

## P1.B.5 THE FEBRUARY 28, 2002 RENO DUST STORM: A CASE STUDY

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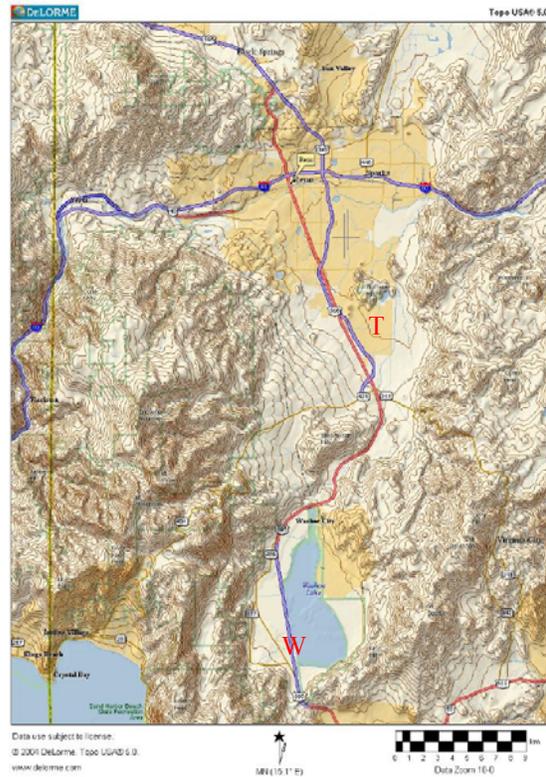
### 1. INTRODUCTION

In late February, 2002 a dramatic windstorm moved over the Sierra Nevada Mountains. The disturbance could be directly tracked to its origin several days earlier over the mountainous region of southeastern Alaska. As it passed over Reno, NV it created a short lived but intense dust storm which affected visibility, air quality, and traffic flow on Interstate 80 and Highway 395.

During the passage, two NCAR Integrated Sounding Systems (ISS) were deployed in western Nevada - one in the Reno basin just south of Huffaker Hills (Trademark Drive), and the other in the Washoe basin just west of Washoe Lake (Fig. 1). The ISS measures wind, thermodynamics and radiation near the ground, monitors profiles of wind and temperature to several kilometers with a radar wind profiler, and extends these profiles as high as 15 km using balloon-borne radiosondes. Additional data was available from particulate monitoring stations operated by the Washoe County District Health Department, and from standard NWS synoptic products.

This paper presents a synoptic overview of the development and evolution of the disturbance, examines the local effects using the two ISS, and details the relationship between the disturbance and the dust storm impacting Nevada and California.

The presence of the two NCAR ISS was serendipitous. The ISS deployment was part of a course and educational project organized by the University of Nevada, Reno and the Desert Research Institute. Students studied the ISS instruments as the instruments monitored the atmosphere. The scientific goals of the deployment included the study of inversion



*Fig. 1: Map of the Reno and Washoe basins. ISS/wind profilers were located at Trademark Drive (T) and Washoe Lake (W).*

formation and breakup, modification of synoptic systems entering the Reno basin, and other processes, including differences in the two basins. Observations of air quality were not among the anticipated goals.

### 2. MESOSCALE DEVELOPMENT

Just as ISS operations were getting underway the disturbance associated with the windstorm moved over the Sierra Nevada Mountains. The disturbance was tracked for three days from its origin over the mountainous region of southeastern Alaska. It followed a path from the northern extreme of the Rocky Mountains and then east of the Cascade Range and finally over the crest of the Sierra Nevada Range. The

