VERIFY GA meeting #1
WP2 Verification methods for CO2_ff emissions

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ECMWF

Reading, UK

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WP2 Introduction

- **Overall objective**: Construct FFDAS to estimate ffCO2 emissions at sub-national resolution (25-50 km) by combining new anthropogenic emissions, natural fluxes (WP3) with in situ and satellite atmospheric data.
- **Specific objectives**:
  - Deliver high-res emission of ffCO2, bfCO2 & co-emitted tracers for Europe, 2005-present
  - Evaluate proxy/ffCO2 ratios near emission hotspot; validate using 14C data in a test-bed experiment
  - Develop framework to support monitoring ffCO2 from different sectors at the national scale using satellite measurements of CO and NO2
  - Demonstrate potential of current and future space-borne data

WP2 VERIFICATION METHODS FOR CO2_FF EMISSIONS TASKS OVERVIEW

- **T 2.1** Bottom-up emission estimates for anthropogenic CO2 and co-emitted tracers (TNO **M01** M48)
- **T 2.2** Assessment of atmospheric proxy/ffCO2 ratios and comparison to independent 14CO2-based ffCO2 emission estimates (UHEI **M03** M48)
- **T 2.3** Annual to monthly budgets and trends of fossil CO2 emissions at the national scale across Europe using CO and NOx satellite measurements (LSCE **M01** M48)
- **T 2.4** Exploring the potential of new data, upcoming instruments, and new methods to improve the pre-operational ffCO2 estimation system (UEDIN **M12** M48)

WP2 – Status of Deliverables M1-24

DEL n°	DEL Title	Leader	Due date	Status	Comments
D2.1	First High Resolution emission data 2005-2015	5 - TNO	12	V	
D2.4	First Present year-1 emission inventory and grids	5 - TNO	14	Error?!	**See Dev.**
D2.9	Uncertainty analysis for the dynamical inventory model	23 - WU	18	ongoing	See MS
D2.10	First, fast-track, Re-analysis of the national scale CO2 anthropogenic emissions over2005-2015	1 - CEA	18	ongoing	See MS
D2.2	Second High Resolution emission data 2005-2016	5 - TNO	24		
D2.7	Temporal variations of proxy/ffCO2 ratios	6 - KIT	24	ongoing	See MS

Deliverables after M24 not shown

WP2 – Status of Milestones

MSn	MIL Title	Leader	Due date	Status	Comments
MS4	Compilation of year 2005-2015 anthropogenic emission data and spatial proxy data for point sources	5 - TNO	6	V	
MS5	Historic evaluation of proxy/ffCO2 ratios for the Heidelberg region available.	17 - UHEI	12	V	
MS6	Compilation of satellite and atmospheric observations for2010 to year n-1 for procedure/method testing of the future operating system	1 - CEA	12	V	
MS7	fast-track inversion product with a system already operational optimizing the EDGAR-JRC inventory at coarse resolution.	1 - CEA	12	V	
MS8	Monitoring of case study area operational	17 - UHEI	14		
MS9	Testing of the ffCO2 emission model (FFDAS) for one source sector	23 - WU	15	Propose merging with MS31 (WP5)	
MS10	Design of OSSE framework and compilation of existing satellite data and specification of future space-borne missions of CO2_CO- NO2_HCHO	19 - UEDIN	18		
MS11	High resolution 1 x1 km CO2, CO, NOx2015 inventory for case study region	5 - TNO	24		Faster M18

WP2 – Name of work package

Deviations and impact on time schedule

- An error appeared in the Del list for WP2.

  D2.4 First Present year-1 emission inventory and grids (M14)

  should be a MS and D2.4 should be at M28 (to than be ready 2M after a new inventory year is added);

  MSXX Test version of year-1 emission inventory (M18)

  - Motivation: It's not feasible to make D2.4 in just 2M after D2.1 (year 2005-2015) – was also not in original WP text (but overlooked in final proposal text)

- High resolution data for case study area will be faster available than planned due to lining up with CHE. (MS 11 at M24)

- Propose merging of MS 9 (WP2) and MS31 (WP3).

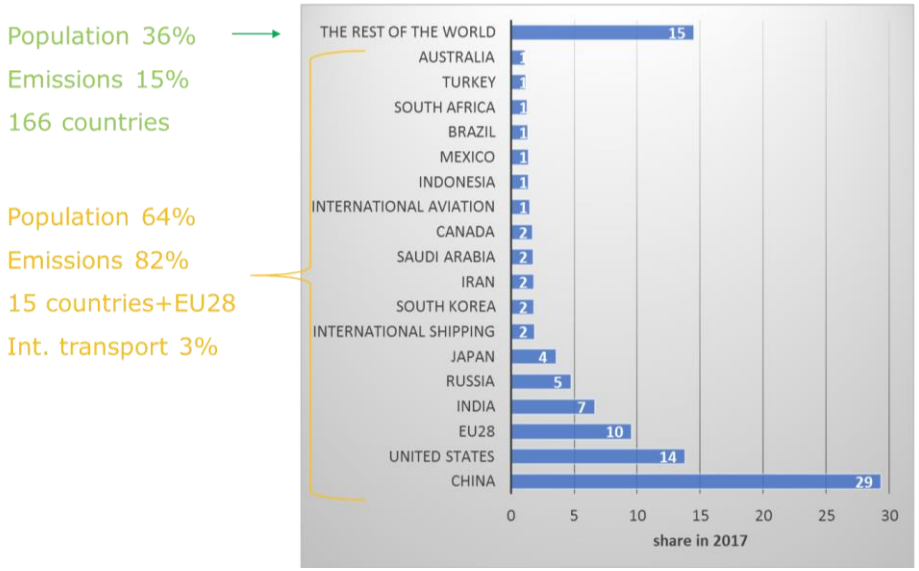
WP2 VERIFICATION METHODS FOR CO2_FF EMISSIONS STATUS YEAR 1

- **Emission inventories – global / regional (TNO / JRC)**
- **Case study region; in situ + data analysis & new measurements (UHEI + KIT)**
- **Inversion system set-up for budgets/ trends of CO2 using CO/NOx satellite measurements (LSCE)**
- **Uncertainty calculation and emission model set-up for test cases (WU / TNO)**
- **CCDAS and FFDAS set up in combination with WP3 (ULUND / WU)**
- **Model systems and configuration document (UEDIN)**

