A WES SIMULATION OF THE EXTREME SANTA ANA WIND EVENT OF 6 - 7 JANUARY 2003

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INTRODUCTION

The goal of this WES TA-LITE is to investigate an extreme Santa Ana wind event using figures from a WES simulation. On 6 - 7 January 2003 the strongest, widespread Santa Ana wind event in over 25 years occurred in southern California (Figure 1 a - b). Wind gusts reached at least 90 miles per hour in highly populated areas and at least 106 miles per hour in the mountains. Visibilities in some areas were reduced to zero in blowing dust. The key features of this event were the combination of extremely strong mountain-wave producing parameters; the surface pressure gradient, winds aloft, upper level height gradients, cold advection, and synoptic scale downward motion behind a cold front. Also there were 2 inversions near mountaintop to help drive the wave to the surface.

In contrast to this case, many events without strong upper level support are basically only "gradient wind events". (Upper support supplied by the strength of the winds aloft, upper level height gradients, cold advection, and synoptic scale downward motion are absent during these types of events). These weaker types of offshore flow events have been referred to as "canyon winds" or "canyon/pass winds" (strongest winds in and below canyons and passes, with little wind elsewhere). The winds in the 6 - 7 January 2003 case were accentuated by the extremely strong parameters, with the extremely strong surface pressure gradients playing a key role in making the event widespread. As an example, 25-30 knots at 850 mb or 700 mb is enough upper level support, as far as wind speed is concerned, to generate high surface winds when "brought down". In this 6 - 7 January 2003 case the winds were over 40 knots at 850 mb, and over 50 knots at 700 mb. The surface pressure gradients strengthen the winds in the favored areas as well as allow the winds to surface in areas that generally get weaker winds. The goal of this WES TA-LITE is to highlight the winds aloft, along with some of the other significant parameters associated with this WES simulation using the MesoETA..

SOME CHARACTERISTICS ASSOCIATED WITH OFFSHORE WIND EVENTS

Surface pressure gradients have been used to forecast wind events for some time with surprising success. In general, the winds surface below Cajon Pass (between the San Gabriel and San Bernardino mountains) when the KLAX-KDAG gradient, traditionally used for this area, approaches zero. The wind usually arrives in the Ontario (KONT) area when the offshore gradient exceed about -3.5 mb. The more moderate events occur when gradients from the coast to northern plateau, for example, the KLAX-KWMC gradient, exceeds about 12 mb, the gradient to the southern plateau (KLAX-KLAS) exceeds about 7 mb, or the gradient to the local deserts (KLAX-KDAG) is at least 5 mb offshore. Those gradients are basically the long distance, middle distance, and short distance gradients. (Of course, for a moderate event usually about 15-30 knots of mean 850-700 mb flow is necessary, otherwise there is little momentum that can be translated to the surface). A frequently used gradient is the compromise between the long and mid distance gradient (KLAX-KTPH). With values of about 7 - 10 mb, weak- moderate events can develop in the favored areas with some upper level support. (About 10 -15 knots of mean 850-700 mb flow at minimum is needed to surface a weak wave). Similar gradients using KSAN as the coastal point are generally about a millibar higher than the values using KLAX.

With strong upper level support, the most widespread, damaging events occur when the long distance gradient (coast to northern plateau) becomes extremely strong (KLAX-KWMC gradient exceeding about 18 mb). From that starting point, it is good to check for an extremely strong mid distance gradient to the southern plateau (KLAX-KLAS) of about 9 mb. Usually at that point the shorter distance gradient to the local deserts (KLAX-KDAG) is at least 7 mb offshore, also considered to be extremely strong. KLAX-KTPH can be expected to exceed about 15 mb. Strong to extreme events need more than just surface gradient, however. "Upper level support" in the form of strong winds aloft and upper level height gradient, a thermal gradient, some synoptic scale subsidence, and an inversion is usually needed. Winds in areas that are generally not favored (away from the canyons/passes and mountain slopes) seem to only respond strongly to surface gradient if the upper level support is extremely strong. For instance, 25-30 knots of 850 or 700 mb winds with extremely strong gradients brings strong to extremely strong winds to the more unusual places. Gradients in the "extremely strong" category generally result in a more widespread, damaging wind event, with widespread, damaging winds almost guaranteed when coupled with 850 mb winds of 40 knots or greater. (This is especially a problem since wind gusts can approach 2 times the 850 mb wind speeds in favored locations where the mountain wave surfaces). This 6 - 7 January 2003 event was associated with nearly all parameters in the "extremely strong" category, including a -20.9 mb KLAX-KWMC pressure gradient and extremely strong winds aloft (about 40 knots at 850 mb). Surface high strength peaked above 1035 mb [near 1040 mb north of Salt Lake City, Utah (KSLC)]. Figure 2 shows the 20 mb offshore surface pressure gradient to the northern plateau, a common feature of very strong to extreme events. The KSAN-KLAS surface pressure gradient of over -9.0, KSAN-KTRM gradient topping about -3.0 mb, and KSAN-KIPL topping -2.0 mb helped to drive the strong winds into not only the southern mountains and valleys, but into the south coastal areas as the surface high moved south on day 2.

