

3.6 Influence on mid-latitudes

Owing to the stability of the vortex during the winter 1999/2000, transport towards mid-latitudes was less intense than during the first two THESEO winters. However, the influence of transport of air from higher latitudes was detected on several occasions by ground-based measurements at stations of lower latitude.

Until the end of February, polar air was isolated and the vortex was stable in the lower stratosphere, resulting in a small number of polar filaments and weak transport from the polar vortex to mid-latitudes. After the strong warming occurring in mid-March, the polar vortex was split in several parts, leading probably to a strong mixing with mid-latitude air, but the European sector was not affected by the polar air.

3.6.1 Filamentation and polar intrusions

Four alerts of polar filamentation were sent to the ground-based network from January to the beginning of March, but they corresponded to small events. During one alert, on 7 March, 2000, a flight through a relatively weak filament was performed by the *Mystère 20* aircraft from Creil near Paris, towards Kristiansand, Norway in early evening, and back to Creil after refuelling the plane. From the PV-advection model MIMOSA, the filament occurred at the isentropic level of 435 K with values slightly above 20 PVU stretching in direction north-west to south-east from Scotland over the North Sea towards Germany (Figure 37). The filament could be observed in the ozone measurements at the end of the first flight and at the beginning of the second flight. The ozone measurements on the flight back from Kristiansand are shown in Figure 37. High ozone mixing ratios were measured at the beginning of the flight. Ozone values inside the filament were up to 1200 to 1300 ppb in the centre and at the outermost parts, and around 900 to 1000 ppb between these three maxima. This structure is in excellent agreement with the PV filament simulated by the advection model: a polar filament clearly distinguished by a sharp PV gradient from the mid-latitude air, and within the filament a structure of three maxima of even higher PV values. However the ozone filament is located further north and seems to be thinner than the PV filament predicted. These results are still preliminary, and the model will be run with higher resolution input data from ECMWF and PV cross-sections along the flight track will be compared to the measured ozone distribution. The decrease of the contrast between high ozone concentration in the filament and low concentration outside due to ozone depletion in the

vortex must also be taken into account in the interpretation of the data.

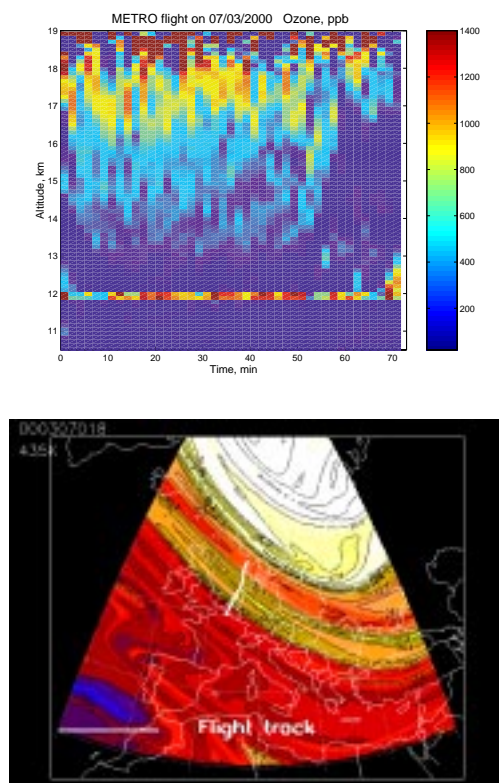


Figure 37: Top: PV map simulated by the PV-advection model MIMOSA at 435K with the flight track. Bottom: 2D section of ozone mixing ratio versus altitude and time during the Mystère 20 flight on 7 March, 2000 (courtesy of A. Hauchecorne, S. Godin and B. Heese).

3.6.2 Ground-based measurements at mid-latitudes

Lerwick (60.1°N , 1.2°W), was affected by 4 major cold troughs at approximately monthly intervals. These passed across Scotland on 4 December, 27 December, 28 January and 29 February. Each of these major cold troughs was associated with low stratospheric temperatures. Lerwick was inside the southern boundary of the vortex for several days at the end of January and at the beginning of February. Temperatures measured at the station fell below the formation temperature for Polar Stratospheric Clouds (PSC I) at this stage. At the end of January, when Lerwick (60.1N , 1.2W) was well inside

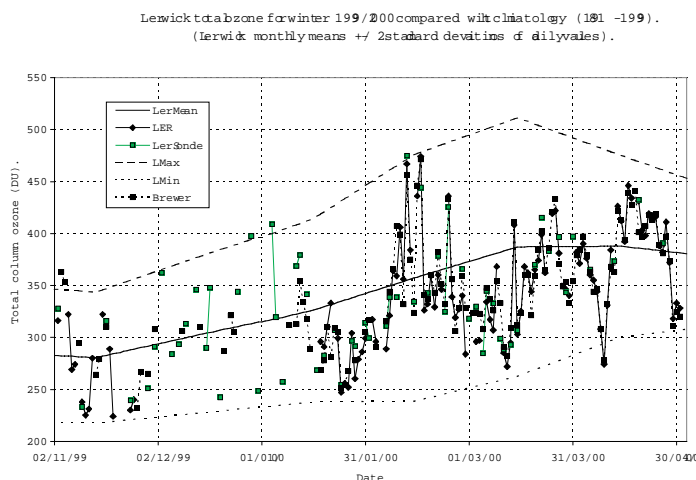


Figure 38: Time series plot of total ozone measurements for Lerwick from spectrophotometer and ozonesonde measurements (courtesy of S. Farmer).

the vortex, ozone values well below normal were observed over the station (Figure 38) presumably as a result of chemical ozone depletion in the vortex.

