# Studying Air Pollution and Climate Change on the African Continent

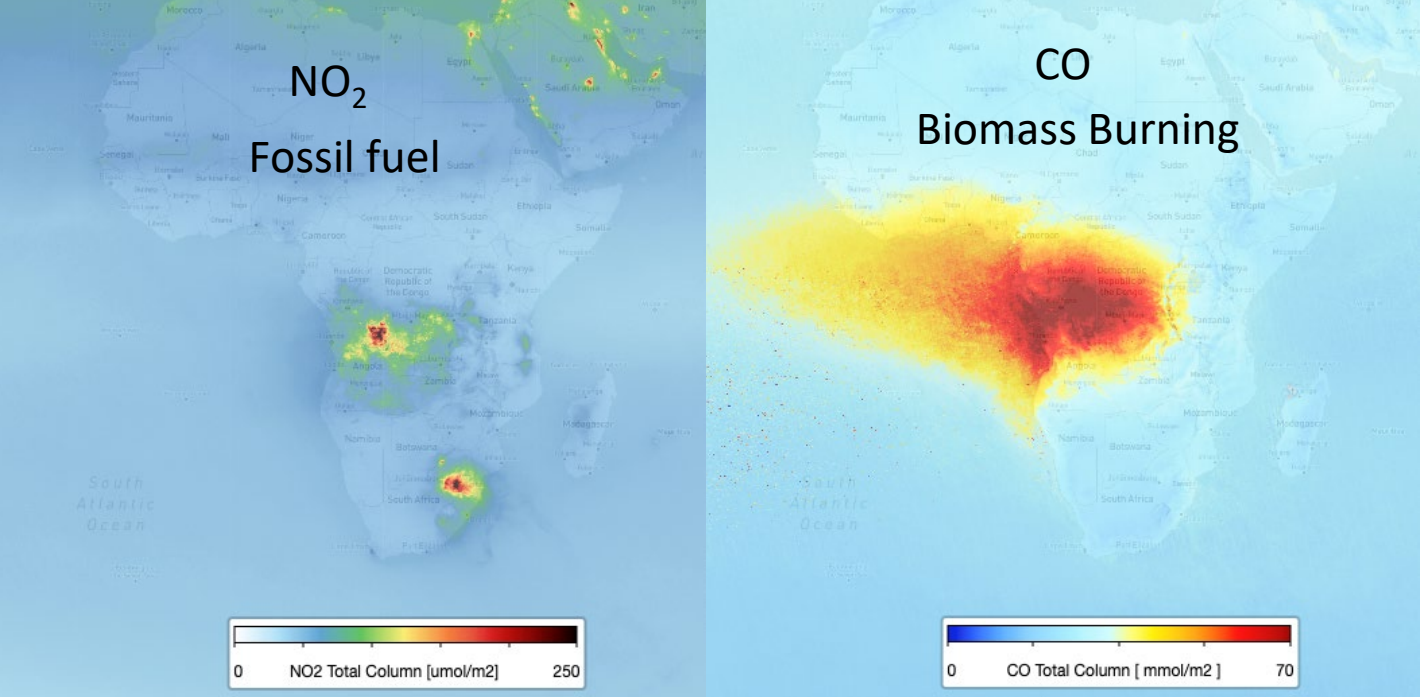
Pieternel F. Levelt, Eloise A. Marais, Wenfu Tang, Sara Martinez-Alonso, David Edwards, Helen Worden, Henk Eskes, Pepijn Veefkind, Steve Brown, Collins Gameli Hodoli, Allison Felix Hughes, Barry Lefer, Drobot Sheldon, Dan Westerfelt.

