The Community Inversion Framework:

a unified atmospheric inversion platform to support standardized GHG monitoring systems

Antoine Berchet[1], Rona Thompson[2], Isabelle Pison[1], Espen Sollum[2], Joël Thanwerdas[1], Grégoire Broquet[1], Dominik Brunner[3], Frédéric Chevallier[1], Philippe Peylin[1], Marielle Saunois[1], Jean-Matthieu Haussaire[3], Jacob van Peet[4,7], Sander Houwelling[4], Élise Potier[1], Audrey Fortems-Cheiney[1], Robin Plauchu[1], Massaer Kouyate[1], Lionel Constantin[3], Friedemann Reum[5], Aki Tsuruta[6], Arjo Segers[7], Eldho Elias[8], Christoph Gerbig[8], Saqr Munas[8].
[1]LSCE, France, [2]NILU, Norway, [3]Empa, Switzerland, [4]VU Amsterdam, the Netherlands, [5]DLR, Germany, [6]FMI, Finland, [7]TNO, the Netherlands, [8]MPI-Jena, Germany. Contact: **antoine.berchet@lsce.ipsl.fr**

1. Context & objectives

a. Future operational and research needs

➥ new types of data (e.g., high resolution satellites) to be integrated as soon as possible when released
➥ design of operational systems for GHG monitoring for implementing the Paris agreement (e.g., Global Stocktake)
➥ coupling global-regional or regional-local scale models, or using CC-FF-DAS approach to track and explain GHG flux variability
➠ multi-species / -models / -scales / -methods systems

b. The CIF as a standard and flexible platform

➢ rationalize development efforts within the community
➢ foster cross-compatibility and inter-comparability of inversion systems
➢ ensure quality control with better traceability and transparency
➢ open the way towards operational systems

2. Current status

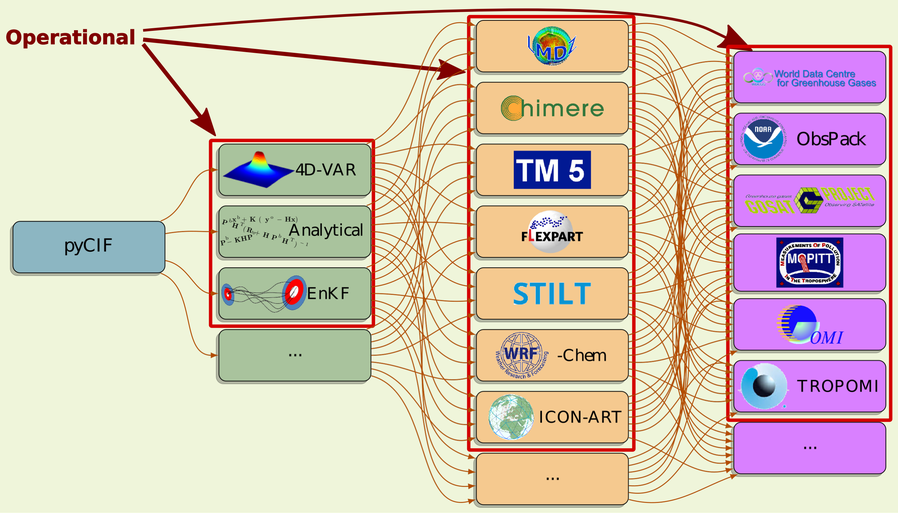
✓ **python-based framework fully defined:**
- ➢ classes for inversion blocks defined
- ➢ recursive interaction between classes functional
- ➢ python installer distributed with the code

✓ **code accessible to anyone:**
- ➢ gitlab server hosted by NILU
- ➢ documentation of main features, user and developper tutorials on-line
- ➢ test cases distributed to get familiar with the system

✓ **several running modes implemented:**
- ↪ forward simulations
- ↪ footprints
- ↪ test of the adjoint
- ↪ variational inversions
- ↪ ensembles, EnKF
- ↪ analytical inversions

✓ **transport models plugged to the CIF:** see below

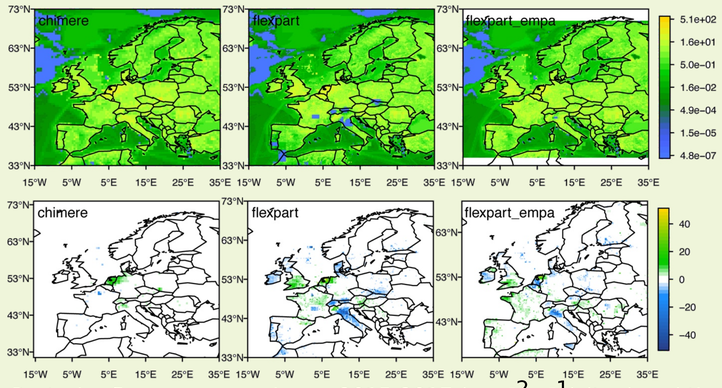
✓ **numerous functionalities implemented:**
- ↪ satellite and surface observations
- ↪ temporal and spatial covariances
- ↪ automatic spatial and temporal reprojection



