Estimating the natural fluxes of CO_2 and CH_4 in Amazonia based on the application of a mass balance approach to GeoCarb images

Sarvesh Kumar Singh, **Grégoire Broquet**, Luis Molina, Bo Zheng, Yilong Wang, Francois-Marie Bréon, Frédéric Chevallier, Philippe Ciais, Isabelle Pison, Diego Santaren, Pascal Prunet, Claude Camy-Peyret, Sean Crowell, and Berrien Moore

- Computation of mass balance between two GeoCarb XCO_2/XCH_4 images to get surface fluxes.

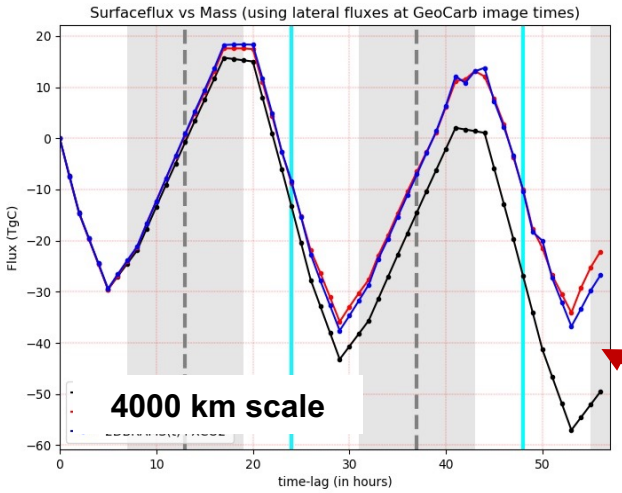
$$\int_{t_0}^{t} Surface\ flux = \mathrm{mass(t)} - \mathrm{mass(t_0)} - \int_{t_0}^{t} lateral\ flux$$

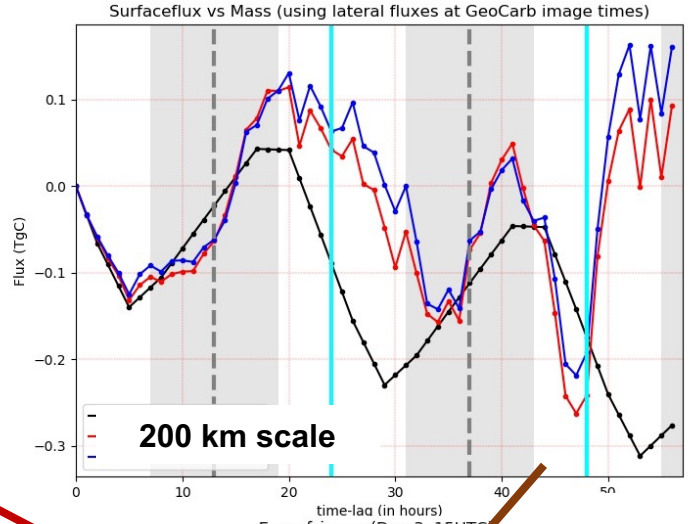
$$\int_{t_0}^{t} lateral\ flux \sim (t - t_0) * \frac{1}{2}(lateral\ flux(t) + lateral\ flux(t_0))$$

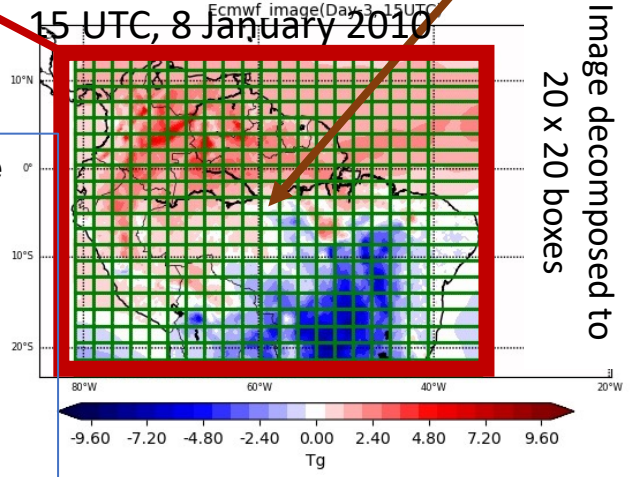
- Applications to whole GeoCarb scan over Amazonia and smaller regions.
- Extraction of targeted flux by removing other flux estimates from inventories/models.
- Analysis with a wind field (BRAMS) that is different from the one (ECMWF) used to generate the XCO_2 / XCH_4 image.
- Daily XCO_2 images allow to estimate 24-h mean CO_2 NEE within 40% uncertainty at scales down to 200 km.

