# Understanding and quantifying $CO_2$ and $CH_4$ greenhouse gas fluxes on the regional scale with COSMO: The project CarboCount CH

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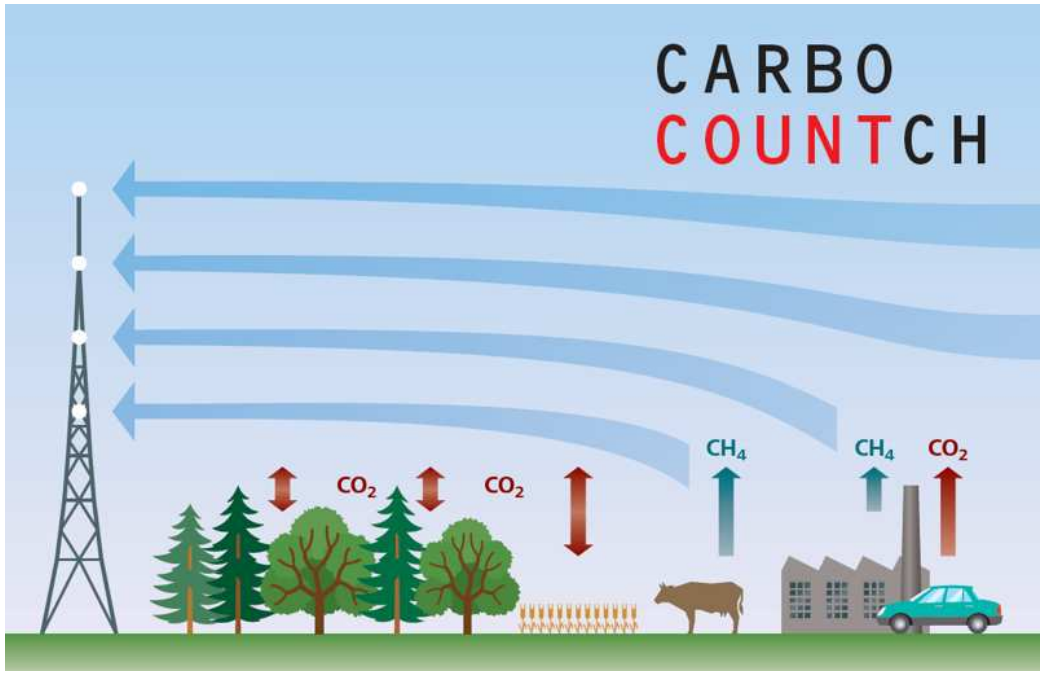
*[5]Umweltphysik, ETH Zurich, [6]Klima und Umweltphysik, Universität Bern*

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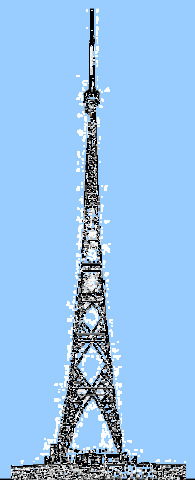

# Outline

## Motivation

- Global $CO_2$ budget & role of land vegetation
- Integrated Carbon Observation System ICOS

## Project CarboCount CH

- measurement network
- model system
- collection of input data

## First results

- Evaluation offline CLM4.0
- FLEXPART simulations for site Lägern

## Conclusions and Outlook

**CARBO COUNT CH**

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- Global budget
- ICOS

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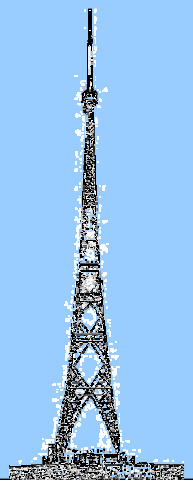
- Model system
- input data

**First results**
- transport simulations for Lägern

**Conclusions**



# Motivation – Global $CO_2$ budget

## Fate of anthropogenic $CO_2$ emissions in 2010

9.1±0.5 PgC $y^{-1}$

\+

0.9±0.7 PgC $y^{-1}$

5.0±0.2 PgC $y^{-1}$
50%

2.6±1.0 PgC $y^{-1}$
26%
Calculated as the residual of all other flux components

24%
2.4±0.5 PgC $y^{-1}$
Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

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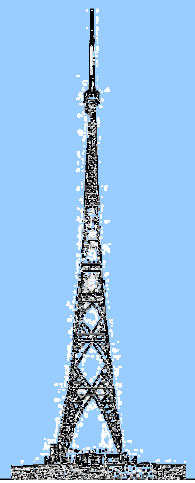
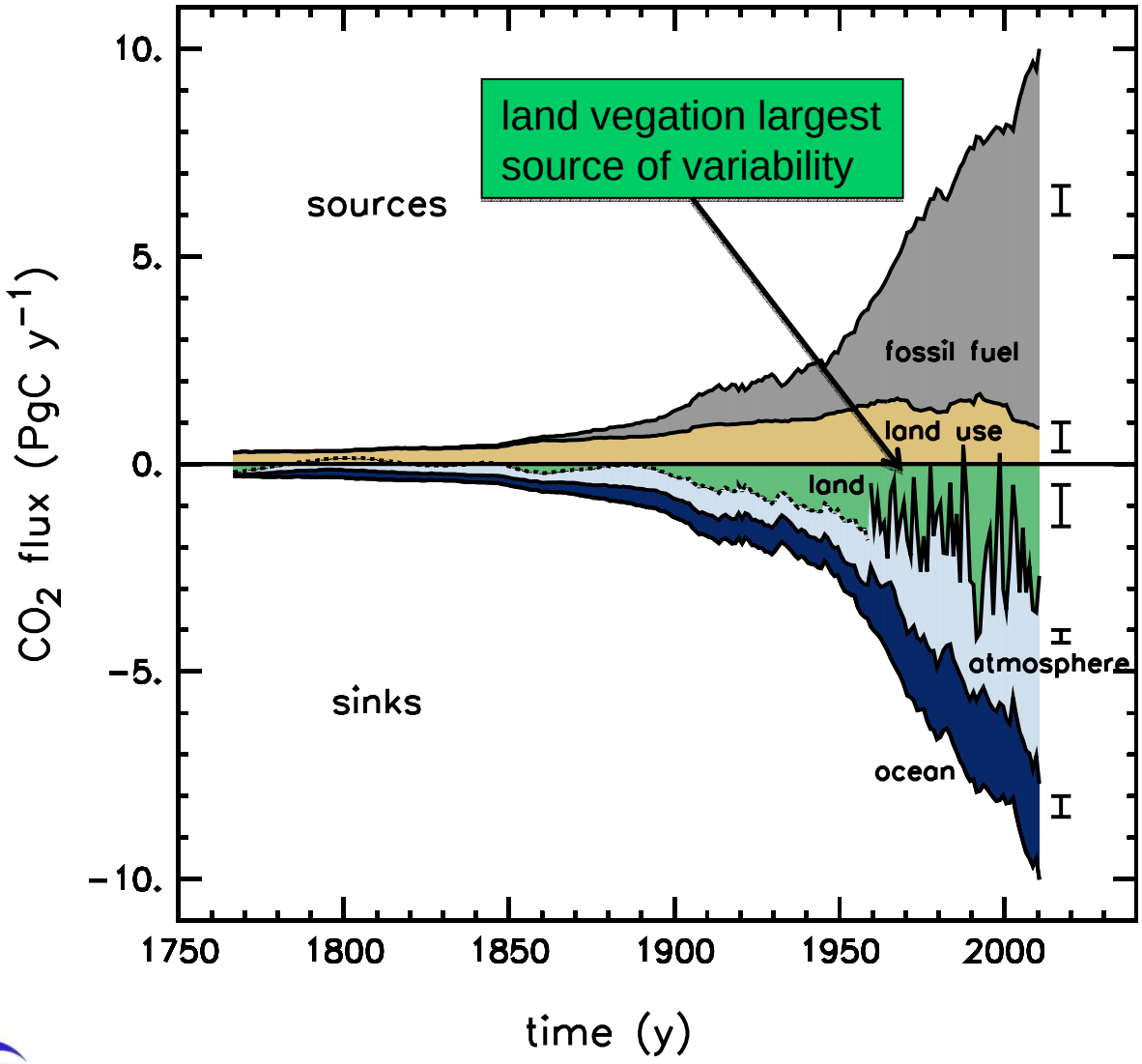


