Royal Belgian Institute
for Space Aeronomy
BIRA•IASB

ICOS-Belgium-atmospheric component

Monitoring of greenhouse gases in the atmosphere at Belgian and other ICOS sites.

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Outline

- La Réunion ICOS site
  - Embedding in international networks & RI
  - Data and scientific valorisation
- Addition of atmospheric component to other Belgian ICOS sites
  - Ongoing developments
- Future perspectives

La Réunion ICOS site

La Réunion: combined ICOS, ACTRIS, TCCON and NDACC site

Maido observatory,
-21.079° N, 55.384° E
2157.7 masl

Saint Denis,
-20.901° N, 55.485° E,
85 masl

In-situ surface
concentrations of
CO_2, CO, CH_4
2014 →

In-situ surface
concentrations of
CO_2, CH_4, (CO)
2010 →

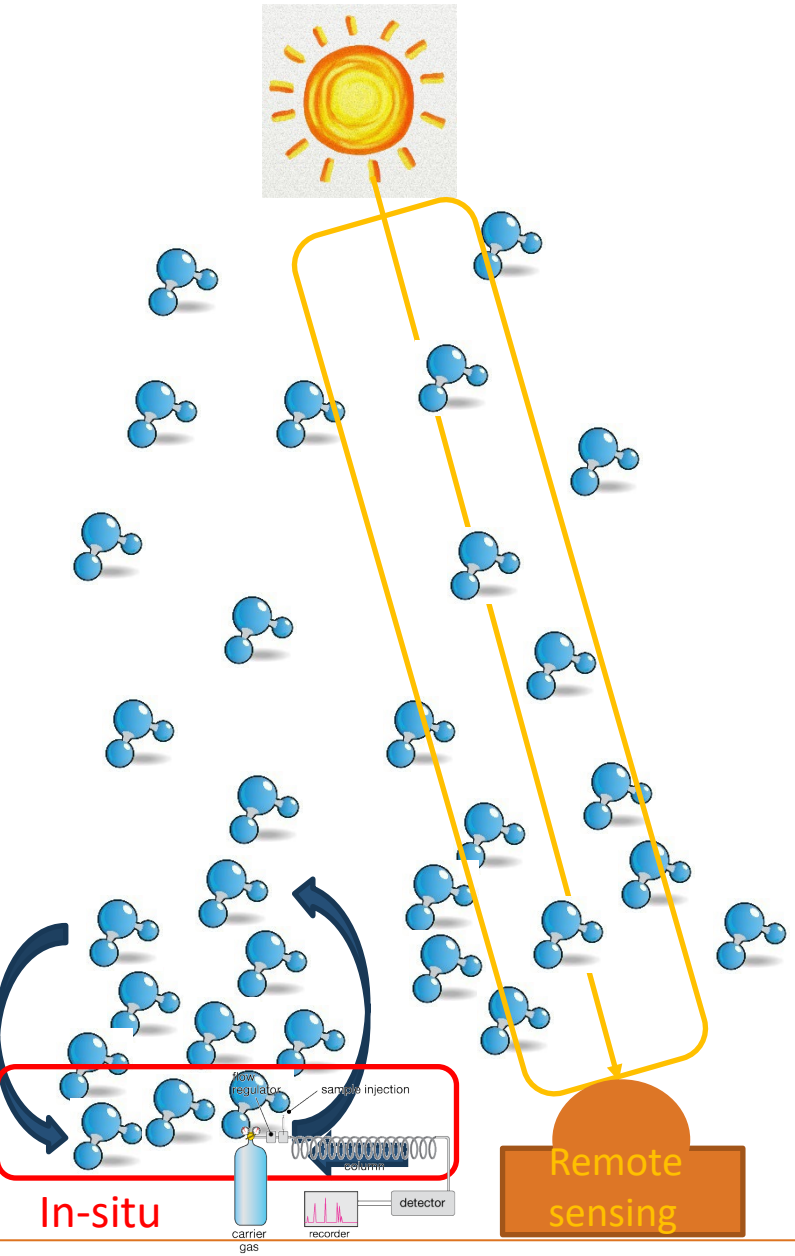
Remote sensing column
abundances of
CO, CH_4
2013 →

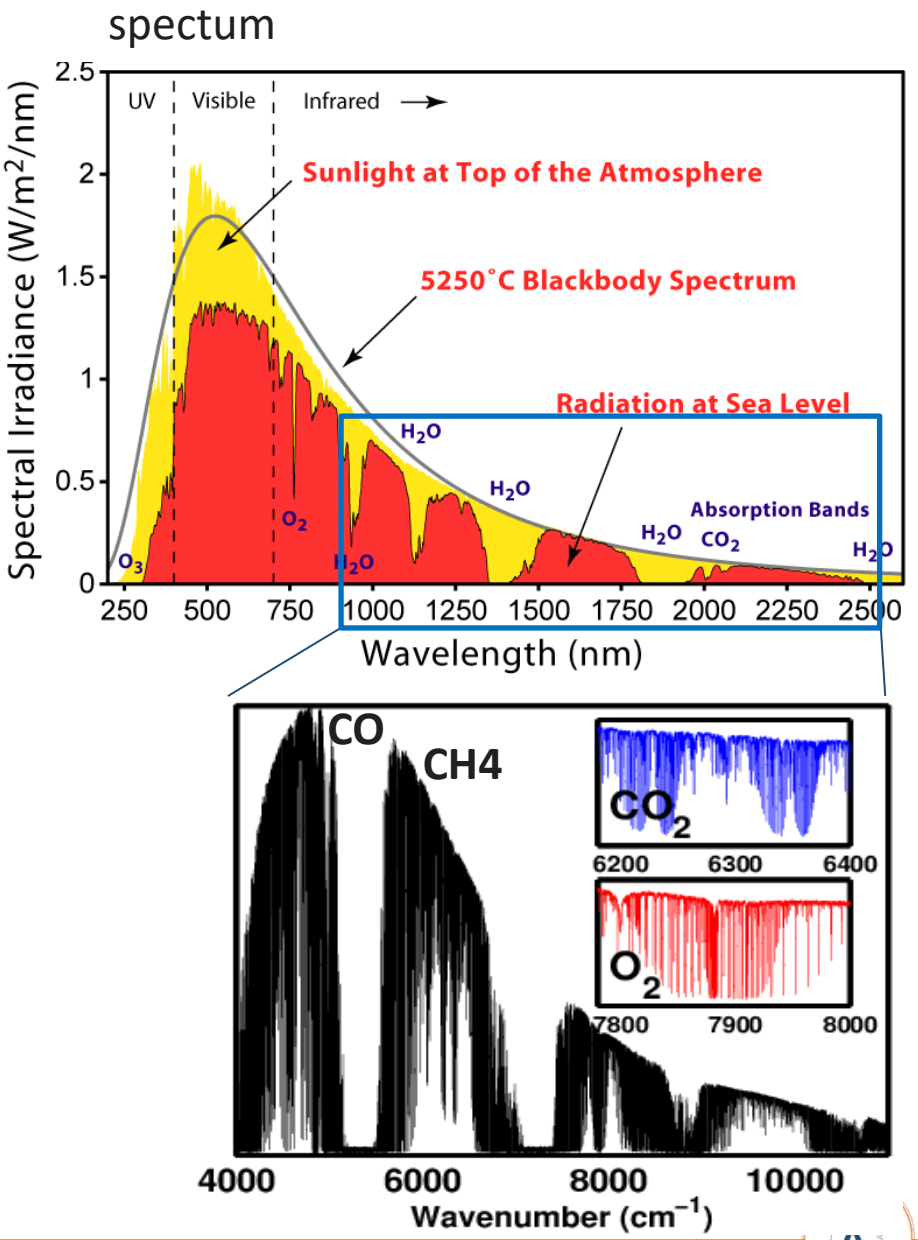
→ XCO_2, XCH_4, XCO
Dry-air column-averaged VMR ←

