SOLVE-II Flight Report: Thursday, 01/16/2003
Paul A. Newman

Flight Type: Vortex scan & SAGE-III occultation flight

Flight Objectives:

1. SAGE III occultation at 09:54:30 UT, 68.44ºN 19.83º E
   a. 3 sun runs at similar zenith angles
2. Scan vortex into the central core for O_3 and temperature distributions.
3. Scan O_3 and T across vortex edge
4. In-situ tracer scan from polar air-mass across jet
5. Scan of mountain waves across Scandinavian mountains - possible PSCs.

Flight Plan:

09:15 Takeoff
09:48 Sun run #1
09:54:30 SAGE-III overpass
10:27 Sun run #2
11:05 Sun run #3
13:21 Northern point
16:39 Begin cross Scandinavia mountain wave scan
18:21 Land

Forecast Meteorology:

The pool of air with temperatures cold enough to maintain PSC Ia clouds at equilibrium (196K) is forecast to completely disappear at both 50 and 30 mb today (at least on a synoptic scale). If the forecast is accurate, the deterioration is rapid (two days), since the cold pool has maintained the approximate size it had during the last flight (January 14) for quite some time. The vortex itself is elongating and rotating counterclockwise, with a warm pool growing over eastern Siberia. The axis of this elongated vortex extends from northern Greenland to Nova Zemlya, resulting in strong west-northwesterly 50mb flow over central Scandinavia. Further elongation is projected in the near term, with the vortex developing two separate 50mb closed circulations by 12Z on January 18.

In the troposphere, a major storm in the eastern Atlantic has brought moist air from 30 degrees latitude to 60º-66ºN at longitudes near Scotland. The result is an upper tropospheric ridge that will be between Scotland and Norway by the southwestern waypoint (60ºN, 3ºE) is reached at about 3Z. The tropopause will probably be above 39000 feet at 60ºN and 3ºE, but just barely (models disagree). Cirrus is likely up to the tropopause, as the air is moist and has experienced an upward trajectory. Thus, some cirrus is possible around the southwestern waypoint.

The jet stream over this ridge exceeds 90 knots at FL390 (stronger below that level). As the flow leaves the ridge, it weakens somewhat and turns to a west-northwesterly direction. This, coupled with strong flow in the same direction at both 700mb and 50mb implies strong gravity wave activity over Scandinavia. This will be somewhat further north than on the previous flight. Since temperatures in the stratosphere are substantially warmer, much less (if any) PSC activity is expected.

No mountain-wave induced turbulence is expected at flight level. However, due to the strong vertical shears in the jet, other mechanisms may produce some light turbulence. It is not expected to be a problem for this flight.

Flight Meteorology:

Flight Report:

Takeoff was at about 9:14Z. We climbed out to the SE and then turned towards the SW to get onto the sun run. We passed through the tropopause at about 30 kft, ozone increase and water fell off. At 35 kft, water was about 7 ppmv, ozone was about 250 ppbv, and CO was about 32 ppbv. The -61ºC temperature was near the predicted value.

Figure 1. The landscape of Northern Sweden seen from the NASA DC-8 on January 16, 2003, immediately prior to sunset and shortly after take-off. The DC-8 is banking towards the west to begin the first sun run of this flight.

We started the first sun run at 09:46Z with a zenith angle of 90.5º. DIAS, AATS-14, and GAMS/LAAB all reported lock onto the sun. The relatively low clouds gave us a good view of the sun. The solar imager showed a fine layer across the top of the sun – unknown origin. As we progressed westward GAMS reported a decrease of ozone. We ended the run at 10:02 with a 20º bank to the left (southward) and a descent of about 200 ft. The descent was executed in an attempt to acquire another plume intercept. DIAS, GAMS/LAABS, and AATS-14 all reported a good sun run. GAMS reported fairly uniform ozone and water changes that were consistent with a changing air mass.

