Photo courtesty of Vanda Grubisic; DRI

University of Wyoming
ASP 2009

June 5, 2009 - June 6, 2009

UWKA Web Page

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- **Contacts**
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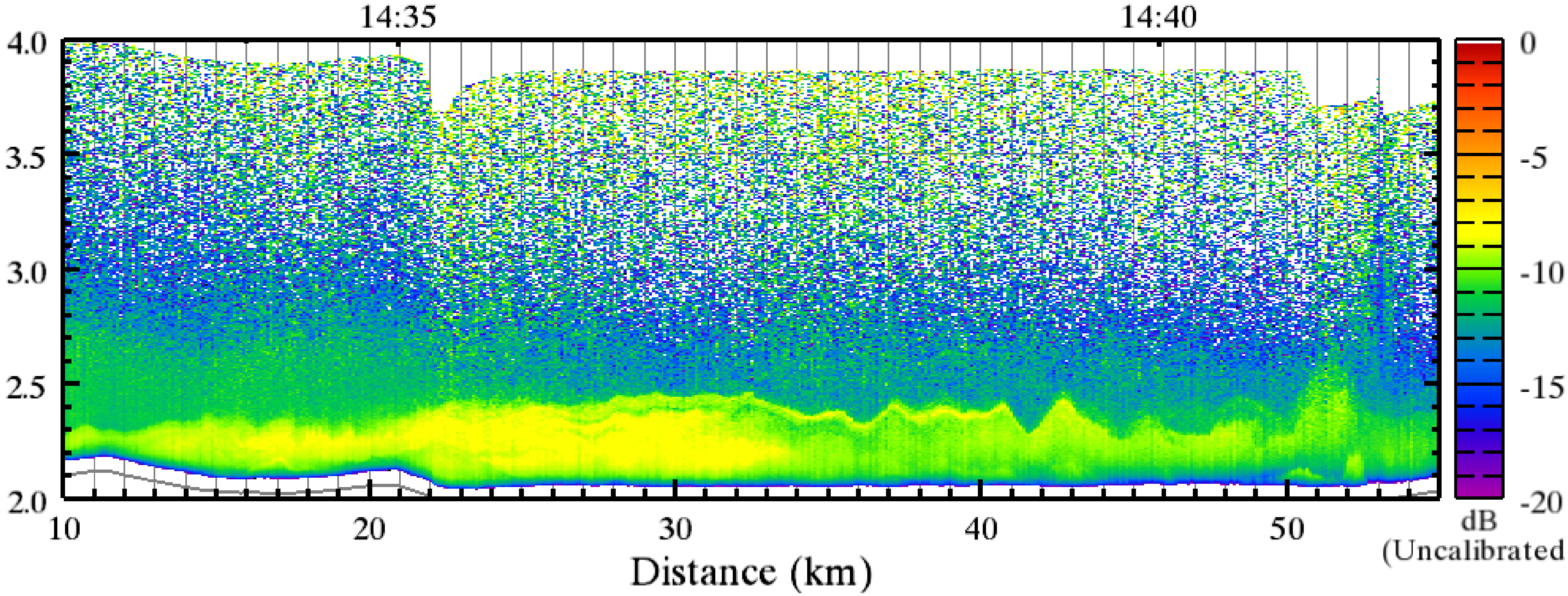
Date (*.kml)	Flight #	Status	Times (UTC)	Hours	Crew/Notes
Research Flights					
6 Jun - B	RF04	Stacks of three cumulus clouds.	2130-0114	3.8	Tom Drew Veronique Meunier Larry Oolman
6 Jun - A	RF03	BL flight, consisted of (1) Marshall Pattern (4 legs), (2) Marshall/Platteville pattern (4 legs), (3) Marshall Pattern (5 legs), (4) Marshall/Platteville (5 legs), (5) Platteville Pattern, (6) 1 final leg for Marshall/Platteville.	1553-1927	3.7	Brett Wadsworth Rouz Nazari

					Jeff French
5 Jun - B	RF02	This mission was to target cumulus clouds in the Chill/Pawnee dual-Doppler lobes. The CAPE, from a sounding taken at Marshall, was reported to be 3000 with a capping inversion. Mid-level clouds around 6 km suppressed heating and made the mission more difficult. Much of the flight was over Pine Bluffs, WY during the development of a meso-cyclone to the north. The northern storm was being studied by VORTEX and produced 4.5 inch hail and numberous tornadoes. We considered flying some of the developing cells on the SW flank but were concerned about lightning out of the overshooting anvil/mammatus.	1958-2342	3.8	Tom Drew Marcia DeLonge Larry Oolman
5 Jun - A	RF01	BL flight anchored around Marshall and Platteville surface stations, aft blower was not working, shutdown radar and lidar 3/4 through flight due to overheating, no other known instrument problems.	1429-1656	2.6	Brett Wadsworth Nick Guy Jeff French



