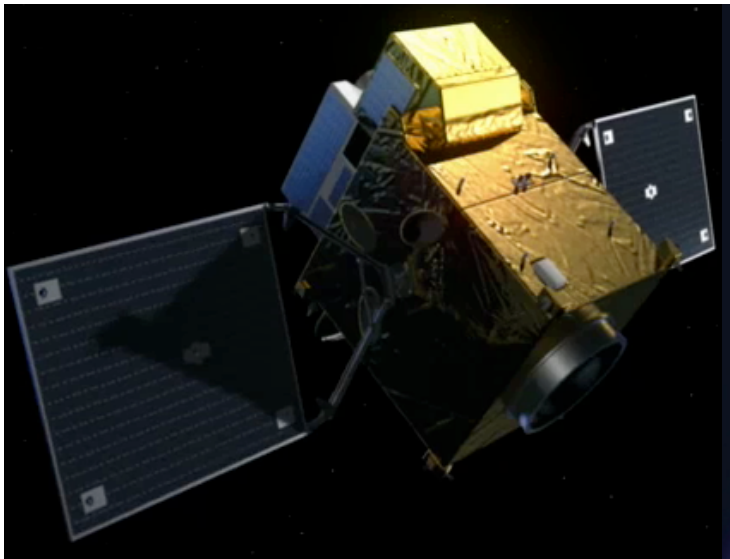
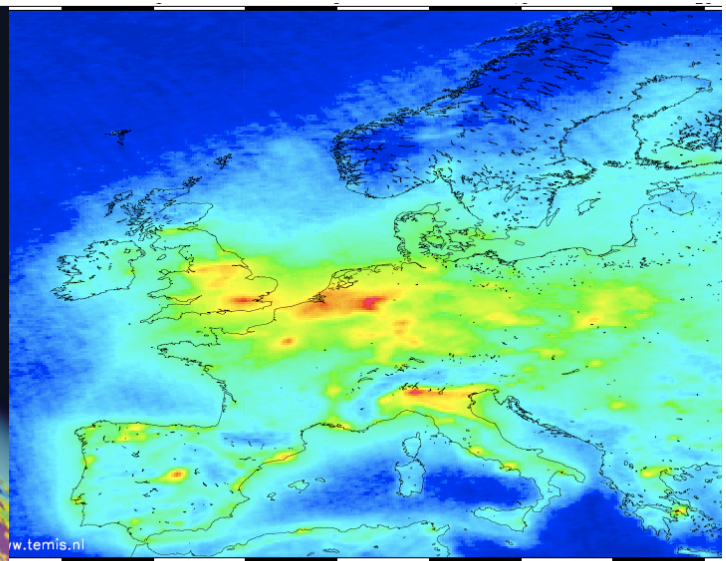
Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

An OSSE to Study the Impact of Sentinel S4, S5 and S5P spaceborne Observations on Air Quality Data Assimilation Systems

Henk Eskes, KNMI, The Netherlands,
ISOTROP project partners, ESA

OSSE workshop, ECMWF, 9-11 Nov 2016





The ISOTROP Project Team

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

KNMI
- Henk Eskes (coordination)
- Jason Williams
- Pepijn Veefkind
- Johan de Haan
- Albert Oude Nijhuis

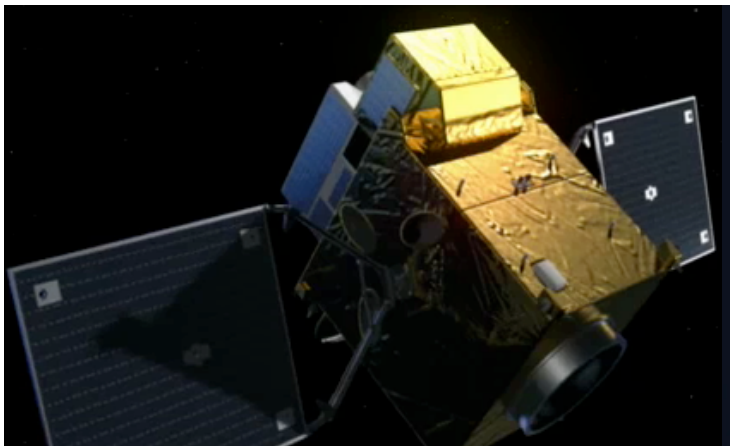
TNO
- Lyana Curier
- Arjo Segers
- Renske Timmermans

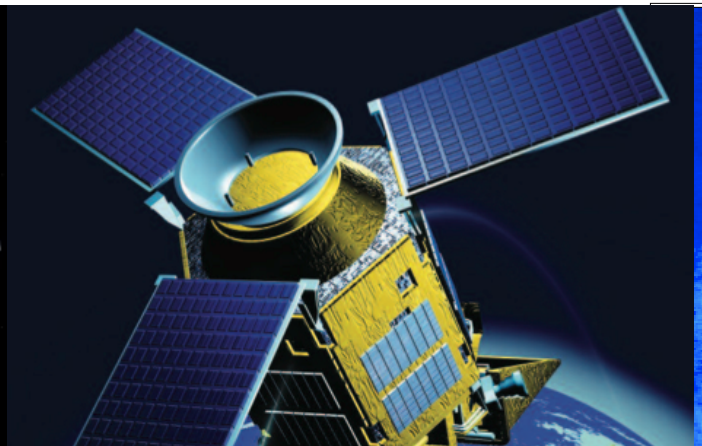
NILU
- William Lahoz

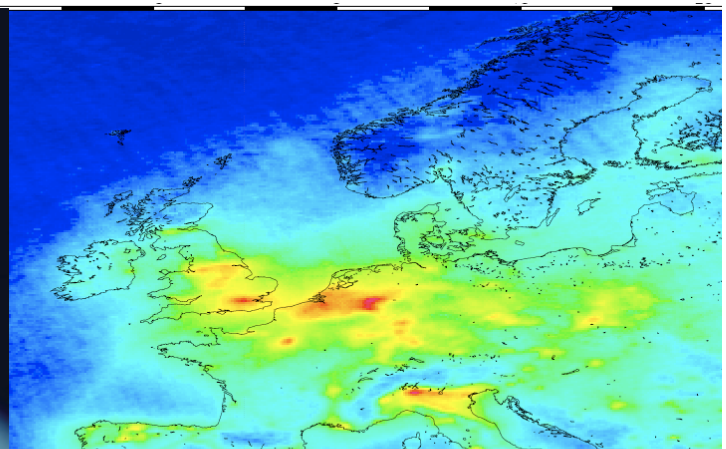
CNRM-GAME
- Jean-Luc Attie
- Rachid Abida
- Laaziz El Amraoui
- Philippe Ricaud

FMI
- Jukka Kujanpää
- Johanna Tamminen

ESA
- Dirk Schuettemeyer
- Ben Veihelmann







Project objectives

Objectives of ESA study

1: To assess the value of LEO+GEO satellite observation system measuring in the UV for tropospheric composition monitoring using data assimilation.
Focus on O3, CO, NO2, HCHO

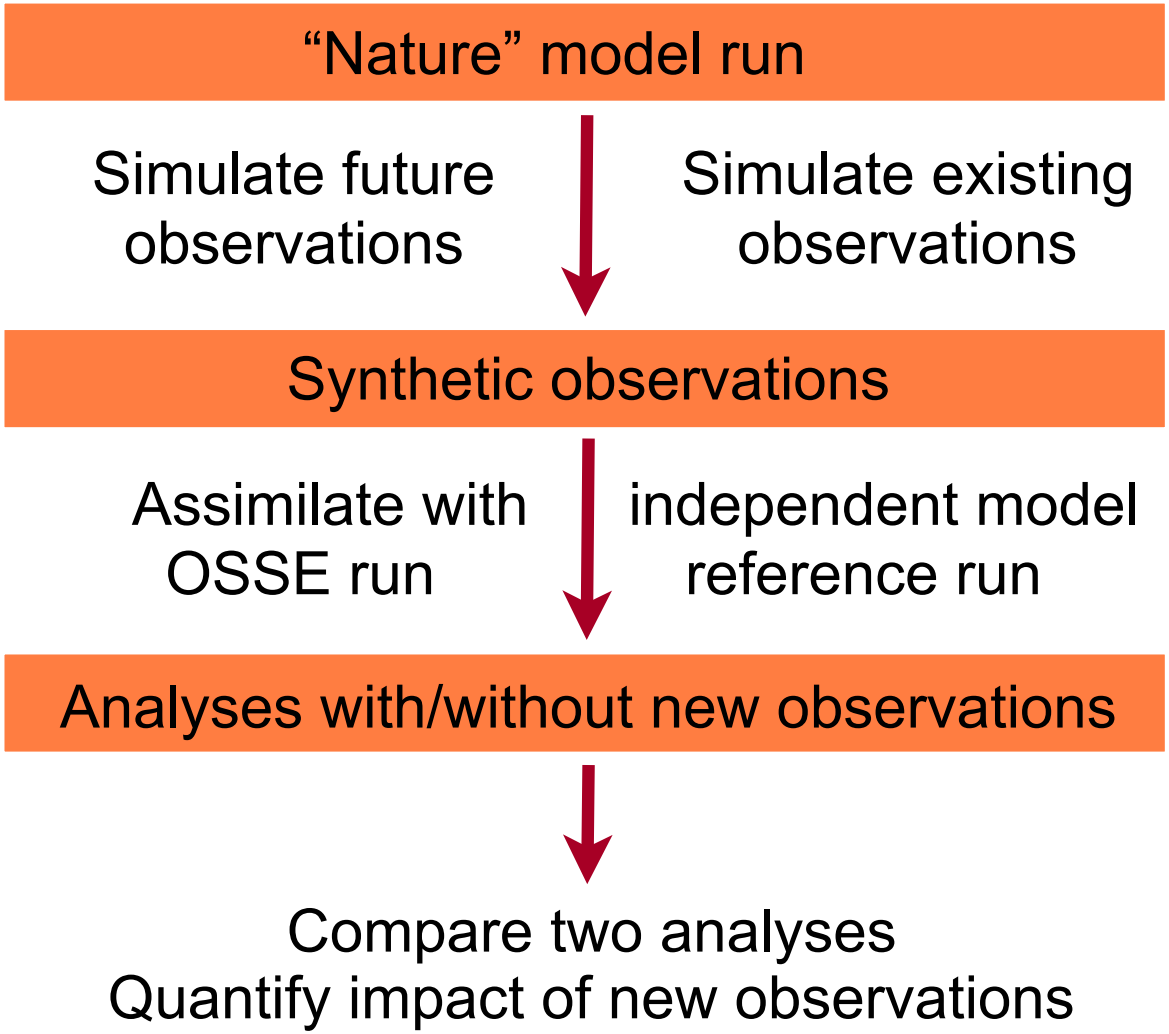
- Gain in model + forecast skill.
- Improvement of boundary layer (BL) concentrations.
- Improvement of impact long-range transport on BL.
- Improvement of continuous and episodal sources.
- Optimisation of surface emission rates.

2: To study the impact of cloudiness, aerosol, surface albedo and uncertainty in the dynamical fields (vertical transport) on model and forecast skill. Optimise the assimilation approach.

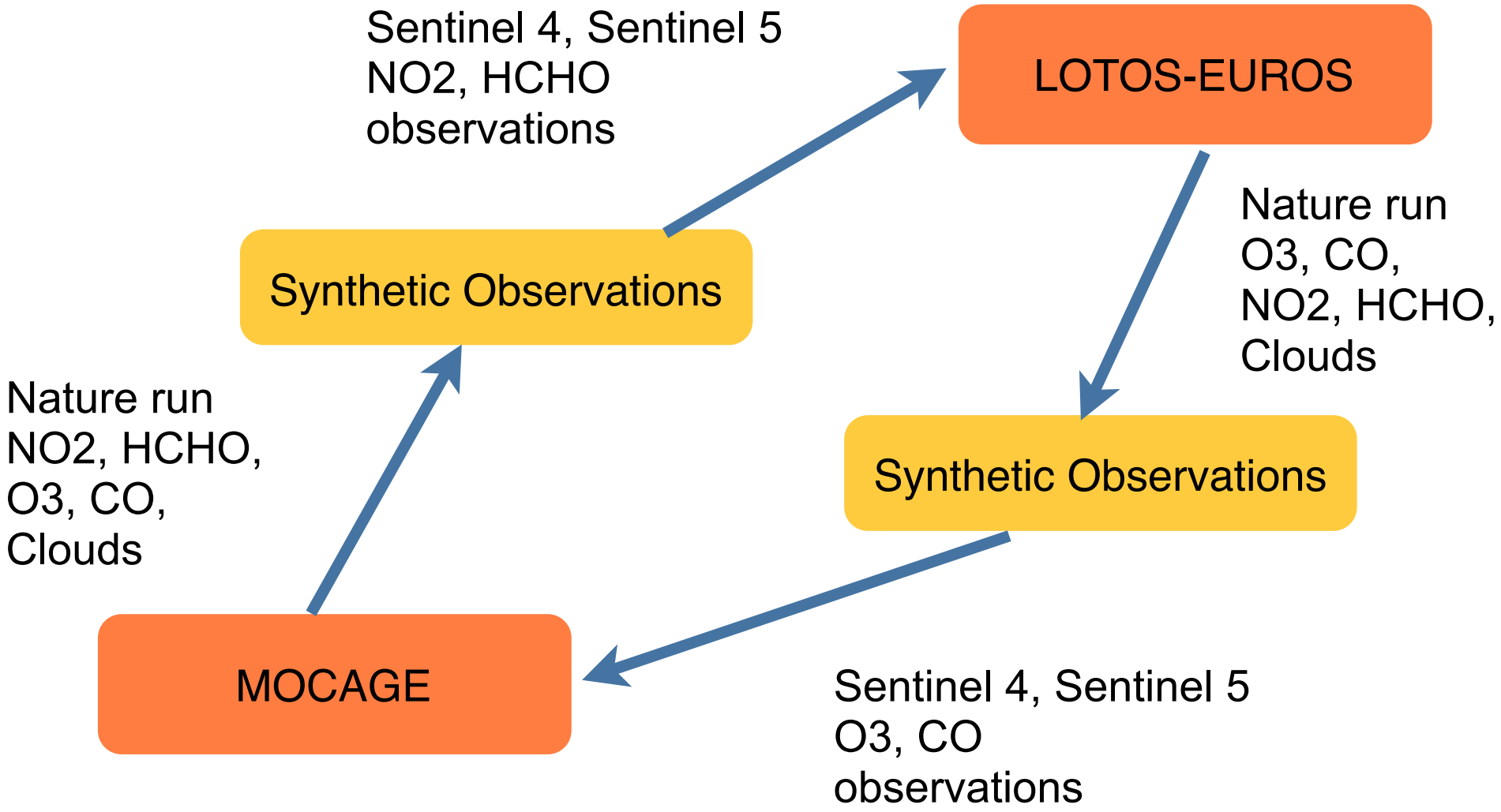
Approach and partner roles

KNMI, FMI: synthetic observations
TNO, KNMI: OSSE with LOTOS-EUROS for NO2, HCHO (BL and emissions)
CNRM-GAME, NILU: OSSE with MOCAGE for CO and O3 (transport)

