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Sources of systematic differences in global CO_2 inverse model results

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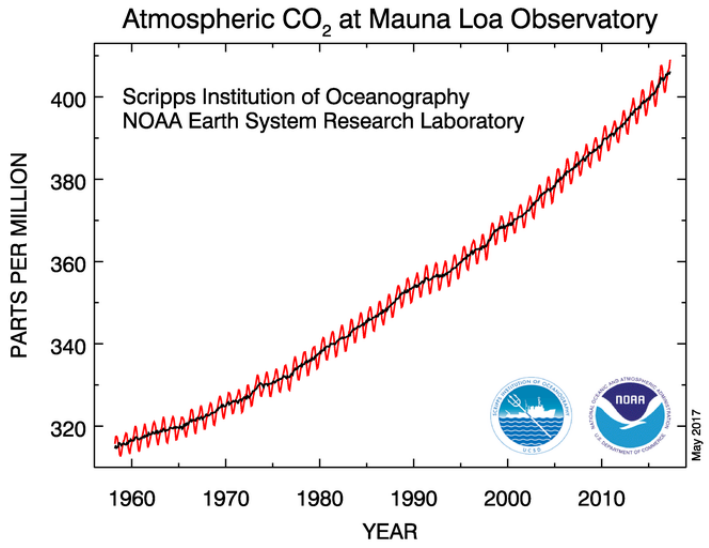
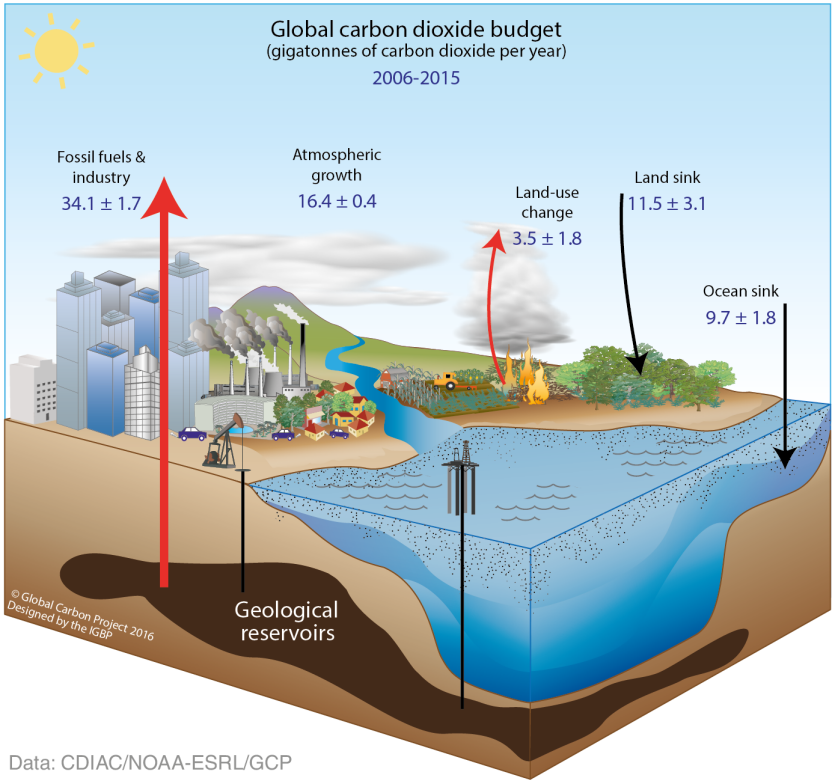
Understanding the global CO_2 budget :

AGR = FF + OCEAN + LAND

1. The atmospheric growth rate is well known (derived from observations)
2. Fossil Fuel total emissions are well known
3. Global land = Residual



Global Carbon Project
Le Quéré et al. [2016]

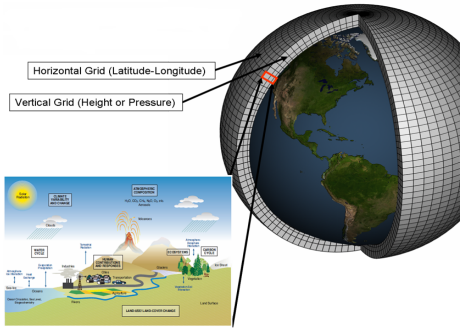


Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2006–2015 ($GtCO_2$/yr)

GLOBAL CARBON PROJECT

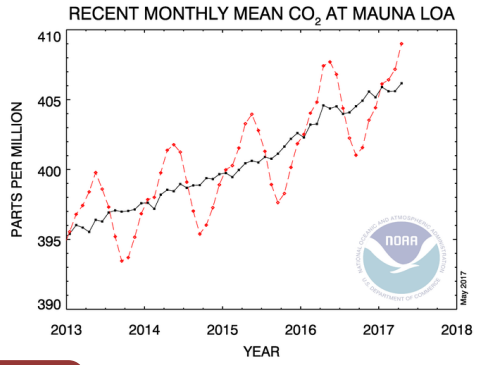
Source: CDIAC; NOAA-ESRL; Le Quéré et al 2016; Global Carbon Budget 2016

Derive CO_2 fluxes knowing priors and observations



- In-situ surface and aircraft observations
- Satellite retrievals

- Atmospheric Transport Model (H)
- CO2 = H(x) + r



- Prior fluxes (x)

$(\Delta)_{land} + (\Delta)_{ocean} + S_{FF}$

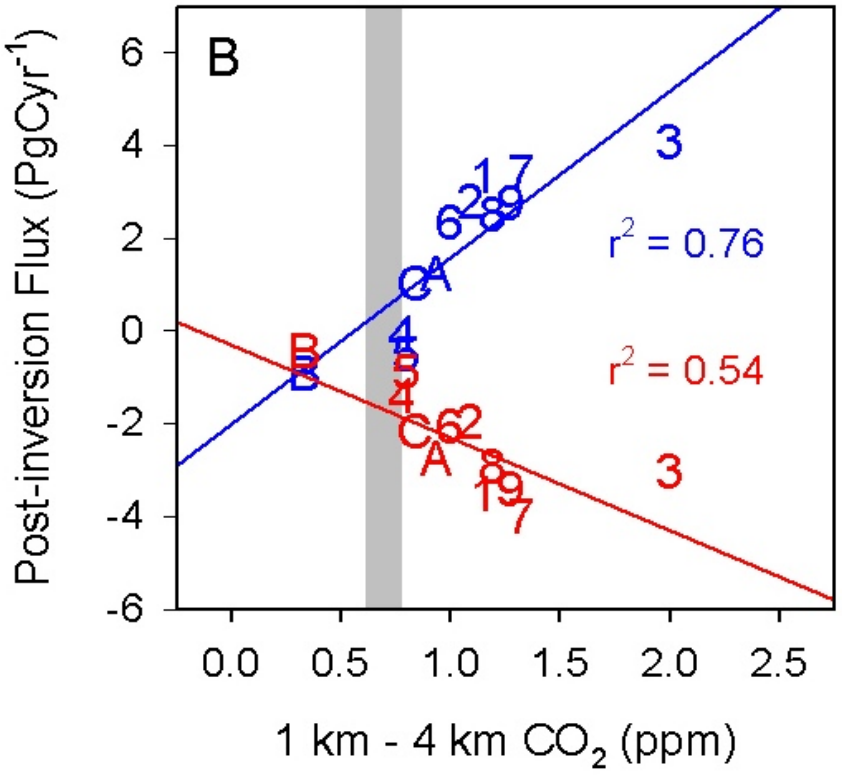
Optimized fluxes

➢ Are inverse models still highly dependent on transport errors and a priori assumptions ?

