Error characterisation and super-observations

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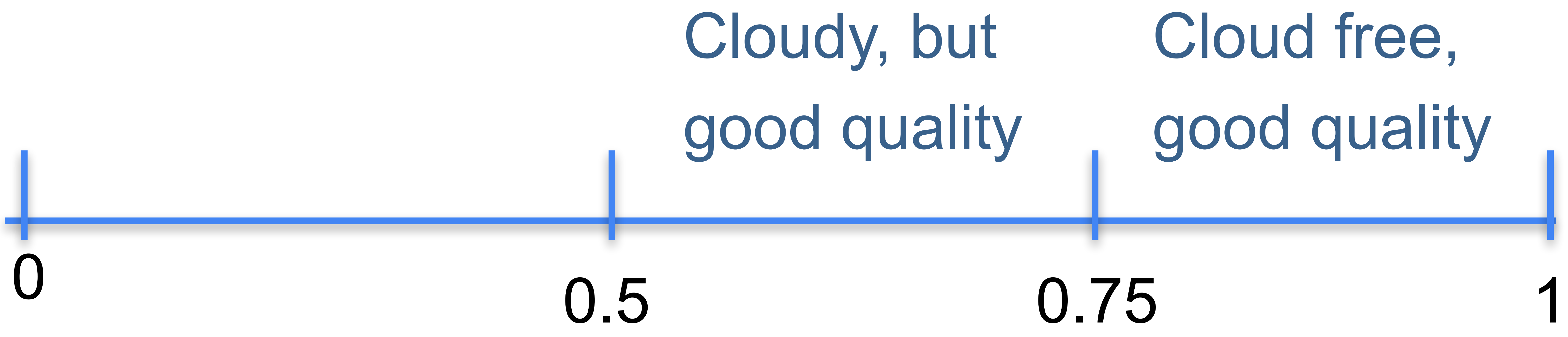
TROPOMI NO2: Use of the data (model validation, assimilation)

Filtering: the qa-value



Make use of averaging kernels …

- This removes the a-priori dependence

$$\mathbf{Ax} - y$$

… or apply an a-priori replacement.

- Using high-resolution regional model output - see PUM

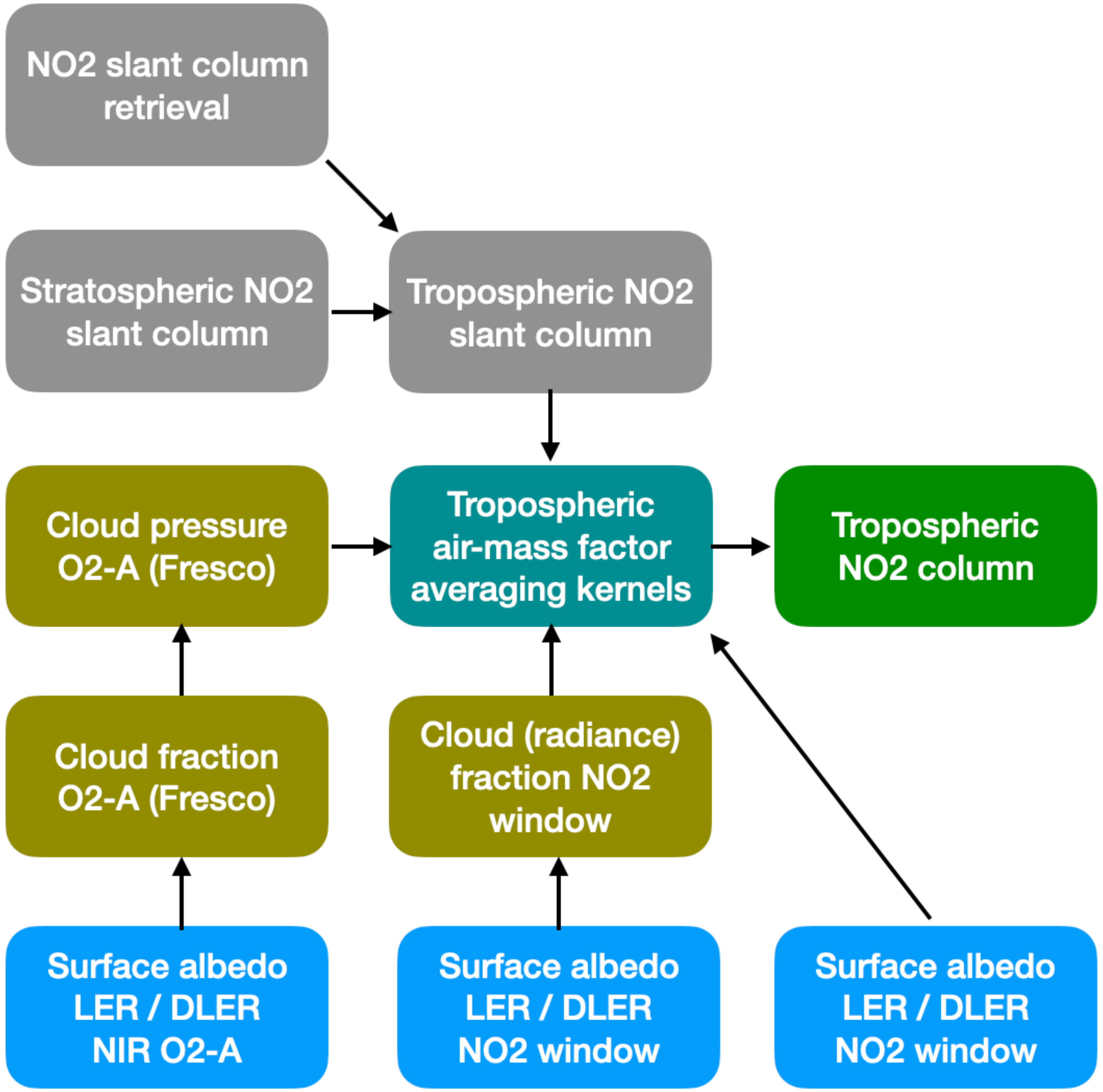
$$N_\mathrm{v}^{\mathrm{trop}\prime} = \frac{M^\mathrm{trop}}{M^{\mathrm{trop}\prime}} N_\mathrm{v}^\mathrm{trop}$$

$$\mathbf{A}^{\mathrm{trop}\prime} = \frac{M^\mathrm{trop}}{M^{\mathrm{trop}\prime}} \mathbf{A}^\mathrm{trop}$$

$$M^{\mathrm{trop}\prime} = M^\mathrm{trop} \sum_l A_l^\mathrm{trop} x'_{m,l} / \sum_l x'_{m,l}$$

Douros et al., GMD 2023, 10.5194/gmd-16-509-2023

TROPOMI NO2 retrieval: Error estimate



Contributions to uncertainty from:

- Measurement noise and slant column uncertainty
- Stratosphere/troposphere split
- Surface albedo (UV-Vis, NIR)
- Cloud fraction (aerosol)
- Cloud pressure (aerosol)

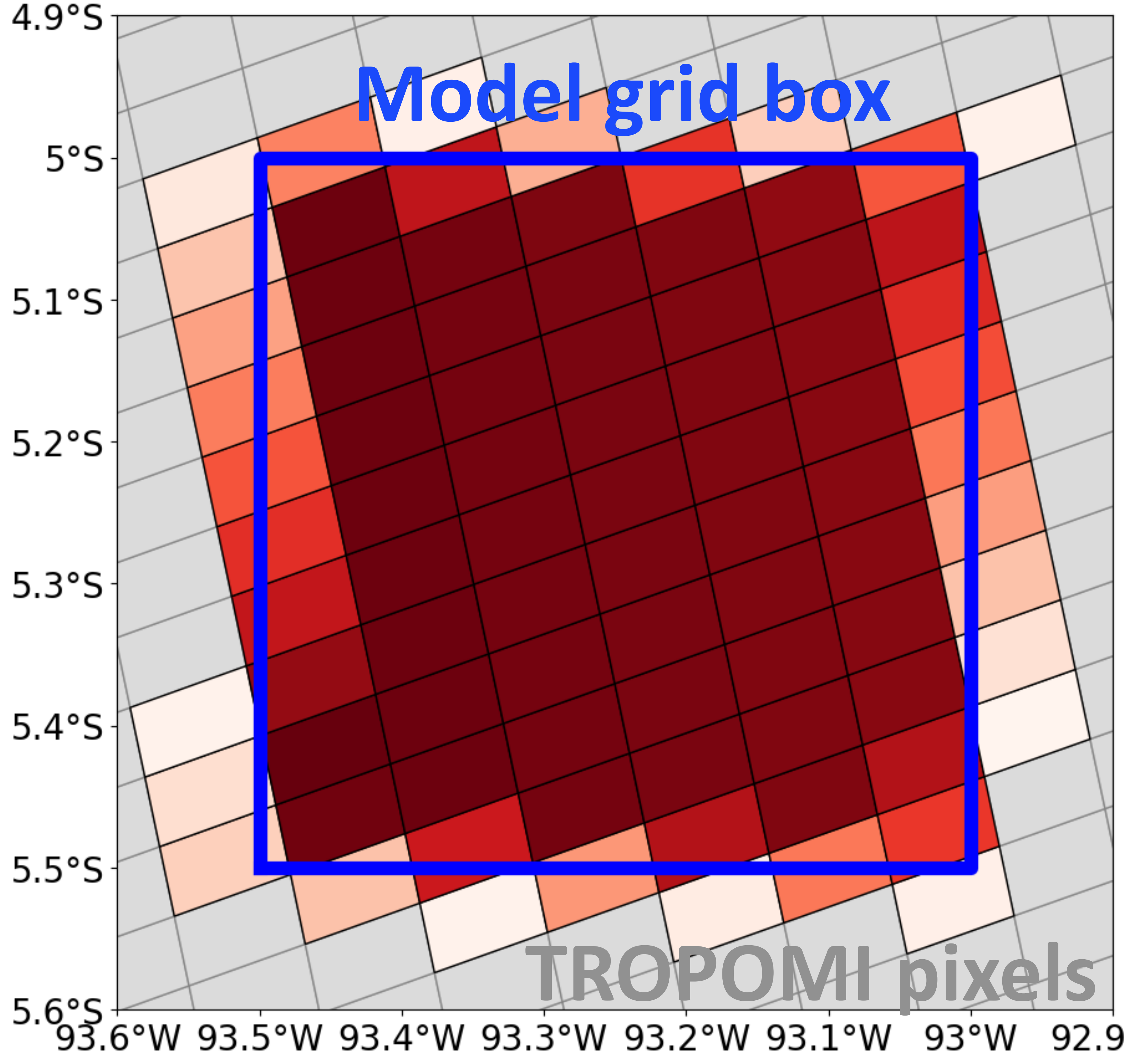
But no information provided on error correlations between (nearby) observations

Superobservations: mitigate resolution mismatches

Construct one effective observation
from all individual satellite pixels overlapping
a model grid cell
(Instead of comparing with individual obs)

