# Simulation of Carbonyl Sulfide (COS) to better understand the urban biosphere signal

Gara Villalba[1,2], Andrew Zumkehr[2], Mary Whelan[2], James Stinecipher[2], Timothy Hilton[2], Xavier Gabarrell[1], Elliott Campbell[2]
[1]Dept. of Chemical, Biological and Environmental Engineering, Autonomous University of Barcelona, Spain (Gara.Villalba@uab.cat)
[2]Sierra Nevada Research Institute and School of Engineering, UC Merced, California

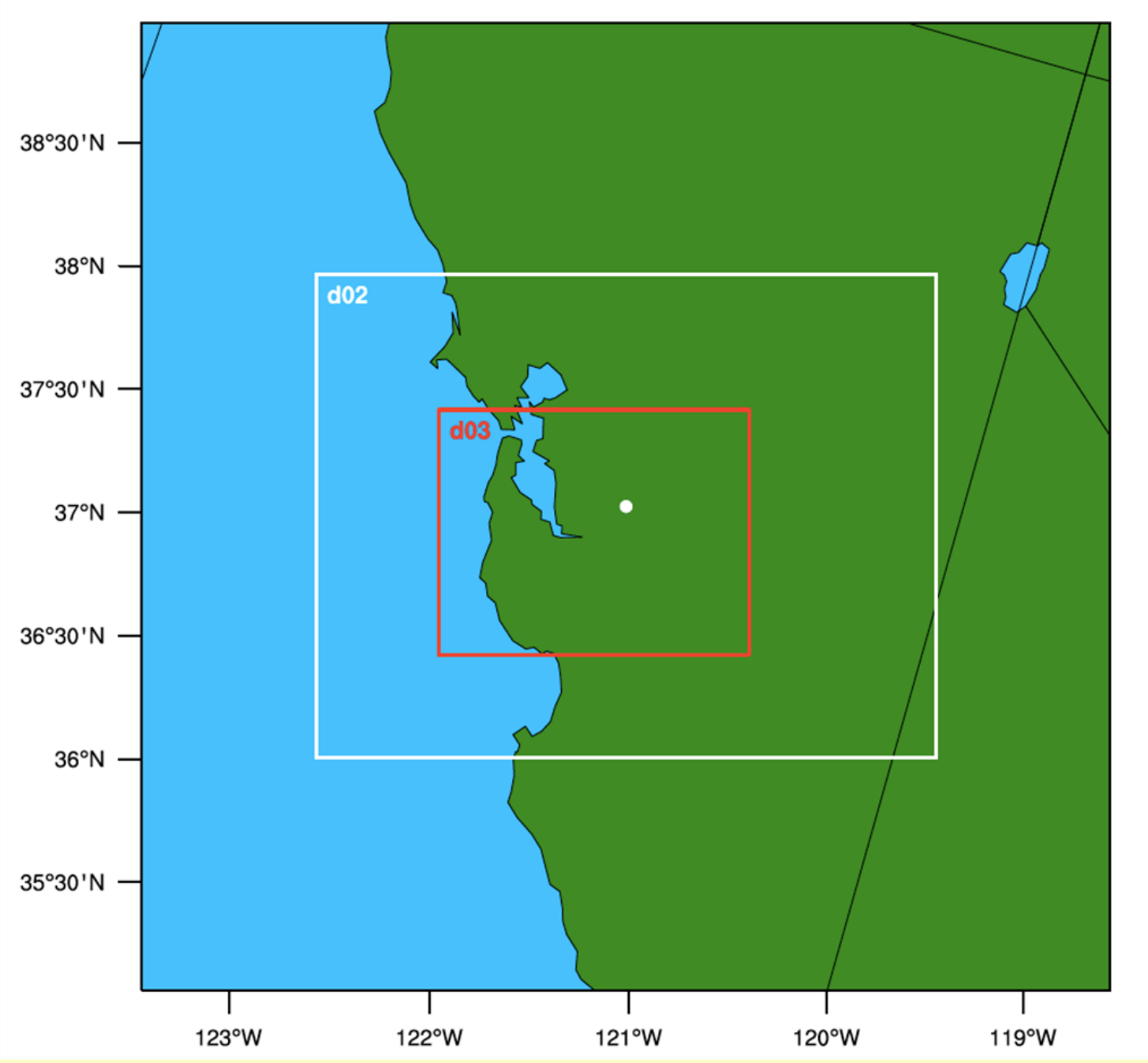
## Background

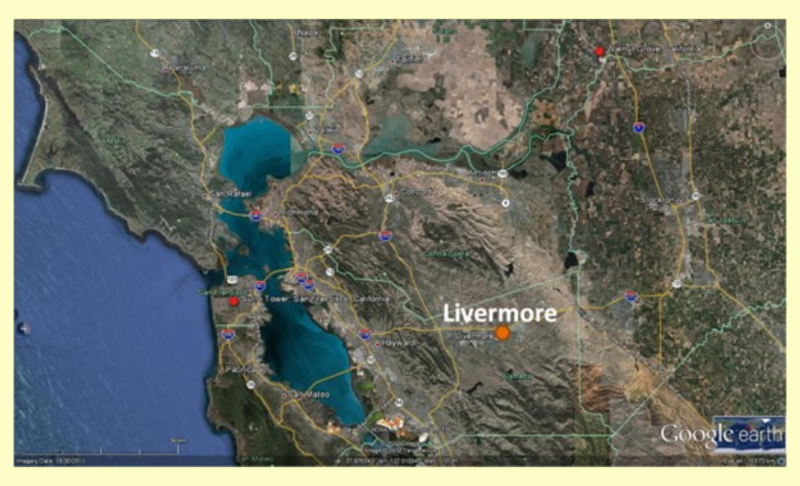
Currently, anthropogenic $CO_2$ emissions over urban regions can be calculated in several ways: 1) bottom-up approaches (or inventories) based on energy consumption within city limits and emission factors that depend on type of fuel and processes, 2) using $^{14}CO_2$ as tracer for fossil $CO_2$, and 3) subtracting the biosphere signal from observation (measured) $CO_2$ data. All of these approaches have their limitations. Given the immense amount of time and resources needed to develop inventories, generic emission factors and data assumptions are often used which result in a high degree of uncertainty. Additionally, temporal extrapolation and spatial redistribution lead to further uncertainties. Albeit $^{14}CO_2$ is an ideal tracer for fossil $CO_2$ because $^{14}C$ is entirely lost to radioactive decay in fossil fuels, the high costs and technological requirements of radio isotope measurements make this method hardly reproducible in the long term and high frequency required to monitor urban emissions. Subtracting the biosphere signal is not always straight forward because there are many biosphere models and they all give different results.

## Abstract

We suggest that COS can be used to determine which ecosystem model best represents the biosphere signal. Just like $CO_2$, COS is taken up by photosynthesis but is not given off in respiration and can thus be used as a trace gas to estimate GPP. We begin with COS surface fluxes provided by SiB and CASA, regridded to lower resolution using NDVI values, for a 9, 3, and 1 km-resolution domains over the Bay Area of San Francisco and part of the San Joaquin Valley. Simulations using the atmospheric model WRF provide the meteorological data, which along with the COS fluxes, are used to run the transport model STEM over a 20-day period in March 2015. Simulations of COS mixing ratio based on the various surface flux models are compared to observed data available from several locations (see abstract B42B-06 by Whelan, M. et al). The model that best represents COS uptake consequently also provides the most accurate simulation of $CO_2$ biosphere signal, and can be used to estimate fossil fuel $CO_2$ emissions.