14:35
14:40
4.0
3.5
3.0
2.5
2.0
10
20
30
40
50
Distance (km)
0
-5
-10
-15
-20
dB
(Uncalibrated

Flight #4: Convective Clouds 2

Flight time: 15:30 to 19:30 LST (11:30 to 1:30 UTC)

<u>As climbing after take off:</u>

5000' MSL	24°C
7500' MSL	17°C
11700' MSL	5°C
15000' MSL	0°C

<u>21:55 UTC</u>: First Cu congestus cloud over the Wyoming/Nebraska/Colorado borders (state triple point)

Cloud top (estimated) : 24000' MSL
Cloud base (estimated) : 15 000' MSL

Cloud passes: 23000' MSL
22000' MSL
20000' MSL
18000' MSL
16000' MSL
14000' MSL (under cloud base)
12000' MSL (1.5°C nearest to melting layer)
10000' MSL

Nota : Presence of rain and graupel within the second pass (i.e. 22K')
Cut in SE to NW transects approx. perpendicular to the wind

<u>22:06 UTC</u>: 1st sounding

start: 10000' MSL
finished: 26000' MSL
Sounding done roughly towards ESE

Nota: not perfectly strait had to avoid some non-precipitating clouds

<u>22:55 UTC</u>: 2nd Cu cloud over Cheyenne, Wyoming airport

Cloud top (estimated): 23 500' MSL
Cloud base (estimated): 17000' MSL

Cloud passes: 24000' MSL (above cloud to get view)
22000' MSL
20000' MSL
18000' MSL
16000' MSL (below cloud base)
14000' MSL (2°C nearest to melting layer)
12000' MSL

Nota: During passes in cloud no noticeable rain on windshield.
However, the cloud base was dissipating and virga was
Passed through at cloud base. Base was not sharp.
Cut in N-S transects approx. perpendicular to shear.

Around 22:20UTC: 2nd sounding

Start: 12000’ MSL
Finished: 26000’ MSL
Sounding was done roughly towards ENE

Nota: very clear sounding. Winds quite strong at upper levels.

Around 11:30 UTC : Travelling to next cloud as suggested by CSU-CHILL at 25000’ MSL

12:05 UTC: 3rd Cu congestus cloud over Sydney, Nebraska

Cloud top (estimate): 27000’ MSL
Cloud base (estimate): ???

Cloud passes: 26000’ MSL
24000’ MSL
22000’ MSL
20000’ MSL
18000’ MSL
16000’ MSL
14000’ MSL
12000’ MSL

Nota: Rain and Graupel present at upper level in cloud
First cloud got too strong to continue so switch to younger cloud in front of line at 16000’ MSL. Very difficult to work as in presence of very strong clouds to the North and East. Had to pull out early from completion as the cloud to the East produced wet microburst. Thus, no cloud base done here.

00:30 UTC: 3rd Sounding

Start: 12000’ MSL
Finished: 24700’ MSL
Sounding done in SW direction as heading back to Jeffco

Nota: Encountered rain at 16000’ MSL.
Sounding not terminated to hoped 26000’ MSL as DIA requested to start decent to Jeffco .

