Terrestrial observation requirements for reanalysis of the carbon cycle

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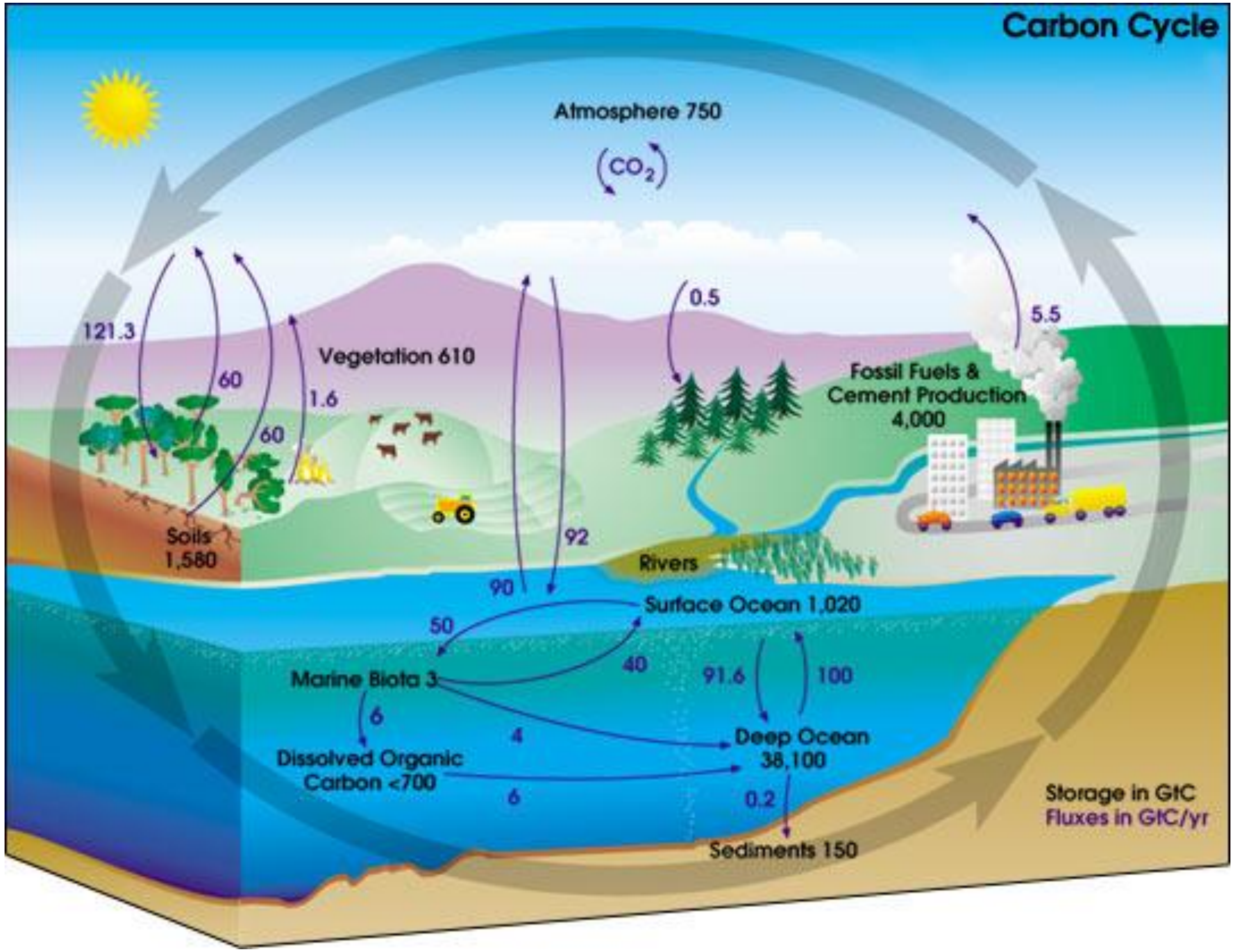
Acknowledgements: Gianpaolo Balsamo, Anna Agusti-Panareda, Frederic Chevallier, Philippe Peylin, Sebastien Massart

What does “reanalysis of the carbon cycle” mean?



Enormous reservoirs exchange CO_2 in large amounts with an almost net result on an annual basis.

Anthropogenic emissions are the main *one-way* flow of CO_2 and therefore increase the amount of CO_2 in the atmosphere.

Better understanding of terrestrial carbon cycle is crucial for understanding of impact of anthropogenic emissions on atmospheric CO_2 burden.

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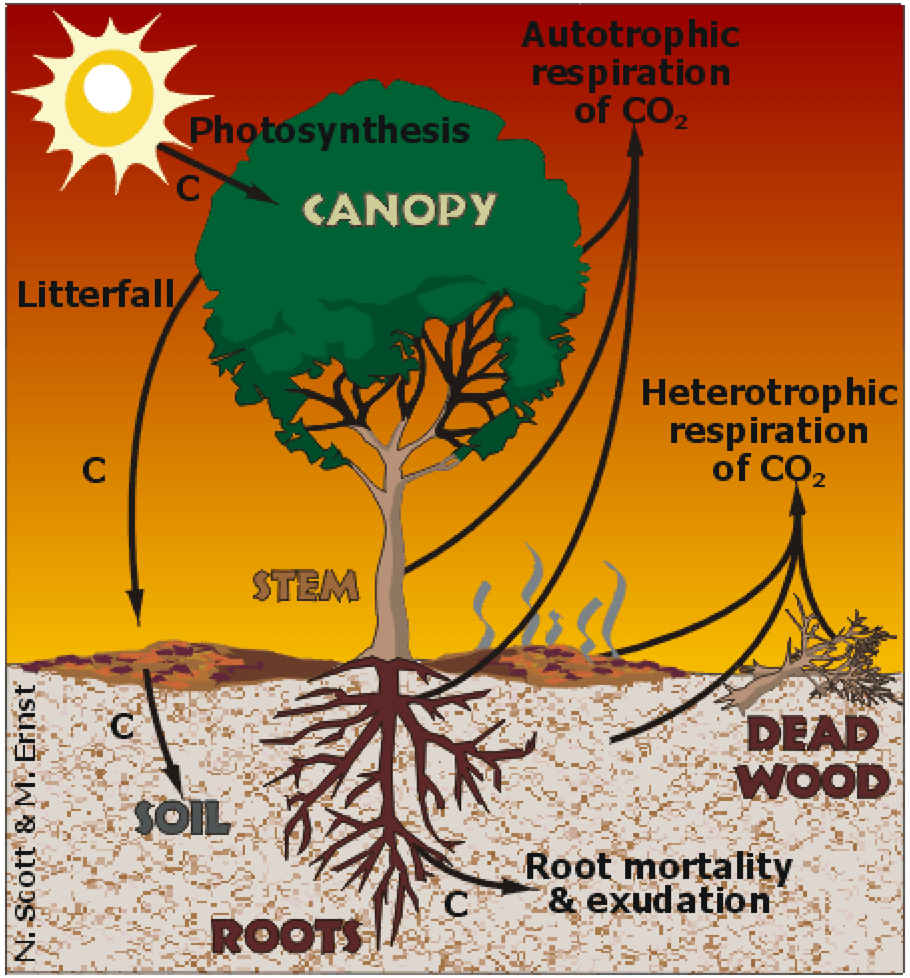


Terrestrial carbon cycle

Exchange between reservoirs at very different time scales:

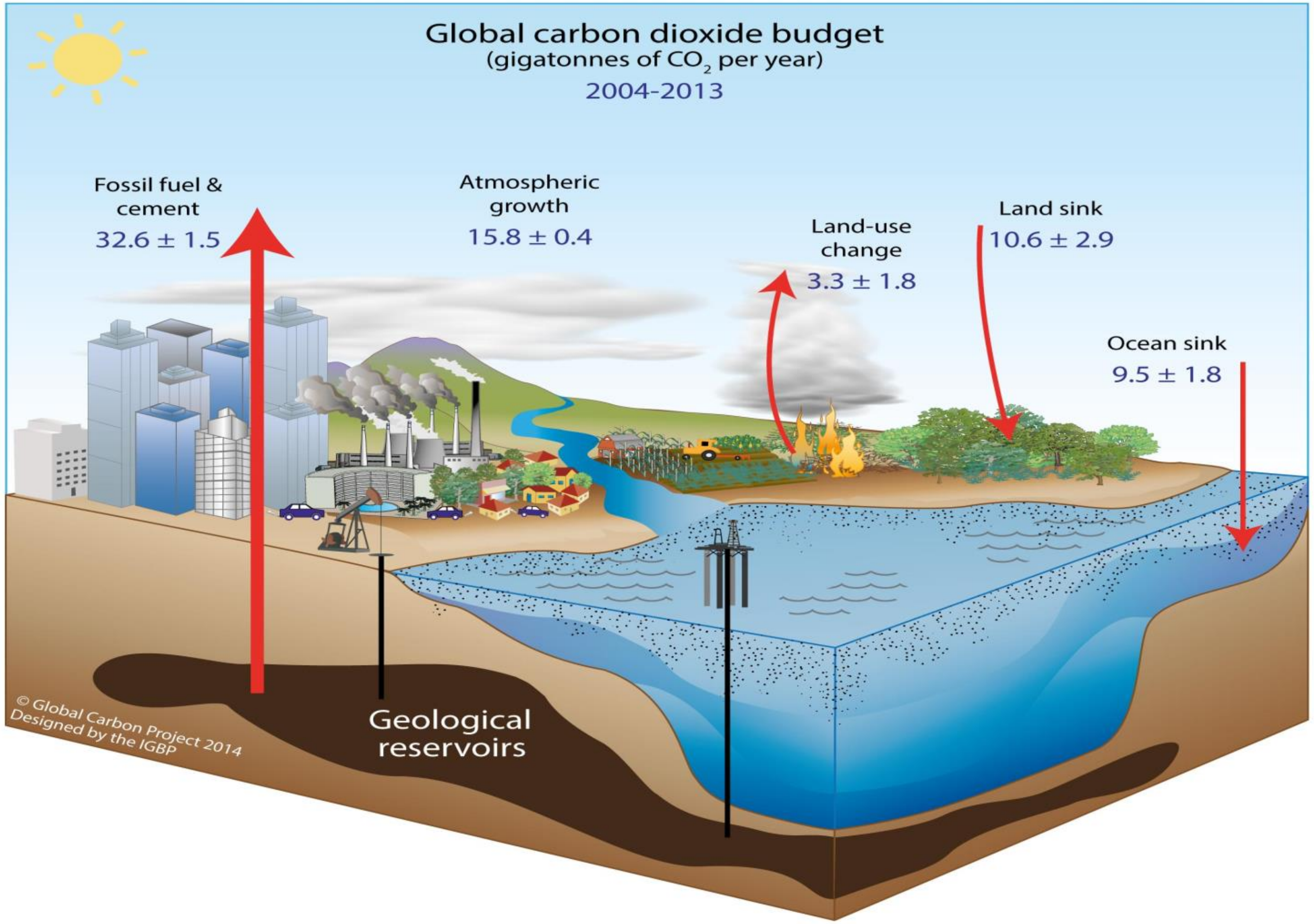
fast

- Living plant: Photosynthesis and autotrophic respiration
- Surface litter: heterotrophic respiration
- Soil: carbon reservoirs

slow

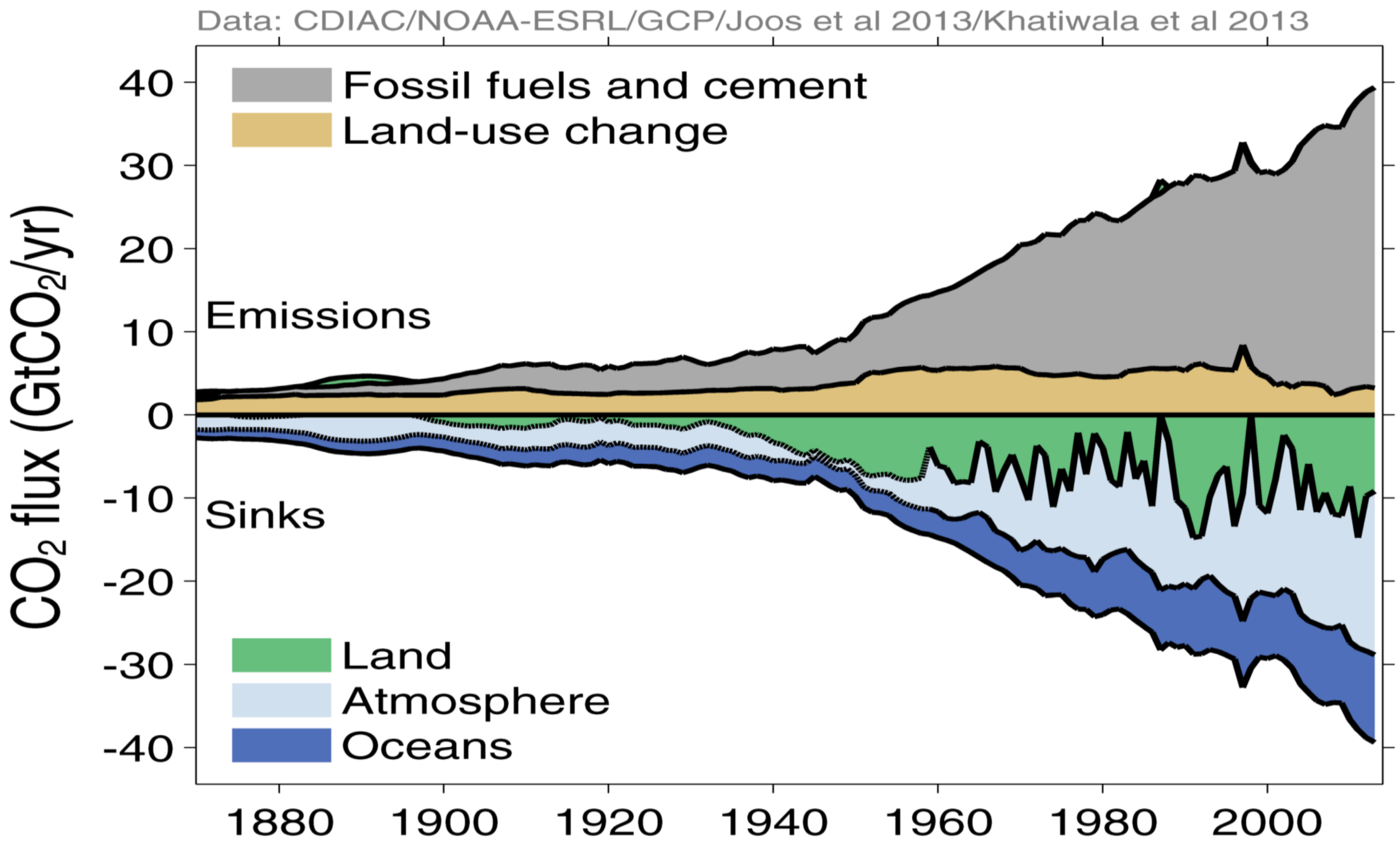
Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2004–2013 ($GtCO_2$/yr)

Data: CDIAC/NOAA-ESRL/GCP



Source: CDIAC; NOAA-ESRL; Le Quéré et al 2014; Global Carbon Budget 2014

Emissions are partitioned between the atmosphere, land, and ocean



If we want to accurately monitor the impact of anthropogenic emissions, we need to accurately monitor the natural biosphere!

Source: CDIAC; NOAA-ESRL; Houghton et al 2012 Giglio et al 2013; Joos et al 2013 Khatiwala et al 2013
Le Quéré et al 2014; Global Carbon Budget 2014

