

SUPPERROBBING: CREATING AGGREGATE OBSERVATIONS

Pieter Rijdsdijk^{1,2,3}, Sander Houweling^{2,1}, Henk Eskes³, Ilse Aben^{1,2}, Takashi Sekiya⁴, Kazuyuki Miyazaki⁵

1:SRON 2:VU 3: KNMI 4:JAMSTEC 5:JPL

PROJECT BACKGROUND

SRON

Netherlands Institute for Space Research



Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

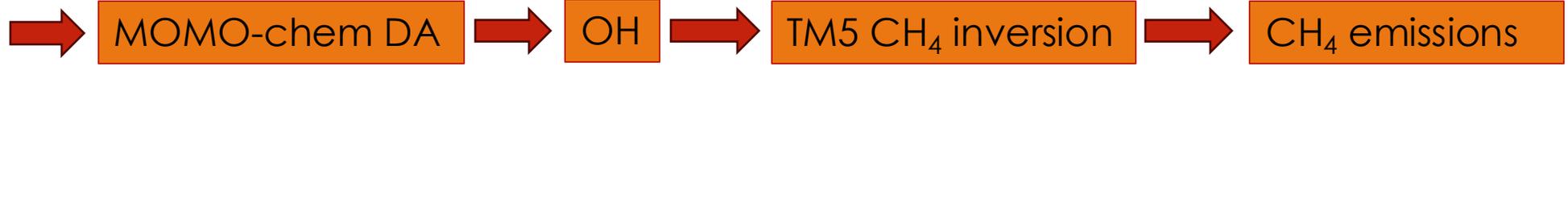


国立研究開発法人海洋研究開発機構
JAMSTEC
JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

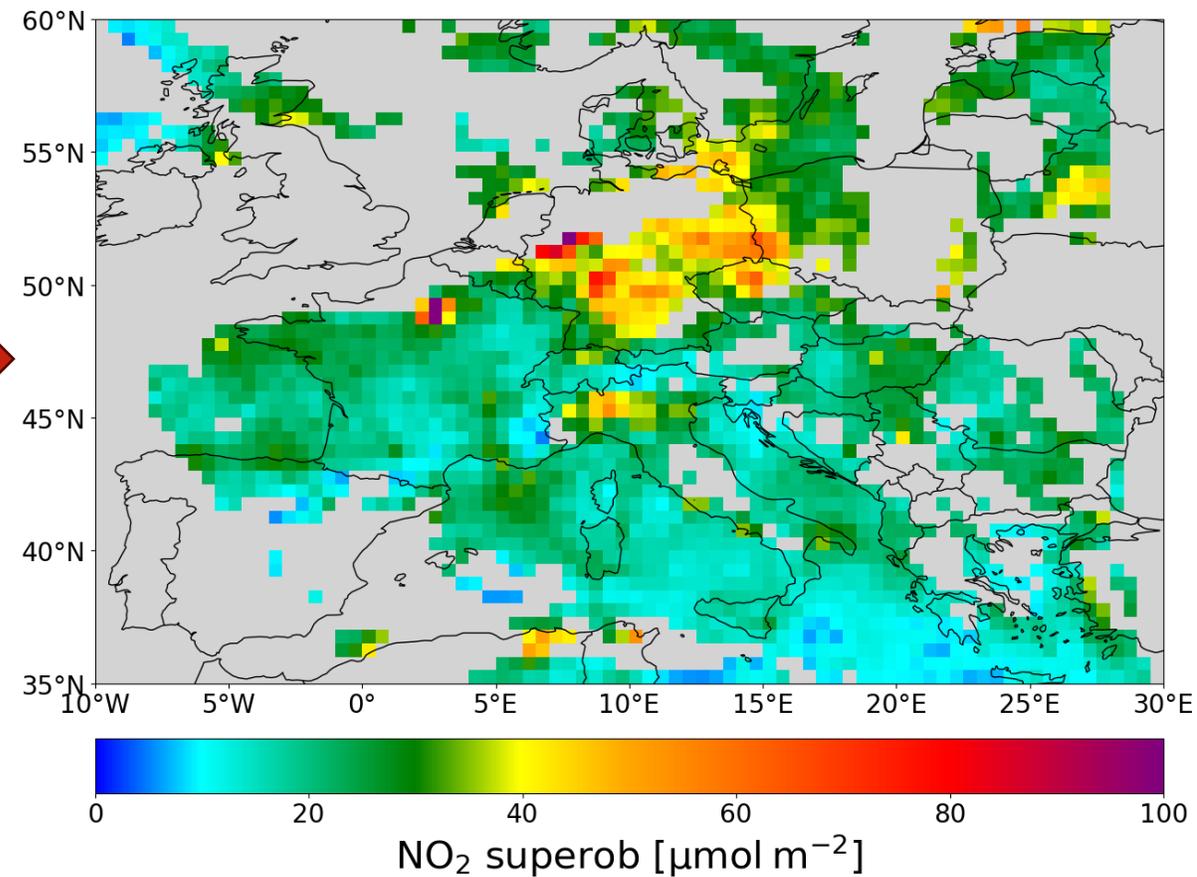
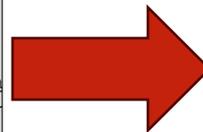
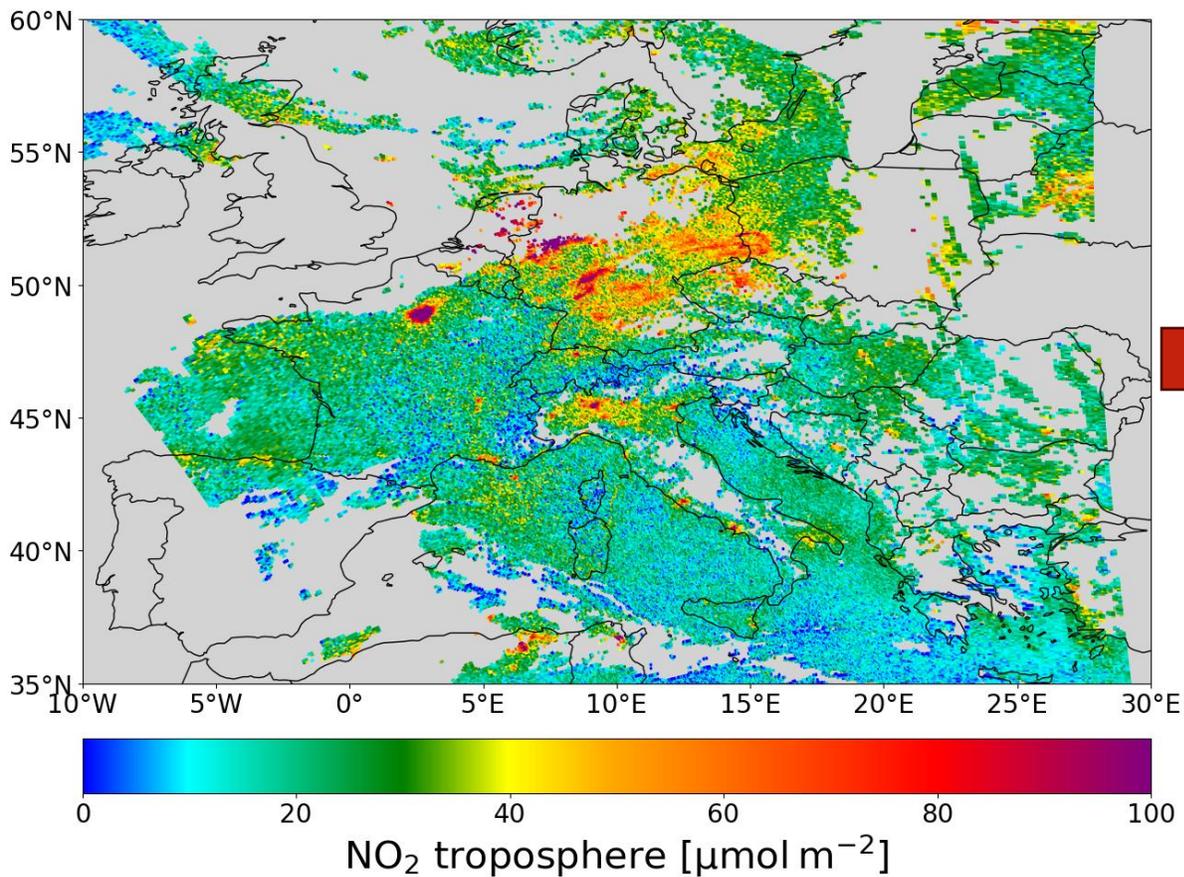
VU  **VRIJE
UNIVERSITEIT
AMSTERDAM**

TROPOMI
superobs:

NO₂
HCHO
SO₂
CO



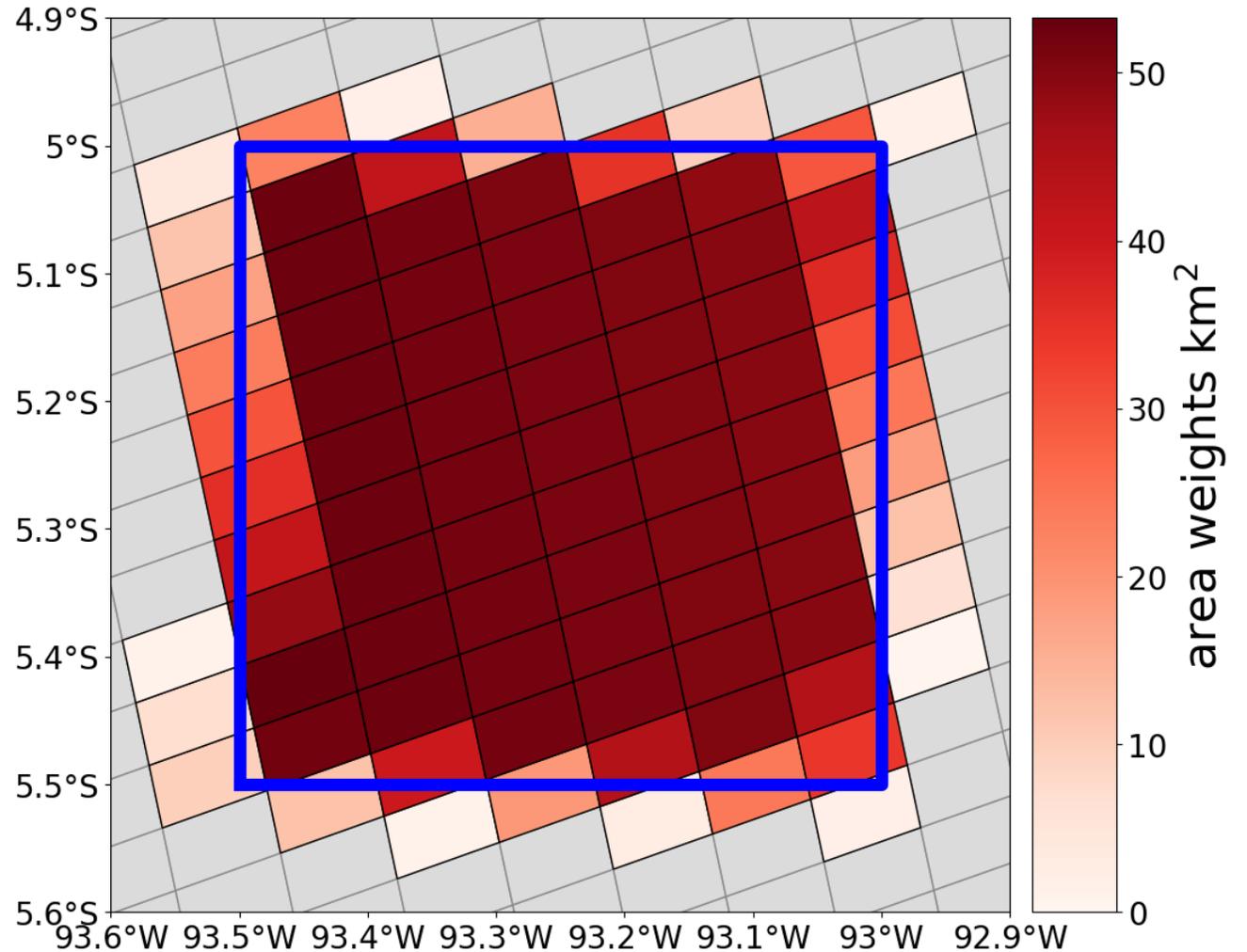
SUPEROBSERVATIONS



CREATING SUPEROBSERVATIONS

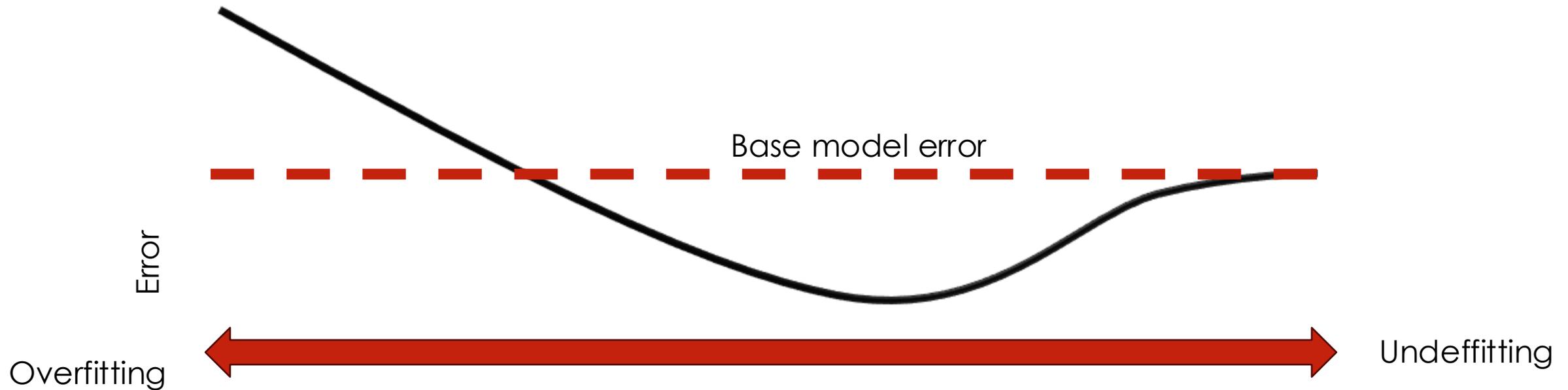
- Average with area weights

$$y_S = \frac{\sum_i^n w_i y_i}{\sum_i^n w_i}$$



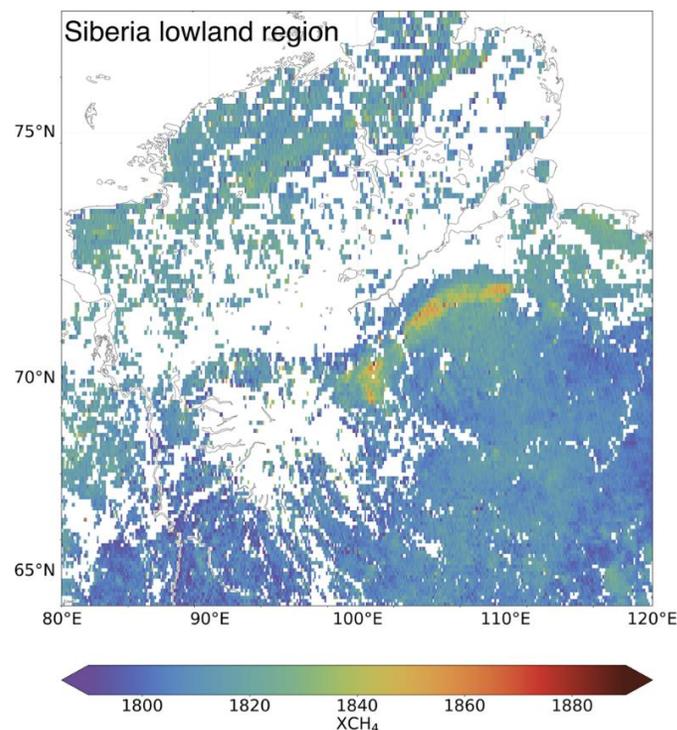
IMPACT OF UNCERTAINTY

- Extract information
- Too large -> Underfitting
- Too small -> Overfitting



IMPACT OF SPATIAL CORRELATIONS

- Observational uncertainties are correlated
 - Clouds
 - Albedo
 - Surface temperature
 - Pressure
- Assimilated as uncorrelated
- Not part of retrieval
- Overfitting



