SUMMARY REPORT

Educational Deployment of the University of Wyoming King Air

for the collaborative program

Student Training in Airborne Research and Technology (START)

submitted by

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1. Overview

A two-week deployment of the University of Wyoming King Air (UWKA) was conducted at Embry-Riddle Aeronautical University (ERAU) in Prescott, Arizona during late March and early April 2014. The primary goals of this program were to build knowledge on airborne atmospheric research for students as well as faculty across multiple Departments, and to collect a diverse set of aircraft observations for use in teaching, atmospheric model validation and the development of meteorological analysis and forecasting procedures that will support the ERAU pilot training operations.

Research aircraft orientation, logistical planning and data collection for 10 flights, as well as preliminary data analysis, were incorporated into a two-week time frame. Students and faculty were engaged in the project from Departments of Meteorology, Aeronautical Sciences, Engineering and Global Security. Direct flight experience was made possible for seventeen students, eight faculty members and one participant from the National Weather Service (NWS) Flagstaff office. Data obtained from the UWKA and concurrent radiosonde launches are being utilized for student research in the latter part of the current semester, and will be integrated with future courses for specific instructional content and student projects.

Broader outreach impacts of this program included presentation of a campus-wide seminar with pilot and scientist contributions and an open house for the UWKA at the ERAU Flight Center. Attendees at these events included AMS Chapter members from across Arizona, local middle school and high school students, ERAU students and their parents, ERAU faculty and other ERAU supporters from the community. Meteorology faculty members are also incorporating the outcomes of the deployment project into outreach activities planned for campus and regional schools.

2. Educational Objectives and Training Activities

The START program engaged students, faculty and other participants in learning several interdisciplinary aspects of airborne research programs that bridge the atmospheric and aeronautical sciences. ERAU is a private university but has a non-profit organizational structure with limited support for investment in research facility development. The ERAU Prescott campus has recently acquired (through donation) an experimental aircraft which is planned to be instrumented to allow interdisciplinary studies. The educational deployment of the UW King Air with advanced instrumentation was an excellent means to initiate teaching on airborne research across multiple programs such as meteorology, aeronautical sciences, engineering, aviation safety, computer sciences and physics.

The standard UWKA instrumentation to provide thermodynamic, kinematic, radiative and microphysical parameters including aerosol and cloud microphysics size distributions was requested for this deployment (Figure 1). Utilization of the Wyoming Cloud Radar or Lidar instrument systems was not requested, to provide the maximum space for student participants on the flights, and to focus this project on utilizing *in situ* data similar to measurement capabilities that may be considered for future development of an instrumented aircraft at ERAU.

Fig. 1. Photo of UWKA wing-mounted instrumentation with background view of San Francisco Peaks during a flight mission (6 April 2014).

The START project was a unique opportunity to bring together ERAU participants to learn aspects of aircraft-based research activities that could be directly applied to a campus-based initiative to construct an experimental aircraft for student research projects. The UWKA flight missions were also used for collection of valuable data sets for study and instruction in aviation hazards characteristic of the ERAU flight training base and region, for application to operational weather forecasting and for event simulation in support of the aviation degree programs.

Students participating in this project have gained experience and knowledge that is highly relevant to their academic program and career opportunities. ERAU students majoring in Meteorology have two

choices for Area of Concentration (AOC). The first AOC is Meteorology Research, which includes requirements for three semesters of atmospheric dynamics, two semesters of thermodynamics, atmospheric physics, engineering physics, engineering math, advanced differential equations, and specialized courses such as operational forecasting and remote sensing. The second AOC is Meteorology for Aviation Operations, including most of the courses as required for Research Meteorology, with specialized classes in flight (Private Pilot and Instrumented), applied climatology, aerodynamics, aircraft performance, domestic and international navigation, and airline dispatch operation. Within other Departments (primarily Aeronautical Sciences, Aviation and Aviation Safety), 65 students have Meteorology as a degree minor, which requires at least five full courses in Meteorology.

The UWKA deployment activities were based at Love Field (KPRC), which is a small community airport but is extremely busy due to flight training operations (Figure 2). Many events of strong wind shear including convective outflow conditions have been noted, and visibility in the flight training area can become restricted due to blowing dust and the occurrence of prescribed (or wildfire) smoke plumes. Study of local meteorological scenarios with airborne sampling and integration of these studies with forecast modeling have the potential to enhance aviation education and contribute significantly to the operational aspects of the flight training program.

Fig. 2. Example of approach and landing at KPRC airfield by an ERAU pilot training flight. The primary runway is oriented at 030-210 deg. The approach trajectory indicates higher terrain to the west of Prescott associated with the Granite Mountain range.

The timeline selected for the deployment was late March – early April in order to target a period of high wind events and the possible occurrence of springtime convective and orographic cloud systems. Since the ERAU spring semester courses end in late April, the UWKA deployment took place in the latter part of the semester. Students involved with the START project period were therefore primarily involved with identifying flight mission objectives, participating in onboard data collection, launching radiosondes in support of the project missions, and conducting preliminary analysis of data sets. Some of the aircraft and radiosonde data were utilized for student research and classroom activities during April. Faculty members are now developing instructional projects using the UWKA, radiosonde and

associated data resources for future classes in multiple Departments and are collaborating on development of interdisciplinary research opportunities with an educational focus.

In advance of the deployment, students from a range of classes in Meteorology, Engineering and Aeronautical Sciences worked with faculty members to select observational goals. Students (teams and individuals) proposed these as primary goals:

1. Observe the effects of atmospheric wave dynamics on turbulence and orographic cloud development.
2. Collect observations of cloud microphysical conditions associated with aircraft icing risk due to high concentrations of supercooled large droplets.
3. Produce case study data sets for mesoscale model prediction of strong cross-wind conditions which limit ERAU pilot training operations.
4. Demonstrate the potential for leeside eddies and flow reversal at KPRC due to Granite Mountain located to the west of Prescott.
5. Characterize particulate size distributions associated with aerosol sources such as wind-driven dust lofting and wildfires which restrict visual range for pilots.
6. Determine the correspondence of UWKA precipitation particle measurements with parameters derived from the NWS dual-polarization radar (located on the Mogollon Rim northeast of Prescott).
7. Obtain aircraft data sets that can be used to improve flight simulator scenarios for pilot training on aviation safety factors such as icing, turbulence, wind shear and restricted visibility.
8. Document the potential value of operationally implementing the WRF model at ERAU with specialized forecast products that support the ERAU pilot training program.

The flights captured a wide variety of event conditions (described in Section 3 below) during the two-week project, including dust lofting, boundary layer and elevated turbulence, cloud microphysical structure, as well as case studies for verification of WRF mesoscale model simulations at ERAU and the NWS-Flagstaff dual-polarization radar. Concentrating the flight operations in a region close to KPRC allowed capture of multiple conditions within single flight periods.

An aircraft orientation and safety briefing was provided for project participants on April 25 at the UWKA hangar base (Figure 3). Tom Drew (UWKA Research Pilot) presented information on aircraft layout, inflight communications, logistics and procedures. Participants were introduced to the aircraft instrumentation (Figure 4) and onboard data visualization consoles (Figure 5). Larry Oolman (UW Senior Research Scientist) presented a software training session on April 26 in an ERAU classroom for operation of the inflight data display functions and utilization of AEROS software for real-time and post-flight data access.

Fig. 3. Flight safety briefing at UWKA hangar base at KPRC on 25 April 2014, with participation of ERAU students and faculty planning to serve as flight scientists for the START project missions.

Fig. 4. Students and faculty members viewing the external configuration and sensor systems of the UW King Air at KPRC base operations site.

Fig. 5. Interior view of UWKA from entryway, showing instrument racks, data access / visualization computers used by onboard scientists (ERAU students and faculty), and pilot Tom Drew. Additional seats are located on the right side of the aircraft -- in the cockpit next to the pilot (allocated for ERAU faculty) and immediately to right of the middle console (allocated for UW lead scientist). Each of these seats also have data visualization computer systems.

Data collected during the deployment period have been utilized by students following the deployment operations. The AEROS software made available by NCAR EOL facilitates rapid viewing the aircraft data using time series, 2-D and 3-D scatterplots and flight tracks, size distributions and vertical profiles with multiple simultaneous parameters, visualization options and time segment selection. AEROS is also particularly valuable for students from a wide variety of Departments and ranging from freshman level upward, due to the ease of implementation. The AEROS real-time flight data monitoring capabilities were also very instructive when used for classes in session during individual flight missions (Figure 6).

The instructional applications of the UWKA case study data sets primarily used AEROS software in the initial data analysis, since this can be easily downloaded by any student on their own computers. Further data analysis for coursework will also utilize other NCAR-provided applications software and IDL, while the evaluation of WRF model simulations is typically conducted with the IDV software. Dr. Ivanova teaches courses which include student training in use of meteorological applications software such as IDL and IDV for scientific analysis and visualization. IDL and IDV will be applied in courses with upper-division students who have had prior training with these packages.

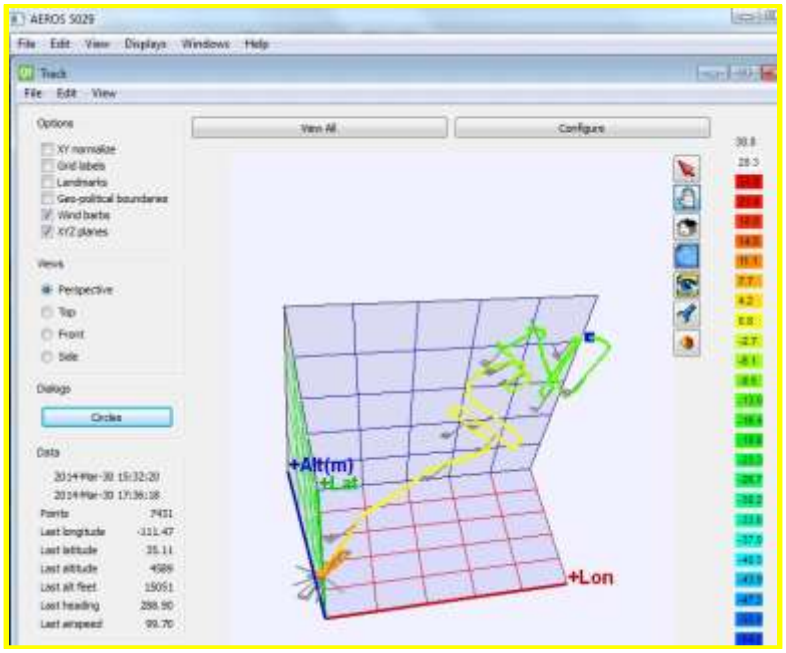

Fig. 6. Three-dimensional flight track visualization as displayed in real-time for a Meteorology class session during the 30 March flight mission.

