Investigating atmospheric chemistry on the African continent: need for a GEO perspective

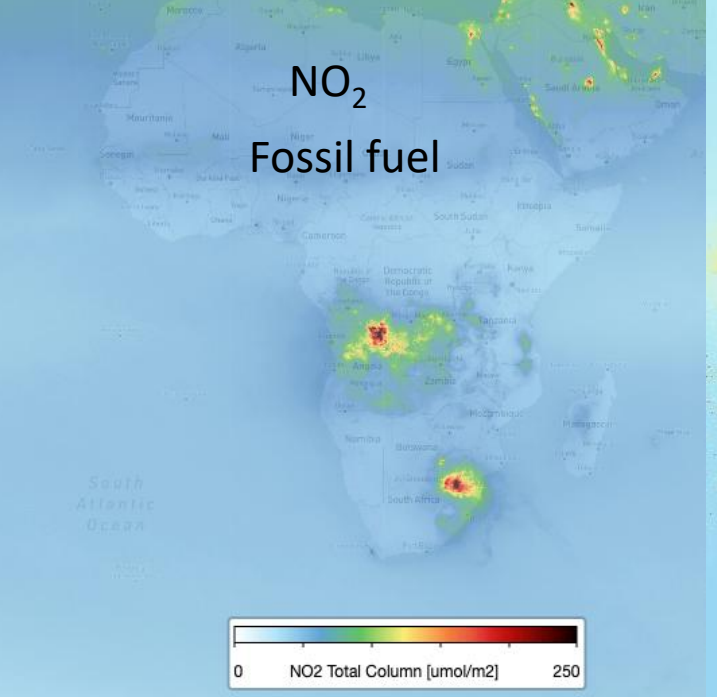
Pieternel F. Levelt, Omar Ali, Shoba Kondragunta, Eloise A. Marais, Wenfu Tang, Sara Martinez-Alonso, David Edwards, Helen Worden, Henk Eskes, Pepijn Veefkind, Steve Brown, Collins Gameli Hodoli, Allison Felix Hughes, Oman Emam, Barry Lefer, Drobot Sheldon, Dan Westerfelt.

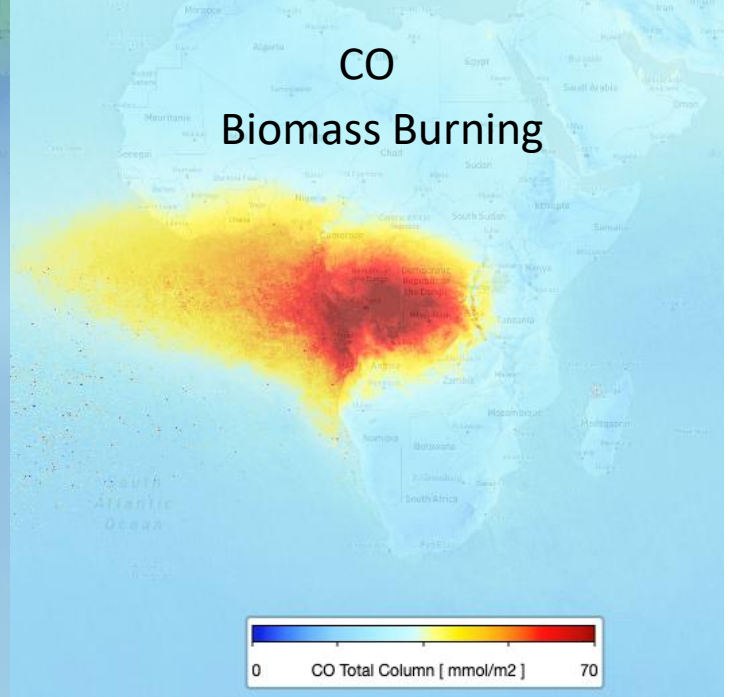
ACVC #22, Leiden, The Netherlands, June 1, 2026

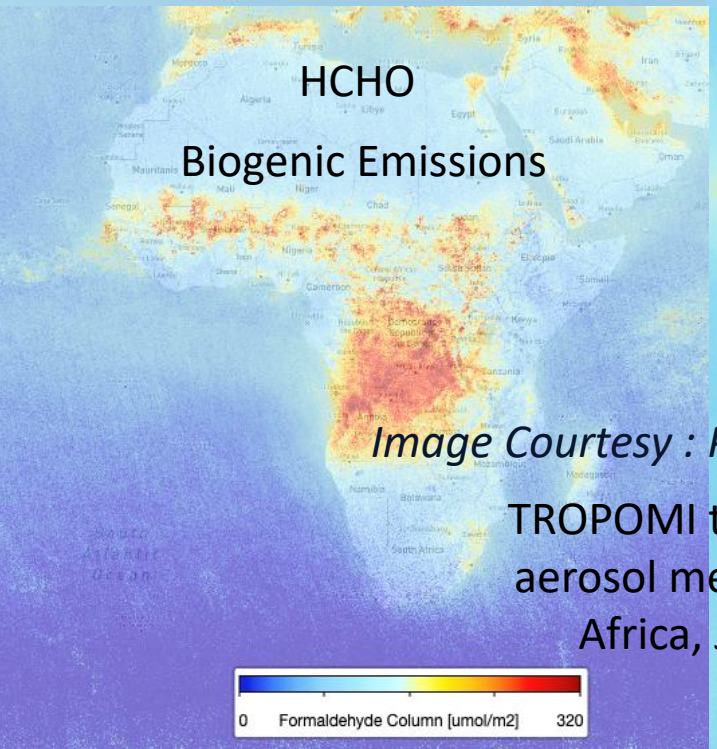
Prof. Dr. Pieternel Levelt, NSF NCAR ACOM Director
OMI Principal Investigator (NASA Eos Aura)
TROPOMI scientific initiator (ESA sentinel-5 precursor)
KNMI, TU Delft

Courtesy, Henk Eskes, KNMI

Africa







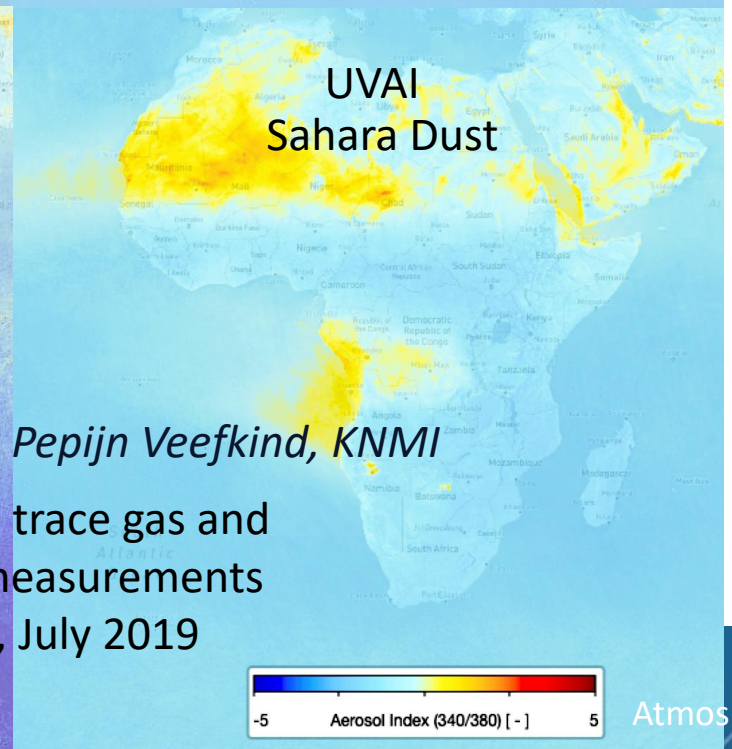


Image Courtesy : Pepijn Veefkind, KNMI

TROPOMI trace gas and aerosol measurements Africa, July 2019

Population is expected to double in 2050 (2.5 billion) and triple in 2100 (3.8 billion)

