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CORSO
CO2MVS Research on Supplementary Observations

WP2: USE OF CO-EMITTED SPECIES IN DATA ASSIMILATION SYSTEMS

Kick-off Meeting

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WP-2 partners

European Centre for Medium-Range Weather Forecasts (ECMWF)


Inversion Lab (iLab) (+ M. Scholze)

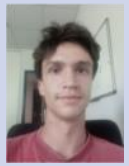

Netherlands Organisation for Applied Scientific Research (TNO)




The University of Edinburgh (UEDIN)

Universite Paul Sabatier Toulouse III (UT3)






Wageningen University (WU)

Swiss Federal Laboratories for Materials Science and Technology (EMPA)



WP-2 motivation, main objective and expected outcomes

Motivation:

- CO_2 satellite observations will have limited temporal coverage (3-4 days for global coverage with 3 CO2M) making it difficult to resolve the temporal variability of hot spot emissions.
- Temporal sampling bias contributes ~50% to the uncertainty of annual emissions (Kuhlmann et al. 2021).
- Since co-emitted CO and NO_2 satellite observations are available at sub-daily temporal coverage (e.g., Sentinel-5P, GEMS), they can be used for reducing the temporal sampling bias.
- Observations of CO and NO_2 also provide additional constraints that can help disentangle the anthropogenic signal from the biogenic influence.

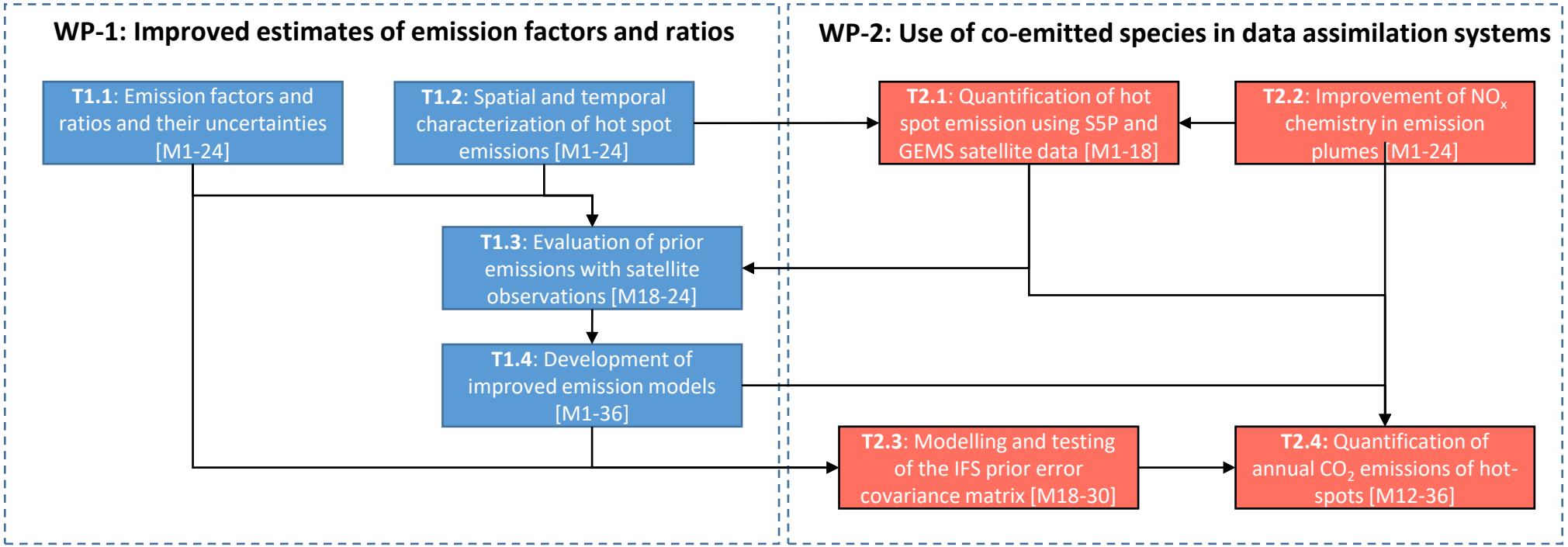
Main objective: Improve the use of observations of co-emitted species (NO_2, CO) to better estimate anthropogenic CO_2 emissions in the future CO2MVS capacity by:

- Identifying emission hot spots in NO_2 observations from LEO and GEO satellites for validating bottom-up inventories.
- Improving data-driven methods for detecting and quantifying hot spot emissions and applying them to quantify NO_x and CO emissions from LEO and GEO satellites.
- Improving the knowledge of NO_2:CO_2 ratios in emission plumes and develop, test and implement a simplified NO_x chemistry scheme that can be used in data assimilation systems.
- Modelling and testing an improved prior emission error covariance matrix (**B**) using the new information on prior emissions obtained in WP1.
- Implementing the improved **B** matrix for the quantification of annual CO_2 emissions from CO and NO_x emission estimates and provide multi-scale global IFS inversion outputs with assimilated posterior emissions from hot-spots.

WP-2 tasks & interactions

- **Task 2.1:** Data-driven detection and quantification of emission plumes in satellite observations (**Empa***, TNO, UEDIN, UT3)
- **Task 2.2:** Improvement of knowledge of NO_2:CO_2 ratios in plumes and larger point sources and improvement of treatment of NO_x chemistry in data assimilation systems (**UEDIN***, WU, ECMWF)
- **Task 2.3:** Modelling and testing of the IFS prior error covariance matrix (**ECMWF***, UEDIN)
- **Task 2.4:** Quantify annual CO_2 emissions of hot spots (**ECMWF***, EMPA, iLab)

(* task leader)



Task 2.1: Data-driven detection and quantification of emission plumes in satellite observations (Empa, TNO, UEDIN, UT3)

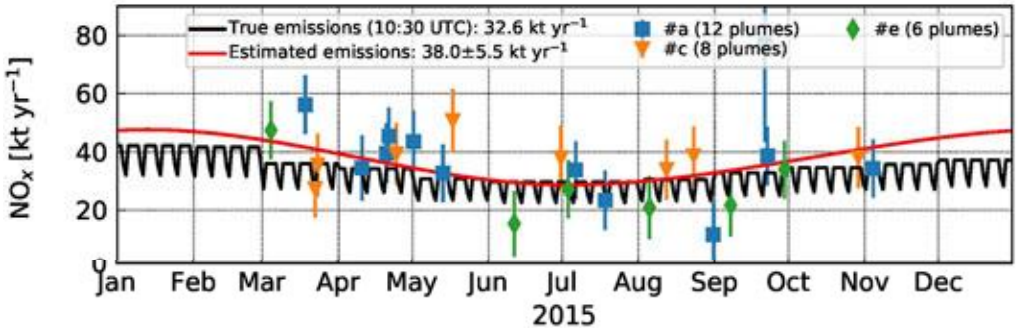
Objective: Develop and apply data-driven method to detect and quantify CO and NO_x emissions of hot spots using Sentinel-5P and GEMS satellite images for Africa, Europe and SE Asia for 2021

Tasks:

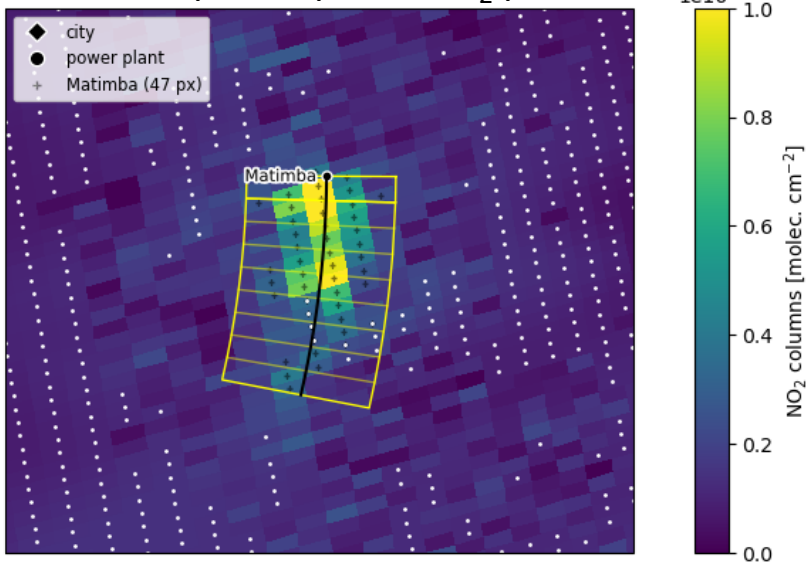
A) Generate a list of hot spot locations from NO_2 satellite observation for evaluating the bottom-up emission inventories in Task 1.2.A.

