Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management

on the use of daily S5p trace gas & aerosol observations for characterizing wildfires

Jos de Laat#

Royal Netherlands Meteorological Institute (KNMI)

Vincent Huijnen | KNMI | NL
Niels Andela | Cardiff University | UK
Matthias Forkel | Technical University Dresden | GE

Christopher Marrs (GE)
Christine Wessollek (GE)
Alfred Awotwi (UK)
Martin de Graaf (NL)

TECHNISCHE UNIVERSITÄT DRESDEN | CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD | Sense4 Fire | esa

wildfires

- important contribution to the global carbon budget
- important for air quality

- numbers and intensity may increase in a warmer climate
- increased damages due to increased human activities in fire-prone areas

- wildfire (carbon) emissions are notoriously uncertain

ESA Sense⁴Fire project

wildfires

- satellite observations have played a crucial role in estimating wildfire (carbon) emissions
- use of (new) satellite observations is still underdeveloped and/or underused

• suite of **ESA sentinel** satellites provide new/additional wildfire-relevant information
  - fuel load
  - fuel moisture
  - vegetation type
  - spatio-temporal fire dynamics
  - trace gases
  - aerosols

poster 64809, Huijnen et al.
Tuesday 17:00-19:00

poster 64815, Forkel et al.
Wednesday 17:00-19:00

talk Andela et al.
Understand Earth Systems
Friday 14:30-14:45

The ESA **Sense⁴Fire** project (start fall 2021; 2+ years):

improve the quantification of fire carbon emissions
by integrated use of ***sentinel*** *satellites* ***((1)-2-3-5p)***

sentinel-5p

- launched October 2017
- designed to observe air quality
- legacy GOME/SCIAMACHY/OMI satellites
- much improved spatial resolution (3.5x5.5 km at best)
- much improved instrument-noise

allows for daily observations of emission plumes:

- NO_2, CO, absorbing aerosol index (AAI), aerosol height (ALH or O_2A/O_2O_2-based cloud tops), HCHO, CH_4, HONO

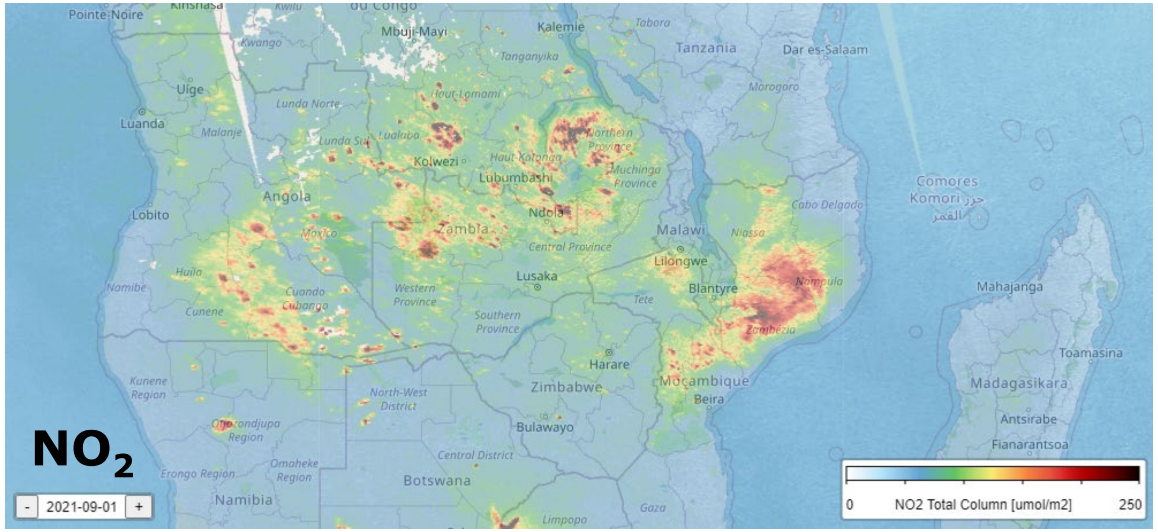
many studies on localized source published in the past years:

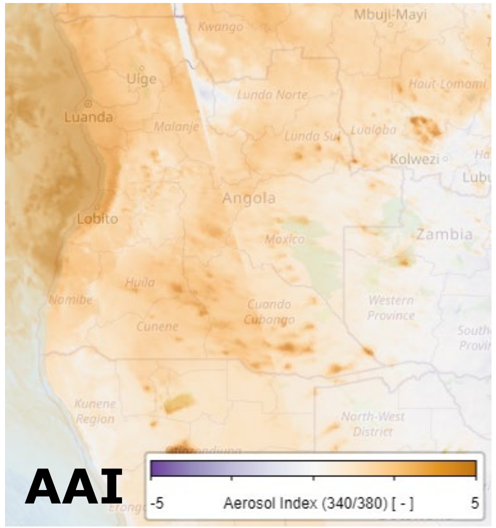
- power plants, industrial complexes, ships, etc.

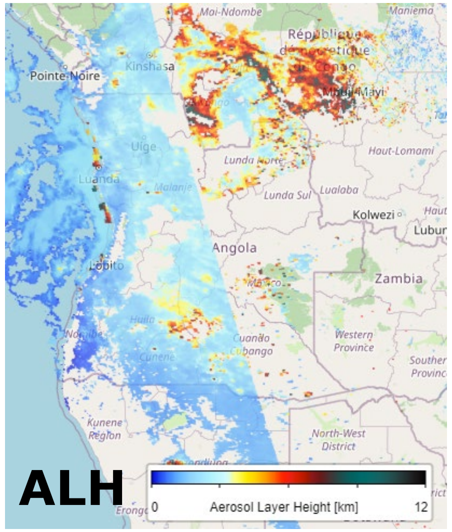
wildfires:

