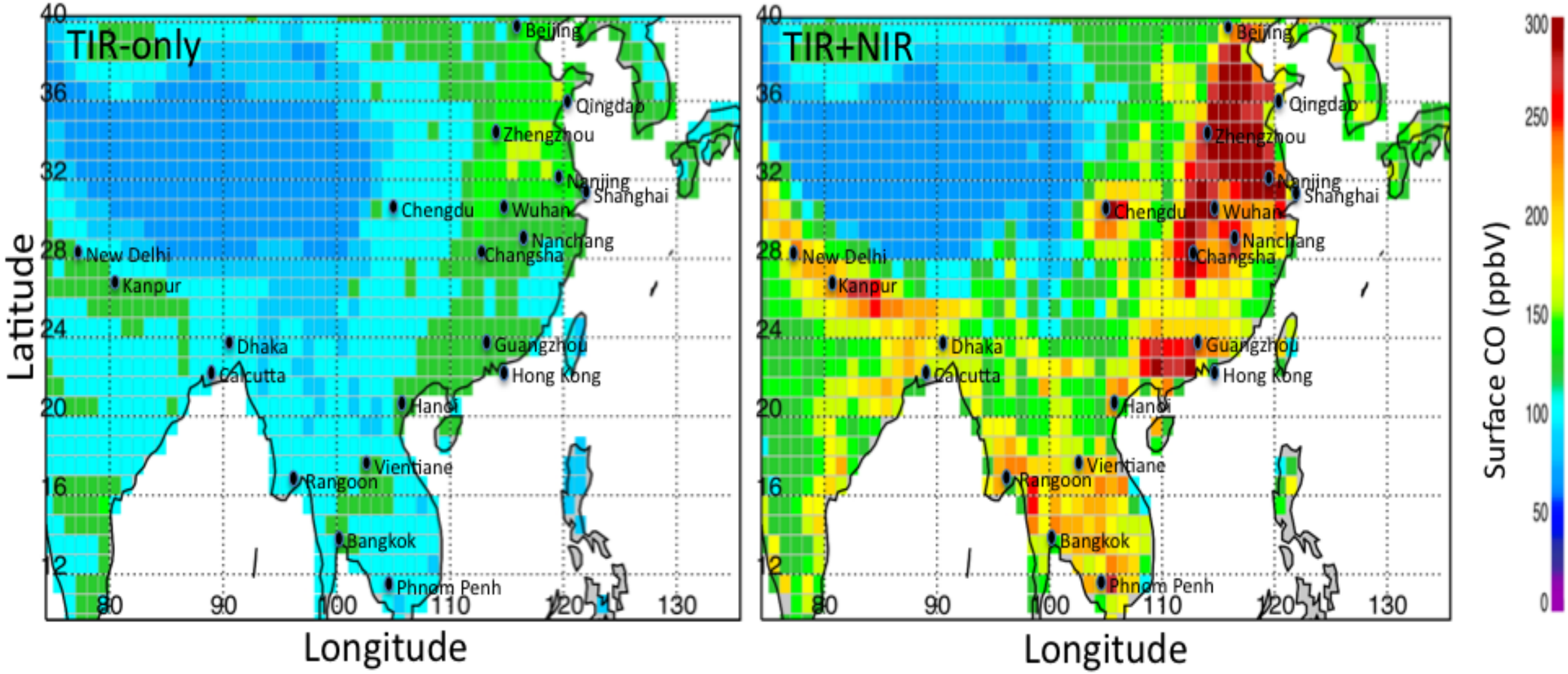
MOPITT multispectral DA tests

Tang and Gaubert, et al., paper in preparation
For AMT

MOPITT Multispectral CO Observations



Worden et al., JGR, 2010

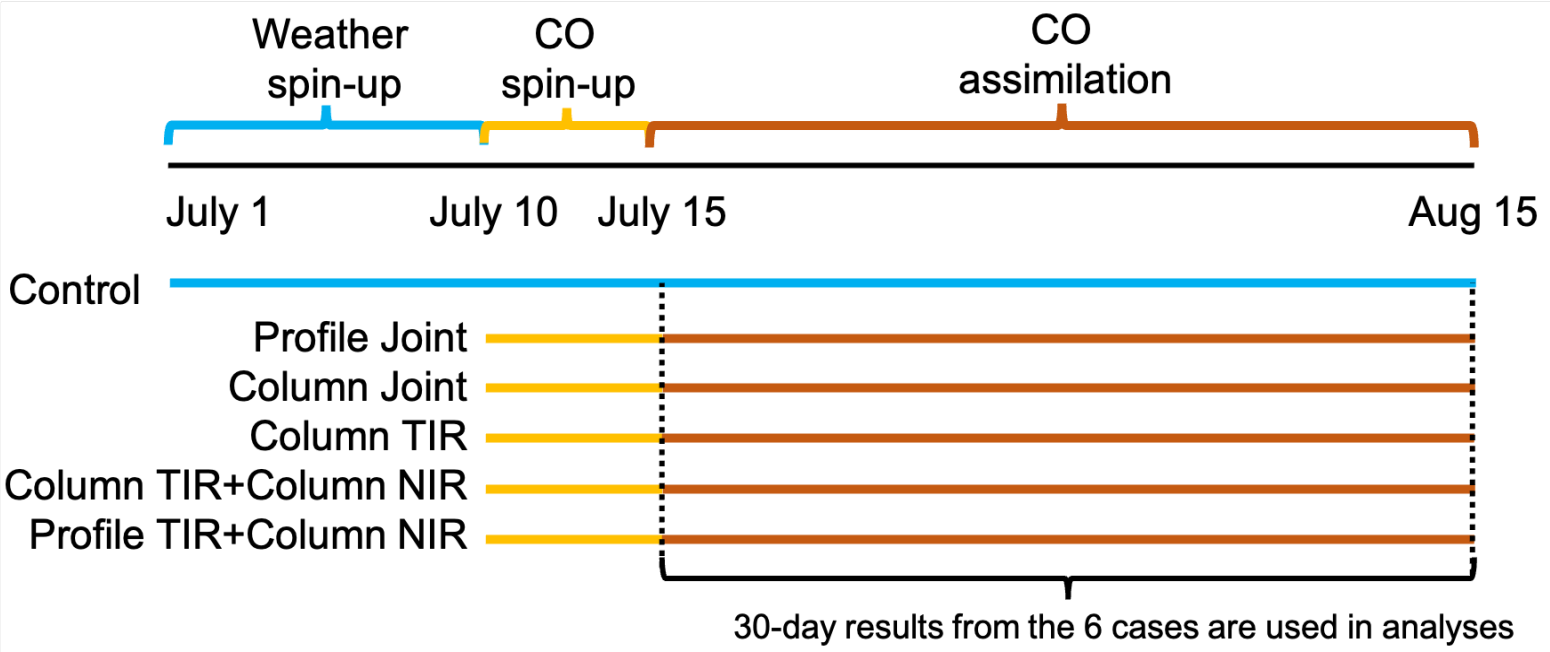
DA comparison set-up

CAM-chem + DART

Initial emissions:

CAMS-GLOB-ANT v5.1

FINNv2.4

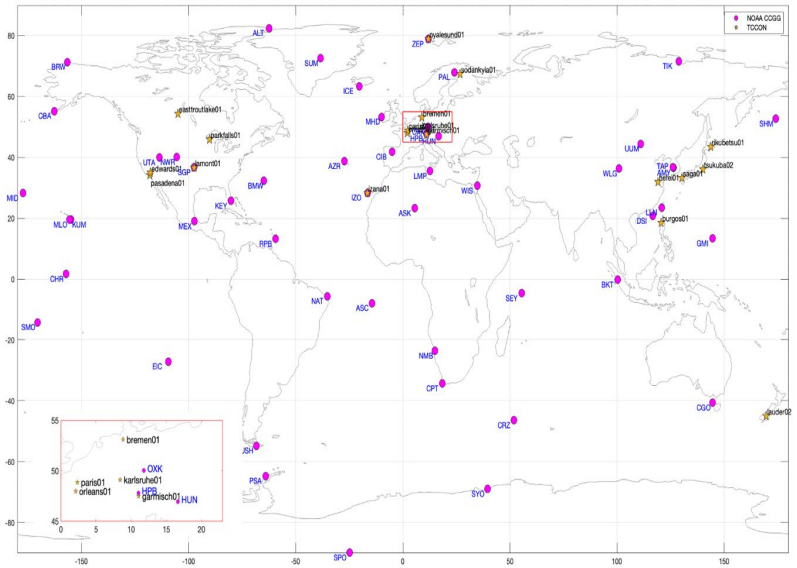


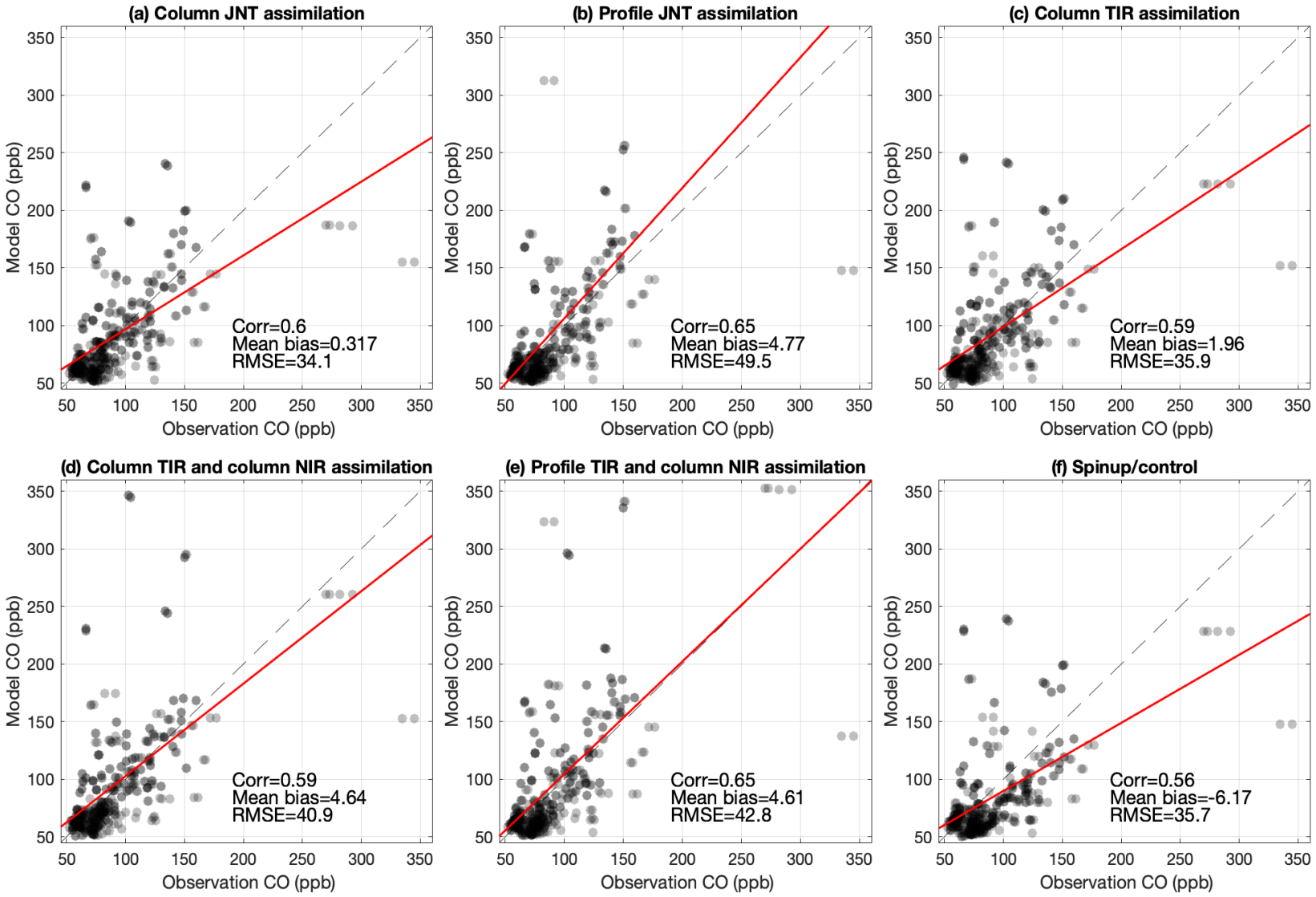
CAM-chem simulations with updated emissions

