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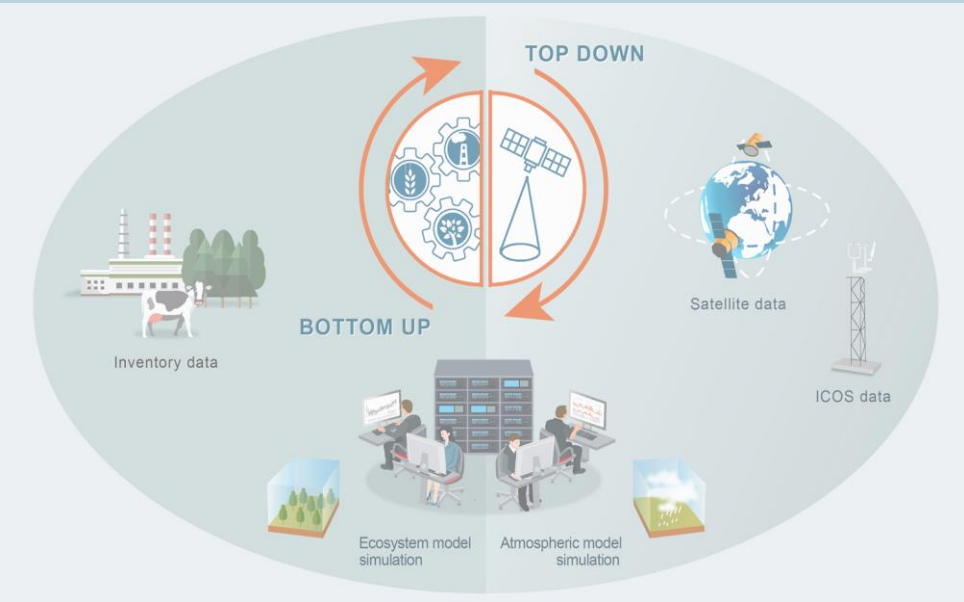
WP4 - Peter Bergamaschi (JRC), Arjo Segers (JRC, TNO), Dominik Brunner & Jean-Matthieu Haussaire (EMPA)

High-resolution inverse modelling of European CH_4 emissions



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  "CH4 fluxes at very high resolution"
- Bergamaschi et al., *"High-resolution inverse modelling of European CH_4 emissions using novel FLEXPART-COSMO TM5 4DVAR inverse modelling system"*,
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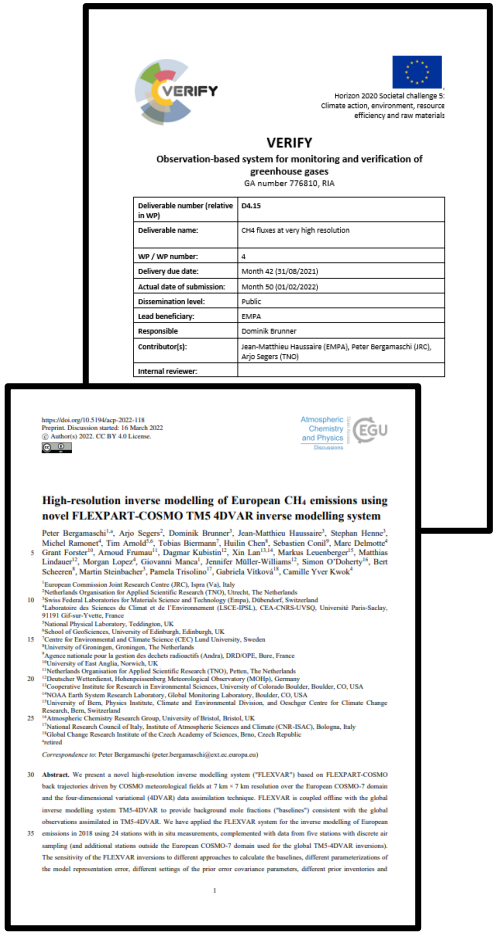

