

# ICOS



INTEGRATED  
CARBON  
OBSERVATION  
SYSTEM

## CARBON PORTAL STATUS

Alex Vermeulen, CP team

# ICOS Carbon Portal, system elements

- ✓ All services fully scalable and portable (**dockerized**)
- ✓ Open software, shared through GITHUB, GPL licence
- ✓ Data objects in **trusted long term repository** (B2SAFE, 2 replicates)
- ✓ **Semantic web (WEB 3.0), linked open data**
  - ✓ Metadata based on ontology, all elements have (linked) URIs
  - ✓ nonSQL, RDF database
  - ✓ Open SPARQL endpoint
  - ✓ Versioned meta data store: roll-back, time dependent queries
- ✓ **Persistent identifiers, linking to data object and metadata: DOI and/or Handle system**
  - ✓ PID based on SHA256 checksum of data object: Data Integrity control
  - ✓ Maximum granularity of Data Objects
- ✓ Support for versioning, collections for DOI
- ✓ Machine actionable through standard http(s) protocol, RESTful API in backend and frontend
- ✓ NGiNX proxy redirects to services (<https://service.domain.eu>), domain completely configurable and stylable
- ✓ Can be deployed as single portal backend with multiple frontends or as set of federated portals using one or more interoperable metadata stores



# Identification as essential basis

- Globally **unique** and **eternally persistent** identifiers
- The identifiers resolve globally in human and machine readable ‘landing pages’
  - Point or give directly access to the data
  - Provide and further link to essential metadata
- Examples:
  - Handle PID: Persistent Identifier, e.g.  
<https://hdl.handle.net/11676/MpfOrQHnpLf3BMDDAGaAEafc>
    - In Handle only metadata required is a redirect URL (web link)
  - DOI: Digital Object Identifier (based on Handle), e.g.  
<https://doi.org/10.18160/CE2R-CC91>
    - For DataCite additional metadata fields are required ([Datacite Metadata Schema V4.2](#))
    - Metadata include abstract, keyword, authors and other contributors



# FAIRifying, the process

FAIRness involves “everyone”: data producers, data managers and the end users of our data!

- ✓ documenting data during collection & processing
- ✓ organized & secure repository for data & metadata
- persistent identifiers for data & resources
- ✓ web portal for search, visualization & download
- clear licensing
- linked data approach for metadata cataloguing
- interfaces for humans and machines
- support for end users
- engage with other initiatives projects to share resources



<https://www.coretrustseal.org/>

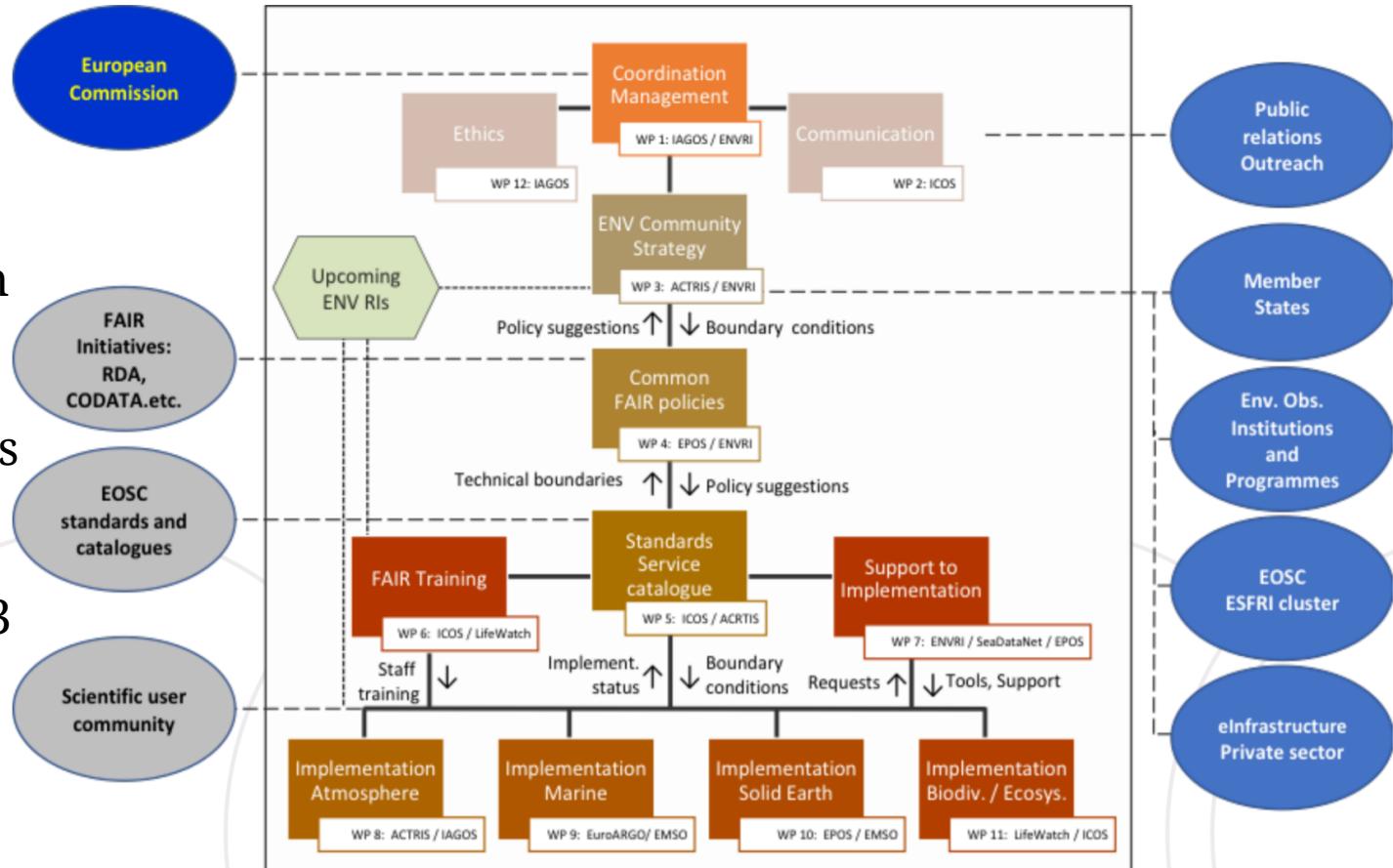
# FAIRifying in Europe -> EOSC Cluster project: ENVRIFAIR

12 Env. RIs

Other clusters:

- Life Sciences
- Photo & Neutron Science
- Astronomy + Particle Physics
- Social Sciences