Estimates of the CO_2 NEE based on couples of XCO_2 images as a function of time lag t-t_0 (t_0 = 15 h UTC, 8Jan 2010)

True NEE
Perfect knowledge of 3D wind
Imperfect knowledge of wind





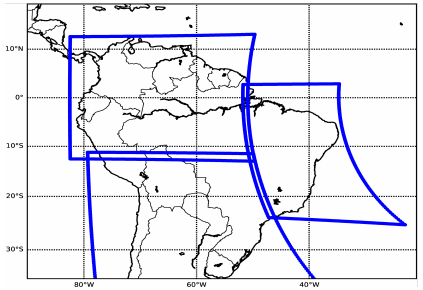


Simulation of a GeoCarb XCO_2 image (ignoring cloud cover) using:

- CHIMERE CTM (35 km res)
- ECMWF meteo
- flux = ORCHIDEE (NEE) + EDGARv4 (FFemis) + GFEDv3 (Biomass burning)+ Takahashi et al. 2009 (air-sea exchange)
- adding observation noise

Motivation

- GeoCarb XCO_2/XCH_4 images could support a critical improvement of the estimates of the natural fluxes in Amazonia.
  - GeoCarb provides basin wide images over Amazonia at a spatial resolution of 20-30 km^2 one to several times during the day (cloud cover ignored here)
  - At Nadir: Lattitude resolution – 3 km; Longitude resolution – 6 km
  - Typical errors on the retrievals - 1.2 ppm for XCO_2 and 18ppb for XCH_4

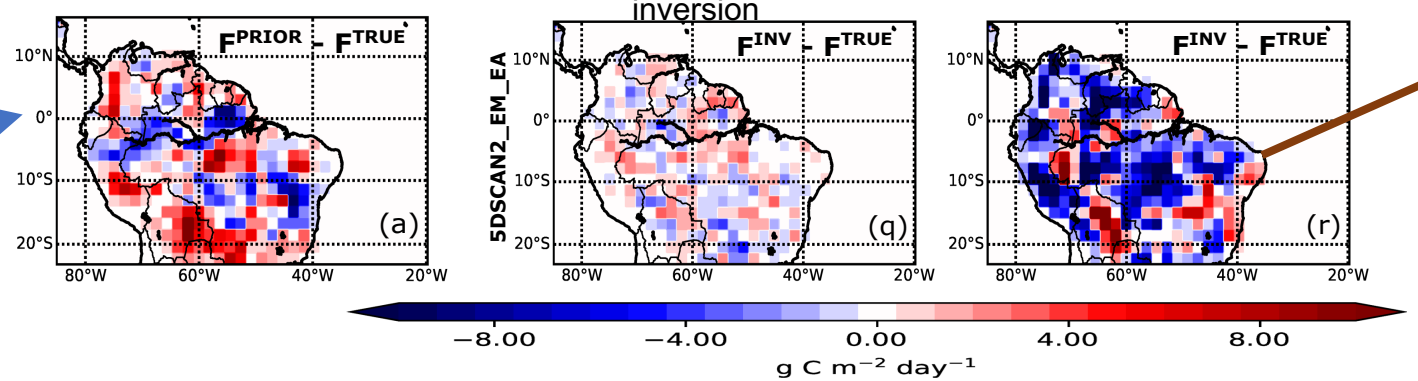


- Weakness of traditional variational inversion : high sensitivity to the transport model errors (illustrated with OSSE's).
  - CO_2 modeling and CO_2 NEE inversions with CHIMERE transport model at 35 km spatial resolution and two meteorological forcing – ECMWF and BRAMS during wet season (6-10 January 2010).

