# 4.3 HI-RISE – HAZARDOUS INCIDENT RAPID IN-FLIGHT SUPPORT EFFORT: USE OF ASYNOPTIC UPPER-AIR DATA TO IMPROVE WEATHER FORECASTS AT WILDLAND FIRES & OTHER HAZARDOUS INCIDENTS

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## 1. INTRODUCTION

Quality weather forecasts for wildland fires and other hazardous material (HAZMAT) incidents depend on surface and upper air observations along with model data. Often, meteorologists deploy directly to the wildfire or incident. These on-site meteorologists are called Incident Meteorologists (IMETs). Off-site meteorological support is also provided by National Weather Service (NWS) Weather Forecast Offices (WFOs).

Routine and non-routine surface observations provide invaluable information to monitor current weather, warn others of impending hazards, and to improve incident forecasts. Surface observations from fixed Remote Automated Weather Station (RAWS) sites, portable RAWS or other nearby sensors (Automated Weather Observing System − AWOS, Automated Surface Observing System − ASOS, etc.) usually provide adequate spatial and temporal resolution to understand surface weather conditions. In addition, supplemental surface observations taken by IMETs or trained incident crew members can provide a relatively dense observation grid in even the most remote areas. Two or more observation points with at least hourly data are common within 16 to 40 km (10 to 25 miles) of the incident, according to National Fire Weather Operations Coordinator L.J. VanBussum (personal communication, 2005). Manual observations using a belt weather kit can be taken more frequently by the IMET or the incident crew.

However, the spatial and temporal resolution of upper air observations is much coarser. The average distance between rawinsonde stations in the Continental U.S. is 315 km (Fig. 1; OFCM, 1997). These upper air observations are taken two times per day around 0000 and 1200 UTC. There is a processing and transmission time-delay of one to three hours from the time of the upper air observation until data is available for use by the IMET. Despite the spatial and temporal limitations of the synoptic upper air observation network, IMETs use this data to make forecasts.

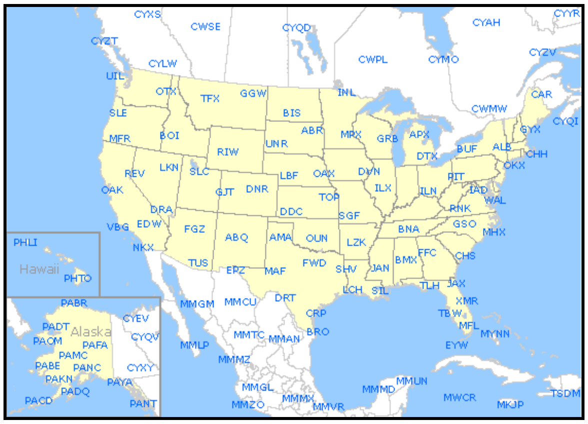

Figure 1: Continental U.S. rawinsonde sites.

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The HI-RISE (Hazardous Incident − Rapid In-flight Support Effort) concept would allow routine access to real-time local upper air observations at an incident similar to surface observations; which would significantly improve weather forecasts. On April 21, 2005 at a controlled burn site in central Texas, asynoptic upper air data were collected and relayed in real-time from a single-engine air tanker aircraft to on-site IMETs and to a meteorologist at WFO Austin/San Antonio, TX (EWX). This HI-RISE test was a collaborative effort between four organizations: NWS, Texas Forest Service (TFS), USDA Agricultural Research Station (USDA-ARS), College Station, TX, and Aventech Research Inc. (Aventech), Barrie, ON, Canada. NWS participants included meteorologists from EWX, WFO Midland/Odessa, TX (MAF), and Southern Region Headquarters in Fort Worth, TX.

Two on-site IMETs provided forecasts and briefing support for the incident (controlled burn). One lead IMET served as the official weather source for both ground and air operations. This IMET had access to the HI-RISE upper air data to adjust the forecast if necessary. The second IMET served as a control without access to the supplementary data. Any adjustments to this control forecast would come from the routine sources of weather data available to IMETs. EWX would also have access to the HI-RISE data for incident support and preparation of routine, daily fire weather forecasts. This paper will discuss: templates for HI-RISE, the sensing and communication equipment used, the HI-RISE aircraft, the sounding analysis software used, a discussion of weather conditions, analysis of the HI-RISE data, input from the fire crew, and conclusions and recommendations for additional HI-RISE tests.

## 2. TEMPLATES FOR HI-RISE

The ability to collect routine weather data from aircraft has been available for several decades, but was not necessarily cost effective. This changed with the development of automated weather sensors and improvements in communication technology. First developed as part of the Global Weather Experiment in 1979 (Fleming, 1996), the Aircraft Communications, Addressing, and Reporting System (ACARS) is now utilized in commercial aircraft to provide over 130 000 daily wind and temperature observations. This data is processed by NOAA's Forecast Systems Laboratory (FSL) to provide real-time sounding and forecast data to operational meteorologists. While these reports have greatly enhanced the availability of upper air data to supplement rawinsonde observations, most of this data are confined to ascent/descent regions around major hubs or elevations above 7620 m (25 000 ft) MSL (Moninger et al. 2003).