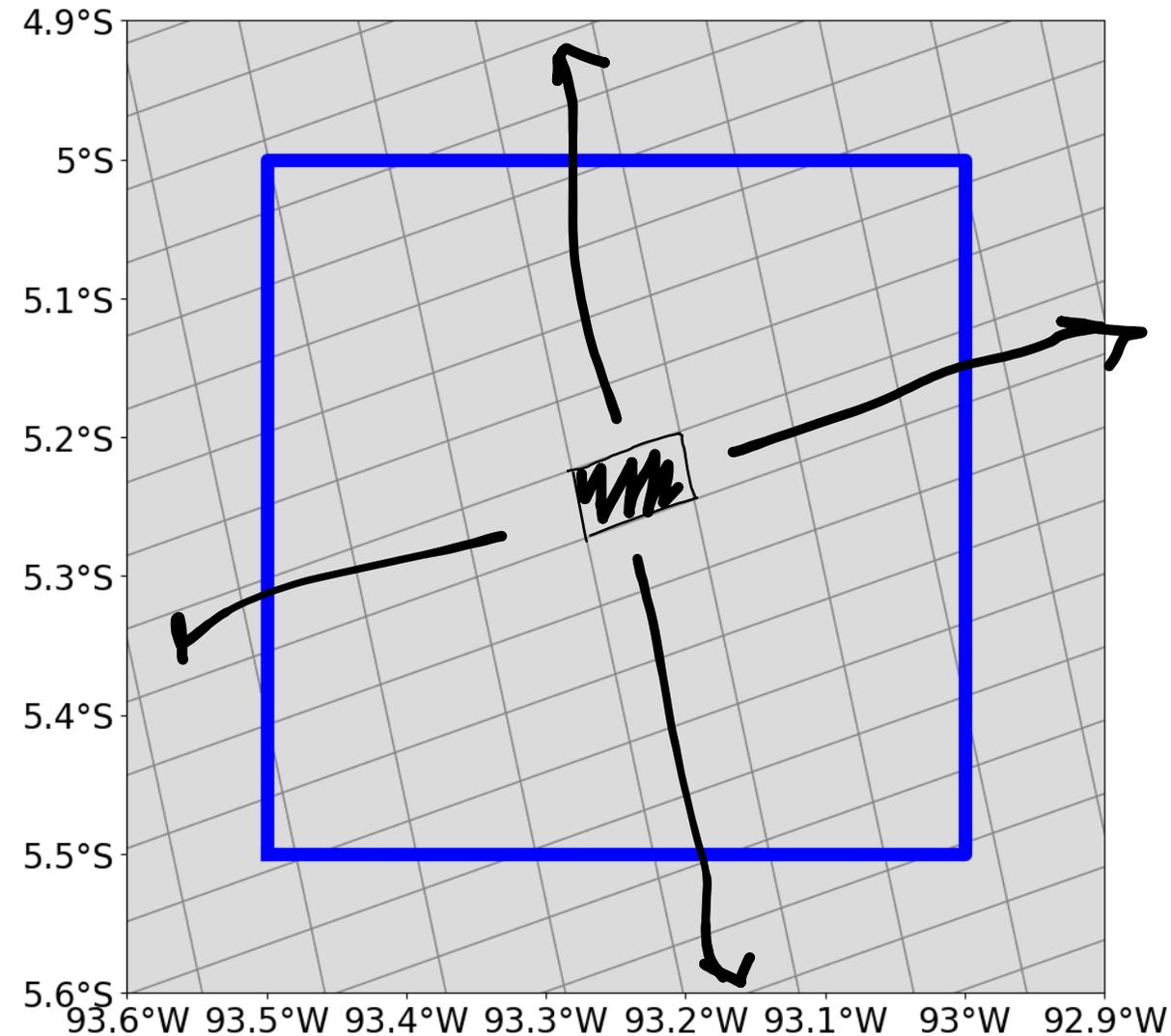
(a)

(b)

Figure 1. (a) TROPOMI XCH₄ retrieved over the North Siberian Lowland region (64–77° N, 80–120° E) averaged from March 2019–March 2020 to a 0.1° × 0.1° grid and (b) Landsat imagery provided by Google Earth © Google, 2022.

ACCOUNTING FOR CORRELATIONS

- How to assimilate?
 - Thinning
 - noisy
 - Underfitting
 - Safe
- Superobservations!

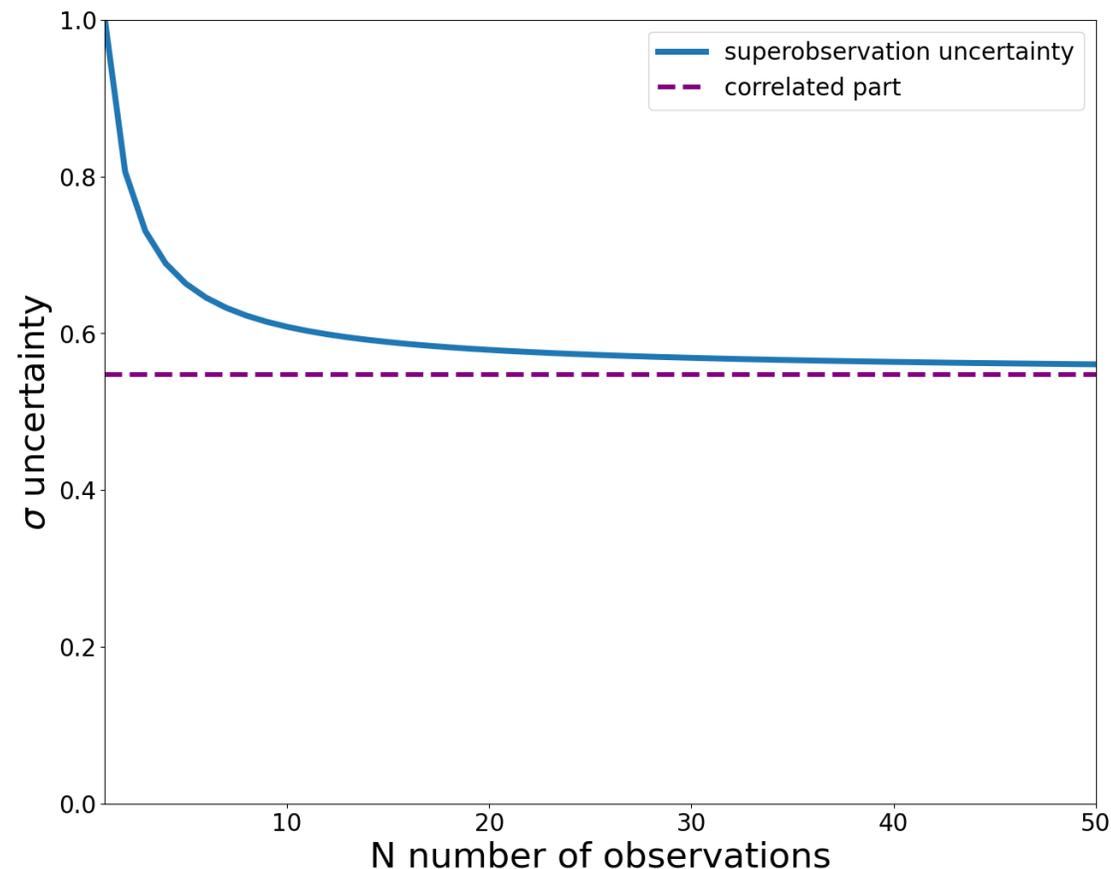


SUPEROBSERVATION UNCERTAINTY

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

$$\tilde{w}_i = \frac{w_i}{\sum_i^n w_i}$$

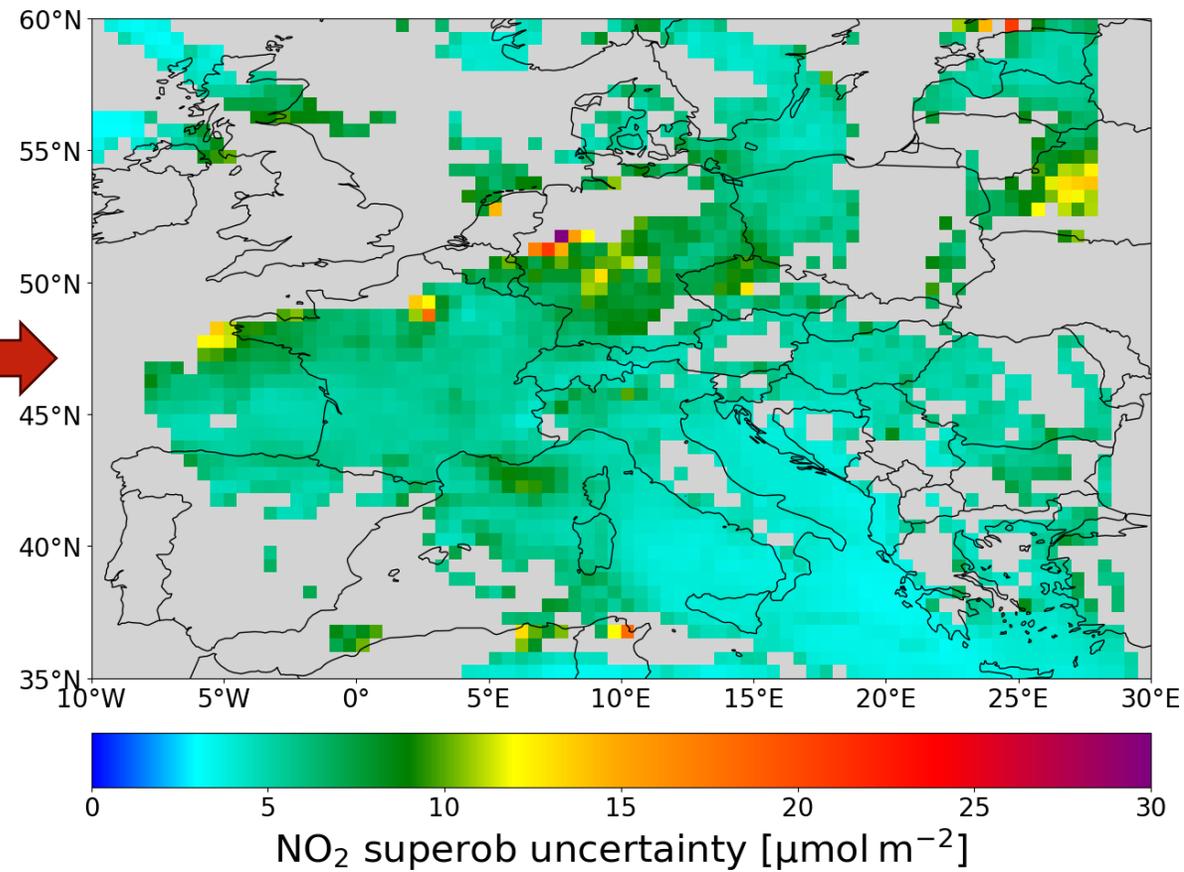
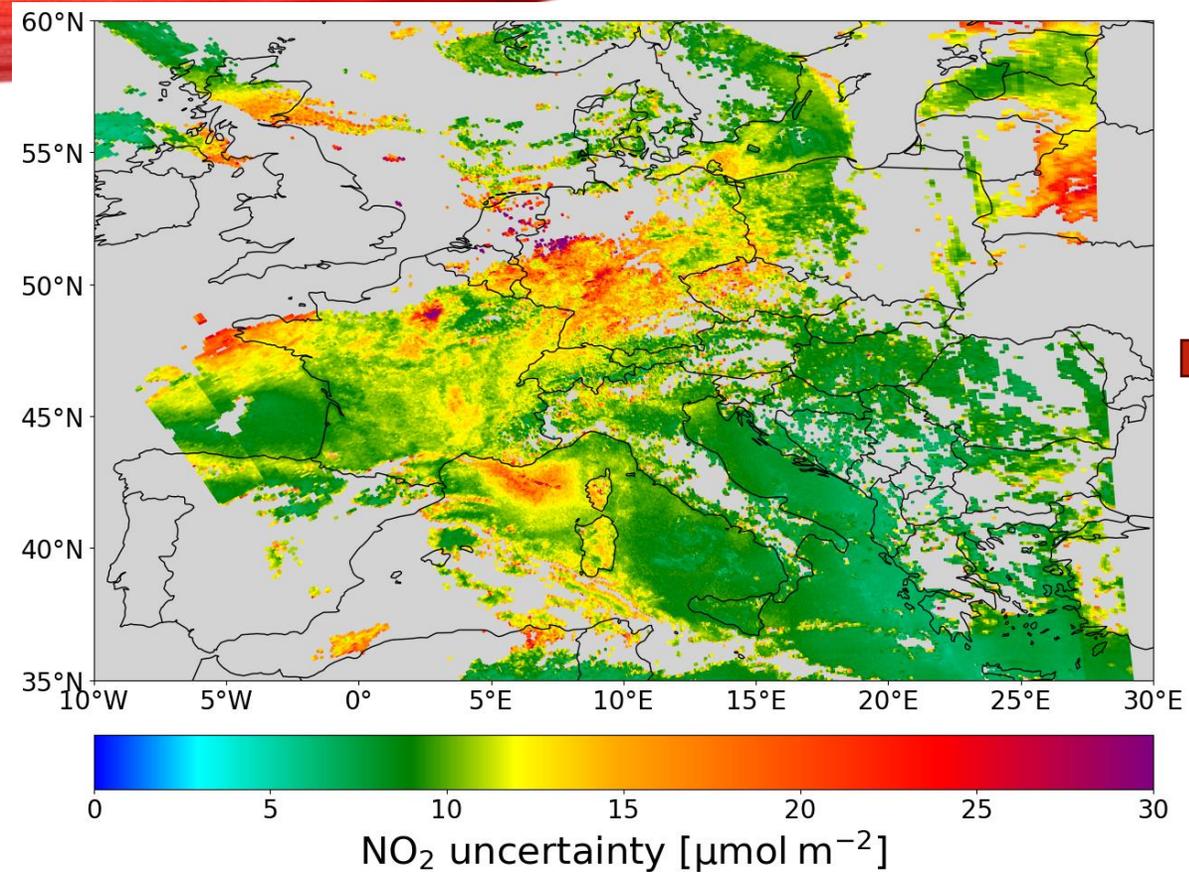
- (spatial) Correlation C
- Asymptote at \sqrt{C}



TROPOMI NO₂

- Slant column -> uncorrelated (C=0)
- Troposphere separation -> fully correlated (C=1)
- Air mass factor -> partially correlated (correlation length -> C~0.3)

$$\sigma_{N_t}^2 = \left(\frac{\partial N_t}{\partial N_{slant}} \right)^2 \sigma_{N_{slant}}^2 + \left(\frac{\partial N_t}{\partial N_{strat}} \right)^2 \sigma_{N_{strat}}^2 + \left(\frac{\partial N_t}{\partial M_t} \right)^2 \sigma_{M_t}^2$$



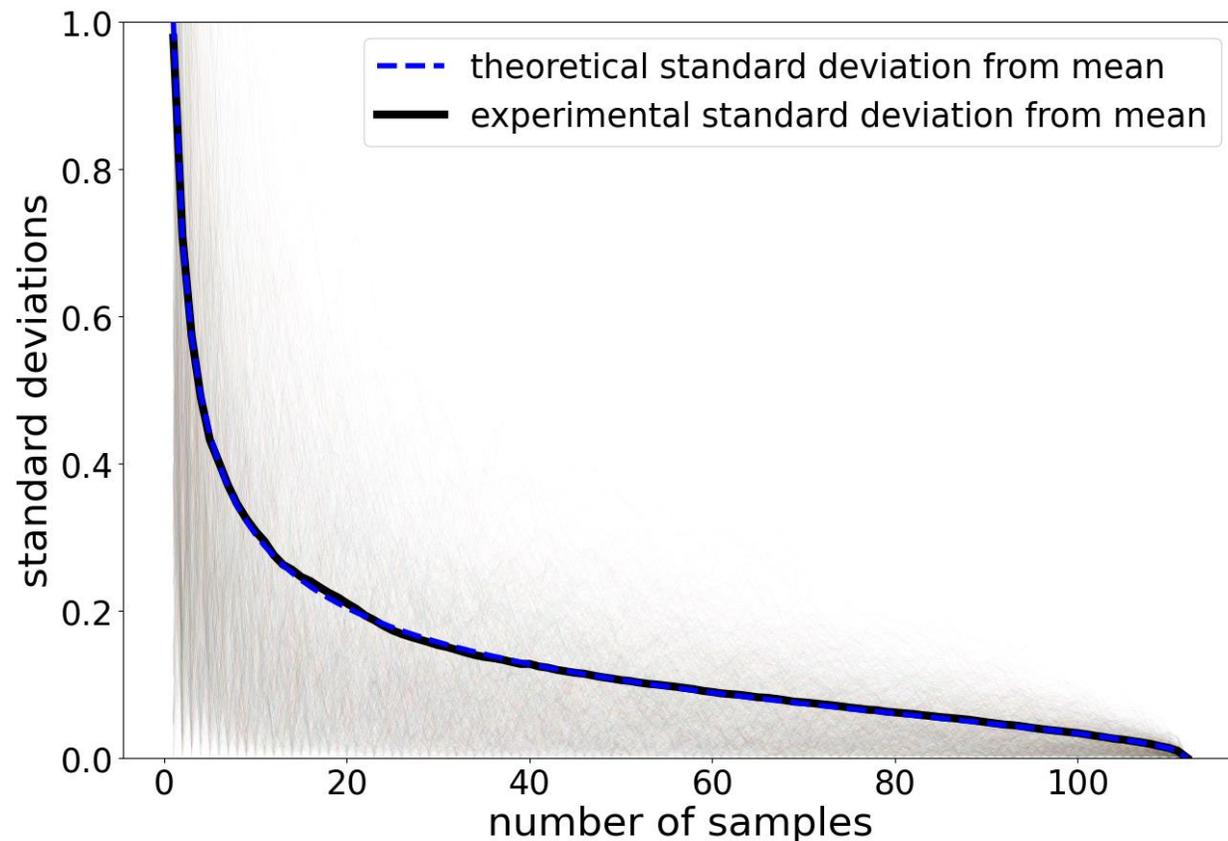
$$\sigma_{obs}^2 = (1 - c) \sum_{i=1}^N \tilde{w}_i^2 \sigma_i^2 + c \left(\sum_{i=1}^N \tilde{w}_i \sigma_i \right)^2$$

