



Near real-time assimilation of volcanic sulfur dioxide from different satellites in the MOCAGE model during volcanic eruptions.

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CNRM, Météo-France and CNRS

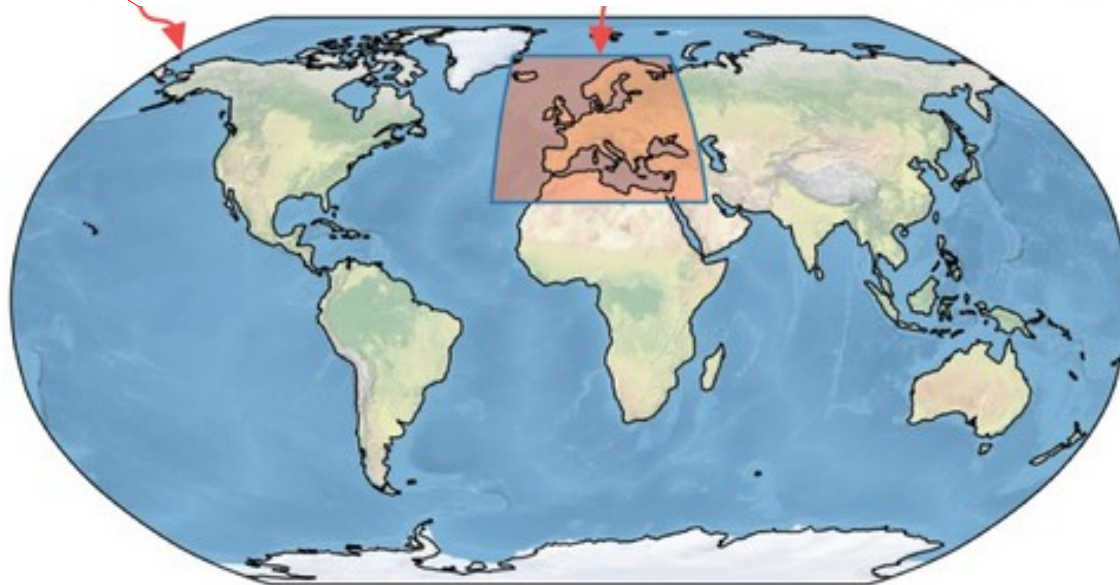
Modelling, Assimilation, Surface for Atmospheric Composition and Air Quality

IUGG 2023 - Berlin, 2023, July 16th

Chemistry Transport Model MOCAGE at Météo-France

- 47 vertical levels (hybrid sigma-pressure coordinate) – *60 levels*
~7 layers in the boundary layer, 20 in the troposphere,
20 in the stratosphere, *13 upper strato.*
- Model top at 5hPa (~ 35 km) – *at 0.1 hPa*
- Two domains :
 - Globe at 1°, using ARPEGE for meteorological forcing – *0.5°*
 - Europe at 0.1°, using IFS for meteorological forcing

In violet: Operational from Nov. 2023



Data assimilation in MOCAGE in operations

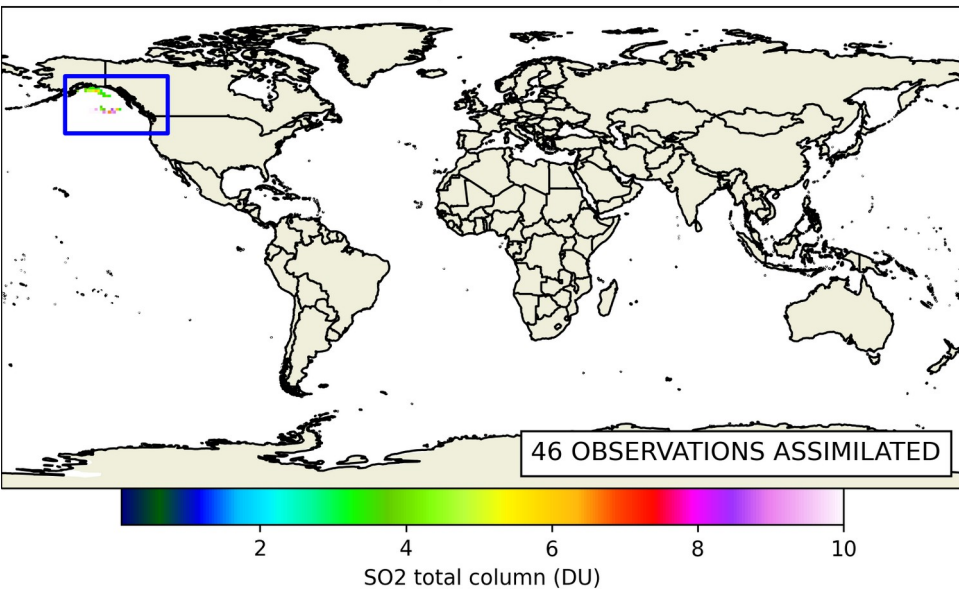
- Hourly 3D-VAR
- In the global domain
 - Satellite observations of Aerosol Optical Depth (AOD) – level 2 products
 - MODIS Aqua + Terra, VIIRS S-NPP + NOAA-20
 - **Satellite observations of SO2 total column – level 2 products**
 - **Tropomi SO2**
- In the regional domain
 - Ground-based observations from ceilometers and lidars (backscatter profiles)
 - European network e-profile
 - **Satellite observations of SO2 total column – level 2 products**
 - **Tropomi SO2**
- For aerosols, only the 3D total mass of aerosols is modified (no speciation info)
- **For satellite Tropomi SO2 columns, averaging kernels are used**