1. Comparison of modelled a posteriori fluxes and Global Carbon Project
2. CO_2 modelled after flux optimisation is compared to HIPPO observations

Modelling system	References	Grid Spacing	Transport Model	Meteorological fields
MACC-II (v14r2)	Chevallier et al. (JGR 2010; GMD 2013)	3.75° x 1.875°	LMDZ	ECMWF wind
Jena (S04_v3.8)	Rödenbeck (2005)	4° x 5°	TM3	ERA interim
CTE2016	van der Laan-Luijkx et al. (2017)	1° x 1°	TM5	ERA interim
CT2016	Peters et al. (2007) with updates documented at http://carbontracker.noaa.gov	1° x 1°	TM5	ERA interim
ACTM IEA & CDIAC	Saeki and Patra (2017)	T106 (0.88 x0.84)	ACTM	NCEP2
TM5-4DVar	Basu et al. (2013)	3° x 2°	TM5	ERA interim

Model results were systematically dependent on atmospheric transport



Northern Land

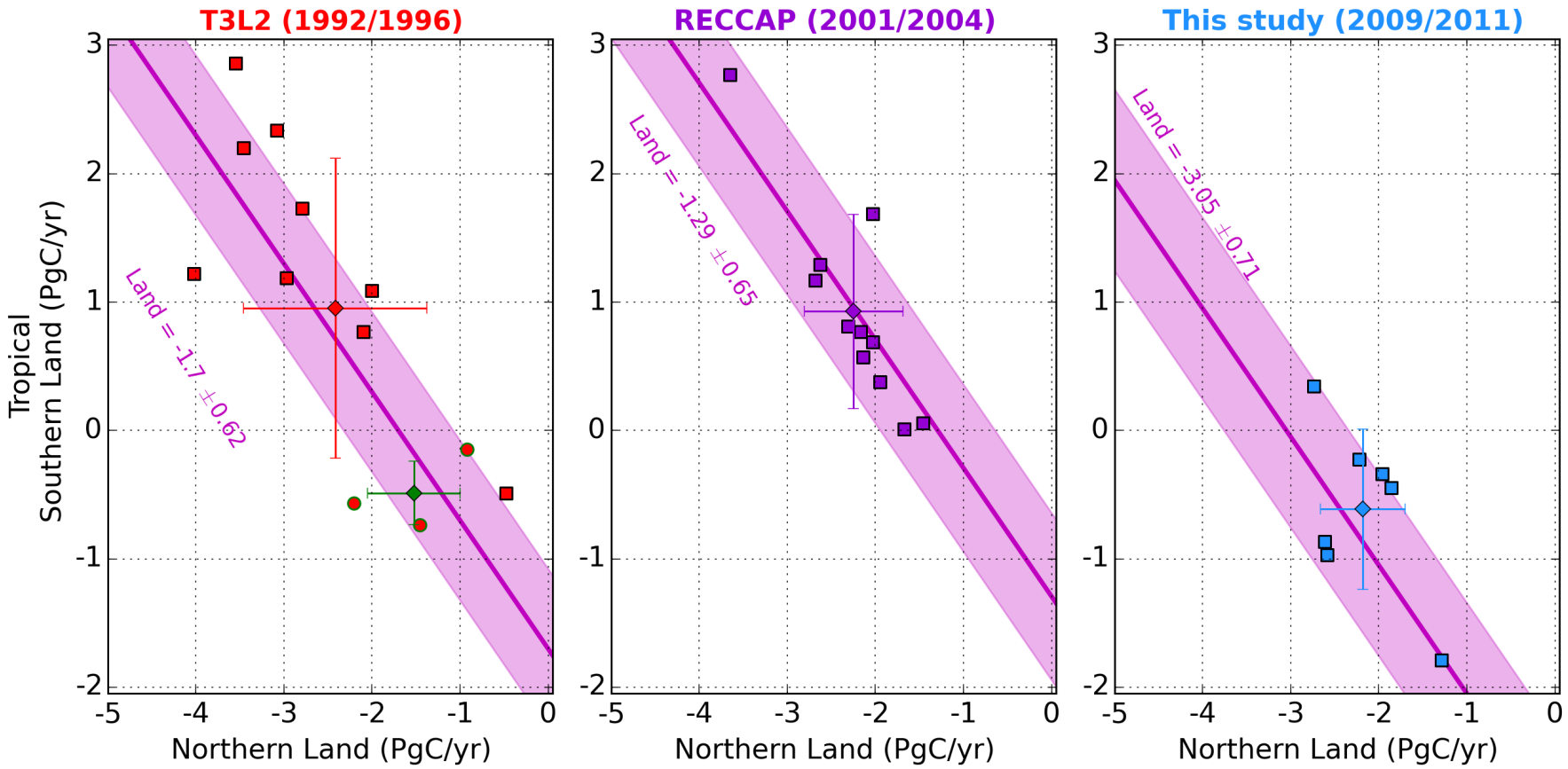
Tropical Land

Weak Northern and Strong Tropical Land Carbon Uptake from Vertical Profiles of Atmospheric CO_2

Britton B. Stephens,[1]* Kevin R. Gurney,[2] Pieter P. Tans,[3] Colm Sweeney,[3] Wouter Peters,[3] Lori Bruhwiler,[3] Philippe Ciais,[4] Michel Ramonet,[4] Philippe Bousquet,[4] Takakiyo Nakazawa,[5] Shuji Aoki,[5] Toshinobu Machida,[6] Gen Inoue,[7] Nikolay Vinnichenko,[8]† Jon Lloyd,[9] Armin Jordan,[10] Martin Heimann,[10] Olga Shibistova,[11] Ray L. Langenfelds,[12] L. Paul Steele,[12] Roger J. Francey,[12] A. Scott Denning[13]

22 JUNE 2007 VOL 316 SCIENCE www.sciencemag.org

All units are PgC/yr	Northern extra-tropical flux	Trop + Southern Land flux
T3L2 (Gurney et al. 2004)	-2.42 +/- 1.09	0.95 +/- 1.22
T3L2 subset (Stephens et al. 2007)	-1.52 +/- 0.64	-0.49 +/- 0.3
RECCAP (Peylin et al. 2013)	-2.25 +/- 0.58	0.93 +/- 0.9
This work	-2.18 +/- 0.52	-0.62 +/- 0.67



