High resolution transport modeling of CO_2 sources and sinks and comparison with continuous observations in Europe

A.T. Vermeulen (ECN, NL)

R. Rodink (ECN, NL)

W. Peters (WUR, NL)

B. Thiruchittampalam (IER, D)

G. Pieterse (TNO;UU;ECN, NL)

Presented at the 8th International Carbon Dioxide Conference, September 13-19 2009, Jena, Germany

ECN-M--09-124 September 2009

High resolution transport modeling of CO_2 sources and sinks and comparison with continuous observations in Europe

A.T. Vermeulen[1], R. Rodink[1], W. Peters[2], B. Thiruchittampalam[3], G. Pieterse[4]

1: ECN, NL
2: WUR, NL
3: IER, D
4: TNO;UU;ECN, NL

Introduction

In this work we use two high resolution transport models (resolution 0.1° lat/lon; COMET, Lagrangian and WRF/CHEM v3, Eulerian) to describe the CO_2 concentration changes at continuous observation points due to emissions and uptake by ocean, biosphere and fossil fuel emissions at the diurnal timescale. The time period for the simulations is 14 April 2008-30 June 2008. The presented results are preliminary, work is still in progress.

The challenge

Tracking carbon emissions and net biospheric uptake in the heterogeneous continental regions using observational data (whether in-situ or satellite) will require detailed and accurate transport models. The resolution of models and data in space and time should match. As soon as these conditions are met, inverse exercises and data assimilation that use observations to improve our estimates of carbon uptake and emissions can be applied at the regional/local scale.

Observational and emission data

Observational data for the hourly concentrations is used at the tall towers:

-Cabauw (CBW, Netherlands: 51.92°N 4.97°E),
-Lutjewad (LUT, Netherlands: °N °E) and
-Hegyhatsal (HUN, Hungary: °N °E).

CBW is a site with a mixture of strong local influences of fossil fuel sources, managed grassland uptake and peat degradation respiration. Lutjewad is a coastal site and does not have the strong fossil fuel local influences. Hegyhatsal is a continental site with little fossil fuel influence and a strong biospheric signal.

The emission data tested in the models are:

-IER fossil fuel emission data (res. 0.1°, hourly) [1]
-Edgar v4 (res. 0.1°, using IER time functions) [2]
-Takahashi ocean uptake (res. 2°, update 2009) [3]
-FACEM biospheric fluxes (res. 0.1°, hourly) [4]
-SIB3 biosphere fluxes (res. 1°, hourly) [5] outside Europe

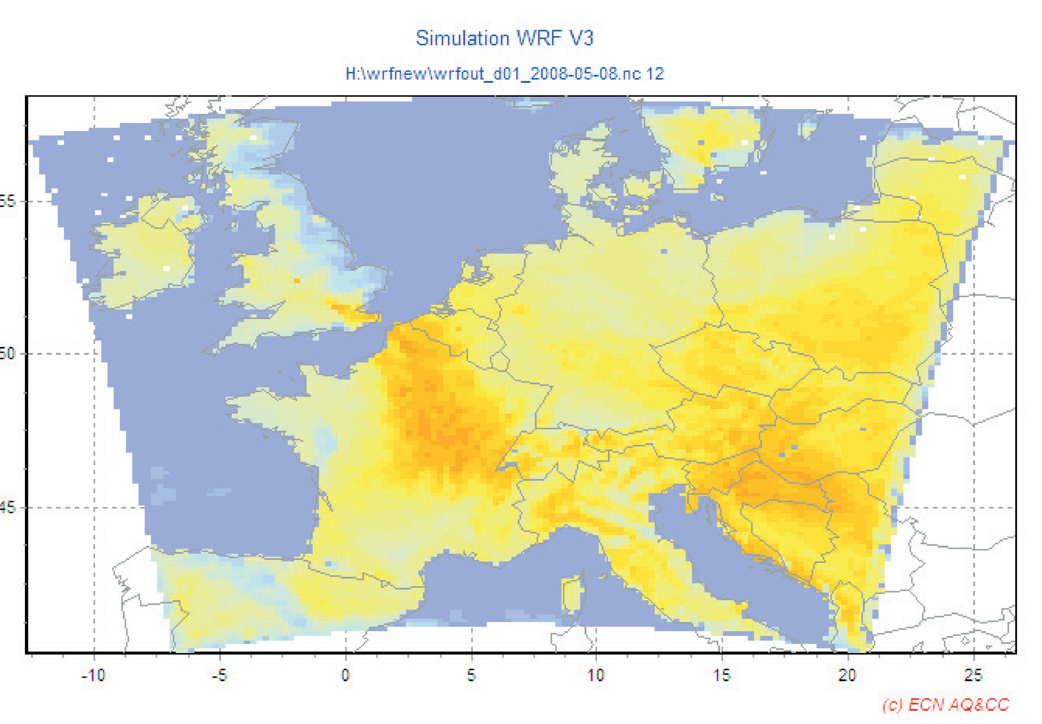
Bounday and initial conditions for the CO_2 mixing ratio were taken from a simulation by CarbonTracker Europe [6] (non-optimized) for the time period considered.

