ARNIKA

MY CITY KILLS
ჩემი ქალაქი მკლავს

WORLD FROM SPACE

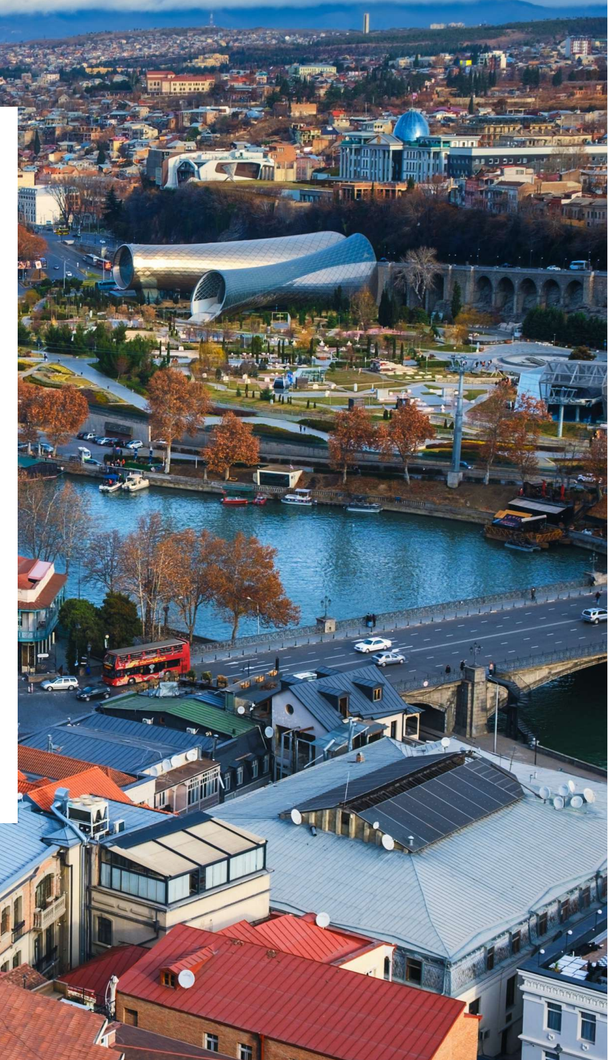
TRANSITION
Ministry of Foreign Affairs of the Czech Republic

Funded by
the European Union

AIR POLLUTION IN GEORGIA

AS SEEN FROM SPACE

STUDY BASED ON THE SATELLITE IMAGERY & COPERNICUS DATA



CONTENT

INTRODUCTION

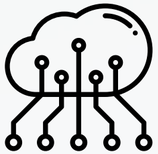
Georgia in the 21st century:

- political transition
- economic growth, technological advancements
- a lot of challenges remain

→ **air pollution, deforestation, water pollution, invasive species**

- **traffic emissions, industrial activities, household heating** as main sources of air pollution

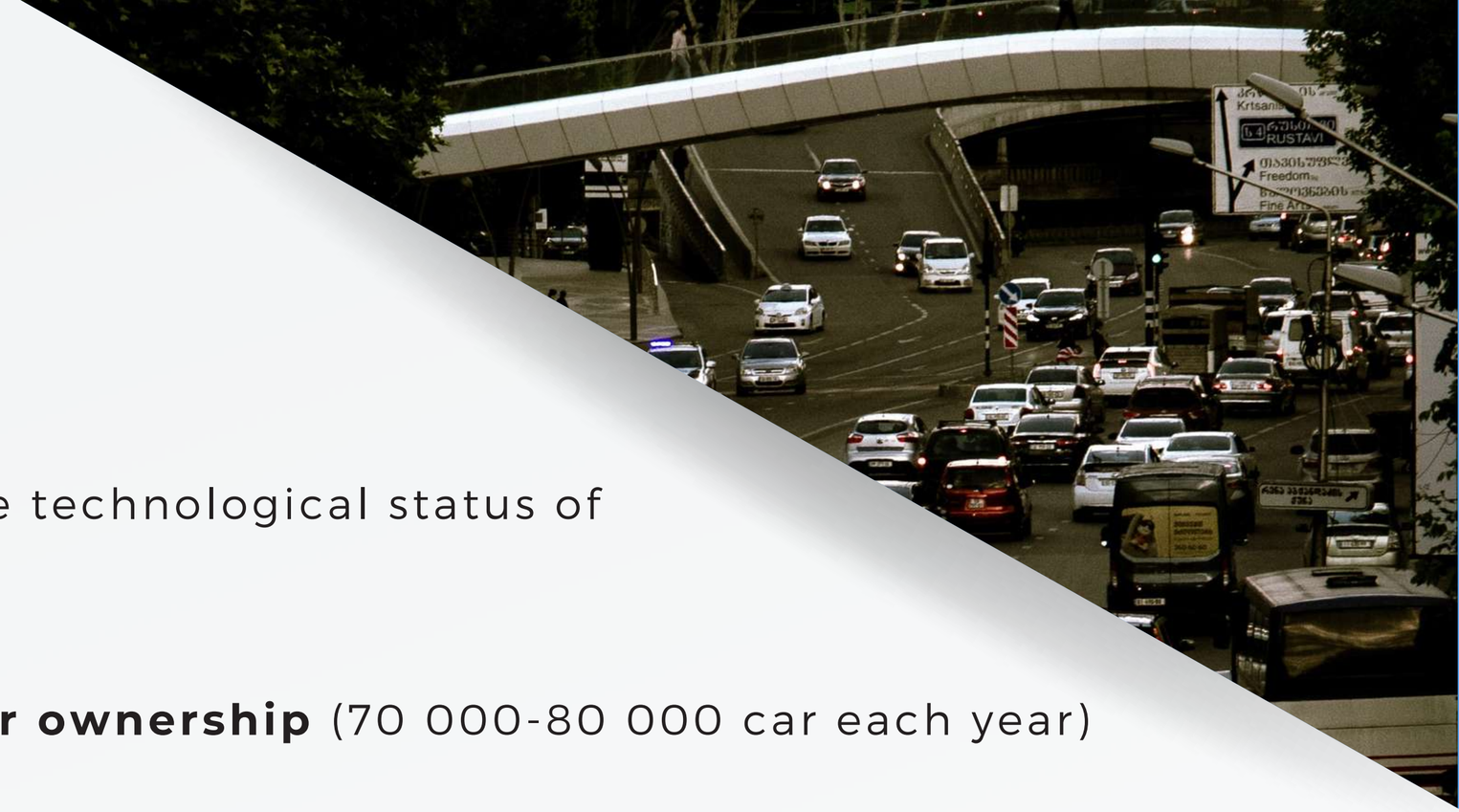
1960s



6 %

2020

AIR POLLUTION & TRANSPORT



01 Increasing traffic load and the technological status of transportation

02 Rapid **growth of personal car ownership** (70 000-80 000 car each year)

03 **Technical inspections compulsory** since 2019

3.7 mil.

1.6 mil.

71 %

>90 % cars older than 10 years (2019)

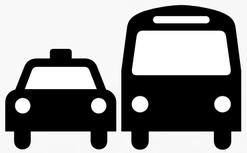
CLIMATE CHANGE & AIR POLLUTION

AIR POLLUTION CAUSES:

- transport
- pollutants
- physical geography

Nitrogen dioxide (NO_2)	Carbon monoxide (CO)	Particulate matter (PM_{10})

KEY POLLUTANTS

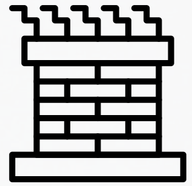


Nitrogen dioxide (NO_2)

- mainly from transport and chemical industry
- natural sources include microbiological processes in soil, wildfires and lightning
- causes respiratory infections and acid rains

Carbon monoxide (CO)

- mainly from fossil fuel consumption, waste incineration, biomass burning
- important indirect GHG (40 % from natural sources)
- toxic effect on the organ tissues with high oxygen consumption



Particulate matter (PM_{10})

- mainly from combustion sources
- cassified by size
- toxic and genotoxic
- catalyst for chemical reactions and the toxicity is enhanced by other pollutants

DATA & METHODS

Sentinel-5P

Copernicus Atmospere Monitoring Service (CAMS)

Processing

SENTINEL-5P

01 **Satellite for atmosphere monitoring -** launched in 2017 (EU Copernicus Programme)

02 TROPOMI spectrometer

S5P measures gases such as **NO_2**, CH_4, O_3, CH_2O, SO_2, **CO** and aerosols

Daily measures with a **spatial resolution** of approx. **5.5 km x 3.5 km** (~7 km to ~5.5 km until August 2019)

P stands for "Precursor", as the Sentinel-5P reduces gaps in the availability of global atmospheric data products between Envisat (ended in 2012) and the and the future Copernicus Sentinel-4 and Sentinel-5 missions.

COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)

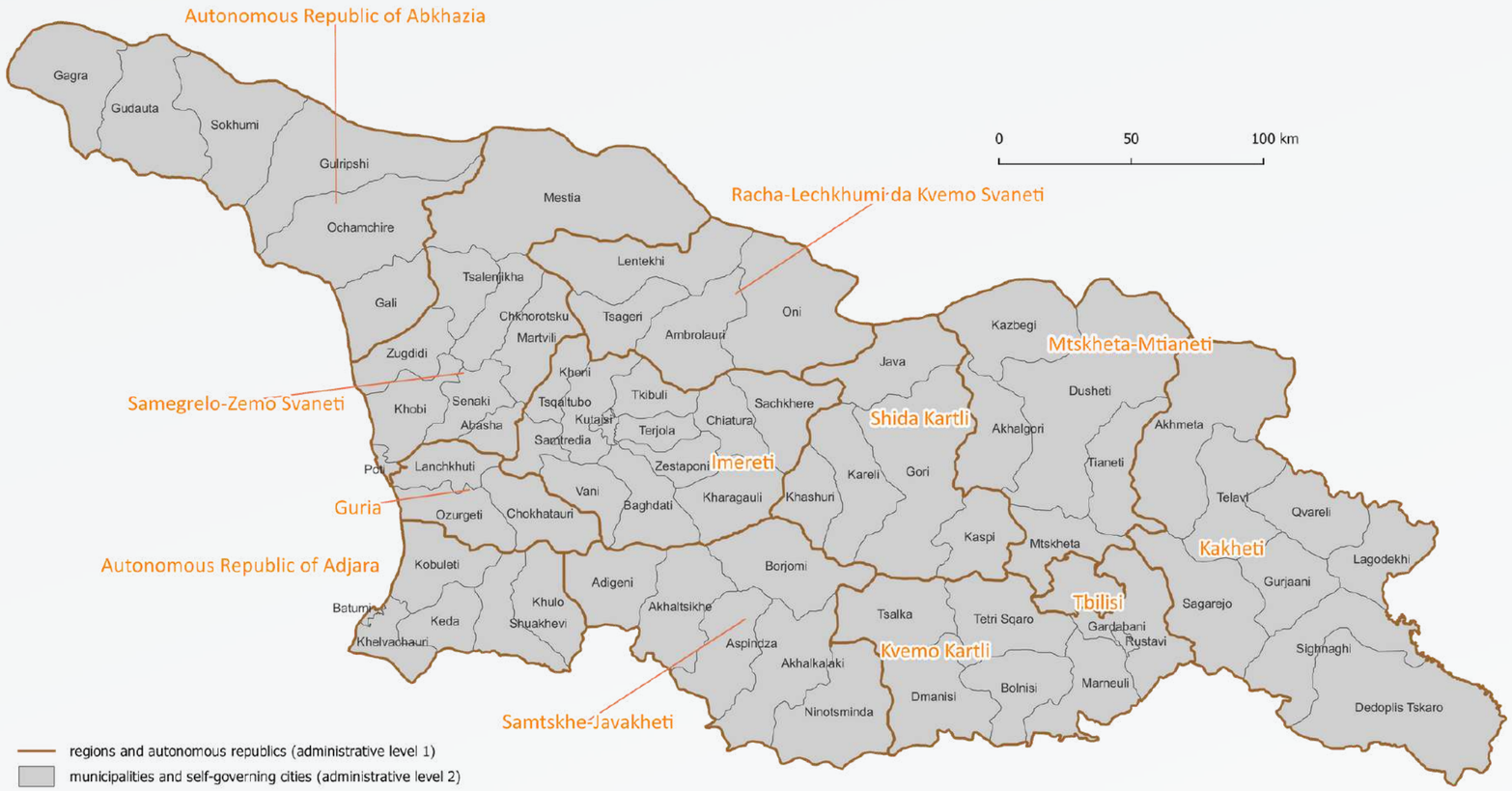
01 CAMS provide **global, quality-controlled information related to air pollution, solar energy, greenhouse gases and climate forcing**.

02 CAMS global atmospheric composition forecasts used for measuring **PM_{10}**

Two types of datasets (European + Global)

Forecast + Analysis (combination of satellite data, ground-based observations, and numerical models) **available at hourly time steps**

ADMINISTRATIVE DIVISIONS OF GEORGIA



1. Country
2. Region
3. Municipality (self-governing cities)

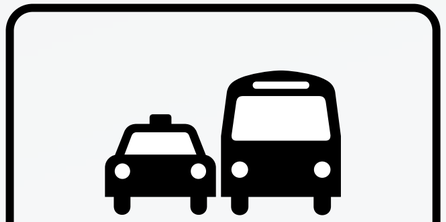
RESULTS

BASIC ANALYSIS

SEASONALITY OF AIR POLLUTION

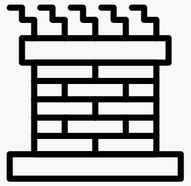
AIR POLLUTION IN CITIES

AIR POLLUTION FROM TRANSPORT



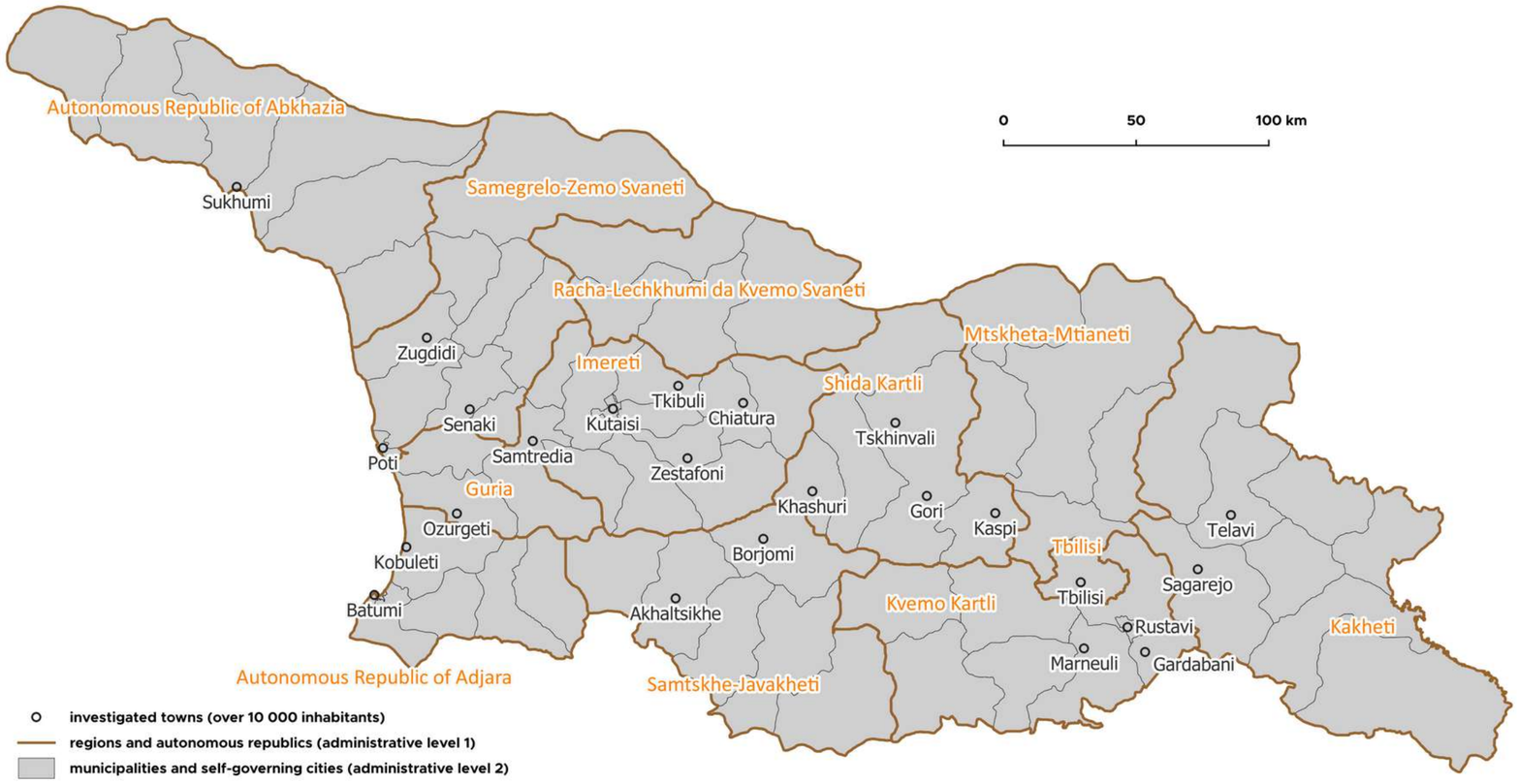
Nitrogen dioxide (NO_2)

Carbon monoxide (CO)



Particulate matter (PM_{10})

