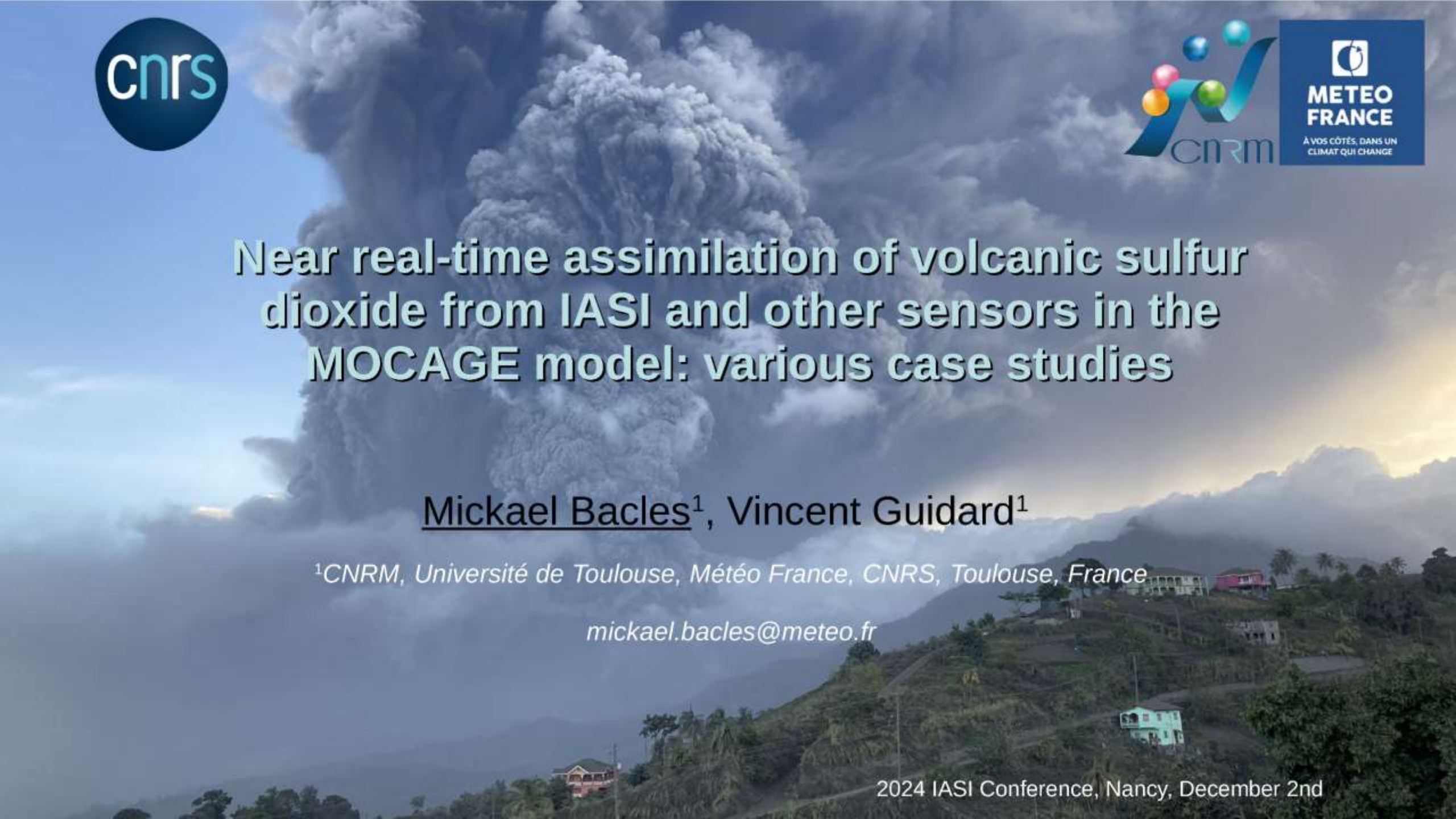


Near real-time assimilation of volcanic sulfur dioxide from IASI and other sensors in the MOCAGE model: various case studies

