

# Validation measurement program for the Atmospheric Chemistry Experiment (ACE)

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## ABSTRACT

SCISAT-1, the Atmospheric Chemistry Experiment, will use the solar occultation technique to make measurements of trace gases, atmospheric extinction, temperature, and pressure in the stratosphere and upper troposphere. The accuracy and reliability of the ACE results will be demonstrated through a validation program including ground-, balloon-, and satellite-based observations. This program will be ongoing throughout the lifetime of the mission. To provide sufficient global coverage, a worldwide group of participants will be collaborating with the ACE Validation team. Descriptions and locations of the validation experiments are given.

**Keywords:** ACE, SCISAT-1, solar occultation, validation experiments

## 1. INTRODUCTION

The Atmospheric Chemistry Experiment will be launched by the Canadian Space Agency in December 2002 on board the scientific satellite SCISAT-1. The mission lifetime is expected to be greater than two years. The goal of ACE is to improve our understanding of the chemical and dynamical processes that control the distribution of ozone in the upper troposphere and stratosphere. In particular, it will focus on the decline of stratospheric ozone at northern mid-latitudes and in the Arctic. A high inclination (74 degrees) low earth orbit (650 km) was chosen for SCISAT-1 to provide the measurements necessary to meet this objective.

The ACE payload consists of two instruments: a Fourier transform infrared spectrometer and a UV/visible spectrograph. These sensors will use solar occultation to measure a series of atmospheric absorption spectra during each sunrise and sunset. Vertical profiles of trace gases, aerosol/cloud extinction, temperature, and pressure will be derived from these observations.

The accuracy and reliability of these profile results will be established through comparisons with a series of measurements made by satellite-, balloon-, aircraft-, ground-, and ship-based instruments. This paper outlines the approach to validation which will be used for the ACE validation program and the experiments that have been assembled to provide comparison data and collaborate with the ACE Science team in making the validation analyses.

## 2. ACE INSTRUMENTS AND MEASUREMENTS

The primary ACE instrument is ACE-FTS which is a high resolution ( $0.02 \text{ cm}^{-1}$ ) Fourier transform infrared (FTIR) spectrometer with an operating range of  $750\text{-}4100 \text{ cm}^{-1}$ . This instrument also includes a two channel visible/near infrared imager measuring at  $0.525 \mu\text{m}$  and  $1.02 \mu\text{m}$ . The fourteen baseline trace gas measurements to be made by the ACE-FTS are listed in Table 1. The solar imagers will be used to provide data on atmospheric extinction caused by clouds and aerosols. Pressure and temperature profiles will be determined using a fixed  $\text{CO}_2$  volume mixing ratio. ACE-FTS will provide results over 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 baseline species are listed in Table 1. The temperature and pressure retrievals will be made with estimated accuracies of 2-3 K and 2 %, respectively.

MAESTRO (Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation), is a dual spectrograph that will provide measurements in the UV/visible/near infrared region for the ACE

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

Species	Altitude Range (km)	Accuracy (%)
O <sub>3</sub>	10-50	5
CH <sub>4</sub>	10-50	5
H <sub>2</sub> O	10-50	5
NO	15-100	5
NO <sub>2</sub>	15-50	5
ClNO <sub>3</sub>	15-40	20
HNO <sub>3</sub>	15-40	15
N <sub>2</sub> O	10-50	5
N <sub>2</sub> O <sub>5</sub>	20-40	20
HCl	15-50	5
CCl <sub>3</sub> F	10-30	10
CCl <sub>2</sub> F <sub>2</sub>	10-30	10
HF	15-50	5
CO	15-100	5

mission. This secondary instrument will cover the range from 285 to 1030 nm with 1-2 nm resolution. Profiles of O<sub>3</sub>, NO<sub>2</sub> and aerosol/cloud extinction are to be retrieved from MAESTRO observations on an operational basis. The altitude range, estimated accuracy and vertical resolution for these baseline measurements are given in Table 2. Also, an independent determination of atmospheric temperature and pressure will be made using the oxygen *A*-, *B*-, and  $\gamma$ -bands. The accuracies are estimated to be 5 % for pressure and 2 K for temperature.