# Motivation – Global $CO_2$ budget

## Evolution of global sources and sinks 1750 - 2010




| 2000-2010 (PgC $y^{-1}$) |
|---|
| 7.9±0.5 |
| 1.0±0.7 |
| 2.5±1.0 (Residual) |
| 4.1±0.2 |
| 2.3±0.5 (5 models) |

Global Carbon Project 2011; Updated from Le Quéré et al. 2009, Nature G; Canadell et al. 2007, PNAS

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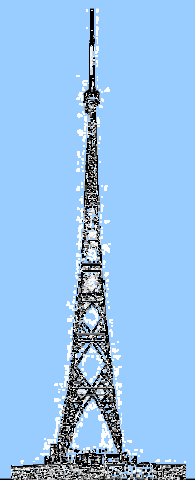
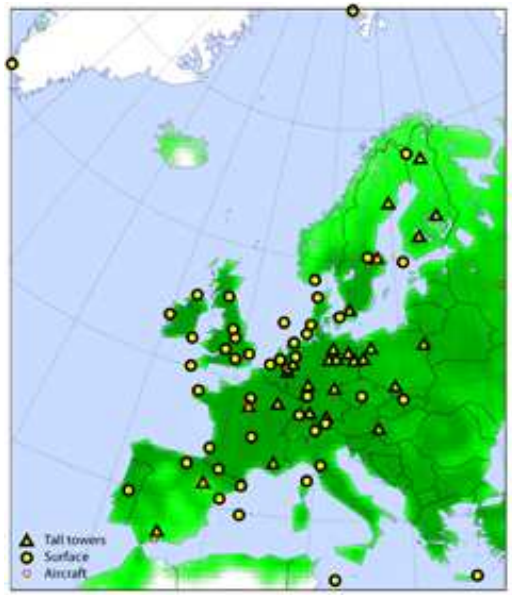


# Integrated Carbon Observation System

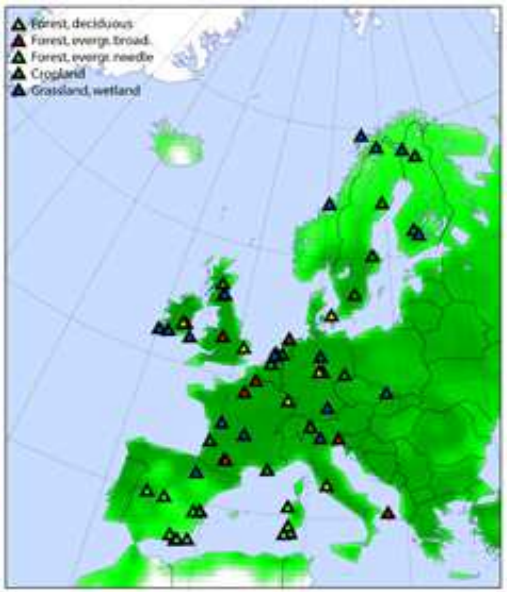
## Mission statement

- understand present state and predict future behavior of carbon cycle
- monitor and assess effectiveness of carbon sequestration and/or greenhouse gases emission reduction activities

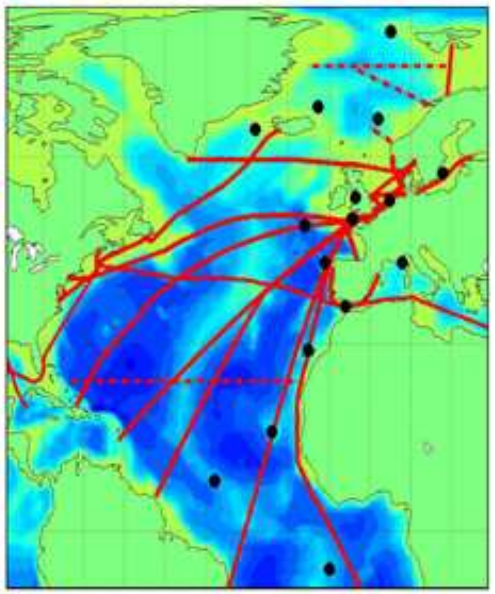
### Envisioned ICOS network




Atmospheric network




Ecosystem network



Marine network

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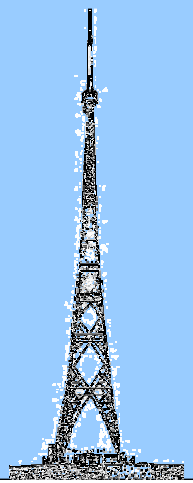

