SOLVE-II Flight Report: Tuesday, 01/21/2003

Paul A. Newman

Flight Type: SAGE-III & POAM occultation flight

Flight Objectives:

1. Sun run from mid-latitude air into vortex lobe over in western hemisphere at a zenith angle of 84º.
2. Two POAM occultations near sun run: 65.12N, 23.43W at 1620 UT and 65.12N, 48.74W at 1801 UT.
3. Near pass of 67.0N, 50.7W Sondrestrom Upper Atmospheric Research Facility near Kangerlussuaq, Greenland at approximately 1700Z.
4. Altitude profile on lower stratopheric cold pool after completing sun run.
5. Scan of mid-stratospheric ozone, aerosols, and temperatures from western vortex lobe to eastern vortex lobe by lidar systems
6. Overpass of Ny Alesund at 20:50 UT.

Flight Plan (UT):

12:15 Takeoff
14:34 Begin sun run (waypoint 6)
17:09 End sun run (waypoint 12)
17:36 Turn NE towards Spitzbergen
19:35 Leave Greenland
20:50 Overfly Ny Alesund
20:53 Turn SE for Kiruna
22:28 Land

Forecast Meteorology:

The stratospheric situation remains basically similar to that on January 19, with two closed circulations at 460K, one centered just off the southeastern corner of Hudson's Bay and the other just northwest of Nova Zemlya. The eastern lobe seems tight and well-isolated, while the western lobe appears to have absorbed some midlatitude air on its southern side.

At flight levels, the region of the flight (which essentially spans the Atlantic north of 60N), the circulation is dominated by a deep trough whose axis extends from Spitsbergen to Iceland to southeast England. There is a closed circulation over Spitsbergen that extends well into the stratosphere and is linked to the eastern lobe of the vortex. The result is low tropopauses (below 33Kft) throughout most of the flight region. The exceptions are, first, right over Kiruna, where a strong southwesterly jet is present at 35000 feet and below. A strong horizontal gradient in tropopause height is associated with this jet, though the aircraft will be expected to be in the stratosphere at flight level on climbout out of Kiruna. The jet produces some interesting structures in the tropopause, which may be observable below the aircraft as we travel upstream and towards the cyclonic side of the jet. A second exception is at the far western extremity of the flight, where a very high tropopause is associated with a cold pool of air at the top of the troposphere centered at (60W,60N). The tropopause here extends above 41000 feet, with temperatures near 195K. This implies saturation mixing ratios less than 5 ppmv. This region, however, is beyond the western end of the flight track. At 37Kft, the aircraft may penetrate the troposphere and experience some cirrus cloud at the far western end of the flight track (56E,65N).

The upward distension of the tropopause is surrounded by a downward distension, which the aircraft will pass over as it travels westward over the southern tip of Greenland.

As the aircraft travels northeastward over Greenland, the tropopause may rise under the aircraft, but not reach the expected flight level of 37000 feet.

Winds are expected to be generally unremarkable, except on climbout, on return to Kiruna, and during the expected dip at (56E,66N). In these regions, winds will be over 70 knots and about 60 knots respectively.

Some mountain wave activity is expected over eastern Greenland. Some wave motions produced by the southeastward jet stream west and south of Great Britain are predicted by the EC model.

Flight Meteorology:

Flight Report:

The Kiruna skies were overcast as we took off at 12:12 UT. We passed through the top of this cloud at about 26 kft, we then passed through a fairly strong jet from the SW that had winds upto about 75 kts between 25 and 30 kft, and then, as we climbed through about 32 kft (theta=310.7), the ozone, H2O, and CO values showed that we were in the stratosphere. DAACOM noted layers of constant H2O that seemed to be correlated with layers of constant potential temperature.

AATS-14 reported a relatively constant optical depth of 0.014 @ 350 nm, 0.007-0.008 @ 500 nm, and 0.002 at 1 micron. However, at 66º34'N, water suddenly increased by about 10% and then remained constant as we tracked southward towards our sun run. Interestingly, the stratospheric forecasts showed relatively uniform air over this region.