### 3. VALIDATION APPROACH

The starting point for the ACE validation program is the following definition of validation: *the process of assessing, by independent means, the quality of the data products derived from system outputs.*<sup>1</sup> To do this, the ACE results will be compared to observations made from a range of locations and platforms by instruments employing a number of different techniques. The validation data set will consist of both vertical profile and column measurements made by satellite-, balloon-, aircraft-, ship- and ground-based instruments. These experimental results will overlap in space and time with the ACE data as much as possible. Coincidence will be evaluated during analysis by employing atmospheric modelling techniques.

The term “validation experiment” is used to describe both validation and correlation measurements that are part of the validation data set. Observations that are coincident with ACE data (in both space and time) will be designated as validation results. Those not meeting the spatial and temporal overlap requirements but providing complementary information will be designated as correlation results. These results will provide useful data for regions and species not covered by the ACE instruments. The distinction between these two types of results will be made during analysis.

#### 3.1. Validation Process and Pre-validation Checks

The validation process will be undertaken in two phases: initial and ongoing. Following the commissioning of the ACE instruments, the initial phase will commence with comparisons of ACE data to results from other satellite-based experiments. The second phase will expand these comparisons to include balloon-, ground-, aircraft, and ship-based instruments as well as satellite measurements. This phase will be ongoing throughout the life of the ACE mission.

Prior to these validation comparisons, two checks will be done to ensure that the results are reasonable. Results from both instruments will be compared to those expected from climatology. Profile data from the two

**Table 2.** Baseline target species for MAESTRO measurements

Profile	Altitude Range (km)	Accuracy	Vertical Resolution (km)
O <sub>3</sub>	50-80	10%	1
	20-50	3%	1
	10-20	10%	1
	8-10	15%	2
NO <sub>2</sub>	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

instruments will also be intercompared. This comparison will be done for O<sub>3</sub> and NO<sub>2</sub> from ACE-FTS and MAESTRO and for the atmospheric extinction results from the ACE-FTS imagers and MAESTRO.

#### 4. VALIDATION EXPERIMENTS

A group of validation experiment teams has been assembled to collaborate on the ACE validation program. These teams make measurements using satellite-borne, balloon-based, aircraft-based, ship-borne and ground-based instruments. The experiments use Fourier transform spectrometers (FTS) (both infrared and UV/Visible), differential optical absorption spectroscopy (DOAS), Brewer, filter and grating spectrometers and lidar techniques. For each of the baseline species, atmospheric extinction, temperature and pressure, there are several measurement sites/platforms to provide validation data. These experiments can also provide data for validating most of the additional species which may be retrieved from the ACE measurements on a non-operational basis.

The validation experiments will provide either vertical profile or column results. Observations from balloon- and satellite-borne instruments, ozonesondes and ground-based lidar sites generate vertical profiles. Total column and/or coarse resolution vertical profiles are produced by ground-based instruments, such as FTS, DOAS, and Brewer spectrometers. Nadir-looking satellite instruments provide total column results in addition to vertical profiles. Figure 1 shows the global distribution of vertical profile and column measurements made by the ground- and ship-based validation experiments.

General descriptions of the experiments involved in the ACE validation program are given in the following sections. More detailed descriptions of each validation experiment are given in the ACE Validation and Ground Truthing Plan.<sup>2</sup>

##### 4.1. Satellite-based Instruments

Profile and column data from satellite-based instruments will be used for both the initial and ongoing phases of the ACE validation. These observations will have wide global coverage which will be very useful for the initial validation phase. Eleven satellite-based instruments will participate in the ACE validation program and these are listed in Table 3 by measurement technique (occultation, limb scanning, or nadir-viewing). The combined results from these satellite-based experiments will provide data for all ACE baseline species, atmospheric extinction, temperature, and pressure.