Models

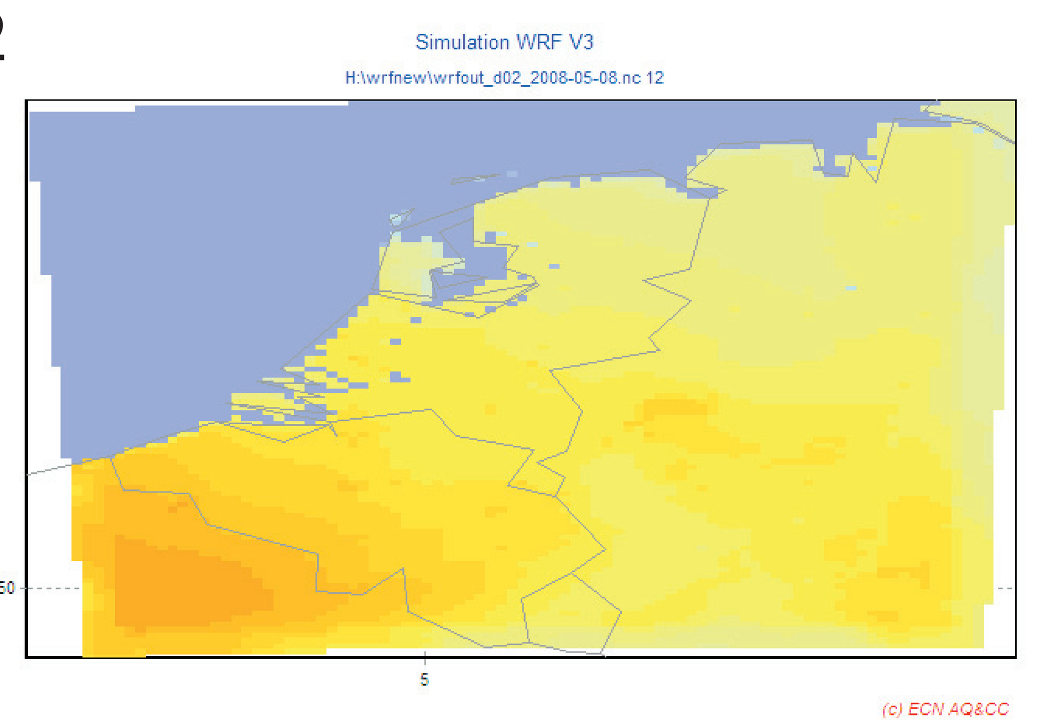
The COMET [7] model is a lagrangian two-box model, driven by FLEXTRA 3d trajectory data, calculated here from 0.5° resolution ECMWF met. fields. The model domain is NW-Europe

