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AIR POLLUTION IN KARAGANDA REGION

AS SEEN FROM SPACE

FUNDAMENTAL ANALYSIS, FOCUS ON KARAGANDA REGION, AND NOTES ON KAZAKHSTAN'S BROADER IMPACT ON CLIMATE CHANGE

CONTENT

INTRODUCTION

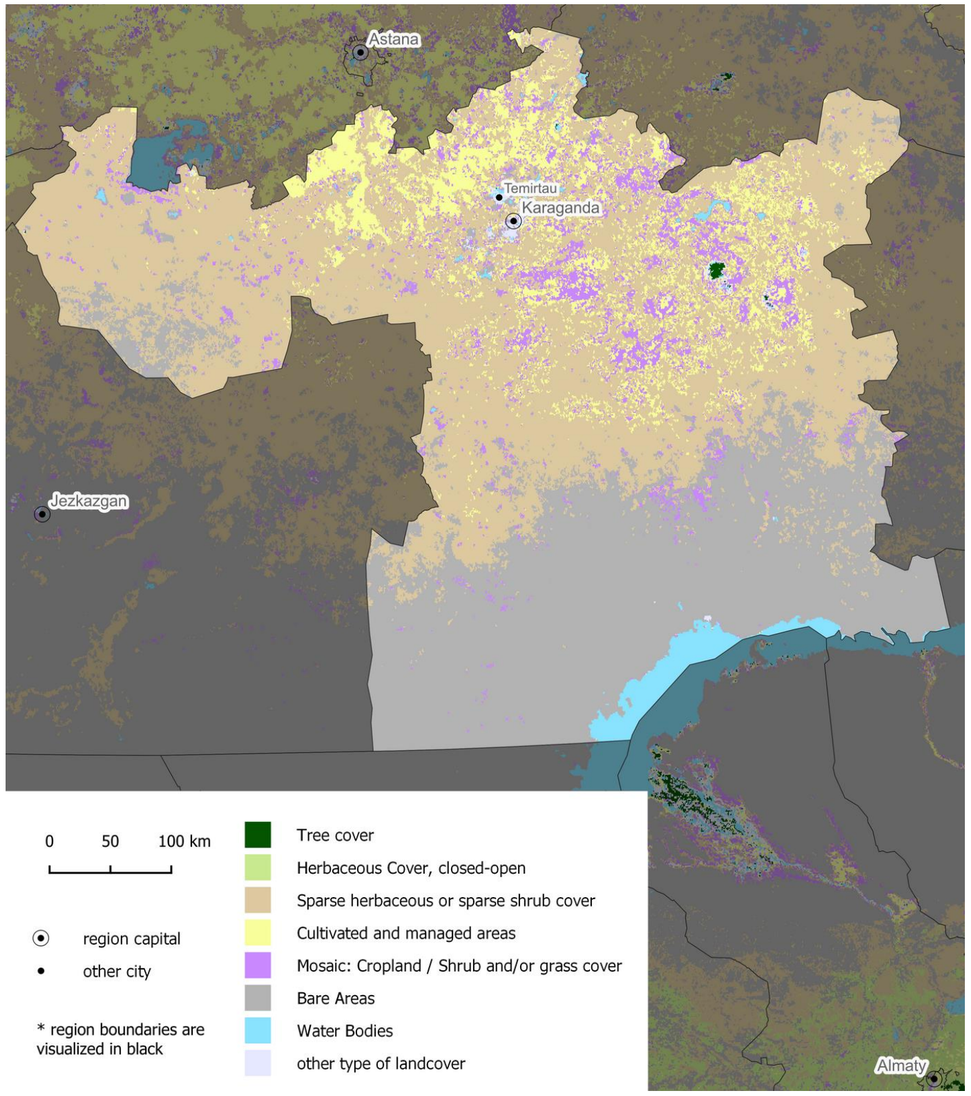
Karaganda Region:

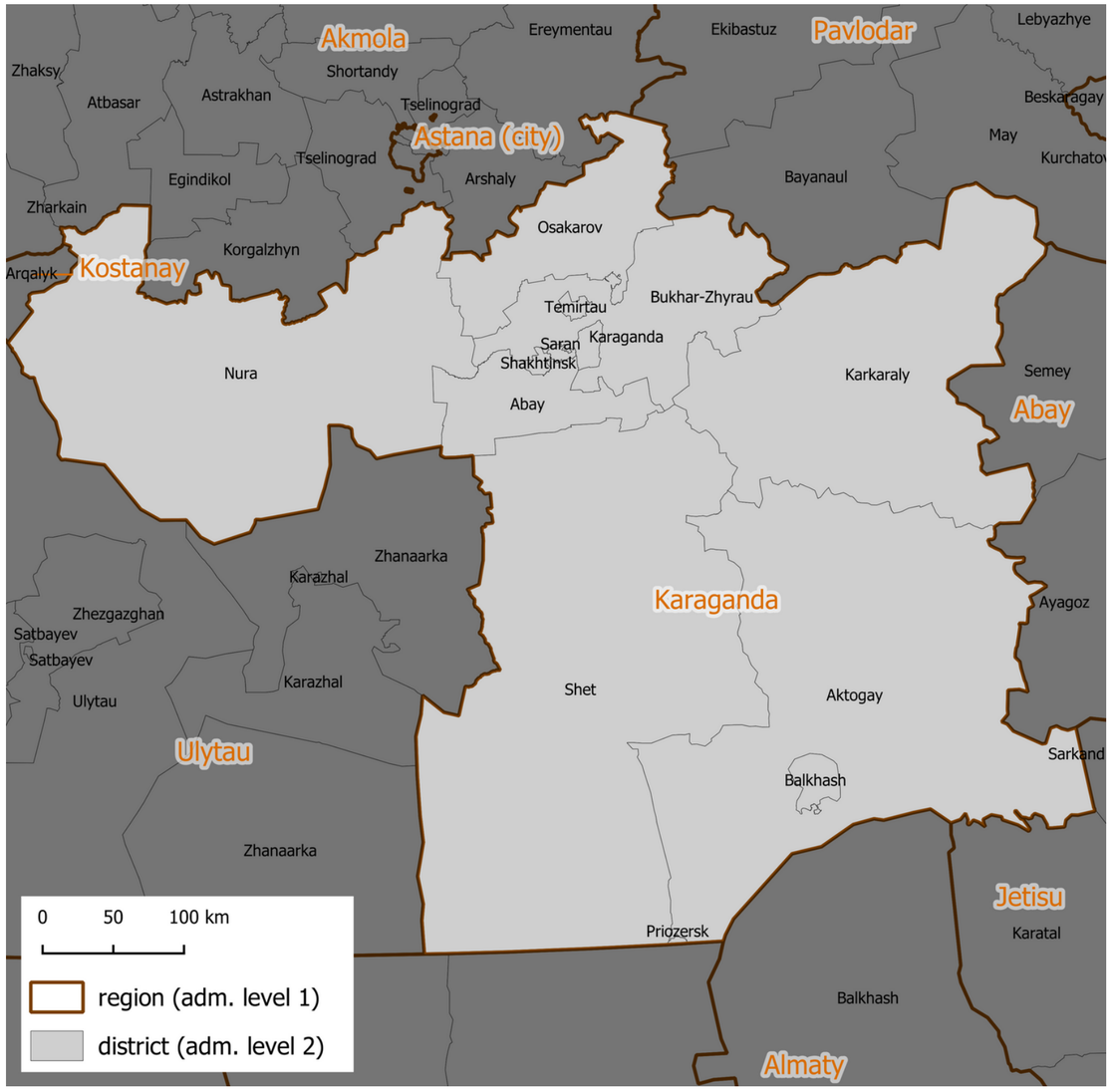
- 4th largest in KZ
- approx. 239 000 km²
- 1.3 million people
- **rich mineral resources (coal, Fe, Cu, Sn, Mo, Mn, Pb, W, Au, Ag, U, ...)**
- **Karaganda Coal Basin -** one of the largest in the world → Karaganda is referred to as the "Coal Capital"

- Metallurgy, mining, machinery

→ **Kazakhstan as 21st leading polluter due to CO_2 (2019)**
→ **Kazakhstan as 23rd most polluted country ($PM_{2.5}$ levels) (2021)**

LAND COVER & ADMINISTRATIVE DIVISION OF KARAGANDA REGION





INTERPLAY OF CLIMATE CHANGE AND AIR POLLUTION IN KZ

01 Potential to curtail the country's footprint despite significant amount of emissions **(CO_2)**

02 Changing precipitation and escalating droughts → **heightened risk on agriculture, forestry and water resource management**

03 2021 Environmental Code - improved accessibility of climate and environmental information (**Kazhydromet** - accountable for climate data)

04 Kazakhstan pledges
- **Kyoto Protocol,**
- **Paris Agreement**
- **Carbon neutrality by 2060**

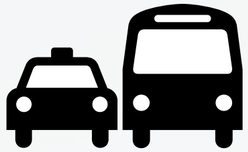
Air pollution + Climate change in Kazakhstan?

Black snow in Temirtau

CLIMATE CHANGE & AIR POLLUTION

AIR POLLUTION CAUSES:

- pollutants
- physical geography
- unexpected impactful events (covid-19)



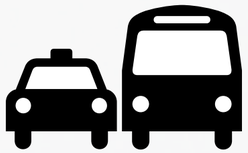
Nitrogen dioxide (NO_2)

Methane (CH_4)

Sulfur dioxide (SO_2)

Particulate matter (PM_{10})

KEY POLLUTANTS



Nitrogen dioxide (NO_2)

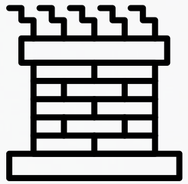
- Mainly from transport and chemical industry
- Causes respiratory infections and acid rains

Methane (CH_4)

- Mainly from agricultural activities and fossil fuel production
- Potent GHG with over 80 times higher global warming potential than CO_2

Sulfur dioxide (SO_2)

- Mainly from power plants and dust storms
- 30 % globally from volcanoes
- Affects respiratory system and causes acid rains



Particulate matter (PM_{10})

- Mainly from combustion sources
- Classified by size
- Toxic and genotoxic
- Catalyst for chemical reactions and the toxicity is enhanced by other pollutants

AIR POLLUTION FROM MINING ACTIVITIES

01

Concentrated in several regions **- Karaganda, East KZ, Pavlodar, Atyrau**

02

Type of air pollutants depend on extracted minerals and extracted methods:

- NO_2 - **coal mines** (Karaganda Coal Basin, Pavlodar)
- CH_4 - **oils and gas** (Aktobe, Atyrau. Mangistau, Karaganda, Kyzylorda, South KZ)
- SO_2 - **copper mines and smelters** (Balkhash)

03

CH_4 - underground coal mining produces more emissions that open-pit mining

04

Power generation and **metallurgy sectors** -responsible for **37 % and 30 %** of the country's gross industrial emissions

AIR POLLUTION LIMITS IN KAZAKHSTAN

01

KZ - **explicit guidelines for monitoring atmospheric air quality**
The state supervises pollutant concentration levels using stationary and mobile posts (Kazhydromet)
Legally, **all the collected data must be stored in the "National Data Bank on the State of the Environment and Natural Resources of the Republic of Kazakhstan," with public access**

02

Other **independent monitoring systems** - not integrated into state monitoring
→ **independent data from satellites**

03

Environmental limits for air pollution (MAC)
→The permissible limit values of pollutants in Kazakhstan are higher than the WHO recommendations

Pollutant	One-Time MAC, μg m^{-3}		Average Daily MAC, μg m^{-3}		Average Annual MAC, μg m^{-3}	
	Kazakhstan	WHO	Kazakhstan	WHO	Kazakhstan	WHO
TSP	500	-	150	-	-	-
PM_{10}	300	-	60	50	-	20
$PM_{2.5}$	160	-	35	25	-	10
SO_2	500	-	50	20	-	-
NO_2	200	-	40	-	-	40

INFLUENCE OF PHYSICAL-GEOGRAPHICAL CONDITIONS ON THE DISTRIBUTION OF AIR MASSES

01

- **Weather** - extremely continental position o KZ + large temperature amplitude during the year

02

- Significant **increase in solar radiation from North to South** - the largest amount of solar energy recieved from June to August.

