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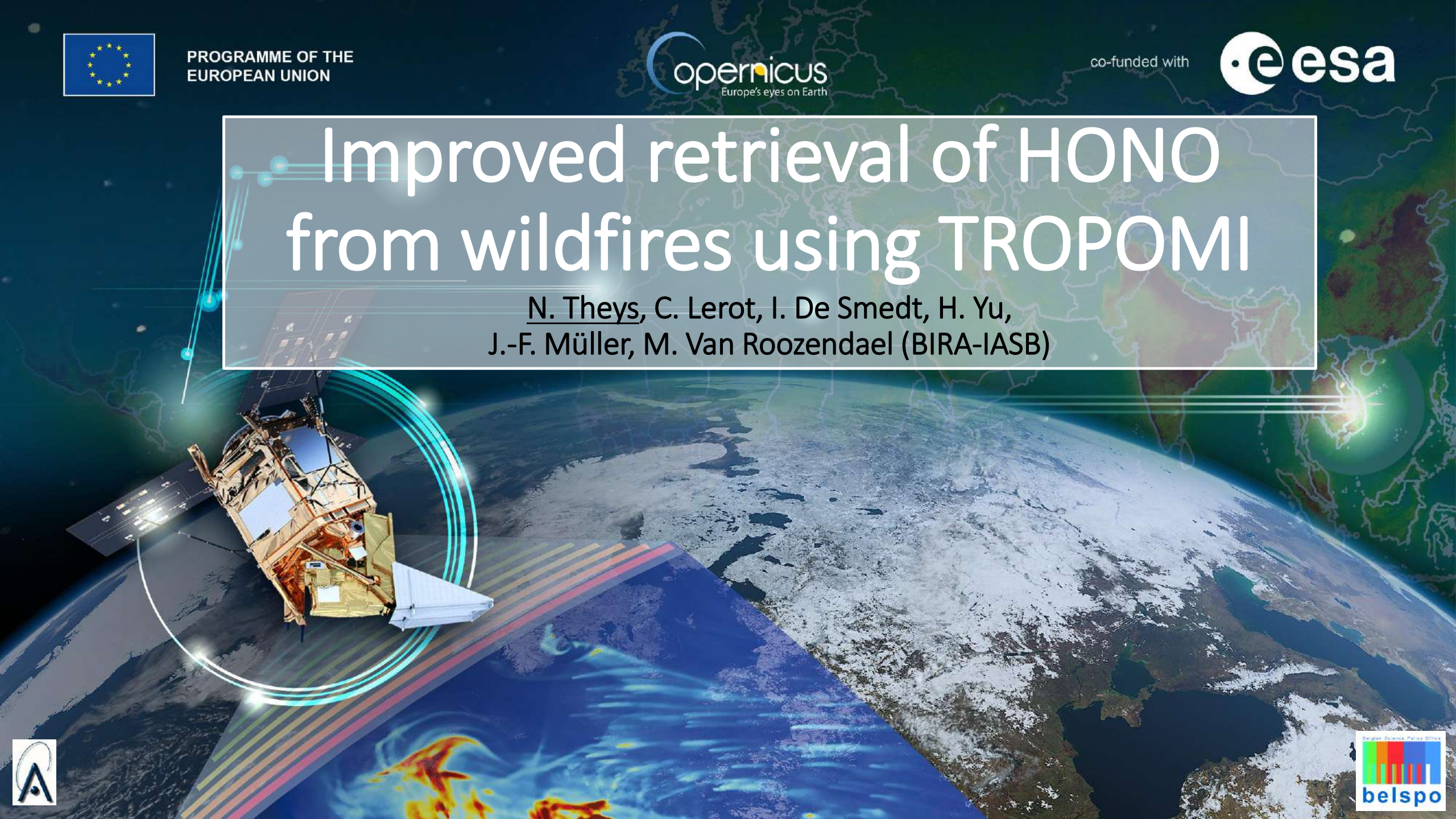
Improved retrieval of HONO from wildfires using TROPOMI

N. Theys, C. Lerot, I. De Smedt, H. Yu,
J.-F. Müller, M. Van Roozendael (BIRA-IASB)



Atmospheric HONO

- HONO is a source of hydroxyl radical (OH).

$$HONO + h\nu \rightarrow NO + OH$$

enhanced VOC oxidation

ozone formation

secondary organic aerosol formation & aging

- HONO emission budget and formation mechanisms are poorly constrained => impact on tropospheric chemistry remains uncertain.

- Until recently, measurements of HONO mostly using in-situ and spectroscopic techniques from instruments on the ground or onboard aircrafts

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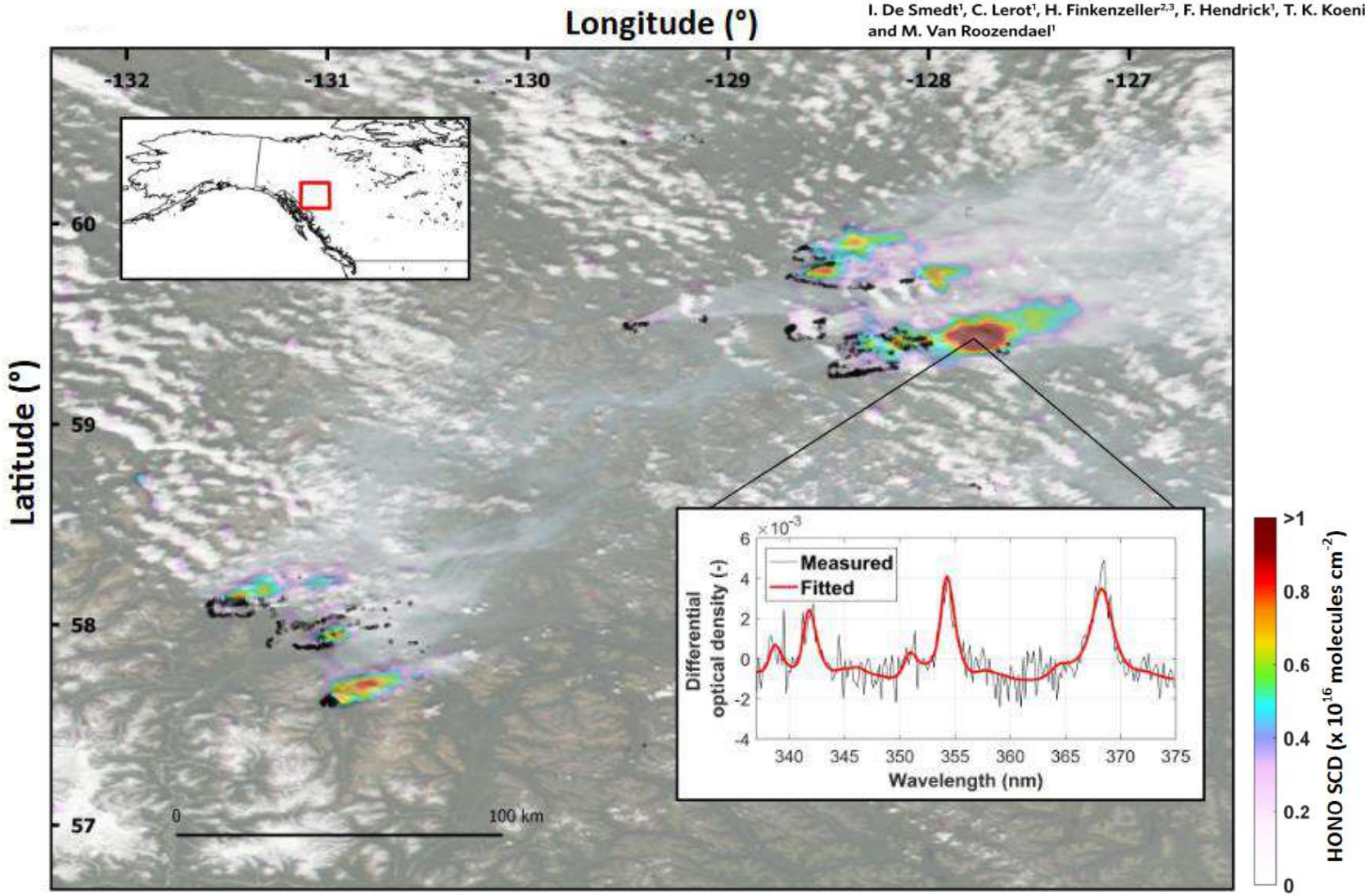
Detection and mapping of pyrogenic HONO is possible using high spatial resolution instruments like TROPOMI

nature geoscience
ARTICLES
https://doi.org/10.1038/s41561-020-0637-7
Check for updates

Global nitrous acid emissions and levels of regional oxidants enhanced by wildfires

N. Theys[1], R. Volkamer[2,3,4], J.-F. Müller[1], K. J. Zarzana[2], N. Kille[3,4], L. Clarisse[5], I. De Smedt[1], C. Lerot[1], H. Finkenzeller[2,3], F. Hendrick[1], T. K. Koenig[2,3], C. F. Lee[2,3], C. Knote[6], H. Yu[1] and M. Van Roozendael[1]



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First global survey

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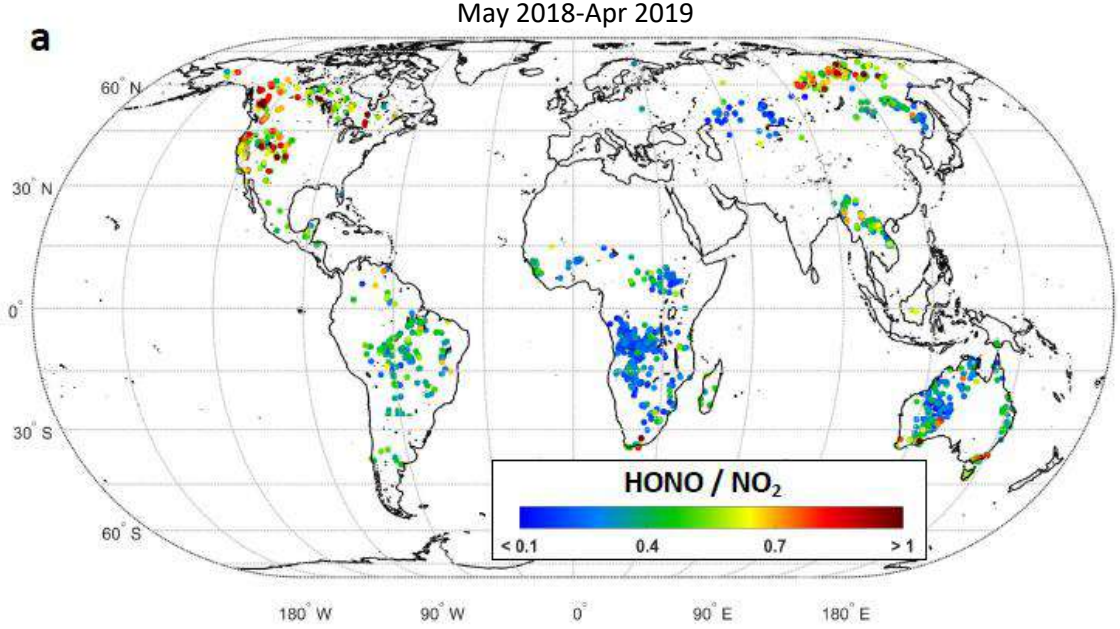
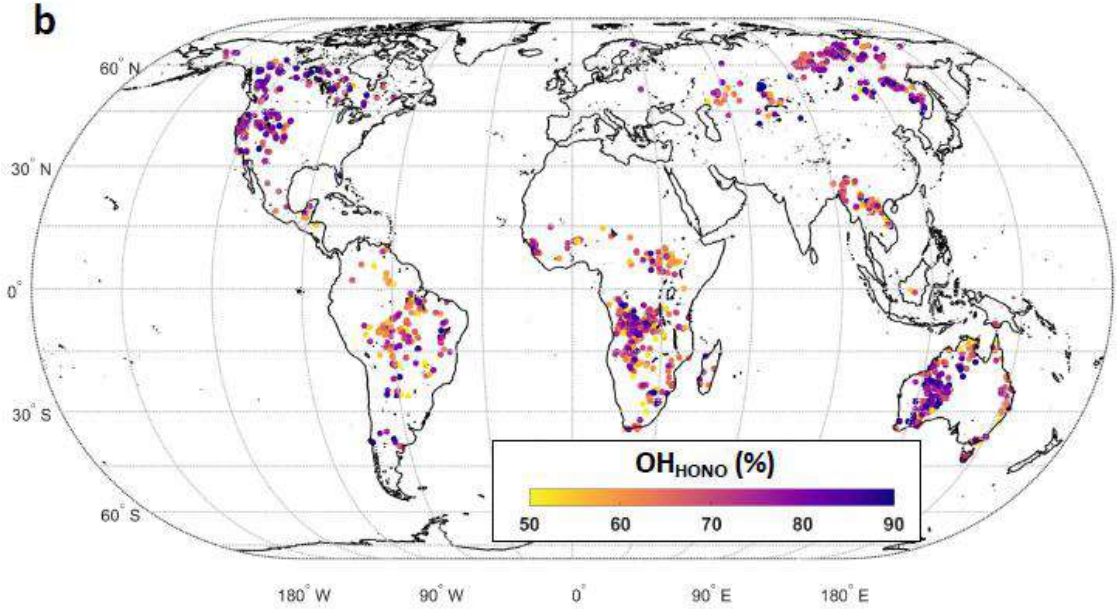
May 2018-Apr 2019





$HONO/NO_2$ (proxy of HONO production)

- Strong dependence with ecosystem type.
- Larger than previous estimates by a factor of 2-4.

