Support for the verification of the Swiss National Emission Inventory

Dominik Brunner and Stephan Henne

Empa, Swiss Federal Laboratories for Materials Science and Technology

Support for the Swiss National Inventory Report (NIR)

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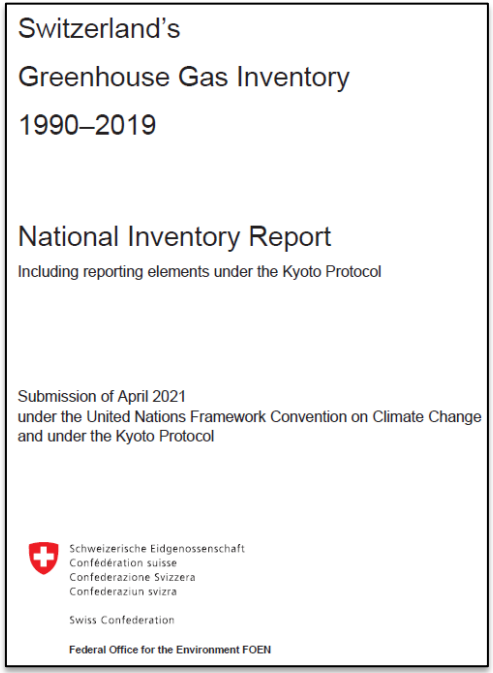

Switzerland's

Greenhouse Gas Inventory

1990–2019

National Inventory Report

Including reporting elements under the Kyoto Protocol

Submission of April 2021
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol

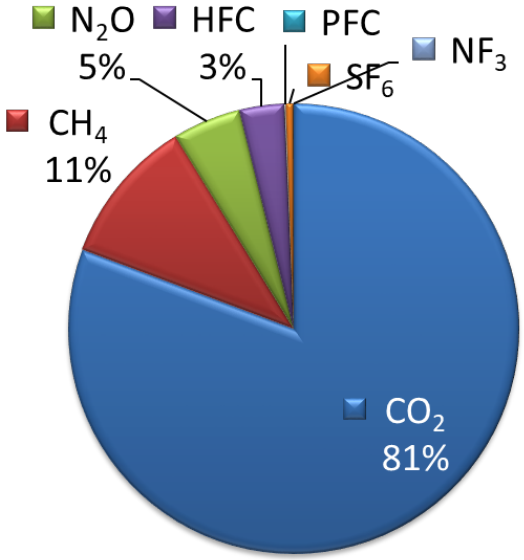
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

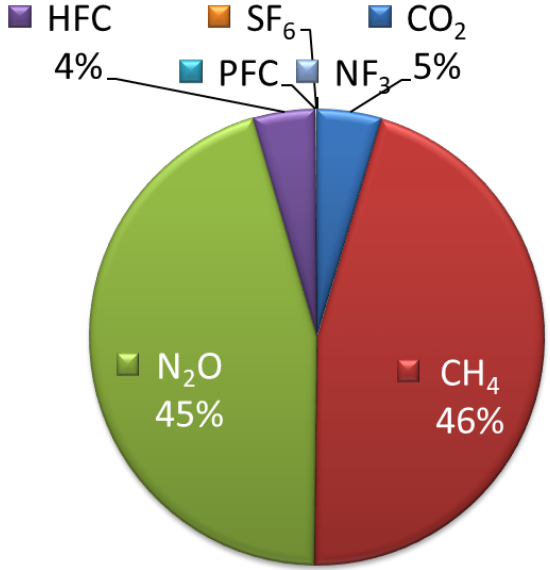
Contribution of individual gases to total Swiss emissions in 2016

100% = 49'414 CO_2 eq (kt)



Contribution of individual gases to total emission uncertainty

Total uncertainty = 3.6%



Support for the Swiss National Inventory Report (NIR)

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Pasta Carbonara

INGREDIENTS:

1. Pasta
2. Bacon
3. Egg Yolks
4. Parmesan
5. Parsley

Top-down emission estimation

INGREDIENTS:

1. Observations
2. Atmospheric transport model
3. Gridded emission inventory
4. Mathematical inversion algorithm

1. Swiss greenhouse gas observation network

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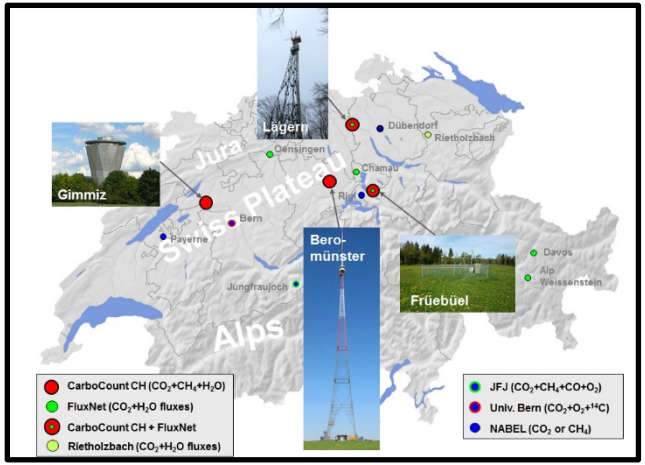
High-altitude research station Jungfraujoch

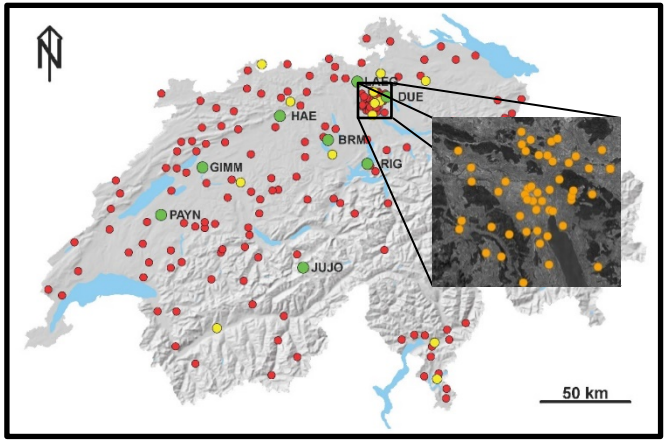
- CO_2, CH_4, N_2O
- >40 synthetic gases (CFCs, halons, HCFCs, HFCs, PFCs, HFOs, solvents, SF_6)
- CO_2 stable isotopes (^{13}C, ^{18}O)
- Radiocarbon