ESA 4 Africa EO Meeting, September 2024
Frascati, ESA-Esrin , Italy

*Courtesy, Henk Eskes, KNMI*


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

# Africa







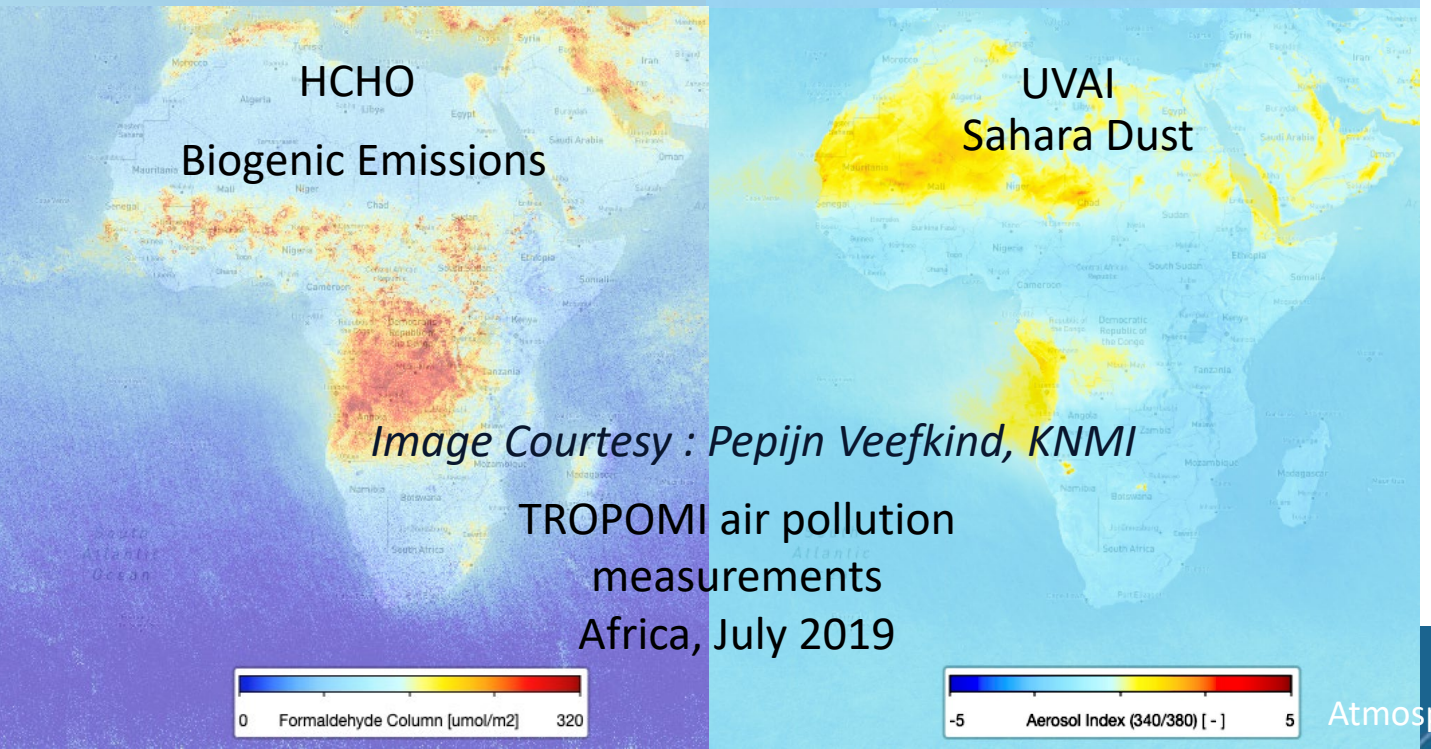






*Image Courtesy : Pepijn Veefkind, KNMI*

TROPOMI air pollution 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 pollution sources are present in Africa:

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

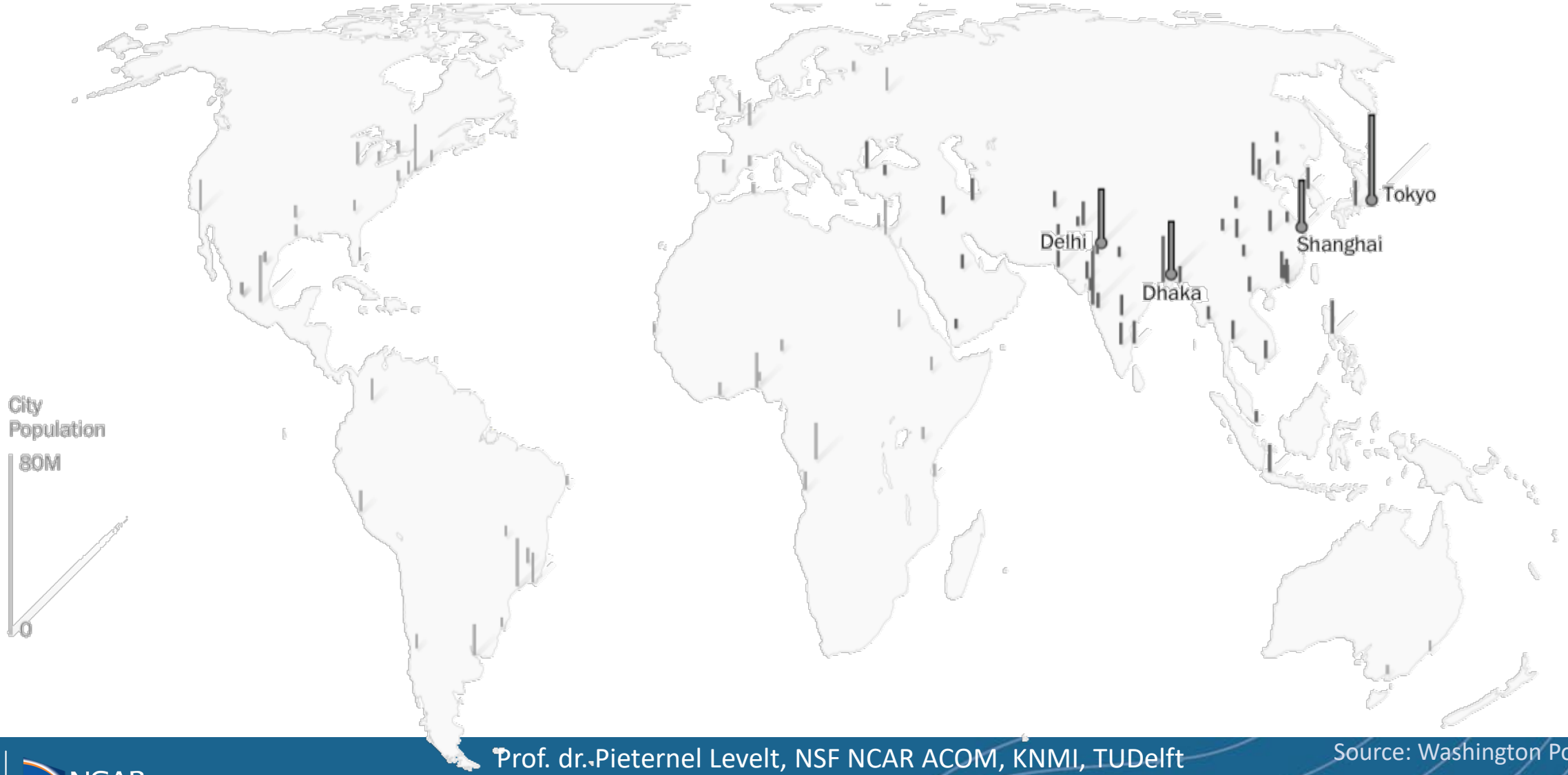
There is a lack of groundbased measurements over Africa

