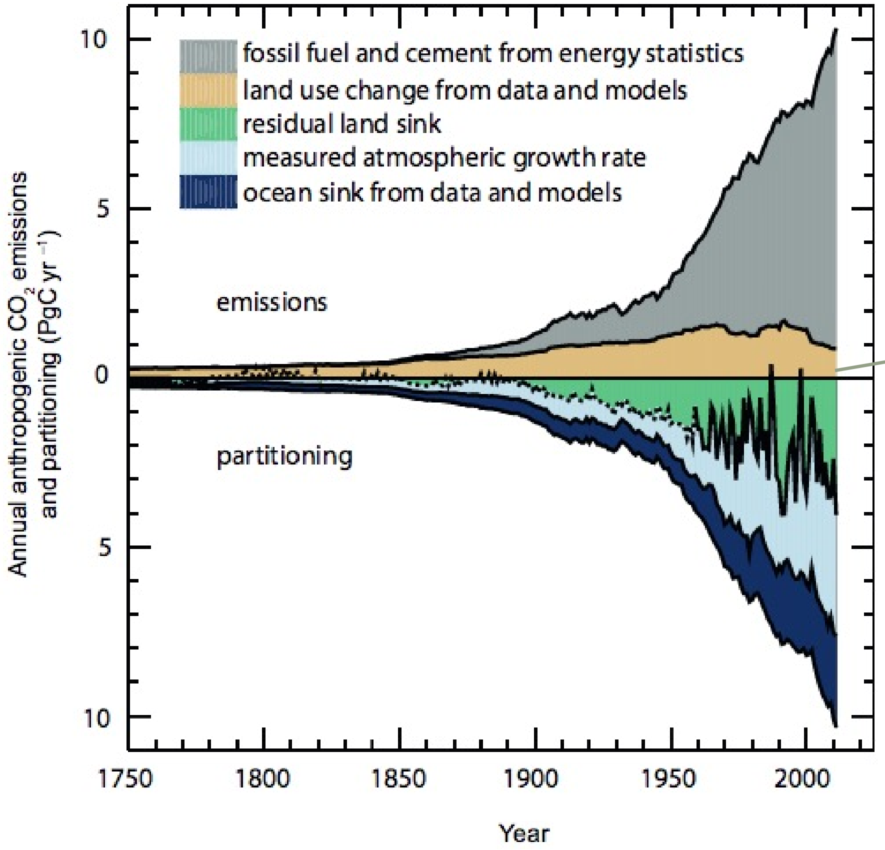
Joint CO-CO_2 inversion setup and first simulations