As technological improvements to sensing equipment have become more cost effective, a recent initiative capitalized on the lower level flight patterns of smaller aircraft. The National Aeronautics and Space Administration (NASA) spearheaded the Tropospheric Airborne Meteorological Data Report (TAMDAR) project (Daniels et al. 2004). The TAMDAR goal was to utilize regional commercial aircraft serving smaller airports to collect data mainly below 7620 m MSL. This effort complemented the high-level ACARS data collection by dramatically increasing data points in both time and space.

From Fall 2004 through Spring 2005, the Great Lakes Flight Experiment (GLFE) tested the utility of TAMDAR. GLFE equipped TAMDAR sensors on 64 turbo-prop Saab 340 aircraft. The aircraft flew routes to 75 airports around the Great Lakes (Moninger et al. 2004). The aircraft collected wind speed, wind direction, temperature, humidity, turbulence, and icing data. In addition to access through the FSL ACARS website, the data were incorporated into the Rapid Update Cycle (RUC) Model and provided to NWS forecasters for comparative analysis. HI-RISE builds on the ACARS and TAMDAR concepts to provide data at the incident management scale.

## 3. SENSING AND COMMUNICATION EQUIPMENT

### 3.1 AIMMS-20

The Aircraft–Integrated Meteorological Measurement System (AIMMS-20) (Figs. 2 and 3) used for HI-RISE is a fully integrated turnkey system that can be installed on a wide variety of aircraft types. Raw sensor data is processed on-board the aircraft, resulting in datasets comprised of temperature and humidity, each tagged in three-dimensional space and time. The AIMMS-20 combines air data from an externally mounted probe with GPS and inertial signals to compute high-accuracy wind speed and direction data in real time.

The purchase price of the AIMMS-20 is \$28,000 U.S. Dollars (USD). Installation and certification typically costs less than \$3,000 USD. The Iridium satellite communication option adds \$4,000 USD to the hardware cost, and approximately \$10 USD per hour for the data link. Installation typically takes 1-2 days.

Figure 2: Front view of AIMMS-20 mounted on the AT402 HI-RISE aircraft.

Figure 3: Rear view of the AIMMS-20.

Although data can be transmitted to a cockpit display, HI-RISE did not employ this option. The high intensity and dangerous nature of wildland fire and other HAZMAT type missions requires that the pilot's full attention be focused on flying.  Instead, HI-RISE data was sent via the Iridium satellite network, with AIMMS-20 operation being completely transparent to the pilot.

As illustrated in Figure 4, data were transmitted from the aircraft to Iridium satellite constellation 780 km overhead, then from the Iridium constellation to the Iridium ground station. The ground station then forwarded the data via Internet email to Aventech. Aventech extracted slant-vertical ascent segments from the flight record to construct sounding data files in comma-separated variable (CSV) format that can be readily imported into a sounding analysis program. The sounding data files were then sent via Internet email to the IMETs and the WFO meteorologist. The latency of the Iridium network (i.e., time from aircraft transmission to Aventech) is measured in seconds. However, it took approximately 15 min from the top of the aircraft ascent to have the data assembled, inspected, sounding profile extracted, and delivered via email to the IMETs and the WFO meteorologist.

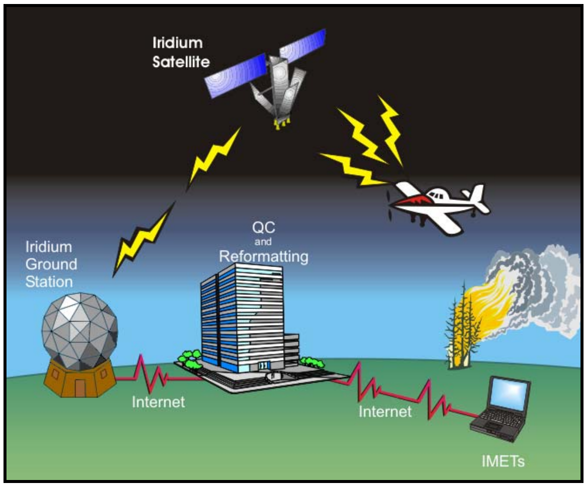


Figure 4: HI-RISE data flow.

The AIMMS-20 logs data records every 20 s during level flight and once every 5 s during periods of ascent or descent.  Data transmission is automatically scheduled by the AIMMS-20 once an internal data buffer has accumulated 20 records, which translates into a 400 s period during cruise and a 100 s period during ascents and descents.  This variable frequency scheme was selected to minimize the volume of data by focusing on flight segments with rapidly changing altitude to provide good vertical resolution for the resulting sounding profiles. A 5 s update period corresponds to a vertical resolution of ~25 m if the climb or decent rate is 305 m $min^{-1}$ (~1,000 ft $min^{-1}$).  A 20 s update period corresponds to a horizontal resolution of 1.2 km at a cruise speed of 62 m $s^{-1}$ (~120 kts).

### 3.2 Calibration and Comparison with Ledbetter NOAA Profiler

The AIMMS-20 requires an initial flight calibration for each installation to achieve full accuracy of 0.5–1.0 m $s^{-1}$ for the wind vector components. A calibration flight requires only 10 min of flight time and a post-analysis to determine the set of parameters that characterize aerodynamic errors due to the host aircraft platform.

