SOLVE-II Flight Report: Tuesday, 01/14/2003

Paul A. Newman

Flight Type: Vortex edge scan & SAGE-III occultation flight

Flight Objectives:

1. Scan for PSCs from Kiruna through edge of vortex with AROTAL and DIAL
2. SAGE III occultation at 10:31 UT, 68ºN 9.6º E
    a. Arrive at occultation point prior to sunrise to sample ozone and PSC distributions, PSC scan along tangent
    b. Sun runs at 3 zenith angles
3. Sun run at a zenith angle of 84º
4. Observation of ozone and temperature distributions in the edge of the vortex.
5. In-situ tracer scan from polar air-mass across jet
6. Scan of trop-fold by DIAL and MTP

Flight Plan:

05:30 Takeoff
07:35 southernmost point (waypoint 5)
09:40 Sun run #1
10:17 Sun run #2
10:55 Sun run #3
11:58 Sun run #4
13:26 Land

Forecast Meteorology:

The pool of air with temperatures cold enough to maintain PSC 1A clouds at equilibrium (196K) continues to hover at relatively low latitudes, with cold temperatures extending to 54°N in the NCEP model 60-hour forecasts for 12 Z January 14 at 50 mb. The cold pool is slightly smaller than on January 12, and has moved eastward about 10-15 degrees of longitude over central Scandinavia, consistent with an overall eastward progression of the planetary wave number 1 in which the cold pool is embedded. A strong tropospheric jet from the west-northwest over southern Scandinavia, right under a portion of the stratospheric polar vortex, has resulted in strong gravity wave activity in the stratosphere. The eastward movement of the cold pool over results in strong temperature perturbations along the southern edge of that pool, with the possibility of the formation of both Type Ia and Type II PSCs.

Previous forecasts had indicated a much smaller cold pool for January 14 than January 12, with complete disappearance of sub 196K temperatures by January 15. The newer runs maintain a small cold pool on January 15, with complete disappearance by January 16. It appears that the models are over predicting the shrinkage of the cold pool.

At the initial flight level of 35000 feet, the stratosphere should be reached very quickly, probably missing a tropospheric intrusion nearly above Kiruna. The transition to the troposphere should occur at about 60°N. This transition is sharp and coincides with a very strong tropospheric jet, with winds exceeding 130 knots from the west-northwest at FL350. A folded tropopause structure should be found below the aircraft around the jet crossing. The coldest synoptic scale temperatures will be found in the troposphere south of the jet axis, with temperatures down to 206K FL350 and 202K at FL370. Given the strong winds (and associated ascending secondary circulations), high relative humidity, and wave excitation by the flow over the Scandinavian mountains, there is a high likelihood of both jet stream and mountain-induced cirrus clouds in the upper troposphere south of the jet axis.

The sun runs will be north of the jet axis, and thus in the stratosphere. The last sun run will be near the jet axis. Given the fuel loading at that time, however, ascent into the stratosphere and out of potential cirrus should be possible.

Flight Meteorology:

Flight Report:

Took off on the mark at 05:30. Initially we had cirrus above us at about 35 kft, but we were cleared for 36 kft. At 5:59Z we leveled off at 36kft, and just managed to clear the cirrus that was below us. MTP reported us 250 meters above the tropopause at this altitude. However, MTP reported that the tropopause was variable, and DIAPER showed that occasional cirrus was evident as we flew along. Ozone was at about 120-140 ppbv, while H2O was about 19 ppmv. Winds after we leveled off were about 34 kts W, while T was about –67°C.

Both DIAL and AROTAL immediately identified a Type Ib PSC at 19 km after we cleared this cirrus. MTP had a temperature of about 198K at this location, while AROTAL reported about 188K at this location. At about 64°N, the PSC became about 2km thick, and AROTAL reported that there was some depolarization, possibly indicating a Type Ia particle layer.

Wind speeds at flight altitude continued to increase as we progressed southward. At 61°40'N the winds had increased to about 60 kts. The jet core was expected at about 58°30'N. Ozone was at about 300 ppbv, while water was about 5.9 ppmv at 36 kft.