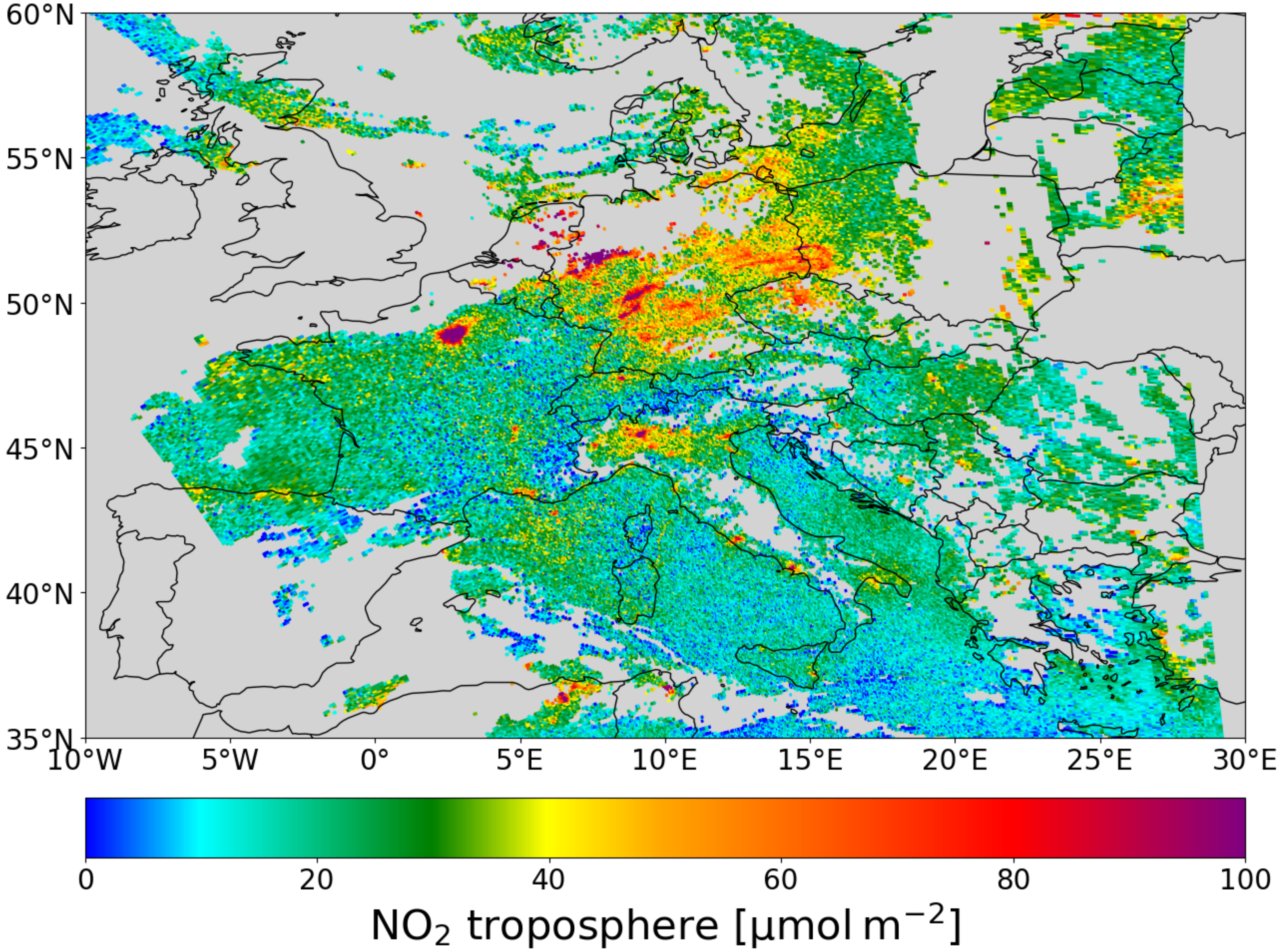
Advantages:

- Computationally very efficient
- Use all satellite information at model scale
- Avoid biases (sat error scaling with column)
- Allow (partial) treatment of
  - Spatial error correlations between obs
  - Representativity errors

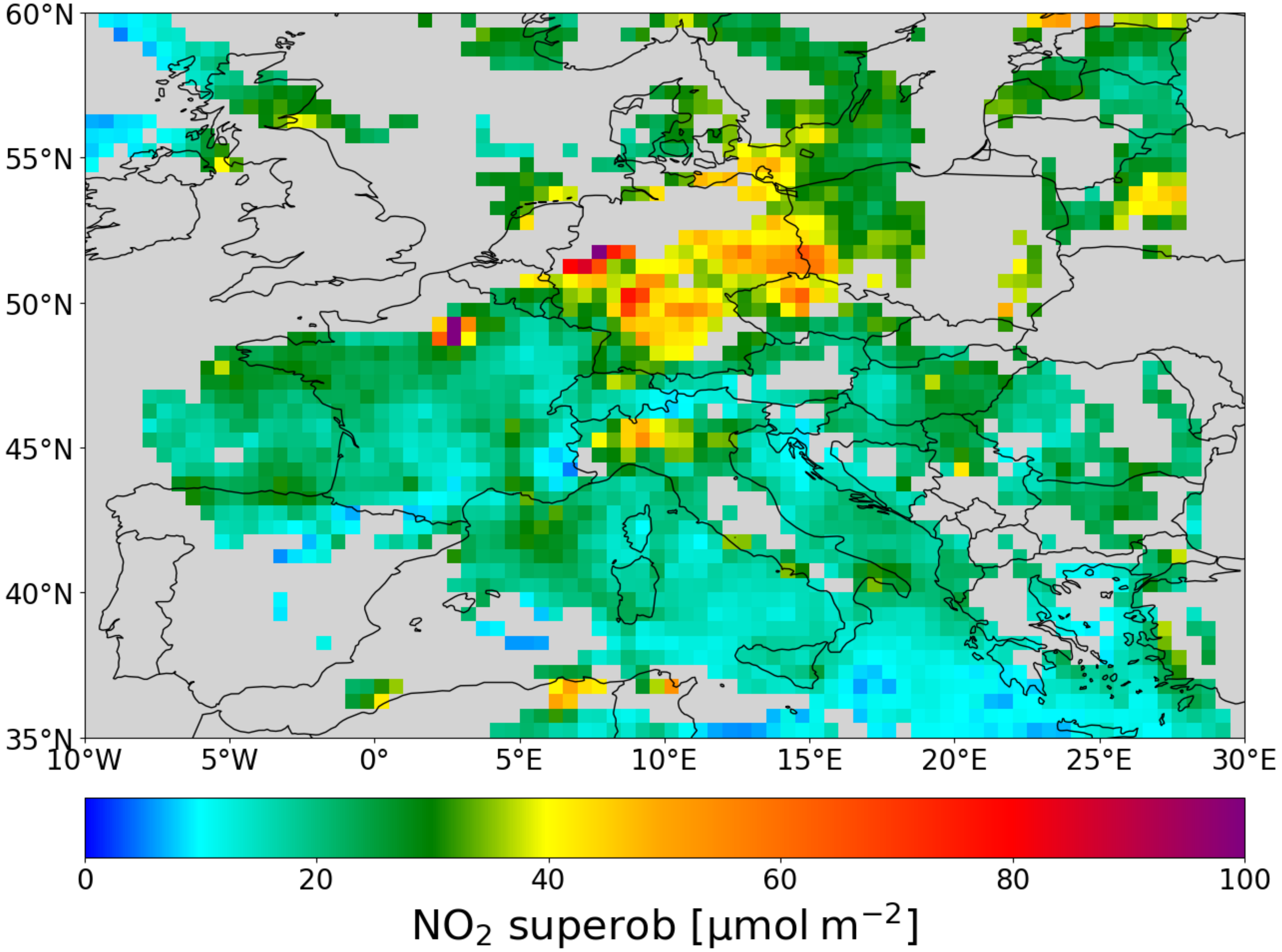


0.5 x 0.5 degree model

Superobservations: mitigate resolution mismatches



TROPOMI NO2, full resolution



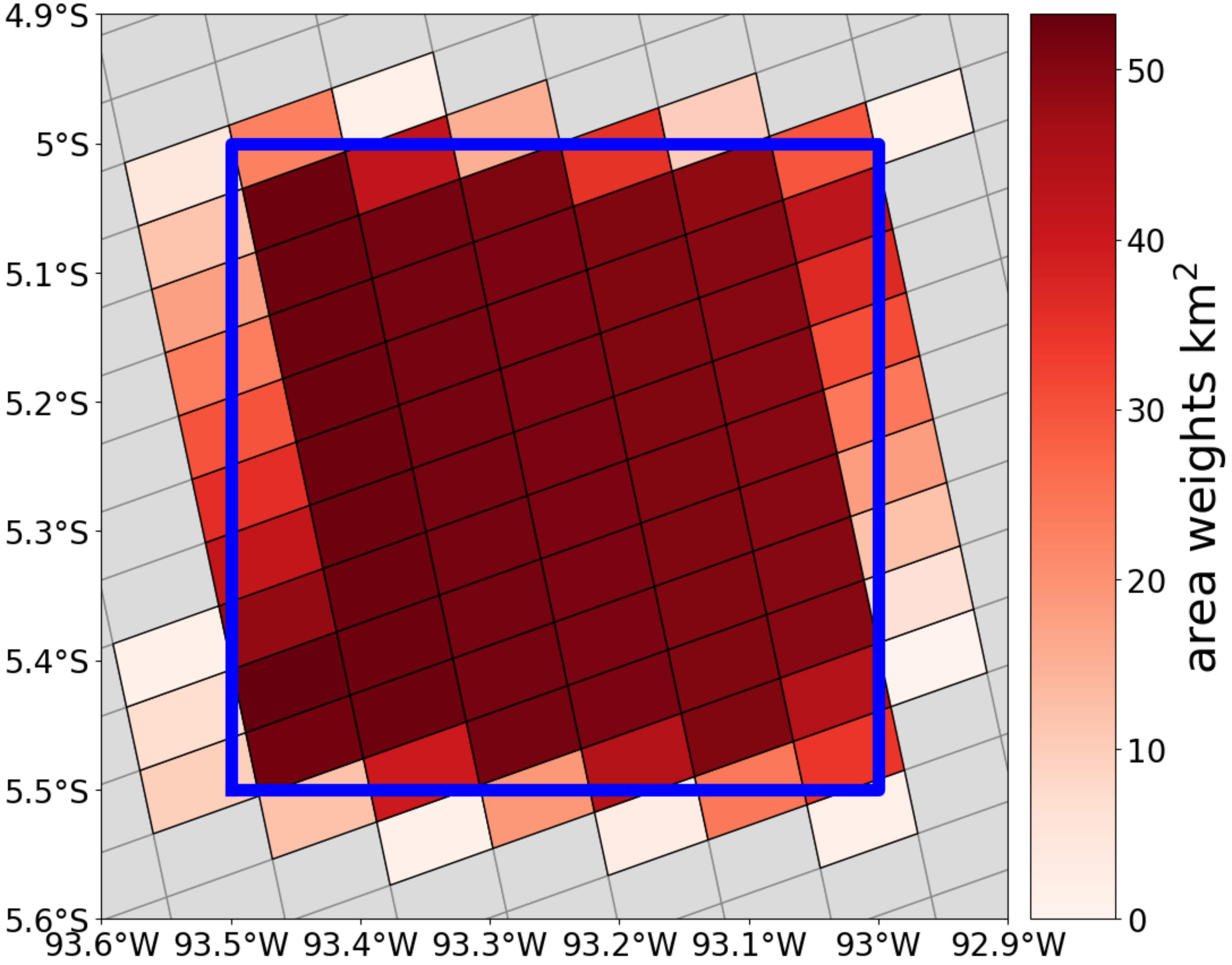
TROPOMI NO2, superobservations
0.5 x 0.5 degree model

