SOLVE-II Flight Report: Sunday, 02/02/2003

Mark R. Schoeberl

Flight Type: SAGE-III occultation, North Pole flight, & cold-pool probe

Flight Objectives:

1. SAGE Occultation for SAGE III scan
2. Vortex probe for ozone loss
3. Return flight along edge of cold pool
4. Vertical profile north of Norway
5. Run to Kiruna at 20 kft
6. Vortex Edge crossing
7. Takeoff 9:22 GMT
8. Flight Length ~10 hrs

Flight Plan (UT):

10:22 Takeoff
10:45 Sun run #1 – Waypoint 4
11:35 Sun run #2 – Waypoint 7
12:27 Sun run #3 – Waypoint 10
12:37 SAGE III occultation – Waypoint 6 (72˚ 46 N, 3˚ W)
15:26 North Pole – Waypoint 16
18:11 Spiral descent/ – Waypoints 11-12
16:27 Outside the vortex westernmost Waypoint 14
17:59 Landing

Forecast Meteorology:

The vortex still has a triangular shape with the axis extending south from the pole to Iceland. We will begin the flight with three sun runs. We will head to the furthest north point near the northern edge of the vortex and then return. A strong low-pressure system has formed over England that seems to be anchoring the southern end of the vortex. We expect some turbulence along this front at aircraft altitude. The vortex is shedding material at a rapid rate.

Flight Meteorology:

Relative humidity forecasts were again right on target. Clouds formed below the aircraft just about exactly where predicted.

Flight Report:

The Geophysica took off about 40 minutes ahead of us (8:40UT). They will be bracketing our final flight leg back to Kiruna. Their outbound leg will be to the east of our flight track and the inbound leg will be to the west. The in situ measurements should be useful for comparison with the lidars. The Geophysica will land at 13:10 UT. They will travel to 72N, 30E at 18 km, then to 75N, 30E, do a dive and fly at 11.8 km (just into the cirrus decks). They then turn west to 75.5N, 10 E and rise to 19.5 km for the leg back to Kiruna.

Figure 1. Geophysica taking off.

Took off at 9:22 UT. Kiruna cirrus overcast. As we flew to waypoint 4 over the Atlantic, we moved through some cirrus that was just below flight level 35. We were flying just above the tropopause (~10 km). Ozone 180 ppbv, CO 61 ppbv, and H_2O 11 ppm.
Problems developed with the AROTAL laser – broken flash lamp – DIAL has a spare but cooling water leaked into the casing creating some problems.

As we flew just above the trop, the plane experienced some chop and DIAPER reported some particle hits of cirrus. Ozone declined to 154 ppbv, CO 68 ppbv, and H_2O 17 ppm. As predicted, cirrus decks below the aircraft decreased as we approached the sun run WP 4. Ozone rose to 216, CO 48, H_2O 8.3, RH 58% as we moved into the subsidence region. Clear view of the horizon at WP4. Sun run #1 began on time at 10:45 UT.

Winds from the south along the first part of the sun run weakening to no wind near the center of the run. DIAPER reports CN counts decreased as the wind died. The CN count is probably from aircraft flight lanes to the south of us. Ozone 307 at the center of sun run #1. Cirrus to the south as predicted – did not interfere with the sun run.

