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
 - \checkmark 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
- $\checkmark\,$ Support for versioning, collections for DOI
- ✓ Machine actionable through standard http(s) protocol, RESTful API in backend and frontend
- ✓ NGiNX proxy redirects to services (<u>https://service.domain.eu</u>), 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. <u>https://hdl.handle.net/11676/MpfOrQHnpLf3BMDDAGaAEafc</u>
 - 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 (<u>Datacite Metadata</u> <u>Schema V4.2</u>)
 - 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!

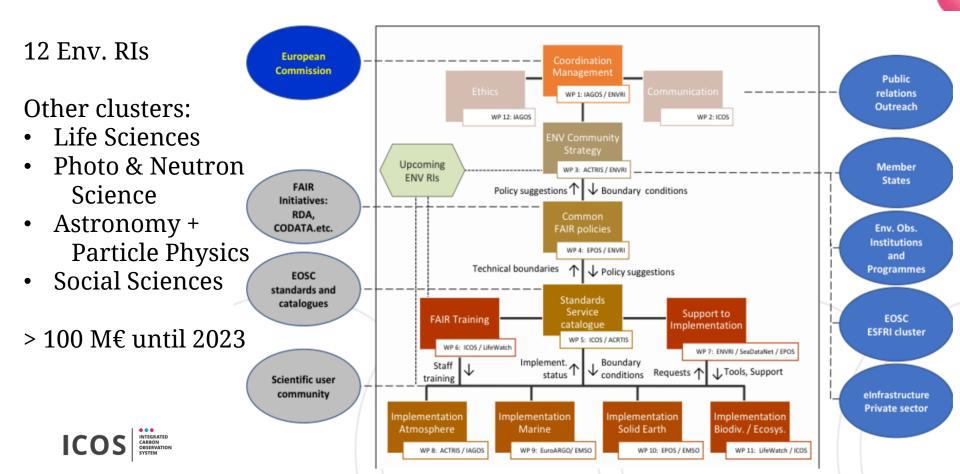
- \checkmark documenting data during collection & processing
- \checkmark organized & secure repository for data & metadata
- persistent identifiers for data & resources
- \checkmark web portal for search, visualization & download
- clear licensing
- linked data approach for metadata cataloguing
- interfaces 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

