What IASI can tell us in the aftermath of the Hunga Tonga exceptional eruption

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SO2 volcanic plumes - IASI/Metop

Introduction

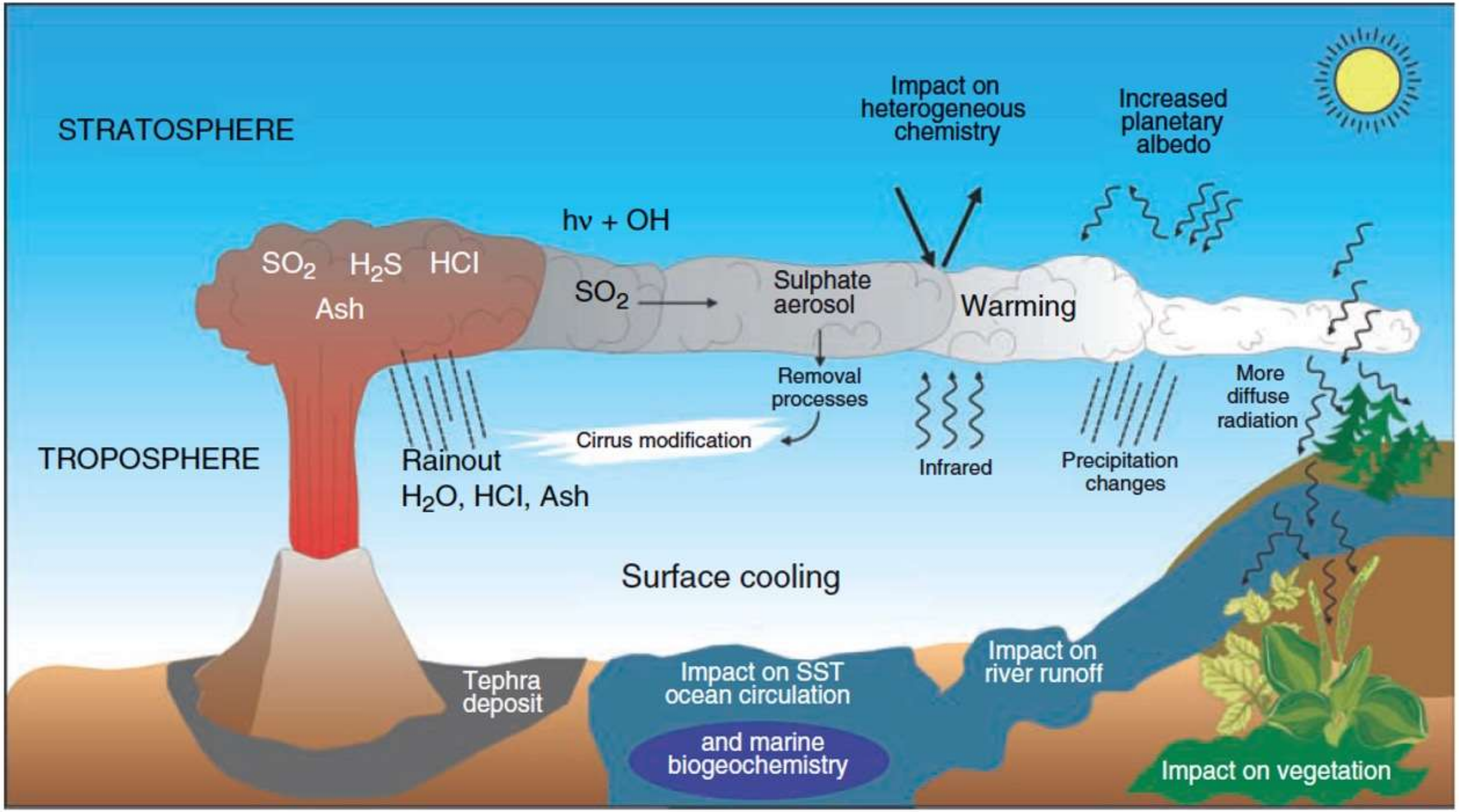


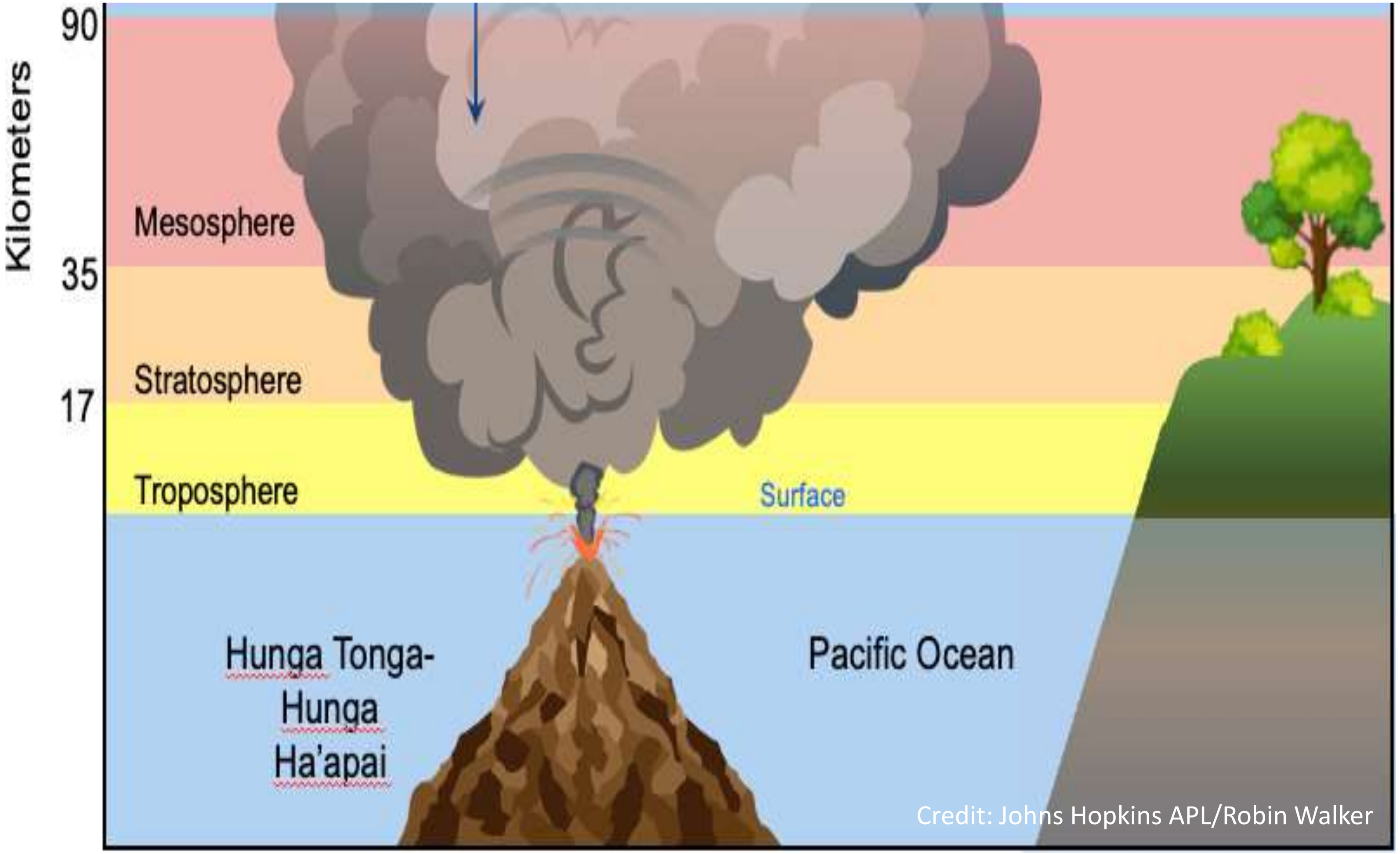
***Figure 1**: Schematic diagram illustrating influences from volcanic aerosol on stratospheric chemistry and climate (from Timmreck, 2012 WIREs Clim Change 2012, 3:545–564. https://doi.org/10.1002/wcc.192)*

Day 1 : Eruption of Hunga Tonga, on January 14 2021 (04:20 local time)

A NASA satellite captured the explosive eruption of Hunga Tonga–Hunga Ha'apai in the South Pacific. Credit: Joshua Stevens/NASA Earth Observatory, using GOES-17 imagery courtesy of NOAA and NESDIS

Eruption of Hunga Tonga, on January 14 2021 (04:20 local time)

As the volcanic vent was only tens to hundreds of metres below water the seawater did not suppress the blast but was instead flash-boiled and propelled into the atmosphere



