Challenges for operational greenhouse gas monitoring
The Swiss perspectives

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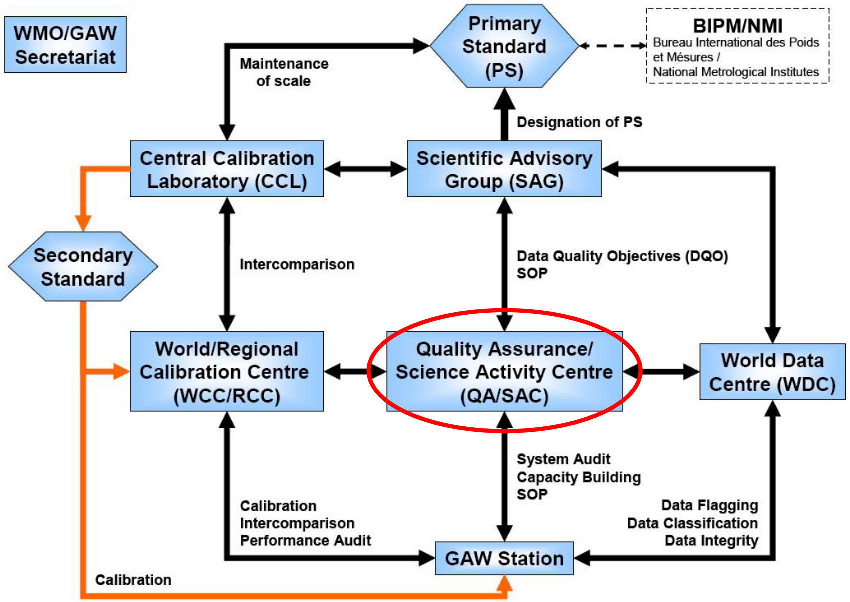
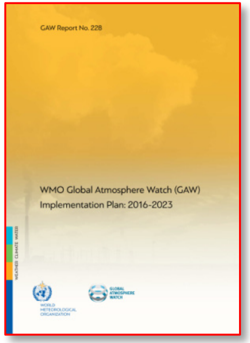
WMO GHG/Carbon Monitoring Workshop, Geneva, 10-12 May 2022

Empa
Materials Science and Technology

Quality Assurance / Science Activity Centre (QA/SAC)

Elements of the Quality Assurance system,
QA activities and workflow in GAW





GAW report #228

5.2.2 Quality Assurance/Science Activity Centres (QA/SACs)

Specific activities:

QA-1. Provide an operating framework for GAW quality assurance activities and calibration facilities for a specific variable and geographical area of responsibility (world, regional, national).

QA-2. Coordinate the activities of WCCs and RCCs in the area of their responsibility.

QA-3. Provide advice and support for the local QA system at individual GAW sites.

QA-4. Where appropriate, coordinate instrument calibrations and intercomparisons and other measurement activities.

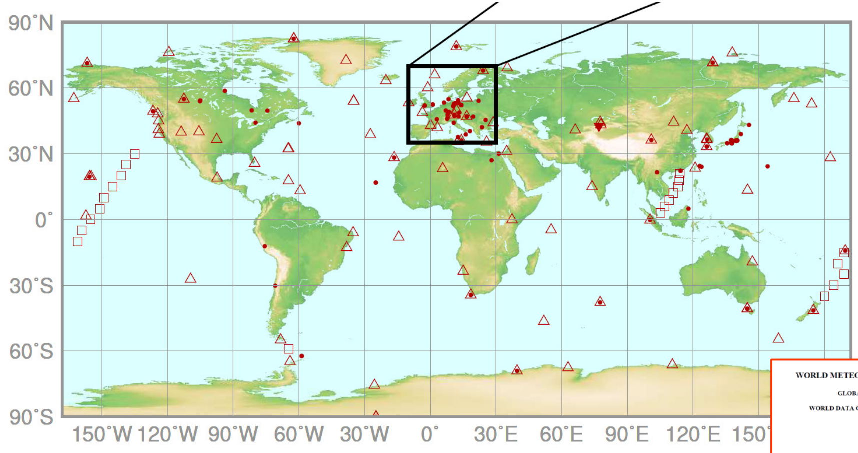
QA-5. Perform or oversee regular system audits at GAW sites.

QA-6. Provide training, long-term technical help, and workshops for station scientists and technicians.

QA-7. Promote the scientific use of GAW data, and encourage and participate in scientific collaboration.

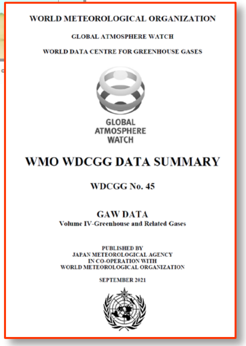
GHG Monitoring Worldwide

Stations reporting CO_2 data



This map shows locations of the stations that have submitted data for monthly mean mole fractions.