High-precision GHG network started in CarboCount-CH



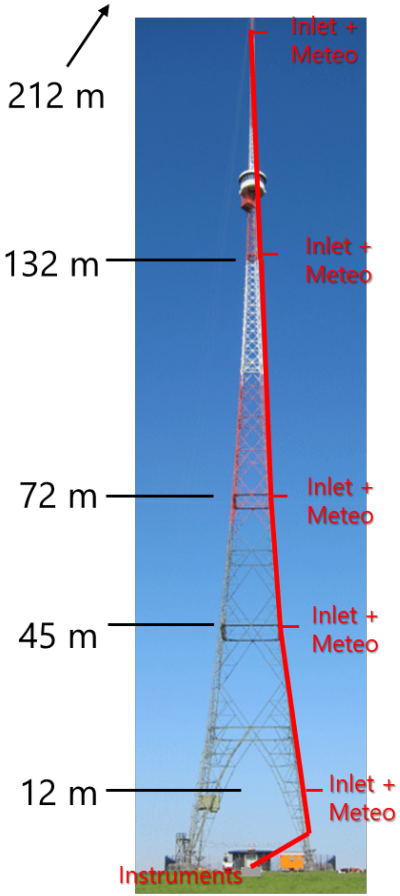
- CO_2, CH_4, CO
- Swiss Fluxnet Eddy Covariance flux sites

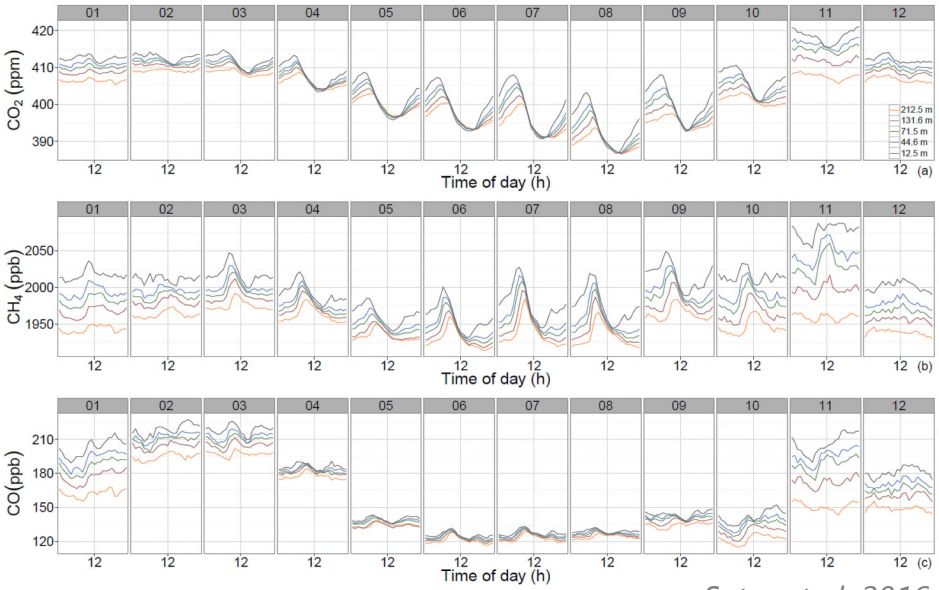
Low- and mid-cost CO_2 sensor network Carbosense



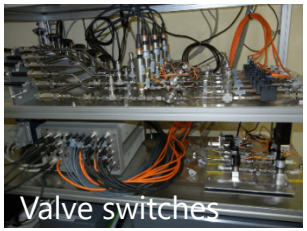
- 200 low-cost CO_2 sensors (Sensair LP8)
- 14 mid-cost CO_2 sensors (Sensair HPP + active calibration)
- Strong focus on city of Zurich (project ICOS-Cities PAUL)

Tall tower Beromünster





Satar et al. 2016


Valve switches


Medusa GC-MS

University of Bern

Since 2012

CO_2, CH_4, CO (Picarro G2401)
^{14}C (biweekly samples)

Empa

Since 2017

N_2O, CO (Picarro G5310)

Since 2016

Site of Swiss Air Pollution Monitoring network NABEL
O_3, NO_x, PM, VOCs, NH_3, …

2020 – 2021

Synthetic gases (Medusa GC-MS)

2. Atmospheric transport models

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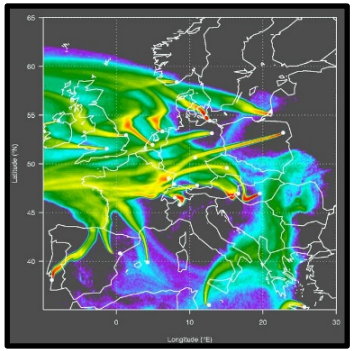
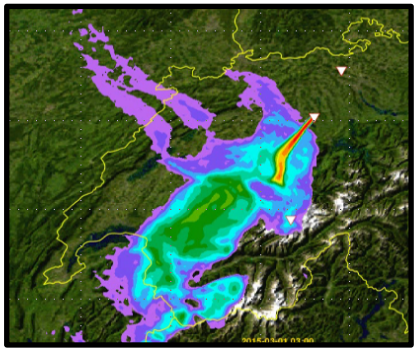
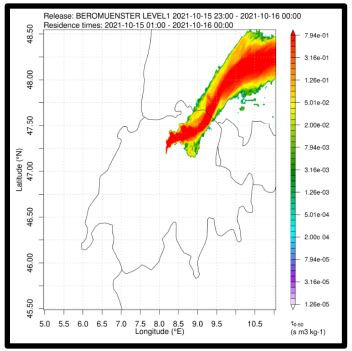
FLEXPART-IFS
resol. 10-100 km