NARCISA NECHITA-BANDA, MAARTEN KROL, SOURISH BASU

Motivation



Land CO_2 fluxes

- 122.0 Pg C/yr   Photosynthesis

115.8 Pg C/yr   Respiration

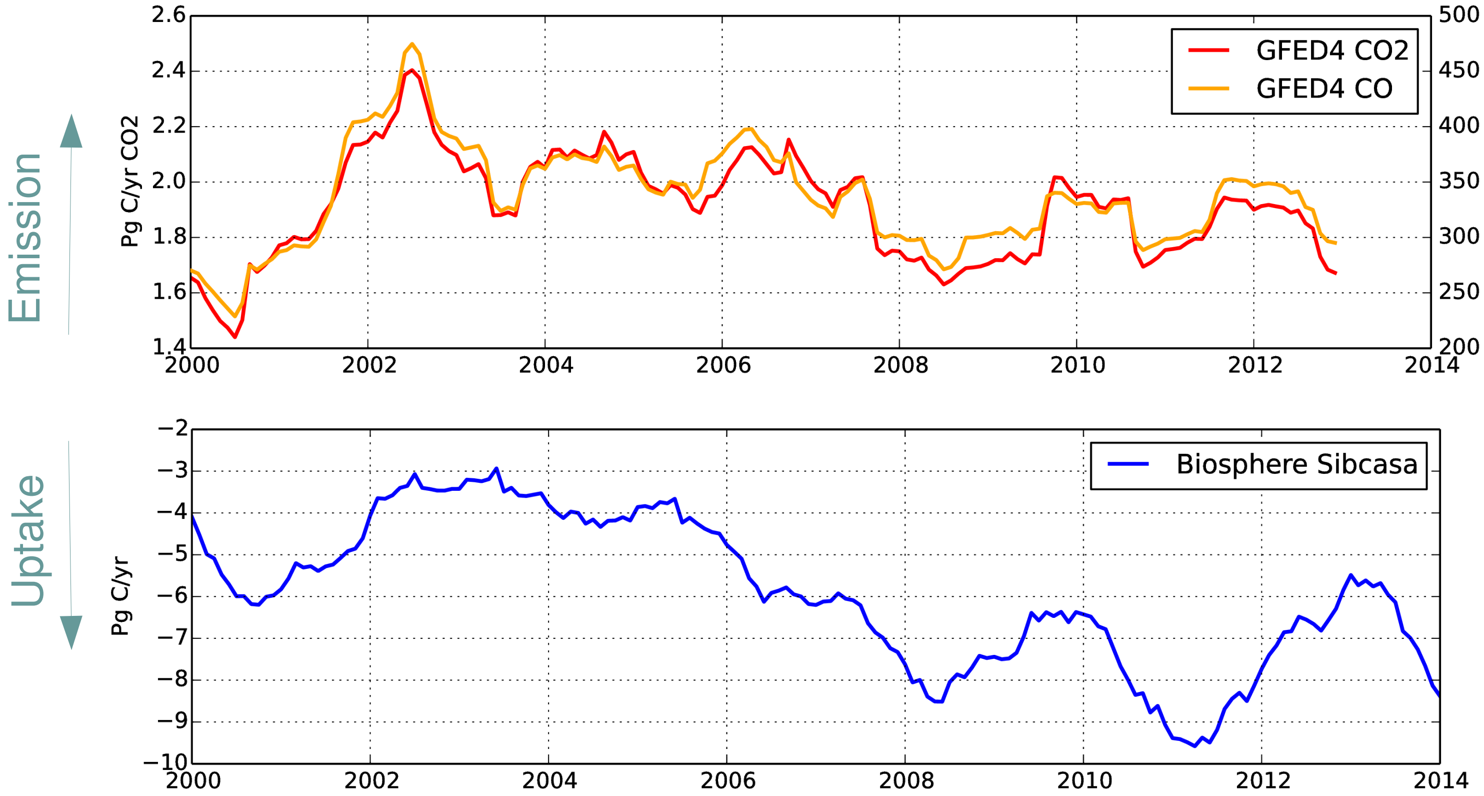
2.0 Pg C/yr   Biomass burning

- 4.3 Pg C/yr   Net

CO_2 biosphere and biomass burning

Anti-correlation between global biomass burning emissions and biosphere uptake
-> both climate driven

Can we use satellite data to quantify these contributions to the CO_2 budget?



CO for constraining biomass burning

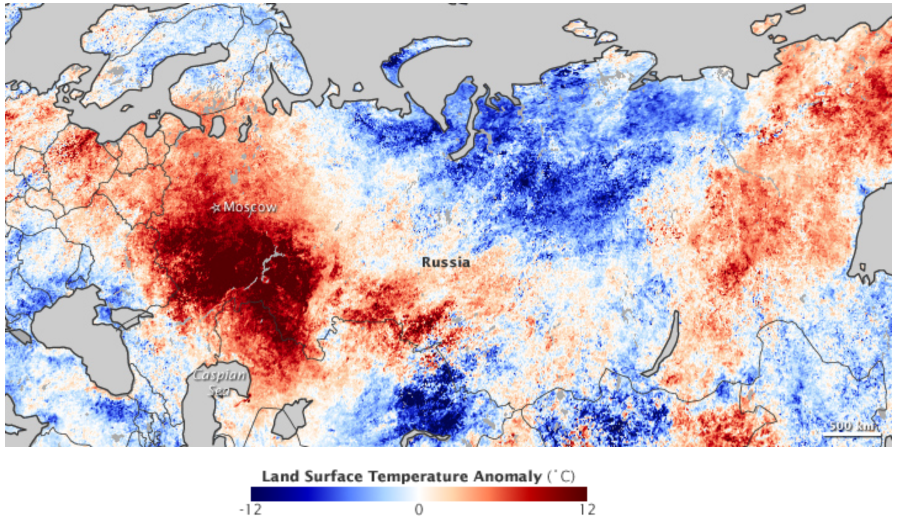
- well known tracer for biomass burning
- lifetime of weeks to months
- data available from ground stations
- satellite data:
  - IASI TIR since 2006
  - MOPPIT TIR/NIR since 2000
  - TES TIR since 2004
  - SCHIAMACHI NIR 2002-2012
  - TROPOMI to be launched in 2016

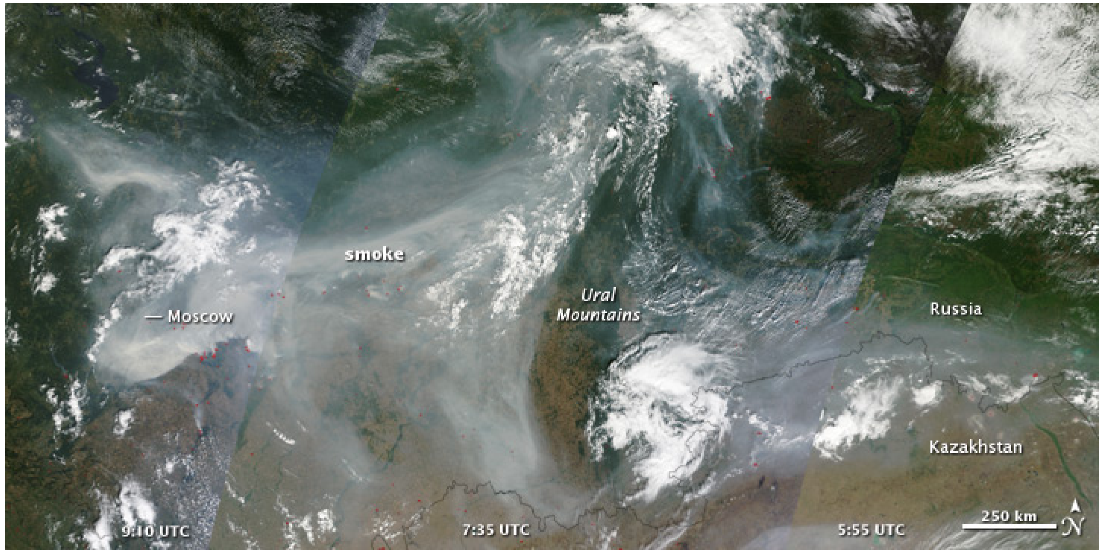
Source	Tg CO
Anthropogenic	500
Biomass burning	**350**
Natural	100
Oxidation of CH_4	770
Oxidation of NMVOC	730
Sink	
Soil deposition	150
Oxidation by OH	2300

from EDGAR4.2, GFED4 and Shindell et al. (2006)