OH production by HONO photolysis

- Dominant in fresh BB plumes, about 2/3 of total OH production.
- Possible large impact of HONO on oxidative plume chemistry and ozone production.

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The DINAR project

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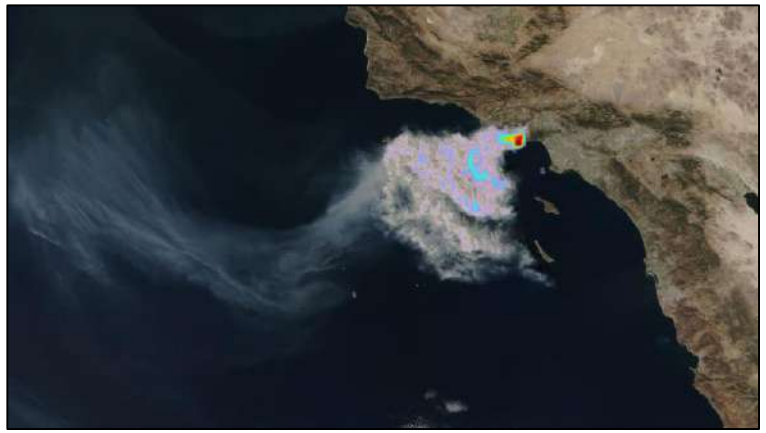
Development and **I**nterpretation of improved **N**itrous **A**cid **R**etrievals

- Development of HONO VCD product from UV-vis sensors (TROPOMI, OMI, GEMS)
  - spectral fitting (SCDs) **=> This talk: Can we improve the HONO spectral fitting?**
  - radiative transfer in smoke plumes (AMFs)
- Development of HONO VCD product from TIR sensors (IASI, GIIRS)
- Cal/Val activities
- Interpretation and modelling
- Dissemination of output data sets

- Webpage: http://hono.aeronomie.be
- Contact: theys@aeronomie.be



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ULB

Spectral fitting improvement

Covariance-based retrieval algorithm (COBRA)

Theys et al., ACP, 2021

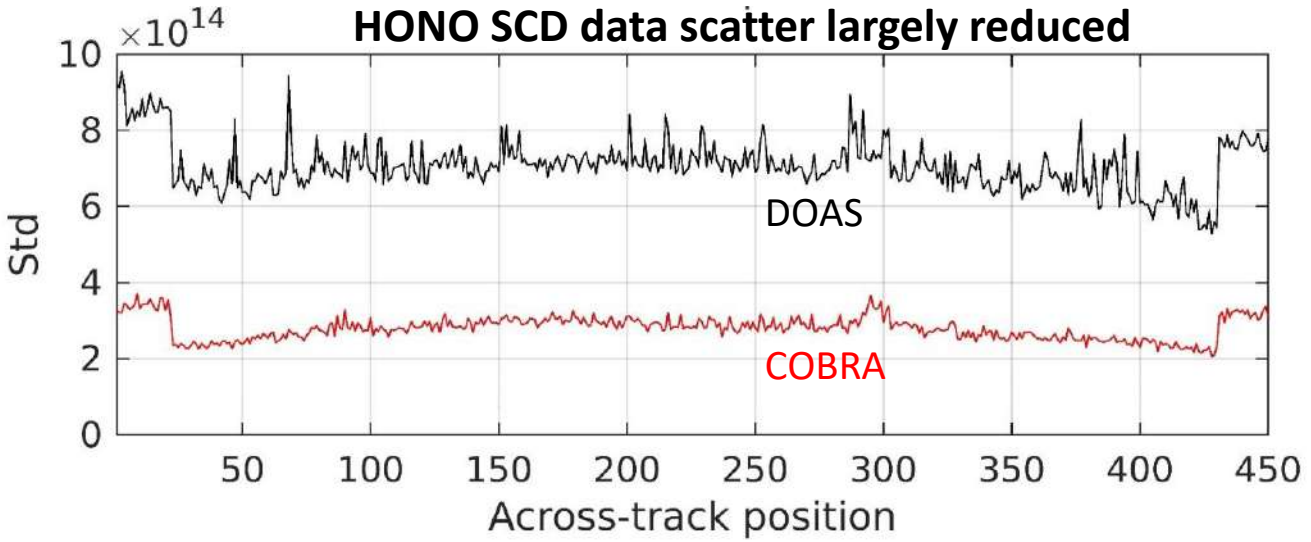
$$y = k.SCD + y_{bkg} + \epsilon$$

y: -log(I/Io) (I, Io: wvl calibrated spectra)
k, SCD: cross-section and slant column of HONO
y_{bkg}: optical depth without contribution from HONO
ϵ : measurement noise

y_{bkg} statistical characterization from a set of HONO-free spectra by S and $\bar{y}$ (covariance matrix and mean spectrum)

$$\longrightarrow \quad \boxed{\widehat{SCD} = (k^T S^{-1} k)^{-1}.k^T S^{-1}.(y - \bar{y})}$$

HONO SCD data scatter largely reduced



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Spectral fitting improvement

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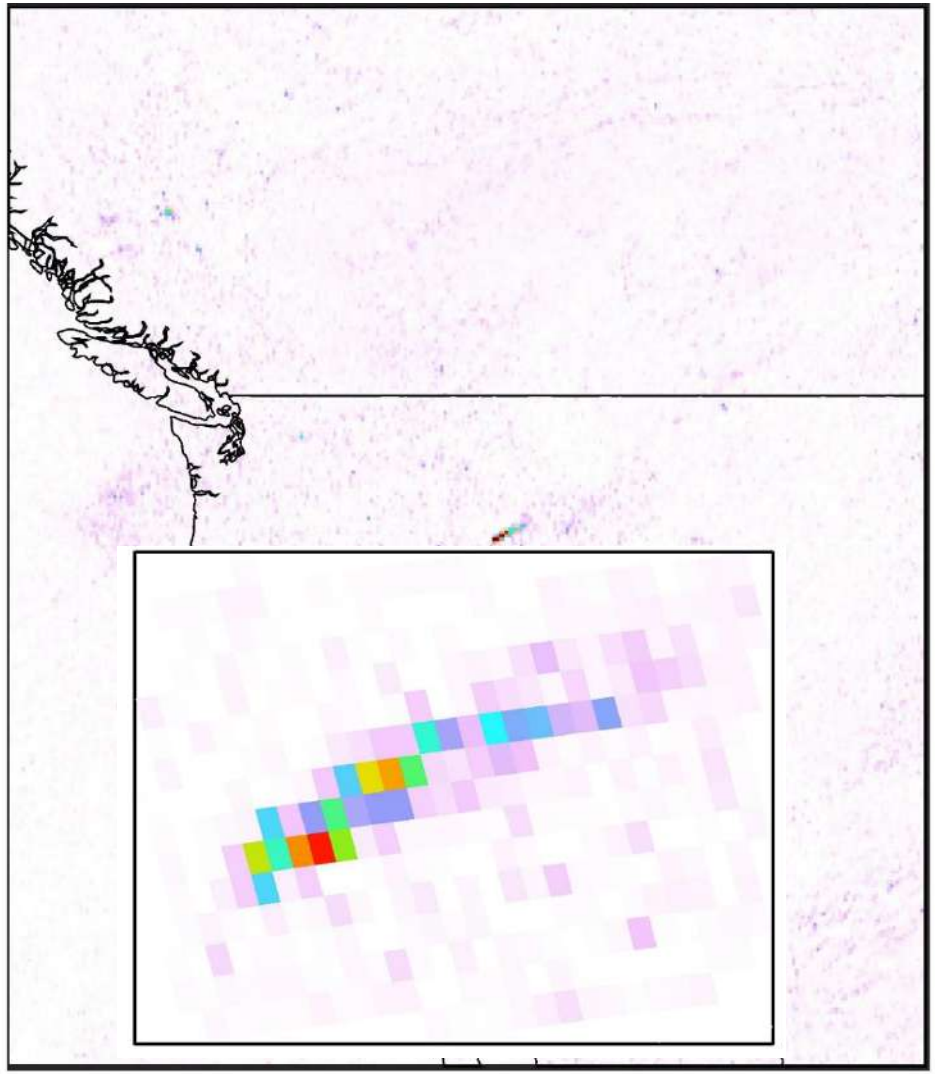
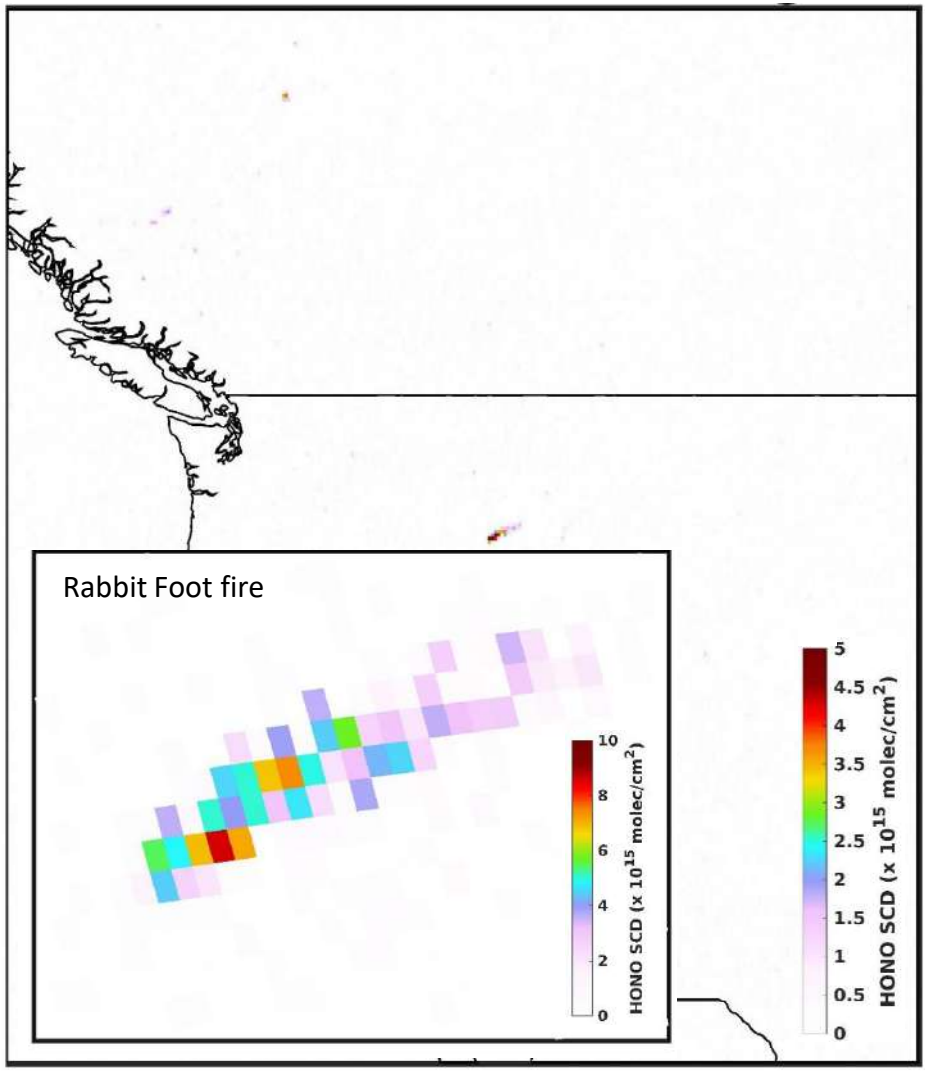
DOAS