Figure 1. The NASA/Ames Research Center AATS-14 instrument is mounted on the top of the plane. This picture shows the instrument in operation during the track southward from Kiruna to the start of the extended sun run. The two monitors in the lower portion of the figure are for the NASA Langley GAMS/LAABS instrument.

After we reached flight altitude, water was about 8.8 ppmv, CO was about 44 ppbv, and O3 was about 236 ppbv (definitely stratospheric air) with a potential temperature of 329.3 K and winds at 58 kts 238º. As we crossed the prime meridian at 65º42'N, the theta value had increased to about 333 K, and ozone had increased to 355, H2O dropped to 4.7, and CO dropped to 25 ppbv. Winds had also slackened off to 31 kts at 227º.

At 13:35 UT, we adjusted the heading slightly farther to the west to bring the sun into the field of view of the DIAS instrument. This maneuver shaved a couple of minutes off of our flight plan, but was not quite enough to bring the sun into the DIAS field of view.

As we continued southward we encountered a filament of stratospheric ozone that was clearly evident in the DIAL and AROTAL data. We first encountered this filament at about 1340Z, widn a strong downward tilt toward the south. There also appeared to be an aerosol layer associated with this filament.

Started the sun run at 14:36 with a zenith angle of 83.7º. DIAS started tracking immediately, AATS-14 had been tracking since shortly after takeoff, and GAMS/LAABS began tracking at 14:37 UT. At this southern point, the H2O was 5.2, CO=27.3 ppb, O3=315 ppbv, T=-54ºC, theta=330K, V = 27kts @ 284º. MTP had a tropopause below us at about 30 kft, consistent with the DIAL zenith ozone probile. DIAL also show low clouds below us at about an altitude of 2 km.

As we moved westward, south of Iceland, it was apparent in the DIAL data that the ozone isopleths were moving downward (or ozone was increasing along a constant altitude of about 18 km). There was virtually no vertical gradient between about 12 and 16 km, then an increase of ozone at about the 17 km level, followed by a second layer between 17 and 21 km with a small vertical gradient.

As we passed Iceland, ozone showed a dramatic increase in both the DIAL and AROTAL data at 20 km, showing that we'd passed underneath the western lobe of the split stratospheric polar vortex.

About midway between Greenland and Iceland (63º47'N, 30W) we noted a sudden decrease of ozone between 12 and 22 km (max altitude of the lidars in daylight). AATS-14 also reported this ozone decrease. It appears that AATS-14 ozone channels are sensitive to ozone levels between 15-17 km, based upon the DIAL and AROTAL ozone profiles.

As we progressed towards Greenland, ozone at 20 km had some interesting variations, but remained high with respect to the values that we were observing on the eastern end of the track. The tropopause appeared to have increased in altitude to about 32 kft, based upon the MTP data. This increase in altitude of the tropopause was consistent with the DIAL nadir ozone.

On the westward track, temperatures were forecast to cool at 35 kft. This was consistent with the observations, as the temperature was –63.1ºC as we reached the coastline of Greenland. Because the temperatures were colder, the theta level was only 316K, and ozone=220 ppbv, H_2O=7.5 ppmv, and CO=50. Winds were light (9 kts @ 244º).

Between 17 and 20 km, we observed patches of air that had ozone values less than 2 ppmv of ozone just prior to reaching Greenland and over Greenland.

Over Greenland we began to see cirrus clouds below us that were quite close to the altitude of the aircraft. In order to avoid these clouds, and to gain some altitude for the solar instruments during the sun run, we requested and increase of altitude to 39 kft. We began our ascent at 16:25 UT. Prior to ascent, H_2O = 6.3 ppmv, CO=39 ppbv, O_3= 250 ppbv, and theta= 319K. After ascent, H_2O = ppmv, CO=27.3 ppbv, O_3=365 ppbv, and theta= 332.5 K. AATS-14 reports that at 380 nm the optical depth changed by 0.002 as we ascended.

