Canadian Arctic Validation of ACE

Mission Description Document

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Supported by

Canadian Space Agency (Space Science Program)

Meteorological Service of Canada

NSERC

Northern Scientific Training Program

February 2004

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1. Introduction

The Atmospheric Chemistry Experiment (ACE) is a scientific satellite (Scisat-1) that was launched by the Canadian Space Agency on August 12, 2003 with an expected mission lifetime of greater than two years. The goal of this mission is to improve our understanding of the chemical and dynamical processes that control the distribution of ozone in the upper troposphere and stratosphere. It will focus on one important aspect of the atmospheric ozone problem – the decline of stratospheric ozone at northern mid-latitudes and in the Arctic. To this end, a high inclination (74°), low Earth orbit (650 km) has been chosen to give ACE both global and high-latitude coverage. Two instruments make up the ACE payload: a Fourier transform infrared spectrometer and a dual optical spectrograph. Using the solar occultation technique, these sensors will measure the vertical distribution of the atmospheric trace gas species and aerosols.

The primary ACE instrument is a high resolution (0.02 cm^{-1}) infrared Fourier Transform Spectrometer (ACE-FTS), operating from 750-4100 cm^{-1}, with a two-channel visible/near IR imager (0.525 µm and 1.02 µm). The FTS has an adapted version of the classical Michelson interferometer employing a compact optical layout. The baseline target species for the ACE-FTS, in addition to ozone, are: CH_4, H_2O, NO, NO_2, $ClNO_3$, HNO_3, N_2O, N_2O_5, HCl, CCl_3F, CCl_2F_2, HF, and CO. The solar imagers will measure the atmospheric extinction caused by clouds and aerosols. Pressure and temperature profiles will be determined using a fixed CO_2 volume mixing ratio. The ACE-FTS results will cover the 10-100 km altitude range with a vertical resolution of 3-4 km. The specific altitude ranges and estimated accuracies for each of the fourteen baseline target species are listed in Table 1. The temperature and pressure retrievals will be made with estimated accuracies of 2-3 K and 2%, respectively.

Table 1. Baseline target species for ACE-FTS measurements.

Species	Altitude Range (km)	Accuracy (%)
O_3	10-50	5
CH_4	10-50	5
H_2O	10-50	5
NO	15-100	5
NO_2	15-50	5
$ClNO_3$	15-40	20
HNO_3	15-40	15
N_2O	10-50	5
N_2O_5	20-40	20
HCl	15-50	5
CCl_3F	10-30	10
CCl_2F_2	10-30	10
HF	15-50	5
CO	15-100	5

The second instrument, MAESTRO (Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation), is a UV/visible/near-infrared spectrograph that will measure from 285 to 1030 nm (1-2 nm resolution). These measurements will target O_3, NO_2 and aerosol/cloud extinction with ~1 km vertical resolution. An independent determination of atmospheric temperature and pressure will be made from the MAESTRO results using the oxygen A-, B-, and γ-bands. The accuracy is estimated to be 5% for pressure and 2 K for temperature. The altitude range, estimated accuracy and vertical resolution for the baseline O_3, NO_2 and aerosol measurements are given in Table 2.

Table 2. Baseline target species for MAESTRO measurements.

Species	**Altitude Range (km)**	**Accuracy (%)**	**Vertical Resolution (km)**
O_3	50-80	10	1
	20-50	3	1
	10-20	10	1
	8-10	15	2
NO_2	40-50	15	1
	20-40	10	1
	10-20	15	1
	8-10	25	2
Aerosol Extinction	30-50	10^{-3} O.D.	1
	10-30	10^{-3} O.D.	1
	8-10	0.01 O.D.	2
Aerosol Extinction (Wavelength Dependence)	15-30	0.005 O.D. per 100 nm	2

The accuracy and reliability of the ACE results will be established by comparison with a series of measurements made by satellite-, balloon-, aircraft-, ship-, and ground-based instruments. Both vertical profile and column measurements will be used as part of the validation data set. As much as possible these experimental results will overlap in space and time with the ACE data. Coincidence requirements will be assessed during analysis using atmospheric modelling techniques. Full details of the validation approach, validation experiments, and measurement and data guidelines are described in the "*ACE Validation and Ground Truthing Plan*" provided to the Canadian Space Agency, and will not be repeated here.

With the mothballing of Environment Canada's Arctic Stratospheric Ozone Observatory (ASTRO) at Eureka, Nunavut (80.05°N, 86.438°W) in summer 2002, we no longer have an Arctic measurement capability in Canada for the validation of ACE Arctic measurements. The exception to this are the routine ozone measurements made by the Meteorological Service of Canada using ozonesondes and Brewer spectrometers at the Eureka weather station, Resolute (75°N), and Alert (82.5°N). Validation of the 13 other ACE-FTS and MAESTRO baseline trace gases under Arctic conditions, which are the focus of the ACE science, currently relies entirely on data to be provided by our international colleagues. There are now no permanent FTS, DOAS, or lidar instrument sites in Canada north of Egbert/Peterborough/Toronto/Waterloo/London (all near 45°N). This represents a geographical hole in view of the primary ACE science goal of monitoring stratospheric ozone decline at northern mid-latitudes and in the Arctic. This document describes a Canadian validation campaign for ACE taking place at Eureka in spring 2004.

2. Scientific Objectives of the ACE Canadian Arctic Validation Campaign

The primary scientific objective of the Arctic Validation Campaign is to measure total columns and (where possible) vertical profiles of the 14 ACE baseline target species, atmospheric extinction, temperature, and pressure in the Canadian Arctic for use in validation of ACE satellite data. This campaign is from February to April 2004. Two of the instruments deployed are adaptations of ACE-FTS and MAESTRO, and so provide spectral, as well as trace gas, measurements. These can be used to help assess the quality of both the Level 1 and Level 2 ACE data under the chemically perturbed conditions found in the springtime Arctic.

These measurements are being performed at the ASTRO facility using a combination of on-site instrumentation and instruments deployed there on a campaign basis. ASTRO was built by Environment Canada in 1993 and is situated on a ridge about 15 km from the Eureka weather station, as seen in Figure 1. This is an ideal site for an Arctic validation, as it has all the infrastructure needed to support such a campaign. In addition, Eureka has a large number of "clear sky" nights for optical measurements, which was why the building was originally located there. For example, Duck *et al.* (2000) showed measurements for 77% of the days during the 1997-98 winter. Furthermore, Eureka lies directly below the point of maximum stratospheric variability (Harvey and Hitchman, 1996) which makes it an ideal site for stratospheric measurements. The winter polar vortex regularly passes over Eureka and thus measurements both inside and outside the vortex region can be made from this single location. As understanding of the chemical and physical processes associated with the Arctic polar vortex is a key scientific goal of ACE, validation of ACE measurements under the unusual conditions found in the Arctic springtime will be vital to establishing their credibility.

Figure 1. The Arctic Stratospheric Ozone Observatory (ASTRO) located at Eureka, Nunavut.

The Arctic Validation Campaign is planned for a total period of two months in spring 2004, which is the critical time when the perturbed stratospheric conditions can lead to chemical ozone loss. It will include the full suite of instruments both on-site and deployed on a campaign basis, and is taking place after Scisat-1 commissioning is completed.

Figure 2 shows the location of ACE occultations from February 21 (when polar sunrise begins at Eureka) through March 7, 2004, based on the current orbit prediction. A total of 25 occultations are within 500 km of Eureka for this two-week period. The highest latitude reached is 78.3°N on February 28, as seen in Table 3. By March 20, the highest latitude has moved south to about 60°N.

