King Air N2UW flight report for January 23, 2005. Second flight, 17:44 -21:04 UTC.

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Summary:

Not a stellar day. Flight area was centered on 20 km N and 100 km E of SPol. Mesoscale context of study area was evolving rapidly. Cloud clusters were also changing rapidly. Hence, no comprehensive sampling sequences could be constructed. That difficulty led to rapidly changing objectives: repeat passes, some with attempts to relate sample locations to BAE146 activities; collected data on vertical profile of precipitation; and finally, tried to get detailed samples just above cloud base altitude.

Best part of the study was in a cloud cluster within an area that fell between open cell patterns a little earlier. Some strong updrafts and downdrafts (± 10 m s^{-1}) with sharp boundaries were encountered.

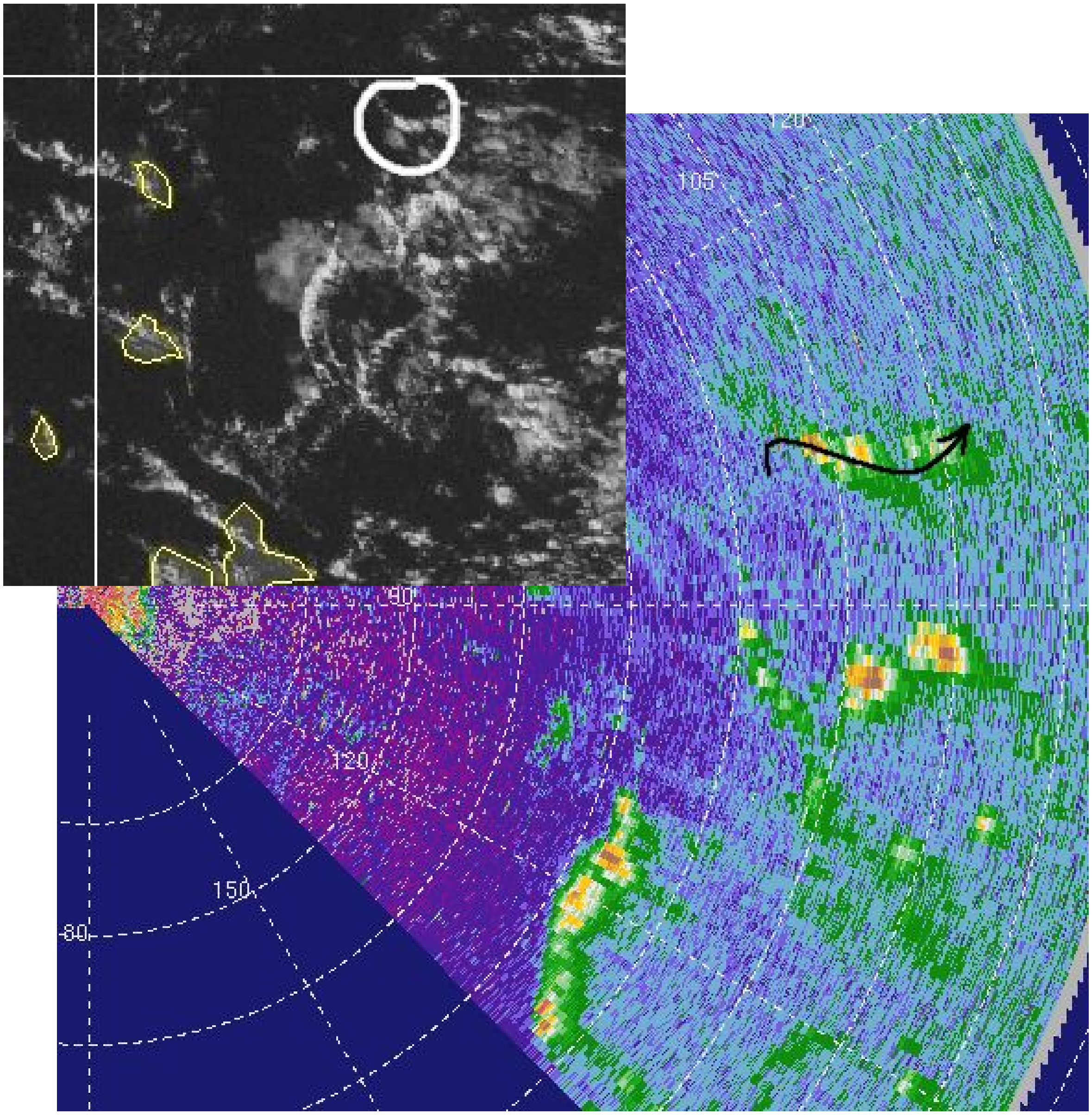
Narrative:

This is the second flight of the day. There was and earlier one at ~ 12Z with Bart. C130 took off at ~10Z and the BAE146 at about 15Z(?). K/A studied a small line about 80 km to NE.