Temperatures

SO_2/H_2SO_4

H_2O

Ozone

1-3 days

1-3 months

1-3 years

DAY 1 Honga Tunga

Objet Automated SO2 Alert - Extended version 20220113.214536
De Automated SO2 Alert <daniel.hurtmans@ulb.be>
À Undisclosed recipients:
Date 2022-01-14 00:42

```
Maximum Brightness Temperature difference:
==========================================
Location                 > -177.221 -20.2703
Value                    > 9.30142 K
#Pixels above threshold  > 22

Maximum Partial Column:
=======================
Location                 > -176.498 -19.1573
Value                    > 12.0275 DU at 15 km

#Pixels in plume         > ~47

File     > W_XX-EUMETSAT-Darmstadt,SOUNDING+SATELLITE,METOPC+IA
Link:    > http://cpm-ws4.ulb.ac.be/Alerts/index.php?
NewYear=2022&NewMonth=01&sel_day=13&AlertList=SO2_iasi_20220113
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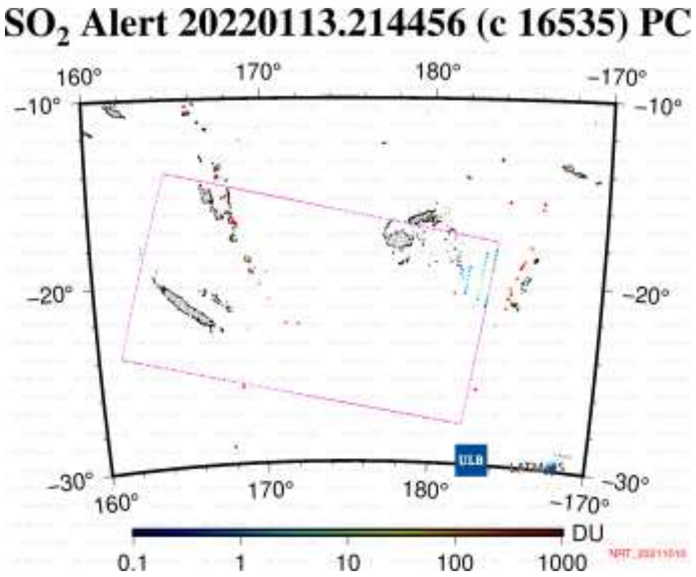
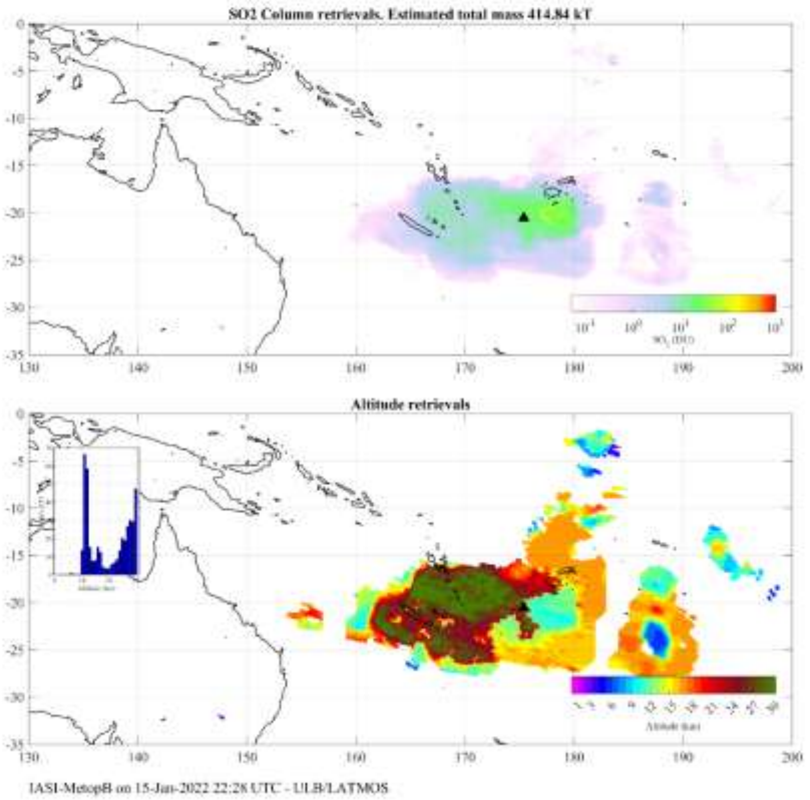
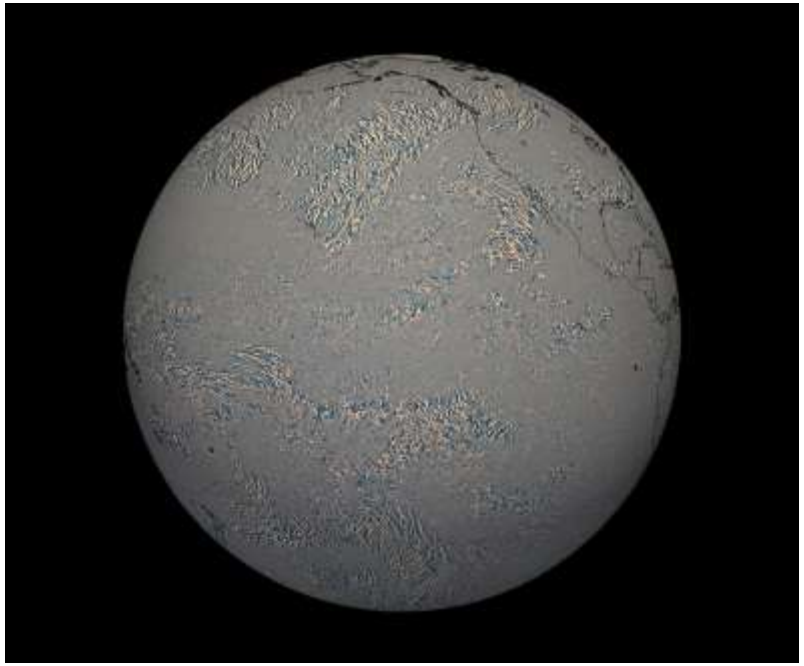
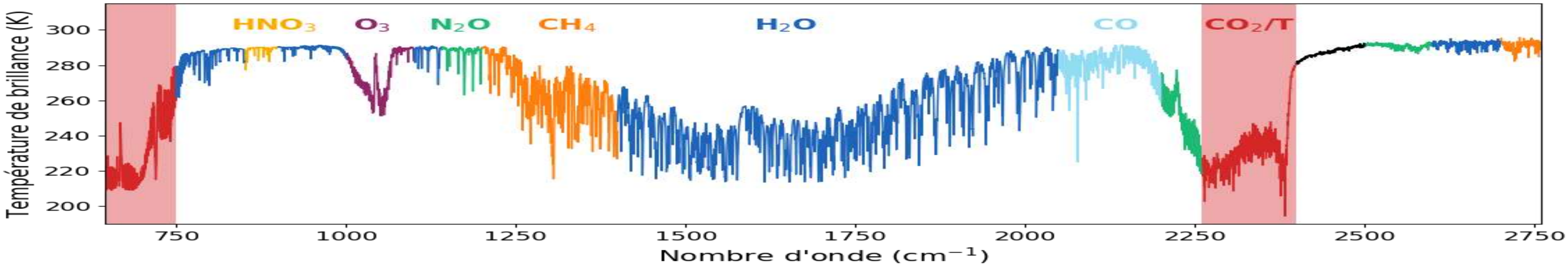


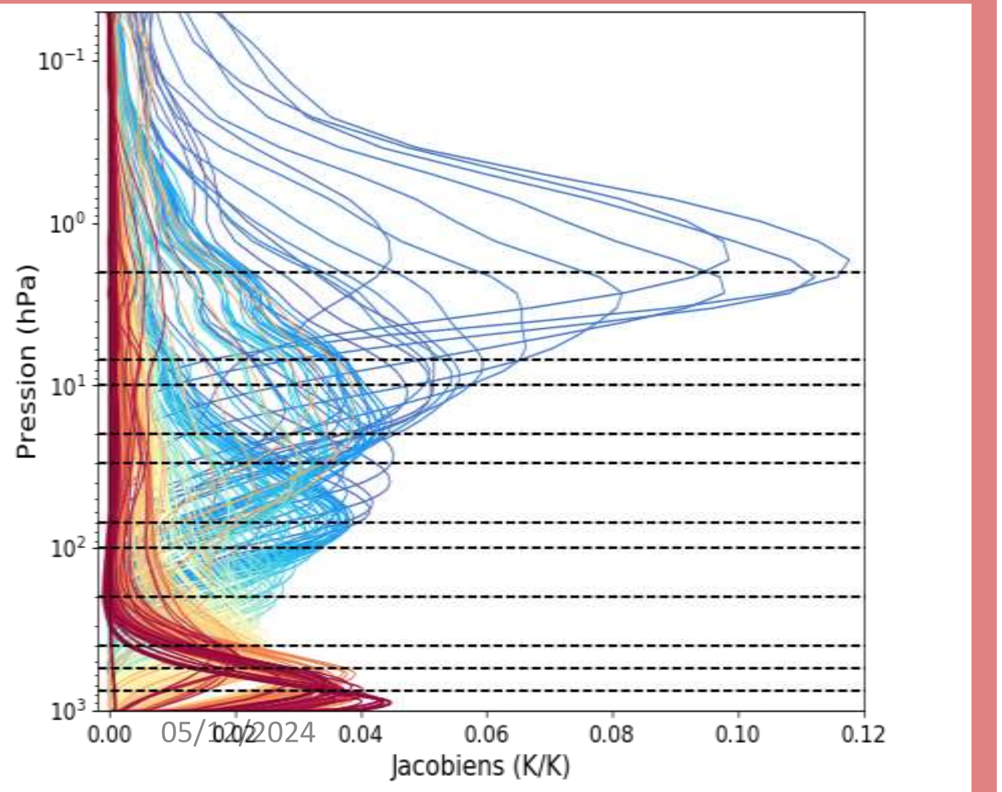




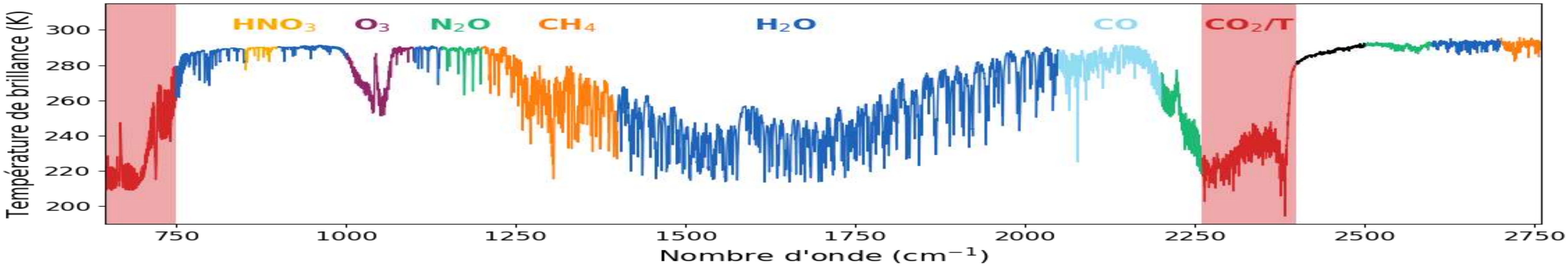
Courtesy Mathew Barlow (University of Massachusetts Lowell). Images taken by NOAA's GOES-West satellite (BT band 13, IR)

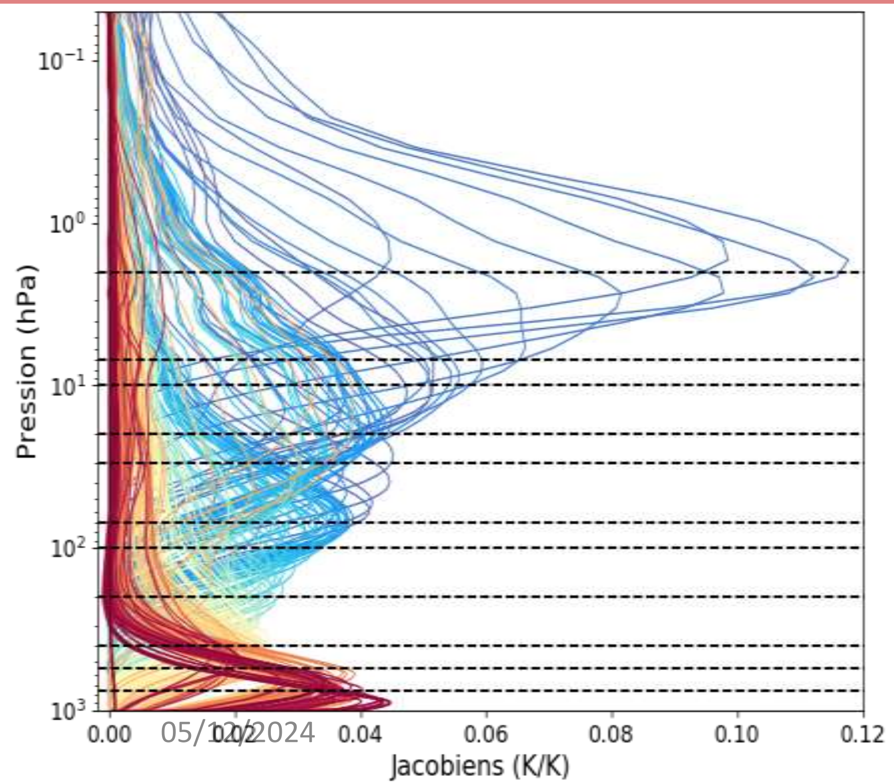
DAY 1 IASI spectra > Temperatures

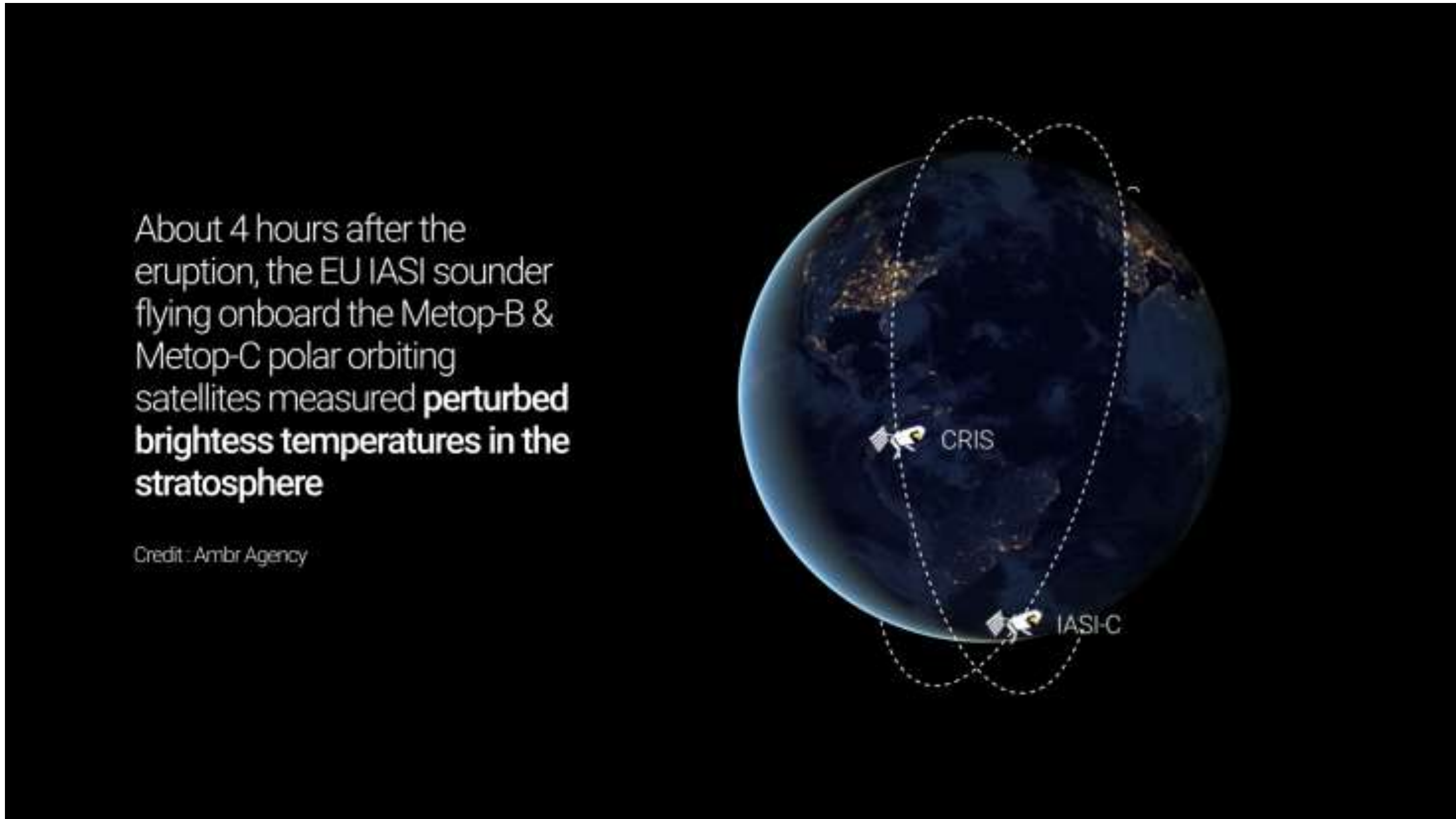




DAY 1 IASI spectra > Temperatures







nature

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Surface-to-space atmospheric waves from Hunga Tonga–Hunga Ha'apai eruption