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

All emission sources are present in Africa:

- NO_2 – fossil fuel combustion
- CO – biomass burning
- HCHO – Biogenic Emissions
- UVAI – Sahara Dust

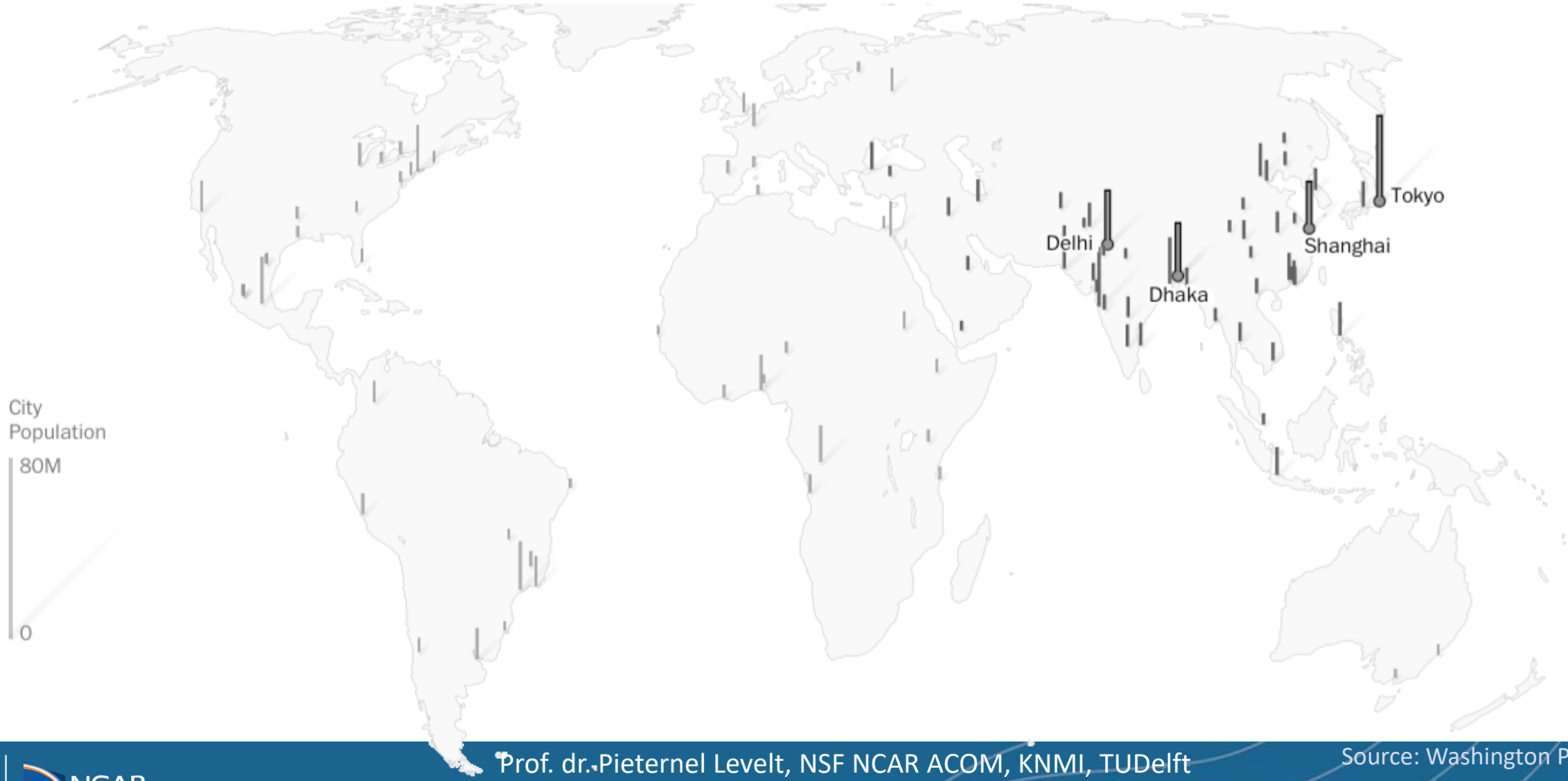
There is a lack of groundbased measurements over Africa

There is a lack of emission estimates over Africa

There is an urgent need for new capability for air quality management for health and environment
AGU Advances (Dylan Millet et al.), 2024

Prof. dr. Pieternel Levelt, NCAR ACOM
Atmospheric Chemistry and Observations Laboratory

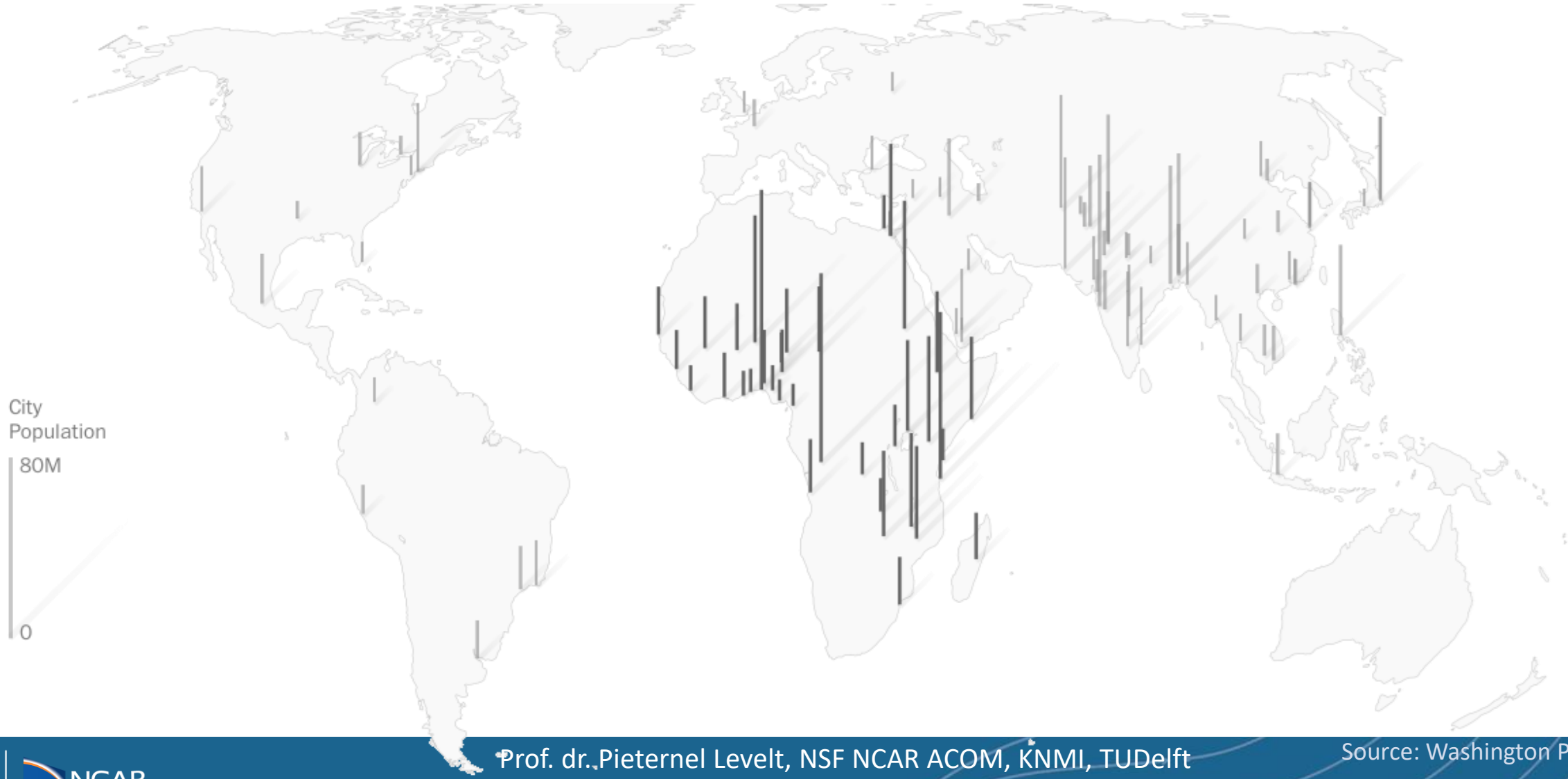
100 Largest Megacities 2025



Prof. dr. Pieternel Levelt, NSF NCAR ACOM, KNMI, TUDelft
Atmospheric Chemistry and Observations Laboratory