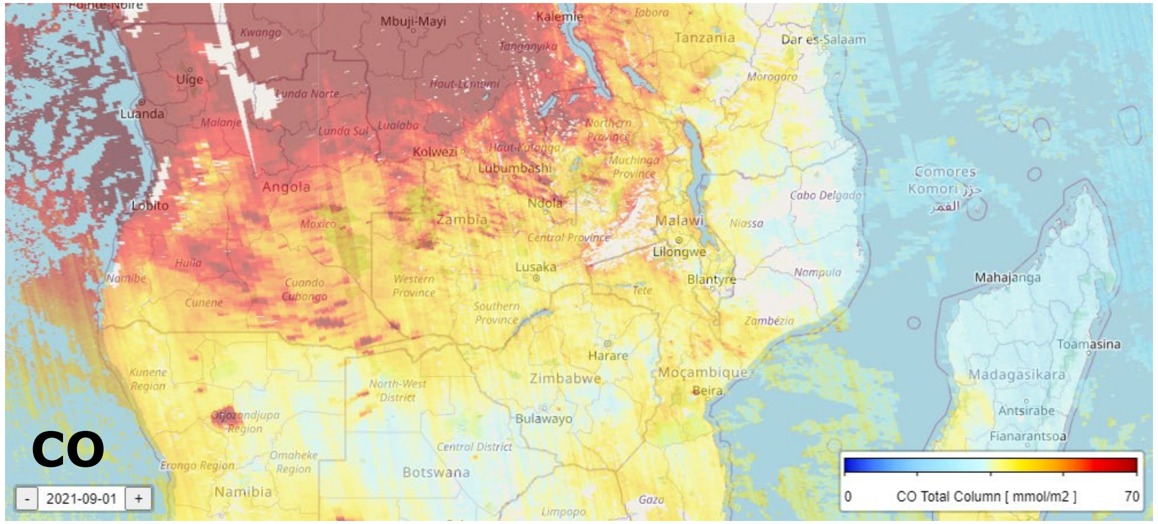
- also well captured
- sentinel-5p data use for wildfire characterization is underdeveloped/underused (untapped information)
- NO_2 : high temperature burning
- CO : low temperature burning
- burning temperature > fuel load, fuel type, fuel moisture, combustion completeness, atmospheric conditions etc.