AIMMS-20 wind data from a test run on April 14, 2005, and the two HI-RISE flights on April 21, 2005, were compared to the Ledbetter, TX, NOAA Wind Profiler. Detailed comparisons of these data, model analysis soundings, and ACARS profiles, will be in a future paper. In the context of this paper, the HI-RISE AIMMS-20 data were found to be within 5-10 degrees azimuth for wind direction, and 1-2.5 m $s^{-1}$ speed compared to the Ledbetter profiler. Considering the distance from the HI-RISE site to Ledbetter site is approximately 80 km, the variation could simply be due to differences in ambient conditions. In addition, differing sampling periods and averaging schemes could also result in differences. Mickle (2005) found the AIMMS-20 provided wind profile measurements within 0.5 m $s^{-1}$ of those taken with a sonic detection and ranging (SODAR) instrument.

## 4. HI-RISE AIRCRAFT

Figure 5. The Air Tractor AT-402B aircraft used in HI-RISE.

An Air Tractor AT-402B aircraft (Figure 5), equipped with the AIMMS-20 system, was used in the meteorological profiling. This is an agricultural aircraft typically used in spray application of crop protection products (herbicides/fungicides). While this aircraft does not have any wildland fire fighting capabilities, the larger model AT-802 can be adapted for fire suppression activities. As a research aircraft, the AT-402B used in this study was IFR (Instrument Flight Rated) certified, which is not typical of most agricultural aircraft. The flight requirement of this study could not have been completed without the IFR capabilities. The flight plan was an ascending box pattern near the burn site. The aircraft started at 152 m (~500 ft AGL) and climbed 914 m (~3000 ft) on a fixed heading. The aircraft then banked 90° and climbed an additional 914 m and repeated the turn/climb maneuver twice more for a final height of approximately 3962 m (13 000 ft) at 1700 UTC and 3810 m (12 500 ft) at 1900 UTC. The climb rate was approximately 305 m $min^{-1}$, which resulted in a 9.65 km square box. The total flight time was between 1 and 1.5 hrs, well within the aircraft's 3 hr flight time range. One major issue encountered with the flight schedule was the presence of dense, low-level cloud cover, combined with the close proximity to the commercial aircraft approach path into Austin Bergstrom Airport International Airport (KAUS). The pilot had to fly IFR to ascend above cloud cover, and maintain radio contact with air traffic controllers to provide navigation fixes in order to reach the desired profiling height. This resulted in only two profiling flights instead of the planned three flights.

## 5. SOUNDING ANALYSIS PROGRAM

HI-RISE IMETs needed an analysis tool for quick interpretation of the upper air sounding data. The software package chosen was RAOB (Rawindsonde Observation) Program (Shewchuk, 2005). RAOB provides a complete sounding analysis program, including Basic, Analytical, and Interactive modules. Advantages of the program include; flexible data input and interactive editing, and comprehensive parameter calculations. RAOB also has the ability to group parameters into specific displays including; severe weather, winter weather, soaring, and fire weather.

## 6. WEATHER DISCUSSION

Early morning conditions across the Southern Plains showed the potential for afternoon thunderstorms to be the primary forecast concern for the day. 1200 UTC analyses at 500 mb, 700 mb, and 850 mb showed a strong shortwave trough over the southern Rockies. The 1200 UTC surface analysis showed a trough/dry line from southwestern Kansas extending south into the Texas Big Bend. Morning upper air soundings from CRP (Fig. 6)/DRT/FWD indicated CAPE in excess of 1500 J $kg^{-1}$, precipitable water around one inch (near the long-term mean for April), and a capping inversion between 800 and 825 mb.

The mid-level shortwave trough and daytime heating were expected to increase destabilization, while the surface trough/dry line initiated deep convection. In addition, the destabilization might be sufficient for the sea-breeze to initiate convection along the Upper Texas Coast. The primary forecast concern on the synoptic scale was whether the destabilization and surface forcing would be sufficient to produce deep convection.

Examination of the 0000 UTC 500 mb, 700 mb, 850 mb, and surface analyses shows the short wave trough lost amplitude and propagated east to an axis from eastern Oklahoma to southwestern Texas. The surface trough/dry line was in a similar location. Meanwhile, destabilization had occurred at DRT, but the cap held at FWD and CRP. A special 1800 UTC sounding from FWD indicated the cap remained in place through the afternoon. Consequently, deep convection did initiate along the dry line in West Central Texas, and the resulting thunderstorms produced one tornado and five severe hail reports. However, the cap prevented deep convection east of the dry line, including over Camp Swift.

An early morning low level jet brought Marginal Visual Flight Rules (MVFR) ceilings to the burn site prior to the commencement of the test. A sharpening and advancing dryline to the west and surface high pressure over the northeast Gulf of Mexico helped maintain southerly low level flow. Due to diurnal heating, low clouds lifted as low level lapse rates neared dry adiabatic around noon CDT. A 700 mb to 500 mb temperature difference of 22°C also indicated the presence of mid-level instability, confirming the chance for thunderstorms.

