An ozone mini-hole associated with the record-breaking Australian bushfires 2019/20: satellite observations with IASI and TROPOMI and the modelled impact on surface UV radiation

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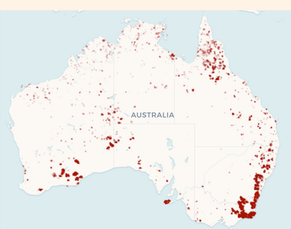
THE RECORD-BREAKING AUSTRALIAN BUSHFIRES 2019/20 – FACT SHEET

Record-breaking fires have ravaged Australia during the 2019/20 fire season (June 2019 - March 2020) (aka the Black Summer):

- Burned surface: 12.6 millions hectares → >x10 Ile de France surface
- CO2 emissions: 436 millions tons → x1.5 overall annual emissions in France
- 3 billions terrestrial vertebrates impacted; 34 humans dead
- Economic loss estimation: >100 billions A$ → largest known economic impact of a natural disaster

Bushfires concentrated and intensified in South New Wales starting from September 2019

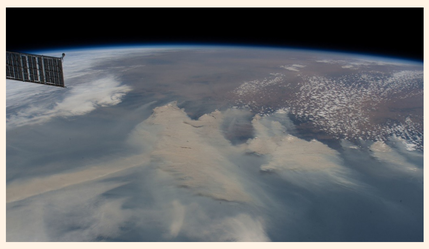


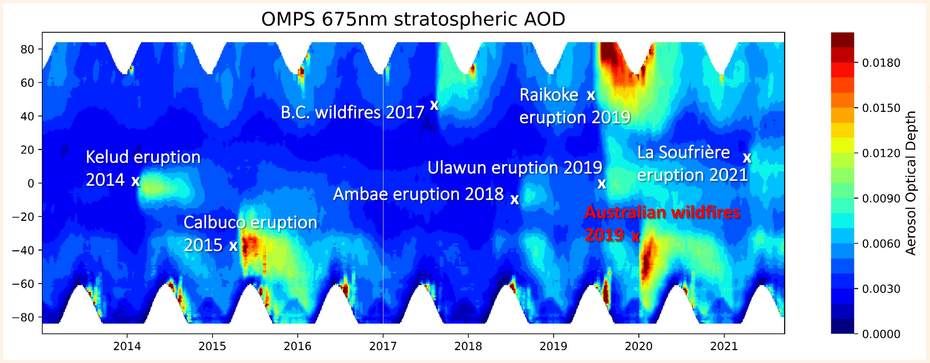
PYRO-CONVECTIVE CLOUD AND THE VORTEX

Fire intensity further intensified in South New Wales in December 2019:

→ generation of a pyro-convective cloud (PyroCb) that reached the stratosphere

→ hemispheric impact observed by many satellite instruments



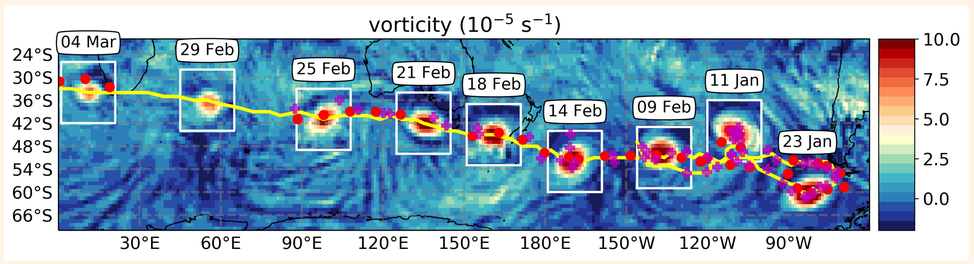


Associated with the PyroCb activity, CALIOP detected a smoke-charged bubble in the stratosphere

A compact smoke-particles-containing anticyclonic vortex that:

→ Travelled thousands km in the Southern Hemisphere: About 70000 km "bouncing" from Australia, Patagonia and South Africa

