Surface CO2 and CH4 fluxes simultaneously inferred from proxy GOSAT XCH4:XCO2 retrievals: Trend and Inter-annual variations

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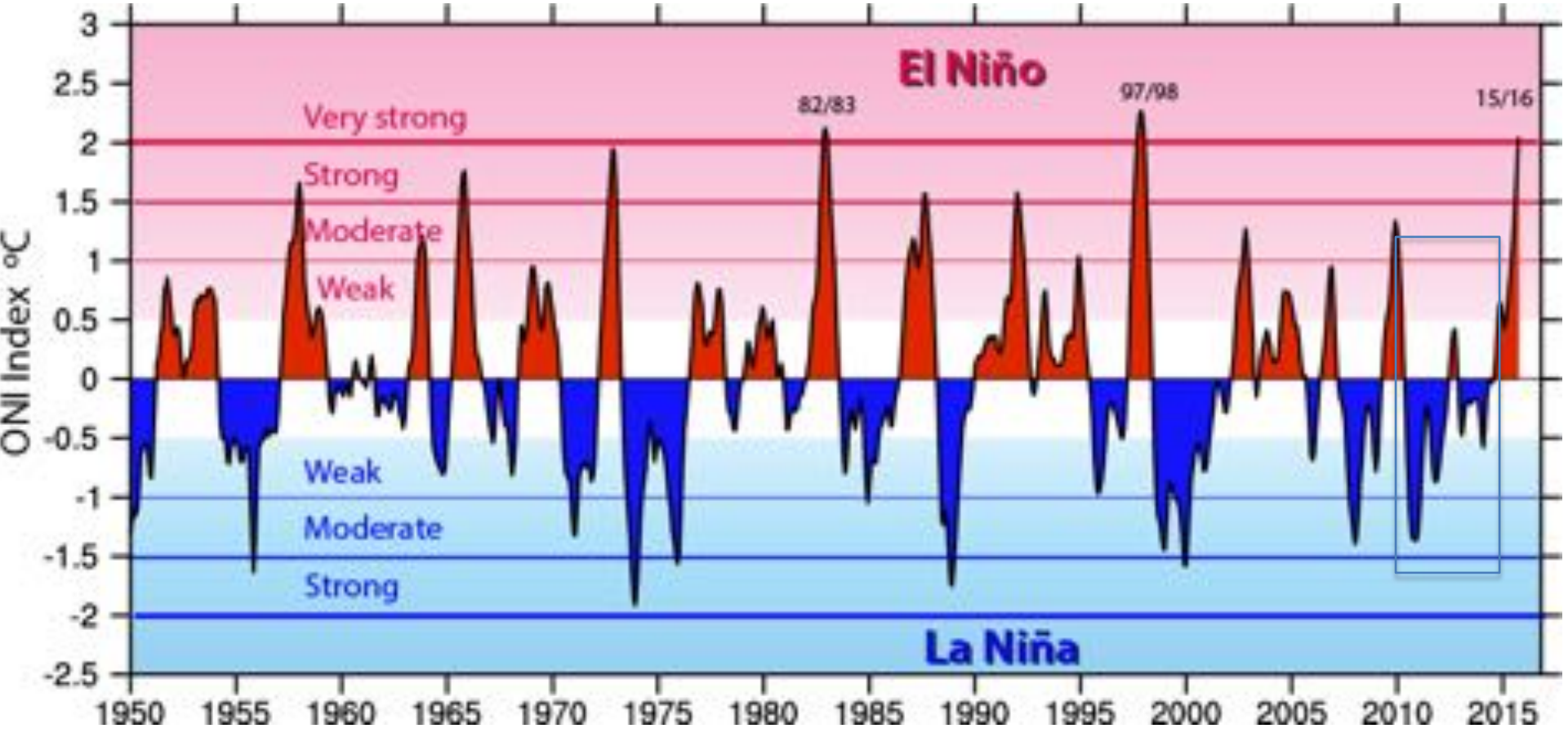
NERC SCIENCE OF THE ENVIRONMENT

