Advances in CRTM aerosol simulations with v3 release

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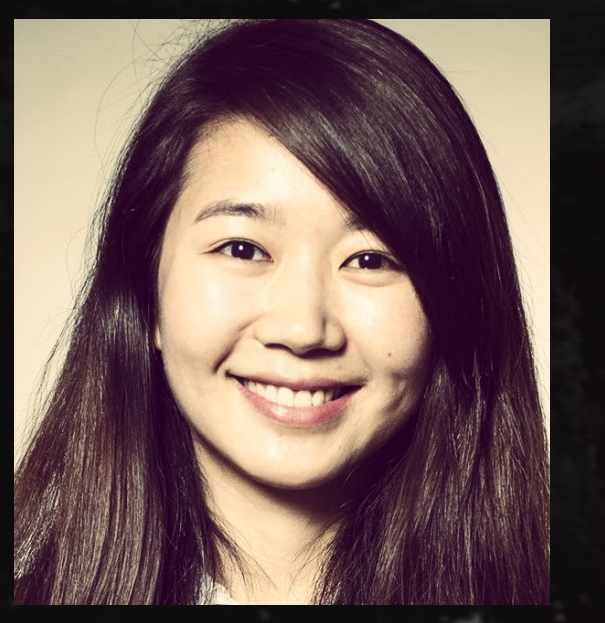
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Introduction

The **Community Radiative Transfer Model (CRTM)** is operationally used for aerosol radiative-property (such as AOD) data assimilation. CRTM simulates the aerosol light absorption and scattering based on offline **aerosol optical property lookup tables (LUTs)**; the accuracy of computed radiative quantities is therefore primarily constrained by the a priori knowledge of aerosol optical properties stored in LUTs.

Over a decade ago, CRTM implemented an aerosol LUT for five species following the then Goddard Chemistry Aerosol Radiation and Transport (GOCART) model; this LUT has been used as the default LUT for CRTM simulations since then. However, with the recent theoretical and observational advancements on aerosol properties and the growing interest in modeling more species, a more flexible CRTM aerosol interface is desirable.

Data Assimilation: estimate the optimal atmospheric states

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x_b})^{\mathbf{T}}\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x_b}) + \frac{1}{2}[H(\mathbf{x})-\mathbf{y}]^{\mathbf{T}}\mathbf{R}^{-1}[H(\mathbf{x})-\mathbf{y}]$$

$$\nabla J_{\delta x} = \mathbf{B}^{-1}\delta\mathbf{x} + \mathbf{H}^{\mathbf{T}}\mathbf{R}^{-1}(\mathbf{H}\delta\mathbf{x}-\mathbf{d}) = 0$$

H(x) - Observation operator, *Community Radiative Transfer Model (CRTM)*

Overview of CRTM aerosol modules

Binary I/O
netCDF I/O

CRTM_Init (SENSOR_ID, &
    chinfo, &
    Aerosol_Model, &
    AerosolCoeff_Format, ...)