Constructing superobservations

Tiling principle

Weight equal to the **overlap** between satellite footprint and model grid cell

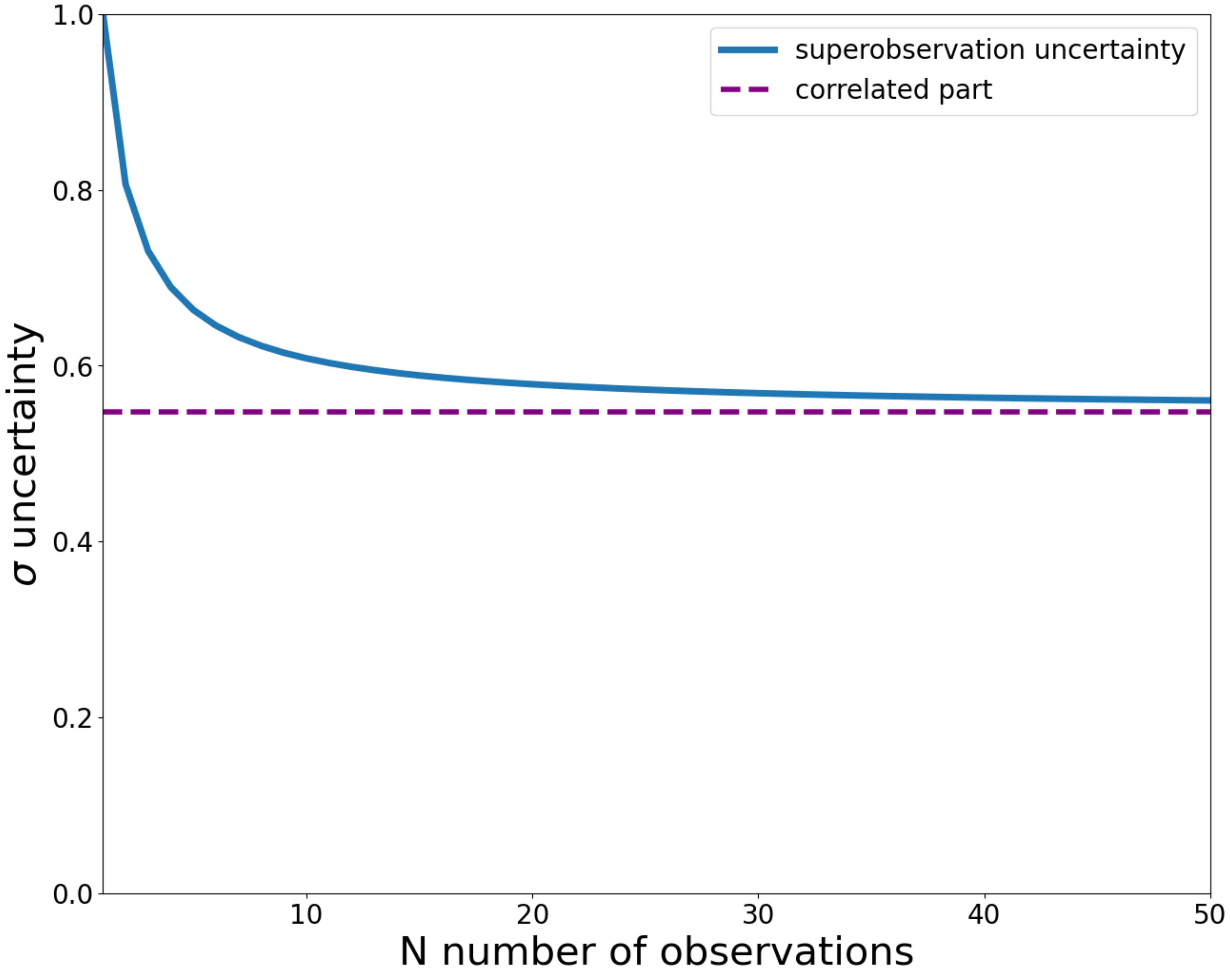
Averaging kernel is averaged with same weights



Superobservation error: Inter-pixel error correlations

Superobservation error as sum of uncorrelated and correlated part, modelled with single correlation factor “c”

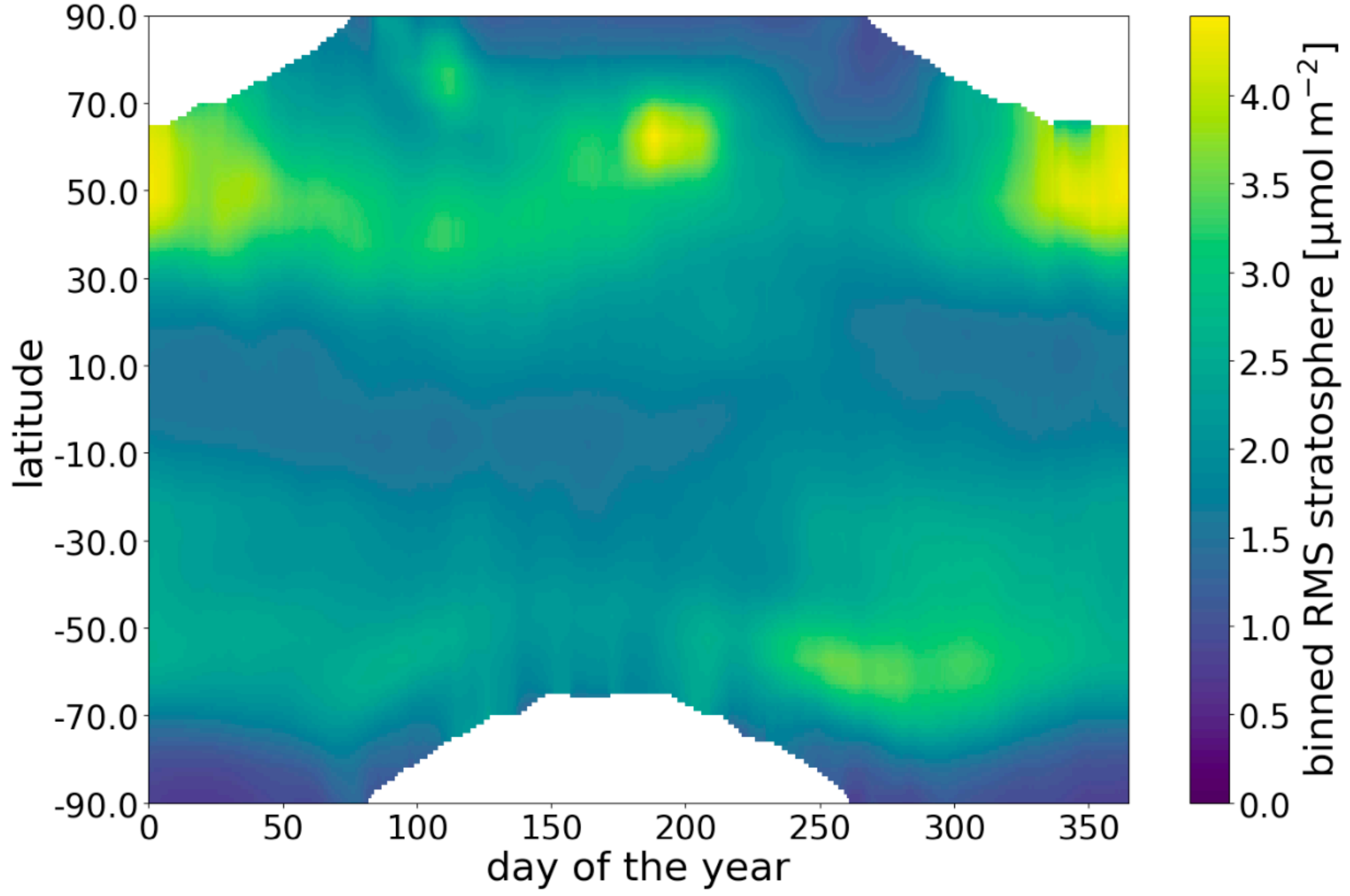
$$\sigma_{obs}^2 = (1-c)\sum_{i=1}^{N}\tilde{w}_i^2\sigma_i^2 + c\left(\sum_{i=1}^{N}\tilde{w}_i\sigma_i\right)^2$$



Inter-pixel error correlations

Error contribution	Correlation
Stratosphere-troposphere separation	⬤ (large)
Air-mass factor (cloud fraction, pressure, albedo, aerosol)	⬤ (medium)
Slant column	• (small)

