Constraining terrestrial carbon fluxes by assimilating the SMOS soil moisture product into a model of the global terrestrial biosphere

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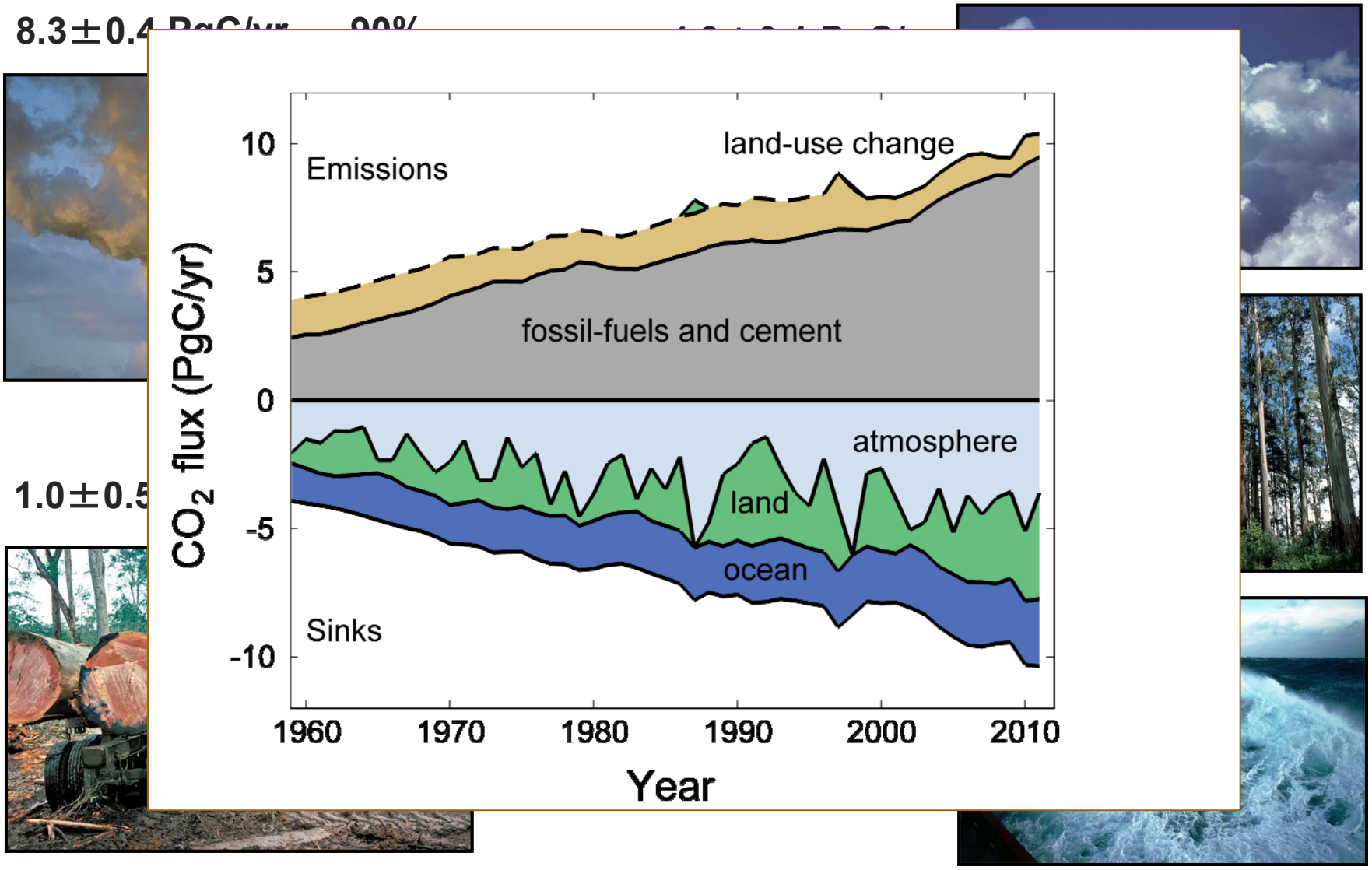
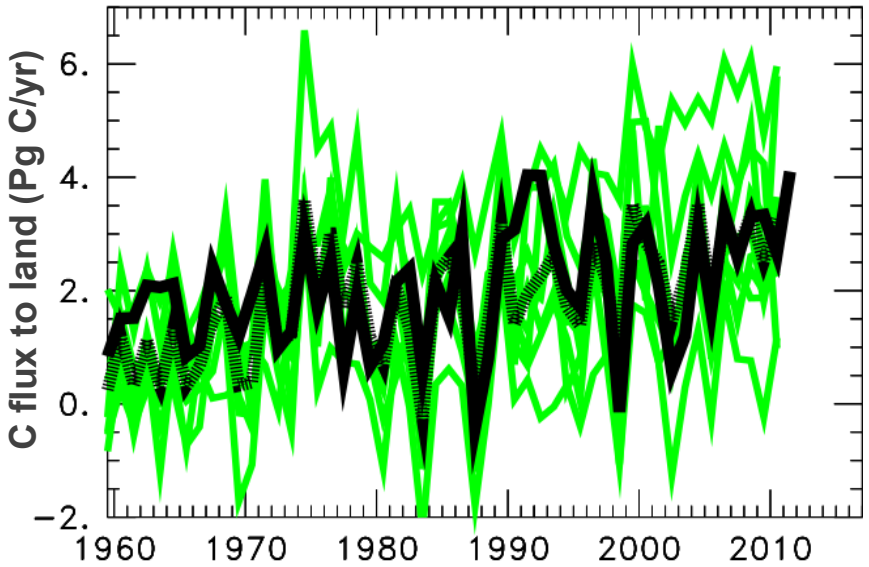
Global Carbon Budget



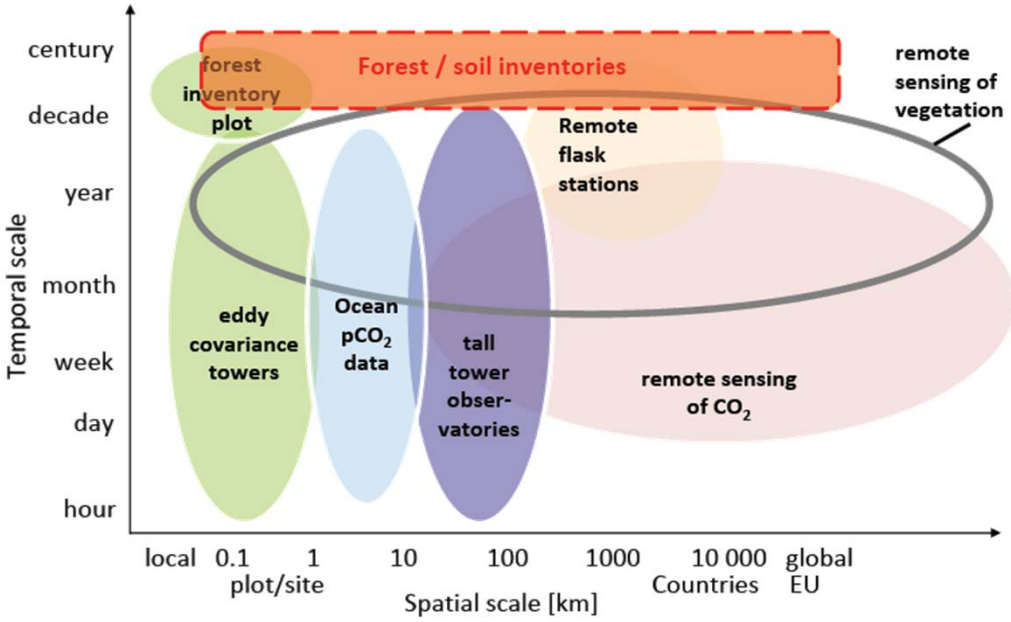
The case for data assimilation

Large uncertainty from land to predict C-balance (GCP)



