Rapid ozone loss following humidification of the stratosphere by the Hunga Tonga Eruption

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Balloon Soundings

- Maïdo Observatory, La Reunion 21°S
- ECC ozonesonde, CFH water vapor, SO_2 sonde, POPS, COBALD backscatter sonde
- Concurrent LIDAR
- 2-4 launches per night with different payloads,
- 6 consecutive nights (a week after the eruption)

H_2O/O_3 Measurements

- ECC ozonesonde is part of all payloads
- 4 out 5 successful CFH water vapor profiles
- 8 out 11 successful ECC O_3 profiles

- COBALD backscatter sondes present with CFH&ECC O3 payload on 20/01 (pre-plume flight) and 22/01(max of H_2O), measures backscatters @455 and 940 nm

Ozone Data processing

- Follows the guidelines of SHADOZ: Witte et al., 2017

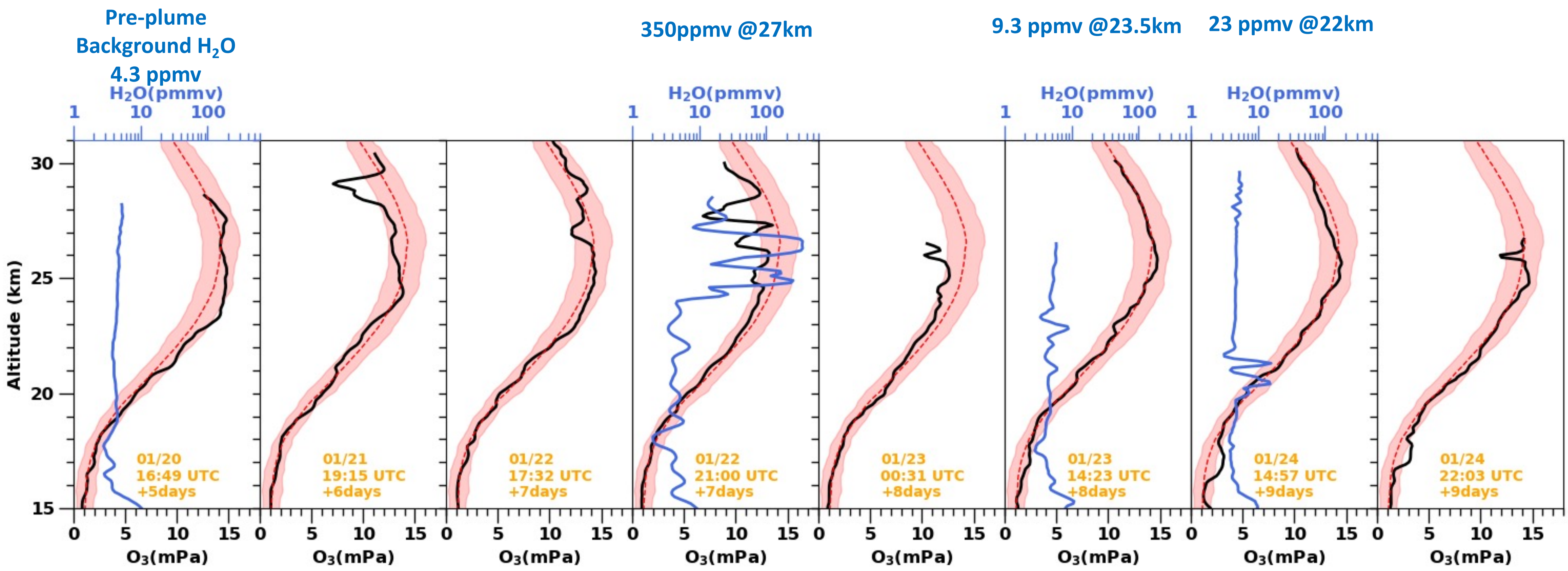
➢ Absorption Efficiency Correction

➢ Pump Temperature Correction, pump efficiency factors from Komhyr et al., 1986

➢ Correction for evaporative effects using RH, Pressure and Temperature conditions during the ozonesonde preparation Smit et al., 2014

The same corrections are used for all ozonesondes profiles at Maïdo Observatory and to compute an ozone climatology for La Réunion for Jan/Feb.

Evolution of water vapor/ozone over La Réunion



An inverse modeling (FLEXPART lagrangian model + in situ H2O measurements) model calculation shows that the Hunga Tonga volcano Injected 120 Tg of water vapor in the stratosphere.

SO_2 interference: example of 2022/01/21 19UTC

The presence of SO_2 interferes with ECC ozonesonde measurement, resulting in – 1 molecule of O_3 reported for each molecule of SO_2 present (if [O3]>[SO2]), causing the O_3 reported to be too low.