Source: Washington Post, 2021

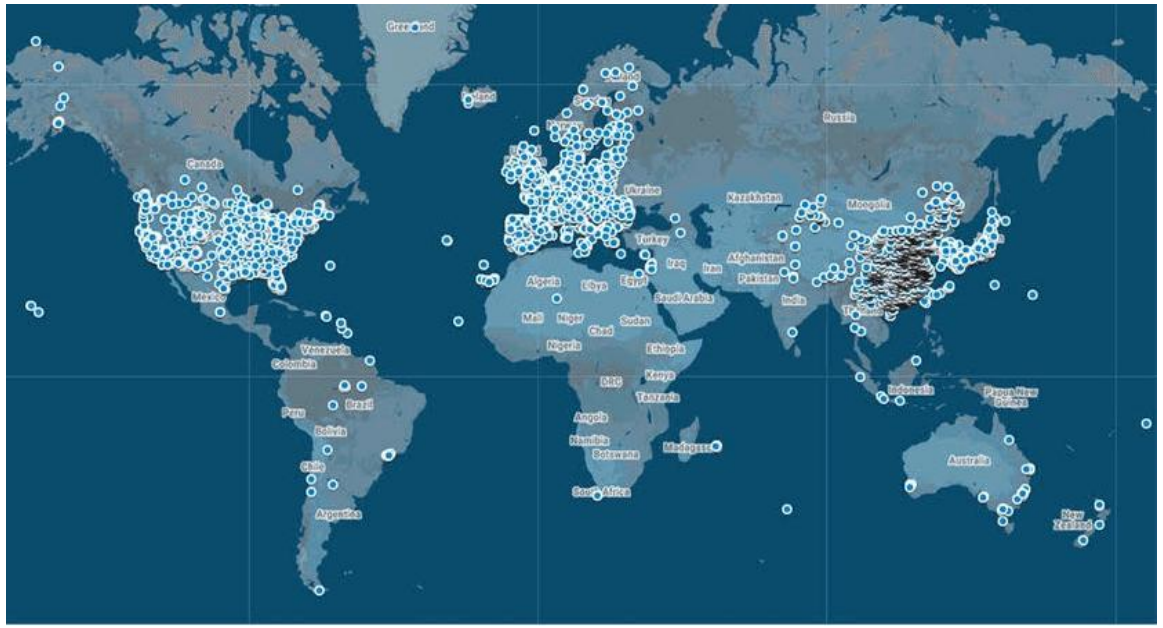
100 Largest Megacities 2100



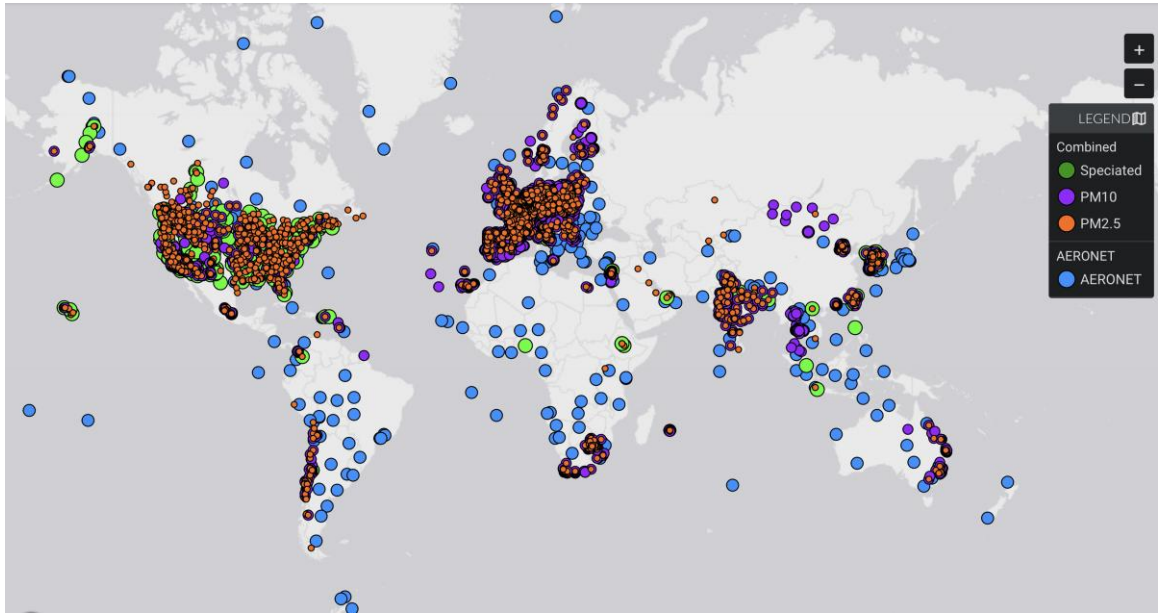
Prof. dr. Pieternel Levelt, NSF NCAR ACOM, KNMI, TUDelft
Atmospheric Chemistry and Observations Laboratory