Le Quéré et al. 2013

Available Observations



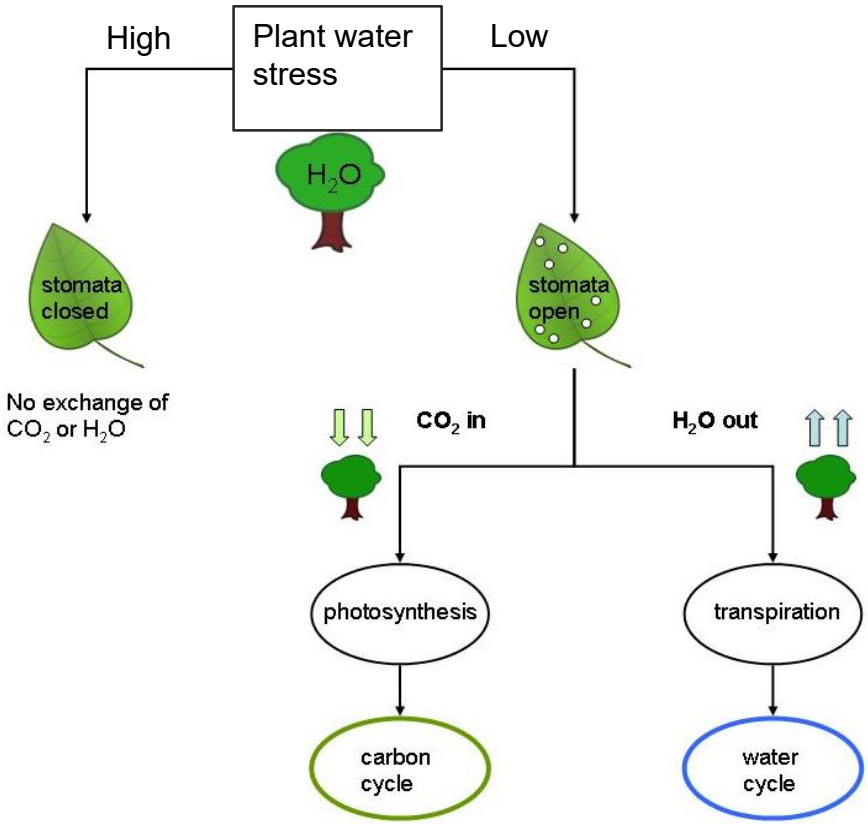
⇒ Carbon Cycle Data Assimilation System

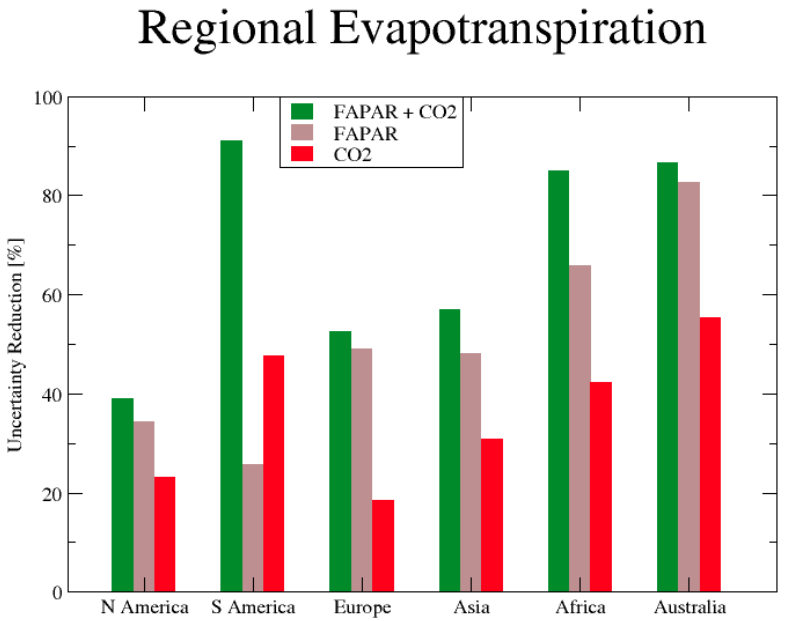
= ecophysiological constraints from forward modelling

+ observational constraints from inverse modelling

Previous results

- Water and Carbon Cycles tightly coupled
- Assimilation of FAPAR and atmospheric CO_2 constrains water fluxes





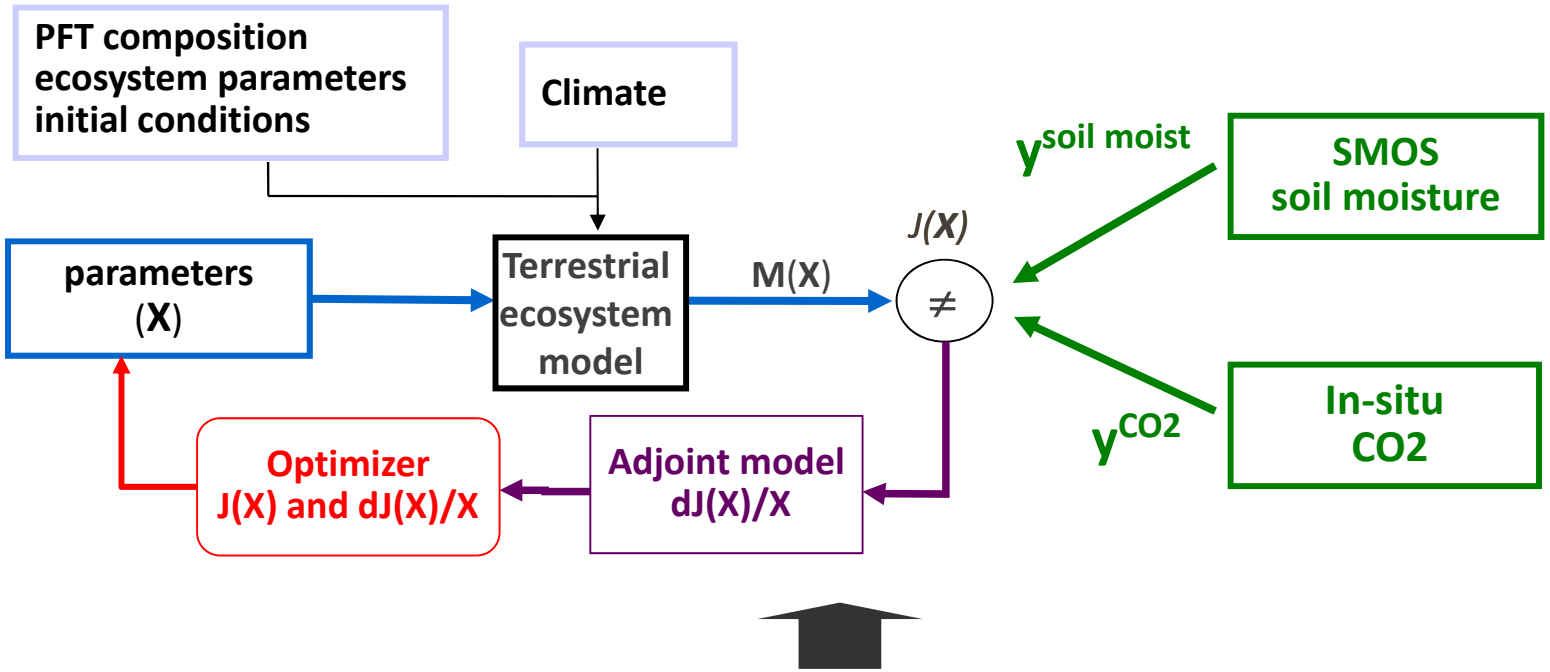
Kaminski et al. (2012)