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Horizon 2020 Societal challenge 5: Climate action, environment, resource efficiency and raw materials

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Observation-based system for monitoring and verification of greenhouse gases

GA number 776810, RIA

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Atmospheric Chemistry and Physics Discussions

High-resolution inverse modelling of European CH_4 emissions using novel FLEXPART-COSMO TM5 4DVAR inverse modelling system

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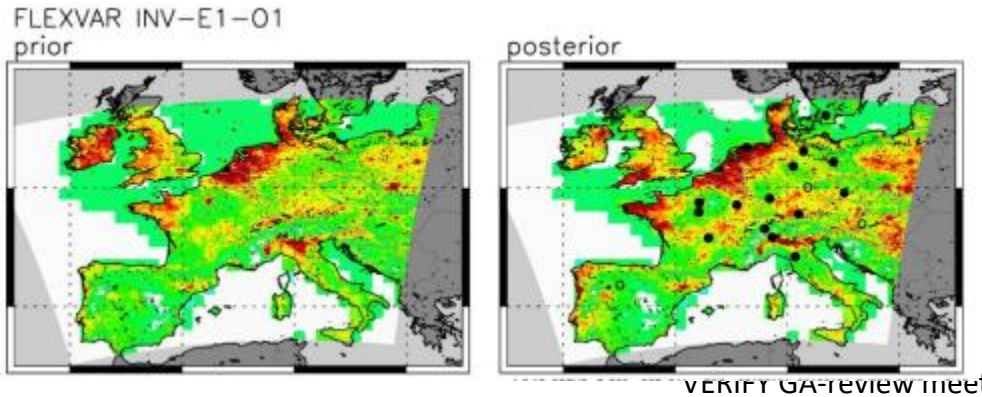
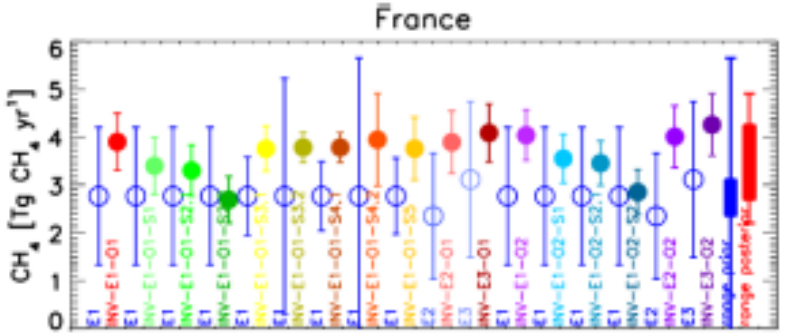
Abstract. We present a novel high-resolution inverse modelling system ("FLEXVAR") based on FLEXPART-COSMO back trajectories driven by COSMO meteorological fields at 7 km × 7 km resolution over the European COSMO-7 domain and the four-dimensional variational (4DVAR) data assimilation technique. FLEXVAR is coupled offline with the global inverse modelling system TM5-4DVAR to provide background mole fractions ("baselines") consistent with the global observations assimilated in TM5-4DVAR. We have applied the FLEXVAR system for the inverse modelling of European emissions in 2018 using 24 stations with in situ measurements, complemented with data from five stations with discrete air sampling (and additional stations outside the European COSMO-7 domain used for the global TM5-4DVAR inversions). The sensitivity of the FLEXVAR inversions to different approaches to calculate the baselines, different parameterizations of the model representation error, different settings of the prior error covariance parameters, different prior inventories and