Example: 2010 heat wave in Russia

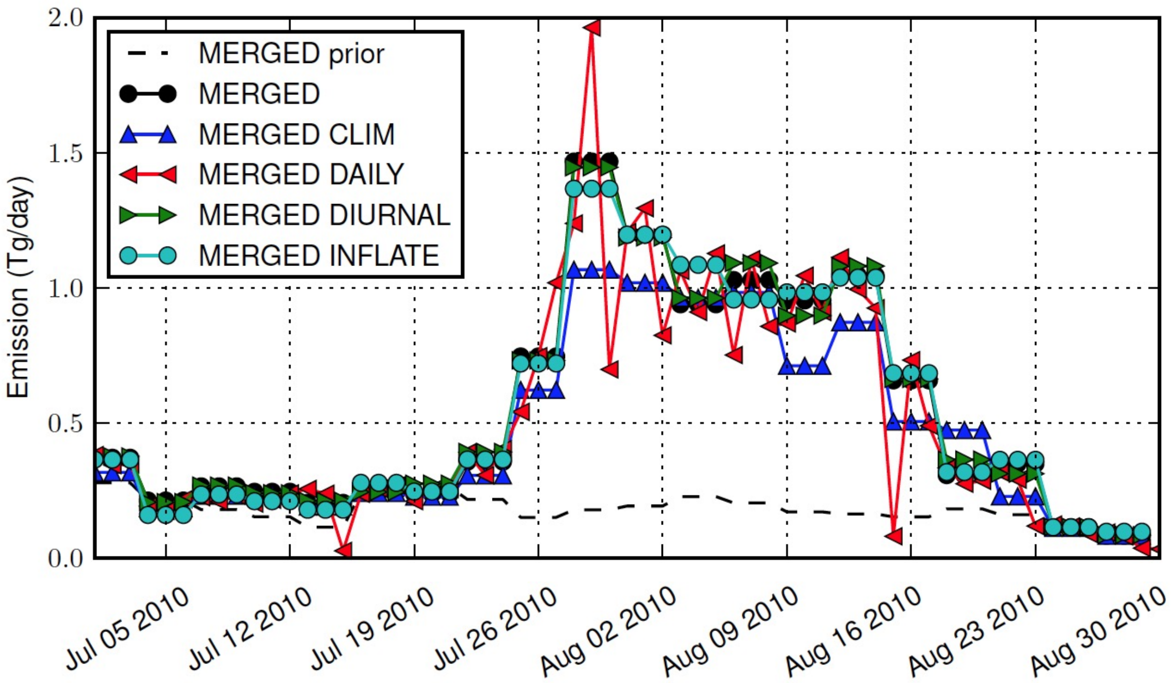
Temperature anomaly July 20-27 2010





from MODIS

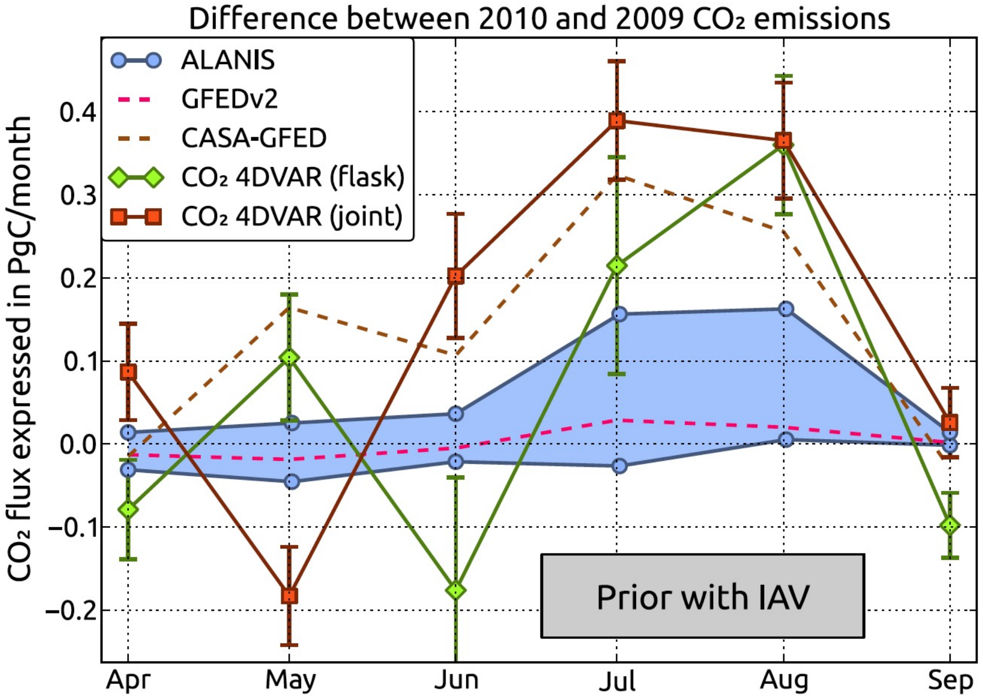
2010 Russia fires CO emissions



IASI data shows large CO emission over the region near Moskow during 26 July – 16 August 2010, with a total of about 24 Tg.

