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Evaluation of the new 4D-variational inverse modelling system, CIF-CHIMERE: Inversion of NOx emissions over China using OMI NO2 observations

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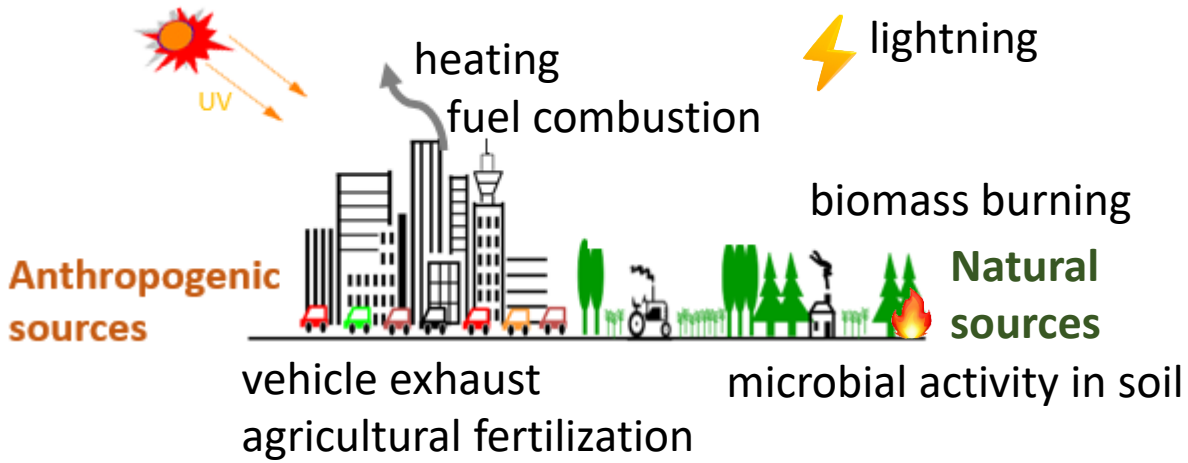
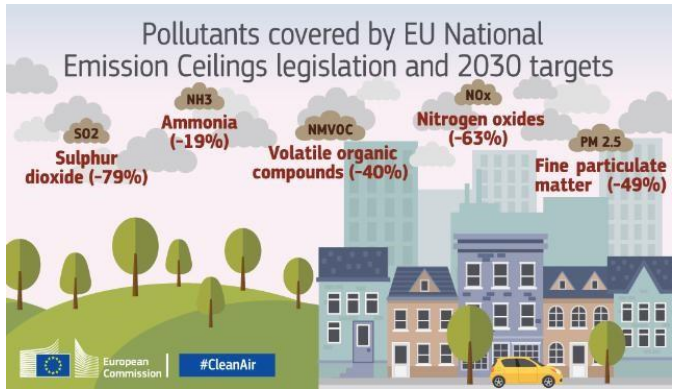
1. Introduction

NOx (NO2+NO) primary pollutant

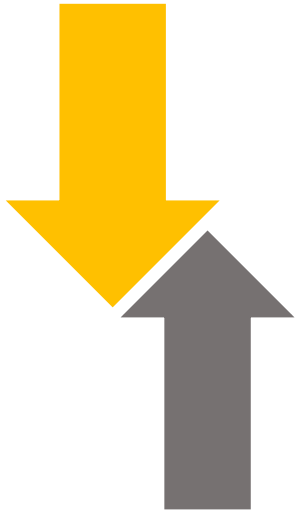




credits : European commission

credits: Clean Air Asia

Top-down emission inventories (observation & model)



Bottom-up emission inventories (sources)

<u>Uncertainties in NOx:</u>

±35 % in China,
±60 % in East Asia other than China
for an inventory REAS v3

(Kurokawa et al., 2020)

