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The Impact of Accounting for 3-D CO_2 Production on Inversion for Natural Fluxes Using GOSAT and In Situ Observations

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1. Introduction

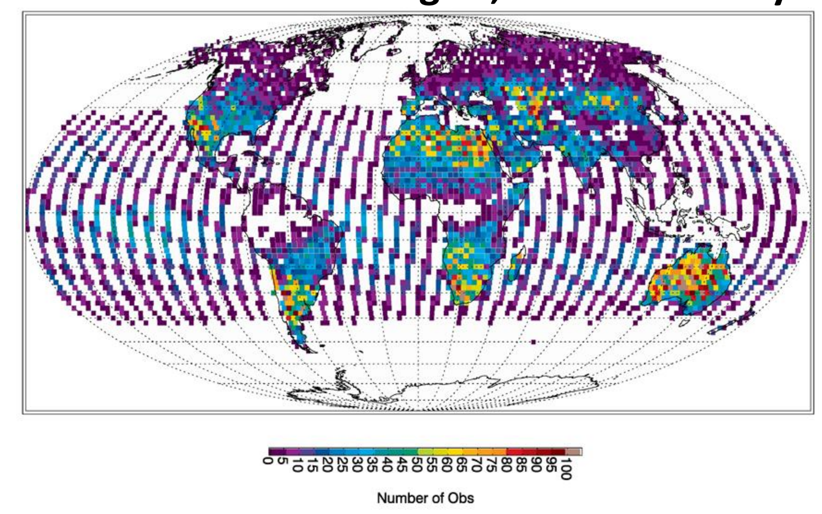
Most atmospheric inversions for estimating natural carbon dioxide (CO_2) fluxes have placed CO_2 release from fossil fuel combustion and other sources entirely at the surface. However, a portion of fossil fuel and biospheric carbon emissions (~1 Pg C y^{-1}) occurs in the form of reduced carbon species including carbon monoxide (CO), methane (CH_4), and non-methane volatile organic compounds (NMVOCs), which are oxidized to CO_2 downwind of the emissions. Omission of this 'chemical pump' can result in a shift in the distribution of the inferred fluxes, e.g. in the global sink from the tropics to the northern extratropics. A few inversion studies using surface CO_2 observations have accounted for the chemical pump, the most thorough analysis being conducted by Suntharalingam et al. [2005]. Nassar et al. [2010] presented a forward model analysis using advanced chemistry model output.

We further examine the impact of accounting for the chemical pump on flux inversions, with the added dimension of **considering satellite observation-based as well as surface in situ-based inversions**. Our hypothesis is that there will be differing regional impacts in GOSAT and in situ inversions due to differences in horizontal and vertical observational sampling. This study employs a relatively high spatiotemporal resolution Bayesian inversion approach, and atmospheric CO_2 production rates derived from a state-of-the-art NASA chemistry model historical simulation. Early results are presented below.

