Using a New Scattering Order Formulation of the Discrete Dipole Approximation to Calculate Scattering by Irregularly Shaped Aerosols

Carynella Haspel (caryn@vms.huji.ac.il) and Masada Tzemach Tzabari

The Fredy and Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem 91904 Israel

The discrete dipole approximation (DDA):

1. break-up a target into a three-dimensional grid of polarizable points (dipoles)
2. near field dipole fields dictate the radiative interactions among the dipoles
3. far field dipole fields dictate the total radiance of radiation scattered by the target

Conventional implementations of the DDA:

1. a matrix equation for the dipole moment per unit volume at each point
2. calculate the scattered radiance as a function of angle

The scattering order formulation of the DDA (SOF-DDA):

1. A scattering target is divided into polarizable points. Points are only defined near the target's boundary.
2. The dipole moment per unit volume at each defined point is calculated according to the electromagnetic field incident on the target from the outside only. This is called the 0th order dipole moment.
3. The 1st order scattered field in the far field is calculated according to the electromagnetic field incident on the target and the 0th order dipole moment, added to the 1st order scattered near field at each defined point.
4. The 2nd order dipole moment per unit volume at each defined point is calculated according to the electromagnetic field incident on the target from the outside and the 1st order scattered far field.
5. The 2nd order scattered field in the far field is calculated.

Sample calculations for highly irregular shapes:

The SOF-DDA approach for this simple target:

Note that the iterations converge after only 5 orders of scattering, demonstrating the efficiency of the SOF-DDA approach for this simple target.

Note also the interesting progression of the ratio of backscattering to forward scattering that one can observe using the SOF-DDA rather than a conventional numerical iteration procedure.

Advantages of the SOF-DDA:

1. hierarchies are "physical" rather than numerical
2. dipoles may be placed with arbitrary spacing
3. no system of coupled equations, no resort to invert
4. no grid points needed, the target is not a rectangle
5. readily parallelizable with no theoretical maximum number of CPUs

Our new SOF-DDA "marcching scheme":

1. The plane wave hits one side of the particle first, exciting a wall of dipoles nearest to the point of incidence.
2. The wave advances and the second gets its 1st order dipole moment while the first will advance to its 2nd order dipole moment.
3. This pattern advances the entire particle, all dipoles have been "activated" and they are all set at all the same "teaching step".

How thick should the wall of dipoles be?

1. Use the model of an under-damped forced harmonic oscillator.
2. The r-folding time for transients to die down (~W/2Pi) / where W is the linewidth of the absorption peak within which the frequency of the incident radiation is contained.
3. Using a close estimate for a dielectric material, the linewidth of water is 100 GHz
4. Multiplying the speed of light in vacuum, the incident plane wave has a wavelength of 0.500 microns, which means the dipoles have already started oscillating with a period of 100 GHz.

The wall of dipoles should be no more than one dipole-thick.

The SOF-DDA Marching scheme on a larger sphere:

1. The wall of dipoles should be no more than one dipole-thick.
2. Extinction calculations were performed on HPA for the first time using dipole spacing 1 nm, which is equivalent to 17,972,210 dipoles
3. The original DDA model was able to fold...