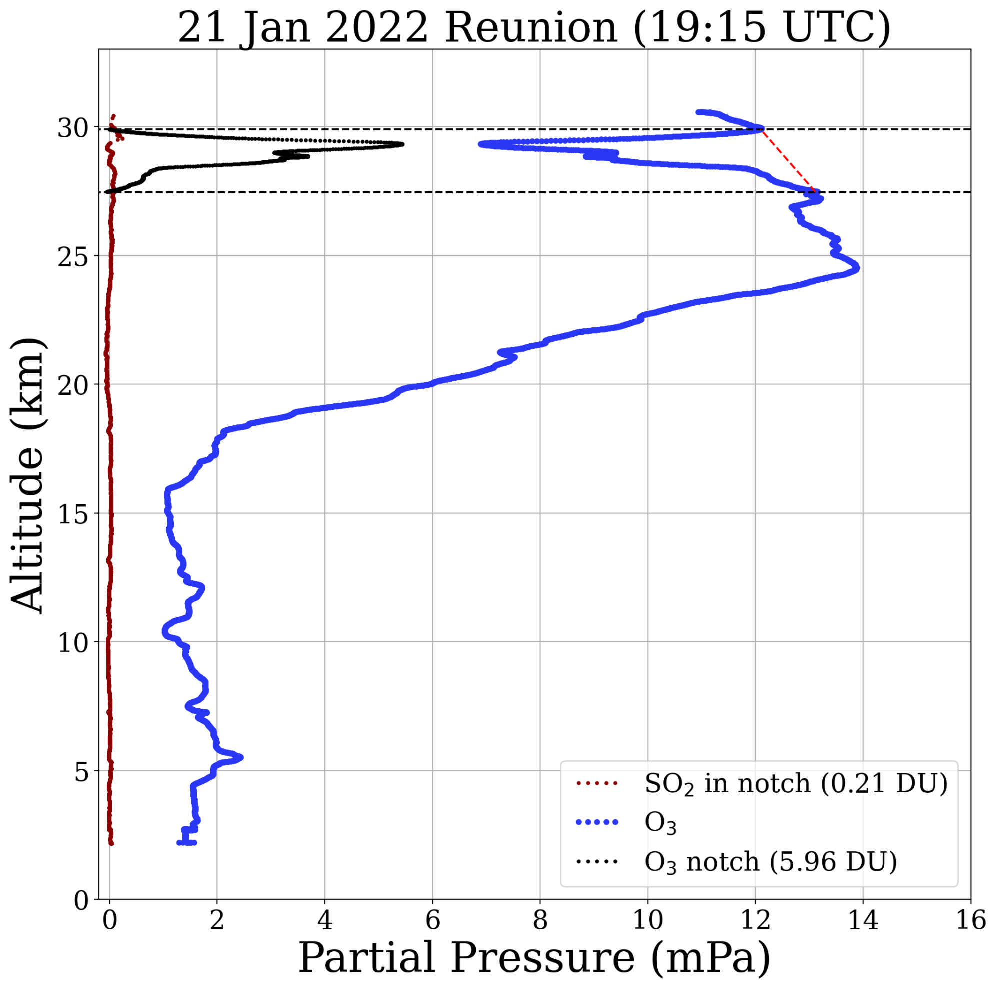
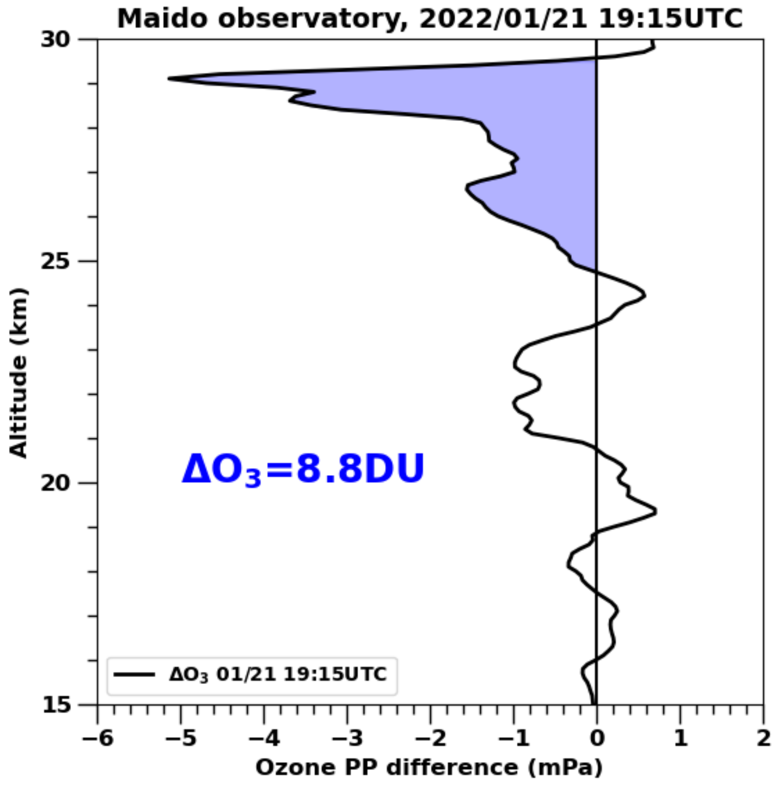


Figure courtesy of Paul Walter

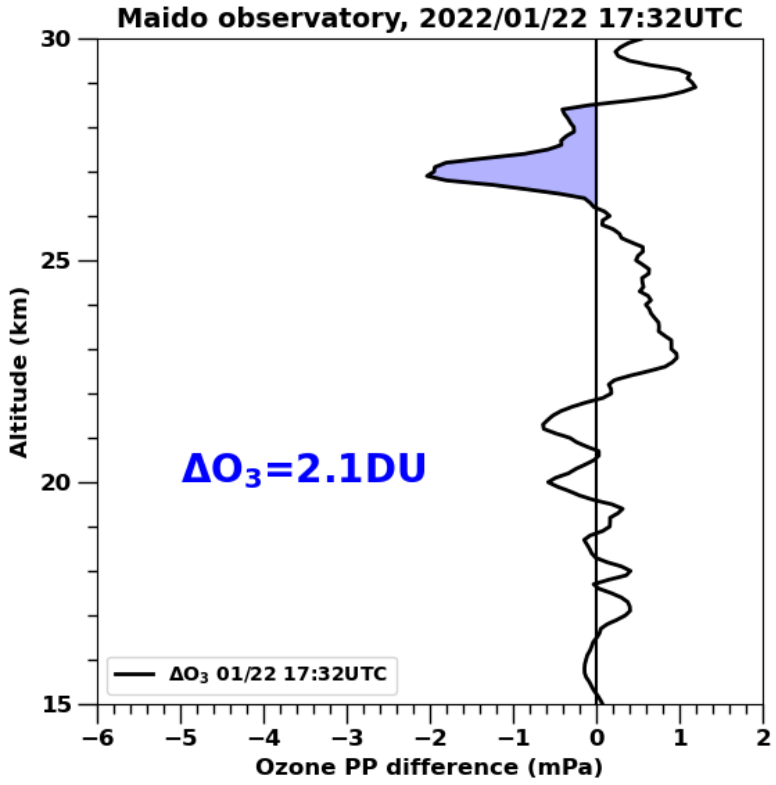
Actual O_3 loss (28.5-31km) = 5.96-0.21 = 5.75DU