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

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

# 100 Largest Megacities 2025

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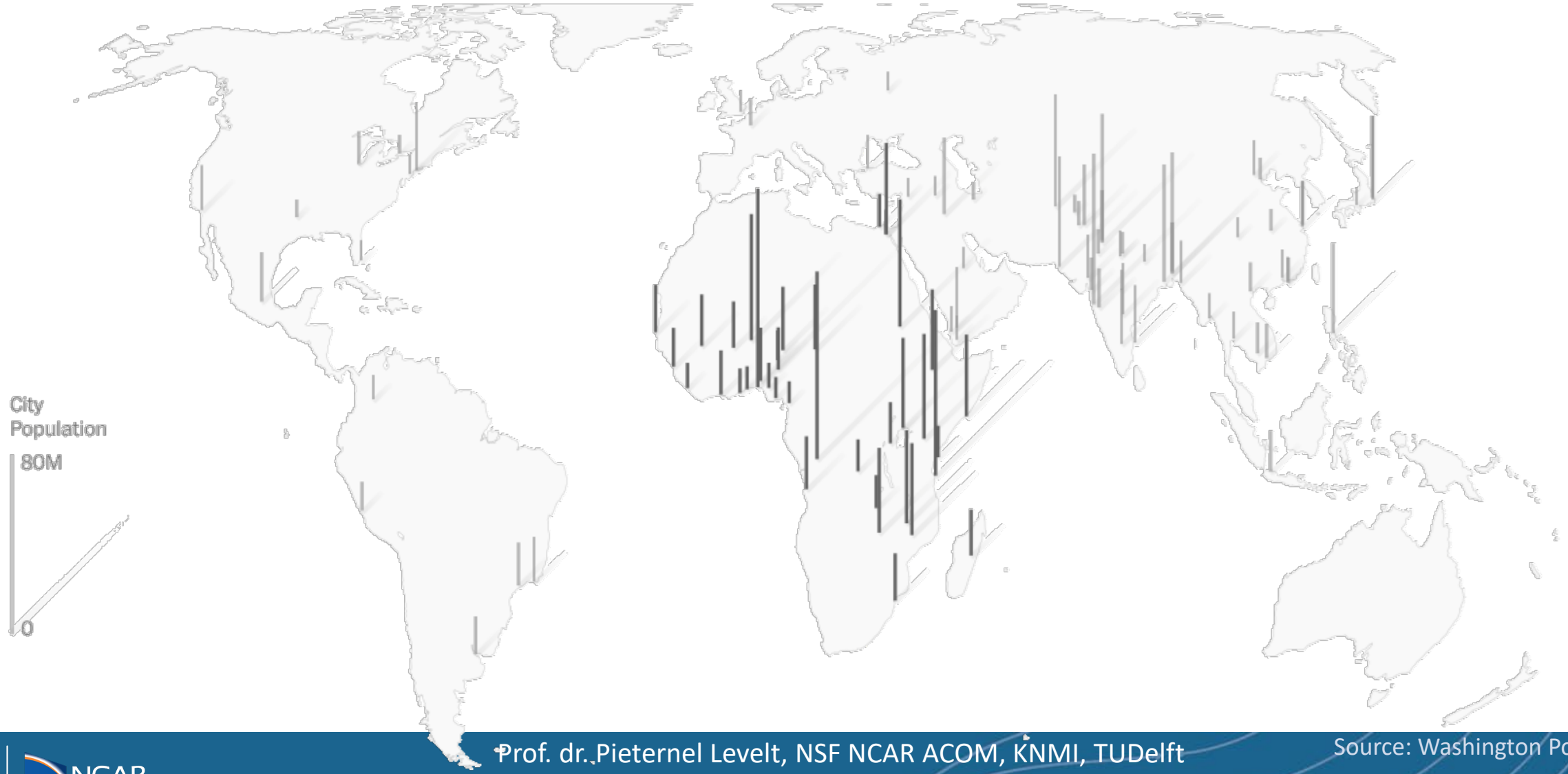
Source: Washington Post, 2021

# 100 Largest Megacities 2100

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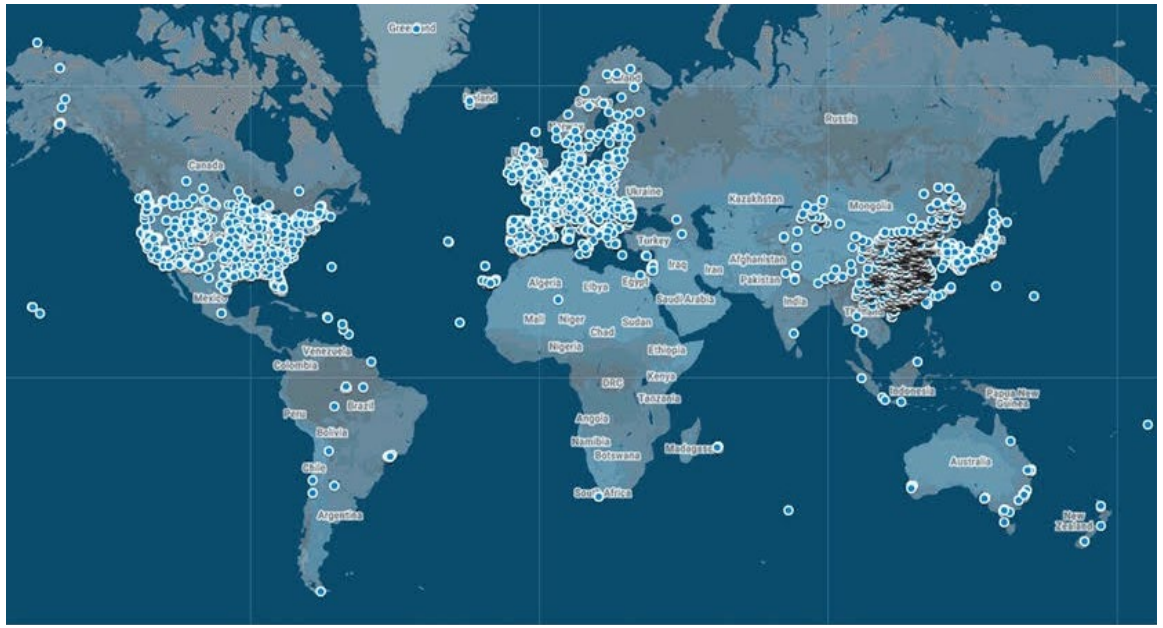
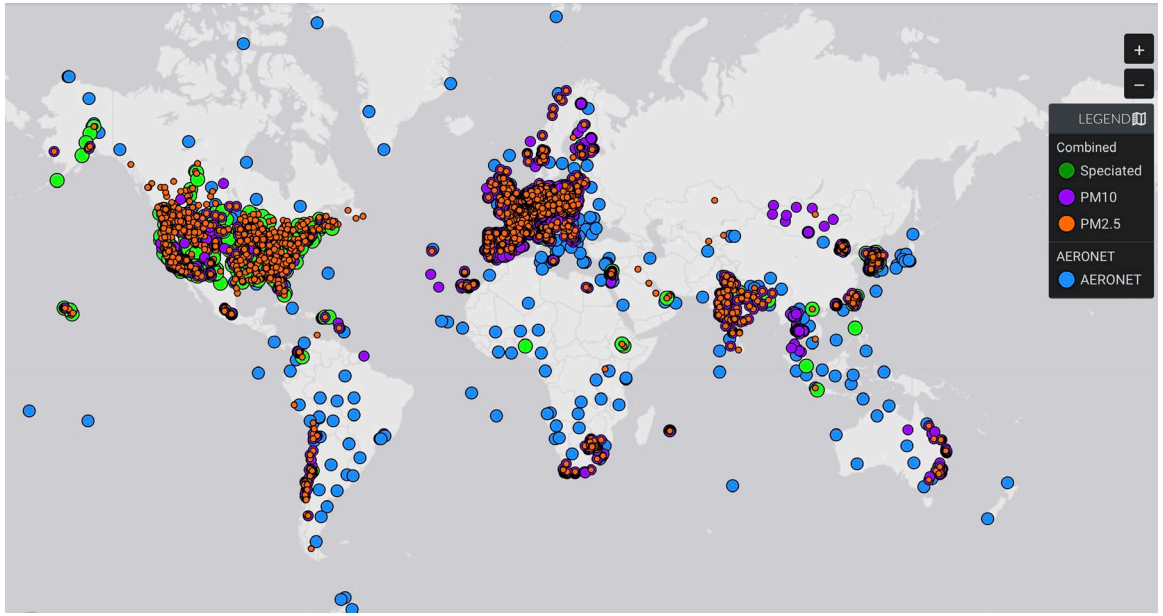
Source: Washington Post, 2021