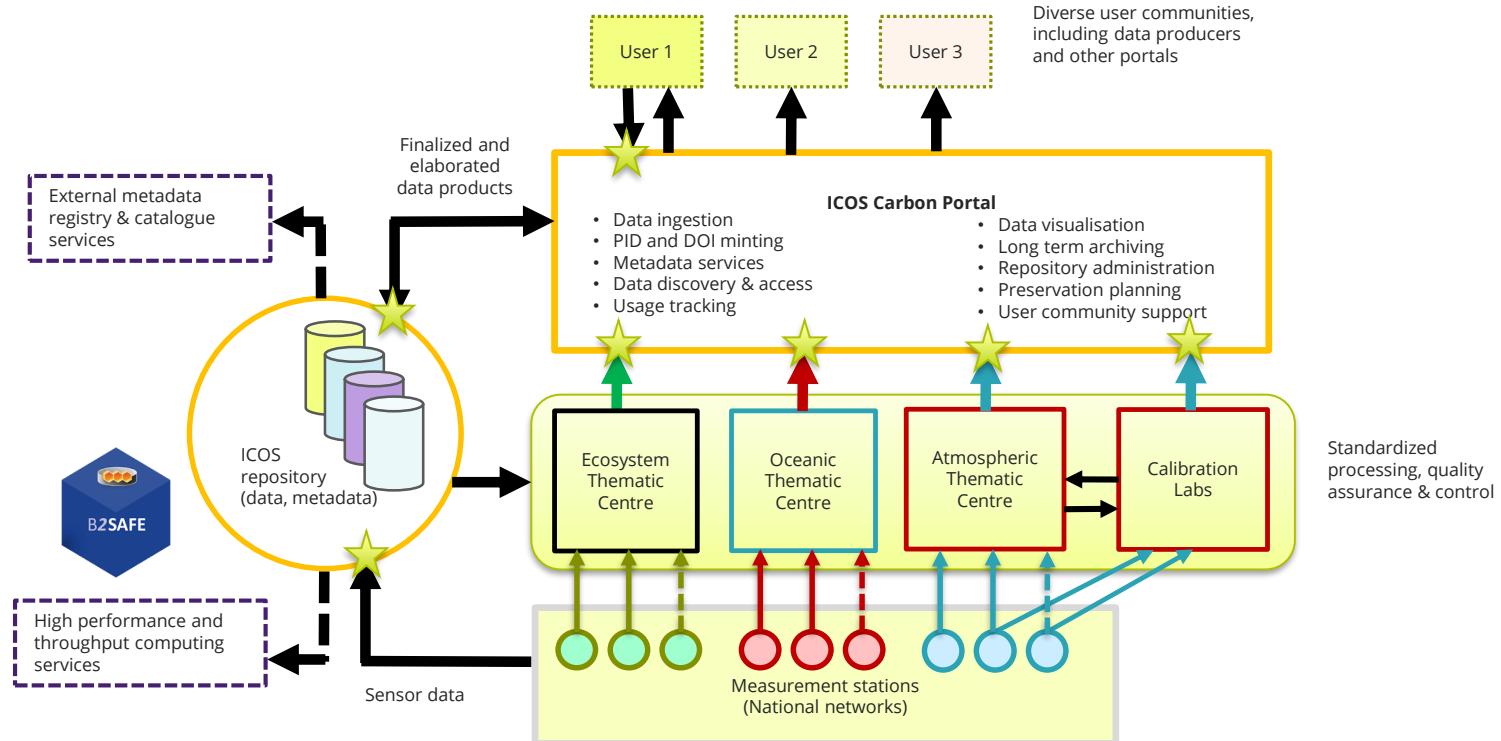
> 100 M€ until 2023

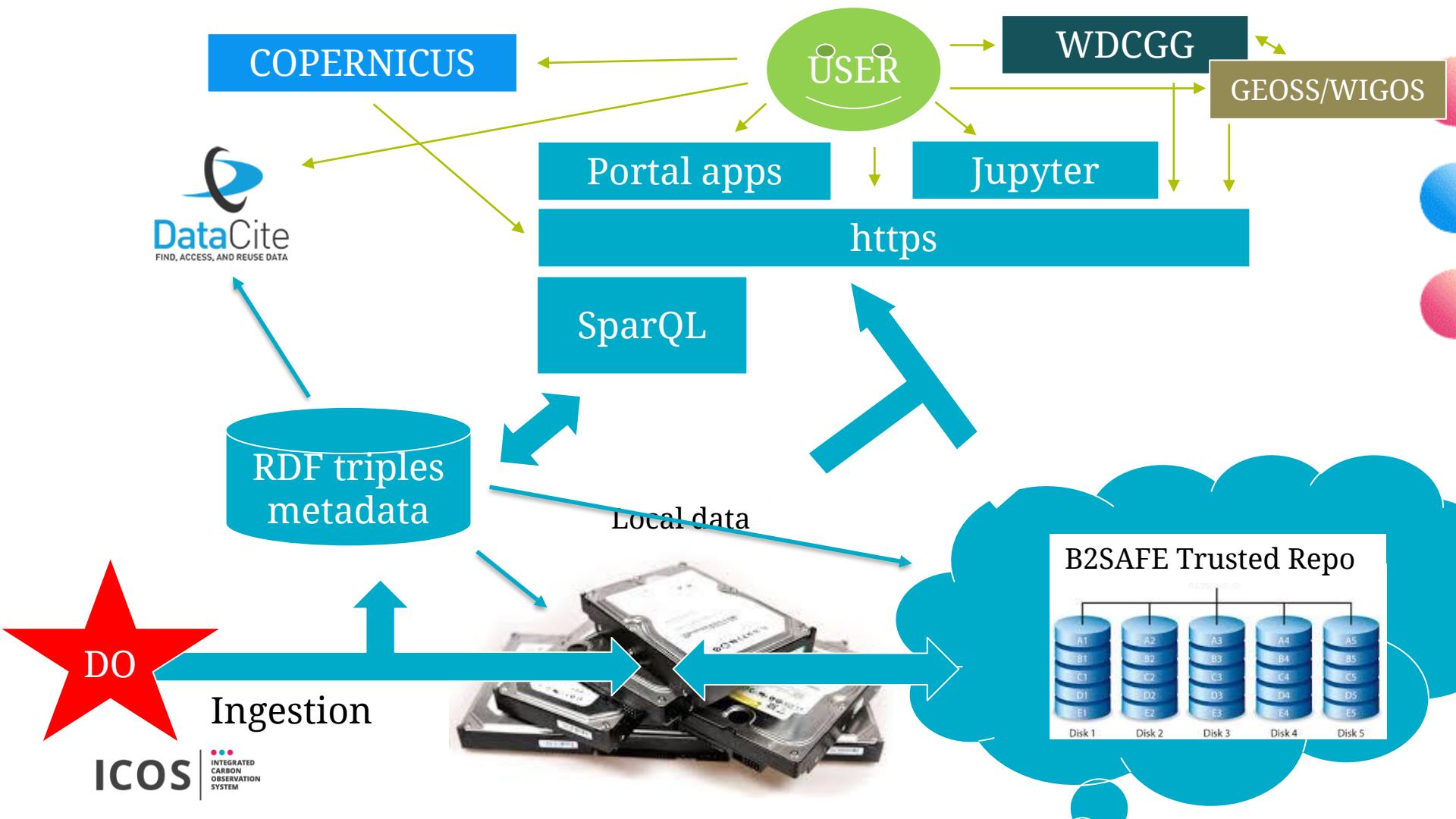


# ICOS Carbon Portal as an illustration

- In ICOS all data objects, from raw to model analyses get a PID and/or DOI
- ICOS PID contains checksum of data: data integrity assured!
- Identifiers are essential for data citation!
- Support for collections and data versioning
- Access through RESTful interfaces through a simple URL
  - Standard HTTP get and put: browser or prompt-cli is enough
- No drivers or proprietary software needed
- All software is versioned and provided open source (e.g, [GitHub](#)), ICOS CP: GPL
- Interfaces build on same protocols and Linked Open Data approach
- Upload restricted to known Data Objects supported by correct metadata by specific authorized users, data validated at ingestion
- All data download open and free according to data license (ICOS: CC4BY)
- High reliability and availability: >99%, persistent data storage
- Now operational for multiple domains

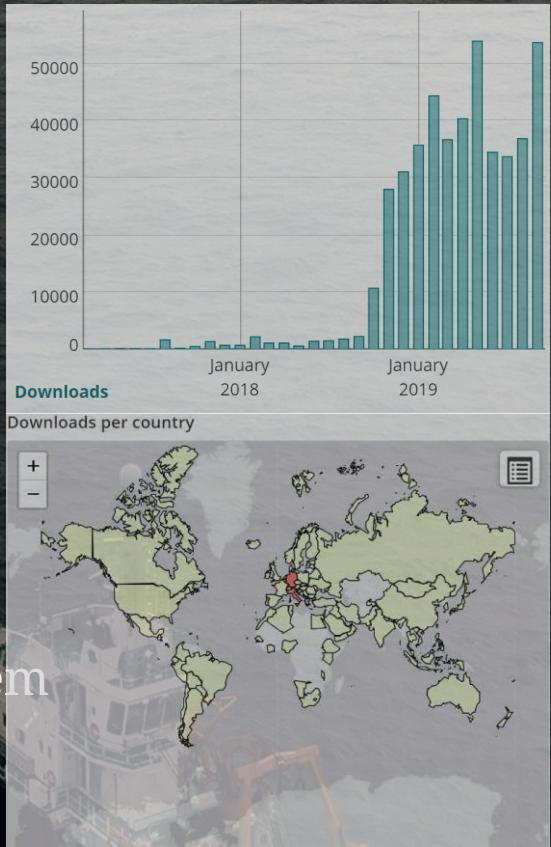
# ICOS data flow





# Factsheet Data Sep 2019

- 210 000 data objects
- 450 000 data downloads
- 40 000+ downloads per month
- 24 000 unique users
- 2 700 active users per month
- 294 CP user accounts (56 OrcID)
- 170 users of Nextcloud/OnlyOffice
- >99% uptime
- NRT data for Atmosphere+Ocean, soon Ecosystem
- Level 2 data for all domains
- Jupyter VREs and STILT footprint apps



# Find, preview and download data

<https://data.icos-cp.eu/portal>

<https://data.icos-cp.eu/portal/#search?theme=%5B%22Atmospheric%20data%22%5D&level=9>

- >200 000 visible data objects
- Data cart
- License check
- Download/preview count
  - Per data object
  - Per domain
  - Per contributor
  - Per country

Etc.



Downloads

ICOS data portal Search, preview, download data objects

Categories Filters

Clear categories

Data origin ICOS / non-ICOS data ICOS x

Theme Atmospheric data x

Station of origin SMEAR II-ICOS Hyttälä x

Data submitter Atmosphere thematic center

Data types

Data type ICOS ATC CO2 Release

Data level 2 x

Format ICOS ATC time series

Value types

Column name CO2 x

Value type CO2 mixing ratio (dry mole fraction)

