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Continuous Thermodynamic Profiling for Air Quality Applications

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Stability within the atmospheric boundary layer is a fundamental parameter to understanding air quality dispersion. Stable and inversion conditions trap pollutants and limit the upward dispersion. Rapid changes in these capping layers commonly occur, making continuous boundary layer temperature measurements essential for effective local air quality monitoring and prediction. Cloud, liquid content and boundary layer moisture are also key to air quality monitoring, modeling and prediction. We present continuous thermodynamic (temperature, humidity and liquid) profiles measured by commercial microwave radiometers at Las Vegas and in the Denver Basin.

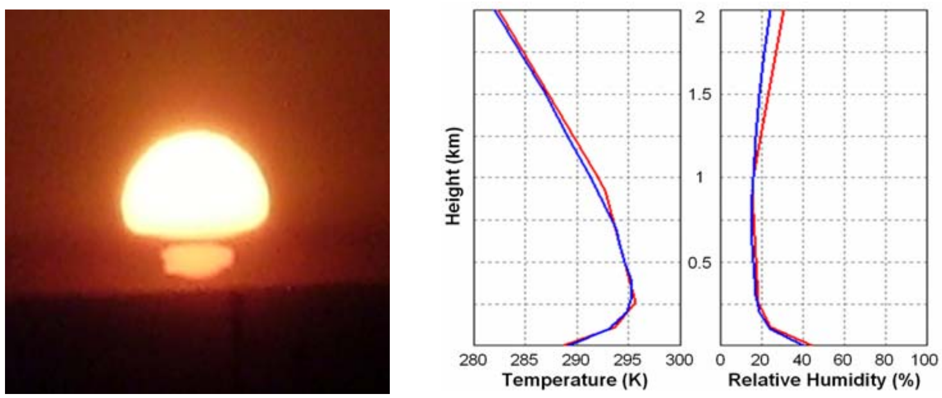

Figure 1. Sunrise (left) with radiometer (blue) and radiosonde (red) temperature and humidity profiles (right), at 6 am local time 11 June 2007, Denver, Colorado.

A strong capping inversion is seen at sunrise in a digital image and in radiometer and radiosonde soundings in Figure 1. The solar image is distorted refractivity gradients inherent in temperature inversions. The inversion "caps" the lowest 250 meter layer, trapping airborne pollutants and contributing to degraded air quality.

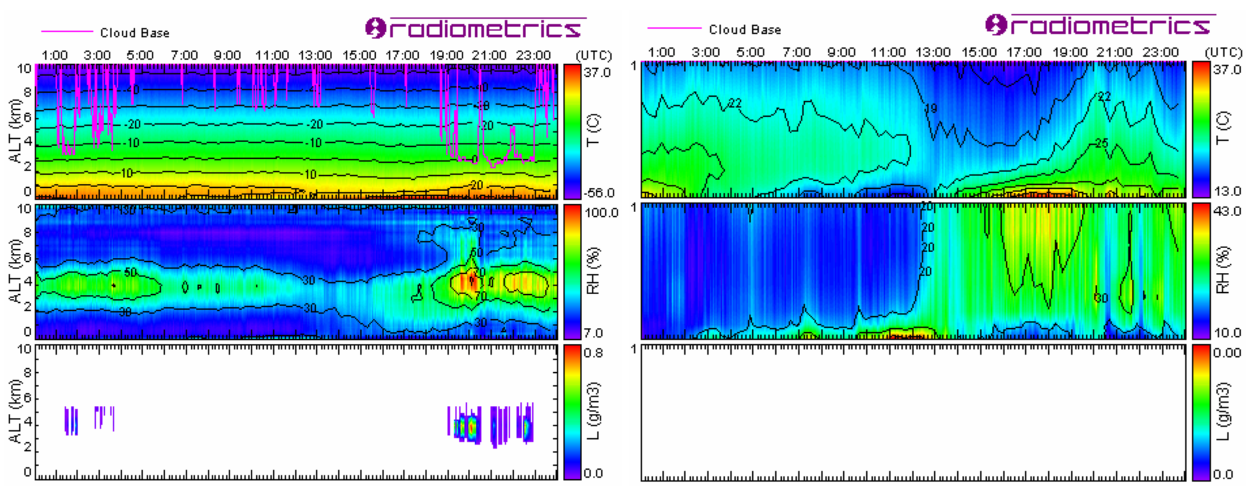

Figure 2. Radiometric temperature, humidity and cloud liquid profiles to 10 km (left) and 1 km (right) height 11Jun07 (UT) at Denver. Cloud base height is indicated by the magenta line.

Atmospheric temperature, relative humidity and liquid density evolution on 11 June 2007 (UT) is shown in Figure 2. Variable cloud (magenta line, upper left) reaching 0.8 g/m^3 maximum and corresponding saturation in relative humidity is seen around 2 pm local time (20:00 UT). Development of a strong nocturnal radiative inversion below 300 meters is evident in the boundary layer temperature plot (upper right) from 9 pm to 7 am local time (3:00 to 13:00 UT).