An estimated 3-5% and an upper limit of 9% of ozone decrease can be explained by SO_2 interference

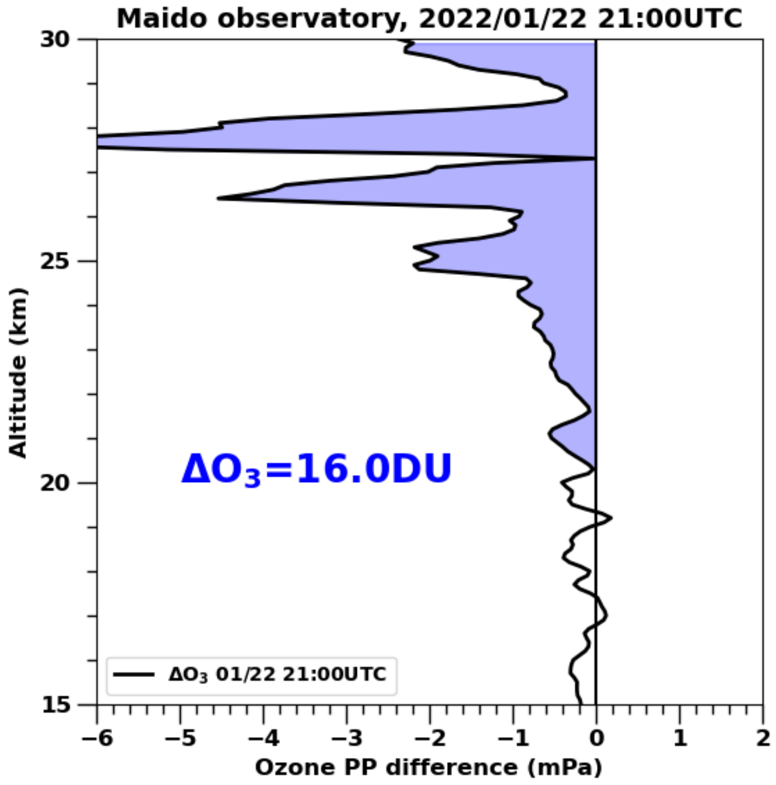
Fast ozone loss following the eruption



Coincident SO_2 measurement, peak of 1.1mPa at 29.5km



Coincident SO_2 measurement, max SO2 of 0.1 mPa at 27.5km

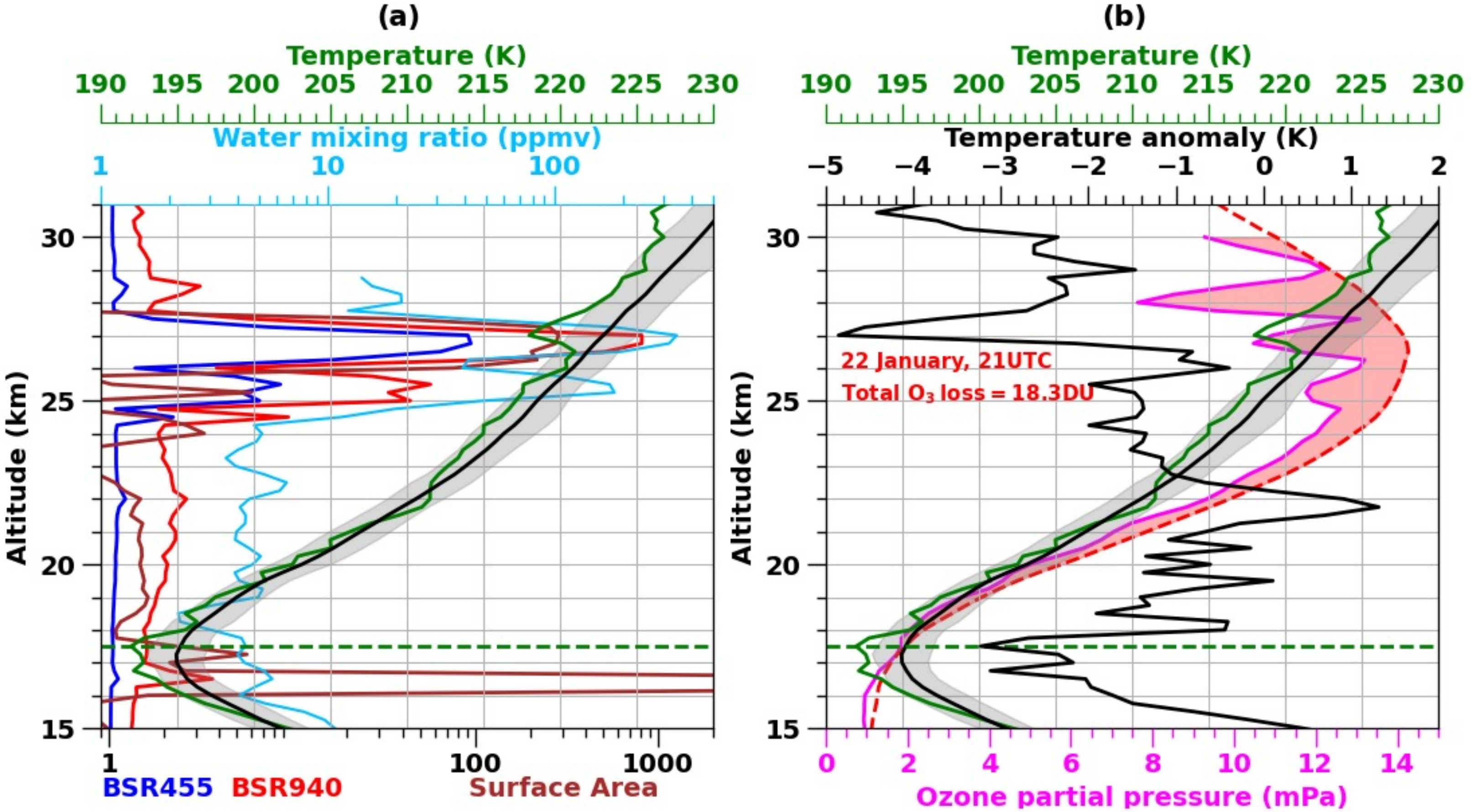


Presence of high water vapor

O_3 column loss observed a week after the Hunga Tunga eruption is around 2 to 16DU

Ozone loss under enhanced water vapor conditions on 22/01 21UTC