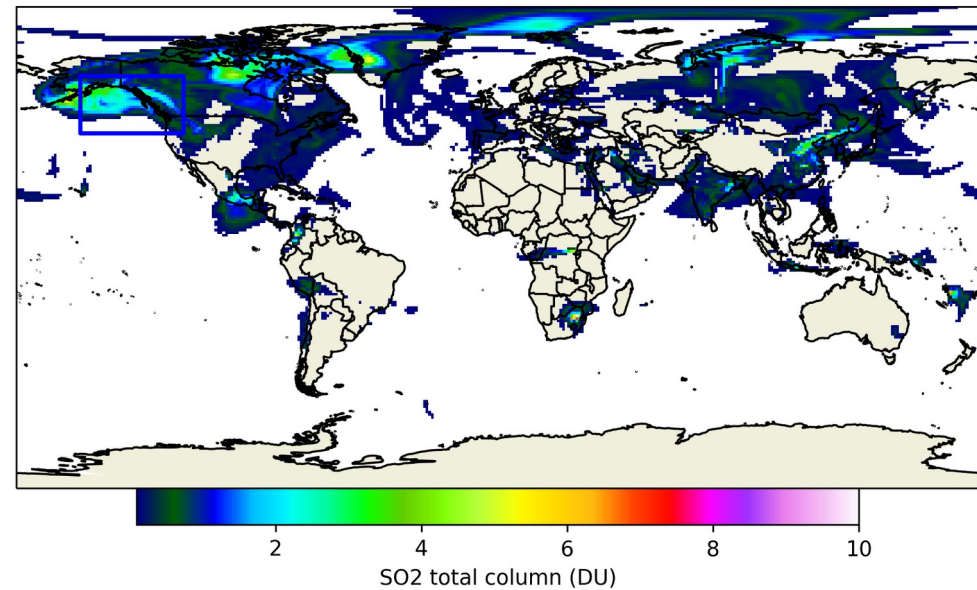
Example Kamtchatka eruption 11 April 2023 – Tropomi

- 8 days after the eruption, the SO₂ plume has already traveled around the Northern Hemisphere