The inversion rapidly dissipates after sunrise with surface temperature rising from 13 to 37 C by mid-afternoon. Short term surface temperature variability seen near 2 am and 2 pm local time (8:00 and 20:00 UT) in the boundary layer temperature plot (upper right) is correlated with presence of ice and liquid clouds, respectively (ice cloud is deduced when cloud base with no liquid content is detected). This example demonstrates the potential for surface temperature inversion and associated air quality prediction improvements based on radiometric cloud measurements.

Figure 3. Wind radar, radiometer and sodar (left to right) operated by the Clark County Department of Air Quality and Environmental Management.

Wind, temperature and moisture profiling equipment operated by the Clark County Department of Air Quality and Environmental Management (DAQEM) at the North Las Vegas Airport (http://tbsys.serveftp.net/nlv) is shown in Figure 3. The merging of these instruments forms a "virtual radiosonde" with wind, temperature and moisture profiles generated hourly.

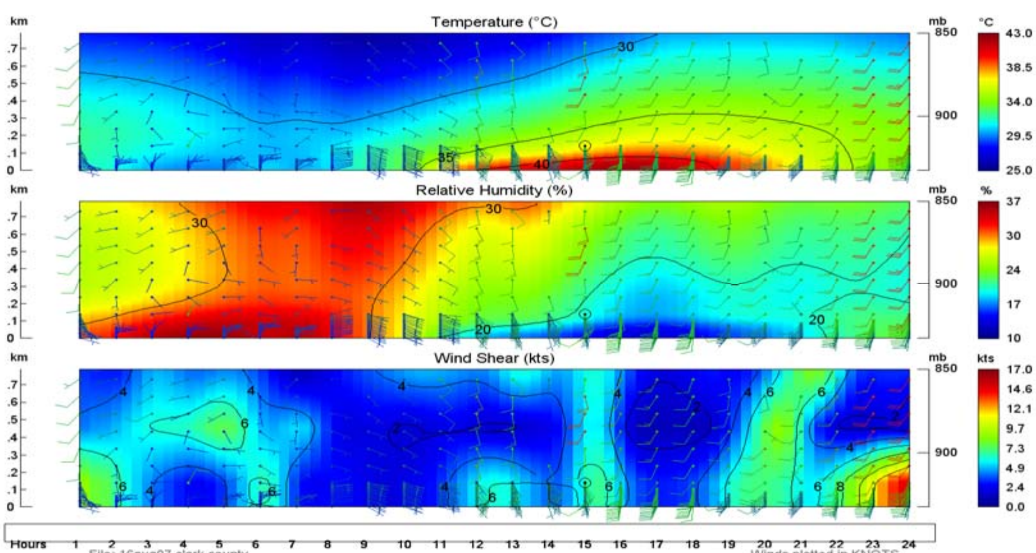

Figure 4. Boundary layer temperature, relative humidity and wind shear at North Las Vegas Airport automatically displayed real-time by RDX-RAOB software.

Temperature, humidity and wind measurements from the Clark County operational system are shown in Figure 4. The image is automatically generated in real time from continuous thermodynamic and wind profiler measurements using RDX-RAOB software (www.raob.com). Web postings of the data can be tailored to display specific parameters.

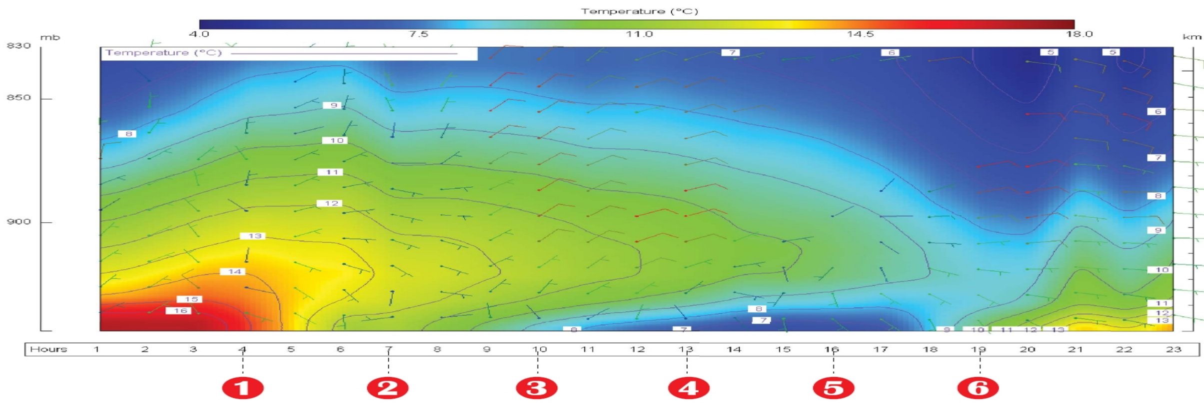

Figure 5. Diurnal evolution of boundary layer temperature and wind at North Las Vegas Airport displayed real-time by RDX-RAOB software.