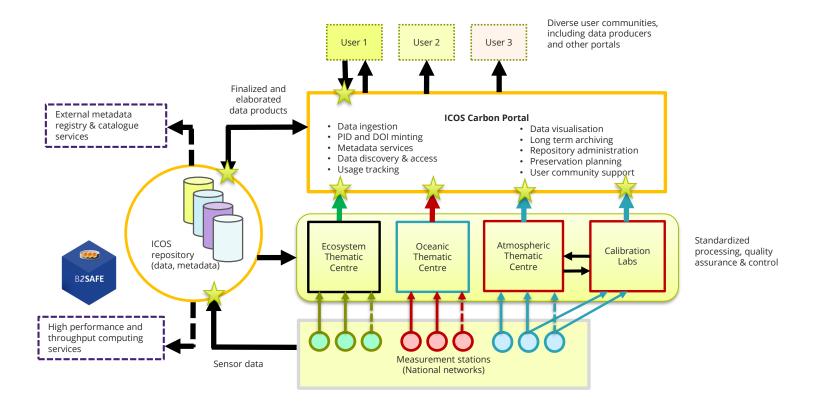


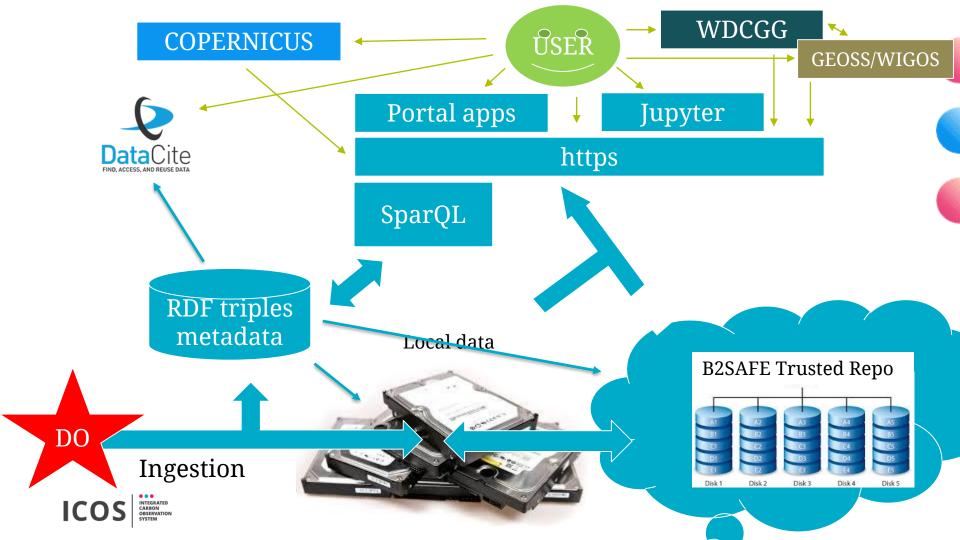
ICOS Carbon Portal as an illustration

- 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, <u>GitHub</u>), 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



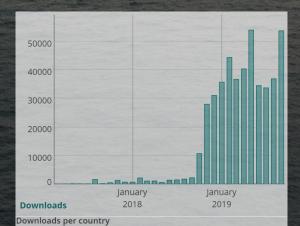


Factsheet Data Sep 2019

- 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

ICO

- NRT data for Atmosphere+Ocean, soon Ecosyste
- Level 2 data for all domains
- Jupyter VREs and STILT footprint apps





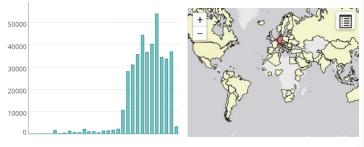
Find, preview and download data

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

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

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

Etc.



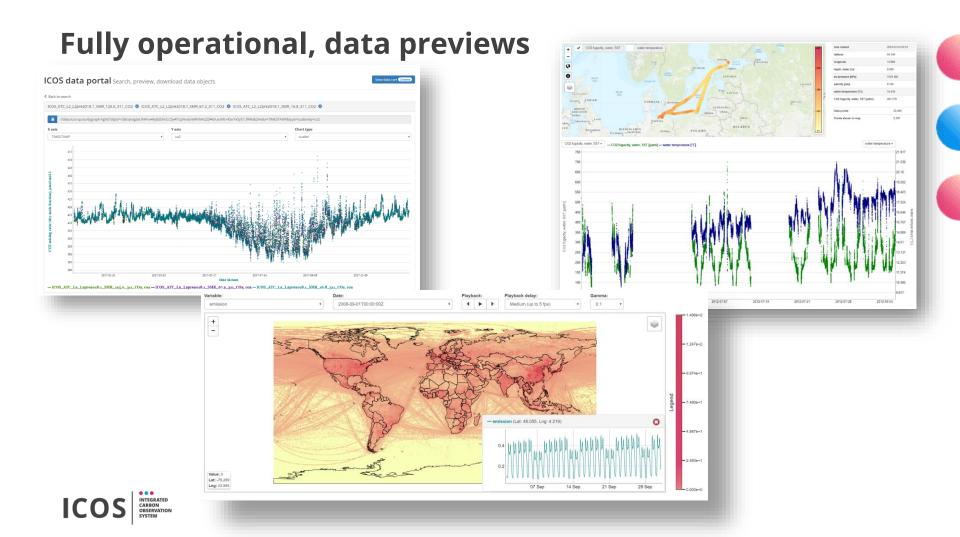
Downloads

COS INTEGRATEI

ICOS data portal Search, preview, download data objects

ategories Filters	Search results Compact view
Clear categories	Data objects 1 to 3 of 3
Data origin	Sort by 🕶
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CO2 mixing ratio (dry mole fraction)	
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Data origin
ICOS / non-ICOS data
Theme Atmospheric data ×
Station of origin SMEAR II-ICOS Hyytiälä×
Data submitter Atmosphere thematic center
Data types
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Value types
Column name co2× Value type



www.icos-cp.eu/dataproducts



ICOS Data Products

NEAR REAL TIME OBSERVATIONAL DATA (Level 1)