Obs assimilated at
Wed 19 Apr 2023 - 21 UTC

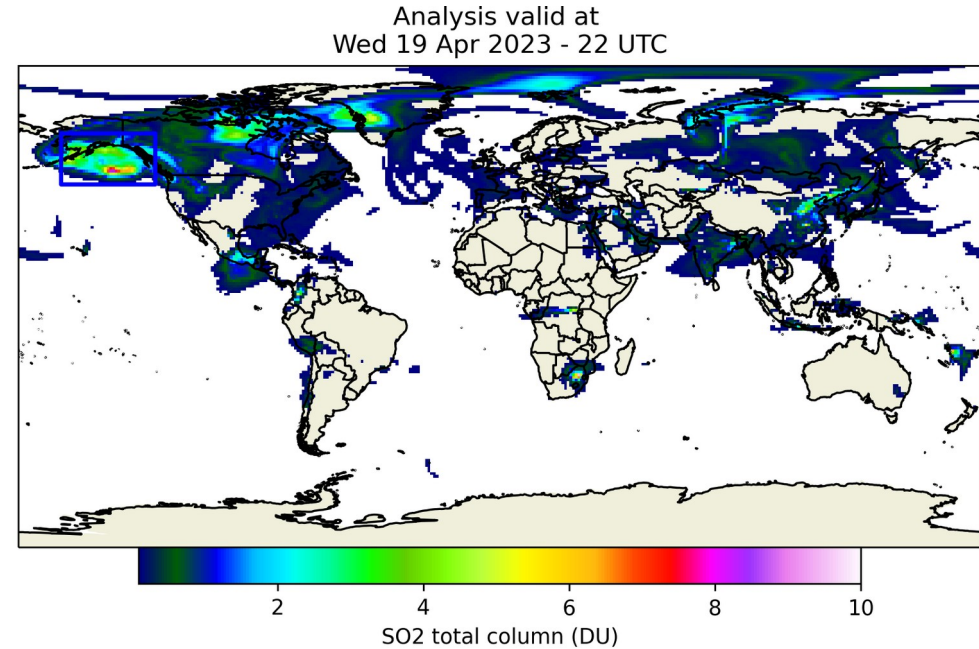


Forecast valid at
Wed 19 Apr 2023 - 21 UTC



Example Kamtchatka eruption 11 April 2023 – Tropomi

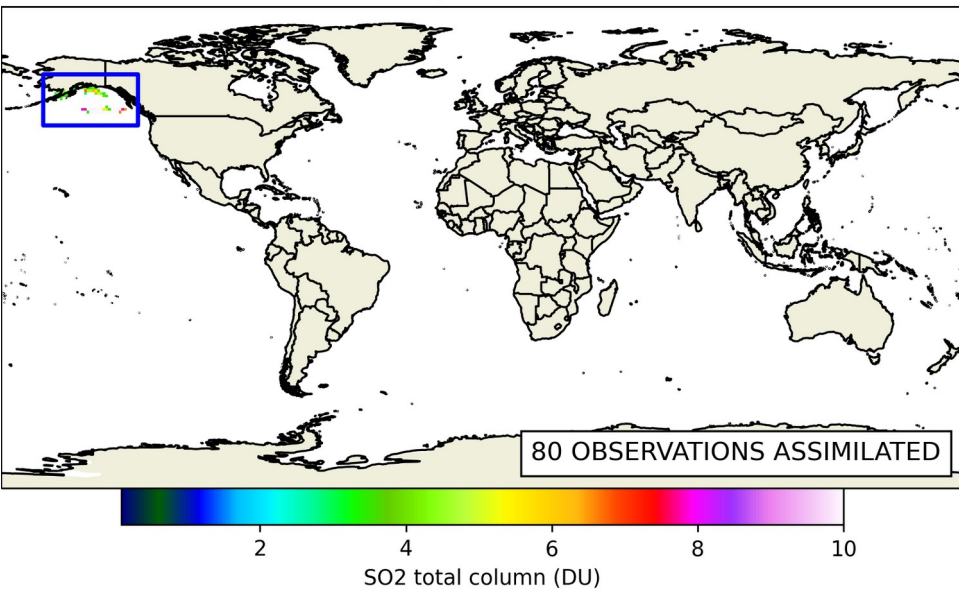
- 8 days after the eruption, the SO₂ plume has already traveled around the Northern Hemisphere



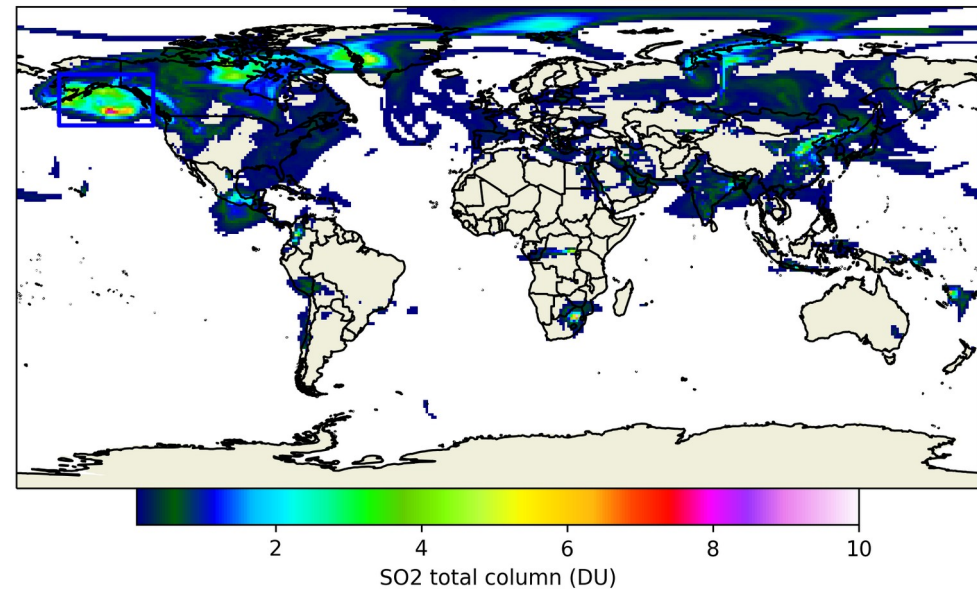
Example Kamtchatka eruption 11 April 2023 – Tropomi

