→ ATMOS 2015

Advances in Atmospheric Science and Applications

Quantifying the impact of column integrated CO2 observations data on NEP and NPP by supplementary assimilation into CCDAS

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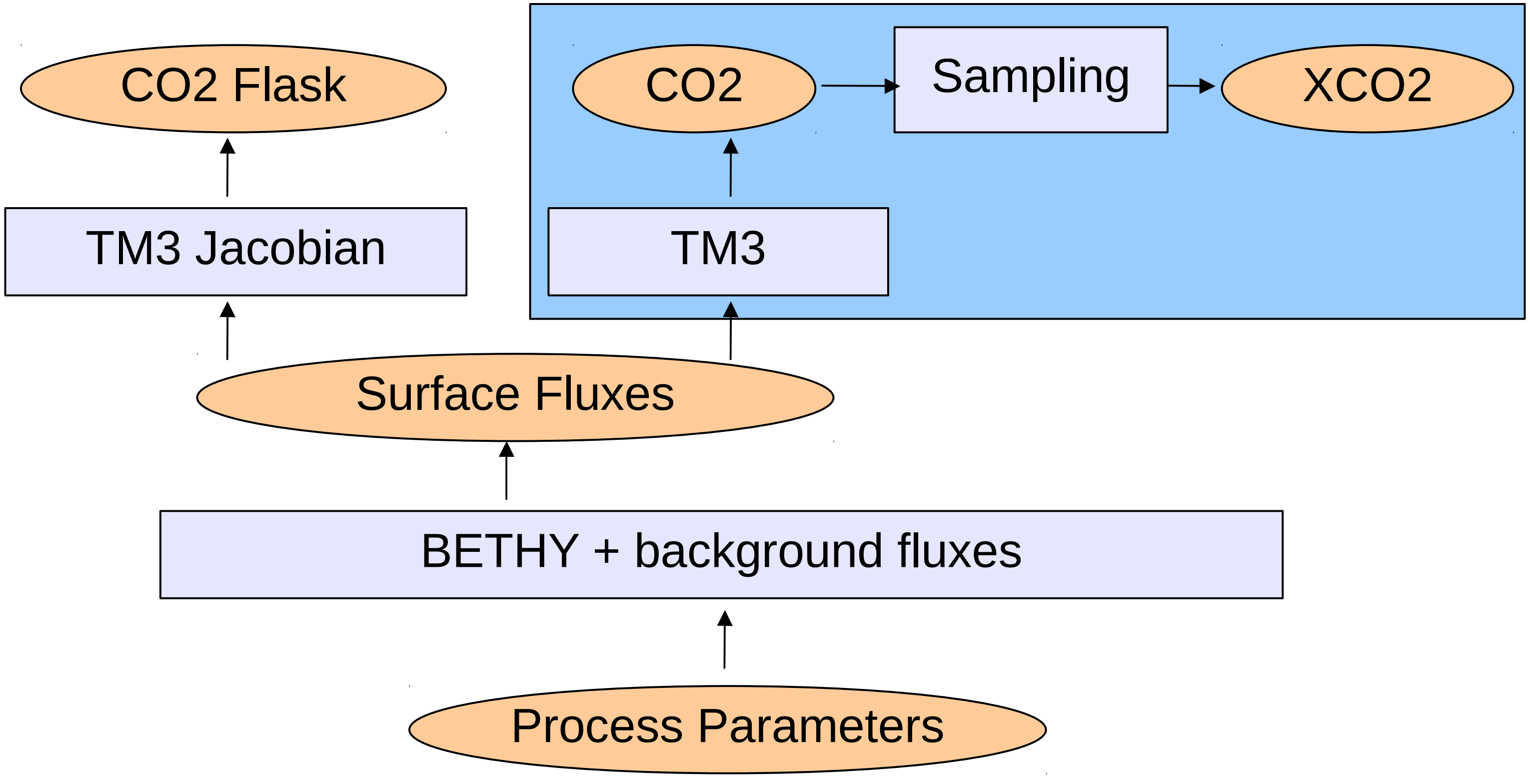
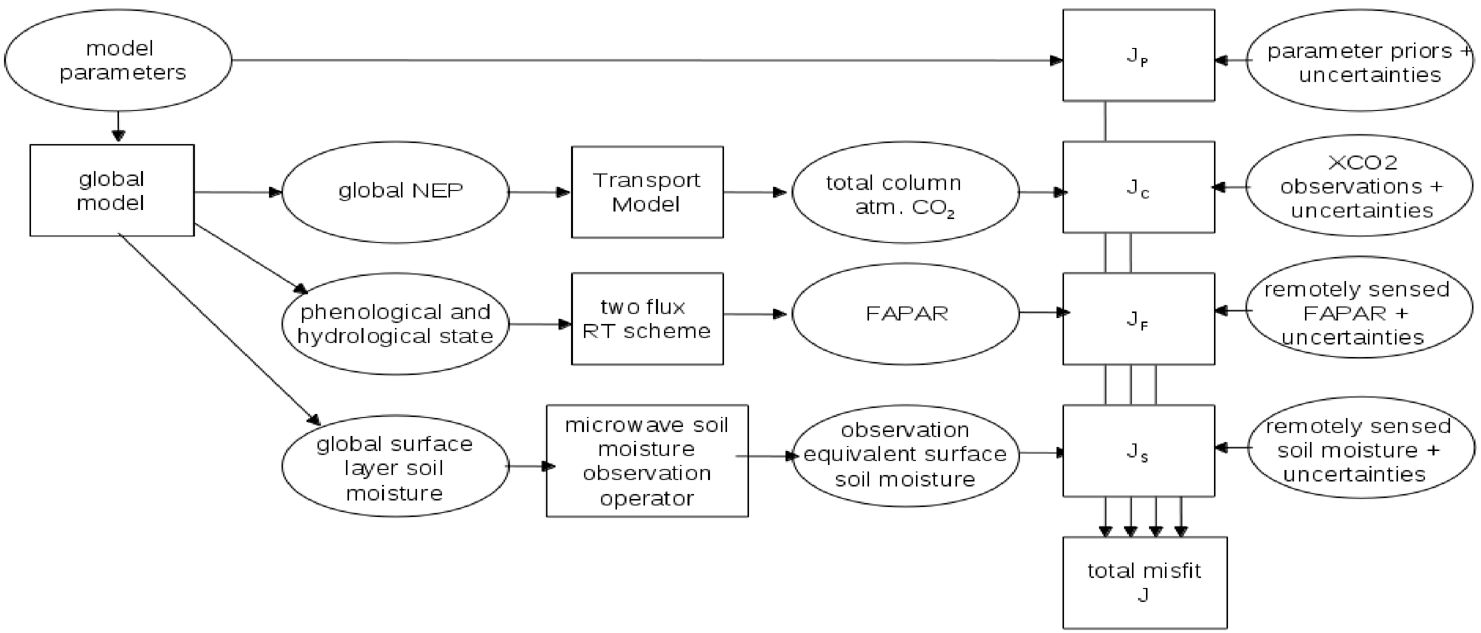
Outline

