WESTERN REGION TECHNICAL ATTACHMENT
NO. 98-11
MARCH 24, 1998

WASHINGTON COUNTY HIGH WINDS

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[Editor's Note: The case studies and Fig. 1 of the Technical Attachment can be accessed at the following URLs:]
http://nimbo.wrh.noaa.gov/Saltlake/projects/gap_winds/gap_public/Gap_Winds.htm and
http://nimbo.wrh.noaa.gov/wrhq/98TAs/9811/

Abstract

An approach to forecasting potentially strong winds reaching either wind advisory or high wind warning levels in southwest Utah (Washington County) has been developed using surface pressure gradient and 700 mb thermal advection. Strong north-south surface pressure gradients are known to produce strong winds in central Washington County due to topographic channeling of the flow (a.k.a. gap winds) through the narrow nearly north-south oriented canyons. Examining nearly two dozen cases from two years of data revealed another meteorological process that directly influences the strength of these gap winds; magnitude of 700 mb cold advection.

From a quantitative approach of evaluating the strength of thermal advection and surface pressure gradient, a decision-tree table was developed. This table enables forecasters to easily determine wind speed potential based on ETA forecast's strengths of surface pressure gradient and 700 mb thermal advection. Two wind advisories, two high wind warnings, and one non-event cases are presented to illustrate the strengths and limitations of this procedure as it might be applied operationally. By recognizing which parameter is most important during an event, forecasters are able to predict its duration.

Limitations of this procedure are directly related to the accuracy of the ETA model forecasts. However, as revealed in this Technical Attachment (TA), identifying ETA model biases can reduce these limitations.

Introduction

Based on a little over two years of observations from January 1995-97, there were over two dozen events of strong local northerly winds in and at the mouths of several north-northeast oriented drainages of east central Washington County. These wind episodes were typically associated with; 1) passage of a surface cold front or a developing tight surface pressure gradient 2) mechanical mixing of strong winds aloft down to the surface, 3) a combination, or 4) microbursts from thunderstorm activity originating over the higher terrain north of central Washington County. Although some of the strongest but also shortest lived events were associated with the thunderstorms (conversation with spotters, in particular Grant Twitchell, former NWS employee), this TA focuses on the so-called long-fuse wind events associated with cold fronts and the downward transport of momentum during the cool season (Oct-Apr). Enhancement of the surface winds was found to occur in and at the canyon mouths due to the channeling effects of the terrain, typically referred to as gap winds. In general, these events are not dissimilar to canyon wind or gap flow episodes along the Wasatch Front where key ingredients are a strong surface pressure gradient, winds aloft nearly parallel to canyon orientation, and tight thermal gradient straddling the mountain barrier.

The purpose of this TA is to provide guidance (based on 13 case studies from Jan 96-Mar 97) to NWSFO SLC forecasters on what parameters are necessary for the occurrence of these events and how to determine the magnitude and duration.

Data

Data were collected from 13 case studies from January 96 through March 97. Various parameters collected for each case include analyses and forecasts from the AVN/NGM/ETA of surface pressure, lowest level winds, 850 and 700 mb winds and temperatures, three-hour hand-drawn analyses, hourly surface observations from AWOS, METAR, and RAWS sites across portions of both southern Nevada and Utah, and spotter reports. Due to a lack of full documentation of each parameter for each case and to keep evaluations of each case simplified, guidance developed from these events are based on surface and 700 mb fields. Of particular importance are the surface pressure (gradient and orientation), 700 mb temperature advection, and 700 mb wind (strength and direction) over southwest Utah. Radiosonde data are used for a quick reference and rough evaluation of the conditions encompassing an event, but due to sparse radiosonde network in this region leading to wide interpretation of isotherm analyses by NWSFO SLC forecasters, 700 mb model analyses with gridded data winds are used exclusively for case-to-case comparisons and evaluations. As for surface pressure, model forecasts are used prior to the commencement of an event, but model analyses are used in conjunction with three-hourly hand-drawn analyses whenever possible during an event. Model analyses inherently smooth isobars, so that subtle areas of tight gradients are not analyzed properly. In the Case Study portion of this TA, mention is made as to when hand-drawn analyses were used in place of model analyses, due to this smoothing. Hourly, pressure differences between both Cedar City (CDC) and Las Vegas (LAS) and CDC and Grand Canyon (GCN) (whichever is greater) are also used to qualify the strength of the surface pressure gradient. However, caution is needed in using strict pressure differences between stations to quantify the surface pressure gradient because frequently this gradient is not homogeneous, but contains varying strengths. If the strongest surface pressure gradient is south of the area of interests, then much weaker winds can be expected.

Locations of data sources used in verifying an event will be discussed under the Topography section.