Similarly, in Camborne (50.1°N, 5.2°W), low total ozone values were observed on 1 December, 31 December, 30 January and 2 March. These low values were associated with the passage of the major cold troughs in the stratosphere. Total ozone measurements at Camborne were below normal during the first three weeks of March due to persistent anticyclonic conditions over the southern part of the British Isles and chemically enhanced ozone depletion in the stratosphere.

At the Jungfraujoch (ISSJ; 46.5°N, 8.0°E), the measurements performed by FTIR solar intrusions showed 3 periods of polar intrusions with the station under the edge of the polar vortex. Between 15 and 20 November 1999, all columns of the most important stratospheric compounds (e.g., O₃, HNO₃, HCl, ClONO₂ and HF) increased significantly by 40% up to 70%, while the columns of tracers (e.g., N₂O, CFC-12 and HCFC-22) decreased by about -5%. The local tropopause dropped from 11.0 to 7.6 km. The NO_y and Cly columns increased, respectively from 2.1x10¹⁶ to 3.0x10¹⁶ and from 4.5x10¹⁵ to 6.8x10¹⁵ molec./cm². This event resulted from intrusions of cold air masses from over central Greenland which had not experienced heterogeneous processing prior to their arrival above ISSJ. The PV at 475 K above ISSJ was

21 PVU on 15 November and 31 PVU on 20 November.

Between 12 January and 15 January 2000, the NO_y and Cly columns measured at ISSJ increased, respectively from 2.1×10^{16} to 2.4×10^{16} and from 4.8×10^{15} to 5.8×10^{15} molec./cm², while the HF and O₃ columns increased by 30%. The tracers decreased by 2 to 3%. This event was similar but weaker than in November 1999, resulting from southward transport of air masses that had originated from 60-65°N latitudes (south tip of Greenland). The PV at 475 K above ISSJ was 20 PVU on 01/12 and 23 PVU on 15 January.

Between 3 and 7 February, a sudden decrease of the mid-stratospheric ozone volume mixing ratio (VMR) was observed over Bern (47.0°N, 7.4°E). The VMR drop was about -25% at 40 km and -20% at 30 km. The total ozone values computed from composite microwave and radiosonde profiles show a large increase (+ 25%) after this episode, between 7 and 10 February. This low ozone event seems related to the occurrence of a stratospheric warming event, as it coincides well with increased stratospheric PV and temperature gradient values over Bern.

A third period of polar intrusion at ISSJ was detected between 28 February and 5 March 2000. During that period, the NO_y and Cly columns increased respectively from 2.1×10^{16} to 2.3×10^{16} and from 5.0×10^{15} to 6.3×10^{15} molec./cm², while the column of HF increased by 50%; the HCl and O₃ remained nearly unperturbed. The tracers decreased by an average of 2-3%. The HCl/HF ratio decreased from a background value of 3.1 to 2.15 on 03/05, which is indicative of a significant prior activation of the air masses observed above ISSJ during this event.

O₃ loss The loss values estimated from the SAOZ/REPROBUS techniques outside vortex are plotted on Figure 39. Most of the loss occurred in late December and early January indicating a chemical cause rather than a dynamical one. Dilution processes might have contributed to increase the apparent ozone loss at mid-latitude from the beginning of March. Further analysis will be needed to quantify this contribution.

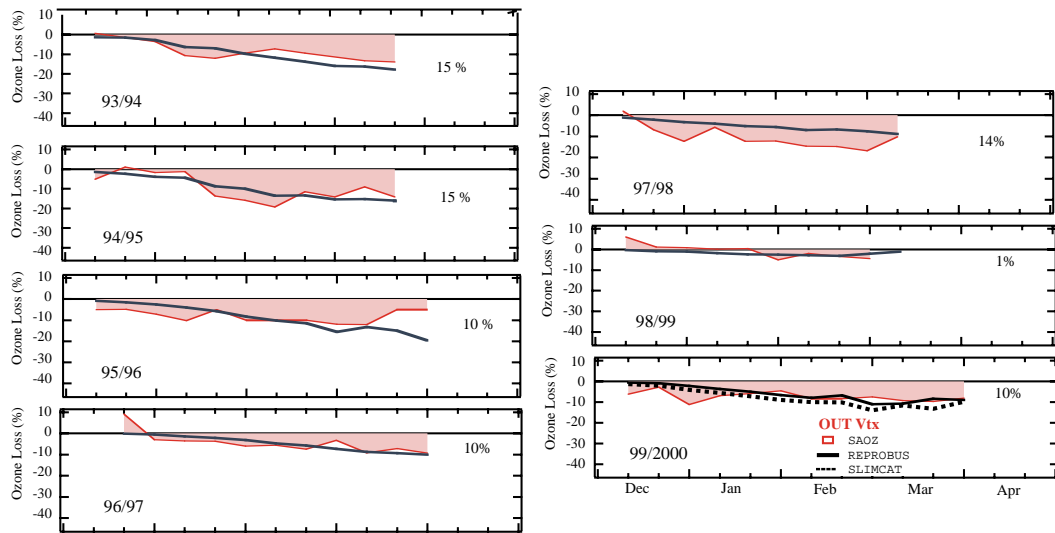


Figure 39: Ozone loss in the total column outside vortex for winters between 1993/94 and 1999/2000 determined from the SAOZ technique (courtesy of F. Goutail and J.P. Pommereau).