COBRA



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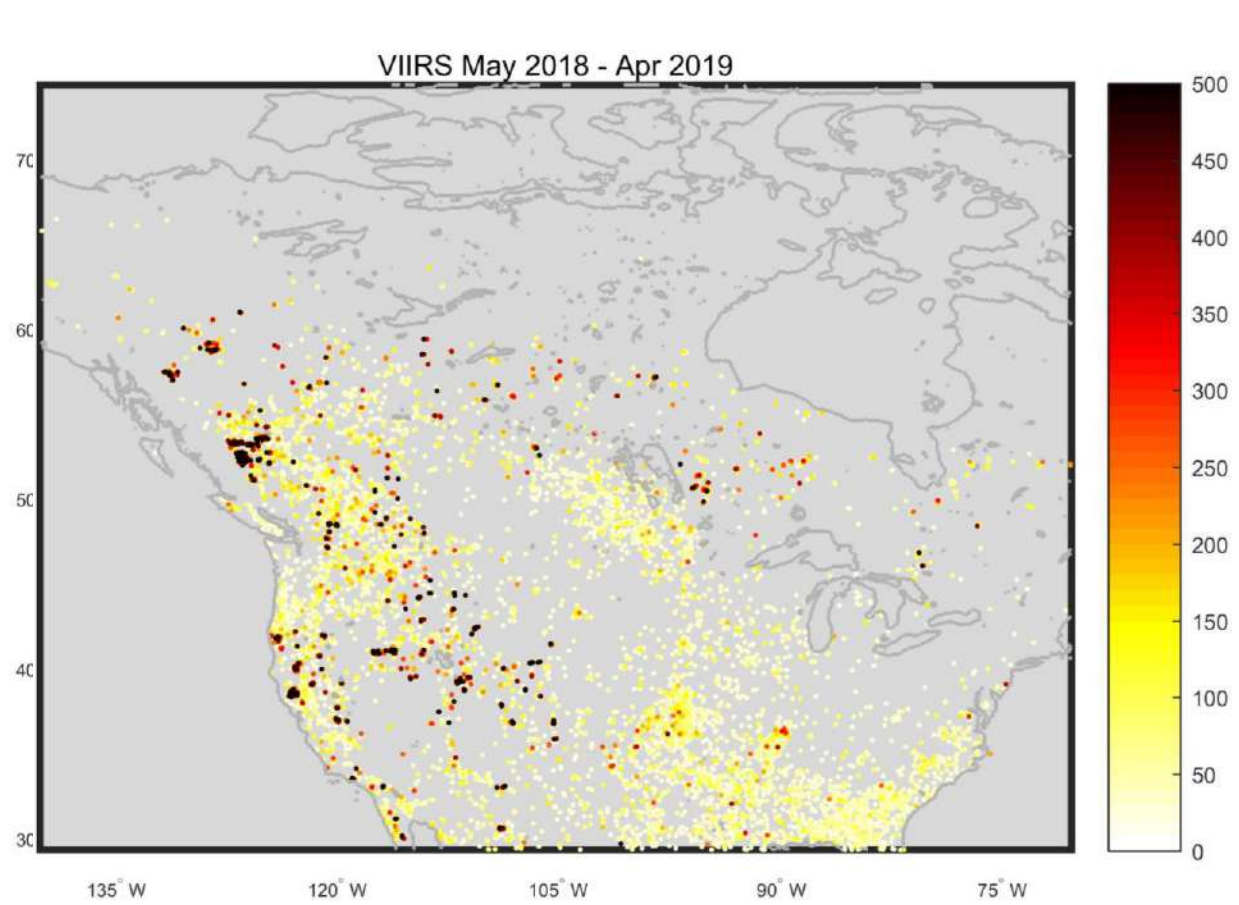
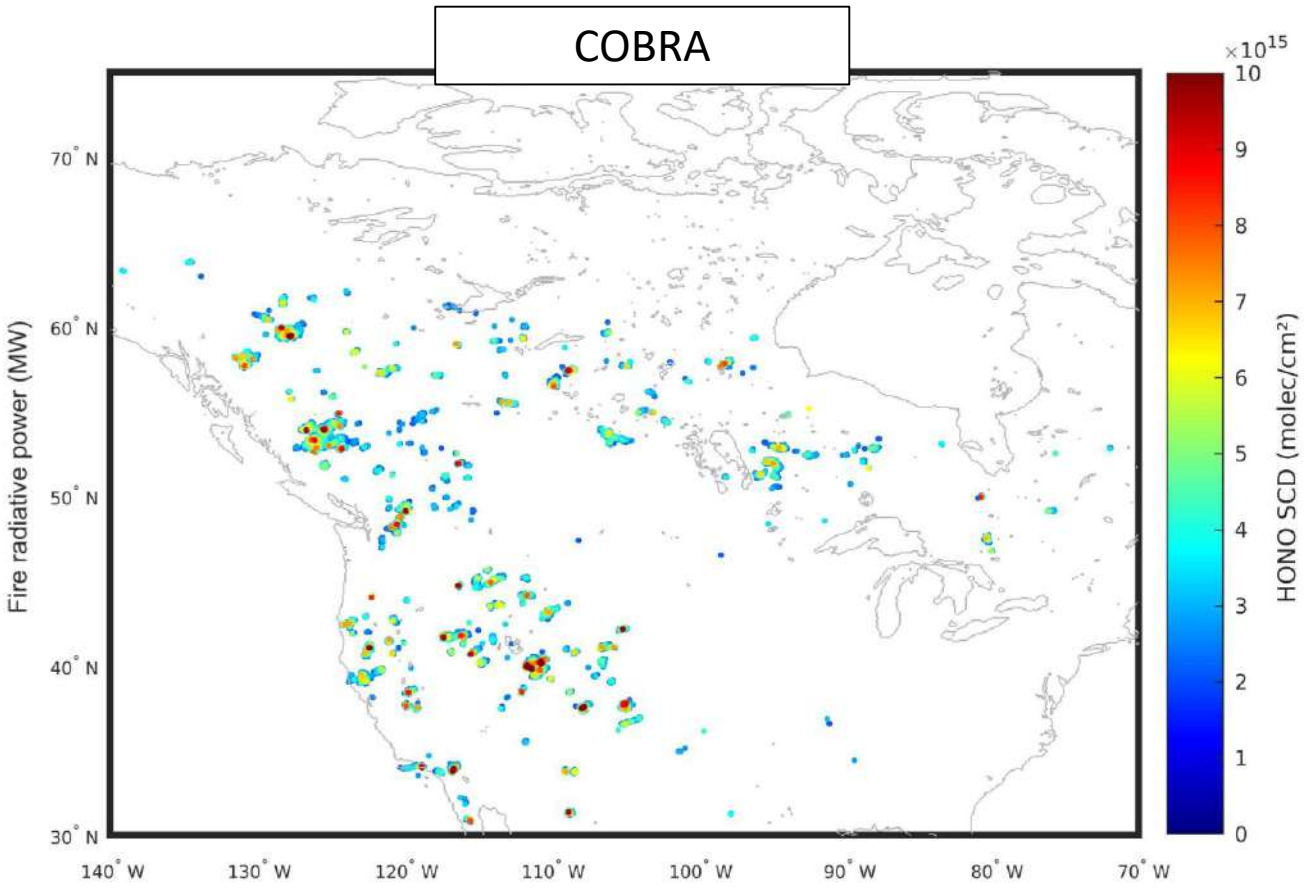
12 August 2018

Spectral fitting improvement

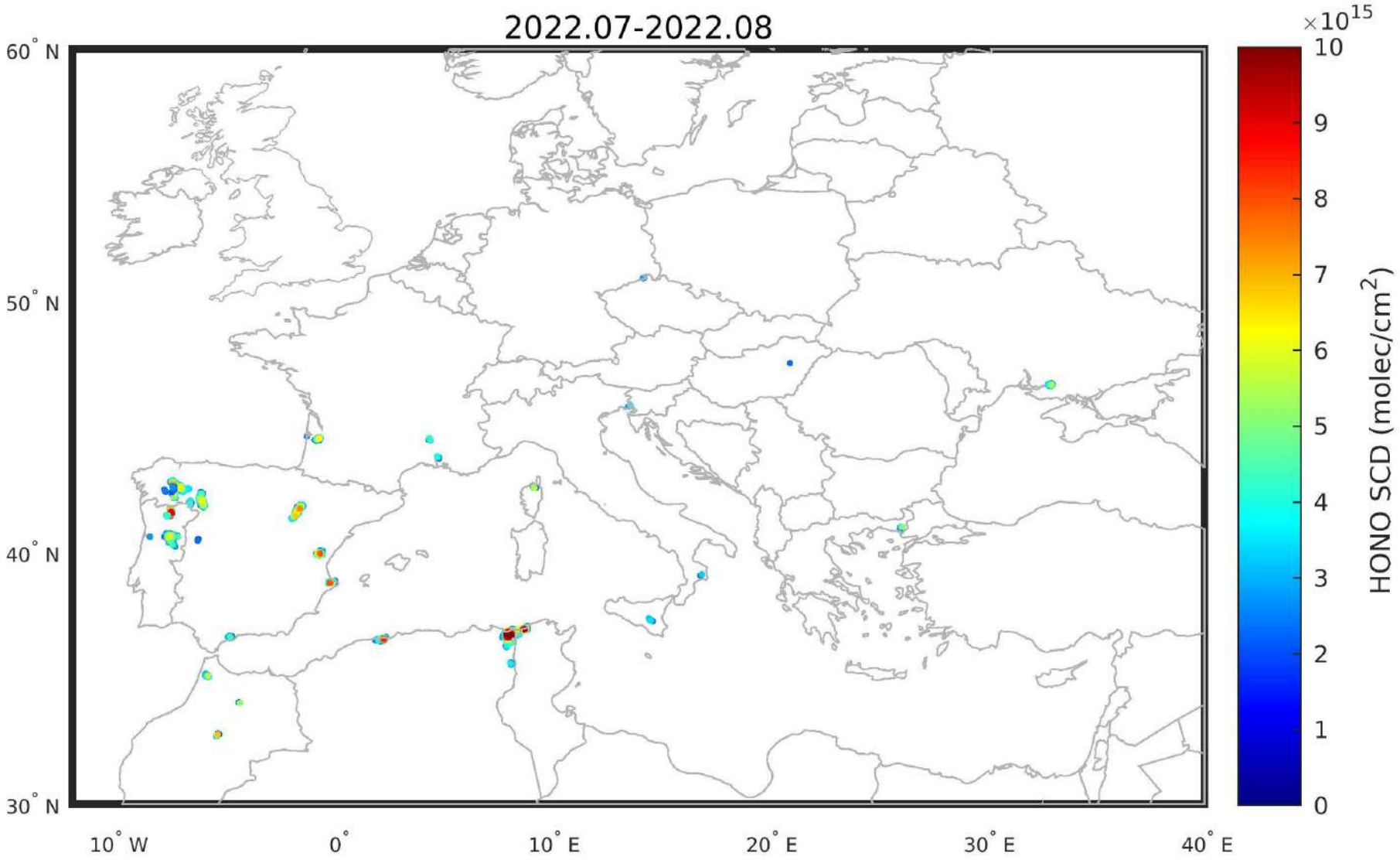
Number of HONO detections increased by a factor of 4 using COBRA





