Co-ordinated by ECMWF

CoCO2
Prototype system for a Copernicus CO_2 service

ESTIMATION OF TERRESTRIAL BIOGENIC CO_2 FLUXES FROM IFS MODEL INVERSIONS: FIRST RESULTS FROM THE COCO2 PROJECT AND FUTURE PROSPECTS FOR THE CAMS GLOBAL CO_2 EMISSION MONITORING SERVICE

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- ***Objectives of Copernicus Monitoring and Verification System (MVS)***
- ***IFS global inversion system: the core of MVS***
- ***Illustrations of some results of the system: CH_4 and CO_2***

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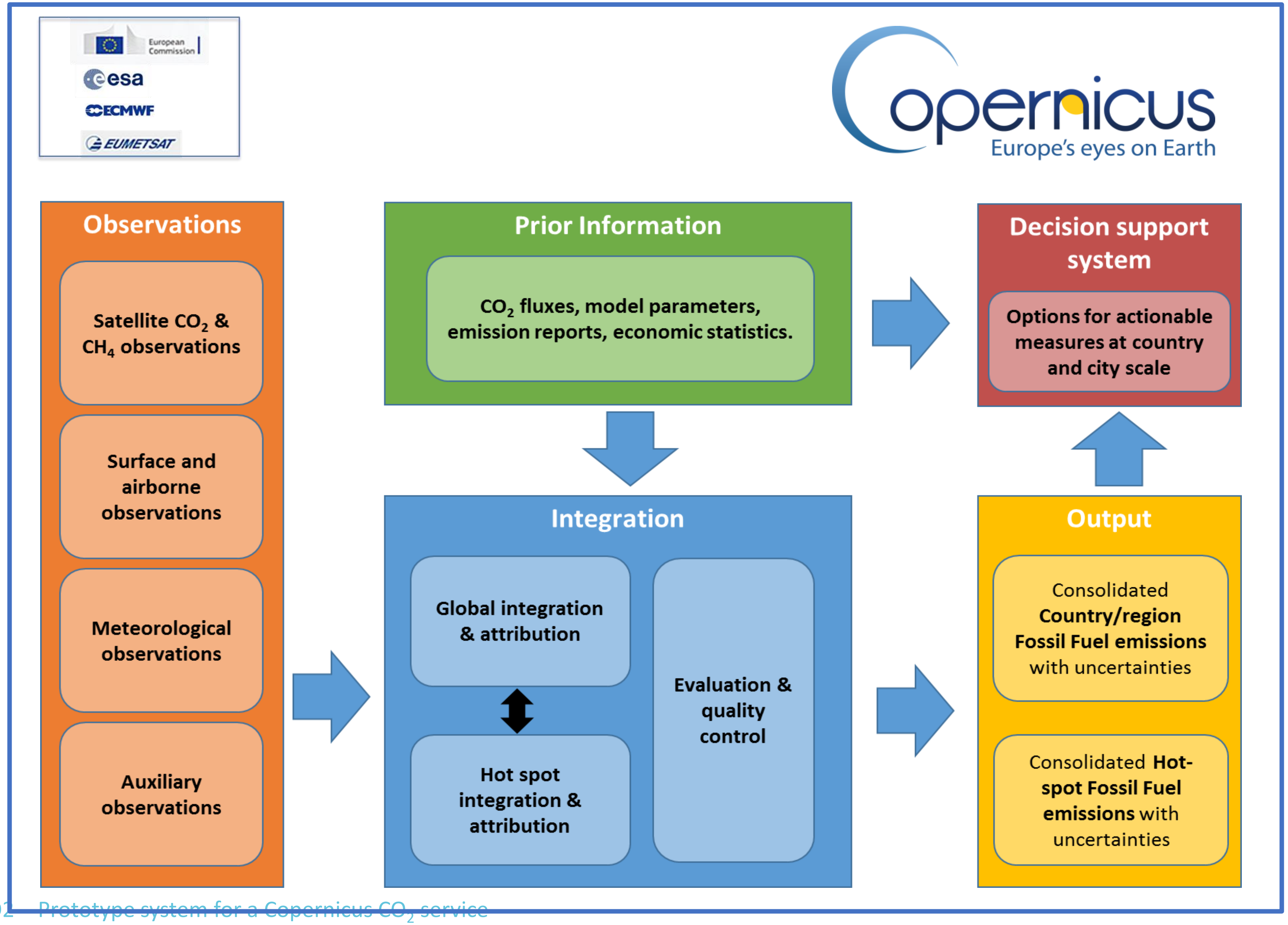
Prototype Copernicus Monitoring and Verification System (MVS)