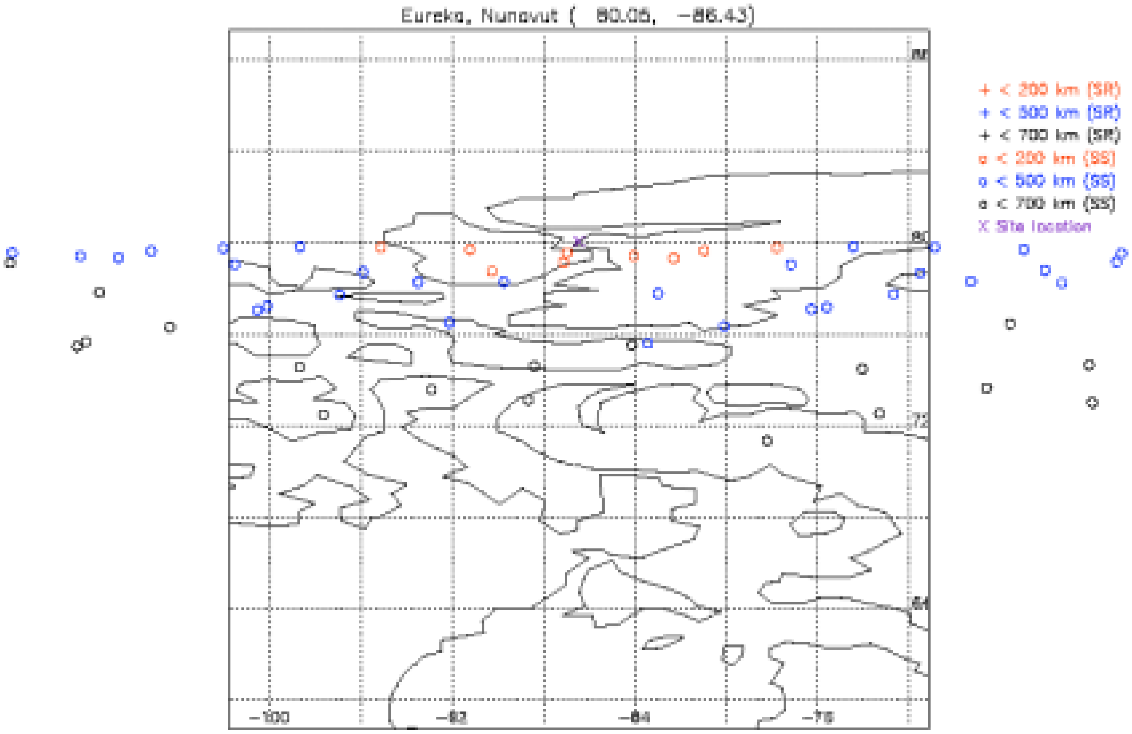

Figure 2. Occultation predictions for the ACE mission from January 12 to March 31, 2004 using ephemeris data from January 27, 2004. All occultations shown here are within 700 km of Eureka. Note that all are sunset occultations.

Table 3. ACE occultations within 1000 km of Eureka for the spring 2004 campaign.

Occ ID	Date	Time (UTC)	Latitude	Longitude	Type	Great Circle Distance (km)	Beta Angle	Too Long?
ace.ss553	2004-02-18	19:40:11.07	72.9953766	-63.9733049	sunset	964.0762769	57.4953163	t
ace.ss554	2004-02-18	21:17:55.76	73.1055310	-88.6622096	sunset	775.0449271	57.4234849	t
ace.ss568	2004-02-19	20:06:18.21	74.4677870	-74.0457293	sunset	688.3892928	56.1535558	f
ace.ss569	2004-02-19	21:44:02.43	74.5498234	-98.6816738	sunset	678.4580096	56.0524753	f
ace.ss582	2004-02-20	18:54:35.26	75.5375100	-58.8329913	sunset	807.7780493	54.7163634	f
ace.ss583	2004-02-20	20:32:19.16	75.6054419	-83.4382324	sunset	499.5502174	54.6227975	f
ace.ss584	2004-02-20	22:10:03.04	75.6682532	-108.0233514	sunset	694.6149650	54.5057211	f
ace.ss597	2004-02-21	19:20:31.58	76.4485633	-67.5687709	sunset	581.1853707	53.0353414	f
ace.ss598	2004-02-21	20:58:15.17	76.5013158	-92.1178163	sunset	414.9870372	52.8992788	f
ace.ss599	2004-02-21	2:35:58.79	76.5510455	-116.6532647	sunset	772.5390362	52.7901555	f
ace.ss611	2004-02-22	18:08:40.62	77.1375133	-51.0886404	sunset	826.2786404	51.3071558	f
ace.ss612	2004-02-22	19:46:24.02	77.1820123	-75.6071984	sunset	396.7733046	51.1760467	f
ace.ss613	2004-02-22	21:24:07.40	77.2230760	-100.1046054	sunset	432.6720810	51.0569203	f
ace.ss614	2004-02-22	23:01:50.83	77.2643806	-124.5964165	sunset	871.6894822	50.9155001	f
ace.ss626	2004-02-23	18:34:30.24	77.7476109	-58.5165089	sunset	642.7461499	49.3446034	f
ace.ss627	2004-02-23	20:12:13.44	77.7842358	-82.9849297	sunset	262.6610693	49.2028399	f
ace.ss628	2004-02-23	21:49:56.67	77.8178124	-107.4374241	sunset	508.9632760	49.0627260	f
ace.ss629	2004-02-23	23:27:39.93	77.8512604	-131.8891335	sunset	972.1501272	48.9338817	f
ace.ss640	2004-02-24	17:22:34.24	78.2230134	-40.8729870	sunset	950.3845018	47.4091336	f
ace.ss641	2004-02-24	19:00:17.30	78.2539696	-65.3087255	sunset	482.0123403	47.2535753	f

ace.ss642	2004-02-24	20:38:00.35	78.2837520	-89.7287412	sunset	208.2968489	47.1193478	f
ace.ss643	2004-02-24	22:15:43.47	78.3113808	-114.1410103	sunset	603.6402936	46.9757066	f
ace.ss655	2004-02-25	17:48:19.46	78.6523948	-47.1182279	sunset	806.8437399	45.2297735	f
ace.ss656	2004-02-25	19:26:02.40	78.6776854	-71.5153935	sunset	341.0926778	45.0902921	f
ace.ss657	2004-02-25	21:03:45.37	78.7016576	-95.8933576	sunset	244.9820371	44.9340601	f
ace.ss658	2004-02-25	22:41:28.39	78.7242401	-120.2693090	sunset	698.4964984	44.7854420	f
ace.ss670	2004-02-26	18:14:03.02	79.0099940	-52.8135663	sunset	679.7273195	42.9833458	f
ace.ss671	2004-02-26	19:51:45.85	79.0300148	-77.1673256	sunset	218.5811857	42.8258198	f
ace.ss672	2004-02-26	21:29:28.75	79.0492581	-101.5093292	sunset	323.0889056	42.6770067	f
ace.ss673	2004-02-26	23:07:11.67	79.0678712	-125.8546002	sunset	786.9947446	42.5231713	f
ace.ss685	2004-02-27	18:39:45.15	79.3005294	-57.9892544	sunset	567.5977101	40.6614899	f
ace.ss686	2004-02-27	20:17:27.93	79.3159864	-82.3042790	sunset	115.8891960	40.5051449	f
ace.ss687	2004-02-27	1:55:10.77	79.3309146	-106.6149613	sunset	407.8083074	40.3425607	f
ace.ss688	2004-02-27	23:32:53.63	79.3476589	-130.9404407	sunset	867.6101933	40.1873791	f
ace.ss699	2004-02-28	17:27:43.51	79.5162856	-38.3982074	sunset	923.2591423	38.4421981	f
ace.ss700	2004-02-28	19:05:26.20	79.5294153	-62.6955704	sunset	468.5455957	38.2776462	f
ace.ss701	2004-02-28	20:43:08.94	79.5396633	-86.9789726	sunset	57.8310744	38.1125744	f
ace.ss702	2004-02-28	22:20:51.72	79.5506168	-111.2627793	sunset	488.8278701	37.9590554	f
ace.ss703	2004-02-28	23:58:34.52	79.5646699	-135.5698912	sunset	940.7310279	37.7920001	f
ace.ss714	2004-02-29	17:53:23.60	79.6844029	-42.7036556	sunset	837.1668899	36.0049316	f
ace.ss715	2004-02-29	19:31:06.24	79.6921319	-66.9670952	sunset	381.2756345	35.8439655	f
ace.ss716	2004-02-29	21:08:48.95	79.6977822	-91.2249015	sunset	101.6666342	35.6823651	f
ace.ss717	2004-02-29	22:46:31.67	79.7056800	-115.4891317	sunset	563.8398528	35.5079286	f
ace.ss729	2004-03-01	18:19:02.90	79.7856107	-46.6283172	sunset	761.0834485	33.5350309	f
ace.ss730	2004-03-01	19:56:45.52	79.7879354	-70.8664278	sunset	303.7342054	33.3620692	f
ace.ss731	2004-03-01	21:34:28.20	79.7898837	-95.1039616	sunset	171.2919941	33.1952308	f
ace.ss732	2004-03-01	23:12:10.89	79.7945881	-119.3564247	sunset	633.4252290	33.0369353	f
ace.ss744	2004-03-02	18:44:41.53	79.8170507	-50.2341813	sunset	693.3998631	31.0116332	f
ace.ss745	2004-03-02	20:22:24.14	79.8141780	-74.4532336	sunset	234.1178249	30.8511243	f
ace.ss746	2004-03-02	22:00:06.78	79.8121635	-98.6758550	sunset	239.3413233	30.6751830	f
ace.ss747	2004-03-02	23:37:49.42	79.8130059	-122.9162498	sunset	698.9271028	30.5054531	f
ace.ss759	2004-03-03	19:10:19.56	79.7730269	-53.5857210	sunset	632.6622255	28.4728047	f
ace.ss760	2004-03-03	20:48:02.16	79.7652739	-77.7928990	sunset	171.2694518	28.2884023	f
ace.ss761	2004-03-03	22:25:44.77	79.7588515	-102.0088230	sunset	304.7788660	28.1313932	f
ace.ss762	2004-03-04	00:03:27.35	79.7557652	-126.2358977	sunset	762.3956022	27.9528183	f
ace.ss774	2004-03-04	19:35:57.19	79.6505738	-56.7673933	sunset	577.2003709	25.8889521	f
ace.ss775	2004-03-04	21:13:39.77	79.6372659	-80.9678597	sunset	116.5906281	25.7253115	f
ace.ss776	2004-03-04	22:51:22.36	79.6276879	-105.1827633	sunset	369.6065015	25.5357669	f
ace.ss777	2004-03-05	00:29:04.89	79.6182064	-129.3995163	sunset	826.3856734	25.3788560	f
ace.ss788	2004-03-05	18:23:51.86	79.4636984	-35.6557539	sunset	975.2544794	23.4690068	f
ace.ss789	2004-03-05	20:01:34.40	79.4450296	-59.8516036	sunset	526.1379407	23.2875973	f
ace.ss790	2004-03-05	21:39:16.96	79.4270481	-84.0535269	sunset	83.8288239	23.1116107	f
ace.ss791	2004-03-05	23:16:59.50	79.4126576	-108.2656532	sunset	436.3710925	22.9490458	f
ace.ss792	2004-03-06	00:54:41.97	79.3973366	-132.4776141	sunset	893.2675467	22.7577958	f
ace.ss803	2004-03-06	18:49:28.78	79.1771698	-38.7192467	sunset	935.1552115	20.8334998	f
ace.ss804	2004-03-06	20:27:11.33	79.1525630	-62.9189537	sunset	479.2892643	20.6722333	f
ace.ss805	2004-03-06	22:04:53.88	79.1313191	-87.1265809	sunset	103.2182011	20.4894649	f
ace.ss806	2004-03-06	23:42:36.38	79.1106634	-111.3399362	sunset	508.0627742	20.3114409	f
ace.ss807	2004-03-07	01:20:18.79	79.0884443	-135.5508395	sunset	965.7769905	20.1478980	f
ace.ss818	2004-03-07	19:15:05.54	78.8022668	-41.8337609	sunset	898.1415608	18.2108362	f
ace.ss819	2004-03-07	20:52:48.07	78.7735790	-66.0422827	sunset	437.8473710	18.0155113	f
ace.ss820	2004-03-07	22:30:30.60	78.7463797	-90.2590123	sunset	164.8724269	17.8553250	f
ace.ss821	2004-03-08	00:08:13.06	78.7202769	-114.4763828	sunset	587.4166457	17.6724801	f
ace.ss833	2004-03-08	19:40:42.09	78.3378145	-45.0591201	sunset	864.0669798	15.5441368	f
ace.ss834	2004-03-08	21:18:24.61	78.3041041	-69.2785987	sunset	405.6551886	15.3786813	f
ace.ss835	2004-03-08	22:56:07.11	78.2721318	-93.5047848	sunset	246.8351034	15.1833192	f
ace.ss836	2004-03-09	00:33:49.52	78.2383857	-117.7300530	sunset	676.8694850	15.0212726	f
ace.ss848	2004-03-09	20:06:18.63	77.7829191	-48.4445522	sunset	833.5724966	12.8784972	f

