Remote sensing of aerosol from space: A more direct role for in situ measurements?

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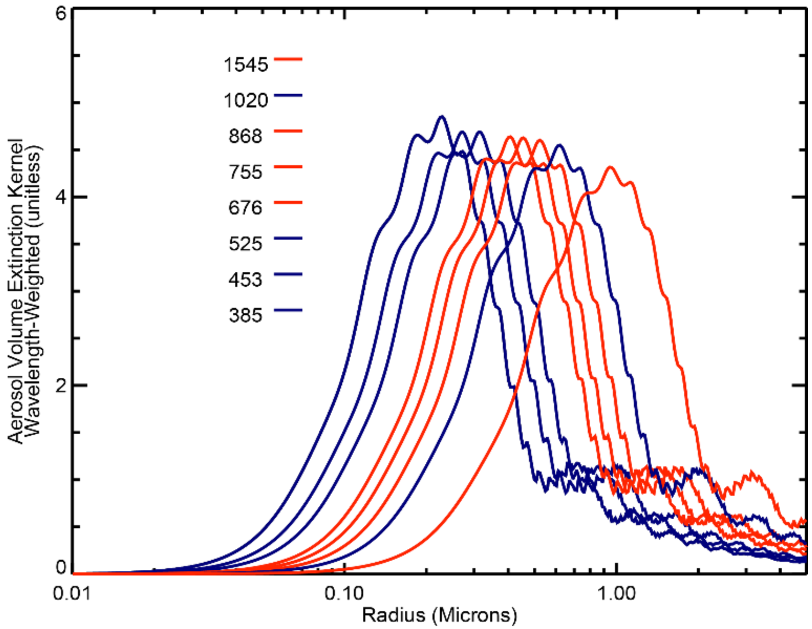
Goals for Space-based Measurements

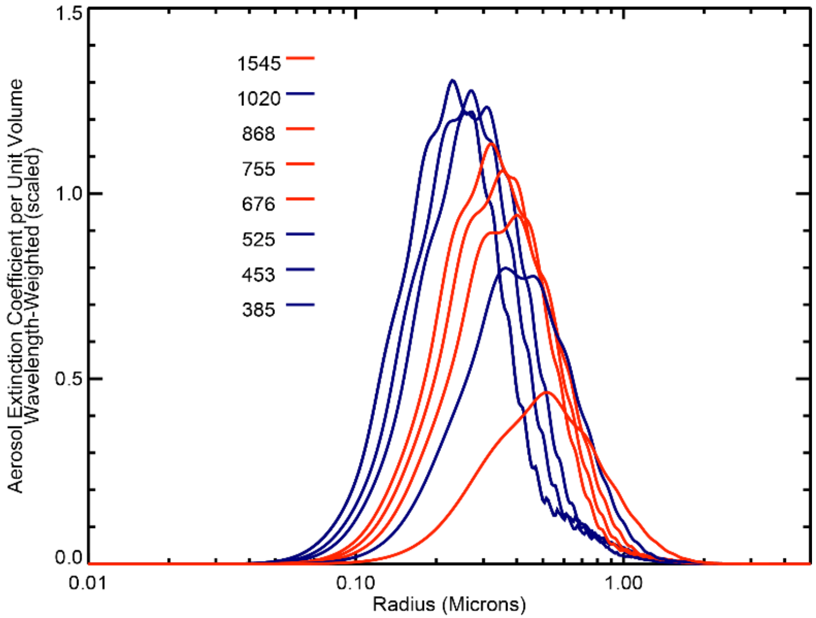
- Robust optical measurements of the global distribution of stratospheric aerosol (Mission)
  - And science based on those measurements
- Properties inferred from those measurements; often for our ‘customers’
  - Bulk properties like SAD, volume (mass), radiative effects, etc.
  - More detailed descriptions of the aerosol including
    - Size distribution
    - Composition

The SAGE II/III retrieval world

SAGE II/III aerosol extinction kernels (times wavelength and per aerosol volume)



SAGE II/III kernels weighted by a nominal single mode log-normal (*r_m = 0.1, σ = 1.6*)