The educational aspects of this project encompassed training in research flight operations as well as radiosonde launch procedures (Figure 7). Students and faculty members discussed meteorological analysis and forecast information with the UWKA group for daily mission decisions, typically meeting at 8 am and 4 pm, utilizing the ERAU Weather Center or the UWKA hangar base location (Figure 8). Radiosonde launches were scheduled at noon on flight days, from atop the three-story academic building which houses the Meteorology Department at the ERAU campus (a few km southwest of KPRC).

ERAU participants gained new knowledge on many aspects of research flight logistics, including the constraints of having multiple agency centers coordinating airspace control, flight altitude limitations in the vicinity of designated wilderness areas and other federal lands. The XChat utility was kept open during certain class sessions to engage students in real-time monitoring of conditions encountered as the flights progressed. XChat was also used for communication between the students launching the radiosondes and the scientists aboard the aircraft.

Students and faculty from multiple Departments understood that the UWKA flight experience and education related to aircraft instrumentation was an opportunity to evaluate types of sensors for a small experimental aircraft for ERAU. The recently acquired Van's RV-12 aircraft will be assembled during the coming year for future use in student research. This is a two-seat fixed-wing aircraft which will be suitable for research pilot training and atmospheric case studies, and will also be developed for testing of remotely-piloted control functions and systems.

Fig. 7. Radiosonde release at 1916 UTC 30 March 2014 from rooftop launch facility at ERAU campus.

Fig. 8. Flight mission planning session held at UWKA hangar operations base.

The WX270 course on instrumentation and measurement held this semester included instruction on sensors aboard the UWKA. A component of this class also guides students in building their own basic sensors, including some activities related to comparison of ground-based and aircraft measurement parameters. An example of a student project from this semester was the construction of a basic hot-wire anemometer, with testing and calibration of the sensor using one of the ERAU wind tunnels.

Professional pilot training relies on flight simulator technology, and the ERAU Flight Center has state-of-the-art simulation equipment and software for pilot education. This project was utilized to collect measurement data that can be applied to flight simulation models for scenarios of moderate turbulence, wind shear and cloud icing conditions.

3. Deployment Activities

3(a). Logistics

The UWKA was based at Prescott's Love Field (KPRC) in a leased hangar that included an office area which served as the base of flight operations. The UWKA group was comprised of Dr. Jeff French, Larry Oolman, Tom Drew and Ben Heesen. Jeff French and Larry Oolman provided essential scientific advice and inflight decision-making support that allowed for the maximum involvement of new students and faculty members on successive flights. Discussion between UWKA pilot (Tom Drew), UWKA scientists and ERAU faculty facilitated planning flight mission options and making in-flight track adjustments, and was extremely helpful in considering factors such as flight track limitations due to minimum altitude restrictions and avoidance of KPRC-based pilot instructional flights (Figure 9).

Flight operations for this project commenced with a Test Flight on March 25, followed by nine Research Flight days during March 26 to April 8. The entire allocation of 32 flight hours was utilized, and a wide range of conditions were sampled. Flight data are being posted to the UWKA flight web site and will be available after reprocessing of final data sets is complete. Radiosonde and auxiliary data collected by ERAU are available for educational purposes.

Figure 9. Depiction of ridge transect flight pattern used in initial discussion of this type of flight mission, with background terrain and major highways shown for geographic reference.

3(b). Flight Missions

Descriptions of each UWKA flight day are provided below with the aircraft track, radiosonde profiles and examples of data parameters that are being extracted for use in courses and student projects. Our initial emphasis is on application of the NCAR AEROS software which is easily usable by undergraduate students on their own computers.

25 March 2014: Test Flight (first flight from KPRC ; TF02) 1931 – 2025 UTC
ERAU Participants: Curtis James (Meteorology faculty) ; Jared Testa (Aviation faculty)
UW Participants: Tom Drew, Jeff French, Larry Oolman

Figure 10 presents the aircraft track for the 25 March test flight, during which the ERAU Chief Flight Instructor (Jared Testa) was aboard to familiarize the UWKA pilot (Tom Drew) with areas of high traffic activity for the ERAU pilot training operations. The mission included overflight of two locations for potential sampling of smoke from planned Forest Service prescribed burn operations near Flagstaff. Cloud microphysics sampling was also a "target of opportunity" for the short flight, collecting microphysics observations in a mixed-phase cloud with high liquid water contents, supercooled droplets and ice crystals. Cloud bases were high with accompanying virga, a typical condition for convective clouds in this region. Preliminary subsets of cloud microphysical characteristics have been analyzed, with a time series of cloud liquid water content shown in Figure 12. Analysis of 2-D cloud probe data and images for this cloud profile will be accomplished using NCAR software such as the XPMS2D package.

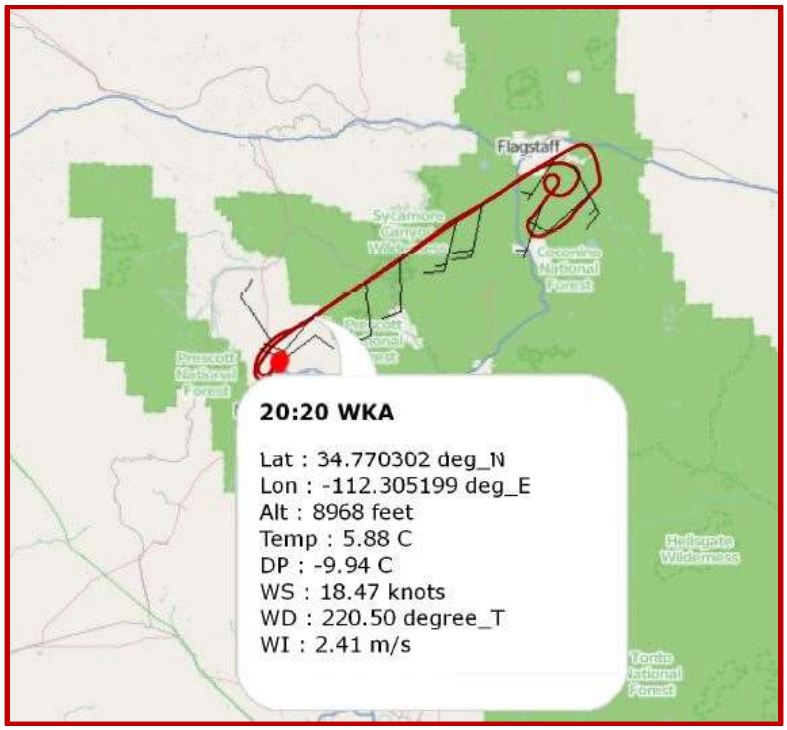

Fig. 10. Flight track (red line) for 25 March (1935 – 2025 UTC), with wind barbs shown along the track and an inset of flight data parameters at 2020 UTC. The location of the cloud vertical sampling period is immediately south of Flagstaff (corresponding to location A in Figure 11).

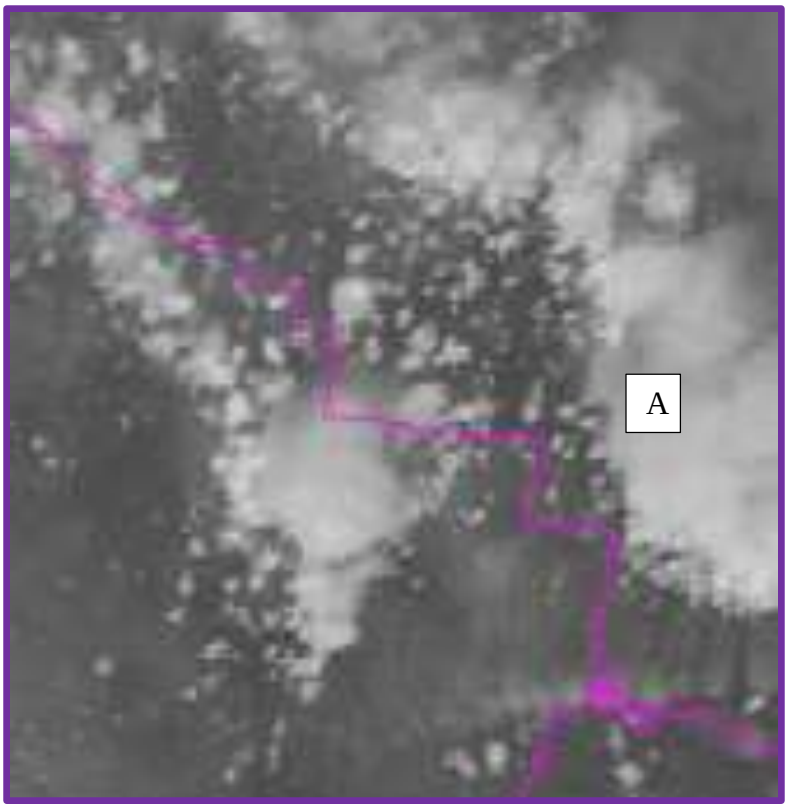

Fig. 11. GOES Visible image at 2100 UTC on 25 March 2014. Vertical sampling of a convective cloud area was conducted near location designated A. County line border is shown (magenta line).

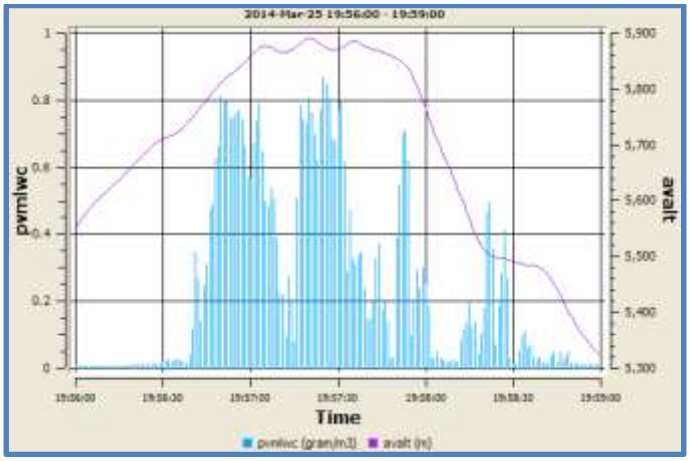

Fig. 12. Time series of cloud liquid water content (from Gerber PVM; pvmlwc) and aircraft flight altitude (avalt) during sampling of a convective cloud 1956-1959 UTC on 25 March 2014.