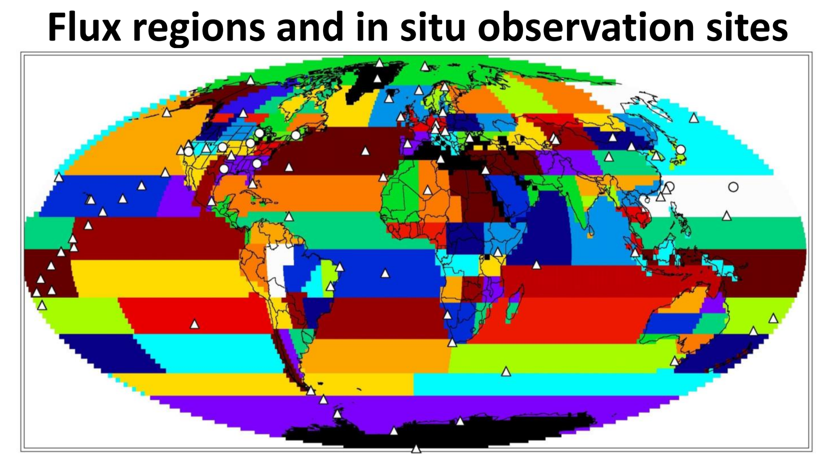
2. Methods

- **Assimilated observations**
  - In situ: Individual flask and afternoon-averaged continuous measurements from NOAA ESRL and JMA
  - GOSAT: ACOS B3.4 retrieval of weighted column-average CO_2, filtered and bias-corrected (figure on the right)
- **Prior constraints**
  - Net ecosystem production (NEP) and fire fluxes from CASA-GFED v.3 model
  - Ocean fluxes from Takahashi et al. [2009]
  - Fossil CO_2 emissions from CDIAC
- **Atmospheric CO_2 production and surface correction**
  - CO oxidation (≈ CO_2 production) rates from NASA GEOS-5 GMI chemistry-climate model nudged to MERRA-2 reanalysis meteorology
  - Fossil fuel CO and NMVOCs: As initial estimate, assume a uniform 4.89% of fossil CO_2 as with Nassar et al. [2010]
  - Biomass and biofuel burning: Apply non-CO_2 emission factor from GFED averaged over ecosystem types
  - Biospheric CH_4: TransCom-CH_4 interannually varying emissions [Patra et al., 2011]
  - Biospheric NMVOCs: Initially, apply global NMVOC/CH_4 ratio from Nassar et al. [2010] uniformly to our biospheric CH_4 distribution
- **Transport model**
  - PCTM, with MERRA meteorology, 2° latitude x 2.5° longitude x 56 levels
- **Inversion technique** [Wang et al., 2018, in review, *ACP*]
  - "TransCom"-style batch Bayesian synthesis inversion
  - Optimize natural fluxes in **108 regions** (map on the right) over **8-day intervals**, and initial concentrations; high resolution minimizes aggregation error.

GOSAT retrievals in model grid, June 2009-May 2010



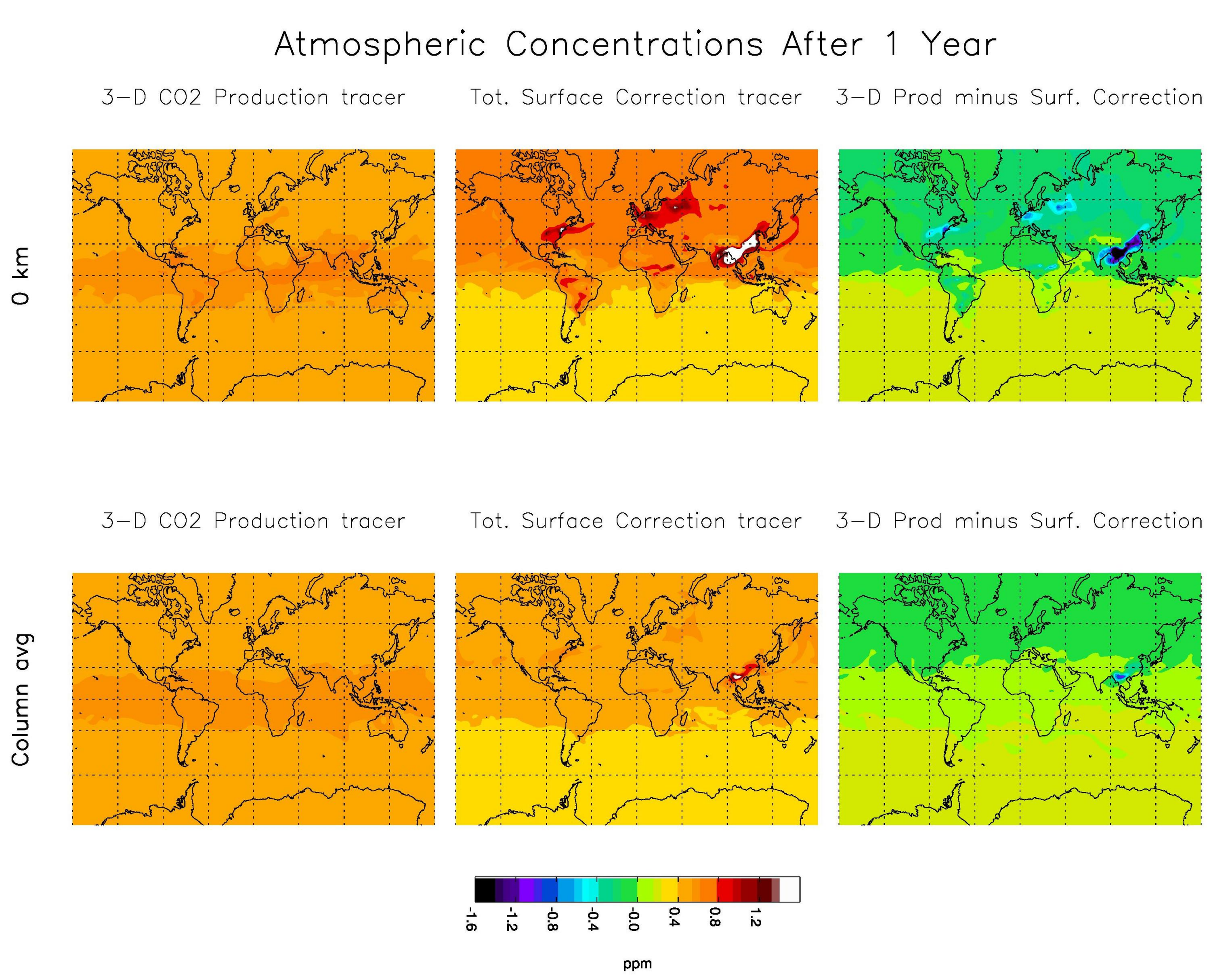
Flux regions and in situ observation sites