Since the launch dates for ACE and ADEOS-II are both near the end of 2002, the two validation programs will be nearly coincident. A validation cooperation program has been initiated with the ILAS-II team to take

**Table 3.** Satellite validation experiments

Solar/Lunar and Stellar Occultation Instruments	
Instrument (Platform)	Launch Date
GOMOS on ENVISAT	3-Jan-02
HALOE on UARS	15-Sep-91
ILAS-II on ADEOS-II	Nov-02 <sup>a</sup>
SAGE III	10-Dec-01
SCIAMACHY on ENVISAT	3-Jan-02

Limb Emission Measurements	
Instrument (Platform)	Launch Date
MIPAS on ENVISAT	3-Jan-02
OSIRIS on Odin	20-Feb-01
SABER on TIMED	7-Dec-01
SMR on Odin	20-Feb-01

Nadir Viewing Radiometers	
Instrument (Platform)	Launch Date
MOPITT on Terra	18-Dec-99
SBUV/2 on NOAA-17	21-Sep-00

<sup>a</sup> Current launch date for ADEOS-II satellite is near the end of November 2002.

advantage of this coincidence. This program will have two components: intercomparison of results from ACE and ILAS-II and collaboration on validation measurements. The second component will provide an opportunity to involve more validation experiment teams in each program and thus increase the geographical coverage of each.

It may be possible to arrange a similar cooperation agreement with the ENVISAT Calibration/Validation team. This opportunity is currently being investigated.

#### 4.2. Balloon and Aircraft Campaigns

Airborne platforms, such as balloons and aircraft, provide a method for obtaining profile measurements for atmospheric trace gases with a suite of instruments. Two balloon flights (LPMA and MANTRA 2003) have been committed for validation of ACE data and a further four have been identified as potential validation flights. The high altitude research aircraft Geophysika (M-55) will make mid-latitude and Arctic flights as part of the ENVISAT validation campaign. Three instruments in this program will also participate in ACE validation. The instruments for these balloon and aircraft missions are listed in Table 4 and are described below. When combined, the measurements from these missions will provide comparison data for all of the ACE baseline species, aerosols, temperature and pressure.

The Limb Profile Monitor of the Atmosphere (LPMA) experiment makes solar absorption measurements using a Fourier transform spectrometer (DA2 FTS). A DOAS spectrometer has been included as a secondary instrument on previous flights and may be included for the ACE validation flight. The location for the LPMA flight will depend on when the ACE satellite instruments are operational. The three possibilities for 2003 are Kiruna (ESRANGE) (in February/March, May/June or August/Sept.), Aire-sur-l'Adour (in April/May or Sept./Oct.) or Gap (in June). This flight is provided by CNES as part of the French contribution to the ACE mission.

The MANTRA (Middle Atmosphere Nitrogen TRend Assessment) 2003 mission will be launched from Vanscoy, Saskatchewan during turnaround in August 2003. The primary instruments are two Fourier transform

instruments (one of which is a copy of the ACE-FTS), SunPhotoSpectrometer (SPS) and/or MAESTRO clone, emission radiometer, ozonesonde and aerosol sonde. These will be accompanied by zenith sky UV/visible (SAOZ) and acousto-optic tunable filter (AOTF) spectrometers and a second emission radiometer. This mission is organized by the University of Toronto and their partners and is funded through the Canadian Space Agency Second Small Payloads Program and by the Meteorological Service of Canada (MSC) and the Natural Sciences and Engineering Research Council of Canada.