REPRESENTATION ERROR (RE)

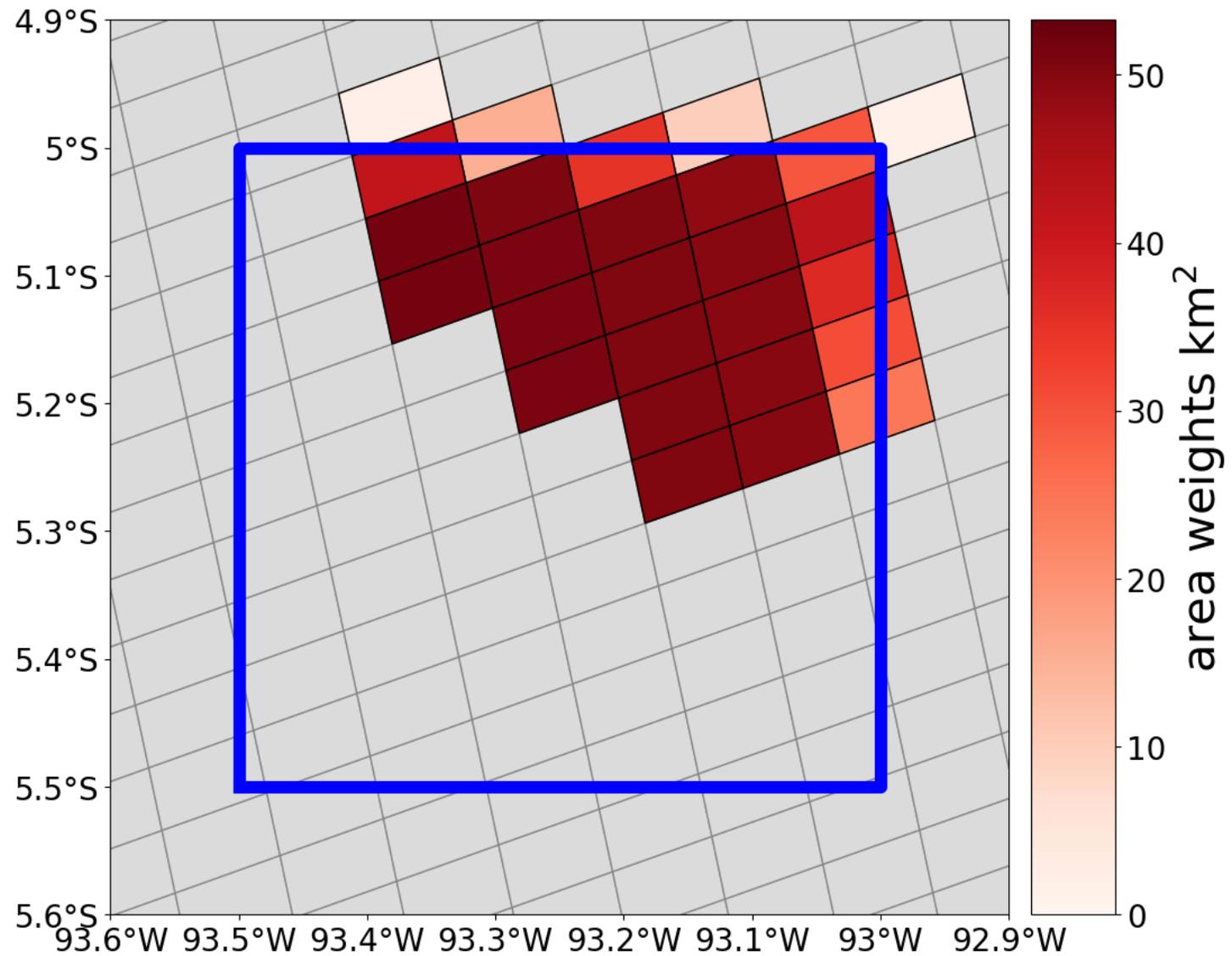
- Experiment
 - Remove observations
- Standard error without replacement

$$SE = \frac{\sigma}{\sqrt{n}}$$

$$SE_{corr} = \frac{\sigma}{\sqrt{n}} \sqrt{\frac{N-n}{N-1}}$$



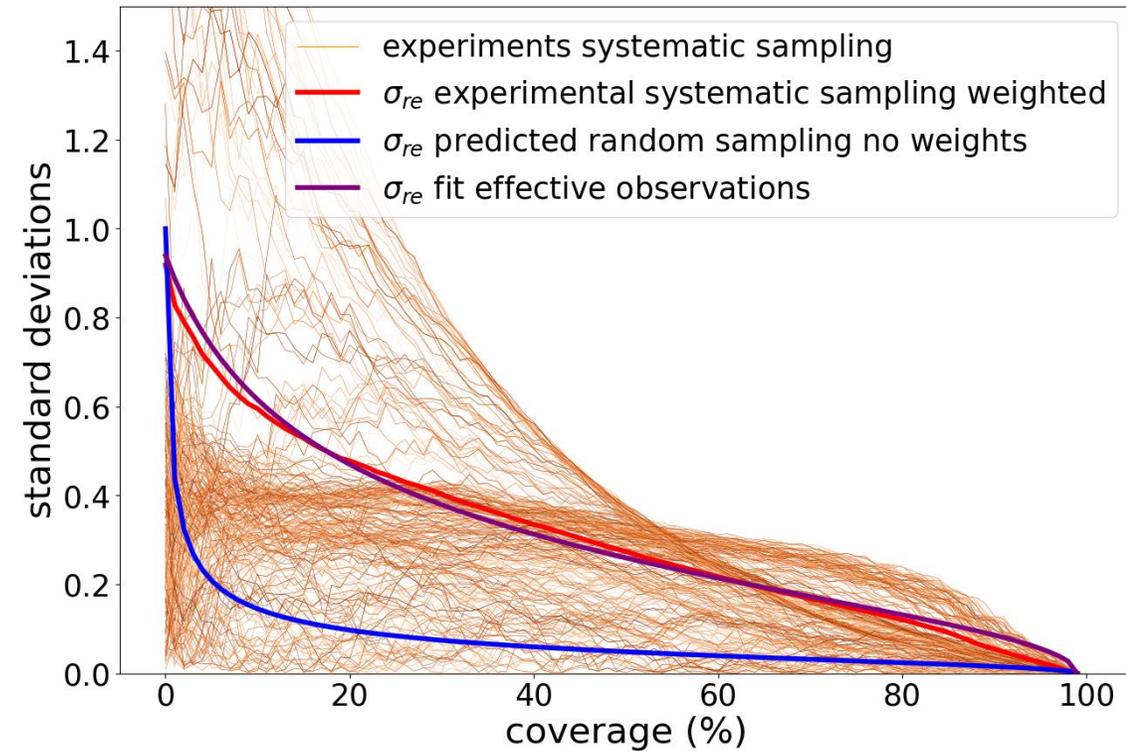
- Systematic sampling
- Clouds



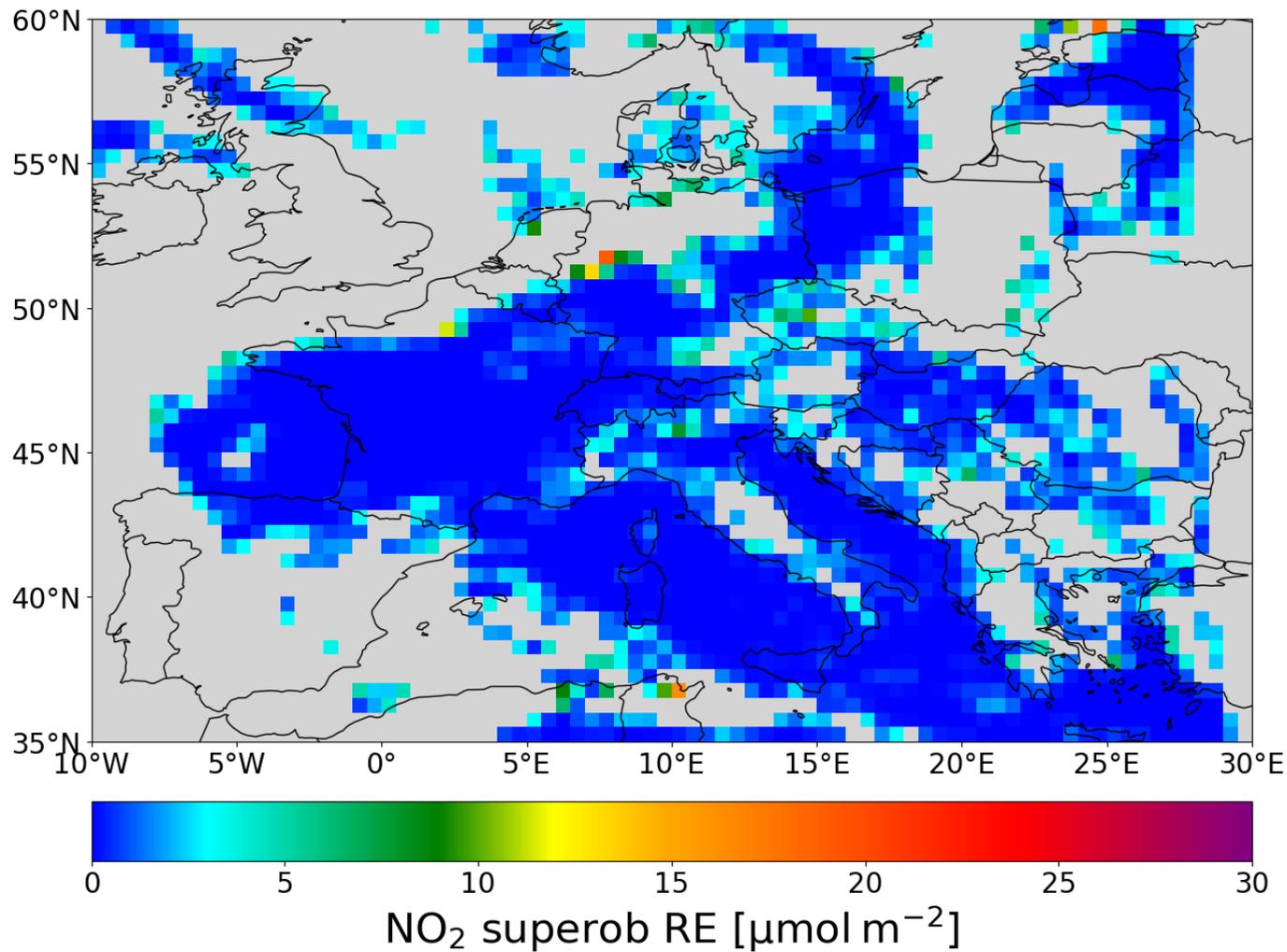
SYSTEMATIC RE

- Increased RE
- Fit by decreasing N/n
 - Effective observations

$$\sigma_{re} = \frac{\sigma}{n} \sqrt{\frac{N - n}{N - 1}}$$



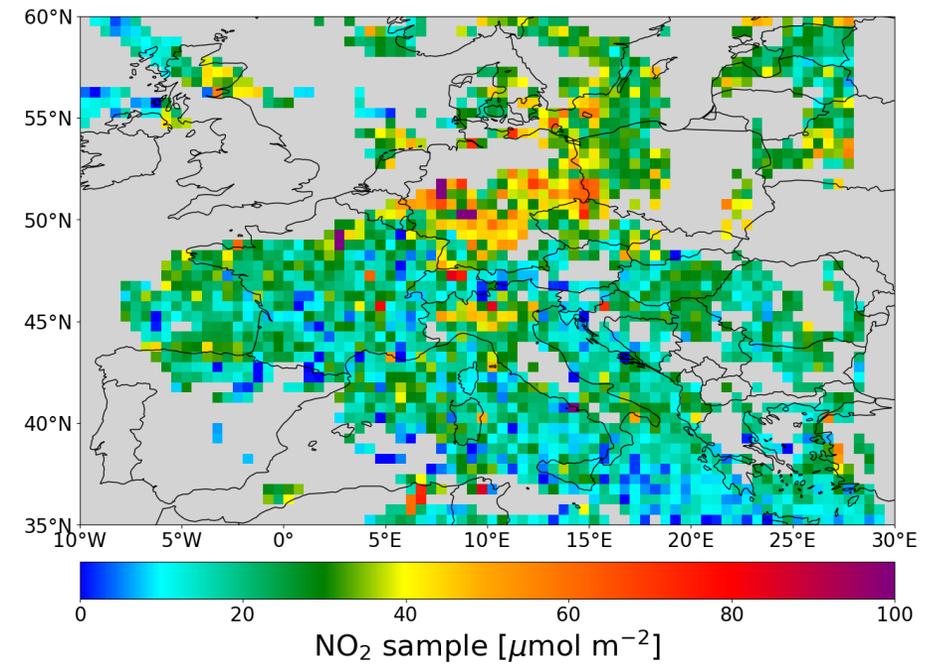
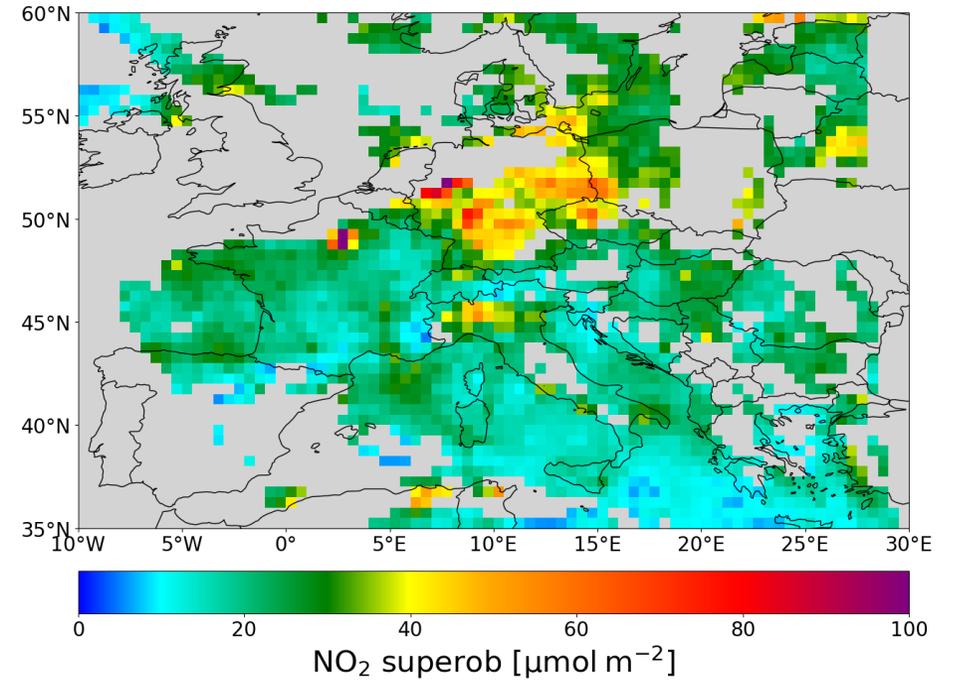
REPRESENTATION ERROR

