borehole image. This will produce a core image with all the fractures in that interval re-oriented to true north. This final orientation of drilling induced fractures in the core will thus provide the direction of maximum horizontal compressional stress in this area.

Figure 1

A program called CoreBase uses “stitching” (shown in white) to join core run breaks, fix any depth inconsistencies, and fix misfits across fractures of the red scribe line.
Probabilistic analysis of rainfall thresholds for Western Oregon

In western Oregon, many rainfall thresholds have not been analyzed systematically. As a result, landslide prediction is uncertain. This project examined rainfall thresholds throughout western Oregon to estimate the percentage of threshold exceedance events that will produce landslides. For this study, the geologic characteristics, precipitation data, and historical events of western Oregon were collected and analyzed. After filtering the data, we compared the results of the threshold exceedances with landslide occurrences to test the accuracy of the predictions made by the thresholds. Landslides were found to occur both when the threshold was exceeded and also when it was not exceeded. Since rainfall data and landslide data have an incomplete record, only preliminary threshold values were determined. More extensive analysis of the rainfall data and landslide events needs to be performed to determine rainfall threshold values for western Oregon.

Figure 1
Precipitation Intensity and Duration Graph of Exceedance Events.
Seismic investigation of the Southern Rio Grande Rift

An upwelling of basaltic magma 29 million years ago caused the earth’s crust to spread apart and create a region known today as the Rio Grande Rift (RGR). The RGR extends from central Colorado through New Mexico to northern Mexico near El Paso. The RGR has different geologic features that distinguish it from most other valleys (e.g., RGR was not cut by a river nor does a river branch upstream). A growing body of evidence shows that geologic activity still occurs in the RGR, with a continuation of faulting, seismicity, and widening at a small rate. This research focuses on the Southern Rio Grande Rift (SRGR) to develop a contour map of velocity structures and moho depth using data from seismograms that have been installed around the region. The topographic mapping, Vp/Vs ratio, and the crustal thickness of the SRGR will define the crustal structure and the tectonic evolution of the region. The results will assist in understanding the crustal structure of not only the SRGR, but the RGR in general. Results have been obtained for the SRGR using Generic Mapping Tool which includes a contour plot of the Vp/Vs ratio and crustal thickness in that region.

Figure 1
Maps have been obtained for the Southern Rio Grande Rift using Generic Mapping Tools which include a contour plot of the Vp/Vs ratio and crustal thickness in that region.
The effects of differential rotation on 1-2 solar mass stars

To understand the nature of stars, we must learn about their internal structure. This can help us better understand how and why stars—more importantly our sun—behave the way they do. The internal structure and the internal distribution of angular momentum of our sun are known. Two conservative rotation laws are used to express the angular velocity as a function of the perpendicular distance from the equatorial plane. One of the conservative rotation laws concentrates the angular momentum in the outer portions of the star and has not been tested for stars with low masses. Using a new Self Consistent Field (SCF) method to analyze stars of one to two solar masses, we can determine if differential rotation affects their internal structure. The SCF method is a two-step iterative process used to produce models describing the internal structure of rotating stars. The SCF method is run using one-dimensional functions for temperature and pressure distributions. Temperature, pressure, and density were not sensitive to change in the deep interior of stars with one to two solar masses, but the convective envelope deepens as angular momentum increases.

Figure 1

From left to right, top to bottom, the properties of differentially rotating 1 solar mass star: the surface equatorial velocity $V_e$; the luminosity $L$ in units of $L_\odot$ (the non-rotating model); the average effective temperature $T_{\text{eff}}$; the central temperature $T_c$ in units of $T_c0$ (the non-rotating model); the radii of the base of the convective envelope are measured in the equatorial plane relative to $R_e$; the central pressure $P_c$; the equatorial radius $R_e$ in units of $R_\odot$; the polar radius $R_p$ in units of the $R_e$. 
Impacts of climate change on the summer rainfall of the southern Rocky Mountains