sentinel-5p







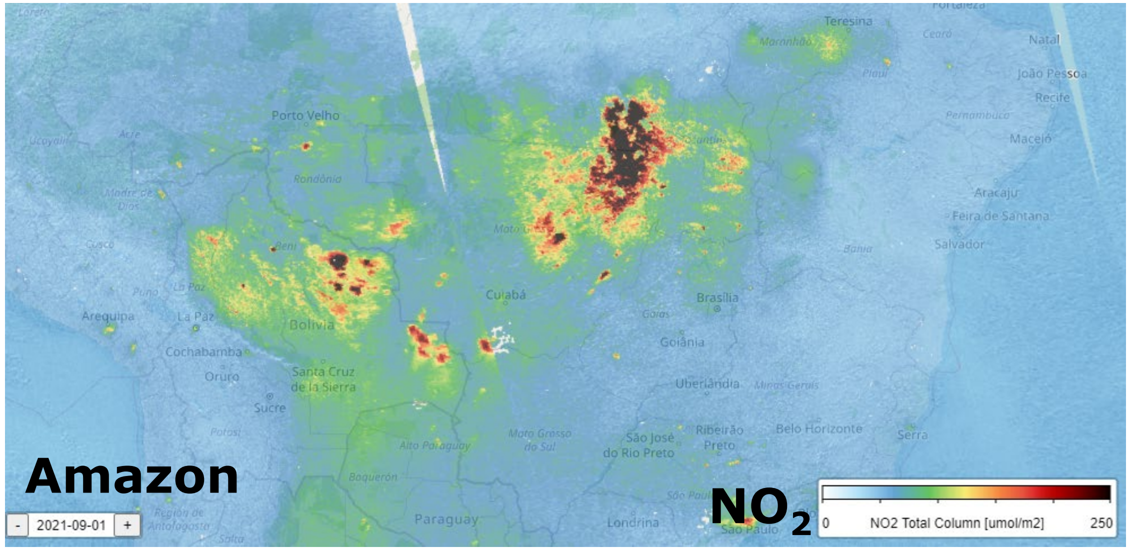


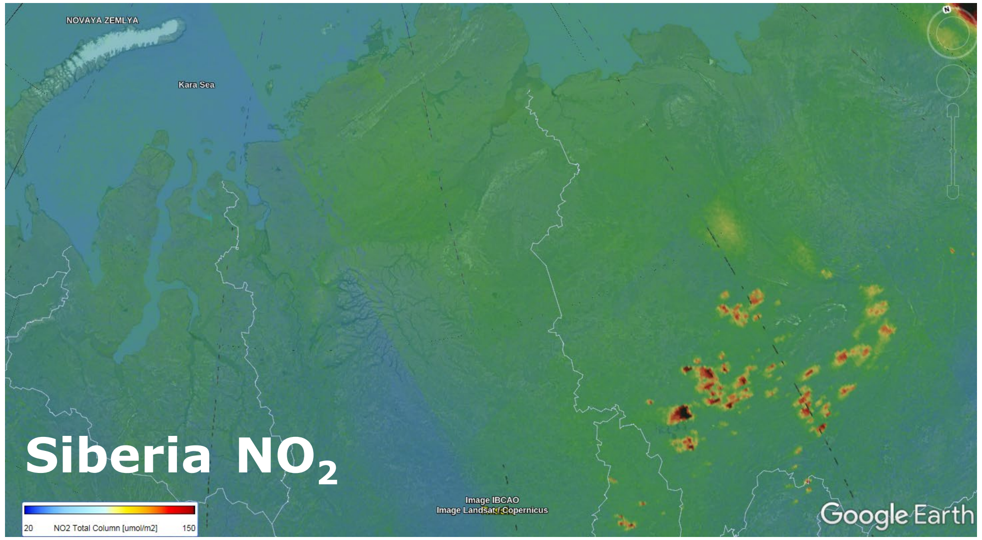
S5P identifies localized small fires

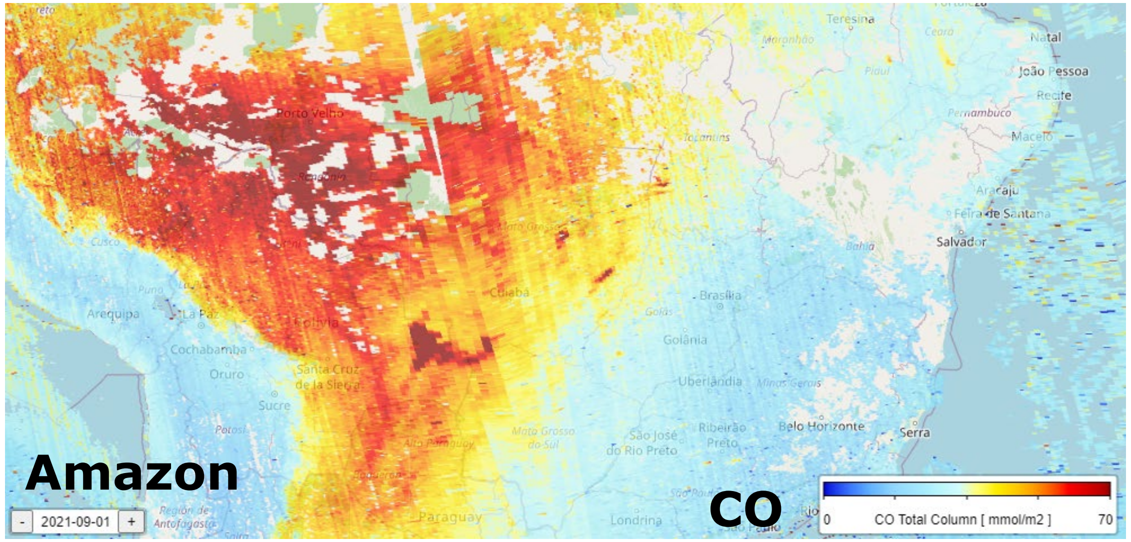
NO_2, CO, AAI, ALH spatially consistent

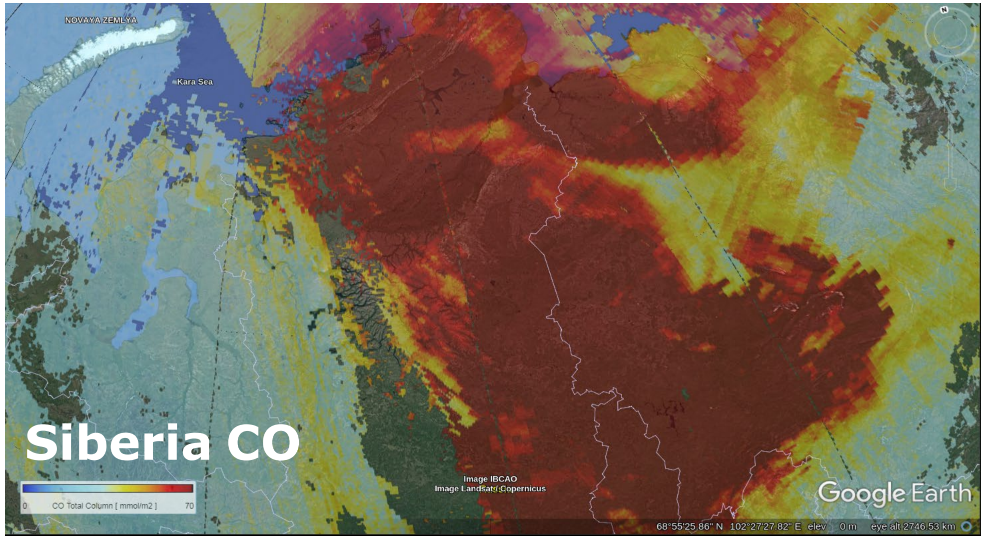
example: Africa, 1 September 2021

S5P: Amazon, Siberia

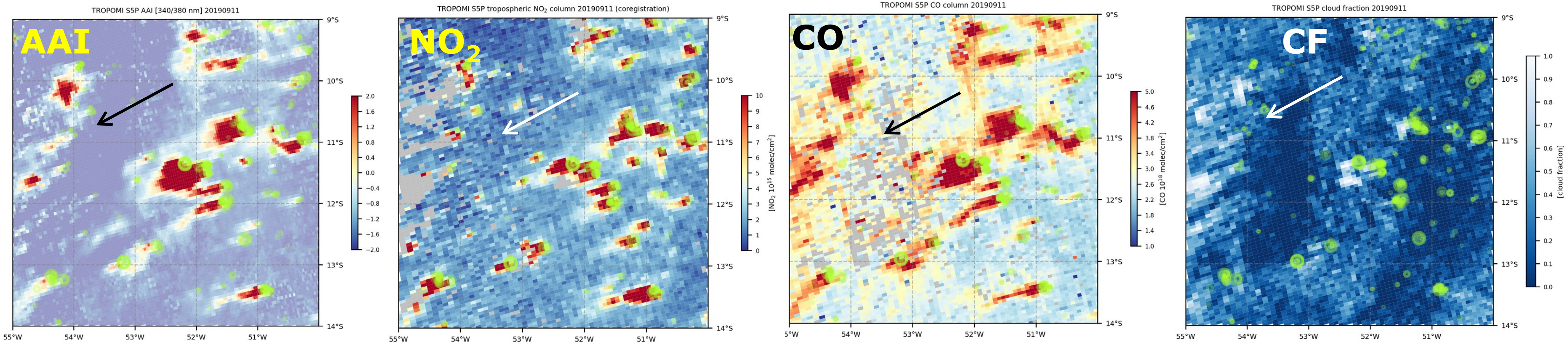






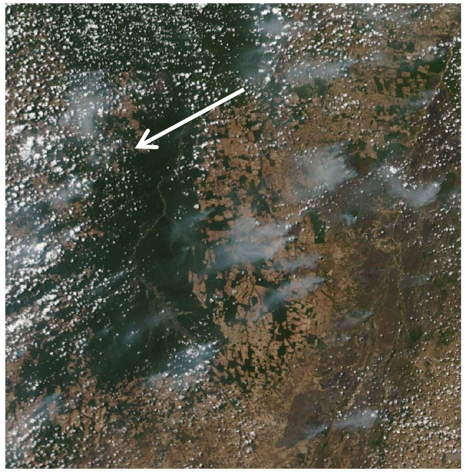


AMAZON 11 September 2019



green circles = SUOMI/NPP VIIRS FRP