May 2018-Apr 2019

Europe summer 2022



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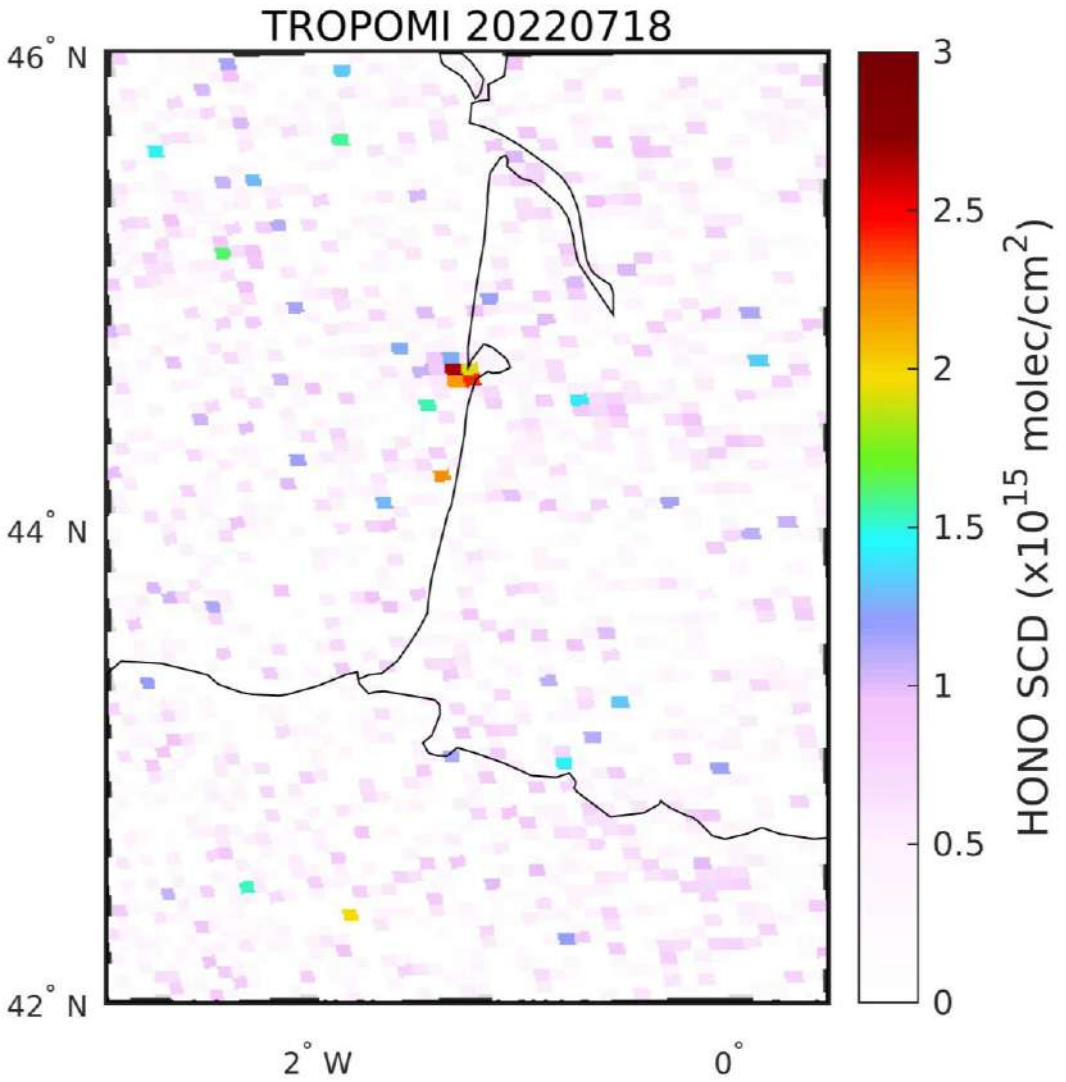
Girondes (France)



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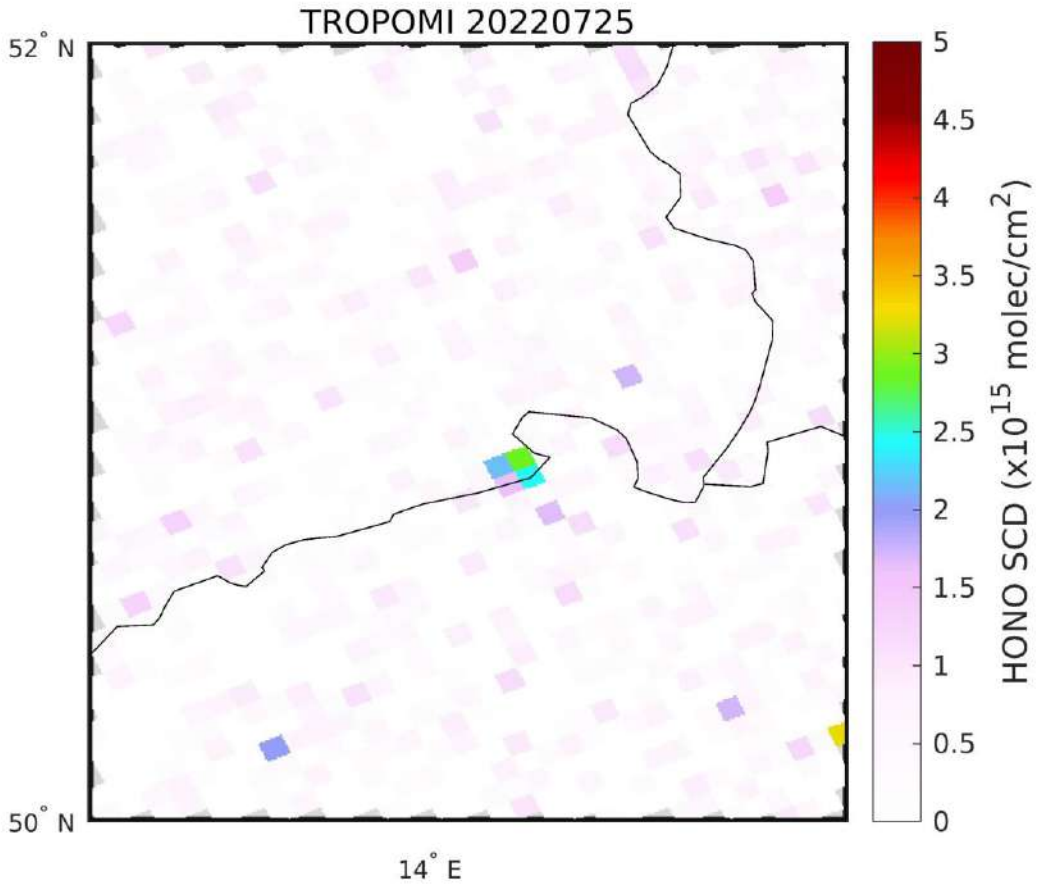
Germany-Czech Republic border



