King Air N2UW flight report for January 17, 2005.

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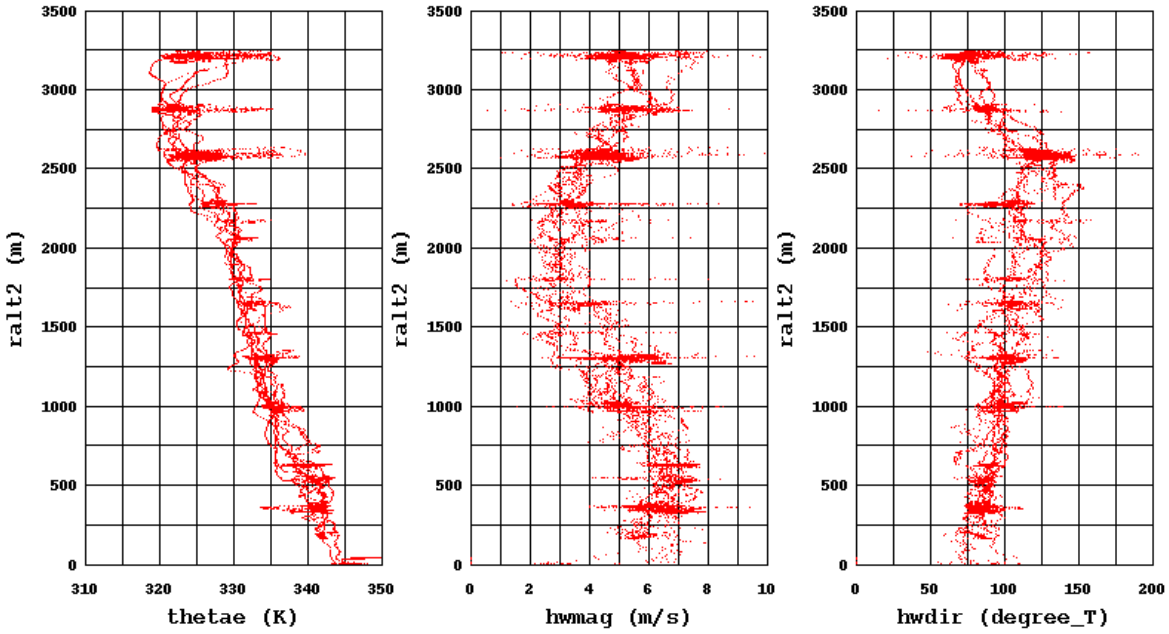
General: As the soundings below indicate, the wind profile in the altitude range sampled by the King Air showed some complexity; above this range, at the inversion near 4 km, winds changed to northerly, then westerly.



Instability was practically nil above about 2500 m, and the inversion maximum was at about 4.5 km.

Clouds, and SPol echoes, are widely scattered in the study area, though hints of meso-cells can be seen in the satellite images. Turrets rise vertically with little preferential location for new development. Turrets are narrow, straight – bunches of sticks. Rain development less intense and evaporation below cloud base more effective.

Single aircraft mission by the King Air consisted of three cloud studies. First one centered about 20 km W, 20 km N (roughly 12:20 – 12:50), second one about 35 km E, 35 km N (13:20 – 14:00) and the third (14:10 – 14:50)10 km W and 35 km N of SPol. The second sequence was organized to mesh with RVSJ observations; those data will receive extended scrutiny later on, so no details will be given here.

Narrative:

A. The first sequence yielded nice data on small cloud with up to 12 m s^{-1} updrafts and

moderate precipitation. Good WCR data, including a side view.

B. The second segment of the flight consisted of a series of penetrations in a butterfly pattern of a relatively small but persistent cloud that produced intense rain to the surface. The SPol echo was about 8 km in diameter at its maximum (but changed relatively little throughout the life of the cloud); echo tops extended to about 4.5 km, and reflectivities reached 50 dBZ. A near-surface echo can be first noted at 12:44, at 060˚/68 km, and can be followed till 14:15, at 036˚/45 km.

Twelve penetrations were made: four at 2620 m, four at 3220 m, and four while stepping down to 1000 m. One of the early passes (13:33) was to the side of the cloud, for a view with the side-looking mode of the WCR. During most of the passes the up-down mode was employed, but three passes were with dual-Doppler mode in the nadir plane.

The rather complex wind profile did not result is any perceptible organization in cloud structure. The flight pattern chosen also made it difficult to recognize a pattern. Targeting was by visual selection of the most vigorous turret, or, for a brief period around 13:50, by the the echo that became detectable during that time by the storm-avoidance radar ("nose radar").