AIR POLLUTION IN CITIES



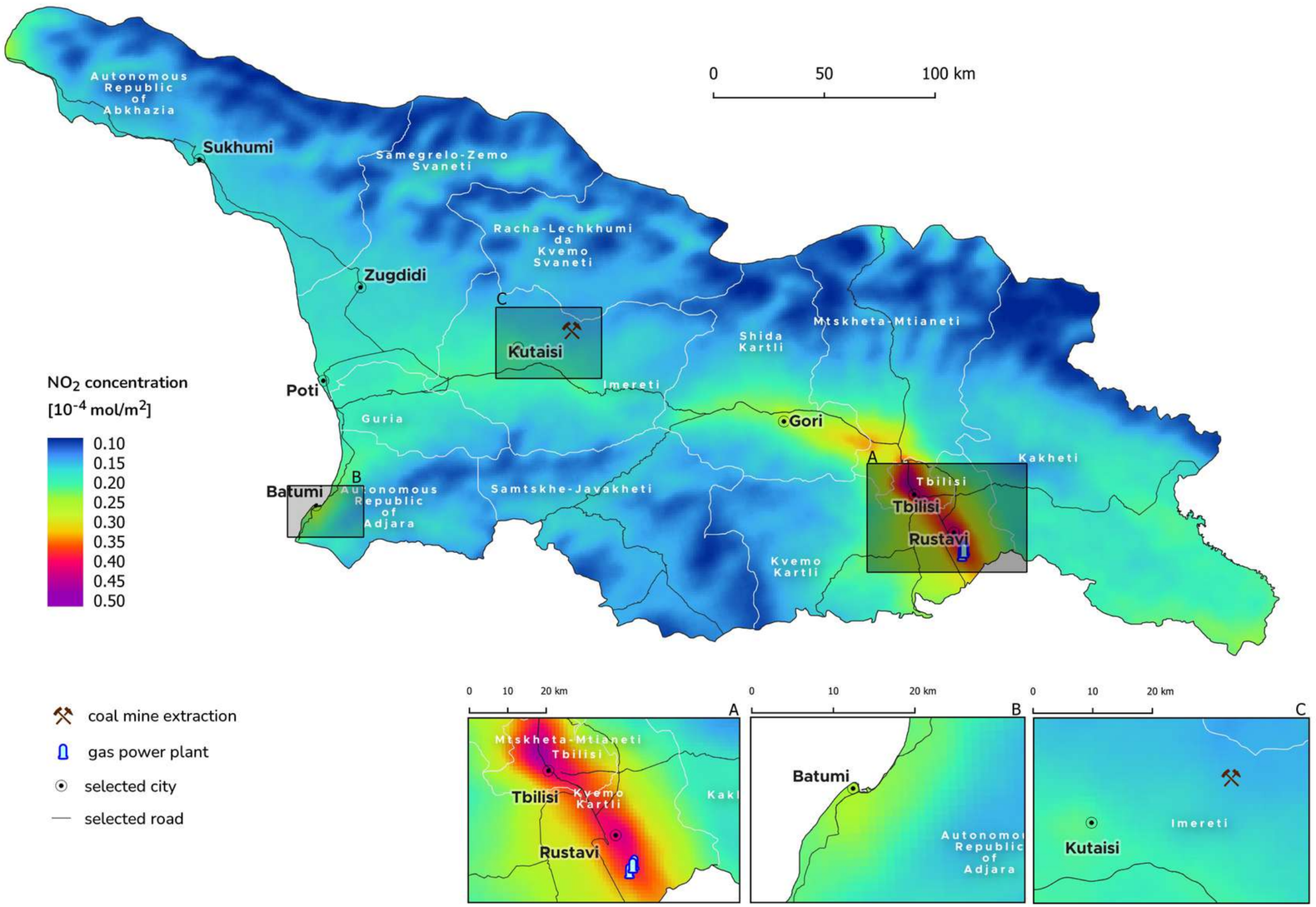
Selected cities with a population over 10 000 inhabitants being further analysed

NO_2

- **Highest concentration in urban areas (transport, industry)**
- **Tbilisi, Rustavi, Garbadani** (major industrial enterprises)
- **Mountains and valleys** influence the distribution

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



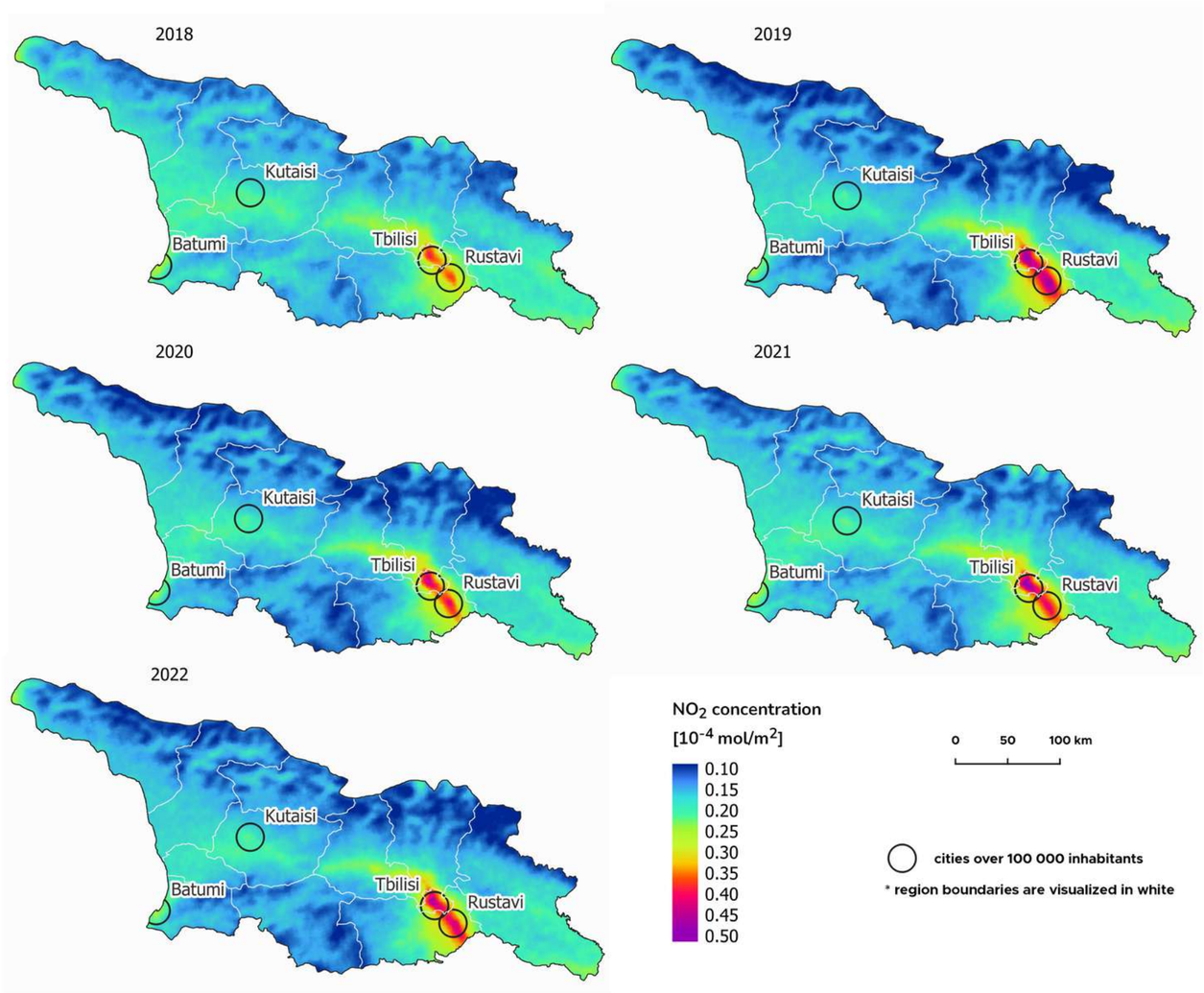
NO_2

- **Yearly concentration increase in Tbilisi and the surroundings regions** (highest population density + strong transport)
- **Noticeable rise between 2018-2019** (absence of data - domestic heating increases emission concentration)

NITROGEN DIOXIDE (2018-2022)

BASIC ANALYSIS

YEARLY COMPARISON



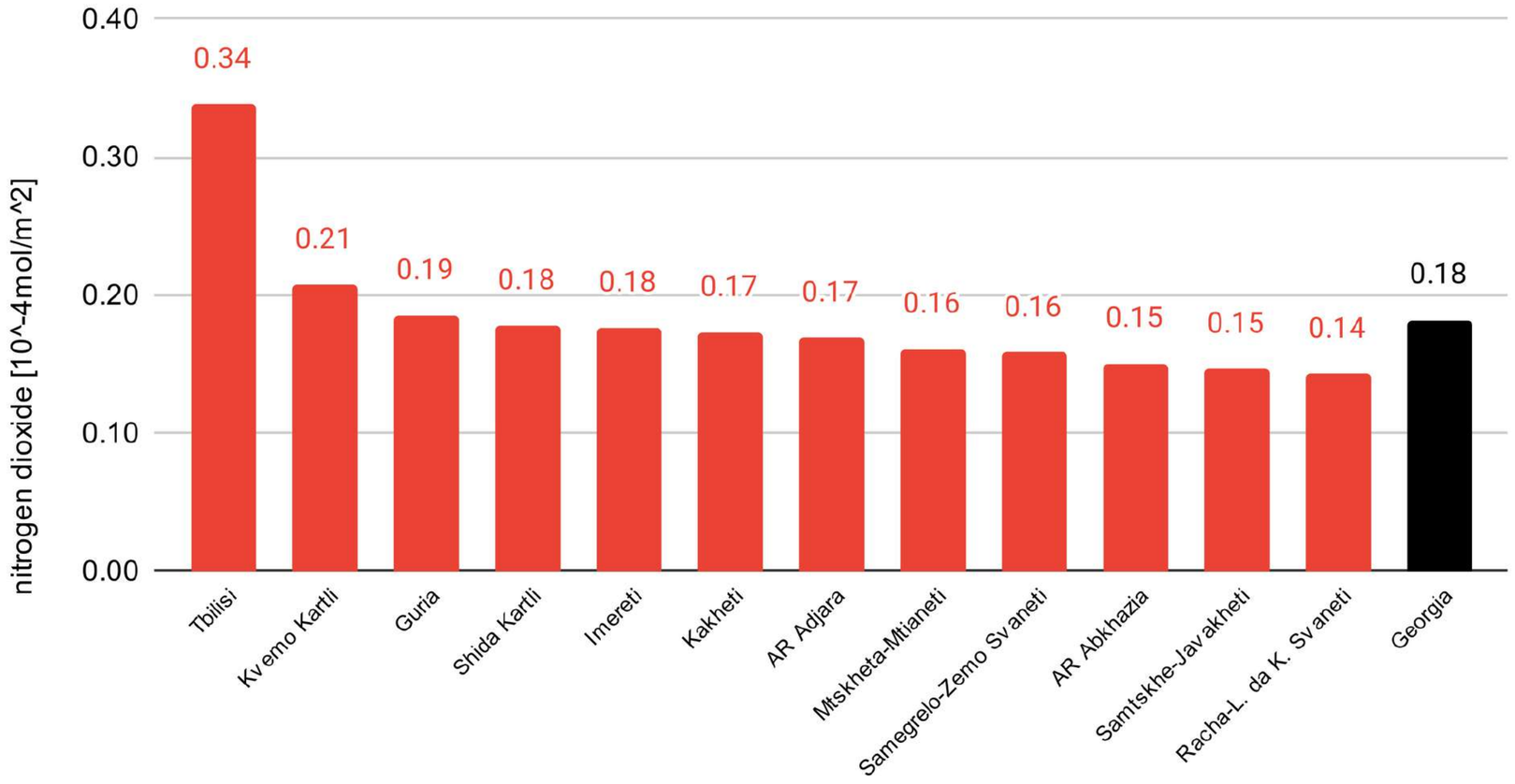
NO_2

Ø NO_2 concentrations in the regions of GE

- Tbilisi
- Kvermo Kartli
- Guria

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



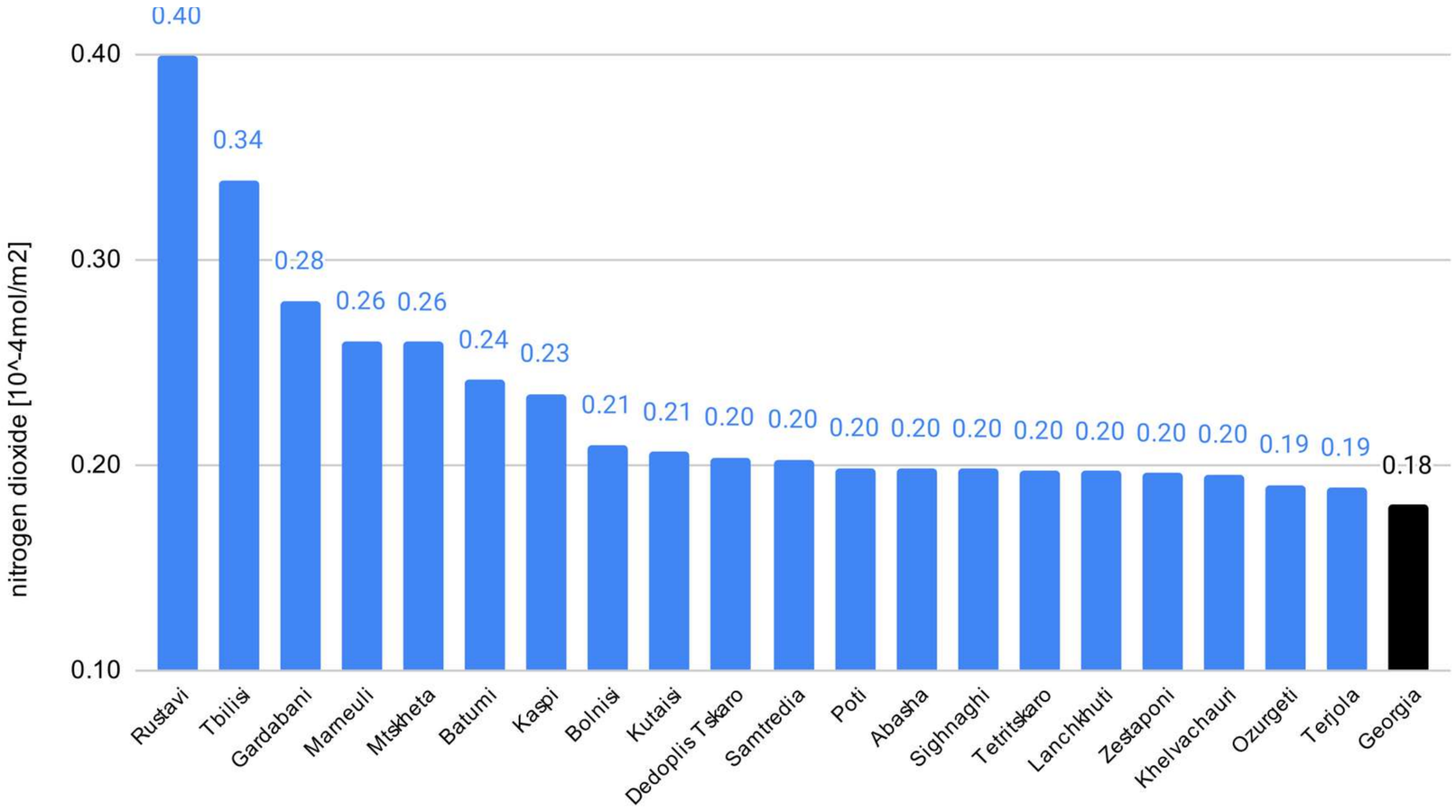
NO_2

Ø NO_2 concentrations in municipalities and self-governing cities of GE

- **Rustavi** (steel production, heavy industries, personal car transport)

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS

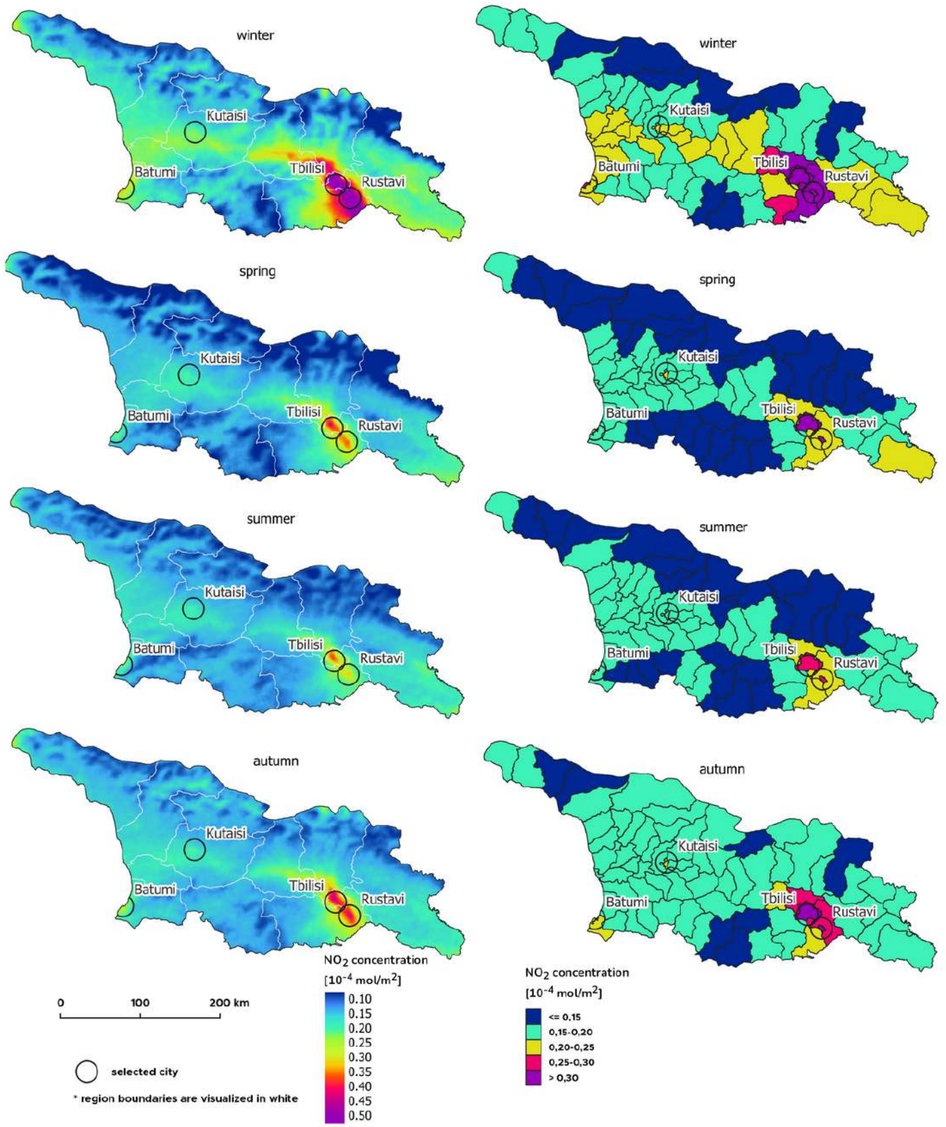


NO_2

- In general, **air pollution more pronounced in winter in GE**
- **Tbilisi, Rustavi, Colchis Lowland**
- **winter** - greater need for heating
- **other seasons** - consistent distribution