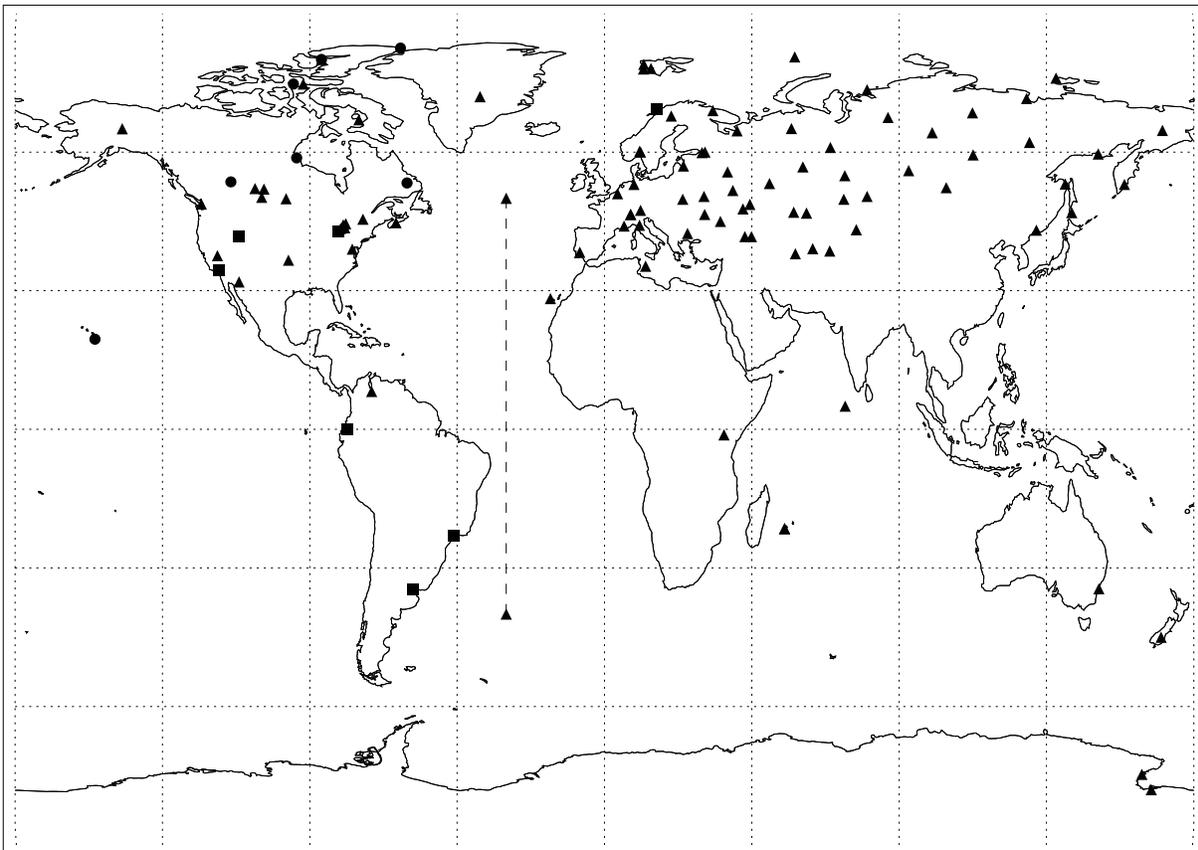
Of the potential flights, two have scheduled missions for 2003 while the other two are still in the planning stages. The University of Tokyo is coordinating a balloon flight from Kiruna, Sweden in February 2003 in sup-

**Table 4.** Balloon and aircraft campaigns

Committed Balloon Flights for 2003		
Flight	Instrument(s)	Location <sup>a</sup>
LPMA	LPMA DA 2 FTS	Kiruna, Sweden (68 N, 21 E) Aire-sur-l'Adour, France (44 N, 0 W) Gap, France (44 N, 4 E)
MANTRA 2003	ACE-Copy FTS Aerosol sonde AOTF Emission Radiometer 1 Emission Radiometer 2 FTS Ozonesonde SAOZ SPS/MAESTRO Brewer - ground-based DOAS - ground-based	Vanscoy, SK (52 N, 107 W)
<sup>a</sup> LPMA flight will be from one of these sites. Location will depend on the timing of the ACE launch and commitments to other validation programs.		
Potential Balloon Flights for 2003		
Flight	Instrument(s)	Location
U. Tokyo / ILAS-II	Aerosol Counter CASESR Chemiluniscence Detector Cryogenic Sampler Grab Sampler Ozonesonde	Kiruna, Sweden (68 N, 21 E)
MIPAS-B	MIPAS-B	Kiruna, Sweden (68 N, 21 E) Aire-sur-l'Adour, France (44 N, 0 E)
FIRS-2	Thermal Emission FTS	TBD
MkIV	MkIV FTIR	TBD
Potential Aircraft Flights for 2003		
Flight	Instrument(s)	Location
ENVISAT Validation	FOZAN-II GASCOD-A/4 $\pi$ SAFIRE-A	Kiruna, Sweden (68 N, 21 E)