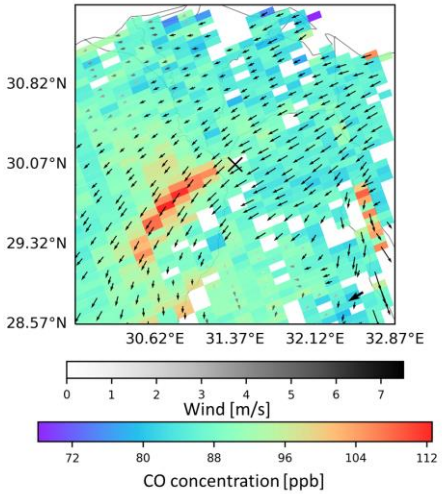
B) Generate a time series of CO and NO_x emissions of cities and power plants in Africa, Europe and SE Asia using Sentinel-5P and GEMS.

Time series of NO_x emissions of Jänschwalde power plant



Matimba power plant, NO_2 plume





Cairo, CO plume
January 19th, 2019

Task 2.2: Improvement of knowledge of NO_2:CO_2 ratios in plumes and larger point sources and improvement of treatment of NO_x chemistry in data assimilation systems (UEDIN, WU, ECMWF)

Objective: To improve the knowledge of NO_2:CO_2 ratios in emission plumes and develop, test and implement a simplified NO_x chemistry scheme that can be used in data assimilation systems.

Tasks:

- Use model simulations to analyze the relationship between atmospheric (column) ratios of CO_2:NO_2:CO and how they are related to the corresponding emission ratios of CO2:NOx:CO.
- Develop computationally efficient chemistry schemes that can be applied in data-driven emission quantification and low-resolution global models.

Task 2.3: Modelling and testing of the IFS prior error covariance matrix (ECMWF, UEDIN)

Objectives:

- Use information on prior emissions from WP1 to build a model for the prior error covariance matrix (**B**) used in the global IFS inversion system.
- Use IFS 4D-Var system to refine prior information (uncertainties, correlations) based on atmospheric observations.

Tasks:

A. Cross-species emission error correlations will be derived based on combining their emission factors and associated uncertainties provided by WP1.

B. The current **B** model will be extended to include the time dimension and the temporal variations in cross-species emission error correlations derived in WP1.

C. The information on **B** model parameters (i.e., prior error variances, spatial and temporal error correlation length scales, cross-species correlations) provided by WP1 will be further refined using atmospheric observations and cross-validation approaches.

Task 2.4: Quantify annual CO_2 emissions of hot spots (ECMWF, EMPA, iLab)

Objective: Improve annual CO_2 emission estimates using additional constraints from individual CO and NO_x estimates available from the data-driven approaches (T2.1) and improved time profiles and emission ratios.

Tasks:

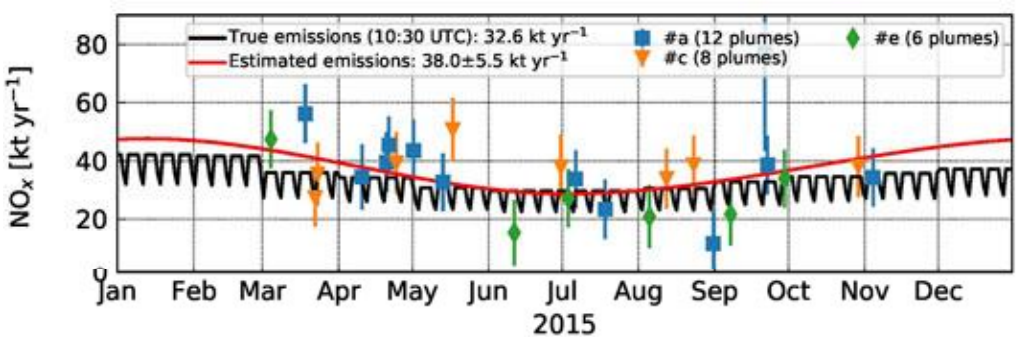
A. Use time series of CO & NO_x estimates together with time profiles and emission ratios from WP1 as prior information to obtain a posterior optimal estimate for annual CO_2 emissions for individual hotspots.

