Washington County Utah Gap Wind Study Revisited

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ABSTRACT

An updated approach is presented to identify and forecast winds reaching wind advisory or high wind warning criteria in Washington County, Utah using a combination of the surface pressure gradient, 700 hPa temperature change per twelve hours, and 700 hPa flow speed. Thirty-nine wind advisory or high wind warning events are identified during the cool seasons (October – April) from 1997-2016 using wind observations from the White Reef (WRRU1) observing site, located along I-15 northeast of St. George, UT. A quantitative decision tree is presented by retrieving the mean sea level pressure gradient from Cedar City (CDC) to Las Vegas (LAS) or Cedar City to Grand Canyon (GCN) from MesoWest observations and 1-hour METARs; 700 mb temperature and wind speed data is then retrieved from the North American Regional Reanalysis (NARR) using the Weather Archive and Visualization (WAVE) software.

In addition to the decision tree, a synoptic climatology is also presented for wind advisory and high wind warning events. It is shown that high wind warning events are associated with a Rossby Wave breaking pattern. Advisory and warning events occur under two distinct synoptic regimes: frontal passages and backside shortwave trough environments. Warning events are typically associated with strong frontal passages, while advisory events are associated with the backside of a vigorous shortwave trough moving across southwestern Utah, with the trough axis positioned across the Utah and Colorado border.

1. Introduction

Gap wind episodes in Washington County, Utah are associated with three primary ingredients: a strong surface pressure gradient, winds aloft parallel to canyon orientations, and a tight 700 hPa temperature gradient. These events typically take place during the cool season (October – April). The strongest gap wind events can generate wind gusts greater than 60 mph and result in property damage. Long-fused gap wind events can generate hazardous driving conditions along the I-15 corridor north and east of St. George, Utah (St George News, 2017). The strongest winds are typically located just downstream of canyon mouths where the local surface pressure gradient is maximized; however, high impact events can produce high wind speeds several miles downstream of canyon mouths. This research aims to 1) produce an updated Washington County gap wind decision tree to help provide NWS Salt Lake City forecasters a guide in the warning decision making process and 2) to investigate the synoptic climatology associated with wind advisory and high wind warning events and the associated differences.

2. Data and Methodology

2.a Data Sources

MesoWest observations were collected during the cool seasons (October – April) of 1997-2016 at Cedar City (CDC), Las Vegas (LAS), Grand Canyon (GCN), and White Reef (WRRU1) (MesoWest and SynopticLabs, 2017). Mean sea level pressure, wind speed, and wind direction data were collected for CDC, LAS, GCN, and WRRU1. Thirty-nine case studies meeting wind advisory (WA) or high wind warning (HWW) criteria were examined. WA criteria winds are defined by sustained winds greater than or equal to 31 mph for three hours or wind gusts greater than or equal to 45 mph for three hours or more, and high wind warning (HWW) criteria winds are defined by, winds greater than or equal to 40 mph for 1 or more hours, or wind gusts equal to or exceeding 58 mph anytime. For each WA and HWW event from 1997-2013, 700 hPa wind and temperature data were retrieved from the North American Regional Reanalysis (NARR) data set. NARR data was visualized using the Weather Archive and Visualization (WAVE) software. Using WAVE's data readout option, 700 hPa temperature and wind speed values were collected at the data point closest to the White Reef observing station located along I-15 approximately fifteen miles northeast of the St. George airport. Since the NARR dataset was only available to visualize in WAVE through 2013, 700 hPa temperature and wind speed data for case studies following 2013 were retrieved from the Storm Prediction Center's RAP reanalysis (NOAA/National Weather Service Storm Prediction Center, 2018). One should note that the 700 hPa temperature and wind speed data retrieved from the NARR and RAP were taken from model analyses of different resolutions. The NARR is a regional reanalysis dataset with 32-km resolution while the RAP is a 13-km resolution model output grid.