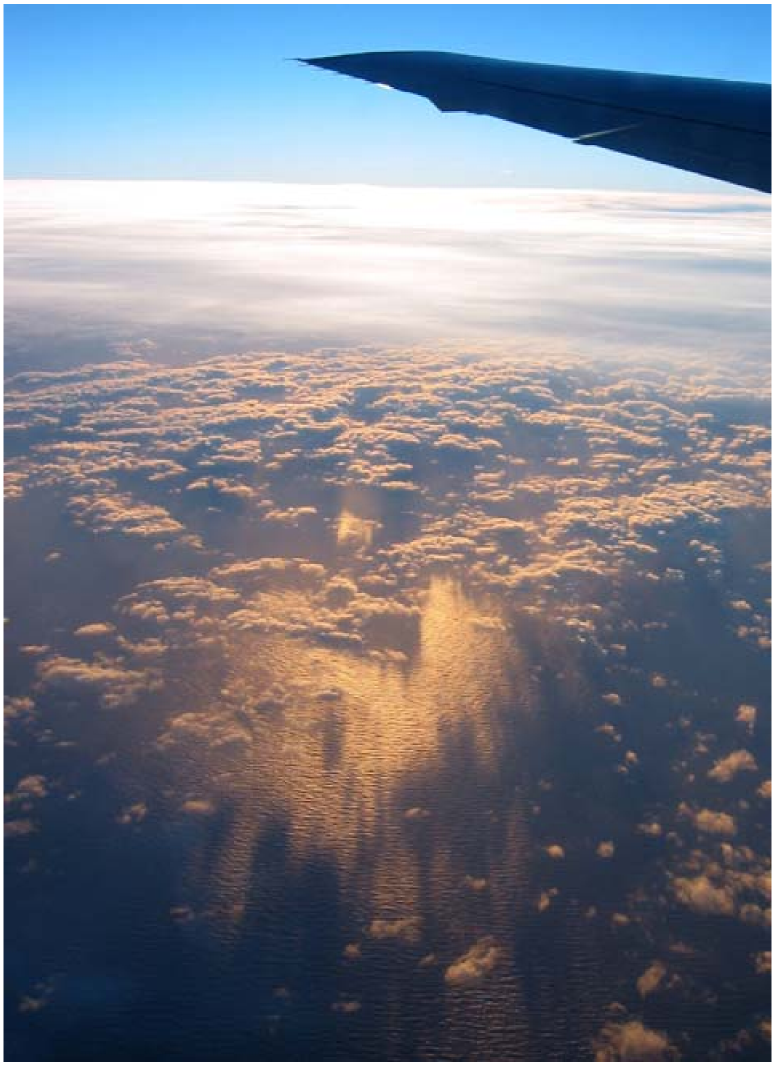

Figure 2. Photograph out the window for sun run #1 showing sun glint through broken clouds below. The aircraft wing hides the sun.

Sun run #2 began at 11:37. Ozone 247, CO 42, H_2O 7, PT 317, RH 71%. AROTAL was repaired – DIAL supplied a spare flash lamp. We used drinking water to refill the chillers. This is a good example of how instruments can be repaired onboard, and an example of the team spirit of the SOLVE II investigators. Lining up for sun run #3 at 12:00, we overflew Jan Mayen – a small volcanic island (Norwegian) with meteorological station WMO 01001. Jan Mayen is often the source for beautiful Karman Vortices in the cloud structure seen by satellites. Ozone rose to 308, CO 30, H_2O 4.5, PT 318, RH 42%. AROTAL reports ozone at 1.5 to 2.0 ppmv at 20 km with considerable structure – ozone is showing some structure.

DIAL and AROTAL report an aerosol layer near 14 km, the ref (below) shows that material may have entered the vortex in this region. Sun run #3 began at 12:28. Ozone

185, CO 65, H_2O 13, PT 315, RH 96%. DIAL reports elevated aerosols almost to 18 km almost at the occultation point. Low ozone was seen in the aerosol enhancement layer. DIAL reported a small stratospheric intrusion below the aircraft at 12:41UT. In situ ozone showed some structure dropping to 123, CO 82, H_2O 14, RH 100%, PT 311. Sun run #3 ended at 12:47. As we turned north, ozone fell to 50 ppb and CO rose to 106 ppb, H_2O 18 ppm. We seemed to be in a tropospheric intrusion. We ascended to 37.5 kft, ozone rose to 182, CO 64, H_2O, RH 75%, PT 317.

The sun run region overall had a complex ozone and aerosol structure between 16 and 20 km. This may be associated with the intrusion indicated in the flight plot figure below. As we went northward the variability decreased and ozone began to fall.

Sea ice was visible off the coast of Greenland (74˚N). In situ ozone rose to 219, CO 61, H_2O 7.6, RH 94%. Structure in CO and ozone seen – winds veered to the west (from the north) – this allows orographic waves off of Greenland to be ducted to our altitude. In situ ozone continued to rise. At 13:10, the troposphere rose to close to our altitude. SP2 and DIAPER reported a number of particles, as we appeared to be in some sort of haze layer. Ozone fell to 40.

Higher up, AROTAL reported ozone of 1.2 to 1.3 ppm at 20 km, with low ozone all the way up to 25 km. Gravity wave chop increased as we approached the "ear" of Greenland. In situ ozone rose to 320, CO 41, H_2O 5, RH 97, PT 322. Gravity-wave structure continued to 77N; DIAL reported a stratospheric intrusion below us.

