Uptake of OCS in Alaska North-America Land Region

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1. Abstract

We Carbonyl sulfide (OCS), a sulfurcontaining analogue of carbon dioxide (CO2), is taken up by plants during photosynthesis, and has been shown to be a potentially useful tracer for photosynthesis by plants. In this study, we examine the vertically resolved OCS data from the Carbon in Arctic Reservoir Vulnerability Experiment (CARVE, https://carve.jpl.nasa.gov) over the summer months from 2011 to 2015 in Alaska. The results are compared to model. The OCS concentrations are simulated by GEOSChem, a global chemical transport model, with a horizontal resolution of 2° × 2.5° and 47 vertical levels. The model is driven by assimilated meteorological data from the NASA Goddard Earth Observing System5 (GEOS5) meteorological data and OCS fluxes from 2004 to 2006. The primary land sink is the same as Berry et al. (2013), calculated by a carbon cycle model, the Simple Biosphere Model (Sib3) (Baker et al., 2007, 2008). Berry et al.'s inventory includes terrestrial fluxes that were ~3 times larger than terrestrial fluxes in Kettle et al.'s inventory. However, the land sinks at Alaska are still quite small and insufficient to account for the CARVE observations. An attempt is made to estimate the additional fluxes needed to reconcile the model to observations.