date	instrument or aircraft	location	PI	project
09/11/99	Descartes	Esrange	Kirkwood	THESEO 2000 - SKERRIES
17/11/99	SAOZ,Descartes	Andoya	Goutail/Pommereau,Kirkwood	THESEO 2000 - O ₃ loss
19/11/99	OMS in situ	Esrange	Elkins/Oltmans/Webster/Wofsy/Margitan	SOLVE
30/11/99	DC-8	transit	Schoeberl/Toon	SOLVE
02/12/99	DC-8		Schoeberl/Toon	SOLVE
03/12/99	OMS-remote, Descartes	Esrange	Stachnik/Toon, Kirkwood	SOLVE
05/12/99	DC-8		Schoeberl/Toon	SOLVE
07/12/99	DC-8		Schoeberl/Toon	SOLVE
10/12/99	DC-8		Schoeberl/Toon	SOLVE
12/12/99	DC-8		Schoeberl/Toon	SOLVE
14/12/99	DC-8		Schoeberl/Toon	SOLVE
15/12/99	Descartes	Esrange	Kirkwood	THESEO 2000 -SKERRIES
16/12/99	DC-8	transit	Schoeberl/Toon	SOLVE

Table 3: List of field activities within THESEO 2000 and SOLVE (phase 1).

4 Reports on THESEO 2000 activities

4.1 Overview of field activities in Northern Scandinavia

The most intensive Arctic phase of THESEO 2000 took place at Kiruna (67.9N, 21.1E), Sweden, between mid-January and early April. During this period, 7 large balloons, 14 small balloons and 3 long duration balloons carrying scientific payloads were launched successfully from the base at SSC Esrange. Two other small balloons were launched from the Norwegian station Andoya. Aircraft measurements were made on board the DLR Falcon, the CNRS/INSU ARAT, the Swiss Air Force Learjet and the NASA DC8 (with the ASUR Submillimeter radiometer) and simultaneous ground-based activities from the Scandinavian stations (ALOMAR, Kiruna, Ny-Ålesund, Sodankylä, Harestua). In coordinated activities, the aircraft often flew along upwind and downwind of the balloon flight path. Further measurements were made by GOME and POAM data. Meteorological support was provided by the FU-Berlin. Modelling support, especially by providing daily mesoscale forecasts of temperatures, was essential for the planning of operations. The main activities in Northern Scandinavia are listed in Tables 3 to 5.

4.2 Balloons

PSC-Analysis Within the PSC-analysis project ("In-situ analysis of aerosols and gases in the polar stratosphere: A contribution to the THESEO campaign") two balloonborne payloads have been launched from Esrange in January 2000 for detailed studies of Polar Stratospheric Cloud (PSC) particles.

date	instrument or aircraft	location	PI	project
14/01/00	DC-8	transit	Toon	SOLVE
16/01/00	DC-8		Toon	SOLVE
19/01/00	HALOZ 1, Dirac	Esrangle	Toohey, Deshler, Harris/Robinson	THESEO 2000- HALOZ 2000
19/01/00	PSC-Analysis 1	Esrangle	Schreiner, Larsen, Deshler, Ovarlez, Adriani	THESEO 2000-PSC-Analysis
19/01/00	ARAT	transit	David	THESEO 2000
20/01/00	DC-8		Toon, Anderson	SOLVE
20/01/00	ER-2		Newman	SOLVE
23/01/00	Salomon 1	Esrangle	Renard/Pirre	THESEO 2000
23/01/00	DC-8		Toon, Anderson	SOLVE
23/01/00	ER-2		Newman	SOLVE
25/01/00	micro-Radibal	Esrangle	Brognez	THESEO 2000
25/01/00	PSC-Analysis 2	Esrangle	Schreiner, Larsen, Deshler, Ovarlez, Adriani	THESEO 2000-PSC-Analysis
25/01/00	ARAT		David	THESEO 2000
25/01/00	DC-8		Toon	SOLVE
26/01/00	ARAT		David	THESEO 2000
27/01/00	TRIPLE	Esrangle	Stroh,Engel,Schiller,Ovarlez	THESEO 2000
27/01/00	HALOZ 2, Dirac	Esrangle	Toohey,Deshler,Harris/Robinson	THESEO 2000-HALOZ 2000
27/01/00	Falcon		Flentje	THESEO 2000
27/01/00	DC-8		Toon, Anderson	SOLVE
27/01/00	ER-2		Newman	SOLVE
27/01/00	ARAT	transit	David	THESEO 2000
28/01/00	SAOZ,SAOZ-BrO, Descartes, CH ₄ , O ₃ sensor	Esrangle	Goutail/Pommereau,Kirkwood,Gardiner,Jones	THESEO 2000-O ₃ loss
29/01/00	DC-8	transit	Toon	SOLVE
31/01/00	Falcon		Flentje, Anderson	THESEO 2000
31/01/00	ER-2		Newman	SOLVE
02/02/00	ER-2		Anderson/Newman	SOLVE
03/02/00	Falcon		Flentje, Anderson	THESEO 2000
03/02/00	ER-2		Newman	SOLVE
09/02/00	S A O Z , S A O Z - B r O , Descartes,CH ₄ ,O ₃ sensor	Esrangle	Goutail/Pommereau,Kirkwood,Gardiner,Jones	THESEO 2000-O ₃ loss
13/02/00	S A O Z , S A O Z - B r O , Descartes,CH ₄ ,O ₃ sensor	Esrangle	Goutail/Pommereau,Kirkwood,Gardiner,Jones	THESEO 2000-O ₃ loss

Table 4: List of field activities within THESEO 2000 and SOLVE (phase 2).

