Empa
Materials Science and Technology

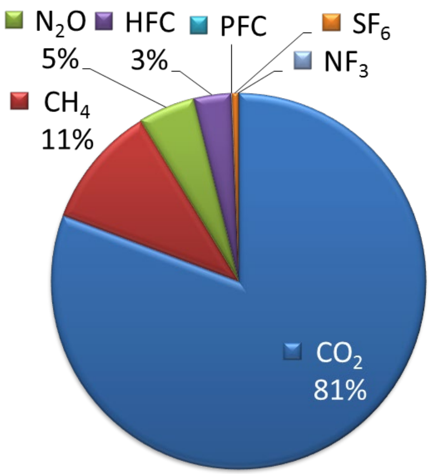
Top-down Support of Swiss non-CO_2 Greenhouse Gas Emissions Reporting to UNFCCC

S. Henne[1], M. K. Vollmer[1], M. Steinbacher[1], M. Leuenberger[2], F. Meinhardt[3], J. Mohn[1], L. Emmenegger[1], D. W. Brunner[1], S. Reimann[1]

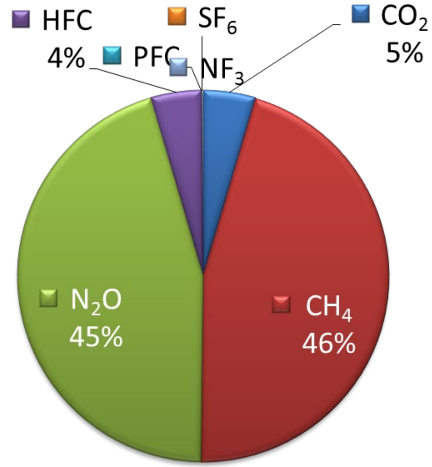
(1) Laboratory for Air Pollution/Environmental Technology, Empa, Dübendorf
(2) University of Bern, Climate and Environmental Physics Division, Switzerland
(3) Umweltbundesamt (UBA), Kirchzarten, Germany

Swiss GHG Emissions According to National Inventory Reporting (NIR) to UNFCCC

Empa
Materials Science and Technology

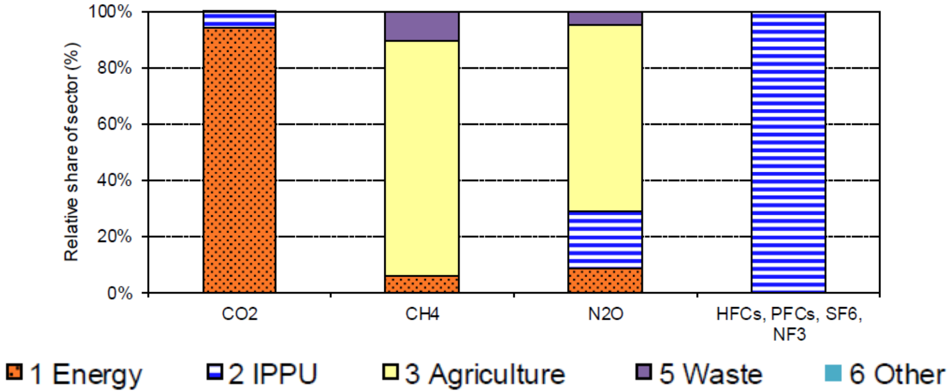


Emissions



Uncertainty

Contribution by sector



Non-CO_2 GHGs in Switzerland

- Emission contribution 19 %
- Uncertainty contribution 95 %

w/o LULUCF

Total: 46 Tg yr^{-1} (CO_2 equivalent)
(+ ~6 Tg yr^{-1} international flights)

