French NO_X emissions as estimated from TROPOMI-PAL NO_2 observations

R. Plauchu[1], A. Fortems-Cheiney[1], G. Broquet[1], I. Pison[1], A. Berchet[1], E. Potier[1], A. Coman[2], D. Savas[2] and G. Dufour[2]

Contact: robin.plauchu@lsce.ipsl.fr

[1]Laboratoire des Sciences du Climat et de l'Environnement, LSCE-IPSL (CEA-CNRS-UVSQ), Université Paris-Saclay, 91191 Gif-sur-Yvette, France.

[2]Laboratoire Interuniversitaire des Systèmes Atmosphériques, LISA-IPSL (CNRS), Université Paris-Est Créteil and Université de Paris, 94010 Créteil, France.

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ARGONAUT

PollutAnts and Greenhouse Gases EmissiOns MoNitoring from SpAce at high ResolUTion

Introduction

ANR ARGONAUT: monitoring French GHG and pollutants emissions at high resolution from space

- A configuration to improve implementation of observation and control vectors to strengthen robustness of inversion
- Evaluation of TROPOMI-PAL observations potential to quantify emissions at national to local scale and at annual to monthly scale based on analysis of the reference inversions for years 2019 and 2020 (and part of 2021)
- Focus on differences found between emission estimates and inventory for spring 2020 and 2019 to assess impact of covid-19 pandemic and limitations

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NO_X variational inversions using CIF[1]-CHIMERE

Prior fluxes

NO_X anthropogenic emissions: CITEPA/INERIS INS (2012)

NO_X biogenic emissions: MEGAN

Model

Regional CTM CHIMERE: 0.1°x 0.1°x 20 vertical levels

MELCHIOR-2 gaseous chemistry

Adjoint of CHIMERE: with adjoint of chemistry

ECMWF meteorological fields

Obser-vations

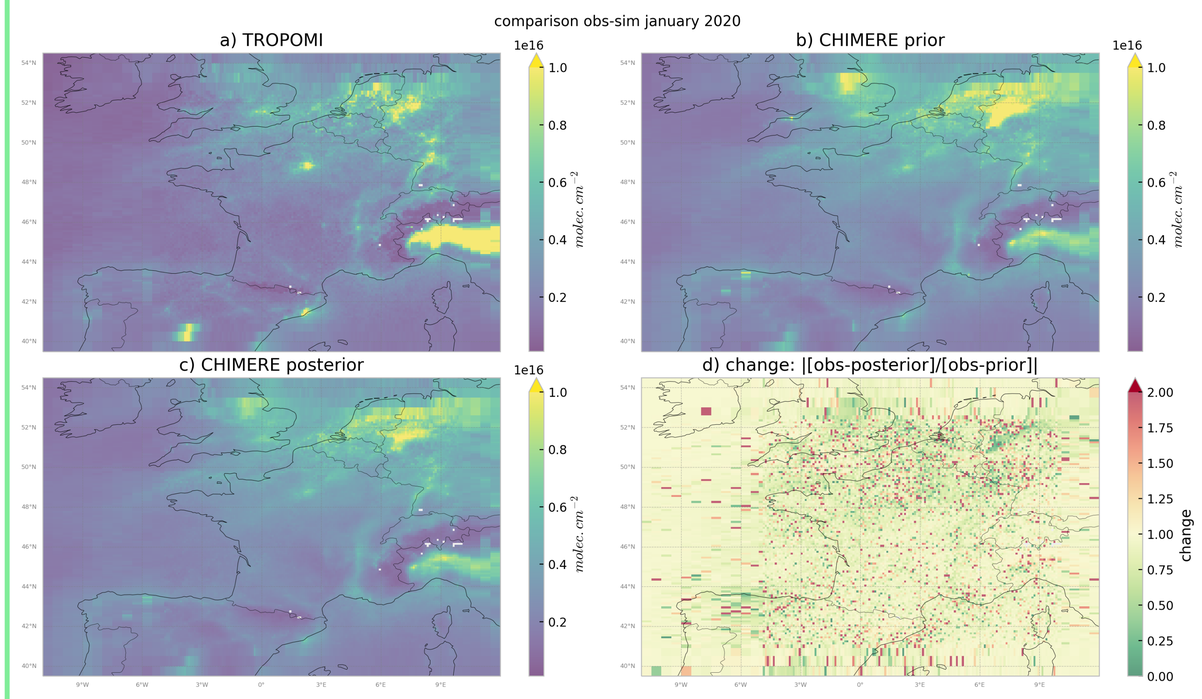
NO_2 TROPOMI-S5P PAL product

[1]Community Inversion Framework (Berchet, A. et al : The Community Inversion Framework v1.0: a unified system for atmospheric inversion studies, Geosci. Model Dev., 14, 5331–5354, 2021)

CIF

- Weekly assimilation window
- Assimilation of super-observations: TROPOMI column nearest of cell mean value
- Control vector: logarithmic fluxes (ensure positive emissions) at 24h temporal and 10km spatial resolutions
- Prior uncertainties:
  → No spatial correlation for anthropogenic fluxes
  → 30 km horizontal correlation for biogenic fluxes