Remote sensing column
abundances of
CO_2, CO, CH_4
2011→

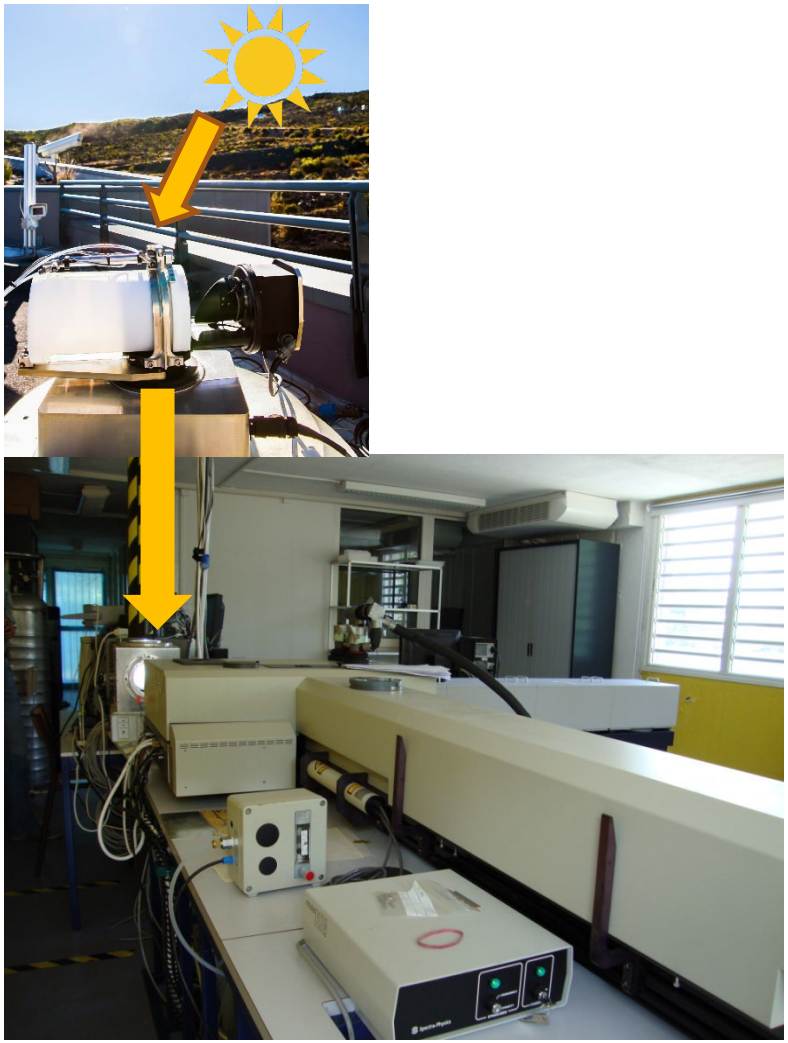
+ many other (FTIR) species like HCHO, VOC, NOx, O_3, … + aerosol , wind, …

In-situ versus remote sensing observations





FTIR remote sensing observations



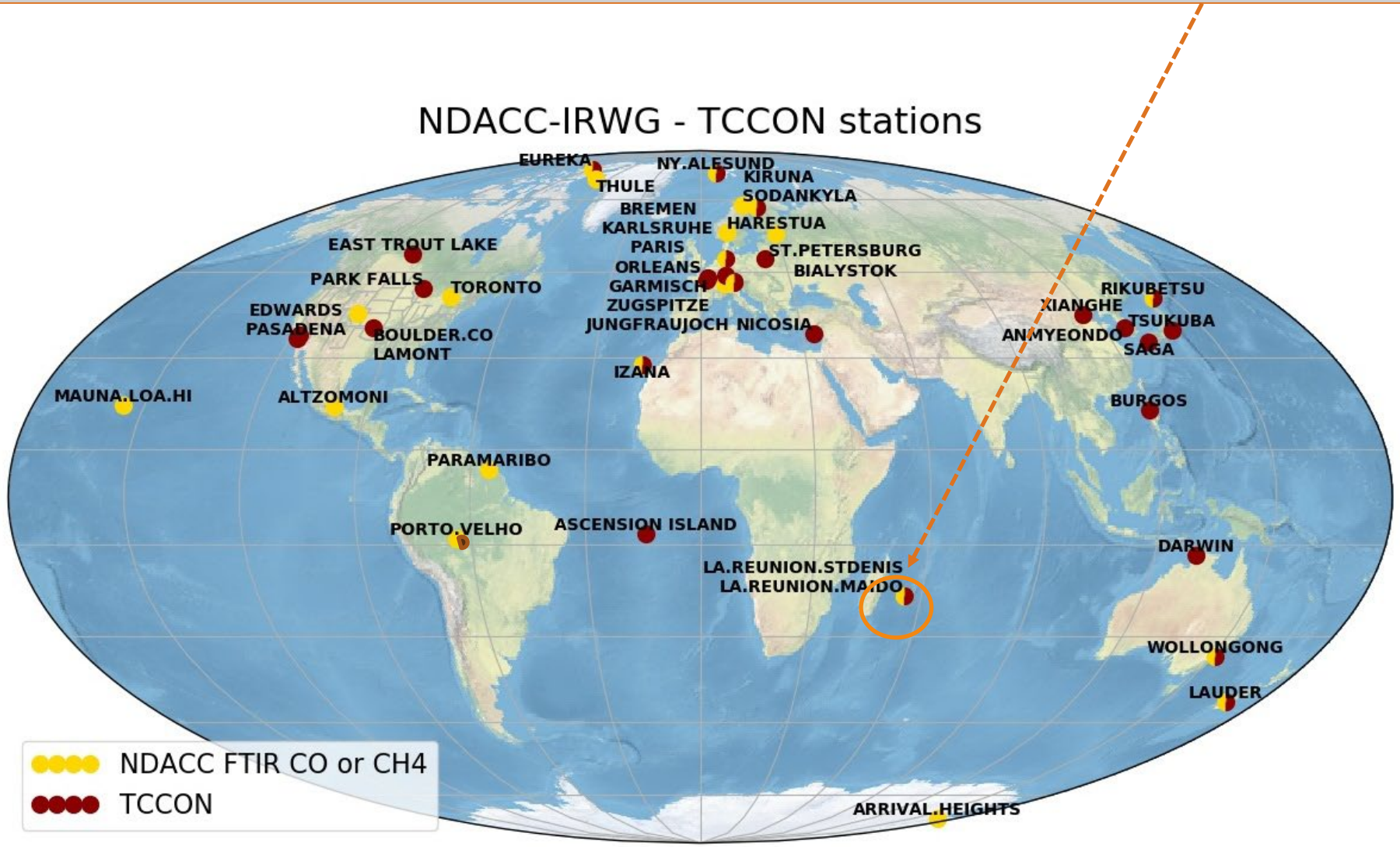
Fourier-Transform InfraRed (FTIR) observations