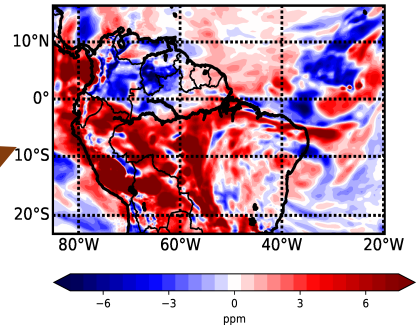
Comparing errors on 24hr budgets of NEE (for 1st day) in 5 days inversion OSSE's using GeoCarb observations(2 scans per day at 13hr and 19hr UTC).

When transport errors summarized as noise whose STD is perfectly known by inversion

When transport errors are characterized by use of BRAMS to generate obs and ECMWF to conduct inversions



Differences between CHIMERE-ECMWF and CHIMERE-BRAMS



- Exploiting the full coverage of XCO_2/XCH_4 field by GeoCarb (when no cloud cover) to apply mass balance approach. $\int_{t_0}^{t} Surface\ flux = \mathrm{mass(t)} - \mathrm{mass(t_0)} - \int_{t_0}^{t} lateral\ flux$

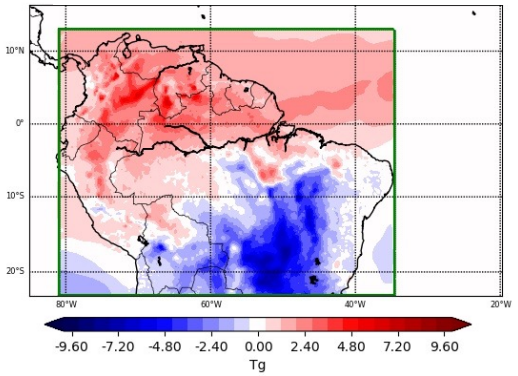
  where $\int_{t_0}^{t} lateral\ flux \sim (t-t_0)*\frac{1}{2}(lateral\ flux(t) + lateral\ flux(t_0))$

  - Extraction of targeted flux by removing other flux estimates from inventories/models.

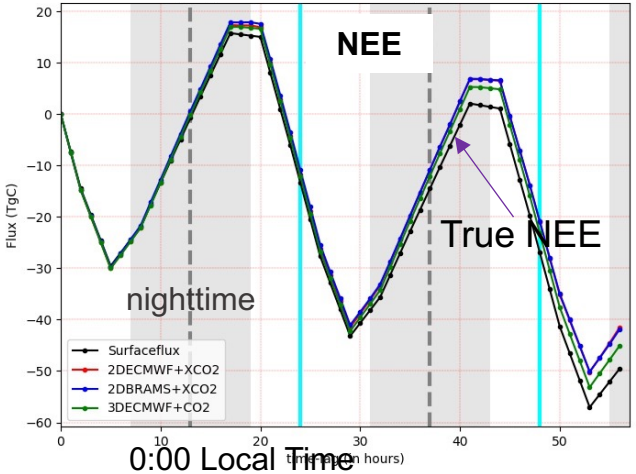
Estimation of CO_2 NEE from XCO_2 psuedo-images at 4000 km scale

Simulation of a GeoCarb XCO_2 image using CHIMERE model with ECMWF meteo and flux = ORCHIDEE (NEE) + EDGARv4 (FFemis)+GFEDv3 (Biomass Burning)+ Takahashi et al. 2009 (air-sea exchange) adding observation noise

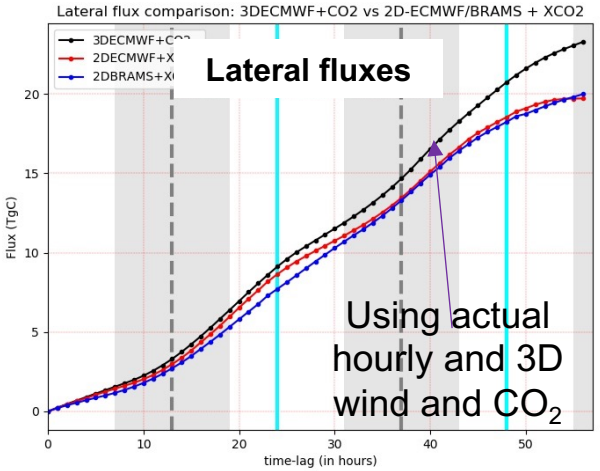
t_0=15 UTC, 8 Jan 2010



Theoretical flux estimate as a function of t-t_0 assuming hourly fields are available between t_0 and t