Mickael Bacles[1], Vincent Guidard[1]

[1]*CNRM, Université de Toulouse, Météo France, CNRS, Toulouse, France*

mickael.bacles@meteo.fr

2024 IASI Conference, Nancy, December 2nd

Chemistry Transport Model MOCAGE at Météo-France

- Two domains :
  - 0.5° global domain forced by ARPEGE NWP
  - 0.1° regional domain forced by IFS NWP

- 60 vertical levels from the ground to 0.1 hPa :
  - 7 layers in the planetary boundary layer
  - 20 layers in troposphere
  - 20 layers in stratosphere
  - 13 layers in upper stratosphere

Data assimilation in MOCAGE

Hourly 3D-VAR algorithm

Global domain

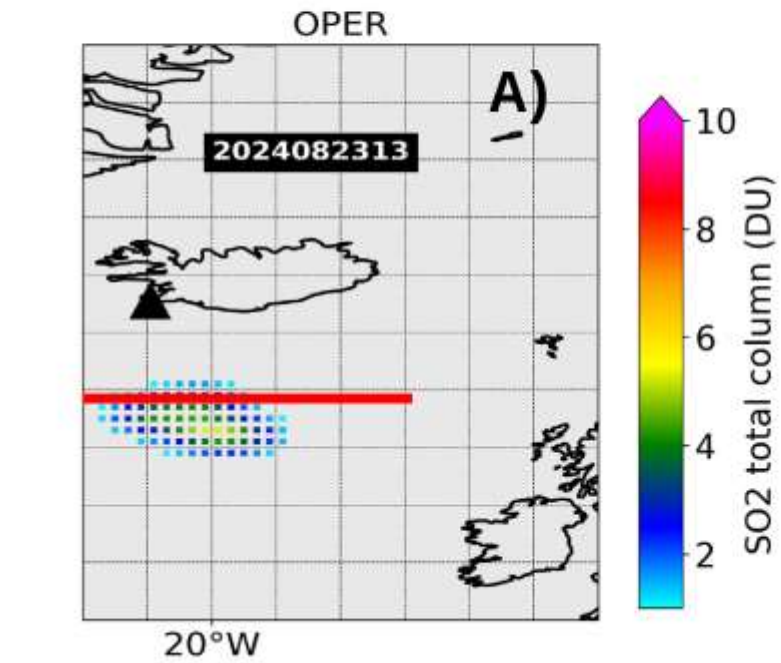
- Aerosol Optical Depth (AOD) - level 2
  - MODIS : Aqua + Terra
  - VIIRS : S-NPP + NOAA-20 + NOAA-21
- O_3 et CO – level 1 product
  - IASI : Metop-B + Metop-C
  - CRIS : NOAA-20 + NOAA-21
- **Volcanic SO_2 total columns – level 2**
  - **TROPOMI without height information**

Regional domain

- Ground based attenuated backscatter from lidars and ceilometers
  - European network E-PROFILE
- **Volcanic SO_2 total columns – level 2**
  - **TROPOMI without height information**

TROPOMI data assimilation in operation

SO_2 plume is constrained between 3 and 10 km. Averaging kernels are used.
All observations above 1 DU are assimilated in the regional domain.
In the global domain, the maximum of the observations by meshgrid is assimilated if it is stronger than 3 DU.