# CarboCount CH

## Goals

- Improved understanding of $CO_2$ and $CH_4$ fluxes in Europe and their sensitivity to climate variations
- Develop prototype of a modeling and observation system of $CO_2$ and $CH_4$ fluxes in Switzerland

## Approach

- Simulations of biosphere-atmosphere exchange of $CO_2$ in Europe over past 33 years (1979-2012)
- Setup of CarboCount-CH GHG observation network in CH
- Estimation of $CO_2$ and $CH_4$ fluxes in CH through combination of **top-down** & **bottom-up** methods:
  - Top-down: Two independent inversion systems
  - Bottom up 1: Hi-res inventories of $CO_2$ und $CH_4$ emissions
  - Bottom up 2: Biogeochemistry model to simulate exchange of $CO_2$ between biosphere and atmosphere

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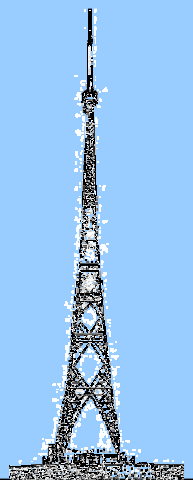
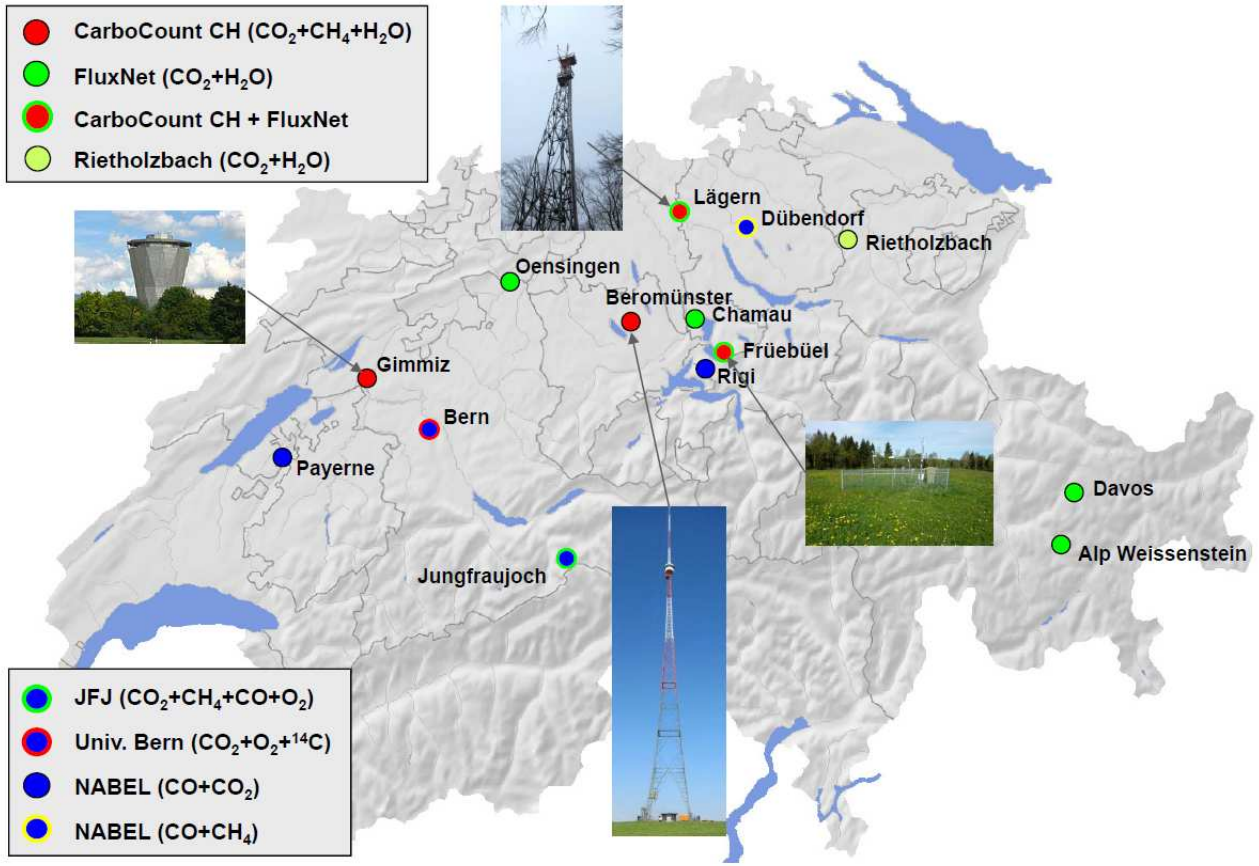


# Measurement network

- **4 new sites** for $CO_2$, $CH_4$ and CO dry VMR
- regular $^{14}C$ samples at Beromünster
- 3 NABEL CO and $CO_2$ + 2 CO and $CH_4$
- 4 FLUXNET sites
- central calibration lab at Empa



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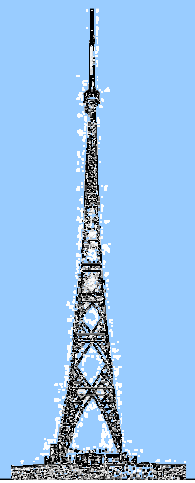
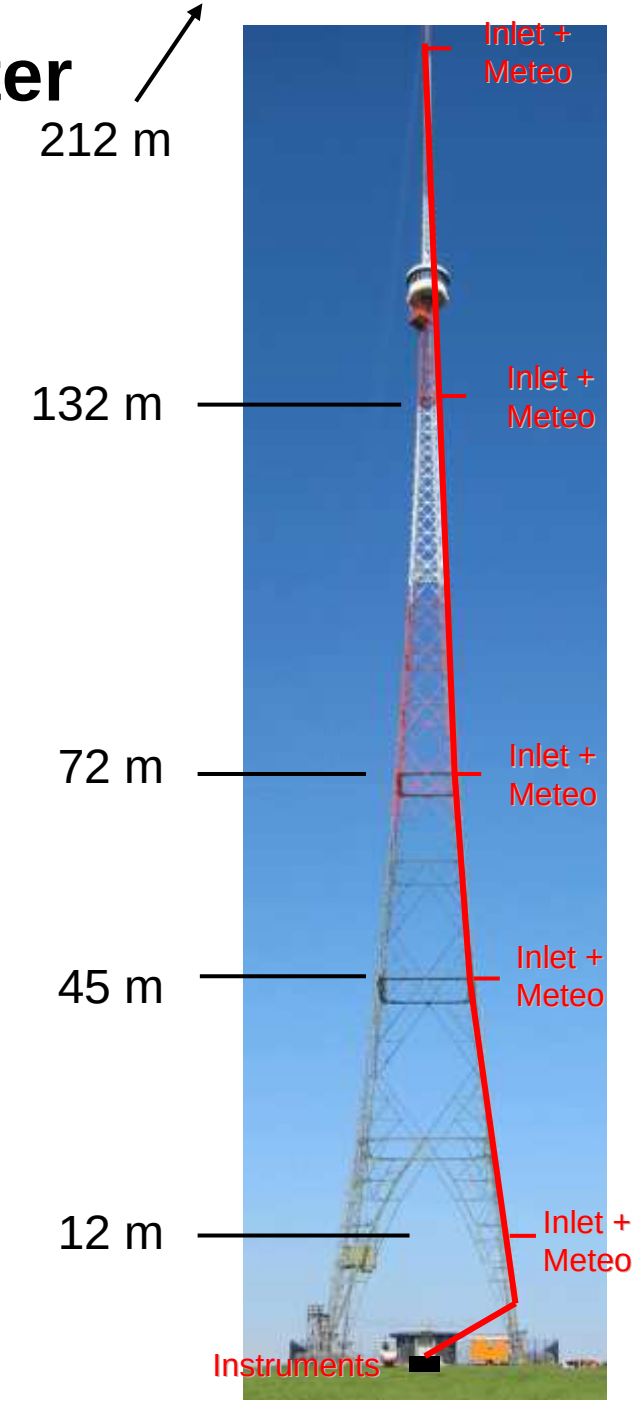