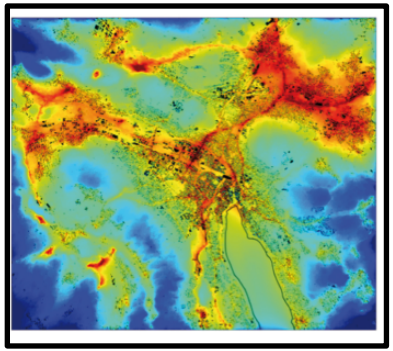
FLEXPART-COSMO
resol. 1- 7 km



FLEXPART-ICON
(under development)

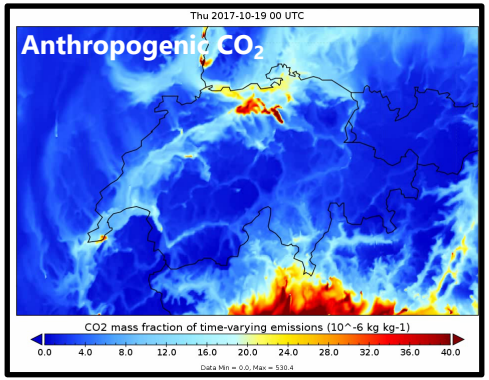


GRAL
resol. 2-10 m

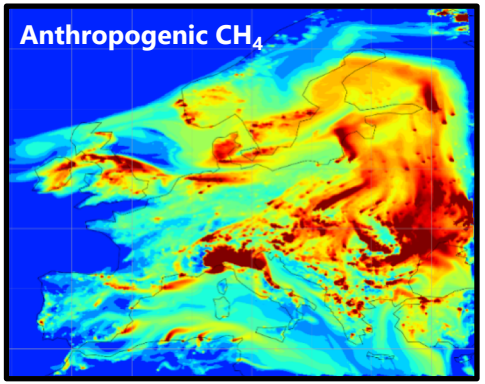


Lagrangian

COSMO-GHG
resol. 1-10 km



ICON-ART
Global to local

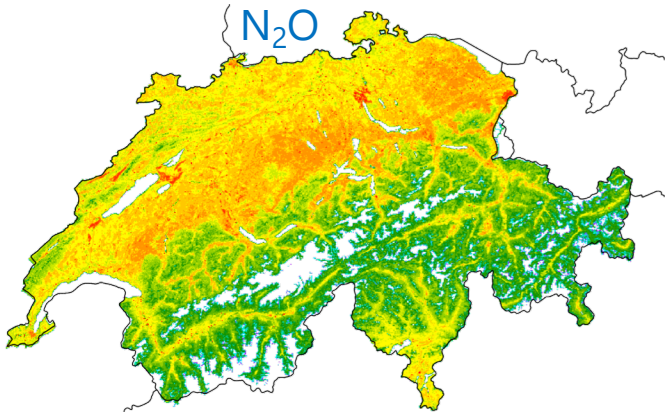


Eulerian

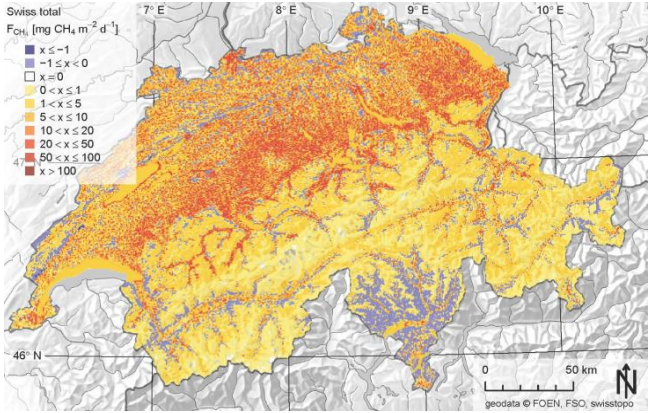
3. High-resolution gridded emission inventories

- Produced at 5-year intervals by company Meteotest
- Emissions per sector consistent with official Swiss National Inventory
- Spatial mapping based on detailed geo-statistical data (at 100 m x 100 m resol.)

N_2O

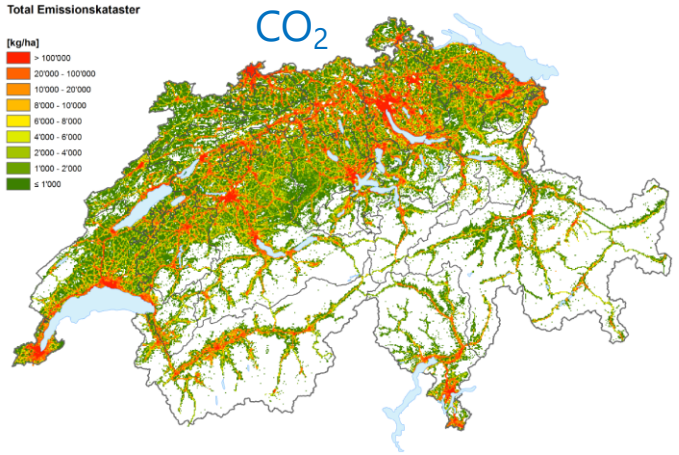


CH_4



Hiller et al. (2014)

CO_2



4. Inversion algorithms

Bayesian inversion (Henne et al. 2016)

- Estimation of spatial emission distribution
- Five-daily prior **baseline** and its uncertainty from JFJ baseline fit

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

Deviation from a-priori

model - obs.

- Analytically solve for posterior state

$$x = x_b + \boldsymbol{B}\boldsymbol{M}^{\boldsymbol{T}}\left(\boldsymbol{M}\boldsymbol{B}\boldsymbol{M}^{\boldsymbol{T}} - \boldsymbol{R}\right)^{-1}(\chi_o - \boldsymbol{M}x_b)$$

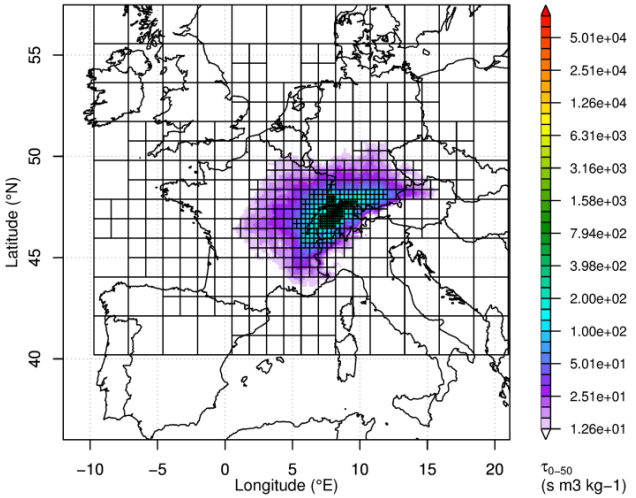
Common features

- Footprints (source sensitivities) from FLEXPART-COSMO
- Reduced inversion grid
- Use of selected observations only
- Treatment of temporal and spatial correlations

