The EM27/SUN FTIR spectrometer for columnar GHG measurements and COCCON (the Collaborative Carbon Column Observing Network)

JPL seminar Aug-11-2022

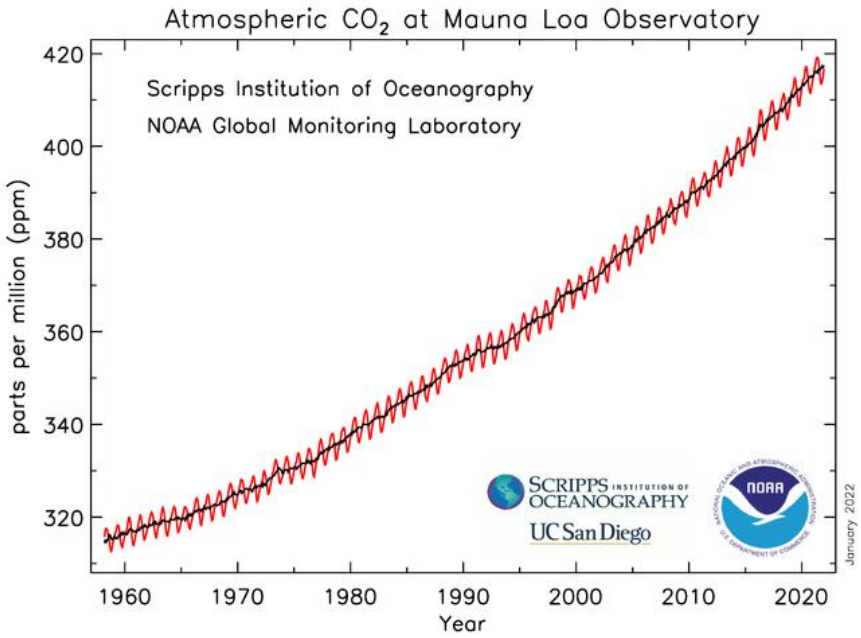
Presenter: PD Dr. Frank Hase, IMK-ASF (frank.hase@kit.edu)

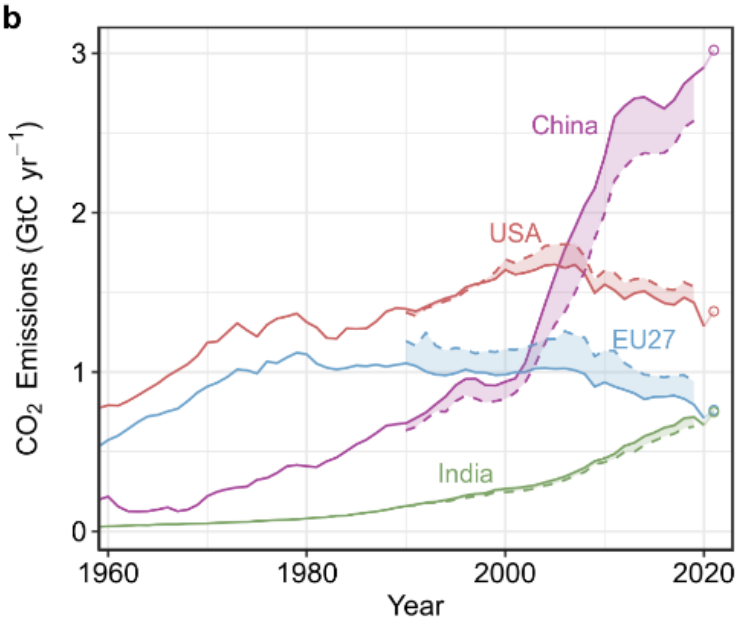
Contents

- Greenhouse gases and anthropogenic climate change, EU green deal
- Chemical remote sensing of the atmosphere using infrared radiation
- The portable EM27/SUN FTIR spectrometer for GHG observations
- The COCCON (COllaborative Carbon Column Observing Network)
- Some COCCON achievements and future plans

GHGs and anthropogenic climate change

Anthropogenic GHG emissions are the main driver of climate change!

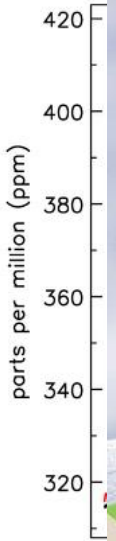


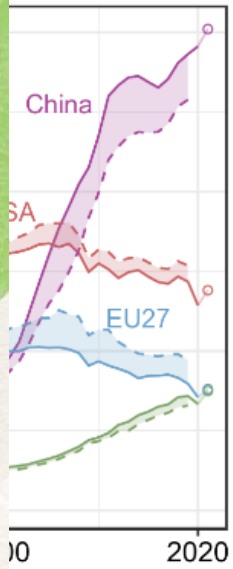


https://gml.noaa.gov/ccgg/trends // Global Carbon Budget 2021, Friedlingstein et al., ESSD, 2021

GHGs and anthropogenic climate change

Anth ange!





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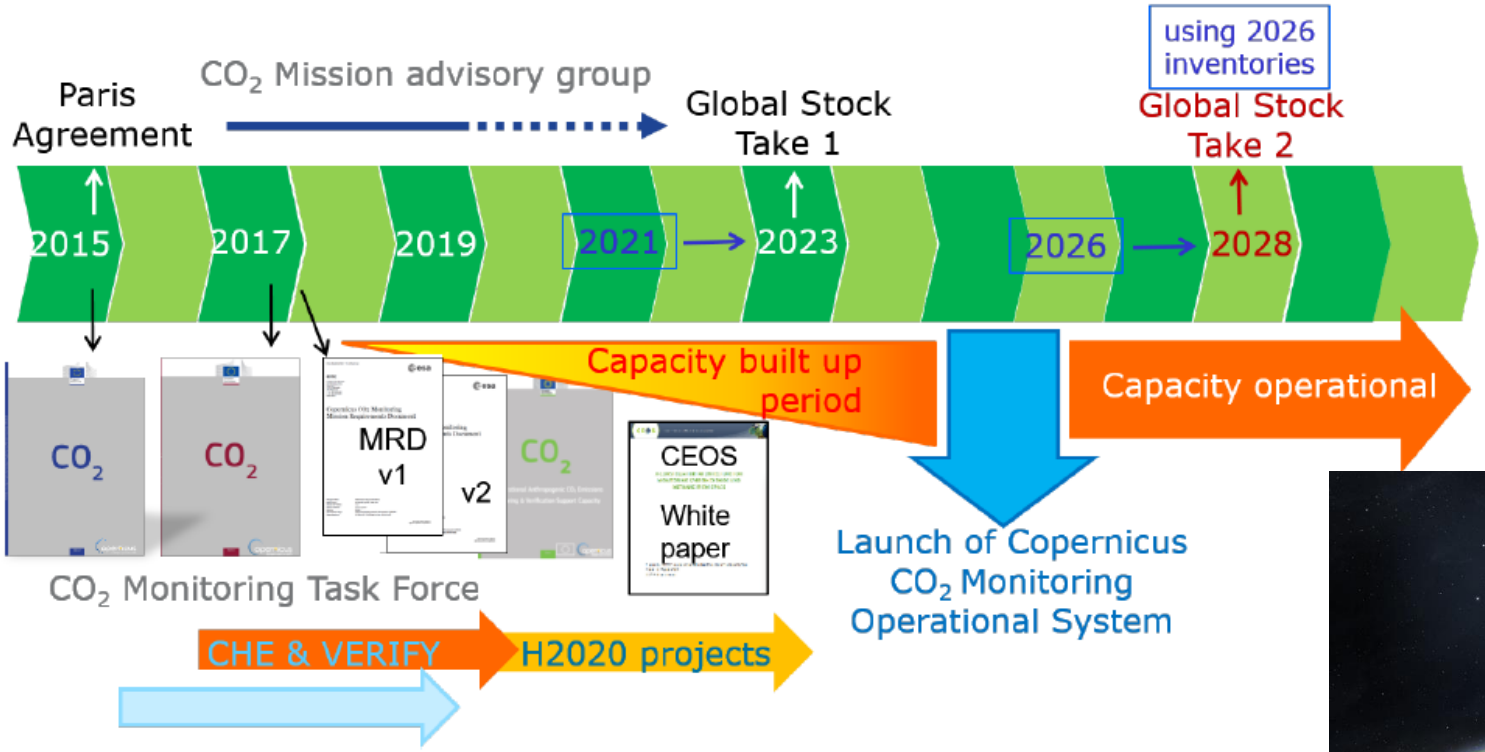
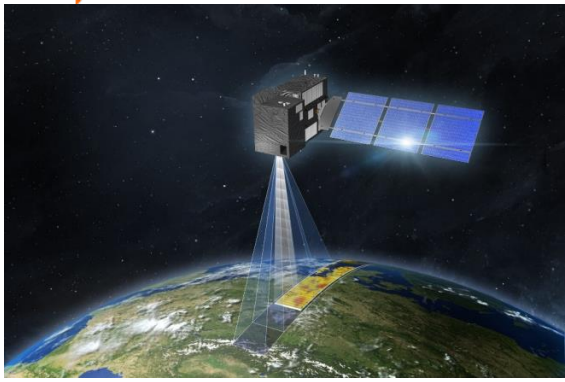
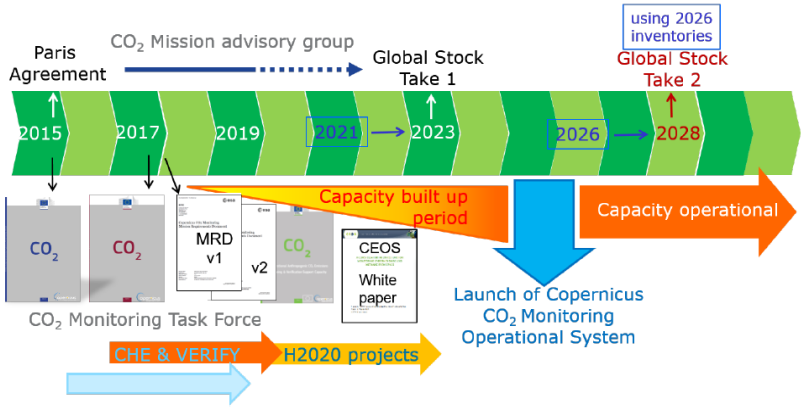
GHGs and anthropogenic climate change