- ● : CONTINUOUS STATION
- △ : FLASK STATION
- □ : FLASK MOBILE (SHIP)
- ▼ : REMOTE SENSING STATION



WORLD METEOROLOGICAL ORGANIZATION

GLOBAL ATMOSPHERE WATCH

WORLD DATA CENTRE FOR GREENHOUSE GASES

GLOBAL ATMOSPHERE WATCH

WMO WDCGG DATA SUMMARY

WDCGG No. 45

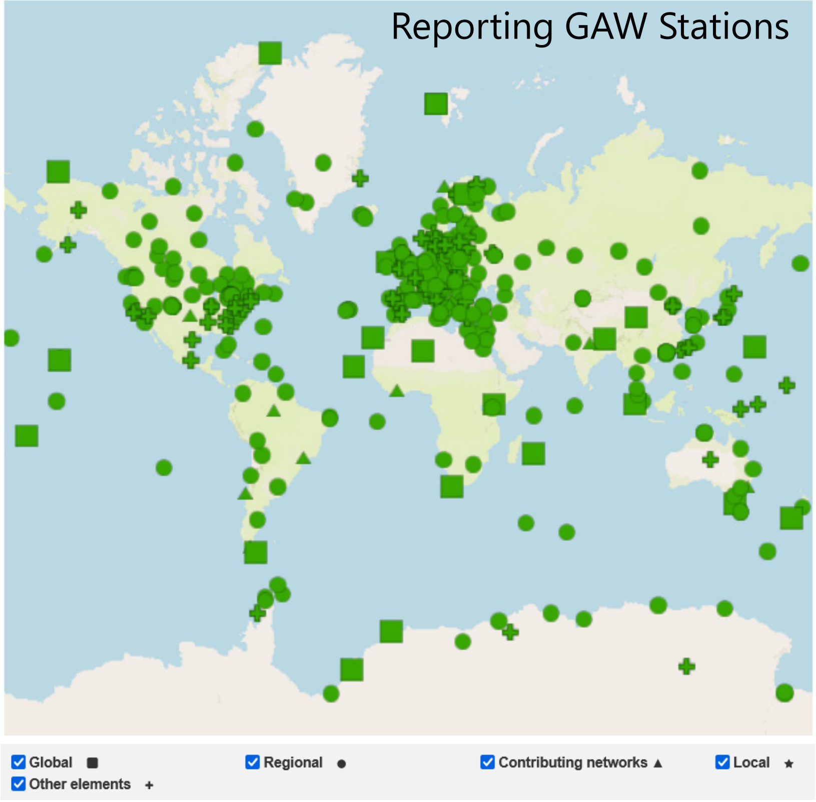
GAW DATA

Volume IV-Greenhouse and Related Gases

PUBLISHED BY JAPAN METEOROLOGICAL AGENCY IN CO-OPERATION WITH WORLD METEOROLOGICAL ORGANIZATION

SEPTEMBER 2021

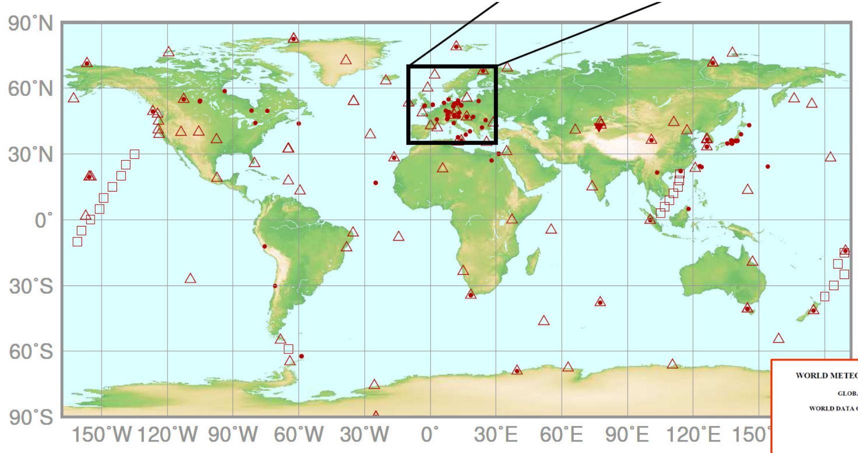
WDCGG Data Summary, No. 45, 2021



see GAW Station Information System, https://gawsis.meteoswiss.ch

GHG Monitoring Worldwide

Stations reporting CO_2 data



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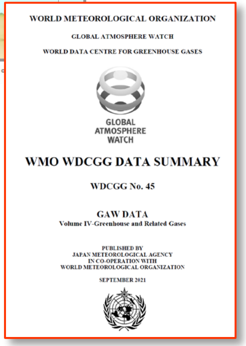

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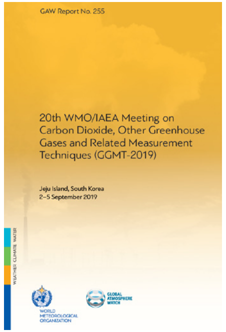


GAW Report No. 255

20th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Measurement Techniques (GGMT-2019)

Jeju Island, South Korea
2–5 September 2019

GAW report #255

" … Building expertise in developing countries including the establishment of high-quality measurement capabilities remains a critical issue for achieving adequate spatial coverage of the globe in the coming decades. WMO and IAEA can make large contributions here through training courses, and stimulating partnerships between laboratories. …"

The long process of capacity building

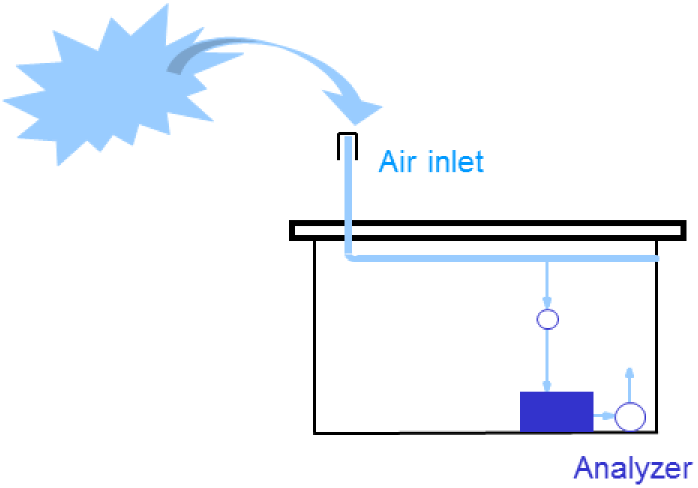
A-priori: basic equipment / infrastructure available, willingness to perform high-precision air quality observations in a pristine environment

- advice for instrument selection
- technical support / advice to set up measurement capabilities
- regular on-site training
- remote support / trouble shooting
- facilitating the provision of spare parts
- support for data processing / data submission
- support for (research) proposal writing
- support for scientific data analysis and publication

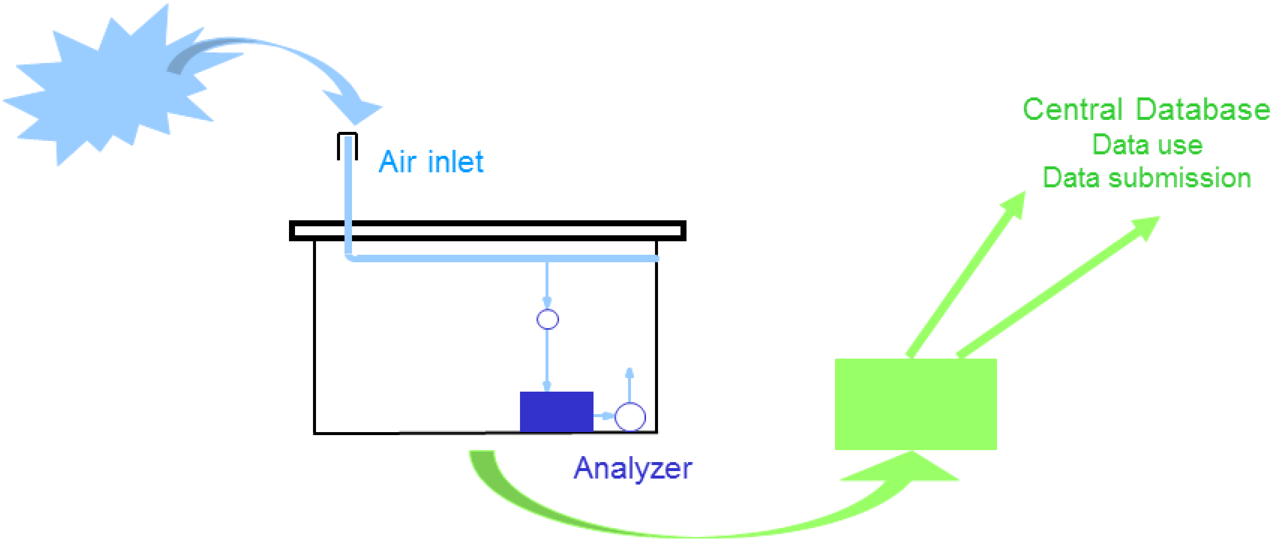
(> 10 years)

