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Remote sensing of water vapour in the atmospheric column using laser heterodyne radiometer

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Measurements of greenhouse gases (GHGs) in the atmospheric column are crucial because column-averaged mixing ratio integrate concentrations over the full vertical extent of the atmosphere, making them far less sensitive to local mixing and transport errors than surface in situ measurements. Water vapour (H₂O) is a very highly variable and most common greenhouse gas in the Earth's atmosphere. Column measurements of water vapour provide robust information on the total atmospheric moisture content, which is essential for the study of Earth's radiation budget. Complementing this, vertical concentration profiles remain essential for investigating regional water cycle and its role in climate variability and environmental change. Together, column measurements and vertical profiles provide a more complete and reliable understanding of atmospheric water vapour distribution and its relevance to climate processes [1].

A portable, fully fiber-coupled laser heterodyne radiometer (LHR) has been developed at the Laboratoire de Physico-Chimie de l'Atmosphère (LPCA) for ground-based remote sensing of atmospheric carbon dioxide (CO₂) [2] and water vapour (H₂O). The system employs a wide-band, tunable external-cavity diode laser operating in the 1520–1620 nm spectral range as the local oscillator. Field measurements were conducted during a dedicated campaign at the CNES balloon launch facility in Aire-sur-l'Adour, France, within the framework of the CNES ATMOSFER project.

This study demonstrates the capability of the LHR to sensitively retrieve vertical water vapour concentration profiles from ground-based measurements using optimal estimation method. The retrieved H₂O profiles were further validated against high-vertical-resolution in-situ balloon-borne observations, including measurements from the Pico-Light H₂O instrument and the Micro-hygrometer. In addition, a real-time intercomparison was performed using simultaneously radiosonde launches, providing an independent assessment of the temporal consistency of the LHR retrievals. Instrument sensitivity and information content were further evaluated through

averaging kernel analysis, and the data inversion was carried out using the ARAHMIS (Atmospheric Radiation Algorithm for High-Spectral Resolution Measurements from Infrared Spectrometers) radiative transfer model [3]. Furthermore, the diurnal variation of water vapour concentration was investigated using successive LHR measurements, demonstrating the instrument's capability for continuous daytime monitoring.

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