26 March 2014: Research Flight (RF01) 1727 - 2144 UTC
ERAU Participants: Melanie Wetzel (Meteorology faculty) ; Davey Meress (Global Security student) ; Dante Tabarracci (Meteorology student)
UW Participants: Tom Drew, Jeff French

This mission included a set of five constant-altitude legs oriented parallel to ridgetop airflow, from west of Granite Mountain across Verde River Valley toward terrain in the region of Mingus

Mountain, to document mechanical turbulence generated by the topographic barriers and wind shear conditions in region of ERAU training operations for model verification studies. Additional sampling of cloud microphysical structure was conducted with passes through cells at multiple heights in the area west of Flagstaff (Figure 14). Further east, legs at multiple altitudes were flown above/within an area of dust lofting located SE of Flagstaff (Painted Desert region).

Fig. 14. Westward portion of UWKA flight track for 26 March 2014, to focus on cross-valley transects and in-cloud microphysics sampling periods.

Increasing values of cloud liquid water content and droplet diameter are shown in the time series for a limited period during the cloud penetrations (Figure 15). Computational applications for the senior-level Atmospheric Physics course using these time series will provide instruction on the calculation of basic cloud microphysical parameters from individual size distributions for droplets and ice crystals. Latitude/longitude coordinates for the entire flight track for this mission are plotted in Figure 16. Sampling during the eastward portion of the track took place at varying altitude within an area of dust lofted from the surface. Dust plumes originated from multiple surface locations and merged to create a wide layer that expanded downwind. Aerosol concentrations along the aircraft coordinate lines and altitudes are being extracted for input to NOAA Air Resources Laboratory applications software for modeling particle trajectories and plume dispersion. Students in the Atmospheric Environment course will apply these methods for analysis of long-distance dust transport.

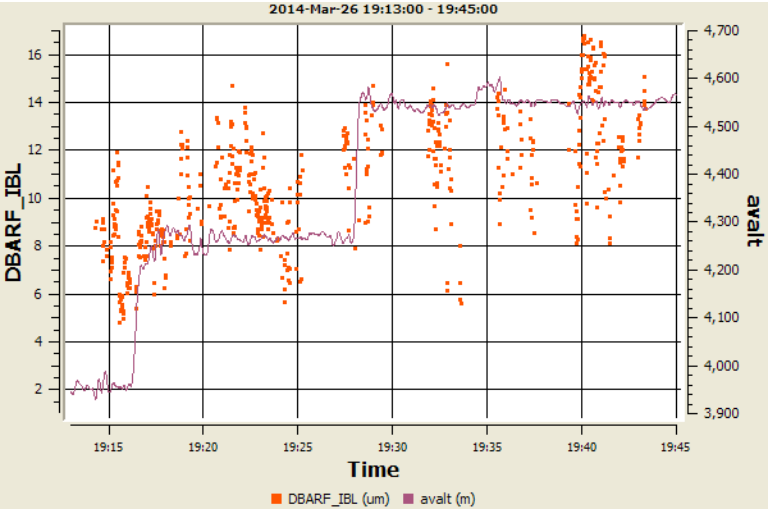

Fig. 15. Cloud droplet mean diameter (DBARF_IBL) obtained from the FSSP for a time period of successive cloud passes at increasing altitude (avalt) for 1913-1945 UTC during the UWKA flight on 26 March 2014.

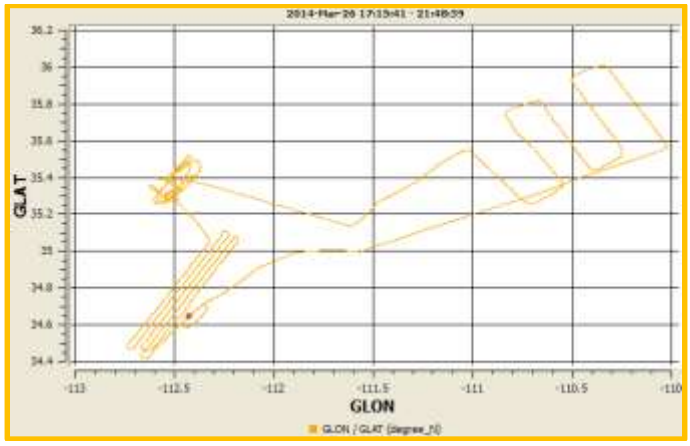

Fig. 16. Coordinate plot for UWKA flight track on 26 March 2014.

30 March 2014: Research Flight (RF02) 1623 – 2034 UTC
ERAU Participants: Erica Diels (Aviation faculty) ; Matt Kibby (Meteorology student) ; Sidney Scott (Aeronautical Sciences student)
UW Participants: Tom Drew, Jeff French

The RF02 flight track is presented in Figure 17. The initial objective of this flight was to sample smoke aerosol from a wildfire southwest of Flagstaff. A low approach at KPRC was conducted after take-off to provide validation parameters for WRF model simulations in Atmospheric Dynamics coursework. Reaching the fire location, a plume was visible but it was too shallow and diffuse for sampling. The next priority was flight acratoss an orographic wave feature generated by the San Francisco Peaks range (located to the north of Flagstaff). Aircraft measurements of a significant downdraft in a lee wave were collected during legs across the ridge (1711 – 1937 UTC). Turbulence along one of these constant-altitude transects is shown in Figure 18. Dr. French created an IDL procedure after the flight to demonstrate the compositing of vertical velocity and turbulence measurement at multiple altitudes. This procedure and other IDL visualizations will be further

developed by students in coursework on atmospheric dynamics. After the series of transects across the San Francisco Peaks, the UWKA returned to a location west of Granite Mountain and collected a sounding descent, to supplement WRF model case studies. Profiles of air temperature and wind direction from this descent are shown in Figure 19.

Fig. 17. UWKA track for the flight on 30 March 2014.

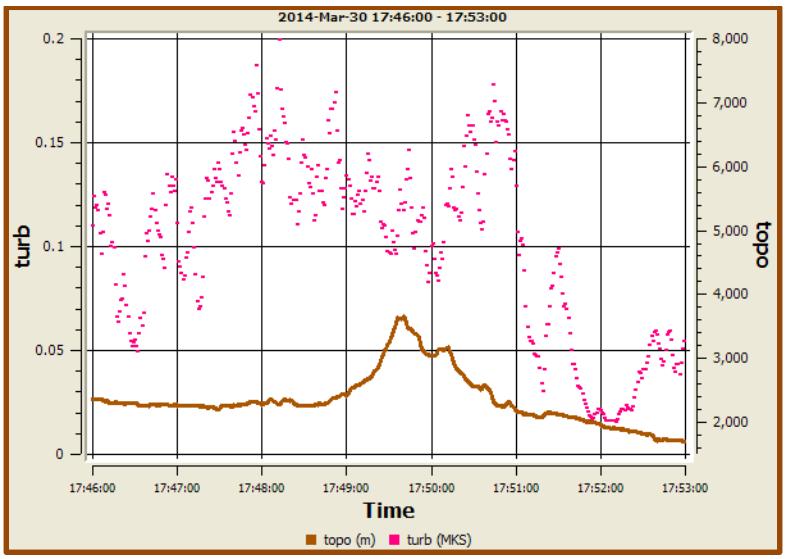

Fig. 18. Topographic elevation (topo) and turbulence (turb) sampled along a transect at 15,500 ft MSL across the San Francisco Peaks, 1746-1753 UTC on 30 March 2014.

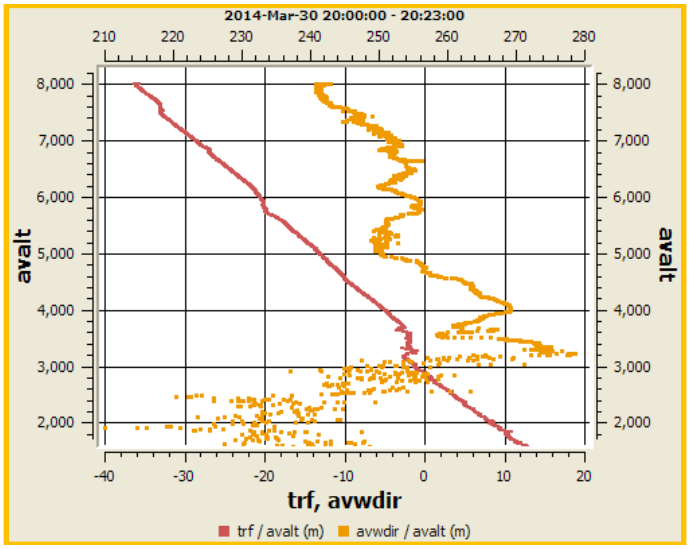

Fig. 19. Vertical profiles of air temperature (trf) and wind direction (avwdir) for an aircraft descent west of Granite Mountain during 2000-2023 UTC on 30 March 2014.

31 March 2014: Research Flight (RF03) 1725 - 1840 UTC
ERAU Participants: Dorothea Ivanova (Meteorology faculty) ; Darin Baker (Engineering student) ; Logan Puckett (Engineering student)
UW Participants: Tom Drew, Jeff French

A low approach pass at KPRC was conducted immediately after take-off for this flight (Figure 20), followed by an aircraft sounding profile (Figure 21) to 26,000 ft altitude in an area upwind (west) of Granite Mountain. One downwind transect leg was completed across the valley, followed by return and landing at KPRC. A radiosonde was launched at 1922 UTC (Figure 22) from the ERAU campus, on the lee side of Granite Mountain. The downwind radiosonde sounding and upwind profile obtained from the aircraft are being used by an Aeronautical Sciences / Engineering student to investigate the role of terrain-forced lee convergence on wind shear conditions in the vicinity of KPRC.

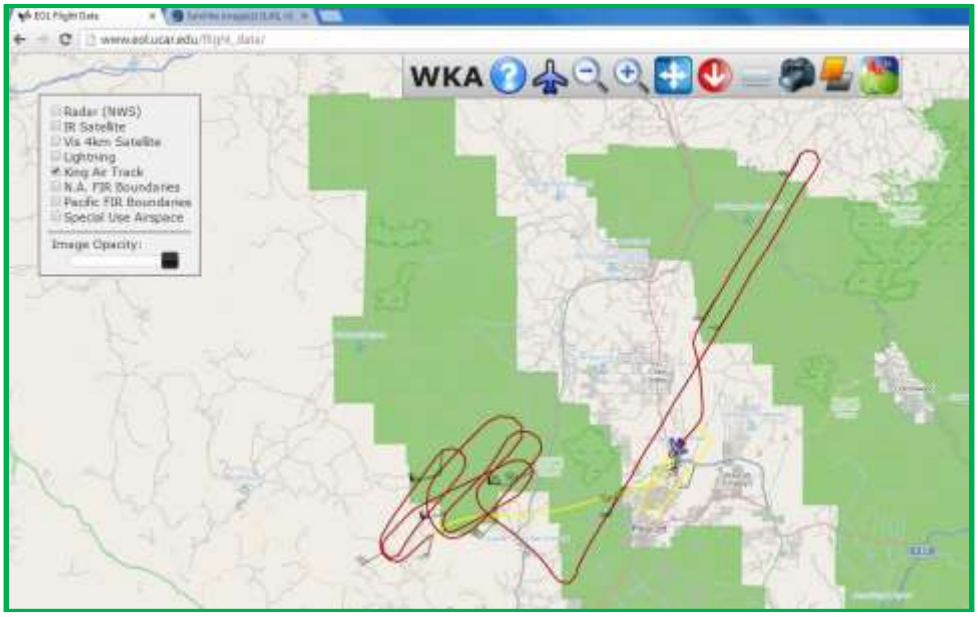

Fig. 20. Aircraft track for Research Flight RF03 on 31 March 2014.