Source: Washington Post, 2021

Severe Lack of reliable ground based observations in the Global South



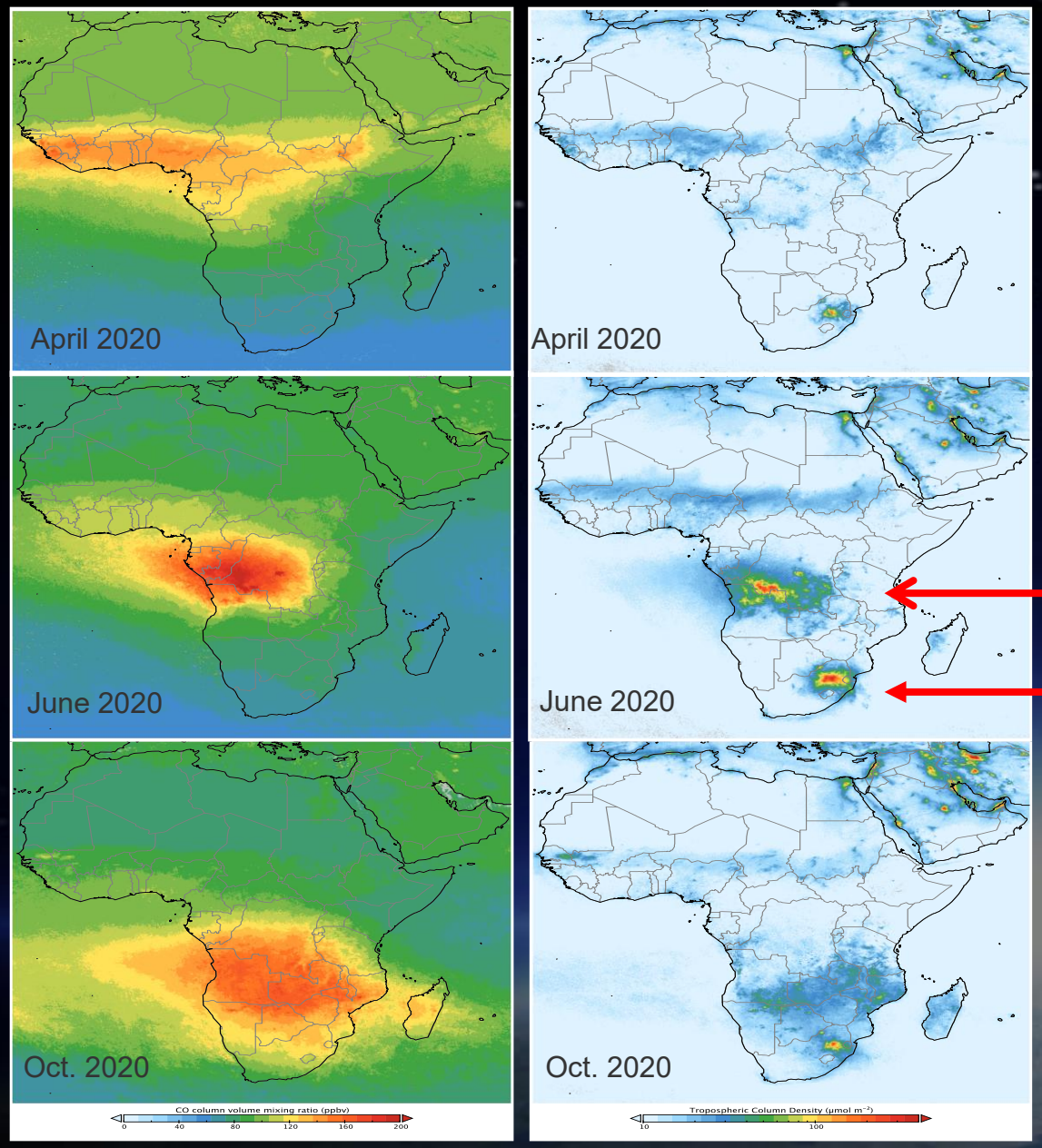
Ozone Monitoring sites
(TOAR and Open AQ)



Aerosol Surface Monitoring sites
(MAIA Data Visualization Tool)

CO

NO_2



Biomass Burning over Africa as measured by TROPOMI CO and NO_2

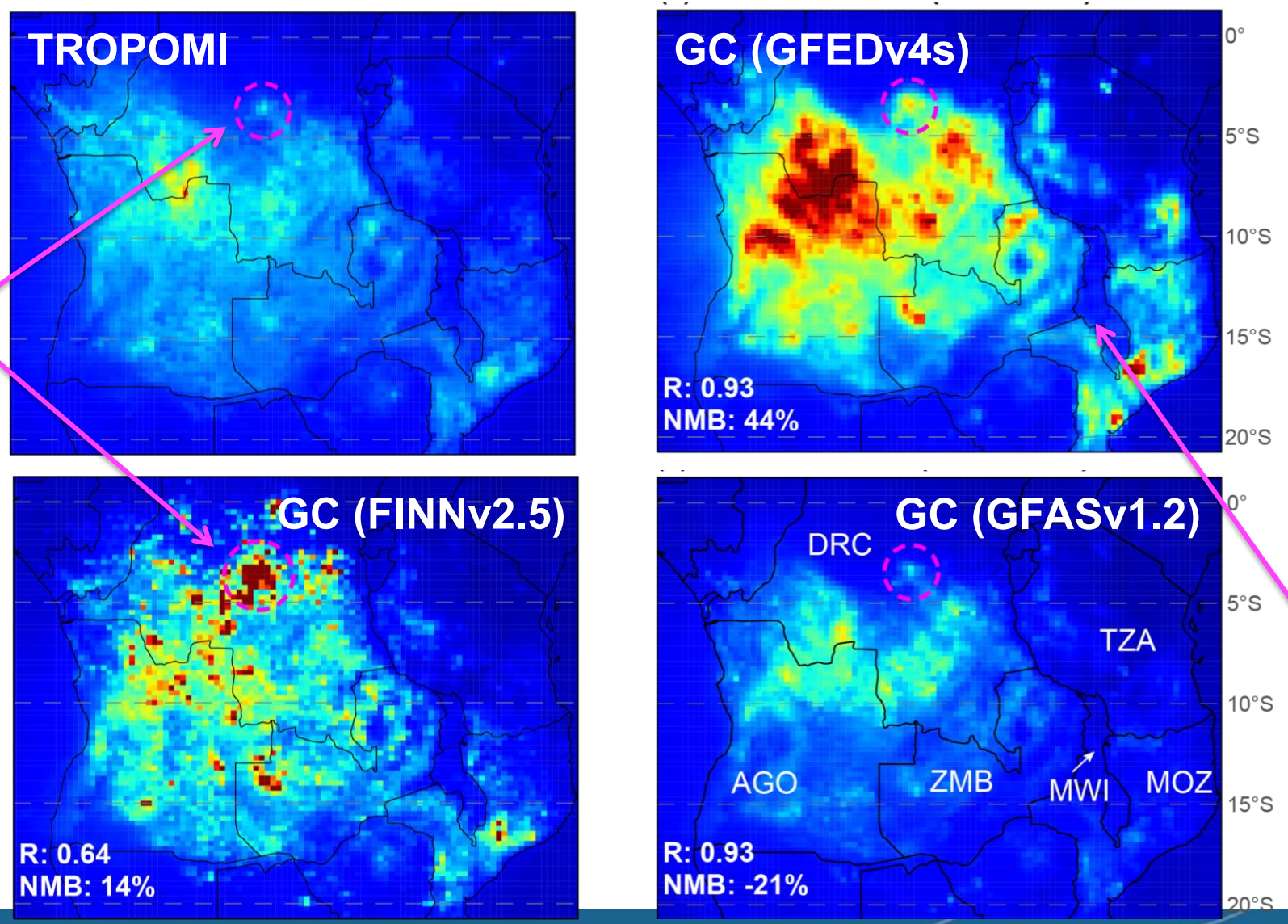
Biomass burning in tropical Africa

Power plants near Johannesburg

Pepijn Veefkind, KNMI

Evaluation of Biomass Burning Inventories with Satellite Observations

NO_2 vertical column densities for Jun-Oct 2019



GC: GEOS-Chem

Far more NO_x from tropical forests in FINN (fuel load)