The most striking feature seen in all of the penetrations at 2600 and 3200 m altitude was that the most intense precipitation rates and largest drops were found to be co-located with updrafts. Examples of this pattern are given in the two figures that follow.

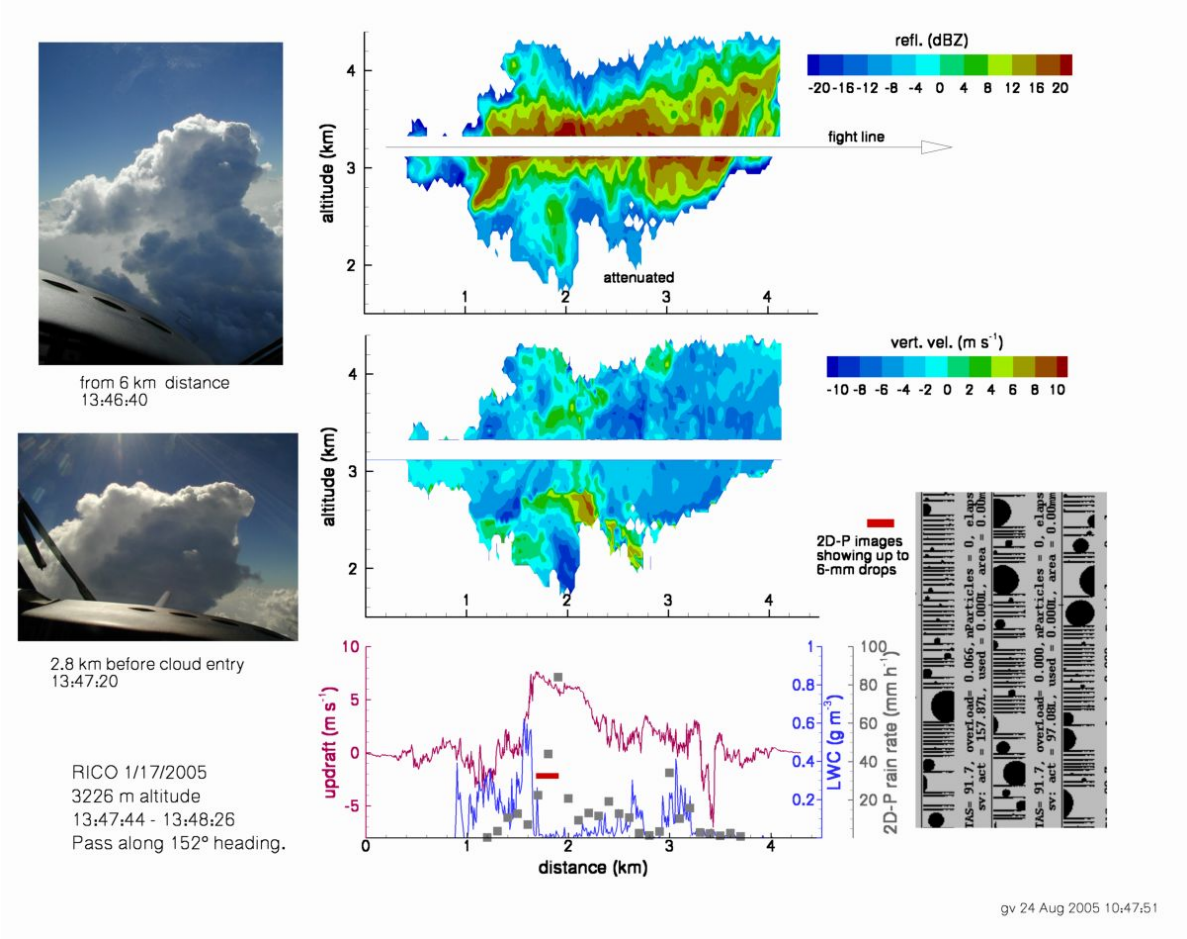
The first one is for a penetration at 3220 m in a direction nearly perpendicular to the winds at that level. The sheared appearance in the photos reflect the northerly winds (from the left rear in the photos) which prevailed near the inversion.

The reflectivity pattern showing maximum values near the flight level is influenced by attenuation and without knowing the LWC distribution throughout the sampled volume it is not possible to evaluate its effect. Attenuation is most severe below the flight level in the vicinity of 3 km horizontal distance.