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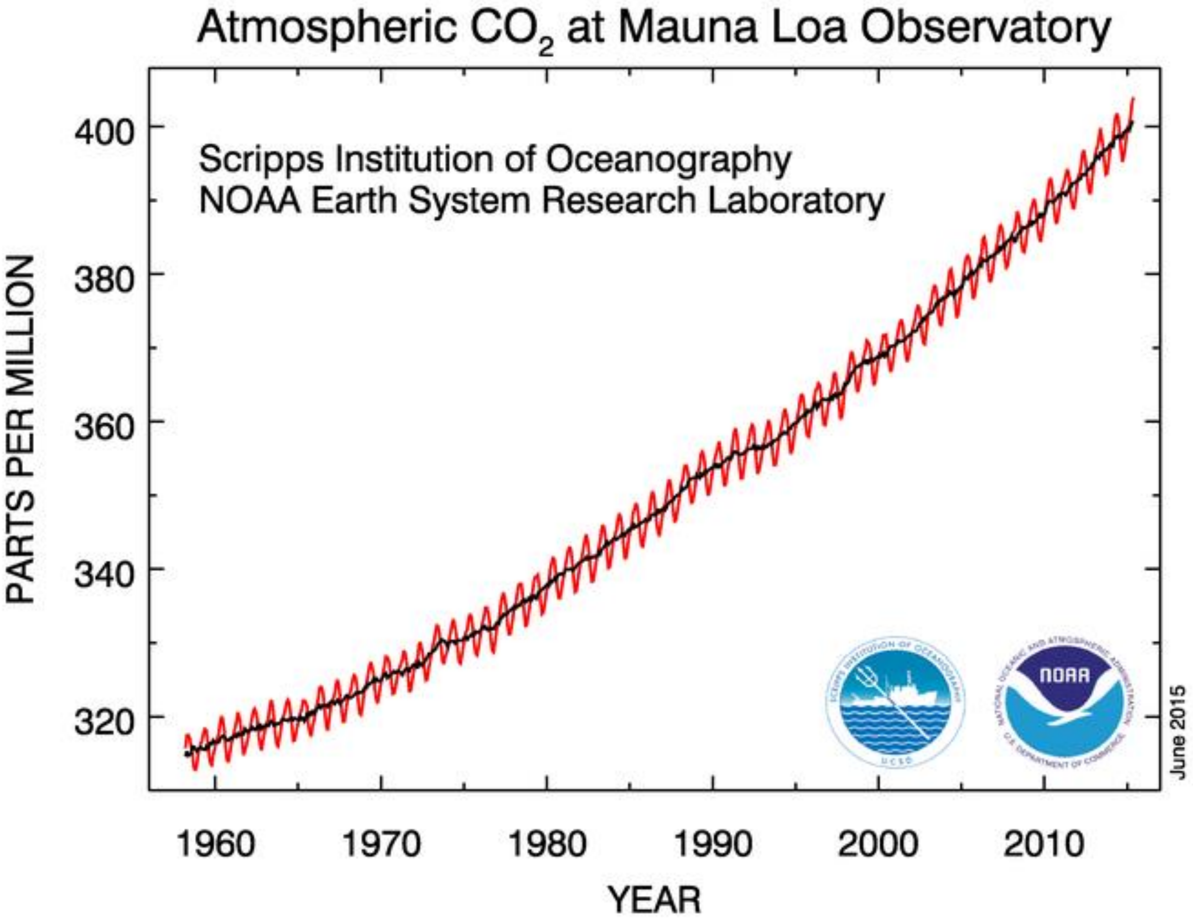
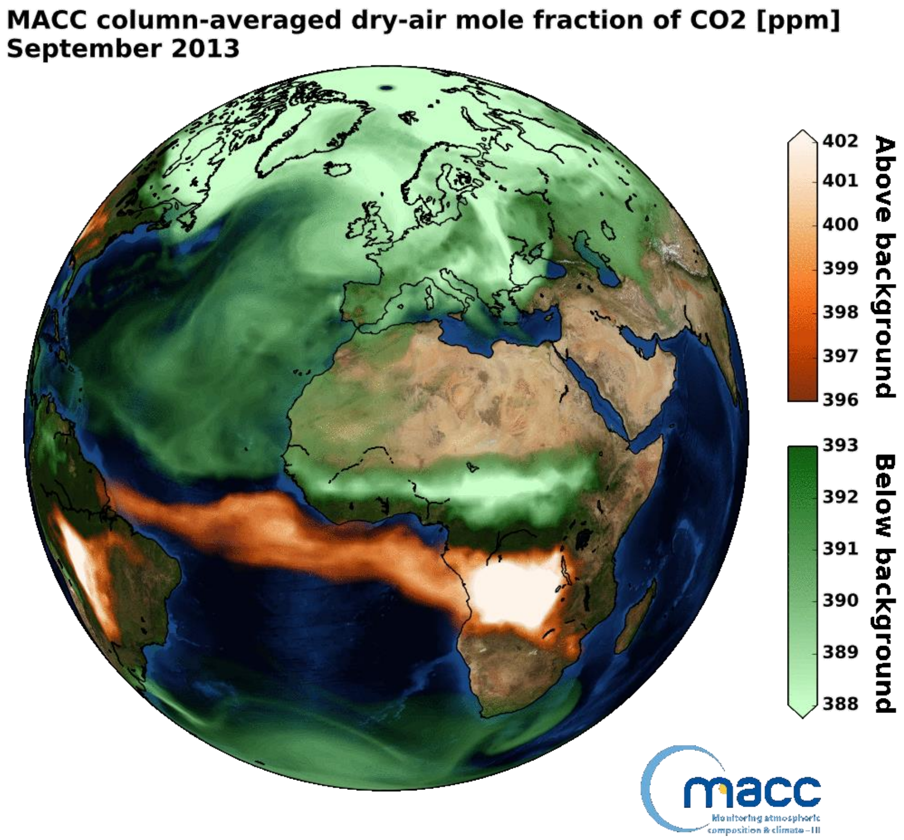


Ed Dlugokencky and Pieter Tans, NOAA/ESRL
(www.esrl.noaa.gov/gmd/ccgg/trends/)

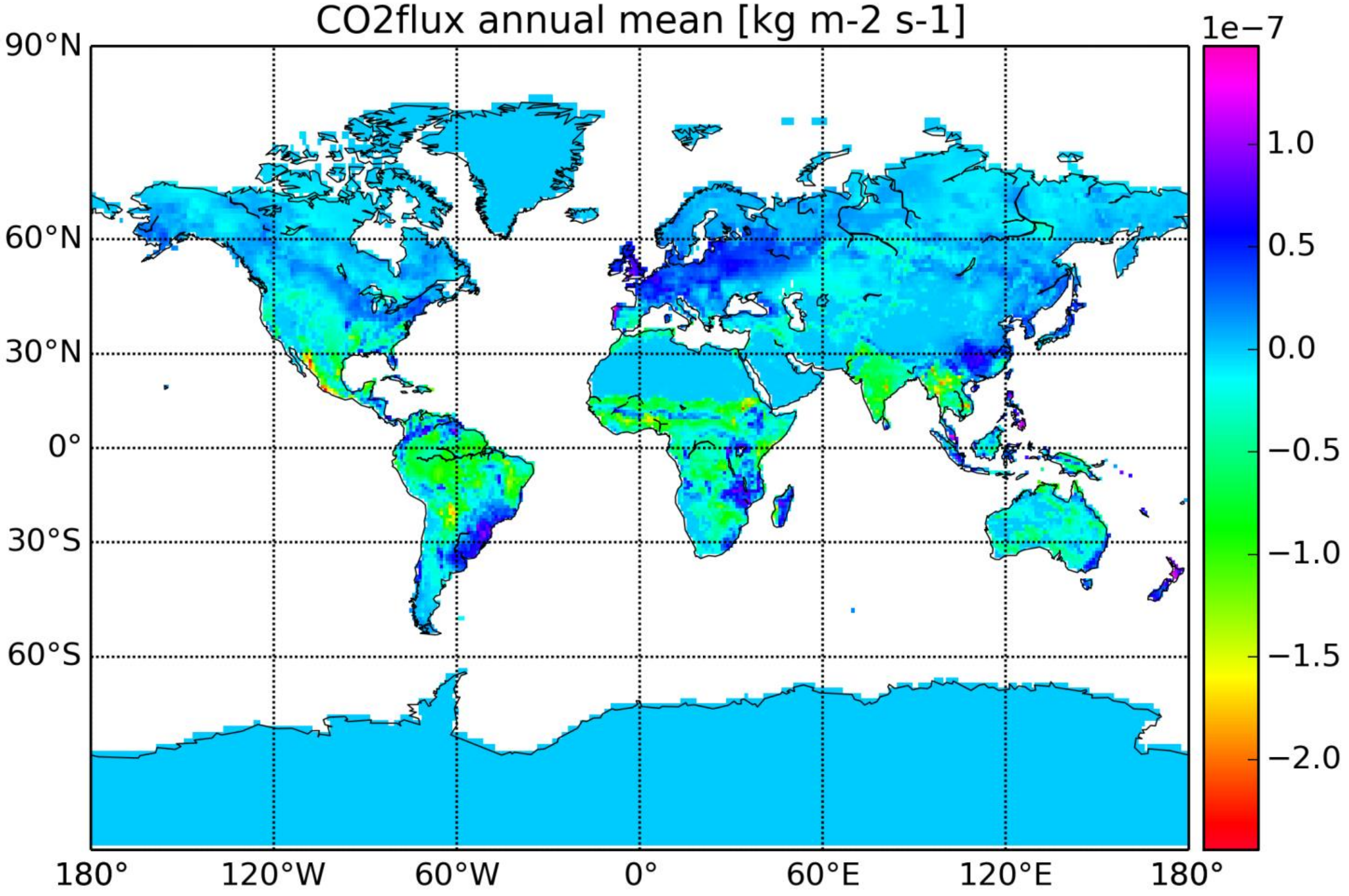


Anna Agusti-Panareda, Sebastien Massart,
Miha Razinger, ECMWF

What does “reanalysis of the carbon cycle” mean?

- **Observation time series**
  - Very accurate, but with large gaps
- **Flux inversions**
  - No gaps
  - Directly depends on availability and accuracy of observations
  - No predictive capability
- **Flux models**
  - No gaps and predictive capability
  - Need to be tuned with observations
- **Carbon Cycle Data Assimilation Systems (CCDAS)**
  - No gaps and predictive capability
  - Sometimes suffers from ambiguity