Corwin J. Wright, Neil P. Hindley, M. Joan Alexander, Mathew Barlow, Lars Hoffmann, Cathryn N. Mitchell, Fred Prata, Marie Bouillon, Justin Carstens, Cathy Clerbaux, Scott M. Osprey, Nick Powell, Cora E. Randall & Jia Yue

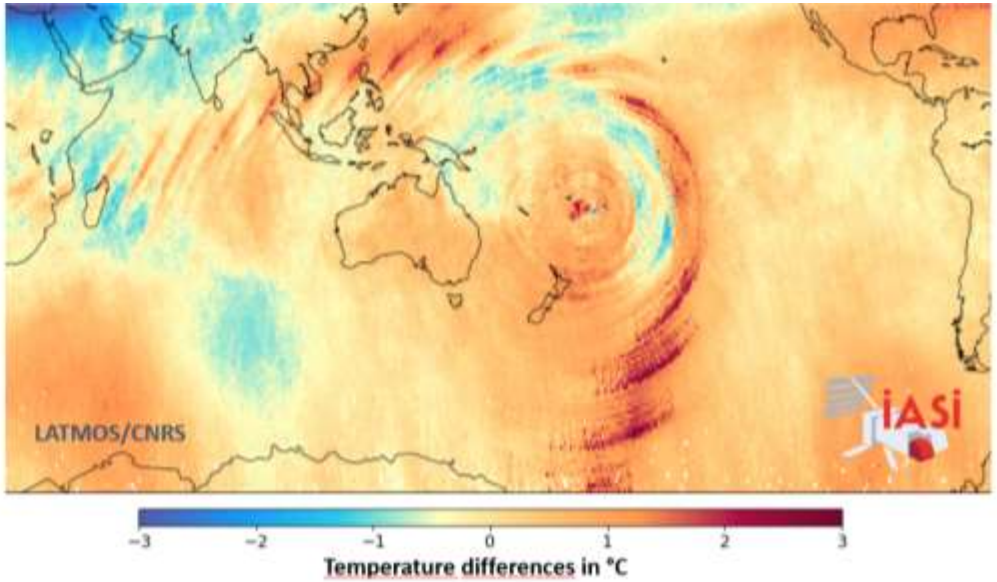
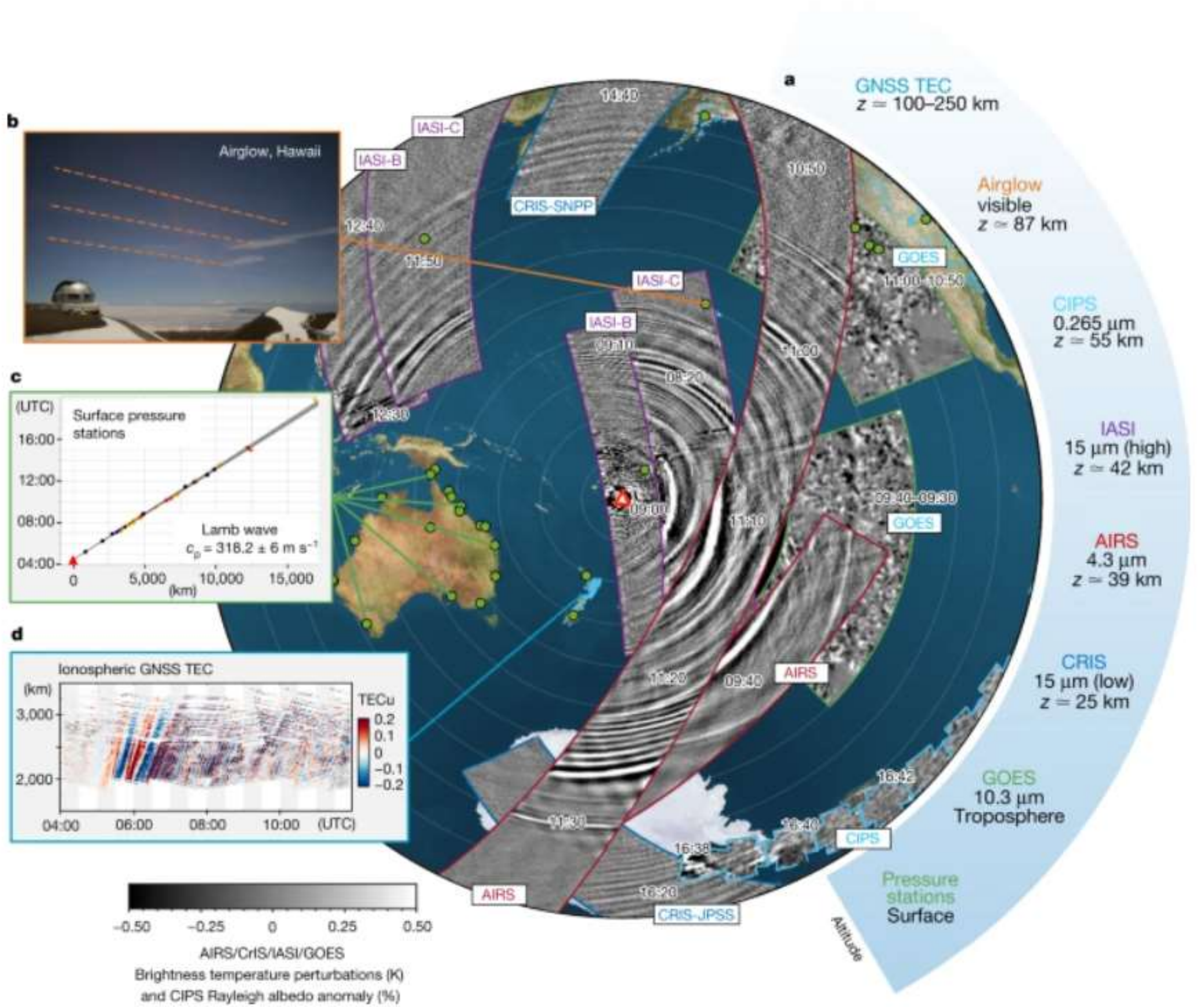
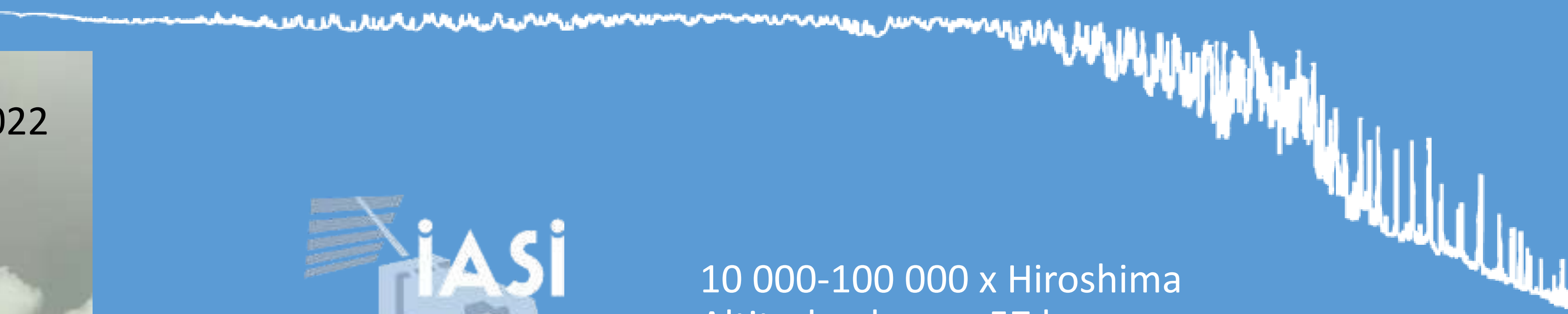
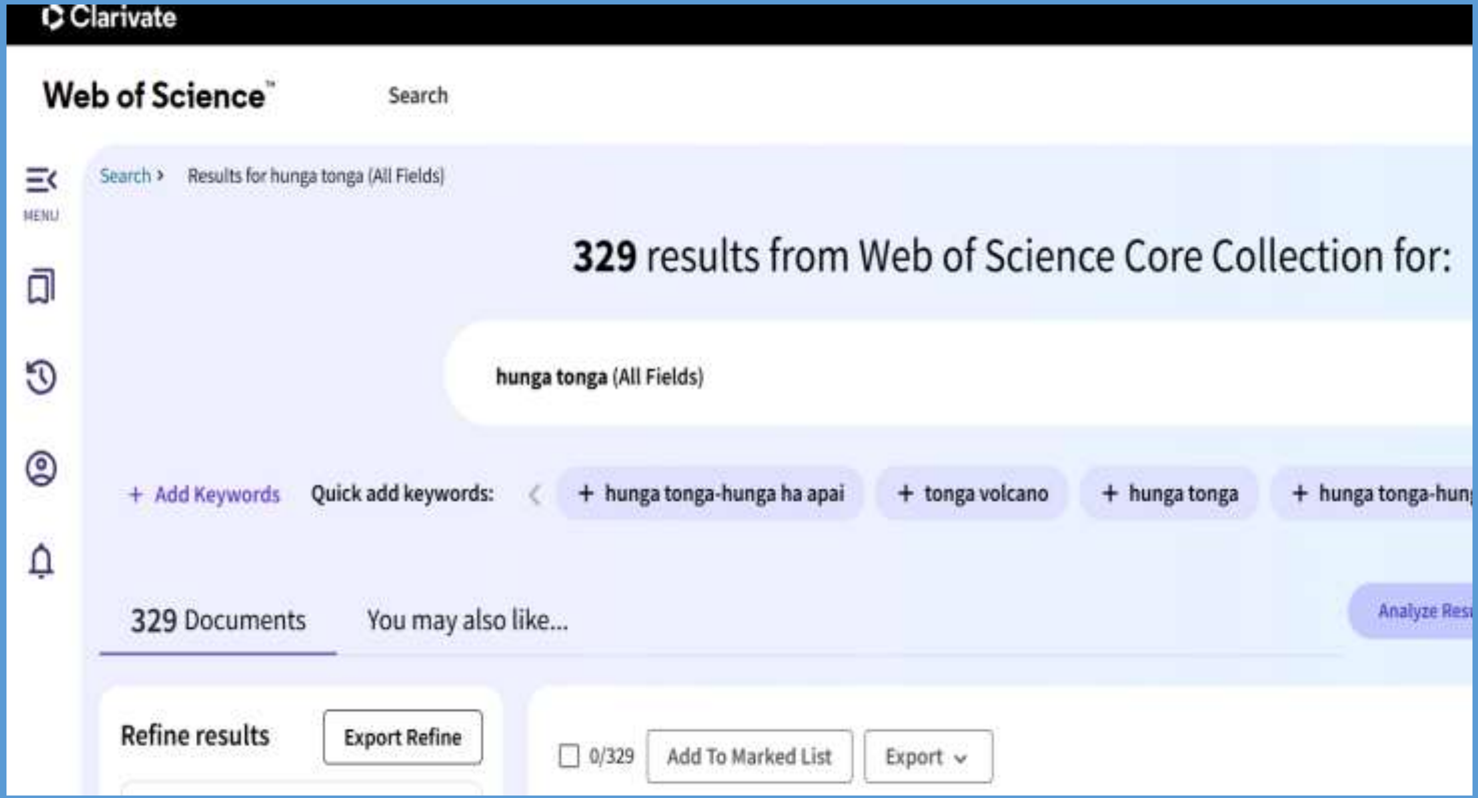


Fig. 2: Initial gravity wave and Lamb wave propagation at all heights.

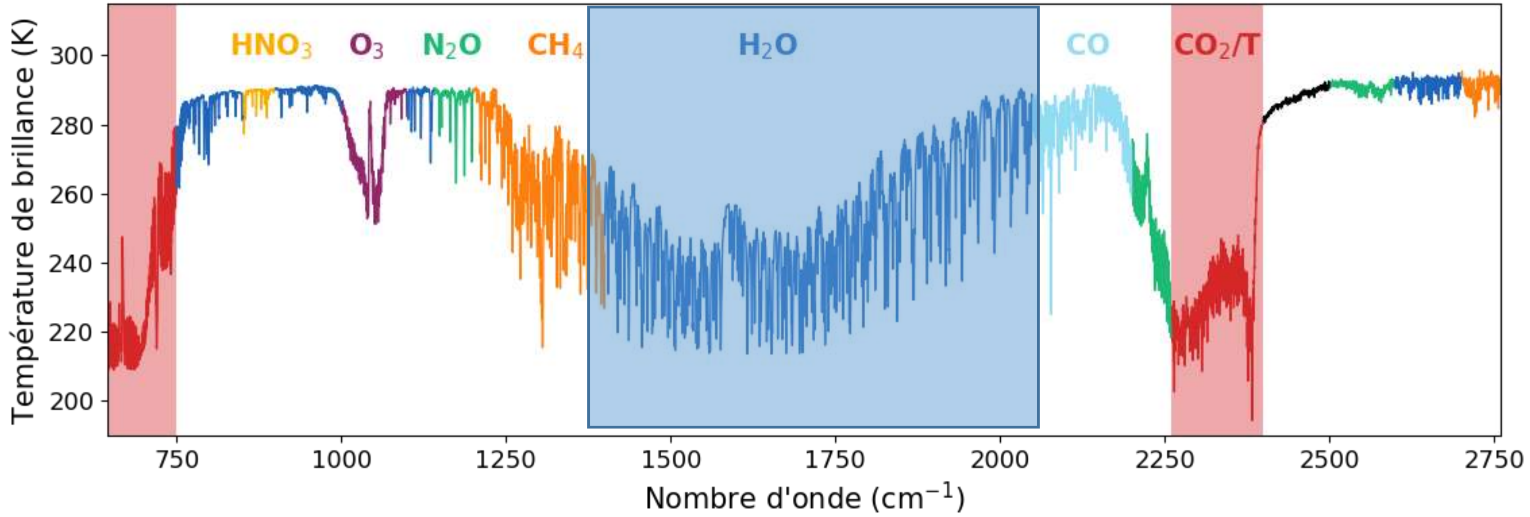


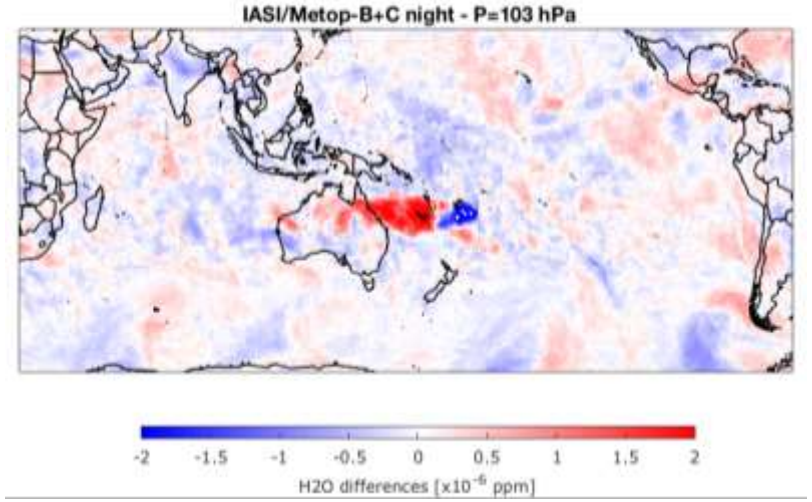


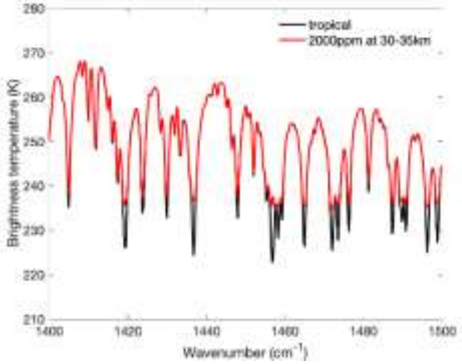
10 000-100 000 x Hiroshima
Altitude plume : 57 km
146 10^6 tons of H_2O, + 10%

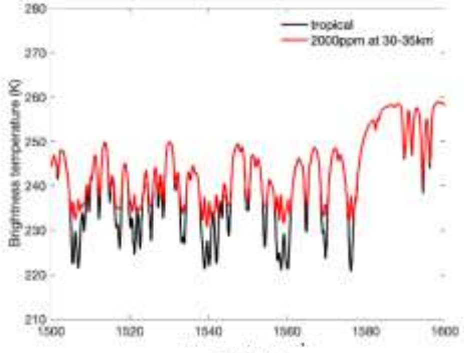


