

Atmospheric Wave Detection and Parameter Estimation using Passive Measurements of Thermal Emission near 118 GHz

by

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Abstract

Measurements of atmospheric thermal emission near the 118.75-GHz ($1\bar{v}$) oxygen line were made with a scanning multi-channel spectrometer and used to measure thermodynamic effects of buoyancy wave motions in the lower atmosphere. A system model incorporating the physics of radiative transfer with the geometry and timing of the observation process is derived and then interpreted for small perturbations in atmospheric temperature and composition. A set of properties specific to plane wave inputs, which include an altitude-dependent distortion of the planar wavefronts and a viewing-angle-dependent amplitude attenuation, is developed, and the implications of these properties on the mathematical inversion process are investigated.

The wave detection and parameter estimations problems are posed in a maximum-likelihood (ML) framework whose structure is similar to that used in the classical bearing estimation problem. The wavefront distortion and attenuation effects are accommodated using a signal model in which individual spatial frequency components are mapped to distinct altitudes in the atmosphere. The strict ML solution and two suboptimal but efficient variants of this method are derived. A complete analytical evaluation of estimator performance and minimum detection thresholds follows. For a typical 8-channel, 10-minute observation segment, assuming a single-spot brightness accuracy of 0.5 K rms, theoretical detection thresholds of ~ 0.05 K and vertical profile accuracies of 0.1 K (at 4-km resolution) are achieved for a 10-km wavelength disturbance. Three methods for discriminating between the radiometric signatures of atmospheric waves and periodic interference are also developed and evaluated.

The detection and parameter estimation methods are applied to an extensive database of 118-GHz imagery gathered from high-altitude aircraft and ground-based platforms. A statistical survey of the aircraft-based database elicits fewer than 14 wave candidates in a 33-hour statistical sample, and no evidence of wave activity above 0.17 K amplitude. Ground-based imagery from the New Hampshire White Mountains regions reveals an abundance of ~ 5 -10 K periodic brightness structure which is demonstrated to be consistent with 2-10 km-wavelength modulations in either relative humidity or cloud liquid density.

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