AVENGERS

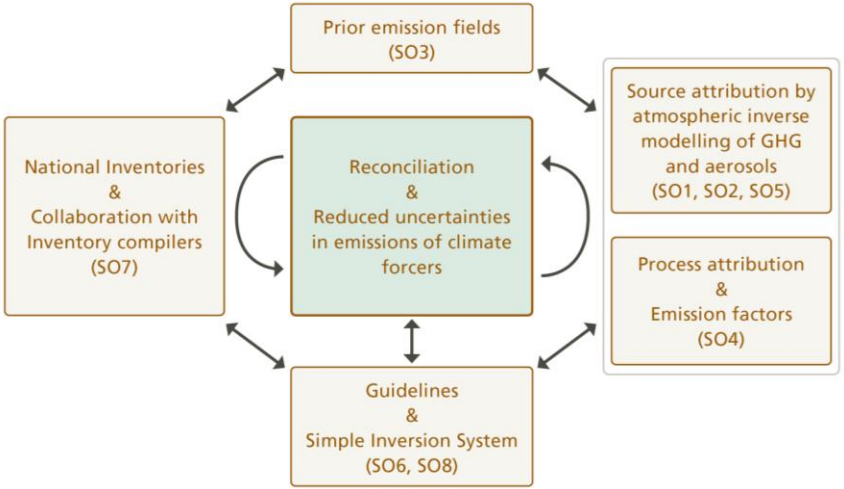
Attributing and **V**erifying **E**uropean and **N**ational **G**reenhouse gas and aerosol **E**missions and **R**econciliation with **S**tatistical bottom-up estimates

Part. No.	Participant organisation name	Country
1 Coordinator	LUNDS UNIVERSITET (ULUND)	Sweden
2	THE INVERSION LAB (iLab)	Germany
3	ISPRA	Italy
4	RIVM	The Netherlands
5	UNIVERSITAET HEIDELBERG (UHEI)	Germany
6	CMCC	Italy
7	TNO	The Netherlands
8	ICOS ERIC	Finland
9	UMWELTBUNDESAMT (UBA)	Germany
10	SVERIGES LANTBRUKS-UNIVERSITET (SLU)	Sweden
11	EMPA	Switzerland
12	SRON	The Netherlands
13 Co-Coordinator	STICHTING VU (VUA)	The Netherlands

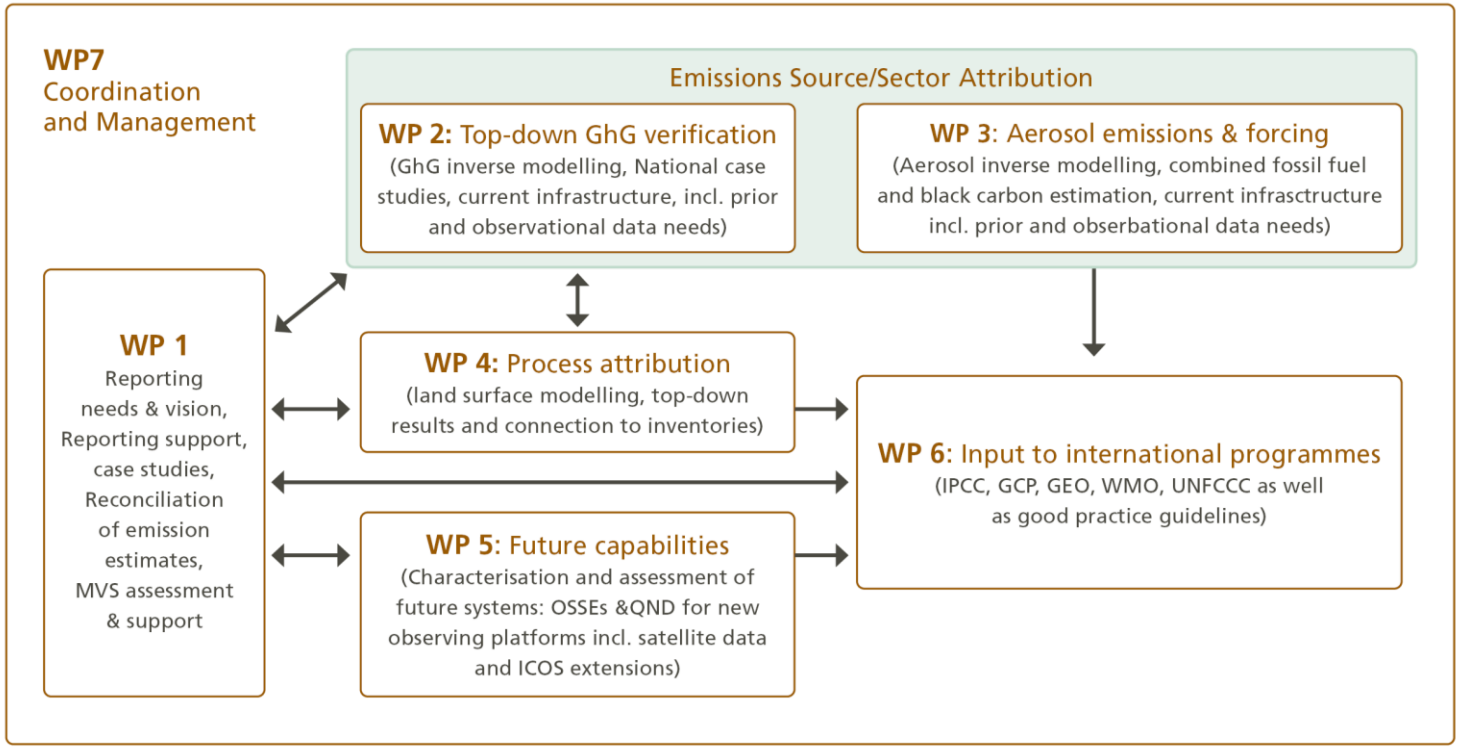
Advisory Board: M. Dowell (JRC), P. Friedlingstein (U Exeter) & S. Mikaloff-Fletcher (NIWA)

