THE ATMOSPHERIC PROCESSES ASSOCIATED WITH THE TORNADIC SUPER-OUTBREAK OF APRIL 25TH THROUGH 28TH 2011 IN RELATION TO GLOBAL CHANGE

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ABSTRACT

A large and violent super-tornado outbreak occurred from April 25th – 28th, 2011, becoming the deadliest 24-hour outbreak in U.S history. According NOAA and the SPC, there were approximately 190 tornadoes reported with 320 deaths within the southern, mid-western and northeastern U.S. In the current study, Arctic sea ice loss affecting the North Atlantic Oscillation, a negative ENSO episode, Gulf of Mexico Sea Surface Temperatures (SST's) and an unusual shift of dry-line associated with parent mid-latitude cyclone (MCL) are potentially influenced by global change in association with the outbreak and studied using NCEP/NCAR reanalysis, GFS modeling, NCEP/CPC CAMS & NOAA/ESRL/PSD NOAA/AOML/TCHP analysis, and stability parameters obtained from remote sensing. Larger implications state the Arctic sea ice lost reversed upper-level wind distribution and affected major wind systems such as the jet stream. Reduced albedo in the arctic increased solar insolation and shifted the temperature differential between latitudes, potentially perturbing Earth's feedback system.

1. INTRODUCTION

The super-tornado outbreak that occurred during April 27th – 28th, 2011 in the southern and eastern United States redefines the state or behavior of the atmosphere and the systems that interact with it accordingly. According to the National Oceanic and Atmospheric Administration (NOAA), four EF-5 tornadoes, and six EF-4 tornadoes (including Tuscaloosa, AL) were among the reported 190 tornadoes in an alarming amount of time and under incredibly volatile conditions. One potential cause and influences relative to global change - as complex and broad a suspect as it is. Indeed, the issue of anthropogenic influences negatively affecting the sensitive systems of Earth has widely been studied by many divisions under NOAA and more specifically by the International Panel for Climate Change (IPCC), but this does not justify that their Studies have not proven anything relative to global change as a direct impact of some event over another with respect to atmospheric chaos, natural system oscillations or a combination of them all. In the present study, we investigated the atmospheric processes associated with the super –tornado outbreak of April 25-28, 2011in relation to global change. These processes include (a) arctic sea-ice loss, (b) geopotential anomalies, (c) El Nino-Southern Oscillation (ENSO)/La Nino and (d) sea surface temperatures over the Gulf of Mexico.

2. MATERIALS AND METHODS

Data for temperature, pressure, precipitation, geopotential height, wind systems and stability parameters were obtained from satellite data, numerical models and remote sensing products including NOAA NCEP/NCAR reanalysis, GFS modeling, NCEP/CPC CAMS & NOAA/ESRL/PSD NOAA/AOML/TCHP, NOAA/NESDIS analysis, NASA/GISS analysis and Plymouth State University models.

3. RESULTS AND DISCUSSION

3.1 Impact of 2010 Arctic Sea-Ice Loss

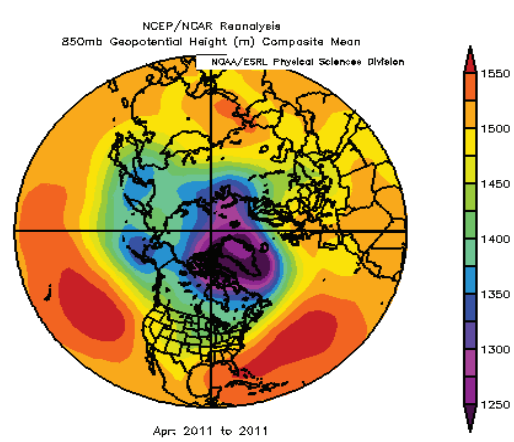

Figure 1: NCEP/NCAR Reanalysis 850 mb Height composite mean for April 2011

The processes of discussion considered here are first the North Atlantic Oscillation (NAO). Its function (alongside the Atlantic Oscillation) includes (and certainly not limited to) influencing source areas of air masses, development and intensity of polar highs and distribution of the polar jet stream. According to NOAA 2010 Arctic Reports, significant sea ice melt of 2007, there is a periodic reversal of polar vorticity from positive to negative well into 2010[1]. Because ice has a high albedo (or reflectance) it helps to keep surface temperatures cooler as southerly air travels northward and descends at the poles; however if these conditions do not persist, descending southerly air becomes more centralized at the poles resulting in vorticity reversal, further creating more areas of semi-high pressure systems and displacing the area of warm-cold air collision that forms the polar-jet to lower latitudes causing anomalous geopotential heights —such was the case observed using NCEP/NCAR reanalysis of geopotential mean with GFS modeling where semipolar-highs dominated much of the Arctic. This climatic pattern forced strong cold air into the interior United States and Europe while the Arctic began to warm, causing the so-called Warm Arctic-Cold Continent climate pattern. The report also identified that although the extent of the sea ice melt was not as significant as 2007 (approximately 4.13 million km^2 according to NSIDC), the resultant change in upper-tropospheric wind patterns, surface temperature anomalies exceeding 2° to 4°C and displacement of Polar-jet stream to lower latitudes persisted with varying intensity in all variables through 2010, potentially giving rise to that year's sea ice melt.