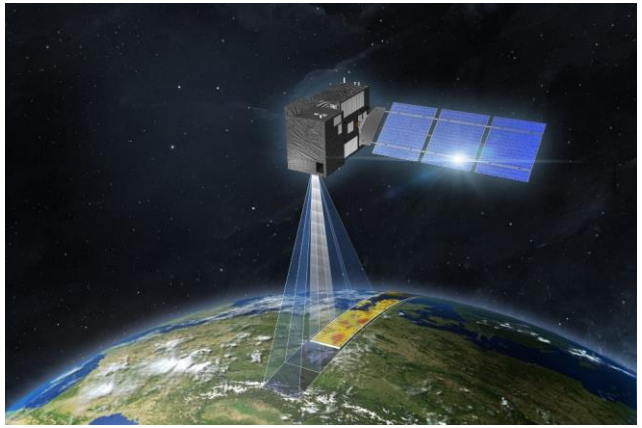




CO2M MRD 2020 // Artistic view of a CO2M satellite (ESA)

GHGs and anthropogenic climate change



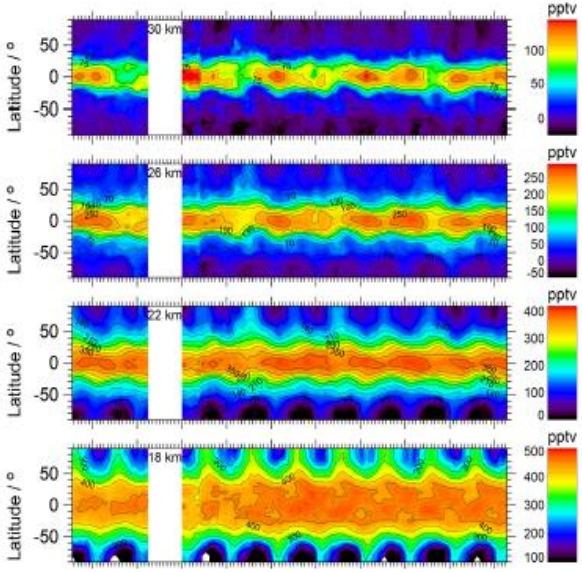


… A very strong calibration-validation segment based on anchor ground based stations measuring XCO2 [Wunch et al., 2011a, 2011b, 2017 for TCCON, and Gisi et al., 2012; Hase et al., 2015; Klappenbach et al., 2015; Butz et al., 2017 for COCCON coordinated by the Karlsruhe Institute for Technology] will be required in particular across regions where anthropogenic CO2 emissions concentrate. …

CO2M MRD 2020 // Artistic view of a CO2M satellite (ESA)

Chemical remote sensing: IMK-ASF achievements

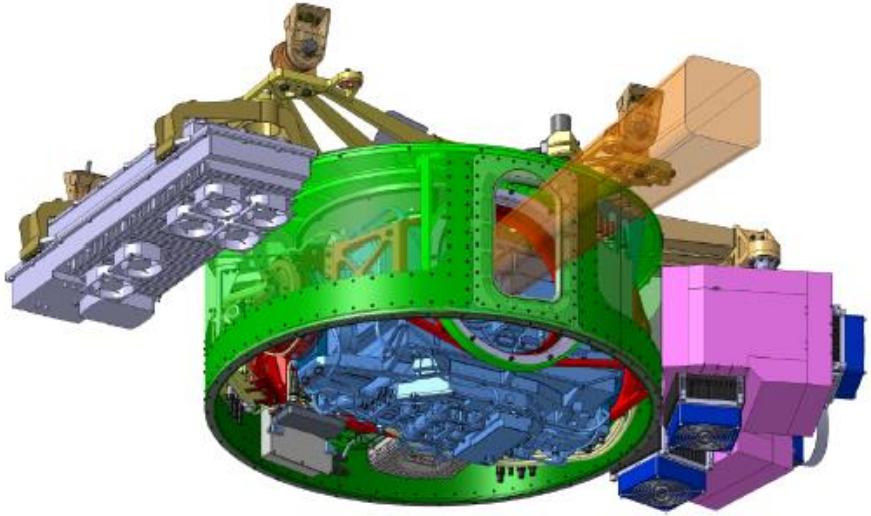
- Spectrometer development + campaigns: MIPAS, GLORIA
- MIPAS-ENVISAT and IASI data analysis
- Operation of FTIR stations within global networks