Atmosphere: NRT CO₂ and CH₄ mole fraction growing time series at ICOS stations

DOI: 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, Hyltemossa, Ispra, Jungfraujoch, Krešin u Pacova, Lindenberg, Monte Cimone, NOFL, Pallas, Puy de Dome, SMEAR II (Hyytialä), Svartberget, Torfhaus, Trainou, and Zeppelin Observatory. This collection contains the NRT hourly averaged data for the mole fractions of CO₂ and CH₄, 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 I<u>COS Atmospheric Station specification V1.3</u> 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 CO₂, CH₄, CO, ¹⁴CO₂ and meteorology at ICOS stations

DOI: 10.18160/RHKC-VP22

Release 2018-2, containing data from the atmospheric network of ICOS Research Infrastructure for the stations Gartow, Hohenpeißenberg, Hyltemossa, Jungfraujoch, Křešin u Pacova, Norunda, OPE, Puy de Dome, SMEAR, Svartberget, and Zeppelin Observatory. This collection contains the final quality controlled hourly averaged data for the mole fractions of CO₂, CH₄, CO and meteorological observations measured at the relevant vertical levels of the measurements stations, and where available ¹⁴C in CO₂ in two-weekly integrated samples, for the years 2016-2018. All stations follow the <u>ICOS Atmospheric Station specification V1.3</u> and are certified as ICOS atmospheric stations Class I or II. Data processing has been performed as described in <u>Hazan et al.</u>, 2016.

Download this complete dataset

ELABORATED PRODUCTS (Level 3)

Gridded product: Global anthropogenic CO₂ emissions for 2007 based on EDGARv4.3 and BP statistics 2016

DOI: 10.18160/VG28-H2QA

Global anthropogenic CO₂ emissions based on EDGARv4.3, fuel type and category specific emissions provided by Greet Janssens-Maenhout (EU-JRC), <u>BP statistics 2016</u>, temporal variations based on MACC-TNO, temporal extrapolation and disaggregation described in COFFEE (Steinbach et al. 2011).

ICOS

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 CO2 and CH4, 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 CO2 and CH4, 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

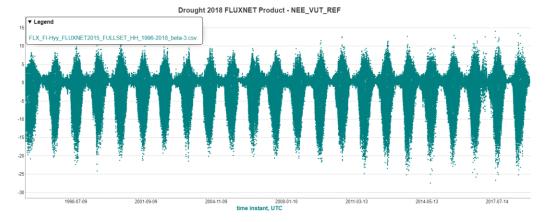
Abstract: Near Real-Time growing time series containing data from the atmospheric network of ICOS Research Infrastructure for the stations Gartow, Hohenpeißenberg, Hyltenossa, Ispra, Jungfraujoch, Krešin u Pacova, Lindenberg, Monte Cimone, Norunda, OPE, Pallas, Puy de Dome, SMEAR II (Hyytiäla), Svartberget, Torfhaus, Trainou, and Zeppelin Observatory. This collection contains the NRT hourly averaged data for the mole fractions of CO2 and CH4, 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 VI.3 (https://www.icosri.eu/fetch/ba12290c-3714-4dd5-39f0-43119900ad1;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).

CO₂ preview

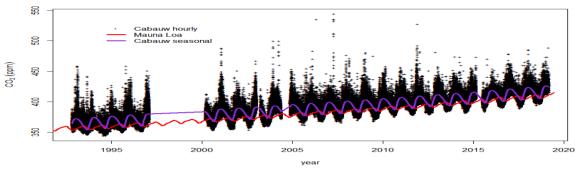
Station	height 1	height 2	height 3	height 4	height 5	
Gartow (ATC_413)	30.0	60.0	132.0	216.0	341.0	All
Gartow (ATC_489)	30.0	60.0	132.0	216.0	341.0	All
Hohenpeißenberg (ATC_382)	50.0	93.0	131.0			All
Hyltemossa (ATC_463)	30.0	70.0	150.0			All
ICOS Utö – Baltic sea (ATC_486)	57.0					AI
Ispra (ATC_619)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



