Interhemispheric differences in cirrus properties from anthropogenic emissions

INCA

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PROJECT HOMEPAGE: http://www.pa.op.dlr.de/inca/

CONTENT:

1. Executive summary

Contract n°	EVK2-1999-00039	Reporting period:	Months 1-12
Title	Interhemispheric differences in cirrus properties from anthropogenic emissions		

Objectives:
The INCA project has two overall objectives and these are:

1) Determine the difference in cirrus properties, which are of importance for climate and ozone distribution in the upper troposphere and lower stratosphere, in air masses with low and high aerosol loading.

2) Provide a first set of data of the michrophysical and morphological properties of young cirrus clouds at southern and northern mid-latitudes, in relatively clean and polluted air masses, under otherwise comparable conditions.

Scientific achievements:
The INCA project conducted two experiments during the first year. The first campaign took place from Punta Arenas, Chile. This was the first experiment conducted in the Southern Hemisphere mid-latitudes aimed at studying aerosol and cirrus clouds in-situ. As a result of this being the first experiment of this kind in this region, all the measurements are part of a unique dataset. The goal of the first campaign was to collect data from an environment as pristine as possible to serve as reference to data collected in a more polluted environment. The second campaign took place from Prestwick Scotland close to the European continent and the North Atlantic flight corridor, and down stream of the North American continent. The aerosol properties and trace gas levels show clearly a difference between the two campaigns. As expected the second campaign was performed in an environment much more affected by anthropogenic emissions, both from the surface as well as from aircraft.

The instruments generally worked very well and where comparisons are possible the different measurements show very good consistency. For instance, an excellent correspondence in observed cloud properties using different techniques was observed. The crystal number density observed by the PMS FSSP-300 and the CVI (Counterflow Virtual Impactor) presented an almost perfect match. Derived optical properties from observed crystal size distributions using the 2D-C and FSSP-300 probes match very well with directly measured properties by the Polar nephelometer. The two NOy channels (one for gas phase) and one for gas and particle phase), give identical response outside of clouds.

All the data is now being processed and the task to upload the data to the database have started. When this process is done, the second objective of the INCA project is completed. From the preliminary analysis done so far it is clear that the INCA project can deliver: the first set of data of the michrophysical and morphological properties of young cirrus clouds at southern and northern mid-latitudes, in relatively clean and polluted air masses, under otherwise comparable conditions.

Socio-economic relevance and policy implications:
There are considerable efforts in science to better understand the complex dynamics of the Earth's atmosphere and to improve models to predict future climate trends. These efforts suffer from incomplete knowledge about cirrus properties and the influence of aerosols on them. New insights on the formation and evolution of cirrus clouds might be inferred from the two campaigns performed within the INCA project. Changing the atmospheric composition through anthropogenic emissions from sources at the Earth surface or from air traffic affect many fields of science and society. Hence, the objective of INCA to contrast cirrus properties in clean and polluted environments are relevant with regards to assessments such as: IPCC, WMO and the Second Assessment of Stratospheric Research in Europe.

Conclusions:
There clearly exists a difference in the degree of pollution around the tropopause between the northern and southern hemisphere mid-latitudes. If this difference in air mass properties also translates into differences in the microphysical properties of cirrus remain to be answered in the second phase of INCA.

Keywords:
Cirrus, aerosols, aircraft, emissions, contrails, ozone, climate, tropopause

2. Objectives

The INCA project has two overall scientific objectives which are:

1) Determine the difference in cirrus properties, which are of importance for climate and ozone distribution in the upper troposphere and lower stratosphere, in air masses with low and high aerosol loading.

2) Provide a first set of data of the michrophysical and morphological properties of young cirrus clouds at southern and northern mid-latitudes, in relatively clean and polluted air masses, under otherwise comparable conditions.

The objectives of the reporting period were to prepare for and conduct the two field campaigns in Punta Arenas (Chile) and Prestwick (Scotland), respectively. The two campaigns serve to collect concurrent observations of: trace gase concentrations, aerosol properties, and cirrus cloud properties. To be able to compare the observation from the two campaigns the two experiments were performed at equal relative latitudes, in equivalent season, using the same set of instruments, using the same observation strategy, and conducted within the same year.

To catch the right conditions support for flight planning daily meteorological, chemical and aerosol forecasts from various sources had to be transferred to the campaign sites. The NILU CTM model was modified to be operated fro the SH and aerosol codes where implementation. Automatic transfer of meteorological products (RH, wind, geopotentials satellite images etc.) from DLR was set up through the internet.

The objectives after the successful completion of the two campaigns include the quality control of the data by the different partners and to upload the data to a common database. The different partners also participate in the post-flight data meetings to exchange ideas and new findings.

3. Methodology and scientific achievements related to Work Packages

The work packages of the INCA project and contributing partners is presented in Table 1. Reports of the progress in each of these are given in the sub chapters below.

Table 1. Resource planning according to work package and partner

WP No	Workpackage title	Person months*	Start month	End month	SU	DLR	UBP	LMD	UHEL	NILU
1	Project coordination	14 (10)*	0	24	8	2	2	0	2	0
2	Campaign support	14 (11)	0	12	3	4	3	0	0	4
3	Cloud microphysical properties	39 (30)	0	24	3	7	26	0	3	0
4	Aerosol properties	22 (14)	0	24	10	11	0	0	1	0
5	Residual particle properties	33 (23)	0	24	23	3	6	0	1	0
6	Air mass trace gases	16 (9)	0	24	0	6	0	9	1	0
7	Atmospheric state	12 (6)	0	24	0	7	0	4	1	0
8	Process modelling	13 (11)	12	24	2	2	2	2	4	1
	TOTAL	163 (114)			49	42	39	15	13	5

* Numbers in parenthesis is man-months requested by European Union.

3.1 WP1 Project coordination
Start date: 0
End date: 24
Lead contractor: 1

Project coordination is not a scientific task per see, but helps to achieve the scientific goals and objectives. Already in the beginning of the project much of the practical aspects of coordination was divided among different partners and individuals. The main responsibility, however, lies on Stockholm University that acts as interface towards the European Union and governs that the project proceeds as planed.

The INCA project is a study of the tropopause region in two hemispheres by using an aircraft platform and involves some 30 people from the 5 partners within the project. In addition people from other institutes in the USA, Chile, Argentina and other European member states have been contributing in one way or other to the INCA project. National programs or their own institutes have funded the participation of associated partners. Some of the participants are present in Figure 1.

Figure 1. Part of the INCA team before the Falcon returns from Prestwick to Oberpfaffenhofen.

The aircraft operations and logistics associated with the flight operations were handled by the Flight department and the Atmospheric Physics department at DLR Oberpfaffenhofen. This task is substantial. In preparation to the field campaigns recognisance trips to both field sites (Punta Arenas and Prestwick, see Figure 2) was carried out. Logistical preparations, especially negotiations regarding office space, hangar, and accommodation of the campaign participants needs to be taken care of ahead of the campaign. In addition contacts for local support regarding different requests, ranging from liquid nitrogen to office supplies, was also established. The two bases of the INCA project (Punta Arenas, Chile and Prestwick, Scotland) poses two rather different challenges in terms of operations.

Figure 2. The ferry flights to (via North America) and from Punta Arenas. The two campaign bases are indicated with white arrows (Punta Arenas in the south and Prestwick in the north).

There is very little air traffic around the area of the southern most tip of South America. However, this is politically a very sensitive region and a certain amount of diplomatic activity was necessary in order to get the permissions to fly scientific flights in the area. After a two flights with a Chilean air force official the INCA team had the permission to operate more or less freely in Chile air space. However, the INCA project was never given the permission to enter Argentinean air space. As it turned out this did not affect the measurements. To get spare parts and other equipment quickly from Europe to Patagonia can sometimes be a demanding task. Hence, a lot of the gear had to be shipped by airfreight after the integration phase in Germany. Figure 3 shows pictures from the Integration. More than two metric tons of material (calibration equipment, computers, spare parts, instruments etc.) was sent to Punta Arenas. Thanks to thorough preparations the customs handling etc was trouble-free.

Prestwick, on the other hand, is situated right next to the main flight routes for traffic between Europe and North America. The Air Traffic Control Center (ATC) in Prestwick provided the INCA team with forecasted traffic pattern for use in our flight planning. Hence, a close collaboration with the local ATC was necessary and had to be established in advance of the field phase. During all our flights at least one person from the INCA team was present at the ATC to provide support, both to the ATC as well as a relay link between the INCA operation centre and the aircraft. One other task was to document the radar screen for post flight analysis of emission patterns. The experience of the Atmospheric Physics department at DLR came well into use for these operations.

Figure 3. Left, Integration at Oberpfaffenhofen. Right,INCA payload inside the Falcon.

Very early into the INCA project a web page was established. The web page describes the experiment but also provide a tool for exchange of information. The page was updated on a daily bases during the course of the field campaigns. Mission log, flight log, pictures, preliminary data, links and handy information can be found on the INCA web page. Material for evaluation of the data is also found on this page such as weather charts, satellite images, chemical transport fields, and the data archive is accessible from this address http://www.pa.op.dlr.de/inca/. The web page also provided a social interface to people back home since many of the participants in INCA would stay more than 2 months away from family and friends during the first year. By entering the web page whoever was interested could follow the project. Figure 4 shows the temporary homes of the falcon during the two campaigns.

Figure 4. The Falcon aircraft in the hangars Punta Arenas (left) and Prestwick (right)

During the campaign daily briefings were held, except for a few occasions when flight operations where on hold. The main purpose of these briefings was to update everyone on the weather conditions and coordinate potential missions or other practical issues. In planning of the mission flights a team consisting of representatives from each partner, the project meteorologist, pilots and however in the INCA team that found an interest to participate come together to discuss how to make best use of the flight hours. The decisions were based on a multitude of sources for information, where satellite imagery, weather forecasts, chemical tracer forecast, instrument status, air traffic patterns, represents the main sources of information.

After the missions post flight briefings were held to review the findings and instrument status. Some day or so after the flight, quick plots of the measurements were available for most parameters, which were presented during data meetings. The information and knowledge gained from previous measurements were fed back to the decision making of deployment the aircraft. Table 2 show a summary of the flight activities within the INCA project.

Table 2. Flight activities within the INCA project.

Campaign	Flight activity	Time (hhh:mm)
Punta Arenas, Chile		
	Test flight	1:30
	Transfer to Chile	30:00
	2 technical flights	3:25
	10 mission flights	39:40
	Transfer back	21:50
	First campign total	**96:25**
Prestwick, Scotland		
	Test flight	2:05
	Transfer to Prestwick	2:25
	9 mission flights	30:35
	Transfer back	2:20
	Second campaign total	**37:25**
	INCA project Total	**133:50**

Activities on board the aircraft also need attention. This task has rotated among the different partners. Within the INCA team this occurs seamless. During each flight, one person onboard the aircraft function as mission scientist. This person decides on necessary changes in altitude, heading and flight pattern, which is different from the original plan. During mission planning a general goal of the flight is defined and a flight pattern is proposed. Since actual cloud top and cloud cover can change quickly it is the task of the mission scientist to direct the aircraft for detailed manoeuvres. Since this cause the flight to differ from the filed flight plan, any changes must be approved by the ATC.