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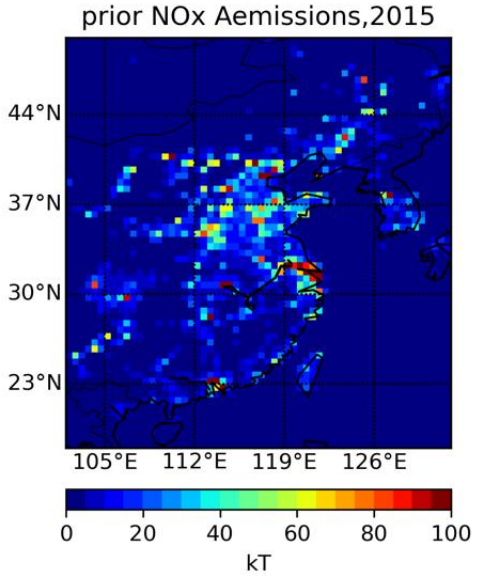
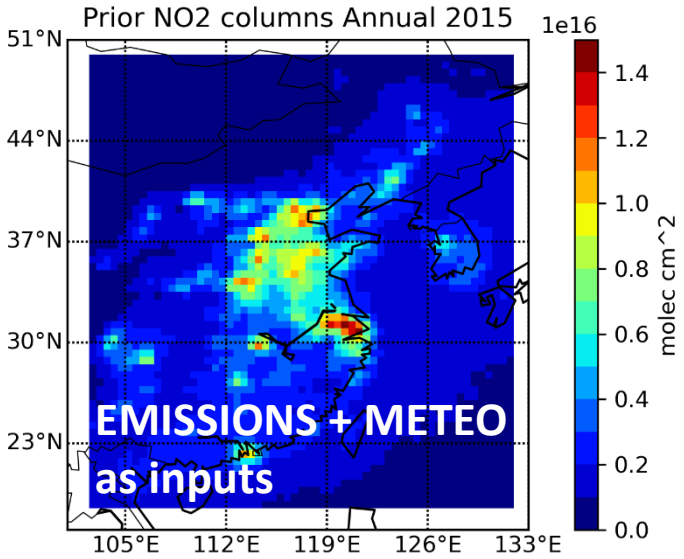
2. New 4D Variational Inverse Modelling System: CIF - CHIMERE



Prior Emissions



Simulated Concentrations (CTM)

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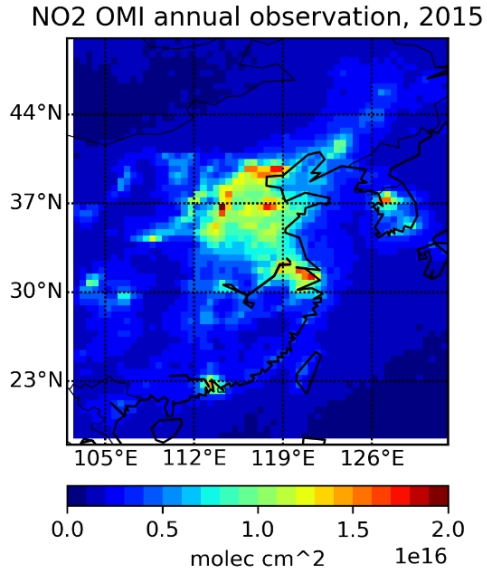


Observed Concentrations

INVERSION (CIF)

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x}_b)^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x}_b) + (\mathcal{H}(\mathbf{x}) - \mathbf{y})^T \mathbf{R}^{-1} (\mathcal{H}(\mathbf{x}) - \mathbf{y})$$

Community **I**nversion **F**ramework
(Berchet et al., 2021)

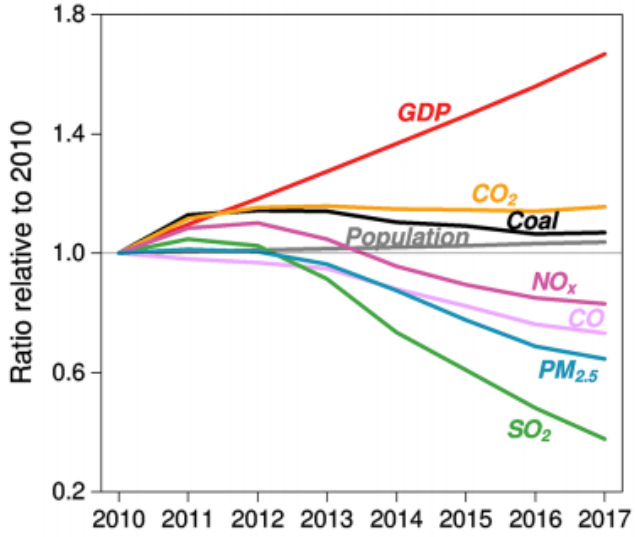
x state vector
$\mathbf{X_b}$ background estimate
B background error matrix

y observation vector
R observation error matrix
H(x) simu conc. in obs space

Estimated emissions
(Posterior emissions)

3. Case Study: Inversion of NOx emissions over China using OMI NO2 observations

China's Clean Air Action since 2010



(Zheng et al., 2018)

Our goal: Estimating daily NOx emissions for 2015 and 2019 using OMI NO2 observations & HTAP bottom up inventory for 2010 over East China.