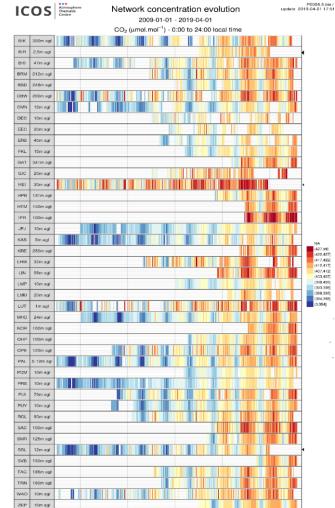
Long high quality time series





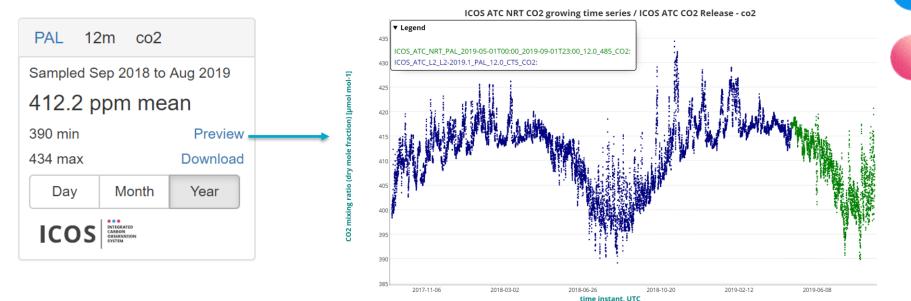






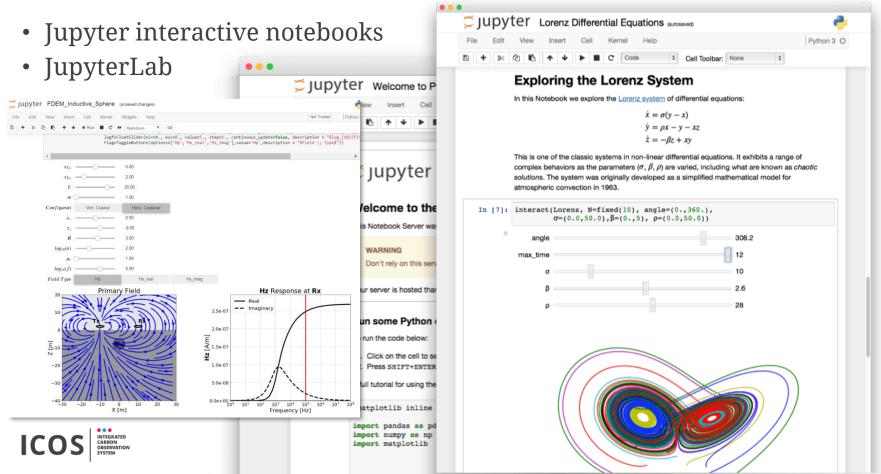
Example dashboard servlet

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





The future of the research data lifecycle



Interactive analysis tools for model results & data

- Analysis of simulated fossil fuel CO₂ time series (RINGO) •
- Evaluation of sampling strategies

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wind direction at HE and BG3

jupyter RINGO T1.2 notebook v0.6 (autosaved)

logout

Jupyter notebooks for educational purposes

- Teaching material for university and high-school combining data analytics, coding, and natural sciences
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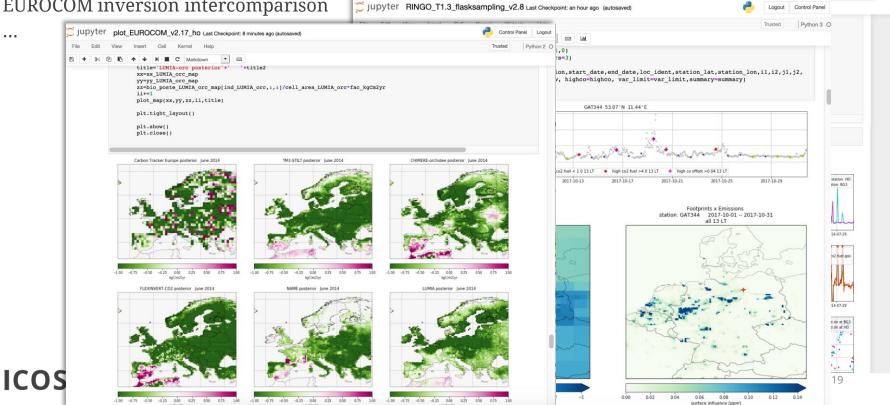
Project-specific Jupyter notebooks

