National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters“

https://nnpos.wordpress.com/

9 partners; Goals - generation and transfer of new knowledge about: a/ processes and interactions in the atmosphere, hydrosphere, lithosphere and biosphere from local to national scale; b/ their impact on quality of life, health risks, and ecosystems condition.

WPI.5 Quality of life in Bulgaria:

What we have learned in the past 5 years?

Reneta Dimitrova

Sofia University “St. Kliment Ohridski”
Faculty of Physics, Department of Meteorology and Geophysics

5th Scientific seminar “Physics and chemistry of the Earth System”
Hotel Seven Seasons, Banya, 25 - 27 September, 2023

Motivation

- Half of the worlds' population lives in urban (55%) rather than rural, areas; this distribution is expected to reach 68% by 2050 with one in three people living in cities with at least half a million inhabitants.
- The world's population - around 8.5 billion in 2030 and 9.7 billion in 2050; reach a peak of around 10.4 billion people during the 2080s and to remain at that level until 2100.

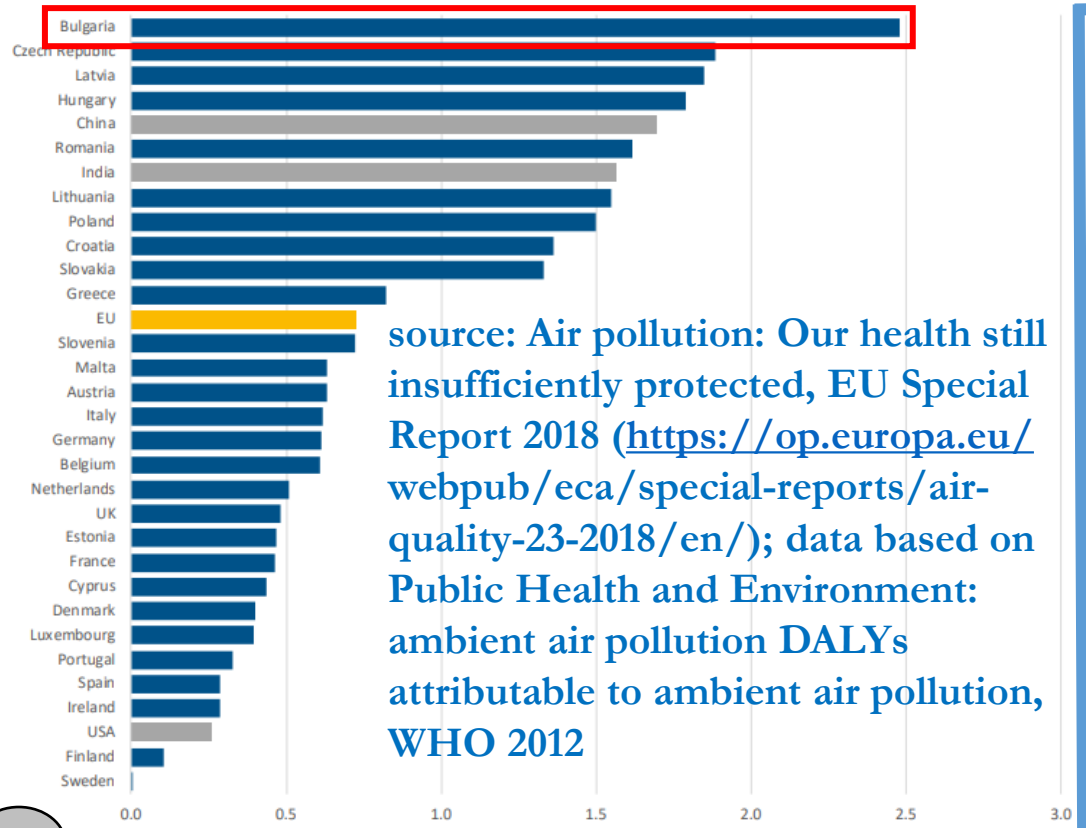
  (*United Nations: DESA/Population Division World Urbanization Prospects: 2018/2022 Revision of World Population Prospects*)


Sofia, January 2018

- Bulgaria, note that about 70% of population lives in urban areas, and more than one third lives in the four largest cities: Sofia, Plovdiv, Varna, and Burgas. *(Bulgarian National Statistical Institute 2017)*
- The air pollution ranked 4th among the leading risk factors for premature mortality on a global scale (4.2 million cases) in 2019. It is associated with both acute adverse health effects (e.g., higher risk of hospital admissions in people with chronic diseases on days when air quality is poor), as well as with chronic health impacts, even at low exposure levels. *(WHO Ambient (outdoor) air pollution; December 2022)*

Motivation

Bulgaria has the highest rate of premature deaths due to air pollution in Europe. The lost years of healthy life in some EU Member States are similar to countries often associated with poor quality air, such as China and India.



source: Air pollution: Our health still insufficiently protected, EU Special Report 2018 (https://op.europa.eu/webpub/eca/special-reports/air-quality-23-2018/en/); data based on Public Health and Environment: ambient air pollution DALYs attributable to ambient air pollution, WHO 2012

WHO recommendations published in 2005 and 2021 years (https://www.who.int/publications/i/item/9789240034228)

*The lowest level registered among all the 1000 studied cities

Premature mortality due to air pollution in European cities; an Urban Burden of Disease Assessment (Khomenko et al., 2021)

