SOLVE-II Flight Report: Sunday, 01/26/2003

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Flight Type: SAGE-III occultation & vortex survey flight & coordination with Geophysica and Falcon

Flight Objectives:

1. Fly to a far Northern Way Point (80N) on a track to also be followed by the DLR Falcon and the Geophysica. This will allow us to compare ozone data.
2. Overflight of Ny Ålesund
3. SAGE III occultation sun run 1: 71.05˚N, 6.28˚E to 70.48, 11:40 W at 12:09 UT
4. Cross the edge of the vortex
5. SAGE III occultation sun run 1: 71.03˚N, 33.39˚W to 70.40, 39 W at 13:46 UT
6. Fly to western lobe of the vortex
7. Follow a streamline east to the Northern edge of Greenland
8. Return to Kiruna

Flight Plan (UT):

08:35	Takeoff
10:19	Northern Way Point (80˚N, 30˚E)
12:09	Sun run #1
13:30	Sun run #2
14:40	West of Greenland
15:51	North of Greenland
18:47	Land

Forecast Meteorology:

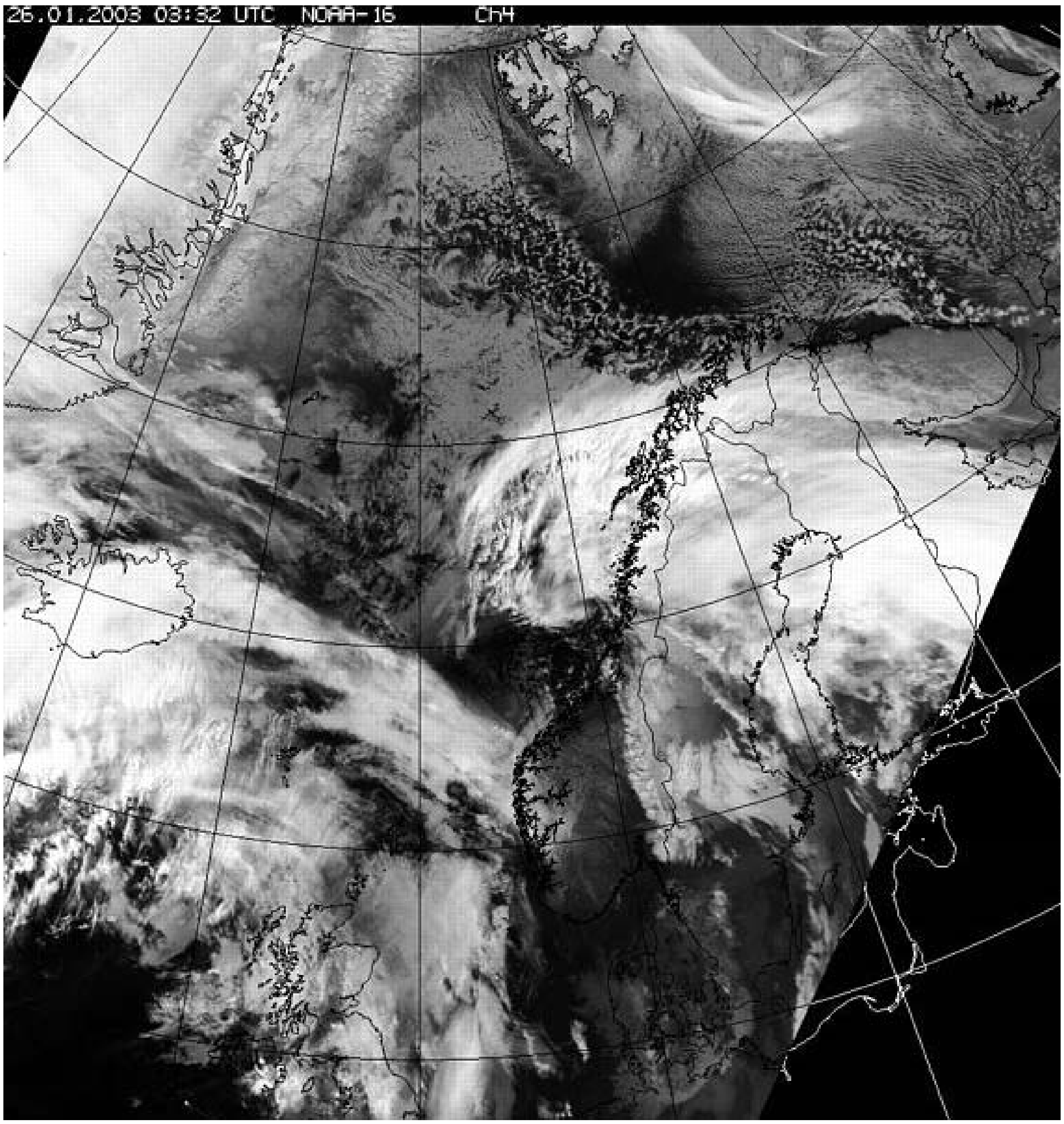
The vortex is a single, albeit elongated elliptical circulation system at 480K. The bulk of the vortex is in the western hemisphere, centered about 15˚ north of Hudson's Bay, with a long arm extending across the pole into Russia. The ellipse rotates clockwise with altitude slightly, which means that at our longitudes the edge of the vortex slopes poleward with latitude. At 460K, the edge of the vortex should be near Kiruna.