0:00 Local Time



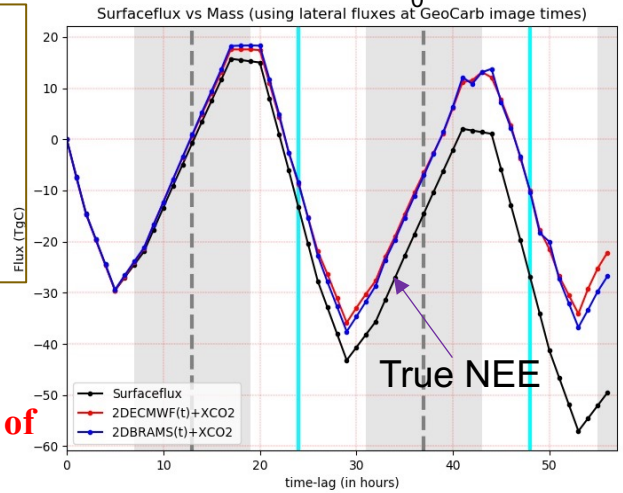
NEE estimates based on Mass Balance over the whole simulation domain
FF, BB and ocean fluxes are supposed to be perfectly known

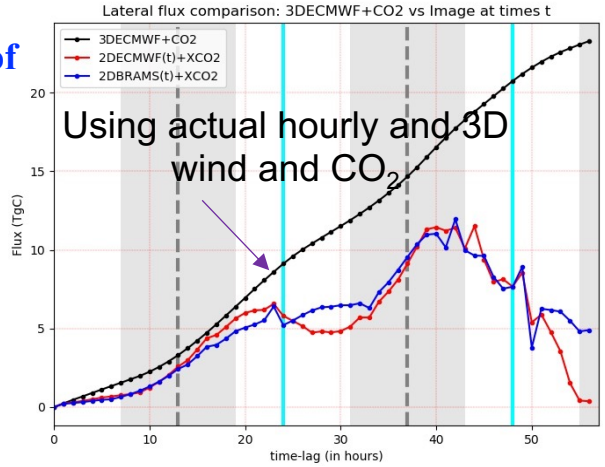
MB with 3D fields of CO_2 and wind

MB with 2D field of CO_2 and 3D field of ECMWF wind (need for vertical integration of wind)

MB with 2D field of CO_2 and 3D field of BRAMS wind (need for vertical integration)

Estimate as a function of t-t_0 based on data at times t_0 and t



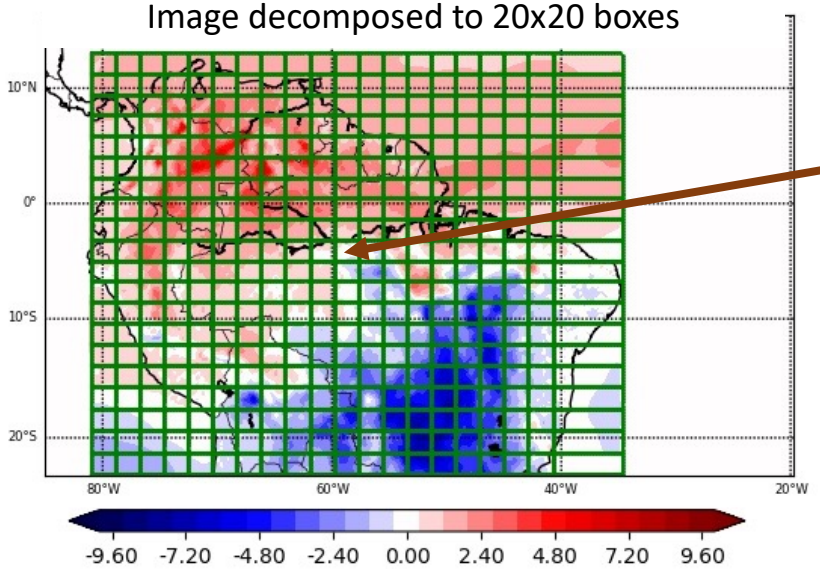


- Deviation to true fluxes is mainly due to approximation in lateral fluxes.
- 24 hr NEE can be estimated with 20% uncertainty when using daily images.