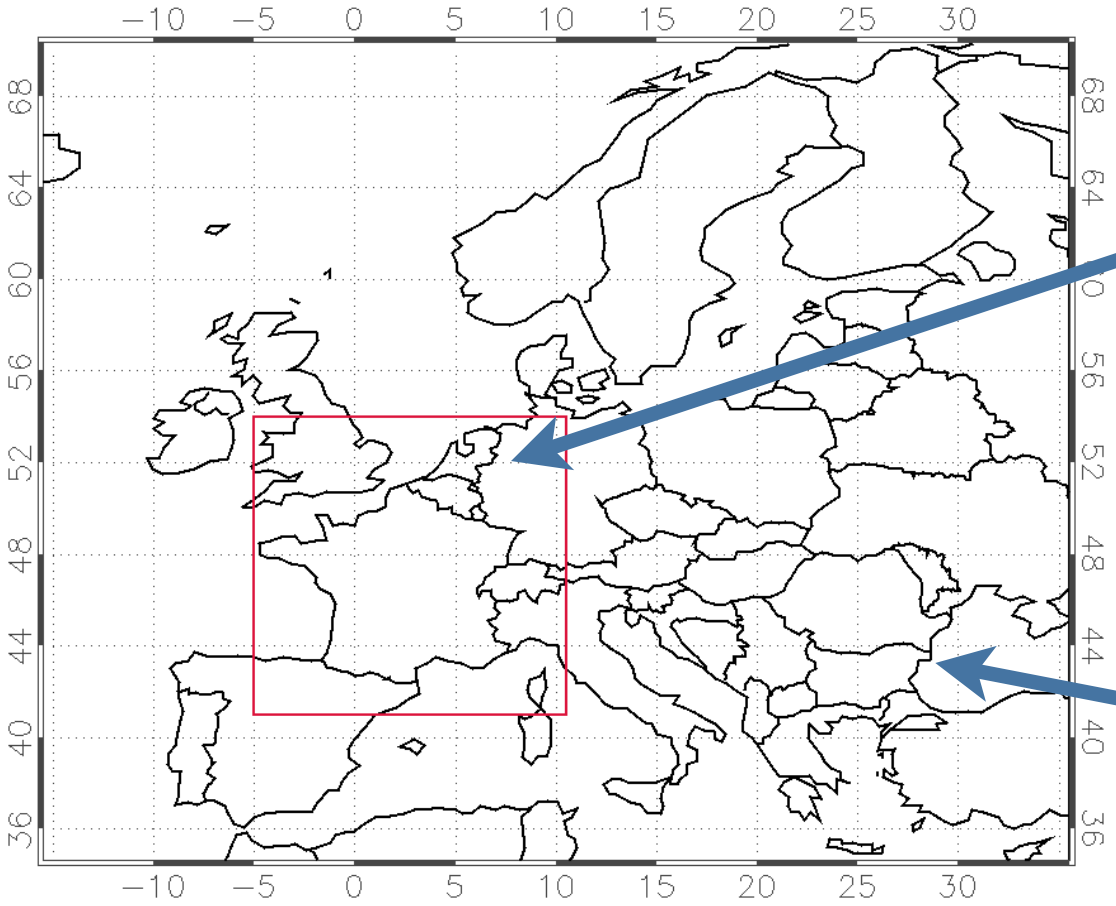
OSSE


"Nature" model run
Simulate future observations
Simulate existing observations
Synthetic observations
Assimilate with OSSE run
independent model reference run
Analyses with/without new observations
Compare two analyses
Quantify impact of new observations

Cross-OSSE


Sentinel 4, Sentinel 5
NO2, HCHO
observations
LOTOS-EUROS
Nature run
O3, CO,
NO2, HCHO,
Clouds
Synthetic Observations
Nature run
NO2, HCHO,
O3, CO,
Clouds
Synthetic Observations
MOCAGE
Sentinel 4, Sentinel 5
O3, CO
observations

Study domains



OSSE domain for
NO2, HCHO
LOTOS-EUROS
resolution 0.0625 x 0.125

OSSE domain for
CO,O3
MOCAGE
resolution 0.2 degree

Periods: Summer 2003, Winter 2003-2004

Nature run comparisons

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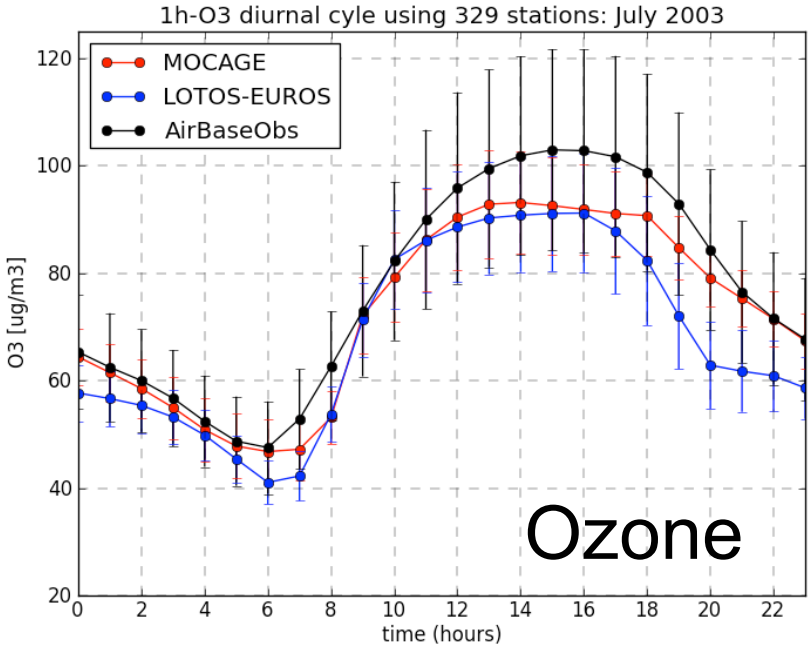
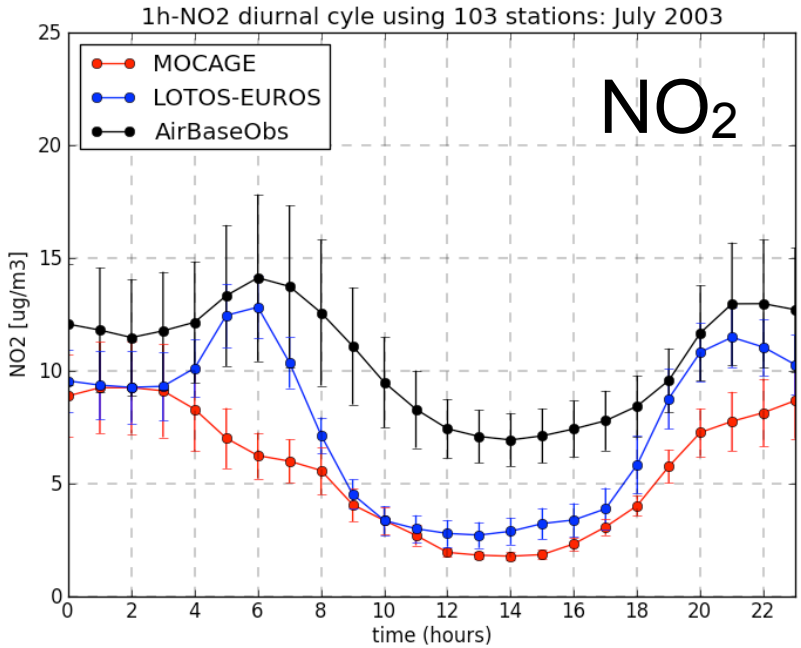
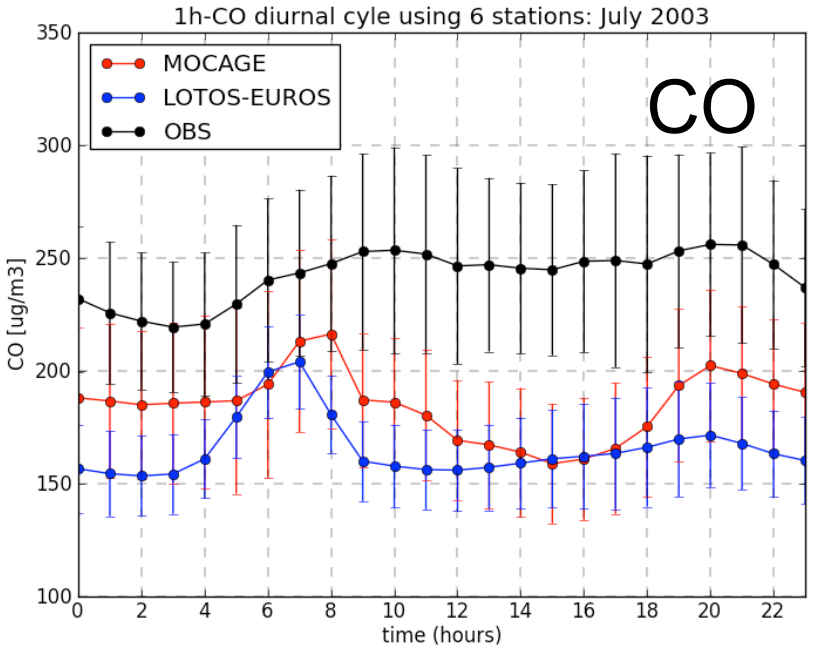
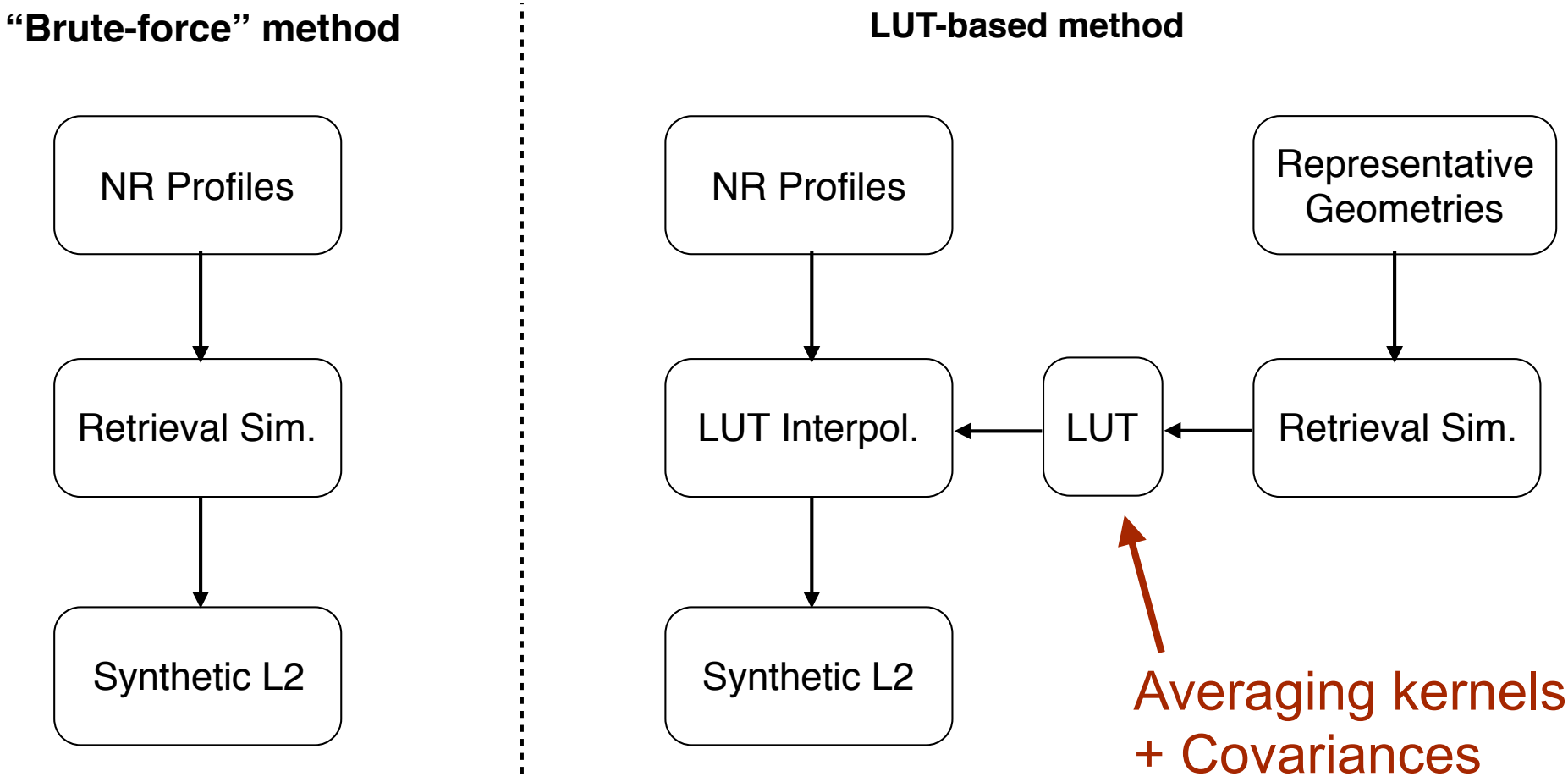