RDF calculations at 460 K show significant filamentary entrainment of extra-vortex air. The calculations suggest we may encounter a filament just at the end of our northern flight track and perhaps some structure between last sun run and the trip back north.

In the lower troposphere a strong southwesterly flow at 700 hPa from about (30˚W, 50˚N) to the northwest Russian Arctic is carrying successive waves toward central Scandinavia. A weak system is moving through northern Sweden so light to moderate snow is expected at takeoff, no winds. Snow is expected to cease around noon with clear weather for landing. Kiruna is still north of the jet core so air pushing in from the south and associated cirrus should not overrun our region. Neither occultation points should be affected by cirrus.

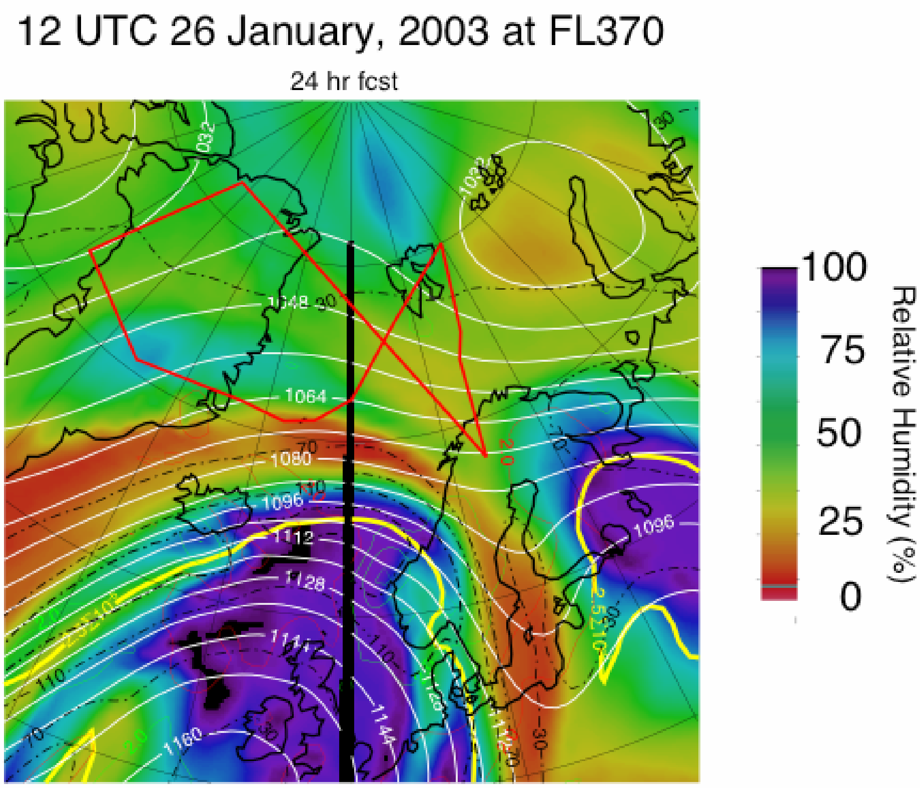
Little gravity wave activity is expected over the flight period according to the forecasts. Significant gravity wave activity over southern Scandinavia and Iceland is forecast.

Synoptic situation:



Met. Figure 1. NOAA 16 AVHRR IR cloud imagery for Jan. 26, 2003

A fast-moving cyclonic system dominated northern Scandinavia Sunday morning producing widespread snowfall and reduced visibilities. The extent of the system is shown in the 0332 UT 10.5 µm (ch 4) NOAA 16 picture above. A second system moving across Iceland was producing high-level cirrus that potentially may impact the high SZA sun runs at 71°N during the DC-8 flight. The FL370 plot below, valid at 12UT, shows a >130 kt jet crossing the cloud head of the system immediately south of Iceland. Super-geostrophic winds as the flow pattern turns sharply southward to cross Norway should produce interesting dynamical features at flight level.