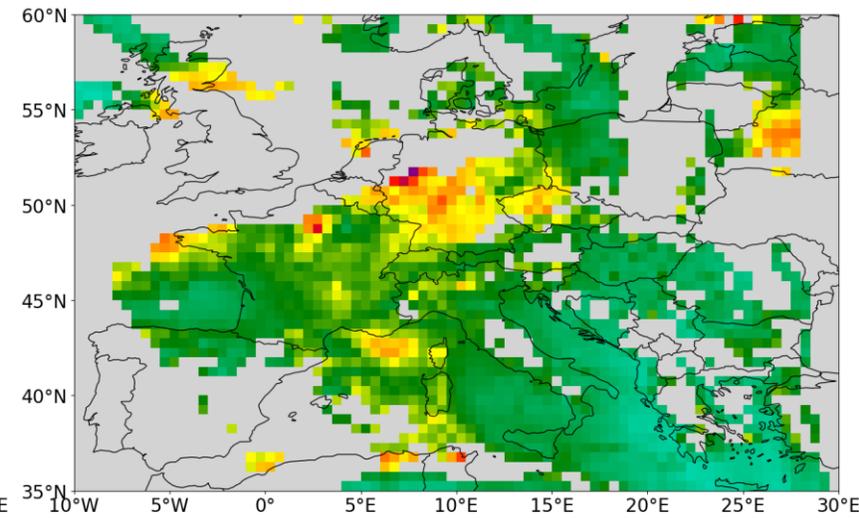
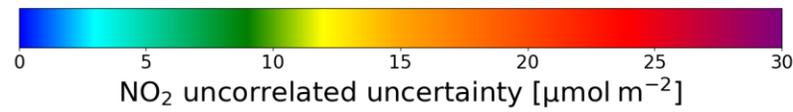
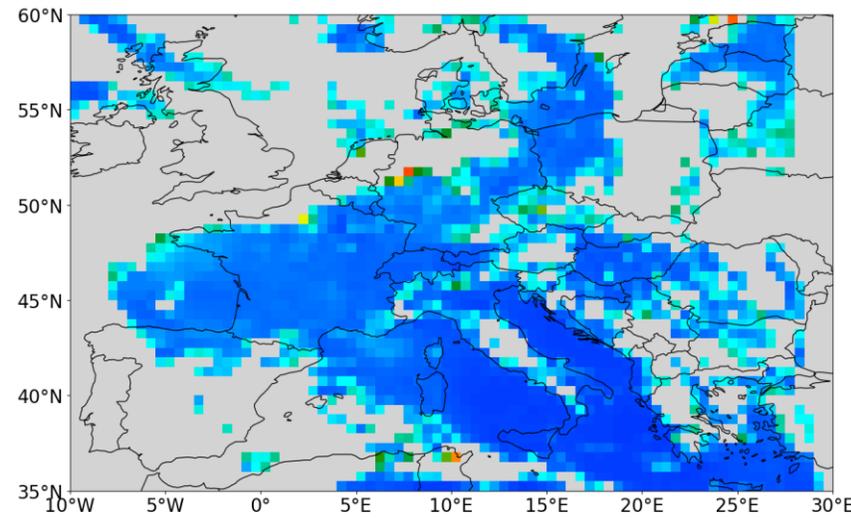
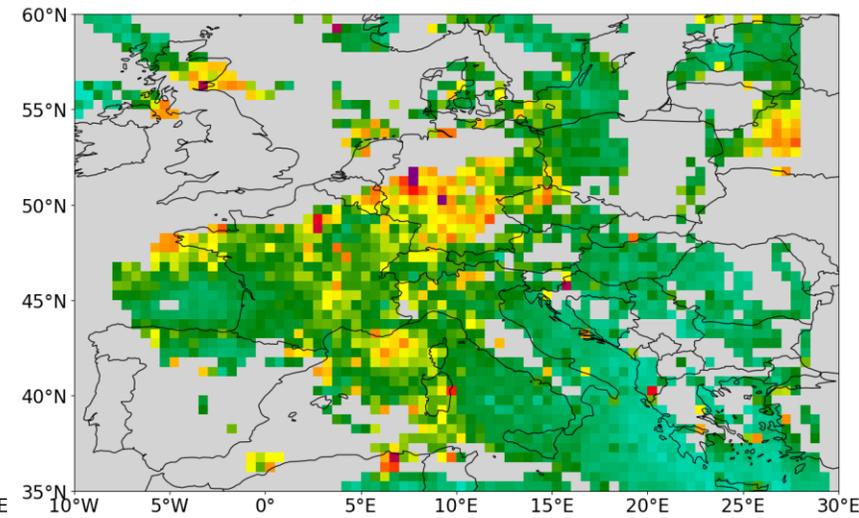
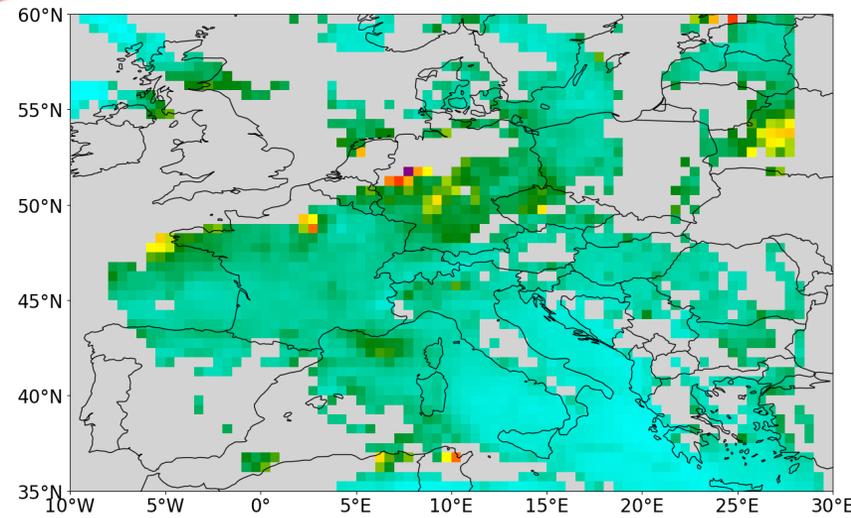


Experiments:

- Superobservations (normal)
- Superobservations (uncorrelated)
- Superobservations (fully correlated)

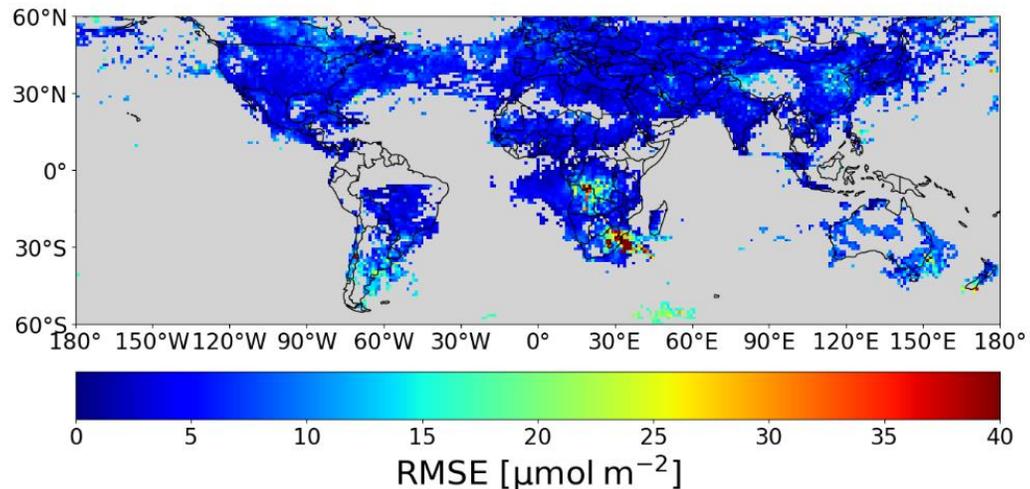
- Thinning



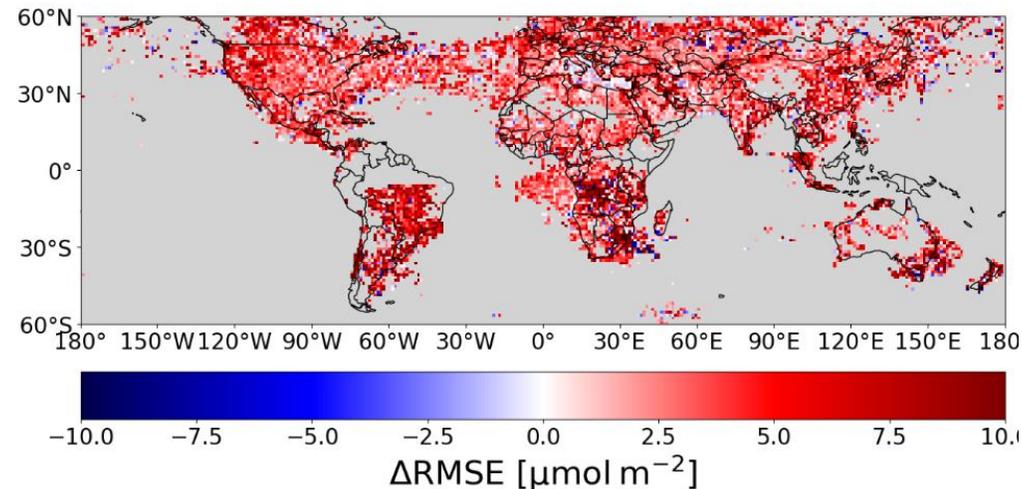


$$RMSE_{x,y} = \sqrt{\frac{1}{t} \sum_1^t (O_{t,x,y} - F_{t,x,y})^2}$$

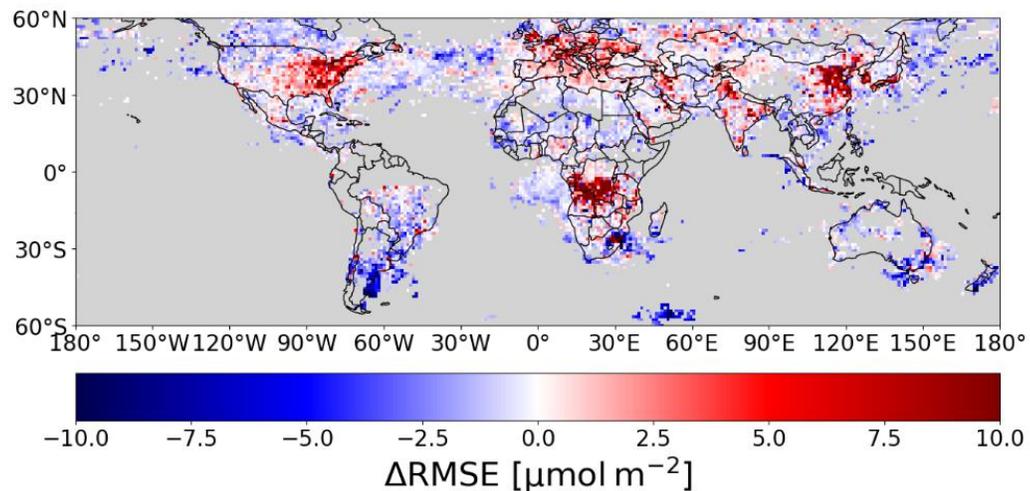
(a) RMSE superobservations



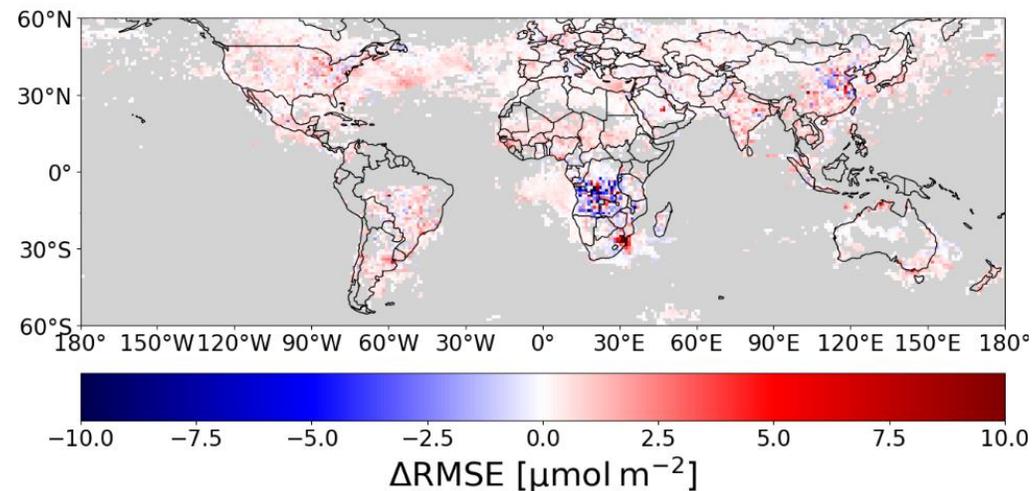
(b) difference thinning - superobservations



(c) difference uncorrelated - superobservations

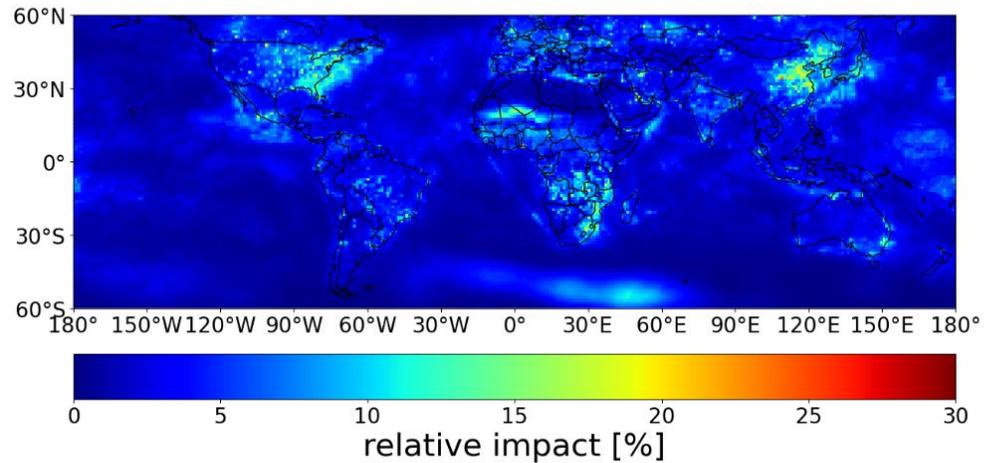


(d) difference fully correlated - superobservations

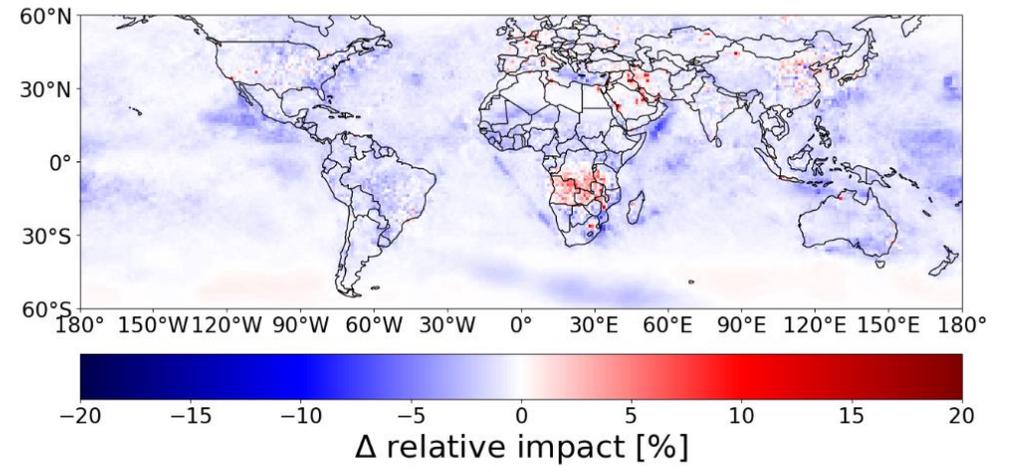


$$Impact[\%] = \frac{1}{t} \sum_1^t \frac{|A_t - F_t|}{F_t} * 100$$

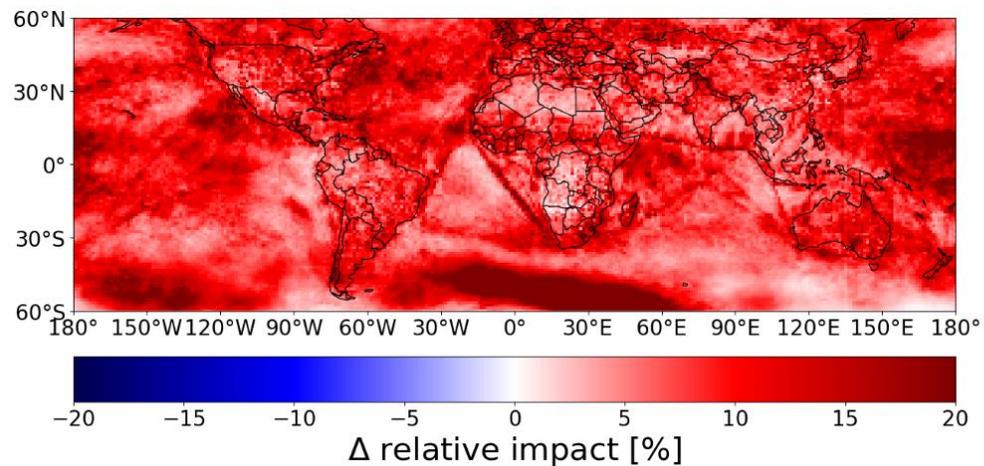
(a) Impact superobservations



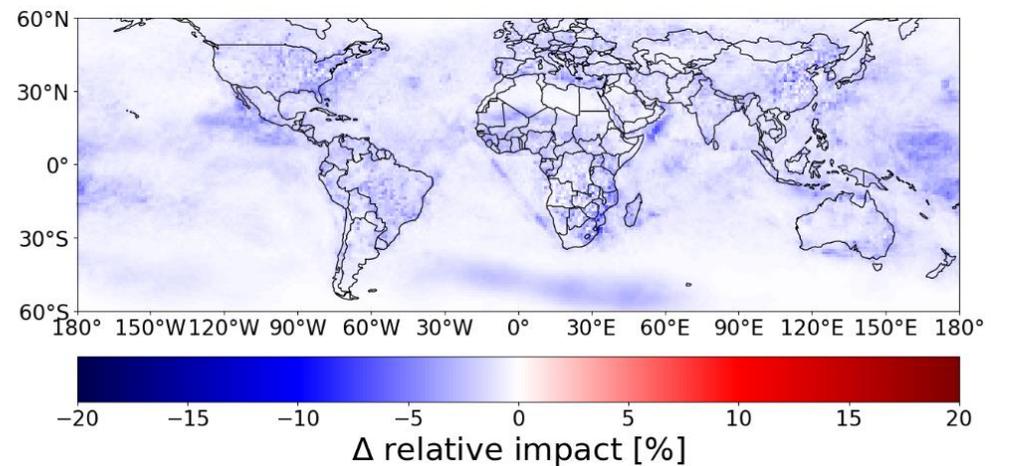
(b) difference thinning - superobservations