Solar absorption spectrometry in the infrared spectral domain (~1 μm – 16 μm)

- principle of Michelson interferometry
- high spectral resolution ($\lambda/\Delta\lambda$~ 1E4 to 1E6)
- signal = spectrum
- Data processing ('inversion') consists of analysis of molecular absorption lines

$\Rightarrow$ Result = concentrations of target species in column above observatory

FTIR Remote sensing observation networks

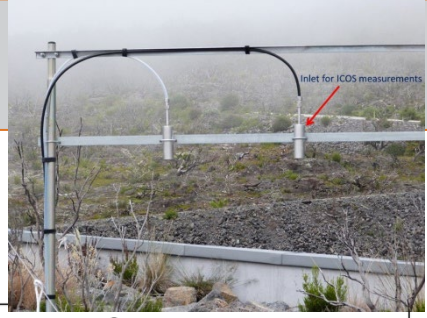


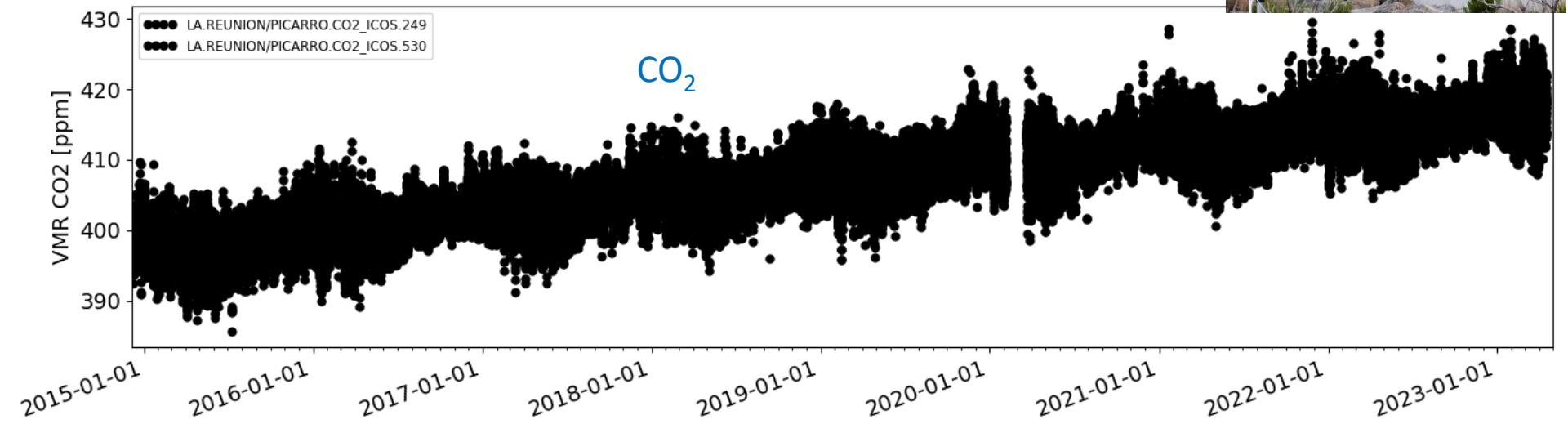
In-situ versus remote sensing observations

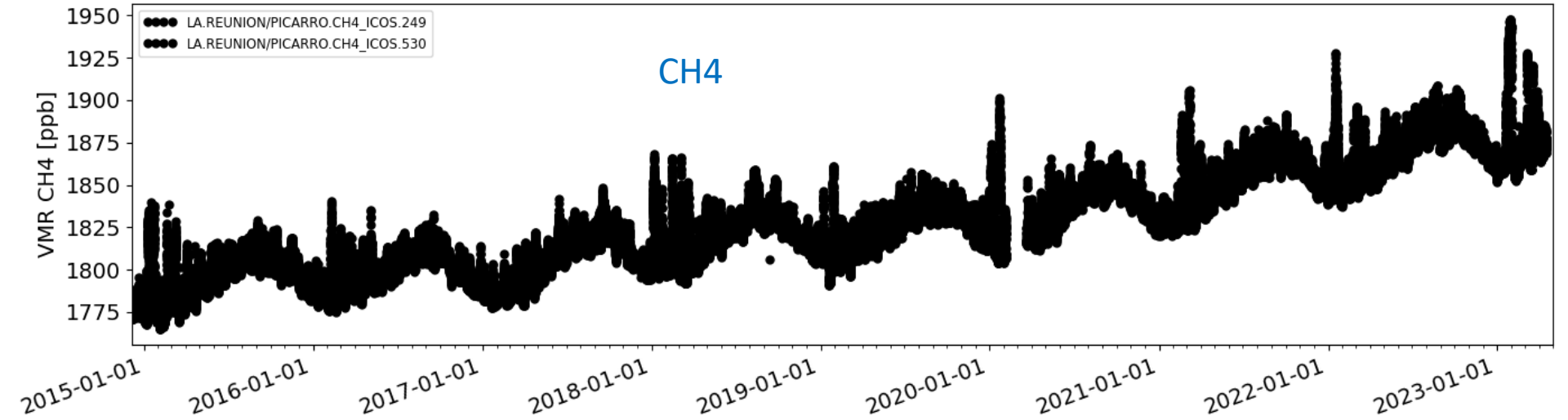
In-situ	Remote sensing
Local concentrations	Columns / vertical profiles
Sensitive to local emissions	Representative of larger region in vertical & horizontal directions
Sensitive to local dynamics – e.g., winds, PBL	More sensitive to (long-range) transport; less
ICOS-ATMOSPHERE - ATC @ LSCE	**TCCON – TCCON.Caltech.edu**
PICARRO G2401	Bruker IFS 125HR
Cavity Ring-Down Spectroscopy (CRDS)	Fourier-transform Infrared spectrometry (FTIR)
Spectral range: NIR - single frequency	Spectral range: NIR - Resolution 0.02cm^{-1}
CO_2, CH_4, CO, H_2O + meteo data	CO_2, CH_4, N_2O, CO, H_2O/HDO, HF (+ meteo data)
Dry-air near-surface volume mixing ratio (VMR)	Total column only retrievals → dry-air column averaged VMR
Continuous, high-frequency, day-and-night (+ regular calibration measurements)	Clear-sky daytime only; global coverage
Data back to 2015 → ICOS Carbon Portal	Data back to 2004 → https://tccondata.org/
Strict measurement, data analysis and QA/QC protocols, centralized at ATC + site labelling	Strict measurement, data analysis and QA/QC protocols + site certification

