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Near real-time assimilation of volcanic sulphur dioxide in the MOCAGE model

Mickael Bacles¹ and Vincent Guidard¹

¹CNRM, Université de Toulouse, Météo France, CNRS, Toulouse, France

mickael.bacles@meteo.fr

Introduction

Motivation: Large quantities of SO₂ and ash are released during eruptions, threatening aviation safety. The aim of VAAC is to forecast the transport of volcanic plumes in near-real time.

Model: MOCAGE is the CTM developed at Météo-France. It allows to forecast the atmospheric composition on both global and regional domains. Assimilation of volcanic SO₂ total column provided by TROPOMI is already in operations. It allows to correct the model between 2 fixed altitudes.

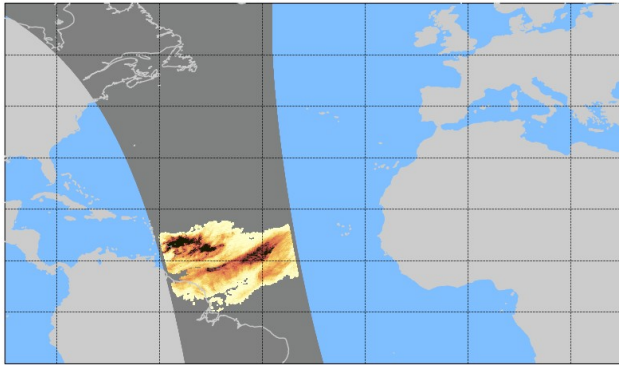
Goal: Improve our assimilation through the use of height information provided by satellites.

La Soufrière Saint Vincent eruption – 11th April 2021

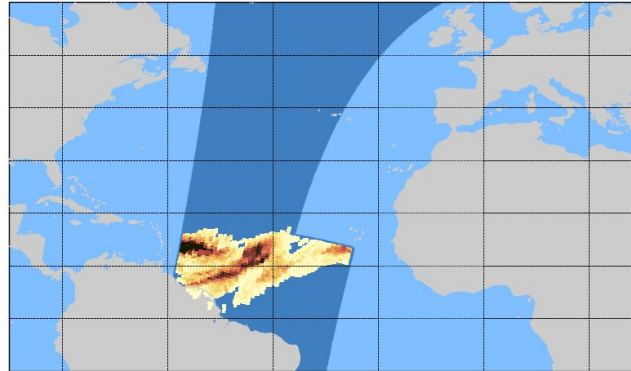
Several explosions between the 9th and the 12th April 2021.

SO₂ plume transport is observed by many satellite instruments :

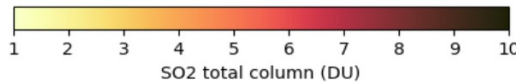
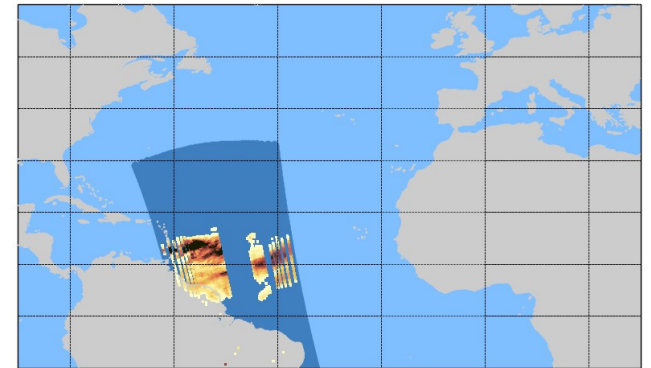
TROPOMI on 11th April
2021 at 16UTC



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



OMI on 11th April 2021 at
17UTC



MOCAGE settings

- Global domain with 1° resolution
- Hourly meteorological forcing provided by ARPEGE model
- Hourly 3D-VAR
- Validation with OMI observations (independant observations)
- All available observations are assimilated (no thinning)

Previous method:

Assimilation of TROPOMI and IASI SO₂ total columns using averaging kernels. The modeled plume height was constrained by the B matrix.

Presented at 2022 Eumetsat conference.



New method:

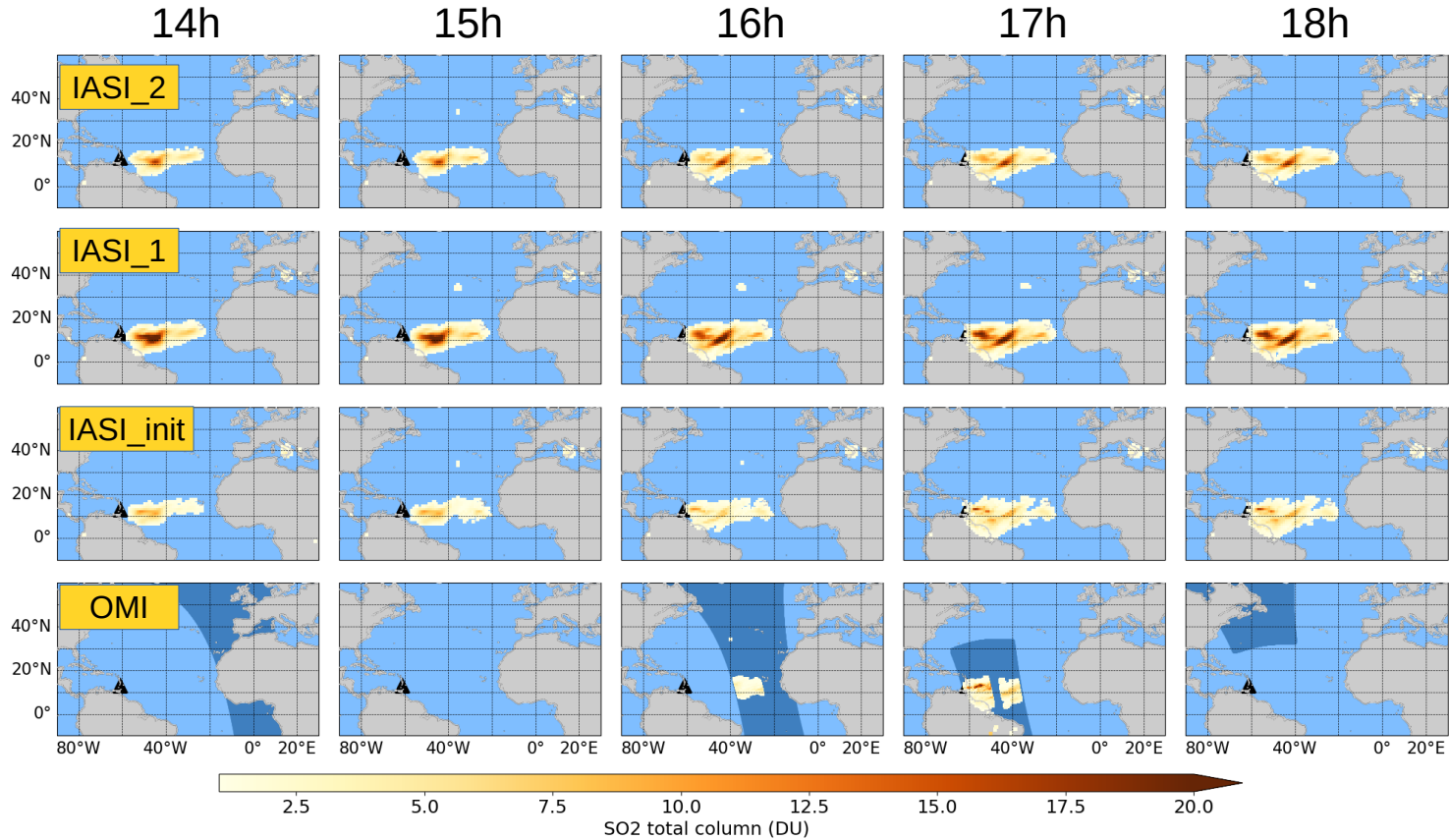
It is assumed that the entire column observed by satellites instruments is between 2 altitudes. These altitudes are given by the satellites products.

We assimilate this partial column in MOCAGE.

MOCAGE for IASI assimilation

Simulation	Method	B matrix	Horizontal correlation	Vertical correlation
IASI_init	Previous method	1e-8 ppv between 9 and 21km	1°	1 level
IASI_1	New method : partial columns with a thickness of 2km centered on the height given by IASI instruments	1e-8 ppv	1°	1 level
IASI_2		1e-8 ppv	0.5°	0.5 level

IASI assimilation – 11th April 2021



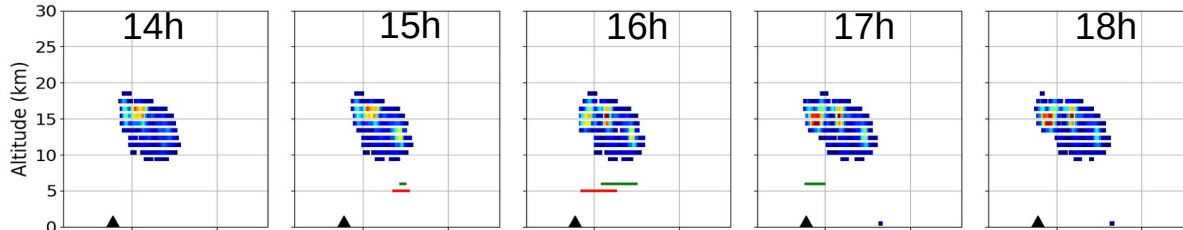
Structures ok with OMI

Values are stronger when taking the height of the plume into account.

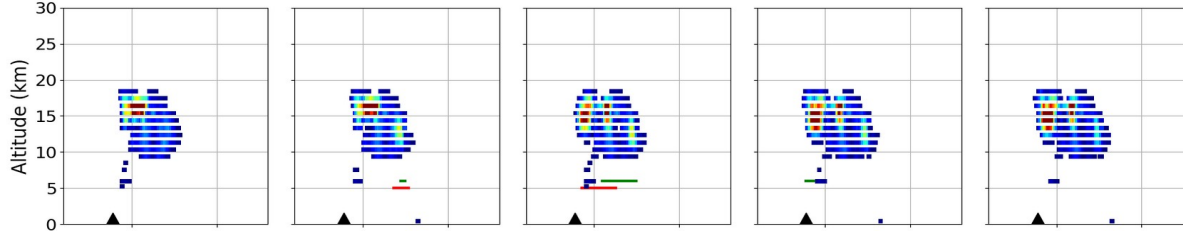
Using a smaller correlation reduces the modeled total columns.