CoCO2

Prototype system for a Copernicus CO_2 service

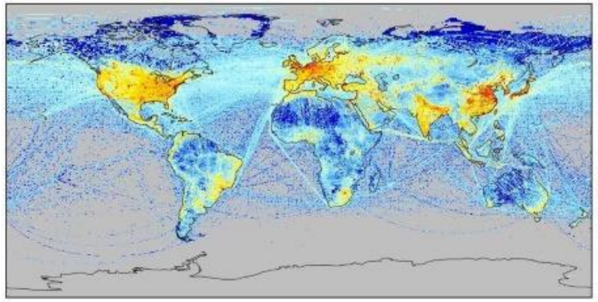
Atmosphere Monitoring Service

atmosphere.copernicus.eu

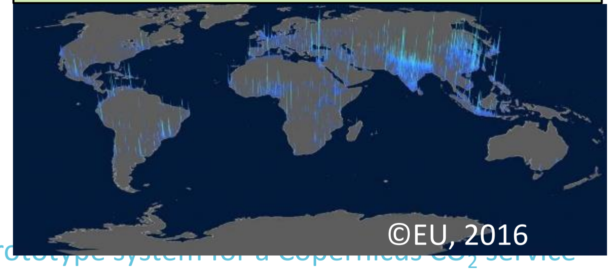
The IFS global inversion system

INPUT DATASETS

EMISSION INVENTORIES WITH TEMPORAL/VERTICAL PROFILES & UNCERTAINTIES
(JRC EDGAR,TNO/BSC, CAMS81)

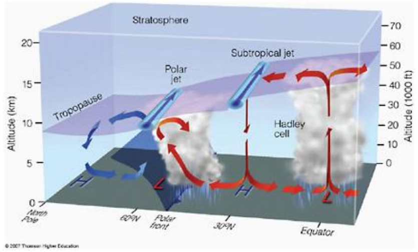


VEGETATION & URBAN MAPS
(ESA-CCI, JRC GHSL)
OCEAN FLUXES (CMEMS)

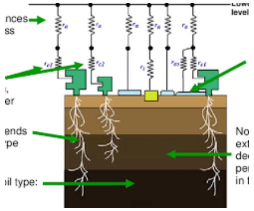


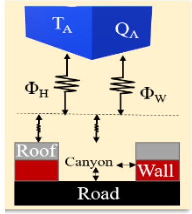
IFS FORECAST MODEL & DATA ASSIMILATION

IFS ATMOSPHERIC TRANSPORT

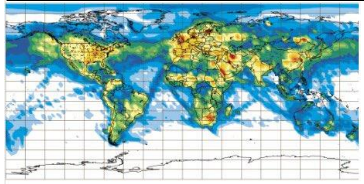


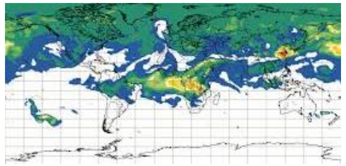
URBAN & VEGETATION MODEL, LAND SURFACE DATA ASSIMILATION



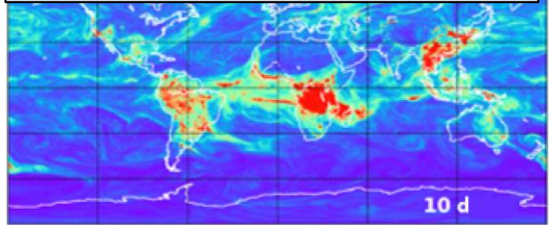


CAMS REACTIVE SPECIES
(NOx, CO, OH, CH4)

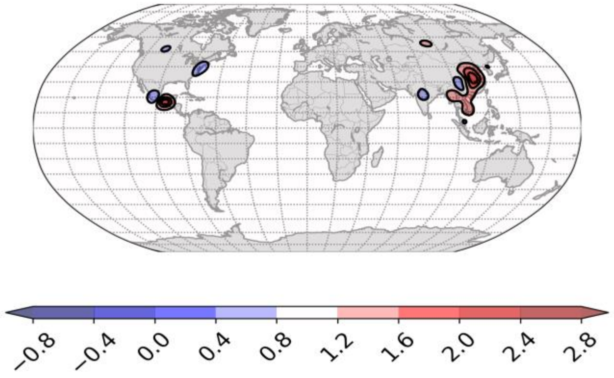




ENSEMBLE APPROACH
(uncertainty estimation & propagation)



