Interferometric Characterization of the Earth's Atmosphere from Lagrange Point 2

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Part of the NASA plans for future Earth-Science missions calls for observations using novel vantage points that can produce science products otherwise unobtainable. Observations of the Earth from the Lagrange-2 point, L-2, (1.5 million kilometers behind the Earth on the Earth-Sun line) affords a unique vantage point for atmospheric science (see Figures 1 and 2).

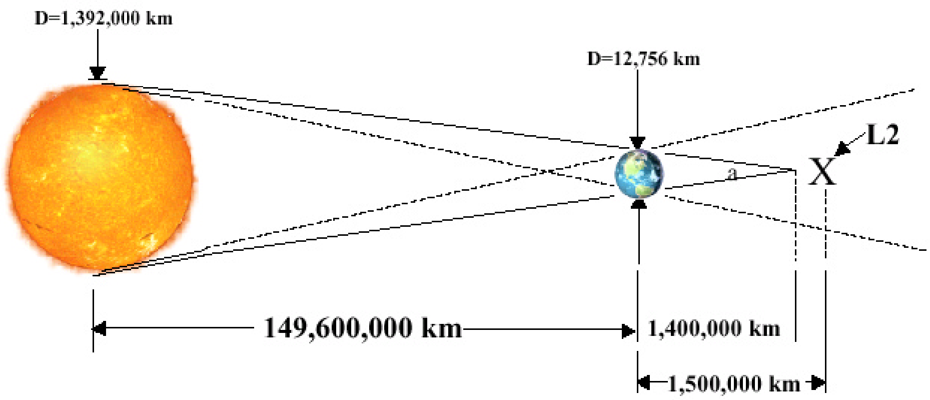


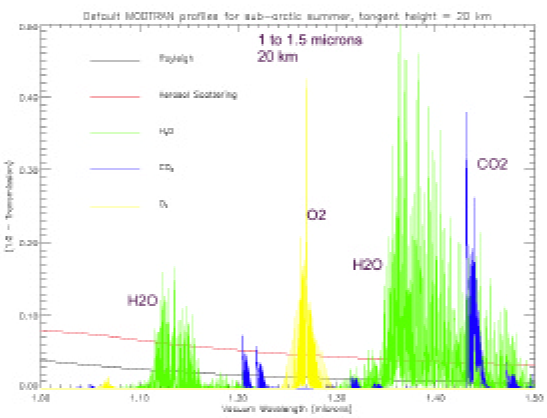
Figure 1 Relationship of L-2 Orbit Position to the Earth's Umbra. The spacecraft is always illuminated by the direct sun. This means that the atmosphere can be continuously viewed in solar occultation.

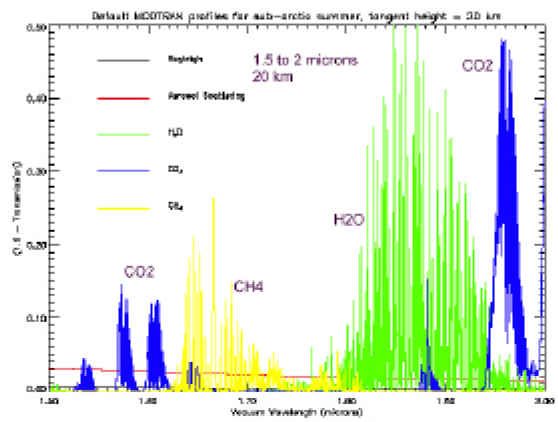
Spectral observation of the Earth's atmosphere using solar occultation techniques in the near infrared (1 to 4 microns) provides one of the most accurate methods of passively sensing altitude profiles of the major species (CO_2, O_3, O_2, CH_4, H_2O, N_2O). The ability to measure the altitude profiles of these species can be estimated using radiative transfer calculations (MODTRAN) for the appropriate geometry including the scattering atmosphere, aerosols, and the absorption spectra (see Figure 2a). Fortunately it is possible to select wavelengths where there is little or no overlap with other major absorbing species. This is especially important as the viewpoint shifts towards lower altitudes where there are more overlapping lines, and fewer choices because of saturation.

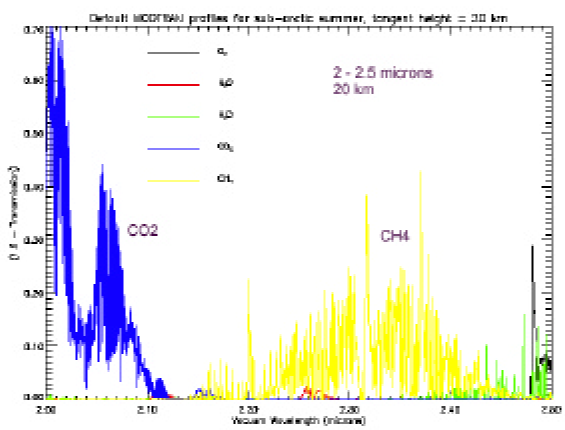
Preliminary calculations show that 7 species (CO_2, O_3, O_2, CH_4, H_2O, N_2O) have clearly separated spectral features in the 1 to 4μ range with sufficient absorption to produce profile information from near the Earth's surface to the middle stratosphere. For CO_2 the estimated sensitivity to change is 0.33% or 1 part in 330. This should be sufficient to detect changes that are significant for the carbon cycle studies.

