2.2 APPLICATIONS OF AIRCRAFT SOUNDING DATA IN SHORT-TERM CONVECTIVE FORECASTING

Phillip G. Kurimski* and Eugene S. Brusky Jr.
NOAA/National Weather Service, Green Bay, WI

1. INTRODUCTION

Automated real-time reports of atmospheric conditions from commercial airlines continue to increase across the globe, as a result of the AMDAR (**A**ircraft **M**eteorological **D**ata **R**elay) program (Moninger et al. 2003). Although AMDAR data have been available for nearly two decades, its widespread incorporation into NWS forecast operations has been slow, partly because available soundings were generally confined to a few of the larger regional hubs, and moisture information was not available. Despite these limitations, the increased temporal frequency of the aircraft temperature and wind profiles alone has demonstrated considerable utility in the more accurate assessment and timely monitoring of short-term convective potential (Mamrosh 1998). With the advent of WVSS in the late 1990s (Fleming 1996) and more recently, TAMDAR (Tropospheric AMDAR) (Daniels et al. 2004), atmospheric moisture information (in addition to temperature and wind) has also become available, providing forecasters with a more complete picture of the current state of the atmosphere. The TAMDAR Great Lakes Fleet Experiment (GLFE) (conducted from January 2005 to January 2006) was designed to determine whether TAMDAR-equipped regional aircraft could provide timely and reliable upper-air soundings comparable to radiosonde observations (Mamrosh et al. 2005). Recent case studies have demonstrated the value of the regional aircraft soundings in evaluating convective potential (Brusky and Kurimski 2006; Fischer 2006; Szoke et al. 2006). These data have also been shown to have a positive impact of short-term RUC (Rapid Update Cycle) model forecasts (Benjamin et al. 2006).

The purpose of this paper is to demonstrate the short-term operational forecast utility of regional aircraft data in assessing convective potential. Emphasis was placed on its utility as an observational and short-term forecast tool to more accurately monitor and assess convective cap strength, horizontal extent and temporal evolution.

* *Corresponding author address:* Phillip G. Kurimski, 2485 South Point Road., Green Bay, Wisconsin 54303; e-mail: phil.kurimski@noaa.gov

2. DATA AND METHODOLOGY

Aircraft data were made available to NWS forecasters through the Earth System Research Laboratory (ESRL) interactive JAVA website, and the NWS AWIPS system via the Meteorological Assimilation Data Ingest System (MADIS). This enabled forecasters to assess aircraft soundings in an operational setting in near real-time, along with other observational and model forecast output. The sounding analysis included routine examination of temperature, moisture, and wind profiles, and the generation of a variety of sounding-derived parameters including convective available potential energy (CAPE) and convective inhibition (CIN). Because the TAMDAR sensors were installed on regional aircraft serving primarily smaller airports, the soundings were generally limited to below 500 mb*.* Despite this limitation, studies by Maddox et al. (1980), Johns and Doswell (1992), Brooks et al. (1994), Caruso and Davis (2005), and others have shown that the key ingredients for assessing short-term convective potential and initiation lie in the boundary layer through the mid-troposphere.

Cases chosen for study were based primarily on whether or not the NWS Green Bay (GRB) forecast area was located initially within (or near) a Day 1 convective outlook and/or a convective watch that was issued by the Storm Prediction Center.

3. UTILITY OF REGIONAL AIRCRAFT SOUNDING DATA IN ASSESSING CAP STRENGTH

Two "null" cases will be presented in which severe convection was anticipated within the next 12 hour period but did not materialize. A key factor in these events was the presence of a substantial elevated warm layer or cap which is often poorly sampled by the existing radiosonde network and frequently underestimated by short-term model forecasts. It will be shown that regional aircraft soundings provided near real-time monitoring of cap location and strength, and enabled forecasters to more accurately assess short-term model forecasts of its evolution.

3.1 07 June 2005 Case

3.1.1 Overview and Synoptic Situation

Early on 07 June 2005, a linear Mesoscale Convective System (MCS) was moving across the northern Mississippi Valley. The MCS developed north of a surface warm front in a region of low-level warm advection associated with a nocturnal low-level jet. As the MCS moved across southern Minnesota, it produced some scattered straight-line wind damage. By 1500 UTC, the MCS extended from near Eau Claire, Wisconsin (EAU) to west of La Crosse, Wisconsin (LSE) (Fig. 1) with the convection primarily elevated in nature.

