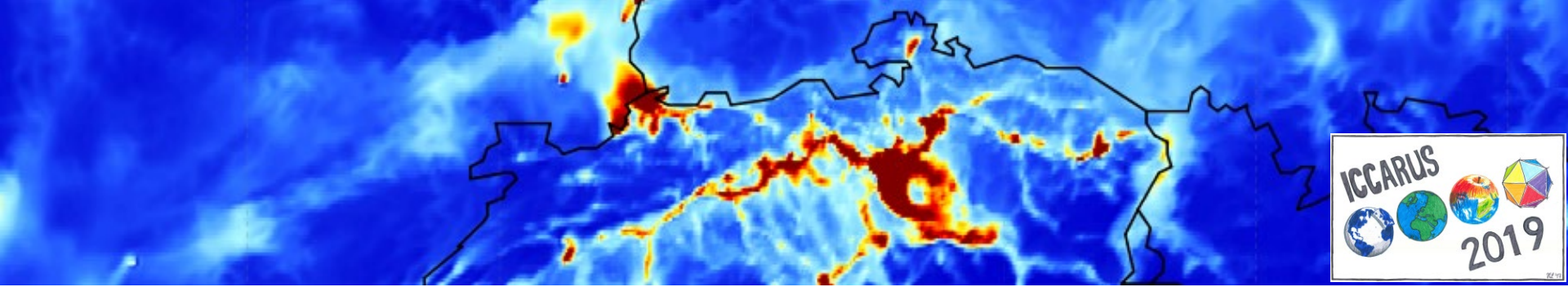

Simulating Greenhouse Gas Emissions and Transport with COSMO-GHG at Kilometer-scale

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(2) ETH Zürich, Center for Climate Systems Modeling (C2SM), Switzerland

ICCARUS 2019, DWD, Offenbach, Germany, 18 - 20 March 2019

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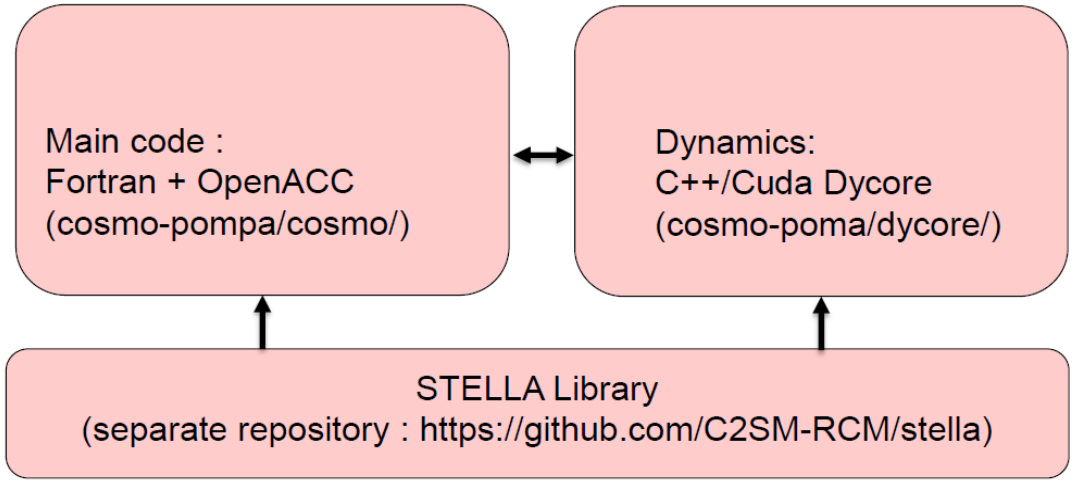
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

COSMO-POMPA and COSMO-GHG

- COSMO-POMPA (Performance On Massively Parallel Architectures)
- GPU accelerated version v5.0_2017.6
- Computations on CSCS (Piz Daint)
- 3x faster on GPU, 1.5x faster on CPU
- Greenhouse gas (GHG) tracer extension by Empa
- Structure:



Input Data for COSMO-GHG

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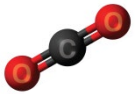
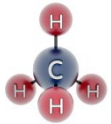
8 GHG Tracers



- Background
- Anthropogenic
- Respiration
- Photosynthesis (GPP)

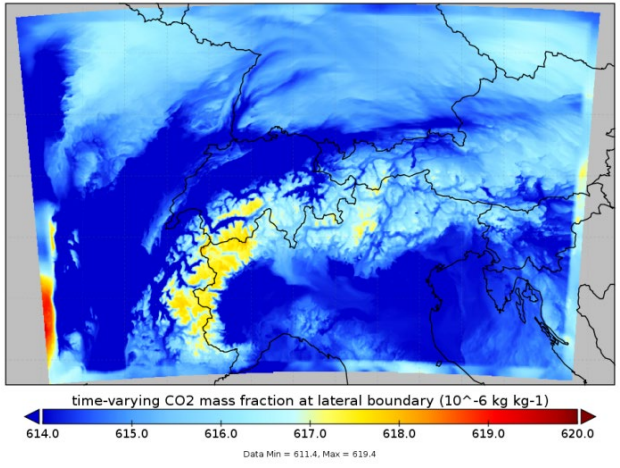
- Background
- Anthropogenic



- Background
- Anthropogenic

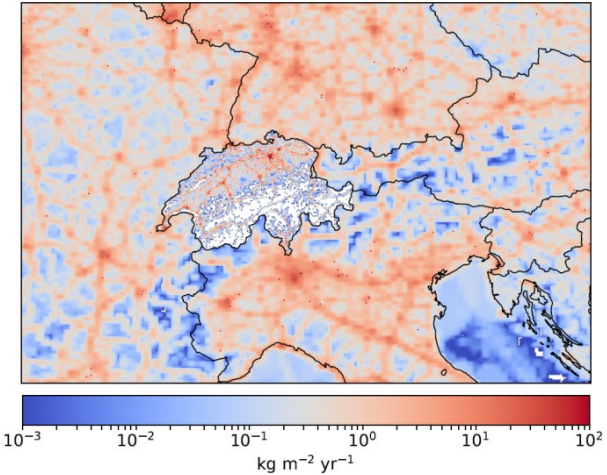
Boundary conditions

Global CO_2 model CAMS
(ECMWF, experiment ghqy)