4D-VAR ATMOSPHERIC ANALYSIS & INVERSION CAPABILITY

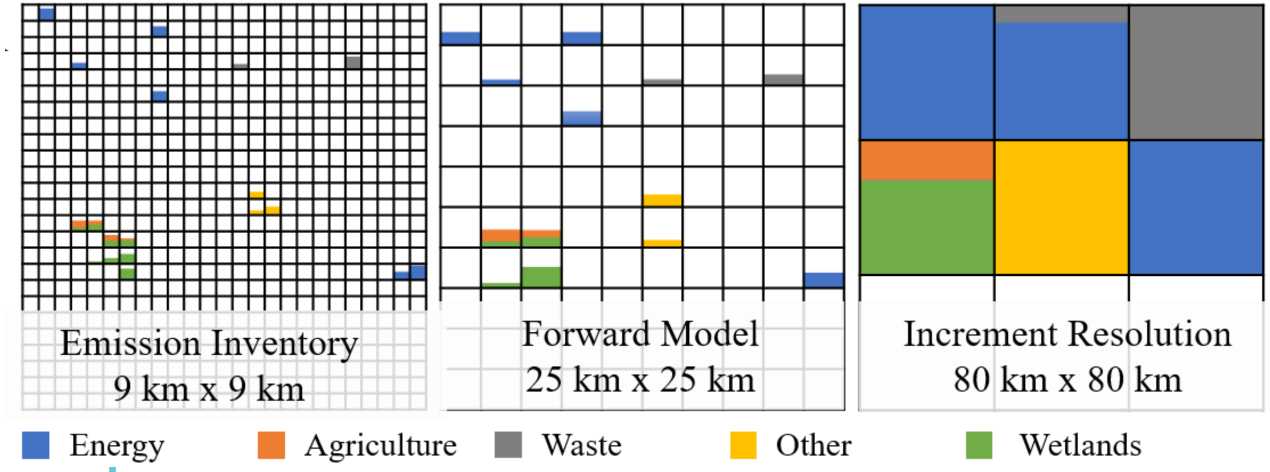


IFS 4D-Variational inversion

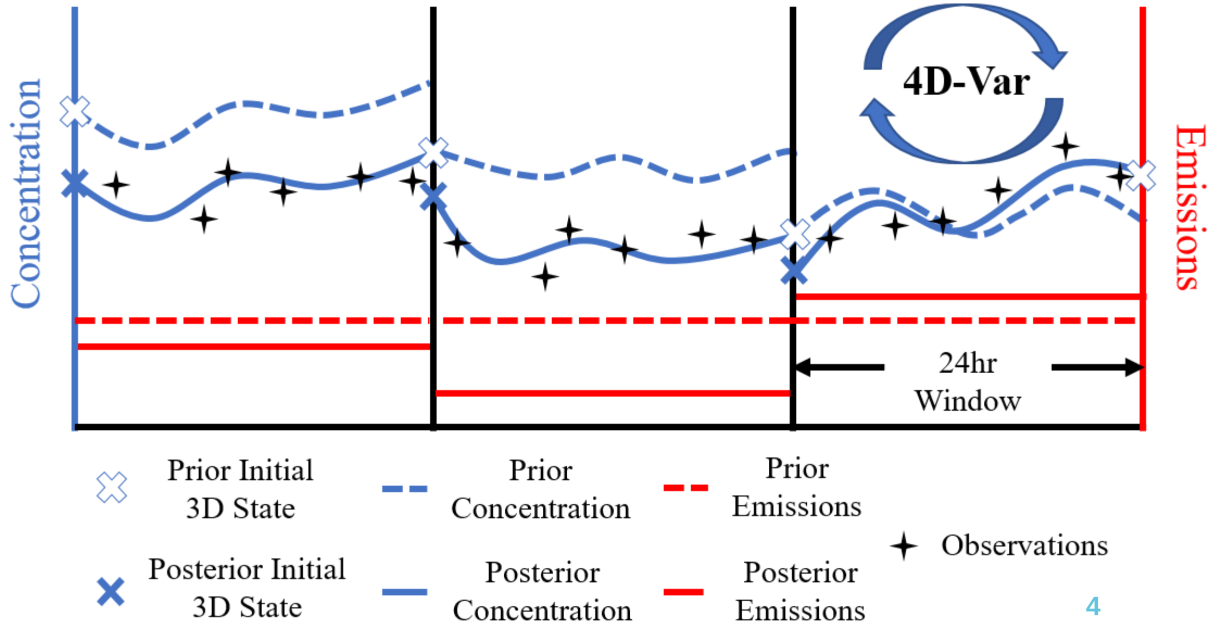
$$J(\mathbf{x},\mathbf{p}) = (\mathbf{x}-\mathbf{x}_b)^T\mathbf{B}_{\mathbf{x}}^{-1}(\mathbf{x}-\mathbf{x}_b)+(\mathbf{p}-\mathbf{p}_b)^T\mathbf{B}_{\mathbf{p}}^{-1}(\mathbf{p}-\mathbf{p}_b)+(\mathbf{y}-h(\mathbf{x},\mathbf{p}))^T\mathbf{R}^{-1}(\mathbf{y}-h(\mathbf{x},\mathbf{p}))$$

state (prognostic) — parameter (e.g., emission scaling factors) — Observations

- Characteristics of current system:
  - Joint 3D state/fluxes 4D-Var optimisation
  - 12-hour or 24-hour window
  - Emissions: CO_2, CH_4, NO_x, CO
  - Biogenic CO_2 fluxes (GPP and respiration)
  - Observations: OMI NO_2; TROPOMI NO_2, CO, CH_4 ; IASI CH_4, CO_2; GOSAT CO_2, CH_4; OCO-2 & OCO-3 CO_2
  - **B** model: spatial error correlation, cross-species correlations