The WRF-CHEM v3 model is the well known community mesoscale eurlerian model, here driven by ECMWF 0.2° resol. met. fields (3-hourly). We used two zoomed domains: Outer domain (W-Europe) horiz. resol. is 15 km, inner domain is the Benelux area, horiz. resol. is 5 km. (Fig 1 and 2)

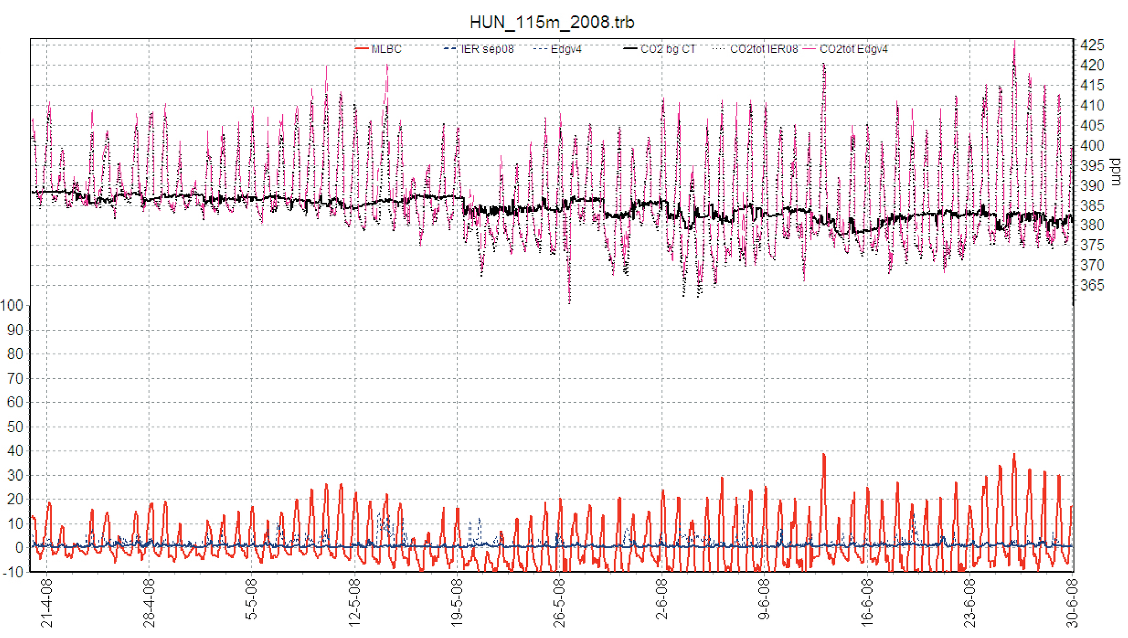
1



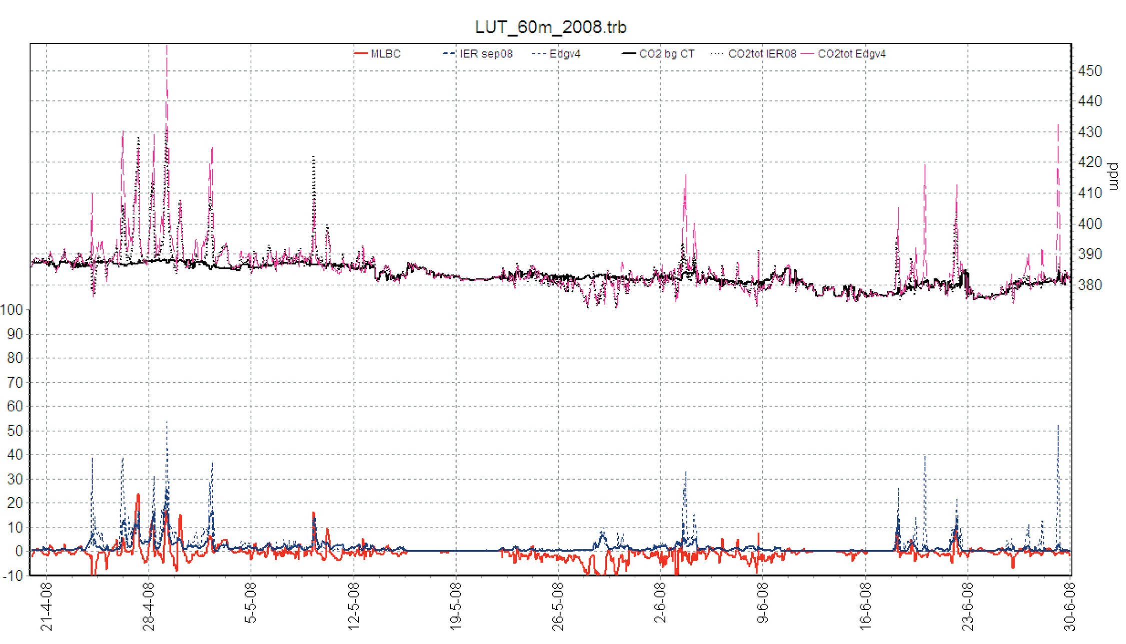
2



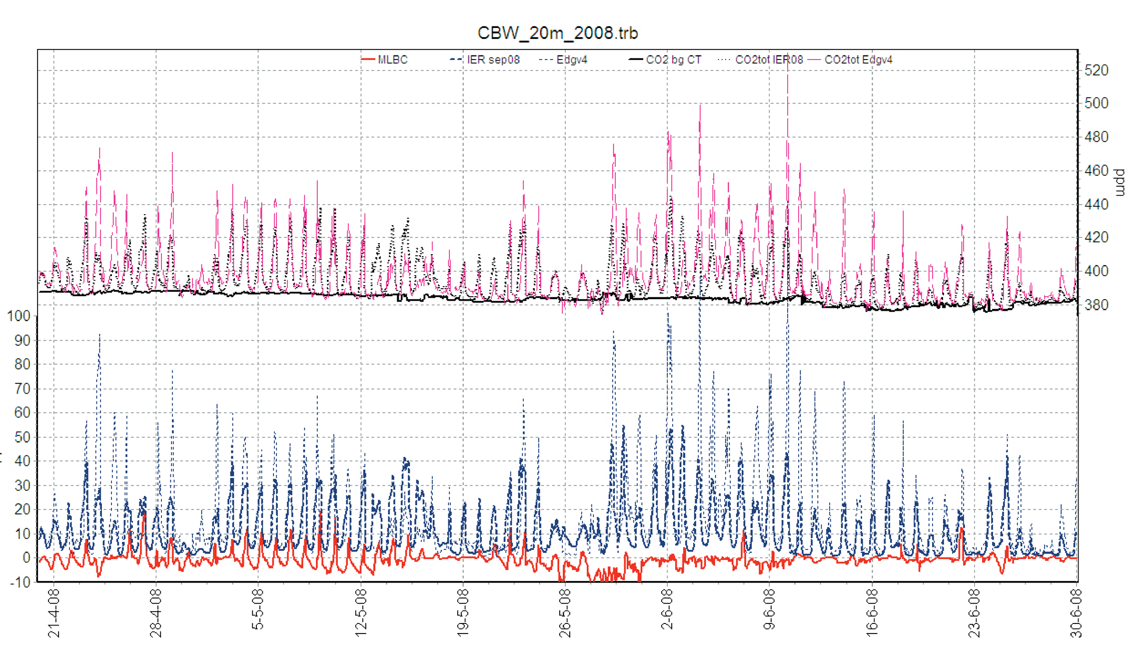
3



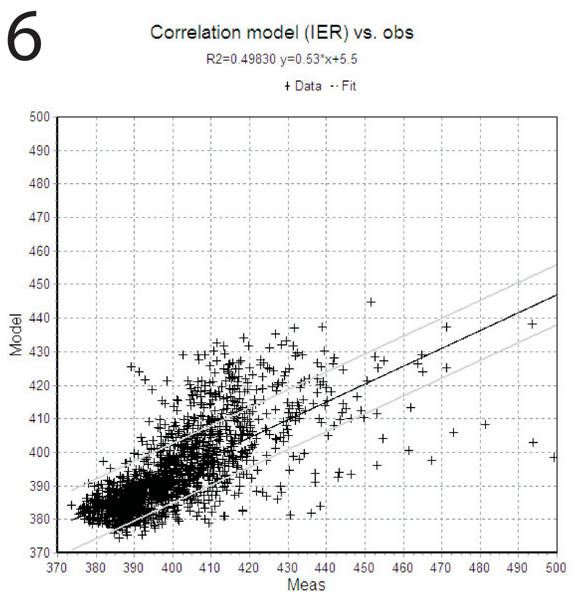