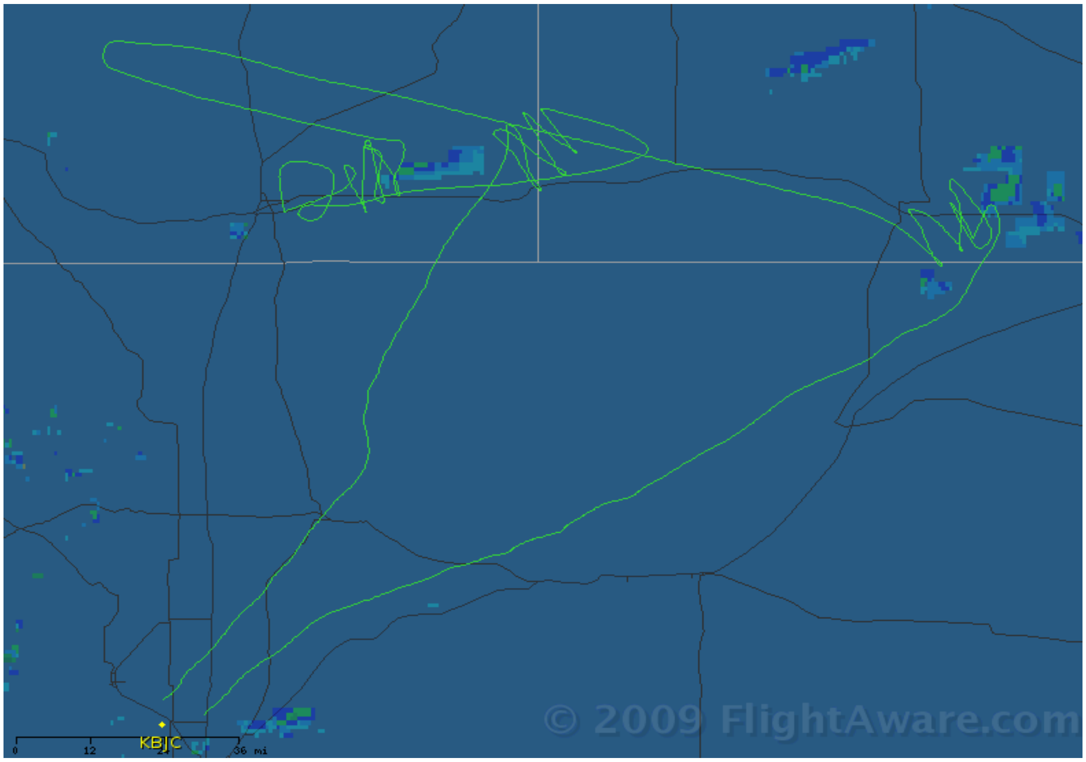


Photo notes:

P6060036 time stamp on N2UW near takeoff
P6060037 near LCL at takeoff (15500’ MSL)
P6060038 1st Cu (23000’ MSL)
P6060039 top of 1st Cu (23000’ MSL)
P6060040 top of 2nd Cu (24000’ MSL)
P6060041 base of 2nd Cu (12000’ MSL)
P6060042 idem.
P6060043 2nd sounding
P6060044 over Laramie, WY (for fun)
P6070045 fuzzy picture of 3rd Cu (on on the left, 25000’ MSL)
P6070046 top of 3rd Cu with pilieus (25000’ MSL)
P6070047 3rd Cu
P6070048 cloud flanking ours towards North
P6070049 idem.
P6070050 Mammatus on the north flanking cloud
P6070051 cloud base of the next cloud as the other was too hot
P6070052 fuzzy of idem.
P6070053 Rainbow in rainshaft of the north flanking cloud (for fun)
P6070054 cloud base of that next cloud
P6070055 idem.
P6070056 cloud top of that cloud
P6070057 cloud top of the previous cloud (i.e. the top penetration cloud after got too hot)
P6070058 Microburst in cloud to the west of ours

P6070059 get away from this line, too dangerous (same microburst)

Rest are for fun as we head back to Jeffco:

P6070060 rain shaft of cloud near to our line
P6070061- P6070064 & P6070067- P6070068 & P6070071 Kelvin-Helmholtz wave clouds

ASP RF04

6 June 2009, 2130-0114 Z (3.8 hours)

Larry Oolman flight notes.

Crew: Tom Drew, Marcia DeLonge, Larry Oolman

This mission was to target cumulus clouds in the Chill/Pawnee dual-Doppler lobes. Stacks of three clouds was flown. The passes were separated by 2000 feet. The first cloud was over Pine Bluffs, the second over Cheyenne, and the last over Sydney, NE. Soundings were taken after the end of the stack.
This was an excellent case of flying through isolated cumulus.

2130	Take off - climb to FL230
2156	Start first stack near Pine Bluffs, WY. Start at 23,000 feet, step down to 22,000 feet and then down 2,000 feet at a time to 10,000 feet. Note: above 18,000 feet, the aircraft uses pressure altitude. Below this level, the local altimeter is used.
2227	Start sounding, climbing into the wind to 26,000 feet
2255	Start second stack over Cheyenne, descending 2,000 feet per leg from 26,000 feet to 10,000 feet.
2325	Start sounding, climbing to 25,000 feet.
0004	Start third stack over Sydney, NE, again descending 2,000 feet per leg from 26,000 feet to 10,000. Large cumulonimbus just to the east of the cloud we were flying. This cloud was more embedded in a field of clouds than the other two we flew.
0033	Finished with stack. Start sounding to 25,000 feet and head back to Rocky Mountain Metro Airport.
0114	Land

ASP 09

RF03

20090606a

Crew:
B Wadsworth
Rouz Nazari
J French

Preflight:

Target BL development, examine fluxes over different land use type, investigate residual layers from previous day, flight pattern will consist of several long (~100 km) legs at different altitudes from 1000' AGL to ~10000 MSL. Long legs conducted on line from Marshall Site to just NE of Platvil site. (essentially same patterns as ASP-1 flight)