date	instrument or aircraft	location	PI	project
18/02/00	LPMA/DOAS	Esrange	Camy-Peyret, Pfeilsticker	THESEO 2000
18/02/00	Mir 1	Esrange	Pommereau/Garnier, Jones, Adriani, Vial	THESEO 2000 -Lagrangian
18/02/00	Mir 2	Esrange	Pommereau/Garnier, Gardiner, Yushkov	THESEO 2000 -Lagrangian
22/02/00	Salomon 2	Esrange	Renard/Pirre	THESEO 2000
27/02/00	support Mir 2	Esrange	Goutail/Pommereau, Adriani, Jones, Gardiner	THESEO 2000 -Lagrangian
28/02/00	DC-8	transit	Schoeberl	SOLVE
28/02/00	Mystère 20		Godin	THESEO 2000 - METRO
29/02/00	techno. Mir 3	Esrange	Pommereau/Garnier, Goutail, Vialle	THESEO 2000 -Lagrangian
01/03/00	TRIPLE	Esrange	Stroh, Schiller, Engel/Muller, Adriani	THESEO 2000
01/03/00	HALOZ 3, Descartes	Esrange	Toohey, Kirkwood	THESEO 2000 -HALOZ 2000
03/03/00	DC-8		Schoeberl	SOLVE
05/03/00	ER-2		Anderson/Newman	SOLVE
05/03/00	DC-8	Esrange	Schoeberl	SOLVE
05/03/00	OMS in situ, Dirac, Descartes	Esrange	Brune, harris/Robinson, Kirkwood	SOLVE
07/03/00	SAOZ, O3 sensor, Labs, Descartes	Esrange	Goutail/Pommereau, Adriani, Nilsson/Arvelius	THESEO 2000 -O ₃ loss
07/03/00	ER-2	Esrange	Anderson/Newman	SOLVE
07/03/00	Mystère 20		Godin	THESEO 2000
08/03/00	DC-8		Schoeberl	SOLVE
08/03/00	HALOZ 4, Dirac	Esrange	Toohey	THESEO 2000 -HALOZ 2000
09/03/00	DC-8		Schoeberl	SOLVE
10/03/00	Learjet		Feist/Kampfer	THESEO 2000 -WAVE
11/03/00	DC-8		Schoeberl	SOLVE
11/03/00	ER-2		Anderson/Newman	SOLVE
11/03/00	Learjet		Feist/Kampfer	THESEO 2000 -WAVE
12/03/00	ER-2		Anderson/Newman	SOLVE
13/03/00	DC-8		Schoeberl	SOLVE
15/03/00	OMS remote	Esrange	Stachnik/Toon	SOLVE
15/03/00	DC-8	transit	Schoeberl	SOLVE
15/03/00	ER-2	transit	Anderson/Newman	SOLVE
25/03/00	SAOZ, Dirac, CH ₄	Esrange	Goutail/Pommereau, Harris/Robinson, Gardiner	THESEO 2000 -O ₃ loss
26/03/00	Mystère 20		Godin	THESEO 2000 - METRO
28/03/00	Mystère 20		Godin	THESEO 2000 - METRO
03/04/00	SAOZ, Descartes	Andoya	Goutail/Pommereau, Kirkwood	THESEO 2000 -O ₃ loss
04/04/00	HALOZ 5, Descartes	Esrange	Toohey	THESEO 2000 -HALOZ 2000

Table 5: List of field activities within THESEO 2000 and SOLVE (phase 3).

The project aims at a complete characterisation of PSC particles in terms of their chemical composition, physical phase, size distributions, and optical properties together with observations of the ambient atmospheric environment in which the particles form. These aims have been accomplished by performing balloonborne multi-instrument measurements using an aerodynamic focusing lens and a mass spectrometer for condensed phase chemical analysis, optical and CCN counters for measurements of PSC particle size distributions, (laser) backscatter sondes for observations of optical properties and physical phase (backscatter ratios and depolarisation), and a hygrometer for measurements of gas phase concentrations of water vapour. The balloonborne measurements have been supported by airborne lidar observations of the PSC evolution. The measurements will be analysed using meteorological mesoscale, microphysical, and optical modelling.

TRIPLE The TRIPLE payload included a ClO/BrO chemical conversion resonance fluorescence instrument, the cryogenic whole air sampler BON-BON, the Lyman-alpha hygrometer FISH, the filter radiometers, and an aerosol instrument. This payload was flown on a stratospheric balloon on 27 January, 2000 and 1 March, 2000 from ESRANGE near Kiruna, Sweden.

The main objectives of the measurements were to investigate: ClO/BrO photochemistry/diurnal variation, chlorine activation and O₃ loss, subsidence and tracer correlations inside vortex, water vapour and particle formation inside vortex.

LPMA-DOAS A 100 Z balloon carrying the LPMA/DOAS payload reduced in weight (465 kg) and size was launched successfully from ESRANGE by CNES at 12:15 UT on 18 February, 1999. Solar absorption measurements were performed by the FT-IR (Fourier Transform-InfraRed Spectrometer) and DOAS (Differential Optical Absorption Spectrometer) instruments during balloon ascent from 3 km up to the float altitude at about 31 km. Sunset measurements were then performed at float until final loss of sun for tangent altitudes in the 10 km range. The balloon separation took place over Russia, as planned.

The spectrometers on board carried out simultaneous profile measurements of HCl, ClONO₂, CH₄, N₂O, HNO₃, NO₂, NO, O₃ and HF in the infrared spectral range and of O₃, BrO, IO, NO₂, O₄ and OCIO in the UV/vis spectral range. The preliminary data retrieval shows that the observations were made within a denoxified and chlorine activated vortex.

SALOMON SALOMON is a UV-Visible spectrometer (350 - 700 nm) using the moon as the light source. The instrument is dedicated to the measurement of the vertical distribution O_3 , NO_2 , NO_3 , $OCIO$, ($OBrO?$) and of the extinction coefficient of aerosols. Two SALOMON flights were performed in different geophysical conditions, allowing a comparison of various aspects of the stratospheric polar chemistry to be made.

