Shipping Emissions in Rapidly Growing Seaports in Africa Determined with TROPOMI

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Abstract

Seaports in Africa are expanding rapidly to meet an increasing demand for imported goods in Africa and for natural resources and manufactured goods from the continent. Emissions from shipping and anthropogenic activities at seaports, in particular nitrogen oxides (NO_x), are challenging to estimate. This impacts our ability to determine the impacts of shipping activities on ozone air pollution for a continent that is NO_x limited. Here we develop an approach to oversample tropospheric column observations of nitrogen dioxide (NO_2) from the recently launched high spatial resolution TROPOMI instrument to determine NO_x emissions from shipping activities at major seaports along the African coastline from August 2019 to July 2020. We use these to evaluate state-of-science emission inventories and determine temporal variability in these emissions for improved implementation in global and regional models.

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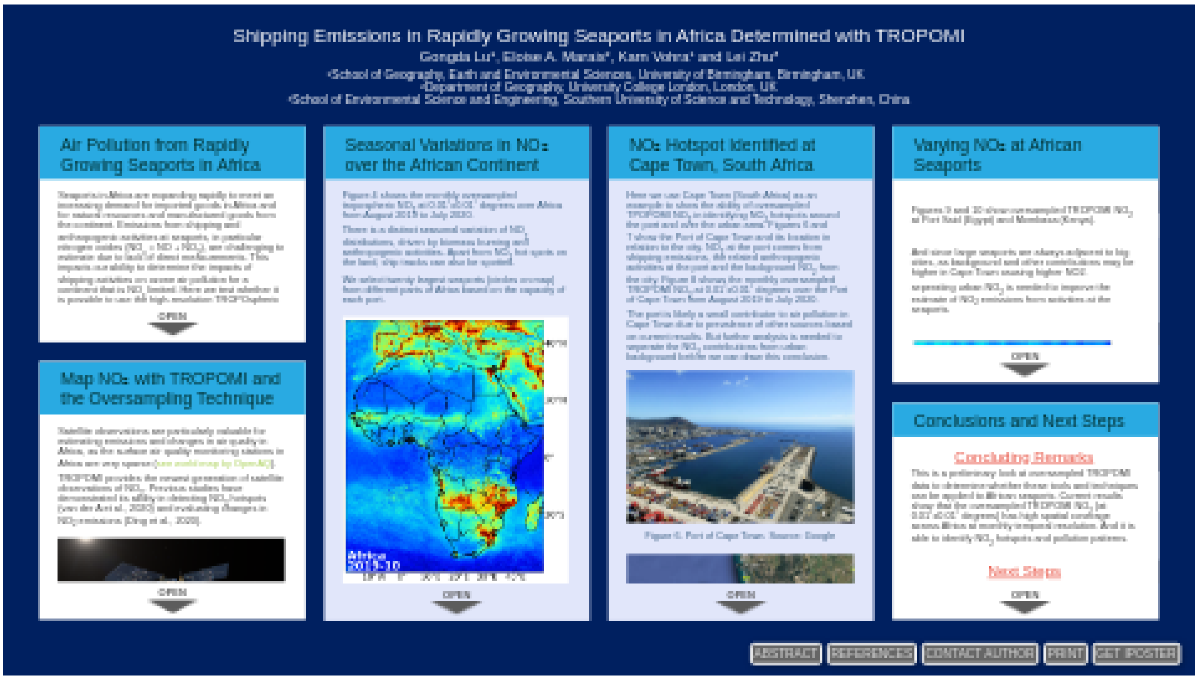

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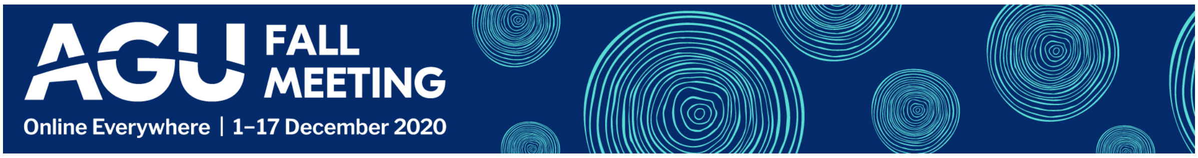

AIR POLLUTION FROM RAPIDLY GROWING SEAPORTS IN AFRICA

Seaports in Africa are expanding rapidly to meet an increasing demand for imported goods in Africa and for natural resources and manufactured goods from the continent. Emissions from shipping and anthropogenic activities at seaports, in particular nitrogen oxides ($NO_x = NO + NO_2$), are challenging to estimate due to lack of direct measurements. This impacts our ability to determine the impacts of shipping activities on ozone air pollution for a continent that is NO_x limited. Here we test whether it is possible to use the high-resolution TROPOspheric Monitoring Instrument (TROPOMI) and an oversampling technique to determine the influence of shipping activities on air quality.