Mortality ranking	City	$PM_{2.5}$ annual mean	Avoidable deaths WHO 2021 lev	WHO 2005 lev	WHO lower lev*
81	SOFIA	17.0	888	528	980
133	PERNIK	15.3	61	32	69
176	VIDIN	15.3	25	13	28
178	RUSE	14.2	82	38	93
183	HASKOVO	14.5	40	20	46
218	PAZARDZHIK	13.6	25	10	28
221	STARA ZAGORA	13.9	50	22	57
224	PLOVDIV	13.8	218	96	250
288	SHUMEN	12.7	31	11	36
294	VRATSA	13.0	27	10	31
295	PLEVEN	13.4	45	19	51
309	SLIVEN	12.3	34	11	40
310	BURGAS	12.8	97	35	112
321	YAMBOL	12.7	43	16	50
356	VARNA	12.8	159	58	185
401	DOBRICH	12.0	24	7	28
410	BLAGOEVGRAD	12.8	27	10	31
626	VELIKO TARNOVO	11.7	11	3	13

source: BlueHealth, pan-European research initiative (Funded by the EU's Horizon 2020 programme, https://isglobalranking.org/ranking/bulgaria#air)

WPI.5 Quality of life in Bulgaria - subject

- to identify the potential risks of climate change (prevailing and typical extreme phenomena) and their impact on the urban environment, as well as, to assess the impact of climate change on people's quality of life by introducing appropriate pollution and comfort
  - Analysis of the health status of the population.
  - Health impacts assessments are based on exposure-response relationships, which describe the risk of disease as a function of the level of air pollution.
  - Current pollution climate and future climate projections.
  - Assessment of the quality of life and human health – development of forecasting systems for air pollution, air quality and bio-meteorological indices (comfort).
  - Biologically active UV radiation and human health prevention – development of advanced empirical model for prediction of UV index values and safe exposure time.
  - Ecological monitoring of the radiation situation in the surface atmospheric boundary layer.
  - Using Lidars to study aerosol pollution at the atmospheric boundary layer.

Achievements and challenges

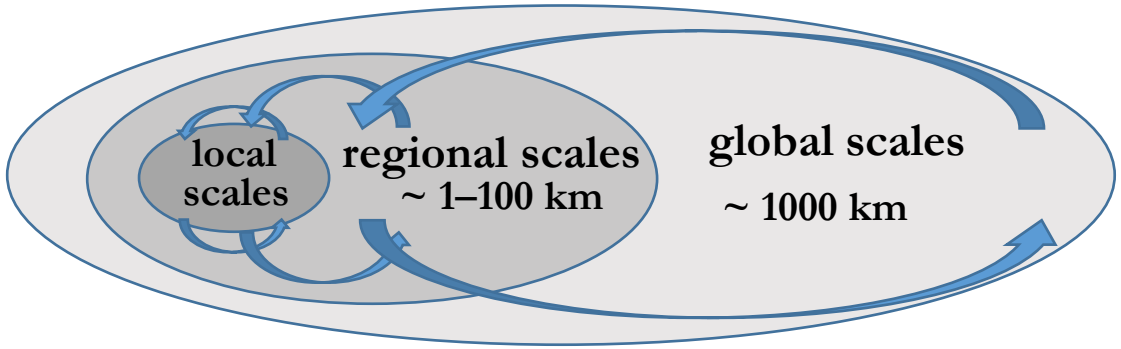
- Long-term data from meteorological stations and air quality sites collected in official monitoring networks
- Recent stationary geographic data - SRTM Digital Elevation Data (30 m) и CORINE2018 Land Cover data (90 m) adapted to the weather prediction model
- More recent regional and local emission inventory data
- Laboratory study of emissions during thermal conversion of fossil and alternative energy carriers, solid biofuels and biomass - done for the first time in Bulgaria
- Collected available demographic and health information – from the National health insurance fund (daily data on selected specific diseases in Sofia, Plovdiv and Varna for 10 years); from the Regional Health Inspectorate (aggregated data on selected specific diseases by regions for 5 years)
- Knowledge and traditions using numerical modelling to study the structure of the ABL and air pollution at different scales, long-term simulated data for Bulgaria region
- A study on the short-term effects of air pollution on hospitalizations in Sofia, Plovdiv and Varna – the first of its kind for Bulgaria, because it covers such a long period of time (ten years - from 2009 to 2018)

Can we combine all available data and team expertise across different fields to improve the air quality research?