La Réunion – Maido data

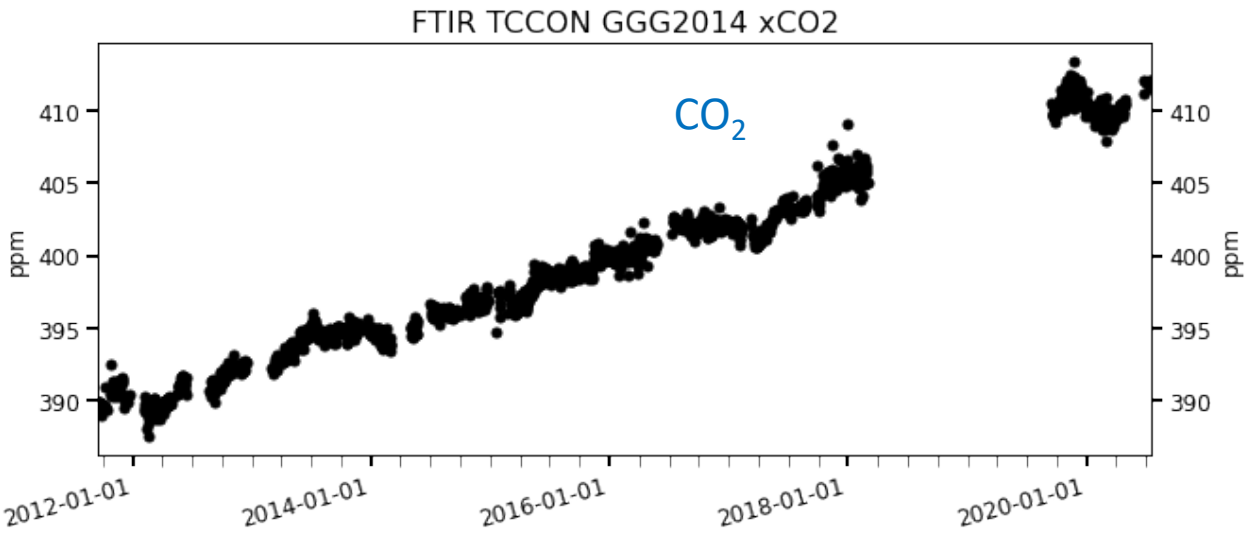
Time series of in-situ surface concentrations @ Maido

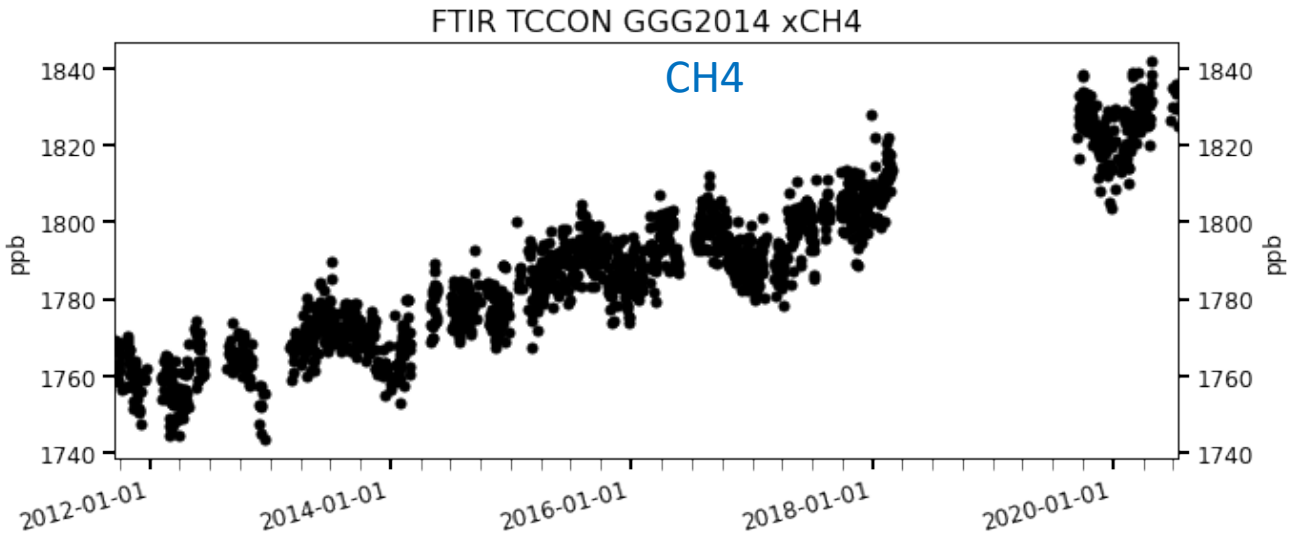






Total column time series @St Denis





Over 8 years (2012 -2020), CO_2 increased from 390 ppm to 410 ppm –
i.e., trend of +2.5 ppm/year or > 0.6%/year on average.

Over the same period, CH_4 increased from 1760 ppb to 1825 ppb –
i.e., trend of +8.1 ppb/year or ~ + 0.46 %/year on average.

Models indicate that at this remote site in the Indian Ocean, these observations are mainly influenced by long-range transport of emissions on other continents.

Why methane concentrations continue to rise so sharply ?.