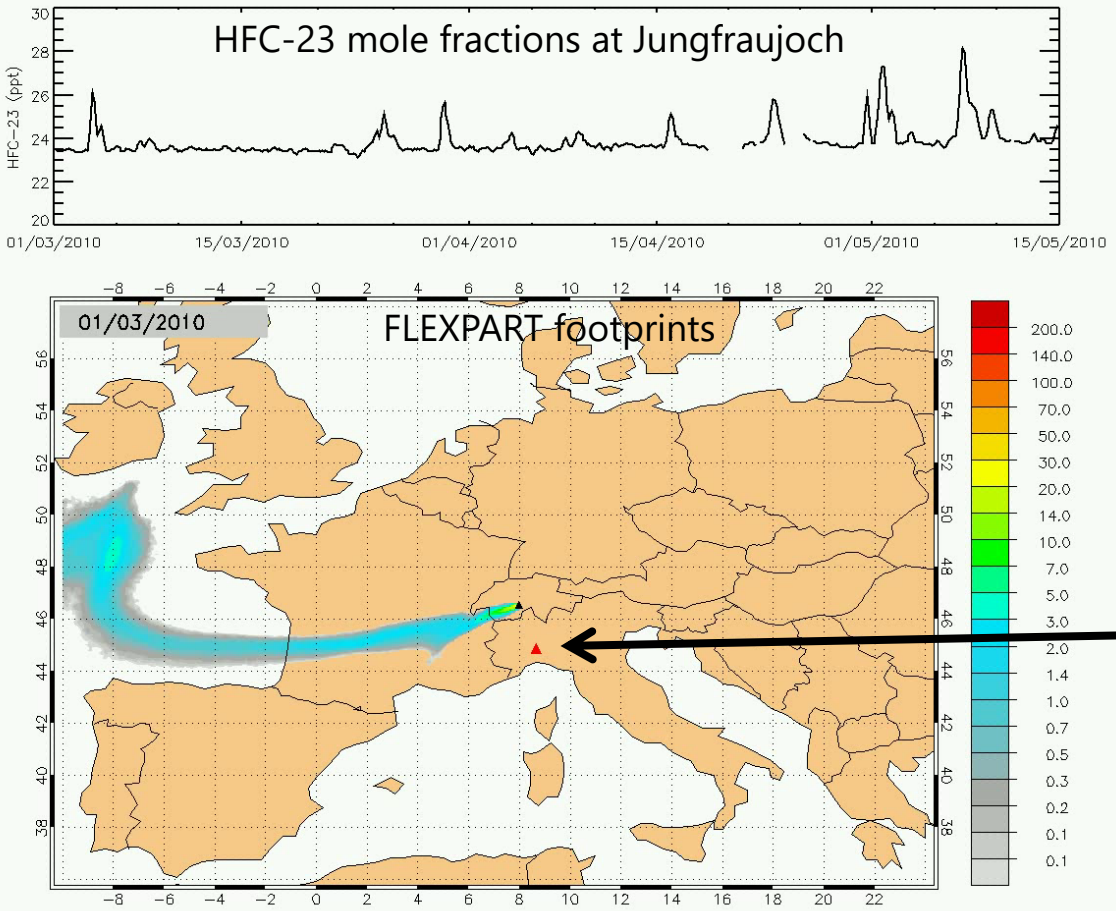
Extended Kalman Filter (Brunner et al. 2012)

- Estimation of spatial and temporal emission distribution
- Sequential assimilation
- **Baseline** contained in state vector
- Positive fluxes enforced

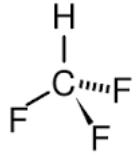
Reduced inversion grid



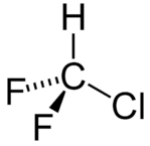
An early example: Detection of HFC-23 emission hot-spot



HFC-23
Lifetime 270 years
GWP = 14800



byproduct of
HCFC-22
production



observed: 26-56 t/y
reported: 2.6 t/y (UNFCCC)

Keller et al. (GRL 2011)

