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An introduction to the SCOUT-AMMA stratospheric aircraft, balloons and sondes campaign in West Africa, August 2006: rationale and roadmap - Supplementary Material

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Abstract. A detailed M55 and balloon flight description is hereby provided.

1 Geophysica flights

1.1 31 July 2006 (Julian Day 212), Verona-Marrakesh transfer flight

The Geophysica left Verona at 23:26 LT (21:26 UTC) arriving in Marrakesh at 01:17 LT (01:17 UTC) roughly following the south-west European and African coastline. In order to perform a remote sensing of the UTLS region from middle to low latitudes, the flight was planned to provide optimal performance for the spectrometers on board, i.e. at the maximum altitude compatible with the route safety concerns. A first leg at 17.5 km altitude lasting one hour was followed by a second leg at 18.5 km, until the destination. The weather on the route was fine and with clear sky.

1.2 1 August 2006 (Julian Day 213), Marrakesh-Ouagadougou transfer flight

The aircraft took off at 10:59 UTC following a straight flight path with two constant altitude legs at 17.5 km and 18.5 km to Ouagadougou, crossing the Sahara and Sahel regions which had not been recently affected by convection. Part of the flight track is shown in Fig. 11, panel a.

1.3 4 August 2006 (Julian Day 216), Long range transport

The aim of the flight was to sample the TTL region along a north-south transect to cross the latitudinal gradient of the region likely to be affected by the general transport. In particular, it aimed to measure the long range transport from the summer monsoon circulation over Asia into the TTL over West Africa in order to compare it with the influence of local convection. So, this flight tried to take place when MCS activities in the region were at a minimum. There was no convection predicted for the day in the region where the mission took place. Nevertheless, convection which could have influenced the measurements was present the evening before over Ghana and on the morning of the mission over the western part of Burkina Faso, moving westward. The flight profile was designed to have constant level legs and vertical profiles from 19 to 12 km at the final points of the transect, over the Guinea Gulf coasts, to acquire full vertical profiles of atmospheric constituents. The plane took off at 08:26 UTC heading southward at a constant altitude of 16 km. Before reaching the southernmost point over the Gulf of Guinea, it performed an altitude excursion climbing at 19 km and descending down to 12 km, before turning back and heading northward at a constant altitude of 15 km. In proximity of Ouagadougou, a climbing up to 19.5 km was performed followed by the final descent to land at 12:13 UTC. The flight track is shown in figure 11, panel b. The F-20 Falcon performed a flight at the same time, following a similar geographical pattern at lower levels.

1.4 7 August 2006 (Julian Day 219), MCS close-up

The flight on the 7 August attempted a MCS close-up. The MCS originated in the night over central Mali, developed overnight slowly moving south-westward. The MCS evolution was monitored in real time by continuous inspection of MSG images. The aircraft took off at 12:15 UTC, chasing the system as it moved westward and reaching its back and wake over southwest Mali. Unfortunately the more active part of the system had already passed over. The aircraft performed frequent altitude excursion during the ferry legs and when in the region of the MCS wake where cloudiness was present below and the presence of a cloud tower to the left of the aircraft was reported. As the aircraft turned northward, it performed a dive from 18 km to 12 km, then climbed up to the ceiling altitude of 19.5 km before leaving the MCS wake area. In the lowermost part of this altitude excursion, it entered into layered clouds and the pilot reported light turbulence. It then got back eastward and landed in Ouagadougou at 16:07 UTC. The flight track is shown in Fig. 11, panel c. The F-20 Falcon flew at the same time, following a geographical pattern slightly displaced northward with respect to the M55, sampling the atmosphere from 8 to 12 km.

1.5 8 August 2006 (Julian Day 220), CALIOP validation

The flight was designed to follow the footprint of the CALIOP lidar on board the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite, to validate its cloud products with observations of upper clouds structure and microphysics, including size and shape of ice crystals. CALIPSO is part of the A-train and follows a sun-synchronous orbit, the ascending node crossing the equator at 13:43 local time with a 16-day repetition cycle.

In the region close to Ouagadougou, daytime over-passes are for ascending orbits from South-East to North-West. The M55 was aimed to fly along the CALIPSO footprint, about 30 min before and after CALIPSO overpass with altitude excursions, to vertically sample thin cirrus clouds, while the ferry flights, and the time of flight out of the CALIPSO validation time, would have been eventually devoted to cirrus sampling in that region. The flight was designed to meet the CALIOP footprint along a line extending from 9.04° N, 2.55° E to 12.77° N, 1.77° E which the satellite was going to overpass from 13:28 UTC to 13:30 UTC. The meeting point of the two platforms was forecasted to be in the middle of this line, at 13:29 UTC.