from Krol et al. (2013)

2010 Eurasia CO_2 land sink anomaly



from Guerlet et al. (2013)

Both surface and GOSAT satellite data point to higher emissions / lower uptake of CO_2 over Eurasia in the summer of 2010.

Alanis shaded area = the potential contribution of biomass burning, based on Krol et al. (2013) CO fluxes and the range of measured CO_2/CO ratios.

Joint inverse modelling system

$$J(x) = \tfrac{1}{2}(x - x_a)^T B^{-1}(x - x_a) + \tfrac{1}{2}(y - Hx)^T R^{-1}(y - Hx)$$

A priori emissions and error covariance matrix

Observations and observation covariance matrix

x = CO biomass burning emissions, CO_2 biosphere flux, (& CO/CO_2 bb)

y = CO and CO_2 observations

H = model operator, converting emissions into observations

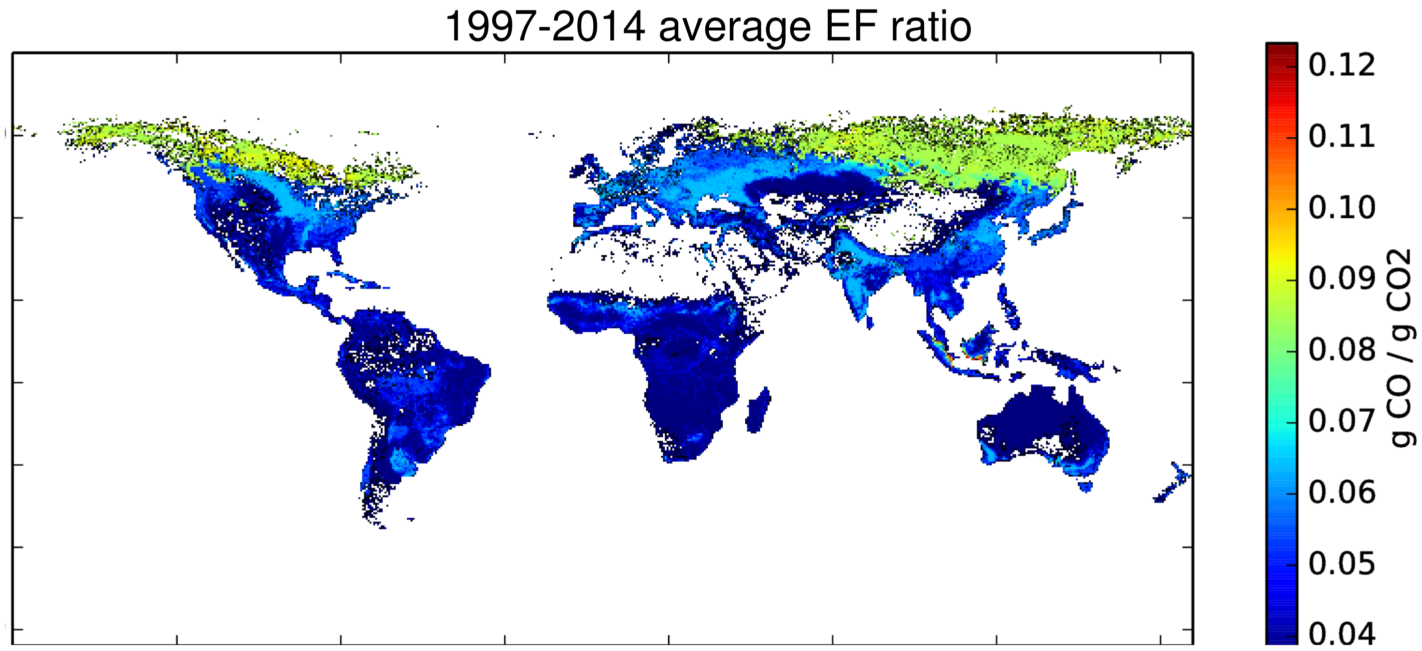
Emission factors

Biomass burning CO/CO_2 emission factors vary with:

- Biome
- Temperature, precipitation, wind

GFED4 emission factors

Biome	g CO / g CO_2
Tropical forest	0.056
Temperate forest	0.053
Boreal forest	0.085
Peat	0.123
Gras	0.037
Agricultural waste	0.065



