9.5 THE UTILITY OF TAMDAR REGIONAL AIRCRAFT SOUNDING DATA IN SHORT-TERM CONVECTIVE FORECASTING

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1. INTRODUCTION

Tropospheric Airborne Meteorological Data Report (TAMDAR) is a joint project between NASA/FAA/NOAA and a private company called Airdat (Daniels et. al 2004). As part of the TAMDAR project, a year-long evaluation period referred to as the TAMDAR Great Lakes Fleet Experiment (GLFE) was conducted. One of the goals of the GLFE were to determine whether TAMDAR units are a reliable, cost effective means of gathering upper air data, and whether this data could improve warnings and forecasts (Mamrosh et al. 2005). During the GLFE which began on 15 January 2005, the regional TAMDAR aircraft data filled in many of the data sparse areas in the United States and southern Canada, particularly over the Midwest and Great Lakes regions. The increased spatial and temporal resolution sounding data available during the experiment allowed National Weather Service (NWS) forecasters a valuable opportunity to assess the utility of a near mesoscale dataset to address a variety of forecast problems.

Until recently, there have been few studies that have addressed the utility of aircraft sounding in short-term convective forecasting. Although only temperature and wind information were available from the aircraft, the soundings examined in these early studies were still found to be quite valuable in assessing short-term convective potential (Mamrosh, 1998). In addition to temperature and wind data, the TAMDAR aircraft soundings include valuable moisture information, providing forecasters a more complete picture of the current state of the atmosphere. The focus of this paper is to illustrate, via several case studies, the potential operational forecast utility of the regional aircraft sounding data in assessing short-term (0-12 hour) convective potential. A preliminary examination of these cases suggest that regional aircraft soundings have significant potential in increasing the probability of detection (POD) and reducing false alarms related to convective warnings, watches and short-term convective outlooks.

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2. DATA AND METHODOLOGY

TAMDAR data were made available to NWS forecasters in near real-time through the Earth System Research Laboratory (ESRL) interactive JAVA website located at http://amdar.noaa.gov and the NWS AWIPS system via the Meteorological Assimilation Data Ingest System (MADIS) (http://www-ssd.fsl.noaa.gov/MADIS). Utilizing these two data sources, forecasters analyzed aircraft sounding profiles along with other observational and model forecast data to assess the convective potential in an operational forecast setting. This was accomplished through the examination of vertical temperature, moisture, and wind profiles, and the generation of a variety of sounding-derived parameters helpful in assessing convective potential including convective available potential energy (CAPE), convective inhibition (CIN), and vertical wind shear. Because the TAMDAR instruments were installed on turboprop aircraft serving smaller regional airports, the assessment of convective potential utilizing the aircraft soundings was generally limited to below 500 mb. Despite this limitation, studies by Davies (2004), Maddox et al. (1980), Caruso and Davis (2005), Johns and Doswell (1992), Brooks et al. (1994), and others have shown that many of the key ingredients for assessing convective potential and initiation lie in the boundary layer through the mid-troposphere.

Case study selection was based primarily on whether or not the NWS Green Bay, Wisconsin (GRB) forecast area was located initially within (or near) a Day 1 convective outlook and/or a convective watch. The Storm Prediction Center (SPC) issues convective outlooks to highlight areas of greatest severe weather threat in the short and medium range (beyond 6 hours) and convective watches when conditions have become favorable for severe thunderstorms within the next 0 to 6 hours (Novy et al. 2005). Available cases were then divided into two general categories: those highlighting the usefulness of TAMDAR data in anticipating marginally severe weather and/or weak tornados, and those highlighting the utility of the data in assessing convective potential via monitoring of convective cap strength and evolution.

3. UTILITY OF AIRCRAFT SOUNDINGS IN ANTICIPATING MARGINALLY SEVERE AND SUBTLE WEAK TORNADO EVENTS

Perhaps the greatest operational forecast value of increased temporal and spatial resolution observational sounding data lies in its potential for more accurate assessment and monitoring of subtle, marginally severe or rapidly changing environments. In this section, two cases will be presented to illustrate the utility of the regional aircraft soundings in assessing weak, more subtle convective episodes in which the environment was changing rapidly and was not initially favorable for supporting tornadic activity.

3.1 04 June 2005 Case

3.1.1 Overview and Synoptic Situation

A surface warm front was advancing northward toward the western Great Lakes region on 04 June 2005. By 2100 UTC the warm front was located south of the GRB forecast area and extended from near Minneapolis, Minnesota (MSP), southeastward toward LaCrosse, Wisconsin (LSE) and Lone Rock (LNR) Wisconsin (Fig. 1). South of the front, the atmosphere was forecast to destabilize rapidly over Iowa, southeast Minnesota into extreme southwest Wisconsin. In addition, deep layer wind shear was forecast to become favorable to support severe thunderstorms as indicated by the 2200 UTC Blue River, Wisconsin (BLRW3) wind profiler plot (not shown). As a result, the SPC highlighted this area in a

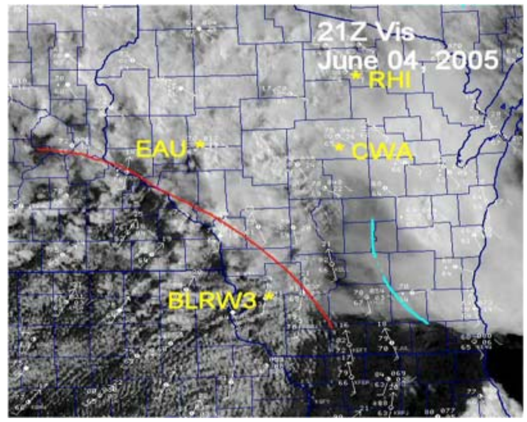

Fig. 1. Visible Satellite Image for 2100 UTC 04 June 2005 and surface plot. Warm front denoted by red line.

moderate to high risk of severe thunderstorms for the afternoon and evening (Fig. 2). Further north, 1200 UTC RAOB soundings north of the warm front at GRB Fig. 3) and MSP (not shown) indicated initially stable conditions with relatively weak winds throughout the lower to middle troposphere, accompanied by veering in the boundary layer. As the warm front advanced northward, the low to mid-level winds and instability were forecast to increase somewhat over central Wisconsin during the day. However, persistent overcast conditions along and north of the front, in combination with marginal deep layer wind shear forecast over the region, limited the severe weather potential, thus SPC highlighted the area north of the front in a slight risk for severe

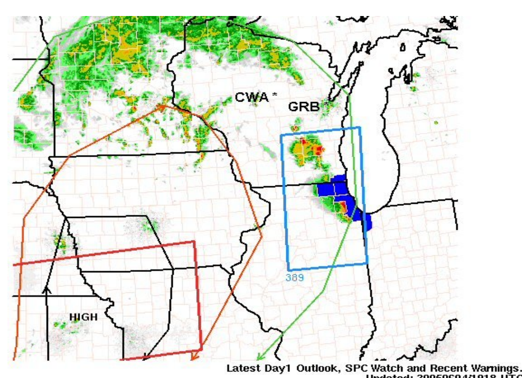

Fig. 2. SPC Day 1 Outlook issued at 1918 UTC 04 June 2005.

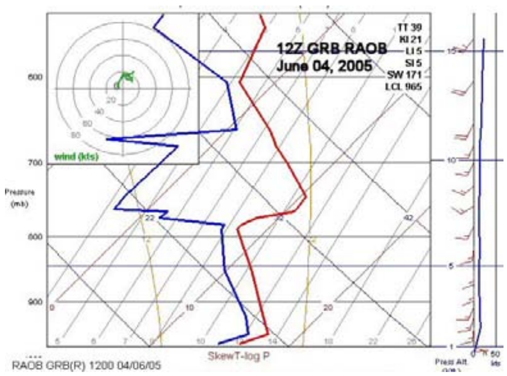

Fig. 3. RAOB sounding for GRB at 1200 UTC 04 June 2005.

3.1.2 Mesoanalysis and Radar Evolution

Scattered thunderstorms developed by early afternoon across central and east-central Wisconsin ahead of the advancing warm front. These storms were accompanied by several weak (F0) tornadoes that occurred between about 1900 and 2200 UTC in the western portion of the GRB forecast area (Fig 4). Although NWS GRB forecasters were anticipating the possibility of marginally severe weather, the widespread nature of the weak tornadic activity was not expected.