Beautiful views of Western Greenland: glacier covered mountains. Very forbidding.

Figure 2. View of Western Greenland taken from the NASA DC-8 on January 21, 2003 from an altitude of 29,000 feet looking northward from approximately 65ºN.

We ended the sun run at 17:05 UT with a zenith angle of 87.1º. AATS reported that their field of view experiment showed no ice on their window. At this western point, h2o=5, co =35, O3=295, 321K. We turned and began our descent to 29 kft at 2 kft/minute. DIAPER detected thin cirrus at about 34 kft. Ozone fell below 100 ppbv at about 306K. At 29 kft, H2O = 15 ppmv, CO=150, o3=49, theta=300.3, winds of 54 @ 341. After our turn, DIAL reported that the 2 ppmv ozone layer at 20 km was measured near the end or our sun run leg, and was re-measured after we had descended to 29 kft.

We started our ascent back to 39 kft at 17:22 UT. During the ascent, the shadow of our contrail was evident against a hazy layer to our north. After returning to altitude, H2O= 4.2, CO=29.4, O3=356, theta=331K, t=-64.5ºC, and wind = 9 kts @ 22º.

During the track back across Greenland, DIAPER reported that we hit our own plume ~17:37UT. Winds at this altitude and time were quite light suggesting that the plume had not moved off from our original track.

We turned northward at 17:50 UT. H2O=4, CO=31.5, O3=376, T=-64, theta=333, wind = 13 @ 287. At 1800Z on this NE track across Greenland, we had a rather sharp drop of ozone to about 310 ppbv. Ozone then jumped to over 500 ppbv over central Greenland. A lot of structure in the in-situ fields.

Near the coast of Greenland, DIAL and AROTAL showed ozone decreasing at an altitude of 18 km. This was consistent with the split of the vortex. AROTAL also reported a low ozone notch near 36 km with a depth of about 2 km. AROTAL also noted some interesting wave structure in both the ozone and temperature structure. As we neared Scoresbysund and the coast line, got some light to moderate turbulence at our altitude of 39 kft. This sort of mountain wave activity was predicted by the NRL group.

We went up to 41 kft at about 19:34Z. H_2O went to 3.5, CO went to 27, O_3 to over 600, theta went to 357.5 and winds went to 33 kts at 331. During our ascent, ozone briefly went to approximately 700 ppbv. DIAL showed that the tropopause in ozone mixing ratio moved down to quite low altitudes (less than 6 km). There was a thick cloud deck below us at about 3 km.

Both DIAL and AROTAL noted here that it appeared that we had now re-entered the eastern lobe of the split vortex. DIAL pointed out that ozone was now below 2 ppmv near 20 km, and AROTAL remarked on the symmetry of ozone vertical structure as we moved northeastward.

During our track from the Greenland coastline to Spitzbergen, the forecasts suggested that we would fly into the core of a cyclonic flow system that was approximately centered on Ny Alesund. At our altitude of 41 kft, H_2O remained low at 3.4 ppmb, CO was low at 23 ppbv, and ozone was high at 650 ppbv. The temperature was approximately –57C and winds were slackening 13 @ 22 as we approached Ny Alesund. We overflew at 20:39 UT, about 11 minutes early. We could see the town in the nadir camera as we overflew. In situ ozone was about 620 ppbv at 41 kft, theta = 352K. Amazingly, the overcast clouds disappeared only 5-10 minutes before we arrived over Ny Alesund. Presumably, we got a good intercomparison.

Turned south towards Kiruna a bit ahead of schedule. Good view of Longyearbyen as we passed just to its west.

Heading south, DIAL noted that the chemical tropopause (i.e., the 100 ppbv ozone contour) began to move upward. A thin cloud was observed immediately below this chemical tropopause. This same phenomena was noted in a number of locations on our flight.