To evaluate DA results, we use ensemble mean of updated fire & anthro emissions in 6 CAM-chem simulations for the same period

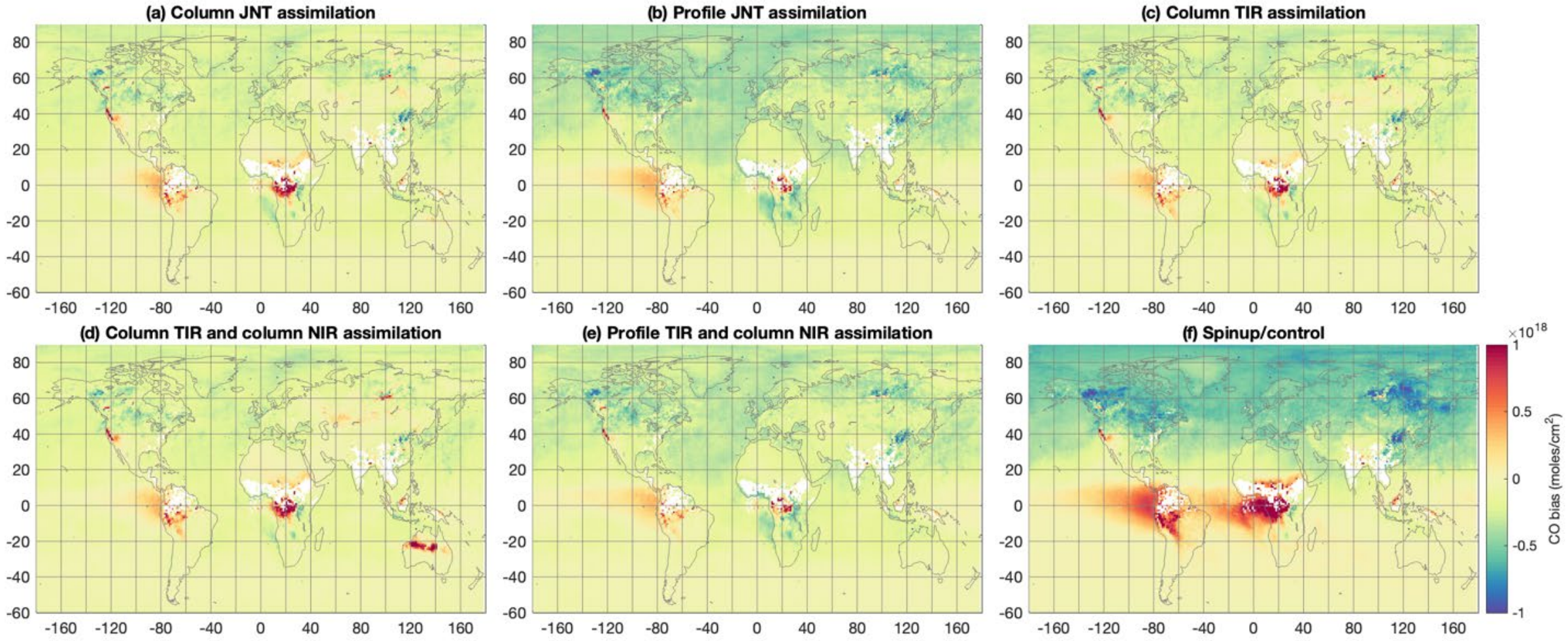
Bias with NOAA CCGG sites (surface CO)

Comparisons of modeled surface CO and observations from the NOAA Carbon Cycle Greenhouse Gases (CCGG) sites during July 16th, 2018 to August 14th, 2018





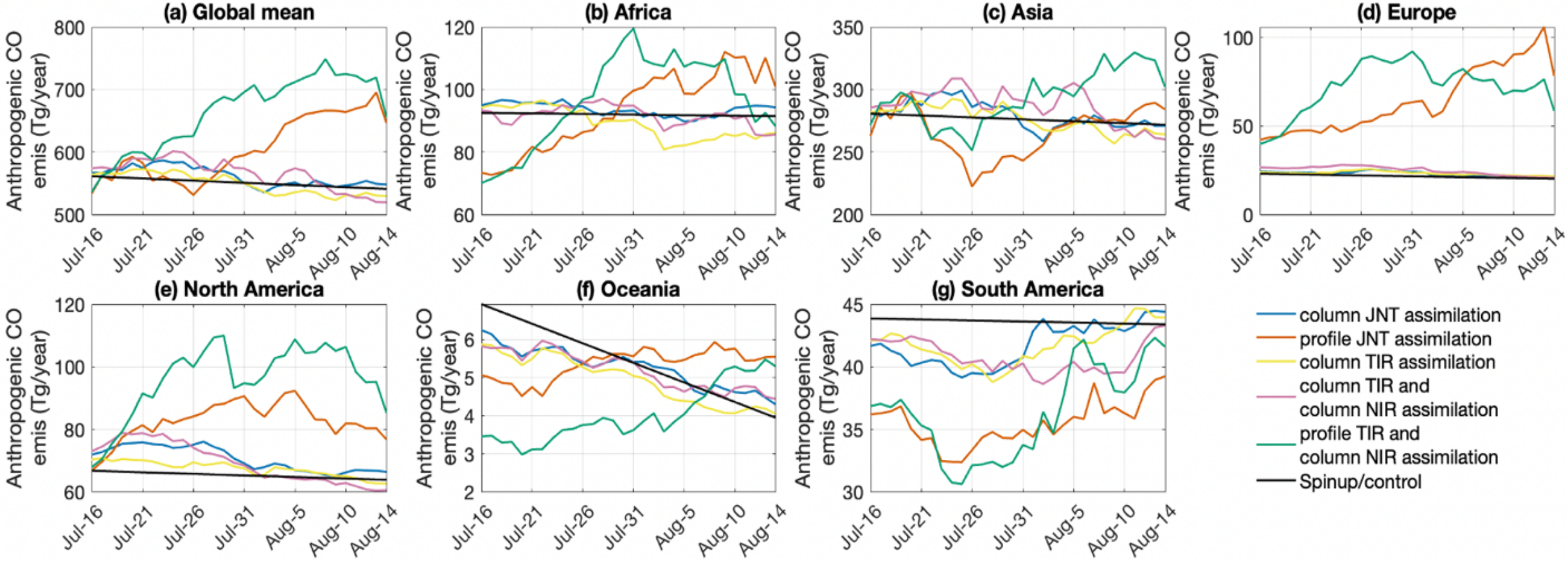
Bias with TROPOMI (column CO)



Best agreement over ocean/background for column products

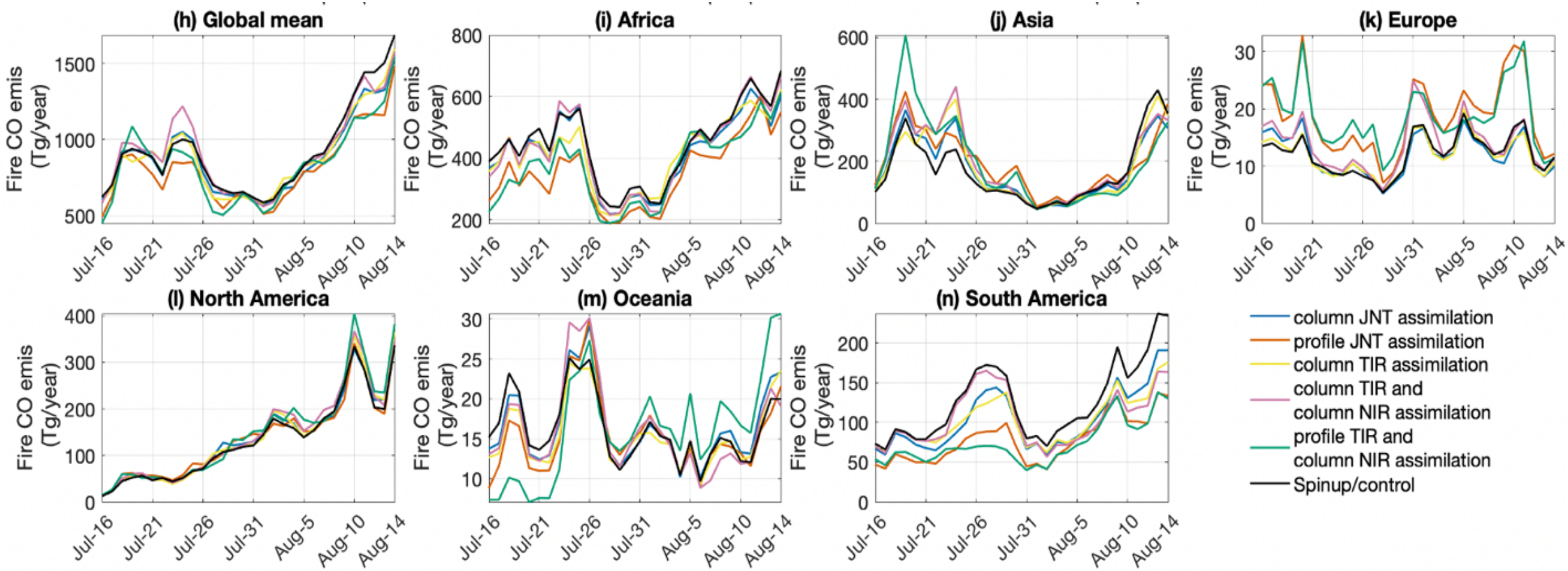
Best agreement over source regions for JNT profiles and TIR profile+column NIR.