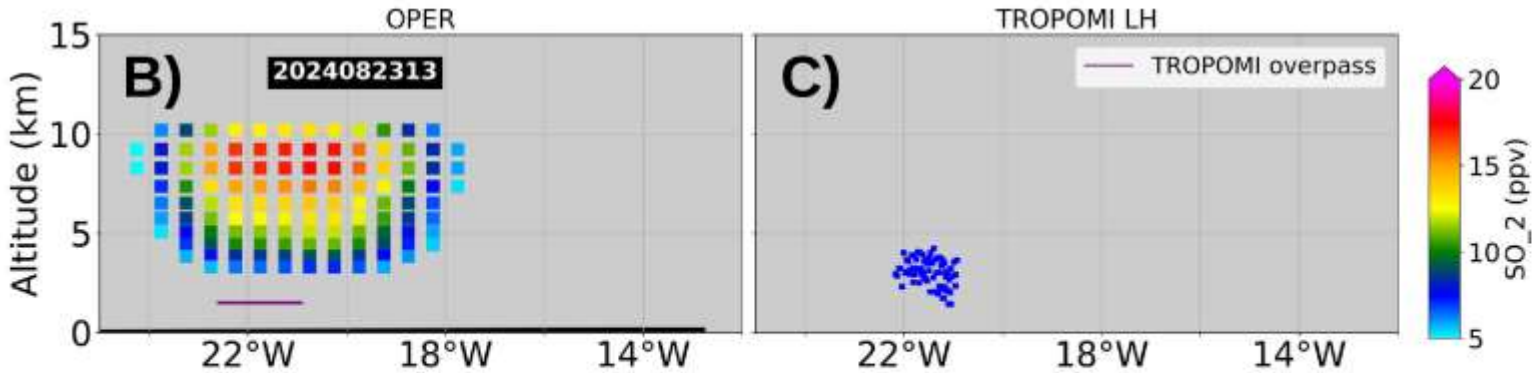


Figure : *On 23rd August 2024 at 13 UTC :*
A) analysed SO_2 total column in MOCAGE
B) SO_2 concentration at 58.75°N in MOCAGE
C) SO_2 plume altitude given by TROPOMI Layer Height product between 58.25 and 59.25°N

Altitudes of the plume seem to be wrong in the model

➡ **Objectives :**
Use height information from IASI and TROPOMI Layer Height to improve the representation of the plume in MOCAGE

SO_2 data assimilation with height information

TROPOMI Layer Height : Information about height for observations > 20 DU.
Data available on dataspace.copernicus website.
Every total columns are assimilated but we use the median of the altitude by meshgrid.

IASI : Information about height for all observations.
Data available on aeris-data website.
Every total columns and altitude are used

OMI : Use to compare the MOCAGE analyses to observations.
Data available on NASA website.

3 experiments :

- Tropomi assimilation with operational settings (OPER)
- Tropomi Layer Height assimilation (tropo_lh_assim)
- IASI assimilation (iasi_assim)

The plume is assumed to be **2.5 km thick and SO_2 is between these altitudes**.