Limitations to remote sensing of aerosol from space

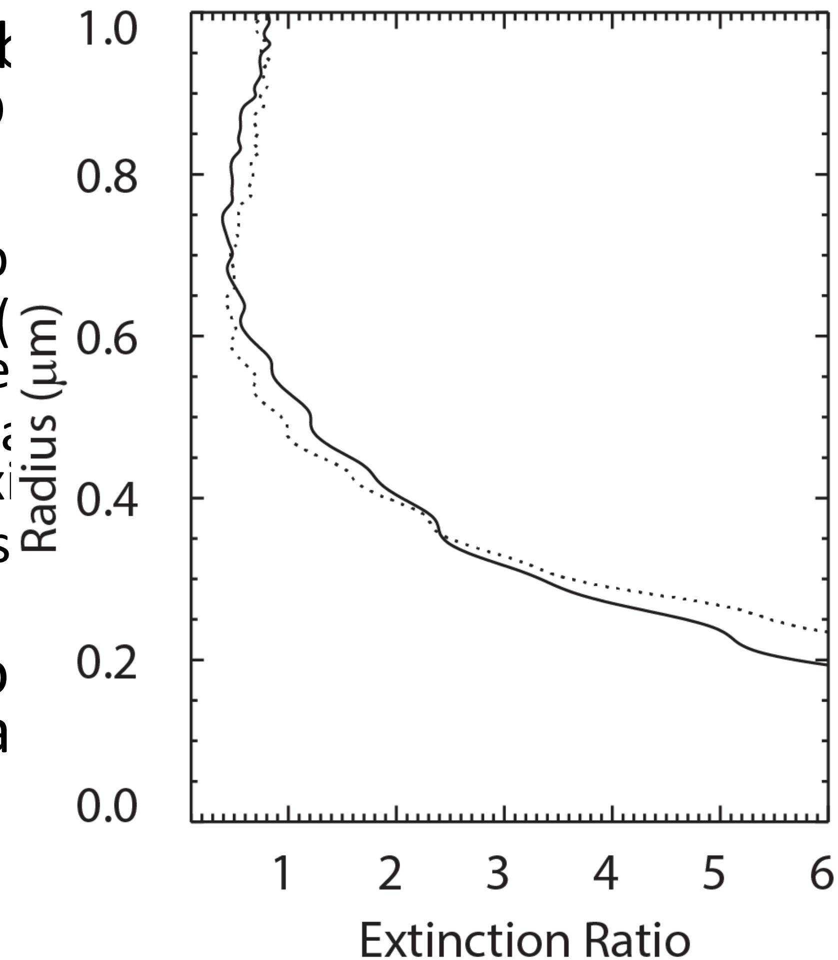
- Fact 1: Due to correlation between measurement kernels and how that interacts with measurement uncertainty, there is never a situation that allows solving 'N-measurements for N unknowns'
  - 3 of SAGE II's measurement wavelengths are very correlated and relate just a little information more than one of them alone does
- Fact 2: Whatever the number of pieces of information you may have from a set of measurements, selecting which pieces of information they are is not an option
  - E.g., UV/vis measurements of aerosol extinction effectively have no information about small particles (<0.1 μm) and thus 'don't know' parameters like total number density. Results become model dependent.

Tales of the single mode log-normal (SMLN)

- Applications of SMLNs are attractive because
  - They are mathematically compact (3 variables to do it all)
  - They reduce the solution space to a solvable size
  - The general perception is that they are broadly appropriate
- Outcomes of using SMLNs
  - The assumption of size distribution shape has a powerful impact on available solution space and key parameters like SAD
  - My experience is fitting SMLNs to SAGE II data yield very narrow size distributions essentially fitting the positive tail of the size distribution while doing ‘whatever’ at the short end.