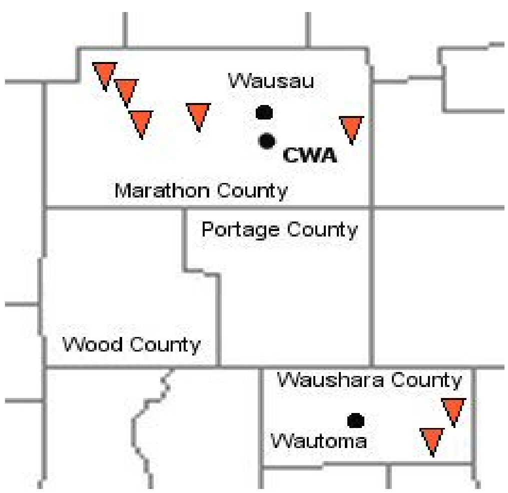

Fig. 4. Tornado reports from central Wisconsin in the GRB forecast area on 04 June 2005. June 2005. Numerous additional funnel cloud reports not plotted.

Examination of hourly SPC mesoanalysis graphics during the morning and early afternoon hours indicated that the atmosphere was rapidly becoming supportive of severe thunderstorms and the possibility of tornadic spin-ups along and north of the approaching warm front. Low-level (0-3 km) CAPE, surface vorticity (Fig. 5) and 0-1 km storm relative helicity (not shown) increased significantly over central Wisconsin between 1800 and 2100 UTC. Storms evolving in this environment have been shown to have a greater potential to produce tornadoes due to enhanced stretching of boundary layer vorticity (Caruso and Davies 2005).

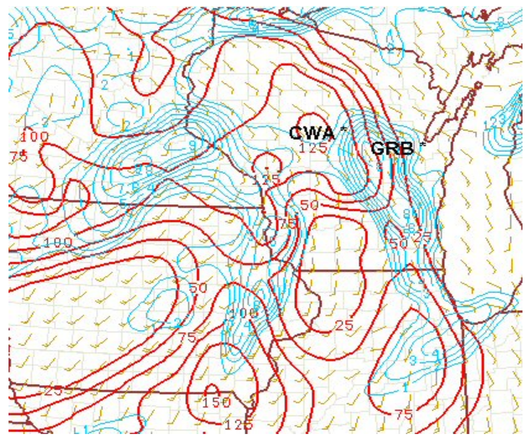

Fig. 5. SPC mesoanaysis graphic for 2100 UTC 04 June 2005. Low-level (0-3 km) CAPE (J kg^{-1}) denoted by red contours and surface vorticity (s^{-1}) denote in blue contours.

3.1.3 TAMDAR Aircraft Soundings

Examination of TAMDAR aircraft soundings between 1400 and 2000 UTC at Mosinee, Wisconsin (CWA) located in central Wisconsin not only substantiated the SPC analysis, but also suggested that conditions supportive of tornadic activity may have been in place as early as 1500 UTC. Comparison of 1428 UTC descent (not shown) and 1514 UTC ascent soundings (Fig. 6) indicated erosion of the stable layer around 900 mb and a notable increase in wind speeds below 700 mb. By 1943 UTC, the CWA TAMDAR sounding (Fig. 7) indicated wind speeds between 700 and 800 mb had nearly doubled to 40 kts (20 m s^{-1}). In addition to the increased wind shear below 700 mb, the lifted condensation level (LCL) heights had become quite low with substantial CAPE below 600 mb of about 275 J Kg^{-1}. Davies (2004) has shown that the potential for tornado formation is increased when LCL heights are low.

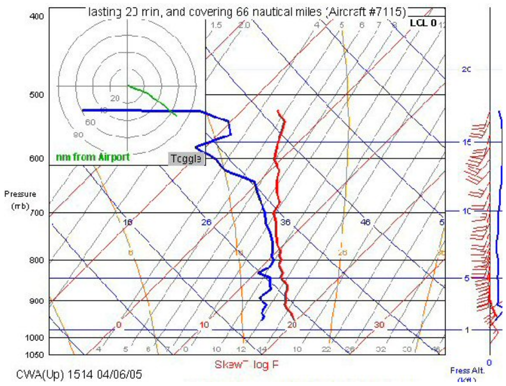

Fig. 6. TAMDAR sounding for CWA at 1514 UTC 7 June 2005.

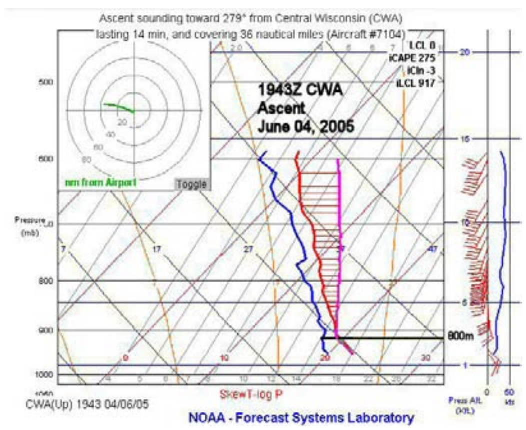

Fig. 7. TAMDAR sounding for CWA at 1943 UTC 7 June 2005.

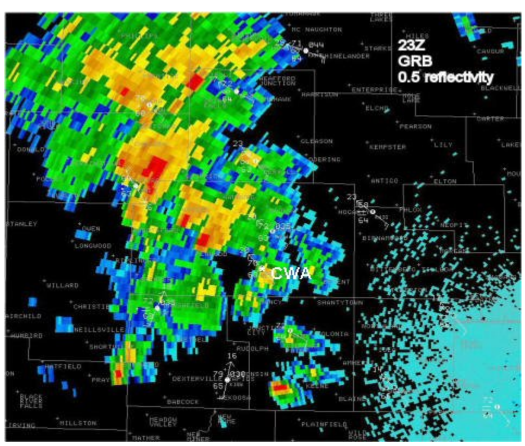

Fig. 8. GRB Radar and surface plot for 2300 UTC 04 June 2005.

The tornadic storms that formed ahead of the warm front in central Wisconsin were generally small, low-topped, and non-supercellular in nature, although a few did appear to briefly attain mini-supercell characteristics at times (Fig. 8). The circulations associated with these storms were small, transient, and generally confined to the lowest levels of the storm. Because the tornadic storms evolved generally beyond 80-90 n mi from the GRB Doppler radar, limitations pertaining to radar beam height and aspect ratio significantly limited the detection of the circulations. The timely aircraft sounding data available at CWA in this example supplemented the limited radar observations thereby providing potentially valuable insight to the forecaster with respect to the near-storm environment and short-term tornado potential.

3.2 13 June 2005 Case

3.2.1 Overview and Synoptic Situation

A strong, negatively tilted upper-level trough and associated surface low pressure system were forecast to move into the Central Plains and upper Mississippi Valley regions late in the day of 13 June 2005 (Figs. 9 and 10). Ahead of this system, instability and deep layer wind shear were forecast to become sufficient in the warm sector to support an outbreak of severe thunderstorms over much of southern Minnesota, Iowa, and Illinois by late in the afternoon. Severe thunderstorms were also forecast in the vicinity of the advancing warm

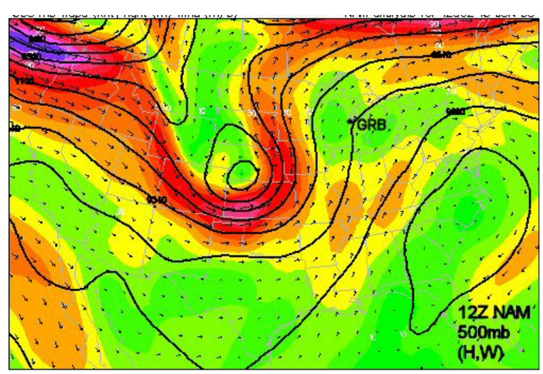

Fig. 9. 500 mb NAM initialization height and wind vectors (black) with wind speed contours at 1200 UTC 13 June 2005.