Emission estimate results (anthro)



RESULTS: Assimilating profile products tends to have a larger change to the emissions compared to only assimilating column products. The 5 experiments overall increase anthropogenic CO emissions while reducing fire CO emissions.

Emission estimate results (fires)



RESULTS: Simulations using emissions from profile assimilation experiments in general perform better than column assimilation especially near the surface and at fire source regions.

CONCLUSIONS

- Better model-observation agreement at and near the surface for DA with MOPITT multispectral column product compared to assimilating MOPITT TIR-only column product.
- DA with column products has larger impacts and improvement for background and large-scale CO compared to assimilating profile products due to vertical localization in profile assimilation.
- Profile assimilation can out-perform column assimilations in fire-impacted regions and near the surface.
- Similar or slightly better agreement to in situ observations for DA with multispectral products compared to assimilating the single-spectral products separately.
- Assimilating multispectral products is also more computationally efficient – a consideration for other species (e.g., O3 and CH4)
- CAM-chem+DART improvement on small-scale features is limited model resolution. Developing DA capability using MUSICA+DART (higher spatial resolution) to address this issue.

Investigating expanding air pollution and climate change on the African continent

Pieternel Levelt, Deborah Stein, Sara-Eva Martinez, Wenfu Tang, **Helen Worden**, Louisa Emmons, David Edwards, Joost de Gouw, Benjamin Gaubert, Henk Eskes, Ronald van der A, and Pepijn Veefkind

NCAR ACOM (Atmospheric Chemistry Observations and Modeling) Laboratory, Boulder, CO, USA
Colorado University Boulder, CO, USA
KNMI, TU Delft, The Netherlands

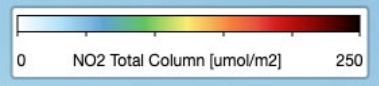
Pieternel Levelt, Helen Worden, NCAR ACOM Directorate
CEOS, October 2023

TROPOMI satellite instrument flies on ESA's s5p, launched in 2017
Daily global coverage; 3,5 x 5,5 km2 pixel size

Image Courtesy : Pepijn Veefkind, KNMI

NO_2

Fossil fuel



CO

Biomass Burning

HCHO

Biogenic Emissions

UVAI

Sahara Dust

TROPOMI air pollution measurements
Africa, July 2019

Africa

TROPOMI

Population is expected to double in 2050 (now 1.1 billion)

4th industrial revolution: will lead to huge increase in air pollutants and greenhouse gases

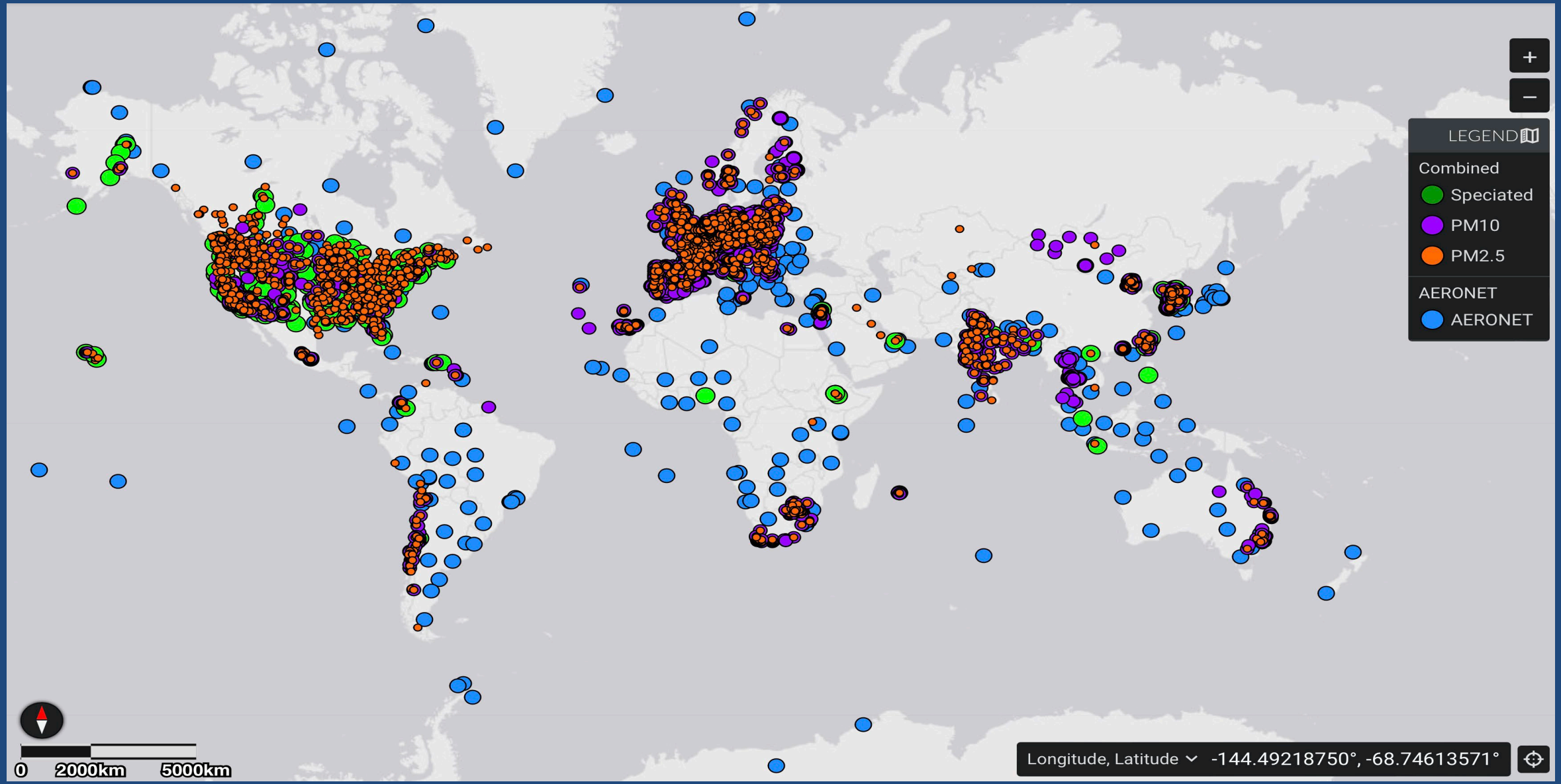
All pollution sources are present in Africa:

NO2 – fossil fuel combustion
CO – biomass burning
HCHO – Biogenic Emissions
UVAI – Sahara Dust

There is a lack of groundbased measurements over Africa

There is a lack of emission estimates over Africa

Pieternel Levelt, NCAR ACOM

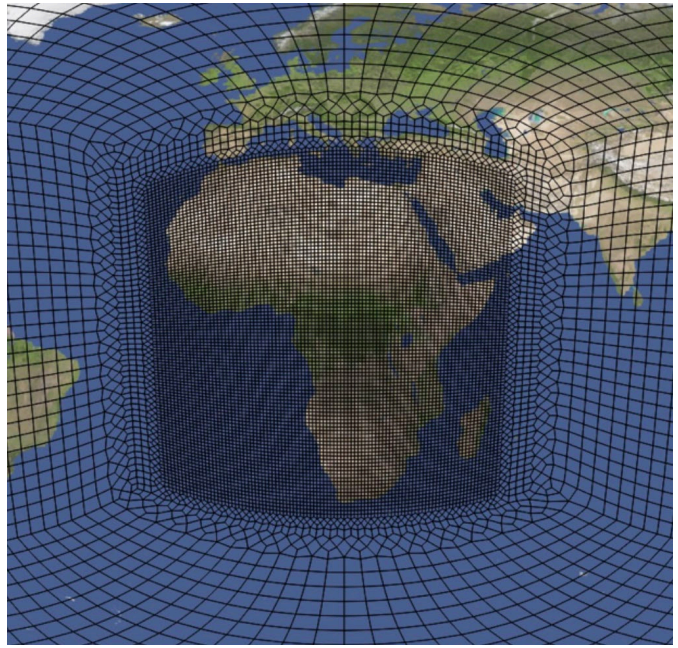


MAIA data visualization tool shows the locations of air pollution surface monitors. Relatively few are available in the global south.

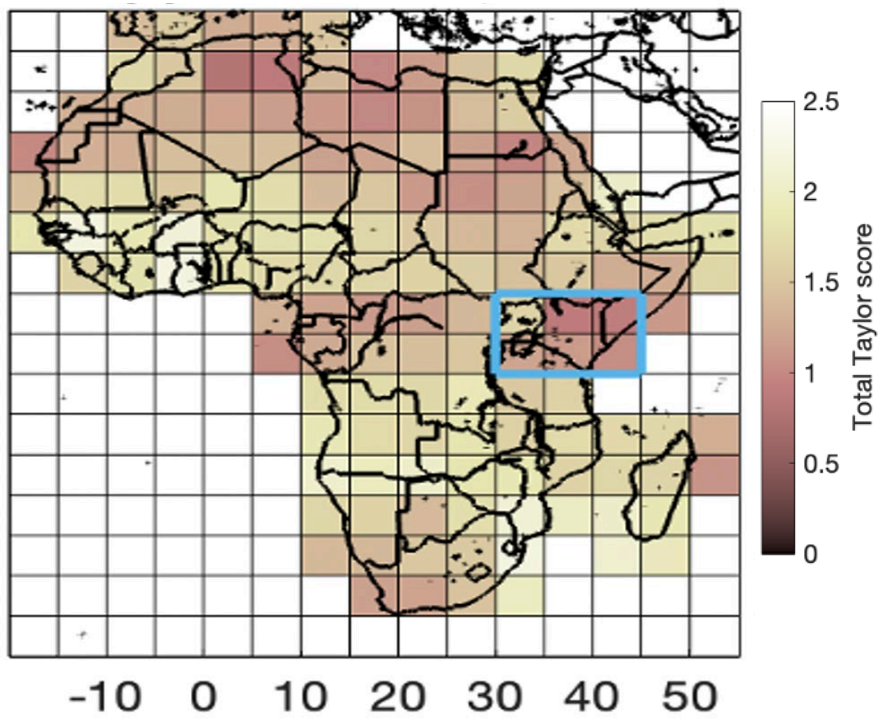
Identifying potential regions in Africa for field campaign(s) using MUSICAv0

- We quantify model-satellite discrepancies over Africa with MUSICAv0.
- The highlighted East Africa region has the largest model-satellite discrepancies.
- A field campaign there can help understand model-satellite discrepancies and improve model predictability.