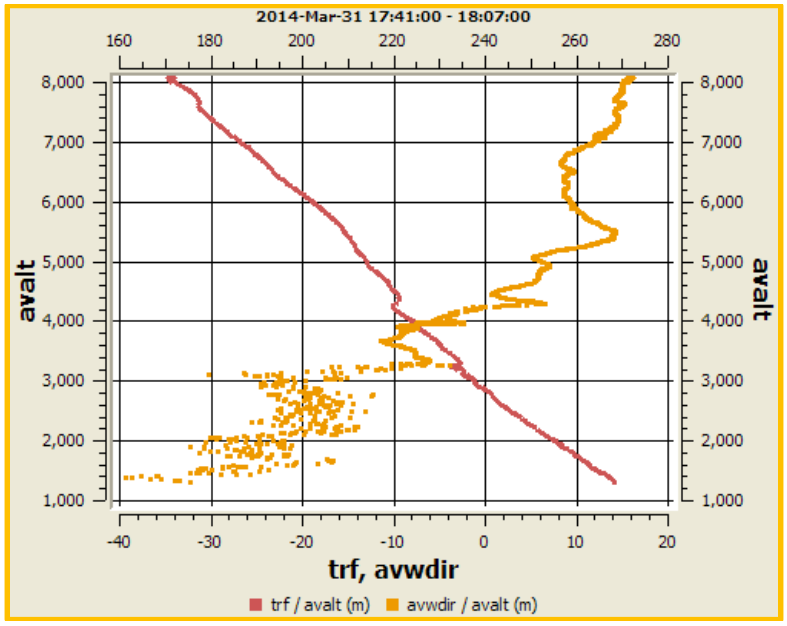

Fig. 21. Vertical profiles of air temperature (trf, ^{o}C) and wind direction (avwdir) for an aircraft sounding in an area to the west of Granite Mountain during 1741-1807 UTC on 31 March 2014.

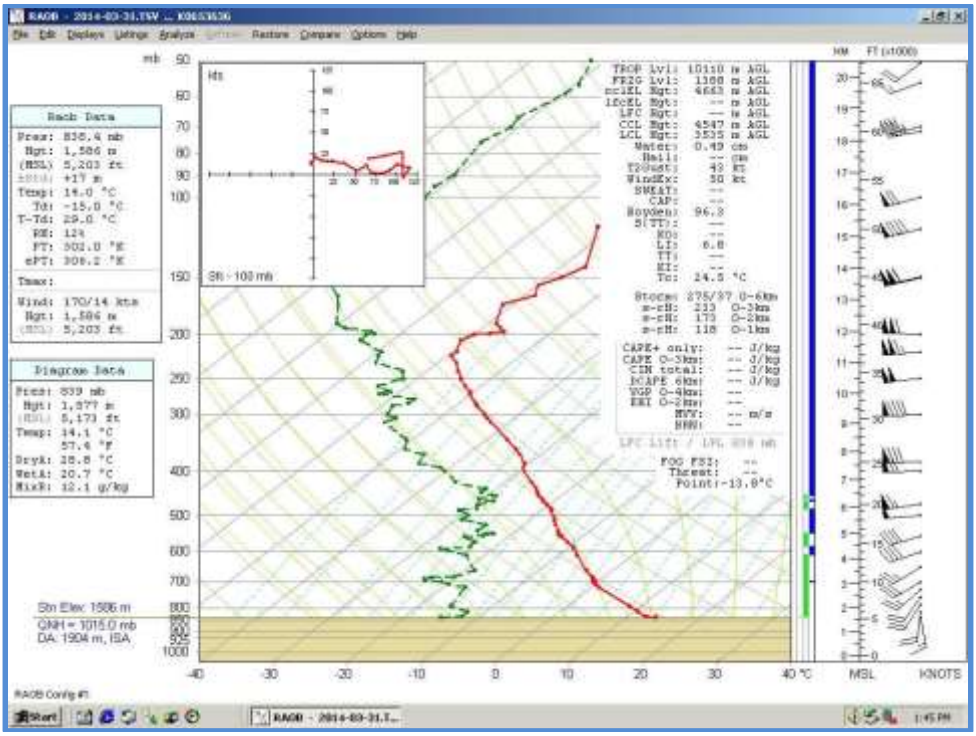

Fig. 22. Thermodynamic chart for ERAU radiosonde launched at 1922 UTC on 31 March 2014.

1 April 2014: Research Flight (RF04) 1826 - 2303 UTC
ERAU Participants: Curtis James (Meteorology faculty) ; Adin Herzog (Aeronautical Sciences student); Celeste Moreno (Meteorology student)
UW Participants: Tom Drew, Jeff French

The mission objective for 1 April (Figure 23) was characterization of atmospheric dynamics associated with mountainous terrain in the KPRC flight training area including the Mingus/Bradshaw Mountain orography and approaching the Mogollon Rim. Forecast model verification will be conducted at the local (airport) scale and mesoscale. A radiosonde was launched from the ERAU campus at 1910 UTC during this mission (Figure 24).

The first aircraft maneuver was a low approach to KPRC after take-off (Figure 25), followed by a constant-altitude leg from west of Granite Mountain along WSW airflow at 14,000 ft MSL across Rimrock, AZ and the Mogollon Rim escarpment, with a return along this track at 10,000 ft. Several additional legs were accomplished at multiple altitudes along a transect displaced approximately 10 miles northward (across Sedona, AZ) and along the original transect. Wind speeds along the upper legs exceeded 70 kts. Mesoscale model products generated by NOAA indicated strong wave dynamics across northern Arizona and especially well organized along the Mogollon Rim.

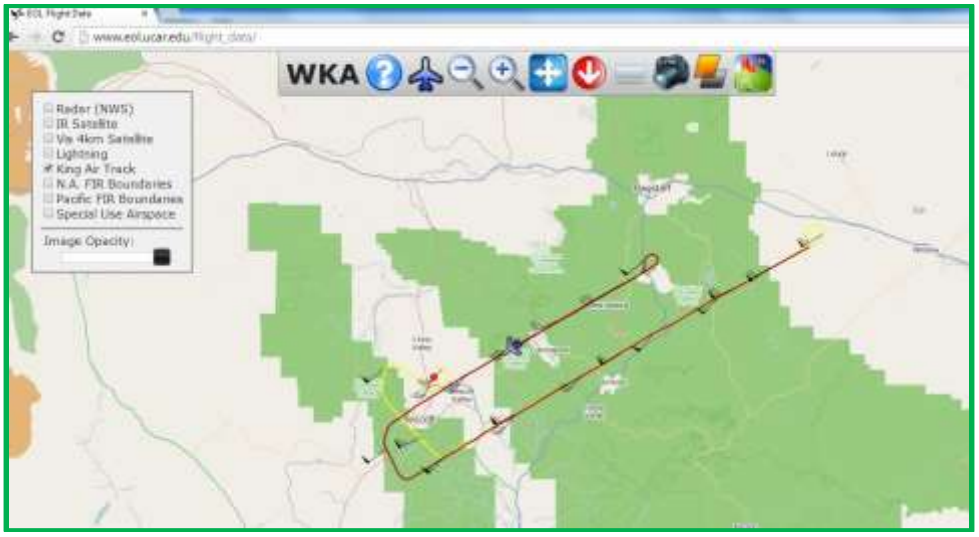

Fig. 23. UWKA flight track for mission on RF04 on 1 April 2014 (1826 - 2303 UTC).

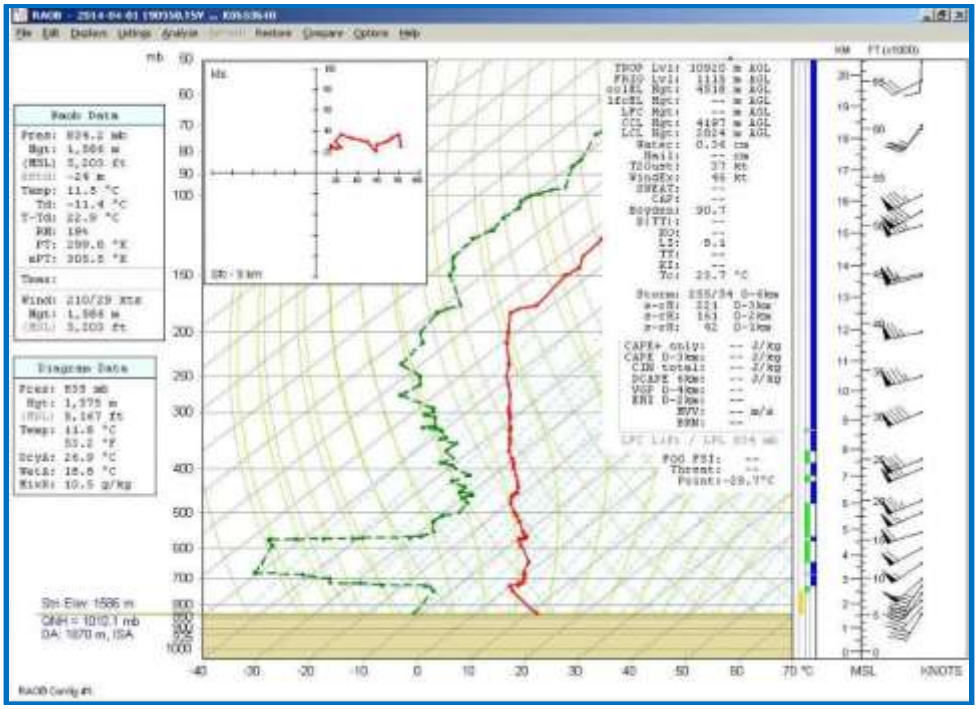

Fig. 24. Thermodynamic chart for radiosonde launched from ERAU at 1910 UTC on 1 April 2014.