## Domain





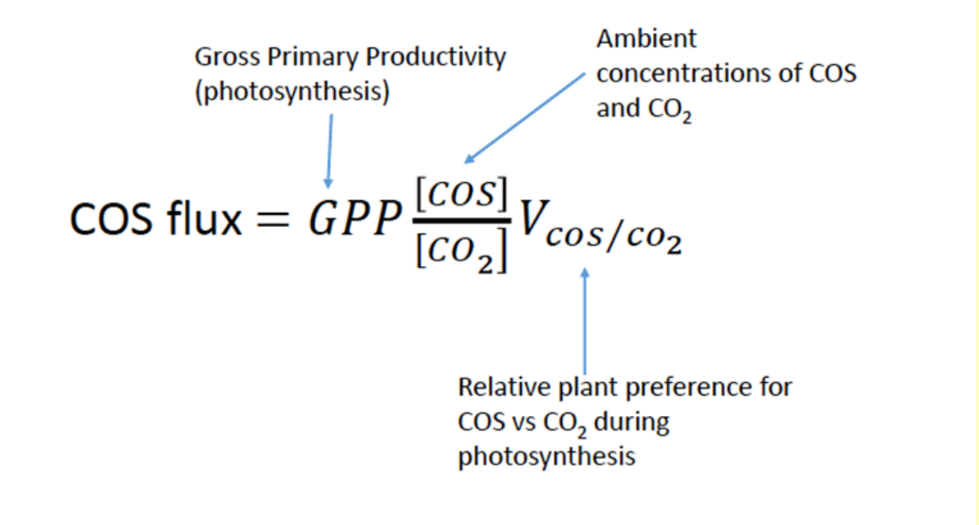
3 nested domains are centered over the city of Livermore, CA. Resolutions: d01 9km, d02 3km, and d03 1km.

## Model

WRF
Model version: 3.7.1 (August 13, 2015)
Simulation period: March 5-25 2015
PBL scheme: Mellor-Yamada-Janjic (Eta) TKE
Land surface model: NOAH
Cumulus: Grell-Devenyi ensemble scheme

STEM Sulfur Transport.dEposition Model

### Calculations:



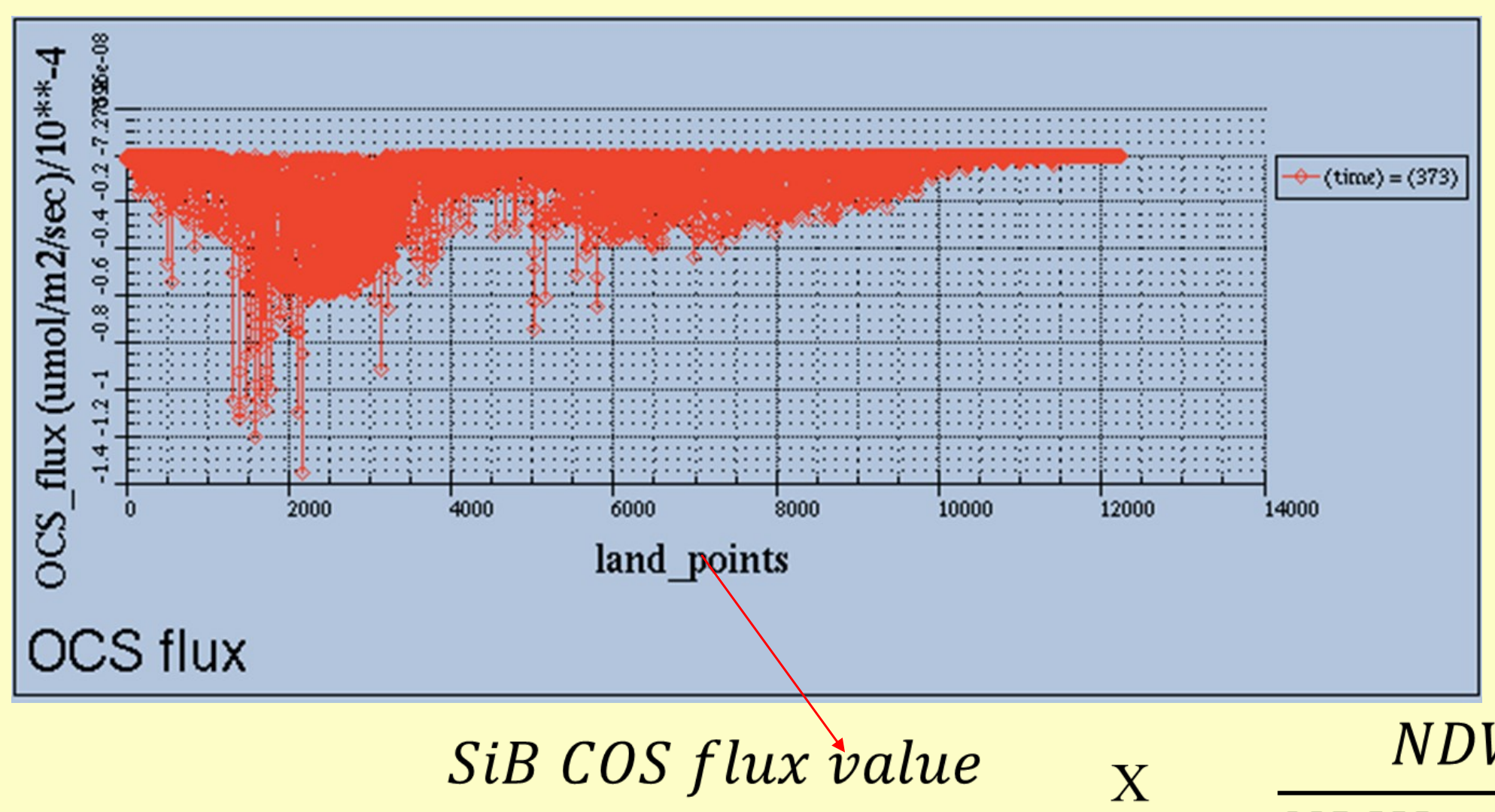
$$\text{COS flux} = GPP\frac{[COS]}{[CO_2]}V_{cos/co_2}$$