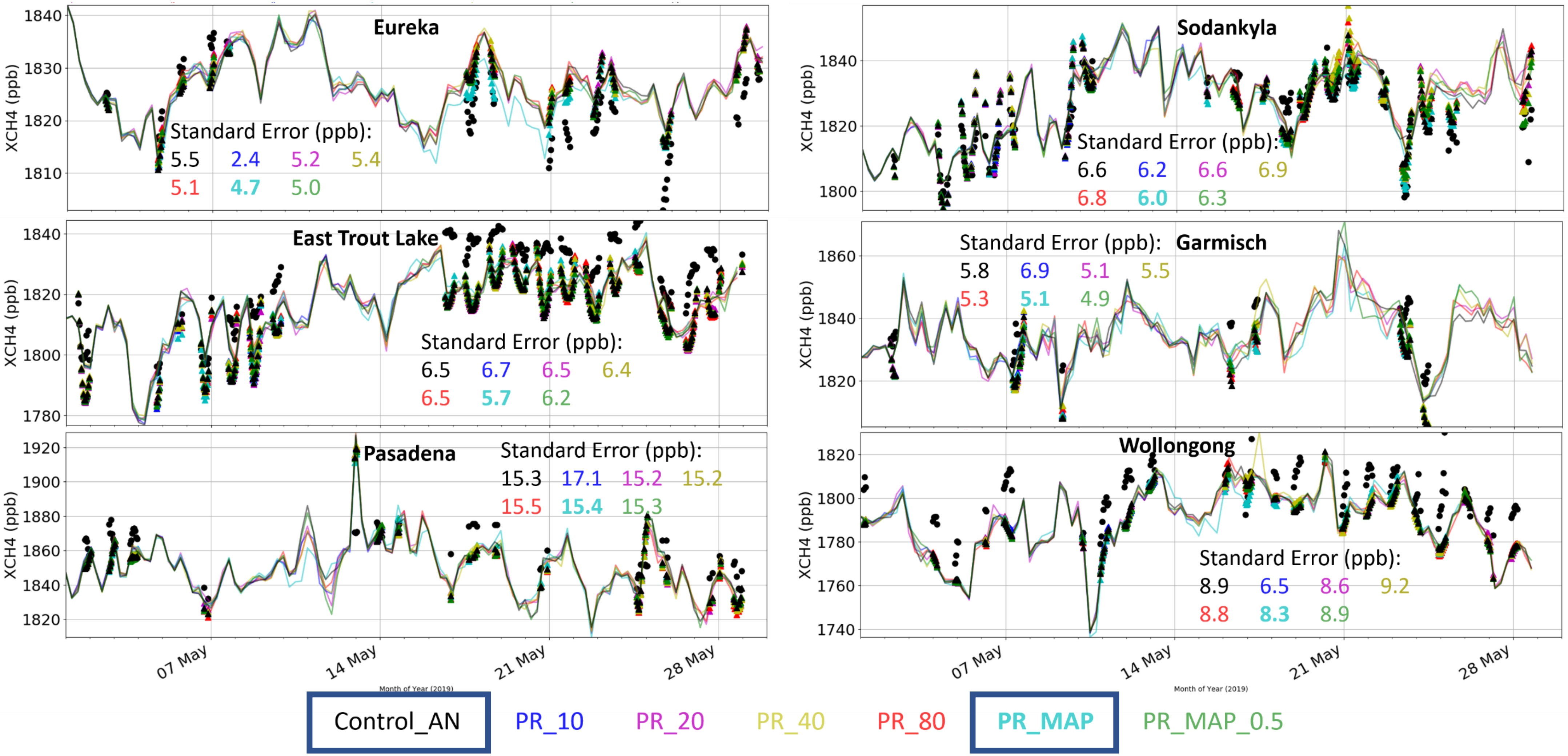


Case of CH_4 emission categories



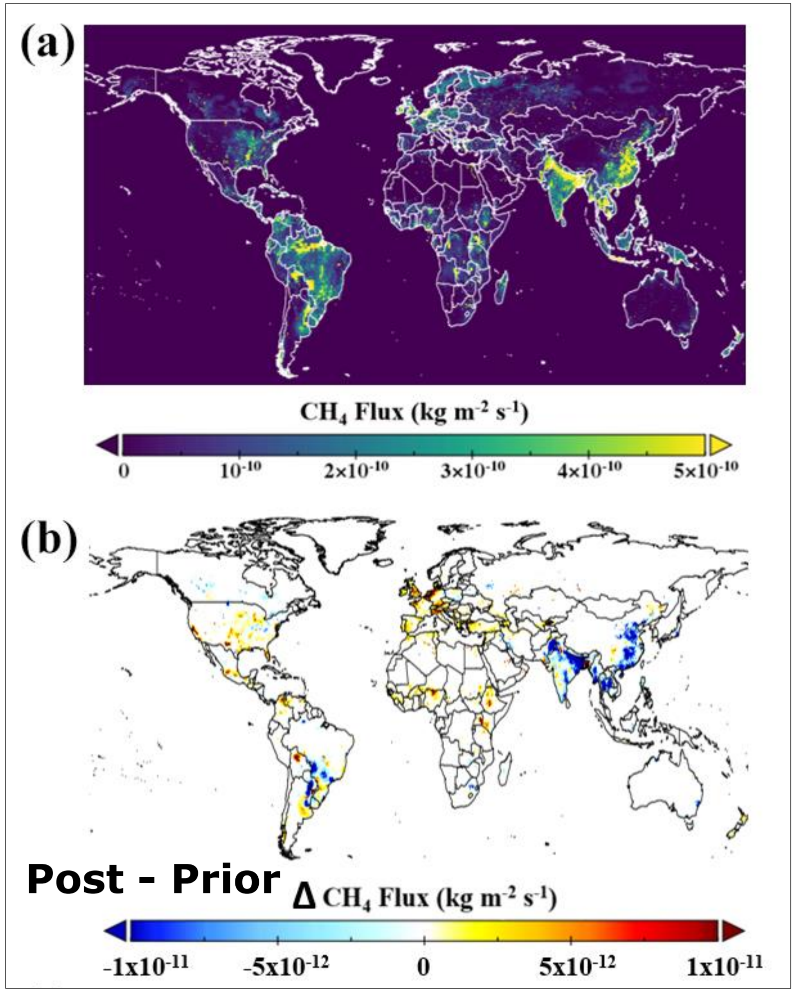
Inversion of CH_4 emissions: Validation of the optimized CH_4 concentrations