The two field phases of INCA are completed and data are becoming available as they are checked for quality and consistency. The original plane was to collect all the data in France. From there it later could be uploaded to the NILU database that has been used in many previous experiments. Meanwhile, the Physics department at DLR has developed an infrastructure for storing data. We chose this option because it was a very practical and much data including aircraft parameters and videos reside at DLR and are readily accessible from the web page. The option to mirror this to the NILU database is still an opportunity once the data is final.

Several meetings have been held to review results to plan future activities. Details on activities or events related to the INCA project is listed in Table 2 below. After the last flight there have been quiet on INCA events but not on the work. Much effort has been devoted to quality control and post-flight calibrations. First analysis of the data is starting to give results in the form of several conference proceedings.

Table 3. INCA events

Date	Event
24-25 Nov., 1999	INCA planning meeting in Oberpfaffenhofen, Germany
27 January, 2000	Contract signed by the EU
1 February	Official start of the project
6 March	Start of integration of payloads on the aircraft
7 March	Chemical forecast available from NILU
9 March	Test Flight
10 March	INCA Kick-off meeting in Oberpfaffenhofen, Germany
13 March	Start of ferry flight to South America
18 March	Aircraft arrives Punta Arenas, Chile
23 March	Technical flight
24 March	First mission flight
3 April	Coordinators meeting in Brussels (Prof. U. Schumann represents INCA)
13 April	Last mission flight in the southern hemisphere #10
16 April	Start of ferry flight back to Europe
20 April	Aircraft arrives Germany
6 June	Presentation of INCA data at AEAP meeting in Snowmass, USA
28-29 June	INCA data meeting in Paris, France
12-14 July	Presentation of INCA data at the A2C3 workshop at Seeheim, Germany
14-18 August	Presentation of.INCA data at the ICCP conference in Reno, USA
14 September	Start of integration of payloads at Oberpfaffenhofen
20 September	Test flight over the Alps for two hours
25 September	The Falcon arrives Prestwick airport
27 September	First mission flight in Prestwick.
9 October	Ad-hock meeting with visits by Dr. Georgios Amanatidis, Prof. Ulrich Schumann, and Prof. Otto Schrems.
12 October	Final INCA missions flown. This was mission flight #9 in the northern hemisphere.
13 October	The Falcon returns to Oberpfaffenhofen

3.2 WP2 Campaign support

Start date: 0
End date: 12
Lead contractor: 6

This work package is the only one that terminates at the time of this report. All the measurements are completed but the information from the campaign support is still useful in the interpretation of the data. Since the INCA project aim to contrast properties in clean and polluted environments, the support tools are very important to characterise the air mass in which the measurements where conducted.

Forecast fields from the ECMWF have been used to characterise the weather development in the experimental area for a period over +84 h. The 6 hourly forecast fields had a spatial horizontal resolution of 0.5° in latitude and longitude. Essentially, the mean sea level pressure, temperature, relative humidity, geopotential height and wind have been displayed on a specially generated web page sat up by DLR for flight planning. GOES and NOAA satellite data have been processed in real time (NOAA). This important tool was of great help in finally determining the flight track for the actual mission depending on the latest information on cloud position and movement. In some cases, especially during the Prestwick campaign, latest information on changes in the cloud forecast have been transmitted to the airborne crew for adjustments of the flight pattern. This was necessary in order to be able to perform a so called Lagranian experiment where the same air mass is probed at two different times with about half a day in between.

The main contribution from NILU in the reporting period has been to deliver daily chemistry and aerosol forecasts from the 3D NILU-CTM during the two field experiment campaigns. The model used for this purpose is driven by meteorological data from a numerical weather prediction model using global meteorological analyses and forecast from ECMWF (European Centre for Medium Range Weather Forecasts) as initial and boundary conditions. The model includes full tropospheric O_3, NO_y, CO and VOC chemistry. The model is self-nesting and can be used on horizontal grid resolutions from 150 to 20 km. In the vertical, 10-30 unequally spaced levels with a model top at 50-100 hPa can be used. Surface emissions are specified for NO_x, CO, VOC and SO_2. The 3D NILU-CTM is documented in Flatøy et al. (1995), Flatøy and Hov (1996a, b) and Flatøy and Hov (1997).

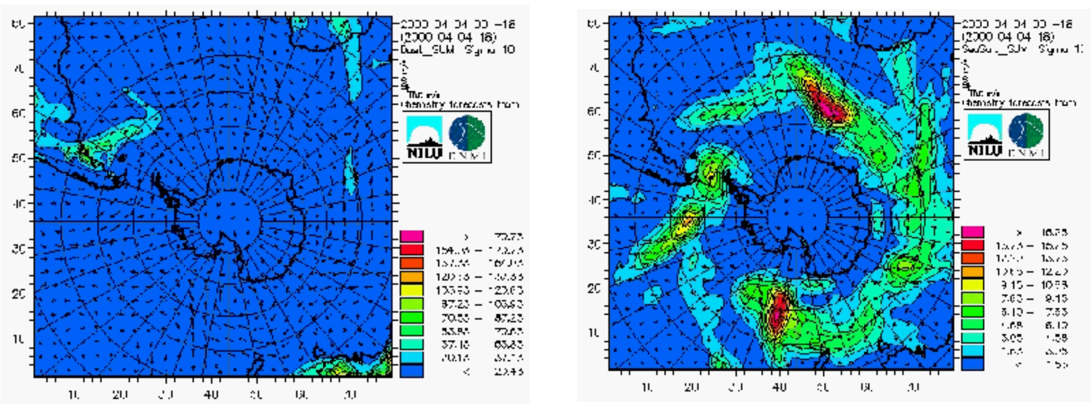

Figure 5. 18 hour forecasts of total dust and sea salt concentration (µg/m^3) at the surface on the SH on 04.04.00. The arrows indicate the wind directions.

The model domain previously covered only the Northern Hemisphere (NH) (30-90°N). During the INCA project a domain was prepared for the areas of interest in the Southern Hemisphere (SH) (30-90°S). For that purpose ECMWF analyses and forecasts of zonal and meridional wind, relative humidity, height of pressure surfaces for the SH were used as input to the model. In addition, information on topography, snow cover, albedo, and surface type was updated on a daily basis, while sea temperature was updated weekly. The 3D NILU-CTM was further improved and extended to also include different types of aerosols. A simple module describing the production, loss and distribution of sea salt and dust particles was made.

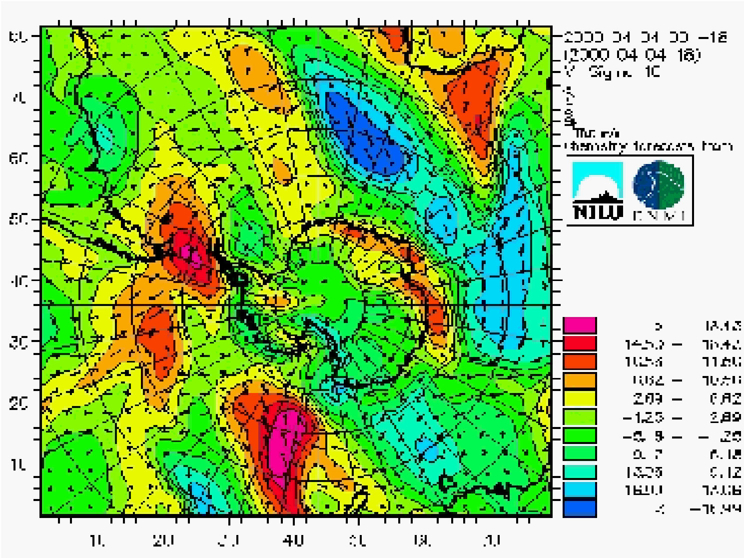

Figure 6. The same as Figure 5, but for zonal wind**.**

Monthly mean global fluxes (kg/m^2/day) of clay and small silt (less than 10 μm) were provided by Dr. Ina Tengen, now at the Max-Planck Institute for Biogeochemistry, Germany. These fluxes are calculated with a global 3-D model of the atmospheric mineral dust cycle (e.g. Tengen and Fung, 1994, 1995) and the estimates are based on surface wind speed, soil water content and vegetation cover. The dust particles are dived into 8 size classes with a radius of 0.1, 0.2, 0.4, 0.8, 1, 2, 4, 8 μm, respectively. Clay and small silt particles were assumed to have radii from 0.1–1 μm and 1–10 μm, respectively, with a lognormal size distribution (Tengen and Fung, 1994).

The concentration and size distribution of sea salt particles in the first model layer were calculated based on the surface wind speed using the empirical relationships

$$
\begin{aligned}
&Q = e^{0.16u+1.45} \quad (u < 15\ m/s),\\
&Q = e^{0.13+1.89} \quad (u < 15\ m/s), \qquad (1)\\
&r = 0.422u + 2.12,
\end{aligned}
$$

where Q is the concentration of sea salt (μg/m^3), u is the surface wind speed and r is the sea salt mass median particle radius (μm) (Tengen et al., 1997, and references therein). In the 3D NILU-CTM the sea salt particles were divided into 8 classes with median particle radii of 2, 2.5, 3.5, 5, 7, 10, 13, 16 μm, respectively.

Both the dust and sea salt particles were lost due to gravitational settling (v) using Stokes law:

$$v = \frac{2pr^2}{9ng}, \quad (2)$$

where *r* is the particle radius (µm), *p* is the particle density, *n* is the air viscosity and *g* is the gravitational acceleration. The density of dust and salt particles are set to 2.65 g cm^{-3} (Tengen and Fung, 1994) and 1.60 g cm^{-3}, respectively.

The loss by rainout (*L_rain*) is described by the scavenging ratio and the precipitation rate.

$$L\_rain = Z \cdot \frac{R}{H},$$

where *Z* is the scavenging ratio, *R* is the precipitation rate and *H* is the height of the vertical layer. The scavenging ratio is an empirical parameter defined as the ratio of species concentration in collected precipitation divided by the air. This ratio was set to 750 for both dust (Tengen and Fung, 1994) and salt particles. The particles are transported according to the wind field.

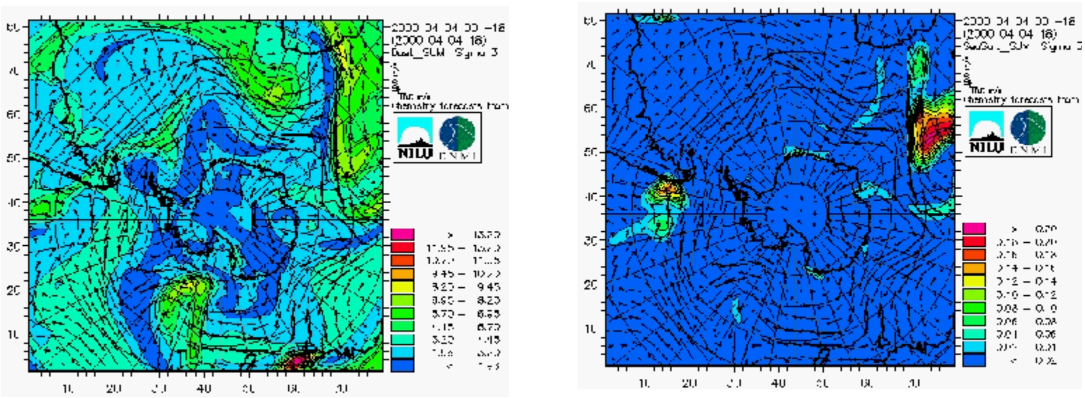

Figure 7. 18 hour forecast of dust and sea salt particles at 8 km height.