Objective of this study

Assimilation of SMOS soil moisture observation together with atmospheric CO_2 concentration:

- To quantify the added value of remotely sensed soil moisture observations (as provided by SMOS) on constraining terrestrial C fluxes.
- To assess the potential of a SMOS-based NEE product.

C-cycle data assimilation system

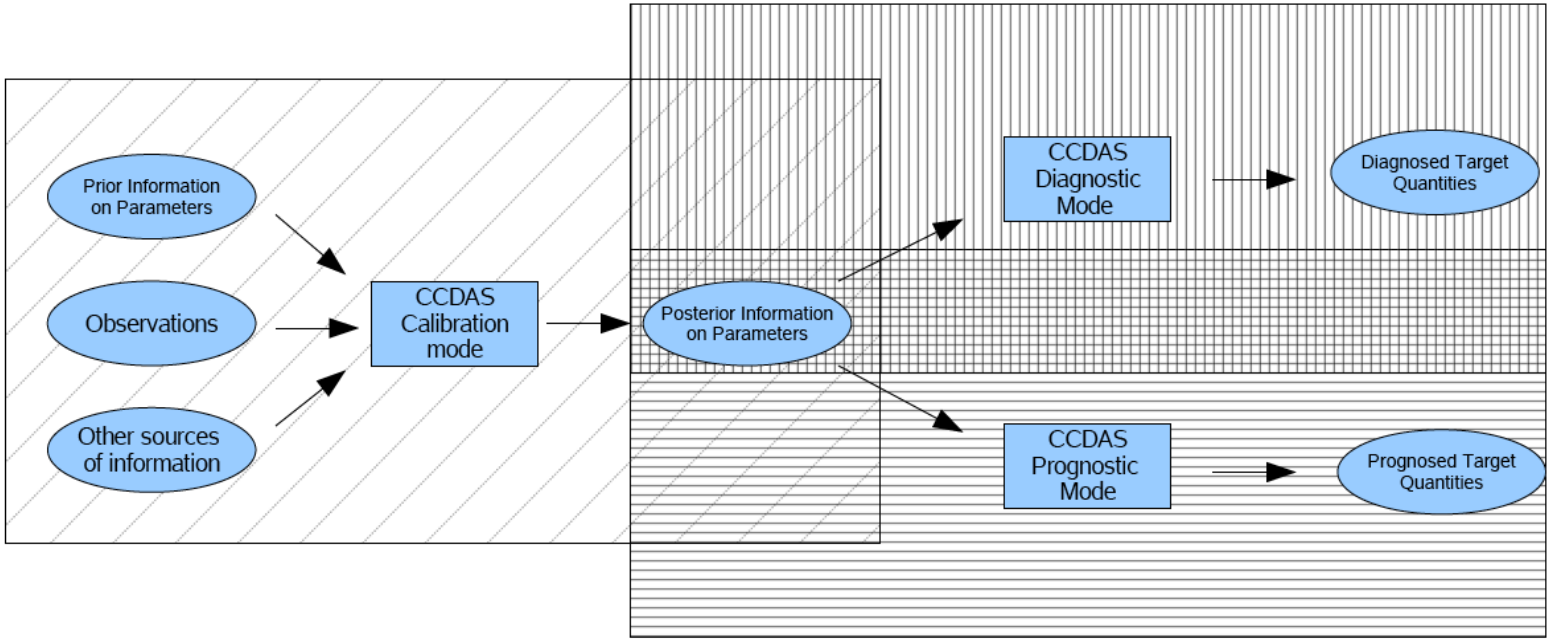


Cost function: $$J(x)=\frac{1}{2}\left[\sum\left(y-M(x)\right)^{t}C_{y}^{-1}\left(y-M(x)\right)+(x-x_{p})^{t}C_{p}^{-1}(x-x_{p})\right]$$

- Need to define the error matrices C_y^{-1}, C_p^{-1}

CCDAS methodology

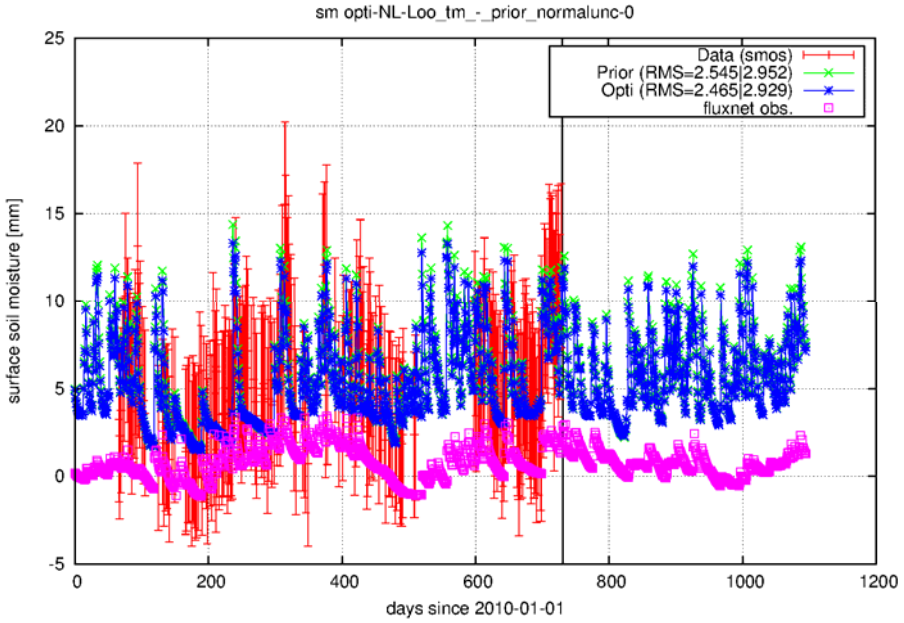
- Based on process-based terrestrial ecosystem model (BETHY)
- Optimizing parameter values (~100) based on gradient method
- Hessian (2nd deriv.) to estimate posterior parameter uncertainty
- Error propagation by using linearised model