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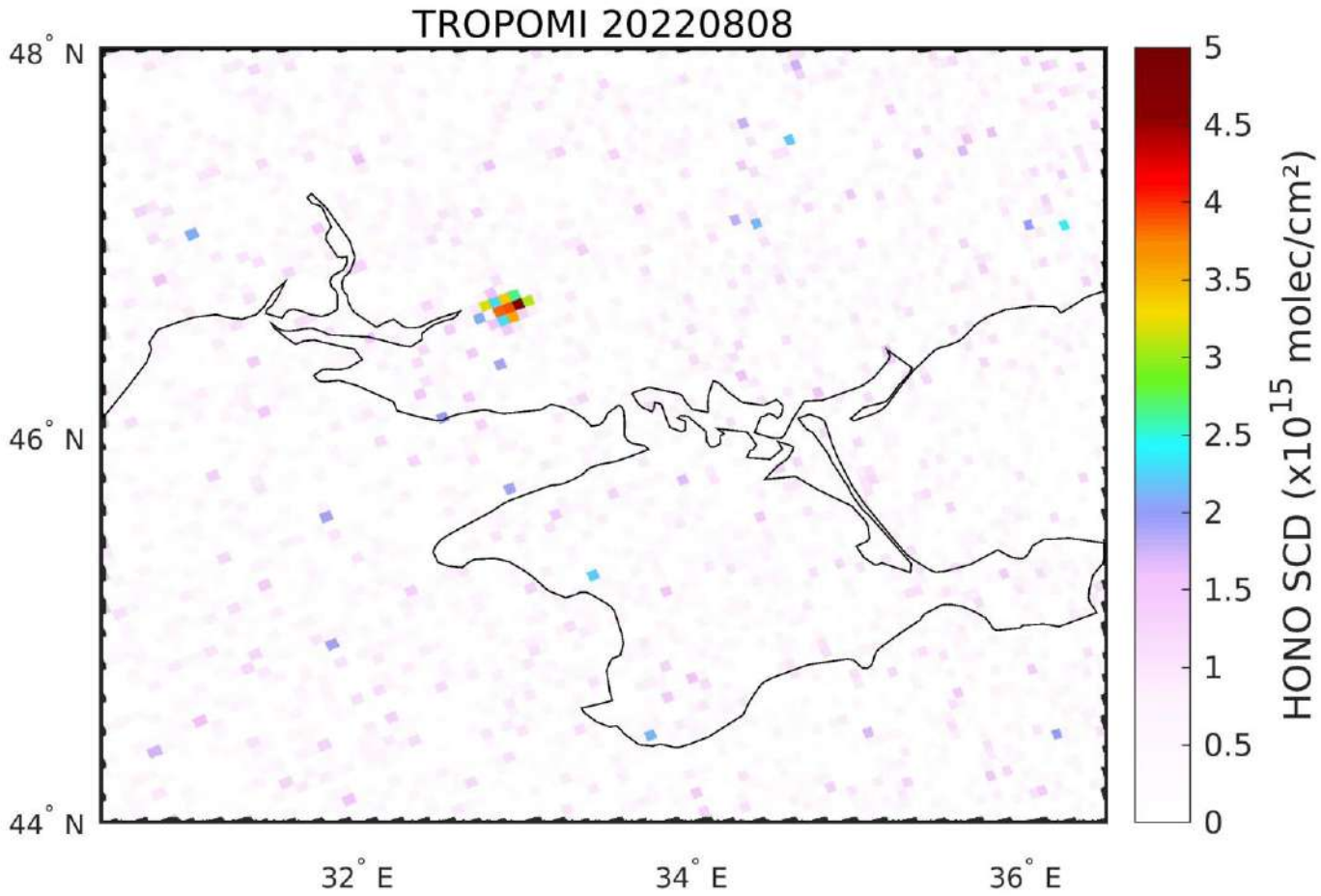
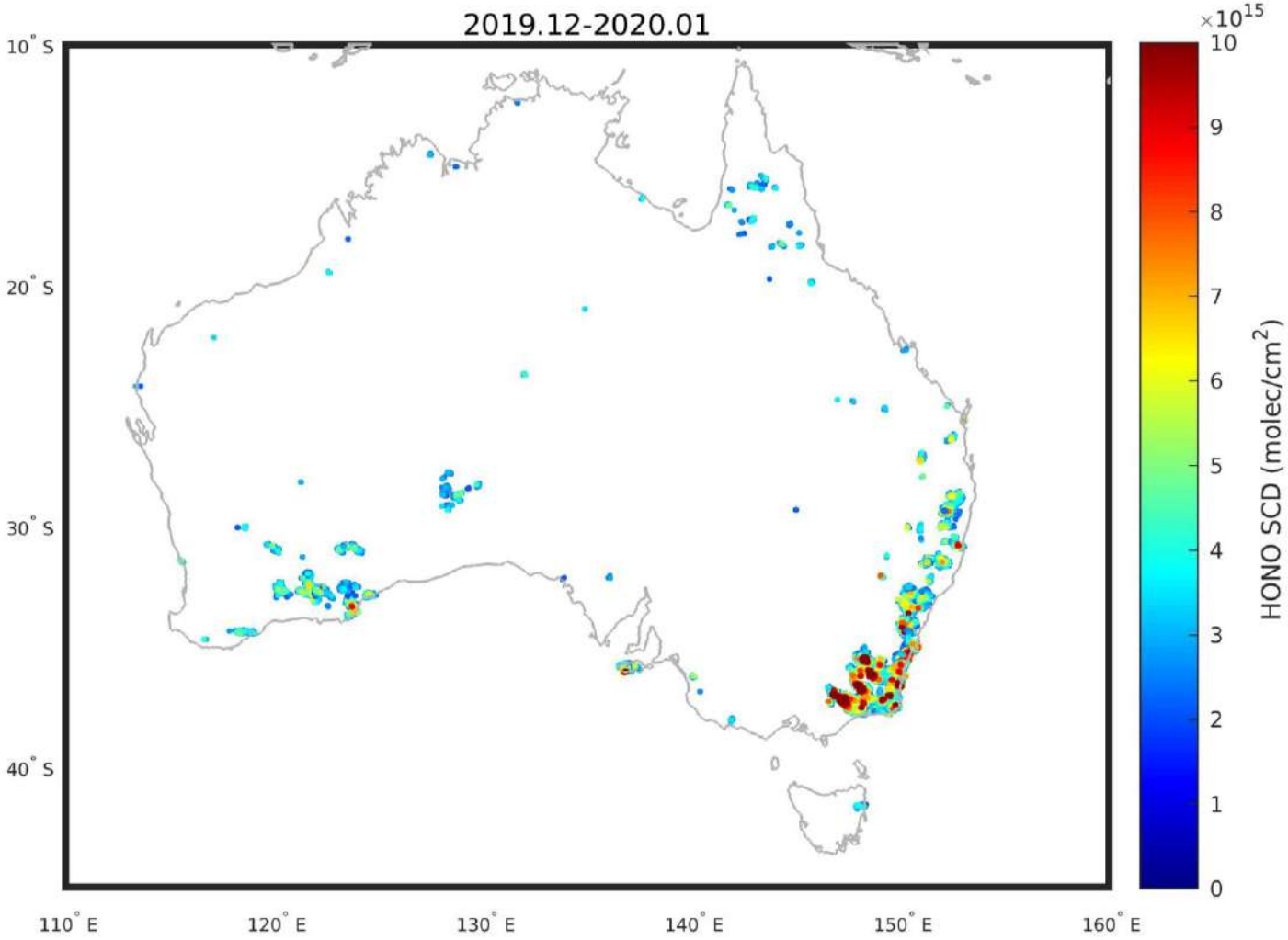
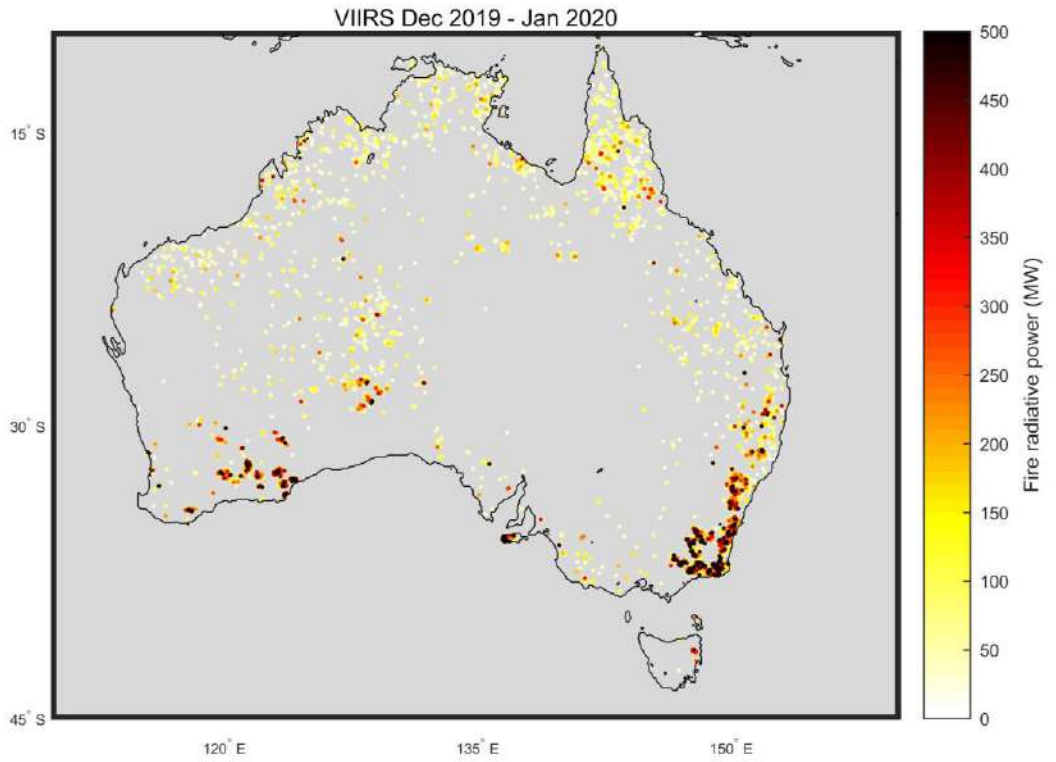
Ukraine


Mykolaiv
Kherson
Ochakiv
Nova Kakhovka
Chaplynka
Skadovsk
Krasnoperekopsk

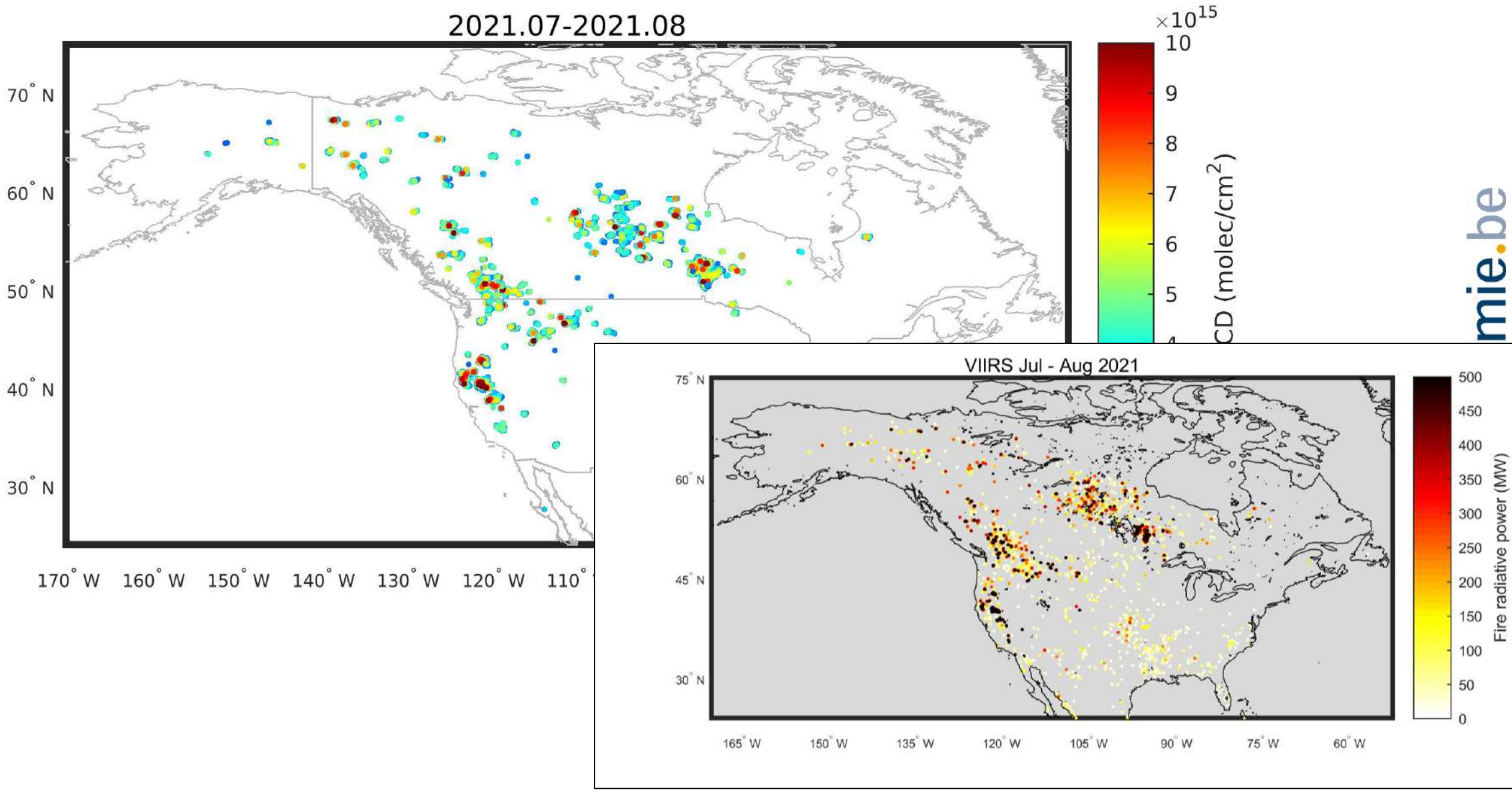

TROPOMI 20220808
48° N
46° N
44° N
32° E
34° E
36° E
HONO SCD (x10^15 molec/cm²)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

Australia

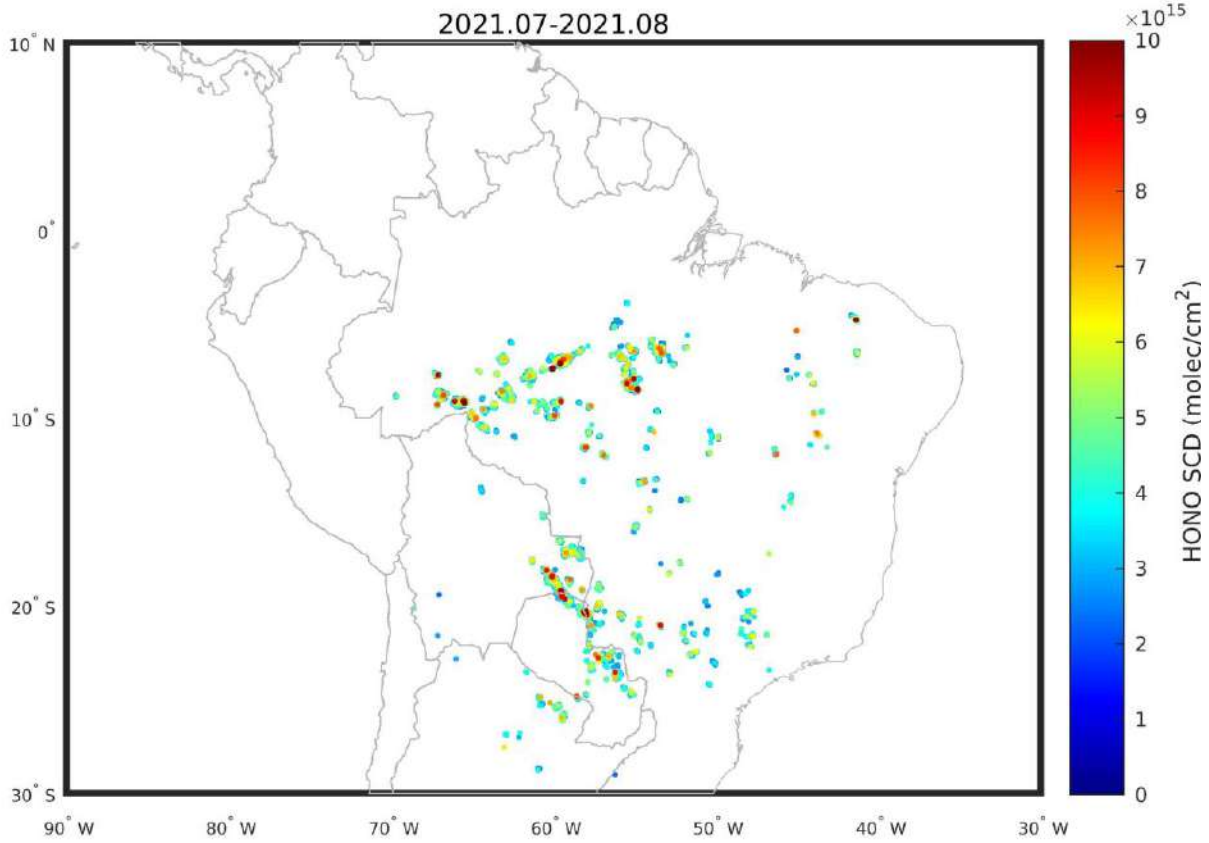

2019.12-2020.01
10° S
20° S
30° S
40° S
110° E
120° E
130° E
140° E
150° E
160° E
×10^15
10
9
8
7
6
5
4
3
2
1
0
HONO SCD (molec/cm^2)