The first flight of SALOMON occurred from ESRANGE on 23 January 2000, with a launch at 14:38 UT. The observations were performed at the edge of the vortex. For the first time, the observations were performed during a moonrise. Due to temperatures lower than expected, the trajectory of the balloon differed from the one forecast, and the flight was stopped only two hours after the launch for safety reasons. Nevertheless, the flight was a success in terms of technological tests since the pointing system found the Moon immediately at an elevation of -4° (tangent point just above the tropopause). Some observations were conducted and 14 minutes of data were recorded. Preliminary analysis shows that the tangent altitudes of the observations are in the 13-20 km range, which is suitable for $OCIO$ retrieval. By using a Moon reference spectrum obtained during the previous SALOMON flight, the other species can probably be retrieved in this altitude range.

The second flight occurred on 22 February, 2000, between 16:45 and 19:30 UT. The measurements were performed this time outside the polar vortex, with a minimum temperature of 207 K. The totality of a moonrise was observed, leading to vertical profiles of O_3 , NO_2 , NO_3 , $OCIO$, ($OBrO?$) and extinction coefficient of aerosol between 16 and 30 km. Despite strong winds at float (up to 270 km/h), the pointing system operated perfectly, and reached a precision of a few tens of arc second. The landing was in Russia.

Micro-Radibal Micro-Radibal is a balloon-borne instrument developed to study stratospheric aerosols and measures the radiance and polarisation degree of the sunlight scattered by the atmosphere at 730, 865, 1000, 1620 nm. The rotation of the gondola around a vertical axis enables the observations to be made under various scattering angles. The measurements are obtained at several altitudes during the ascent of the balloon.

Micro-Radibal flew on 26 January, 2000. It was launched at 0900 UT from ESRANGE and performed measurements between 13 and 23 km. At many altitudes the measurements show that the layer was very inhomogeneous, so the preliminary analysis has been conducted on radiance scattering diagrams

only. At 22km, the normalised radiance dependence on scattering angle at the four wavelengths shows the inhomogeneity of the layer. The scattering diagrams are characteristic of rather large aerosols (very sharp in the forward direction, with weak spectral variations in this direction). The measured scattering diagrams at two wavelengths are compared with diagrams obtained with a submicron size distribution ($r_m = 0.25 \mu\text{m}$, $\sigma = 0.3$) and with a micron size distribution ($r_m = 1 \mu\text{m}$, $\sigma = 0.3$) for spherical particles. The bad agreement obtained with the first model shows that the aerosols measured are not mean ("classical") aerosols. The agreement is better with the second model, and the aerosol slant optical thickness is rather large: about 1 at 865 nm.

The temperature profiles from the two PTU soundings (at 0458 UT and 0929 UT) indicate values lower than 195 K around 19-25 km, so that the measurements probably correspond to PSC observations, with large particles.

The polarisation measurements are currently analysed and non-spherical particles will be considered in a further analysis.

SAOZ balloon flights 6 flights inside vortex have been successfully launched since the beginning of the winter. 2 flights were also performed from Kiruna when the station was far away from the vortex.

SAOZ provides O_3 , NO_2 and OCIO vertical profiles. SAOZ-BrO, providing BrO and OCIO vertical profiles, was on 3 flights inside the vortex, and on all flights outside vortex. One flight inside the vortex was made in parallel with a HALOZ flight, so that a comparison can be made with the CU resonance-fluorescence instrument. In addition, tracers have been measured during all flights with either DESCARTES or DIRAC instruments (CFC11, CFC113, CCl_4) or TDL instrument (CH_4).

Long-duration balloons The objective of the long duration balloon flights within the THESEO 2000 project Lagrangian was to complement the measurements of 1999 by two new instrumented scientific MIR flights in the vortex as well as an additional technical MIR, all carrying payloads recovered in 1999. The two first MIRs were launched on the same day (18 February, 2000) when the vortex passed rapidly above Kiruna. They lasted for 2 and 18 days, both being automatically cut-down when reaching 55°N . Their payloads were recovered respectively in the Hudson Bay and in Bielarus near

Minsk. The third (technical) balloon failed during the initial ascent and no useful measurements were made.

The vortex into which the balloons flew was one of the deepest and of the largest area ever observed in contrast to the 1999 one which was one of the weakest. As a result of its large latitudinal extension it was very difficult to avoid flying near 55°N and the payloads were cut down for Air Traffic Control reasons.

The scientific data collected include temperature, pressure, altitude and IR radiation measurements every 15 minutes along the two flights, five methane and water vapour profiles, and ten ozone, NO_2 and OCIO profiles half in the morning and half in the evening. They are being currently used, in conjunction with similar measurements carried out throughout the winter with small balloons, for conducting a variety of investigations:

- the evaluation of wind, trajectory and temperature errors in the global meteorological models (GCM) used by Chemistry Transport Models (CTM) for simulating the photochemical ozone loss. Preliminary analyses show that trajectory predictions using ECMWF have been more accurate in 2000 than in previous years;
- the study of mesoscale processes gravity and orographic waves - along the 5 turns of the second balloon around the pole;
- the calculation of cooling rates in the vortex from global IR measurements along the flight tracks and the testing of the amplitude of diabatic sink, particularly large in 2000, by comparison between measured and modelled methane and water-vapour profiles;
- the testing of NO_x and ClO-BrO photochemistry at low temperature from the diurnal variation of NO_2 and OCIO , and finally;
- comparisons of various methods in use for deriving ozone photochemical loss rates.