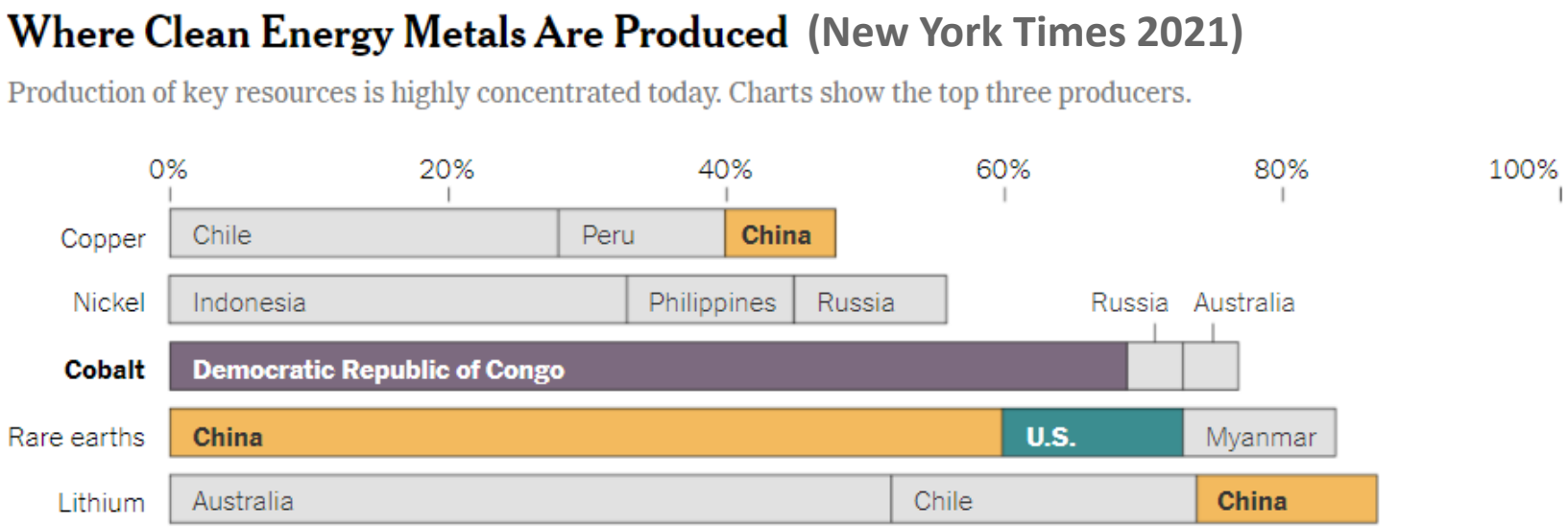
GFED and GFAS NO_2 spatially similar, but >50% difference due to emission factors

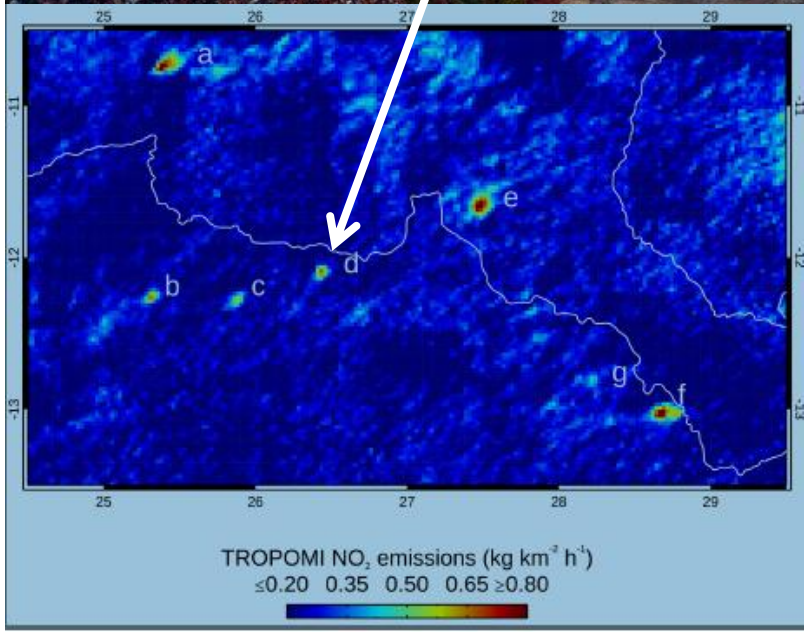
Low emissions in Malawi, as spread of fire suppressed by dense population

Elios Marais, UCL

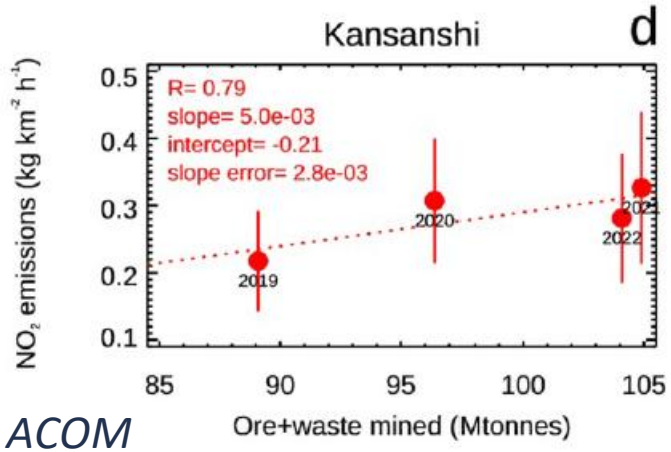
EGU talk
April 28, 2025

Emissions from metal mining in Africa





NOx Emissions follow Production

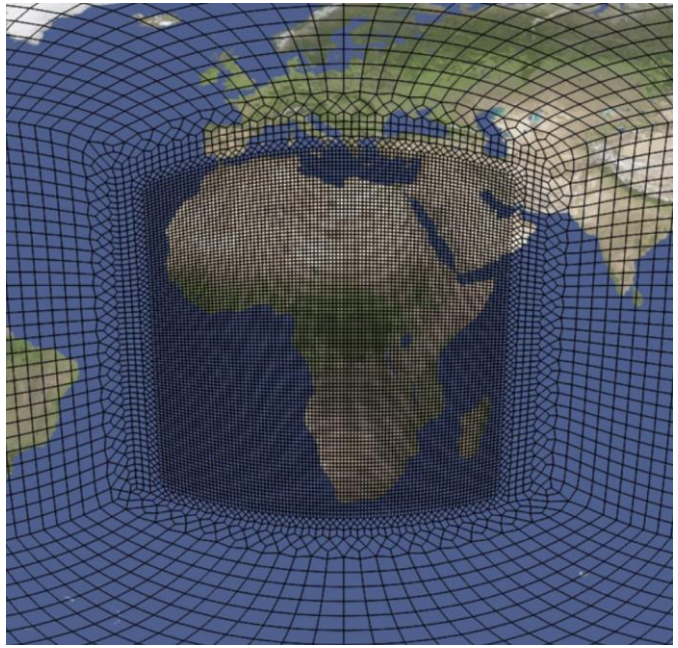


Martinez-Alonso et al., JGR 2023, NCAR ACOM

Air Quality Modelling over Africa using MUSICA

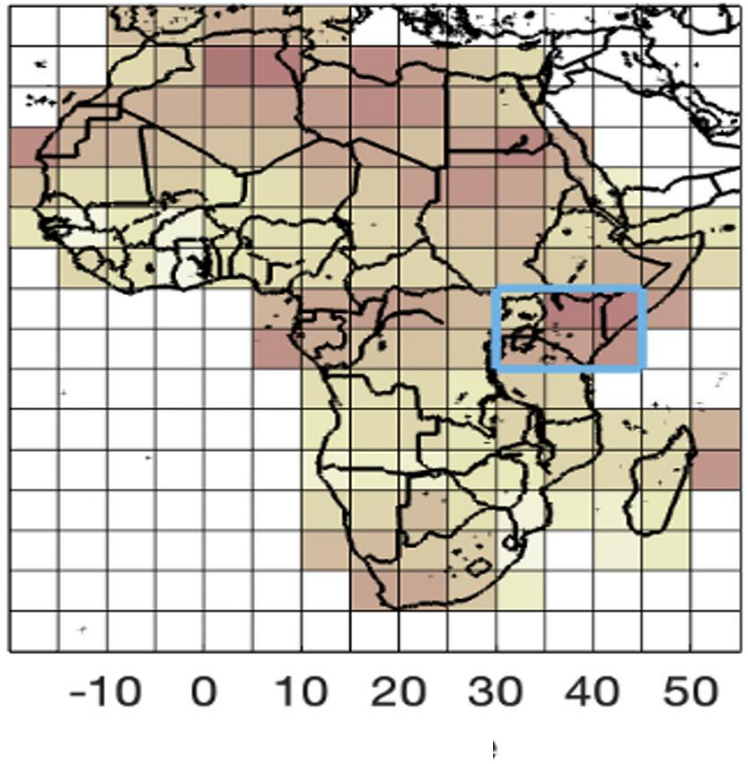
- We quantify model-satellite discrepancies over Africa with MUSICAv0.
- The highlighted East Africa region has the largest model-satellite discrepancies.
- A field campaign there can help understand model-satellite discrepancies and improve model predictability.