Access to data

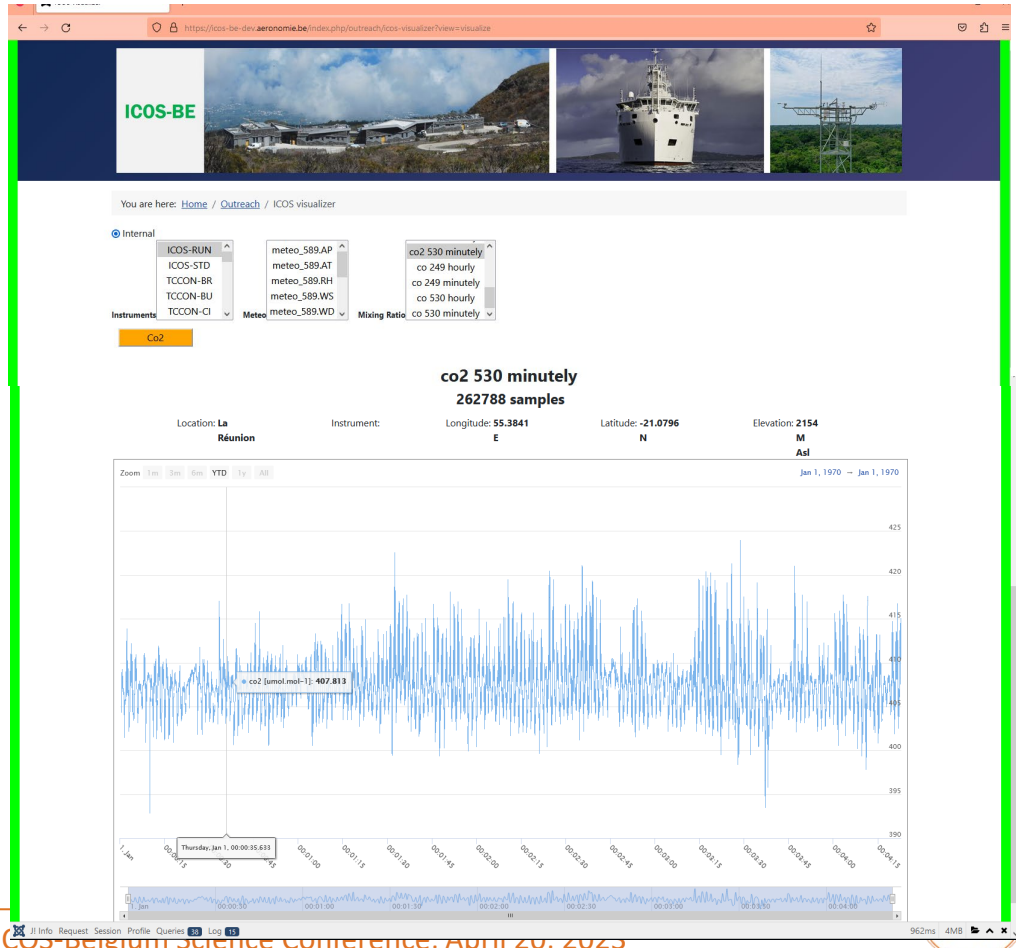
ICOS data: https://doi.org/10.18160/10QG-6RP6

TCCON data : https://doi.org/10.14291/tccon.ggg2020.reunion01.R0

NDACC data: https://www-air.larc.nasa.gov/missions/ndacc/data.html#

Soon to come: data available on icos-be.aeronomie.be with interactive visualization options.

Offer to include additional ICOS data



Valorisation and scientific exploitation of data

- Valorisation as ‘in-situ’ reference data for validation of satellite data products and Copernicus products
- Study of sources/sinks, variabilities and trends using WRF-GHG

Analysis of GHG observations at La Réunion using WRF-GHG

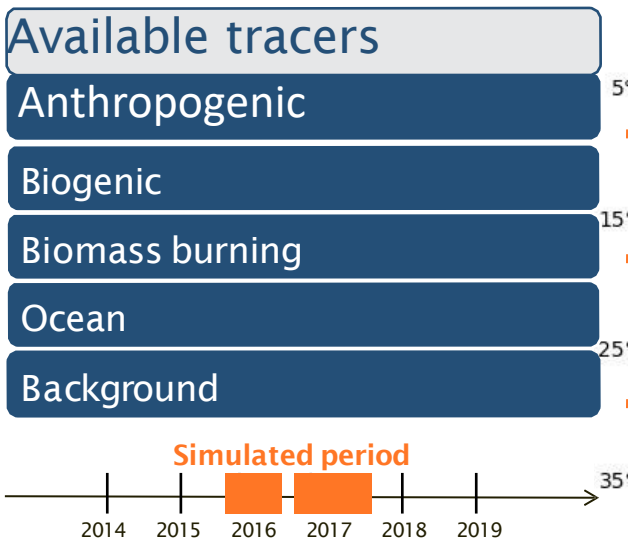
WRF-GHG : Weather Research and Forecasting model coupled with chemistry (WRF-Chem) in its passive tracer option.

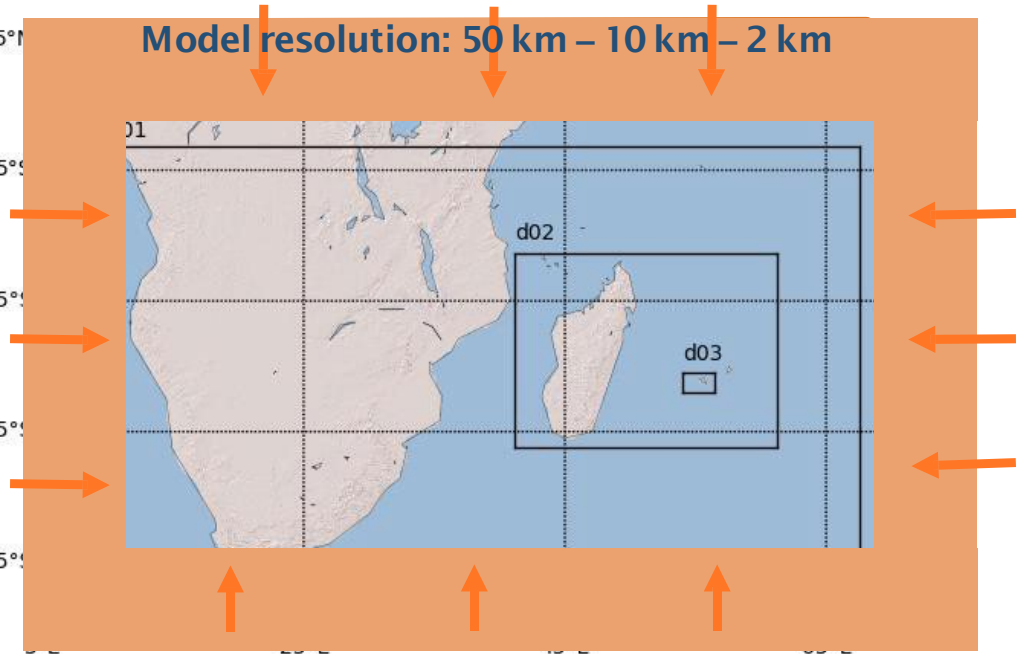
→ regional atmospheric model simulating 4D fields of CO_2, CH_4, and CO, resulting from their sources, sinks, and transport in the troposphere, without interaction with other species, while accounting for the meteorology.