WP2 – Highlights

EDGAR NEW UPDATES: CO_2 FROM FOSSIL FUEL

- Time series of fossil CO_2 emissions for all world countries from **1970 until 2017** are included in EDGARv5.0_FT2017
- Data and full documentation are available at http://edgar.jrc.ec.europa.eu/overview.php?v=booklet2018
- Share of fossil CO_2 emissions in total global, 2017

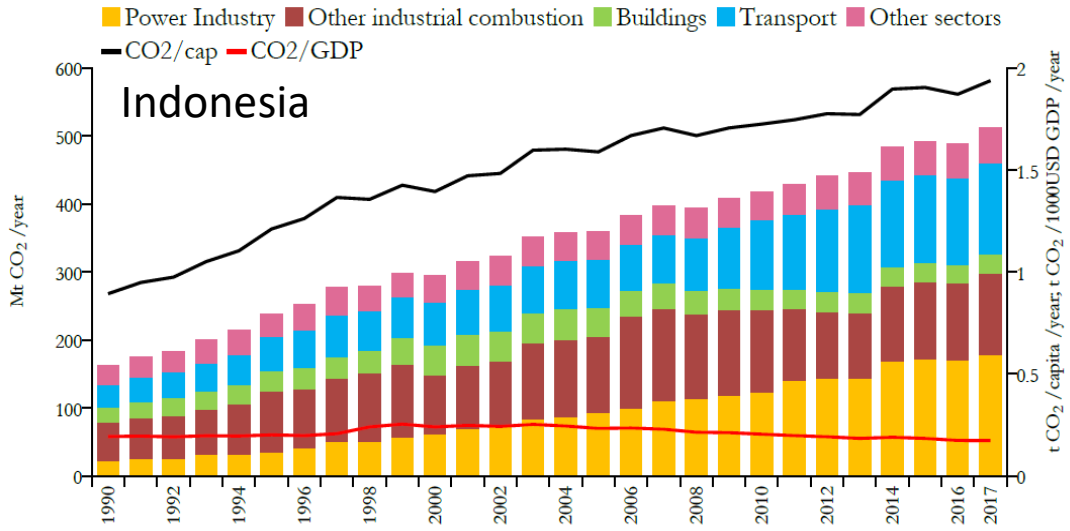


Source: JRC, EDGARv5.0_FT2017

HISTORICAL EMISSIONS DATA: EDGARV5.0_FT2017

FOSSIL CO_2 EMISSIONS BY SECTOR

- The fossil CO_2 emissions are aggregated in 5 sectors and provided for each country; an example is provided below.
- Fossil CO_2 emissions include sources from fossil fuel use (combustion, flaring), industrial processes (cement, steel, chemicals and urea) and product use.

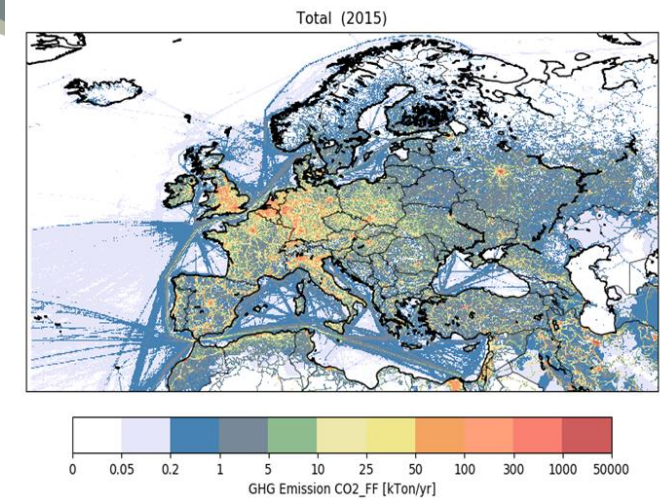


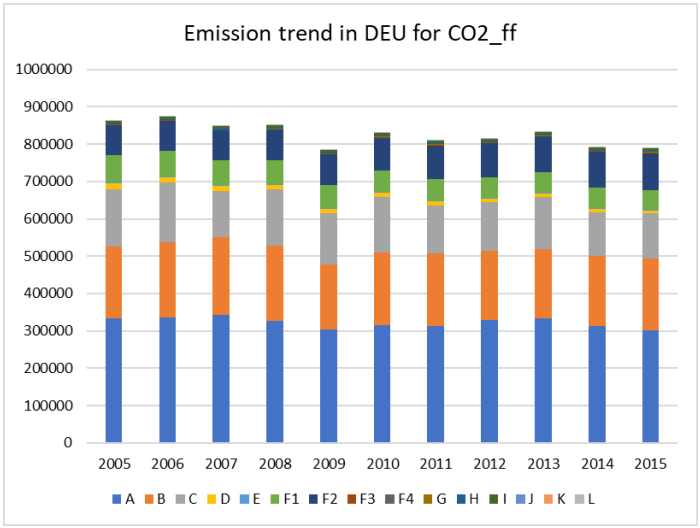
Source: JRC, EDGARv5.0_FT2017

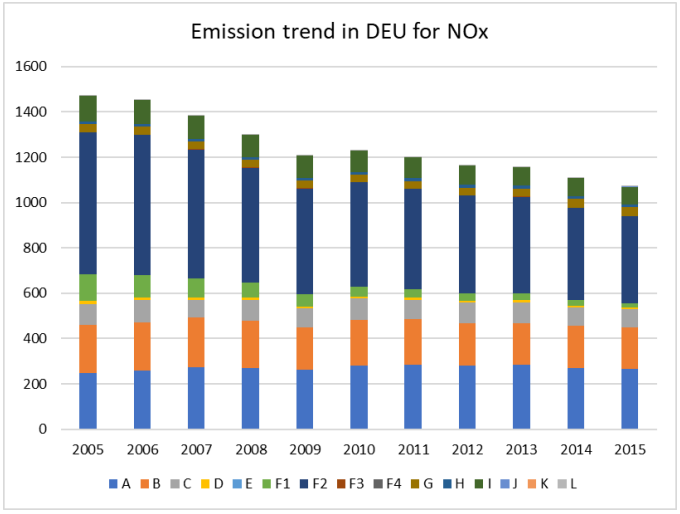
For 2019 – discuss next steps:
Add uncertainty?
Input to fact sheets?

