Kernel flows to infer the structure of convective storms from satellite passive microwave observations

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Abstract:

Satellite passive microwave observations over precipitating clouds are used mostly to estimate the underlying surface precipitation rate. Yet the measured brightness temperatures are in fact far more sensitive to the vertical distribution of condensed water than to the amount of condensed water at any single height in the cloudy column, let alone the height that is deepest in the cloud, namely the surface. To retrieve the vertical structure from the microwave observations, careful attention is required in four steps of the estimation process, namely: 1) identification of the specific vertical-structure geophysical variables that are most directly related to the observations; 2) the a-priori constraints on the underlying variables; 3) the definition of the distance that quantifies how close or different two sets of observations are; and 4) the kernel (all-too-often assumed to be Gaussian) that is used to infer the vertical-structure variables from the observed brightness temperatures. We performed analyses to examine the last two elements of the retrieval: the optimal transformation of the measured brightness temperatures and the corresponding norm in the transform space, and the derivation of an optimal kernel. The algorithm that we used to find an optimal retrieval algorithm is called Kernel Flows. Each of seven different scalar geophysical variables (including surface rain rate, and 6 distinct measures of opaqueness of the observed storm column) was retrieved using the corresponding transformed microwave measurements and kernel, and the retrievals were compared in each case with the retrieval using the brightness temperatures assuming a Gaussian kernel, as well as with the retrieval using the "emissivity principal components" transformation of the measured brightness temperatures. The reference truths for the evaluation are the coincidence sets of nearly simultaneous radar and radiometer observations compiled for the Global Precipitation Measurement mission. Our performance comparison of the retrieval algorithms against the reference truth revealed that Kernel Flows significantly outperformed the currently adopted algorithms.