ace.ss849	2004-03-09	21:44:01.16	77.7447392	-72.6797252	sunset	389.1124681	12.6975393	f
ace.ss850	2004-03-09	23:21:43.63	77.7065812	-96.9165005	sunset	343.5996613	12.5308882	f
ace.ss851	2004-03-10	00:59:26	77.6669015	-121.1526472	sunset	778.3543112	12.3380701	f
ace.ss863	2004-03-10	20:31:55.16	77.1384665	-52.0267031	sunset	808.2408143	10.2060003	f
ace.ss864	2004-03-10	22:09:37.67	77.0943029	-76.2768653	sunset	396.7984734	10.0204800	f
ace.ss865	2004-03-10	23:47:20.10	77.0493792	-100.5266138	sunset	454.4279636	9.8388071	f
ace.ss866	2004-03-11	01:25:02.46	77.0036451	-124.7750498	sunset	893.4399801	9.6696220	f
ace.ss878	2004-03-11	20:57:31.75	76.4020528	-55.8269430	sunset	791.2002681	7.5037195	f
ace.ss879	2004-03-11	22:35:14.25	76.3514628	-80.0913046	sunset	435.6595164	7.3377067	f
ace.ss880	2004-03-12	00:12:56.65	76.3008609	-104.3549668	sunset	579.6063770	7.1537883	f
ace.ss893	2004-03-12	21:23:08.58	75.5746445	-59.8562737	sunset	786.6413169	4.8251940	f
ace.ss894	2004-03-12	23:00:51.06	75.5181660	-84.1344572	sunset	507.2615261	4.6324205	f
ace.ss895	2004-03-13	00:38:33.44	75.4604034	-108.4135374	sunset	719.7446467	4.4607045	f
ace.ss908	2004-03-13	21:48:45.59	74.6544995	-64.1156731	sunset	799.9356359	2.1135916	f
ace.ss909	2004-03-13	23:26:28.05	74.5925231	-88.4091409	sunset	609.3437180	1.9419938	f
ace.ss910	2004-03-14	01:04:10.47	74.5274714	-112.7023533	sunset	875.3478528	1.7552057	f
ace.ss923	2004-03-14	22:14:23.01	73.6414035	-68.6018570	sunset	836.3747575	-0.5855613	f
ace.ss924	2004-03-14	23:52:05.46	73.5726247	-92.9092519	sunset	738.4780207	-0.7691889	f
ace.ss938	2004-03-15	22:40:00.89	72.5331919	-73.3053516	sunset	900.3945109	-3.2896274	f
ace.ss939	2004-03-16	00:17:43.36	72.4569810	-97.6258447	sunset	891.7998676	-3.4690547	f
ace.ss953	2004-03-16	23:05:39.31	71.3260701	-78.2133511	sunset	994.7187630	-5.9976887	f

3. Proposed Instruments and Measurements

A suite of six ground-based instruments, complemented by frequent ozonesonde flights, are participating in the Arctic Validation Campaign, as listed in Table 4. The anticipated measurements and their accuracies are summarized in Table 5. Two spectrometers, the DA8 FTS and the Brewer, are already at Eureka, along with the DIAL. Three additional instruments are being deployed at ASTRO from mid-February through to mid-March or to the end of April 2004: two are ground-based versions of the ACE instruments, and one is a spectrometer that has been deployed at ASTRO on a campaign basis for the past five years.

Table 4. The proposed instruments for the Canadian Arctic Validation campaign.

ON-SITE INSTRUMENTS (location)	CAMPAIGN INSTRUMENTS
• MSC DA8 FTS (ASTRO)	• U of Waterloo PARIS FTS
• MSC DIAL (ASTRO)	• MSC MAESTRO-G
• MSC Brewer spectrophotometer (weather station)	• MSC SPS-G
• MSC ozonesondes (weather station)	• U of Toronto grating spectrometer

Bomem DA8 Fourier Transform Infrared Spectrometer

The primary instrument is the Bomem DA8 Fourier transform infrared spectrometer (FTS) permanently installed at ASTRO since 1993, which is operated by MSC. ASTRO has been a component of the primary Arctic station of the international Network for the Detection of Stratospheric Change (NDSC), and the FTS is an NDSC-validated instrument with a 10-year data set (Donovan *et al.*, 1997). It is used to record atmospheric absorption spectra in the near-infrared with an apodized resolution of 0.004 cm^{-1}, using the sun as light source. A liquid-nitrogen-cooled InSb and MCT detector combination and several interference filters are employed to acquire spectra from about 650 cm^{-1} to 4500 cm^{-1}.

The spectra can be analyzed using the spectral fitting algorithm SFIT 1.09e (Rinsland *et al.*, 1982), for the retrieval of vertical column densities of nearly all the target gases to be measured by the ACE-FTS and MAESTRO. Figure 3 shows HNO_3 columns retrieved at Eureka during winter 2001-02, when both solar and lunar measurements were made. Profile information for some of the gases such as O_3, HF, HCl, CO, HNO_3, CH_4, and N_2O, may be derived also, using the advanced spectral fitting routine, SFIT2 (Rinsland *et al.*, 1998). A side-by-side intercomparison of the Eureka FTS with a mobile Bruker FTS from the National Physical Laboratory (NPL) in England was carried out in the spring of 1999. This work was done in compliance with the high standards of the NDSC for quality controlled atmospheric measurements. By comparing the retrieved column densities from the two instruments for O_3, N_2O, CH_4, HNO_3, HCl and HF, it was concluded that the differences between the two instruments are typically less than ±3%. This precision is achieved when the same spectral line parameters and initial gas concentration profiles are assumed in the analysis of the two sets of spectra recorded simultaneously by the two spectrometers. The results from this intercomparison thus demonstrate the capability of the Eureka FTS in the validation of most of the gases to be measured by the ACE FTS and MAESTRO. Estimates of the accuracy (percent uncertainty) expected for column measurements of the primary species of interest are ±10% for O_3, ±6% for N_2O, ±6% for CH_4, ±13% for HNO_3, ±5% for HCl, ±10% for HF, ±25% for NO, ±25% for NO_2, ±30% for $ClNO_3$, and ±8% for CO.