The aircraft took off at 11:46 UTC and climbed to 17.5 km to descend to 14.5 km and perform a stepwise ferry flight

with legs at 15.5 and 16.5 to reach the first intersection with the CALIOP footprint. The aircraft followed the CALIOP footprint initially at an altitude of 16.5, then just before reaching the meeting point with CALIOP, it started ascending to 19.5 km. The meeting point was reached at 13:29 UTC during the climbing. It then followed the CALIOP footprint with 100 km stepwise horizontal legs at this level, and at 18, 16, and 15 km. Upon leaving the footprint and turning to Ouagadougou, a final slow climbing to the ceiling altitude of 20 km was performed. The flight track is shown in Fig. 11, panel d. High level clouds were observed in proximity of Ouagadougou and, of use for the CALIOP validation, on the last part of the footprint leg.

1.6 11 August 2006 (Julian Day 223), MCS aged outflow

This flight aimed at sampling a TTL air that was likely to have been processed by an MCS system in the previous days; one of such systems developed two days earlier over the eastern border of Nigeria, then moved north-westward extending from the Niger-Nigeria border to Benin and Togo, to continue its westward movement over Burkina Faso and starting to dissipate the day of the flight. An encounter with airmasses containing aged MCS outflow was forecasted, based on MSG satellite imagery and foreward trajectory calculations using LAGRANTO with a spectral resolution of T319L91. The forward trajectories were started from positions of any active MCS upwind of the investigation area identified by very low brightness temperations. On the 11th of August, aged MCS outflow was predicted for the region of the Burkina Faso-Niger-Mali borders. To sample these air masses, the Geophysica took off at 14:44 UTC heading northeast at 16.5 km, then 17.5 km altitude for the ferry part of the flight to reach the region of possible outflow. Once it reached the northernmost point, it turned twice southeast and southwestward to come back to Ouagadougou. During this part of the flight, it repatedly performed dives to 12 km and ascents to 15 km. On the last part of the light it climbed up to the ceiling altitude of 20 km before the final descent to Ouagadougou, where it landed at 18:22 UTC. During the first part of the flight, solid cloudiness was observed at an altitude of 9–10 km below the aircraft, probably remnants of the MCS passing over the Ouagadougou region. The flight track is shown in Fig. 11, panel e. The F-20 Falcon performed a flight on the same day, sampling the same region at lower levels.

1.7 13 August 2006 (Julian Day 225), UTLS survey

The flight aimed at a survey of the UTLS over a meridional transect in relatively quiescent conditions, but took the advantage of a very close overpassing of the CALIOP footprint over Ouagadougou, so the flight track was planned to follow this footprint while heading south. There was no local convective activity, although large MCS activity was occurring over Chad and the Central African Republic since the day before. Very few low level clouds were encountered while flying over the continent, while no clouds at all were present over the ocean.

The aircraft took off at 12:50 UTC and reached the CALIOP trajectory at 13:21 UTC (its overpassing was foreseen between 13:46 UTC and 13:48 UTC) which was carried out with a stepwise descent from 18.5 km down to 12 km. Then, before reaching the southernmost point of the track over the Gulf of Guinea, an ascent was made up to 18.5 km. On the way back a further stepwise ascent was performed to reach the ceiling altitude of 20 km before landing at Ouagadougou, at 16:23 UTC. The flight track is shown in Fig. 11, panel f.

1.8 16 August 2006 (Julian Day 228), Ouagadougou-Marrakesh transfer flight

A large MCS developed in the early morning in central Burkina Faso, and was over Ouagadougou by noon. The aircraft left Ouagadougou at 13:27 UTC when the meteorological conditions allowed to take off. It followed a straight flight at a constant level of 17.5 km to Marrakesh, where it landed at 17:16 UTC.

Part of the flight track is shown in Fig. 11, panel g.

1.9 17 August 2006 (Julian Day 229), Marrakesh-Verona transfer flight

The take off was made at night at 04:10 UTC The aircraft followed the African a nd south European coast line, at a constant altitude of 17.7 km, in the dark for the first hour of the flight. It landed in Verona at 07:51 UTC.

2 Balloons and sondes flights

2.1 31 July (Julian day 212) OPC and CN counter and Ice and Aerosols #1

The balloon was launched at 08:30 UTC before the arrival of an MCS (gust front and squall line at 09:20, lightning at 24 flashes per minute due south, cloud tops around 13 km). It ended at 11:00. Subsequent analysis coupled with additional flights suggests that the measurements were contaminated in the UTLS by outgassing of water vapour from the gondola on both ascent and descent.

The *Ice and Aerosols* flight was launched at 17:23 and ended at 19:26 UTC. No data could be recovered for OPC, Micro-Dirac and micro-SDLA due to a rough launch. LABS only acquired backscatter ratio and depolarization data up to 22 km during ascent and descent.

