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Potential of using Earth observation data for producing UNECE air quality indicators

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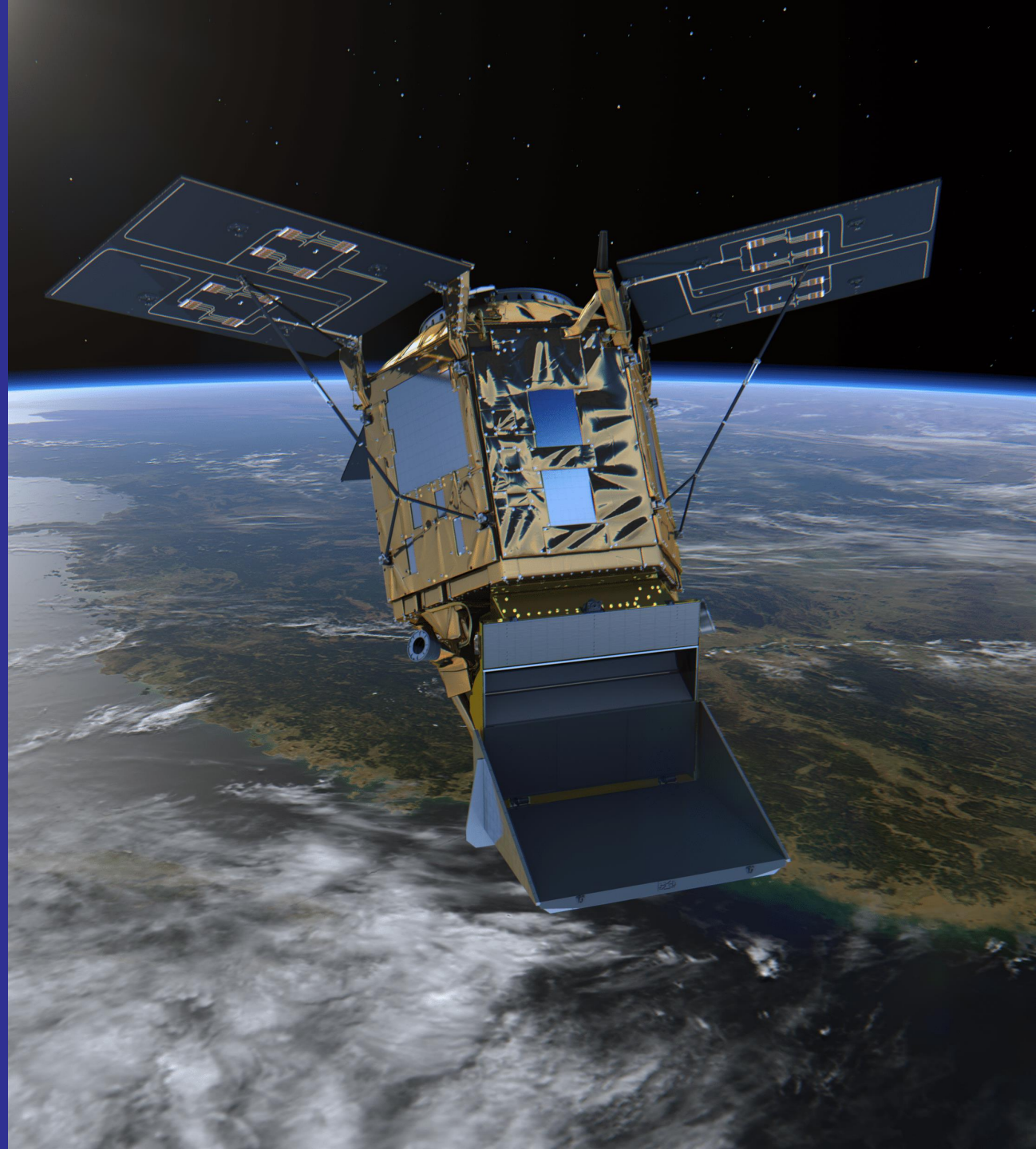
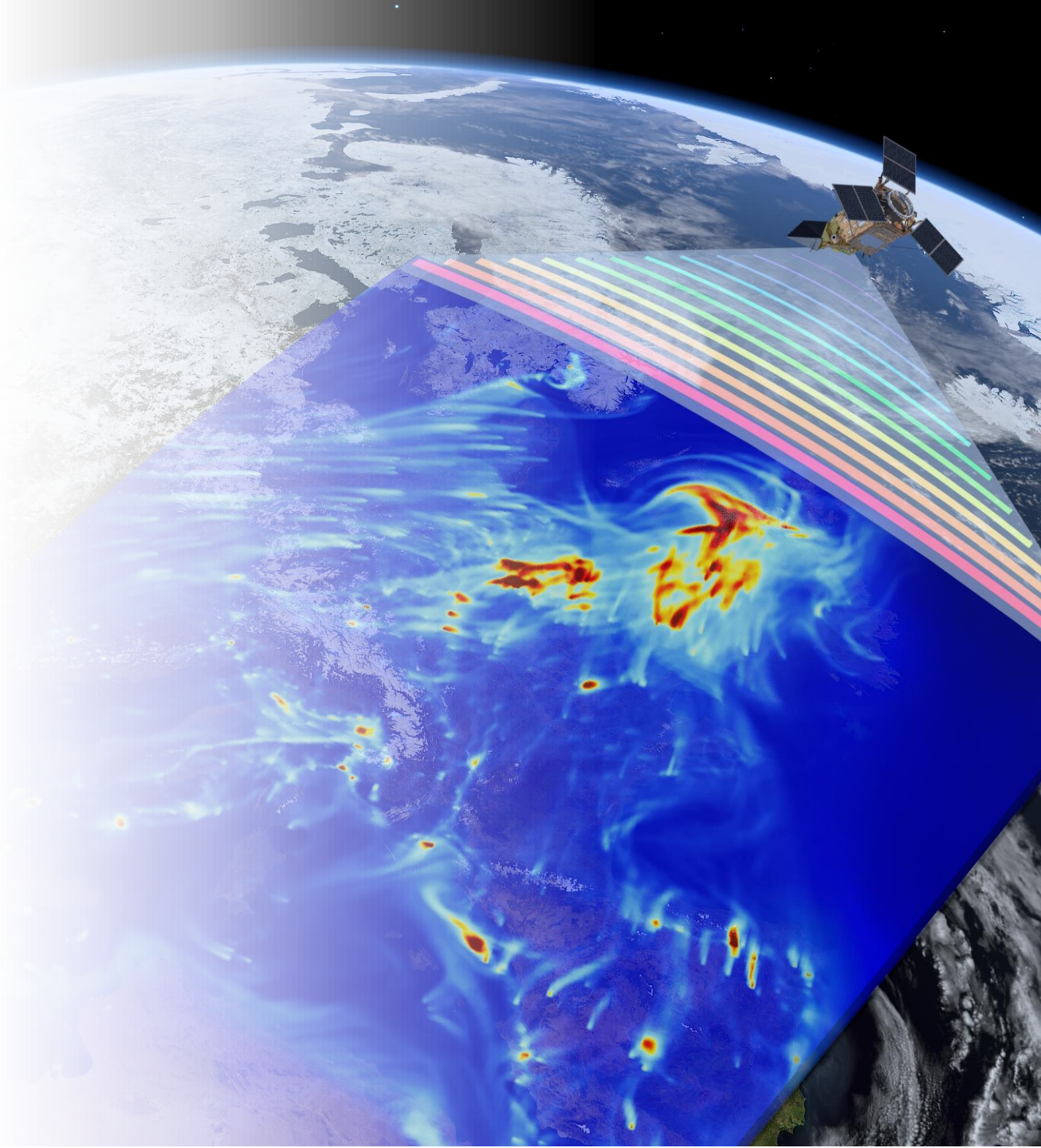
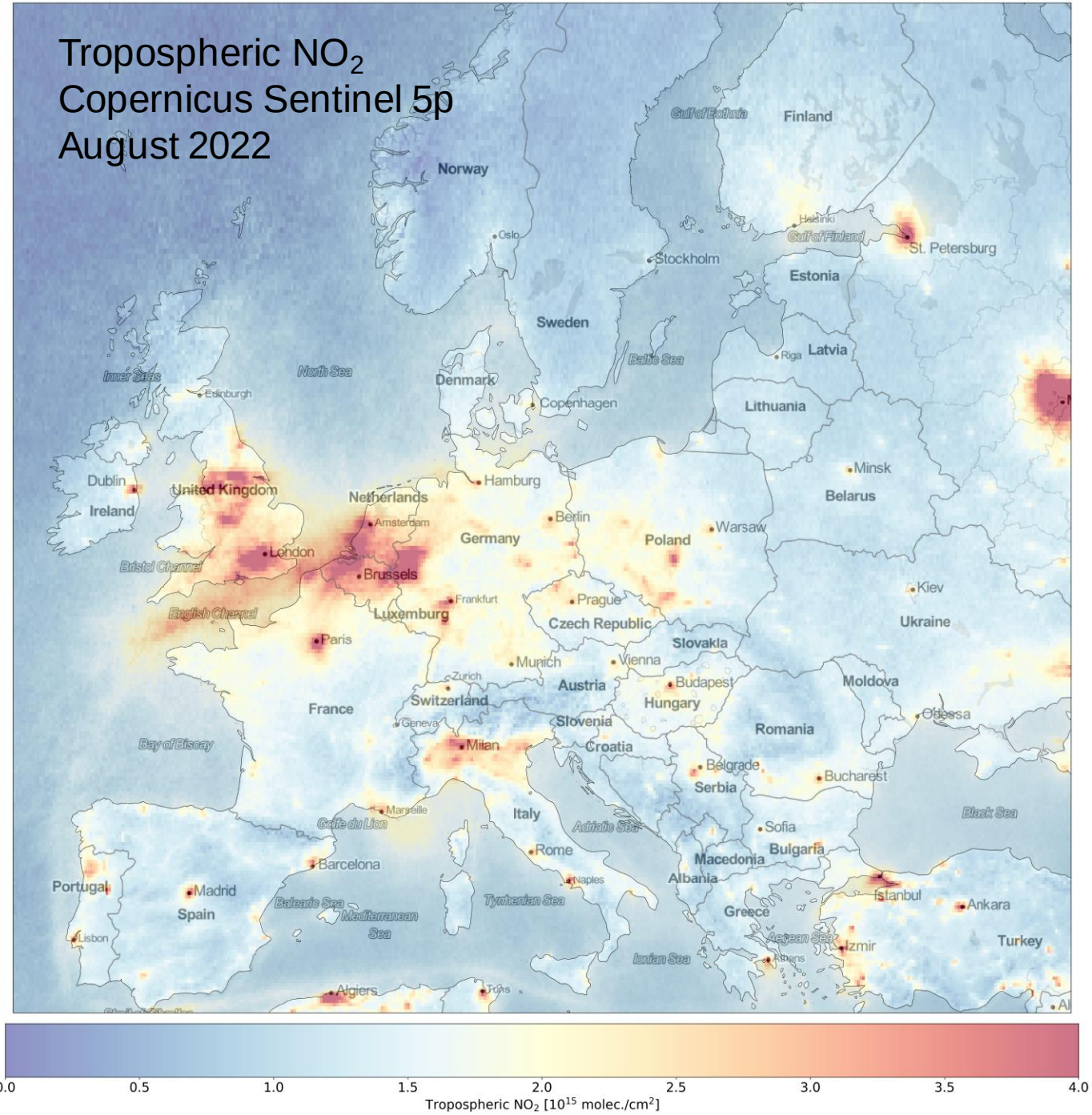