A-posteriori: fully autonomous monitoring station, high-quality data, good visibility in the GAW and the scientific community

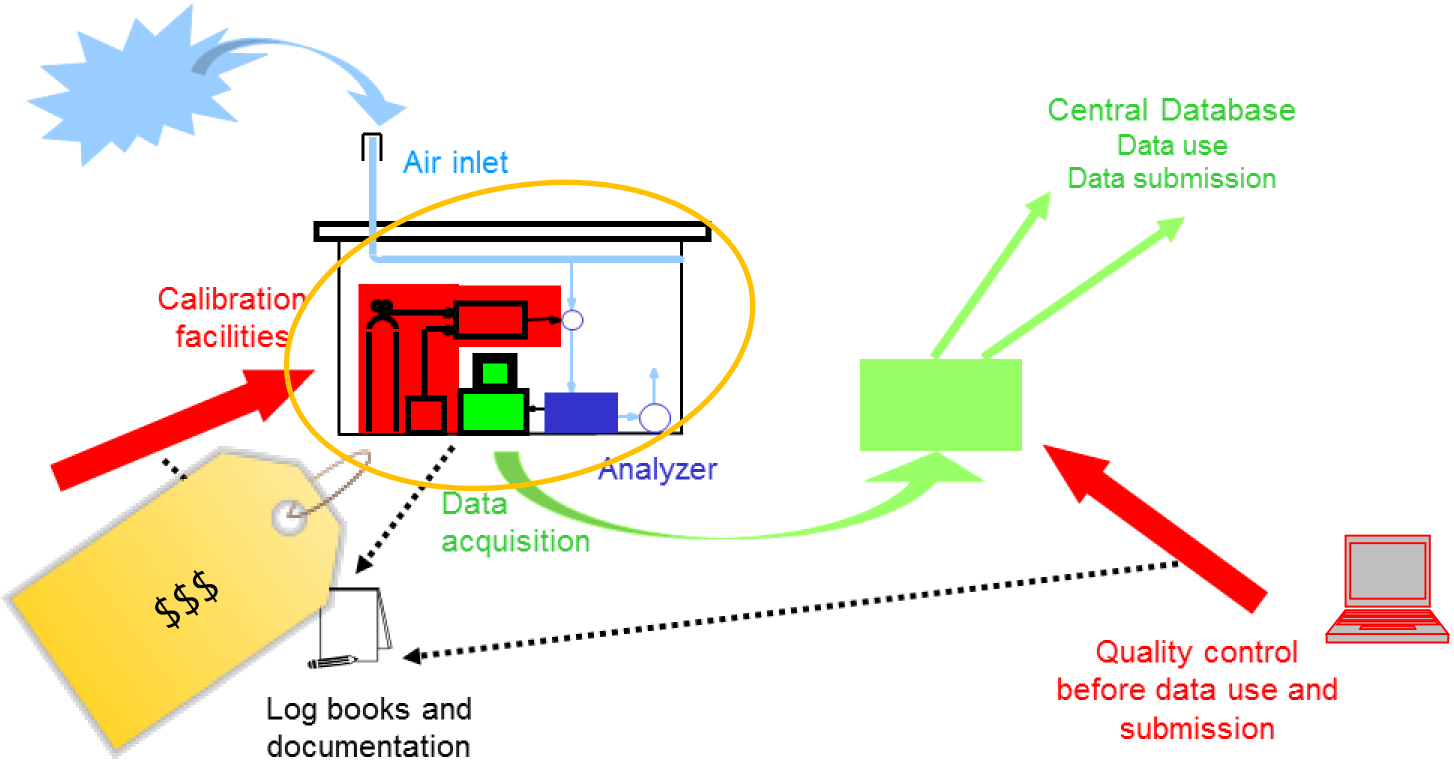
Infrastructure requirements for in-situ GHG observations?



Infrastructure requirements for in-situ GHG observations?



Infrastructure requirements for in-situ GHG observations?



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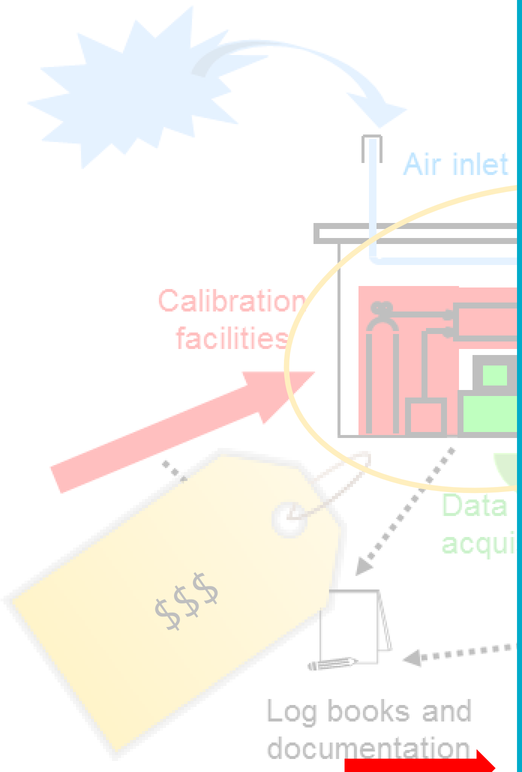