4.3 Aircraft

ARAT The LEANDRE backscatter lidar on board the ARAT/Fokker 27, flew in evening of 25 January, 2000 in coordination with the second PSC-Analysis gondola. Two flights were performed.

Falcon On the basis of the MM5 forecasts 8 science flights (including 2 transfer flights) of the FALCON lidar have been carried out during the late January/early February deployment of the DC-8 and the ER-2. The flight legs were chosen to be quasi-Lagrangian as referred to the PSC level (about

30/50hPa). During the missions various extended PSCs, either synoptic as well as wave induced, have been measured. On 27 January the FALCON precisely tracked two balloons (HALOZ and TRIPLE), which carried various *in situ* aerosol probes. A diminishing mountain wave PSC was observed, the upper part of which was depolarizing. Its lower, mainly liquid part was sampled by the balloons. The PSC was crossed twice with about half an hour time difference and reduced significantly in its backscatter during this time.

Learjet The microwave radiometer operated by the University of Bern on board the Swiss Learjet provided measurements between 8 March and 14 March, 2000. This instrument recorded spectra of stratospheric water vapour at 183 GHz and ozone at 176 GHz. From these spectra, the vertical distribution of these trace gases can be derived over an altitude range of roughly 20-70 km.

Several flights were performed from Arena Arctica in Kiruna during the last deployment of the NASA ER2 and DC8 aircraft. The main objectives of these flights were:

- measurements of H₂O and O₃ inside and outside the polar vortex;
- correlative measurements with the instruments onboard the two NASA aircraft;
- correlative H₂O and O₃ measurements with the POAM-III satellite;
- measurements of the distribution of H₂O and O₃ over a large latitude range

Several flights were performed from Kiruna to Iceland, from Kiruna to the North Pole, and from Kiruna to the North Atlantic. After the Arctic mission, the plane flew south to the Canary Islands to increase the latitude range of the measurements to the subtropics.

The retrieval of measurements is in progress and first results are expected for summer 2000.

ASUR on board the NASA DC8 The Airborne Submillimeter Radiometer (ASUR) has been used on board the NASA aircraft DC-8 during all three SOLVE missions in the period November 1999 to March 2000. The microwave sensor using a superconducting SIS mixer allows the detection of weak molecular thermal emission lines of key chemical constituents in stratospheric photochemistry like ClO, HCl, HNO₃, ozone and others. ASUR observes at a zenith angle of 78 degrees. Vertical profiles of volume mixing ratios over an altitude range of 15 to 55 km can be retrieved with good hori-

zontal resolution. During the THESEO 2000 / SOLVE campaign ASUR was able to take numerous measurements during all phases of the vortex evolution, such as latitudinal variations of minor constituents, information of the vortex structure and in particular the vortex edge. Also chlorine activation and ClO variations with respect to various sun zenith angles, effects of PSCs and aerosols on the gas phase compounds have been investigated.

Mystère 20 From alerts of polar filaments forecast by the MIMOSA model, four mission flights were performed in Europe by the *Mystère 20*, on 28 February, 7 March, 26 March, and 28 March, 2000. During those flights, ozone measurements by the airborne lidar were made across the filaments, in order to characterise the influence of polar air at mid-latitudes.

4.4 Ground-based activities

THESEO 2000 campaign was supported through the COSE project with coordinated ground-based measurements from lidars, Fourier-transform infrared and UV-VIS (DOAS) spectrometers, microwave radiometers and ozone and backscatter sondes, from the network of mid- and high-latitude European stations (Figure 40). The ozonesondes were often launched in the frame of Match. The data products are columns/profiles of ozone, NO₂, OClO and ClO, ClONO₂, HCl, HF, HNO₃, CO, CH₄, N₂O and HF, and aerosol/PSC.

During winter 1999-2000 all instruments performed regular monitoring activities, with some exceptions, mentioned briefly below. The SAOZ network issued real-time PSC alerts during the whole winter. Bad weather conditions in December over Europe, especially over France, have resulted in fewer than normal observations in the case of weather-sensitive measurement techniques or sites. At Andoya, the UV-Vis instrument was in repair: so O₃ and NO₂ data are missing for the whole winter. At Thule, an instrument upgrade was performed in early winter; the instrument has been operational again since January.

The EMCOR instrument at the Jungfraujoch has been tuned to the ClO line since January 20; the data analysis is still in progress. Before January 20, EMCOR has made simultaneous measurements of H₂O¹⁸ and O₃ profiles. Data concerning ozone loss and chlorine activation have been gathered at several stations, e.g., Harestua (see section 3) and Ny-Ålesund; data analysis and interpretation are ongoing. It is clear that much chlorine activation has taken place this winter.

