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Scientific Evaluation of RTTOVSCATT

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VISITING SCIENTIST SUMMARY FOR NWP-SAF

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Objective: To allow independent review of the RTTOVSCATT model for microwave and sub-mm wavelengths.

Rationale: The NWP SAF will shortly deliver RTTOV-8, which includes the new microwave scattering model RTTOVSCATT. In 2003 extensive comparisons of this radiative transfer model with the ARTS model was undertaken. However ARTS has no gradient capability. NOAA have developed an adjoint model for a scattering model for microwave and sub-mm frequencies. It would assist the on-going evaluation of RTTOVSCATT for the Met Office to be visited by a leading expert from the NOAA team which developed this independent model.

Place: The work will be undertaken at the Met Office, Exeter, UK.

Dates: June 14-15, 2004.

Contact point: Steve English, the Met Office.

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RTTOVSCATT Model Summary & Reviewer Comments: The RTTOVSCATT radiative transfer model currently under development at the UK Met Office incorporates a two-stream scattering-based solution implemented by Peter Bauer and Frederick Chevallier at ECMWF. The solution uses the Eddington approximation for radiative transfer to permit a reduction of complexity of the problem to two streams of radiation. Up to six hydrometeor phases are considered in the hydrometeor absorption and scattering model: rain, snow, graupel, hail, cloud liquid water, and cloud ice, however, not all of these are expected to be used by the Met Office. The four types to be used (rain, cloud water, cloud ice, and snow) span those commonly found in predominantly stratiform storm systems associated with the Northeast Atlantic and European continent. The gaseous component of the model is based on the RTTOV8 clear sky absorption model, which is ultimately based on the well-established Liebe model for water vapour and oxygen absorption. Surface reflection and emission are obtained from the RTTOV8 model.

The primary application of RTTOVSCATT is radiance assimilation of clear and cloudy microwave data at the AMSU-A/B channels, specifically, those at or near 23.8, 31.65, 50-57, 89, 150, and 183 GHz, but also including those to be used for EGPM. Accordingly, a tangent linear (Jacobian) capability and adjoint are incorporated into the model. Variational assimilation schemes requiring RTTOVSCATT are being studied at the Met Office, including 1D-var and two-step 1D/4D-var.

The Eddington approximation assumes the radiation field to be composed of two counter-propagating radiation streams coupled by hydrometer scattering. A dipolar ($\cos \Theta$) perturbation field is introduced to describe radiation propagating out of the principle directions of propagation. To provide an analytical solution the Eddington approximation also assumes a phase matrix with a uniform scattering pattern. The Eddington approximation thus avoids numerical angular quadrature error associated with discrete ordinate schemes.

While the Eddington technique provides a computationally simple and elegant means of solution for any given layer, the accuracy of a first harmonic angular brightness approximation under a wide range of albedos and hydrometeor phase matrices is an area of concern. Actual hydrometeor scattering patterns and angular brightness functions are more complex than assumed under Eddington, and better represented by, e.g., Henyey-Greenstein phase functions and arbitrary angular brightness functions. Accordingly, the suitability of the Eddington approximation under all anticipated hydrometeor states needs to be studied. Ongoing work at the UK Met Office comparing RTTOVSCATT with the University of Bremen's ARTS model show sizeable differences in brightness (10-20K, depending on conditions). Such work should be continued to fruition, but care needs to be taken so that the intercomparisons provide for an unambiguous means of identifying the root causes of any differences. Additional intercomparisons with the NOAA/ETL DOTLRT V1.0 would also be valuable, and collaborative efforts to conduct such intercomparisons will be pursued.

Potential discrepancies between RTTOVSCATT and other RT models can arise from variations in the calculation of the Mie parameters for hydrometeor distributions. Such variations can arise from the differences in the specific dielectric constant model, dielectric mixing assumptions, Mie series convergence criteria, and averaging over the hydrometeor size distribution. Discrepancies can also arise from differences between the type of phase matrix assumed (e.g., Eddington, Henyey-Greenstein, Rayleigh, etc…). Recent efforts at NOAA/ETL in this area include the development of an exact Mie library which incorporates full phase matrix calculations for anticipated hydrometeor distributions so as to circumvent the need for phase matrix approximations. While the exact Mie library is explicitly designed for use in a multi-stream RT model such as DOTLRT, its application to RTTOVSCATT is not precluded, and tests of RTTOVSCATT using different implementations of Mie libraries and/or Mie routines are encouraged.

The utility of RTTOVSCAT (or any other scattering-based RT model) in variational assimilation not only hinges on the accuracy of the RT solution, but quite heavily on the partitioning of moisture into the gas phase and various other hydrometeor phases. This is an ongoing area of study at both the Met Office and other organizations (for example, NOAA). While there exist physically plausible partitioning models for certain classes of precipitating atmospheres (e.g., pure stratiform, convective), it is unclear whether these models will be sufficient to take advantage of the information available from microwave spectra. Specifically, a fundamental question exists as to whether sub-grid scale cloud models based on only one or two prognostic variables (e.g., water vapour and, possibly, cloud water density) can adequately represent the complex and spatially inhomogeneous cloud processes associated with even a single class of precipitation. Accordingly, much of the discussion with members of the Met Office focussed on contemporary cloud water partitioning models for both global and regional scale NWP models. It is acknowledged that much more work is needed in this area to derive the full benefit of microwave observations. However, improvements in forecast skill have been demonstrated using even simple partitioning schemes, thus, the assimilation of microwave radiances over clouds and rain using even nascent partitioning and RAT modelling schemes is an important and fruitful area of study, and a relevant topic of discussion at the upcoming ITSC-14 meeting, to be held in Beijing in the spring of 2005.