Previous and Current Research
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My objective is to improve the predictability of high-impact weather events with high-resolution numerical models. My specific interest is for convective periods in the western United States at lead times of 0-3 days. Since 2013, I have assisted with operations for the MesoWest program—a cooperative network of environmental sensors—and the maintenance of the University of Utah mesonet. As a graduate student working with Dr. John Horel, I built and now manage an archive of the High-Resolution Rapid Refresh (HRRR) model. Much of my research uses this model which is the highest resolution operational weather forecast system run by the National Oceanic and Atmosphere Administration's Environmental Modeling Center (EMC) and is capable of forecasting convective-scale storms at lead times of 0-18 hours. During my research, I have developed extensive Python skills. My experience spans environmental instrumentation, numerical weather modeling, and big data analytics applied to the study of air quality, wildfires, and high-impact wind events.

1. Master's Degree: Great Salt Lake Summer Ozone Study

Many Utah residents are exposed to poor air quality during the winter and summer months. While previous studies focused on wintertime particulate concentrations that occur during persistent cold-air pools, little work had been done to examine summertime ozone pollution near the Great Salt Lake. Forecasting the spatial distribution of ozone and the time of peak concentrations has been difficult for the Utah Division of Air Quality (DAQ). One reason is that the Great Salt Lake influences ozone production and pollution transport. During summer 2015, DAQ funded a project known as the Great Salt Lake Ozone Study lead by John Horel. The three primary goals were: (1) determine the distribution of ozone over and surrounding the Great Salt Lake in the summer, (2) understand meteorological processes that control ozone concentrations over and surrounding the Great Salt Lake in summer, and (3) improve the Division of Air Quality ozone forecasts (Horel et al. 2016).

During the project, I was extensively involved in the planning and execution of three intensive observation periods (IOP). The study involved fieldwork with ozone and meteorological instrumentation around the Great Salt Lake and observations made from mobile platforms including a van and truck, electrified light-rail commuter train, and a local news helicopter. Following the summer's fieldwork, I investigated the role of lake breezes on ozone concentration in Salt Lake City. During one of the IOPs, we observed elevated ozone concentrations after the passage of a lake breeze front. With the Weather Research and Forecast (WRF) model, I showed how the lake breeze influenced ozone pollution. The model's set up required careful attention to land-atmosphere interactions that affect lake breezes. After adjusting the model's lake size and temperature to reflect the observed conditions better and account for urban frictional effects, the simulation produced a better representation of the observed lake breeze than the HRRR forecasts used by DAQ.

The WRF results showed that ozone concentrations ahead of the lake breeze were lower because the boundary layer was deeper which facilitated more vertical mixing, whereas a shallow boundary layer within the lake breeze restricted vertical mixing (Blaylock et al. 2017a). Another hypothesis is that the area near the Great Salt Lake is conducive for ozone production due to the vegetation, reflective playa, and anthropogenic emissions, but understanding those processes require additional measurements not made during this project. Still, my findings show that timing and intensity of subtle mesoscale features, like a lake breeze, impact air quality. My experience with WRF will benefit my proposed work at the Naval Research Laboratory.

2. Doctorate Degree: Forecasts for Wildland Fire

Wildland fires are a concerning hazard that threatens life and property. Firefighters are especially vulnerable during periods of erratic or atypical wind conditions. When the weather is expected to impact fire behavior, fire managers rely on HRRR model forecasts for critical decisions. My current research focuses on evaluating the ability of the HRRR model to forecast the characteristics of mesoscale atmospheric boundaries arising from convective outflows caused by thunderstorms. The Joint Fire Science Program funds this project with John Horel as the principal investigator and Robert Ziel from the University of Fairbanks as a co-principle investigator.

The study of the HRRR model's past performance has historically been difficult for researchers because EMC only makes HRRR data available for 48 hours and there was no official archive of past HRRR runs. I filled this data availability gap when I created a HRRR archive. HRRR forecasts are retrieved from the EMC daily and archived on a new object-storage system—similar to Amazon Web Services—known as Pando at Utah's Center for High-Performance Computing (Blaylock et al. 2017b). The archive contains continuous HRRR output since July 2016, exceeds 80 terabytes in size, and grows daily. This dataset is publicly accessible, and over 400 people have utilized the archive for various research projects.

Historical details of prior numerical weather forecast behavior are useful for incident meteorologists who provide weather support at fires. My work utilizes the HRRR archive to inform incident meteorologists of typical HRRR model behavior and its accuracy in remote areas that fires occur. One challenge with using the historical HRRR dataset is its massive volume of data. While the Pando archive provides a cost-effective way to store and access the data, using the data efficiently required high-throughput computing strategies. With the Open Science Grid—a high-throughput computing resource typically used in astronomy and biology, but seldom in atmospheric sciences—I efficiently accessed vast amounts of archived HRRR data and estimated cumulative distributions for seven different model output variables at all 1.9 million model grid points. These statistics are used to identify atypical wind events in the vicinity of fires that may pose a threat to firefighting operations. For example, Blaylock et al. (2018) showed that unusually strong winds during the Pocket and Tubbs fire in California contributed to the rapid fire spread that led to 22 fatalities and over 5,000 structures destroyed. The fires started from trees fallen into power lines caused by the winds.

Wind forecasts have become more important to power companies to avoid damages like that caused by the California fires. Since December 2018, Taylor McCorkle (another graduate student of John Horel) and I have collaborated with John Muhs and Amarachi Umunnakwe in the University of Utah electrical engineering department on a project to help power companies determine where power transmission lines are at risk of strong winds and rapid wildfire spread. The expected results of our research are to help power companies know when they should de-energize transmission lines before those lines are damaged by wind and start new fires.

The remaining of my dissertation focuses on wind events arising from convective outflows from thunderstorms. Although the HRRR model resolves convective processes, the placement, timing, and intensity of these storms are not highly accurate. To address how often the HRRR forecasts the correct location and severity of thunderstorms, I compare predicted thunderstorms to lightning observations made by the Geostationary Lightning Mapper (GLM) on board the Geostationary Operational Environmental Satellite (GOES) satellites GOES-East and GOES-West. GLM is the first instrument to measure total lighting from geostationary orbit and is an independent dataset to verify the HRRR lightning forecasts. This work is ongoing, but initial findings suggest that skill in HRRR forecasted lightning degrades rapidly after the first two or three hours. This model behavior is useful knowledge for incident meteorologists who rely on the HRRR forecasts to warn firefighting crews of the potential of lighting in the area at a short lead time. The expected conclusion of this work is to highlight the need for an operational ensemble forecast systems with the same spatiotemporal resolution as HRRR which can better inform fire managers of the uncertainty of convective situations.

3. References

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