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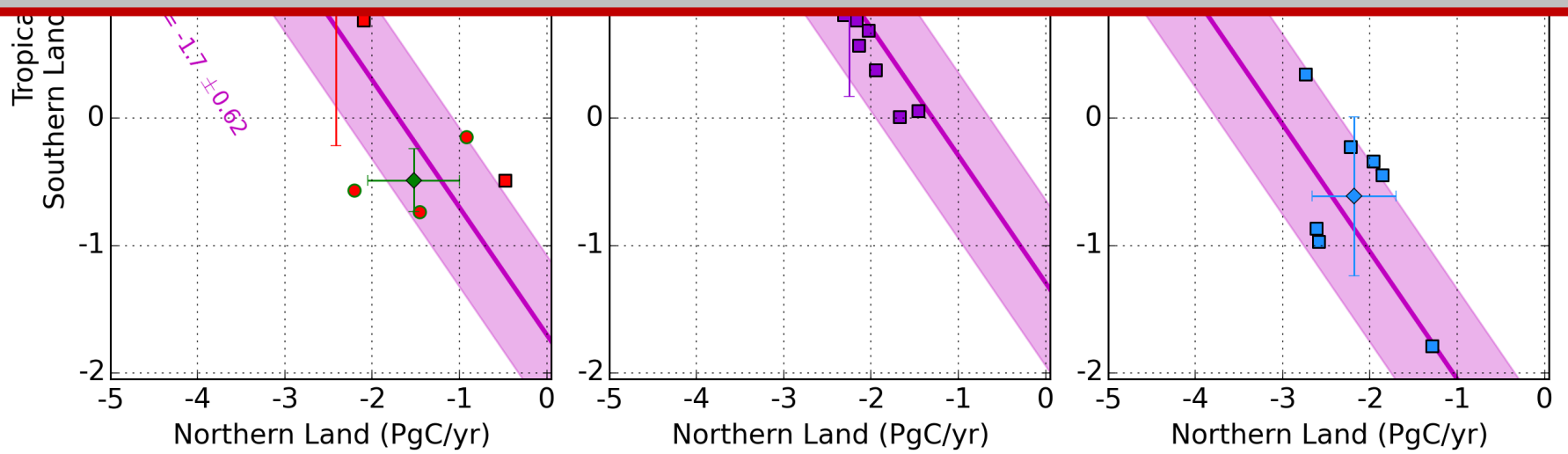
- **Is the remaining spread still due to transport error ?**



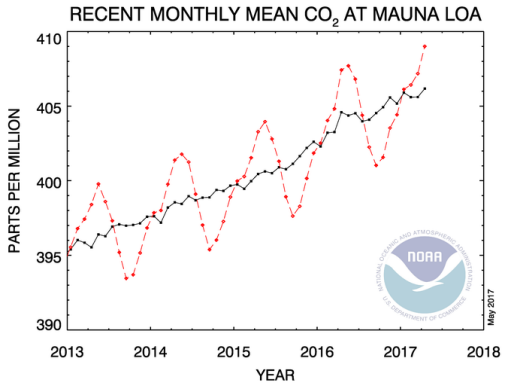
HIPPO

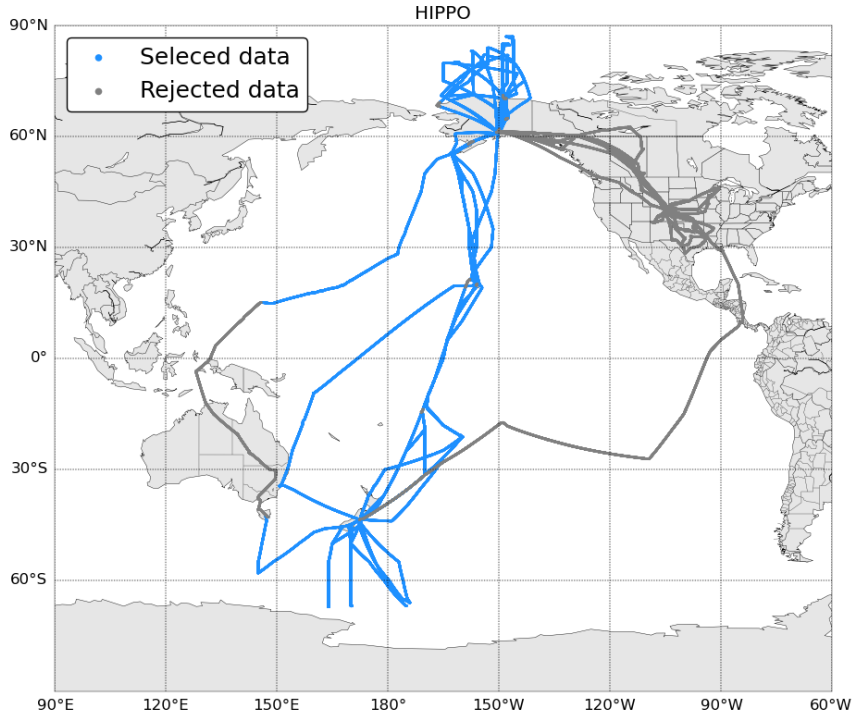
HIAPER
Pole-to-Pole
Observations

Evaluation of posterior CO_2 concentration vs. HIPPO data

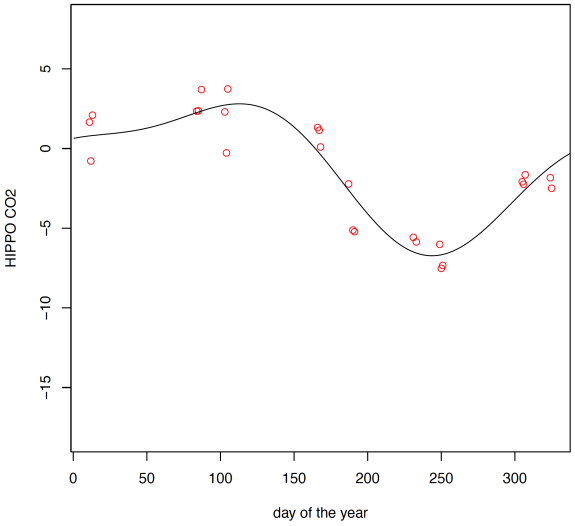
- **Provide large scale CO_2 measurements with coverage in latitude, time, and vertical gradients**