- Carbon Cycle Data assimilation system (CCDAS)
- Land biosphare model Bethy
- atmospheric Transport Model TM3
- Data
- Parameter
- Results
- Summary and Conclusions

CCDAS


CO2 Flask
CO2
Sampling
XCO2
TM3 Jacobian
TM3
Surface Fluxes
BETHY + background fluxes
Process Parameters

Cost function



consistent assimilation of different data streams

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CCDAS

- Iterative minimisation of the cost function J(**x**)

$$J(x) = ½ [(x-x_{pr})^T C_{pr}^{-1} (x-x_{pr}) + (M(x)-d)^T C_d^{-1} (M(x)-d)]$$

- Optimisation uses the gradient of J(**x**) with respect to the parameters (adjoint model)
- Second order derivatives (Hessian) at minimum provide approximation of parameter uncertainties (a posteriori error bars)

$$C_{po}^{-1} = \partial^2 J(x_{po}) / \partial x^2$$

- Uncertainties on target quantities (e.g. NEP) via linearisation of model (Jacobian matrix)

$$C_{NEP} = \partial M / \partial x \; C_{po} \; \partial M / \partial x^T$$

- All derivatives provided via automatic differentiation of model code (TAF, FastOpt)
-

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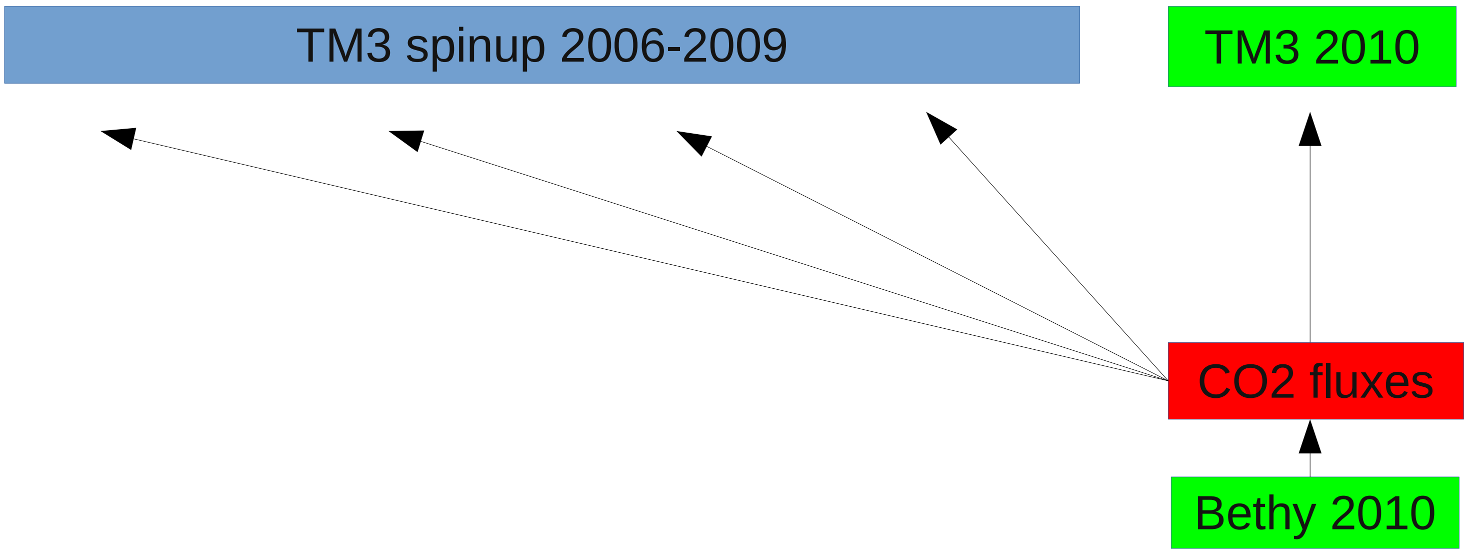
CCDAS setup

