Progress Report

Project Title: Probabilistic Forecasts of Extreme Events and Weather Hazards over the United States

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Abstract

The occurrence of extreme weather events such as heavy precipitation, high surface wind speeds and low temperatures are frequently associated with severe and hazardous conditions with major socio-economic impacts. This project aims to contribute to the goals of the NOAA Climate Test Bed (CTB) Program by carrying on a study of probabilistic forecasts of extreme events and weather hazards over the contiguous United States, Alaska and Hawaii during winter.

The project will use retrospective forecasts (RF) from the NCEP Climate Forecast System (CFS) model to specifically develop probabilistic forecasts of extreme events in precipitation, surface temperature and wind speeds on 30-day lead times. Second, an important and novel aspect of this project will be to construct probabilistic forecasts of winter hazards conditioned on the probability of extreme events in precipitation, surface temperature and wind speeds. This component of the project will make use of historical records of weather related hazards in the U.S. and available from the National Climatic Data Center (NCDC).

The proposed research consists of four objectives:

I. Evaluate the skills of CFS RF probabilistic forecasts of extreme events of precipitation, surface temperature and wind speeds on 30-day lead times.

II. Develop probabilistic forecasts of extreme events of precipitation, surface temperature and wind speeds on 30-day lead times.

III. Develop conditional probabilistic forecasts of winter hazards over the U.S.

IV. Implement experimental probabilistic forecasts of extreme events of precipitation, surface temperature, wind speeds and winter hazards over the U.S.

The monthly probabilistic forecasts will be examined in the context of intraseasonal-to-interannual variations such as Madden-Julian Oscillation (MJO), El Niño/Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) (Arctic Oscillation, AO) and how they can modulate the skills of probabilistic forecasts. The proposal will greatly contribute to other projects currently being developed at the Climate Prediction Center (CPC) such as the U.S. Hazard Assessments, MJO monitoring/assessment/research with applications to a weekly global tropics benefits/hazards product and storm track monitoring/assessment/and research with a focus over the Alaska domain.

Research progress to date

a. ***Forecast skill of extreme precipitation events in the contiguous United States***

In this second year of the project, we concluded the analysis of forecast skill of extreme precipitation derived from NCEP CFS reforecasts. The following paper is being submitted for publication:

Jones, C., J. Gottschalck, L. M. V. Carvalho, and W. R. Higgins, 2010: Winter forecast skill of extreme precipitation in the contiguous United States: An assessment of NCEP CFS reforecasts. *Monthly Weather Review*.

Abstract

Extreme precipitation events are among the most devastating weather phenomena, since they are frequently accompanied by significant potential of human fatalities, injuries and property losses. This study uses reforecasts of the NCEP Climate Forecast System (CFS) model to evaluate the skills of non-probabilistic and probabilistic forecasts of extreme precipitation in the contiguous United States (CONUS) during boreal winter and lead times up to 2 weeks.

The CFS model realistically simulates the spatial patterns of extreme events over the CONUS, although the magnitudes of the extremes in the model are much larger than in the observations. Heidke skill scores (HSS) of forecasts of two levels of extreme precipitation (75th and 90th percentiles) showed that the CFS model has good skill on Week-1 leads and some modest skill at Week-2. Forecast skill is usually higher when the Madden-Julian Oscillation (MJO) is active (phases 1-2 and 7-8) than in quiescent periods. In these situations, HSS greater than 0.1 extends to 13-14 days lead times. Approximately 10-30% of the CONUS has HSS greater than 0.1 on lead times of 1-14 days when the MJO is active.

Probabilistic forecasts of 75% percentile extreme precipitation vary between 10-40% improvements over climatology at 1-day lead to about 0-5% over a few regions at 7-day lead. The CFS model has better skill in forecasting severe extremes (i.e. events exceeding the 90th percentile) at longer leads than moderate extremes (75th percentile). Improvements over climatology between 10-30% at 3-day lead are observed over several areas across the CONUS especially in California and the Midwest.

b. Forecast skill of Santa Ana winds in southern California

Another research activity accomplished during the second year was the investigation of forecast skill of the synoptic conditions that lead to the development of Santa Ana winds in southern California. The following paper was submitted for publication

Jones, C., F. Fujioka and L. M. V. Carvalho, 2010: Forecast skill of synoptic conditions associated with Santa Ana winds in southern California. Submitted to *Monthly Weather Review*.

Abstract

Santa Ana winds (SAW) are synoptically driven mesoscale winds observed in southern California usually during late fall and winter. Due to the complex topography of the region, SAW episodes can sometimes be extremely intense and pose significant environmental hazards especially during wildfire incidents. A simple set of criteria was used to identify SAW conditions in the NCEP/DOE reanalysis. SAW events start in late summer and early fall, peak in December-January and decrease by early spring. The typical duration of SAW conditions is 1-3 days, although extreme cases can last more than 5 days. In addition, SAW events exhibit large interannual variations and possible mechanisms responsible for trends and low-frequency variations need to be further understood. A climate run of the NCEP Climate Forecast System (CFS) model showed good agreement with the observed climatological characteristics of SAW conditions and generally small differences.