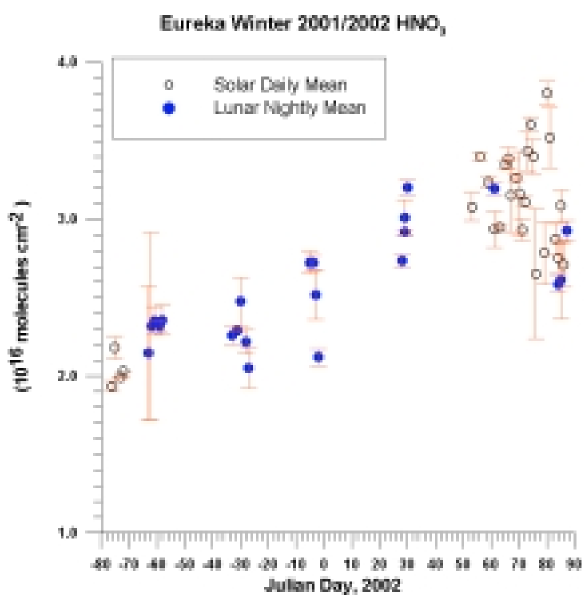

Figure 3. Time series of daily and nightly mean vertical column densities of nitric acid above Eureka from October 2001 to the end of March 2002, with error bars representing the standard deviation of the individual measurements from the mean. (Fast et al., 2003)

Differential Absorption Lidar

There are two existing lidars on site at ASTRO. One is a Canadian ozone DIAL system that has been operated by MSC, CRESTech, and York University in the past (Bird *et al.*, 1996; Donovan *et al.*, 1997). It can provide vertical profiles of ozone, temperature, aerosol, and water vapour. The second is a Japanese aerosol lidar which previously measured aerosol profiles (e.g., Arctic Haze, Polar Stratospheric Clouds). Only the former is included in this campaign due to cost and personnel limitations.

This Differential Absorption Lidar (DIAL) is based on a XeCl laser with hydrogen Raman shifter to provide outputs at 308 nm (the "on" or ozone absorbed wavelength) and 353 nm (the "off" or unabsorbed wavelength). A 1-meter Newtonian telescope collects the elastic backscattered radiation at these wavelengths as well as the Raman scattering from atmospheric nitrogen and water vapour. Photomultiplier detectors are used to record the radiation at the different wavelengths employed.

The deliverables from Spectral Applied Research are the raw lidar data and altitude profiles of stratospheric ozone and temperature, for which analysis software exists at MSC. Potential additional products are profiles of aerosol and water vapour; these will require additional algorithm development, but are expected to be retrievable. To determine the ozone profiles, two different methods are used depending on altitude range. The Rayleigh, or elastic backscattered radiation, can be used to measure ozone from 25 km to approximately 60 km, where the returned signal becomes too weak for accurate results. Below 25 km, aerosols contribute significantly to the return signal. Therefore the two atmospheric nitrogen Raman-shifted wavelengths, 332 and 385 nm, corresponding to the 308-nm and 353-nm outputs, respectively, are used because these Raman lines are less affected by aerosols than the Rayleigh pair. The 353-nm unabsorbed radiation is used to determine aerosol profiles from 5 to 30 km. For temperature profiling, the 353-nm Rayleigh signal is employed for the altitude range 25-85 km and the Raman return at 385 nm is used for the 5-35 km region. The water vapour profile is measured from 6 to 10 km and is obtained from the 353-nm Rayleigh and the 406-nm water vapour Raman shifted line. Ozone concentration profiles are retrieved with a standard error of 6% and a vertical resolution of 1.2 km near 30 km altitude. At this altitude the temperature profiles have a standard error of 3 degrees K and a vertical resolution of 300 m. The aerosol scattering-ratio profiles are derived with an absolute error of about 0.0005.

Brewer Spectrophotometer

Also on site, at the Eureka weather station, is a Brewer spectrophotometer, which MSC is contributing to the campaign (this is already in the ACE Validation Plan). The Brewer is fully automated and can make quasi-simultaneous observations of total column ozone to 1% accuracy, SO_2 columns to 0.2-0.6 Dobson units accuracy, aerosol optical depth, and UV-B radiation (Savastiouk and McElroy, in press). Measurements are usually made using direct solar viewing. In addition, vertical profiles of ozone can be derived using the Umkehr inversion technique.

Ozonesondes

MSC regularly launches ozonesondes from the Eureka weather station (also already in the ACE Validation Plan). Ozonesondes make *in situ* measurements of ozone partial pressure on ascent, typically at 0.01 mPa vertical resolution with an accuracy of ±10% (Davies *et al.*, 2000). Associated radiosondes also provide profiles of pressure (0.1 mb resolution, ±0.5 mb accuracy) and temperature (0.1 °C resolution, ±0.2 °C accuracy). Under routine operations, typically one ozonesonde is launched from Eureka per week. We are increasing the frequency of launches to daily during the intensive phase of the Arctic Validation Campaign, to provide much better temporal resolution of the evolution of the ozone profile over Eureka and greater likelihood of coincidences between ozonesonde flights and ACE overpasses.

Portable Atmospheric Research Interferometric Spectrometer

The Portable Atmospheric Research Interferometric Spectrometer (PARIS) is an adapted version of the ACE-FTS, the high-resolution Fourier transform spectrometer on board SciSat-1. PARIS will have two interchangeable configurations which will make it capable of measuring solar absorption spectra both in the infrared and in the visible-ultraviolet. As part of the calibration and validation of the ACE satellite mission, we plan to make ground-based measurements with PARIS as well as fly it on the MANTRA 2004 balloon campaign.

The PARIS FTS has a symmetric compact design, as seen in Figure 4, with a maximum optical path difference of 25 cm (0.02 cm^{-1} resolution). The infrared configuration, which is being employed for the Arctic Validation Campaign, provides wide wavenumber coverage (750-4100 cm^{-1}) using a ZnSe beamsplitter and HgCdTe and InSb detectors in a sandwich arrangement. It is anticipated that PARIS will make measurements covering almost the same range of species as ACE-FTS (except for N_2O_5), namely O_3, CH_4, H_2O, NO, NO_2, $ClNO_3$, HNO_3, N_2O, HCl, CCl_3F, CCl_2F_2, HF, and CO. Vertical column amounts will be retrieved from the PARIS spectra using the SFIT 1 and 2 fitting programs. The measurement accuracy of the derived column results are expected to be similar to those for the MSC FTS instrument. PARIS will contribute total column measurements for almost all of the ACE baseline target species to the Arctic Validation Campaign and these will complement the profile measurements made by the MSC FTS. Since the design and operation of PARIS are very similar to those of the ACE-FTS, the ground-based instrument will provide comparison data to relate ground-based and on-orbit measurements. The Arctic Validation Campaign will also provide an important opportunity for intercomparison between the MSC and PARIS FT instruments.

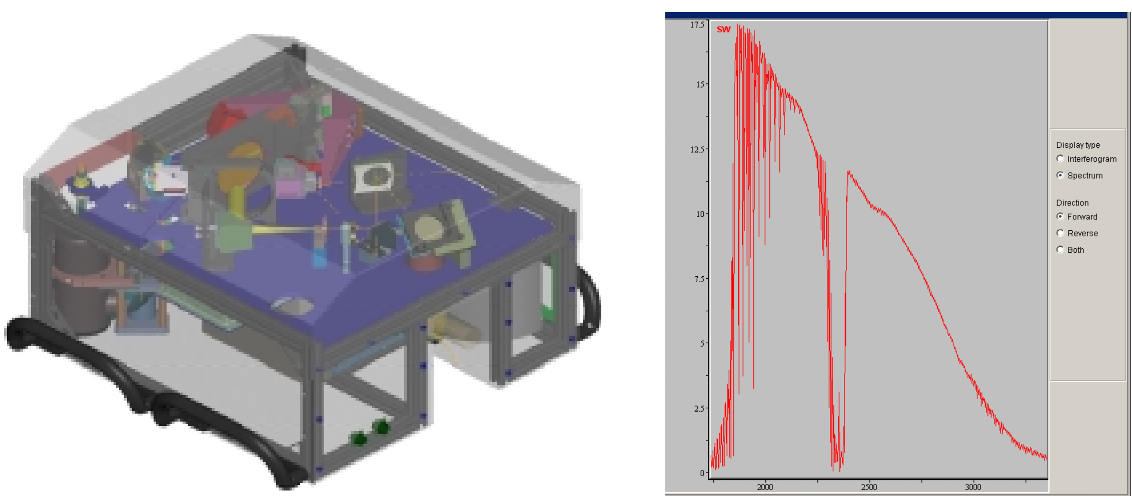

Figure 4. (a) Schematic of the PARIS FTS, and (b) the first spectrum measured with the PARIS instrument. This was recorded with the InSb detector using a 800°C blackbody source, a resolution of 1 cm^{-1}, and no co-adds.