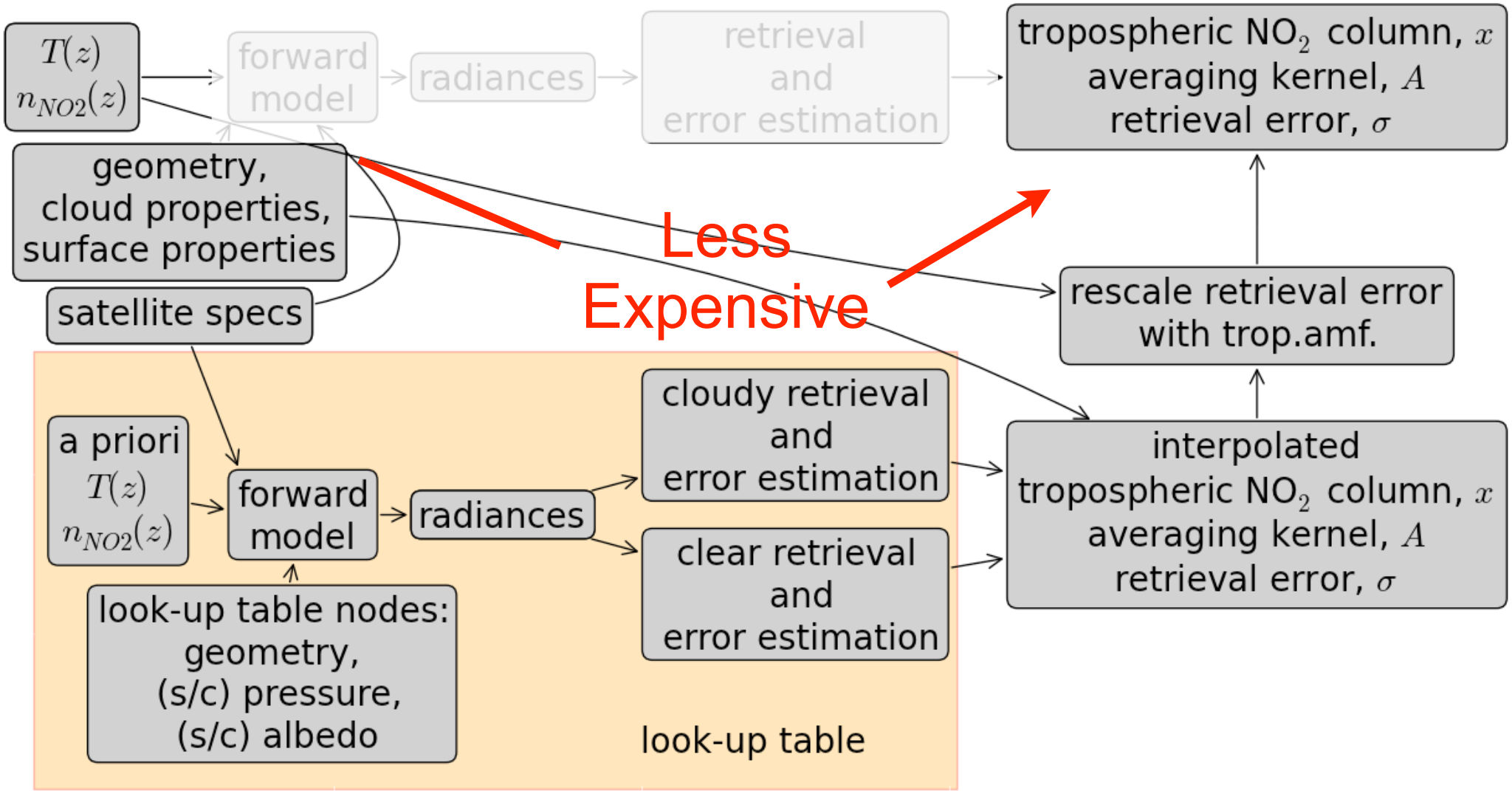


Synthetic observations



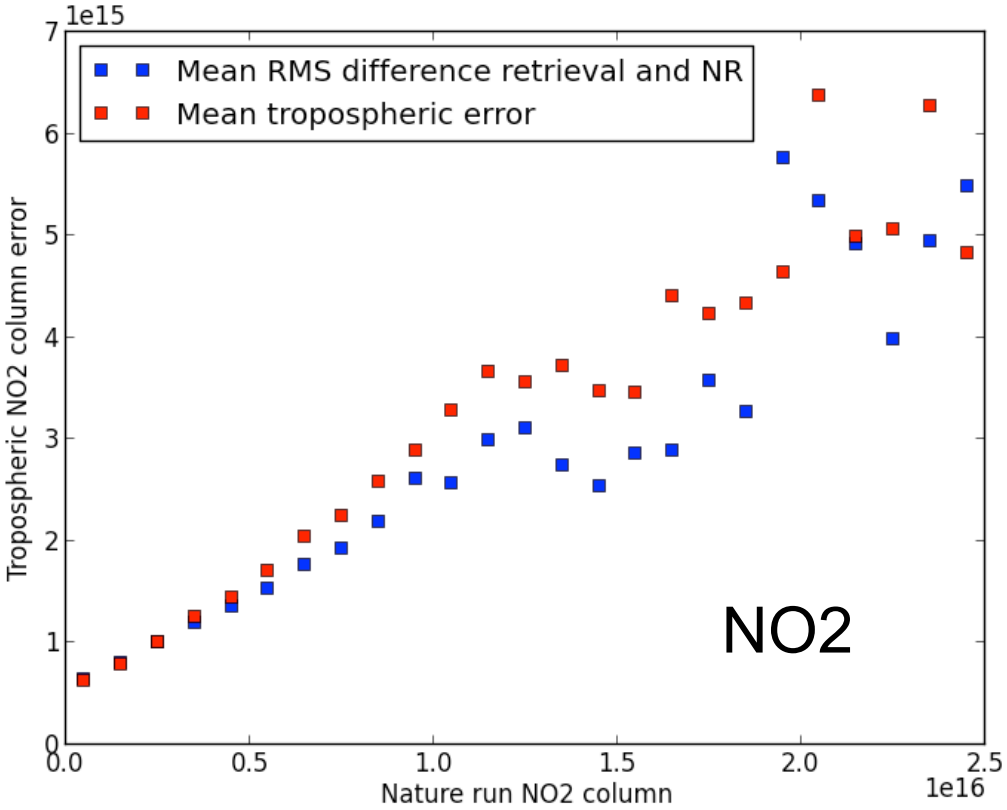
Based on optimal Estimation (Rodgers) and DOAS
Observation error covariance matrices, kernels
Orbit simulator

Synthetic observations

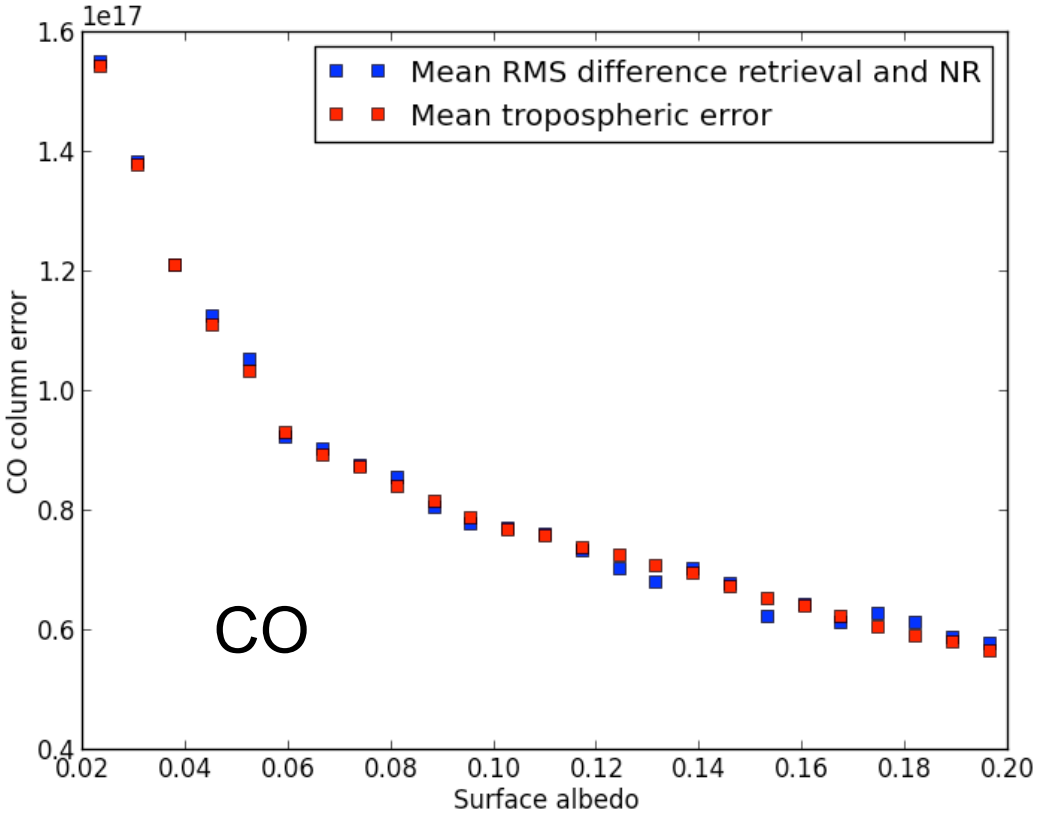


Albert Oude Nijhuis

Perturbation check

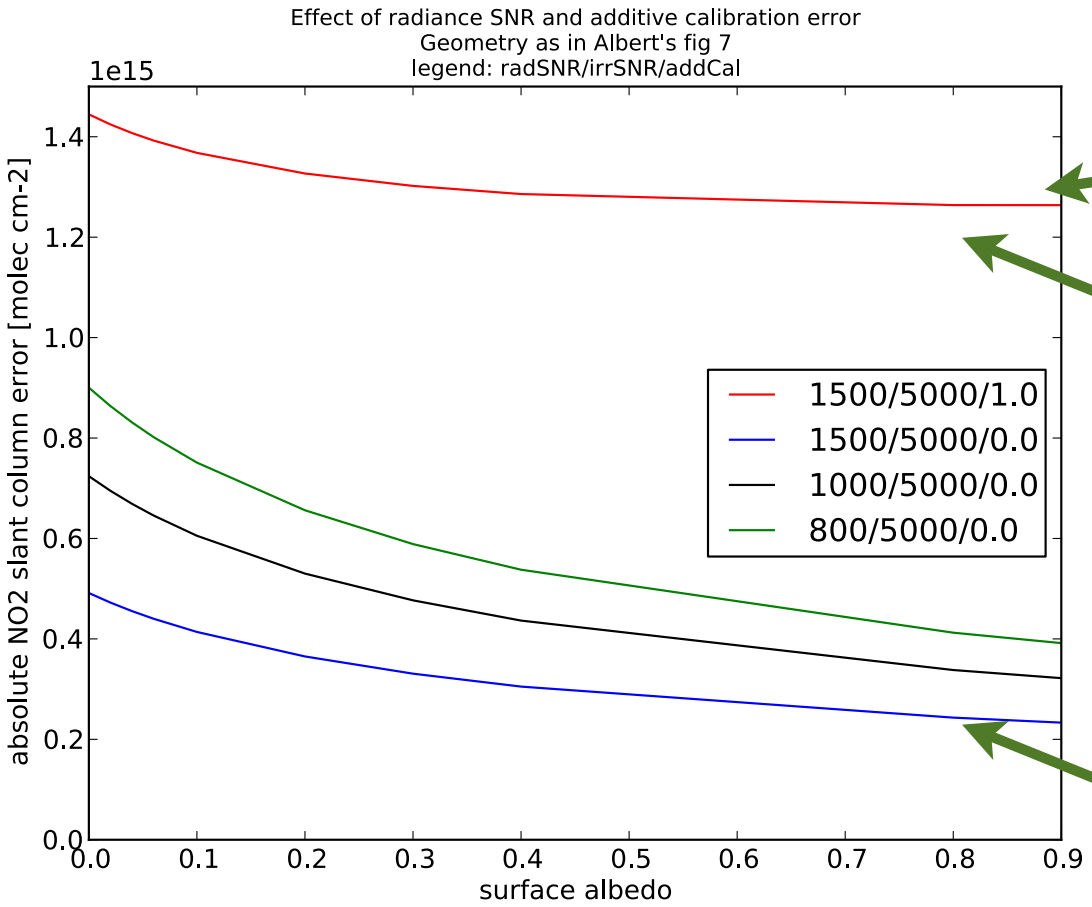


NO2 column



albedo

NO2 - slant column error



With noise correlated in wavelength space

Little dependence on albedo, but value is very high.
Slant column error set to 0.7e15 in v2.