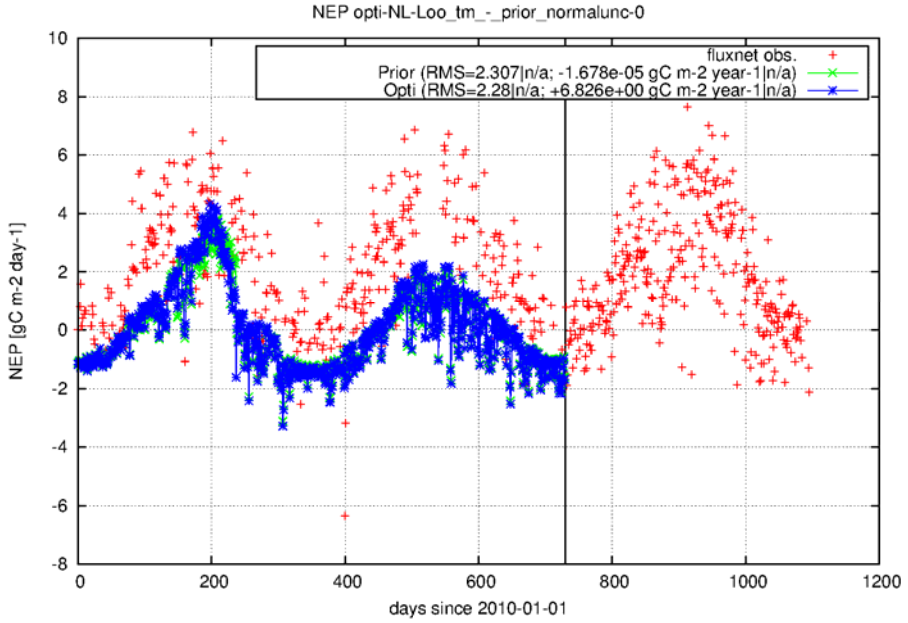


Scholze et al. (2007)

Site-scale experiments

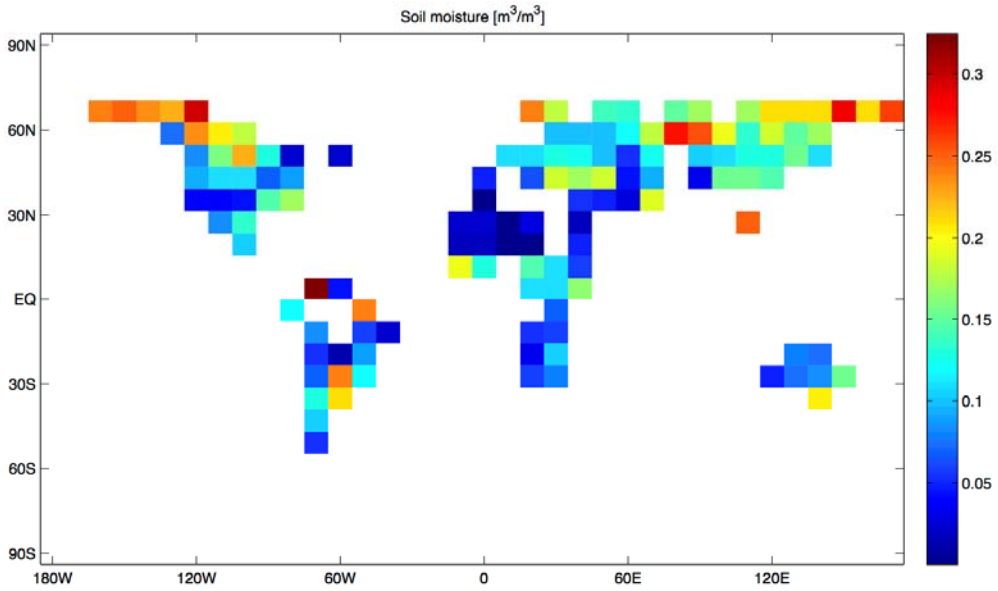
- Substantial model development to simulate surface soil moisture
- Joint assimilation of SMOS daily SM data for 5 sites
- 5 member ensembles from different starting points
- All 5 converge to same minimum

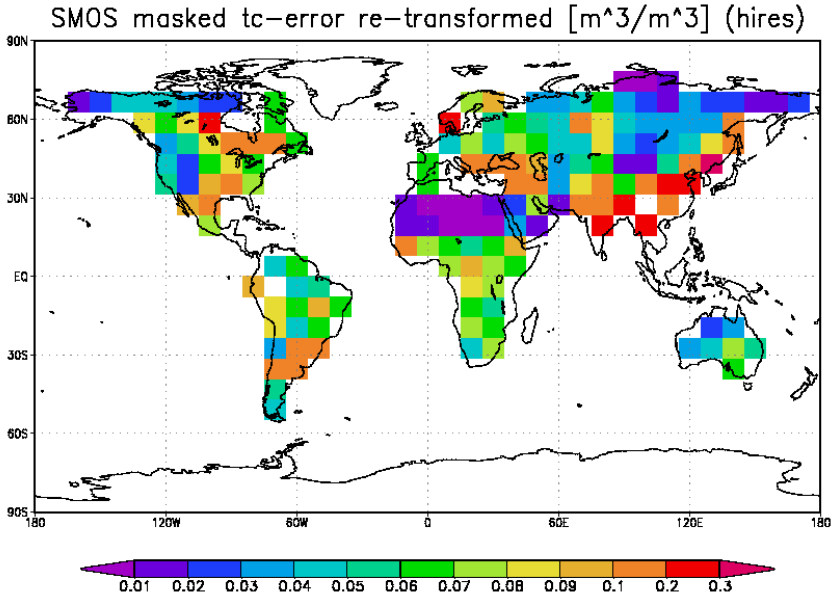




Global Experiments

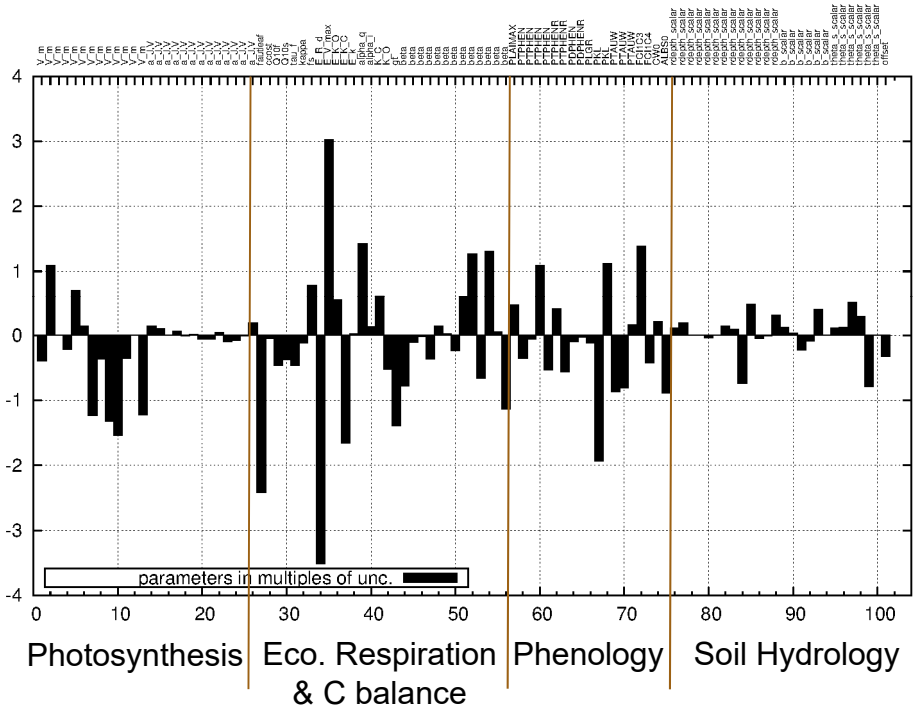
- Coarse resolution, 2 years (2010/11)
- Running 3-member ensembles from different starting points
- Baseline: in-situ atm. CO_2 (10 sites) concentrations only
- Baseline + SMOS daily soil moisture with variance/mean scaling



