Estimating aerosol radiative effects using HSRL-derived aerosol type-specific optical properties and CATCH algorithm

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Introduction

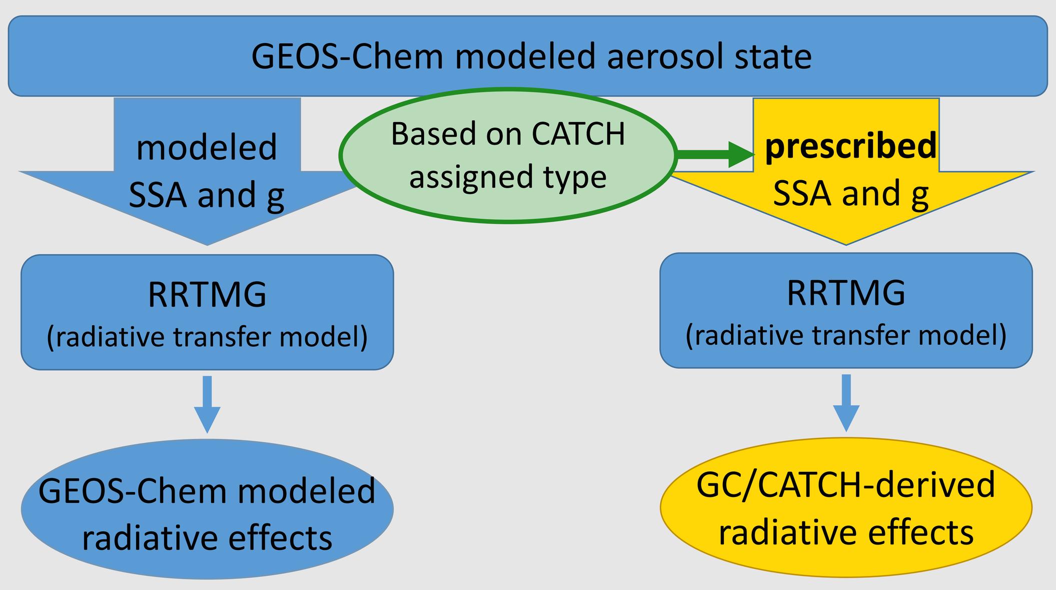
- Numerous studies have been conducted to reduce the uncertainty in the aerosol direct radiative effect (DRE) and direct radiative forcing (DRF).

→ We present a novel methodology for estimating DRE and DRF utilizing vertically resolved High Spectral Resolution Lidar (HSRL) type-specific values for single scattering albedo (SSA) & asymmetry parameter (g).

- The NASA Langley HSRL derives aerosol types (i.e. smoke, urban, dust, marine, etc.) using measurements of aerosol intensive properties (Burton et al. 2012). It has been shown that HRSL-derived aerosol types can be linked to chemical composition (Meskhidze et al., 2021; Sutherland et al., 2023).
- Continuous global coverage of aerosol types is not currently available. Therefore, to test the methodology vertically-resolved aerosol types (analogous to the HSRL-derived types) have been generated using the Creating Aerosol Types from CHemistry (CATCH) algorithm (Dawson et al., 2017), which assigns types based on the GEOS-Chem model output.
- We approximate the uncertainty of our methodology using GEOS-Chem and CATCH outputs during the Ship-Aircraft Bio-Optical Research (SABOR) and the Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality San Joaquin Valley (DISCOVER-AQ SJV) campaigns over the North American domain.

Methods

The feasibility of using aerosol type-specific single scattering albedo (SSA) and asymmetry parameter (g) in combination with High Spectral Resolution Lidar (HSRL)-derived aerosol types to calculate the direct radiative effect (DRE) and direct radiative forcing (DRF) of aerosols is assessed.