# Tall tower site Beromünster

**building hosting instruments**

**valve switch box**



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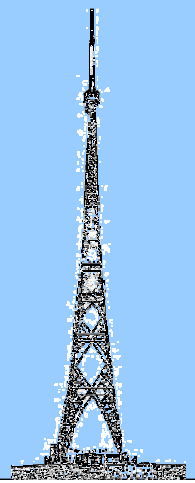
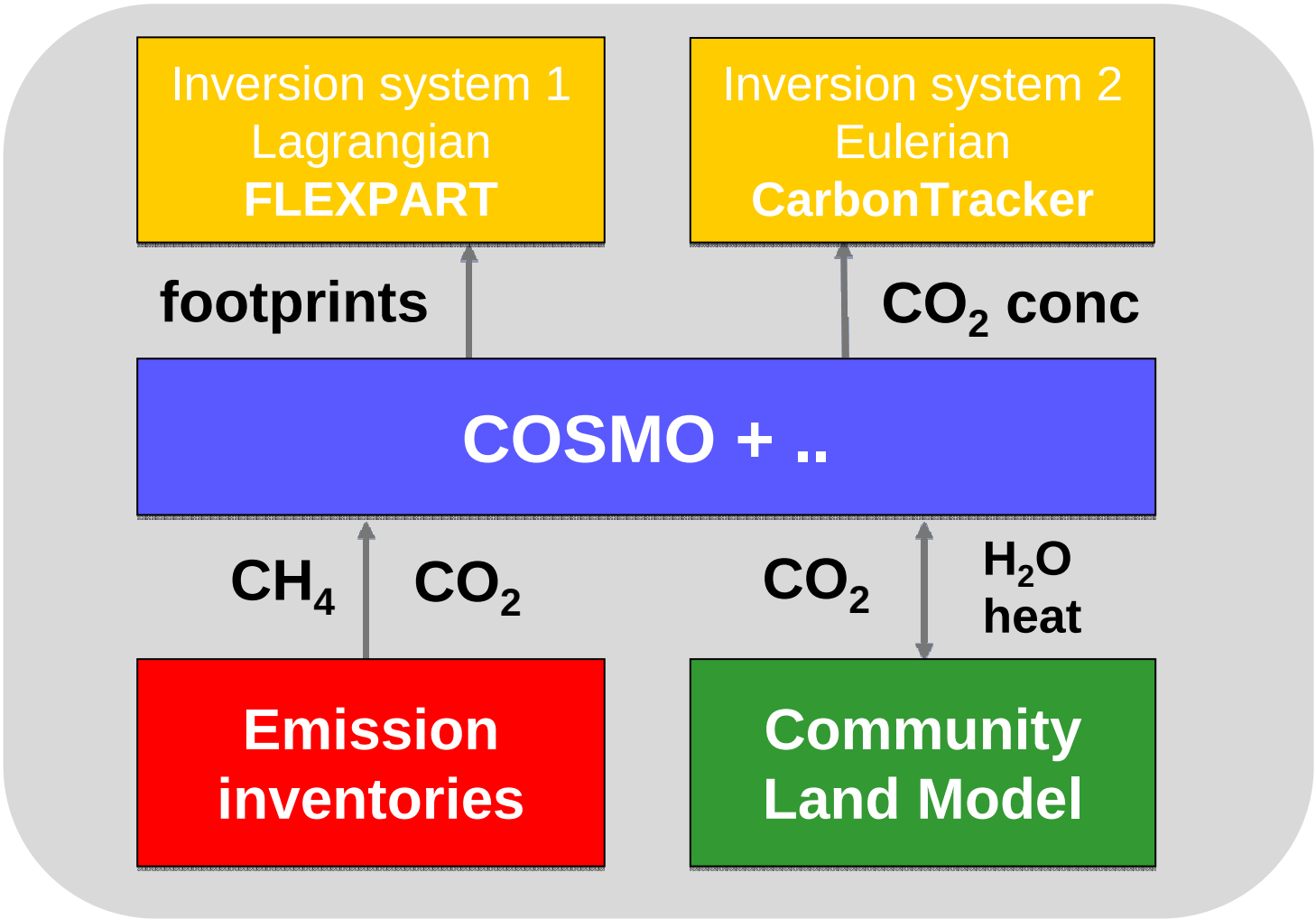