To better understand how summer rainfall in the Southern Rocky Mountain region may be changing due to global warming, simulations from the National Center for Atmospheric Research (NCAR) Nested Regional Climate Model (NRCM) for summer 1970 and summer 2020 were compared and contrasted. The NRCM is unique in that it combines the global climate simulation capabilities of the Community Climate System Model (CCSM) with the regional forecasting capabilities of the Weather Research and Forecasting (WRF) model in an attempt to provide more accurate high-resolution regional climate simulations. The IPCC (Intergovernmental Panel on Climate Change) scenario A2 (“business as usual” emissions) was used for these NRCM runs. For this study, the NRCM was run at a horizontal resolution of 36 km. The model predicts increased summer rainfall totals in summer 2020 when compared to summer 1970. Average NRCM summer temperature was found to be lower in 2020, probably as a result of increased rainfall and more mid-afternoon convective clouds. Surface elevation had a definite effect on both the simulated rainfall and the surface temperature. Overall, higher elevations experienced fewer changes in both summer accumulated rainfall and average surface temperature. Longer time periods need to be compared, and the data set currently available from the NRCM is limited. As more NRCM simulation data becomes available, we can begin to determine if this is a climate change trend or the result of natural inter-annual variability.
An outline of the process needed for student understanding of hurricanes and El Niño Southern Oscillation (ENSO) events

As climate change receives more media attention, public interest in the possible connection between rising global temperatures and the severity of tropical cyclones is increasing. Research into this relationship is also increasing, but incorporating student research experiences on these topics into secondary schools has been slow. We hypothesized that a research-based approach to learning increases student understanding about severe storms. However, the first step toward encouraging students to conduct hurricane research and improve science education in the United States is to understand and address students’ misconceptions about hurricanes.

This hypothesis commenced with investigating hurricane frequency during El Niño Southern Oscillation (ENSO) events between 1958 and 2007 in the six tropical cyclone basins (North Atlantic, Western North Pacific, Eastern North Pacific, North Indian, South Indian, and South Pacific). Data was gathered from international warning centers including the National Hurricane Center and the Joint Typhoon Warning Center. In addition to the relationship study of hurricane frequency and ENSO events, sea-surface temperature was also considered.

The science described here was used as the basis for developing a survey to assess secondary school students’ understanding of the two phenomena. Personal interviews involved 50 students from eight countries at the Global Learning and Observations to Benefit the Environment Learning Expedition (GLOBE) in Cape Town, South Africa. It found that high school students generally had accurate perceptions of basic hurricane formation, relationship to ENSO events, and risks. However, 34% of the students interviewed expressed interest in conducting research on hurricanes, and 72% wanted traditional classroom instruction to be combined with field-based learning experiences. This study opens up future research into methods for teaching high school students about hurricanes.

### Table 1

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<td></td>
<td>Hurricanes are huge thunderstorms in the Atlantic, Pacific, and Indian Oceans – 24%</td>
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<td>They are dangerous – 76%</td>
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<td>El Niño is the oscillation of warm waters in the Pacific Ocean – 34%</td>
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<td>Warm ocean temperatures – 72%</td>
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<td></td>
<td>El Niño – 66%</td>
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<td></td>
<td>Maximum sustained wind speed is 64 knots or 74 miles per hour – 64%</td>
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<td></td>
<td>Research supplements in-class learning – 34%</td>
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<td>Teaching and learning method: regular in-class teaching style or a practical field-based learning</td>
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<tr>
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<td>In-class – 4%</td>
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<tr>
<td></td>
<td>Practical field-based – 24%</td>
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<td></td>
<td>Both – 72%</td>
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Preconceptions and prior knowledge of secondary students attending the GLOBE Learning Expedition
Comparison of water vapor measurements from GPS atmospheric remote sensing techniques

This work compares a space-based technique of measuring precipitable water vapor (PWV) in the atmosphere with a ground-based technique. Understanding the spatial and temporal distribution of PWV is potentially useful in weather prediction and weather and climate research, and PWV sensing over the tropical oceans can improve weather analysis and prediction, especially for tropical cyclones. Comparing these two types of measurement allows us to use the satellite-based system with greater precision in areas where ground-based receivers are not present—especially over the oceans. The two techniques obtain their results using different procedures and different parts of the atmosphere. The ground-based measuring stations in this study use Global Positioning System (GPS) radio waves to infer PWV at fixed locations and times. The space-based measurements were made by Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) satellites using radio occultation soundings; they use GPS radio waves to derive PWV at variable locations and irregular times. For June 1 – November 30, 2007, we identified 910 satellite soundings that were within two hours and 200 km of a ground-based measuring station, with penetration to at least 200 meters from the surface. Since these satellite soundings do not reach the surface, they recorded lower PWV values than the ground-based stations. To complete the vertical water profiles, global models were assimilated with the satellite data. Good overall agreement was established between the two techniques, with a correlation coefficient between 0.92 and 0.93. This work enhances the usefulness of COSMIC measurements to other research programs around the world.