Per capita: ~5.5 t yr^{-1}
(+ ~0.8 t yr^{-1} international flights)

w/o LULUCF

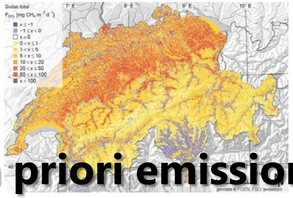
Values for 2018; Swiss NIR, FOEN (2020)

stephan.henne@empa.ch

Top-Down Support of Swiss NIR

Empa
Materials Science and Technology

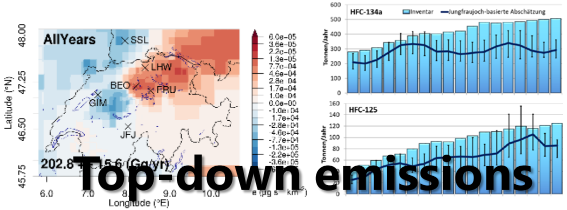
We aim at supporting national bottom-up inventory reporting by using atmospheric observations, transport simulations and inverse methods to derive national total emissions and compare those to NIR reported values.



Inverse methods

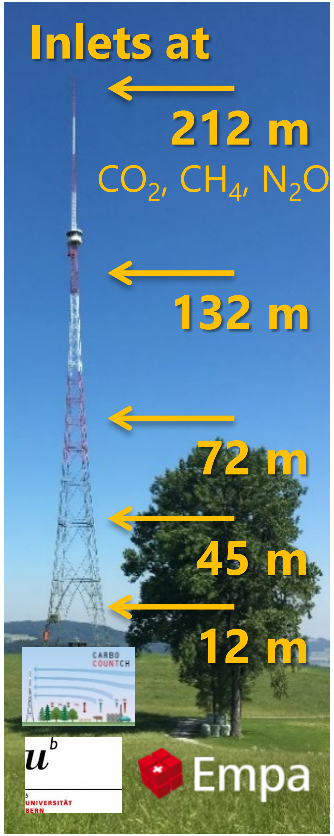
Bayesian inverse modelling: CH_4, N_2O

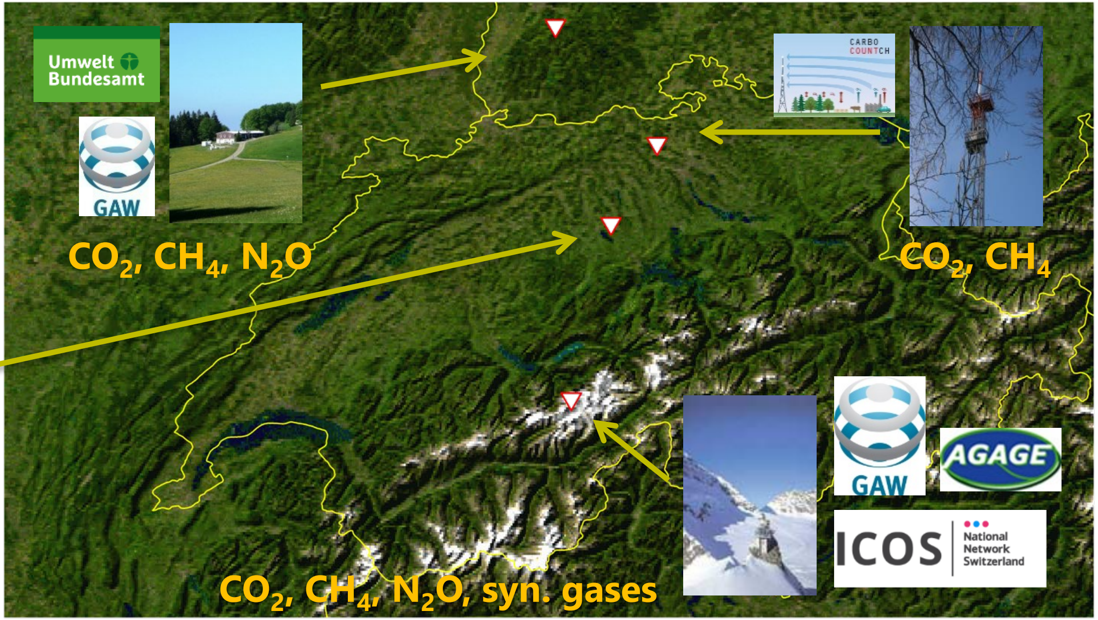
Tracer ratio method: Synthetic gases



https://doi.org/10.5194/egusphere-egu2020-17176
stephan.henne@empa.ch

Swiss GHG Observation Network

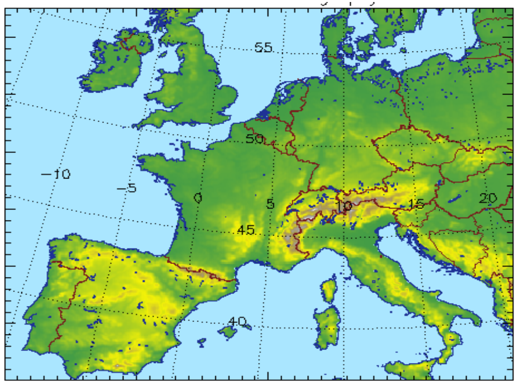




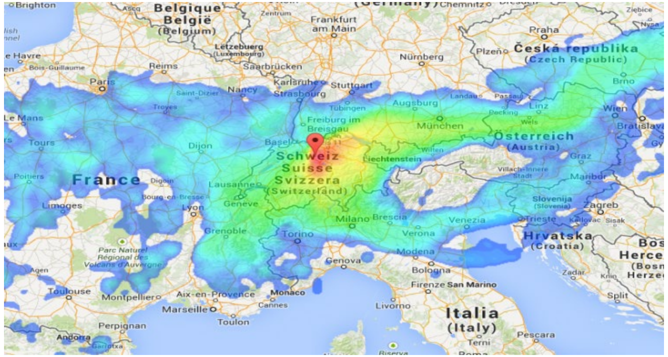
Atmospheric Transport Simulations

Empa
Materials Science and Technology

- FLEXPART-COSMO (V8C2.0)
  - Lagrangian Particle Dispersion Model
- Input: COSMO-7
  - 7 km x 7 km resolution
  - MeteoSwiss analysis
- Backward simulations for individual sites
  - 3-hourly release of 50'000 particles per site