Figure 3a shows the 850 and 700 mb winds as well as the 850-700 mb thickness and the 700 mb temperatures at 0600 UTC 6 Jan 2003. The 50 knot 700 mb winds sweeping southwest from KDRA seems to have surfaced at Ontario (KONT) with gusts to 78 knots (90 mph), well above the 700 mb wind speed. (This will be further illustrated later). A double digit 700 mb temperature gradient between KVBG and KDRA usually helps generate sustained winds at the speed of the 700 mb winds at KONT during the peak of a windstorm. The temperature gradient peaked above 10 degrees C. The arc-shaped leading edge of the water vapor darkening reflects the leading edge of the cold front/cold advection/deep subsidence region. The tight gradient in temperature and thickness can be seen near the leading edge. Figure 3b shows the mean layer 850-700 mb wind and associated temperature advection. There is a -70 degree C per 12 hour maximum inside the -50 contour, which is then embedded in an arc-shaped subsidence region inside a -20 contour. Figure 4 a-b shows the 0600 UTC 6 January 2003 cross section taken at the location shown in figure 1b, indicating the classic low level maximum in vertical velocity at about 850 mb west of the Santa Ana Mountains (on the lower left hand side of figure

4a). The value of approximately 42 microbars is the maximum in figure 4 a - b, and would continue to increase. There is a sharp drop (nearly vertical near KONT) in the 298.5 degree K potential temperature contour from about 700 mb over the southern plateau to the surface in the KONT area, bringing down the 50 knot 700 mb winds as well as warming, drying adiabatic flow. The 50 knot 700 mb wind is close to the 56 knot sustained wind reported at KONT. It has been noted in this case and others that the Workstation Eta model simply surfaces the 850 mb winds in the higher mountains during strong events. This was close to what actually occurred, however, in the Santa Ana Mountains and KONT area the winds were much stronger than indicated by the model, and also well above MOS guidance. (A local wind program verified far better in the Santa Ana Mountains and KONT areas, and will be discussed in a future paper). Another interesting feature of this event is the temperature. On the second day of the event, KSNA reported a maximum sustained wind of 40 mph, peak gust of 49 mph, and a low temperature of 66 degrees. The low matches the normal high temperature for 6 January. After falling no lower than 71 degrees F the following morning, the afternoon high on 7 January rocketed to a record 84. Local morning low temperatures in the 60s to lower 70s with afternoon high temperatures in the 80s and even 90s are quite high for a location in the coastal plain in the winter, but common for strong Santa Ana wind events. At such times the flow following the adiabatic surfaces mixes down the above normal potential temperatures from aloft. Adiabatic lowering of the unusually warm 14 degree Celsius 850 mb and 21 degree Celsius 950 mb temperatures resulted in the morning lows in the 70s and the afternoon high in the mid 80s at KSNA (since the inversion has been wiped out and sea breeze delayed by the offshore flow).

In addition since the cold advection reduced the afternoon high temperatures in the inland areas and subsidence increased afternoon high temperatures closer to the ocean (Newport Beach at the coast, Ontario in the inland valleys, and Palm Springs in the lower deserts were 84, 80, and 78 respectively), a "reverse heating" pattern had developed. The normal pattern of lower temperatures at the coast and higher temperatures inland areas had been reversed, which can occur with offshore (especially strong offshore) wind patterns.