Introduction

- Satellites have provided observations on multiple air-quality relevant parameters for several decades.
  - Trace gases, aerosols
  - Supporting data e.g. fire observations
- In recent years the development of satellite observations has been significant (instrumentation, spatial resolution, methods)
- It is likely that with satellites' improved spatial and temporal resolution, the use of satellite observations to support air quality monitoring will increase in the future.

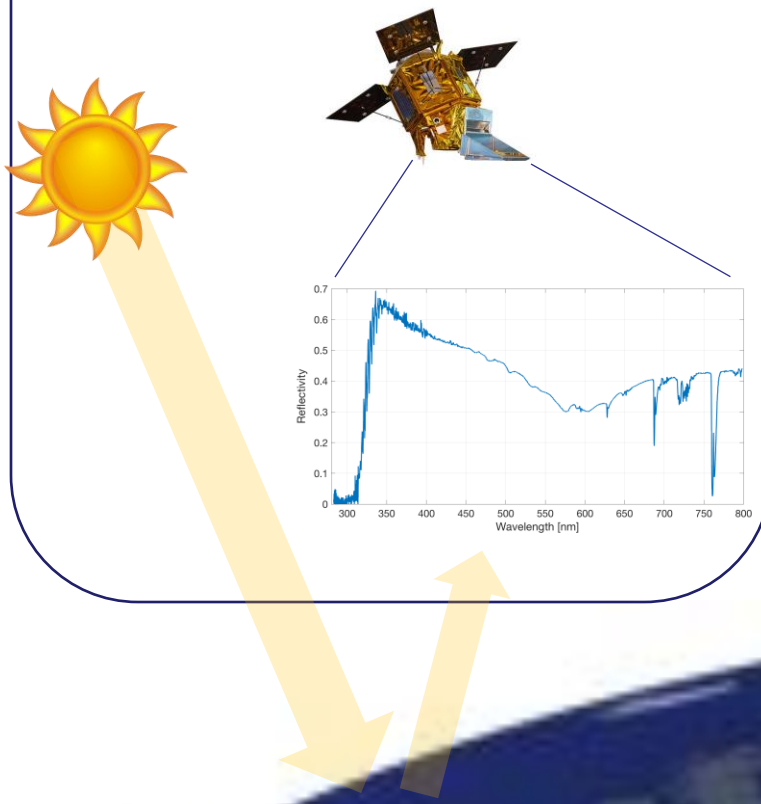


- Advantages of satellite observations
  - Filling gaps between in situ stations and increase understanding of regional-scale air quality variation.
  - Potential to detect emission hot spots.
  - Observations over area where in situ measurements are completely missing.
  - Long global timeseries available (+15yrs)
  - Data from the largest providers (EU Copernicus, NASA, ESA, EUMETSAT etc.) are **free** and **open** for everyone.
- Challenges of satellite observations
  - Interpretation and handling datasets require expertise
  - With new instruments data amounts are large.
  - Cloudiness, lack of solar light (winter, night) can prevent observations -> uneven sampling.