In the lower portions of the atmosphere, aerosols become an important consideration in the 1 to 1.5 micron range. This will make it necessary to correct the measured radiances for the scattered component from both Rayleigh and Mie scattering.

It is also clear that many of the lines are saturated. This means that the line selections that were optimum at higher altitudes are not appropriate for observations in the lower atmosphere. Shifting wavelengths to weaker portions of the absorption features will permit observations at all altitudes. The lower altitude limit will be governed by the presence of clouds and ray-path optics. A further limitation occurs as the observing wavelength nears 4 microns, since the thermal emission of the Earth becomes nearly equal in brightness to that of the Sun.







20 km limb view
1 to 2.5 microns
CO_2, CH_4, O_2, H_2O
Band width 1 to 10 nm

H2O: 1.12, 1.3 microns

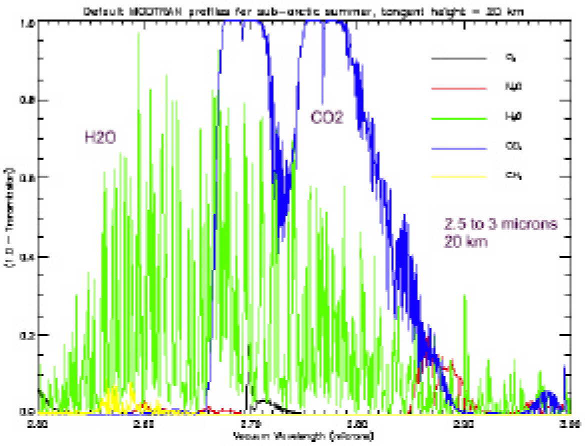
CO2: 1.45 microns

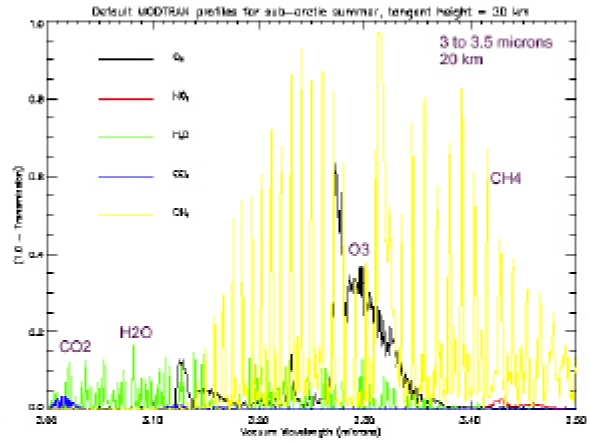
O2: 1.25 microns

Figure 2a Absorption spectra at 20 km in the Earth's atmosphere as seen in a limb view for 1 to 2.5 microns

While traditional polar orbiting occultation measurements can obtain about 14 measurements per day (2 per orbit), solar occultation observations from the Lagrange-2 point will yield hourly profile measurements at all latitudes. The expected spatial resolution is 2 km in altitude, 0.5 degrees in latitude, and 2 degrees in longitude. The result from 24 hours of observations will be a 3-dimensional map of atmospheric composition.

In addition to observations of the Earth's atmosphere, it will be possible to observe a portion of the solar disk at moderate spatial resolution without interference from the Earth. The resolution will be approximately 0.3 x 10 arc seconds.





20 km
2.50 to 4.00 microns

CH_4, H_2O, CO_2, N_2O, O_3

Selected bands can clearly distinguish individual species

The exact bands to use are a function of altitude. This requires a tunable spectrometer.

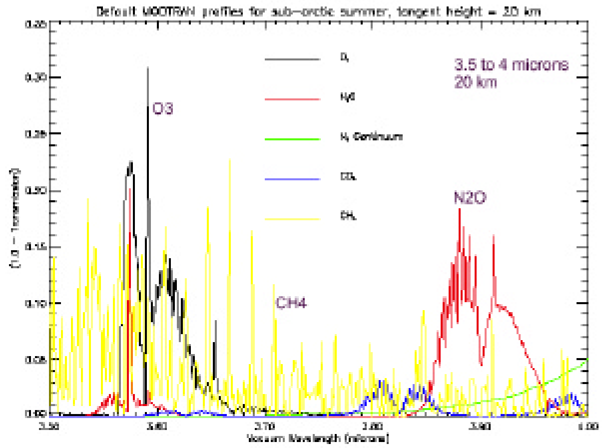


Figure 2b Absorption spectra at 20 km in the Earth's atmosphere as seen in a limb view for 2.5 to 4 microns

To accomplish the task of observing the Earth's atmosphere with 2 km vertical resolution from L-2 requires the development of a large moderate spectral resolution instrument whose entrance aperture is about 10 meters. Use of a standard telescope design with a 10-meter circular mirror or a 10-meter strip mirror would be prohibitively expensive and excessively massive. Instead, we are proposing the development of a 10-meter linear interferometer coupled to a Fourier transform imaging spectrometer. The result will be a highly efficient design with sufficient sensitivity, while having both spatial and spectral resolution to produce the desired results. Initial instrument design studies are underway to determine the optimum optical design for the interferometer-spectrometer as well as the necessary highly stable mechanical designs. Separate design studies are being conducted for the spacecraft, shuttle launch facility, low-light solar power design, thermal control, and unique navigation requirements to reach and maintain the tight halo orbit about L-2.