2.b Research Methodology

The purpose of this study is to recreate a gap wind decision tree developed by Struthwolf and Carle (1998) which related the surface pressure gradient between CDC and LAS or CDC and GCN to 700 hPa temperature advection and 700 hPa wind speed to provide NWS forecasters in the Salt Lake City Weather Forecast Office an operational aide in the WA and HWW warning decision-making process. The gap wind decision tree developed by Struthwolf and Carle (1998) relied on data collected for 13 case studies from January 1996 through March 1997, whereas this research will focus on reconstructing the decision tree using data collected from 39 case studies from 1997 through 2016. Struthwolf and Carle (1998), collected 700 hPa temperature advection and wind speed from the ETA model using AWIPS. As a proxy for 700 hPa temperature advection, this study will instead use 700 hPa temperature change across a 12-hour period.

2.c Topography of Southwest Utah

This study focuses on developing a gap wind decision tree for identifying WA and HWW criteria winds originating out of three main canyons in Washington County (Figure 1). These canyons are north to northeast oriented and are nearly parallel to one another. Each canyon slopes roughly from the north to the south dropping around 2,000 feet in elevation. I-15 lies in the westernmost canyon between Hurricane Cliffs to the east, and the Pine Valley Mountains to the west. Consistent and representative gap wind observations are recorded at the White Reef sensor (WRRU1), located 15 miles northeast of St. George and 6 miles southwest of the canyon mouth. To the east, WA and HWW observations are sometimes received from weather spotters in La Verkin and Virgin, located downstream of the next two canyons.

