# Assessing the Contribution of Oceanic Fluxes to the Global Budget of Carbonyl Sulfide

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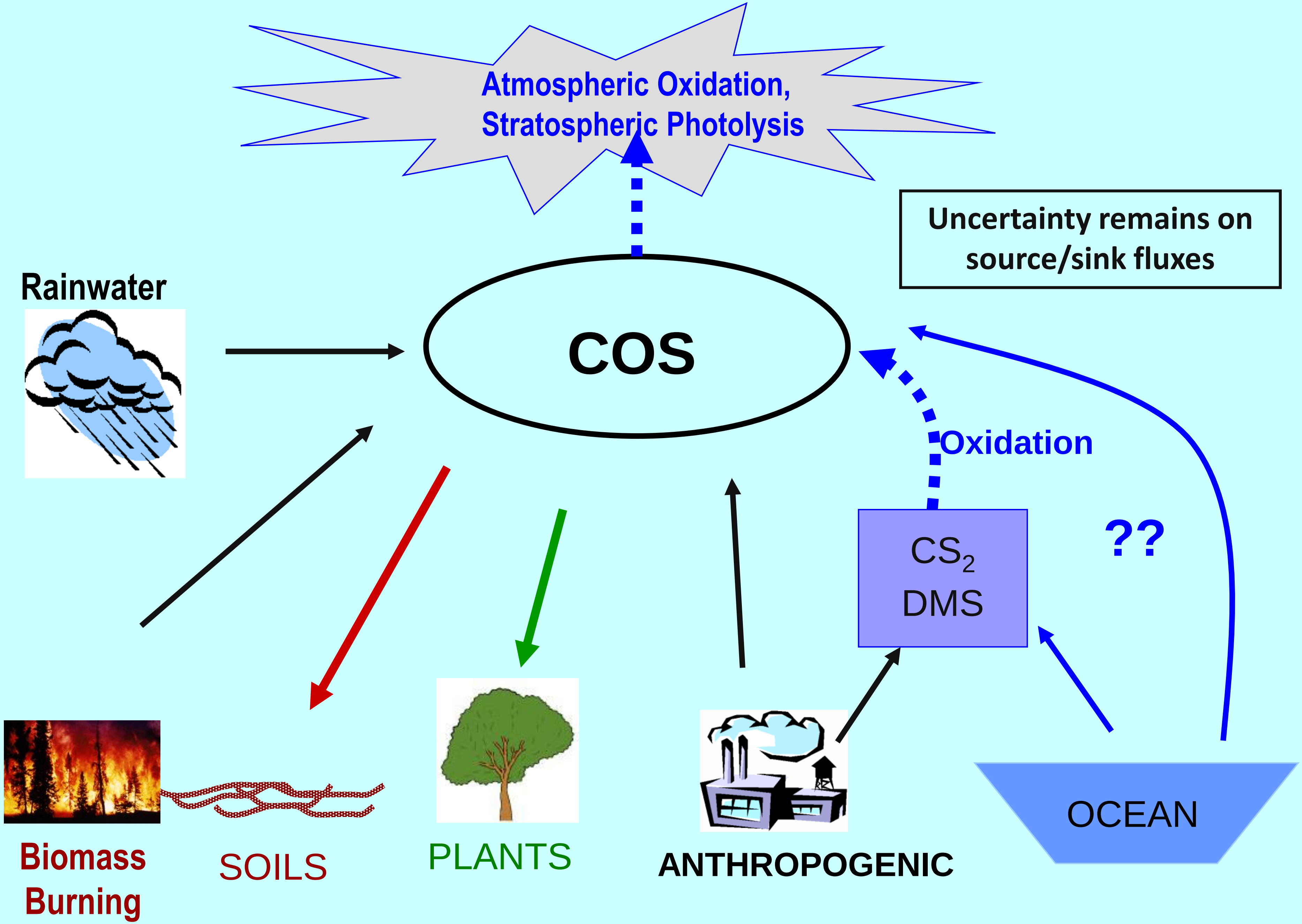
# SUMMARY

Carbonyl sulfide (COS) is an agent of stratospheric ozone depletion. Measurements of its tropospheric variation also provide constraints on terrestrial primary productivity. The ocean is a major source of COS to the troposphere through direct emission, and potentially through emission of COS precursors such as carbon disulfide ($CS_2$). Recent estimates of the global COS budget, show large imbalances between known sources and sinks, with significant uncertainty in the magnitude of the oceanic flux (the largest natural COS source to the atmosphere).

Here we assess the role of oceanic fluxes in the global COS budget using top-down constraints from a global model analysis incorporating atmospheric COS measurements from a global network of surface sites (NOAA-HATS). Our initial results estimate oceanic COS fluxes in the range 98-191 Gg S/yr, and smaller than those of recent studies.