2. Carbonyl Sulfide (OCS)

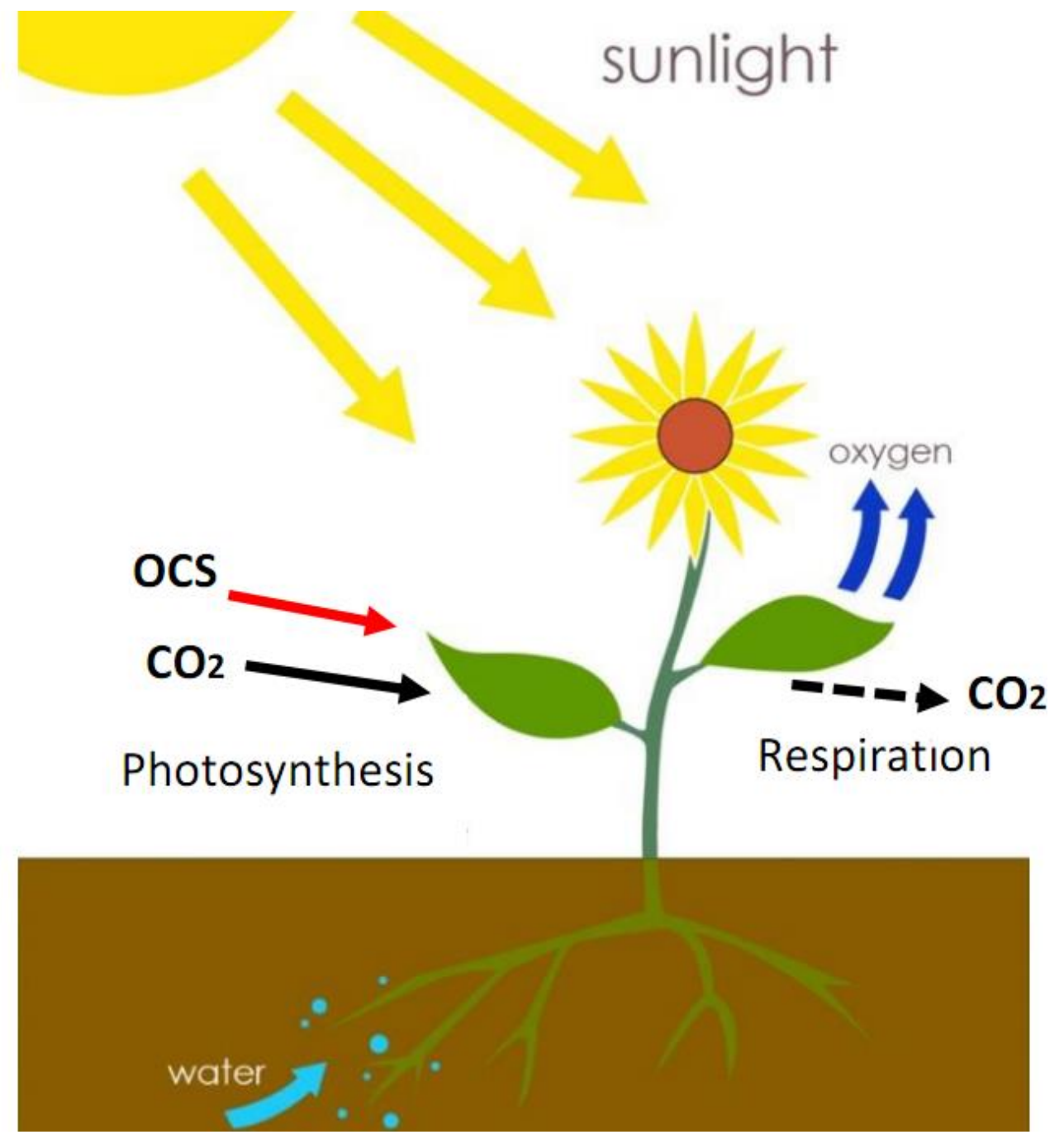


Figure 1. Carbonyl sulfide (OCS), a sulfur-containing analogue of carbon dioxide (CO_2), is taken up by plants during photosynthesis. OCS is an atmospheric organic compound with atmospheric mixing ratios of about 500 parts per trillion (ppt). It has an atmospheric lifetime of about 2 to 4 years. OCS and CO_2 fluxes are taken up by leaves in the same physical, diffusion, pathway during photosynthesis (Asaf et al., 2013). Different from CO_2 which is a two-way flux including photosynthesis uptake and respiration release, OCS is one-way flux with negligible competing fluxes to/from soils. Therefore, OCS has been shown to be a potentially useful tracer for photosynthesis by plants (Campbell et al., 2008; Asaf et al., 2013).