MAESTRO-G and SPS-G

The MAESTRO-G spectrometer is a ground-based version of the Scisat-1 MAESTRO instrument. It was successfully flown as MAESTRO-B on the MANTRA 2002 balloon flight that took place on September 3rd 2002, when it recorded sunset occultation spectra from a float altitude of 34 km, from which ozone profiles have been derived as shown in Figure 5. It consists of two independent spectrometers, operating from 285 to 550 nm and from 525 to 1030 nm. It uses a concave holographic grating with 1024 pixel photodiode array detector, providing 1-2 nm spectral resolution. The MAESTRO-G detector is uncooled, but operation on the roof of ASTRO at typical temperatures of –30 to -40°C should provide sufficient cooling to reduce the dark current down to about 1%. Spectra will be collected using both zenith-sky and direct solar viewing. These raw spectra will be corrected for bias, stray light, dark current, and both wavelength and absolute lamp calibration. A chi-squared minimization technique will be used to retrieve slant column densities as a function of solar zenith angle, from which vertical columns will be derived (McElroy *et al.*, 1994; McElroy 1995). In addition to providing complementary data for comparison with the flight instrument, MAESTRO-G should measure total columns of ozone, NO_2, H_2O, OClO, BrO, SO_2, and aerosol optical depth for validation.

MSC's SunPhotoSpectrometer (SPS), the forerunner of MAESTRO, is also included in the campaign. SPS instruments have been flown on STS-52, aboard the ER-2 as part of the NASA Upper Atmospheric Research and High Speed Research Programs (McElroy, 1995; McElroy *et al.*, 1995), and on the MANTRA 1998, 2000, 2002 balloon flights. A ground-based version, SPS-G, has also been deployed during the MANTRA campaigns and at the Toronto Atmospheric Observatory.

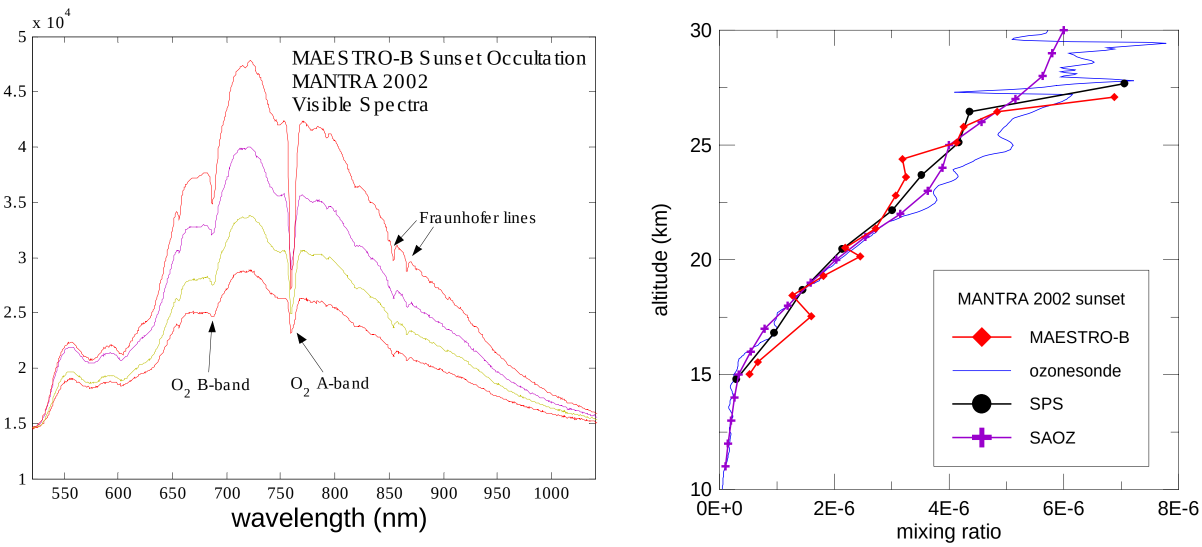

Figure 5. (a) Visible spectra recorded by MAESTRO-B at sunset from 34 km float altitude during the MANTRA 2002 balloon campaign (signal is in raw detector counts). (b) Preliminary sunset ozone profile retrieved from MAESTRO-B, and compared with three other MANTRA 2002 ozone profiles. (Nowlan *et al.*, 2003)

University of Toronto UV-visible Grating Spectrometer

The University of Toronto UV-visible grating spectrometer was assembled in 1998, and has been deployed on eight field campaigns: at Vanscoy for MANTRA 1998, 2000, and 2002, at ASTRO in spring 1999, 2000, 2001, and 2003, and at Resolute Bay in spring 2002 (Bassford *et al.*, 2000; 2001; in press). It consists of a triple-grating spectrometer with diffraction gratings of 400, 600 and 1800 grooves/mm, providing spectral resolutions of 2.0, 0.9, and 0.5 nm (FWHM). The detector is a thermoelectrically cooled CCD array. The instrument is automated and will be used to record UV-visible absorption spectra of the light scattered from the zenith sky. These will be analyzed using the technique of differential optical absorption spectroscopy (DOAS) to retrieve vertical columns of O_3 and NO_2. Vertical profiles of NO_2 will also be derived from the measurements of NO_2 slant column variation with solar zenith angle, as shown in Figure 6. Typical accuracies for the O_3 and NO_2 vertical columns are ±5% and ±10-12%, respectively. NO_2 volume mixing ratio profiles can be retrieved at a vertical resolution of 5-7 km with accuracies ranging from 10-50% depending on altitude, location, and profile.

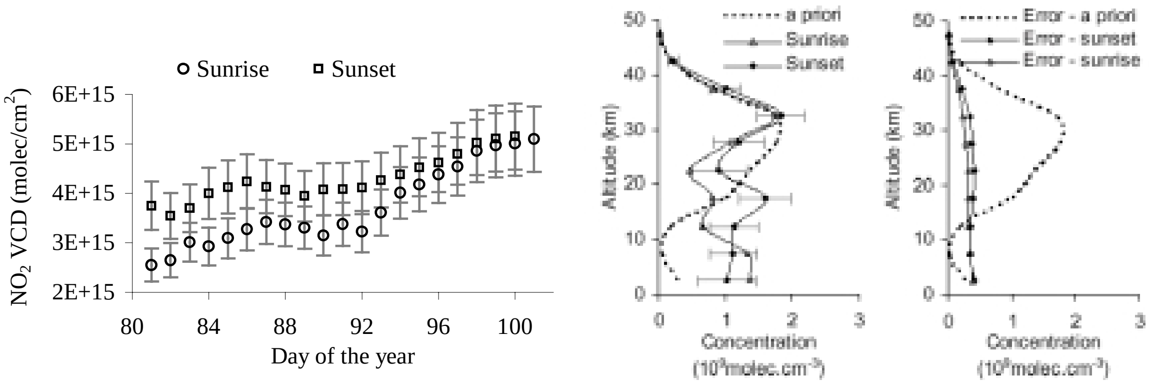

Figure 6. (a) NO_2 vertical column densities measured at Eureka in winter-spring 1999 using the University of Toronto UV-visible spectrometer. (b) Left: NO_2 profiles retrieved for SZA=90° on March 31, 1999 (day 90) compared with the initial profile. Right: the error in the a priori and retrieved profiles. (Melo *et al.*, in press)

Table 5. The baseline target species for ACE-FTS and MAESTRO, and the measurements and accuracies anticipated from the proposed Arctic Validation Campaign. C = column, P = profile.

Species	**DA8 FTS**	**Lidar**	**Brewer**	**Sondes**	**PARIS**	**MAESTRO-G**	**DOAS**
O_3	10% (C), ✔ (P)	6% (P)	1% (C), Umkehr (P)	10% (P)	✔ (C)	✔ (C)	5% (C)
CH_4	6% (C), ✔ (P)				✔ (C)		
H_2O	✔ (C)	✔ (P)			✔ (C)		
NO	25% (C)				✔ (C)		
NO_2	25% (C)				✔ (C)	✔ (C)	10-12% (C) 10-50% (P)
$ClNO_3$	30% (C)				✔ (C)		
HNO_3	13% (C), ✔ (P)				✔ (C)		
N_2O	6% (C), ✔ (P)				✔ (C)		
N_2O_5							
HCl	5% (C), ✔ (P)				✔ (C)		
CCl_3F	✔ (C)				✔ (C)		
CCl_2F_2	✔ (C)				✔ (C)		
HF	10% (C), ✔ (P)				✔ (C)		
CO	8%(C),				✔ (C)		

	✔ (P)						
Aerosol		0.0005 (P: scattering ratio)	aerosol OD			aerosol OD	
Pressure, & Temp.		3°C (P)		P: 0.5mb (P) T: 0.2°C (P)			
Other species			SO_2, UV-B			H_2O, OClO, BrO, SO_2	

4. Relationship to Future Plans for Eureka and to the ACE Validation Plan

Relationship to Future Plans for Eureka

As noted in Section 1, the Arctic Stratospheric Ozone Observatory was mothballed in summer 2002 due to budget constraints at Environment Canada. This decision was greeted with dismay in the Canadian and international atmospheric science community, and had a direct impact on the research program of Prof. K. Strong, as a fifth springtime Arctic campaign had been planned for 2003 using her UV-visible grating spectrometer, as part of a CFCAS-funded project to study the Arctic stratosphere. A formal request to the Canadian Foundation for Climate and Atmospheric Science for one-time supplementary funds to enable deployment of this instrument and operation of MSC's Fourier transform spectrometer was successful, and three graduate students flew to Eureka in late February to set up the instrument, along with an MSC scientist and an ASTRO operator. After the campaign ended in April, ASTRO was mothballed again. As Strong's CFCAS project ends this year, a repeat of this scenario in 2004 is not possible.