2.2 2 August (Julian day 214) BKS /O_3 sonde

The flight was launched at 18:52 UTC. Cloud layers from 15 to CPT at 17 km with high colour indices (around 15) indicating the presence of ice particles, and a layer of particles between 19–21.5 km with low colour indices, indicating small liquid sulphate aerosols, were observed. This high altitude layer, present in all BKS soundings, was later identified to be volcanic aerosols from the eruption of the Soufriere Hills volcano in Monserrat Island in the Caribbean on 20 May 2006.

2.3 3 August (Julian Day 215) BKS/FLASH/O_3 sonde

It was launched at 18:38 UTC. Thick clouds between 11–13 km and 14–16 km and the volcanic plume between 19–21.5 km were observed.

2.4 5 August (Julian Day 217) Water Vapour #1 and BKS/FLASH/O_3 sonde

The balloon was launched after sunset at 18:40 UTC in local "suppressed convection" situation with a MCS 600–800 km upstream in the NE over the Aïr mountains and another very large one 1000 km East, over SW Chad. Satellite observations as well as mesoscale modelling studies show that the Aïr MCS was generated orographically over Aïr and has induced overshoots up to 18.3 km.

2.5 7 August (Julian Day 219) Anvil and Cirrus #1 and BKS/FLASH/O_3 sonde

The balloon was launched at 16:45 UTC before an intense MCS travelling from the East (tops at 19 km seen by the radar 2 h before, lightning 18 flashes/min), which caused heavy rain as the balloon was already in flight. After a 40 min float at 22.5 km, the balloon descended slowly down to 18.7 km at 20:10 UTC. At the time of the launch, a large convective area was located 100 km S-SE and a MCS 100 km west. Another active cell developed 200 km to the west, which was over-flown by the balloon at the end of the flight.

2.6 9 August (Julian Day 221) BKS/FLASH/O_3 sonde

Launched at 18:39 UTC, it showed a a CPT of $-78°$C at 17 km. No cloud or ice particles were observed during this flight but the volcanic plume at 20 km.

2.7 10 August (Julian Day 222) Chemistry #1

The balloon was launched at 16:42 UTC reaching float altitude at 28.8 km for 44 min followed by descent after sunset for 39 min. The radar could see a MCS at 200–300 km in the SE topping at 15 km, and convective cells on the west organising in squall line on the west, flown over by the balloon. The CPT of $-78°$C was crossed at $\sim$17.3 km.

2.8 12 August (Julian Day 226) BKS/O_3 sonde

Launched at 18:38 UTC it reached the CPT of $-78°$C at 17 km after crossing depolarizing clouds between 13.3–14.5 km. Some small particles were reported between 15–17 km followed by the volcanic plume at 20 km.

2.9 14 August (Julian Day 226) BKS/FLASH/O_3 sonde

Launched at 18:46 UTC, it crossed a CPT of $-81°$C at 16.5 km. The BKS reported thick cloud layers at 9–13 km, 13.5–15 km and 15–17 km, followed by thin particles layers between 17–18 km, and the volcanic plume above.

2.10 17 August 2006 (Julian Day 229) Ice and aerosol #2

Launched at 11:45 UTC it ascended to $\sim$22 km followed by 30 min at ceiling and a slow descent to 14.5 km in 1.5 h. There was no convective activity in the proximity of the balloon but a large MCS over eastern Niger, 800 km east. The CPT of $-78°$C was observed at 16.5 km.

2.11 19 August (Julian Day 231) Chemistry #2

Launched at 16:45 UTC it reached the float level at 29.2 km at 18:00 and was cut down after sunset. No local convective activity was present but a strong MCS 100–200 km upwind on the east. The CPT was at $-74°$C at 17 km.

2.12 21 August (Julian Day 235) BKS/FLASH/O_3 sonde

Launched at 21:52 UTC with a 400 km size MCS nearby on the East it crossed a CPT of $-82°$C at 16.5 km. BKS observed a thick cloud from 11 to 16.8 km, several thin layers of particles up to 18.5 km an the volcanic plume above.

2.13 23 August (Julian Day 235) Water vapour #2 and BKS/FLASH/O_3 sonde

Water vapour #2 was launched at 18:15 UTC reaching a ceiling altitude of 24.7 km followed by a slow descent to 14 km in 1 h20 min. This flight took place after a two day period of intense convection over Niamey area. The MSG images were showing an MCS immediately north, local convection on the west of the Niger river and other MCS along the Nigeria border. Before launch, the MIT radar was reporting convective cells reaching 18 km.

The temperature profile was singular showing a marked LRT of $-76°$C at 15 km followed by a CPT of $-80°$C at 17 km.

A BKS /FLASH/O_3 sonde was launched 53 min later at 19:07 UTC. A CPT of $-78°$C was observed at 15.5 km. The backscatter sonde sampled a thick cloud between 13–16 km on both ascent and descent and a 1 km thick particles layer during descent around 18 km with high colour indices (15–20) but low depolarization.