I. Introduction

➢ Changing condition

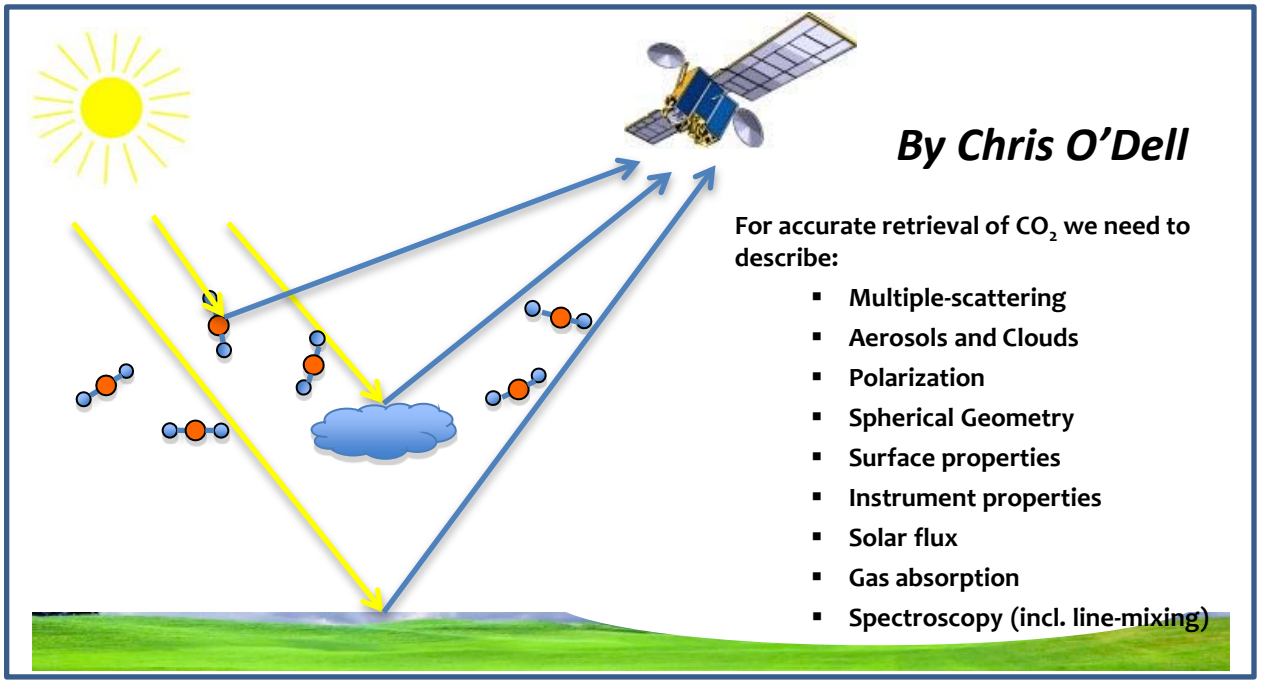
By NCAR



- Biosphere response to anomalies, such as high temperature, and low water supply etc are of great interest.
- In the past 6 years, 2009, 2010, and 2011 have moderate EL Nino activities, while 2013 and 2014 are two relatively 'quiet' years, which provides a good chance to study how the bio-system recovers after strong disturbing.

➢ Continual GOSAT GHG observations

- Since launched in 2009, the JAXA GOSAT provides continual global measurements of XCH4 and XCO2.
- However, full physics XCO2 and XCH4 retrievals are sensitive to the presence of aerosols and clouds.
- XCH4/XCO2 ratio is a more reliable product (Parker et al.,2015)
  - Fits CO2 band at 1.61 mm & 1.65 mm CH4
  - Key assumption: clouds and aerosols affect both gases the same way

