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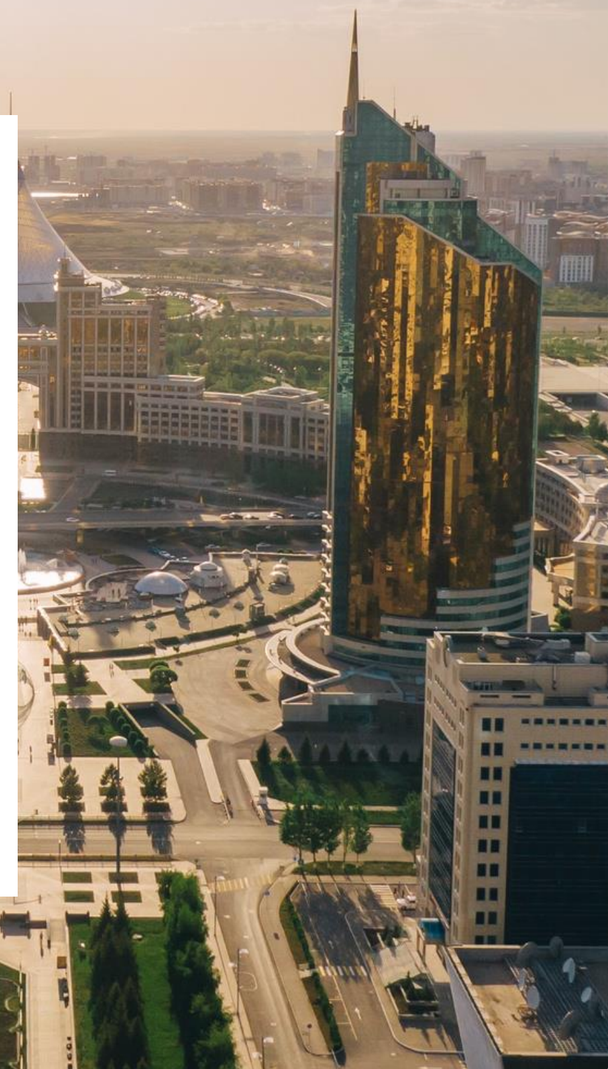
AIR POLLUTION IN KAZAKHSTAN

AS SEEN FROM SPACE

FUNDAMENTAL ANALYSIS AND NOTES ON KAZAKHSTAN'S BROADER IMPACT ON CLIMATE CHANGE



CONTENT

01 Introduction

02 Climate change & Air pollution

03 Data & Methods

04 Results

05 Recommendations

06 Executive Summary

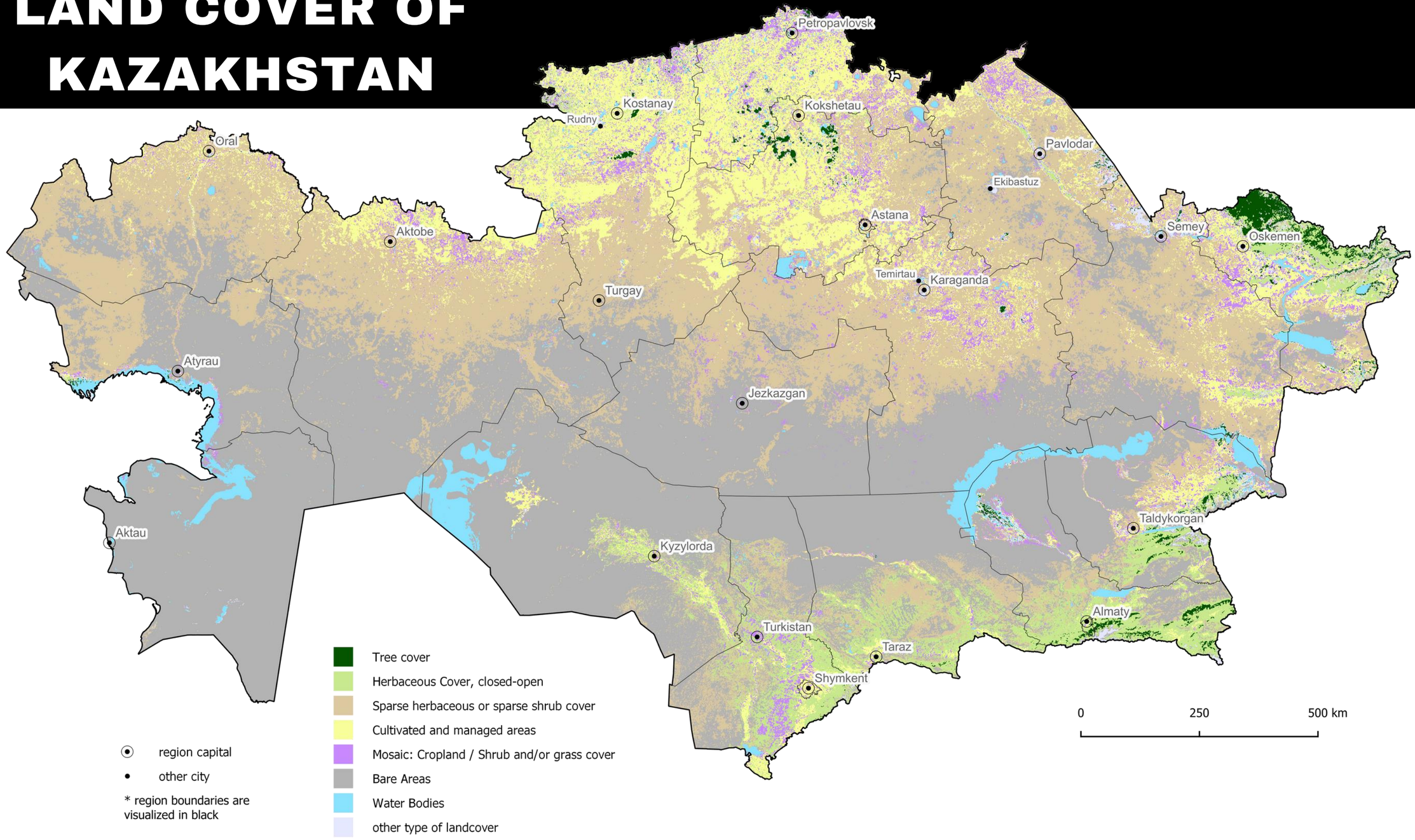
INTRODUCTION

Kazakhstan in the 21st century:

- economic development
- export of fossil fuels and metals
- growth built on Soviet industrial groundwork → **environmental challenges and consequences**

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

LAND COVER OF KAZAKHSTAN



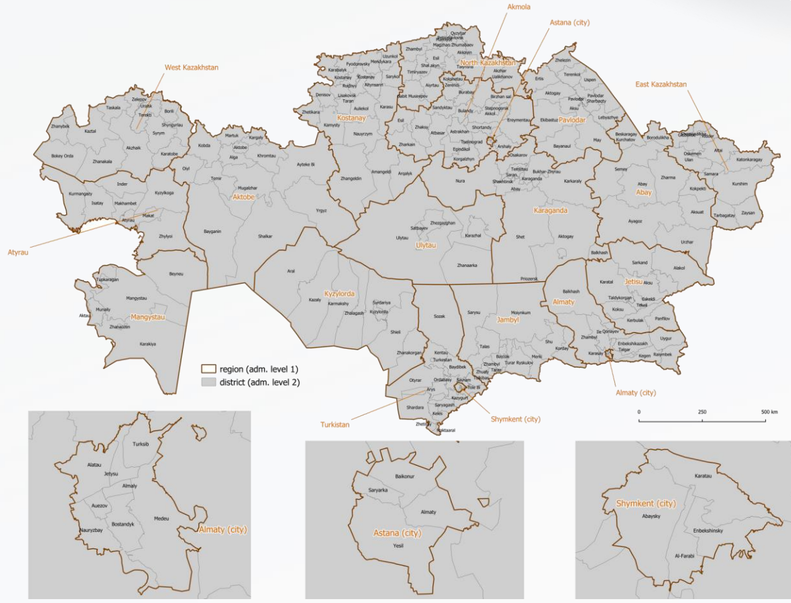
ADMINISTRATIVE DIVISIONS OF KAZAKHSTAN

17 REGIONS

3 CITIES

ASTANA
ALMATY
SHYMKENT

DISTRICTS



INTERPLAY OF CLIMATE CHANGE AND AIR POLLUTION

01 Potential to curtail the country's footprint despite significant amounts 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**

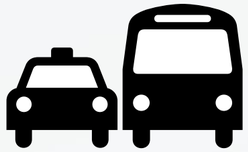
Air pollution + Climate change in Kazakhstan?

Black snow in Temirtau

CLIMATE CHANGE & AIR POLLUTION

AIR POLLUTION CAUSES:

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



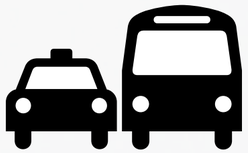
Nitrogen dioxide (NO_2)

Methane (CH_4)

Sulfur dioxide (SO_2)

Particulate matter (PM_{10})

KEY POLLUTANTS



Nitrogen dioxide (NO_2)

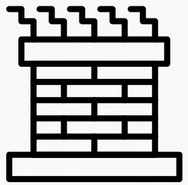
- Mainly from transport and chemical industry
- Causes respiratory infections and acid rains

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
- Cassified 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. Mangystau, 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 of 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)

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} 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)

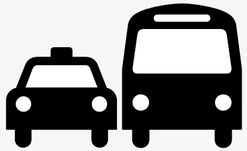
03

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

RESULTS

BASIC ANALYSIS

SEASONALITY OF AIR POLLUTION



Nitrogen dioxide
(NO_2)

Methane
(CH_4)

Sulfur dioxide
(SO_2)

Particulate matter
(PM_{10})

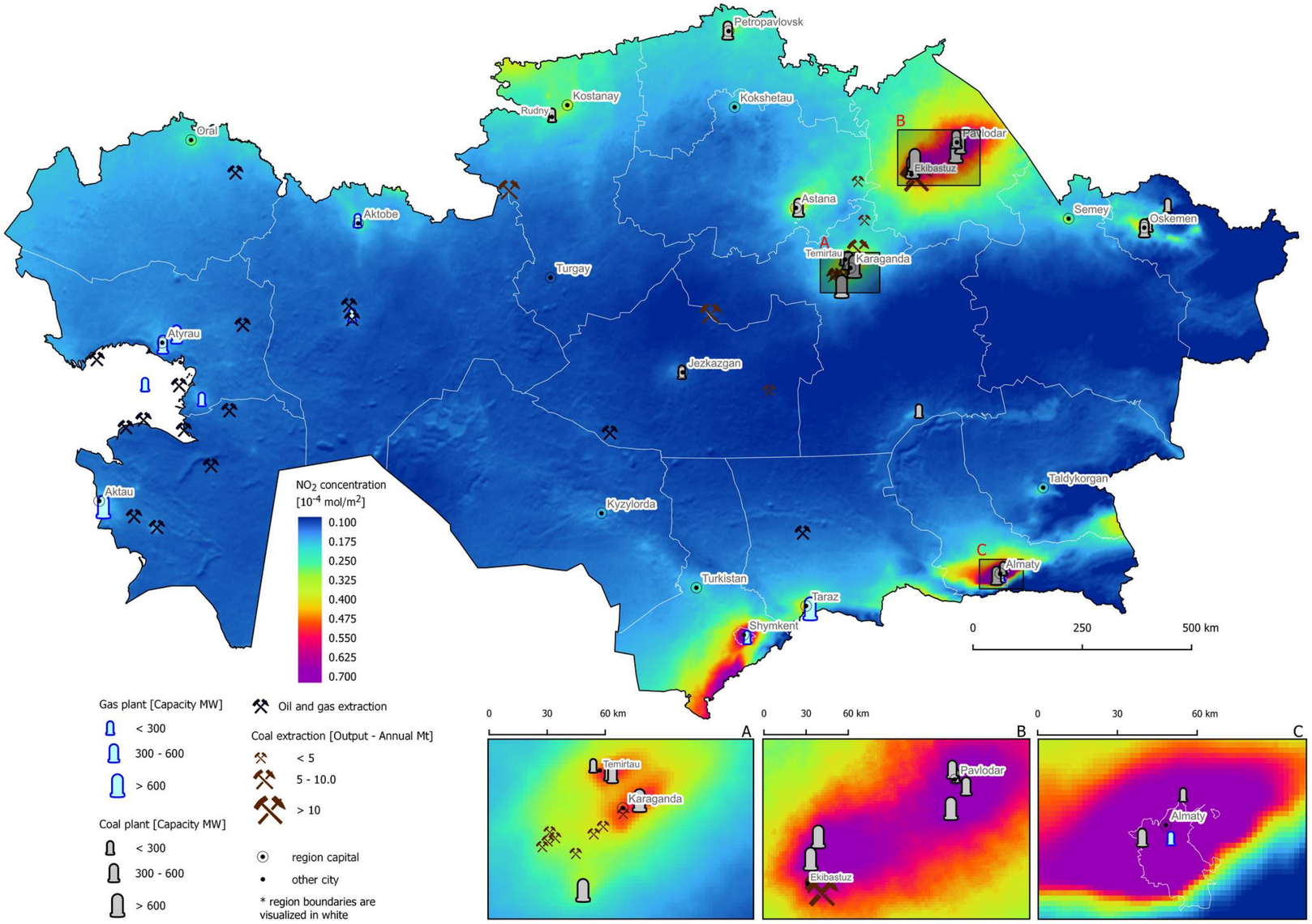
NO_2

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

- **Karaganda** - many mining sites
- **Pavlodar** - one of the most important industrial cities of KZ
- **Almaty** - the most populous city (location in the foothills of the mountains)