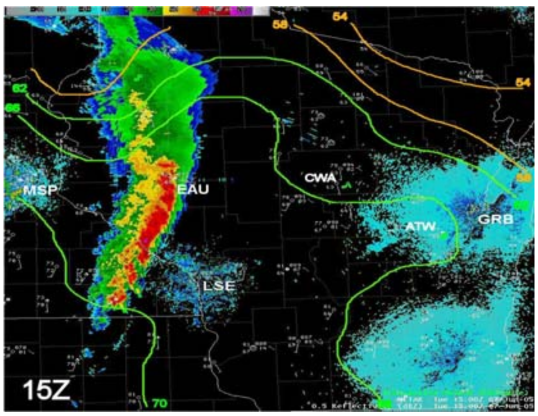

Fig. 1. Radar reflectivity and surface plot for 1500 UTC 07 June 2005 with dew point contours.

Downstream of the MCS, the atmosphere was forecast to destabilize over Wisconsin as surface temperatures rose into the lower 80s ˚F with dew points approaching the upper 60s ˚F.

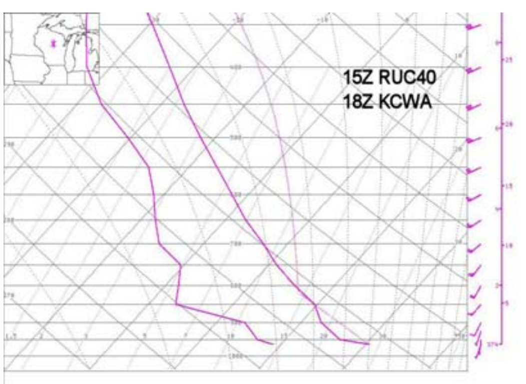

Fig. 2 1500 UTC RUC40 model forecast sounding valid at 1800 UTC for CWA.

Although the MCS had weakened somewhat by 1500 UTC, both the North American Model (NAM) (not shown) and RUC (Fig. 2) forecast soundings suggested that with adequate insolation, the convection would likely become surface-based and re-intensify later in the day. As a result, a Severe Thunderstorm Watch was issued for parts of central and east-central Wisconsin from 1530 to 2100 UTC (Fig. 3).

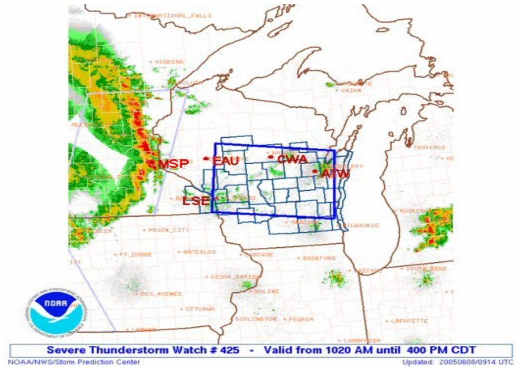

Fig. 3. Severe Thunderstorm Watch #425 issued at 1530 UTC 07 June 2005 and TAMDAR sounding locations.

3.1.2 Aircraft Soundings

Morning and early afternoon regional TAMDAR aircraft soundings were examined downstream of the approaching MCS. A representative 1513 UTC ascent sounding from Mosinee (CWA) Wisconsin revealed a rather deep dry layer above 900 mb and a substantial capping inversion (Fig. 4). Based on forecast maximum temperatures over central-Wisconsin, it appeared unlikely for the cap to break and allow surface-based convection later in the day.

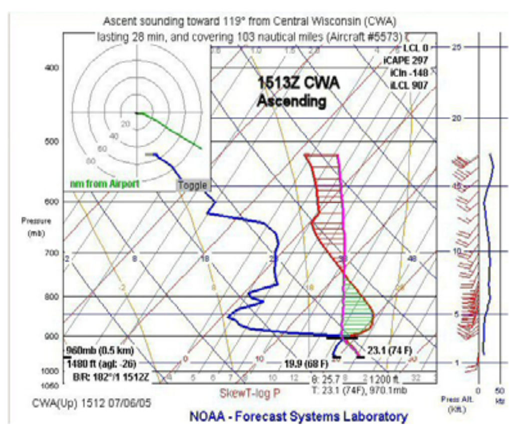

Fig. 4. CWA TAMDAR sounding from 1513 UTC 07 June 2005.