Stratospheric error update

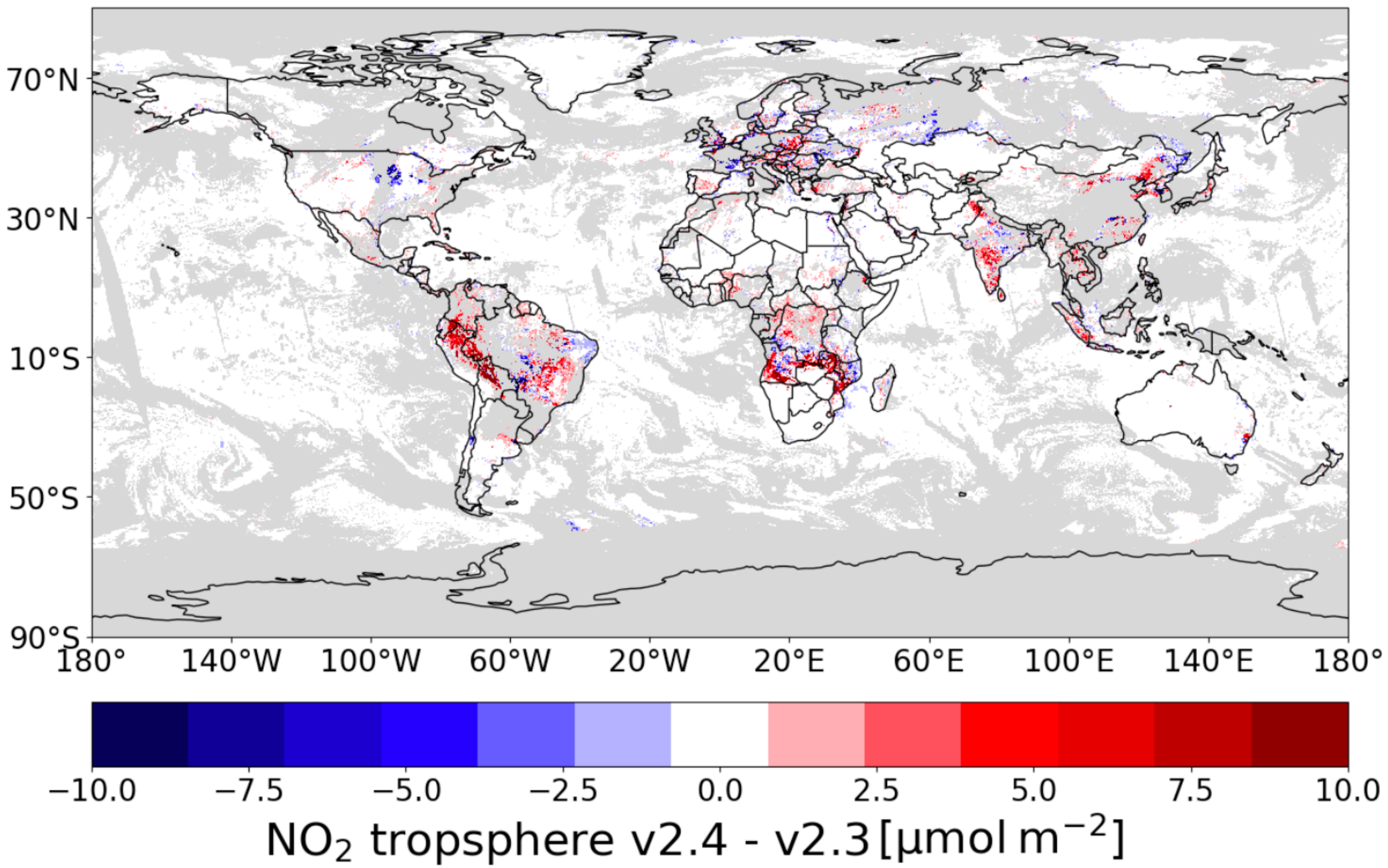


Derived from O-F statistics

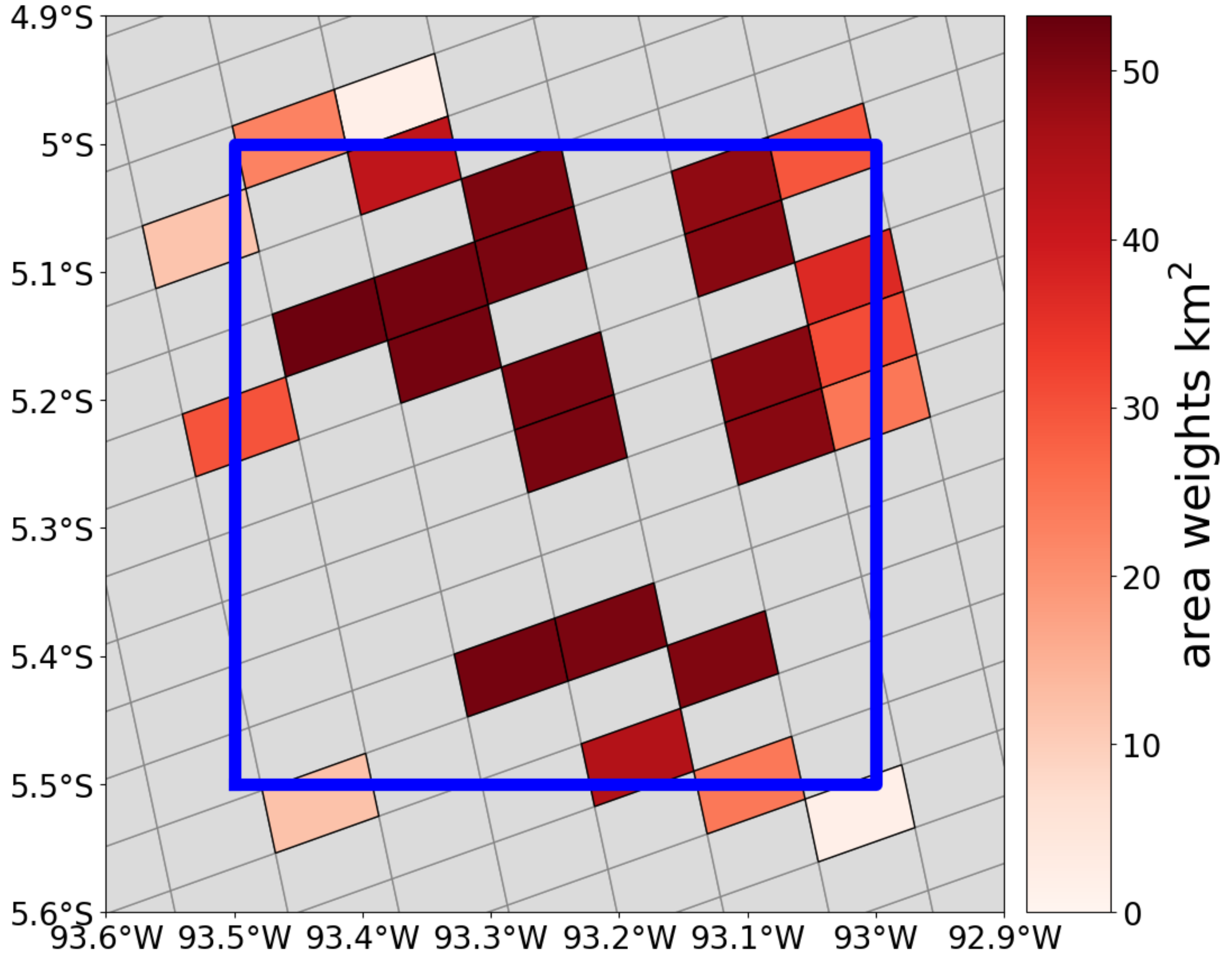
Air-mass factor error correlations

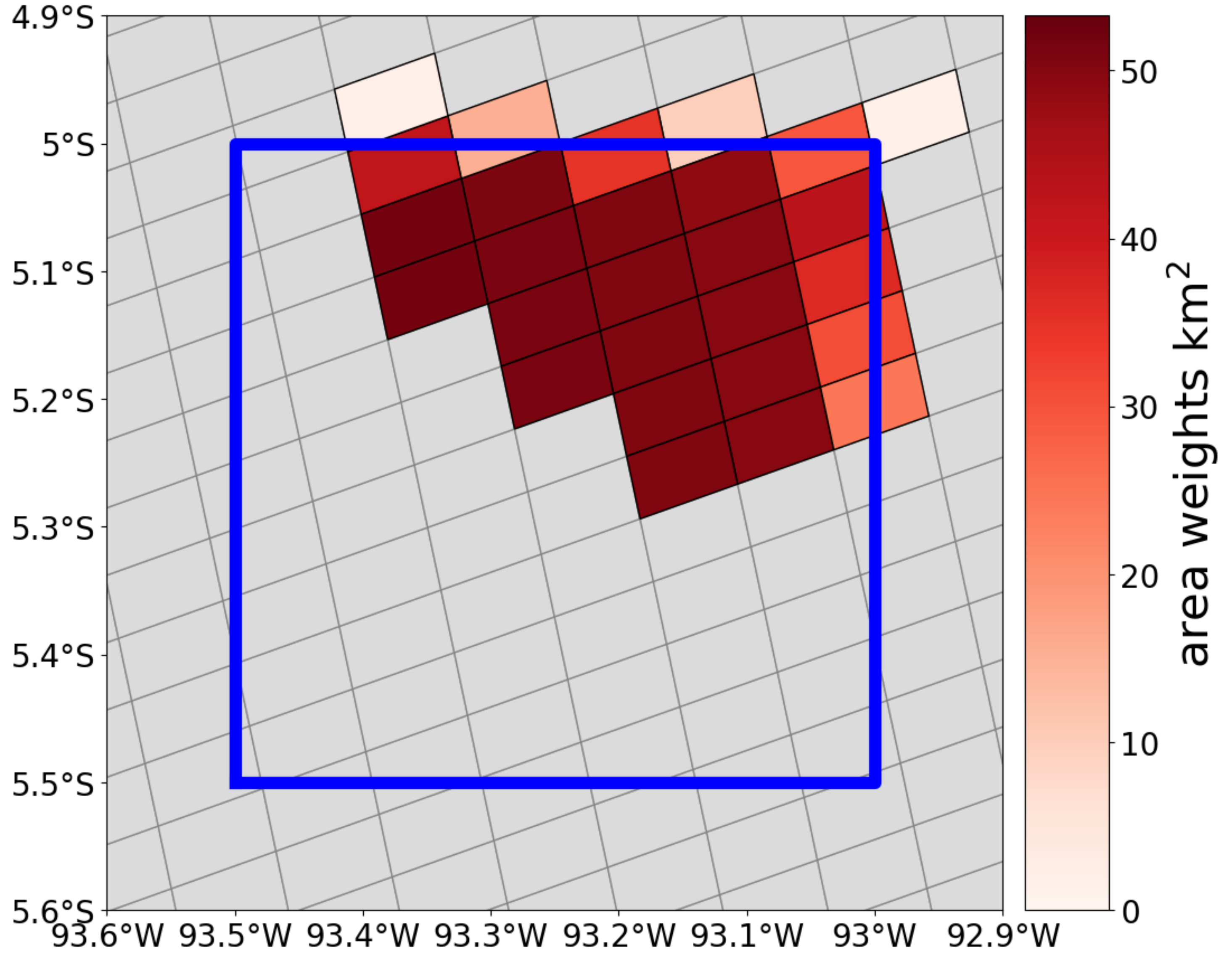
TROPOMI v2.4 and 2.3 differ by the albedo dataset used, influencing cloud fraction, pressure and direct AMF calculation.

Assumption:
spatial correlation v2.4 - v2.3 representative of spatial error correlation length scale