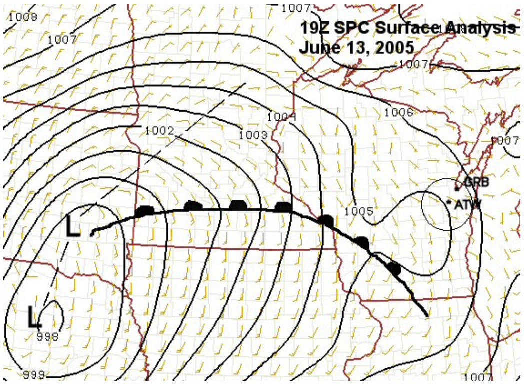

Fig. 10. SPC Surface Analysis from 1900 UTC 13 June 2005.

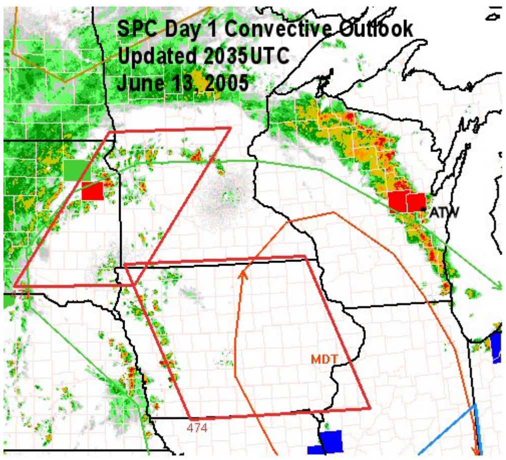

Fig. 11. SPC Day 1 Outlook issued at 2035 UTC 13 June 2005.

front over the southwest portion of Wisconsin. SPC highlighted much of this region in a moderate risk for severe thunderstorms by late in the day (Fig. 11). Further to north across northeastern Wisconsin, severe thunderstorms were not anticipated primarily because the deep layer wind shear was forecast to be quite weak. In fact, the 1200 UTC GRB RAOB sounding revealed light and variable winds through much of the troposphere with speeds generally less than 15 kts (7.5 m s^{-1}) through 500 mb (Fig. 12).

During the morning, within the warm advection zone north of the surface warm front, a northwest-to-southeast oriented band of showers and thunderstorms developed over southwest Wisconsin (Fig. 13). By early afternoon, the activity extended from near Park Falls (PKF) and Wausau (AUW), to near Milwaukee (MKE). Although the activity was expected to weaken, it maintained its intensity throughout the morning into the afternoon as it progressed northeast across the central portion of the state. As expected, other than some locally heavy rainfall, no severe weather had been reported with this activity through 2000 UTC. However, as the activity moved into northeast Wisconsin, scattered straight-line wind damage, a few funnel clouds and a brief tornado were reported between about 2000 and 2200 UTC mainly in Outagamie County (Fig. 14).

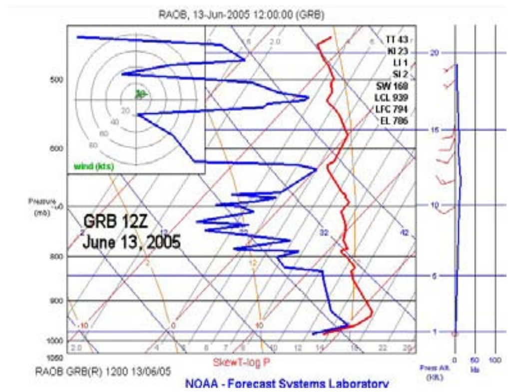

Fig. 12. RAOB sounding for GRB at 1200 UTC 13 June 2005.

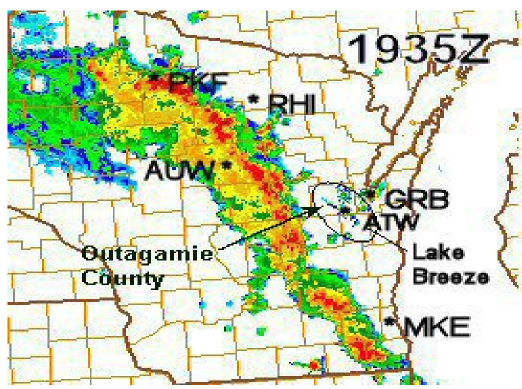

Fig. 13. Radar Reflectivity at 1935 UTC 13 June 2005 with Lake Breeze highlighted.

3.2.2 Mesoanalysis and Radar Evolution

Downstream of the approaching convection, the atmosphere was becoming increasingly unstable over east-central Wisconsin where skies had remained mostly sunny through early afternoon allowing temperatures to climb into lower 80s ˚F (Fig. 15). In addition, a moist southeasterly low-level flow and moisture pooling along and ahead of the approaching warm front allowed surface dew points to climb into the upper 60s ˚F. By 2000 UTC, surface based CAPES were approaching 2000 J Kg^{-1} over portions of southeast and east-central Wisconsin (Fig. 16). A supplemental 1800 UTC GRB RAOB sounding revealed a slight increase in moisture below 700 mb along with a stable layer centered around 950 mb. Modifying this sounding using a 2000 UTC GRB surface observation (T = 81 ˚F, Td = 66 ˚F) still gave rather modest CAPE values of around 300 J Kg^{-1} (Fig. 17). The associated 1800 UTC GRB wind profile continued to show light winds through mid-levels with some weak veering evident in the boundary layer. The low-level southeasterly flow was a reflection of the marine boundary layer as a lake breeze boundary had pushed west of GRB by 1935 UTC (Figs. 13).

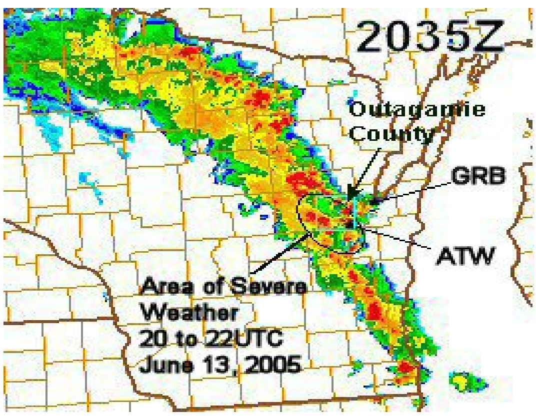

Fig. 14. Radar Reflectivity at 2035 UTC 13 June 2005 with area of severe weather reports.

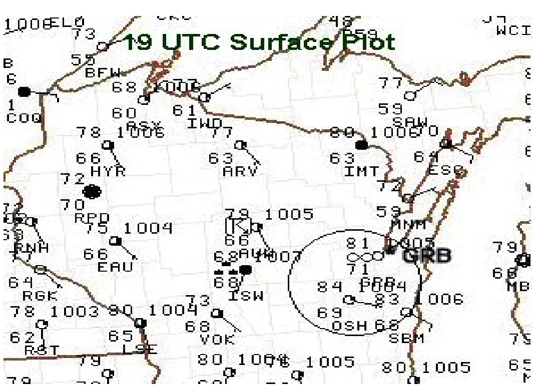

Fig. 15. Surface observations from 1900 UTC 13 June 2005.

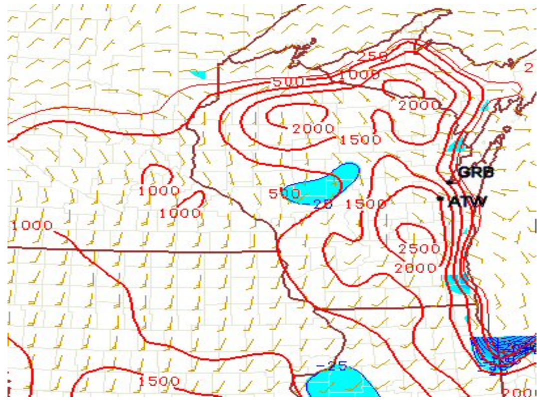

Fig. 16. SPC mesoanalysis from 2000 UTC 13 June 2005 with Surface based CAPE (red lines) and CIN (blue lines and shaded areas).