Joint inverse modelling system

Alternatives:

x = CO biomass burning emissions, CO_2 biosphere flux, CO/CO_2 biomass burning

x = CO biomass burning emissions, CO_2 biomass burning, CO_2 biosphere

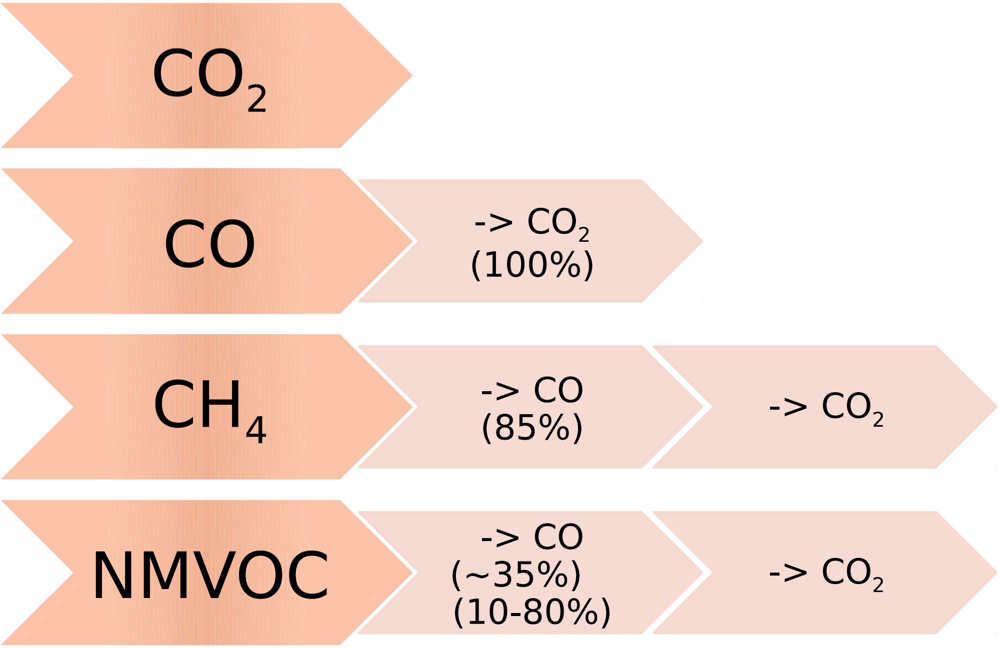
B – accounting for correlation between CO and CO_2 biomass burning

First steps

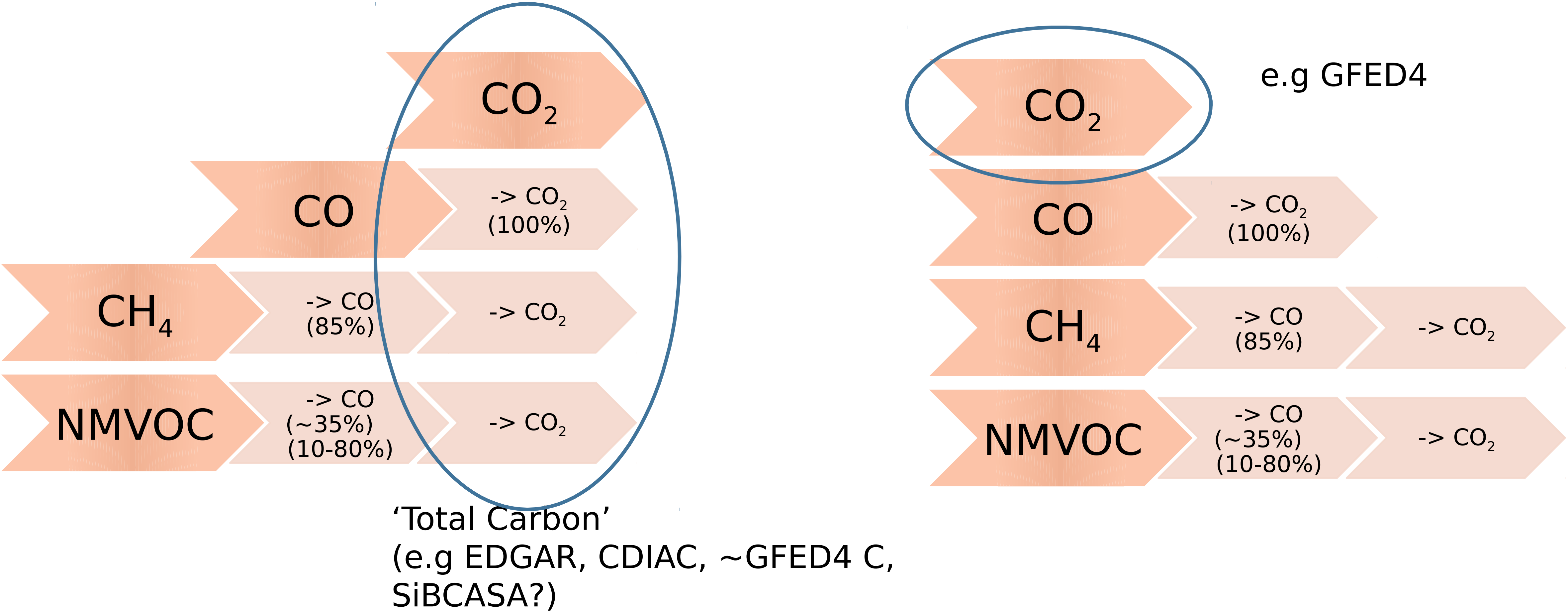
Take into account CO_2 production from CO oxidation CO+OH -> CO_2 (~1 Pg C / yr). Previously this CO_2 was assumed to be emitted at the source, not taking into account the transport in the atmosphere in the form of CO, CH_4 and NMVOC.