3. Applications so far

a. GHG regional inversions based on surface measurements

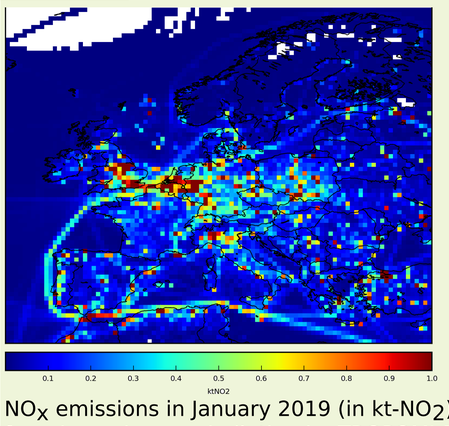
➢ CH_4 and N_2O inversions in Europe with FLEXPART and CHIMERE in VERIFY from 2006 to 2018.
➢ CO_2 biogenic flux inversions in Europe with CHIMERE from 2005 to 2020 (shared in VERIFY and RECCAP2).



Posterior fluxes averaged over 2015-2017 (g m^{-2} y^{-1}) (top) and the flux increments (g m^{-2} y^{-1}). From VERIFY D4.10 (2022).

b. Regional inversions based on satellite measurements

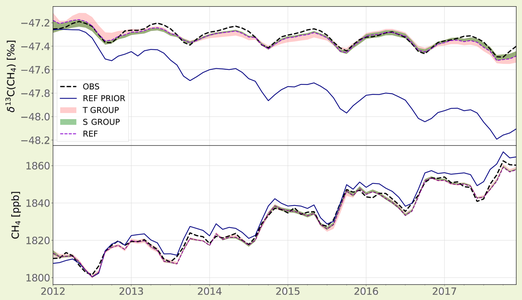
➢ CH_4 inversions in Europe using TROPOMI data with CHIMERE
➢ NO_x/CO/CO_2 anthropogenic and biogenic inversions at the regional (Europe, China) and national (French) scales in-situ and satellite data (MOPITT, OMI, TROPOMI)
➢ OSSEs for CO_2 flux inversions including pseudo CO_2M retrievals



NO_X emissions in January 2019 (in kt-NO_2) from inversions assimilating by TROPOMI-PAL

c. Other applications

➢ CH_4 global inversions with LMDZ using isotopes
➢ pre-processing of inputs (emissions: TNO, EDGAR, Carbon Monitor, etc.; observations: WDCGG, ObsPack, etc.; fields: CAMS, IFS, etc.)



Global monthly $\delta^{13}C(CH_4)$ and CH_4 means between 2012 and 2017. The 'REF' line represents the prior simulations. The use of isotopic data in the inversion allows to fix the drift of isotopic simulations.

4. Next steps

➢ Further support for use in various groups
➢ Extend further models compatible with CIF
➢ Improve the documentation and tutorials

➢ Detailed inter-comparison of inversions with various models in an identical set-up within CIF: test case in Europe with CO_2, CH_4 and N_2O and surface observations
➢ Deployment for pre-operational applications (e.g., CAMS flux estimates)
➢ Couple transport models at different scales to design efficient zooms on target areas
➢ Couple transport models with process models to optimize underlying parameters beyond fluxes

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5. References

➢ Berchet et al., The Community Inversion Framework v1.0: a unified system for atmospheric inversion studies, Geosci. Model Dev., 14, 5331–5354, https://doi.org/10.5194/gmd-14-5331-2021, 2021.
➢ Potier et al., Complementing XCO_2 imagery with ground-based CO_2 and $^{14}CO_2$ measurements to monitor CO_2 emissions from fossil fuels on a regional to local scale, Atmos. Meas. Tech., https://doi.org/10.5194/amt-2022-48, 2022.
➢ Thanwerdas et al, Variational inverse modeling within the Community Inversion Framework v1.1 to assimilate $\delta^{13}C(CH_4)$ and CH_4: a case study with model LMDz-SACS, Geosci. Model Dev., 15, 4831–4851, https://doi.org/10.5194/gmd-15-4831-2022, 2022.
➢ Public deliverables from H2020 project VERIFY (D4.10, D2.11 and D2.12): https://verify.lsce.ipsl.fr/index.php/repository/public-deliverables/

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