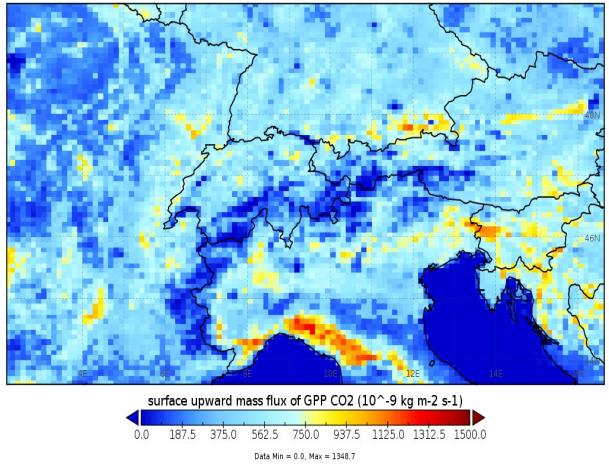
Anthropogenic emissions

TNO/MACC-3 (Europe) +
CarboCount (Switzerland)

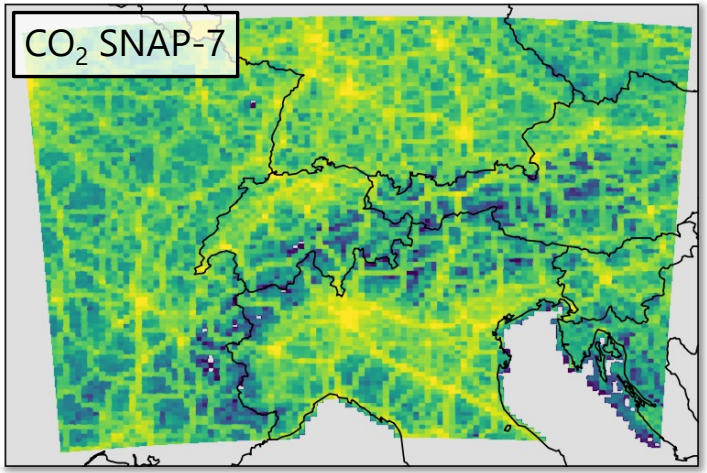


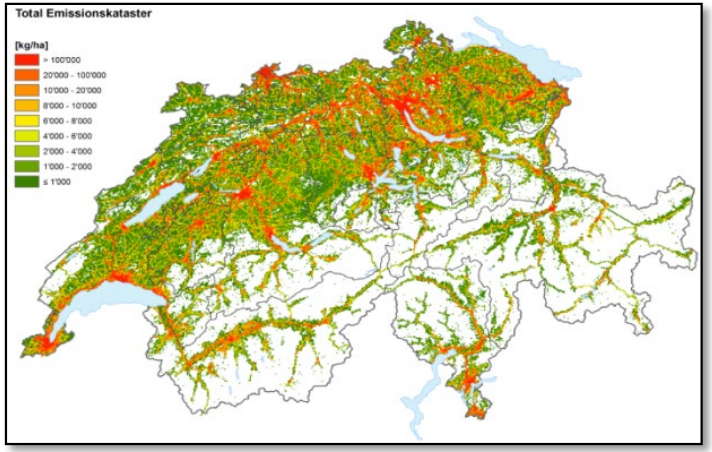
Biosphere fluxes

VPRM (MPI Jena)
ECMWF hourly forecasts (0.125°)



Input Data: Anthropogenic Emissions

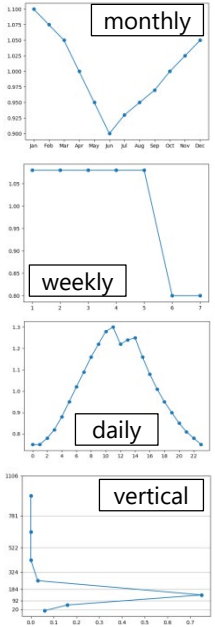




Σ SNAP Categories

X

Scalings



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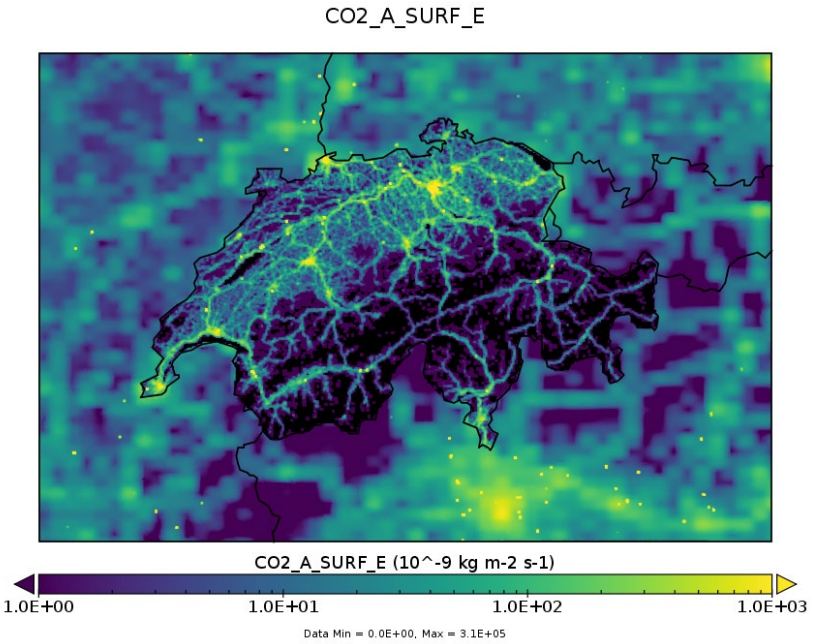