Unit µmol mol-1

Quantity kind portion

Search results Compact view

Data objects 1 to 3 of 3

Sort by ▾

ICOS ATC CO2 Release Atmospheric data SMEAR II-ICOS Hyttälä

ICOS ATC CO2 Release Atmospheric data SMEAR II-ICOS Hyttälä

ICOS ATC CO2 Release Atmospheric data SMEAR II-ICOS Hyttälä

Data origin

ICOS / non-ICOS data ICOS x

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Data types

Data type ICOS ATC CO2 Release

Data level 2 x

Format ICOS ATC time series

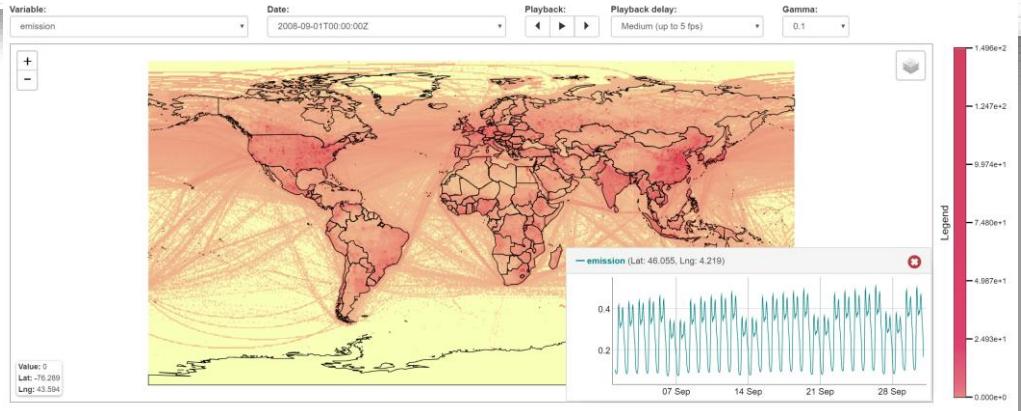
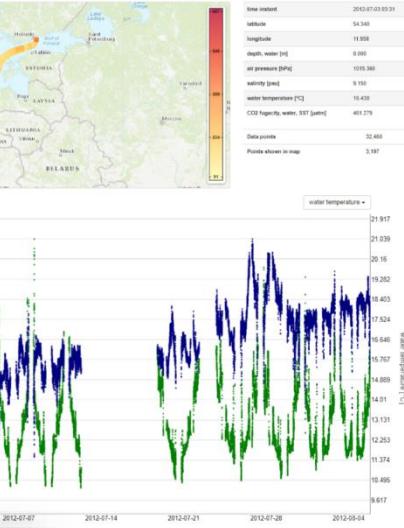
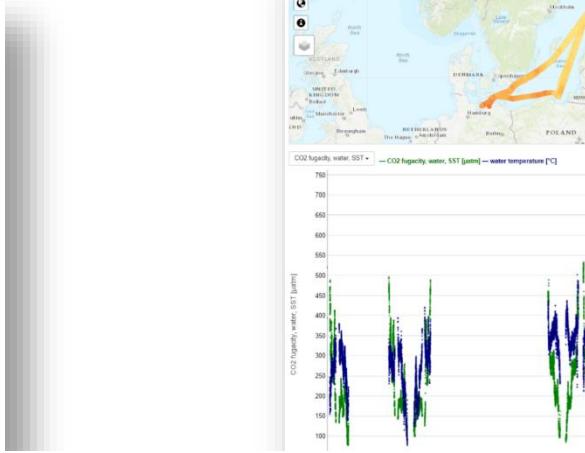
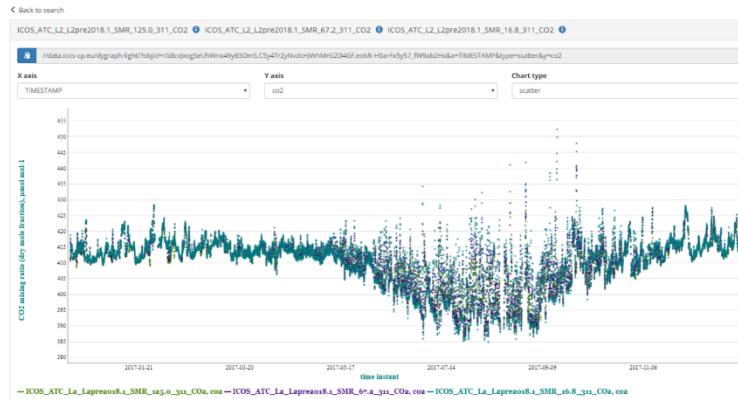
Value types

Column name CO2 x

Value type

# Fully operational, data previews

ICOS data portal Search, preview, download data objects



# [www.icos-cp.eu/dataproducts](http://www.icos-cp.eu/dataproducts)



The screenshot shows the ICOS Data Products homepage. At the top, there's a navigation bar with links for Home, Data, Other services, About, Help, and Log in. The main content area features a large banner image of a landscape with a grid overlay. Below the banner, the title "ICOS Data Products" is displayed, followed by "NEAR REAL TIME OBSERVATIONAL DATA (Level 1)". A section titled "Atmosphere: NRT CO<sub>2</sub> and CH<sub>4</sub> mole fraction growing time series at ICOS stations" includes a DOI link ([10.18160/ATM\\_NRT\\_CO2\\_CH4](https://doi.org/10.18160/ATM_NRT_CO2_CH4)) and a detailed description of the data collection. Another section below it, "Atmosphere: NRT meteorological observations at ICOS stations", notes that data will follow soon. Further down, there's a section for "FINAL FULLY QUALITY CONTROLLED OBSERVATIONAL DATA (Level 2)" with a similar structure. At the bottom, there's an "ELABORATED PRODUCTS (Level 3)" section featuring a "Gridded product: Global anthropogenic CO<sub>2</sub> emissions for 2007 based on EDGARv4.3 and BP statistics 2016".

## ICOS Data Products

### NEAR REAL TIME OBSERVATIONAL DATA (Level 1)

#### Atmosphere: NRT CO<sub>2</sub> and CH<sub>4</sub> mole fraction growing time series at ICOS stations

DOI: [10.18160/ATM\\_NRT\\_CO2\\_CH4](https://doi.org/10.18160/ATM_NRT_CO2_CH4)

Near Real-Time growing time series containing data from the atmospheric network of ICOS Research Infrastructure for the stations Gartow, Hohenpeissenberg, Hyttemossa, Ispra, Jungfraujoch, Kresin u Pacova, Lindenberg, Monte Cimone, Norunda, OPE, Pallas, Puy de Dome, SMEAR II (Hyttila), Svarberget, Torfhaus, Trainou, and Zeppelin Observatory. This collection contains the NRT hourly averaged data for the mole fractions of CO<sub>2</sub> and CH<sub>4</sub>, measured at the relevant vertical levels of the measurements stations, starting from the latest date of final released Level 2 data or the date of labelling. All stations follow the [ICOS Atmospheric Station specification V1.3](#) and are certified as ICOS atmospheric stations Class I or II. Data processing has been performed as described in [Hazan et al., 2016](#).

#### Atmosphere: NRT meteorological observations at ICOS stations

Will follow soon

### FINAL FULLY QUALITY CONTROLLED OBSERVATIONAL DATA (Level 2)

#### Atmosphere: Final quality controlled Level 2 data of CO<sub>2</sub>, CH<sub>4</sub>, CO, <sup>14</sup>CO<sub>2</sub> and meteorology at ICOS stations

DOI: [10.18160/RHKC-VP22](https://doi.org/10.18160/RHKC-VP22)

Release 2018-2, containing data from the atmospheric network of ICOS Research Infrastructure for the stations Gartow, Hohenpeissenberg, Hyttemossa, Jungfraujoch, Kresin u Pacova, Norunda, OPE, Puy de Dome, SMEAR, Svarberget, and Zeppelin Observatory. This collection contains the final quality controlled hourly averaged data for the mole fractions of CO<sub>2</sub>, CH<sub>4</sub>, CO and meteorological observations measured at the relevant vertical levels of the measurements stations, and where available <sup>14</sup>C in CO<sub>2</sub> in two-weekly integrated samples, for the years 2016-2018. All stations follow the [ICOS Atmospheric Station specification V1.3](#) and are certified as ICOS atmospheric stations Class I or II. Data processing has been performed as described in [Hazan et al., 2016](#).

[Download this complete dataset](#)

### ELABORATED PRODUCTS (Level 3)

#### Gridded product: Global anthropogenic CO<sub>2</sub> emissions for 2007 based on EDGARv4.3 and BP statistics 2016

DOI: [10.18160/VG28-HZQA](https://doi.org/10.18160/VG28-HZQA)

Global anthropogenic CO<sub>2</sub> emissions based on EDGARv4.3, fuel type and category specific emissions provided by Greet Janssens-Maenhout (EU-JRC), BP statistics 2016, temporal variations based on MACC-TNO, temporal extrapolation and disaggregation described in COFFEE (Steinbach et al. 2011).

[Download this complete dataset](#)

[Find similar emission data on the Carbon portal](#)

# www.icos-cp.eu/dataproducts

## ICOS Near Real-Time (Level 1) Atmospheric Greenhouse Gas Mole Fractions of CO<sub>2</sub> and CH<sub>4</sub>, growing time series starting from latest Level 2 release

**Disclaimer:** Near Real-Time (NRT, Level 1) data is not the final highest quality ICOS data. This data is generated using only completely automated quality control procedures. These NRT time series are generated within 24 hours after measurement and will not be updated later using improved information or become completed with missing data. For your analysis and publications we recommend to use the final completely quality controlled and flagged (Level 2) data that is released with a delay between 6-12 months, that includes all corrections and maximum completion of missing data, also listed in [our data products catalog](#).

**Citation:** ICOS Research Infrastructure: ICOS Near Real-Time (Level 1) Atmospheric Greenhouse Gas Mole Fractions of CO<sub>2</sub> and CH<sub>4</sub>, growing time series starting from latest Level 2 release., doi:10.18160/atm\_nrt\_co2\_ch4, 2018.