![PWV Comparison between the Radio Occultation and other techniques during the months of Jun-Nov, 2007](image)

**Figure 1**

A comparison of precipitable water vapor measured from GPS radio occultation with measurements from ground-based GPS receivers and from two reanalysis data sets.
Investigating the ability of CLM-CN 3.5 to accurately simulate vegetation density

Terrestrial vegetation engages in important feedbacks with the carbon cycle and the climate system. The National Center for Atmospheric Research (NCAR) Community Land Model version 3.5 coupled to carbon/nitrogen cycling (CLM-CN 3.5) was compared to satellite observations of Normalized Difference Vegetation Index (NDVI) to investigate its ability to simulate temporal and spatial variability in vegetation density. High-resolution satellite-derived NDVI data obtained from the University of Maryland Global Inventory Modeling and Mapping Studies (GIMMS) project was regridded and temporally averaged to match the monthly 2.5° × 1.875° resolution of CLM-CN 3.5 NDVI values. In CLM-CN 3.5 the NDVI was calculated from near-infrared and visible spectrum reflectances. Gridded monthly and annual climatological time series were produced to determine model accuracy at different spatial and temporal scales. Interannual variability simulation accuracy was examined using NDVI-anomaly plots for historically documented droughts. Multidecadal trends in vegetation were investigated using time series of CLM-CN 3.5 NDVI data for 1870-2004 to see if the model captured the recent greening trend documented by previous research.

Our findings indicate CLM-CN 3.5 tended to overestimate NDVI when values were less than 0.15, and underestimate otherwise. Modeled NDVI peaked a month sooner than observed values. Regionally, CLM-CN 3.5 did not capture the monsoon-induced vegetation response in the Sahel. Drought-vegetation response simulation varied in accuracy. CLM-CN 3.5 captured recent (1960-2004) multidecadal greening trends with a high degree of certainty (R=0.96). These results will form a foundation for future research to determine the causes of error and to address biases in future model development.

Figure 1

Monthly climatological NDVI, predicted by CLM-CN 3.5 and observed values for the Sahel region of Africa. Years considered: 1982-2004.
Effects of meteorology on particle transport at the Storm Peak Laboratory (SPL)

The Storm Peak Aerosol and Cloud Characteristics Study (SPACCS) was conducted from March 24 to April 15, 2008 at the Storm Peak Laboratory located in the Colorado Rocky Mountains (40.45N, 106.73W) at an elevation of 3,200 m. The study objectives included measurements of aerosol concentrations, size distributions, and composition for this remote site. Aerosols affect cloud radiative properties, can potentially cause respiratory problems, and can affect visibility. Average fine particle number concentrations measured using a scanning mobility particle sizer (diameters ranging from 8 to 300 nm) were 1,900 per cm$^{-3}$ and particles measured with an aerodynamic particle sizer (diameters ranging from 500 nm to 5 microns) were 141 per cm$^{-3}$. Meteorological data and models were used to describe air mass characteristics and possible aerosol sources. During the study period, the site was frequently in-cloud or was experiencing precipitation. The dominant wind direction was from the northwest. However, there were several short-term episodes of transport from different regions. Asian dust, dust storms occurring in Oregon, Arizona, and New Mexico, and fires from Siberia were possible sources of particulate matter measured during these episodes. The results of this meteorological analysis will contribute to determining the sources and origins of the measured particles at the Storm Peak Laboratory during SPACCS.

Figure 1

This figure shows a three-dimensional view of the site. Both mesoscale and synoptic scale winds affect the transport of aerosols at this site.
Analysis of daily monsoonal wind circulations in the lower troposphere over Estación Obispo, Mexico using wind profilers and GSI