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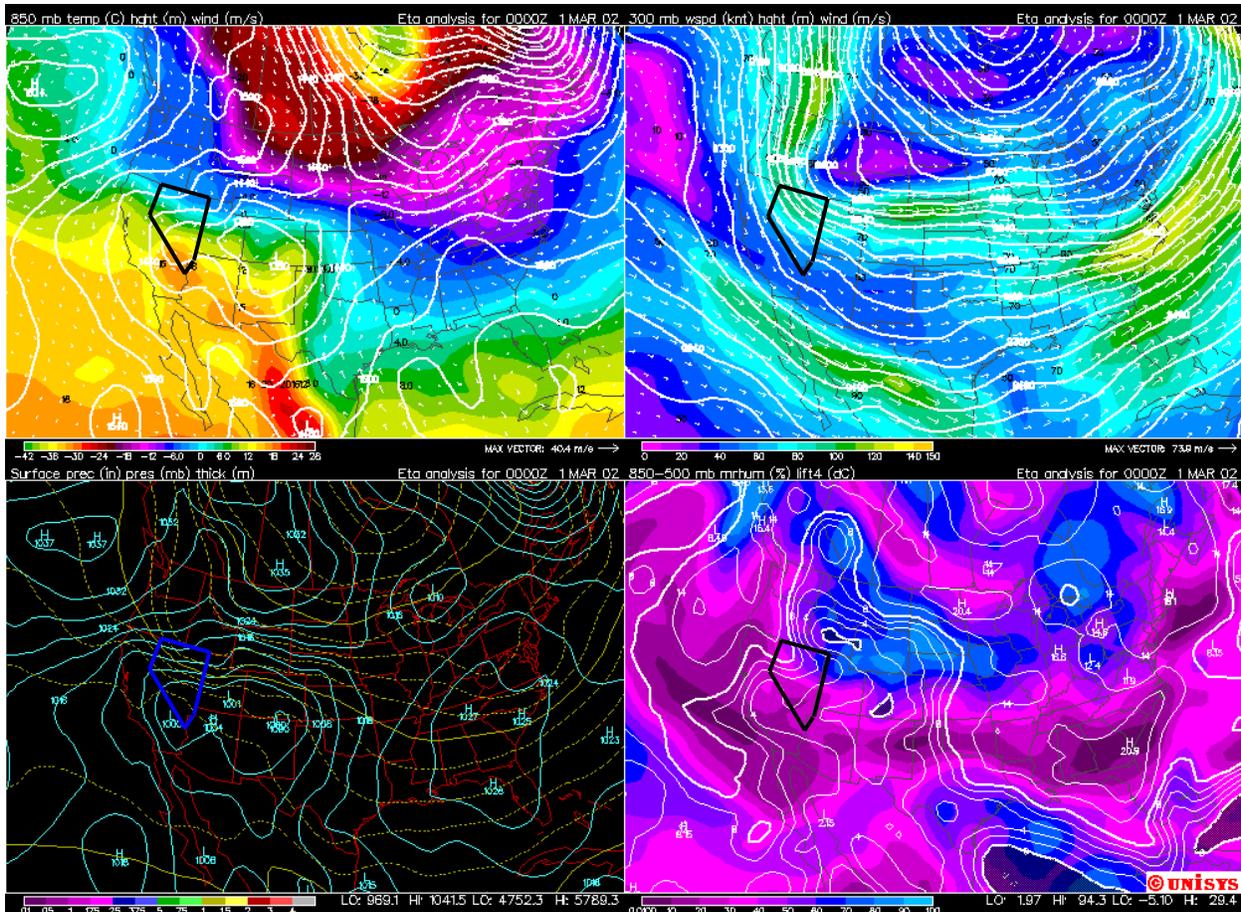


Figure 2: Synoptic summary at 00Z on March 01, 2002, during the period of high winds in Reno.

disturbance moved in an upper-level steering current that was directed along these mountain ranges and was present at the surface and throughout the troposphere. The signature at the surface reporting stations was a sharp wind shift from westerly to northerly flow (with gusts to  $20 \text{ m s}^{-1}$ ) with abrupt drops in dew point temperature. The wind disturbance appeared to be split by the crest of the Sierra Nevada, with wind maxima both west and east of the crest.