NITROGEN DIOXIDE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION



NO_2

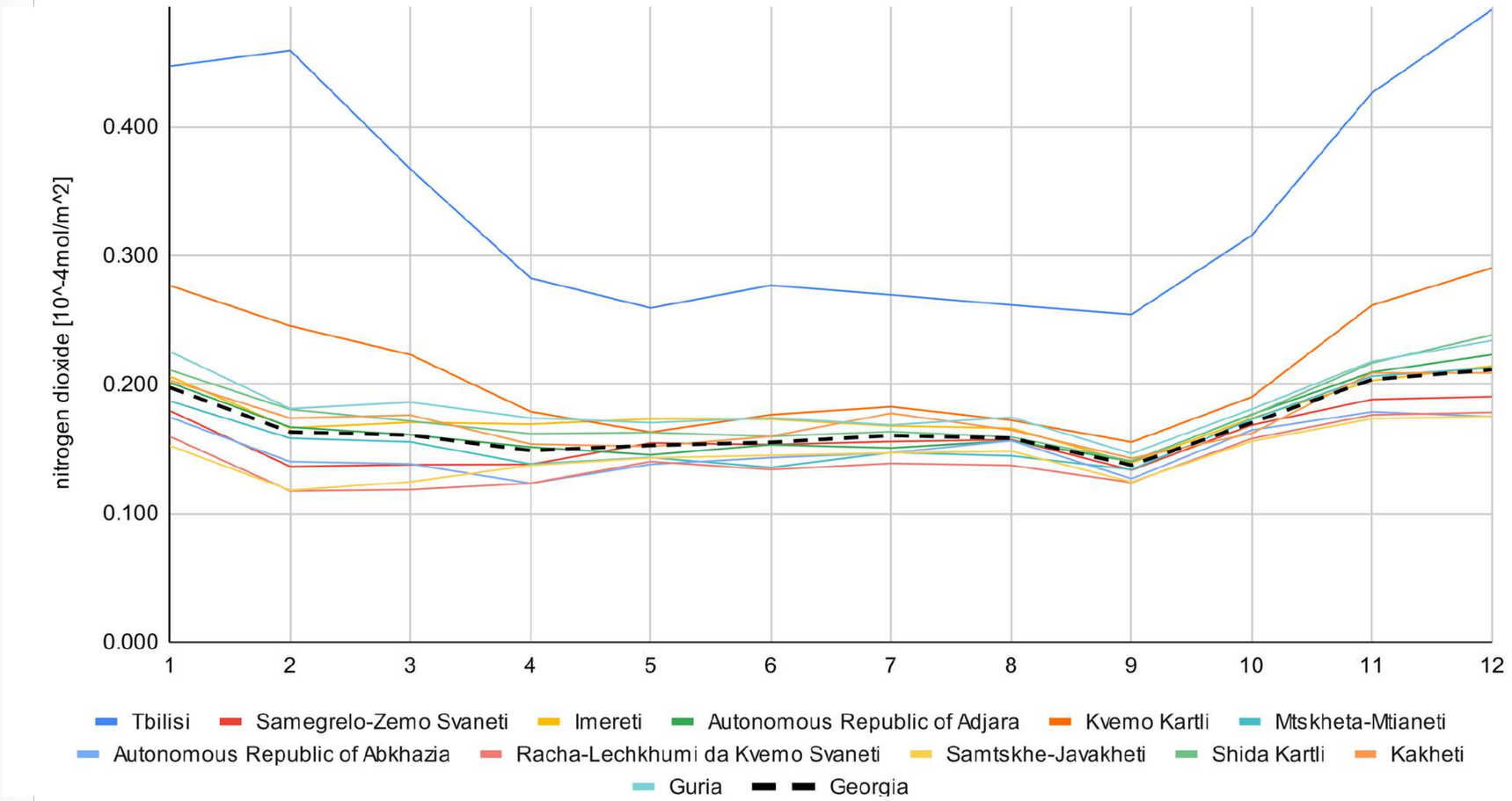
- In general, **air pollution more pronounced in winter**
- **northern KZ, Almaty, Pavlodar, Shymkent**

- **spring, summer** - general decrease (apart from some major cities)

- **summer** - higher concentration in the uninhabited territory (natural processes in the atmosphere)

NITROGEN DIOXIDE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION

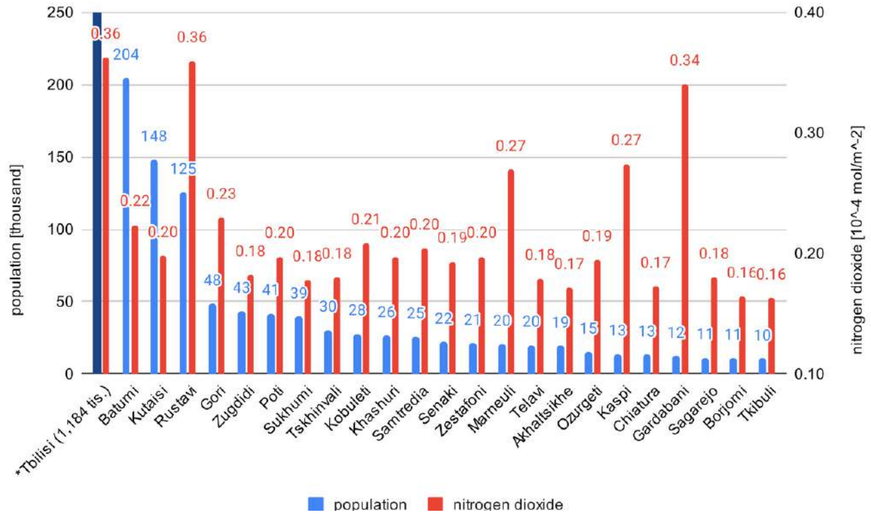


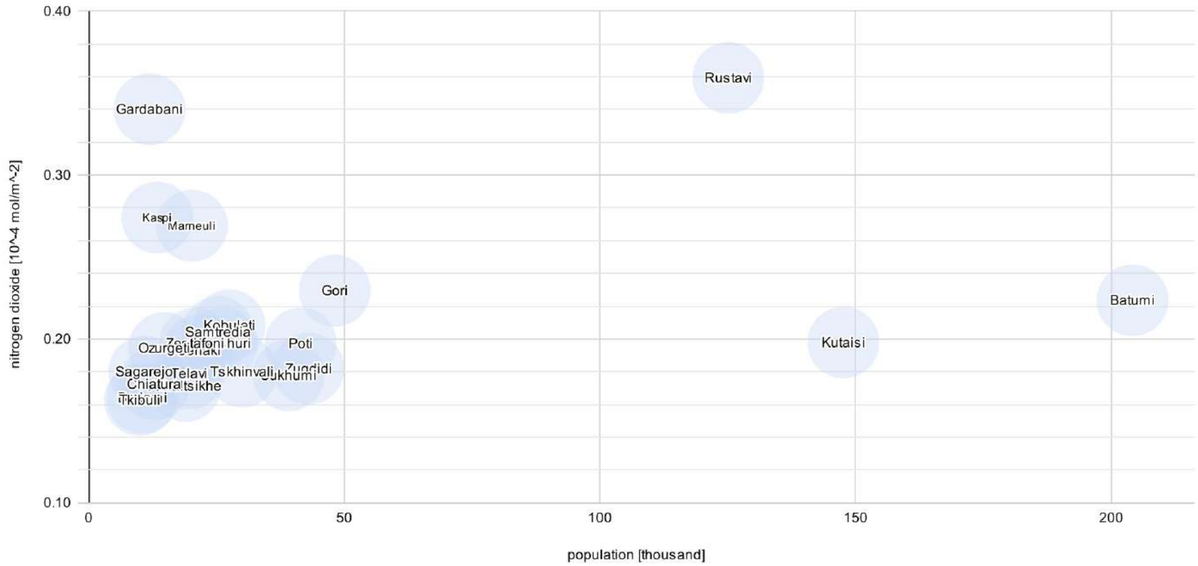
NO_2

- **Ø NO_2 concentrations in the GE cities with a population over 10 000**
- In general, **population decrease = level of pollution decrease**
- several exceptions **(Kaspi, Marneuli, Gardabani)**
- **Kutaisi, Batumi** - concentration level as of cities with three times less populated

NITROGEN DIOXIDE (5/2018-12/2022)

AIR POLLUTION IN CITIES





NO_2

Ø NO_2 concentrations in:

01 Tbilisi
- city centre + “sleeping districts”
- direction towards SE (Gardabani, Rustavi)

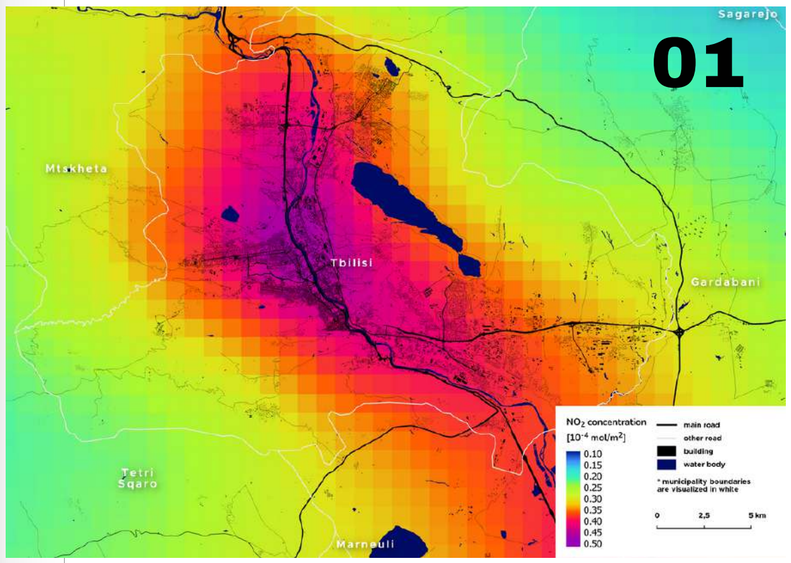
02 Batumi
- adjusted color scale (NO_2 lower in general) - no heavy industry, windy conditions

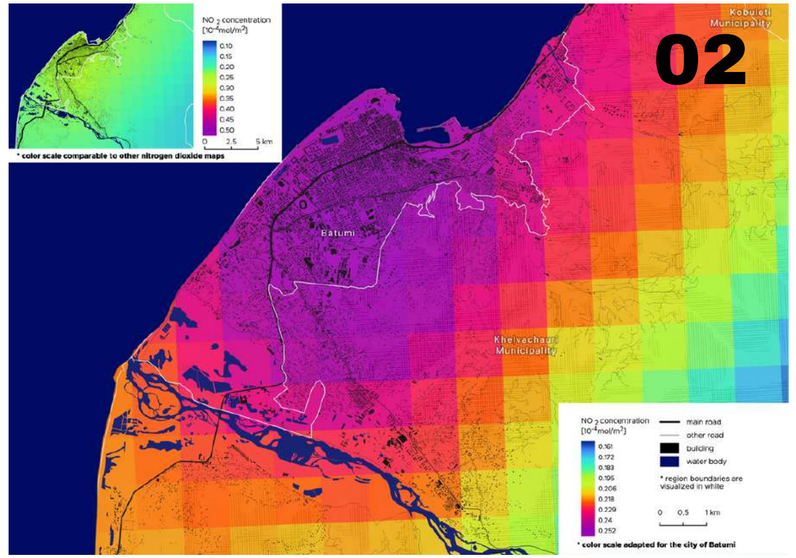
03 Kutaisi
- city centre
- NO_2 concentrations lower compared to other cities

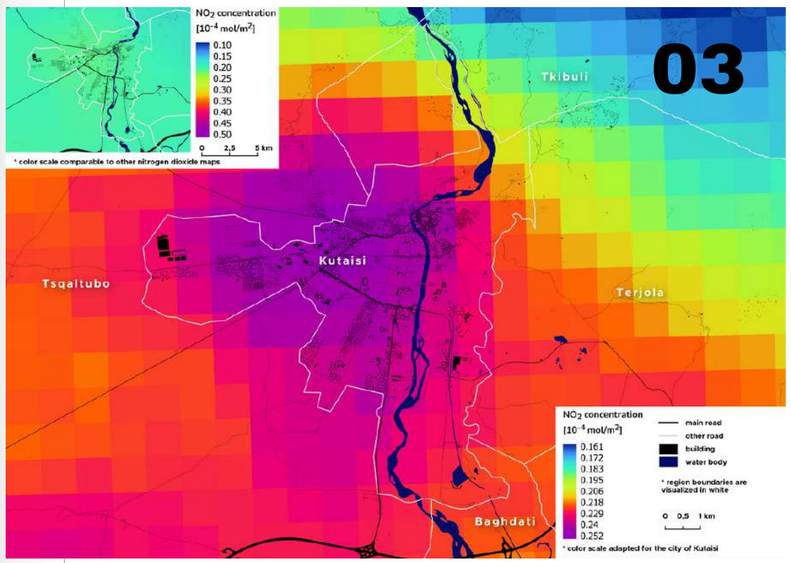
04 Kaspi
- cement plant
- Ksani Glass Factory

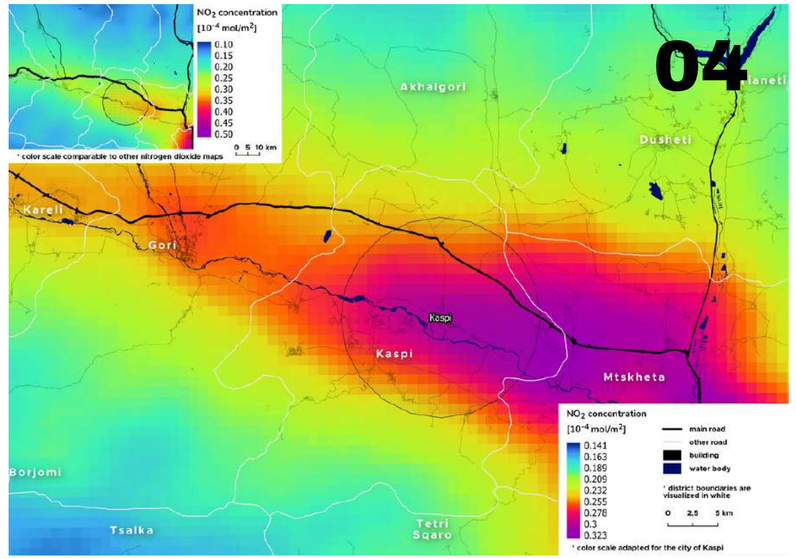
NITROGEN DIOXIDE (5/2018-12/2022)

AIR POLLUTION IN CITIES









NO_2

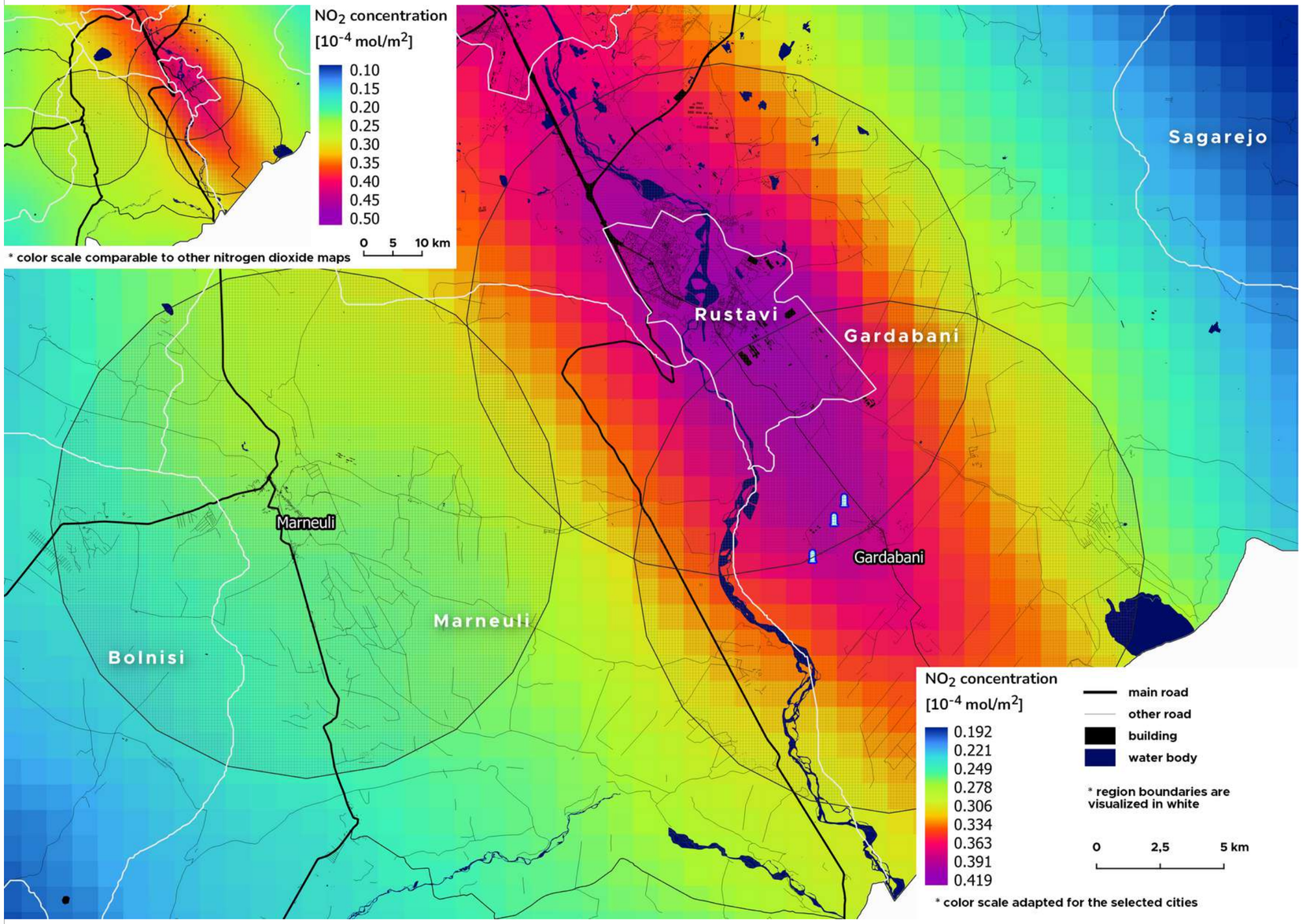
Ø NO_2 concentrations in:

05 **Aglomeration of Rustavi, Gardabani, Marneuli**

- 321 000 inhabitants
- industrial hinterland
- NO_2 concentrations significantly higher
- **Rustavi**
  - Rustavi Metallurgical Plant
  - Rustavi Azot
  - cement plant
  - +- 22 other factories
- **Garbadani**
  - cement factories, transport

NITROGEN DIOXIDE (5/2018-12/2022)