IASI assimilation – 11th April 2021 – 13,5°N

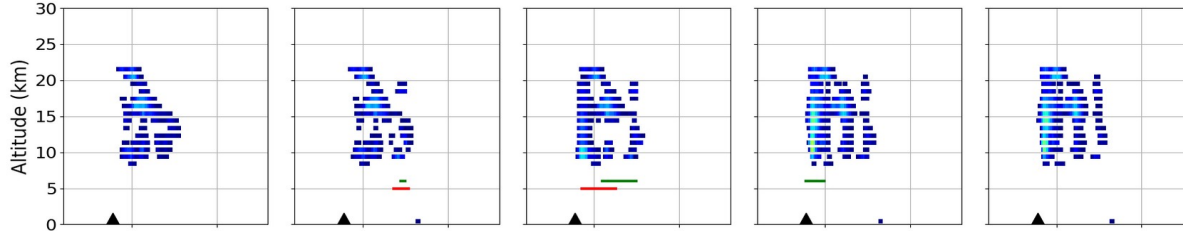
IASI_2



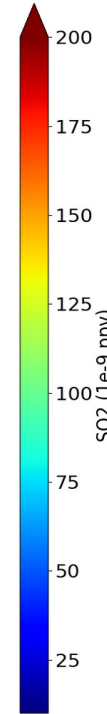
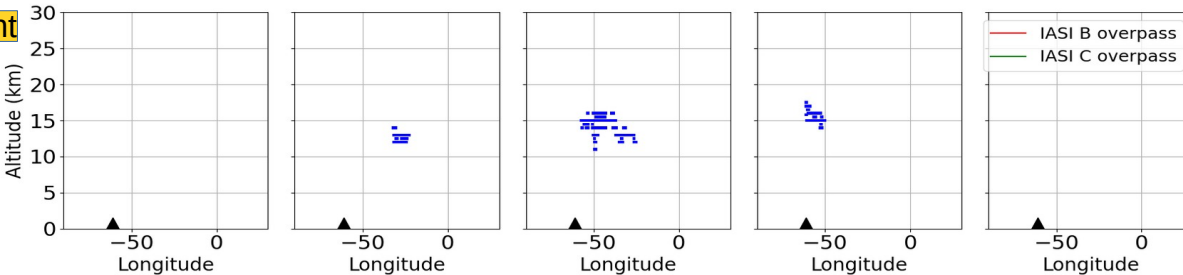
IASI_1



IASI_init



IASI_height



- Plume representation seems to be more realistic by using height information.

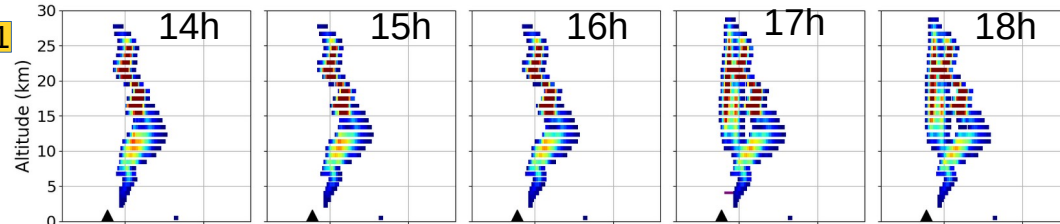
- Reducing correlations in our assimilation gives a less extended plume.

MOCAGE for TROPOMI/TROPOMI_LH assimilation

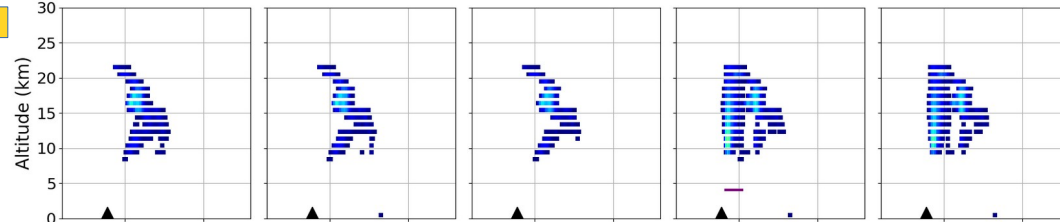
Simulation	Method	B matrix	Horizontal correlation	Vertical correlation
TROPOMI_init	Previous method	1e-8 ppv between 9 and 21km	1°	1 level
TROPOMI_LH1	New method. Partial columns > 15DU. Bottom and top altitudes are given by TROPOMI_LH product	1e-8 ppv	1°	1 level
TROPOMI_LH2	New method : Selected partial columns > 15DU.	1e-8 ppv	1°	1 level
TROPOMI_LH3	Bottom and top altitudes are given by TROPOMI_LH product	1e-8 ppv	0.5°	0.5 level