Presence of larger particles



Stronger O_3 decrease observed on 22 Jan, 21UTC is correlated to the presence of aerosols , high water vapor layers and negative temperature anomalies.

The amplitude of the O3 loss is agreement with post-Pinatubo observations

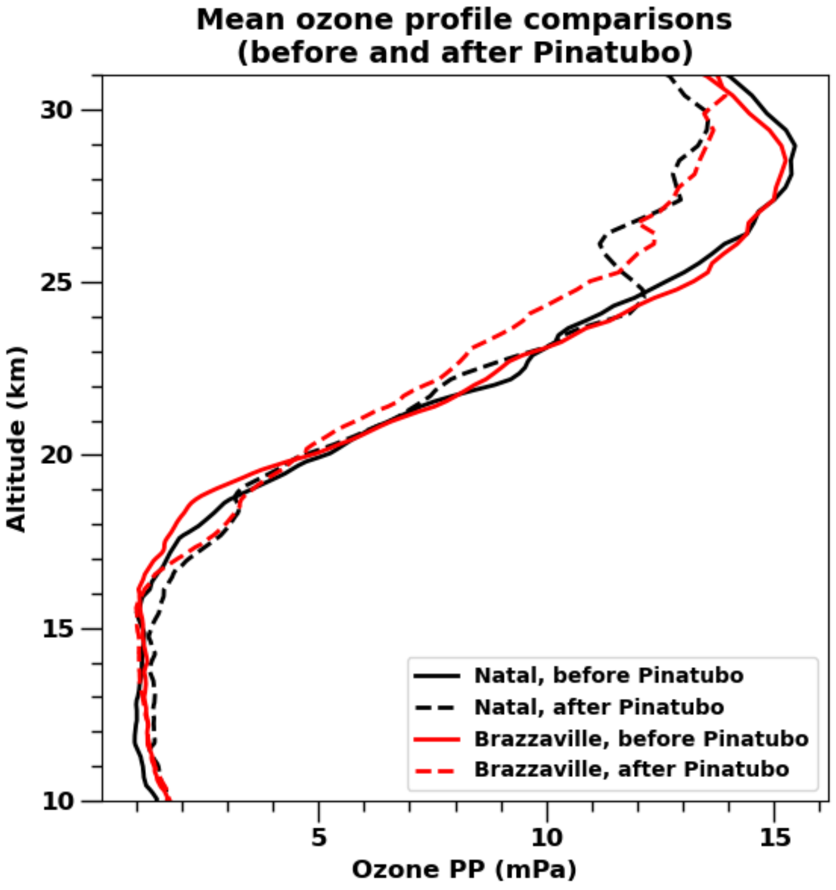
Tropical ozone loss following the eruption of Mount Pinatubo

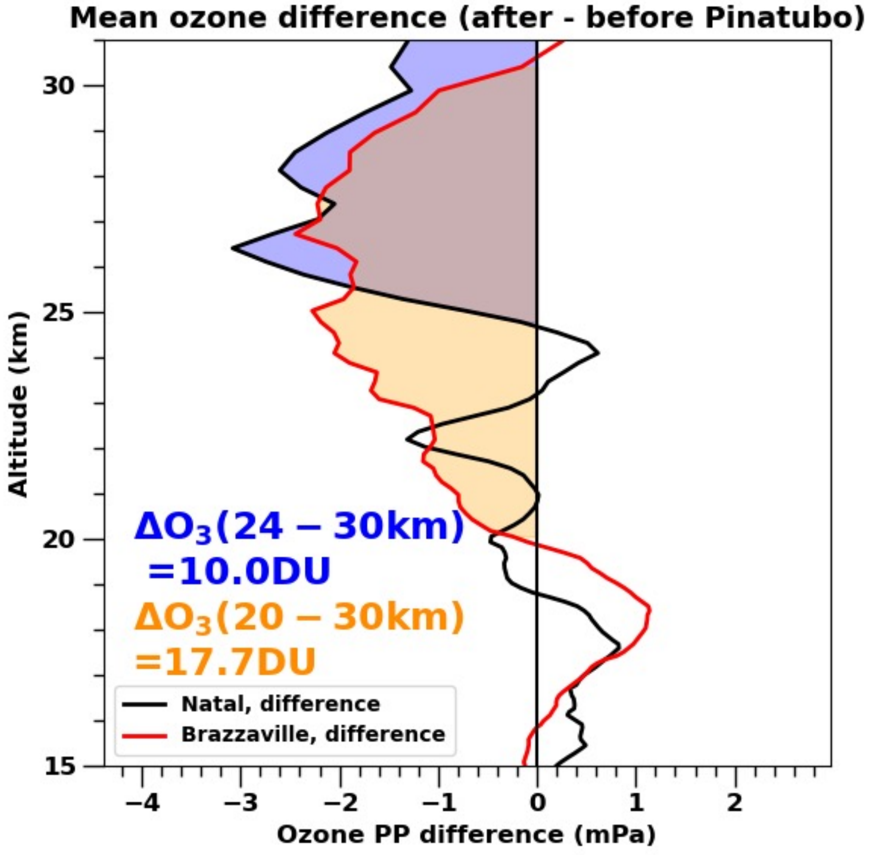
- Schoeberl et al., 1993: decrease of 6% of equatorial total ozone a month after the eruption of Mt. Pinatubo.