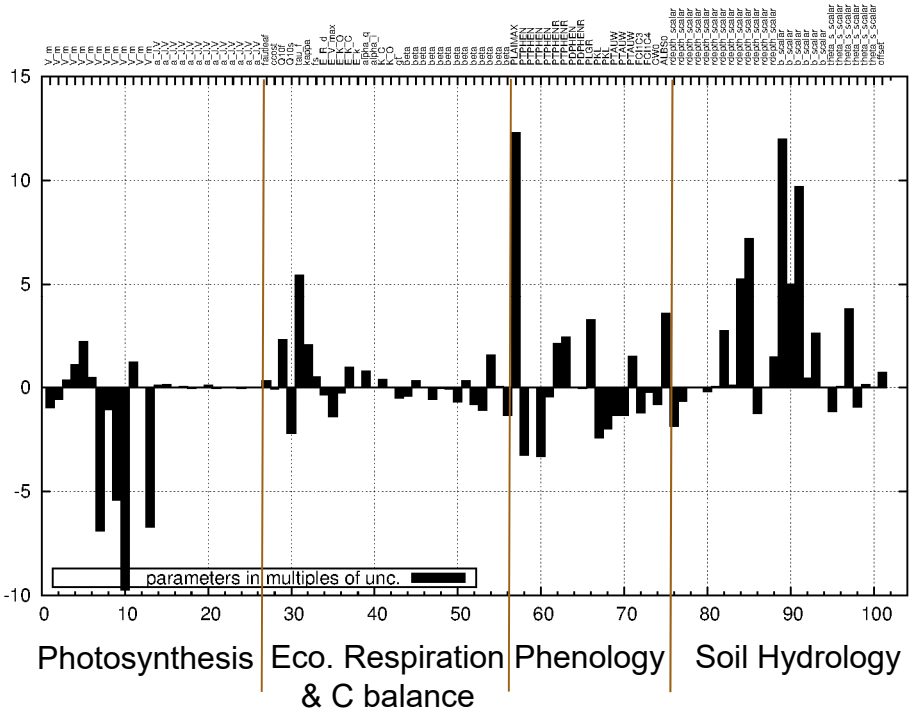


Results: process-parameters

CO_2 only

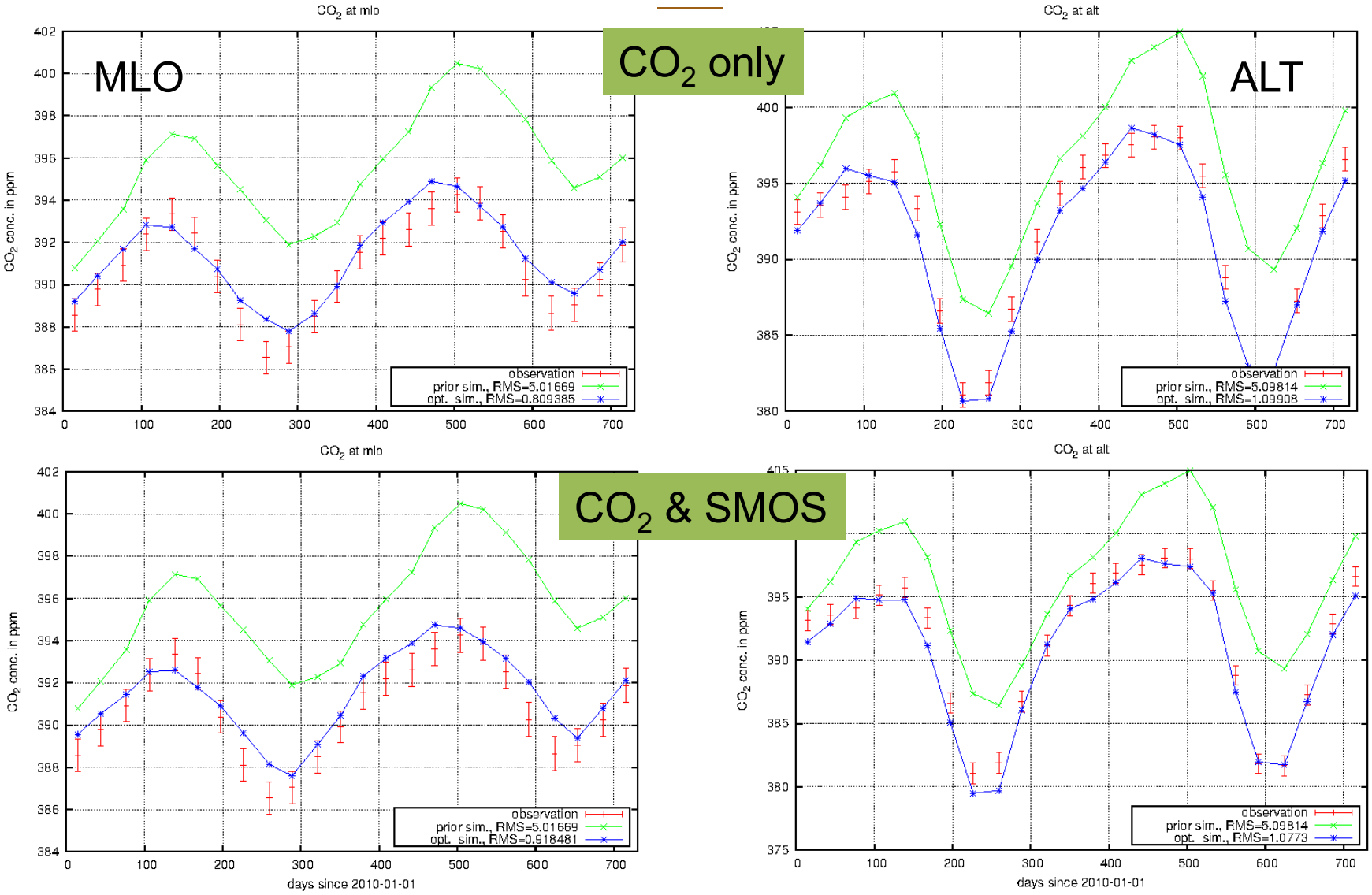


CO_2 & SMOS



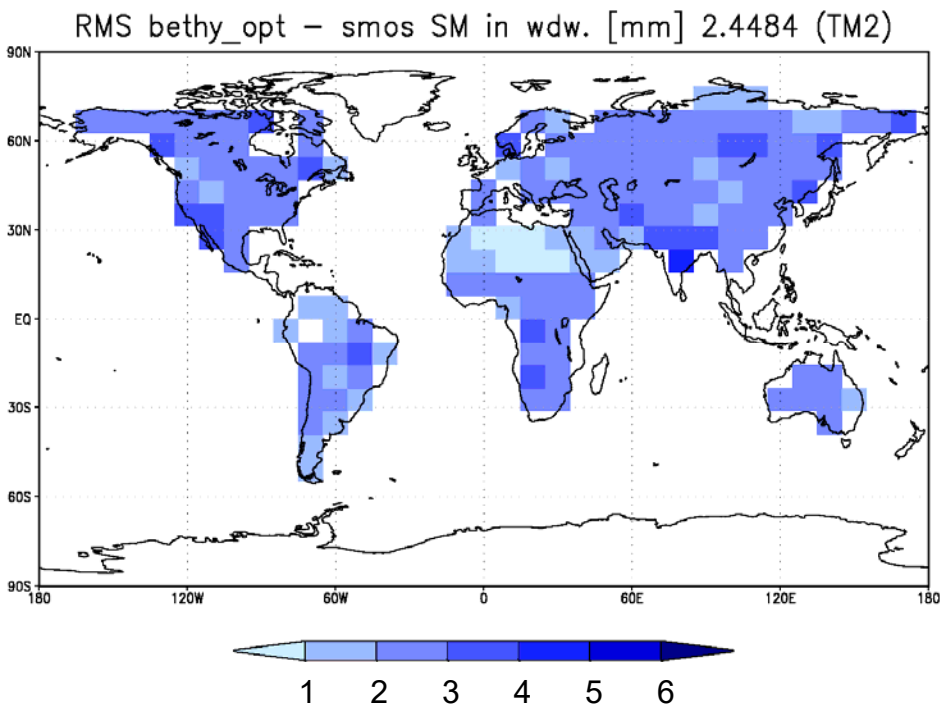
Scholze et al. (2016)

Results: atm CO_2 (also for validation)

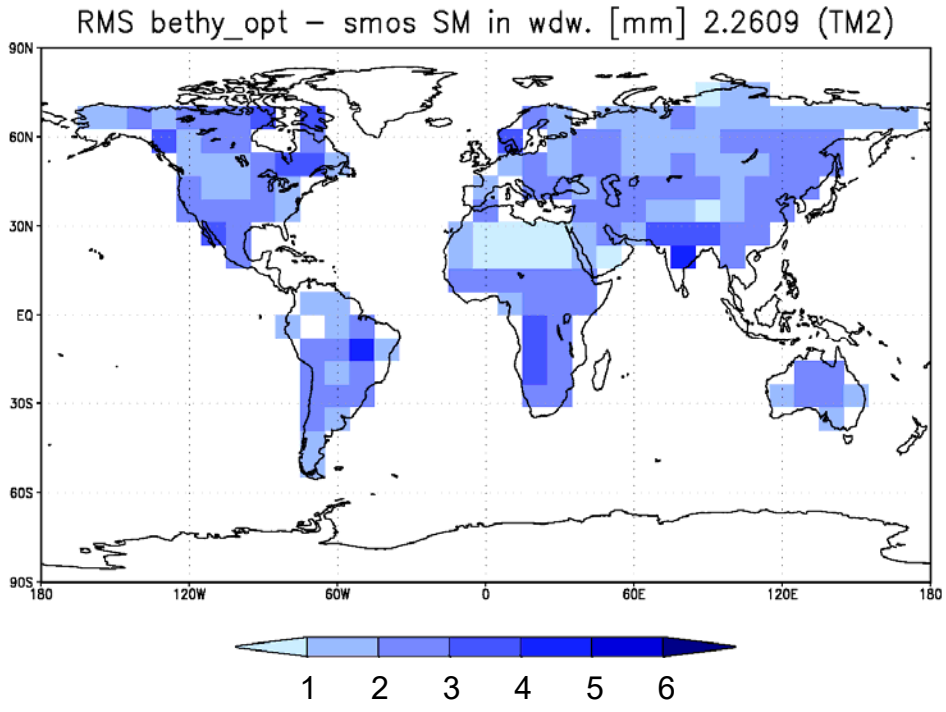


Results: soil moisture (RMS)