Flux modelling

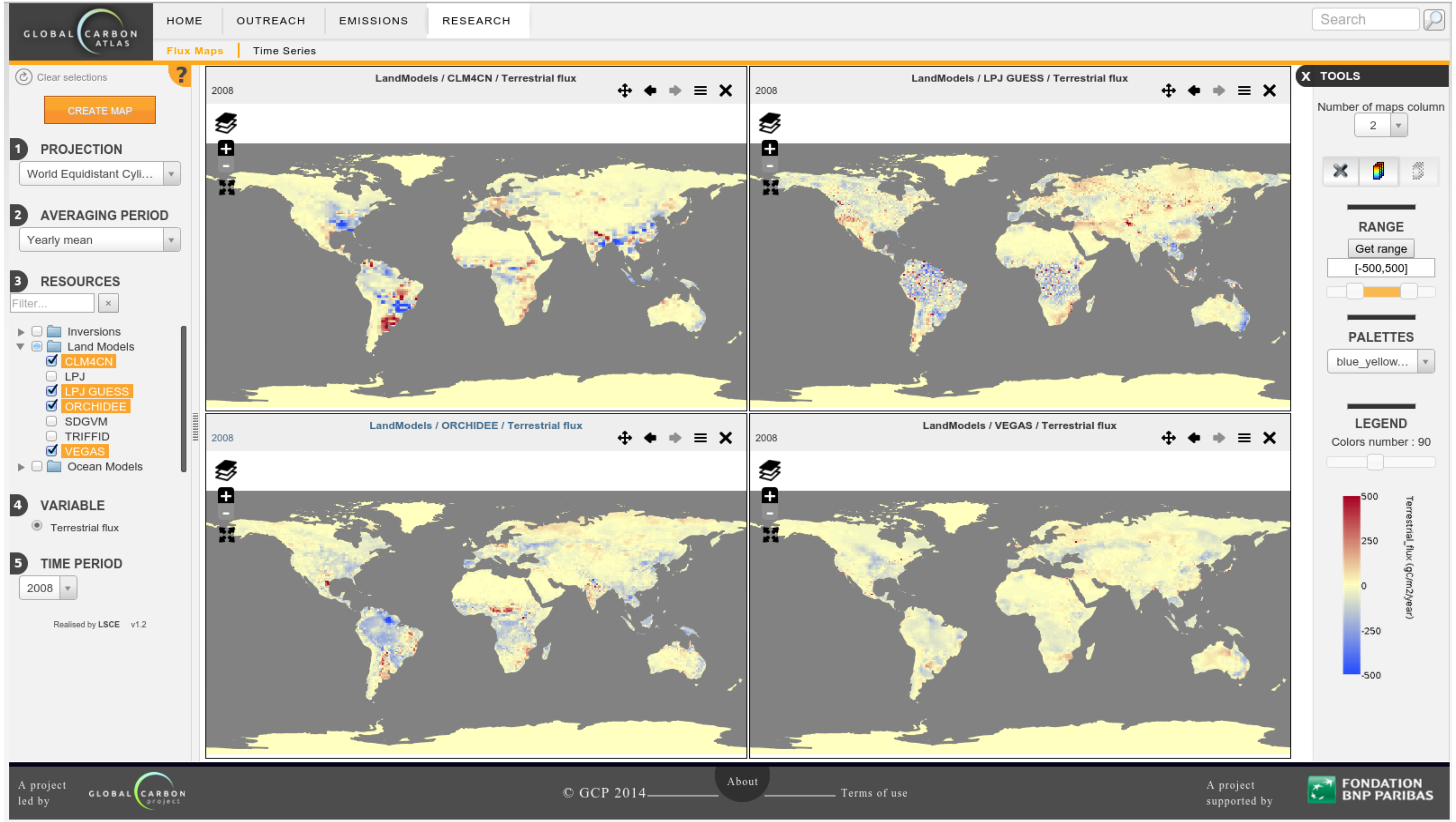


As part of ERA-CLIM2 simulations with CHTESSEL and ORCHIDEE have been performed.

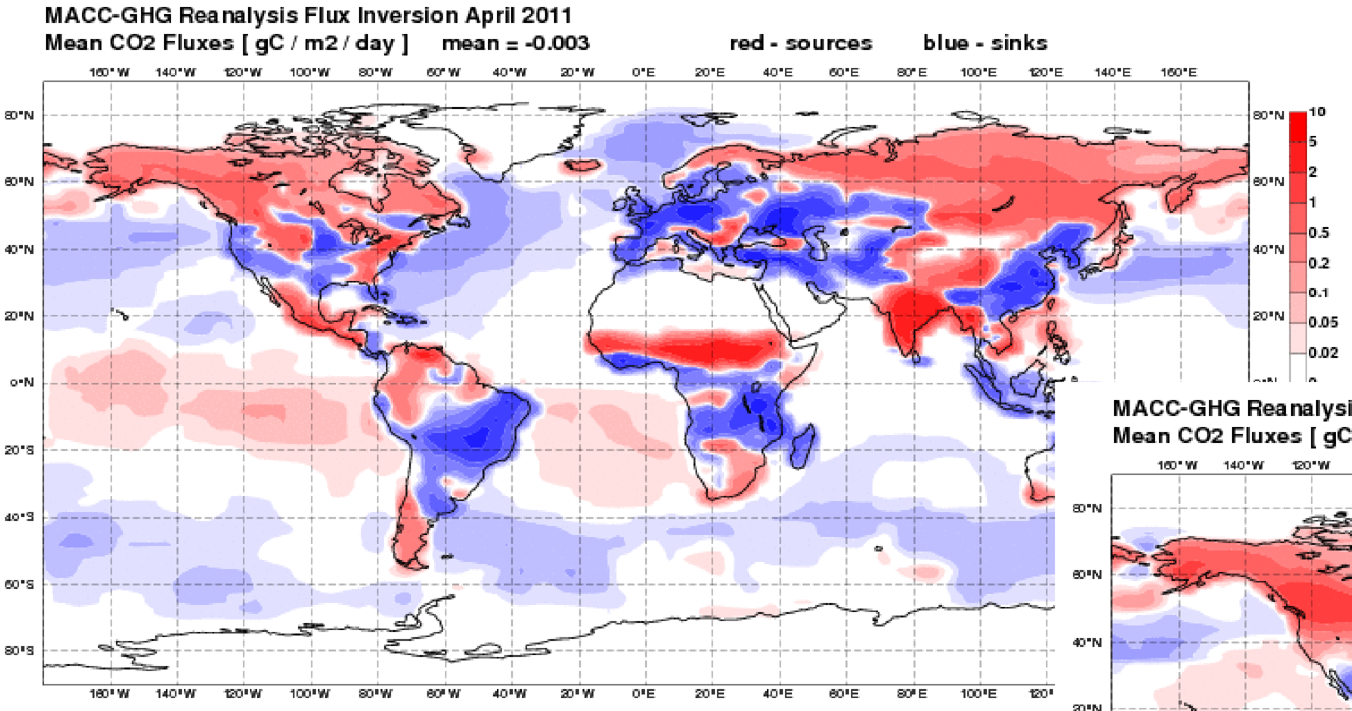
Significant differences can be seen due to the different complexities of the models.

Verification with observations is crucial.

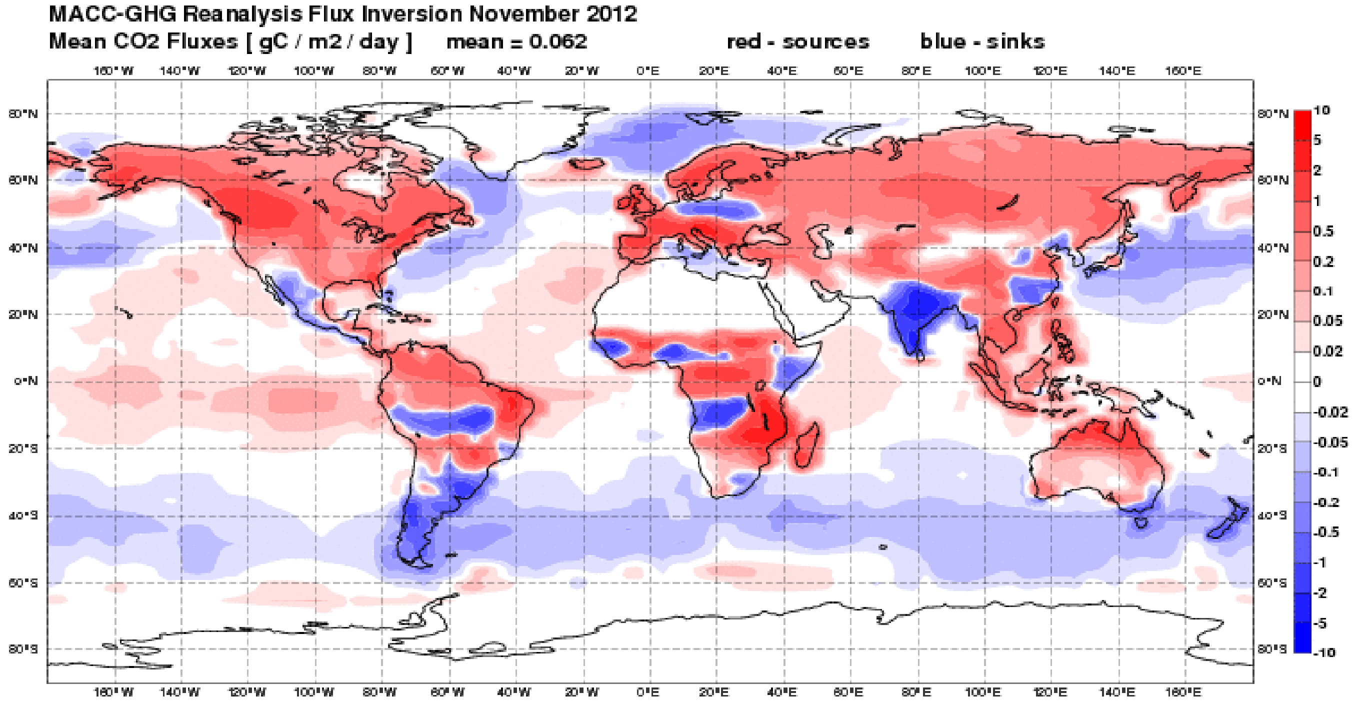
Global Carbon Atlas – model result comparisons