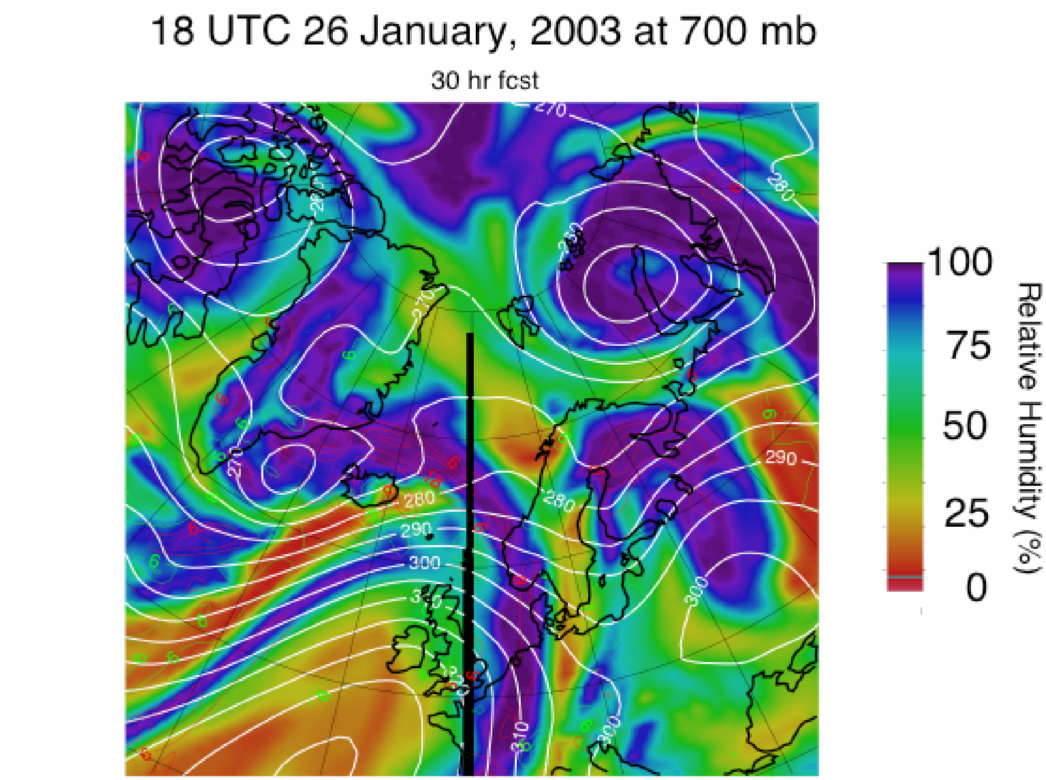


Met. Figure 2 Flight level 370 relative humidity, geopotential height and isotachs. Flight track in red. Tropopause is the yellow contour.

Surface forecast for Northern Interior: (courtesy Swedish Met Service, translation by H. Selkirk; issued: 2003-01-26 06:45)
Westerly winds, changing to northerly tonight. Widespread snow, drawing away to the east in the evening with clearing in north Lapland, but mostly cloudy elsewhere. Temperatures in west and southern Lapland –4 to –8°C, otherwise –10 to –15°C, at night a bit colder.

Interpretation:

The 700-hPa forecast (below) for near-landing time shows that the storm has moved off to the east of the Northern Interior, at least at Kiruna, and we should see an interval of clearing this evening before the next system affects the region.



Met. Fig. 3 700-hPa relative humidity and geopotential height predicted at landing time.

Flight Report:

Snowing at take off. The snow delayed the Geophysica so we took off first so to make our sun run. Ice formation on the zenith ports and on the optical windows. Cleared cloud decks at 31 kft as predicted by our crack meteorologist Rennie Selkirk. MTP reported tropopause height at 32 kft. We learned that both the Falcon and Geophysica took off behind us. Because both planes are slower than the DC-8 we will beet them to the Northern way point. The Falcon appeared to be about 30 minutes behind us. AATS 14 has frozen vertical gimbals and will probably not be able to take data during the sun run.

At 9:03 we passed through the tropopause, ozone began to climb sharply from 50 ppbv below the tropopause to 300 ppbv at 35 kft where we leveled off. Ozone continued to slowly rise and CO slowly fell to 36 ppbv as we headed northward. About 74˚ N we encountered variable values on both CO and ozone. AROTAL ozone showed a weakening of the vertical gradient in ozone 18-19 km indicating ozone loss. By 10:15 – near 79N we began to see significant ozone loss in the AROTAL data – the ozone values descended from 3 ppmv (at 9:30) to below 2 ppm at 19 km. Below the aircraft there was significant convective activity creating some bumpiness. *In situ* ozone began to decrease to ~150 ppb, ozone and water structure were strongly anticorrelated.

At 10:25 we turned south again. Ozone at 19 km began to increase. No evidence of the filament at the northern end – but the forecast put it just outside of our range. As we turned south we had a spectacular view of Spitzbergen. The ozone at 19 km began to increase and then decreased as we entered a region of higher PV ozone loss was again evident. This loss region slowly diminished as we went south of 75˚N. *In situ* ozone rose to 400 ppbv with CO at 30 ppbv, water was at 10 ppmv.

We did not get permission to fly over Jan Mayen so we diverted south 20 miles from the planned southern sun-run waypoints. As we approached the sun-run waypoint DIAS began to take data. Water vapor decreased to 4 ppmv, ozone was 350 ppmv and CO was 30 ppmv. The sun run is just outside the vortex. DIAL and AROTAL saw a sharp increase in ozone at 20 km as we exited the vortex region (near 72˚N) a lot of aerosol structure just outside the vortex was also seen. There appeared to be some overrunning of air from the troposphere into the stratosphere – from the cyclonic side of the decelerating tropospheric jet. At higher levels, the vortex edge was very sharp. DIAL also noted a weak stratospheric intrusion or some low-level ozone loss.