MUSICAv0 grid for Africa:

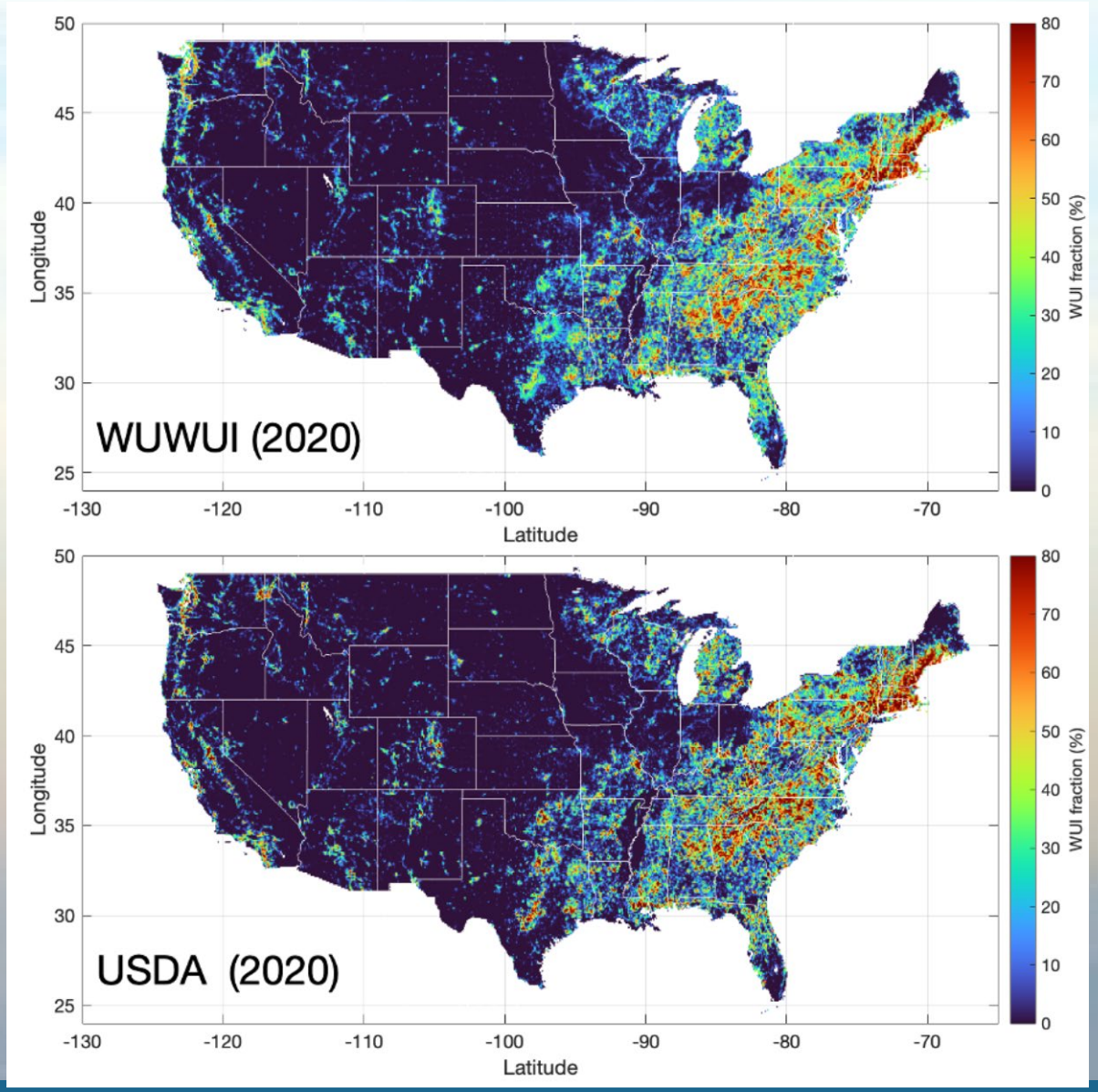


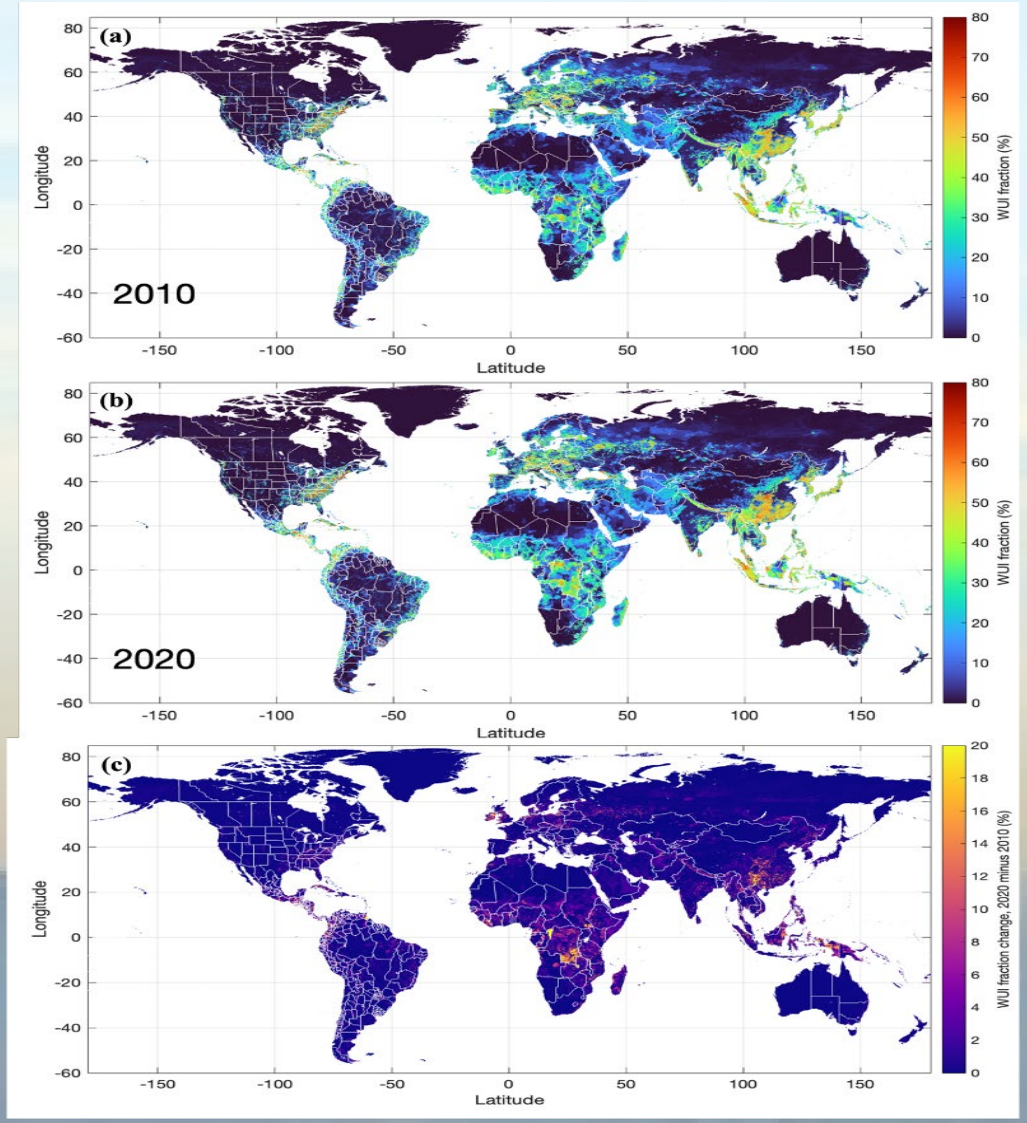
MUSICA-satellite discrepancies:



Pieternel Levelt, NCAR ACOM

Machine learning for identifying Wildfire/Urban Interface (WUI)





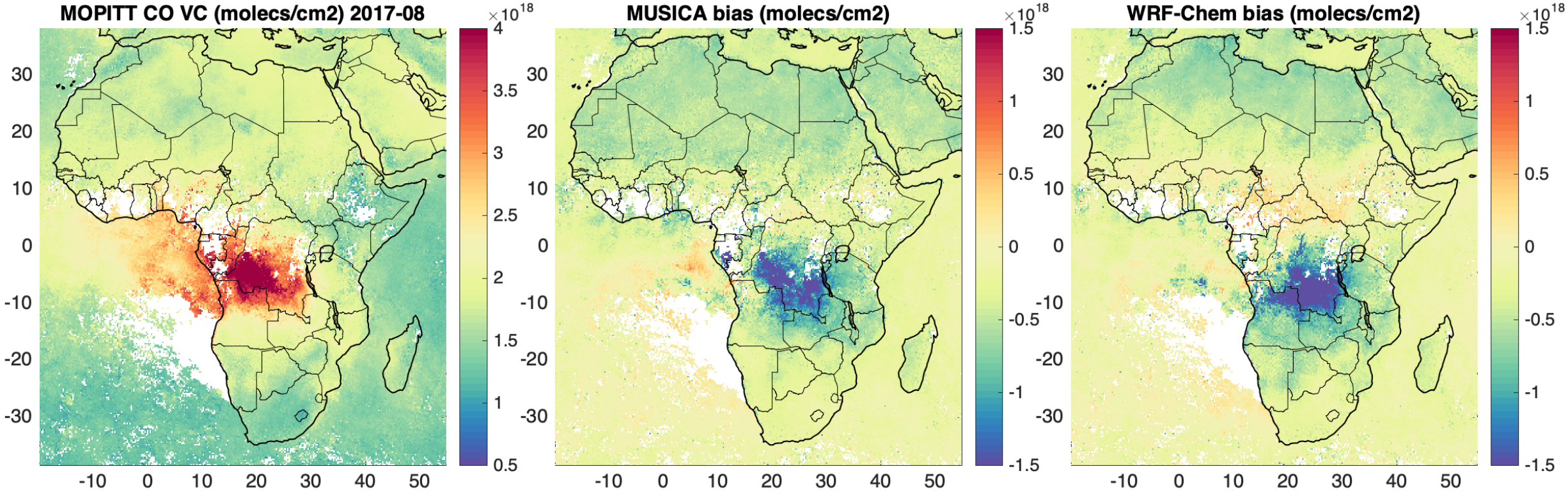
Completing the GEO constellation

- The current GEO c
least about - whe
composition resea
- Africa is the cente
- Capacity building
this takes time
- Initiatives to impr
provide a way for
- Ball Aerospace is
experience to dep
- The Ibis project h
ensure local expe