  - 4 day backward or until out of domain
  - Different release heights to account for smoothed model topography
- Background from observations or larger scale models



COSMO-7 model domain



Source sensitivities: one site, one time

https://doi.org/10.5194/egusphere-egu2020-17176

stephan.henne@empa.ch

Bayesian Inversion: Gridded or by Source Sector

$$J = \frac{1}{2}(x - x_b)^T \boldsymbol{B}^{-1}(x - x_b) + \frac{1}{2}(\boldsymbol{M}x - \chi_o)^T \boldsymbol{R}^{-1}(\boldsymbol{M}x - \chi_o)$$

Data-mismatch (R)

- Uncertainty set proportional to model sensitivity ($\boldsymbol{\sigma_{min}}, \boldsymbol{\sigma_{srr}}$)
  - Estimated iteratively from model residuals
- Covariance determined from auto-correlation function of residuals

Likelihood optimisation

[Michalak et al., 2005]

- By site: $\sigma_{min}, \sigma_{srr}$, f_b
- By region: σ_E
- Globally: L, T, τ_B

A-priori emissions (B_E)

- Uncertainty set for individual country ($\boldsymbol{\sigma_E}$) or category by country
  - Total CH: N_2O ±40 %, CH_4 ± 18 %
- Covariance between same emission categories in different regions
  - Distance-dependent length scale: **L**
  - Time-dependent length scale: **T**

A-priori Baseline (B_B)