At 78˚ N, the gravity-wave chop decreased as the wind veered to the north. Ozone values above the aircraft stayed at 1.3 ppmv as we crossed northern Greenland. AROTAL reported a large aerosol layer above 28 km. At 84N there was a tropospheric intrusion evident below the aircraft, the high-altitude aerosol layer continued. Vortex analysis shows that the "edge" is very soft above 1000 K, so it is likely that these are aerosols from midlatitudes. In situ ozone rose to 530, CO to 22, and H_2O 3.3 – very stratospheric air.

To prevent problems with the navigation system, we will decouple the inertial system from the other navigation systems as we near the Pole. We flew past the Pole and then turned around. Our highest latitude was 89˚59.6; we were within 0.4 nautical miles of the Pole. (Post-analysis comment – For the cross-polar flight, the pilots tested a new procedure. They decoupled the GPS from both FMS boxes, then relashed in one to the #2 FMS. The INS stayed coupled throughout. This worked like a charm.) DIAL detected a pollution layer below us (little depolarization). The maximum longitude was 160˚W – we all set our watches to Hawaii time – then reset them when we flew back. Ozone at 20 km began to slowly increase and we noticed some anticorrelated structure in ozone and methane. H_2O was 2.3 ppmv – maybe a record low value. (Post-analysis comment – Glenn Diskin has noted that 2.3 ppmv was a cal point; the actual H_2O numbers were between 3.5 and 4.0 ppmv.) Ozone 480, CO 25.

As we approached the cold pool, AROTAL temperatures approached 195 K (84˚N, 24˚W). An aerosol layer existed above 30 km. AROTAL reports a minimum temperature of 194 K at 70˚N, this (as usual) is about 1 to 2 K lower than predicted. No evidence of PSCs in the cold pool area we sampled (but read on …).

We ascend to 41 kft at 16:40. East of Spitsbergen, in situ ozone fell to below 400 ppbv and then rose again. H_2O at 3.3 ppmv, CO 29, PT 338, RH 60%.

Satellite photos and DIAL showed cirrus below the aircraft as we approached WP 20 for our planned spiral down. We decided to continue on past WP20 at altitude and spiral down over Kiruna at 71˚N.

AROTAL reported a very thin aerosol layer forming (500-m thick) at 21 to 22 km – perhaps some STS. AROTAL shows temperatures at 197 K in this layer. This is the region where we may cross a piece of air injected into the vortex from midlatitudes. This air, unlike the rest of the vortex, would not have been denitrified and could potentially form PSCs (and may have been trying if the temperatures had been colder). DIAL did not see this layer, but AROTAL has higher sensitivity in this region. The layer continued to thicken as we proceeded south, and then disappeared as we crossed into northern Norway. Temperatures, according to AROTAL, were well above PSC temperatures. Perhaps this was volcanic aerosol injected along the filament.

At this point, in situ ozone was about 500 ppbv, CO 22 ppbv, and H_2O 3.2 ppmv.
The spiral descent occurred over Kiruna with the lidars operating until 35 kft. Landing in overcast and light snow – ceiling 500 ft. Landing time 18:56.

Pilots: Dick Ewers & Ed Lewis
Navigator: Kevin Hall
Mission managers: Chris Miller & Tom Mace
Mission scientist onboard: Mark R. Schoeberl

Status Report: Instrument – PI

DIAPER (in situ aerosols) – Anderson
Good flight. Everything worked.

SP2 - Had a good flight. Worked well

FastOz – Avery
Instrument had a good flight. Initial problems with boot up

DACOM/DLH (in situ trace gases and open path water vapor) – Diskin
One of best flights.

PANTHER (in situ PAN and other trace gases) – Elkins
Worked for five hours – then the mass spec quit. ECD worked during the whole flight.

MTP (microwave temperature profiler) – Mahoney
Good flight. Saw leewaves off Greenland.

AATS-14 (sun photometer) – Russell
Excellent flight. Worked well during the sun runs.

GAMS/LAABS (solar occultation ozone, aerosols and oxygen A band) – Pitts
Worked fine.

DIAL (Lidar ozone and aerosol above and below the AC) – Browell
Worked well. Saw stratospheric intrusions.

AROTAL (Lidar ozone, aerosols and temperature above the AC) - McGee/Hostetler
GSFC – Good flight after a rough start. Burned-out flash lamp was repaired in sun run #2.
LaRC – Good flight.

ICATS – Good Flight.