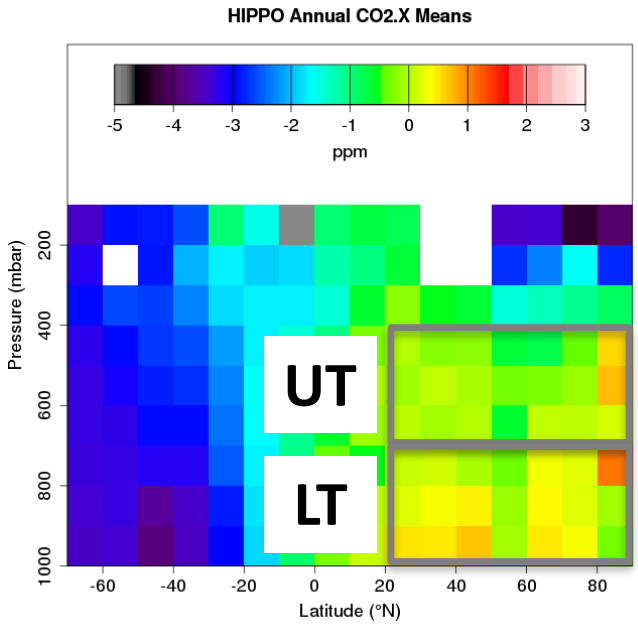
- Filter out continental BL, Airport, stratospheric air
- Detrended time series using Mauna-Loa trend component

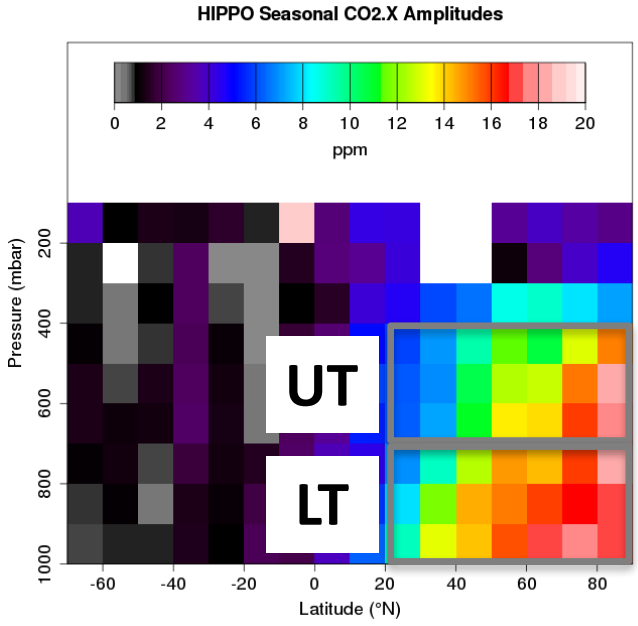




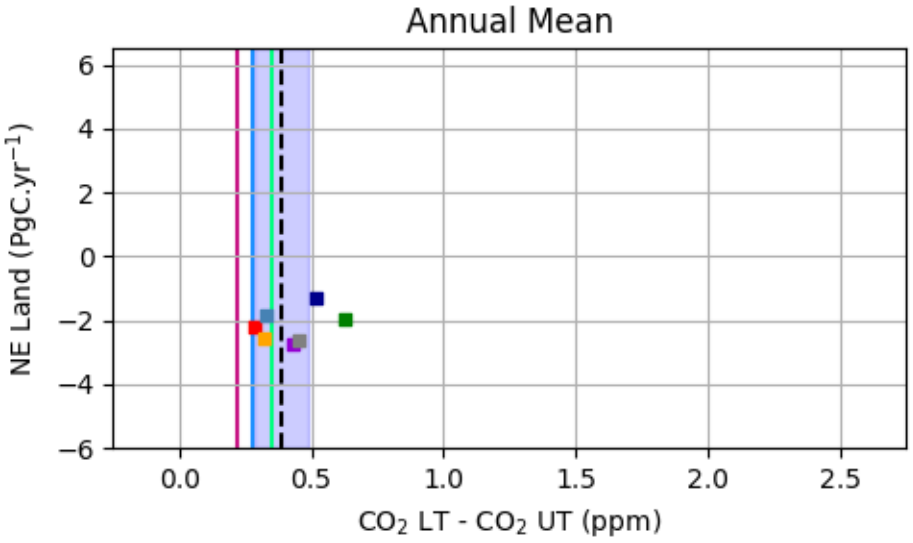
- Fit of the time series for each box (5 degrees latitude and 100 hPa), using 2 harmonics
- Focus on vertical gradients
  - Northern Extratropical Lower Troposphere (LT, surface 700hPa) and Upper Troposphere (UT, 700hPa to 300hPa)
- Weighting average using cos(latitude)
- Repeat for every model output using CO2.X mask

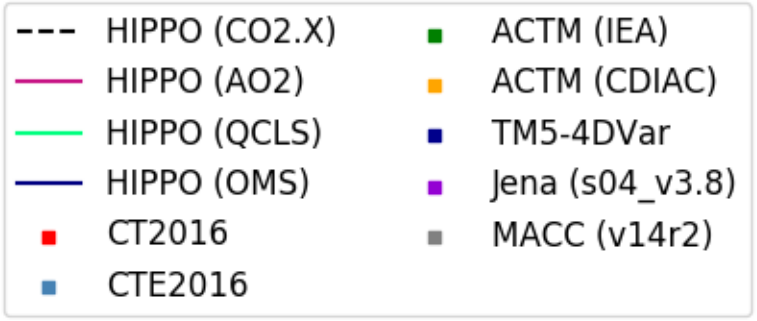






CO_2 modelled after flux optimisation is compared to HIPPO observations
NE Land flux versus NE vertical gradients





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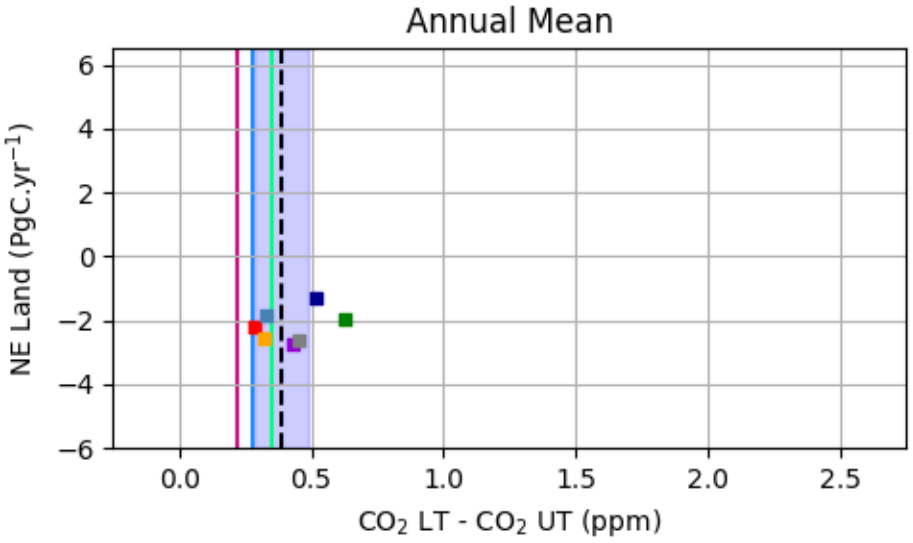