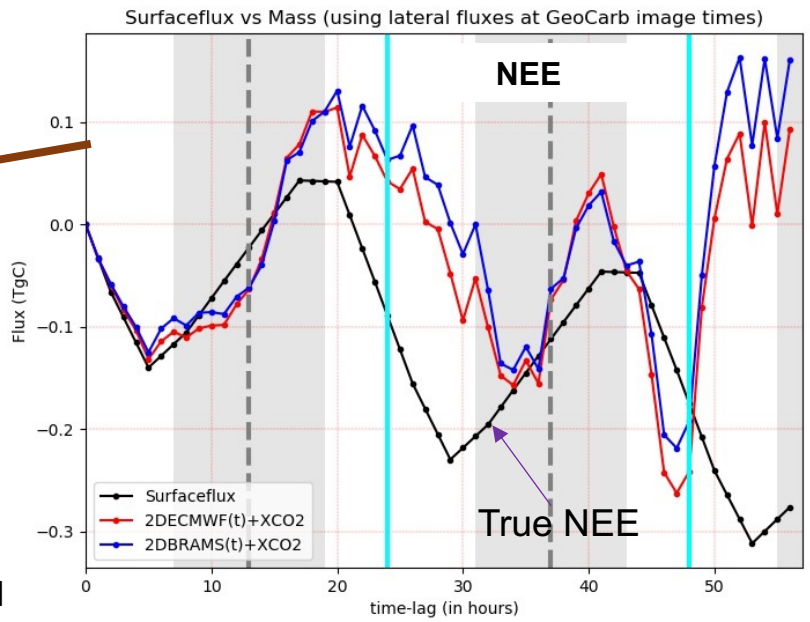
Estimation of CO_2 NEE from XCO_2 psuedo-images at 200 km scale