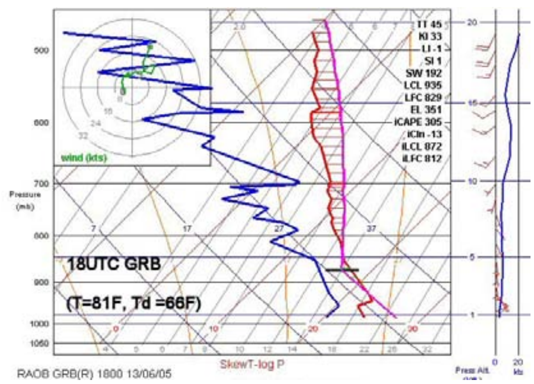

Fig. 17. Modified GRB RAOB Sounding from 1800 UTC 13 June 2005.

Given the combination of weak wind shear and modest instability as indicated by the GRB 1800 UTC sounding, the possibility of organized severe weather seemed quite small. However, the sounding did suggest a potential for high precipitation efficiency and locally heavy rainfall.

3.2.3 TAMDAR Soundings

Comparison of the 1200 and 1800 UTC GRB RAOB soundings (Figs. 12 and 17) with morning Appleton, Wisconsin (ATW) TAMDAR aircraft soundings (located only about 30 miles to the southwest of GRB) revealed subtle but important differences. Examination of three ATW soundings between approximately 1300 and 1800 UTC indicated that a considerably deeper southeasterly low-level flow had developed during the morning which led to a deep moist layer that extended up to about 850 mb by 1524 UTC (Fig. 18).

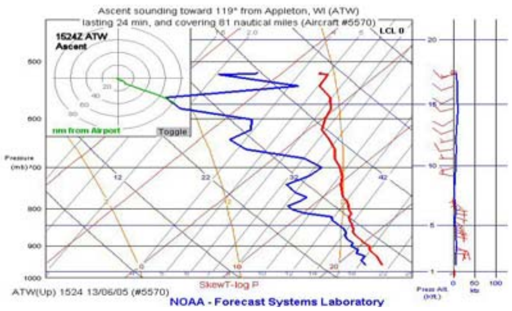

Fig. 18. ATW TAMDAR sounding at 1524 UTC 13 June 2005.

During the subsequent two hours, morning insolation allowed for the formation of a deep surface-based mixed layer by 1733 UTC (Fig. 19). The combination of increased low-level moisture and steepening low-level lapse rates led to considerably more low-level CAPE in this area by early afternoon. Comparison of the modified 1800 UTC GRB and 1733 UTC ATW soundings indicated nearly twice as much CAPE below 600 mb (~526 J Kg^{-1}) at ATW than what was observed in the entire 1800 UTC GRB soundings (~305 J Kg^{-1}). Also note that although winds in the 1733 UTC ATW sounding were still rather weak, there was substantially more veering below 700 mb.

As the band of showers and thunderstorms moved into Outagamie County shortly after 2000 UTC, they merged with thunderstorms that had quickly developed along the lake breeze boundary. The boundary interactions and storm mergers that took place in this region were associated with the majority of the damaging straight-line winds, funnel clouds, and the weak tornado that occurred

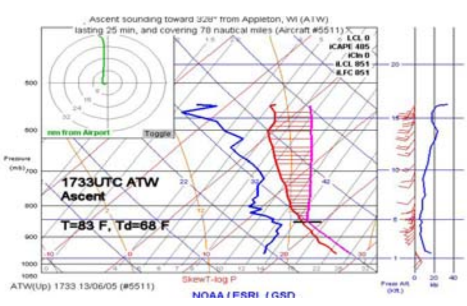

Fig. 19. Modified ATW TAMDAR Sounding at 1733 UTC 13 June 2005.

between 2000 and 2200 UTC. The presence of steep low-level lapse rates and substantial low-level CAPE, in concert with the enhanced convergence associated with the storm mergers and boundary interactions, provided a favorable environment for brief, weak ("landspout") tornadoes (Caruso and Davies, 2005). The timely ATW TAMDAR aircraft soundings allowed forecaster to monitor subtle changes in the low-level winds, moisture, lapse rates and the changes in low-level instability that were not evident even from a supplemental 1800 UTC GRB RAOB sounding located only 30 miles away. This allowed forecasters to not only better anticipate the potential for marginally severe weather and weak tornados, but also be more proactive in providing the public and local media with more timely and accurate information regarding the "marginal" severe weather threat (Fig. 20).

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE GREEN BAY WI
337 PM CDT MON JUN 13 2005

SHORT-TERM UPDATE...

...**1733 UTC ATW TAMDAR AIRCRFAT SOUNDING INDICATES STEEP LOW-LEVEL LAPSE RATES AND SUBSTANTIAL LOW-LEVEL CAPE.** THIS ENVIRONMENT...IN CONCERT WITH BOUNDARY INTERACTIONS ASSOCIATED WITH WARM FRONT AND LAKE-INDUCED BOUNDARIES...CAUSING FEW STORMS TO GENERATE VERY BRIEF WEAK SPIN-UPS...WITH A PUBLIC AND LAW ENFORCEMENT REPORT OF A TORNADO NEAR NEW LONDON. **IT APPEARS ENVIRONMENT WILL CONTINUE TO BE FAVORABLE FOR A FEW GENERALLY WEAK BRIEF SPIN-UPS NEXT HOUR OR SO...ESPECIALLY NEAR BOUNDARIES...**

Fig. 20. Excerpt from an NWS GRB Area Forecast Discussion issued at 2037 UTC 13 June 2005.

4. UTILITY OF REGIONAL AIRCRAFT SOUNDING DATA IN ASSESSING SHORT-TERM CONVECTIVE POTENTIAL VIA MONITORING THE CAP

In this section, three "null" cases will be presented in which severe convection was anticipated within the next 12 hours but did not materialize. In each case, an important limiting factor was the presence of substantial convective inhibition (CIN) or cap that was not adequately sampled by the existing radiosonde network and/or was underestimated by short-term model forecasts. It will be demonstrated that increased temporal and spatial resolution soundings available from the regional aircraft allowed for a more accurate determination of the cap location (both horizontally and vertically) and strength. This improved detection allowed NWS forecasters to more accurately assess short-term model forecasts of the cap and therefore holds promise in reducing false alarms rates (FARs) related to convective warnings, watches and short-term convective outlooks.

4.1 07 June 2005 Case

4.1.1 Overview and Synoptic Situation

During the morning of 07 June 2005, a linear Mesoscale Convective System (MCS) was moving across the northern Mississippi Valley. This system developed overnight north of a surface warm front in a region of strong low-level warm advection associated with a nocturnal low-level jet. As the system moved across southern Minnesota into far western Wisconsin, it produced some scattered straight-line wind damage. By 1500 UTC, the MCS extended from near Eau Claire, Wisconsin (EAU) to west of LSE (Fig. 21) with the convection primarily elevated in nature.

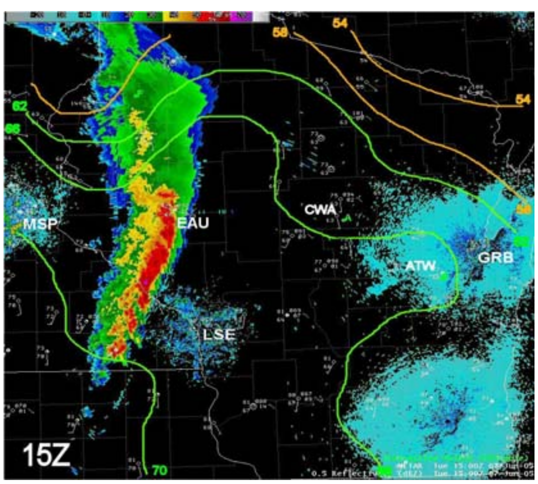

Fig. 21. Radar reflectivity and surface plot for 1500 UTC 07 June 2005 with dew point contours.

Downstream of the approaching MCS over southwest into central Wisconsin, the atmosphere was forecast to destabilize as temperatures rose into the upper 70s to lower 80s ˚F with surface dew points in the mid to upper 60s ˚F. Although the MCS had weakened somewhat by 1500 UTC, model forecast soundings suggested that with continued surface heating, the convection would become surface-based and re-intensify later in the day. As a result, SPC issued Severe Thunderstorm Watch #425 for parts of central and east-central Wisconsin from 1530 to 2100 UTC (Fig. 22).