TROPOMI LH assimilation – 11th April 2021 – 13,5°N

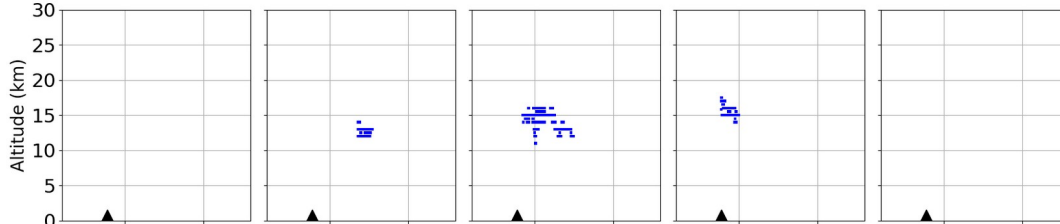
TROPOMI_LH1



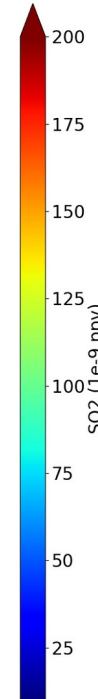
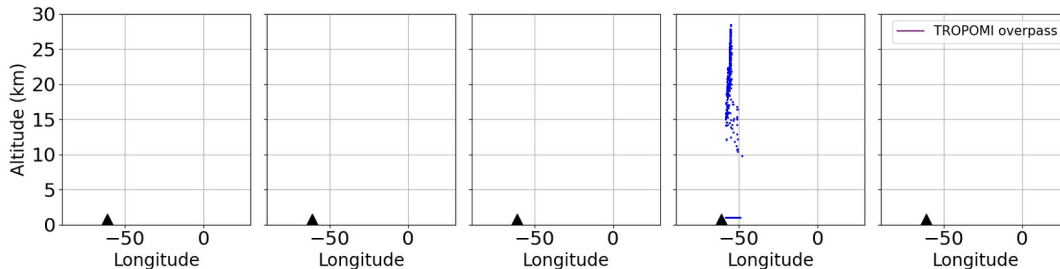
TROPOMI_init



IASI_height



TROPOMI_LH



- Plume is too thick compared to IASI observations but consistent with TROPOMI_LH height values.

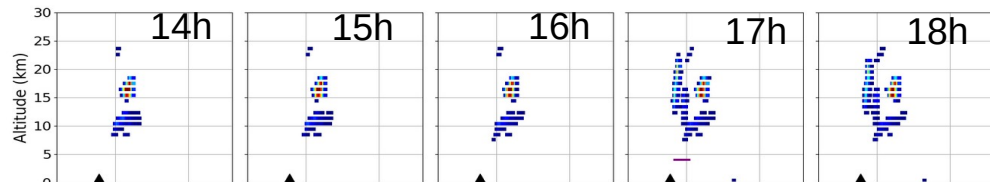
- This strong vertical extent leads to overestimated total columns compared to OMI observations.

- Observations with high or low height are not assimilated.

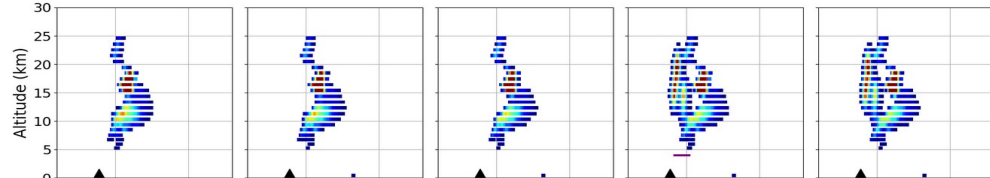
=> TROPOMI_LH2 and TROPOMI_LH3

TROPOMI LH assimilation – 11th April 2021 – 13,5°N

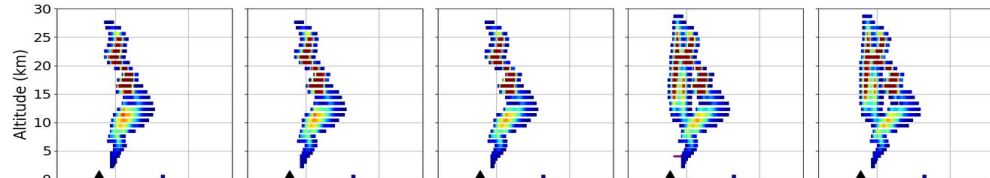
TROPOMI_LH3



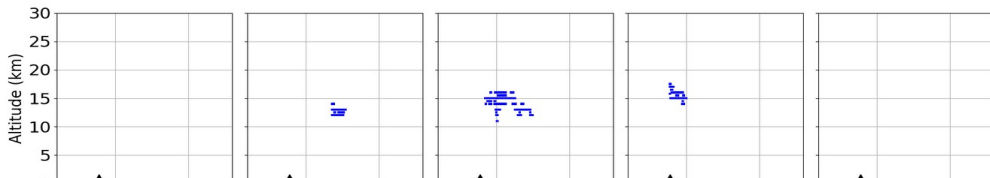
TROPOMI_LH2



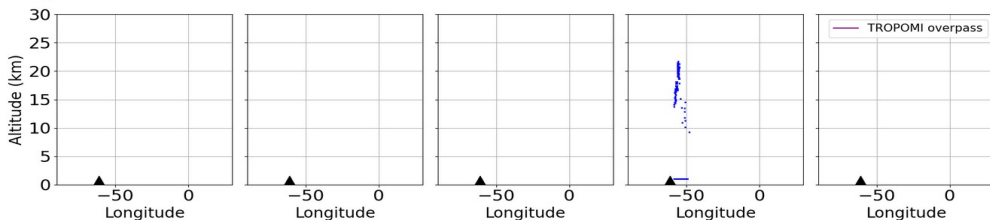
TROPOMI_LH1



IASI_height



TROPOMI_LH

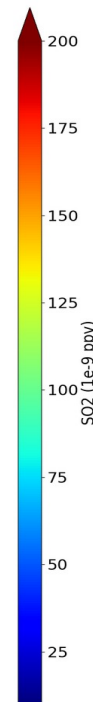


- SO2 plume is less extended on the vertical with the deletion of some observations.

- Strongest modeled concentrations are around the height given by IASI and TROPOMI_LH products.

- Using smaller correlations leads to a thinner plume in MOCAGE.

- Total columns are overestimated and the plume is smaller than plume observed by OMI.



Take home messages

- Height information is very useful to model the SO₂ plume height. Vertical structures are better represented.
- Nevertheless, simulated total columns are often stronger compared to OMI observations.
- Using smaller correlations allow to get smaller total columns in MOCAGE.
- Forecasts initialized by analyses allow to better represent vertical structures.