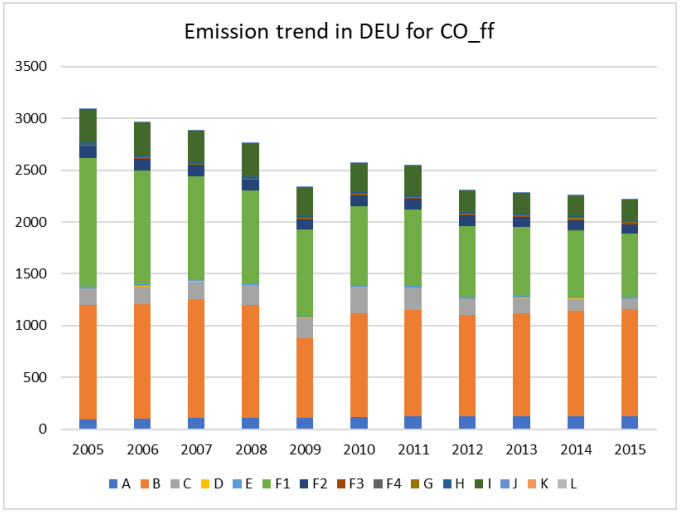
T2.1.1 HISTORICAL EMISSIONS DATA

D2.1 FIRST HIGH RESOLUTION EMISSION DATA 2005-2015 (M12)



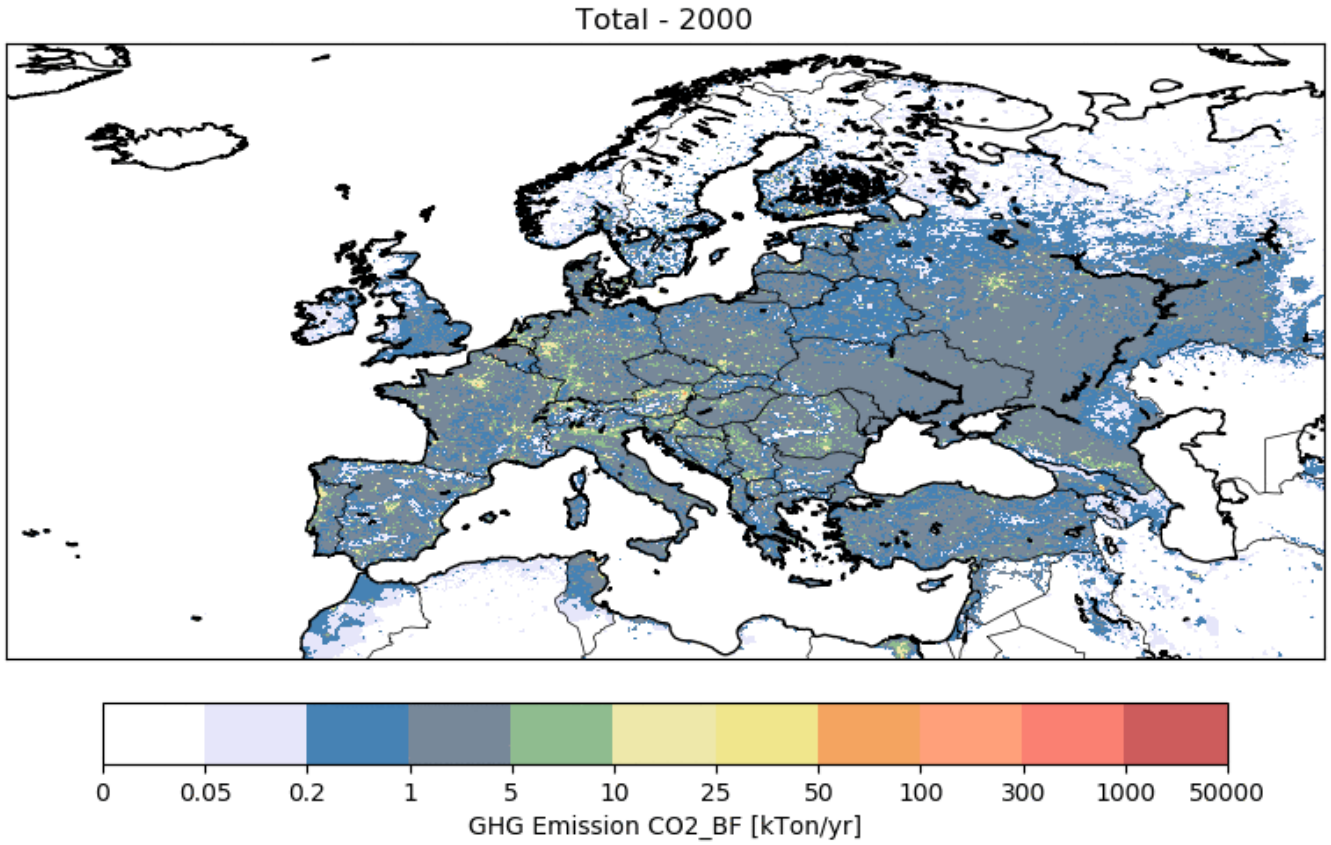






See Deliverable report D2.1 for details

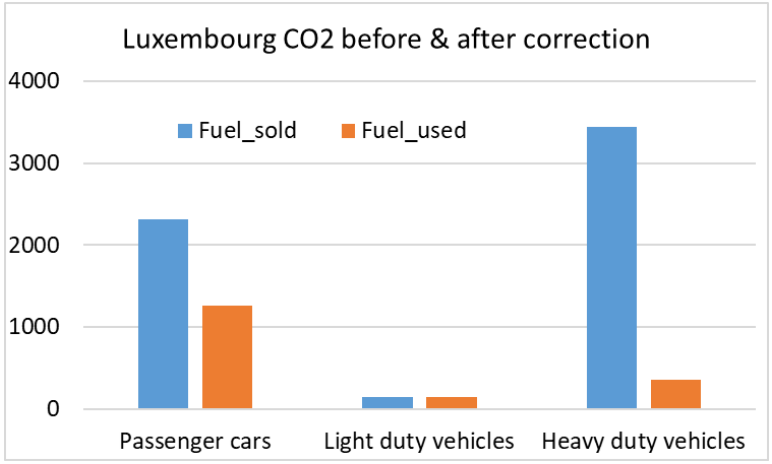
CO_2 FROM BIOFUELS IS CHANGING AND REPRESENTS ~10-15%



CORRECTIONS ON CO_2 EMISSION DATA

- Luxembourg – fuel used vs fuel sold ✓
- Include CO_2 from international Aviation LTOs
- Include CO_2 from underground coal mines
- Improve distribution road transport Urban – highway (1x1 km)