Figure 2 shows the synoptic situation at 00Z March 01 2002, during the time the disturbance was affecting Reno. The state of Nevada is outlined for reference. The disturbance is seen in the strong 850 mb temperature gradient as well as the 850-500 mb thickness. The 300 mb steering jet is also seen.

Since the disturbance moved over the North American landmass where coverage by upper air stations in Alaska, Canada, and the Northwestern US was excellent, the upper-air

analysis was able to accurately depict the structure of the disturbance. Yet, the operational numerical prediction models exhibited significant differences in the movement of the disturbance. This has led us to conduct research on the sensitivity of the low-level wind structure to the control elements in the prediction model. We are employing the MAMS (Mesoscale Adjoint Modeling System) that has been developed at NCAR over the past two decades. This model produced a forecast that was faithful to the wind event. The adjoint model has produced the sensitivity fields (derivatives of the model output with respect to the control variables in the forward model — the initial and boundary conditions). From these derivatives we can determine which meteorological variables have the most impact on the output (forecasted low-level wind in our case).

The short-lived dust storm (about 12-h duration) developed east of the crest, and moved through Reno, NV on the evening of February 28. The

wind storm in the Sacramento and San Joaquin Valleys of central California was slightly delayed relative to the storm on the eastern slopes but was unequivocally associated with the same upper tropospheric disturbance.

### 3. LOCAL WIND AND THERMODYNAMICS

ISS measurements show details of the gust front and disturbance at both the Reno (Trademark drive) and Washoe Lake sites. In the 24 hour period before this event, winds were light, less than  $2 \text{ m s}^{-1}$ , with a variable direction influenced more by the basin flows and terrain than by the larger synoptic situation. Figure 3 shows the surface measurements in Reno (blue) and Washoe (red) from 12 Z on February 28 through 12 Z on March 1. At 18 Z on February 28 the surface winds shift to northerly and begin to increase. They steadily build to more than  $10 \text{ ms}^{-1}$  over the next 9 hours and then begin to decrease after 03 Z on March 1. By 07 Z they are again light and the direction rotates through easterly to southerly. Note that these are 1-min

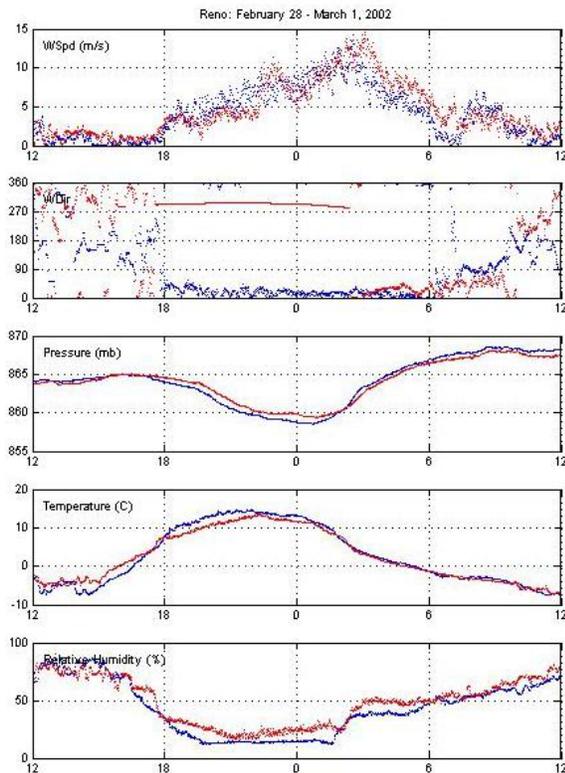


Fig 3: Meteogram showing the ISS surface measurements from 12 Z February 28 through 12 Z March 1. Reno (Trademark Drive) is blue, and Washoe is red.

sustained winds, and wind gusts were probably much stronger. The pressure trace associated with this shows a similar pattern. The pressure drops by 6 mb between 17 Z (Feb 28) and 01Z (Mar 01) as the winds build, and then quickly increases again over the next few hours. The air is also seen to warm and dry considerably during the passage and cool again following it. The warming is likely caused by turbulent mixing of warmer air aloft down to the surface. The surface observations at the two sites are similar, but features of the Washoe Lake data are delayed in time by about 45 minutes. Note that the wind direction sensor at Washoe failed from 17Z-03Z, and that a calibration correction has been applied to the pressure measured at this site.