3. OCS Observations at Alaska

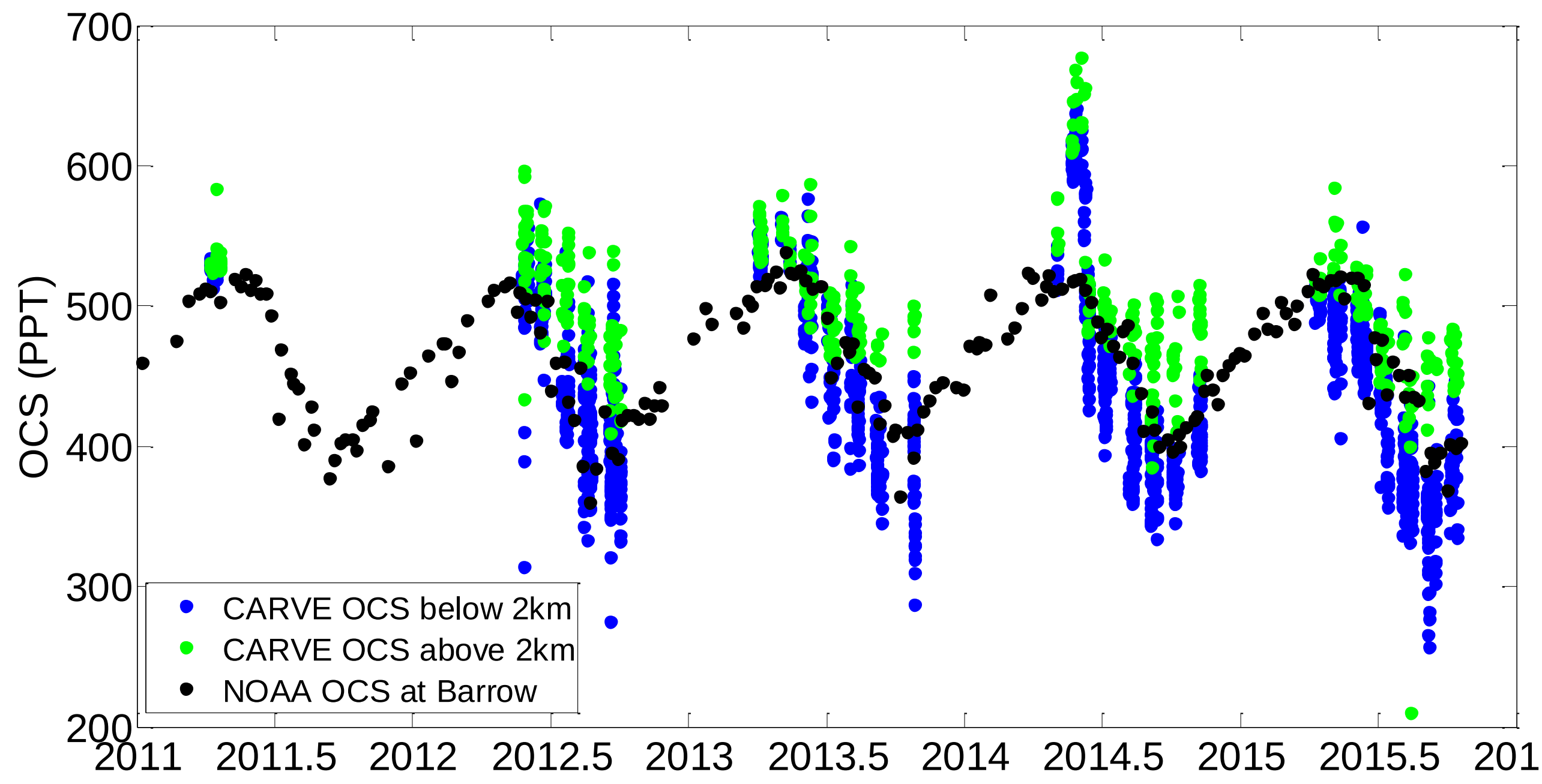
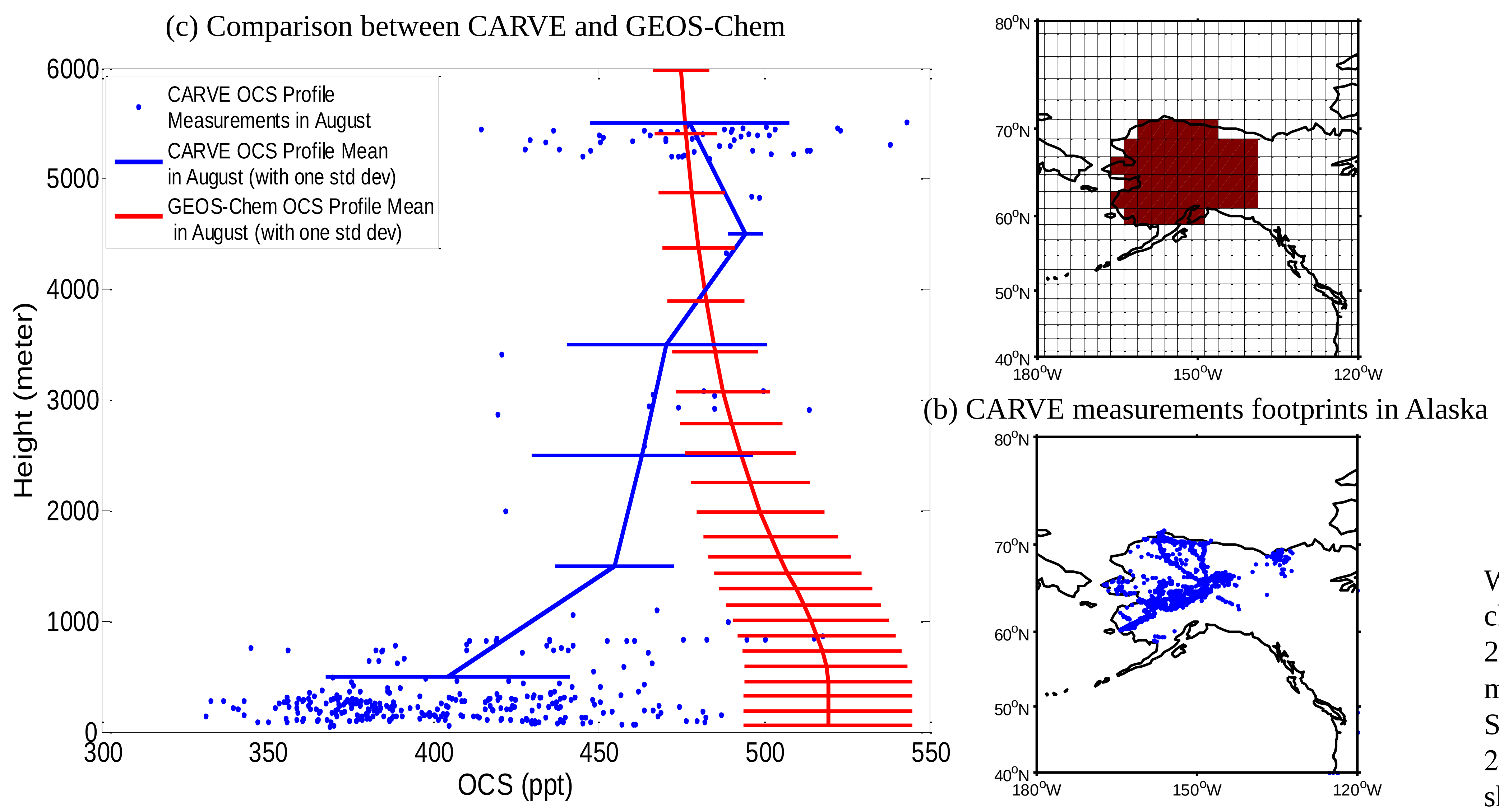