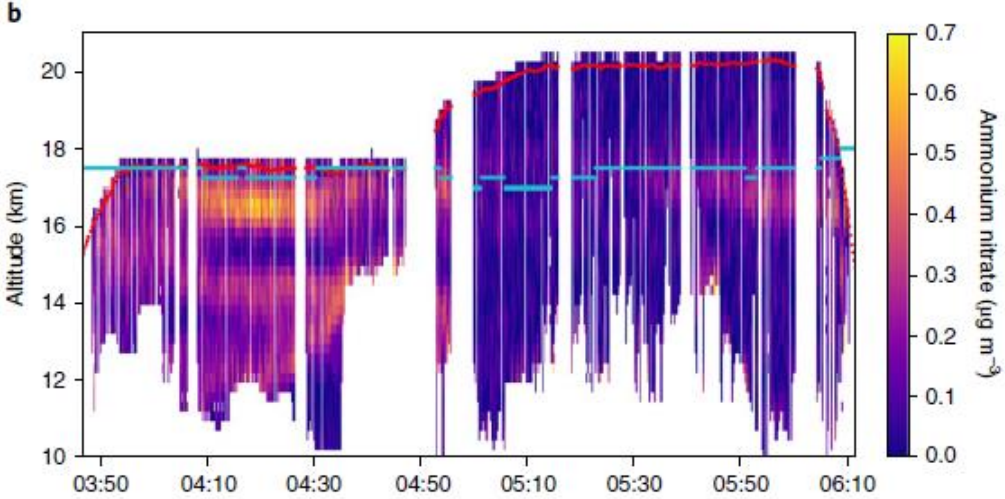


N. Glatthor. et al.: Global OCS measured by MIPAS/Envisat during 2002–2012, ACP, 2017

Chemical remote sensing: GLORIA

- Gimballed Limb Observer for Radiance Imaging of the Atmosphere

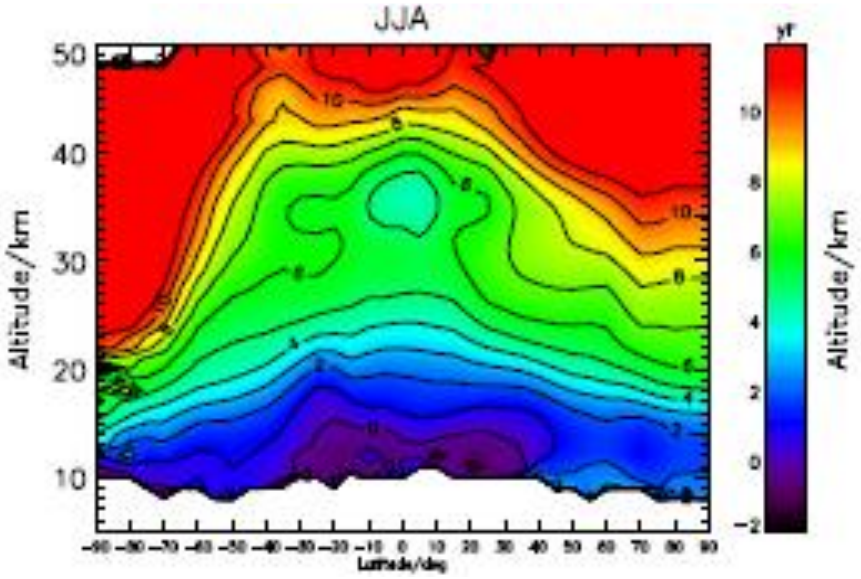




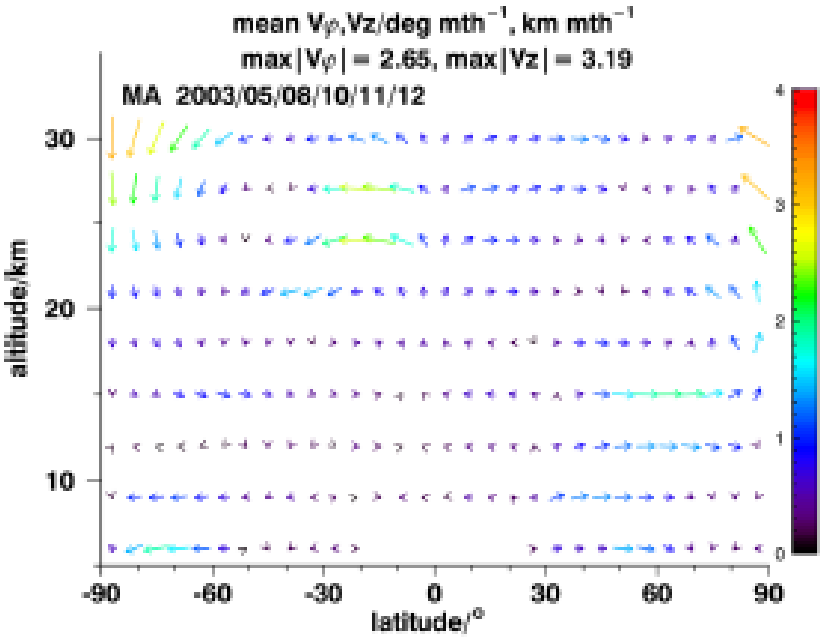
F. Friedl-Vallon et al.: Instrument concept of the imaging Fourier transform spectrometer GLORIA, AMT, 2014

M. Höpfner et al.: Ammonium nitrate particles formed in upper troposphere from ground ammonia sources during Asian monsoons. Nat. Geosci., 2019

Chemical remote sensing: MIPAS-ENVISAT



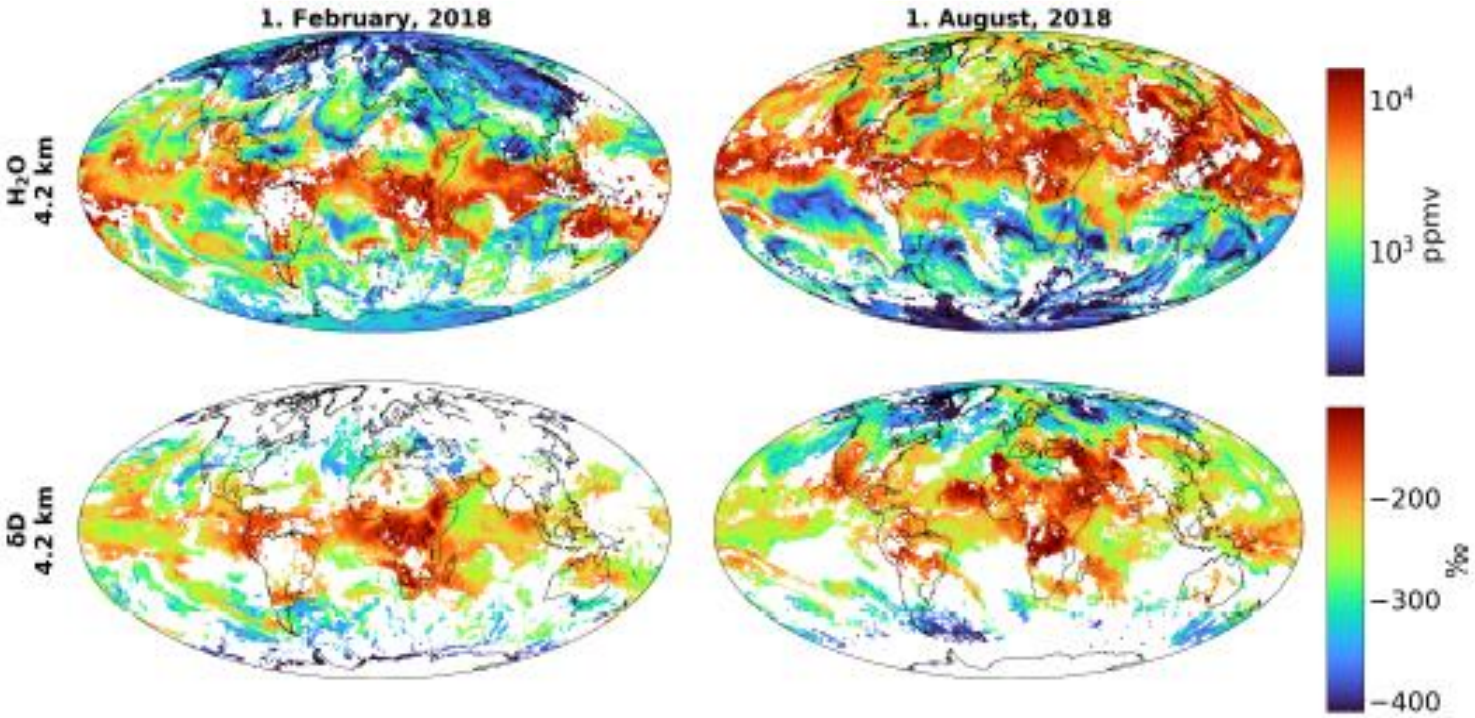
G. P. Stiller et al.: Observed temporal evolution of global mean age of stratospheric air for the 2002 to 2010 period, ACP, 2012



T. von Clarmann et al.: The middle atmospheric meridional circulation for 2002–2012 derived from MIPAS observations, ACP, 2021

Chemical remote sensing: IASI

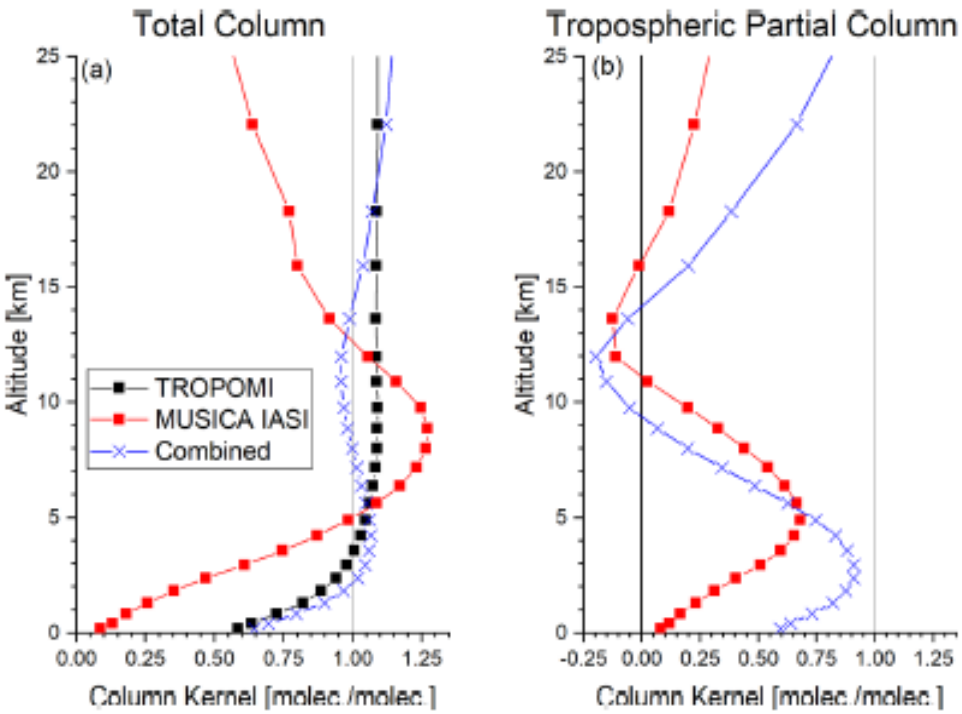
- Data analysis for IASI



M. Schneider et al.: Design and description of the MUSICA IASI full retrieval product, ESSD, 2021

Chemical remote sensing: IASI

- Combining IASI and S5P methane



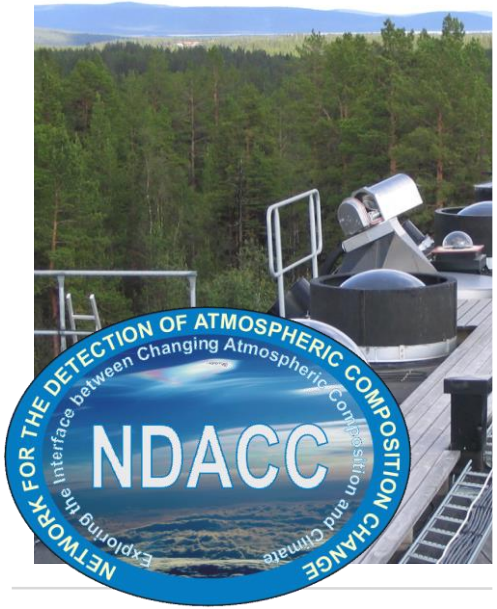
M. Schneider et al.: Synergetic use of IASI profile and TROPOMI total-column level 2 methane …, AMT, 2022