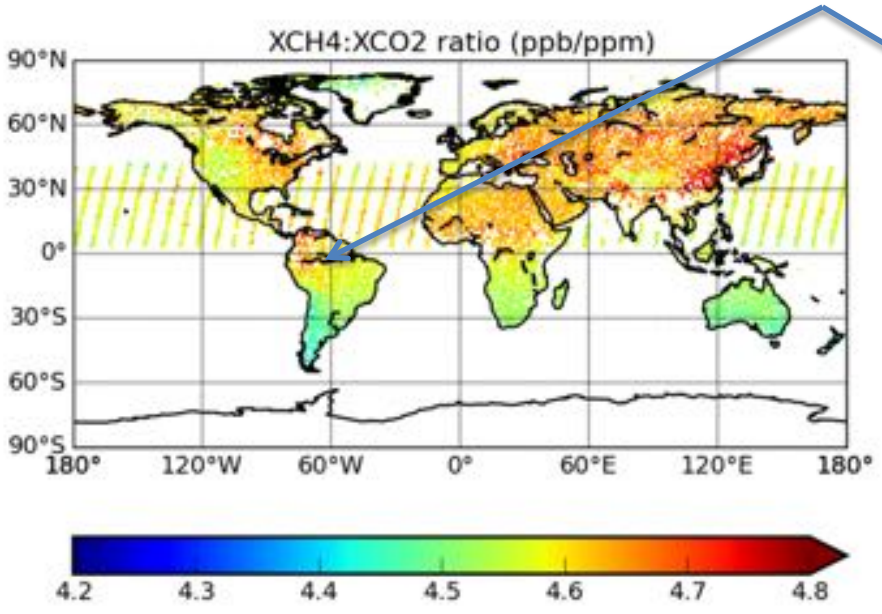


- **Advantages:**

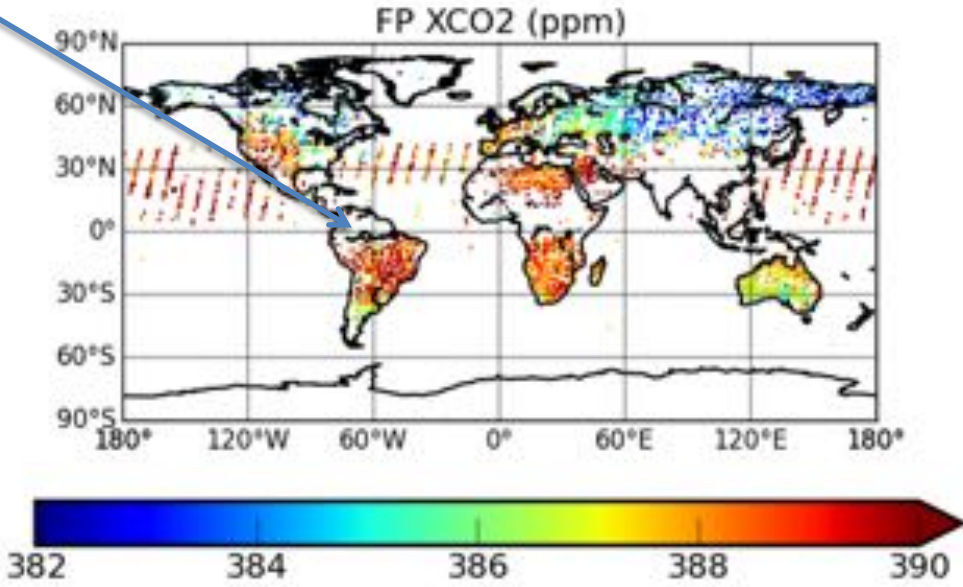
✓ Product more bias-free, but subject to error from high cirrus clouds

✓ Lots more data than the full-physics approach

Good XCH4:XCO2 retrievals in 2010.07



Good full-physics XCO2 retrievals in 2010.07



Good coverage by ratio data is important for studying inter annual variations.

II. Direct assimilation of GOSAT proxy XCH4:XCO2 ratio

- **Fraser et al (2014)** detailed a MAP approach for inferring CO2 and CH4 fluxes by directly assimilating GOSAT proxy XCH4:XCO2 ratios, together with in-situ CO2 and CH4 observations.

- Based on this study, we develop an **Ensemble Kalman Filter** to assimilate XCH4:XCO2 ratios, so that we can
  - ✓ use a larger state vector:
    CH4 Fluxes: 66 land regions × 4 categories+11 ocean fluxes.
    CO2 fluxes: 66 land regions × 3 categories+11 ocean fluxes.
  - ✓ assimilate individual XCH4:XCO2 ratios, instead of their monthly means.
  - ✓ include temporal and spatial error correlations of prior estimates.