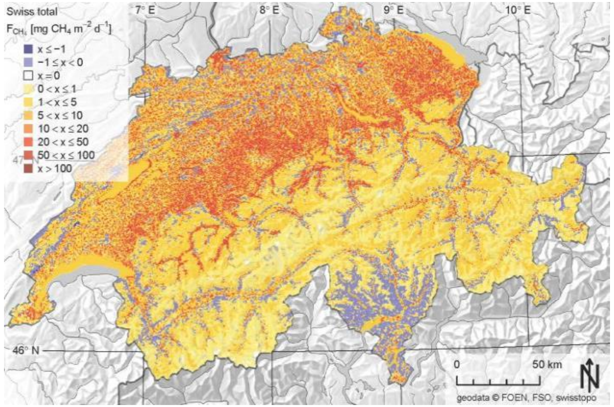
- Uncertainty as from statistical baseline fit (REBS; scaling factor $\mathbf{f_B}$)
- Covariance according to temporal length scale ($\boldsymbol{\tau_B}$)

[Henne et al., 2016, ACP]

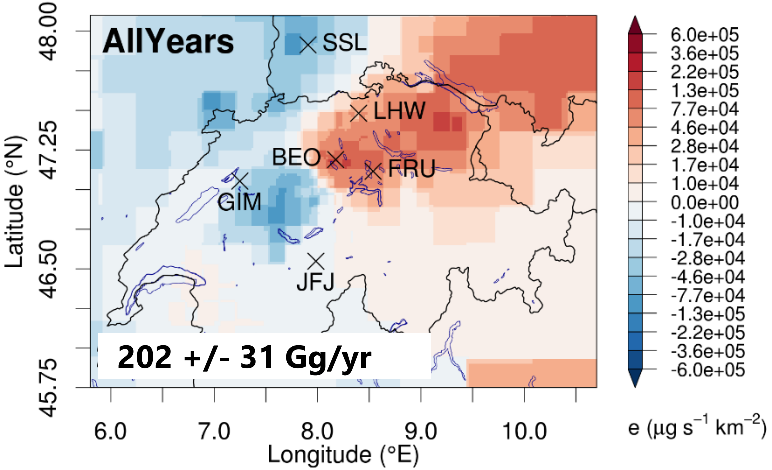
Swiss Methane Emissions (2013-2019)

Empa
Materials Science and Technology

A priori inventory *[Hiller et al., 2014]*



A posteriori difference



NIR (w/o 2019): 198 ± **36** Gg yr^{-1}, ±18 %

A posteriori: **202 ± 31** Gg yr^{-1}, ±15 %

95 % CI

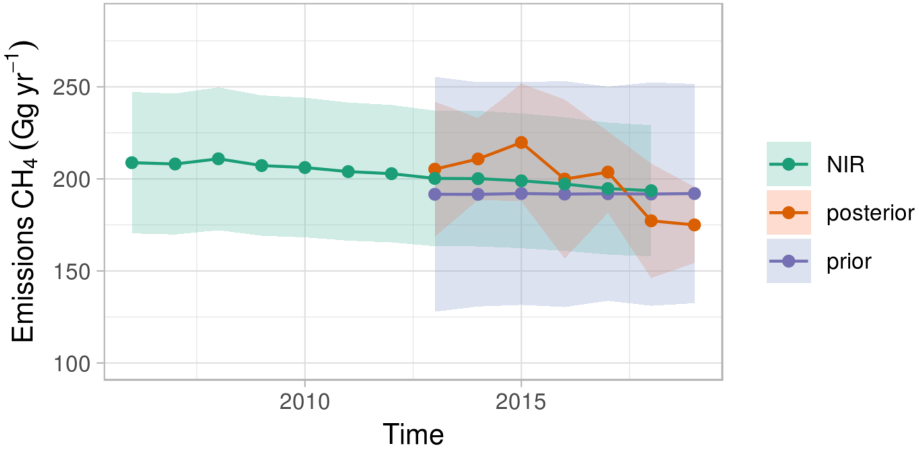
- National total very similar and well established by inversion
- Spatial distribution less well constrained by current network
- East/west shift in emission distribution (potentially boundary effect)

stephan.henne@empa.ch

Swiss Methane Emissions (2013-2019)