# Severe Lack of reliable ground based observations in the Global South

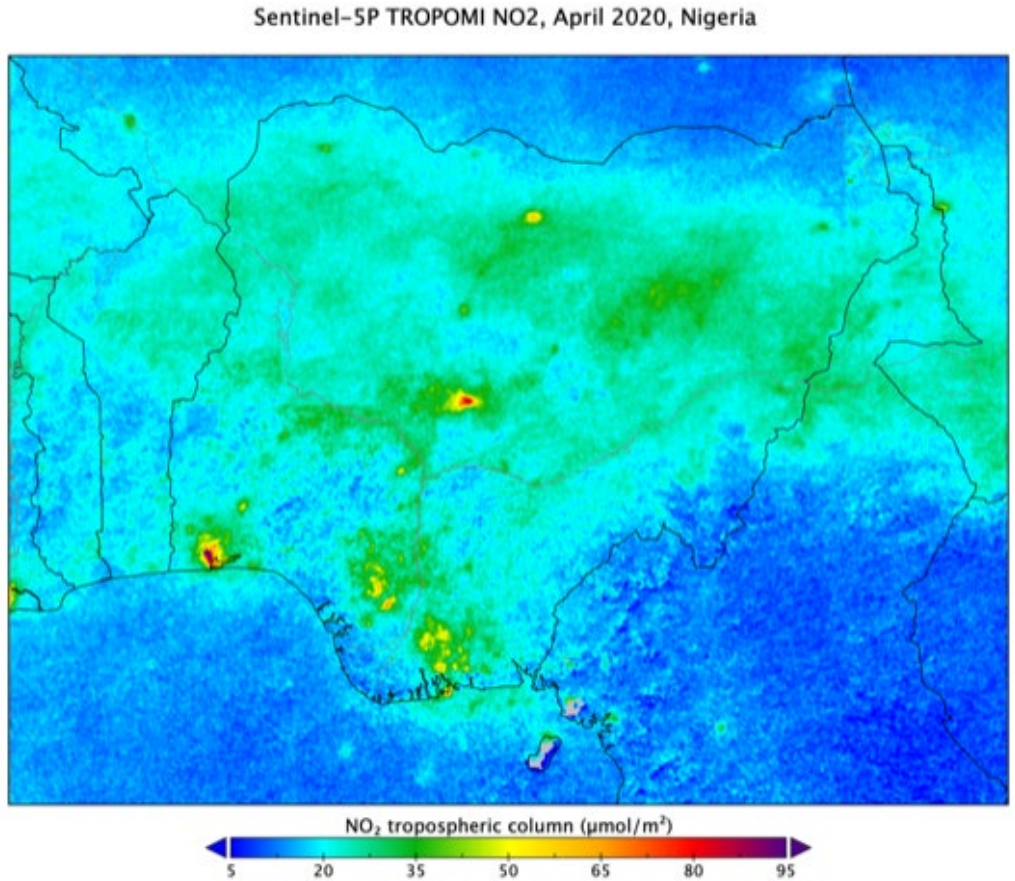


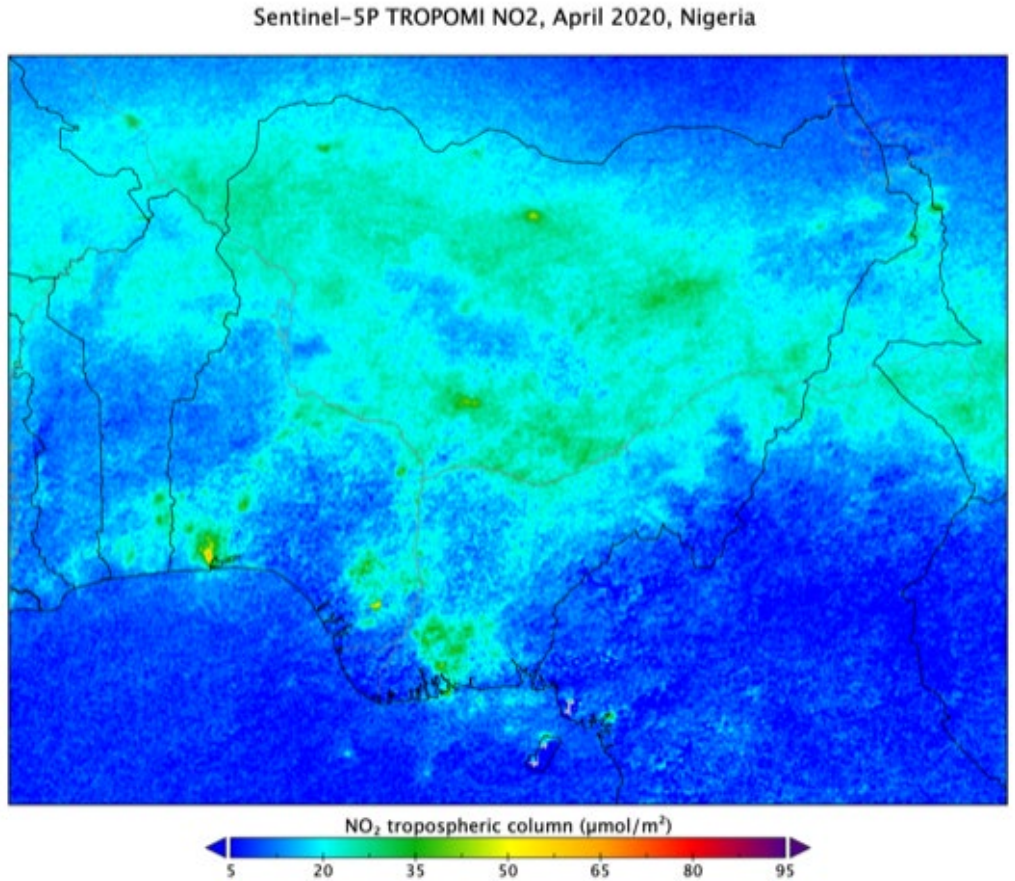

Ozone Monitoring sites
(TOAR and Open AQ)