The North American Monsoon dominates over northwest Mexico during the summer, and many people both depend on and can be endangered by increasing rains. Atmospheric General Circulation models have not been able to accurately simulate monsoonal rains due to the poor representation of lower-tropospheric wind circulation. This project utilizes wind profiler data from the North American Monsoon Experiment 2004-2006 summers for a better understanding of land/sea breeze characteristics and daily cycles. The 915-MHz wind profiler data is obtained from the 2005 North American Monsoon Experiment ‘supersite’ along the coast of northwest Mexico near the mouth of the Gulf of California. Even though in previous work sea breezes are clearer in the seasonal mean, results show that 36 out of 58 days had sea breezes. Sea breezes in August occurred less often than in July or September. Before this “break,” prevailing winds were from the southeast going into the sea breeze. After the “break,” northwesterlies transitioned into the sea breeze. Plots of all sea breezes for the summer of 2005 show them typically occurring from ~12:00PM to ~5:00PM LT. Finally, when hourly wind direction is plotted along with hourly Gulf Surge Index values, they show no obvious relationship between surge events and occurrences of sea breezes. This new understanding of the lower-tropospheric wind patterns over northwestern Mexico will help monsoon forecasters evaluate the monsoon prediction models’ likeness to real-time observations.

Figure 1
Plot of wind direction during all days with a Sea Breeze “event” (range highlighted in grey horizontal box). Each graph shows 6-10 events. The top panel starts around the beginning of the summer (22 June) progressing close to the end (20 September).
Coastal nutrient and water budget assessments for Puerto Ayora, Academy Bay, Santa Cruz Island

Santa Cruz Island is arguably the most visited island in the Galapagos. The coastal zone of Puerto Ayora, Academy Bay, Santa Cruz Island is susceptible to changes from land-ocean interactions, climate shifts, and human activities. Human activities from urbanization, tourism, and waste production are altering nitrogen and phosphorus nutrient levels in groundwater and along this coastline. The ecosystem metabolism of the coastal waters is sensitive to these human activities. Direct and indirect anthropogenic influences were examined within Academy Bay, but data sources were sparse. Relevant data were obtained during 2005-2006. The Land Ocean Interaction Coastal Zone (LOICZ) methodology was used to quantify the water-salt and nutrient budgets for Academy Bay. The hydrographic budget described inputs and outputs within this system, and it was used to determine the salinity and residence time. Dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) nutrient budgets were used to determine the net ecosystem metabolism (NEM) equation, which defines a system as a source or a sink. DIN and DIP concentrations revealed that the NEM is autotrophic dominated by primary producers. The targeted area is also a sink for DIN and DIP. The Pressure-State-Impact-Response (PSIR) assessment was used to identify socio-ecological stresses; through which it was determined that tourism and urbanization highly affected nutrient concentrations. An increase in these stresses may induce state changes and result in impacts such as eutrophication and algal blooms (toxic or non-toxic). The PSIR and budget analyses may be used as a framework to advise on coastal management and policy.

Figure 1
Galapagos Islands, East Pacific Ocean (1°40’ N -1°36’ S, 89°16’ - 92°01’W), 1000 km from the mainland of Ecuador.
An analytical study of tropical flows using an improvement of the longwave model

Climate modeling is performed almost exclusively with the primitive equations (PEs). These equations are used to produce the most realistic simulations, but often Global Climate Models (GCMs) do not accurately simulate tropical weather phenomena such as the Madden-Julian Oscillation (MJO). Analytical models based on the PEs are used to address this issue. We produced a new analytical model of equatorial waves based on the PEs; it filters out inertia-gravity waves to gain insight on the MJO. Filtered models are usually derived by partitioning the flow into nondivergent and irrotational parts that are expressed in terms of the streamfunction and velocity potential. Then approximations are introduced into the divergence and potential vorticity equations, with the result that inertia-gravity waves are filtered. Such procedures have led to the disadvantage that, in the process of filtering the inertia-gravity waves, the Kelvin waves are distorted. In this work we took a different approach to the filtering problem. We partitioned the flow into Kelvin and non-Kelvin waves, expressing the non-Kelvin waves in terms of a single potential function, which satisfies a master equation (Schubert et al., 2008). The methods also yielded an improvement of the longwave approximation (Gill, 1980), in that they provided a more precise approximation of Rossby waves of all wavelengths. This is very promising for learning more about the MJO because an accurate representation of the MJO requires well-represented Rossby and Kelvin waves. We also derived an analytical solution for convectively coupled equatorial waves using this same filtering method.