- 8 days after the eruption, the SO₂ plume has already traveled around the Northern Hemisphere

Obs assimilated at
Wed 19 Apr 2023 - 22 UTC

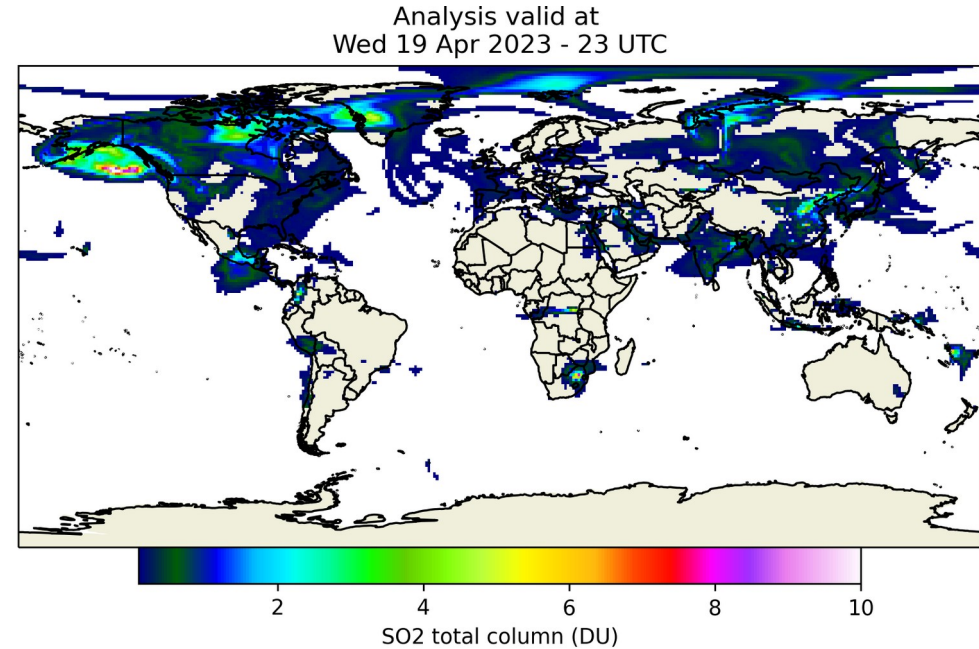


Analysis valid at
Wed 19 Apr 2023 - 22 UTC



Example Kamtchatka eruption 11 April 2023 – Tropomi

- 8 days after the eruption, the SO₂ plume has already traveled around the Northern Hemisphere

