Detailed reports from the scattering working group including the scattering database focus session

IPWG/IWSSM, Bologna 3rd-7th October, 2016

General session

It was **recommended** to create a single scattering focus group to discuss common formats, sharing of databases, and exchange of information (which then had its first meeting in the afternoon, see later). The wider community need a platform which provides an interface to what different users need and what scattering community can provide, and an overview of what databases are available. Also, the single scattering properties are just the start of a process towards knowing the bulk scattering and other physical properties of hydrometeors, so that cloud and precipitation physics can be better represented in models and in forward operators.

It is **recommended** that developers of radiative transfer tools (e.g. RTTOV, CRTM, Quickbeam) start to decouple their forward models from their scattering datasets. At best, there is usually just a hard-coded choice of Liu shapes. A common single scattering database format will be a great help in this process.

The space agencies are asked to **note the importance** of developments in representing particle scattering and improved microphysical knowledge towards full exploitation of current and future microwave missions.

Towards the simulation of bulk scattering properties, it is important to know how much detail is required for any particular application. Sensitivity studies are needed to that we know the required complexity of scattering solvers, particle choices, and other microphysical details. There is a demand for a "one-shape fits it all" strategy, particularly for global passive microwave applications. Is this possible without incurring large errors, is there a physically justified approach, such as ensemble shape averages, that can meet this need? There are similar problems in the optical scattering community, from whom we could learn. We can use microphysical models or aircraft datasets to determine ensemble shape properties from which we can derive ensemble scattering properties. More generally we need to know more about, and validate, PSDs and other physical particle properties (m-D, v-D, AR, etc.)

The variability of scattering and microphysical properties even within a satellite footprint or model grid box is important to understand. This is why most applications need to average over scattering properties of many particles. Knowledge of the spatial variability will show us how to do these integrals more accurately. This particular aspect could be addressed by aircraft campaigns and ground based networks.

It is important to understand what is missing in current single scattering databases, where there are science gaps:

- rimed particles
- melting particles, mixtures of liquid water and ice, important when melting layer is present for passive (emission) and active (attenuation) observations
- particles from convective cores (e.g. densely rimed particles, graupel, hail, special aggregate types?)
- Some in-situ properties (e.g. distribution of monomers in aggregates) are still unknown/scarce; the in-situ community could give guidance

We considered how to validate scattering properties:

- Case studies:
    - triple-frequency moments and Doppler spectral constraints,
    - in-situ (new PSD in-situ measurements should also measure mass)
    - matching ground-based radar and MWR
    - 183 GHz radiometer scattering observations are dominated by convective cores for which airborne observations are very hard to make (though some airborne observations with in-situ MC3E available)
- Laboratory scattering measurements (cloud chamber snowflakes, measuring scattering for different incident angles, determine refractive index of ice)
- Model-to-satellite approach: using global NWP or convective-scale model simulations, and analyzing biases
- Match-ups of DPR+GMI or similar (deriving IWC from radar and matching with simulated GMI TBs, e.g. Kulie 2010 approach)

Focus session on scattering databases

The single scattering community is very keen to come together to define **common data conventions** (for basic scattering properties, physical shape data and detailed scattering properties like scattering matrices), a **repository** to help share scattering datasets with the wider community, and a forum for discussion and exchange of **tools, guidelines and best practice**.

We now have a committed group of scattering database developers (to which others will be invited, e.g. Guosheng Liu, etc.) who are prepared to work together on these common definitions, and wider sharing of data and methods.

One general point is that this is not meant to restrict innovation and any common conventions need to be flexible enough to allow for new scientific developments and new ways of representing scattering properties.

There may be a possibility to learn from the infrared and optical community.

Common data conventions

The very first priority is to work on the common data conventions. Stefan Kneifel will set up a google doc to enable a coordinated discussion on the new conventions.

To define a common set of:

- core scattering variables (e.g. scattering cross section, asymmetry parameter, phase function, particle mass, physical cross section, maximum dimension, frequency, temperature, and other basic properties taking the Liu database as a starting point for the parameter set, any other variables?)
- variable names, units (definitely SI)
- conventions (e.g. dividing by 4pi?)
- metadata (e.g. how the scattering simulations have been done, permittivity/dielectric constant)
- orientation flag and reference frame definition (either randomly averaged, or for specific orientations)

- physical shape data: 3D particle description in x,y,z space, unit vector of incident wave in that coordinate system, polarization of the incoming radiation. The physical shape is useful not just for repeating scattering calculations at new frequencies and orientations, but also for in-situ validation.
- is there a minimum set of parameters that will support a large number of users (e.g. RTTOV-SCATT, DISORT, ARTS, CRTM, other communities like radar?)

More detailed scattering outputs are harder to define, take up very much more storage (e.g. terabytes) and will take more discussion. We hope to have the core common set defined first, and then iteratively work towards the more challenging aspects.

Data format is likely to be NetCDF 4.3 (or HDF) although it is far more important to establish the conventions than the precise format at this stage. Almost everyone was happy to use NetCDF.

Repository

There is no compulsion for everything to go into one repository, and with common conventions it is possible for many different groups to host files with common conventions. However, the NASA STORM PPS repository already holds Kuo's scattering databases and they are very willing to host other databases from the community. This is great and would be recommended. It will be possible to take advantage of Kuo's tools for interfacing to the database, filtering out specific subsets of data, and creating bulk scattering properties.

Tools

Later on, we hope the forum will allow for exchange of tools like:

- Conversion of formats (e.g. between different scattering conventions, e.g. Mischenko vs Bohren-Huffman; input formats for tools like ARTS, radar forward operators)
- Orientation averaging
- Interpolations across T and frequency, sizes

Methods

We need a better understanding of methods to calculate scattering properties. Available are:

- DDA accurate but slow;
- Invariant-imbedded T-matrix IITM = any particle shapes up to size parameter 50, particle orientations are free. But for non-symmetric particles matrix may not converge;
- Characteristic Basic Function Method (CBFM) has similar advantages (matrix gives all orientations for free; fast);
- clusters of spheres approach;
- Is there anything that geometrical optics can do? (some say it might be possible down to 660 GHz, down to a size parameters of 10?)

Speed is needed for bigger aggregates and higher frequencies.

Validation

There is a possibility of having a set of "reference" shapes for groups to model and to check their scattering properties agree. More validation will be done across the broader community.

Outreach/advertising the group

- Ben Johnson will advertise at GPM science team meeting; contact Guosheng Liu, Grant Petty and Ping Yang etc.
- AGU session run by Jussi Leinonen and Ben Johnson
- Alan Geer to talk to Robin Hogan and others in EarthCare community
- Eugene to communicate to ASR community
- Group members to ask around their communities