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The Atmospheric Chemistry Experiment (ACE)

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ABSTRACT

The Atmospheric Chemistry Experiment (ACE), also called SCISAT, is a Canadian-led small satellite mission for remote sensing of the Earth's atmosphere. ACE was launched into a low Earth circular orbit by NASA on August 12, 2003 and it continues to function nominally. The ACE instruments are a high spectral resolution (0.02 cm^{-1}) Fourier Transform Spectrometer (FTS) operating from 2.2 to 13.3 μm (750–4400 cm^{-1}), a spectrophotometer known as Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (MAESTRO) with wavelength coverage of 285–1020 nm and two filtered detector arrays to image the Sun at 0.525 and 1.02 μm. ACE operates in solar occultation mode to provide altitude profiles of temperature, pressure, atmospheric extinction and the volume mixing ratios (VMRs) for several dozen molecules and related isotopologues. This paper presents a mission overview and a summary of selected scientific results.

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1. Introduction

Satellite instruments such as the ACE-FTS provide a global view of the state of the Earth's atmosphere in a way that is not possible from the ground, aircraft or balloon-borne platforms. The original primary ACE goal [1] was to improve our understanding of “the chemical and dynamical processes that control the distribution of ozone in the stratosphere and upper troposphere, particularly in the Arctic”. Stratospheric ozone is important because it protects us from deleterious ultraviolet radiation and in the upper troposphere ozone is a greenhouse gas that contributes to climate change. Because of ACE's longevity (more than 12.5 years in orbit), changes in atmospheric composition can be measured: e.g., CO_2 increases in the upper atmosphere [2] that are associated with climate change and decreases in halogen-containing gases [3] due to the beneficial effects of the Montreal Protocol banning substances that deplete the stratospheric ozone layer. ACE also can measure a wide variety of organic molecules and nitrogen oxides in the upper troposphere that are responsible for air pollution. Process studies with ACE data have discovered the direct injection of pollution into the stratosphere by the Asian monsoon [4] and the effects of the Arctic and Antarctic oscillations on the variability of upper tropospheric water vapor in polar regions [5].

The primary instrument [6] on ACE is a high resolution ($0.02\ cm^{-1}$) infrared Fourier transform spectrometer (ACE-FTS), operating from 750 to 4400 cm^{-1}, used to determine the vertical profiles of trace gas volume mixing ratios (VMRs) and temperature. During sunrise and sunset, the FTS measures sequences of atmospheric absorption spectra in the limb viewing geometry (Fig. 1) with different slant paths and tangent heights; when these spectra are analyzed on the ground, the results are converted into vertical profiles of numerous atmospheric constituents. The vertical resolution is about 3 km from an altitude of 5 km (or the cloud tops) up to 150 km. Aerosols and clouds are being monitored using the extinction of solar radiation as measured by two filtered imagers and with an instrument called Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (MAESTRO). MAESTRO is a dual optical spectrophotometer [7,8] that covers the 285–1020 nm spectral region with a spectral resolution of about 2 nm. It has a vertical resolution of about 1 km and measures primarily ozone, nitrogen dioxide and aerosol/cloud extinction.

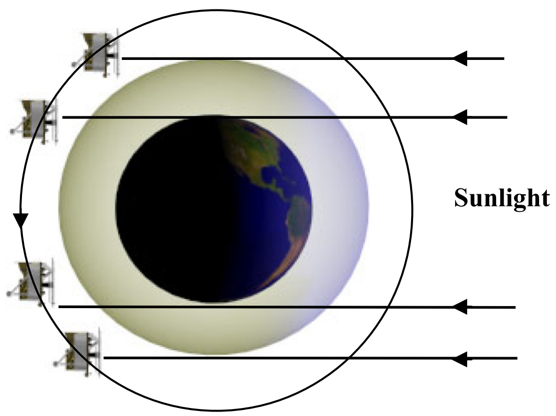

Fig. 1. Solar occultation geometry showing sunrise and sunset [28].

In general, limb sounders like the ACE-FTS offer high vertical resolution (~3 km), but low horizontal resolution (~300 km) in the limb direction. In contrast, nadir sounders usually have poor vertical resolution (often retrieving only the total column density), but high spatial resolution (e.g., 13 km by 24 km for OMI, Ozone Monitoring Instrument, on Aura [9]). Some instruments such as Tropospheric Emission Spectrometer (TES) on Aura [10] and SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) on Envisat [11] are capable of both limb and nadir observations, although TES now operates only in nadir mode. The loss of Envisat in 2012 after a 10-year mission was very unfortunate; it had three instruments, Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) [12], Global Ozone Monitoring by Occultation of Stars (GOMOS) [13] and SCIAMACHY [11] that made limb measurements.

There are currently six limb sounders making observations in addition to ACE-FTS and MAESTRO: Submillimeterwave Radiometer (SMR) [14] and Optical Spectrograph and Infrared Imaging System (OSIRIS) [15] on Odin, Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) [16] on Thermosphere Ionosphere Mesosphere Energetics Dynamics (TIMED), Solar Occultation For Ice Experiment (SOFIE) [17] on Aeronomy of Ice in the Mesosphere (AIM), Microwave Limb Sounder (MLS) [18] on Aura, and Ozone Mapping Profiler Suite-Limb (OMPS-L) [19] on National Polar-orbiting Operational Environmental Satellite System Preparatory Project (Suomi-NPP). SMR and MLS measure pure rotational emission of atmospheric molecules in the limb direction. OSIRIS and OMPS-L measure limb-scattered sunlight in the UV/visible/Near Infrared spectral regions. SABER is a broadband limb-scanning infrared emission radiometer and SOFIE, like ACE-FTS, is an infrared solar occultation instrument but uses filters like SABER, rather than a spectrometer. Except for OMPS-L, these instrument are all well past their design lifetimes, which for example was just 2 years for ACE.

The rapid global coverage possible with nadir sounders is very attractive for many applications such as numerical weather forecasting; for example, Infrared Atmospheric Sounding Interferometer (IASI) [20] on MetOp-A offers global