First detection of thermospheric metastable helium by lidar

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We report on the first measurements of vertical profiles of thermospheric metastable (3S) helium. The measurements were acquired in January and February 2022 in southern Germany by a novel fluorescence lidar system developed at the German Aerospace Center (DLR). The concept of the helium fluorescence lidar was already proposed in a theoretical study by Gerrard et al. (1997) in the late 1990s. However, technical challenges have prevented its realization until now. We use a pulsed Nd:GdVO₄ laser to excite the 2⁢3⁠₁⁻⁡₂⁠₃⁠₂ manifold of helium at 1083.034 nm wavelength and detect the resulting fluorescence. Because impacts of photoelectrons with energies >19.8 eV are required to excite helium atoms from their ground state to the long-lived metastable (3S) state from which they can be further exited by the lidar, a significant abundance of He(3S) is expected only for periods when the thermosphere is illuminated by sunlight. This limits any practical observations of He(3S) to the periods of about three hours after sunset and three hours before sunrise (solar zenith angles between 90° and 120°), as the solar background is too strong to detect the faint fluorescence signal during daylight hours. We find peak He(3S) densities of up to 8 atoms/cm³ at 600 km altitude just before sunrise. However, we also have indications of low He(3S) densities of about 0.1 atoms/cm³ at midnight. This suggest that a more powerful lidar could provide meaningful thermospheric observations throughout the night. In this paper we discuss our lidar system and show profiles of thermospheric He(3S) density.