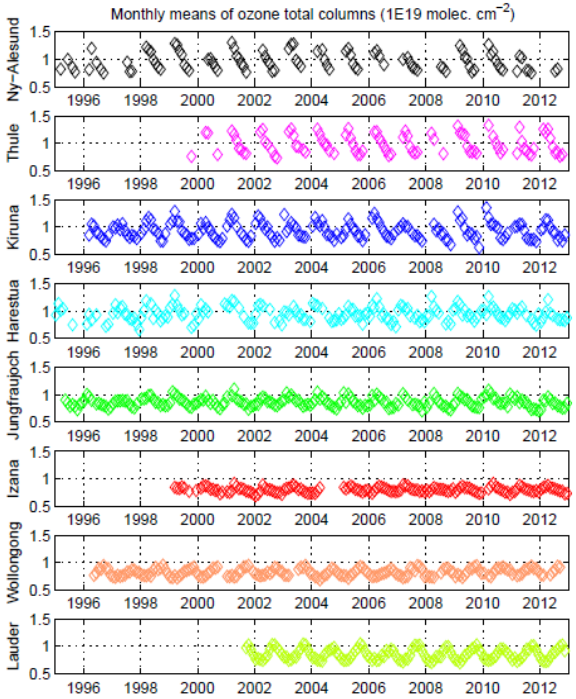
Chemical remote sensing: NDACC + TCCON

Operation of ground-based spectrometers (NDACC & TCCON)

MIR: C_2H_6, $ClONO_2$, CO, HCl, HCN, HF, HNO_3, N_2O, O_3, ...

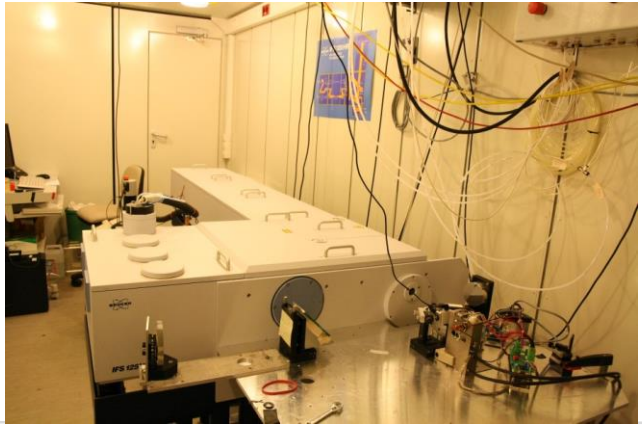
NIR: CO_2,CH_4,…





C. Vigouroux, T. Blumenstock, et al.: Trends of ozone total columns and vertical distribution from FTIR observations at eight NDACC stations around the globe, ACP, 2015

A portable spectrometer for GHG observations



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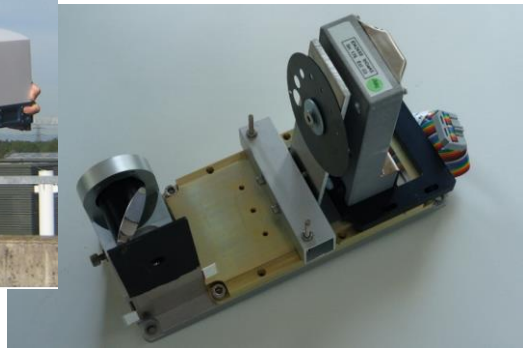
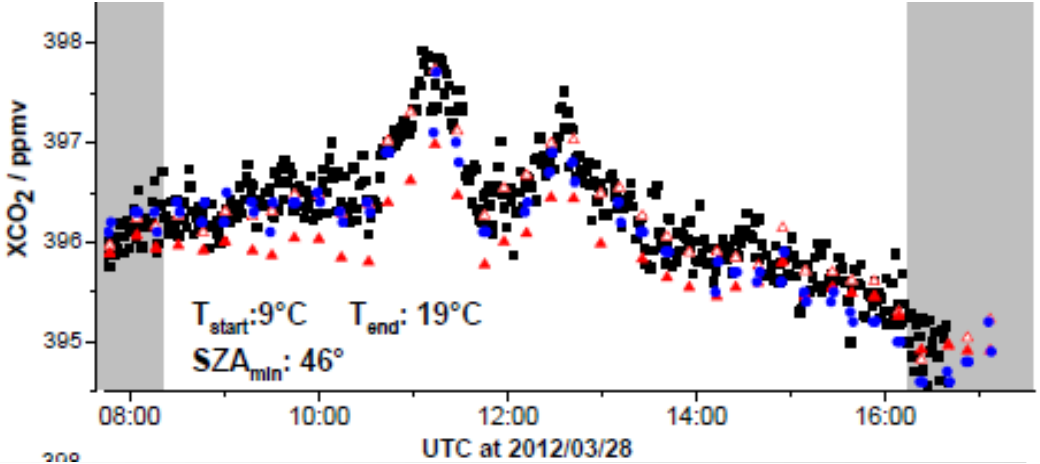
A portable spectrometer for GHG observations

KIT started in 2011 the development of a novel compact NIR-FTIR spectrometer for carbon cycle research, in cooperation with Bruker Optik GmbH. We decided for Bruker's EM27 FTIR spectrometer as starting point.



Gisi, M., Hase, F., Dohe, S., Blumenstock, T., Simon, A., and Keens, A.: XCO_2-measurements with a tabletop FTS using solar absorption spectroscopy, Atmos. Meas. Tech., 5, 2969–2980, 2012.



A portable spectrometer for GHG observations

KIT started in 2011 the development of a novel compact NIR-FTIR spectrometer for carb
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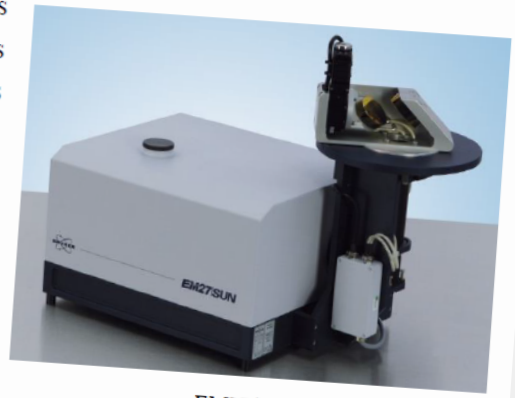
spectrometer as starting po

Gisi, M., Hase,
with a tabletop

Das neue kompakte EM27/SUN Spektrometer für Atmosphärenmessungen

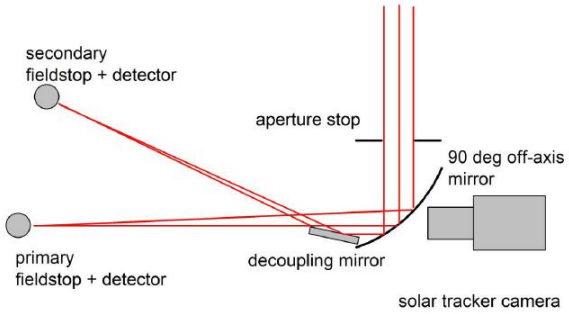
München, Deutschland, – April 2, 2014 – Die Bruker Corporation hat heute die erfolgreiche Einführung des neuen kompakten Spektrometers ***EM27/SUN*** für Atmosphärenmessungen durch solare Absorptionsspektroskopie bekannt gegeben.

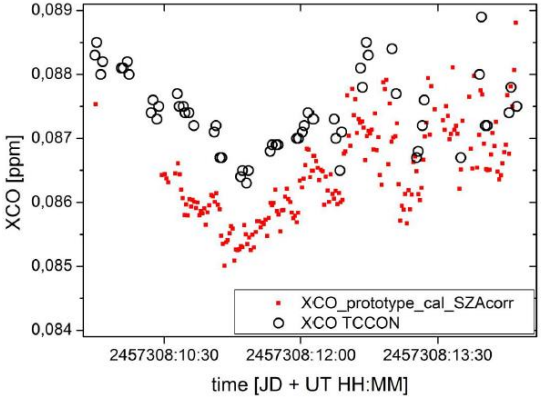
Das ***EM27/SUN*** verfügt über ein neues CAMTracker-System, das eine weiterentwickelte Version des wohlbekannten Solar Tracker darstellt, wobei ein innovatives Kamera-basiertes Rückkopplungssystem der Sonne als Lichtquelle folgt. Die herausragende Akkuratheit bei der Verfolgung der Sonnenstrahlung ist die Grundlage für hoch präzise Quantifizierungen. Zusätzlich bietet das neue CAMTracker-System direkte Informationen über das Sichtfeld und ist gegenüber inhomogener Ausleuchtung unempfindlich. Aufgrund des sehr kompakten und robusten Aufbaus, des relativ geringen Gewichts und der intuitiven Benutzerführung ist das ***EM27/SUN*** leicht zu transportieren und somit auch ideal geeignet für Langzeitmesskampagnen an entlegenen Orten mit geringer Infrastruktur.