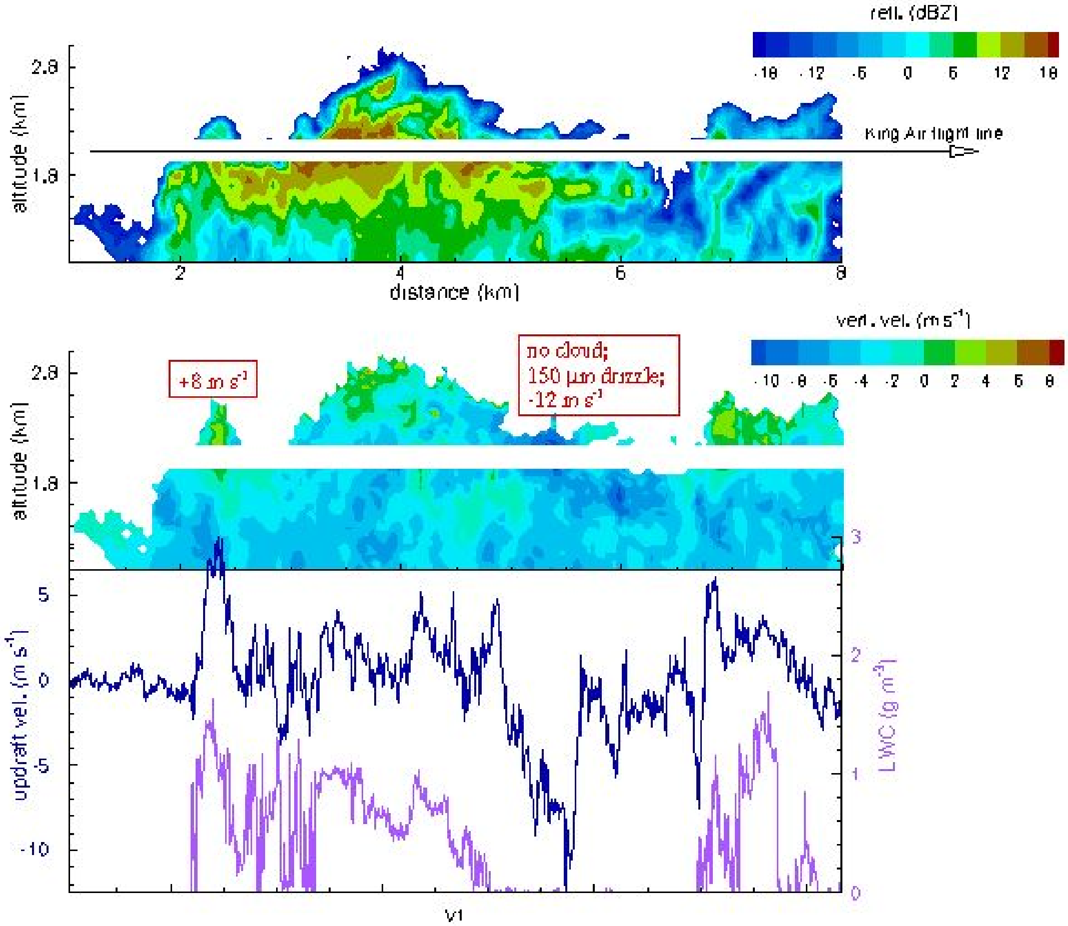
Clouds were changing rapidly in the area. Outflow circles of 30-50 km diameter were interacting to the immediate S of the flight area (as seen in the satellite images). These patterns faded by 19:15 UTC, with a rather abrupt change in the half hour following that. The clear band that separated the outflow circles from the more randomly scattered are to the NW, suddenly filled with clouds, so that the flight area switched from being in the NW (downwind) portion of the large-scale cloud band to being on the back (SE) end, all the while having clusters of various sizes in the immediate vicinity. All this made real-time decisions difficult.