FLEXVAR inversions

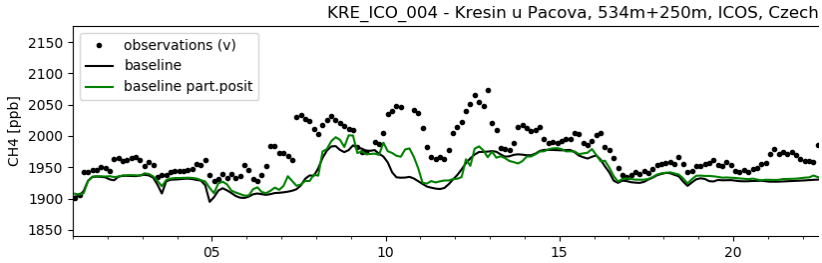
- Inversion of European CH4 emissions
  - 2018, at 7x7 km resolution
  - 4DVAR technique that combines:
    - surface observations
    - FLEXPART-COSMO back-trajectories
  - provides estimates of uncertainty
  - evaluated sensitivity to emissions, errors, …
  - compared to other inversions

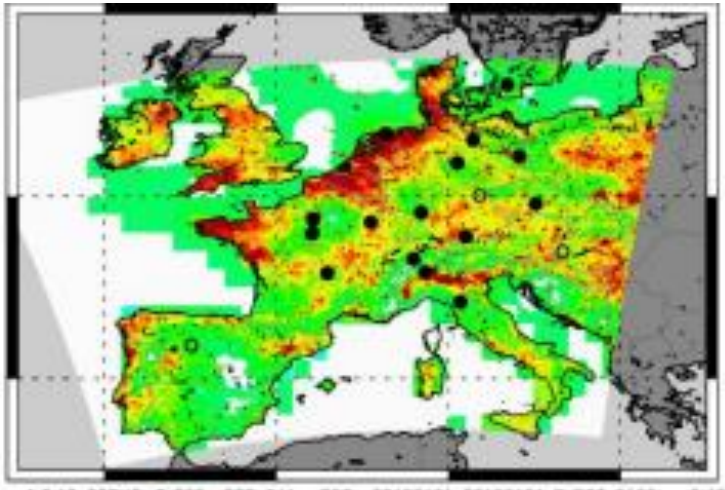


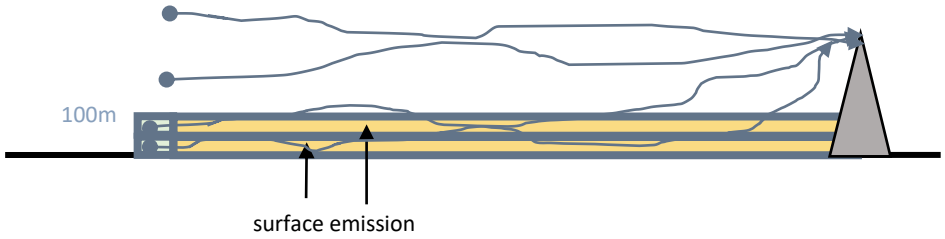


FLEXVAR inversions

- Ingredients for regional inversions:
  - timeseries of CH_4 from 24 sites
  - FLEXPART back-trajectories from sampling locations (10k particles) based on COSMO meteo
  - boundary conditions from global CAMS inversion
  - *apriori* emissions + uncertainty
  - simulation model + uncertainty
  - 4D-var optimizer