A WIND POTENTIAL INDEX (PRELIMINARY)

It is sometimes difficult to convey how strong or widespread the effects of a wind event will be. Therefore the introduction of a "wind potential index" is in order. The index would give a general determination of how strong and widespread a wind event is or will be. The formula is easy enough to be mentally computed. Simply add the maximum wind gusts or peak wind for a selected coastal, a selected inland site (in this case, a valley site), and the strongest site in the WFO San Diego forecast area, and check to see which 25 mph category the sum falls in. For example, Ontario International Airport (KONT), San Diego Lindbergh Field (KSAN) and a site in the Santa Ana Mountains reported wind gusts of 90, 38, and 106 mph respectively during the 6-7 January 2003 event. The total of 90 + 38 + 106 = 234. By simply dividing 234 by 25 (the size of each category) and rounding up, a rating of 10 is given to this windstorm [since it falls in the 10th category (225 - 249 mph)]. More on this index will be given in a later paper.

Figure 1 a-b

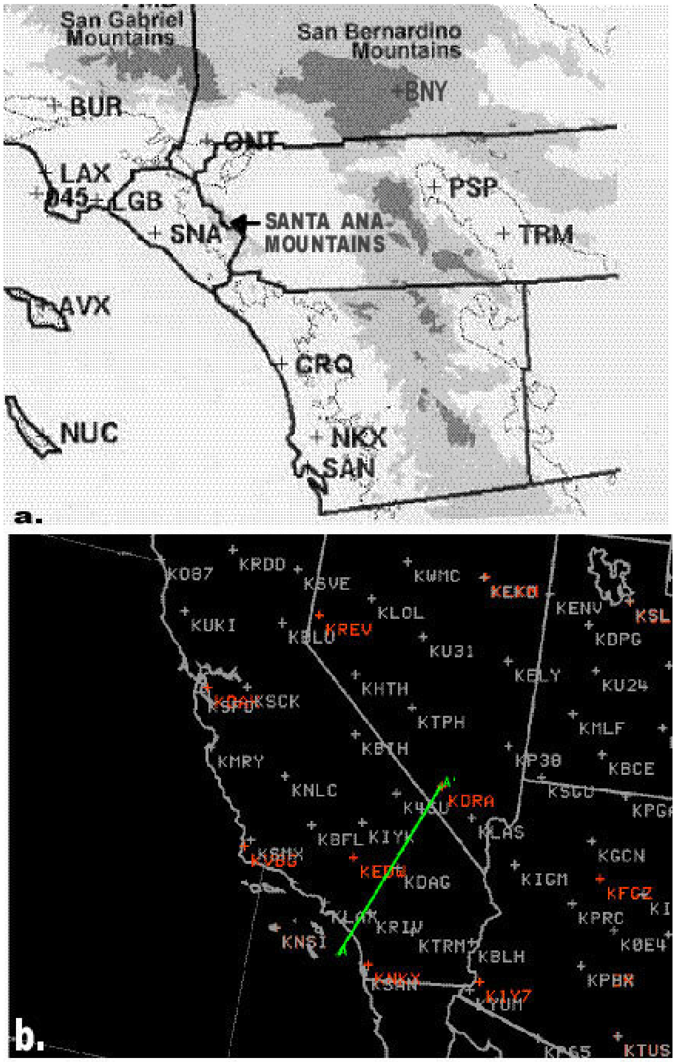

Fig. 1. Map of southern California (a) terrain and selected locations and (b) location of crossection, sounding sites (red) and selected metar sites (white).