Simulated Concentrations (CTM)

Chimere v2013 (Menut L. et al., 2013)

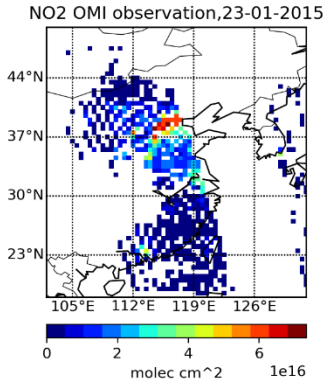
Input Data

- Boundary Conditions: LMDZ-INCA
- Meteorological Conditions: ECMWF
- Anthropogenic Emissions: EDGAR HTAP v2.2 2010
- Biogenic Emissions: MEGAN (Guenther et al., 2006)

0.7 error in B for anthropogenic emissions

Observed NO2 Concentrations

OMI QA4ECV retrieval (Boersma et al., 2017)



daily OMI < error100%

East China Domain:
[18°N-50°N] &
[102°E-132°E]
50x50 km^2
17 vertical layer
up to 200hPa

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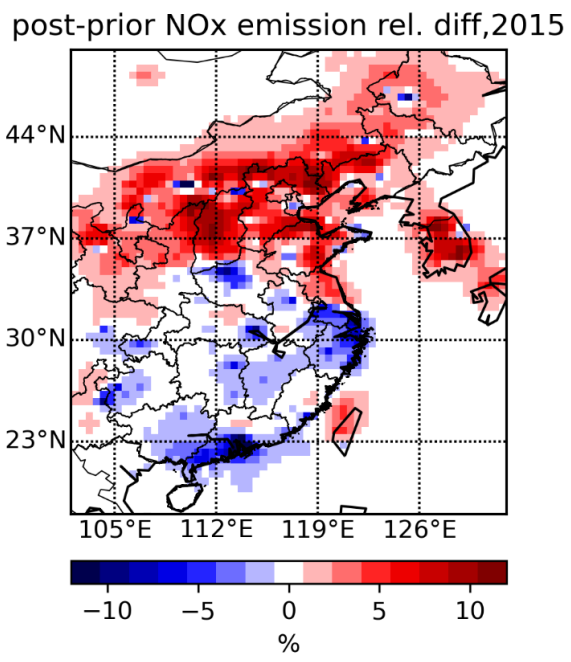
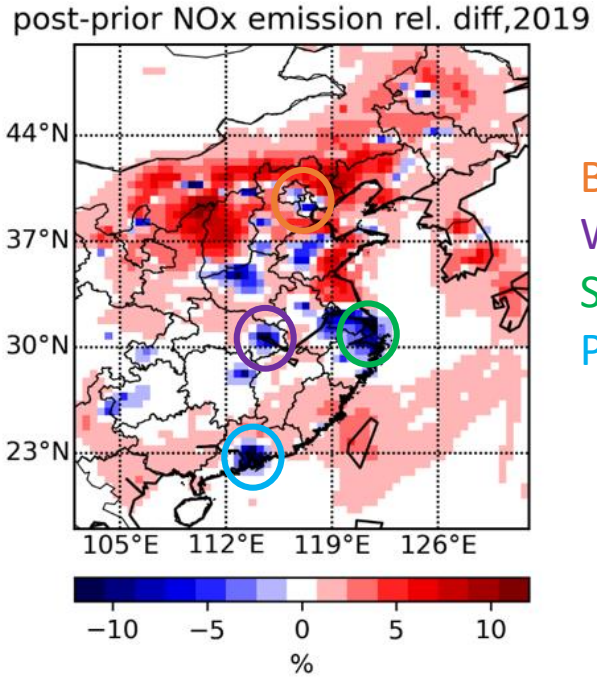
3. Case Study: Inversion of NOx emissions over China using OMI NO2 observations

Differences of annual posterior-prior NOx emissions (%)