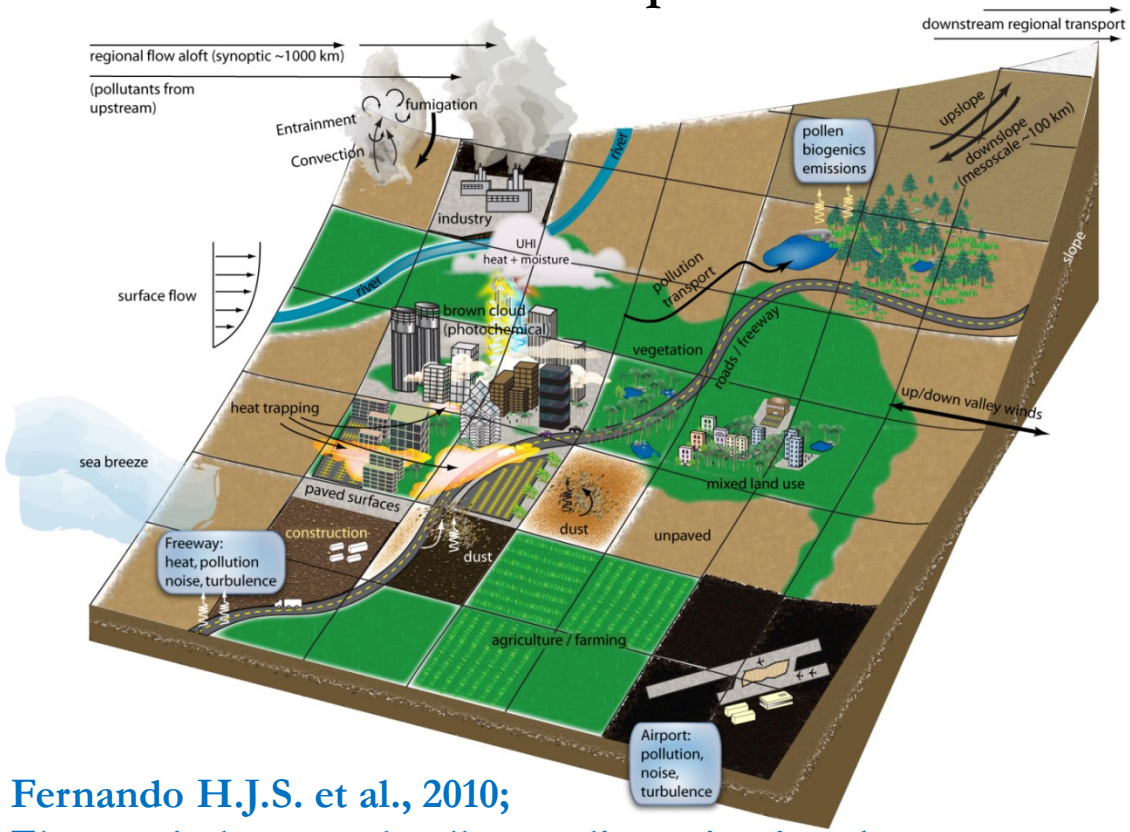
Complexity of the urban system

Environmental impacts of urban development

- Landscape changed – increase in temperature, decrees in evaporation, reduced infiltration of water into the ground.
- Affect the urban biosphere – loss of vegetation, replaced of native plants by exotic species, affect the ecology of nonhuman inhabitants.
- Modify the flow regime and atmosphere composition – urban heat island, urban plume, anthropogenic heat flux and emissions.



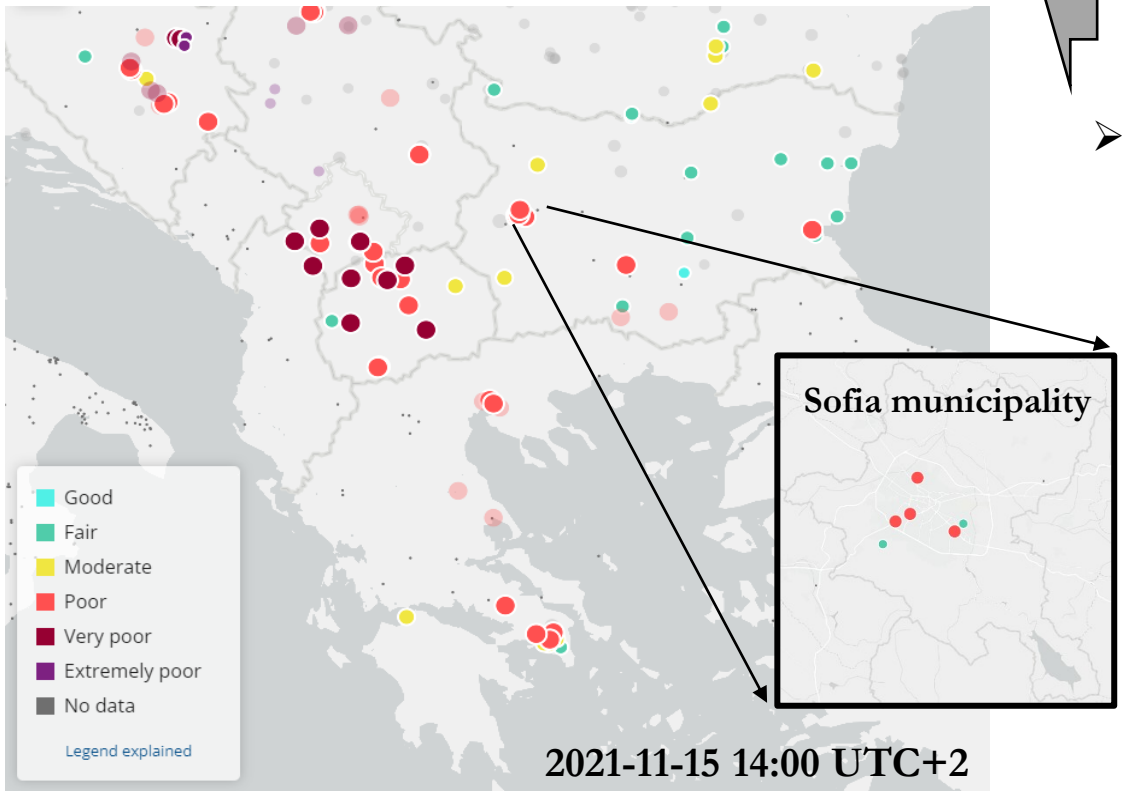
- Complicated interactions between different scales and phenomena.