The wind profilers capture the vertical structure of the gust front. Figure 4 shows the profiler winds at both sites from 12 Z on February 28 through 12 Z March 1. The storm is well underway during this period and winds aloft exceed  $15 \text{ m s}^{-1}$  with frequent sustained winds of  $20 \text{ m s}^{-1}$ . During the peak surface winds, the profilers show increased winds throughout the lowest 1 km. Figure 4 shows the northerly gust

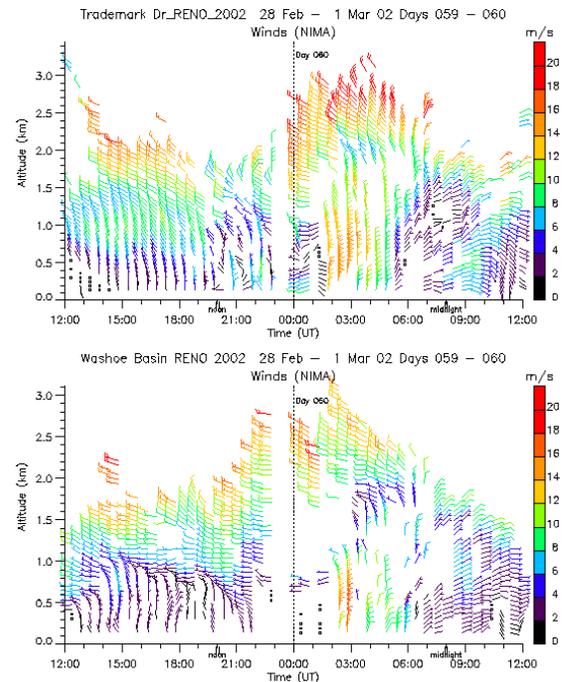


Figure 4: Wind profiler horizontal winds from 12 Z Feb 28 through 12 Z Mar 1, 2002. Wind bars are color coded by speed. The Washoe ISS (bottom) shows the strongest winds slightly later than the Reno ISS (top).

front in the Washoe basin (bottom) at 03:30 GMT is limited to below 1 km (red barbs), and a corresponding structure is seen slightly earlier in winds at the Reno site (top; orange barbs). 03 GMT corresponds to 19 LT, which we will see in the next section is near the time of the dust storm. Following the passage of the disturbance, winds become easterly with a southerly component near the surface.

Rawinsondes were launched during this event from the Reno site and show great changes in the air mass overhead. Figure 5 shows an ascent launched just before midnight UT (at 23:24 Z on Feb. 28). Surface temperatures are around 10 C, the airmass is fairly dry throughout the lower troposphere, and winds increase with height from the WNW. Five hours later another rawinsonde was launched (05:15 Z on Mar. 1) shown in figure 6. Now surface temperatures have dropped to near 0 C, relative humidity is noticeably larger up to 2 km AGL (although with the cold temperatures this represents a small specific humidity), and the lowest winds have become northerly (this sonde lost wind telemetry soon after launch). Comparing the two ascents shows that an arctic airmass brought by the disturbance has replaced the air over Reno below about 300 mb.