CO_2 only

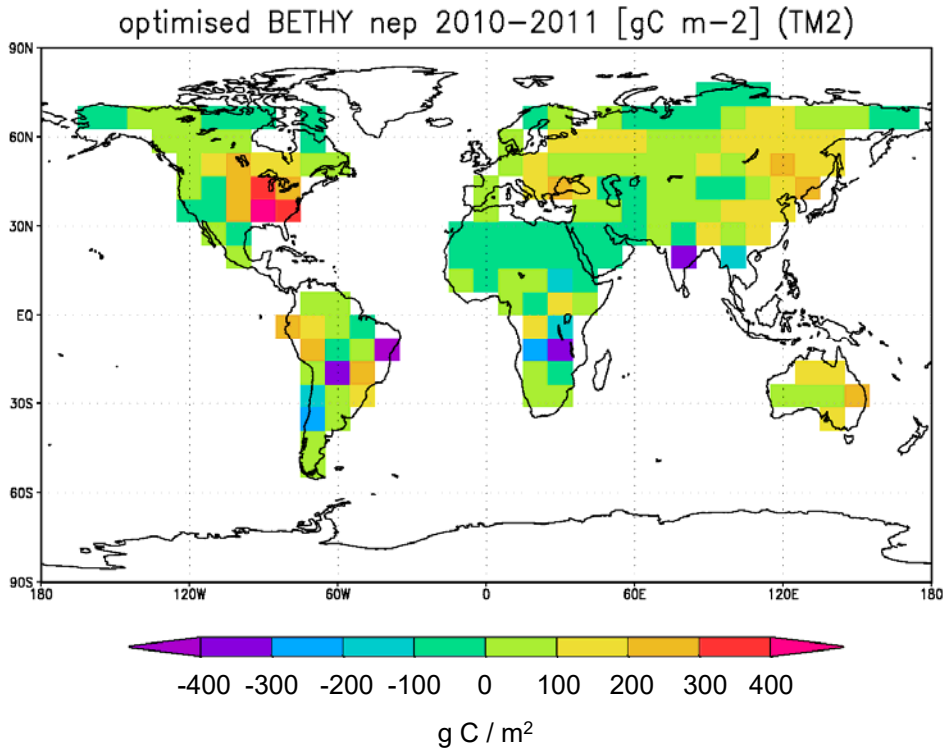


CO_2 & SMOS

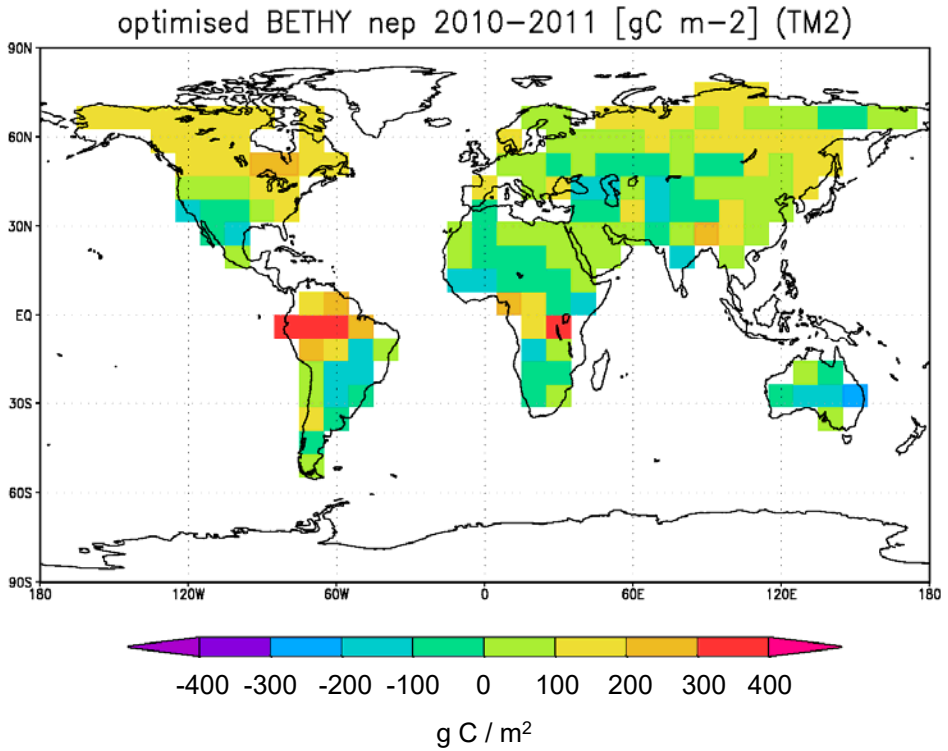


Results: CO_2 fluxes (NEP)