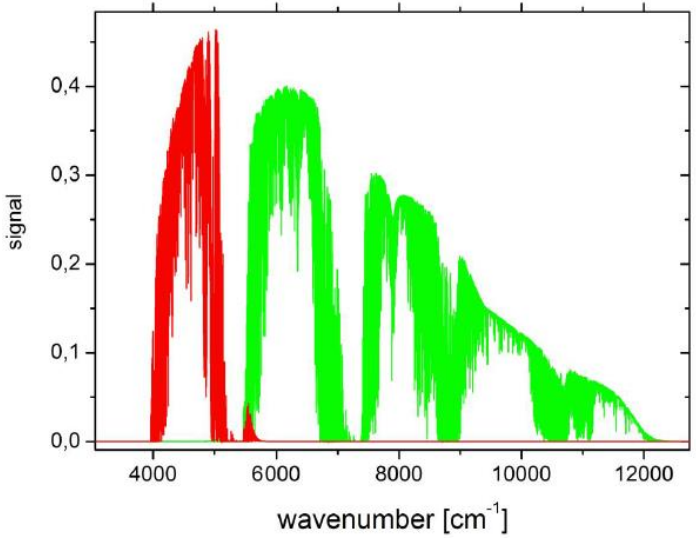


EM27/SUN

CO channel extension

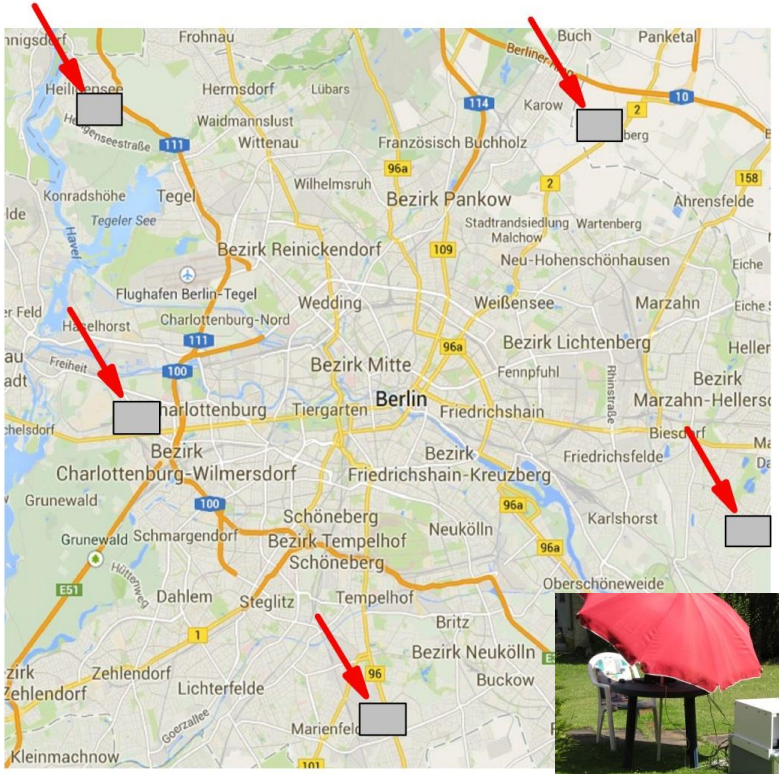




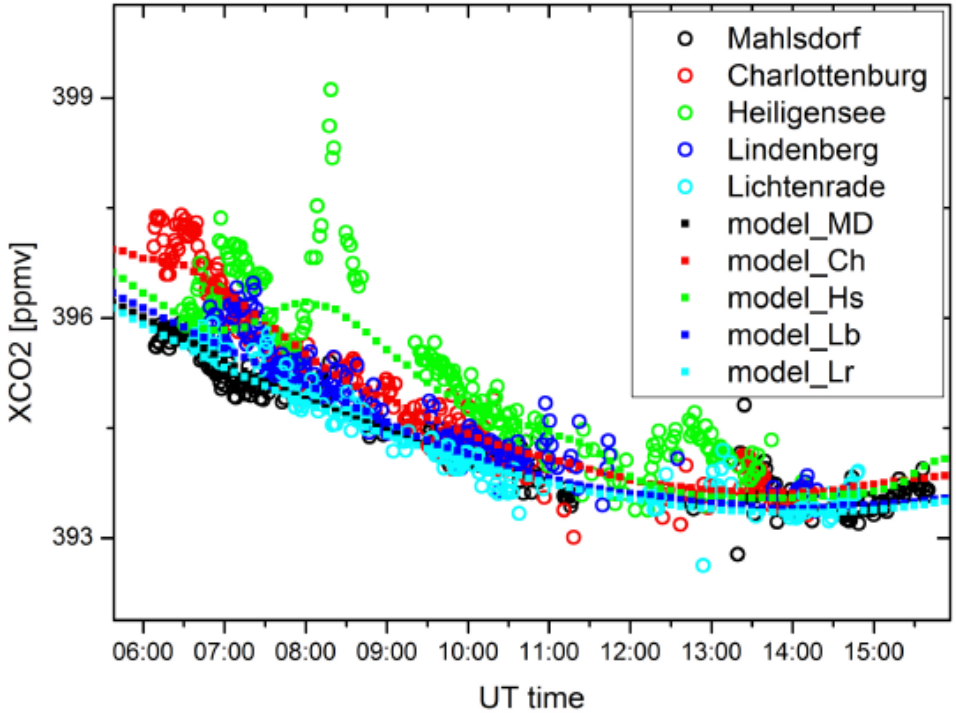


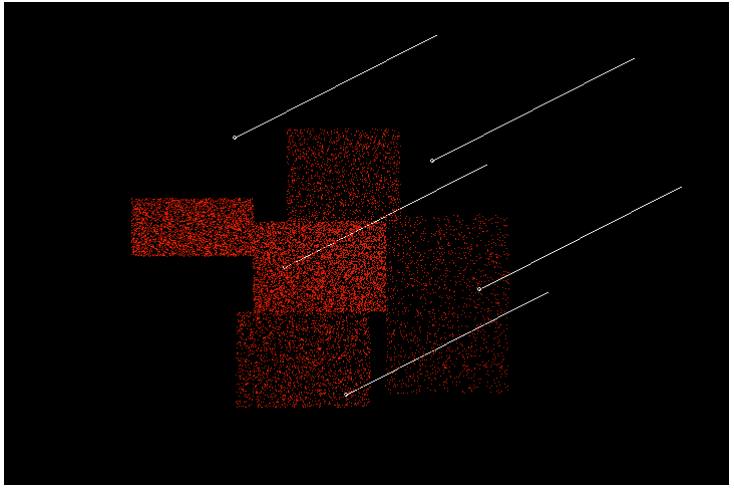
F. Hase et al."Enhancing the capabilities of a portable FTIR spectrometer for greenhouse gas measurements…“ , AMT, 2016

First demonstration: Berlin campaign June 2014



First demonstration: Berlin campaign 2014





Hase et al.: “Application of portable FTIR spectrometers …“ AMT, 2015

Performance of the EM27/SUN

XCO_2 calibration factors

(M. Frey et al.: “Calibration and instrumental line shape characterization of a set of portable FTIR spectrometers…“, AMT, 2015)

Spectrometer #	Before campaign	after campaign
1	1.00000	1.00000
2	0.99924	0.99921
3	1.00015	1.00016
4	0.99987	0.99987
5	0.99960	0.99962

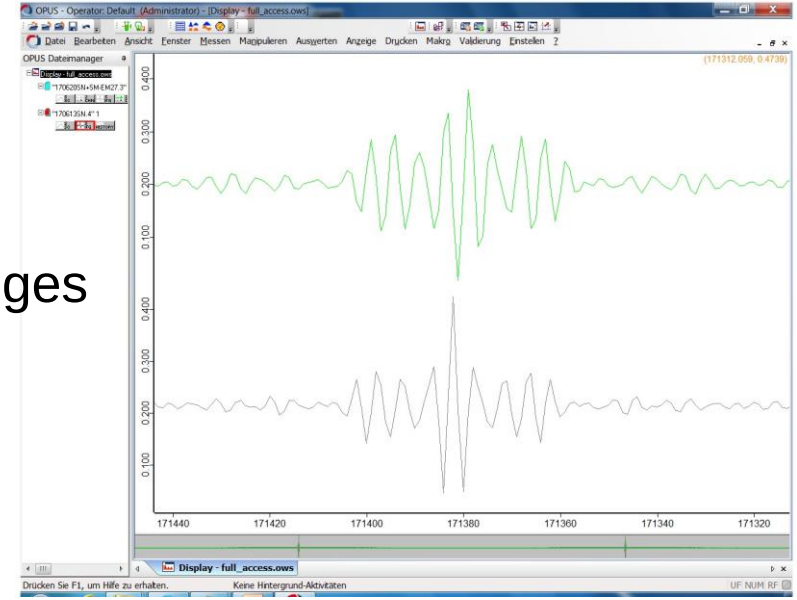
XCO_2 calibration stable within 0.003% !! (#2)

(TCCON site-to-site consistency: 0.05%)

Technical interlude: EM27/SUN FTS performance

Some relevant design features:

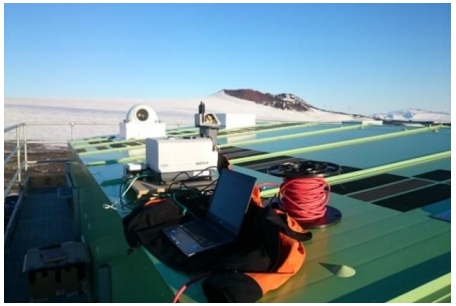
- ✓ Very stable interferometer (pendulum with steel spring suspension)
- ✓ Well-defined ILS
- ✓ Measures for reducing channeling
- ✓ Avoid double-passing
- ✓ Collect double-sided interferograms
- ✓ Self-compensating BS (phase spectrum)
- ✓ Optically well-defined narrow spectral ranges
- ✓ Camtracker