**Link to data:** [Carbon Portal Search](#)

**DOI:** [10.18160/ATM\\_NRT\\_CO2\\_CH4](https://doi.org/10.18160/ATM_NRT_CO2_CH4)

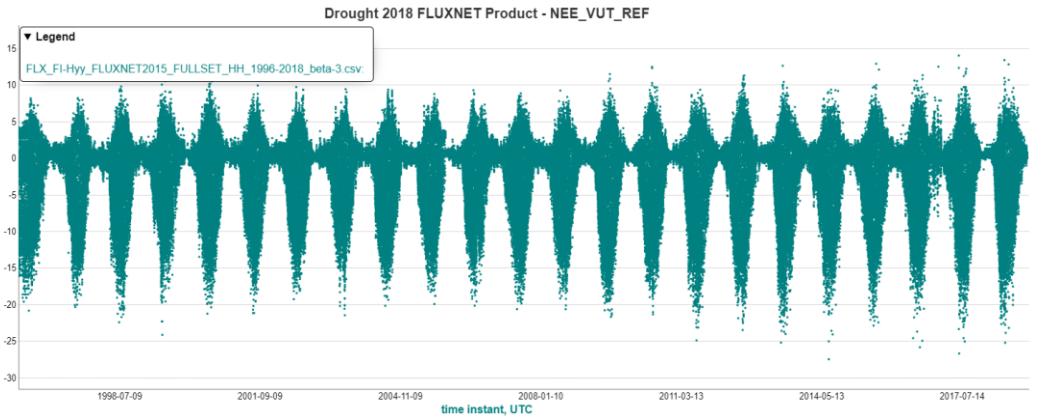
**Abstract:** Near Real-Time growing time series containing data from the atmospheric network of ICOS Research Infrastructure for the stations Gartow, Hohenpeissenberg, Hyttemossa, Ispra, Jungfraujoch, Kresin u Pacova, Lindenber, Monte Cimone, Norunda, OPE, Pallas, Puy de Dome, SMEAR II (Hyttiala), Svarberget, Torfhaus, Trainou, and Zeppelin Observatory. This collection contains the NRT hourly averaged data for the mole fractions of CO<sub>2</sub> and CH<sub>4</sub>, measured at the relevant vertical levels of the measurements stations, starting from the latest date of final released Level 2 data or the date of labelling. All stations follow the ICOS Atmospheric Station specification V1.3 (<https://www.icos-ri.eu/fetch/ba12290c-3714-4dd5-a9f0-c431b9900ad1;1.0>) and are certified as ICOS atmospheric stations Class I or II. Data processing has been performed as described in Hazan et al., 2016 (doi:10.5194/amt-9-4719-2016).

### CO<sub>2</sub> preview

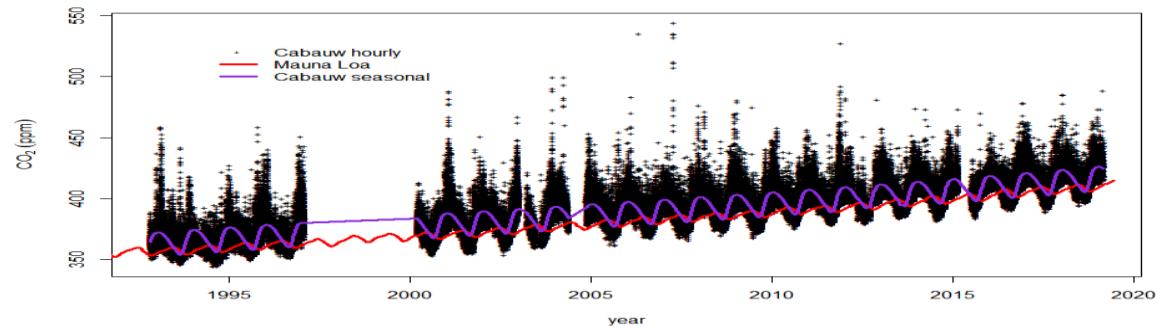
Station	height 1	height 2	height 3	height 4	height 5	
Gartow (ATC_413)	30.0	60.0	132.0	216.0	341.0	All
Gartow (ATC_489)	30.0	60.0	132.0	216.0	341.0	All
Hohenpeissenberg (ATC_382)	50.0	93.0	131.0			All
Hyttemossa (ATC_463)	30.0	70.0	150.0			All
ICOS Utø – Baltic sea (ATC_486)	57.0					All
Ispra (ATC_619)	40.0	60.0	100.0			All
Jungfraujoch (ATC_225)	5.0					All
Karlsruhe (ATC_458)	30.0	60.0	100.0	200.0		All
Karlsruhe (ATC_489)	30.0	60.0	100.0	200.0		All
Kresin u Pacova (ATC_172)	10.0	50.0	125.0	250.0		All
Lindenber (ATC_399)	2.5	10.0	40.0	98.0		All
Lutjewad (ATC_465)	60.0					All
Monte Cimone (ATC_590)	8.0					All
Norunda (ATC_462)	32.0	59.0	100.0			All
Observatoire Pérenne de l'Environnement (ATC_187)	10.0	50.0	120.0			All
Observatoire Pérenne de l'Environnement (ATC_379)	10.0	50.0	120.0			All
Observatoire Pérenne de l'Environnement (ATC_728)	10.0	50.0	120.0			All
Pallas (ATC_485)	12.0					All
Puy de Dome (ATC_473)	10.0					All
SMEAR II-ICOS Hyttiala (ATC_311)	16.8	67.2	125.0			All
Svarberget (ATC_464)	35.0	85.0	150.0			All
Torfhaus (ATC_271)	10.0	76.0	110.0	147.0		All
Torfhaus (ATC_457)	10.0	76.0	110.0	147.0		All

# Long high quality time series

net ecosystem exchange [ $\mu\text{mol m}^{-2} \text{s}^{-1}$ ]



Cabauw CO<sub>2</sub> time series



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CARBON  
OBSERVATION  
SYSTEM



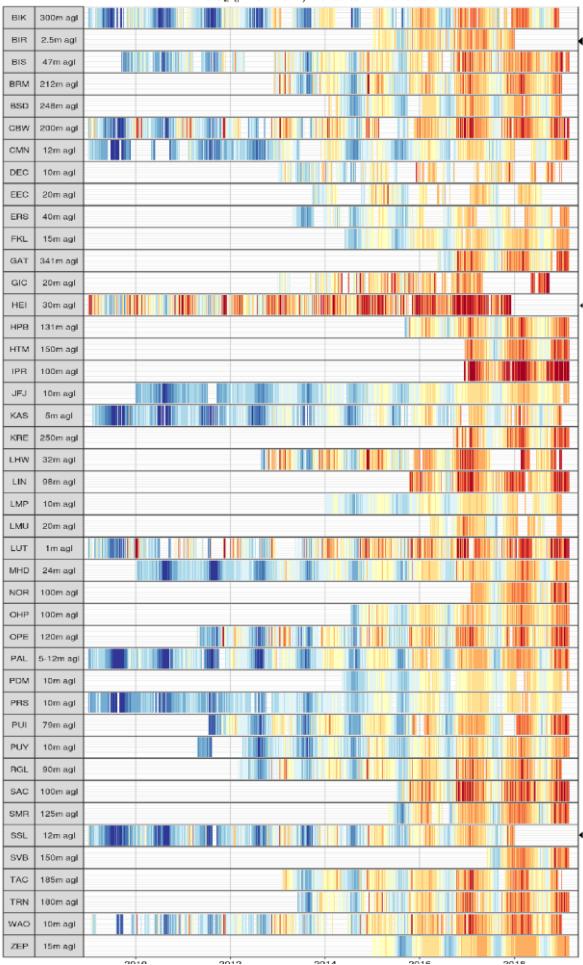
Atmosphere  
Thematic  
Centre

Network concentration evolution

2009-01-01 - 2019-04-01

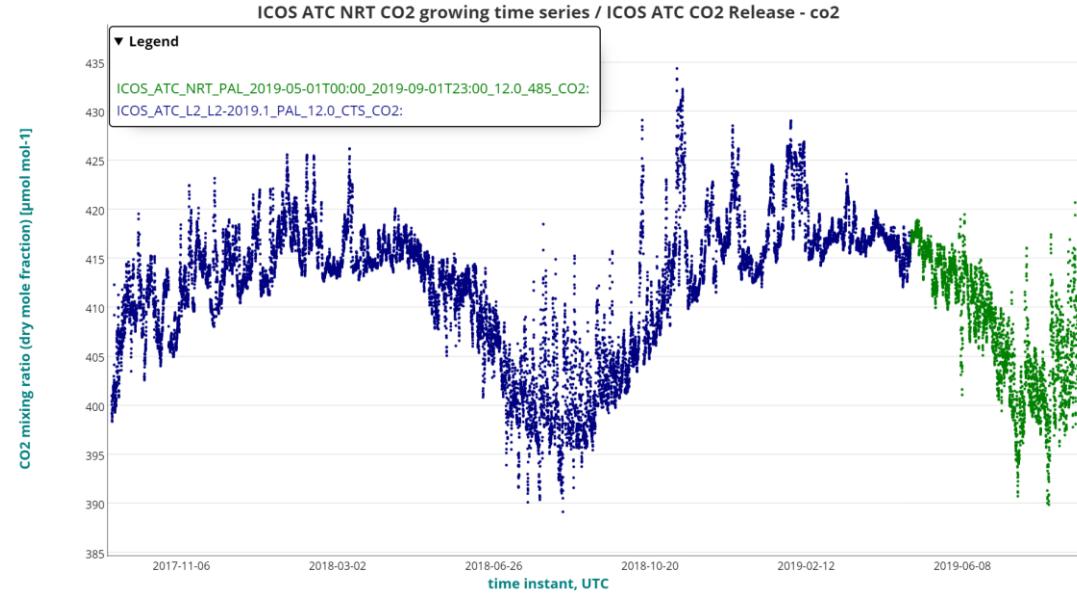
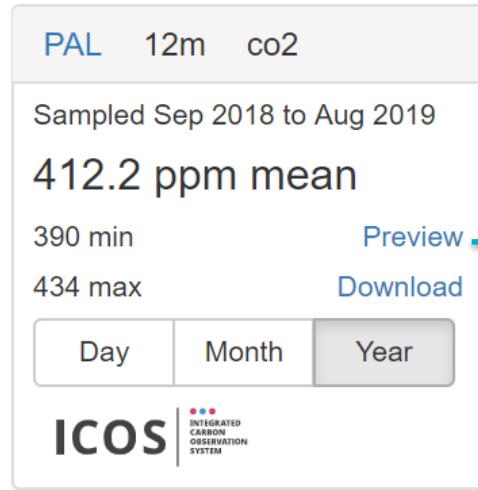
CO<sub>2</sub> ( $\mu\text{mol mol}^{-1}$ ) - 0:00 to 24:00 local time