Results show that inversion (colours) captures quite well the TCCON XCH_4 variations (black dotted)

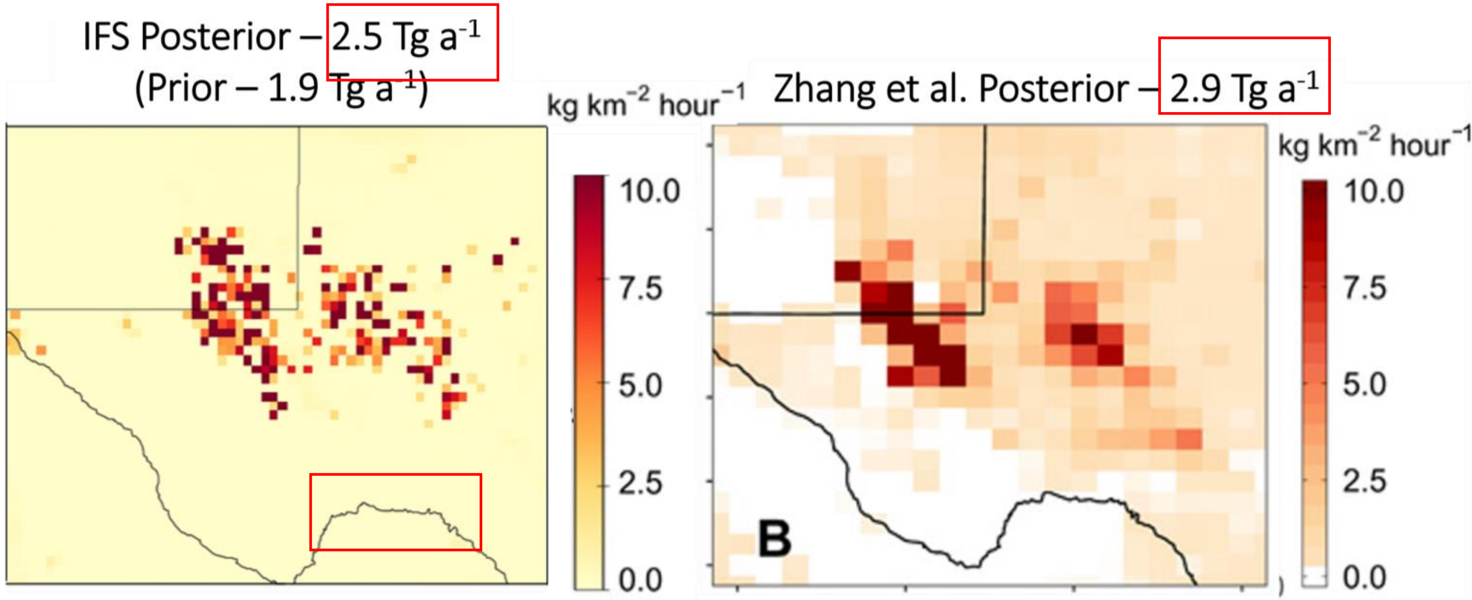


2019

Inversion of CH_4 emissions



Case from oil & gas fields over USA



Context : The Permian Basin, largest oil & gas field in USA, operations rapidly increased in the past decade, this may be missing in inventories. Assimilated TROPOMI & GOSAT XCH_4 for 03/01/19

This study: (McNorton et al., 2022)