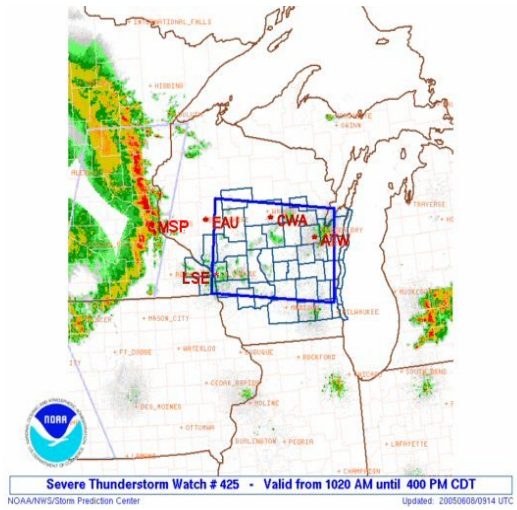

Fig. 22. Severe Thunderstorm Watch #425 issued at 1530 UTC 07 June 2005 and TAMDAR sounding locations.

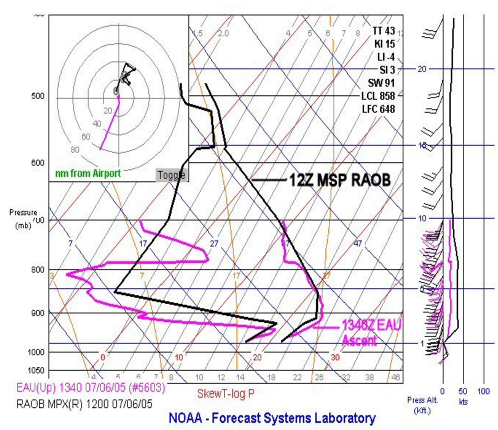

Fig. 23. MSP RAOB (black) from 1200 UTC with EAU TAMDAR (pink) sounding from 1340 UTC 07 June 2005.

4.1.2 TAMDAR Soundings

TAMDAR aircraft soundings were examined downstream of the approaching MCS during the morning into the early afternoon hours of 07 June 2005. Observed soundings immediately downstream of the convective system at MSP, LSE, and EAU revealed the surface-based inversion and the elevated nature of the convection through about 1500 UTC (Fig. 23.) Also note the deep dry layer located between about 950 and 700 mb. Further downstream at CWA, a substantial capping inversion was in place at 1513 UTC (Fig. 24) and based on forecast maximum temperatures, it appeared unlikely for the cap to break allowing convection to become surface-based later in the day. In fact, by 1930 UTC, the convection almost completely dissipated, except for some isolated storms that

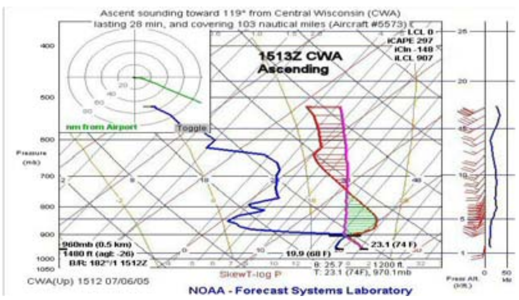

Fig. 24. CWA TAMDAR sounding from 1513 UTC 07 June 2005.

persisted along the outflow boundary over southwest Wisconsin (Fig. 25). The 1932 UTC CWA TAMDAR sounding continued to indicate a deep dry layer through much of the lower to middle troposphere along with a substantial cap (Fig. 26). A comparison of the 1900 UTC CWA TAMDAR sounding with a 1900 UTC Rapid Update Cycle (RUC) sounding indicated that the RUC had significantly under-forecast the strength of the cap (Fig. 27).

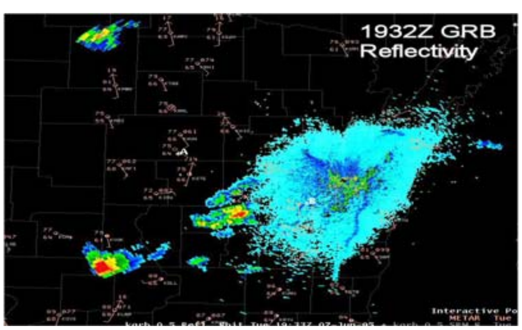

Fig. 25. Radar and surface data for 1500 UTC 07 June 2005.

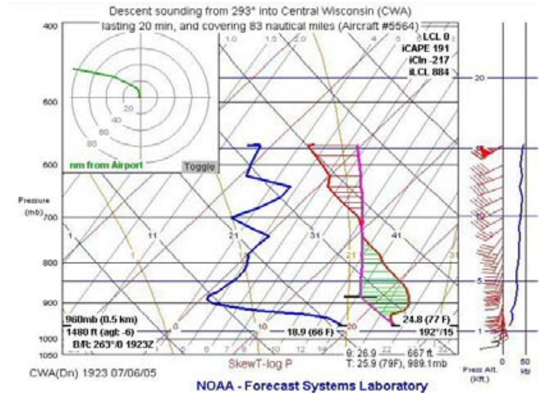

Fig. 26. CWA TAMDAR sounding from 1923 UTC 07 June 2005.

Routine monitoring of available TAMDAR soundings in this case indicated that there was little chance for surface-based convection to develop. As a result, no severe weather was reported anywhere within Severe Thunderstorm Watch #425 which was cancelled prior to 2100 UTC.

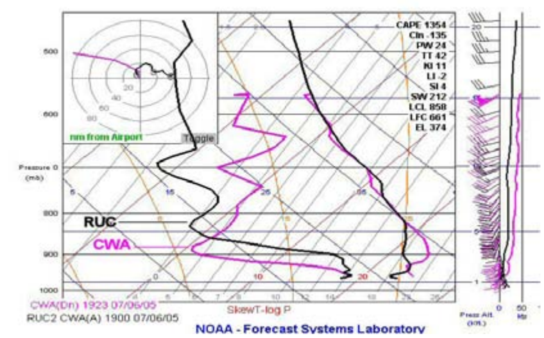

Fig. 27. TAMDAR (pink) and RUC (black) sounding for Mosinee, WI at 1923 UTC 07 June 2005.

4.2 23 July 2005 Case

4.2.1 Overview and Synoptic Situation

During the late morning and early afternoon of 23 July 2005, a damaging mesoscale convective system (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 convective complex developed overnight over the eastern Dakotas 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. 28).

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. 29). The updated 2000 UTC SPC Convective Outlook continued to highlight 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. 28). Model forecasts (not shown) and 0000 UTC 08 June 2005 analyses (Figs. 30 and 31) indicated that the low-level jet would intensify ahead of a weak mid-level short-wave trough

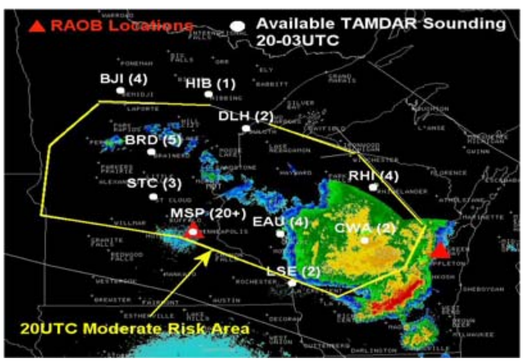

Fig. 28. Composite Reflectivity and SPC Day 1 Outlook from 2000 UTC 23 July 2005 and TAMDAR sounding locations.

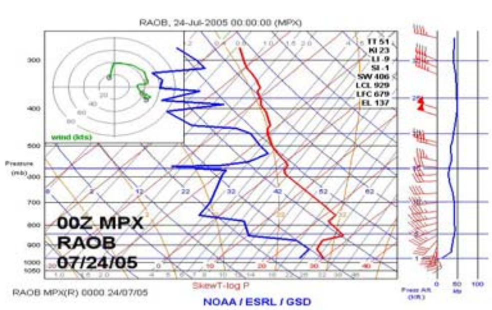

Fig. 29. MSP RAOB sounding from 0000 UTC 24 July 2005.

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 model performance in this case can be found in a recent study by Fischer (2006).

