



Atomic Oxygen and Temperature Retrieval in the MLT region by Terahertz Heterodyne Measurements from a Satellite: Single vs. Dual-frequency Scenarios

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Atomic oxygen is a key component of the mesosphere and lower thermosphere (MLT) in Earth's atmosphere. It plays a crucial role in the energy balance and chemical processes within the MLT region, along with the temperature.

The Keystone mission, which is an upper-atmosphere limb-sounding satellite initiative, has entered its phase-0 study [1]. Operating from a low Earth orbit, Keystone will scan the atmosphere at varying tangential heights to measure several atmospheric gases. Most notably, Keystone aims to observe atomic oxygen through its terahertz (THz) fine-structure transitions at 2.1 THz and 4.7 THz. These transitions, being in local thermodynamic equilibrium (LTE), enable the retrieval of vertical atomic oxygen concentration profiles without reliance on photochemical models, but requiring only the local temperature.

The fine-structure transitions of atomic oxygen can be spectrally resolved using heterodyne spectroscopy technology [2,3]. Temperature can then be derived from either the Doppler broadening of these transitions or from the relative intensities of the two transitions, as they originate from distinct upper electronic levels (0.028 eV for the 2.1 THz transition and 0.020 eV for the 4.7 THz transition).

This study evaluates the retrieval uncertainties in temperature and atomic oxygen density for a limb sounding satellite mission such as Keystone. We use the methodology also presented in [4] to compare scenarios with two THz channels measuring both the 2.1 THz and 4.7 THz transitions against those measuring only one transition. For two channels with similar noise levels we find that measuring both transitions improve the precision in atomic oxygen concentration beyond what is gained from the increased signal by using two detectors.

[1] D. Gerber, webpage, <https://ceoi.ac.uk/eo-missions/earth-explorer-11/keystone/>, visited 14th January 2025.

[2] Richter, H., et al., *Commun Earth Environ* 2, 19 (2021).

[3] Wienold, M., et al., *IEEE Transactions on Terahertz Science and Technology*, vol. 14, no. 3

(2024).

[4] Hansen, P., et al., EGU General Assembly 2024, Vienna, Austria, (2024).