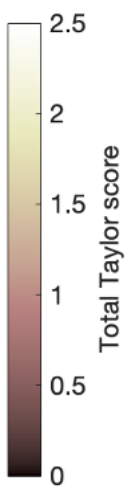
MUSICAv0 grid for Africa:



Wenfu Tang et al., GMD 2023, NCAR ACOM

MUSICA-satellite discrepancies:



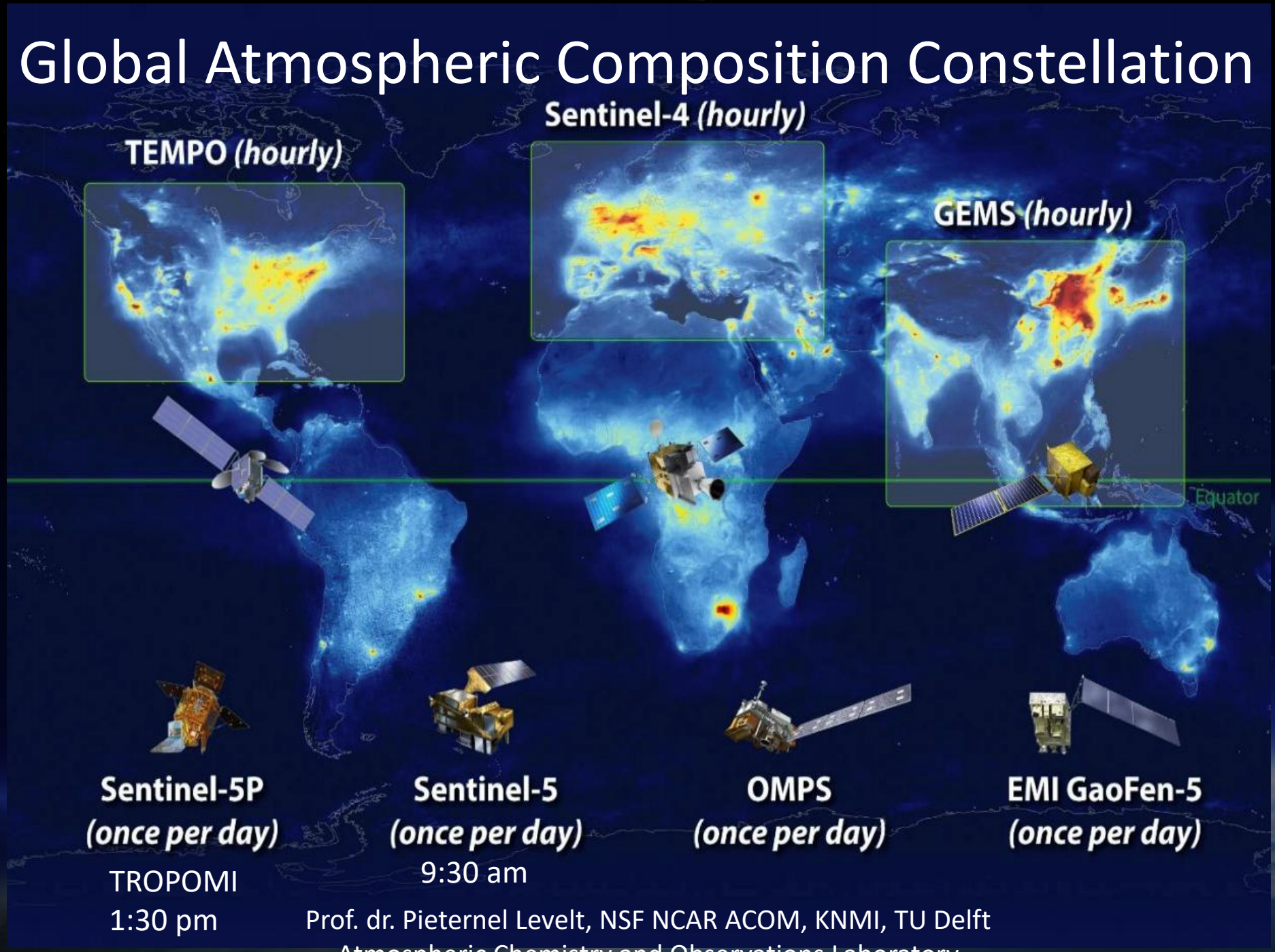


Better agreement
for CO, NO2, HCHO, AOD

Worse agreement
For CO, NO2. HCHO. AOD

Aircraft campaign
East Africa?

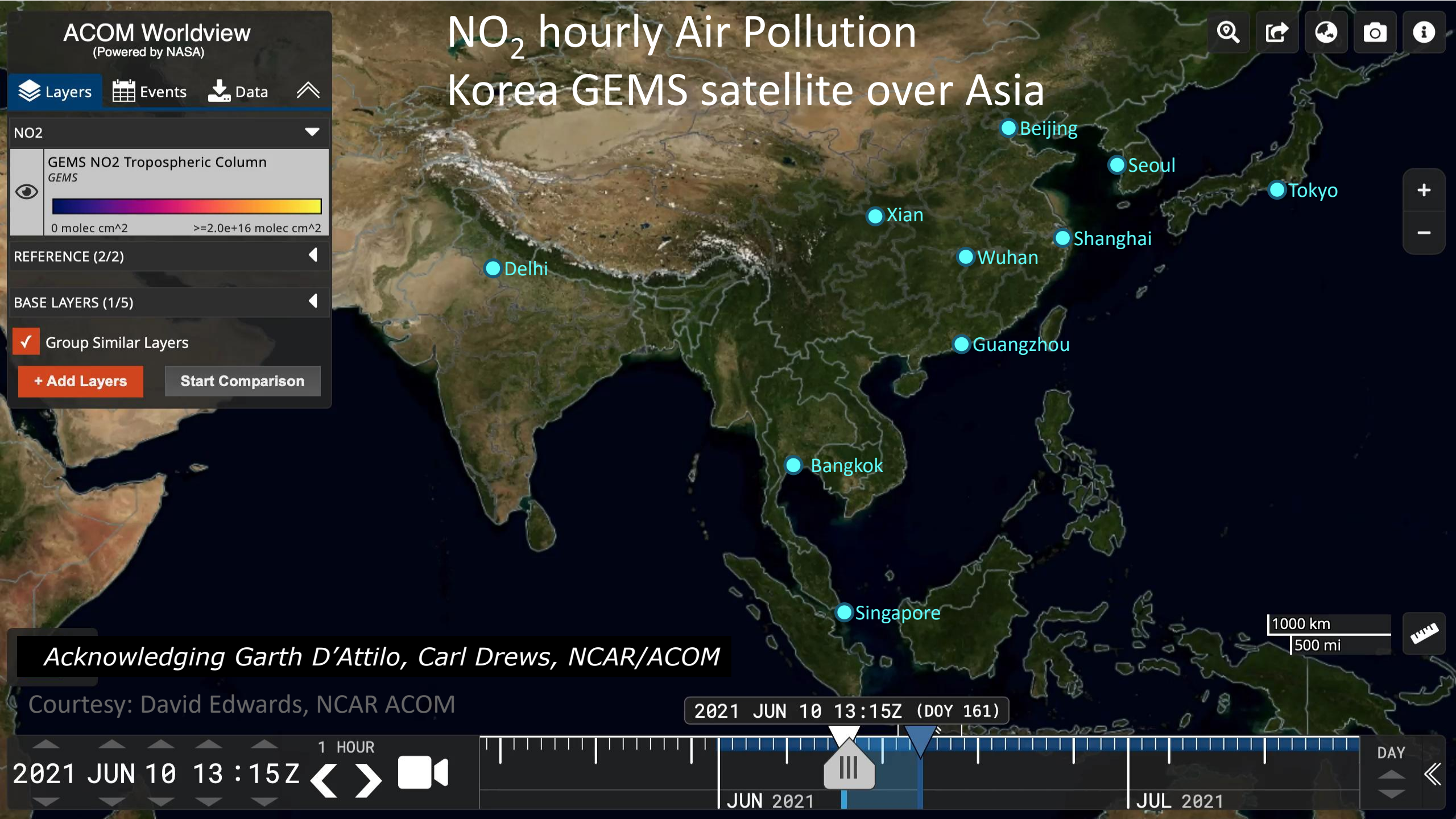
Global Atmospheric Composition Constellation