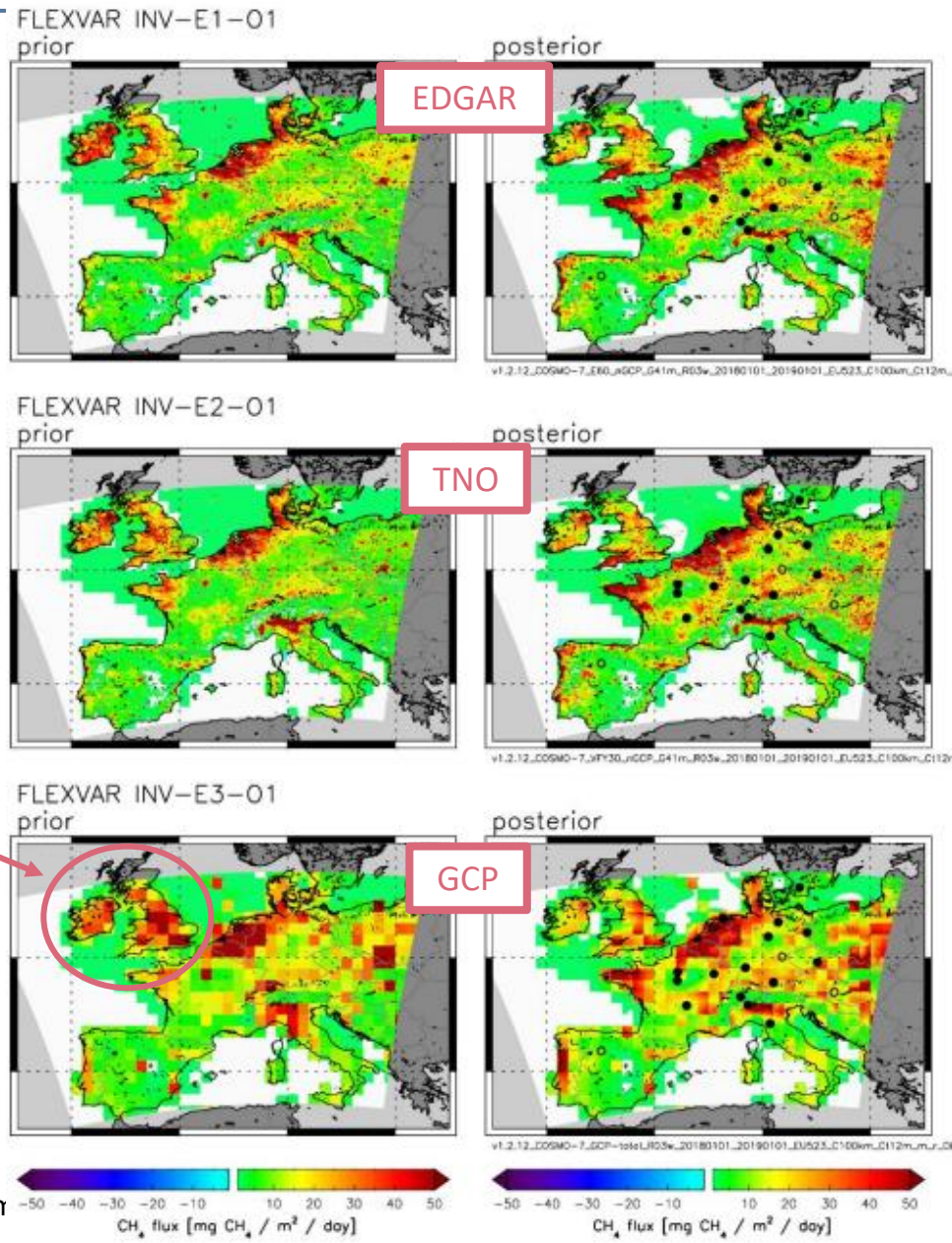




$$J(x) = \frac{1}{2}(x - x_b)^T \mathbf{B}^{-1}(x - x_b) + \frac{1}{2}(H(x) - y)^T \mathbf{R}^{-1}(H(x) - y)$$