Fernando H.J.S. et al., 2010;
Flow, turbulence and pollutant dispersion in urban atmospheres. Phys Fluids, 22, doi:10.1063/1.3407662

Lack of ground air quality data

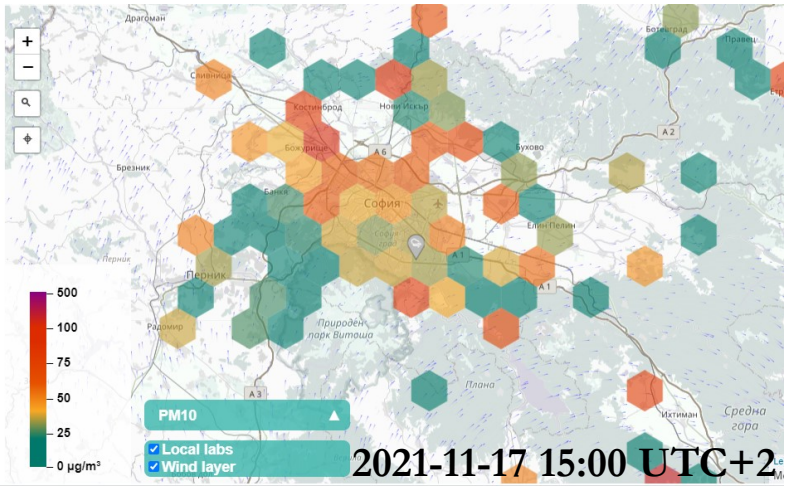
Kriging or land use regression (LUR) modelling only if you have high number of observational points!



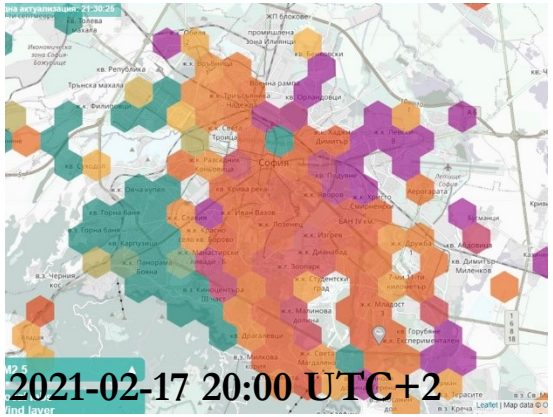
https://airindex.eea.europa.eu/Map/AQI/Viewer/

Executive Environment Agency, Ministry of Environment and Water - 34 stationary automatic measuring stations (4 in forest ecosystems), 5 differential optical absorption spectroscopy, 9 points with manual sampling and subsequent laboratory analysis. (http://eea.government.bg/bg/nsmos)

- Sparsely distributed official AQ monitoring stations in Sofia 5 automatic and 1 manual sampling measuring stations, less in other cities.
- Additional 22 measuring sensor stations operated by the Sofia municipality (https://air.sofia.bg/) and a civil network of low cost sensors AirBG stations, need verification and calibration.



https://airbg.info/map/



Satellite Earth Observations

NASA Earth Data

https://earthdata.nasa.gov/

Static data

- Topography
- Land cover

Dynamic data

- Cloud cover
- Visibility
- Wild fires
- Surface temperature

Use of remote sensing technologies to monitor land, marine and atmosphere.

Copernicus Atmosphere Monitoring Service

https://atmosphere.copernicus.eu/

Areas

- Air quality and atmospheric composition
- Ozone layer and ultra-violet radiation
- Emissions and surface fluxes
- Solar radiation
- Climate forcing

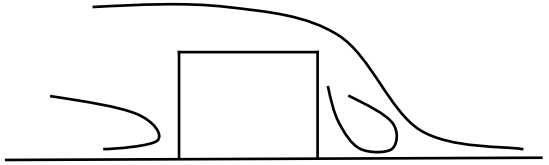
Products

- Maps and data for regional air quality forecasts
- Retrospective assessments of air quality
- Identification of pollutants and their source
- Pollen concentration levels in the
- atmosphere
- Resources for evaluating possible
- emission control measures
- Inputs to local air quality forecasts, health information and warnings

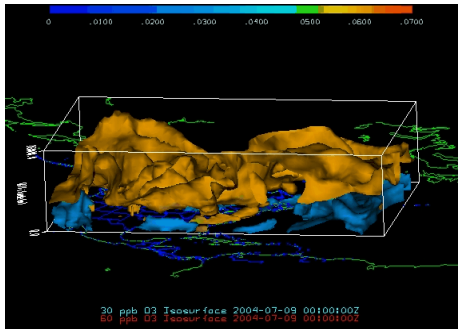
A lot of data are available, but with different temporal and spatial resolution, missing periods, uncertainty with data retriever for the lower troposphere…

Air quality modelling – different models need for different scales

CFD
DNS (direct numerical simulation)
RANS (Reynolds av. Navier-Stokes)

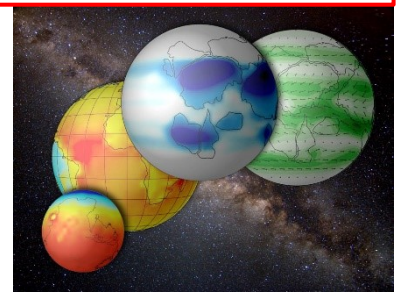


LES (large eddy simulation)