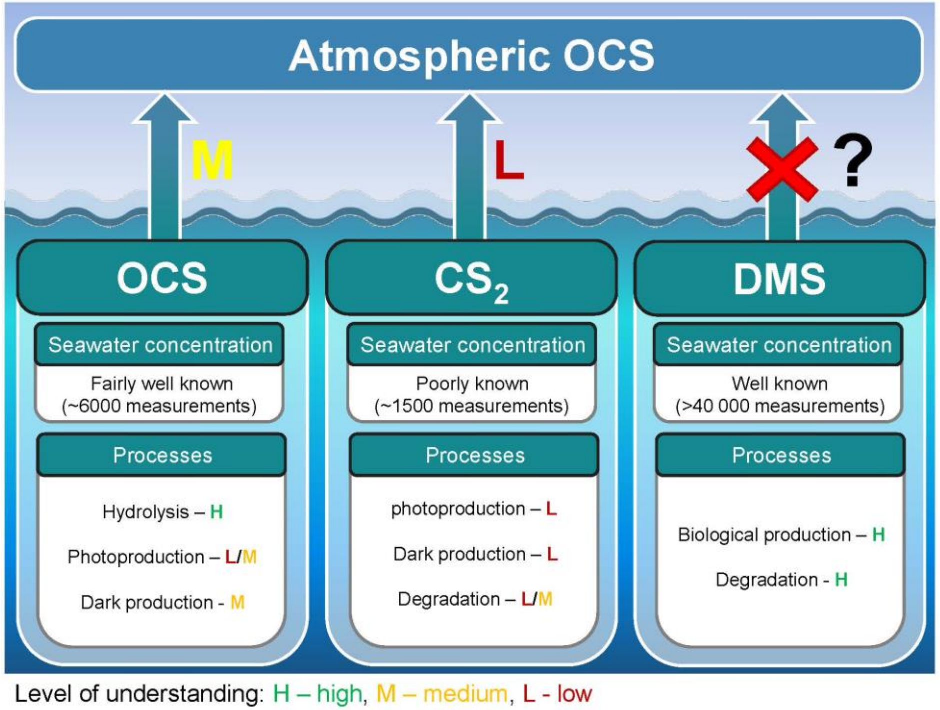
Our ongoing and planned work will address improvements to the methodology, including updates of prior flux inventories, and incorporation of additional COS measurements.

# SOURCES AND SINKS OF ATMOSPHERIC CARBONYL SULFIDE



## Recent Estimates of Ocean COS Fluxes (Gg S/yr)

| | |
|---|---|
| Lennartz et al. 2017<br>*Reported in Whelan et al. 2018* | **265 (± 210)** *Direct + from $CS_2$* |
| Launois et al. 2015 | **573-3997** *Direct (Dark + photoproduction)* |
| Berry et al. 2013 | **276** *(prior)* + **600** *(photochemical ocean flux)* |
| Suntharalingam et al. 2008 | **230** *(Adjusted from Kettle et al. 2002)* |

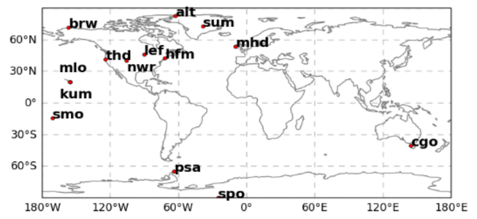



- Large range in recent estimates of ocean COS fluxes
- Uncertainty on direct and indirect production mechanisms