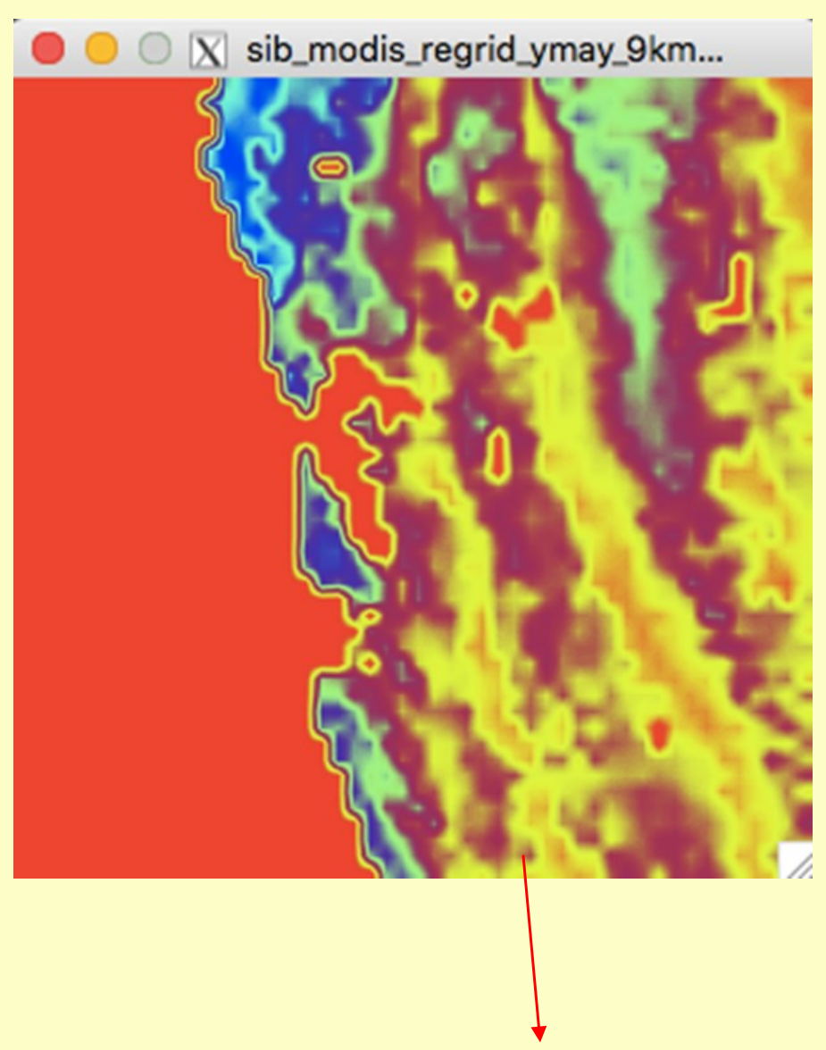
Where:

1.84: LRU (Stimler et al 2012)
1.1: average ambient [COS]/[CO2] ratio from INTEX/NA experiment (Blake et al 2004)

## Methods

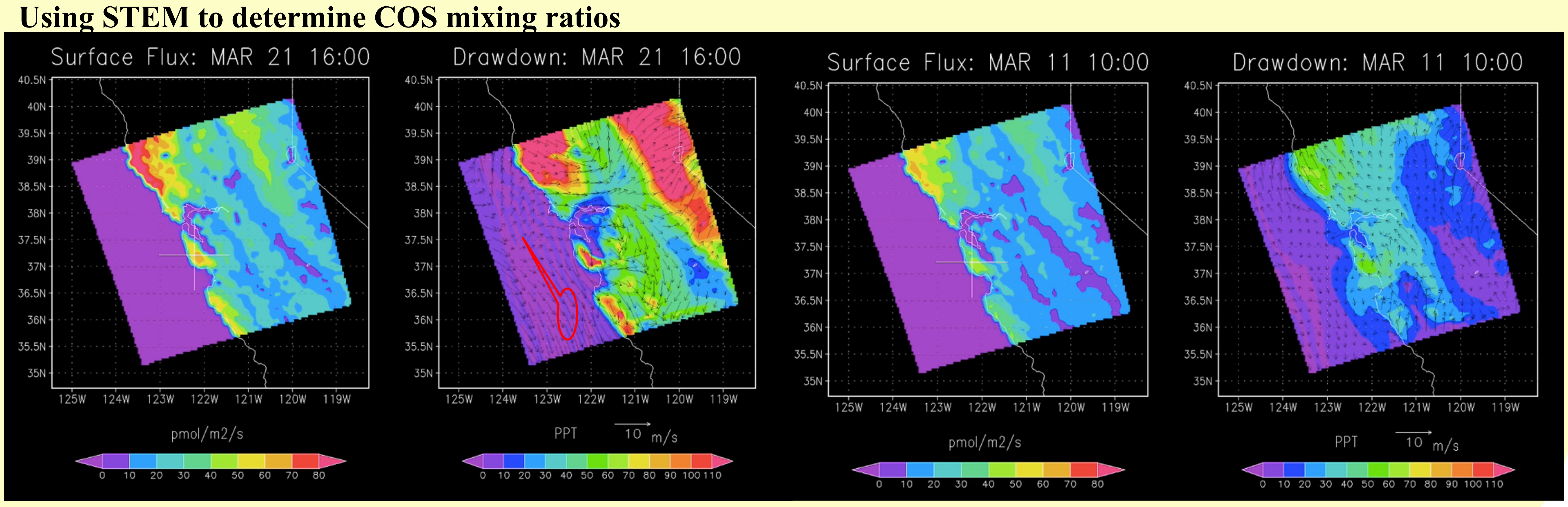
### Calculating COS surface fluxes based on NDVI