GHGs
CO_2, CH_4, CO, N_2O, O_3, CFC's

GCM (Global Climate System)

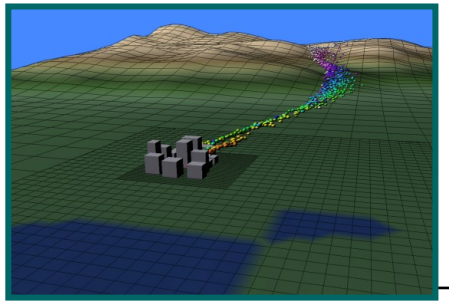


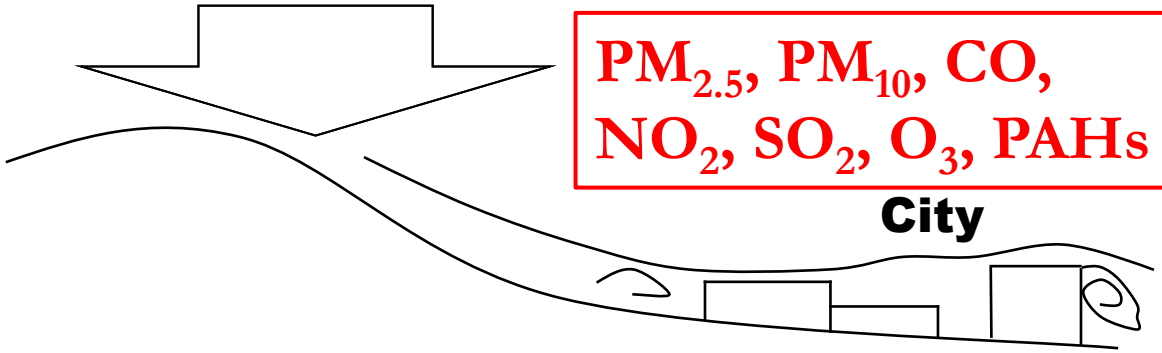
Mesoscale models (weather forecasting)

micro-scale models | local models | regional models | weather forecasting | global models