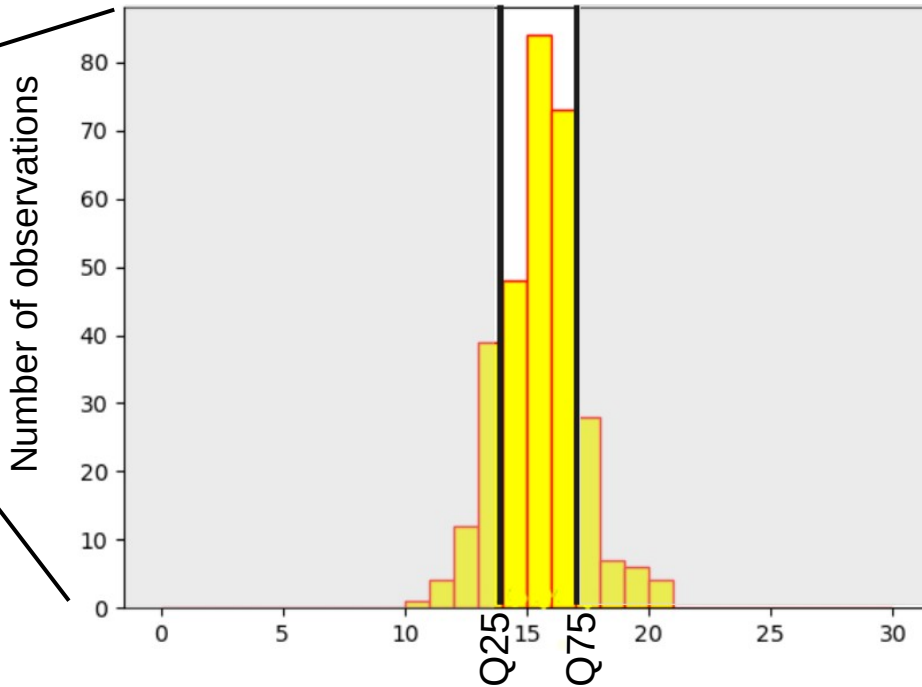
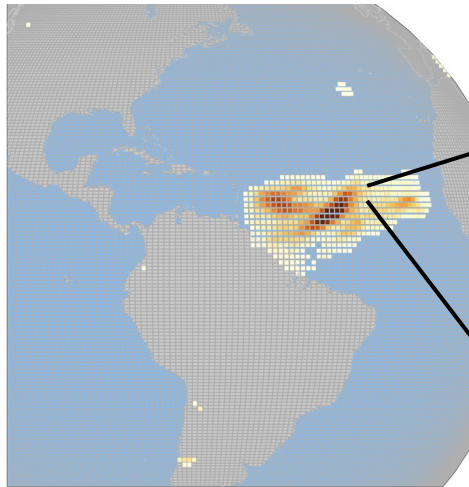
- Work on R and B matrices and on the correlations
- Assimilation of 'no volcanic SO₂ detected' observations
- Combined assimilation of products (TROPOMI+TROPOMI_LH+IASI)
- Assimilation of other instruments



Thank you for your listening

TROPOMI LH assimilation – Observations selection

Example of TROPOMI_LH height distribution in one MOCAGE meshgrid



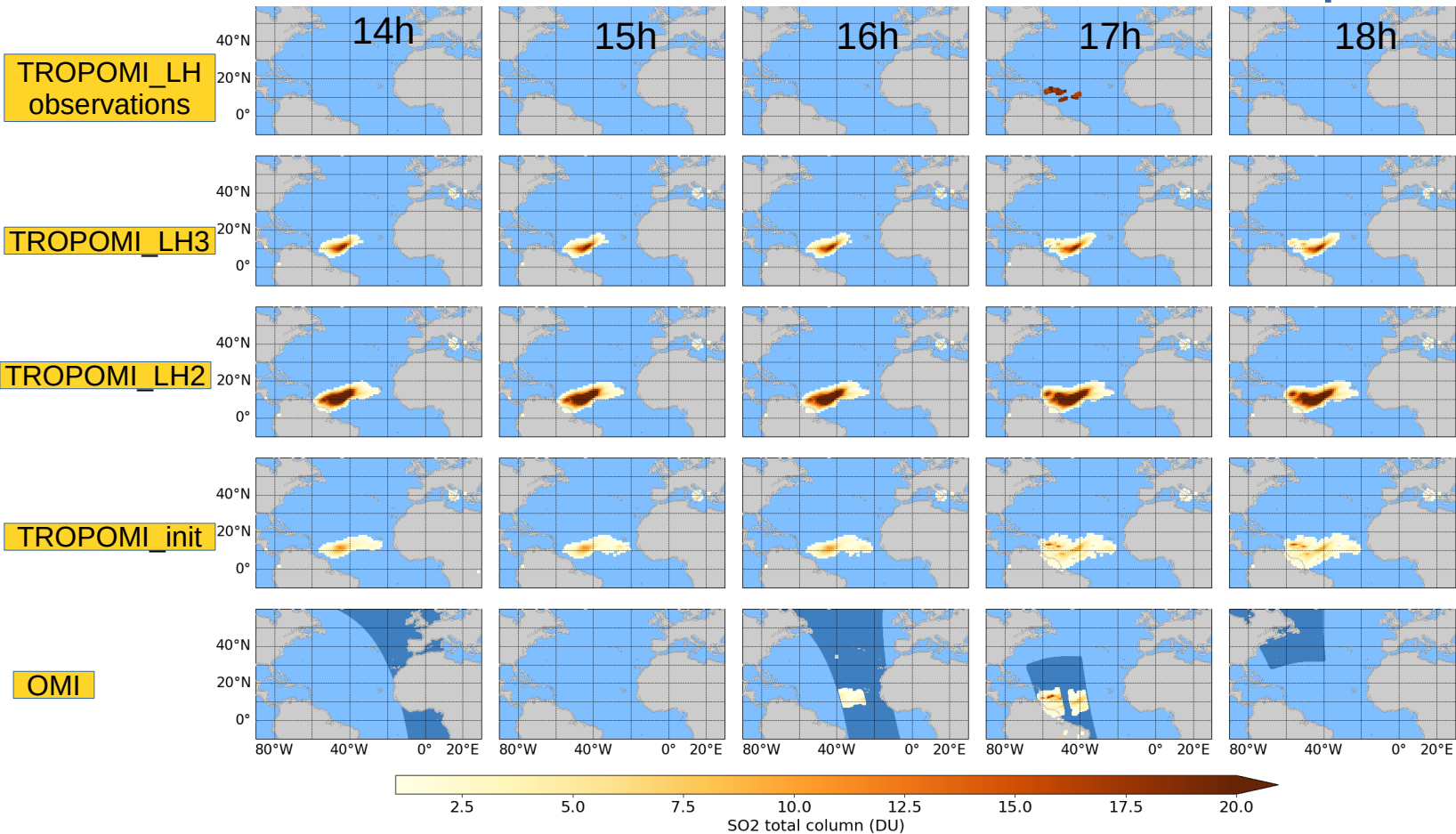
Observations are not assimilated when the plume height is not included between Q25 and Q75.