AIR POLLUTION IN CITIES



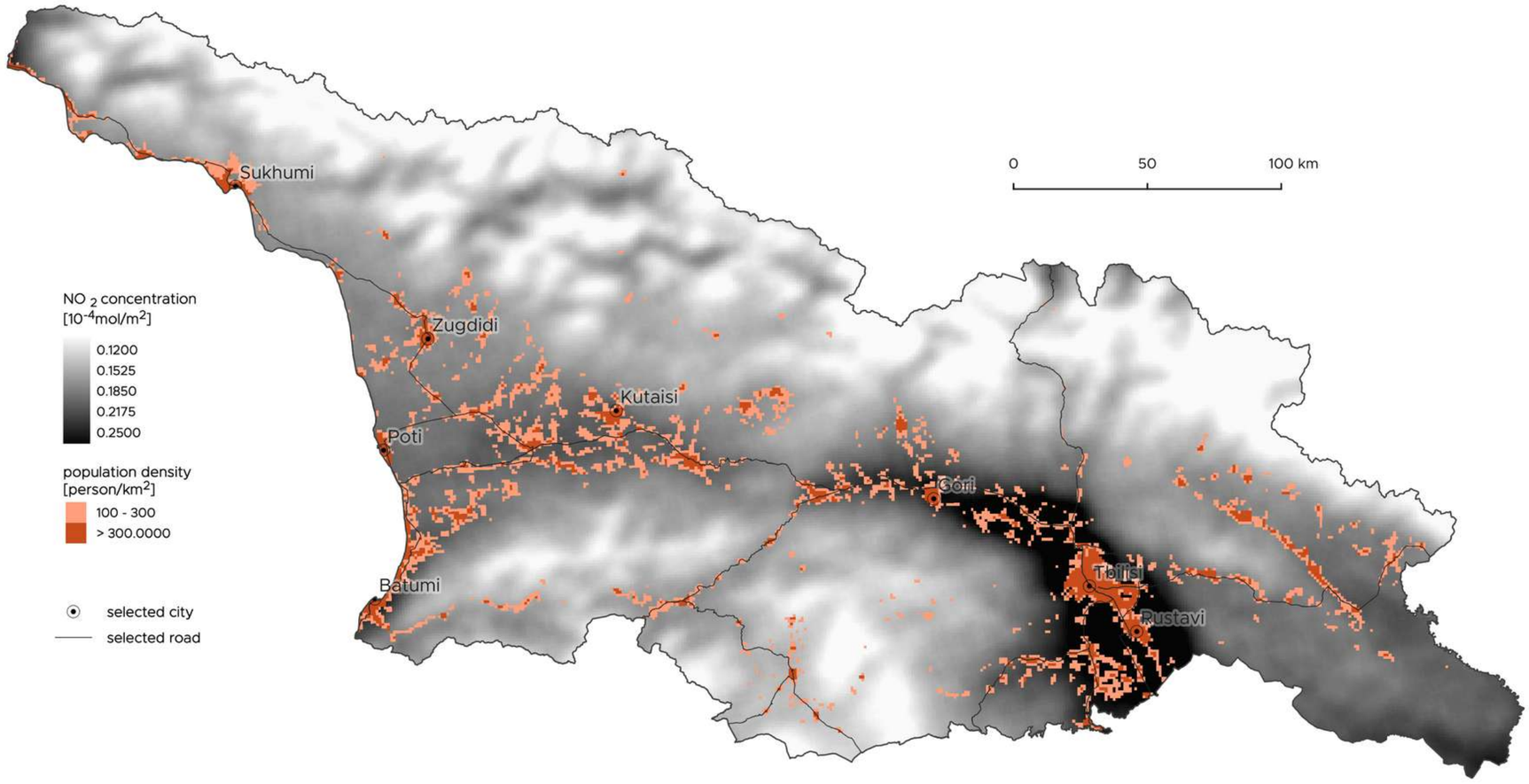
NO_2

Ø NO_2 concentrations in GE in the context of 2019 population density data

- higher population density → more vehicles and greater economic activity → higher emissions

NITROGEN DIOXIDE (5/2018-12/2022)

AIR POLLUTION IN CITIES



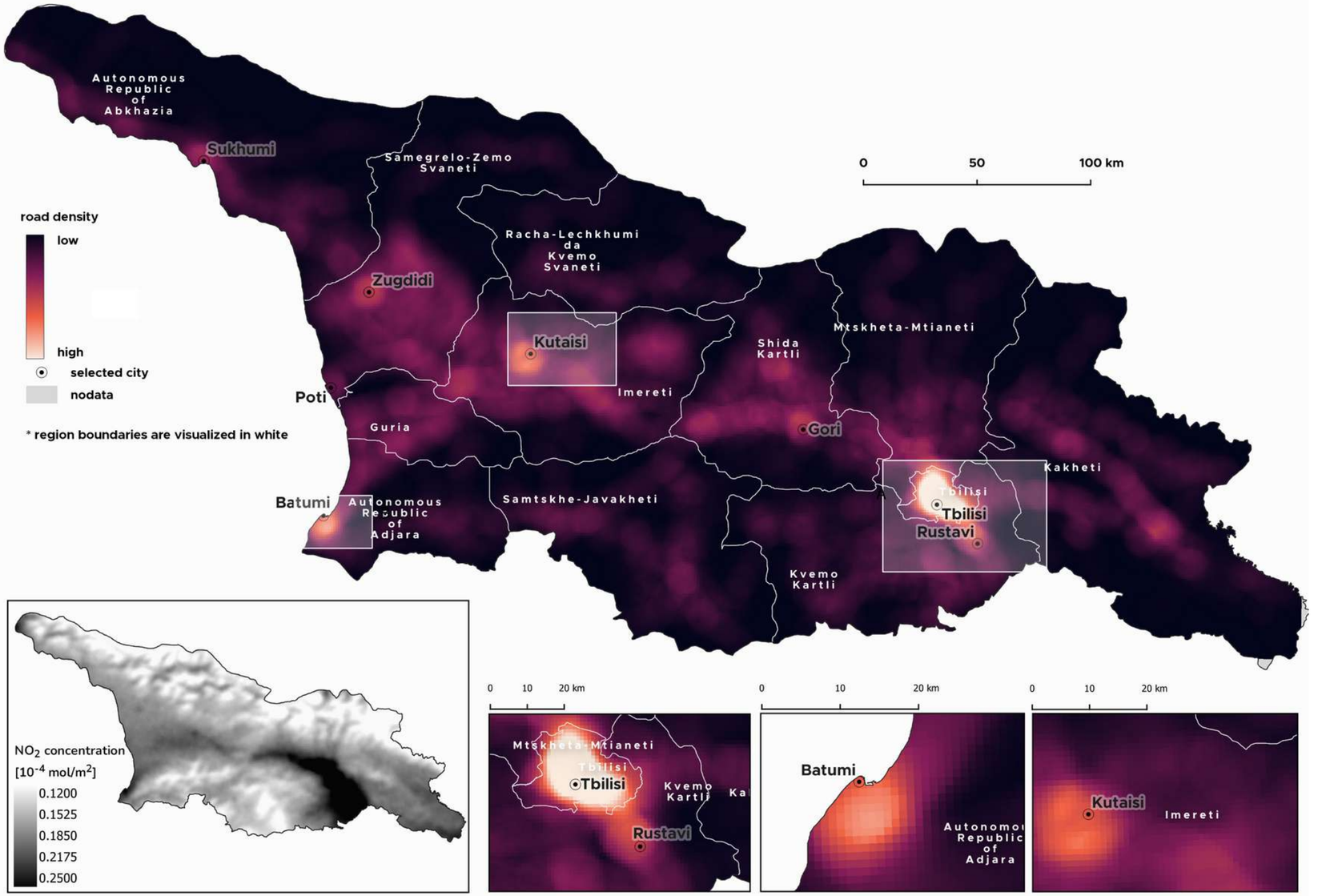
NO_2

Ø NO_2 concentrations in GE in the context of road density

- transport as a significant contributor to air pollution
- many vehicles old and poorly maintained

NITROGEN DIOXIDE (5/2018-12/2022)

AIR POLLUTION FROM TRANSPORT

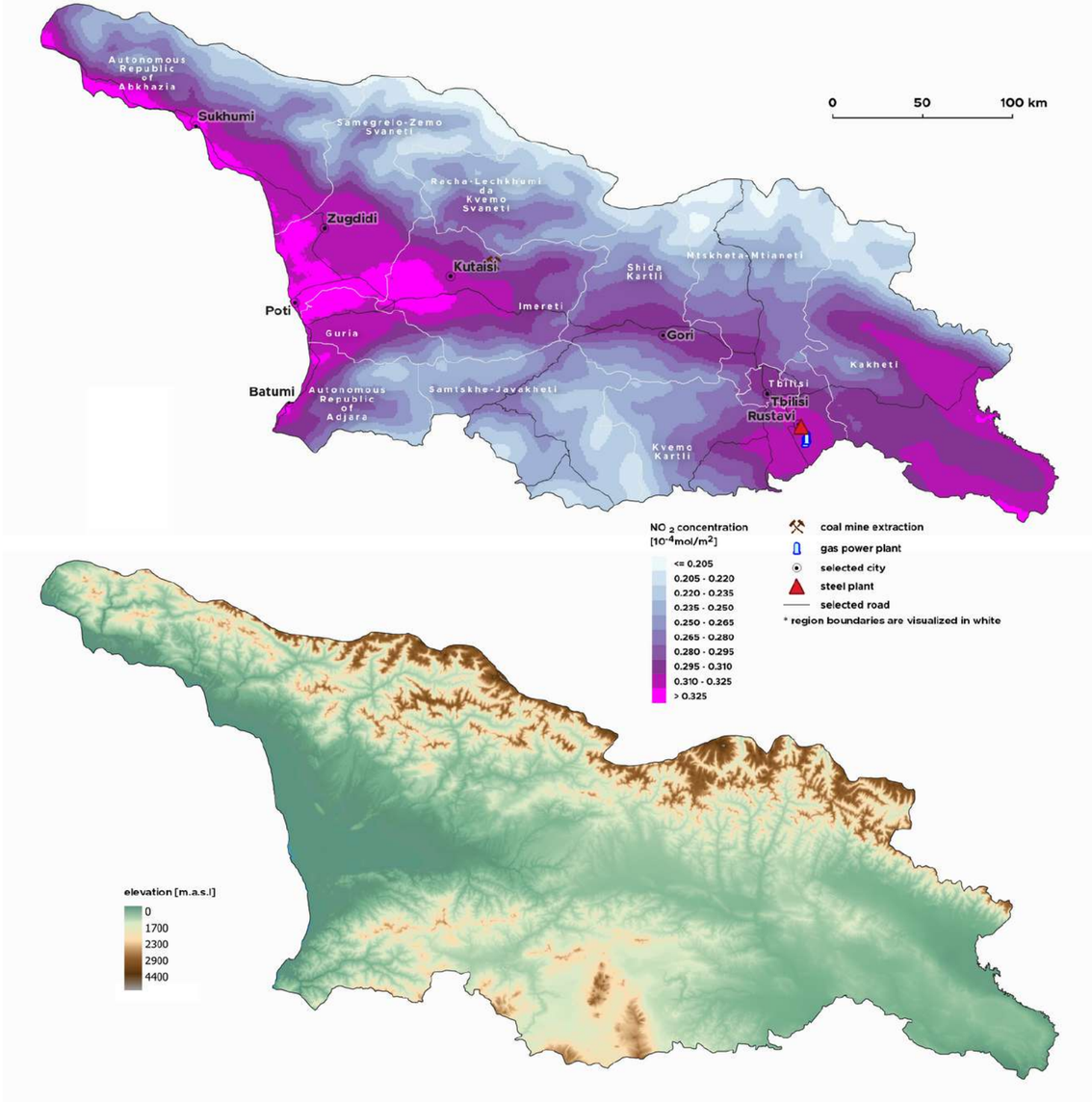


CO

- **Ø CO** concentration **negatively correlates with elevation** (natural cycle of CO in the air)
- Probably the only potential **anthropogenic factor around the S1 highway** (Tbilisi-Kutaisi)
- Fossil fuel burning not significant observed cause

CARBON MONOXIDE (5/2018-12/2022)

BASIC ANALYSIS



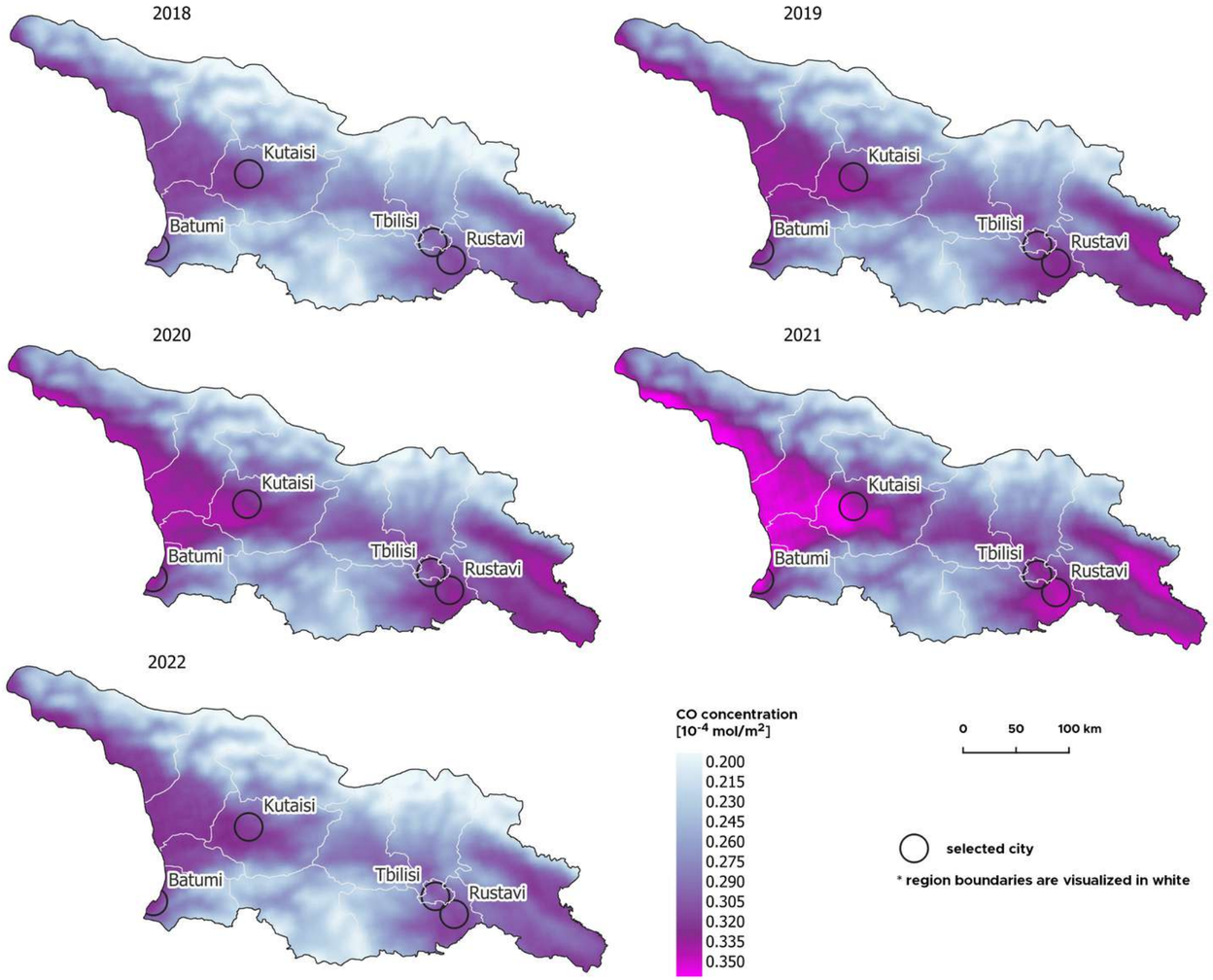
CO

CARBON MONOXIDE (2018-2022)

BASIC ANALYSIS

YEARLY COMPARISON

- **Yearly overall concentration similarly distributed**
- **2021** - possibly due to **natural conditions** (warm summer air brings moisture which helps to reduce CO in the atmosphere - possible droughts from wider Caucasus region could have transfered CO towards GE)



CO

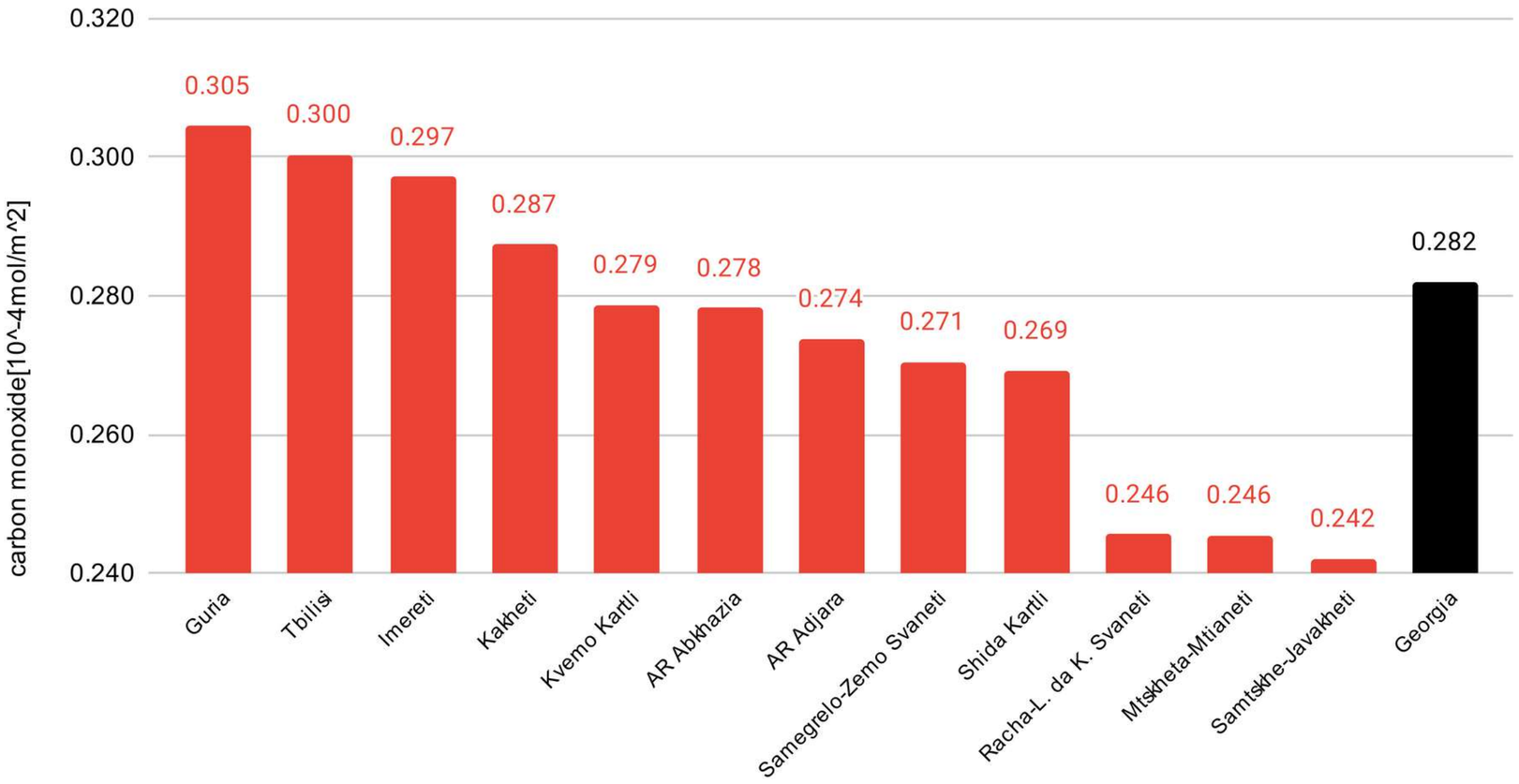
CARBON MONOXIDE (5/2018-12/2022)