P0004.5.bis /  
update 2019-04-01 17:51



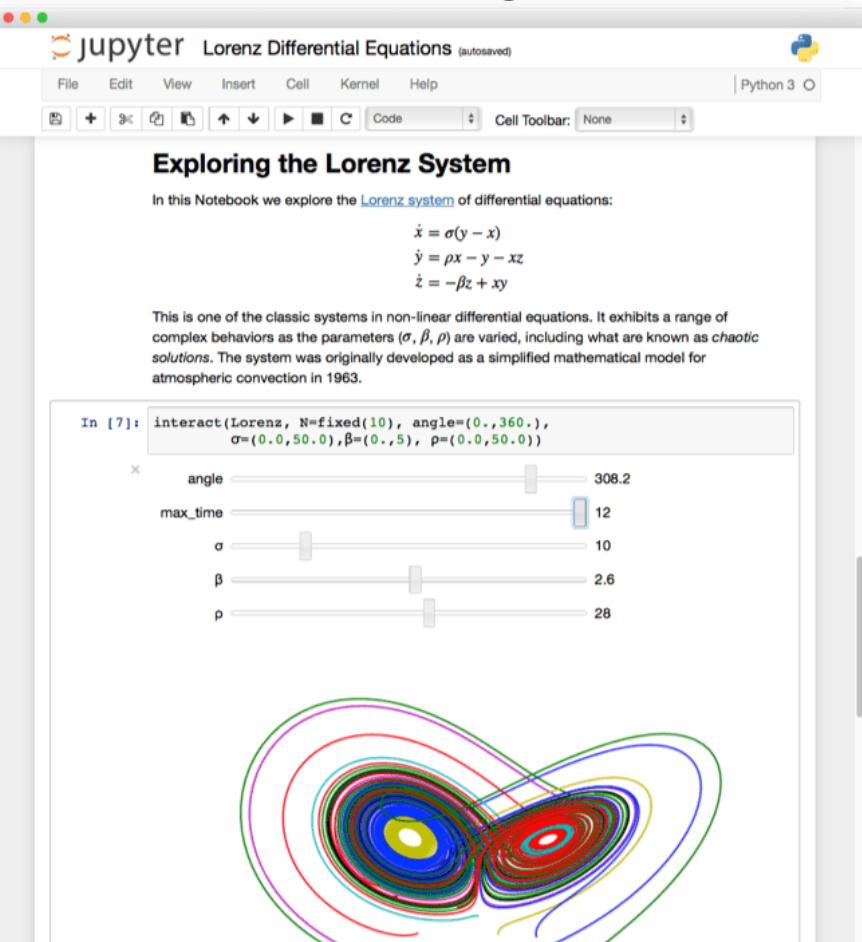
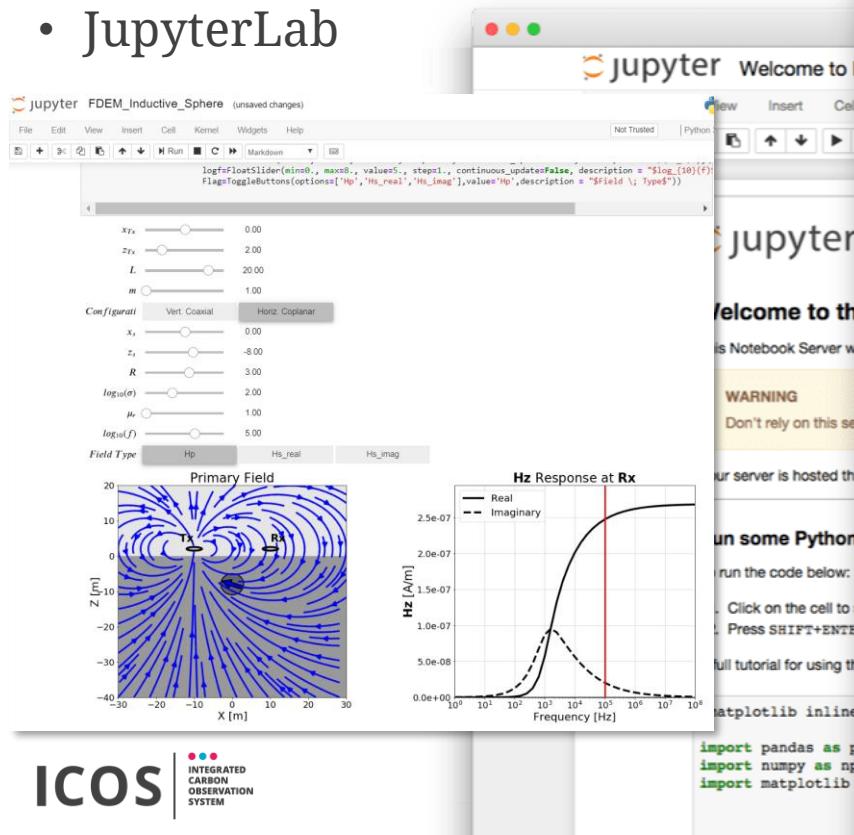
# Example dashboard servlet

Station L2+NRT data average for dissemination, e.g. as servlet in news web site:  
<https://data.icos-cp.eu/dashboard/?stationId=PAL&valueType=co2&height=12>



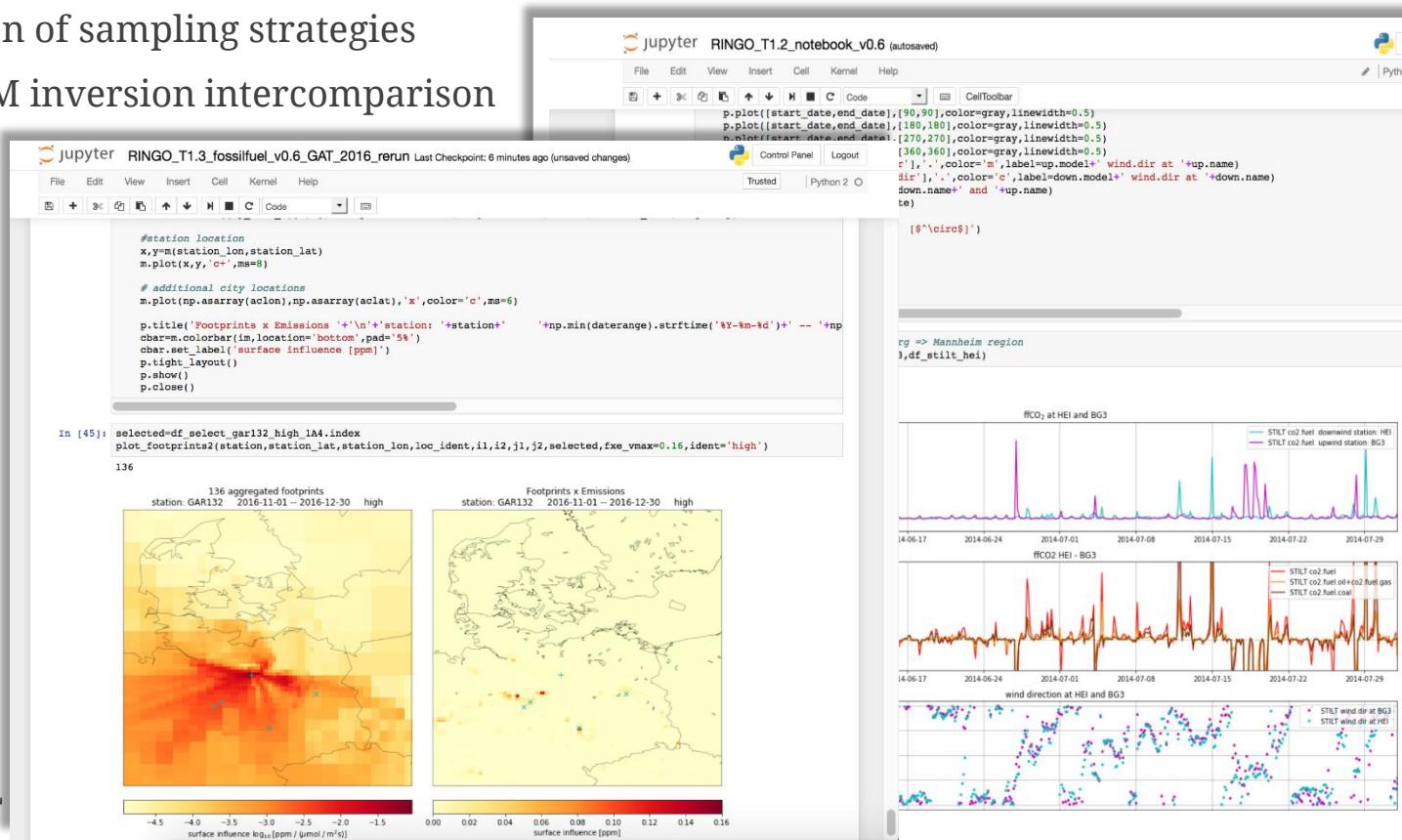
# The future of the research data lifecycle

- Jupyter interactive notebooks
- JupyterLab



# Interactive analysis tools for model results & data

- Analysis of simulated fossil fuel CO<sub>2</sub> time series (RINGO)
- Evaluation of sampling strategies
- EUROCOM inversion intercomparison
- ...