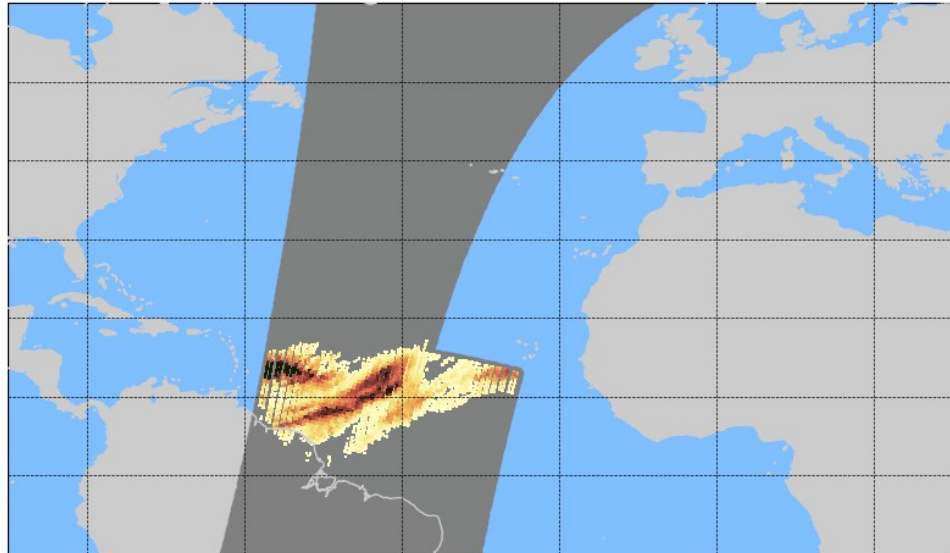


La Soufrière Saint Vincent eruption 9-12 April 2021

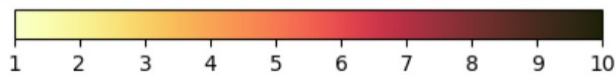
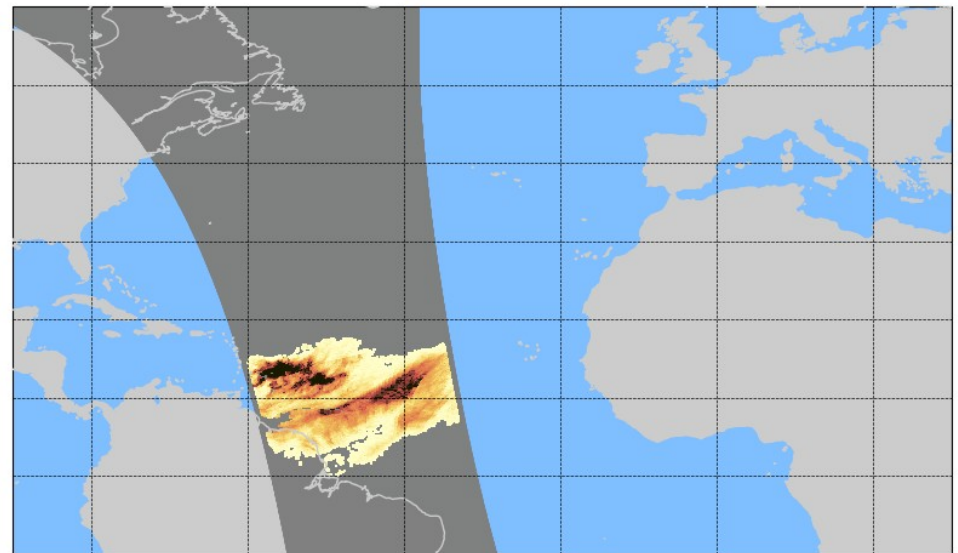
Several explosions between 9 and 12 April 2021.
SO2 plume crossed the Atlantic Ocean and reached Africa.

SO2 total column observed by:

IASI B and C on 11th April 2021 at 13UTC



TROPOMI on 11th April 2021 at 16UTC



July 16^h :

SO2 total column (DU)