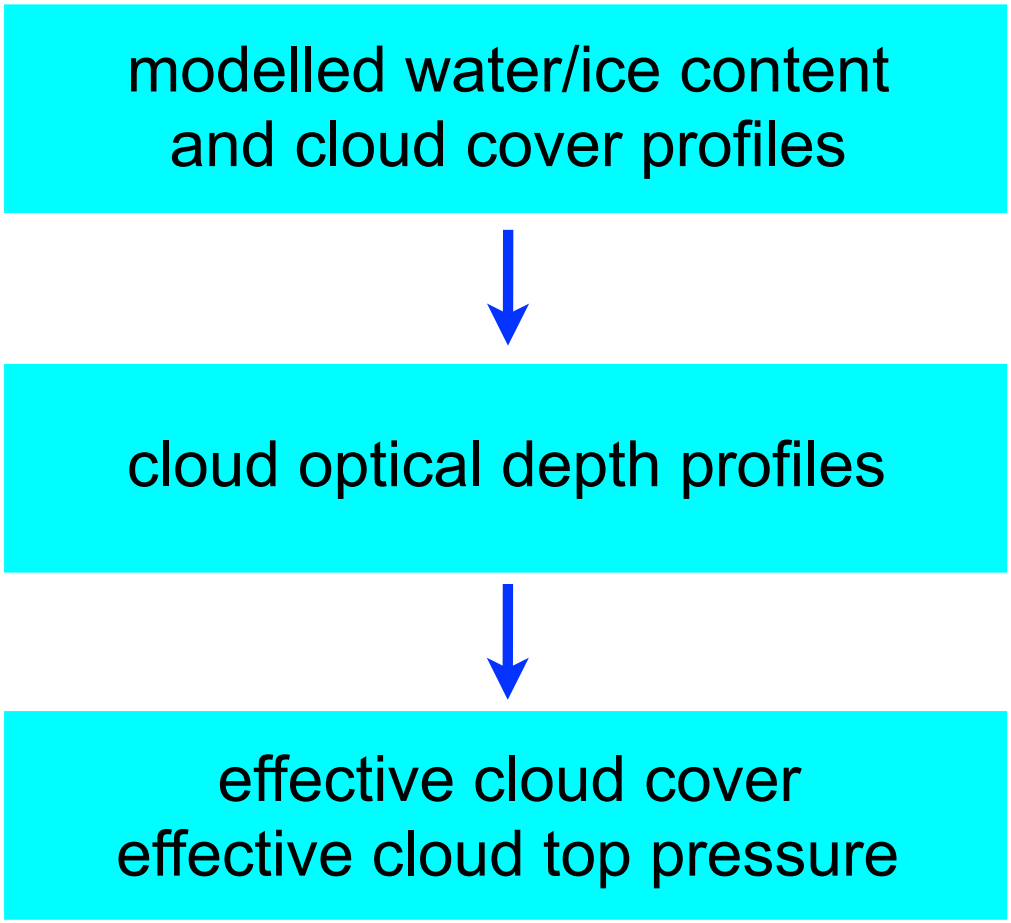
Without correlated noise

Note: TROPOMI ATBDs start from fixed slant column error for HCHO and NO2

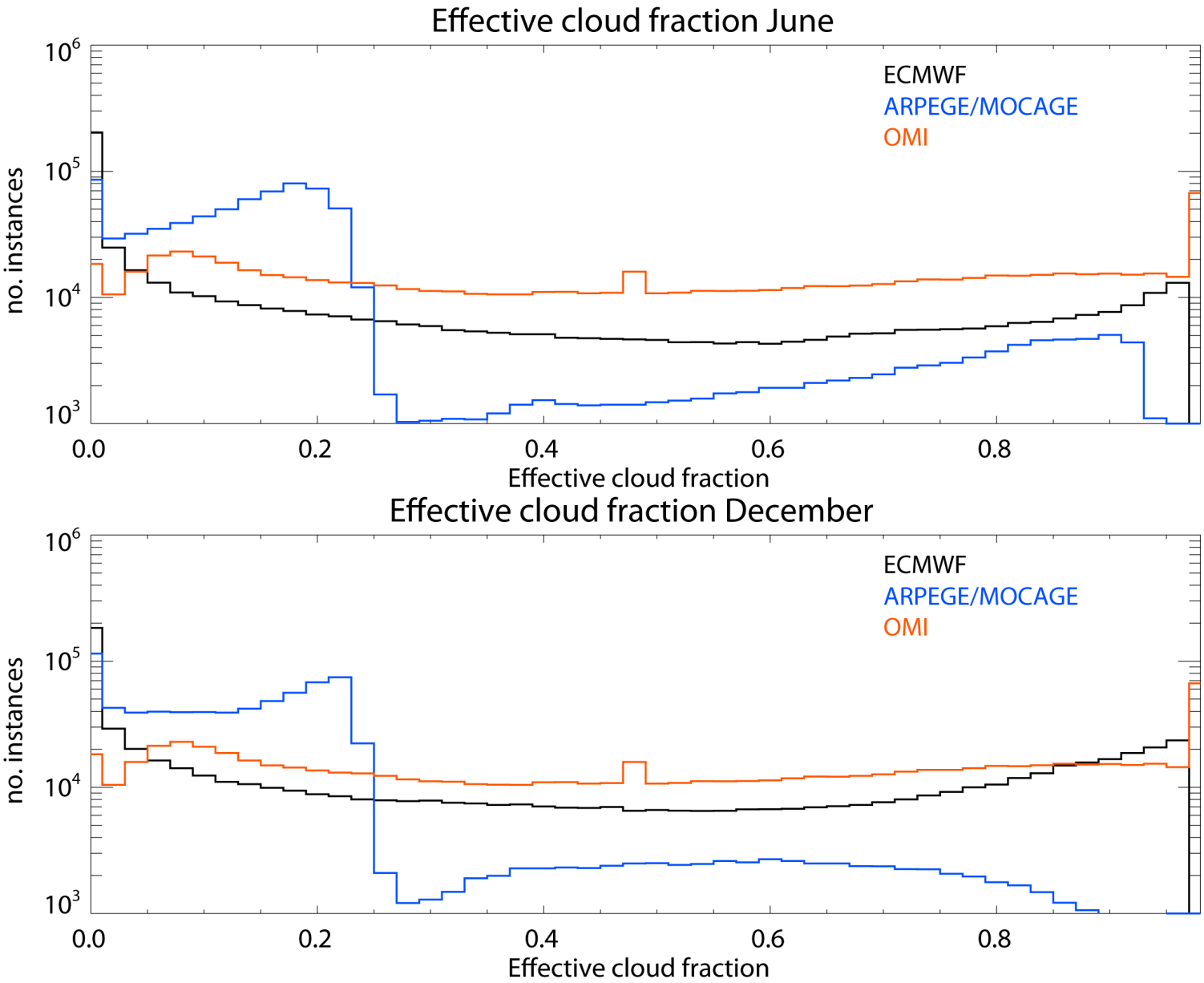
Jukka Kujanpää

Clouds

Satellite: cloud parameters are retrieved from spectra
For OSSE: use model clouds to create synthetic cloud observations



Clouds: ECMWF vs MOCAGE



Jason Williams

Results: CO, S5, nature run

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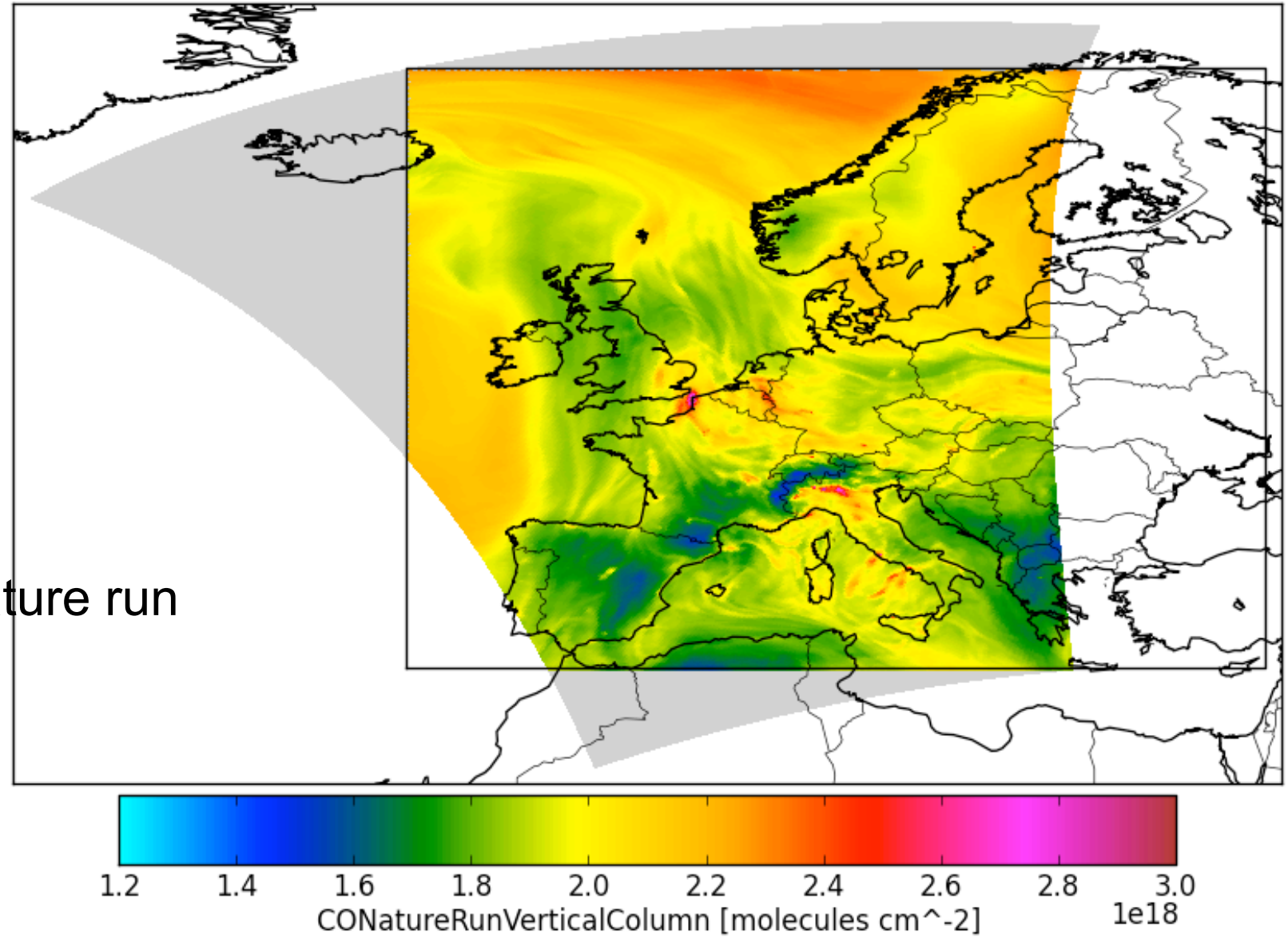
CO nature run



Results: CO, S5, albedo

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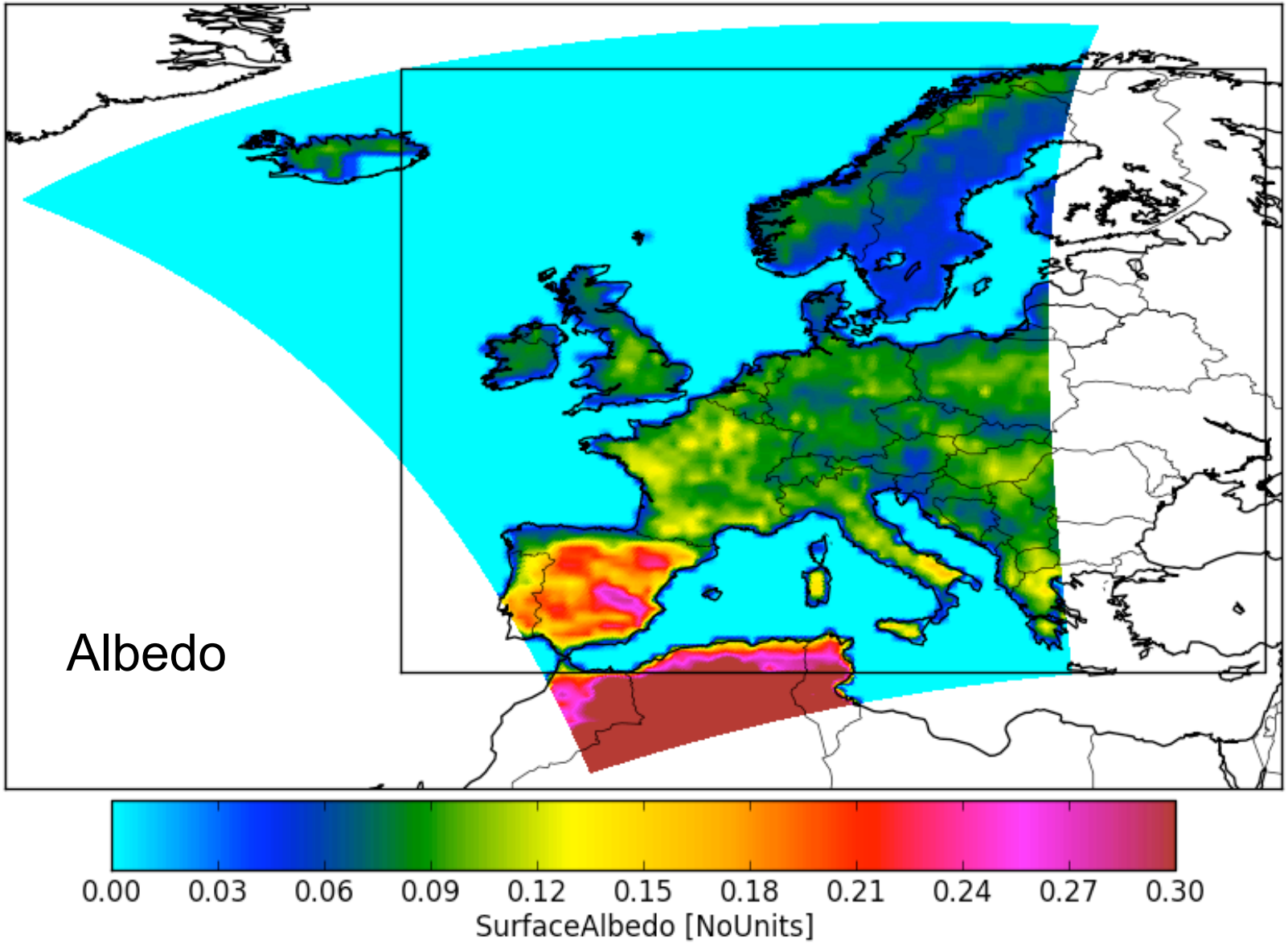
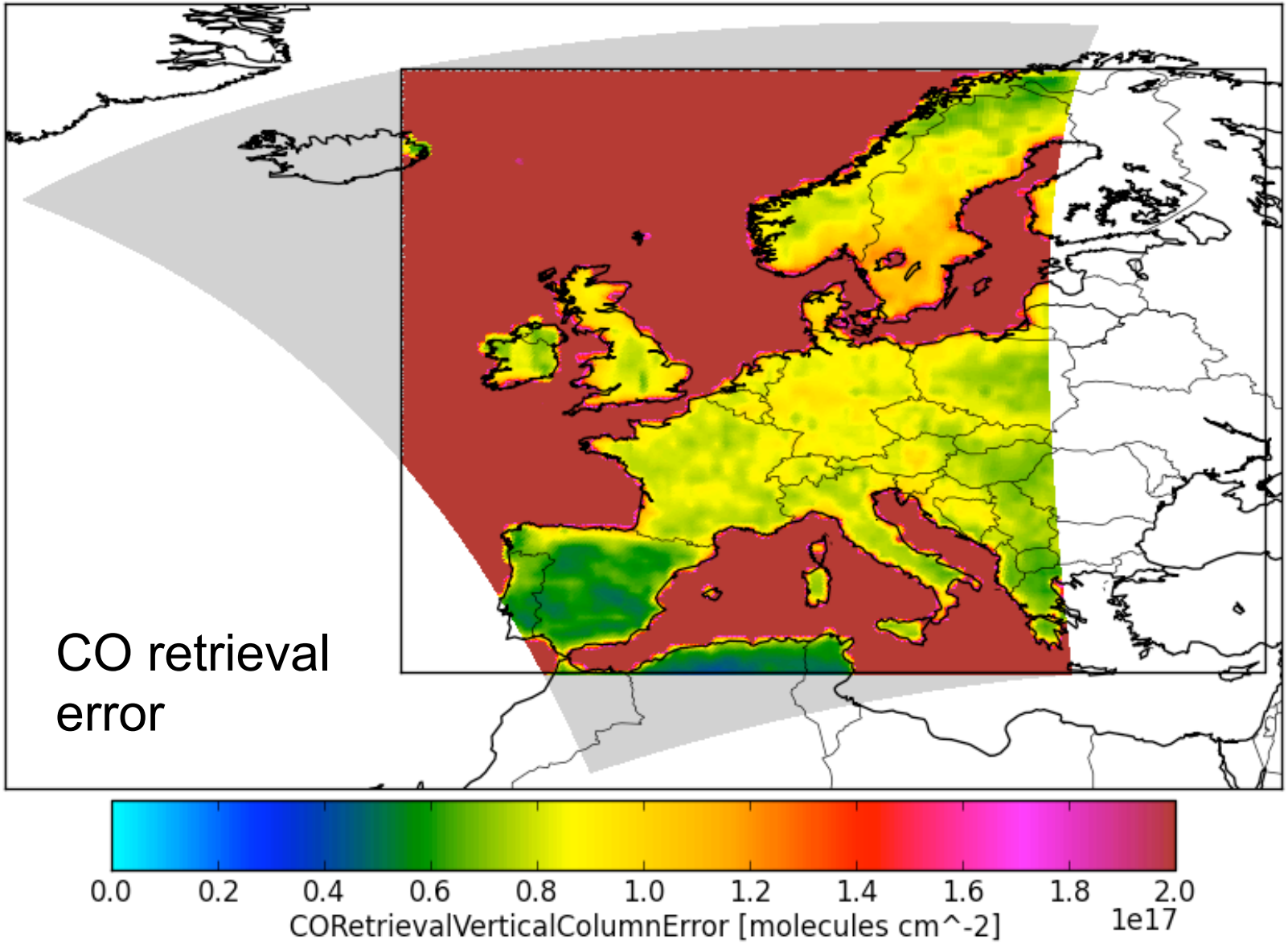


