Light scattering on non-spherical particles

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Interaction of electromagnetic waves with small particles is a vast field of research with applications in such diverse fields as atmospheric science, ocean optics, biomedical imaging, nano-optics, material science, process engineering, combustion diagnostics, as well as in observational astronomy of dust in the solar system, the interstellar medium, protoplanetary disks, exoplanets, and the circumstellar environment of red giant stars. In atmospheric physics the interaction of radiation with aerosols and hydrometeors has important applications in both climate research and earth observation. Atmospheric particles can be found from nucleation aerosols at the nanometre scale up to hailstones at the centimetre scale; they have complex morphologies, and aerosols have varying, often heterogeneous chemical composition. To represent the optical properties of such complex particles in remote sensing retrieval algorithms, data assimilation observation operators, or in the radiation scheme of climate models generally necessitates simplifying assumptions about the particles' morphological properties.

If such approximations are made carelessly, then one runs a risk of introducing errors that can exceed those caused by model or measurement errors. Several examples of recent studies on such complications will be reviewed in this presentation. For instance, the optical properties of black carbon aggregates internally mixed with weakly absorbing water-soluble compounds are significantly different from those computed with the commonly employed homogeneous sphere or concentric core-shell models [1]. A novel "core-greyshell" model, which attempts to better mimic the physics of the electromagnetic scattering process in such particles, yields a substantially improved representation of the optical properties of such particles [1]. When employed in the observation operators of a chemical data assimilation system, the over-simplified model particles can yield errors of comparable magnitude as those introduced by simplified aerosol process descriptions, such as bulk models that neglect aerosol dynamics.

Another example are porous volcanic dust particles, which are commonly represented in remote sensing retrieval methods by a homogeneous sphere model. Recent computations based on porous irregular model particles demonstrates that the homogeneous sphere approximation introduces significant errors in computed IR brightness temperature differences (dBT) [2]. When used for mass load retrieval of volcanic dust plumes from dBT satellite observations, the homogeneous sphere assumption results in errors of as much as 30 %, which is almost as high as all other error sources combined [2].

In both of these examples the particles were both geometrically irregular and topologically complex. More fundamental recent modelling studies on the optical properties of particles with different morphologies seem to confirm that inhomogeneity is a topological property with a profound impact on optical properties that is difficult to mimic with over-simplified homogeneous model particles [3].

[1] M. Kahnert, T. Nousiainen, H. Lindqvist. Opt. Express 21 (2013) 7974-7992.

[2] A. Kylling, M. Kahnert, H. Lindqvist, T. Nousiainen. Atmos. Meas. Tech. 7 (2014) 919-929.

[3] T. Nousiainen, M. Kahnert, H. Lindqvist. J. Quant. Spectrosc. Radiat. Transfer 112 (2011) 2213-2225.