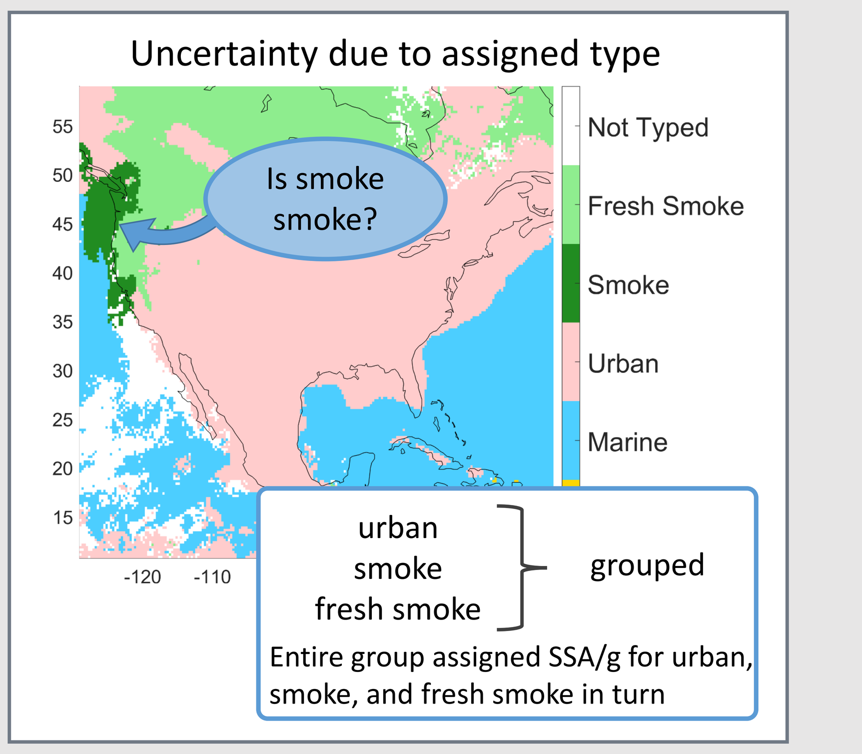


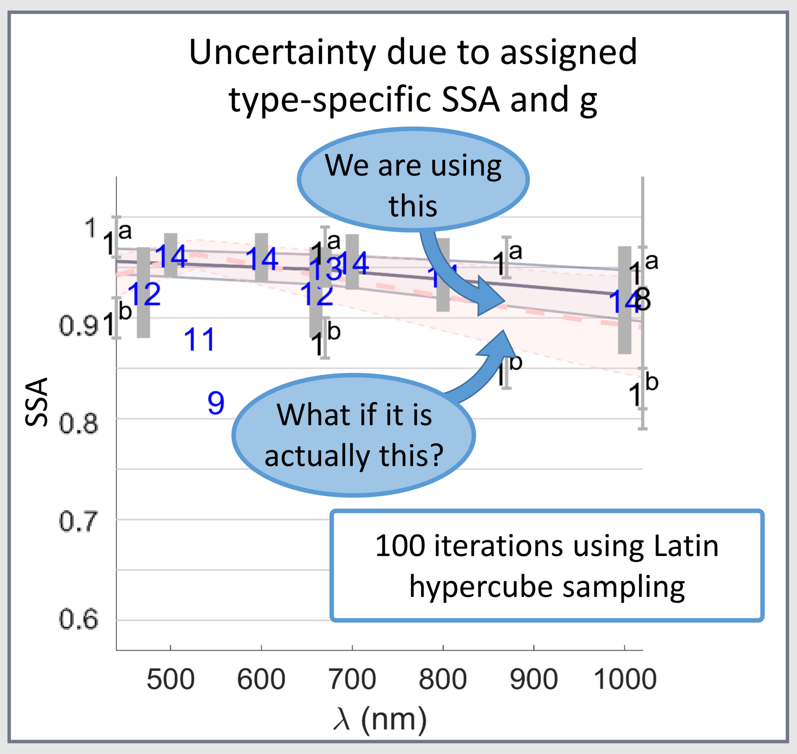
As largescale spatiotemporal distributions of HSRL-derived aerosol types are not currently available, the methodology is tested using:

- GEOS-Chem to model aerosols and the state of the atmosphere
- CATCH (Dawson et at. 2017) to assign HSRL-analogous aerosol types

→ GEOS-Chem has been modified to re-run RRTMG radiation scheme using substituted type specific SSA and g.