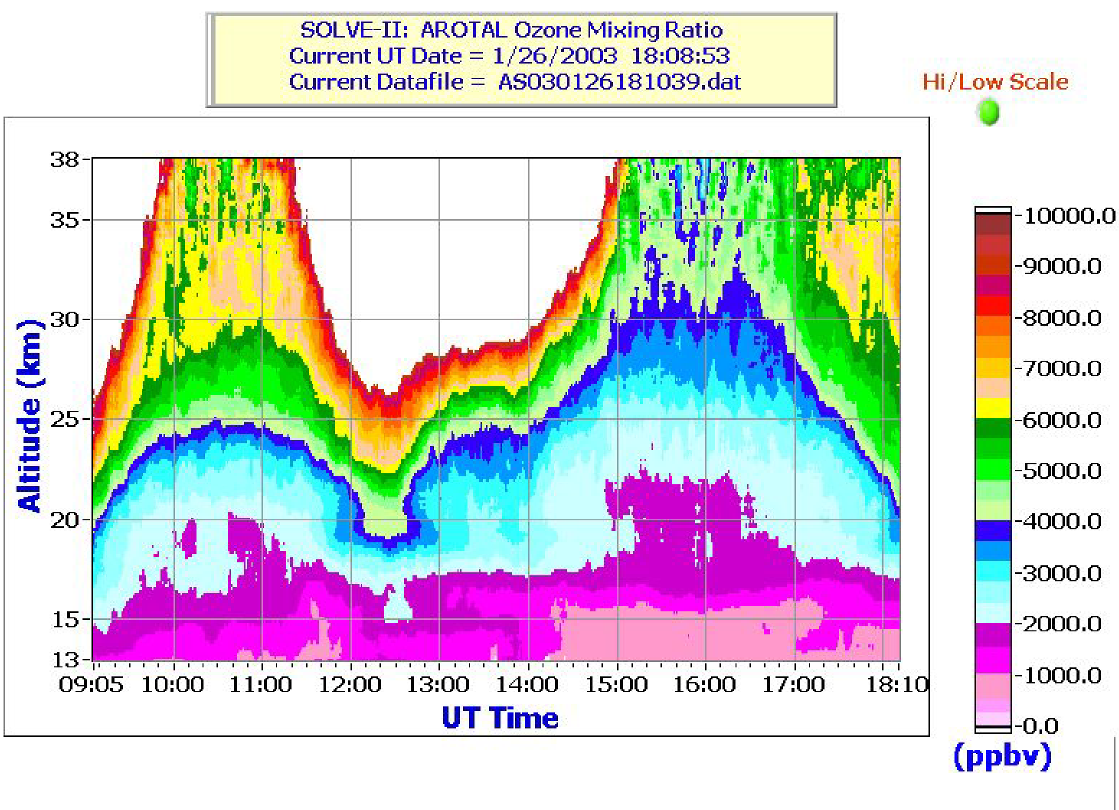
Photo 1. Crossing the coast of Greenland we could see immense glaciers off to the starboard side of the aircraft.

Photo 2. Ice leads off the east coast of Greenland.

We began the sun run at 12:09:18 PM; cirrus below the aircraft. We ascended to 38 kft to avoid some cirrus on the horizon. The sun run went well except for AATS, which did not work. Ozone was about 450 ppbv, H_2O at 3.8 ppmv, CO at 27 ppbv.

We began the second sun run over Greenland. The second sun run began at 13:32.06. We then turned north-west, ozone began to decrease as water rose slowly. We were moving toward the western lobe of the vortex. Ozone at 16 km began to decrease. The depletion seen in this region looks like the one seen just before we exited the vortex (prior to the sun run). If this is loss then the loss region is being advected around the edge of the vortex. Back trajectory calculations indicated that this air has been to latitudes south of 60˚N within a day or so … because the vortex is so elongated, we are probably seeing much more loss earlier than expected. Ozone in the vortex continued to drop as we moved from waypoint 13 to 14. AROTAL showed almost no vertical ozone gradient from 17 to 22 km. This lack of gradient persisted toward the center of the vortex. Very low ozone values (below 1ppm) were seen below 15 km.

We began to cross the northwestern "ear" of Greenland. By 78˚ N latitude, *in situ* ozone had reached in excess of 500 ppbv. H_2O was about 3.3 ppmv with CO at 26 ppbv. At this part of the flight track mild gravity wave turbulence was forecast and the plane bounced around a little. AROTAL saw 3- to 5-K temperature anomalies above the aircraft between 31-50 km. These are probably the gravity waves propagating downstream from the costal orography to the west.



Ozone figure from AROTAL shows loss regions at 20 km inside the vortex (purple).

Turning back toward Kiruna, AROTAL temperatures showed 196 or warmer in the lower stratosphere. Ozone loss was less evident as we headed back – most significant ozone depletion was over Greenland and just east. As we moved off the Greenland coast the plane ascended to 41 kft. *In situ* ozone rose to 700 ppb, CO at 20 ppbv. At 20 km, AROTAL shows no vertical gradient in ozone, stratospheric temperatures are at 205K.

Landed at 18:35

Pilots: Bill Brockett, Ed Lewis
Navigator: Kevin Hall
Mission managers: Chris Miller & Bob Curry
Mission scientist on board: Mark R. Schoeberl

Status Report: Instrument – PI

DIAPER (*in situ* aerosols) – Anderson
A good flight worked

SP2
SP2 worked well today. Got data over whole flight.