SUOMI-NPP VIIRS RGB 20190911 source © NASA EARTHDATA



SUOMI/NPP VIIRS

~500 km region in the south equatorial Amazon

visual correlation enhanced AAI, NO_2, CO, cloud fraction

differences: NO_2 more localized than CO, AAI

CO, AAI lifetime/residence (days-weeks) time longer than NO_2 (hours)

visual correlation with SUOMI/NPP VIIRS Fire Radiative Power

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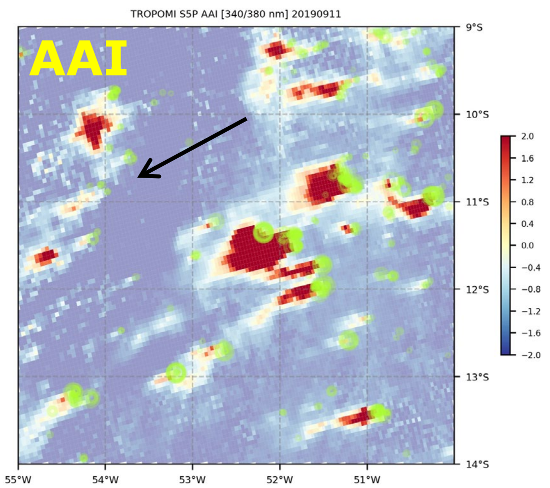