Weather forecast: BL drier than yesterday, some low clouds NE of JeffCo, but expect faster BL growth than yesterday…

1530Z winds 360 at 4 kts, sky: few at 010, T17/Td7, 29.82

Flight:

1552 Wheels up

Marshall Pattern (north/south legs west of JeffCo over Marshall site, flown at ~1000 AGL)

?????? Begin Leg A
155915 end leg A
160045 Begin Leg B
160330 end leg B (cut short on north end due to clouds)
160511 Begin Leg C
160720 end leg C
160852 Begin Leg D
161120 end leg D (elevated midway through leg due to traffic)

Marshall/Platteville Pattern (SW/NE legs with dogleg in middle to avoid towers, SW end over marshall site, NE end 10 km past Platteville)

161535 Begin Leg 1 @ 9500' MSL
162015 DogLeg pt
162525 end leg 1
Descend to 8500', turn radar & lidar off for this pass

162935 Begin Leg 2 @ 8500’ MSL
163450 dogleg pt
164130 end leg 2
Descend to 7500’, radar and lidar on for this pass
164400 Begin Leg 3 @ 7500’ MSL
164930 dogleg pt
165451 end leg 3
Descend to 6500’ some clouds on west end, we may not be able to complete entire leg
165800 Begin Leg 4 @ 6500’ MSL
170350 dogleg pt
170840 Off track due to ATC/End leg 4

<u>Marshall Pattern</u>
171235 Begin Leg A
??????? end leg A→ leg was messed up due to ATC requirement, subsequent legs will be conducted ~1 mile to the west…
171630 Begin Leg B
171915 end leg B
??????? Begin Leg C
172300 end leg C
172423 Begin Leg D
172705 end leg D
172902 Begin Leg E
173130 end leg E

<u>Marshall/Platteville Pattern</u> (will not come back to any more Marshall patterns due to air traffic, way too many aircraft to work area safely)
173652 Begin Leg 1 @ 9500’ MSL
174140 dogleg pt
174625 end leg 1
Climb to 12500’
175030 Begin Leg 2 @ 12500’ MSL
175800 dogleg pt
180645 end leg 2
Descend to 7500’
181145 Begin Leg 3 @ 7500’ MSL
181700 dogleg pt
182230 end Leg 3
Descend to 6500’
182623 Begin Leg 4 @ 6500’ MSL
183130 dogleg pt
183700 end leg 4
Climb to 7500’
184042 Begin Leg 5 @ 7500’ MSL
184545 dogleg pt
184940 end leg 5

Platteville Pattern (N/S legs at 1000’ AGL, southern point of line is Platteville, northern point of line is 40 17.25 N and 104 43.74 W)

185200	Begin Leg A’ @ 1000’ AGL
185415	end leg A’
185632	Begin Leg B’
185845	end leg B’
190125	Begin Leg C’
190322	end leg C’
190530	Begin Leg D’
190730	end leg D’

Setup for last leg back to Marshall climb to 8500’ MSL

191155	Begin Final Leg @ 8500’ MSL
191600	dogleg pt
192130	end leg

Return to Base

192715	Wheels Down

Postflight:

Flight went well, no instrument issues. Was hot, so ran radar and lidar sparingly, primarily on low legs. Lidar did not see much if anything, Radar saw relatively strong insect plumes on lowest legs.

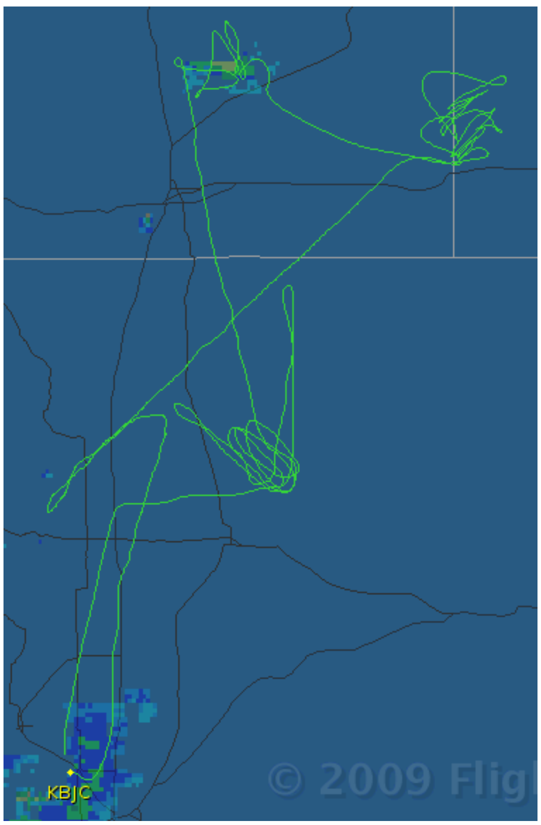
Traffic was difficult to work around on Marshall pattern and west end of Marshall/Platteville pattern. It got progressively worse as the flight wore on….because of traffic did not conduct 3rd set of Marshall legs at end of flight, but instead conducted a Platteville pattern.