port of the ILAS-II validation program. The payload includes an emission radiometer (CASESR), ozonesonde, chemiluminescence detector, aerosol counter and cryogenic and grab samplers. The Institute for Meteorology and Climate Research (IMK) in Karlsruhe, Germany is flying the MIPAS-B instrument, a balloon-borne version of the MIPAS limb-emission sounding mid-infrared Fourier transform spectrometer, as part of ENVISAT validation. Campaigns are planned for Kiruna in February 2003 and Aire-sur-l'Adour in autumn 2003. The JPL MkIV Interferometer is a mid-infrared solar absorption instrument and the Harvard-Smithsonian Center for Astrophysics FIRS-2 spectrometer is a high-resolution thermal emission FTS working in far- and mid-infrared regions. Both of these teams are applying for funding to mount campaigns in 2003-2004. Previous flights have been made from Ft. Sumner, New Mexico, Lynn Lake, Manitoba, ESRANGE, Sweden and Fairbanks, Alaska.

From the ENVISAT Validation aircraft mission, three instruments from the CNR-Italy will also participate in ACE validation. They will provide vertical profile measurements from the tropopause to  $\sim 20$  km. FOZAN-II is a chemiluminescence detector which provides profile results during ascent/descent and dives. The GASCOD-A/ $4\pi$  UV/visible grating spectrometer makes column and profile measurements by the DOAS technique. The SAFIRE-A instrument is a far infrared emission spectrometer performing limb-sounding measurements. The Arctic flight is planned to go from Kiruna in February/March 2003.



**Figure 1.** Map showing locations of ground- and ship-based validation experiments. Stations making profile measurements (from lidar or ozonesonde) are denoted by squares and those producing column and/or coarse resolution profile results (from FTS, DOAS, Brewer or filter spectrometers) are shown by triangles. Sites where both types of measurements are made are shown by circles. The dashed line shows the approximate route of the RV Polarstern.

### 4.3. Routine and Campaign Fourier Transform, DOAS and Lidar Experiments

Solar absorption spectra measured by infrared and UV/visible FTS instruments and IR grating spectrometers supply total columns and coarse resolution profiles for almost all of the ACE baseline species (except  $N_2O_5$ ). In addition to the twenty-three instruments of this type that make routine ground-based measurements from sites around the world, there is a ship-based FTS which makes measurements during Atlantic cruises on board the RV Polarstern. The ship is operated by the Alfred Wegener Institute for Polar and Marine Research (AWI). It will travel from Capetown, South Africa to Bremerhaven, Germany in January/February 2003 and travel south from Bremerhaven to Punta Arenas, Chile in October/November 2003. Three teams also make ground-based campaign measurements with their FTS instruments. The groups from the Université Libre de Bruxelles (ULB) and the Belgian Institute for Space Aeronomy (BIRA-IASB) are planning a measurement campaign at Ile de la Réunion. Their two FTS instruments will be located at different elevations, one on a mountain top