We started the 2nd sun run at about 10:24 at a zenith angle of about 89.9º. We hit a plume after coming onto the track of our original run. Again, all 3 instruments reported locking onto the sun. During the run, $H2O$ was about 6 ppmv, ozone was 265 ppbv, and CO was about 36 ppbv. Temperature was -60ºC and wind was 39 kts at 280 (nearly westerly). We ended the sun run at 10:41Z at a zenith angle of 89.7º. Again, a 20º bank to the left (southward) and a descent of about 200 ft. AATS-14 tracked and acquired data. GAMS/LAAB tracked late, but had a very interesting increase of ozone at the end of the run. They also saw an interesting anti-correlation between ozone and optical depth in the last quarter of the run. DIAS locked on and tracked through the whole sun run. On the return leg to the 3rd sun run, both DIAPER and DAACOM both saw our plume. DIAPER saw a particle enhancement, while DAACOM saw the plume in both H2O and CO.

We started our 3rd sun run at 11:04 at a zenith angle of 89.8º. AATS-14 and DIAS locked on immediately at the start of the run, with GAMS/LAABS locking on a couple of minutes later. Water, CO, ozone, temperature, and winds were similar to the first 2 runs. There seemed to be some in-situ variation of ozone near the plane that GAMS/LAABS was able to pick up. We ended the sun run at 11:22. All 3 solar instruments successfully tracked the sun. AATS-14 reported that their window had again iced-up and that all but 2 channels were affected.

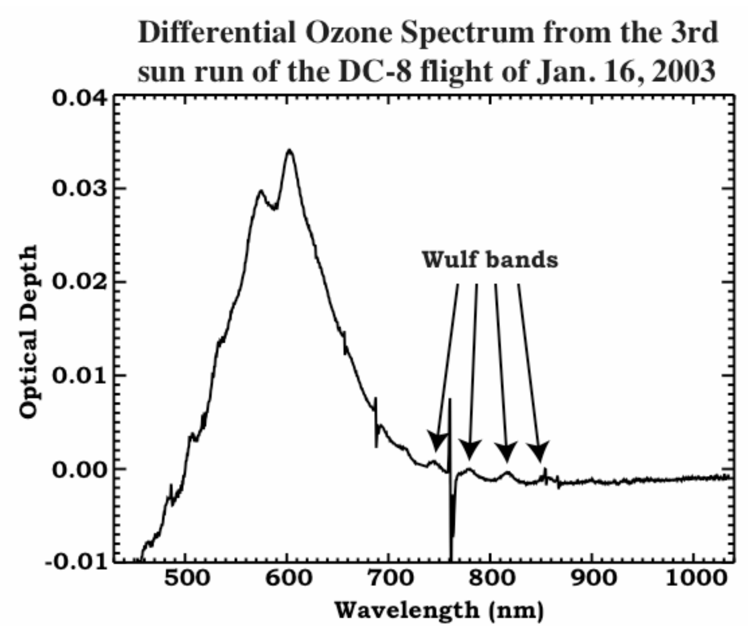

Figure 2. Ratio of 2 GAMS ozone spectra during a period of ozone variability on the third sun run of the DC-8 flight of Jan. 16, 2003. Optical depth variations are primarily due to ozone and allow the evaluation of temperature variability of Wulf bands relative to the Chappuis.

After completing the 3rd sun run, we turned NNE to begin our circle of Spitzbergen. At this time, we ascended to 37 kft. FastOz reported a sharp increase of ozone to about 335 ppbv, while water fell off to about 4.3 ppmv, and CO was about 24.6 ppbv. Winds were about 54 kts at 292 and the temperature was about -58ºC.

At 11:40Z we overflew a fairly high cloud system that extended up to about 8 km (26,000 feet). We also began to see a steady downward drift of ozone just above 20 km as we progressed northward towards the vortex core. At 22 km, it had decrease from 3.5 to 3 ppmv. From 15-20 km, there was not much evidence of a change, perhaps a couple of tenths of a degree.

At 74ºN, winds had fallen off to about 21 kts at 290 (WNW), and temperatures were at about -62ºC. Ozone, CO, and H2O were about the same. We were at a zenith angle of 96º at this time.