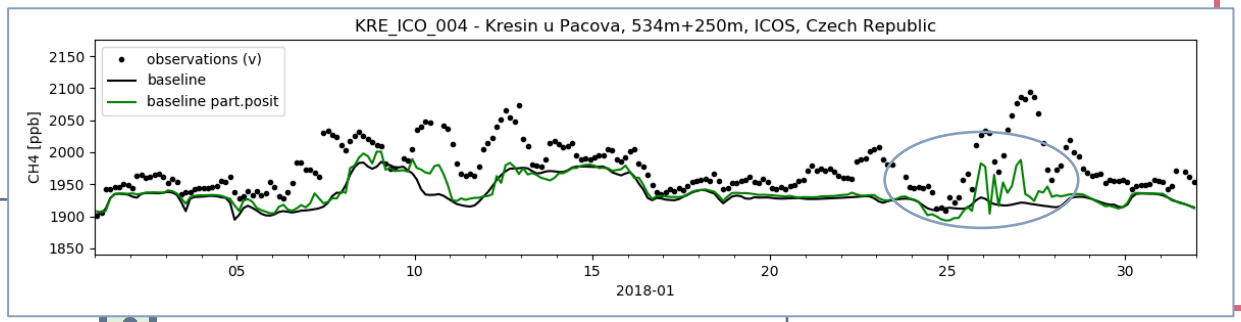
FLEXVAR inversions - sensitivities

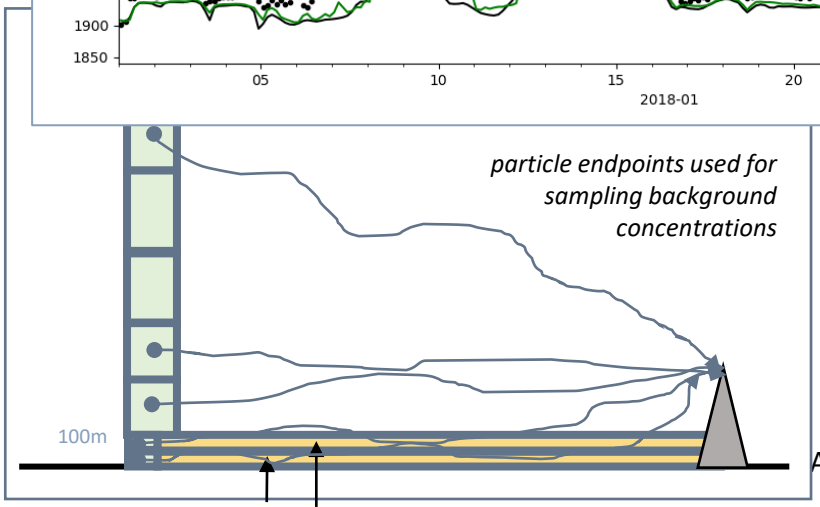
- *a priori* emissions
  - inventories:
    - EDGAR v6.0
    - TNO "VERIFY"
    - GCP
    - …
  - in country totals sometimes large differences
  - … but *posterior* emissions rather similar

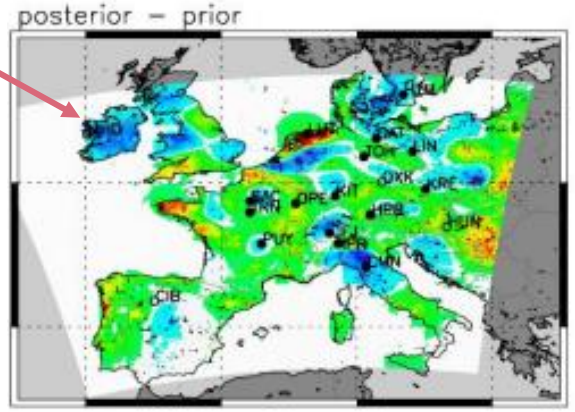


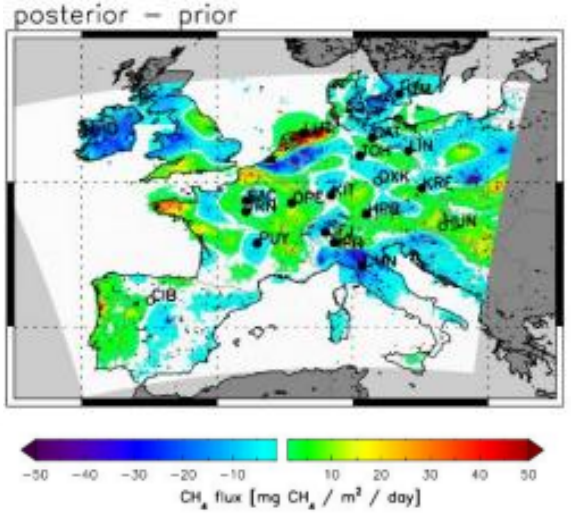
FLEXVAR inversions - sensitivities

- boundaries based on global inversion:
  - remove global "baseline" concentrations from observations:
    - simulations following Rödenbeck approach
    - .. or sample at endpoints of trajectories
  - similar changes in emission pattern, Rödenbeck better under "background" conditions?