In fact, by 1930 UTC, the linear MCS almost completely dissipated, except for some isolated storms that persisted along the outflow boundary over southwest Wisconsin (Fig. 5).

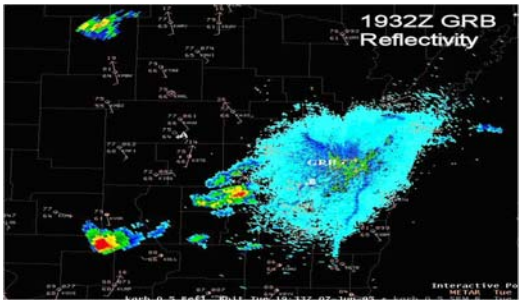

Fig. 5. Radar and surface data for 1923 UTC 07 June 2005.

A 1932 UTC CWA aircraft sounding continued to indicate a deep dry layer through much of the lower to middle troposphere along with a strong cap (Fig. 6).

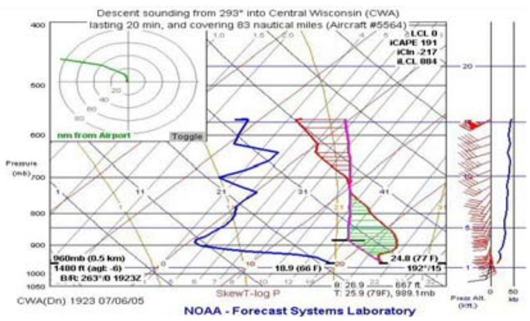

Fig. 6. CWA TAMDAR sounding from 1923 UTC 07 June 2005.

Comparison of the 1923 UTC CWA TAMDAR sounding with a 1900 UTC Rapid Update Cycle (RUC) analysis sounding indicated that the RUC had significantly underestimated the strength of the cap at this time (Fig. 7).

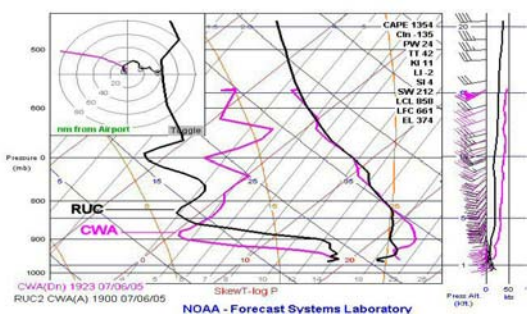

Fig. 7. TAMDAR (pink) and RUC (black) sounding for Mosinee, WI at 1923 UTC 07 June 2005.

Routine monitoring of the aircraft soundings indicated that there was little chance for surface-based convection. No severe weather was reported within the Severe Thunderstorm Watch area in the GRB forecast area during the day.

3.2 23 July 2005 Case

3.2.1 Overview and Synoptic Situation

During the late morning and early afternoon of 23 July 2005, a MCS raced across the western Great Lakes region producing a large swath of straight-line wind damage from central Minnesota eastward to central Wisconsin. The MCS organized over the eastern Dakotas earlier in the day in response to a mid-level disturbance and strong low-level warm advection associated with a nocturnal low-level jet. By 2000 UTC, the leading convective line had moved into southern Wisconsin with an extensive trailing stratiform precipitation region covering much of central Wisconsin (Fig. 8).

In the wake of the MCS, convective overturning stabilized the lower half of the troposphere with much of the deep moisture being scoured from the area, leaving a relatively shallow moist layer. In addition, an elevated mixed layer was being advected into the region contributing to a strong mid-level cap (Fig. 9). The Day 1 Convective Outlook issued at 2000 UTC, highlighted a large moderate risk area for the potential for primarily elevated severe convection north of a surface warm front later in the evening, from central Minnesota to central Wisconsin (Fig. 8).