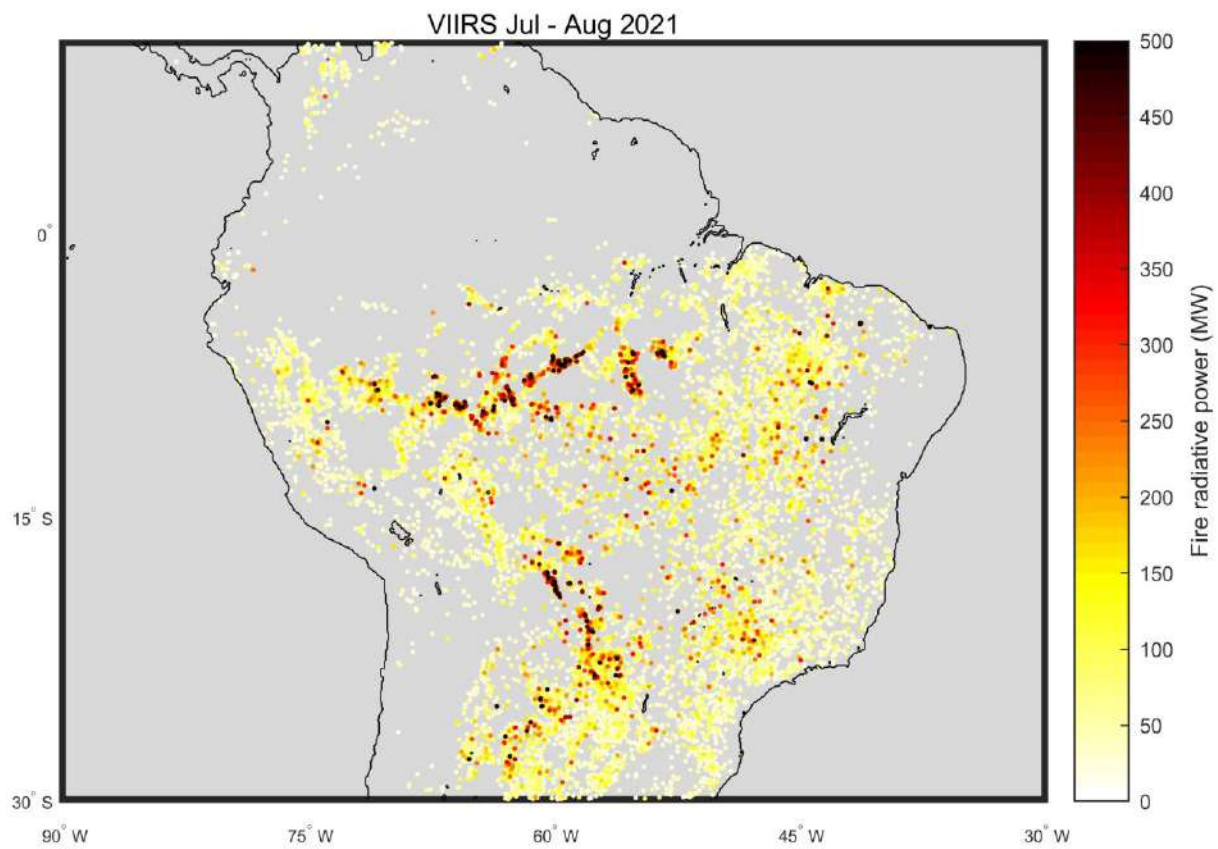

VIIRS Dec 2019 - Jan 2020
15° S
30° S
45° S
120° E
135° E
150° E
500
450
400
350
300
250
200
150
100
50
0
Fire radiative power (MW)

US-Canada


2021.07-2021.08
70° N
60° N
50° N
40° N
30° N
170° W
160° W
150° W
140° W
130° W
120° W
110°
×10^15
10
9
8
7
6
5
CD (molec/cm^2)
VIIRS Jul - Aug 2021
75° N
60° N
45° N
30° N
165° W
150° W
135° W
120° W
105° W
90° W
75° W
60° W
500
450
400
350
300
250
200
150
100
50
0
Fire radiative power (MW)

Amazon


2021.07-2021.08
10° N
0°
10° S
20° S
30° S
90° W
80° W
70° W
60° W
50° W
40° W
30° W
×10^15
10
9
8
7
6
5
4
3
2
1
0
HONO SCD (molec/cm^2)


VIIRS Jul - Aug 2021
0°
15° S
30° S
90° W
75° W
60° W
45° W
30° W
500
450
400
350
300
250
200
150
100
50
0
Fire radiative power (MW)

HONO detections

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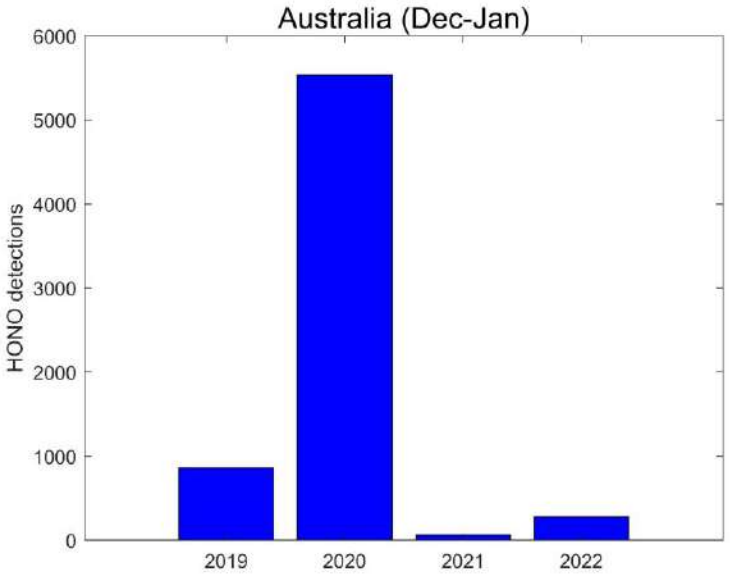