Annual top-down estimation of Swiss CH_4 & N_2O emissions

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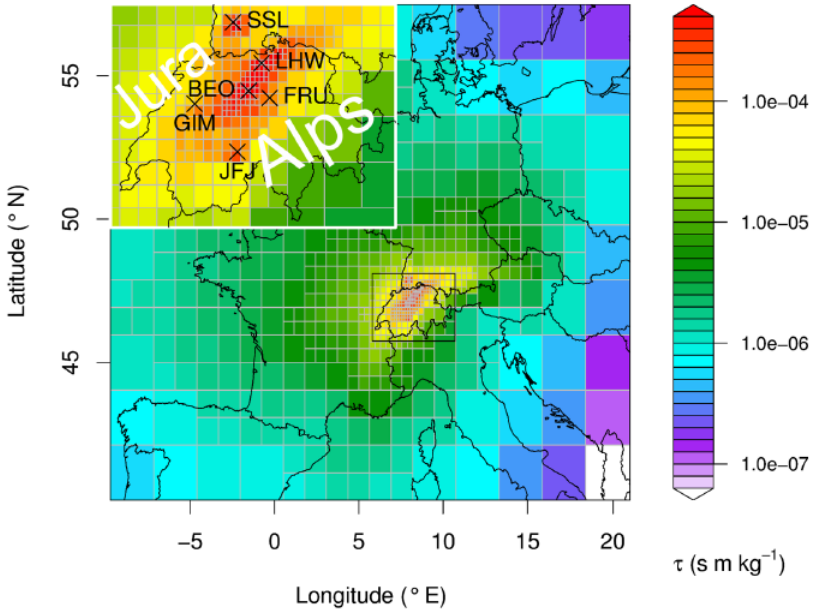
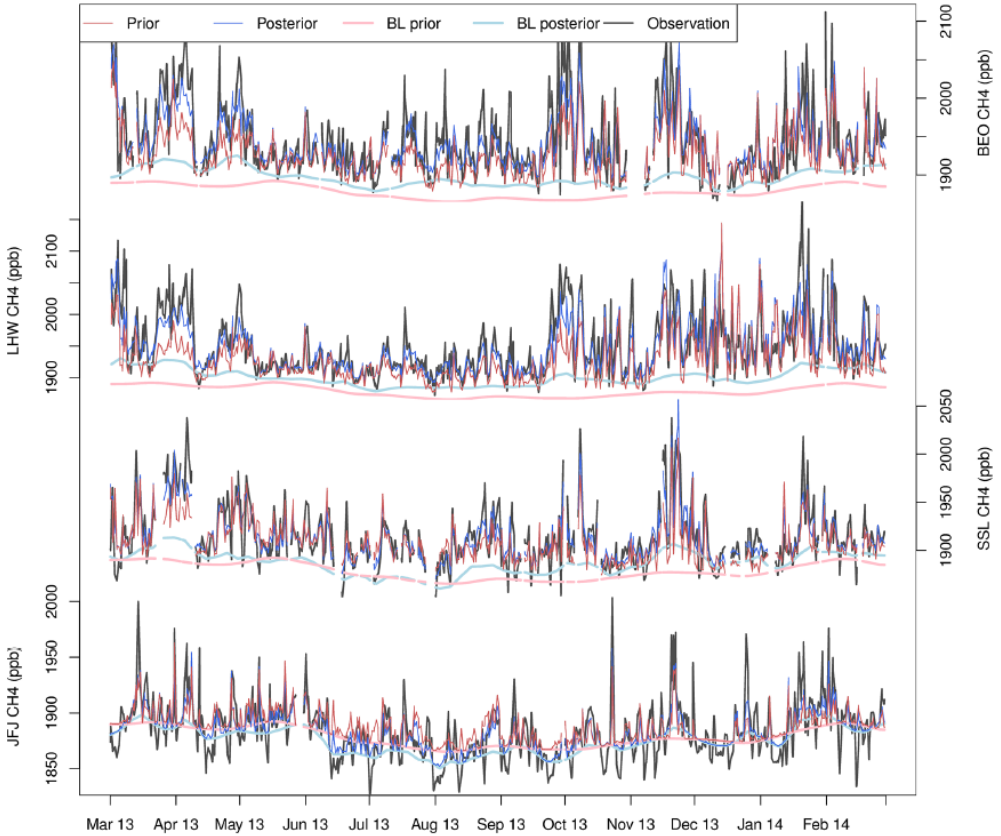
Measurements from 4 sites:

- Beromünster (BEO)
- Lägern-Hochwacht (LHW)
- Jungfraujoch (JFJ)
- Schauinsland (SSL)

Annual mean footprint for all sites



Comparision of simulated with observed CH_4



Annual top-down estimation of Swiss CH_4 & N_2O emissions

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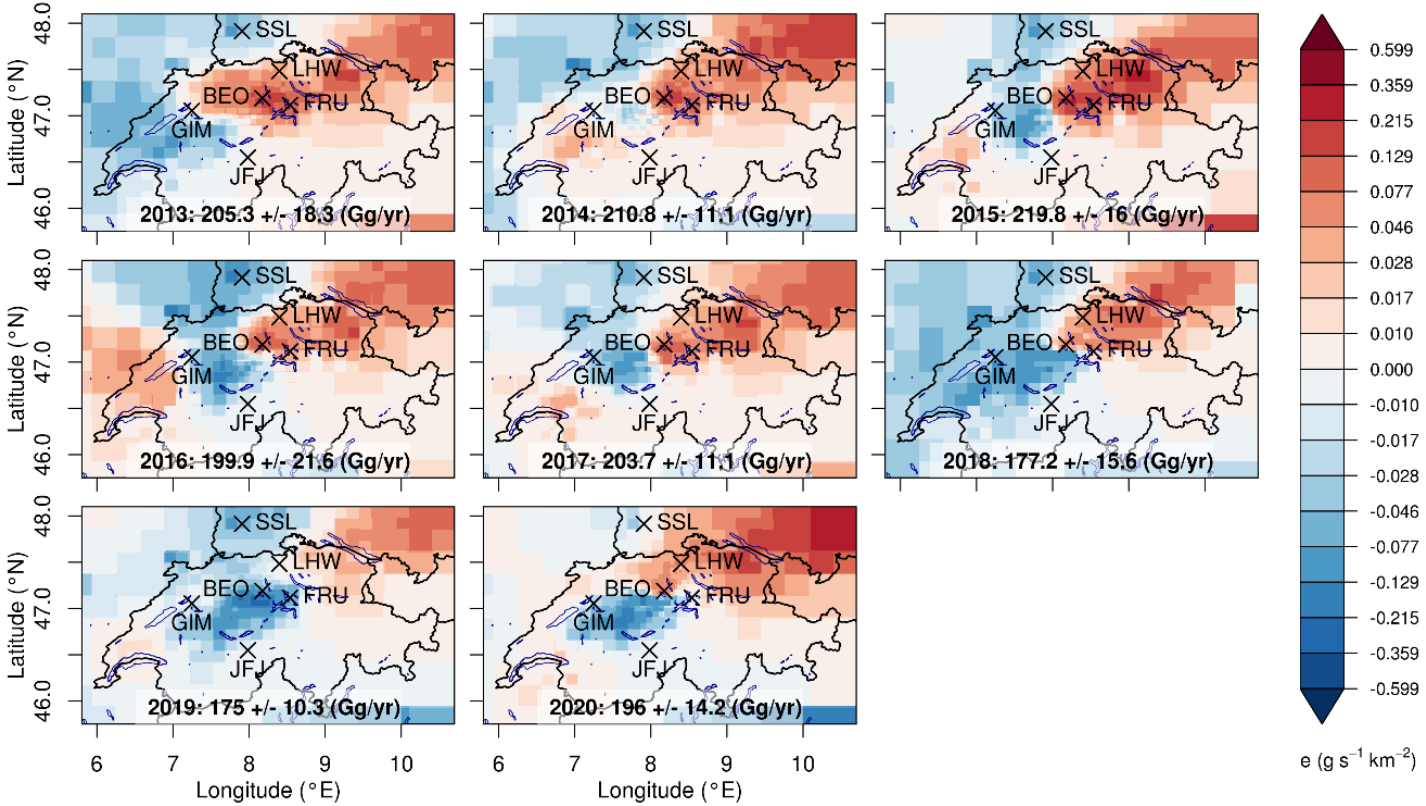
Annual mean results for 2013-2020: Difference from priori emission estimates