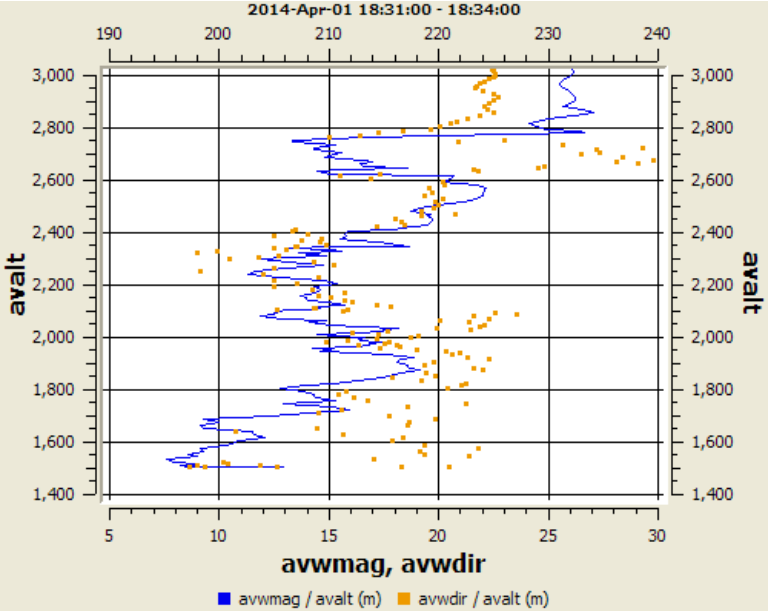

Fig. 25. Near-surface profiles sampled by the UWKA during a low approach to KPRC, for wind speed (avwmag, m s^{-1}) and wind direction (avwdir) on 01 April 2014.

2 April 2014: Research Flight (RF05) 2048 – 0048 (3 Apr) UTC
ERAU Participants: Brian Davis (Engineering faculty) ; Adam Kriete (Meteorology student) ; Gretchen Wachenheim (Meteorology student)
UW Participants: Tom Drew, Larry Oolman

The mission focus on April 2 was the collection of cloud and precipitation microphysical data for evaluation of the dual-polarization parameters, reflectivity and Doppler products of the NWS Flagstaff (FGZ) radar. Flight legs aligned at 130 / 310 deg Magnetic were conducted at 1,000 ft intervals from 12,000 to 18,000 ft MSL along two transects approximately 20 nm apart (Figure 26). A radiosonde was launched from the ERAU campus at 1921 UTC (Figure 27). Aircraft observations indicated convective cloud cells with top heights 17-18 kft, cloud top temperatures -18^{o} C and strong southwest winds (> 75 kt).

The cloud sampling area is indicated on the NWS radar scan in Figure 28. Cloud liquid water contents were high (> 1 g m^{-3}) and the Cloud Imaging Probe detected precipitation particle diameters greater than 2 mm (Figure 29). The NWS Flagstaff office Science and Operations Office, Dr. Andrew Taylor, collaborated on the archival of radar and associated AWIPS data resources for use in analysis of this and other case study days during the START project.

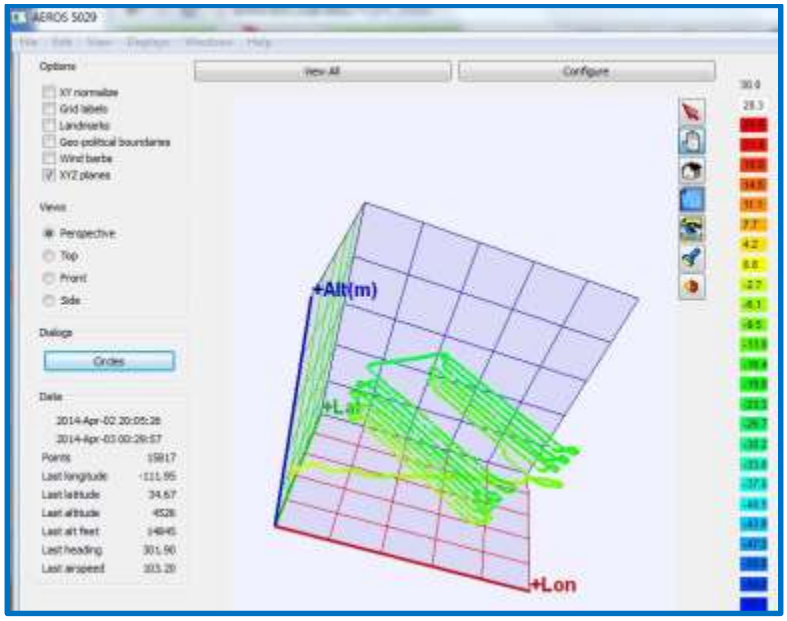

Fig. 26. 3-D track for the UWKA flight on 2 April 2014, depicting a series of constant-altitude legs along two transects, in an area of convective clouds with large liquid water content and ice crystals.

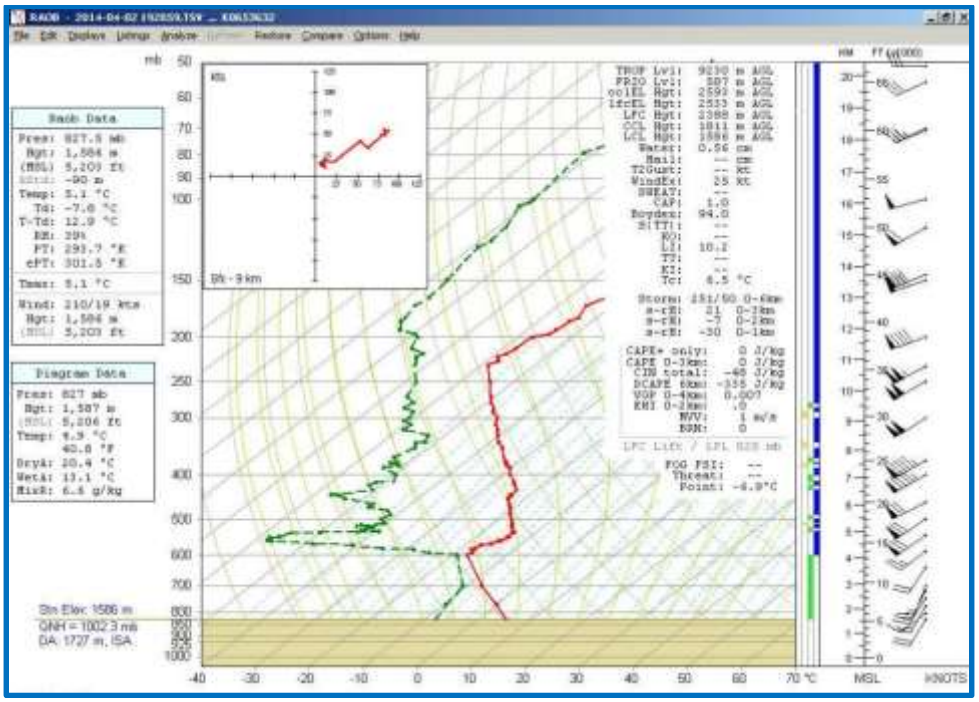

Fig. 27. Radiosonde data obtained from the launch from the ERAU campus on 2 April.

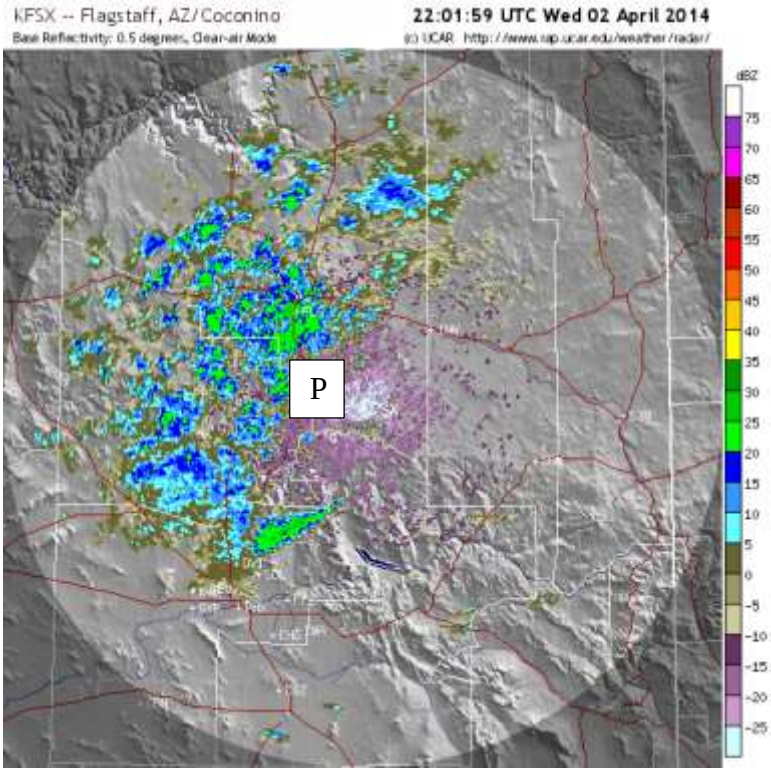

Fig. 28. NWS radar reflectivity (dBZ) for base angle scan at 2202 UTC on 2 April 2014. The UWKA sampled convective cloud adjacent to the area labeled P.

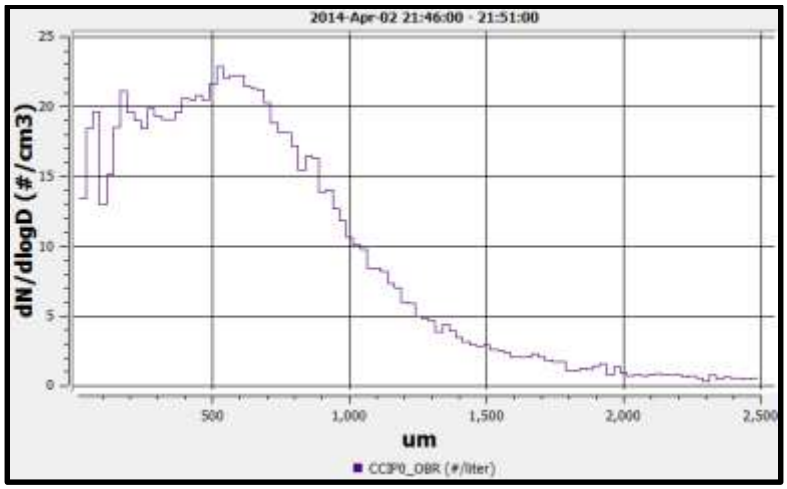

Fig. 29. Cloud Imaging Probe particle size distribution during 2146-2151 UTC on 2 April 2014.