assimilation time: 2010
TM3 spinup: 4 years using Bethy 2010 fluxes



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Bethy (Knorr et.al 2010)

GPP:

C3 photosynthesis – *Farquhar et al. (1980)*

the Canopy is devided into 3 layers

Respiration:

autotrophic respiration = $f\,(N_{leaf}, T, frac_{leaf\text{-}plant})$ – *Farquhar, Ryan (1991)*

heterotrophic respiration = $r0 * w^{\kappa}\, Q_{10}^{\;T/10}$

Stomatal control:

stomatal conductance – *Knorr (1997)*

Soil respiration:

fast/slow pool respiration

temperature and soil moisture dependant

Energy and radiation balance:

PAR absorption - *Sellers (1985)*

diffuse radiation absorption - *Weiss and Norman (1985)*

evapotranspiration - *(Penman and Monteith (1965)*

Time step *1 hour*

grid *10°x8°*

TM3 (Heimann et.al. 2003)

- time step 1 month, using precomputed Jacobians
- spinup over 4 years
- fluxes used
  - land biosphaere (Bethy)
  - ocean fluxes (Takahashi + Lequere et al. 2007)
  - fossil fuel fluxes
  - fire flux patterns (Scholze, for transcom regions)
  - land use change (GCP 2010 carbon budget + factors from Houghton 2008)
- forced by meteorological fields
- observation operators (matrices) have been precomputed
  - assuming CO2 zonally mixed after 1 month
  - assuming CO2 globally mixed after 4 years

Data and uncertainties

- CO_2 fluxes from 10 **FluxNet** stations
  - stations: asc,brw,gmi,key,kum,mlo,nwr,psa,smo,spo
  - used monthly means
- **SMOS** L3 daily soil moisture product
  - CATDS L3, 2012, version 246
  - filtered, regridded (Bethy grid 10°x8°, 1h)
  - data inside one grid cell are fully correlated
  - otherwise no correlation in space and time
  - Bias correction of avarage mean and standard deviation
- Column integrated CO_2 (**XCO2**)
  - Bremen Optimal Estimation DOAS (BESD, v02.00.04, Reuter et.al. 2013)
  - regridded (TM3 grid 5°x4°, monthly)
  - uncorrelated in space and time
- Fraction of Absorbed Photosynthetically Active Radiation (**FAPAR**)
  - Effective LAI and FAPAR with uncertainties retrieved by applying TIP to white-sky albedos of GlobAlbedo (Product V1.1, GlobAlbedo_Albedo_ATBD_V3.0, 2011)
  - regridded (Bethy grid 10°x8°, 1h)

Parameter and uncertainties

- 4 Bethy parameters for each of 13 Plant Functional Types (PFT)
- 13 Bethy parameters for different PTFs
- 2 Bethy parameters for 6 soil texture classes
- 23 global Bethy parameters
  - photosynthesis
  - energy and radiation balance
  - stomatal control
  - carbon balance
- initial atmospheric CO2 concentration
- = **101 parameters**

Uncertainties

- mostly between 5% and 25%, some up to 100%
- initial atmospheric CO2 concentration 374ppm +- 1ppm