- IFS 4D-Var inversion
- TROPOMI, GOSAT, IASI observations

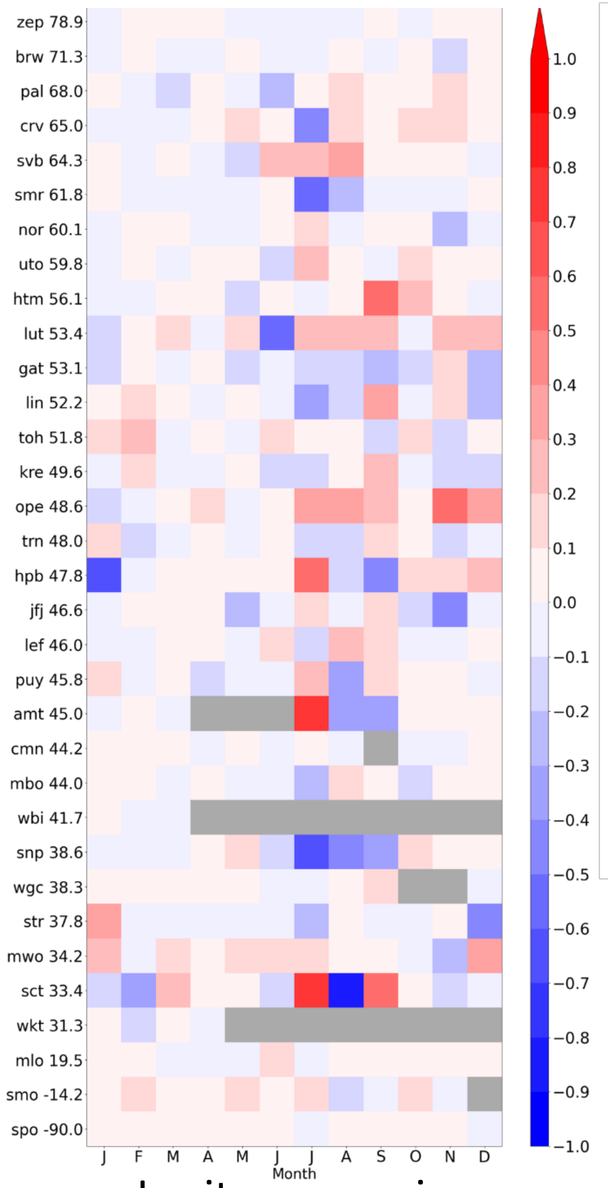
Zhang et al., 2020

- GEOS-CHEM 0.5°
- TROPOMI observations

➢ IFS inversions are in good agreement with Zhang et al., 2020

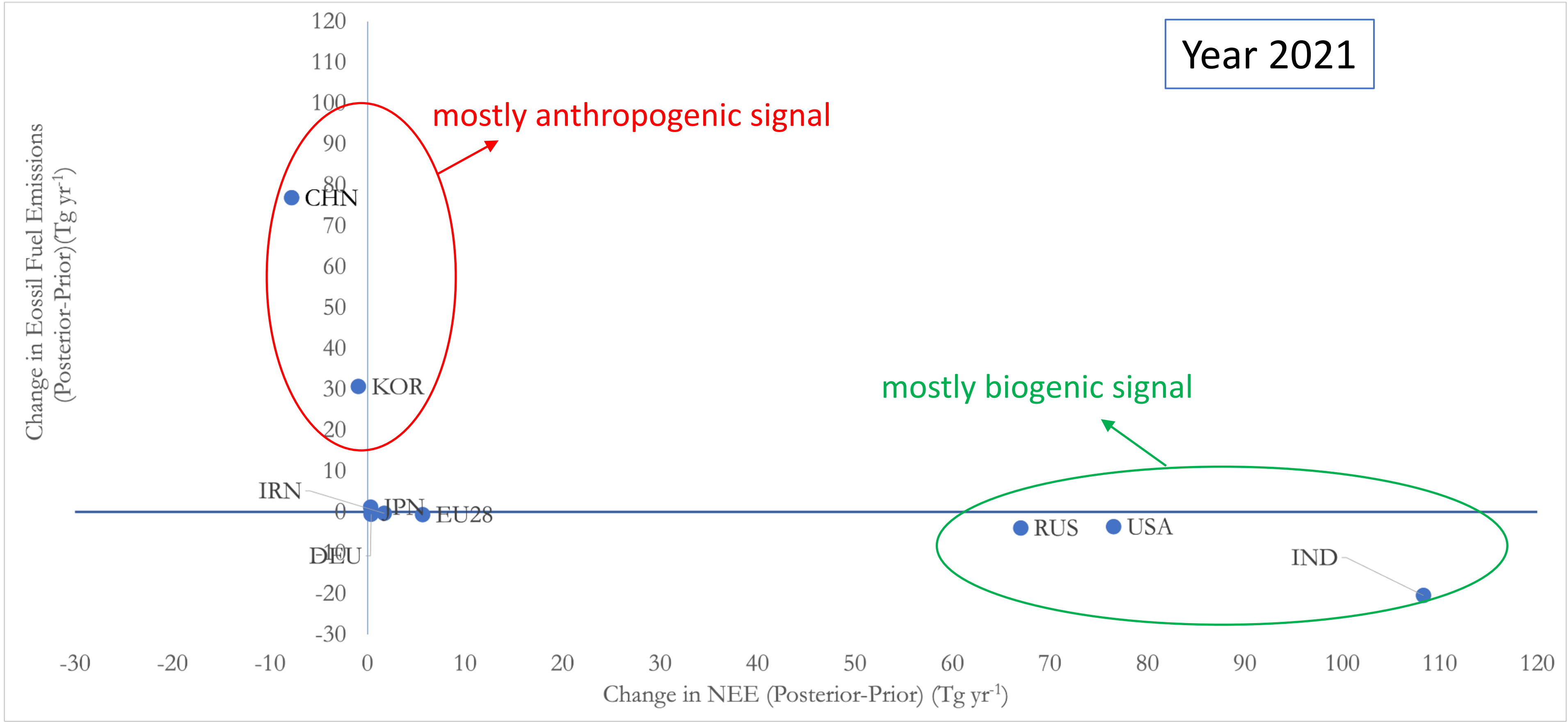
➢ Both studies estimate higher emissions compared to prior

RMSE diff (inversion-ctrl) (ppm)