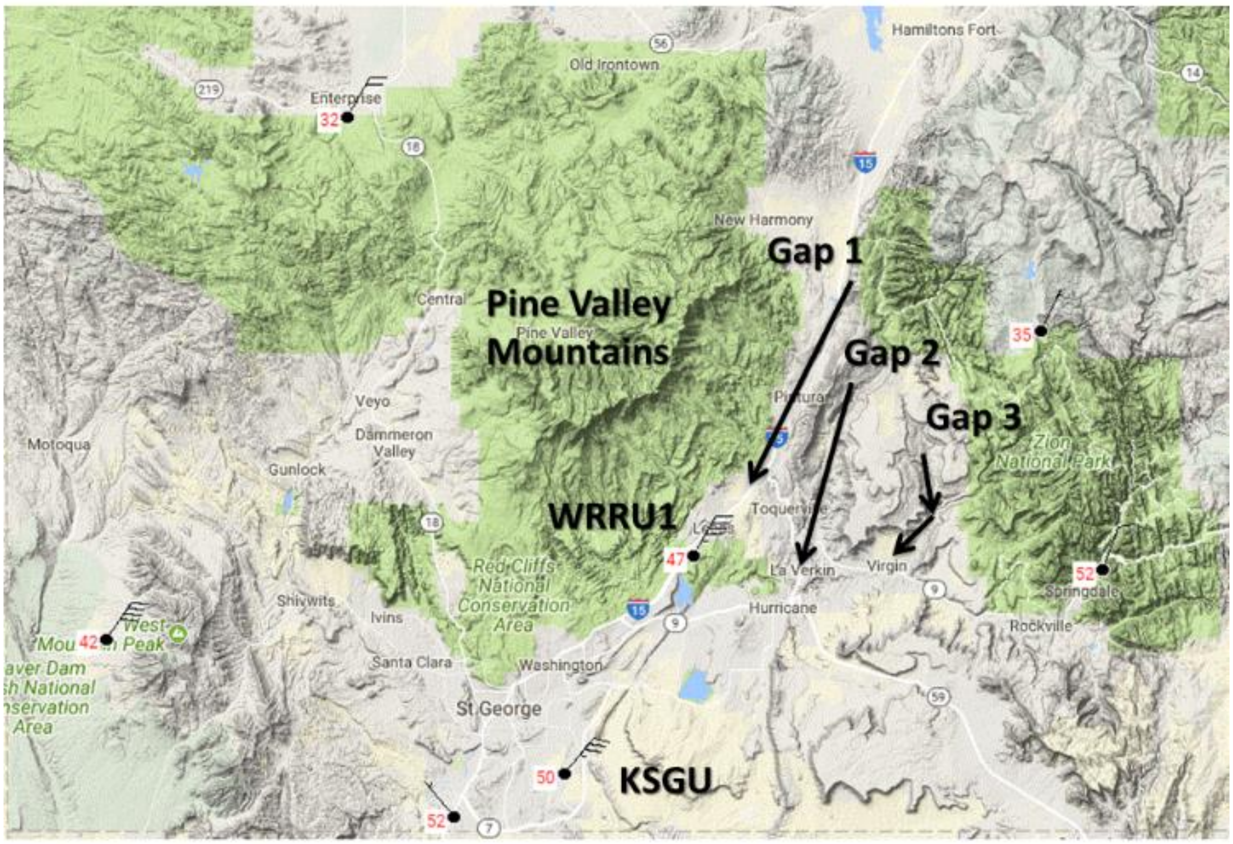

Figure 1. Terrain map of Washington County in southwestern Utah. Overlaid observations are taken from MesoWest for a HWW event valid 2315 UTC December 1st, 2011 (MesoWest, 2017).

3. Results

3.a Climatology of Washington County Gap Wind Events

A relative peak in the frequency of WA and HWW Washington County gap wind events occurs during December and January (Figure 2). From 1997 to 2016, zero HWW events were observed at White Reef during October, while two HWW events occurred in April. The majority of HWW and WA Washington County gap wind events took place from November through March. Breaking down the WA and HWW warning events by event start time reveals a frequency minimum from 1100 UTC through 1700 UTC or the local morning hours (Figure 3). During this timeframe, only three WA events initiated and zero HWW events initiated. The number of HWW and WA event starts increases with diurnal heating in the afternoon. Instability and mixing of air during the afternoon allows for the downward transport of momentum to the surface, bringing stronger winds aloft down to the surface.

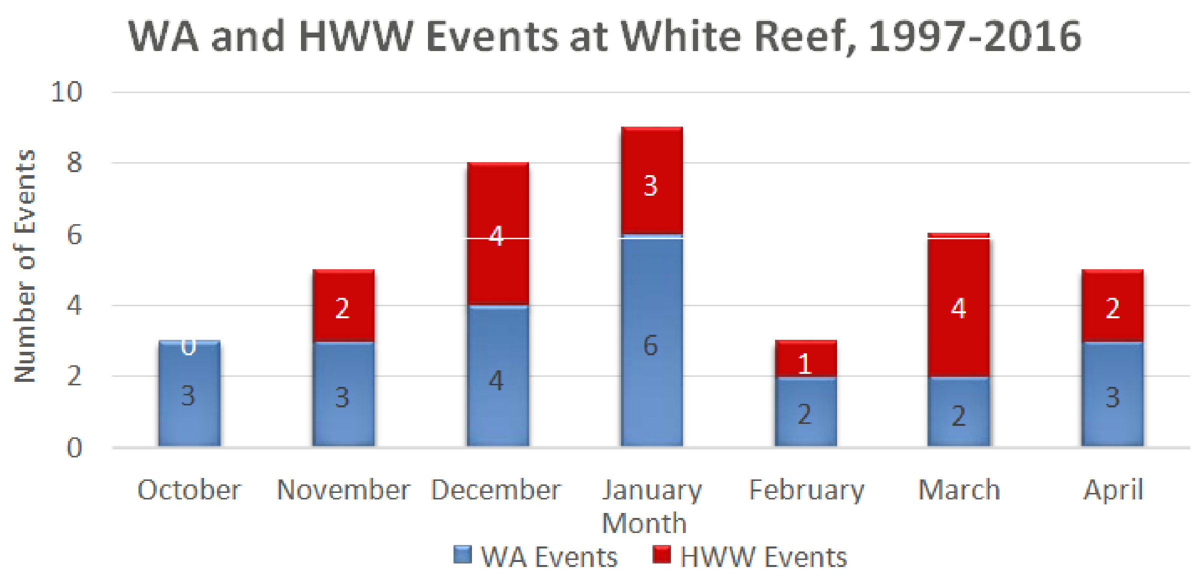

Figure 2. Monthly frequency distribution of WA and HWW Washington County gap wind events, 1997-2016.