TROPOMI_LH bottom plume height (km)

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TROPOMI LH assimilation – 11th April 2021



- Compared to OMI, the plume in MOCAGE has smaller shape and it is overestimated.

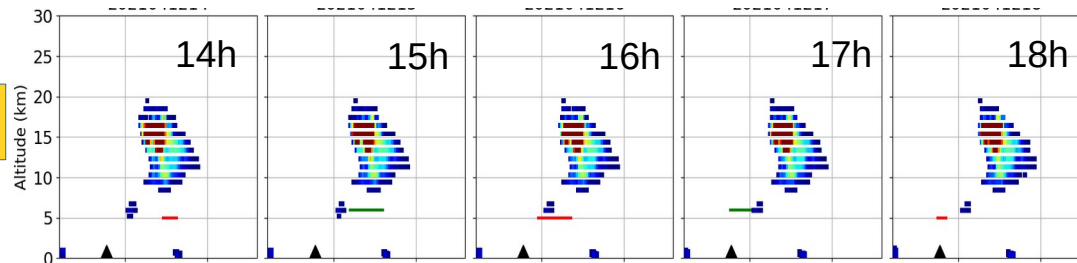
- Reducing correlations allows to get more accurate total columns but the plume is too small.

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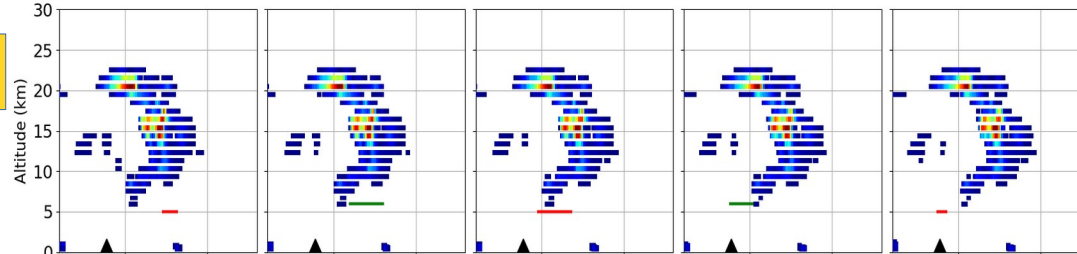


Forecast skills – IASI – 12th April 2021

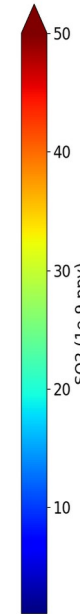
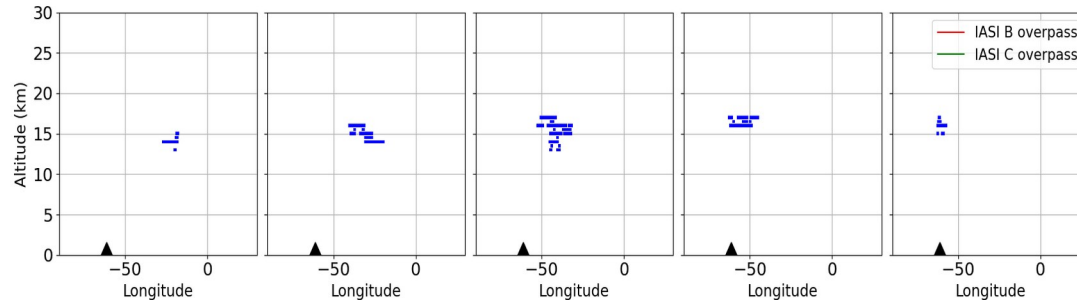
Forecast from IASI_2



Forecast from IASI_init



IASI_height



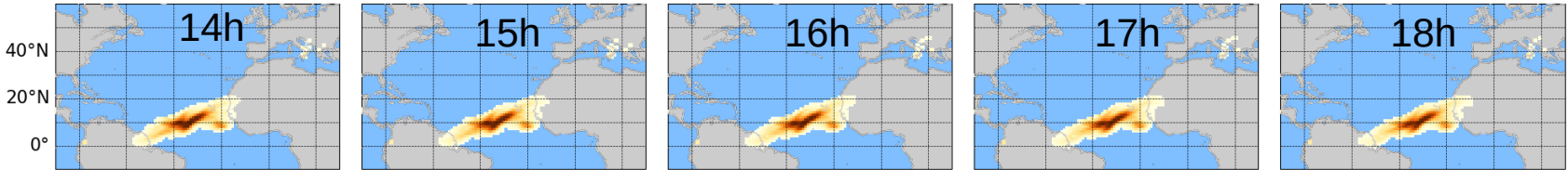
- Forecast are computed using analyses.
Here forecast valid on 12th April are computed from the 11th April analyses. This is a 14 to 18 forecast range.