➢ Inversion configuration

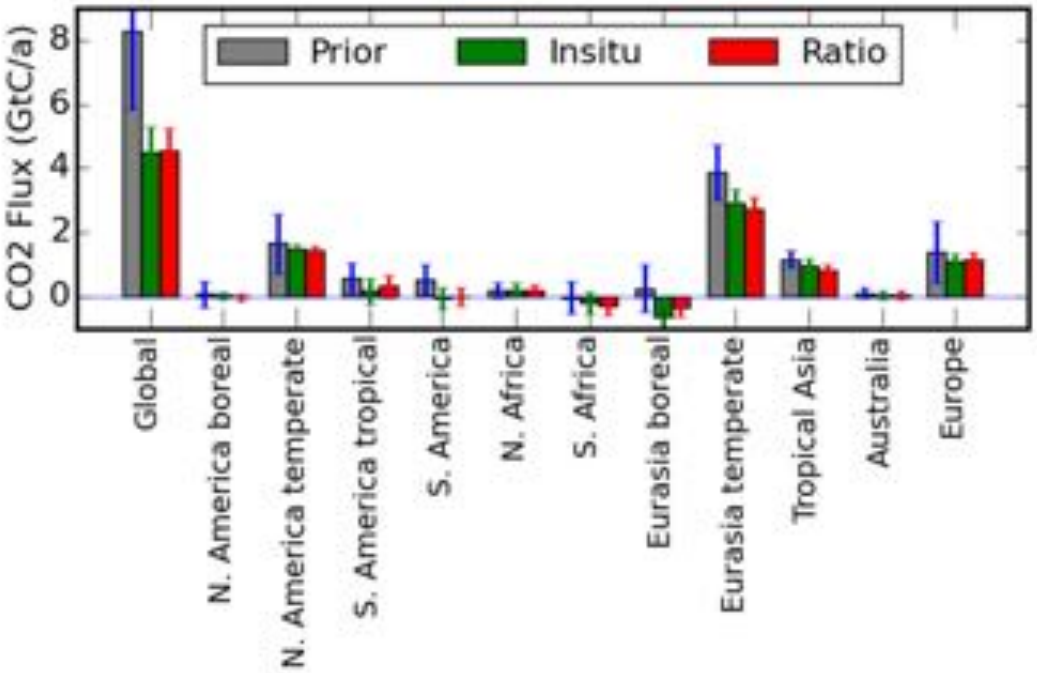
- **Prior CO2 Inventories:** Fossil fuel ; Biospheric fluxes: Oceanic surface fluxes; Biomass burning.
- **Prior CH4 Inventories:** Wetland; Rice; Termites; Animal; Biomass burning; Fossil fuel ; Waste; Gas Industry; Coal mine; Ocean; Biomass burning…
- **Prior Uncertainties**:

  Land: 50%; Ocean: 50%
- **CTM (Geos-Chem v9.02)**
  - ✓ Vertical Res: 47 levels from surface to 0.1 hPa.
  - ✓ Horizontal Res: 4^{o} (latitude) × 5^{o} (latitude)
- **Observations:**
  - ✓ Proxy GOSAT XCH4/XCO2 ratio of Version 6) from 2009.06-2014.12
  - ✓ In-situ CH4 from 52 stations .
  - ✓ In-situ CO2 from 78 stations .