Input Data: Biosphere Fluxes (VPRM)

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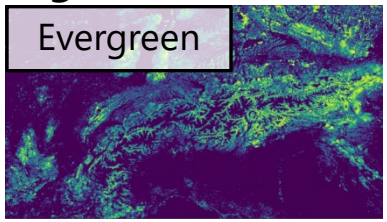
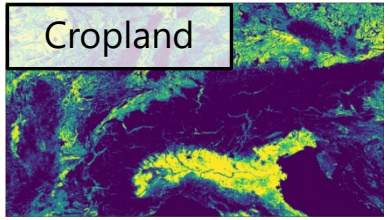
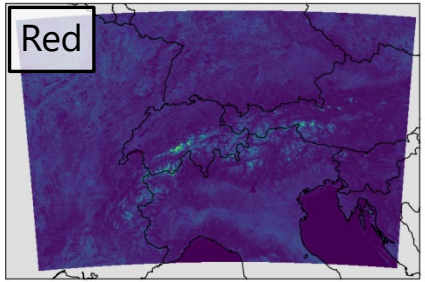
Vegetation Class Fractions (8 classes), e.g.:

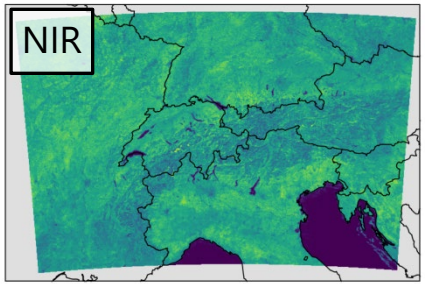


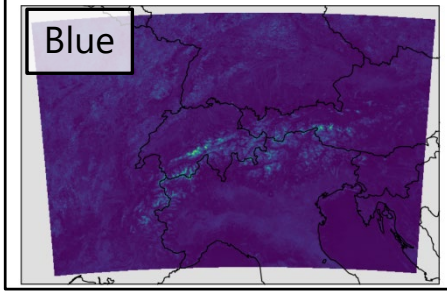


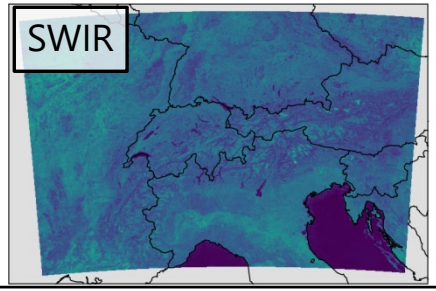
...

MODIS Surface Reflectances (MOD09A1):









VPRM Parameter Table
Mahadevan et al., 2008

T_2M
SWDIR_S

Biosphere Fluxes (VPRM)
- Respiration (RA)
- Gross Photosynthetic Production (GPP)

Vegetation Indices
- Enhanced Vegetation Index (EVI)
- Land-Surface-Water Index (LSWI)

Offline vs. Online Emissions/Fluxes

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	Offline	Online
Anthropogenic Emissions	▪ Non modular ▪ Costly pre-processing ▪ Large amount of files (hourly) ▪ Lot of I/O during runtime	▪ Easier to manipulate ▪ Computation during runtime ▪ Parallelized on GPU ▪ Only I/O during initialization
Biospheric Fluxes (VPRM)	👎 Different meteorology 👎 Coarser resolution 👎 incoherent	👍 Meteorology (T_2M, SWDIR_S) directly from COSMO 👍 Same resolution as model grid 👍 coherent

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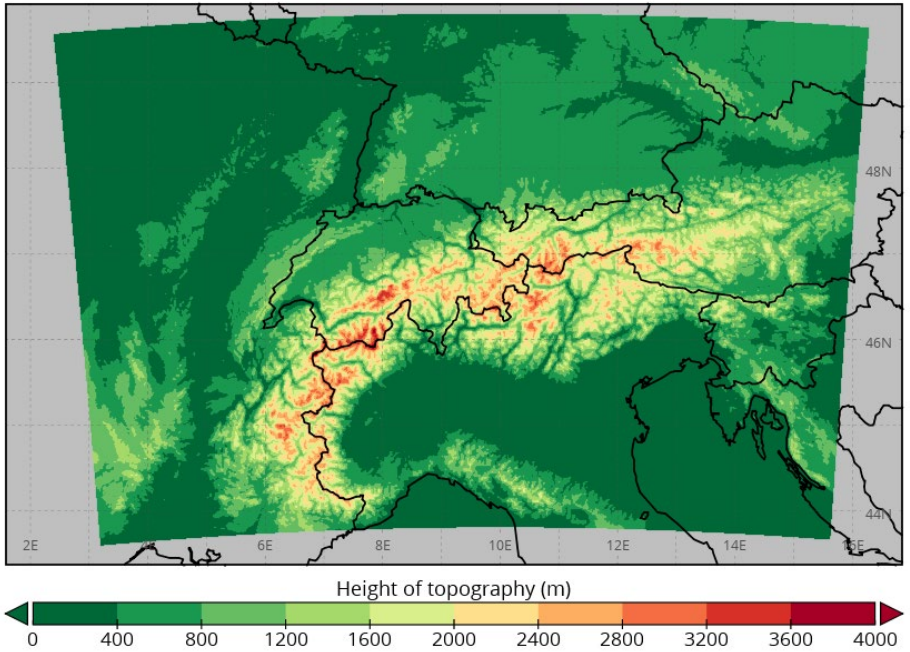
Model configuration