(c) difference uncorrelated - superobservations



(d) difference fully correlated - superobservations



OTHER SUPEROBSERVATIONS

- TROPOMI
 - HCHO
 - SO₂
 - CO
- NO₂
 - TROPOMI
 - SCIAMACHY
 - OMI
 - GOME-2

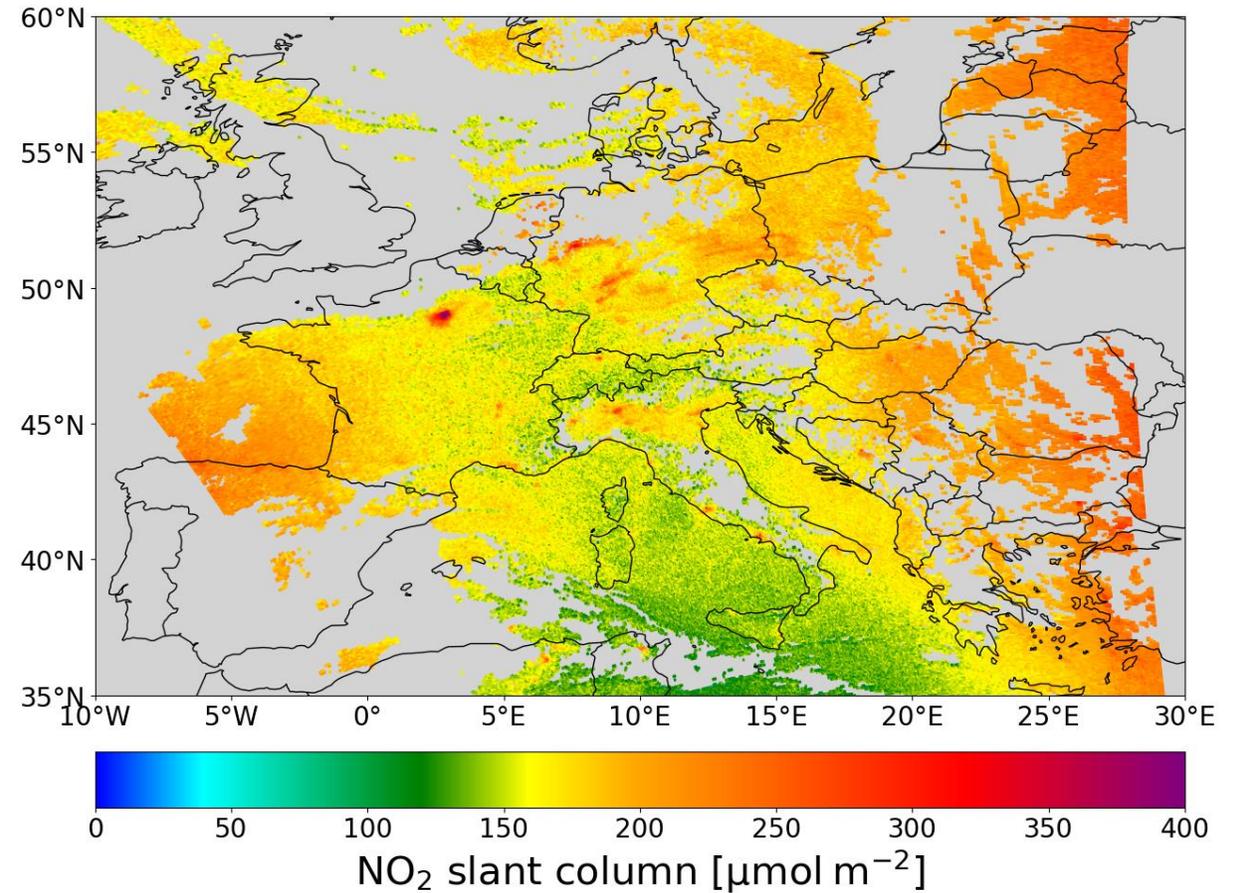
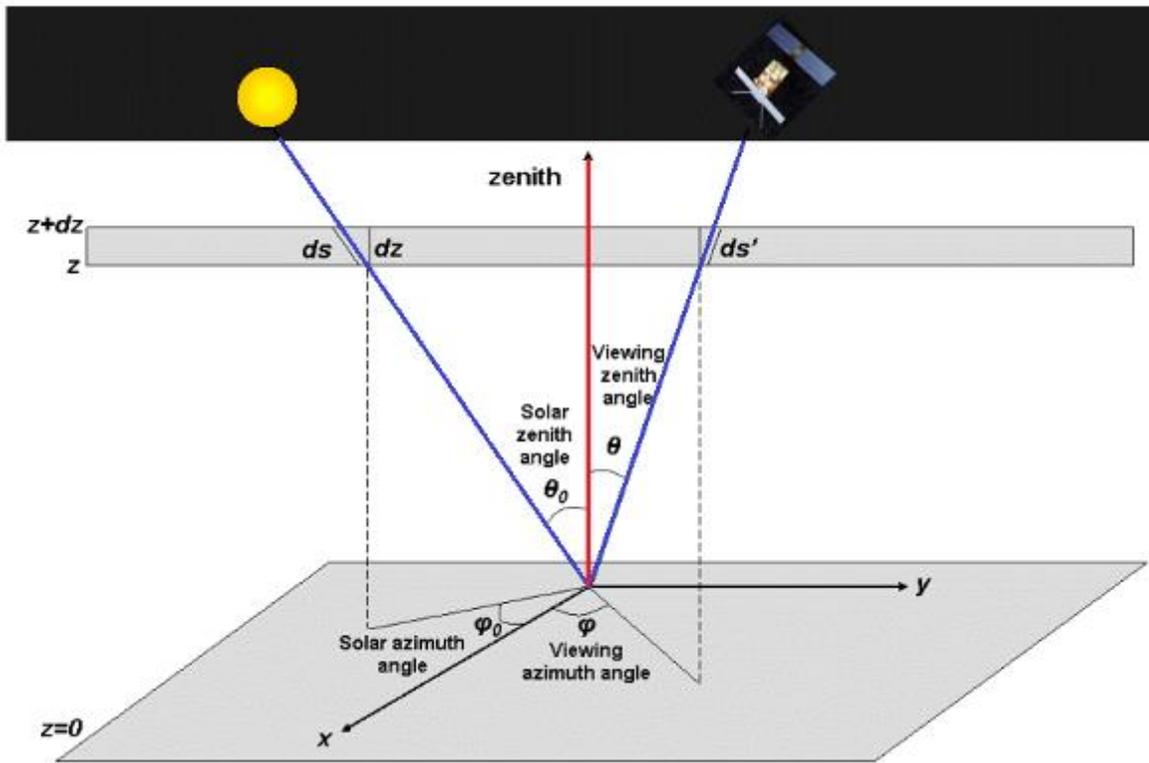
QUESTIONS?

- P.Rijsdijk@sron.nl
- Interested in using superobs
 - Email me!



EXTRA SLIDES:

SLANT COLUMN

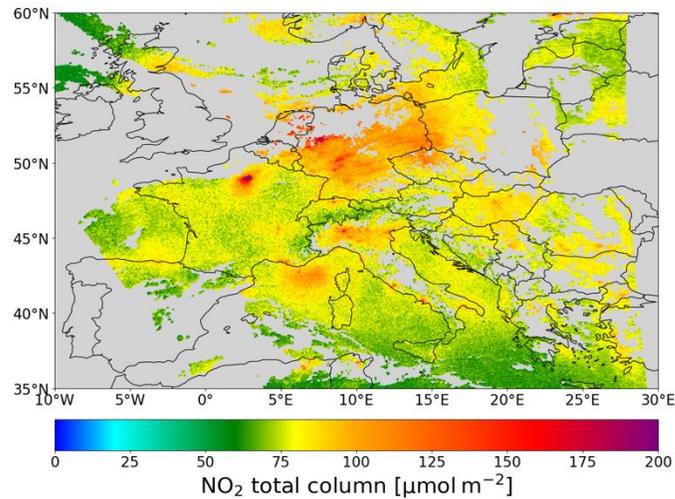


Sentinel online, technical guides, s5p,
DOAS.

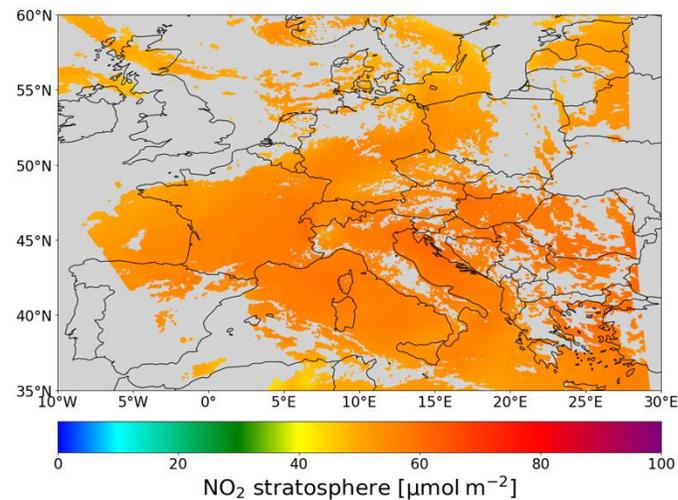
<https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-5p/level-2/doas-method>

TROPOSPHERE SEPARATION

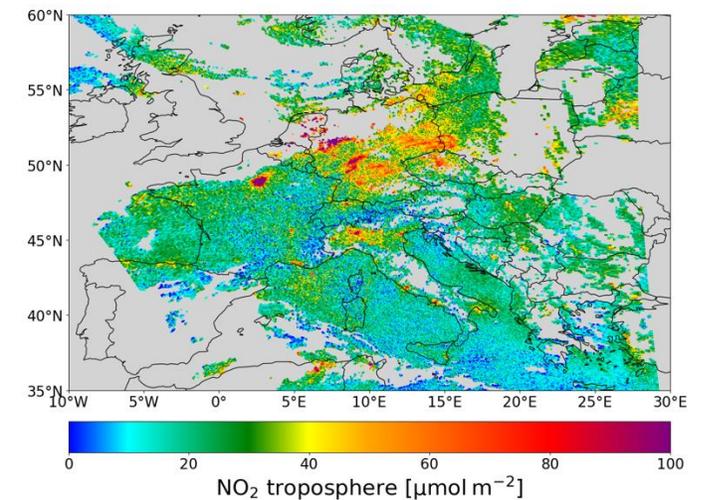
Total column



Stratosphere (TM5-MP)

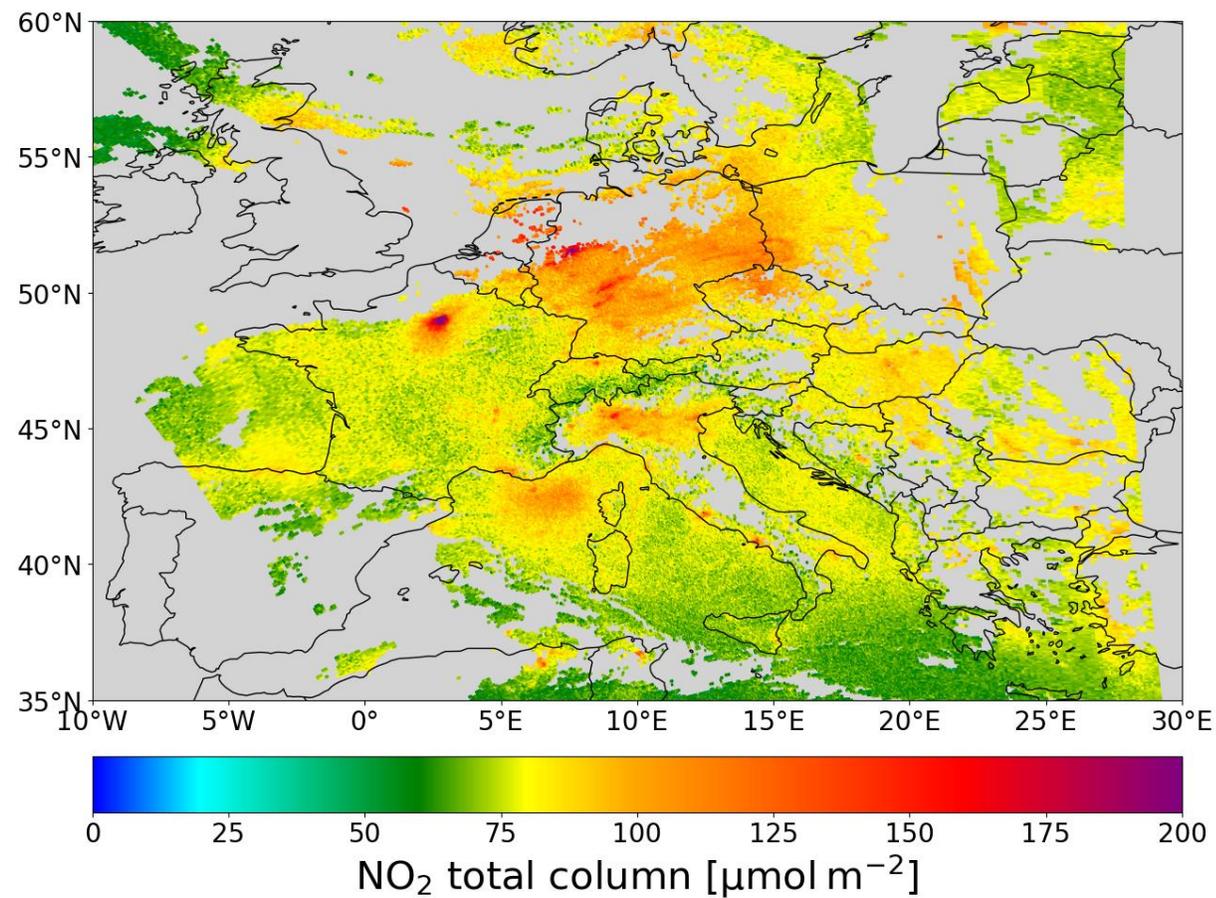
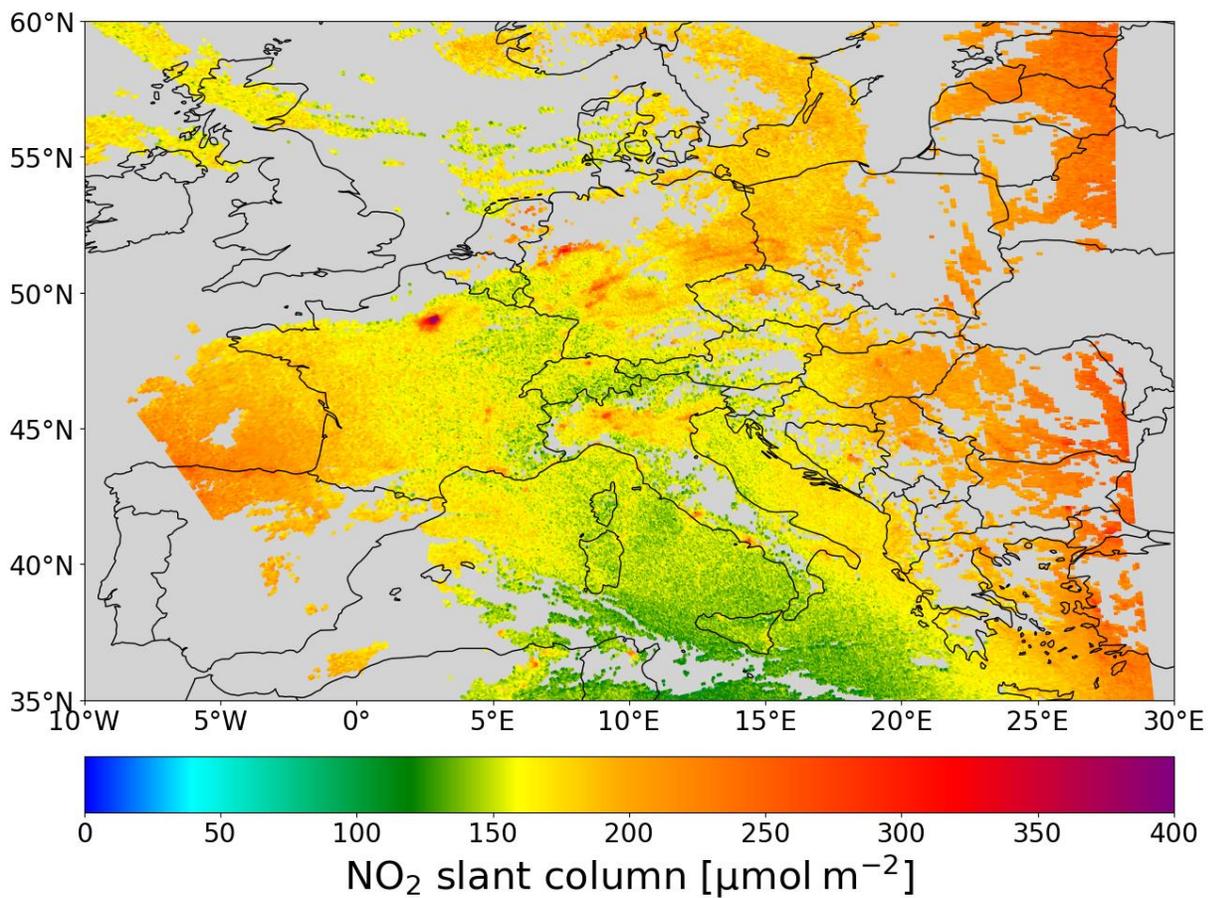