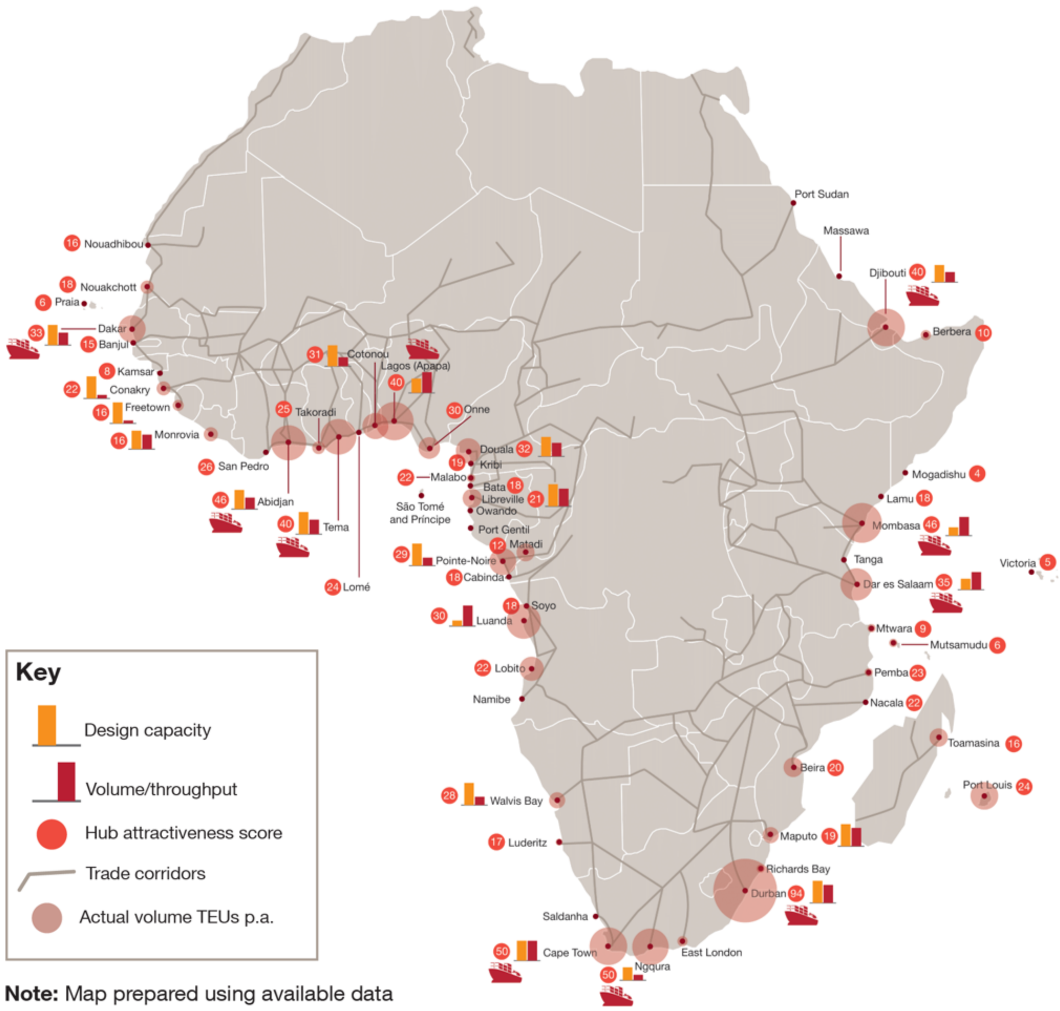

Figure 1. Major ports of sub-Saharan Africa. Source: PwC South Africa (2018)

MAP NO_2 WITH TROPOMI AND THE OVERSAMPLING TECHNIQUE

Satellite observations are particularly valuable for estimating emissions and changes in air quality in Africa, as the surface air quality monitoring stations in Africa are very sparse (see world map by OpenAQ (https://openaq.org/#/map?parameter=no2&_k=0shc04)).

TROPOMI provides the newest generation of satellite observations of NO_2. Previous studies have demonstrated its ability in detecting NO_2 hotspots (van der A et al., 2020) and evaluating changes in NO_2 emissions (Ding et al., 2020).