The EM27/SUN: a wide range of applications

Karlsruhe Institute of Technology

Travel standard for TCCON



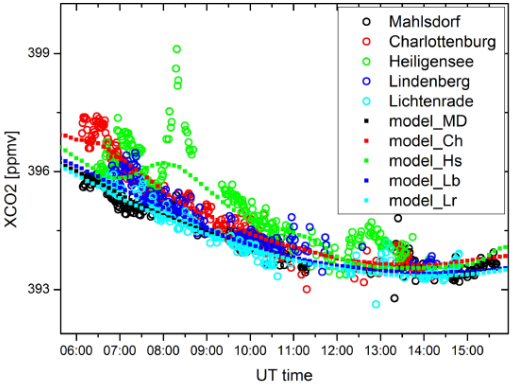
Arrival Heights (NIWA, Pollard)

Reunion (BIRA, De Mazière, Sha)

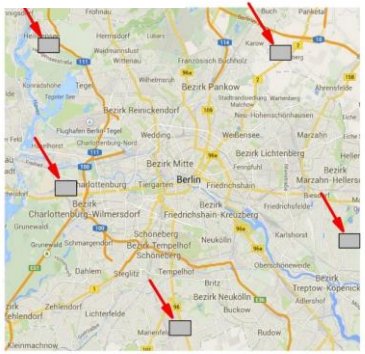
Supplement TCCON sites (satellite validation)

e.g. Mexico, Namibia, India, …

Quantify localized sources



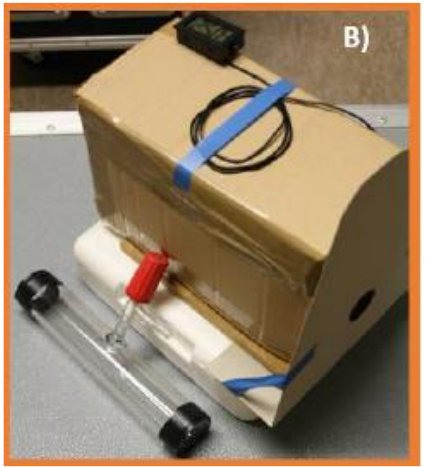
Berlin

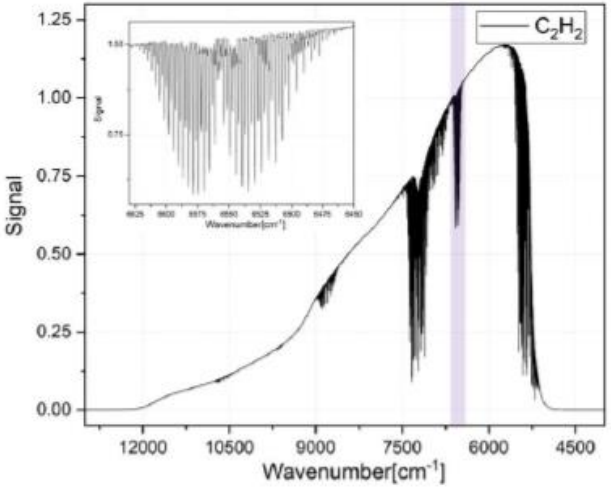


COCCON: centralized QC and data processing

- ✓ Centralized calibration & QC methods (performed at KIT, cooperation with Bruker)
- ✓ Common software standards, community telcos
- ✓ Centralized data processing, data provision via EVDC
- ✓ Travel standard COCCON spectrometer

COCCON: centralized QC and data processing





Frey, M., Sha, M. K., Hase, F., Kiel, M., Blumenstock, T., Harig, R., Surawicz, G., Deutscher, N. M., Shiomi, K., Franklin, J. E., Bösch, H., Chen, J., Grutter, M., Ohyama, H., Sun, Y., Butz, A., Mengistu Tsidu, G., Ene, D., Wunch, D., Cao, Z., Garcia, O., Ramonet, M., Vogel, F., and Orphal, J.: Building the COllaborative Carbon Column Observing Network (COCCON): long-term stability and ensemble performance of the EM27/SUN Fourier transform spectrometer, AMT, 2019.

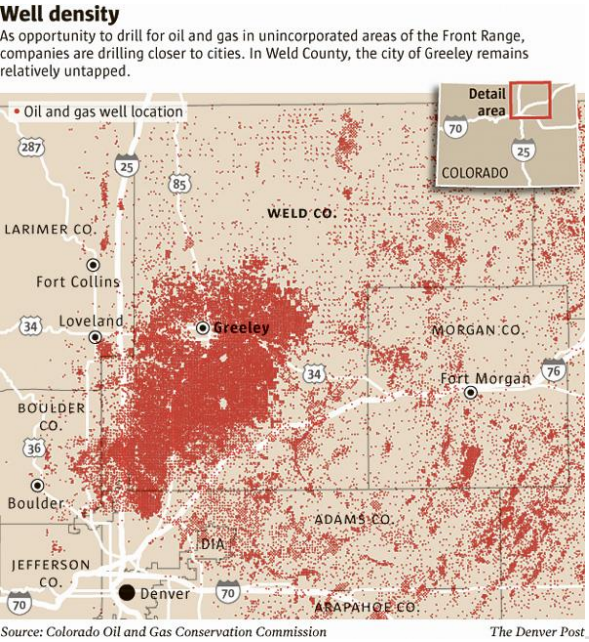
Alberti, C., Hase, F., Frey, M., Dubravica, D., Blumenstock, T., Dehn, A., Surawicz, G., Harig, R., Orphal, J., & EM27/SUN-partners team: Improved calibration procedures for the EM27/SUN spectrometers of the COllaborative Carbon Column Observing Network (COCCON), AMT, 2022

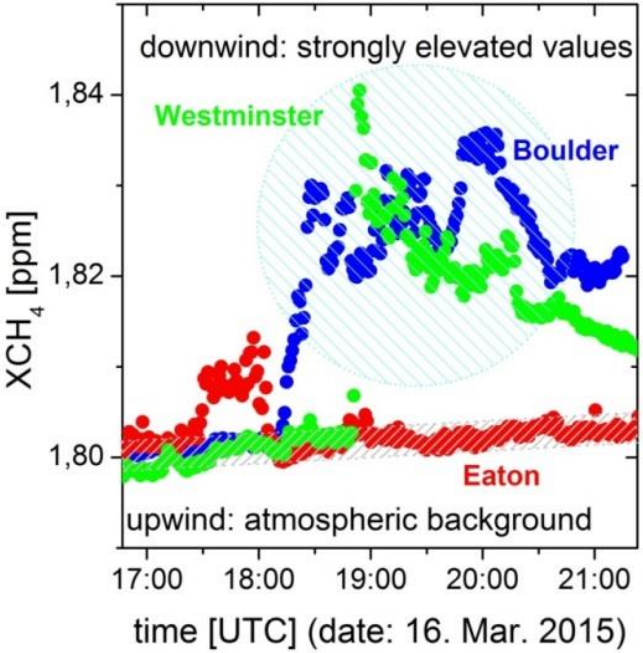
COCCON: a dedicated travel standard

COCCON travel standard - first destination TCCON station Tsukuba
(activity lead: B. Herkommer, cooperation with TUM, project framework: FRM4GHGII)

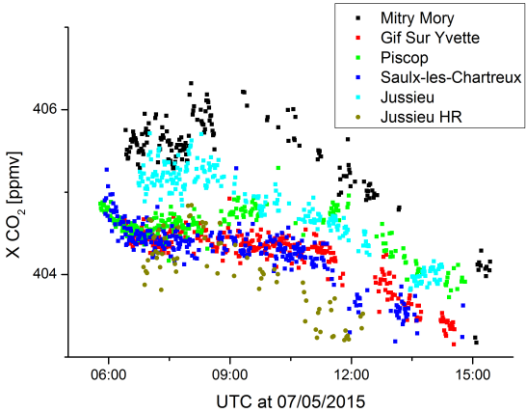
Colorado campaign 2015

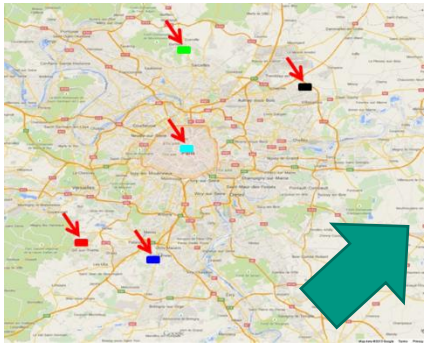
N. Kille, R. Chiu, M. Frey, F. Hase, M. K. Sha, T. Blumenstock, J. W. Hannigan, J. Orphal, D. Bon, R. Volkamer: Separation of Methane Emissions From Agricultural and Natural Gas Sources in the Colorado Front Range, GRL, 2019