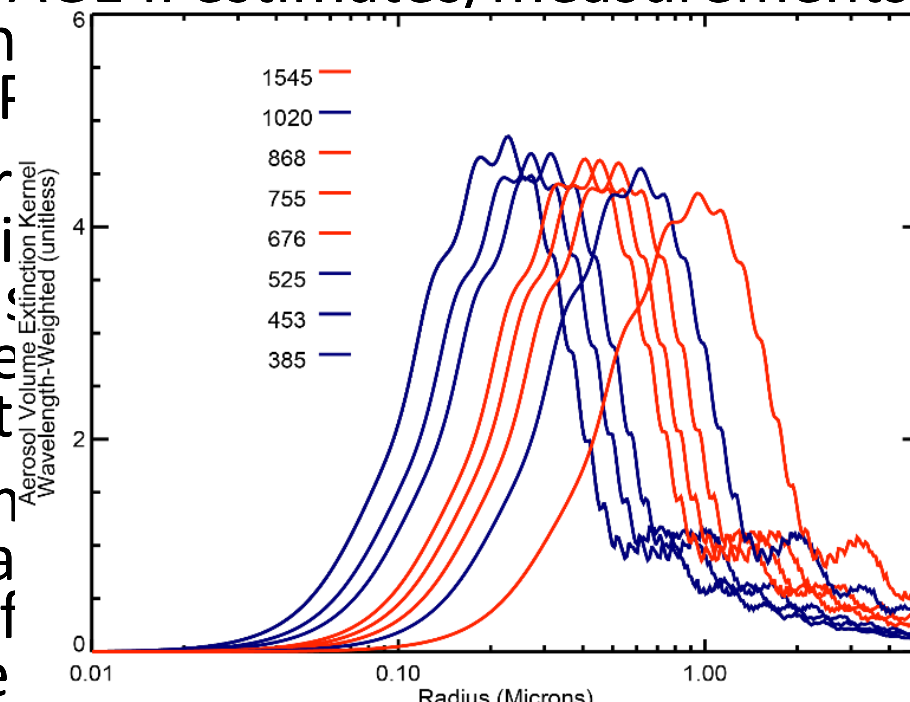
The apostate retrieval approach (2008)

- Started as a bet "I can fit ol a delta function size distrib
- Result:
  - Fit is not quite perfect but p
  - Number densities and SAD ((e.g., ~1 cm^{-3} for number de
  - Use a second 'invisible' delta density to 20 cm^{-3} as a 'maxi
  - Obviously, not a real size dis not ridiculous either
- Results are stored in Versio data set more to bracket ra anything else.



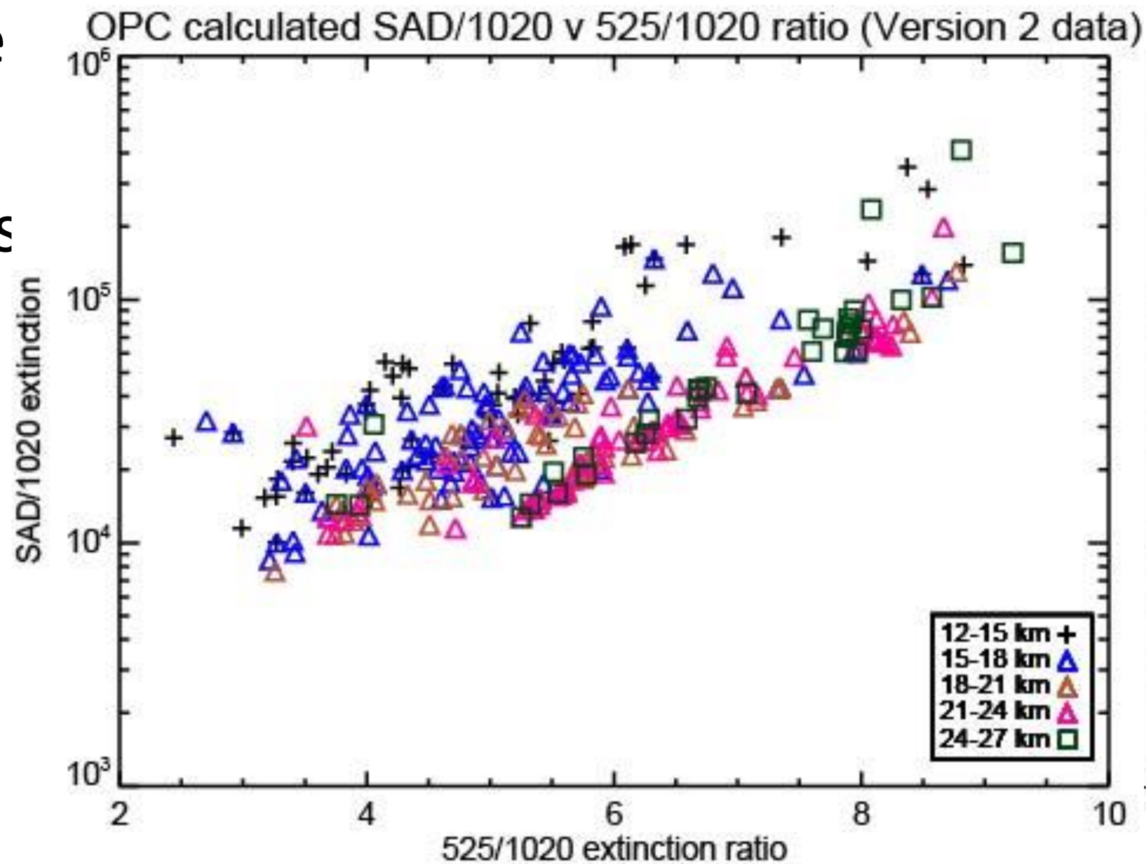
An alternative: Leveraging *in situ* observations