Sundhnukagigar eruption from 23rd August 2024

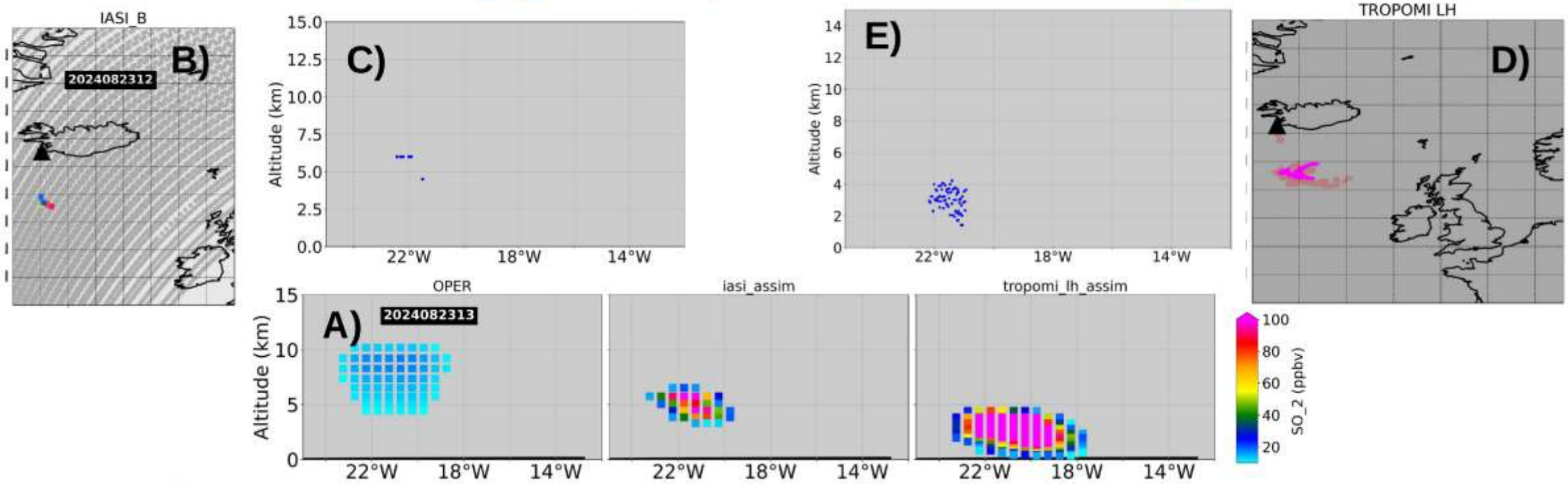


Figure: *A) SO_2 concentration at 58.75°N in MOCAGE on 23rd August at 13 UTC in the global domain*
B) & C) IASI SO_2 total column and diagnosed altitude between 58.25 and 59.25°N at 12 UTC
D) & E) Location of the plume from TROPOMI and TROPOMI LH SO_2 total column and diagnosed altitude between 58.25 and 59.25°N at 13 UTC

- Altitudes diagnosed by IASI and TROPOMI LH are different.
- SO_2 can be hidden by water vapor with IASI and also by clouds for both instruments.
- SO_2 data assimilation with height information allows to have a plume at the same altitudes given by observations.

Sundhnukagigar eruption from 23rd August 2024

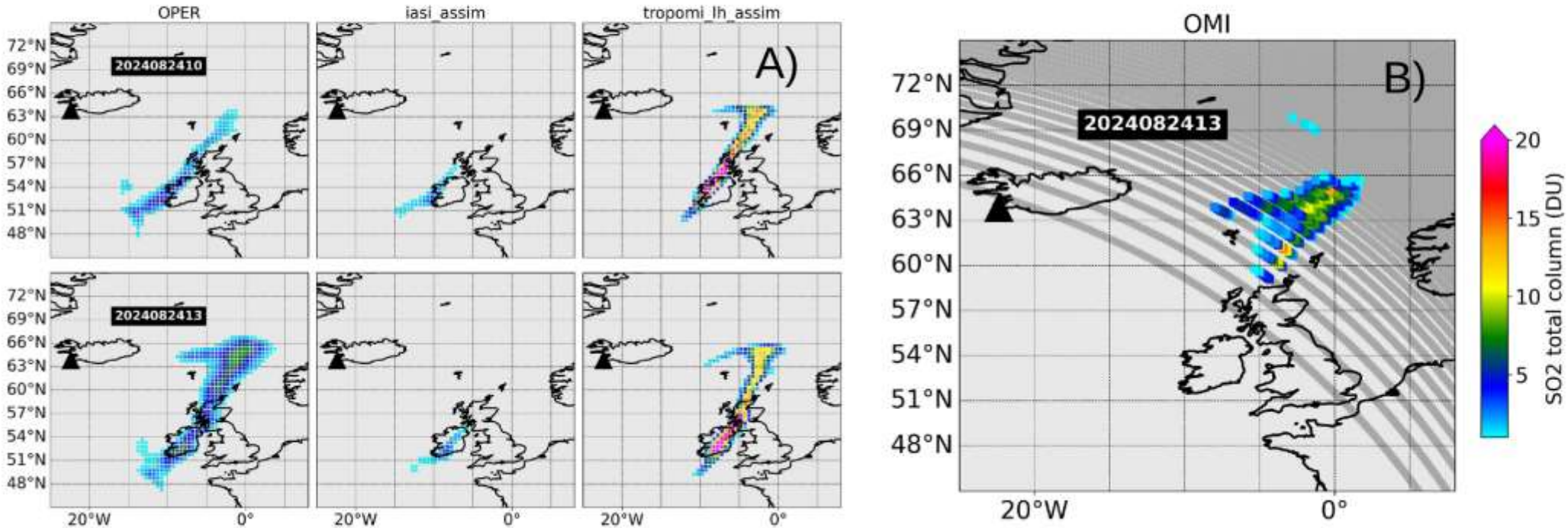


Figure: *A) SO_2 total column in MOCAGE on 24th August at 10 and 13 UTC*
B) SO_2 total column observed by OMI on 24th August at 13 UTC