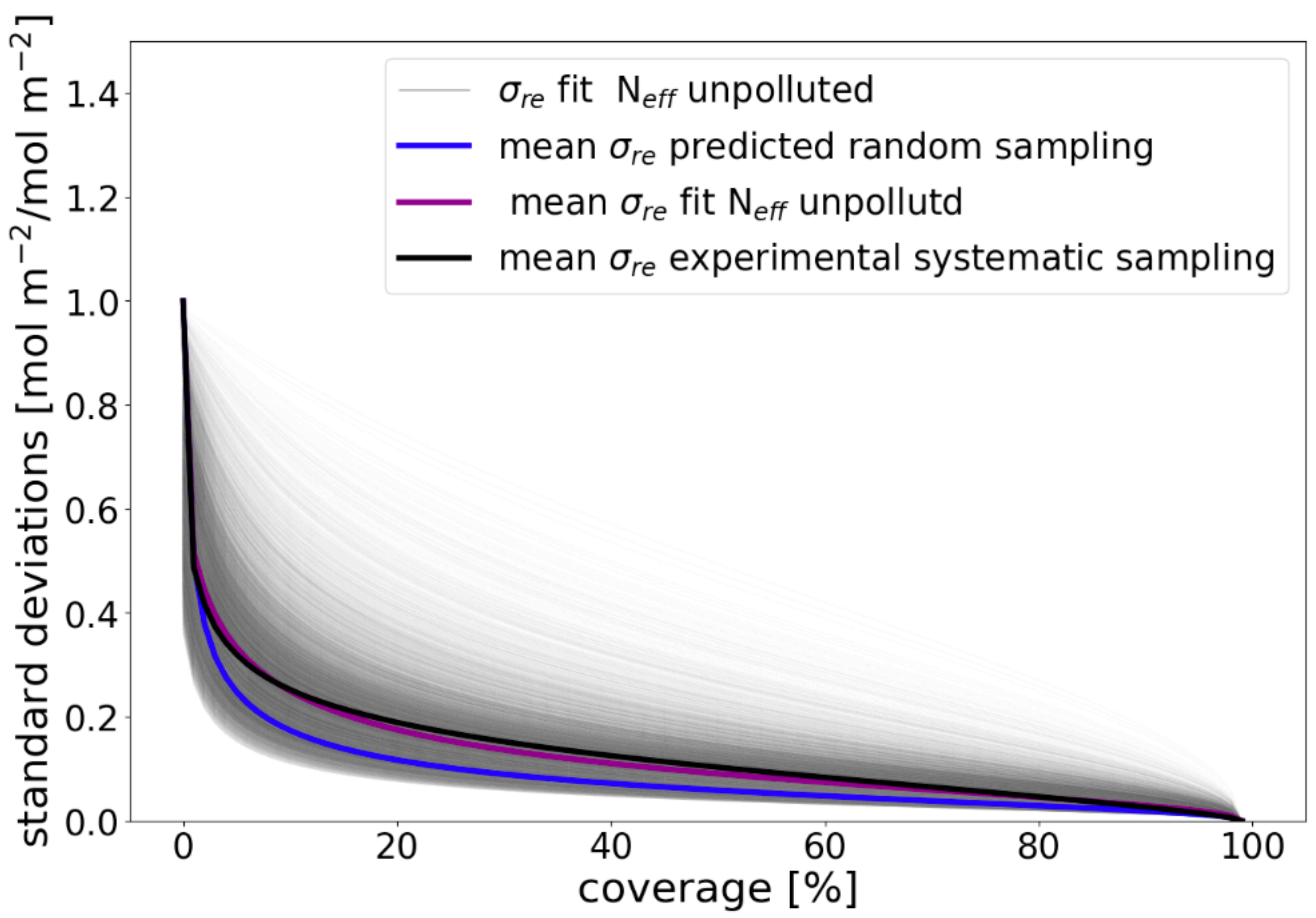


Representation error

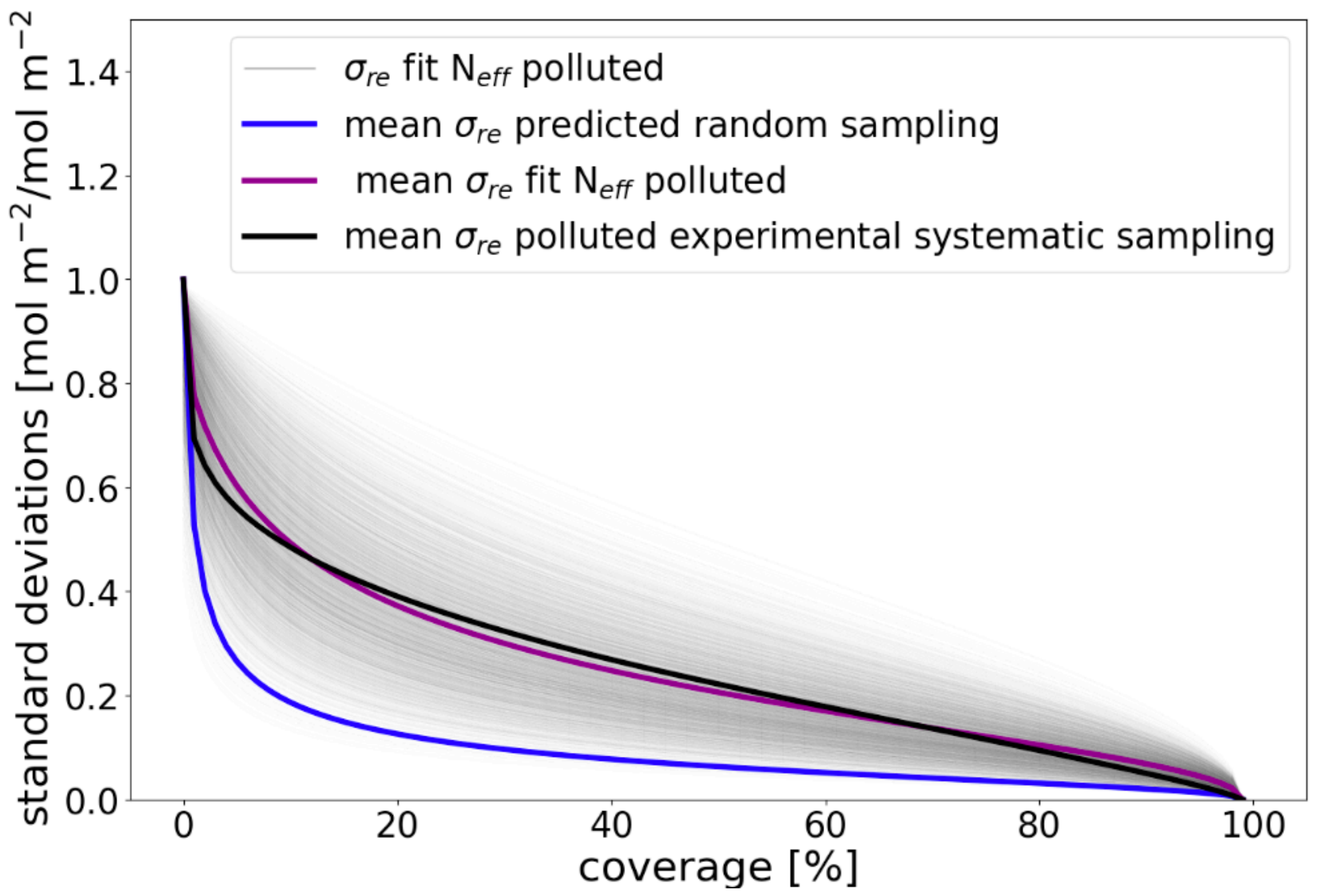




Unpolluted regions



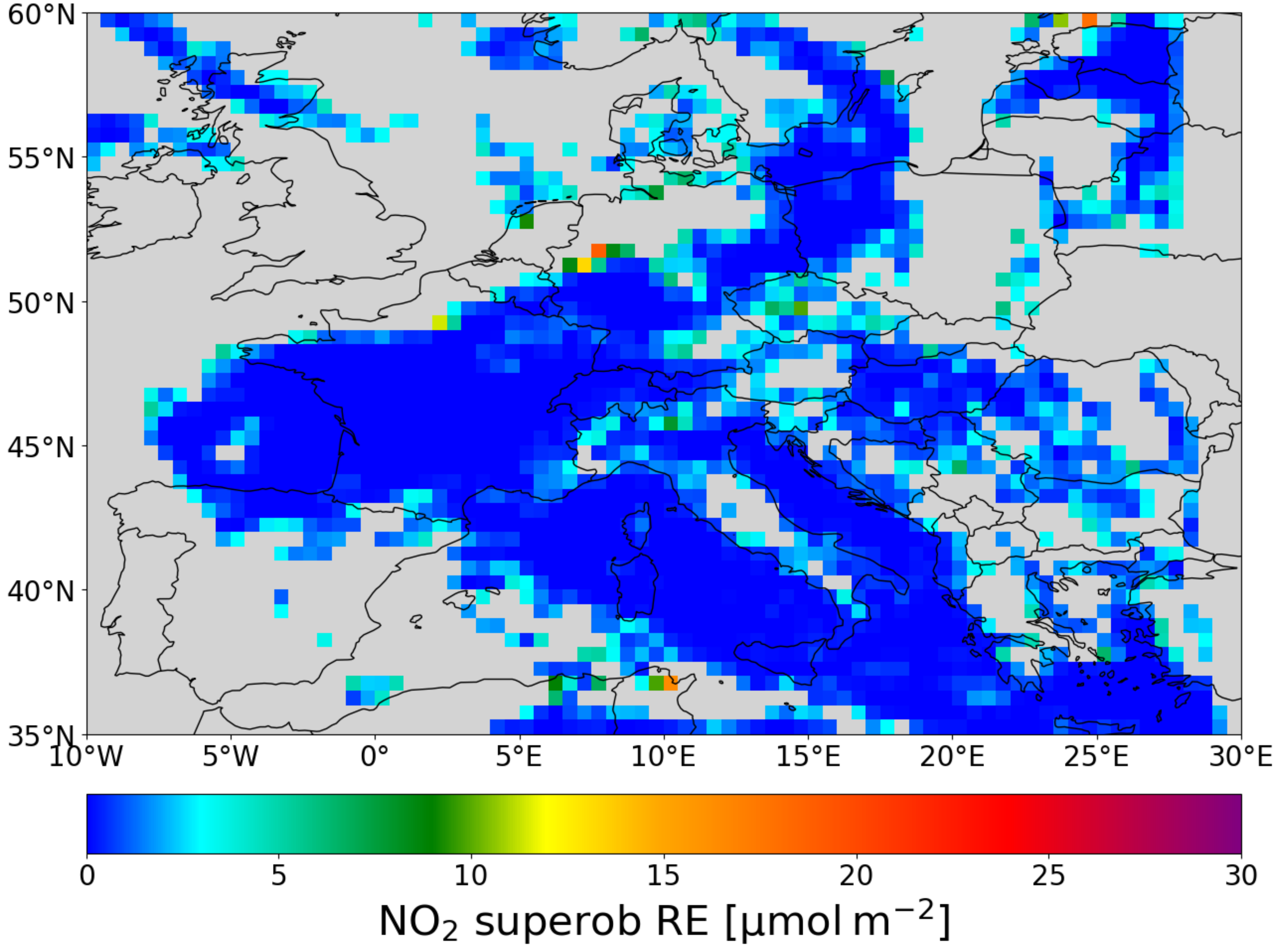
Polluted regions



Detailed study of effect of partial cloud cover
- Random cloud cover vs cloud field (latter implemented)
- Polluted regions show larger relative error than unpolluted regions
- Representation error = variability within gridcell * coverage-dependent factor