At about 21Z, a sharp temperature decrease was noted by AROTAL in their temperature data at altitudes above 22 km. Since we were flying southward at an angle almost perpendicular to the jet axis, this indicated (via the thermal wind relationship) that the jet was above us and centered at an altitude near 22 km. DIAL also noted a lifting of the aerosol layer to 18-19 km at the same time, an increase in the height of the tropopause to 7 km, and an increase of ozone in the levels above 20 km (decrease at levels below 20 km).

A great aurora display out my window on the left side of the plane at about 21:30 UT on the way back to Kiruna.

We started crossing the southern rim of the cyclonic system that was centered on Ny Alesund. During this flight winds to over 40 kts from the SW, temperatures rose to about –54C and ozone peaked out at about 820 ppbv. There were large variations of ozone and other tracers as we profiled through this upper tropospheric cyclonic system. The tropopause continued to rise as we approached Kiruna, and winds continued to strengthen. High clouds (to 8 km) were observed as we crossed over the Norwegian coast.

Because of icy runway conditions, we diverted to Lulea near the head of the gulf of Bothnia. Spent the night in Lulea, and after they cleared the runway in Kiruna, we returned at approximately 1900Z on January 22, 2003.

Pilots: Bill Brockett, Craig Bomben
Navigator: Russ Padula
Mission managers: Chris Miller & Bob Curry
Mission scientist on board: Paul A. Newman.

Status Report: Instrument – PI

DIAPER (in situ aerosols) – Anderson
Good flight. Good data.

SP2
No onboard.

FastOz – Avery
Had a good flight. Saw over 800 ppbv. Lots of structure.

DACOM/DLH (in situ trace gases and open path water vapor) – Diskin
Everything went very well. Saw extremely low values of N2O and CH4 when ozone was very high.

PANTHER (in situ PAN and other trace gases) – Elkins
Had a good flight.

MTP (microwave temperature profiler) – Mahoney
Had a good flight. Hickup when we weren't getting ICATS data.

AATS-14 (sun photometer) – Russell
Very good flight. Tracked sun over the entire course of the flight when sun was visible. Altitude variations were very nice for our instrument.

GAMS/LAABS (solar occultation ozone, aerosols and oxygen A band) – Pitts
A really good mission. Preliminary comparison with AATS was excellent.

DIAL (Lidar ozone and aerosol above and below the AC) – Browell
A really exciting flight. A lot of variability. Saw some evidence for ozone loss in both lobes. Saw a lot of dynamics below the aircraft.

AROTAL (Lidar ozone, aerosols and temperature above the AC) - McGee/Hostetler
GSFC – A very good flight. Interesting stuff in ozone and temperature data.

LaRC – A very good flight. Some interference on the detectors.

DIAS (Direct beam solar irradiance) – Shetter
Sun run went very well. Data looked very good. Not a lot of UV.

FCAS/NMAS (in situ aerosols) – Reeves
Automated. No fail lights.

Differential GPS – Muellerschoen
Worked, but a problem feeding data to AROTAL.

ICATS
OK. Had a system crash.

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

Figure 3. Plot of the actual flight path of the DC-8 for the SOLVE-II flight of January 21, 2003.

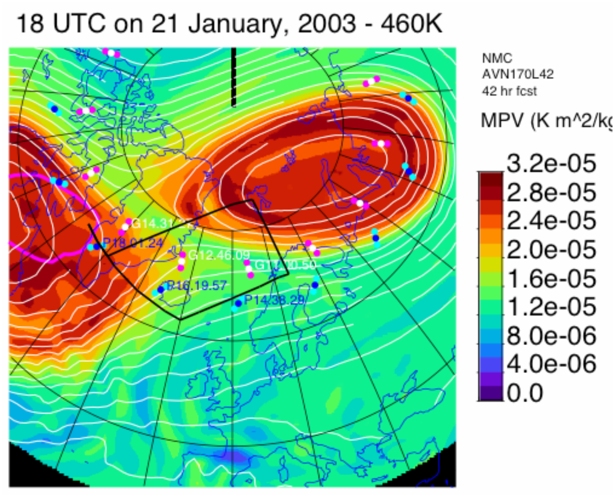

Figure 4. . January 21, 2003 DC-8 flight plan (black) superimposed on a 12Z map of modified potential vorticity (color image) for the 460K isentropic surface. The thick magenta line on the left shows the 200 K temperature contour. The white point indicates the SAGE III occultation point and the dark blue points are POAM occultation points. The white lines are Montgomery stream function lines (winds blow parallel of these line).