Results: CO, S5, retrieval



Results: CO, S5, retrieval

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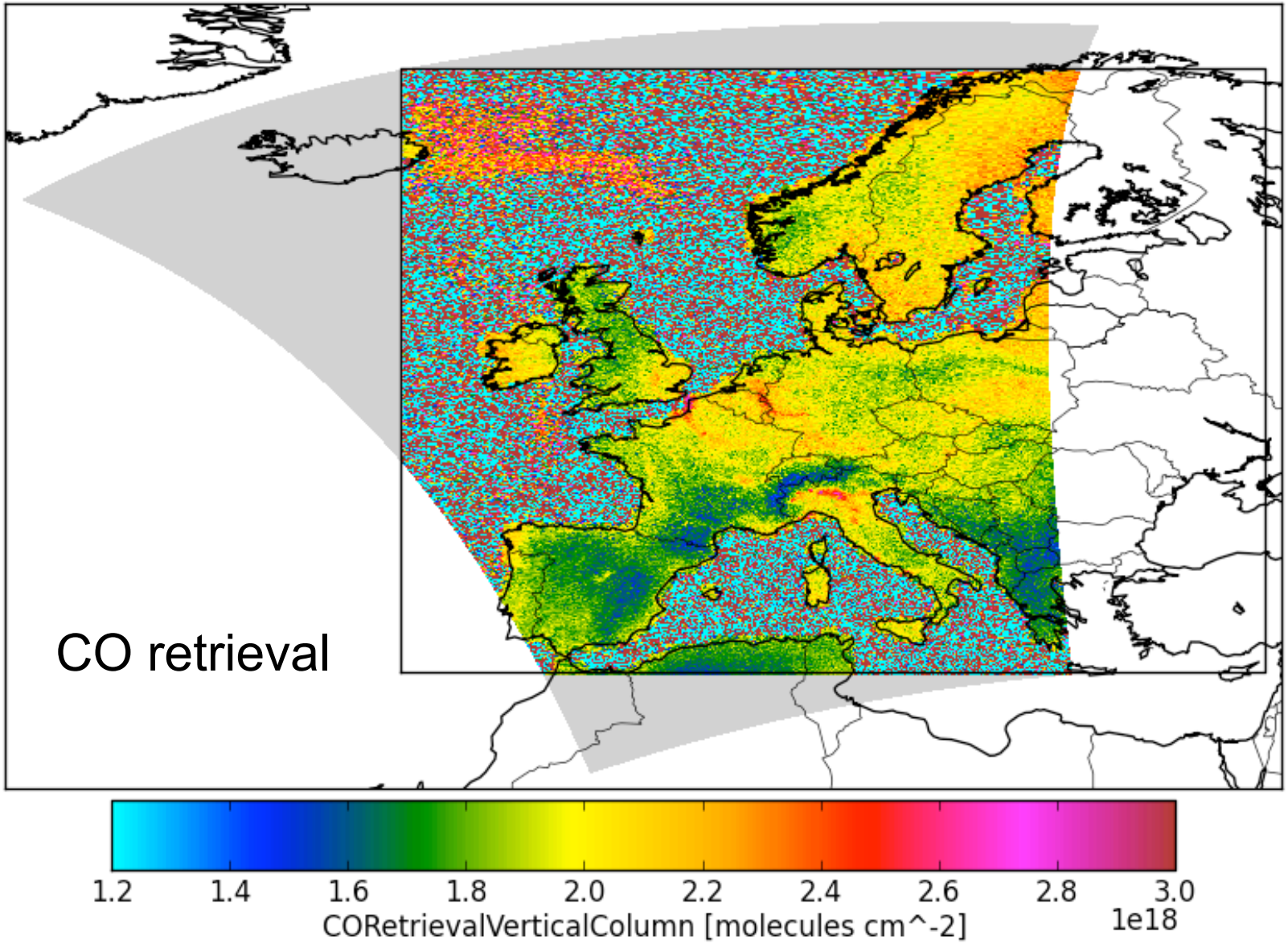

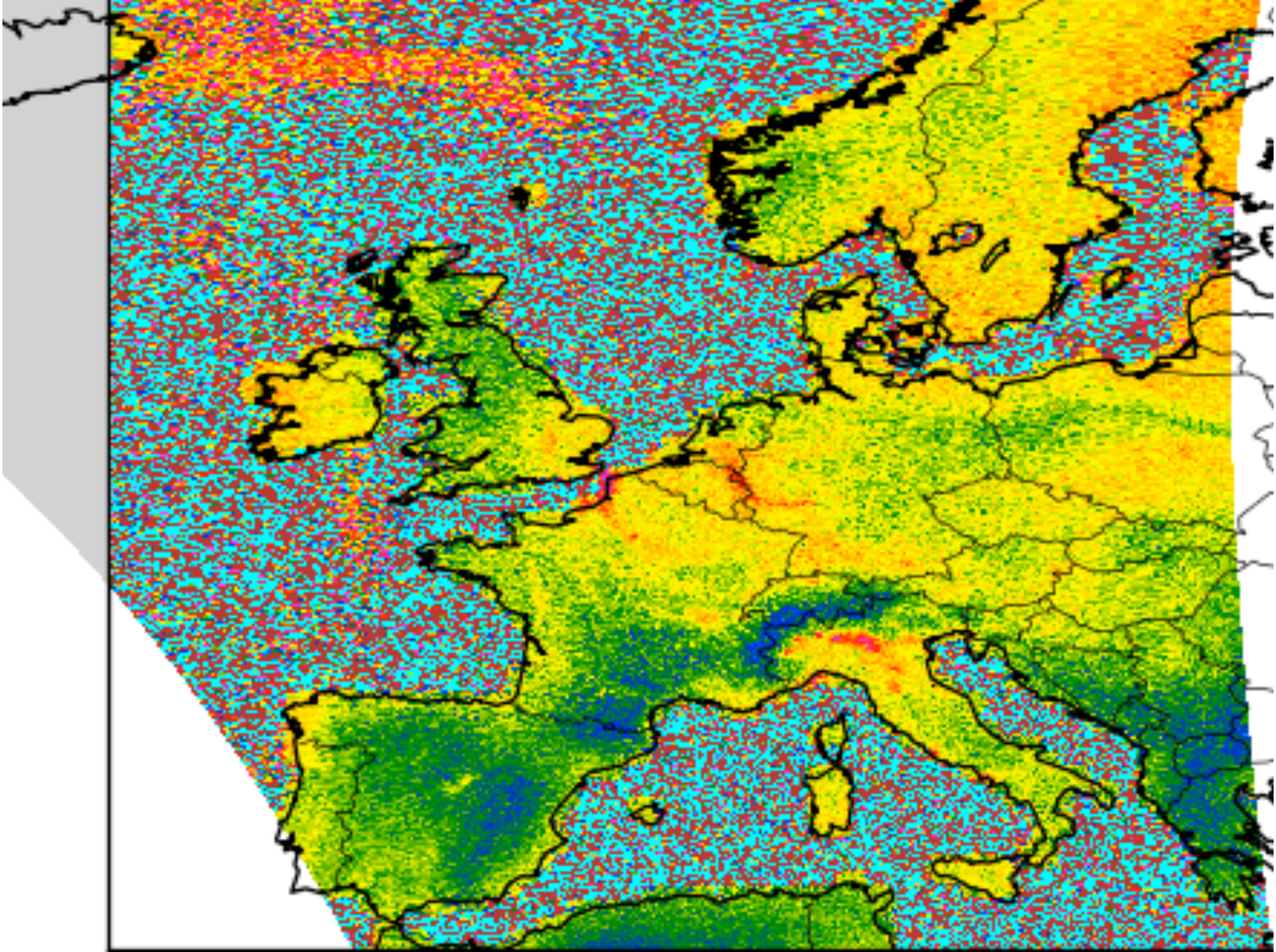

Results: NO2, S5, inputs

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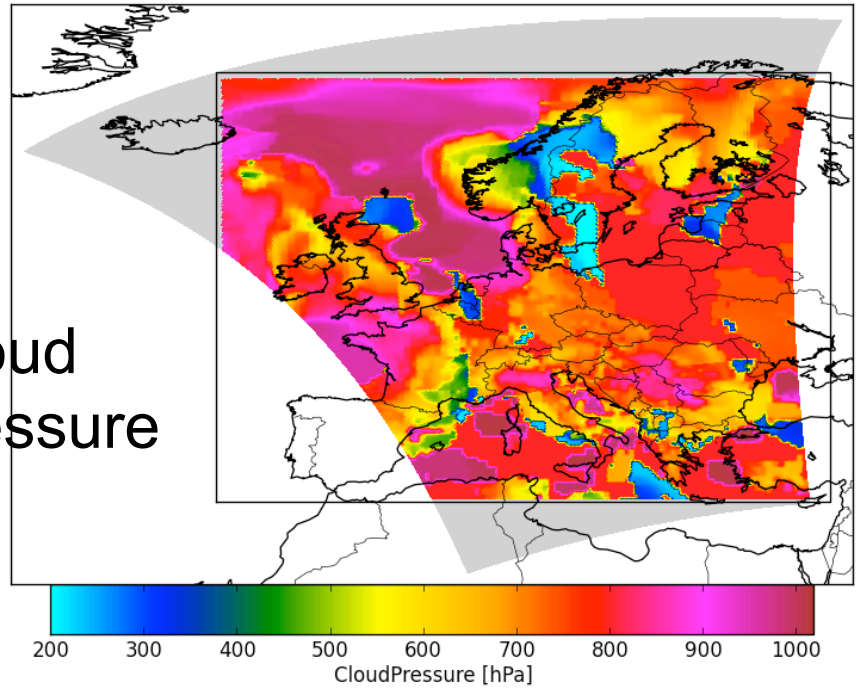
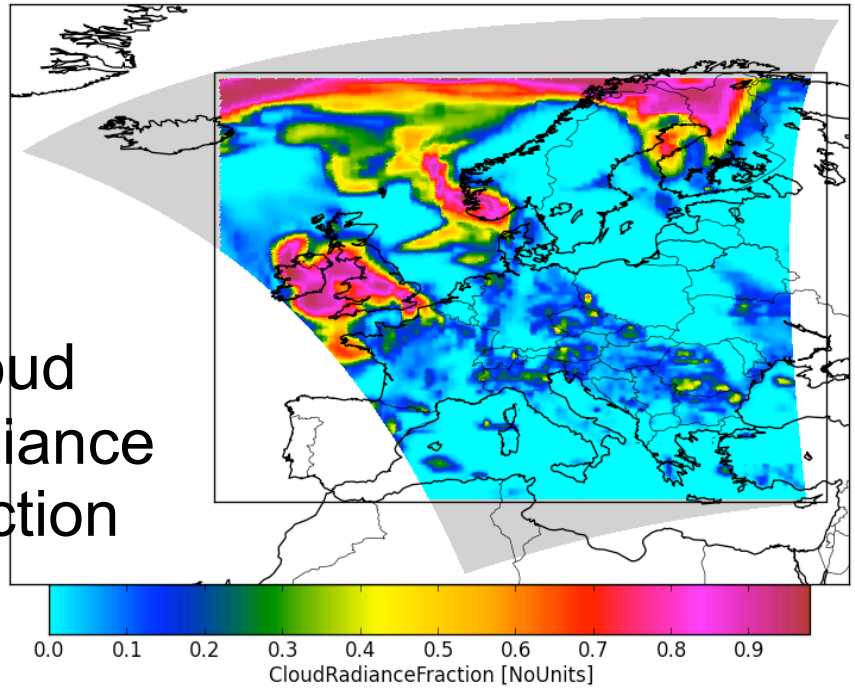
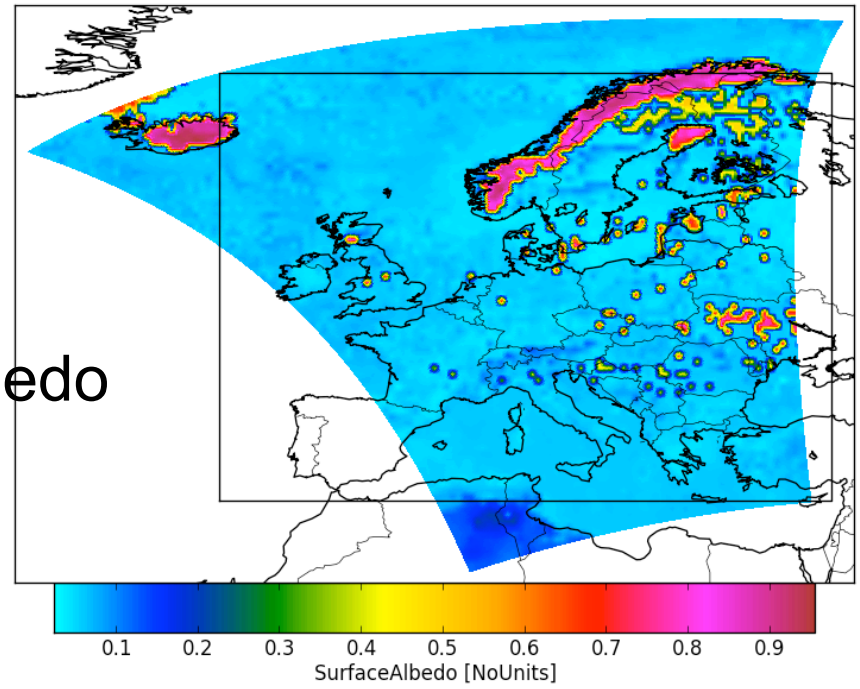
Cloud pressure