In situ comparison

Obspack co2_1_NRT_v6.1.1_2021-05-17



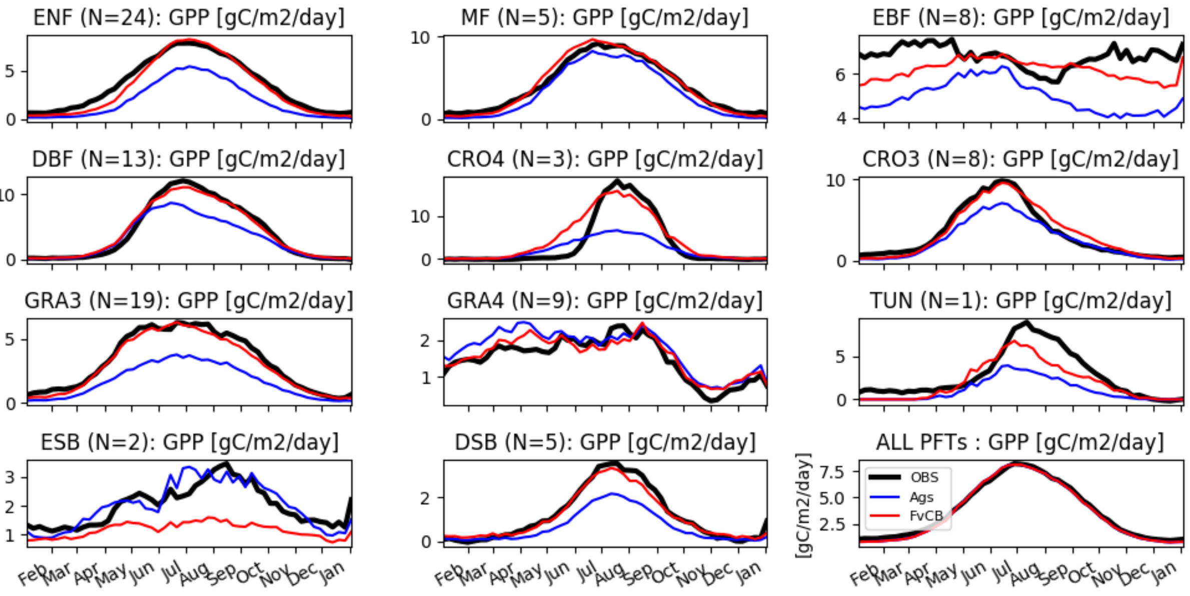
- In situ evaluation: averaged impact neutral but significant spatial variations
- Results show geographically contrasted observational constraints on fossil fuel and biogenic fluxes
- Need to include additional observational constraints from co-emitters such as NO_2 to disentangle the biogenic from the anthropogenic signal and improve posterior estimates

service

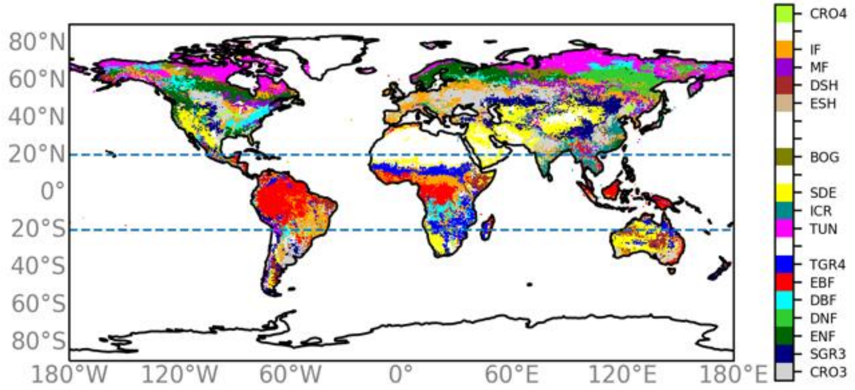
Modelling GPP : New photosynthesis model and LAI climatology

Evaluation with FLUXNET2015 eddy covariance observations [Pastorello et al., 2020]

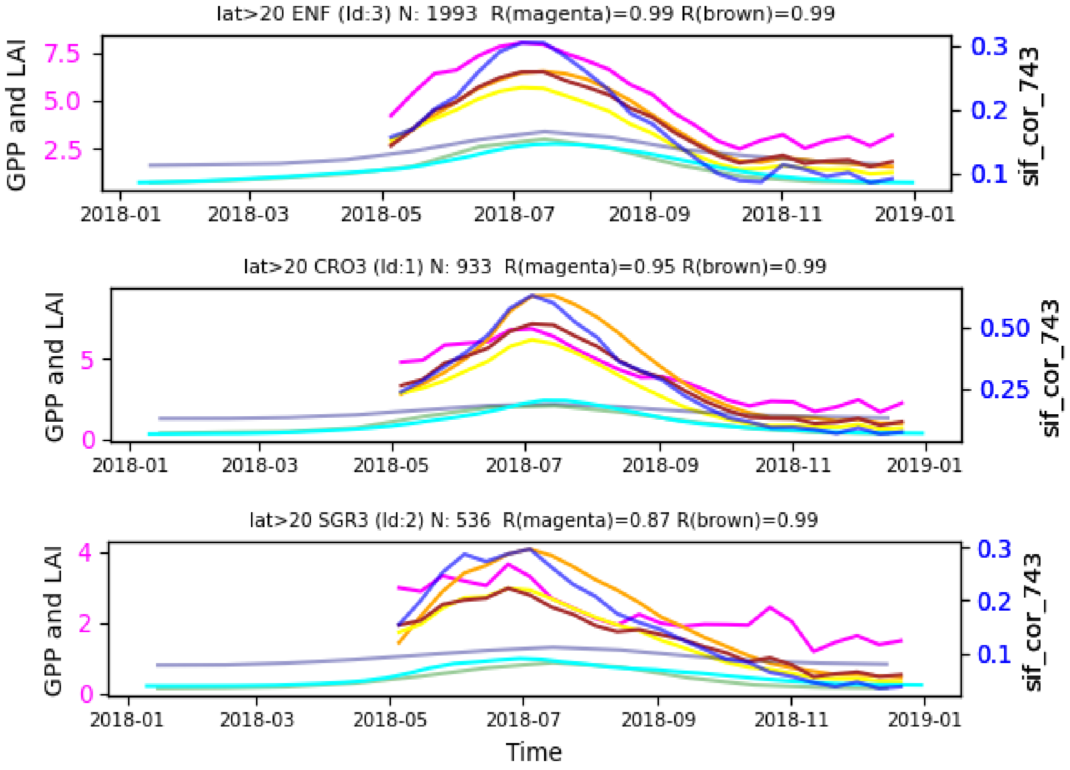
A-gs photosynthesis model   Farquhar photosynthesis model