Several proposals are currently in progress, under the leadership of Prof. J.R. Drummond, to find a long-term solution for ensuring the continuity of the Eureka facility in future years. A proposal to the Canada Foundation for Innovation (CFI) was submitted in May 2003 to equip the Polar Environment Atmospheric Research Laboratory (PEARL) at Eureka for comprehensive measurements of the Arctic atmosphere. The PEARL will use the ASTRO facility, and will effectively replace it, as it will be significantly upgraded with a broader range of instrumentation and science goals than ASTRO. This CFI proposal is the first from a new network of researchers known as the Canadian Network for the Detection of Atmospheric Change (CANDAC). This network of researchers and resources is being initiated to address the challenges of air quality, the health of the ozone layer, and climate change. The CFI proposal is thus part of a larger set of proposals that are being prepared for submission to other agencies for ongoing support for the PEARL and other related activities. If such support is not forthcoming, then Canada will lose a unique observing facility. Because it costs a significant amount of money to keep viable even while mothballed, if it is not used, then the ASTRO building will probably be demolished.

A decision from CFI is not expected until March 2004, which is too late to provide any support for spring 2004 measurements at Eureka. Therefore, without the funding provided by the Canadian Space Agency for this campaign, there would be no measurements at ASTRO in spring 2004 that could be used for ACE Arctic validation. In addition to providing the only comprehensive set of Canadian Arctic measurements for validation of the ACE mission, CSA's support will have several additional benefits. Firstly, it will maintain the continuity of ASTRO measurements, which have been made since 1993. The loss of spring 2004 measurements (assuming another source of funding can be found to enable the reopening of ASTRO for measurements in 2005 and beyond), would leave a gap in our understanding of the Arctic stratosphere over Canada. Secondly, CSA support will ensure that the MSC lidar and the MSC DA8 FTS are kept in working order for possible future use. Both are complex instruments that require careful maintenance and alignment. The longer they are left unattended, the more difficult it will be to return them to operation in the future. Finally, the proposed Arctic measurements can also be used to complement and validate other satellite missions, particularly the OSIRIS and SMR instruments on the Swedish Odin satellite, which is also studying Arctic ozone loss. OSIRIS is a Canadian instrument, funded by CSA.

MSC is fully supportive of this effort to reopen ASTRO for the spring 2004 campaign. MSC is contributing scientific personnel to participate in the campaign and to operate the MSC FTS, MAESTRO-G, and SPS-G, along with the Brewer and ozonesondes.

Costs for the Arctic Validation Campaign are being controlled through the University of Toronto, which is managing the contract with CSA. The overall management of the program is under the joint direction of ACE Validation Team Co-Leaders K. Walker and K. Strong, including tracking of costs and schedule.

Relationship to the ACE Validation Plan

As noted in Section 1, ACE validation will rely on measurements provided by groups using satellite-borne, balloon-based, aircraft-based, and ship-borne instruments and sites making routine or campaign ground-based measurements using Fourier transform (both infrared and UV/Visible), differential optical absorption spectroscopy (DOAS), Brewer spectrometer, filter spectrometer and lidar techniques. Validation must be done for all locations and seasons of interest, as the concentrations of many of the ACE baseline species have significant spatial and temporal variability.

The focus of this project is validation during the Arctic springtime, as well-validated profile measurements under such conditions will be essential to meet the Priority One science goals for the ACE mission.

(a) Measurement of regional polar O_3 budget to determine the extent of O_3 loss. This will require measurements of O_3, tracers (CH_4 and N_2O), and meteorological variables (pressure and temperature).
(b) Measurement / inference of details of O_3 budget by detailed species measurements (for O_3, H_2O, NO, NO_2, N_2O_5, HNO_3, HNO_4, HCl, $ClNO_3$, ClO) and modelling.
(c) Measurement of composition, size and density of aerosols and PSCs in the visible, near IR and mid IR.
(d) Comparison of measurements in the Arctic and Antarctic with models to provide insight into the differences, with emphasis on the chlorine budget and denitrification.

The following is a brief summary of other Arctic measurements that are expected to be available for ACE validation, as discussed in the "*ACE Validation and Ground Truthing Plan*". Figure 7 indicates the locations of some of the sites mentioned below.

- **Balloons:** There are only two balloon flights committed for the ACE validation program. One is the mid-latitude MANTRA 2004 campaign, and the other is a flight of the Limb Profile Monitor of the Atmosphere (LPMA) experiment that makes solar absorption measurements using a Fourier transform spectrometer (DA2 FTS). The target species for the LPMA are profiles of O_3, CH_4, H_2O, NO, NO_2, $ClNO_3$, HNO_3, N_2O, HCl, CCl_2F_2, HF. However, the location for the LPMA flight will depend on when the ACE satellite instruments are operational. The three current possibilities for 2003-2004 are Kiruna (March 2004), Aire-sur-l'Adour (ASA) (September/October 2003) or Gap (June 2004). Only Kiruna (68°N, 21°E) would provide Arctic measurements.

- **Aircraft:** The high altitude research aircraft Geophysika (M-55) will make several flights as part of the ENVISAT validation campaign, carrying three instruments to measure vertical profile from the tropopause to ~20 km of O_3, NO_2, HNO_3, N_2O, and HCl. Aircraft are flying in the tropics (Bauru, Brazil) in January/February 2004, but no Arctic flights are planned.
- **Satellites:** There are eleven satellite-based instruments, currently on-orbit, which will participate in the ACE validation program. These are HALOE on UARS (measuring profiles of O_3, CH_4, H_2O, NO, NO_2, HCl, HF), MOPITT on Terra (CO, CH_4), SBUV/2 on NOAA-17 (O_3), OSIRIS on Odin (O_3, NO_2, aerosol), SMR on Odin (O_3, H_2O, CO, NO, HNO_3, N_2O, HCl), SABER on TIMED (O_3, CH_4, H_2O, NO, NO_2, HCl, HF), SAGE III (O_3, H_2O, N_2O, aerosol), GOMOS on ENVISAT (O_3, NO_2, aerosol), MIPAS on ENVISAT (O_3, CH_4, H_2O, NO, NO_2, HNO_3, $ClNO_3$, N_2O, N_2O_5, CCl_3F, CCl_2F_2, aerosol), SCIAMACHY on ENVISAT (O_3, CH_4, H_2O, NO_2, N_2O, HF?), and ILAS-II on ADEOS-II (O_3, CH_4, H_2O, NO_2, $ClNO_3$, HNO_3, N_2O, CCl_3F, CCl_2F_2, aerosol).
- **Ozonesondes and ground-based Brewer spectrometers:** The primary source of ozone data for the ACE validation program will be the MSC. Arctic data will be provided from Eureka, Alert (82.5°N, 62.5°W), and Resolute Bay (75°N, 95°W)**.** The Brewer spectrometers provide total column measurements of O_3 every 15-20 minutes throughout the daylight hours, and weekly ozonesonde measurements are made at these locations. Ozone data for sites outside of Canada will be obtained from the World Ozone Data Centre and the Russian ozone monitoring network coordinated by St. Petersburg State University, and includes several Arctic sites in Europe. NASA Goddard (Brewer, SSBUV) and NIWA (ozonesondes) will also provide ozone measurements.
- **Ground-based Fourier transform spectrometers:** There are about two dozen infrared and UV-visible Fourier transform spectrometers and IR grating spectrometers that will provide routine measurements of total columns and/or coarse resolution profiles for ACE validation. Of these, only four are located north of 60°N: FTSs at Ny Aalesund, Spitzbergen (79°N, 12°E), Thule, Greenland (77°N, 69°W), Kiruna, Sweden (68°N, 20°E), and Poker Flat, Alaska (65°N, 147°W). Two others are at 60°N: a FTS at Harestua, Norway (60°N, 11°E), and an IR grating instrument at St. Petersburg, Russia (60°N, 30°E).
- **Ground-based UV-visible DOAS instruments:** A number of UV-visible spectrometers will contribute validation data, including the networks operated by the Belgian Institute for Space Aeronomy, the CNR-ISAC in Bologna, Italy (GASCOD-GB), and the BREDOM group of spectrometers, coordinated by the University of Bremen. Of these, only three are located at 60°N or higher: Summit, Greenland (72°N, 38°W), Ny Aalesund, and Harestua.
- **Ground-based lidars:** Several lidar instruments will participate in ACE validation, but only one Arctic lidar. This is the ALOMAR Differential Absorption Lidar at Andøya, Norway (69°N, 16°E), which measures profiles of O_3 and temperature.