Result of interaction @ WP1 Workshop

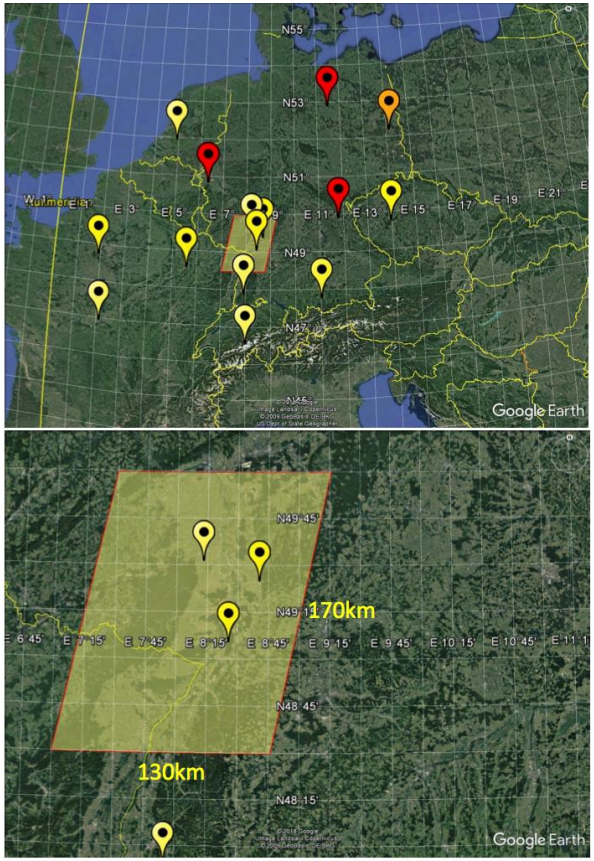


AVERAGE – shares redistribution based on border traffic counts	DEU	FRA	BEL
	15%	50%	35%

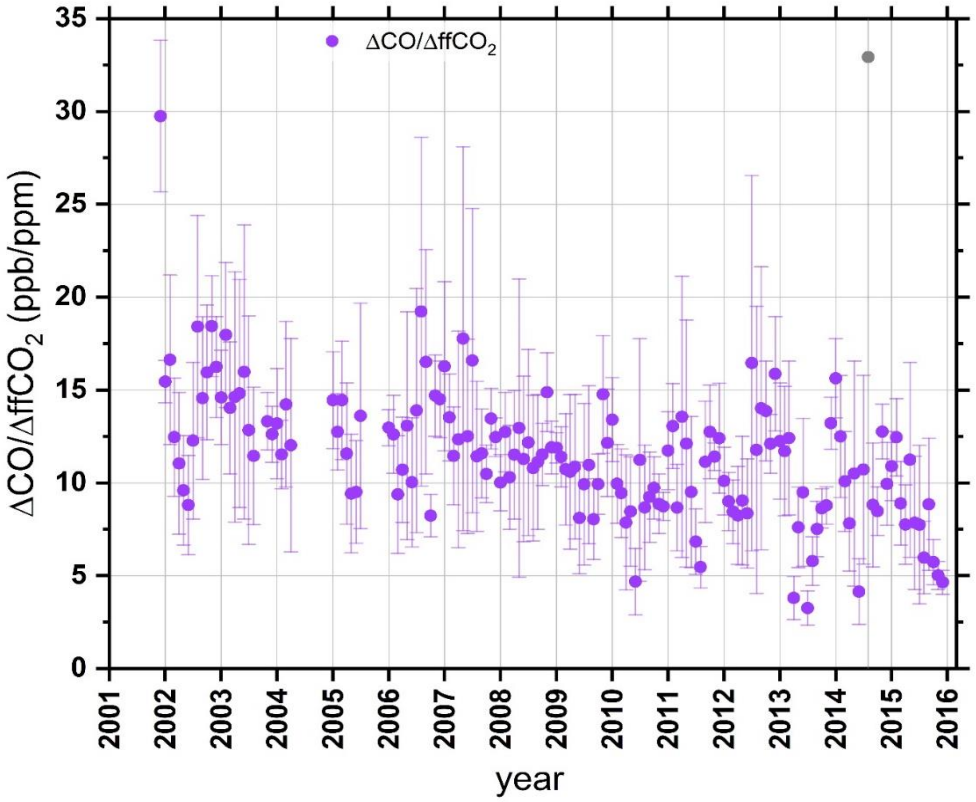
WP 2 IMPRESSION....

Line-up for the case study

- UHEI analysed 15 years of local data, implement new measurements
- KIT installing new instruments and new locations
- TNO Prepare 1 x 1 km inventory of CO2 and co-emitted species (to be combined with UHEI work)
- WU, ULUND set up FFDAS, CCDAS, provide uncertainties and fluxes
- Set-up models across different scales (UEDIN, LSCE, WU)



