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A field scale laser-tomography spectrometer for mapping trace-gases

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Evaporation and condensation of water play an important role in redistributing energy as they transfer heat from the Earth's surface to the atmospheric boundary layer. If the spatial distribution of water vapor is known, it can be used in modeling all kinds of processes taking place in the critical zone. Likewise, knowing the areal distribution of atmospheric trace gases within the lowermost meters of the atmosphere is of great interest for exploring fundamental questions related to soil carbon cycling. Currently, concentrations of water vapor and trace gases, such as carbon dioxide (CO_2) and methane (CH_4), close to the terrestrial surface are mostly measured on the point scale using atmometers and soil chambers. The possibility to detect the areal distribution of, e.g., CO_2 concentration has been demonstrated by means of passive infrared remote sensing techniques. However, such measurements reveal concentrations integrated over the paths between the surface and the sensor position that is typically high above the surface. Recently tomographic setups of active infrared spectroscopy have been proposed to measure spatially resolved gas concentrations. Most of this research was either performed on relatively small spatial scales for industrial applications (e.g. for thin film deposition chambers), or in environments (such as e.g. above volcanoes) exhibiting plumes with high gas concentrations relative to the background concentration.

Aiming to increase the understanding of the basic biological and chemical processes within the undisturbed vadose zone that drive the carbon exchange across the soil-atmosphere interface we propose the construction of a field scale laser-spectroscopy system that allows for the tomographic reconstruction of the spatial distribution of CO_2 concentration including isotopic sensitivity at atmospheric conditions. The system proposed uses tunable diode lasers, allowing for measuring high-resolution absorption spectra centered at around 2004 nm and 2744 nm along approximately 300 intersecting atmospheric paths in close proximity to the ground. The 2004 nm measurements are almost exclusively sensitive to the integrated concentration of the $^{12}CO_2$ isotope, while the spectra obtained at around 2744 nm will provide information on the isotopology $^{12}CO_2$ / $^{13}CO_2$. Simulations of the spectral transmission of a 100 m path across a standard atmosphere were performed to estimate the system sensitivity with regard to CO_2 concentration. This investigation showed that it is feasible to detect a 1% change (3.3 ppmV) of the standard CO_2 concentration (330 ppmV) along a 1 m segment. This ensures that spectroscopy it not the limiting factor for the spatial resolution expected for the tomographic inversion.

The tomographic spectrometer will be realized in the framework of the development of a new terrestrial observatory in the German northeastern lowlands within the Terrestrial Environmental Observatories initiative (TERENO) of the Helmholtz association. After setting up the system, careful characterization of the performance, and optimizing the tomographic inversion, the field scale spectrometer will be installed on the CarboZALF site in Dedelow which is already part of the TERENO´s SoilCan activities.