The mission scientist had his Takeoff Café salmon for lunch.

At 77ºN the "chemical " tropopause suddenly dropped to about 4-5 km. About the same time, MTP began to show the indistinct temperature profile that characterizes deep polar air. Slightly prior to this the high clouds (noted about 11:40Z) fell away. Ozone values at 37 kft were about the same values that we had been seeing since leaving the Norwegian coastal region. Wind speeds had fallen further to only 15 kts at NNW. Temperature was still about –61ºC.

At 79ºN (about 13Z) we ascended to 39,000 feet (FL390). Ozone increase to 390 ppbv, CO dropped to 28 ppbv, and water decreased to 3.9 ppmv. Temperatures fell to about -62ºC, and winds dropped to 6 kts northerlies. Slightly before we began our ascent, the tropopause increased to about 8 km from its very low value.

At 8035'N (north of Spitzbergen), AROTAL observed a temperature minimum of something below 185 at about 17-18 km (possibly a noise problem). At this latitude, temperatures was about -64ºC, winds were 9 kts NNW, ozone was 333 ppbv, H2O was 4 ppmv, and CO was about 30 ppbv. We rounded waypoint 13 at 13:50Z.

At 75ºN (SW of Spitzbergen) ozone had increased to 420 ppbv, H2O was 3.6 ppmv, and CO was 23 ppbv. Winds had increased from low values to about 19 kts westerlies, while the temperature was -61ºC. Ozone remained high as we progressed southward at 39 kft, and by 70ºN, the chemical tropopause had dropped to about 4 km again. The minimum value for temperature also began to move upward in altitude, in reasonable agreement with forecast transect. At 70ºN, the minimum in the temperature profile was at 22 km.

At 15:34 we ascended to 41,000 feet (66º30'N) to an isentropic level of 344 K. Ozone jumped to about 500 ppbv, CO decreased to about 16 ppbv, and H2O decreased to about 3.5 ppmv. Winds were at 75 kts westerlies, and the temperature was about -62ºC.

At about 65º30'N (1545Z) ozone dropped for about 350 ppbv with rises by DLH water and DAACOM CO values. Winds fell off to about 70 kts westerlies. At an altitude of 41 kft, we were always in the stratosphere. From the AROTAL and DIAL data, it could be seen that we passed the core of the polar vortex at about 15:30Z.

At 60º45’N, the winds were back up to 86 kts W. Ozone had fallen to less than 200 ppbv, H2O was about 10 and CO had failed. Theta was about 331 K and T was about -71ºC. At 16:28Z, just prior to waypoint 18, a faint PSC was seen at about 23-24 km.

We began our turn at waypoint 18 (the southernmost point, 60ºN) at 16:31Z. As we traveled across Norway and Sweden to waypoints 19 and 20, we encountered some very large amplitude waves in temperature and ozone. These waves were clearly predicted by the ECMWF model. No PSCs were detected as we flew eastward, but an enhanced aerosol layer was observed in the 23-24 km region. This layer was probably a result of sulfate particles that were swelling as we moved across the mountains. The cirrus below us and the enhanced sulfate layer disappeared at about the same time that we crossed the Norwegian-Swedish border. FastOz reported a correlation of the wind speed and ozone values along this track.

As we approached way-point 21 in the Gulf of Bothnia, there was a large increase of ozone to over 500 ppbv, with water at about 3.4 ppmv, and CO at about 11.6 ppbv. The top of an enhanced layer of particles was at 21 km, while the bottom was at 18 km. The ozone levels increased to over 650 ppbv and water dropped to 3.3 ppmv. The potential temperature increased to over 350 K on this track. We turned northward toward Kiruna at this point, and ozone began to slowly fall off.

The enhanced aerosol layer continued to descend as we proceeded northward. This was consistent with the descent of the cold temperature layer.

The DC-8 landed at 18:37 UT. Great flight.