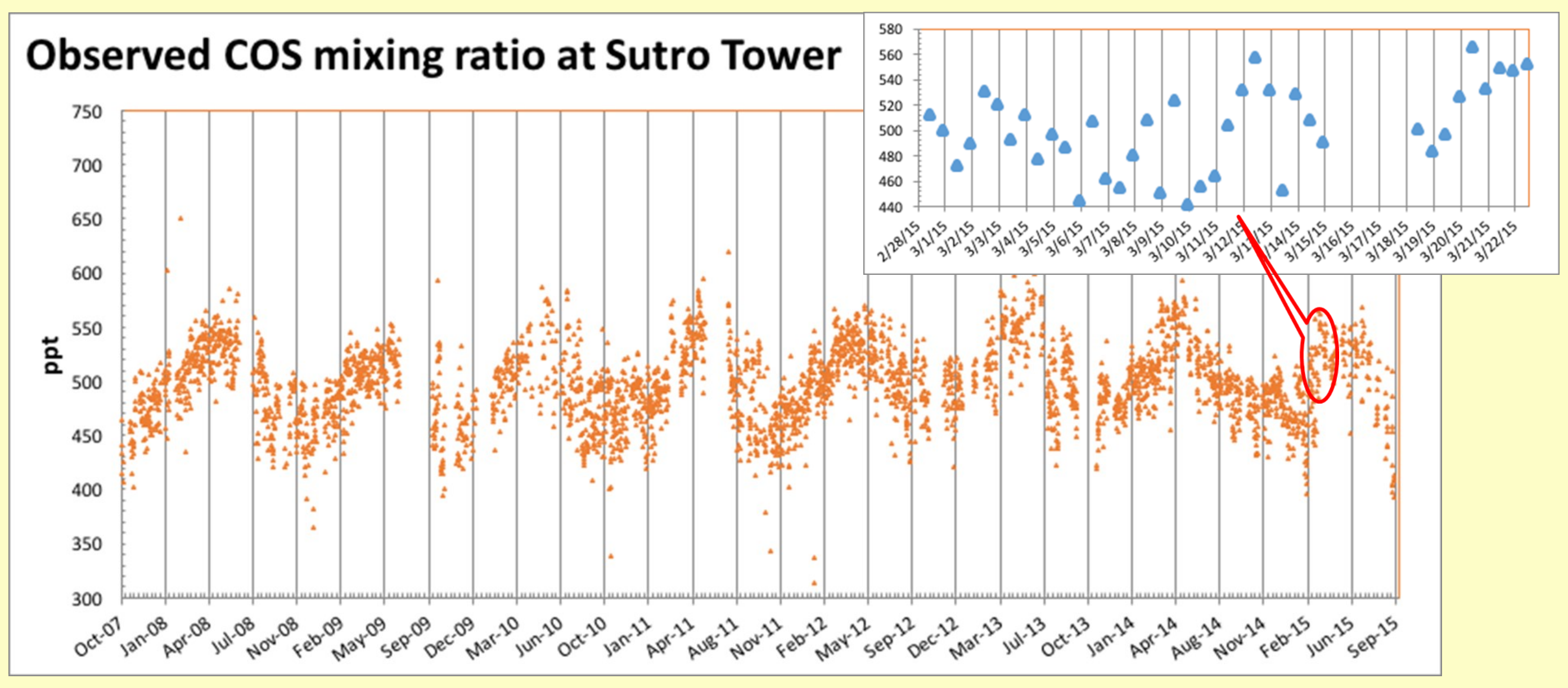
$$\frac{\textit{SiB COS flux value}}{\text{(entire STEM domain)}} \times \frac{\textit{NDVI value for 1 NDVI pixel}}{\textit{NDVI value for entire STEM domain}} = \textit{COS flux value for 1 pixel}$$