FastOz – Avery
Worked well. Saw a lot of nice wave structure.

DACOM/DLH (*in situ* trace gases and open path water vapor) – Diskin
Worked well. Problem with methane channel – sensitive to vibration.

PANTHER (*in situ* PAN and other trace gases) – Elkins
A very good flight. Six reboots – lost 20-25 minutes of data.

MTP (microwave temperature profiler) – Mahoney
Had a great flight. Tropopause at 10 k almost whole flight.

AATS-14 (sun photometer) – Russell
Frozen gimbals – no data. May need to pull instrument.

GAMS/LAABS (solar occultation ozone, aerosols and oxygen A band) – Pitts
Instruments worked well – excellent data.

DIAL (Lidar ozone and aerosol above and below the AC) – Browell
Worked well. Got a lot of interesting aerosol and ozone data.

AROTAL (Lidar ozone, aerosols and temperature above the AC) - McGee/Hostetler
GSFC – Had a real good flight. Saw wave structure in temperature over Greenland and evidence of ozone loss. The predicted behavior. Saw inversion at 45 km again.
LaRC – Slow start due to amplifier problem. Good data. Interesting aerosol layers

DIAS (Direct beam solar irradiance) – Shetter
Good flight. Got data all through the sun runs plus some additional data. Not much in the UV.

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

Differential GPS – Muellerschoen
Failed to get carrier signal.

ICATS
Had an OK flight – 1 computer crash – maybe a gap in 1- and 10-Hz data..

Plots (flight plan, solar zenith angles, Relative humidity):

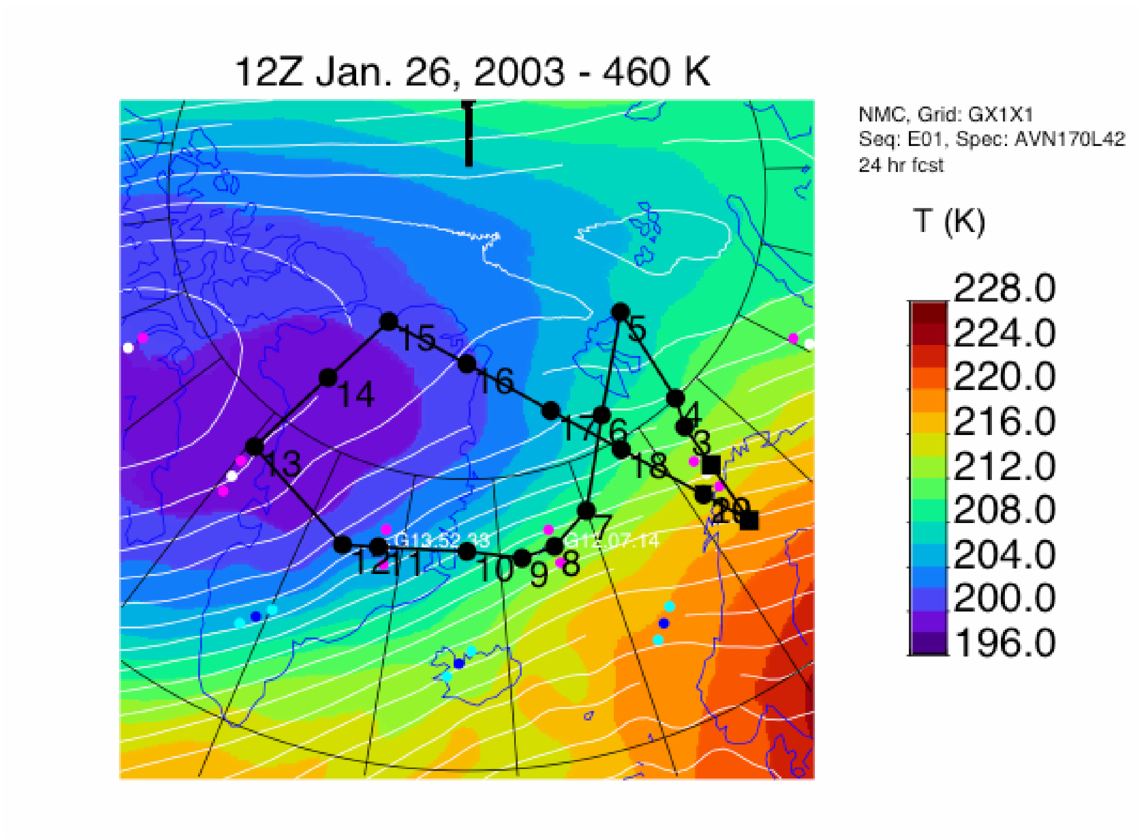


Figure 1. January 26, 2003 DC-8 flight plan (black) superimposed on an AVN 12Z map forecast map of temperature (color image) for the 460K isentropic surface. The white point indicates the SAGE III occultation point and the dark blue points are POAM occultation points. The white lines are Montgomery stream function lines (winds blow parallel of these line).