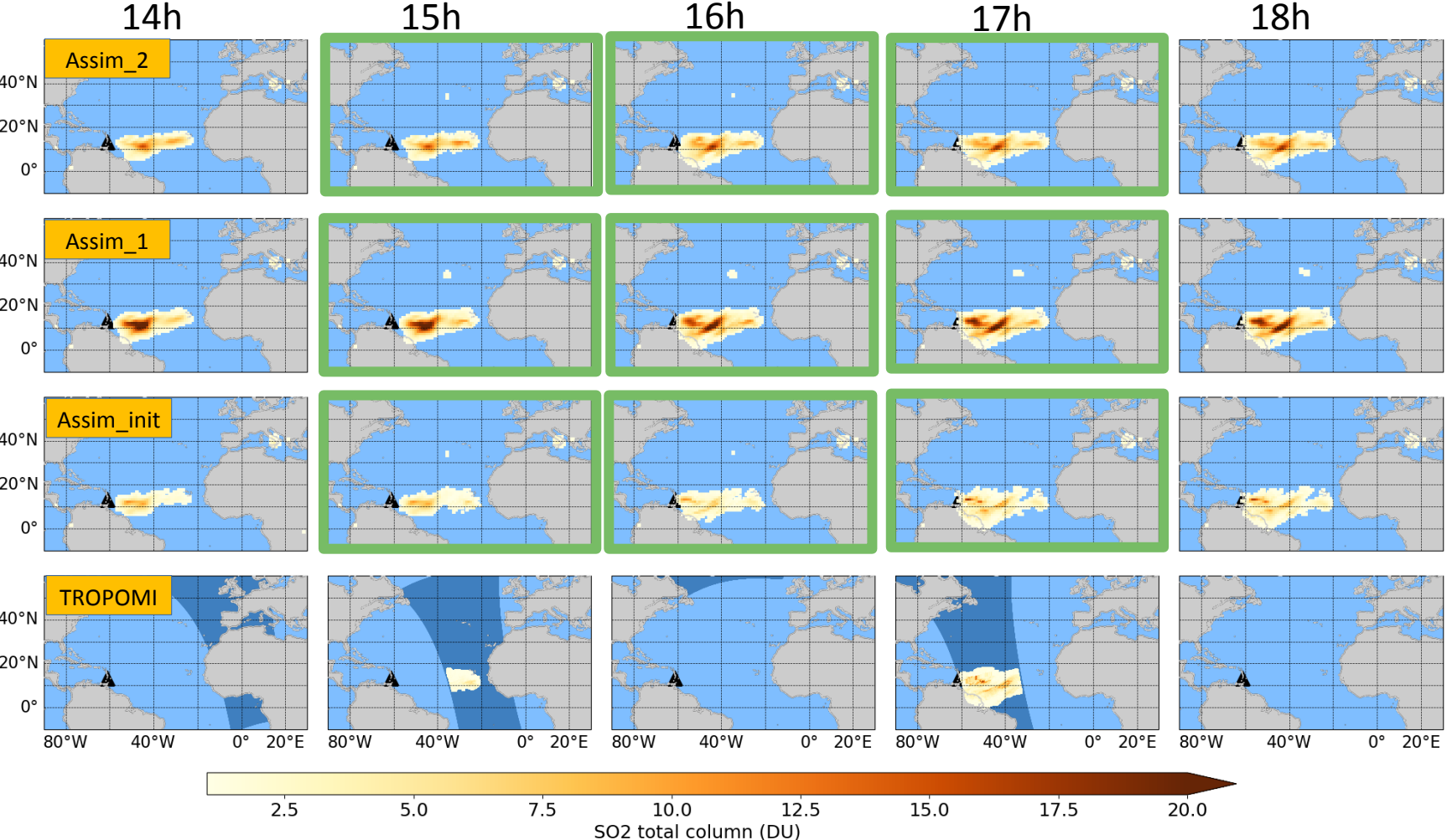


Configuration of MOCAGE in IASI (only) assimilation trials

- Global domain with a 1° resolution
- Hourly meteorological forcing provided by ARPEGE model
- Hourly 3D-VAR
- 3 configurations have been tested :

| Simulation | Using height | B matrix | R matrix | Horizontal correlation | Vertical correlation |
|------------|------------------------------|--|----------------------|------------------------|----------------------|
| Assim_init | No | 1e-29 ppv or 1e-8 ppv between 9 and 21km | 15 % of observations | 1° | 1 level |
| Assim_1 | Yes with 2km thickness plume | 1e-8 ppv | 15 % of observations | 1° | 1 level |
| Assim_2 | Yes with 1km thickness plume | 1e-8 ppv | 15 % of observations | 0.5° | 0.5 level |