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS



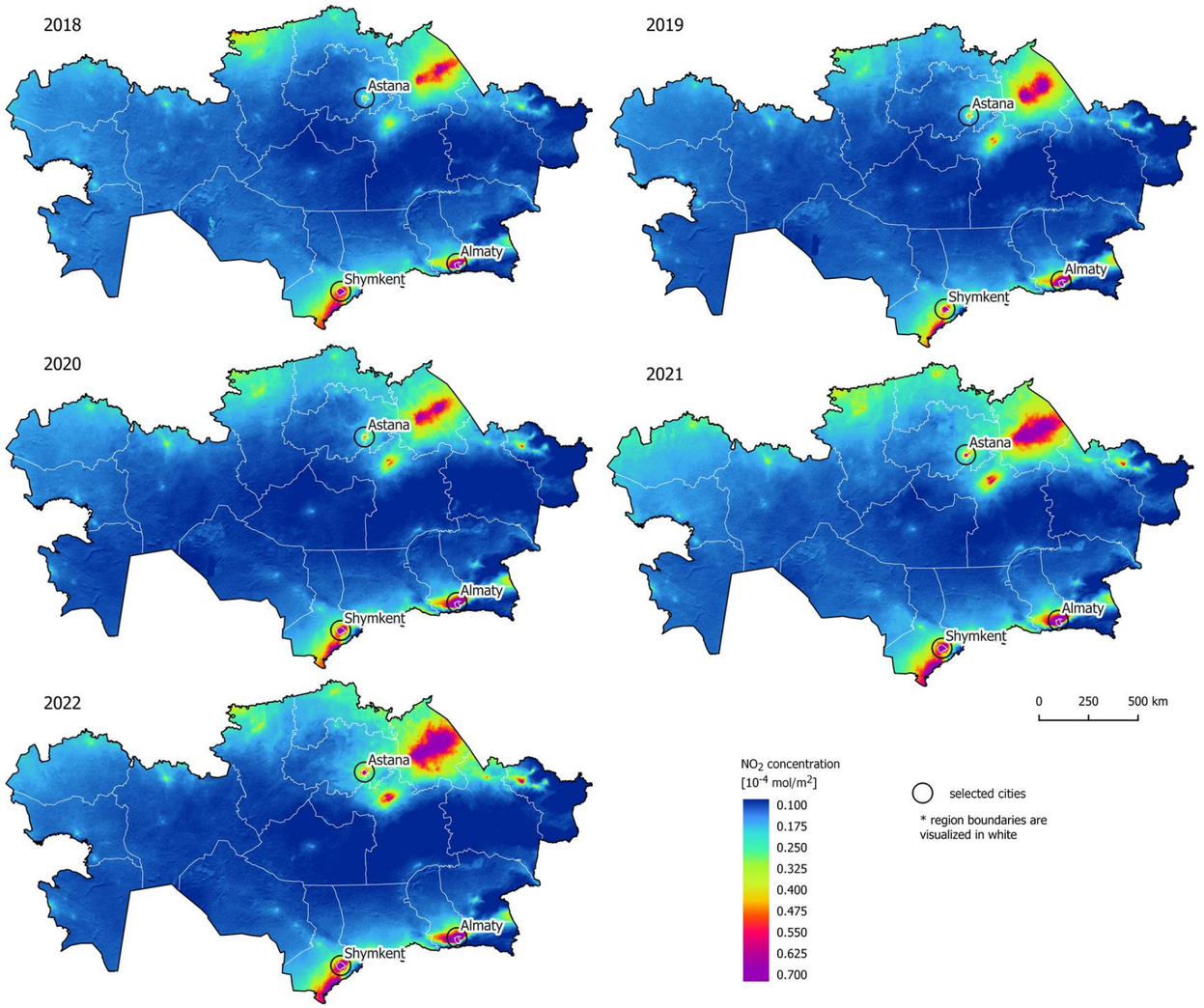
NO_2

- 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



NO_2

- **Ø NO_2 concentrations in the regions of KZ**
  - cities **(Almaty, Astana, Shymkent)**
  - regions **(Pavlodar, Turkistan, North KZ)**
- **20 highest NO_2 concentrations in the districts of KZ**
  - blue for Almaty
- **Ø NO_2 concentrations in selected cities and towns of KZ**
  - Almaty, Shymkent Karaganda
- **Ø NO_2 concentrations in selected coal-fired power plants of KZ**
  - Almaty (2,3), Pavlodar

NITROGEN DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS

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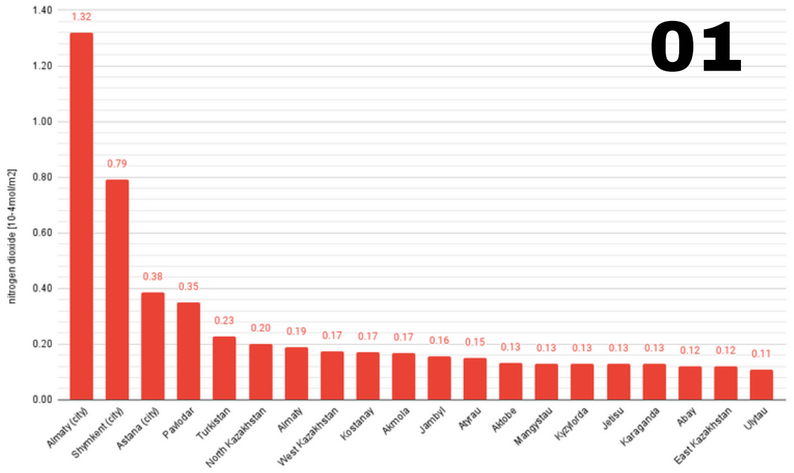

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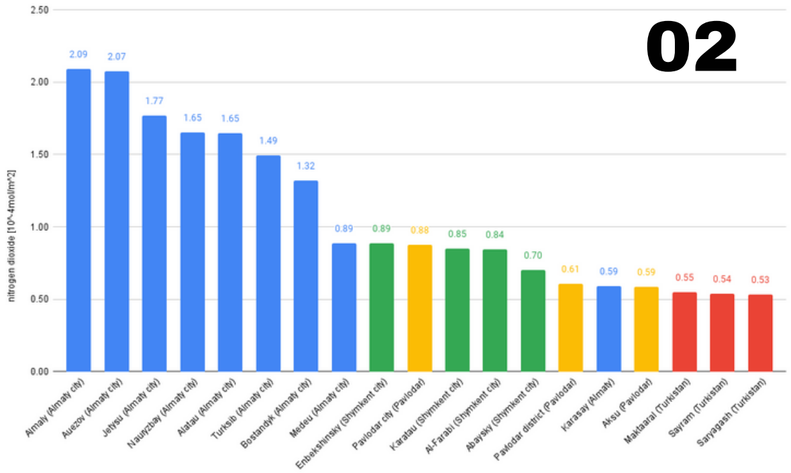

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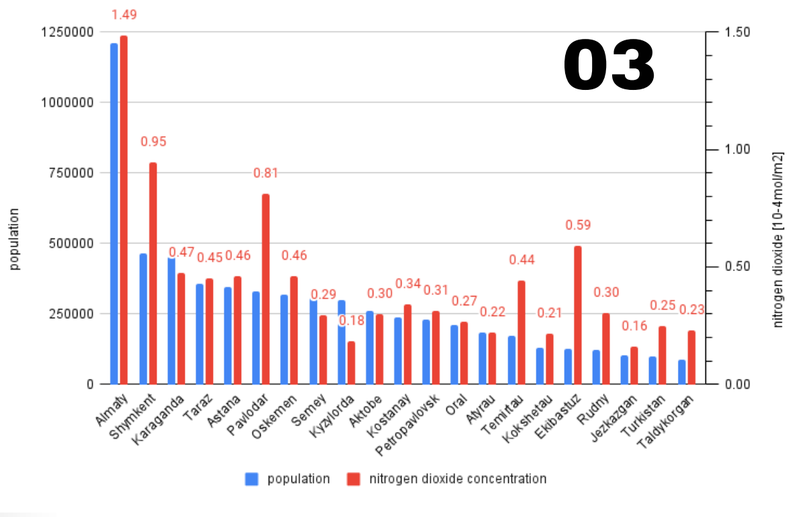

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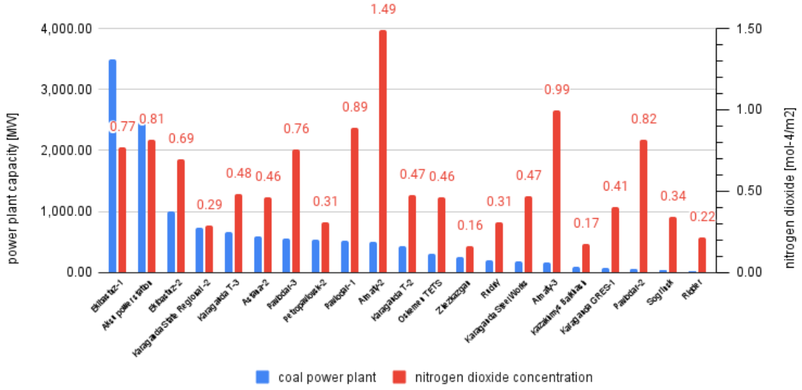
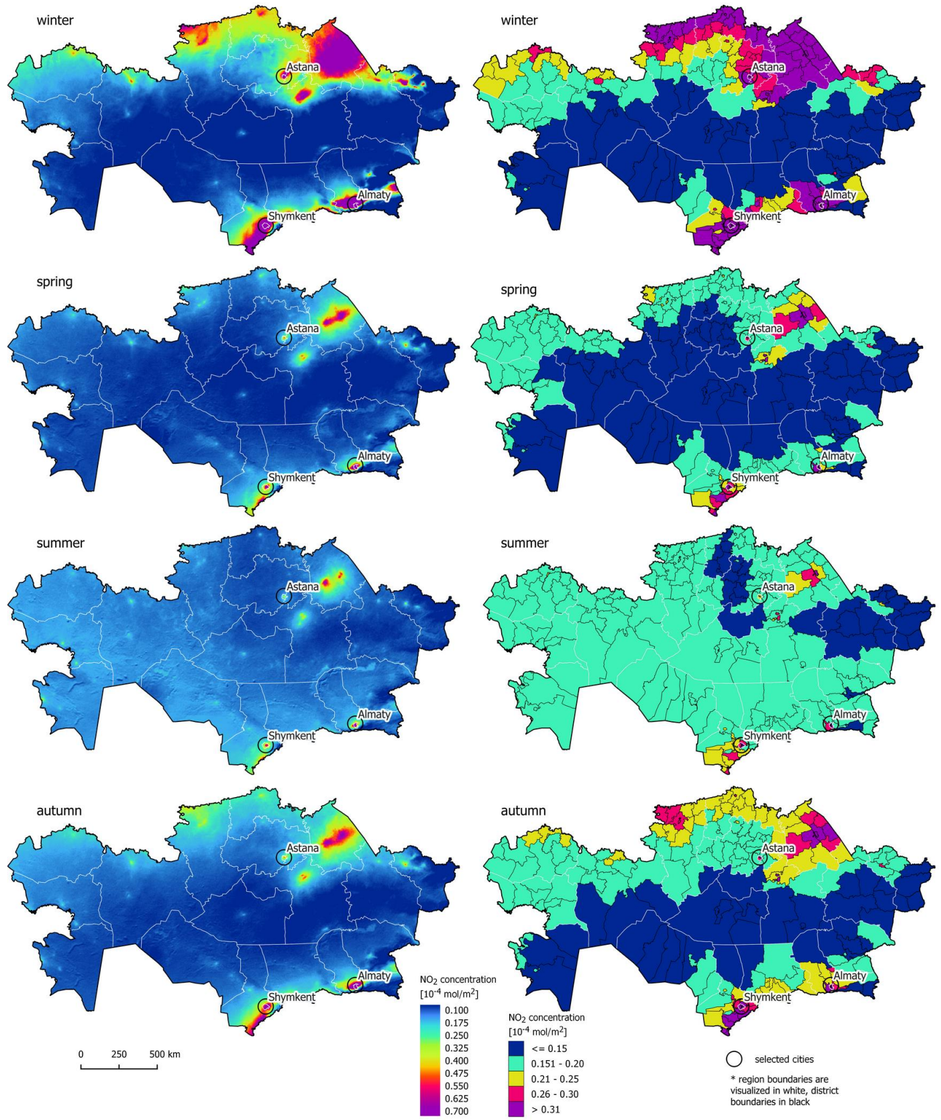