- No observations from IASI and TROPOMI LH are assimilated since the day before. SO_2 total columns under 20 DU are assimilated at 13 UTC in OPER experiment.
- Assimilation of IASI leads to a too small plume compared to OMI observations.Plume in OPER and tropomi_lh_assim experiments are consistent (in shape) with OMI observations
- SO_2 total columns are too strong with the assimilation of TROPOMI LH.

Etna eruption on 4th August 2024

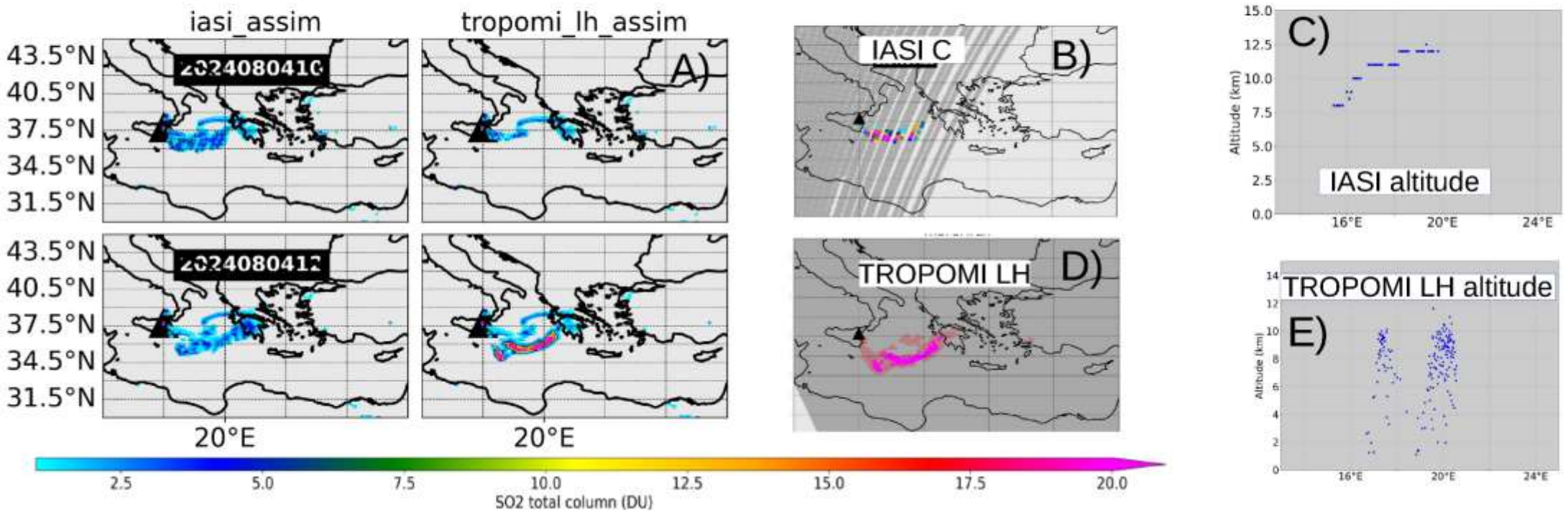


Figure: *A) SO_2 total column in the regional domain of MOCAGE on 4th August at 10 and 12 UTC*
B) & C) SO_2 total columns and altitude of the plume between 35.6 and 36.6°N with IASI C at 10 UTC
D) & E) SO_2 total columns and altitude of the plume between 35.6 and 36.6°N with TROPOMI LH at 12 UTC

- SO_2 total columns are weak with the assimilation of IASI compared to IASI observations.
- Strong SO_2 total columns are simulated thanks to the TROPOMI LH assimilation.
- Important differences between IASI and TROPOMI LH altitudes.