Troposphere



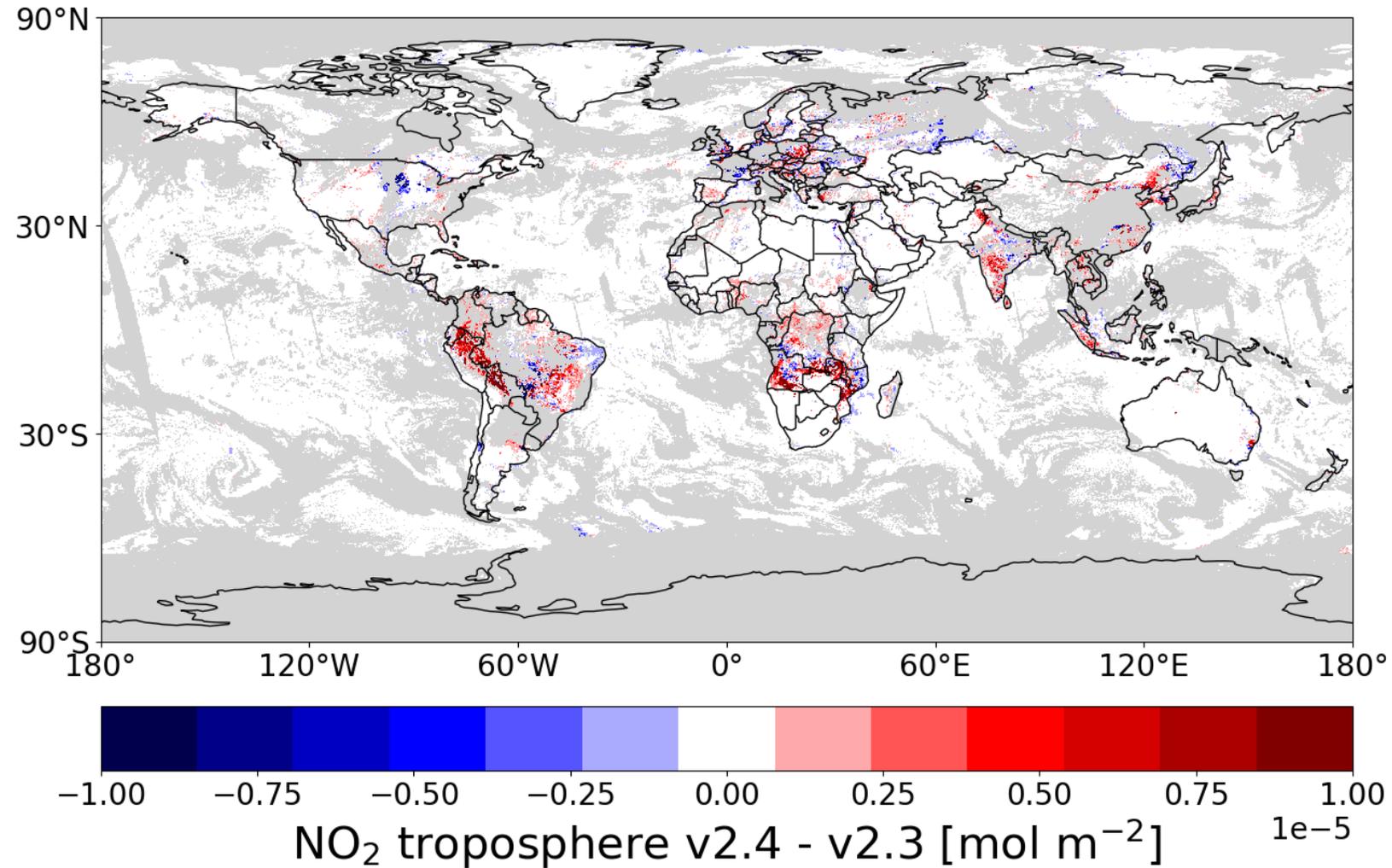
AIR MASS FACTOR

Correlated?



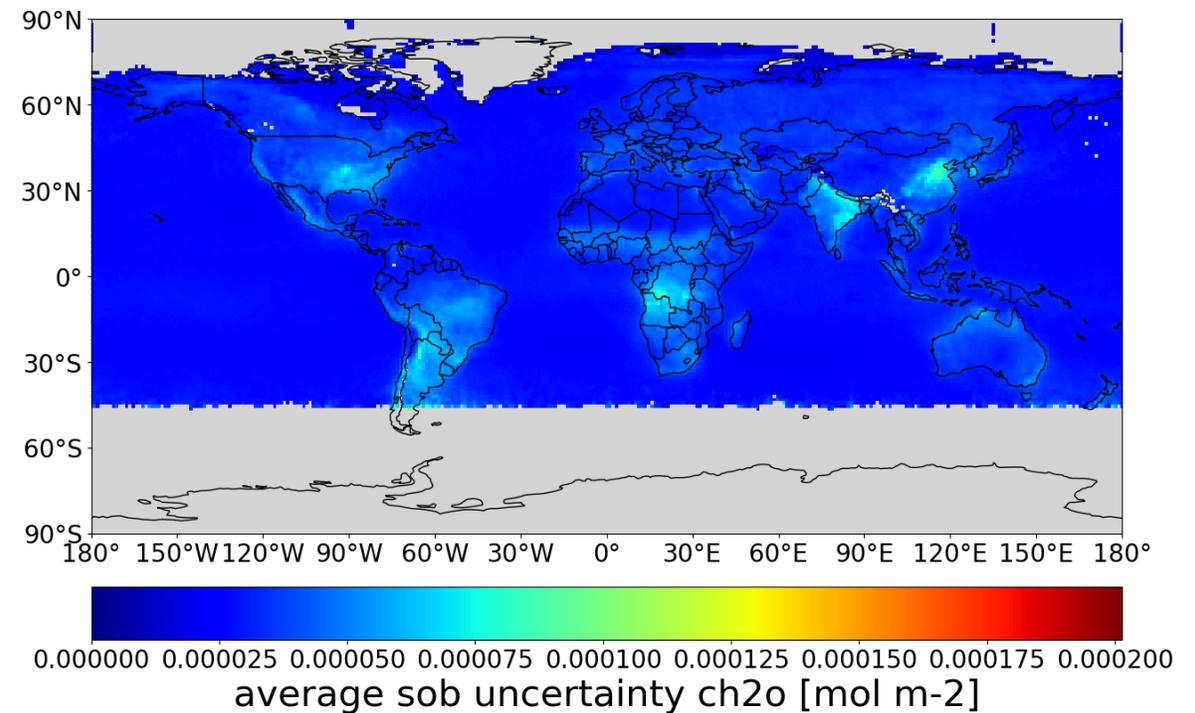
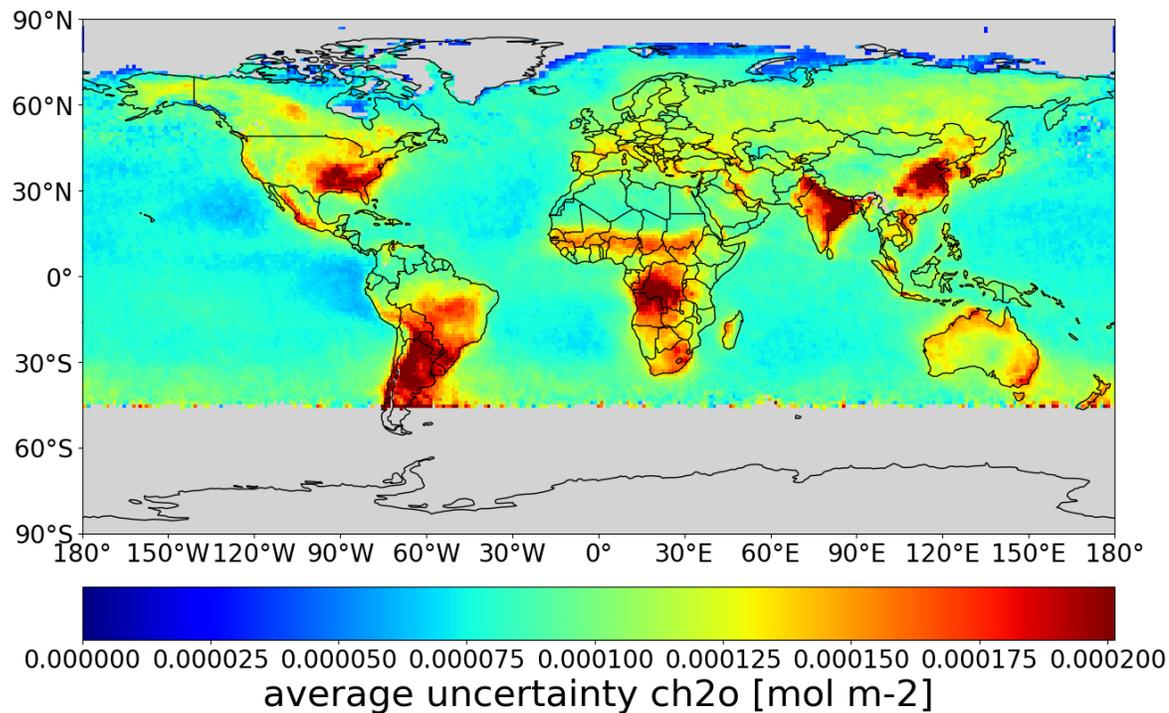
AMF UNCERTAINTY

- New albedo
- Correlation
- 35 km length



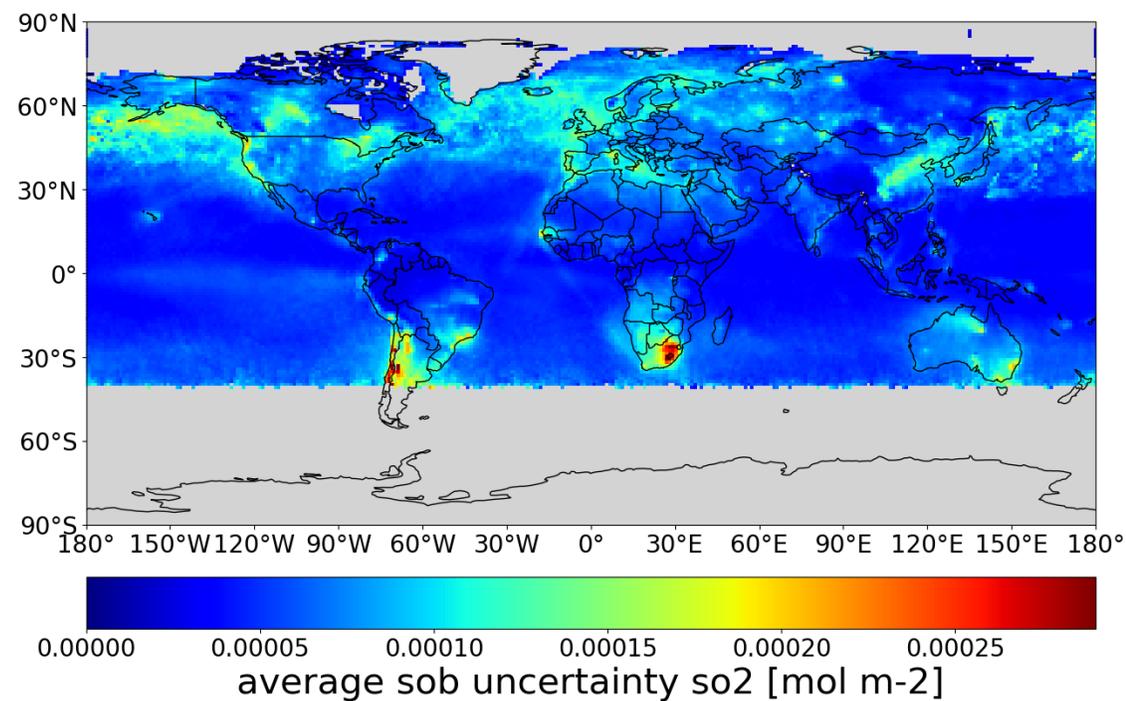
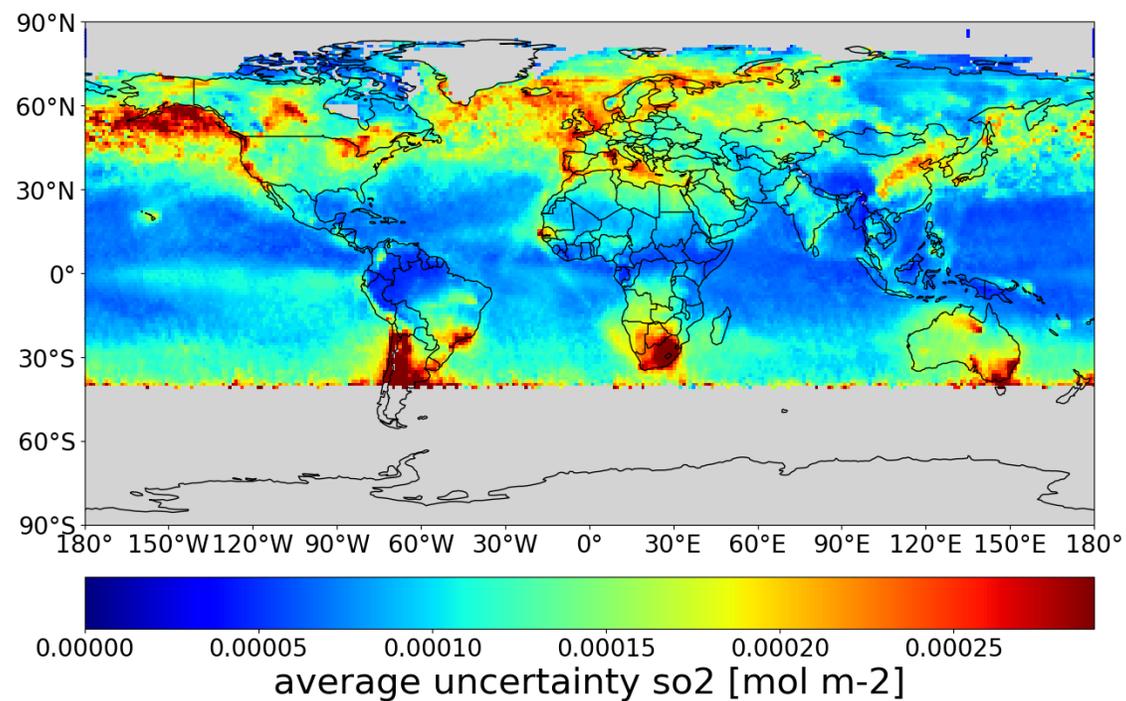
HCHO

- Product contains:
 - Random error (c=0)
 - Systematic error (c=1)