→ Progressively rose in the stratosphere due to its radiative heating: from 16 to 35 km, an altitude never reached by surface-emitted aerosols since Pinatubo eruption in 1991

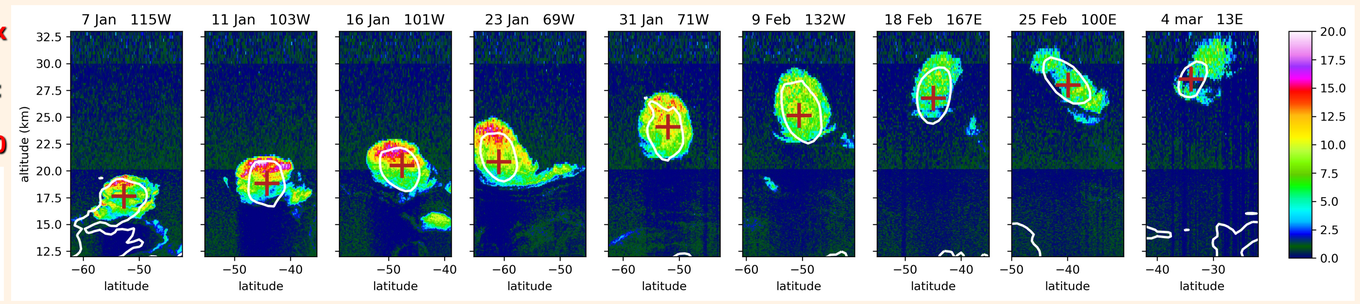


For more details on the PyroCb, the vortex and their hemispheric impacts: Khaykin et al., Nature CommEE, 2020


COMMUNICATIONS EARTH&ENVIRONMENT

ARTICLE

The 2019/20 Australian wildfires generated a persistent smoke-charged vortex rising up to 35 km altitude