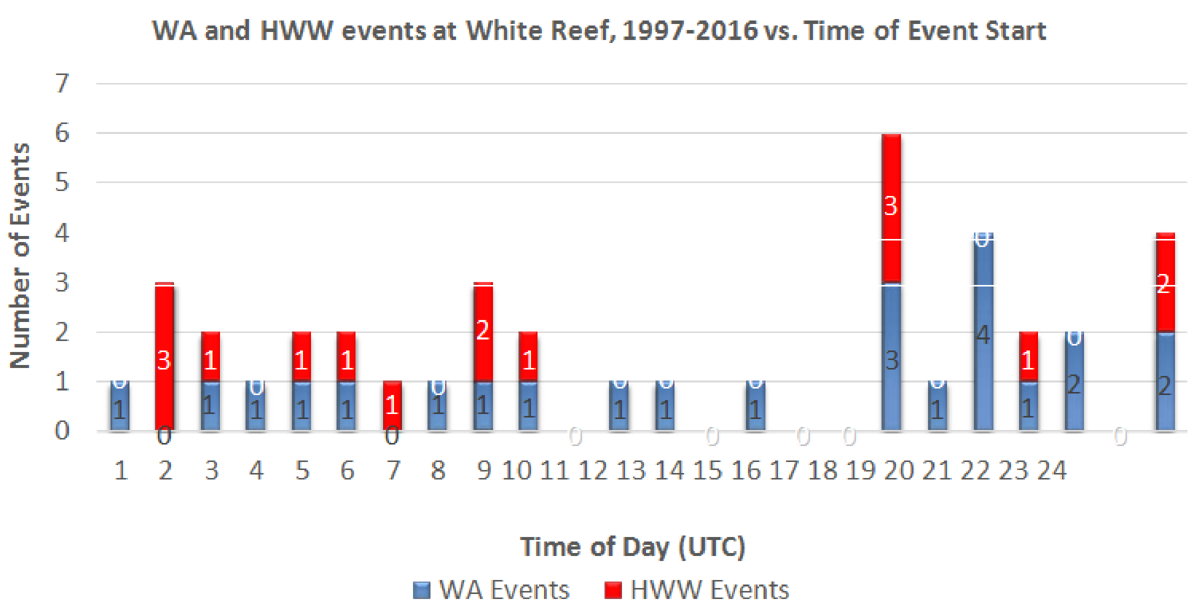

Figure 3. Diurnal frequency distribution of WA and HWW Washington County gap wind time of event initiation, 1997-2016.

3.b Synoptic characteristics of wind advisory and high wind warning events

Investigation of NARR reanalyses reveals that Washington County gap wind WA and HWW events tend to be associated with a Rossby wave breaking pattern across the western U.S. The synoptic pattern is characterized by a high amplitude omega block off the coast of the western U.S. with a low amplitude upper level ridge across the southeastern U.S (Figure 4). In WA events, a shortwave trough rides over the top of the omega block and digs southwestward into Utah, but progresses downstream in 12-24 hours after moving into northern Utah. In contrast, HWW events feature a vigorous shortwave trough digging southwestward, splitting from the main trough across south-central Canada, and closing off near the Idaho and Utah border.