Figure 2. The time series of OCS measurements from CARVE campaign and NOAA ground based station at Barrow from 2011 to 2016. Obvious OCS seasonal cycle can be seen in Alaska, with peak at around April-May and trough at around August during the growing season, a pattern similar to CO_2 seasonal cycle. By comparison of CARVE data above and below 2 km, we can see the OCS is lower in the boundary layer than the that in the free troposphere, indicating the strong draw down due to plant uptake during the growing season.

4. Model simulations of OCS by GEOS-Chem


(c) Comparison between CARVE and GEOS-Chem

(a) GEOS-Chem grids (2x2.5) in Alaska

(b) CARVE measurements footprints in Alaska

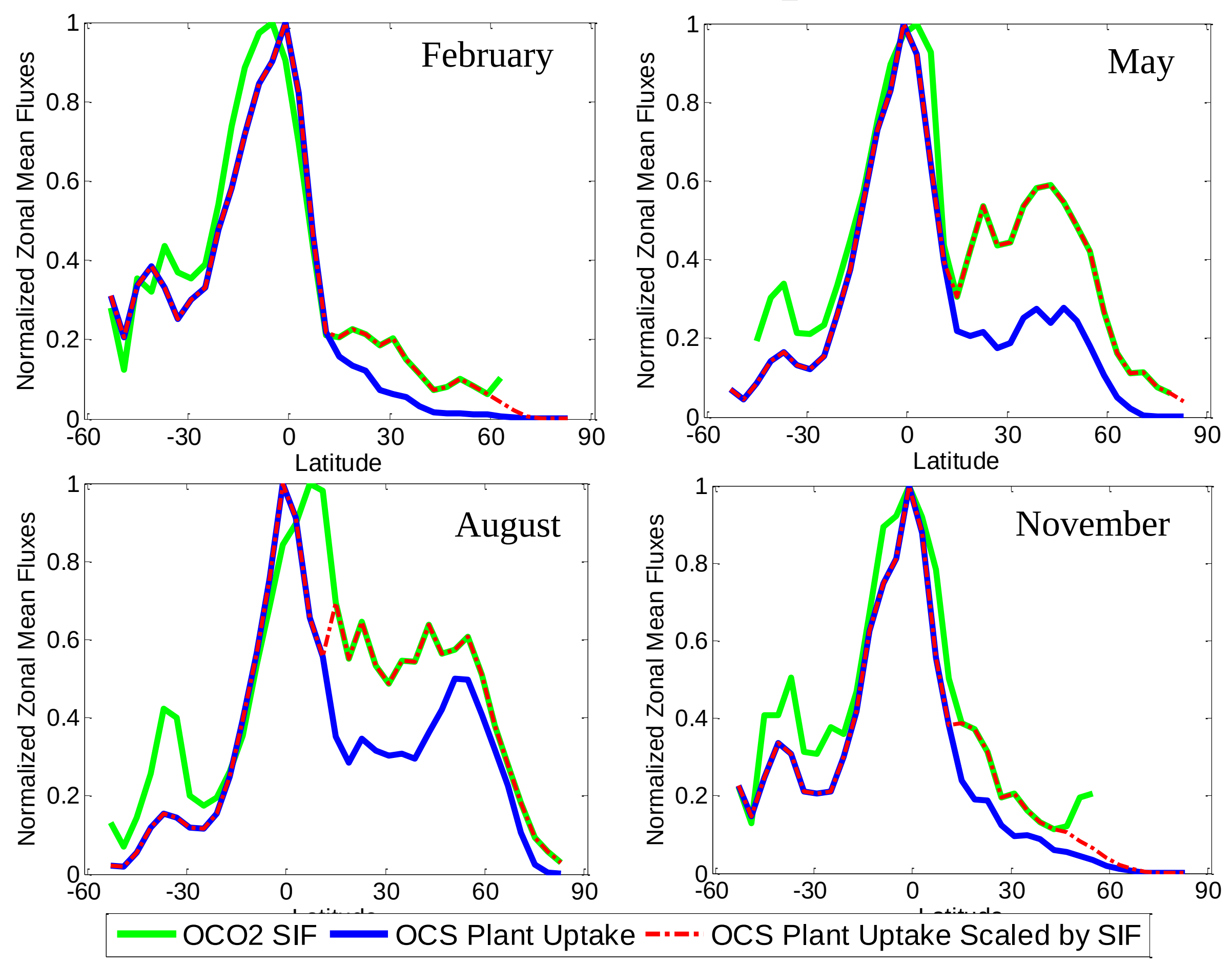
Figure 3. Comparison of OCS profiles in Alaska between CARVE measurements and GEOS-Chem simulations. All August data are used. We can see that while model simulations agree with measurements in the free troposphere, there is a significant discrepancy within the boundary layer. The modeling fails to reproduce the drawdown of OCS during the growing season. **Conclusions:** Even the modeling uses Berry et al.'s inventory for plant uptake, which includes terrestrial fluxes that were ~3 times larger than terrestrial fluxes in Kettle et al.'s inventory, however, the land sinks at Alaska are still quite small and insufficient to account for the CARVE observations, possibly indicating the underestimation of OCS plant uptake by current inventory in Alaska.