DIAS (Direct beam solar irradiance) – Shetter
Worked fine through the sun runs. Saw 320-nm photons.

FCAS/NMASS (in situ aerosols) – Reeves
Automated.

Differential GPS – Muellerschoen
Worked well. Some drop outs in transmission to AROTAL

Plots (flight plan, solar zenith angles, Rel. humidity):

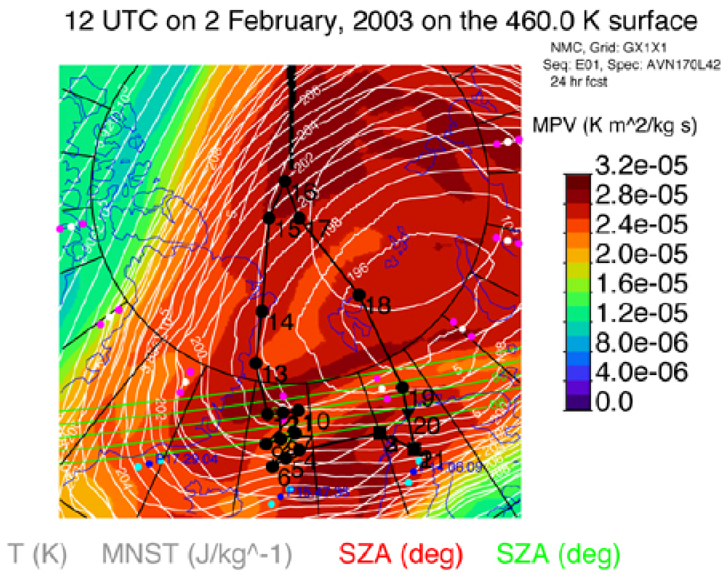

Figure 3. January 31, 2003 DC-8 flight plan (black) superimposed on a 12Z map of modified potential vorticity (color image) for the 460K isentropic surface. The thick magenta line on the left shows the 200- and 205-K temperature contours. The white point indicates the SAGE III occultation point and the dark blue points are POAM occultation points. The white lines are Montgomery stream function lines (winds blow parallel of these line) and temperature (K). The green lines are solar zenith angles for the occultation point.

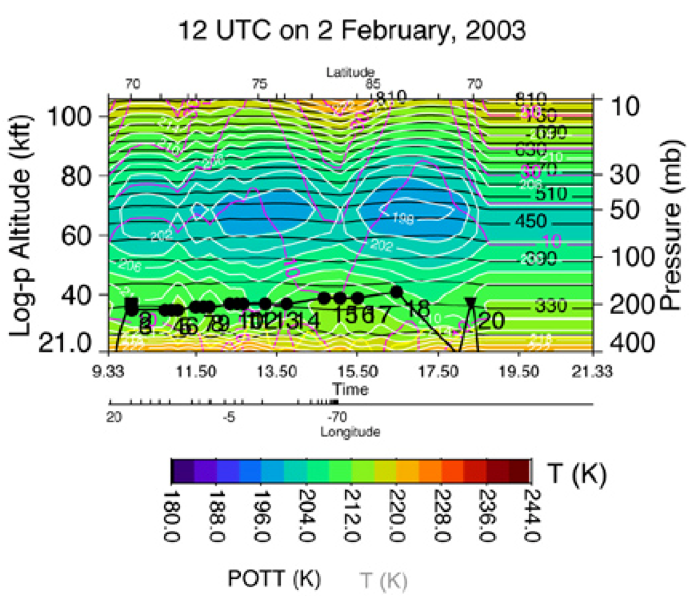

Figure 4. Curtain plot following the flight of February 2, 2003. The colors indicate temperature values (see scale at bottom of the figure).