kgC/m2/vr

- Analysis of simulated fossil fuel CO₂ time series (RINGO) •
- Evaluation of sampling strategies (RINGO)

kgC/m2/yr

EUROCOM inversion intercomparison

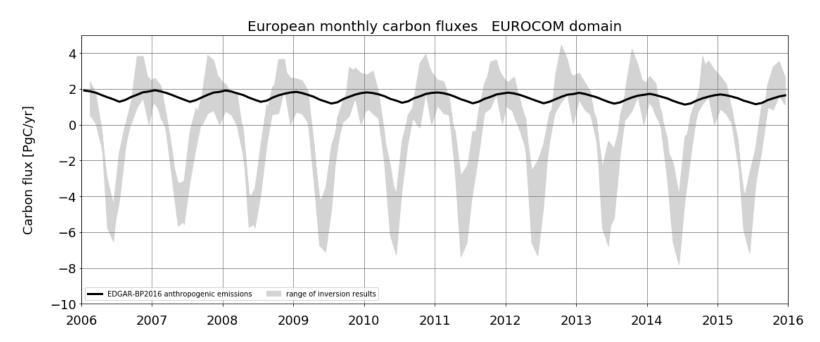


Jupyter RINGO T1.2 notebook v0.6 (autosaved) File Edit View Insert Cell Kernel Hel

Logout

Python 2 C

EUROCOM inversions: fuel & biospheric CO₂ flux estimates



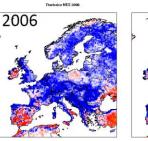
- Inversion results still show large differences => model development & inherent uncertainties
- Inversion results will be uploaded soon at ICOS CP
- Inversions are currently extended to 2018

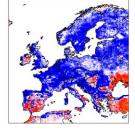


VERIFY regional inversion results 2006-2017

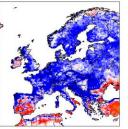




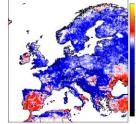




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Poetorior NEE 2008



Poetorior NEE 2000

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-500 flux [gC/y/m2]

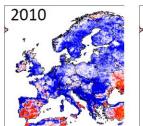
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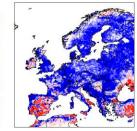
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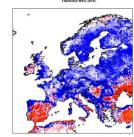
Poetsrior NEE 2010

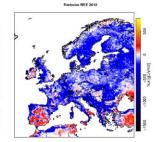
Poeterior NEE 2011

Posterior NEE 2012





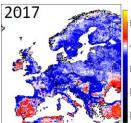






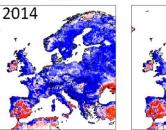
Posterior NEE 2015

Posterior NEE 2016



Posterior NEE 2017

... ICO INTEGRATED OBSERVATION







SEACRIFOG

ICOS Carbon Portal; Flexpart footprint of AM-TIMAN

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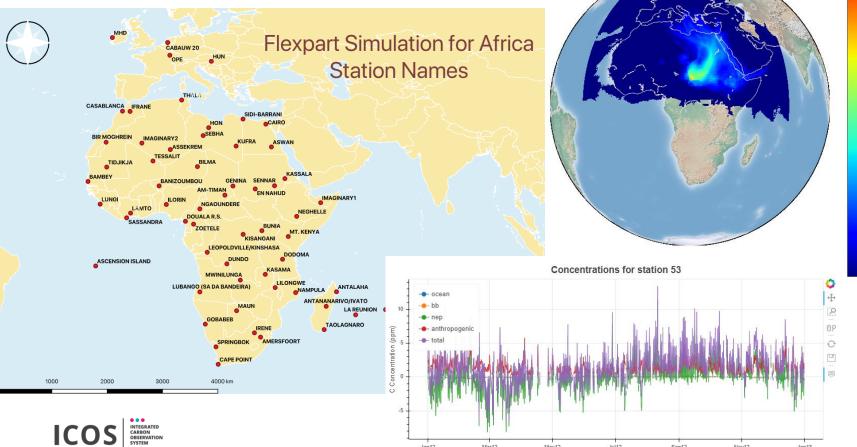
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Jan12