At 61°N, it was clear that some smaller scale wave activity was embedded in the PSCs. We could also visually identify a PSC to the east of the plane as a series of stacked clouds. The main PSC that we'd been following disappeared at a latitude of about 60°20'N on our southbound track. The cloud reappeared at altitudes above 24 km with terrific structure and extremely large scattering ratios. This very high PSC (25 km) was probably a type II PSC (water ice). This cloud had tremendous embedded wave structure.

Wind speeds were at 80 kts at 60°N. Ozone was still over 300 ppbv, and water was about 5.9 ppmv. The jet peaked at over 120 kts at a latitude of about 58.7°N. Began to see cirrus again after passing the core of the jet. We then ascended to 38 kft to get clear of this cirrus. However, even at this altitude, we were not clear of the cirrus. At a latitude of 57°10'N, the large PSC had disappeared, but another PSC was apparent at 19 km. At 38 kft on the southern side of the jet, we were in the troposphere, with ozone values at about 64 ppbv.

We turned on time at our waypoint 5. The winds were about 100 kts WNW at this point with temperatures of about -70°C, ozone of 77 ppbv, and water of about 9.6 ppmv. We were still in cirrus at 38 kft. In spite of this cirrus, AROTAL was able to detect a double layer of PSCs at 22.8 and 24.1 km.

As we moved north, we escaped the cirrus and passed back across the jet. Again, ozone jumped up to over 300 ppbv and water fell to about 4.4 ppmv. We continued to observe PSCs, and had the most spectacular visual display of PSCs that I have ever seen. DIAL reported that the PSCs above us were composed of a Type II over-riding a type Ib.

Figure 1. PSC observed over southern Scandinavia on January 14, 2003 at about 08:15Z from the NASA DC-8 on the SOLVE-II mission.

As we continued north (61°52'N), ozone went to values over 400 ppbv, H2O fell to 3.7 ppbv, and the tropopause became very indistinct below us. About 9:12Z we climbed up to FL390. By this point (66°N), the winds had fallen to about 50 kts WNW and temperatures were about -64°C. Ozone had fallen off somewhat and water had come up. The PSCs had a 1-2 km thick layer near 20 km off of the Norwegian coastline, but these PSCs disappeared as we continued northward.

 **Figure 2.** During the SOLVE-II DC-8 flight of January 14, 2003. Dr. Steve Eckerman of the U. S. Naval Research lab displays the results of his mountain wave forecast model to Dr. Lawrence Twigg of NASA's Goddard Space Flight Center. Dr. Twigg's console on the NASA DC-8 displays information from the AROTAL lidar on ozone, temperature, and polar stratospheric clouds.

We began our first sun run at approximately 9:46Z, a few minutes late (the solar disk was not fully apparent at the start of this first run). There was a very-very faint localized PSC at approximately 20 km slightly to the north of this run, but nothing as we made the run. All 3 solar instruments locked onto the sun shortly after we began the run. The clouds below us were at about 35,000 feet (10 km).

We started our second run at 10:21Z (a zenith angle of 90.7° at the start of the run). Again, all three instruments began tracking shortly after the start of the run. Some very fine structure was seen on the solar imager that was contributed by the PSCs. The SAGE-III overpass occurred during this sun run at 10:31:11 UT, our position at that time was 68°17.1'N 8°38.2'E. We ended the run at 10:36 at a zenith angle of 90.2°.

At the end of the 2nd run during our turn we descended 200 ft to try and catch our exhaust plume. During this turn, AROTAL observed a very faint PSC at 21.5 km on the western end of this 2nd sun run. It observed a 2nd faint PSC right at about the SAGE-III tangent track. On this track and during the turn to start the 3rd run, DIAPER observed our plume a total of four times.