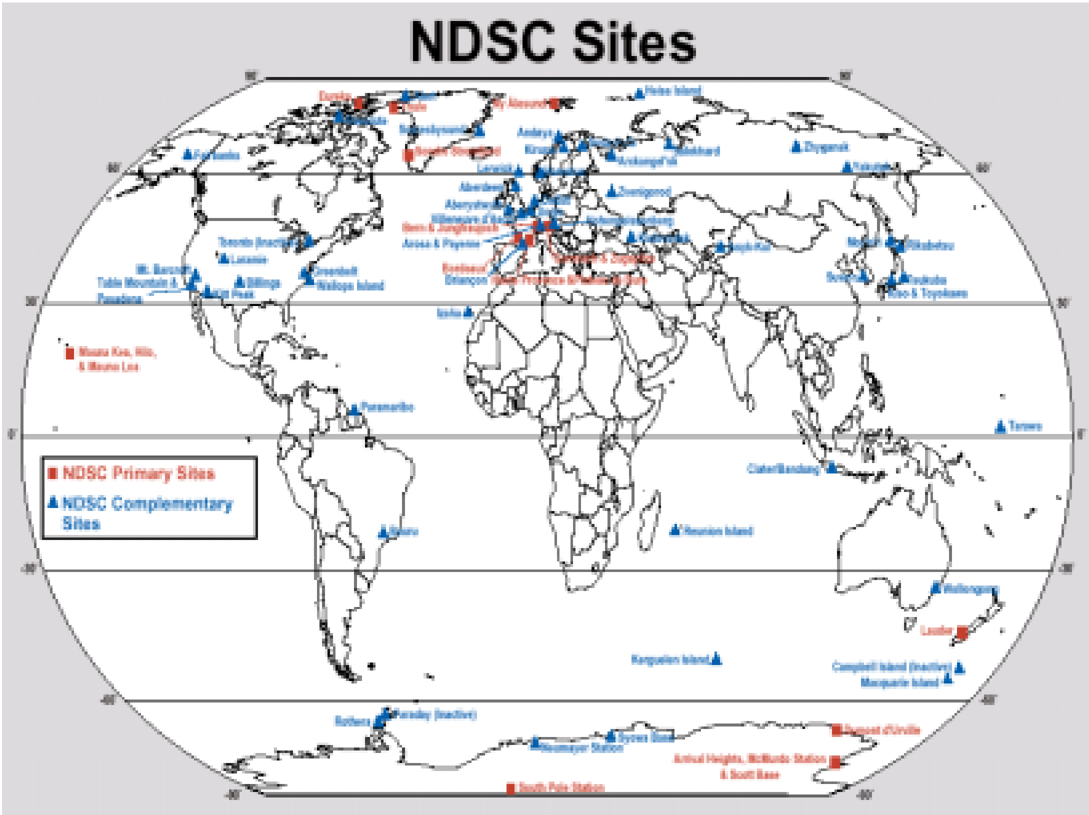

Figure 7. Global map showing sites belonging to the Network for the Detection of Stratospheric Change. Many of ground-based instruments that will participate in ACE validation are located at these sites. (http://www.ndsc.ncep.noaa.gov/)

Clearly, validation of ACE-FTS and MAESTRO will benefit from comparisons with all of the above data sets, with each offering its own particular advantages and disadvantages. Comparisons of each of the various satellite data sets with ACE will be a major component of the validation effort, however, none of the satellite instruments will provide a continuous measurement at any location and not all will provide good coverage of the springtime Arctic stratosphere. The strength of the ground-based measurements, such as those proposed for the ACE Arctic Validation Campaign, is the provision of daily measurements at high temporal resolution that will give context to the sparse (in time and space) ACE occultation measurements. In this way, the proposed campaign will also provide correlative data that can be used to complement the ACE measurements and thereby augment the scientific return from the mission, particularly with regard to the investigation of Arctic stratospheric processes. Of the ground-based stations that will participate in ACE validation, only one (Ny Aalesund, Spitzbergen at 79°N, 12°E) is at a comparable latitude and has a similar instrument suite. The ASTRO site is truly unique in Canada and with its particularly clear skies and location relative to the polar vortex, also one of the best sites in the world for making ground-based observations of the Arctic stratosphere.

5. Science Team

ACE Validation Team Co-Leader Kimberly Strong (University of Toronto) will share responsibility for managing the Arctic Validation Campaign. She will contribute her research experience in remote sounding of atmospheric composition from ground-based, balloon-borne, and satellite instruments. She is the PI for the Middle Atmosphere Nitrogen TRend Assessment (MANTRA) balloon mission to investigate the changing chemical balance of the mid-latitude stratosphere, and PI for the University of Toronto Atmospheric Observatory (TAO) which includes both UV-visible and Fourier transform infrared spectrometers. Strong is a Co-Investigator on the Canadian Odin/OSIRIS Aeronomy Science Team, and for both instruments on SCISAT-1. In addition to ensuring that the Arctic Validation Campaign achieves its scientific objectives, Strong will have primary responsibility for deployment of the University of Toronto UV-visible grating spectrometer at Eureka and the subsequent data analysis.

ACE Validation Team Co-Leader Kaley Walker (University of Waterloo) will share responsibility for managing the Arctic Validation Campaign with Strong. She will also have primary responsibility for deployment of the University of Waterloo PARIS FTS and analysis of the data taken during the campaign. Walker has a leading role in the both the testing and validation of the instruments on the ACE satellite. She is also in charge of the development and operation of the Waterloo Atmospheric Observatory (WAO), where the PARIS FTS will be located when it is not in the field. She has expertise in microwave and millimeter wave spectroscopy, Fourier transform spectroscopy, and instrument construction, which she will contribute to the Arctic Validation Campaign.

Peter Bernath (University of Waterloo) is the Mission Scientist for ACE. He is an experimental molecular spectroscopist with experience working primarily in the infrared and visible regions. He works with both lasers and Fourier transform spectrometers to study species found in the laboratory, in the Earth's atmosphere and in astrophysical environments. He is director of the Waterloo Atmospheric Observatory, and will be providing the PARIS FTS to the the proposed campaign. He holds the NSERC/Bomem/CSA/MSC Industrial Chair in Fourier Transform Spectroscopy.

Co-Investigator James R. Drummond (University of Toronto) is an experimentalist in the area of remote sounding instrumentation and specializes in measurements of atmospheric constituents using radiative techniques. He is the PI of the MOPITT space instrument, a Co-I on both the MAESTRO and ACE-FTS instruments, and holds the COMDEV/Bomem/MSC/CSA/ University of Toronto/NSERC Industrial Research Chair in Atmospheric Remote Sounding from Space. He is leading the establishment of the Canadian Network for the Detection of Atmospheric Change and associated proposals for equipping and operating the Polar Environment Atmospheric Research Laboratory at Eureka. Drummond will serve as liaison for these projects and will also support the deployment of the MAESTRO-G instrument during the campaign.

Co-Investigator Hans Fast (Meteorological Service of Canada) has extensive experience in measurements of atmospheric constituents using FTS infrared solar absorption spectrosccopy. He has carried out ground-based FTS measurements of atmospheric gases at the Arctic Stratospheric Ozone Observatory at Eureka and at Environment Canada's Centre for Atmospheric Research Experiments at Egbert north of Toronto. Fast has managed the various measurement programs of the Eureka observatory. He is also PI of the DA8 FTS at Eureka and a science team member for the validation of the MOPITT and ACE satellite measurements. Fast will manage ASTRO operations for the Arctic Validation Campaign. He also will participate in the campaign, operate the MSC Fourier transform spectrometer there, and contribute to analysis of the resulting data.

Co-Investigator C. Thomas McElroy (Meteorological Service of Canada) has extensive experience in remote sounding of the stratosphere from ground-based, balloon, aircraft, and Space Shuttle platforms. He was a co-inventor of the Brewer Ozone Spectrophotometer, and designed a novel double spectrometer version which is now in commercial production. He was Deputy PI for the SunPhotometer Earth Atmosphere Measurement flown on the US Space Shuttle in October 1992, PI for the CPFM experiment flown as part of the NASA SPADE, ASHOE/MAESA, and STRAT projects, and is Environment Canada Lead Scientist on the MANTRA balloon project. He is also PI for MAESTRO. McElroy will have primary responsibilty for the deployment, operation, and subsequent data analysis for the MAESTRO-G instrument.