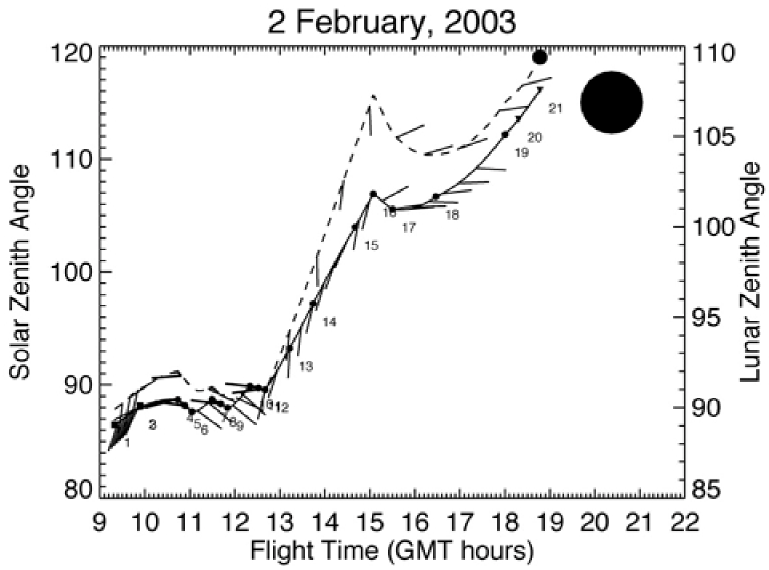

Figure 5. Solar and lunar zenith angles for the flight path shown in the previous figures.

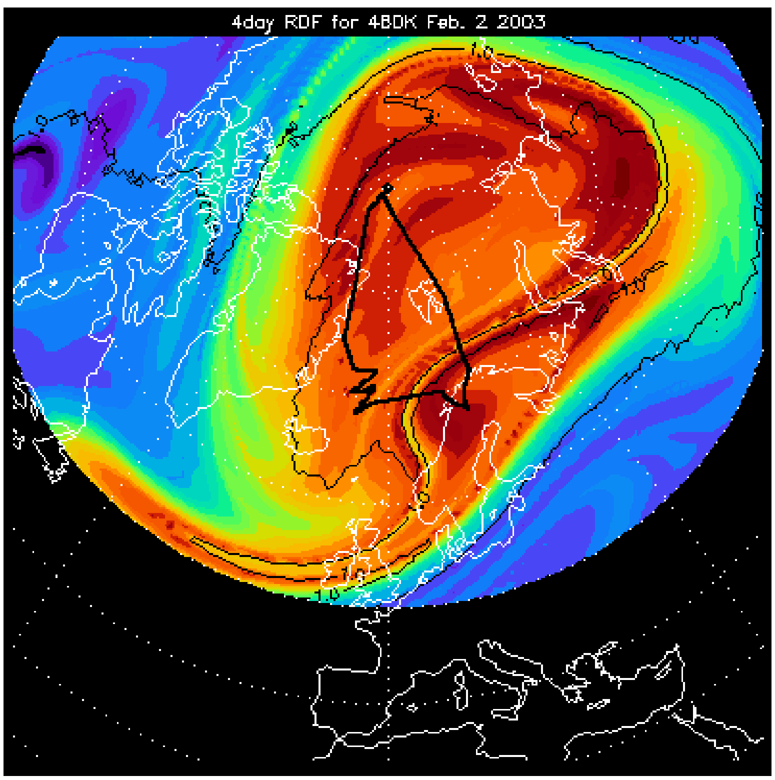

Figure 6. Four-day RDF of the vortex using Data Assimilation Office data. Black line indicates the flight track. Colors indicate high PV values (red) to low (blue).

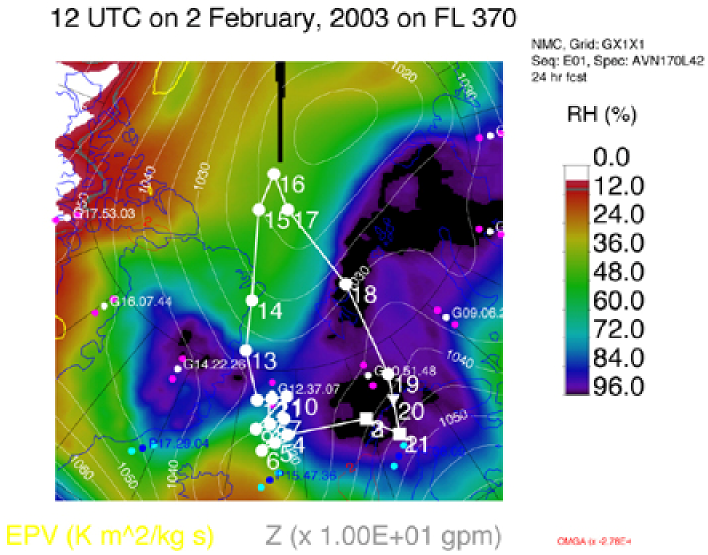

Figure 7. Relative humidity plots for flight level 37 kft. The dark-blue and black areas show high relative humidity.