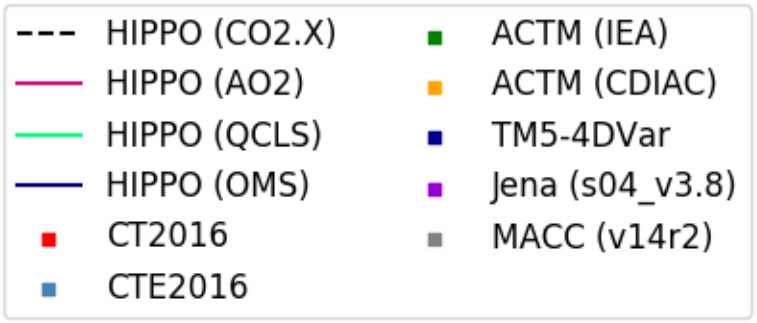

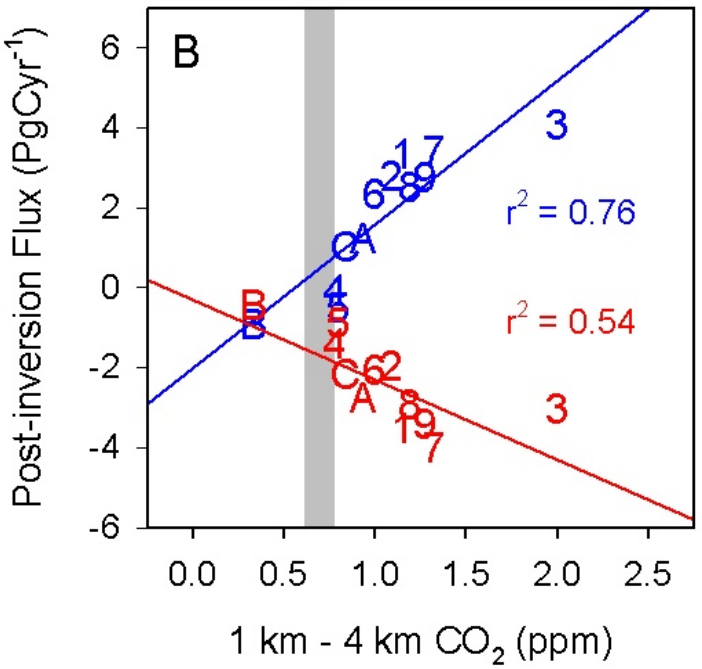

Stephens et al. 2007

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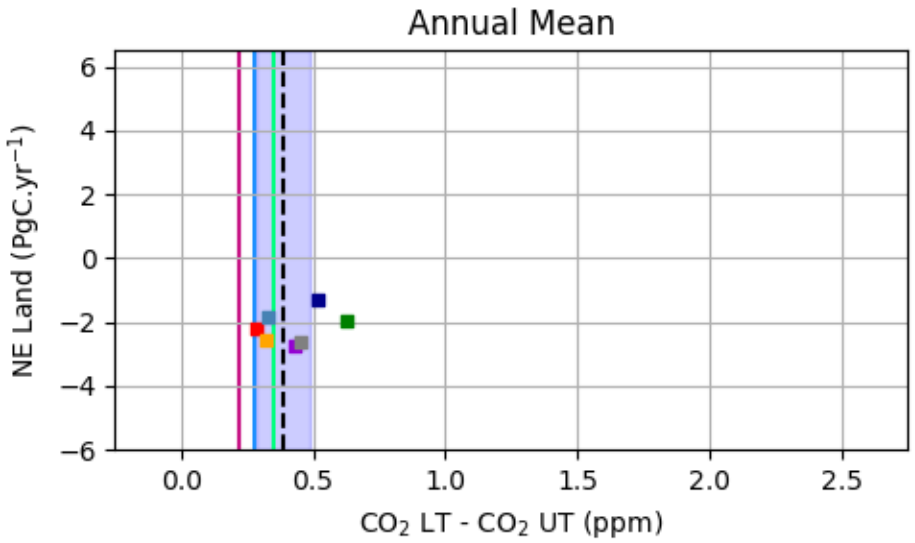