2015-2010



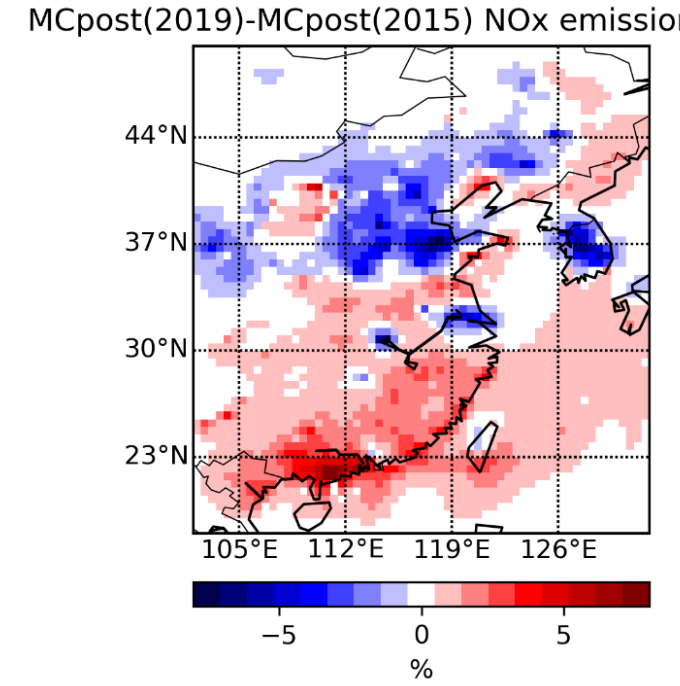
2019-2010



Beijing
Wuhan
Shanghai
Pearl River Delta

- NOx emission annual corrections in the range of 15% in 2015, and in the range of 25% in 2019.
- NOx emissions are decreasing in the southern China and over the populated cities in the northern China.
- Annual changes are minor but on a monthly base they are larger.

Differences of annual posterior NOx emissions (%) 2019-2015



- Differences in corrections limited with ±8%.

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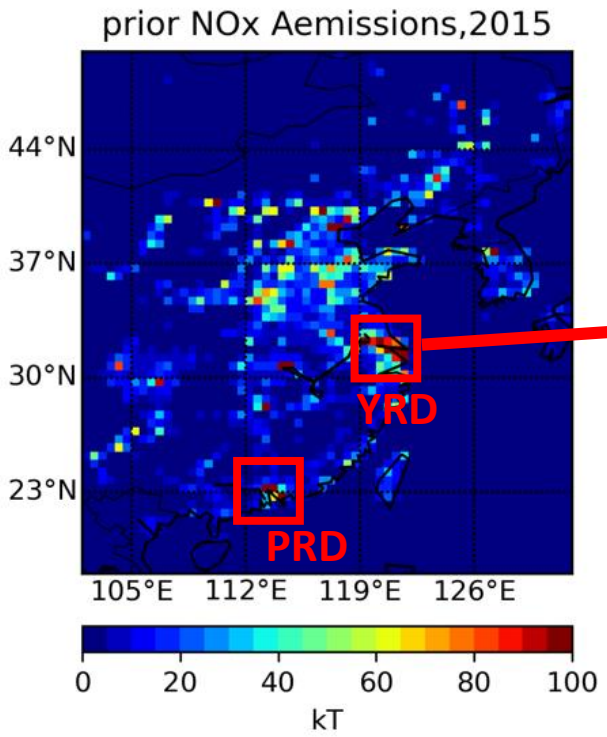
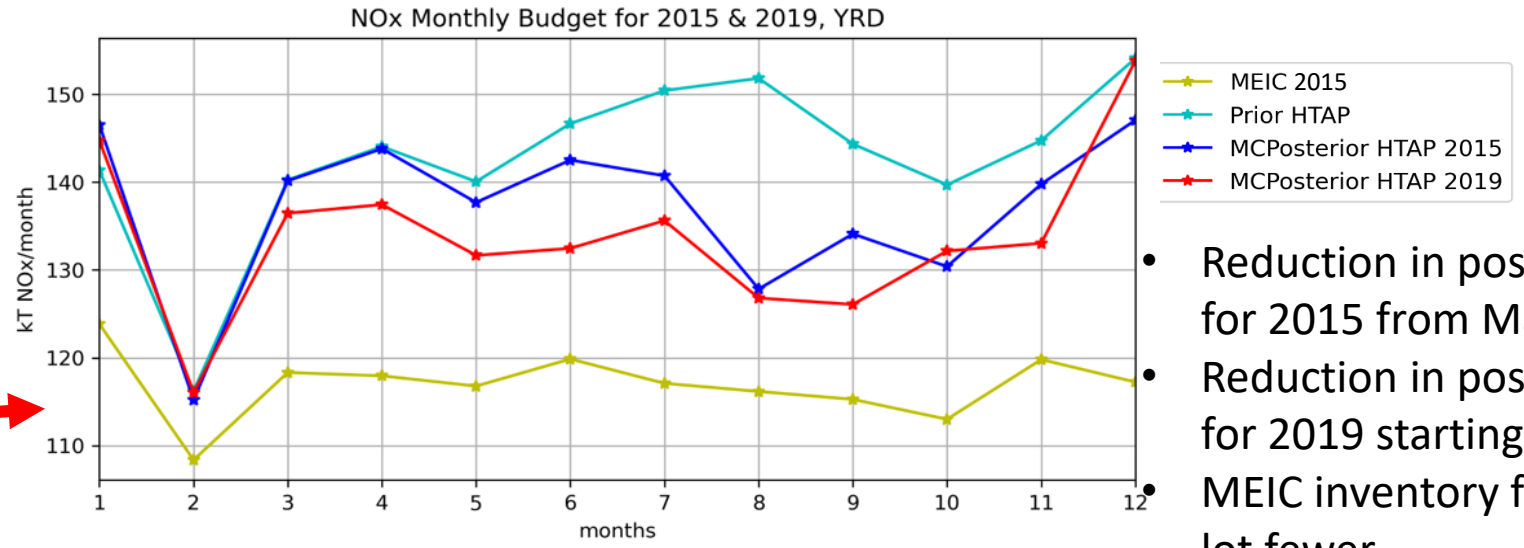
3. Case Study: Inversion of NOx emissions over China using OMI NO2 observations