Model set-up

Available tracers

- Anthropogenic
- Biogenic
- Biomass burning
- Ocean
- Background





Driven by **ERA5** (meteo) and **CAMS reanalysis** (gases)

What factors contribute to the observed concentrations ?

In situ PICARRO measurements

Local signals

Anthropogenic

Biogenic

Biomass burning

Background

Saint-Denis
Main factor for CO_2
Accumulation at night *(urban dome)*
Model overestimation for CH_4

Saint-Denis
Small contributions for CO_2 when strong winds from rural surroundings

Saint-Denis
No impact

Saint-Denis
Important for CH_4

Maïdo
Minor signals during day for all gases: anabatic winds

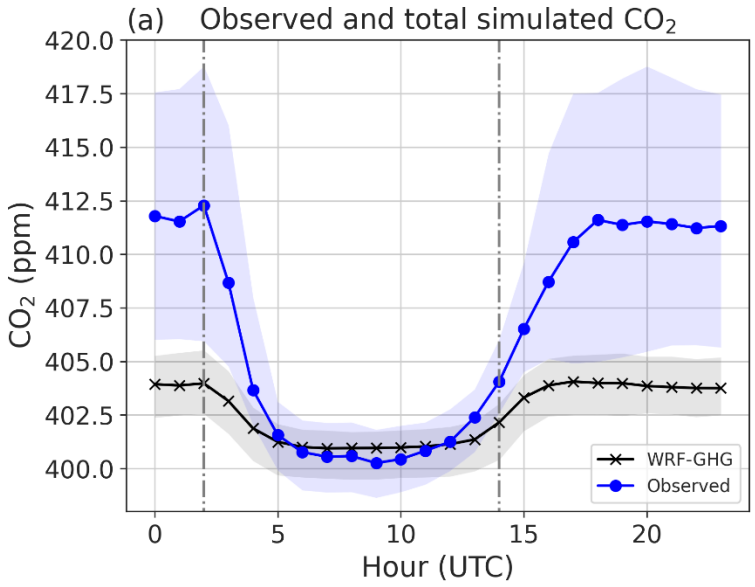
Maïdo
Main factor for CO_2

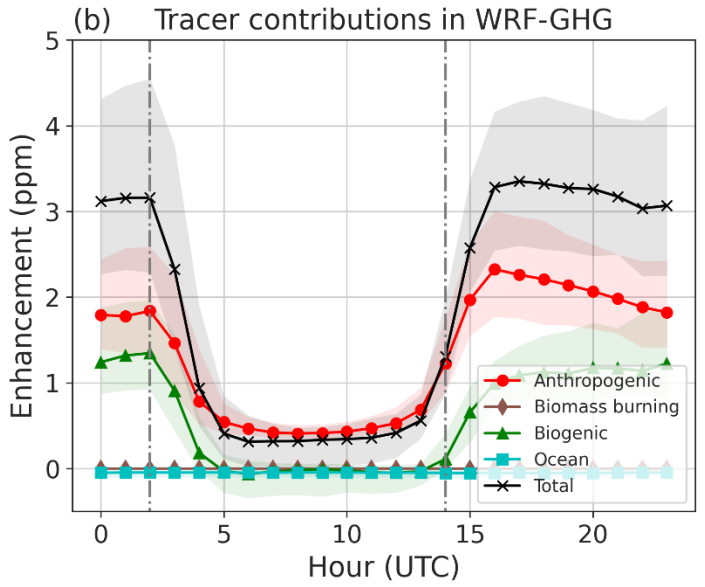
Maïdo
Small signals for CO at night when in free troposphere

Maïdo
Important for CO and CH_4

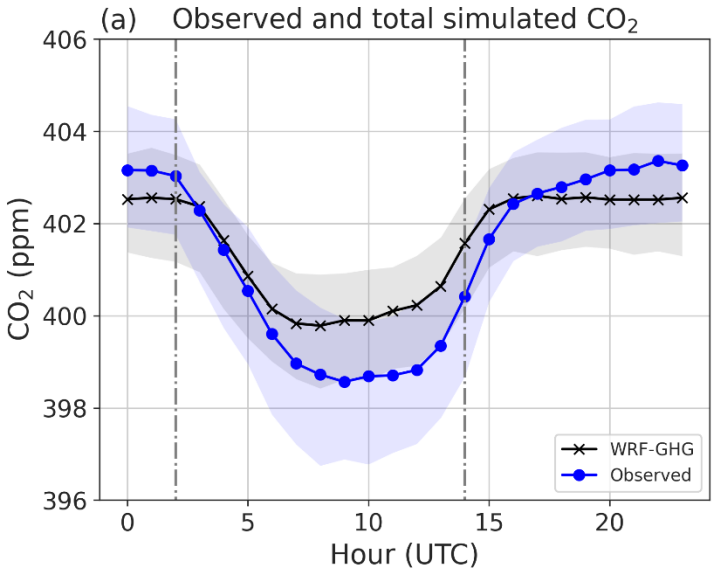
Diurnal variations of surface concentrations

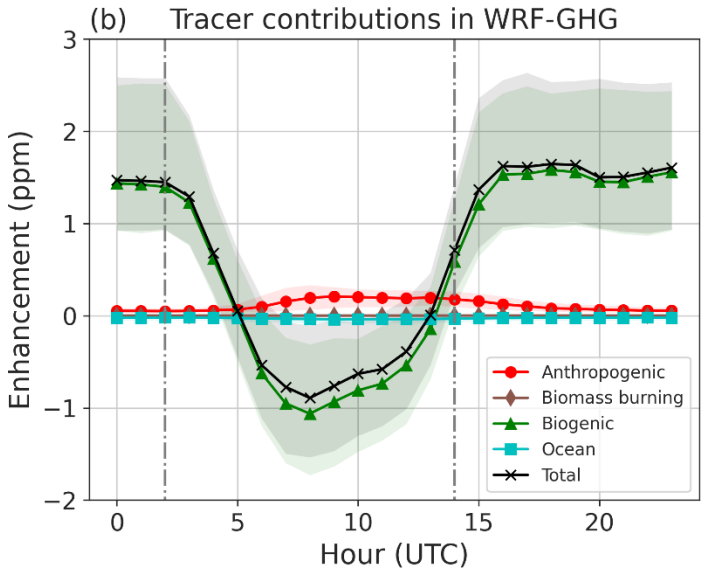
St Denis





Maido





What factors contribute to the observed column concentrations ?