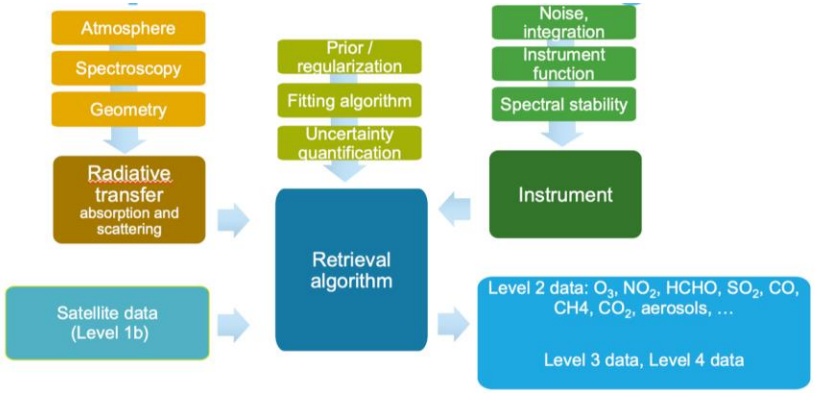


From radiation measurements to atmospheric observations

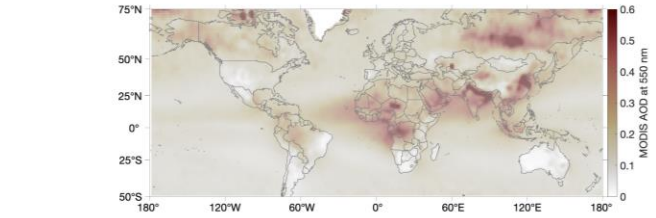
Satellite measurement of reflected solar radiation or emitted thermal radiation

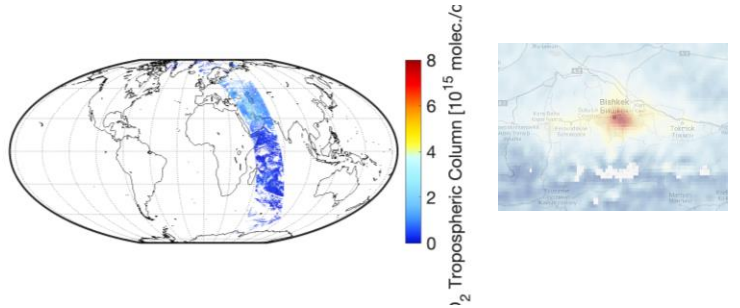


Retrieval algorithm



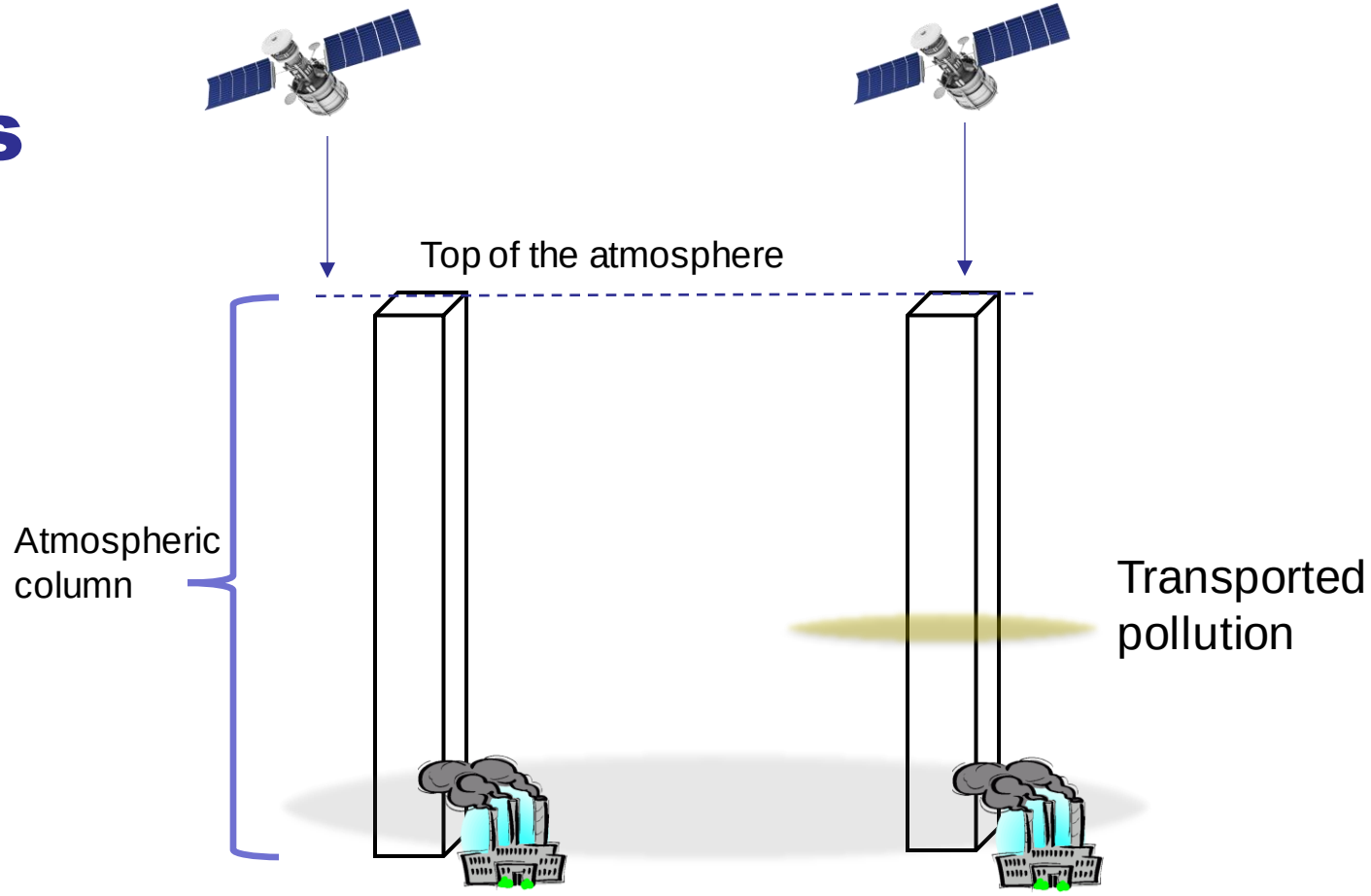
Atmospheric observations





Interpretation of satellite observations

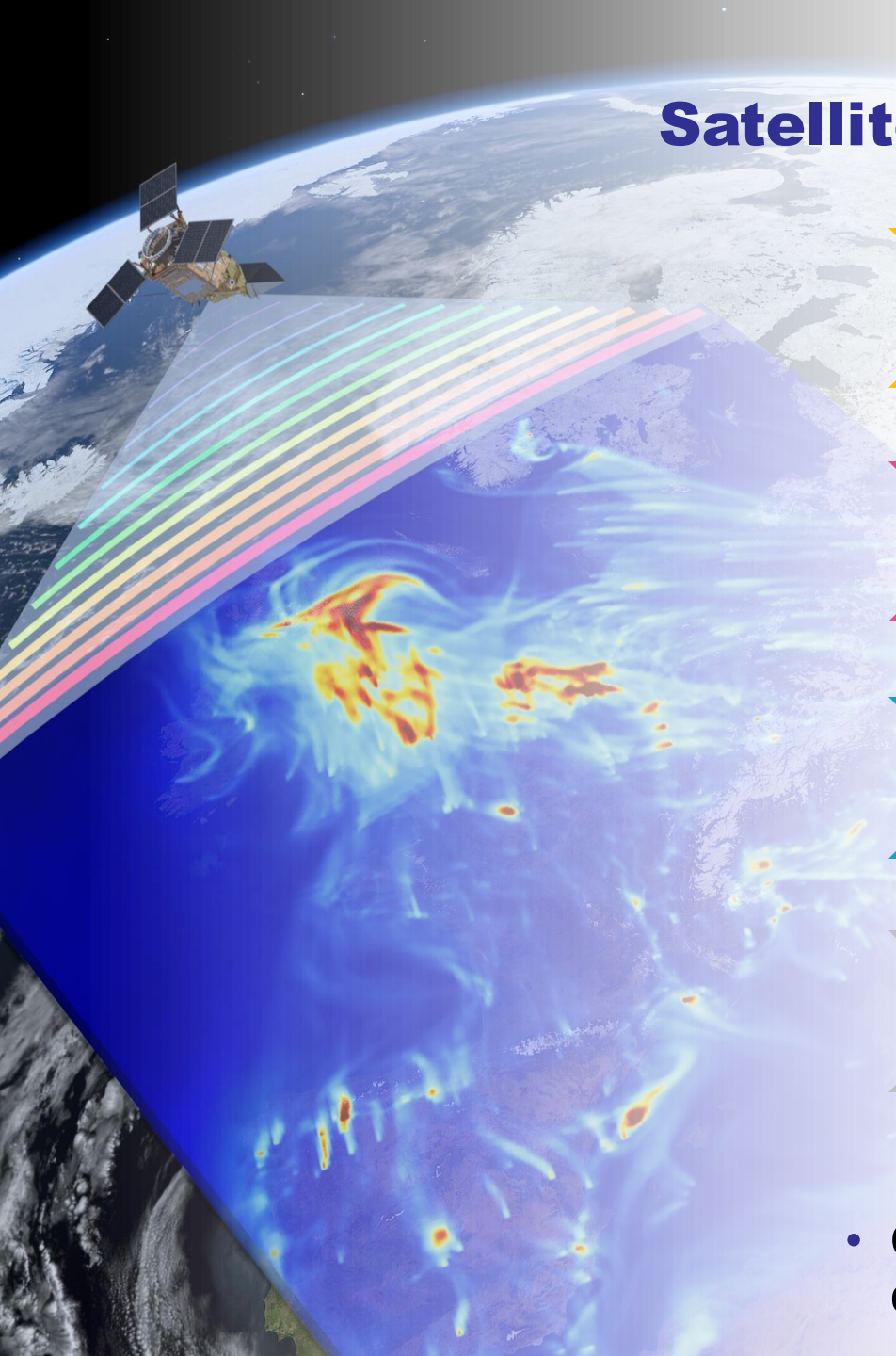
- Satellites measure concentrations or other quantities in an atmospheric column.
  - This is the essential difference as compared to in situ measurements.
  - Satellite measurements are not directly comparable to in situ measurements, also units are different.
- How representative column measurements are to pollution at surface depends on many factors
  - Which parameter is considered (trace gases, aerosols)
  - Meteorology
  - Strength of emission source
  - Transported pollution
  - Vertical sensitivity of satellite instrument
  - etc.



