Mass to optics

MECs, AE and fine / coarse AOD

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Phase III Control reference paper

AeroCom phase III multi-model evaluation of the aerosol lifecycle and optical properties using ground and space based remote sensing as well as surface in situ observations

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Under revision in ACP:

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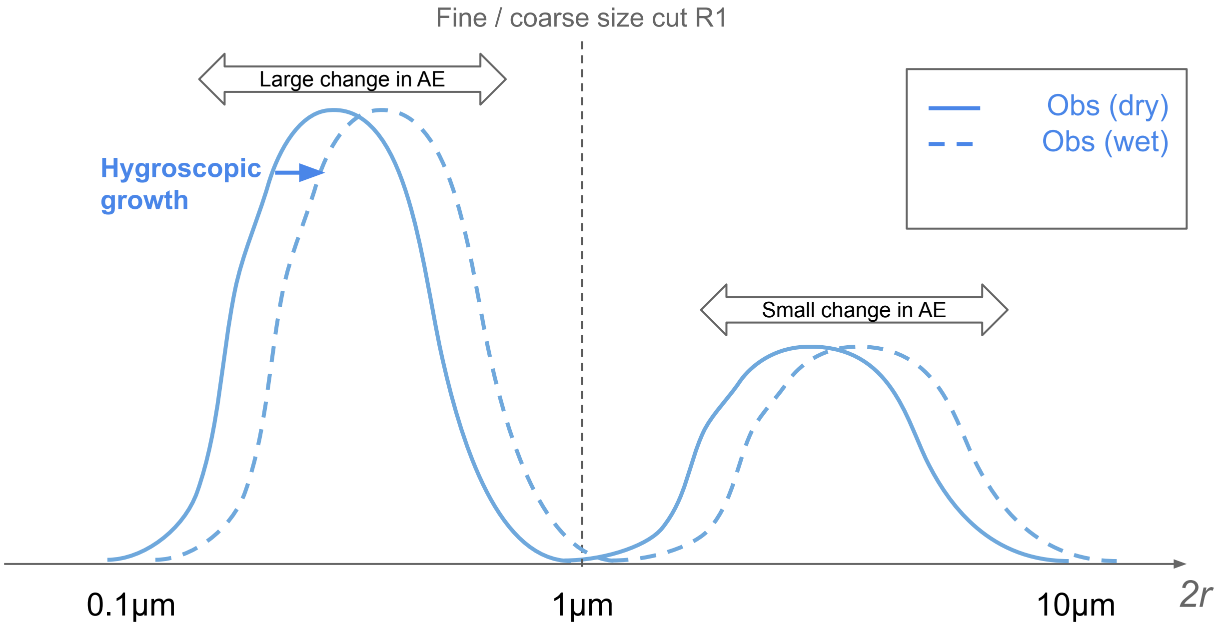
⇨ ***Revised manuscript available in AeroCom workshop material***

Background / Motivation

Simplified scheme of bimodal size distribution - optical effects are indicated for mid-visible wavelengths

- **Angstrom Exponent (AE)**: qualitative indicator of size (inversely related, intensive property).
- **Fine / coarse AOD (AOD_f, AOD_c)**: extensive properties (proportional to mass).
- Coarse regime spectrally flat at 550 nm →Variations in AE more sensitive to fine mode.
- Mie extinction efficiency Q_{ext} at 550 nm higher for "finer" particles ($MEC \rightarrow MEC(Q_{ext})$)
- Scattering enhancement due to water uptake depends on size too →larger for smaller particles (e.g., Zieger et al., 2013).



$$AOD_f = \int_0^{R1} A_p(r)\, Q_{ext}(r,m)\, n(r)\, dr = \mathbf{LOAD \times MEC}\, \Big|_0^{R1}$$

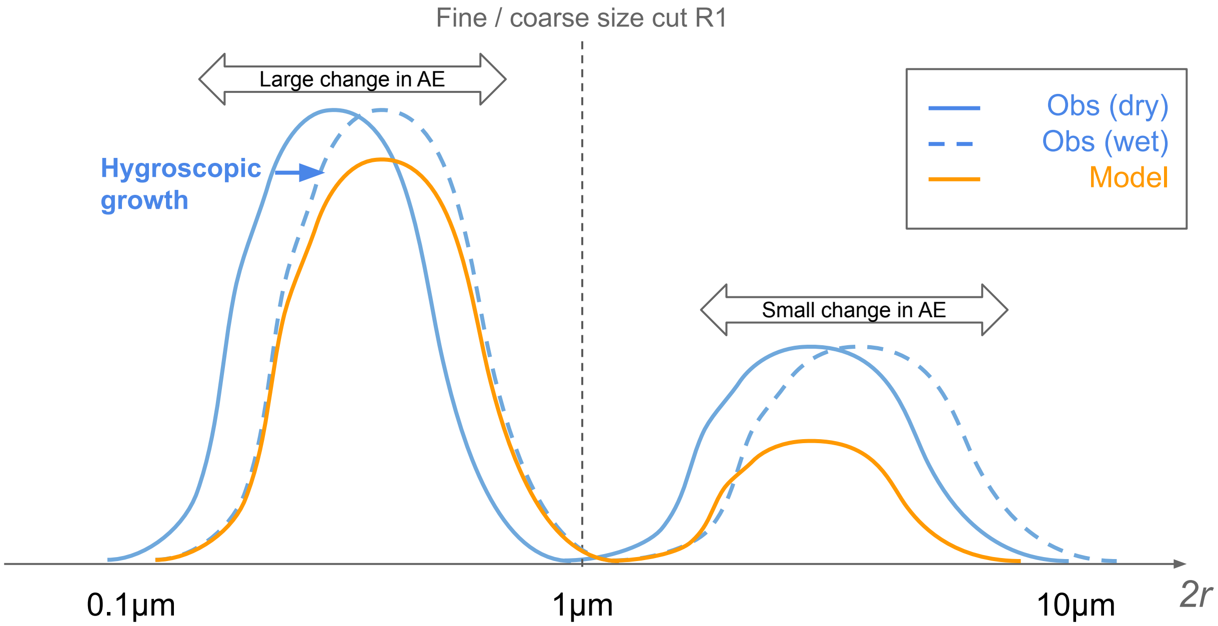
$$AOD_c = \mathbf{LOAD \times MEC}\, \Big|_{R1}^{\infty}$$