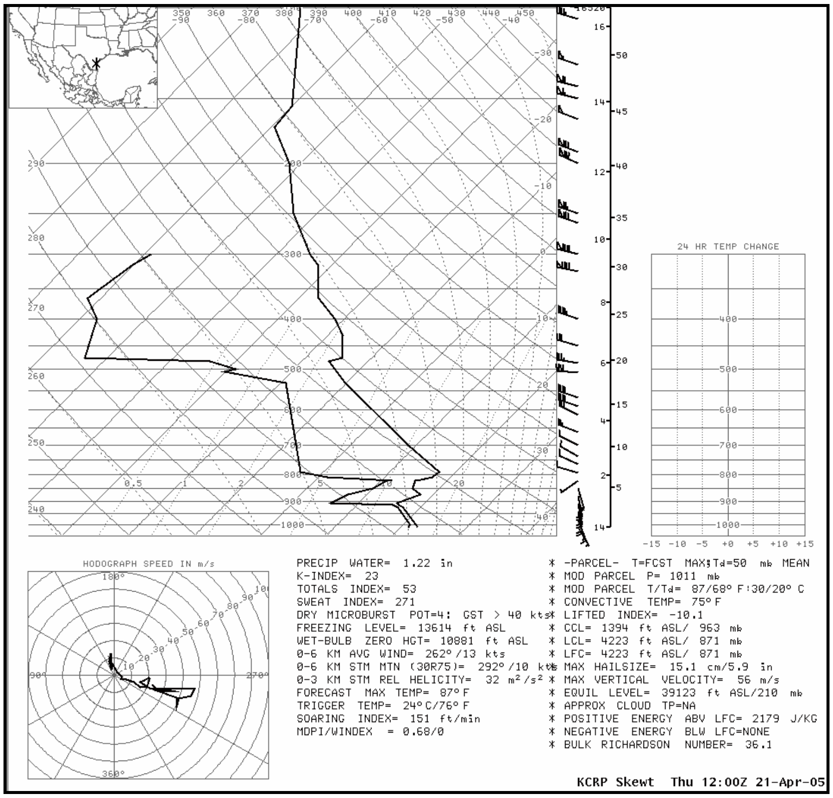
## 7. ANALYSIS OF THE HI-RISE DATA

Once the 1700 UTC HI-RISE sounding data (Table 1) was received and analyzed, a sharp low level inversion was the most pronounced feature (Figure 7 and Table 2). Using the RAOB program, the IMET was able to determine the inversion base was at 1368 m and 863 mb, while the top of the inversion was 2156 m and 786 mb. Thus, the depth of the inversion was 788 m and 77 mb, with a temperature increase of 2.7°C.

Based on this information, the lead IMET determined the following: 1. there would be a reduced chance of deep convection that afternoon, and 2. mixing heights would be lower, and transport winds weaker than originally forecast, resulting in poor ventilation. This amended fire weather forecast was briefed to the HI-RISE burn team. They were concerned that the poor ventilation would cause smoke to drift across a busy highway (U.S. 290). Because of these safety concerns, the burn team decided to move the burn site one mile to the west. In contrast to the lead IMET, routine data did not provide the control IMET enough certainty to reduce the risk of thunderstorms. However, surface data and visual observations indicated poor ventilation, but adjustments to the forecast lacked the precision that the HI-RISE data afforded the lead IMET. Later that day and evening, isolated thunderstorms eventually developed across West Central Texas. These storms were west of the burn site and occurred in proximity to the surface boundary.

The HI-RISE flights compared well with the special 1800 UTC FWD sounding and 2100 UTC RUC2 model sounding at the nearest point to Camp Swift (17.2 km at 315° from Giddings-Lee County Airport [KGYB]), in terms of showing the persistence of the capping inversion near 800 mb. Even though the RUC2 model soundings are generally available from across the contiguous United States, the points at which model soundings are available can be some distance from the fire location, and in steep terrain, completely misrepresent local conditions at the fire location. The special sounding at FWD was to evaluate the potential for severe convection, and would not normally occur. Therefore, the HIRISE soundings were crucial for decision making at the burn site.