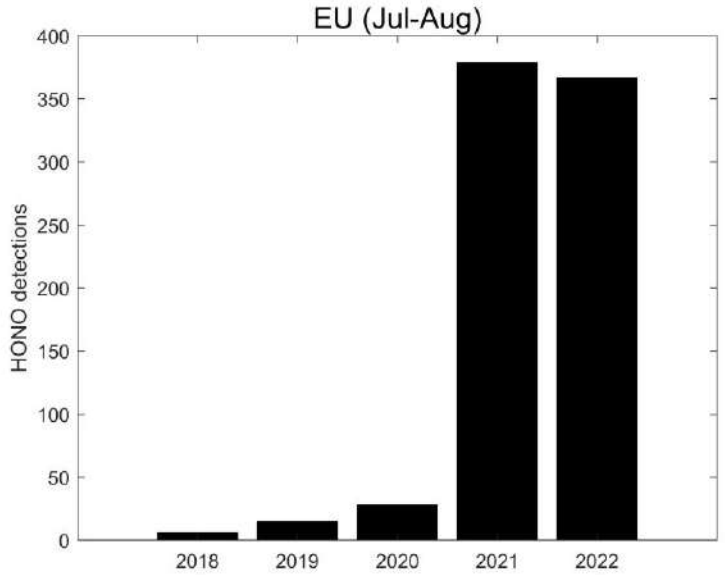

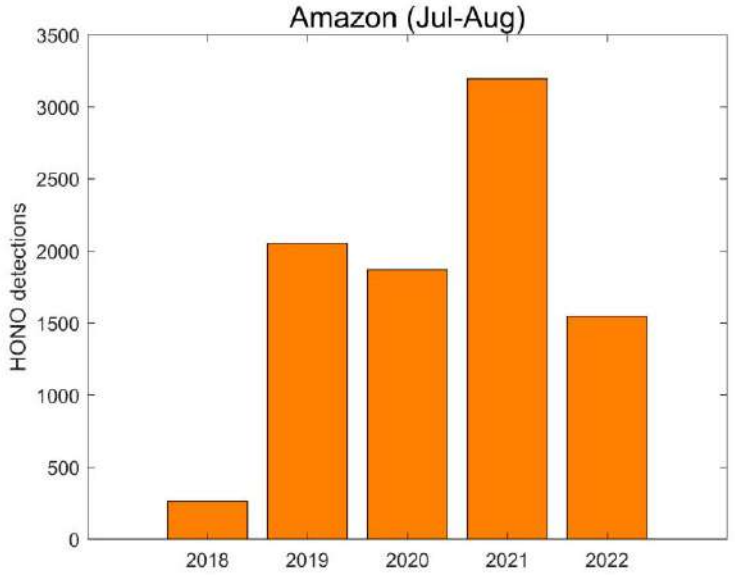

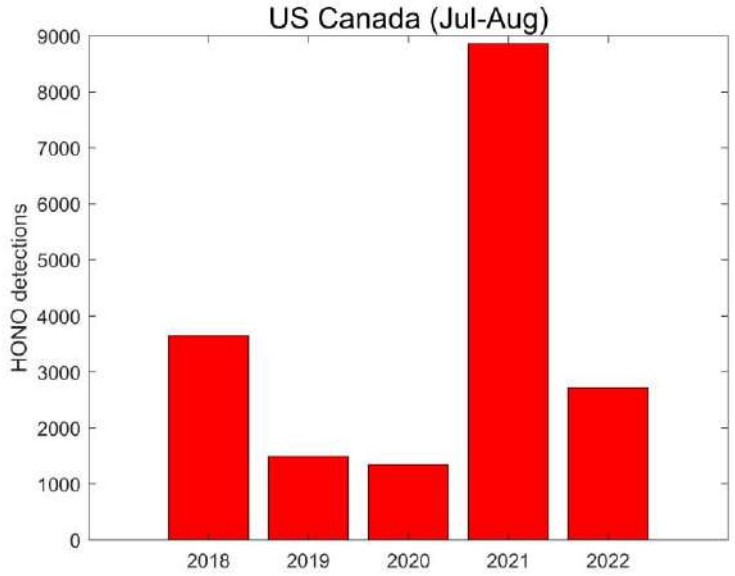

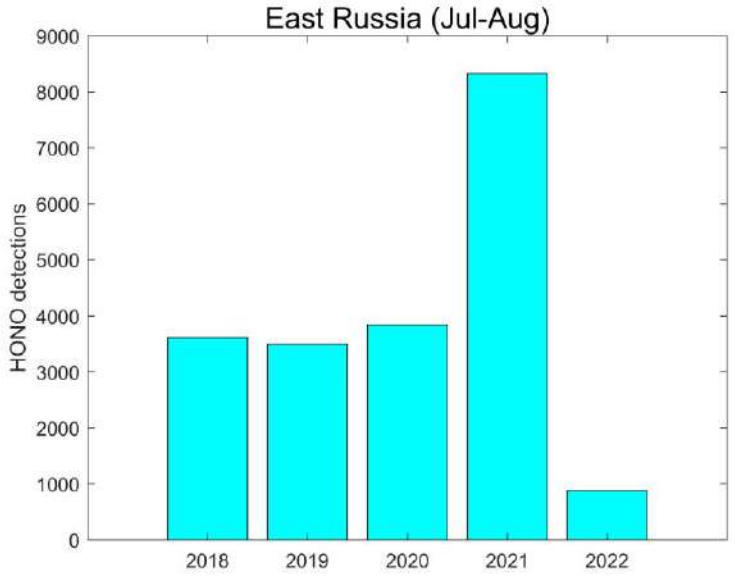

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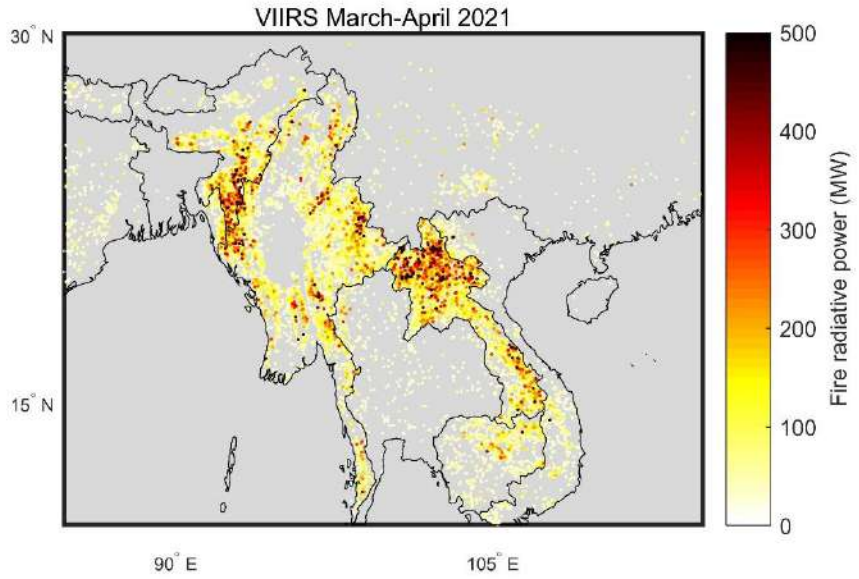
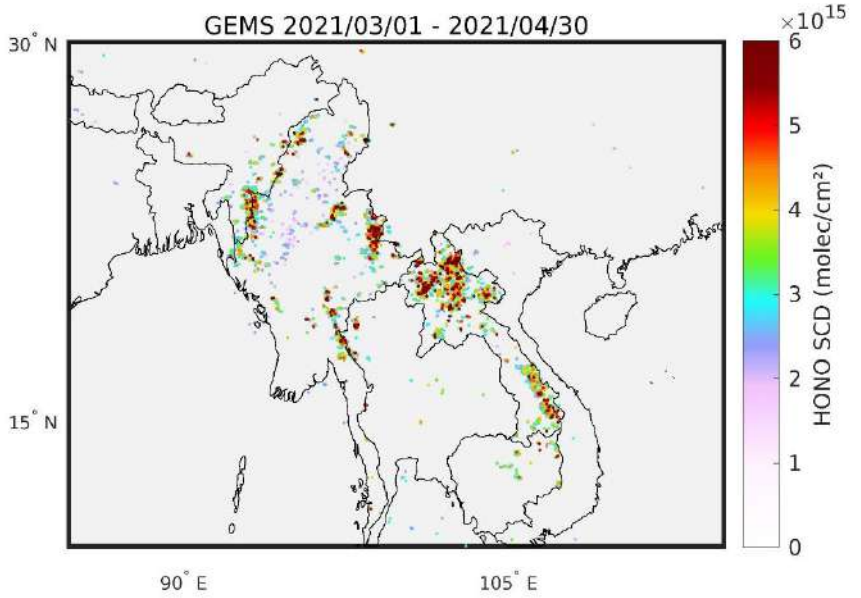
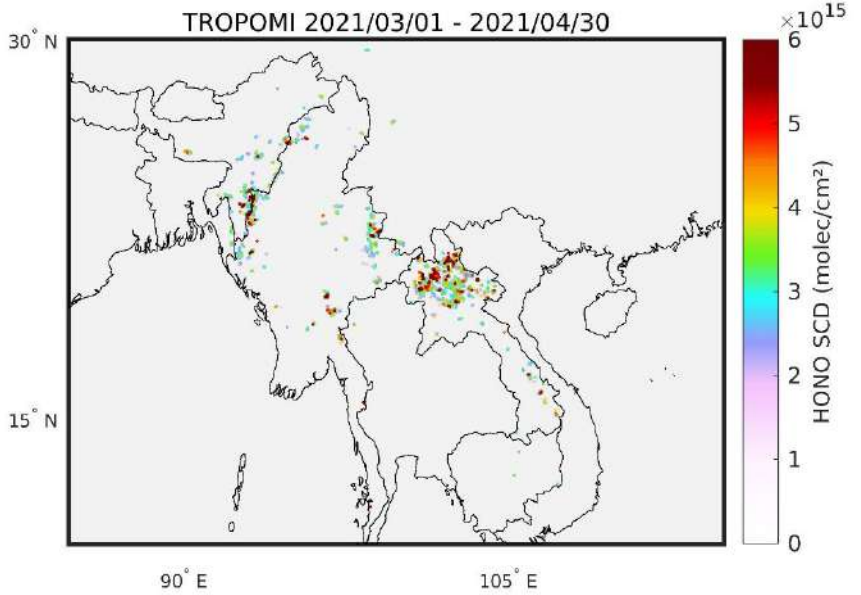
Geostationary HONO observations







- Good spatial match between FRP-based fire locations and pixels with confident HONO detection.
- Many more HONO detections with GEMS compared to TROPOMI, in part due to better temporal sampling.

The next steps

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Development and **I**nterpretation of improved **N**itrous **A**cid **R**etrievals

- Development of HONO VCD product from UV-vis sensors (TROPOMI, OMI, GEMS)
  - spectral fitting (SCDs)
  - radiative transfer in smoke plumes (AMFs)
- Development of HONO VCD product from TIR sensors (IASI, GIIRS)
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- Interpretation and modelling
- Dissemination of output data sets

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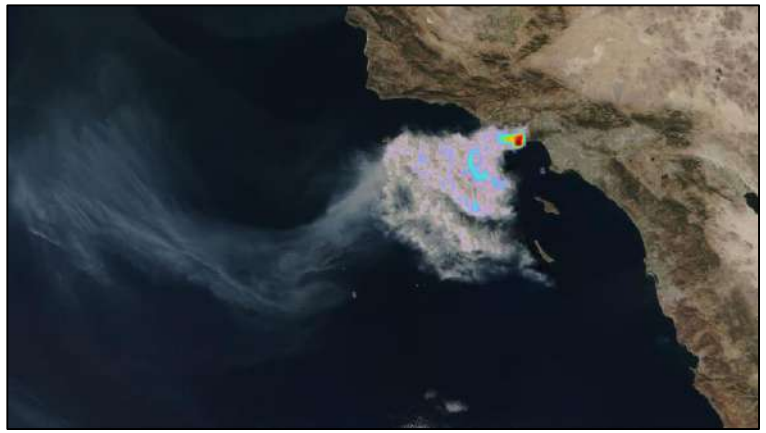

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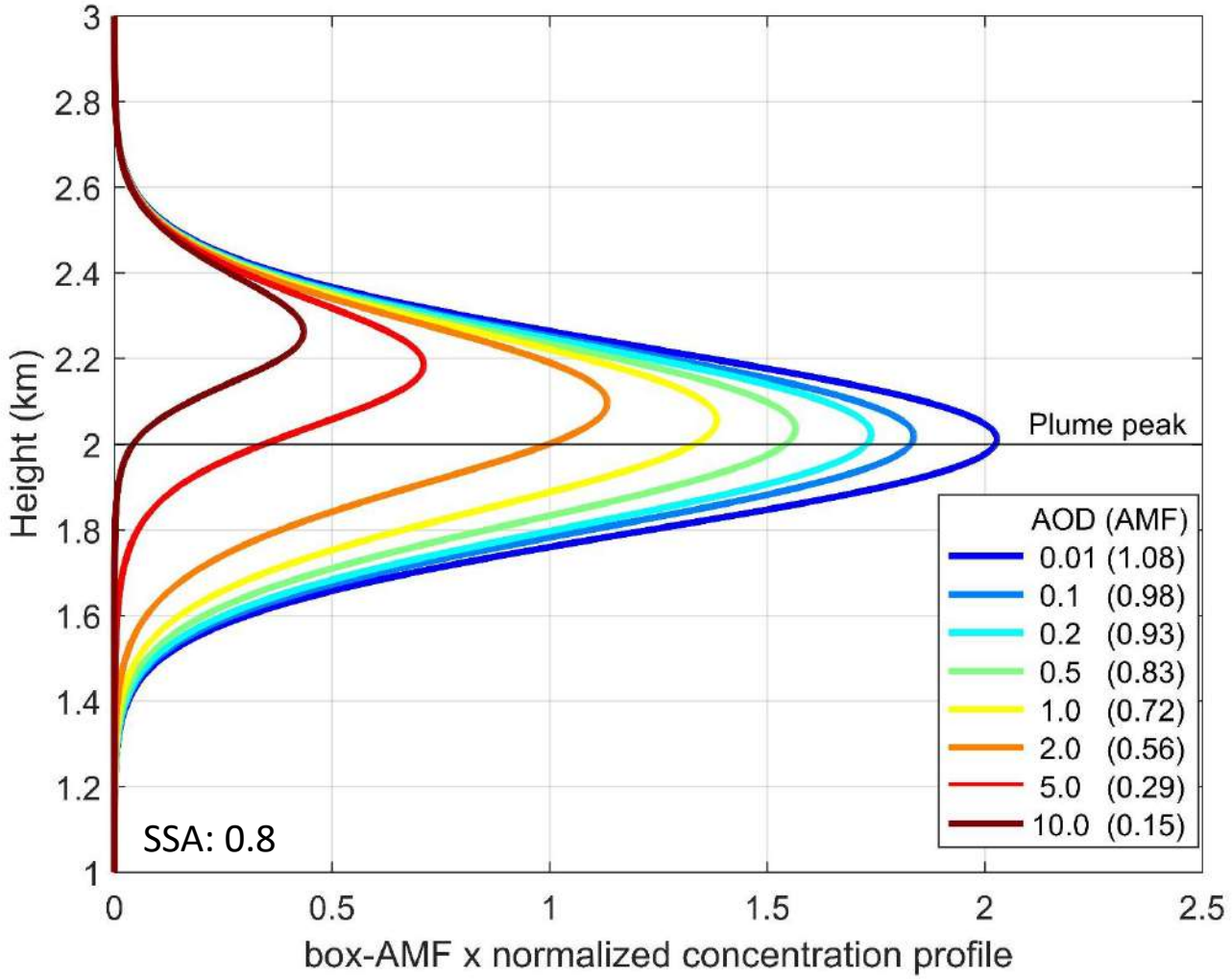
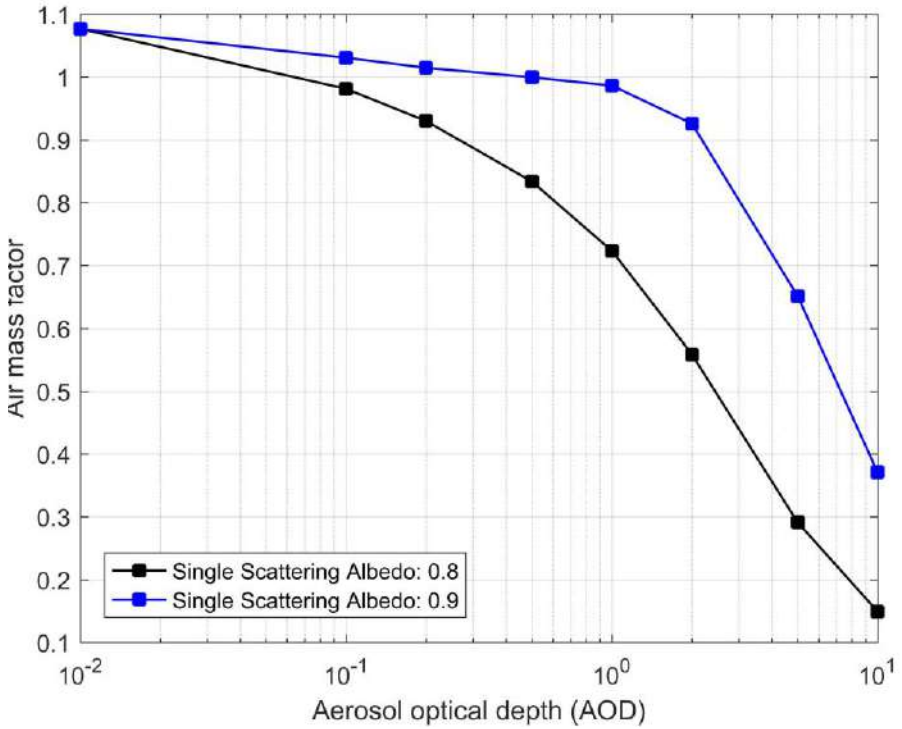
ULB