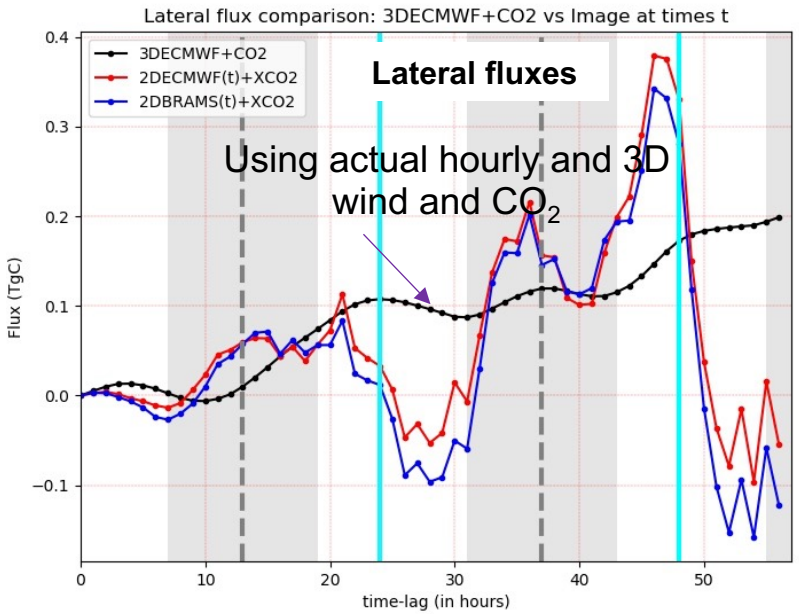
t_0 = 15 UTC, 8 January 2010

Image decomposed to 20x20 boxes

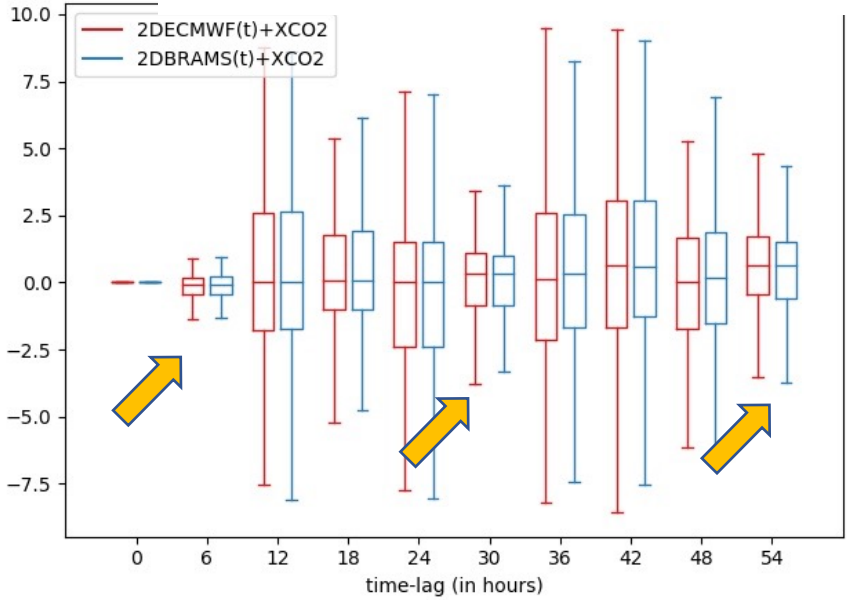


Estimate as a function of t-t_0 based on data at times t_0 and t





Normalized error for all the boxes on land

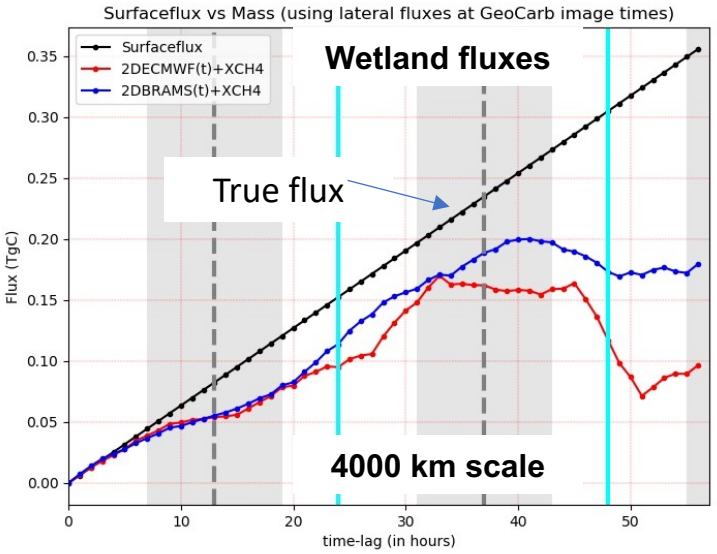


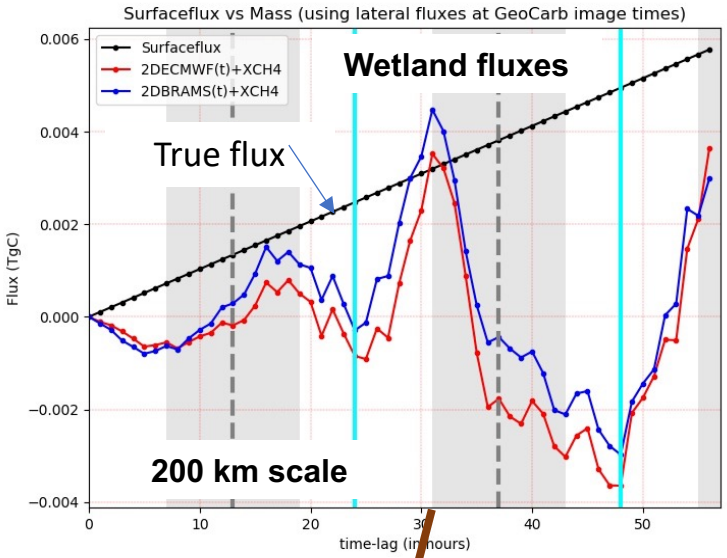
- Uncertainties increases with increasing spatial resolution.
- Deviations in lateral fluxes grows during daytime.
- 24 hr NEE can be estimated with 50% uncertainty when using daily images.

Estimation of CH_4 natural fluxes from XCH_4 psuedo-images

- At 4000 km scale, 24-30 hr fluxes can be estimated with 40% uncertainty when using daily images.
- At 200 km scale, two GeoCarb images at an interval of max. 30 hr can help to estimate natural fluxes within 50% errors to the truth.