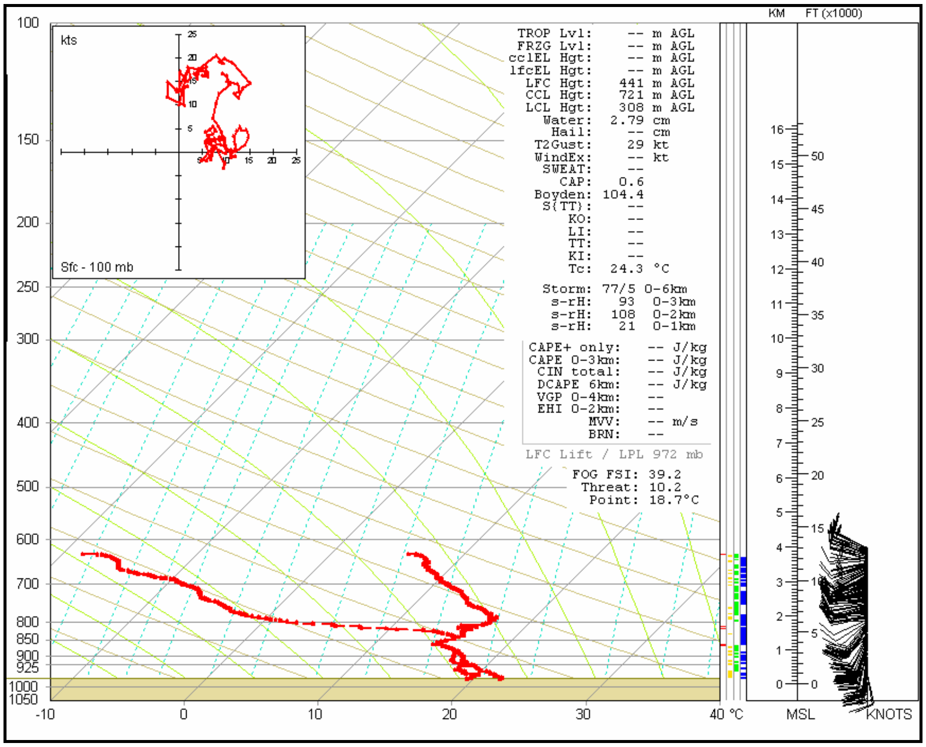
The 1700 UTC HI-RISE sounding began at 1641 UTC. The first data point was recorded at a height of 343 m (MSL) and a pressure of 972 mb. The last data were collected at 1653 UTC at a height of 3984 m and pressure of 631 mb. During the ascent, meteorological data was collected at 143 points. The difference between points averaged around 30.5 m (~3 mb), dependent on the rate of ascent. The data packet arrived via email to the IMETs and the WFO meteorologist at 1708 UTC. Based on the 9.65 km square box flight pattern, and the recorded latitude and longitude at each data collection point, the sounding sample was nearly equivalent to balloon sounding trajectories.



```
PRECIP  WATER=  1.22  in                   *  -PARCEL-  T=FCST  MAX;Td=50  mb  MEAN
K-INDEX=  23                               *  MOD  PARCEL  P=  1011  mb
TOTALS  INDEX=  53                         *  MOD  PARCEL  T/Td=  87/68° F:30/20° C
SWEAT  INDEX=  271                         *  CONVECTIVE  TEMP=  75° F
DRY  MICROBURST  POT=4:  GST  >  40  kts   *  LIFTED  INDEX=  -10.1
FREEZING  LEVEL=  13614  ft  ASL           *  CCL=  1394  ft  ASL/  963  mb
WET-BULB  ZERO  HGT=  10881  ft  ASL       *  LCL=  4223  ft  ASL/  871  mb
0-6  KM  AVG  WIND=  262°/13  kts          *  LFC=  4223  ft  ASL/  871  mb
0-6  KM  STM  MTN  (30R75)=  292°/10  kts  *  MAX  HAILSIZE=  15.1  cm/5.9  in
0-3  KM  STM  REL  HELICITY=  32  m²/s²    *  MAX  VERTICAL  VELOCITY=  56  m/s
FORECAST  MAX  TEMP=  87° F                *  EQUIL  LEVEL=  39123  ft  ASL/210  mb
TRIGGER  TEMP=  24° C/76° F                *  APPROX  CLOUD  TP=NA
SOARING  INDEX=  151  ft/min               *  POSITIVE  ENERGY  ABV  LFC=  2179  J/KG
MDPI/WINDEX  =  0.68/0                     *  NEGATIVE  ENERGY  BLW  LFC=NONE
                                           *  BULK  RICHARDSON  NUMBER=  36.1

                                              KCRP  Skewt   Thu  12:00Z  21-Apr-05
```

Figure 6: The 21 APR 1200 UTC Corpus Christi Sounding.



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 TROP Lvl:     -- m AGL
 FRZG Lvl:     -- m AGL
cclEL Hgt:     -- m AGL
lfcEL Hgt:     -- m AGL
  LFC Hgt:    441 m AGL
  CCL Hgt:    721 m AGL
  LCL Hgt:    308 m AGL
    Water:   2.79 cm
     Hail:     -- cm
   T2Gust:     29 kt
  WindEx:      -- kt
    SWEAT:     --
      CAP:    0.6
   Boyden:  104.4
    S(TT):     --
       KO:     --
       LI:     --
       TT:     --
       KI:     --
       Tc:   24.3 °C

    Storm:  77/5 0-6km
     s-rH:    93  0-3km
     s-rH:   108  0-2km
     s-rH:    21  0-1km