1mm | 1m | 10m | 100m | 1km | 10km | 100km | 1000km | 10000km

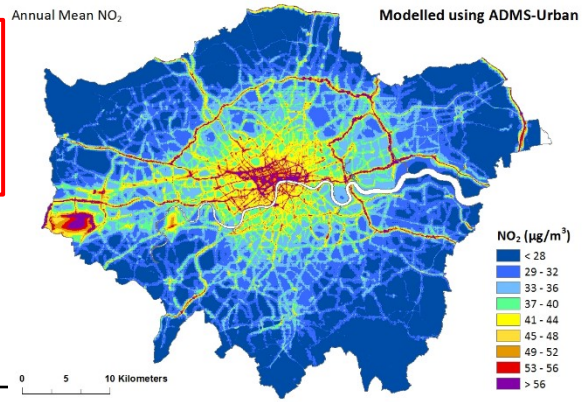
Scale of the phenomenon





$PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, O_3, PAHs

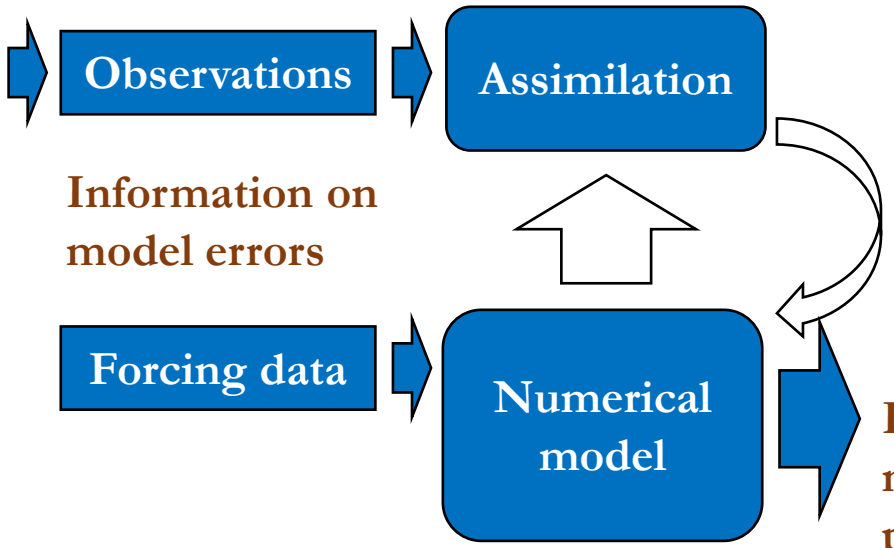
City

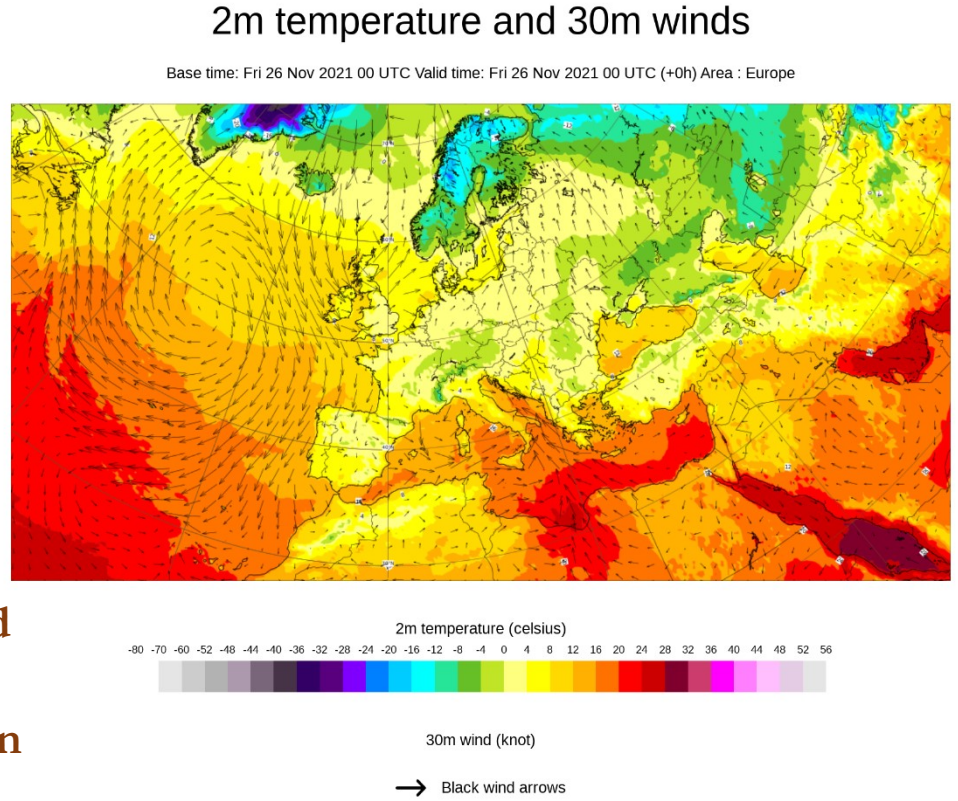


Data assimilation in the global weather forecasts

Data assimilation - provide the best estimate of the state of a physical system by combining modeling and observations.

- Surface observations
- Upper air observations
- Geostationary satellite data, including retrieved data for NO_2, SO_2, Aerosol Optical Depth





Global Forecast System (GFS) - the National Oceanic and Atmospheric Administration (NOAA) and its subsidiary agency National Centers for Environmental Prediction (NCEP).

https://www.ncei.noaa.gov/products/weather-climate-models/global-forecast

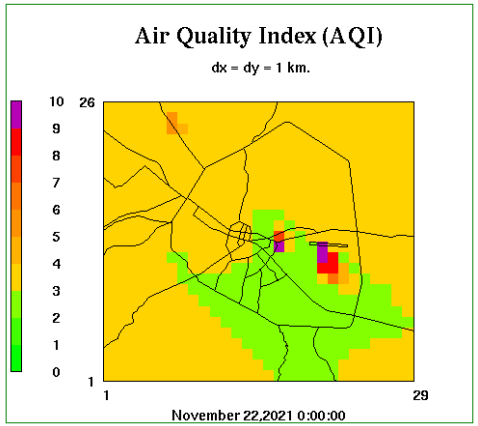
European Center for Medium-Range Weather Forecasts - independent intergovernmental organization supported by 34 states.

https://www.ecmwf.int/en/forecasts

Regional scale air quality modelling

http://info.meteo.bg/cw2.1/; http://info.meteo.bg/cw2.2/
http://www.niggg.bas.bg/cw3/index.php/

Bulgarian Chemical Weather Forecast System



POLLUTANTS

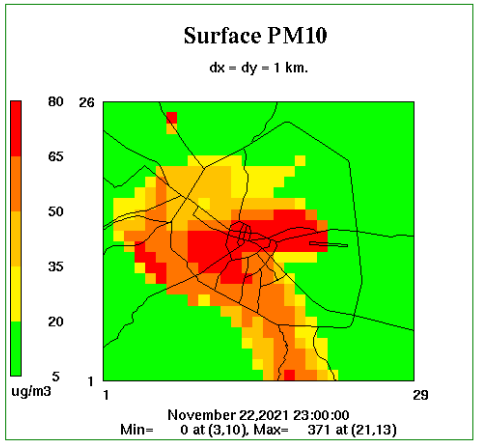
Nitrogen dioxide (NO2)
72-hours forecast
Sulfur dioxide (SO2)
72-hours forecast

OZONE
72-hours forecast

First day
Daily maxima
8-hour daily maxima
Second day
Daily maxima
8-hour daily maxima
Third day
Daily maxima
8-hour daily maxima

PM10
72-hours forecast

Description of Bulgarian Chemical Weather Forecast and Information System (ver. 2)(PDF)



Bulgarian legislation for Fine Particulate Matter (PM10):
Daily threshold value (DT): 50 μg/m3
Permitted number of exceedings of DT in a year: 35
Yearly threshold value (YT): 40 μg/m3
Permitted number of exceedings of YT: impermissible