### Using STEM to determine COS mixing ratios

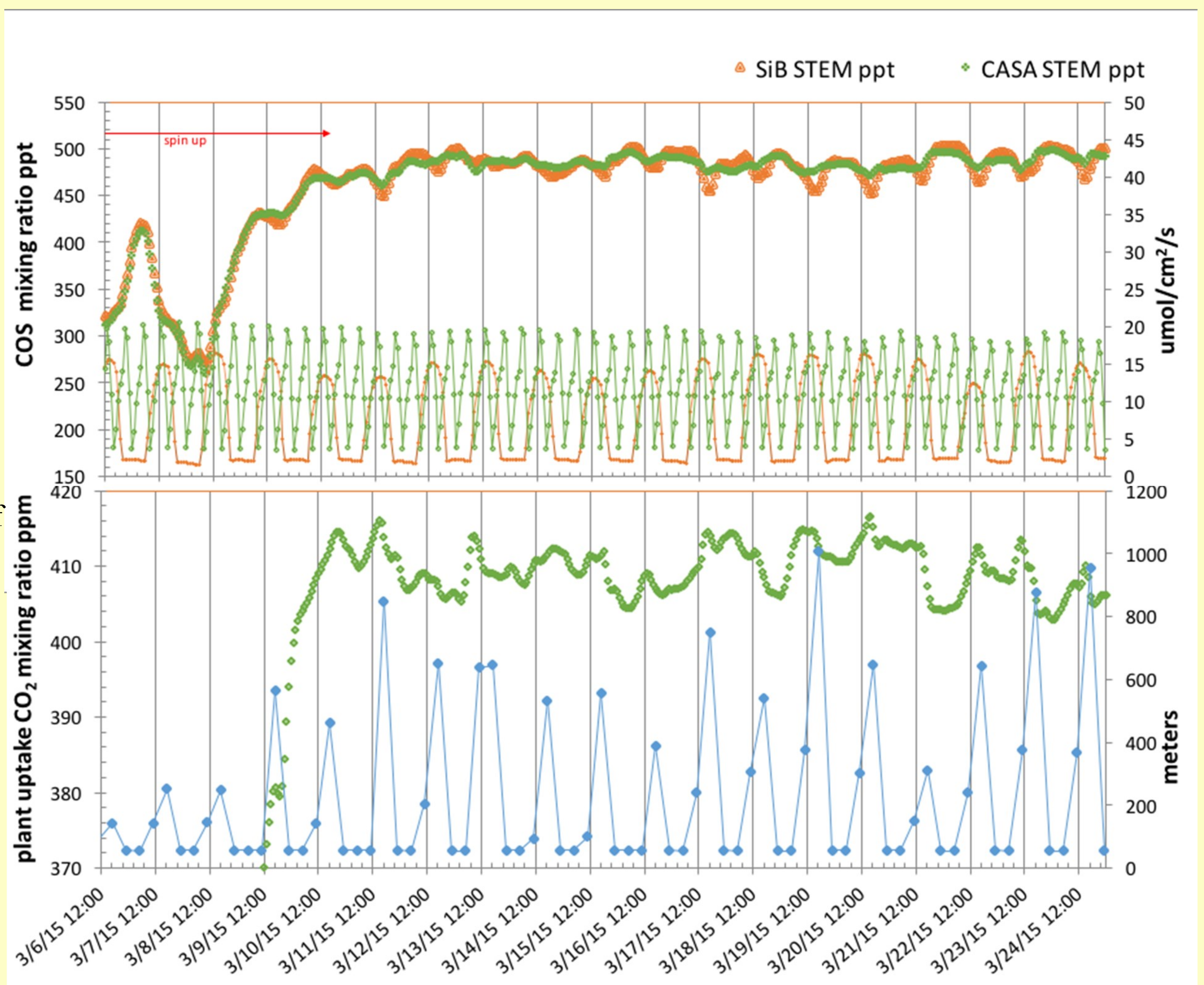


Surface flux and drawdown (difference between 450 ppt and simulated COS surface concentrations) is shown below on left for a typical day reflecting mean flow conditions, northwesterly winds, significant drawdown over the continent and less drawdown over the ocean. The model also showed some synoptic events in which continental air is brought to the