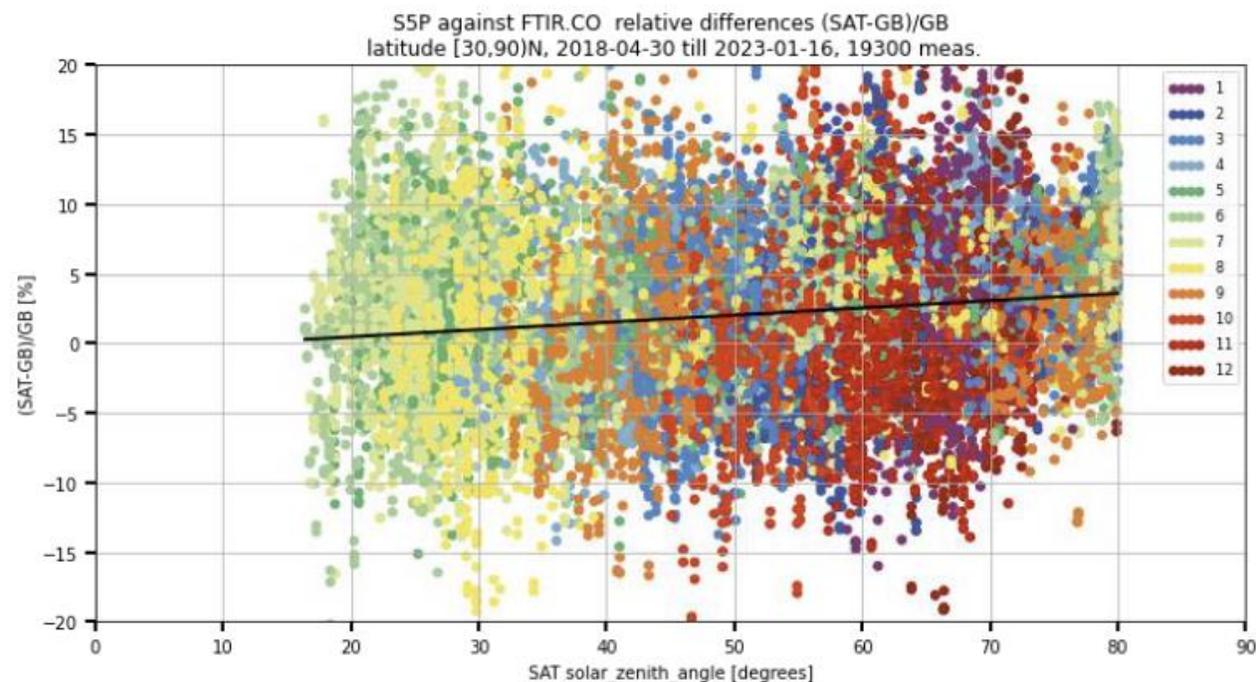
SO₂

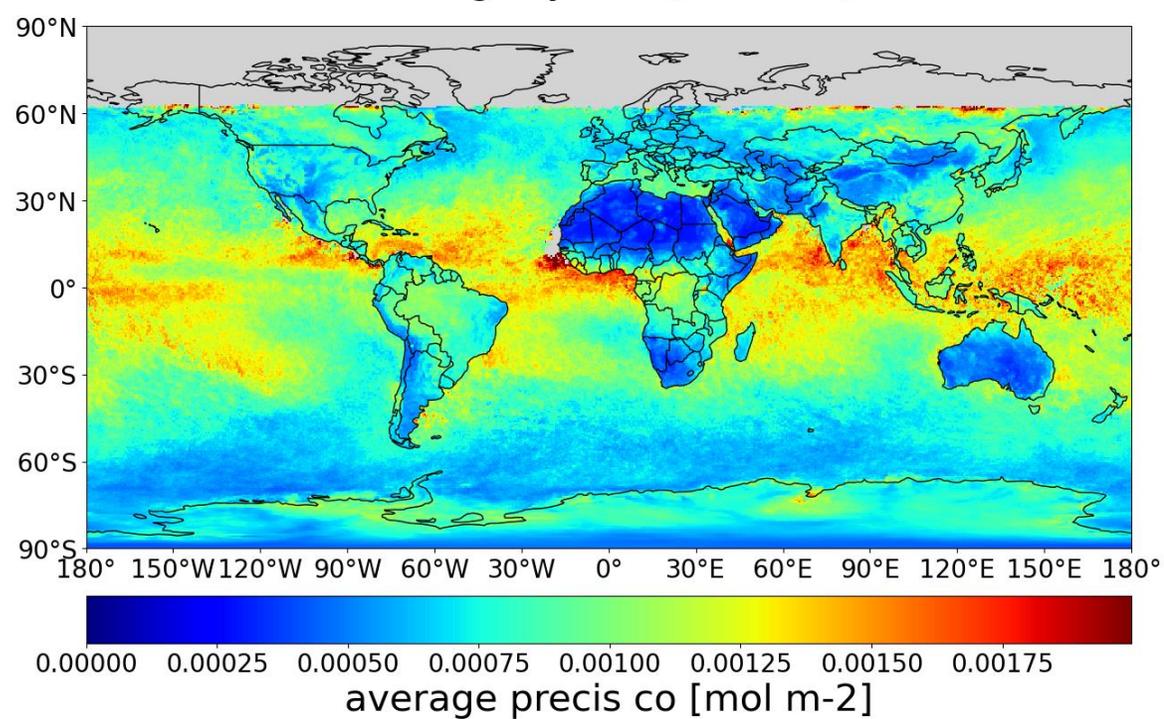
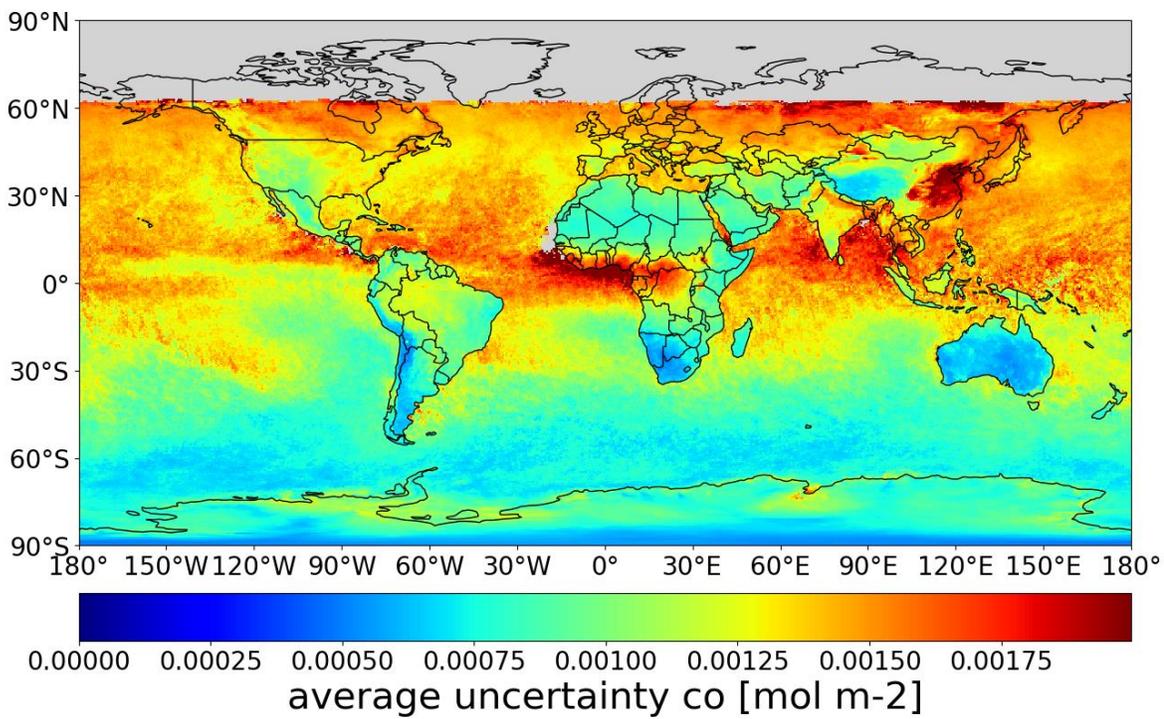
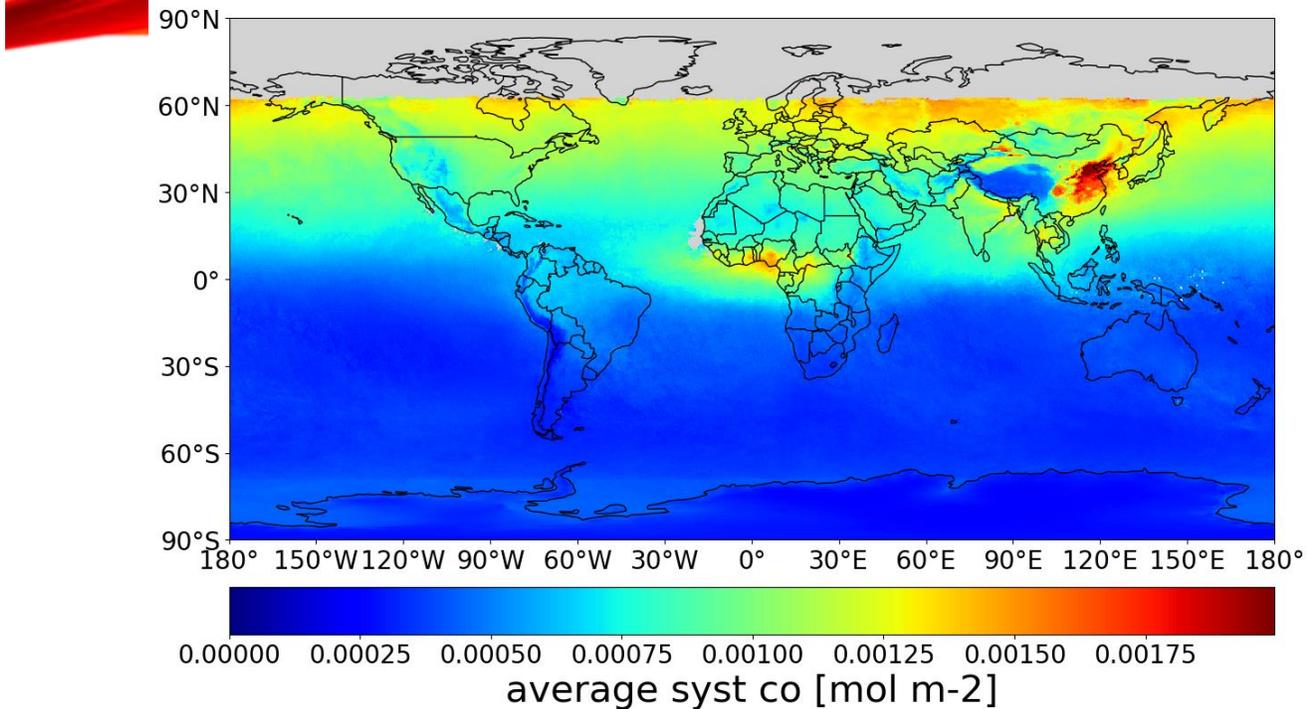
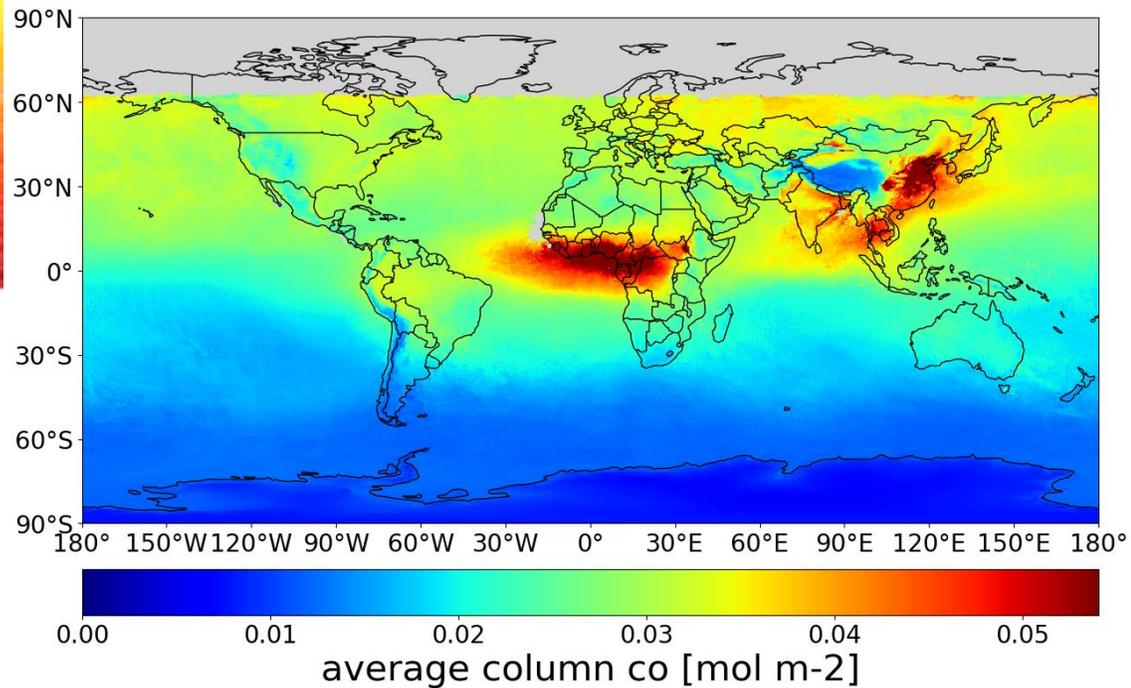
- Product contains:
 - Random error (c=0)
 - Systematic error (c=1)

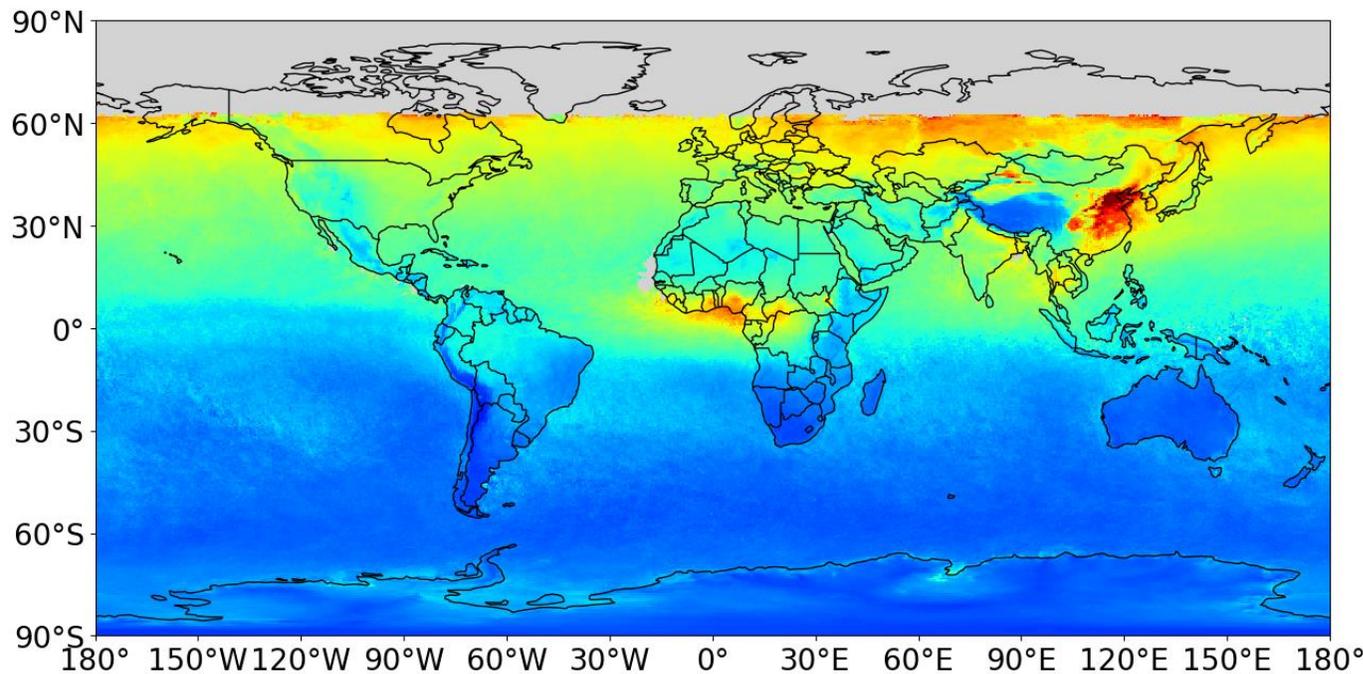


CO

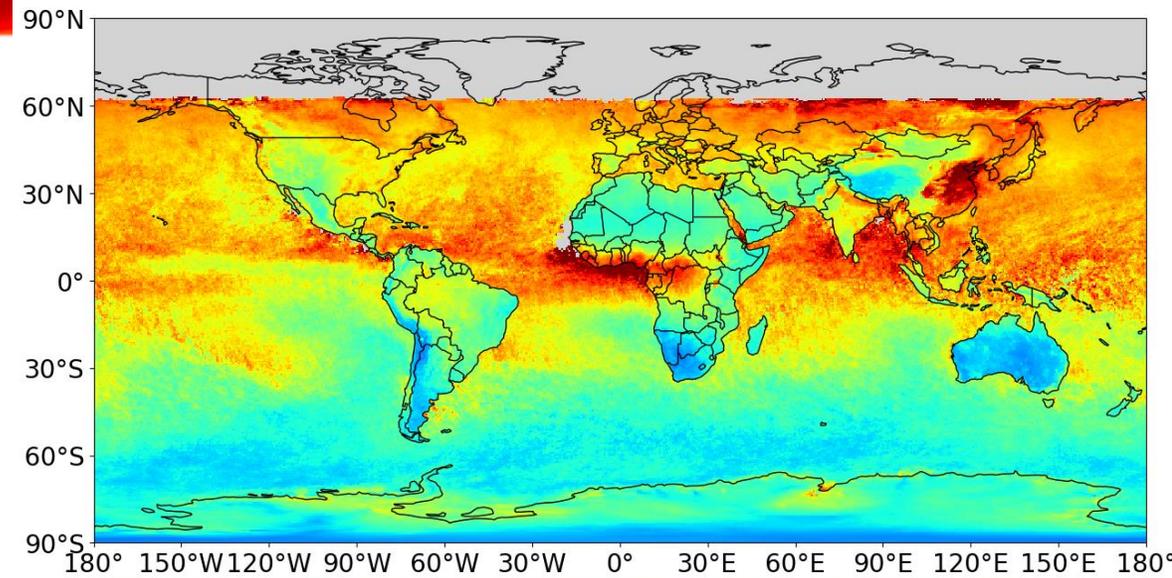
- No systematic uncertainty from retrieval
- Simple approach based on validation
 - 2-3% average bias vs FTIR
 - SZA dependance (0.05% / degree)
 - Combine
 - 1% + 0.0375% / degree