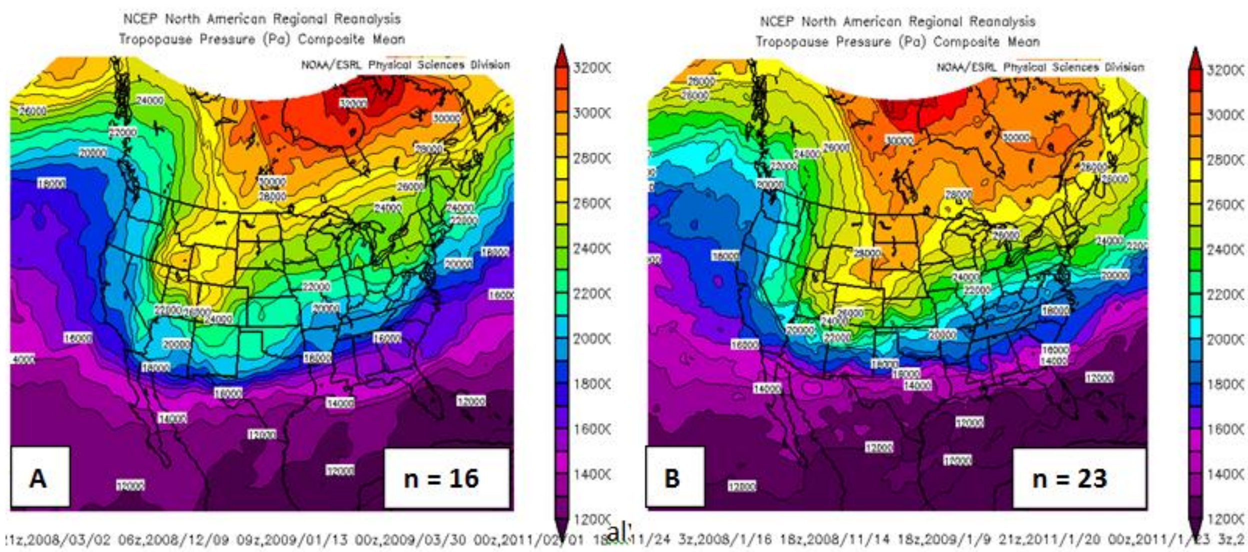

Figure 4. NCEP North American Regional Reanalysis tropopause pressure (pa) composite for HWW (panel A) and WA (panel B) Washington County gap wind events at event start time, 1997-2016 (NOAA/ESRL Physical Science Division, 2018).

In HWW events, the upper level cold pool at 500 hPa is positioned upstream of Washington County with the trough axis centered along the Nevada and Utah border during the event initiation phase (Figure 5). In contrast, WA events show a slightly different synoptic picture. WA events feature a similar 500 hPa cold air pool, but the position of the trough axis is shifted downstream near the Utah and Colorado border. This suggests the majority of WA events begin as the backside of the shortwave trough slides across Washington County in southern Utah. As the backside of the trough slides through, the 700 hPa wind turns out of the N-NE and the winds become orientated parallel to the N-NE orientated canyons in Washington County. In addition, as the backside of the trough moves through, 700 hPa wind speed also increases, providing an increase in the cross-barrier flow. Furthermore, as the backside of the trough moves through, warm air advection begins at 700 hPa. Thus, in many WA events, the magnitude of the 700 hPa temperature change plays little role in helping initiate gap wind events.

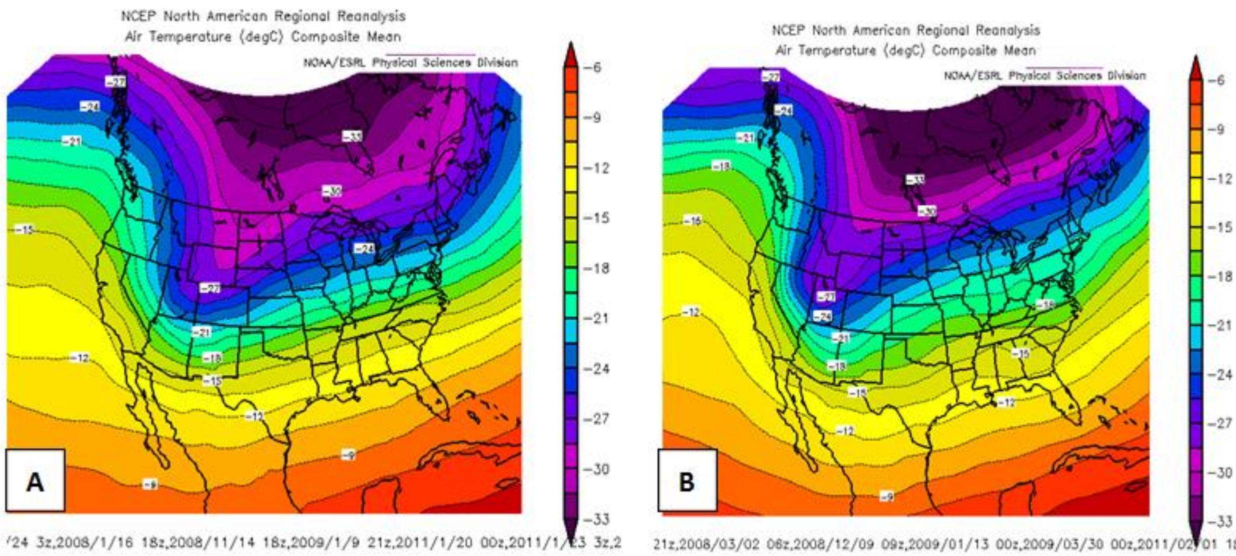

Figure 5. NCEP North American Regional Reanalysis 500 hPa temperatures (degC) composite for HWW (panel A) and WA (panel B) Washington County gap events at event start time, 1997-2016.