03

- Very variable wind regime throughout the year

  Local winds in mountains and coastal areas

  Mountains in the S ans SE influences the air currents globally → natural barrier to the cold air masses passage towards South

DATA & METHODS

Sentinel-5P

Copernicus Atmospere Monitoring Service (CAMS)

Processing

SENTINEL-5P

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

02 TROPOMI spectrometer

S5P measures gases such as NO_2, O_3, CH_2O, SO_2, CH_4, 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)

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} and SO_2**

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

PROCESSING

01

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

Grid with a **resolution 1x1 km**

02

Pollutants' units:

- NO2 and CO in 10-4 mol/m2
- PM10 and SO2 in µg/m3
- CH4 in parts per billion (ppb)

03

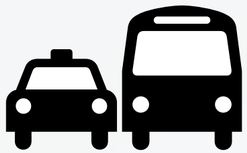
Daily values used to calculate various statistics → all-time/yearly/seasonal/monthly **averages and medians**

RESULTS

BASIC ANALYSIS

CITIES AND DISTRICTS COMPARISON

YEARLY COMPARISON FOR KAZAKHSTAN



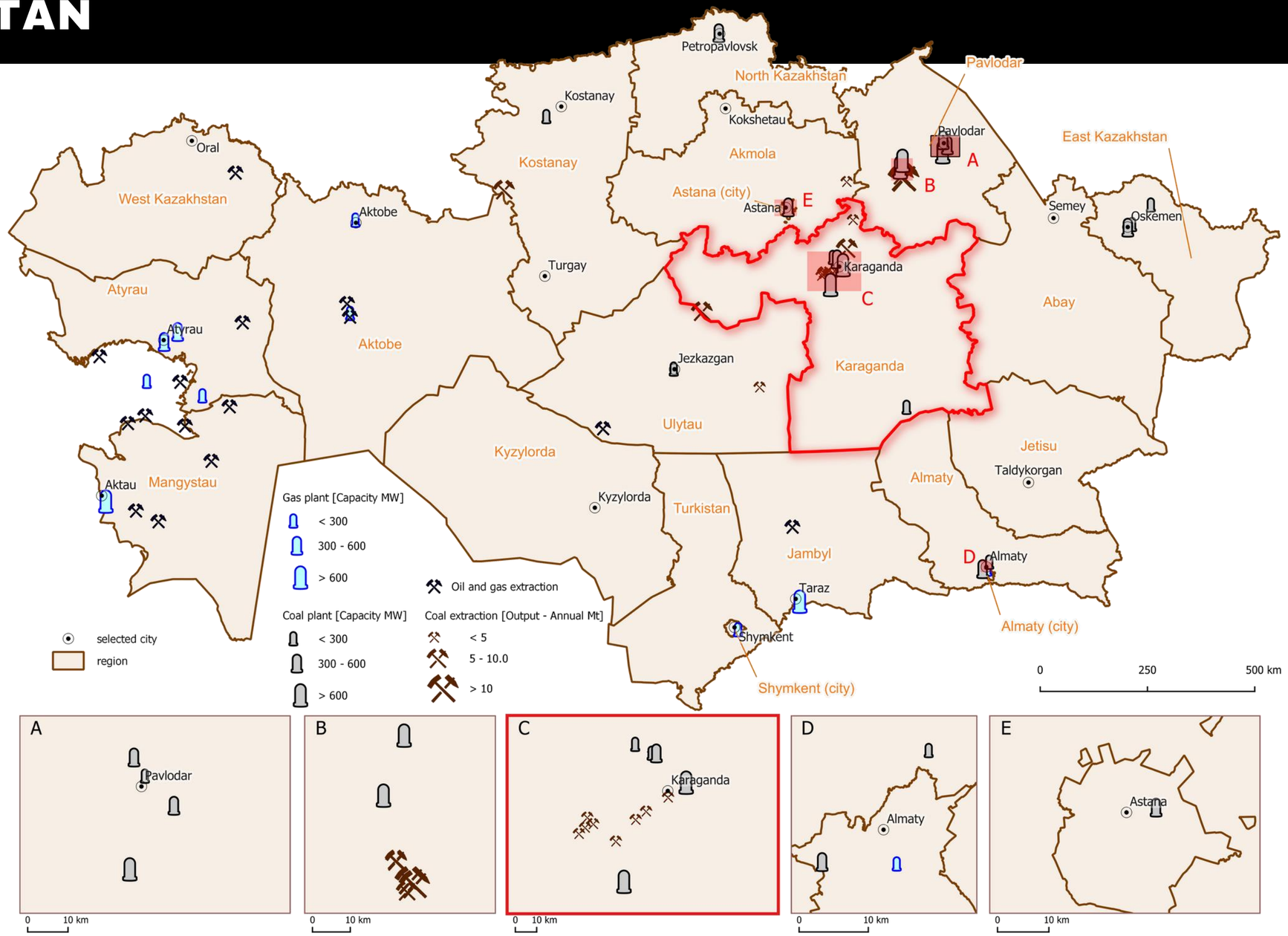
Nitrogen dioxide
(NO_2)

Methane
(CH_4)

Sulfur dioxide
(SO_2)

Particulate matter
(PM_{10})

DISTRIBUTION OF MAJOR COAL, OIL AND GAS MINING SITES IN KAZAKHSTAN



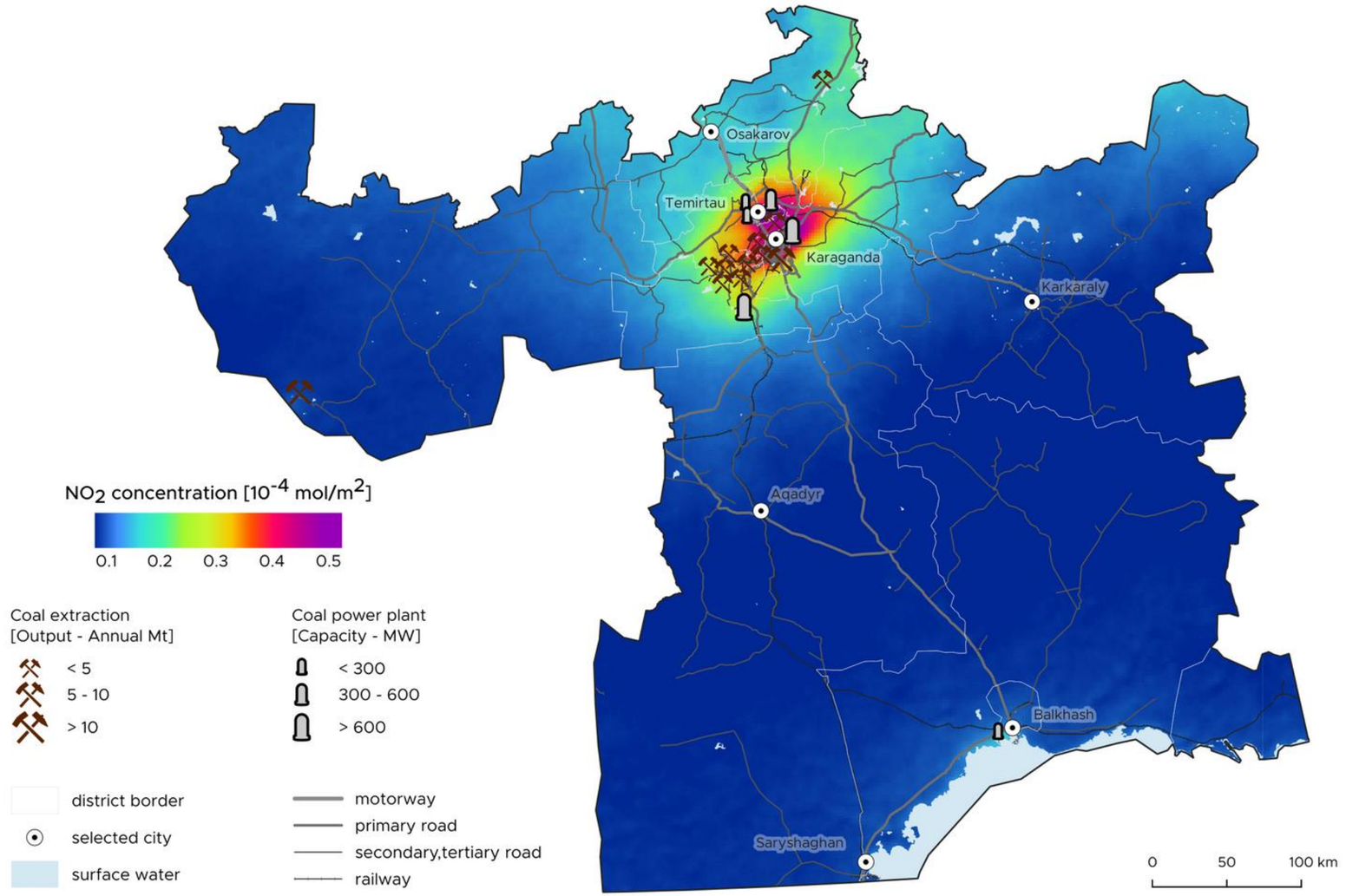
NO_2

- **Highest concentration in residential areas and major industrial sites**

- **Karaganda** - many mining sites, center of coal mining
- **Temirtau** - steel industry (ArcelorMittal Temirtau JSC)

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS

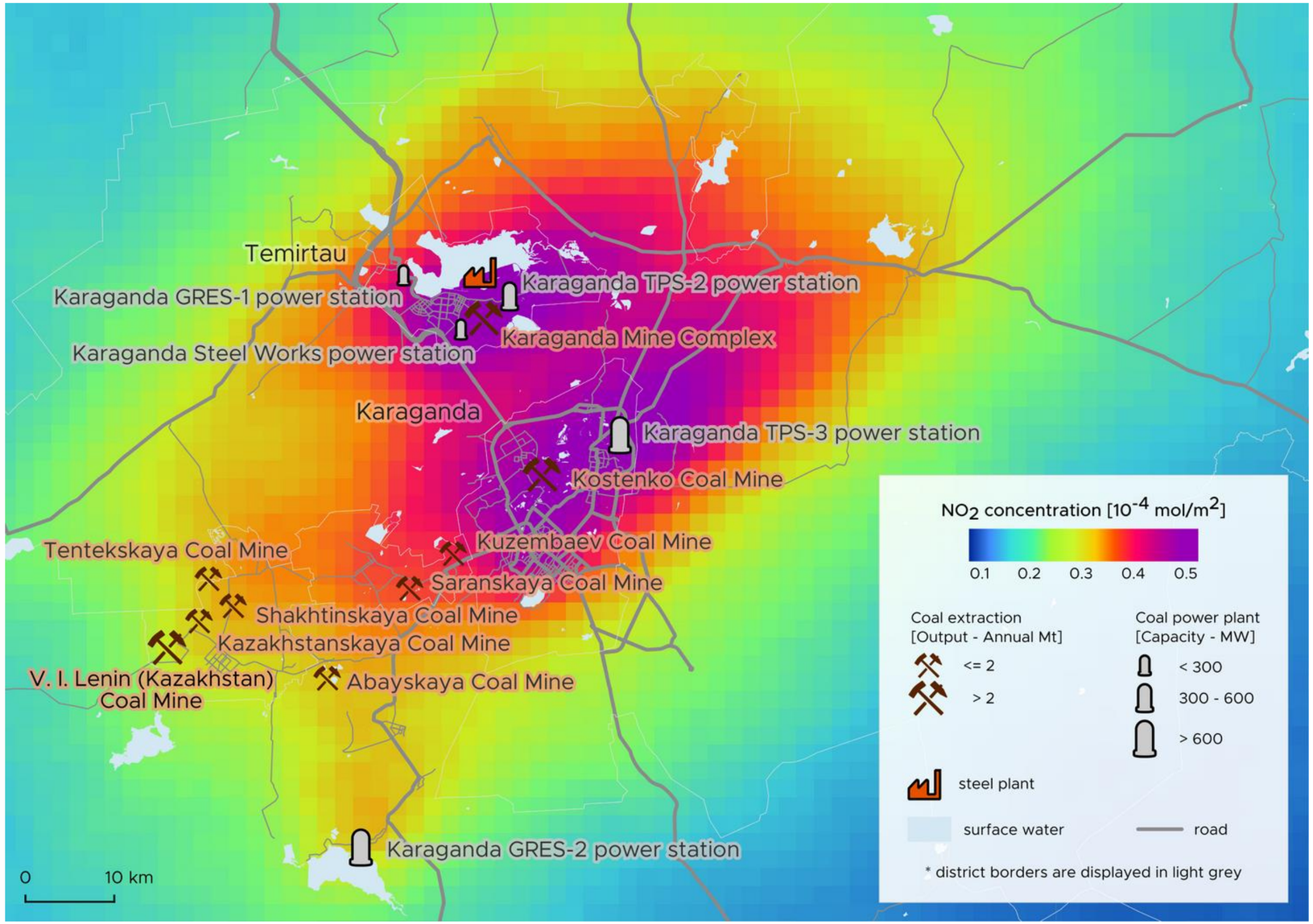


NO_2

- **8 underground coal mines** (above 10 Mt annual output (2020))
- **5 coal-fired power plants** (over 2100 Mw)
- **ArcelorMittal Temirtau steel plant** - the biggest polluter withing the area