Find appropriate emission inventories… CO_2 emissions vs Total Carbon.

C emissions ending up as CO_2



What inventories give



Emission totals of non-CO_2 species

Source	Pg C Em	Pg C CO2/ yr
Fossil CO	0.21	**0.21**
Fossil CH_4	0.26	**0.22**
Fossil NMVOC	0.1	0.03
Biomass burning CO	0.15	**0.15**
Biomass burning CH_4	0.12	**0.1**
Biomass burning NMVOC	0.01	0.004
Biogenic CO	0.04	0.04
Biogenic CH_4	0.16	**0.13**
Biogenic NMVOC	0.7	**0.24**
TOTAL		**1.12**

Forward runs – Impact of CO_2 chemistry

CO_2-only vs Joint CO-CO_2 forward runs

Subtract contributions of non-CO_2 species from total carbon anthropogenic and biosphere fluxes

CO production fields from CH_4 and NMVOC from TM5-mp chemistry runs

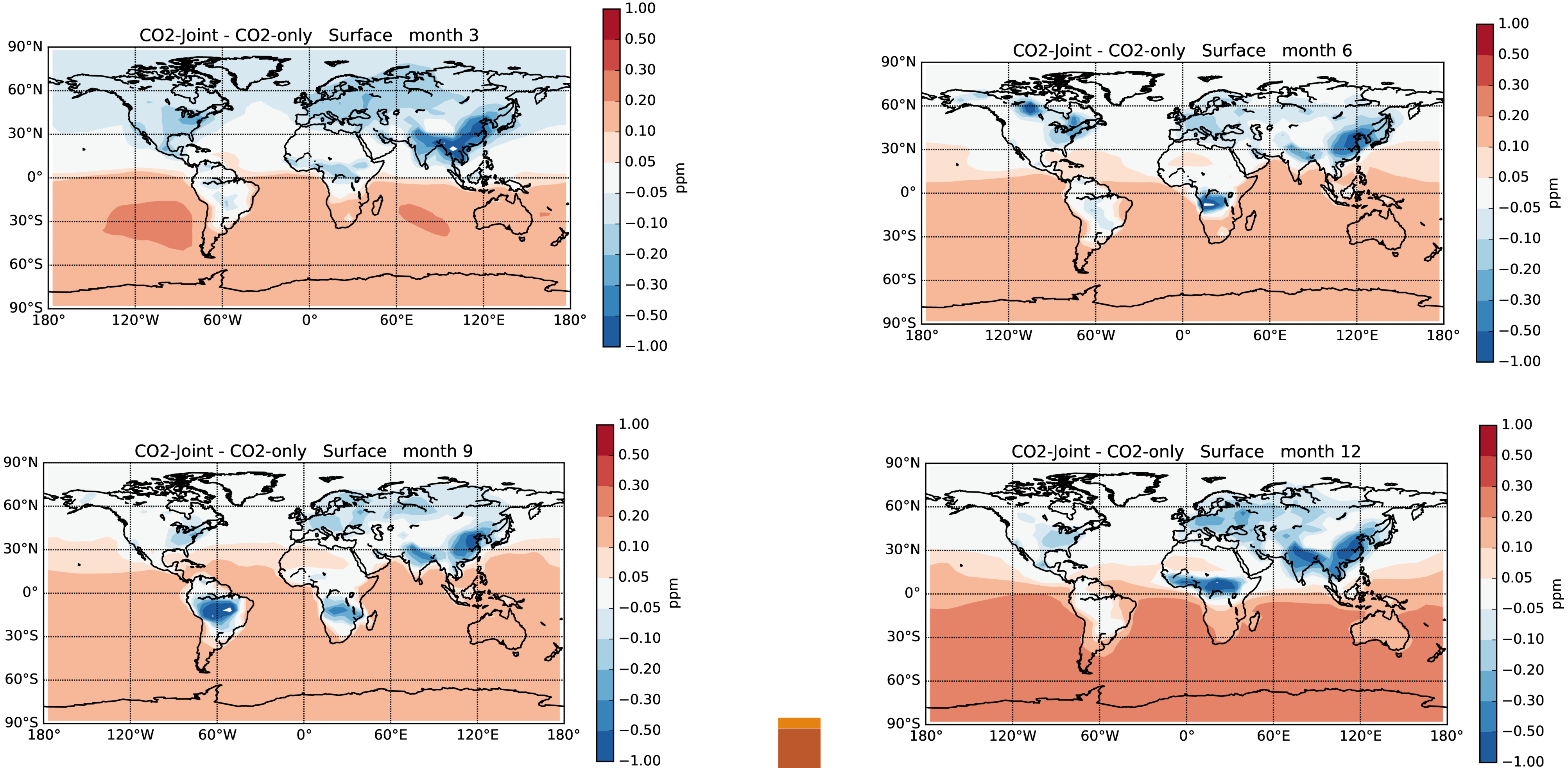
–> Small budget inconsistency (0.1 Pg/yr)