An example of the TEMPO measurement grid resolution over Kigali, Rwanda

Model evaluation with satellite data: monthly bias
Wenfu Tang et al, NCAR ACOM

CO



Summer

Pieternel Levelt, NCAR ACOM

NEW YORK TIMES: RACE TO THE FUTURE

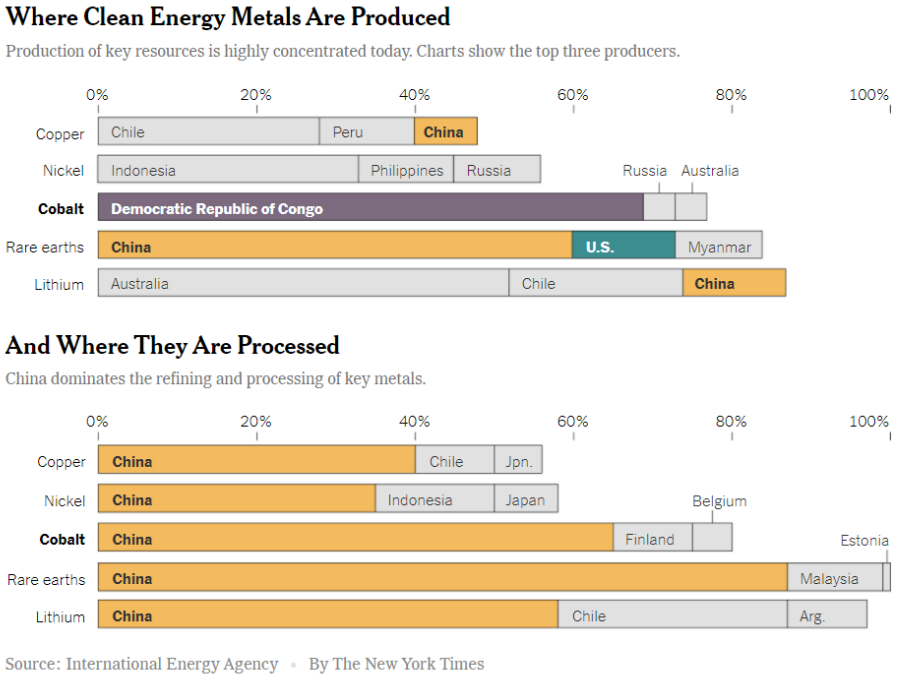
A Power Struggle Over Cobalt Rattles the Clean Energy Revolution (21 nov 2021)

Race to the Future: What to Know About the Frantic Quest for Cobalt (20 nov 2021)

By Dionne Searcey, Michael Forsythe and Eric Lipton

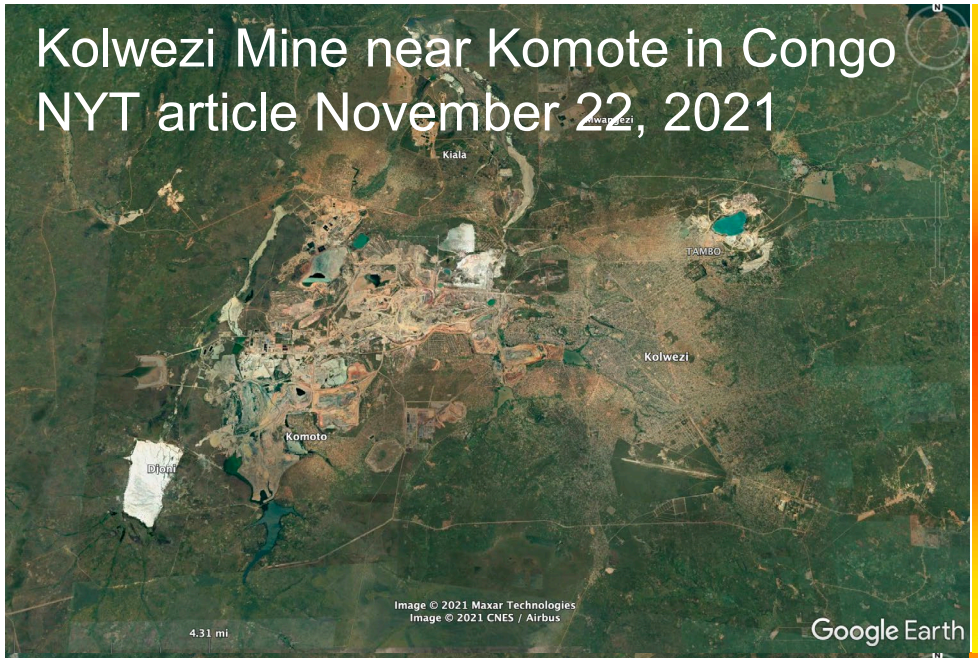
An industrial cobalt and copper mine in mineral-rich Congo.

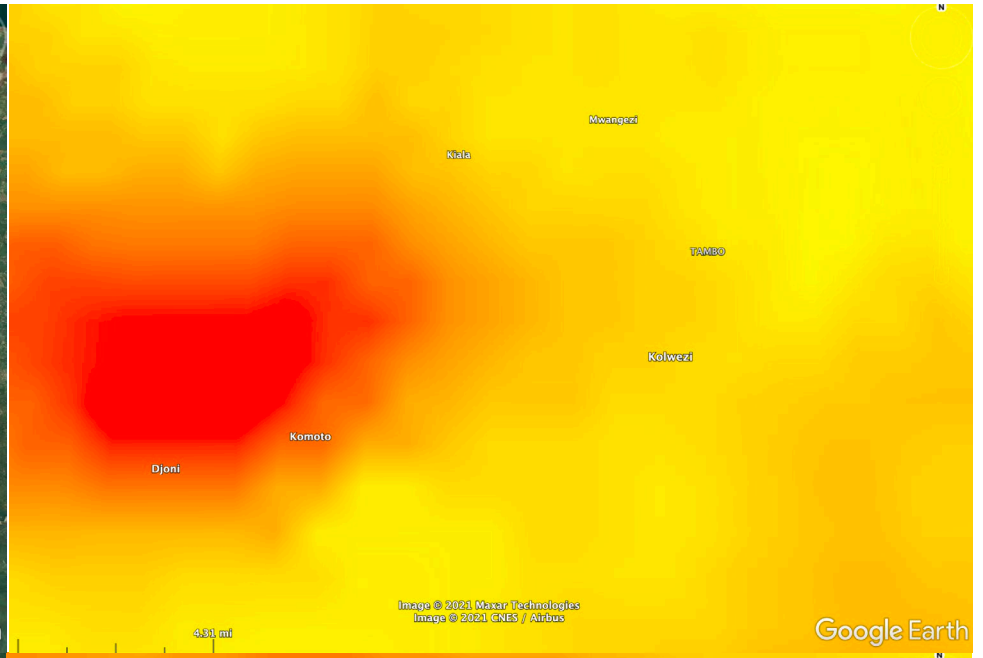
Credit Ashley Gilbertson for The New York Times

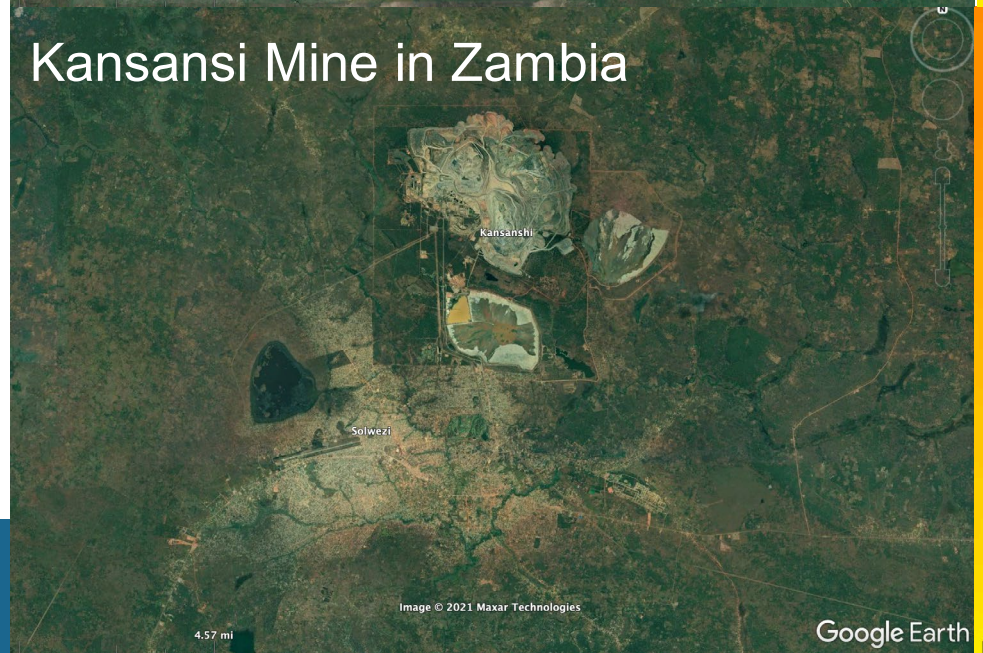


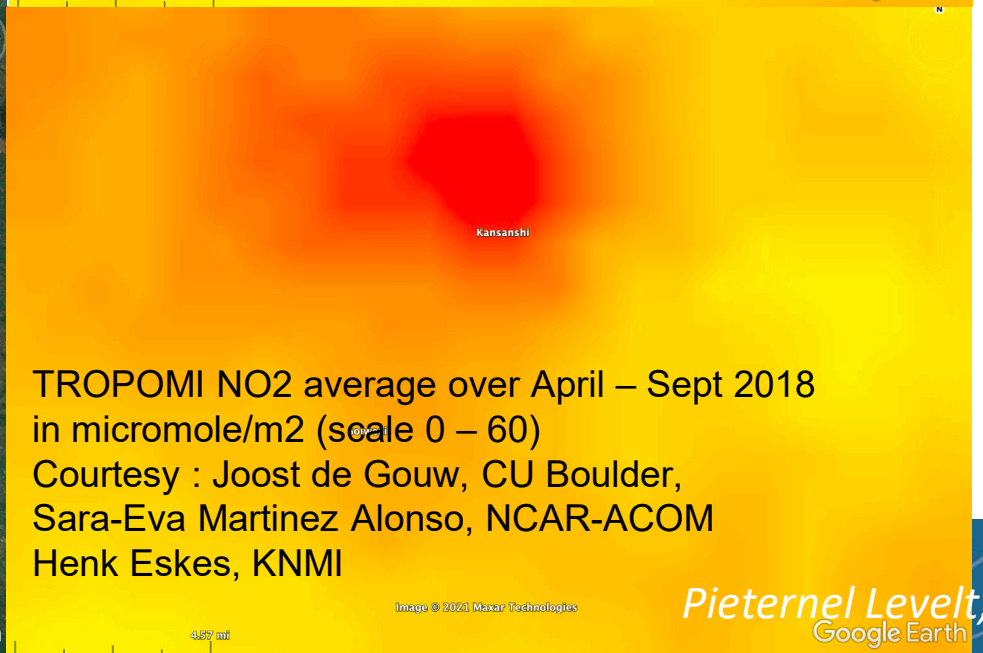
Pieternel Levelt, NCAR ACOM

TROPOMI NO2 measurements over mines in Africa









TROPOMI NO2 average over April – Sept 2018
in micromole/m2 (scale 0 – 60)
Courtesy : Joost de Gouw, CU Boulder,
Sara-Eva Martinez Alonso, NCAR-ACOM
Henk Eskes, KNMI