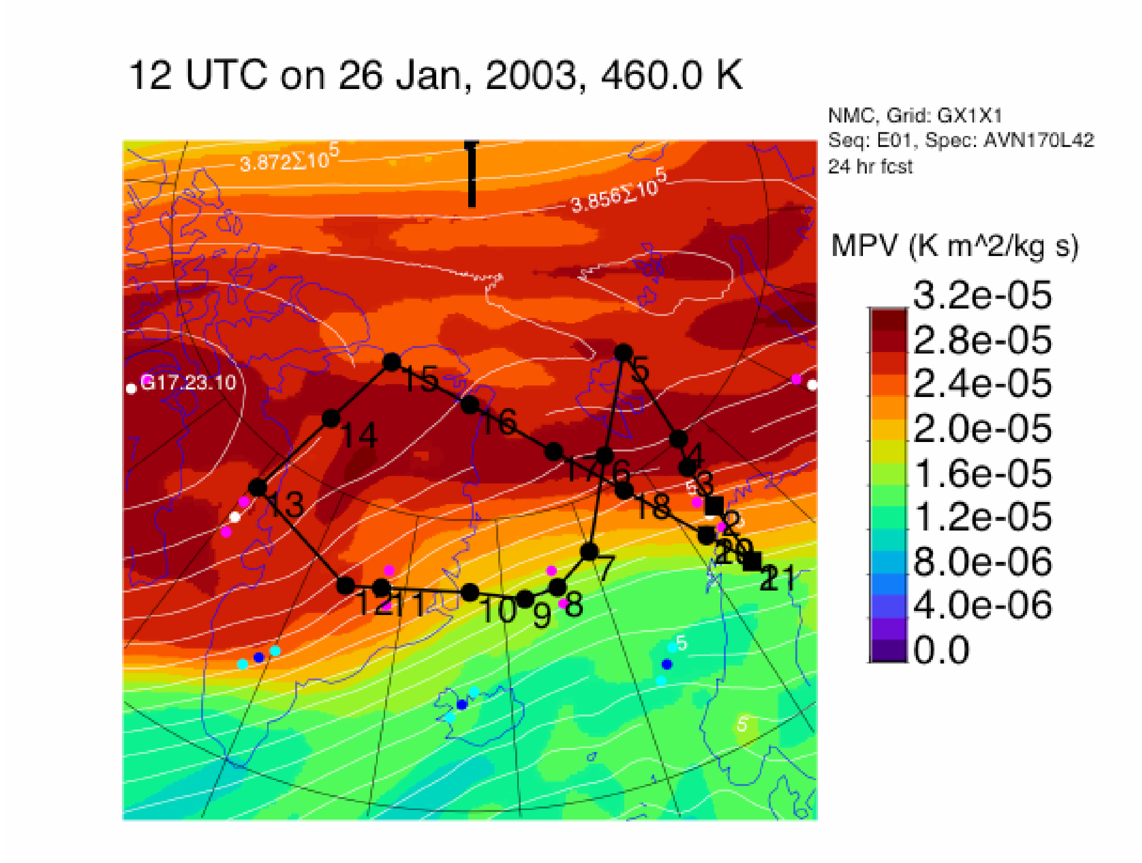


Figure 2. January 26, 2003 DC-8 flight plan (black) superimposed on an AVN 12Z map forecast map of PV (color image) for the 460K isentropic surface. The white point indicates the SAGE III occultation point and the dark blue points are POAM occultation points. The white lines are Montgomery stream function lines (winds blow parallel of these line).

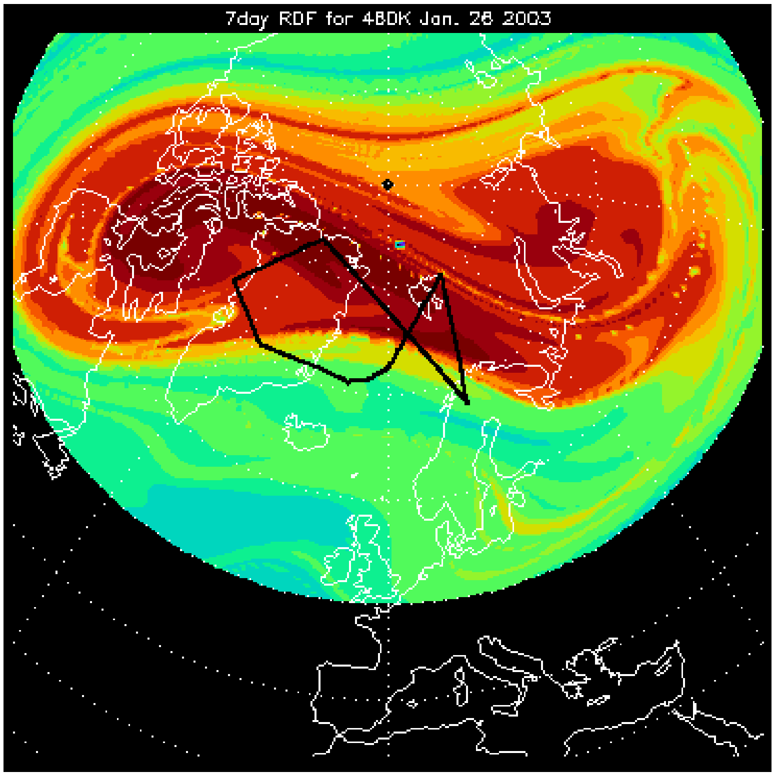


Figure 3. 460-K, 7-day RDF calculation showing high-resolution structure. RDF means "reverse domain fill" which is a back trajectory technique used to artificially boost the resolution of the fields. Note the filament of extra vortex air at Way Point 5. This filament can be tracked along to extend around the vortex to almost touch the track between Way Point 12 and 13