3.c Frontal vs. Shortwave trough events

Washington County WA and HWW events are associated with two distinct regimes: frontal passages and the backside of shortwave troughs. By analyzing surface observations and the synoptic conditions in WAVE and SPC mesoscale archived RAP analyses, each WA and HWW case were grouped into each of these two categories. The majority of HWW events are associated with frontal passages (n =10), while the majority of WA events are associated with the backside of the shortwave trough moving across Washington County (n =13). The 700 hPa cold air advection and MSLP gradient are the dominant factors during HWW cold frontal passages. For all events, the average 700 hPa 12-hour temperature change is 5.5 (degC), but for HWW cold frontal passages the average 700 hPa 12-hour temperature change is 8.0 (degC). Meanwhile the average MSLP gradient for all events is 7 hPa, and for HWW cold frontal passages is 7.6 hPa. On the other hand, WA events associated with the backside of the shortwave trough are dependent on flow speed and orientation. The MSLP gradient during these events is weaker (6.5 hPa) than average (7.0 hPa), and the 700 hPa wind speed is greater (35 knots) than average (32 knots).

In analyzing the cold frontal and backside of shortwave trough regimes synoptic set-up, they relate closely to the associated HWW and WA synoptic set-up, respectively. During backside shortwave trough events, the trough axis is located along the Utah and Colorado border, while in the cold frontal regime, the upper level cold air pool is located near the Utah and Nevada border as in the HWW case, but is shifted slightly to the east (Figure 6).

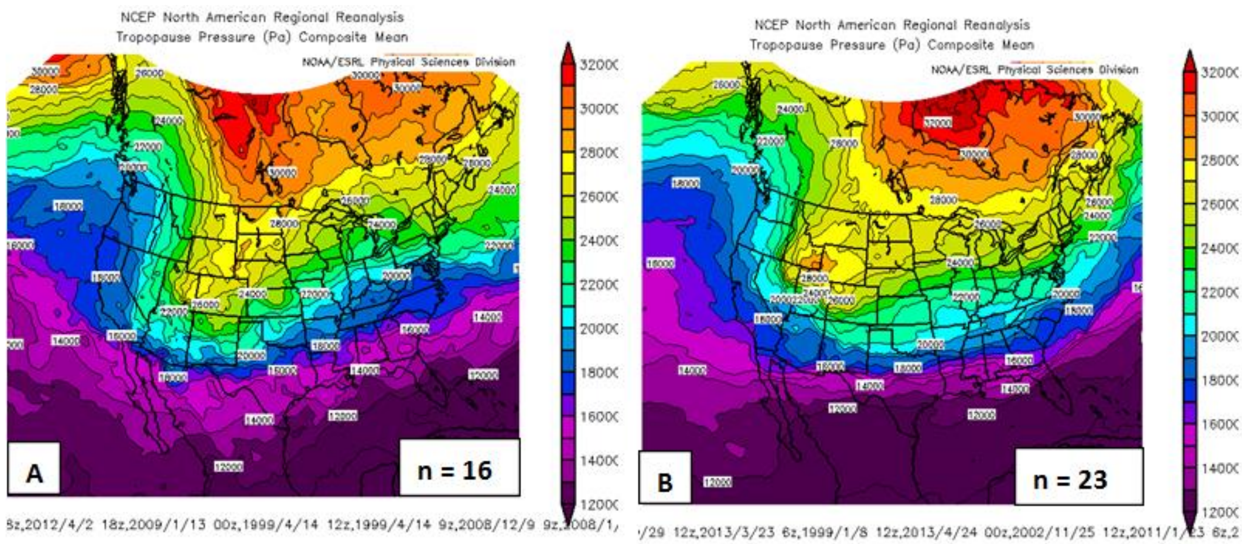

Figure 6. NCEP North American Regional Reanalysis tropopause pressure (Pa) composite for frontal (panel A) and shortwave (panel B) Washington County gap events at event start time, 1997-2016.