*Whelan et al. 2018*

# COS Flux Estimates from Atmospheric Inverse Analyses

## Atmospheric COS Observations



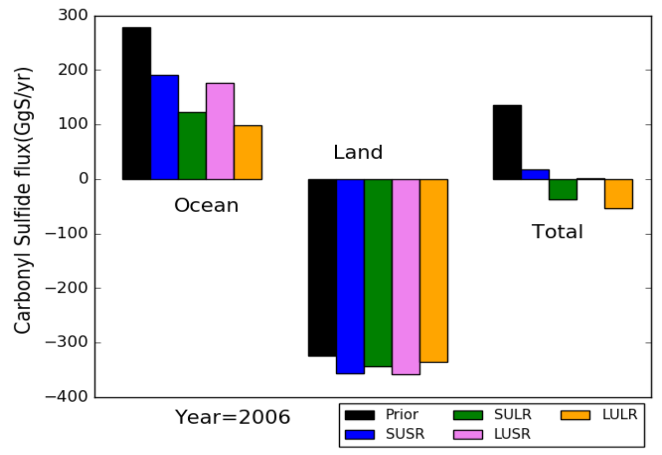

*Surface sites*

**INVERSE MODEL**

LETKF-GEOSChem

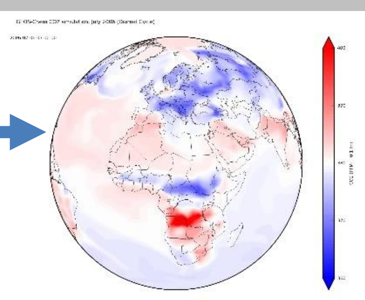
Local Ensemble Transform Kalman Filter

## Optimized Inverse Flux Estimates




## Model Concentrations

Prior Fluxes



**Atmospheric Transport Model**

GEOS-Chem v11.01

**Atmospheric COS measurements in conjunction with inverse analysis methodologies provide 'top-down' constraints on surface COS fluxes**

# COS Inverse Analysis Specifications

**ATMOSPHERIC TRANSPORT MODEL : GEOS-Chem v11-01**
Global 3-D model of atmospheric chemistry driven by meteorological input from the Goddard Earth Observing System (GEOS) of the NASA Global Modeling and Assimilation Office.

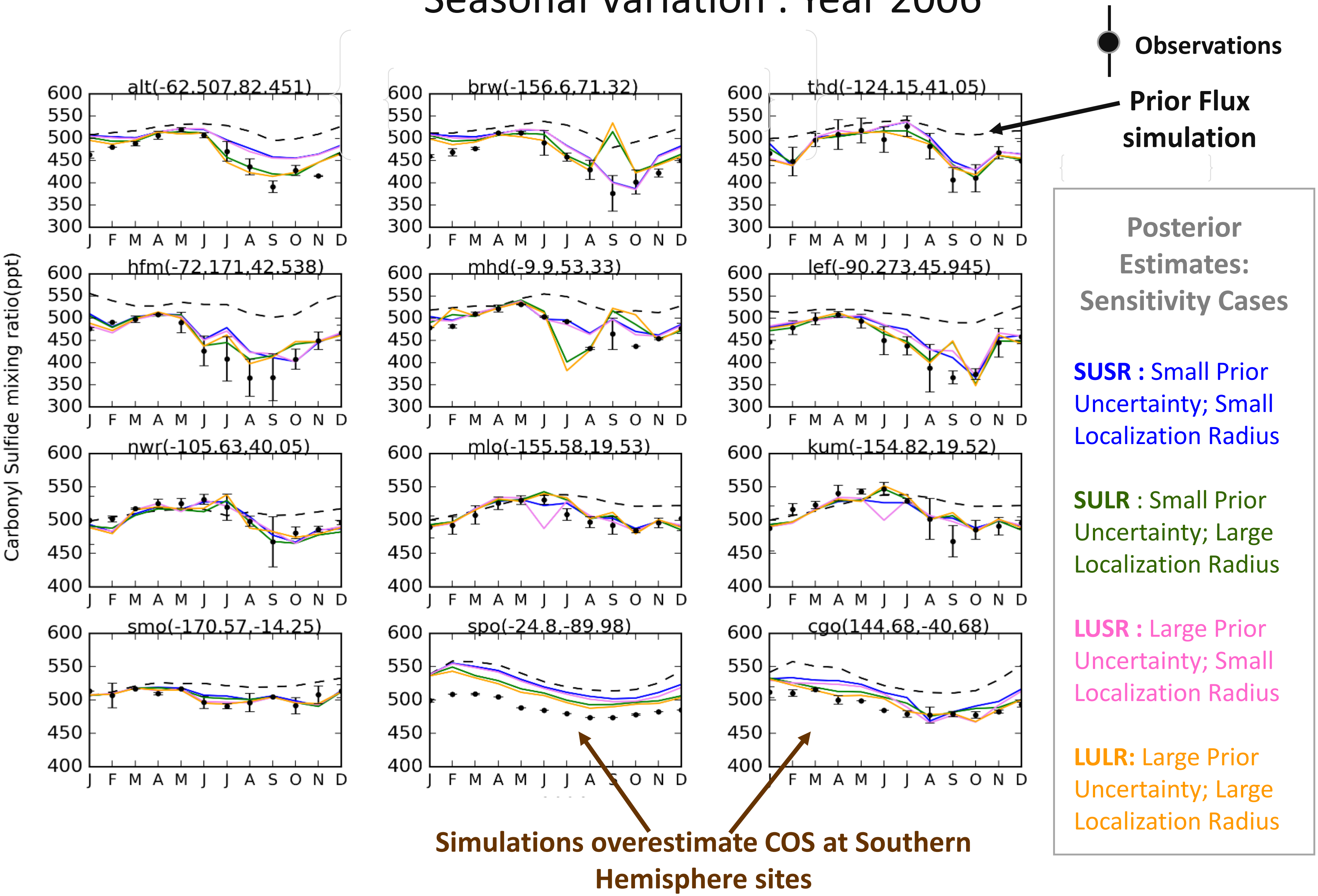
**Resolution** : $2^o$ (lat) x $2.5^o$ (lon) ; 72 vertical levels
**Meteorology** : NASA GMAO GEOS-FP, GEOS-5, MERRA-2 (Available 1980-present)
**COS Prior Fluxes** : Wang et al. 2016; Suntharalingam et al. 2008; Kettle et al. 2002