Fig. 30. 850 mb wind vectors (ms^{-1}) from 0000 UTC 24 July 2005.

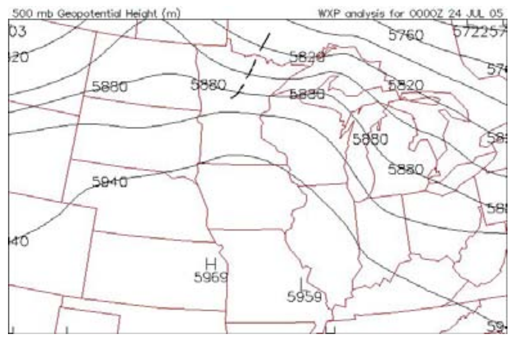

Fig. 31. 500 mb heights from 0000 UTC 24 July 2005. Short wave axis denoted by dashed line.

During the late afternoon and early evening, the short-term forecast challenge was to properly 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 as the low-level jet intensified.

4.2.2 TAMDAR Soundings

Numerous TAMDAR soundings were available to forecasters during the late afternoon and early evening to help monitor short-term convective potential within the initial 2000 UTC SPC moderate risk area (Fig. 28). Note the number of available TAMDAR aircraft soundings **(47+)** between 2000 and 0300 UTC within the SPC moderate risk area compared to the two RAOBS at MSP and GRB.

Examination of TAMDAR 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 32). Further to the east at CWA, although the low-level moisture was somewhat deeper, the mid-level cap was still quite strong (Fig. 33).

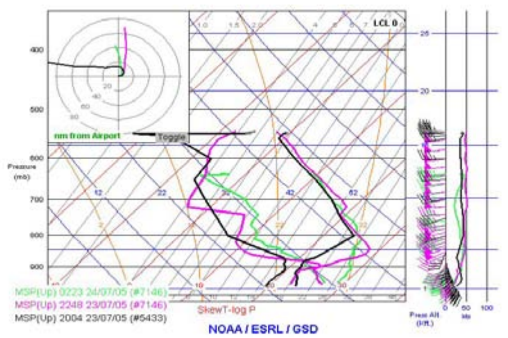

Fig. 32. MSP TAMDAR soundings from 2004 UTC (black), 2248 UTC (pink), and 0223 UTC (green) 23-24 July 2005.

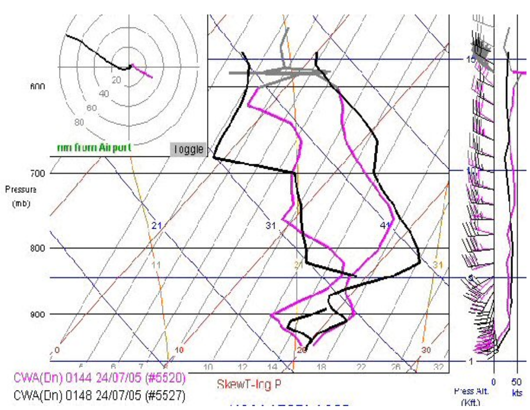

Fig. 33. CWA TAMDAR soundings from 0148 UTC (black) and 0144 UTC (pink) 24 July 2005.

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 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. 33). The veering wind profiles evident at all TAMDAR sounding locations across the southern half of the moderate risk area indicated that warm advection would likely continue to maintain the mid-level cap for the several hours.

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. 34) then across north-central Wisconsin near Rhinelander (RHI) a few hours later (Figs. 35 and 36). However, the mid-level cap remained strong near BRD with a maximum temperature of about 22 ˚C at 2259 UTC (Fig. 34) while at RHI, the mid-level cap appeared to be weakening (Figs. 35 and 36). Based on a TAMDAR sounding at Marquette, Michigan (MQT) (Fig. 37), it appeared that the northern extent of the cap

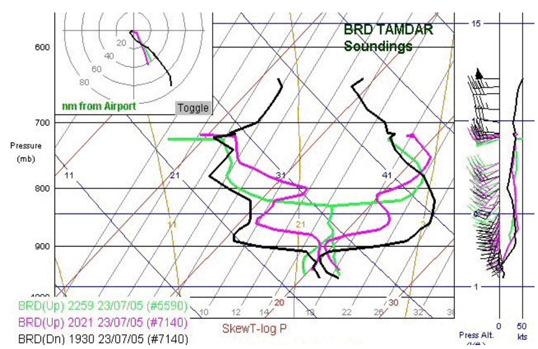

Fig. 34. BRD TAMDAR soundings from 1930 UTC (black), 2021 UTC (pink), and 2259 UTC (green) 23 July 2005.

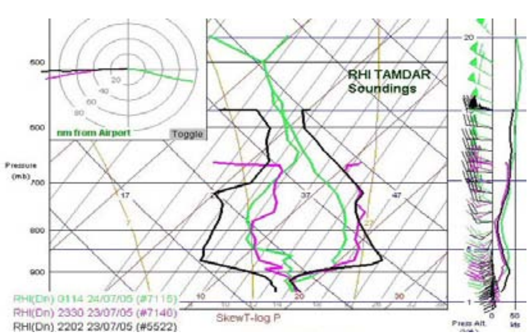

Fig. 35. RHI TAMDAR soundings from 2202 UTC (black), 2330 UTC (pink), and 0114 UTC (green) 23-24 July 2005.

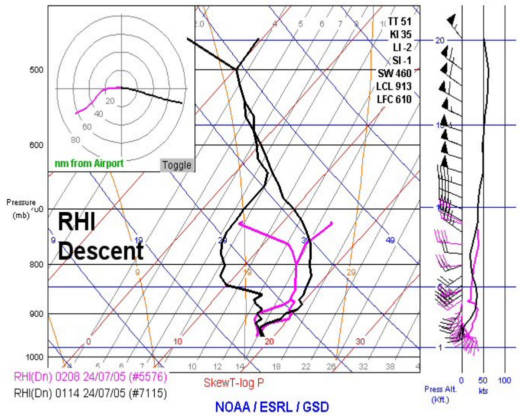

Fig. 36. RHI TAMDAR soundings from 0114 UTC (black) and 0208 UTC (pink) 24 July 2005.

was somewhere between RHI and MQT.

As the low-level jet continued to intensify, deep convection did break out a few hours later between 0400 and 0500 UTC but was confined to an area generally north of a BRD to RHI line (Fig. 38) as suggested by the TAMDAR soundings. 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 along the northern edge of the cap (Fig. 39). The updated 0500 UTC SPC Day 1 Convective Outlook removed the risk of severe thunderstorms over the western Great Lakes region. Only marginally severe weather was expected during the early morning hours with the ongoing convection over far northern Wisconsin (Fig. 38).

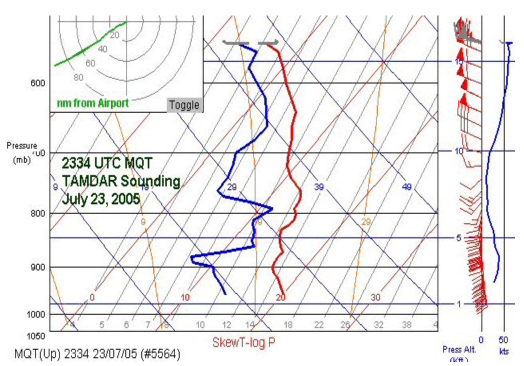

Fig. 37. MQT TAMDAR sounding at 2334 UTC 23 July 2005.

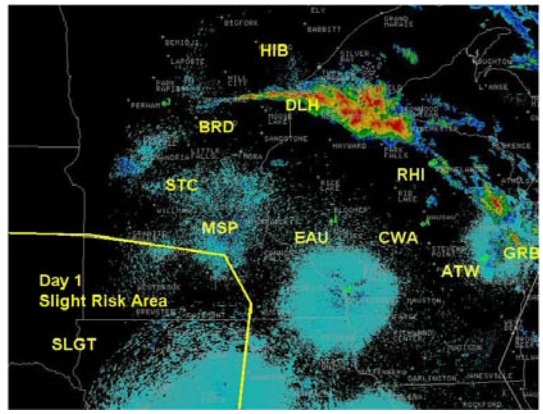

Fig. 38. Radar Reflectivity and SPC Day 1 Outlook for 0500 UTC 24 July 2005.