Sources of pollutants only close to surface, no long range transport →
- changes at surface likely also visible in the total column concentration.

Pollutants at surface and at upper level transported pollution →
- Satellites measure the total column
- In situ measurements see only the pollution close to the surface

Satellite observations for air quality monitoring



NO_2	**NO_2 Tropospheric column density** **Instruments:** TROPOMI (S5p), OMI (Aura), GOME-2 (Metop –A,B,C,)
Aerosols	**Aerosol Optical Depth (AOD)** **Instruments:** SLSTR (S3), MODIS (Aqua, Terra), VIIRS (S. NPP, NOAA-20)
SO_2	**SO_2 total column density** **Instruments:** TROPOMI, OMI, GOME-2, OMPS (S. NPP, NOAA-20)
CO	**SO_2 total column density** **Instruments:** TROPOMI, IASI (Metop A,B,C)

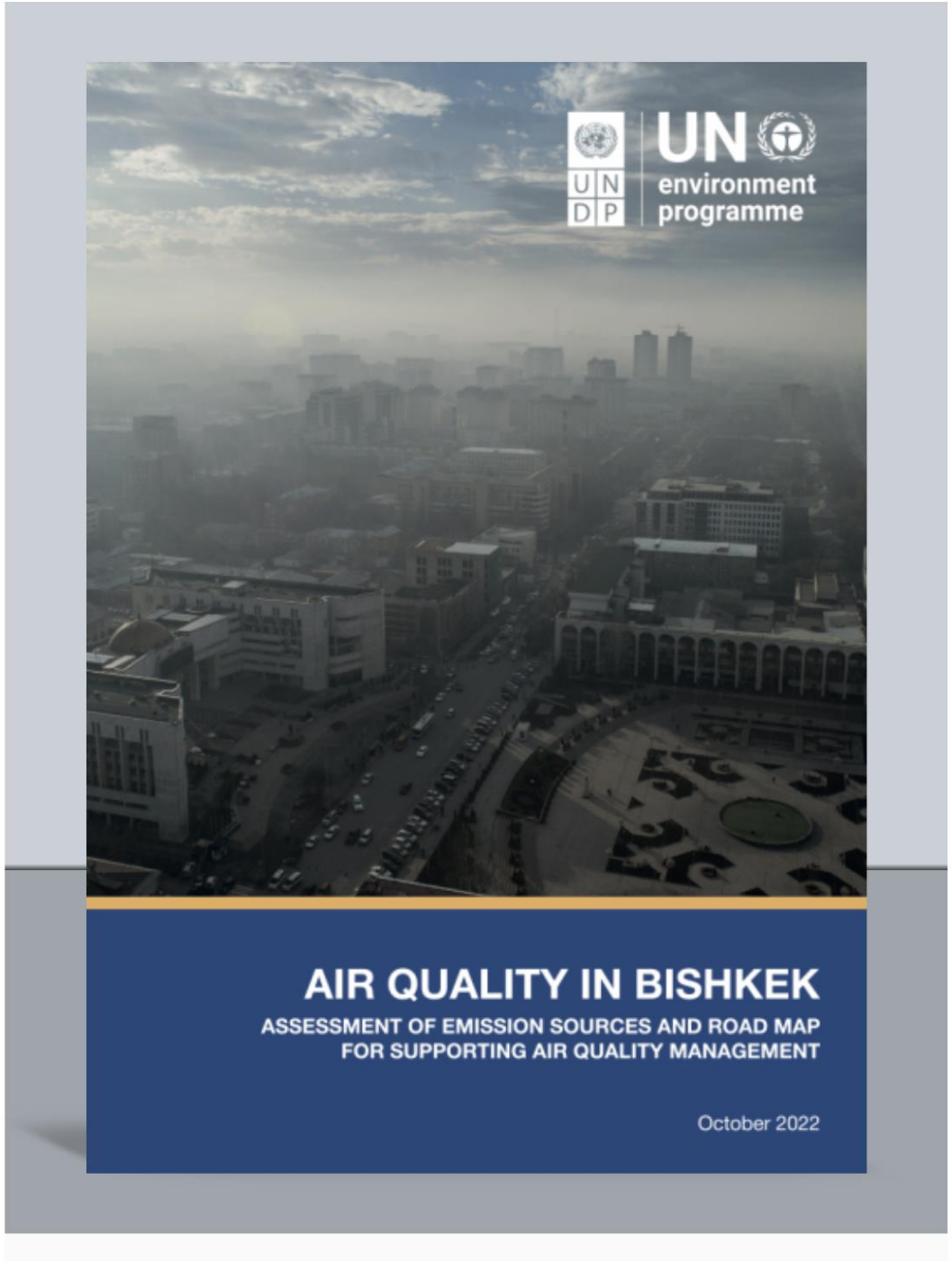
(Satellite instrument list not complete)

- Other potentially useful satellite data: active fires, RGB images, etc.

Air Quality in Bishkek

An Example on the Use of Satellite Data to Support Air Quality Assesment

- The first scientific assessment of key emission sources impacting the air quality in the Bishkek
- Analysis was carried out using KyrgyzHydromet and US Embassy Air Quality Stations, availalable air quality sensor data and satellite observations.
- Analysed satellite parameters included:
  - Tropospheric NO_2,
  - aerosol optical depth
  - total column SO_2
- Report available at: https://wedocs.unep.org/handle/20.500.11822/41090 (English, Kyrgyz, Russian)