4



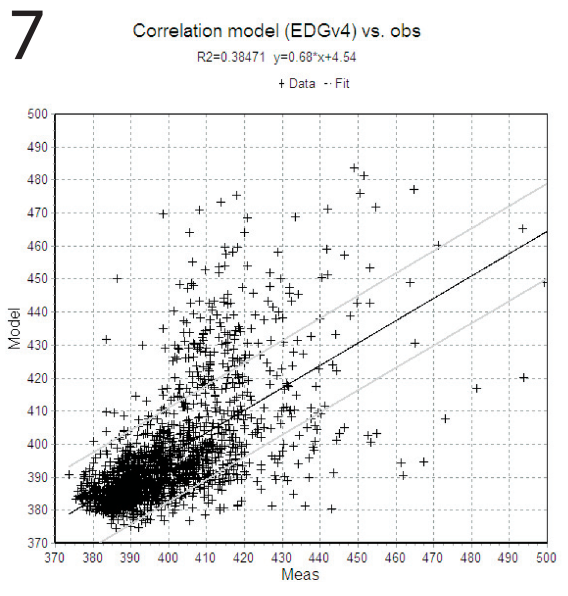
5



6

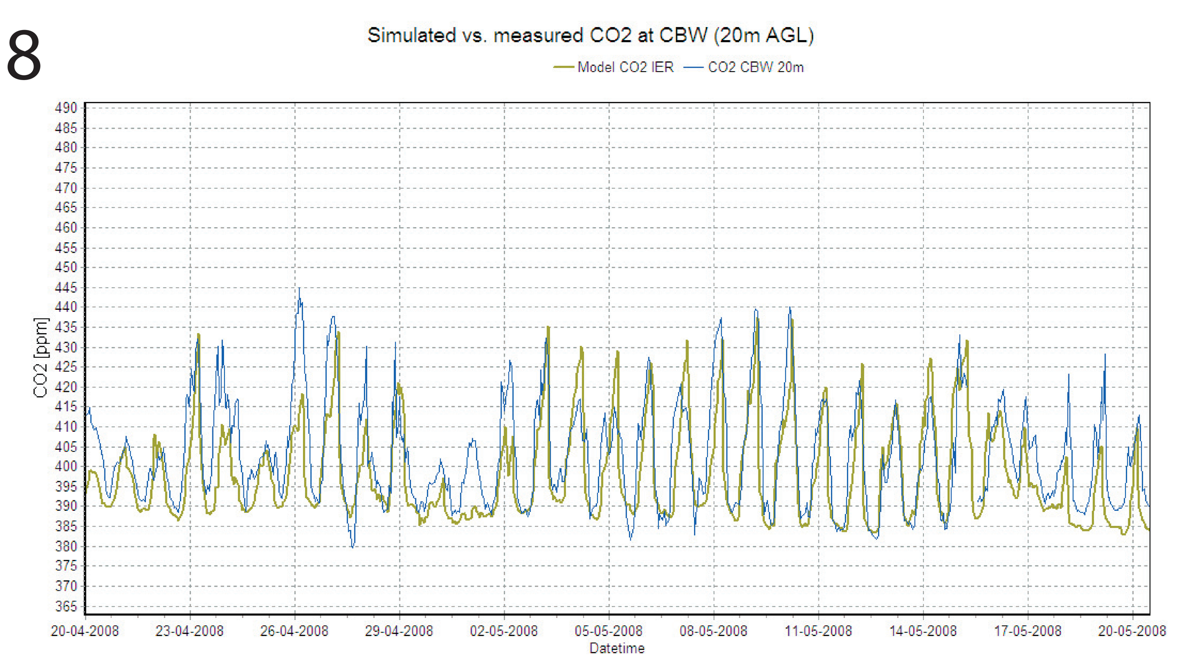


7

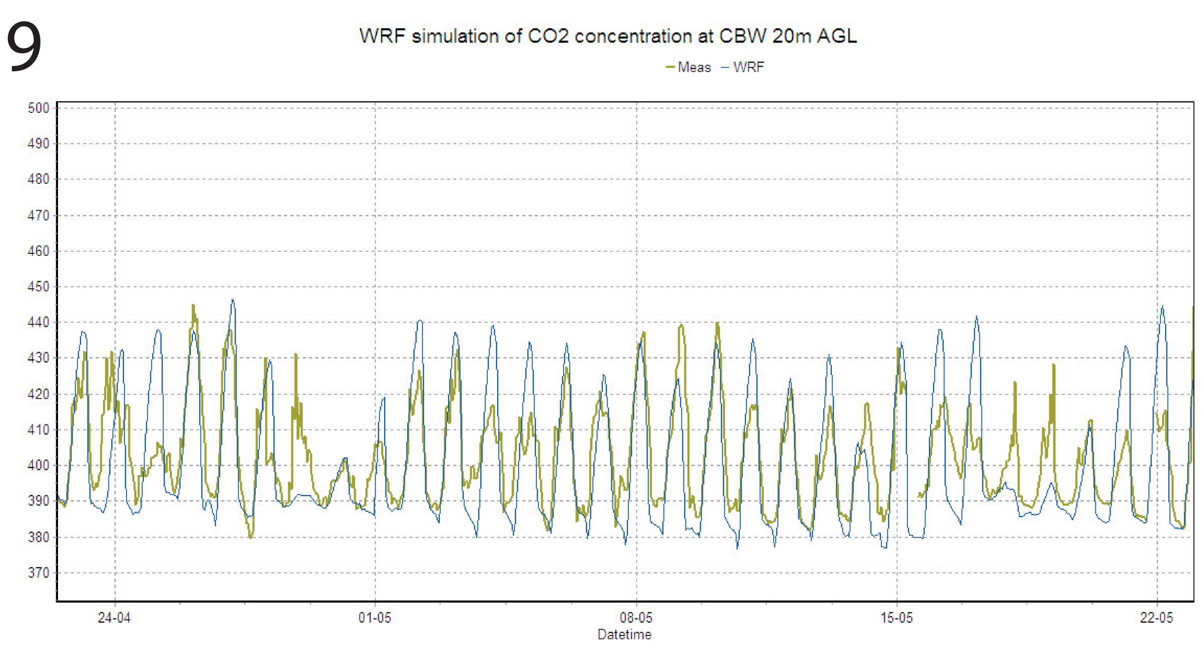


Station:	CBW			HUN		LUT	
Model:	WRF	COMET	COMET	COMET	COMET	COMET	COMET
Fossil Fuel:	Edgv4		IER	Edgv4	IER	Edgv4	IER
R2	0.490	0.407	0.498	0.557	0.571	0.125	0.063
RMSE	13.4	14.0	8.9	7.3	7.0	7.6	6.5
BIAS	0.4	-3.3	-6.3	-11.0	-12.0	-12.2	-12.9
Slope	0.98	0.70	0.53	0.38	0.38	0.30	0.18