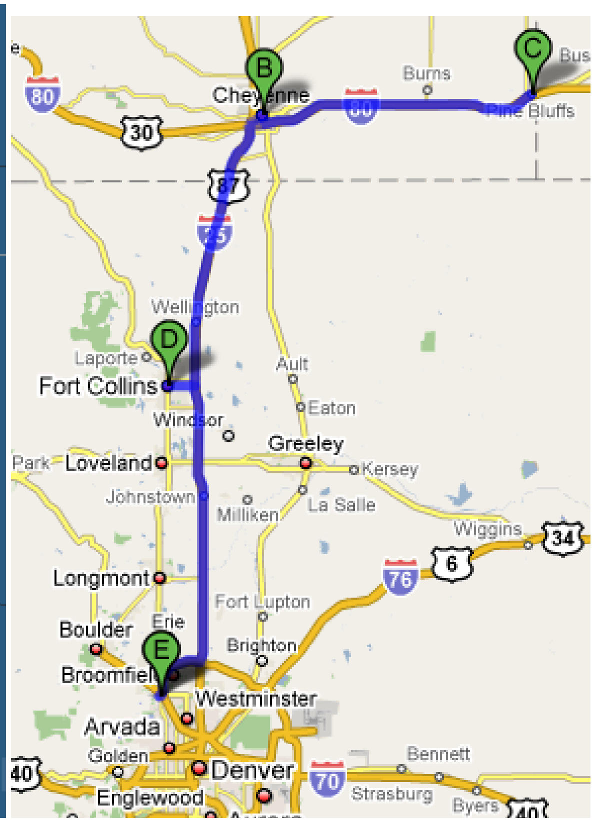
Mission Report for King Air Flight #2, ASP Colloquium 2009

Date: Friday, June 5, 2009
Takeoff: 1400 LST (**2000 UCT**), Jefferson County Airport, CO
Landing: ~1730 LST (**2330 UCT**), Jefferson County Airport, CO

Onboard:

Marcia DeLonge (Student Flight Scientist, msd8y@virginia.edu)
Larry Oolman (Senior Research Scientist)
Tom Drew (Research Pilot)





Objectives:

To sample young non-precipitating and precipitating cumulus clouds from cloud top to cloud base, below-cloud air, and cloud-free air (ambient conditions), to address research questions of the following ASP groups:

1) Cumulus entrainment
2) Precipitation particle initiation
10) Dual-doppler & polarimetric obs (CHILL & Pawnee radar) of convective storms
11) Polarimetric radar identification of precipitation type

Priority Target Area: CSU-CHILL & Pawnee Radar dual-dopper lobe; ideally within 20-30 km of the radar.

Pre-flight weather briefing:
Forecasting throughout the week and up to the morning of the flight suggested the potential for strong convection and cumulus development particularly in northeastern Colorado (e.g., as indicated by high daytime dewpoint temperatures in the 40's and 50's and large CAPE). Conditions prior to the flight were clear-sky and warm. An 1130 LST (1730 UTC) sounding from the Marshall field suggested the presence of a strong inversion above 800 mb which may have inhibited convection. After some debate, the flight was scheduled for 1400 takeoff due to consensus at JeffCo that convection would occur rapidly immediately after the erosion of the inversion. Because one of the objectives of the study was to sample young cumulus clouds, the flight was scheduled to precede convective initiation.

Flight Status:
King Air radar and lidar were noted to be overheating after the morning flight and were turned off and non-operational during the beginning of this flight. All instruments were operational by the time cloud sampling had begun.

The cloud pointer was not functioning properly during this flight, adding an extra challenge to tracking selected clouds for multiple passes.

Initial flight:
Based on observations during flight ascent:

MSL		Temp
5,600 ft	(surface)	22.0 °C
10,500 ft	(~BL height 1,493m)	10 .2 °C
13,500 ft	(~melting layer)	1.3 °C
19,500 ft	(initial cruising altitude)	-13.1 °C

En route to the first coordinates, the atmosphere was primarily clear with limited small, shallow, boundary layer cumulus. As we approached the initial target area, we passed over hazy skies with shallow stratocumulus. Given that there were no suitable young or precipitating cumulus clouds in the target area, we headed north towards a developing cumulus field near **Cheyenne, WY.**

PART I: Cheyenne, WY (~2030 UTC - 2115 UTC?)