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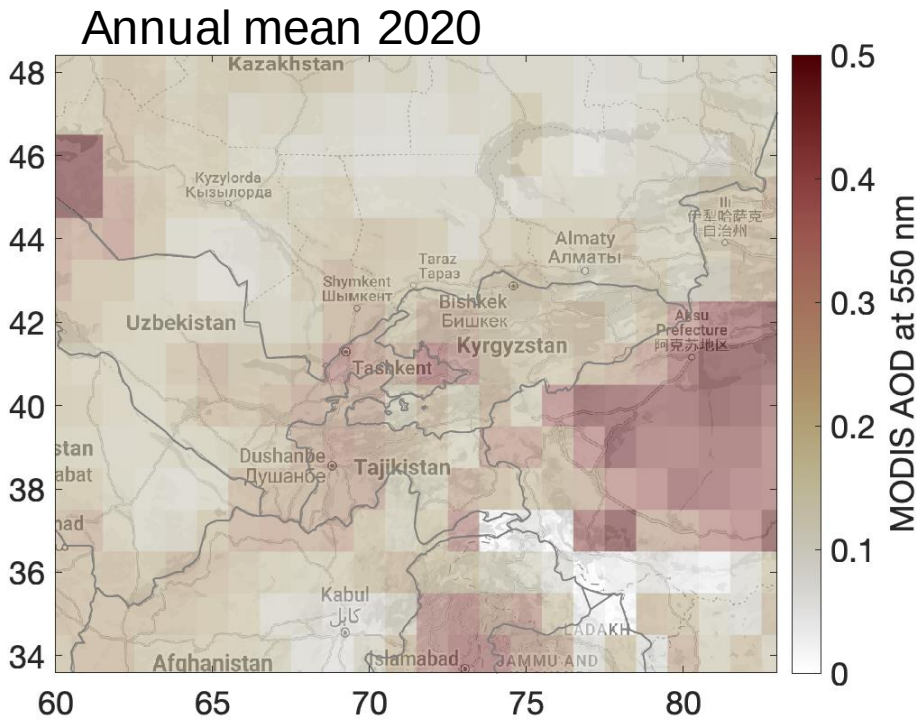
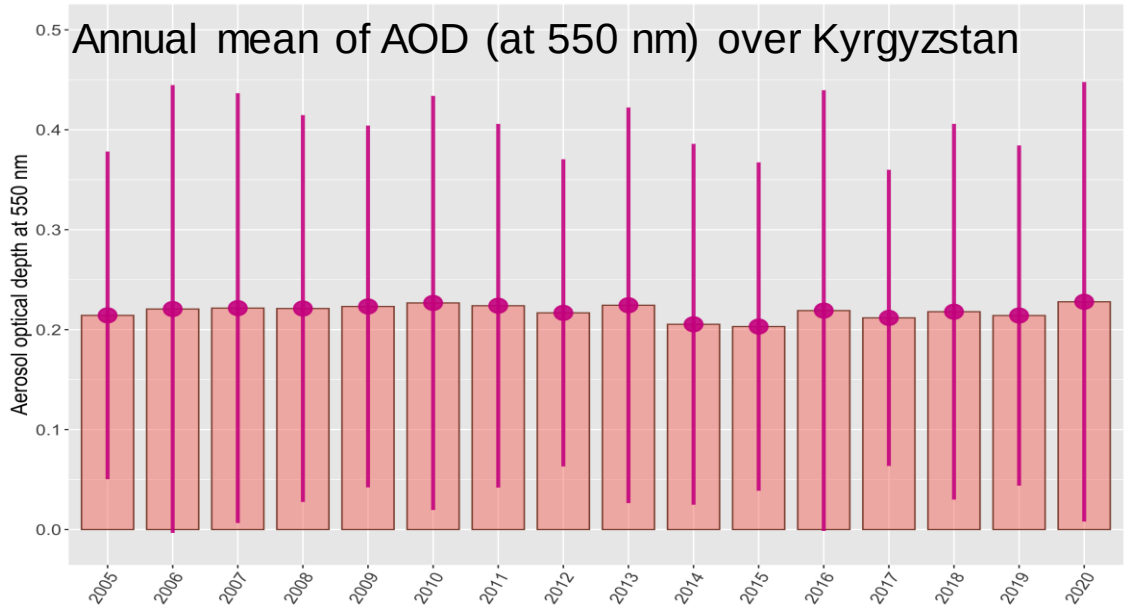
Aerosol Optical Depth (AOD)

- AOD is the primary parameter from satellites to assess the amount of aerosols in an atmospheric column
  - AOD is related to the aerosol number concentration
- AOD correlates to some extent with PM10 and PM2.5, but there are essential differences
  - AOD is sensitive to all sizes of optically active aerosols, AOD is over total column, etc.
  - Estimating PMs from AOD is very challenging, recently machine learning –based methods have been developed
- Over Kyrgyzstan AOD remains at low to moderate level, no trend in the 15 yr annual means
  - Especially during spring time satellites indicate dust transport from Taklamakan desert.