NO_2

- 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

NITROGEN DIOXIDE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION



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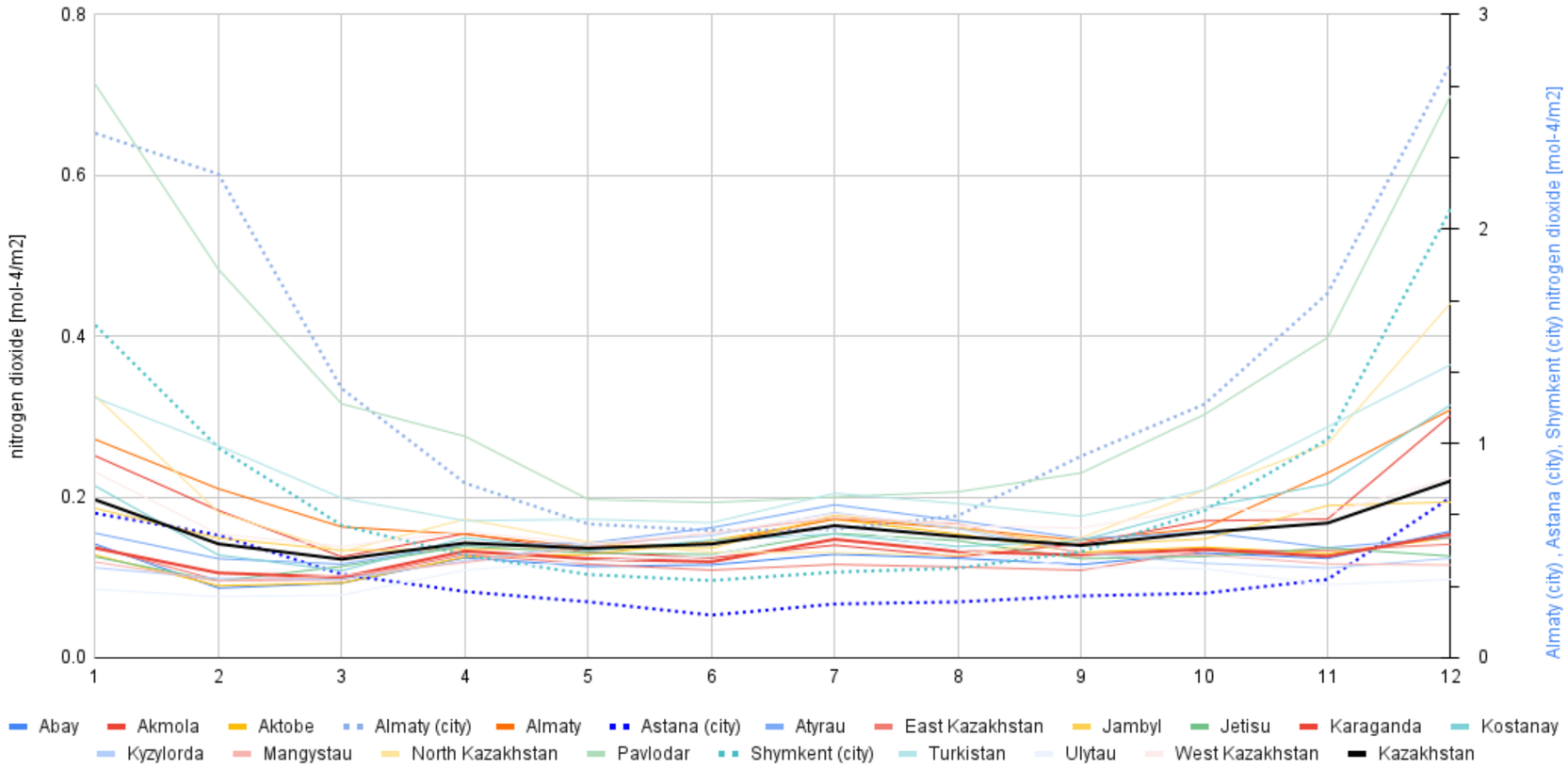
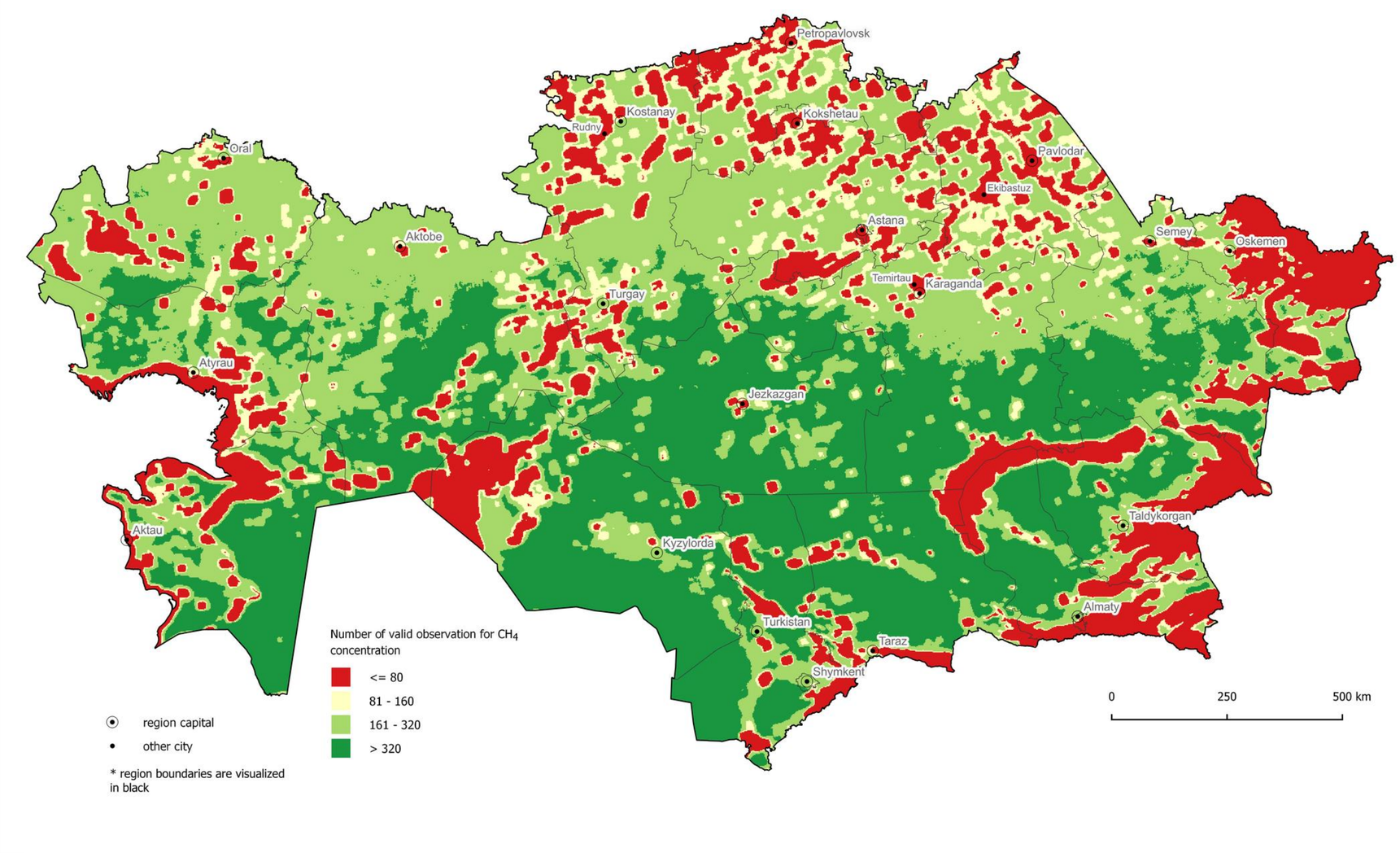


CH_4

- **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

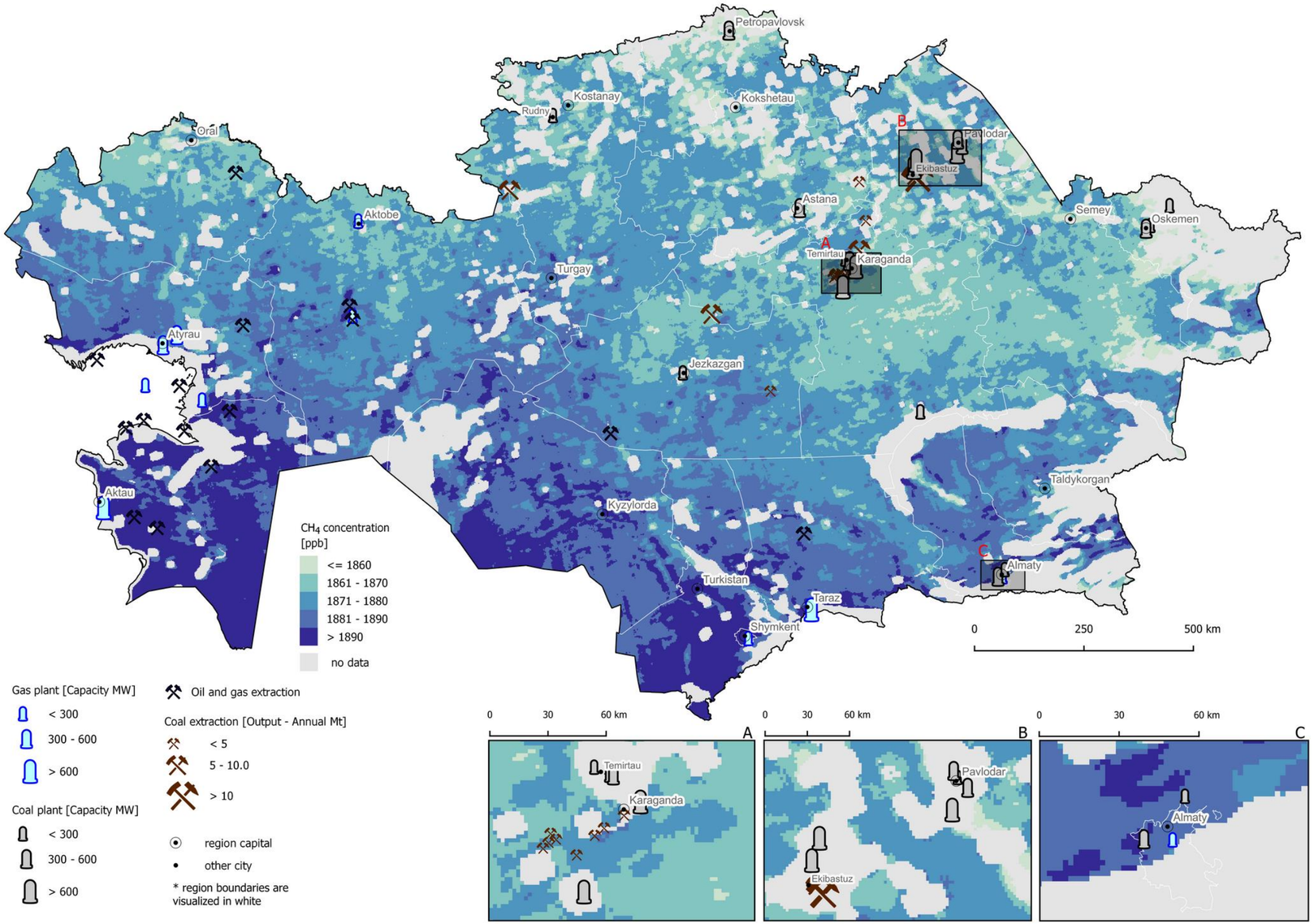


CH_4

METHANE (5/2018-12/2022)

BASIC ANALYSIS

- Spatial pattern of the average CH_4 **not entirely clear (land cover and local climate?)**
- Important role of **natural conditions** (·OH oxidation)

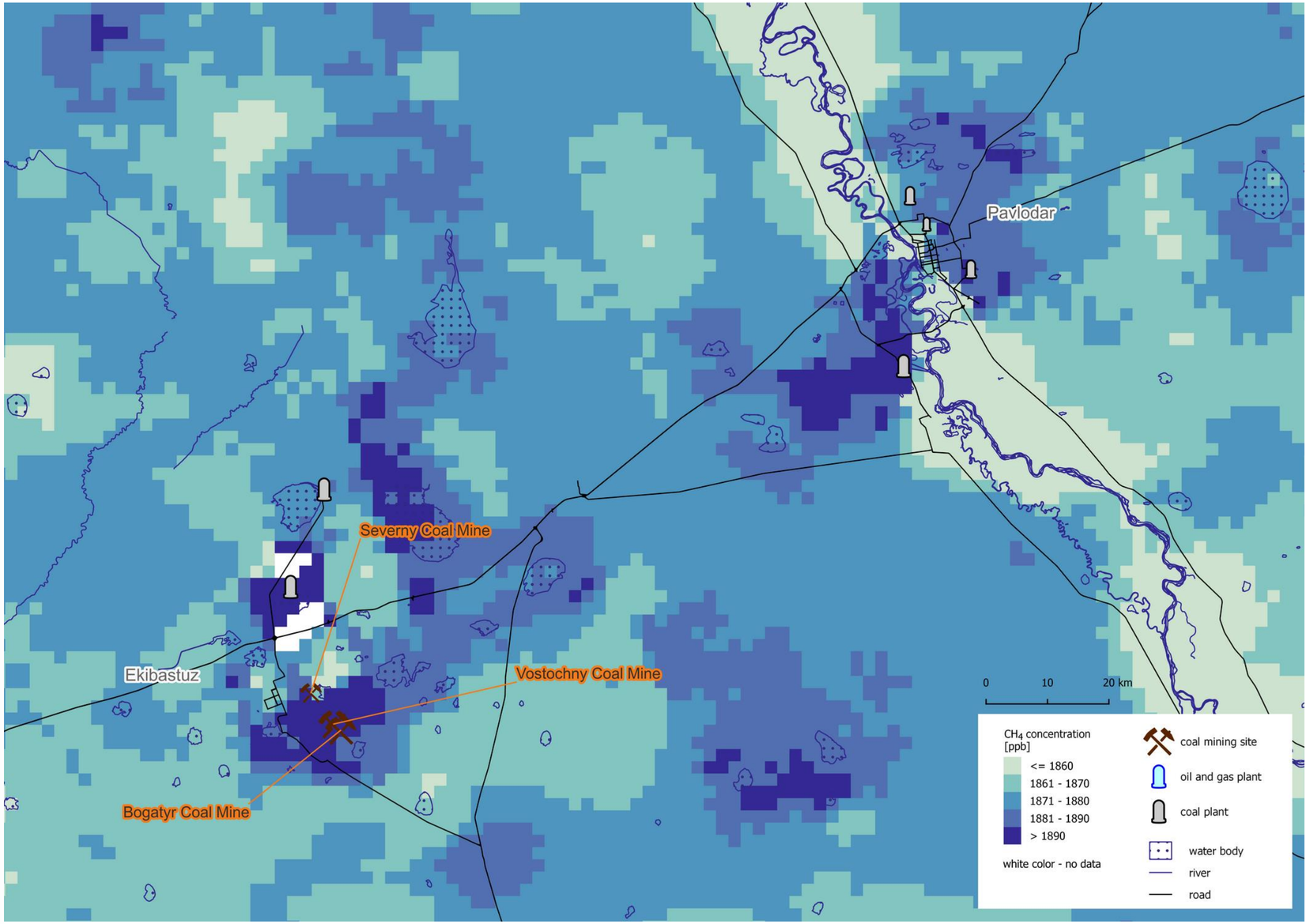


CH_4

METHANE (5/2018-12/2022)

BASIC ANALYSIS

- **Lower CH_4 emissions from surface mines compared to underground mines** (rare)
- **Exceptions for Bogatyr, Vostochny and Severny mines** (higher concentrations)



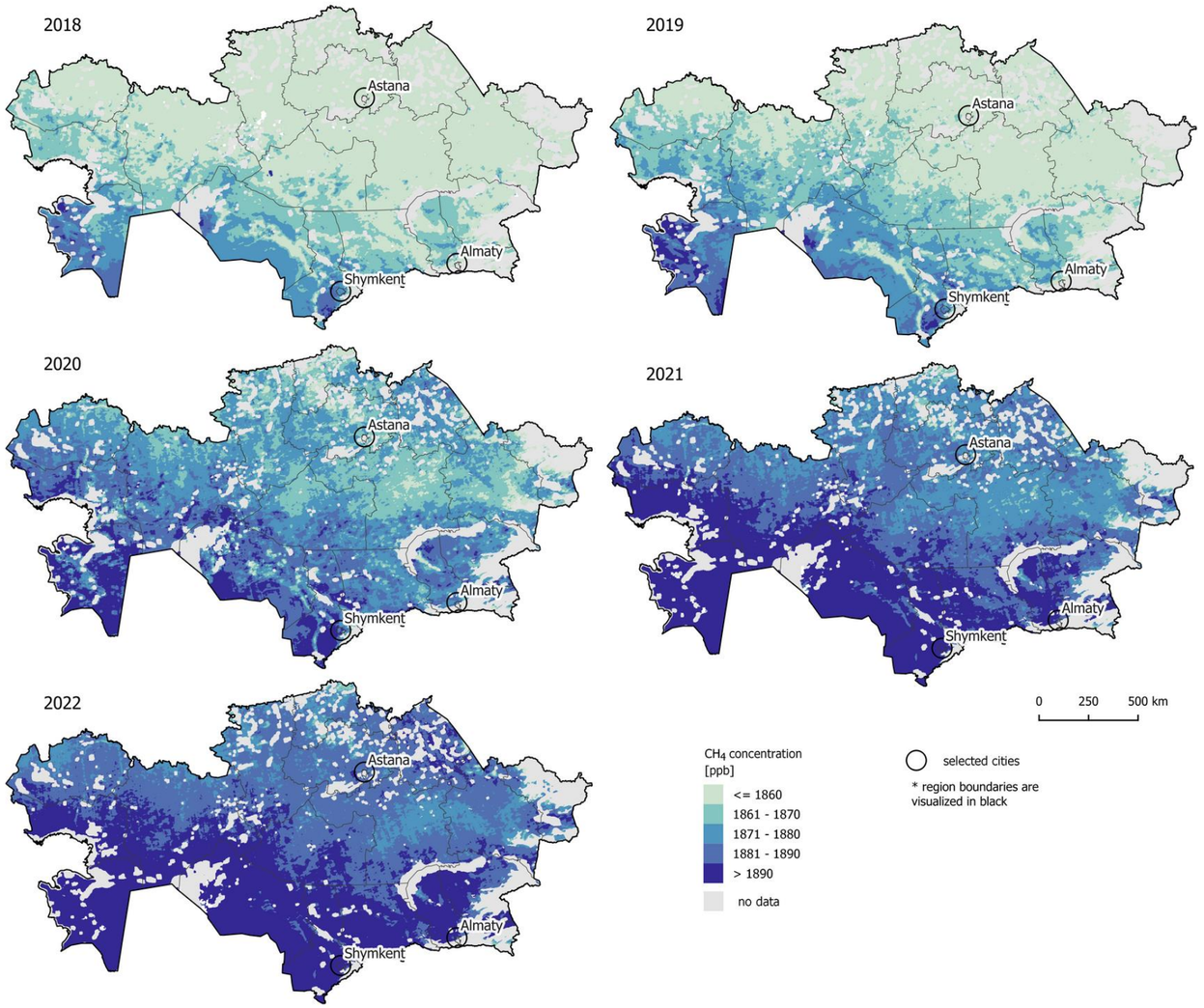
CH_4

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 (9 ppb/year))