 CAPE+ only:     -- J/kg
 CAPE 0-3km:     -- J/kg
  CIN total:     -- J/kg
  DCAPE 6km:     -- J/kg
  VGP 0-4km:     --
  EHI 0-2km:     --
        MVV:     -- m/s
        BRN:     --
LFC Lift / LPL 972 mb
      FOG FSI: 39.2
       Threat: 10.2
        Point: 18.7°C
```

Figure 7: 1700 UTC HI-RISE sounding depicting the moist layer below the inversion.

Table 1: 21 April, 2005 1700 UTC HI-RISE Sounding (abbreviated)

| GPS Altitude (m) | P (mb) | T (°C) | Td (°C) | Wind Direction (deg) | Wind Speed (m $s^{-1}$) | Time (UTC) | Lat. (°N) | Long. (°W) |
|---|---|---|---|---|---|---|---|---|
| 343 | 972 | 21.9 | 19.5 | 178 | 6.7 | 1641 | 30.262 | -97.282 |
| 375 | 968 | 22 | 19.7 | 171 | 7.7 | 1641 | 30.263 | -97.287 |
| 415 | 964 | 21.6 | 19.6 | 168 | 6.2 | 1641 | 30.264 | -97.29 |
| 441 | 961 | 21.3 | 19.8 | 187 | 5.1 | 1641 | 30.264 | -97.293 |
| 476 | 958 | 21.2 | 20 | 186 | 5.1 | 1642 | 30.264 | -97.296 |
| 507 | 954 | 20.8 | 19 | 184 | 7.2 | 1642 | 30.265 | -97.299 |
| 533 | 951 | 20.7 | 18.7 | 187 | 7.2 | 1642 | 30.265 | -97.302 |
| … | … | … | … | … | … | … | … | … |
| 3941 | 633 | 6.5 | -17 | 292 | 6.7 | 1653 | 30.225 | -97.202 |
| 3959 | 632 | 6.4 | -17.4 | 298 | 8.2 | 1653 | 30.223 | -97.202 |
| 3977 | 631 | 6.2 | -17.9 | 299 | 8.2 | 1653 | 30.221 | -97.202 |
| 3984 | 631 | 5.8 | -18.5 | 300 | 8.2 | 1653 | 30.219 | -97.202 |

Table 2: 1700 UTC HI-RISE sounding table. Note: the inversion layer is shaded.

| GPS Altitude (m) | P (mb) | T (°C) | Td (°C) | Wind Direction (deg) | Wind Speed (m $s^{-1}$) | Time (UTC) | Lat. (°N) | Long. (°W) |
|---|---|---|---|---|---|---|---|---|
| 1347 | 865 | 15.1 | 15.1 | 211 | 11.3 | 1644 | 30.279 | -97.378 |
| 1357 | 863 | 14.6 | 14.6 | 226 | 10.8 | 1644 | 30.282 | -97.377 |
| 1368 | 863 | 14.4 | 14.4 | 225 | 9.8 | 1644 | 30.285 | -97.376 |
| 1403 | 859 | 14.6 | 14.6 | 228 | 8.7 | 1644 | 30.287 | -97.374 |
| 1454 | 854 | 14.8 | 14.8 | 223 | 8.7 | 1644 | 30.29 | -97.372 |
| 1461 | 853 | 15.1 | 15.1 | 225 | 9.3 | 1645 | 30.292 | -97.37 |
| … | … | … | … | … | … | … | … | … |
| 2058 | 795 | 16.9 | 1.2 | 269 | 5.7 | 1646 | 30.308 | -97.32 |
| 2079 | 793 | 16.8 | 0.8 | 268 | 5.7 | 1646 | 30.307 | -97.318 |
| 2102 | 791 | 17.1 | 0.4 | 269 | 6.2 | 1646 | 30.307 | -97.315 |
| 2129 | 789 | 16.6 | 0 | 264 | 7.2 | 1647 | 30.307 | -97.312 |
| 2156 | 786 | 17.1 | -0.6 | 258 | 7.7 | 1647 | 30.308 | -97.309 |
| 2186 | 784 | 16.6 | -1.2 | 252 | 7.7 | 1647 | 30.308 | -97.307 |
| 2213 | 781 | 16.5 | -1.7 | 251 | 7.2 | 1647 | 30.308 | -97.304 |

Table 3: Camp Swift observations taken with a belt weather kit. Note: Units kept to U.S. observation standards as they would be taken for a wildfire incident.

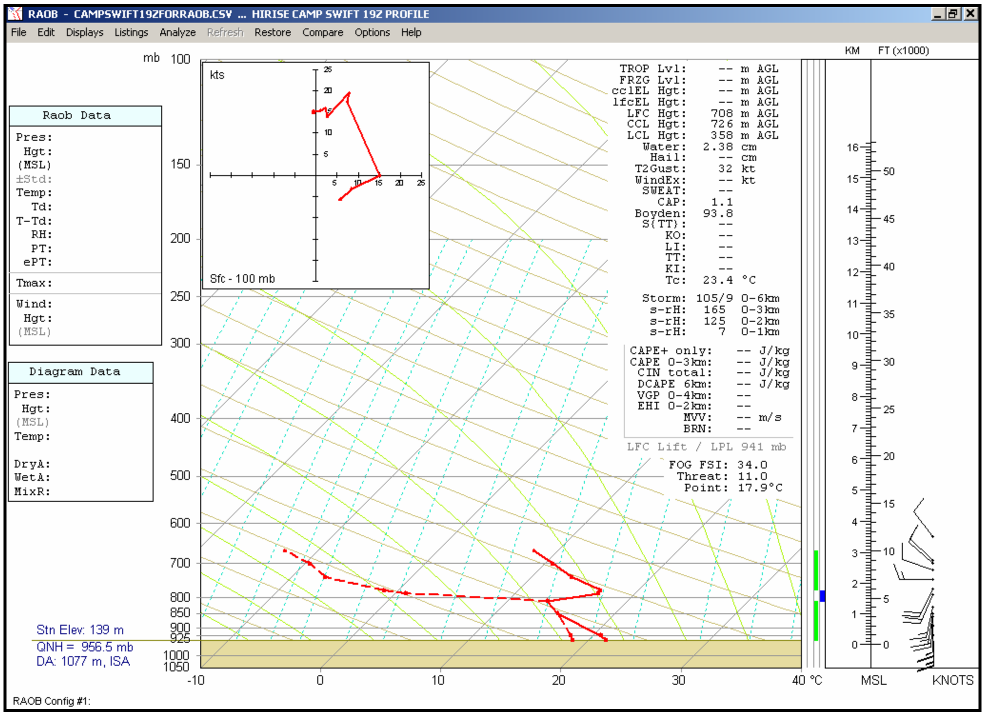
| Time (UTC) | Sky Condition (hundreds of feet, total obscuration) | Visibility (statute miles) | T (°F) | Td (°F) | RH (%) | Remarks |
|---|---|---|---|---|---|---|
| 1100 | 020 BKN | 7 | 69 | 67 | 95 | |
| 1245 | 020 OVC | 6 in fog | 70 | 68 | 90 | |
| 1339 | 007 SCT 020 OVC | 6 in fog | 71 | 68 | 90 | Breaks in overcast (BINOVC) |
| 1415 | 007 SCT 020 OVC | 7 | 72 | 68 | 86 | BINOVC |
| 1450 | 008 SCT 020 OVC | 7 | 73 | 69 | 86 | BINOVC |
| 1518 | 009 SCT 020 OVC | 7 | 76 | 69 | 78 | BINOVC |
| 1600 | 010 SCT 020 BKN | 7 | 77 | 68 | 75 | |
| 1630 | 010 SCT 020 BKN | 7 | 77 | 68 | 75 | |
| 1730 | 025 SCT 040 BKN | 7 | 78 | 69 | 75 | |
| 1815 | 025 SCT 040 BKN | 7 | 81 | 68 | 65 | |
| 1900 | 025 BKN 045 BKN | 7 | 79 | 69 | 71 | |
| 1955 | 028 FEW | 7 | 84 | 70 | 62 | |

The RAOB sounding analysis depiction and the alpha-numeric data indicated a relatively moist layer from approximately 335 m to 1646 m. That fit well with surface observations taken on-site that morning (Table 3). The Camp Swift observation at 1600 UTC and 1630 UTC indicated a 305 m (1000 ft) scattered deck and a 610 m (2000 ft) broken layer of clouds.

The 1900 UTC HI-RISE sounding data range extended between 617 m and 3826 m or from 941 mb to 643 mb. Total time flying time elapsed to collect the data was 17 min. The IMETs and the WFO meteorologist received the data in an email packet at 1950 UTC. This sounding indicated that the depth of the inversion layer had decreased by 788 m, but the temperature change in the inversion increased by 1.0°C. (Figure 8 and Table 4.) The data indicated the base of the inversion was at 1903 m and 810 mb with a temperature of 13.3°C. The top of the inversion was at 2199 m and 782 mb with a temperature of 17.0°C. The depth of the inversion was 295 m with a total temperature change of 3.7°C.

## 8. HI-RISE FIRE CREW COMMENTS

Rich Gray, Texas Forest Service Regional Fire Coordinator and HI-RISE burn crew leader, provided the following summary: *"HI-RISE technology would be invaluable to incident managers. During the HI-RISE test, the data improved the forecast by providing pinpoint accuracy over the general fire area. Even though the HI-RISE controlled burn was small, the real-time on-site access to the upper air data allowed the burn team to better plan for smoke impacts. Based on the 1700 UTC data, we decided to move the burn site and not degrade public safety by risking smoke drifting across a major road, U.S. Highway 290. Had this been a large scale burn, the data could have made the difference in a go/no go decision. While we did not experience critical fire weather during the project, it was evident that the HI-RISE technology could improve forecast timing and help identify the most critical fire weather elements over an area. These two facts are a major plus for incident managers as they make tactical plans, work to ensure crew safety, and better manage land management resources."*