Higher than a priori

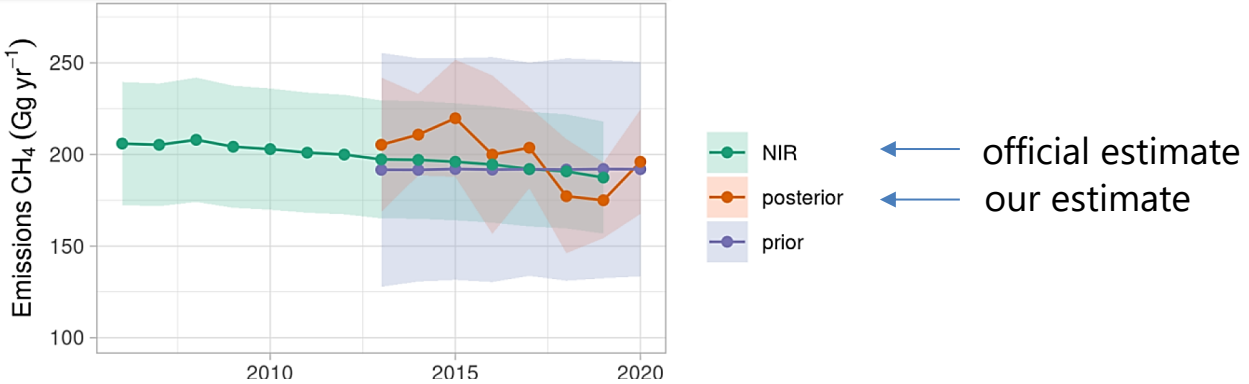
Lower than a priori

Annual top-down estimation of Swiss CH_4 & N_2O emissions

National Inventory Report of Switzerland 2021

Annex 5 Additional information on verification activities

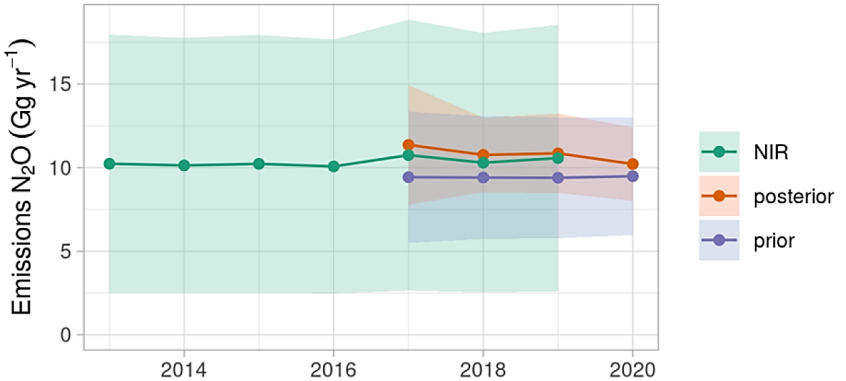
Annual mean CH_4 emissions



official estimate

our estimate

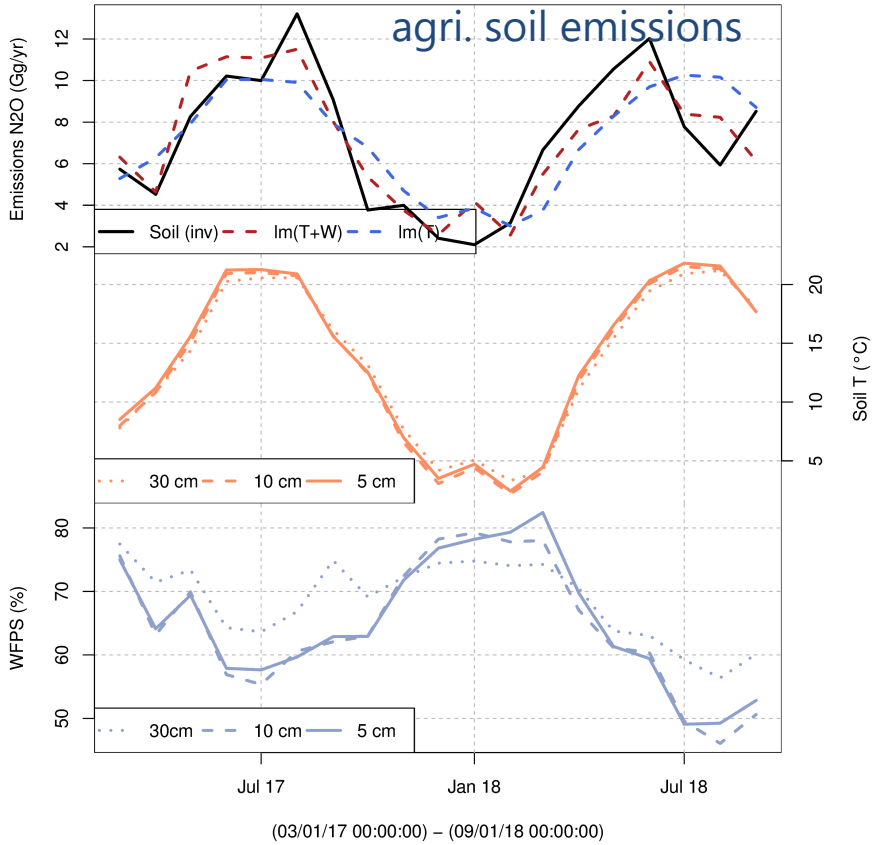
Annual mean N_2O emissions



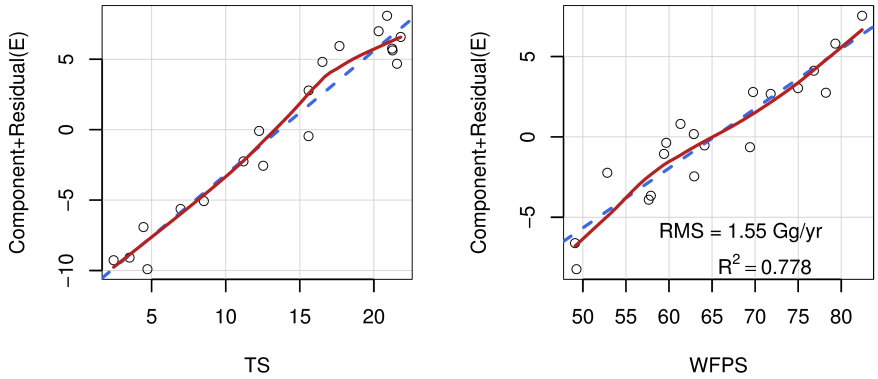
Henne et al. (2016)

Swiss NIR (2021)

N_2O emissions are affected by soil temperature and moisture



Multi-linear model: TS + WFPS



- Variability in ambient temperatures and soil water content explains large proportion of temporal variability in N_2O emissions
- How much is due to correlation between ambient conditions and agricultural practices?