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



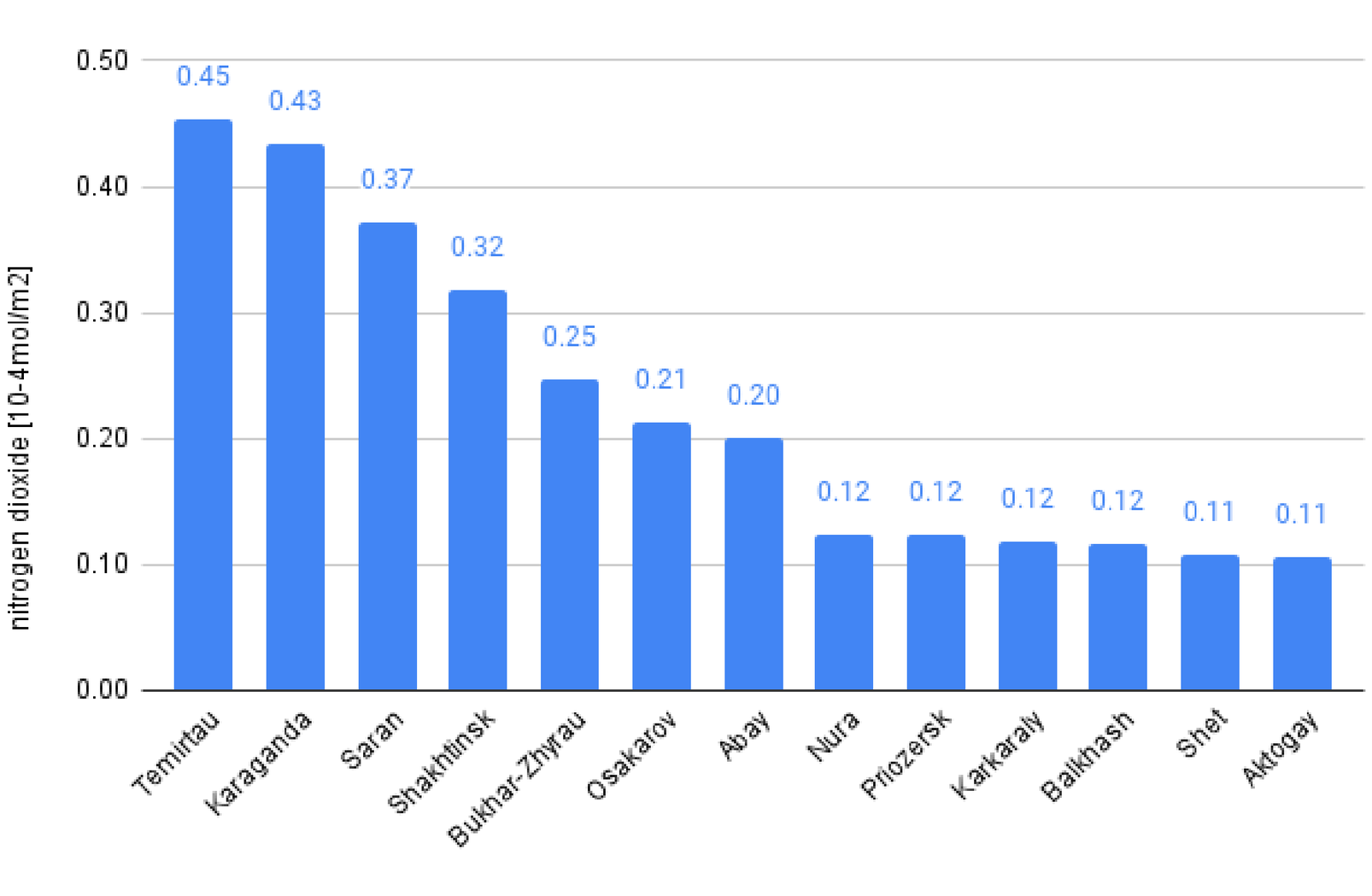
NO_2

Ø NO_2 concentrations in the cities and districts of the Karaganda Region

- **Temirtau**
- **Karaganda**
- **Saran** (mining)
- **Shakhtinsk** (mining)

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



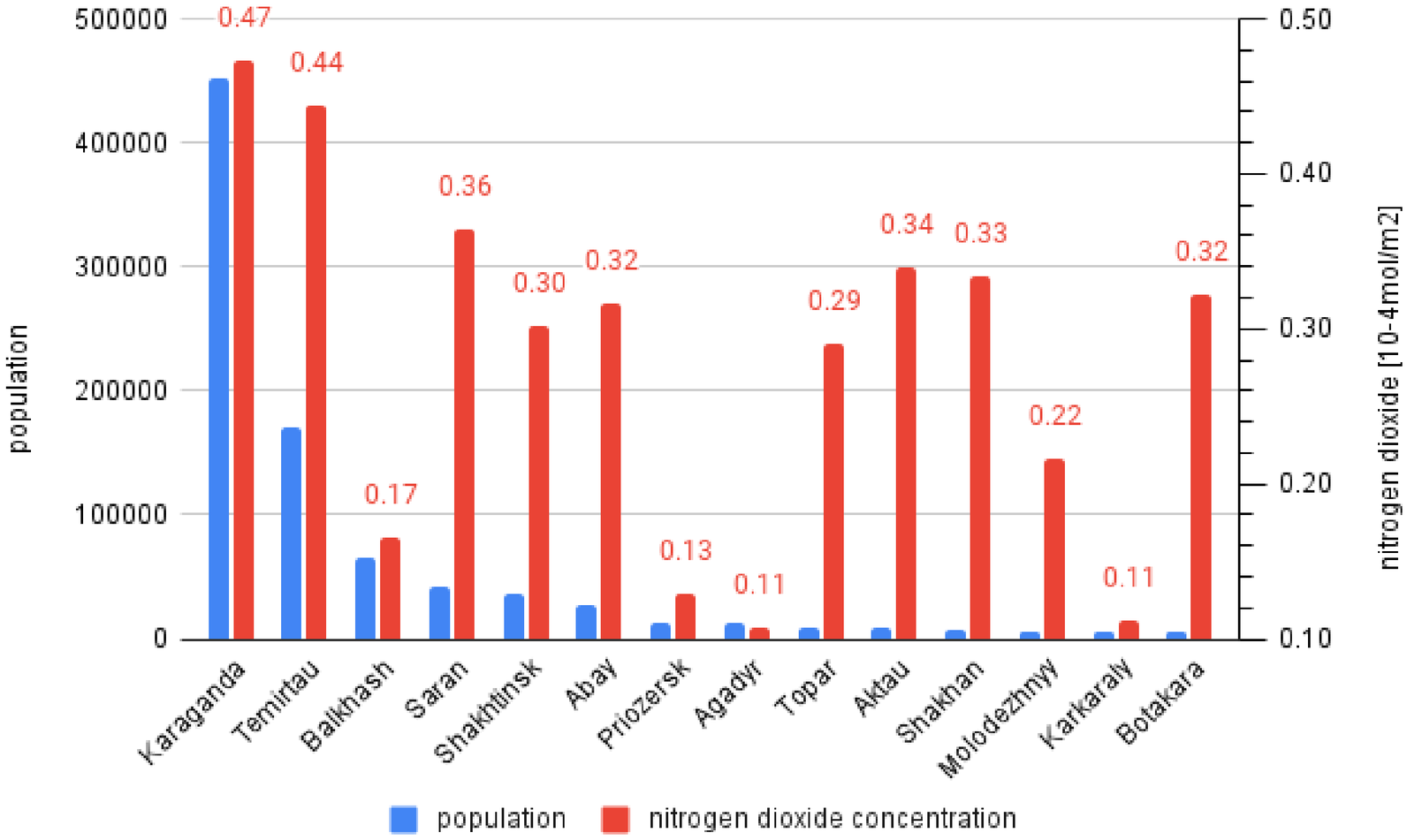
NO_2

Ø NO_2 concentrations in the cities and towns of the Karaganda Region

- **Karaganda**
- **Temirtau**
- **Saran** (mining)
- **Shakhtinsk** (mining)
- **Abay**

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



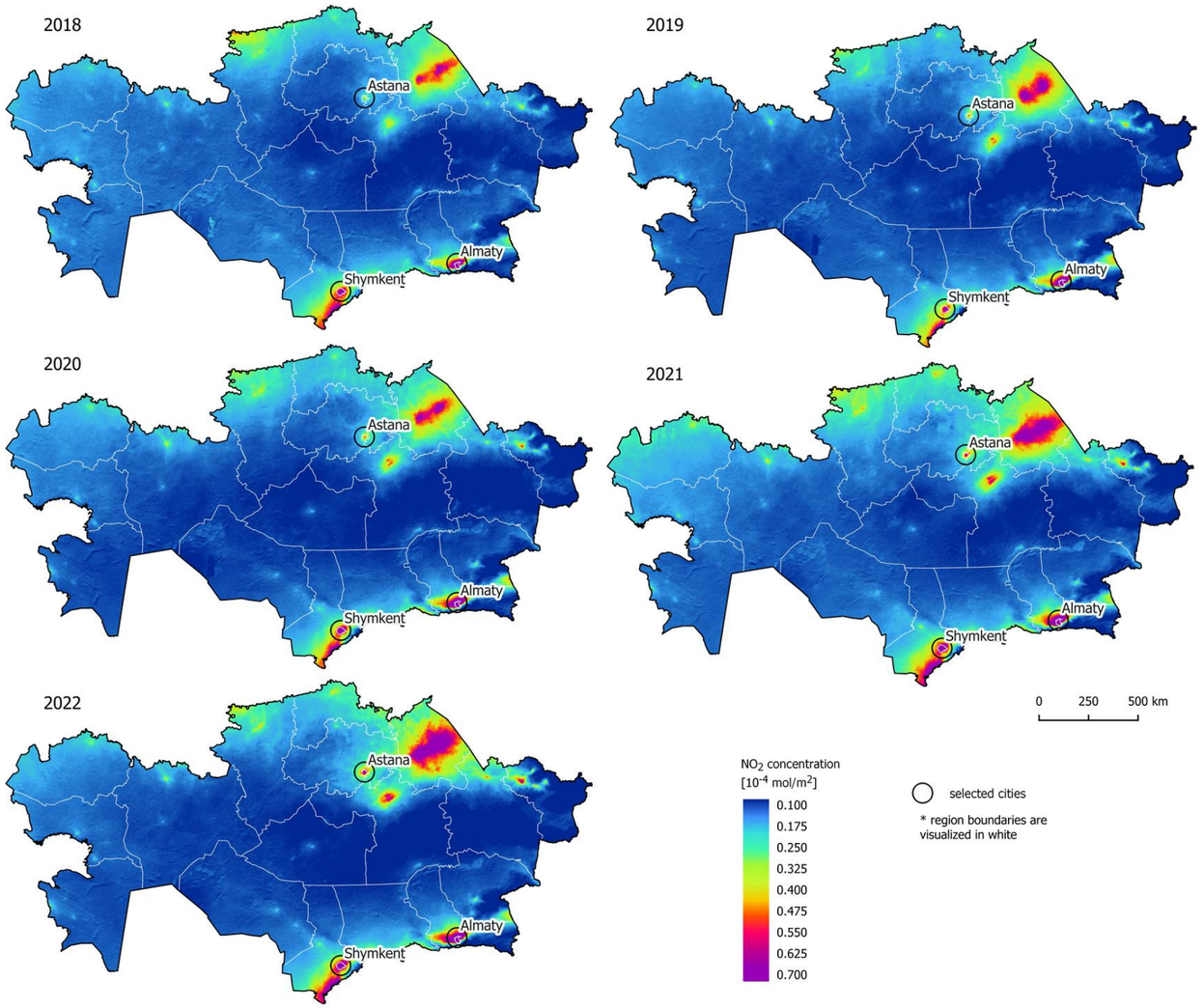
NO_2

- Yearly concentration increase in the surroundings of Pavlodar, Astana, Karaganda
- Partial concentration decrease in the populated areas in 2020 (covid-19)

NITROGEN DIOXIDE (2018-2022)

BASIC ANALYSIS

YEARLY COMPARISON

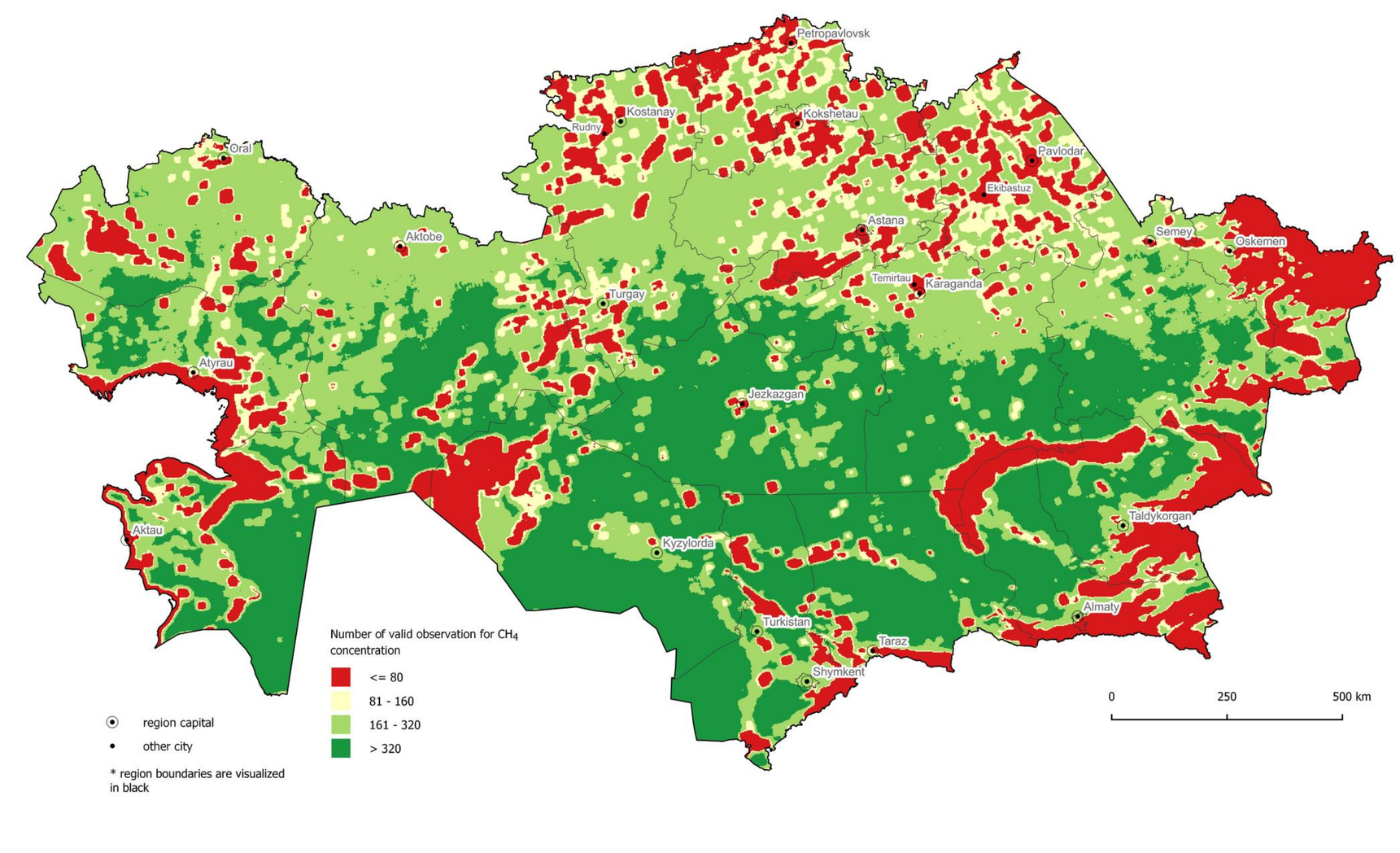


CH_4

- **S5P data limit in valid detection of CH_4 over water bodies and in mountains** (threshold of 80 observations)