Topography of Southwest Utah

The main canyons of interest in Washington County are the three north northeast oriented canyons nearly parallel to each other in the east central part of the county. These canyons slope from north to south dropping nearly 2,000 feet in elevation. The I-15 corridor lies in the western and most well-defined canyon between the Hurricane Cliffs to the east and Pine Valley Mountains to the west. Within this canyon, observations are sometimes received from a spotter located at Anderson Junction (which is the intersection between I-15 and SR-17, where the word White is written, Fig. 1). However, the most consistent observations and best representation wind strength are received from the White Reef automated sensor. This sensor is located next to I-15 about 15 miles northeast of St. George and 6 miles south southwest of the canyon mouth (Fig. 1) at an elevation of 3500 feet. Due to its prime location and hourly observations, most of the case study verifications are based on White Reef reports.

Two lesser sized canyons farther to the east; La Verkin Creek and North Creek canyons have the towns of La Verkin and Virgin, respectively, located near their mouths. Spotter reports are frequently obtained from these towns.

Another RAWS site is located at Badger Spring at an elevation of 3990 feet on the western slopes of the more north-south oriented Beaver Dam mountains. Due to its open exposure away from any enhanced channeling effects of terrain, the observed winds are likely the direct result of the pressure gradient and downward transfer of momentum, more representative of the area in general. However, when 700 mb winds are oriented more from the northeast and east, winds tend to increase at Badger Spring, possibly signifying mountain wave effects from the Beaver Dam mountains. During these episodes winds at Badger Spring are typically 10-25 mph stronger than at White Reef. Therefore, events used in this case study are based on observations from White Reef and from spotters in and around the mouths of the canyons where true channeling effects of the winds occur. Introduction

Figure 1. Washington County Terrain Enhanced Image
See http://nimbo.wrh.noaa.gov/Saltlake/projects/gap_winds/gap_public/Gap_Winds.html or http://nimbo.wrh.noaa.gov/wrhq/98TAs/9811/ for figure.

Definition

Gap Winds - Gap winds occur when a mountain barrier effectively separates two airmasses of different densities. This results in a strong pressure gradient across the mountain barrier causing air to flow through the gaps in the terrain (in this case the north-northeast to south-southwest oriented canyons) from high to low pressure, and since the terrain channels the winds, they are accelerated along the pressure gradient instead of becoming geostrophic. (Dunn, 1996) Introduction

Criteria -

Wind Advisories and High Wind Warnings

Type Sustained Winds Gusts Wind Advisory >= 31 mph/ 27 kts
for 3 hrs
>= 45 mph/ 39 kts
for 3 hrs
Wind Warning>= 40 mph/ 35 kts
for 1 hr
>= 58 mph/ 50 kts
any time

Surface Gradient and 700 mb Cold Advection Strength Classifications

Surface Pressure Gradient between Cedar City (CDC) and Las Vegas (LAS) or between Cedar City and Grand Canyon (GCN) (use whichever is greater). Note: Exact position of the strongest surface pressure gradient between these stations is critical for final evaluation.

- Weak......... 0-3 mb
- Moderate..... 4-7 mb
- Strong....... >= 8 mb

Magnitude of 700 mb Cold Advection (AWIPS instantaneous values).

- Weak........<= 0 to -15 C/12hr
- Moderate....-16 to -32 C/12hr
- Strong......>= -33 C/12hr

Strength of 700 mb Winds.

- Weak........<= 25 kts
- Moderate.... 25-40 kts
- Strong......>= 40 kts

Five Case Studies from January 1996 - January 1997
<u>Individual case studies with time series graphics</u>

See http://nimbo.wrh.noaa.gov/Saltlake/projects/gap_winds/gap_public/Gap_Winds.html or http://nimbo.wrh.noaa.gov/wrhq/98TAs/9811/ for the five case studies.

Quick Reference Guide

Evaluation Decision Tree

Note #1: Temperature Advection is from AWIPS in degrees C/12hr

Note #2: Number of verified occurrences is in the parenthesis following none, Wind Advisory (WA), or High Wind Warning (HWW). Where data has not been observed, the table has been either left blank (for undeterminable) or filled in with the most likely category (categories without parentheses.)

Note #3: Actual surface pressure gradients can vary greatly spatially between these stations, therefore a hand-drawn analysis is recommended to identify areas of strong or weak gradients.

		Surface Pressure Gradient (mb) CDC-LAS or CDC-GCN				
Temp Advection Degrees(C)	**700mb Wind(kts)**	**Weak**		**Moderate**		**Strong**
		0-1	**2-3**	**4-5**	**6-7**	**>= 8**
0-6	**<25**	**none**	**none**	**none(3)/ WA(1)**	**WA(1)**	**WA(1)/HWW(1)**
	25-40	**none**	**none**	**none(1)**	**WA(1)**	**HWW(1)**
	>40	**none**	**none(1)**	**none(1)/ WA(1)**	**WA(1)**	**HWW(1)**
7-15	**<25**	**none**	**none(1)**	**none(2)/ WA(2)**	**WA(2)**	**HWW(1)**
	25-40	**none**	**none(2)**	**none(2)/ WA(1)**	**none(1)/ HWW(2)**	**HWW**
	>40	**none**		**WA(1)**	**HWW(1)**	**HWW**