Model dominant PFTs



Evaluation with SIF and GPP satellite-based products

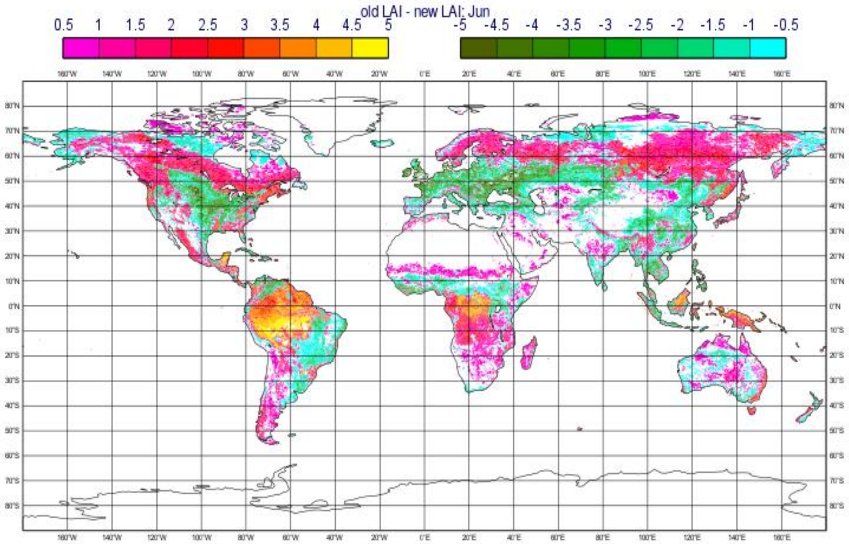


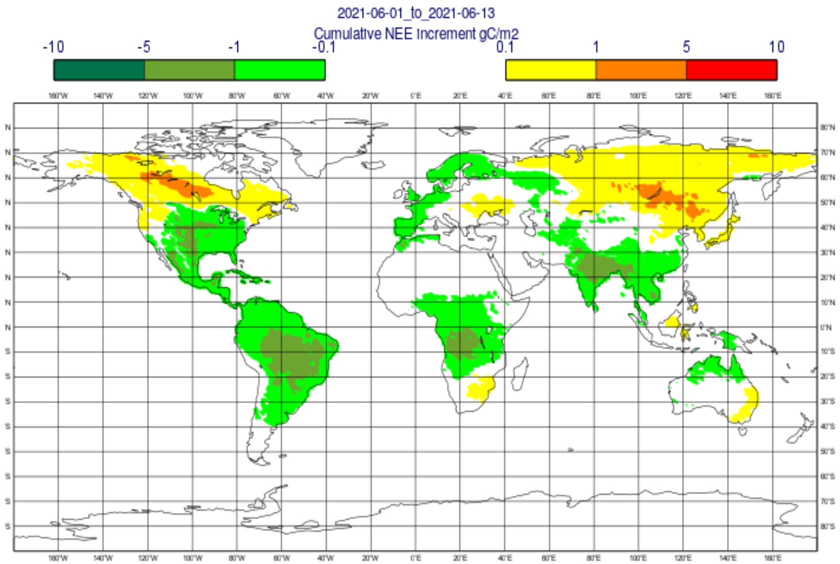
Model GPP with OPERATIONAL MODIS LAI climatology
Model GPP with NEW CGLS LAI climatology
FLUXCOM GPP (Jung et al., 2020)
FLUXSAT GPP (Joiner et al., 2018, Joiner and Yoshida, 2020)

TROPOSIF SIF (Guanter et al., 2021)
clim LAI_op. (Boussetta et al. 2015)
clim LAI_new based on Copernicus LAI
2018 LAI_new

NEE increments from IFS inversion correct for large-scale systematic error in LAI

LAI is too high LAI is too low Sink is increased Sink is reduced





LAI is too high -> Reduction in sink

LAI is too low -> Increase in sink

Summary and perspectives

- Encouraging results obtained for CH_4 emission quantification, evaluation of CO_2 inversion in progress
  - Capability of the IFS inversion to capture regional point source CH4 emissions
  - Preliminary CO_2 inversion results show that NEE correction is able to partly compensate for the large systematic errors in the IFS LAI climatology

- Ongoing developments to implement a multi-species IFS global inversion system, to be integrated in a multi-scale, multi-system operational CO2 MVS (future Copernicus service)

  - CO2M mission will provide operational retrievals of tropospheric CO_2, CH_4 and NO_2 columns→unique opportunity to constrain anthropogenic emissions

  - Link between anthropogenic CO_2 emissions and co-emitters (NO_2, CO) needs to be further characterised →upcoming HORIZON 2022 CORSO project

  - Better use of the GHG observational constraints in the global IFS inversion system requires to implement a long-window 4D-Var→a new hybrid ensemble-variational system is under development that will allow to extend the assimilation window to several weeks

More detailed questions, you can contact:

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