TROPOMI
1:30 pm

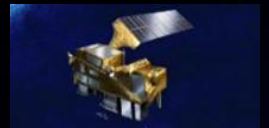
9:30 am

Prof. dr. Pieternel Levelt, NSF NCAR ACOM, KNMI, TU Delft
Atmospheric Chemistry and Observations Laboratory


ACOM Worldview
(Powered by NASA)
Layers
Events
Data
NO2
GEMS NO2 Tropospheric Column
GEMS
0 molec cm^2
>=2.0e+16 molec cm^2
REFERENCE (2/2)
BASE LAYERS (1/5)
Group Similar Layers
+ Add Layers
Start Comparison
NO2 hourly Air Pollution
Korea GEMS satellite over Asia
Beijing
Seoul
Tokyo
Xian
Shanghai
Wuhan
Delhi
Guangzhou
Bangkok
Singapore
1000 km
500 mi
Acknowledging Garth D'Attilo, Carl Drews, NCAR/ACOM
Courtesy: David Edwards, NCAR ACOM
2021 JUN 10 13:15Z (DOY 161)
2021 JUN 10 13:15Z
1 HOUR
DAY
JUN 2021
JUL 2021

Global Atmospheric Composition Constellation

Sentinel-5P
(once per day)
TROPOMI



Sentinel-5
(once per day)

OMPS
(once per day)

EMI GaoFen-5
(once per day)

TEMPO *(hourly)*

Sentinel-4 *(hourly)*

GEMS *(hourly)*

MEASMA-N

GEO - Africa

GEO - Oceania

GEO-S America

Equator

TROPOMI

Coordinated Geostationary, Multispectral Satellite Observations Are Critical for Climate and Air Quality Progress
Dylan B. Millet, Paul I. Palmer, Pieternel F. Levelt, Laura Gallardo, Lerato Shikwambana, AGU Advances, 2024, **https://doi.org/10.1029/2024AV001322**

Prof. dr. Pieternel Levelt, NSF NCAR ACOM, KNMI, TU Delft
Atmospheric Chemistry and Observations Laboratory

NSF | NCAR Operated by UCAR

Action: White paper expanding current AC-VC observations to the Middle East, Africa, South America and the Oceania Region

In 2024, the CEOS Atmospheric Composition Virtual Constellation (AC-VC) commissioned a team to work on a White Paper that calls for global coverage of air quality and greenhouse gas observations and complements the current virtual constellation of GEMS, TEMPO and Sentinel 4

A small team has been meeting bi-weekly to develop this white paper. It has submitted a draft to the CEOS Strategic Implementation Team (SIT) at its October 2025 Meeting. A finalized White Paper by March 31, 2026

Call to Action

- Urgent need for improved atmospheric composition monitoring.
- Geostationary satellites are a vital complement to existing systems.
- Invest in geostationary atmospheric composition monitoring for a sustainable future.

Join our team if you want to participate
Write to: ali.h.omar@nasa.gov

backup

Summary

GEO's over the Global South

- Commentary in AGU Advances (Dylan Millet et al.), 2024
- 2 initiatives for GEO's over Africa (Measma & Africa GEO)
- Start writing **CEOS scientific concept paper**:
  Geostationary Atmospheric Composition Satellite Constellation: Towards Global Coverage
- Currently we are trying to form **science teams** : looking for scientists from all continents - ***interest? Please send me an email.***
- **Townhall Meet GEO over the Global South was held at AMS in January 2025** with leaders in the field and cross disciplinary

AGU ADVANCING EARTH AND SPACE SCIENCES

AGU Advances

COMMENTARY

10.1029/2024AV001322

Peer Review The peer review history for this article is available as a PDF in the Supporting Information.

Key Points:

- Geostationary ultraviolet (UV)/visible air quality missions omit Africa and South America, where pollution can be severe and in situ measurements are few
- Measurements at UV through infrared wavelengths are needed for comprehensive space-based measurements of atmospheric composition
- International coordination is needed for a sustainable and equitable satellite-based global observing system

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

D. B. Millet and P. I. Palmer,
dbm@umn.edu;
pip@ed.ac.uk

Citation:

Millet, D. B., Palmer, P. I., Levelt, P. F., Gallardo, L., & Shikwambana, L. (2024). Coordinated geostationary, multispectral

Coordinated Geostationary, Multispectral Satellite Observations Are Critical for Climate and Air Quality Progress

Dylan B. Millet[1], Paul I. Palmer[2], Pieternel F. Levelt[3,4,5], Laura Gallardo[6,7], and Lerato Shikwambana[8]

[1]University of Minnesota, Saint Paul, MN, USA, [2]University of Edinburgh, Edinburgh, UK, [3]National Center for Atmospheric Research, Boulder, CO, USA, [4]Royal Netherlands Meteorological Institute, De Bilt, The Netherlands, [5]Delft University of Technology, Delft, The Netherlands, [6]Universidad de Chile, Santiago, Chile, [7]Center for Climate and Resilience Research, Santiago, Chile, [8]Earth Observation Directorate, South African National Space Agency, Pretoria, South Africa

Abstract Satellite observations are critical for air quality and climate monitoring, and for developing the process understanding needed for reliable planning and predictions. Our current space-based observing system stands at a crossroads with the early missions approaching their end-of-life. We articulate the challenges and needs to sustain and develop these environmental records into the future, focusing specifically on observations of gas-phase atmospheric composition.

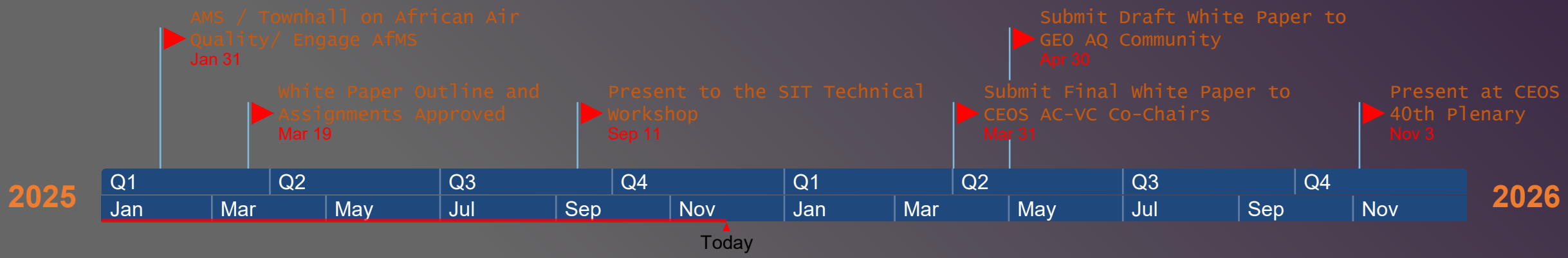
Plain Language Summary We describe challenges and needs for developing a globally comprehensive and equitable satellite-based observing system for air quality and climate pollution.

