Scattering from non-spherical particles in all-sky radiative transfer

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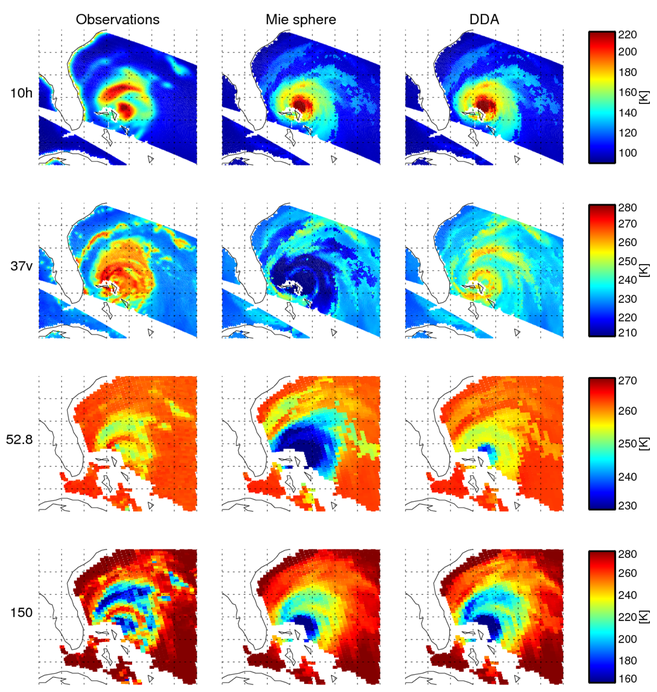
Overview

The assimilation of all-sky microwave radiances from imagers and sounders requires an accurate simulation of scattering from non-spherical frozen particles like cloud ice, snow, aggregates and hail. However, there are many issues to be addressed. This poster outlines the current approach and highlights a few issues for future improvement. To give a wider context, there is also a short status summary for RTTOV-SCATT.

Using NWP closure to choose the "best" representation of snow scattering



Geer and Baordo (2014, doi:10.5194/acp-17-2741-2017) chose a Liu (2008) sector snowflake as a "one shape fits all" model for snow, hail and graupel. Although this gave much better results compared to the old Mie sphere approach, there is still lots to improve. With a now rapidly expanding community working on particle scattering properties*, new particle models becoming available (e.g. melting particles, aggregates, graupel and hail), and better understanding of the issues of modelling cloud and precipitation, it is time to try and improve things further.

Some scattering-related issues:

1. Model convection scheme represents fluxes. Conversion to mixing ratio entails particle size distribution (PSD) and fall-speed approximations. The resulting snow mixing ratios may be up to 100% too large (Geer et al. 2017, ECMWF TM 815).

2. It should be possible to allow more hydrometeor types, e.g. separate large-scale and convective precipitation, allowing more precise habit choices (e.g. aggregate and hail).

3. Microphysical assumptions are made in the forecast model, in the flux to mixing-ratio conversion, and in the generation of bulk scattering properties. These are currently all inconsistent.