Domain:	centered over Switzerland
Grid spacing:	1.1 km × 1.1 km (0.01°)
Grid points:	900 × 600
Vertical levels:	60 (Δz_{min} = 20 m)
Time step:	10 s
Output freq.:	every 1 h
Sim. period:	October 2017
Meteo BC:	COSMO-7
Turbulence:	Prognostic TKE-based scheme

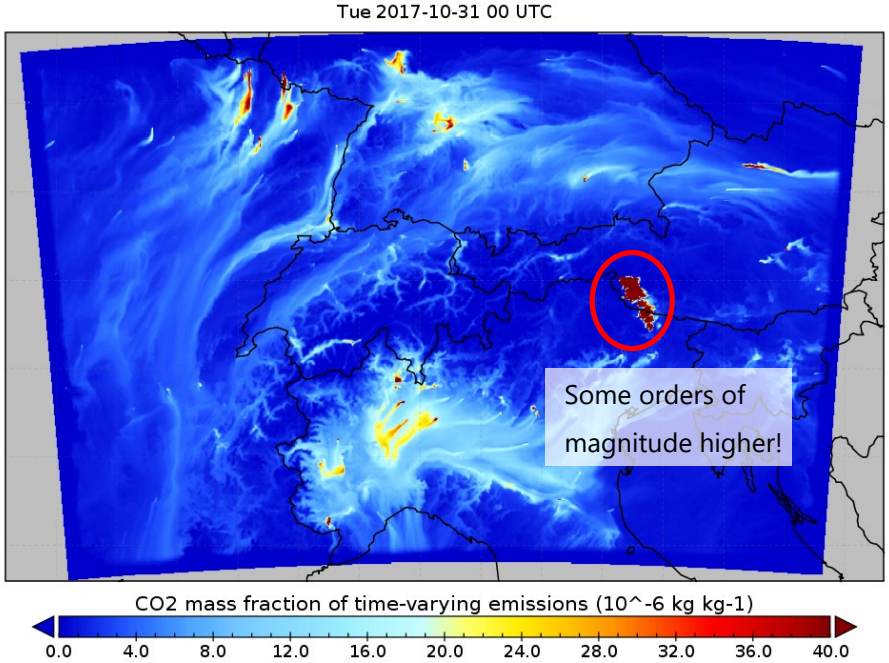
Observation nudging used

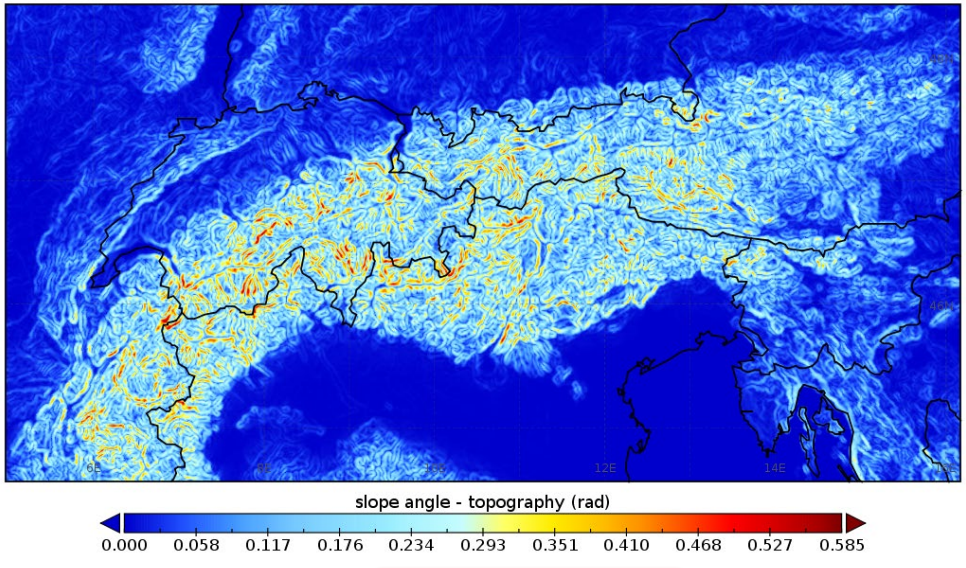
Model orography



Orographic Filtering

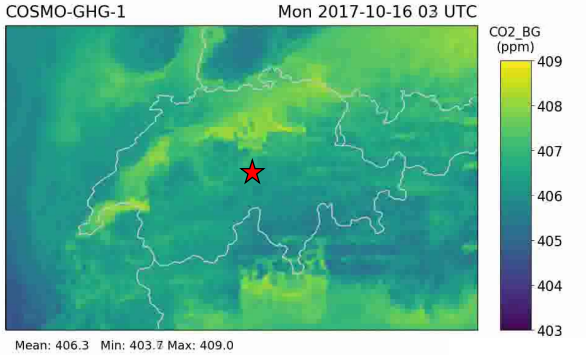
- Numerical instabilities for tracer fields