# Jupyter notebooks for educational purposes

- Teaching material for university and high-school combining data analytics, coding, and natural sciences
- Display at Swedish Science centers

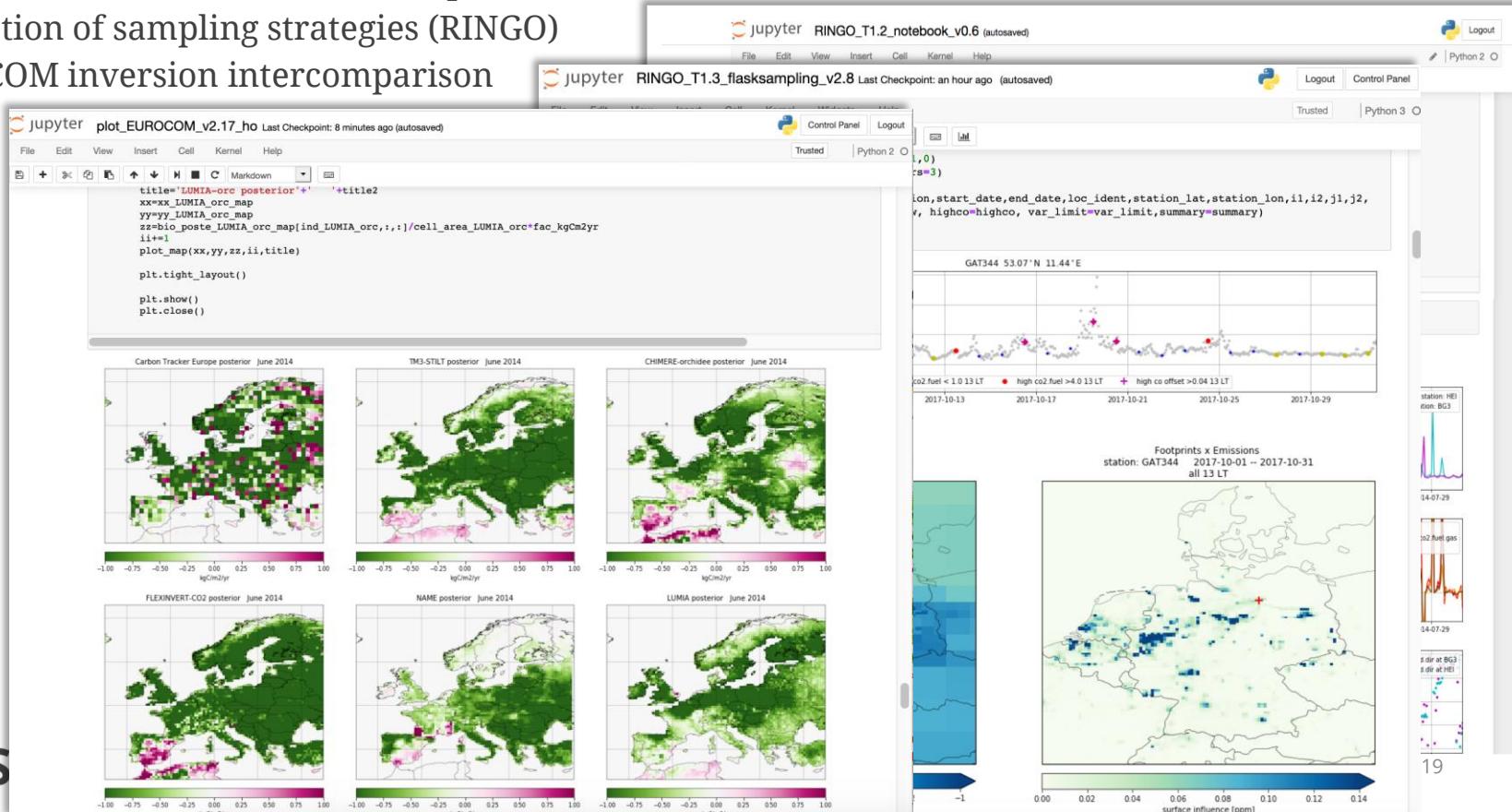
The image displays a web browser window with three separate Jupyter notebook interfaces open side-by-side, illustrating their use for educational purposes.

- Top Notebook:** Shows a quiz titled "6. Quiz - Testa dina kunskaper". It contains several questions related to CO<sub>2</sub> levels, such as "Vilket var det lägsta koldioxidnivån?" and "Vilken var den totala mängden i atmosfären?".
- Middle Notebook:** Titled "Pallas CO<sub>2</sub> time series", this notebook displays a line graph comparing three data series:
  - Pallas hourly (black dots)
  - Mauna Loa (red line)
  - Pallas seasonal (purple line)The x-axis represents the year from 2000 to 2020, and the y-axis represents CO<sub>2</sub> concentration in ppm, ranging from 360 to 420. The graph shows a clear seasonal cycle superimposed on a long-term upward trend.
- Bottom Notebook:** Provides a detailed view of the seasonal component of the Pallas CO<sub>2</sub> data. It shows a zoomed-in view of the purple line (Pallas seasonal) from the middle notebook, highlighting the annual oscillations.

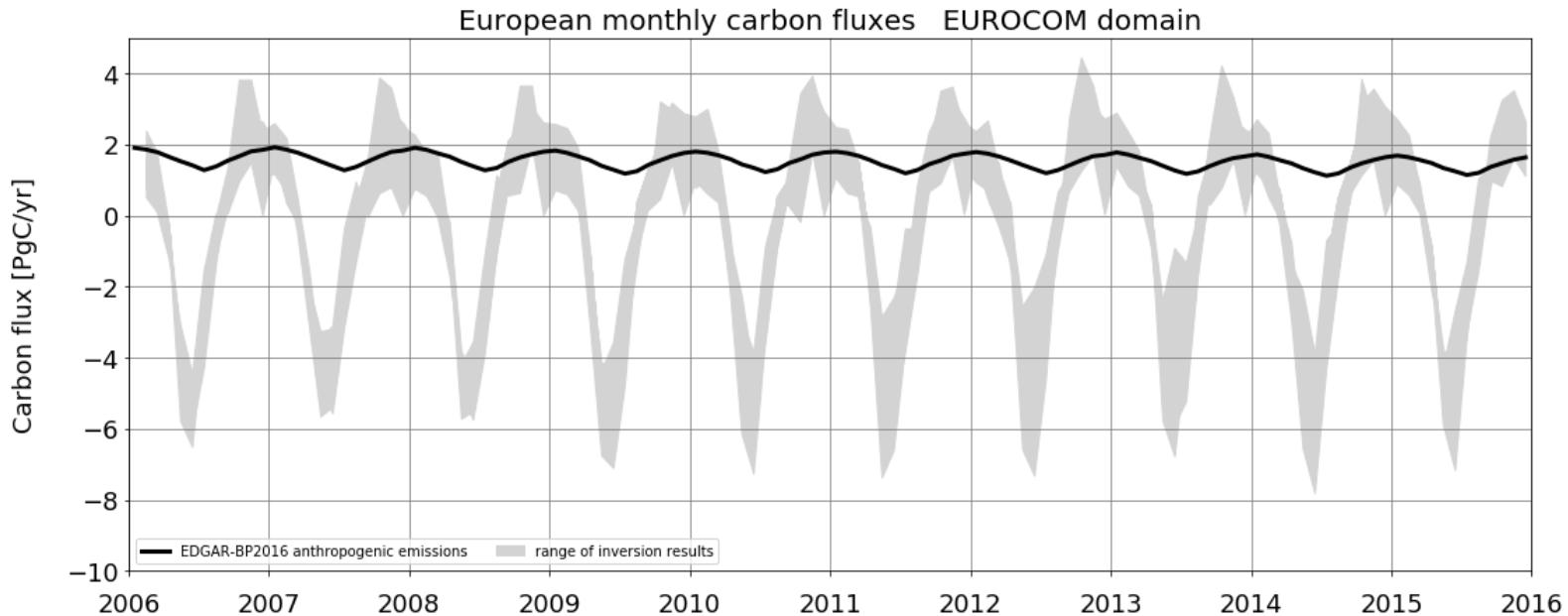
The browser tabs indicate the notebooks are titled "jupyter vattenhallen\_koldioxid\_WorkingVersionFullFunc". The top-right corner of the image features the logo for the "Swedish National Space Agency" and "ICOS" (Integrated Carbon Observation System).

# Project-specific Jupyter notebooks

- Analysis of simulated fossil fuel CO<sub>2</sub> time series (RINGO)
- Evaluation of sampling strategies (RINGO)
- EUROCOM inversion intercomparison
- ...