CRTM default
CMAQ
GOCART-GEOS5
NAAPS
RTTOV

With the release of CRTM version 2.4 in October 2020, we introduced **netCDF interface** for pre-computed aerosol coefficients. Besides the default binary format, CRTM now provides optional look-up tables in the NetCDF-4 format. We also expanded the aerosol schemes to include more coefficient look-up tables based on various aerosol models, including:
(1) the **Community Multiscale Air Quality Modeling System (CMAQ)** model (released in CRTM version 2.4).
(2) the **Goddard Chemistry Aerosol Radiation and Transport (GOCART)** model used in Goddard Earth Observing System Model version 5 (GEOS-5).
(3) the **Naval Aerosol Analysis and Prediction System (NAAPS)** model.
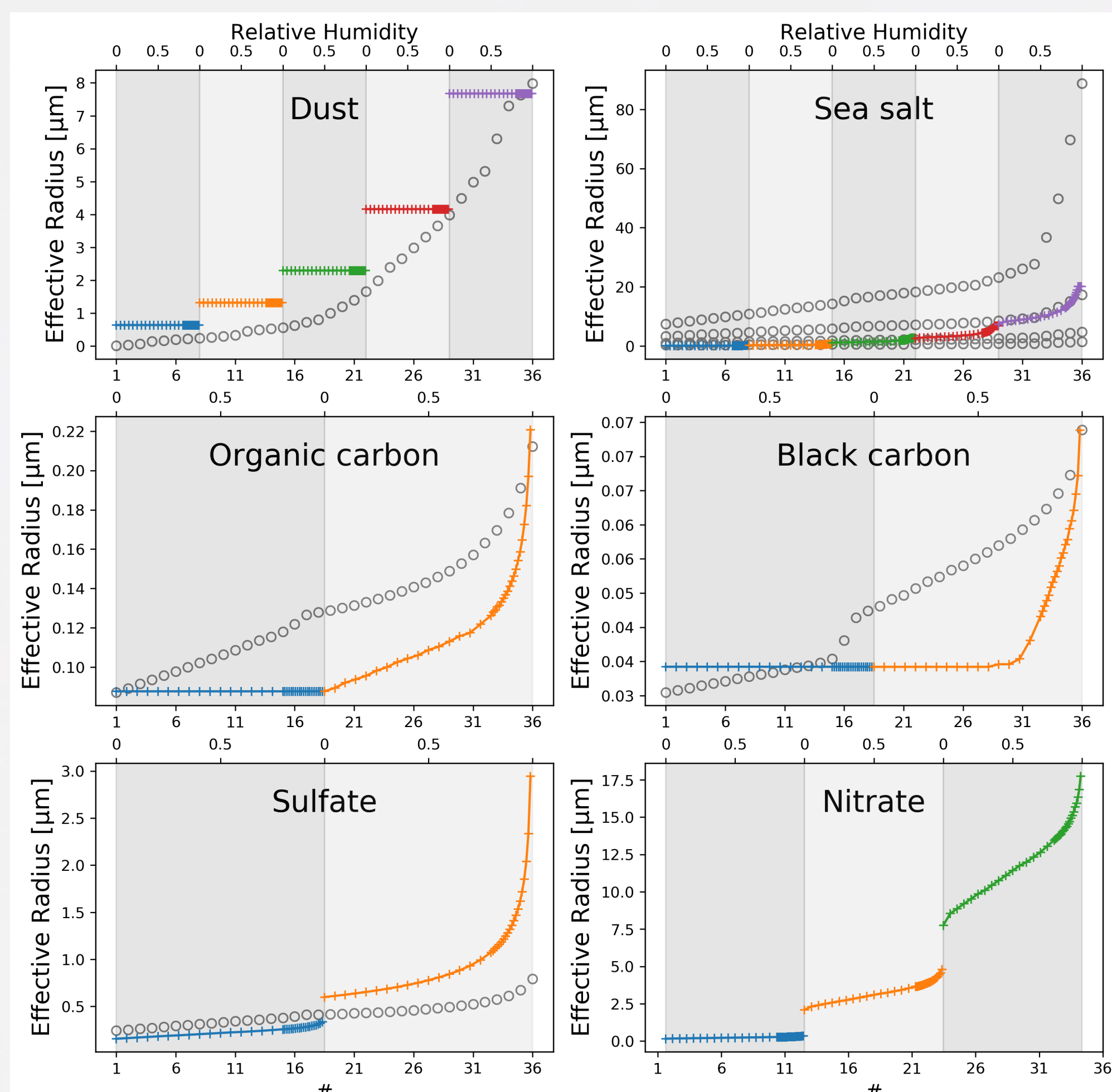The latter two will be released with CRTM version 3.0 soon.