Figure 1
Spectral bands of the five filters. Madden-Julian Oscillation (MJO); equatorial Rossby waves (ER); Kelvin waves (Kelvin); Easterly waves (TD-type); mixed Rossby-gravity waves (MRG) used in the project are outlined with solid curves and plotted over a smoothed tropical Outgoing Longwave Radiation spectrum. From Roundy and Frank (2004).
A statistical comparison of vertical TEC from three ionospheric models

Total electron content (TEC) exhibits significant variations in both space and time depending on latitude, longitude, solar cycle, UTC, and season; these variations can have potentially negative effects on communication and navigation systems. Recently, three models have provided accurate results in reconstructing and/or calculating real-time (or near real-time) vertical TEC values: the Utah State University Global Assimilation of Ionospheric Measurements (USU GAIM) Gauss-Markov Kalman Filter Model, the United States Total Electron Content (US-TEC) Model, and the Coupled Thermosphere Ionosphere Plasmasphere electrodynamics (CTIPe) Model. This research offers a statistical comparison of the vertical TEC outputs from these models on both a global and local (over the continental U.S.) scale during the month of July 2008. We present the average difference and root mean square difference (RMS difference) for three model comparisons (e.g., US-TEC vs. GAIM, US-TEC vs. CTIPe, and GAIM vs. CTIPe). We have documented certain model biases and the differences measured between corresponding data points among the models relative to each comparison. The first two comparisons showed that the US-TEC model’s bias predicted higher values of vertical TEC relative to the other models, while the third comparison revealed a small bias in the CTIPe model to forecast greater vertical TEC values when compared to the GAIM model. By computing the RMS difference, we can better examine the source of these biases relative to the aforementioned model comparisons. This is the first step in documenting the biases, errors, and uncertainties associated with these three models.

Figure 1
Sample map from the GAIM Model of the vertical global TEC for 20:45 UTC on 22 July 2008.
Modeling Antarctica

Current climate models have many difficulties in simulating environmental conditions accurately for high-latitude zones, especially cloud cover and radiation fluxes, because of the unique environmental conditions of the polar regions. To confidently predict future climate change and weather forecasting in the polar regions, more work on improving climate models apt to polar zones is needed. This study examined the Weather Research and Forecasting (WRF) model for the preferred set of physical parameterizations for atmospheric and climate studies. We also considered WRF’s potential for providing real-time operational forecasting in Antarctica. To evaluate the effectiveness of the WRF model in the polar regions, the WRF simulations were compared to observational measurements obtained from the Baseline Surface Radiation Network (BSRN). The BSRN is designed to provide observational data to verify and validate satellite radio measurements and climate models. The meteorological variables that were considered to fine tune WRF are surface pressure, temperature at 2-meter height, long-wave radiation down, and short-wave radiation down. This study improved the capabilities of the WRF model for applications in the polar zones by selecting and modifying radiation parameters to accurately represent observational measurements.

Figure 1

Comparison of downwelling shortwave radiation observed and simulated by the Weather and Research and Forecasting (WRF) model using two existing parameterizations.
Hydroxyl radical and sulfuric acid concentrations in Manitou Experimental Forest

The hydroxyl radical (OH) is an important chemical species. It is the primary oxidizing agent in the troposphere, reacting with many pollutants and consequently maintaining the purity of the air. It also plays an important role in the formation of sulfuric acid (H₂SO₄), which is important to aerosol production. It is this role that made concentrations of OH a measurement of interest to the Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H₂O, Organics and Nitrogen (BEACHON) Project, a study that aimed to improve earth system models by quantifying geophysical systems. High reactivity, short lifespan, and low concentrations of OH make this molecule particularly difficult to measure. Chemical Ionization Mass Spectrometry (CIMS) is one reliable method of measuring OH concentrations and was used in this study. The CIMS instrument measures OH by first converting it to sulfuric acid through the addition of isotopically labeled sulfur dioxide (34SO₂), allowing naturally occurring H₂SO₄ to be measured separately. Concentrations of both OH and H₂SO₄ were taken in the Manitou Experimental Forest (MEF) in Manitou Springs, Colorado in summer 2008. Decay rates of OH were also determined. While OH concentrations and decay rates were unavailable at the conclusion of this research project, concentrations of OH and H₂SO₄ as well as OH decay rates were measured in similar studies conducted in Morgan-Monroe Experimental Forest and Hyytiala, Finland in May 2008.