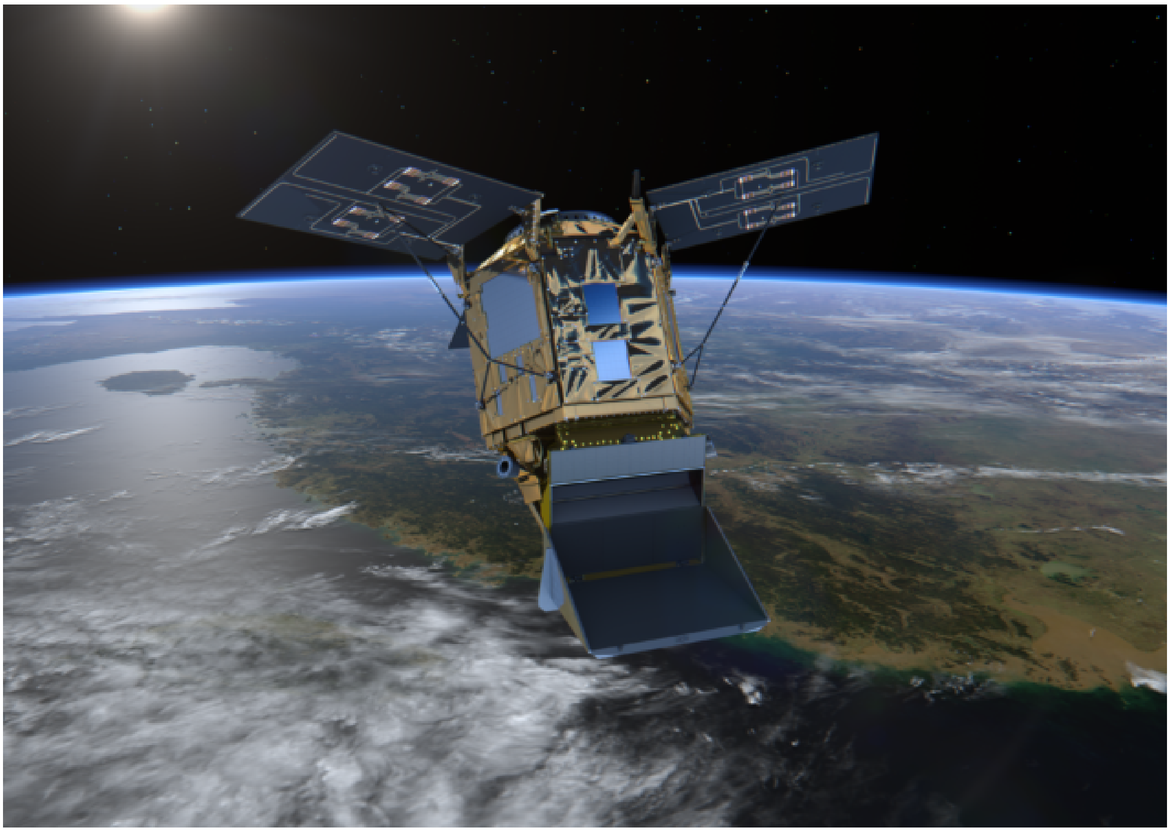

Figure 2. Sentinel 5 Precursor (S5P) carries the Dutch-built TROPOspheric Monitoring Instrument (TROPOMI), a four-band spectrometer. Source: ESA/ATG medialab

Here we apply an oversampling algorithm (as detailed by Zhu et al. (2017)) to the tropospheric vertical column density of NO_2 provided by TROPOMI to estimate NO_2 at 0.01˚x0.01˚ (latitude x longitude) resolutions (~1x1 km) in Africa. Then we aim to determine NO_x emissions from shipping activities at major African seaports from August 2019 to July 2020.