Sensitivity studies are used to determine the uncertainty due to using type-specific optical properties





Using aerosol types has the additional advantage of being able to shed light on possible aerosol sources. Dawson et al. (2017) demonstrated a relationship between large cities and CATCH assigned urban aerosols. Furthermore aerosols classified as smoke tended to be associated with less intense vegetation fires, whereas the fresh smoke class was more associated with high-intensity active fires indicative of wildfires.

∴ in this study we estimate DRF by assuming: urban, smoke } anthropogenic; all other types } natural

Acknowledgements

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References

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Conclusions

- Utilizing aerosol-type specific SSA and g over the North American domain leads to

→ DRE of -1.98 W/m² and -4.20 W/m² averaged during the DISCOVER-AQ and SABOR campaigns respectively.

→ DRF of -0.77 W/m² and -1.41 W/m² averaged during the DISCOVER-AQ and SABOR campaigns respectively.

- We estimate uncertainty of up to 0.41 W/m² in DRE and 0.21 W/m² in DRF due to utilizing type-specific optical properties.
  - The lower spread in collocated AERONET SSA and g for several types could indicate that these uncertainties are overestimated.

Future Work:

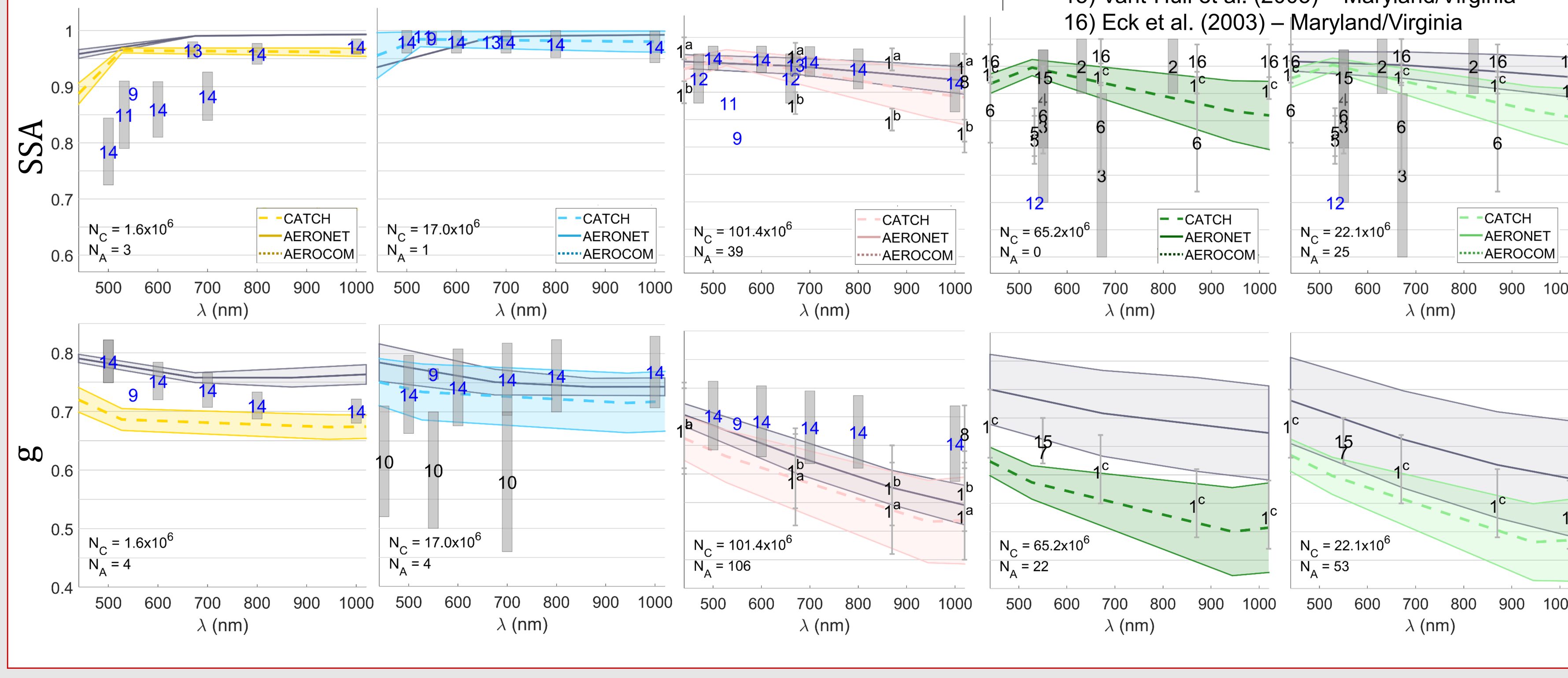
- Currently assessing the contribution of AOD uncertainty.

