Quantifying nitrogen oxides emissions in Egypt using satellite observations

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Nitrogen oxides ($\text{NO}_x = \text{NO} + \text{NO}_2$) in the EMME region

Rationales for the quantification of nitrogen oxides emissions:
- Interacts with different chemicals in the atmosphere
- Participate to air and soil pollution
- Produced by the burning of fossil fuels

TROPOMI (TROPOspheric Atmosphere Monitoring Instrument)
- Launched in 2017 onboard Sentinel 5-Precursor
- Measurement of $\text{NO}_2$, $\text{CH}_4$, $\text{CH}_2\text{O}$, $\text{SO}_2$, $\text{CO}$, $\text{O}_3$, etc.
- Spatial resolution: $3.5 \times 5.5 \text{ km}^2$ (nadir) over a 2600 km swath
- Temporal resolution: 1 day, 13:30 local time
Main sources of nitrogen oxides in Egypt

Industrial facilities

Urban areas (>100 hab/km$^2$)

TROPOMI columns on 03/01/2019
Additional data for inferring NO\(_x\) emissions from NO\(_2\) concentrations

\[
e_{\text{NO}_x} = L (\text{div}(X_{\text{NO}_2}w) + K(T) \cdot [\text{OH}] \cdot X_{\text{NO}_2})
\]

<table>
<thead>
<tr>
<th>Process</th>
<th>Quantity</th>
<th>Data</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport of pollutants with the wind</td>
<td>Horizontal wind</td>
<td>ERA5</td>
<td>3 hr, 0.25°×0.25°</td>
</tr>
<tr>
<td>Reaction between NO(_2) and OH</td>
<td>Temperature</td>
<td>CAMS near-real-time</td>
<td>3 hr, 0.4°×0.4°</td>
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<tr>
<td></td>
<td>OH concentration</td>
<td>CAMS near-real-time</td>
<td>3 hr, 0.4°×0.4°</td>
</tr>
<tr>
<td>Transformations between NO(_2) and NO</td>
<td>NO(_x)/NO(_2) factor</td>
<td>CAMS near-real-time</td>
<td>3 hr, 0.4°×0.4°</td>
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</tbody>
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Distribution of NO\textsubscript{x} emissions

Observations:
- Emissions located in large cities and industrial areas
- Higher emissions during summer

Remarks:
- Top-down model very sensitive to OH concentration and wind module/direction
- Neglect of vertical processes
Weekly cycle

- Monday-Thursday: working days
- Friday: official resting day
- Saturday-Sunday: partial rest

<table>
<thead>
<tr>
<th>Day</th>
<th>Ratio</th>
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<tbody>
<tr>
<td>Monday</td>
<td>1.066/7</td>
</tr>
<tr>
<td>Tuesday</td>
<td>1.055/7</td>
</tr>
<tr>
<td>Wednesday</td>
<td>1.076/7</td>
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<tr>
<td>Thursday</td>
<td>1.020/7</td>
</tr>
<tr>
<td>Friday</td>
<td>0.808/7</td>
</tr>
<tr>
<td>Saturday</td>
<td>0.965/7</td>
</tr>
<tr>
<td>Sunday</td>
<td>1.010/7</td>
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</tbody>
</table>
Seasonal cycle analysis:
- Different dynamics than in the inventories
  - High cycle amplitude
  - Abnormally low values for winter 2019/2020

Interpretation:
- Consistent with the electricity consumption in the country
- Potentially inconsistent with road transport and industrial activity
Has COVID-19 impacted emission levels in the country?

Partial lockdown from March 15th

- Closing of public areas
- Suspension of religious activities in mosques and churches
- Full lockdown for Easter and Eid → drop of the activity
- Lift of some restrictions from June 1st → catch-up of the activity
What about other countries?

Example of Qatar:
Electricity entirely provided by gas power plants
→ Main source of energy consumption of the country