Non-probabilistic and probabilistic forecasts of synoptic scale conditions associated with SAW were derived from NCEP CFS reforecasts. The CFS model exhibits small systematic biases in sea level pressure and surface winds in the range of 1-4 weeks lead time. Several skill measures indicate that non-probabilistic forecasts of SAW conditions are typically skillful to about 6-7 days lead time and large interannual variations are observed. NCEP CFS reforecasts were also applied to derive probabilistic forecasts of synoptic conditions during SAW events and indicate skills to about 6 days lead time.

c. Conference presentations

Jones, C. and L. V. Carvalho, 2010: Decadal variations in the Madden-Julian Oscillation. Predicting The Climate Of The Coming Decades, RSMAS, Miami, USA, January 11-14, 2010.

Jones, C., J. Gottschalck, L. Carvalho and W. Higgins, 2009: Probabilistic forecast skill of extreme weather in weeks 1-4 in the United States during winter. 34th Annual Climate Diagnostics and Prediction Workshop, Monterey, CA, October 26-30, 2009.

Jones, C., 2009: Climate change and the Madden-Julian oscillation. 9th International Conference on Southern Hemisphere Meteorology and Oceanography, Melbourne Australia 9 to 13 February 2009.

Jones, C., 2008: A probabilistic view of the activity of the Madden-Julian. 33nd Climate Diagnostics and Prediction Workshop, Lincoln, NE, October 20-24, 2008.

Research activities in progress

The study above suggests that useful skills at leads of 2-4 weeks might be attained by developing forecasts of opportunity in which significant changes in the mean atmospheric state alter the likelihood of extreme precipitation. One good candidate for forecasts of opportunity is the MJO, since observational and modeling studies have demonstrated important relationships between the oscillation and precipitation variability in the tropics and extra-tropics. However, because current models have limited skill in predicting the evolution of the MJO beyond about 10 days, probabilistic forecasts of extreme precipitation on 2-4 weeks lead will probably employ a combination of empirical and numerical model approaches.

We are currently working in two new studies:

1) The Madden-Julian Oscillation and a probabilistic forecast model of extreme precipitation in the United States

2) Forecast skill of extreme precipitation in the United States on 2-4 weeks: a combined empirical and CFS approach

In the first study, we are developing a simple probabilistic forecast model of extreme precipitation on 2-4 weeks lead time based on diagnostic analyses of the MJO evolution. The second study uses the simple probabilistic forecast model in combination with ensemble forecasts derived from the CFS reforecasts.

2) *Preparation of Storm data and weather hazards data base*

An important dataset that will be employed in this project is the Spatial Hazard Events and Losses Database for the United States (SHELDUS). SHELDUS is based on hazard reports from NCDC Storm Data, SPC (NWS) as well, U.S. Geological Survey (USGS) data and presently covers the period 1960-2007. Events were classified into 18 different hazards categories and geo-referenced by State Counties. Additionally, events in SHELDUS were selected if they caused more than $50,000 in property and/or crop losses. SHELDUS serves as the baseline for county-level event and loss data, and it is used in the compilation of hazard vulnerability assessments under the U.S. federal Disaster Mitigation Act of 2000 (PL 106-390).

We are continuing to develop quality control methods in addition to the ones already included in SHELDUS. This is necessary in order to identify the hazards reports that can be effectively used to perform probabilistic forecasts of weather hazards unambiguously associated with extreme events from gridded CFS forecasts.

We have extracted all storm events which occurred during (extended) winter seasons defined here as from 1 Nov 1979-30 Apr 1980 to 1 Nov 2004-30 Apr 2009. Two main processing steps had to be done in the digital records. First, the types of events were screened to identify weather phenomena which were described by different but similar words. For instance, flood events could be described as “flooding”, “flash flood”, “flash floods”, “flash flooding”, “urban floods”, “urban flooding” etc. In doing so, we generically classified all events into the following categories: 1) coastal event, 2) cold weather, 3) drought, 4) dust storm, 5) flood, 6) heavy precipitation, 7) hurricane, 8) icing event, 9) landslide, 10) snow, 11) tornado, 12) thunderstorm, 13) warm weather, 14) wildfire, 15) wind event, 16) winter storm, and 17) lightning. Events that could not be classified into the previous categories were assigned as others or errors. The second step consisted in converting events that were registered by NWS forecast zones into the corresponding Counties covered by the NWS forecast zone. For example, an event registered as occurred on CAZ039, which covers the Santa Barbara County South Coast, was reassigned to Santa Barbara County. Our plan is finalize the quality control task before July 2009.

Another task that will be performed before the end of the project is the preparation of a hazard reports data base into GIS format. This point will be crucial to merge the hazards reports and the gridded CFS probabilistic forecasts of extreme events. Spatial methods will be developed to consistently merge both data sets. We expect to develop a methodology for probabilistic forecasts of weather hazards during the no-cost extension of this project.