Aerosol Surface Monitoring sites
(MAIA Data Visualization Tool)

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




**TROPOMI NO2 yearly mean 2019**

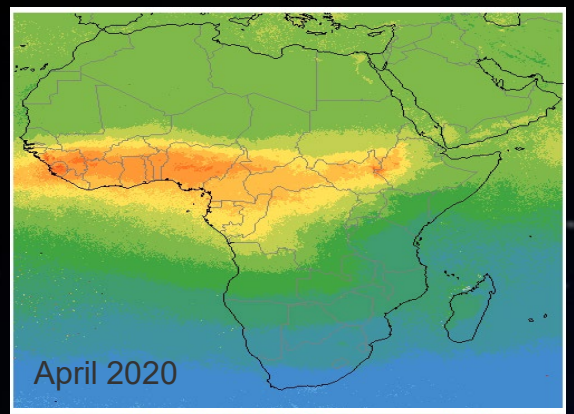
**Nigeria,TROPOMI $NO_2$ , April 2019**

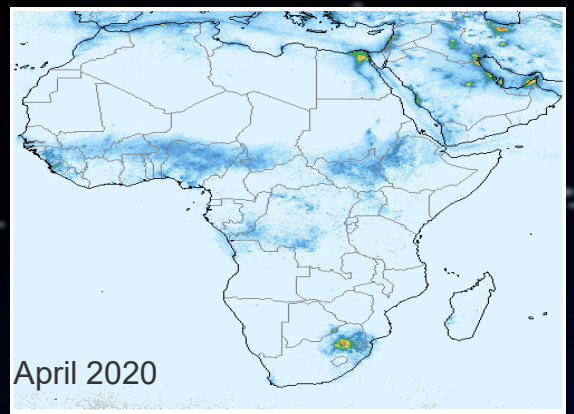
**Nigeria, TROPOMI $NO_2$ , April 2020**