Aerosol Optical Properties

Figure 1. Aerosol effective radii specified in CRTM-default(open circles) and GOCART-GEOS5 coefficient lookup tables (colored crosses)


Figure 2. Intercomparison of select aerosol single-scattering properties between the CRTM aerosol lookup tables. Numbers listed in both figures are aerosol effective radii

CRTM-default vs. GOCART-GEOS5
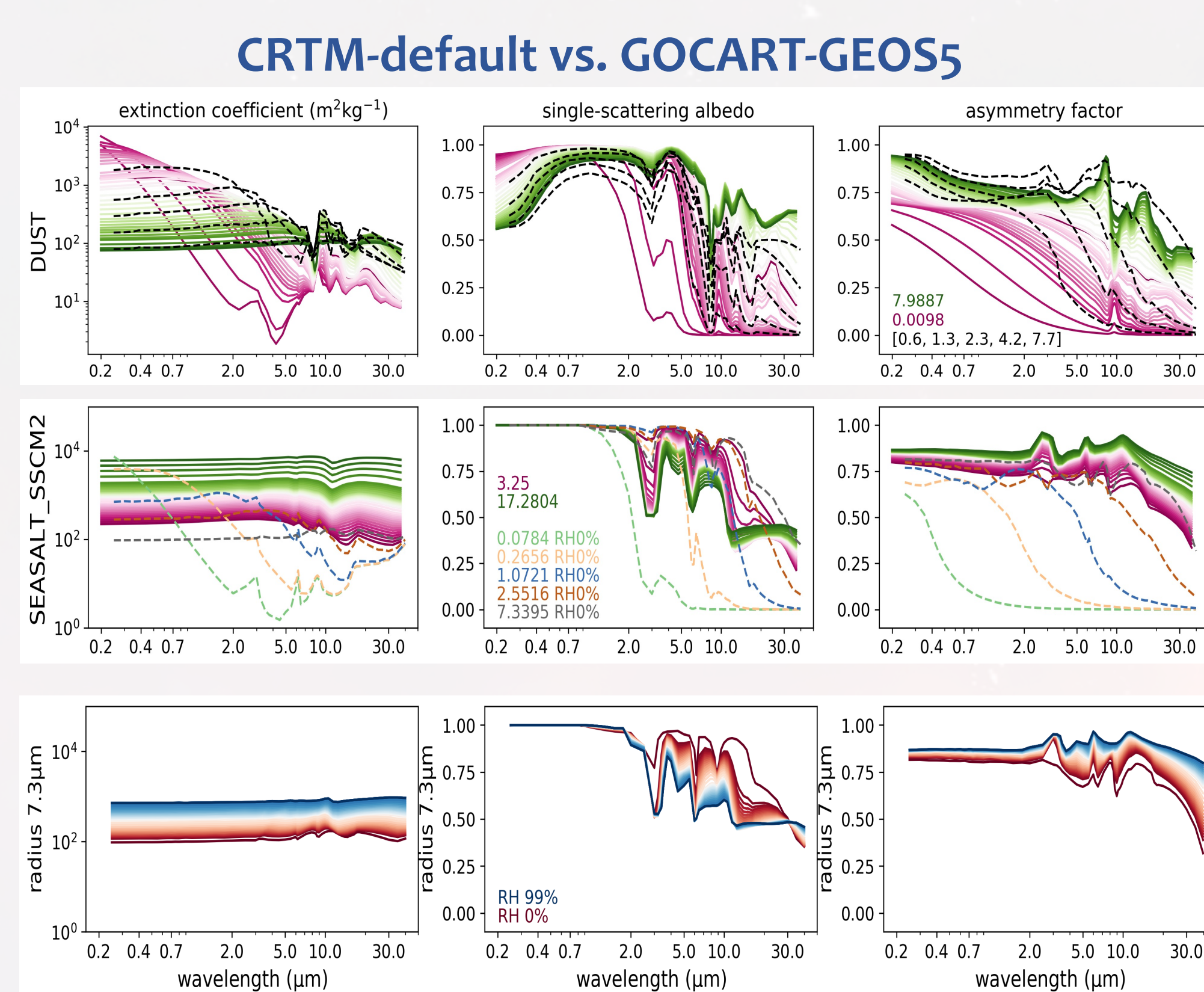
[Pink to green] the default LUT with increasing radius
[Dashed] GOCART-GEOS5
[Red to blue] GOCART-GEOS5 LUT with increasing relative humidity