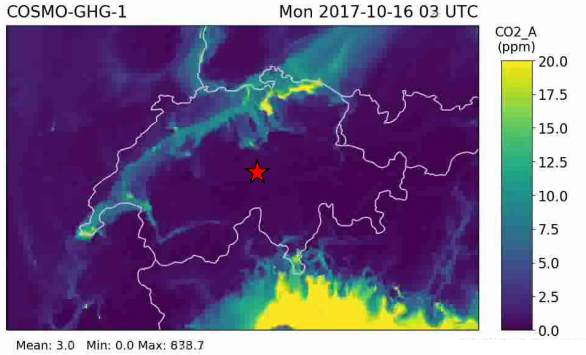


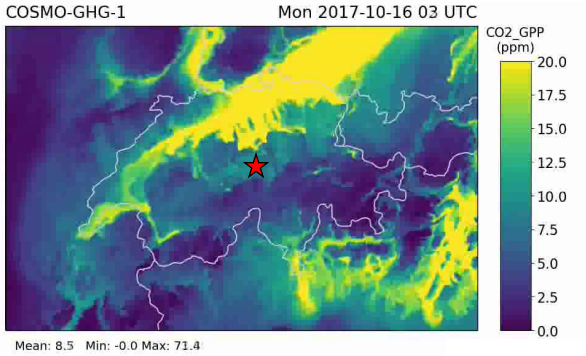


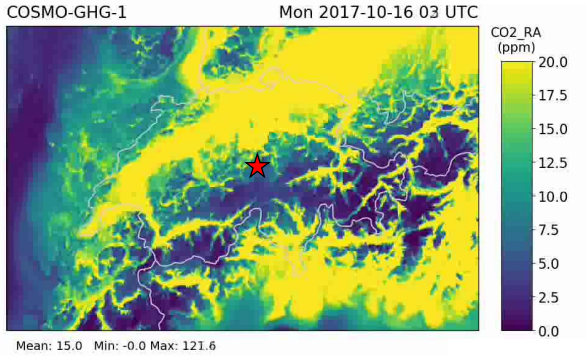
	Old	New
Height (m)	[-91.0 ... 4267.7]	[-96.1 ... 4057.5]
Max. slope angle (rad)	0.585	0.521

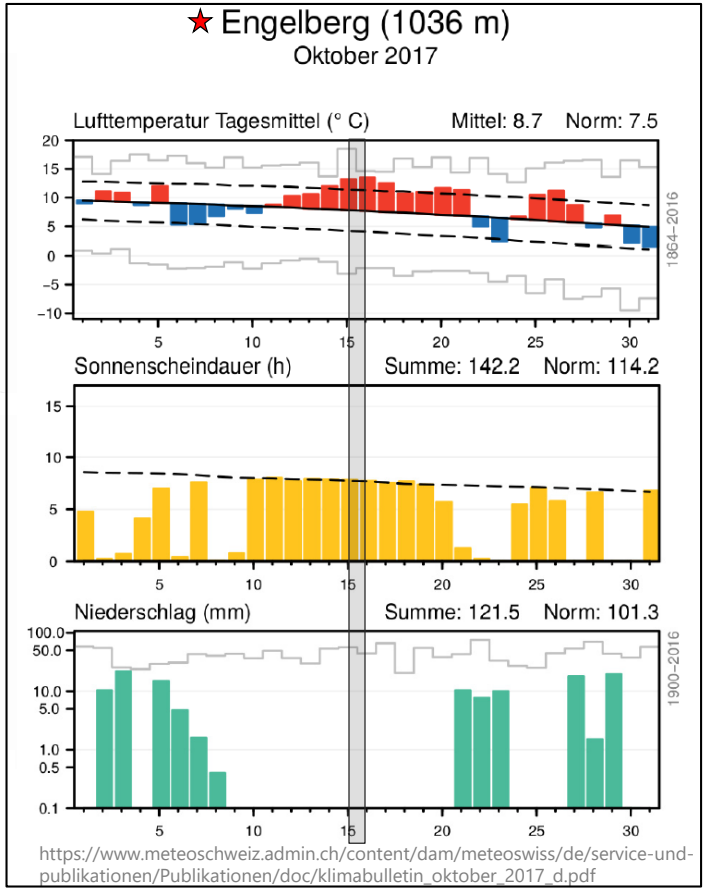
CO_2 Concentration Fields (Ground Level)











CO_2 Measurements – Project Carbosense

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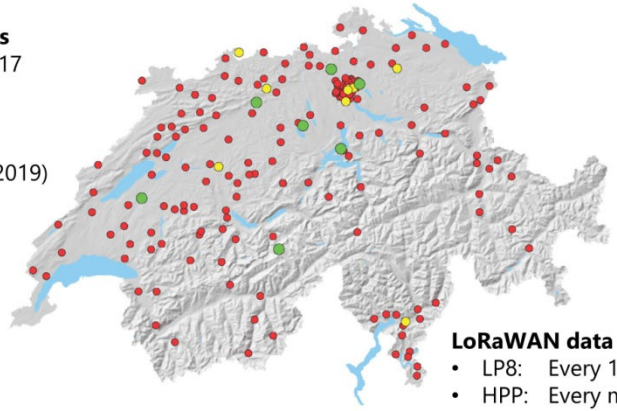
Carbosense CO_2 sensor network