Flux inversion based on in-situ atmospheric CO_2 data

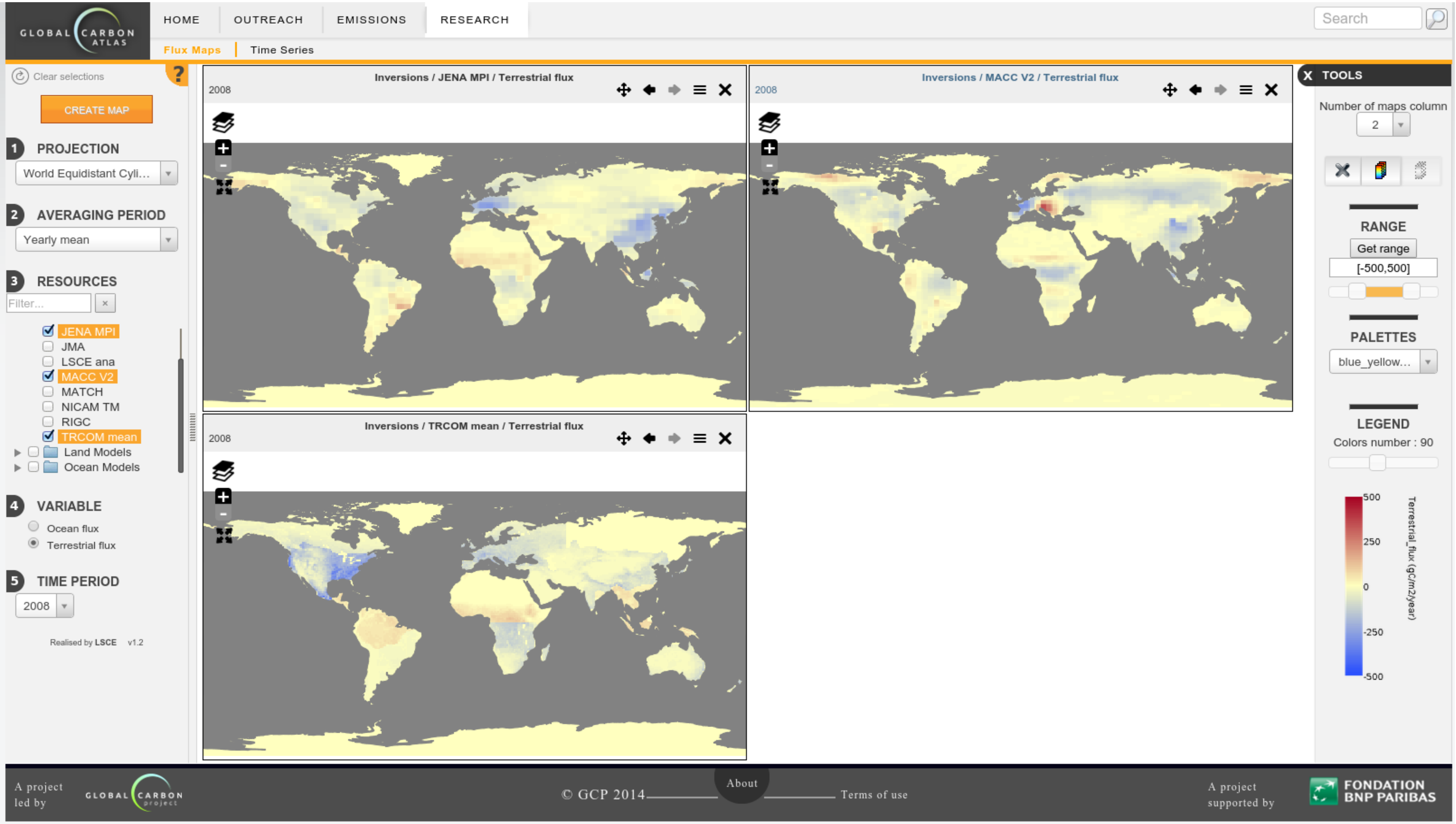


The series of MACC projects has generated flux inversions (1979 – 2013) based on in-situ observations.
Experimental inversions based on GOSAT have also been performed.



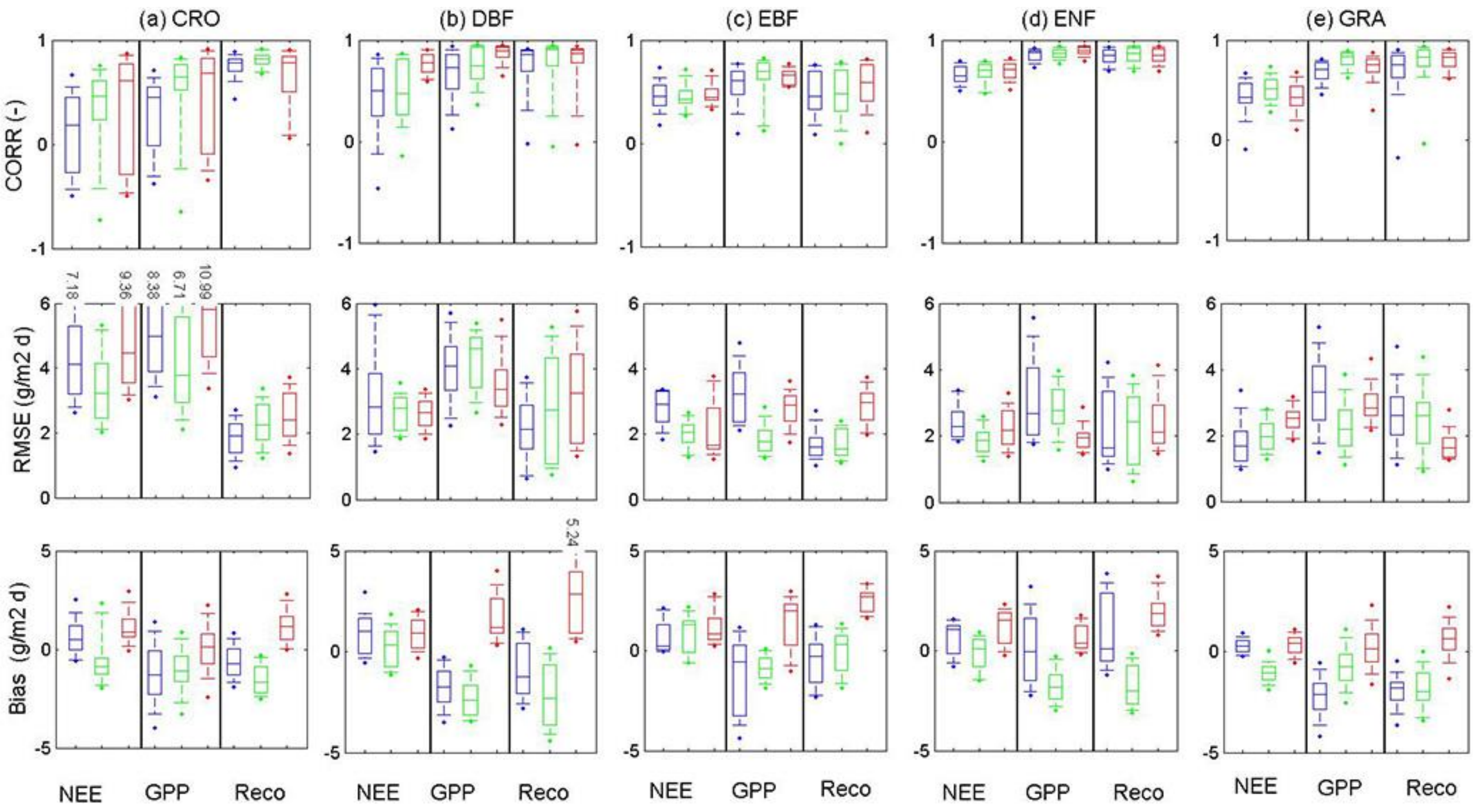
macc
Monitoring atmospheric composition & climate – III

Global Carbon Atlas – inversion results comparisons



How do we use observations?