BASIC ANALYSIS

Ø CO concentrations in the regions of GE

- **Guria**
- **Tbilisi**
- **Imereti**

No significant anthropogenic source found



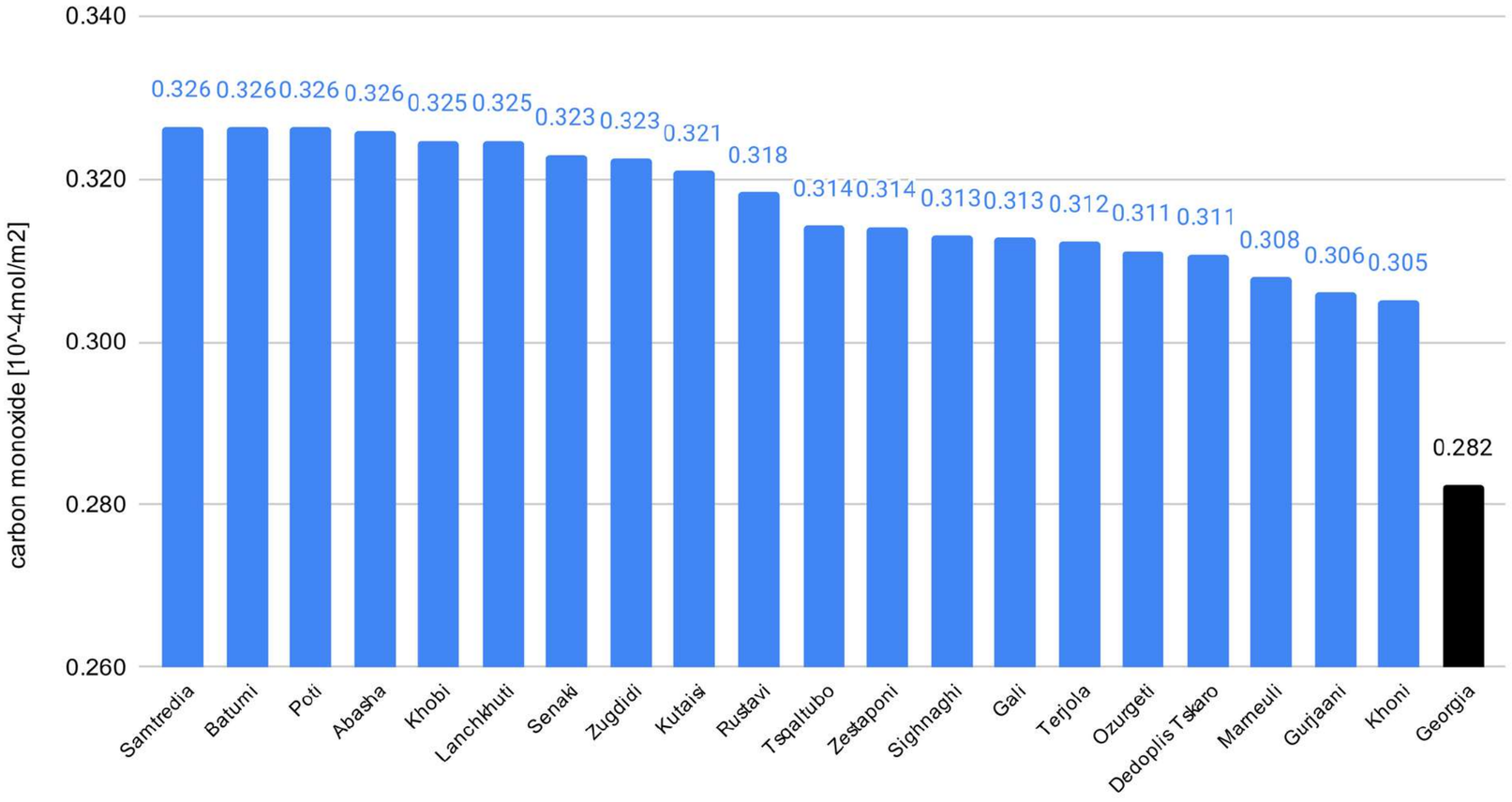
CO

Ø CO concentrations in municipalities and self-governing cities of GE

- all displayed locations tend to be in lowland terrain or on the edge of the mountains

CARBON MONOXIDE (5/2018-12/2022)

BASIC ANALYSIS

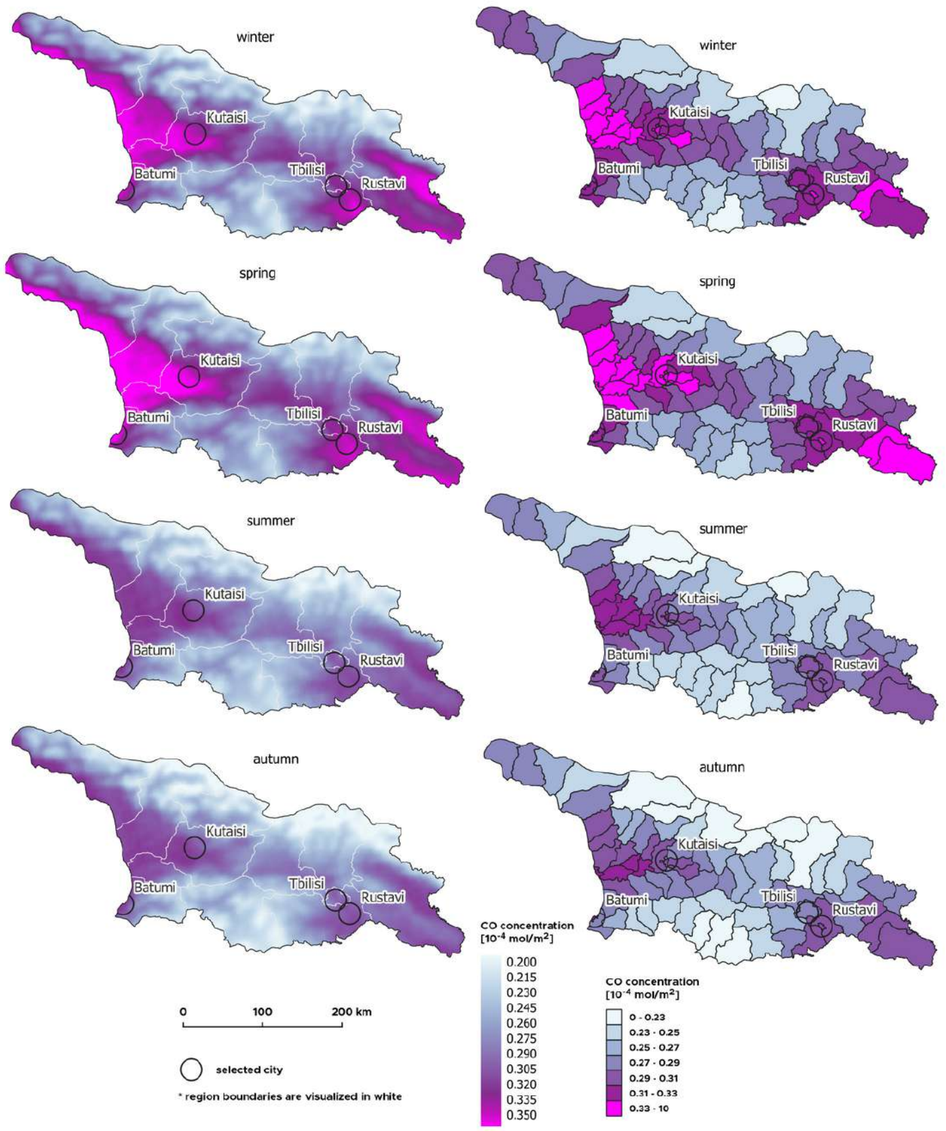


CO

- CO concentration **decrease in the summer** (due to natural cycle)
- **highest CO concentration** in all sesaons in **Colchis Lowland** (= general yearly cycle of CO concentration in the Northern hemisphere atmosphere)

CARBON MONOXIDE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION



CO

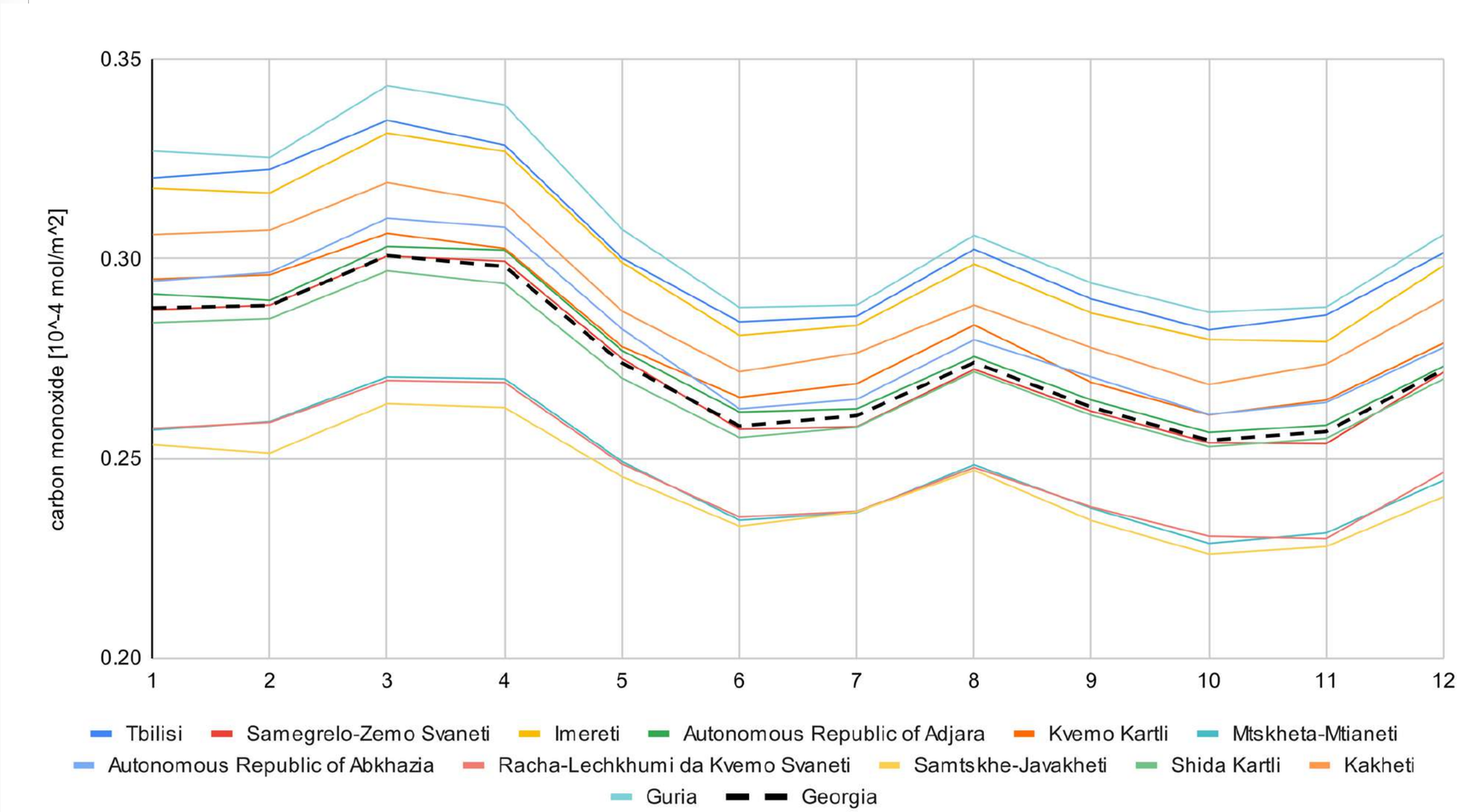
- highest values in **April**
- high values **in winter in general** (cloudy days, increased heating)

- peak in **August** might be due to high temperatures or fires

- filtering out the effect of elevation to detect anthropogenic sources - **Rustavi Met. Plant, Heidelberg Cement Rustavi, Rustavi Azot** sought as major polluters in Rustavi, **however not in the filtered data from Sentinel-5**

CARBON MONOXIDE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION



PM_{10}

PARTICULATE MATTER

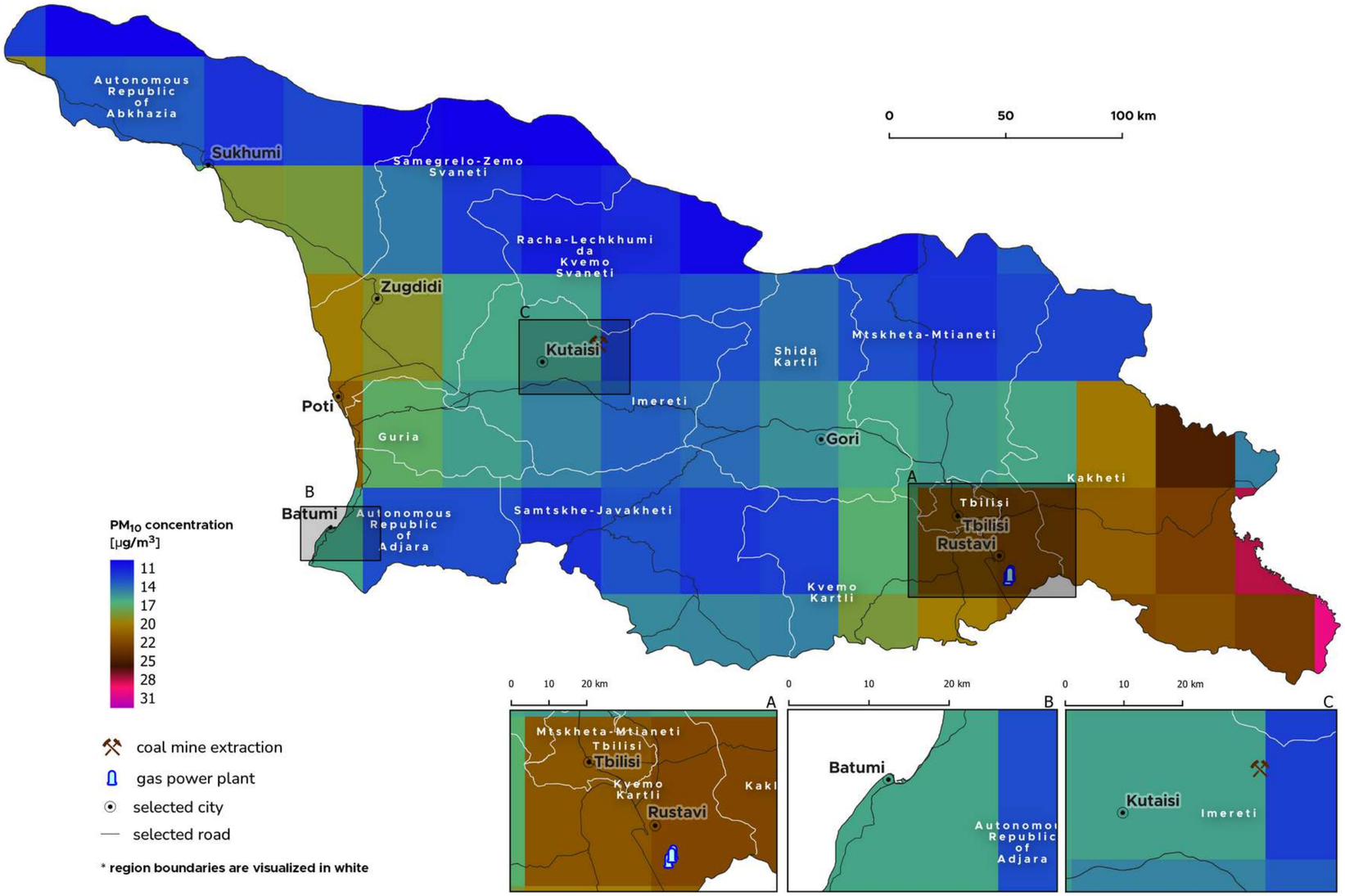
BASIC ANALYSIS (5/2018-12/2022)

- **Highest concentration in SE of GE** (changing land cover from continental → subtropical → semi-arid)
- Sparse vegetation enables PM_{10} spread by wind

- **Elevated PM_{10} concentration along the western coast** $_{10}$ can be related to the coastline or seawater origin

2 models used
GLOBAL + EUROPEAN
2 map visualizations

GLOBAL MODEL



PM_{10}

- Smilar trend in European model

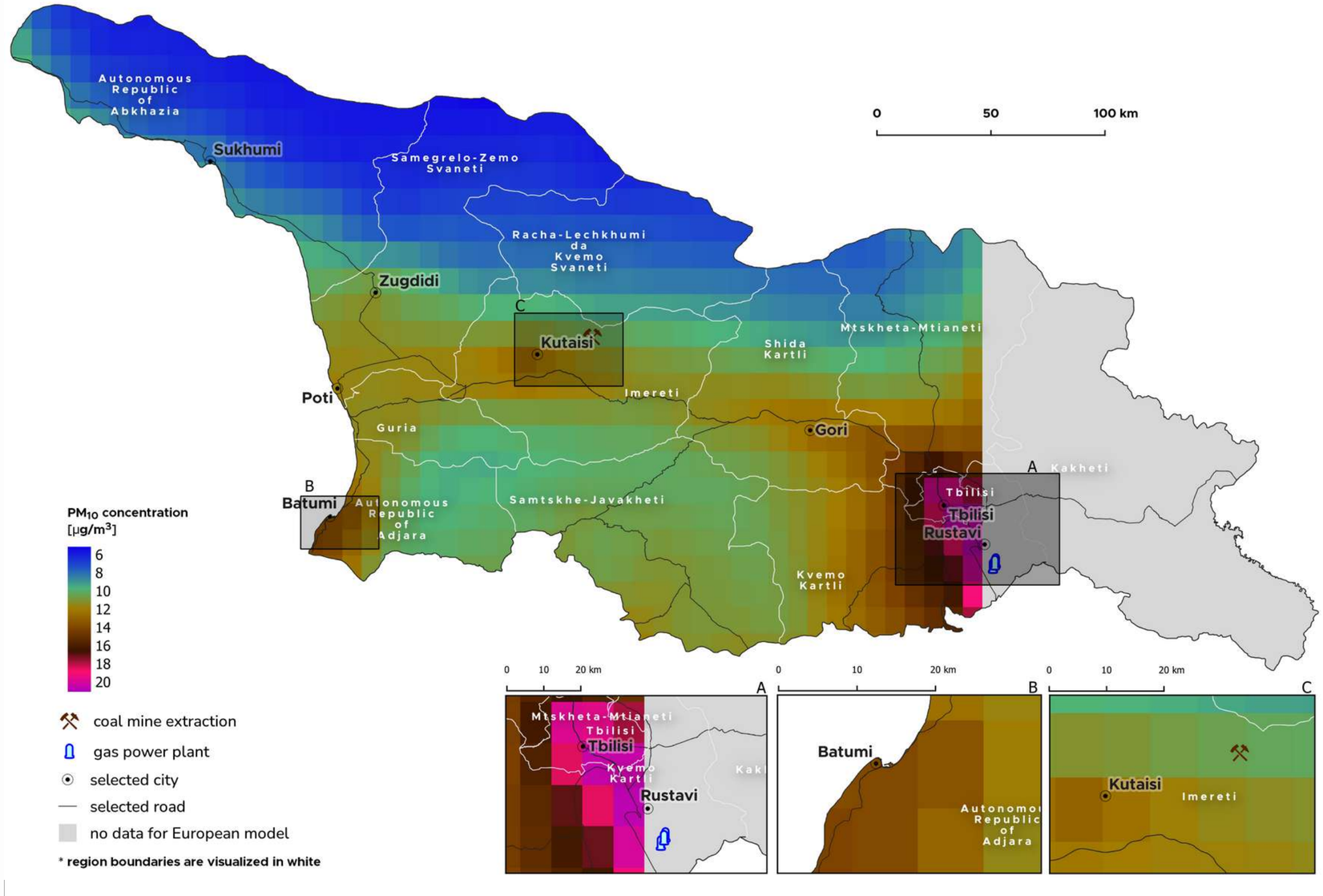
- **highlighted increases around cities**
  - **Tbilisi**
  - **Rustavi**
  - **along S1 highway**