# Model System




➡ *tracer module presented by Anne Roches on Tuesday*

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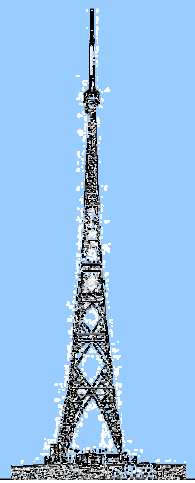
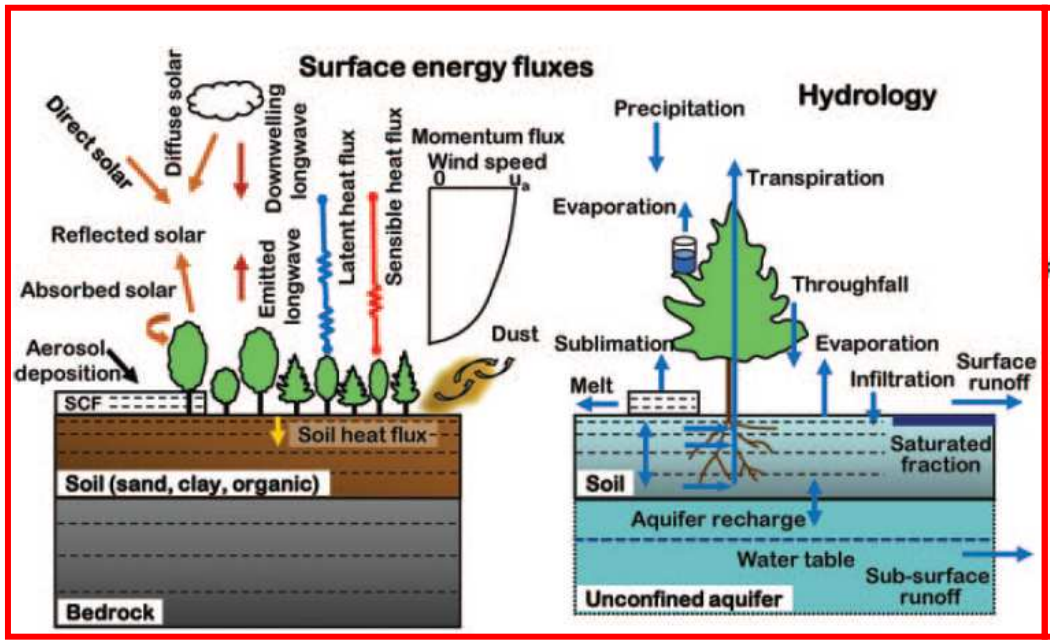


# Coupled system COSMO-CLM²

Davin et al., COSMO-CLM²: A new version of the COSMO-CLM model coupled to the Community Land Model, Clim. Dyn., 2011.

➡ *talk in the afternoon*

## Community Land Model CLM 4.0




*Lawrence et al. (2011)*

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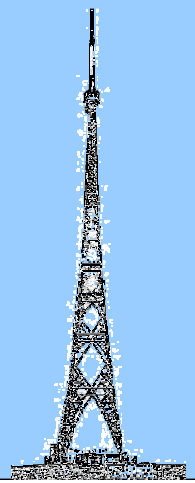

# Two inversion systems

## Goal:

- Inverse estimation of $CO_2$ and $CH_4$ fluxes from observations
- Optimal integration of measurements, model, and a priori knowledge

### Lagrangian

- FLEXPART-COSMO
- 4 day backward simulations from measurement sites
- nested simulations
- footprints (residence time maps) provide source sensitivities
- Kalman filter inversion *Brunner et al. (2012)*

### Eulerian

- COSMO-CLM$^2$ + tracers
- O(100) ensemble simulations, varying $CO_2$ fluxes from PFT
- nested simulations
- source sensitivites approx. with Ensemble Kalman Filter
- CarbonTracker inversion *Peters et al. (2007)*

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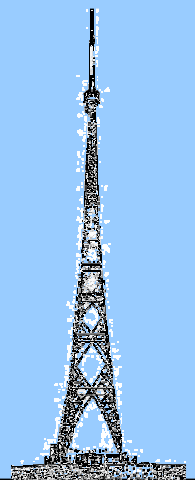


# Collection of high-resolution input data

## Community Land Model 4.0

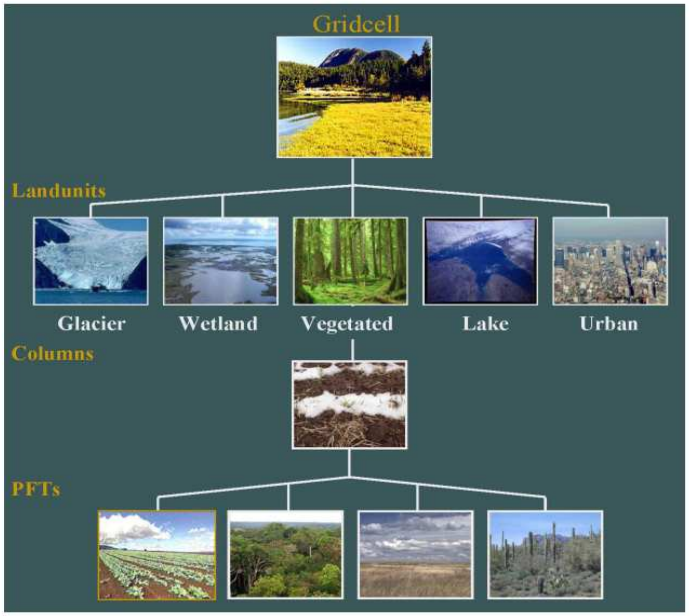
- 1 hydrology parameter
- 4 land cover parameters
- 4 soil parameters
- 7 vegetation parameters

## Emission Inventories

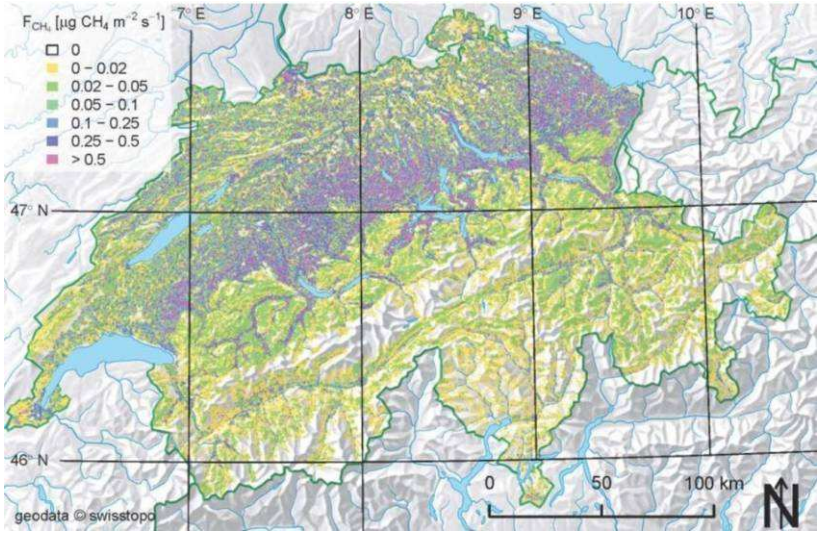
Switzerland
- CarboCount $CO_2$, 500 m x 500 m
- MAIOLICA $CH_4$, 500 m x 500 m