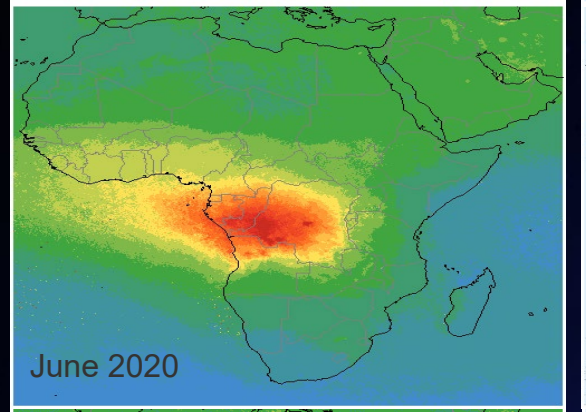
*Courtesy:* ***Henk Eskes, KNMI***

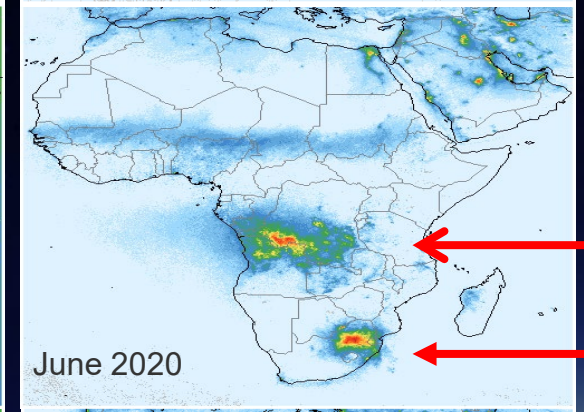
CO

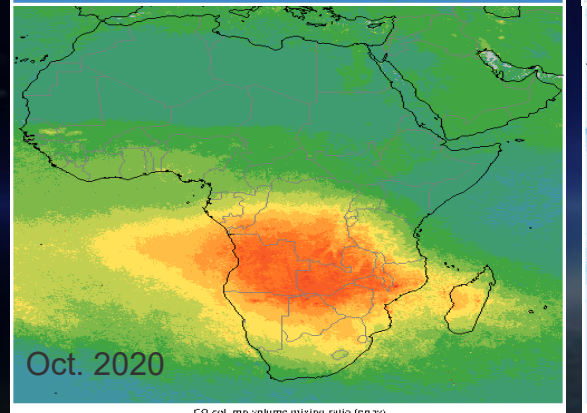
$NO_2$

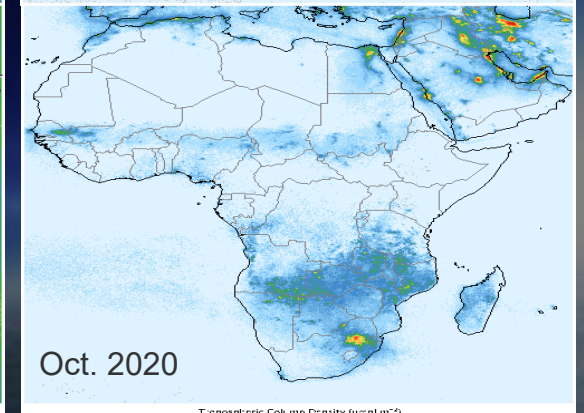



# Biomass Burning over Africa as measured by TROPOMI CO and $NO_2$

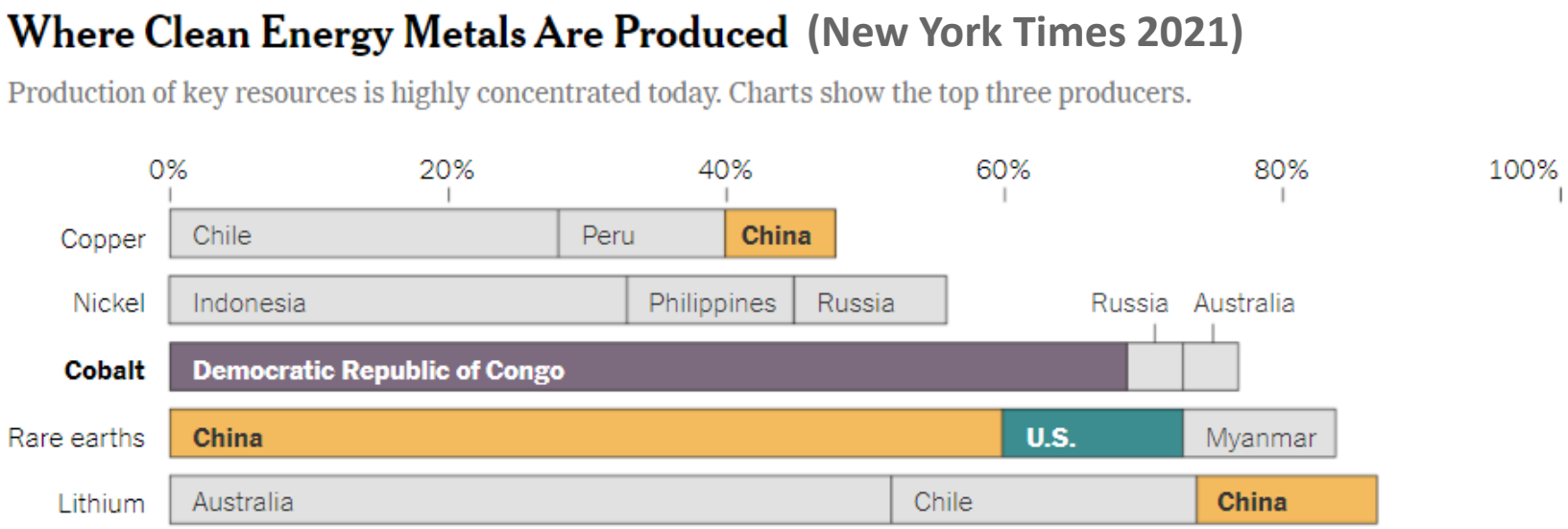
Biomass burning in tropical Africa

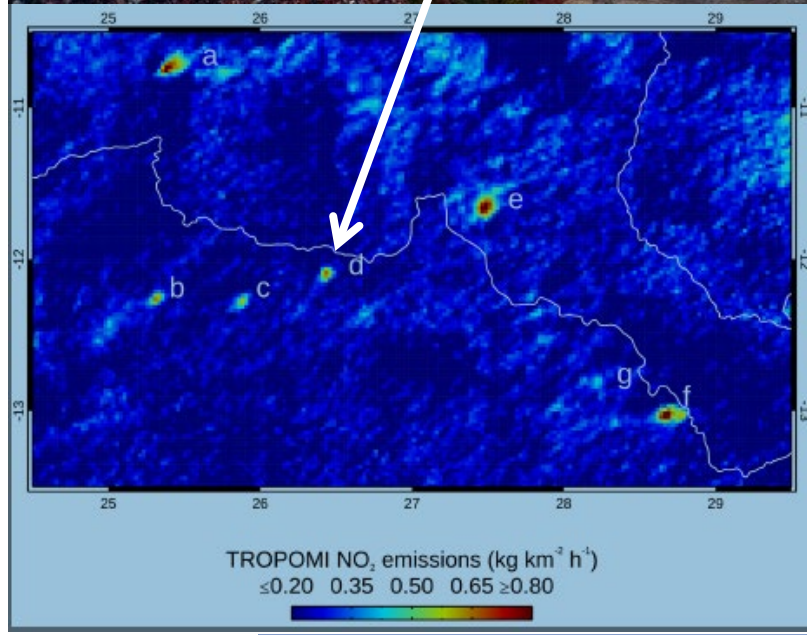
Power plants near Johannesburg

Slide courtesy: Pepijn Veefkind, KNMI

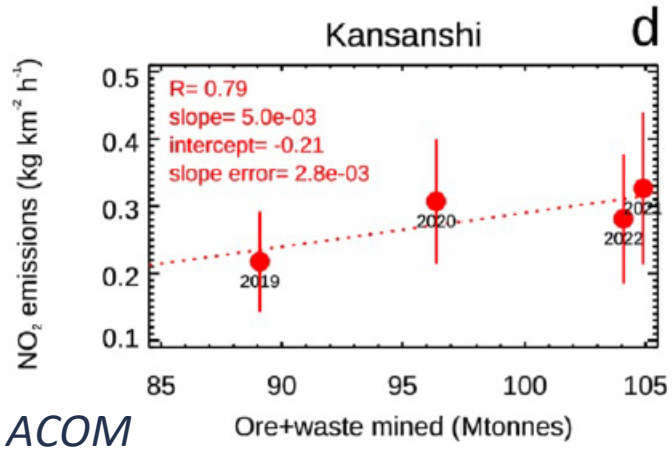
Prof. dr. Pieternel Levelt,
NSF NCAR ACOM, KNMI, TU Delft