16-24	<25	none		none(1)	WA(1)/H WW(1)	HWW
	25-40		none(1)	none(1)/ WA(2)	HWW(1)	HWW
	>40			WA(1)/H WW(1)	HWW(1)	HWW
25-32	<25			none(1)/ WA(1)	WA(1)/H WW(1)	HWW
	25-40		none(1)/ WA(1)	none(1)/ WA(1)	HWW(1)	HWW
	>40		WA(1)	WA(1)/H WW(1)	HWW	HWW
33-41	<25			none(1)/ WA(1)	WA(1)/H WW(1)	HWW
	25-40			WA(1)	WA(1)/H WW(1)	HWW
	>40		WA(1)	WA(1)/H WW(1)	HWW	HWW
>= 42	<25			WA(1)/H WW(1)	WA(1)/H WW(1)	HWW
	25-40			WA(1)/H WW(1)	HWW	HWW
	>40			WA(2)/H WW(1)	HWW	HWW

Summary and Conclusion

A. Open Troughs verses Barotropic Systems

Both WA and HWW have been observed to occur with open troughs and systems with barotropic tendencies; i.e. typically mature closed lows located over Arizona. In nearly barotropic systems, the presiding forces are surface pressure gradient and 700 mb winds, since the thermal advection is nearly zero. In open trough patterns and during developmental stages of closed lows over Arizona, the strength of the surface winds can be dictated by either the surface pressure gradient or the combination of surface pressure gradient, 700 mb cold advection, and 700 mb winds.

B. Duration

With a nearly barotropic system, the duration and strength of a WA or HWW event may be forecast by determining the strength of the surface pressure gradient and timing its decrease in intensity. However, if the 700 mb winds are >40kts, which they frequently are, then downward transport of momentum through either afternoon surface heating or precipitation can bring strong winds (WA or HWW) down to the surface. In these cases, the duration of WA or HWW events is related to afternoon surface heating and/or timing of precipitation while the strength is related to the magnitude of the 700 mb winds.

In open trough systems, a strong pressure gradient alone with little if any thermal advection may produce HWW, but will usually last only 2-6 hours. However, combine the following "strong" attributes;

1) surface pressure gradient....>= 8 mb CDC-LAS/CDC-GCN
2) 700mb wind speed................> 40 kts
3) 700mb thermal advection.....>= 33 C/12hr

and the lifespan of the wind episode is extended. These wind events will usually continue for 6-10 hours but can extend beyond 24 hours. Typically, for winds to continue at HWW levels, at least two-of-three attributes (i.e. 700 mb wind speed, 700 mb thermal advection, surface pressure gradient) must remain strong and the other attribute remain at least moderate. For example, once the surface pressure gradient decreases below about 3 mb, despite strong 700 mb attributes, surface winds will typically decrease below WA levels.

C. Instability and Mixing

The downward transport of momentum to the surface was found to occur under three conditions; 1) through mechanical mixing induced by a moderate to strong surface pressure gradient, 2) through thermal mixing induced by surface heating, and 3) thermal mixing induced by cold thermal advection. When a moderate or stronger surface pressure gradient was coupled with moderate to strong 700 mb thermal advection, the result was stronger surface winds than otherwise would be expected. During the day, cold thermal advection and/or surface heating will create a turbulent environment enabling strong 700 mb winds to mix down to the surface. At night, with at least a moderate surface pressure gradient in place, cold thermal advection will continue to keep surface winds strong. Add to this, channeling effects of the terrain, and the result is much stronger surface winds; both day and night. The bottom-line then, is thermal advection is a significant contributor, but only when its energy can be released. If an inversion is present (a stable environment), mixing down of strong winds aloft can be precluded. The ETA_SND sounding for CDC is can be useful for determining the degree of stability.

D. Magnitude

Typically, the 700 mb wind speed and direction are very similar between WA and HWW, but the magnitude of the cold advection is greater for the HWW events. Although a HWW event was observed with a thermal advection of 16 C/12hr and 700 mb winds >40 kts, in most cases the thermal advection will have a minimum value of 33 C/12hr with winds at 700 mb >40 kts.

If any of the attributes decrease below this criteria then either WA level winds or lesser occur.

E. Orientation

While the orientation of the surface pressure gradient could vary greatly between roughly 290-070 degrees (essentially any northerly component) the winds aloft at 700 mb had the greatest influence when they nearly paralleled the canyon orientation between 360 and 060 degrees. When the flow aloft was oriented more northwest (320-350 degrees), causing winds to flow over much higher terrain of the Pine Valley mountains before descending into central Washington County, strong winds were not observed at White Reef. Also, in the same manner, when the 700 mb winds became oriented more easterly (>=70 degrees), winds at White Reef tended to subside. This suggests, at least in the area of concern, that mountain wave effects are minimal if any. However, at Badger Spring winds tended to increase under a more easterly 700 mb flow, possibly a result of mountain wave effects of the Beaver Dam mountains which run nearly north-south just east of Badger Spring. Individual Cases | Summary |