Europe
- EDGAR v4.2: $CO_2$ & $CH_4$, 0.1°x0.1°

### mosaic concept




### MAIOLICA CH4 inventory

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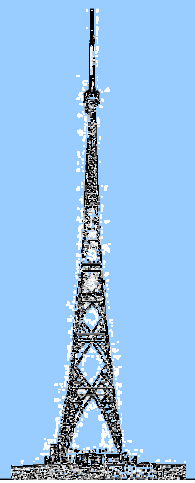
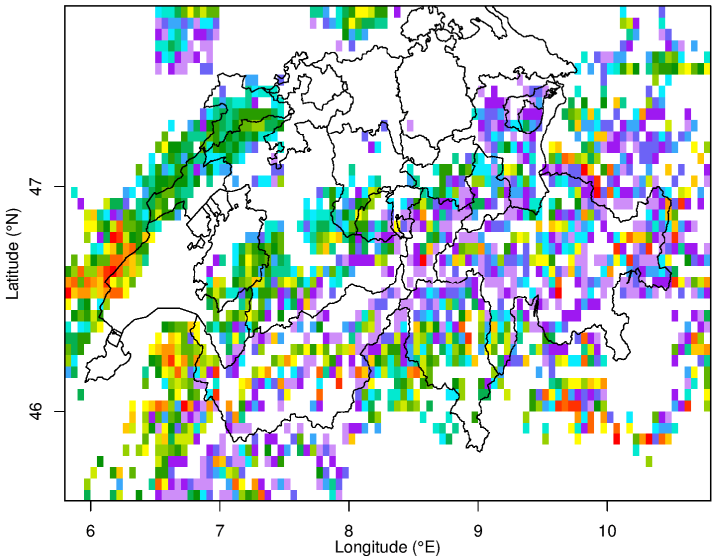


# Collection of high-resolution input data

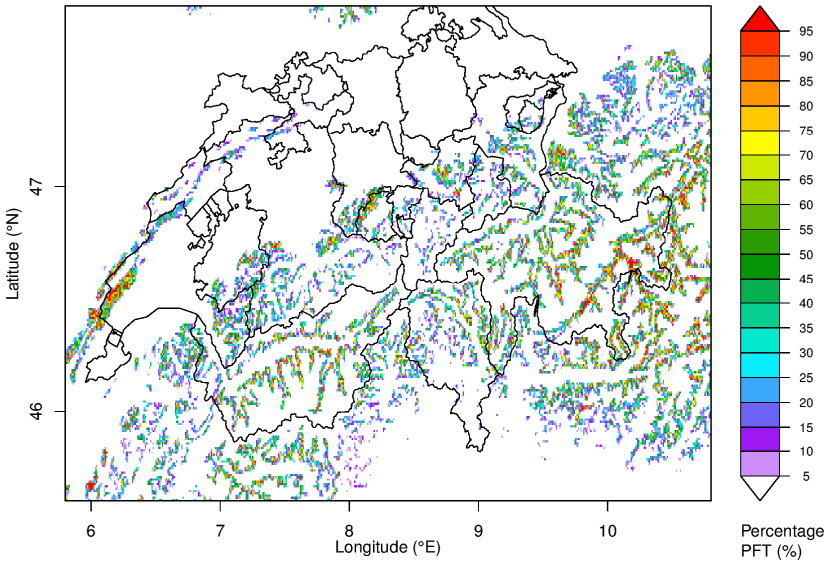
Example for CLM4: PFT Evergreen Needleleaf Boreal Forest

## NCAR, 0.05° resolution




- MODIS
- climatology

## CarboCount CH, 0.01° resolution




- CORINE 2006
- CH-Waldmischungsgrad
- E-OBS climatology
- SRTM topography

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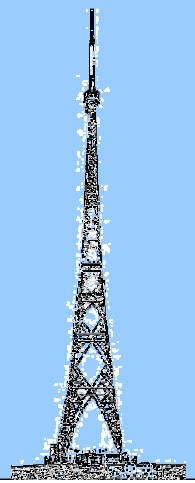
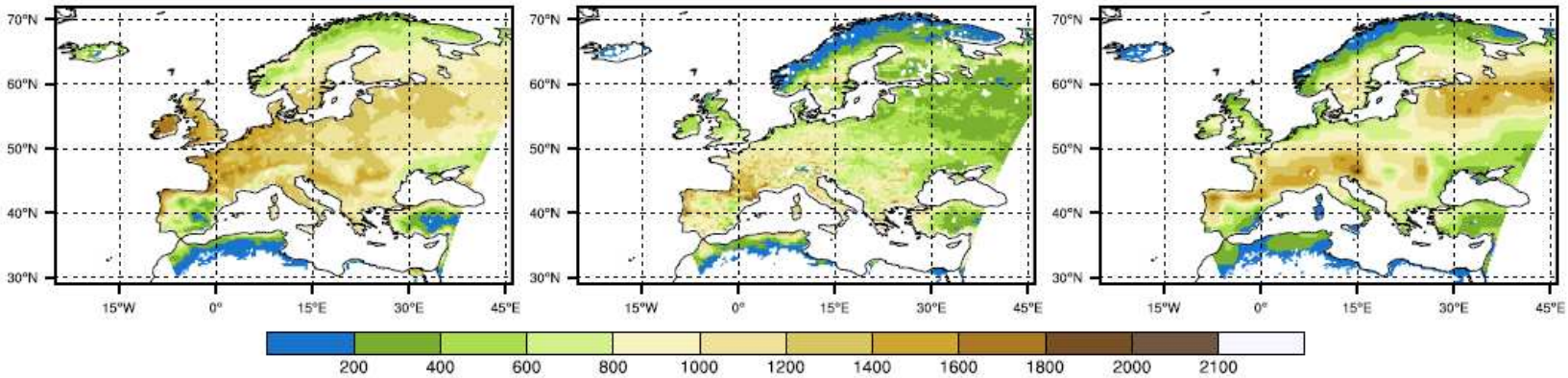