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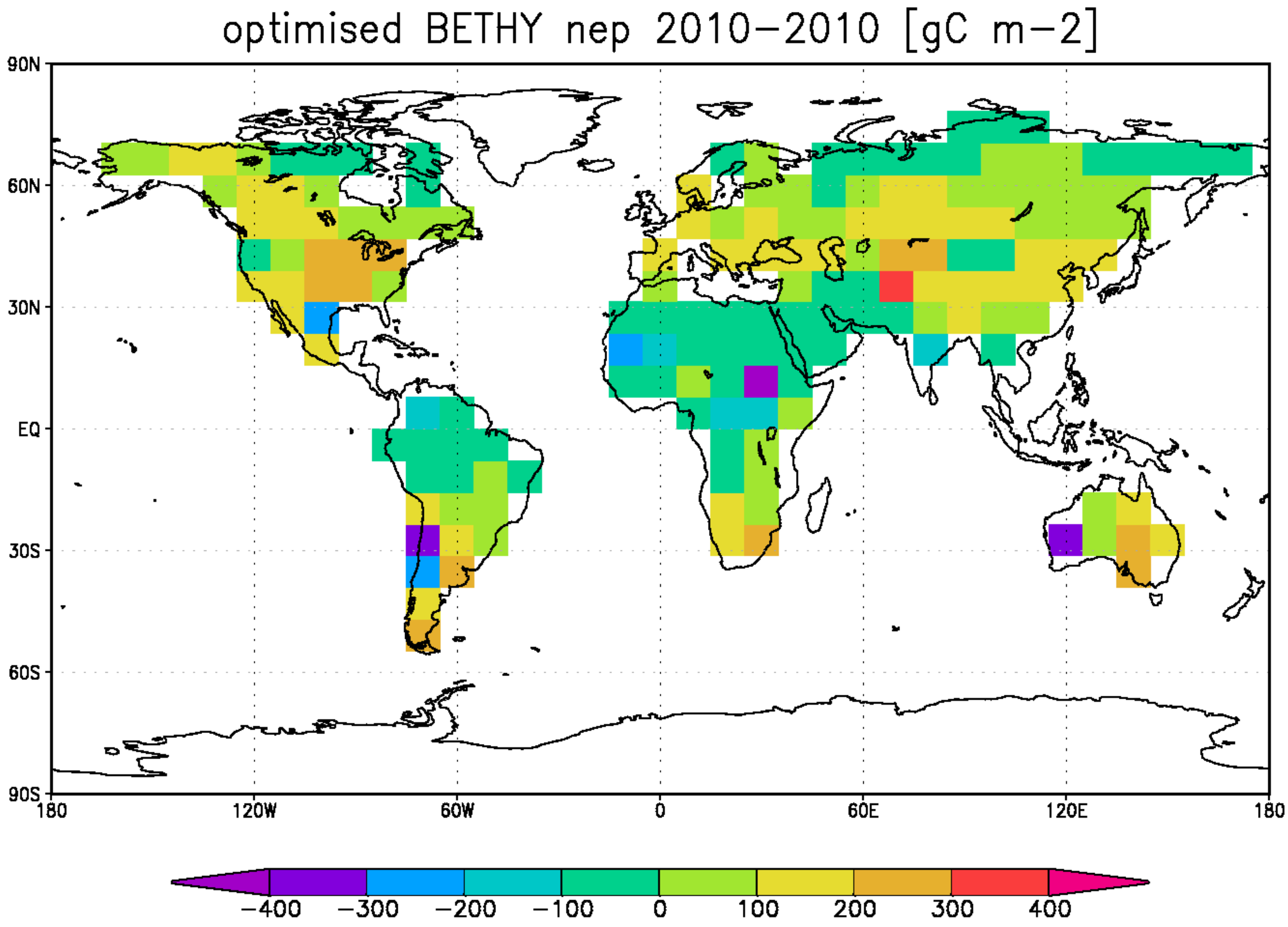
Results



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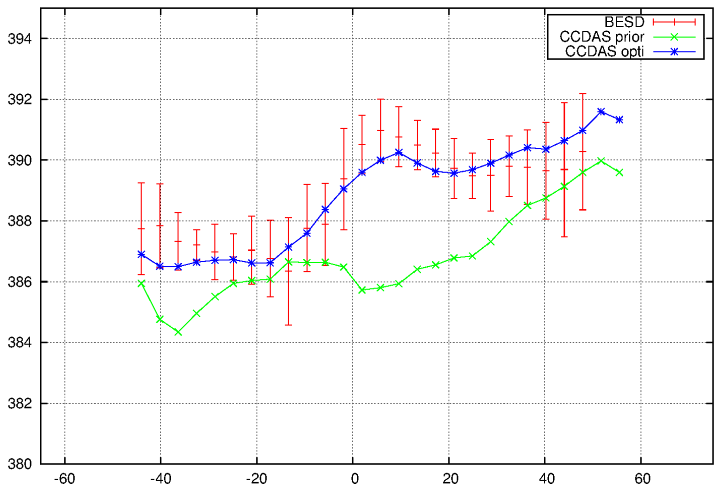
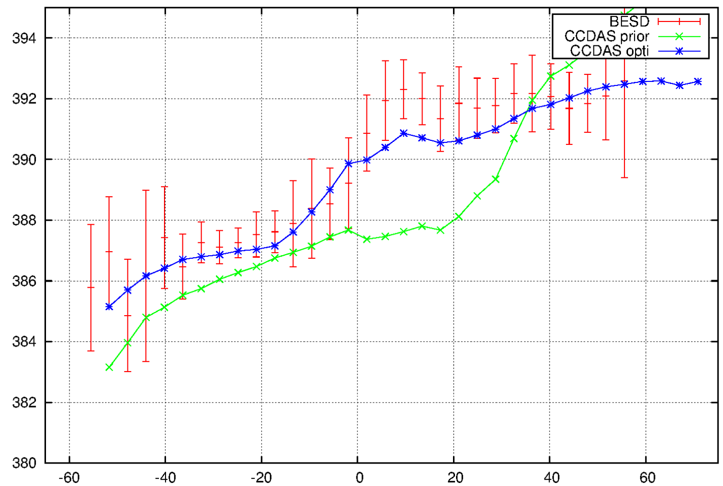
XCO2 zonal mean, all data