# EUROCOM inversions: fuel & biospheric CO<sub>2</sub> flux estimates



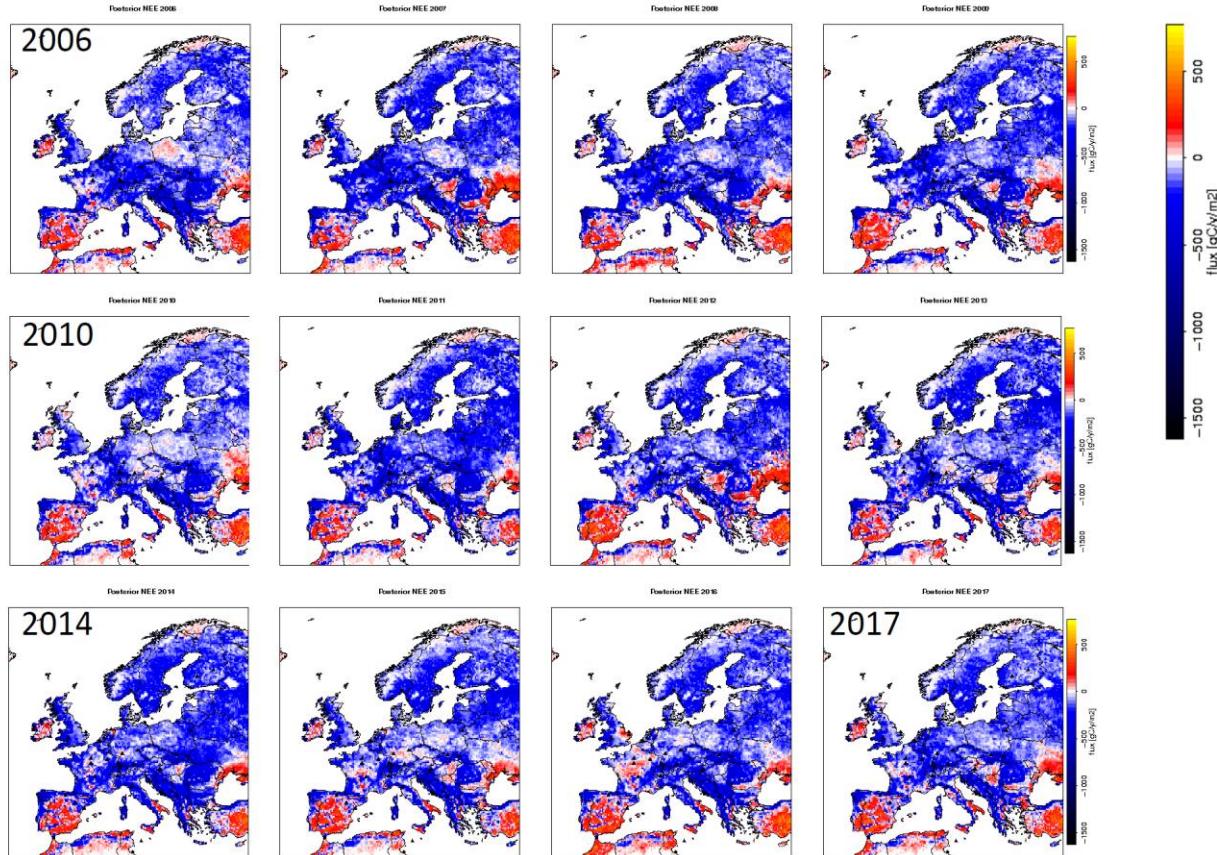
- Inversion results still show large differences => model development & inherent uncertainties
- Inversion results will be uploaded soon at ICOS CP
- Inversions are currently extended to 2018