CH_4

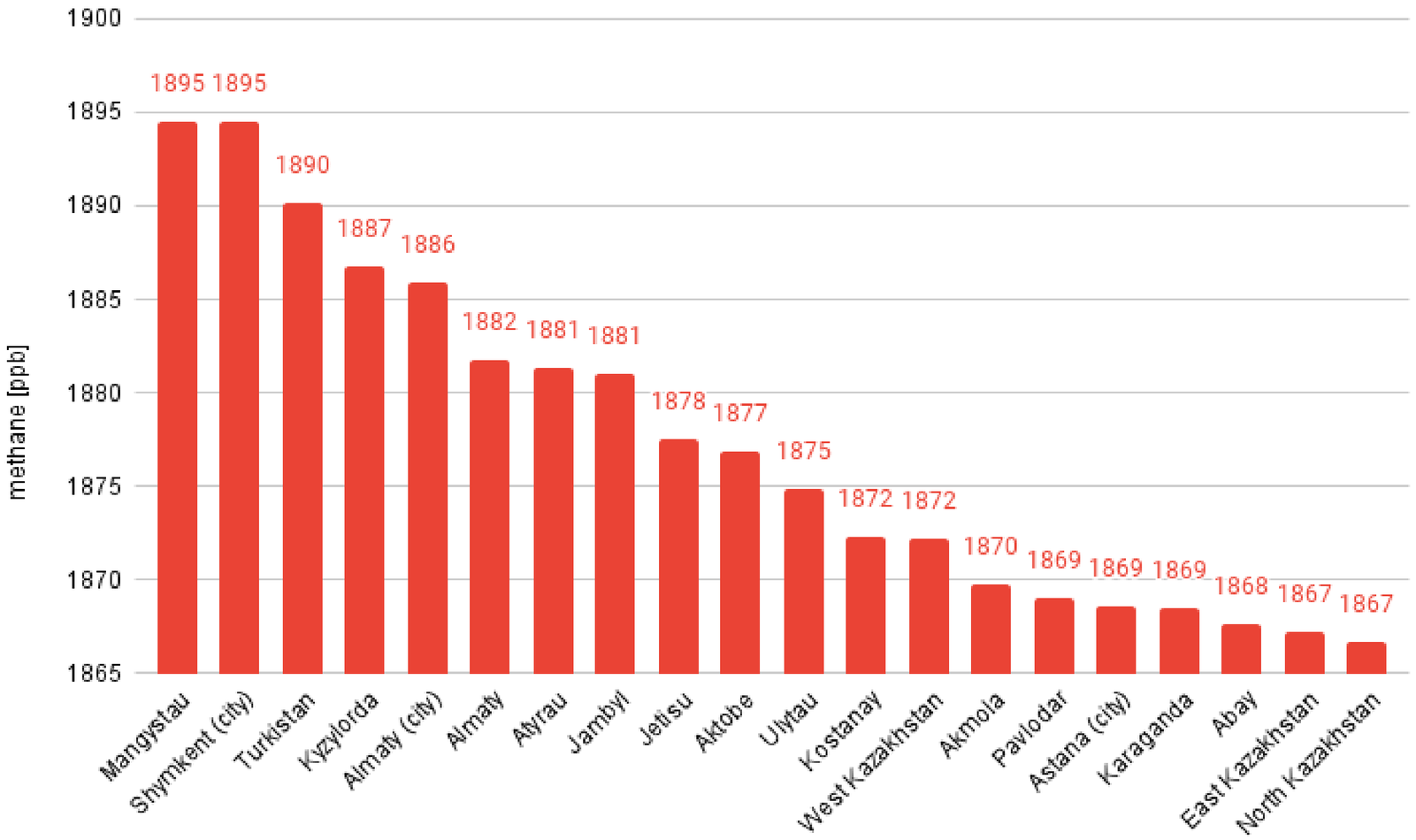
Ø CH_4 concentrations in the regions of KZ

- **Mangystau**
- **Shymkent**
- **Turkistan**
- **Kyzylorda**

lower oxidizing potential of CH_4 in arid south of KZ

METHANE (5/2018-12/2022)

BASIC ANALYSIS

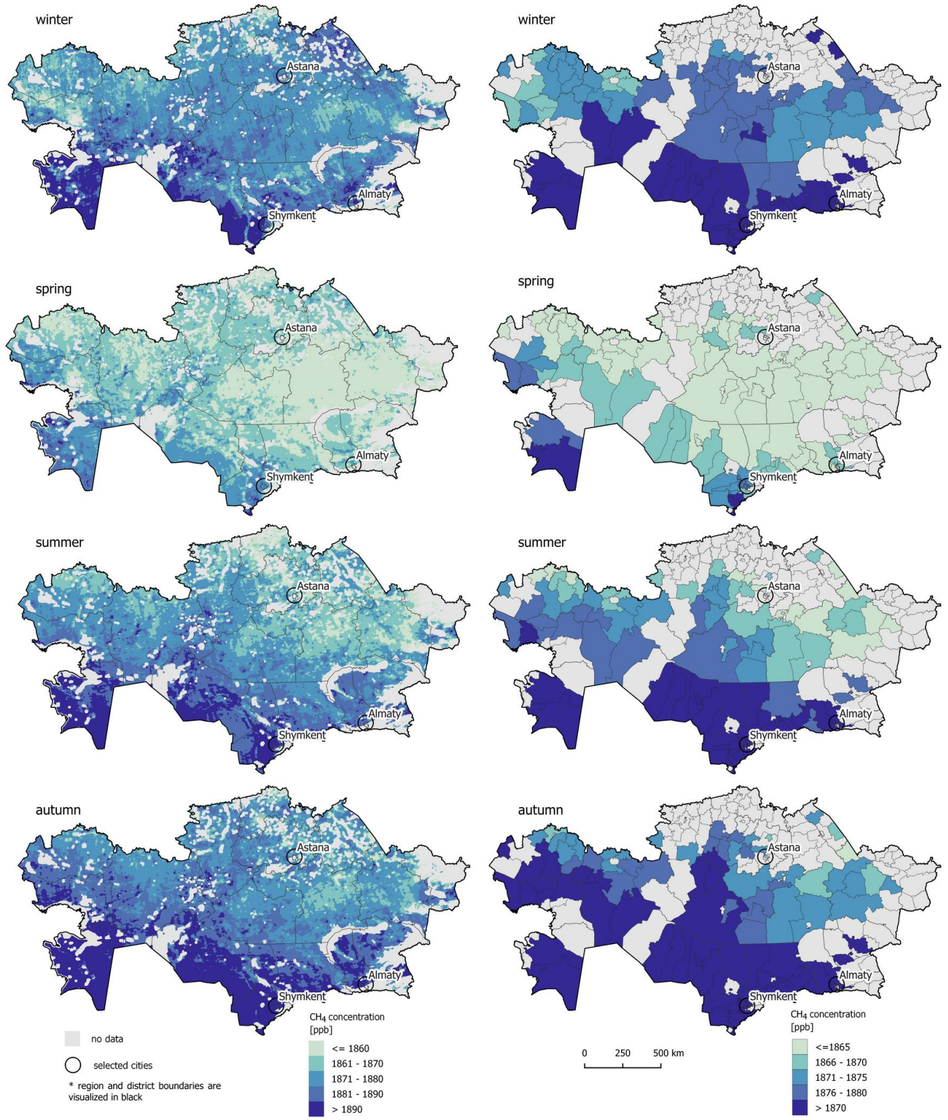


CH_4

METHANE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION

- highest concentration in **areas with little rainfall and humidity and sparse vegetation regardless the season**
- **highest concentration in autumn/winter**
- **lowest concentration in spring**



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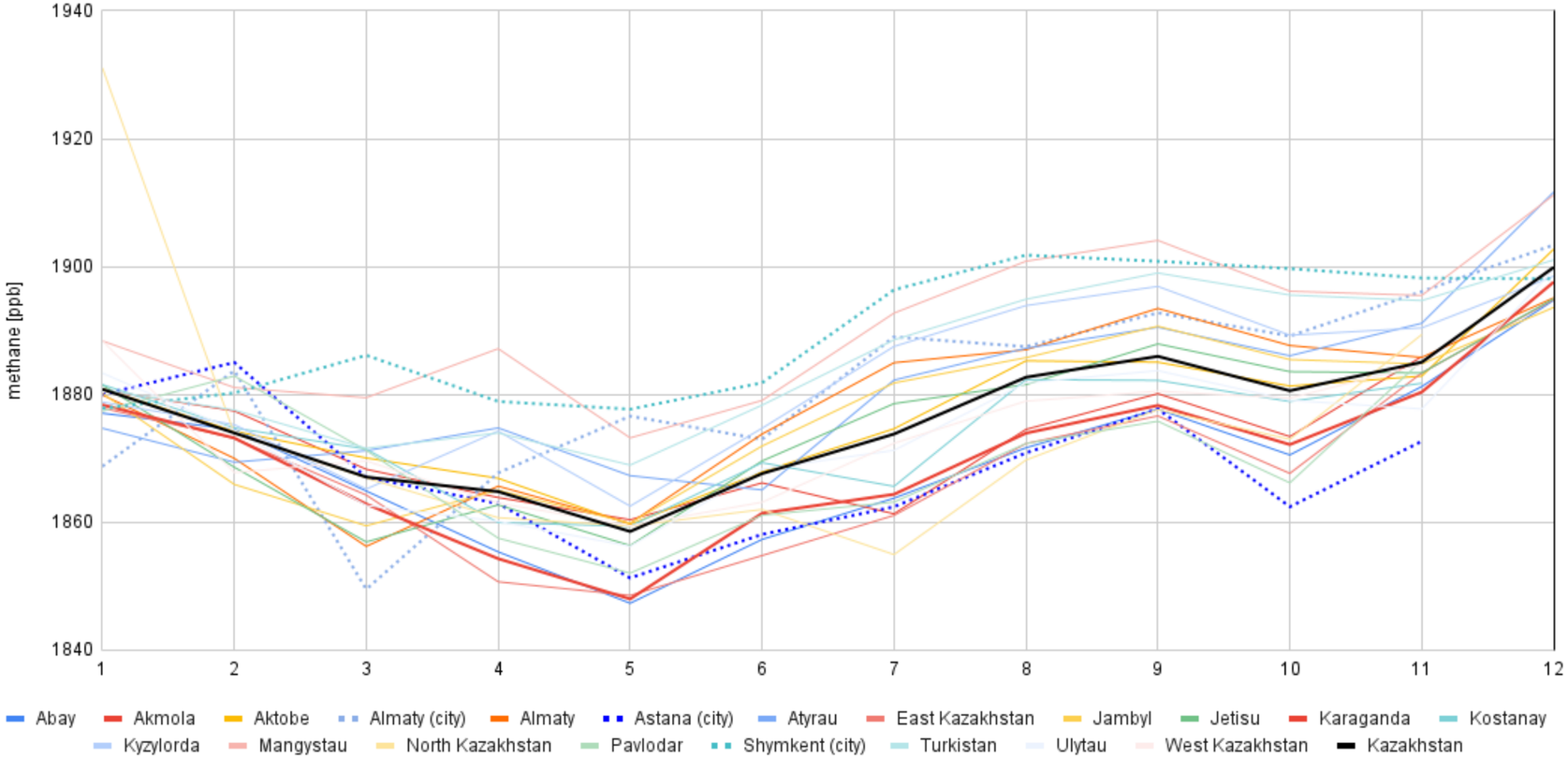