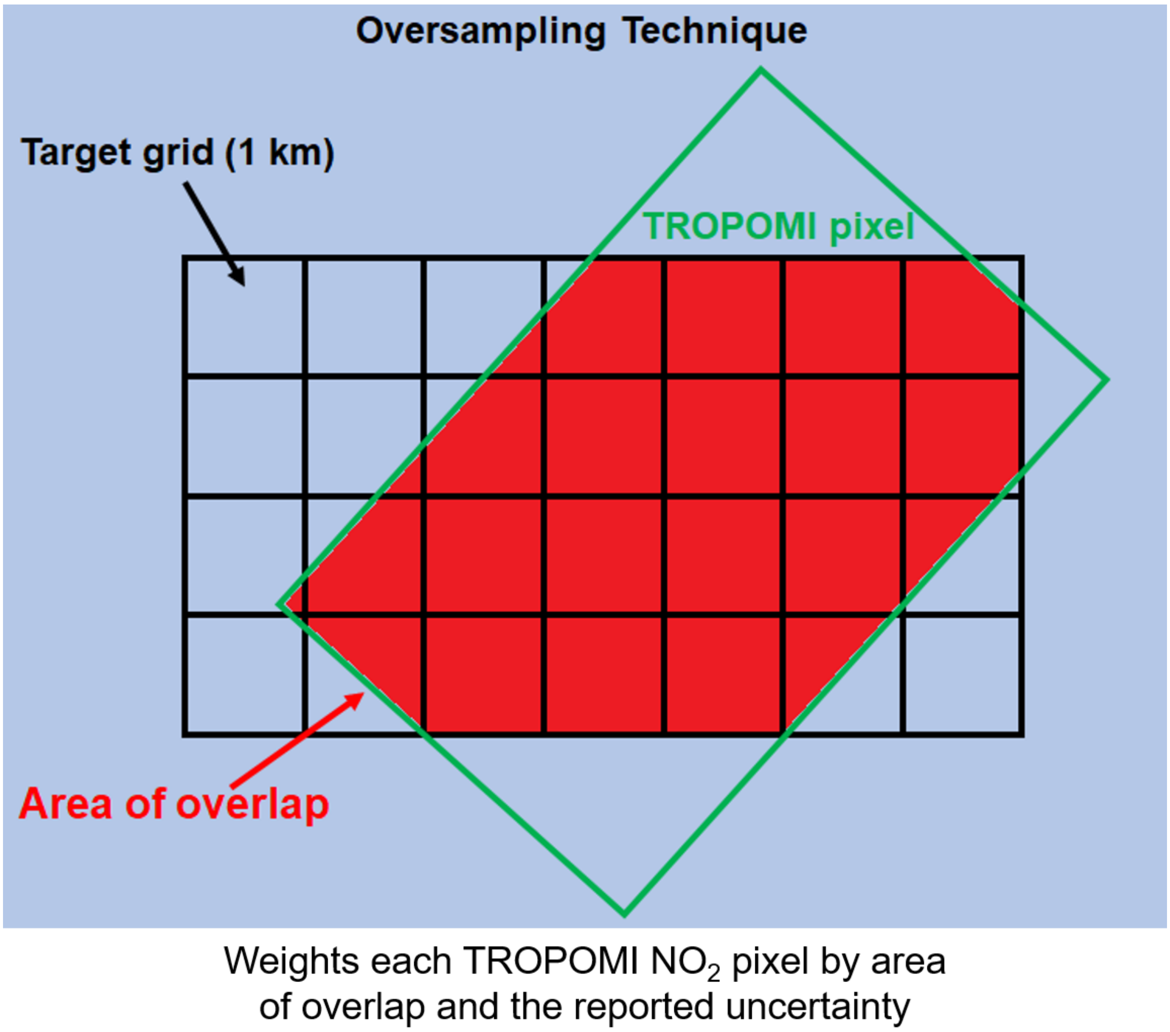

Figure 3. Concept of the oversampling techinque used in this study.

SEASONAL VARIATIONS IN NO_2 OVER THE AFRICAN CONTINENT

Figure 4 shows the monthly oversampled tropospheric NO_2 at 0.01˚x0.01˚ degrees over Africa from August 2019 to July 2020.

There is a distinct seasonal variation of NO_2 distributions, driven by biomass burning and anthropogenic activities. Apart from NO_2 hot spots on the land, ship tracks can also be spotted.

We select twenty largest seaports (circles on map) from different parts of Africa based on the capacity of each port.