The cumulus field over Cheyenne was filled with rapidly developing clouds. Our attempts to find clouds to sample in this airspace was challenging as clouds were quickly either deteriorating or becoming too intense before a 2nd (or even 1st!) pass could be made. During one cloud pass, graupel was observed on the aircraft windshield (~ 19,000 ft?). A second pass was intended for the same cloud, but this cloud was already rapidly dissipating. Corresponding with this dissipation, we noticed the nearby development of a much larger system. The system, which was identified as a mesocyclone from the ground (and was also being studied by the Vortex team!), appeared to be developing at the expense of the other clouds in the region.

At about this time, reports from CHILL scientists indicated that CAPE was reaching 3000 J/kg and a tornado warning had been issued in NE Colorado. Reflectivities in the nearby cells were exceeding mid-30 dBZs according to both CHILL and the aircraft radar.

When convection became too intense ("too hot") for further sampling over Cheyenne, we headed **east to Pine Bluffs, WY**. Along the way, we had some fantastic views of the developing supercell.

PART II: Pine Bluffs, WY (2130 UTC – 2245 UTC)

We found a more promising young cumulus field. Within this field, 2 clouds were thoroughly sampled, both from cloud-base to cloud-top, in increments of about 1500 ft.

The first of these clouds included several passes and precipitation was observed. The sampling was followed by a flight below cloud base (at ~8600 ft). Because the sampled cloud was already matured, the below-base flight was extended to pass under several other developing cumulus (to sample below-cloud aerosols as well as updraft air).

The second cloud was targeted for *Objective 1* at 2152 UTC. At this time, winds were at approximately 230° and an effort was made to pass through the cloud aligned with the winds. The sampling occurred immediately after the below-cloud transect described above, and included passes at 10,600, 12,000, 13,500, 15,000, and 16,000 (?) ft. An aircraft sounding was completed (at 2240 UTC) in a cloud-free area immediately neighboring the sampled cloud from 16,000 ft to 8,000 ft, descending at about 1000 ft/min.

Shortly thereafter, the cumulus field was no longer suitable for sampling and we sought out a new sampling area.

PART III: Fort Collins, CO (2300 UTC – 2330 UTC)

At the recommendation of CHILL radar scientists, we headed to Fort Collins for the final portion of the flight time. Unfortunately, there were no suitable clouds to sample within the available airspace. With limited remaining flight time and no promising nearby options, the decision was made to head back to JeffCo, about 15 minutes ahead of schedule.

Landing

Naturally, we spotted a rather impressive, large mammatus cloud while landing at JeffCo. It was too big to fly through anyway, but somewhat ironic to find something good, closer to home, just as the mission was over… ;)

ASP RF02

5 June 2009, 2000-2342 Z (3.8 hours)

Larry Oolman flight notes.

Crew: Tom Drew, Marcia DeLonge, Larry Oolman

This mission was to target cumulus clouds in the Chill/Pawnee dual-Doppler lobes. The CAPE, from a sounding taken at Marshall, was reported to be 3000 with a capping inversion. Mid-level clouds around 6 km suppressed heating and made the mission more difficult. Much of the flight was over Pine Bluffs, WY during the development of a meso-cyclone to the north. The northern storm was being studied by VORTEX and produced 4.5 inch hail and numberous tornadoes. We considered flying some of the developing cells on the SW flank but were concerned about lightning out of the overshooting anvil/mammatus.

1958	Take off - climb to 8000 feet
2002	Climb to 10,000 feet
2006	Climb to FL230 pressure altitude, east of Chill/Pawnee
2030	Descend to 11,000 feet NW of CHILL. Start the WCR in up/down mode. See clouds centered at 6 km.
2047	Climb to FL190 pressure level into mid-level clouds. WCR reflectivity is 5-10 dBZ. 2D-C particle diameters of 200-300 micron.
2113	Head north to cloud near Cheyenne.
2129	Pass through 3 mm graupel at FL190
2131	Pass beside cell, switched mirror to side.
2135	Four more passes through new cells as they form and collapse Last three passes at FL170.
2139	Switched WCR to Up/Dual-down
2155	Start working some weak convection near Pine Bluffs, WY. 13,000 feet
2201	Start working weak convection near Pine Bluffs, WY. 13,000 feet These clouds formed and disippated very rapidly.
2155	12,000 feet
2212	8,500 feet
2217	12,000 feet
2223	9,000 feet