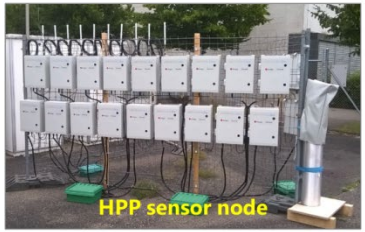
Active nodes
- LP8: 217
- HPP: 9
- CRDS: 7

(14 January 2019)



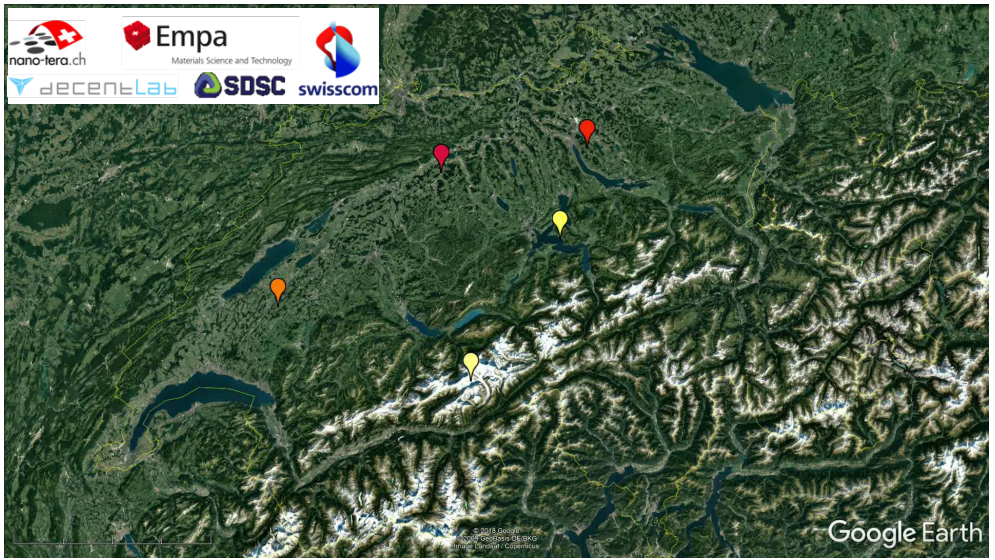
LoRaWAN data transmission
- LP8: Every 10 minutes
- HPP: Every minute

Picarro CRDS


HPP sensor node

LP8 sensor node

Three classes of sensors
- **High precision instruments**: Picarro CRDS
- **Intermediate precision instruments**: SenseAir HPP
  (Temperature stabilization, active sampling, reference gas supply, + P/T/RH sensors)
- **Low-cost sensors**: SenseAir LP8
  (only diffusive, + T/RH sensor)



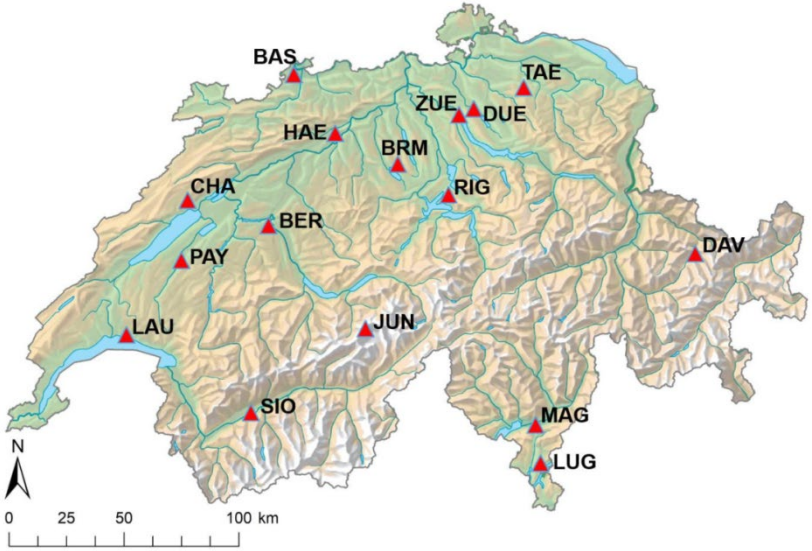
Courtesy of Michael Müller, Empa

Coupling of observations and model simulations

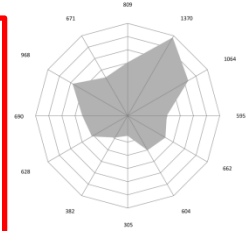
Observations → Model simulations
- Adjustment of CO_2 baseline
- Conversion of model residuals into improved emissions and biospheric fluxes
- Quantification of local impact factors

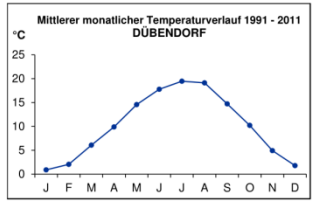
Observations ← Model simulations
- Adjustment of low-cost sensor drifts during selected time periods