CRTM-default vs. CMAQ
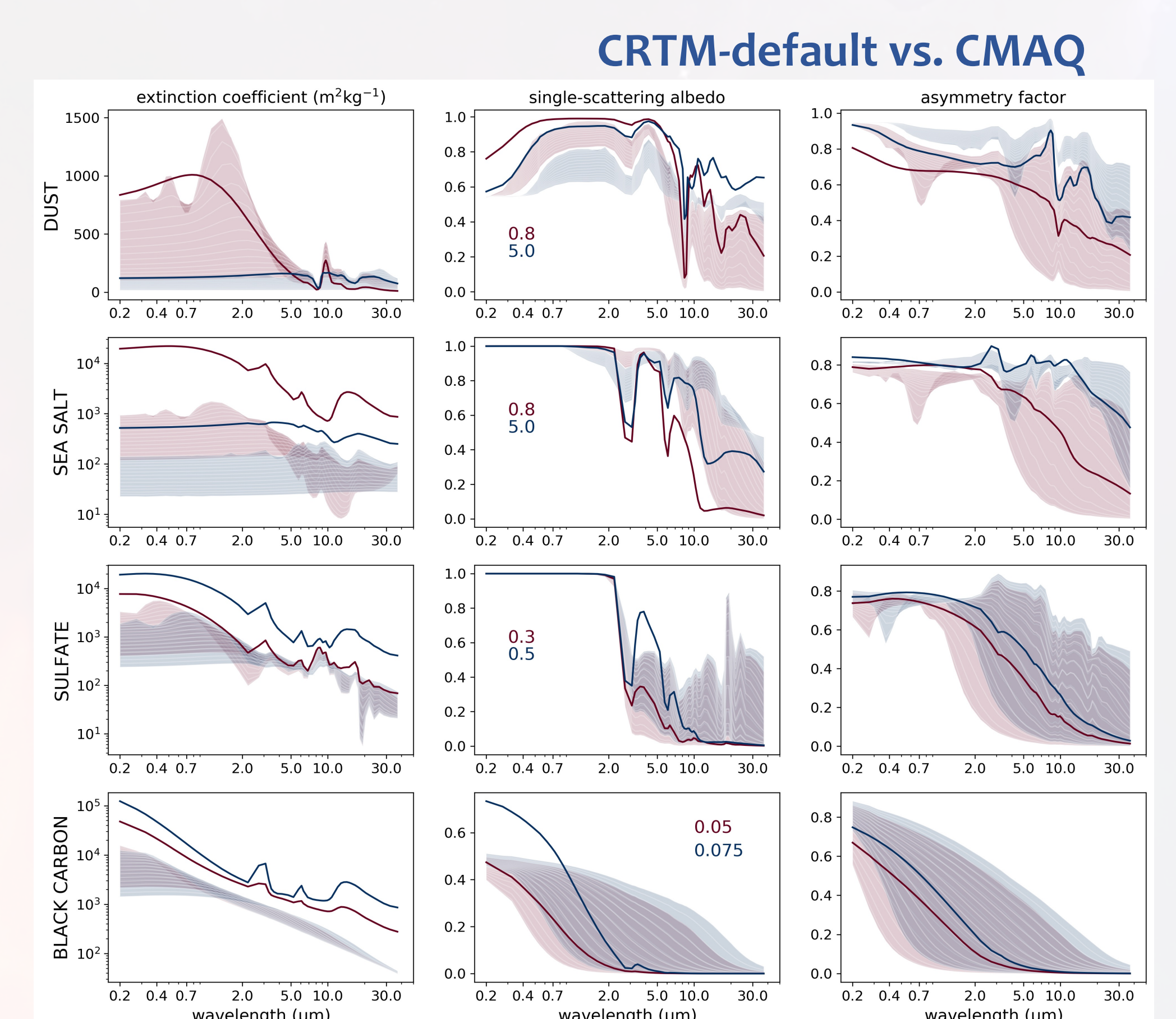
[Curves] the default LUT
[Shade] CMAQ LUT with the similar effective radii but different size variances

Aerosol Optical Depth (AOD)

Figures, *a.* Column total aerosol concentration of May (MERRA-2 climatology) and *b.* the corresponding AOD simulated using CRTM, averaged over six aerosol schemes. *c.* percentage differences in AOD computed using each aerosol scheme.

Dust

Sea Salt