**NOAA/WPC Progress Report 30 May 2016**

**1. Summary**

Investigations of GFS and GEFS forecasts 8–10 days prior to individual extreme weather events (EWEs) impacting the eastern U.S. have demonstrated that the forecasts are strongly influenced by precursor events that produce perturbations along the North Pacific waveguide and contribute to the amplification of the upper-tropospheric flow pattern, such as the extratropical transition (ET) of tropical cyclones (TCs) or extratropical cyclogenesis events. However, it is apparent that considerable variability characterizes the antecedent environments over the North Pacific associated with EWEs. This observation has motivated a comprehensive examination of EWEs (1) to identify the atmospheric flow patterns that are most conducive to the production of EWEs over the U.S., and (2) to evaluate whether certain atmospheric flow patterns exhibit greater predictive skill with respect to the development of EWEs. The discussion that follows summarizes the results from recent case studies conducted during the six-month reporting period ending on 30 April 2016, and details efforts currently underway to identify the antecedent environments over the North Pacific that favor the development of EWEs in the U.S.

**2. Analysis of GFS and GEFS Forecasts of Individual EWEs**

 Prior work for the project examined the quality and characteristics of GFS and GEFS forecasts for four recent EWEs that impacted the eastern U.S. These events included (1) the 22–23 December 2013 Northeast Ice Storm, (2) the 8 November 2014 ET of Super Typhoon Nuri in the western North Pacific and the subsequent period of well below-normal temperatures across the eastern U.S., (3) the 25–27 January 2015 East Coast Blizzard, and (4) the 22–24 January 2016 Mid-Atlantic Blizzard. GFS and GEFS forecasts for all events were found to be sensitive to upstream ridge amplification in the North Pacific and exhibited varying degrees of medium-range forecast skill. For example, GEFS forecasts for the 22–24 January 2016 Mid-Atlantic Blizzard exhibited strong consensus among ensemble members for the development of a surface cyclone along the Mid-Atlantic coast as many as 8 days in advance, while forecasts for the 25–27 January 2015 East Coast Blizzard did not exhibit strong consensus among ensemble members until 4 days prior to that event. Full analyses of cases (1) and (2) were presented at the 96th Annual Meeting of the American Meteorological Society on 14 January 2016 ([PDF](http://www.atmos.albany.edu/facstaff/awinters/MayReport/AMS16poster_Winters.pdf)), cases (2) and (3) were discussed at the Annual Fall Meeting of the American Geophysical Union on 17 December 2015 ([PPTX](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Bosart_AGU.pptx)), and cases (1) and (4) were presented at the weekly meeting of the EMC Global Modeling Branch on 18 February 2016 and at the 41st Annual Northeastern Storm Conference on 5 March 2016 ([PPTX](http://www.atmos.albany.edu/facstaff/awinters/MayReport/WPCvisitFeb16.pptx)).

**3. Antecedent Environments of Extreme Temperature and Precipitation Events**

*a) Identification of EWEs*

 Underpinning an effective composite analysis is the ability to objectively identify extreme temperature and precipitation events. Six-hourly, 0.5°-resolution 2-m temperature data from the Climate Forecast System Reanalysis (CFSR) was employed to identify extreme temperature events during 1979–2014, while the 0.25°-resolution CPC Unified Gauge-Based Analysis of Daily Precipitation was employed over the same 36-year period to identify extreme precipitation events. A climatological distribution of temperature and precipitation at each analysis time was constructed for each grid point prior to the identification of EWEs. These distributions were subsequently used to determine the temperature and precipitation values that correspond to the 99th percentile for cold, warmth, and precipitation at a grid point at a particular analysis time. Climatological distributions were also calculated for the 95th percentile. However, the 99th percentile was determined to be more suitable for identifying EWEs. A sample horizontal plot of 2-m temperatures that represent the 99th percentile threshold for extreme warm temperatures at 1900 UTC 30 May is provided in [Fig. 1](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure1.pdf). More information on the specific methodology used to develop these climatological distributions can be found by considering the example provided in [Fig. 2](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure2.png) for a grid point near Albany, NY (yellow star in Fig. 1).

 To identify extreme warm events, the number of grid points with temperatures that exceeded the 99th percentile was calculated within separate spatial domains east and west of the Rocky Mountains ([Fig. 3](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure3.png)) for each analysis time in the CFSR dataset. All analysis times that featured at least one grid point exceeding the 99th percentile were subsequently ranked within each spatial domain according to the number of grid points that exhibited extreme warmth at a given analysis time. Analysis times that ranked in the top 5% in terms of the number of grid points exceeding the 99th percentile were then isolated and labeled as an extreme warm event. Consequently, our methodology identifies events that are extreme in terms of both their magnitude and spatial coverage. A similar methodology was performed to identify extreme cold and precipitation events and the grid point thresholds used for identifying individual events can be found by consulting [Fig. 4](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure4.png).

 Once identified, extreme temperature and precipitation events were filtered to eliminate analysis times that corresponded to the same event. Specifically, any events that were within 24 h of another identified event were considered to be the same event. Precipitation events were also filtered to remove any analysis times that were associated with heavy precipitation from a TC. Overall, our methodology returned 226 (271) extreme cold events east (west) of the Rocky Mountains, 304 (264) extreme warm events east (west) of the Rocky Mountains, and 351 (333) extreme precipitation events east (west) of the Rocky Mountains. Extreme temperature and precipitation events within each spatial domain were also partitioned further using a *k*-means clustering algorithm that grouped events by geographical region (e.g., Midwest, Northeast, Southern Plains). These geographic event clusters serve as the basis for composite analyses of extreme temperature and precipitation events that occur in different parts of the U.S.