Ozone loss is estimated using ozonesonde data from Natal, Brazil taken before and 2 months after the eruption.

- Grant et al., 1992 used ozone profiles at Brazzaville, Congo obtained months before and after the eruption of Mt. Pinatubo.

A decrease in O_3 is observed between 20 and 29km after the eruption of Mt. Pinatubo, with a maximum difference of 20% at ~25km.





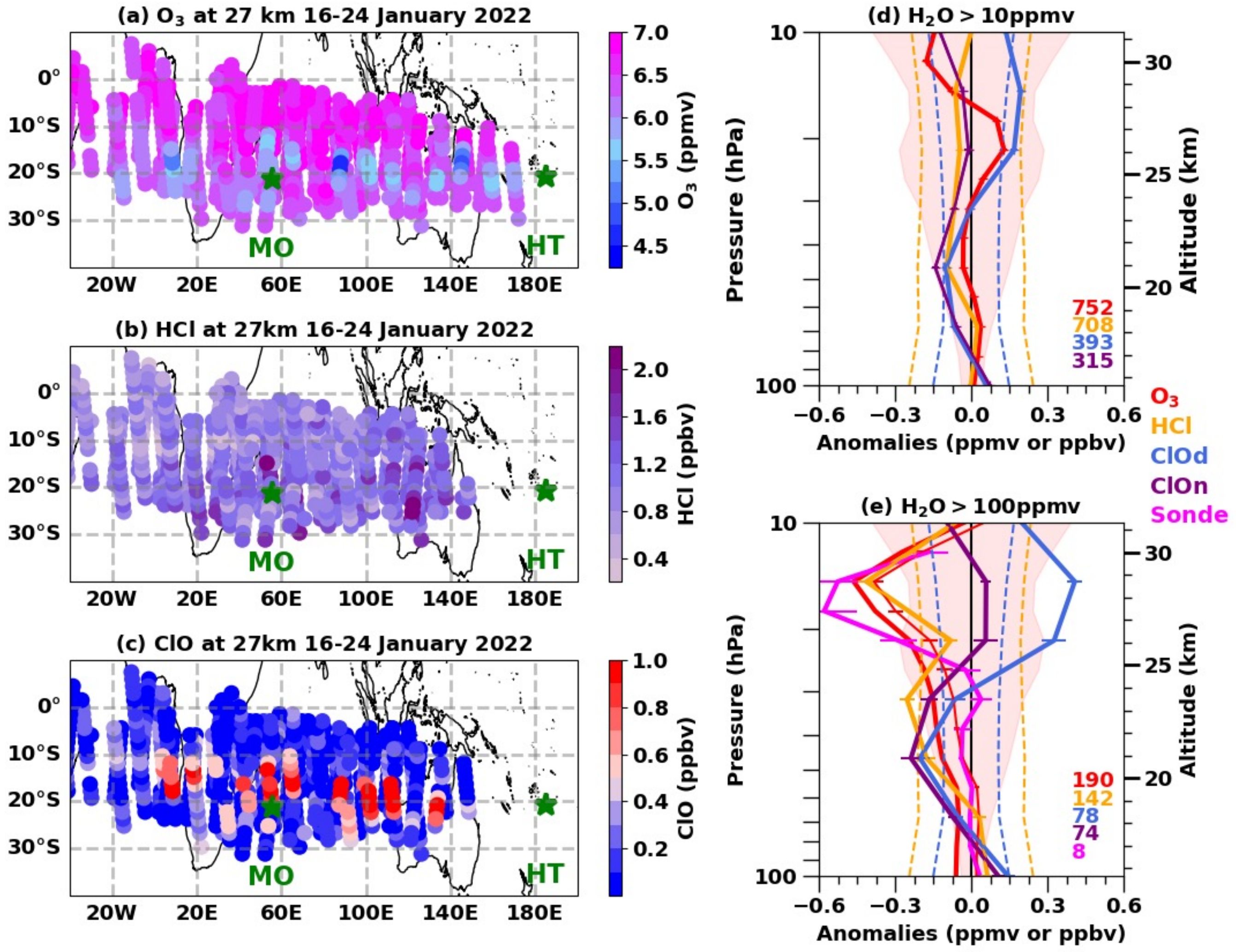
Decrease in O_3 can be due to heterogeneous chemistry, radiative effects or uplift of tropospheric air with lower O_3 to the stratosphere.

MLS HCl/ClO/O_3 observations inside the volcanic plume

MLS HCl, ClO and O_3 v4 data going through standard quality screening.