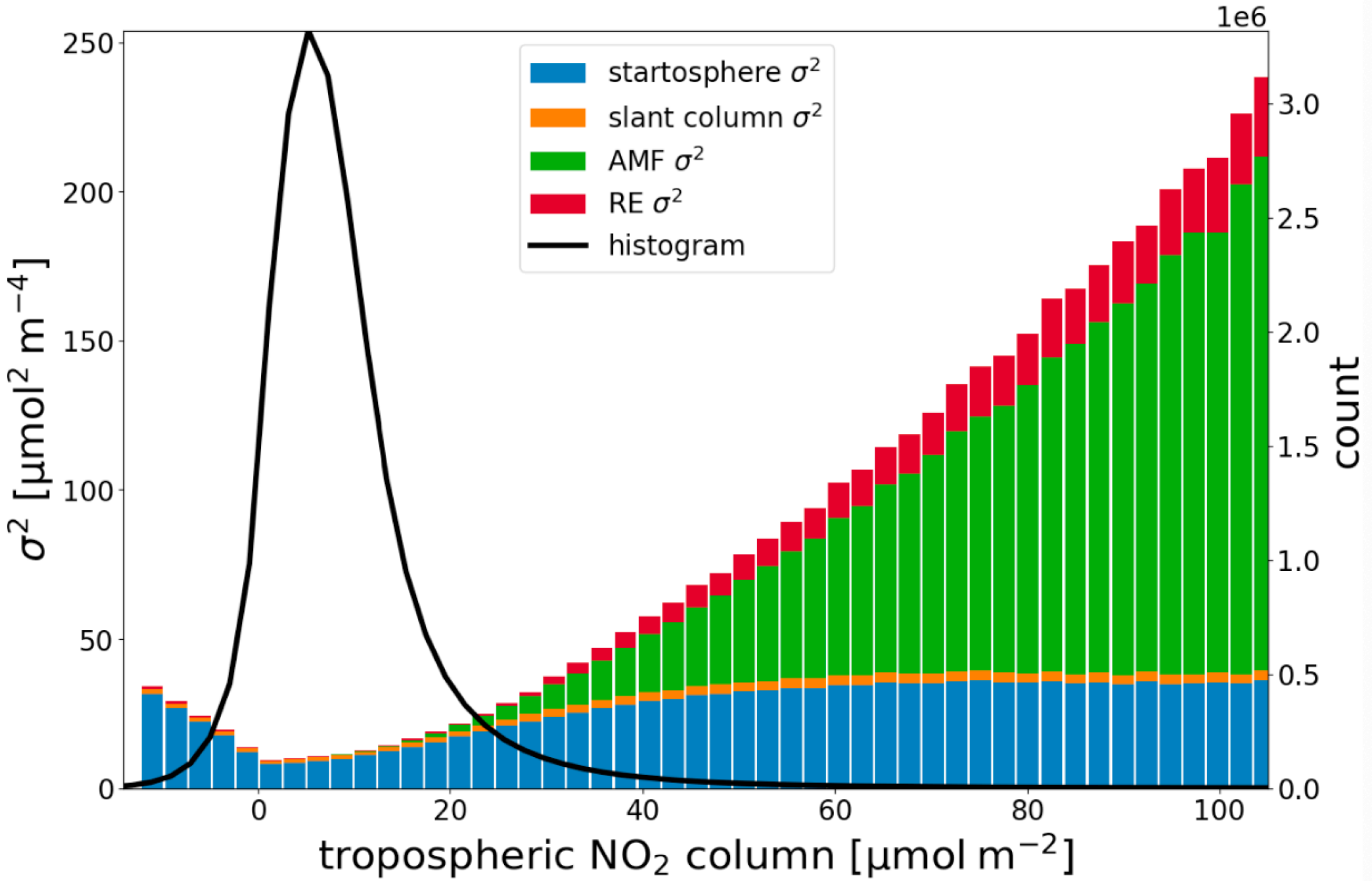
Representation error

Especially important / large
at the edges of the cloud fields



Combined error

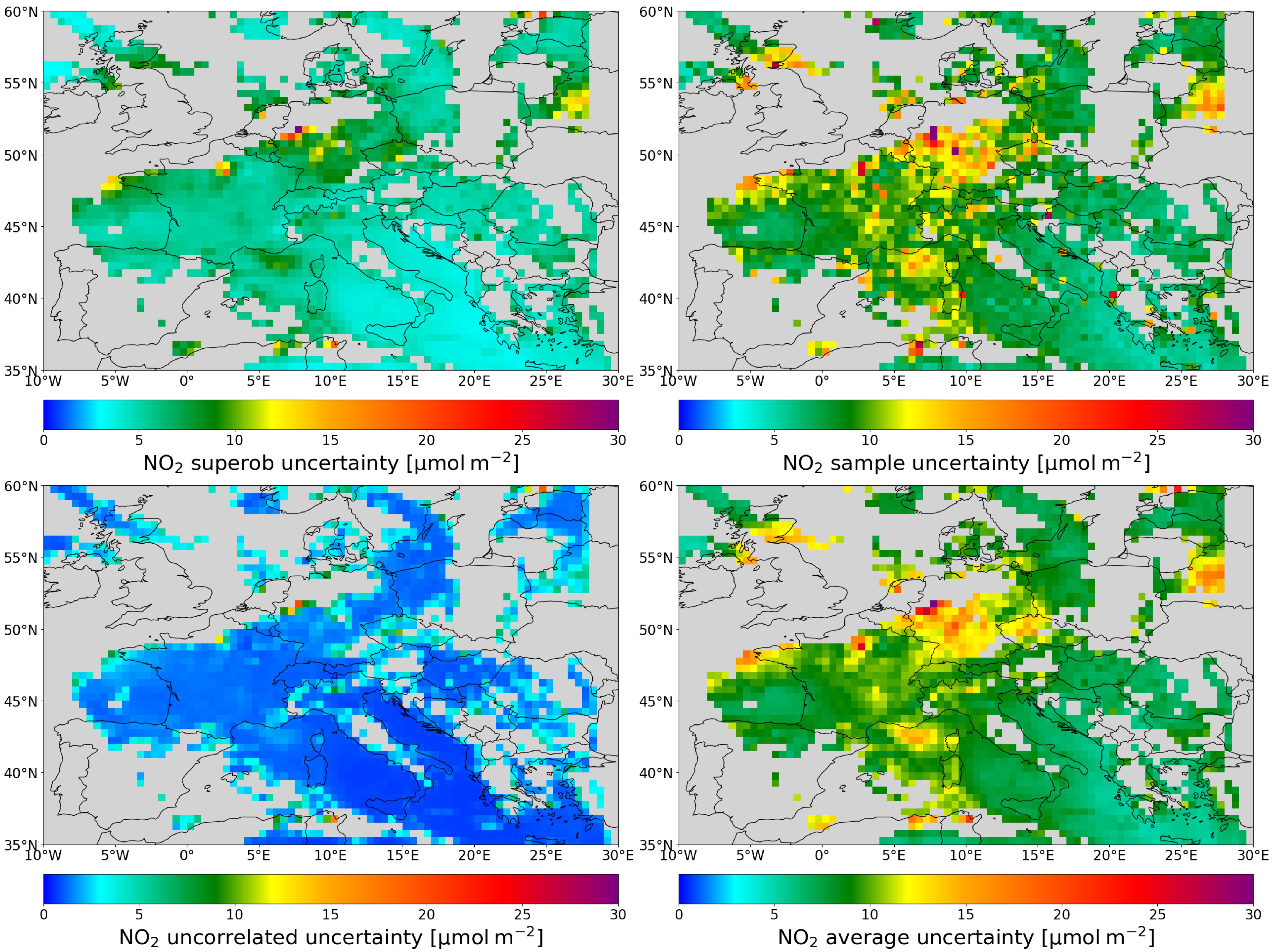
Superobservations: Relative importance stratospheric error large!