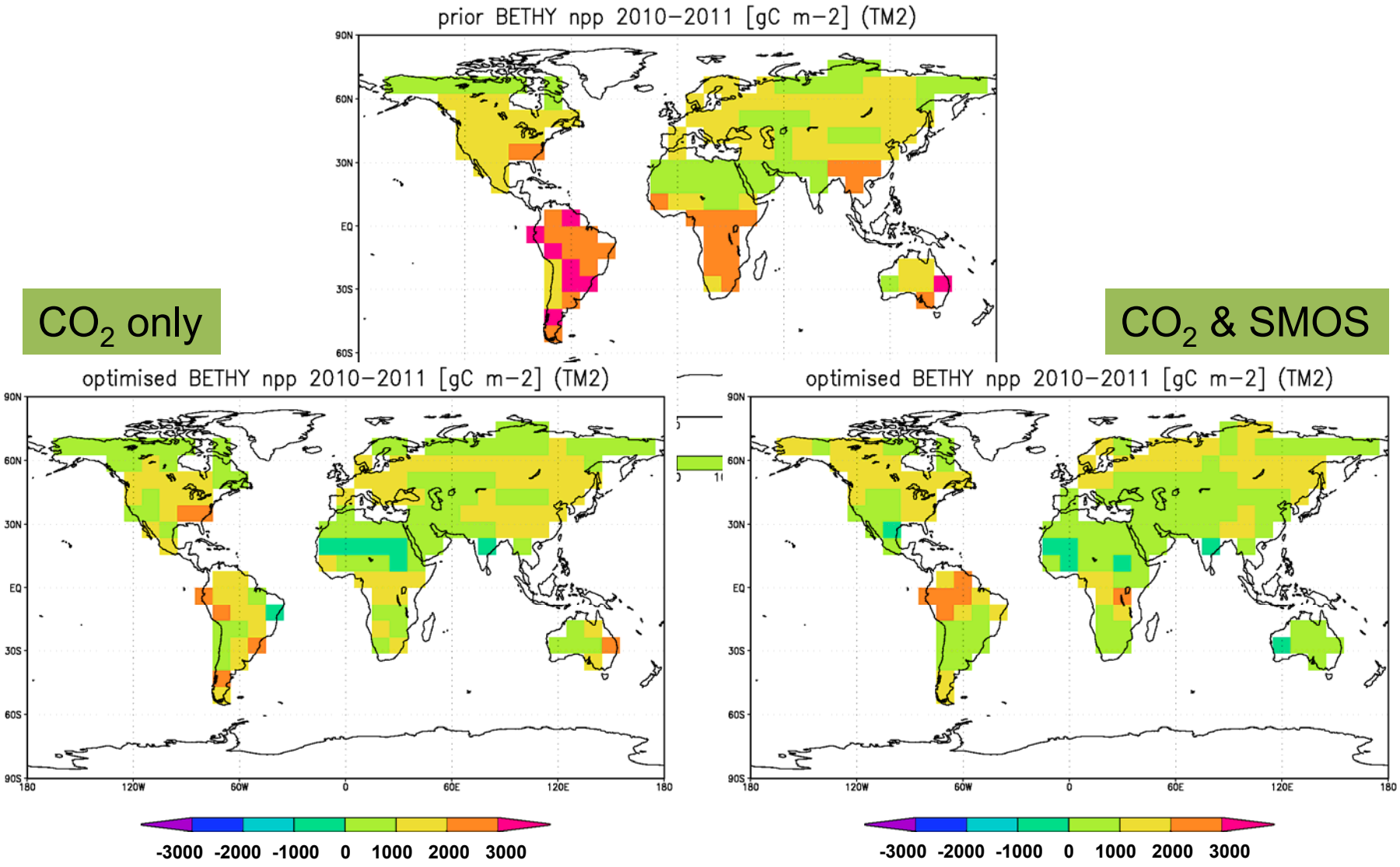
CO_2 only



CO_2 & SMOS

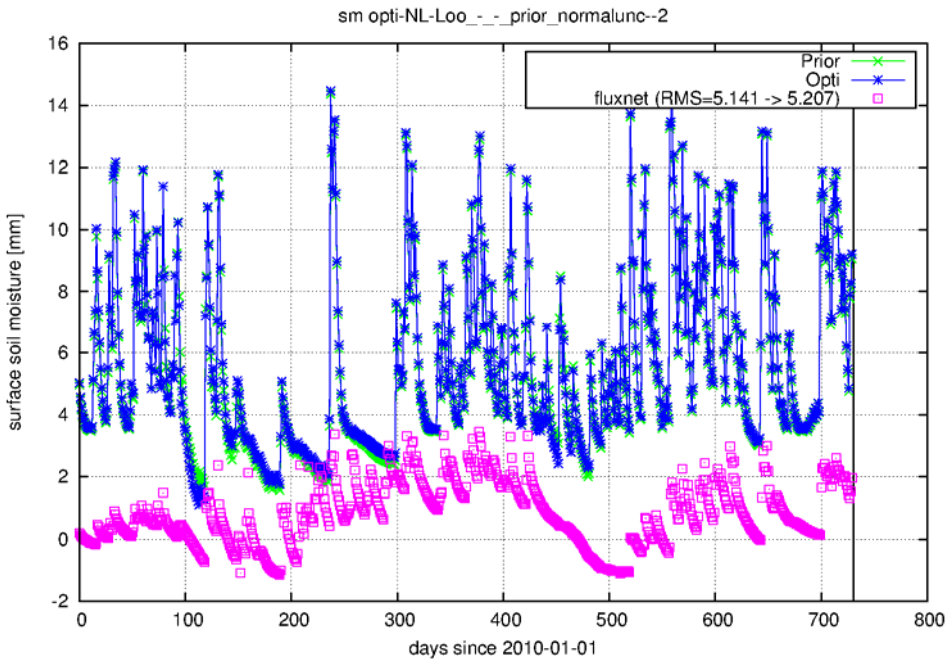


Results: CO_2 fluxes (NPP)