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
Pretty good flight. Lost power on PCAS. Hit several aircraft plumes. Lots of CN structure across the jet.

SP2
Worked the entire flight. Have a data set that they’ll be working with.

FastOz – Avery
Instrument worked well and we had a lot of interesting behavior at the level of the plane.

DACOM/DLH (in situ trace gases and open path water vapor) – Diskin
Really great measurements. Lost DAACOM briefly.

PANTHER (in situ PAN and other trace gases) – Elkins
Pretty good flight. Solid chromatography on the ECD channels. Ran the mass spec.

MTP (microwave temperature profiler) – Mahoney
Good flight. Good retrievals inside the vortex. Eager to see isentropes for wave activity.

AATS-14 (sun photometer) – Russell
Tracked during all sun runs. Did field of view test. Obvious that they iced up again. One channel that is free of ice. Two other channels that are also free.

GAMS/LAABS (solar occultation ozone, aerosols and oxygen A band) – Pitts
Another excellent flight. A lot of interesting variability in the high-resolution data. Possible correlation with FastOz.

DIAL (Lidar ozone and aerosol above and below the AC) – Browell
Great flight. A lot of good stratospheric and tropospheric dynamics. Some good aerosol data.

AROTAL (Lidar ozone, aerosols and temperature above the AC) - McGee/Hostetler
GSFC- Real good flight. Some interferences. Good ozone, very good T, and some nice mountain wave observations.
LaRC – Had a good flight. Plagued by an occasional crash of the computer. Also getting some interference for the first 10-20 minutes of the last 3 flights.

DIAS (Direct beam solar irradiance) – Shetter
Took data through the first 3 sun runs.

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

Differential GPS – Muellerschoen
Good.

ICATS
Good flight.

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

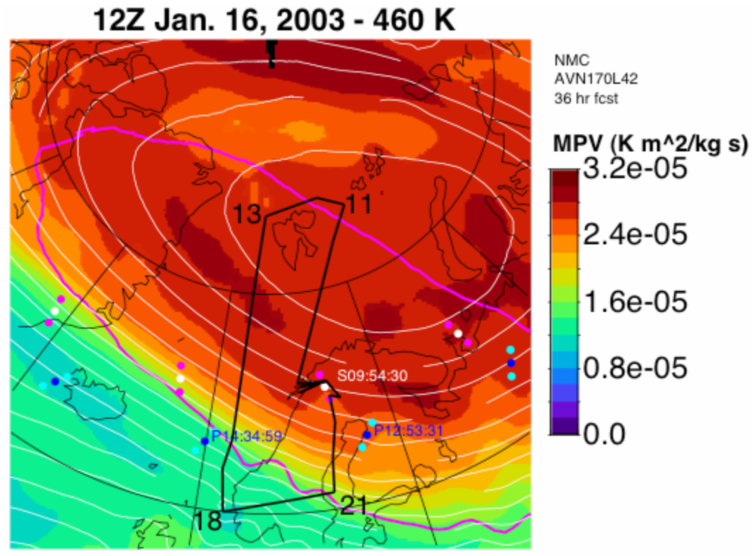

Figure 3. January 16, 2003 DC-8 flight plan (black) superimposed on a 12Z map of modified potential vorticity (color image) for the 460K isentropic surface. The thick magenta line shows the 200 K temperature contour. The white point indicates the SAGE III occultation point (occurring at 09:54Z) and the dark blue point is POAM occultation point (occurring at 12:53Z). The white lines are Montgomery stream function lines (winds blow parallel of these line).

