Geophysical Research Abstracts
Vol. 18, EGU2016-18402, 2016
EGU General Assembly 2016

Simulation of polar atmospheric microwave and sub-millimetre spectra for characterizing potential new ground-based observations

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Advanced detector technologies from the fields of astronomy and telecommunications are offering the potential to address key atmospheric science challenges with new instrumental methods. Adoption of these technologies in ground-based passive microwave and sub-millimetre radiometry could allow new measurements of chemical species and winds in the polar middle atmosphere for verifying meteorological data-sets and atmospheric models. A site study to assess the feasibility of new polar observations is performed by simulating the downwelling clear-sky submillimetre spectrum over 10-2000 GHz (30 mm to 150 microns) at two Arctic and two Antarctic locations under different seasonal and diurnal conditions. Vertical profiles for temperature, pressure and 28 atmospheric gases are constructed by combining radiosonde, meteorological reanalysis, and atmospheric chemistry model data. The sensitivity of the simulated spectra to the choice of water vapour continuum model and spectroscopic line database is explored. For the atmospheric trace species hypobromous acid (HOBr), hydrogen bromide (HBr), perhydroxyl radical (HO_2) and nitrous oxide (N2O) the emission lines producing the largest change in brightness temperature are identified and minimum integration times and maximum receiver noise temperatures estimated. The optimal lines for all species are shown to vary significantly between location and scenario, strengthening the case for future hyperspectral instruments that measure over a broad frequency range. We also demonstrate the feasibility of measuring horizontal wind profiles above Halley station, Antarctica with time resolution as high as 0.5hr using simulated spectroradiometric observations of Doppler-shifted ozone (O_3) and carbon monoxide (CO) lines in the 230-250 GHz region. The techniques presented provide a framework that can be applied to the retrieval of additional atmospheric parameters and be taken forward to simulate and guide the design of future microwave and sub-millimetre instruments.