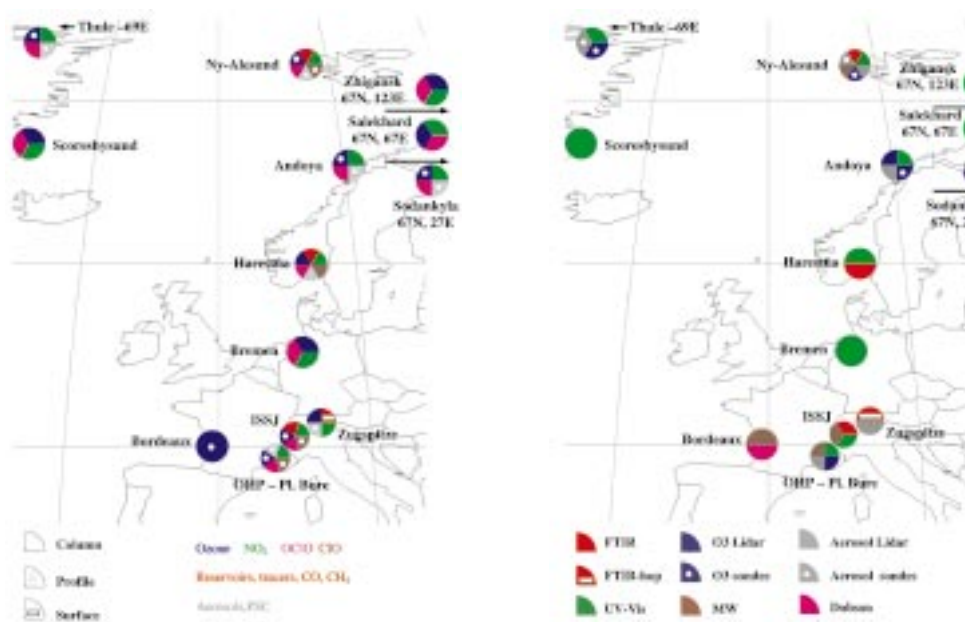


Figure 40: Ground-based stations participating in COSE project during the winter 1999/2000 (courtesy of M. De Mazière).

BrO has been monitored from the ground at Ny-Ålesund, Kiruna, Andoya, Harestua, Bremen and OHP.

Since March 1996 an FTIR instrument is operated in Kiruna in the framework of the Network for Detection of Stratospheric Change (NDSC) by IMK Karlsruhe, IRF Kiruna and the University of Nagoya. In addition to column amounts of several trace gases, profiles of O₃, HF, HCl, HNO₃, NO, N₂O, and CH₄ have been retrieved using the high spectral resolution of the spectrometer.

The mm-wave radiometer MIRA from the Forschungszentrum Karlsruhe, Germany, has been operated almost throughout the entire winter period 1999/2000 in co-operation with the Swedish Institute of Space Physics. Measurements of ClO, O₃, HNO₃, and N₂O have been performed in order to provide a continuous set of data as complementary measurements to the balloon borne instruments and those aboard the research aircraft stationed in Kiruna during SOLVE/THESEO 2000.

The University of Bonn backscatter lidar at ESRANGE (68N) in northern Sweden was operated jointly by teams from University of Bonn and IRF Kiruna from the end of November 1999 to the beginning of February 2000. A total of 106 hours of data were recorded on 19 days with measurement runs lasting from 1/2 hour to 18 hours. Hardware problems in January/February prevented taking more data.

The UV/visible DOAS system of the Institute of Environmental Physics at the University of Heidelberg has been in continuous operation at the Swedish Institute of Space Physics (IRF) in Kiruna since December 1996. Due to reconstruction of the IRF building the instrument had to be moved in late 1999 and, as a consequence, it required some service during the winter. Time series of differential slant columns (the difference of the total column densities at solar zenith angles of 90 and 80 degrees, respectively) of BrO and OCIO have been evaluated, indicating high activation in the beginning of spring. Additionally the presence of PSCs above the instrument during twilight can be inferred by means of the colour index method. The imaging system ALIS, consisting of six remote-controlled stations in the Kiruna region, was also applied for characterisation of PSCs. Due to unfavourable tropospheric cloudiness the results are still unclear.

Horizontally localised temperature perturbations associated with mountain lee waves can induce PSC development under conditions in which the synoptic -temperatures are too warm. The ESRAD, a Mesosphere- Stratosphere-Troposphere (MST) radar situated at SSC ESRANGE (about 30 km NE from Kiruna), is ideally suited for studies of the generation and propagation of such waves. It provides continuous coverage of vertical velocities (above the radar site) with vertical and temporal resolutions of 300 m and a few minutes, respectively, over the altitude interval 1 - (approx.) 15 km.

FTIR solar observations made at the international scientific station of the Jungfraujoch (ISSJ; 46.5°N, 8.0°E) during 46 days between 1 November, 1999, and 22 March, 2000, have allowed to monitor the chemical composition of the atmosphere above the central European continent. The more than 20 atmospheric gases investigated for their vertical column abundances include all important stratospheric reservoirs as well as a large number of source gases.

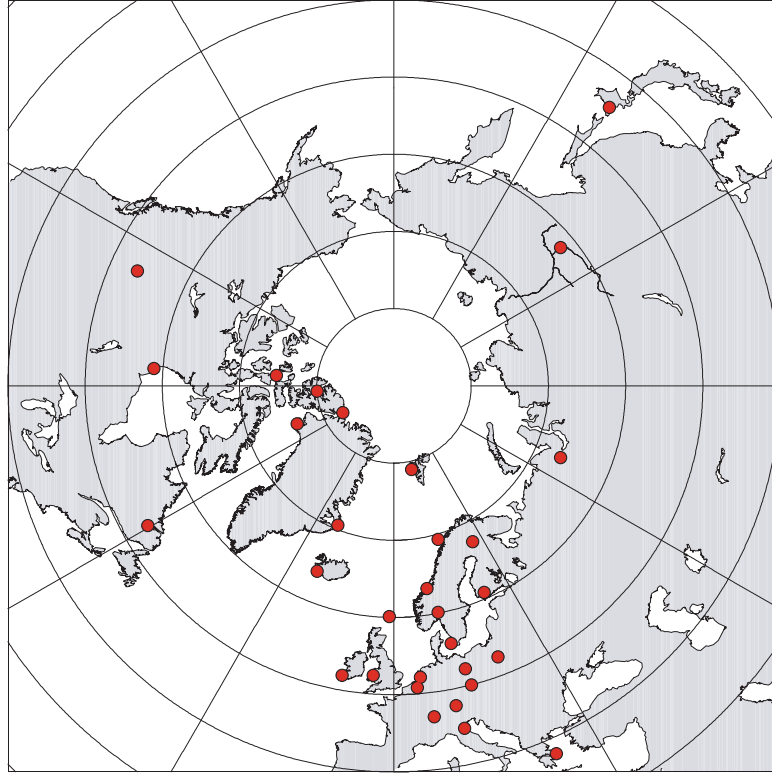


Figure 41: Map of ozonesonde stations (courtesy of M. Rex and P. von der Gathen).