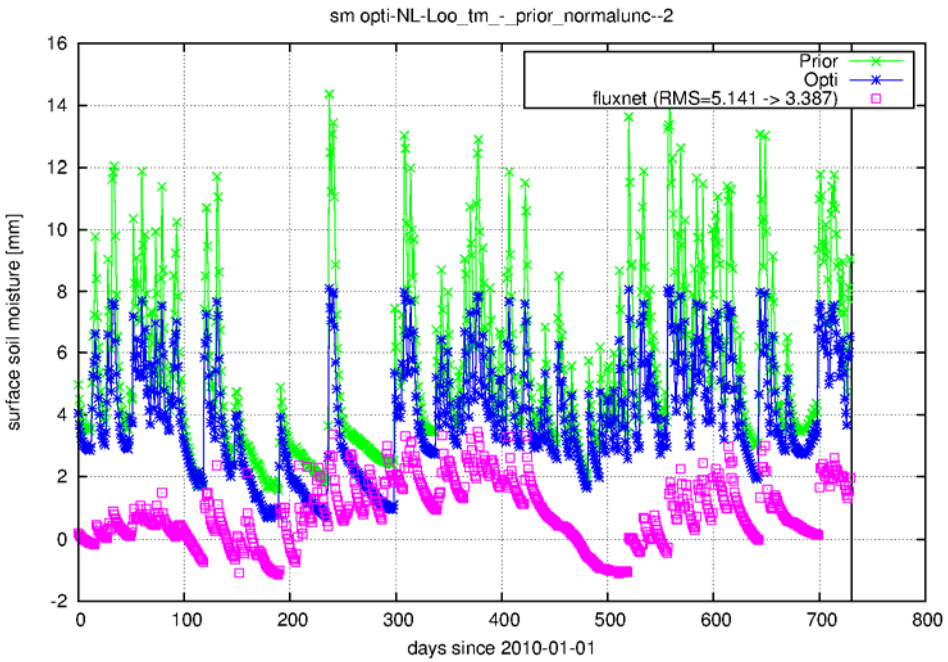


Validation: soil moisture at site level

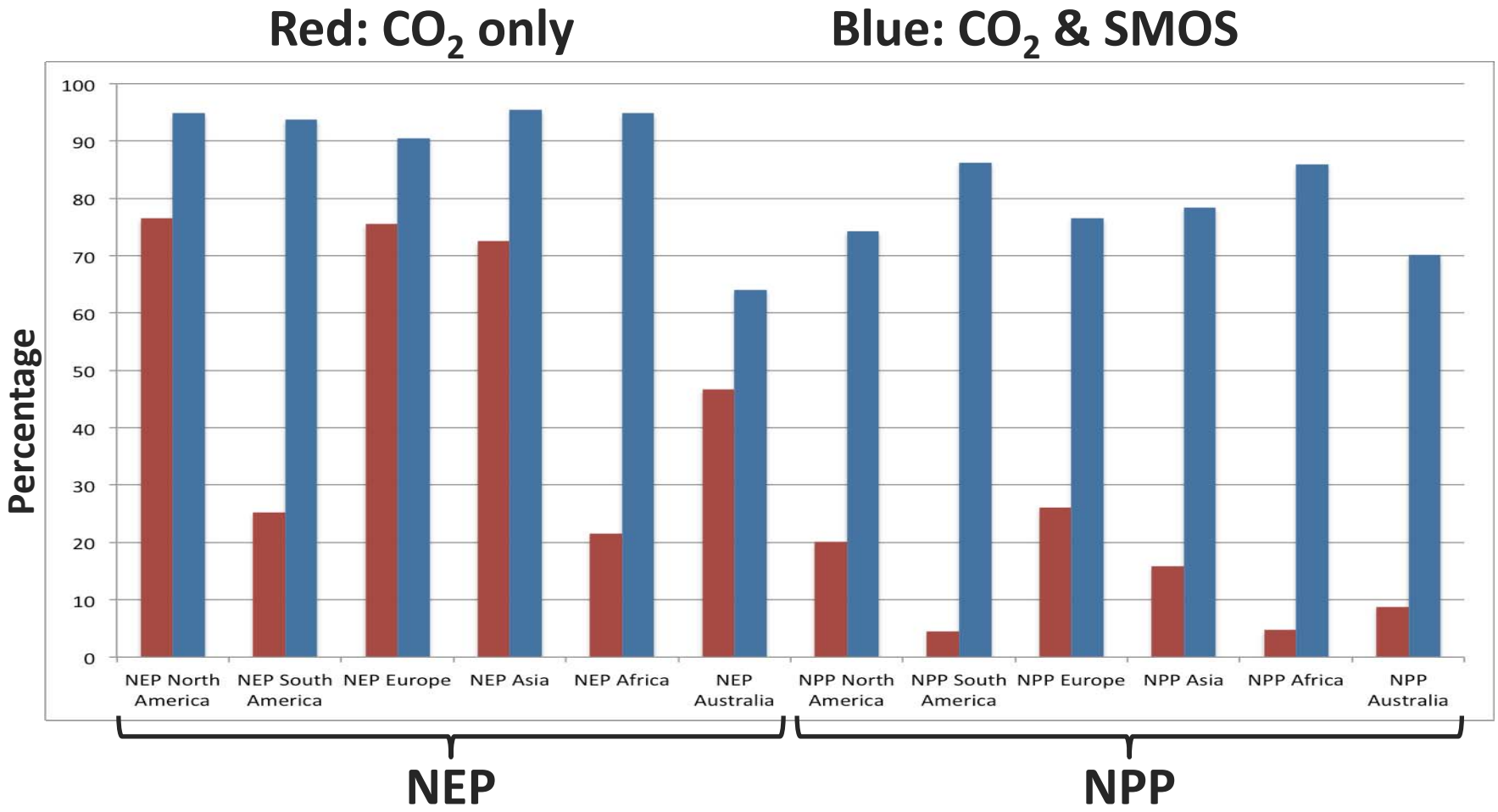
CO_2 only



CO_2 & SMOS



Relative flux (NEP & NPP) uncertainty reduction for 6 regions



Conclusions

- CCDAS combines process understanding with observations, provides an integrated view on global carbon cycle and delivers elaborated products based on ICOS data (among others)
- Site scale experiments to test and validate assimilation system => demonstrates capabilities of CCDAS to assimilate SM
- First global experiments assimilating remotely sensed SM and atm. CO_2 simultaneously
- Significant added value (unc. reduction) compared to CO_2 only
- Further work using SMOS observations together with atm. CO_2:
  - assimilate the full 6 years of SM data at high resolution
  - extend the assimilation system to additionally include microwave Vegetation Optical Depth data as a proxy for above ground biomass (vegetation water content) over various land-cover types