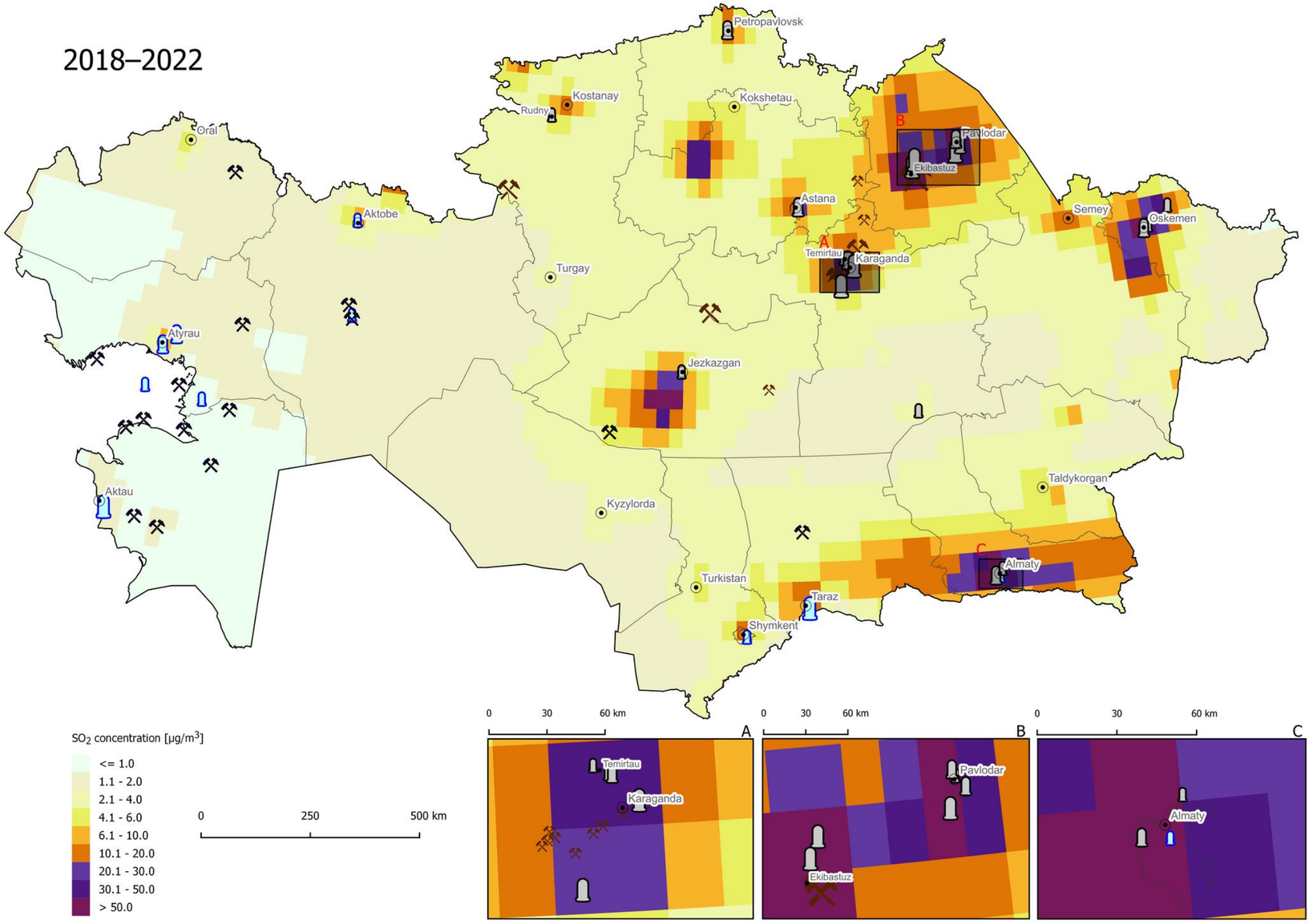
SO_2

SULFUR DIOXIDE (2018-2022)

BASIC ANALYSIS

- **Highest concentration in areas with mining industries and near coal-fired power plants** (Pavlodar, Almaty)
- Before 2019 - model under- or overestimated some areas (**Jezkazgan example**)
- Model reliant on in-situ data (**Balkhash?**)

Model calculation change in 2019
2 map visualizations



SO_2

SULFUR DIOXIDE (2020-2022)

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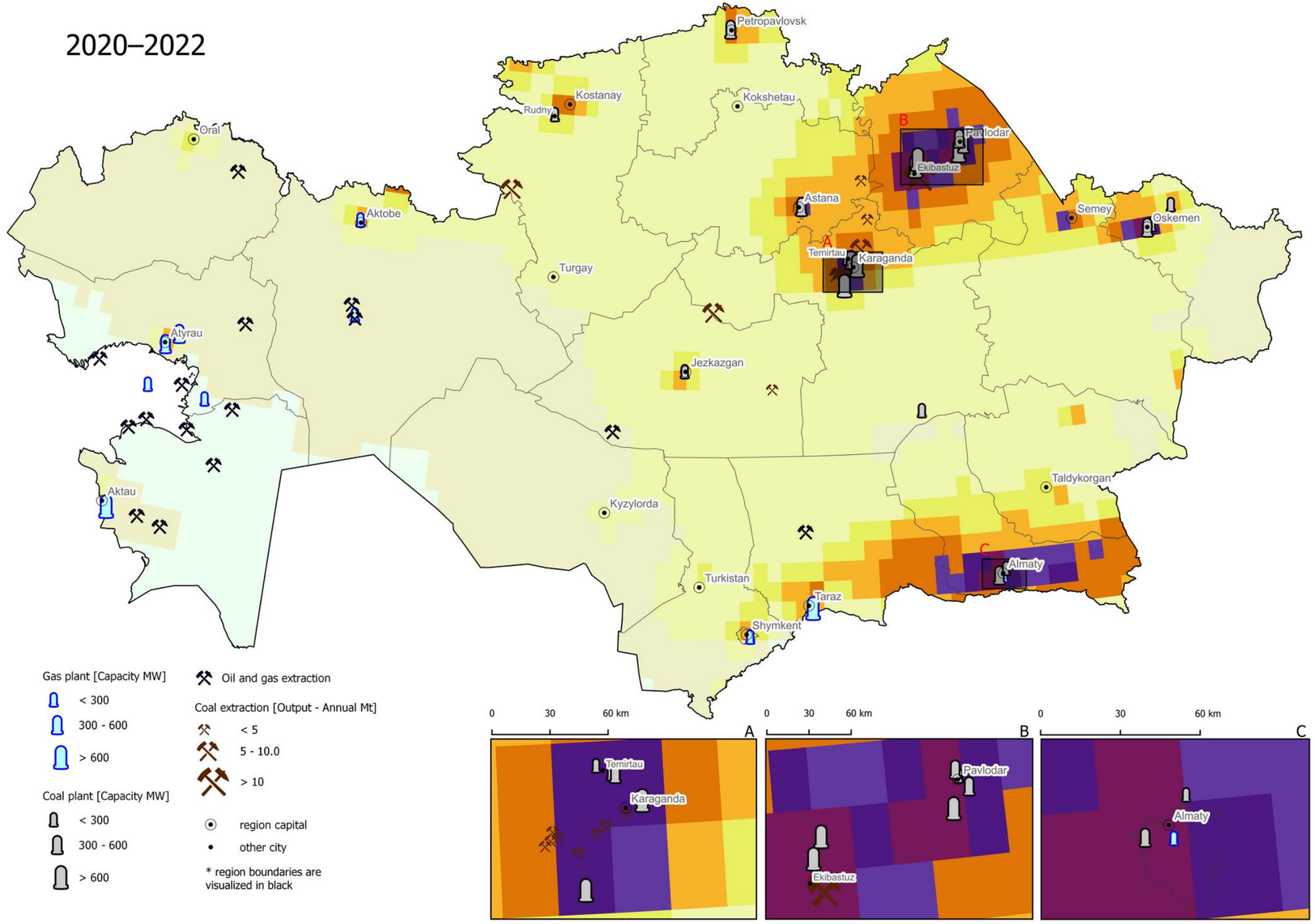


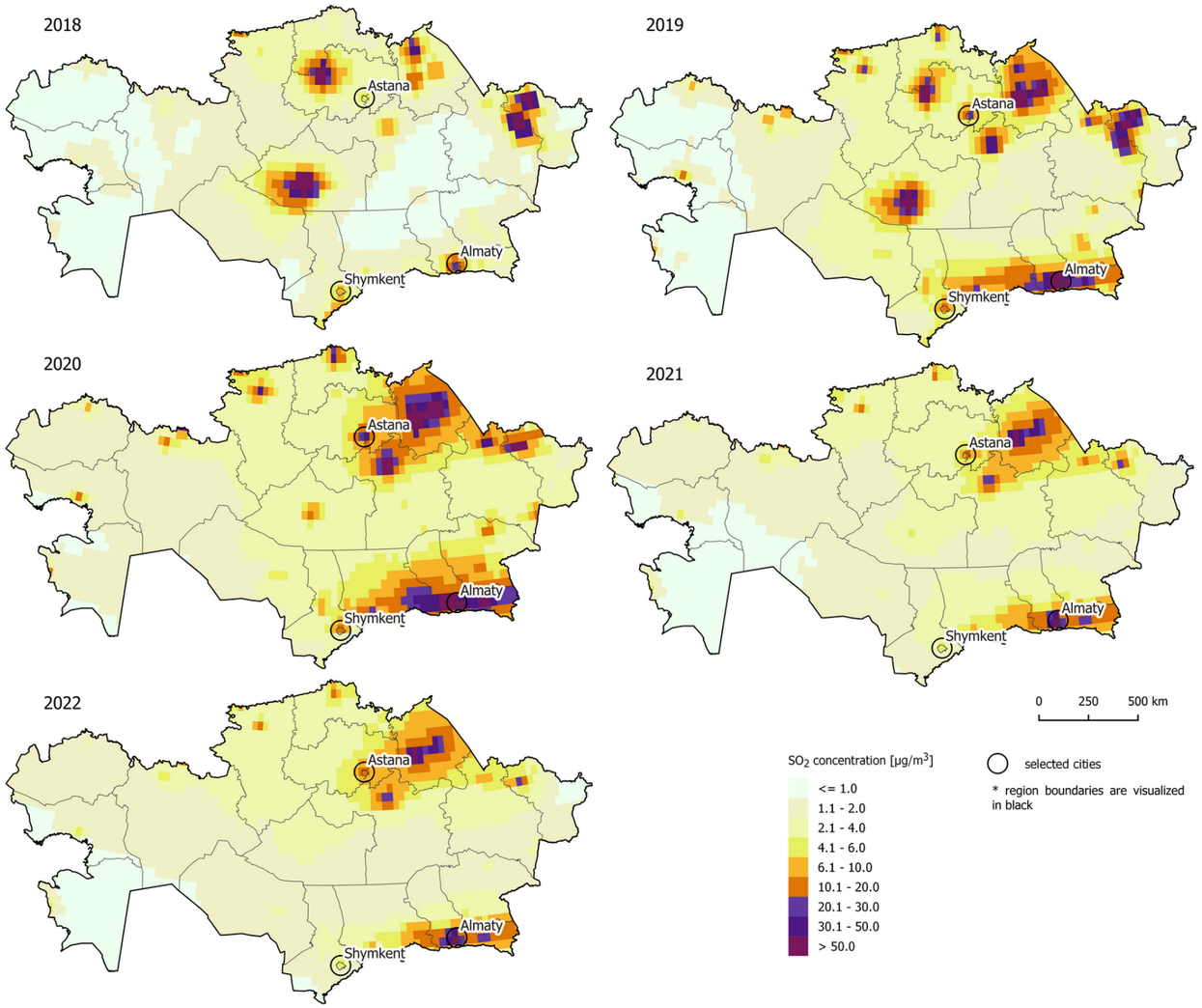
SO_2

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**



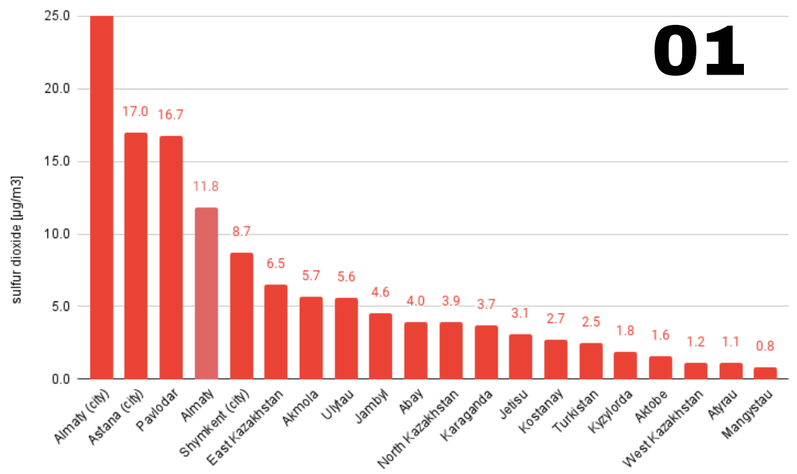
SO_2

SULFUR DIOXIDE (5/2018-12/2022)

BASIC ANALYSIS

- **01 Ø SO_2 concentrations in the regions of KZ**
  - cities **(Almaty, Astana)**
  - regions **(Pavlodar, Almaty)**
- **02 20 highest SO_2 concentrations in the districts of KZ**
  - blue for Almaty
- **03 Ø SO_2 concentrations in selected cities and towns of KZ**
  - Ekibastuz, Oskemen, Pavlodar
- **04 Ø SO_2 concentrations in selected coal-fired power plants of KZ**
  - Ekibastuz 1,2, Almaty 2

01



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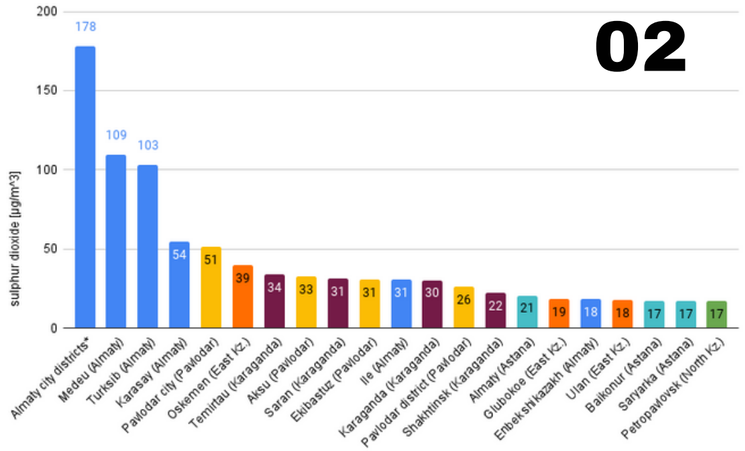

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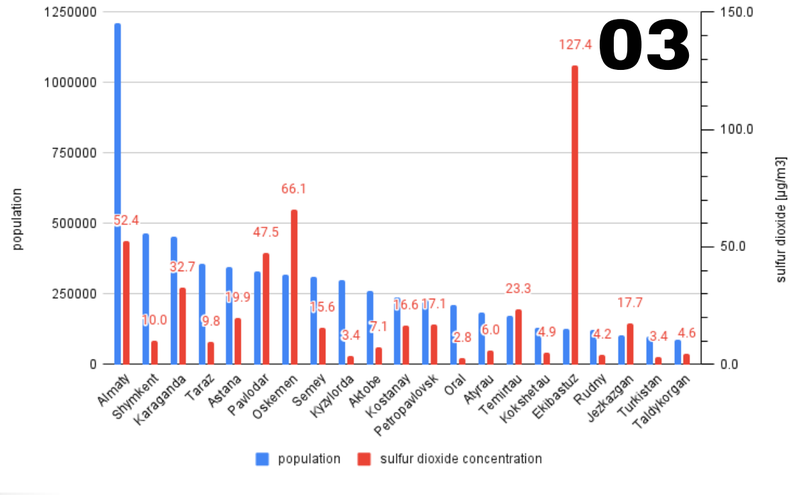