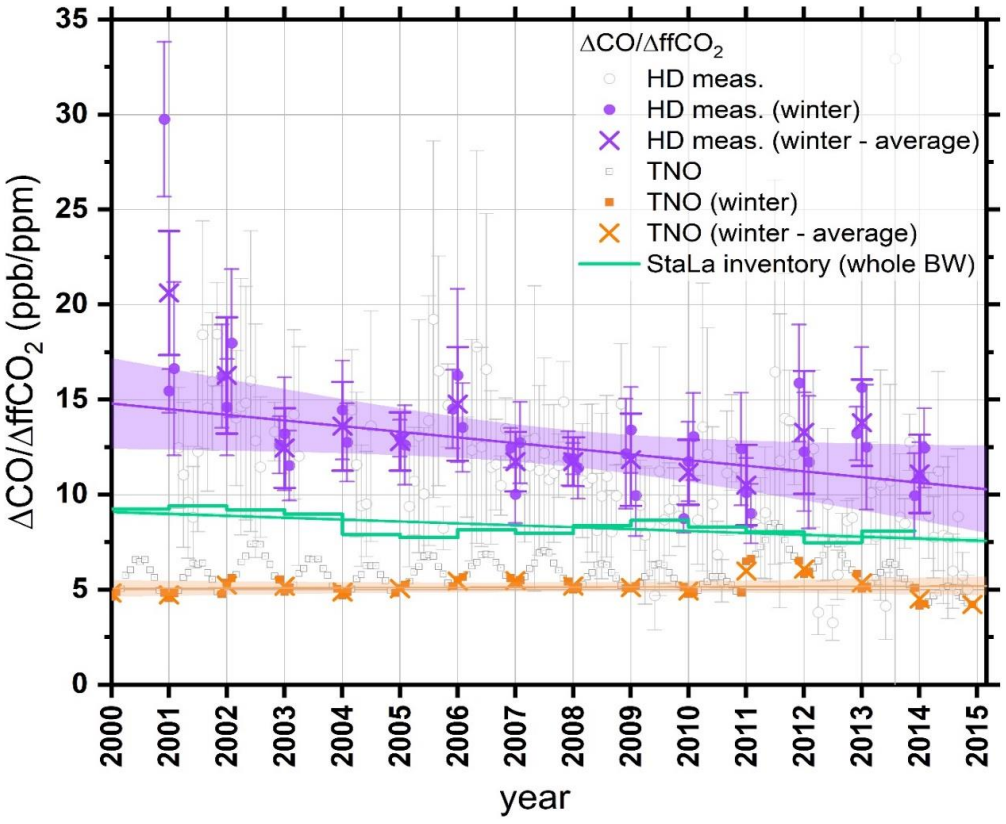
EVALUATION OF HISTORIC ΔCO/ΔFFCO$_2$ RATIOS FOR THE HEIDELBERG REGION



- 15 year data set
- use regional CO enhancements as proxy for ffCO$_2$
- ΔCO/ΔffCO$_2$ ratio is decreasing due to improved combustion efficiency
- larger uncertainties in summer due to small ΔffCO$_2$ enhancements

UHEI - Claudius Rosendahl

EVALUATION OF HISTORIC ΔCO/ΔFFCO$_2$ RATIOS FOR THE HEIDELBERG REGION



- smaller uncertainties in winter
- significant offset between measured and statistical ratio
- little to no trend in statistic ratios
- tested reasons for disagreement:
  1. choice of background
  2. no power plant ffCO$_2$ signal measured
  3. non-fossil CO sources

  non can explain the magnitude of disagreement

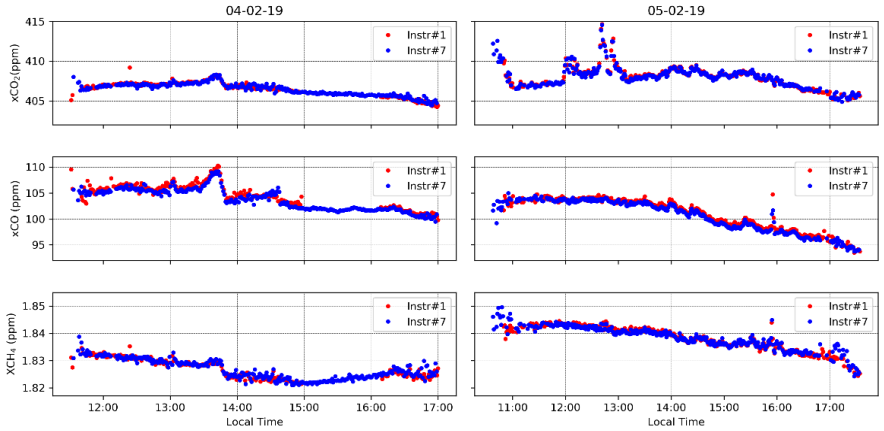
Work done at KIT until now:

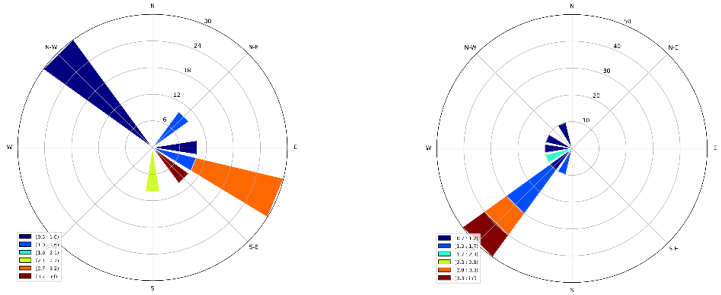
During the last months several activities had been carried out at KIT:

- Adaptation of EM27/SUN instrument and operating software
- Regular measurements with TCCON spectrometer and EM27/SUN spectrometers at Karlsruhe
- Installation and testing of pre-processing and retrieval software
- Laboratory measurements and characterization of Instrument Line Shape (ILS) for several spectrometers by using LINEFIT. Calibration of portable EM27/SUN spectrometers wrt TCCON reference spectrometer operated at KIT.
- Analysis of first results (spectral retrieval).
  - EM27/SUN: Analysis and comparison of the measurements carried out at KIT.
  - MAX-DOAS: 2 years of measurements (from February 2017 to December 2018) are still in the analysis process. This dataset were provided by Dr. Udo Frieß, which is the MAX-DOAS expert from the Institute of Environmental Physics (IUP) at the University of Heidelberg.

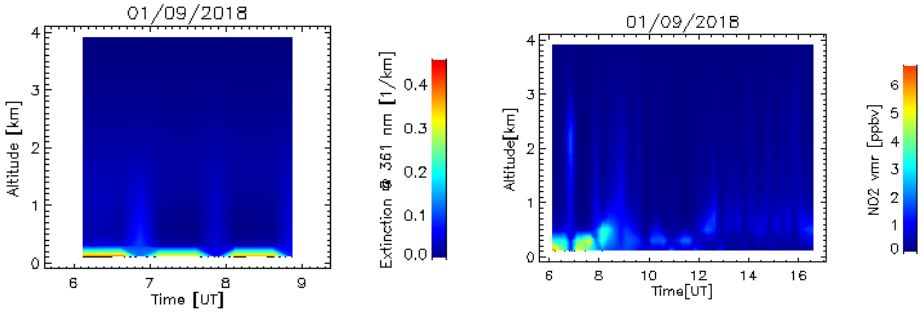
EXAMPLES OF GREENHOUSE GASES ABUNDANCES RETRIEVED

FTIR retrieval of total column of CO_2, CO and CH_4





MAX-DOAS vertical profile retrieval of NO_2 and aerosols



Both profiles are typical results for a mostly sunny day.

Clear enhancements in the three species on 04th of February 2019 which could be related to emissions and transport events.