3. Forward Model Simulations

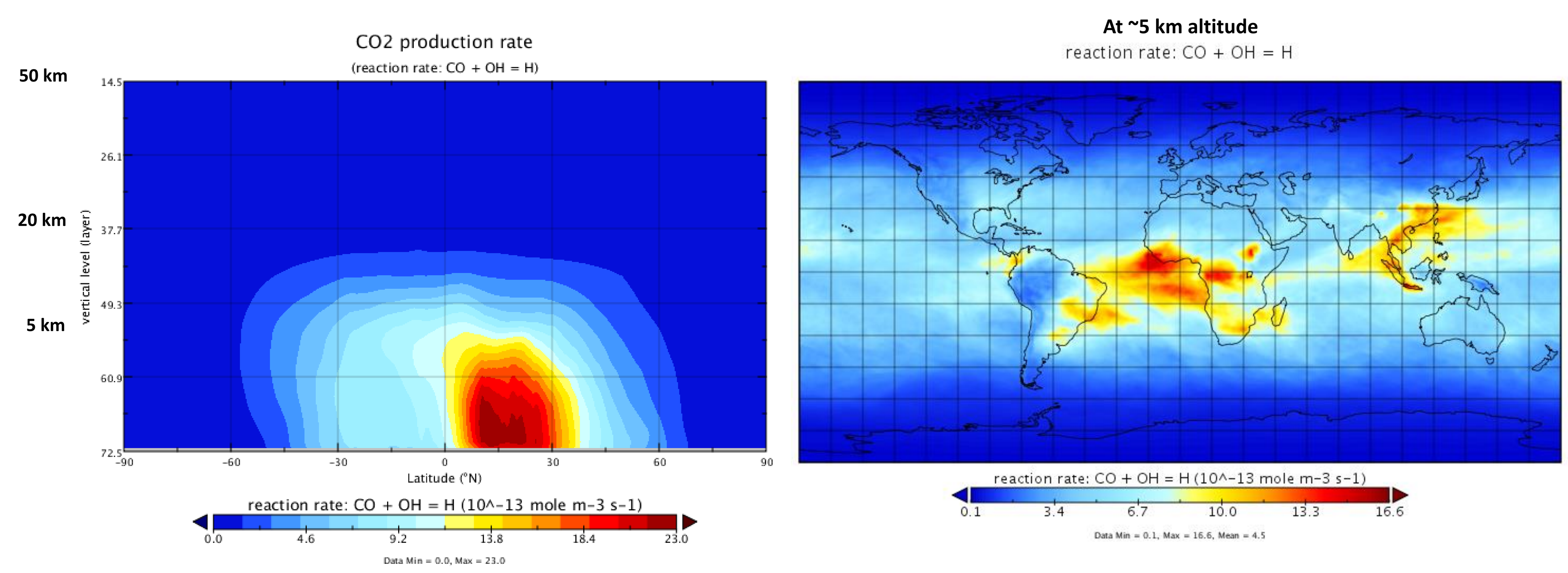
3-D CO2 Production and Surface Correction Budgets		
Component	Global, Annual Total (Pg C/y)	
	2009-2010, this work	2006, Nassar et al. (2010)
Total chemical production	1.15	1.05
Total surface correction	0.97	0.83
Fossil fuel combustion	0.41	0.38
Biomass and biofuel burning	0.23	0.00
Biospheric CH_4	0.16	0.28
Biospheric NMVOCs	0.16	0.16