Table 1. Global Sources and Sinks Used for GEOS-CHEM Simulations of Atmospheric OCS (Kuai et al., 2015)

	Units: Gg S/yr
Direct COS flux from oceans	41
Indirect COS flux as CS2 from oceans	83
Indirect COS flux as DMS from oceans	155
Direct anthropogenic flux	62
Indirect anthropogenic flux from CS2	113
Indirect anthropogenic flux from DMS	0
Biomass burning	49 (GFED3)
Additional ocean flux	559
Destruction by OH radical	-111
Uptake by canopy (SiB3)	-775 (SiB3)
Uptake by soil	-176 (SiB3)
Net total	0

We simulated the OCS concentration using GEOS-Chem, a global chemical transport model, with a horizontal resolution of 2° × 2.5° and 47 vertical levels. The model is driven by assimilated meteorological data from the NASA Goddard Earth Observing System5 (GEOS5) meteorological data and OCS fluxes from 2004 to 2006. The used fluxes adopted from Kuai et al. (2015), as shown in Table 1, are similar to Berry et al. [2013] except a constant extra source (559 Gg S/yr) is added to oceanic regions between 40°S and 40°N. The GEOS_Chem simulation was spun up for three years (2004 to 2006). From Table 1, we can see that the main sources are oxidation of CS2 and dimethyl sulphide (DMS), direct emission from the upper ocean, and anthropogenic sources, and its main sinks are uptake by plants and soils, and oxidation in the stratosphere.

5. Perturbations to OCS Plant Uptake Fluxes according to SIF from OCO-2



Solar-induced chlorophyll fluorescence (SIF), a proxy for gross primary production (GPP, carbon uptake through photosynthesis), can be accurately retrieved from space using high spectral resolution radiances in the 750 nm range from the Orbiting Carbon Observatory-2 (OCO-2), a NASA mission designed to measure atmospheric CO_2. (Frankenberg et al., 2014). By examining the normalized zonal mean of SIF from OCO-2 and OCS plant uptake flux from Berry et al. (2013), as shown in Figure 4, we can see in North Hemisphere (NH), OCS plant uptake is generally smaller than SIF. Therefore, in this study, we use SIF zonal mean to perturb and scale the OCS plant uptake fluxes in NH so that latter has the same latitudinal gradient as the former in NH.

Figure 4. Normalized zonal mean of SIF from OCO-2 and OCS plant uptake from Berry et al. (2013), and the perturbed OCS plant uptake obtained from scaling the original OCS plant uptake in NH according SIF.