METHANE (5/2018-12/2022)

SENTINEL-5P DATA LIMIT

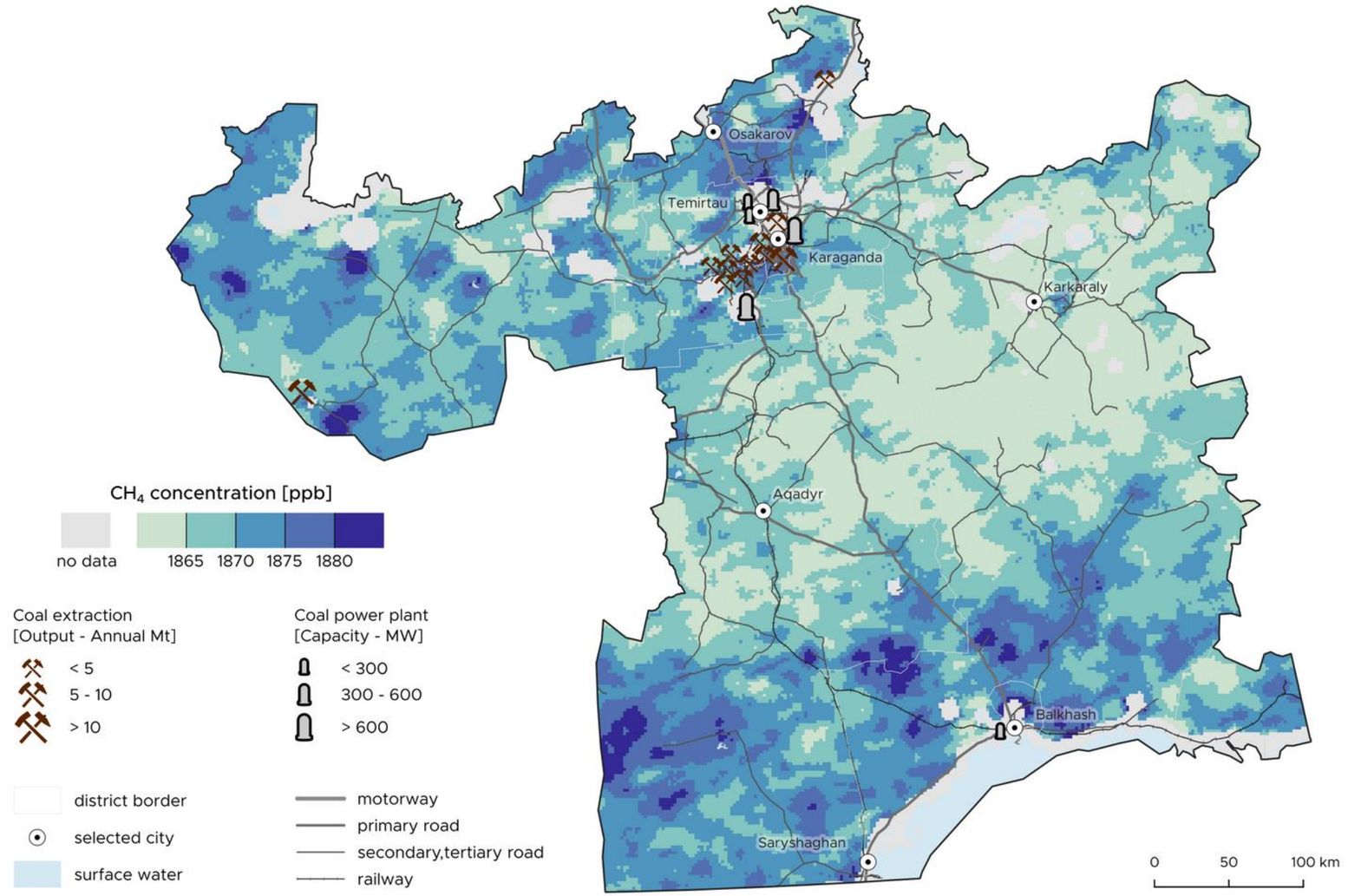


CH_4

METHANE (5/2018-12/2022)

BASIC ANALYSIS

- **Higher concentrations in southern, northwestern parts of the region and around regional capital**
- Lower CH_4 emissions from surface mines compared to underground mines

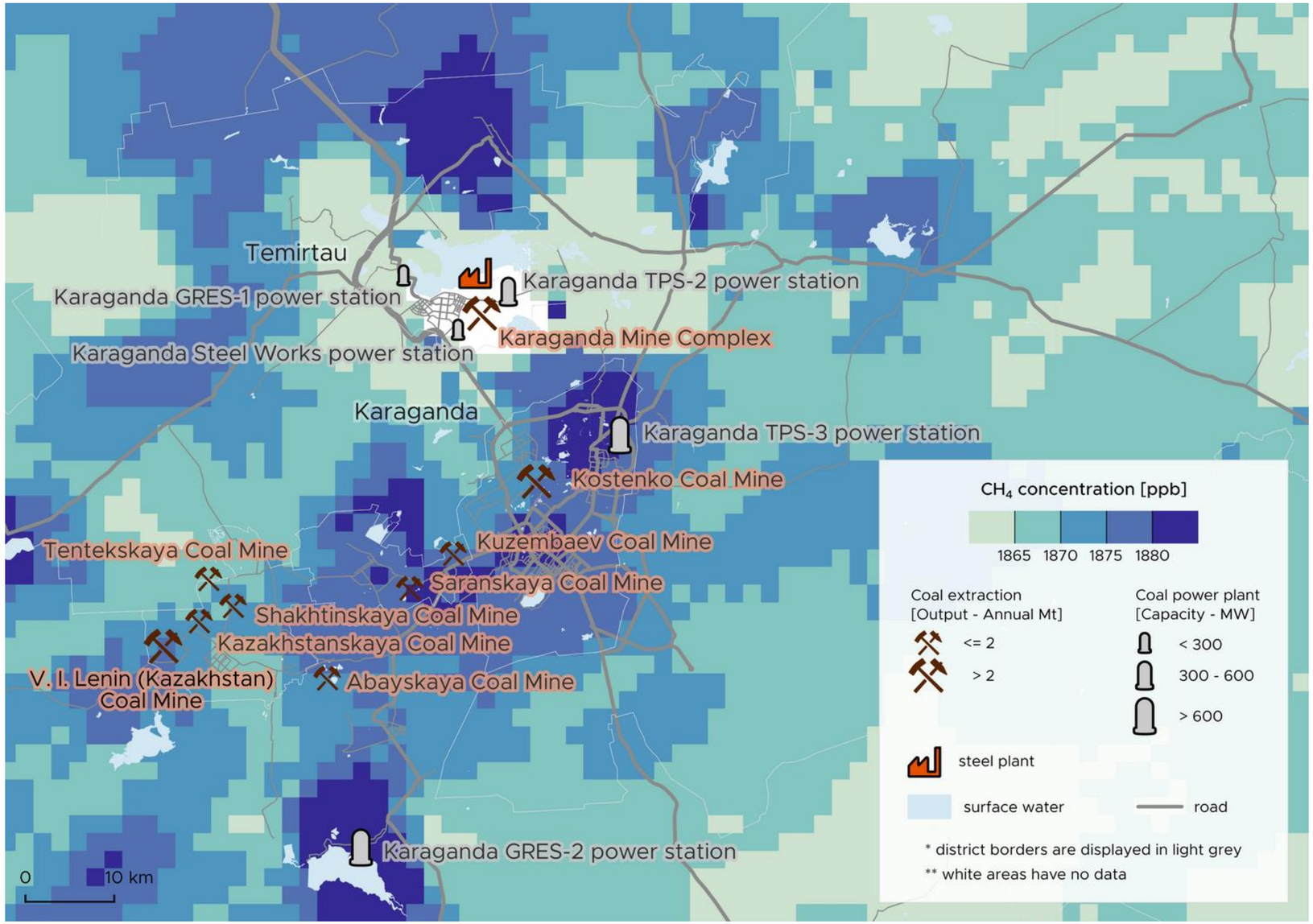


CH_4

METHANE (5/2018-12/2022)

BASIC ANALYSIS

- Slightly elevated CH_4 concentrations **above coal mines and in the vicinity of coal-fired power plants**
  - Karaganda Thermal Power Station (TPS) 3
  - Karaganda GRES-2 (near water body)



CH_4

Ø CH_4 concentrations in the cities and districts of the Karaganda Region

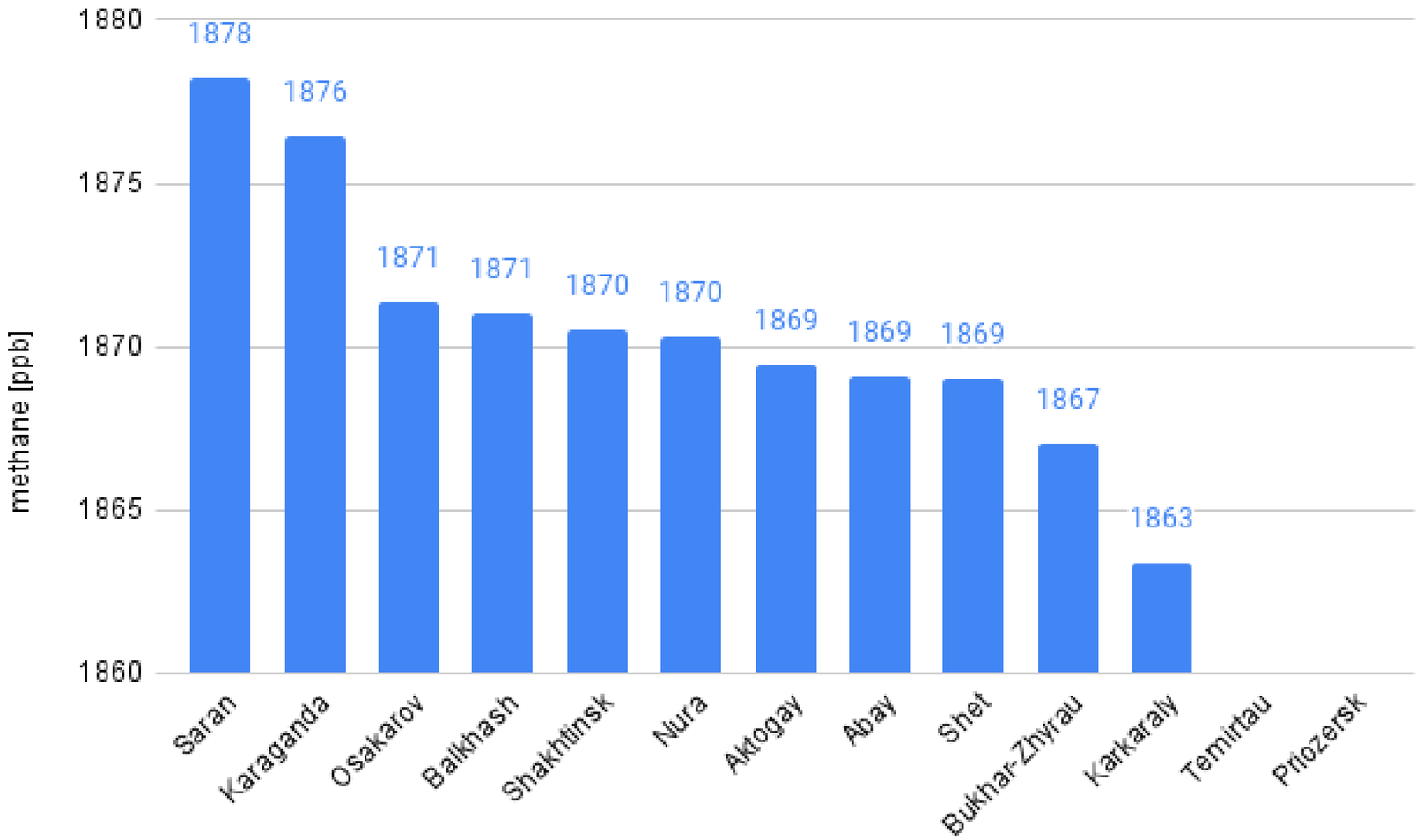
- **Saran** (mining)
- **Karaganda**

Temirtau, Priozersk

- small areas
- located near a large water body

METHANE (5/2018-12/2022)