Column FTIR measurements

Remote signals

Anthropogenic

Small impact on all (XCO_2, XCO and XCH_4)

Biogenic

Positive contribution for XCO_2 (dry season)

Small impact on XCH_4 (wetlands)

Biomass burning

Important for all, during fire season (Sept – Dec)

Main factor for XCO

Background

Very important for all (XCO_2, XCO and XCH_4)

TCCON total carbon column observing network

NDACC

Sieglinde Callewaert, https://doi.org/10.5194/acp-22-7763-2022

Addition of atmospheric component to other Belgian ICOS sites

– Ongoing developments

Atmospheric GHG measurements at other Belgian ICOS sites

Additional ICOS and TCCON-type GHG measurements will be developed in the context of the

- ESFRI-FED project ICOS-BE (icos-be.aeronomie.be), at Congo-Flux tower site

→ on campaign-basis in 2024-2025

- BRAIN2 project VERBE (verbe.aeronomie.be)

→ campaign in neighbourhood of Antwerp , starting 2nd sem. 2023

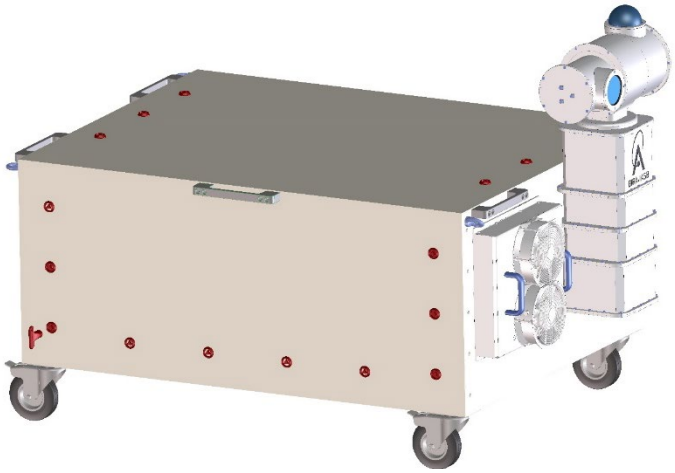
See poster

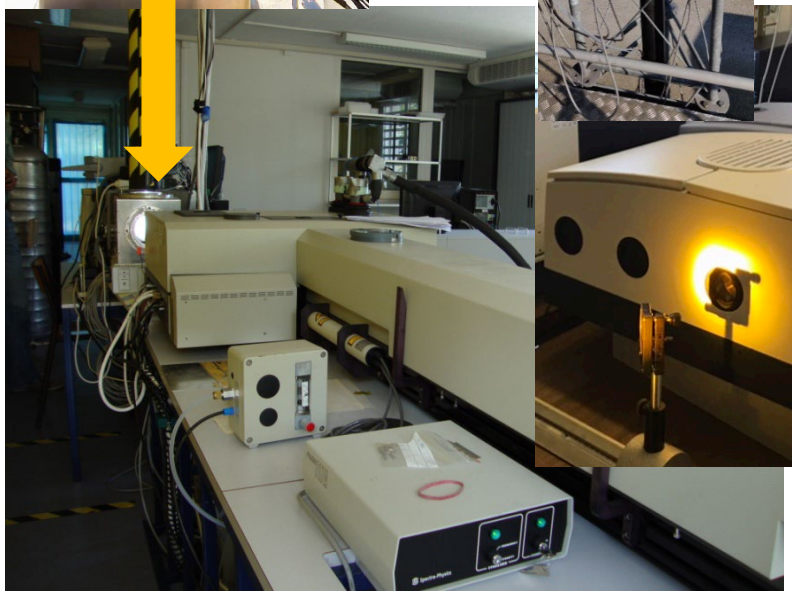
- FEDtWIN project BE-MVS (end 2023 onwards)

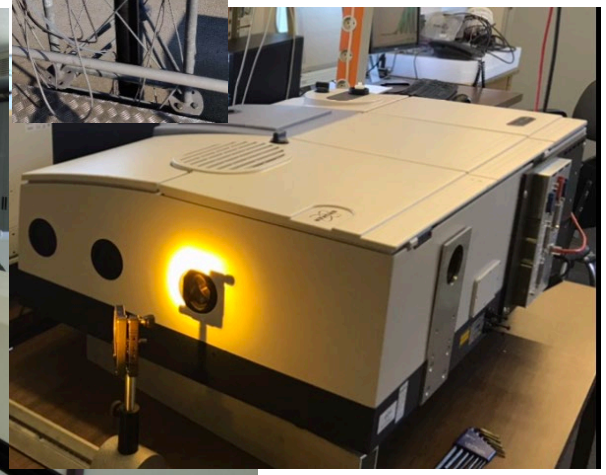
⇒ Requirement of more compact and mobile instruments based on Bruker Vertex 70 or Invenio spectrometer and home-made compact solar tracker

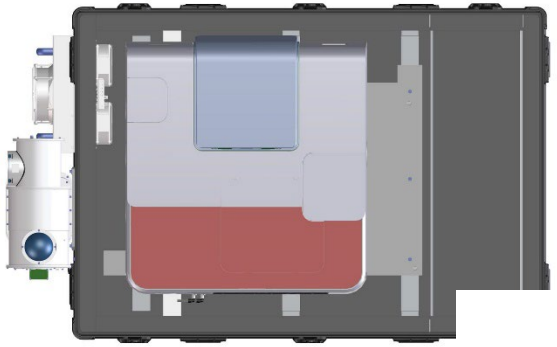
⇒ Characteristics of Bruker Vertex 70 spectrometer have been assessed in comparison to standard TCCON spectrometer in ESA FRM4GHG(2.0) projects

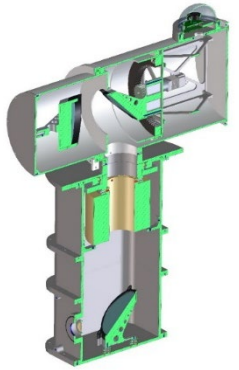
Autonomous, compact TCCON-type FTIR spectrometer set-up











Future perspectives

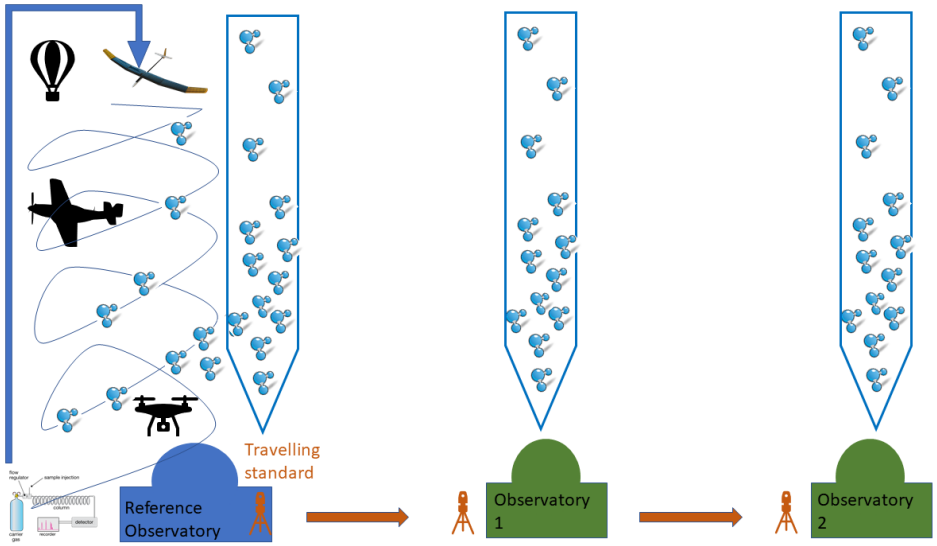
Challenges for the near-future

To fully support climate change mitigation (EU Green Deal, Global Stocktake, …)