4.5 Ozonesondes

During THESEO 2000, over 650 sondes were launched from a network of 36 stations in 20 countries at mid and high latitudes in the northern hemisphere (Figure 41). Most of these stations were underneath the Arctic vortex at one stage or another and so a high proportion of sondes made measurements inside the Arctic vortex. The sondes were either part of regular programmes or were launched in response to requests within the coordinated Match programme. Over 420 matches have been confirmed and more may be found in post-mission analysis.

4.6 Models

REPROBUS The REPROBUS 3D chemical transport model was run in near real time during the THESEO 2000 campaign. The model includes a comprehensive chemical package on 42 levels from the ground up to 0.1 hPa

(about 65 km). Winds and temperature fields were driven by the new 60-level version of the ECMWF 6-hourly analysis. REPROBUS levels coincide with ECMWF levels in the stratosphere and upper troposphere, and have a reduced vertical resolution near the ground. The horizontal resolution is 2° by 2° . The model was initialised on 1 November, 1999 and the passive ozone was initialised from the model ozone field on 25 November, 1999.

SLIMCAT The SLIMCAT 3-dimensional chemical transport model of the University of Leeds was run in near real time as part of the combined SOLVE / THESEO 2000 campaign. The model uses a detailed stratospheric chemistry scheme over the altitude range from 330 K to 3000 K, corresponding to about 10 to 55km altitude, forced by wind fields from the UKMO UARS analyses. The model was initialized in October 1991 and run with a reduced resolution until 1 November, 1999, when the higher resolution seasonal integration with a horizontal resolution of 2.5° by 3.75° and a vertical resolution of about 2km was started. A more detailed comparison of the model with a large number of observations from the SOLVE and THESEO 2000 campaign is currently being performed.

Mesoscale models The mesoscale MM5 forecasts by DLR run successfully from 1 December to mid-March and provided a very useful daily basis for mission planning. Daily predictions of horizontal section at different stratospheric levels and of vertical cross-sections of the temperature above Northern Scandinavia were made available to all THESEO 2000/SOLVE scientists. For instance, PSC measurements on board the German Falcon were planned in conjunction with the MM5 predictions.

EC projects in THESEO 2000

THESEO 2000 - EuroSOLVE

CASSIS

COSE

GODIVA

Lagrangian

METRO

PSC-Analysis

Stratospheric BrO

THESEO-O3 Loss

TRACAS

WAVE

Related projects:

SKERRIES

HALOZ 2000

and other nationally supported projects and research activities which were closely coordinated within THESEO 2000.

Selected acronyms

ARAT: Avion de Recherche Atmosphérique et de Télédétection

ASUR: Airborne Submillimeter Radiometer

CCN: Cloud Condensation Nuclei

CNES: Centre National D'Etudes Spatiales

CNRS: Centre National de la Recherche Scientifique

CTM: Chemical Transport Model

DLR: Deutsche Forschungsanstalt für Luft und Raumfahrt

DOAS: Differential Optical Absorption Spectrometer

DU: Dobson Unit

EASOE: European Arctic Stratospheric Ozone Experiment

EC: European Commission

ECMWF: European Centre for Medium-Range Weather Forecasts

ESA: European Spatial Agency

ESRAD: ESRANGE Radar

FTIR: Fourier Transform Infra-red (spectrometer)

FU, Berlin: Free University, Berlin

GHz: Gigahertz

GOME: Global Ozone Monitoring Experiment

hPa: HectoPascal

INSU: Institut National des Sciences de l'Univers
IRF: Institute of Space Physics, Sweden
ISSJ: International Scientific Station of Jungfraujoch
K: Kelvin
Km: Kilometre
LEANDRE: Lidar Embarqué pour l'étude des Aérosols et des Nuages, de l'interaction Dynamique-Rayonnement et du cycle de l'Eau
MIR: Montgolfier InfraRed Balloon
NASA: National Aeronautics and Space Administration
NAT: Nitric Acid Trihydrate
NDSC: Network for Detection of Stratospheric Change
NILU: Norwegian Institute for Air Research
nm: nanometre
OLEX: Ozone and Aerosol Lidar on DLR Falcon
POAM: Polar Ozone and Aerosol Measurements
ppbv: part per billion by volume
ppmv: part per million by volume
PSC: Polar Stratospheric Clouds
PV: Potential Vorticity
REPROBUS: French Stratospheric Chemical Transport Model
SAGE: Stratospheric Aerosol and Gas Experiment
SAOZ: Système d'Analyses par Observations Zénithales
SESAME: Second European Stratospheric Arctic and Mid-latitude Experiment
SLIMCAT: UK Stratospheric Chemistry Transport Model
SOLVE: SAGE III Ozone Loss and Validation Experiment
STS: Sulphate Ternary Solution
THESEO 2000: Third European Stratospheric Ozone Experiment 2000
 T_{NAT} : NAT Condensation Temperature
TOMS: Total Ozone Monitoring Spectrometer
UARS: Upper Atmosphere Research Satellite
UKMO: United Kingdom Meteorological Office
UT: Universal Time
VMR: Volume Mixing Ratio
WMO: World Meteorological Organisation