# VERIFY regional inversion results 2006-2017

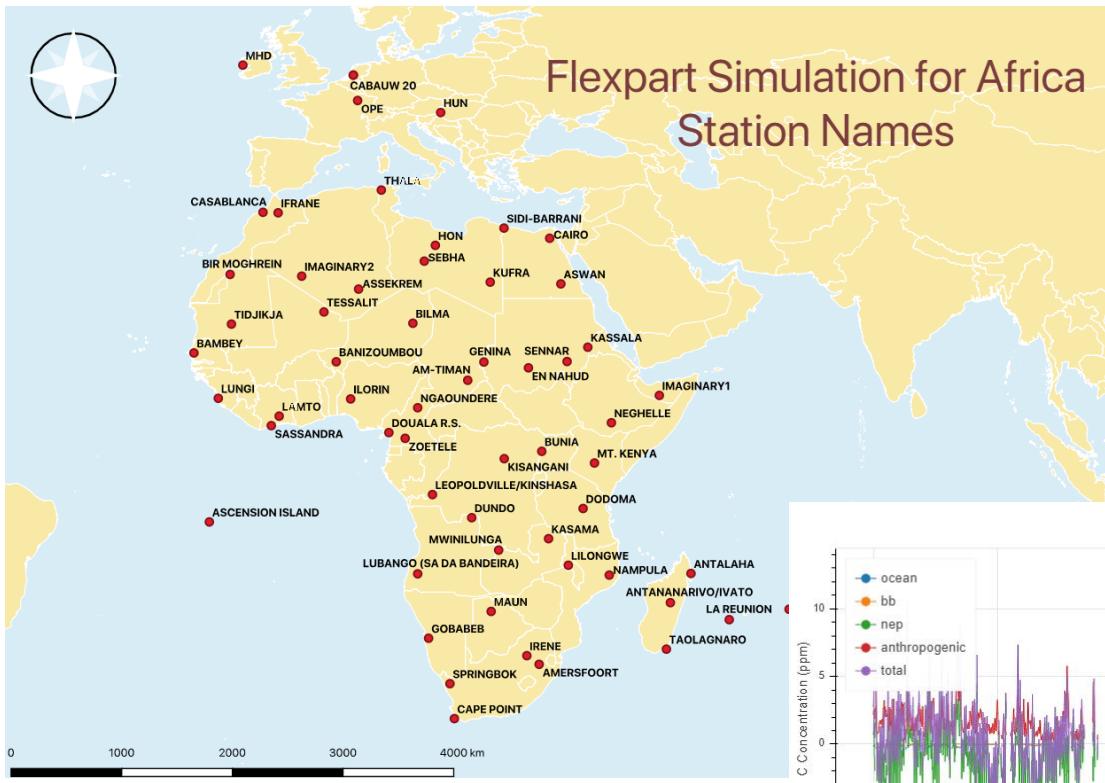


RINGO | Readiness  
of ICOS

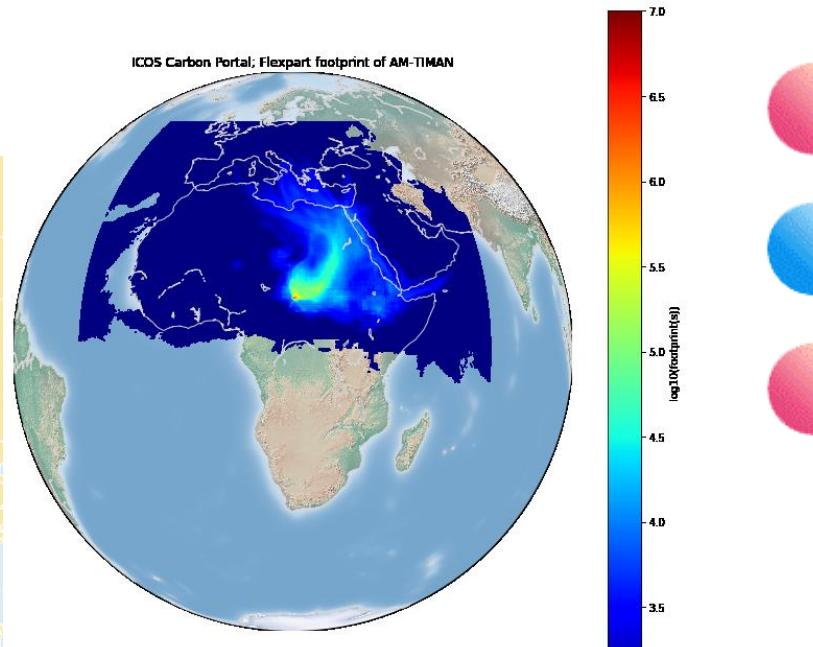
ICOS | INTEGRATED  
CARBON  
OBSERVATION  
SYSTEM



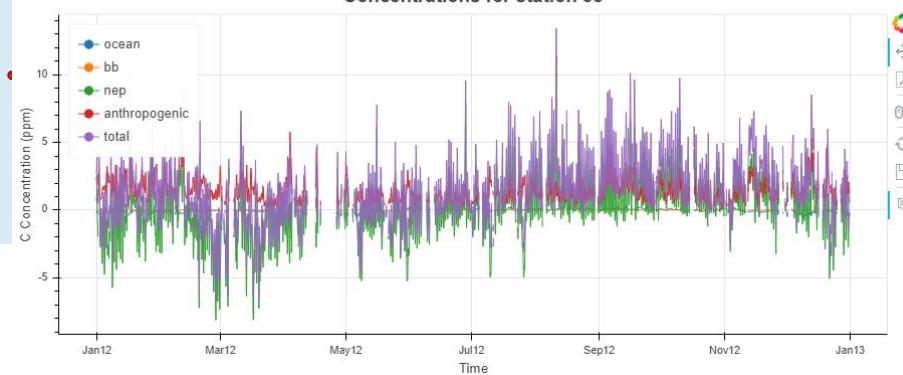
# SEACRIFOG



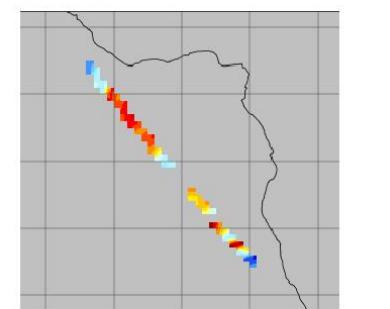
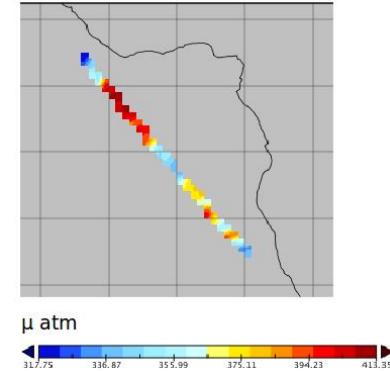
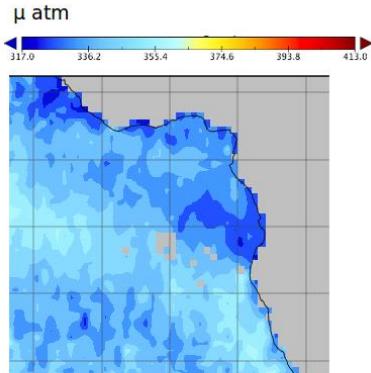
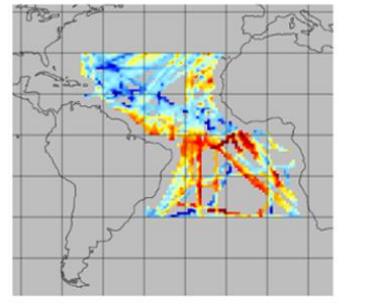
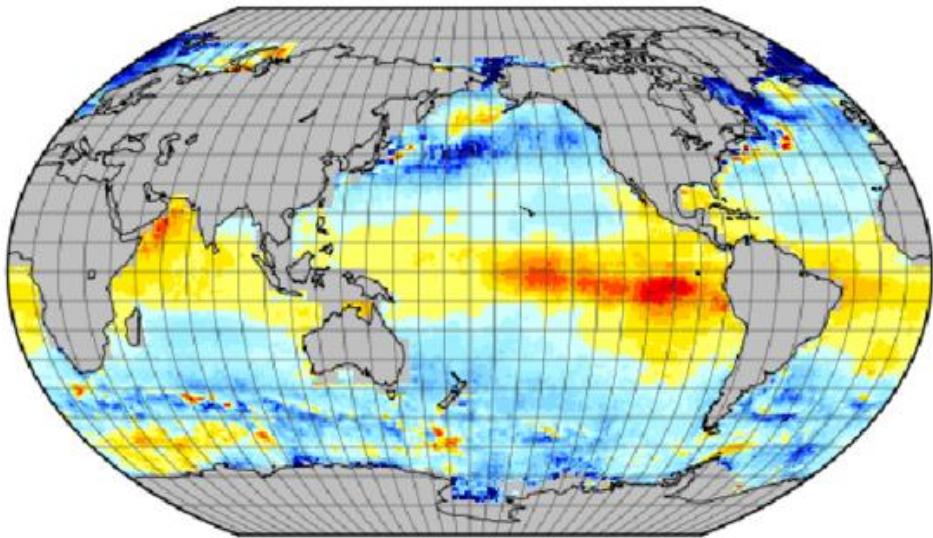
ICOS Carbon Portal; Flexpart footprint of AM-TIMAN



Concentrations for station 53

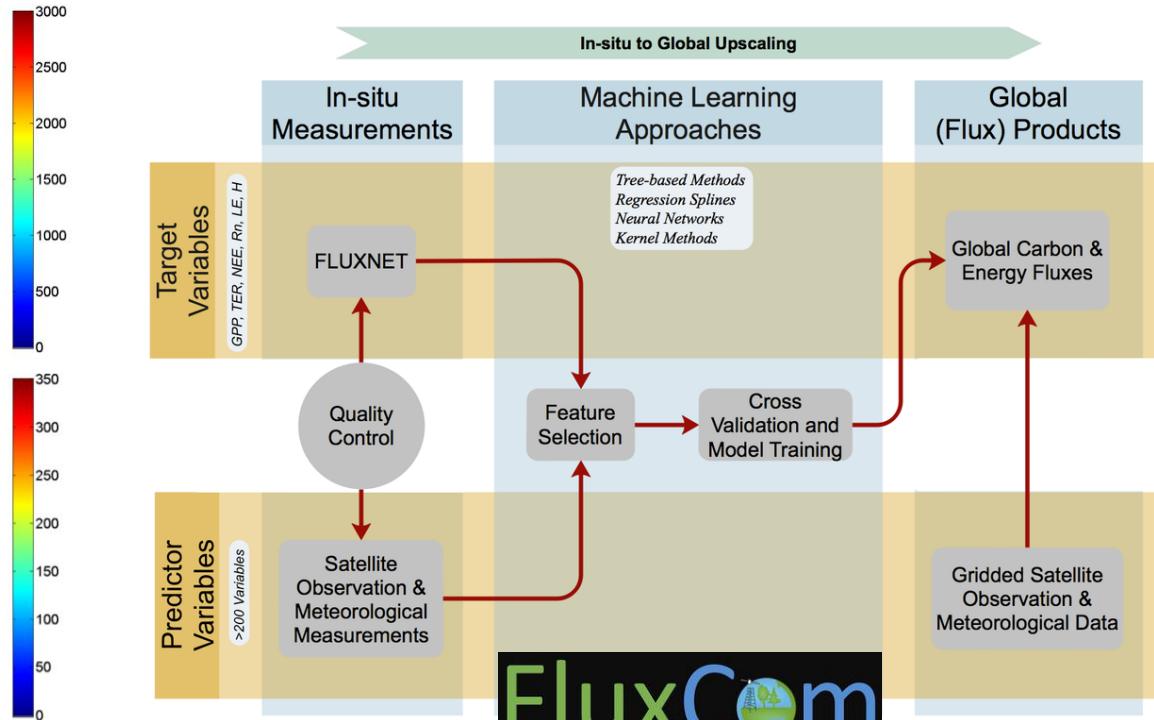
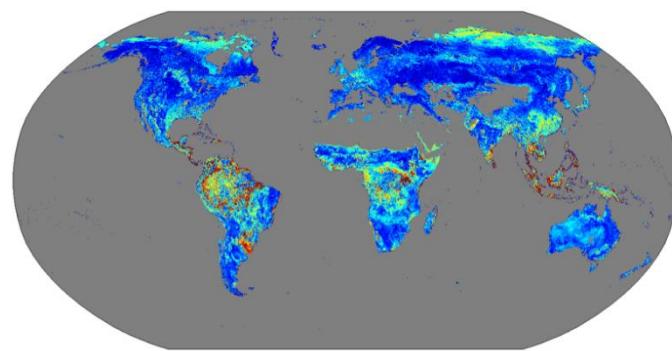
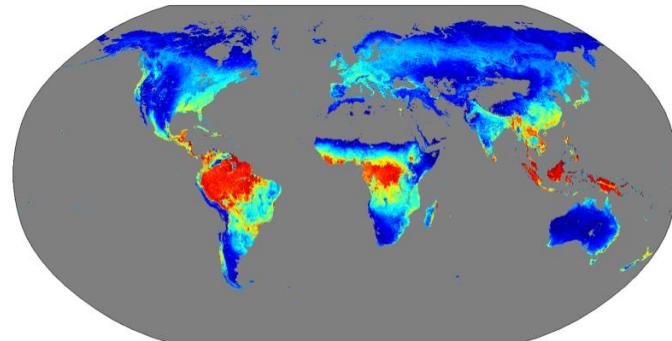


# Examples of potential operational science products



Fluxengine:  
<http://www.oceanflux-ghg.org/Products/FluxEngine>

# Examples of potential operational science products



FLUXCOM GPP+uncertainty (<http://www.fluxcom.org>)

Model-data fusion upscaling of ecosystem flux obs+meteo model+satellite+DGVMs

# High impact



# Climate change: Impacts 'accelerating' as leaders gather for UN talks

By Matt McGrath  
Environment correspondent

⌚ 22 September 2019 | Science & Environment



The signs and impacts of global heating are speeding up, the latest science on climate change, published ahead of key UN talks in New York says.

The data, compiled by the World Meteorological Organization (WMO), says the five-year period from 2014 to 2019 is the warmest on record.

Sea-level rise has accelerated significantly over the same period, as CO<sub>2</sub> emissions have hit new highs.

The WMO says carbon-cutting efforts have to be intensified immediately.

# United In Science: High-level synthesis report of latest climate science information convened by the Science Advisory Group of the UN Climate Action Summit 2019

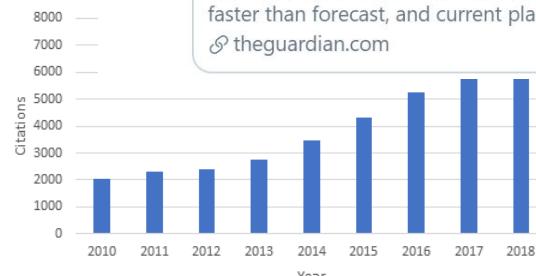


ICOS Carbon Portal @ICOS\_CP · 1m

Countries must triple climate emission cut targets to limit global heating to 2C



Countries must triple climate emissions targets to limit global heating t...  
United in Science report ahead of UN summit says climate is changing faster than forecast, and current plans would lead to 'catastrophic' glob...  
*& theguardian.com*



# Some selected links to the ICOS data portal

<https://data.icos-cp.eu/portal>

<https://exploredata.icos-cp.eu>

<https://www.icos-cp.eu/data-products>

<https://stilt.icos-cp.eu/viewer/>

<https://stilt.icos-cp.eu/worker/>

<https://github.com/ICOS-Carbon-Portal>

<https://data.icos-cp.eu/stats/>

Account required:

<https://cpauth.icos-cp.eu/login/>

<https://jupyter2.icos-cp.eu>

<https://meta.icos-cp.eu/uploadgui/>

<https://doi.icos-cp.eu/>

<https://meta.icos-cp.eu/sparqlclient/>

<https://fileshare.icos-cp.eu>

Main search interface

Anonymous Jupyter notebooks

Main ICOS obs. data products

View footprints and concentrations

Calculate your own footprints

ICOS CP source code repo

Download statistics

Login/create account

Jupyter service (sep. account needed)

User friendly data upload

DOI minting and metadata edit service

GUI for open SparQL endpoint

ICOS fileshare, online document editing

(any name+  
password=msa)



Thank you!  
ICOS

...  
INTEGRATED  
CARBON  
OBSERVATION  
SYSTEM