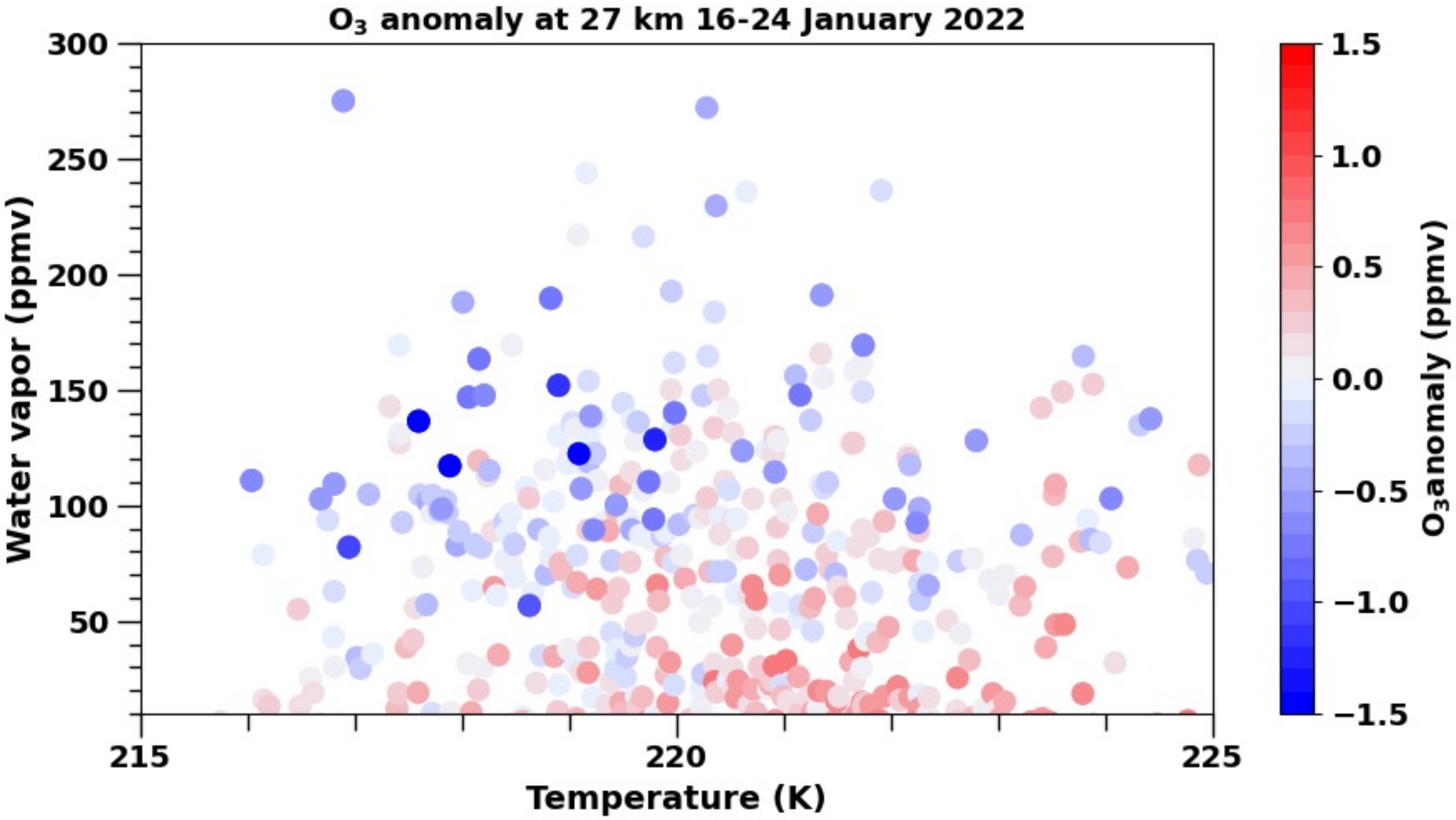
MLS measurements inside the volcanic plume are identified by using a H_2O threshold of 10 ppmv at 21 hPa.

Average O_3/HCl anomaly profiles inside the plume for the period 16-23 January for different H_2O thresholds from 10 to 150 ppmv to assess the sensitivity of stratospheric ozone decrease to H_2O conditions



Ozonesonde and MLS data agree on the altitude and amplitude of the negative O_3 anomaly ~0.5ppmv when water vapor mixing ratios > 100ppmv

Heterogeneous chemistry under enhanced water vapor conditions.