*b) Addressing the Variability in Antecedent Environments in the North Pacific*

 As mentioned in Section 1, considerable variability characterizes the antecedent environments over the North Pacific associated with EWEs. One particular way to investigate this variability is to view the antecedent environments associated with EWEs in the context of the most common modes of North Pacific jet (NPJ) stream variability. Following previous studies[[1]](#endnote-1)1,2, the most common modes of NPJ variability were calculated by performing an empirical orthogonal function (EOF) analysis on 250-hPa zonal wind anomalies over the North Pacific during September–May in the CFSR dataset. The first EOF explains ~12% of the variance and corresponds to an extension or retraction of the exit region of the climatological 250-hPa NPJ ([Fig. 5](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure5.png)). The second EOF explains ~8% of the variance and corresponds to a poleward or equatorward shift of the exit region of the climatological 250-hPa NPJ ([Fig. 6](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure6.png)).

 A benefit of the EOF analysis is that the instantaneous 250-hPa zonal wind anomalies at a particular analysis time can be projected onto first and second EOF patterns in an effort to characterize the state of the NPJ. This projection can be visualized graphically as a single point within a two-dimensional phase diagram, to be referred to as the NPJ phase diagram. An example of such a phase diagram is shown for 8 November 2014 in [Fig. 7](http://www.atmos.albany.edu/facstaff/awinters/MayReport/Figure7.png). Specifically, a purely zonal extension or retraction of the exit region of the NPJ would correspond to a point lying along the x-axis and a purely poleward or equatorward shift of the exit region of the NPJ would correspond to a point lying along the y-axis. Projecting the 250-hPa zonal wind anomalies onto this phase space over a specified time interval also enables examining the evolution of the NPJ. As an example, a trajectory within the NPJ phase diagram during 8–18 November 2014, following the ET of Super Typhoon Nuri in the West Pacific, shows a slow zonal extension of the NPJ ([PPTX](http://www.atmos.albany.edu/facstaff/awinters/MayReport/PhaseDiagram.pptx)). This extension was associated with the development of a persistent upper-level trough and well below-normal temperatures across much of the eastern U.S.

 Our goal is to utilize the NPJ phase diagram in an effort to partition the antecedent environments associated with extreme temperature and precipitation events. For instance, EWEs that project onto similar parts of the NPJ phase diagram will be grouped together and composited to identify the types of upper-tropospheric flow patterns that evolve to produce extreme temperature and precipitation events in the U.S. Furthermore, the NPJ phase diagram has the potential to be produced in real time and can be used to capture the analyzed and predicted evolution of the NPJ. As an example of the latter application, GEFS ensemble member forecasts can be projected onto the NPJ phase diagram in an effort to visualize the forecasted change in the structure of the NPJ and to gauge the uncertainty in those forecasts. Overall, the NPJ phase diagram has the potential to be useful in identifying regime changes and in alerting forecasters to the potential for extreme temperatures or precipitation events in medium-range forecasts.

**4. Anticipated Research Activities**

*a) Examination of EWEs*

Composite analyses of extreme temperature and precipitation events based upon the geographic event clusters are currently underway. We are also in the process of projecting individual EWEs onto the NPJ phase diagram in an effort to cluster and composite events that exhibit similar antecedent conditions. The results from the composite analyses will be presented at the 41st Annual Meeting of the National Weather Association during 10–15 September 2016. To the extent that the NPJ phase diagram produces a meaningful partition of the antecedent environments conducive to the development of EWEs, we also plan to examine whether the medium-range forecast skill for EWEs is dependent upon the antecedent flow regime. It is believed that this examination, in conjunction with the event composites, can help forecasters assess the likelihood of an EWE within a medium-range forecast.

Following the conclusion of the composite analyses, we will begin to investigate medium-range forecasts of extreme temperature and precipitation events within the GEFS. Climatological distributions of temperature and precipitation within 8–10-day forecasts will be calculated in a similar manner as was done with the CFSR dataset. Knowledge of these distributions will facilitate the identification of extreme temperature and precipitation forecasts within the model climate and permit an examination of the skill of 8–10-day forecasts of extreme temperature and precipitation events. A six-month plan for May–October 2016 is found [here](http://www.atmos.albany.edu/facstaff/awinters/MayReport/WPC6moTimelineJune1.docx).

*b) Continued Collaboration with WPC*

 The results from both the composite analyses and the NPJ phase diagram have the potential to improve operational medium-range forecasts at WPC. Preliminary discussions regarding the transition of results from the composite analyses and the NPJ phase diagram into operations are ongoing with Arlene Laing and Mike Bodner at WPC. These discussions have taken place both during a site visit during 16–19 February 2016 and a teleconference on 11 March 2016. We are currently planning a second visit to WPC during summer 2016 to further our collaborative activities with staff at WPC and to better inform ourselves on the types of products that would benefit operational forecasts in the medium-range.

1. 1 Athanasiadis, P. J., J. M. Wallace, and J. J. Wettstein, 2010: Patterns of wintertime jet stream variability and their relation to the storm tracks. *J. Atmos. Sci.*, **67,** 1361–1381.

2 Jaffe, S. C., J. E. Martin, D. J. Vimont, and D. J. Lorenz, 2011: A synoptic climatology of episodic, subseasonal retractions of the Pacific Jet. *J. Climate*, **24,** 2846–2860. [↑](#endnote-ref-1)