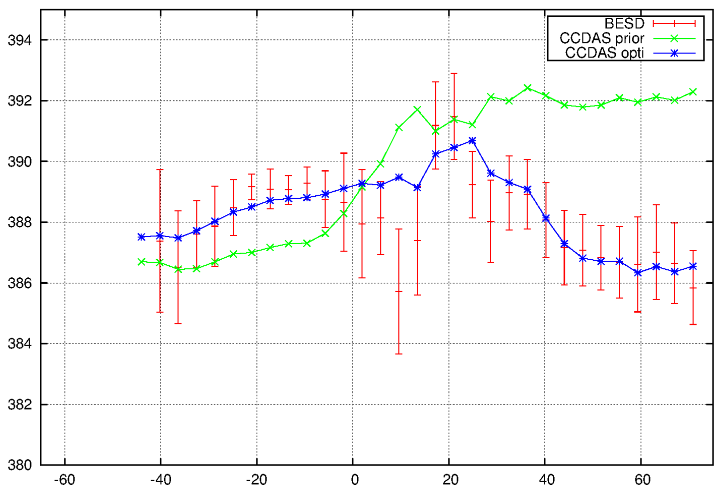
XCO2 zonal mean in DJF



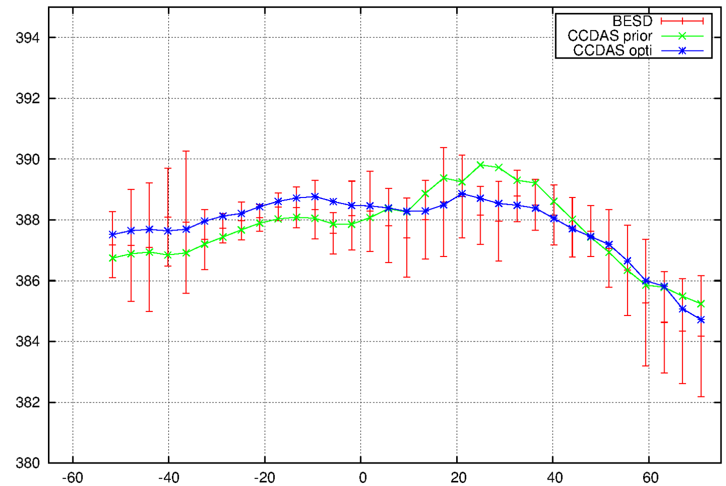
XCO2 zonal mean in MAM



XCO2 zonal mean in JJA



XCO2 zonal mean in SON



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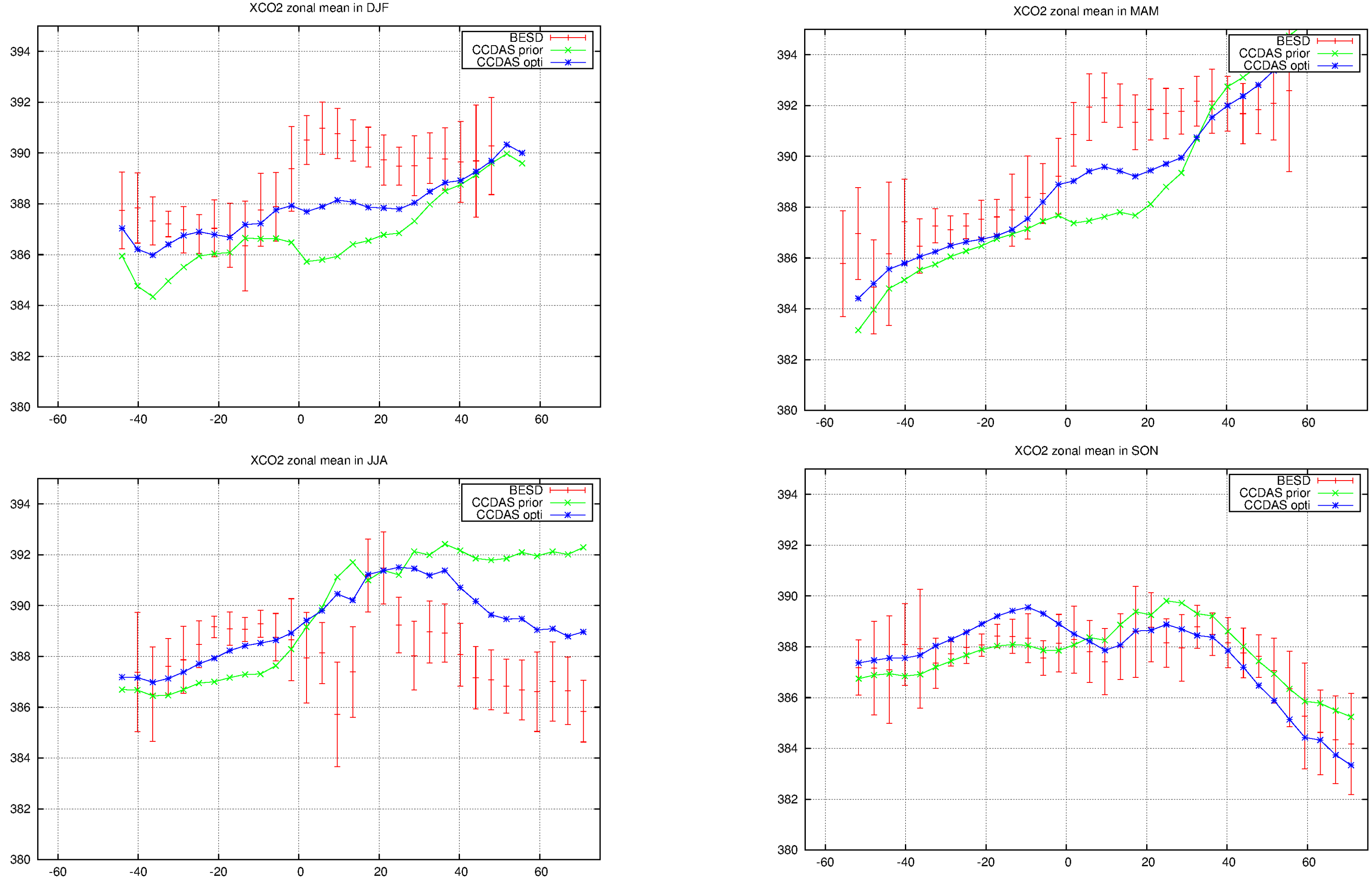
XCO2 zonal mean, no XCO2