Etna eruption on 4th August 2024

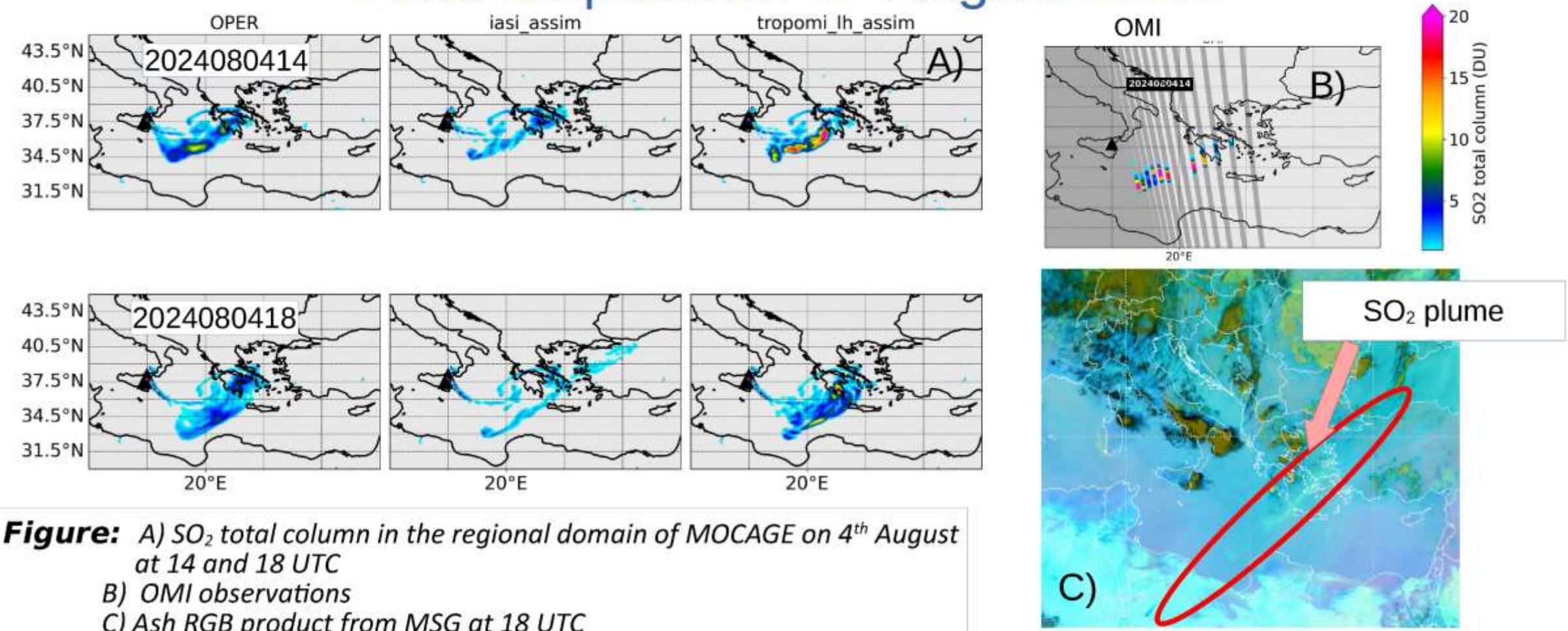


Figure: *A) SO_2 total column in the regional domain of MOCAGE on 4th August at 14 and 18 UTC*
B) OMI observations
C) Ash RGB product from MSG at 18 UTC

- Differences diagnosed height lead to a different shape of the plume. Best representation of the shape of plume with IASI compared to MSG observations.
- Best representation of the SO_2 total columns values with TROPOMI LH.