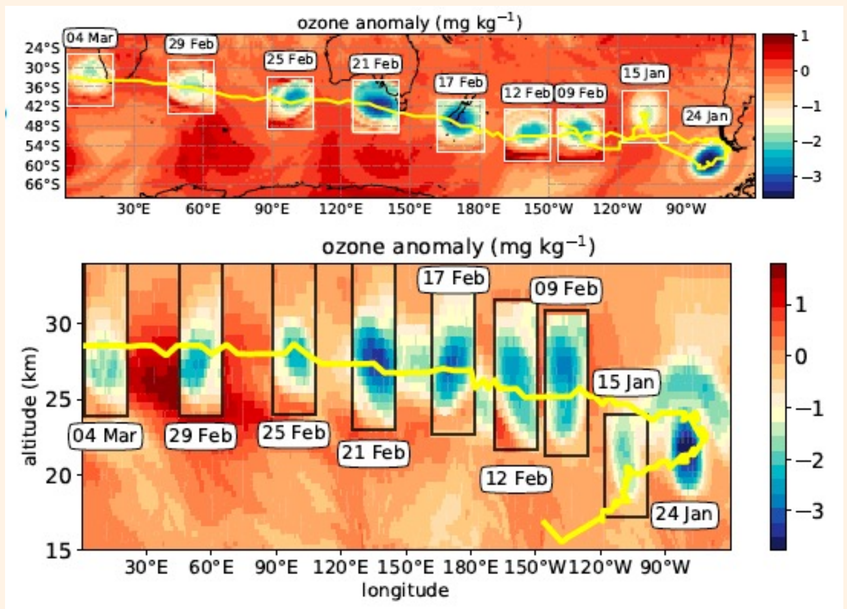


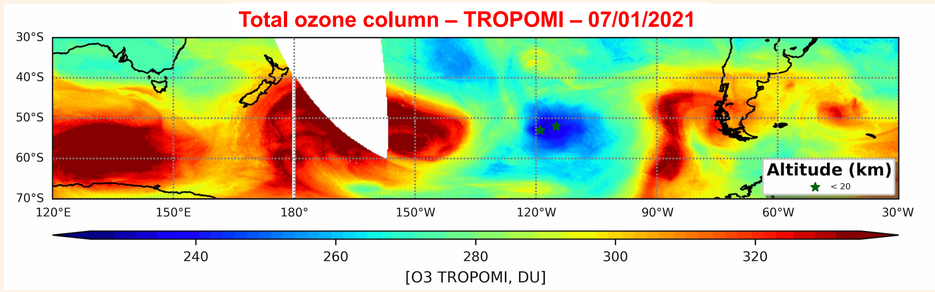
AN OZONE MINI-HOLE ASSOCIATED WITH THE VORTEX

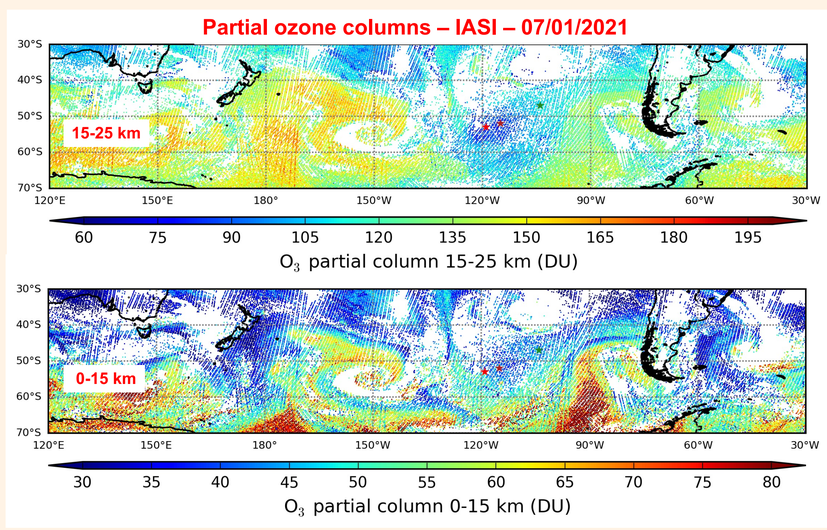
Among other impacts on the stratospheric composition (described in Khaykin et al., Nature CommEE, 2020), the vortex is also associated to an ozone mini-hole:

Fast transport of ozone-poor tropospheric airmasses to the ozone-rich stratosphere + heterogenous chemistry

- Ozone anomalies up to 3.5 mg kg^{-1} are modelled in ECMWF analyses → linked to the assimilation of IASI BT and GOME-2 total column ozone observations
- The ozone mini-hole progressively ascends following the vortex dynamics







The ozone mini-hole is also observed – and can be tracked - by:

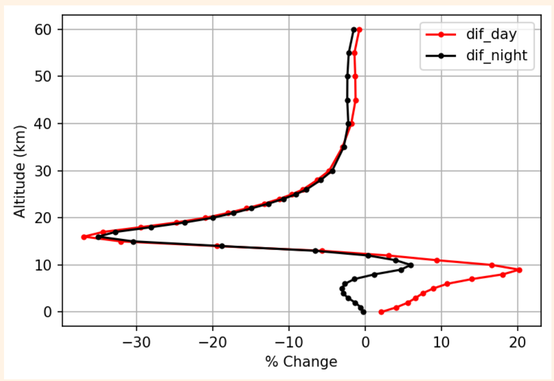
- TROPOMI total ozone column observations
- IASI profiles and partial column observations (LISA product, Eremenko et al., JGR, 2008)

IASI vertically-resolved observations confirm the stratospheric origin of this feature

The ozone mini-hole observations allow the quantification of the ozone depletion associated with the pyro-genic vortex:

- @ 17.5 (vortex core, IASI): -35%
- 15-25 km (IASI):
  - BG: 104.5 DU
  - Vortex: 87.8 DU → -16%
- 0-15 km (IASI):
  - BG: 43.9 DU
  - Vortex: 43.6 DU → ~no impact
- Total column (TROPOMI):
  - BG: 290 DU
  - Vortex: 245 DU → -15%

(estimations for 07/01/2021)



Details on LISA product for IASI O3 retrieval available here:


GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L18005, doi:10.1029/2008GL034803, 2008

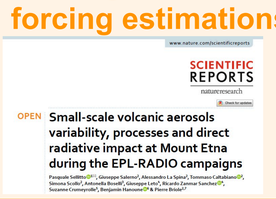
Tropospheric ozone distributions over Europe during the heat wave in July 2007 observed from infrared nadir spectra recorded by IASI

M. Eremenko,[1] G. Dufour,[1] G. Foret,[1] C. Keim,[1] J. Orphal,[1] M. Beekmann,[1] G. Bergametti,[1] and J.-M. Flaud[2]

PERSPECTIVES: THE IMPACT ON THE UV SURFACE RADIATION

The ozone depletion due to the pyrogenic ozone mini-hole is expected to produce effects on the radiative transfer and the surface UV radiation

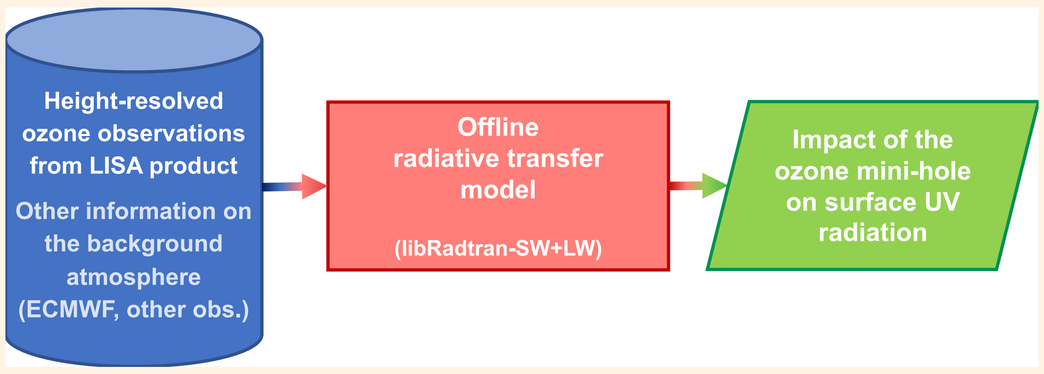
Impact on surface UV radiation will be estimated using ''Offline Radiative Forcing estimations'' → method exploited in the past for aerosol radiative forcing estimations (e.g. Sellitto et al., Scientific Reports, 2020)


SCIENTIFIC REPORTS

nature research

OPEN Small-scale volcanic aerosols variability, processes and direct radiative impact at Mount Etna during the EPL-RADIO campaigns

What concurrent radiative impact of smoke aerosols injection + ozone mini-hole?



Surface UV radiation imbalances will also be measured from ground via remote sensing, e.g. by means of Brewer spectro-photometers network

CONCLUSIONS

The record-breaking Australian bushfires 2019/20 produced a compact smoke-charged anticyclonic vortex in the stratosphere, which rose due to radiative heating up to about 35 km altitude and travelled thousands km in the Southern Hemisphere

An ozone mini-hole, associated with this vortex, was also generated → fast transport of ozone-poor tropospheric air masses + heterogeneous chemistry on smoke aerosols

The ozone mini-hole was detected with satellite observations (TROPOMI, IASI) and is well represented in ECMWF analyses thanks to the assimilation of IASI and GOME-2 data

Up to 45 DU (15%) reduction in the ozone total column is observed, mostly occurring at 10-25 km altitude, with 35% ozone depletion at the vortex core

The likely impacts of the ozone mini-hole on radiative balance and surface UV radiation are yet to be quantified (Offline Radiative Forcing estimations and surface observations)

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