OUTLOOK YEAR 2 - OBSERVATIONAL DATA CASE STUDY RHINE VALLEY (UHEI & KIT)

UHEI:

- **Installation of the NO_x in-situ analyser at KIT station**
- **Evaluation of seasonal cycle in $NO_x/ffCO_2$ and $\delta CO/ffCO_2$ ratios based on ^{14}C measurements**
- **In depth evaluation of the CO and NO_x surrogate tracer system for $ffCO_2$**
- **Joint interpretation between in-situ and total-column data collected at KIT**
- **Implementation of modelling capacities for the Rhine-valley in cooperation with MPI Jena**

KIT

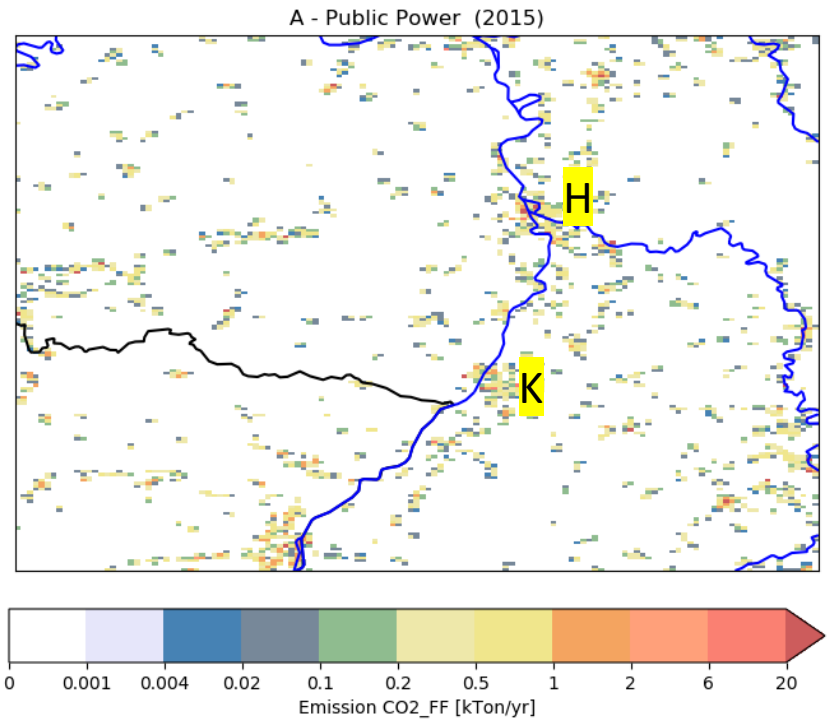
- **FITR and UV-VIS measurements at different locations in the Rhine Valley**
- **Installation/Set up of a MAX-DOAS instrument at KIT Campus North**
- **Evaluation of the temporal variations of proxy/$ffCO_2$ ratios**
- **The seasonal, synoptic and diurnal changes in proxy/$ffCO_2$ ratios will be studied at the ICOS monitoring station in Karlsruhe for at least 12 months using in-situ instrumentation for CO_2, CO, NO_2 and $^{14}CO_2$ spot samples.**
- **In parallel we will also collect ground-based total-column measurements of CO_2, CO, NO_2 and HCHO.**

Essential for evaluating the (inverse) model performance in year 3-4

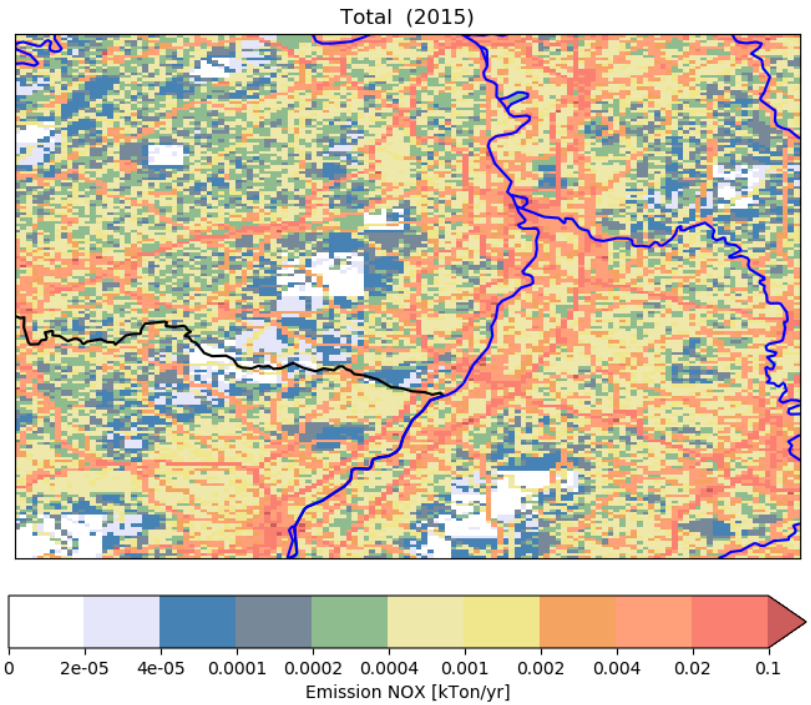
T2.1.4 Case study region contribution to emission data and analysis

1 x 1 km 2015 data for Rhine valley - *under construction*

CO_2 only power generation



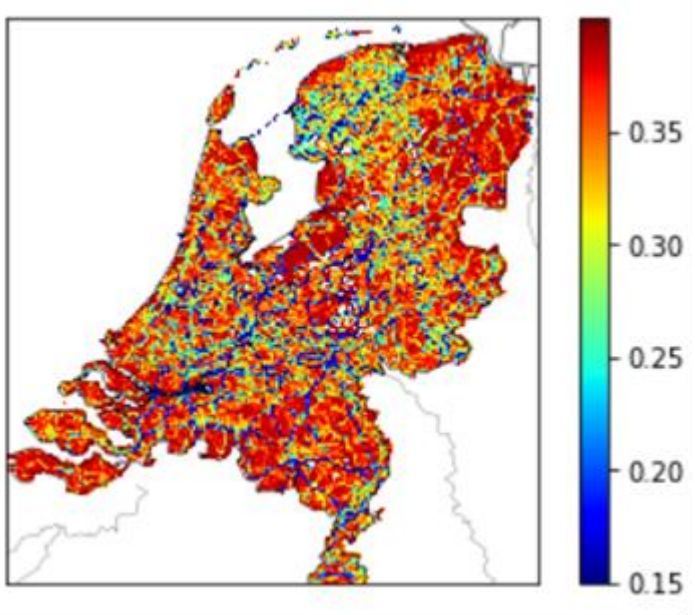
NOx (all sources)



- Few corrections needed (ready April 2019; moves task T2.1.4 forward)
- Use this base map to add uncertainties