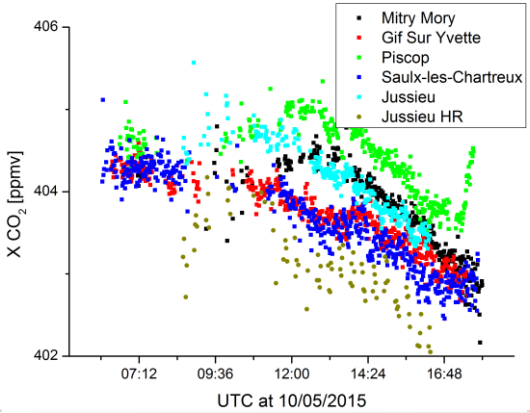


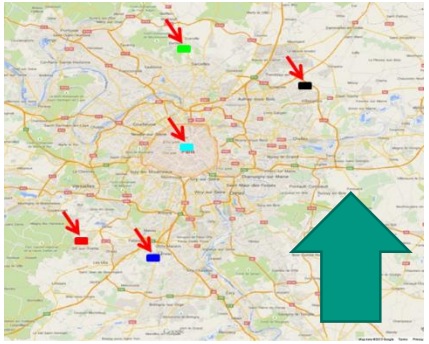


Paris campaign 2015



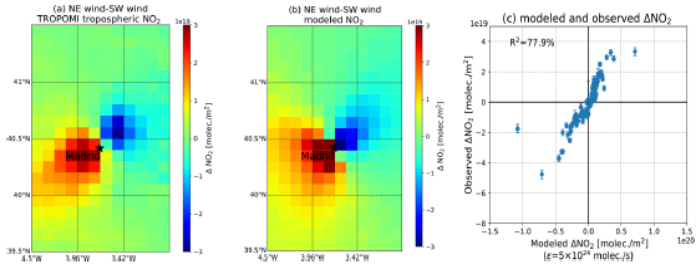


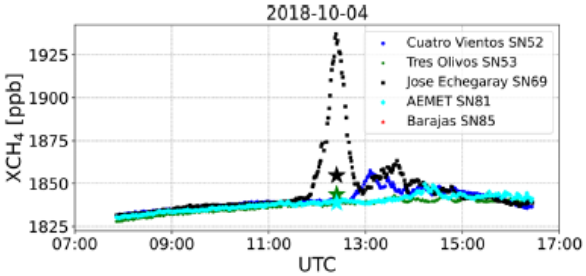


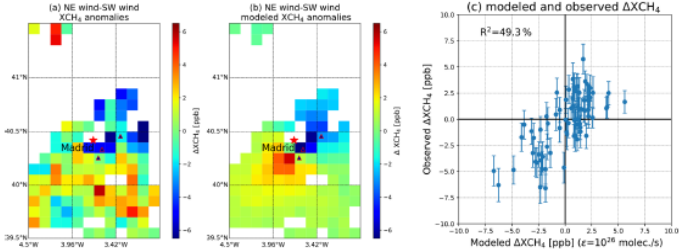


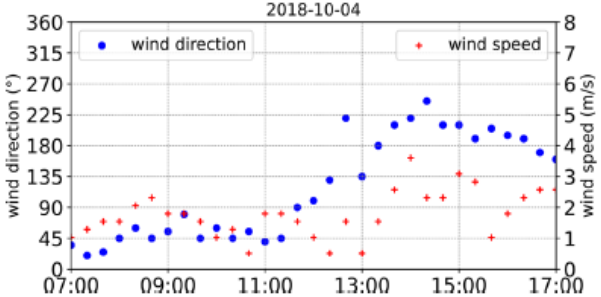
Vogel, F. R., Frey, M., Staufer, J., Hase, F., Broquet, G., Xueref-Remy, I., Chevallier, F., Ciais, P., Sha, M. K., Chelin, P., Jeseck, P., Janssen, C., Té, Y., Groß, J., Blumenstock, T., Tu, Q., and Orphal, J.: XCO_2 in an emission hot-spot region: the COCCON Paris campaign 2015, ACP, 2019.

Madrid campaign 2018









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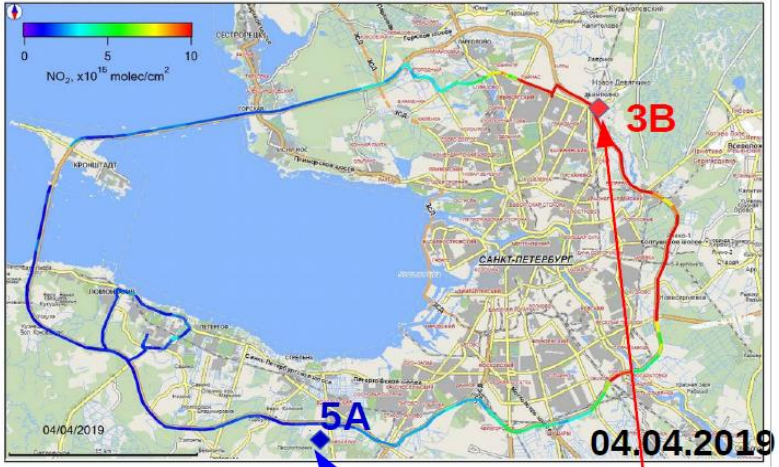
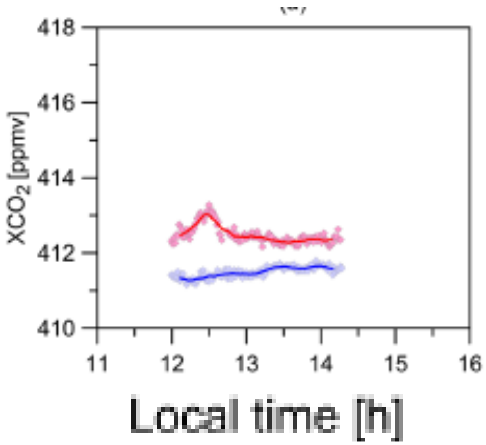
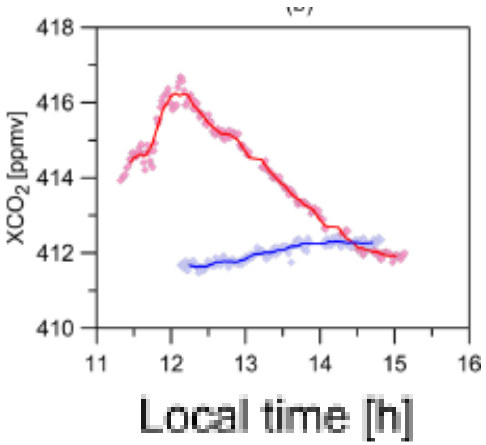
St. Petersburg campaign 2019

▶ ▶ ▶ mobile DOAS monitoring – real-time detection of NO2 city plume



Locations of **#84 (point 5A)** and **#80 (3B)**
FTIR EM27/SUN spectrometers





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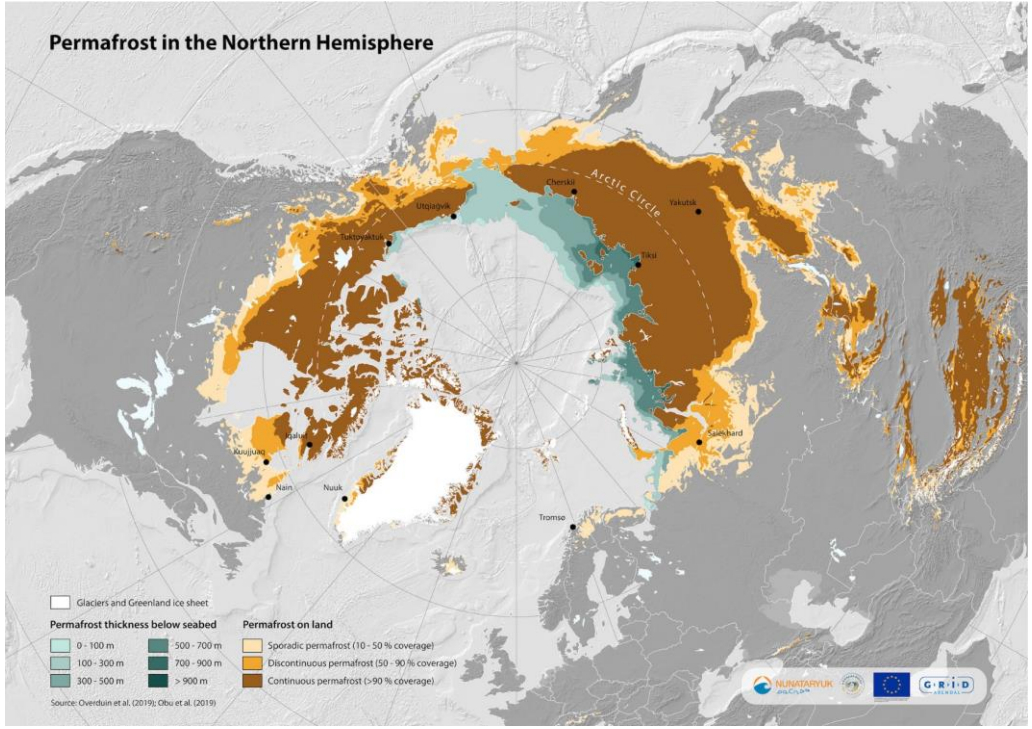
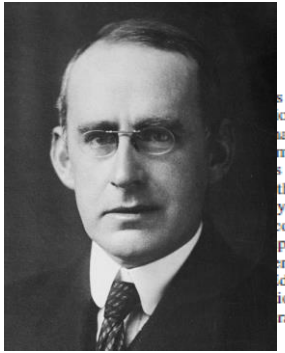


https://nunataryuk.org



"An Expedition to Heal the Wounds of War"