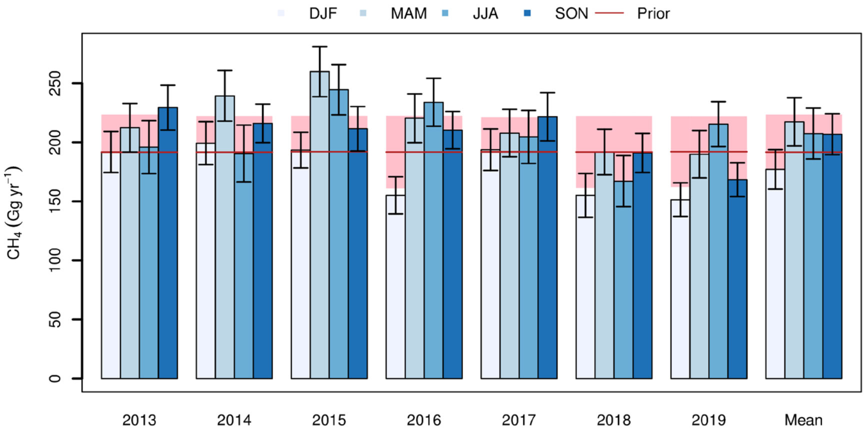
Empa
Materials Science and Technology

Temporal evolution



Based on 8 sensitivity inversions per year

Seasonal variability



Spring maximum & winter minimum
Seasonal amplitude: ±20 %

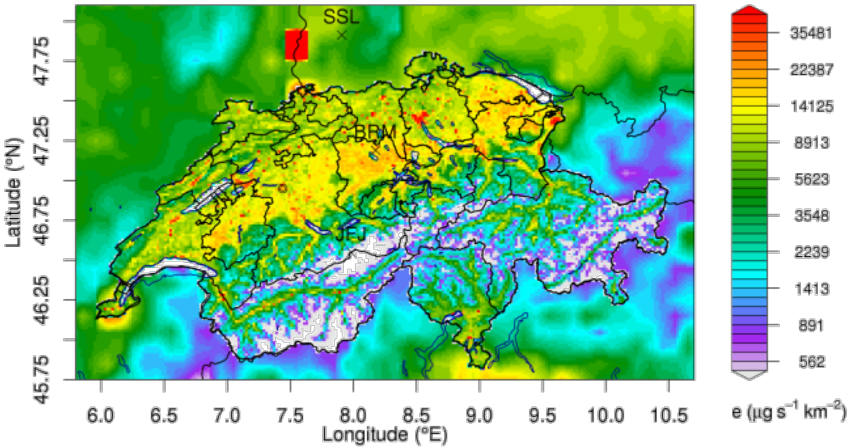
Based on 4 sensitivity inversions with seasonal variability per year

https://doi.org/10.5194/egusphere-egu2020-17176
stephan.henne@empa.ch

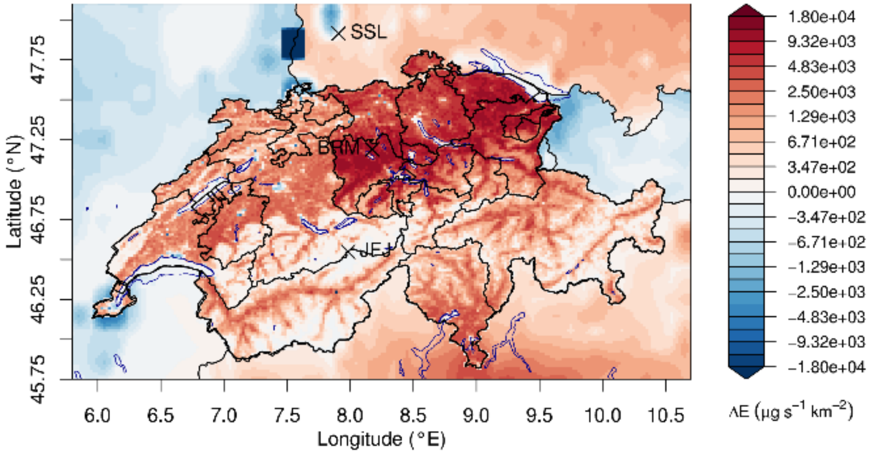
Swiss Nitrous Oxide Emissions (2017-2019)