NOx Monthly Budget Comparison over some regions





- Reduction in post emissions for 2015 from May
- Reduction in post emissions for 2019 starting in spring.
- MEIC inventory for 2015 is a lot fewer

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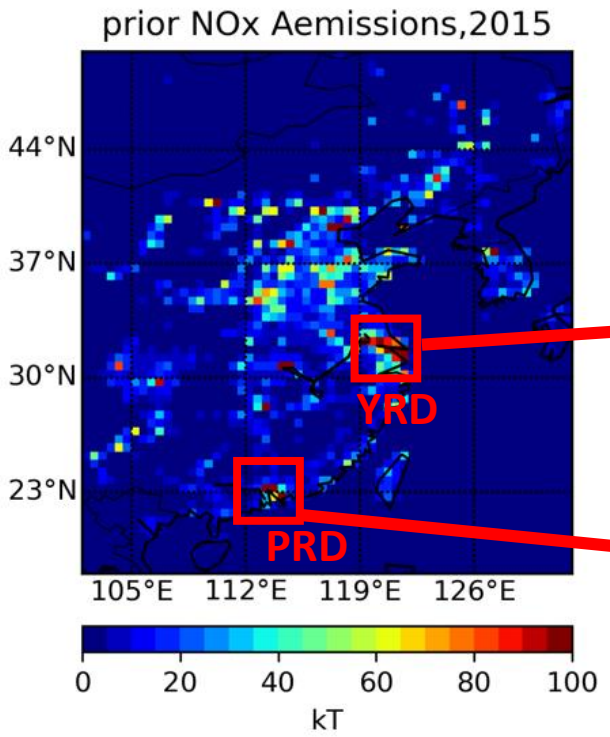