3.d Surface Gradient, 700 hPa temperature change in twelve hours, and 700 hPa wind speed classifications

For each variable classification, percentiles are used to determine weak, moderate, and strong categories. Weak events are characterized by lower 25th percentile events, moderate events range the 25th to 75 percentile, and strong events are contained in the upper quartile.

- Surface Pressure Gradient between Cedar City (CDC) and Las Vegas (LAS) or between Cedar City and Grand Canyon (GCN) (use whichever is greater).
  - Weak......... 0-6 hPa
  - Moderate... 6-8 hPa
  - Strong..........> 8 hPa
- Magnitude of 700 hPa temperature change
  - Weak..........< 3 C/12hr
  - Moderate.... 3-8.5 C/12hr
  - Strong..........>8.5 C/12hr
- Strength of 700 hPa winds.
  - Weak........< 27 kts
  - Moderate.... 27-36 kts
  - Strong......> 36 kts

3. e Updated Washington County Gap Winds Decision Tree

		Surface Pressure Gradient (mb) CDC-LAS or CDC-GCN				
700mb Temp. Change per 12 hours	700mb Wind(kts)	Weak		Moderate		Strong
		0-3	3-6	6-7	7-8	>8
0 3	< 27		none	none	none	none
	27-36		WA[1]	WA/HWW[1,1]	WA	WA/HW W[1]
	> 36		WA	WA	WA[1,1]	WA[1,1]/HWW
3 5	< 27		WA	WA	WA[1]	WA/HWW
	27-36		WA[1]	WA	WA/HWW[1]	WA/HWW
	> 36		WA	WA	WA/HWW	HWW
5 7	< 27		WA	WA	WA	WA[1]
	27-36		WA[1]	WA	HWW[1]	WA[1]/HWW
	> 36		WA/HWW[1]	WA	HWW	HWW
7 8.5	< 27		WA	WA	WA[1]	WA/HWW
	27-36		WA[2]	WA[1]	HWW[1]	HWW[1,1]
	> 36		WA/HWW	HWW[1]	HWW	HWW
8.5 10	< 27		WA	WA	WA	WA[1]/HW W
	27-36		WA	HWW[1]	HWW	HWW
	> 36		WA/HWW	HWW	HWW	HWW[1]
> 10	< 27		WA	WA	WA	HWW
	27-36		WA	WA[1]/HWW	HWW[1,1,1]	HWW[1]
	> 36		WA/HWW	HWW	HWW	WA[1]/HW W

NOTE: WA and HWW within the table are product issuance recommendations. Superscripts [1],[1],[1] represent observed events (n = 33).

LEGEND

Weak WA[1]: 5-6 hours
Moderate WA[1]: 7-8 hours
Strong WA[1]: more than 8 hours

Weak HWW[1]: 1 hour
Moderate HWW[1]: 2 hours
Strong HWW[1]: 3 or more hours

Additional Details: Duration is defined as the maximum number of continuous hours of wind advisory or high wind warning criteria winds during an event. The bottom 25th percentile WA events (0-4 hours; n = 6) were left out of the decision tree table.

*** This chart is just a picture of the actual PDF copy.**

4. Conclusion

A quantitative decision tree has been presented by analyzing the mean sea level pressure gradient, the 700 hPa temperature change per 12-hour period, and the 700 hPa wind speed for 39 WA and HWW case studies during the cool seasons of 1997-2016. In addition, a synoptic climatology was presented for WA and HWW events. It was shown that HWW events are associated with a Rossby Wave breaking pattern. Furthermore, advisory and warning events occur under two distinct synoptic regimes: frontal passages and backside shortwave trough environments. Warning events are typically associated with strong cold frontal passages, while advisory events are associated with the backside of a vigorous shortwave trough moving across southwestern Utah, with the trough axis positioned across the Utah and Colorado border. The synoptic climatology presented will help NWS Salt Lake City forecasters continue to develop pattern recognition skills of potential Washington County gap wind events, while the decision tree will help forecasters determine if a WA or HWW issuance is necessary.

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