Empa
Materials Science and Technology

A priori distribution



Annual mean a posteriori difference



NIR (w/o 2019): **10.2 ± 4.0** Gg yr^{-1}, ±40 %
A posteriori: **11.0 ± 2.8** Gg yr^{-1}, ±25 %

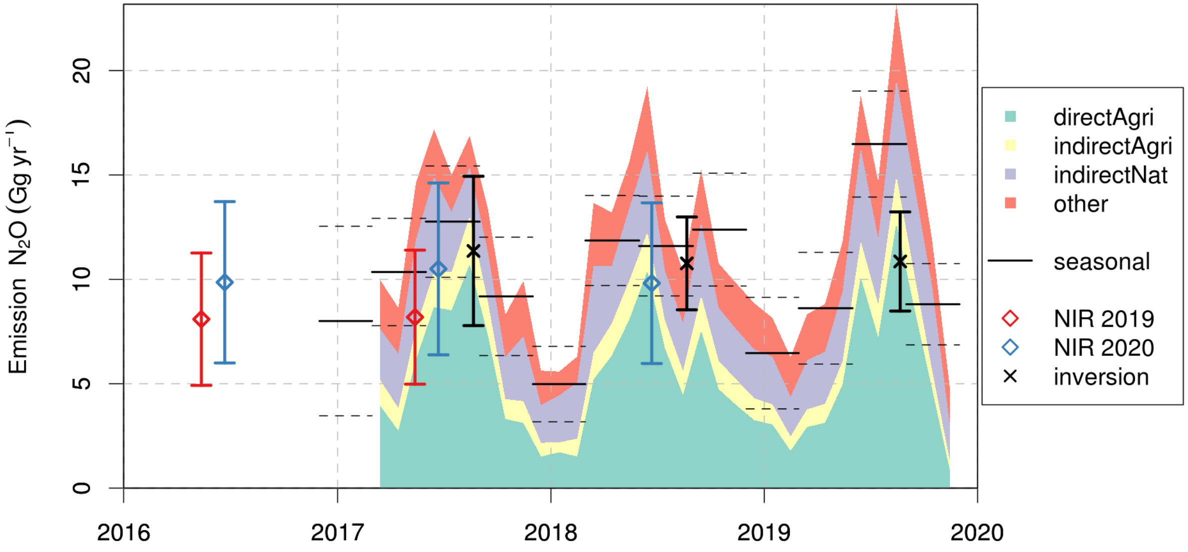
95 % CI

- Absolute increase strongest on central and eastern Swiss Plateau
- Relative increase strongest in Southern Switzerland (indirect natural)
- Considerable decreases limited to urban areas (waste, transport, heating)

stephan.henne@empa.ch

Seasonality of N_2O Emissions

Empa
Materials Science and Technology



- Pronounced seasonality in soil emissions (±50 % summer/winter)
- Variability from year to year
- Clearest seasonal signal from agricultural soils
- Emissions from (semi-)natural soils peak earlier in the year than from agricultural soils