Estimate as a function of $t-t_0$ based on data at times t_0 and t

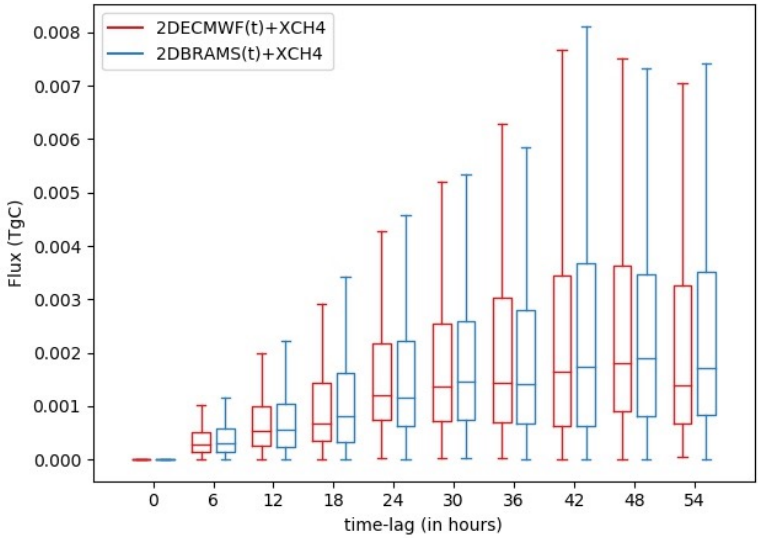




MB with 2D field of CH_4 and 3D field of ECMWF wind (need for vertical integration of wind)

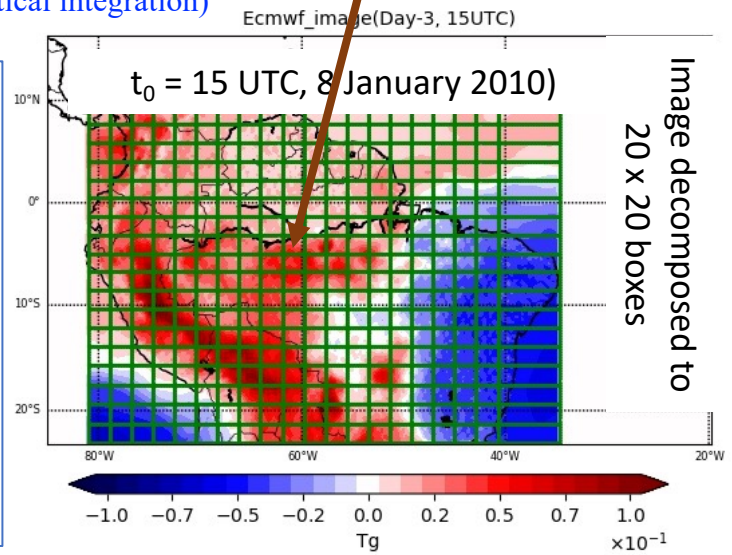
MB with 2D field of CH_4 and 3D field of BRAMS wind (need for vertical integration)

Absolute errors for all the boxes on land



Simulation of a GeoCarb XCH_4 image (ignoring cloud cover) using:

- CHIMERE CTM (35 km res)
- ECMWF meteo
- flux = + EDGARv5 (FFemis) + GFEDv4 (Biomass burning)+WETLAND (Kaplan)
- adding observation noise



Conclusions and perspectives

- Application of Mass balance approach to GeoCarb images is promising for the estimate of natural fluxes.

- Estimate of CO_2 NEE during dry season will be successful as long as the CO_2 anthropogenic and biomass burning fluxes are well known: need to derive these fluxes by exploiting results at high resolution and spatial correlations in NEE?.

- Approximation of lateral fluxes becomes challenging for large (> 24 hours) time lags between two GeoCarb scans and at higher spatial resolution (at scales < 300 km).

- Need to address the impact of cloud cover for the mass balance approach: spatial and temporal extrapolation of results obtained at relatively high resolution in cloud free areas of the scans.

- Uncertainties in the wind field can have a large impact, especially when lateral fluxes are large