Objective

To reconcile reported GHG emissions with independent information from atmospheric observations using top-down methods and process-based models, aiming at reducing the most important uncertainties of national emission inventories



Project Structure



Focus regions (case studies)

- AFOLU sector
  - Forestry: Sweden
  - Agricultural land use: Italy & The Netherlands
- Germany: largest economy in EU, UBA partner
- Switzerland: front-runner of top-down aided emission reporting
- EU+UK: GhG and aerosol (pre-cursor) emissions of SO_2, OC (organic carbon), and BC (black carbon) and their uncertain

Some science highlights…

- Multi-tracer atmospheric inversion systems for GHG and aerosol emissions estimation
  - Co-emitted species (NO_2,$^{14}CO_2$, δ13C, δD, alkanes)
  - Joint Black Carbon-CO_2 inversions
- Coupled fossil fuel carbon cycle data assimilation
- Evaluation of future infrastructures: OSSEs and QND studies (e.g. PRISMA, EnMAP, CO2Imager, CO2M, ICOS extension)
- Emission factor quantification for GHG flux estimation in the AFOLU sector using process-based DGVMs (ORCHIDEE, LPJ-GUESS)
- Comparison of GHG and aerosol radiative forcing

Name	Model	DA method	Application	Reference
CCFFDAS	TM3/CMAQ	4D-VAR	CO_2	Kaminski et al. (2022)
ICON-ART-CTDAS*	ICON	EnKF	CO_2, CH_4, N_2O	Schröter et al. (2018)
LOTOS-Euros	LOTOS-Euros	4D-VAR, EnKF	CH_4, N_2O#, aerosols	Jin et al. (2017)
LUMIA	TM5/Flexpart	4D-VAR	CO_2, CH_4, aerosols & BC#	Monteil and Scholze, (2021)
WRF-CTDAS*	WRF-Chem	EnKF	CO_2, CH_4, N_2O#	Dekker et al. (2019)
TRACE	WRF-Chem	EnKF	CO_2	Chen et al. (2019)

Expected results (some highlights…)

- **Good practice guidelines** on how top-down emission estimation systems can support GHG inventories and the Global Stocktake.
- **A Flexible Inversion Tool for Inventory Compiler** for demonstrating the strengths and weaknesses in estimating GHG emissions, made available to national inventory compilers incl training events.
- **Observation-based estimates of GHG (CO_2, CH_4, N_2O) and aerosol emissions and their uncertainties** for European countries (with a specific focus on Germany, The Netherlands, Sweden and Switzerland such that they can **be used as input in the respective GHG inventories)**.
- **Improved estimates of uncertain emission factors** used in the inventories, based on process modelling in ORCHIDEE and LPJ-GUESS of Sweden and Italy for the AFOLU sector.
- Estimates of the **climate impact of national emissions in terms of radiative forcing** taking into account the **radiative impact of aerosols and GHGs**.
- An **evaluation of future observing systems (both satellite and in-situ)** in terms of their **potential to further reduce uncertainties** in the estimated GHG and aerosol emissions and corresponding guidelines on the design of the networks.