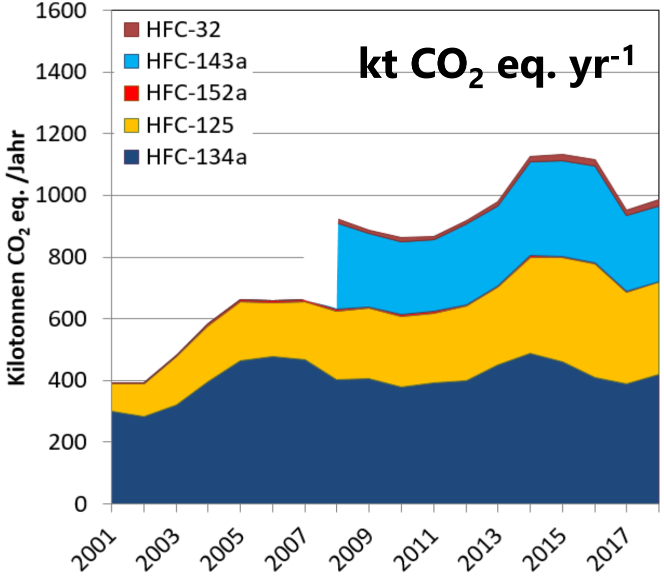
stephan.henne@empa.ch

Swiss Synthetic Gas Emissions Based On Jungfraujoch Observations

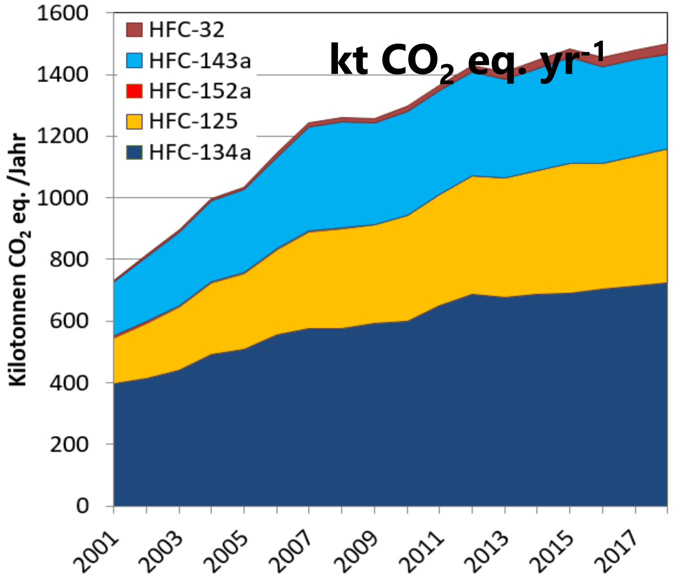
Empa
Materials Science and Technology

AGAGE

JFJ-based estimate



NIR 2020



Tracer-ratio method relying on CO inventory and observations on days with dominating Swiss influence as estimated from FLEXPART-COSMO source sensitivities.

https://doi.org/10.5194/egusphere-egu2020-17176
stephan.henne@empa.ch

Summary & Outlook

Empa
Materials Science and Technology

CH_4

- Swiss CH_4 emissions (2013-2019): **197 ± 18** Gg yr^{-1}, 1.5 % smaller than inventory

N_2O

- Swiss N_2O emissions (2017-2019): **10.7 ± 3.5** Gg yr^{-1}, 20 % larger than inventory
- Strong seasonal variability largest for agricultural soils

CH_4 and N_2O

- Considerable uncertainty introduced by boundary conditions (& availability of observational data)

Synthetic gases

- Jungfraujoch-based tracer ratio method to estimate Swiss emissions
- Measurements at tall tower Beromünster commenced August 2019
- Inverse modelling results expected later 2020

Results included in 2020 submission of Swiss NIR: Annex 5

https://doi.org/10.5194/egusphere-egu2020-17176
stephan.henne@empa.ch

Acknowledgements

- Financial support
  - Federal Office for the Environment (FOEN/BAFU)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU

- Measurements Beromünster
  - Markus Leuenberger, Rüdiger Schanda (Uni Bern)
  - David Steger, Beat Schwarzenbach, Thomas Bruggisser, Joachim Mohn (Empa)
- Measurements Jungfraujoch
  - David Steger, Martin Steinbacher (Empa)
  - Martin K. Vollmer, Stefan Reimann (Empa, AGAGE)
- Measurements Schauinsland
  - Frank Meinhardt (UBA)