TROPOMI-PAL observations vs CHIMERE



Monthly averages in January 2020 of NO_2 tropospheric columns for:

a) TROPOMI-PAL observations
b) CHIMERE simulation using prior INS inventory
c) CHIMERE simulation using posterior emissions
d) Ratio of posterior and prior biases between monthly NO_2 tropospheric columns simulated with CHIMERE and TROPOMI-PAL observations

- In b) and c) model and satellite data show a good spatial agreement
- In c), inversion system is better at decreasing than augmenting model columns (reduced columns in UK and Benelux, concentrations not matching observations in Po valley + Paris, Barcelona, Madrid plumes)
- In d), green ratios (< 1), demonstrate that posterior emission estimates improve simulation compared to prior ones on average → local degradations however

Seasonal and annual estimates of NO_X French anthropogenic emissions

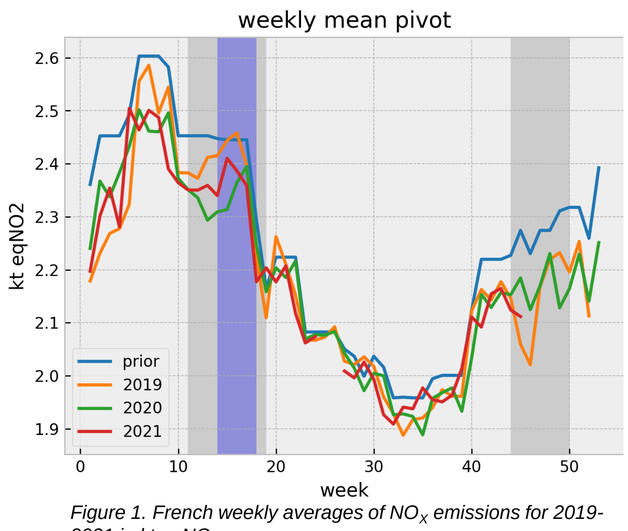


Figure 1. French weekly averages of NO_X emissions for 2019-2021 in kt eqNO_2

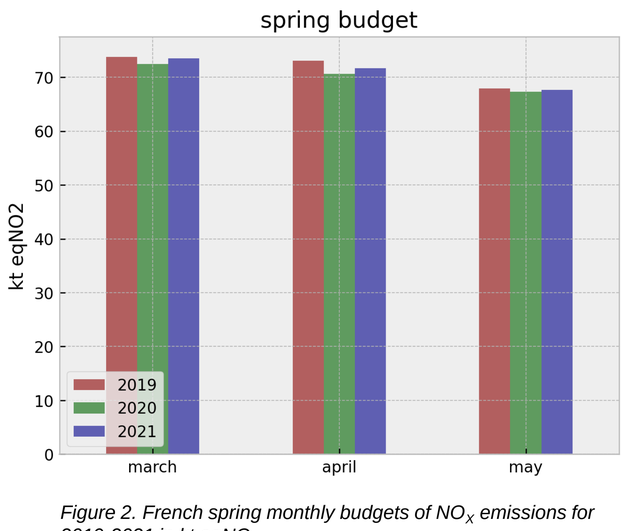


Figure 2. French spring monthly budgets of NO_X emissions for 2019-2021 in kt eqNO_2

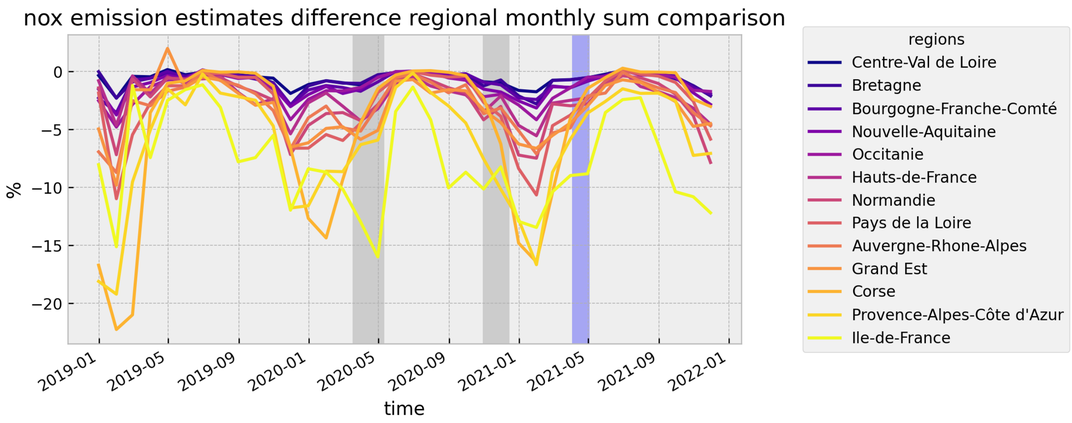


Figure 3. Monthly sums reduction of NO_X (in % of kt eqNO_2) emissions at infra-national scale: results for French regions

Weekly budget estimates for French anthropogenic NO_X emissions (figure 1)