2 models used
GLOBAL + EUROPEAN
2 map visualizations

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)

EUROPEAN MODEL



PM_{10}

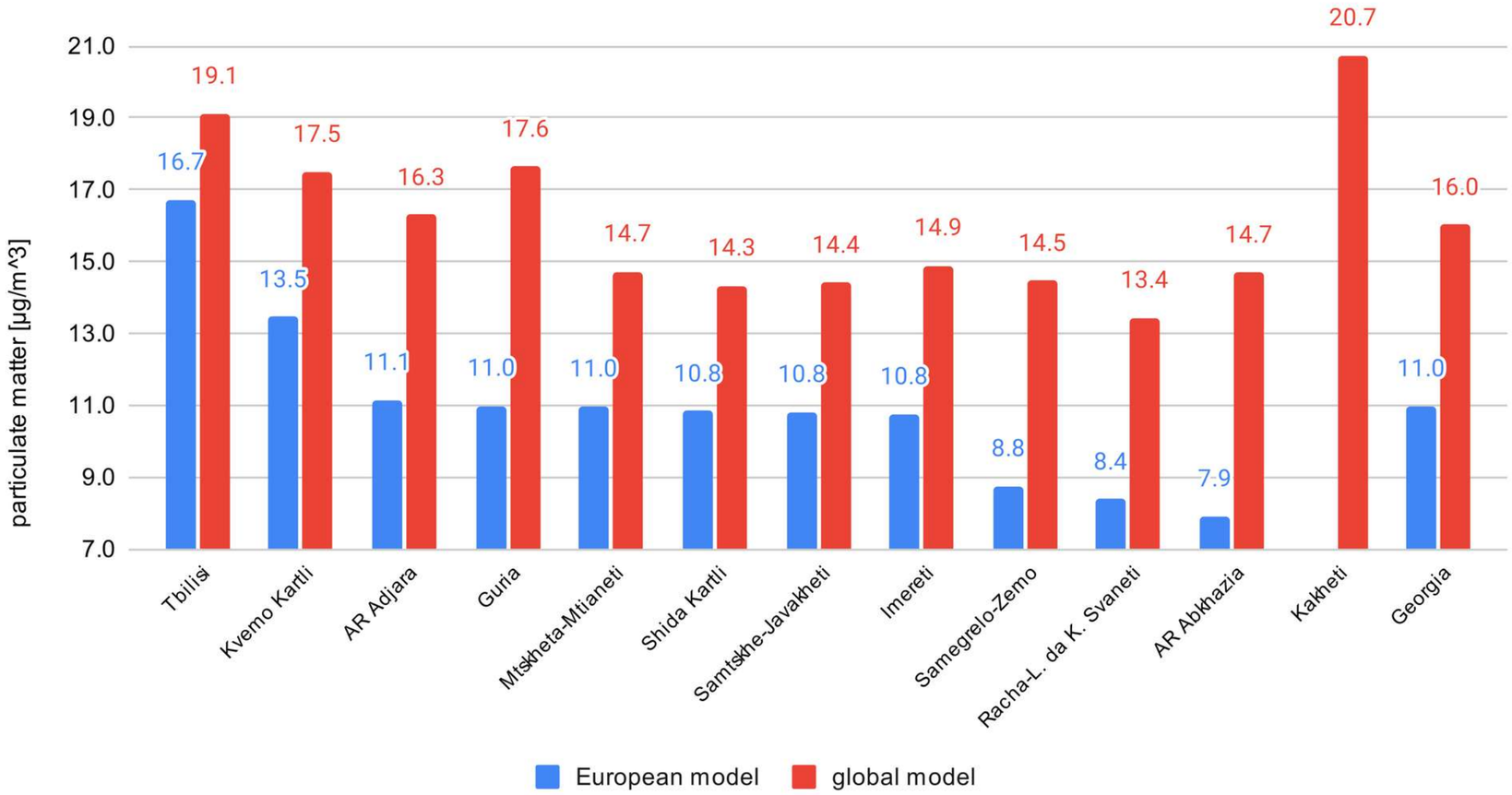
Ø PM_{10} concentrations in the regions of GE

- **Tbilisi**
- **Kakheti**
- (only slightly exceed WHO limit)

- Rest of the regions well below the limit

- **Guria** model differences - probably due to averaging of the global model

PARTICULATE MATTER
BASIC ANALYSIS (5/2018-12/2022)



PM_{10}

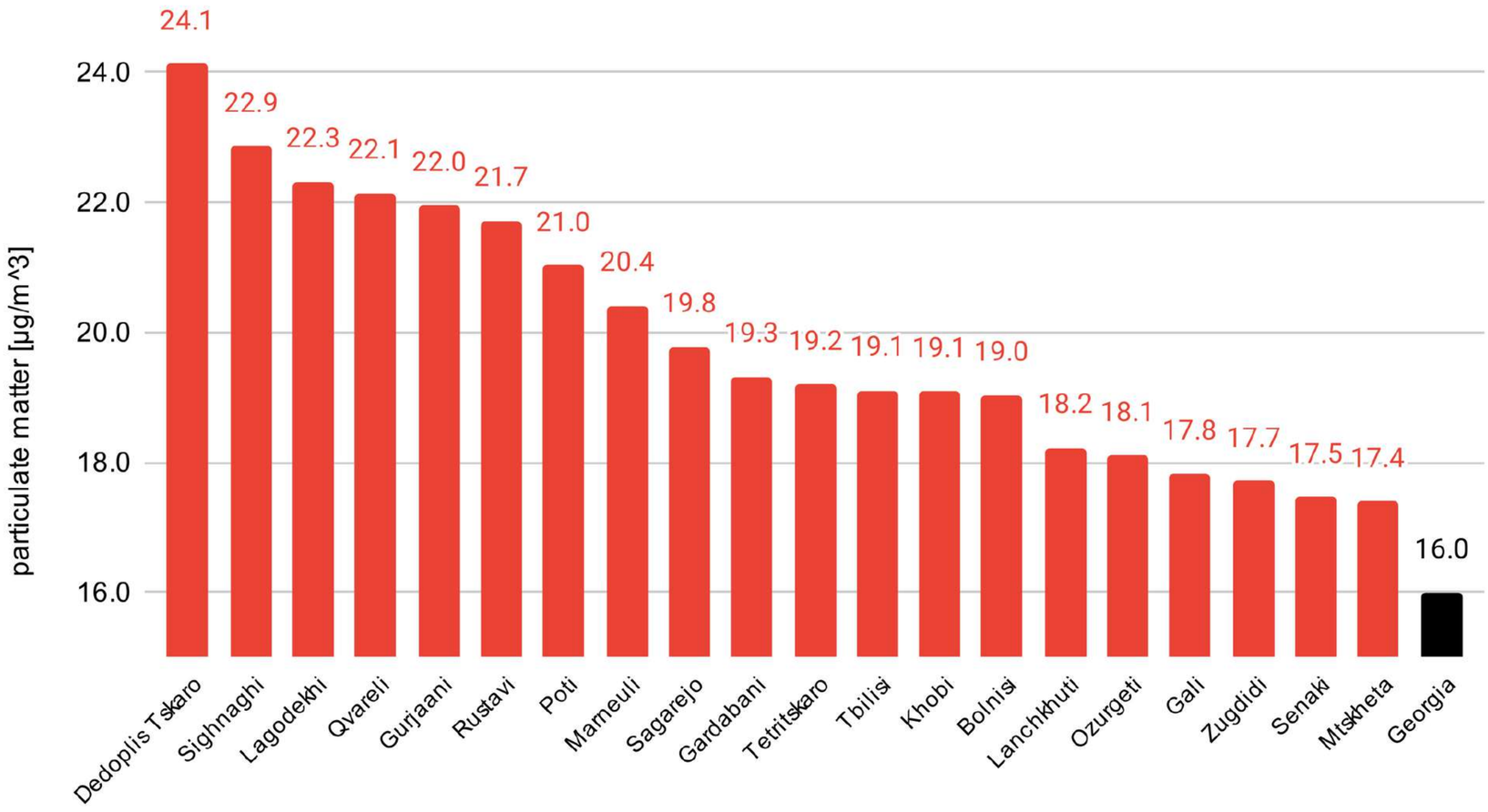
Ø PM_{10} concentrations in municipalities and self-governing cities of GE

- **Dedoplis Tsakro** (Kakheti region) - missing in european model
  - enhanced diffusion of particles from arid climate

GLOBAL MODEL

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)



PM_{10}

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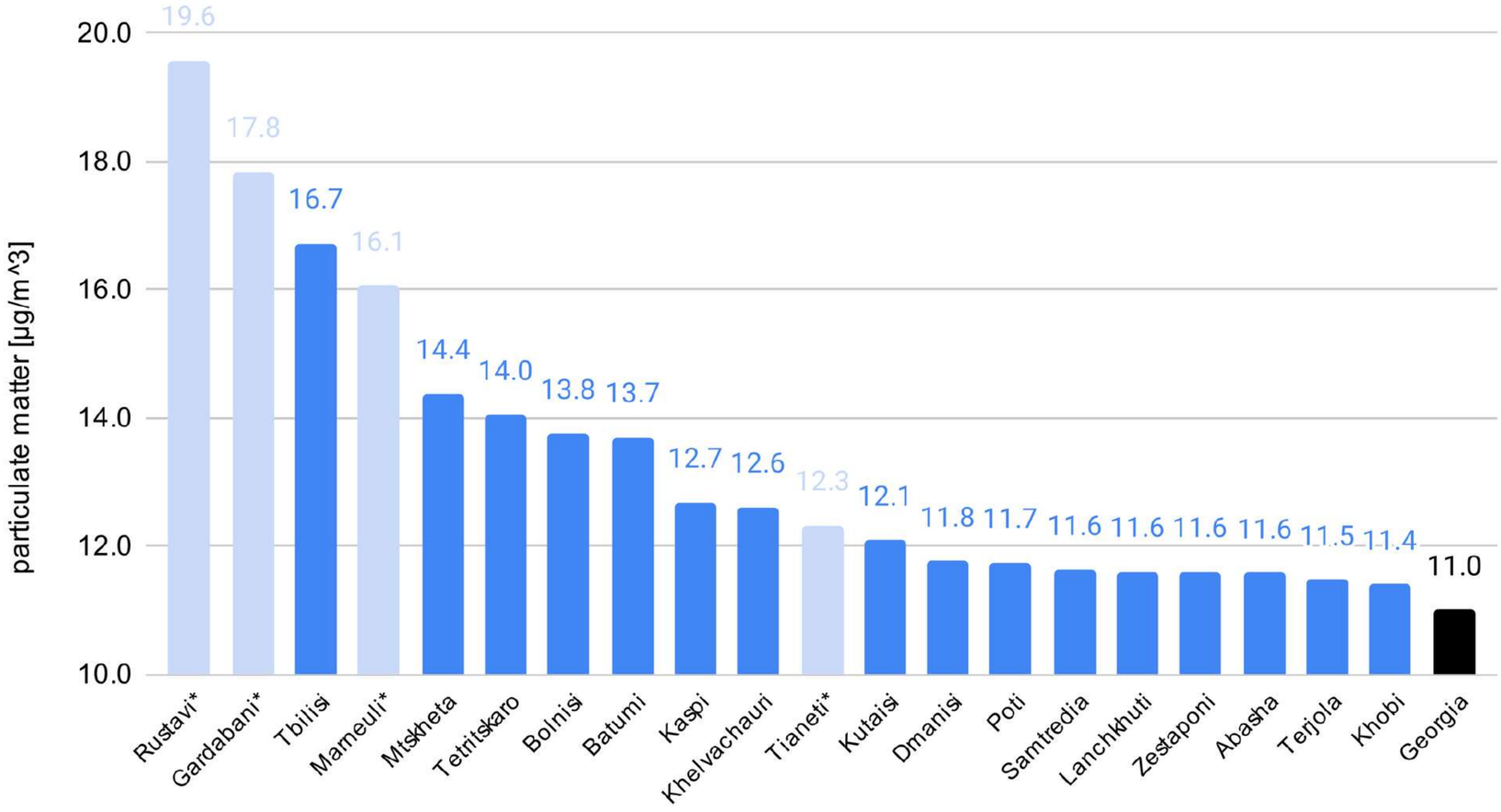
EUROPEAN MODEL

PARTICULATE MATTER
BASIC ANALYSIS (5/2018-12/2022)



PM_{10}

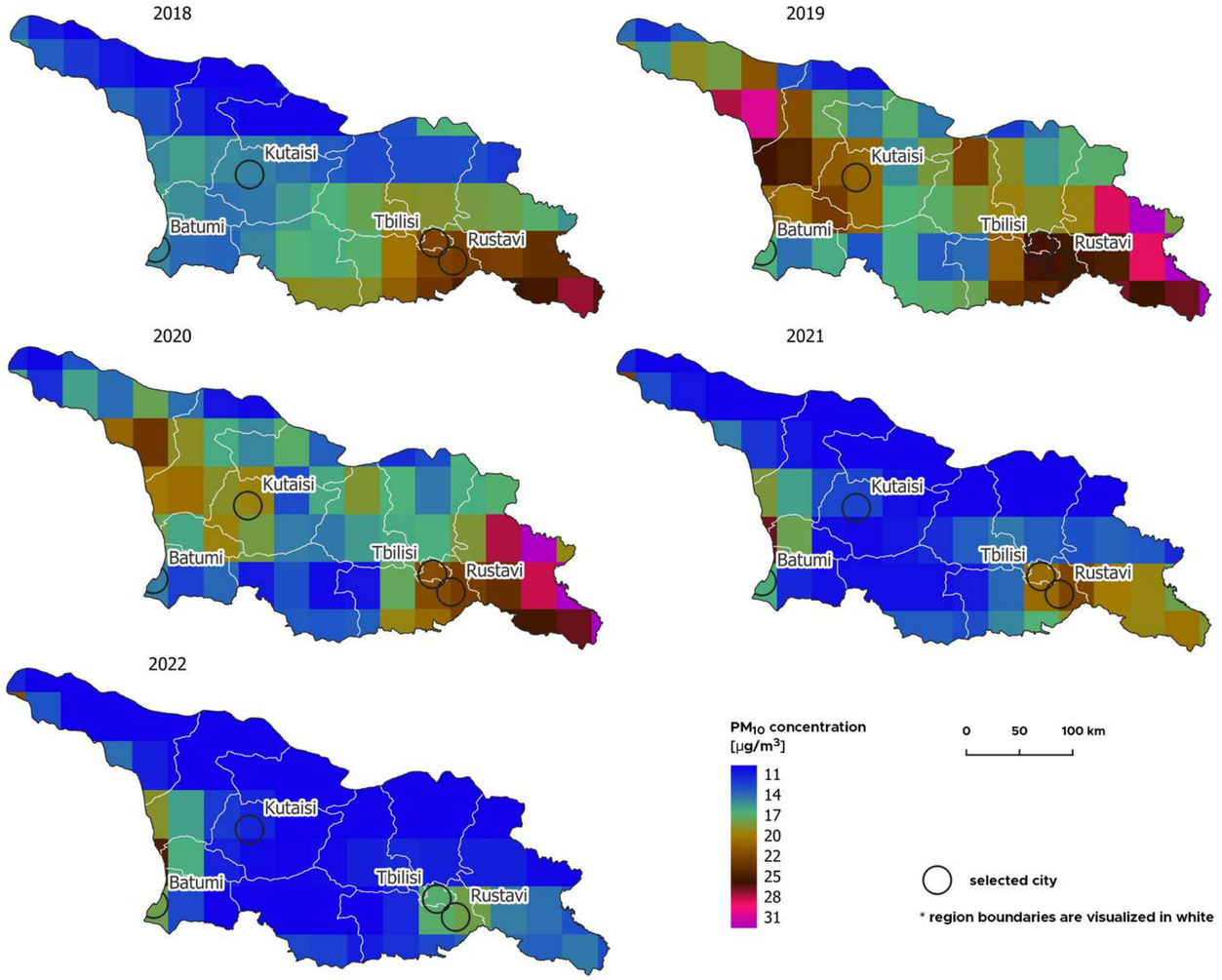
- **PM_{10} pollution higher in the pre-covid years** (2018-2019)

GLOBAL MODEL

PARTICULATE MATTER

BASIC ANALYSIS (2018-2022)

YEARLY COMPARISON



PM_{10}

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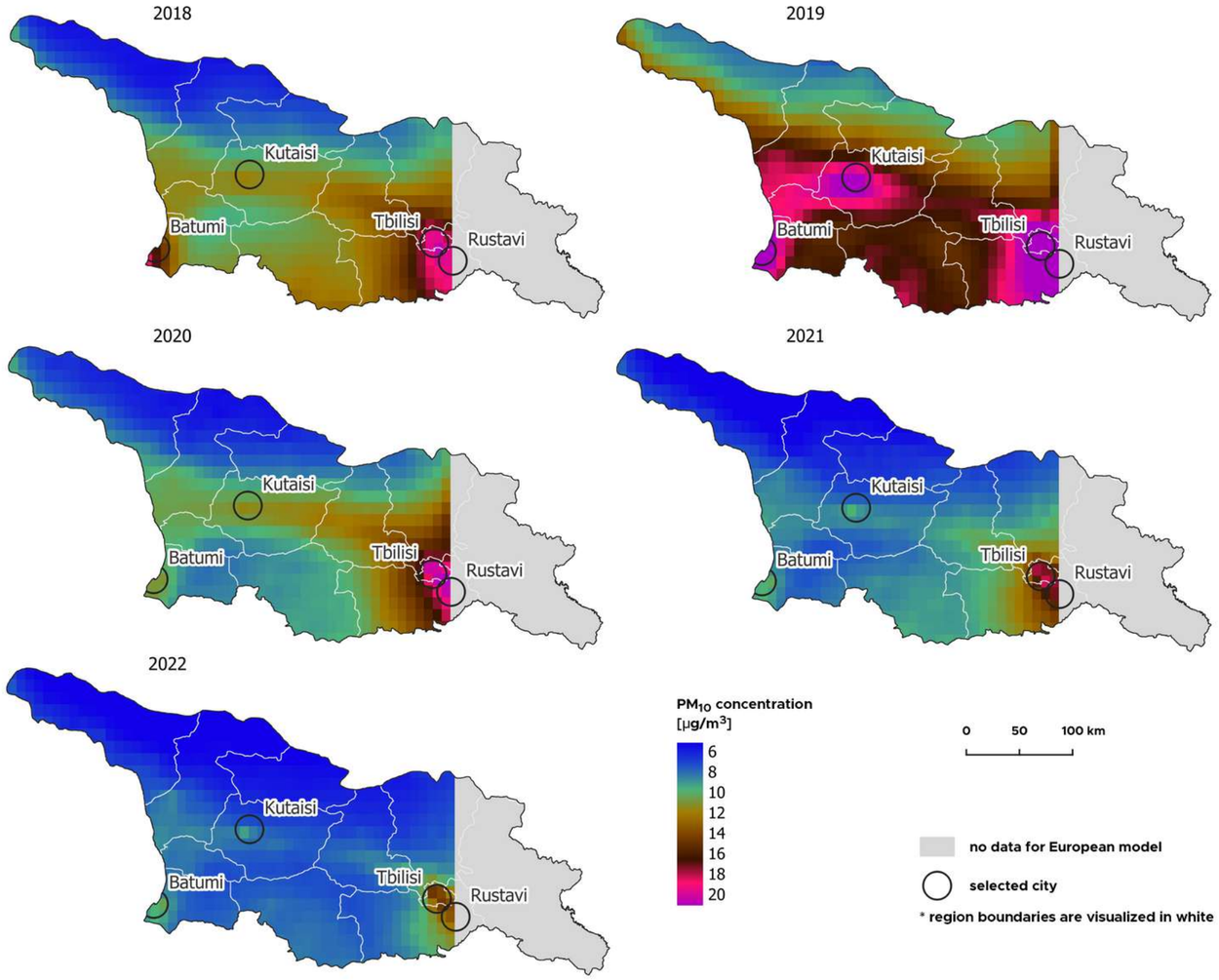
EUROPEAN MODEL