2225 10,500 feet
2228 12,000 feet
2230 14,000 feet
2233 15,000 feet
2236 16,000 feet
2239 sounding to 8,000 feet
2246 9,000 feet
2249 10,000 feet
2300 Transition to NW of CHILL at 14,000 feet
2312 12,000 feet
2325 Head to RMMA
2342 Land

Notes for Wyoming King Air flight #1

Meteorological Conditions:
Cirrus deck evident in the morning, lee trough in E CO developing. No low- or mid-level cloud development is expected in the morning. Light winds at take-off, fog is reported in Denver, though appears to be clearing to the north. A 14LT increase in low level winds is forecast.
Orographic cumulus development between 2-5 pm, with the PBL become more mixed due to downslope flow is also forecast.

Notes during Flight:
Original flight path was a straight-line SW-NE trajectory from near Marshall to Platteville. The levels requested were 1000, 3000, 6000, and 9000 AGL. The alternative path deviated from original due to the presence of two towers in flight path at ~1200 ft AGL height.
The flight path was a two-segment dog-leg that routed around the tower locations. This path was chosen to optimize the amount of straight-line data acquisition, while maintaining aircraft safety.

Longer leg flights
1st Pass:
Note the time correlation between camera (see time/date imprint in lower right corner) and the King Air data acquisition time display units. The times referred to in this document are in King Air units.

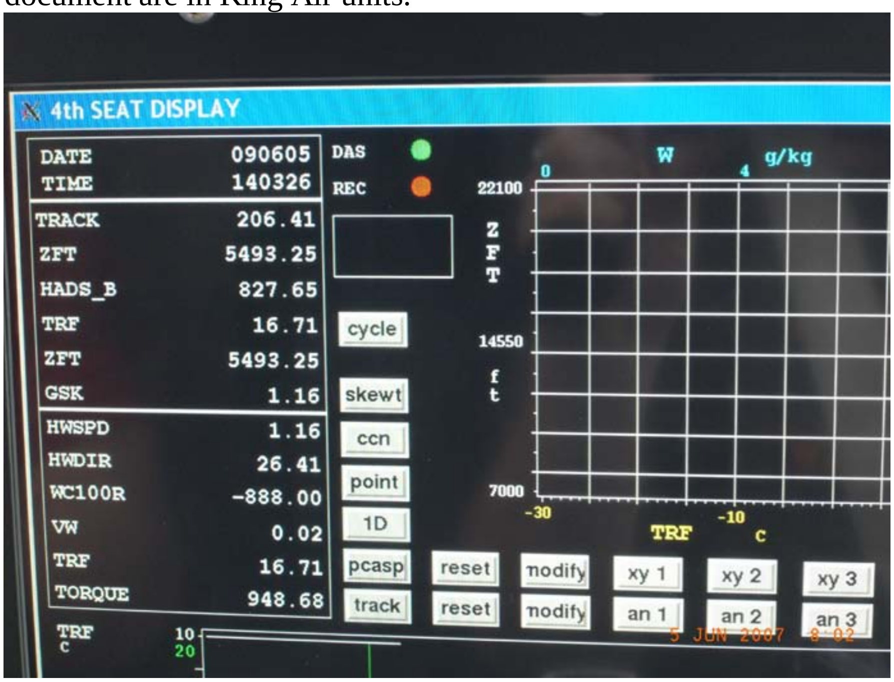


Figure 1 Time reference of King Air data acquisition and camera time/date.

Levels:

Leg 1: 6500 ft. MSL
Leg 2: 7500 ft. MSL
Leg 3: 9500 ft. MSL
Leg 4: 10500 ft. MSL

14????	Pass 1, leg 1 started
143556	At the dog leg, low cloud cover, deeper to the east.
144033	End of leg 1, substantially more high clouds present.
144318	Passage over lake.
144421	Begin the leg 2. Low cloud cover is dissipating.
144934	At the dog leg.
145510	On heading back to Jeffco instead of Marshall. Path will not be overlapping.
145639	Sun beginning to break through upper level clouds.
145950	Begin 3rd leg. Significant drying observed in this layer, T ~ 10C, T_D~-10C.
150411	At dog leg.
150834	At Platteville, extending leg 6 mi. north of Platteville to increase sampling.
151008	End leg 3.
151226	Begin 4th leg, very similar to 3rd leg.
151914	At dog leg.
152201	Upper level cloud deck is ~ 600 ft above aircraft according to radar.
152434	End 4th leg.