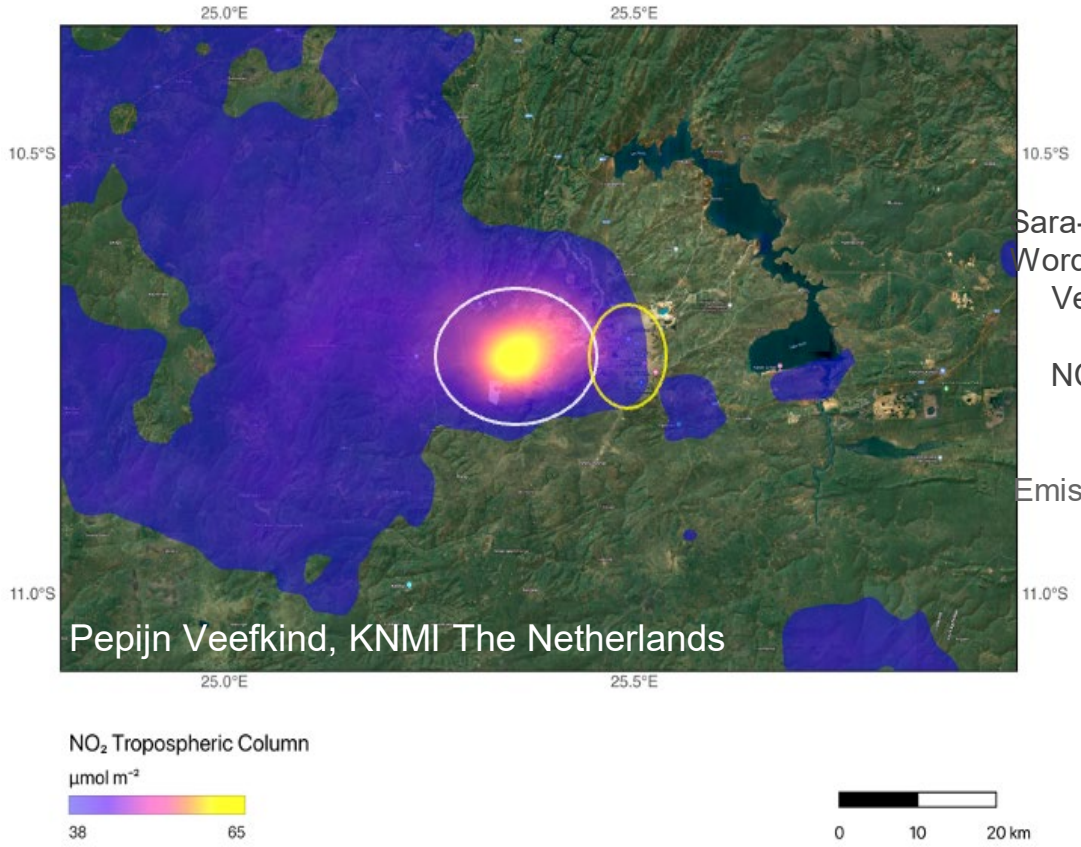
TROPOMI NO2 captures mining activities for green energy over Africa.

NEW YORK TIMES: RACE TO THE FUTURE

A Power Struggle Over Cobalt Rattles the Clean Energy Revolution (21 nov 2021)

Race to the Future: What to Know About the Frantic Quest for Cobalt (20 nov 2021)

By Dionne Searcey, Michael Forsythe and Eric Lipton



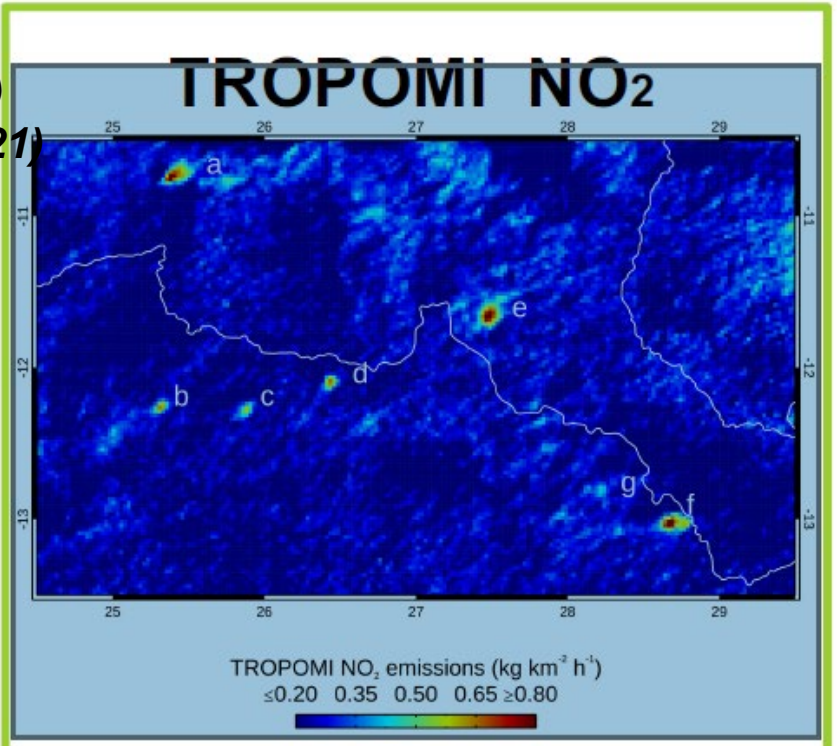
Sara-Eva Martinez-Alonso[1], Wenfu Tang[1], Helen Worden[1], Louisa Emmons[1], Henk Eskes[2], Pepijn Veefkind[2], Joost de Gouw[3] Nicolas Theys[4,] Pieternel Levelt [1,2,3]

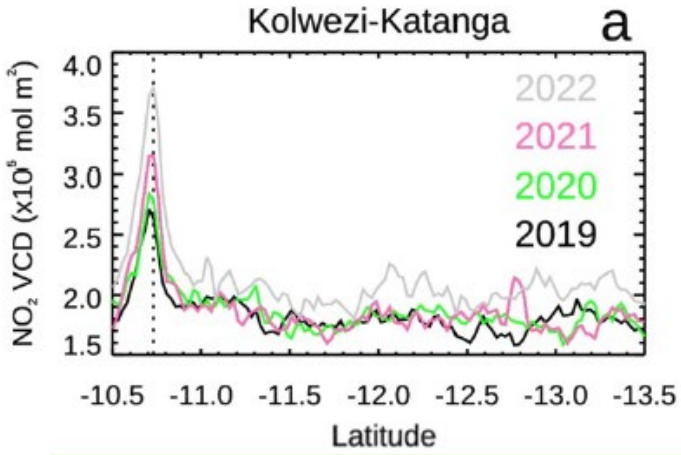
NCAR, KNMI, TU Delft, CU Boulder, BIRA;

sma@ucar.edu

Emissions from mining-related activities in Africa using TROPOMI satellite observations

Submitted to JGR

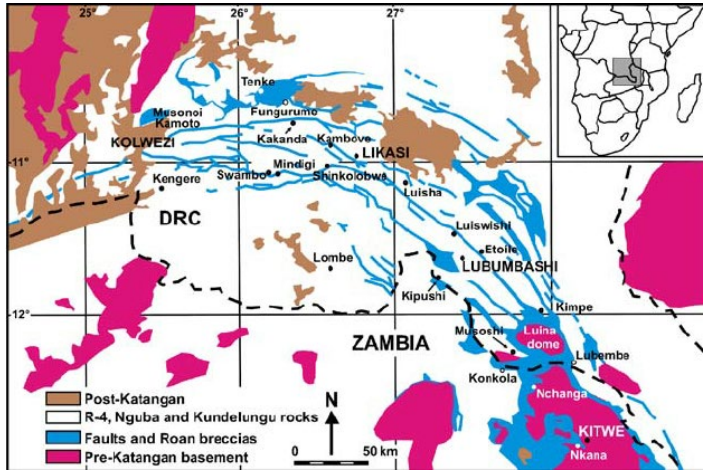




Average nitrogen dioxide detected by the TROPOMI instrument onboard the S-5P satellite over the Democratic Republic of Congo. The image shows the significant increase in nitrogen dioxide over a copper/cobalt mine (circled in yellow) compared to the city of Kolwezi (circled in yellow).

Pieternel Levelt, NCAR ACOM

TROPOMI NO2 captures mining activities for green energy over Africa.



(Geological map from Muchez *et al.*, 2008)

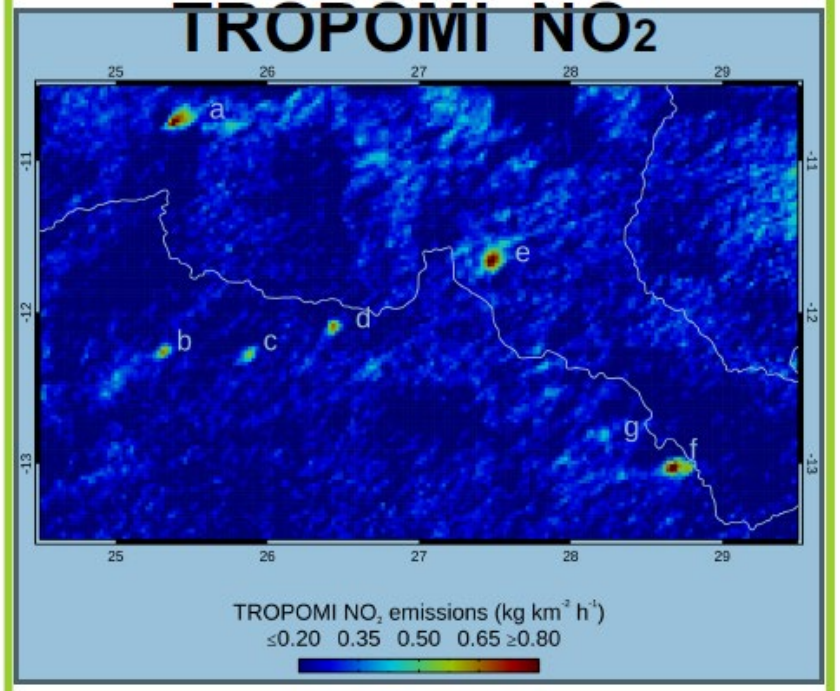
Sara-Eva Martinez-Alonso[1], Wenfu Tang[1], Helen Worden[1], Louisa Emmons[1], Henk Eskes[2], Pepijn Veefkind[2], Joost de Gouw[3] Nicolas Theys[4,] Pieternel Levelt [1,2,3]

NCAR, KNMI, TU Delft, CU Boulder, BIRA;