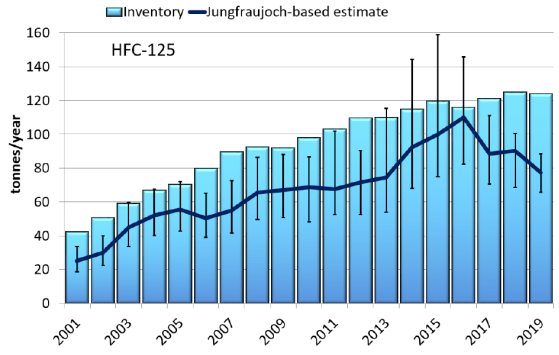
Stephan Henne

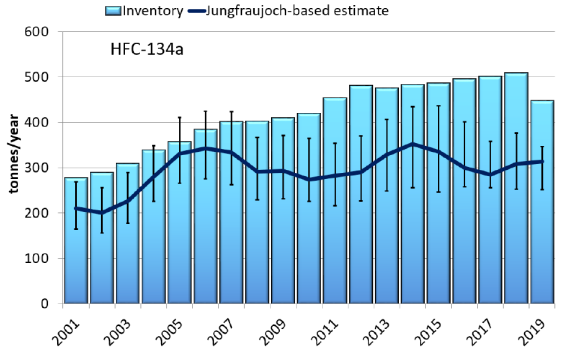
Annual top-down estimation of synthetic GHG emissions

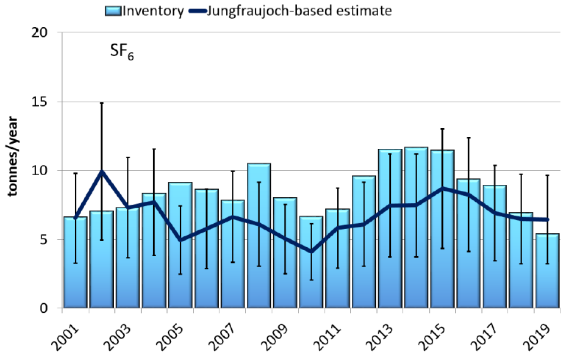
National Inventory Report of Switzerland 2021

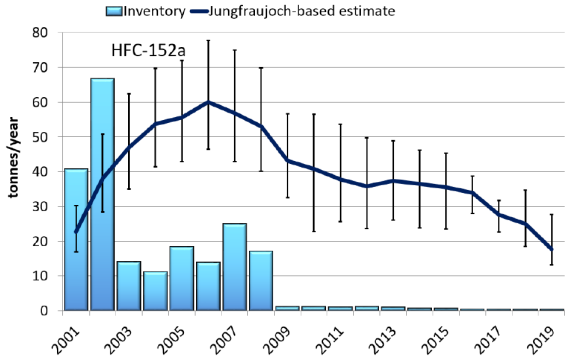
Annex 5 Additional information on verification activities

Estimates of Switzerland's emissions of synthetic gases based on measurements at Jungfraujoch and a simple tracer-ratio method (TRM) using CO as a reference species









Stefan Reimann

Beromünster campaign to estimate synthetic GHG emissions

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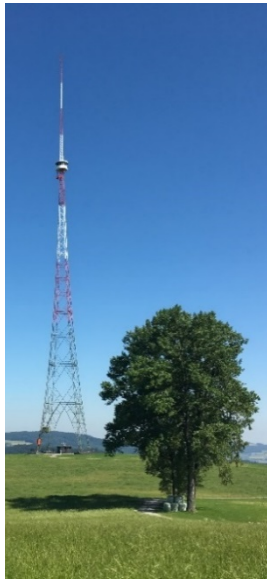
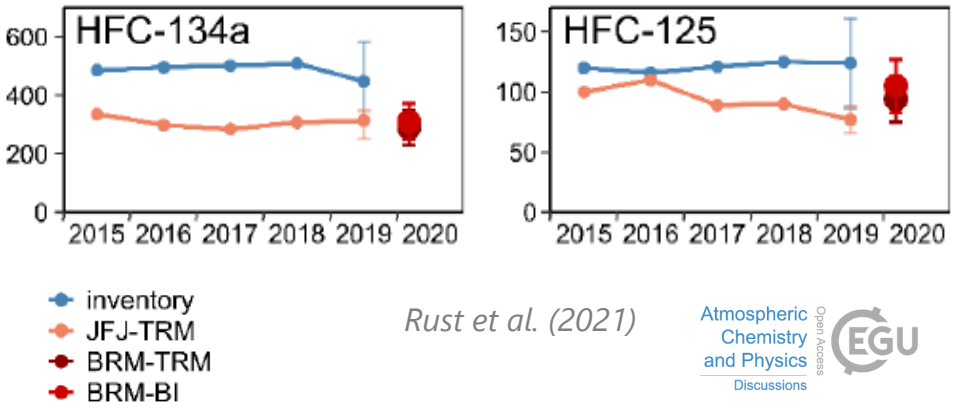
Can we improve the estimates for Switzerland with additional measurements at Beromünster tall tower?