For each day during the measurement campaign, 48 hours chemical and aerosol forecasts were estimated for different height levels (up to 14 km). A model with 150 km grid and 10 vertical layers was used, and results from these runs were used as lateral boundary input to a nested simulation using 50 km grid and 18 vertical layers to give more detailed forecasts near the measurement sites in the SH and NH hemispheres. The forecast products were made available via the INCA interactive web page. Such deliverables have been used in earlier measurement campaigns (see e.g. Flatøy et al., 2000). Table 3 lists some of the different forecast products available.

Table 4. Parameters available from the NILU CTM calculations

Meteorology	Chemistry	Aerosols
cloud cover and water content, specific and relative humidity, potential temperature, latent heat production, U, V,Z	O_3, OH, HO_2, H_2O_2, HNO_3, CO, NO_x, NO_y, NMHC, RO_2	Sea salt, Total Dust (clay and small silt) (only available for SH.)

Figures 5a shows an example of forecasted dust and sea salt concentrations at the surface in the SH on 4 April 2000. The dust particles are produced over land surfaces, and the transported according to the wind field. Although the dust flux from the surface is strongly dependent on the surface wind speed (Tengen and Fung, 1994), this is not reflected in the 3D NILU-CTM as monthly mean dust fluxes are used as input. The estimates of the concentration of sea salt particles are, however, directly coupled to the modelled surface wind (eq. 1). The areas with maximum concentration coincide with the strongest surface wind fields (Figure 5b versus Figure 6). Figure 7 shows the forecasted dust and sea salt concentrations at 8 km height. The concentrations of both particle types have decreased due to loss by gravitational settling and possibly by rainout. Since the smallest salt particles radius was set to 2 µm (eq. 1), less salt than dust are transported aloft. The salt particles that reach the upper troposphere also has a shorter lifetime compared to dust particles, and are not transported over large horizontal distances.

3.3 WP3 Cloud microphysical properties

Start date: 0
End date: 24
Lead contractor: 3

The structure in the first of the five observational work packages is common to the partners that contributed to this WP. One experiment in the SH and one in the NH, therefore gives two times as the following:

(i) to prepare the instruments (calibration) before the experiment and to install the instruments with the acquisition systems onboard the Falcon aircraft ;
(ii) to participate to the experiments by operating the instruments during the flights and by performing first data processing on the site in order to check the data consistency, to fix the possible malfunctions, to re-calibrate the instruments and to get first results on the microphysical and optical cirrus properties ;
(iii) to participate on the site to the organisational briefings.

The two campaigns have provided a first set of data of the microphysical and morphological properties of different kind of cirrus clouds at southern and northern mid-latitudes, in relatively clean and polluted air masses under otherwise comparable conditions. A total of 11 (SH) + 10 (NH) flights (including test flights) (or about 80 flight hours) are available for the description of the microphysical properties of cirrus. The reliability of the instruments was excellent. For instance, only one hour of 2D-C data is missing during one SH experiment flight and the 2D-C data are missing during one SH experiment flight. The instruments used to characterise the microphysical properties of cirrus are listed in Table 4.

Table 5. Instruments used to characterise cirrus microphysical properties.

Instrument	Measurement	Range	Location
PMS-PCASP	Particle size distribution	0.12-3.5 µm	Wing mount
PMS-FSSP-300	Particle size distribution	0.3-30 µm	Wing mount
PMS-2DC	Particle size/habit distribution	25-800 µm	Wing mount
Polar nephelometer	Scattering phase function	1-800 µm	Wing mount
Hygrometer	Cloud water content	< ca 60 mg m^{-3}	CVI probe

INCA data permit the determination of cloud element number and bulk densities by various independent techniques: CVI (operated by partner 1), FSSP-300 (partner 2), 2D-C and Polar Nephelometer (partner 3). The combination of these three techniques provides a full description of particles within a diameter range from a few micrometers (typically 3 µm) to 800 µm. Because of the presence of small ice crystals in cirrus clouds, it is particularly important to overcome the limited accuracy of the sensors used in the experiments for cloud microphysical measurements. This has been the first objective within the strategy of data processing and interpretation.

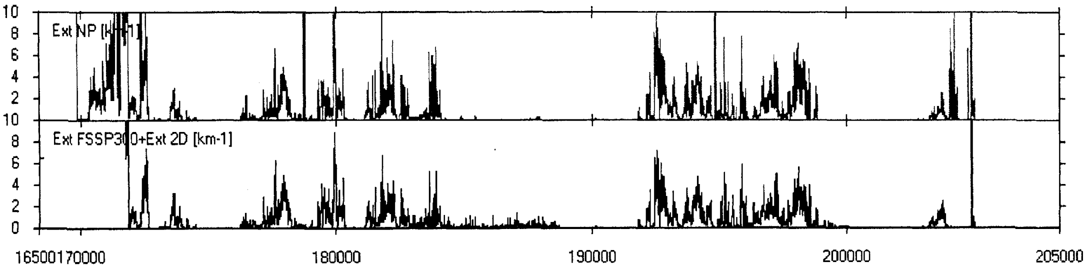

Figure 8. Comparison between the measured extinction coefficient by the Polar nephelometer and the inferred extinction coefficient based on crystal size distributions measured by the FSSP-300 and 2d-c probes.

The CVI calculates the cloud element number density from the number density of measured residual particles. These measurements assume that there is a one to one relation between the residual particles and ice crystals. The measurements may be affect by break-up and other sampling problems that would results in an over- or underestimation of cloud elements. The ice water content (for IWC lower than about 60 mg m^{-3}) is directly measured using a Lyman-α detector fitted into the CVI probe. The evaporated water from the cloud particles is measured as water vapour. Deviations from the one-to-one ratio between the number of residual particles and ice crystals do not affect this measurement.

Optical particle spectrometers cover the size range from below 1 µm to 20 µm (PCASP and FSSP-300) and up to 800 µm (Polar Nephelometer) whereas the 2D-C probe provides additional information on particle size and shape for the size range 25 – 800 µm. The FSSP-300 size-bin limits larger than 3 µm are assumed to be ice crystals with a refractive index n = 1.33. Coincidence effects on particle sizing have not been taken into account on FSSP-300 data processing because these effects are hypothesised to not significantly affect the ice crystal size spectra. The 2D-C data have been processed by using an analysis technique that assumes an empirical crystal mass-size relationship. As for the Polar Nephelometer data, non-absorbing ice particles are assumed in deriving bulk quantities. To clean from optical and electronic noise occurring on the 2D-C and Polar Nephelometer measurements, a specialised and robust software was developed. Inherent probe problems and data processing shortcomings limit the accuracy on derived microphysical parameters from a single instrument. Therefore, a combination of all available measurements in terms of spectral and bulk properties should reduce the uncertainties considerably.

The systematic comparison of the optical properties in cirrus measured by the Polar nephelometer and the calculated properties based on the size distribution measured by the PMS-2D and FSSP-300 probes presents an almost perfect fit. An example is presented in Figure 8. Furthermore, integral values for the PMS-FSSP-300 for particles larger than 3 µm compares well with the crystal number density inferred by the CVI. These first results confirm the reliability of the measurements and provide a robust founding for interpretation of the observations from the two campaigns. An example is presented in Figure 9.

From the intercomparison study mentioned above, proofs and quantitative values have been obtained about the number density of small ice crystals in cirrus clouds, which is much larger than expected up to now from most previous experiments. Numerous small particles are present in cirrus even in very moderate updraft velocities. This has implications for the modelling of the formation and evolution of cirrus clouds since models simulating the INCA cases should arrive to a similar crystal number density.

The database now consists of observations that cover many different types of cirrus cloud situations including frontal-, wave-, jet-stream-, sub-visible cirrus as well as cirrus clouds well above the tropopause. The cloud top temperature range from roughly -35°C to – 60°C.

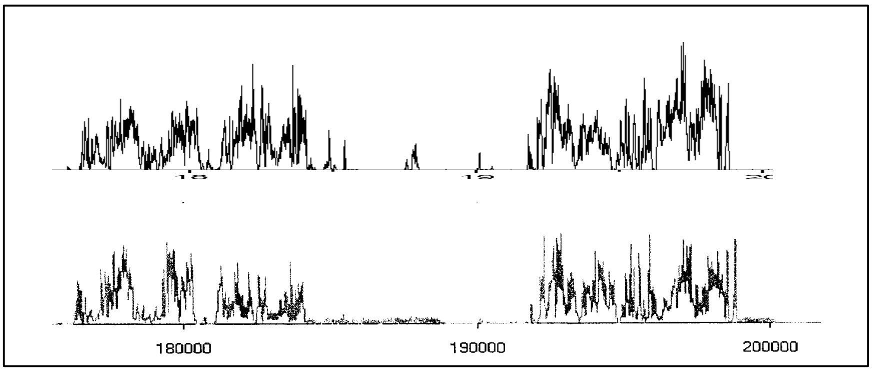

Figure 9. Comparison between the crystal number density measured by the FSSP-300 (upper dataset) and the crystal number density inferred from the number of crystal residual particles measured by the CVI probe (lower dataset).

Comparing the extinction coefficient measured by the Polar Nephelometer and the calculated extinction coefficient inferred from size distributions by the PMS FSSP-300 and the PMS 2D-C probes show that small ice crystals need to be included in the calculation in order to explain the observed optical properties of cirrus clouds.

The interpretation of the asymmetry parameter derived from the Polar Nephelometer show that in both hemispheres no evidence of liquid water below –34°C was observed. For the first time, the scattering phase function obtained by the Polar Nephelometer has been measured at small forward scattering angles (down to 4°). This means that the derivation of optical parameters (asymmetry factor, extinction coefficient, etc) will be noticeably improved with the inversion technique to retrieve the microphysical parameters in ice clouds (ice particle concentration, effective diameter, etc.).

The cirrus cloud microphysical parameters inferred from the CVI, FSSP-300, Polar Nephelometer and 2D-C probes and collected during the first experiment in South Hemisphere have been merged (under the responsibility of each partner) into the INCA data archive hosted by DLR.

3.4 WP4 Aerosol properties
Start date: 0
End date: 24
Lead contractor: 2

To fully cover the relevant size range of ambient aerosol in the tropopause region, a number of instruments working on different physical principles are needed. These instruments consist of different models of condensation particle counters (CPCs), optical particle counters (OPC, PCASP) and a differential mobility particle sizer (DMPS). Two CPCs were set-up with heated thermodenuder inlet lines to derive information on the chemical nature (thermal stability) of aerosol particles. The instrumentation used to characterise the aerosol are listed in Table 5.