3.2: Cool Phase ENSO Event (LA NINA)

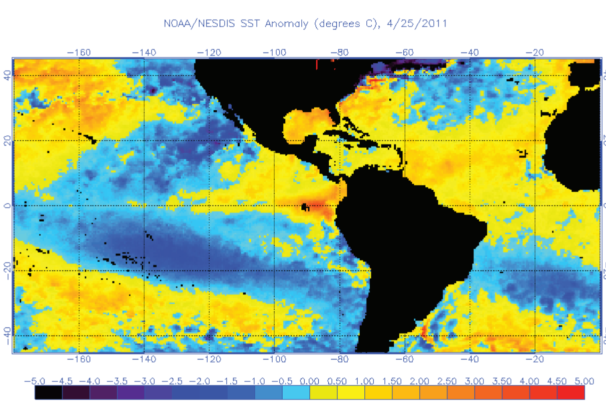

Figure. 2 NOAA/NESDIS SST Anomaly composite for Cool Phase event in eastern Pacific April 25th, 2011

El Nino-Southern Oscillation (ENSO) events are by definition when Pacific trade winds diminish, or to a greater extent, when the Walker Circulation collapses, to allow warmer waters from the western pacific to merge eastward and negate upwelling along the western coasts of Peru and Ecuador. This sudden influx of warmer waters directly increases sea surface temperatures (SSTs), that produce change in atmospheric pressure and winds. Positioning of Rossby waves has been observed to coincide with climatic conditions perpetrated by El Nino, thus producing the idea of ENSO events having a global affect. Studies of climate patterns associated with El Nino in North American continent show anomalous temperature increases in the northeast and northwest, where the northwest experiences a rain deficit; the southwest and eastern portions of interior U.S experience increases in precipitation and below-average temperatures. In contrast on average during a La Nina event, the reverse happens: the northwest and northeast receives above average precipitation and cooler temperatures, while the southern U.S experiences above average temperatures and less precipitation. In the Northern hemisphere these climatic characteristics seem to be most prominent in winter months, according to NOAA ESRL NCEP/NCAR GFS modeling of surface temperature anomaly reanalysis (data not shown), and diminish if the event continues through summer.

During the winter of 2010, a strong La Nina event persisted through February of 2011 and began to diminish in upwelling intensity through April (figure 2). A key average climate response due to Rossby wave interconnectivity is the cooling generally within the northwestern portions of the interior U.S. Northern hemisphere air temperature anomalies observed at lower tropospheric 850 mb with NOAA/ESRL/PSD for 2009-2010 relative to 1968-96 mean according to NCEP/NCAR reanalysis (data not shown) shows below average temperatures between 54 N and 36 N, specifically Mid/Western interior U.S associated with La Nina at -1 C to -2 C. Simultaneously, South/Eastern portions of U.S experience above-average temperatures at +1 C to +4 C, while Eastern/Central portions of U.S with above-average precipitation according to CPC gauge-based precipitation anomaly climatology (relative to 1976-1995 mean) analysis. These conditions provided an already cool environment supported by the 4° - 6° C below average temperatures from cold air constantly spilling from the Arctic due to the polar vorticity reversal. So although we haven't observed any direct correlation with GHG and ENSO events yet, there seems to be a direct correlation between the behavior of the NAO and La Nina in 2011 with respect to establishing a persistent cold air mass necessary for MLC development.

3.3 Gulf of Mexico (GOM) Sea Surface Temperature Anomaly

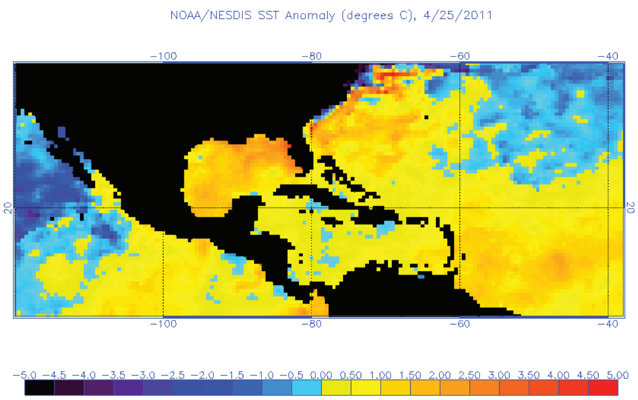

Figure: 3 NOAA/NESDIS GOM SST Anomaly composite for April, 25th 2011

An important climatological feature relative to the interior U.S is the Gulf of Mexico; it is a source area for maritime tropical air masses that infiltrate northward through the southern states and, depending upon the position of upper-wind systems, create warm, humid conditions or potentially unstable atmosphere. According to NOAA NESDIS SST anomaly analysis, beginning February 21st, 2011 a small prominent area of above-average sea surface temperatures (SSTs) arises and continues to intensify throughout March and April (see figure. 3) with anomaly values ranging between 1° - 2.5° C. Upper-wind circulation observations using NOAA SPC wind analysis maps from January 1st through April 25th, 2011 show the polar front trough positioned on average over Pacific northwest and ridge with strong zonal flow from interior U.S Midwest plains to eastern seaboard. Over the period of January 1st through April 25th, the average position of the polar front trough was west of the GOM allowing warm, moist air to remain over GOM waters (reducing the amount of cold air displacement and evaporation-condensation rates) and additionally allowing the ocean heat content or TCHP to remain warmer than average—albeit cooling did continue due to seasonal variations, this rate of cooling as expressed was diminished due to upper-wind distribution.