T2.3.1 Uncertainty analysis with the emission model to define the optimization strategy

- Draft uncertainty framework is developed
- Uncertainties in emission model parameters are translated to uncertainties in emissions using a Monte Carlo simulation

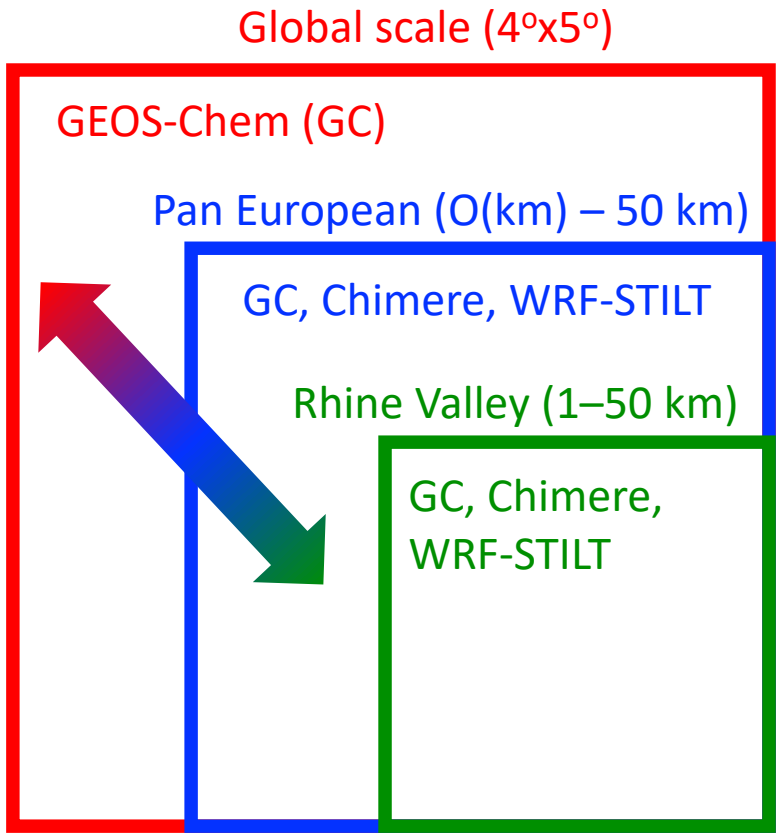


Relatively uncertainty in CO2 emission per pixel

WU/TNO

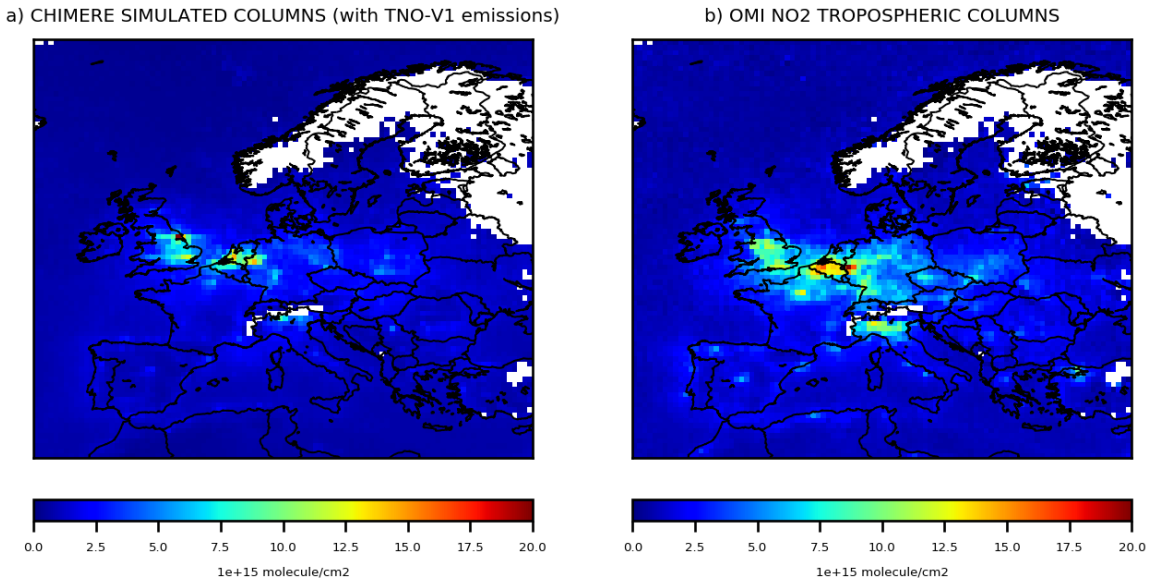
T2.3 Annual to weekly budgets and trends of ffCO2 emissions at the national scale across Europe using CO and NOx satellite measurements

- Model system and configuration document to define experiments
  - Uses VERIFY emissions (WP2 and WP3)
  - Consistent output
  - https://goo.gl/LyhKja
- Three models:
  - GEOS-Chem (UEDIN)
  - Chimere (LSCE)
  - WRF-STILT/OPS (WU)
- Three resolutions:
  - Global (BCs)
  - Pan-Europe (consistent with CHE)
  - Rhine Valley simulation



T2.3.2 PROCESSING OF CO/NO2 DATA AND SIMULATIONS WITH A REGIONAL CHEMISTRY TRANSPORT MODEL

- ✓ Treatment of the OMI QA4ECV tropospheric columns for the period 2005-2017
- ✓ Interpolation of the TNO-v1 NO_x emissions to the 0.5° x0.5° grid of CHIMERE
- ✓ Direct simulations with CHIMERE, taking into account the new TNO-v1 emissions and the averaging kernels of the OMI QA4ECV data



Note – similar work for the MOPITTv7-NIR-TIR CO

Monthly mean of NO_2 tropospheric columns a) simulated by CHIMERE with TNO-v1 emissions and b) observed by OMI, for the month of March 2012, in 1^e15 molec.cm^{-2}