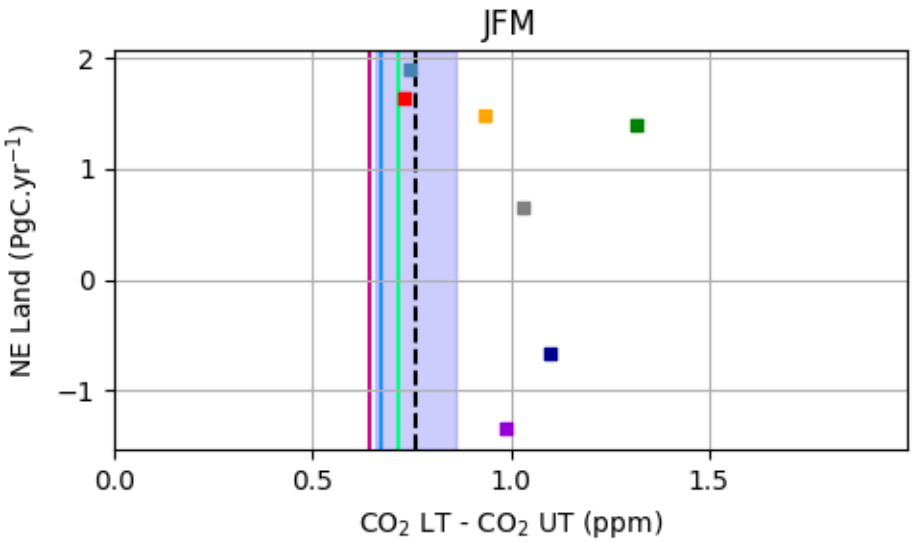

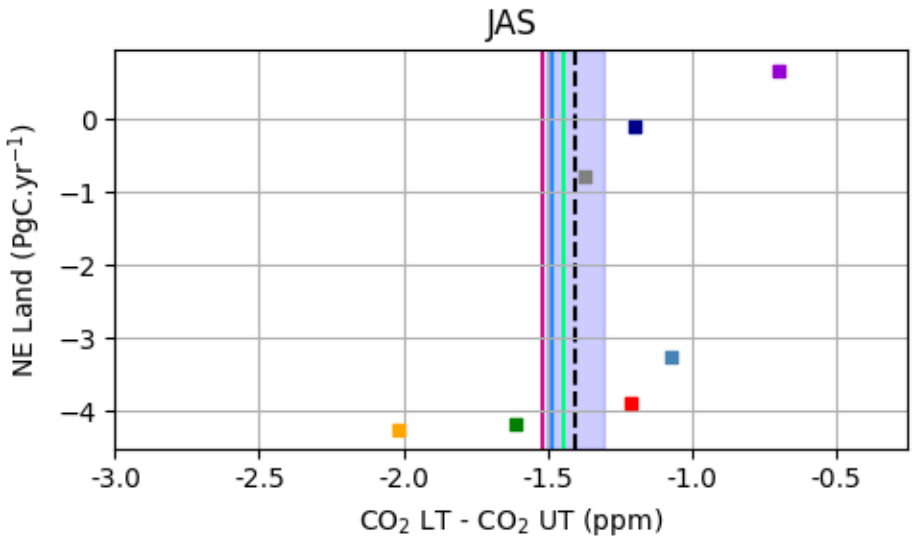

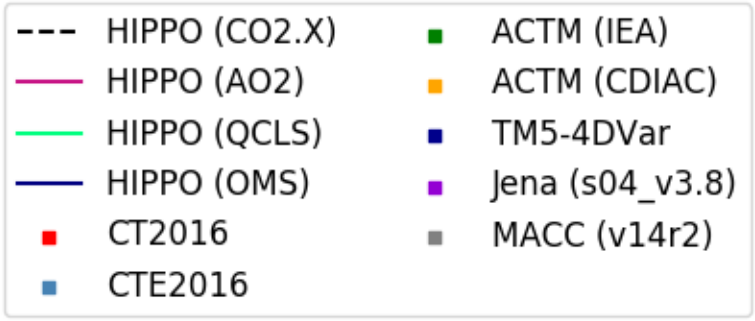

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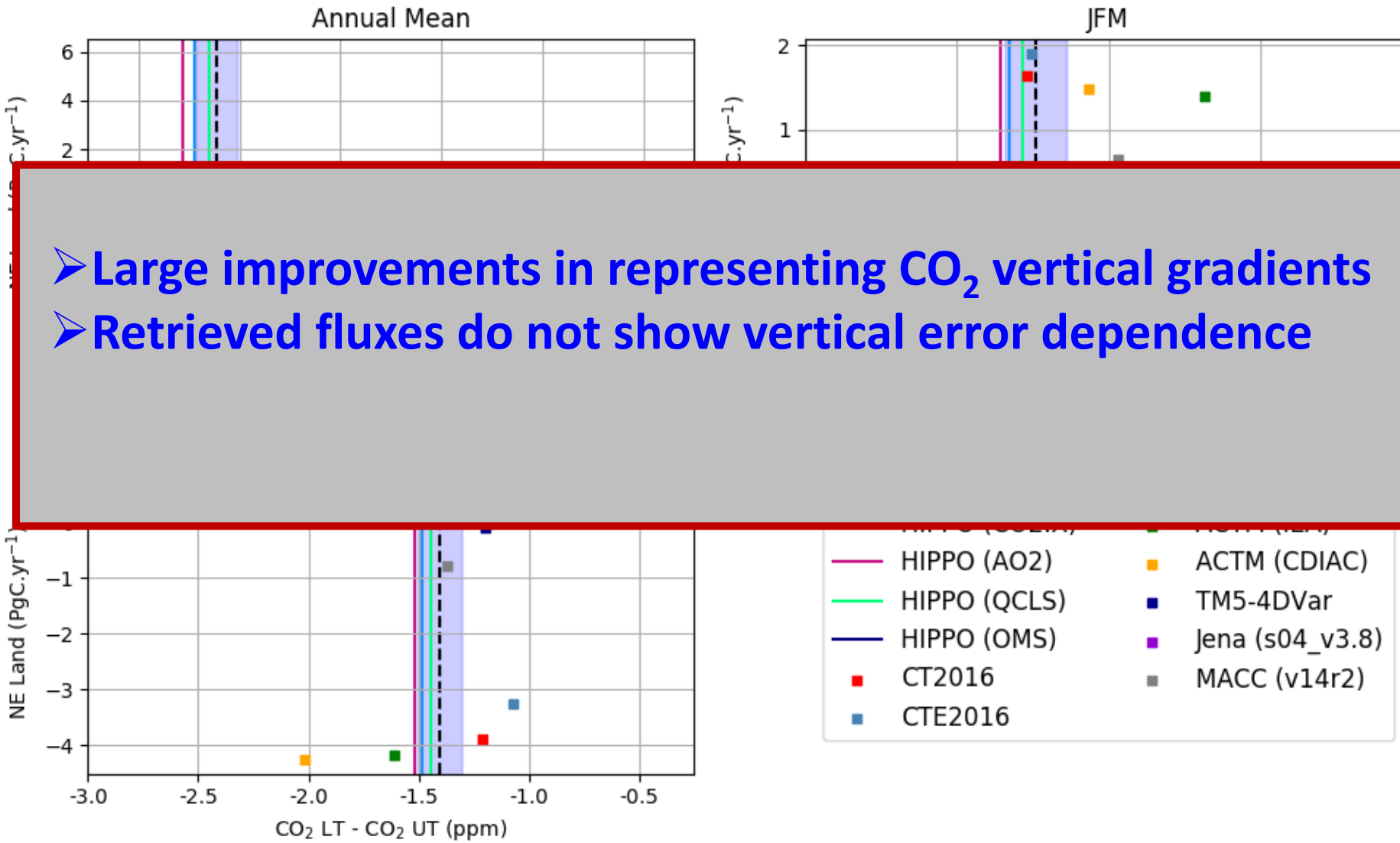
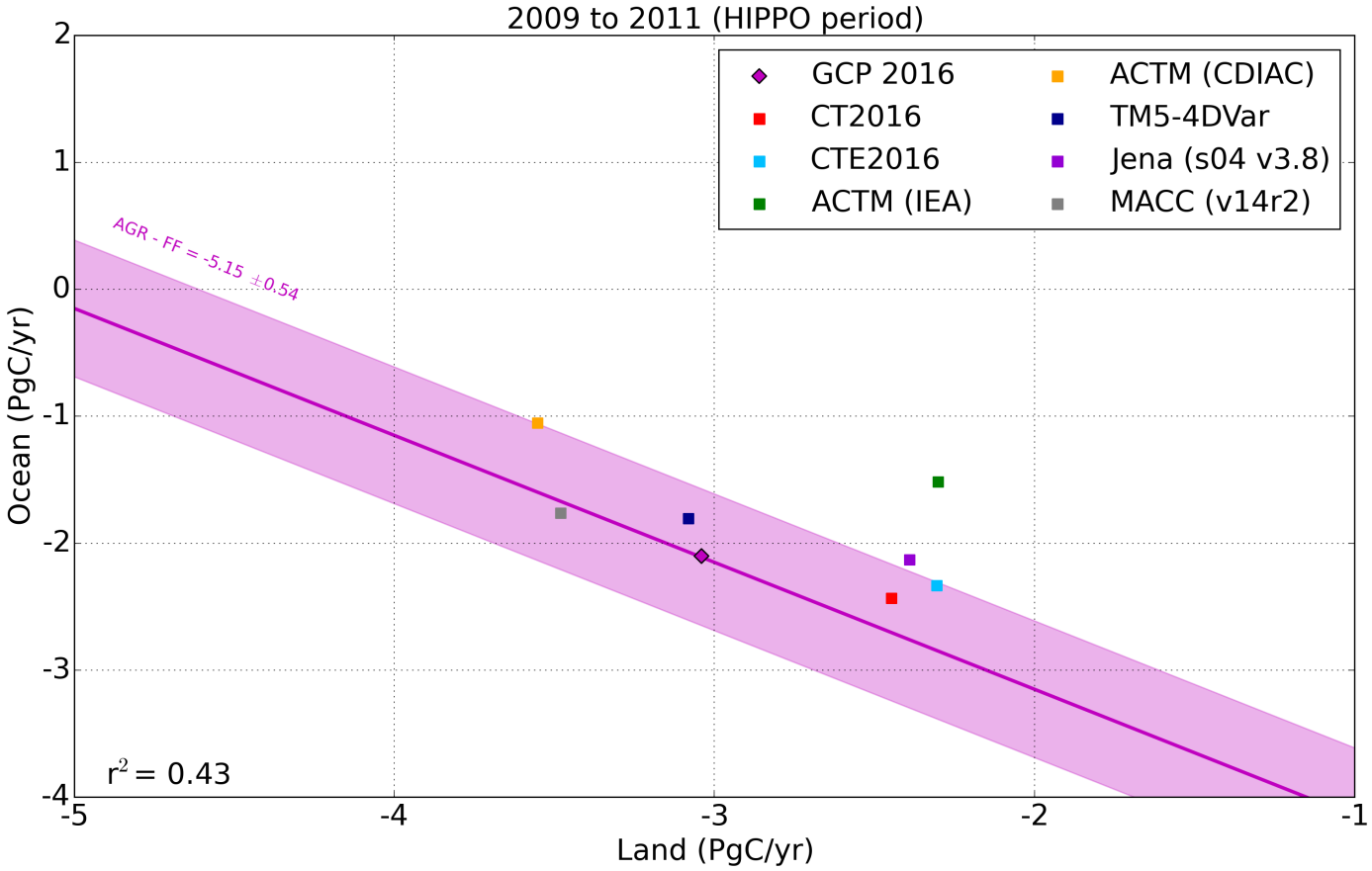