# Emissions from metal mining in Africa




## NOx Emissions follow Production

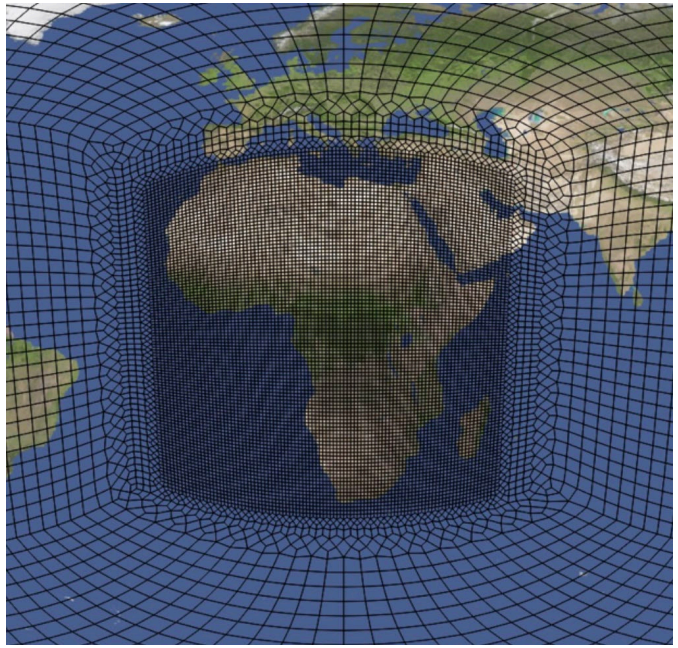



*Martinez-Alonso et al., JGR 2023, NCAR ACOM*

# Air Quality Modelling over Africa using MUSICA

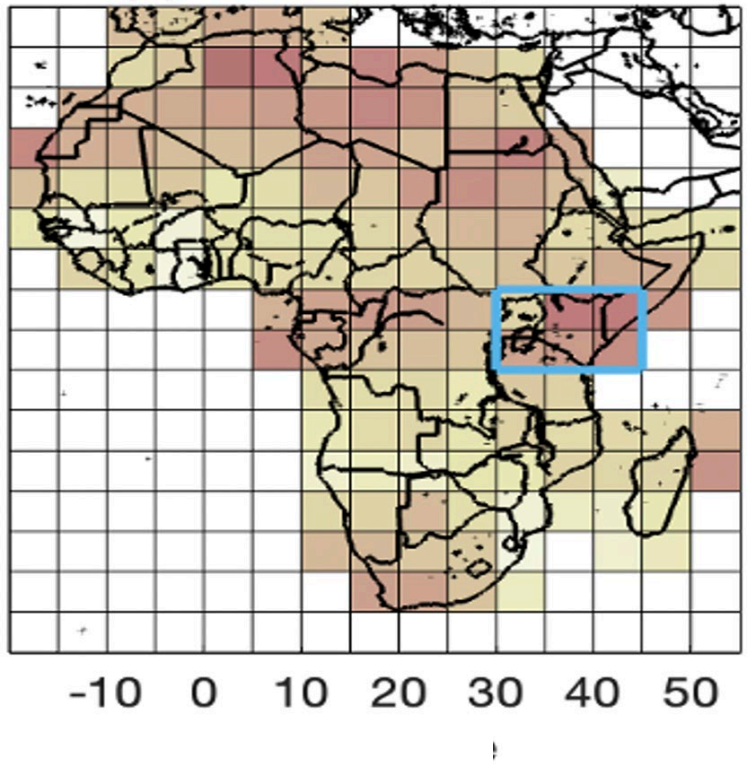
- We quantify model-satellite discrepancies over Africa with MUSICAv0.
- The highlighted East Africa region has the largest model-satellite discrepancies.
- A field campaign there can help understand model-satellite discrepancies and improve model predictability.

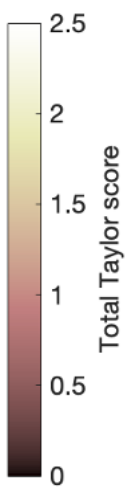
MUSICAv0 grid for Africa:



Wenfu Tang et al., GMD 2023, NCAR ACOM

MUSICA-satellite discrepancies:



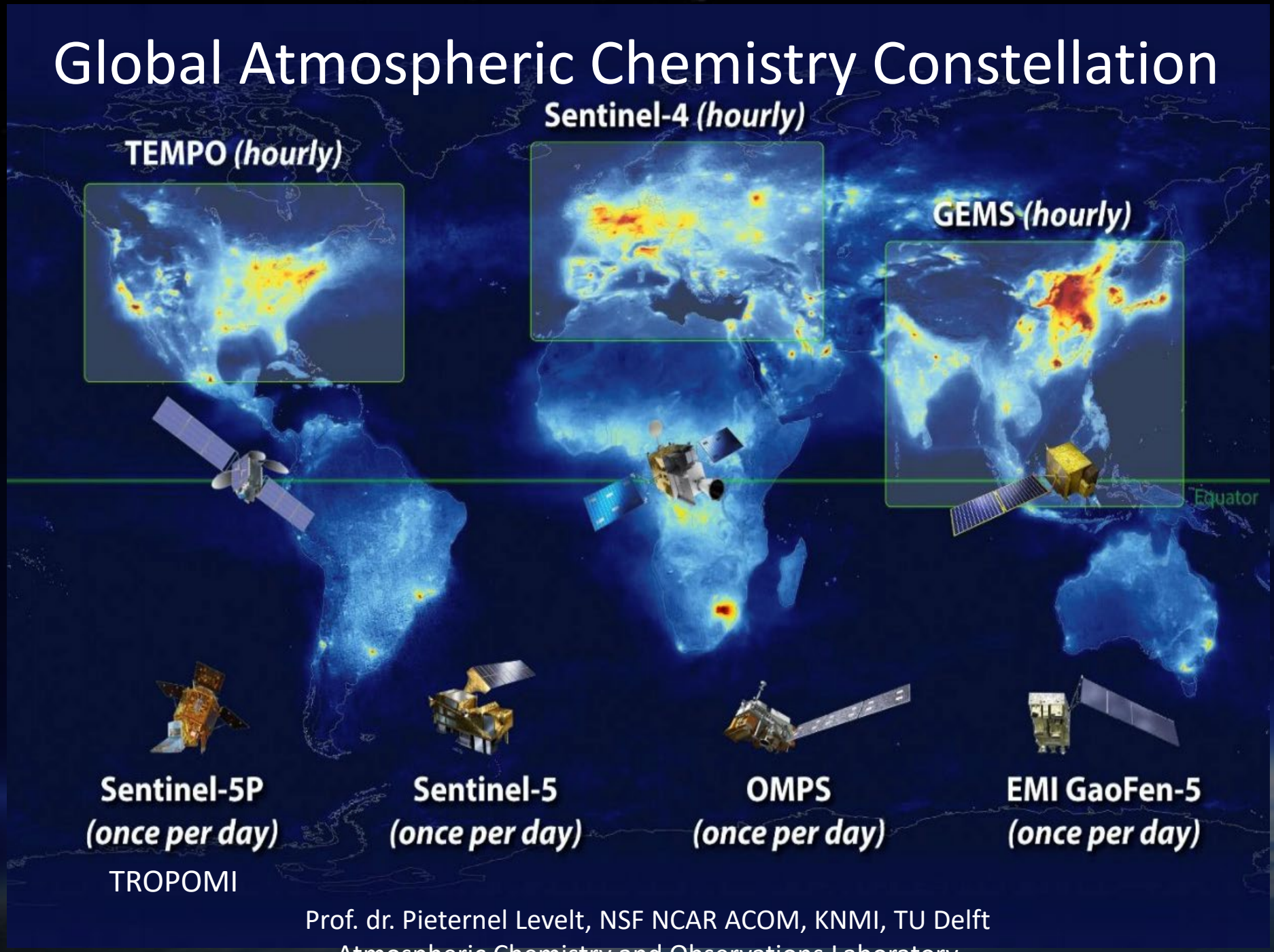




Better agreement
for CO, NO2, HCHO, AOD

Worse agreement
For CO, NO2. HCHO. AOD

Aircraft campaign
East Africa?