We began sun run #3 at approximately 10:57Z (a starting zenith angle of 89.8°). All three solar instruments began tracking during this run. There were weak but intermittent PSCs along this sun run. GAMS/LAABS report that the first two runs gave good water data and the 3rd run was producing good ozone data. GAMS/LAABS also reported PSC layers weakly obscuring the base of the sun. AATS-14 reported that as we flew westward, the optical depth steadily increased. We completed the sun run at 11:15Z at a zenith angle of 89.5°.

As we flew south from the 3rd sun run, we almost immediately flew beneath a Type 1b PSC that we had visually observed to the SW of our sun run. This PSC was over a

kilometer thick. In addition, beautiful PSCs were seen from the cockpit during this track southward.

We began our 4th sun run at 11:58Z with a solar zenith of 83.7°. There was a PSC between the sun and us during this run. As we moved over water, the PSC began to disappear. We ended the sun run at 12:16Z at a zenith of 83.8°. GAMS/LAABS had excellent run. AATS-14 had an excellent run. DIAS was locked from the beginning and managed to see photons down to a wavelength of 305 nm. An estimate of the slant path optical depth from GAMS/LAABS on the PSC shield was about 0.15 at 525 nm.

Started our spiral descent into Kiruna at 13:25Z, and landed at 13:53Z.

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

Status Report: Instrument – PI

DIAPER (in situ aerosols) – Anderson
Good flight. Temporary loss of PCAS. A number of plume intercepts.

SP2
Instrument worked the entire flight, but no archival data yet.

FastOz – Avery
Worked well. Ozone of 400-500 ppmv. Possibly sampled a Kelvin-Helmholtz wave.

DIAL (Lidar ozone and aerosol above and below the AC) – Browell
Had an exciting flight. Saw a lot of Ib, our first type II. A lot of structure. A little bit of difficulty with the cirrus.

DACOM/DLH (in situ trace gases and open path water vapor) – Diskin
Both DAACOM and DLH worked very well.

PANTHER (in situ PAN and other trace gases) – Elkins
Had a good flight. Have a good handle on sample flow. Appreciate the spiral descent.

MTP (microwave temperature profiler) – Mahoney
Excellent flight. Retrievals in the vortex were excellent.

AROTAL (Lidar ozone, aerosols and temperature above the AC) - McGee/Hostetler
GSFC- Reasonably good flight. Temperature PSC good. Lost energy in the 308 nm laser.
LaRC – Great flight. Really pleased. Lots of PSCs.

GAMS/LAABS (solar occultation ozone, aerosols and oxygen A band) – Pitts
Had 4 good sun runs. First two runs had a lot of water. 3rd and 4th runs were excellent. LAABS is working flawlessly.

DIAS (Direct beam solar irradiance) – Shetter
Good flight. Took data on every one of the sun runs.

FCAS/NMAS (in situ aerosols) – Reeves
Automated, not on board.

AATS-14 (sun photometer) – Russell
Had a pretty good flight. Last sun run had some unusual features, might be a contaminated window.

Differential GPS – Muellerschoen
Worked really well until the phone call.