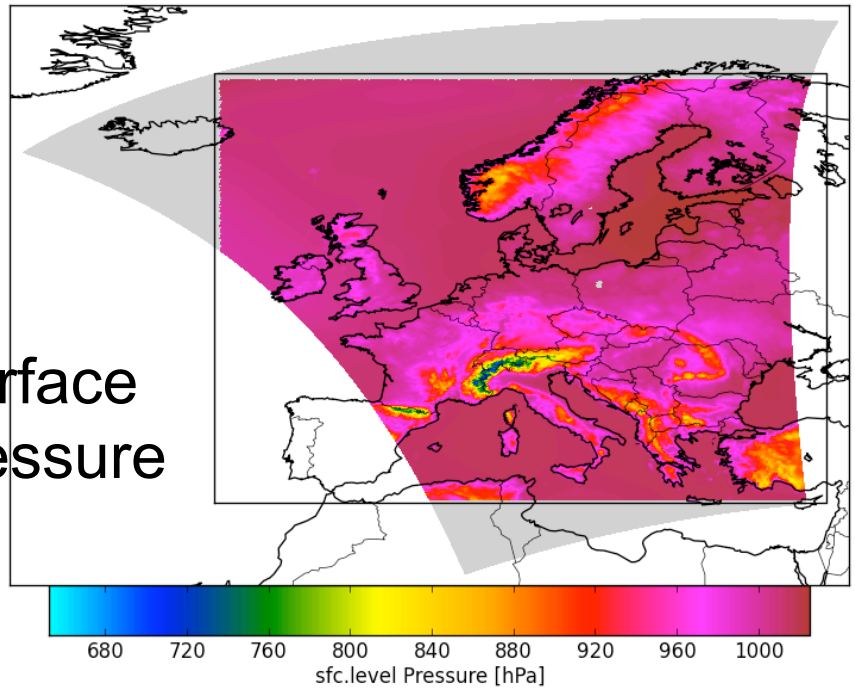
Cloud radiance fraction



Albedo



Surface pressure



Results: NO2, S5, nature run

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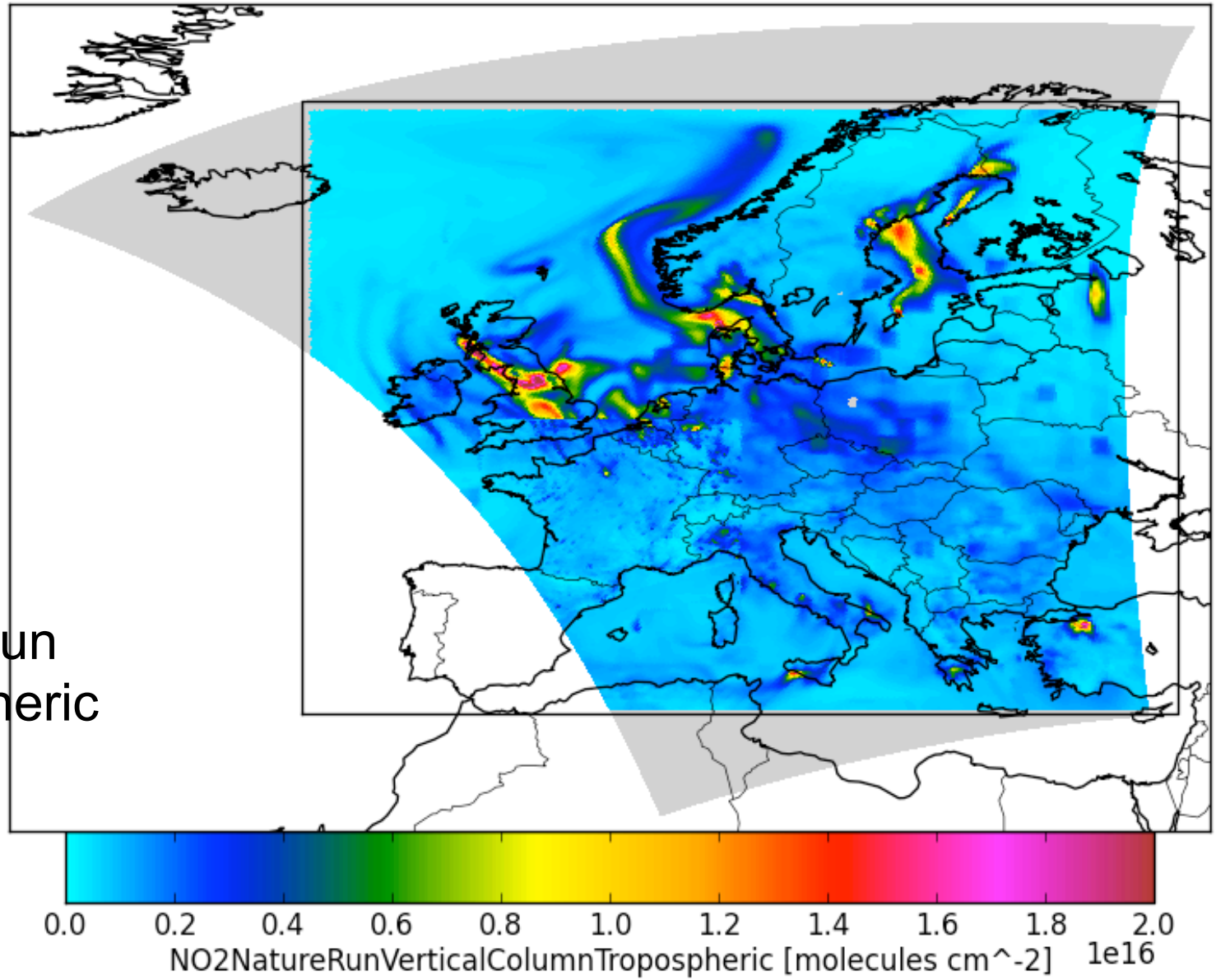
Nature run tropospheric column



Results: NO2, S5, retrieval

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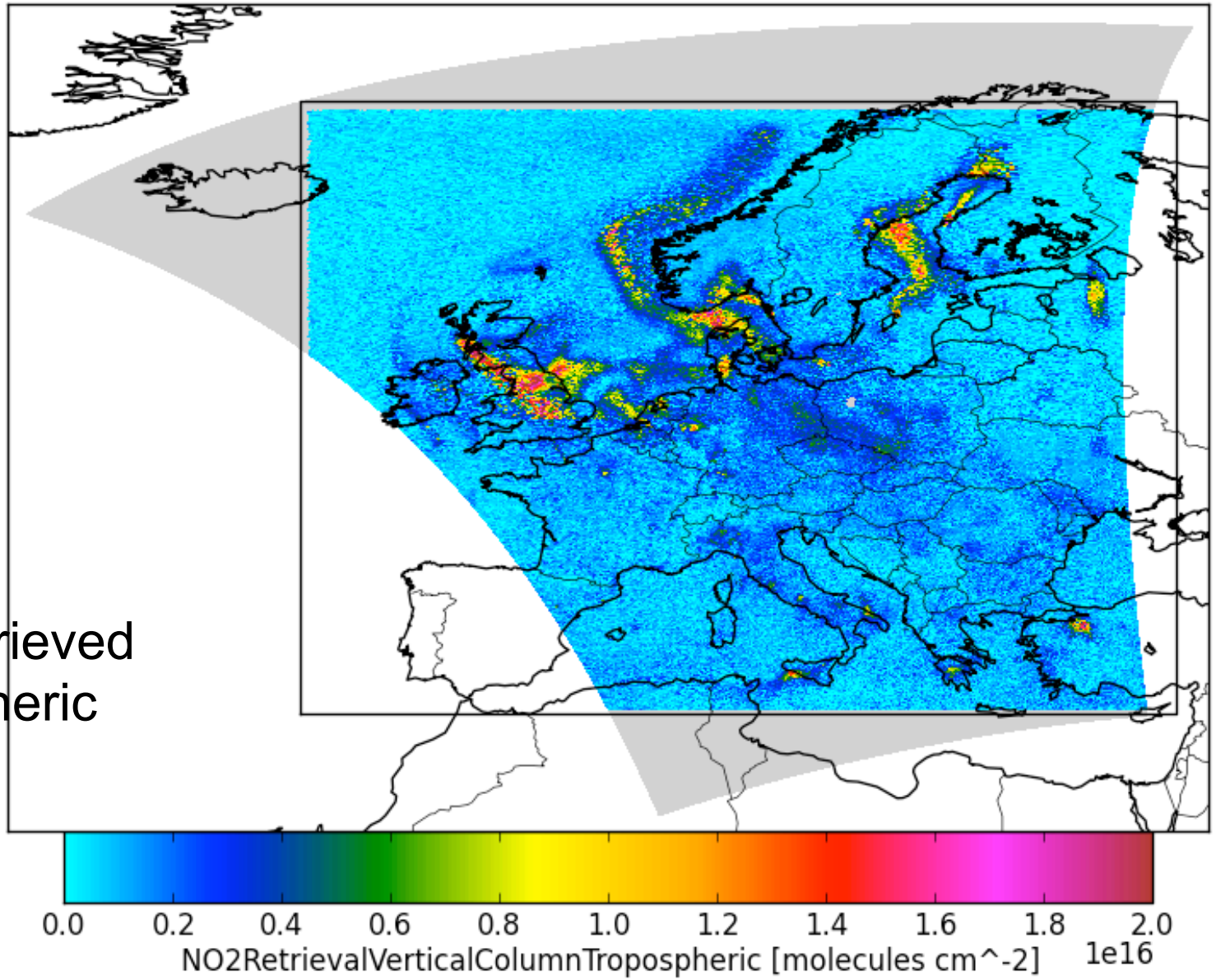
NO2 retrieved tropospheric column