Even so, some interesting 'bits' of data were collected demonstrating the strong small-scale dynamics in these clouds. An example of what I mean is illustrated with the figures below. As t he satellite image indicates, the cloud sampled during this period was not part of the major cloud arc further to the S which appears to be the result of the spreading of an earlier outflow. The clouds is question also formed a short line oriented NE to SW, as demonstrated by the SPol echo. This echo barely emerges above the noise level due to the large distance. The Wyoming Cloud Radar and King Air data shown is from the pass through the cluster of clouds about a kilometer below cloud tops from the WNW toward the ESE, as marked in the SPol image. A photograph taken just before penetration, from about

0.57 km on the distance scale of the WCR data shows a vigorous turret and this fact is confirmed by both the in situ and the WCR data.



However, the strong updraft was limited to a very small turret at the beginning of the pass and to the very tops of the broader turrets behind. These regions are shown in green to red colors in the middle panel of the WCR data. The first updraft patch had a horizontal extent of only about 200 m, according to both the in situ and the WCR data. The updraft region was elongated in the vertical, but still only about 600 m (in the plane sampled). Notably, this updraft emerged from a region with considerable drizzle, as evidenced by the high reflectivity values in the region.



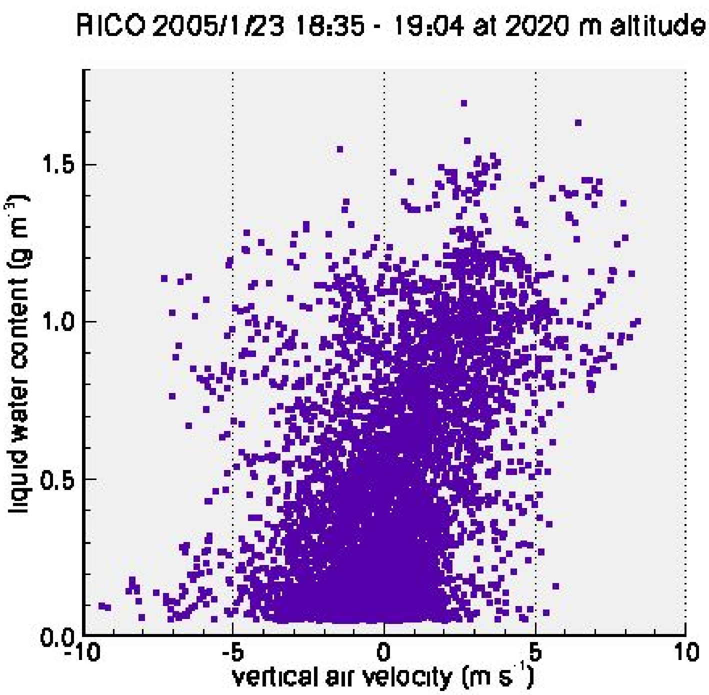
RICO - 2005/1/23 18:43:00 - 18:44:50
Doppler velocity unfolded, but uncorrected for bias.

gv - 30 Jul 5

The last remark is equally valid for the whole cloud cluster. There is echo to the ground everywhere, although this is not shown in the figure. The updraft regions are small and only appear near the tops of turrets. In part this is due to the fact that lower down, where larger drizzle drops are present, the air velocity is masked by the fall velocity of the drizzle, but strong updrafts would still show and the in situ confirms the paucity of updrafts.

The other interesting aspect of this flight segment is the encounter with a strong downdraft in 'clear' air centered near 5.5 km on the abscissa. Both in situ and radar measurements indicate downdraft speeds in excess of -10 m s^{-1}, and the radar data show that such values were present in a series of patches extending downward to the right in the image. At flight level, no cloud droplets were recorded in this region, but there were drizzle drops of about 150 μm maximum dimension. This type of clear air downdraft adjacent to a growing turret was quite a common occurrence, not just on this day but on many other occasions as well.

It is also readily apparent that there is a good correlation between updraft velocity and liquid water content. Looking at the full 30-minute period that sampling in this region was conducted at near 2000 m altitude (geometric), the correlation remains apparent, as shown in the plot here with each point representing roughly 4 meters of flight path. To put these data in perspective it should be noted that the adiabatic liquid water content at this level is close to 3 g m^{-3}, so that even the highest values are only half the adiabatic value.