3 April 2014: Research Flight (RF06) 1658 - 2029 UTC
ERAU Participants: Ken Parsons (Meteorology faculty) ; Travis Gaines (Meteorology student) ; Travis Swaggerty (Meteorology student)
UW Participants: Tom Drew, Jeff French

This flight mission (Figure 30) provided a clear-sky opportunity to collect a sensor intercomparison data set for use in a course on atmospheric measurement. The Heiman and Heitronics

sensors for infrared radiometric determination of equivalent blackbody temperature of the underlying surface (or effective cloud top) are similar in design, with the Heitronics a more recent addition to the UWKA. Several surface types were selected as targets, including snow-covered area northwest of Flagstaff, Havasu Lake reservoir along the Colorado River, a lava flow field, desert terrain (Figure 31) and Ponderosa pine forest. In addition to inter-relating the IR sensor observations, the surface temperatures inferred from the sensors will be applied to mesoscale model verification studies to investigate the impacts of surface energy budget and surface type parameterizations on thermal convection.

The flight track passed across an open-pit copper mine / processing site near Bagdad, Arizona, and high concentrations of particulates were observed (Figure 32). A radiosonde was launched from the ERAU campus at 1917 UTC (Figure 33) and these sounding observations will be used in analysis of dispersion and trajectory modeling from the aerosol source location.

Fig. 30. UWKA flight track for 3 April 2014.

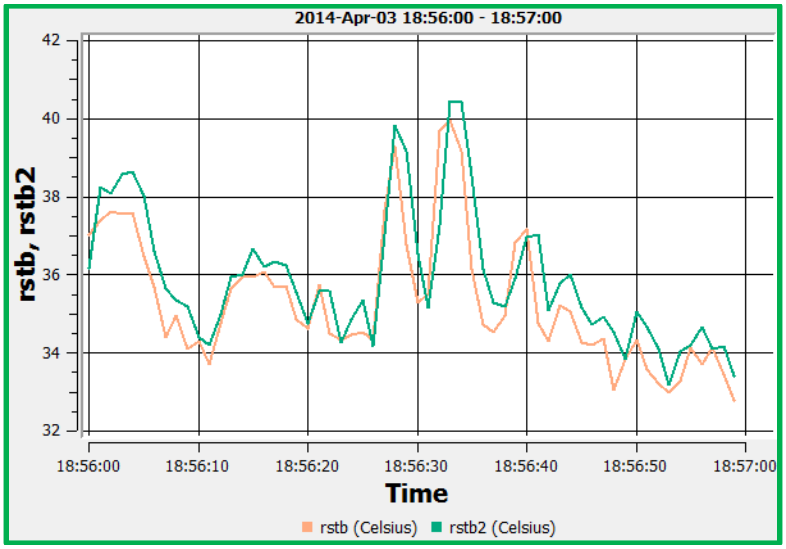

Fig. 31. Infrared temperature (°C) values from Heiman (rstb) and Heitronics (rstb2) sensors for an overpass of desert surface type during 1856-1857 UTC on 03 April 2014.

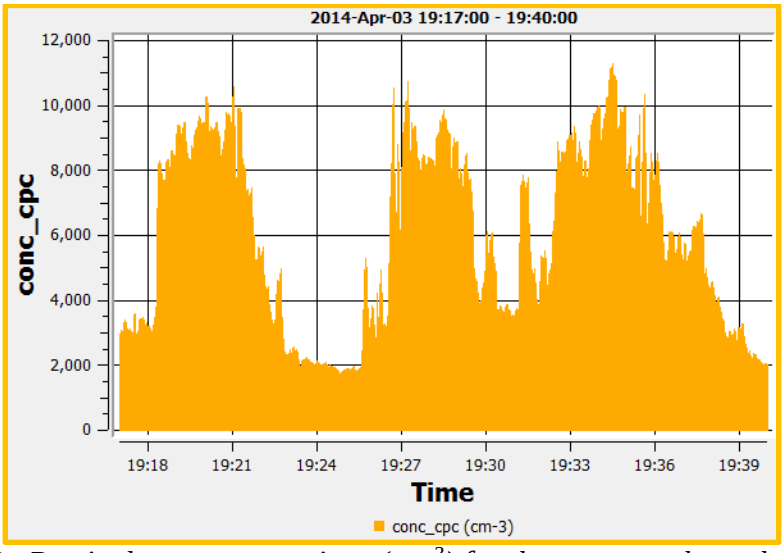

Fig. 32. Particulate concentrations (cm^{-3}) for three passes through a plume from copper mining facility at Bagdad, AZ during 1917-1940 UTC on 03 April 2014.

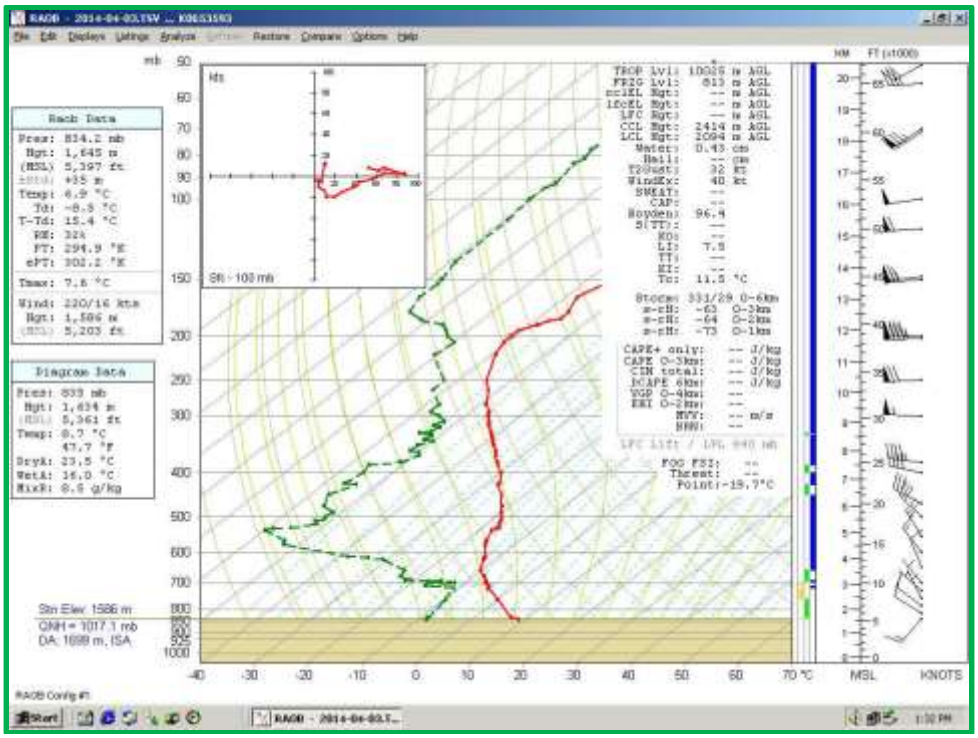

Fig. 33. Thermodynamic chart for radiosonde launched from ERAU campus on 3 April 2014.

5 April 2014: Research Flight (RF07) 2110 – 0016 (6 Apr) UTC
ERAU Participants: Ken Parsons (Meteorology faculty) ; Andrew Taylor (NWS-FGZ Sciences and Operations Officer) ; Tony Nguyen (Meteorology student)
UW Participants: Tom Drew, Jeff French

This mission provided another opportunity to capture data for analysis of the NWS-FGZ radar data, particularly the recent addition of the dual-polarization parameters. Multiple cross-wind legs at constant altitude were flown in a north-south orientation along two transects sampling cloud cells of varying depth (Figure 34). The latter portion of the flight sampled within a more well-defined convective area at several levels (Figure 35). A time series segment of liquid water content and turbulence measurements for this convective area is shown in Figure 36. A photo taken at KPRC portrays the convective cloud and virga characteristics of this event (Figure 37).

Fig. 34. UWKA track for flight mission on 5 April 2014.

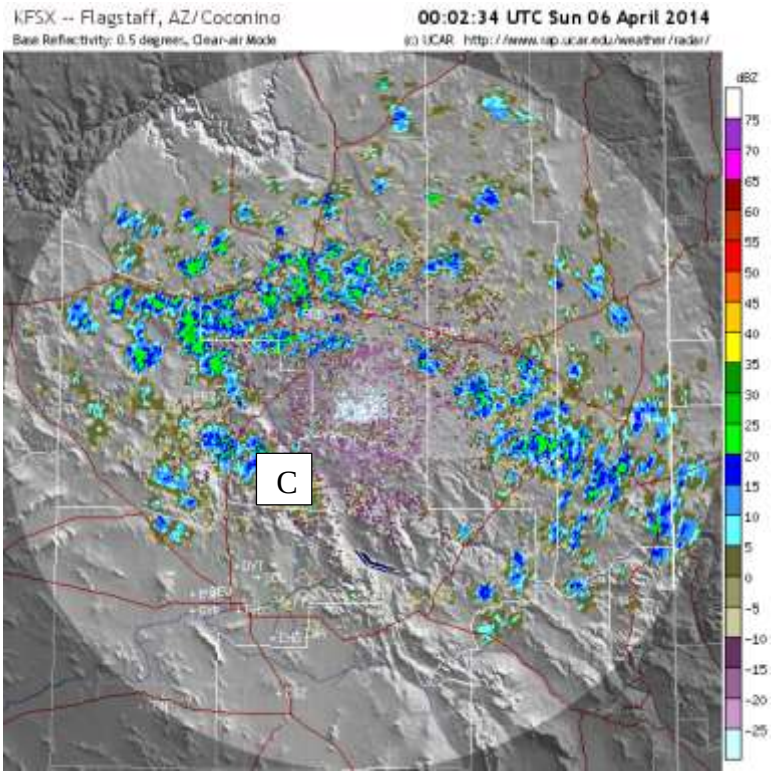

Fig. 35. NWS radar reflectivity (dBZ) for base angle scan at 0002 UTC on 6 April 2014 during Research Flight 7. UWKA sampled a convective cluster near C.

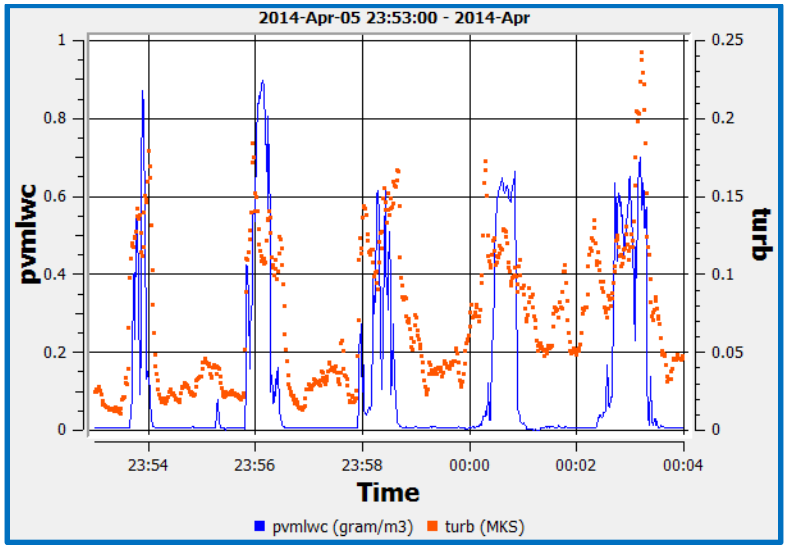

Fig. 36. Liquid water concentration (pvmlwc) and turbulence conditions during cloud penetrations at descending altitude in area C shown in Figure 35, for UWKA flight period 2353 UTC 5 April – 0004 UTC 6 April 2014.