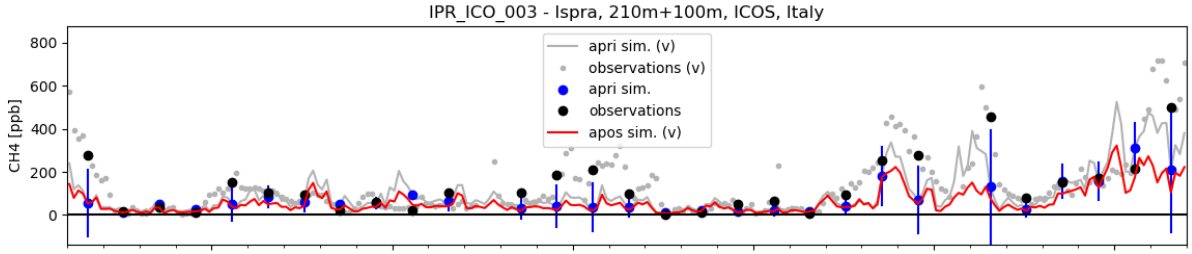


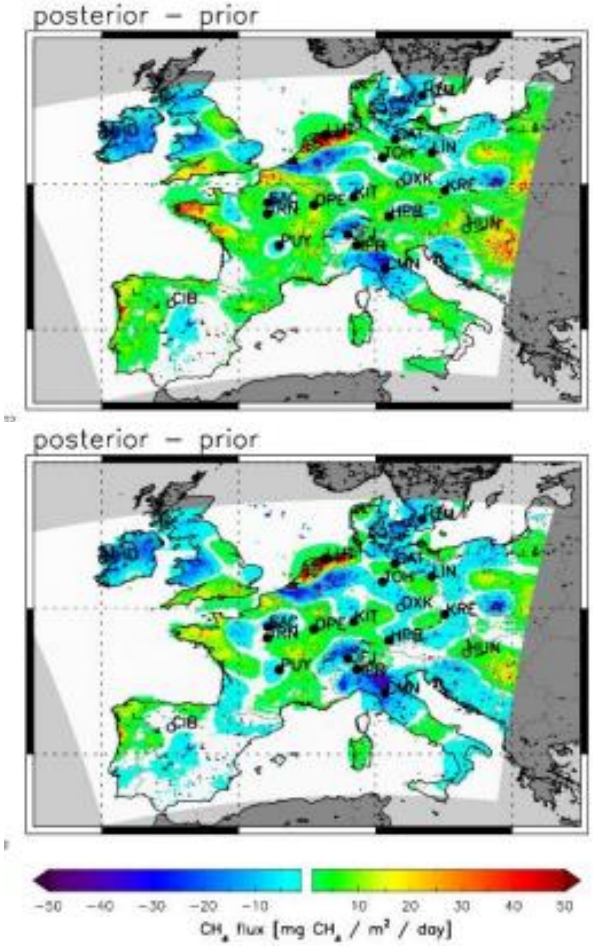




FLEXVAR inversions - sensitivities

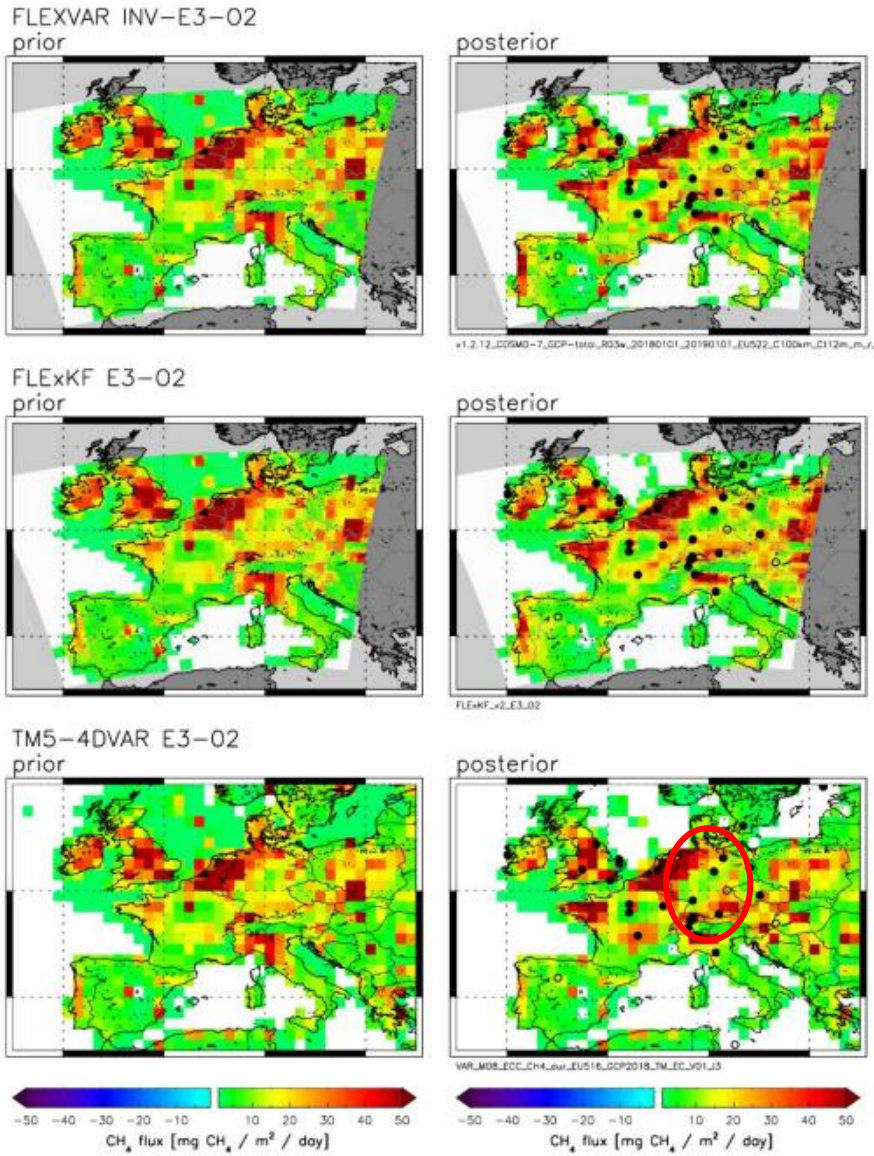
- observation representation error
  - weight of observation in inversion:
    - based on meteorological conditions
    - … or based on observeration-minus -simulation statistics
  - using meteorological conditions, more equal weight of observations, and better *a posterior* correlation with observations