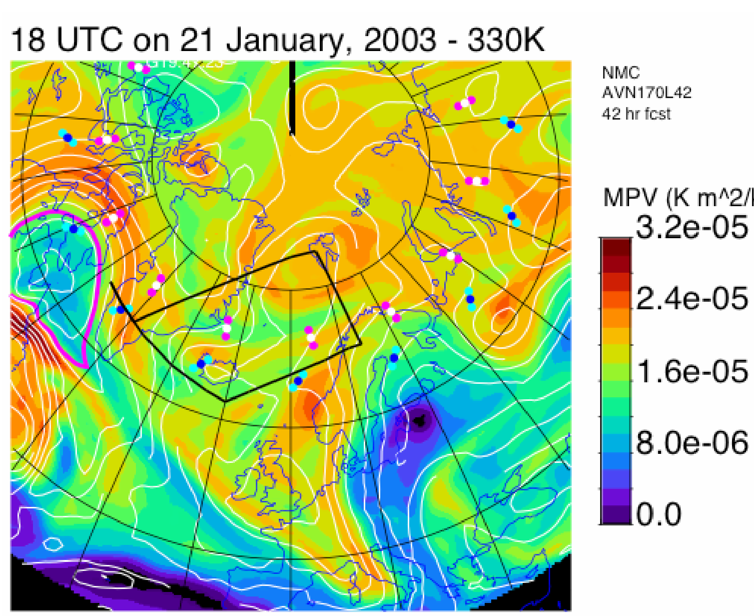

Figure 5. As in the previous figure, but for the 330K isentropic surface (approximately the DC-8 flight altitude).

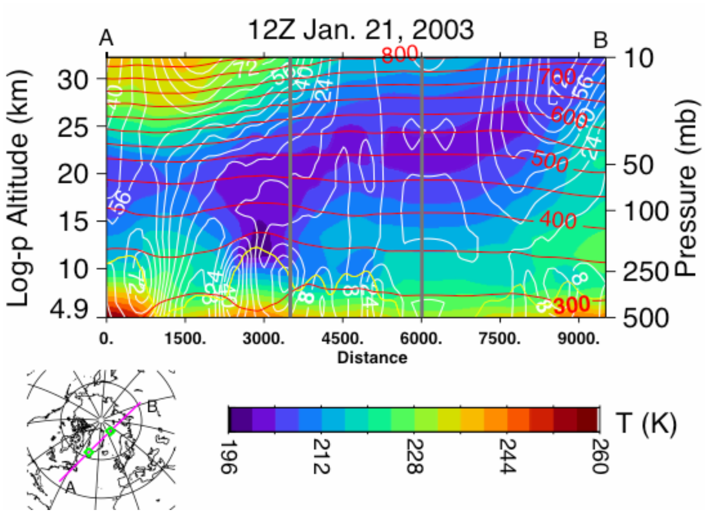

Figure 6. Temperature and wind cross-section along the track from Southern Greenland to Spitzbergen. The map in the lower left displays the orientiation of the cross section on a map. The cross-section extends from the Western Atlantic to a point over Siberia, the points A and B are indicated on the 2 plots, and the way points are indicated by the green symbols on the map, and the vertical bars on cross-section plot. The potential temperature surfaces are shown in red, white lines indicate wind speed (m/s), and the yellow line shows the tropopause.