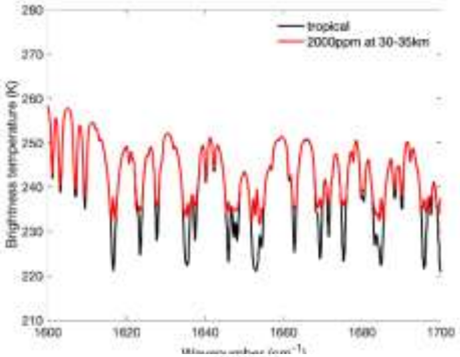
DAY 1 IASI spectra > H_2O

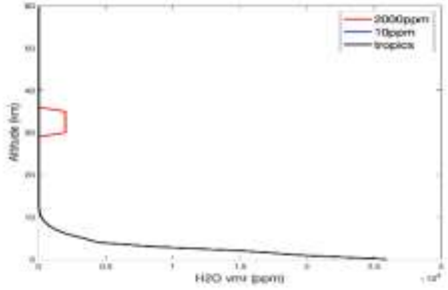




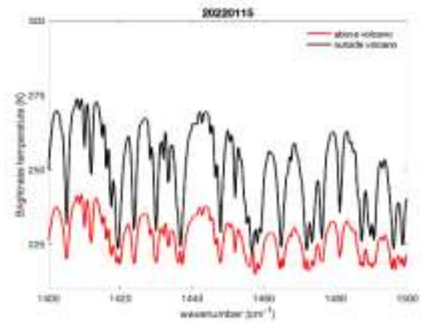


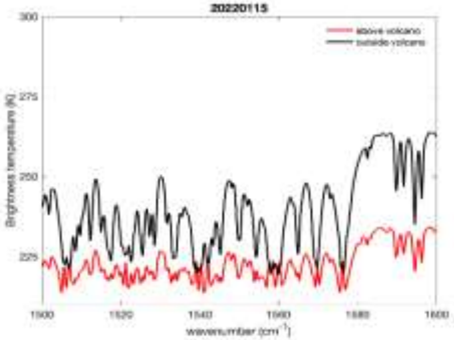


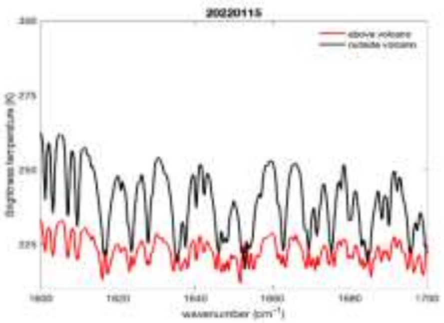


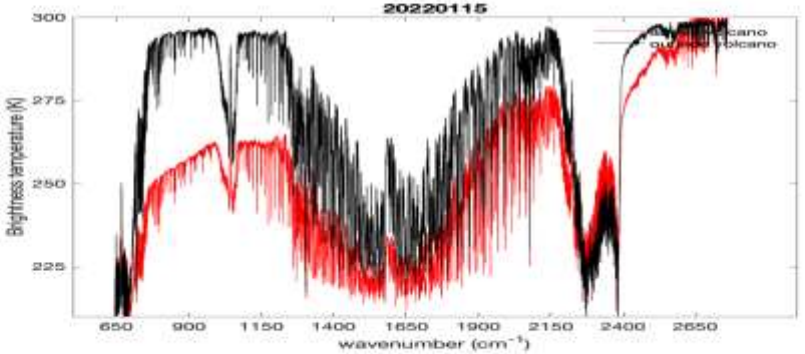


Credit Anne Boynard (LATMOS)

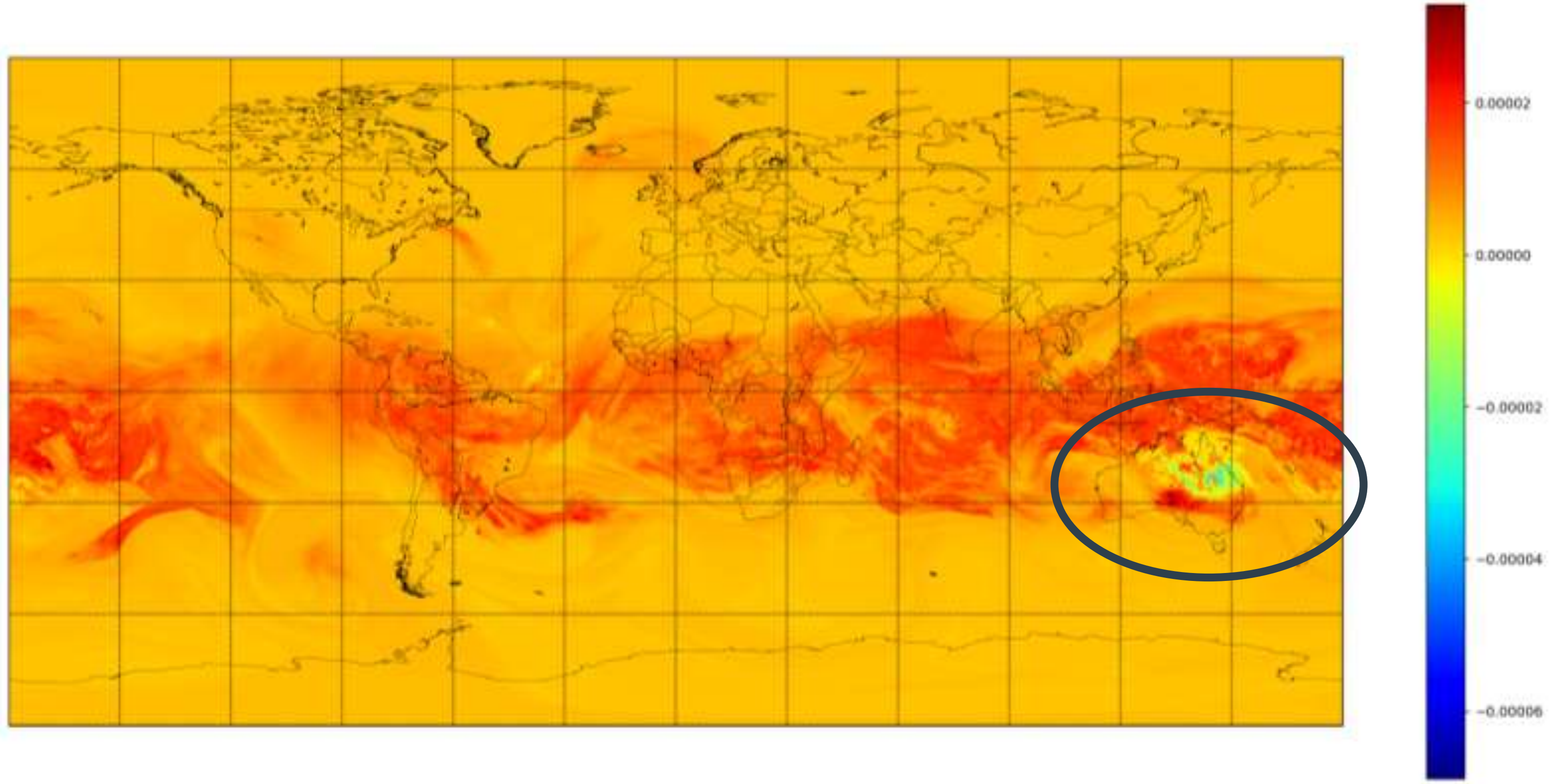


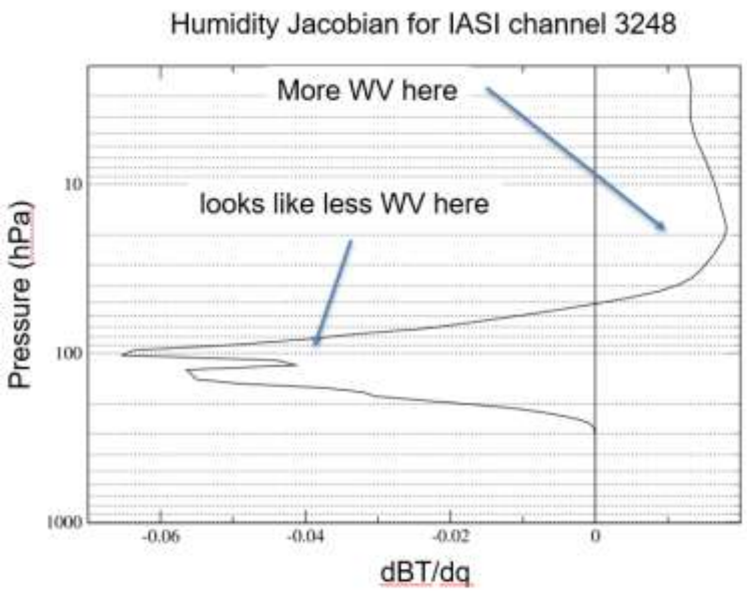






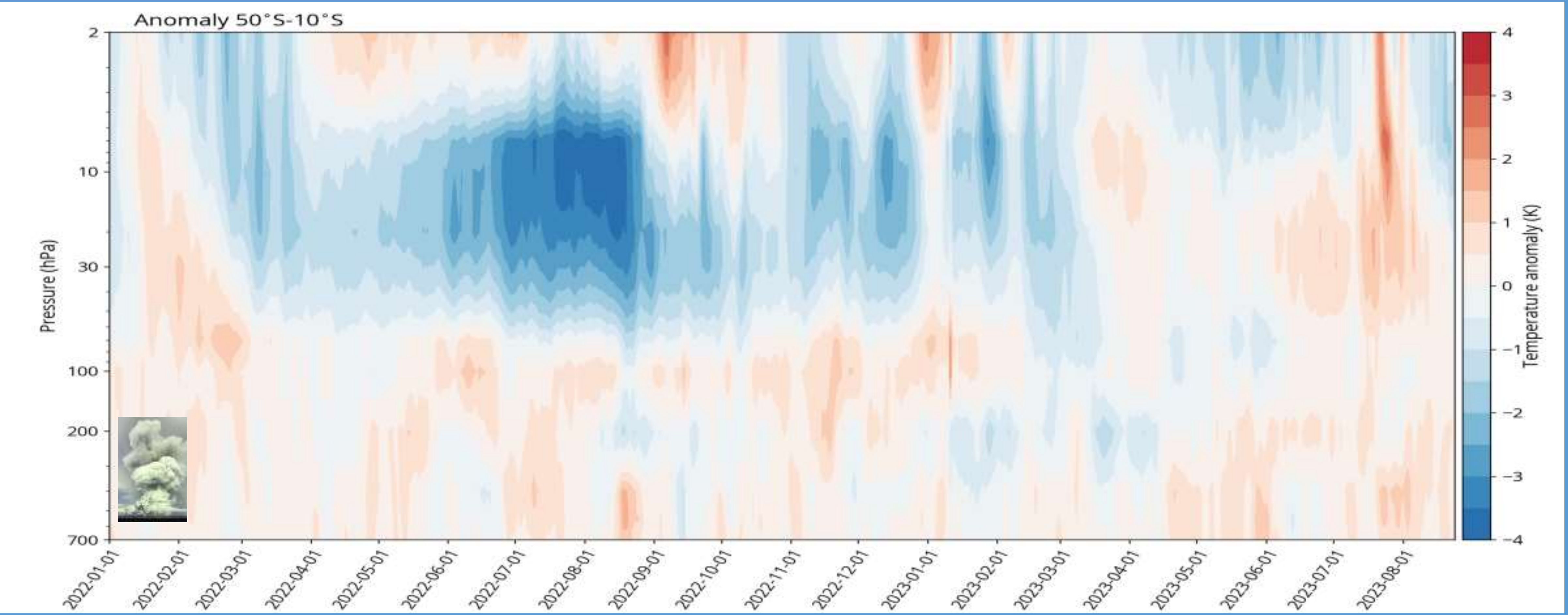
Specific humidity at 150hPa became **negative** in the analyses close to the plume (over Australia here, but persisted for several days as the plume tracked west)



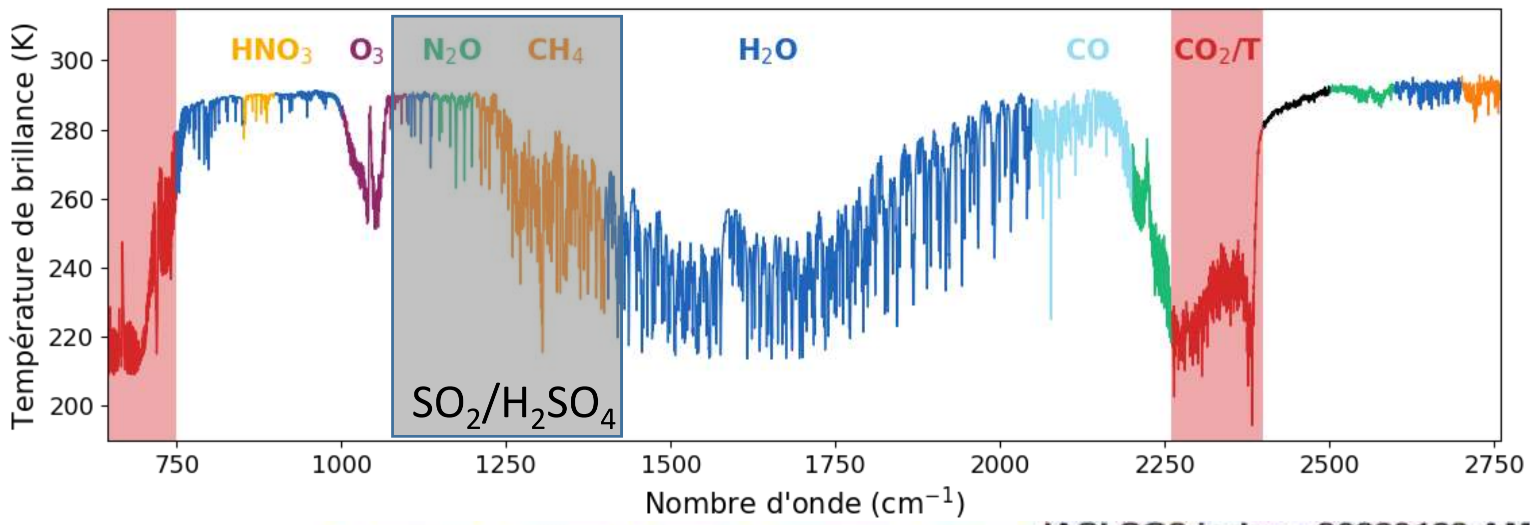


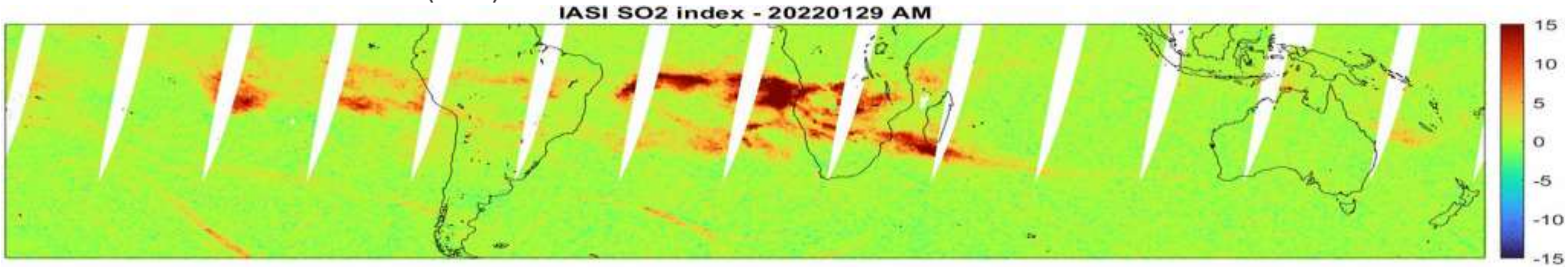
Courtesy Chris Burrows (ECMWF)