Results: NO2, S5, error

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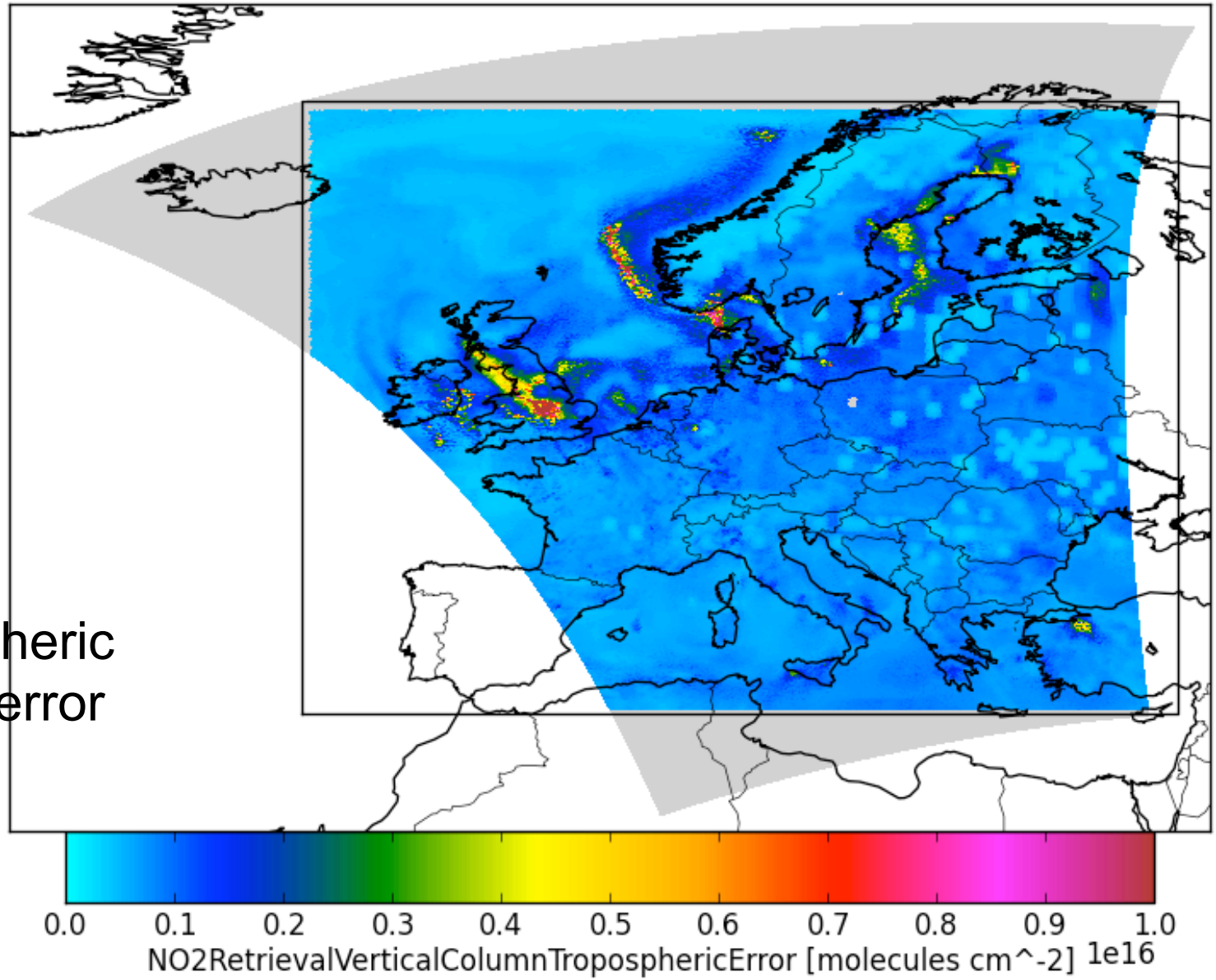
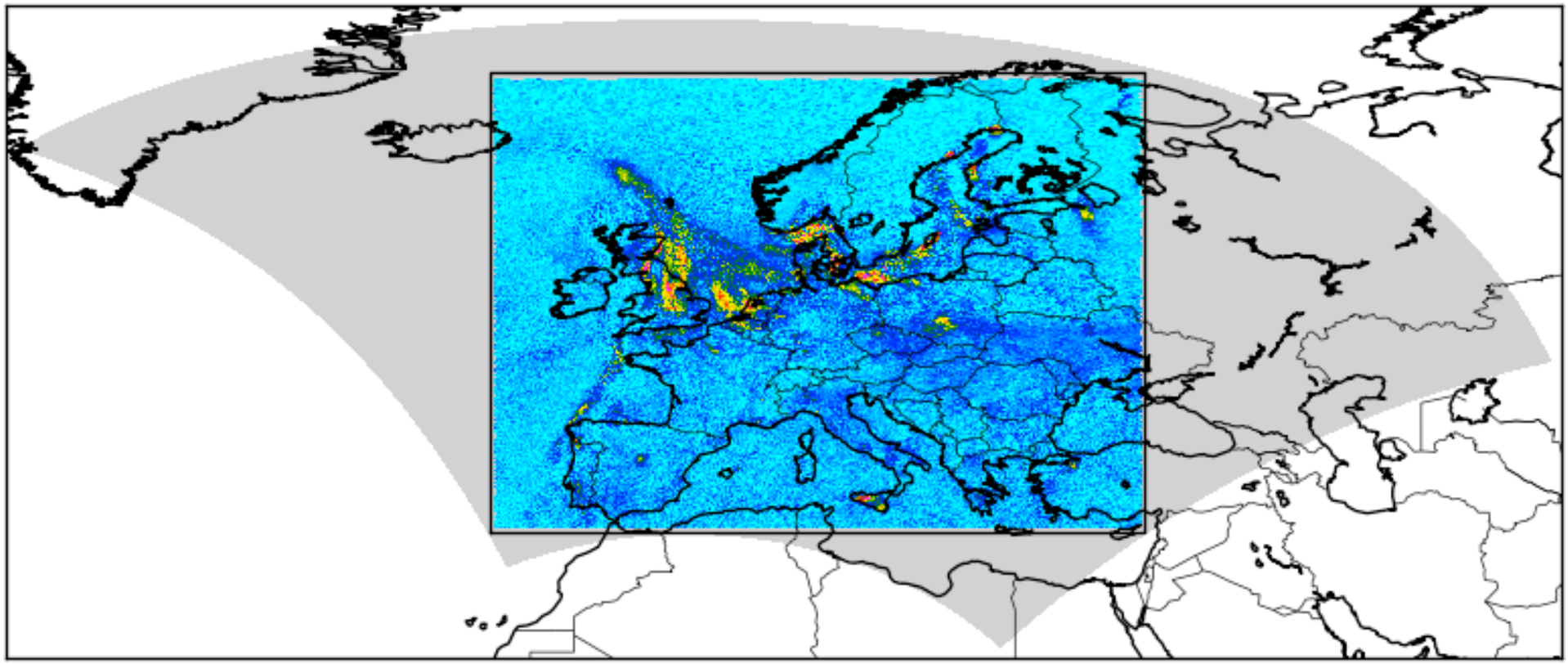
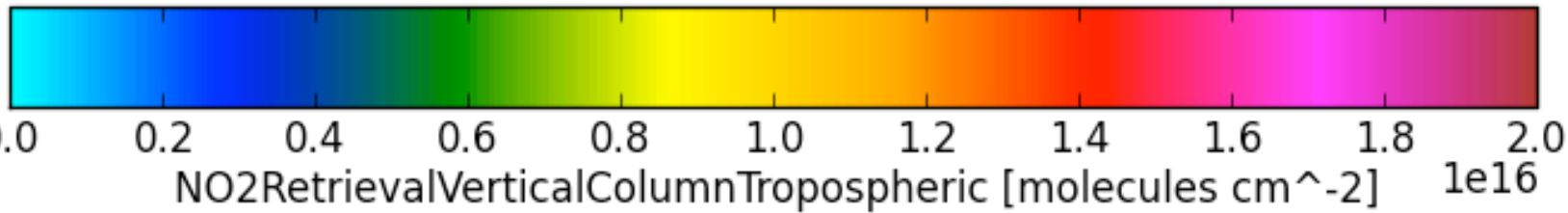
Tropospheric column error



Results: NO2, S4





Results: NO2, S4

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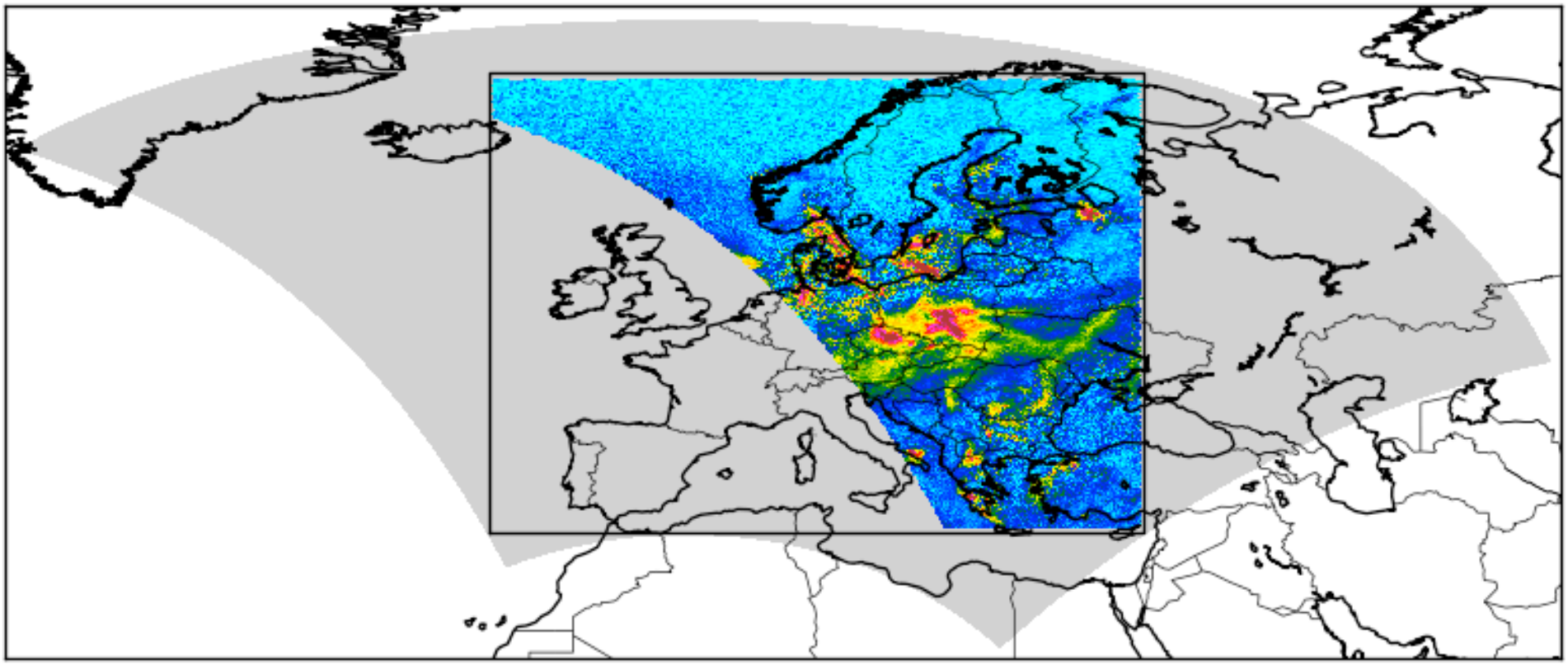

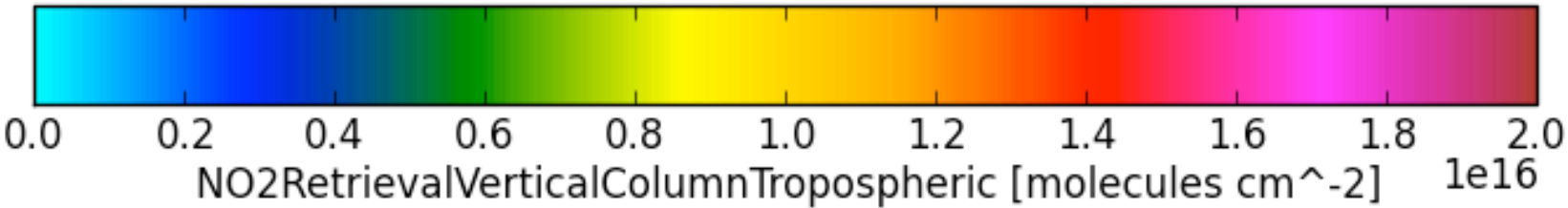

Results: HCHO, S5P, nature run

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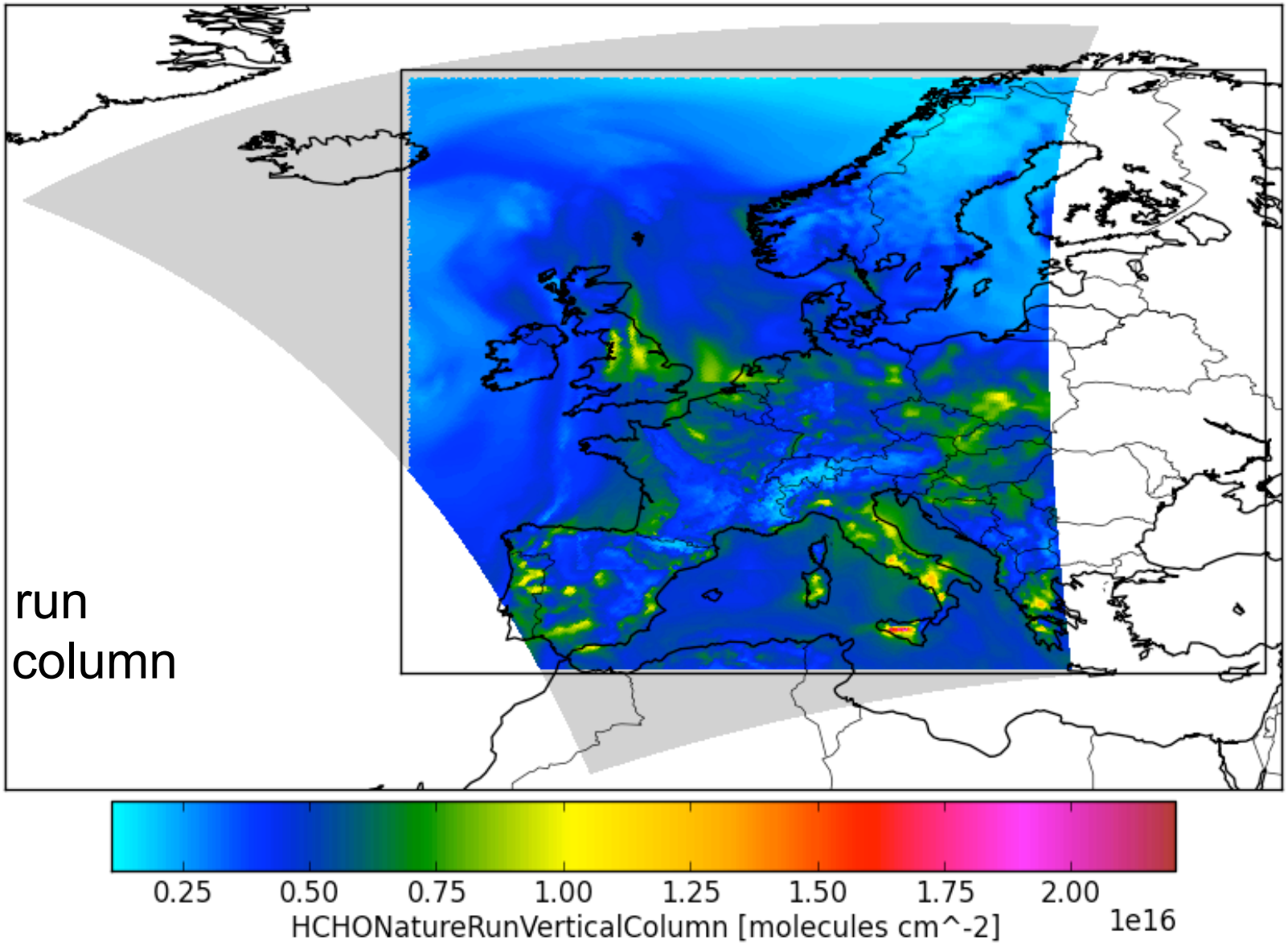
Nature run
HCHO column