La Soufrière Saint Vincent eruption – IASI (only) assim 11 April



La Soufrière Saint Vincent eruption – IASI (only) assim 11 April

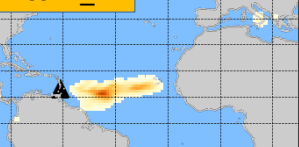
14h

15h

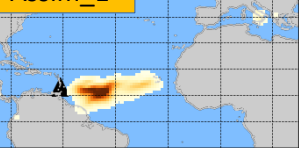
16h

17h

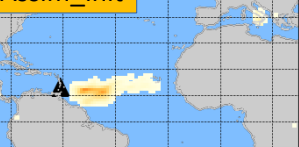
Assim_2



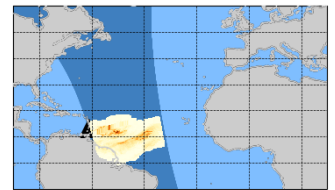
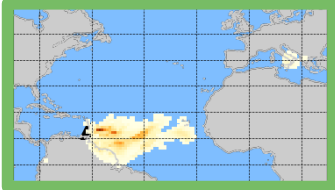
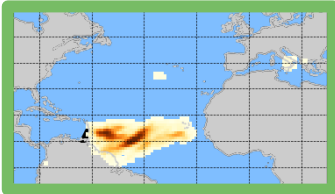
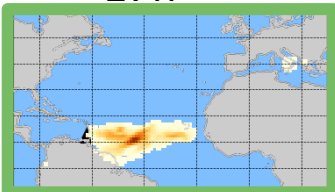
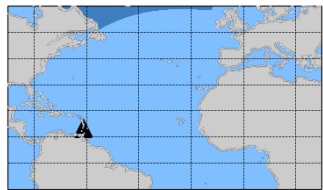
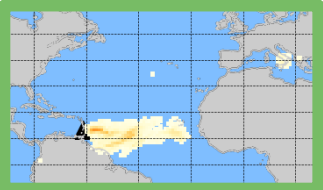
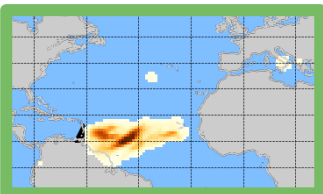
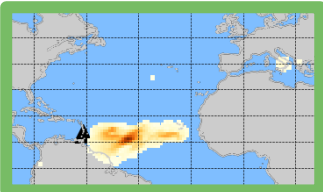
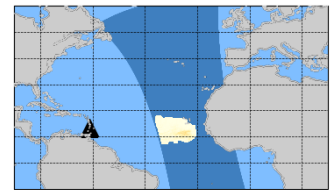
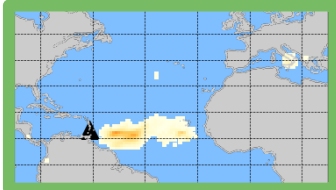
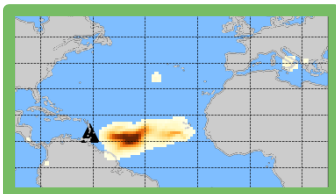
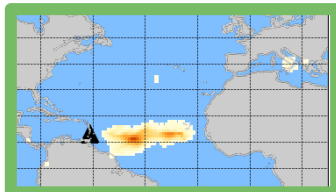
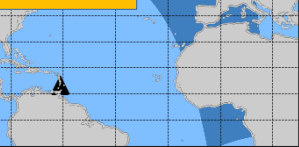
Assim_1