T2.3.4 FAST TRACK INVERSION OF THE EMISSIONS IN EUROPE AND IN CHINA

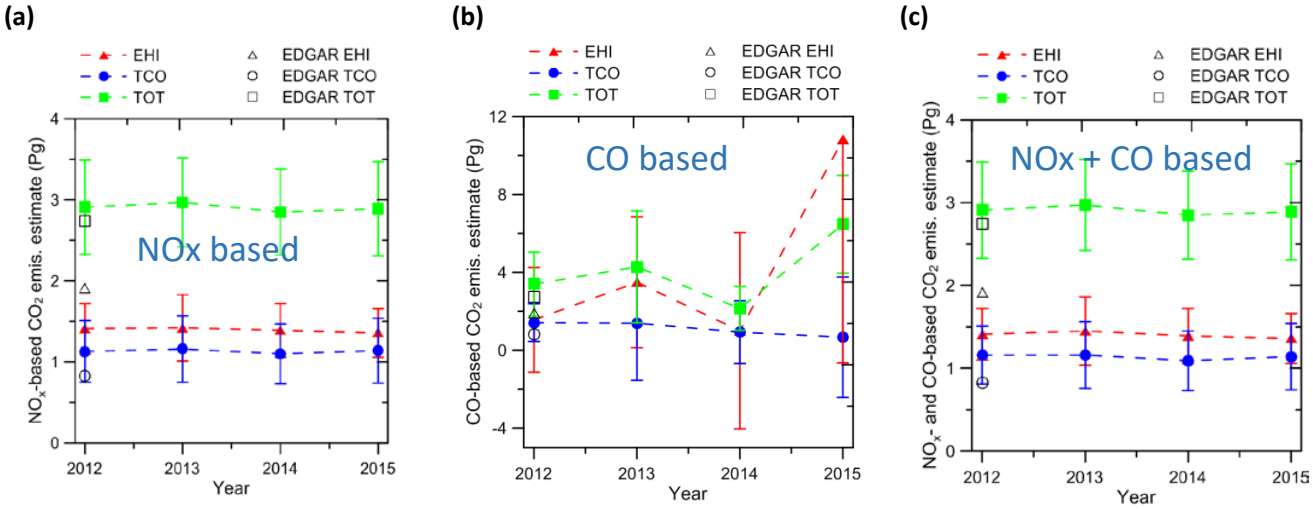


Figure 2. Hybrid estimates of the annual fossil-fuel CO_2 emissions from the study region in comparison with the data of the EDGARv.4.3.2 inventory. The hybrid estimates are based on either (a) only OMI NO_2 measurements, (b) only IASI CO measurements or (c) both NO_2 and CO satellite measurements.

- Conversion of the CO and NOx sectoral emission budgets into CO2 sectoral emission budgets using emission ratios in EDGAR
- Inversions based on CO satellite data only: too uncertain
- Inversions based on NO2 satellite data vs. EDGAR in 2012: significant deviation of the sectoral budgets, consistency for the total CO2 budget.

Note Sector split: EHI (Energy, Heat, heavy Industry) and TCO (Transport, Chemical industry, Others)

Main differences in two assimilation systems

ULUND
Coupled carbon cycle fossil fuel data assimilation system (CCFFDAS)

- More observables to constrain the biosphere
- Spatially explicit FF proxies (e.g. nightlights)
- 4D-Var system with one long assimilation window

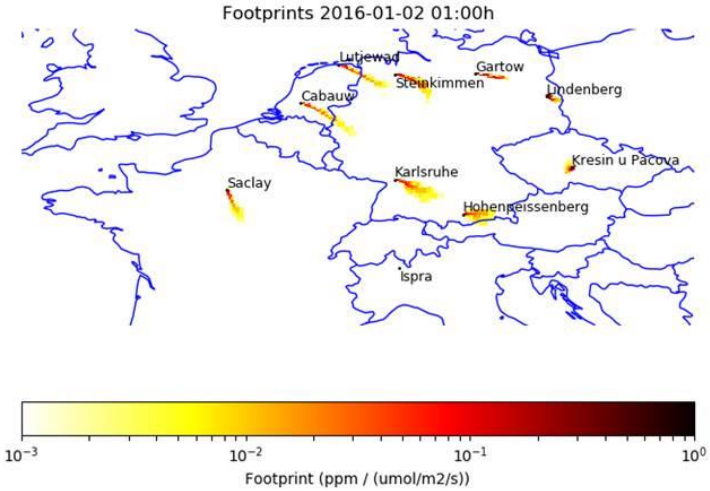
WU
carbon cycle data assimilation system (CTDAS)

- More atmospheric tracers and tracer ratios
- Smaller scale models handling plume dispersion
- Ensemble Kalman filtering in a time-stepping scheme.

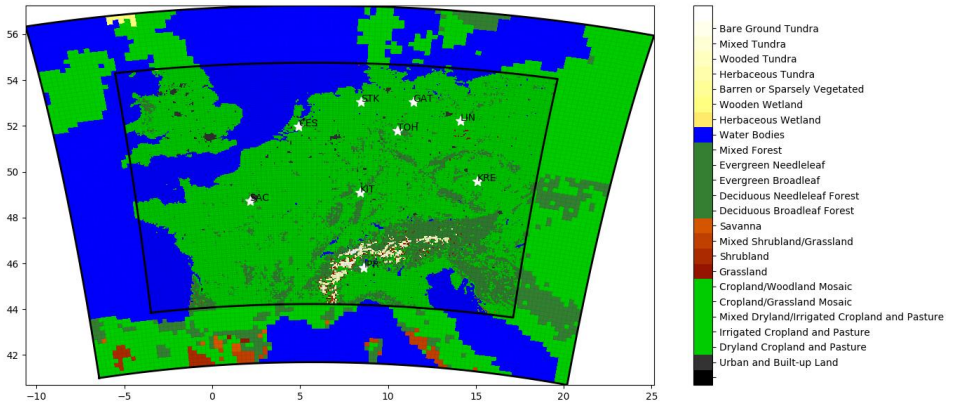
M12-48 Application of regional $\Delta^{14}C$-CO_2 modeling system to Rhine Valley test region /System being prepared within RINGO

VERIFY- WU lead on task, partners (UEDIN, CEA-LSCE, UHEI, MPG) will be activated

ICOS sites + footprints within inner-RINGO domain (T2.4.3)



WRF-CHEM modeling domain inner region = 1x1 km²



WP2 – VERIFICATION METHODS FOR CO2_FF EMISSIONS

Difficulties and actions taken

- Finding suitable candidates at UEDIN
  - Continue recruitment cycle
- Promote pan-WP2 activities.
  - Year 1 has focused on building blocks; year 2 will (need to) develop cross-WP2 activities
  - We need opportunities for researchers to present within WP context – if no space at GA – when?
- Promote cross WP2:WP3 activities (& WP2:WP1?)
  - Easier to engage with WP3 once certain WP2 components have been developed in year 2

Thank you for your attention.