In advance to the SH and NH measurement campaigns, several of these instruments had to be adapted for operation at high altitudes (meaning low ambient sample pressure) in a pressurized aircraft cabin, in particular the CPCs. The inlet of the PCASP-100X probe was specially modified to prevent sampling problems from impacting cirrus ice-particles. In addition to the originally planned instrument package an ultrafine condensation particle counter (a commercial TSI Inc. Model 3025A CPC) was added and modified for aircraft use, thus providing an instrument capable of detecting events of newly formed particles.

Table 6. Falcon instrumentation for interstitial/out-of-cloud aerosol

Instrument	Sample inlet	Measurement, particle diameter range	Instrument operated				Project partner in charge
			Ferry flights OP-PA	Punta Arenas flights	Ferry flights PA-OP	Prest-wick flights	
CPC, 3 nm	Aerosol probe	Ultrafine aerosol, >3 nm		(✓)	✓	✓	DLR-IPA
CPC, 5 nm	Aerosol probe	Aerosol number density, >5 nm		✓	✓	✓	DLR-IPA
CPC, 6 nm	CVI probe as aerosol probe	Aerosol number density, >6 nm	✓				SU-ITM
CPC, 14 nm	Aerosol probe	Aerosol number density, >14 nm		✓	✓	✓	DLR-IPA
CPC, 10 nm (125 °C inlet)	Aerosol probe	Aerosol volatility		✓	✓	✓	DLR-IPA/ SU-ITM
CPC, 10 nm (255 °C inlet)	Aerosol probe	Aerosol volatility		✓	✓	✓	DLR-IPA
DMPS-cvi	CVI probe as aerosol probe	Size distribution, >20 nm, <0.15 µm	✓				SU-ITM
DMPS-int	Interstitial probe	Size distribution, >20 nm, <0.15 µm	✓	✓		✓	SU-ITM
PCASP-100X	Wing mount	Size distribution, >0.12 µm, <1.0 µm		✓		✓	DLR-IPA
OPC	CVI probe as aerosol probe	Size distribution, >0.12 µm, <3.0 µm	✓				SU-ITM
Filter samples	Aerosol probe	Aerosol samples for chemical analysis		✓	✓	✓	DLR-IPA
PSAP	Aerosol probe	Absorption (soot concentration)		✓	✓	✓	DLR-IPA

The integration of all instruments into the Falcon aircraft, in particular the set-up of the sampling probes, the sample flow system and the data acquisition systems have been successfully completed during tests in Oberpfaffenhofen prior to both campaigns. For all mission flights from Punta Arenas (SH) and Prestwick (NH) there were no major instrument problems reported. For the ferry flights from Oberpfaffenhofen to South America and back only a reduced instrument set could be operated due to weight restrictions for the Falcon's payload (see table above). A detailed overview of the instruments status of each flight can be found on the INCA homepage through the internet at http://www.pa.op.dlr.de/inca/data/INCAda-InstrumentStatus.html.

Processing of data takes place in various stages. At campaign level all raw data are processed to quickly derive preliminary atmospheric aerosol concentrations and enable a first graphical visualization of data (so-called quick-looks, see Figure 10 as an example). Quicklooks of all relevant measurement parameters of each flight mission have been exchanged among the project partners.

Further post-campaign processing of the aerosol data (at SU-ITM and DLR-IPA) includes concentration re-calculations using updated atmospheric state data (WP 7), co-incidence and sample-line loss correction of CPC data, processing of size distribution calibrations, careful data validation etc. Processing of data of the Punta Arenas campaign and the ferry flights from Oberpfaffenhofen to Punta Arenas and back has been nearly completed within the first project year. These data have been converted to a standard exchange format and added to the INCA data archive (see the web page at http://www.pa.op.dlr.de/inca/data/), where all INCA partners have access to the data.

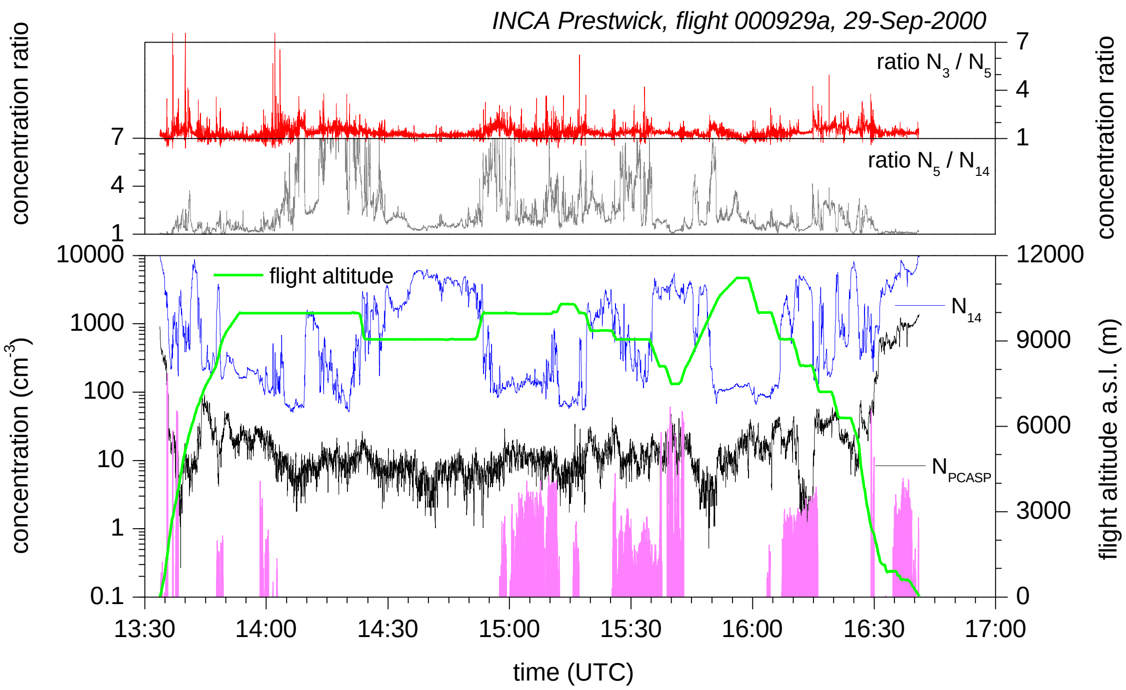

Figure 10. Quick-look example for a Falcon mission flight. Lower panel: condensation particle concentration (N_{14} , upper curve), accumulation mode aerosol concentration (N_{PCASP} , lower curve) and flight altitude (thick line). Upper panel: Ratio of condensation particle concentrations at different lower cut-off sizes, with high values representing events of new particle formation.

The method to determine the volatility of aerosol particles by coupling CPCs with thermodenuder inlets worked well. From the comparison of the different channels, one unheated, one at 125 °C and one at 255 °C, the relative fractions of volatile (sulfuric acid like aerosol), semi-volatile (ammonium sulfate like) and non-volatile (mineral dust, soot, etc. like aerosol were derived.

Chemical analysis of filter samples has started in collaboration with the Technical University of Munich, Institute of Hydrochemistry (Dr. Ulrich Poeschl). The filter samples taken exclusively in the upper troposphere show the expected very low aerosol load. Therefore, the only feasible means of chemical analysis within the INCA project is single-particle elemental analysis. First analysis of samples with a scanning electron microscope equipped with an energy-dispersive X-ray detector (SEM/EDX) were very promising. For the SH it appears that mineral dust and possibly salt particles are fairly frequent while soot particles have not been detected in the samples analysed so far. However, from the first filters analysed, the low particle loading indicate that to complete the work will consume the whole project time.

Aerosol data analysis so far has concentrated on the characterization of differences in mean aerosol concentration levels between both hemispheres. Data were fed into a relational data base framework to allow the application of sophisticated selection criteria for statistical analysis of data. By means of including air mass tracer's ozone and carbon monoxide (WP 6), cloud element concentrations (WP 3) and atmospheric state data (WP 7) into the relational database, a first sub-set of background aerosol data for cloud-free, upper tropospheric air was obtained. The gradient in trace gas concentration and aerosol number densities are shown in Figure 11.

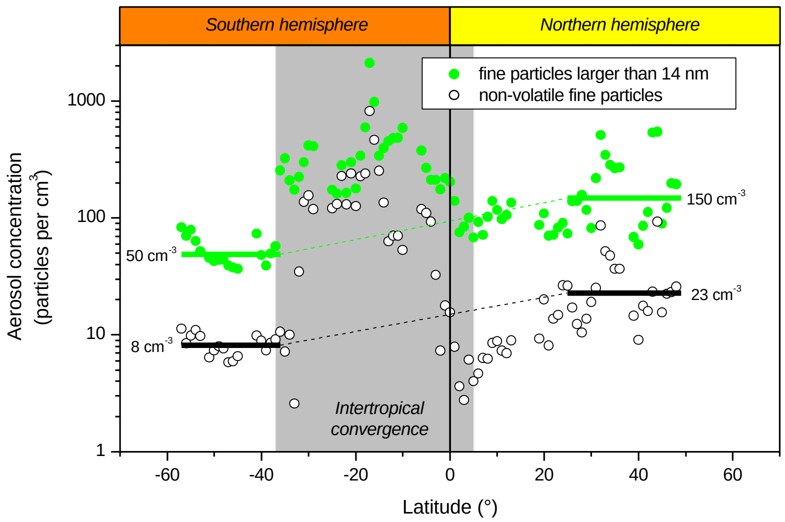

Figure 11. Meridional concentration distribution of fine particles and trace gas species in the upper troposphere. The latter data were obtained within WP 6. Data points are based on averages over one degree of latitude. The figure is a composite picture using data from Punta Arenas and Prestwick mission flights as well as ferry flights from Punta Arenas back to Oberpfaffenhofen. Data are for out-of-cloud situations and altitudes higher than 8000 m.

3.5 WP5 Residual particle properties
Start date: 0
End date: 24
Lead contractor: 1

The main tool to study the residual particles (particles remaining after evaporating the ice) is the Counter flow Virtual Impactor (CVI) operated by partner 1. With this device the cloud elements are separated from the ambient air into a dry and particle free carrier gas. The evaporated water from the crystals is measured by a Lyman-alpha hygrometer, which gives a direct measure of the cloud water content. This particular parameter is part of the WP3 Cloud microphysical properties.

After the water of the crystal has evaporated a small particle remain. This particle has most likely something to do with the particles on which the crystal originally formed. There are three main properties of this residual particle that we strive to achieve: determine their number density, size, and chemical character.

Downstream the CVI a number of different sensors are coupled to the inlet. To count the particles a condensation particle counter (CPC) is used, which register particles larger than about 10nm in diameter. For particles larger than about 100nm diameter a laser spectrometer optical particle counter (OPC) is used. This device registers particles in 32 size classes to a size of about 3.5 µm diameter once every second. The size range between 10 nm and 100 nm is a difficult range in aerosol measurements. The particles are not optically very active. One method that was used for the first time in this configuration was an airborne differential mobility sizer (DMPS). The instrument as was operated on the Falcon aircraft delivers a size distribution between 25 and 125 nm in diameter, which gives some overlap with the OPC instrument. This device is very good to use in this particle size range, but the drawback is that it takes one minute to complete one size distribution.