Co-Investigator Richard Mittermeier (Meteorological Service of Canada) has experience in measurements and analysis of atmospheric constituents using FTS infrared solar absorption spectroscopy and DIAL systems. He has carried out ground-based FTS measurements of atmospheric gases at the Arctic Stratospheric Ozone Observatory at Eureka and at Environment Canada's Centre for Atmospheric Research Experiments (CARE) at Egbert north of Toronto. He has also carried out ground-based DIAL measurements for stratospheric ozone, aerosols and temperature profiles at ASTRO in Eureka and at York University in Toronto. Mittermeier is responsible for the analysis of the FTS data acquired at Eureka and Egbert and is the Egbert FTS Data Originator (DO) for the validation of ENVISAT. He has extensive experience in the development of in-house software (SSFIT) to make the analysis of FTS data with NASA Langley's SFIT software more automated and hence much faster and efficient. Mittermeier will participate in the campaign, will operate the MSC DIAL and FTS, will be responsible for providing the MSC ozonesonde and Brewer data to the project, and will contribute to the analysis of the resulting data.

In addition to the seven members of the Science Team listed above, the Arctic Validation Campaign involves a number of undergraduate and graduate students, post-doctoral fellows (PDFs), and research associates (RAs), thus contributing to the training of highly qualified personnel. The following are participating in the campaign and/or the subsequent data analysis:

- Graduate student Annemarie Fraser (University of Toronto) has participated in two Arctic campaigns with the U of T UV-visible grating spectrometer, and is working on coupling it to a telescope to enable night-time measurements using stars as sources.
- Graduate student Elham Farahani (University of Toronto) has participated in four Arctic and two MANTRA campaigns with the U of T UV-visible grating spectrometer, and is currently working on the analysis and interpretation of the resulting data, including comparisons with measurements by MSC's ASTRO FTS, output from the Canadian Middle Atmosphere Model, and output from the SLIMCAT chemical transport model.
- Graduate student Caroline Nowlan (University of Toronto) has participated in two MANTRA campaigns, working with MSC's SunPhotoSpectrometers and MAESTRO-B.
- Post-doctoral fellow Dr. Hongjiang Wu (University of Toronto) participated in the MANTRA 2002 campaign and is preparing for MANTRA 2004, working with MSC's SunPhotoSpectrometers, which are the predecessors to MAESTRO.

- Post-doctoral fellow Dr. Tobias Kerzenmacher (University of Toronto) recently began working on the ACE project, and will be participating in ACE validation activities.
- Research Associate Dr. Stella Melo (University of Toronto) has participated in two Arctic campaigns with the U of T UV-visible grating spectrometer, is working on the interpretation of data from all three MANTRA flights, and will be involved in NO_2 profile retrievals from the Eureka measurements and in ACE validation activities.
- Undergraduate student Girjesh Dubey (University of Waterloo) is involved in preparations for the installation of the PARIS FTS at the WAO and for its participation in the MANTRA 2004 campaign.
- New graduate student Dejian Fu (University of Waterloo) will be involved in setting up the SFIT retrieval code at the WAO and assisting with the commissioning of the PARIS instrument.
- Post-doctoral fellow Keeyoon Sung (University of Waterloo) will be working with the PARIS FTS instrument at the WAO and will be participating in ACE-FTS validation.

6. Schedule and Milestones

The nominal project schedule and milestones are outlined in Table 6 below, with Table 7 giving details of the travel and shipping schedule for the campaign.. The First Planning Meeting was held on December 9, 2003 and brought together the project team (the ACE Validation Team Co-Leaders, the ACE Mission Scientist, and the Co-Investigators), as well as students, and other relevant scientific and technical personnel. At this time, the status of the instruments was reviewed, tasks required to prepare them for the spring campaign were determined, and details of the spring campaign were discussed. A Second Planning Meeting was held January 15, 2004 to review final preparations for the spring measurements.

DIAL and FTS accessories were to ship to Eureka on the January 25 produce charter flight, and LN_2 was flown to Resolute Bay on February 15 to meet the produce charter flight. Mike Butler and Tobias Kerzenmacher drove to First Air Ottawa on Monday February 9 with equipment from UW, U of T, and MSC. PARIS was sent directly there from Bomem. First Air received a total of 15 boxes weighing 541 kg (1193 lb). This included all instruments from UW, U of T, and MSC, except for MAESTRO-G, some smaller items, and some laptop computers, all of which will go with team members. First Air in Resolute Bay has confirmed that all 15 boxes arrived there on the February 11 flight and was flown onto Eureka on February 17. The science team arrived at Eureka in two groups, one on February 15 and one on February 16.

For most instruments (MSC FTS, PARIS, MAESTRO-G, SPS-G), personnel will have to remain on-site for the duration of the campaign to actively operate the instruments. For others (U of T UV-visible spectrometer, Brewer – already working), it should be possible to leave the instrument running in an automated mode after the initial set-up and testing, as has been done in previous years. Given that the closest ACE overpasses of Eureka occur between February 21 and March 10, this period will correspond to the "intensive" measurement phase, during which all instruments will be operated to the maximum extent possible, and ozonesondes will be launched daily. After this, an "extended" measurement phase will begin, during which the UV-visible spectrometer operation will be automated, the on-site ASTRO operator will be responsible for continuing operation of the MSC FTS, and ozonesondes will resume weekly launches. Instruments will be packed up and shipped back to Toronto in mid-March and mid-April 2004.

As part of the overall ACE Validation Plan, a Preliminary ACE Validation Data Workshop is planned for approximately eight months after the launch of Scisat-1. Initial results from the Arctic Validation Campaign will be presented at this meeting. These results will also be provided to CSA as a Post-Campaign Report by May 31. Analysis of data from the campaign, and comparison with ACE-FTS and MAESTRO measurements will continue through the year. A Second ACE Validation Data Workshop is also planned, this one to be held 6-8 months after the first. At this meeting, more detailed results of the data analysis, validation, and scientific interpretation will be presented. A Final Report on the results from the Arctic Validation Campaign will be submitted to CSA by December 31, 2004.

Table 6. Schedule for the Arctic Validation Campaign.

MILESTONE	**NOMINAL DATE**
ACE Arctic Validation Campaign proposal submitted	August 11, 2003
Launch of Scisat-1	August 12, 2003
Decision from CSA	November 2003
Nominal start of PWGSC contract	December 1, 2003
First Planning Meeting	December 9, 2003
Second Planning Meeting	January 15, 2004
Ship instruments to Eureka for spring campaign	Feb. 9-17, 2004
Science team arrival at Eureka for spring campaign	February 18, 2004
"Intensive" phase of the spring campaign • daily ozonesonde measurements • measurements by all instruments	February 21 – March 10, 2004
"Extended" phase of the spring campaign • weekly ozonesonde measurements • reduced set of measurements	March 11 – April 18, 2004
Ship instruments back to Toronto	April 18, 2004
Preliminary ACE Validation Data Workshop	May 2004
Post-Campaign Report to CSA	May 31, 2004
Second ACE Validation Data Workshop	December 2004
Final Report to CSA	December 31, 2004

Table 7. Detailed travel and shipping schedule for the Arctic Validation Campaign.

Flights to/from Eureka	**People (200 lb each – charter allowance)**	**Equipment**	**Total Mass (lb and kg)**
Resolute to Eureka			
Existing Sunday, January 25 produce charter	None	FTS and DIAL accessories	?
Existing Sunday, February 15 produce charter *(will meet rescheduled Sunday February 15 First Air flight from Ottawa to Resolute)*	MacQuarrie Mittermeier Berman,McElroy Strawbridge + 2 Eureka staff *(total = 1400 lb)*	• approx. 700 lb of produce • 290 lb crate of liquid nitrogen	2390 lb *Max charter load = 2500 lb*
New dedicated charter Tuesday February 17	No people	• PARIS, SPS-G (x2), solar tracker, U of T grating spectrometer, accessories (15 boxes) = 541 kg = 1193 lb • MAESTRO-G = 20 kg = 44 lb • *(total =561 kg = 1237 lb)*	1237 lb
New dedicated charter Wednesday February 18 *(will meet Wednesday February 18 First Air flight from Ottawa to Resolute)*	Walker, Sung Midwinter Wu, Fraser Kerzenmacher *(total = 1200 lb)*	*Strawbridge and McElroy return to Resolute on this charter after it stops overnight in Eureka*	1200 lb
Intensive campaign phase: February 21 to March 10			
Eureka to Resolute			
Existing Sunday, March 7 return produce charter *(use Wednesday, March 10 First Air flight from Resolute to Ottawa)*	TBD, probably Mittermeier Berman + others ? *(total = 400+ lb)*	DIAL accessories	400+ lb *Weight for return charter not critical.*
New dedicated Tuesday, March 9 charter *(use Wednesday, March 10 First Air flight from Resolute to Ottawa)*	TBD, probably Walker, Sung Midwinter Wu, Fraser Kerzenmacher *(total = 1200 lb)*	• PARIS, SPS-G (x2), solar tracker, MAESTRO-G *(total approx. 361 kg = 800 lb)*	2000 lb *Note: can be reduced if more people take March 7 charter*
Extended campaign phase: March 11 to April 18			
Eureka to Resolute			
Existing Sunday, April 18 return produce charter *(use Weds., April 21 First Air flight Resolute-Ottawa)*	MacQuarrie *(total = 200 lb)*	• U of T grating spectrometer = 177 kg = 390 lb • FTS accessories	590+ lb

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