Comparisons of three carbon models against **FluxNet** data by PFT



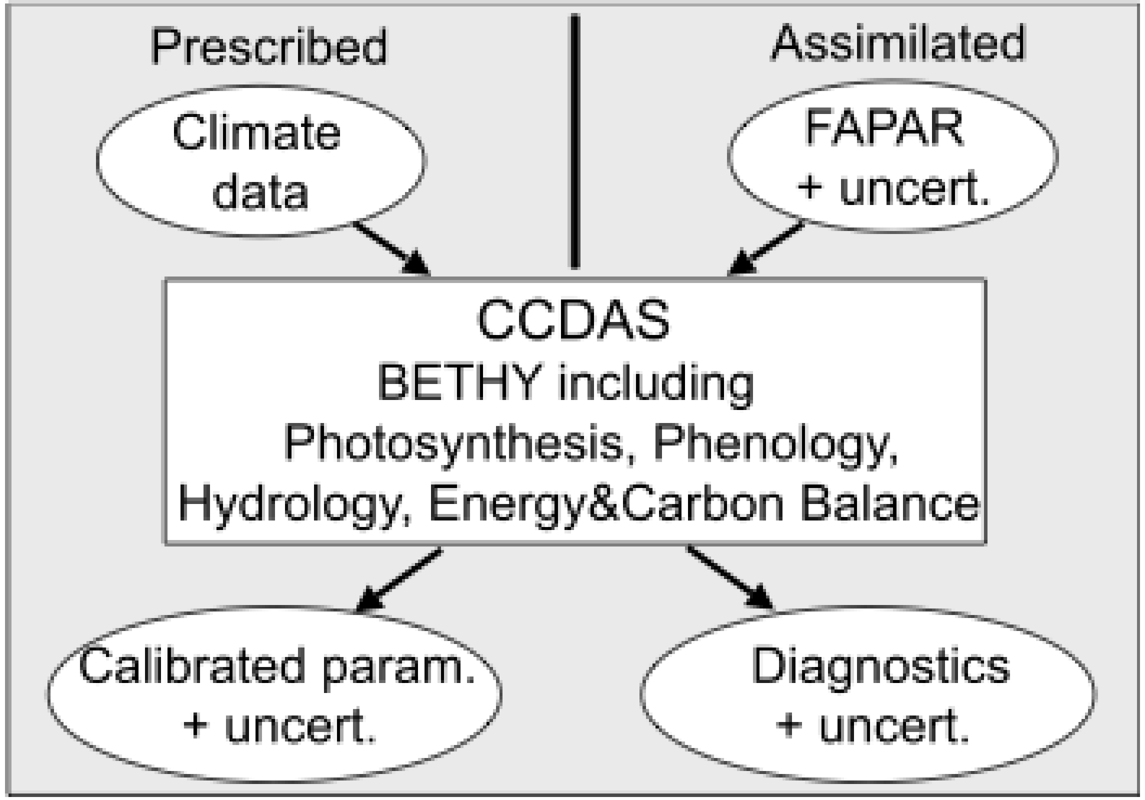
ISBA-A-gs

CHTESSEL

ORCHIDEE

Balzarolo et al., 2014

Carbon Cycle Data Assimilation System (CCDAS)



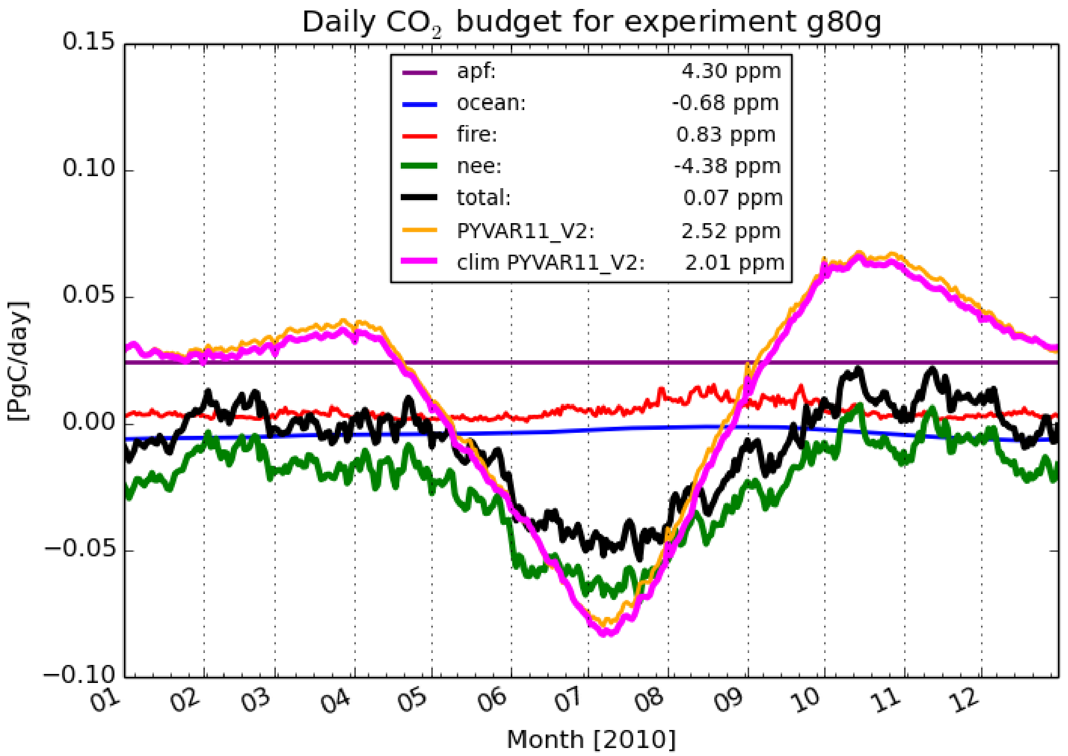
Scholze et al., 2007

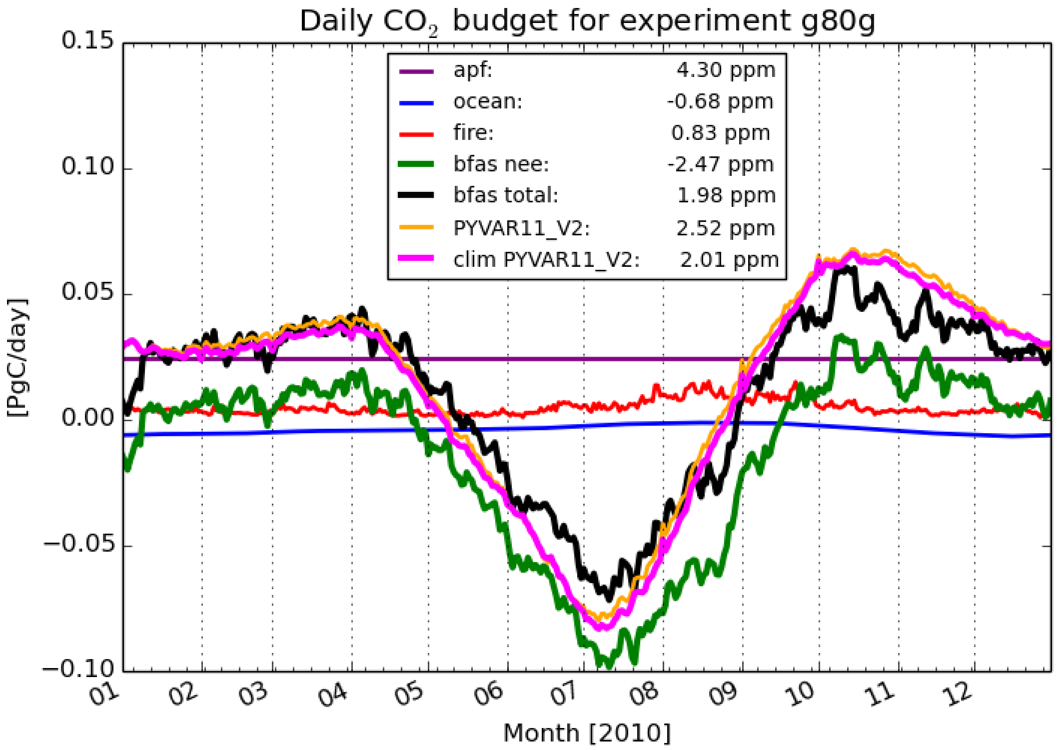
Constrain model parameters through data assimilation.

Most direct way of ‘tuning’ model parameters.

Can suffer from ambiguity.

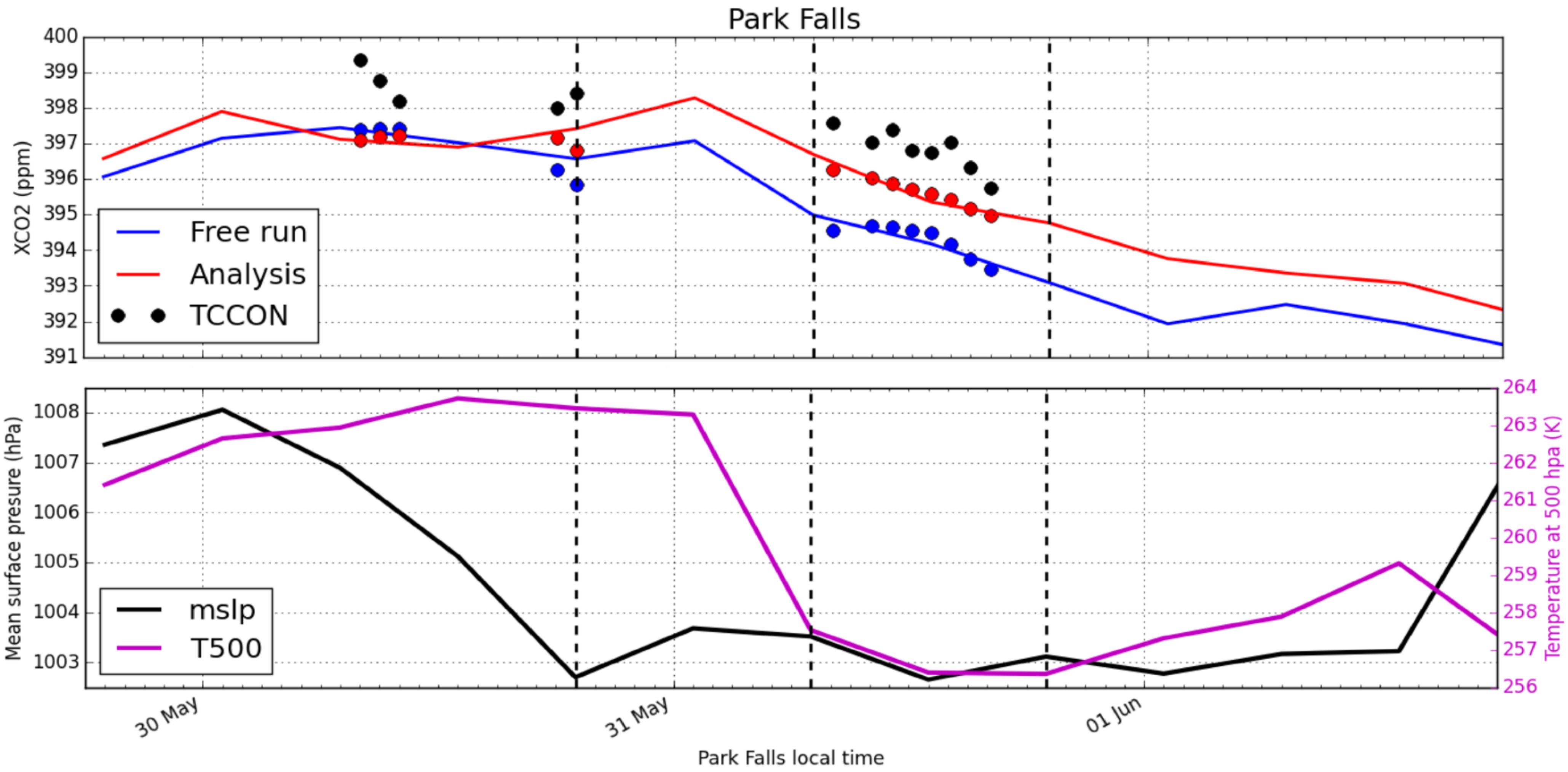
Combining flux inversions and flux models (CAMS BFAS)