- Fact: UW OPC and SAGE II estimates/measurements of extinction coefficien t all aerosol levels from F
- ~Fact: OPC size distr computed optical 'si m extinction ratio) mus density slope (shape sol sizes (generally 0.1 t
- The degree to which averaging OPC s.d. a d 1020 extinction coef 'representative' size AGE II observations. (invisible particles)



SAD and extinction ratio from UW OPC observations

- Obvious altitude dependence
- At times, there is still a fairly large range of outcomes for about the same extinction ratio (no solution)

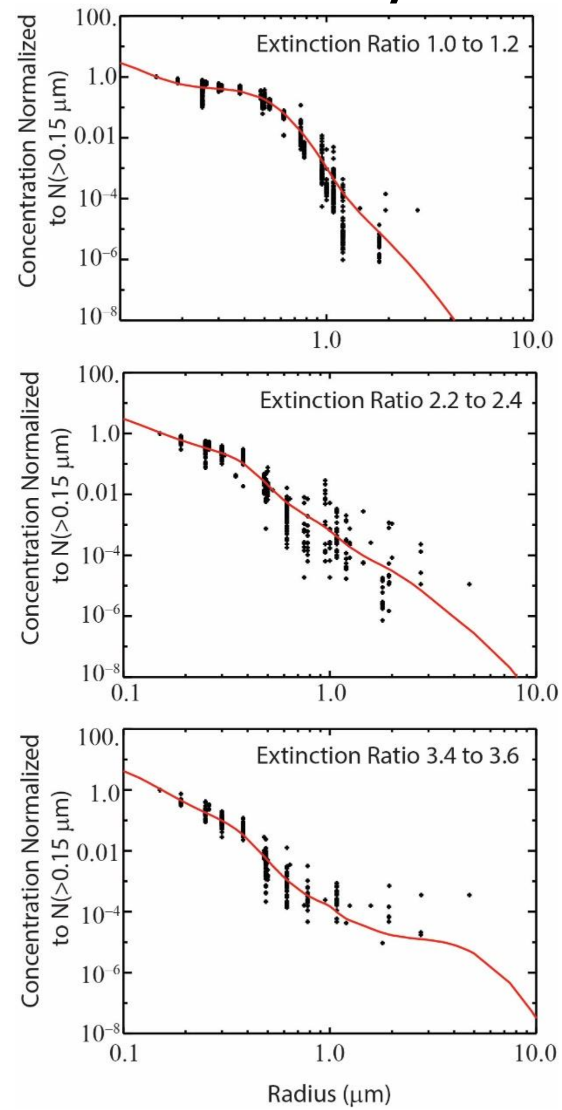


Potential ‘retrieval’ process

- Compute aerosol spectra from available OPC stratospheric measurements (bimodal fits)
- Sort size distributions by 525 to 1020-nm extinction coefficient ratio
  - Every 0.2 in ratio from 0.8 to 6 (width of 0.4)
- Average number densities (scaled to 1.0 at 0.15 micron) and fit a bimodal s.d. for mean s.d.
  - Total number density is quite variable
- For a retrieval for a SAGE II observation, select the size distribution that

Samples of mean size distributions (using old data)

- No mechanism for forcing sensible progressions in the two modes though the pair change from bin to bin sensibly
- S.D. fits from bin to bin are independent and probably not interpolable



Summary

- There is potential for using the extensive in situ observations to help space-based measurements produce improved inferences of aerosol properties
- Unknown the degree to which spatial/temporal sampling of in situ observations compromise this process