BASIC ANALYSIS



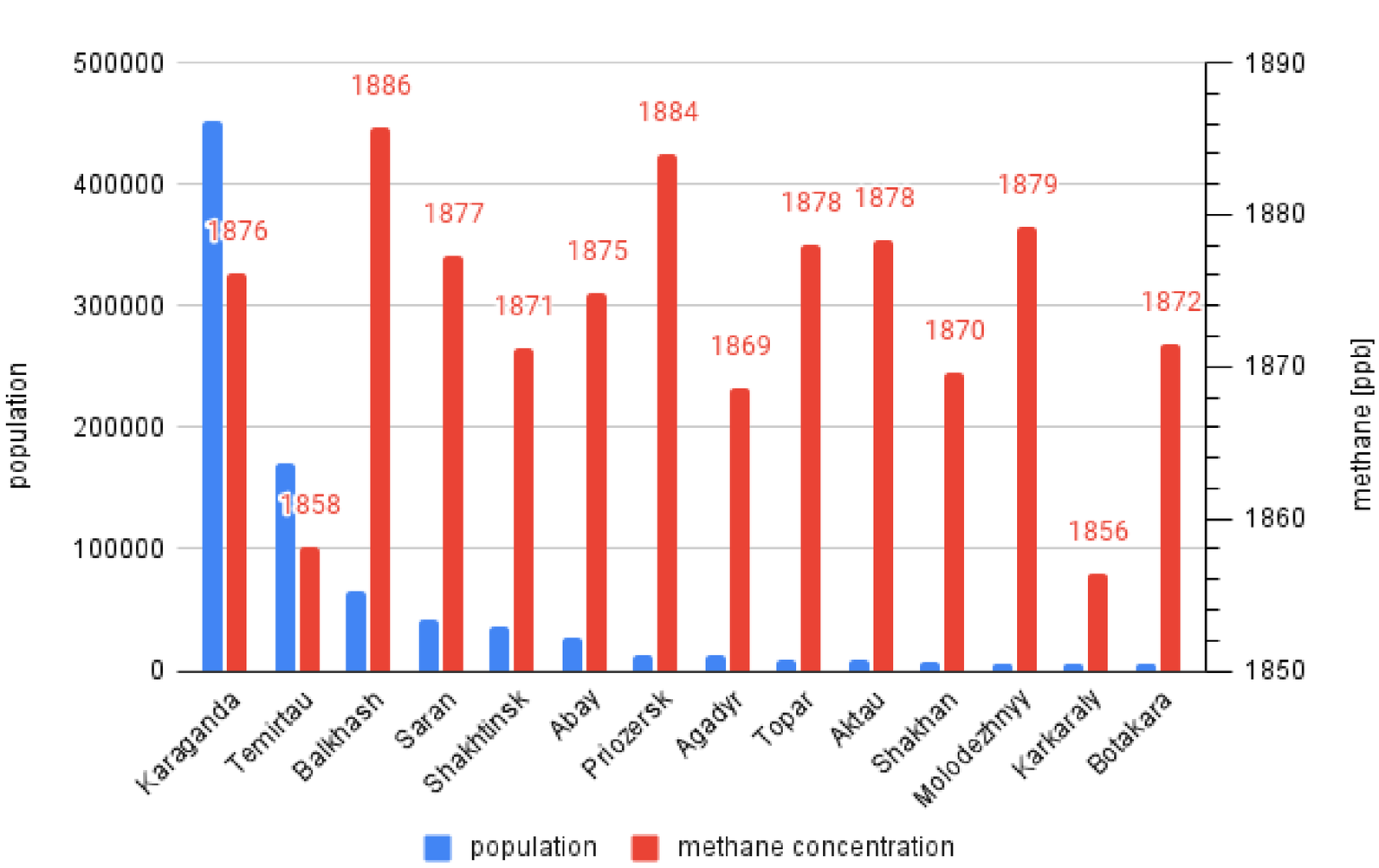
CH_4

Ø CH_4 concentrations in the cities and towns of the Karaganda Region

- no pattern or distinctive relationship

METHANE (5/2018-12/2022)

BASIC ANALYSIS



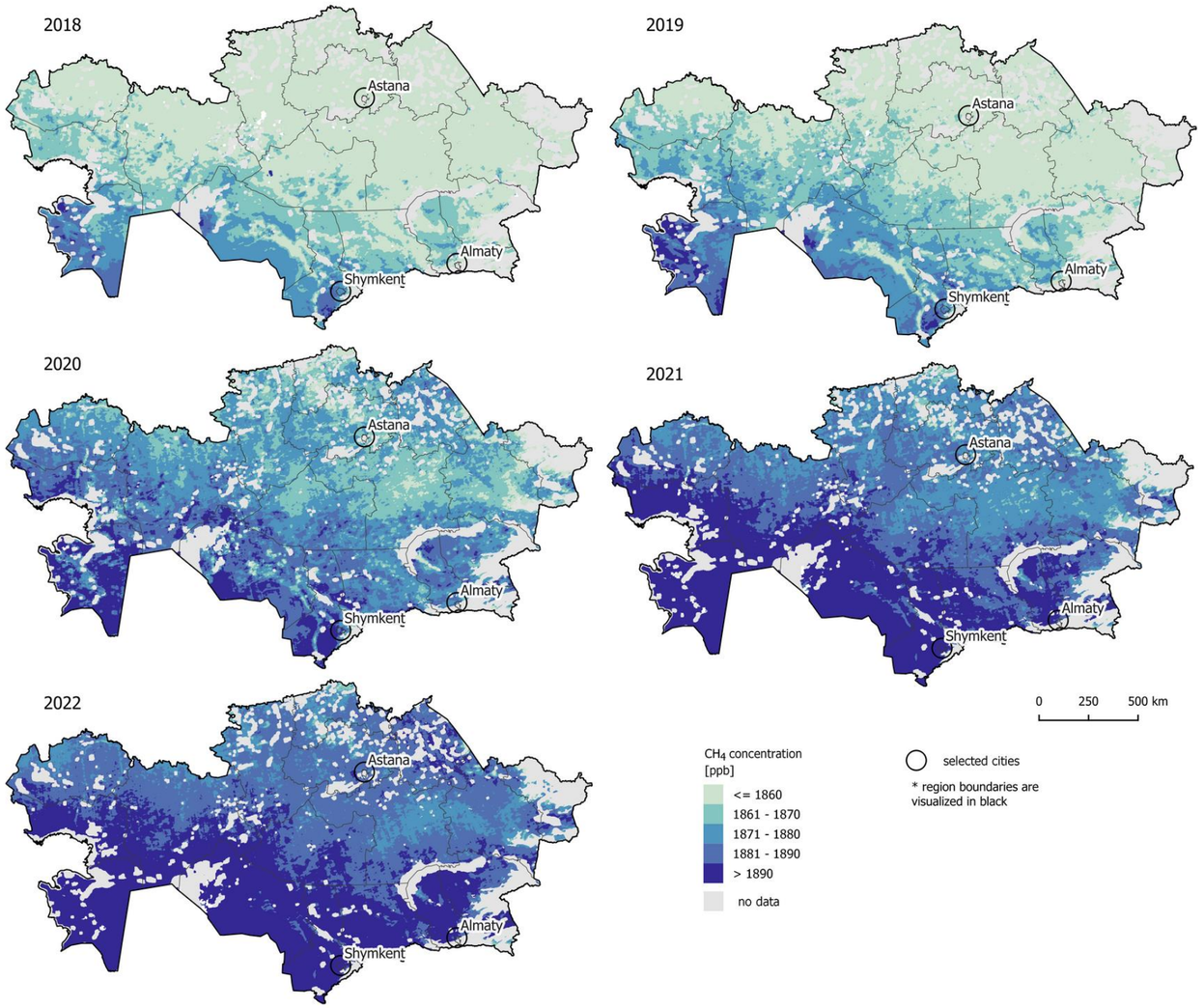
CH_4

METHANE (2018-2022)

BASIC ANALYSIS

YEARLY COMPARISON

- **Yearly overall concentration increase throughout the whole country** - global trend
- **The average annual growth = 9.2 ppb** (very close to the global average rate (9ppb/year))



SO_2

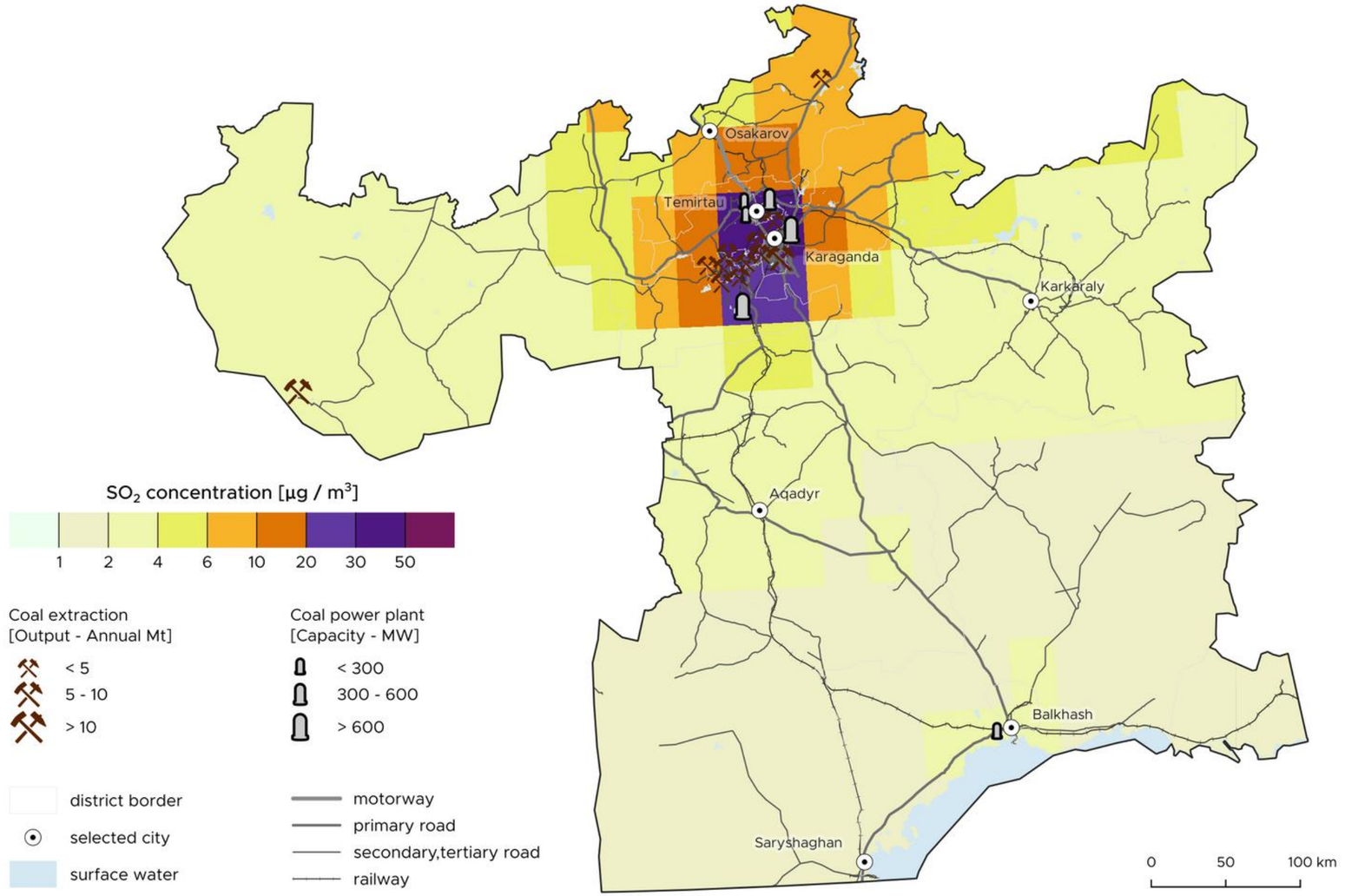
- Similar regional distribution as in the case of NO_2
  - **Karaganda**
  - **Temirtau**

SO_2 pollution around Balkhash city

- **Balkhash is a significant pollution hotspot**- Balkhashcvetmet Copper Smelter
- **CAMS dataset limitation** (absence of local measurements from Balkhash?)