BFAS is an attempt to combine predictive skill of the CHTESSEL forward model with the global constraint from flux inversions by combining **modelled CO_2 flux anomalies** with the budget from a **climatology of optimized fluxes** in order to adjust the ecosystem fluxes during the CO_2 simulation.

Atmospheric data assimilation of GOSAT in CAMS



Observations - GAW CO_2 network

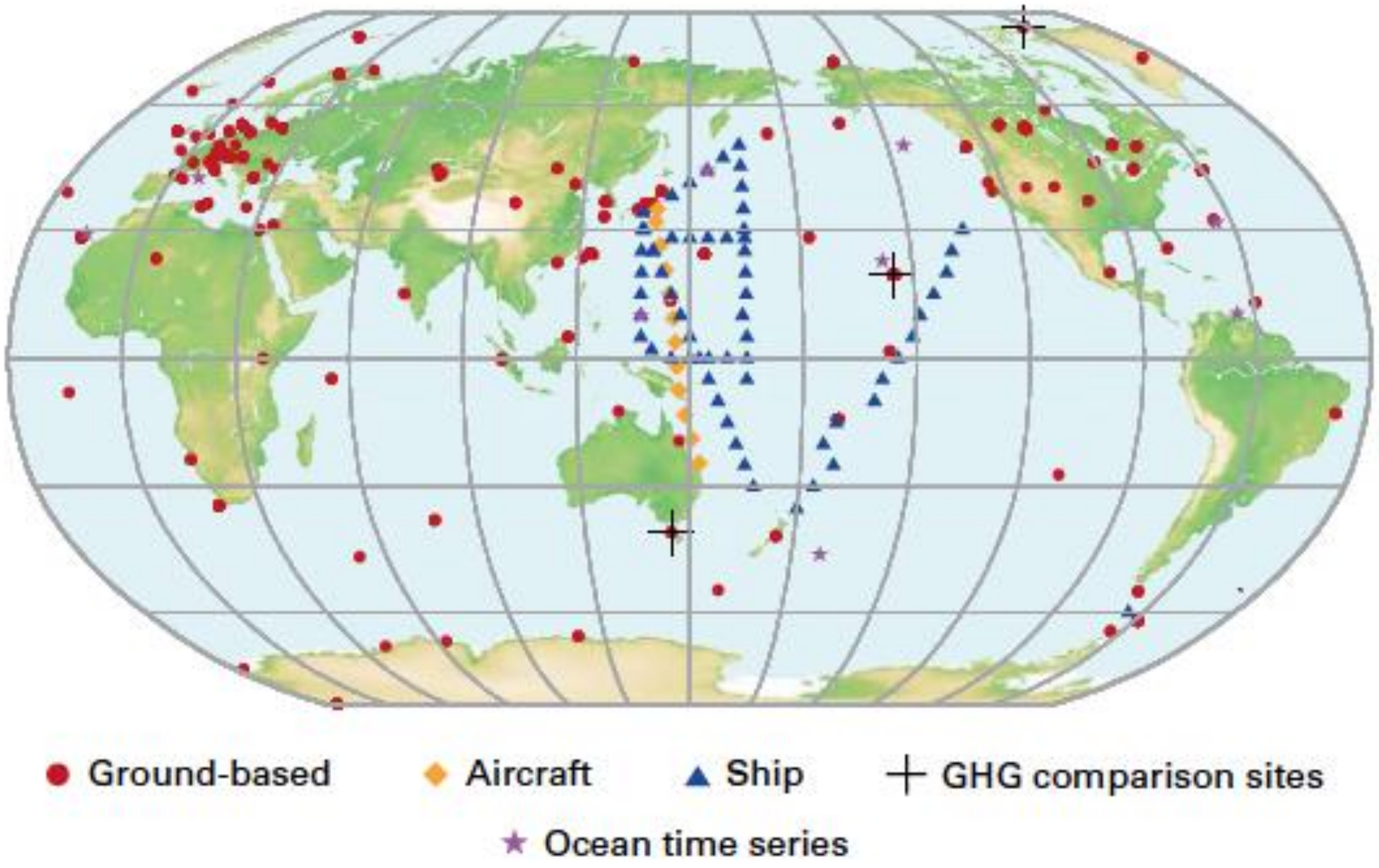
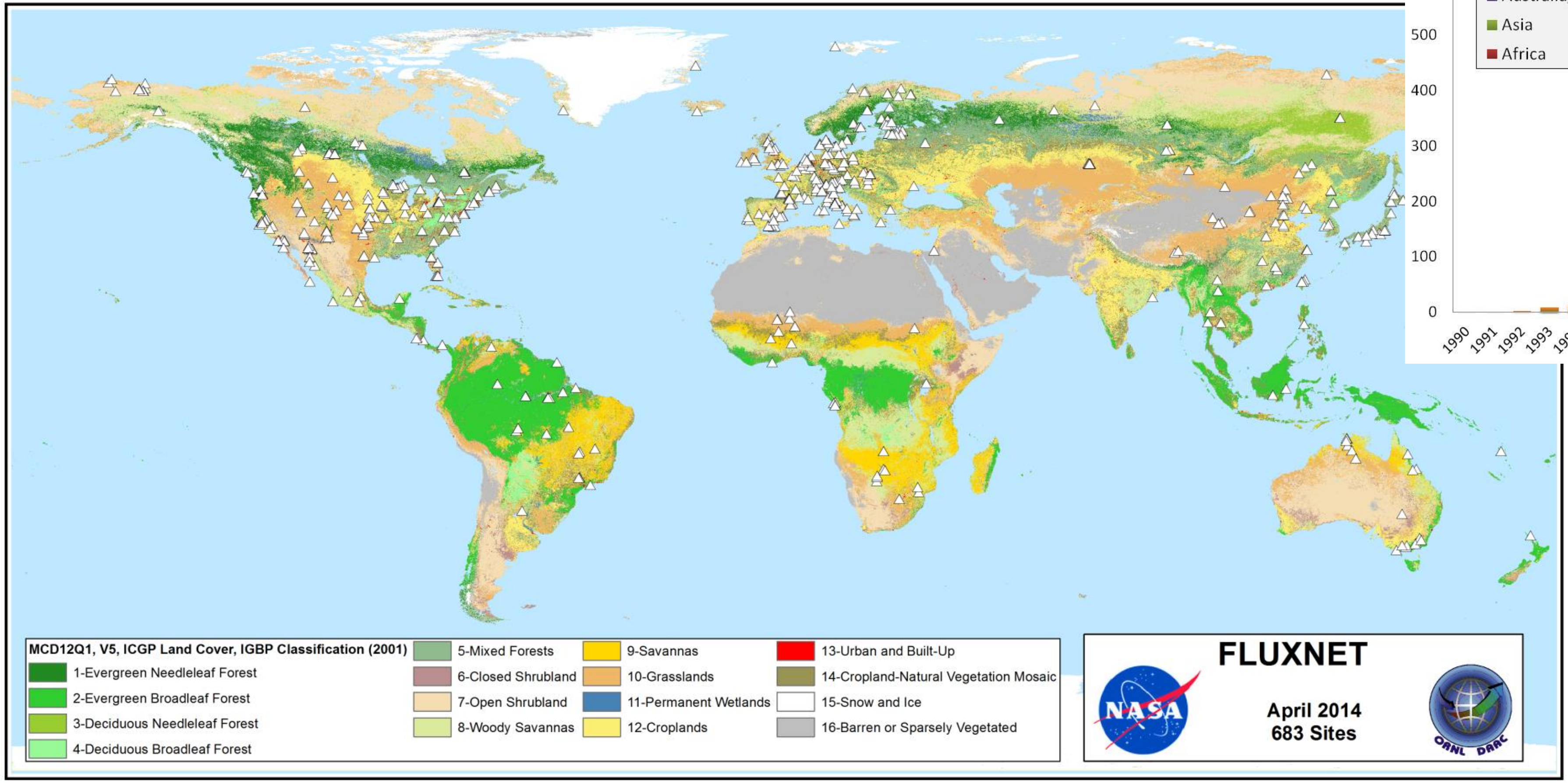
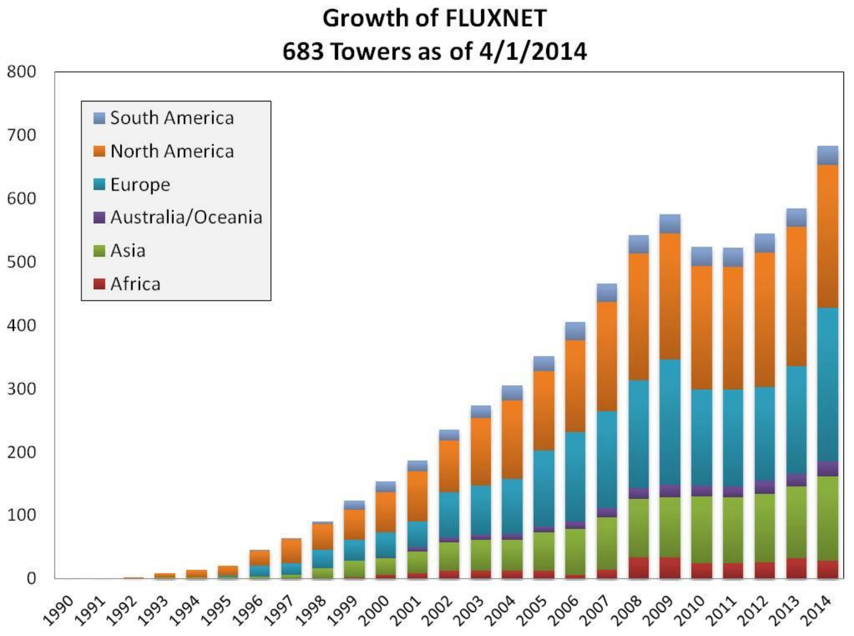