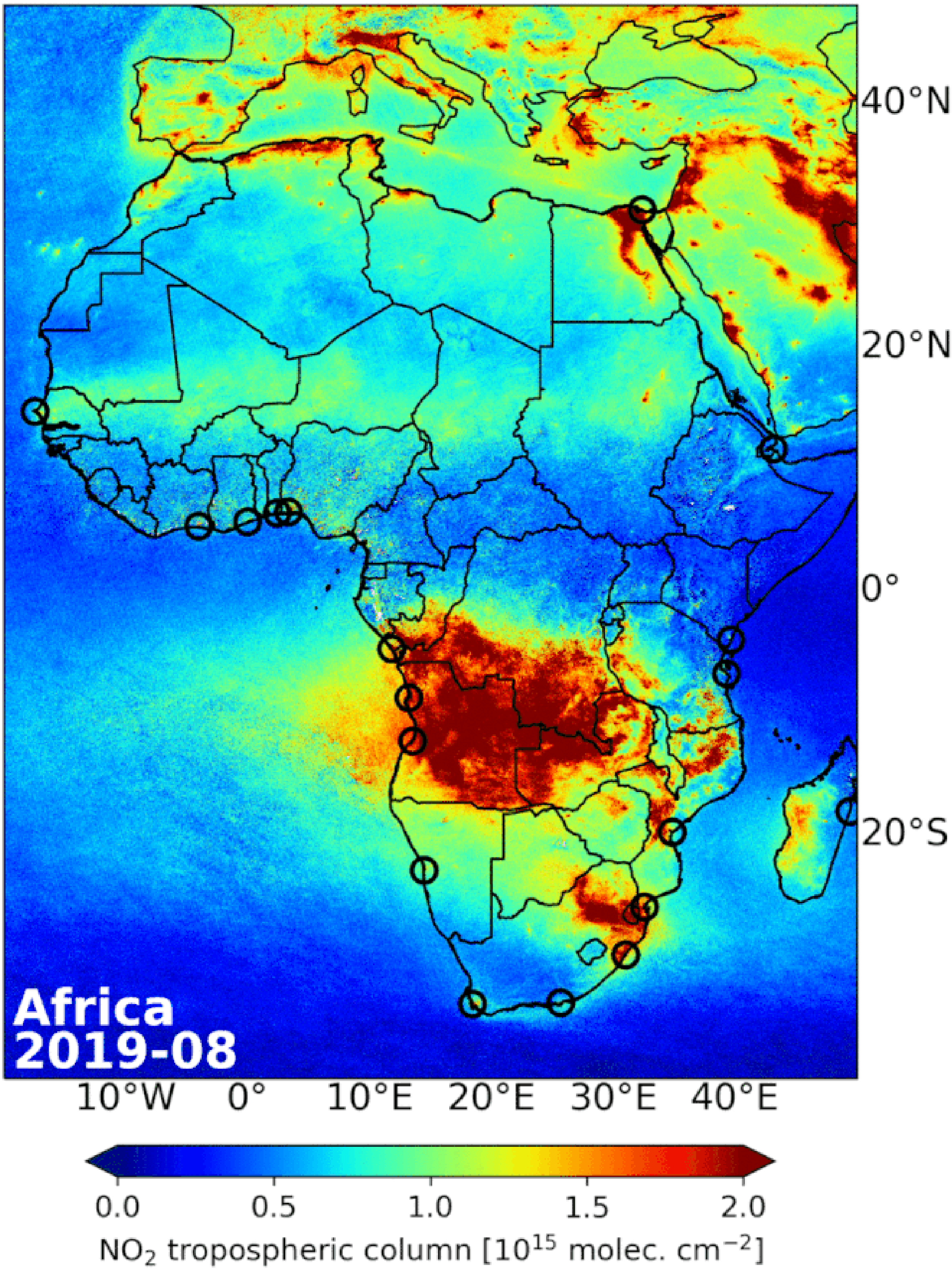

Figure 4. Monthly oversampled TROPOMI NO_2 over Africa at 0.01˚x0.01˚ degrees.

NO_2 HOTSPOT IDENTIFIED AT CAPE TOWN, SOUTH AFRICA

Here we use Cape Town (South Africa) as an example to show the ability of oversampled TPOPOMI NO_2 in identifying NO_2 hotspots around the port and over the urban area. Figures 5 and 6 show the Port of Cape Town and its location in relation to the city. NO_2 at the port comes from shipping emissions, the related anthropogenic activities at the port and the background NO_2 from the city. Figure 7 shows the monthly oversampled TROPOMI NO_2 at 0.01˚x0.01˚ degrees over the Port of Cape Town from August 2019 to July 2020.

Based on current results, the port is likely a small contributor to air pollution in Cape Town due to prevalence of other sources. But further analysis is needed to separate the NO_2 contributions from urban background before we can draw this conclusion.