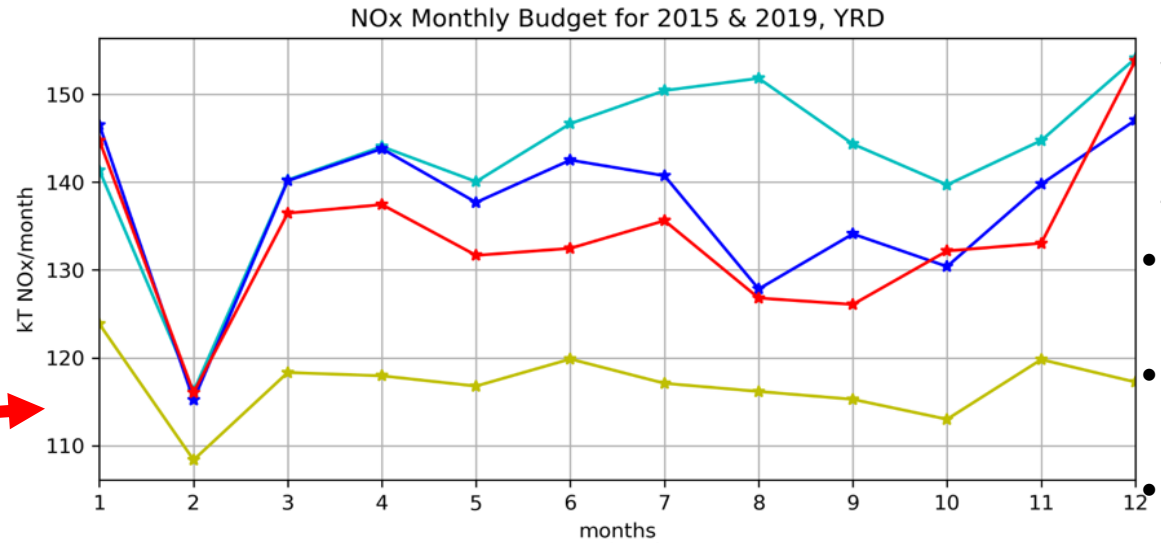

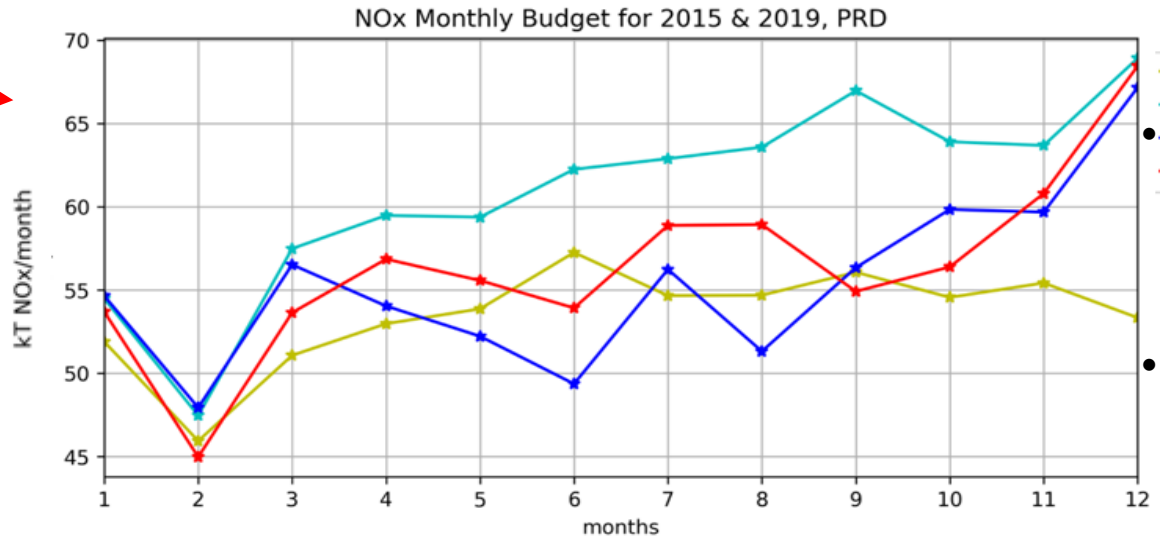

- Reduction in post emissions for 2015 from May
- Reduction in post emissions for 2019 starting in spring.
- MEIC inventory for 2015 is a lot fewer

- Similar to YRD, both post emissions have decreased compared to prior except December and January.
- Both post emissions have good agreement with MEIC inventory

4. Concluding Remarks and Perspectives

- CIF (Community Inversion Framework) is a new inverse modelling system (Berchet et al.,GMD, 2021). It is coupled with chemical transport models (in this work CHIMERE), its adjoint and observations.

- To evaluate the potential of new CIF-CHIMERE inverse modelling system, NOx emissions are inversed over the domain East China (50x50km^2) using OMI satellite observations and CHIMERE chemistry transport model for 2015 and 2019 as a reference to 2010.

- In the southern part of China annual reduction in NOx emissions is observed in both years 2015 and 2019 up to 15 and 25% compared to 2010. In the northern part, reduction limited only with some hotspots.

- Regional monthly time series of NOx budget show variation between months and sometimes good agreement with MEIC sometimes not.

- Validation of NO2 surface columns is still in progress.

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