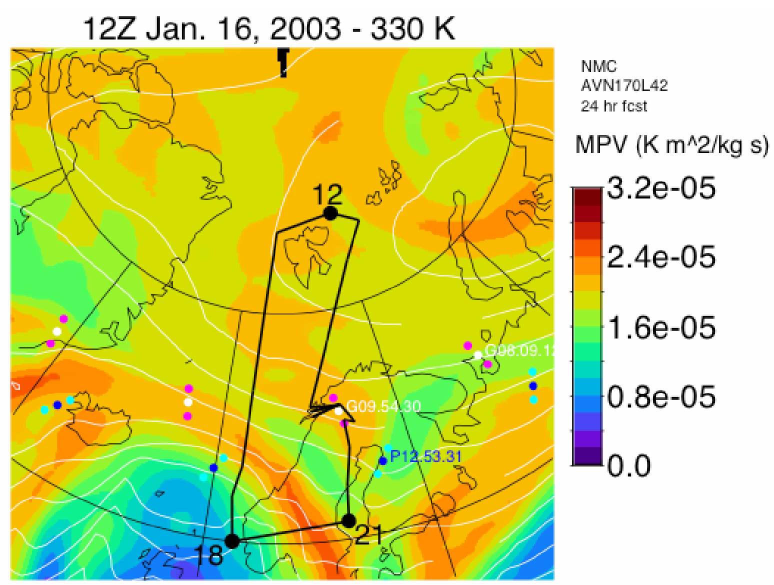

Figure 4. As in the previous figure, but for the 330K isentropic surface (approximately the DC-8 flight altitude).

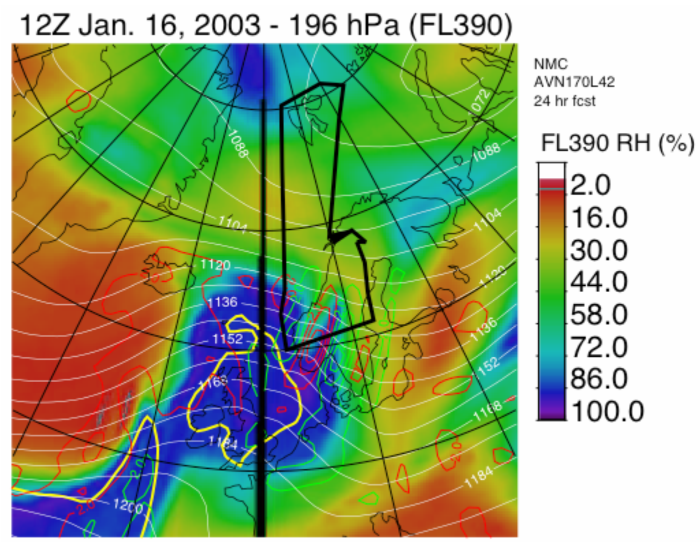

Figure 5. Relative humidity at 196 hPa (FL390). The white lines are geopotential height (the wind blows parallel to these lines and is proportional to the contour spacing). The yellow line indicates the tropopause. The red and green lines display the omega field with red indicating ascent and cooling, while the green indicates descent and warming (contours are 4 hPa/hr). Planned flight track is shown in black.

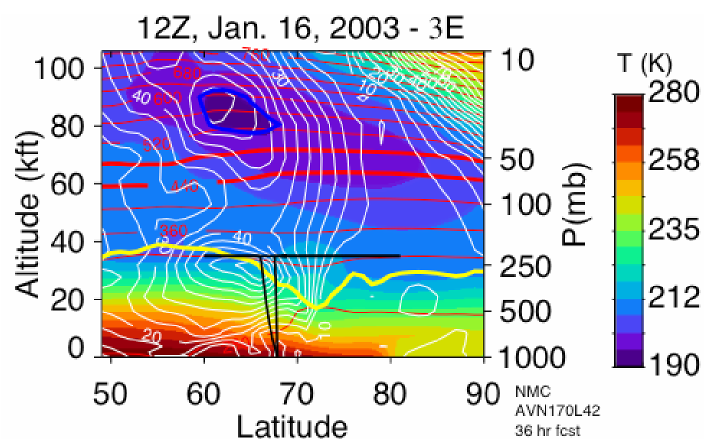

Figure 6. Temperature and wind cross section at the prime meridian (3°E). Potential temperature surfaces are shown in red, white lines indicate wind speed (m/s, the yellow line shows the tropopause, and the thick blue line is the 195K contour.