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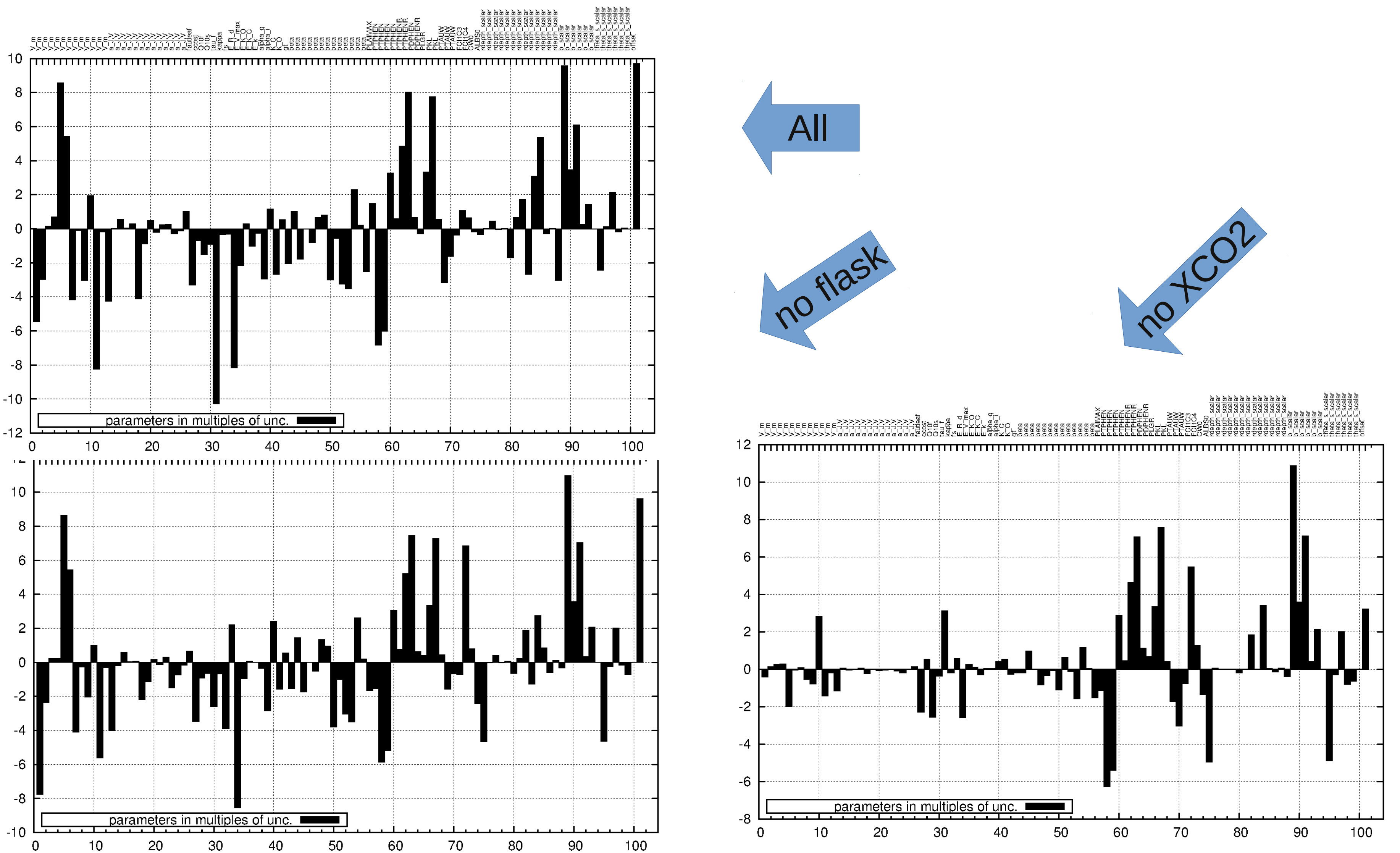
Rel. parameter change