This observation expresses a warming trend in the GOM and using National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) Surface Temperature Analysis global maps from GHCN v3 data (using mean average anomaly datum comparison 1951 – 1980), for the trend period of March-April 2010 and 2011, the model shows mean surface temperature anomalies > 2° C.

Most importantly because of the GOM SST anomaly, a warm, moist and unstable air mass stretched predominantly over the southeastern and east-coast U.S, as represented in NASA GISS maps causing > 1°C inland surface temperature anomaly beginning February, 2011 and persisting through April.

3. 4 Dry-Line Shift Associated with April 25-28, Mid-Latitude Cyclone (MCL)

A dry-line is a meteorological term used to define a boundary between two air masses of different moisture content. An unusual and not often addressed component within the processes responsible for the tornadic super outbreak was a dry line that shifted eastward into the southern states, more specifically Mississippi and Alabama associated with the parent MLC.

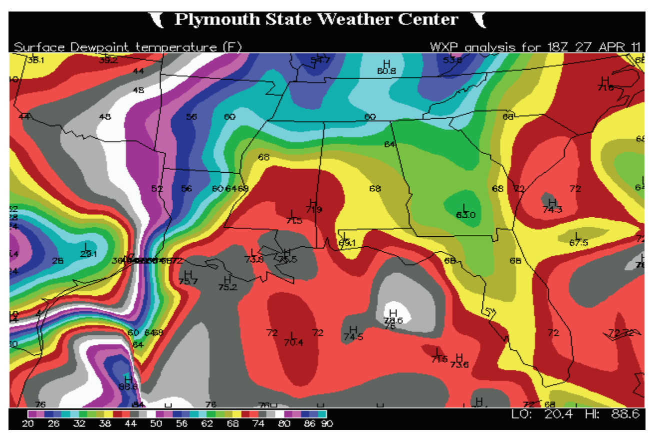

Figure: 4 Dew point surface temperature composite for April 27th 2011. Line with greatest contrast in temperature represents dry-line associated with MLC. (Image courtesy of Plymouth State University)

Dry lines typically form on the lee side of the Rocky Mountain range and begin development at the convergence of warm, moist air from the Gulf of Mexico from the southeast and hot, dry air from the desert area of the southwest United States and Mexico. Additionally cold air descending from the mountains warms adiabatically, and since most of the moisture has already been condensed out of it by being lifted over the mountains, it is fairly dry when it descends from the mountains. Where these two air masses meet is defined as the dryline[2]. Because the dry line is an important mechanism for super cell development in association with large-scale systems such as MLC's, its role was necessary in the case of the April 27th – 28th tornadic outbreak. Typically in the southeastern region of the interior U.S, the tornado season exists roughly between February and April, with conditions necessary for tornado development shifting westward towards the Great Plains or Tornado Alley; the dynamics of the air masses change significantly however as within the plains the general northward-shifting of the polar jet during seasonal changes occurs, allowing the best conditions for super-cellular development. Generally in the southeast, super-cells are moisture laden or high precipitation (HP) storms, bearing weaker, less destructive tornadoes that are quite often rain wrapped—this thunderstorm behavior is signature of the local air mass conditions within the southeast. During the outbreak of April 27th – 28th, much of the same reasons for the GOM SST anomaly relative to upper-tropospheric wind positions are believed to have caused the dry-line shift (figure. 4), resulting in similar air mass collisions commonly found in the Great Plains.

4. SUMMARY AND CONCLUSIONS

Our current hypothesis states that previous geopotential heights caused perturbation to "normal state" of upper tropospheric wind pattern, pushing polar-jet to lower latitudes during 2010 winter season. Coupled with loss of arctic sea ice for that year, polar-jet remained at abnormal latitudinal position, although seasonal shift continued. Climatic pattern persisted into 2010-2011 winter seasons and into spring 2011 where polar vorticities try to regain normal 1968-1998 averages, but geopotential height anomaly analysis shows continued abnormal displacement during polar-jet retreat. This pattern of perturbation of the system into regaining averages relative to severe weather outbreaks within interior U.S is evident in the lack of MLC during 2009, but very prevalent beginning February 2010 and into April, where the southeast was victim to a tornado outbreak during the 23rd – 24th that resulted in a long-track EF-4tornado in Mississippi, with 88 amount of tornadoes during that outbreak. Future research will be to test/validate hypothesis of complex system interactions using empirical and/or theoretical models available to reconstruct the April 27- 28 2011 outbreak.

6. ACKNOWLEDGEMENTS

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