Selection of Sites – NABEL Stations

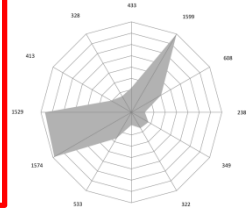


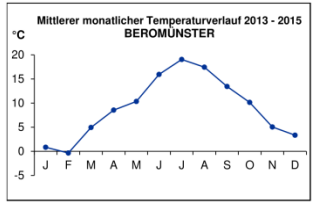
DUE
Dübendorf
suburban



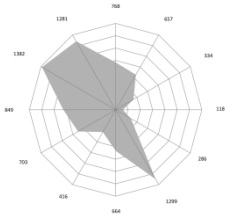


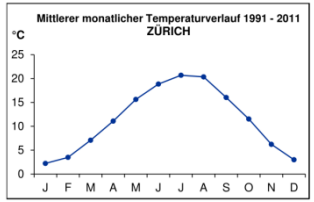
BRM
Beromünster
rural



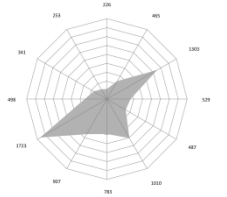


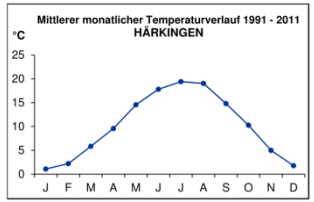
ZUE
Zürich
urban





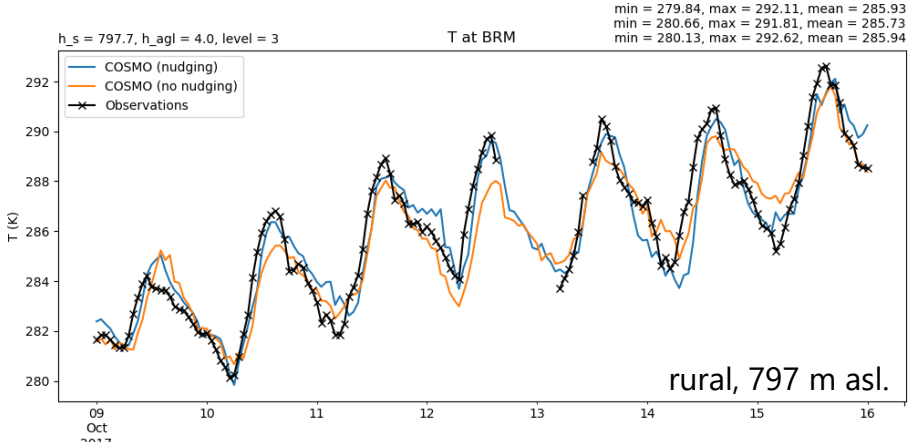
HAE
Härkingen
rural, traffic

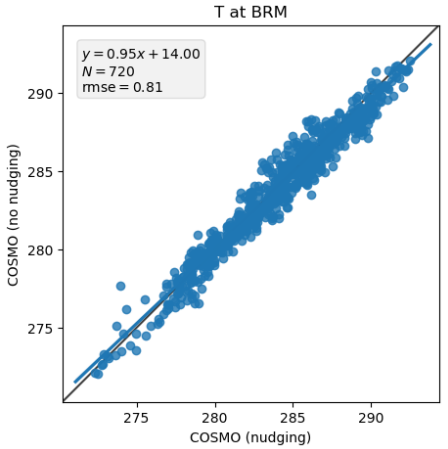


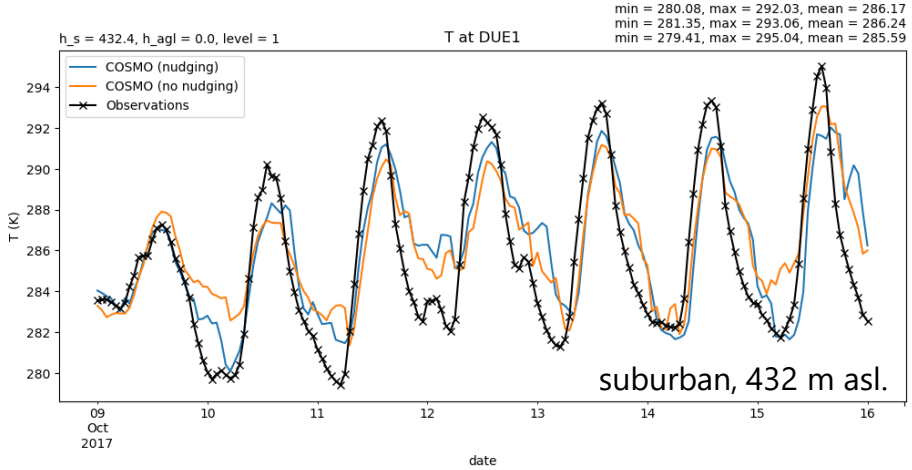


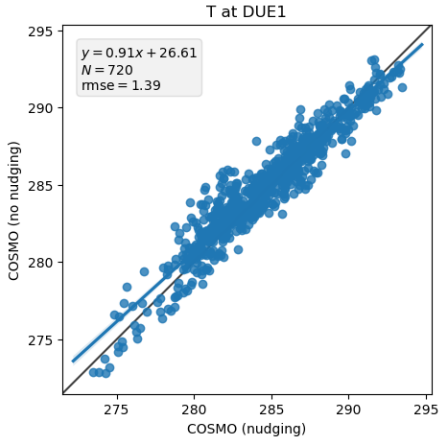
Source: https://www.bafu.admin.ch/bafu/de/home/themen/luft/zustand/daten/nationales-beobachtungsnetz-fuer-luftfremdstoffe--nabel-.html