- Large improvements in representing CO_2 vertical gradients
- Retrieved fluxes do not show vertical error dependence

Posterior fluxes and Global Carbon Project



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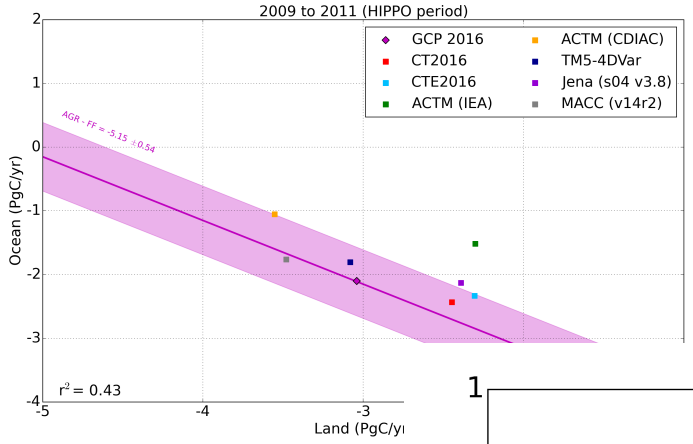
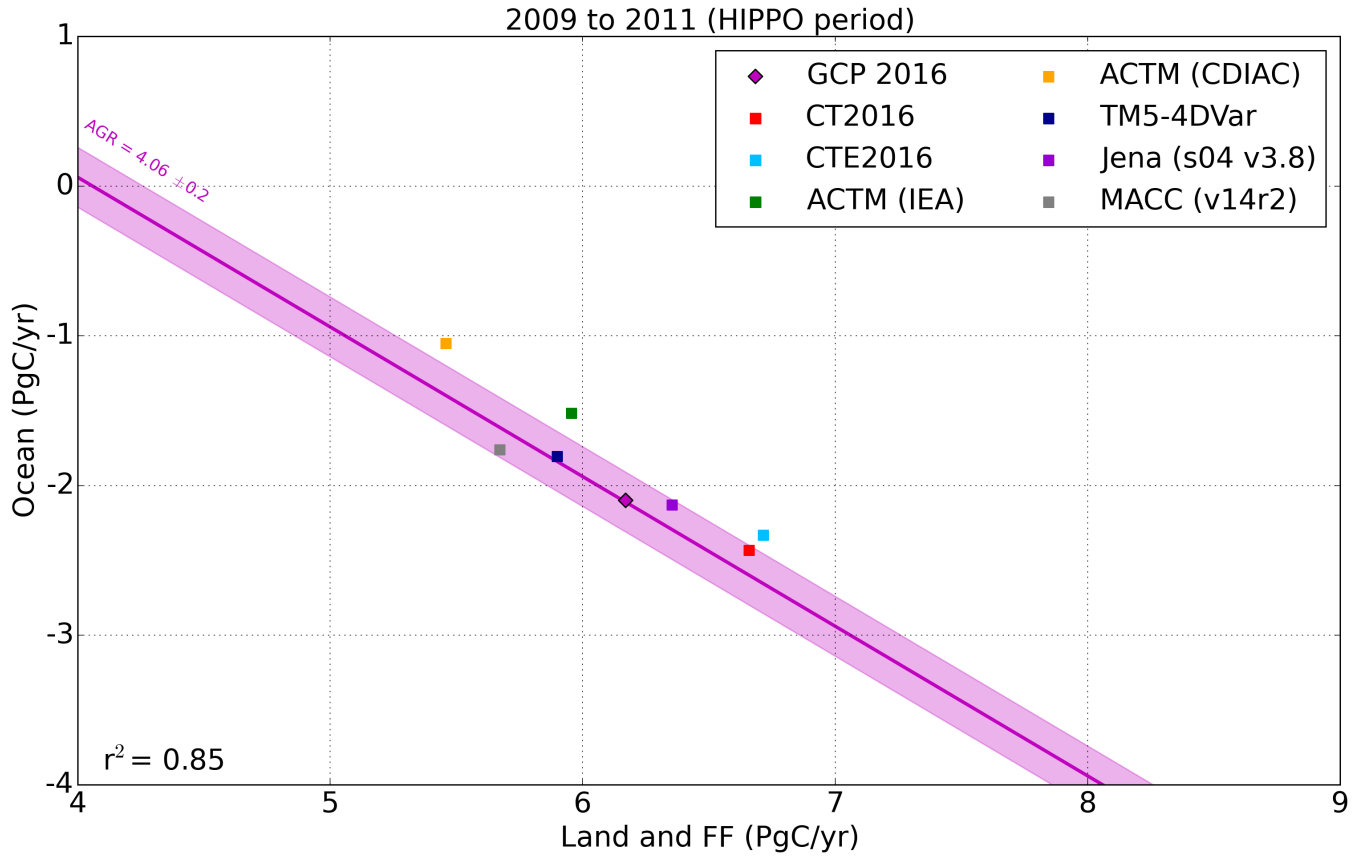
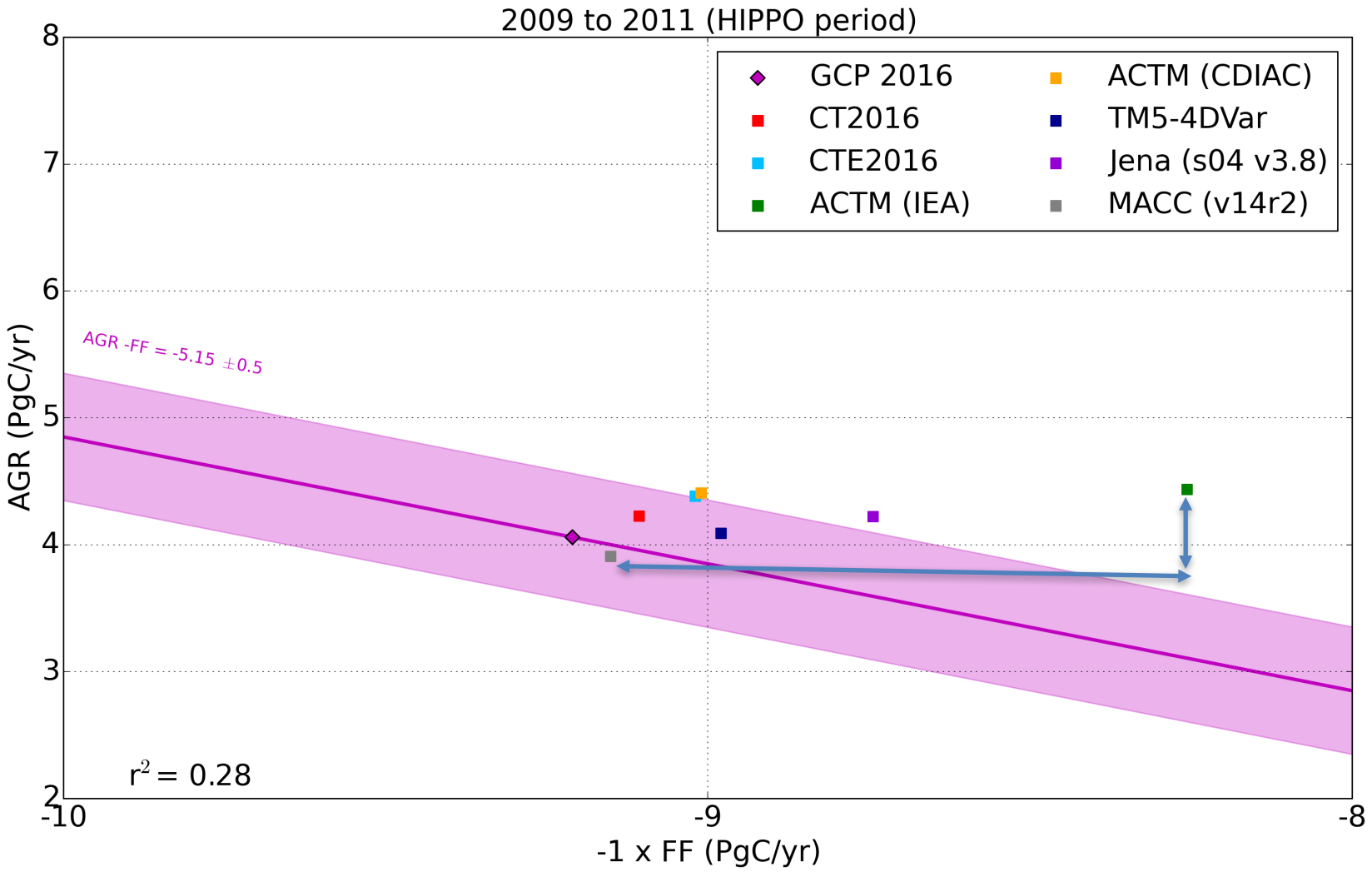