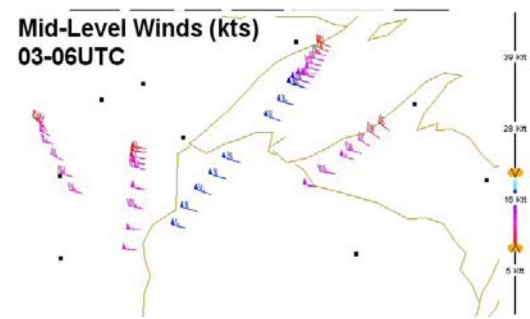

Fig. 39. TAMDAR Aircraft winds between 7000 and 2000 ft for 0300 to 0600 UTC 24 July 2005.

4.3 07 August 2005 Case

4.3.1 Overview and Synoptic Situation

During the morning of 07 August 2005, NWS forecasters at western Great Lakes offices were assessing the potential for convective development later in the day over central Minnesota into western Wisconsin. Although the current forecast was dry for the next 6 to 12 hours across the region, the 1200 UTC models (particularly the North American Model (NAM)) were suggesting convective development toward midday across portions of northeast Minnesota into northwest Wisconsin (Figs. 40 and 41) in the vicinity of a stationary surface boundary and to the east of an approaching upper-level disturbance (Figs. 42 and 43). Model forecasts and SPC mesoanalysis were indicating that most unstable CAPE values (MUCAPE) would likely exceed 3000 J Kg-1 by mid-afternoon with continued low-level moisture advection and surface heating. By 1600 UTC visible satellite imagery indicated some weak elevated convection trying to get organized over central Minnesota in a region of low-level warm air advection and where the surface-based convective inhibition (CIN) was weakening (Figs. 42 and 44). The updated 1900 UTC SPC Day 1 Convective Outlook (Fig. 42) outlined this region for a slight risk of isolated severe convection and possible issuance of a watch based on model forecasts of marginally favorable deep layer shear and assuming that the convection could become surface-based within the next few hours.

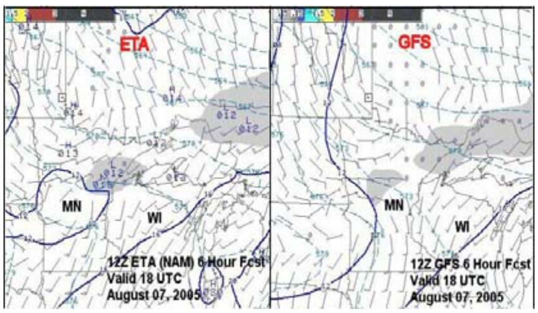

Fig. 40. 1200 UTC runs of the NAM (left) and GFS (right) valid at 1800 UTC 07 August 2005 with surface pressure (dark blue), wind (black barbs), 6 hour precipitation (grey shading) and 500 mb heights (dashed teal lines).

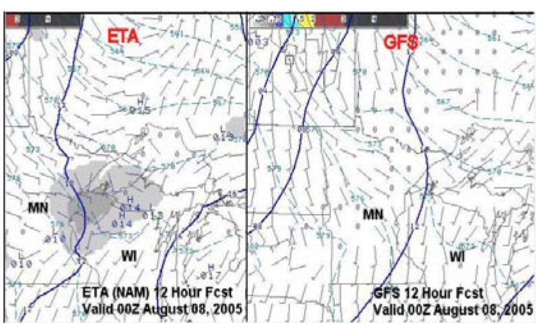

Fig. 41. Same as Figure 52 valid at 0000 UTC 08 August 2005.

4.3.2 TAMDAR Soundings

Several TAMDAR soundings located within and near the SPC Day 1 Convective Outlook area were examined and compared to initial model forecast soundings to assess the convective potential for the next few hours.

A comparison of the 12 UTC Global Forecast System (GFS) and NAM soundings to a TAMDAR sounding located near Brainerd, Minnesota (BRD) indicated that the initial NAM sounding was too moist (Fig. 45). Much of the western Great Lakes and upper Mississippi Valley had been experiencing prolonged drought conditions and the NAM was consistently overdoing the moisture and quantitative precipitation forecast (QPF) prior to the event. This may explain much of the difference in the forecast QPF between the NAM and GFS forecast for later in the day (Fig. 41). The 1200 UTC NAM also did not appear to capture the strength of the morning surface-

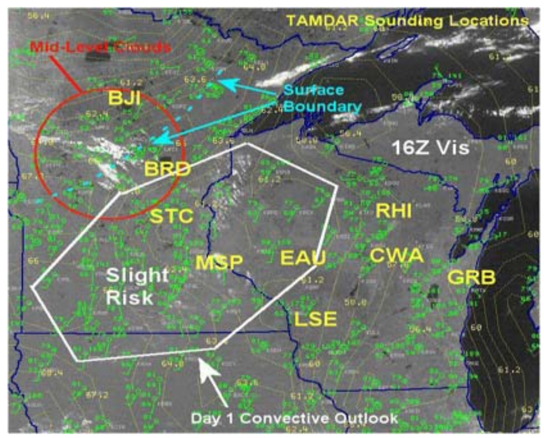

Fig. 42. Visible Satellite Imagery and surface plot from 1600 UTC 07 August 2005 with TAMDAR locations, surface boundary (blue line) and 1900 UTC SPC Day 1 Outlook (white).

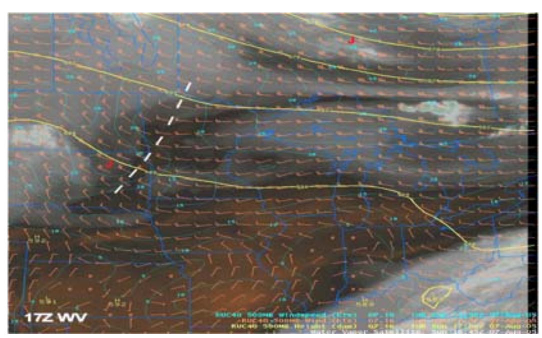

Fig. 43. 1645 UTC Water Vapor Imagery with 500 mb heights (yellow), wind barbs (orange), wind speeds (blue) and shortwave (white) at 1700 UTC 07 August 2005.

based inversion as well as the GFS. Comparison of the 1200 UTC BRD sounding with the corresponding RUC sounding indicated that although the RUC captured the vertical moisture structure fairly well, it too underestimated the strength of the surface-based inversion (Fig. 46). By 1500 UTC these differences were even more apparent as the NAM sounding was still too moist, with both the RUC and the NAM considerably underestimating the strength of the low-level inversion (Fig. 47). A similar situation was noted in a 1400 UTC RUC and Bemidji, Minnesota (BJI) sounding comparison (not shown).

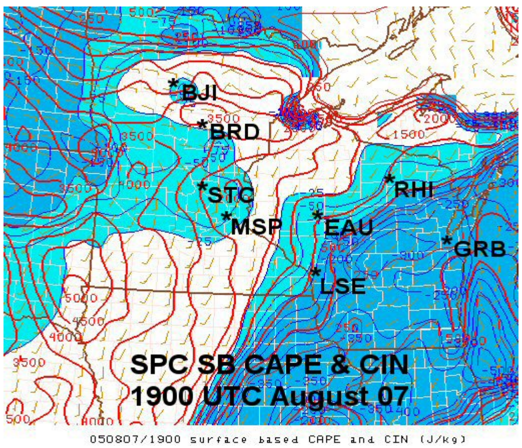

Fig. 44. SPC mesoanalysis from 1900 UTC 07 August 2005 with Surface based CAPE (red lines) and CIN (blue lines and shaded areas).

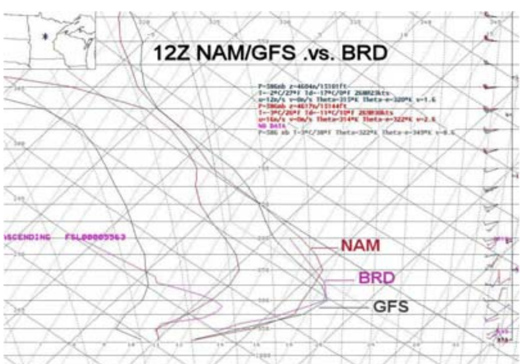

Fig. 45. BRD NAM (red), GFS (black) and TAMDAR (pink) soundings from 1200 UTC 07 August 2005.