B. In the local CCFFDAS, test the impact of uncertainties in height of emissions and chemical evolution of the plumes on the posterior fossil fuel emissions.

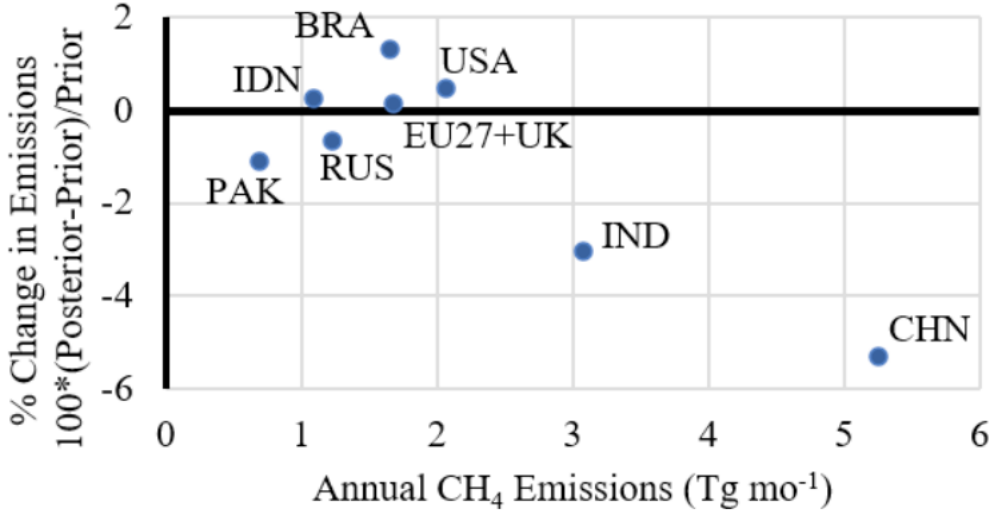
C. Integration in global IFS 4D-Var inversion system: the local hotspot emission estimates (T2.1) will be assimilated into the global IFS-based CO2MVS following the method outlined in the CoCO2 project.

D. The multi-scale IFS-based global CO2MVS CO_2 product will be evaluated against both ground-based data (e.g., TCCON observations (indirect validation), flux tower measurements (direct validation)) and cross- validation methods.

Time series of NO_x emissions of Jänschwalde power plant



CH_4 inversions for 2019 from IFS global system



WP-2 Deliverables and milestones

No	Deliverable Name	Lead	Deadline
D2.1	List of CO_2, NO_2 and CO hot spot locations for the year 2021 identified in satellite observations	UT3	M12
D2.2	Time series of NO_x and CO emissions of hot spots in Africa, Europe and SE Asia in reference year	EMPA	M18
D2.3	Software library for data-driven emission quantification of hot spots	EMPA	M18
D2.4	Analysis of ratios of atmospheric columns over and downwind of emission hotspots located in contrasting geographical regions and the responsible ratios of emitted trace gases	UEDIN	M24
D2.5	A prototype for a simplified chemistry scheme to describe observed variations in NO2 on spatial scales of ~25 km, suitable for global-scale models	UEDIN	M24
D2.6	Optimized B matrix parameters (i.e., temporal, spatial, cross-species correlations)	ECMWF	M24
D2.7	Multi-scale global IFS inversion outputs (2021) with assimilated posterior emissions from hot-spots	ECMWF	M36

No	Milestone	Means of verification	Deadline
4	Methodology available to detect and quantify CO and NO_x emissions from S5P and GEMS	Start of experiments	M12
5	A computationally efficient method to interpret observed variations in NO_2 on spatial scales of ~25 km, suitable for global-scale models	Methodology available for use in IFS	M24

Overall WP-2 discussion & next steps (Tuesday morning)

- Introduction by each group
- Meetings:
  - WP-2 meetings (every two months?)
  - joint WP-1/2 meetings (every two months?)
- Clarifications of tasks and responsibilities
  - interim tasks / milestones
- Code and data sharing (git, ICOS-CP server, …)
- Connection with WP1 activities:
  - Type of prior information and data formatting for integration in WP2 inversion systems
  - Timeline for handover of data

THANK YOU

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