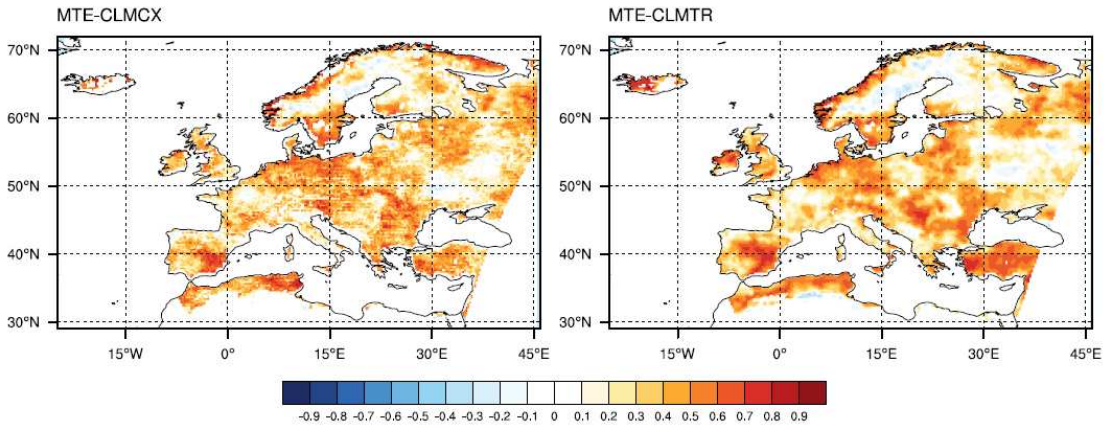
# First results – Evaluation CLM4.0 offline

## Mean annual GPP (1982 – 2010) gC/m²/yr

MTE (upscaled fluxes) | CLM4-CarboExtreme | CLM4-TRENDY




## Correlation interannual variability MTE – CLM4

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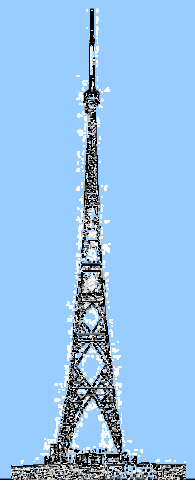
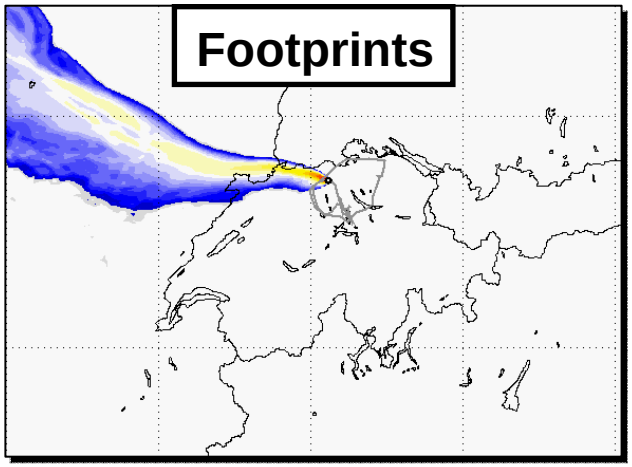
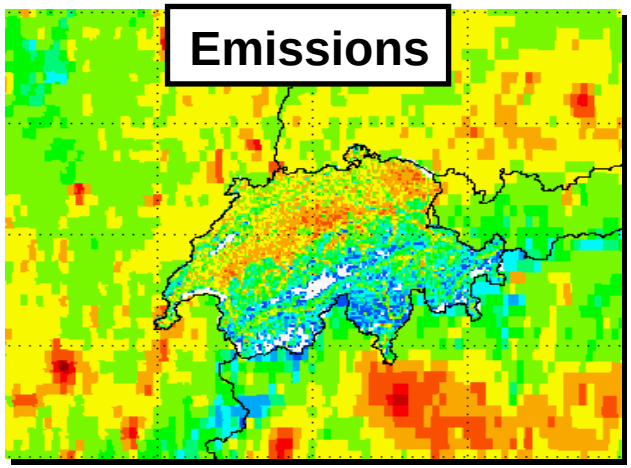


# First results – Simulations for Lägern

## $CO_2$, CO and $CH_4$ simulated with FLEXPART-COSMO

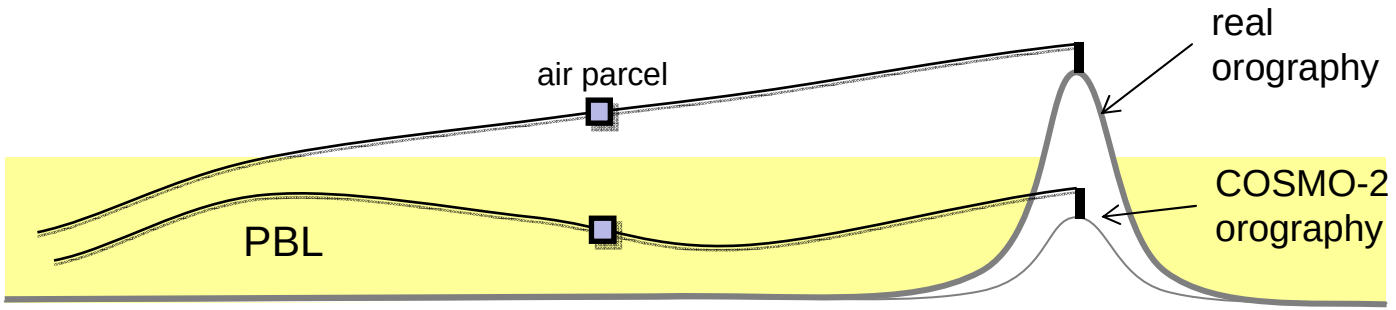



x




**= concentration time series**

## Illustration of problem of mountain sites like Lägern

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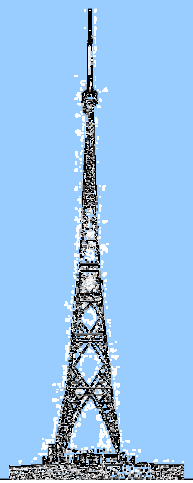

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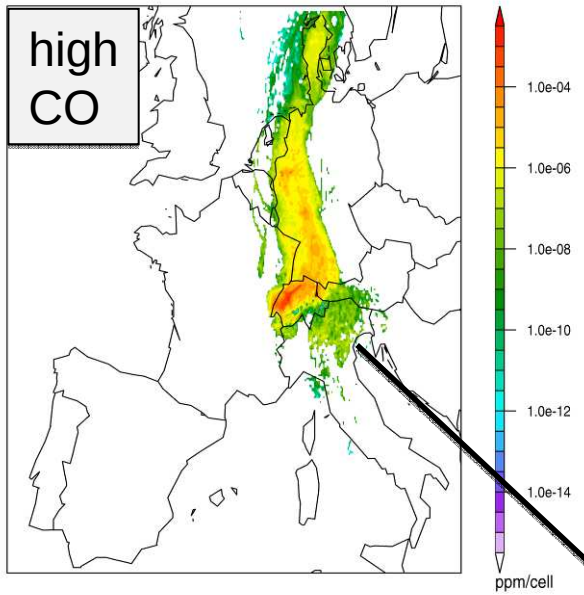