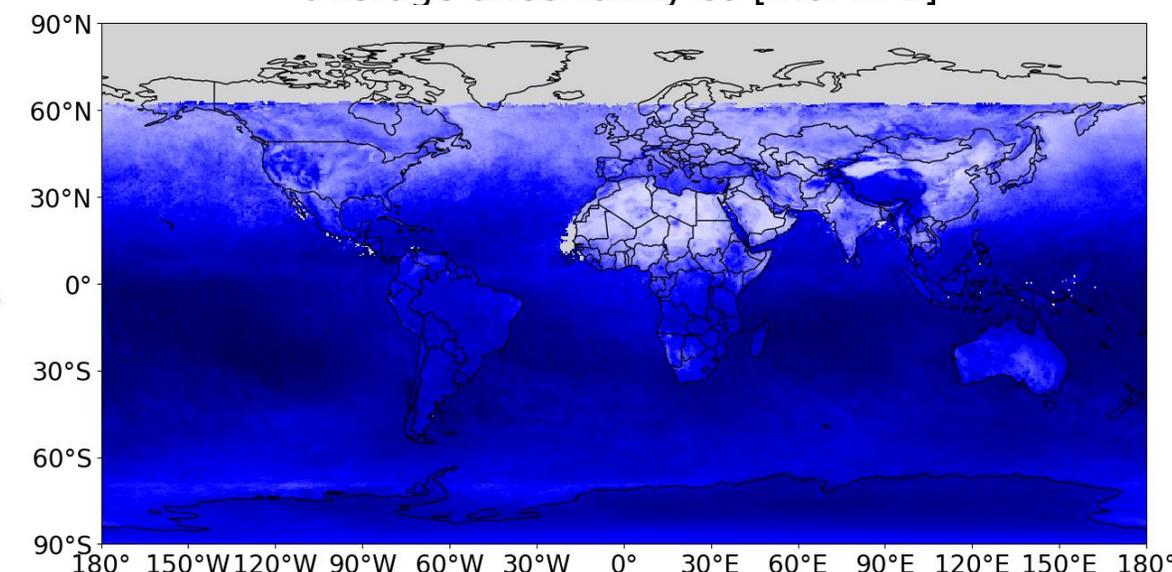




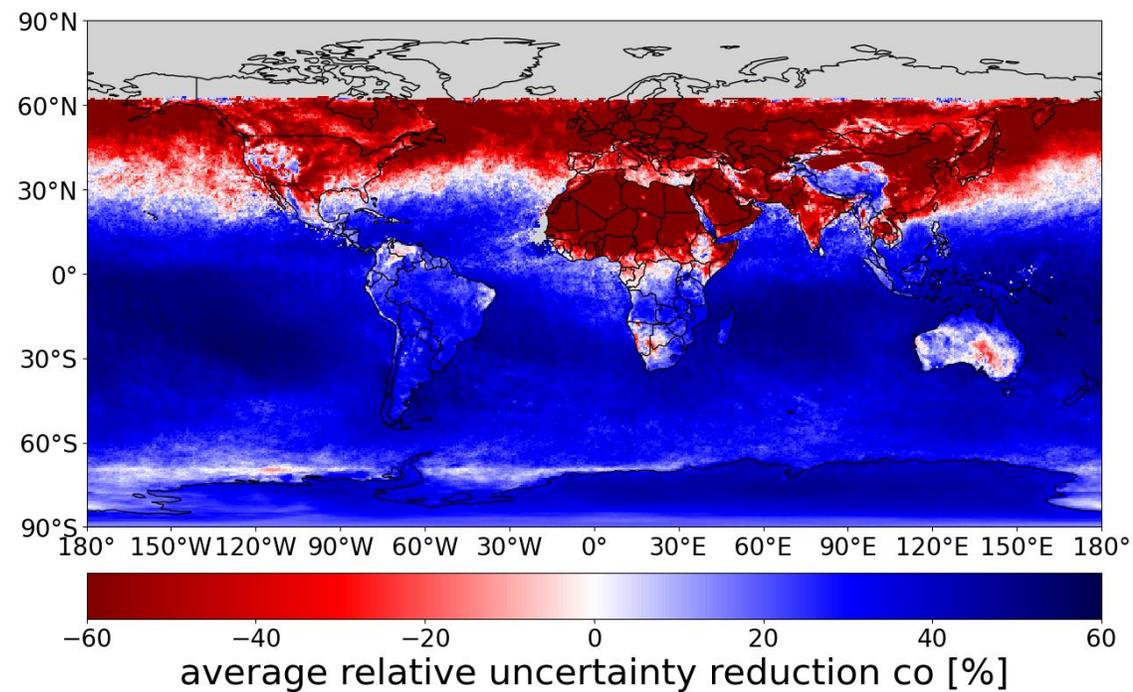
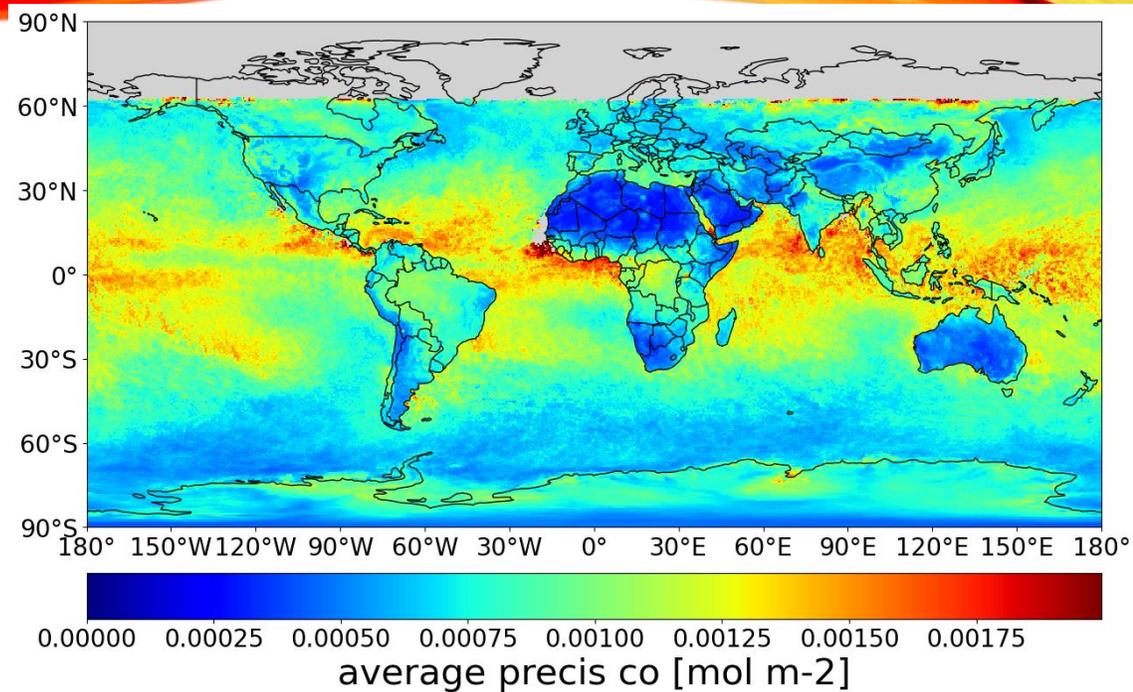
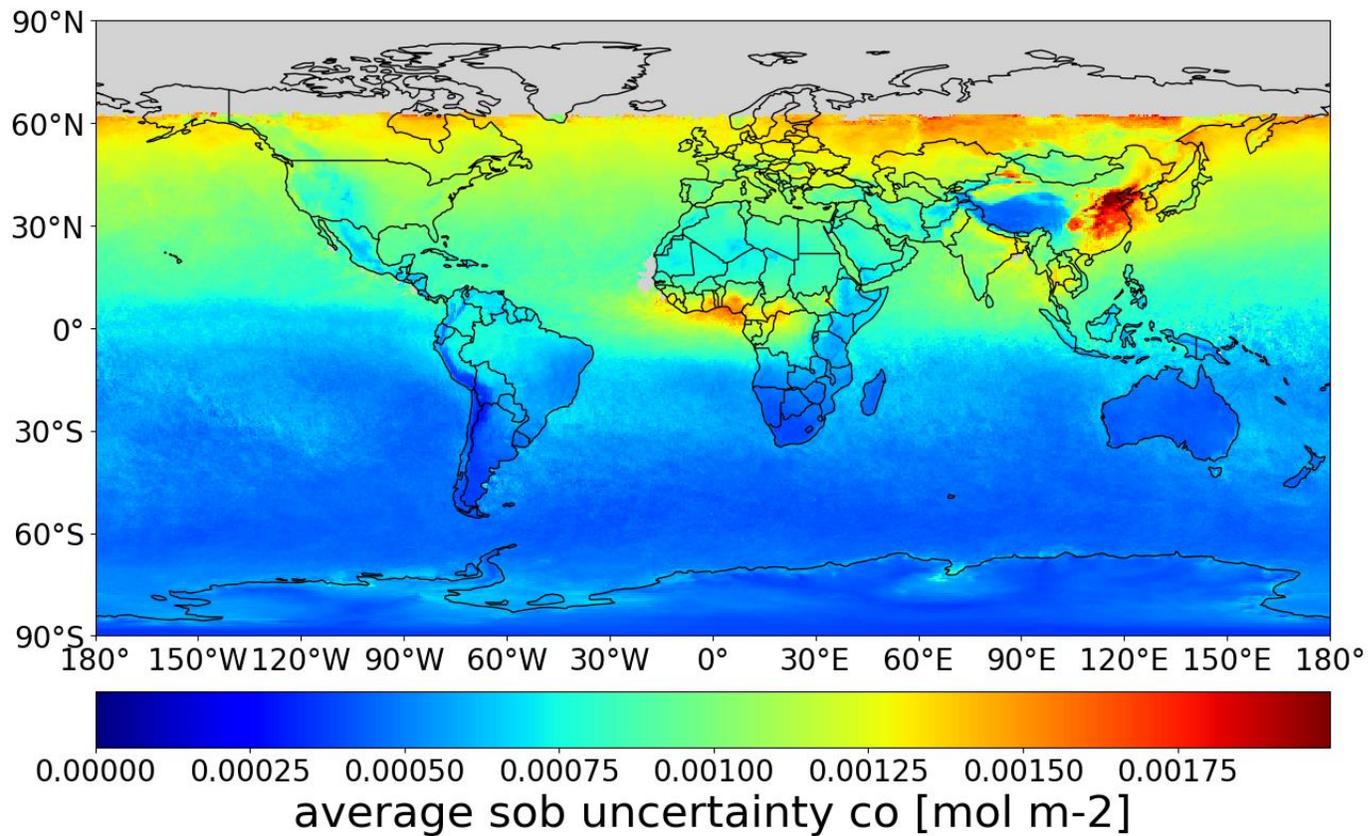
0.00000 0.00025 0.00050 0.00075 0.00100 0.00125 0.00150 0.00175
average sob uncertainty co [mol m⁻²]



0.00000 0.00025 0.00050 0.00075 0.00100 0.00125 0.00150 0.00175
average uncertainty co [mol m⁻²]



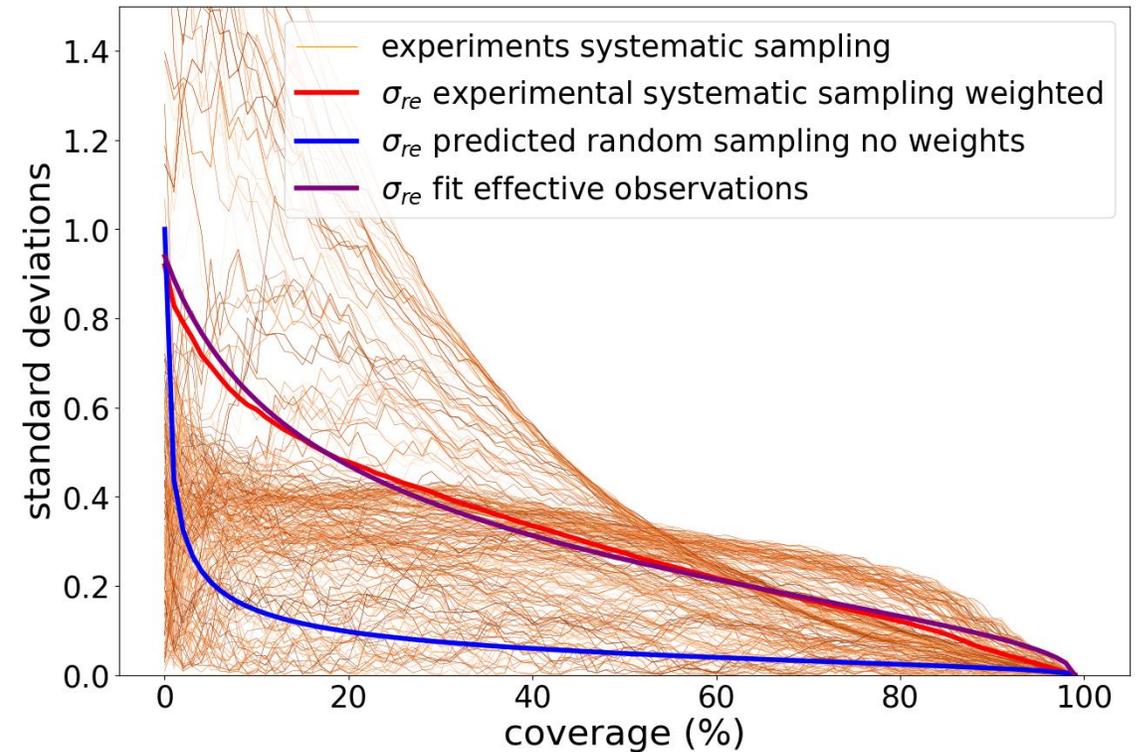
-60 -40 -20 0 20 40 60
average relative uncertainty reduction co [%]



SYSTEMATIC RE

- Increased RE
- Fit by decreasing N/n
 - Effective observations

$$\sigma_{RE,n} = \frac{\sigma}{\sqrt{n}} \sqrt{\frac{N-n}{N-1}}$$



REPRESENTATION ERROR (RE)

$$SE = \frac{\sigma}{\sqrt{n}}$$

$$f_n = \frac{n_{f,n}}{N_f}$$

$$SE_{corr} = \frac{\sigma}{\sqrt{n}} \sqrt{\frac{N - n}{N - 1}}$$

$$\sigma_{RE,n} = \frac{\sigma}{\sqrt{N_f f_n}} \sqrt{\frac{N_f - N f_n}{N_f - 1}}$$

f = coverage fraction

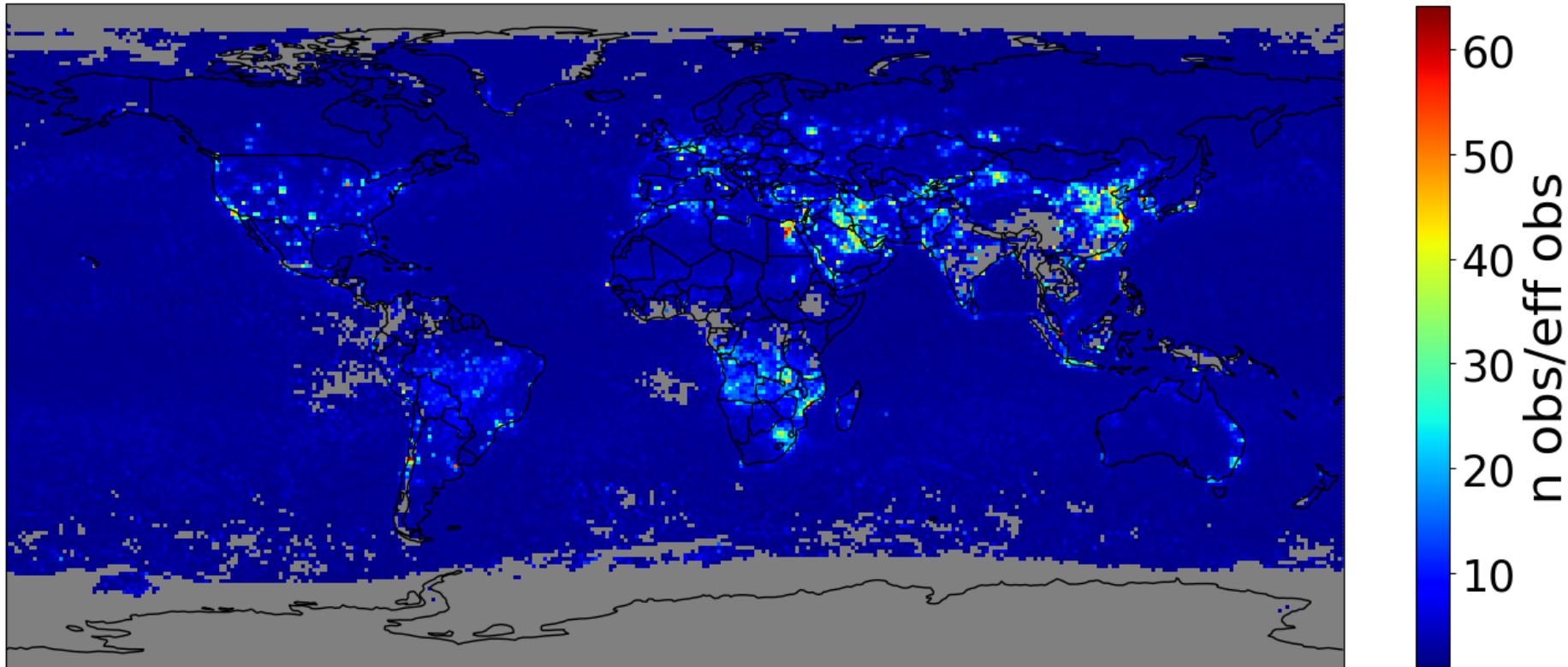
$$f_{z,n} = (f - f_1) * \frac{1}{1 - f_1}$$

$$N f_n = N f_{z,n} + 1 - f_{z,n}$$

$$\sigma_{RE,n} = \frac{\sigma}{\sqrt{N_f f_{z,n} + 1 - f_{z,n}}} \sqrt{\frac{N_f - (N f_{z,n} + 1 - f_{z,n})}{N_f - 1}}$$

SYSTEMATIC RE

- Calculate average N_{eff}
- Calculate ratio N/N_{eff}



SYSTEMATIC RE

- Resolution