https://www2.mmm.ucar.edu/wrf/users/

Input from global models

Pre-processing

https://www.cmascenter.org/smoke/

NCAR/NCEP Weather Research &Forecasting Model WRF

Sparse Matrix Operator Kernel Emission Model SMOKE

MCIP

WRFDA Data assimilation

Community Multiscale Air Quality Model CMAQ

IDV/PAVE Analysis and visualization

Post-processing

https://www.epa.gov/cmaq

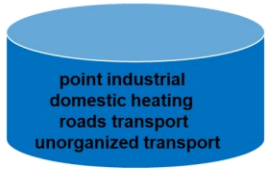
Local scale air quality modelling

Monitoring

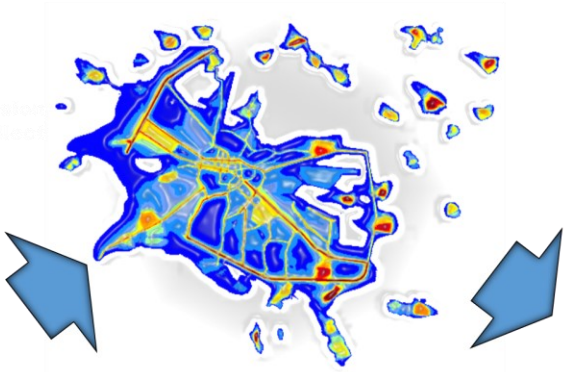
Bulgarian Executive Environment Agency
PM air quality data
Meteorological data

Calculations

Sofia municipality
EMEP CORINAIR emission inventory



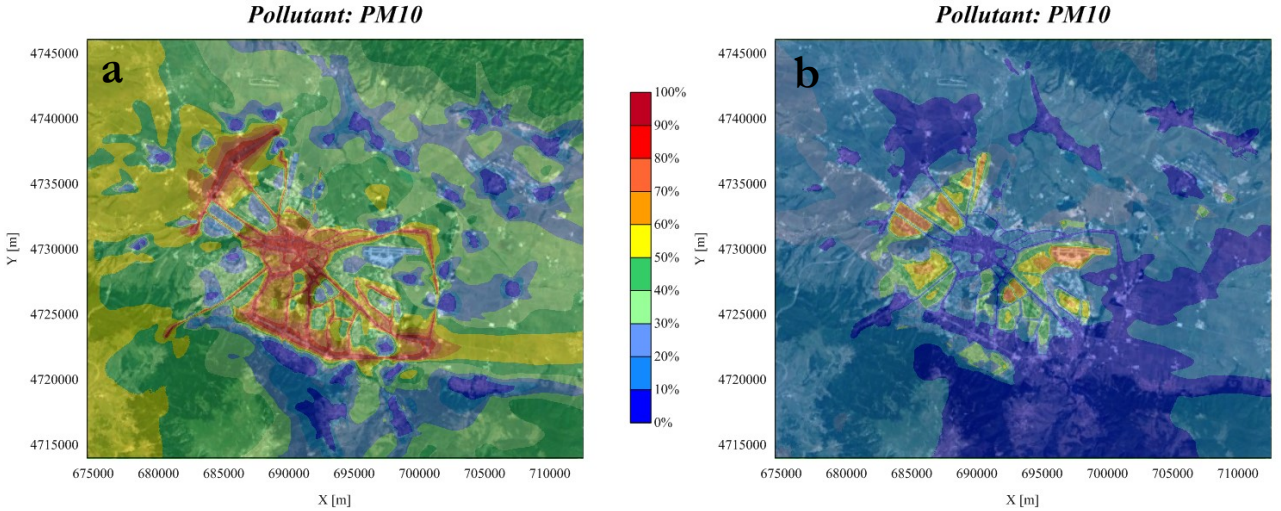
ADMS-Urban model
Cambridge Environmental Research Consultants
https://www.cerc.co.uk



Detailed representation of PM pollution in Sofia municipality

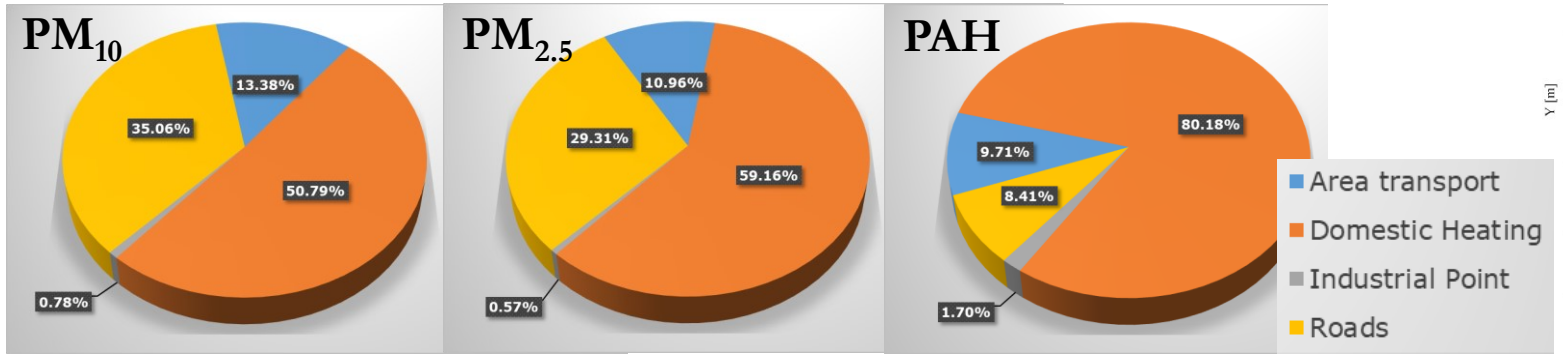
Simulation of different scenarios for future emission reduction that can help the authorities in decision making

Assessment of the contribution of different sources



Contribution (%) of road transport (a), unorganized transport (b) and domestic heating (c) during the cold season.

