The Microwave Limb Sounder on EOS-CHEM for
atmospheric chemistry and global change investigations

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ABSTRACT

The Microwave Limb Sounder (MLS) for NASA's Earth Observing System Chemistry Mission series of satellites is currently under development, with launch planned for 2002 on EOS-CHEM. This sensor builds on heritage from the successful MLS on NASA's Upper Atmosphere Research Satellite (UARS), which was first to demonstrate the microwave limb sounding technique for measuring the abundance of trace species in the Earth's atmosphere from an orbiting satellite[1,2,3,4]. Its relevance to the atmospheric chemistry and global change objectives of Mission to Planet Earth is discussed along with details of the instrumentation being developed.

1. 1NTRODUCTION

The Earth Observing System (EOS) satellites planned by NASA, together with satellites planned by ESA and Japan, will provide a 15 year comprehensive set of measurements which are essential for advancing our understanding of Earth system processes and global change. The. EOS Chemistry series will contribute information on atmospheric chemical composition, troposphere-stratosphere exchange of energy and chemicals, chemistry-climate interactions, and air-sea exchange of chemicals and energy. The first EOS-CHEM satellite is scheduled for launch in late 2002 into a 705 km sun-synchronous orbit, and it will be followed by two later launches at six year intervals. MLS is one of four instruments on CHEM-1, the others being: the High-Resolution Dynamics Limb Sounder (HIRDLS), a joint development of US and UK teams, for measurements of temperature and trace species in the stratosphere and upper troposphere with high vertical and horizontal resolution; NASA's Tropospheric Emission Spectrometer (TES), for tropospheric and lower stratospheric investigations of virtually all infrared active species; and the Ozone Dynamics Ultraviolet Spectrometer (ODUS), being provided by Japan.

2. MLS SCIENCE OBJECTIVES

The scientific priorities and objectives of the ML-S investigation are to study and monitor processes and parameters vital for global change research. To further our understanding of the chemistry of the lower stratosphere and upper troposphere, MLS measures lower stratospheric temperature and concentrations of H_20, 0_3, ClO, HCl, OH, HNO_3, and N_20. These measurements will provide. information on the effects of the constituents on (and diagnoses of,) transformations of greenhouse gases, radiative forcing of climate change, and ozone depletion, MLS measurements of upper tropospheric H_2O and 0_3 will aid understanding of their effects on radiative forcing of climate change and diagnoses of exchange between the troposphere and stratosphere. MLS will monitor ozone chemistry of the middle and upper stratosphere by measuring radicals, reservoirs, and source gases in chemical cycles which destroy ozone. To investigate the effect on global change of volcanic injections into the atmosphere, MLS will measure SO_2, and other gases mentioned above, in volcanic plumes. In addition, pressure (from 0_2 emission lines) and height (from a gyroscope measuring small changes in the field-of-view direction) are measured to provide accurate vertical information for the composition measurements. The choice of instrumentation for these measurements allows a number of species to be detected as secondary objectives, including CO, HCN, HOCl and $H0_2$.

The MLS provides a very important contribution to the EOS program since its measurements are not degraded in regions containing ice clouds (including polar stratospheric clouds) or aerosols. This is significant because phenomena affecting global change, eg water vapor distribution near the tropopause and heterogeneous chemistry, occur in these regions.

It is important to note that the EOS MLS will continue the set of measurements begun by UARS MLS to monitor the chlorine cycle of ozone destruction at a time when stratospheric chlorine is expected to peak. Additional chlorine cycle species will be measured as well as species controlling the nitrogen and hydrogen cycles of ozone destruction.

Measurements are performed continuously, at all times of day and night, and can cover the altitude range from the upper troposphere to the lower thermosphere. The vertical scan is chosen to emphasize the lower stratosphere and upper troposphere, which is now of highest priority, but it can be reprogrammed to emphasize other regions should priorities change. Complete latitude coverage is obtained on each orbit with the EOS-MLS by orienting the instrument on the spacecraft to look forward, along the orbit track.

3. INSTRUMENTATION

The EOS MLS has five total power heterodyne radiometers to receive atmospheric thermal emission at millimeter and sub-millimeter wavelengths. A commercially provided 112 GHz radiometer will measure radi at ion in three bands to provide observations of temperature and pressure throughout the troposphere and stratosphere, and CO. A radiometer centered on 192 G] lz has five bands to measure H_20, N_20, HNO_3, ClO and O_3. This radiometer will provide continuity with UARS MLS measurements by observing the same spectroscopic lines, and also enable $S0_2$ to be measured when enhanced by volcanic eruption. A radiometer at 240 GHz, using planar mixer technology, will provide measurements of upper tropospheric ozone and give redundant temperature and pressure capability. Five bands in a radiometer centered on 643 GHz, which also uses a sub-harmonically pumped planar mixer, will measure C1O, with ten times the sensitivity of the 190 GHz radiometer, tropopause water vapor, BrO, N_20, HCl, and stratospheric ozone. Secondary measurements of HO_2 and HOCl are also covered by these bands. The observations of OH will be provided by measurements of spectroscopic lines near 2.5 THz using a planar technology mixer and a local oscillator signal produced by a methanol gas laser.

The antenna system will be similar to that used on the UARS MLS instrument, but will employ composite reflectors to accommodate the different thermal requirements. The primary reflector has appropriate surface properties, and an elliptical aperture with dimensions 1.6 x 0.8 m to provide a vertical instantaneous field-of-view of 1.2 km at 640 GHz. An optical multiplexing system, with dichroic plates, polarizing grids, and focussing mirrors, directs the incoming atmospheric signals to the radiometer feed horns. Spectral signatures from each of the target species, after down-conversion by the radiometers and another down-conversion in the second IF bands, will be detected with conventional filter bank spectrometers. Each spectrometer has 25 channels with widths varying from 6 to 96 MHz, covering a total bandwidth greater than 1.2 GHz. The antenna system is scanned to cover an altitude range from 5 to 60 km in about 20 s, and six signal integrations are made each second. An additional 5 s is allowed for retrace, during which time radiometric calibration of the signal chain is performed by observing space and an internal calibration target whose temperature is accurately measured.

The instrument data rate is less than 100 kb/s; it has a mass of 450 kg and will use 530 W when fully powered,

4. DATA ANALYSI S

Profiles of the geophysical parameters will be retrieved in ground processing by sequential estimation techniques, using algorithms based on those developed for the UARS MLS investigation. With this approach, calibrated radiance files will be produced as a first step, followed by retrieval of the pressure/height profile, and then profiles of the constituent concentrations and temperature. It is expected that about ten data products will be available at launch and the rest will be developed as routine or special products during the following year.

5. ACKNOWLEDGEMENTS

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