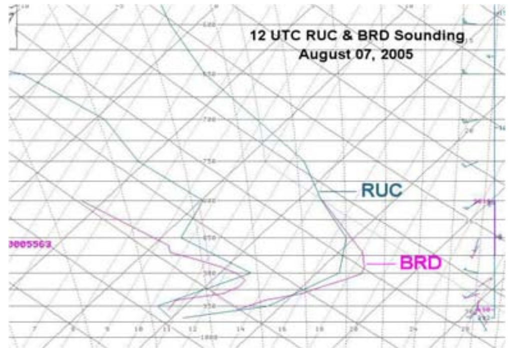

Fig. 46. BRD RUC (teal) and TAMDAR (pink) soundings from 1200 UTC 07 August 2005.

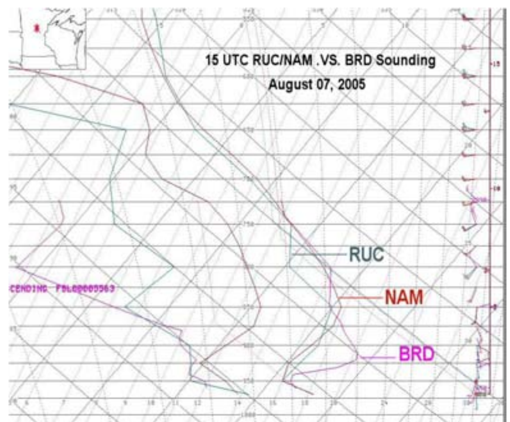

Fig. 47. BRD RUC (teal), NAM (red) and TAMDAR (pink) soundings from 1500 UTC 07 August 2005.

Continued examination of TAMDAR soundings within and near the SPC slight risk area at EAU (not shown) and Saint Cloud, Minnesota (STC) through mid-afternoon indicated that the atmosphere in the low to mid-levels was drier and the capping inversion centered around 900 mb was stronger than anticipated, suggesting that surface-based convection was unlikely for the remainder of the day (Fig. 48). The models, including the RUC, continued to underestimate the location and strength of the inversion during the afternoon in the slight risk area (Fig. 49). This gave GRB forecasters enough confidence to keep the forecast dry over their entire forecast area through the remainder of the afternoon and overnight in their 2100 UTC forecast package (Fig. 50).

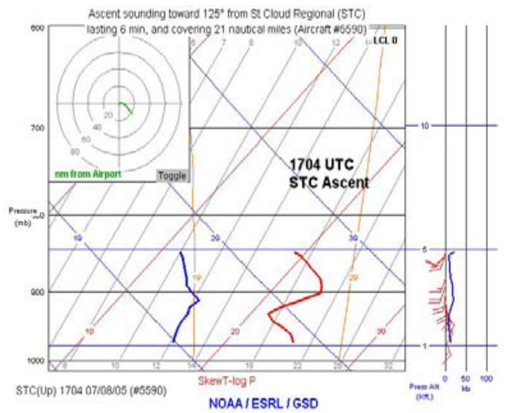

Fig. 48. TAMDAR sounding from STC at 1704 UTC 07 August 2005.

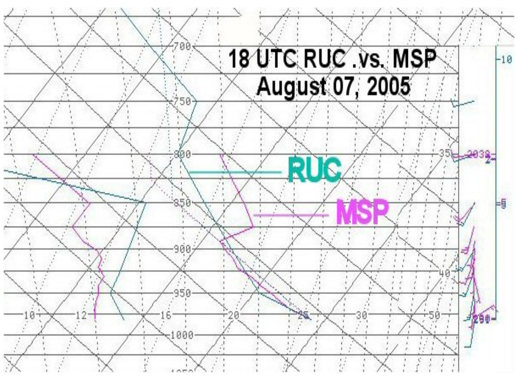

Fig. 49. MSP RUC (teal) and TAMDAR (pink) sounding at 1800 UTC 07 August 2005.

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE GREEN BAY WI
355 PM CDT SUN AUG 7 2005

.SHORT TERM...TONIGHT THROUGH MONDAY...

...**OBSERVED REGIONAL AIRCRAFT SNDGS NEAR MSP...BRD...RHI...CONTINUE TO SHOW PERSISTENT MID-LEVEL DRY AIR AND CAP WHICH IS KEEPING ORGANIZED CONVECTION AT BAY**. FCST NAM SNDGS TOO MOIST AND ONCE AGAIN OVERDOING QPF NEAR WEAK FRONTAL BOUNDARY NE MN AND NW WI THIS EVENING. GFS FCST SNDGS/QPF MORE REALISTIC...

...**THUS CONTIUNED DRY FCST THROUGH MIDDAY MONDAY**...

Fig. 50. Excerpt of Area Forecast Discussion issued at 2055 UTC 07 August 2005 from NWS GRB.

Between 2200 and 2300 UTC, isolated and weak elevated convection did eventually develop over east-central Minnesota and SPC issued Severe Thunderstorm Watch # 702 in effect until 0500 UTC (Fig. 51). However, the convection weakened quickly by 0200 UTC (Fig. 51) with no severe weather reported.

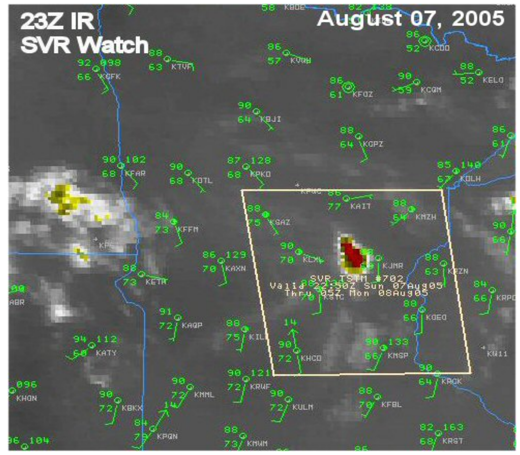

Fig. 51. Infrared Imagery and surface plot from 2300 UTC 07 August 2005 with Severe Thunderstorm Watch # 702 (cream) issued at 2250 UTC.

5. SUMMARY AND CONCLUSIONS

During the year-long TAMDAR Great Lakes Fleet Experiment (GLFE) which began in January 2005, NWS forecasters had a rare opportunity to utilize a near mesoscale sounding dataset in assessing a variety of forecast situations. The focus of this paper was to highlight the utility of the regional aircraft sounding data in short-term (0-12 hour) convective forecasting.

Two cases were presented in which no severe weather or only marginally severe weather was anticipated. The increased temporal and spatial resolution TAMDAR soundings allowed forecasters to frequently monitor and more accurately assess subtle changes in the near storm environment that contributed to the formation of several weak "landspout" tornadoes more characteristic of non-supercellular convection. The TAMDAR soundings helped to increase the forecaster's situational awareness with respect to the subtle tornado potential, resulting in more timely and accurate information to the public. These cases illustrate the potential of regional aircraft data in increasing the probability of detection (POD) of severe weather, particularly in environments marginally supportive of severe thunderstorms and tornadoes, and/or environments that are evolving rapidly.

Several null cases were also presented in which severe weather was anticipated within the next 12 hours but did not materialize. In these cases, an important limiting factor was the presence of a substantial cap that was not adequately sampled by the existing radiosonde network and/or was underestimated by short-term model forecasts. The more frequent sampling of the cap provided by the TAMDAR-equipped aircraft in these cases provided forecasters with a more timely, accurate and complete picture of the horizontal extent and vertical structure (height and intensity) of the cap. This improved detection allowed forecasters to more accurately assess short-term model forecasts of the cap and thereby has potential to reduce false alarms related to convective warnings, watches and short-term outlooks (Kurimski and Schumacher 2005). In addition, a recent study by Szoke et al. (2006), demonstrated that inclusion of TAMDAR data into the RUC data assimilation showed a notable improvement in the RUC short-term (6 hour) precipitation forecasts.

6. ACKNOWLEGEMENTS

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