Popocatépetl volcano in October 2024

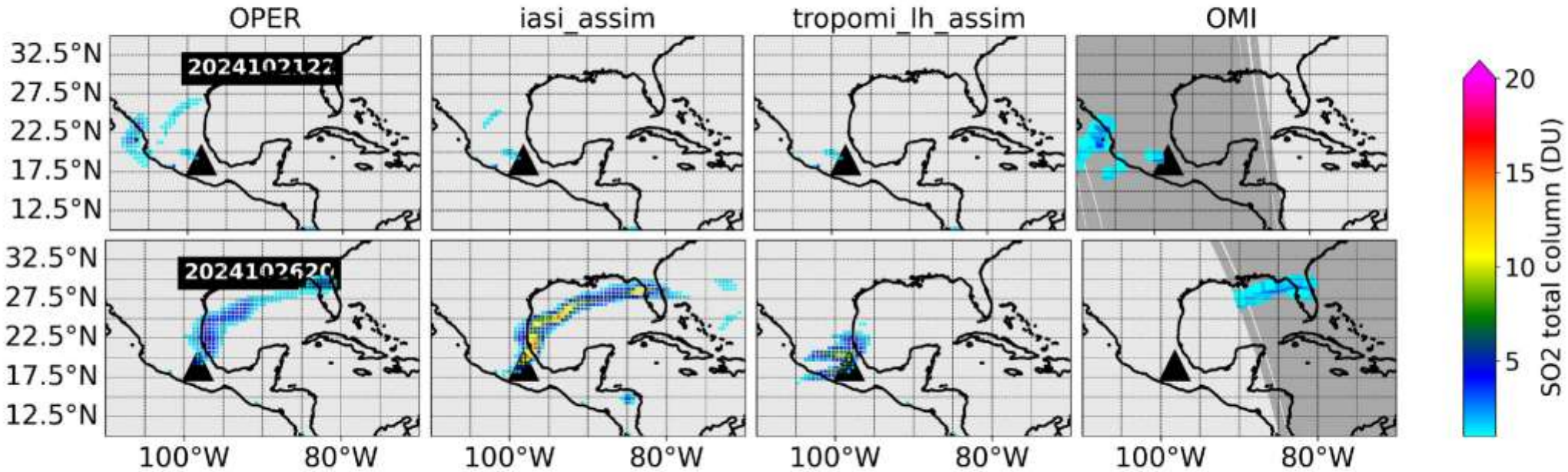


Figure: *SO_2 total column analysed and observed by OMI on 21st October at 22 UTC and on 26th October at 20 UTC*

- No observations from IASI and TROPOMI LH is assimilated before the 21st October but observations from TROPOMI are assimilated. A plume is analysed in OPER experiment in western of Mexico. The plume is observed by OMI.
- Many IASI observations are assimilated from 24th October. TROPOMI LH observations are available near volcano. A larger and stronger plume is simulated thanks to IASI assimilation. This plume is consistent with OMI observations but the total columns are too strong.