Centered at about 2 km on the abscissa, there is clear indication in the Doppler data of an updraft (middle panel), and this is confirmed by the in situ measurement (lower panel). The Doppler values also include particle fall velocities and are therefore much lower than the air velocity measured by the aircraft sensors. Even so, the fragmentation of the updraft into two centers, one at about 3.6 km altitude, the other at about 2.6 km is likely to reflect true characteristics. Also notable is the sharp gradient at the top of the lower bubble.

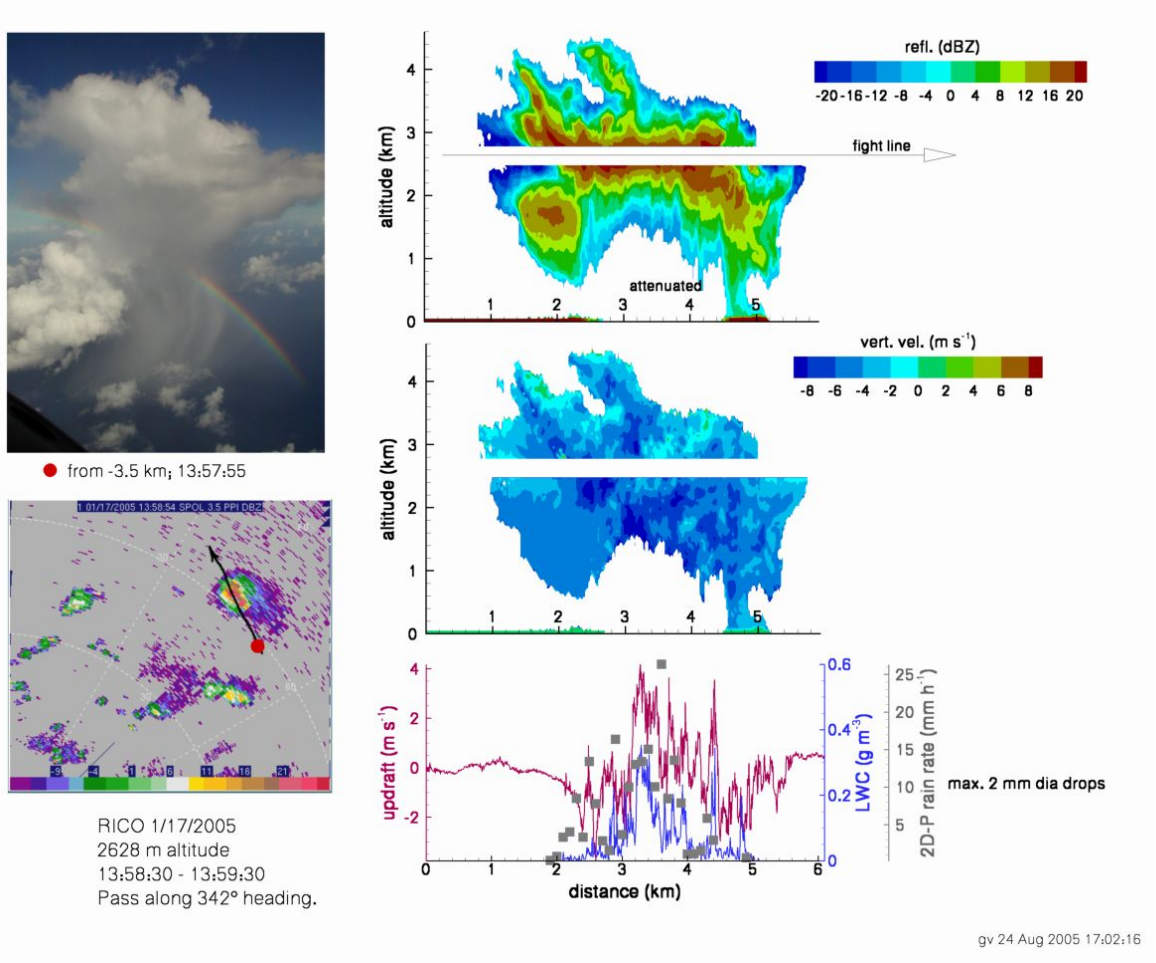
The in situ winds indicate a converging component along the flight line, consistent with the location of an updraft pocket not far above flight level, and with entrainment into the updraft. The latter may be a factor in producing near-zero LWC in the cloud droplet

size range within the updraft, but the main explanation for that fact seems to lie with the intense rain rate coincident with the updraft. Right near the peak in the updraft, at 1.8 – 2.2 km on the abscissa the rain rate (just using the 2D-P probe data) peaks at 100 mm h^{-1} and the particle images show drops up to 6 mm in diameter.