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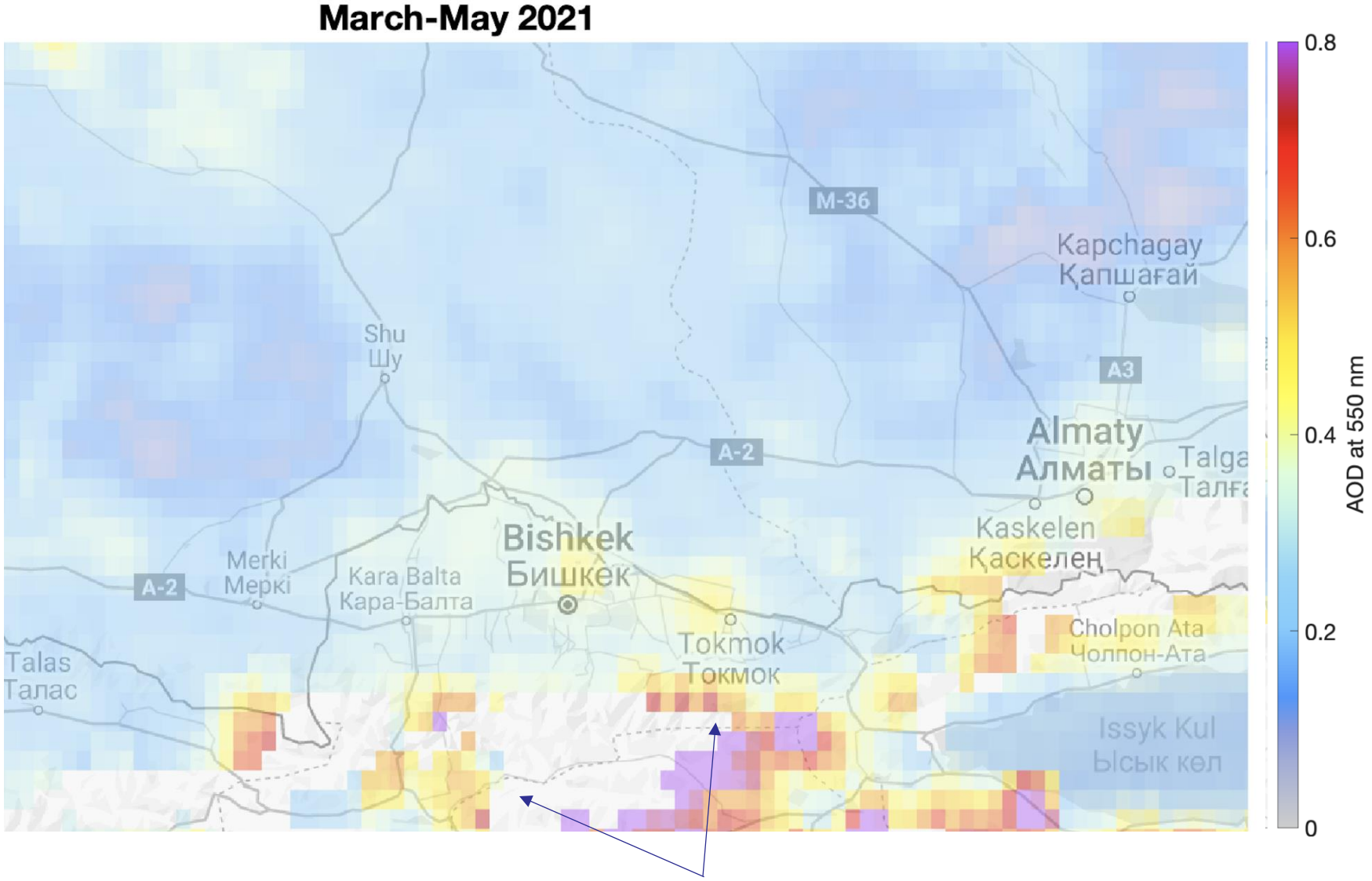
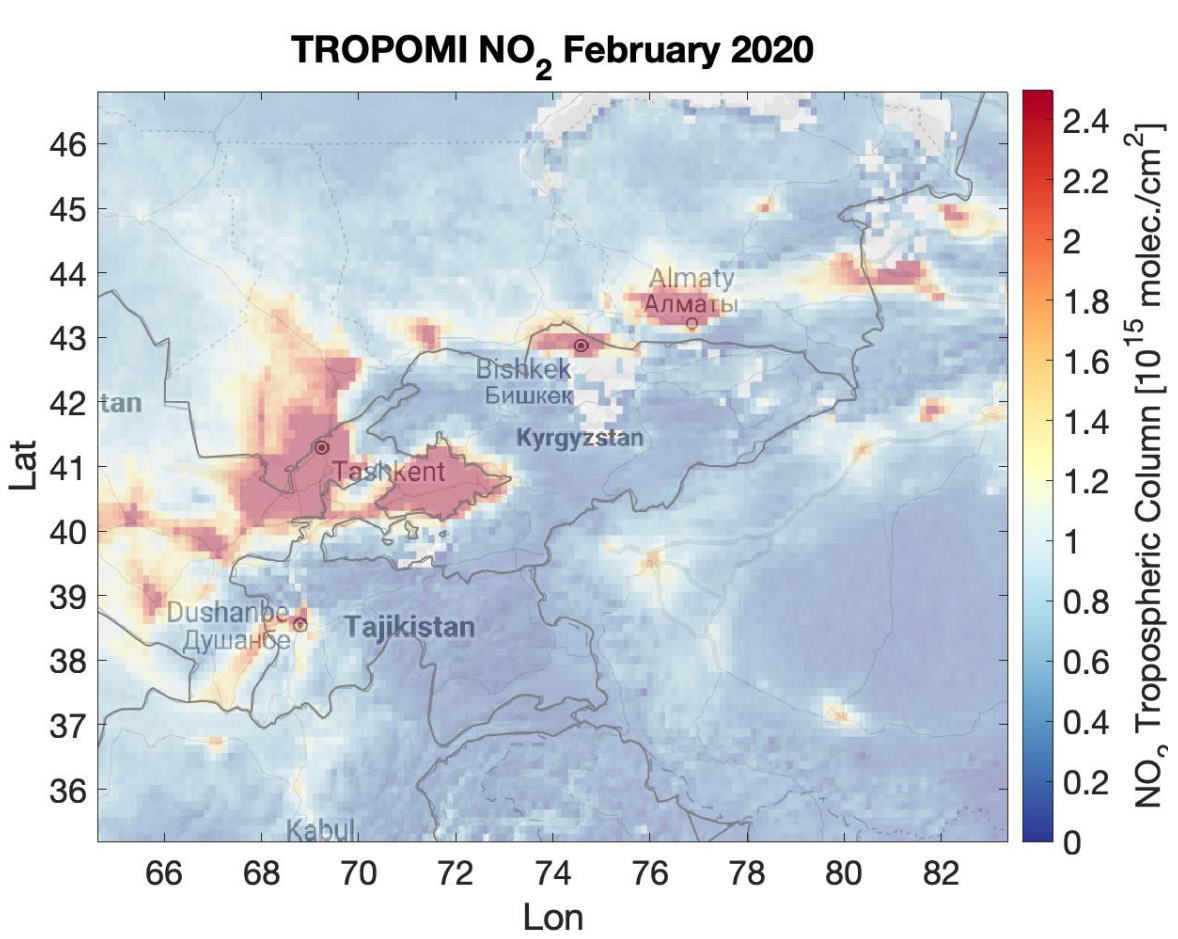
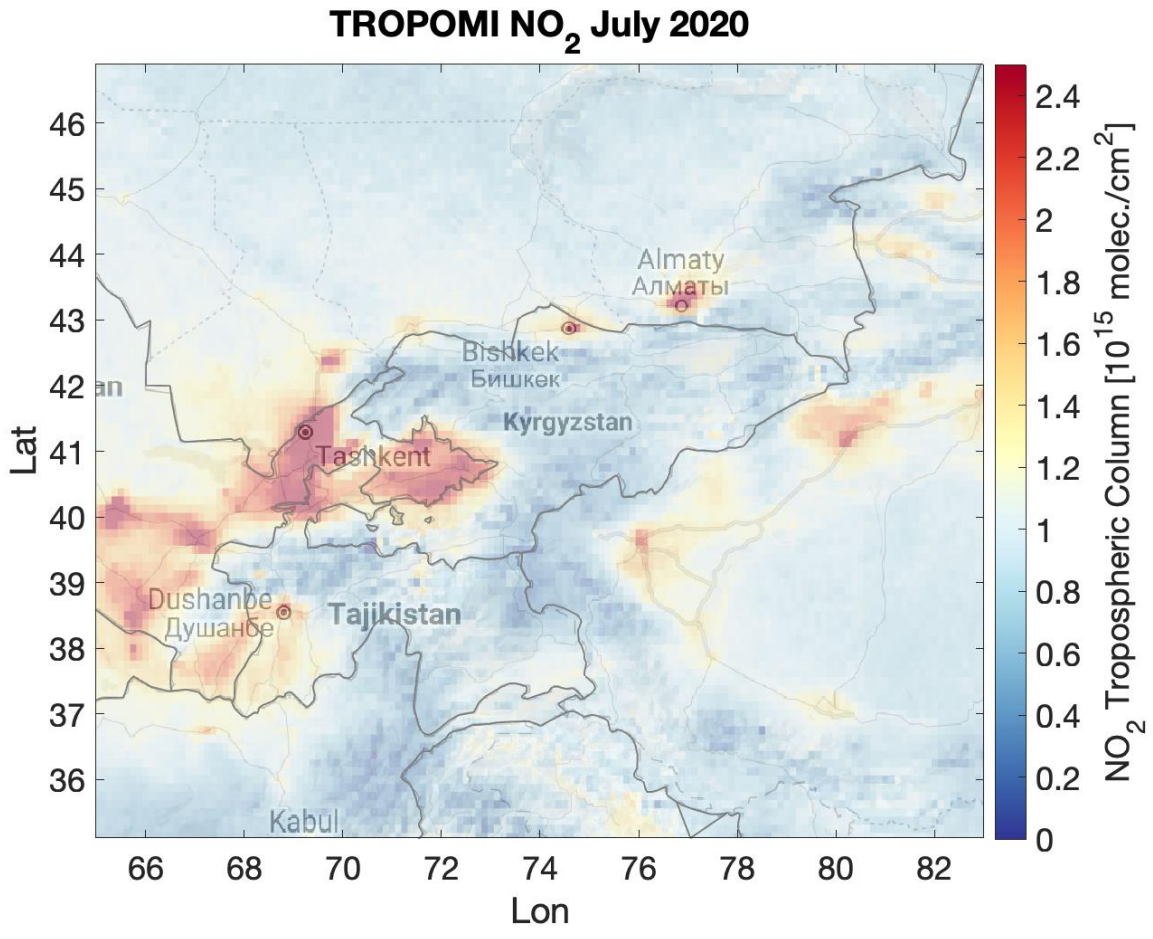
Aerosol Optical Depth (AOD)