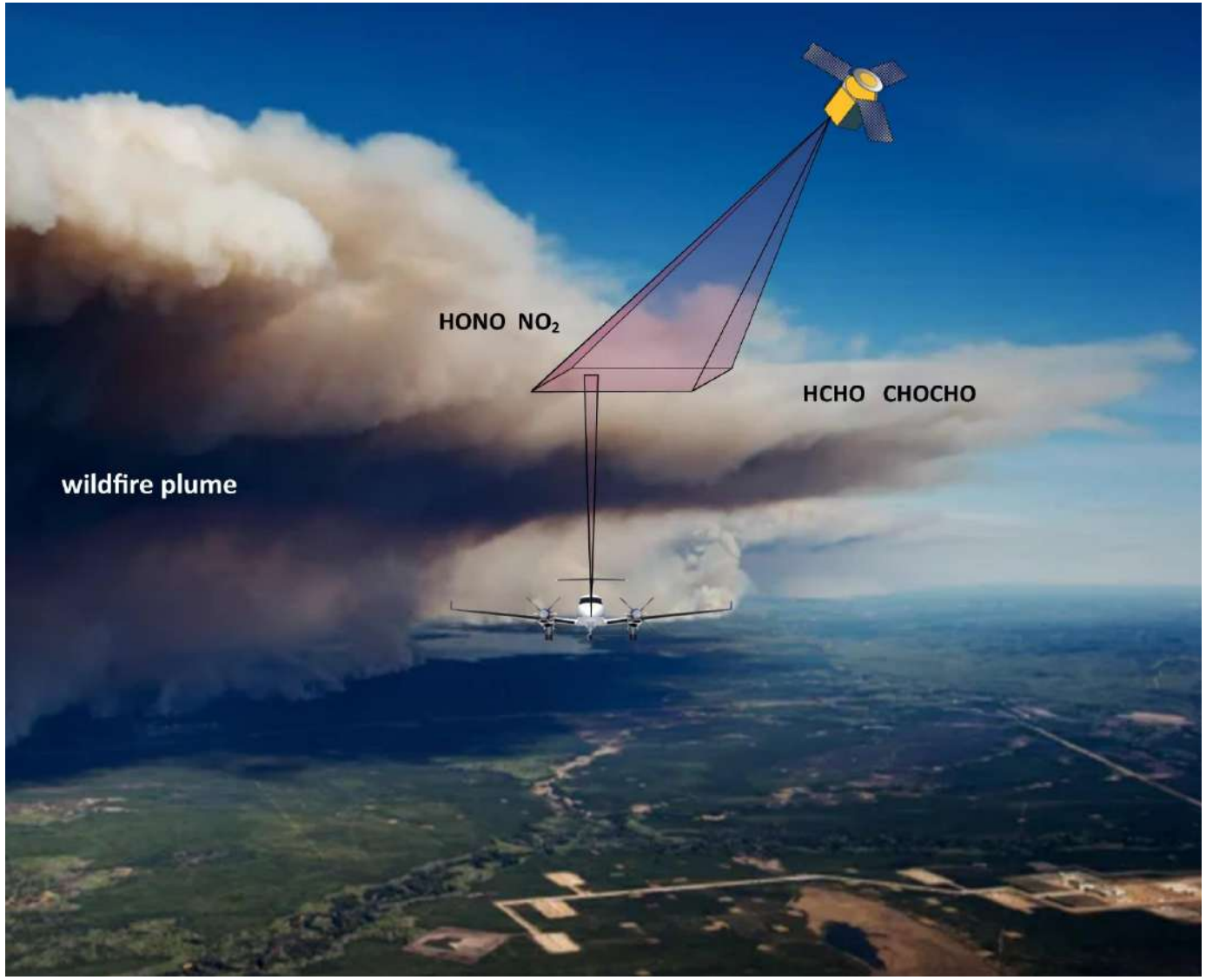
Radiative tranfer in smoke plumes

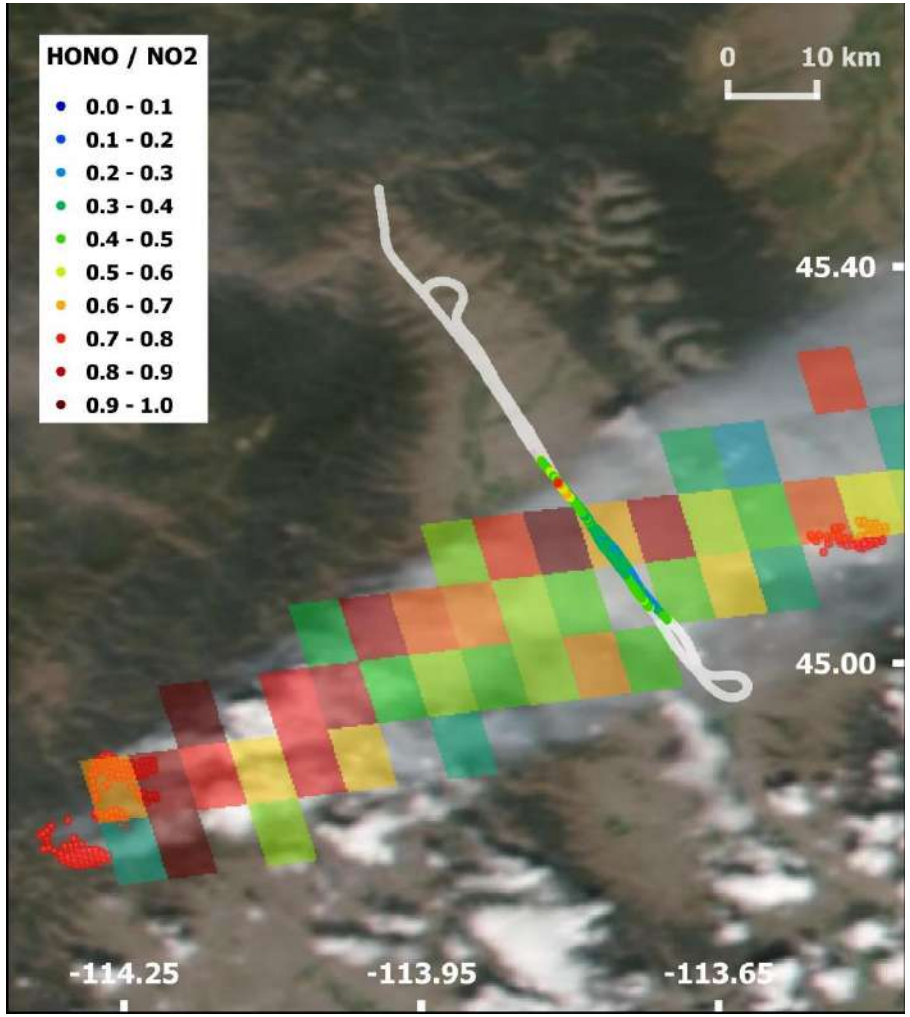
Impact of biomass burning aerosols on measurement sensitivity





Validation: challenging!





Comparison of $HONO/NO_2$ with aircraft data (BBFLUX)

Conclusions

- Covariance-Based Retrieval Algorithm (COBRA) scheme improves significantly the detection of HONO.

- TROPOMI and GEMS HONO SCD retrievals are promising.
  HONO is detected over many fire locations worldwide.

- Development of TROPOMI HONO product ongoing.
  Dissemination expected by the end of the DINAR project (mid-2024).

- More research needed on validation and interpretation of the results, as well as modelling.

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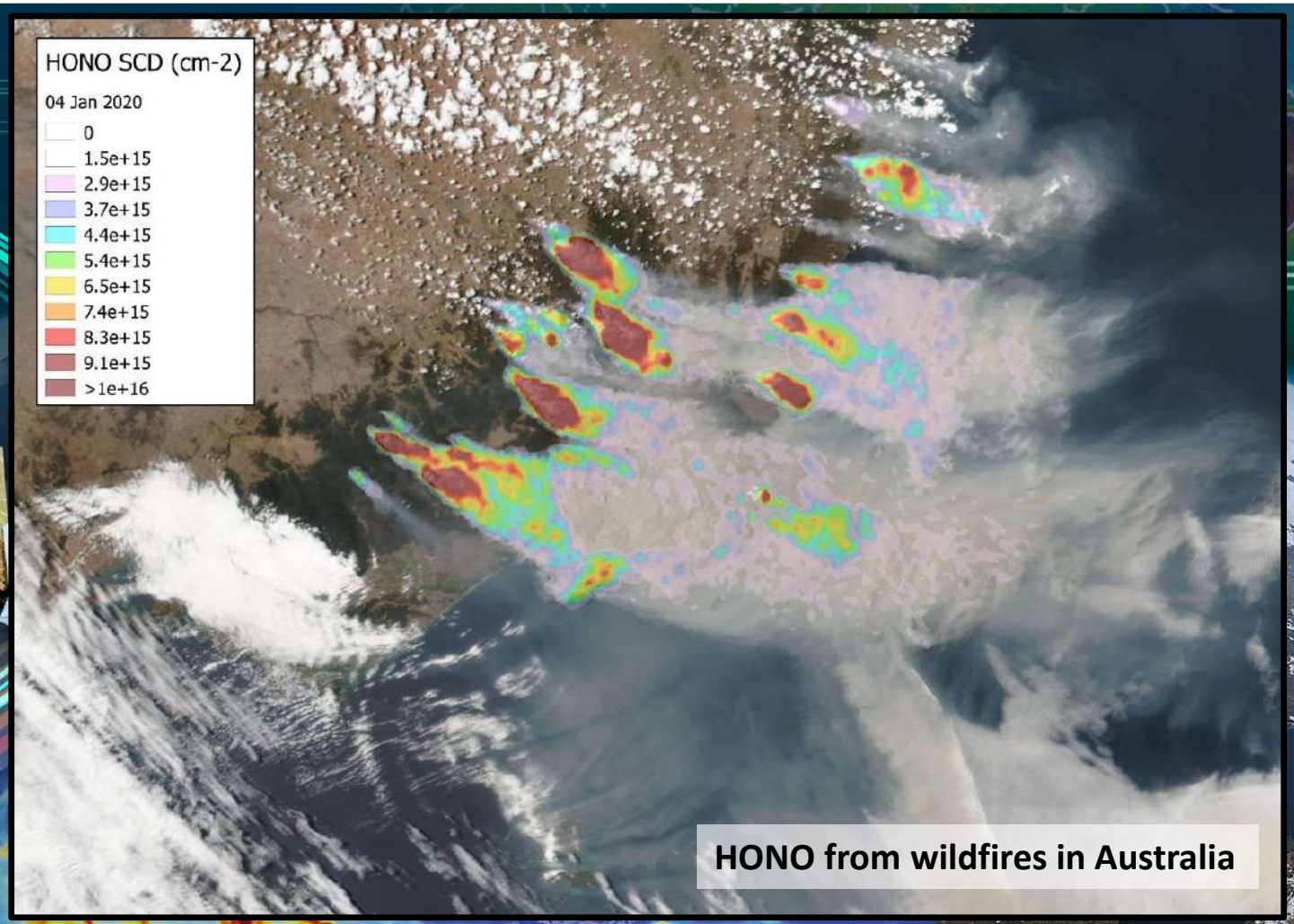
Thank you for your attention!



HONO from wildfires in Australia

belspo