Figure 7
H₂SO₄ concentrations in Manitou Experimental Forest.
Convective transport of chemical constituents at Northern Alabama and Central Oklahoma; A numerical analysis

Chemical constituents are transported from the boundary layer to the upper troposphere via deep convection. Once in the upper troposphere, these constituents have longer lifetimes and are readily advected. Vertical transport of these constituents is important because they affect the Earth’s radiation budget, the flux of UV radiation to the surface, and the creation of radical species that help eliminate certain pollutants. In this paper, carbon monoxide is studied because it is an excellent tracer of convection; its chemical lifetime is much longer than the lifetime of a thunderstorm. Conversely, ozone was chosen because of its high reactivity and effects on both solar and infrared radiation. This research analyzes simulations of constituents from the Weather Research and Forecasting model coupled with chemistry during two storms; one located in northern Alabama and the other in central Oklahoma. At these locations carbon monoxide and ozone data are used to understand the effects of the convective transport in the upper troposphere. Distributions of these constituents are compared before, during, and after the passage of each storm. Results present a stronger, high-reaching storm in Oklahoma versus a broader and less energetic storm in Alabama. Because of these differences, the Oklahoma storm transports constituents more effectively into the upper troposphere. This research concludes that not only the intensity of the storm affects concentrations of a constituent in the upper troposphere but also the original concentration at the boundary layer before convection.

Figure 1
The vertical cross section of carbon monoxide, at 0030 UTC, during the Oklahoma storm. The black contour lines denote total condensed water at 0.1 g/kg indicating where the storm is located.
Regional climate model projections for Northeast Kansas: Access to water on the Kickapoo Reservation

Present and future generations can benefit from preparing contemporary communities for the impacts of changing climate conditions. This project explored future access to water on the Northeast Kansas Kickapoo Reservation by analyzing Regional Climate-Change Projections from Multi-Model Ensembles (RCPM) produced by the National Center for Atmospheric Research. In addition, interviews were conducted to collect data on the region’s climate history, introduce RCPMs to Kickapoo representatives, and assess the Reservation’s water infrastructure through the use of a sensitivity analysis. Climate model projections were run to project change in temperature and precipitation for 2020, 2030, 2040, and 2050. Results from RCPM output data projected that by 2050, annual mean temperatures could increase from 12.39° C to 15.37° C, and annual precipitation could increase from 36.6 inches to 41.84 inches. In interviews Kickapoo representatives described their decision to address drought mitigation planning. To lay a foundation for drought mitigation planning, the sensitivity analysis was used to assess the Reservation’s water infrastructure. The analysis revealed the Reservation’s water infrastructure could neither withstand an increase in precipitation, nor could it compensate for periods of drought. Applying the physical science of RCPMs to locally defined contemporary and upcoming social issues with a focus on water infrastructure empowers communities to plan for the future.

![Fig 1](image)

**Figure 1**

Annual percent change in precipitation over the Kickapoo Reservation under three potential CO₂ emission scenarios.

**Table 1. Year 2050 RCPM annual percent change in precipitation data supporting Figure 1**

<table>
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Urban transport and dispersion model sensitivity to wind direction and source location

Many transport and dispersion (T&D) models need meteorological data and source characteristics to forecast concentration and dosage fields. To do this, the models use observational data or mesoscale-model-generated forecast winds as the prevailing winds for a given scenario. This research examines how errors in these input wind fields translate into T&D model solution errors. In particular, this study focuses on street-level plume errors that occur in building-aware T&D models for a set of scenarios where the release location varies relative to the building locations. First a “truth” plume was created for a given release location and wind direction. Then the T&D model errors associated with input wind errors were determined by comparing plumes calculated using wind directions varied at 2-degree increments to the truth plume. The errors for a given level dosage are quantified as fraction of overlap, figure of merit in space, measure of effectiveness, and normalized absolute difference. These errors were evaluated for a nonurban domain, an urban grid, and an urban radial domain. Two case studies modeled after common city designs were also evaluated. Results show that the relative impact of input errors vary significantly with the release location and the wind direction relative to buildings.

Input Winds

Building Aware Models
QUIC-Urb
QUIC-Plume

Figure 1
This figure depicts how errors in input wind fields can translate into errors in plume transport and dispersion in an urban environment.
Mid-Pliocene (3.4-2.9 Myr) climate: Testing the atmospheric response of Pliocene sea surface temperatures (SST) revised to match proxy observations indicating warmer SSTs in mid- and low-latitudes than prescribed by the USGS PRISM2 SST dataset