SULFUR DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



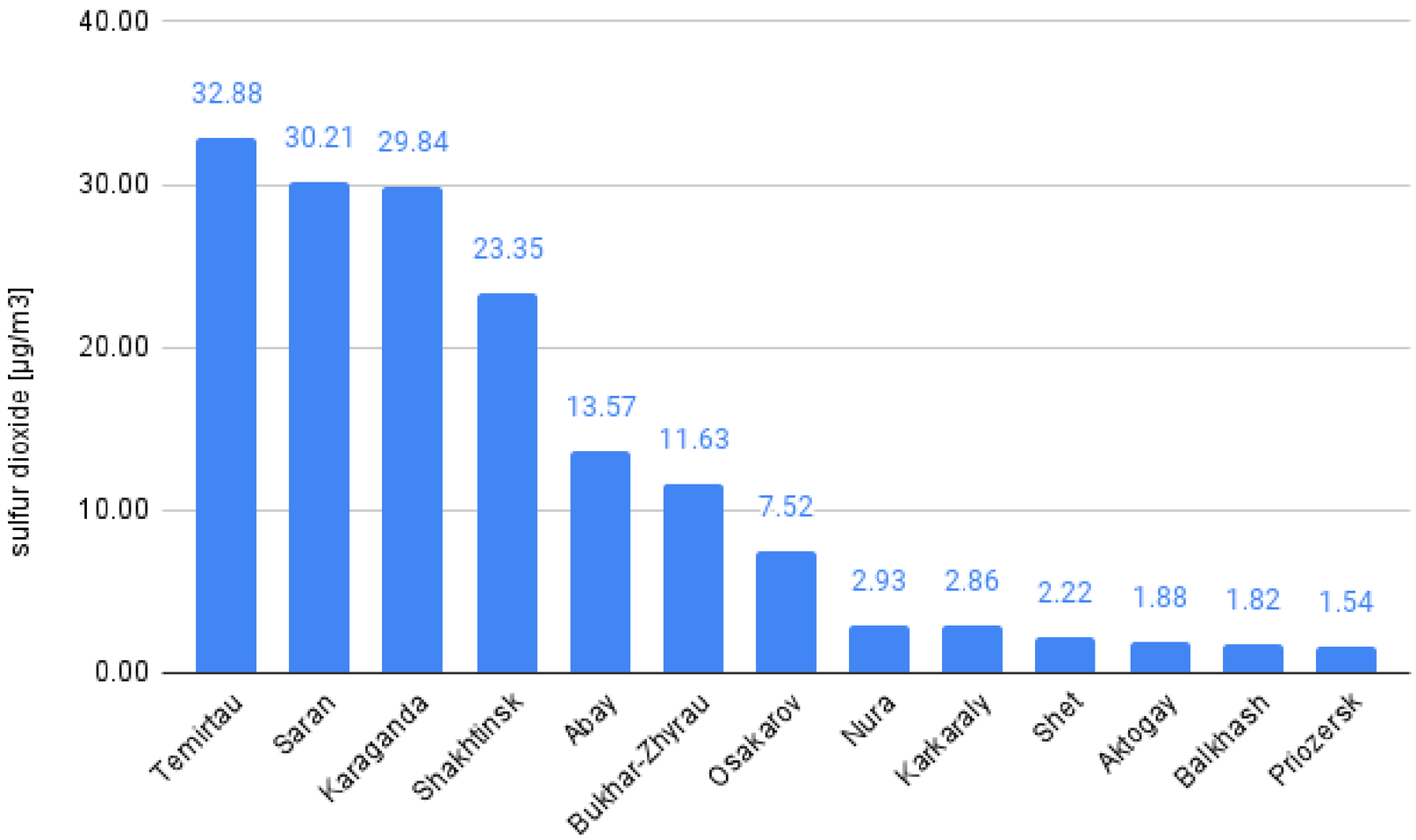
SO_2

Ø SO_2 concentrations in the cities and districts of the Karaganda Region

- **Temirtau**
- **Saran** (mining)
- **Karaganda**
- **Shakhtinsk**

SULFUR DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



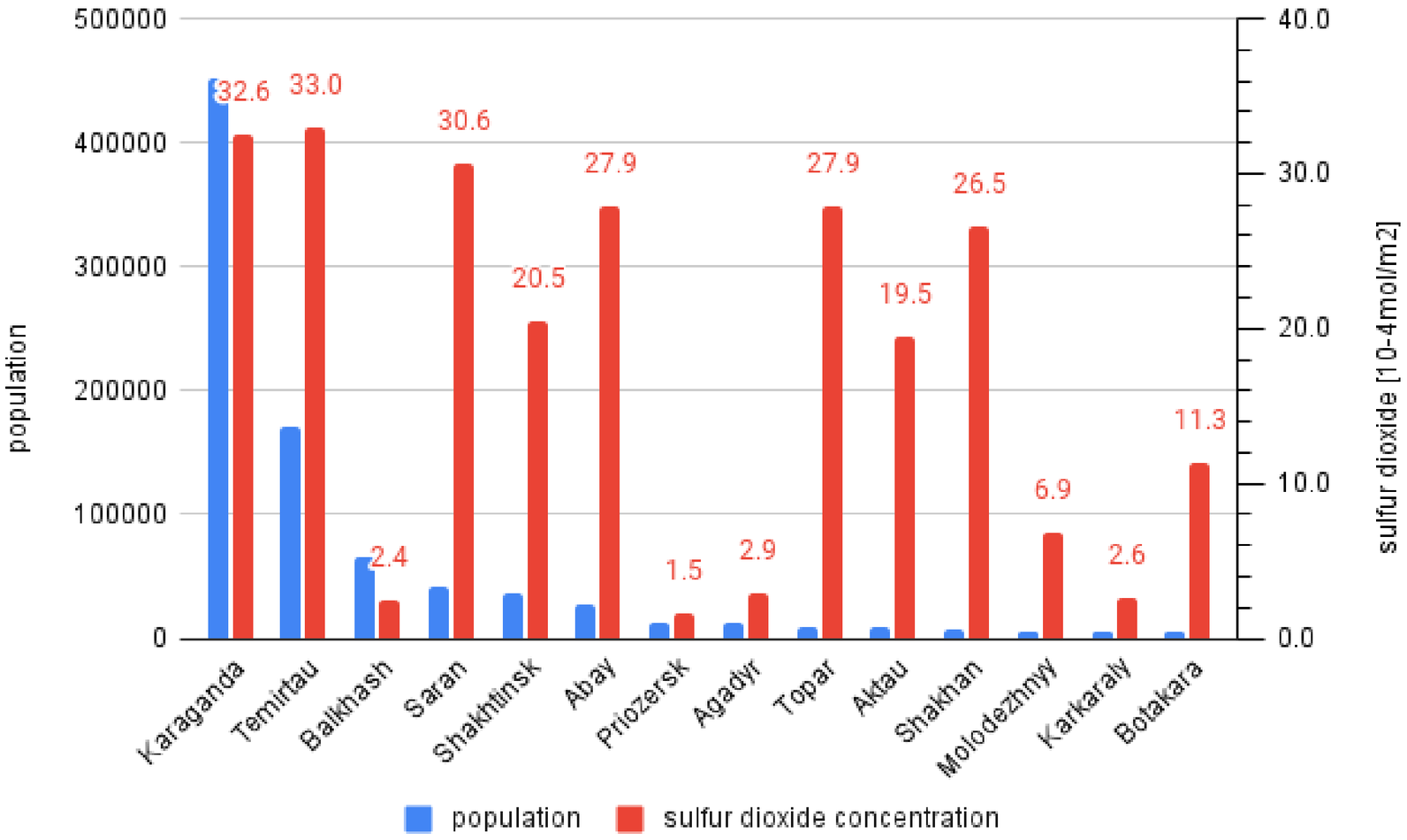
SO_2

Ø SO_2 concentrations in the cities and towns of the Karaganda Region

- cities and towns close to Karaganda and Temirtau

SULFUR DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



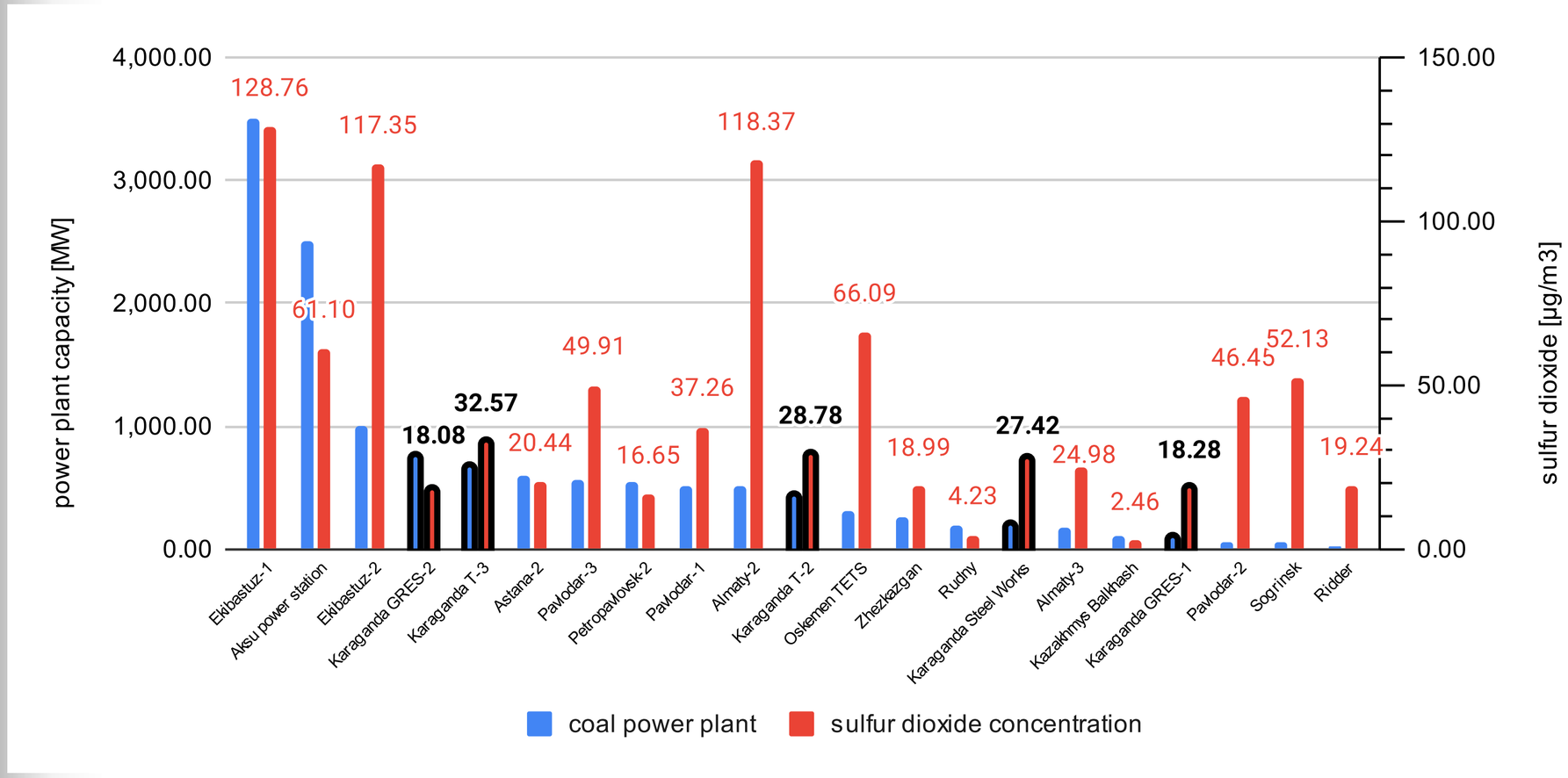
SO_2

Ø SO_2 concentrations in selected coal-fired power plants of KZ (highlighted powerplants in Karaganda Region)

- **Karaganda TPS-3, TPS-2**

SULFUR DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



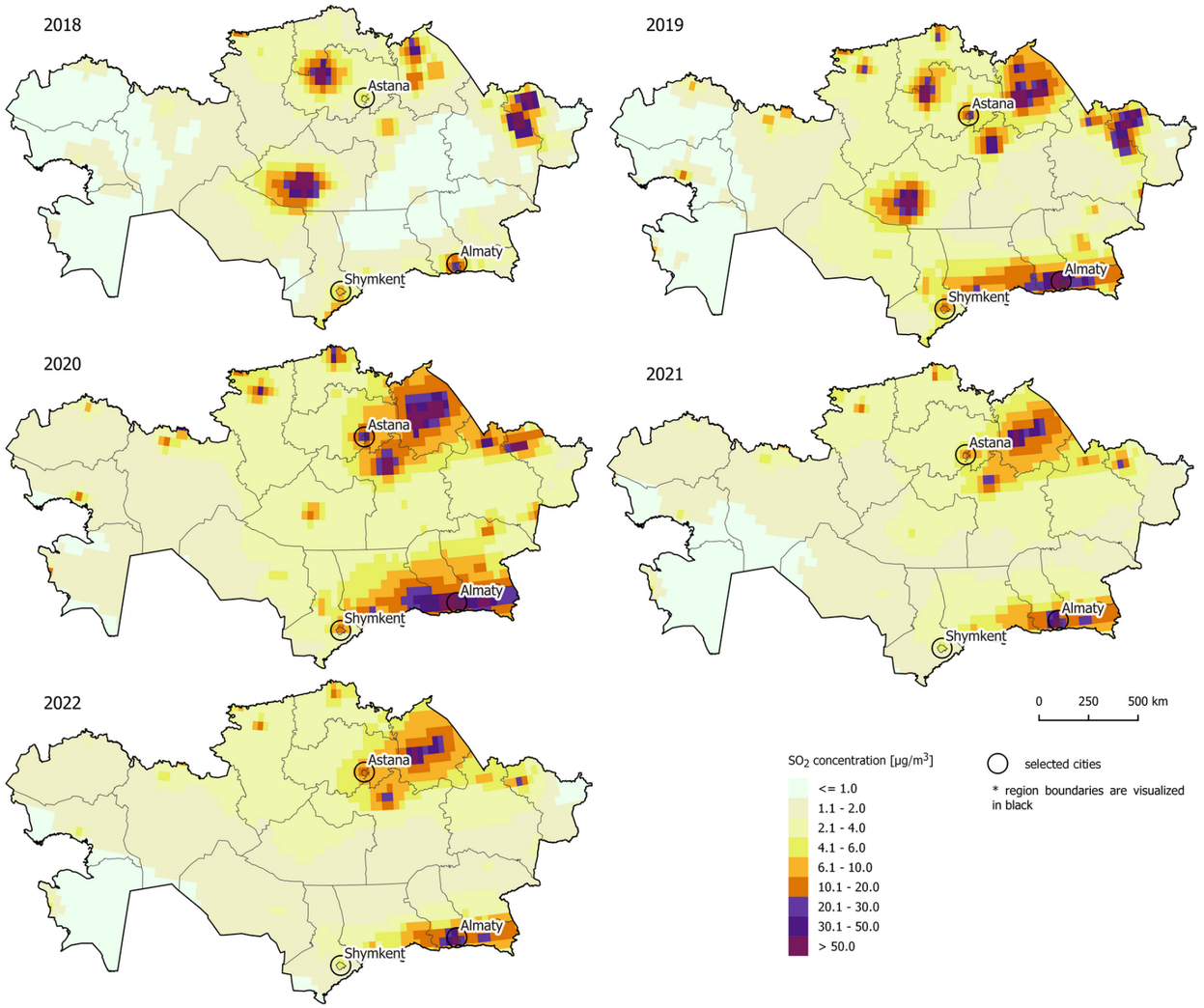
SO_2

SULFUR DIOXIDE (2018-2022)