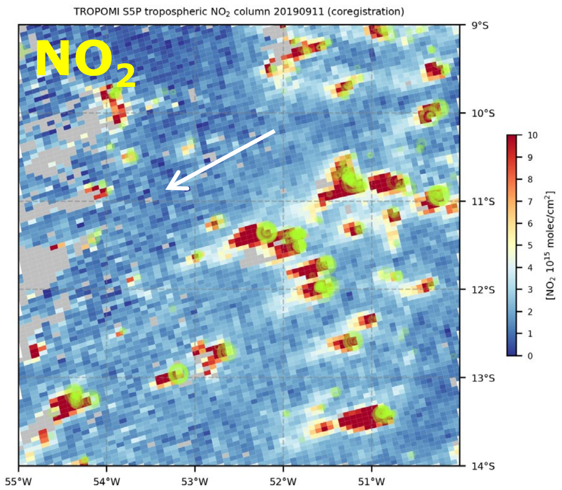

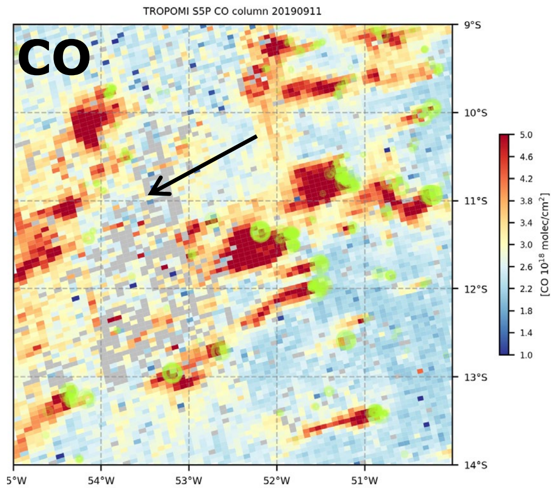

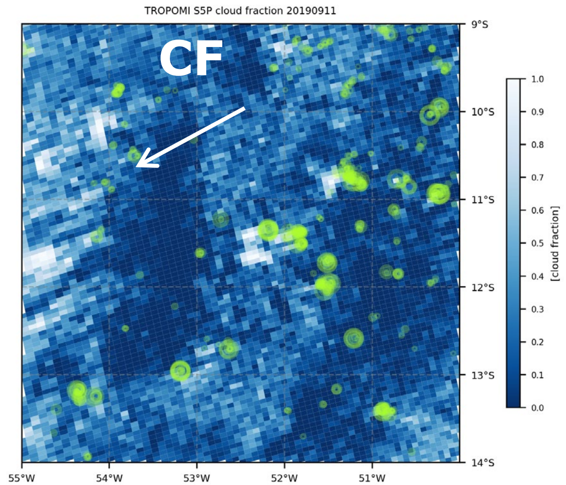

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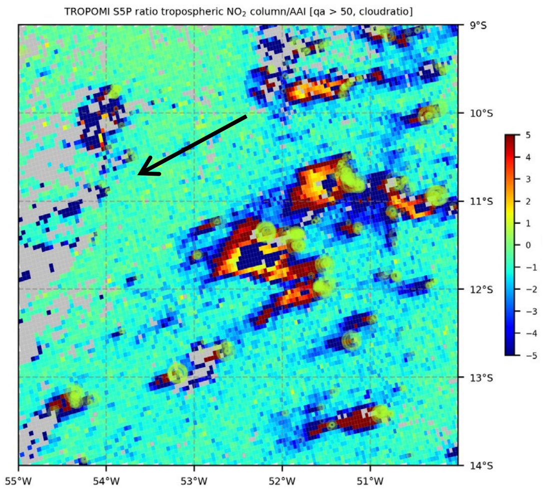
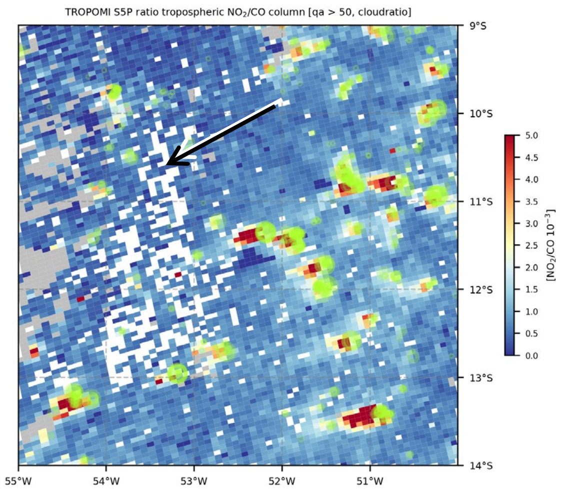
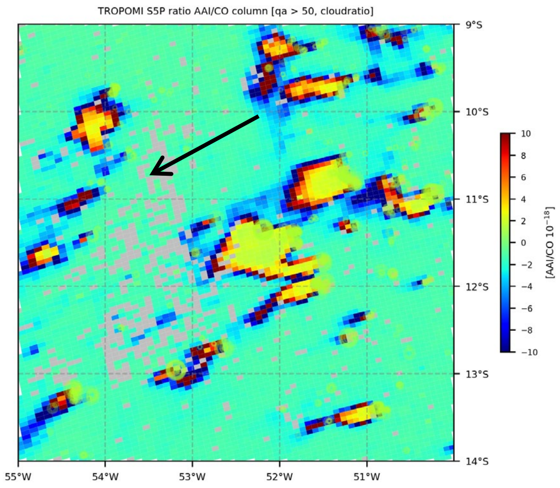


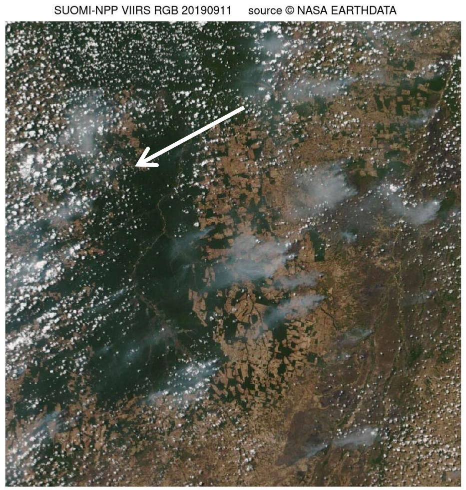
NO_2/AAI ratio



NO_2/CO ratio

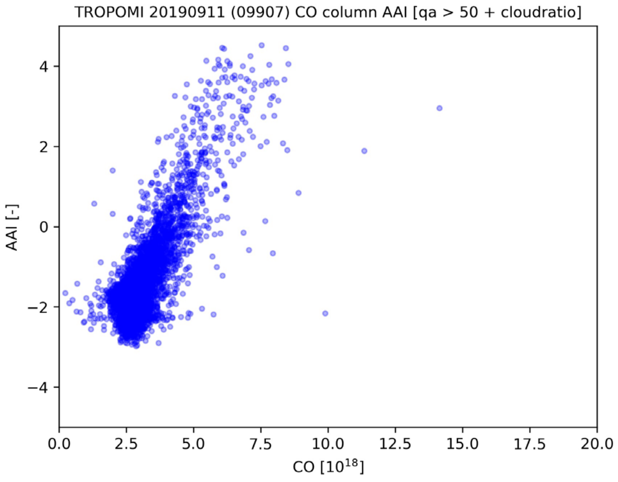


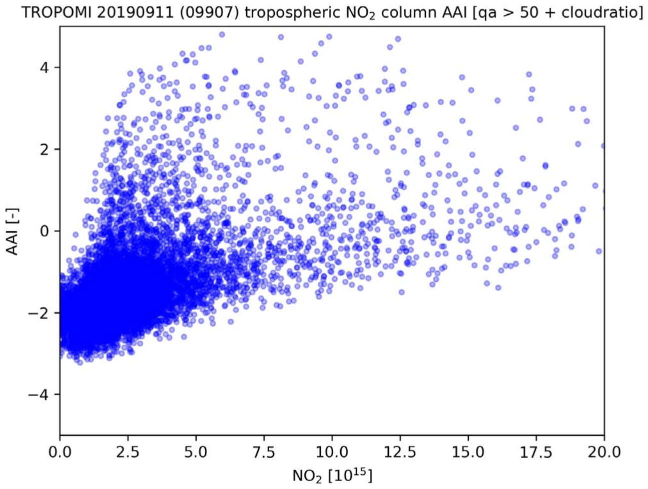
AAI/CO ratio

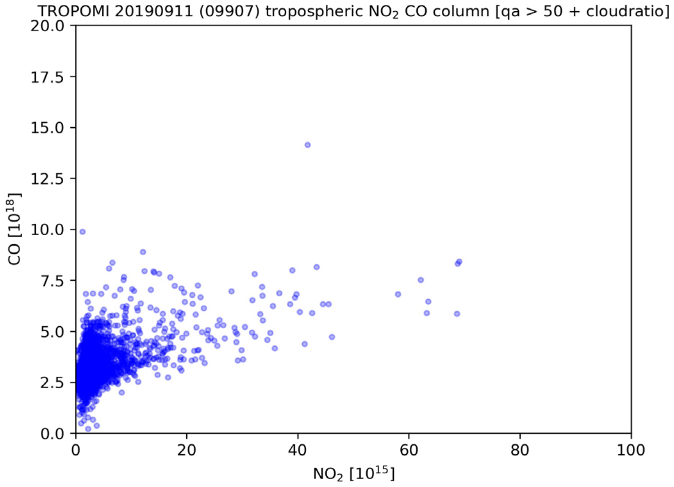


SUOMI/NPP VIIRS

AMAZON 11 September 2019







CO/AAI **NO_2/AAI** **NO_2/CO**

good correlation

some correlation ???

some correlation ???