(Note that Nassar et al. did not apply surface corrections for biomass and biofuel burning since they did not include non-CO_2 carbon emissions for those sources in their baseline CO_2 simulation)



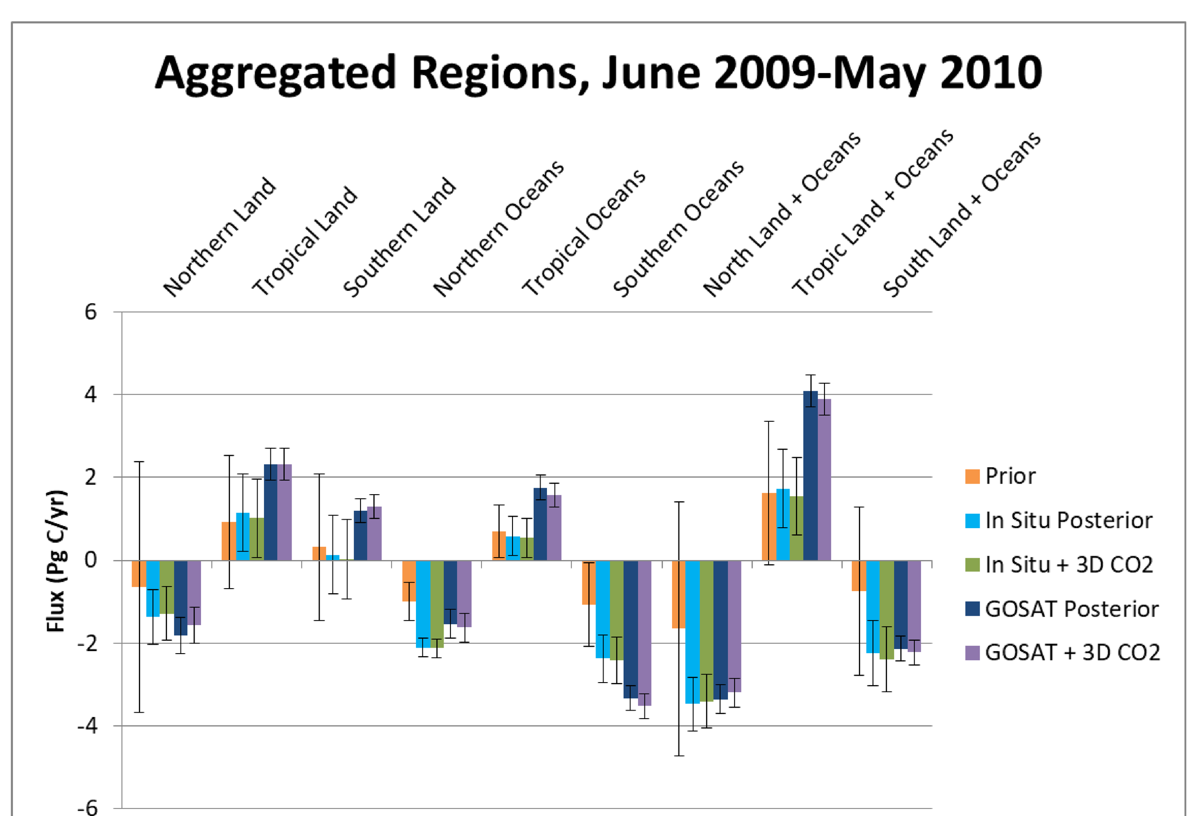
- Surface in situ observations are more sensitive to the surface correction than are satellite column observations, especially over land
- The combination of 3-D CO2 production and the surface correction generally elevates concentrations in the tropics and southern extratropics, lowers concentrations in the north