The Intergovernmental Panel on Climate Change (2007) established with 90% confidence that anthropogenic influences will result in a warmer world. To more fully understand possible future climate, past analogues of warm periods should be analyzed. The Pliocene epoch is an appropriate analogue because the continents were in their current configuration and CO₂ levels were comparable to the present, possibly as high as 400 ppmv. In 1999 the United States Geological Survey (USGS) created the Pliocene Research, Interpretation, and Synoptic Mapping datasets, version 2 (PRISM2), a set of 39 gridded datasets for use as boundary conditions in General Circulation Model (GCM) experiments. Dekens et al. (2007) proxy observations reveal that PRISM2 underestimates sea surface temperatures (SSTs) for the Californian, Peruvian, North African, and South African margin. In this study, we modified the PRISM2 SSTs to match these proxy observations. The sensitivity of the atmosphere to these SST revisions was tested using the National Center for Atmospheric Research (NCAR) Community Atmosphere Model, version 3 (CAM3). The experiment results show increased cumulative precipitation and humidity in regions where PRISM2 predicted drying. For North America the predicted precipitation increase was in better agreement with geologic proxies indicating wetter conditions. Correlation of model results to geologic data for South America and Africa was more difficult due to the lack of Pliocene proxy data for these regions. The patterns of change displayed on wind vector and sea level pressure maps suggest new possibilities for Pliocene air-ocean climate.

Figure 1

Z_PRISM: Modern difference map displaying changes in annual wind stress (N/m²) with revised Sea Surface Temperatures. Z_PRISM is the name given to the CAM3 experiment where Pliocene (3.4-2.9 Myr) SSTs were revised to match new proxy observations indicating warmer than expected SSTs in Pacific and Atlantic upwelling regions.
Analyzing soil moisture and runoff variability in the Manitou Springs Experimental Forest

Hydrologic controls on ecosystem behavior (e.g., rainfall, runoff, infiltration, and soil moisture variability) have yet to be determined within the Trout Creek Watershed, located in the Manitou Springs Experimental Forest. Determining the major hydrological components and how they influence this Ponderosa Pine ecosystem is the primary goal of this project. Developing a better understanding of these components may determine how susceptible the Ponderosa Pine ecosystem will be to seasonal forest fires or storm events. Data collected in this area are used to determine how much rainfall, interception, runoff variability, and infiltration influences moisture availability. Precipitation was recorded using tipping bucket rain gauges to estimate hydrologic inputs within a one square kilometer area. Precipitation measurements included both open and under-canopy rainfall events at 11 sites to determine the amount of interception that occurs over time. Independent measurements of soil infiltration, soil moisture, and soil temperature will also be made. Preliminary results suggest that during dry summer seasons, precipitation and infiltration are a major hydrological component in this ecosystem. It can be suggested that destruction or removal of the Ponderosa Pine canopy will have significant impact on the ecosystem. These measurements will be combined in a GIS database.

Figure 1
Accumulated rainfall events and air temperature from an open canopy site within the Manitou Springs Experimental Forest.
Propagation of precipitating trade wind cumulus clouds using detailed radar images from the RICO Project

The propagation of a precipitating trade wind cumulus cloud was documented by a ground-based S-band weather radar combined with data from the GPS Advanced Upper-air Sounding (GAUS) system on January 19, 2005. Radar reflectivity and Doppler velocities were compared with GAUS soundings to study how subsequent clouds formed during the RICO campaign in the Caribbean. The role of latent heat during condensation in maintaining updrafts from cloud formation is well understood, but this work studies how the updraft is initiated during cloud formation over the ocean. A potential cause of updrafts over the ocean is outflow from nearby clouds with downdrafts. Surface convergence at the edge of this outflow may then initiate new updrafts very close to the old one, but the January 18-19 GAUS soundings showed little potential for evaporative cooling which is the main cause of downdrafts. Further, the Doppler velocities recorded by the radar showed no surface outflow on the low-angle scans. And in many of the radar studies in the RICO project, cloud formation is typically not associated with outflow, so another explanation is needed. The RICO data often showed a new cloud forming in proximity to an existing cloud. In the cloud pair documented on January 18-19, 2005, a second cloud formed near an existing cloud, and we deduced that winds rising over the first cloud created the updraft that formed the second cloud. This obstacle flow is similar to orographic lift that occurs on land. Wind rising above strong updrafts over the ocean may be the mechanism that produces the uplift needed to form new cumulus clouds.