CO+AAI: long lifetime relative to plume dispersion

transport / diffusion / turbulent mixing dominates

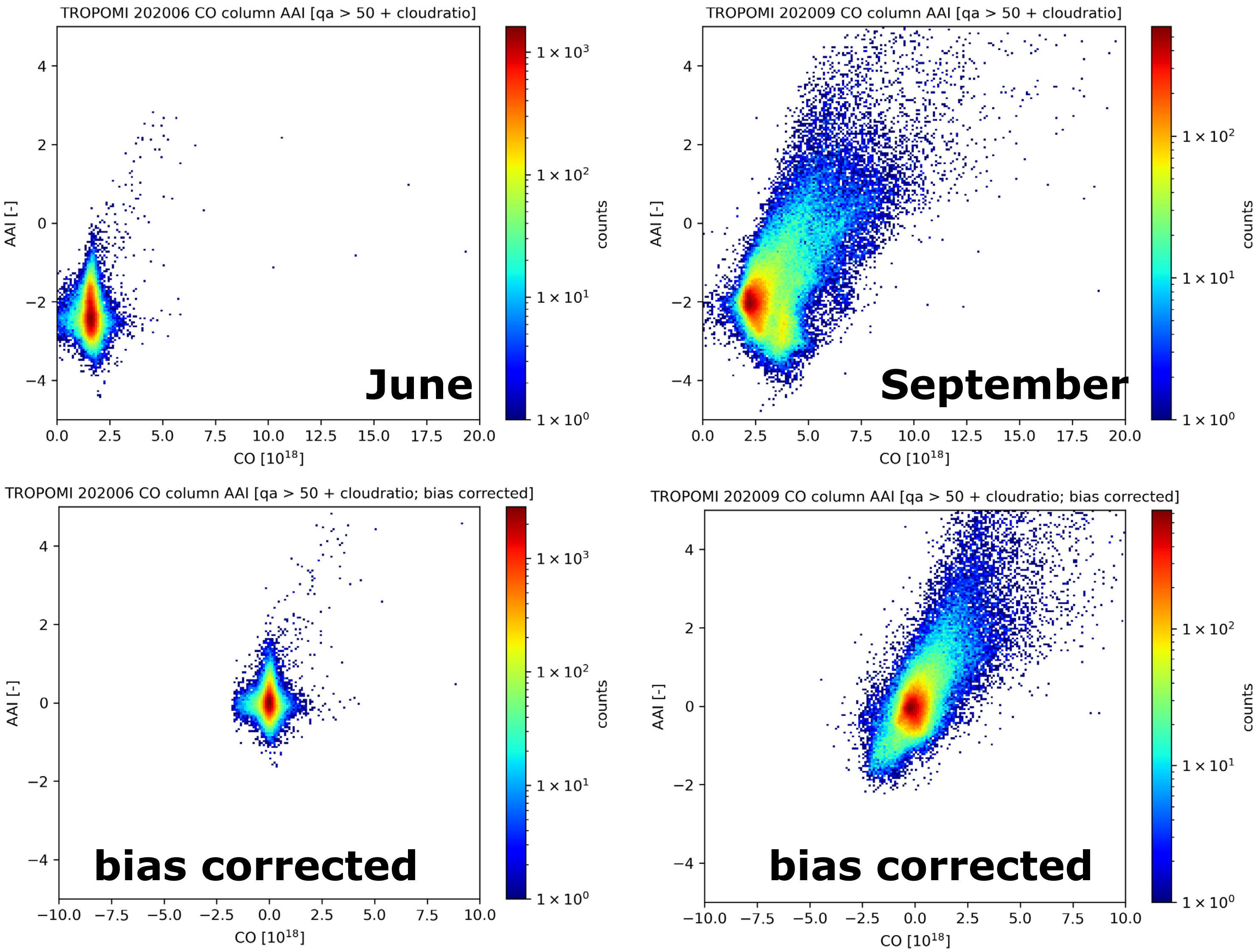
chemistry is of minor importance

NO_2: short lifetime relative to plume dispersion

NO_2 much more local than CO & AAI

short lifetime = chemistry also important

AMAZON CO vs AAI one month 2019



CO + AAI monthly probability distribution

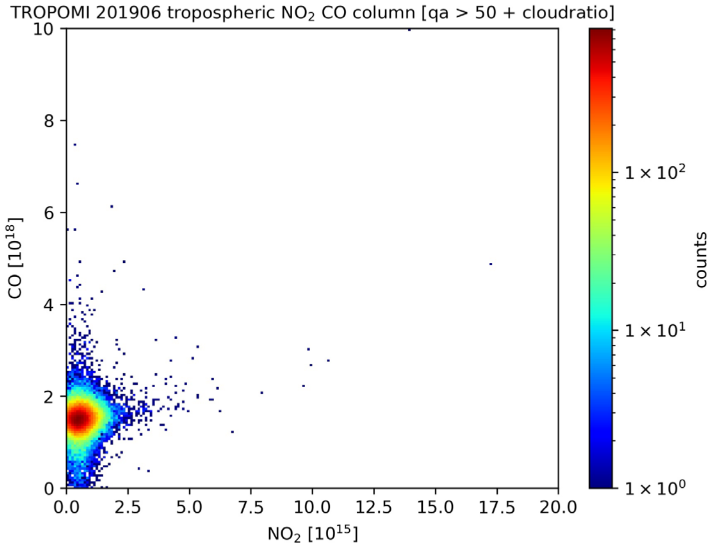
- June + September
- logarithmic scale

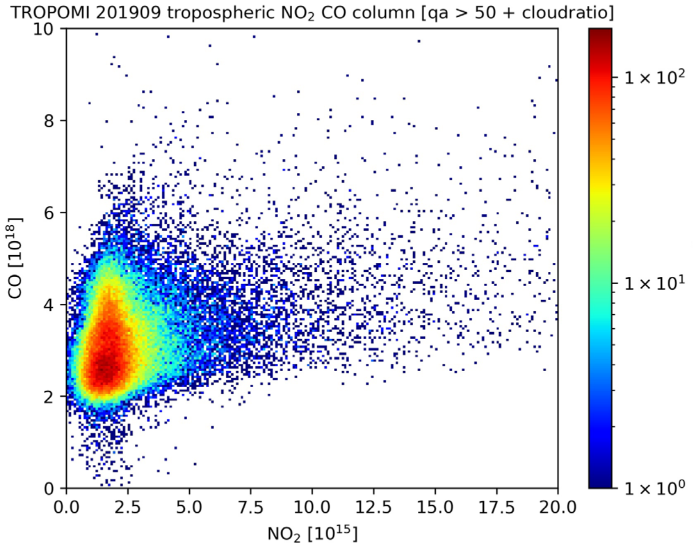
CO + AAI correlate

- for fire plumes
- bias corrections
    - AAI: instrumental (cross swath bias)
    - CO: background CO (seasonal cycle)