Resolution: glb 6x4

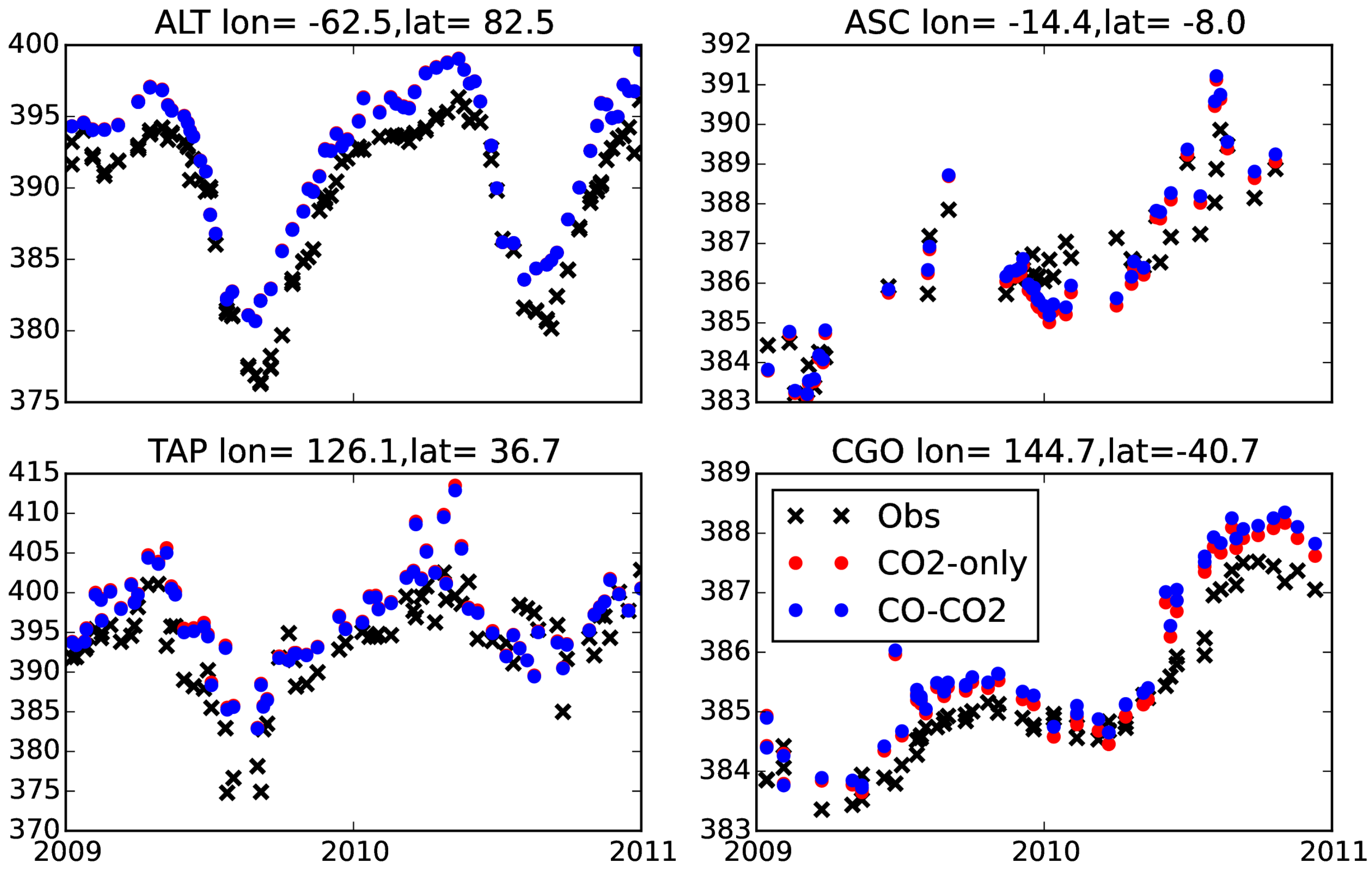
Period: 1 Jan 2009 – 1 Jan 2011

Emission inventories: EDGAR4.2, GFED4, SiBCASA

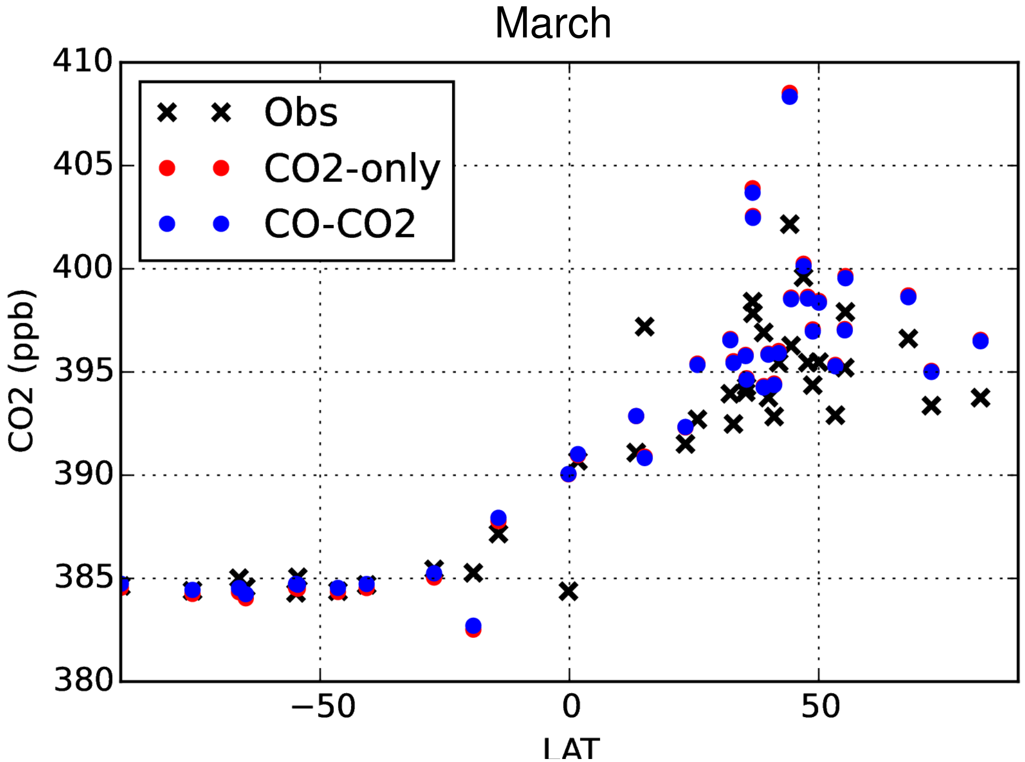
Forward runs – Impact of CO_2 chemistry

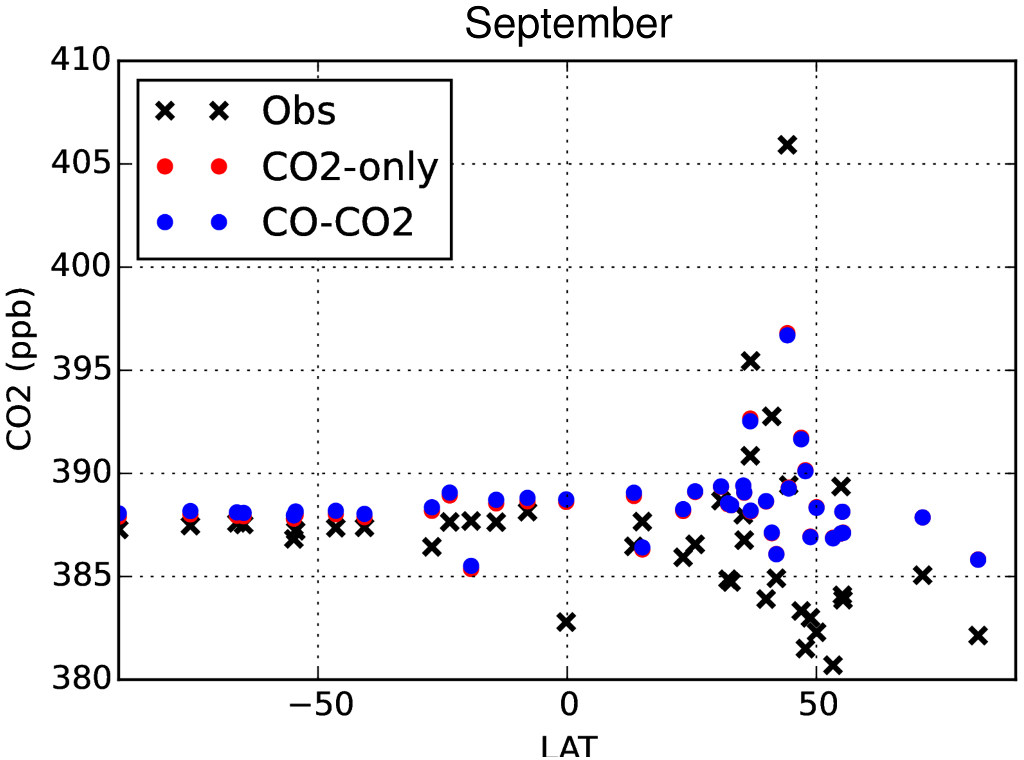


Forward runs – Impact of CO_2 chemistry



Forward runs – Impact of CO_2 chemistry





Summary

We are developing a system to separate the CO_2 biosphere and biomass burning fluxes using CO as a tracer for biomass burning.

~1 PgC/yr is emitted as CO, CH_4 and NMVOC and is then converted to CO_2 in the atmosphere. Taking this into account leads to up to 1 ppm lower CO_2 concentrations in emission areas and 0.1-0.2 ppm higher in SH background.

Next steps

- Use CO production based on formaldehyde satellite data
- Optimize for CO/CO_2 emission factors or optimize parameterization coefficients
- Test the system by performing OSSE (Observation System Simulation Experiment)
- Take into account that transport model errors for CO and CO_2 are correlated (non-diagonal R matrix)

Emission factors

Biomass burning CO/CO_2 emission factors vary with:

- Biome
- Temperature, precipitation, wind

$$\text{CO EF} = 54.710 + 0.6106 \times \text{FTC} + 0.015 \times \text{NDVI} + 0.0041 \times \text{MMP} - 0.7884 \times \text{MAT} + 0.0019 \times \text{MAP} + 0.8577 \times \text{LDS} + 0.4221 \times \text{MMT}$$

–> optimize regression coefficients

from van Leeuwen et al. (2013)