$$\mathbf{AE} = -\log(AOD_{\lambda 1} / AOD_{\lambda 2}) / \log(\lambda 1 / \lambda 2)$$

Background / Motivation

- Scattering enhancement due to water uptake depends on size too →larger for smaller particles (e.g., Zieger et al., 2013).
- Pure (monomodal) fine aerosol: *If a model underestimates AE, it overestimates fine aerosol size effective radius.*
- Things are more complex for bimodal mixtures (Schuster et al., 2006).
    - lower (UV) wavelengths more sensitive to fine mode eff. radius.
    - higher (IR) wavelengths more sensitive to fine mode volume fraction.
- Disagreement between models and observations can be due to wrong size, but also composition.

Simplified scheme of bimodal size distribution - optical effects are indicated for mid-visible wavelengths



$$\mathbf{AOD_f} = \int_0^{R1} A_p(r)\, Q_{ext}(r,m)\, n(r)\, dr$$

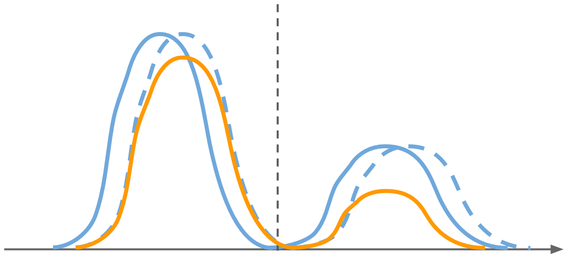
$$= \mathbf{LOAD \times MEC} \,\big|_0^{R1}$$

$$\mathbf{AOD_c} = \mathbf{LOAD \times MEC} \,\big|_{R1}^{\infty}$$

$$\mathbf{AE} = -\log(AOD_{\lambda 1} / AOD_{\lambda 2}) / \log(\lambda 1 / \lambda 2)$$

(Some) remaining issues and open questions

- Diagnosing fine and coarse AOD (AOD_f, AOD_c)
  - Some models use dry aerosol, others ambient to determine AOD_f
  - ca 10% difference in attribution of sea salt optical depth (OD) to AOD_f and AOD_c
- Diagnosing species extinction and absorption optical depth
  - AeroCom requirement: *AOD=∑(all species ODs)*
  - Internal mixtures: in some models $AAOD_{BC} > OD_{BC}$
- Diagnosing NO_3 and other new tracers (NH_4), e.g.,
  - some NO_3 contributions are attributed to other species (e.g. only fine NO_3 is in od550no3 diagnostic and coarse NO_3 is included in od550ss).



(Some) ideas / recommendations / discussion material

- Diagnosing fine and coarse AOD (AOD_f, AOD_c).
  - **Suggestion:** More consistency would be helpful; we suggest to ***use ambient radius for split***.
- Diagnosing species extinction and absorption optical depth.
  - BC MEC vs MAC: needs revision on how to best diagnose component ODs and AAODs for internal mixtures
  - **Requirement**: Models need to ensure that, e.g., $AAOD_{BC} < OD_{BC}$
  - **Requirement**: *AOD=∑(all species ODs)* (ambient)
- Ambient vs dry vs CS
  - **Suggestion:** We recommend diagnosing both clear-sky and all-sky AOD, to better assess impacts of simulated supersaturated environments.
- Diagnosing NO_3 and other new tracers (NH_4), e.g.,
  - **Suggestion:** If diagnosed explicitly, we suggest that all mass / OD should be attributed in the associated diagnostic.
- Additional AE diagnostics?
  - Vertically resolved AE, SAE, AAE → ec440dryaer, ec870dryaer, ac440dryaer, ac870dryaer
  - Spectral curvature: **670-870 nm** → sensitive to fine mode volume fraction; **380-440 nm** → sensitive to the fine mode effective radius (Schuster et al., 2006).
  - **Suggestion:** additional output of dry EC and AC as well as AOD at 4 wavelengths between 380 nm and 870 nm. Feasible?
- AOD Speciation and MECs?
  - **Suggestion:** Total and fine mode burden and optical depth (i.e., loadss, loadlt1ss, od550ss, od550ss, od550lt1ss). Feasible?
- Should there be a CTRL rerun (CTRL 2020) with new diagnostics?
  - Could additional diagnostics be added to existing CTRL 2019 data?
  - Some models may have seen improvements since CTRL 2019, perhaps new runs?