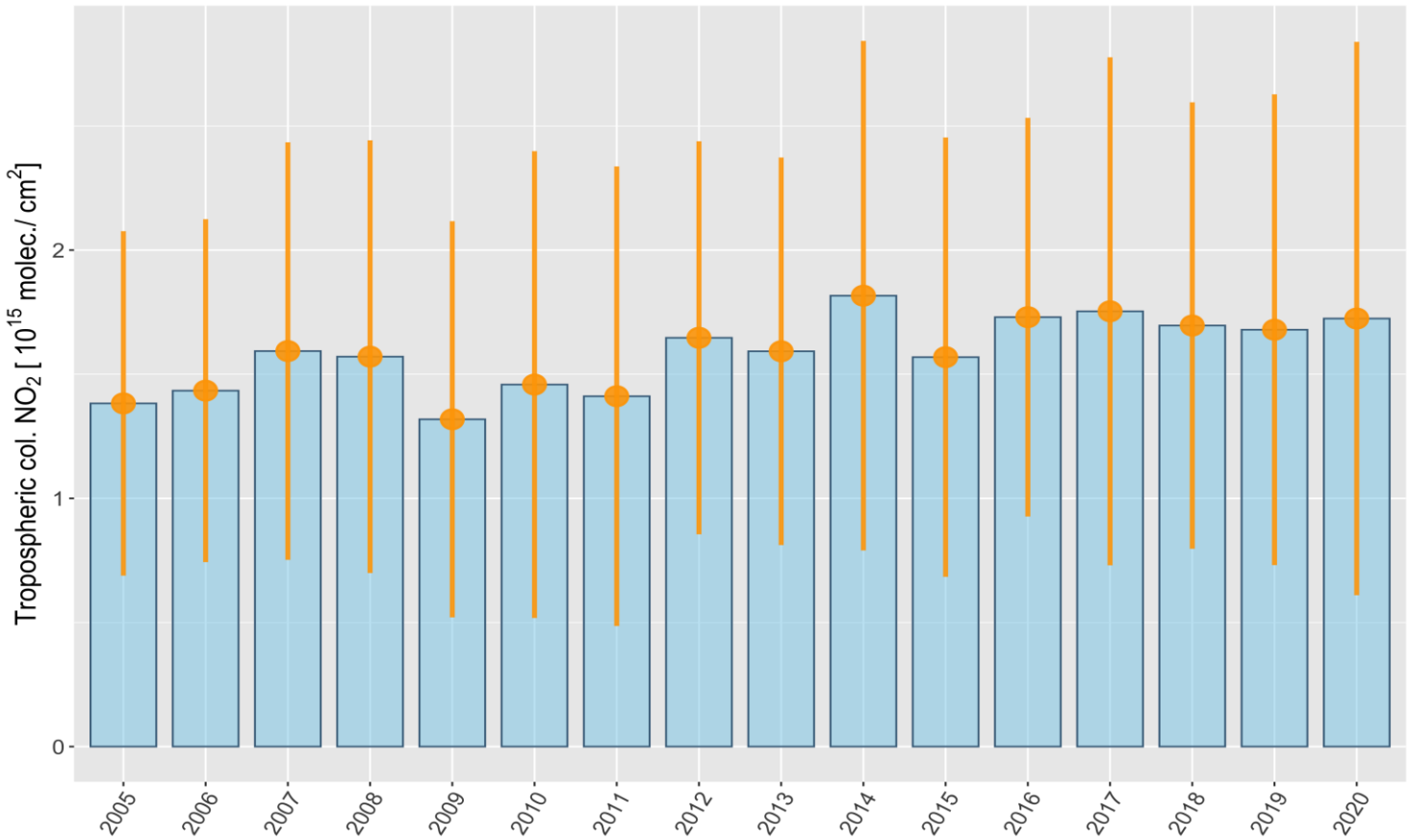
- Challenges over mountaneous area
- part of elevated singnal true and related to dust transport

Satellite observations of nitrogen dioxide Tropospheric column (NO_2)





Annual mean of Tropospheric NO_2 from the OMI instrument for Kyrgyzstan



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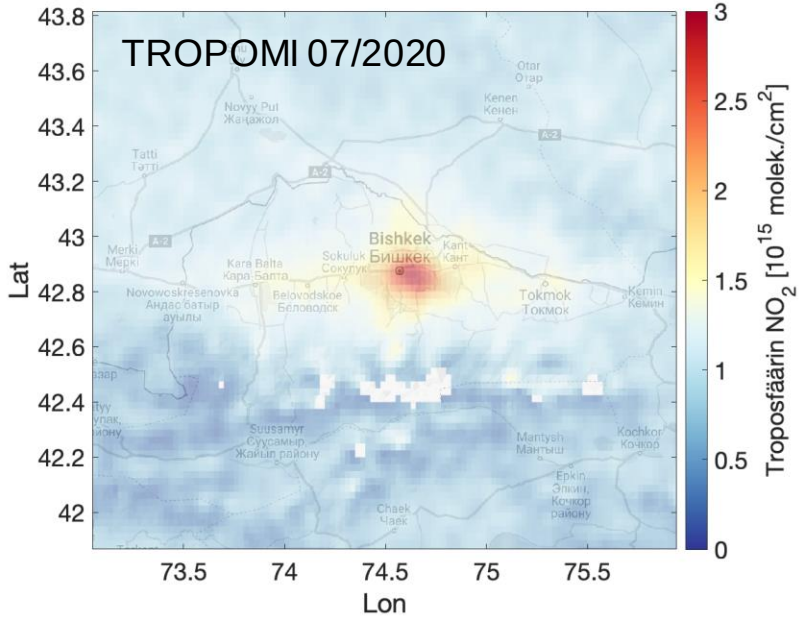
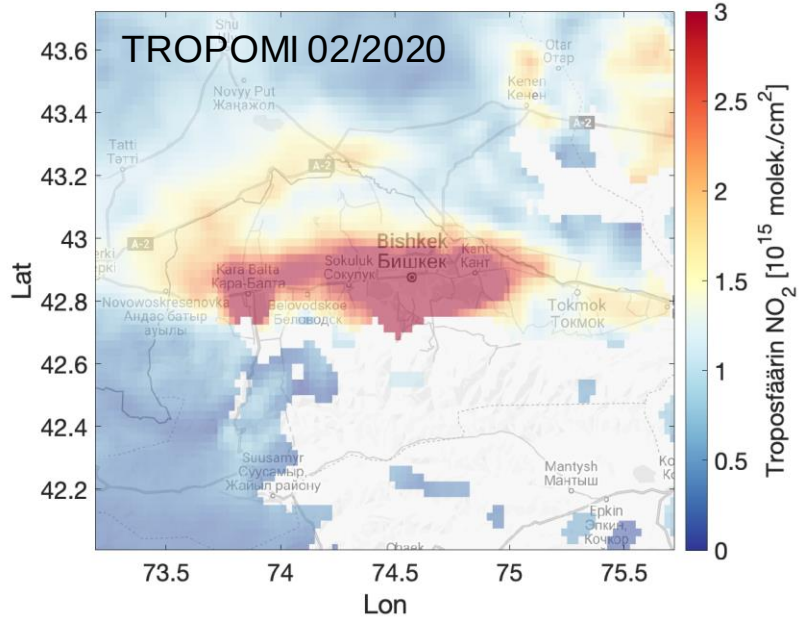
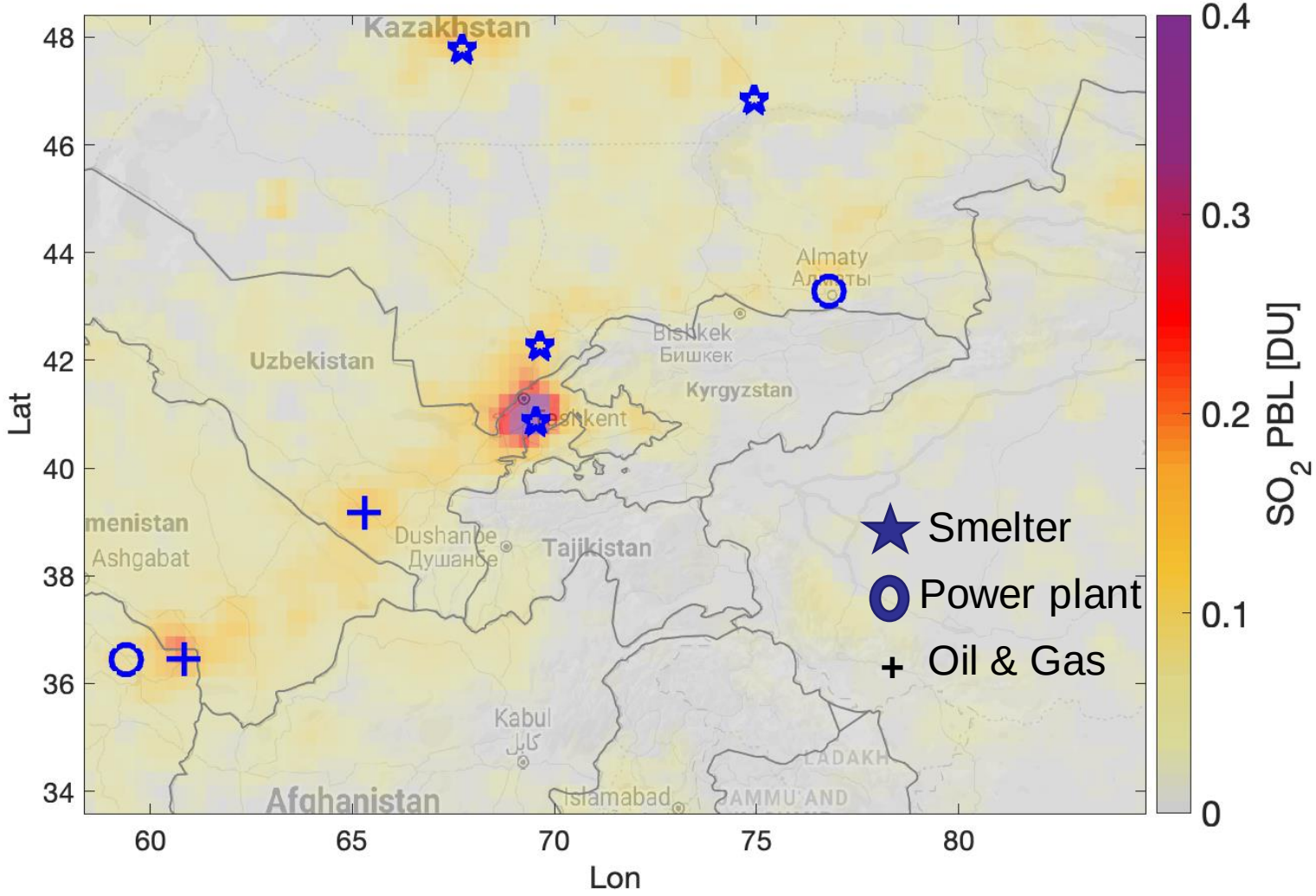
Bishkek