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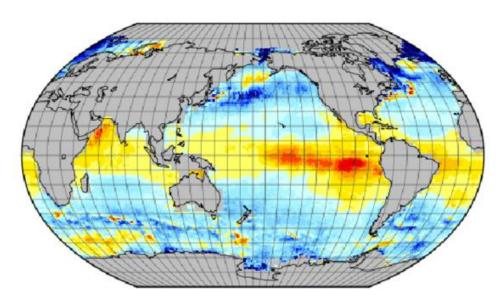
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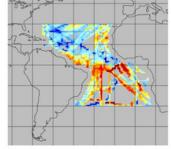
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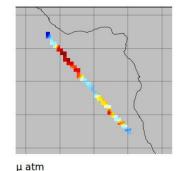
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Examples of potential operational science products

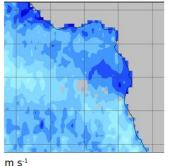






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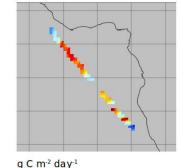




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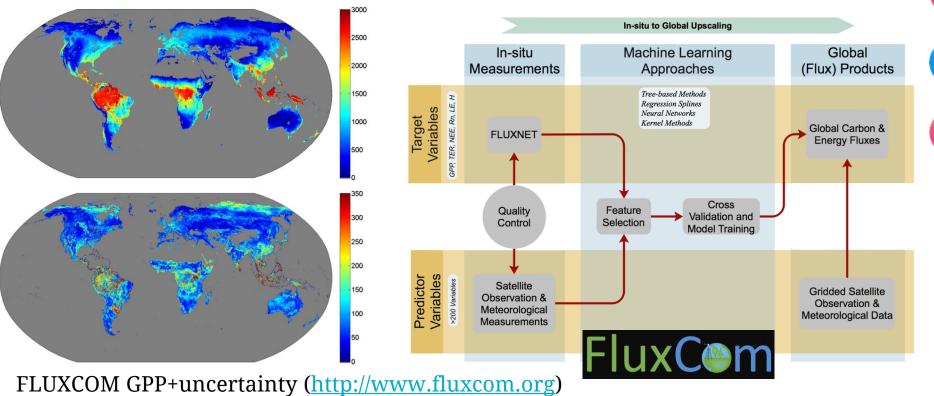
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Fluxengine: <u>http://www.oceanflux-ghg.org/Products/FluxEngine</u>



Examples of potential operational science products



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



High impact

BBCNEWS

UK World Business Politics Tech Science More -

Action Summit 2019 REPORT from UN Enviror

ICOS Carbon Portal @ICOS CP · 1m

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

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

Climate change: Impacts 'acceleratir Published on 22 Sep 2019 as leaders gather for UN talks

By Matt McGrath

Environment correspondent

22 September 2019 Science & Environment



The United in Science Re climate science organizatio assessment in preparation

The report underlines the targets to tackle global w urgency for the developme and actions. The current sta the changes that are proj

The UN Environment Proreport, The Emissions Gay November. It assesses the future greenhouse gas em likely to be and where we r there.



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 CO2 emissions have hit new highs.

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



report.

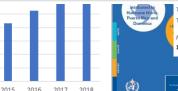
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Countries must triple climate emissions targets to limit global heating t... United in Science report ahead of UN summit says climate is changing faster than forecast, and current plans would lead to 'catastrophic' glob... S theguardian.com



2017 2018

pition of daytime ation

Frevor F. Keenan 🏁, Mirco Migliavacca, Dario Papale, Dennis Baldocchi, Markus Reichstein, Margaret orn & Thomas Wutzler

Nature Ecology & Evolution 3, 407–415 (2019) Download Citation ± 1339 Accesses 7 Citations 14 Altmetric Metrics >>

THE CLOBAL CLIMATE 2015-2019



ion

2015 2016

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/sparglclient/ 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



Thank you!

INTEGRATED CARBON OBSERVATION SYSTEM