```
  TROP Lvl:    -- m AGL
  FRZG Lvl:    -- m AGL
 cclEL Hgt:    -- m AGL
 lfcEL Hgt:    -- m AGL
   LFC Hgt:   708 m AGL
   CCL Hgt:   726 m AGL
   LCL Hgt:   358 m AGL
     Water:  2.38 cm
      Hail:    -- cm
   T2Gust:    32 kt
   WindEx:    -- kt
     SWEAT:    --
       CAP:   1.1
    Boyden:  93.8
     S(TT):    --
        KO:    --
        LI:    --
        TT:    --
        KI:    --
        Tc:  23.4 °C

     Storm: 105/9 0-6km
      s-rH:  165  0-3km
      s-rH:  125  0-2km
      s-rH:    7  0-1km

 CAPE+ only:    -- J/kg
 CAPE 0-3km:    -- J/kg
  CIN total:    -- J/kg
  DCAPE 6km:    -- J/kg
  VGP 0-4km:    --
  EHI 0-2km:    --
        MVV:    -- m/s
        BRN:    --
 LFC Lift / LPL 941 mb

   FOG FSI: 34.0
    Threat: 11.0
     Point: 17.9°C
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Stn Elev: 139 m
QNH =  956.5 mb
DA: 1077 m, ISA
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Figure 8. 1900 UTC HI-RISE with low data resolution settings to improve readability and provide quick interpretation.