Fig. 37. Example photo for convective event sampled on 5 April 2014.

6 April 2014: Research Flight (RF08) 1701 - 1943 UTC
ERAU Participants: Tim Sestak (Aeronautical Sciences faculty) ; Zack Barkell (Meteorology student) ; Madelyn Powell (Meteorology student)
UW Participants: Tom Drew, Larry Oolman

The flight on 6 April provides a case study for local forecast modeling to support the ERAU pilot training operations in northerly air flow conditions. The wind barbs shown along the flight track in Figure 38 indicate channeling of air flow along the Verde Valley. Constant-altitude transects along the wind (oriented at 20 / 200 deg T) were flown at heights between the ridges to the west and east of

KPRC. The UWKA conducted low approaches at the KPRC airport after take-off and just prior to landing. An aircraft sounding profile was also conducted to the north of Prescott. A radiosonde was launched from the ERAU campus at 1909 UTC for the RF08 mission (Figure 39). Vertical profile plots for the earliest and latest low approach descents at KPRC demonstrate the evolution of the near-surface temperature profile and turbulence (Figure 40). Low-altitude profile information from UWKA for this and other flight days are being used to assess the applicability of temperature, wind and g-force parameters from the Garmin-1000 data systems on the ERAU training aircraft for ongoing study of local wind shear, boundary layer stability and turbulence.

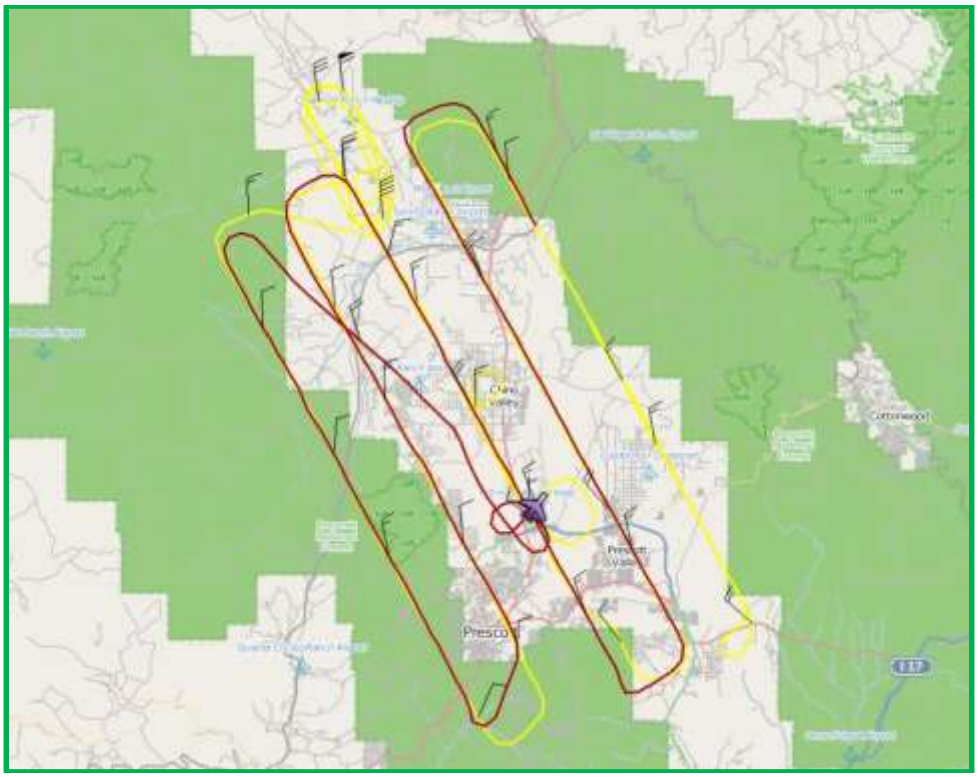

Fig. 38. UWKA track for flight carried out for 6 April 2014 mission.

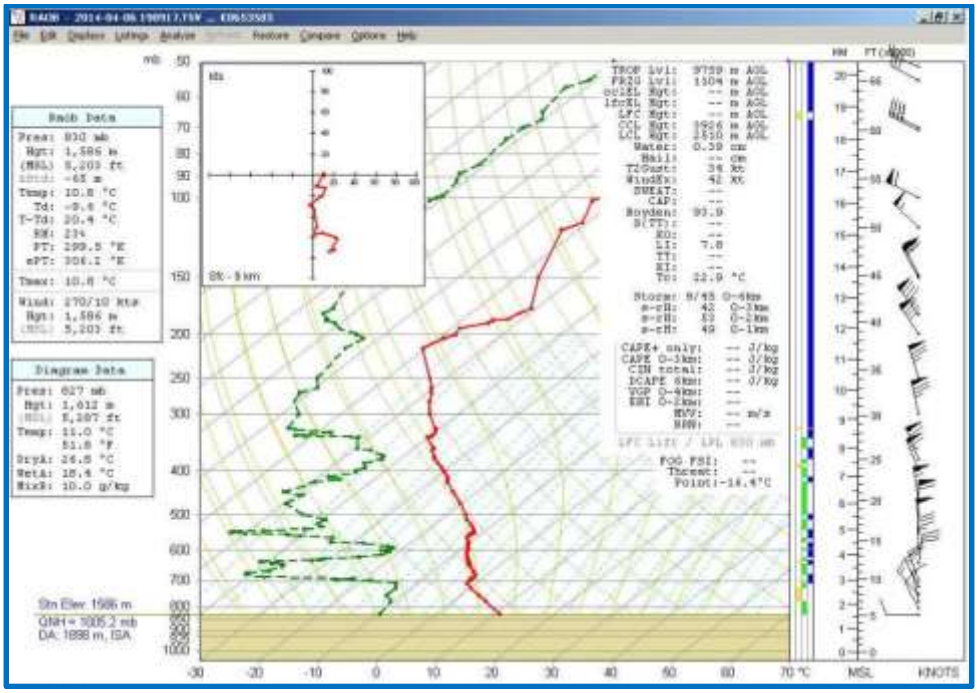

Fig. 39. Thermodynamic chart for a radiosonde launched from the ERAU campus on 6 April during the UWKA flight period.

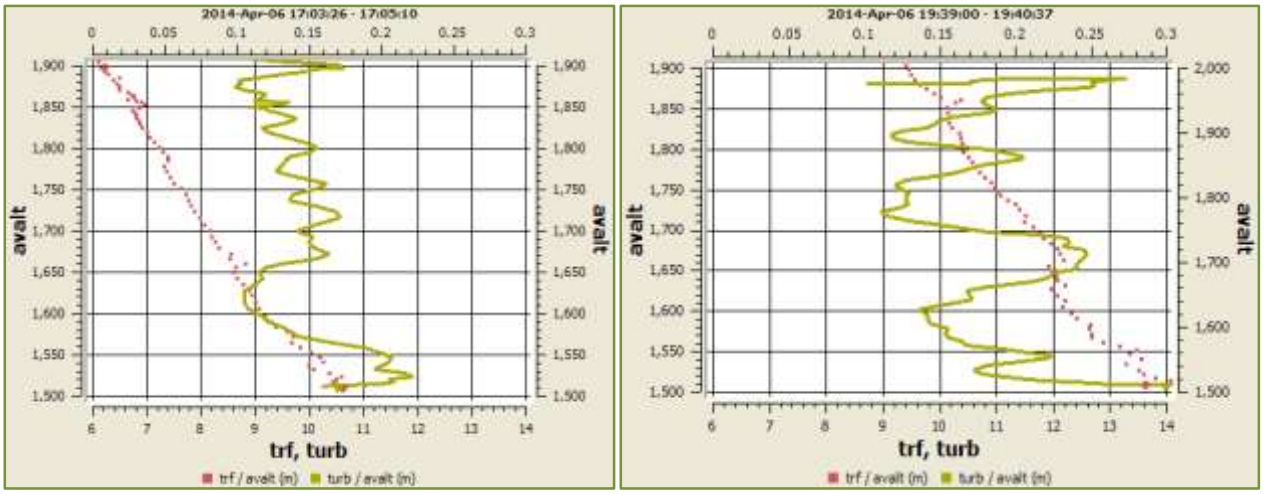

Fig. 40. Air temperature (°C) and turbulence profiles for the surface air layer at KPRC airport during the earliest (1704 UTC) and last (1939 UTC) low approach descent segments, 6 April 2014.

8 April 2014: Research Flight (RF09) 1655 - 2025 UTC
ERAU Participants: Curtis James (Meteorology faculty) ; Austin Wardall (Meteorology student) ; Davis White (Meteorology student)
UW Participants: Tom Drew, Larry Oolman

The final flight day was utilized to obtain a case study for mesoscale model simulations of mountain-valley airflow in light and variable wind conditions (Figure 41). A radiosonde was launched from the ERAU campus at 1911 UTC (Figure 42). The radiosonde data will be used with the aircraft

sounding profile (Figure 43) to identify differences in the sounding profiles upwind versus downwind of Granite Mountain in a WRF model simulation study. The aircraft also conducted a low approach to provide detail on the boundary layer structure and wind profile for model verification.