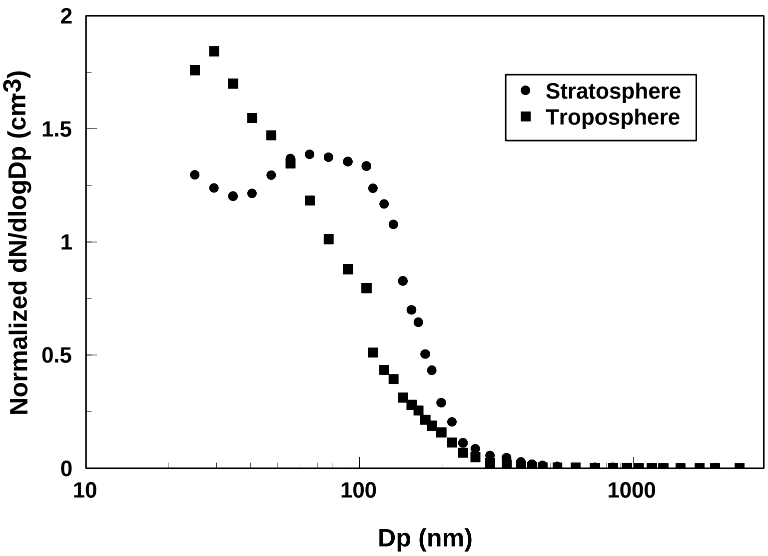

Figure 12. Size distributions of crystal residual aerosol particles. Filled circles represent observations from cirrus clouds located above the tropopause, Filled squares represents observations of cirrus clouds located below the tropopause. Both data sets have been normalized to the integral number in order to compare their shapes.

A lot of work has been put in, and is still to come, to interpret these data. Some preliminary results are presented in Figure 12. The figure presents two different size distributions of residual particles. The data labelled Stratosphere, represents observations of residual particles from cirrus crystals above the tropopause. The data labelled Troposphere subsequently represents residual size distributions below the tropopause. Figure 12 clearly show that the residual particles from crystals in the stratosphere are larger than found in cirrus clouds in the troposphere. This is also true for the part of the distribution that is not visible in the linear presentation of Figure 12. There are several possible reasons for this and more analysis are needed. However, the fact that the ambient aerosol is different above and below the tropopause is of course an important factor.

Comparing the number density of residual particles and the number density of ambient aerosols, the fraction of redidual particles become very small. Typically, this fraction is about 1 %. From Figure 12 it is also clear that residual particles smaller than about 100nm are most frequent. The fact that the integral number of residual particles show an excellent agreement with the crystal number density measured by other probes (WP3), dismiss the fear that the measurements by the CVI should be significantly affected by sampling problems such as break-up of crystals. Since numerical models do not predicted small aerosol particles to have a major influence on cirrus formation, the big question remains to explain this discrepancy.

To chemically characterize the particles several methods are used. The primary method is filter samples. Typically 3 to 6 samples were collected per flight. These filters are at the time not analysed and wait further processing. The information expected from these samples is the elemental composition for residual particles larger than about 200 nm diameter. These results are also to be compared to samples taken of the ambient aerosol see WP4 Aerosol properties.

Figure 13. A picture of a complex cloud field taken from the Falcon during one of the missions.

The other method is the use of thermal denuders. The sample air from the CVI is heated to 125 and 255 C, respectively, before sent to two CPC's (one for each temperature). Particles thermally unstable at these temperatures shrink or evaporate completely. The most volatile disappear at the lower temperature and the least volatile remain even after heating to the highest temperature. By comparing these measurements with those done for the ambient aerosol a comparison of properties between particles incorporated into the crystals and those that remained as interstitial (See WP4 and observations by DLR). Assumption on the material having thermal properties given the temperature threshold one might speculate if cirrus forms preferentially on particles of certain properties.

Finally, the light absorption of residual particles are performed using a custom built Soot photometer. Given the assumptions about the optical properties of soot, the equivalent mass concentration of soot in the residual particles can be inferred.

3.6 WP6 Air mass trace gases

Start date: 0
End date: 24
Lead contractor: 4

The set of instruments installed in the Falcon aircraft and devoted to the observations of trace gases is composed of an Ozone monitor, a CO analyser and a NO/NOy analyser implemented by DLR, and of a hygrometer implemented by LMD. All these instruments operate in-situ using gas phase inlets.

These instruments performed well during all Falcon aircraft flights, so that an extensive data set has been obtained for both campaigns. In addition, the DLR trace gases instruments were operated during the ferry flights between Oberpfafenhoffen and Punta Arenas, and between Oberpfaffenhofen and Prestwick.

Contribution from DLR

Total reactive nitrogen (NO_y) was measured via conversion of its single components to NO within a heated gold tube under addition of a reducing agent and subsequent detection of NO by chemiluminescence. Ozone (O_3) was measured by a fast response UV absorption photometer. Measurements of CO were made with a fast response resonance fluorescence instrument. Particle NO_y was inferred from NO_y signals of sample air passed simultaneously through forward and aft-facing inlets. All these instruments have been already operated successfully during previous European and national funded measuring campaigns on board of the Falcon. Most of the data have been obtained at constant flight levels at the upper troposphere. During several flights, however, measurements were also performed in the lowermost stratosphere.

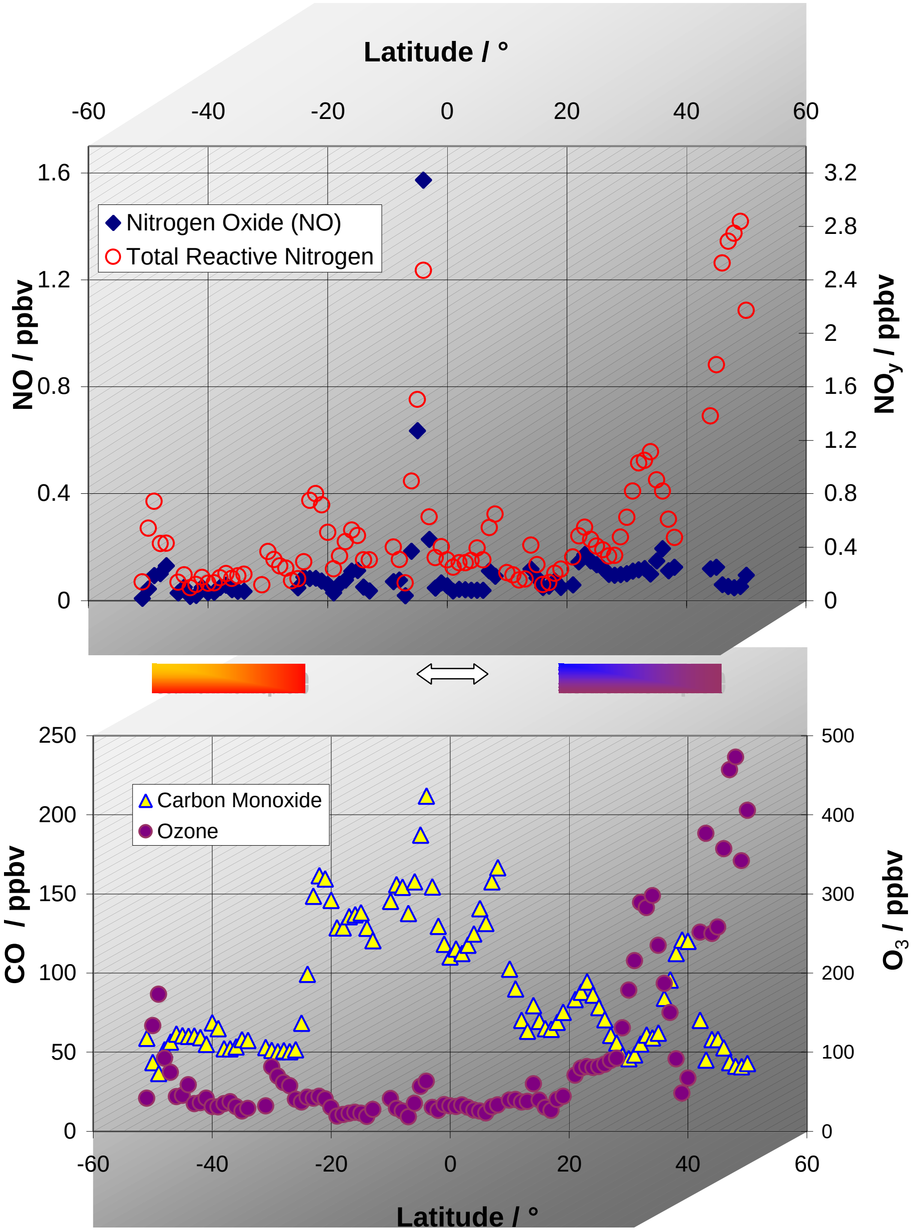

Figure 14. Observed NO_y and CO volume mixing ratios in the upper troposphere and lowermost stratosphere between 50°N and 53°S observed during the ferry flights between Oberpfaffenhofen / Germany and Punta Arenas / Chile. The data were averaged over latitude intervals of 1°.

Altitude profiles of these trace gases were obtained during ascents and descents. The observed trace gas concentrations reveal that during the two campaigns air masses with very low pollution level as well as with high pollution level were encountered associated with NO_y background concentrations between a few tens of pptv and about 2 ppbv. Indications were also found from the trace gas measurements for air masses influenced by air traffic, convective transport from the boundary layer, and lighting activity, respectively.

A first inspection of the trace gas data reveal that the average volume mixing ratios observed in the upper troposphere during the INCA – Prestwick campaign exceed the observed mean concentrations observed at Punta Arenas. Average NO and NO_y concentrations measured at Prestwick are larger by about a factor of 3 – 4 than concentrations observed at Punta Arenas. The observed ozone at northern midlatitudes exceeds the volume mixing ratio at southern midlatitudes by a factor of about 2. Trace gas profiles observed in September and October 2000 at Prestwick compare quite well with concentrations found in this region during previous campaigns like POLINAT 1 and 2 (1994 – 1997). The low trace gas concentrations observed over southern Chile confirm the absence of major anthropogenic pollution at that time and in that region.

During the ferry flights between Oberpfaffenhofen and Punta Arenas NO, NO_y, CO and O_3 were observed at the upper troposphere and lowermost stratosphere. Additionally vertical profiles were obtained during ascents and descents. The meridional distribution of NO/NO_y and $CO/\ O_3$ is shown in Figure 14. NO_y and CO, respectively, show significantly higher values at northern midlatitudes than they do at southern midlatitudes. High concentration levels have also been observed within the inner tropical convergence zone indicating rapid transport of trace species from the boundary layer to the upper troposphere.

The uptake of NO_y by cirrus cloud elements was studied for a variety of ambient conditions (temperature, altitude, surface area) at Punta Arenas and Prestwick. It was found that in general only a few percent of the available gas phase total reactive nitrogen was adsorbed on cirrus particle surfaces.

Contribution from LMD

Water vapor mixing ratio is measured by a frost-point hygrometer, associated to an air pressure sensor. This instrument has been already used on the Falcon aircraft during the POLINAT (POLlution from Aircraft IN the North ATlantic flight corridor) European campaigns. The relative humidity is determined by using the air temperature data provided by the standard instrumentation on board the Falcon (from WP7).