Figure 2. The GAW global network for carbon dioxide in the last decade. The network for methane is similar. Also shown are featured locations where observations of CO_2 are performed in ocean water.

WMO Greenhouse Gas Bulletin

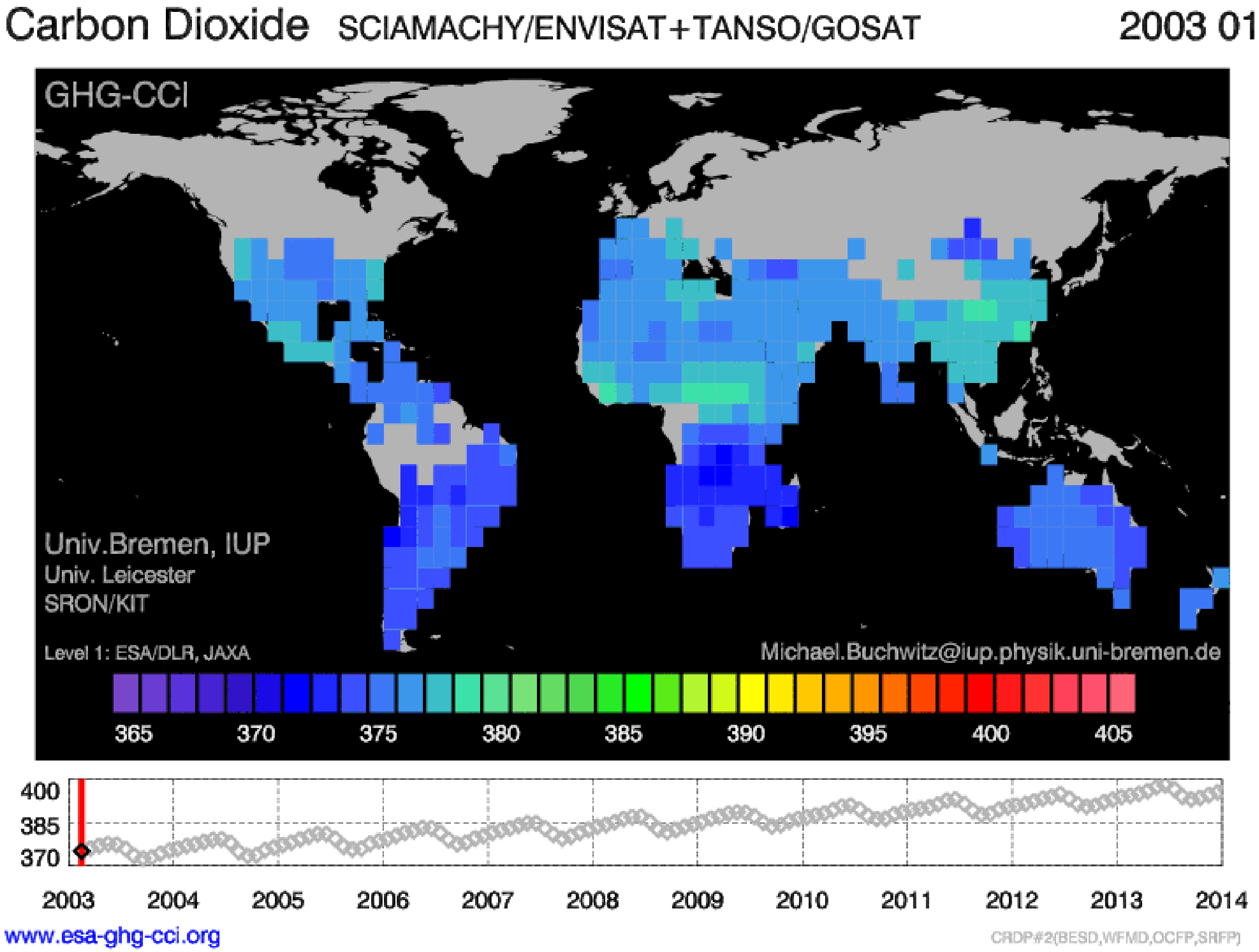
FLUXNET





Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC). 2013. FLUXNET Maps & Graphics Web Page. Available online [http://fluxnet.ornl.gov/maps-graphics] from ORNL DAAC, Oak Ridge, Tennessee, USA Accessed November 5, 2013

Can satellites play a role?



- Atmospheric CO_2
  - SCIAMACHY
  - GOSAT
  - AIRS
  - IASI
  - OCO-2
  - …
- Vegetation (fAPAR, Fluorescence)
  - MODIS
  - GOME-2
  - GOSAT

GEOCARBON aims at **designing a coordinated Global Carbon Observation and Analysis System**, addressing the climate targets of the Group on Earth Observations (GEO) toward building a Global Earth Observation System of Systems (GEOSS) for carbon. Specific objectives are:

1. Provide an aggregated set of harmonized global carbon data (CO_2 and CH_4) and information (integrating the land, ocean, atmosphere and human dimension)

2. Develop improved Carbon Cycle Data Assimilation Systems (CCDAS)

3. Define the specifications for an operational Global Carbon Observing System

4. Provide improved regional carbon budgets of Amazon and Central Africa

5. Provide comprehensive and synthetic information on the annual sources and sinks of CO_2 and CH_4 for the globe and for large ocean and land regions

6. Provide an economic assessment of the value of an enhanced Global Carbon Observing System

7. Strengthen the effectiveness of the global Carbon Community participation in the GEO system.

GEO Task CL-02 Activities toward GEOSS 2015 Targets

(CL-02: more than 60 people from 21 Members and POs and 47 Implementing Entities)

- Global integration and coordination of the carbon monitoring networks
- Improve methodologies for measuring and analyzing carbon cycle data
- Calibrate and validate space based observations
- Annual updates of global and regional carbon (CO_2 + CH_4 including fossil fuel) budgets
- Provide open access to user friendly data and information

Support effective decisions and interventions (mitigation/adaptation) by policy makers

Antonio Bombelli

Some issues

- Sparse networks
- Continuity is challenging
- More harmonization needed between networks (C3S/CAMS focus on Europe or global?)
- Data portals are often project-based
- How to deal with various data policies?
- Better links needed between scientific data and policy applications

Summary and thoughts

- Improved understanding of the carbon cycle is crucial to better understand and therefore predict its role in climate change
- The terrestrial biosphere has the largest impact on the variability of atmospheric CO_2, but is still not understood well enough
- Observations of atmospheric CO_2 and the relevant fluxes exist, but are mostly restricted to the recent period (1950 -)
- As in meteorological reanalyses, models can help to fill the gaps and potentially extend the record backwards. Models also provide predictive skill.
- There has been significant progress in the carbon community to coordinate and provide easy access to observations and model output
- There remains more work to be done and Copernicus can play an important role in this
- Coordination needs to take place between all stakeholders (e.g., GEO, WMO-GAW/IG^{3}IS, NOAA, Global Carbon Project, CAMS, EU)