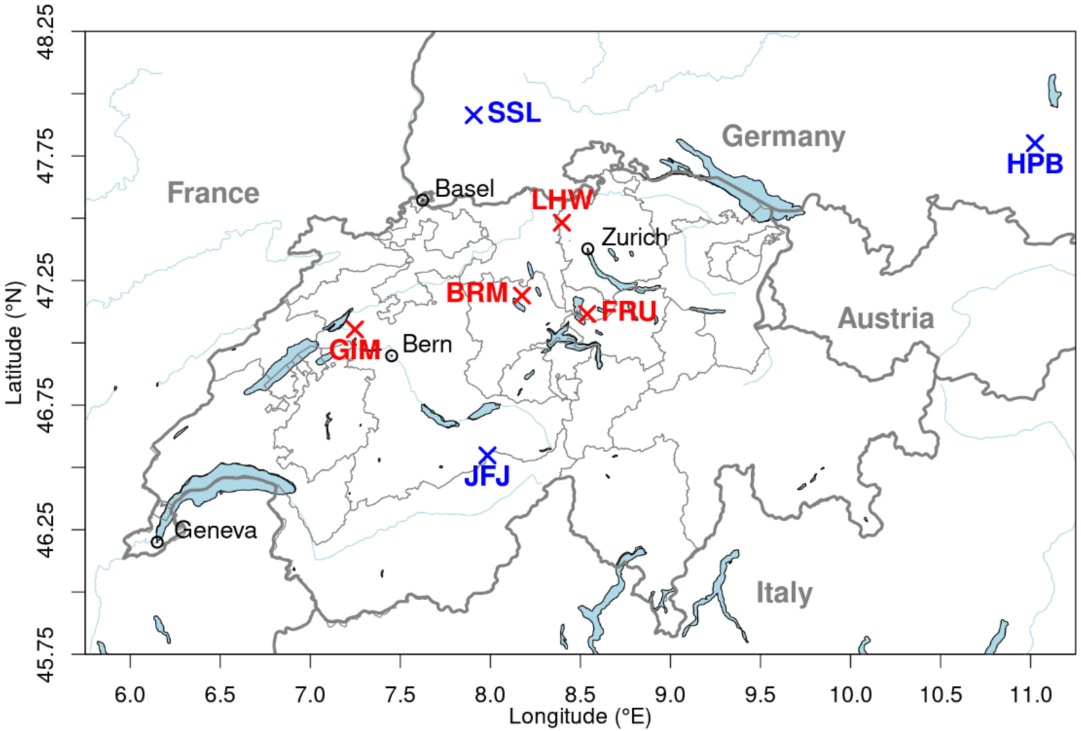
Table 4. Estimated equipment cost (k€) for the ICOS Atmosphere station. Sums depend on e.g. local taxes and markets.

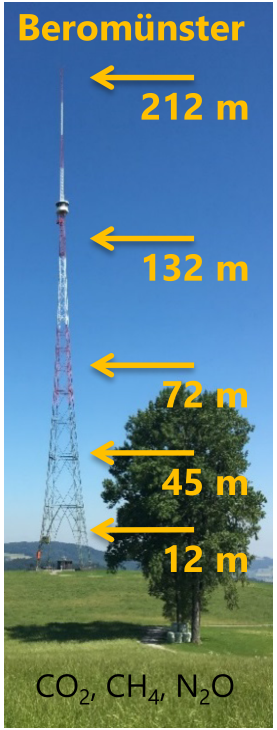
CATEGORIES	DESCRIPTION	EQUIPMENT COST (k€)		
		Class 2	Class 1	Class 1 'Extended'*
Meteorological parameters	At 3 tower heights	10	10	10
CO_2, CH_4 continuous in situ measurement		55	55	55
CO continuous in situ measurement			+ 35 (in addition to CO_2/CH_4 cost)	+ 35 (in addition to CO_2/CH_4 cost)
CO/N_2O continuous in situ measurement				120
Periodic air sampling for CO_2, CH_4, N_2O, SF_6, CO, H_2 and CO_2 isotopes	Flask sampler with dryer + 100 flasks with shipment cases		65 + 25	65 + 25
Radiocarbon ($^{14}CO_2$) periodic sampling	Integrated sampler (NaCl)		10	10
Boundary Layer structure	Ceilometer or Lidar		30-80	30-80
^{222}Rn				30
CO_2 flux by eddy covariance	Fast in situ CO_2 analyser associated with a 3D wind sensor			40
Tubing, valve, pumps...		15-20	15-20	15-20
Calibration				
Tanks, pressure regulators...		10	10	10
Electrical and computing systems, data acquisition, storage and transmission, integration parts (indicative cost; prone to important variation depending on technical choice and station configuration)		10-50	10-50	10-50
TOTAL		**100-145**	**255-350**	**455-550**

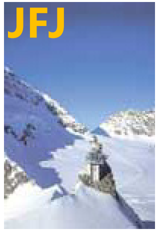
www.icos-ri.eu/resources/reports-and-documents

ICOS Integrated Carbon Observation System

Continuous GHG Observations in the Swiss Domain

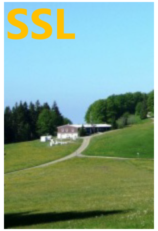






CO_2, CH_4, N_2O, syn. gases

CO_2, CH_4



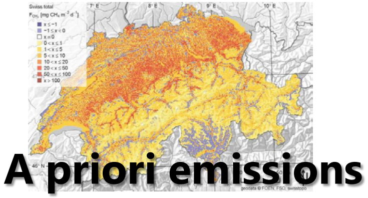
CO_2, CH_4, N_2O

- high precision/accuracy, continuous observations
- traceable to international standards
- substantial QA/QC effort

GAW ICOS Integrated Carbon Observation System AGAGE Empa UNIVERSITÄT BERN DWD UBA

Top-Down Support of Swiss National Inventory Report (NIR)

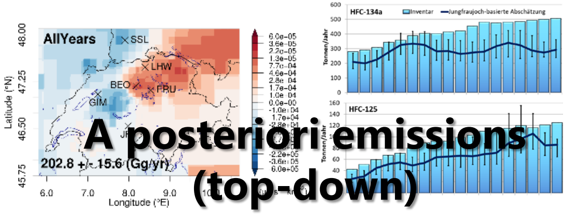
Aim: support of national bottom-up inventory reporting by using atmospheric observations, transport simulations and inverse methods to derive national total emissions and compare those to NIR reported values.



Inverse methods

Bayesian inverse modelling: CH_4, N_2O

Tracer ratio method: synthetic gases



see also:

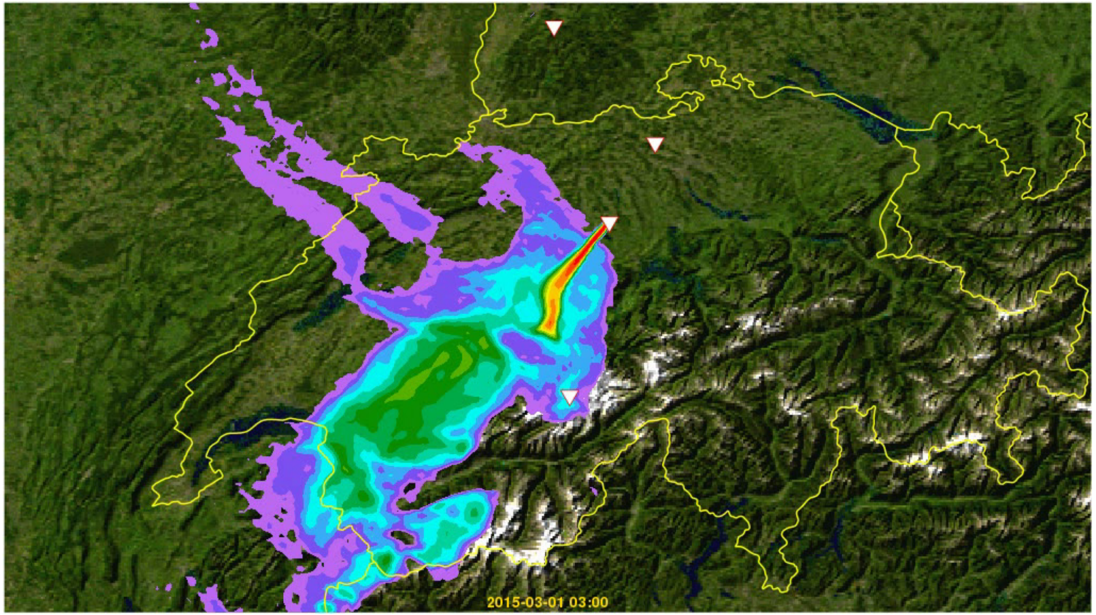
Atmos. Chem. Phys., 16, 3683–3710, 2016
www.atmos-chem-phys.net/16/3683/2016/
doi:10.5194/acp-16-3683-2016

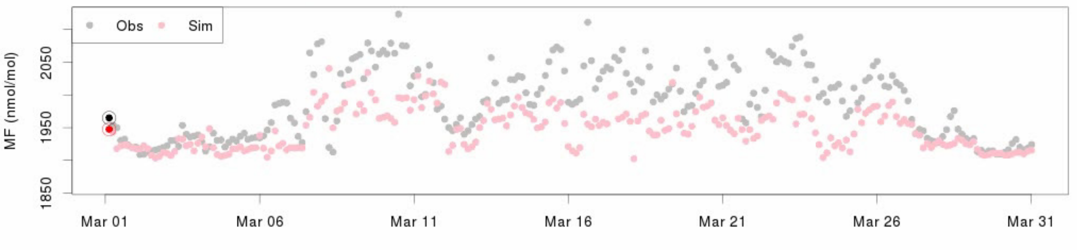
Atmospheric Chemistry and Physics
Open Access
EGU

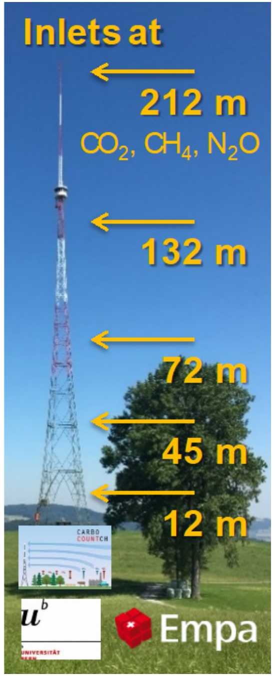
Validation of the Swiss methane emission inventory by atmospheric observations and inverse modelling

Stephan Henne[1], Dominik Brunner[1], Brian Oney[1], Markus Leuenberger[2], Werner Eugster[3], Ines Bamberger[3,4], Frank Meinhardt[5], Martin Steinbacher[1], and Lukas Emmenegger[1]

Simulated Footprints and Concentration Timeseries







Greenhouse Gas Emissions in Switzerland

UNFCCC's National Inventory Report

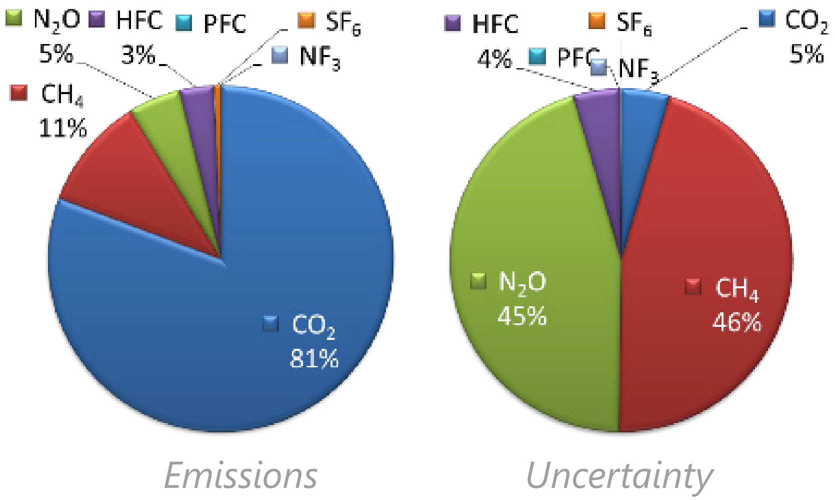
- Annual reporting following IPCC guidelines
- Based on activity data, emission factors (country specific), process models
- Peer-reviewed but not evaluated against independent methods

Non-CO_2 GHGs in Switzerland

- Emission contribution 19 %
- Uncertainty contribution 95 %

Top-down

- CH4, N2O: inverse modelling
- HFCs, SF6: tracer ratio method
- Supporting bottom up estimates as annex to NIR



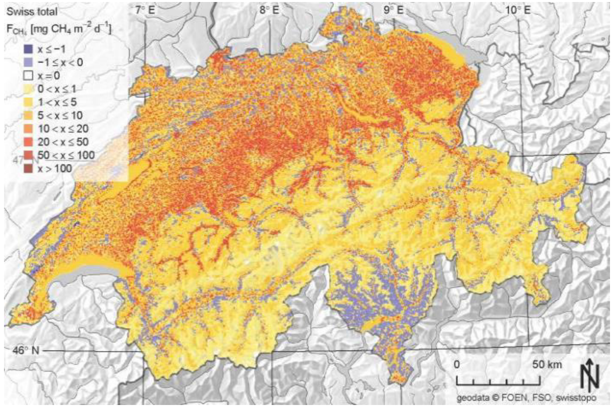
Total:	48 Tg yr^{-1} (CO_2 equivalent) (+ 6 Tg yr^{-1} international flights)
Per capita:	~6.1 t yr^{-1} (+ ~0.8 t yr^{-1} international flights)

w/o LULUCF

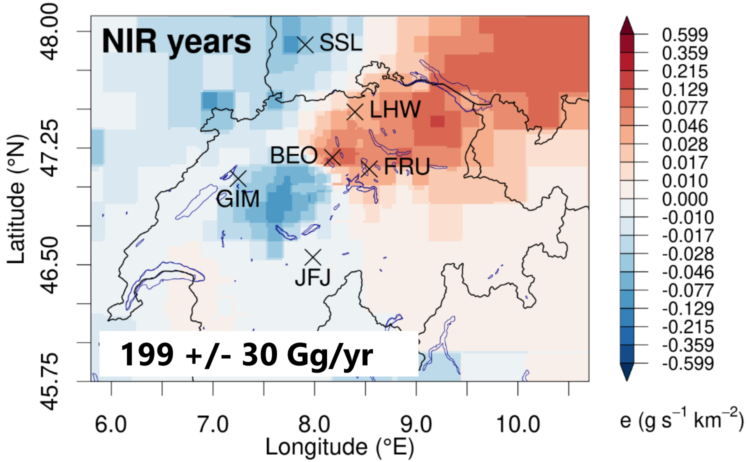
Values for 2016; Swiss NIR, FOEN (2018)