Figure 2

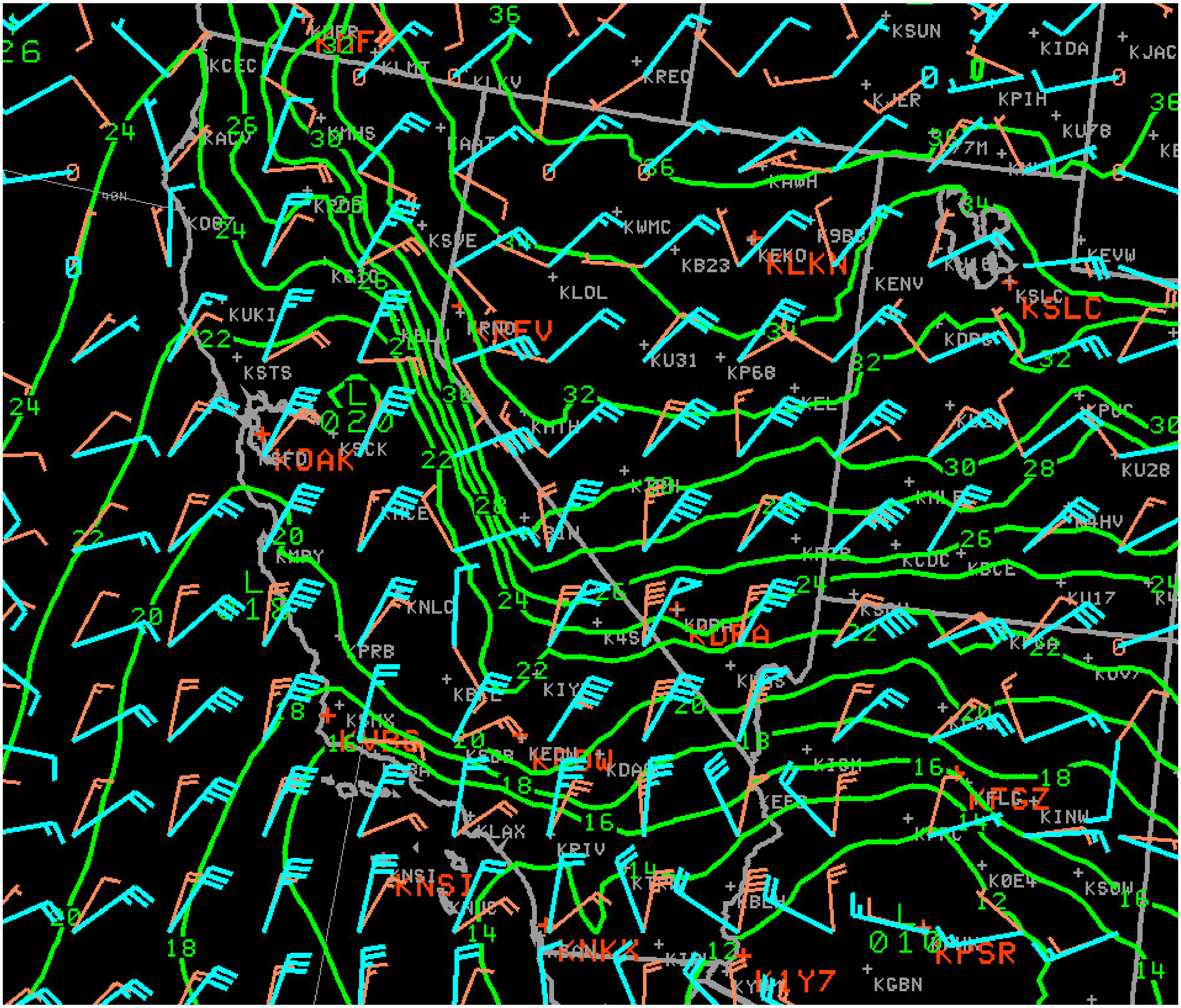

Fig. 2. Mean sea level pressure in 2 mb intervals (solid green lines) 850 mb wind in knots (orange wind barbs), and 700 mb winds (blue wind barbs) at 0600 UTC 6 January 2003.