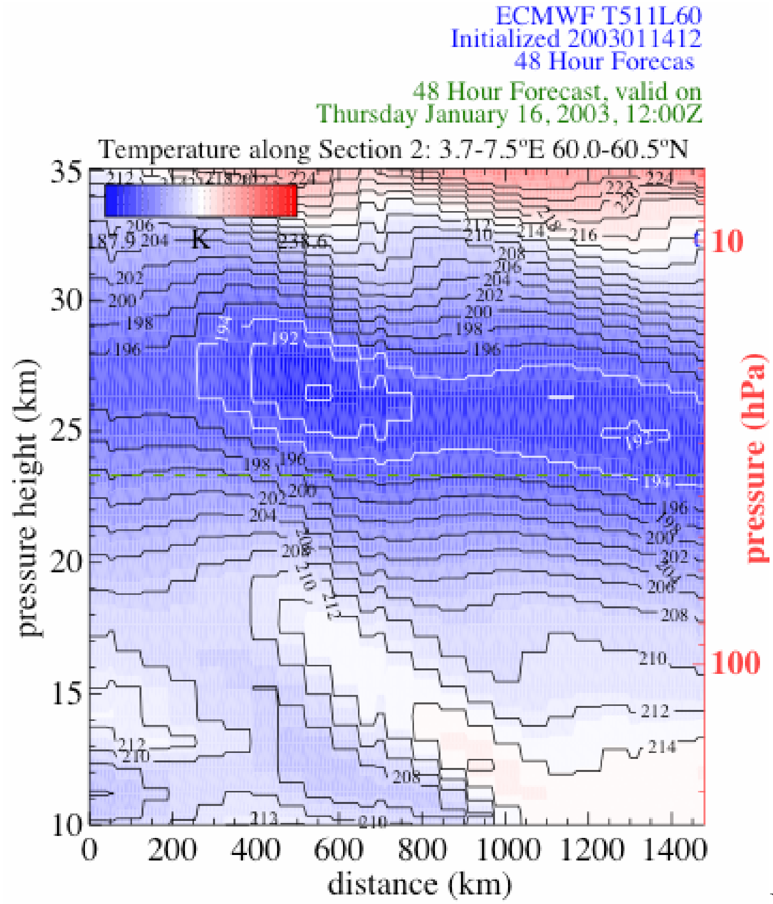

Figure 7. Cross section of temperatures along the track from way-points from 18 to 21 as seen in the flight track figures shown previously. White contours display temperatures colder than 195 K.

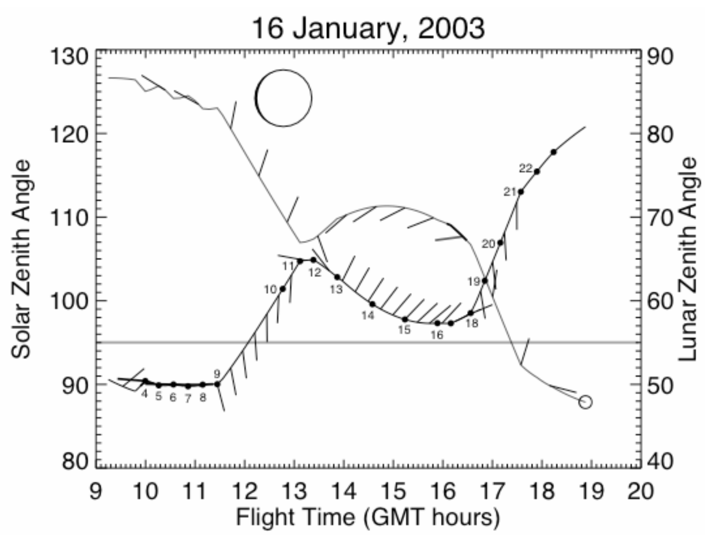

Figure 8. Solar and lunar zenith angles for the flight path shown in the previous figures. The 3 sun runs begin at way-points 4, 6, and 8.