Examples of land coverage are shown in the following photos (Figs. 2-6):

Figure 2 Ground cover along track SW-NE, note the low level clouds. Low clouds cleared toward the west of the flight track as the upper deck receded, while the upper deck stayed in place to the east, resulting in less lower deck decay. There is evidence of irrigated land just to the right of the tip

Figure 3 Looking W-SW at the northern most part of the flight path. More natural land surface along with some irrigated portions were observed.

Figure 4 Land usage near Platteville. A number of small lakes can be seen in the photo, though only one confirmed passage was recorded during the first leg of the 1st pass.

Figure 5 Example of the low level, very small Cumulus that began to initiate near the end of the first pass. Likely associated with thermal surface plumes.

Figure 6 Land usage in the southern most portion of the flight path; note the enhanced tree coverage in this area.

2nd Pass

Levels
Leg 1: 6500 ft MSL
Leg 2: 7500 ft MSL
Leg 3: 9500 ft MSL
Leg 4: 8500 ft MSL

Note this pass continues the extension of the leg in the NE direction to 6 miles past Platteville.

152951	Begin 1st leg.
153459	At dog leg. Insect radar echo is observed, revealing the location of thermals along the flight path, this might be an interesting in combination with the vertical wind measurement form the aircraft data.
153625	Lidar indicates boundary layer ~200 ft above the aircraft altitude.
154103	End of 1st leg.
154439	Begin 2nd leg.
154614	Dewpoint temperature and mixing ration increase dramatically. It appears that the plumes observed in previous leg are penetrating the BL.
154933	At dog leg.
155312	Increase in elevation required due to air traffic.
155455	End of 2nd leg.
155957	Begin 3rd leg.
160438	At dog leg. Not much going on at the upper levels.
160823	Over Platteville.
160950	End of 3rd leg.
161309	Begin 4th leg.
161539	Over Platteville.
161853	At dog leg.
162409	End of 4th leg.

Marshall Site overpass

Some elevation changes will be seen in the data due to the topographical changes. The pilot attempted to remain approximately 1000ft AGL for the flight.

162844	Decent insolation, though some high level cloud cover has begun to move in once more.

Elevation ~7000 ft MSL

163111	At the northern most point.
163402	N → S flight.
163700	At the southern most point.

Elevation 7500-6500 ft MSL

163835	S → N flight. At the southern most point.
163292	Radar and lidar shut down. Overheating due to no air flow into back of cabin.
164104	At the northern most point.

Elevation 6500-7100 ft MSL

164349	N → S flight. At the northern most point.
164702	At the southern most point.

Elevation 6800-6500 ft MSL

164819	S → N flight. At the southern most point.
165045	At the northern most point.

Figure 7 Land usage in the Marshall site region. Note the urban are to N and NW of site, though the open land is representative of the site itself.

ASP 09

RF01

20090605a

Crew:

B Wadsworth
Nick Guy
J French

Preflight:

Target BL development, examine fluxes over different land use type, investigate residual layers from previous day, flight pattern will consist of several long (~100 km) legs at different altitudes from 1000’ AGL to ~10000 MSL. Long legs conducted on line from Marshall Site to just NE of Platvil site.

Weather forecast: moist BL, mid-level clouds, expect very slow BL development…

Flight:

1430 Wheels up

~1431 begin leg 1 @ 1000’ AGL tracking NE
1436 dogleg point (this point added to avoid tall towers along leg line)
1440 end leg 1

Climb to 7500 AGL

1445 begin leg 2 at 7500’ MSL
1450 dogleg pt
1455 (or so) end leg, end is screwed up, incorrect point loaded into FMS

1500 begin leg 3 at 9500’ MSL
1504 dogleg point
1509 end leg

1512 leg 4 at 10500’ MSL
1519 dogleg point
1526 end leg 4

Turn and descent

1530 begin leg 5 at 1000’ AGL (6500 MSL)

1535 Dogleg point
1541 end leg

154430 begin leg 6 at 7500’ MSL
154945 dogleg point
1553 maneuver for traffic
1555 end leg

155940 begin leg 7 at 9500’ MSL
1605 dogleg
1610 end leg

1613 begin leg 8 at 8500’ MSL
1625 end leg

Now on west side of pattern, proceed to repeat several legs on n/s line over Marshall site at 1000’ AGL

162830 begin leg A
163120 end leg A

163351 begin leg B
163715 end leg B

163835 begin leg C
164104 end leg C

??????? begin leg D
164710 end leg D

164825 begin leg E
165100 end leg E

Return to base

165632 wheels down

Postflight:

Flight went well, no major *instrument* issues. Later long legs were generally better than the earlier long legs. Shorter legs we did not maintain altitude too well

Aft blower did not appear to be working, radar and lidar overheated and needed to be shutdown about ¾ through the flight.