Figure 5. Port of Cape Town. Source: Google

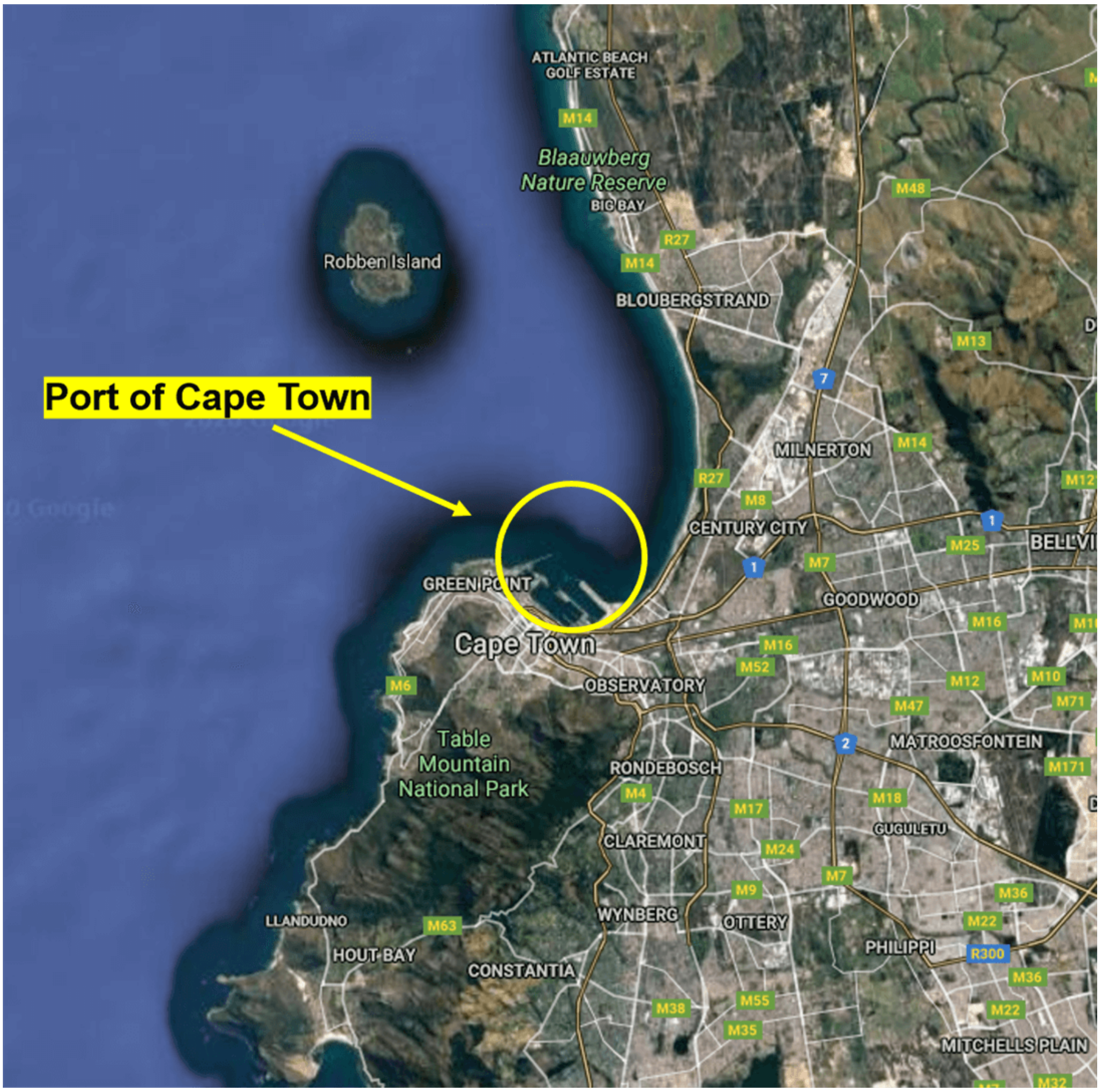

Figure 6. Map of Cape Town, South Africa. Source: Google Maps

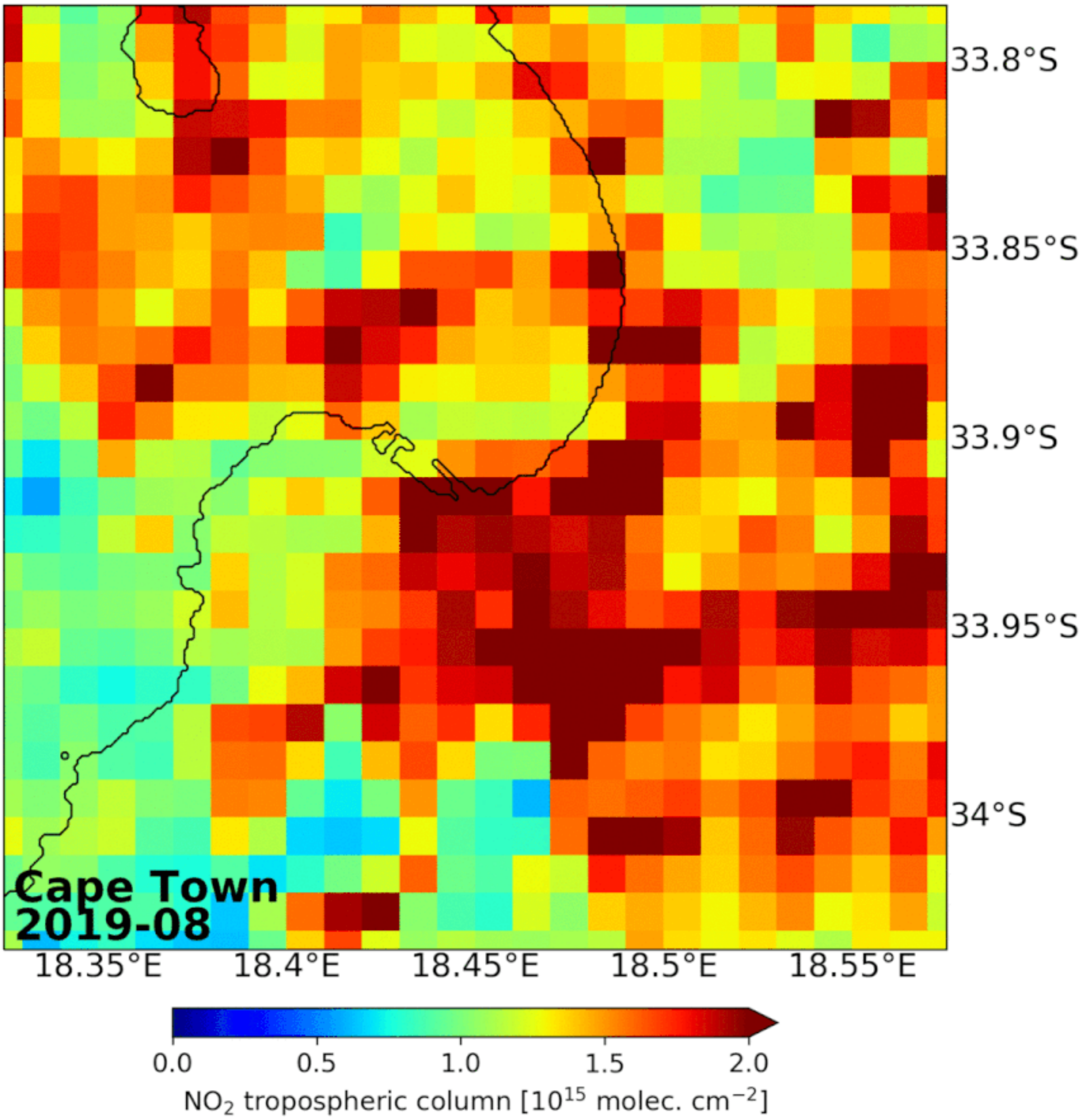

Figure 7. Monthly oversampled TROPOMI NO_2 at 0.01˚x0.01˚ degrees at Cape Town, South Africa.