**INVERSE METHODOLOGY**
**Local Ensemble Transform Kalman Filter (LETKF)**
*(Hunt et al.2007, Miyoshi et al.2007, Chen et al., 2013)*

**ATMOSPHERIC COS MEASUREMENTS**
HATS Flask Program *Montzka et al. 2004, 2007*
*https://www.esrl.noaa.gov/gmd/hats/gases/OCS.html*
*Acknowledgements : S. Montzka, NOAA-GMD*

# Assessment at HATS Sites

## Seasonal Variation : Year 2006




**Posterior Estimates: Sensitivity Cases**

**SUSR :** Small Prior Uncertainty; Small Localization Radius

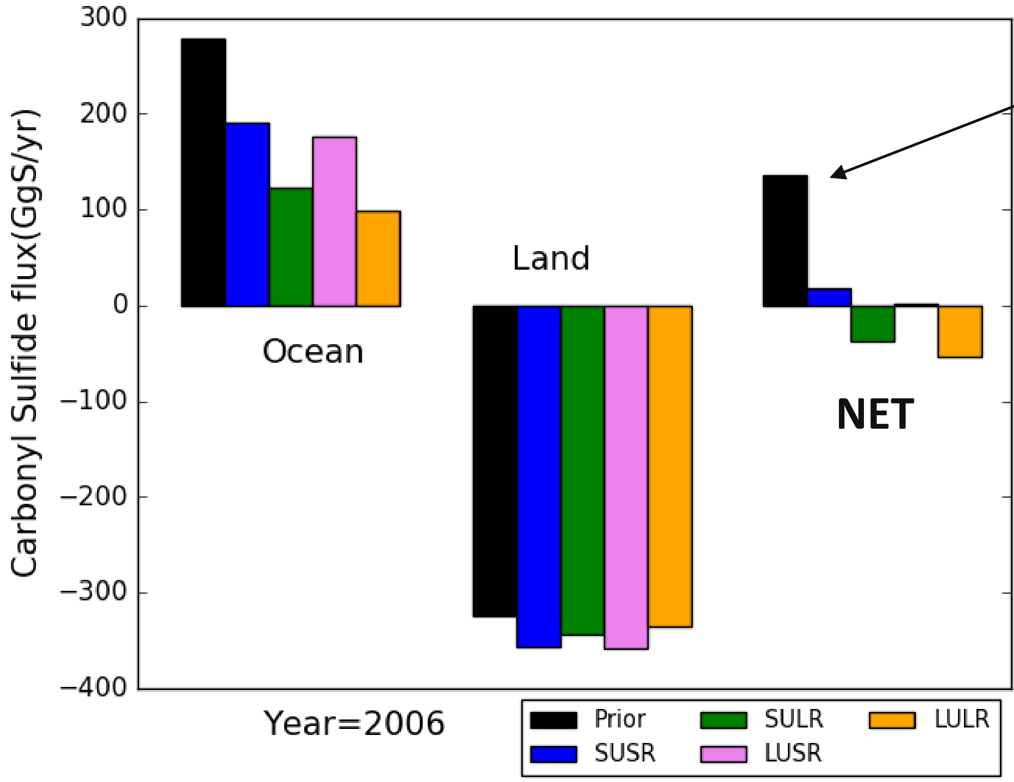
**SULR** : Small Prior Uncertainty; Large Localization Radius

**LUSR :** Large Prior Uncertainty; Small Localization Radius

**LULR:** Large Prior Uncertainty; Large Localization Radius

# COS Flux Estimates

## Global Totals for Year 2006




**BLACK**: PRIOR FLUXES

**Posterior Estimates: Sensitivity Cases**

**SUSR :** Small Prior Uncertainty; Small Localization Radius

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**GLOBAL FLUX TOTALS Year 2006** (Units (Gg S/yr))

| | **Prior** | **Posterior (range)** |
|---|---|---|
| **Ocean** | **280** | **98-191** |
| Land | -325 | -358 to -335 |
| **NET*** | 135 | -54 to +18 |

OCEAN = Direct and Indirect Emissions

LAND = Uptake by Vegetation and Soils + Biomass Burning Emissions

*NET Flux also accounts for Anthropogenic emissions (kept constant at 180 Gg S/yr)