ICATS

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

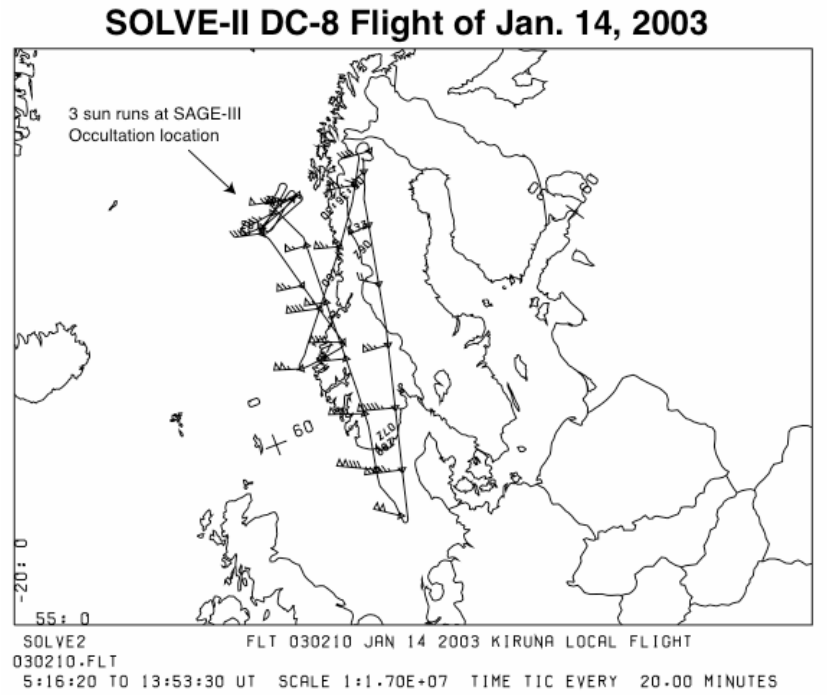

Figure 3. Flight path of the DC-8 for January 14, 2003.

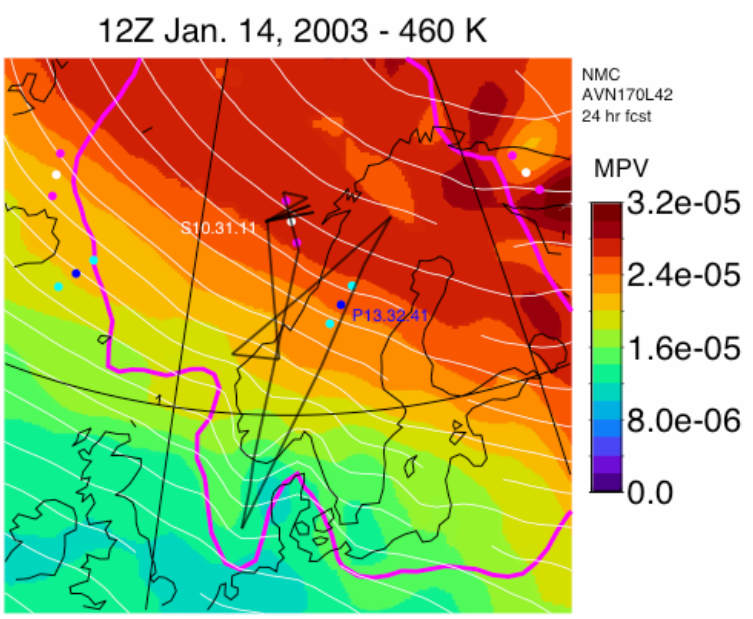

Figure 4 January 14, 2003 DC-8 flight plan (black) superimposed on a 12Z map of modified potential vorticity (color image) for the 460K isentropic surface. The thick magenta line shows the 195K temperature contour. The white point indicates the SAGE III occultation point (occurring at 11:08Z) and the dark blue point is POAM occultation point (occurring at 14:11Z). The white lines are Montgomery stream function lines (winds blow parallel of these line).