- few fires in June
- many fires in September

AMAZON CO vs NO_2 one month 2019





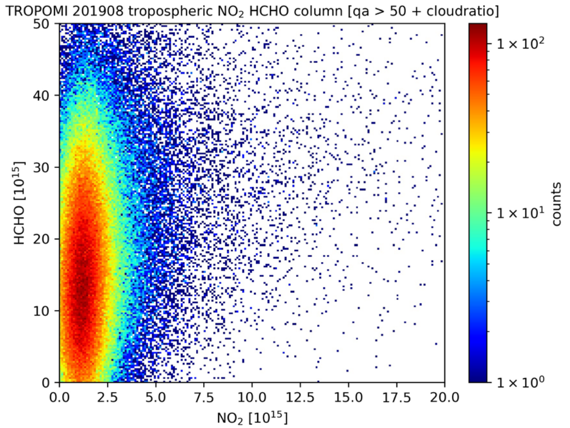
CO + NO_2 monthly probability distribution

- June & September
- logarithmic scale

CO + NO_2

- weak correlations (if any)

- few fires in June
- many fires in September



HCHO + NO_2 monthly probability distribution

- August
- logarithmic scale

- no correlation on daily timescales
- need to average HCHO

Sense⁴Fire

(*poster 64815, Forkel et al., Wednesday 17:00-19:00*)

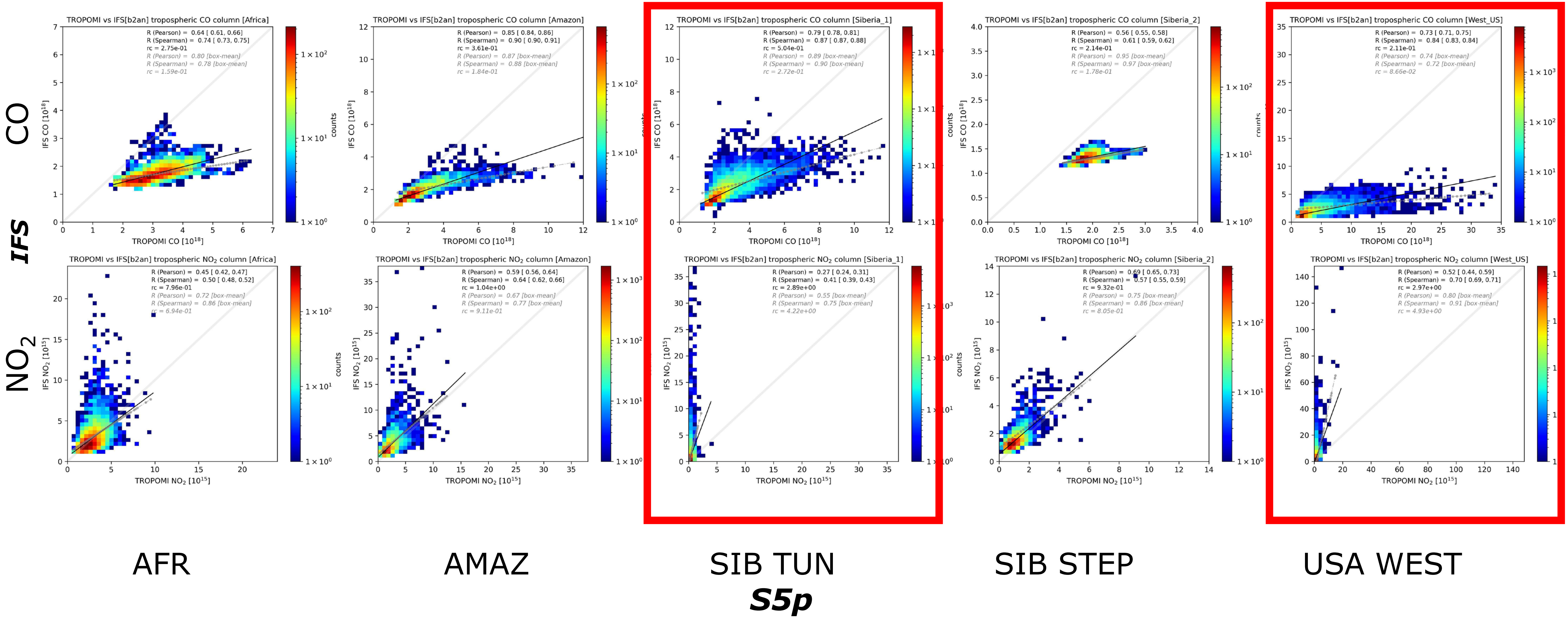
- **Sentinel (1)2-3** data to reconstruct emission for selected regions (*talk Andela et al., Friday 14:30-14:45*)
- **ECMWF/CAMS IFS** model simulations (CO, NO_2, ALH, possibly also HCHO)
- compare with **sentinel-5p** observations
- different fire regimes: Amazon, south-equatorial Africa, Siberia steppe, Siberia tundra (2019, 2020)

Explore:

- comparison **ECMWF/CAMS IFS** with **sentinel-5p** data (*poster 64809, Huijnen et al., Tuesday 17:00-19:00*)
- **ECMSF/CAMS IFS** sensitivities:
    - sub-grid plume chemistry parameterization
    - bottom-up emissions (different databases)
    - injection heights
    - chemistry scheme
    - spatial resolution