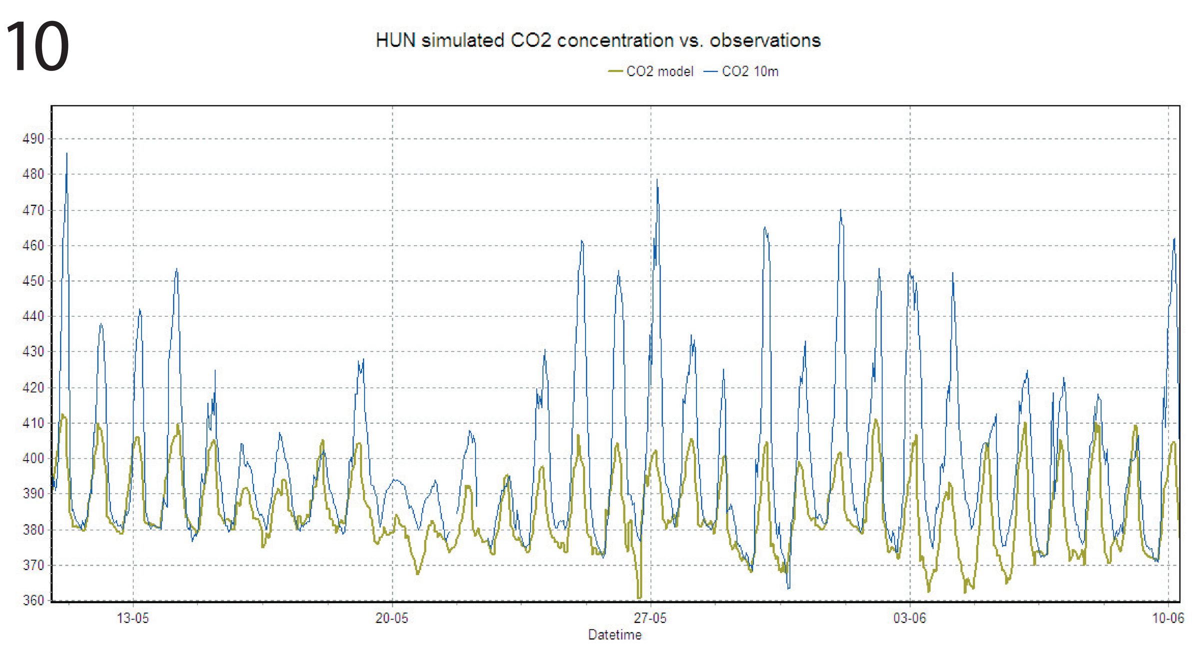
8



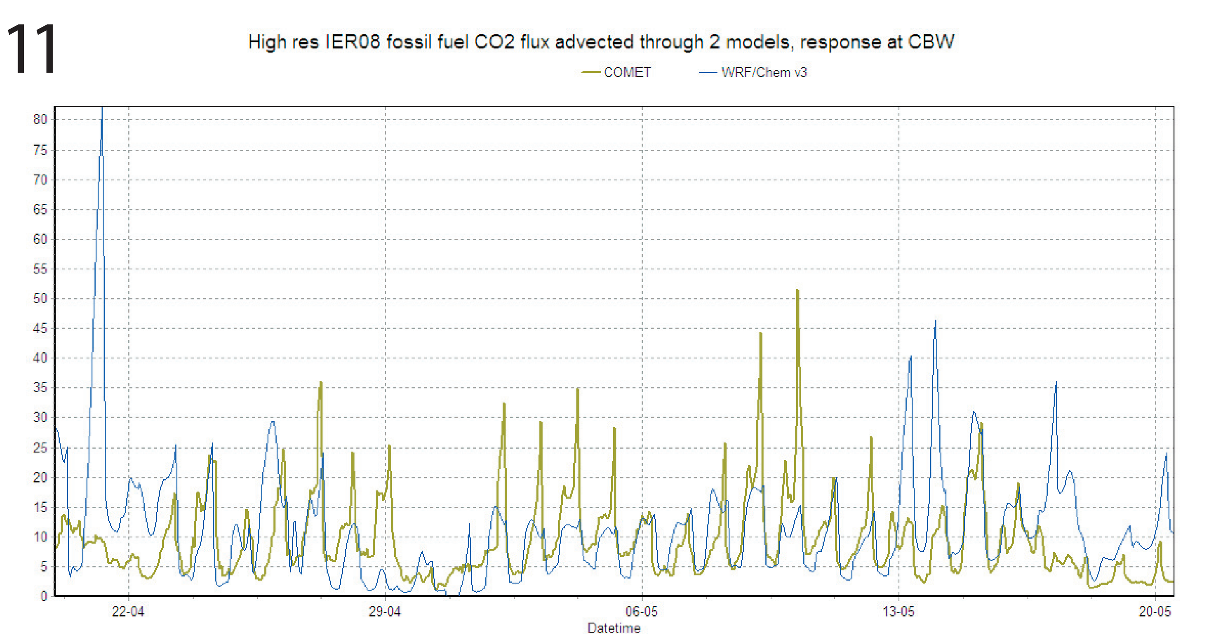
9



10



11



The FACEM biosphere model [4] is driven by the same 0.2° res. met data and actual MODIS monthly (interpolated to the day), 4 km resol. LAI data [8] and gives at hourly resol. the net biosperic exchange of CO_2, comprising of assimilation and heterotrophic and autotrophic respiration.

Results

Modelled CO_2 total concentrations agree best for stations HUN (Fig 3) and CBW (Fig 5) resp. At northerly winds the model does not show much variation at LUT, while measurements show quite some (Fig 4). The usage of IER fossil flux data seems to give slightly more realistic results compared to usage of Edgar v4 fossil fluxes. Model results indicate clearly that CBW is influenced strongly by respiration and fossil fuel fluxes. At HUN station strong assimilation and respiration fluxes can be seen, whereas fossil fuel fluxes are small in this early summer simulation. Assimilation fluxes and the resulting day time minimum concentrations are modelled very realistic at HUN, whereas nighttime concentrations enhancements due to respiration are underestimated with a factor of two (Fig 10), for CBW in the same period correspondence is better (Fig 8), at the end of the period the background from CT-TM5 seems to be underestimated.