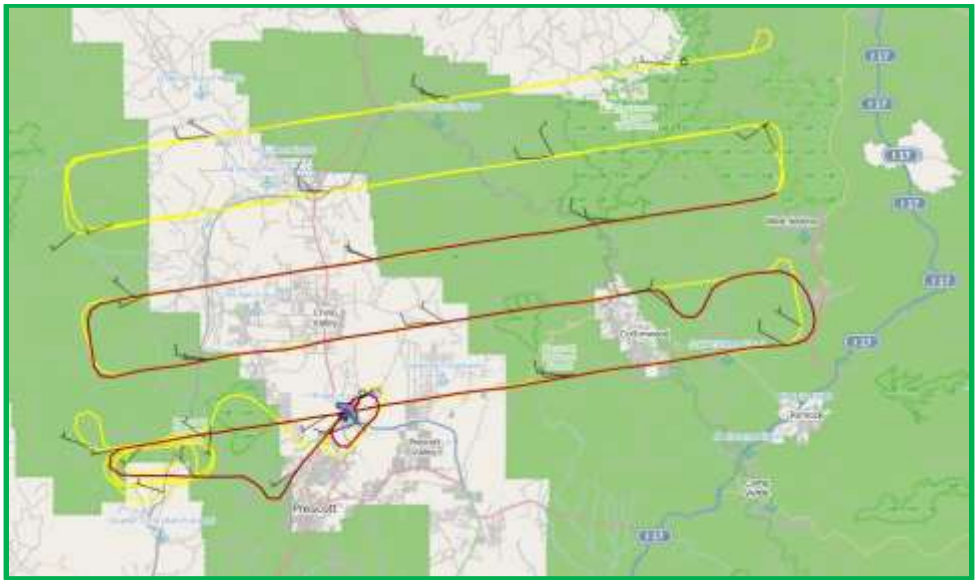

Fig. 41. UWKA track for flight on 8 April 2014.

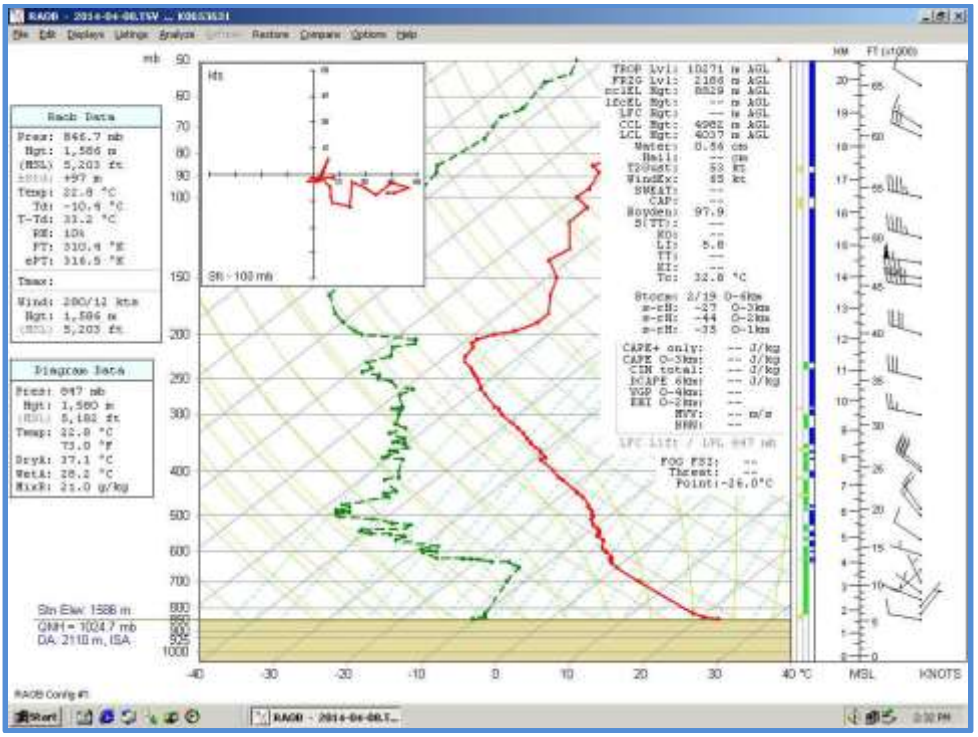

Fig. 42. Thermodynamic chart for a radiosonde launched from the ERAU campus on 8 April.

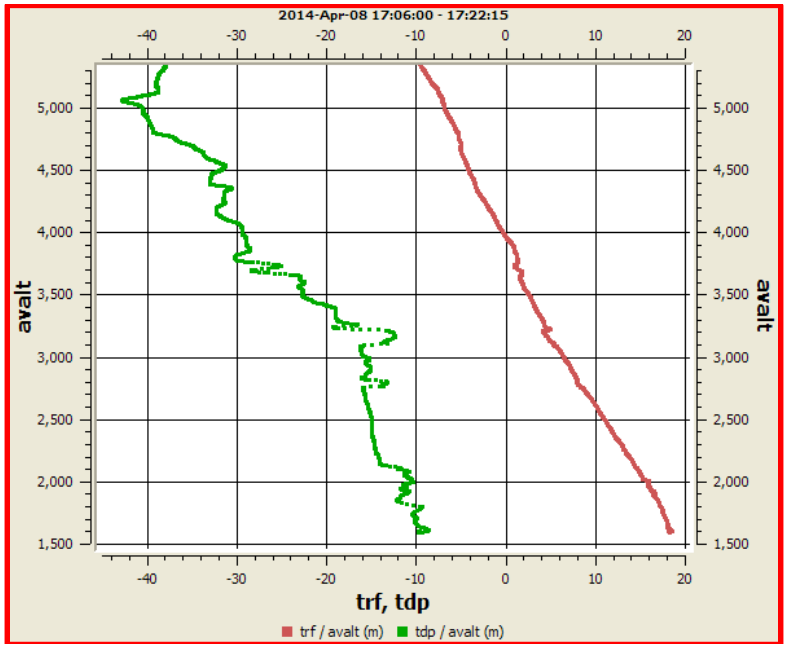

Fig. 43. Air temperature (°C) and dew point temperature (°C) profiles for an aircraft ascent profile conducted west of Granite Mountain on 8 April 2014.

4. Educational Outreach and Public Media

Students and faculty were involved in outreach communication for the project through publication of stories in the *Horizons* campus newspaper, capturing video and photos, and preparing informational resources for the Department of Meteorology media venues (web page and Facebook).

A campus seminar was presented on March 28 with presentations by Tom Drew (UW Research Pilot), Dr. Jeff French (UW Flight Center Director), and ERAU Meteorology Department faculty Dr. Dorothea Ivanova and Dr. Melanie Wetzel. The seminar provided an overview of the START project objectives, a description of multiple scientific applications possible with UWKA research capabilities, case study observations of cloud icing risk from a research pilot's perspective, and a summary of ice crystal and cloud droplet size distributions are related to cloud icing conditions (Fig. 44). It is estimated that 105 people attended this seminar (based on student sign-in sheets and other known participants). Attendees included several AMS Chapter members (from Flagstaff, Phoenix and Tucson), ERAU faculty, and students from multiple Departments.

Fig. 44. Project-related seminar at ERAU on 28 March 2014.

The UWKA was made available for public education at the ERAU maintenance hangar during a Discovery Day event (Figure 45). Shuttles from the main campus to the KPRC airport brought a wide variety of visitors, including students from middle schools and high schools, ERAU students and their parents, and local community members. It is estimated that 75 people attended this event (based on information from shuttle drivers).

Fig. 45. Open house event for the UWKA at the ERAU hangar during Discovery Day campus event.

The project and associated seminar were communicated to the public through a press release from the ERAU Prescott campus:
http://news.erau.edu/top-news/find-news-releases/2014/king-air-research-aircraft.html#.U1qEXFfYO6g

News stories from the *Horizons*, an ERAU campus newspaper, are available here:
http://www.erau-news.com/news/2013/10/29/king-air-article/
http://www.erau-news.com/news/2014/04/22/aircraft-icing-research/

5. Assessment of Benefits to Participants

The START project entrained a broad range of participants during events and instructional sessions. Table 1 presents the participant numbers in these activities. Many participants were involved in multiple events. The number of individual participants who were involved (or directly learned from START project activities) is estimated as 210.

Table 1. Participation in project activities

Event or Role	Date(s)	Participant Numbers
Onboard flight scientist role	25 March – 8 April	26
Aircraft orientation / safety briefings	25 March	29
Aircraft data console briefings	26 March	26
Campus seminar	28 March	105
UWKA Open House at ERAU hangar	4 April	75
In-class utilization of real-time data	3 – 8 April	72

The faculty and students were able to utilize preliminary data files from the flights immediately after the conclusion of each flight, due to the efficient data management process of the UWKA flight group and the availability of AEROS software from NCAR EOL. Data were also plotted in real-time and viewed in classroom sessions during flights. This demonstration of instrument systems and communication technology conveyed the scientific application of these capabilities to students.

Faculty members have initiated new inter-Departmental research collaborations as a result of this project. Dr. Curtis James (Meteorology) and Erica Diels (Aeronautical Sciences) are accessing data from the Garmin-1000 (G1000) avionics data systems aboard all ERAU training aircraft that conducted flights during the time frames of the START project missions. Thousands of hours of G1000 parameter sets are available from the ERAU Flight Safety operations archive from past (and future) training sorties. Comparison of the UWKA with correlative G1000 parameters (such as air temperature profiles, relative winds and g-force data) will be used to evaluate the representativeness and utility of G1000 observations for local-scale analysis of lapse rate, stability, wind shear and turbulence and applicability of these observations for WRF model forecasts and case study simulations of severe weather and aviation hazard events.

The UWKA deployment has provided interdisciplinary education in the aeronautical and atmospheric technology components of airborne research. With the rapidly expanding availability of airborne platforms for observation, research and training, the considerations of flight safety, aircraft instrument configuration and logistical planning are essential to the effective use of airspace. Faculty at ERAU have gained valuable experience and datasets from this project that will be utilized in future instruction related to aeronautical sciences and aviation safety. The UWKA deployment has provided case studies for development of local forecast model products that benefit the flight training of pilots. The project has also expanded awareness of instrument system applications for aeronautical engineering students, and has encouraged aeronautical science students to consider career options for research pilots.

6. **Recommendations**

This educational deployment project allowed students to gain first-hand knowledge of airborne measurement technology and atmospheric sciences research. The entire UWKA team were extremely supportive of the learning process for students and faculty to be directly involved with flight planning, real-time flight monitoring and data access. We recommend that other academic institutions consider an educational deployment proposal for utilization of the UWKA. A suggestion from the current project experience is that as many faculty as possible be drawn into the proposal as a collaborative effort, and that the datasets collected in the process be considered a long-term resource for future courses and student research topics.

Faculty are advised to work with their academic administration office early in the proposal preparation to determine if a memorandum of agreement for risk management is needed for students and faculty to serve as flight scientists aboard the aircraft. The UWKA Flight Center Director contributed to the development of this type of memorandum for the ERAU – University of Wyoming project.

Scheduling the deployment during a summer term is recommended for projects oriented toward undergraduate students, due to the typically large class load the students and faculty carry for undergrad degree programs during fall and spring terms. If a university can devote a summer-semester course to this type of project, the student cohort can be involved in more focused training prior to the deployment period and more extensive data interpretation during and immediately following the deployment. This scenario can also allow for the possible deployment of the participant group at a location other than the host campus, or at a campus with a greater commute distance from the aircraft base. A deployment period of three rather than two weeks is suggested to permit more selectivity of flight days.