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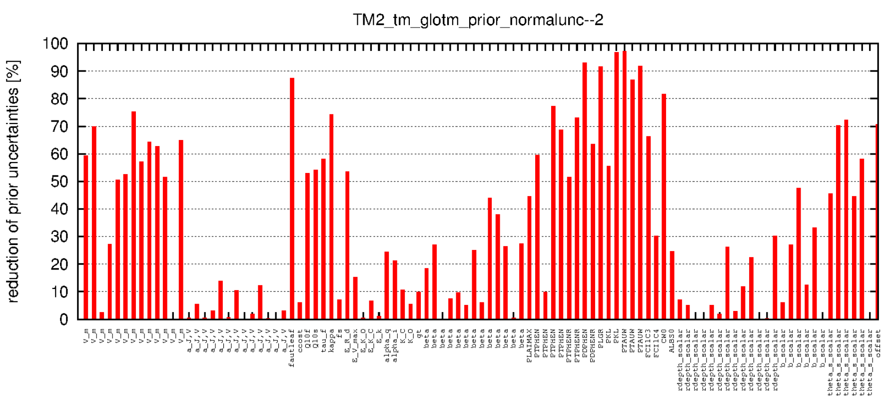
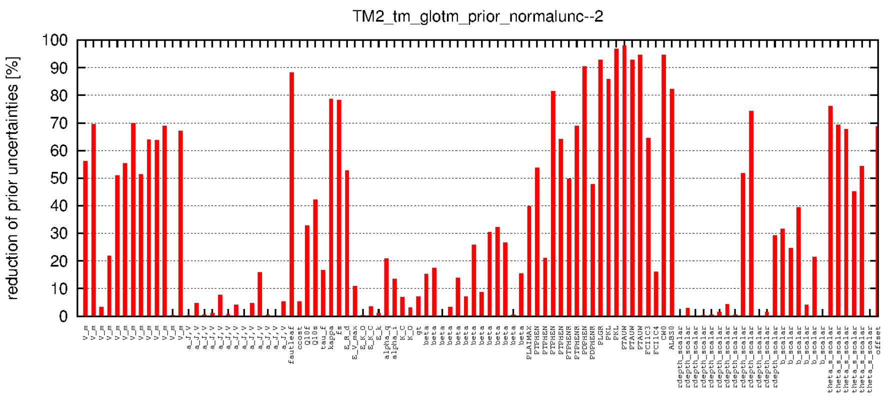
Parameter Uncertainty reduction