For each flight all the parameters describing the humidity of the environment are given: they are mixing ratio, frost-point temperature, relative humidity with respect to ice RHi, and relative humidity with respect to liquid water RHw. Though the cirrus are ice clouds, the relative humidity with respect to liquid water has been calculated, as it is general agreement that homogeneous ice nucleation occurs in the range 0C to – 40C when the ambient air reaches liquid saturation.

A large variety of meteorological conditions have been encountered during the flights, and the cirrus clouds have been investigated in a large range of water vapour mixing ratio for the two campaigns, from "dry" layers (though ice saturated) at around 40 ppmv, to very humid layers up to 2000 ppmv. As well, most of the time the cirrus are found to be ice supersaturated, though the southern hemisphere cirrus have a higher frequency of high supersaturation, as pointed out in the report from the WP7.

Two examples of the characteristics of the humidity of the investigated air masses during two flights of the Punta Arenas campaign are displayed on Figure 15, showing two very different situations.

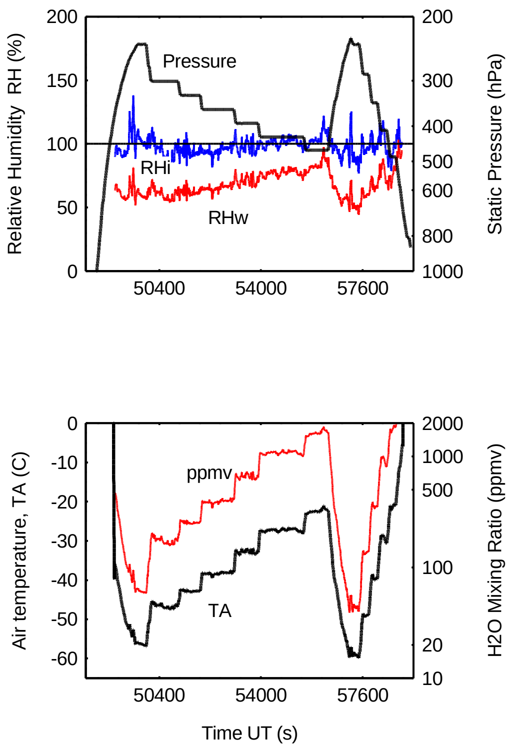

Fig. 15a
Flight 000331a

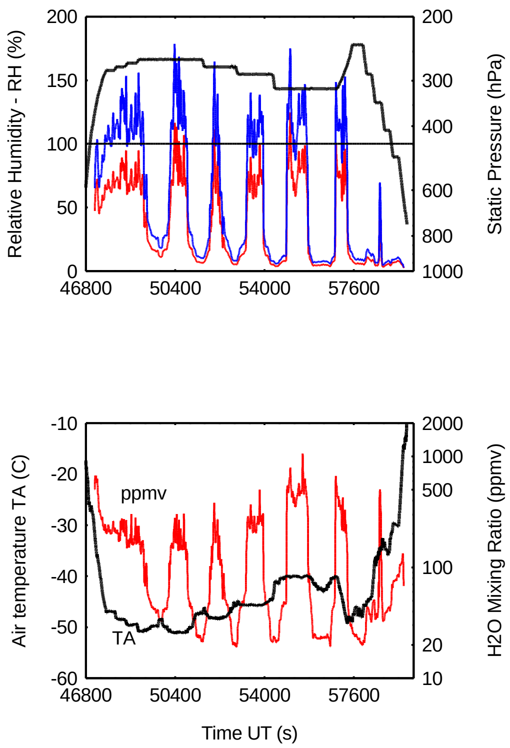

Fig. 15b
Flight 000412

Figure 15. Two examples of characterisation of the water vapour content and relative humidity of the investigated air masses along the aircraft flight level:
a) left upper and lower panels, show a case of observation inside a thick well established cirrus, on 31 March 2000, as RHi remains very stable around 100% from the upper to the lower level of the cirrus (from about 9.5 to km to 6 km altitude).
b) right upper and lower panel, large variations of mixing ratio and relative humidity are measured, from very dry to very humid air, showing a sharp cloud edge. That cirrus was connected to the jet stream, and close to a stratospheric air mass wit a descent of dry air. This subsidence of stratospheric air is also seen on the data from DLR trace gases measurements. Contrary to the case of figure 15a, a lot of perturbations in the humidity are observed, with high peaks of supersaturation even exceeding sometimes water saturation, showing that there was much vertical mixing (RH is smoothed on 1 minute average on that picture).

The combined information from the trace gas measurements give a very clear picture about the sampling conditions in terms of the air mass property. Cirrus clouds often occur close to the tropopause, hence it is important to know how much the cloudy air is influenced by the stratosphere. Moreover, the combined picture from the observations of trace gases give a good signature for the level of pollution of the air mass. This is a key parameter in trying to assess the role of anthropohgenic emissions on cirrus cloudiness.

3.7 WP7 Atmospheric state
Start date: 0
End date: 24
Lead contractor: 2

The atmospheric state data are collected in flight with up to 100 Hz frequency, the parameters include temperature, atmospheric pressure, humidity, wind components, aircraft position, speed, and altitude. The appertaining sensors are part of the basic and permanently installed instrumentation of the Falcon. After the flights these data are processed and preliminary data sets are available for the other groups typically a few hours after landing.

In cooperation with colleagues from NASA Langley the flight track of the individual missions was overlaid to satellite pictures taken during the mission period. These quite impressive presentations appeared to be a valuable tool for the interpretation of flight data. An example is given below. In addition a video camera installed in the cockpit provides a visual documentation for every flight, which has been shown in the past to be very helpful in identifying specific features like cloud edges.

The basic instrumentation of the Falcon worked without any failure during both field campaigns. All data, including also the ferry flights, are available both in numerical and in graphical format from the INCA homepage (http://www.pa.op.dlr.de/inca/, see „Falcon Flight Data“ on the individual campaign sites or the „Data Archive“ section. Falcon humidity data need to be used with due allowance. The basic humidity instrumentation is not able to resolve atmospheric humidity at the trace gas level prevailing at altitudes higher than about 7 kilometers. The status of the three humidity sensors included in the basic package is reported together with the data and an indication on the data quality.

On account of the high importance of reliable humidity data, water vapour mixing ratio is measured by a frost-point hygrometer, associated to an air pressure sensor. The Relative Humidity is determined by using the air temperature data provided by the standard instrumentation on board the Falcon. A pressure correction is applied to retrieve the frost-point temperature of the outside, using the static pressure data from the Falcon aircraft.

For each flight all the parameters describing the humidity of the environment are given: they are mixing ratio, frost-point temperature, relative humidity with respect to ice RHi, and relative humidity with respect to liquid water RHw. Though the cirrus are ice clouds, the relative humidity with respect to liquid water has been calculated, as it is general agreement that homogeneous ice nucleation occurs in the range 0C to – 40C when the ambient air reaches liquid saturation.

Below –40C, homogeneous nucleation occurs at lower relative humidity than the water saturation level, but at high level of ice supersaturation. This level has been discussed from previous aircraft experiments by Heymsfield and Milosevitch (1995) and has been recently established by Koop et al (2000).

There are many formulas used for the determination of the saturation vapour pressure necessary for the calculation of the relative humidity. As few, but some measurements of water supersaturation occurred during both INCA campaigns, particular attention has been made to this calculation, and the relative humidity has been calculated by use of two different formulas, the so called WMO and Sonntag formulations (Sonntag, 1998). The difference in the calculation from the two formulas is negligible for the determination of RHi, but becomes significant for RHw below –40C, exactly when it is considered that supercooled water droplets cannot exist. RHw from Sonntag formula becomes lower than RHw from WMO by about 1.5 % of RHw around –50C and by 2.5% of RHw around –60C. Note that, until now, these uncertainties were not considered besides the high uncertainties of the available water vapour instruments at low temperatures.

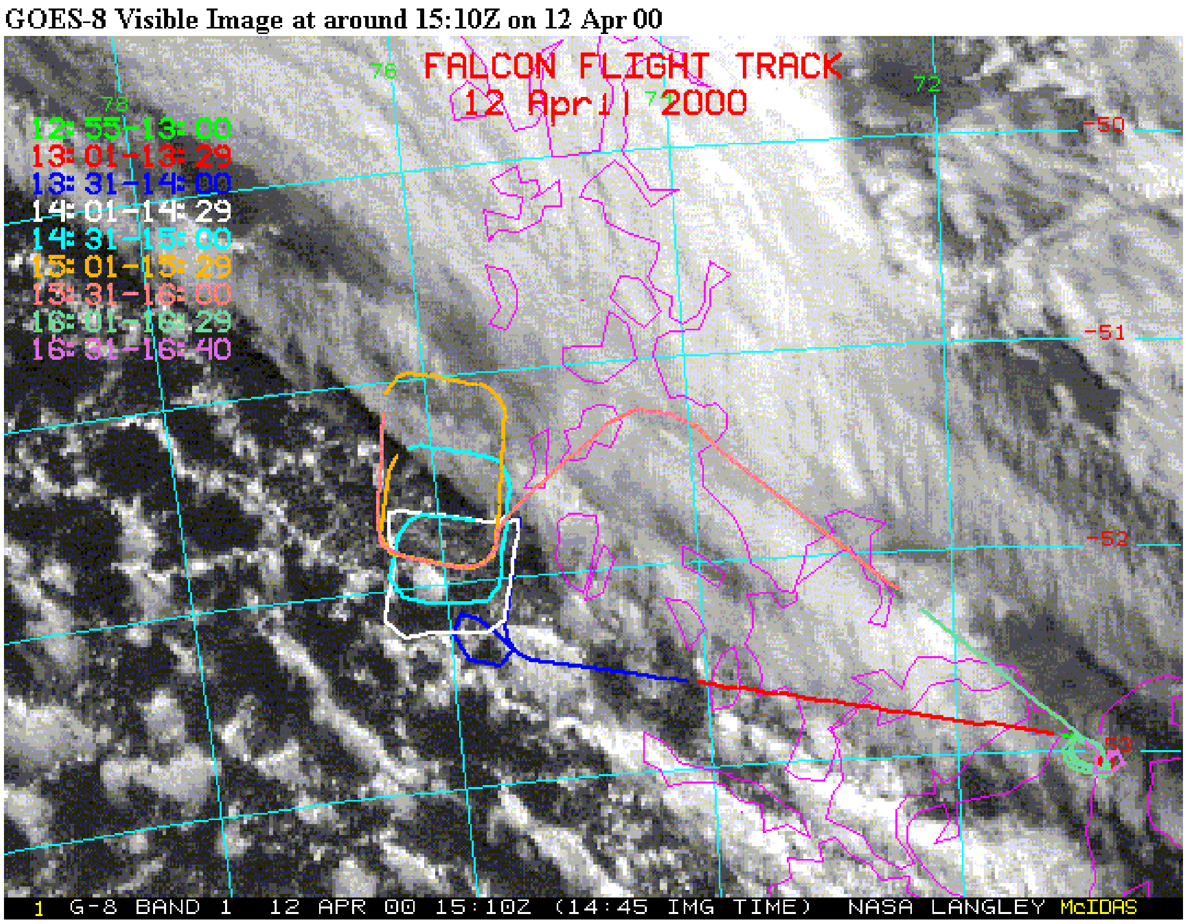

Figure 16. Falcon flight track on April 12, 2000, together with the GOES-8 satellite image taken at about the middle of the mission.