BASIC ANALYSIS

YEARLY COMPARISON

- **Model calculation change**
  - elevated values in 2018 and 2019 for Jezkazgan and NW of Astana)
- **Prevailing concentration decrease in most cities between 2020 and 2022**

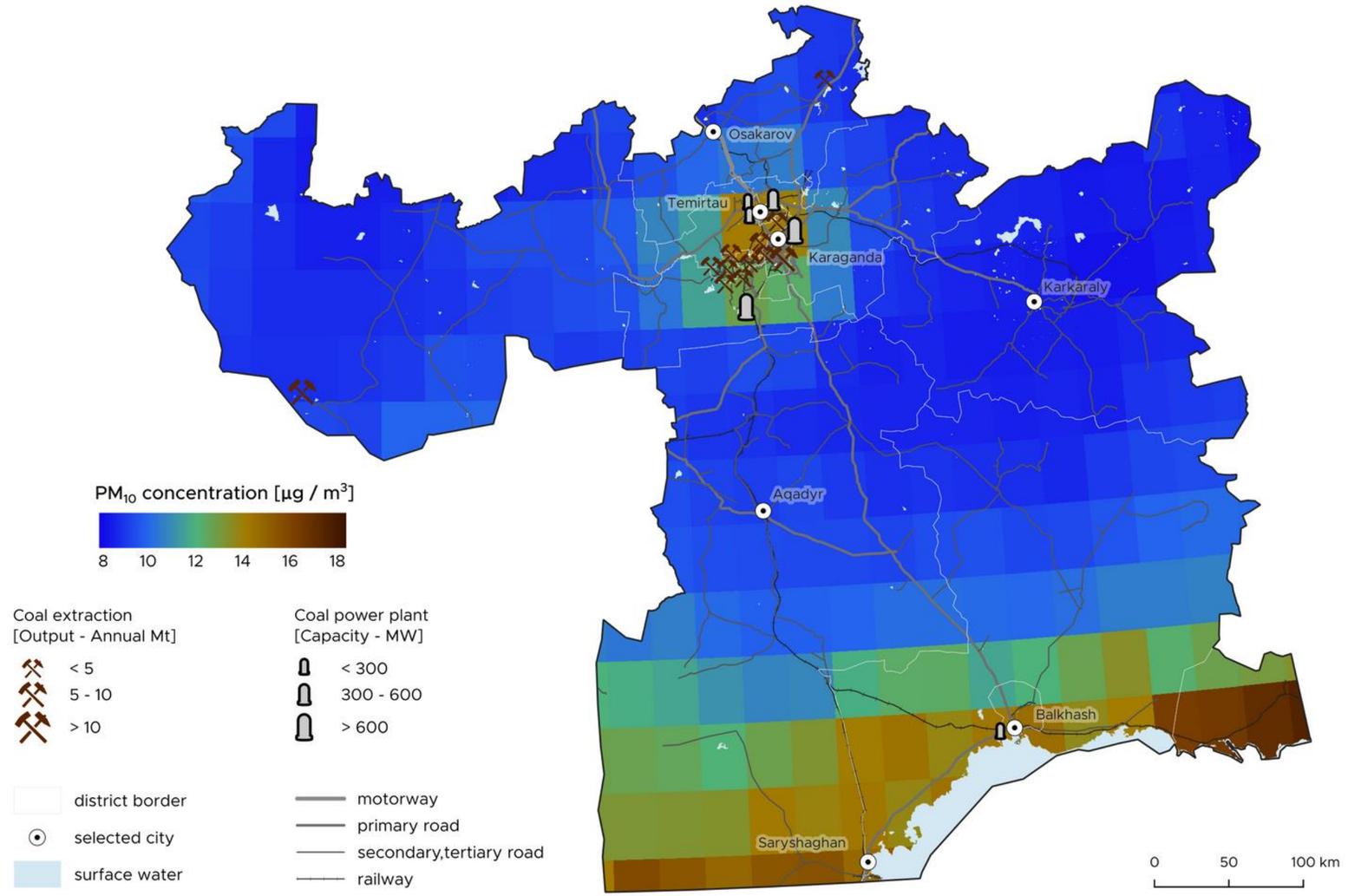


PM_{10}

- **Anthropogenic and natural sources**
- **Karaganda** on the interface of N and S
  - elevated values in the S part of the region
  - anthropogenic influence in the N part
- Mining + metallurgy + coal power plant → higher PM_{10} concentrations around Karaganda and Temirtau

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)

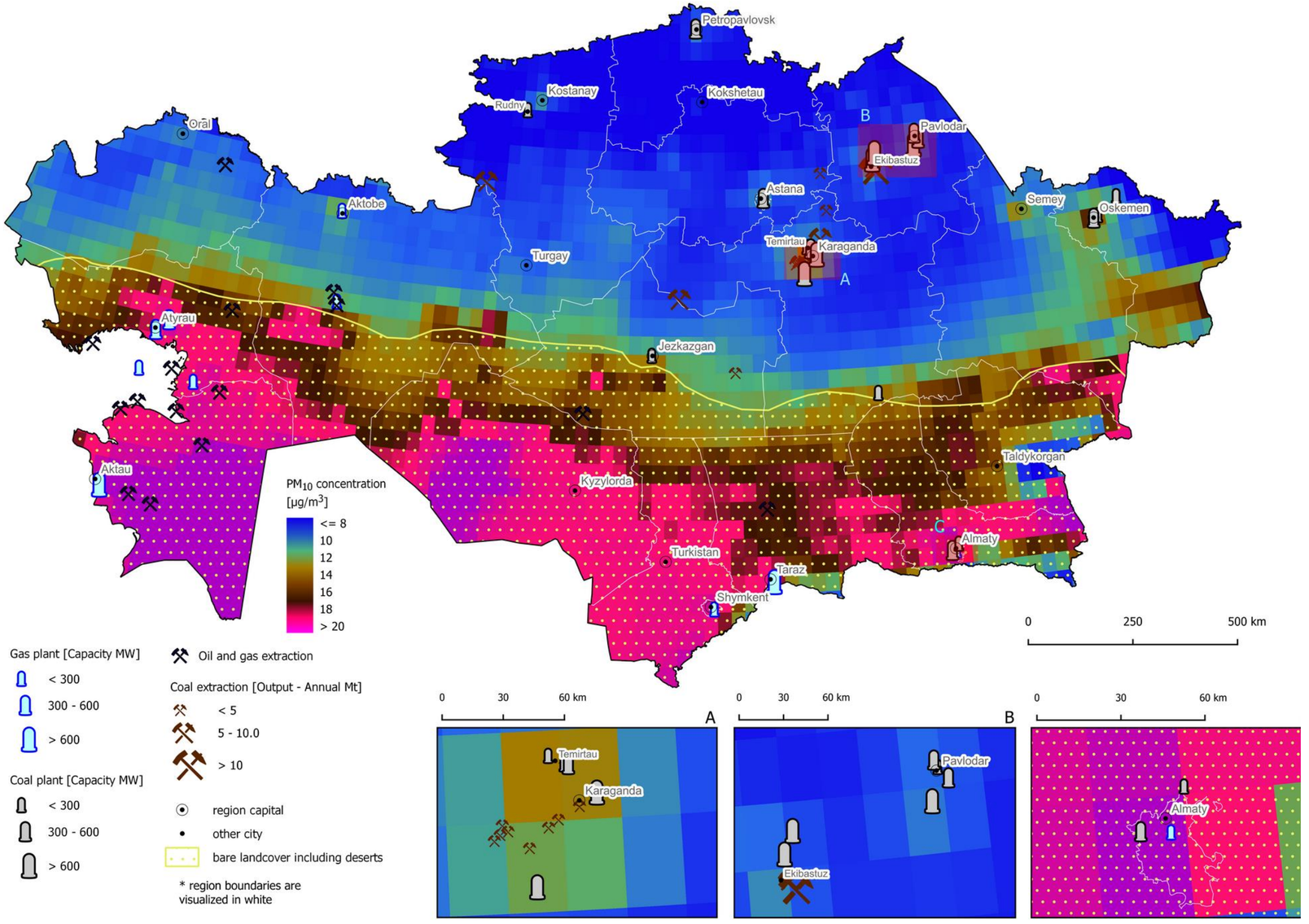


PM_{10}

- **Highest concentration in S and SE of KZ** (bare soils, deserts)
- **Significant part of KZ exceeds the WHO limits for annual PM10** (20 µg/m3, pink colour)
- Outside areas with naturally generated PM_{10} - Karaganda, Oskemen, Aktobe, Astana, Kostanay

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)



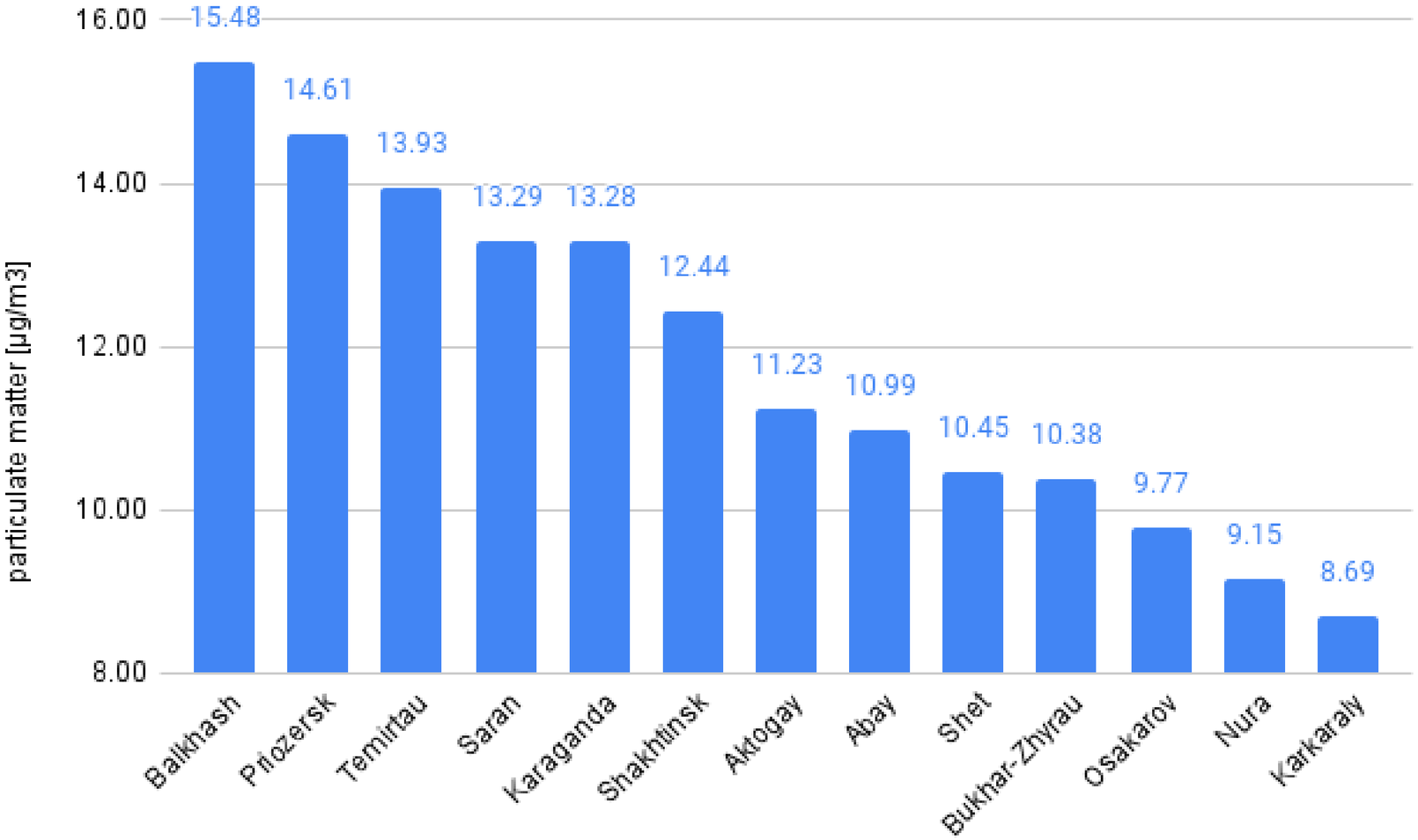
PM_{10}

Ø PM_{10} concentrations in the cities and districts of the Karaganda Region

- **Balkhash** (natural)
- **Priozersk** (natural)
- **Temirtau** (anthrop.)
- **Saran** (anthrop.)
- **Karaganda** (anthrop.)

