RESEARCH STATEMENT

Although I am fascinated by many areas of atmospheric science, my primary research interests lie in determining the predictability of the atmosphere. A better understanding of the predictability of various weather features is obtained by identifying the sources and evolution of errors in numerical weather prediction (NWP) model forecasts. Forecast errors can originate from two primary sources: initial conditions (i.e. analysis) or the model physics (i.e. model error). Modern data assimilation schemes produce the “best” analysis of the current state by incorporating information from a short-term forecast and observations. The key component of any data assimilation system is the specification of the forecast error statistics, which determine how observation information is spread to other locations and variables. Most operational data assimilation systems generate a deterministic analysis using assumed forecast error statistics, which can lead to sub-optimal usage of observations in regions of sparse data, and thus an inferior analysis. The ensemble Kalman filter (EnKF) is an alternative data assimilation system whereby an analysis ensemble is obtained by assimilating observations using flow-dependent forecast error statistics estimated from a short-term forecast ensemble. Furthermore, this analysis ensemble may be integrated forward to produce ensemble forecasts without the need for ad hoc assumptions required to “perturb” a deterministic analysis. In addition, Greg Hakim and I have shown that ensemble analyses and forecasts produced by an EnKF system can be used to determine the sensitivity of a forecast metric to the analyses and infer dynamical relationships between various fields (Hakim and Torn 2005). Regions of high sensitivity indicate where small changes to the initial conditions would have the largest impact on the subsequent forecast and where additional “targeted” observations could provide the greatest benefit. The following paragraphs briefly describe how I have applied ensemble-based data assimilation to understand the predictability of various weather features and my future research plans.

Previous work has shown that the eastern Pacific Ocean is a region of frequent forecast failures due to analysis errors (McMurdie and Mass 2004). During the fall of 2004, I designed and implemented a real-time Weather Research and Forecasting (WRF) model EnKF system to test the benefit of using flow-dependent error statistics in this region of sparse in-situ data. This system generates 90 analysis ensemble members four times daily by assimilating observations from surface stations, rawinsondes, ACARS and cloud wind vectors. Verification against rawinsondes indicate that the WRF EnKF forecasts are comparable to operational center forecasts, even though the WRF system does not assimilate satellite radiances. In addition to testing the impact of flow-dependent error statistics on forecasts, the unique output from this system was used to perform basic research on predictability and observation network design. By analyzing data from this system, I have found that, on average, 24 hour SLP forecasts over western Washington state are most sensitive to an area of the analysis just beyond the Pacific fixed buoy network; however, this area can change depending on the synoptic situation. Moreover, ensemble-based observation impact estimates indicate that only a small subset of observations have a large impact on these SLP forecasts. I am interested in using this dataset in the future to determine where additional observations could improve forecasts of rapidly deepening cyclones and frontal waves along the North American coast.

Extratropical Transitions (ET) – the process by which a warm-core tropical cyclone (TC)
transforms into a cold-core baroclinic system—present a major predictability problem for numerical weather prediction (NWP) models. These events often generate significant errors in global models, even at short lead times (Jones et al. 2003). In particular, western Pacific ET events can spawn Rossby wave packets that impact forecasts for both North America and Europe. The evolution of an ET event is critically dependent on how the decaying tropical cyclone phases with the existing mid-latitude flow features such as shortwave troughs originating over Asia. Previous studies have shown that small changes in the initial position of the TC or mid-latitude features can lead to significant forecast differences (e.g. Browning et al. 2000, Klein et al. 2002). To determine the sensitivity of the ET forecast to the initial conditions and evaluate the impact of observations, I used an EnKF to generate analyses and forecasts of five recent western Pacific ET events. My results indicate that the evolution of the ET forecast is most sensitive to the position of upstream shortwave troughs; small shifts in the location of these features can lead to 48 hour forecast differences of 20 hPa in minimum central pressure and 300 km in position. Observation impact calculations indicate that assimilating 30 key observations can have nearly the same impact on the ET forecast as assimilating all 12,000 available observations. While this research focused on the predictability of the ET storm itself, I would like to extend this work to understand how ET impacts downstream predictability.

Most current operational data assimilation schemes have difficulty assimilating observations near tropical cyclones (TC) because the assumed forecast error statistics are inappropriate for these situations; therefore, these centers use “bogusing” to represent the TC structure in conventional analyses. The EnKF is an attractive alternative for TC state estimation because it assimilates observations using flow-dependent forecast error statistics. To better understand the predictability of TC track and intensity forecasts, I have used an EnKF to generate ensemble analyses and forecasts of Hurricanes Katrina and Rita (2005) from depression stage to landfall. My preliminary results indicate that it is possible to simulate the track and intensity of both tropical cyclones using EnKF data assimilation without bogusing. Moreover, TC track forecasts are most sensitive to the position and intensity of upper-level ridges over the Southeastern US. I plan on extending this work to create high resolution (3-10 km) analyses of these tropical cyclones and to determine where observations would have the greatest impact in the TC forecast.

My future work will involve applying ensemble data assimilation to understand the predictability of other meteorological phenomenon. ET events are a subset of tropical phenomenon that can impact mid-latitude predictability, thus I would like to understand how tropical weather systems, such as large-scale convective flareups, can impact the mid-latitudes. Although several groups have used an EnKF to perform storm-scale data assimilation on mature convective storms (e.g. Snyder and Zhang 2003), there are few studies where an EnKF has been applied to convective initiation. In addition to providing an analysis ensemble for these situations, these experiments could be used to determine the dynamically sensitive regions and the impact of observations during convective initiation. The upcoming increase in hyperspectral satellite radiance data will present a significant computational challenge to data assimilation systems. As a consequence, I would like to explore how ensemble-based sensitivities could be used to identify a subset of radiance observations that provide the largest benefit to the forecast. While the primary focus of my research is predictability, I am eager to expand into related research areas where I can
lend expertise and explore other subjects.

**References**