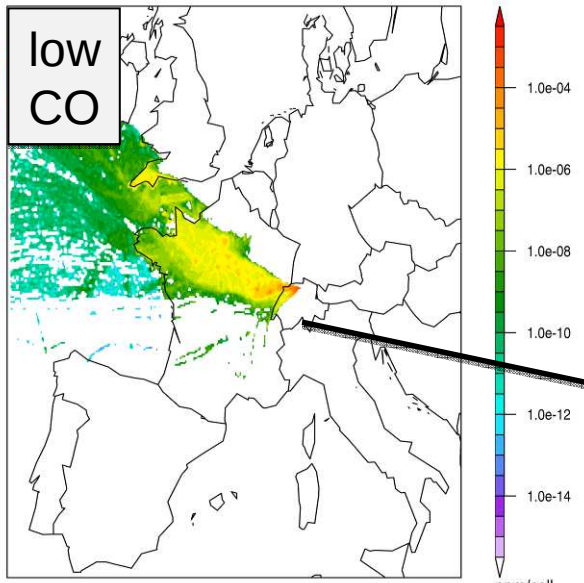








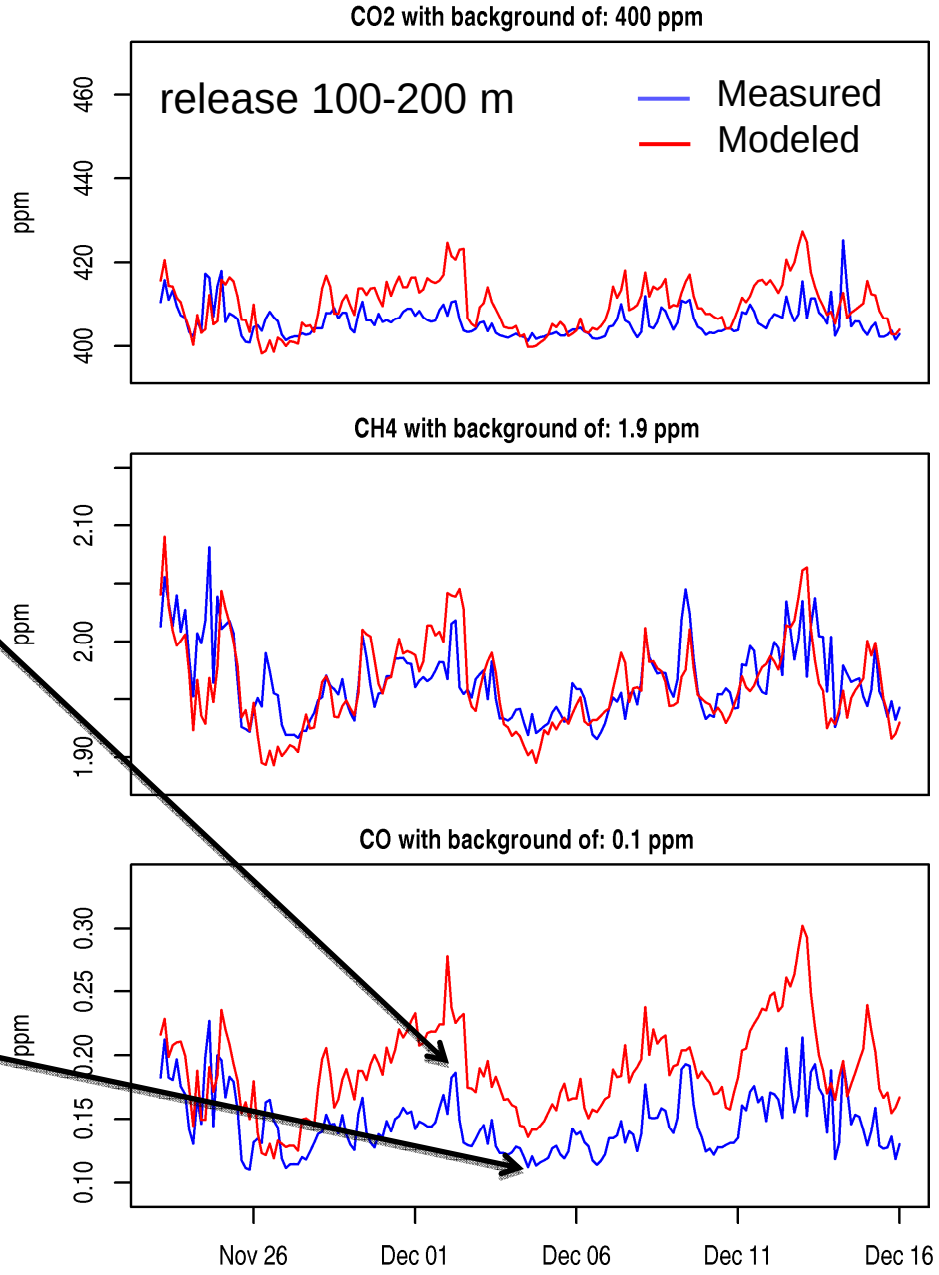

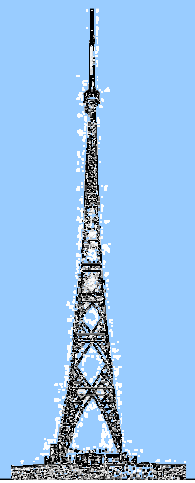

# Outlook and conclusions

## Next steps:

- setup of a reference system with all components: external parameters, emissions, biogenix fluxes, tracers, meteorological and chemical IC/BC, 2 nested domains
- integration of new input data sets into CLM4.0
- coupling COSMO with CLM4.0 through OASIS
- FLEXPART simulations for all sites

## Conclusions:

- Goal of CarboCount CH is to quantify $CO_2$ and $CH_4$ fluxes at regional scale and to understand feedbacks with climate
- Measurement network almost complete
- Model system still under construction
- First results for Lägern demonstrate high quality of transport simulations based on COSMO meteorology