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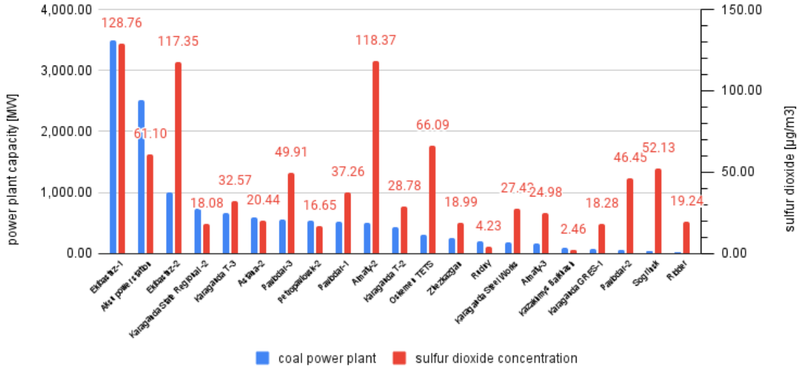
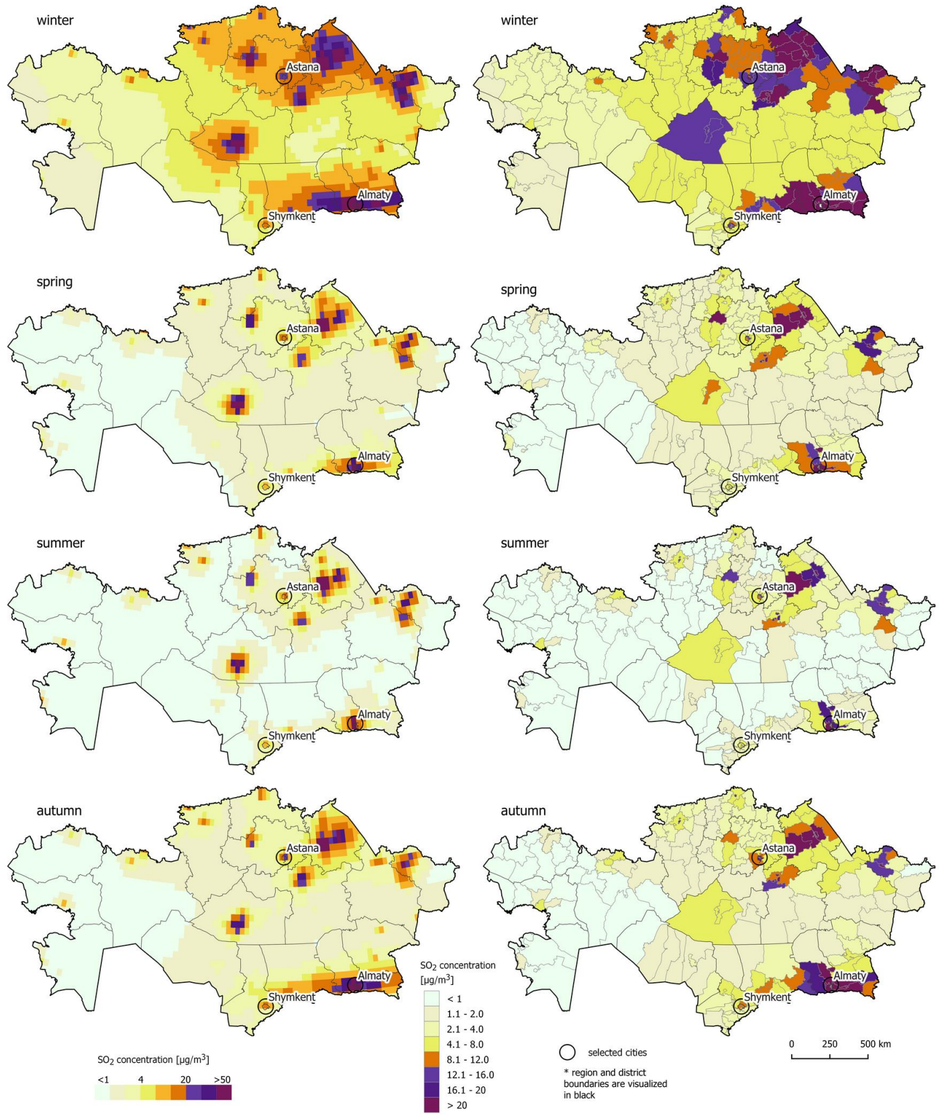


SO_2

- SO_2 **concentration peak in winter** (low deposition + higher emissions due to heating)
- **Consistently high concentrations** in some areas (exceeding WHO and KZ limits)
  - Almaty, Pavlodar, Ekibastuz

SULFUR DIOXIDE (5/2018-12/2022)

SEASONALITY OF AIR POLLUTION



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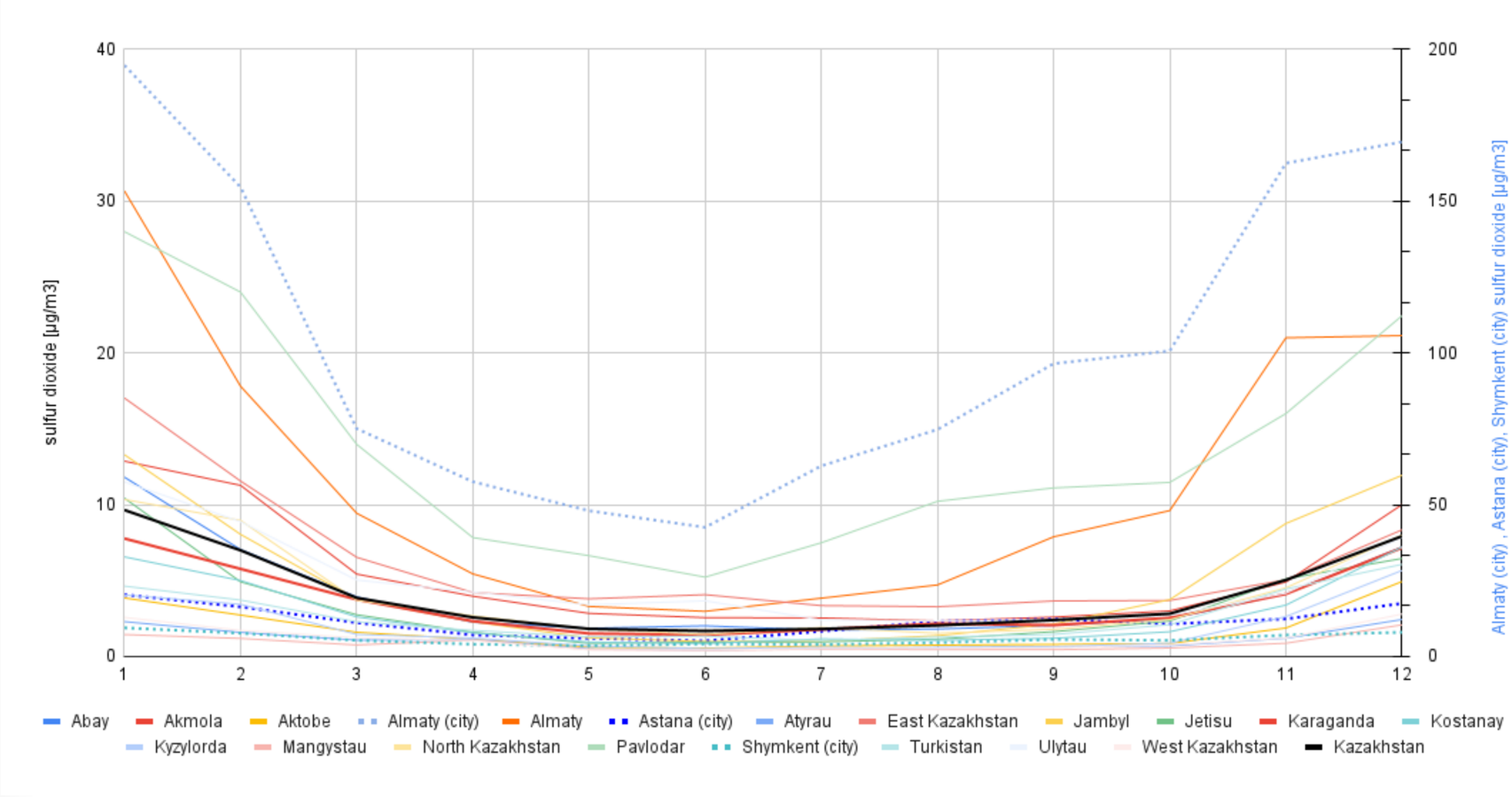
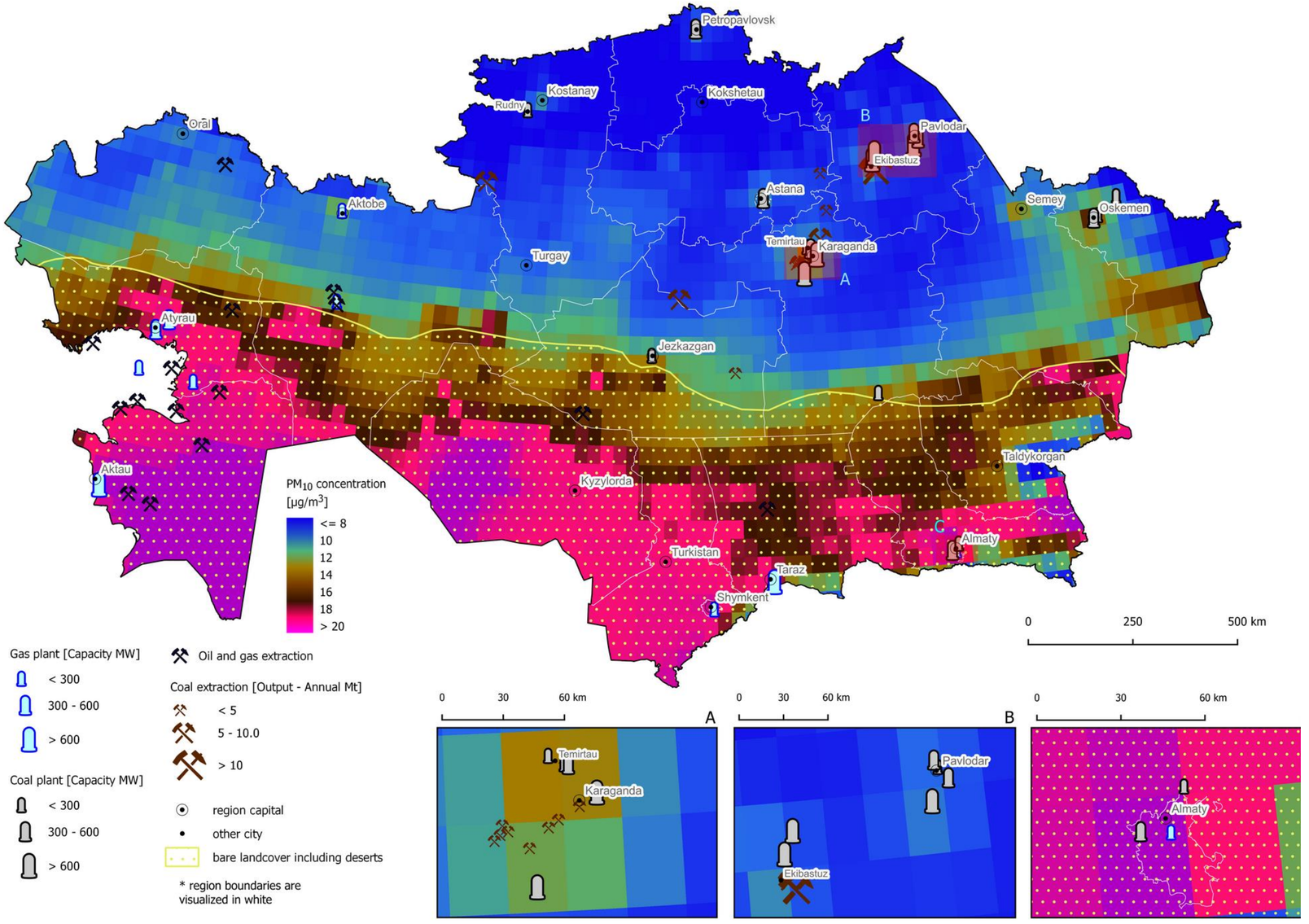


PM_{10}

- **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, Temirtau, Oskemen, Aktobe, Astana, Kostanay

PARTICULATE MATTER

BASIC ANALYSIS (5/2018-12/2022)



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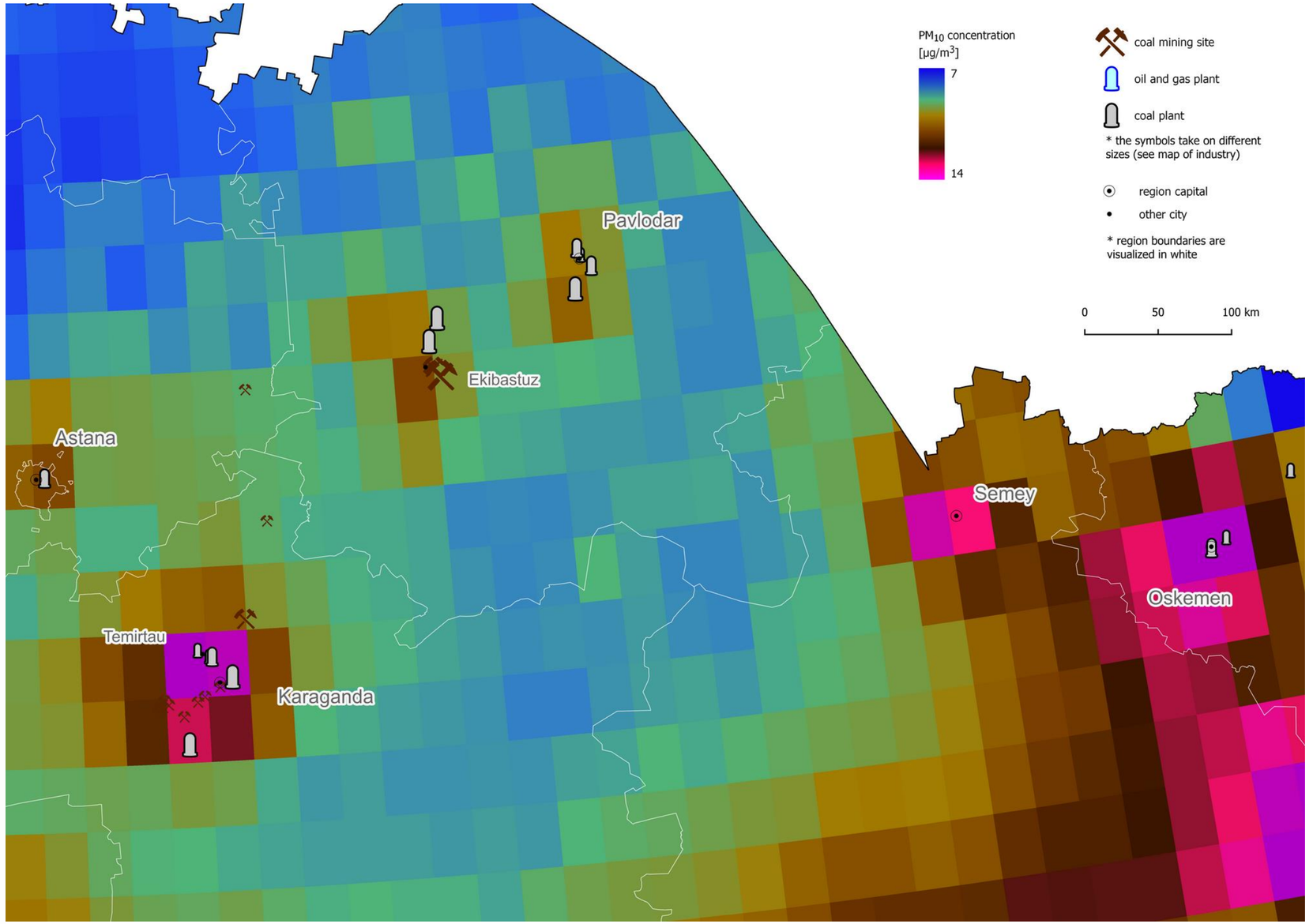