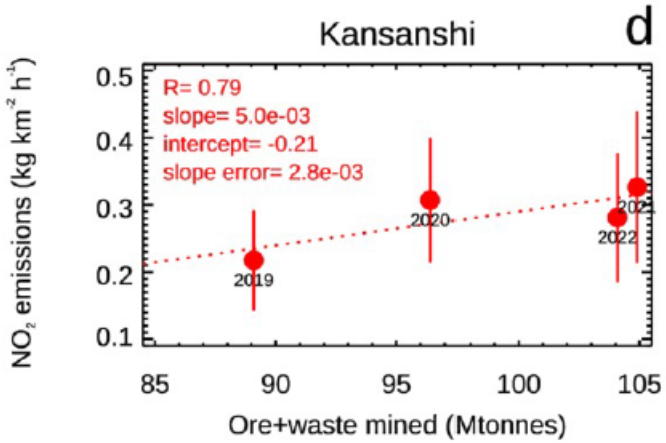
sma@ucar.edu

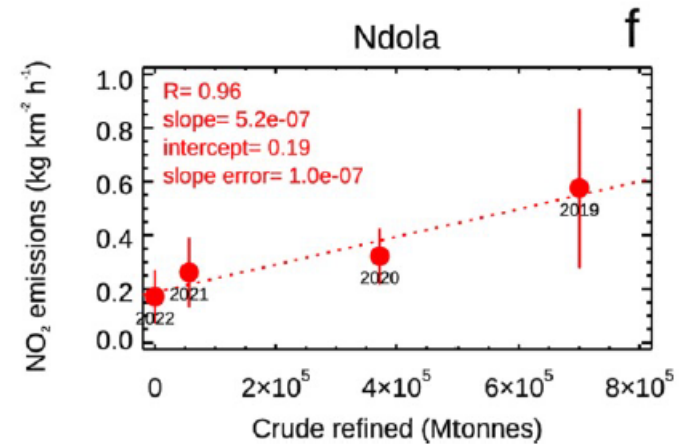
Emissions from mining-related activities in Africa using TROPOMI satellite observations

Submitted to JGR

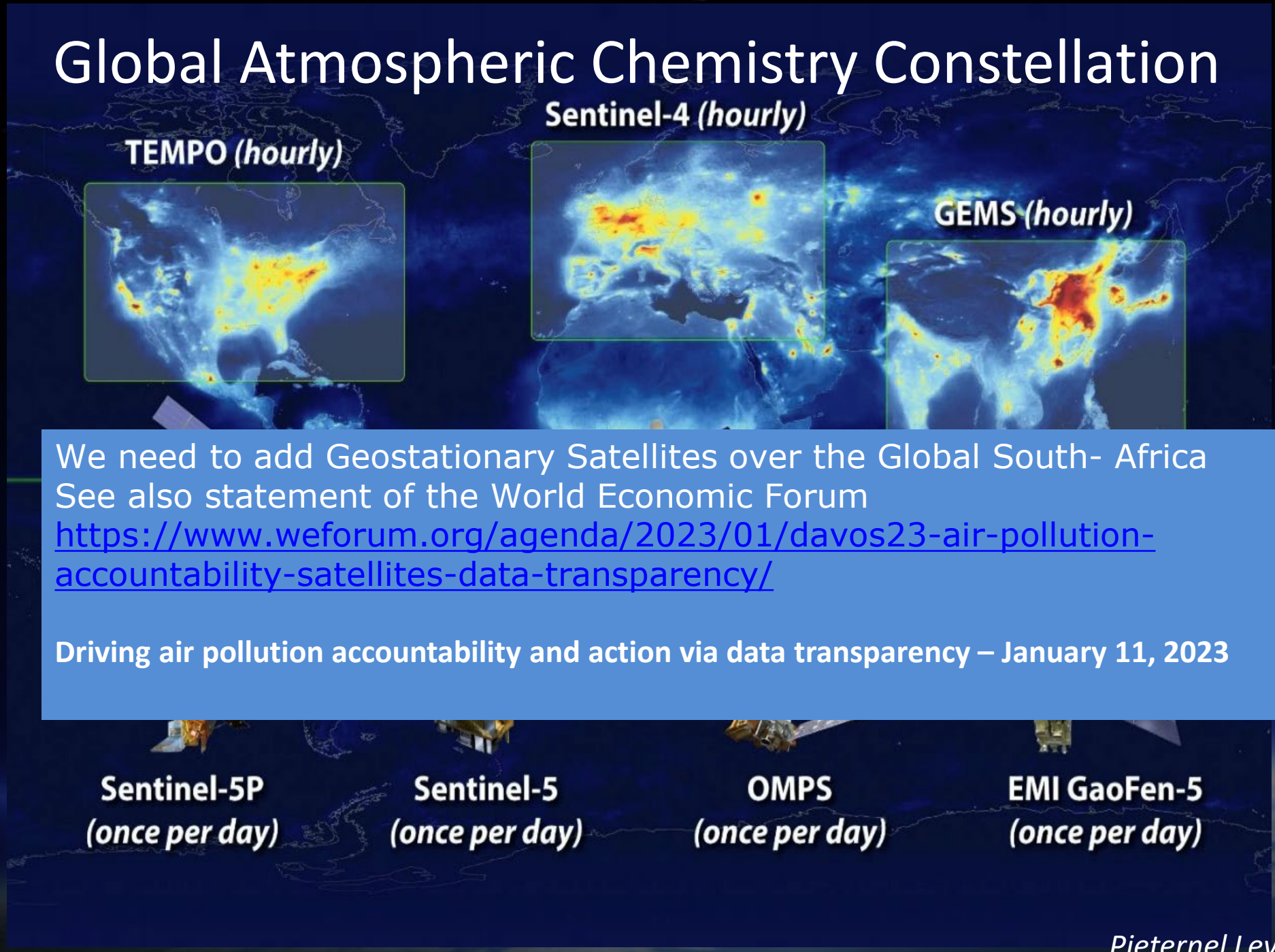


Correlation between annual TROPOMI NO_2 emissions and mine/refinery production





Global Atmospheric Chemistry Constellation

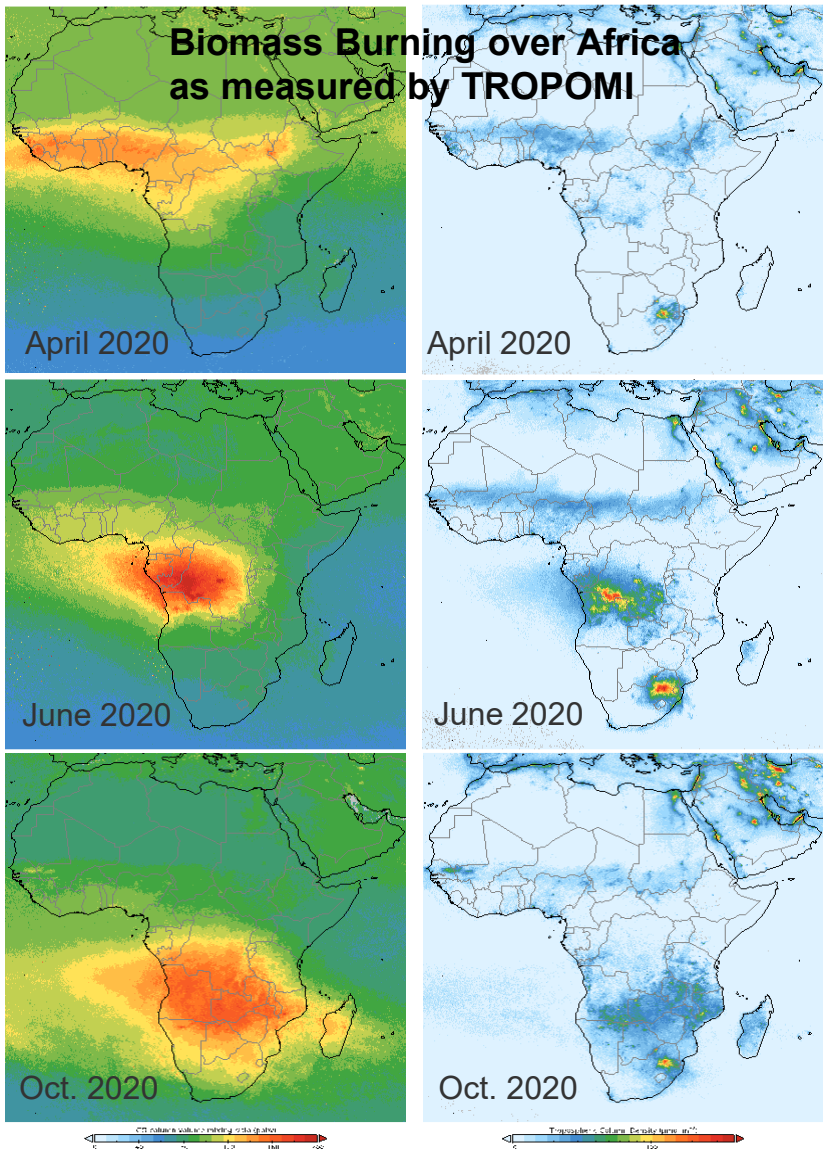


TROPOMI

We need to add Geostationary Satellites over the Global South- Africa
See also statement of the World Economic Forum
https://www.weforum.org/agenda/2023/01/davos23-air-pollution-accountability-satellites-data-transparency/

Driving air pollution accountability and action via data transparency – January 11, 2023

Pieternel Levelt, NCAR ACOM



Credits: Pepijn Veefkind, KNMI

Summary Africa

Population is expected to double in 2050 (now 1.1 billion)
4th industrial revolution: huge increase in air pollutants & green house gases

4 workshops on Africa last years:

- Advancing air quality and carbon science in Africa (Ben Gaubert, NCAR ACOM– March 2021)
- Lorentz Workshop ' The power of TROPOMI to bridge Science and Policy' (Pieternel Levelt and Marleen Dekker KNMI& Leiden Univ- April 2022)
- Workshop on a pilot design for air quality in Africa(Solomon Bililing – June 2022)
- Workshop on AQ in Africa , in Kigali - Africa (Solomon Bililing et al – Jan 2023)

IGAC: Long standing tradition with Africa subgroup, including scientists from Africa

NCAR & KNMI could contribute: Ground based monitoring, modelling, flight campaigns, laboratory , satellite observations

UCAR/NCAR initiative 'Accelerating environmental sustainability solutions in Africa: a UCAR initiative' (Wenfu Tang, wenfut@ucar.edu)

Investigate Potential for GEOstationary satellite over the Global South and Africa

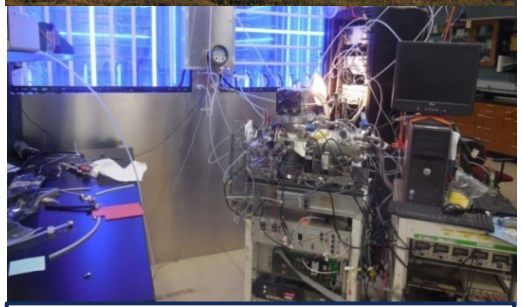
ACOM capabilities for Africa Air Quality Research