Superobservations: Tests with JAMSTEC assimilation system

Estimated superobservation error

Thinning: random selection of 1 observation



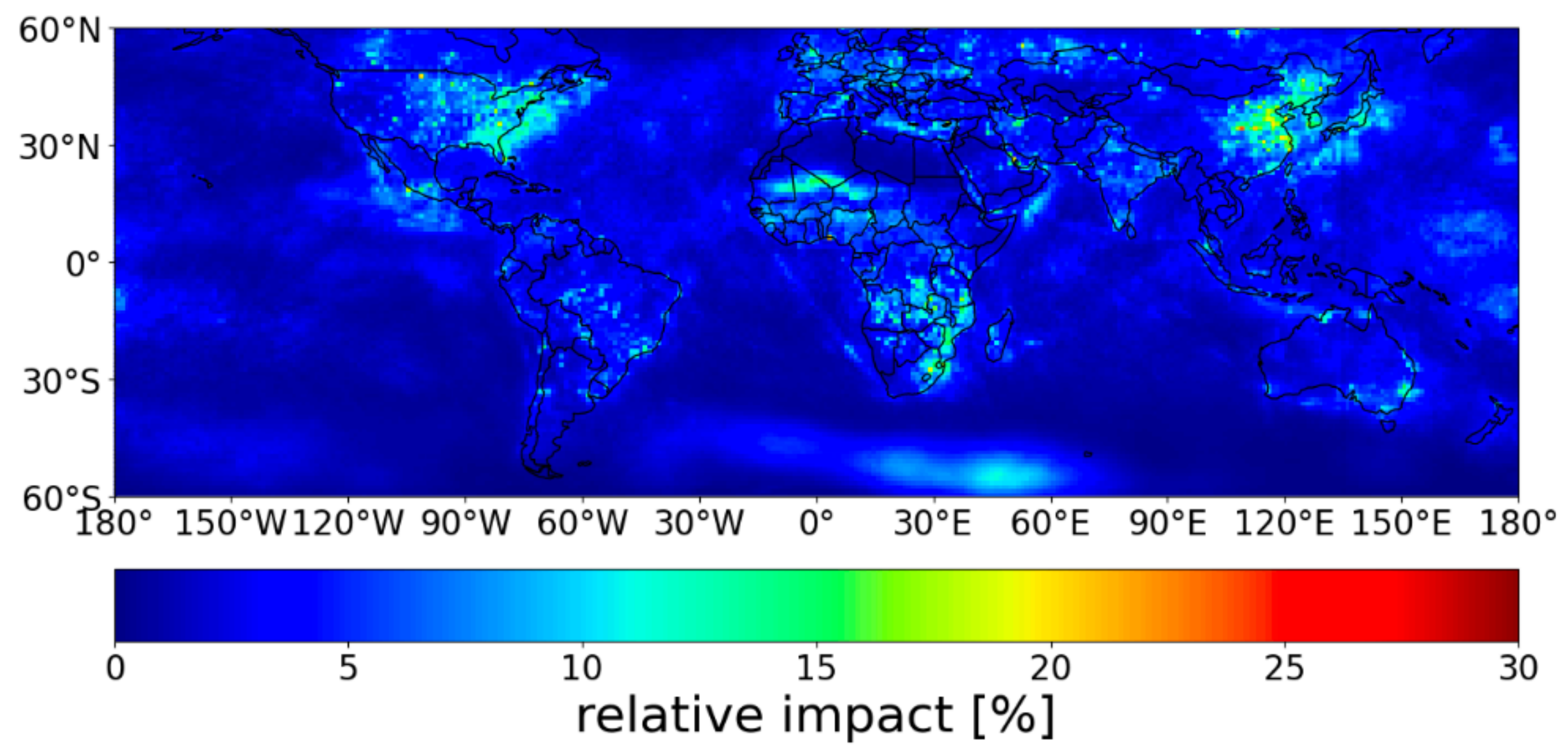
Assuming errors are uncorrelated

Assuming errors are fully correlated

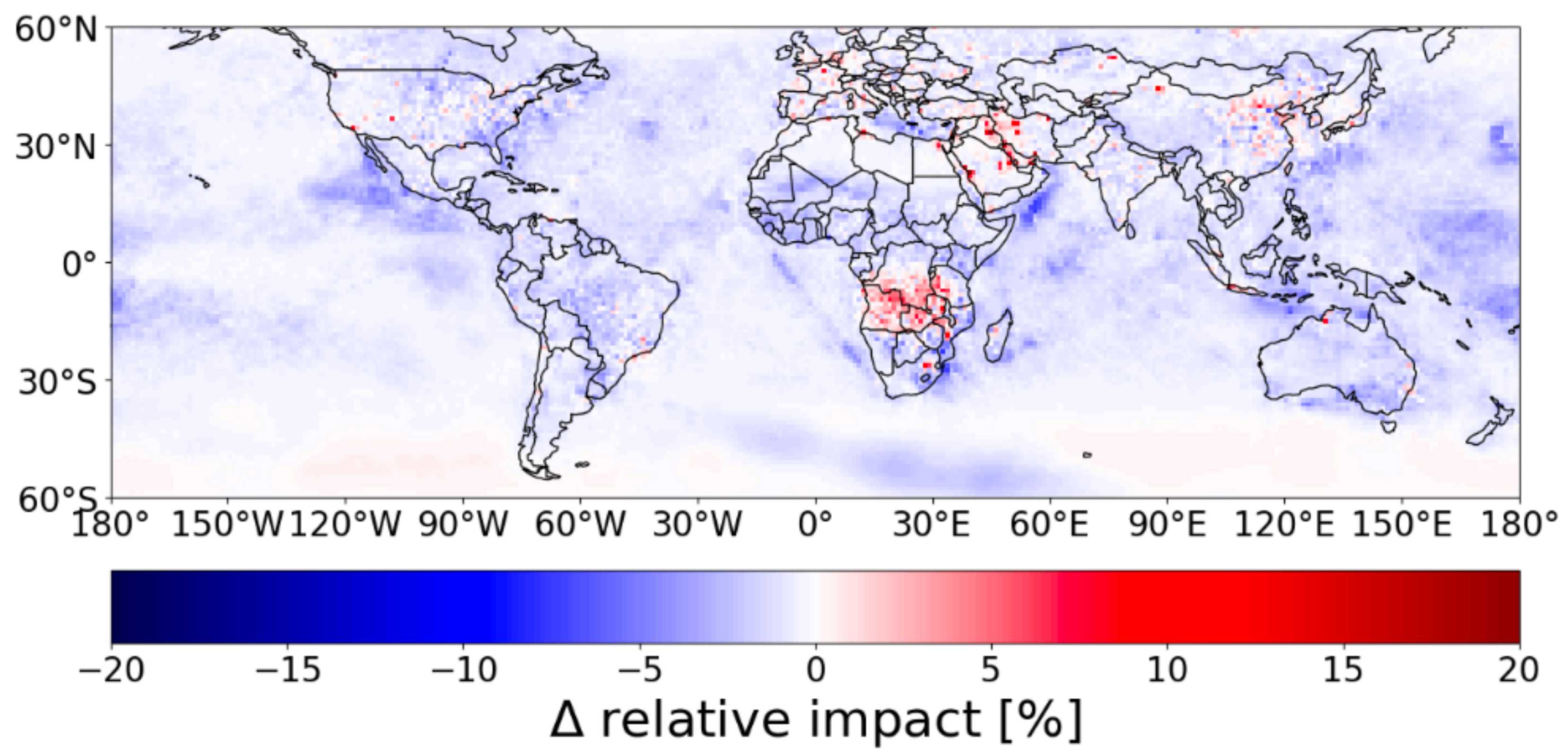
Superobservations: Tests with JAMSTEC assimilation system