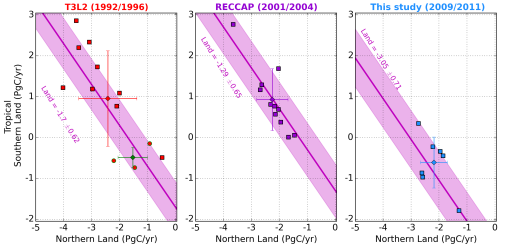


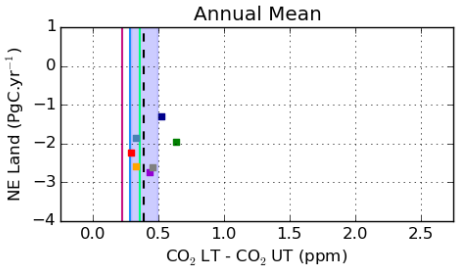
Posterior fluxes and Global Carbon Project

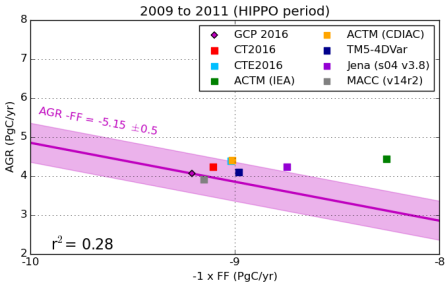


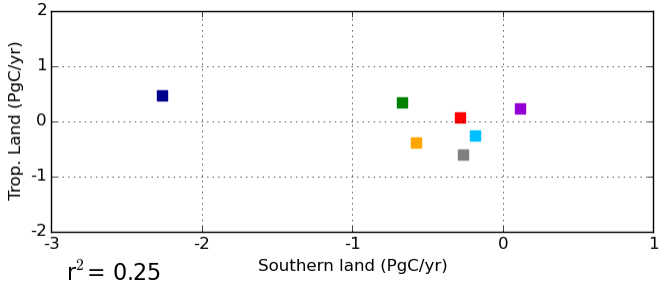
Conclusions

- Analysis of carbon fluxes estimated by a set of inverse models show good consistency, but spread remains in the spatial attribution of land sinks
- The transport errors are not clearly responsible for those fluxes differences
- Error in prior Fossil Fuel emissions is compensated by changes in other estimates such as AGR, or land sink [Saeki and Patra 2017]
- The spread in prior FF emissions is larger than GCP error and of similar magnitude to results spread
- As previously shown [Peylin et al., 2013], the results are sensitive to atmospheric network, so satellite observations from OCO2 may help









Thanks for your attention

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Observations

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