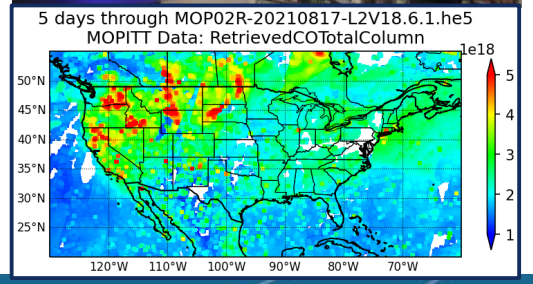
Modelling:
MUSICA Community Infrastructure and MusicBox
(Guy Brasseur, Wenfu Tang – ACOM; Rajesh Kumar– RAL)

Flight instruments and field campaigns
Standard instruments and innovative instrumentation
Flight campaigns
(Frank Flocke)

Laboratory/Chemistry chamber:
Atmospheric chemical processes
Instrument Calibration and Testing

Satellite Observations and ground-based monitoring
NDACC/FTIR and Pandora
MOPITT
(Sara-Eva Martinez, Ben Gaubert, James Hannigan, Pieternel Levelt)





Accelerating environmental sustainability solutions in Africa: a UCAR initiative

- **Severe environmental sustainability challenges in Africa**
  - Urbanization
  - Agriculture and food security
  - Air pollution and health
  - Drought
  - Climate change and variability
  - Water resource and water quality
  - Weather forecast and extreme weather
  - Fires and fire impacts
  - Dust aerosols
  - Early warning of high-impact weather events
  - …

For more information please contact
Wenfu Tang at NCAR-ACOM laboratory, wenfut@ucar.edu

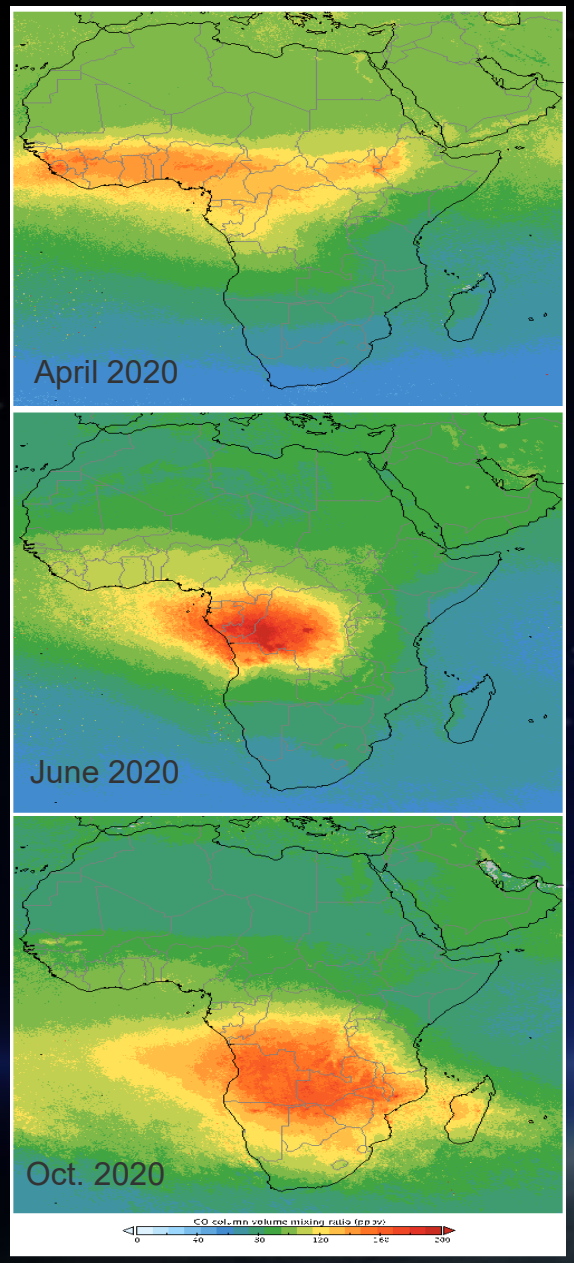
- **UCAR can help!**

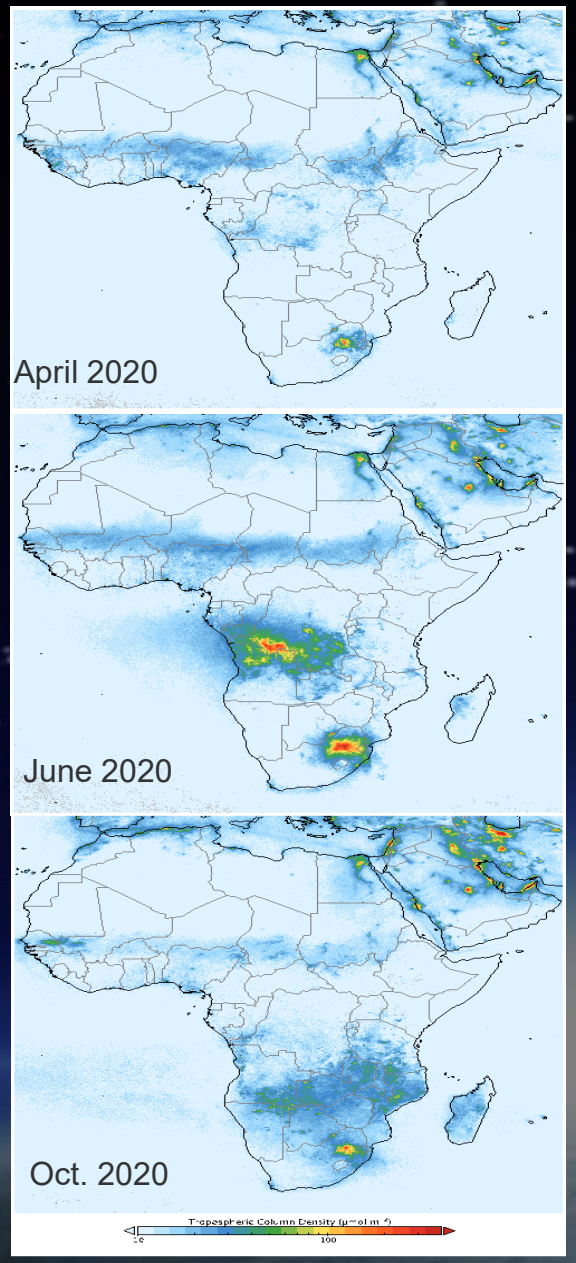
This project addresses the following questions:

Question 1: What are the existing UCAR efforts on Africa environmental sustainability issues?
Question 2: What are the urgent needs and top priority environmental issues in Africa that can be rapidly (< 5 years) addressed by UCAR expertise and tools?
Question 3: What are the potential internal and external collaborations and funding opportunities?

CO

NO_2

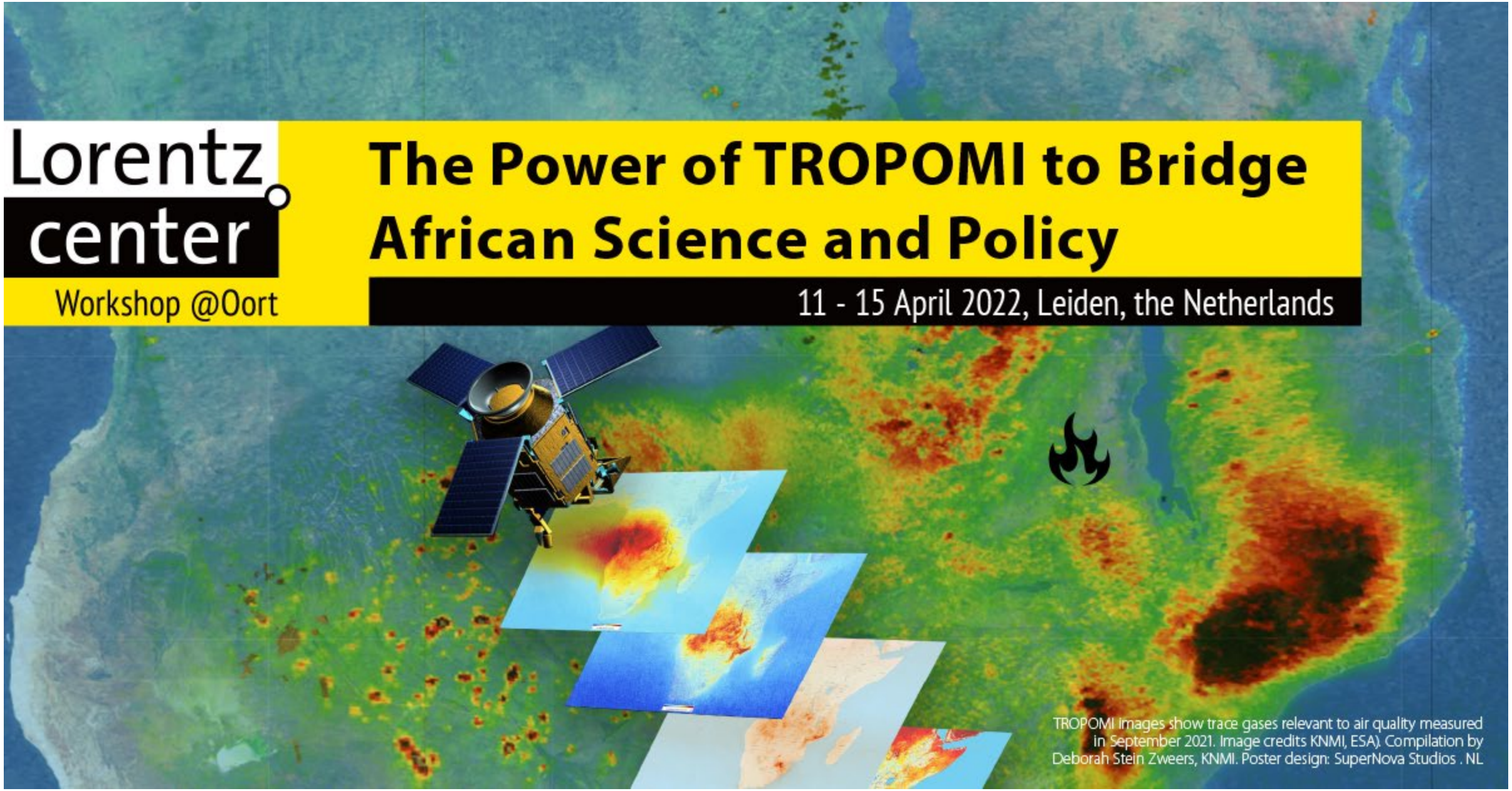




Biomass Burning over Africa as measured by TROPOMI CO and NO2

Image courtesy; Pepijn Veefkind, KNMI

Pieternel Levelt, NCAR ACOM



Pieternel Levelt, NCAR ACOM