Swiss Methane Emissions (2013 – 2020)

A priori inventory [Hiller et al., 2014]



A posteriori difference

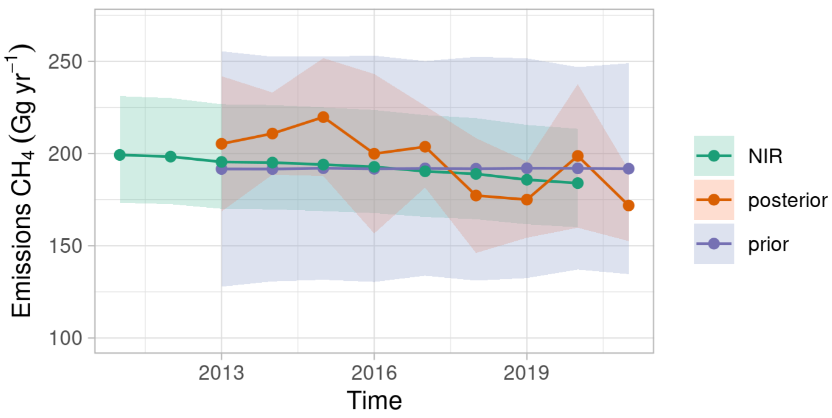


NIR:	194 ± 32 Gg yr^{-1}, ±16 %	
A posteriori:	199 ± 30 Gg yr^{-1}, ±15 %	95 % CI

- 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)

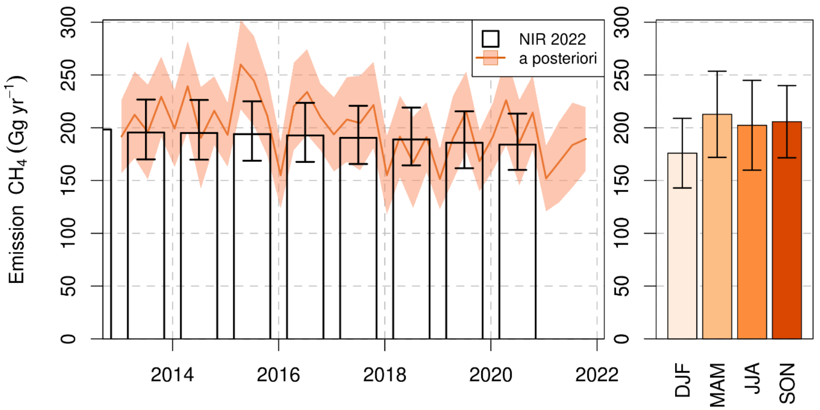
Swiss Methane Emissions (2013 – 2020)

Temporal evolution



Based on 8 sensitivity inversions per year

Seasonal variability

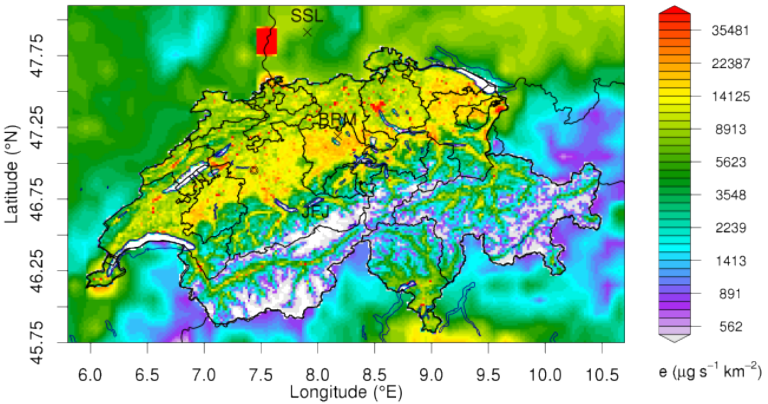


Spring maximum & winter minimum
Seasonal amplitude: ±20 %

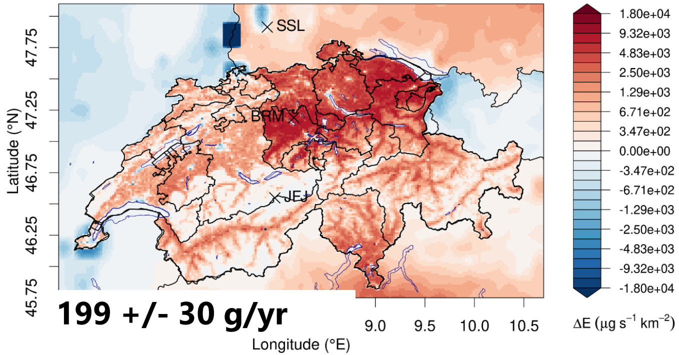
Based on 4 sensitivity inversions with seasonal variability per year

Swiss Nitrous Oxide Emissions (2017 – 2020)

A priori inventory



A posteriori difference

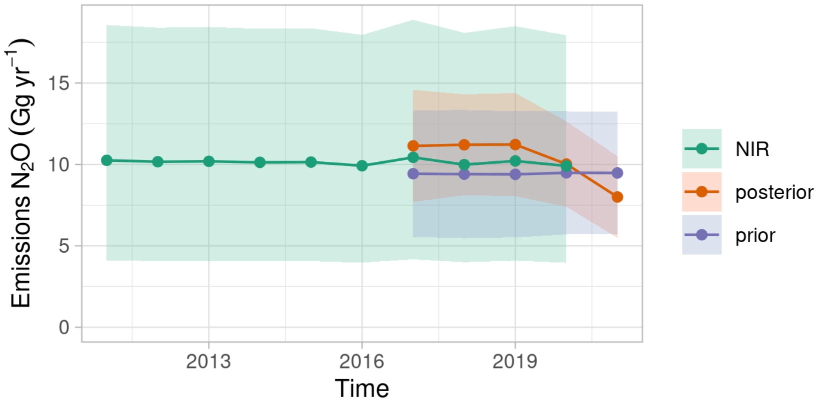


NIR (w/o 2020):	10.1 (4.1 – 18.3) Gg yr^{-1}, ~±70 %	
A posteriori:	10.9 ± 3.1 Gg yr^{-1}, ±28 %	95 % CI