PARTICULATE MATTER
BASIC ANALYSIS (2018-2022)
YEARLY COMPARISON



PM_{10}

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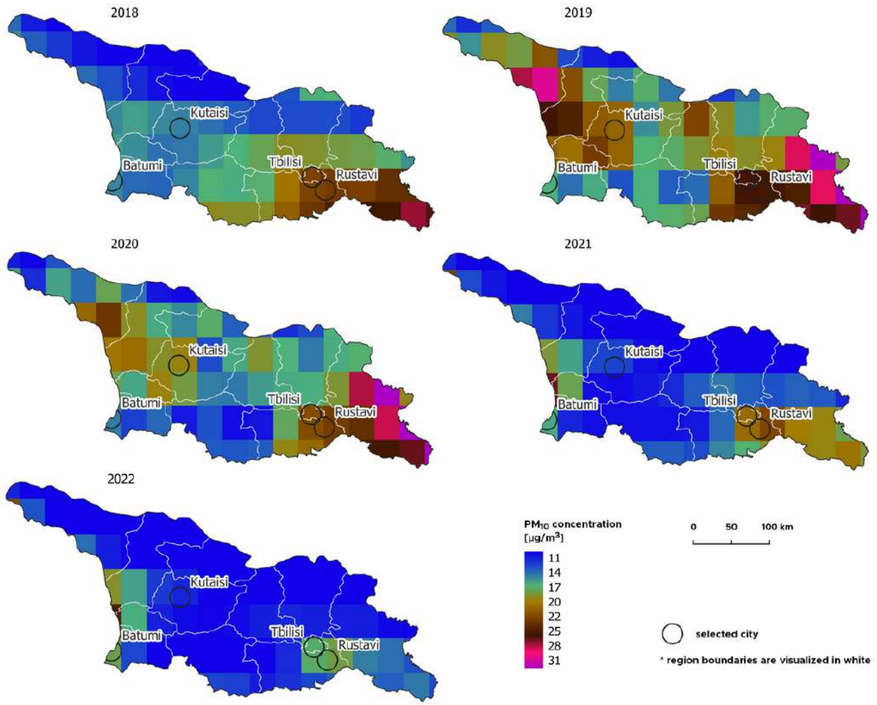
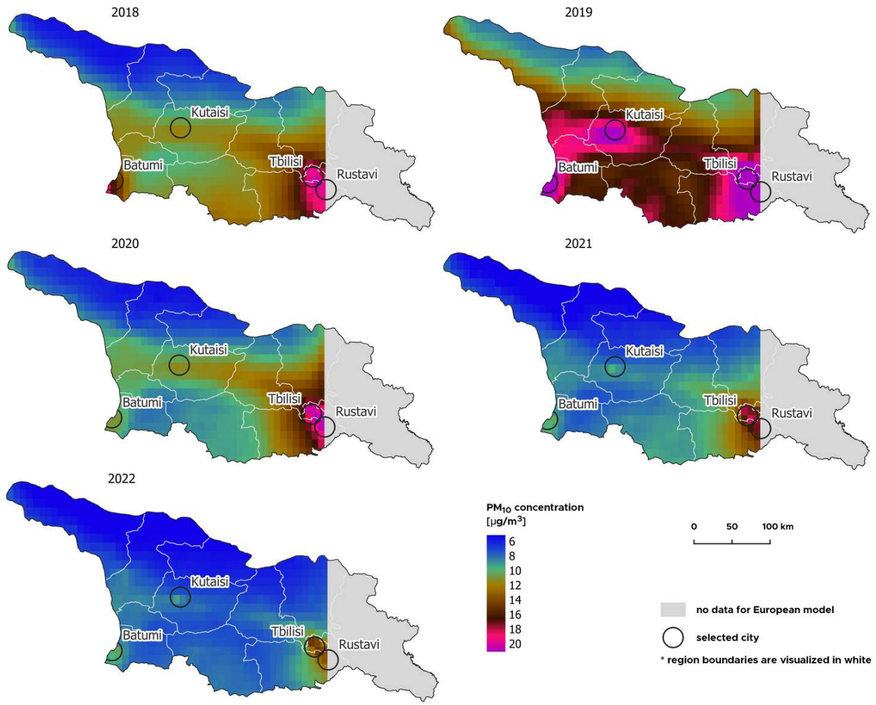
PARTICULATE MATTER
BASIC ANALYSIS (2018-2022)
YEARLY COMPARISON

GLOBAL MODEL



EUROPEAN MODEL

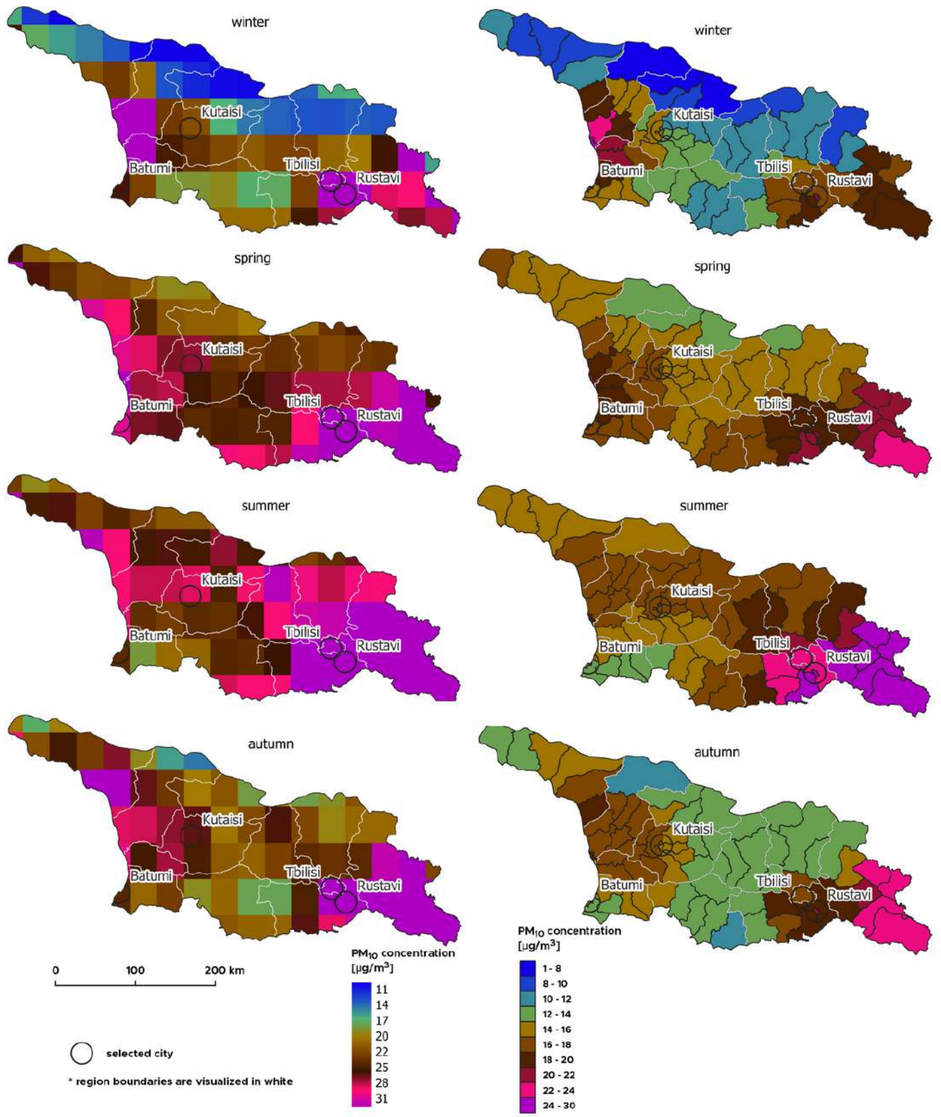


PM_{10}

PARTICULATE MATTER (5/2018--12/2022)

SEASONALITY OF AIR POLLUTION

- **summer, partially spring** - particles spread from the drier part of the country → **Tbilisi, Rustavi** affected
- **winter, autumn** - peaks around larger cities



GLOBAL MODEL

PM_{10}

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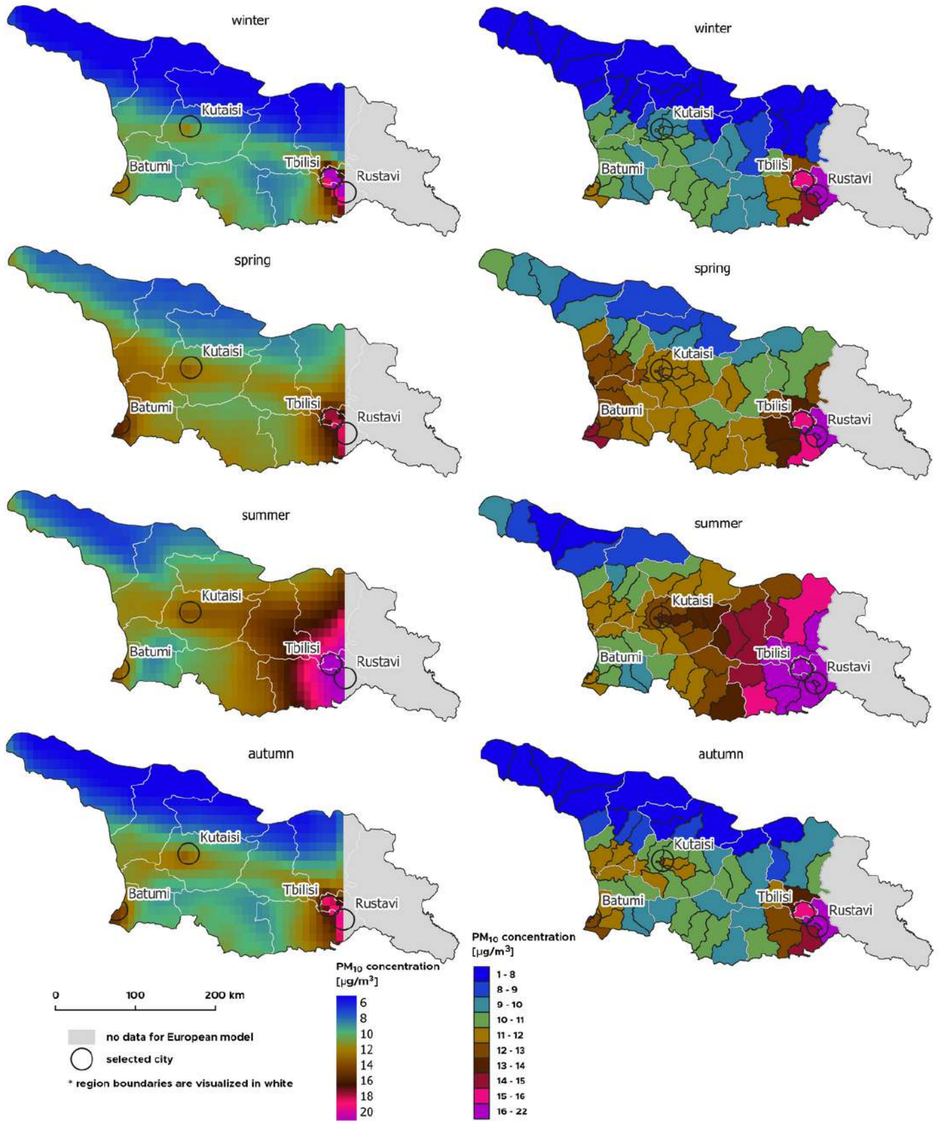

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PM_{10}

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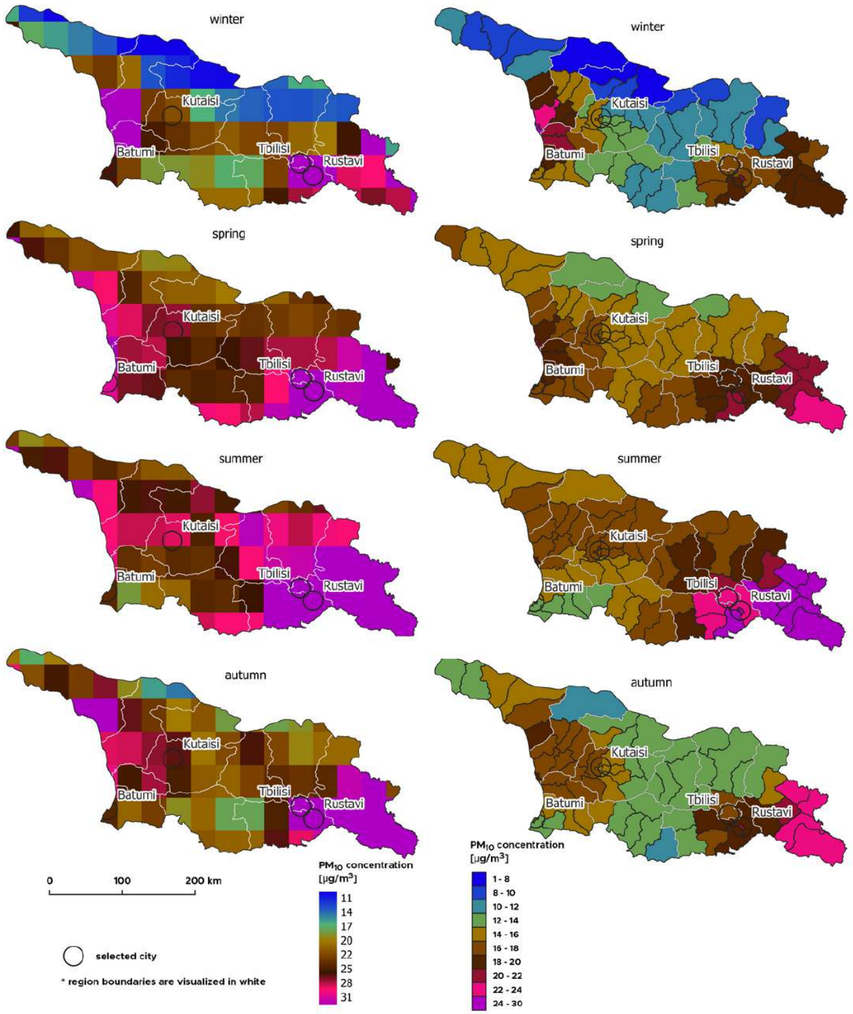
SEASONALITY OF AIR POLLUTION

GLOBAL MODEL



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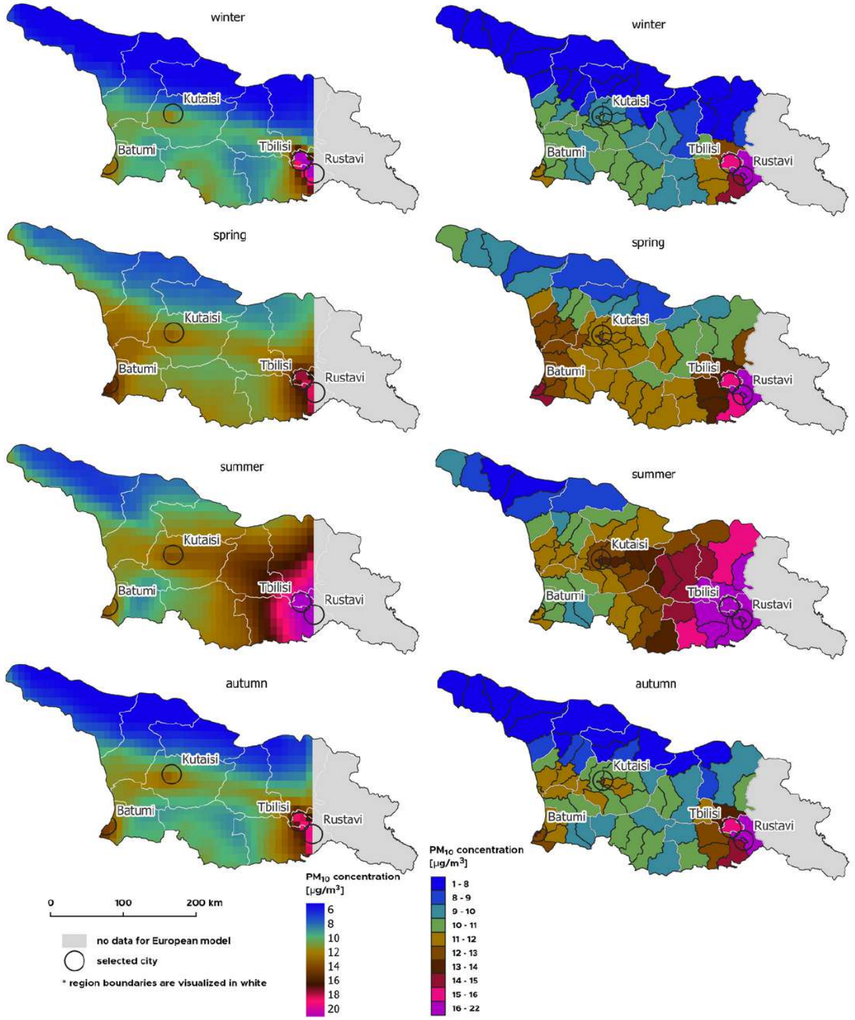
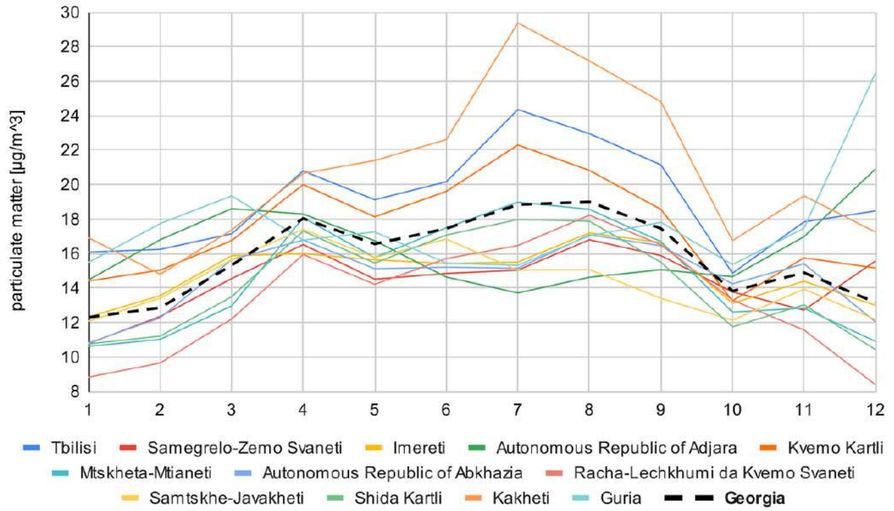