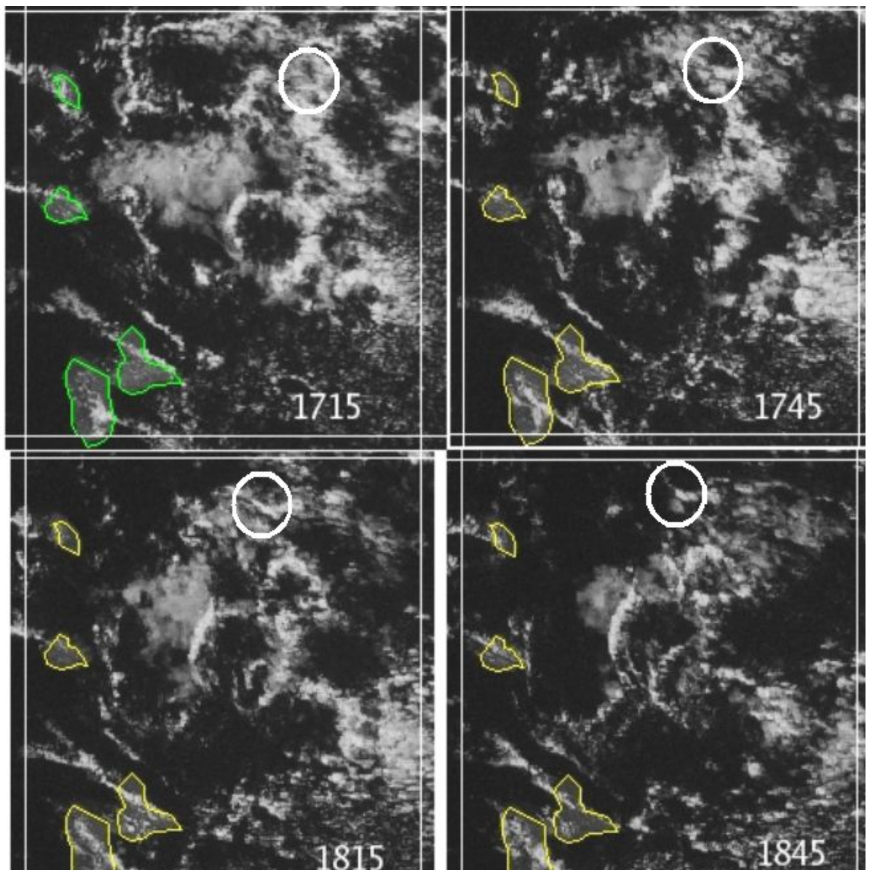
The sizes of all of the updraft regions were quite small. During the period represented in the graph, the total in-cloud (>0.05 g m^{-3}) sample was 21 km in 49 passes, the longest pass being 2.3 km. In this sample, there were only 5 patches of updraft exceeding 3 m s^{-1} at every point in the patch, and greater than 100 meters in length; the longest patch was 277 meters. In the same sample there were only 2 downdraft patches with <-3 m s^{-1} (at all points) and >100 m in length; the longest was 235 meters.

Similar observations were made at lower altitudes, the main features being, again, small intense up and downdrafts, with sharp transitions between them. For example, we recorded changes from +4 to -9 m s^{-1} in ~30 meters of horizontal travel at 1980 m altitude (18:58:06); from -4 to +4 in ~100 meters at 1300 m altitude (19:15:33); from +2 to -3 in ~50 meters (19:23:17) at 1000 m altitude (19:23:17).

In the strongest part of the updraft (2.3 km mark, 18:43:24) drizzle drops of up to 200 μm were recorder, but up to 400 μm drops were present right at entry, at the edge of that cloud.

Importantly, as pointed out earlier, WCR echoes reached to the ocean surface essentially everywhere below where the aircraft passed through cloud, and in a large fraction of the spaces in between as well, so that the updrafts developed within an area of light rain.

Aircraft sounding data in the vicinity of the cloud samples show that there was significant stability above about 1600 m, accompanied by a change from easterly to northwesterly winds and rapid drying. The 1600 m top for the mixed layer is also evident on the SABL images from the C130. Even up 1600 m the sounding was slightly stable with decreasing moisture content. The forcing of vertical motions and clouds rising to about 500 m above the mixed layer is quite surprising.