1. Introduction

Air pollution emissions kill millions of people every year, with disproportionate impacts on lower-income and disadvantaged communities (Rentschler & Leonova, 2023). Many air pollutants are also direct or indirect climate forcers (Szopa et al., 2021) contributing to impacts that include heat waves and altered precipitation patterns (Capua & Rahmstorf, 2023; Wang et al., 2023). Meanwhile, oxidizing and nitrogen-containing air pollutants degrade ecosystems, lower crop yields, and perturb the global N cycle (Groffman et al., 2021; Liu et al., 2013;

Pieternel Levelt, levelt@ucar.edu

Schedule



First Draft of the White Paper — 45 days — Apr 2 - Jun 3

21st CEOS AC-VC Joint with IWGGMS — 5 days — Jun 9 - Jun 13

Second Draft of the White Paper — 36 days — Jun 16 - Aug 4

AGU Fall Meeting — 5 days — Dec 15 - Dec 19

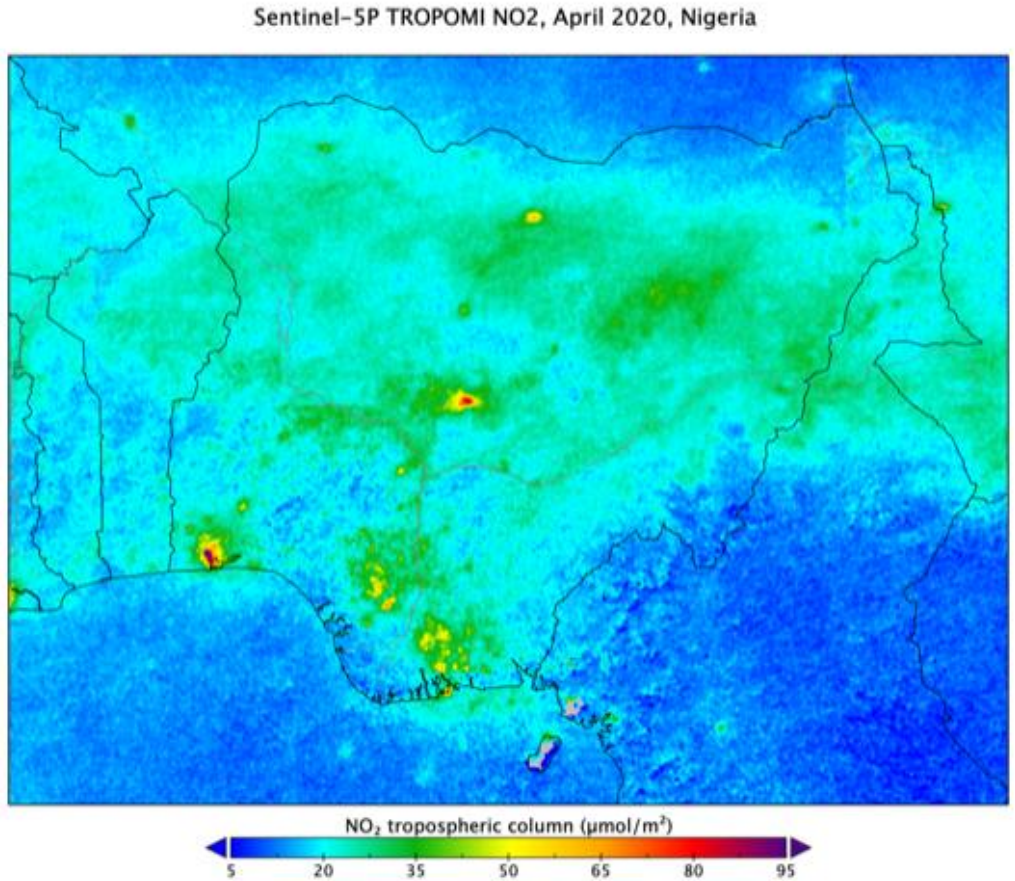
SIT-41 : April 14th - 16th, 2026 | Irvine, California, USA — 3 days — Apr 14 - Apr 16

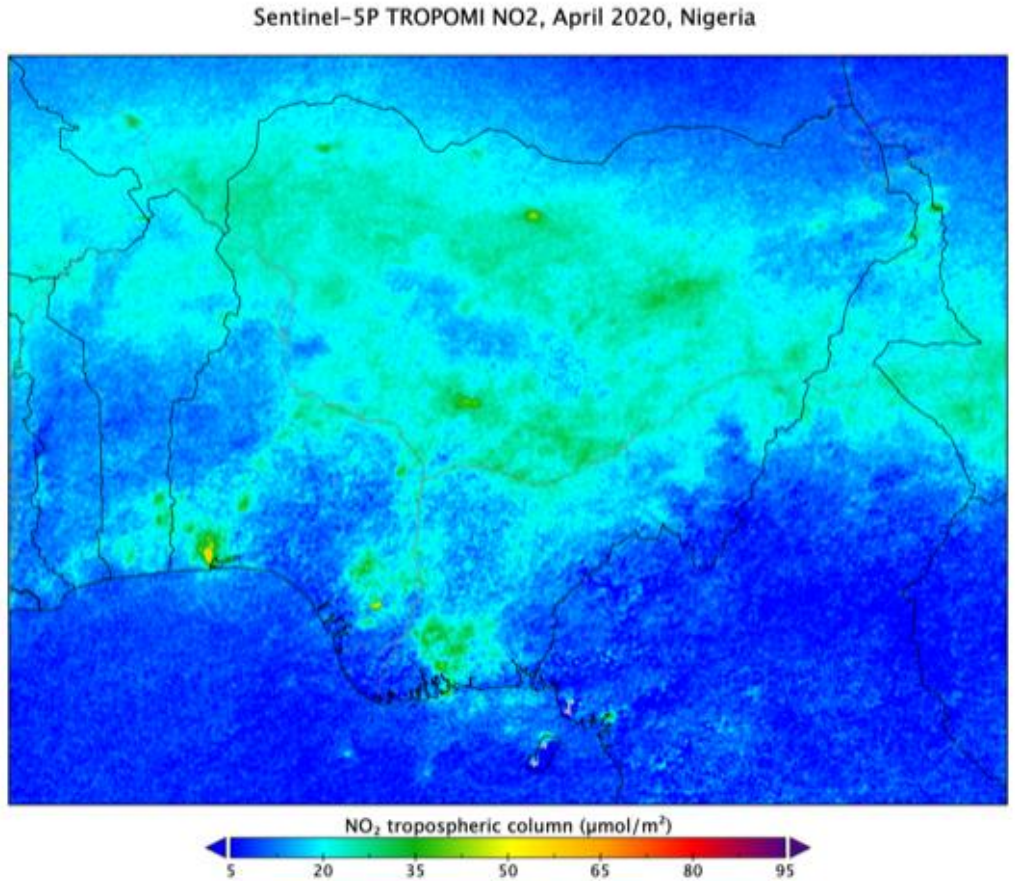
2026 SIT Technical Workshop : September 8th - 10th, 2026 | Washington, D.C., USA — 3 days — Sep 8 - Sep 10

Present at 40th CEOS Plenary : November 3rd - 6th, 2026 | Hobart, Australia. — 4 days — Nov 3 - Nov 6

Third Draft of White Paper including Secondary Co-authors — 159 days — Aug 5 - Mar 15

TROPOMI NO_2 measurements over Africa: **COVID lockdown**





TROPOMI NO2 yearly mean 2019

Nigeria,TROPOMI NO_2 , April 2019

Nigeria, TROPOMI NO_2 , April 2020

*Courtesy: **Henk Eskes, KNMI***