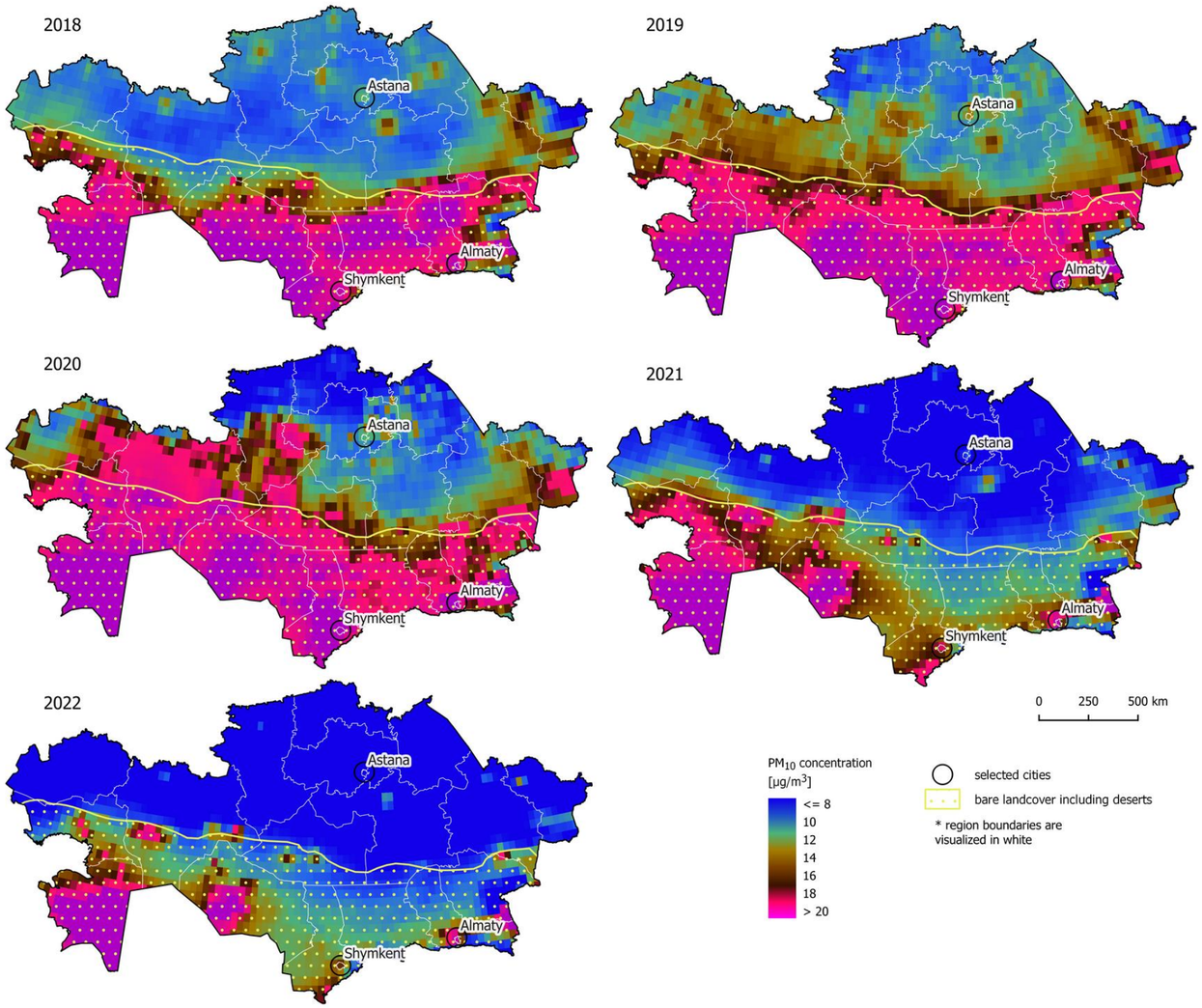
PM_{10}

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

PARTICULATE MATTER

BASIC ANALYSIS (2018-2022)

YEARLY COMPARISON



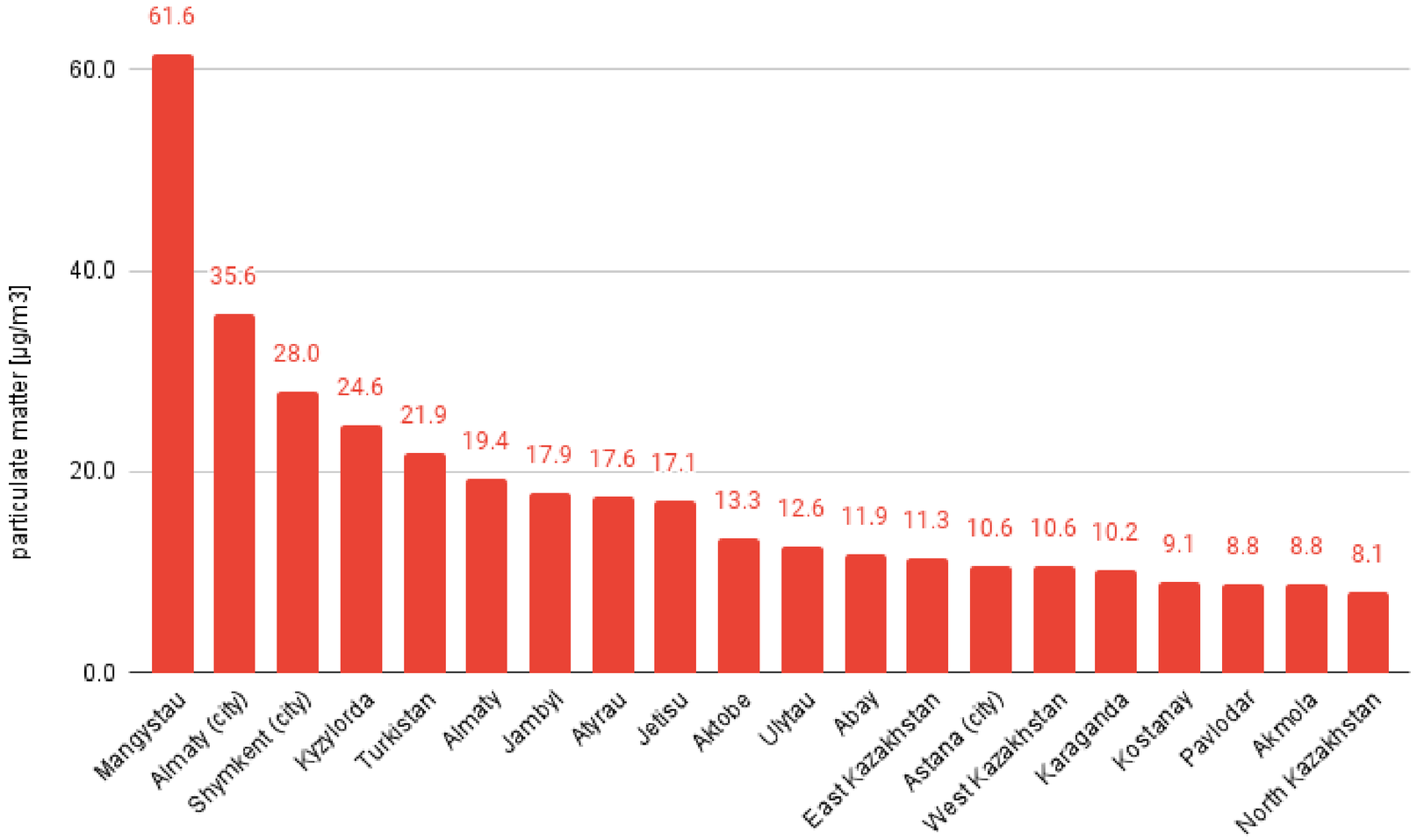
PM_{10}

Ø PM_{10} concentrations in the regions of KZ

- Mangystau
- Almaty (city)
- Shymkent (city)
- Kyzylorda

PARTICULATE MATTER 10

BASIC ANALYSIS (5/2018-12/2022)

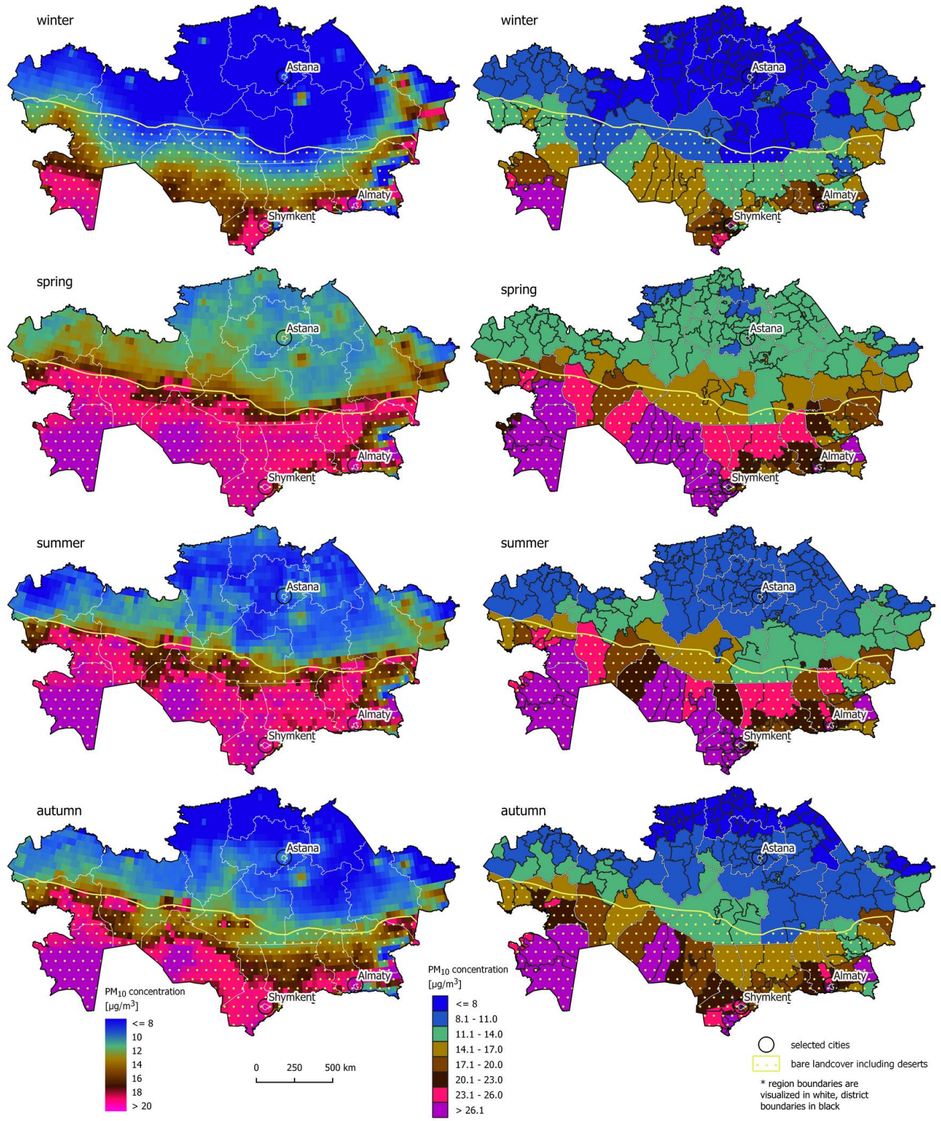


PM_{10}

- seasonal changes influenced by **natural conditions** (national scale)
- **Increased concentrations regardless the season** (south of the KZ)
- **spring, summer** - high due to dust storms
- **lowest in winter in the North of KZ**
- **Karaganda, Oskemen** (in all seasons - anthropogenic activity)

PARTICULATE MATTER 10 (5/2018--12/2022)