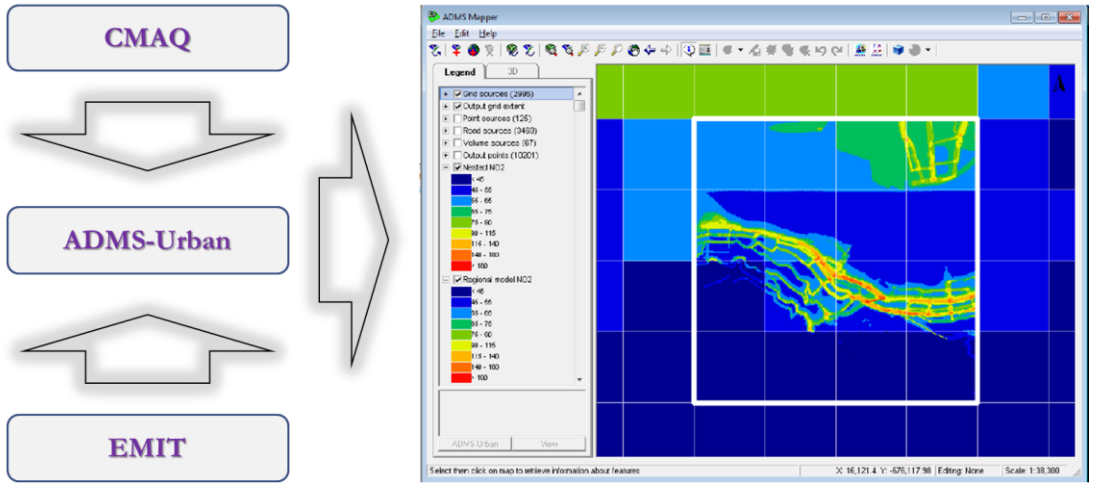
Contribution of different sources to the annual mean concentration over the entire domain.



Dimitrova and Velizarova, Atmosphere 2021, 12, 423. https://doi.org/10.3390/atmos12040423

Air quality modelling – future development

ADMS-Urban Regional Model Link



Combine the complementary advantages of complex chemistry mechanism, which can operate over long spatial and temporal scales with better presentation of fine-scale concentration gradients from explicitly defined sources in detail.

Uncertainties

- Problems with the emission inventory - lack of data of the dynamics and structure of the traffic flow on the major roads, the daily and the weekly profiles, the behavior of the city inhabitants (movement, heating), need to improve the emissions from road transport and domestic heating.
- Different spatial and temporal scales of the phenomena and interaction between scales, complicated chemistry with hundred of reactions.

Advantages

- Continuous in space and time concentration fields;
- Provide forecast over the selected area;
- Estimation of the contribution of each source type to the concentration field;
- Simulation of different scenarios for future emission reduction;
- Ensure helpful information for authorities with decision making.

What we have learned?

- A lack of information in several very important fields:
  - ✓ sparsely distributed AQ monitoring stations, missing data, sometimes questionable quality;
  - ✓ health data are missing for some regions of Bulgaria; daily data are collected for the entire region (city) and do not represent the spatial variability (information for the address of the patient is not included); possible incorrect registration of the disease according;
  - ✓ the available data of the dynamics and structure of the traffic flow on the major road arteries; it is necessary to determine the daily and the weekly profiles of traffic flow, as well as to create an averaged profile of the structure of traffic flow on the different segments, located between junctions;
  - ✓ information of the annual average mileage of the registered in the city vehicles by district and what is the percentage of kilometers travelled in the city; this will help with defining the quantity of unorganized transport from minor roads in residential areas more accurately;
  - ✓ information regarding the objects (neighborhoods, streets, buildings) and the behavior of their inhabitants (movement, heating) to developed realistic emissions from domestic heating.
- The complex topography requires a more realistic flow field and a lot of additional meteorological variables for adequate air quality modelling; reliable background concentration; linking regional with local models.
- New information and sophisticated methods needed to develop more realistic local emission inventory for domestic heating and transportation.
- More accurate health risk assessment is necessary based on the exposure-response relationships derived from the dispersion modelling and epidemiological study (with included geolocation/address).

Future activities

Development of a methodology for air quality and human health risk assessment in urban areas, project supported by the NSF, Bulgarian Ministry of Education and Science

- **Improve the emission inventory for domestic heating and transportation** (more precise description of metadata, digitalization for interoperability of different data sets, geo-referencing, location and mapping, additional sources and software tools e.g. QGIS, COPERT, Atmospheric EMissions Inventory Toolkit - EMIT)
- **High resolution air quality modelling** (automated system for nesting the high resolution local air quality model in a regional air quality model)
- **PM data collected at Geodesic Observatory "Plana" (rural station) and park "Borisova gradina"** (reliable data on background concentration, clarification on the effect of city parks on concentration reduction near boulevards with heavy traffic in different parts of the vegetation life cycle)
- **Epidemiological study** (a bespoke epidemiological study with a representative sample of citizens of Sofia aims to establish the spatial-temporal dimensions of participants' living environment, self-reported health status, morbidity, lifestyle and socioeconomic standard, and other indicators)
- **Modelling of different future scenarios to help city planners solving specific tasks** (alternative situations for the whole city of Sofia, for existing quarters and development areas around major boulevards and „green wedges")

Thank you for your attention!

Acknowledgements: This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № Д01-271/09.12.2022).

https://gigasofia.com/2014.php