## Results



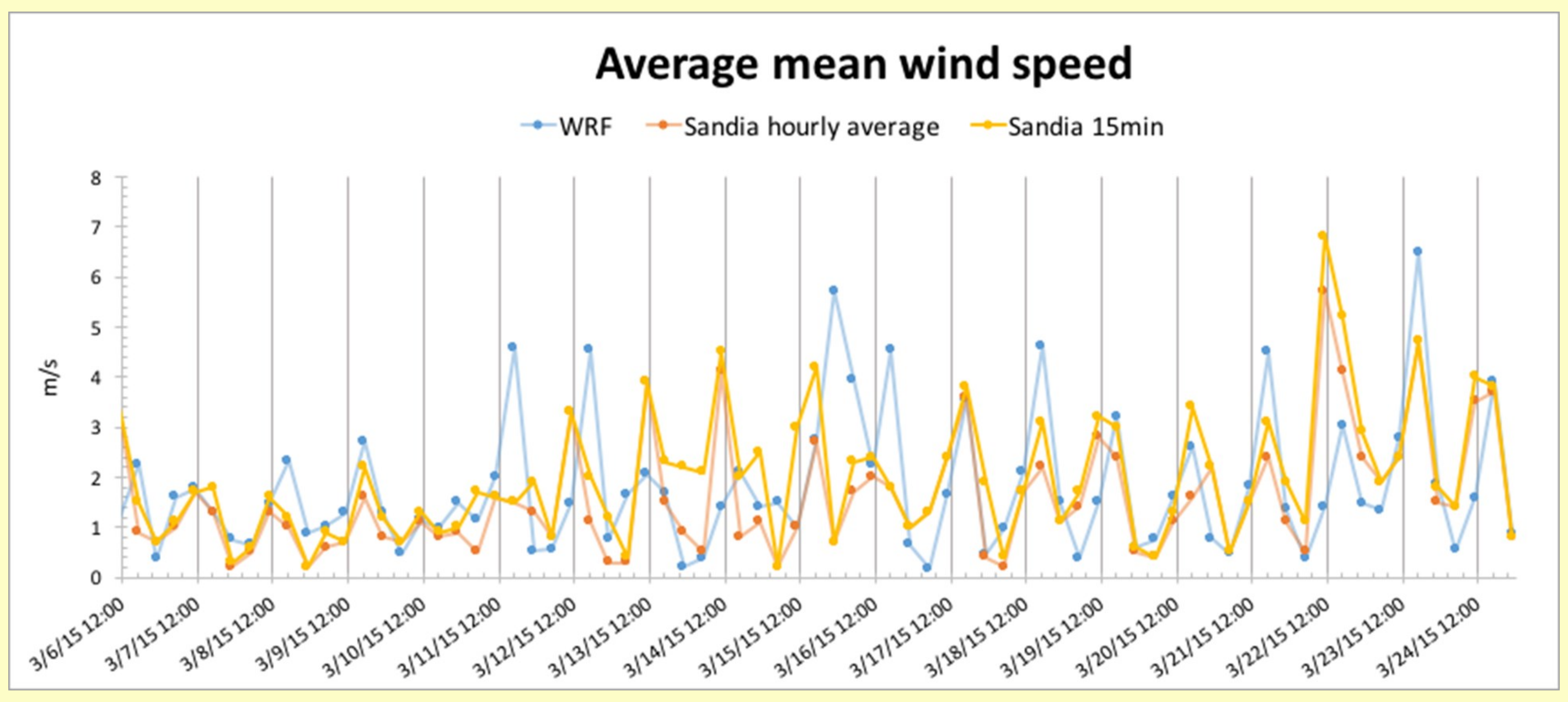
- ⇒ NOAA Sutro tower measurements in San Francisco (Montzka et al JGR, 2007) are on average upwind from study area of Livermore and provides background COS mixing ratio (average of 505 ppt for study period).
- ⇒ Seasonal variations are about 10-15%, and are similar to previous studies.
- ⇒ Synoptic variation during study period shown in zoomed-in box, is about 10%.
- ⇒ COS measurements are taken twice daily, not every day (15 measurements during study period).



- ⇒ Sandia location.
- ⇒ Amplitude: approx 20 ppt (5%Sutro background value of 450 ppt),
- ⇒ Wave: 24 hours variation
- ⇒ Spin-up: 5 days.

- ⇒ Only GPP $CO_2$
- ⇒ $CO_2$ background value of 505 ppm (from Sandia)
- ⇒ The BL is highest late afternoon which corresponds to higher turbulence and higher mixing values.

- ⇒ Mean wind speed at z=1 (Sandia tower at 13 meters).
- ⇒ Similar patterns and phases.



- ⇒ COS mixing ratios (above) are high at night and early morning (up to 505 ppt), then start to drop late morning/noon, reaching lowest values (down to 460 ppt for CASA and 450 for SiB) around 3-4pm.
- ⇒ These are different diurnal patterns than those previously determined for forested areas (where COS mixing ratio is highest in the middle of the day). Possible reasons: lack of photosynthetic activity during this period (caused by drought) which is also reflected by small differences between Sutro (background) and Sandia tower observed COS mixing ratios.
- ⇒ Boundary layer (BL) is highest late afternoon which corresponds to higher turbulence and theoretically higher mixing ratios. Low COS mixing ratios in the pm might suggest that plant drawdown is more significant than mixing.
- ⇒ Synoptic event happening on 3/21 after which COS concentrations rise by 20 ppt. Potential continental influence until 21st, after which marine air (less plant influence) seems more prominent.

**Future work**: 1) run STEM for anthropogenic and respiration $CO_2$, so that together with most appropriate plant uptake $CO_2$ (current work) and observed $CO_2$, we can determine a top-down modified observation anthropogenic $CO_2$ flux. 2) Use dynamic boundaries from global chemical transport models. 3)study other periods to establish diurnal patterns and validate model results with observed data.

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