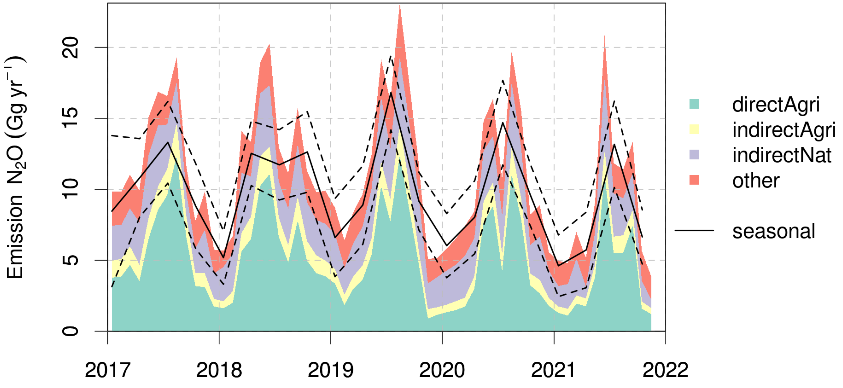
- Absolute increase strongest on central and eastern Swiss Plateau
- Relative increase strongest in Southern Switzerland (indirect natural)
- Considerable decreases limited to urban areas (waste, transport, heating)

Trend & Seasonality of N2O Emissions

Temporal evolution



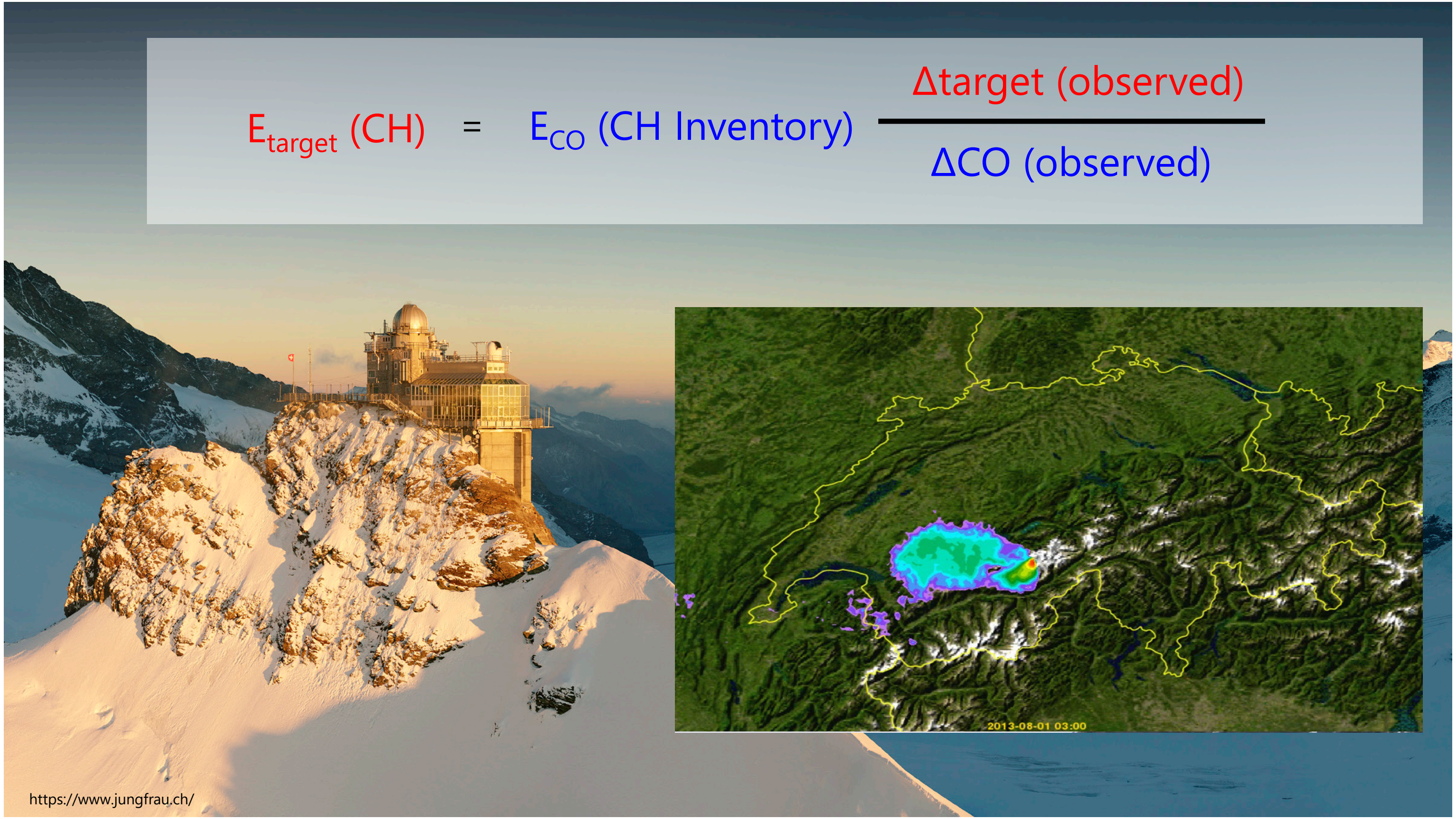
Seasonal variability by source



- 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
- Low emissions in 2021 driven by lower emission in summer (preliminary)

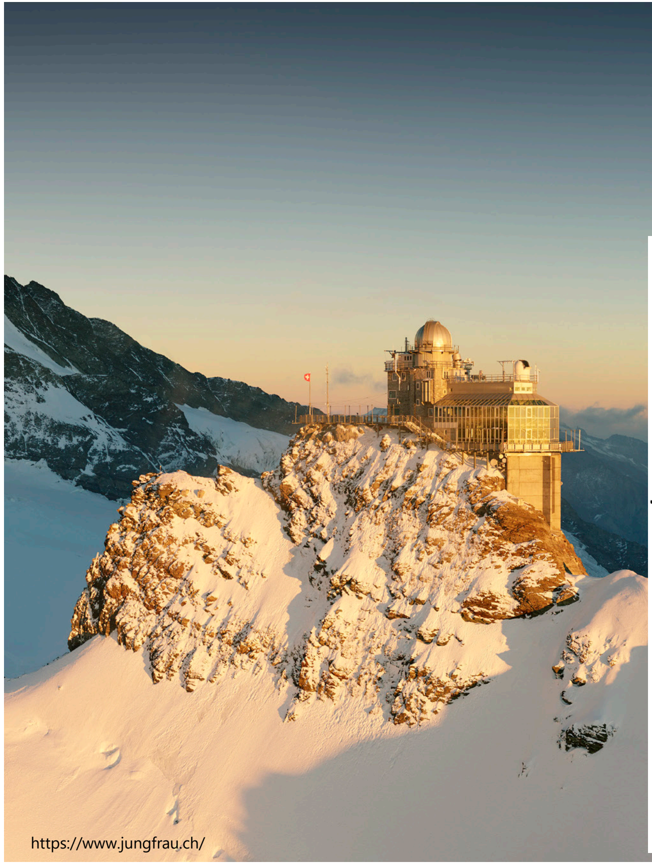
F-gas Emissions Based on Jungfraujoch Observations