**Table 5.** Ground- and ship-based Fourier transform and infrared grating instruments

Affiliation	Instrument(s)	Location
Meteorological Service of Canada	DA 8	Eureka, Nunavut <sup>a</sup> (80 N, 86 W)
Alfred Wegener Institute (AWI)	120 HR	Ny Aalesund, Spitzbergen (79 N, 12 E)
IMK - Karlsruhe	120 HR	Kiruna, Sweden (68 N, 20 E)
Communications Research Lab.	120 HR	Poker Flat, Alaska (65 N, 147 W)
Chalmers University	120 M	Harestua, Norway (60 N, 11 E)
St. Petersburg State Univ.	IR grating	Petergof/St. Petersburg, Russia(60 N, 30 E)
Université Libre de Bruxelles	120 M	Brussels, Belgium (51 N, 4 E) Ile de la Réunion (22 S, 55 E)
University of Liege	120 HR ULg FTIR	Jungfrauoch, Switzerland (47 N, 8 E)
Trent University	DA 8 MAGNA 550	Peterborough, Ontario (45 N, 79 W) Iqaluit, Nunavut (67 N, 75 W) Saskatoon, Saskatchewan (52 N, 104 W)
Meteorological Service of Canada	DA 8	Egbert, Ontario (44 N, 80 W)
Toronto Atmospheric Observatory	DA 8	Toronto, Ontario (44 N, 79 W)
Waterloo Atmospheric Observatory	ACE-Copy	Waterloo, Ontario (43 N, 81 W)
Jet Propulsion Laboratory (JPL)	MkIV FTIR	Mt. Barcroft, California (38 N, 118 W)
University of Denver	120 M	CART facility, Oklahoma (37 N, 97 W)
JPL	FTUVS	Table Mountain, California (34 N, 118 W)
National Solar Observatory	Brault FTS	Kitt Peak, Arizona (32 N, 112 W)
IMK - Karlsruhe	120 M	Izaña, Tenerife Island, Spain (28 N, 17 W)
University of Denver	120 HR	Mauna Loa, Hawaii (20 N, 156 W)
BIRA-IASB	120 M	Ile de la Réunion (22 S, 55 E)
University of Wollongong	DA 8	Wollongong, Australia (35 S, 151 E)
National Institute of Water and Atmospheric Research (NIWA)	120 M or 120 HR 120 M	Lauder, New Zealand (45 S, 170 E) Arrival Heights, Antarctica (78 S, 167 W)
AWI	120 M	RV Polarstern (Atlantic cruises between 50 N and 40 S, typically 30 W)

<sup>a</sup> Contingent on continued operation of Eureka station.

and the other nearer to sea level, and comparisons will be made between the two observation sites. An initial campaign is scheduled for October 2002 and plans are underway for further measurements in 2003. These will be scheduled to take advantage of nearby ACE overpasses. The two FT spectrometers from Trent University plan to make campaign measurements from Saskatoon, Saskatchewan in winter 2003. They will also be involved in the validation campaign for the OSIRIS instrument on the Odin satellite (at Iqaluit, contingent on funding). A list of all of these sites and instruments is given in Table 5.

The DOAS technique derives total column results from measurements of UV/visible spectra of zenith scattered sunlight. This method provides information for the ACE species O<sub>3</sub> and NO<sub>2</sub>. The networks of DOAS instruments operated by BIRA-IASB in Brussels and CNR-ISAO in Bologna will be participating in ACE validation. The DOAS spectrometer at the Toronto Atmospheric Observatory will make routine measurements from its home base in Toronto. It will also be deployed to make campaign measurements from Resolute, Nunavut during winter 2003 and this may continue in 2004 (contingent on funding). The BREMDOM group of spectrometers, coordinated by the University of Bremen, may also take part in ACE validation. A listing of the DOAS measurement sites is given in Table 6.

Lidar stations provide vertical profile information from analysis of scattered laser light. These types of instruments produce results for the baseline target species O<sub>3</sub> and H<sub>2</sub>O, and for aerosols and temperature. Two networks of lidar instruments, the Network for the Detection of Stratospheric Change (NDSC) sites run by the Jet Propulsion Laboratory (JPL) and three of the sites in the recently formed American Lidar Network (ALiNe), will be participating in ACE validation and three additional stations will also be involved. The locations of these measurement sites are given in Table 7.

**Table 6.** Ground-based DOAS instruments

Affiliation	Instrument	Location
Toronto Atmospheric Observatory	DOAS	Resolute, Nunavut (75 N, 92 W)
		Toronto, Ontario (44 N, 79 W)
BIRA- IASB Network	Vis spec	Harestua, Norway (60 N, 11 E)
	SAOZ	Jungfraujoch, Switzerland (47 N, 8 E)
	UV spec	Observatoire Haute Provence, France (44 N, 6 E)
	UV-Vis spec	Ile de la Réunion (22 S, 55 E)
GASCOD-GB Network	GASCOD-GB <sup>a</sup>	Mt. Cimone, Italy (44 N, 11 E)
	GASCOD-GB	Stara Zagora, Bulgaria (42 N, 25 E)
	GASCOD-GB	Evora <sup>b</sup> , Portugal (38 N, 8 W)
	GASCOD-GB	Lampedusa Island, Italy (35 N, 13 E)
	GASCOD-GB	Terra Nuova Bay, Antarctica (75 S, 164 E)
BREMDOM Network <sup>c</sup>	DOAS	Ny Aalesund, Spitzbergen (78 N, 12 E)
	DOAS	Summit, Greenland (72 N, 38 W)
	DOAS	Bremen, Germany (53 N, 9 E)
	DOAS	Zugspitze, Germany (47 N, 11 E)
	DOAS	Merida, Venezuela (8 N, 71 W)
	DOAS	Kashidoo, Maldives (5 N, 74 E)
	DOAS	Nairobi, Kenya (1 S, 37 E)

