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Atomic oxygen and temperature in the lower thermosphere from the O-STATES sounding rocket project

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In October 2015 the O-STATES payload was launched twice from Esrange Space Center (67.9˚N, 21.1˚E) in northern Sweden, first into moderately disturbed and then into calm geomagnetic conditions. The basic idea of O-STATES ("Oxygen Species and Thermospheric Airglow in The Earth´s Sky") is that comprehensive information on the composition, specifically atomic oxygen in the ground state O(^{3}P) and first excited state O(^{1}D), and temperature of the lower thermosphere can be obtained from a limited set of optical measurements. Starting point for the analysis are daytime measurements of the $O_2(b^1\sum_g^+ - X^3\sum_g^-)$ Atmospheric Band system in the spectral region 755-780 nm and the O(^{1}D-^{3}P) Red Line at 630 nm. In the daytime lower thermosphere, O(^{1}D) is produced by O_2 photolysis and the excited O_2(b) state is mainly produced by energy transfer from O(^{1}D) to the O_2(X) ground state. In addition to O_2 photolysis, both electron impact on O(^{3}P) and dissociative recombination of O_2^+ are major sources of O(^{1}D) in the thermosphere.

Laboratory studies at SRI International have shown that O_2(b) production in vibrational level v=1 dominates. While O_2(b, v=0) is essentially unquenched, O_2(b, v=1) is subject to collisional quenching that is dominated by O at altitudes above 160 km. Hence, the ratio of the Atmospheric Band emission from O_2(b, v=1) and O_2(b, v=0) is a measure of the O density at sufficiently high altitudes. In addition, the spectral shape of the O_2 Atmospheric Band is temperature dependent and spectrally resolved measurements of the Atmospheric Bands thus provide a measure of atmospheric temperature.

This O_2 Atmospheric Band analysis has been suggested as a new technique for thermospheric remote sensing under the name Global Oxygen and Temperature (GOAT) Mapping. With O-STATES we want to characterize the GOAT technique by in-situ analysis of the O_2 Atmospheric Band airglow and the underlying excitation mechanisms. By performing this dayglow analysis from a rocket payload, detailed local altitude profiles of the relevant emissions and interacting species can be obtained. The optical measurements are combined with independent detection of O and O_2 (resonance fluorescence and electrochemical detection) as well as measurements of electron and ion densities. In this paper we describe the O-STATES project and present first results.