- Build a sufficiently dense network of ICOS- and TCCON-type observations
  - → also an atmospheric ICOS / TCCON-type station in Belgium
  - → In future: atmospheric GHG measurements onboard RV Belgica II ?
- Augment the network with an infrastructure of mobile observations and an inverse modelling framework for verification and monitoring of emissions
  (see also the VERBE project)
- Ensure consistent calibration of the observing system
  - ⇒ implement the travelling st
- Ensure rapid access to data

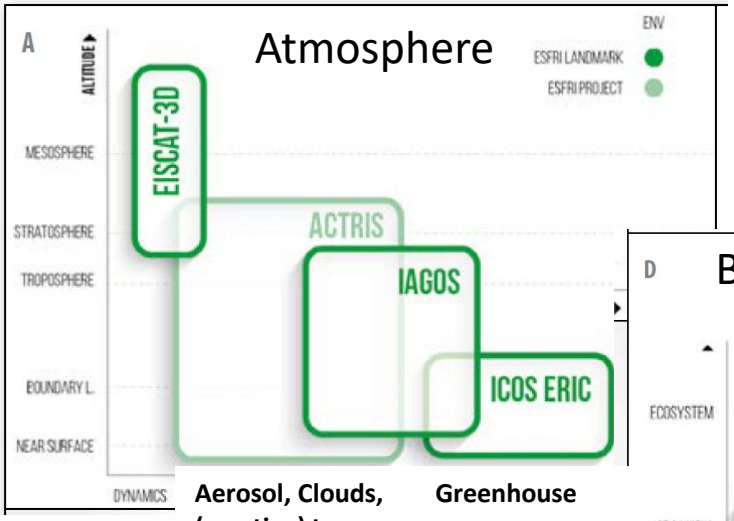
→ centralised TCCON data processing

→ In future: TCCON joining ICOS ?



With thanks to contributing authors and La Reunion & ICOS colleagues

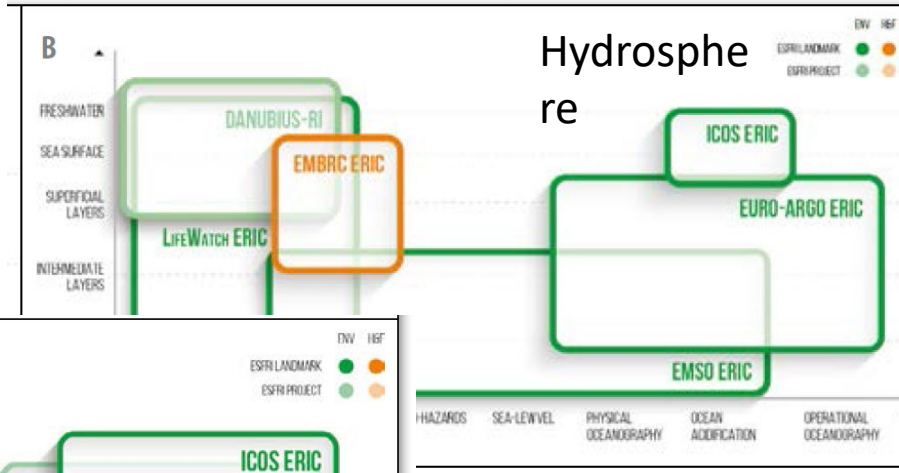
The landscape of environmental research infrastructures



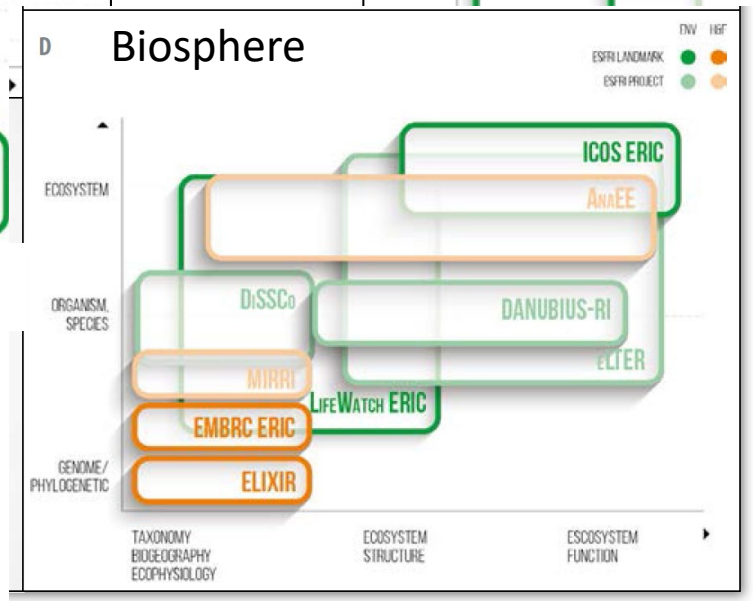
Atmosphere

Aerosol, Clouds, (reactive) trace gas

Greenhouse gas



Hydrosphere



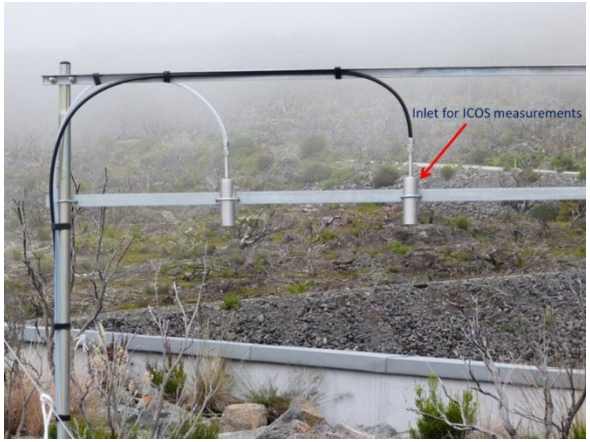
Biosphere

Current ACTRIS targets:

NO2, HCHO, C2H6, NH3, O3
Total/partial columns & profiles

From Rossi G., EPN, 50/1

Picarro at Maïdo



- Installation du Picarro G2401 in December 2014
- CO_2, CH_4, CO, H_2O