ATMOSPHERIC TEMPERATURE SOUNDING AND PRECIPITATION CELL PARAMETER ESTIMATION USING PASSIVE 118-GHZ O_2 OBSERVATIONS

by

Albin John Thomas Gasiewski

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Abstract

The results of a theoretical and experimental investigation of satellite-based atmospheric sounding using passive microwave observations near the 118-GHz (1^-) O_2 resonance are presented. A tropospheric and stratospheric planar-stratified radiative transfer model for the purposes of passive microwave remote sensing of temperature and precipitation is described. Gaseous absorption is by O_2 and H_2O, and absorption and scattering by precipitation are modeled by sparse distributions of Mie spheres, assuming Marshall-Palmer liquid and Sekhon-Srivastava ice size distributions with Henyey-Greenstein phase functions. A novel iterative method of computing the temperature weighting functions for absorbing and scattering precipitation is presented.

Model calculations are compared with passive high spatial-resolution (~1.5 km spot size) 118-GHz multichannel imagery of clear-air and precipitation, as observed by the Millimeter-wave Temperature Sounder (MTS) instrument on board the NASA ER-2 high-altitude aircraft during GALE and COHMEX, 1986. The MTS is a double-sideband eight-channel 118-GHz scanning spectrometer with a 53.65-GHz fixed-beam radiometer. These are the first high spatial-resolution microwave images of atmospheric O_2 emissions, and are used to illustrate the meteorological capabilities and limitations of passive 118-GHz satellite-based observations.

Comparison between the MTS clear air 118-GHz brightness spectra and model calculations show systematic differences in nadiral brightness and scan curvature. The calculations are based on coincident radiosonde observations and use the Rosenkranz overlapping O_2 absorption line model. The cause of the discrepancies could not be unambiguously determined to be either experimental or spectroscopic, however, the discrepancies are consistent with an anomalous increase of ~15% in the 1^- line strength at altitudes near the tropopause.

Retrieval of precipitation cell-top altitude from the MTS 118-GHz data is demonstrated by a non-linear statistical operator. The operator uses the techniques of Karhunen-Loève decomposition, rank reduction, linearization, and linear minimum mean-square-error estimation. The RMS retrieval accuracy is 1.5 km for cumulus cell cores with top altitudes between 1.5 and

16 km. A non-linear decomposition of the MTS precipitation cell perturbation spectra reveals 2 to 3 observable degrees of freedom.

A comparison between the observed MTS 118-GHz precipitation cell brightness perturbation spectra and model calculations based on coincident weather radar observations of a storm cell couplet shows excellent agreement for the radiometrically opaque, mature cell core regions, but indicates that the 118-GHz spectra are quite sensitive to the assumed ice size distribution over the transparent anvil region. The physical retrieval of precipitation parameters is investigated using a cell model parameterized by top-altitude and water density. At 118-GHz, opaque cells are characterized by densities greater than 0.5 g/m^3, and can exhibit transparent-channel cell-top reflectivities of ~50%. The mapping from cell-top altitude and density to the dominant 118-GHz Karhunen-Loève spectral modes justifies the non-linear statistical retrieval of cell-top altitude, but suggests that retrieval of density using only 118-GHz precipitation cell spectral is not possible. The retrieval of cell density is facilitated by coincident observations using similar clear-air channels at 53- and 118-GHz, although the method is sensitive to mean ice size.

Thesis Supervisor: Prof. David H. Staelin
Title: Professor of Electrical Engineering