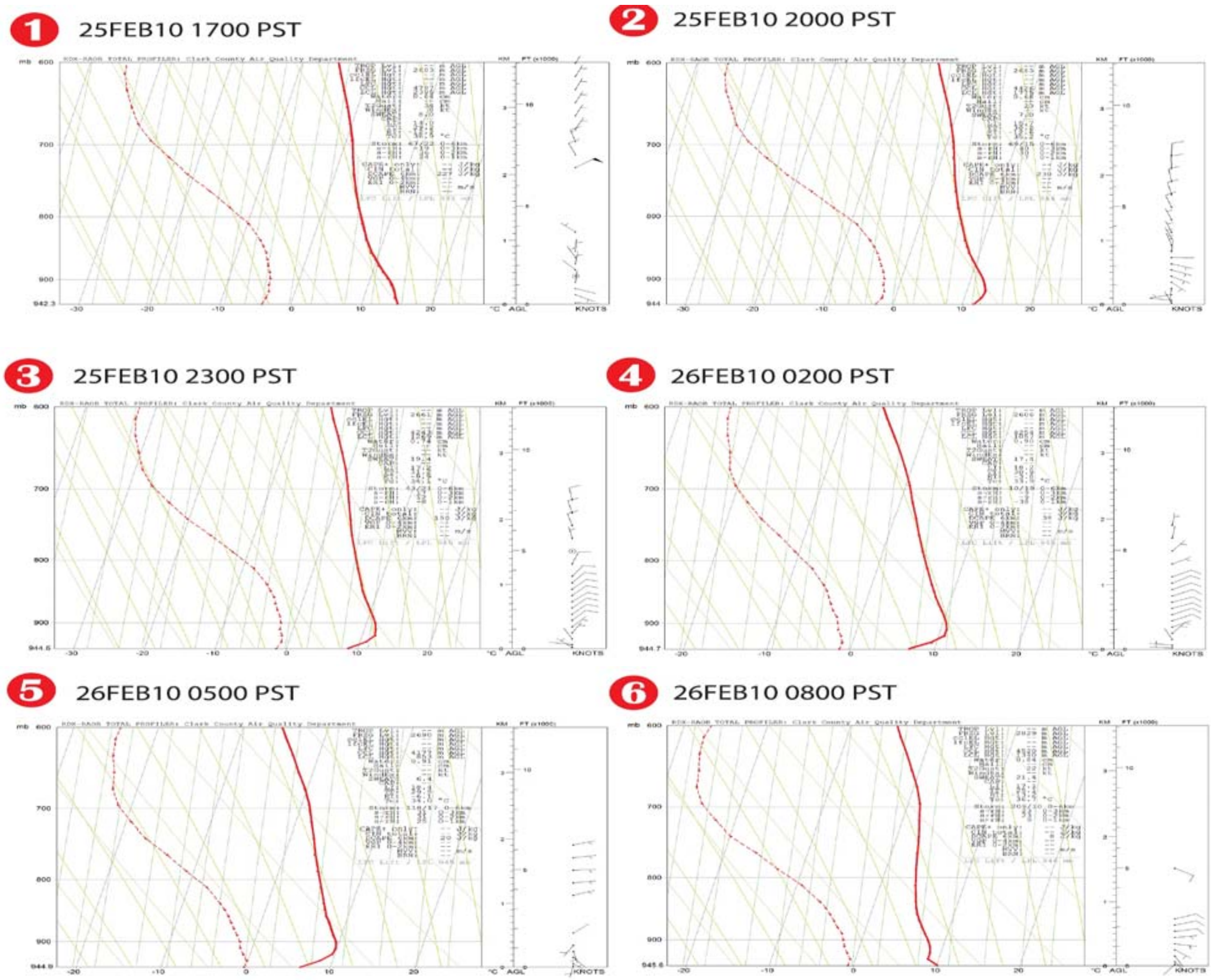

Figure 6. Three-hour Skew-T temperature, dewpoint and wind displayed in RDX-RAOB software.

Development of a boundary layer capping inversion is evident in continuous 24-hr temperature and wind profiles measurements by the Clark County DAQEM system (Figure 5). Corresponding temperature, dewpoint and winds at three-hour intervals are shown in Skew-T images generated by RDX-RAOB software (Figure 6).

Internationally, a comprehensive system that assimilates continuous wind and thermodynamic profiles into high resolution numerical weather models for aviation weather monitoring and prediction is operated by the Dubai International Airport (Thomas, 2009). The Aviation Weather Decision Support System at Dubai also assimilates weather radar, satellite and surface data (Shaw et al., 2008; Barrere et al., 2008) and delivers automated downburst, turbulence and fog alerts to air traffic controllers. Data from this system is being used as inputs to the WRF model to aid in weather and air quality forecasting

Summary

Continuous upper-air thermodynamic and wind profiles are being used for state-of-the-art air quality monitoring and prediction by leading US and international air quality, environmental and airport weather agencies. The ability to have real-time "virtual radiosonde" data has opened up a new chapter in the ability to analyze, understand and utilize the data for forecasting air quality and weather related events. This type of integrated system has been part of the air quality forecasting and analysis toolbox in Clark County, Nevada for well over a year. The system is used to forecast and understand the transport of air pollutants from adjacent air basins and to help analyze the transport and dispersion of wildfire related emissions.

References

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