- Strong seasonal cycle
- Emission reduction compared to prior estimates: negative trend since 2012
- Stronger increments from fall to first half of spring (when emissions are strong)
- Covid-19 pandemic lockdowns (shadowed areas) effects ± visible:
  1) March-April 2020 (grey), 2) November 2020 (grey) and 3) May 2021 (blue)

Annual budget estimates for French anthropogenic NO_X emissions (table 1)

- Budgets estimates are similar in 2019 and 2020 (797 kt eqNO_2)
- Reduction compared to prior budget (820 kt eqNO_2) not significant ~ -3%
- Lack of temporal extrapolation with current set-up (+ limited satellite cover)

Spring budget estimates for French anthropogenic NO_X emissions (figure 2)

- Budget reduction in 2020 compared to 2019 ~ -4%
- Monthly differences between BAU and pandemic years clear

Infra-national results (figure 3)

- Ile-de-France, Provence-Alpes-Côte d'Azur (and Corse) bears the strongest relative reductions (with strongest signal)
- There is a ~ 15% reduction in Ile-de-France in April (1st lockdown)
- Lack of ability to derive emissions for small urban areas

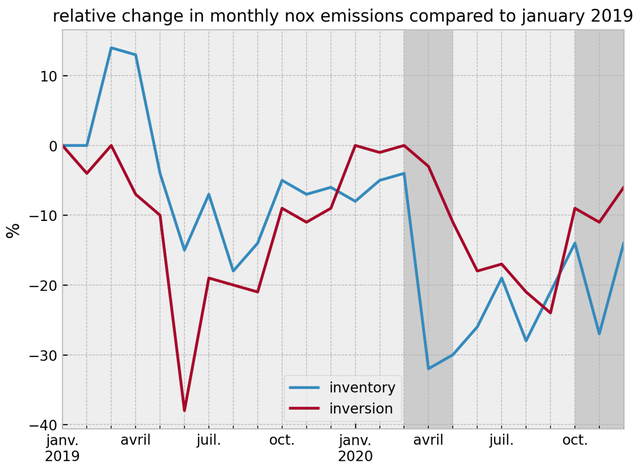
Year	Annual budget [kt eqNO2]
2019	797
2020	797
Prior	820

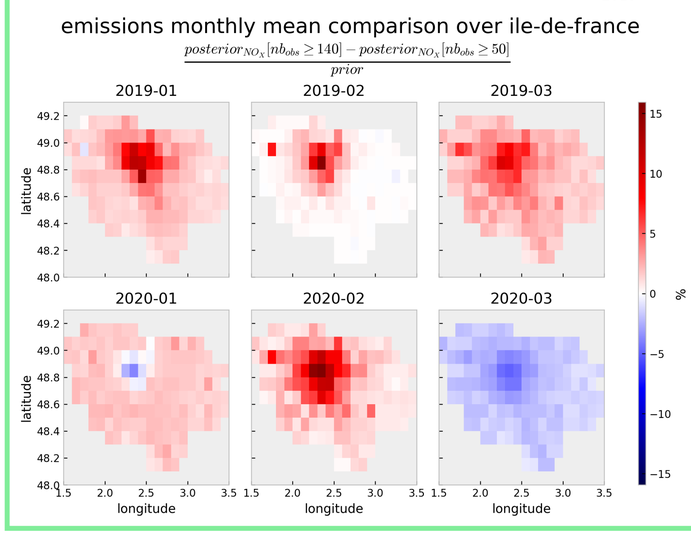
Table 1. French annual NO_X emission budget

Impact of COVID-19 & limitations

At national scale (with latest update from CITEPA):

- Good match for monthly variation but higher relative change in 2019 compared to 2020 for top-down estimate (red curve)
- Covid-19 pandemic relative change from bottom-up estimate anticipates higher reduction (blue curve) → see shadowed areas





Coverage impact on results:

- Comparison btw posterior increments when high coverage (140 px) vs low coverage (50 px) over IDF (150 px) relative to prior emission levels
- Especially in winter when emissions are high → emission increments are affected by satellite coverage (up to 15%)
- When focusing on days with good coverage, Covid-19 effects are enhanced

Key conclusions

- CHIMERE CTM compares well against TROPOMI-PAL TVCDs
- French NO_X emissions reductions limited compared to what is anticipated by latest CITEPA update (even in 2020)
- National results bear small covid-19 impacts but regional scale shows notable effects → study at metropole scale is on-going
- Increments magnitude related to obs coverage and signal amplitude (stronger for large urban areas)
- Need for better spatial and temporal extrapolation of satellite data signal using prior error covariance or more complex control vector

References: Hale, T. et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). Nat Hum Behav 5, 529–538 (2021)
Guevara, M. et al: Time-resolved emission reductions for atmospheric chemistry modelling in Europe during the COVID-19 lockdowns, Atmos. Chem. Phys., 21, 773–797, 2021.
Open Research: The re-processed TROPOMI-PAL dataset is available on https://data-portal.s5p-pal.com (Sekiya, T. et al., 2022).
The CHIMERE code is available here: www.lmd.polytechnique.fr/chimere/ (Menut, L. et al., 2013; Mailler, S. et al., 2017).

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