Two passes subsequent to the one shown above confirm the same pattern of high rain rates coincident with the updraft. In the first of these (13:49:50 – 13:50:45) the maximum updraft was 15 m s^{-1} and the LWC about 1.5 g m^{-3}. On that pass the largest drops detected were about 4 mm. The radar images are also similar on both passes

The second example shown on the following page was made at 2628 m altitude on a near northerly heading. By this time, the cloud was past its peak activity; it dissipated about 15 minutes later. Yet, an updraft was still present; it had a peak value of 4 and was over a kilometer wide along the traverse. And, once again, the highest rainfall rates coincided with the updraft. Maximum drop sizes were about 2 mm.



At this time, the vertical velocities from the WCR are all negative, indicating that fall velocities dominate, except at the tops of the two emerging turrets, where drop sizes are small. Fall streaks from these two turrets are nicely depicted in both the reflectivity and velocity images.

As a side note, it is worth looking at the large area of uniform velocity between 1 and 2 km altitudes and 1 to 3 km distance. There is a reflectivity core in the same location with at least 20 dBZ variation across. Similar regions of even greater dimensions are evident in data from the passes just prior to this. How this comes about is not clear.

Summary:

The main novelty in the flight data described above is the presence of large drops (up to 6 mm) and heavy precipitation (up to 100 mm h^{-1} calculated rate) in updrafts about 1 km below maximum cloud top altitudes. It appears most likely, that these drops grew in the updraft during its rise, having been started by drops falling into the updraft at low altitudes. The updraft being surrounded by precipitation makes this quite plausible. The picture implies a fairly continuous updraft stream, as opposed to bubbles, although there is no

requirement in this for the updraft to be completely jet-like. In fact the radar data indicate a pattern that can be viewed as a jet with bubbles superimposed on it. Lateral injection of large drops into the updraft at the observations level is not consistent with the data.

Flight notes:

1145 start engines, cleared to 030/80 FL100

1156 T/O

1209 no shear, turrets vertical, some fragments near tops; 6 m s^{-1} at 8000'

1210 continue sounding

1225 pointer set in 5 m s^{-1} w/ rain; multi-bubble; echo to sfc.

1229 90/270 and descend to 7000'

1230 at pointer

1235 WCR in mode SD

1239 back to red NRE (nose radar echo); 310 hdg; 4000'
precip signal is attenuated

1243 90/270 descend to 1000'

1250 under Cu, not center
over RVSJ at roughly 016/48

1256 under Cu, 150 hdg

1259 looking for good cloud base: 1834 m on ralt2; 20.6 C

1302 at 2060 m max. 80 cm^{-3}

1308 cloud base at 2060 m; 80 cm^{-3}

1309 climb to 8000' to look around

1317 target ahead, have no clearance for it

1321 target – going to left of tallest turret; smaller ones further to the right

1322 5 m s^{-1}; again on edge of clearance

1327 back at pointer

1332 using 1.5-km offset, but adding 0.7; visual to new rising turret
rainbow among rising bubbles on S side, to right of turret, below higher cloud patch; SD mode

1335 going for DD mode

133608 photo right wing

1337 DD pass in newer part of cld, 8

1340 photo of cld that is not our target

134102 photo on right wing of target

1343 DD pass, all down with precip

90/270 climb to look around

1348 UD mode 4-8 m s^{-1}; 170 hdg

1350 DD; 8-10 m s^{-1} 060 hdg -- doing this with butterfly pattern

1352 photo, right wing

135222 photo while turning on target, DD

1354 NRE is donut shaped; 1.5 nm dia

1357 photo on right wing

1359 8000' following down the precip

1404 3000' weak rain from cld overhead – fallen apart

1406 at 3000'

1410 W-bound run a bit south of RVSJ, 3000'

1412 climb to 5000' for eastbound run; sort of random

1416 taking up E hdg

1418 climb and look for new target

1420 2 m s^{-1} max., pointer set, eastbound, 6300'

1420 9000' westbound; top a bit above us, fuzzy; new tower on E side

1428 9000' DD mode 080 hdg near 022/40

1432 9000' DD, westbound, RVSJ to right; near perfect position, I think!!

1436 5500' DD

1440 3000' UD mode

1443 1000' UD; heading exactly to RVSJ

1448 1000'; UD mode; weak; went past RVSJ a few times

1450 to ANU

1517 L/D