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Table 4: 1900 UTC HI-RISE Sounding (abbreviated). Note the inversion layer in gray.

| GPS Altitude (m) | P (mb) | T (°C) | Td (°C) | Wind Direction (deg) | Wind Speed (m $s^{-1}$) | Time (UTC) | Lat. (°N) | Long. (°W) |
|---|---|---|---|---|---|---|---|---|
| 1859 | 815 | 14 | 14 | 192 | 9.3 | 1929 | 30.258 | -97.509 |
| 1881 | 812 | 13.6 | 13.6 | 205 | 7.2 | 1929 | 30.259 | -97.511 |
| 1903 | 810 | 13.3 | 13.3 | 210 | 7.2 | 1929 | 30.26 | -97.514 |
| 1924 | 809 | 13.4 | 12.3 | 212 | 8.7 | 1929 | 30.262 | -97.516 |
| 1954 | 805 | 13.4 | 11.6 | 214 | 6.2 | 1929 | 30.264 | -97.519 |
| 1982 | 803 | 13.7 | 10.1 | 213 | 5.7 | 1929 | 30.266 | -97.521 |
| 2013 | 800 | 14.1 | 8.4 | 226 | 6.7 | 1930 | 30.269 | -97.522 |
| 2046 | 797 | 14.8 | 6.7 | 241 | 6.7 | 1930 | 30.272 | -97.522 |
| 2071 | 794 | 15.2 | 4.9 | 257 | 6.2 | 1930 | 30.274 | -97.522 |
| 2101 | 791 | 15.7 | 3.6 | 271 | 7.2 | 1930 | 30.277 | -97.521 |
| 2135 | 788 | 16.8 | 2.2 | 270 | 7.7 | 1930 | 30.28 | -97.521 |
| 2164 | 786 | 16.9 | 0.9 | 271 | 7.7 | 1930 | 30.282 | -97.52 |
| 2199 | 782 | 17 | 0 | 274 | 6.7 | 1930 | 30.285 | -97.519 |
| 2231 | 779 | 16.9 | -0.7 | 275 | 6.2 | 1930 | 30.287 | -97.519 |
| 2259 | 777 | 16.8 | -1.2 | 275 | 6.2 | 1930 | 30.29 | -97.519 |

## 9. CONCLUSIONS & RECOMMENDATIONS

During the HI-RISE test, real-time on-site upper air observations provided useful weather information to IMETs and a WFO meteorologist supporting the incident. HI-RISE demonstrated that real-time on-site upper air data can be used to modify and improve the forecast. This helped meet the TFS goal of a safe burn for ground and aviation crews. The test also proved that asynoptic upper air data can be incorporated in real-time into an operational setting using off the shelf technology. HI-RISE data added a third dimension to a relatively dense surface observation network. The IMETs on-site and the WFO meteorologist noted their confidence in the forecast increased by having the asynoptic upper air data in real-time.

Varying degrees of uncertainty characterize weather forecasting. HI-RISE data reduced the variables (unknowns) resulting in a more reliable forecast. Being able to communicate that increased confidence in the forecast has a high value to decision makers applying weather information. On incidents where the loss of life and property are at great risk, the usefulness of this data would be apparent to the decision makers. To further explore the utility of HI-RISE data, future tests should be completed.

Testing the concept at a wildfire or a large controlled burn that involves an Incident Command Team, multiple crews, and different types of aircraft would provide a more rigorous operational setting. In addition to fixed wing aircraft, a HI-RISE test using a rotary wing aircraft should be tested. Helicopters offer more operational freedom, conferred by vertical takeoff and landing ability and slow forward flight speeds including hover.

The use of HI-RISE data as input for a mesoscale model, either run on-site by the IMET or from a WFO, would demonstrate if asynoptic upper air data improved model forecasts for the incident area. This type of test would emulate a 1997/98 Great Lakes snow study that used ground-based portable sounding equipment instead of an aircraft (Scott and Sousounis, 2001).

In addition, HI-RISE demonstrated the utility of flexible, on-site sounding analysis software (RAOB program). This type of software should be purchased and installed on IMET laptop computers to enable quick analysis of asynoptic or synoptic upper air data.

## 10. ACKNOWLEDGMENTS

The first author thanks Aventech, USDA – Agricultural Research Station at College Station, Texas Forest Service, WFO Midland/Odessa and WFO Austin/San Antonio for the time, talents, and tools that they contributed to conduct the HI-RISE test. Special thanks to TFS photographer Jan Amen, who provided outstanding photographic support and to USDA-ARS pilot Hal Tom, who flew two perfect HI-RISE missions. Thanks to Joe Arellano, Jr., for reviewing this paper.

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