<sup>a</sup> GASCOD-GB is a ground-based version of the aircraft instrument, GASCOD-A/4 $\pi$ .

<sup>b</sup> Instrument to be installed in 2002.

<sup>c</sup> May participate in the ACE validation program.

**Table 7.** Ground-based lidar instruments

Affiliation	Instrument(s)	Location
ALOMAR Ozone Lidar	Differential Absorption Lidar	Andøya, Norway (69 N, 16 E)
Purple Crow Lidar	Raman Scatter Lidar Resonance Scatter Lidar	London, Ontario (43 N, -81 W)
Atmosp. Lidar Observatory	Rayleigh Lidar Resonance Scatter Lidar	Logan, Utah (42 N, -112 W)
JPL-NDSC Lidar Stations	Differential Absorption Lidar Differential Absorption Lidar	Table Mountain, California (34 N, -118 W) Mauna Loa, Hawaii (20 N, -156 W)
ALiNe Network Stations	Nd:YAG Lidar Resonance Scatter Lidar Raman Lidar	Jerusalén, Ecuador (0 S, -79 W) Sao Jose dos Campos, Brazil (-23 S, -46 W) Buenos Aires, Argentina (-35 S, -59 W)

#### 4.4. Routine Ozone Experiments

There are three groups which will provide ozone measurements for ACE validation. The primary source of ozone data for the ACE validation program will be the Meteorological Service of Canada. They operate the Canadian Ozone Monitoring Network, which consists of thirteen sites across Canada and one at Mauna Loa, Hawaii. The Brewer spectrometers at these locations provide total column measurements throughout daylight hours and profile information is provided by weekly ozonesonde measurements from the six most northern locations. The locations of the Canadian Ozone Monitoring Network stations are listed in Table 8. Data for sites outside of Canada will be obtained from the World Ozone Data Centre, which is part of World Meteorological Organization and is based at MSC.

Additionally, the ozone monitoring network coordinated by St. Petersburg State University will provide data from forty-five sites, throughout Russia and the former Soviet Republics. These filter spectrometers (Ozonometer M-124) will provide daily total column measurements. The team at the Radiometric Calibration and Development Facility at NASA/Goddard has reconfigured a Solar Backscatter UV (SSBUV) instrument, which flew eight times on the Space Shuttle, to make zenith sky measurements. This instrument and an associated Brewer spectrometer will provide total column measurements from Greenbelt, Maryland. The locations of these additional ozone measurement stations are listed in Table 8.

#### 4.5. Ground-based Validation Campaign

A validation campaign involving a number of ground-based instruments, including the ACE-FTS copy and MAESTRO clone, is being considered. It has been suggested that these measurements be made during a time of low atmospheric variability in order to focus on validating instrument performance. A second campaign during Arctic spring, to compare the changes in ozone and related species observed from the ACE platform and the ground-based instruments, may also be considered.

#### 4.6. Modelling Studies

A key to the successful validation of the ACE data is the use of techniques such as trajectory hunting. Meteorological data can be used to calculate backward and forward trajectories that will allow ACE results to be projected several days backward or forward in time to bring them into closer coincidence with ground-, balloon-, aircraft- or satellite-based validation experiments. This trajectory hunting technique can effectively increase the number of coincidences between ACE and other satellites. These analyses will require close collaboration with the modelling group of the ACE Science Team.