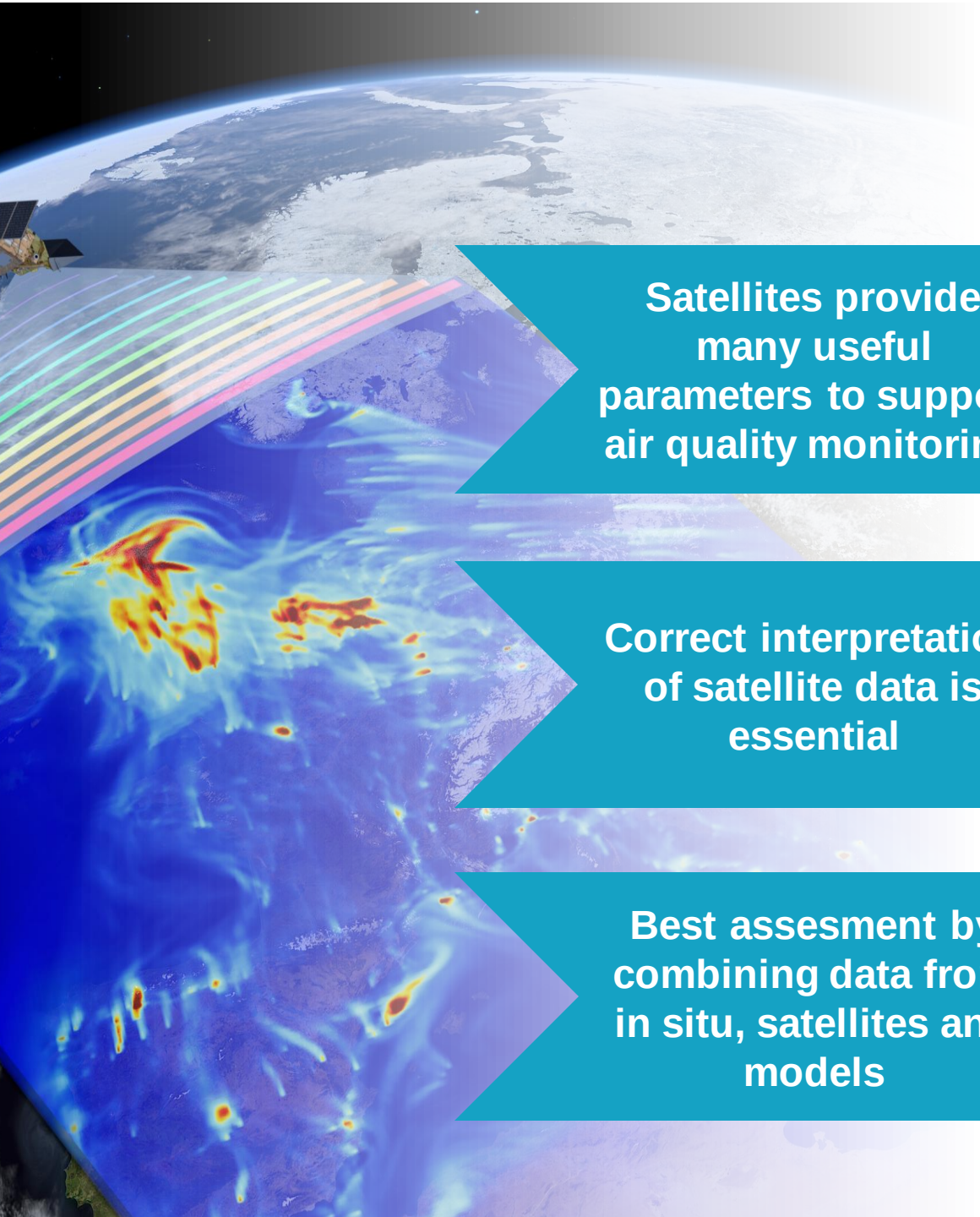


Satellite-based total column of sulphur dioxide (SO_2)

2019 Annual Mean (OMI instrument)



- In situ observations in Bishkek showed high SO_2 concentrations
- From satellite data no major emission sources could be identified over Kyrgyzstan, and total column SO_2 remained low
  - Detecting SO_2 from satellites is challenging.
  - Anthropogenic source needs to be strong point source to be "visible" for satellites.
- The most likely explanation for the difference is that in Bishkek SO_2 is orignating from multiple smaller sources that "averages out" in satellite pixels (single pixel several square km).



Summary

Satellites provide many useful parameters to support air quality monitoring

- Regional information, observations over areas where in situ measurements are missing.
- Long time series available.
- Data are free and open for everyone.

Correct interpretation of satellite data is essential

- Concentrations in an atmospheric column.
- In situ and satellite observations not directly comparable.
- Need to consider how well satellites represent variations close to surface.

Best assesment by combining data from in situ, satellites and models

- Satellites can’t replace in situ observations, but they can support and help to extent the analysis into a wider regional scale.
- Satellites can also help to estimate long range transport of pollutants.