- evaluation of small-scale fire **sentinel-5p** data with emissions based on sentinel **(1)2-3** data
    - relation with emission characteristics, like fuel type, fuel load, FRP, soil moisture, etc.

regional comparisons IFS-S5p NO_2 & CO



Aug-Sep 2020, five ~ 500 km regions: south equatorial Africa, south equatorial Amazonia, Siberia Tundra, Siberia Steppe, USA west coast

comparison TROPOMI NO_2 and CO (x-axis) and IFS + GFAS NO_2 and CO (y-axis)

findings/conclusions

[1] visually coherent wildfire patterns in S5p CO, NO_2, AAI, and VIIRS FRP on a daily basis

- combination of AAI/CO to define plume extent

- different regimes, different correlations, different spatial extents

- plume extent + CO indicative of emitted carbon
- NO_2 indicative of burning efficiency

[2] Regional comparison IFS (GFAS) & S5p NO_2 + CO

- overestimating NO_2 <--> underestimating CO (to be continued and explored …)
- burning efficiency --> wildfire fuel characteristics

[fresh result] first indications that IFS comparison with S5p improves with emissions based on Sentinels (1)2+3

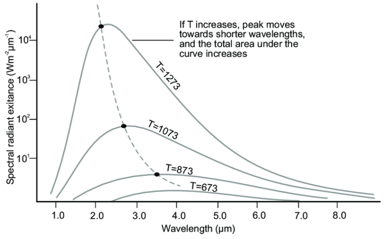
… and finally something unexpected from S5p …

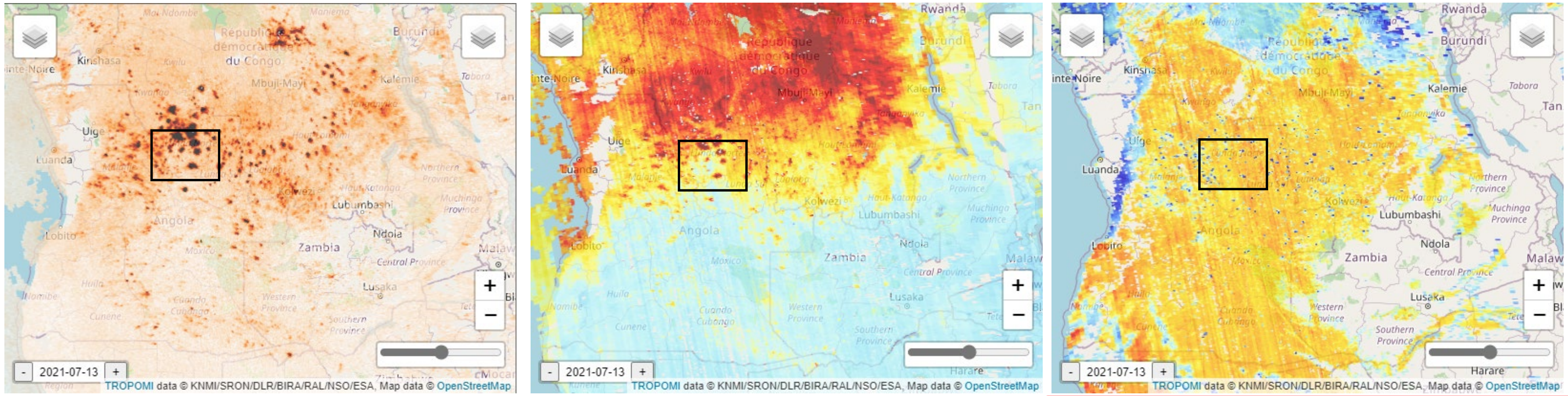
BONUS: fire information in S5p SWIR?

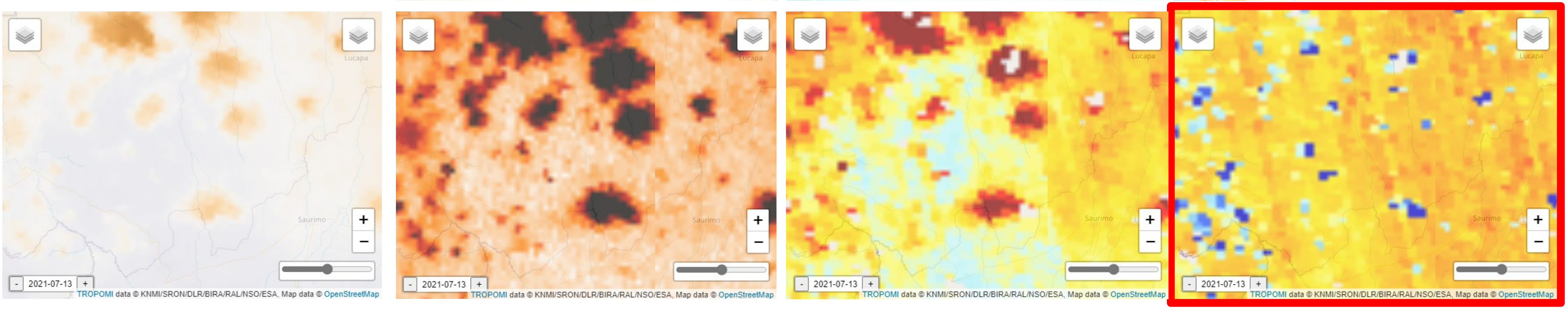
(case south-equatorial Africa 13 July 2021)

mysterious very localized daily S5p CH_4 reductions over fire hot spots (10-20% less CH_4)

- light pollution by fire? (Stefan-Boltzmann around 1000°C maximizes near 2 micron = SWIR)
- unknown/unaccounted spectral absorption by short lived trace gases? (analogy: S5p detection of HONO [Theys et al., BIRA])
- *albedo effect? (effect is non-stationary so lasting < 24 h)*
- *aerosol shielding? (no CH_4 plume)*
- *burned? (how ?)*
- *unknown chemistry (how ?)*
- *...*







AAI **trop. NO_2** **CO** **CH_4**

That's it, thank you for your attention !