The 1919 Eclipse and Eddington as Quaker Adventurer

*By Matthew Stanley**

ABSTRACT

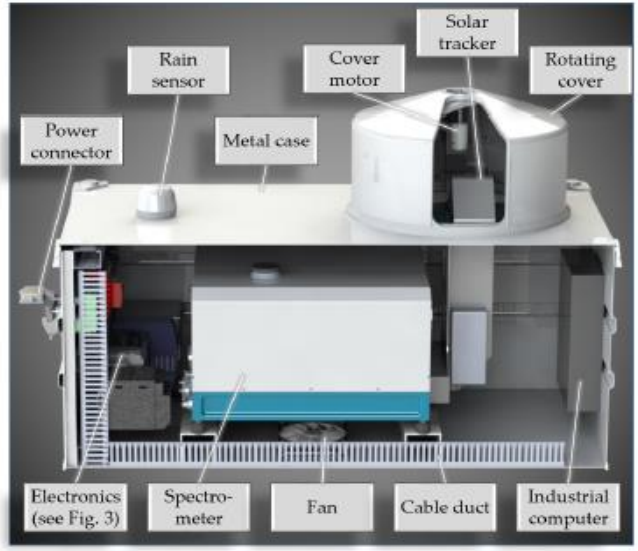
s confirmation of general relativity is often celebrated as a
ionalism. However, British scientific opinion during World
hanent severance of intellectual ties with Germany. That the
mbered as a progressive moment of internationalism was
s of A. S. Eddington. A devout Quaker, Eddington imported
the strategies being used by his coreligionists in the national
y through personal contact and dramatic projects that high-
cooperation. The essay also addresses the common miscon-
pathy for Einstein led him intentionally to misinterpret the
ence gives no reason to think that Eddington or his coworkers
ddington's pacifism is reflected not in manipulated data but
ion and the way it entered the collective memory as a cele-
ration in the wake of war.

Science is above all politics.

—*Sir Oliver Lodge (1914)*

Arthur Stanley Eddington (1882-1944)
M. Stanley, JSTOR, 2003

Permanent city observatories



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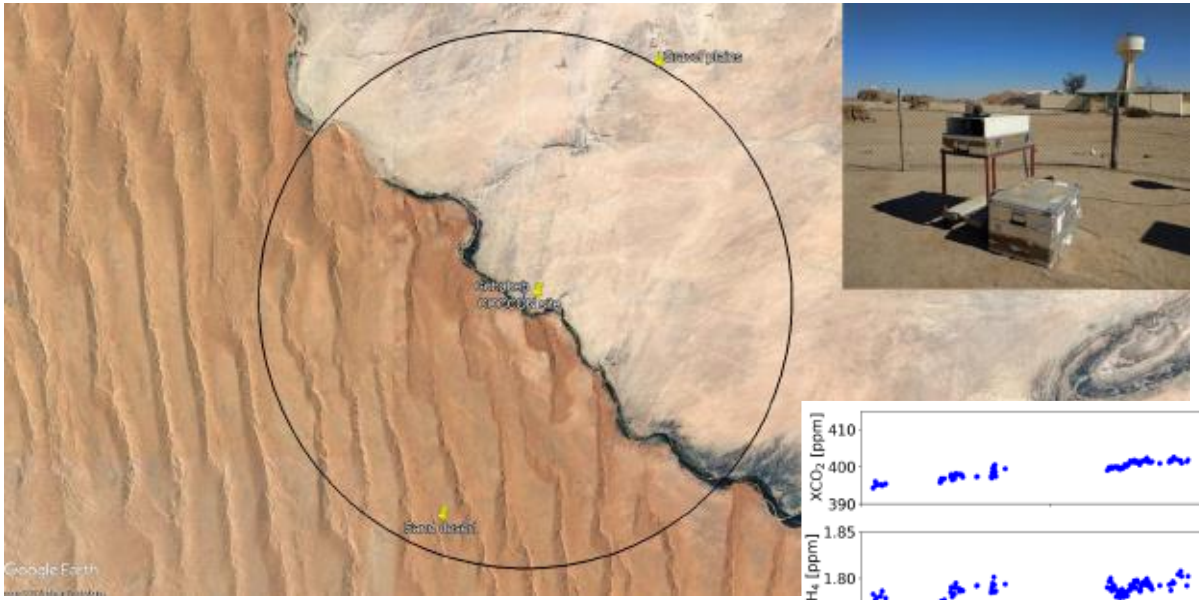
Remote sites: COCCON station Gobabeb, Namibia



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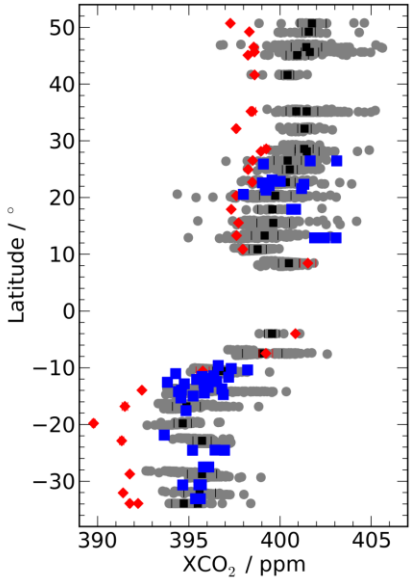
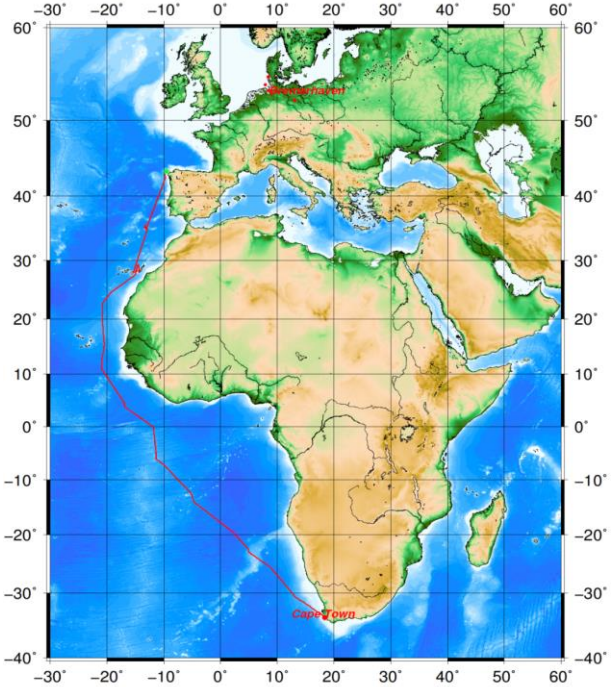
The EM27/SUN: shipborne GHG observations

Grey/Black: EM27 (all/daily mean)
Red: MACC forecast (daily mean)
Blue: RemoTeC/GOSAT (10°x10°)





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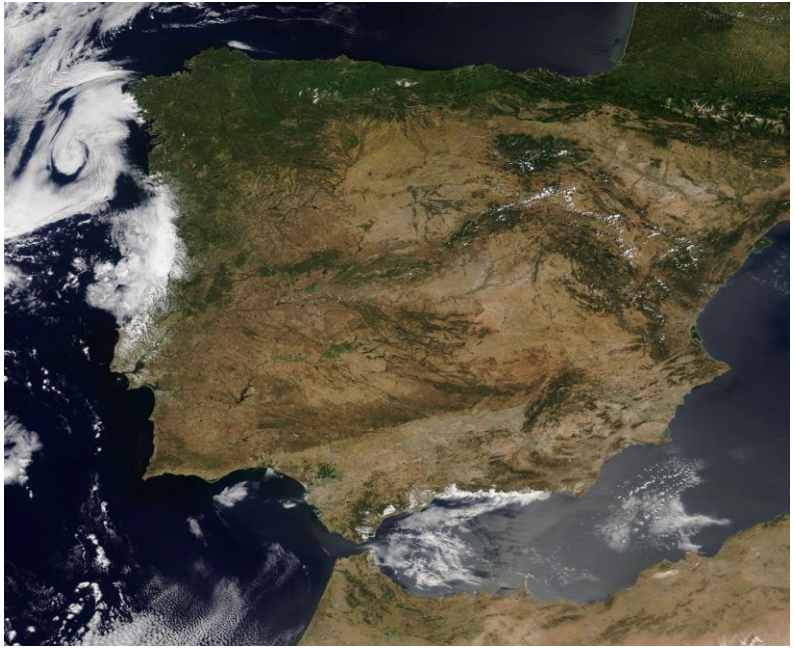
Plans: COCCON Spain

Setup and permanently operate ~12 spectrometers covering the Hiberian Peninsula demonstrating seamless coverage from city to synoptic scale!



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