Assim_init



TROPOMI

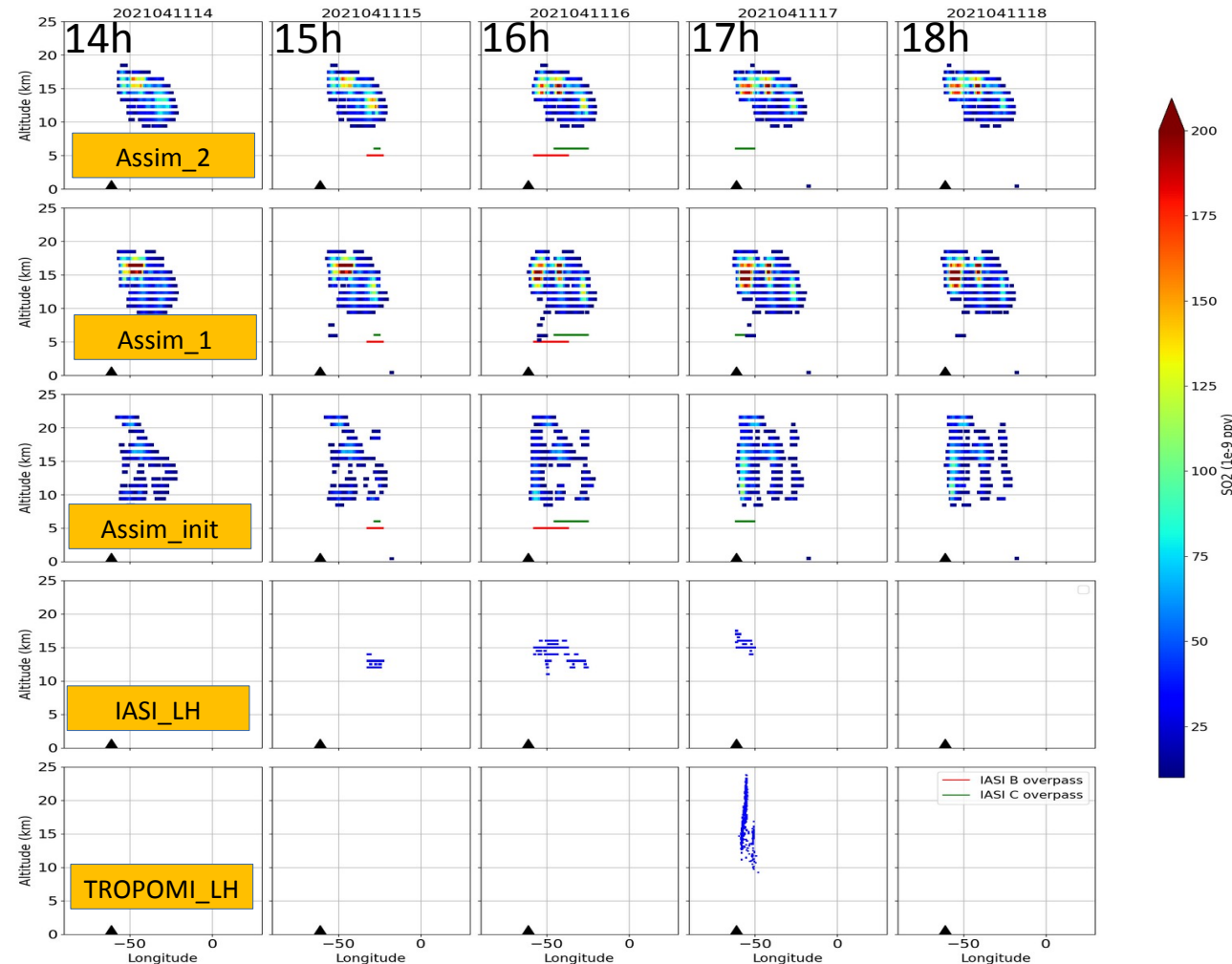


Structures okay vs Tropomi

Values are stronger when taking the height of the plume into account but are larger than Tropomi



La Soufrière Saint Vincent – Plume altitude with IASI assim.



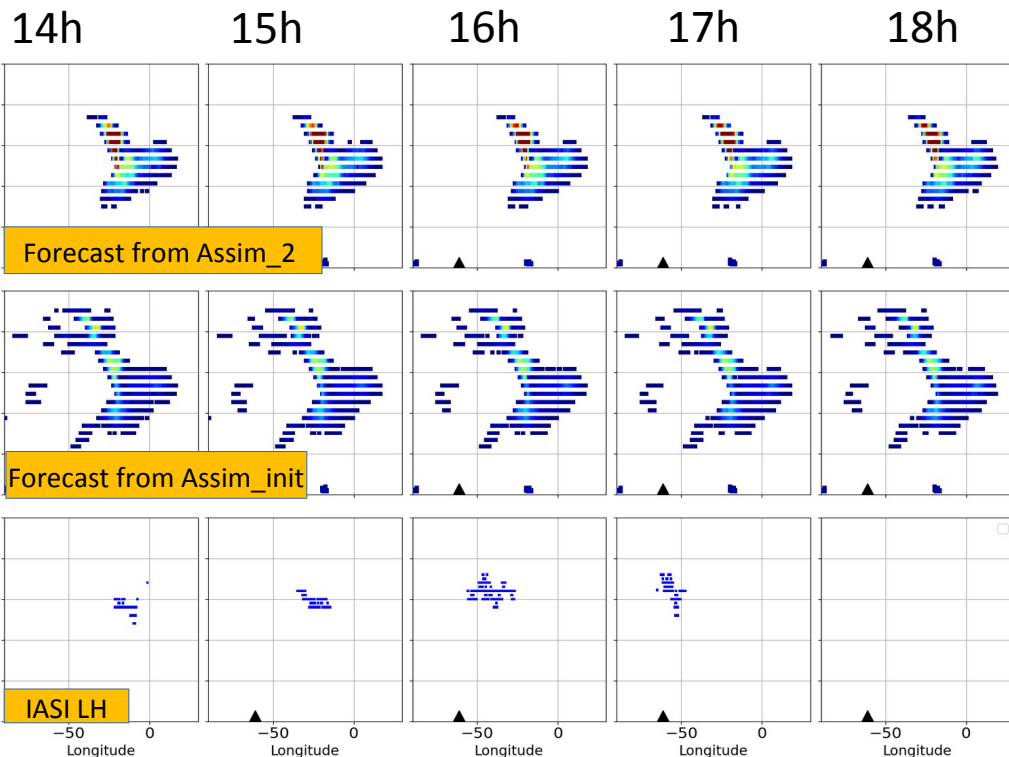
Plume representation seems to be more realistic by taken into account the height of the plume.

The plume is too thick compare to the IASI observations. We assume that the plume thickness is 1 or 2km and the plume is centered around the height read in the observation file. Nevertheless, sometimes before the assimilation SO₂ is simulated outside of the plume.

Vertical correlation could be too strong.

La Soufrière Saint Vincent – forecast skills

Forecasts are computed using the analyses
Here forecast valid on 13 April from full 11 April analyses
ie 38 to 42 h forecast range



Using height allow to simulate strong SO2 concentration around the observed plume height. The modeled plume is less extended thanks to the IASI height information.

Take home messages

- Height information is very useful to modelize or forecast the SO₂ plume height and the shape of the plume.
- By using the observed SO₂ plume height, simulated total columns are too strong.
- Work on R and B matrices and on the correlations
- Assimilate observations of “no volcanic SO₂ detected”
- Assimilate other instruments (TROPOMI_LH, TROPOMI...)
- Combined assimilation of instruments !