A graph of the relative humidity with respect to ice, RHi, as function of the air temperature is shown in Figure 17, for all the flights of the Punta Arenas campaign together, for the supersaturated area. Measurements during the first ascent and last descent of the aircraft are excluded. Also indicated is the level of RHi necessary for liquid water saturation as well as the level for homogeneous nucleation below –40C, from Koop et al. Most of the measurements are below the level for ice nucleation, some of the measurements being very near or at that level showing a possible nucleation activity. Some, though very few of the measurements even exceed water saturation in the range –40 to – 52C. These measurements occurred for two particular flights, one in a wave cloud and the other one in a cirrus cloud connected to the jet stream, at the edge of a cold trough. In these situations the occurrence of strong updraft could have produced an excess of water vapour with respect to the available condensation nuclei.

Though the data from the Prestwick campaign are not completely analysed for the moment, a rough statistical comparison has been made concerning the repartition of the measurements of relative humidity with respect to ice for the two campaigns. Figure 17 shows that the peak in the repartition of RHi lies at 100%, for the two campaigns, this is the relative humidity for the equilibrium between the ice particles and the environment. However the repartition RHi is different: In Punta Arenas there is a higher frequency of supersaturation from and above 110%. This may be caused by the higher concentration of condensation nuclei produced by the polluted air masses, which then decreases the relative humidity by more nucleation activity, and induces differences in the microphysical properties of the cirrus clouds.

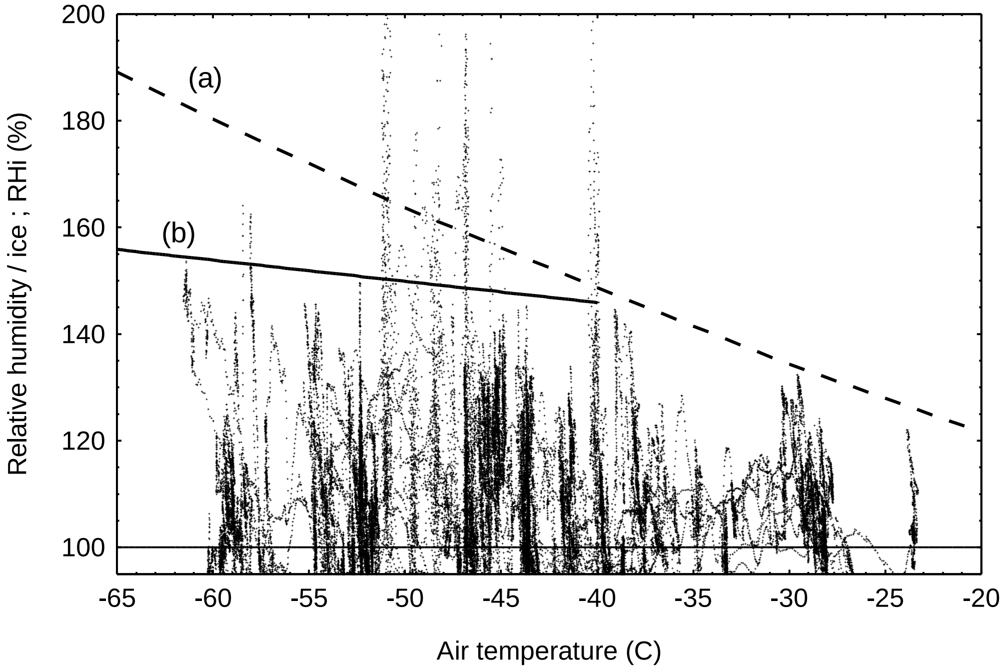

Figure 17. Repartition of the measurements of ice supersaturation for the Punta Arenas campaign as a function of the air temperature. The dashed line represents the level for liquid water saturation. The thin line is the level for homogeneous nucleation for air temperature below – 40C, from Koop et al (RHi = 238.7 – 0.398T ; with RHi in %, T in C).

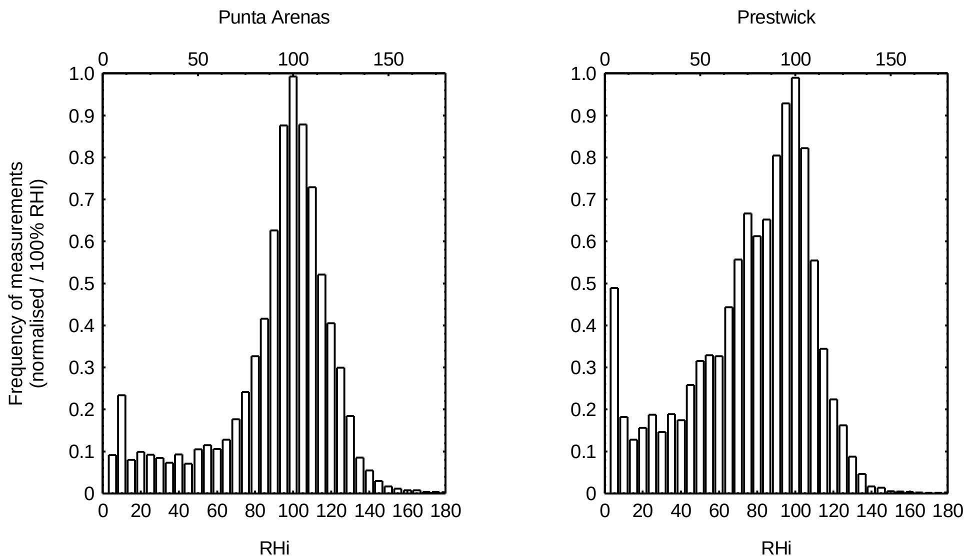

Figure 18Fs. Repartition of measurements of RHi for the two campaigns and for air temperature below –20C**.** Outside the clouds, below 100%, the air was more humid in the northern hemisphere**.** The repartition of supersaturation shows that there is a higher frequency of high supersaturation in the non-polluted air masses around Punta Arenas. As example, compared to the maximum at 100%, the frequency of RHi at 110% ±2.5% is 0.73 for Punta Arenas and 0.55 for Prestwick; at 120% ±2.5% it becomes 40% for Punta Arenas and 22% for Prestwick

3.8 WP8 Process modelling
Start date: 12
End date: 24
Lead contractor: 5

According to the plan the work package 8 (Process modelling) start in the second year. Some first calculations by the University of Helsinki study the role of Nitrogen species in the cirrus formation. As was mentioned in WP6 only a small fraction of NOy is found in the crystals compared to the ambient levels. However, it is possible that HNO_3 is important at during the nucleation. As the humidity increases and become close to water saturation the HNO_3 co-condense with water vapour that swell the ambient aerosol. A fraction of these particles freeze and quickly grow from the high supersaturation over an ice surface. The aerosol or haze droplets that did not freeze evaporate and release the HNO_3 back to the vapour phase. Thus, only a small fraction of the total NOy is found in the crystals. This hypothesis is based on the fact that adsorption of onto the crystals is a very slow process and the fraction of NOy found in the crystals typically is in the range of percent, which is in the same order of magnitude as the fraction of crystals to the total number of aerosols. These activities have just started and more work is planed for the coming year.

4. Socio-economic relevance and policy implication

There are considerable efforts in science in Europe, the USA, and elsewhere to better understand the complex dynamics of the Earth's atmosphere and to improve models to predict future climate trends. These efforts suffer from incomplete knowledge about cirrus properties and the influence of aerosols on them. The INCA project aim to fill as much as possible in this gap of crucial knowledge.

Industry seeks information to optimise their investment and development strategies such as to comply with potential environmental regulations. For example, aero-engine and car industries are currently making substantial investments into low emission engine technologies. They need to know about the relative importance of various aerosols and preferably well ahead in time before regulations are endorsed.

For policy makers, this research provides information on an important climatic and environmental issue as considered in the Kyoto, Montreal and the Hage protocols. Increased knowledge will enforce the European position and help to find optimal solutions for environmental protection and sustainable development.

Through normal channels such as publications in scientific journals, conferences and gathering observations in a database, the project will disseminate the results for easy access to user groups in the modelling community. The number of groups in Europe directly involved in cirrus modelling is currently not very large. But with a unique data set this part of scientific work could be strengthened.

Both on the ground and in the air, environmental research concerning air pollution has to aim towards long-term strategic planning. By responding to a potential problem at an early stage usually proves to be less resource intensive than trying to correct a problem after it has occurred. In the INCA project we test observationally if, and to what extent, air pollution may affect the properties of high clouds. If a saturation effect already exists for cirrus clouds formed in polluted air masses, as has been observed for low-level clouds, an anthropogenic signal may be difficult to distinguish from the natural variability. By performing measurements of cirrus-aerosol interactions in the pristine Southern Hemisphere now, we can learn about our European atmosphere of today and about the atmosphere of the world of tomorrow.

New insights on the formation and evolution of cirrus clouds might be inferred from the two campaigns performed within the INCA project. Changing the atmospheric composition through anthropogenic emissions from sources at the Earth surface or from air traffic affect many fields of science and society. Hence, the objective of INCA to contrast cirrus properties in clean and polluted environments are relevant with regards to assessments such as: IPCC, WMO and the Second Assessment of Stratospheric Research in Europe.

By feeding new knowledge and experience back into the education system, young researchers will stand better prepared and become more attractive to a competitive world market. Keeping a high standard will also gain proper international recognition. At present xx (1 in UBP 2 in SU) post-docs and xx (1 in UBP1 in SU) students are working on INCA data at the Universities of Stockholm, and Blaise Pascal in Clermont-Fd.

5. Discussion and conclusion

The INCA project did exactly what was planed for the first year. Two field campaigns were performed, one in the Southern Hemisphere and one in the Northern Hemisphere. With the completion of the uploading of data to the database the INCA project have provided the first set of data of the michrophysical and morphological properties of young cirrus clouds at southern and northern mid-latitudes, in relatively clean and polluted air masses, under otherwise comparable conditions. It is too early to assess the full picture of all the data collected during the two campaigns, but from the preliminary analysis made thus far it is clear that the necessary data to make break through in this field is available. Below follow a few highlights and preliminary conclusions.

- A first preliminary analysis shows that the distribution of observed relative humidity differ between the two hemispheres. Both distributions peak at 100% RHi but the polluted environment present less supersaturation events and the distribution is skewed towards lower values of RHi. Saturation levels close to liquid water were observed for temperatures above –40C. Below this temperature peak humidities typically followed the ice nucleation threshold as given by Koop et al. (2000). However some measurements of supersaturation exceeding water saturation have been made, and have to be carefully analysed.

- The trace gas levels of NO, NO_y, O_3, and CO observed in the Northern Hemisphere campaign significantly exceed the concentrations found in the Southern Hemisphere campaign. It was found that only a few percent of the available gas phase NO_y was adsorbed on cirrus cloud elements. This difference between the hemispheres was also evident in the aerosol data. Background fine particle number concentration is on average in the order of a factor of three higher in the northern hemisphere. In the region of the intertropical convergence, upper tropospheric aerosol (and trace gas) concentrations are apparently enhanced due to strong convection. Systematic differences between both hemispheres show up as well in the vertical concentration profiles of fine particles obtained during the ascends and descends of the aircraft.