**Table 8.** Ozone measurement sites

Affiliation	Location	Instrument(s)
MSC Ozone Network	Alert, Nunavut (83 N, 62 W)	Brewer, Ozonesonde
	Eureka, Nunavut (80 N, 86 W)	Brewer, Ozonesonde
	Resolute Bay, Nunavut (75 N, 95 W)	Brewer, Ozonesonde
	Churchill, Manitoba (59 N, 94 W)	Brewer, Ozonesonde
	Edmonton, Alberta (54 N, 114 W)	Brewer, Ozonesonde
	Goose Bay, Newfoundland (53 N, 60 W)	Brewer, Ozonesonde
	Saskatoon, Saskatchewan (52 N, 107 W)	Brewer
	Regina, Saskatchewan (50 N, 105 W)	Brewer
	Winnipeg, Manitoba (50 N, 97 W)	Brewer
	Saturna Island, British Columbia (49 N, 123 W)	Brewer
	Montreal, Quebec (45 N, 74 W)	Brewer
	Halifax/Dartmouth, Nova Scotia (45 N, 64 W)	Brewer
	Toronto, Ontario (44 N, 79 W)	Brewer
	Mauna Loa, Hawaii (20 N, 156 W)	Brewer
Russian Network <sup>a</sup>	Barentsburg (78 N, 14 E)	Ozonometer
	Murmansk (69 N, 33 E)	Ozonometer
	Petchora (65 N, 57 E)	Ozonometer
	Arhangelsk (65 N, 41 E)	Ozonometer
	St.Petersburg (60 N, 31 E)	Ozonometer
	Ekaterinburg (57 N, 61 E)	Ozonometer
	Moscow (56 N, 38 E)	Ozonometer
NASA/Goddard	Greenbelt, Maryland (39 N, 77 W)	SSBUV, Brewer

<sup>a</sup> Table shows only the seven primary stations of the 45 station filter spectrometer network.

## 5. MEASUREMENT AND DATA GUIDELINES

### 5.1. Coincidence

As much as possible the validation experiment results should overlap in space and time with the ACE occultation data. During analysis, the coincidence of the measurements will be evaluated using meteorological data from a weather forecast model. A suggested guideline is that the validation experiment measurement location should be no more than  $\sim 200$  km away from the ACE occultation point and that both measurements should be taken within a time period of a few hours. These values will have to be varied to account for factors such as species, season, location and time of day.

This guideline is quite narrow for scheduling ground-based measurements because of the limited number of occultation events near any one site. Therefore a wider “maximum” distance will be employed in order to generate lists of measurement opportunities for the experiment teams and to aid in planning ground-, balloon-, and aircraft-based campaigns. This value will need to be flexible and must be adjusted to account for species, season, location, time of day and experiment platform. A value of 500 km is proposed for generating lists of measurement opportunities for each experiment team. This will be done using the current predicted orbit and updated lists will be provided once SCISAT-1 is in orbit.

### 5.2. Validation Data

The results produced by the validation experiments will be collected and stored in a dedicated validation database at the ACE Science Operations Centre. The validation of ACE data products will be performed by members of the ACE Science Team in collaboration with our validation partners.

A common data format will be used for submission of data to the ACE Validation database. Possible formats include NASA Ames (used by the ILAS-II team) and HDF (used by ENVISAT and other programs). This issue is still under consideration by the ACE validation team.

A data protocol will be established for ACE validation participants who are not members of the ACE Science team since they will not have access to all the ACE mission data. It is proposed that these participants have access to the ACE data generated for each occultation for which they submit data to the ACE validation program. This data will not be limited to the species monitored by the particular validation experiment.

## 6. CONCLUDING REMARKS

The reliability and accuracy of the atmospheric profiles derived from the ACE observations will be demonstrated through comparisons with a series of measurements made by satellite-, balloon-, aircraft-, ship-, and ground-based instruments. The group of validation experiments assembled for this purpose has been outlined along with the approach to be taken for planning this program. The ACE Validation and Ground Truthing Plan is currently being prepared by the ACE validation team and the development of this plan will continue through the months leading up to launch of SCISAT-1.

## ACKNOWLEDGMENTS

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