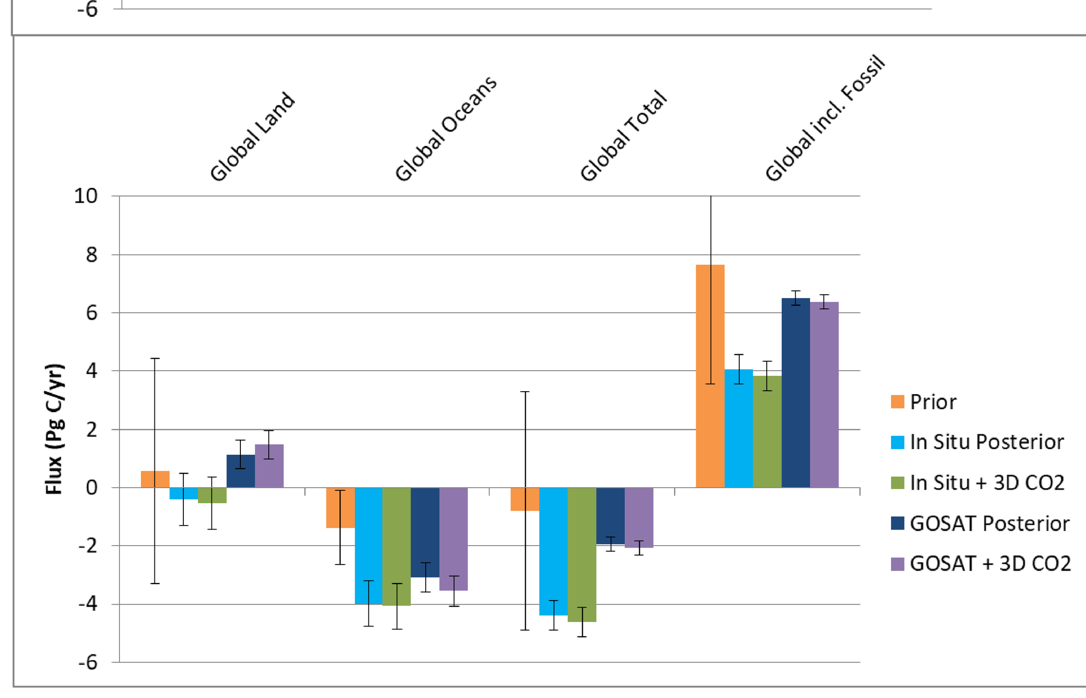
Distribution of CO_2 chemical production (March, 2010)



- CO_2 production is greatest where OH oxidant is most abundant, i.e. in the tropics, and secondarily where CO and VOC concentrations are highest

4. Inversion Results





- Similar to previous studies, accounting for chemical pump **shifts** a portion of the global CO_2 **sink from the north to the tropics and south**
- In addition, we see a **shift** in the sink from **land to oceans in the GOSAT inversion**
- **GOSAT inversion appears more sensitive** to chemical pump than in situ inversion **in ocean regions** → The available GOSAT observations can see more of the chemical production throughout column than the surface observations
- Overall, the impact of accounting for 3-D CO_2 production appears minor compared to difference between in situ and GOSAT inversions

5. Conclusions and Further Work

- Our analysis of the impact of 3-D CO_2 production and surface correction on flux inversions confirms small but possibly significant shifts in the global sink seen in a previous analysis
- In addition, we find that a GOSAT inversion may be more sensitive to the 'chemical pump' in ocean regions than a surface observation-based inversion
- We will examine in more depth the impact of the chemical pump on posterior fluxes via column vs. surface observations
- We will also test an alternative fossil CO_2 emissions database, ODIAC, in place of CDIAC

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