- Upper tropospheric fine particle concentrations at Punta Arenas were often as low as 30 particles/cm³ (ambient conditions, 14 nm CPC). Though there were situations in Prestwick where the upper troposphere was occasionally almost as clean as in the SH, the general situation in the NH was much more variable for all measurement parameters, with on average significantly higher background concentrations. The air mass origin at a NH site like Prestwick is much more complicated with possible influences from the North American continent, the north polar region, the Atlantic and the European continent if compared to Punta Arenas where back trajectories basically all originate from marine areas far west of the South American continent (Pacific Ocean).

- A first inspection of the volatility CPC data indicated that the relative fraction of non-volatile aerosol compounds in the upper troposphere of the SH is very low, typically ranging from 2 to 10 percent. At the NH campaign a much larger range extending up to 30 percent of this fraction was observed, which is consistent with the picture of more abundant anthropogenic combustion-derived aerosols in the NH.

- The chemistry and aerosol forecast made by NILU were produced to help the planning of the measurement flights. The model was run on two domains covering 30-90°N and 30-90°S, respectively, and forecast products were made available on an interactive web page. A simple estimate of the production, loss and transport of dust and sea alt particles were developed.

- An excellent agreement in observed cirrus microphysical properties was found when comparing the CVI, FSSP-300, 2D-C, and Polar Nephelometer. The observed scattering properties by the Polar nephelometer and the derived properties from the FSSP-300 and 2D-C probe can be used to arrive to a closure study of the crystal size distribution. This very important study gave the definite picture that cirrus clouds typically contain numerous small crystals.

- The comparison of residual aerosol particles found in cirrus crystals above and below the tropopause, show that these different clouds form on different aerosols. In the stratosphere cirrus clouds form on larger aerosol particles than in the troposphere.

6. Plan and objectives for the next period

With the start of the second year the INCA project enters the evaluation and interpretation phase. The first year was mostly devoted to the preparation and performing the two campaigns that took place in spring and fall of 2000. This was a major undertaking that was possible due to hard work and good collaboration. An upcoming INCA meeting in March, 2001 will give the latest from the second campaign and serve to plan the remainder of the project. In particular modelling activities are due to begin (see WP8). The main goal is to finalise the data and upload this to the database and to work towards the objectives. Clearly, the wealth of information gathered during the two campaigns will not be fully exploited during the two-year frame of the INCA project. Work will certainly continue beyond the contract period. Below follow in bullet form some highlights and objectives for the coming period.

- Data collected during the second experiment in South Hemisphere will be merged into the INCA data archive later in the year 2001 once validated and intercompared.

- First representative statistical results on the distribution of microphysical & optical cirrus properties obtained at southern and northern mid-latitudes in relatively clean and polluted air masses under otherwise comparable conditions will be derived from the extensive set of data obtained from both campaigns.

- Insights on formation and evolution of cirrus clouds in SH versus NH might be derived from the analysis on the (non) dependence of cirrus clouds on air mass properties (in terms of aerosol characteristics and humidity)

- The inversion technique to retrieve the microphysical parameters in ice clouds (ice particle concentration, effective diameter, etc.) will be implemented by using measured scattering phase function.

- Coordinated measurements in space and time are available from both in-situ and multi channel satellite (NOAA / AVHRR) instruments. This data set will provide quantitative information to be used for the validation of retrieval techniques of microphysical and optical cirrus properties.

- The repartition of the ice supersaturation with respect to the air temperature will be analysed for the two campaigns, with the distinction of the measurements made inside and outside the cirrus clouds. The statistical analysis will be continued to put forward the difference in the properties inside and around the cirrus, for the 2 campaigns. The cases of high, unexpected, supersaturation will be analysed carefully in connection with the data from the other partners.

- A complete analysis of the air mass trace gases content will be performed with a distinction between the cloudy and non cloudy area for the 2 campaigns, and the characteristics of the air masses for the northern and southern hemisphere campaign will be compared in relation to the cirrus properties.

- The result from the 3D NILU-CTM will be used to analyse the measured air masses to assist interpretation of the observations. The history of air masses will be studied in more detail in order to locate possible large scale and local sources that explain the measured particle loading. The observed particle loading will be compared to the modelled results for selected flights in the southern hemisphere.

- The next step to take in the analysis of data is the completion of the processing of the Prestwick campaign data, including the addition of these data sets to the data archive. Once the Prestwick data have been processed, a very comprehensive, full set of interstitial/out-of-cloud aerosol data will be availalble for all flights of the INCA experiment in both hemispheres. With respect to the information on particle production occurring in the upper troposphere, gained from the addition of ultrafine condensation particle counters, the data set is even more valuable than originally expected in the project proposal.

- First, the characterization of differences in upper tropospheric background aerosol properties between both hemispheres. Second, the role of (cirrus) cloud processing in determining the properties of fine aerosol particles, and vice versa. Future data interpretation will also make intensive use of satellite image and back trajectory analysis data (WP 2, 7 and collaboration with NASA Langley) to obtain information on air mass origin and cirrus cloud history.

- The extensive data set permit to not only contrast clean and polluted troposphere situation, but also open to compare cirrus formed above the tropopause. This study might provide some unique insight to the formation process of cirrus clouds.

- First papers of preliminary results have been accepted for presentation at the 2001 European Geophysical Society Symposium in Nice. For further presentation of work abstracts will be submitted to the European Aerosol Conference at Leipzig and the IAMAS conference at Innsbruck, all in 2001.

- First ideas of publications to be submitted to peer reviewed journals include:
  a) On the number density in cirrus.
  b) On the optical properties of cirrus: A comparison of in-situ observations observed in polluted and clean air masses.
  c) On the relation between relative humidity in cirrus clouds and microphysical properties: Is there a measurable difference between polluted and clean air masses.
  d) On the comparison between optical properties inferred from in-situ data and satellite data.
  e) On the formation of cirrus: A link to aerosol properties.
  f) On the evolution of cirrus.
  g) On the upper tropospheric aerosol: A Southern and Northern Hemisphere contrast
  h) On the cirrus-aerosol interaction: Cloud processing of aerosols.
  i) On the uptake of NOy on cirrus particles: Dependence on atmospheric state and pollution level. On the difference in trace gas levels in the Southern and Northern Hemisphere.

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Flatøy, F. and Hov, Ø. (1996b) 3-D model studies of the effect of NO_x emissions from aircraft in the upper troposphere over Europe and the North Atlantic. *J. Geophys. Res., 101*, 1401-1422.

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Annex 1: Publications (cumulative list)[1]

General rules about publicity and communications are defined within the Annex II ,"General conditions" Part B, to the contract, mainly obligations, responsibilities and reference to Community support. This should be prepared as a separate page to be annexed to the report and updated annually.

Peer Reviewed Articles:

Authors	Date	Title	Journal	Reference

Non refereed literature:

Authors / Editors	Date	Title	Event	Reference	Type[2]
Ström, J., U. Schumann, J.-F. Gayet, J. Ovarlez, F. Flatoy, M. Kulmala, O. Schrems, P. Minnis, S.B. Diaz, B. Milicic, V. Valderama, E. Amthauer, J. Pettersson, and F. Arnold	2000	Aerosol and Cirrus Measurements at Midlatitudes on the Southern Hemisphere- An overview based on the first INCA Experiment	Aviation, Aerosols, Contrails andCirrus Clouds (A2C3), European Workshop, Seeheim	Seeheim (nearFrankfurt/Main), Germany, July 10-12	Proceeding
Ovarlez, J., H. Schlager, P. van Velthoven, E. Jensen, U. Schumann, H. Ovartlez, and J. Ström	2000	Water vapour measurements in the upper troposphere from POLINAT campaigns	Aviation, Aerosols, Contrails andCirrus Clouds (A2C3), European Workshop, Seeheim	Seeheim (nearFrankfurt/Main), Germany, July 10-12	Proceeding
Strom J., F. Flatoy, J.-F. Gayet, M. Kulmala, J. Ovarlez and U. Schumann,	2000	Observations in cirrus clouds during the INCA Southern Hemisphere campaign	*13th Int. Conference on Clouds and Precipitation.*	Reno, USA, 14-18 August 2000	Proceeding
Auriol F., J.F. Gayet, J. Ström and A. Petzold,	2001	On microphysical & optical properties of cirrus clouds in Southern and Northern hemispheres.	*XXVI General Assembly, European Geophysical Society*	Nice, France, 25-30 March 2001	Proceeding

[1] Two copies of publications issued during reporting period should be annexed to the report, specific cases should be agreed by the Project Officer

[2] Type: Abstract, Newsletter, Oral Presentation, Paper, Poster, Proceedings, Report, Thesis

Seifert M., J. Ström, R. Krejci, A. Petzold, A. Minikin, J.F. Gayet, F. Auriol, U. Schumann, R. Busen	2001	In situ observations of aerosols particles remaining from evaporated cirrus crystals :a comparison between clean and polluted conditions	*XXVI General Assembly, European Geophysical Society*	Nice, France, 25-30 March 2001	Proceeding
Ziereis H., J. Baehr, A. Petzold, A. Minikin, P. Stock, H. Schlager , J.-F. Gayet, J. Ström, R. Busen,U. Schumann	2001	In situ observations of Noy uptake by cirrus clouds during INCA	*XXVI General Assembly, European Geophysical Society*	Nice,France, 25-30 March 2001	Proceeding
J. Ovarlez[1], H. Ovarlez[1], F. Auriol[2], J. F. Gayet[2], R. Busen[3], A. Minikinn[3], A. Petzolt[3], U. Schumann[3] and J. Ström[4]	2001	Some observations on the difference of cirrus clouds water vapor saturation level in polluted and not polluted area during the INCA campaign.	*8th Scientific Assembly of IAMAS*	Innsbruck, Austria, 10-18 July 2001	Proceeding
Minikin, A., A. Petzold, J. Ström, R. Krejci, M. Seifert, H. Ziereis, H. Schlager, R. Busen, and U. Schumann,	2001	Interhemispheric differences in the fine particle Load of the upper troposphere	*XXVI General Assembly, European Geophysical Society*	Nice,France, 25-30 March 2001	Proceeding
A. Minikin[1], A. Petzold[1], J. Ström[2], R. Krejci[2], M. Seifert[2], J. Baehr[1], H. Ziereis[1], H. Schlager[1], R. Busen[1], U. Schumann[1]	2001	Properties of the upper tropospheric background aerosol in the southern hemisphere	IAMAS Innsbruck, 10-18 July 2001		Proceeding
A. Minikin[1], A. Petzold[1], J. Ström[2], R. Krejci[2], M. Seifert[2], J. Baehr[1], H. Ziereis[1], H. Schlager[1], R. Busen[1], U. Schumann[1]	2001	Interhemispheric differences in the properties of the upper tropospheric background aerosol	EAC 2001 Leipzig, Sept. 3-7, 2001		Proceeding

Others: (Patents, CD ROM's, videos,…)

Planning of future publications: (type, date, contents, …)