PM_{10}

- **summer, partially spring** - particles spread from the drier part of the country → **Tbilisi, Rustavi** affected
- European model without **Kakheti region** - highest in the Global model
- Tbilisi dominating in European model

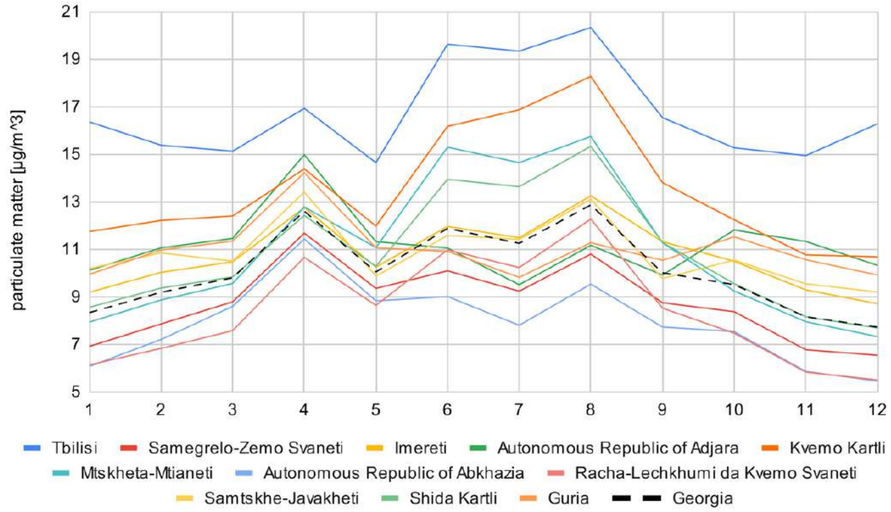
PARTICULATE MATTER
SEASONALITY OF AIR POLLUTION

(5/2018-12/2022)



GLOBAL MODEL

EUROPEAN MODEL

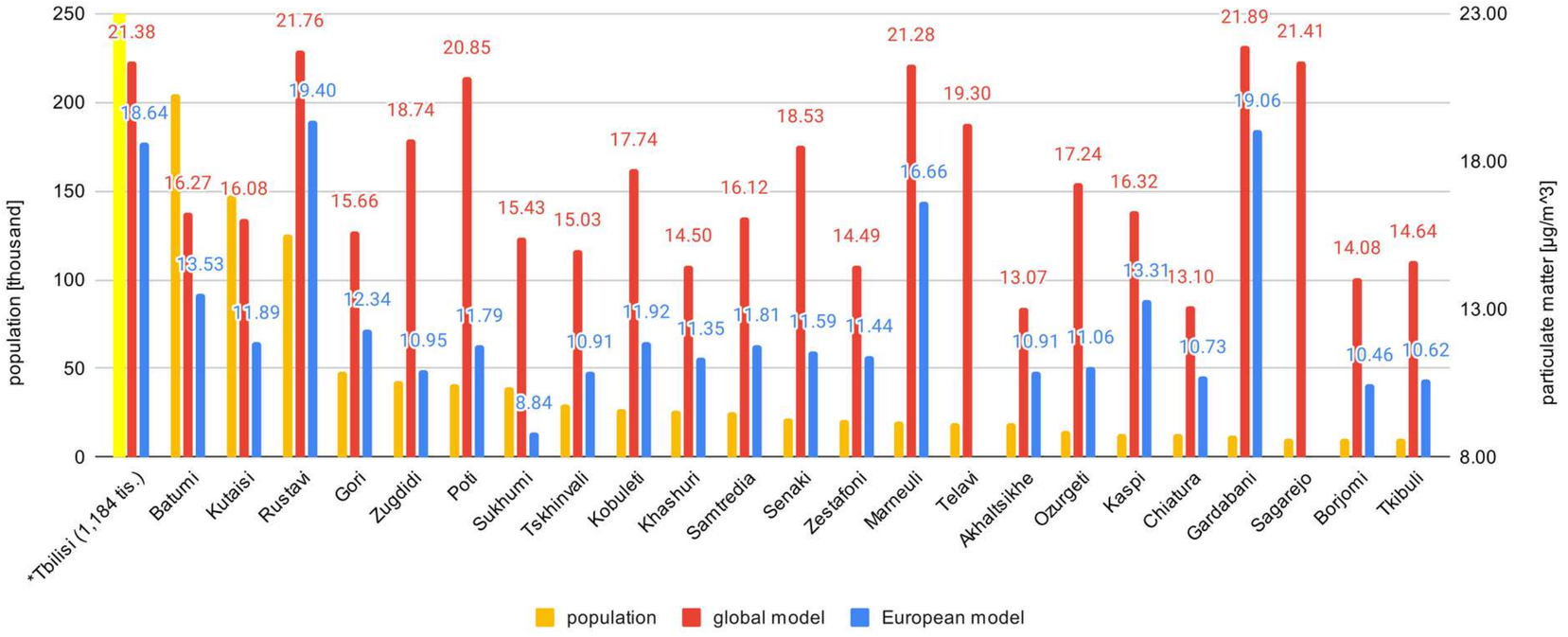


PM_{10}

- **Ø OM_{10} concentrations in the GE cities with a population over 10 000**
- Both models **not vastly dependent on the popuation**

PARTICULATE MATTER
AIR POLLUTION IN CITIES

(5/2018-12/2022)



RECOMMENDATIONS

Georgia has already adopted many of the **EU environmental standards and legislation**

Neccessary follow-up in the areas of:

- transport and transit
- industry accountability
- enforcing regulatory frameworks
- energy diversification
- public involvement

RECOMMENDATIONS

Energy efficiency measures

Modernisation of transport

Emission control measures for industries

Regulatory frameworks and environmental liability

Renewable energy depoyment

Monitoring and open data

Public awareness and participation

ENERGY EFFICIENCY MEASURES

01 **Implementing financial instruments** backed by strong energy efficiency rules and obligations **based on EU policies** (in the areas of)**:**

- renovation of buildings
- industries
- transport

02 Promoting:

- energy-efficient equipment
- building retrofitting
- smart transportation solutions

03 **Policy instruments:**

- audit obligations
- technical competence requirements
- energy management systems implementations

with specific focus on efficient district heating and cooling

MODERNISATION OF TRANSPORT

01 **Strenghtening the authority of emission and technical controls** for cars, trucks and motorised means of public transport

02 **Continuing in replacing old diesel buses with new CNG vehicles**

03 **Analysis of a daily commute regime and busiest road sections to Tbilisi** for a propoer reinforcement of public transport from the hinterland (benefits for other larger cities

EMISSION CONTROL MEASURES FOR INDUSTRIES

01 Numerous factories with questionable pollution management (Rustavi zone).
- **implementing regular pollution control technologies**
- **require cleaner production methods**
- **enforce strict emission standards** for such industries (BAT within EU directive)

02 **Financial support** (subsidies, low-interest loans, tax incentives) to help introduce better technologies and reduce emissions

03 **Stricter regulation to reduce dusting from the construction sites in cities**
- ban on dry cutting of construction stone

04 **Sector-specific roadmaps** for emission reduction
- outline the key steps, milestones and targets towards more sustainable production
- guidance in the development and progress monitoring by providing support and tech transfer from international institutions

05 **Support for research and development initiatives** focused on inovative solutions for emission reduction
- fostering international competition, new business opportunities

REGULATORY FRAMEWORKS AND ENVIRONMENTAL LIABILITY

01 Georgia has taken steps to **unify the legislature on environmental protection with the EU**

- Air quality monitoring framework (2020)
- 2030 Climate Change Strategy + Action Plan (2021)

02 **Strengthen the capacity of regulatory agencies to enforce the air quality standards and regulations**

- allocation of adequate resources (funding, staffing, training)

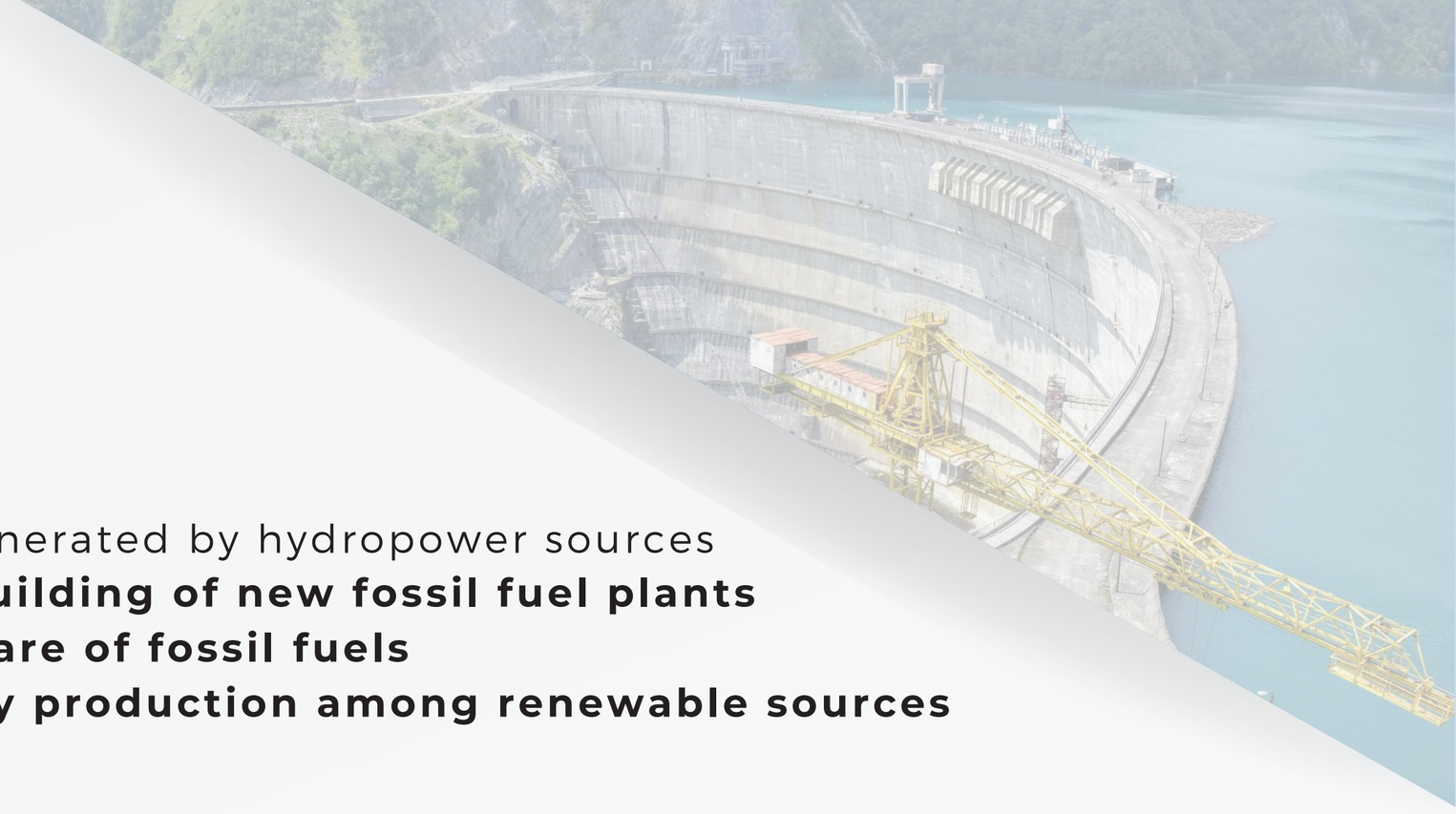
Enforcing the legislature against the lobby and corruption activities

03 **Regular inspections and audits** of industries, power plants, and others to verify compliance with environmental regulations

04 **Stringent penalties for non-compliance** should rise awareness about the consequences

05 Georgia has a big transit potential. **Introduce appropriate tolls** for personal and cargo transport after the S1 highway is finished (similarly for Baku-Tbilisi-Kars railway)

RENEWABLE ENERGY DEPLOYMENT



01 More than 80 % of electricity generated by hydropower sources

- **appeal on preventing the building of new fossil fuel plants**
- **gradual reduction of the share of fossil fuels**
- **diversification of the energy production among renewable sources**

02 **Establish supportive policies, feed-in tariffs, investment incentives**

- to attract business interest into renewable energy projects

MONITORING AND OPEN DATA

01 **Introduction of an automated nation-wide system of air pollution monitoring**

- continuous data on concentrations of individual pollutants to the authorities and the public

02 **Development of open information systems**

- to contribute to better understanding of air pollution and its sources
- PRTR (Pollution Release and Transfer Register), presenting annual volume of emissions from major industrial sources

PUBLIC AWARENESS AND PARTICIPATION

01 **Actively involve the public in decision-making processes on**

- spatial planning, clean air plans approval, EIAs
- regional air quality control plans
- major industrial and infrastructural projects

02 **Raising public awareness** and educating **about the importance of individual actions in reducing emissions**

03 **User-friendly platforms and tools**

- to access and understanding environmental data
- to encourage public and involve stakeholders
- such as **operational public air quality monitoring portal** (https://www.air.gov.ge/)

EXECUTIVE SUMMARY

KEY FINDINGS

NO_2

- **in places with highest population density** (Tbilisi, Kutaisi, Batumi, Gori)
- **highest in winter** (heating)
- high concentrations around road network

CO

- **elevation** has the greatest influence
- **highest concentrations at the lowest elevations**
- natural emissions more significant

PM_{10}

- **around cities and their main highway connectors**
- seasonality caused by natural processes (strong in **summer, spring**)

RECOMMENDATIONS

01 **Energy efficiency measures**

02 **Modernisation of transport**

03 **Emission control measures for industries**

04 **Regulatory frameworks and environmental liability**

05 **Renewable energy deployment**

06 **Monitoring and open data**

07 **Public awareness and participation**

ARNIKA

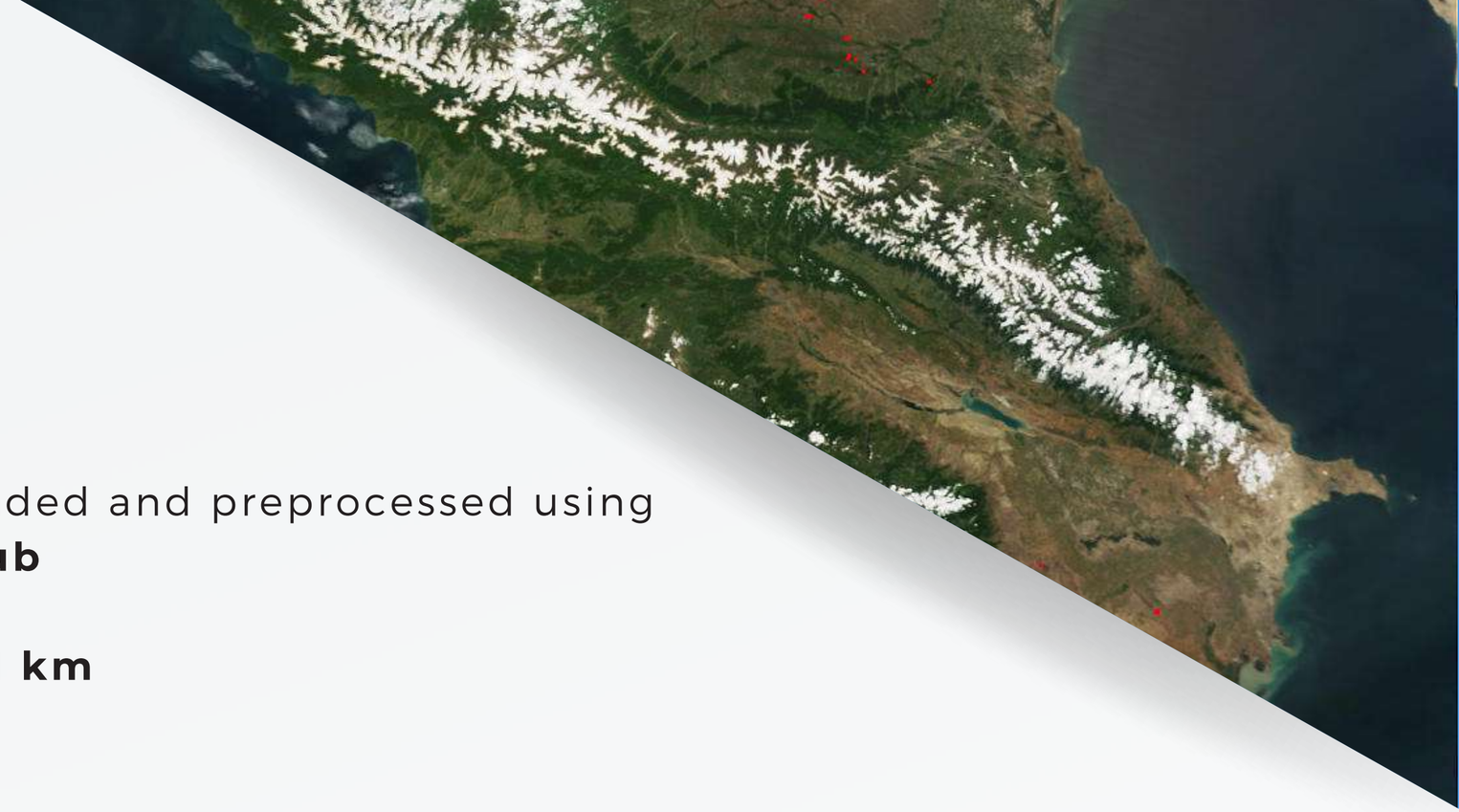
MY CITY KILLS
ჩემი ქალაქი მკლავს

WORLD FROM SPACE

TRANSITION
Ministry of Foreign Affairs of the Czech Republic

Funded by
the European Union

PROCESSING



01 Data **(5/2018 - 12/2022)** downloaded and preprocessed using **Python scripts and Sentinel Hub**

S-5P - grid with a **resolution 1x1 km**

02 **Pollutants' units:**

- NO_2 and CO in $10^{-4}mol/m^2$
- PM_{10} in $\mu g/m^3$

03 Daily values used to calculate various statistics → all-time/yearly/seasonal/monthly **averages and medians**