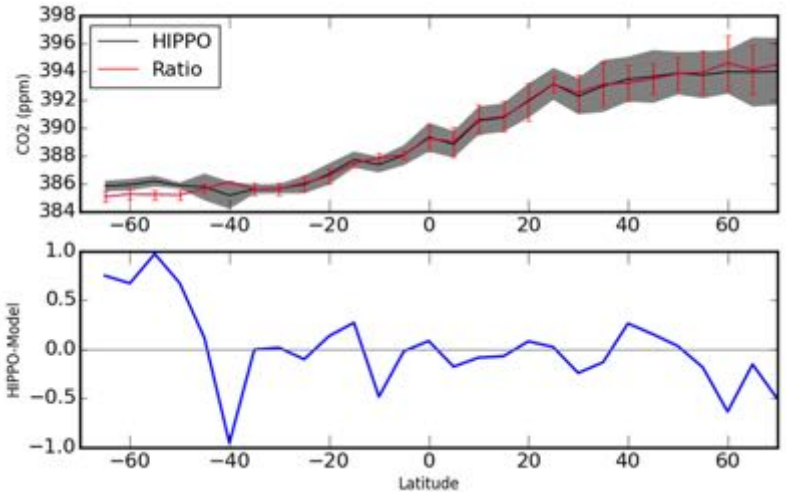
III. Results

➢ CO2 fluxes

Annual total



Compared to HIPPO-3

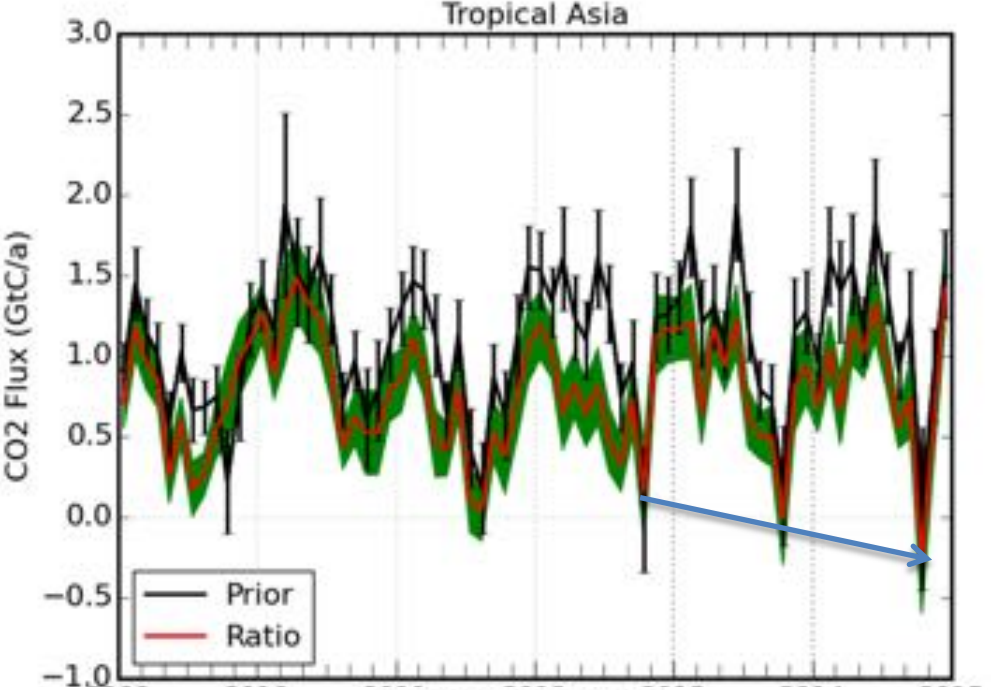


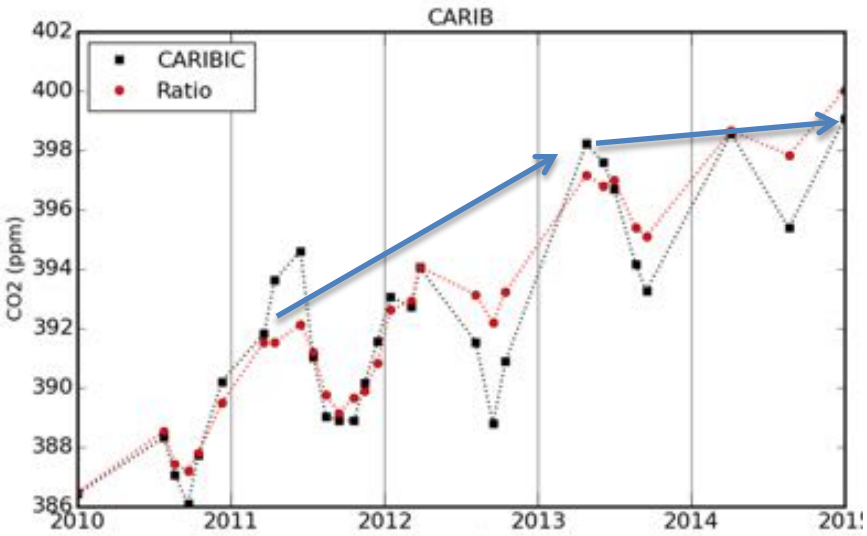
Bias: -0.07 ppm.
Std: 0.88 ppm.