Results

CATCH/AERONET/AEROCOM comparison – CATCH-derived aerosol type-specific and wavelength-dependent SSA and g values (mean and range) are compared with collocated AERONET retrievals, and values reported in literature.

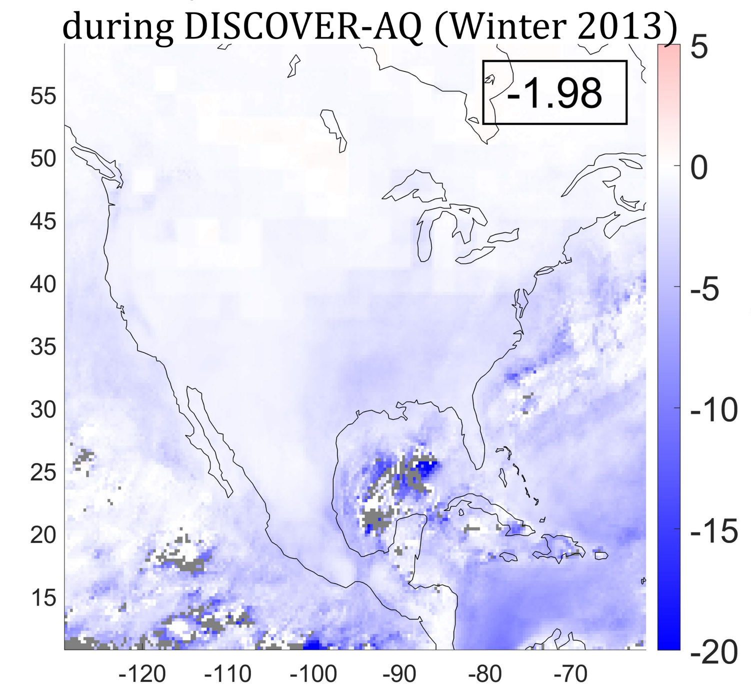
→ Generally, we find that our GEOS-Chem/CATCH derived values compare favorably and are suitable for the purposes of our study.

Sources:
1) Dubovik et al. (2002) – [a]Maryland, [b]Mexico City, [c]Boreal Forest, USA/Canada
2) Ferrare et al. (1990) – western Canada
3) Miller and O'Neill (1997) – boreal forest, Canada
4) Kleinman et al. (2020) – Pacific Northwest
5) Fu et al. (2020)– Arizona
6) Puthukkudy et al., (2020)– California
7) Andrews et al. (2006) – SGP, Oklahoma
8) Zeng et al. (2020) – Caltech, California
9) Hess et al. (1998) – OPAC aerosol models
10) Fiebig and Ogren (2006) – ESRL marine stations
11) Liu et al. (2005) – CALIOP aerosol models
12) Remer et al. (2005) – MODIS models
13) Bellouin et al. (2003) – aerosol models
14) D'Almeida et al. (1991) – aerosol models
15) Vant-Hull et al. (2005) – Maryland/Virginia
16) Eck et al. (2003) – Maryland/Virginia