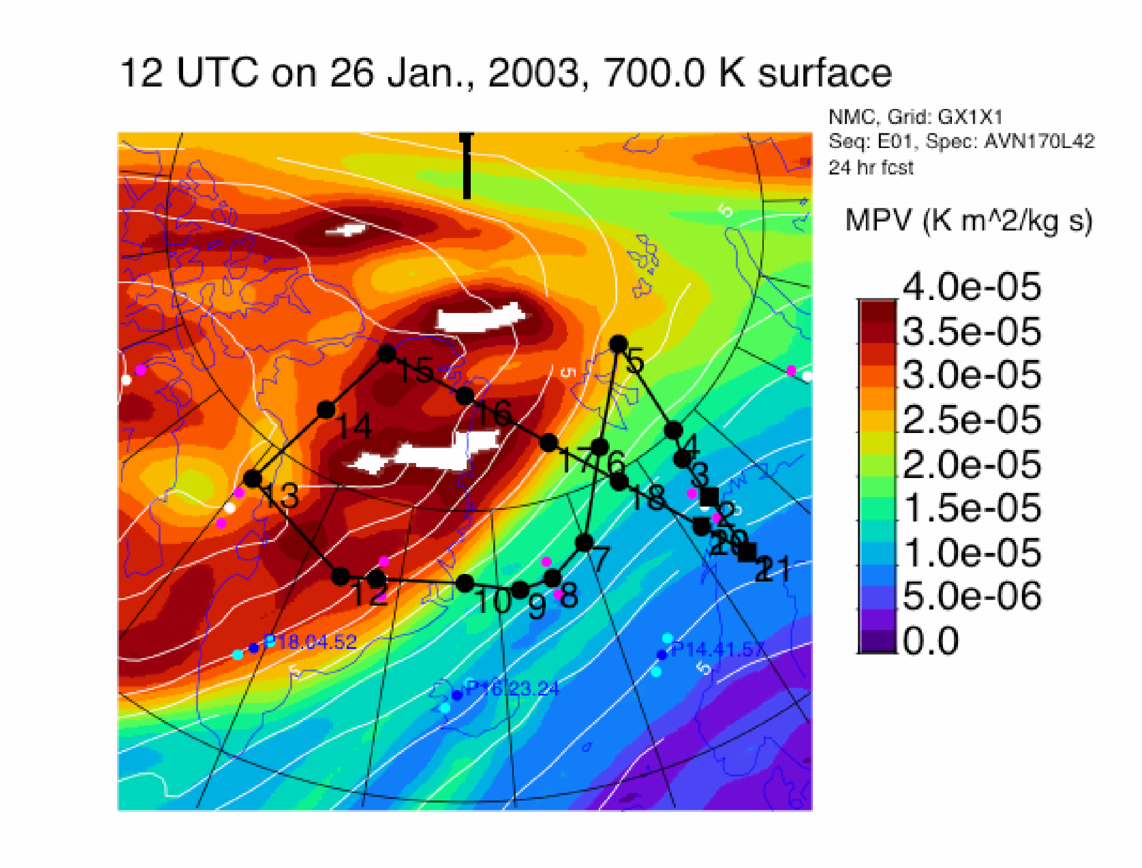


Figure 4. Same as Figure 2 but at 700 K. Comparing Figure 2 at 460 K, it is evident that the vortex is tilting away from an axis connecting Iceland and northern Scandinavia