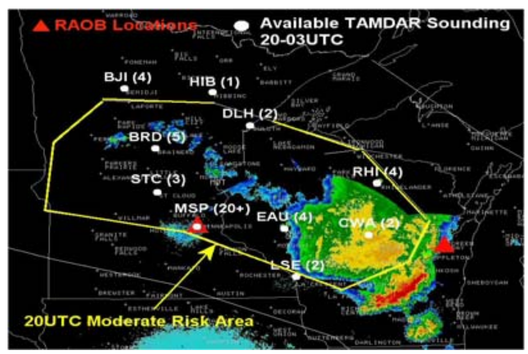

Fig. 8. Composite Reflectivity and SPC Day 1 Outlook from 2000 UTC 23 July 2005 and TAMDAR sounding locations.

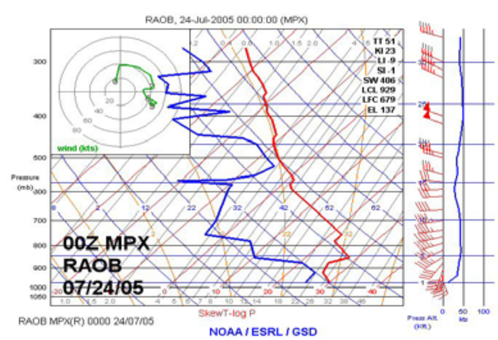

Fig. 9. MSP RAOB sounding from 0000 UTC 24 July 2005.

Model forecasts (not shown) and 0000 UTC 24 July 2005 analyses (Figs. 10 and 11) indicated that the low-level jet would intensify ahead of a weak mid-level short-wave trough and transport moisture rapidly back northward into the western Great Lakes region where favorable wind shear profiles were already in place. A more detailed discussion of the synoptic situation and model performance in this case can be found in a recent study by Fischer (2006).

During the late afternoon and early evening, the short-term forecast challenge was to accurately assess the strength and northward extent of the capping inversion, and determine when and where elevated convection might breakout near the northern edge of the cap.

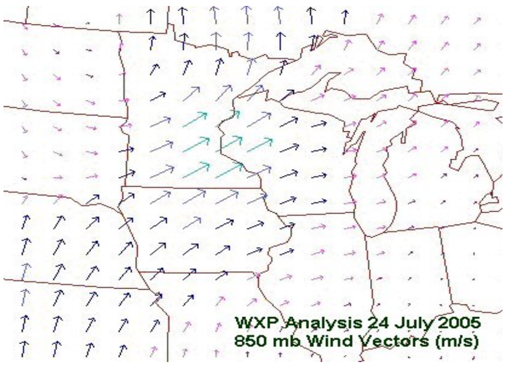

Fig. 10. 850 mb wind vectors (ms^{-1}) from 0000 UTC 24 July 2005.

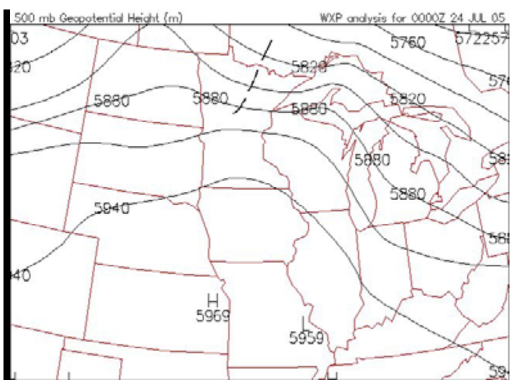

Fig. 11. 500 mb heights from 0000 UTC 24 July 2005. Short wave axis denoted by dashed line.

3.2.2 Aircraft Soundings

Numerous aircraft soundings were available to forecasters during the late afternoon and early evening to monitor short-term convective potential within and near the initial 2000 UTC Moderate Risk area (Fig. 8). In fact, over **47** aircraft soundings were available between 2000 and 0300 UTC compared to two RAOBS (GRB and MSP).

Examination of aircraft soundings located in the southern half of the convective outlook area (MSP, EAU, and CWA) indicated generally shallow moisture topped by a deep dry layer above, with a persistent and strong cap centered around 800 mb (Fig 12). Further east at CWA, although the low-level moisture was somewhat deeper, the mid-level cap was still quite strong (Fig. 13).