Impact

(a) Impact superobservations

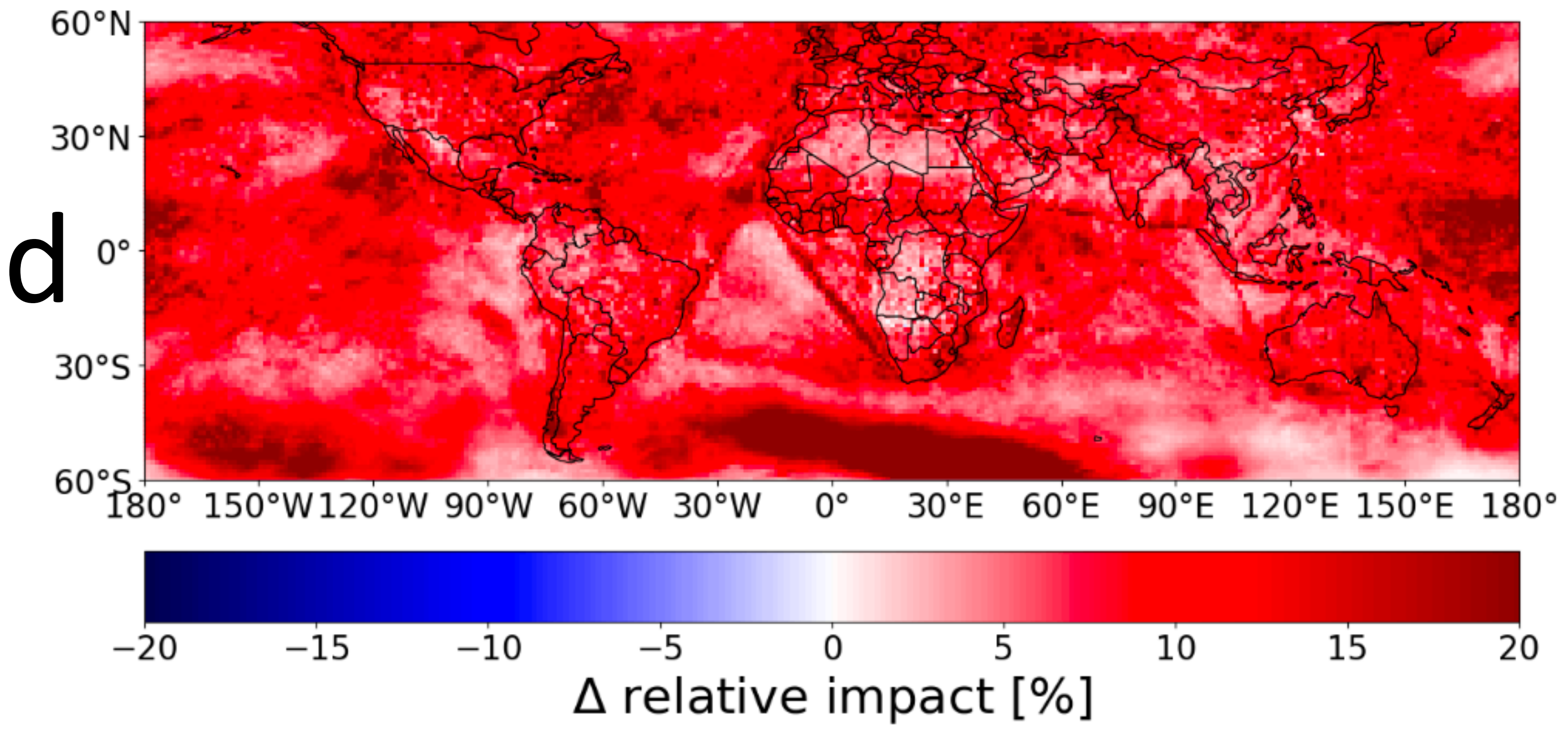


(b) difference thinning - superobservations



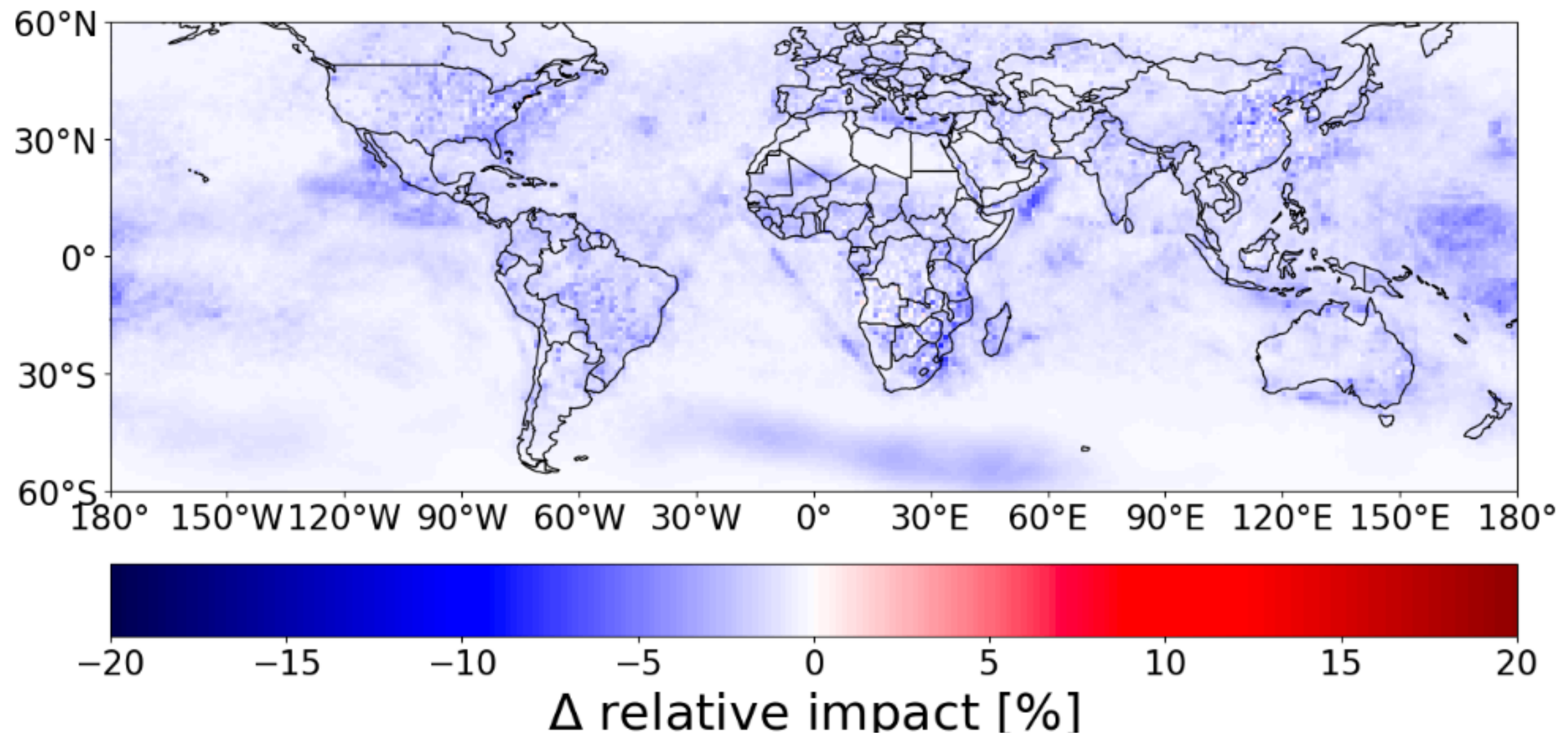
Thinning bit smaller

(c) difference uncorrelated - superobservations



Un-correlated bigger

(d) difference fully correlated - superobservations



Fully correlated smaller

$$Impact[\%] = \frac{1}{t}\sum_{1}^{t}\frac{|A_t - F_t|}{F_t} * 100$$

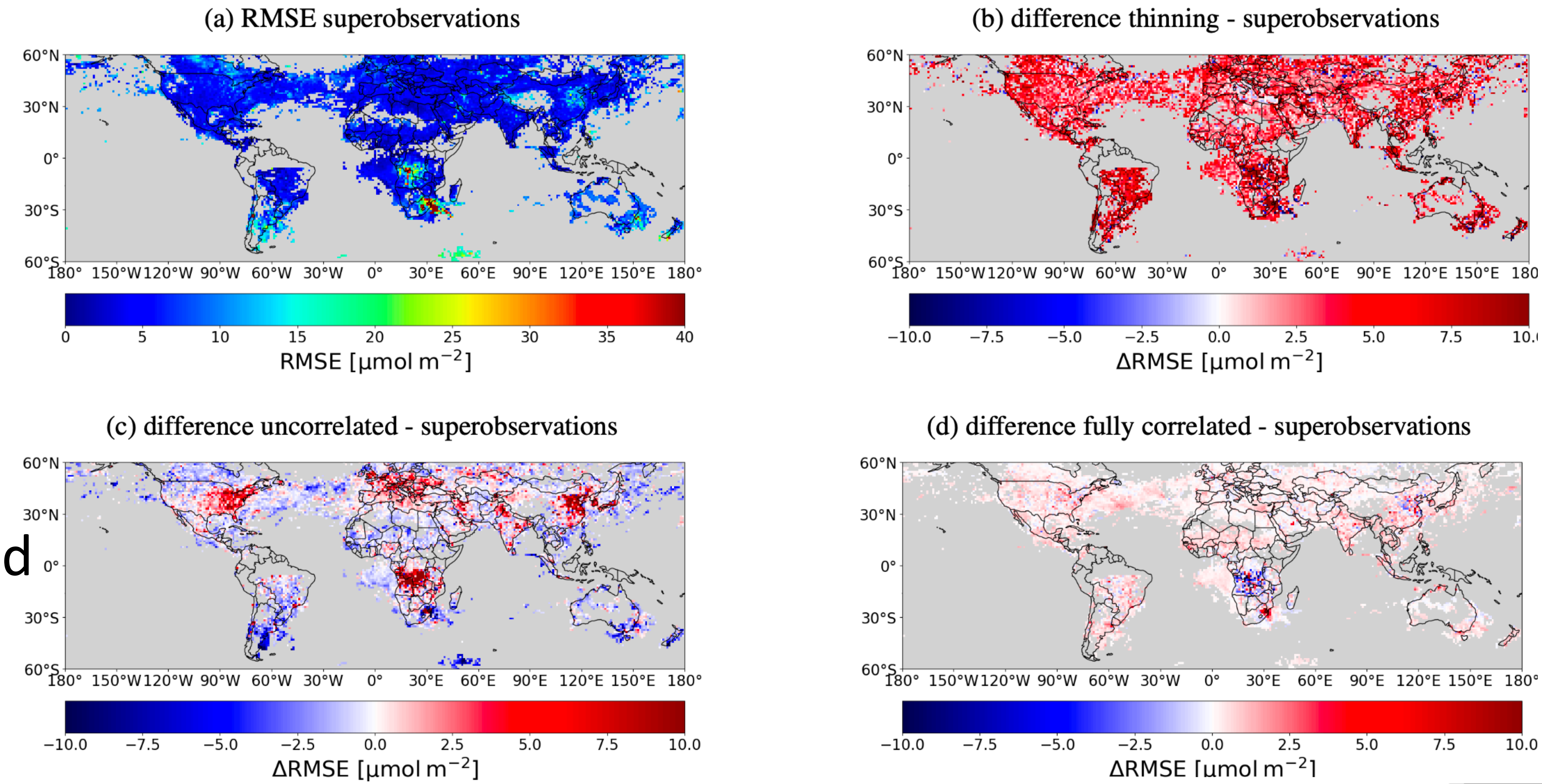
Superobservations: Tests with JAMSTEC assimilation system

Forecast performance

Thinning much worse

Un-correlated worse

Fully correlated worse



$$RMSE_{x,y} = \sqrt{\frac{1}{t}\sum_{1}^{t}(O_{t,x,y} - F_{t,x,y})^2}$$

Application: global-scale data assimilation

Chaser-4/LETKF; MOMO-Chem; TCR-3

Instruments: TROPOMI, OMI, GOME-2, SCIAMACHY

Period: 2003-2023

Species: NO_2, SO_2, HCHO, CO

Filtering: Cloud-free and cloud-covered

ECMWF-CAMS forecasts

Experiments comparing NO_2 superobservations with in-house superobbing approach (ongoing work)

CAMEO project

L3 gridded fields

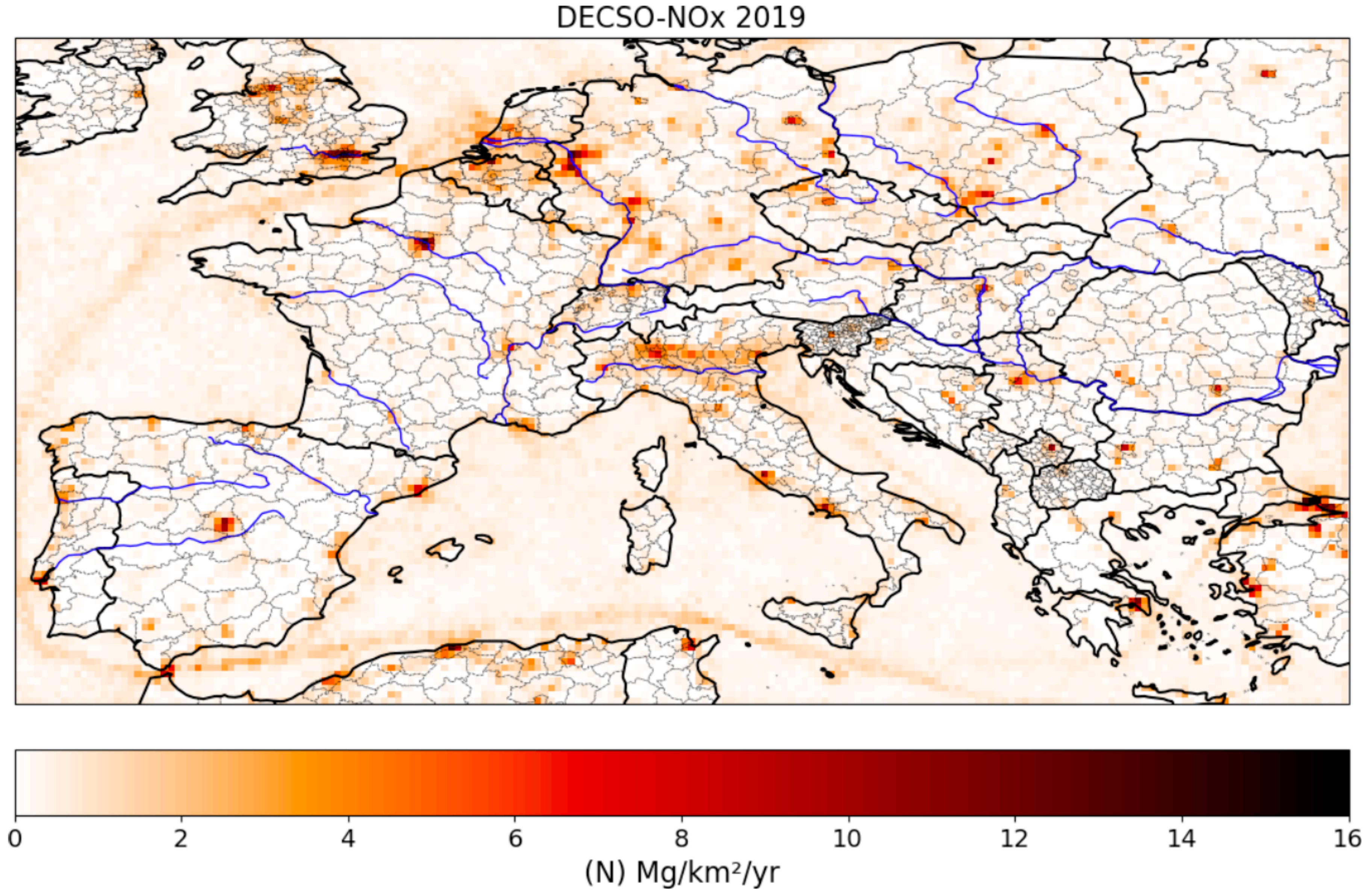
Climate records using multiple instruments, OMI-TROPOMI

ESA CCI+

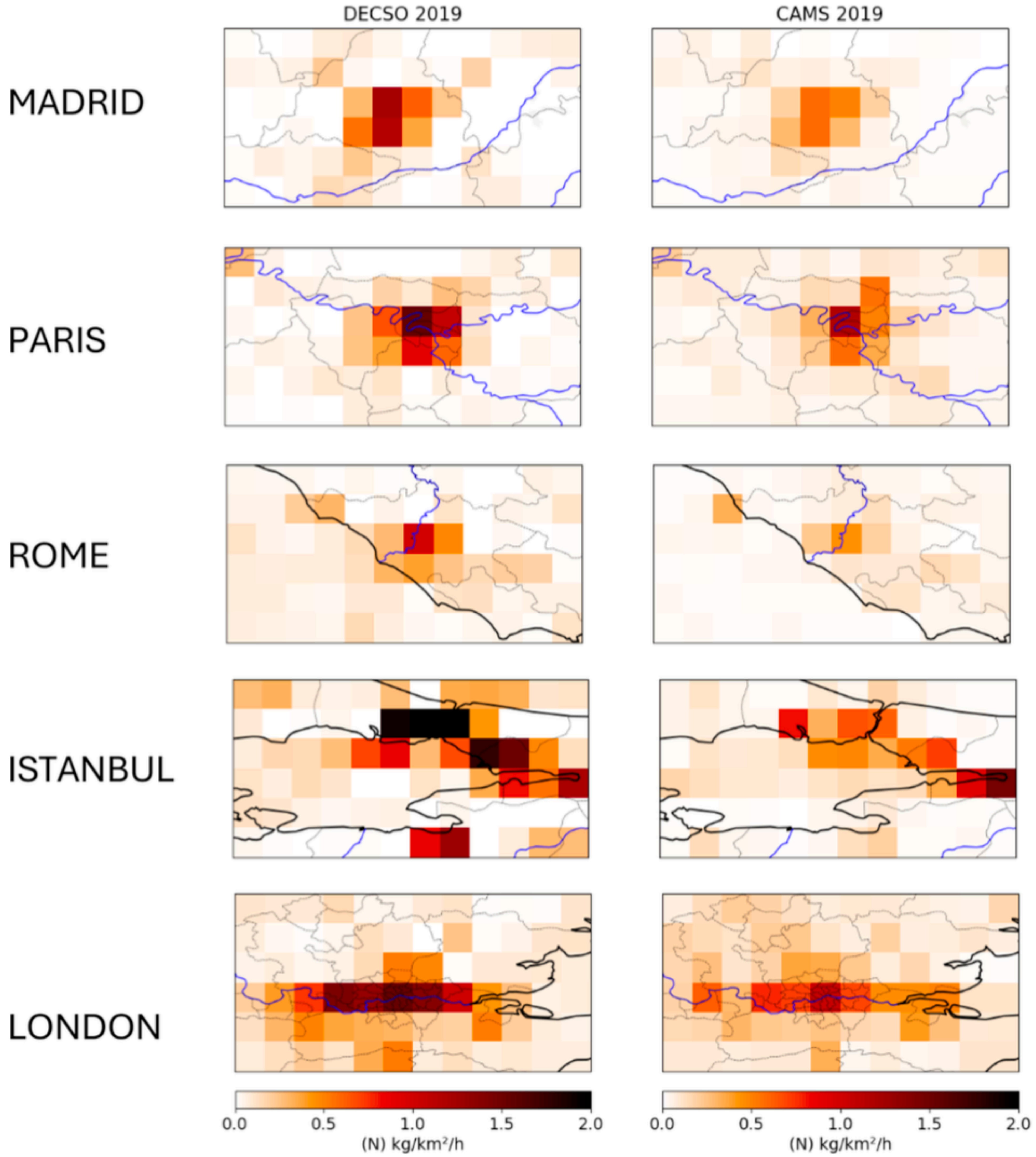
Application: NOx emissions with DECSO-CHIMERE (Europe)

Also for regional applications the superobbing can be beneficial,
up to resolutions of 0.2 (0.1) degree

DECSO NOx emissie, 2019



Ronald van der A, et al., ACP 2024



Thanks for your attention!

Paper:

Pieter Rijsdijk et al.,

Egusphere preprint 2024

https://doi.org/10.5194/egusphere-2024-632

Superobbing code:

Available (Python)

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