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)



PM_{10}

Ø PM_{10} concentrations in the cities and towns of the Karaganda Region

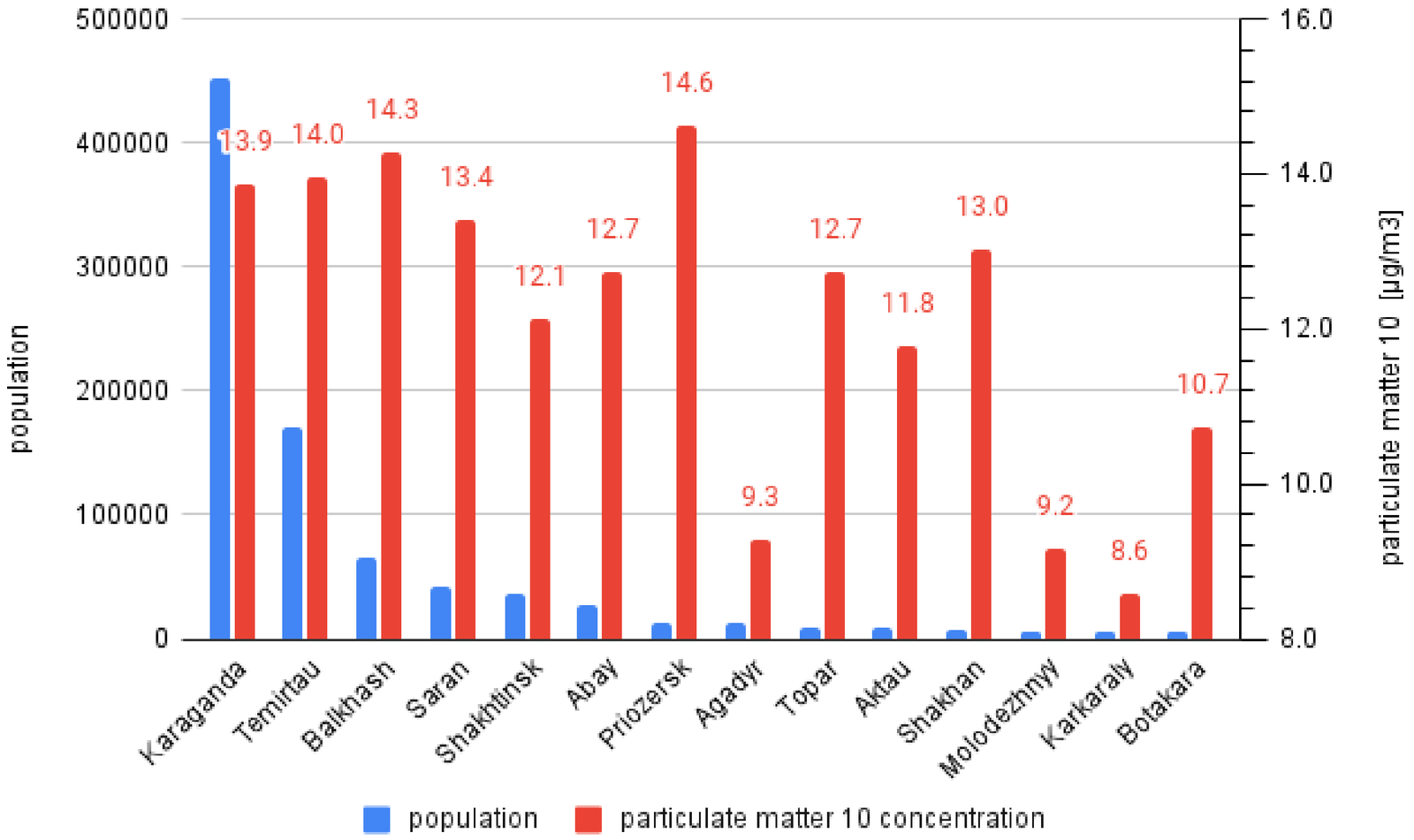
- **comparable for most cities**

High concentration levels in the south of the region

- Balkhash (Balkhashcvetmet Copper Smelter)
- Priozersk (natural sources)

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)



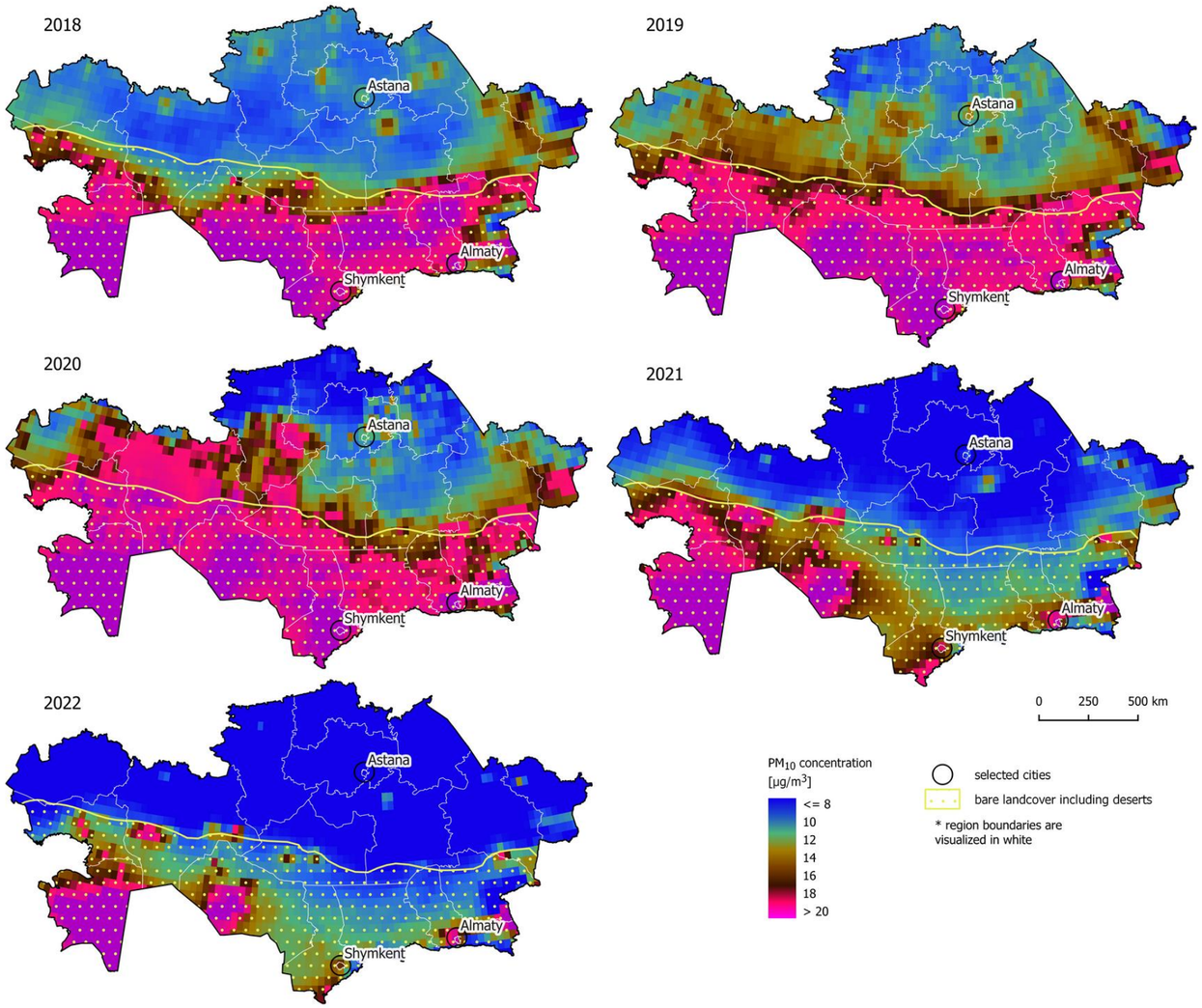
PM_{10}

- **PM_{10} distribution varies each year** (2020 - probably dust storms)
- Consistently highest in **Mangystau**

PARTICULATE MATTER

BASIC ANALYSIS (2018-2022)

YEARLY COMPARISON



RECOMMENDATIONS FOR KAZAKHSTAN

Kazakhstan introduced its **Environmental Protection Code in 2021**

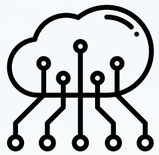
Path towards **carbon neutrality in 2060**

Contribution to fulfilling **UN Sustainable Development Goals** and **UNFCCC Paris Agreement**

Large reserves of earth resources → **mining, resource processing and heavy industries**

Crucial interplay between the economic drivers and environmental commitments

RECOMMENDATIONS FOR KAZAKHSTAN



Strengthen air quality monitoring and data collection

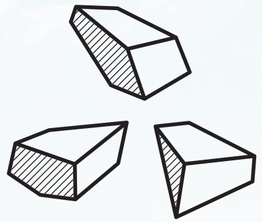
Ramp down coal use and renewable energy deployment

Regulatory frameworks, environmental liability and local emission inventories

Energy efficiency and emission control measures for industries

Public awareness and participation

RECOMMENDATIONS FOR KARAGANDA REGION



Prioritize efforts towards coal-related industry

Mitigate dust emissions from mining operations

Prioritize efforts towards metallurgical industry

Improve monitoring effects

Public awareness and participation

PRIORITIZE EFFORTS TOWARDS COAL-RELATED INDUSTRY

01

Key focus on **incentivizing coal power stations to adopt advanced pollution control technologies**

02

Enforce strict emission standards

- encourage coal power stations to invest in state-of-the-art flue gas desulfurization systems, electrostatic precipitators, fabric filters

MITIGATE DUST EMISSIONS FROM MINING OPERATIONS

01

Including **technologies improving dust suppression**, utilizing enclosed conveyor systems

02

Regular **monitoring of dust levels**, conducting inspections
→ identify areas that require improvements

03

System in place to monitor the compliance of coals sold in the retail market

PRIORITIZE EFFORTS TOWARDS METALLURGICAL INDUSTRY

01

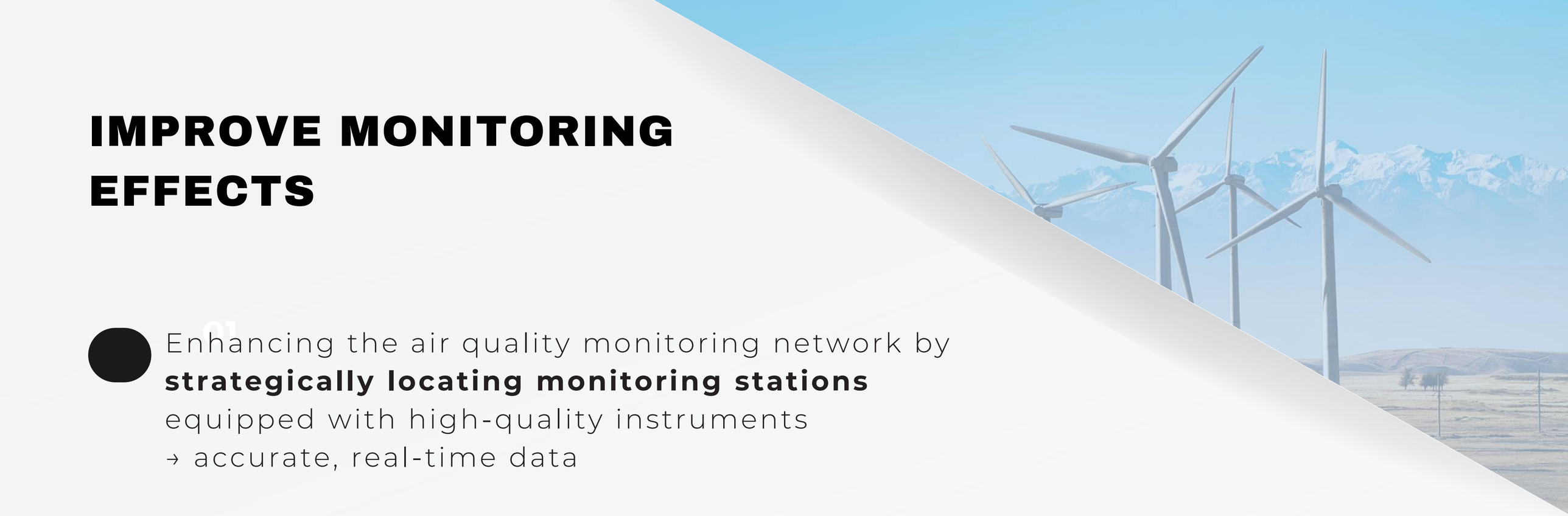
Especially **steel mills, ferroalloy facilities, copper smelters**

02

Encourage the adoption of cleaner production technologies

- electric arc furnaces

IMPROVE MONITORING EFFECTS



01

Enhancing the air quality monitoring network by **strategically locating monitoring stations** equipped with high-quality instruments
→ accurate, real-time data

02

Data use to assess the effectiveness of pollution reduction measures → Identify areas requiring further attention

PUBLIC AWARENESS AND PARTICIPATION

01 Local government should **involve citizens in decisions**
- spatial planning
- approving local clean air plans
- conducting EIAs
- permitting industrial activities

02 Public engagement fosters **transparency, mitigates opposition, allows oversight of fund use**

05 **Public awareness campaigns** and educating **about the importance of sustainable transportation options**
- significant reliance on passenger car transport, **(old models with low fuel efficiency)**
- widespread use of highly polluting heating methods (coal, gas, biomass, heating oils)

06 **Early warning system** to alert authorities and the public about emergency air pollution events
- → taking timely preventive actions and minimizing the adverse effects

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WORLD FROM SPACE

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