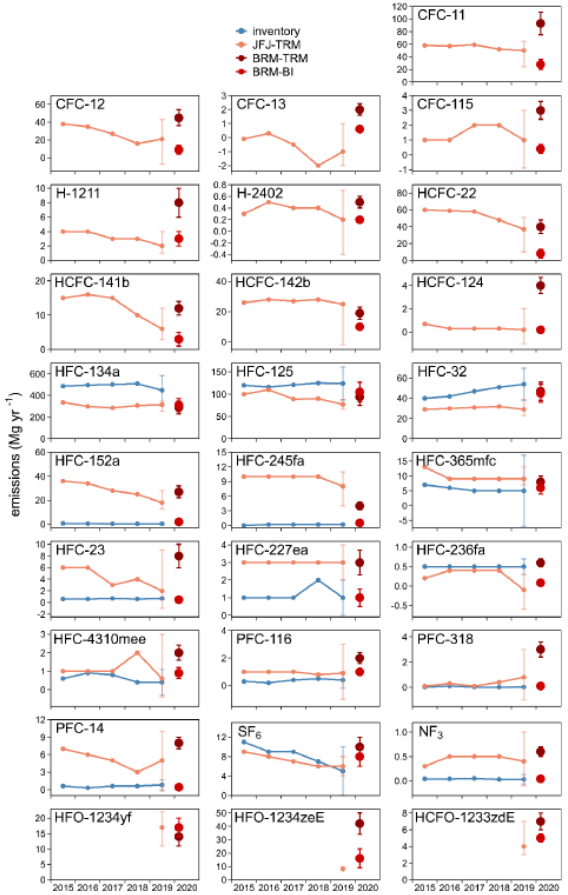
Comparison of estimates from

- tracer ratio method (TRM) applied to Jungfraujoch data
- tracer ratio method (TRM) applied to Beromünster data
- Bayesian inversion with Beromünster data (BI)



Rust et al. (2021)

Atmospheric Chemistry and Physics Discussions — Open Access — EGU



- Good consistency for major species (HFC-134a, HFC-125)
- Large discrepancies for minor species (CFC-11, HFC-23). Reasons not entirely clear yet.

Large unaccounted industrial N_2O source

Tages-Anzeiger – Dienstag, 11. Februar 2020

Klima-Leiche im Wallis aufgetaucht

Treibhausgas Die Chemiefirma Lonza hat jahrzehntelang klimaschädliches Lachgas produziert – ohne es zu merken. Damit wird es für die Schweiz schwieriger, das Klimaziel 2020 zu erreichen.

Stefan Häne

Die Schweizer Industrie stösst umgerechnet rund 0,6 Millionen Tonnen mehr CO_2 aus als bisher ausgewiesen – die Menge entspricht gut einem Prozent aller Treibhausgasemissionen im Land. Grund dafür ist eine Lachgasquelle im Wallis, genauer in Visp. Dort stellt Lonza seit bald 50 Jahren das Vitamin Niacin her.

Doch erst vor zwei Jahren hat das Chemie- und Pharmaunternehmen – dank moderner Messgeräte – bei einer Kontrolle erste Hinweise auf eine unbekannte Emissionsquelle erhalten. Mittlerweile ist klar: Es handelt sich um Lachgas. Über den Fall haben das Bundesamt für Umwelt (Bafu) und Lonza gestern informiert.

Lonza «bedauert die Situation ausserordentlich», sieht sich aber keiner Schuld bewusst. Lachgasemissionen sind nicht in der Luftreinhalteverordnung geregelt, weil sie als gesundheitlich unbedenklich gelten. Aus diesem Grund hat das Unternehmen auch nicht danach gesucht. Aufgrund seiner Eigenschaften hat Lachgas aber ein erhebliches Treibhauspotenzial. Lonza bezeichnet sich als weltweiten Marktführer bei der Herstellung von Niacin. Ein zweiter Produk-

Wie viel zusätzliches Treibhau

Neue Zürcher Zeitung

Die Treibhausgasemissionen der Schweizer Industrie sind höher als angenommen

Die Treibhausgasemissionen des Schweizer Industriesektors liegen laut dem Bund jährlich um rund 600 000 Tonnen CO2-Äquivalente höher als bisher angenommen. Grund sei eine bisher unbekannte Lachgasquelle.

10.02.2020, 10.50 Uhr

[FOEN, news release, 2020-02-10]

Previously Unaccounted Swiss N_2O Source

- Niacin (vitamin B3) production by Lonza in Valais (Visp), by-product N_2O currently vented to atmosphere
- Previously not reported in national inventory to UNFCCC
- Emissions of **2** Gg N_2O yr^{-1} = **600** Gg CO_2-eq. yr^{-1}
- ~**20 %** of previously reported Swiss N_2O emissions

Big disappointment for our top-down method!
The source was not detected in our measurements, because they were not sensitive to emissions in the Alpine Valley where Lonza factory is located

Conclusions

- 20 years of fruitful collaboration with Swiss Federal Office for the Environment (FOEN)
- FOEN financially supports research projects to improve inventory estimates
- Original interest was in synthetic gases like CFCs, HFCs, SF_6
- Today also strong interest in CH_4 and N_2O, which dominate uncertainty budget
- Little interest in CO_2, because emissions are well-known at national level
- High-resolution gridded emission inventories produced regularly and consistently for air pollutants and major greenhouse gases
- Measurement network is still sparse, especially for N_2O and halocarbons
- Further improvements of transport and inverse modelling system ongoing
  - Transition to FLEXPART-ICON & ICON-ART
  - Improved representation of boundary layer turbulence (Katharopoulos et al. 2021, submitted)
  - Integration into global inversion system (Bergamaschi et al., in prep.)
  - Possibly transition to CIF in the long-term

Thank you for your attention

Special thanks to

Stefan Reimann, Martin Vollmer, Joachim Mohn, Markus Leuenberger, Ioannis Katharopoulos, Dominique Rust and Lukas Emmenegger