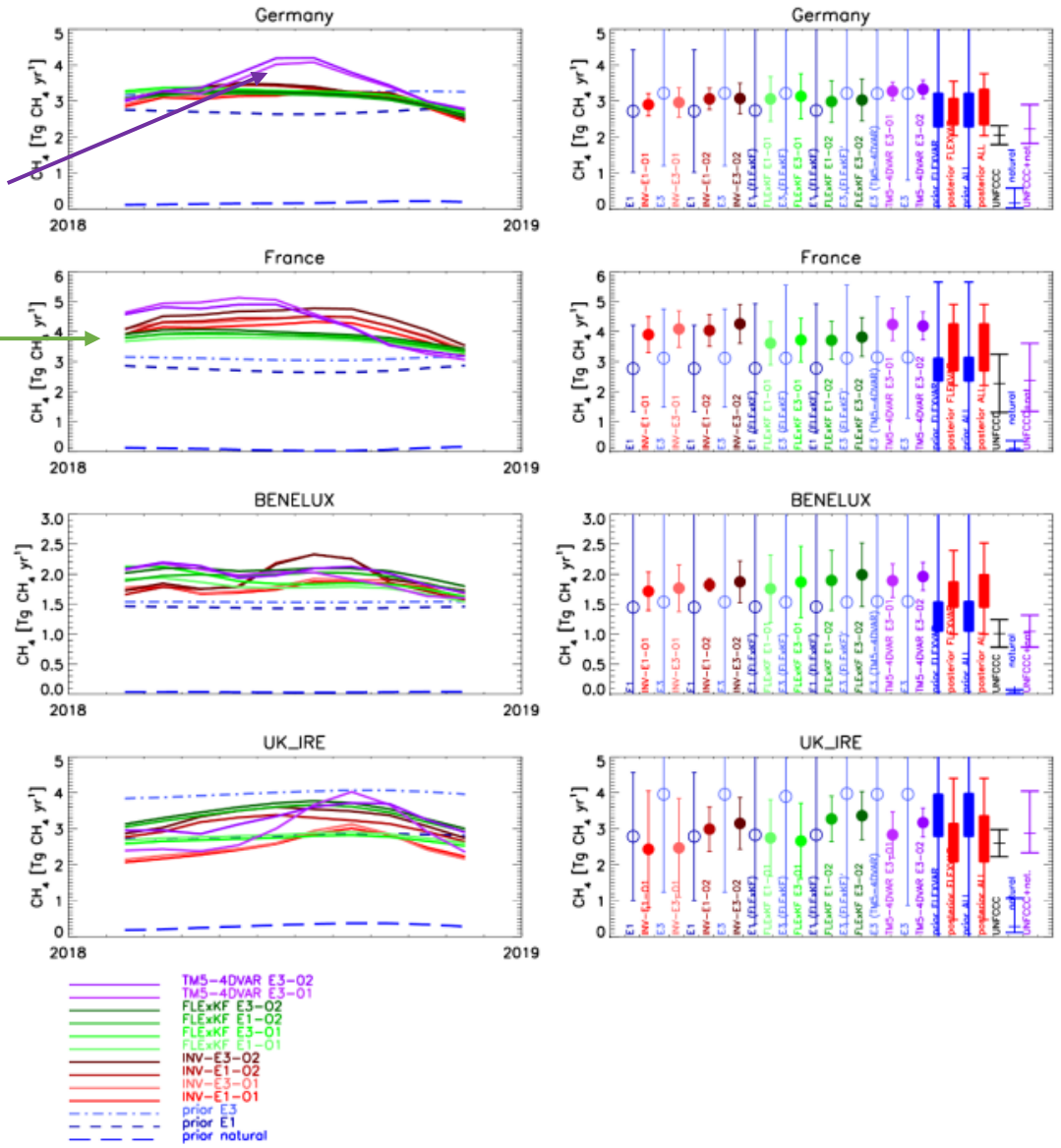
FLEXVAR inversions - inter comparison

- inter comparison:
  - FLExKF
    - same model (FLEXPART)
    - Extended Kalman Filter
  - TM5-4DVAR
    - model on 1x1 deg
    - similar inversion system
  - overall consistent *posterior* emissions and changes
  - moderate differences at country level, but within range of sensitivity runs



FLEXVAR inversions - country totals

- Estimated country emissions:
  - Germany: higher estimate by TM5-TM5-4DVAR (1x1 deg ..)
  - France: lower estimate by FLExKF, less variation
- Compared to UNFCCC:
  - higher emissions estimated for Germany, France, and BeNeLux; but uncertainty ranges overlap
  - smallest difference for UK+Ire



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