VARYING NO_2 AT AFRICAN SEAPORTS AND NEARBY CITIES

Figures 8 and 9 show monthly oversampled NO_2 at Port Said (Egypt) and Port of Mombasa (Kenya). Higher NO_2 is observed at Port Said compared to Port of Mombasa throughout the year. Statistics of the ports including capacity and utilization rate, as well as knowledge of shipping activities may be useful in interpreting differences in NO_2 at these two seaports. However, these are normally lacking.

Separating TROPOMI NO_2 from urban background may provide an alternative solution to better estimate and compare NO_2 emissions from shipping and other activities at different seaports.

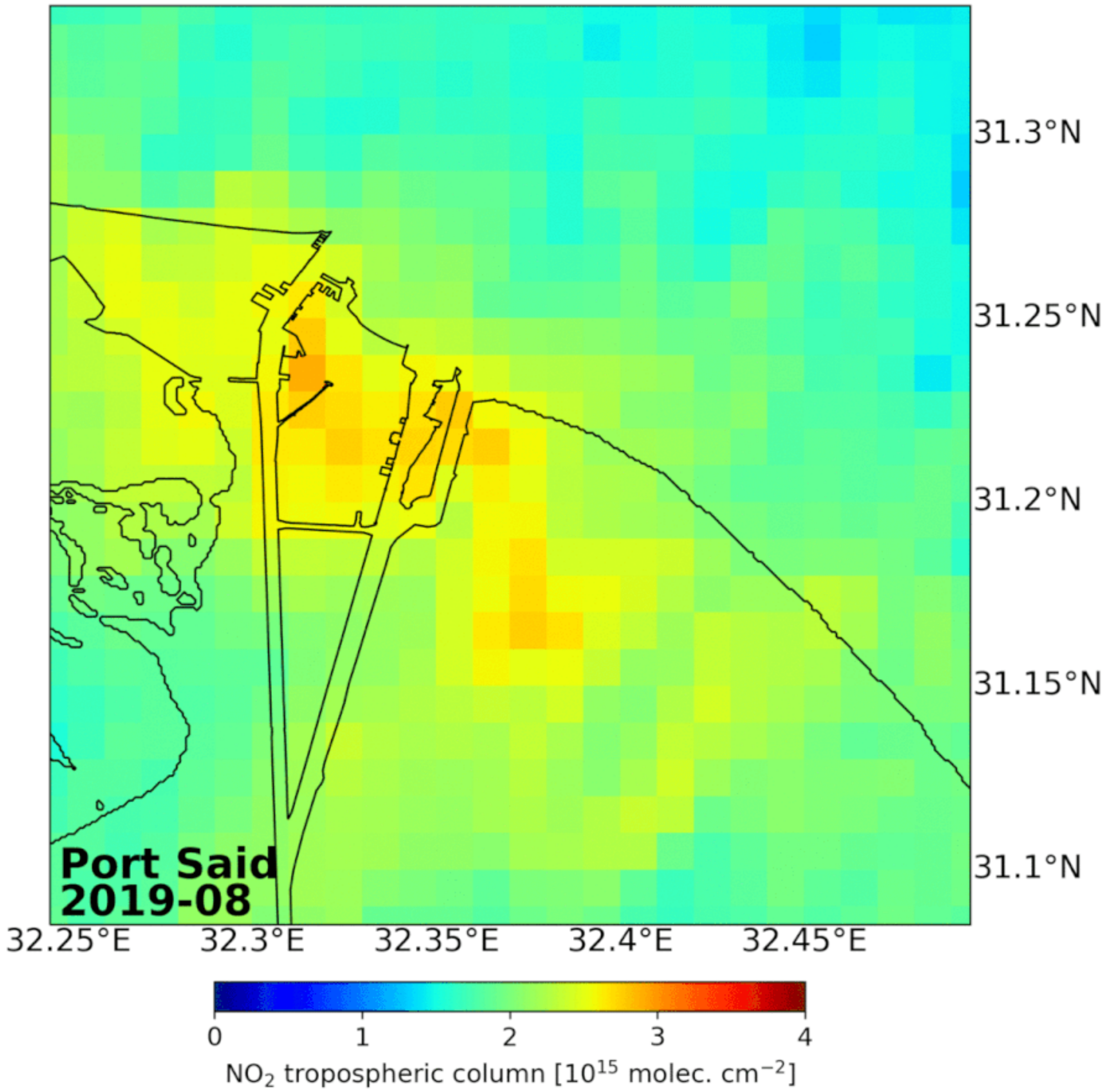

Figure 8. Monthly oversampled TROPOMI NO_2 at 0.01˚x0.01˚ degrees at Port Said, Egypt.