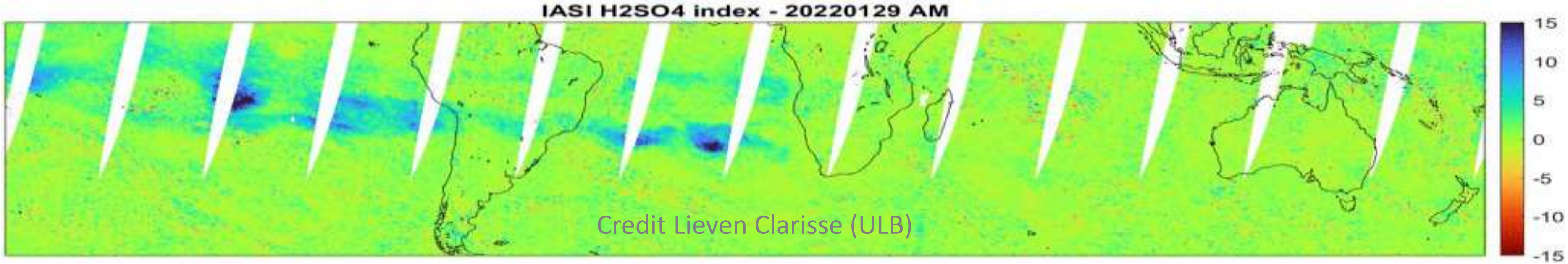
3-20 months after the eruption…



SO_2/H_2SO_4

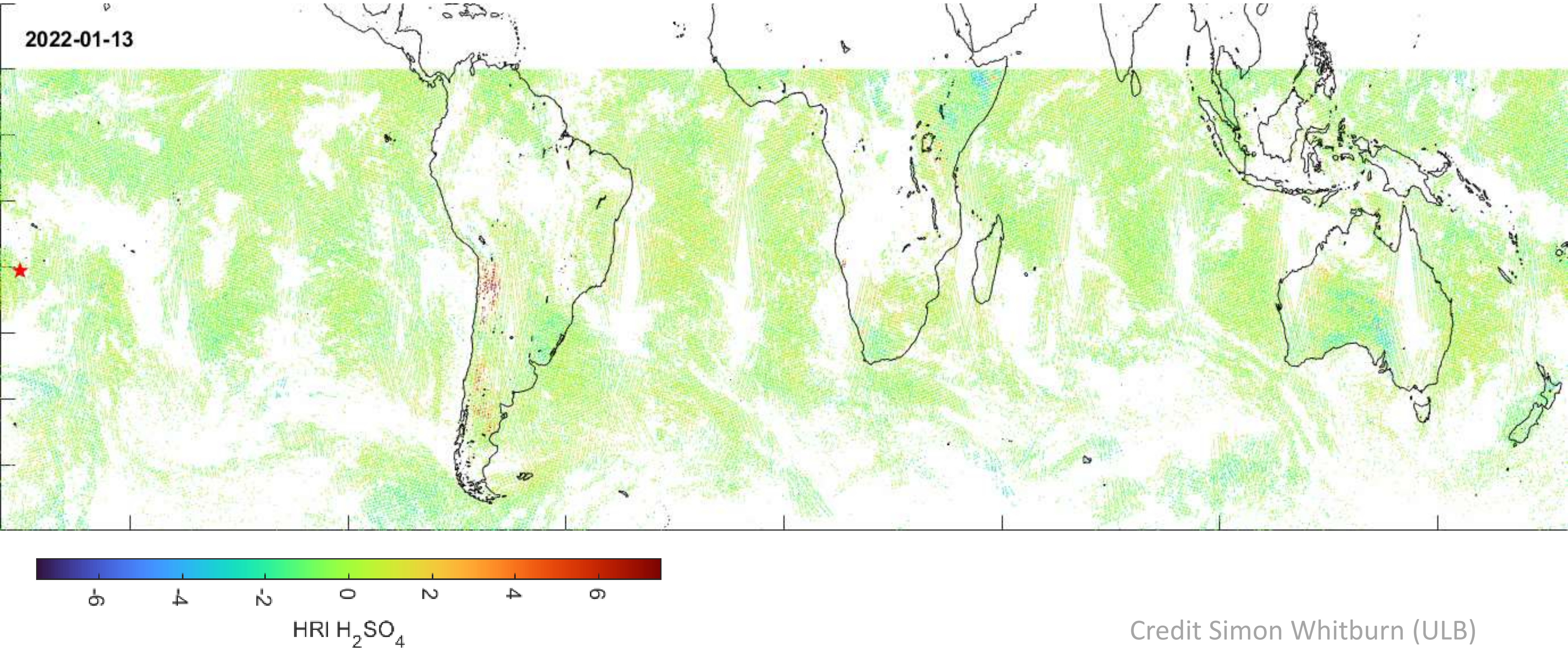

Température de brillance (K)
300
280
260
240
220
200
HNO3
O3
N2O
CH4
H2O
CO
CO2/T
SO2/H2SO4
750
1000
1250
1500
1750
2000
2250
2500
2750
Nombre d'onde (cm−1)


IASI SO2 index - 20220129 AM
15
10
5
0
-5
-10
-15


IASI H2SO4 index - 20220129 AM
15
10
5
0
-5
-10
-15
Credit Lieven Clarisse (ULB)

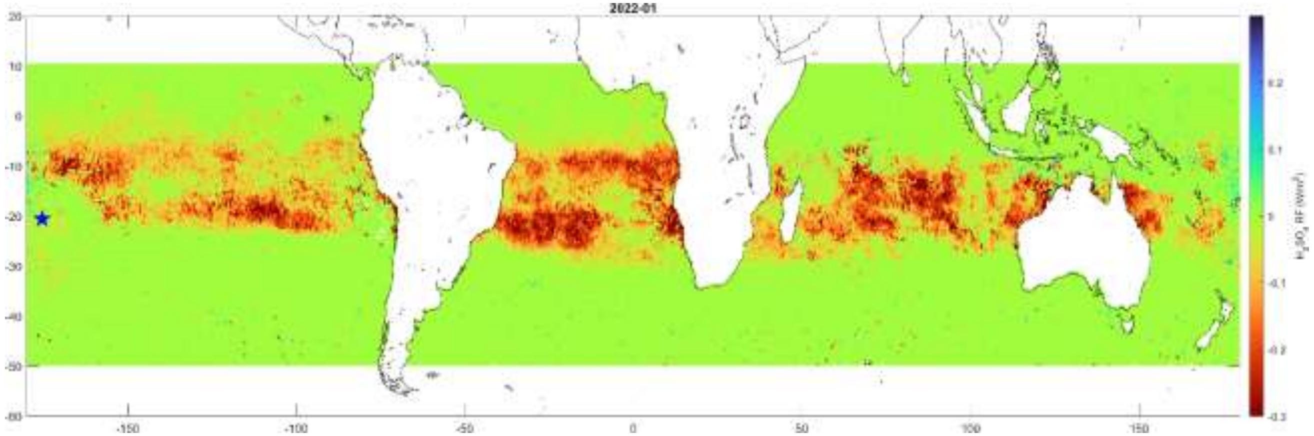
$$HRI_{H2SO4} = \frac{K^T\, S_y^{-1}(y - \overline{y})}{K^T\, S_y^{-1} K}$$

Animation of **HRI** $\mathbf{H_2SO_4}$ between 13 of January 2022 and beginning of march
We can see the plume moving around the globe and then diluting progressively

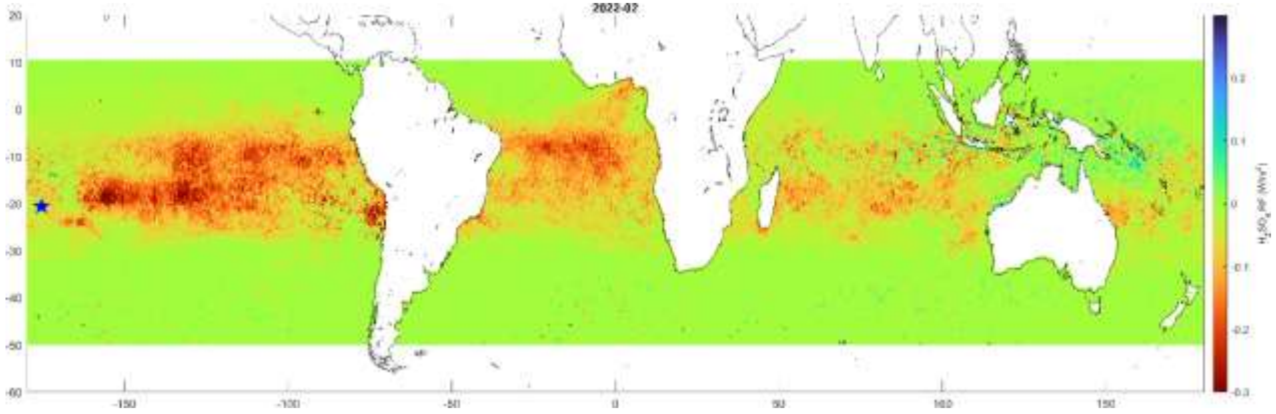