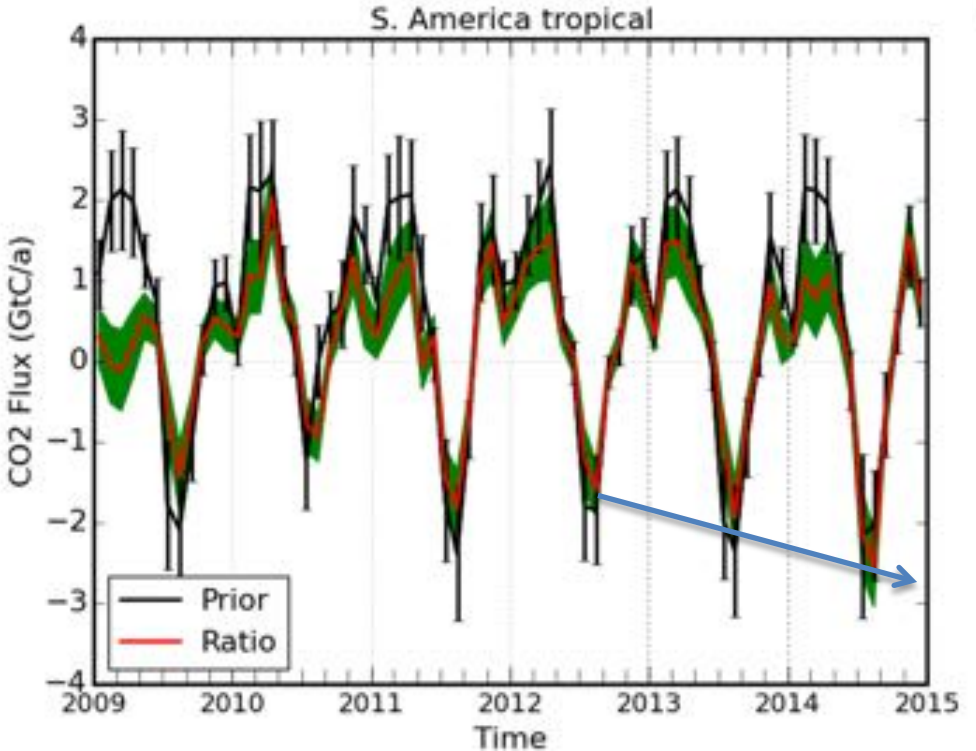
1. Annual net regional fluxes by **ratio** inversion are broadly similar to the **in-situ** only inversions, but with **less uncertainties**, particularly over tropical lands.
2. Resulting model concentrations generally agree with independent observations such as **HIPPO**.

Trends in monthly fluxes

1. Over both Tropical Asia, and Tropical South America, ratio inversion shows enlarged peak uptakes **after mid-2012**.
2. Also their **peak emissions** are slightly lower for 2013 and 2014.
3. Aircraft measurements (CARIBIC) imply a possibly **slower increase** of the peak tropical CO2 concentrations between 2013 and 2014.