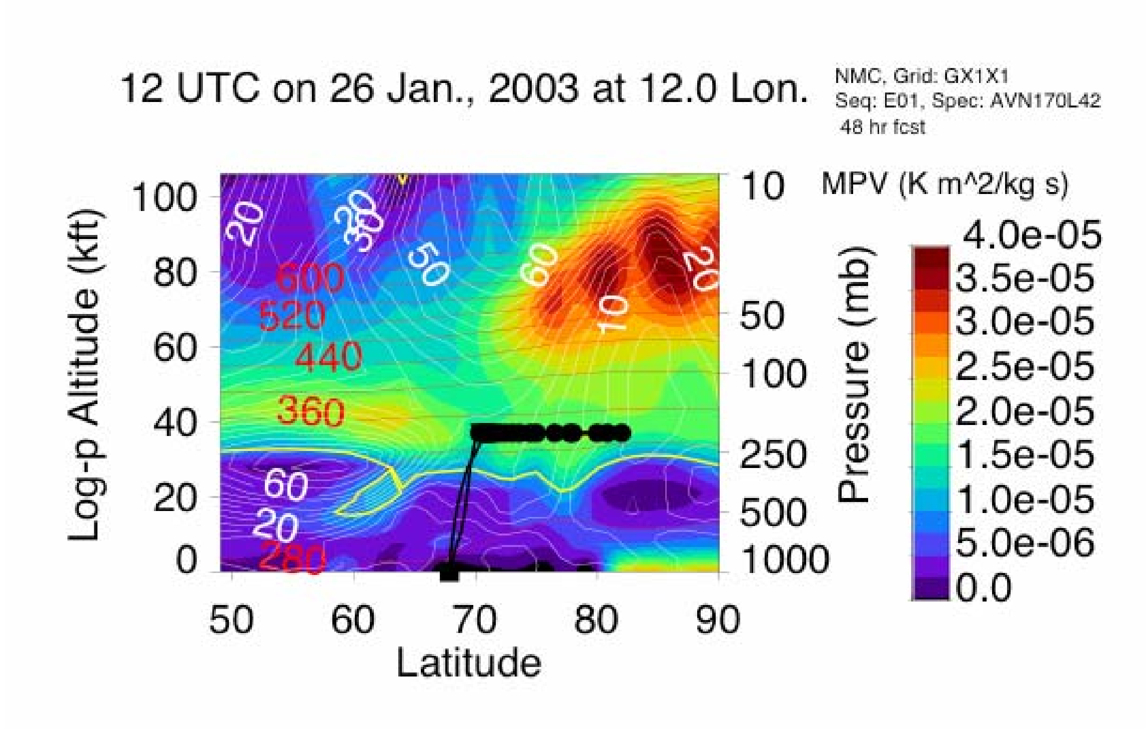


Figure 5. Cross-section plot at 12˚ longitude of the flight of January 26, 2003. The colors indicate temperature values (see scale at bottom of the figure). Red contours are potential temperature (K), white contours are wind speeds (m/s), and the yellow contour shows the tropopause. Note the fold at 60˚ N.

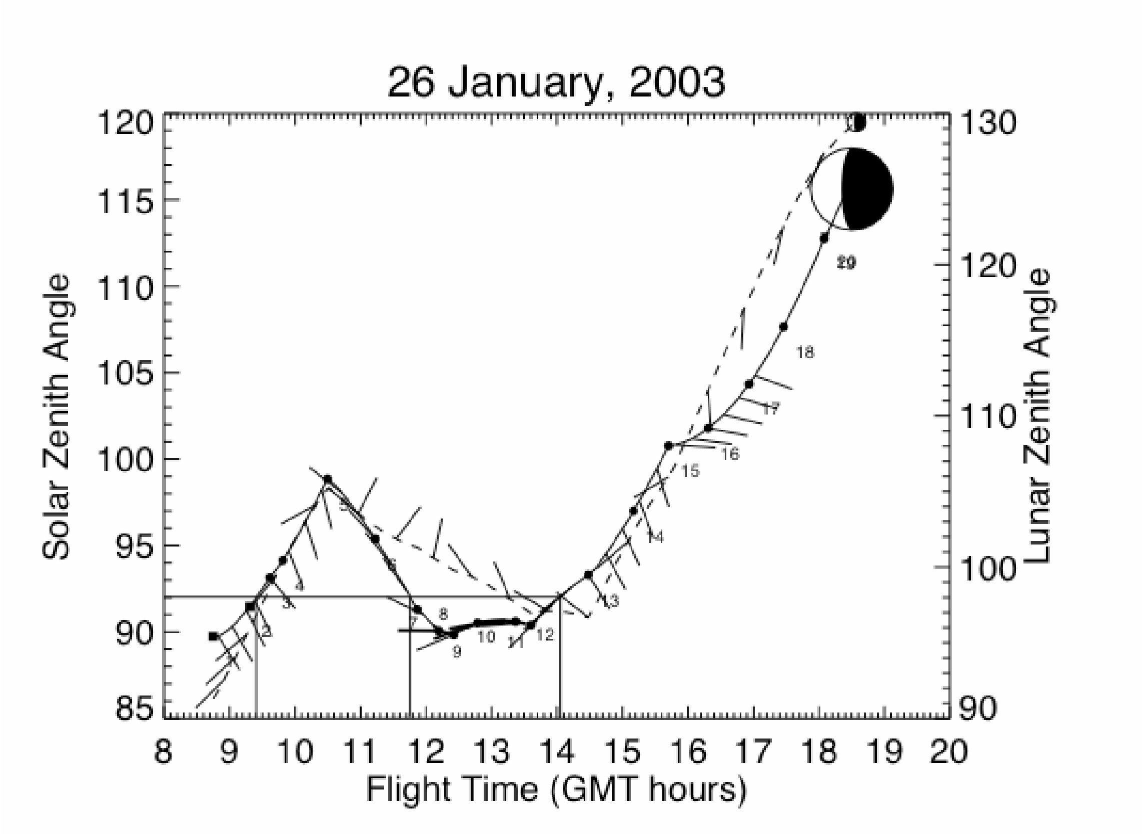


Figure 6. Solar and lunar zenith angles for the flight path shown in the previous figures.