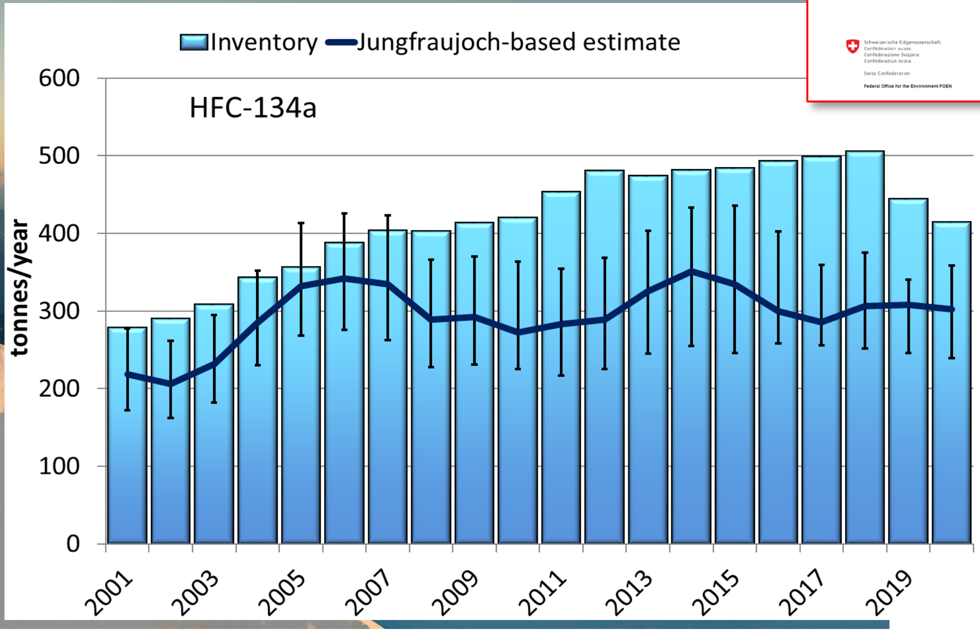
$$E_{target}\ (CH) = E_{CO}\ (CH\ Inventory)\ \frac{\Delta target\ (observed)}{\Delta CO\ (observed)}$$

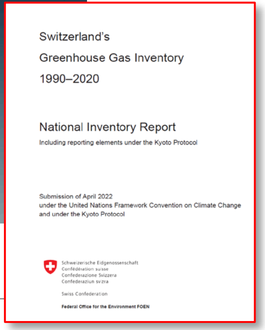


https://www.jungfrau.ch/

F-gas Emissions Based on Jungfraujoch Observations






Switzerland's
Greenhouse Gas Inventory
1990–2020

National Inventory Report
Including reporting elements under the Kyoto Protocol

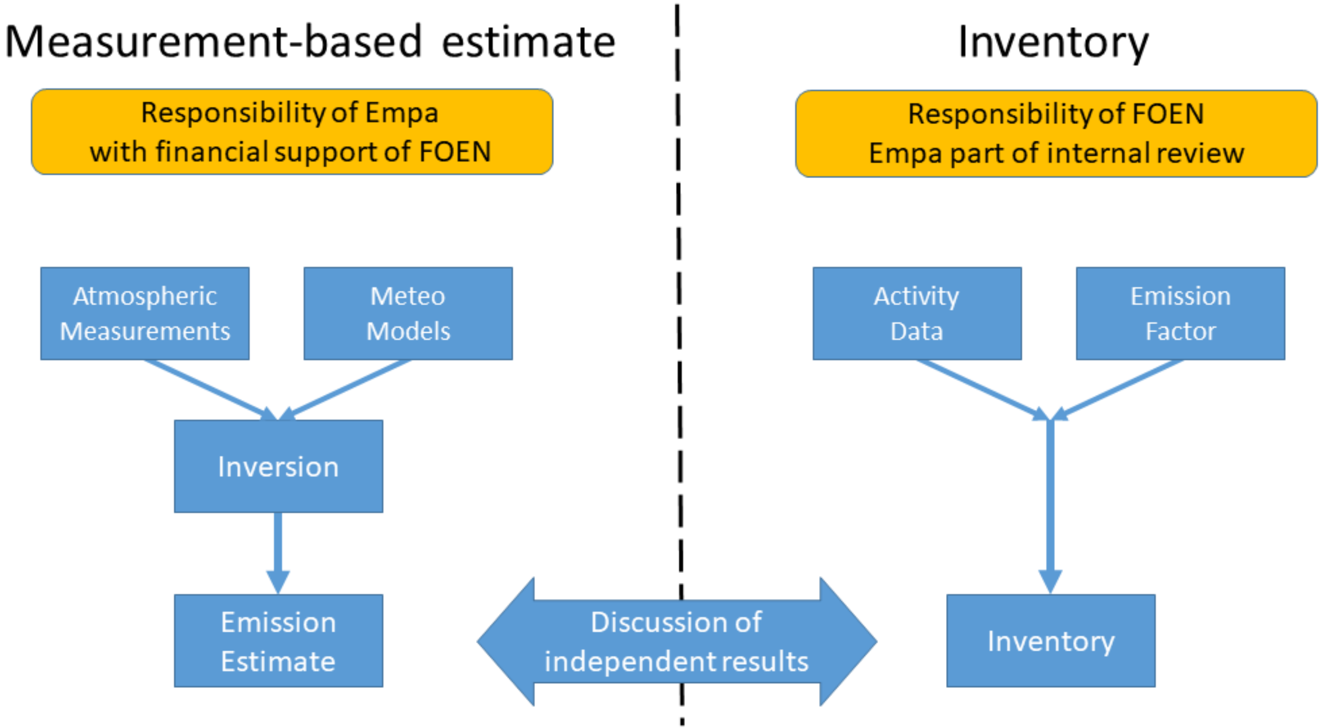
Submission of April 2022
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

The Swiss Verification System



Empa: Swiss Federal Laboratories for Materials Science and Technologies
FOEN: Swiss Federal Office of the Environment