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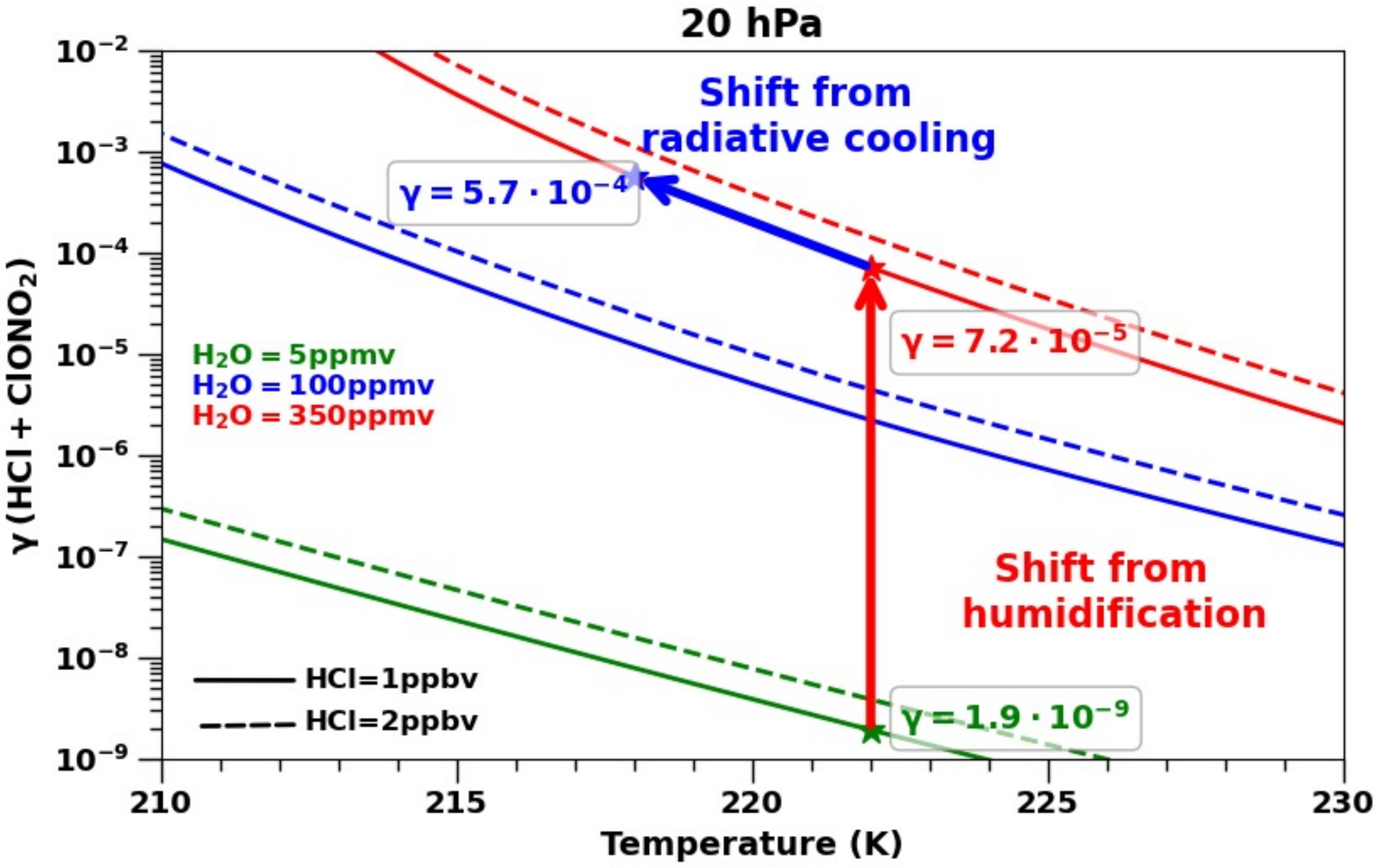
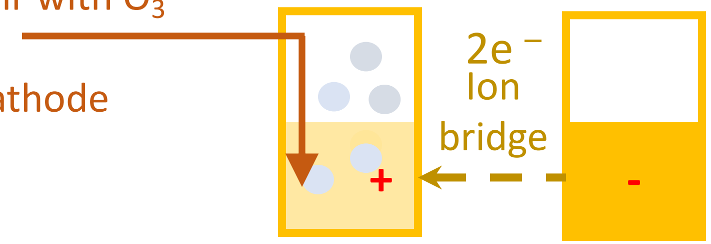


Conclusions

- High water vapor (up to 350ppmv) was observed above Reunion island a week after the eruption, total of 120Tg of water vapor injected in the stratosphere
- Varying ozone loss of 2 to 16DU was observed one week after the eruption, previously ozone loss reported after Mt Pinatubo was 10 to 17DU 2 months after the eruption
- The vast majority of the decreases in the ozone profiles are NOT explained by SO_2 interference
- Rapid Ozone loss can not be explained by dynamics
- Ozone loss (-0.5 ppmv between 25-30 km) confirmed by MLS observations
- The rapid strong O_3 loss was chemical and most likely facilitated by halogen chemistry on humidified surfaces of sulfate or ash aerosols.

Interference of SO_2 with O_3 by the KI method



Principle of KI method to measure O_3:

- Cathode reaction:

$2KI+O_3+H_2O \rightarrow I_2+O_2+2KOH$

Iodide Potassium **Free iodine**

$I_2 + 2e^- \quad Pt \rightarrow 2\,I^-$

The iodine makes contact with a platinum cathode and is reduced back to iodide ions by the uptake of 2 electrons per molecule of iodine

An electrical current I_M is generated in the external circuit of the electrochemical cell

Partial Pressure $O_3 \propto I_M$ cell current

$3\,I^- \rightarrow I_3^- +$ **$2e^-$** (anode)