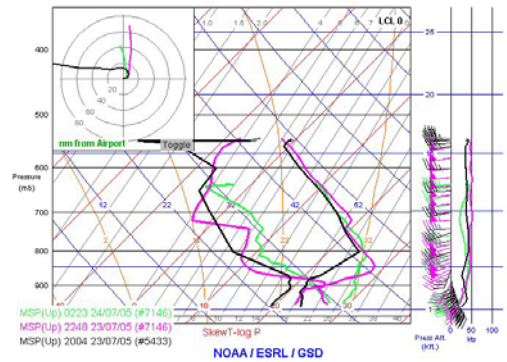

Fig. 12. MSP TAMDAR soundings from 2004 UTC (black), 2248 UTC (pink), and 0223 UTC (green) 23-24 July 2005.

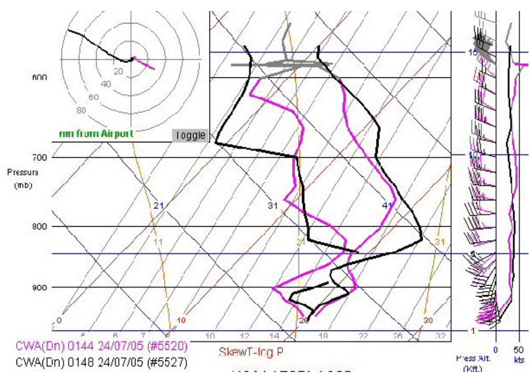

Fig. 13. CWA TAMDAR soundings from 0148 UTC (black) and 0144 UTC (pink) 24 July 2005.

Maximum temperatures in the elevated warm layer ranged from 26 ˚C at MSP to about 23 ˚C further east at CWA. Note, however, that a comparison of the two CWA soundings from aircraft descending from *opposite* directions and only 4 minutes apart, reveals a nearly 5 ˚C difference in the magnitude of the elevated warm layer (23 ˚C vs. 18 ˚C). The lower temperature from the aircraft descending from the east suggests that the mid-level cap was considerably weaker east of CWA (Fig. 13). Strong veering wind profiles at aircraft sounding locations over the southern half of the moderate risk area suggested that warm advection would likely continue to maintain the mid-level cap in this area.

Examination of TAMDAR soundings along the northern periphery of the moderate risk area indicated more substantial moistening in the lower levels, first across north-central Minnesota near Brainerd (BRD) (Fig.14) then across north-central Wisconsin near Rhinelander (RHI) a few hours later (Fig. 15). Note, however, that the mid-level cap remained strong near BRD while at RHI, the cap appeared to be weakening.

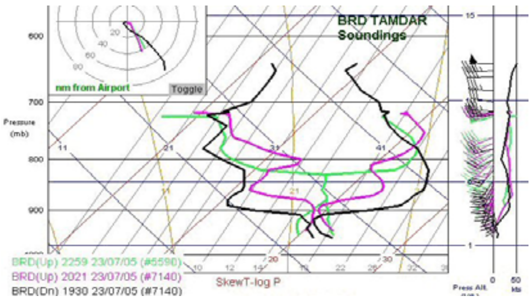

Fig. 14. BRD TAMDAR soundings from 1930 UTC (black), 2021 UTC (pink), and 2259 UTC (green) 23 July 2005.

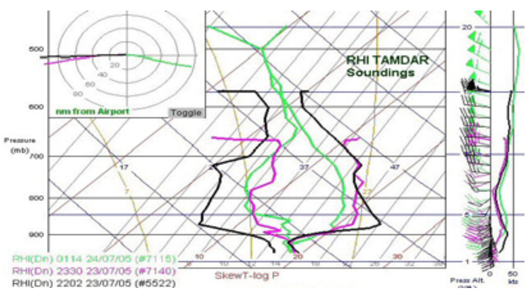

Fig. 15. RHI TAMDAR soundings from 2202 UTC (black), 2330 UTC (pink), and 0114 UTC (green) 23-24 July 2005.