Figure 1
Scans at 1.5° elevation vary in height from about 0.6 to 0.4 km as the cloud approaches the radar. Scans were moved 4.2 km southwest between each 3-4 min scan to keep them from overlapping. Tracking of the first cloud was stopped to study better the formation of the second cloud.
Application of the statistical theory of extreme values to heat waves

Heat waves can have devastating impacts on society, but a current weakness with the analysis and modeling of heat waves is the negligible use of the Statistical Theory of Extreme Values (EVT). This branch of statistics is appropriate for studying extreme events such as heat waves, floods, etc. For this study, EVT was used to develop methods for analyzing heat waves and their characteristics (frequency, intensity, duration, etc.). This analysis was performed using temperature data from Phoenix, Arizona and Fort Collins, Colorado. This study signaled how Statistical Theory of Extreme Values can be applied to model certain features of heat waves. Results from the analysis showed an increase in the summer highest temperature and in the number of heat waves per year for both cities. This study also explored other characteristics of heat waves (heat wave duration and individual maximum temperatures within heat waves), indicating how the extreme-value approach would need to be extended to fully model all features of heat waves. The results showed there hasn’t been a significant change in the intensity or duration of heat waves for either city. Further, the results descriptively imply a temperature dependence of daily temperatures within a heat wave for both cities. More reliable quantification of return levels for severe heat waves, including any trends in their characteristics, and other extreme events involving spells will be achieved with the continual development and future use of these methods.

Figure 1

This is a plot of Phoenix’s number of clusters per year from 1948 to 1990. A cluster (i.e. Heat Wave) in this study is defined by temperatures exceeding a threshold for at least 1 day, and then falling below the threshold. There is a statistically significant trend in the number of clusters per year (solid black line).
Assessing tropical cyclone contribution to annual global rainfall

Any change in tropical cyclone (TC) rainfall could positively and/or adversely impact the well-being of humans worldwide. This first global 10-year Rainfall Climatology and Persistence (R-CLIPER) model TC rainfall study seeks to enhance the basic understanding of TC contribution to annual global rainfall. The Tropical Rainfall Measuring Mission (TRMM) satellite data provided accurate rainfall rates that were incorporated in R-CLIPER and were used in conjunction with rain gauge data by the TRMM global rainfall algorithm (3B-43) to make best estimates of the monthly mean global precipitation amount between 50° N and 50° S. R-CLIPER integrated the TRMM-derived climatological rainfall distribution at every 10-minute time step over the lifetime of each TC to estimate the individual TC rainfall. Annual TC and global rainfall estimates were integrated on 0.25° × 0.25° latitude/longitude grids for the years between 1998 and 2007. The annual TC rainfall totals were compared to annual global rainfall totals to assess TC rainfall percent contribution to global rainfall. The results suggest TCs contributed between ~2-3% of the annual global rainfall during the 10-year period with regionally higher percentages reaching 10-15% in the subtropics and as high as 25-40% in certain local areas. The results of this study could be useful to risk and water management agencies for identifying which regions around the world depend on TC rainfall for agriculture and other uses. These results have added value considering that climate change may impact TC rainfall contributions.

Figure 1

Percent contribution of tropical cyclone rainfall to total rainfall, by latitude, over the 10-year period from 1998-2007.
RESESS combines structured mentoring, ongoing research internships, and a supported learning community for undergraduate students from underrepresented groups in order to increase the diversity within solid earth sciences. RESESS will build upon the knowledge and skills that make an existing program, SOARS,® so successful.

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Key to Mentors’ Affiliations

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<td>COMET</td>
<td>Cooperative Program for Operational Meteorology, Education and Training</td>
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SOARS AND RESESS PROTÉGÉS 2008 IN FRONT OF THE FLATIRONS IN BOULDER, COLORADO


Front Row (L to R): Cecille M. Villanueva-Birriel, Dana Pauzauskie, Sandra L. Diaz, Roque V. Cespedes, Miriam E. Garcia, Zi Zi Searles, Marques Cameron, Alex O. Gonzalez, Cynthia Boshell, Katherine F. Fornash, Yexary Rodriguez, Ian C. Colón-Pagán


Not pictured: Ezer Patlan
SOARS
National Science Foundation, Directorate for Geosciences, Atmospheric Sciences
National Oceanic and Atmospheric Administration, Climate Program Office
National Oceanic and Atmospheric Administration, Oceans and Human Health Initiative
Center for Multi-scale Modeling of Atmospheric Processes at Colorado State University
Cooperative Institute for Research in Environmental Sciences
University Corporation for Atmospheric Research

RESESS
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UNAVCO
The Incorporated Research Institutions for Seismology
The United States Geological Survey

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