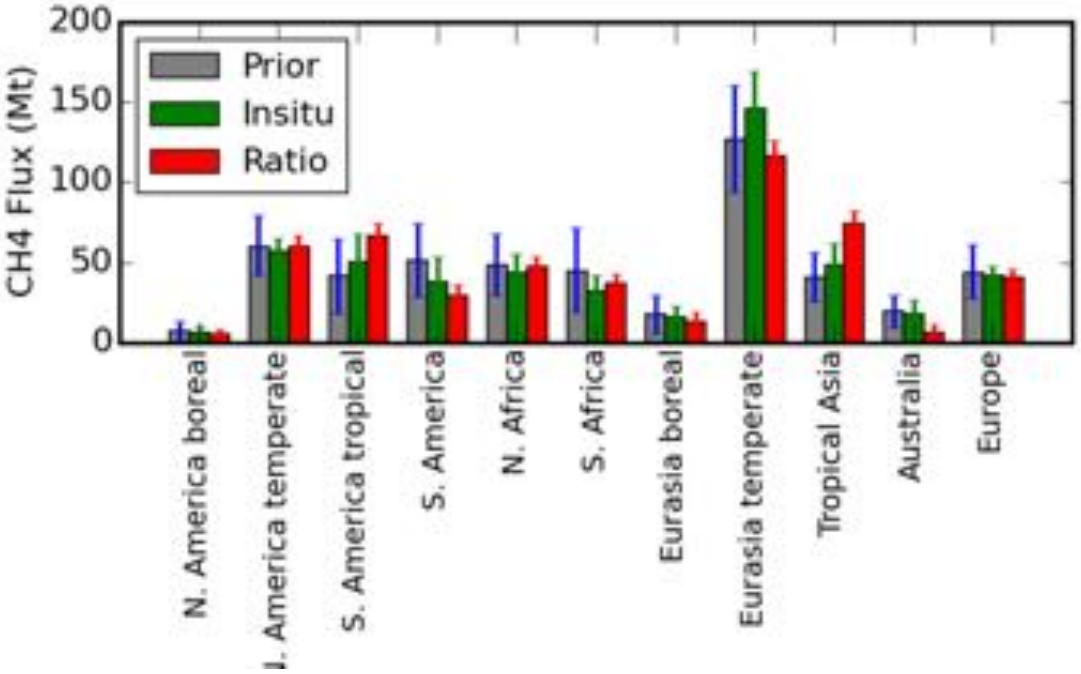




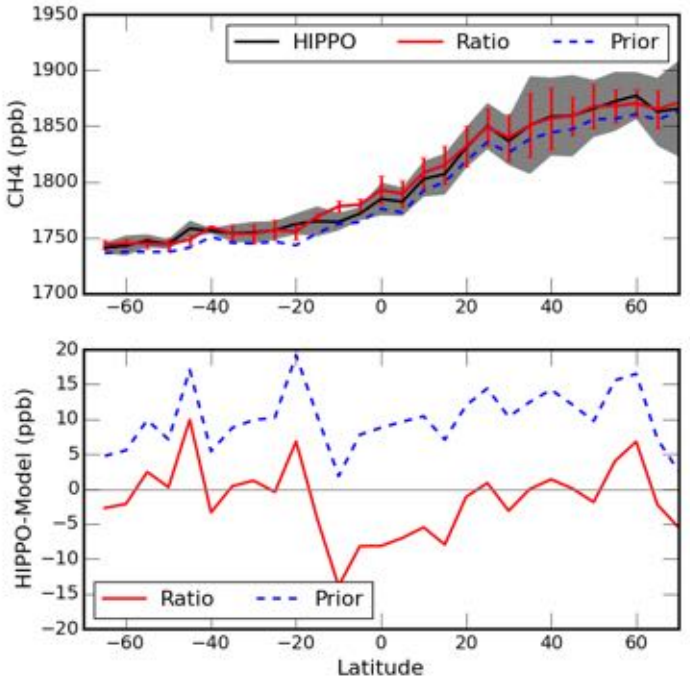


➢ CH4 fluxes:

Annual total



Compared to HIPPO-3

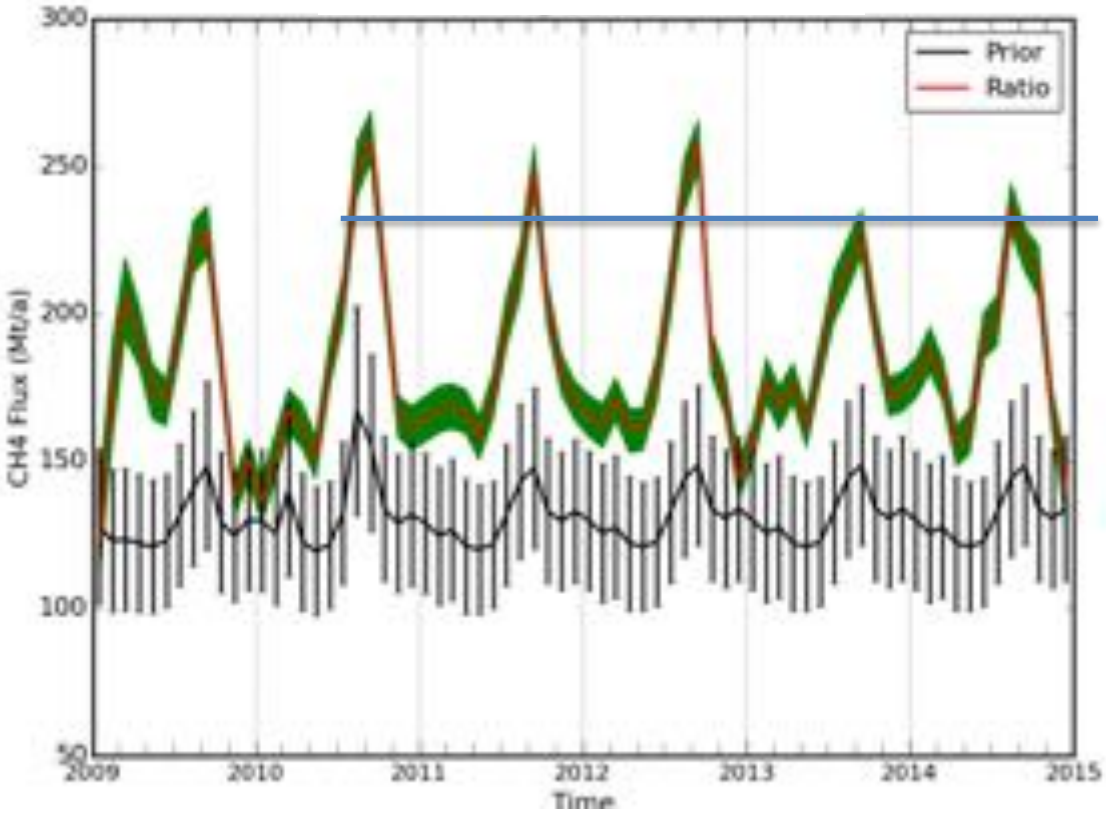


Bias: 4.3 ppb.
Std: 11 ppb.

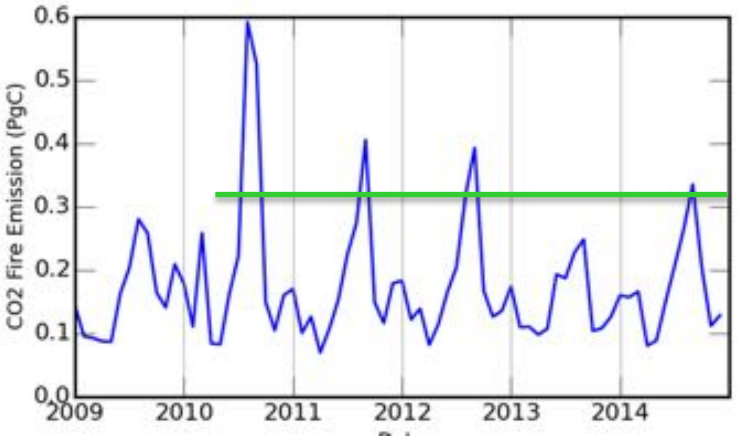
1. **Ratio** inversion shows much smaller uncertainties for regional **CH4** fluxes.
2. Assimilation of XCH4:XCO2 Ratio results in larger tropical CH4 emissions, compared to both the prior and posterior estimates based on in-situ data only.
3. Resulting model CH4 concentrations generally agree with independent observations such as **HIPPO**, but with **a positive bias** (up to 15 ppb) over tropical regions.

Trends in CH4 monthly fluxes

Tropical CH4 emissions



GFED CO2 fire emissions -30S to 30N



- The ratio inversion show that tropical CH4 emissions over 2013 and 2014, are weaker than previous years.
- They might be due to **less fires** in 2013 and 2014, as suggested by the GFED fire emissions. But there are *other possible causes*.

IV. Conclusions

- XCH4:XCO2 proxy product is assumed to be less biased, with more spatial and temporal coverage than the full-physics XCO2 or XCH4 product.
- We used an EnKF approach to assimilate the XCH4:XCO2 data to simultaneously estimate CH4 and CO2 regional fluxes.
- **Resulting CO2 and CH4 fluxes have less uncertainties.**
- **Resulting model concentrations reproduce independent aircraft measurements well, particularly outside the tropical regions.**
- Our results show much higher CH4 emissions from tropical regions than prior estimates.
- The trends for CO2 and CH4 are interesting, but need further investigations.