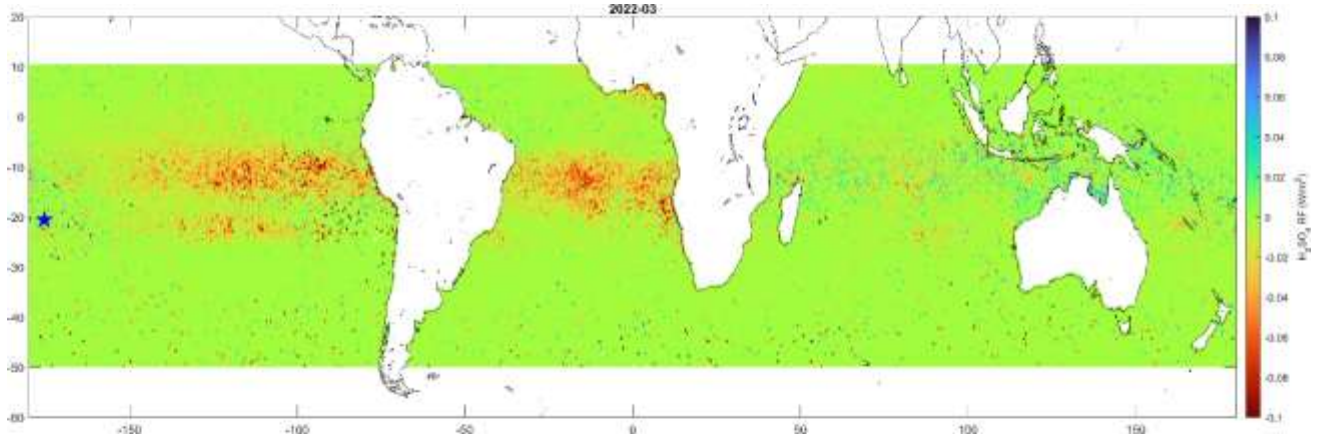
Credit Simon Whitburn (ULB)

SO_2/H_2SO_4



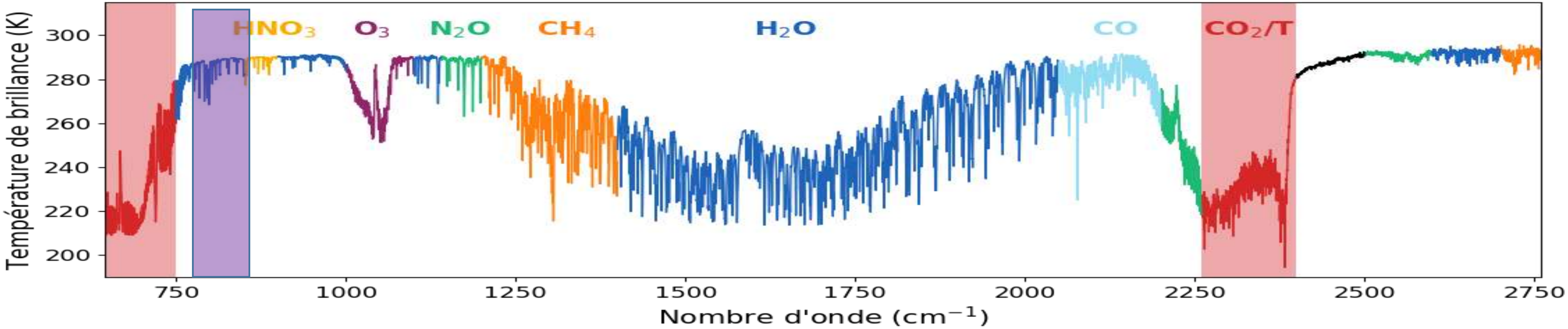
Monthly mean **radiative forcings** in the [800 1250] cm^{-1} spectral region

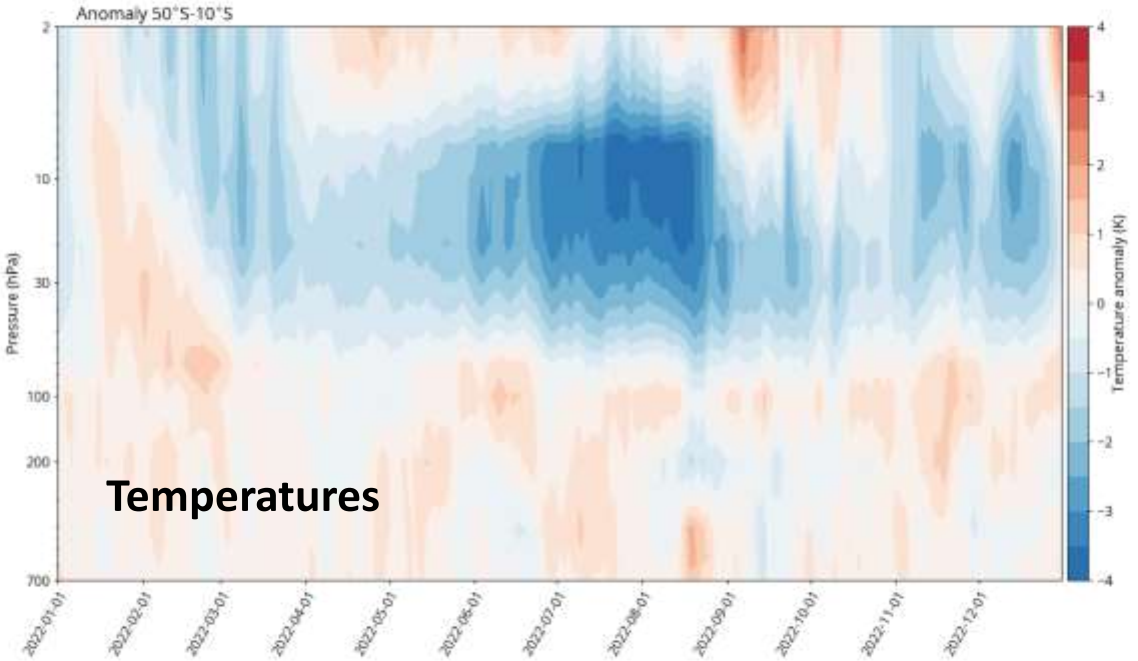




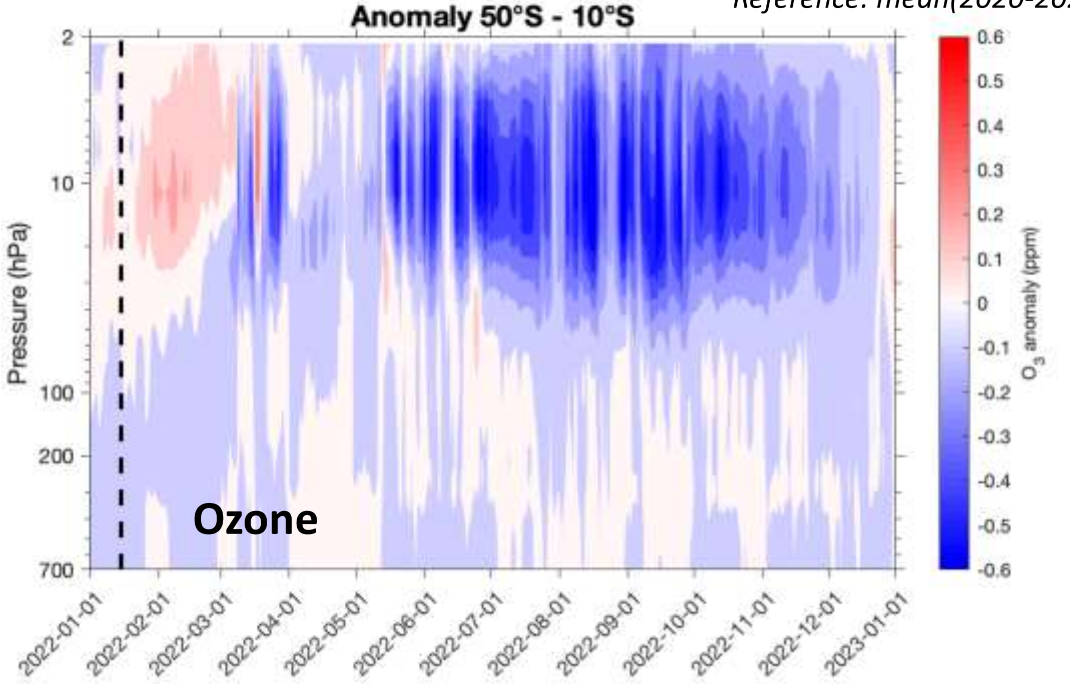
Credit Simon Whitburn (ULB)

Temperatures and O_3

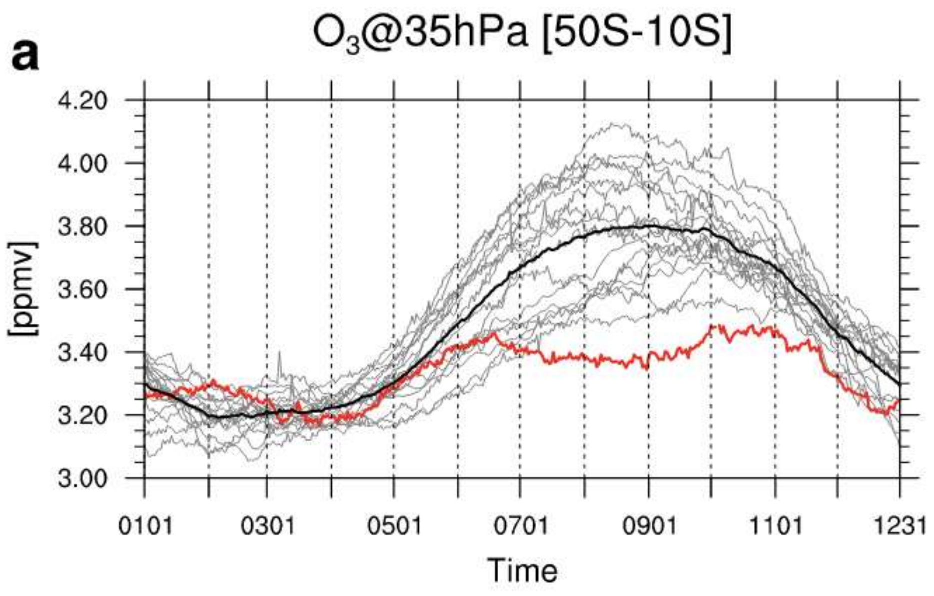




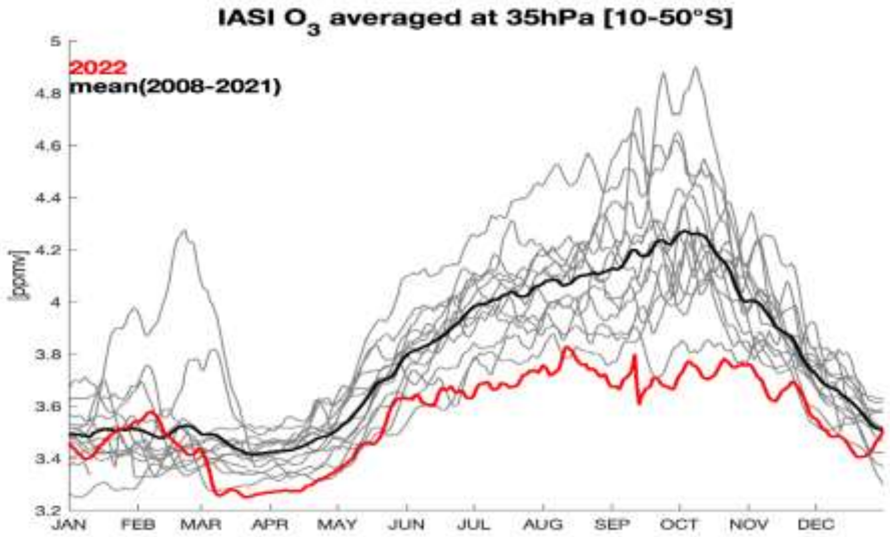
Reference: mean(2020-2021)

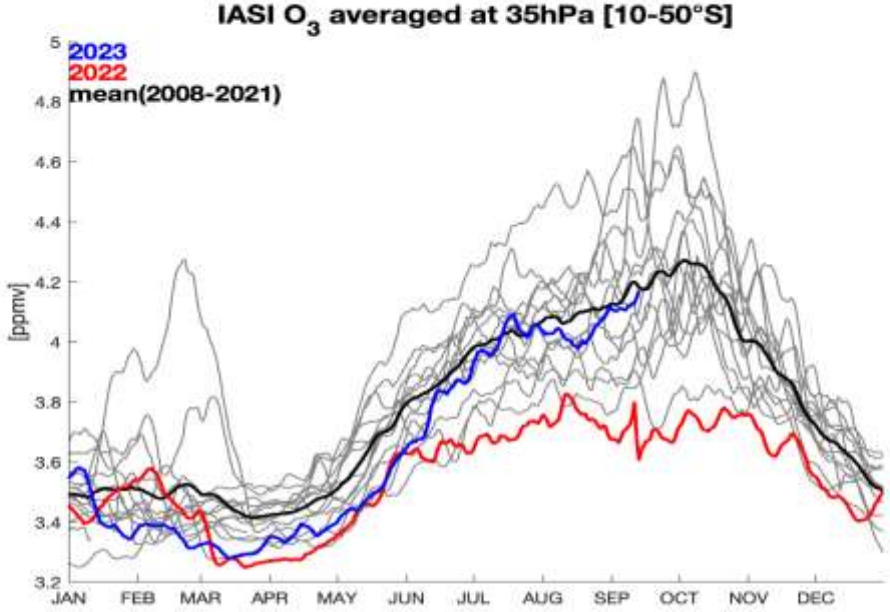


Ozone (MLS vs IASI)

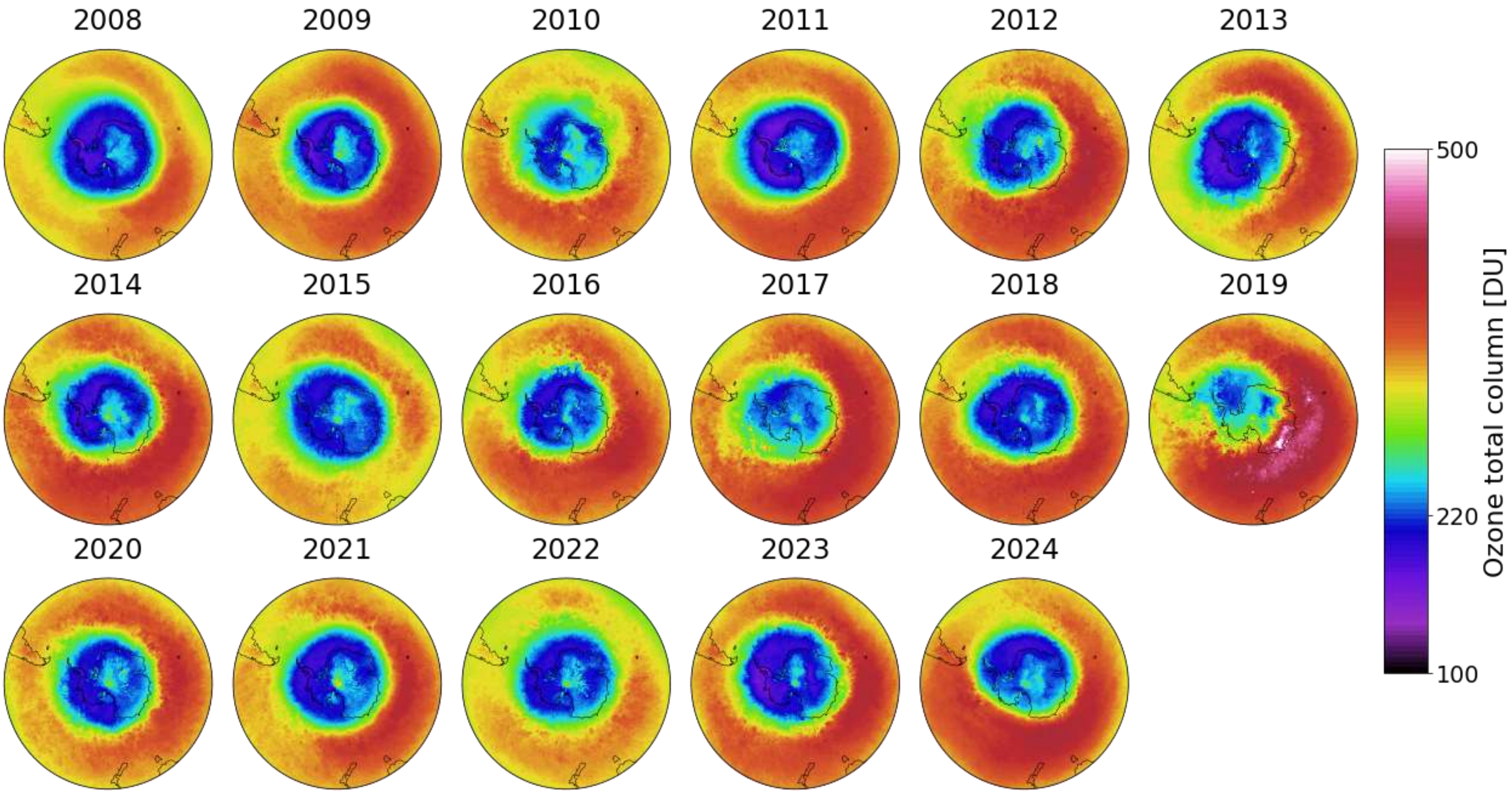


MLS – Wang et al.

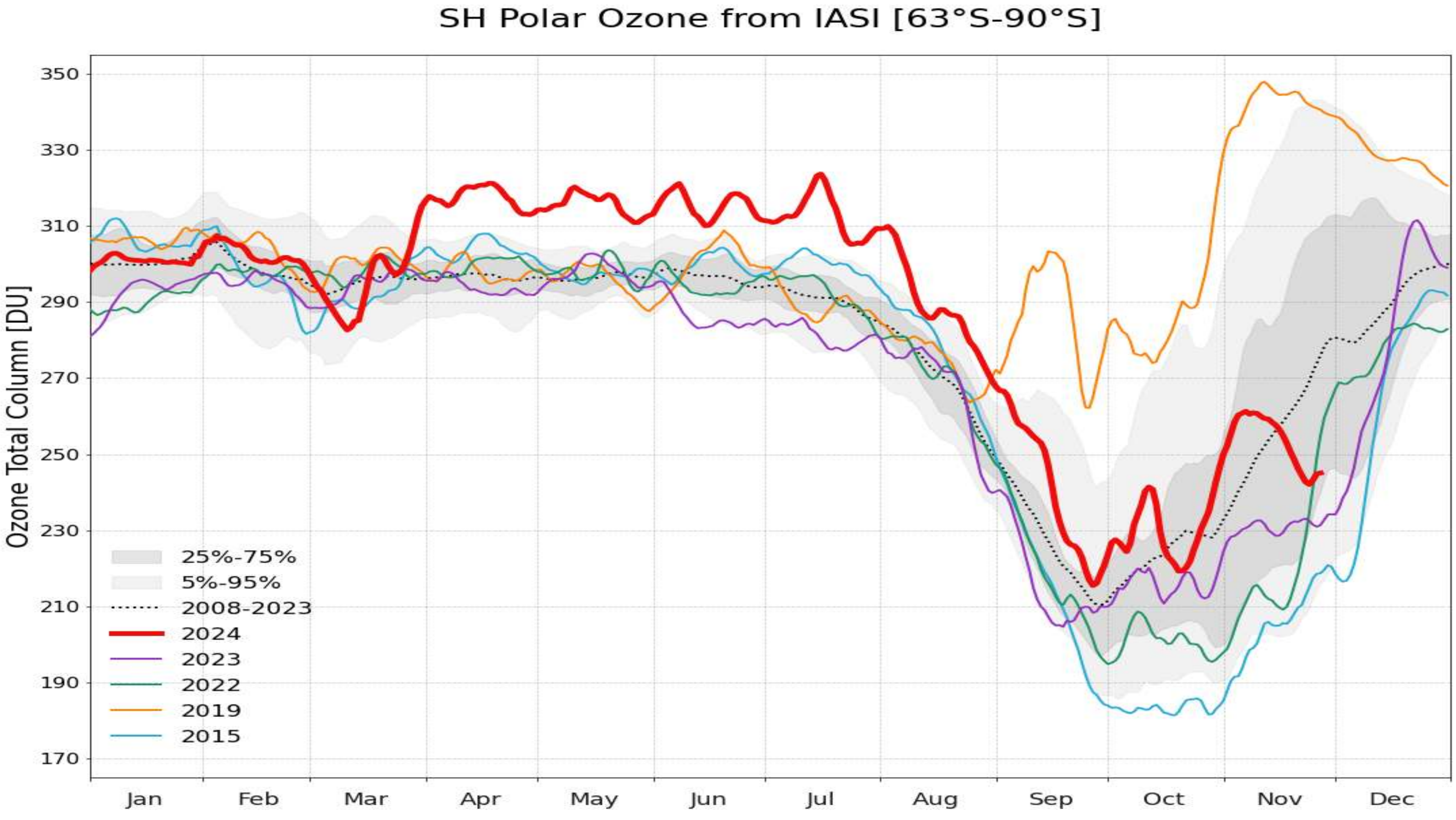




Ozone (IASI)


2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
500
220
100
Ozone total column [DU]

Ozone (IASI)



Credit Valentine Jacquet (LATMOS)

Wrap-up

- **Waves** : Lamb wave + gravity wave combined, initially
- **H_2O** : in excess on day 1 + perturbed signal on the following months but retrieval algo issues (the water is still there, but too high to be detected by IASI)
- **SO_2/H_2SO_4** : strong signatures + first negative RF values derived for Jan-March
- **Temperatures** : the stratospheric water vapor anomaly initially increased the downward infrared radiative flux, but this forcing diminished as the anomaly disperses. The H_2SO_4 aerosols caused a solar flux reduction that dominated the net flux change over most of the 2 yrs period.
- **O_3** : Small local impacts + early start of the ozone hole in sept 2023