Observation Nudging – Effects on 2 m Temperature

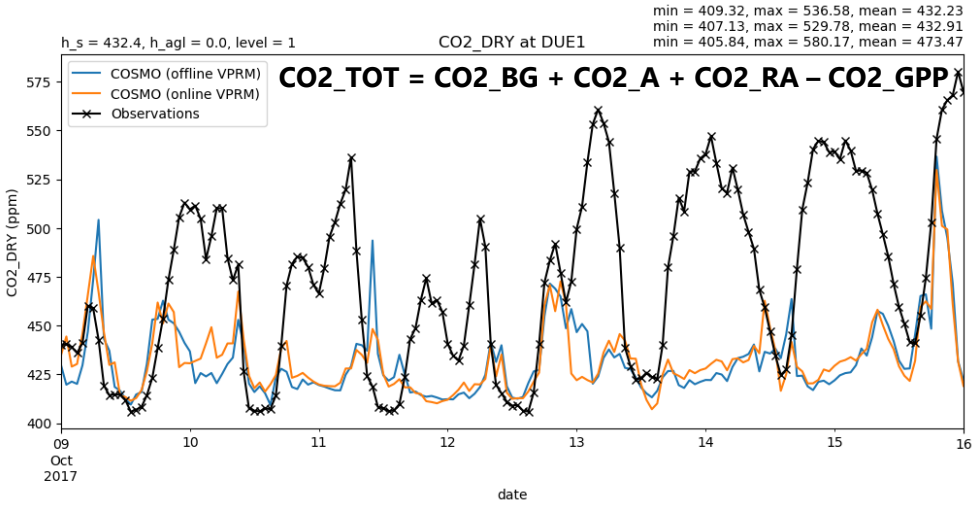


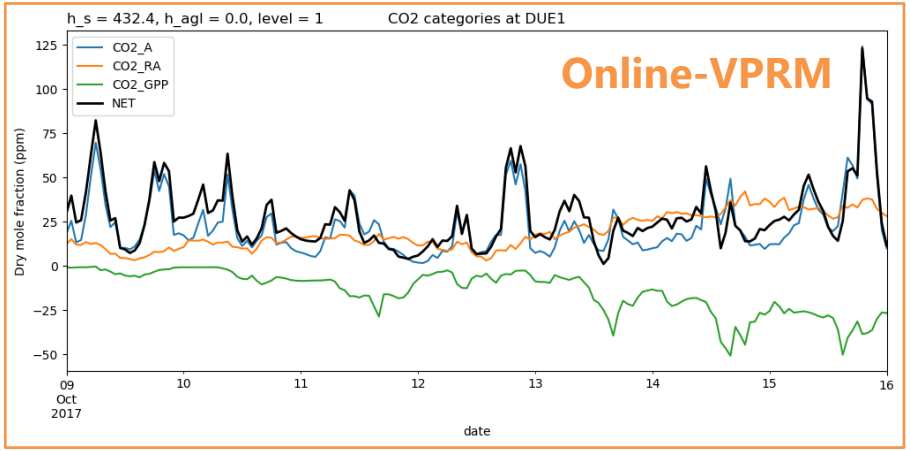




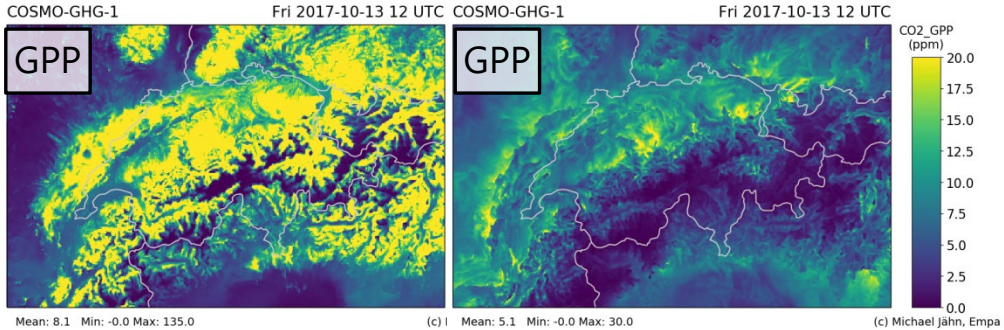


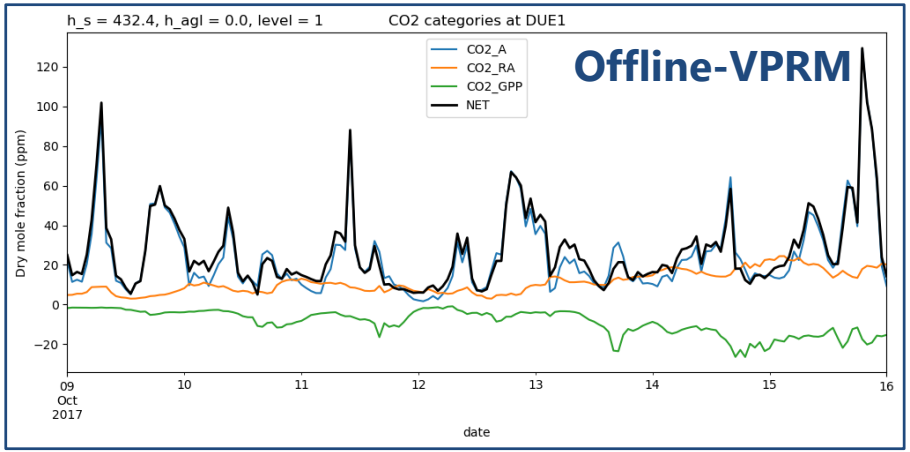
Differences Online vs. Offline VPRM





Online-VPRM **Offline-VPRM**





Summary and Outlook

- Stronger orography smoothing necessary to avoid tracer instabilities
- Observation nudging → meteo fields closer to measurements
- Two major issues:
  - Too strong vertical mixing during nighttime (“terra incognita”)
  - Point measurements vs. grid cell values
- Planned:
  - Analyzing spatial variability between nearby CO_2 sensors
  - Vertical profiles (e.g., BRM: 5 height levels up to 212 m a.g.l.)

Thank you!