Figure 3

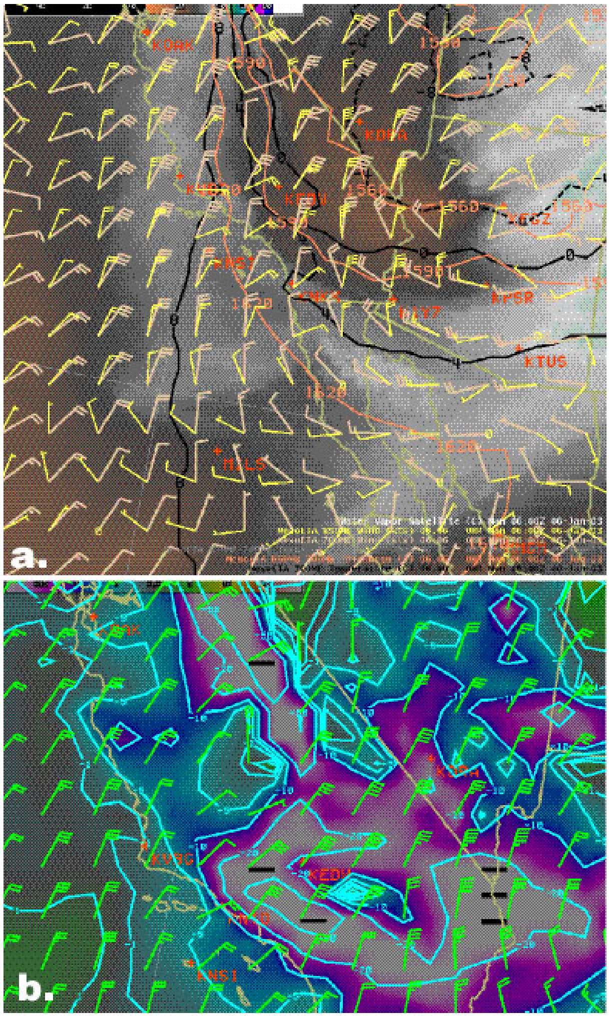

Fig. 3. Conditions at 0600 UTC 6 January 2003. (a) Water vapor imagery, 700 mb temperature in intervals of 4 degrees C, 850-700 mb thickness in decameters, 850 mb winds in knots (yellow) and 700 mb winds in knots (tan). (b) Mean 850-700 mb cold advection in degrees C per 12 hours and 850-700 mb mean flow in knots.

Figure 4 a-b

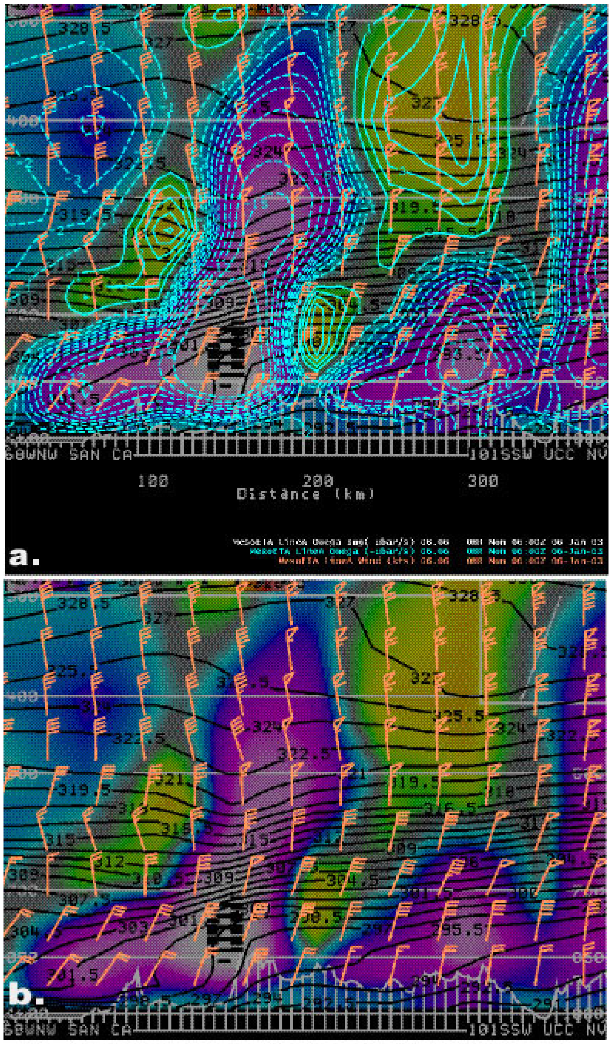

Fig. 4. Vertical crossections along AA' in Figure 1b at 0600 UTC 6 January 2003. (a) Vertical velocity in microbars per second (blue), wind in knots, and potential temperature in degrees K (black). (b) Same as in Fig 4a, without vertical velocity contours.