- Strong SO₂ concentration is simulated around the observed plume height thanks to the IASI height information.

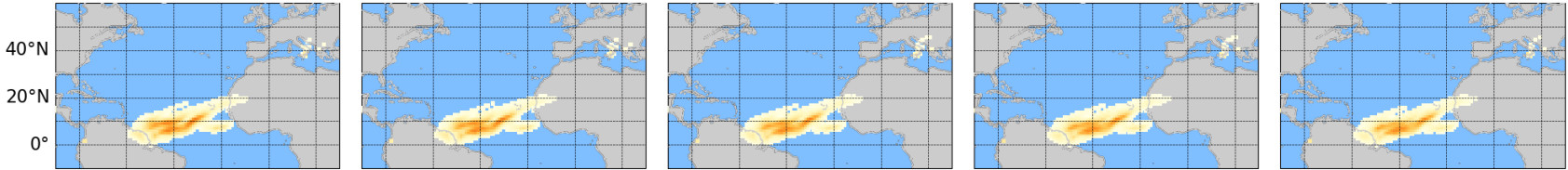
- Plume is less extended and lower than the plume observed by OMI.

Forecast skills – IASI – 12th April 2021

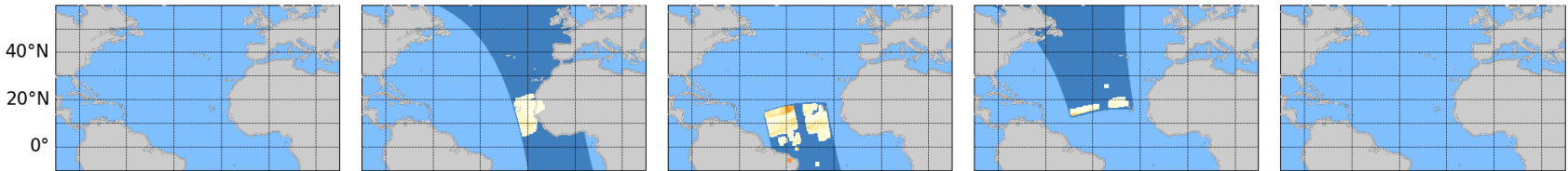
Forecast from IASI_2



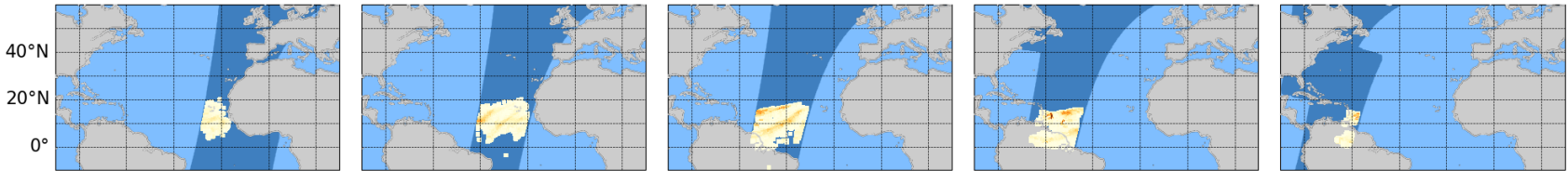
Forecast from IASI_init



OMI



IASI

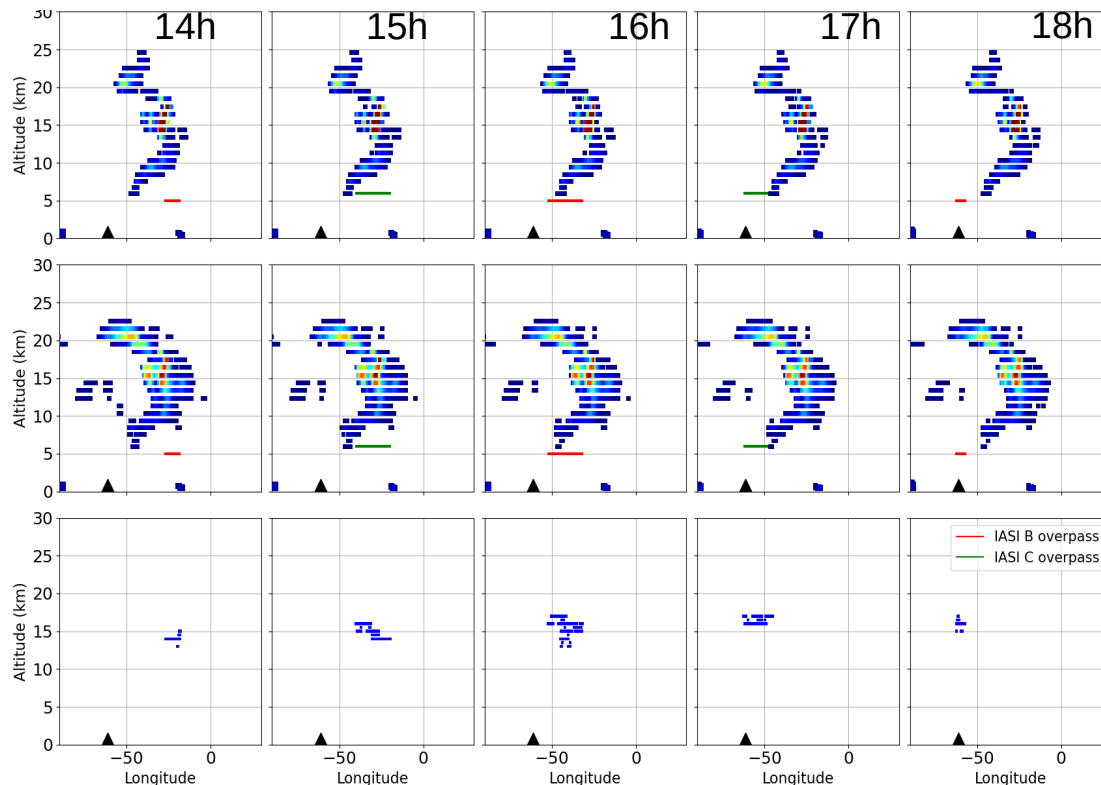


Forecast skills - TROPOMI – 12th April 2021