# Global Atmospheric Chemistry Constellation




TROPOMI

# Global Atmospheric Chemistry Constellation

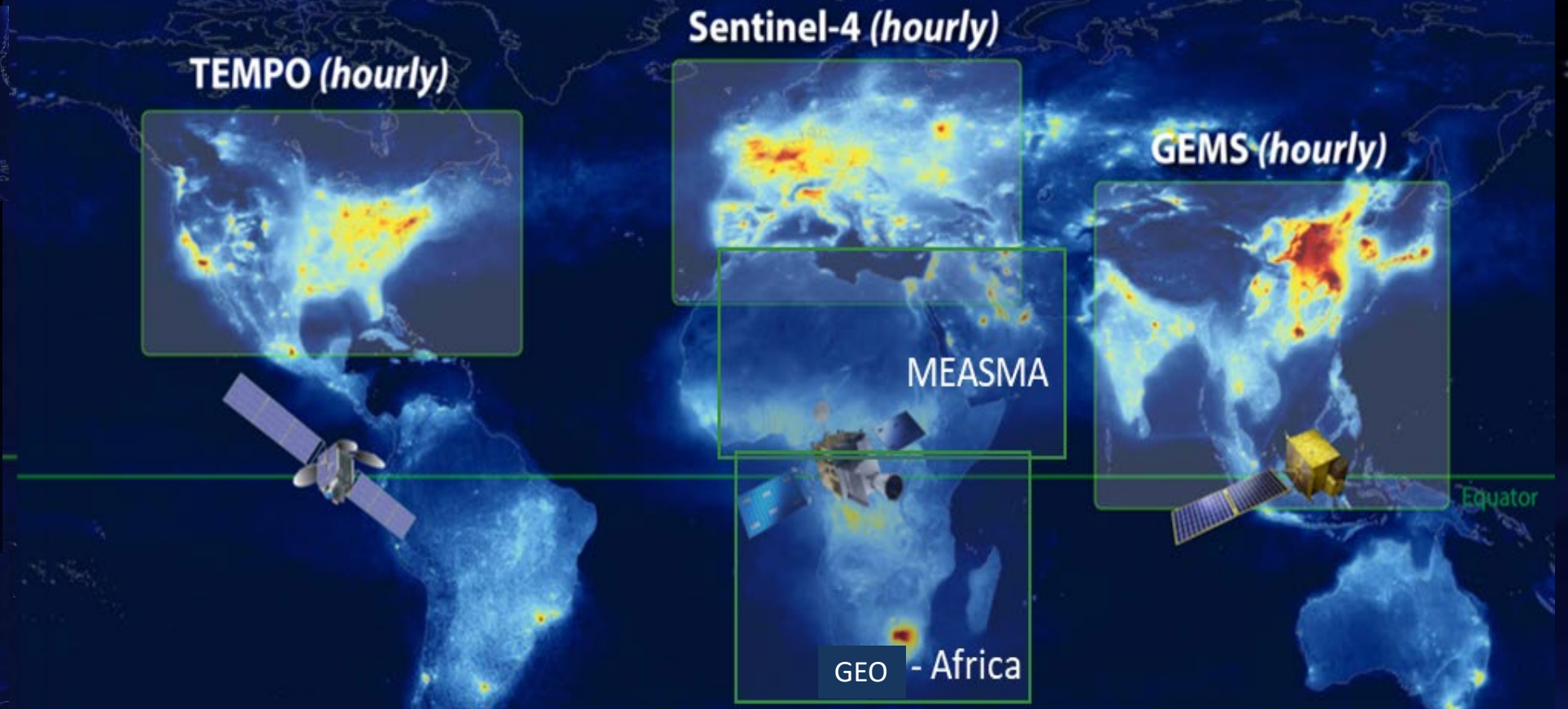
Sentinel-5P
*(once per day)*

TROPOMI

Sentinel-5
*(once per day)*

OMPS
*(once per day)*

EMI GaoFen-5
*(once per day)*




TROPOMI

## Field of Regard for MEASMA: GEO over Middle East and North Africa

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

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# Current activities in the international space community

- Perspective in AGU Advances (Dylan Millet et al.), 2024
- There are 2 initiatives for GEO's to measure over Africa
  - Measma (Omar Emam , Raid Suleiman et al)
  - Africa GEO (Pieternel Levelt et al)
- Currently we are trying to form **science teams** : focus on scientists from the Global South – ***interest? Please send me an email.***
- 2024 presentations: EGU 2024 (Vienna)  GEOXO meeting (Washington DC) , OMI-TROPOMI STM  (NCAR-ACOM, Boulder, CO)
- Coming AGU & AMS 2024/2025:
  - **Townhall Meet at AMS** with leaders in the field and cross disciplinary (last year we had a townhall at AGU 2023)
  - Abstracts  AGU 2024 and AMS 2025 (Levelt et al.)
- **ACVC/CEOS** meeting October 14-18, 2024 in Washington DC, presentation - start of scientific concept paper for the need of GEOs over the Global South ***(interested?- please contact me)***
- Ball Aerospace Corporate talks to private funders and foundations

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.

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## 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;

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# Summary Africa


**UCAR/NCAR initiative 'Accelerating environmental sustainability solutions in Africa: a UCAR initiative', Workshop at NCAR, Boulder CO, (Wenfu Tang et al – March 21-22, 2024)**

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Population is expected to triple in 2100 (now 1.1 billion, becomes 3.8 billion)
4th industrial revolution: huge increase in air pollutants & green house gases

5 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

Investigate Potential for GEOstationary satellite over the Global South and Africa, working on a GEO Science Team with USA, European and African scientist representation, several science meetings focused on GEO capability.