Results: HCHO, S5P, retrieval error

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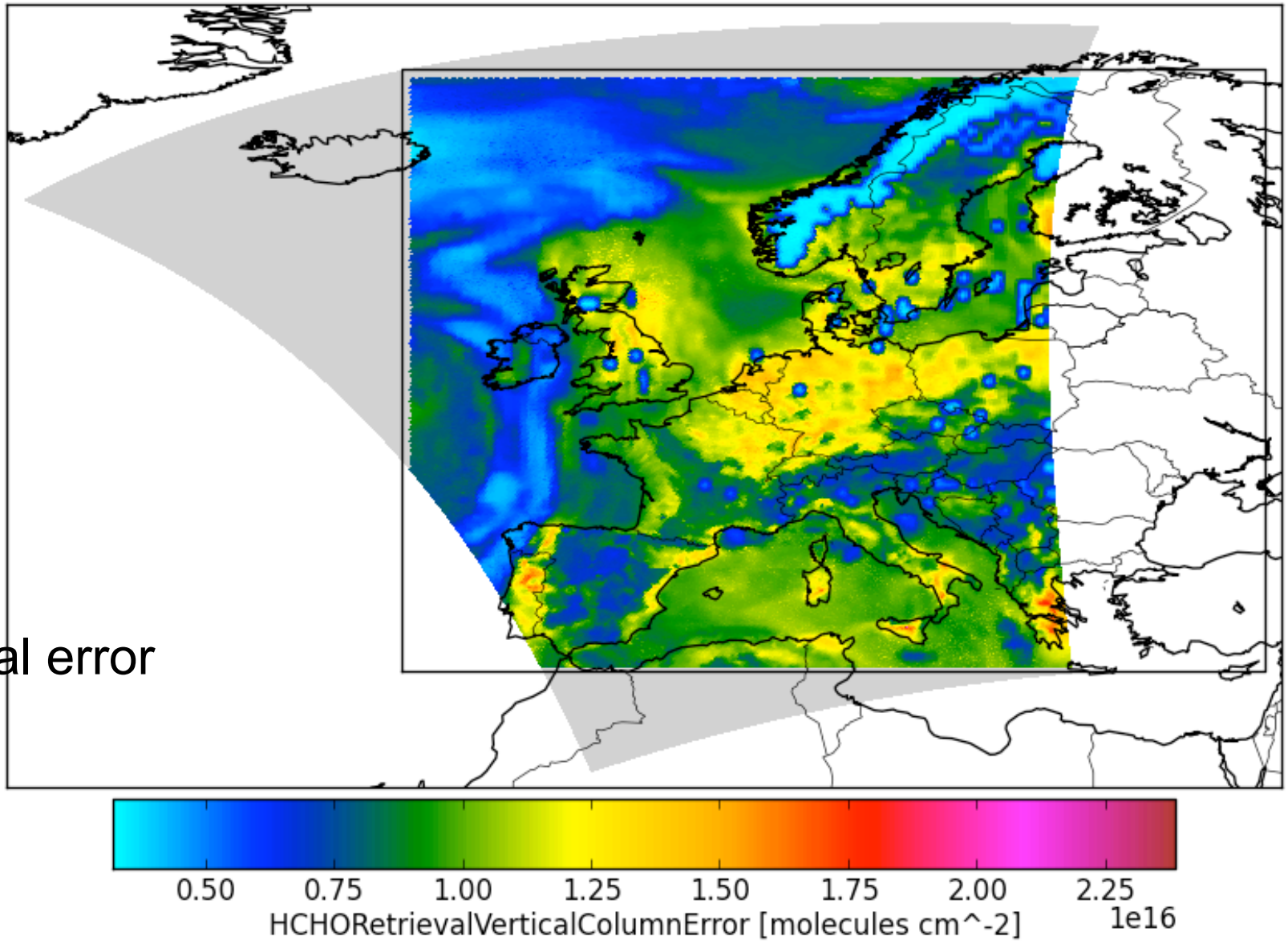
HCHO retrieval error



Results: HCHO, S5P, retrieval

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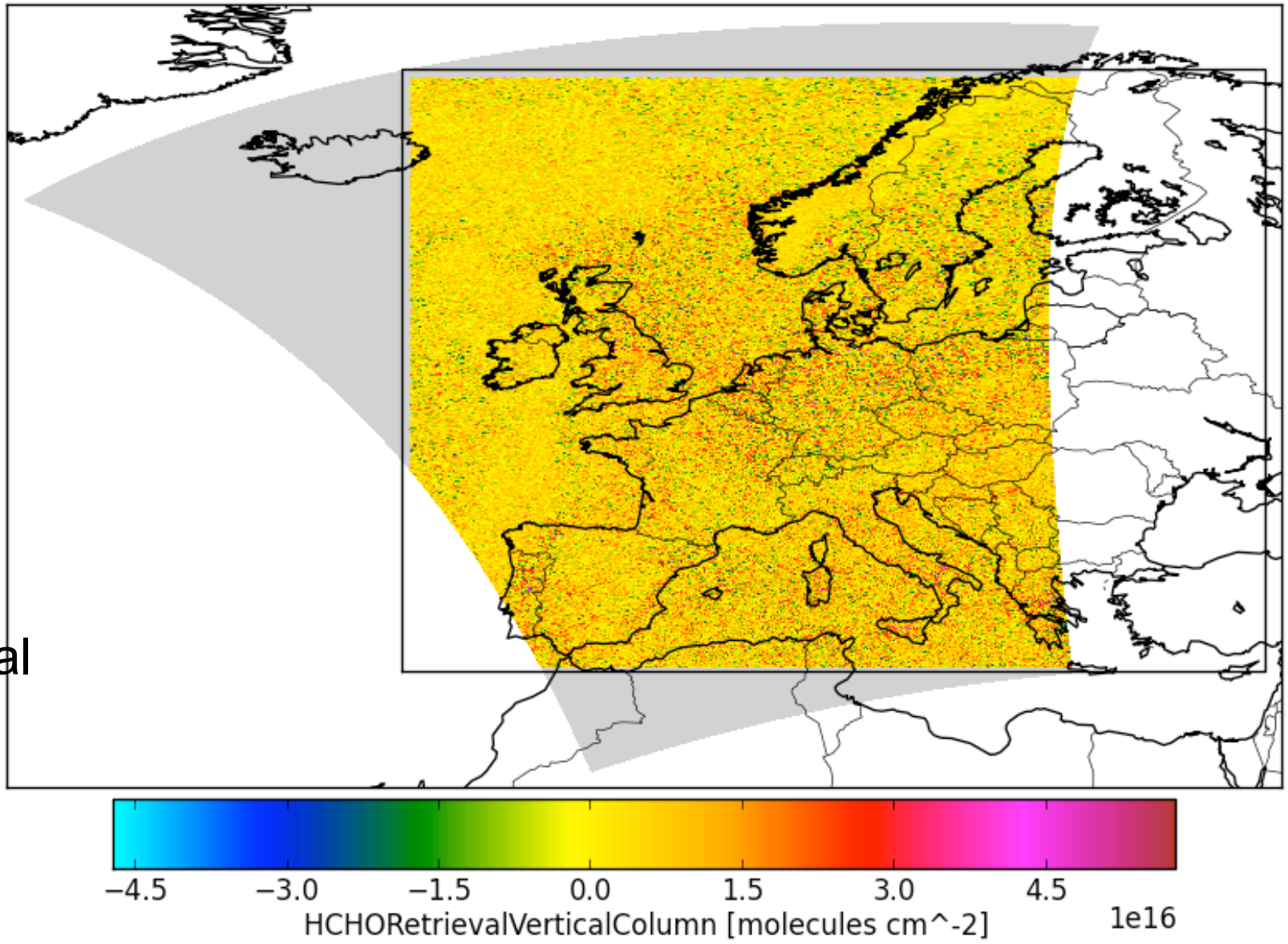
HCHO retrieval



Observations - Ozone

Migliorini, MWR 2008

"Use of Information Content for … efficient interface to DA"

Suppose retrieval is done on 40 vertical layers
and provides DFS = 5

Kernel : 40 x 40
Covariance : 40 x 40
Retrieval : 40
A-priori : 40

Conventional optimal estimation data product

Kernel : 40 x 5
Covariance : -
Retrieval : 5
A-priori : -

Product that stores only real information (Migliorini)

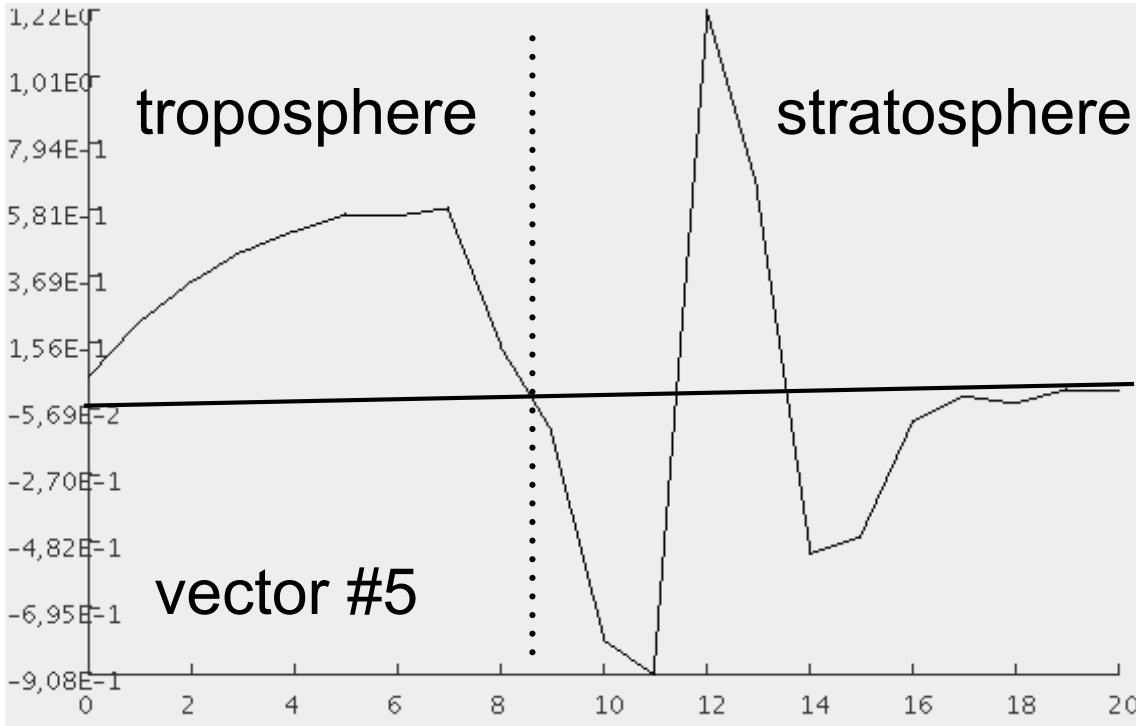
Observations - Ozone

Follow approach of Migliorini, MWR 2008

1. Efficient storage: Only kernel vectors and retrieval value for leading eigenvectors
2. Convenient for data assimilation: smaller nr of observations + diagonal obs. covariance

KNMI DISAMAR RTM:

* Forward + Optimal Estimation retrieval following Rodgers
* 300-320 nm range @ 7x7 footprint
* 6 leading eigenvectors
* S4 + S5P



Summary ISOTROP project

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

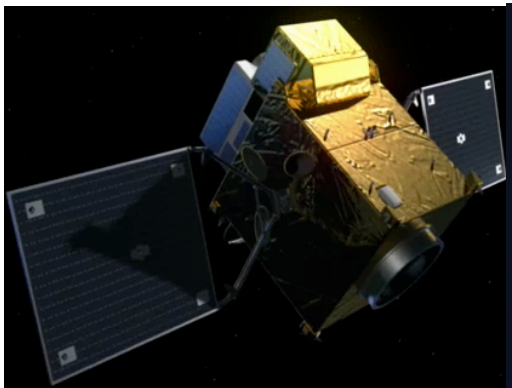
An OSSE to study the impact of Sentinel 4 and 5 data on air quality forecasts

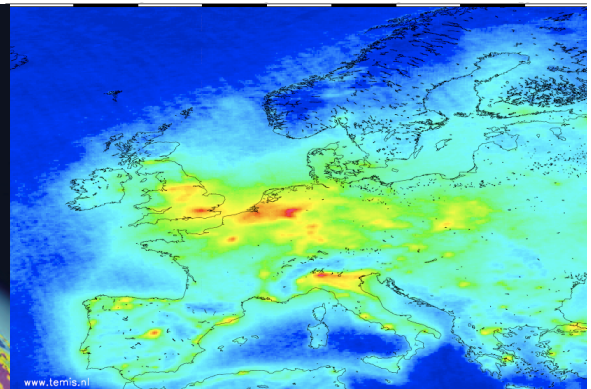
- Target species O3, CO, NO2, HCHO

Synthetic observations for S4 and S5(P), over Europe

- Based on high-resolution 7km model nature runs
- Full level-2 product (error estimation, kernels, covariances)
- Of use for other projects?

OSSE results: talks by Renske Timmermans, William Lahoz





Spin-off ISOTROP

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Papers

- Timmermans et al., OSSE review, Atmos. Env. 115, 2015.
- Abida et al., S5P CO OSSE, ACPD 2016 (under review).

Synthetic observations for new mission proposals

- NitroSat proposal for ESA Earth Explorer call 9
- TropoLite (Talk Renske Timmermans)