Based on an aircraft sounding at Marquette (MQT) (Fig. 16), it appeared the northern edge of the cap was somewhere between RHI and MQT. As the low-level jet intensified, convection did break out between 0400 and 0500 UTC but was confined to an area generally north of a BRD to RHI line (Fig. 17) as suggested by examination of the regional TAMDAR soundings.

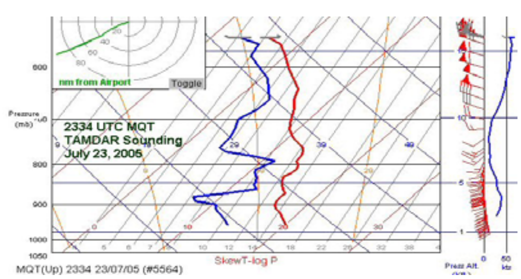

Fig. 16. MQT TAMDAR sounding at 2334 UTC 23 July 2005.

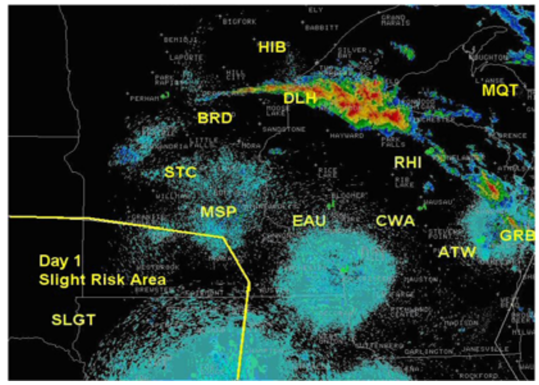

Fig. 17. Radar Reflectivity and SPC Day 1 Outlook for 0500 UTC 24 July 2005.

A plan view of TAMDAR aircraft winds between 0300 and 0600 UTC also revealed the presence of the weak mid-level disturbance moving across northwest Wisconsin that helped to release the elevated instability near the northern edge of the cap (Fig. 18). However, no severe weather was reported overnight across the western Great Lakes region (Fig. 19).

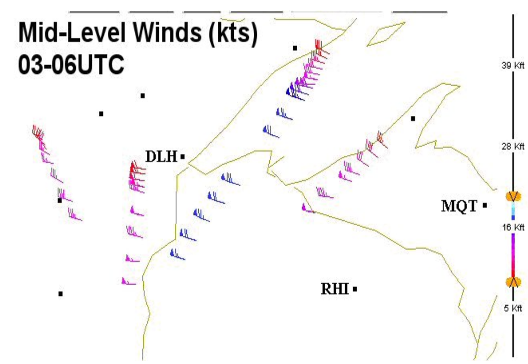

Fig. 18. TAMDAR Aircraft winds between 7000 and 20000 ft for 0300 to 0600 UTC 24 July 2005. Winds greater than 55 knots in blue.

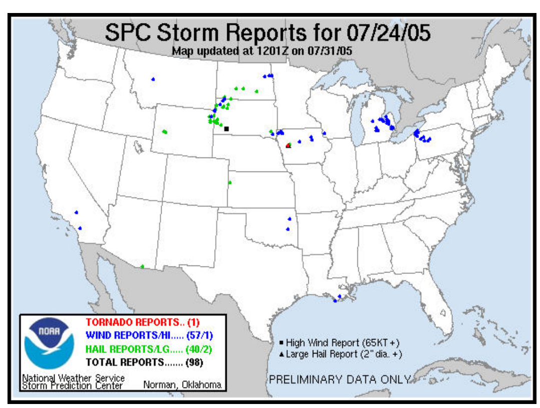

Fig. 19. Preliminary storm reports for July 24, 2005.

5. SUMMARY AND CONCLUSIONS

Two null cases were presented in which severe weather was anticipated within the next 12 hours, but did not materialize. An important factor in these cases was the presence of a strong capping inversion that was inadequately sampled by the existing radiosonde network and poorly forecast by the operational models. The frequent sampling of the cap provided by the regional aircraft soundings, gave forecasters a timelier, more accurate and complete picture of the location and strength of the cap. This allowed forecasters to more accurately assess short-term model forecasts of the cap, demonstrating the potential of regional aircraft data to reduce false alarms related to short-term convective watches and outlooks.

6. ACKNOWLEGEMENTS

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