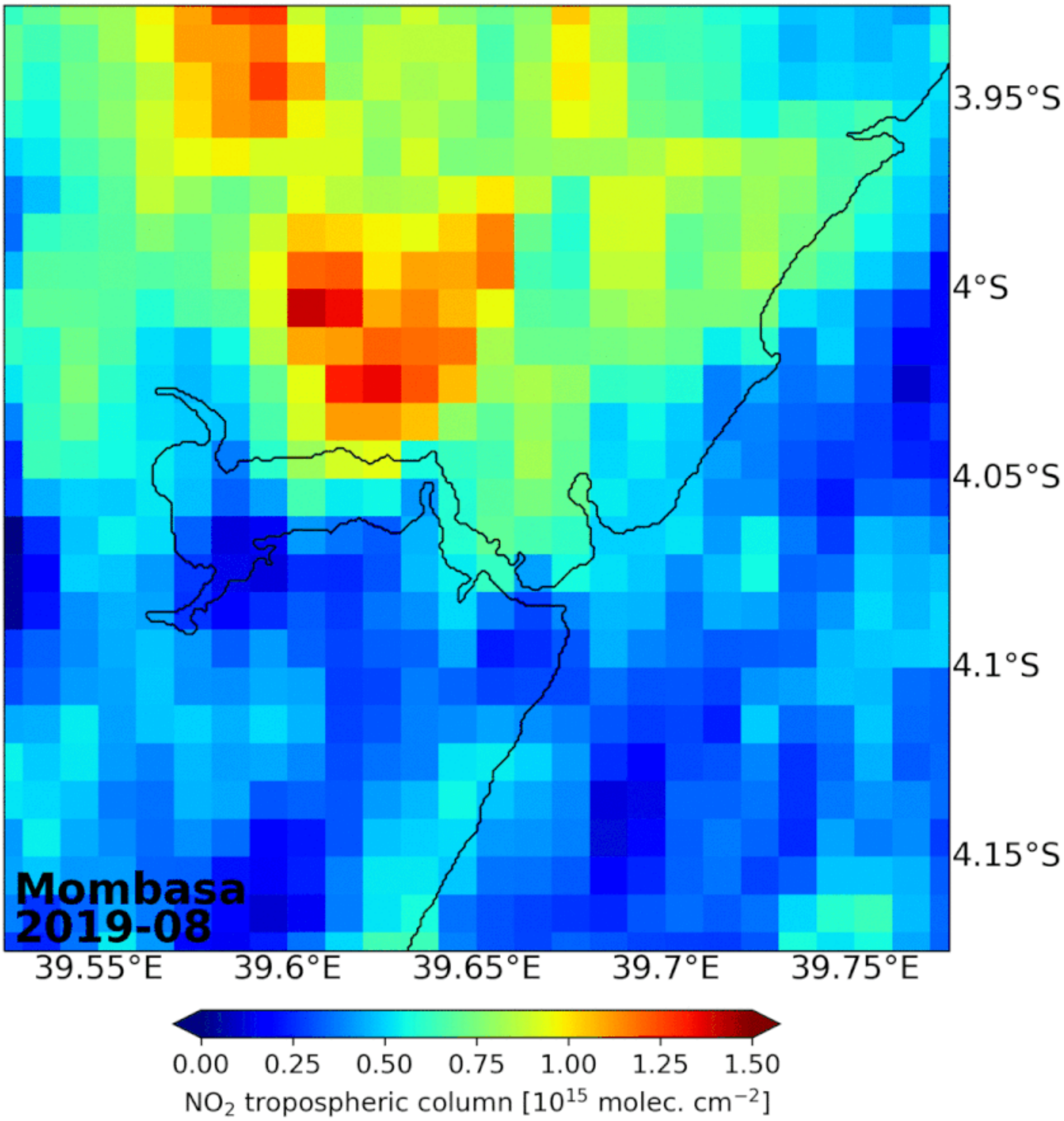

Figure 9. Monthly oversampled TROPOMI NO_2 at 0.01˚x0.01˚ degrees at Port of Mombasa, Kenya.

CONCLUSIONS AND NEXT STEPS

Concluding Remarks

This is a preliminary look at oversampled TROPOMI data to determine whether these tools and techniques can be applied to African seaports. Current results show that the oversampled TROPOMI NO_2 (at 0.01˚x0.01˚ degrees) has high spatial coverage across Africa at monthly temporal resolution. And it is able to identify NO_2 hotspots and pollution patterns.

Next Steps

- Use surface NO_2 measurements to evaluate the ability of the oversampled TROPOMI NO_2 in capturing spatial and temporal variations of surface NO_2.
- Separate the NO_2 contributions from urban background to provide an improved estimate of the NO_2 emissions from shipping activities at the seaports.
- Use the state-of-the-art chemical transport model (GEOS-Chem) to estimate the emissions from shipping activities in Africa.
- Evaluate state-of-science emission inventories and determine temporal variability in these emissions for improved implementation in global and regional models.

ABSTRACT

Seaports in Africa are expanding rapidly to meet an increasing demand for imported goods in Africa and for natural resources and manufactured goods from the continent. Emissions from shipping and anthropogenic activities at seaports, in particular nitrogen oxides (NO_x), are challenging to estimate. This impacts our ability to determine the impacts of shipping activities on ozone air pollution for a continent that is NO_x limited. Here we develop an approach to oversample tropospheric column observations of nitrogen dioxide (NO_2) from the recently launched high spatial resolution TROPOMI instrument to determine NO_x emissions from shipping activities at major seaports along the African coastline from August 2019 to July 2020. We use these to evaluate state-of-science emission inventories and determine temporal variability in these emissions for improved implementation in global and regional models.

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