Rapid Calculation of Incremental Profiles for Satellite Radiometer Data Assimilation

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Assimilation of microwave radiometric data from satellite- and airborne sensors under all weather conditions is an important challenge in numerical weather prediction. Microwave radiances upwelling from the atmosphere depend strongly on frequency and carry a wealth of information on moisture and temperature profiles as well as clouds, rain, and surface parameters. Such sub-cloud top information is not available using infrared and optical wavelengths that are opaque over to clouds.

Microwave brightness temperatures generally depend on the electromagnetic scattering properties of hydrometeors through a process well described by the radiative transfer. Statistically optimal retrieval of the environmental parameters requires accurate calculation of the derivatives of the brightness temperature with respect to variations of all atmospheric and surface parameters. To accommodate the dense data stream from modern passive microwave satellites one requires calculations times of ~0.1 msec per profile or better. This talk will present an algorithm addressing these problems and some results obtained with it for Hurricane Bonnie (1998) simulations.

In our approach the atmosphere is represented as a stack of homogeneous horizontal layers. The differential radiative transfer equation (RTE) used models processes of photon generation and absorption by gases and particles as well as scattering by particles. Symmetry properties of scattering are very essential for building a fast solution, and the RTE is first cast into an explicitly symmetric form. Each layer is characterized by transmittance and reflection matrices that provide a complete description of the layer as far as its interaction with other layers is concerned. Accurate and stable calculation of those operators for arbitrary layer parameters represents a non-trivial task since the opacity and scattering coefficients vary over a wide range. Moreover, the layer can be fairly transparent at steep incident angles and opaque at grazing angles. Computationally, this problem results in the need to invert ill-conditioned matrices. We solve the inversion problem by first analytically factoring the matrix to be inverted into a product of five matrices. Four of them are regular, and only one diagonal matrix remains ill-conditioned. After explicit inversion the result includes only benign matrices and works well in all cases.

Once the transmittance and reflectance operators for all layers are known, the overall brightness temperature field is easily built using the method of slab doubling via two profile sweeps. Calculation of incremental profiles generally requires only one extra sweep. Thus, the number of operations required is directly proportional to the number of layers, and not to this number squared, as it would be for straightforward divided difference calculation.