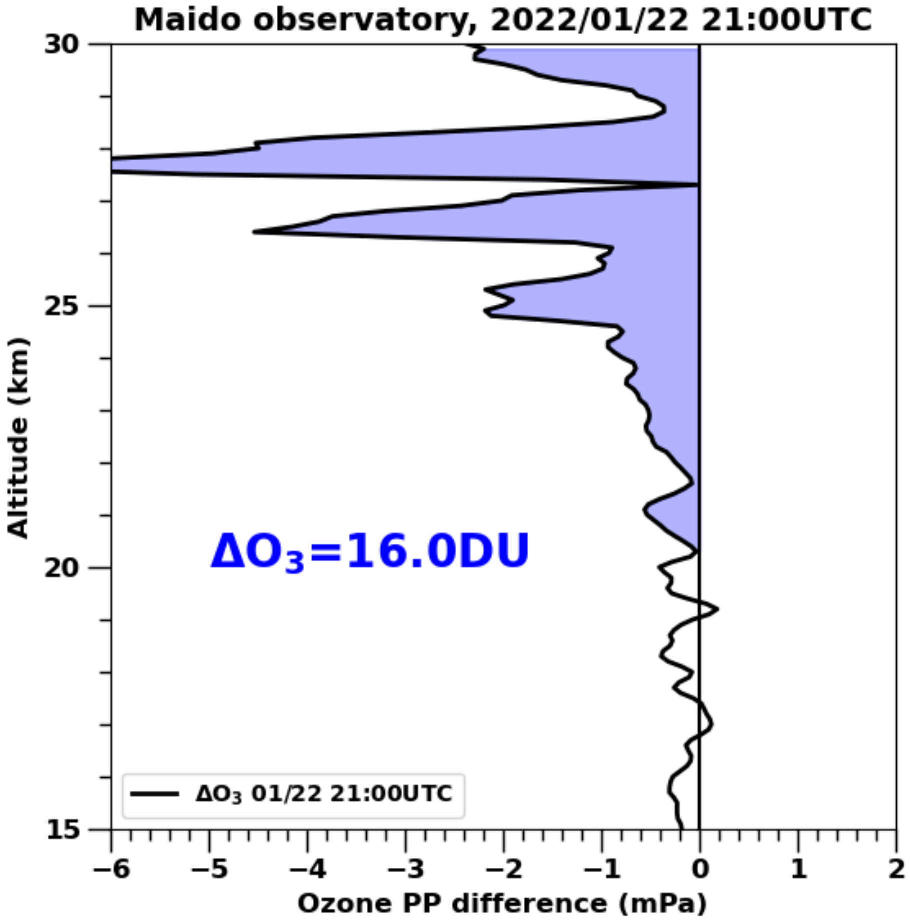
$I_2 +$ **$2e^-$** $\quad Pt \rightarrow 2\,I^-$(cathode)

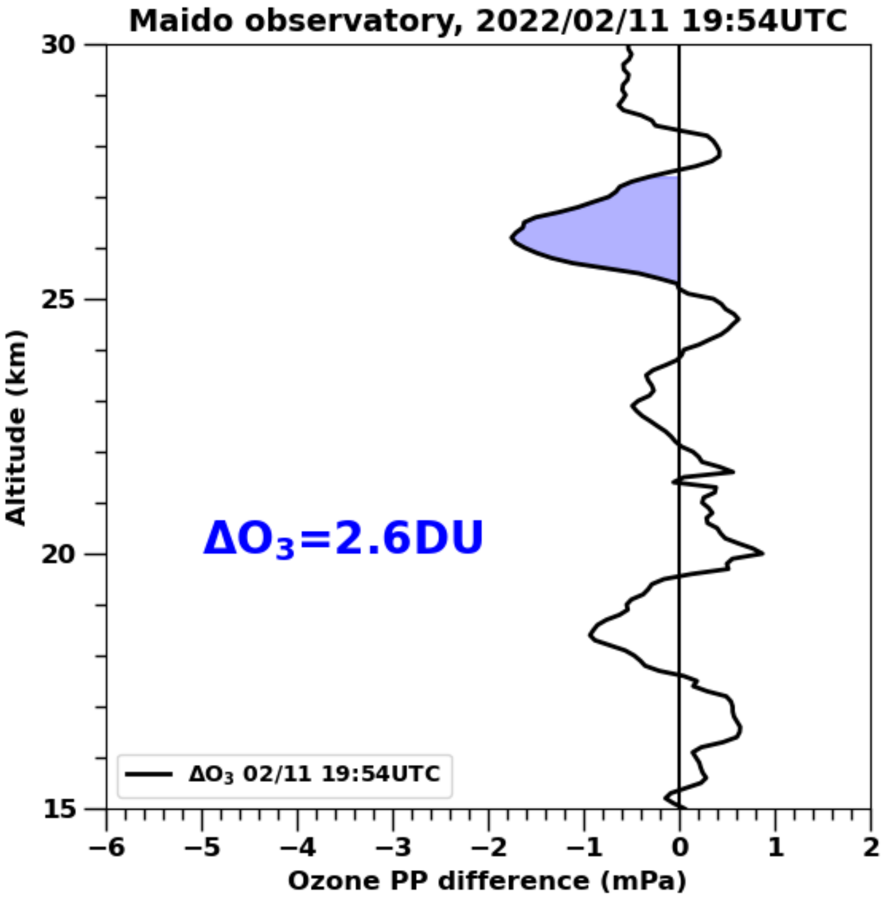
If SO_2 is present, the cathode chamber chemistry is altered: $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$

The SO2 reaction in the cathode chamber supplies the electrons needed to rebalance the ECC

The ozonesonde actuallyreports [O3] – [SO2], causing the O_3 recorded to be too low.

Ozone loss a week and a month after the eruption





Summary of flights/Data

	Burst altitude (km)	ECC O3	CFH	COBALD	POPS	SO2	LOAC
20/01 17UTC	28.8	X	X	X			
21/01 19UTC	30.3	X			X	X	
21/01 21UTC	19.9	X	X	X			
22/01 18UTC	31.6	X			X	X	
22/01 21UTC	31.5	X	X	X			
23/01 00UTC	26.4	X			X	X	
23/01 14UTC	30.0	X			X	X	
23/01 18UTC	30.6	X	X	X			
23/01 21UTC	33						X
24/01 15UTC	31.2	X			X	X	
24/01 17UTC	31.05	X	X	X			
24/01 22UTC	27.8	X					
25/01 17UTC	30				X	X	
25/01 20UTC	33						X
26/01 15UTC	36						X

MLS SO_2 near Réunion Island