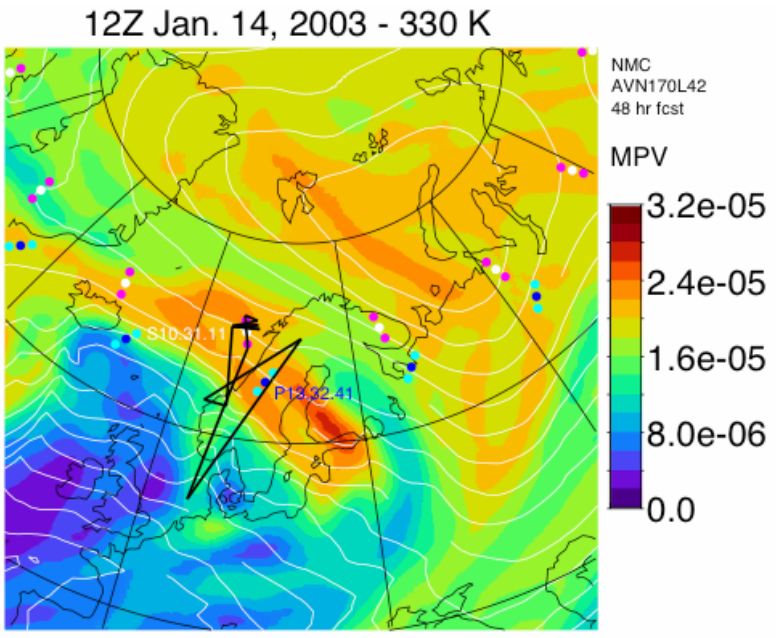

Figure 5. As in the previous figure, but for the 330K isentropic surface (approximately the DC-8 flight altitude).

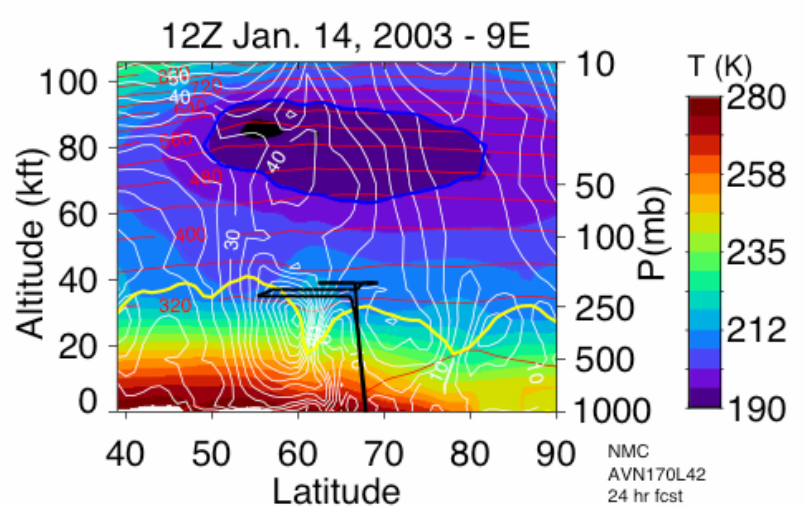

Figure 6. Temperature and wind cross section at the prime meridian (0°E). Potential temperature surfaces are shown in red, white lines indicate wind speed (m/s, the yellow line shows the tropopause, and the thick blue line is the 195K contour.

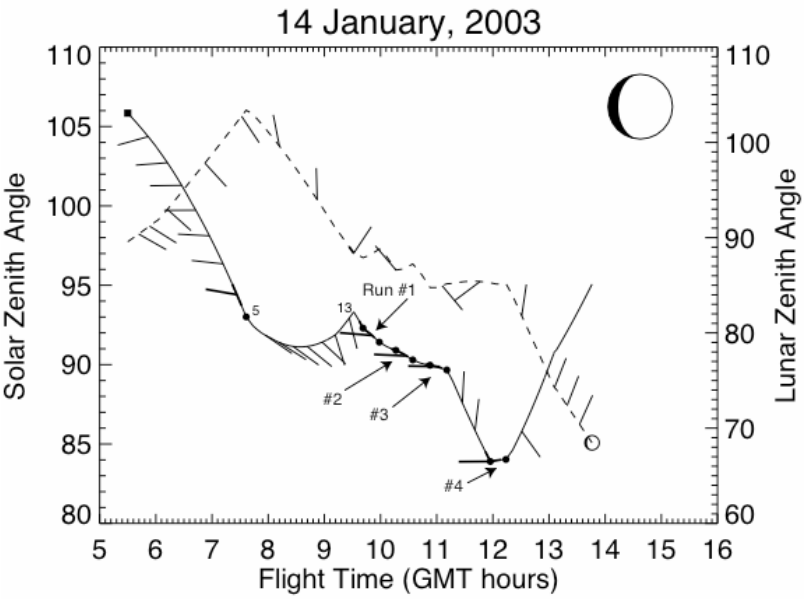

Figure 7. Solar and lunar zenith angles for the flight path shown in the previous figures. The 4 sun runs are indicated by the arrows.