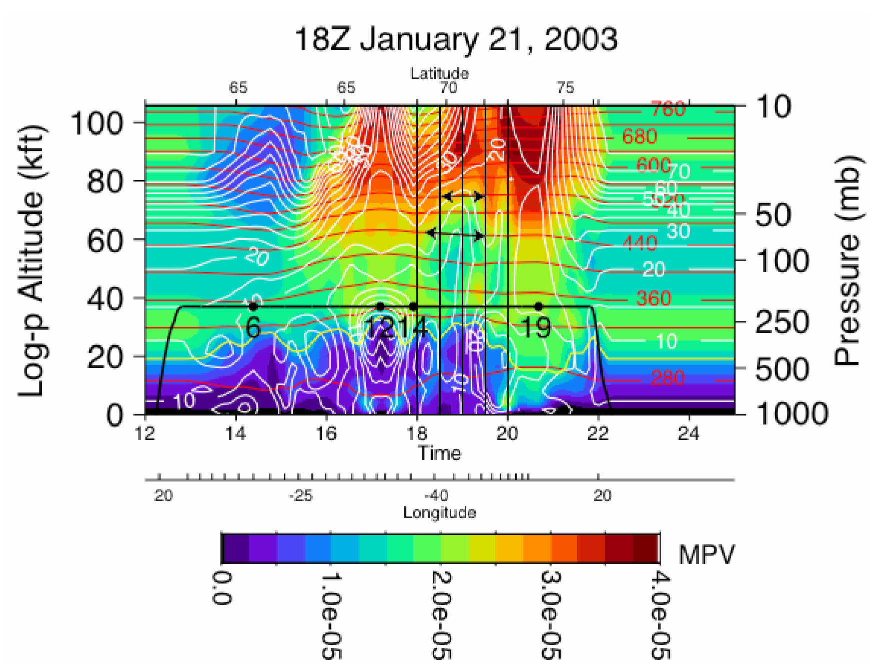

Figure 7. Curtain plot following the flight of January 21, 2003. The colors indicate potential vorticity values, where red-orange shows vortex material, and blues-green shows mid-latitude material. Red contours are potential temperature (K), white contours

are wind speeds (m/s), and the yellow contour shows the tropopause. Ignore PV values below the tropopause. Double arrowed lines indicate the region of the split.

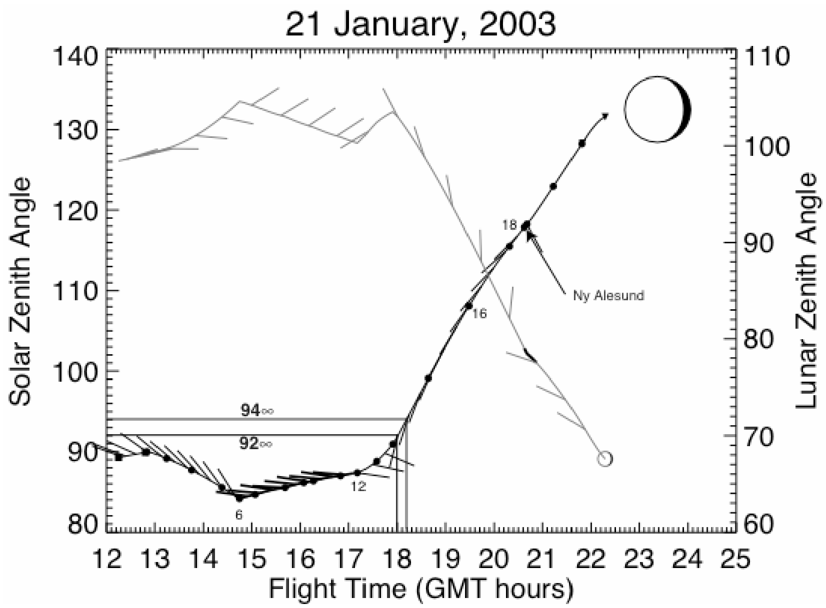

Figure 8. Solar and lunar zenith angles for the flight path shown in the previous figures.