The high resolution WRF simulated concentration values agree as well with observations as the concentrations simulated with the COMET model (Figs 8,9,11), but both models have better or worse agreement in different periods.

Outlook

After the WRF run will be finished also attention will be paid to diagnostics of the underlying meteorology like PBL height, wind fields, as compared with observations. It is well possible that WRF derived trajectories and PBL parameters will allow to improve the COMET results.

References

[1] http://carboeurope.ier.uni-stuttgart.de/
[2] http://edgar.jrc.ec.europa.eu/
[3] Takahashi, et al. (2009), DSR II, 56, 554-577
[4] Pieterse et al, 2007. Tellus B, 59, 412-424; ACPD, 8, 4117-4154.
[5] Baker, I.T. and A.S. Denning. 2009. http://daac.ornl.gov/
[6] Peters et al, 2009. BGC, accepted
[7] Vermeulen AT, et al, 2007. ACPD, 6, 8727-8779, 2006
[8] Climate and Vegatation research group, Boston University. http://cliveg.bu.edu

Acknowledgements

Thanks to Sander vd Laan (CIO-NL) for provision of the LUT CO_2 data and Laszlo Haszpra (HMS, HU) for the HUN CO_2 data.
This work was possible thanks to contributions from the EU-FP6 project CarboEurope-IP, EU-FP5 project CHIOTTO, and the Dutch KvR project ME-2, next to support from the Dutch ministries of Environment and Economic Affairs.

ECN   CARBO EUROPE IP   climate changes spatial planning