#### 4. DUST STORM OBSERVATIONS

The strong winds from this disturbance brought a large amount of particulate matter (PM) into the Reno area. Atmospheric PM concentration is recognized as important because of its effects on human health, possible climate feedbacks, effects on vegetation, and on visibility. Particulates may also have a microphysical effect as they are advected into clouds, creating large droplets and ice particles depending on temperature. When inhaled, PM suspended in the air can be toxic or have mutagenic effects, depending on its chemical and physical characteristics. Climate and visibility effects are related to the particulate optical properties, and suspension time in the atmosphere is also a factor. Positive and negative climatic energy balance feedbacks are suspected and remain subject to study and controversial discussions. PM concentration also has application to considerable research devoted to the study of visibility, particularly in the vicinity of National Parks.

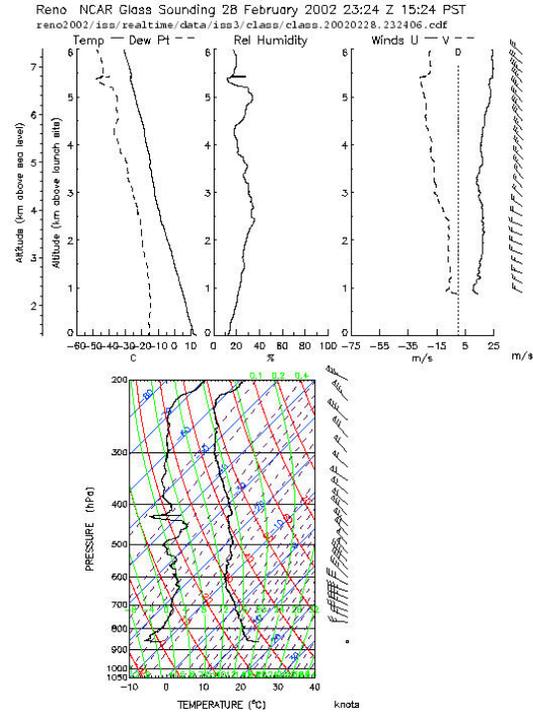


Figure 5: Rawinsonde observation at 23:24 Z on February 28, during the disturbance passage in Reno.

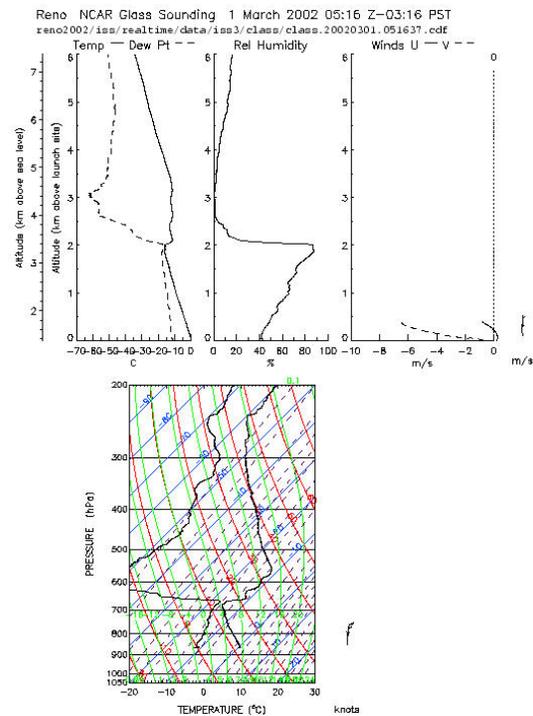


Figure 6 Rawinsonde observation at 05:15 Z on March 1, during the disturbance passage in Reno.