Forecast from TROPOMI_LH3

Forecast from TROPOMI_init

IASI_height

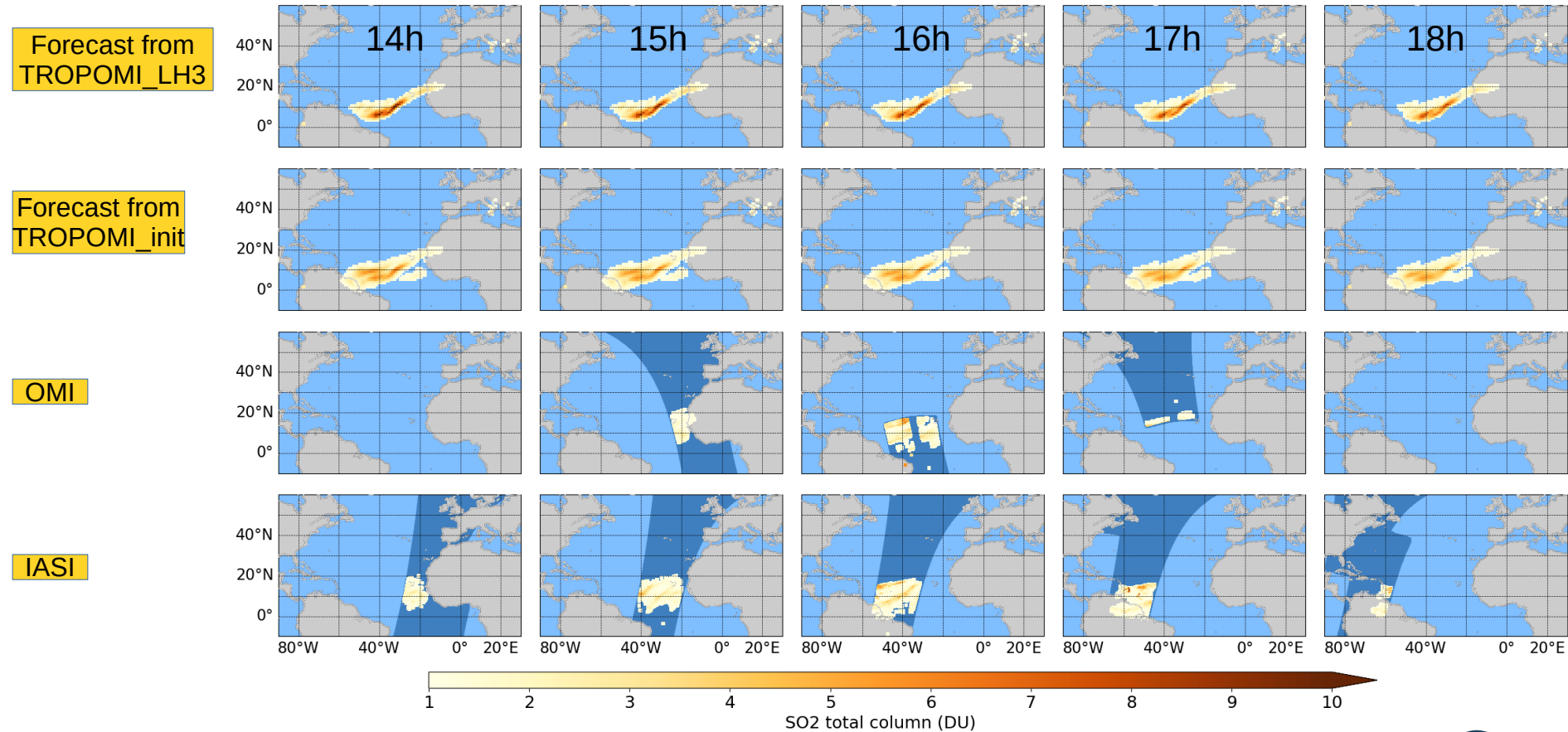


- Forecast valid on 12th April from full 11th April analyses

- Strong SO₂ concentration is simulated around the IASI plume height.

- The shape of the plume is similar to the observed one. Modelized total columns are often stronger than the OMI observations.

Forecast skills – TROPOMI – 12th April 2021



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