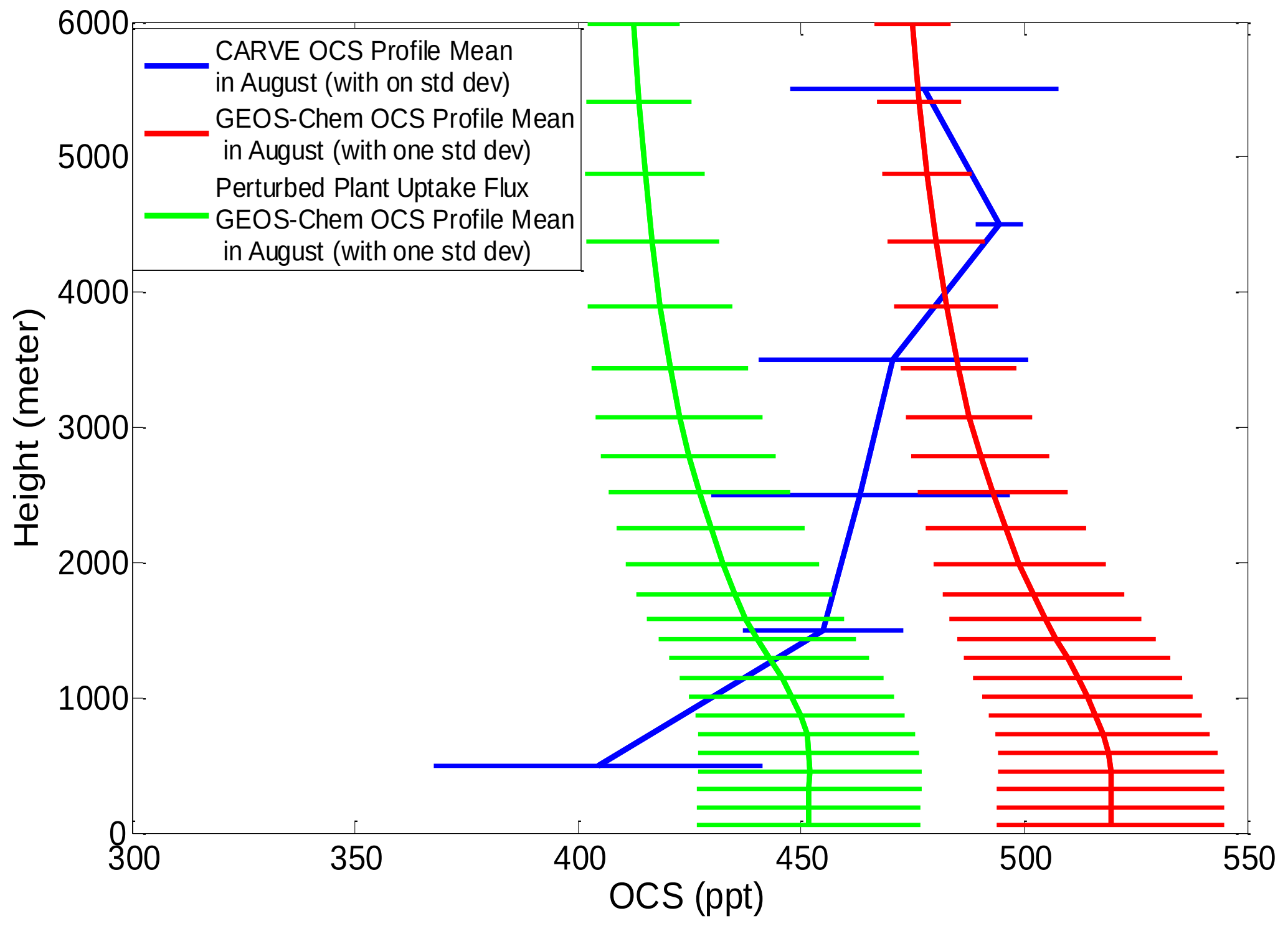


Figure 5. Comparison of OCS profiles of the GEOS-Chem simulations using the perturbed and original plant uptake fluxes, and CARVE OCS measurements.

6. CONCLUSIONS

(1)Stronger drawdown of OCS can be observed within boundary layer in Alaska. Model simulations using current estimated plant uptake flux fails to reproduce this drawdown, possibly indicating the underestimation of OCS plant uptake by current inventory in Alaska.

(2)By incorporating the perturbed OCS plant uptake flux, which is obtained by scaling according to SIF from OCO-2 in NH, model simulations, in general capture the strong uptake of OCS within the boundary layer.

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