The likely explanation for the cloud development is that they formed at the boundaries of open cell structures. These cells were evolving quite rapidly, as seen in the image sequence shown here.

The cluster we sampled was part of a longer line earlier (1815). The NW portion of that line faded and the back (SE) part became dominant. SPol echoes also show that the maximum extent of this echo patch was at 1812, at which time the 0.5° echo (nearly 2 km altitude at this range) extended about 40 km in SE-NW direction and was about 8 km wide. Yet earlier (1745) the corresponding area is on the NNE boundary of a somewhat fuzzy and never fully developed open cell. This is the first time that an SPol echo is detected. A half an hour before that (1715), the area is between three open cells, a large on to the East and two smaller ones to the West. The sequence reveals the rather ephemeral nature of some of the open cells, yet their role seems fairly clear. At the same time the sequence provides food for thought about how this comes about.

The flight segment at close to 500 m altitude (19:27 – 19:50) shows patchy shifts in wind speed (from 5 to 8 m s^{-1}) and in wind direction (from 110° to 130°), still indicating significant perturbations in the boundary layer, but by that time the system was fading. Rainfall was very weak, in fact no SPol echoes were detectable after 19:18.

On the cloud scale, the picture that emerges from all of the above is that the fairly intense but small updrafts rose through drizzle/rain. We cannot be sure about the level of origin of these parcels, since they all underwent rapid mixing as they rose, and the lowest level at which significant updrafts were measured by the aircraft was at 1000 m altitude ; activity weakened by the time measurements were made at lower altitudes, below cloud base. Above the condensation level the cloud liquid water content was significantly reduced due to collection by the larger drops, thereby intensifying the downward flux of water. This scavenging, the small dimensions of the updrafts, plus mixing contribute to the reduced water contents near cloud top. How the updrafts were generated remains to be examined. It seems conceivable that the intense downdrafts generated next to turrets that emerged above the general cloud top height may also have contributed to the initiation of updrafts.

The BAE 146 did some sampling in the same cluster between about 17:30 and 19:30, so it will be of interest to combine the two data sets. There was no close coordination of the flight patterns, except for swapping between periods of sub-cloud and in-cloud sampling, but especially the sub-cloud data from the 146 should be pretty revealing.

Flight notes:

1744 engines started; 1750 – taxi; filed for 090/45 FL100

1754 T/O; CB ~ 2000'. C130 is near 045/60. Cleared for 070-120 / 30-80 up to 10 kft.

1816 over target; DD – top well below , near 8000'

1819 targets further W

1824 tower on 070/68 W of main mass; 8000' short bump!

1828 to W; -10 m/s; rain to the ground

1831 to E; +5 m/s; sharp bump!

1832 to W; -10 and +5 m/s; on autopilot

1836 150 hdg to pointer now in mass of cld; photo

1843 lined up on 120 hdg

1845 got out on E side; correct back

1848 reverse to pointer on 290 hdg; this is directly to 146; lot of time in weak cloud

1853 reset pointer in last pass to +ve w

1854 90/270; adjust to try along line of gradually taller series of towers

1859 big bump!; left butterfly to pointer

1910 MM (BAE146) on nose 7 mi ahead, 1 mi left

1912	MM on left, visual; reverse hdg; we are 180 left 4000'
1916	jog; new tower
1918	down to 3000', 180 hdg; hard to pick centers
1920	no NRE (nose radar echo)
1924	echo to surface; pointer set; down to 1500'
1928	few drops at 1500' at pointer
1932	passed under new growth; scud; 0.3 m/s
1935	following behind and under MM, using TCAS
1937	breaking from MM; track to pointer; down to 800'
1950	end of runs at 800' sub-cloud w/ MM; head to cluster at 086/54
2000	at 10,000' end of sounding in clear zone
2007	descend toward echo Bart reported earlier; now weak; 066/45; small WCR echo to sfc from 4000'
200720	down to 3000'; butterfly BUT no data for last 13 min; at 1700' just above CB
202856	data back; no WCR
203031	2105' 115 cm^{-3}; 2310' 150 cm^{-3}; CB sample – 2477' on ralt
2042	good w; 130 cm^{-3} at 2434' ralt; 1-2 m/s; last cloud
2055	on arc - +6 m/s in cloud but data system already off
2104	L/D