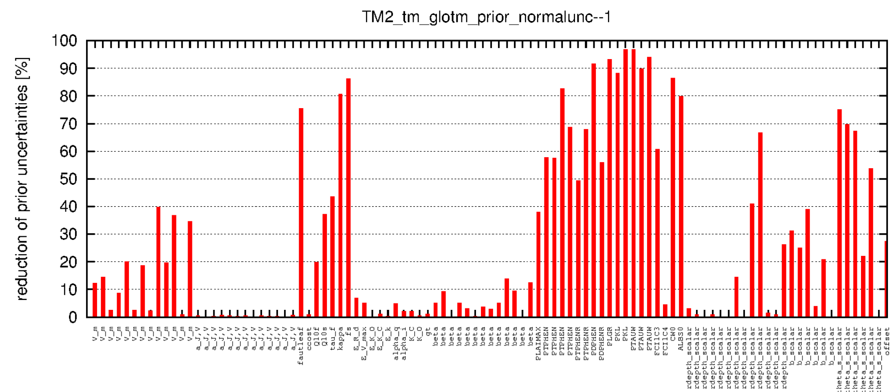


All

no flask

no XCO2





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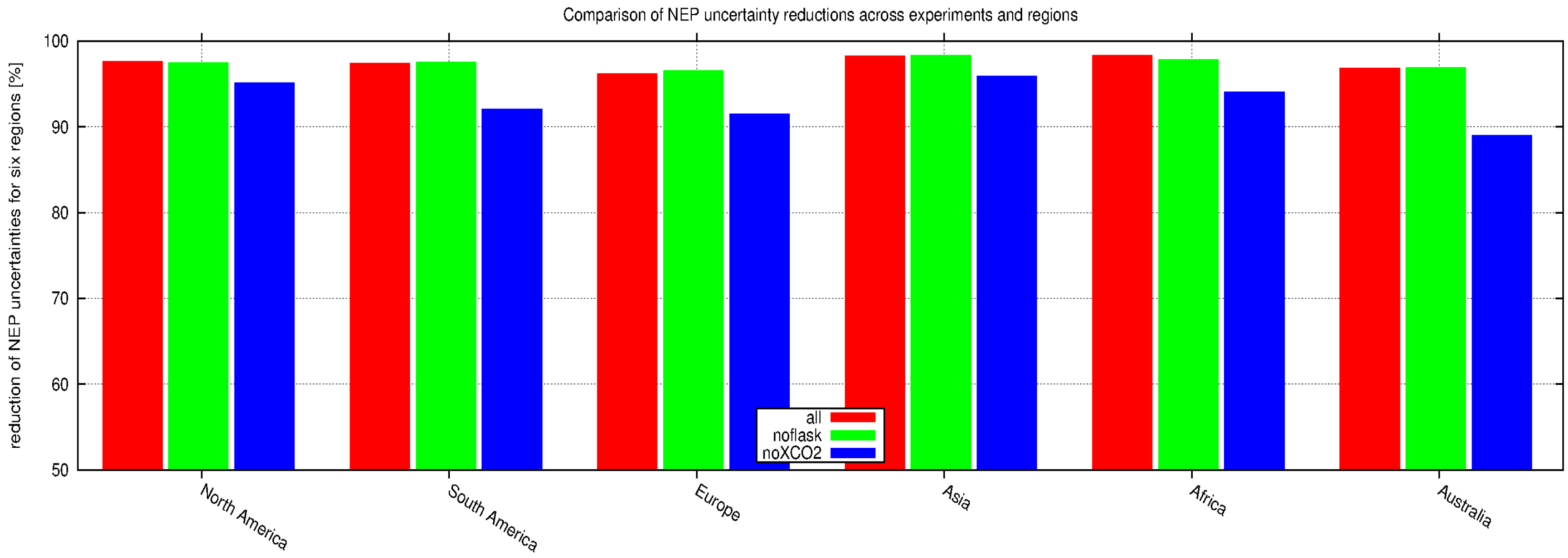
NEP



Comparison of NEP uncertainty reductions across experiments and regions
reduction of NEP uncertainties for six regions [%]
100
90
80
70
60
50
all
noflask
noXCO2
North America
South America
Europe
Asia
Africa
Australia

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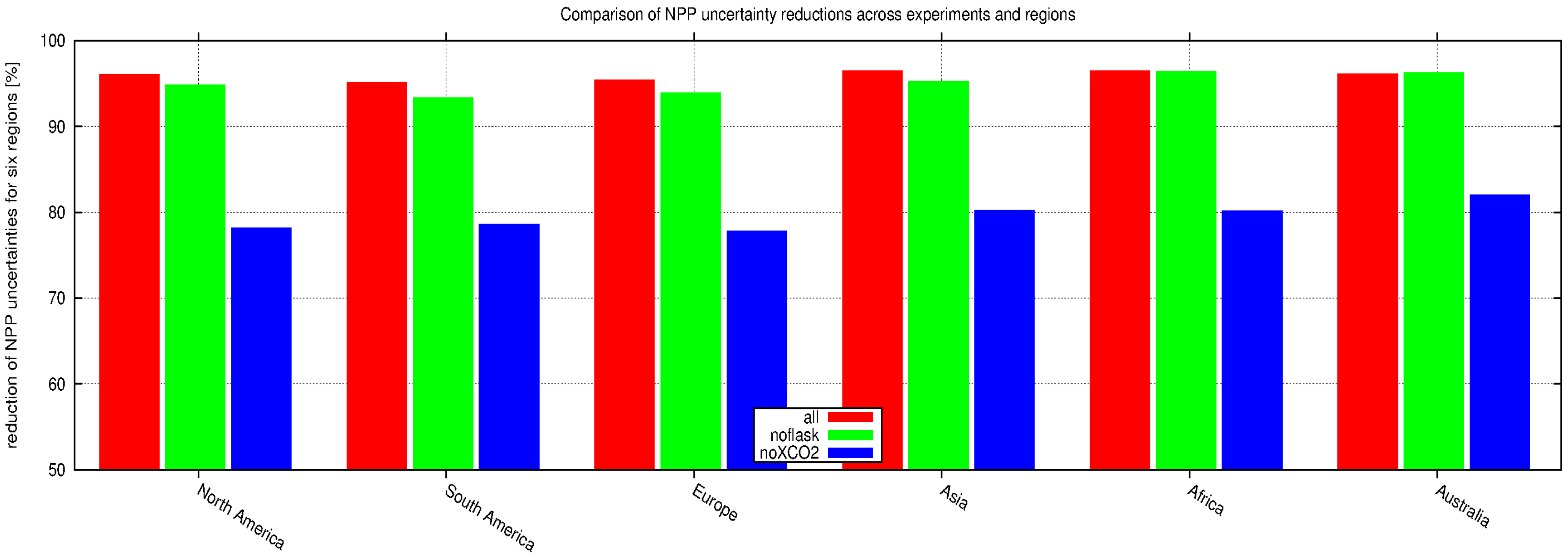
NPP


Comparison of NPP uncertainty reductions across experiments and regions
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100
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North America
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Summary and Conclusions

- Column integrated CO2 measurement successfully assimilated
  - Information content larger than FluxNet flask
- Very flexible Data Assimilation System
  - consistent assimilation with respect to uncertainties
  - Can assimilate additional data by adding a term to the cost function
- Results with posterior error estimates
  - uncertainties and their correlation
  - values and uncertainties for target quantities (NEP, NPP)
- Impact of new data streams can be evaluated

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Outlook

- assimilate leaf area index (LAI)
- extend assimilation window
- improve soil moisture simulation