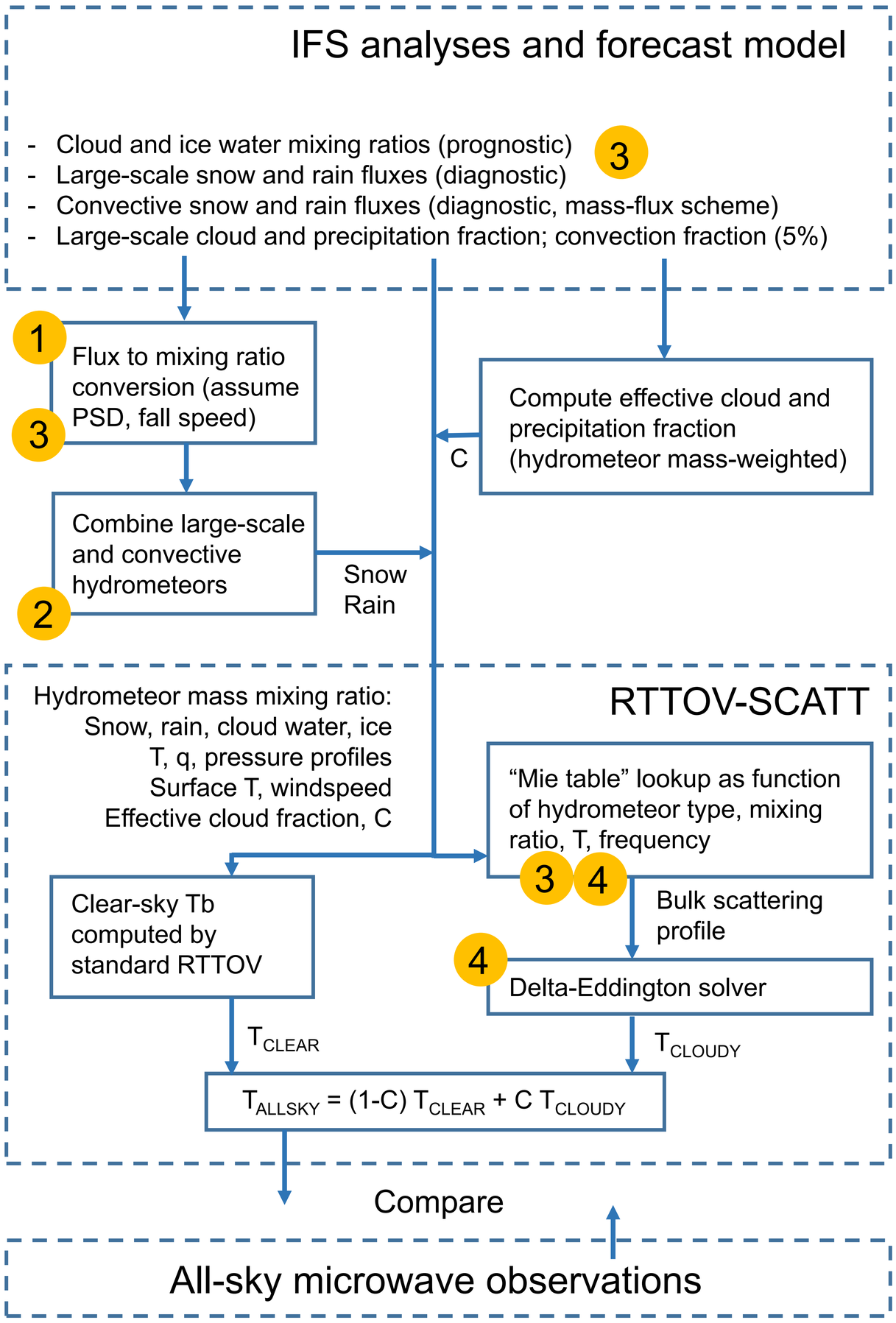
4. Polarisation effects of scattering are not taken in account, but they really should be (Gong and Wu, 2017, doi:10.5194/acp-17-2741-2017). Hopefully this does not need representation of the full Stokes vector – RTTOV only does scalar radiative transfer.

Re-examine everything

The problem is not simply a matter of choosing a better particle. Everything needs to be re-examined, and if for example a new flux-to-mixing ratio conversion is implemented, particle shapes will need to change in response. The ongoing work will be to critically examine all the assumptions, conversions and approximations involved in running RTTOV-SCATT, and to produce an observation operator chain that gives better fit to observations, while using more consistent microphysics assumptions in the forecast model and observation operator.

Aim for "microphysical closure"

For the future, we need to start constraining these microphysical assumptions using other observational sources: solar and infrared all-sky radiances, and active instruments like GPM DPR. This means we have to add all of these observational capabilities into NWP systems.



*A global effort to develop single scattering databases for science and NWP:

June 2017: "The First International Summer Snowfall Workshop: Scattering properties of realistic frozen hydrometeors from simulations and observations, as well as defining a new standard for scattering databases" Stefan Kneifel et al., BAMS

RTTOV-SCATT upgrades in v12.2, spring 2018

- Full capability to simulate all-sky sub-mm instruments (e.g. ICI and ISMAR).
- Radiative transfer done with radiances, not brightness temperatures, for accuracy at high frequencies (> 90 GHz)
- Framework to access ARTS single scattering database from Jana Mendrok, Robin Ekelund, Manfred Brath and Patrick Eriksson, giving access to new habits and scattering properties up to 886 GHz.
- New liquid permittivity models in "Mie table" (Katrin Lonitz)

Future developments (v13?)

- More modular, flexible "Mie table" generation code, including the ability to read standard-format scattering database files*, once a global standard has been defined.
- Hail and/or graupel hydrometeor types? Particle ensembles rather than "one shape fits all"? Additional degrees of freedom (e.g. additional moments of the size distribution)?