SEASONALITY OF AIR POLLUTION



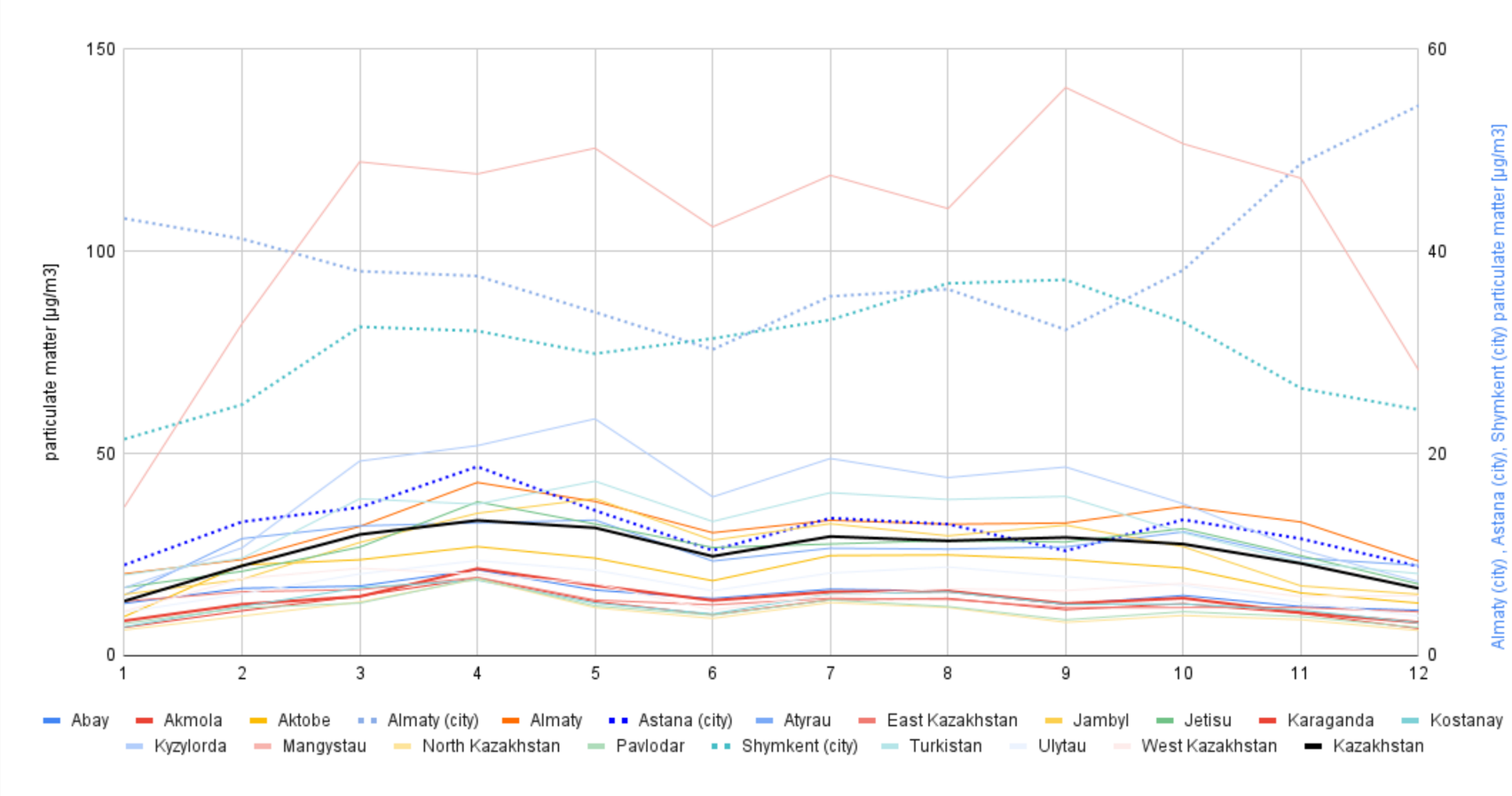
PM_{10}

- **Highest PM_{10} concentrations in spring and summer**
- **Mangystau Region**
- **PM_{10} increase for some cities in the winter months** (anthropogenic activities)
- Significantly **higher concentrations in cities with mines, power plants or the metallurgy industry**
  - Oskemen
  - Karaganda
  - Temirtau
  - Semey

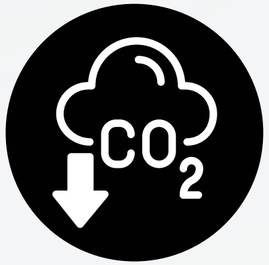
PARTICULATE MATTER 10

SEASONALITY OF AIR POLLUTION

(5/2018-12/2022)



RECOMMENDATIONS



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

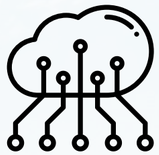
Path towards **carbon neutrality in 2060**

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



Strengthen air quality monitoring and data collection

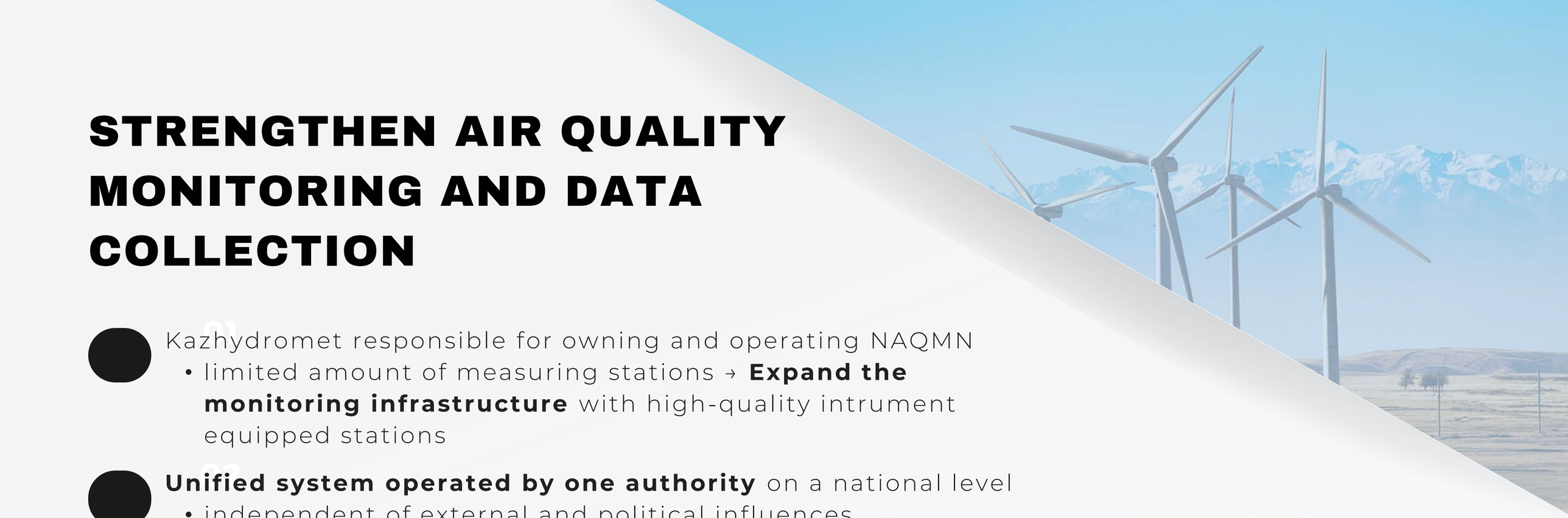
Ramp down coal use and renewable energy deployment

Regulatory frameworks, environmental liability and local emission inventories

Energy efficiency and emission control measures for industries

Public awareness and participation

STRENGTHEN AIR QUALITY MONITORING AND DATA COLLECTION



01

Kazhydromet responsible for owning and operating NAQMN
- limited amount of measuring stations → **Expand the monitoring infrastructure** with high-quality intrument equipped stations

02

Unified system operated by one authority on a national level
- independent of external and political influences
- data validation
- standardized measurement techniques

03

Potential of citizen monitoring network
- AirKaz.org
- engaging public to contribution (online tools, applications, mobile platforms)
- accessible real-time data

04

Regular utilization of satellite monitoring
- broader perspective on spatio-temporal changes (+ transborder pollutants)

RAMP DOWN COAL USE AND RENEWABLE ENERGY DEPLOYMENT

01
Preventing the building of new fossil fuel power plants
- diversification of the energy production among renewable sources.

02
Development of a **comprehensive plan for gradually reducing coal consumption**
- essential collaboration with coal plant operators, miners, and relevant stakeholders

03
Planning for the exit of coal plants and coal mines should take into account the **upstream impact on the coal mining sector** (potential job losses, the need for alternative livelihood opportunities)
- support programs, diversification of local economies

04
Focus on maximizing the decarbonization this sector - efforst to **maximally reduce flaring and venting**, (+ minimize leaks during the handling of oil and gas products)
- using gas to balance the fluctuations in renewable energy generation

05
Investing in solar and wind farms
- supportive policies, feed-in tariffs, investment incentives to attract private sector

06
Efficient district heating and cooling + Centralized heating system
- 55 % of residential houses in KZ rely on individual heating systems (55 % of which using coal)
- subsidy programs to enhance insulation and heating systems (fund from pollution-related

REGULATORY FRAMEWORKS, ENVIRONMENTAL LIABILITY AND LOCAL EMISSION INVENTORIES

01 **Strengthening of legislation enforcement**
- lack of monitoring and enforcement to establish emission limit values (ELVs)

02 **Stringent, but proportional penalties for non-compliance** with air quality standards and regulations
- allocation of resources, legislature against lobby and corruption activities, inspections and audits

03 Issue of cross-border emissions → **establishing bilateral agreements with Russia and Uzbekistan**
- emission reduction targets, information sharing, joint monitoring

04 Development of **clean air plans**
- emission inventories to identify sources of pollutants → cost-effective mitigation measures

05 **Combat climate change and desertification** in other regions
- PM_{10} will remain persistent challenge due to natural factors

ENERGY EFFICIENCY AND EMISSION CONTROL MEASURES FOR INDUSTRIES

01 Heavy industries oftenin close proximity to or even within cities
- **need of high performance filters and adhering strict standards**

02 **Implementing financial instruments** backed by strong energy efficiency rules
- promoting energy-efficient equipment, retrofitting buildings, smart transportation solutions

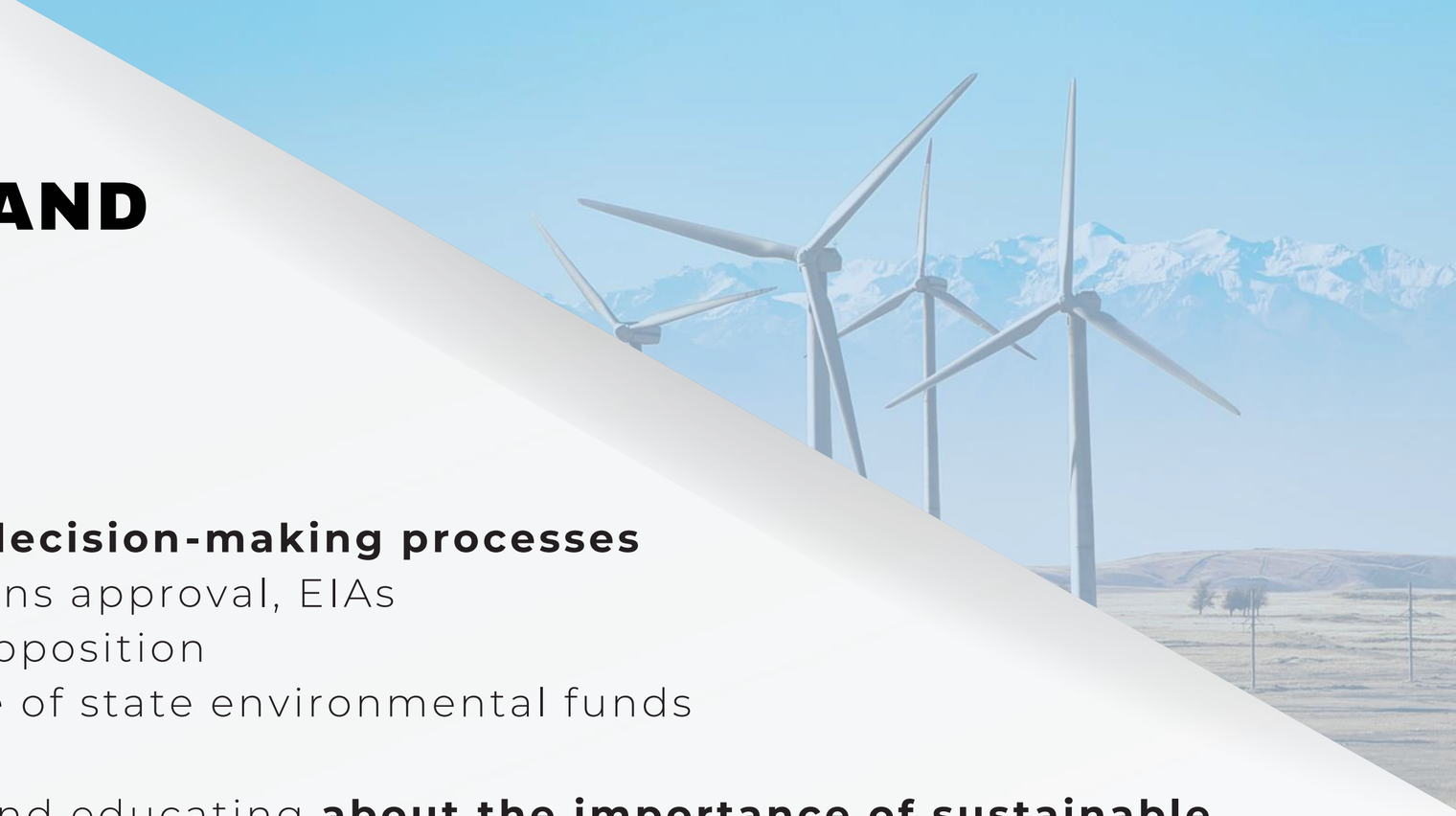
03 Use of the **Best Available Techniques (BAT)** to create attractive investment environment
- transition to low-carbon processes, green funding programs, tax break, subsidies

04 Adoption of **energy management systems** (ISO 50001)
- monitoring and optimizing energy consumption

05 **Sector-specific roadmaps** for emission reduction
- support, guidance and technology transfer, supports for research and development

06 Establishing a functional **Pollution Release and Transfer Register (PRTR) + emission quotas**
- Protocol of the Aarhus Convention (2020)

PUBLIC AWARENESS AND PARTICIPATION



01

Actively involve the public in decision-making processes

- spatial planning, clean air plans approval, EIAs
- help to overcome potential opposition
- public involvement in the use of state environmental funds

02

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)

03

Early warning system to alert authorities and the public about emergency air pollution events

- → taking timely preventive actions and minimizing the adverse effects
- user friendly platforms and tools

EXECUTIVE SUMMARY

KEY FINDINGS

NO_2
- **in major cities and industrial sites**
- **highest in winter** (decrease in summer and spring except for Almaty, Shymkent, Pavlodar)

CH_4
- **in the vicinity of coal mines**
- **annual increases** from 2018 to 2022
- Shymkent, Mangystau, Kyzylorda

SO_2
- **around mining industries, coal fired power-plants** (Almaty Region, Pavlodar, Oskmen, Astana, Karag.)
- **highest in winter** (low deposition, heating emissions

PM_{10}
- **S and SE** (natural sources)
- increase in all seasons due to human activity

RECOMMENDATIONS

01 **Strenghtening of air quality monitoring and data collection**

02 **Reducing coal usage and promoting the deployment of renewable energy**

03 **Bolstering regulatory frameworks and environmental liability**

04 **Promoting energy efficiency measures**

05 **Public awareness and participation**

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TRANSITION
Ministry of Foreign Affairs of the Czech Republic

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https://ecocitizens.kz