Popocatépetl volcano in October 2024

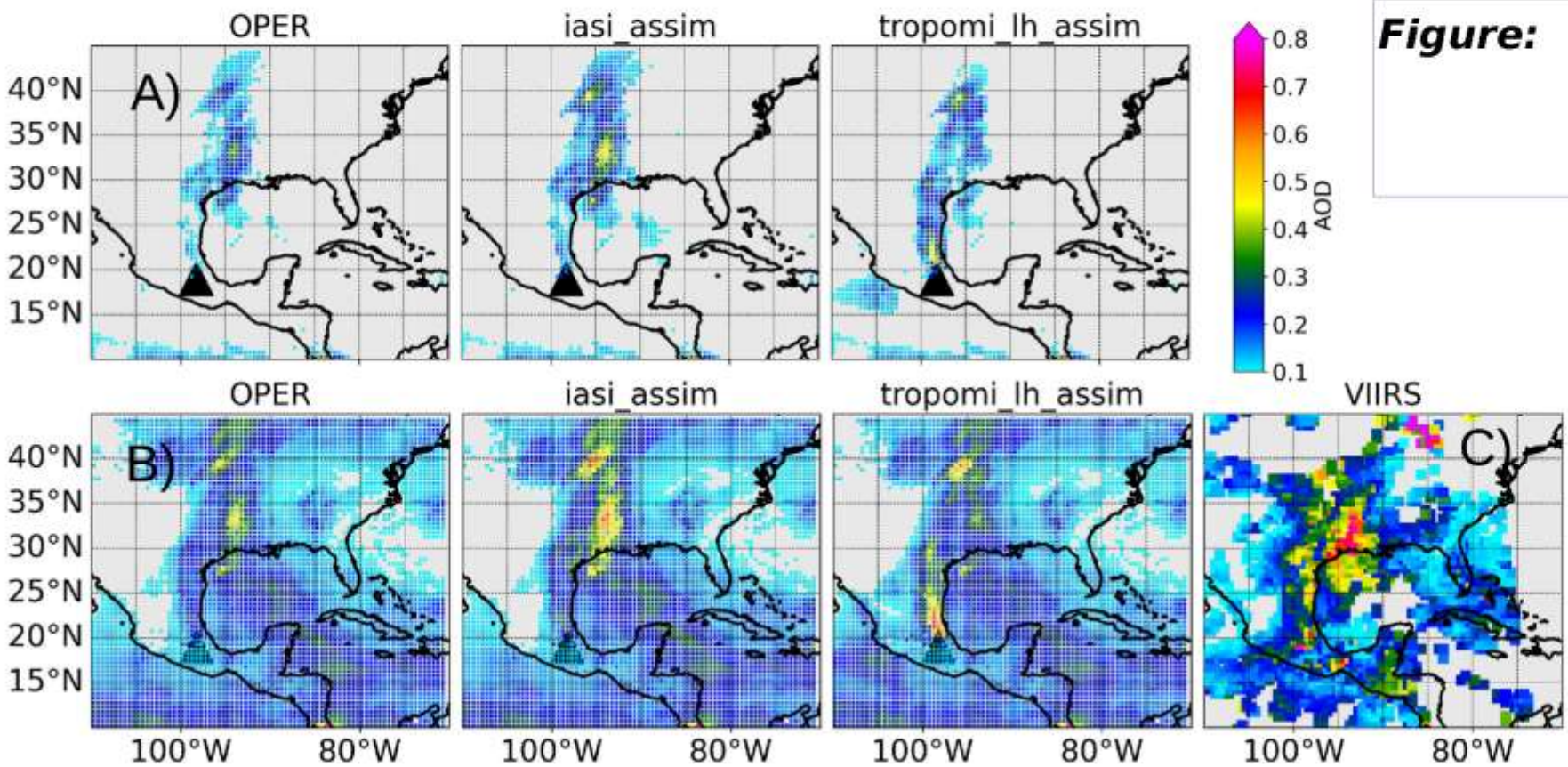


Figure: *On 30th October at 20 UTC :*
A) Simulated sulfate AOD
B) Simulated total AOD
C) AOD observed by VIIRS

- Sulfate aerosols are simulated thanks to the SO_2 data assimilation. Sulfate AOD is stronger with IASI assimilation in particular in Texas.
- Simulated AODs from iasi_assim are closer to VIIRS observations in Texas and near volcano in tropomi_lh_assim experiment.

Take home messages

- SO_2 plume is better represented on the vertical in some conditions :
  - IASI : plume is not near the surface/ the plume is not hidden by water vapor
  - TROPOMI LH : total columns are stronger than 20 DU but the range of altitudes given by TROPOMI LH can be large.

- IASI and TROPOMI LH can be complementary but information about height are different. How to jointly assimilate these instruments ?

- Use of the product developped by BIRA IASB allowing to know the plume altitude when TROPOMI total columns are stronger than 5DU. → More observations with height information

- Correct the plume shape by using the no SO_2 detection flag of TROPOMI.

- Work on R and B matrices and on the correlations.

Thank you for your listening

Mickael Bacles[1] and Vincent Guidard[1]

[1]*CNRM, Université de Toulouse, Météo France, CNRS, Toulouse, France*

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