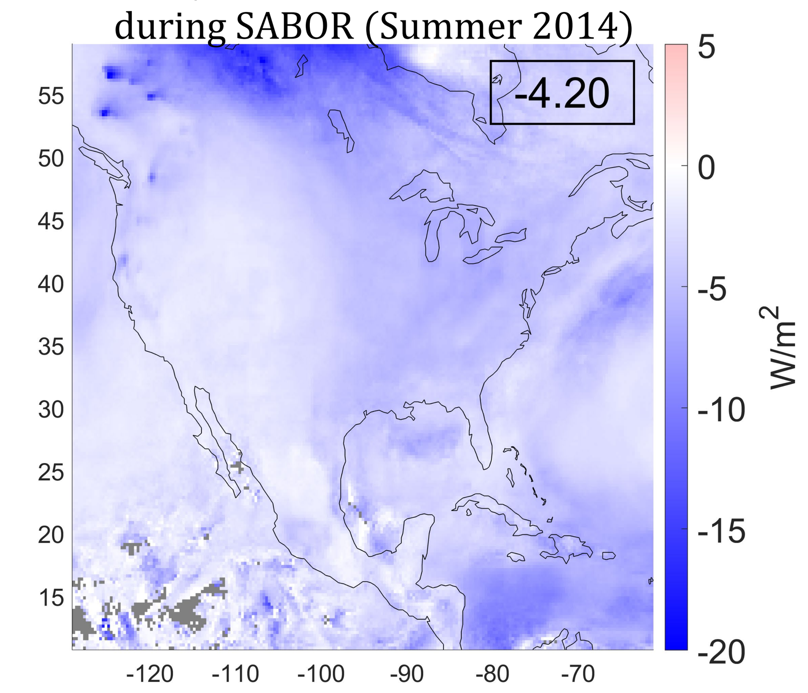


CATCH DRE – calculated by substituting CATCH-derived aerosol type-specific values for SSA and g in radiative transfer calculations performed by RRTMG within GEOS-Chem.

$\overline{\mathrm{DRE}}_{GC/CATCH} = -1.98 \pm 0.21\ \mathrm{W/m^3}$ during DISCOVER-AQ (Winter 2013)

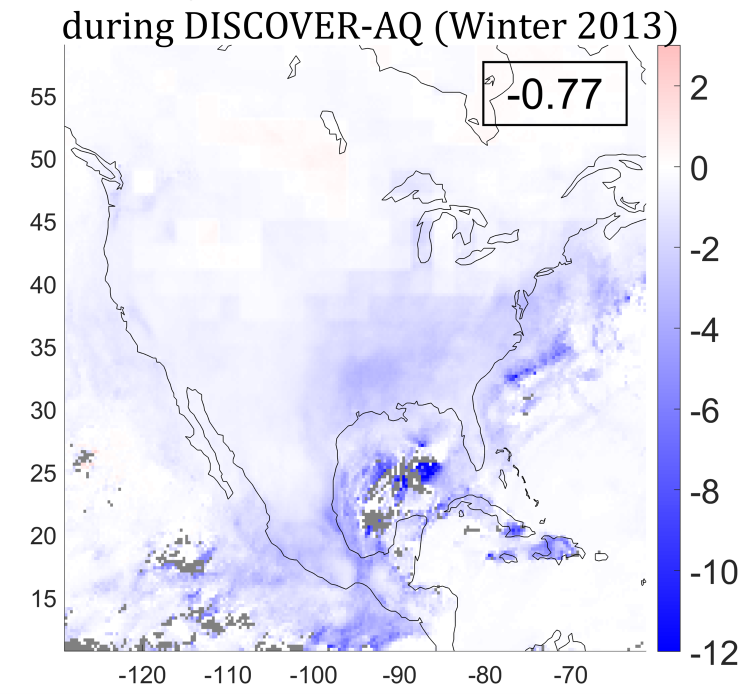


$\overline{\mathrm{DRE}}_{GC/CATCH} = -4.20 \pm 0.41\ \mathrm{W/m^3}$ during SABOR (Summer 2014)



CATCH DRF – the radiative perturbation of only aerosols assigned an anthropogenic type (smoke and urban).

$\overline{\mathrm{DRF}}_{GC/CATCH} = -0.77 \pm 0.13\ \mathrm{W/m^3}$ during DISCOVER-AQ (Winter 2013)



$\overline{\mathrm{DRF}}_{GC/CATCH} = -1.41 \pm 0.21\ \mathrm{W/m^3}$ during SABOR (Summer 2014)