In the Reno basin, several stations of a pollution monitoring network collect hourly measurements of PM<sub>10</sub> concentration (in  $\mu\text{g}/\text{m}^3$ ). PM<sub>10</sub> is the concentration of PM with diameter less than 10  $\mu\text{m}$ . The hourly PM<sub>10</sub> data during the February 28 event is being studied in the context of ISS surface measurements, and wind and temperature profiles, to document the time evolution of the dust event in Reno. Special attention is devoted to the time decay of the PM concentration after the maximum, which can be related to mixing processes and particulate sedimentation. Figure 7 shows the hourly PM<sub>10</sub> concentration, which reached a maximum value of 474  $\mu\text{g}/\text{m}^3$  between 03-04 Z (19 and 20 LT). This value may be compared with the National Ambient Air Quality Standard maximum of 150  $\mu\text{g}/\text{m}^3$  for a 24-hour average. The ISS wind and temperature profiles shown in the previous section show the gust front at both the Reno and Washoe sites to be well correlated in time with this maximum PM<sub>10</sub> measurement.

The gust front was associated with high PM<sub>10</sub> because, prior to reaching Reno, the high winds passed over dry lake beds north of Reno. In this case it was probably the Honey Lake area. There the gust front picked up considerable particulates which were transported through the Reno and Washoe basins. This event was dramatic for the general public. The reduced visibility and high winds make driving difficult on the local highways. The blowing dust was responsible for a 6-car accident on Hwy 395 south of Reno. The Reno Gazette-Journal

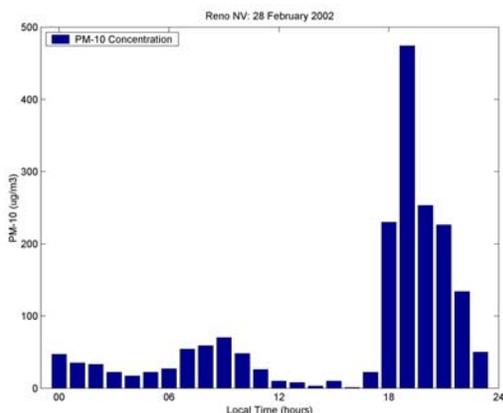


Figure 7: PM-10 concentration ( $\mu\text{g}/\text{m}^3$ ) on February 28, 2002. The extremely large values from 18-21 Z are dust carried through Reno by the strong gust front.



Figure 8: Video image showing reduced visibility at 01:25 Z (17:25 LT). This image is looking to these into the Reno basin and was taken from the Desert Research Institute on Raggio Parkway.

quotes the Highway Patrol trooper at the accident scene regarding visibility: “It was really strange. I was sitting in my patrol car after the accident and you couldn’t see 10 feet in front of you”. The dust storm was captured on a time lapse video recorded from the Desert Research Institute building looking to the southeast into the Reno basin. Figure 8 shows an image from this camera at 01:25 Z (17:25 LT) showing reduced visibility due to the storm.

## 6. CONCLUDING REMARKS

The near-term forecast of this dust storm was quite good. The local newspaper informed the public of a possible dust storm the morning before the evening event. This forecast was based on local knowledge of the upwind dry lake beds and on the NWS numerical guidance. However, the details of the guidance could be improved. While not common, similar dust storms occur intermittently in Reno. A more severe example took place later the same year on April 14. In that case wind gusts of 25-30  $\text{m s}^{-1}$  accompanied the dust, blowing down a scaffolding tower and a large tree. The presence of the two NCAR ISS and the DRI time-lapse video allowed the February 28 event to be documented in detail. The dust, combined with blowing wind, impacted both driving conditions and air quality for the local population, emphasizing the importance of forecasting and documents these events

## **ACKNOWLEDGEMENTS**

The resources and support of the NCAR Atmospheric Technology Division and NSF made this project possible. Students participating in dust storm analysis were Claudio Mazzoleni and Lynn R. Rinehart. Data collection and analysis benefited from contributions by Andy Goodrich and Linda O'Brien of the Washoe County District Health Department, John Bowen, John Gilles, and Greg McCurdy of DRI, Steve Cox of the NWS/Reno, and Lou Verstraete of NCAR/ATD. The map of Figure 1 is courtesy of DeLorme, from Topo USA software. NCAR is operated by UCAR under sponsorship of the NSF.