RSHU & UHEL meeting on academia/university education collaboration

23 April 2020, Thursday, 13-17 pm

Anthropogenic impacts on urban atmosphere: observations and modelling

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- The aim is to obtain a complex of scientific knowledge that allows students to understand the regularities of transport, dispersion and transformation of anthropogenic pollution in the atmosphere.

- **I consider the main directions as**: classification of anthropogenic emission sources, typification of impurities transfer and dispersion processes in the atmosphere, classification of mathematical models of impurities transfer and dispersion in the atmosphere, methods of calculation of atmospheric characteristics determining impurities transfer and dispersion on the basis of standard hydrometeorological information.

- **The main task is the study** of physical processes and factors that determine the pollution of the atmosphere by anthropogenic emissions based on physical and mathematical methods.

What are the anthropogenic factors?

The term "***anthropogenic***" means of, relating to, or involving the impact of humans on nature.

Anthropogenic sources of pollution

The anthropogenic chemical pollution has no borders and no matter where the pollutants are released into the atmosphere will have an impact over global environment. The most relevant sources are the incineration of fossil fuels to produce energy (heat and electricity), major industrial processes (like metallurgy industry or cement/construction industry) and transportation. We will classify the anthropogenic chemical pollution sources into two major groups:

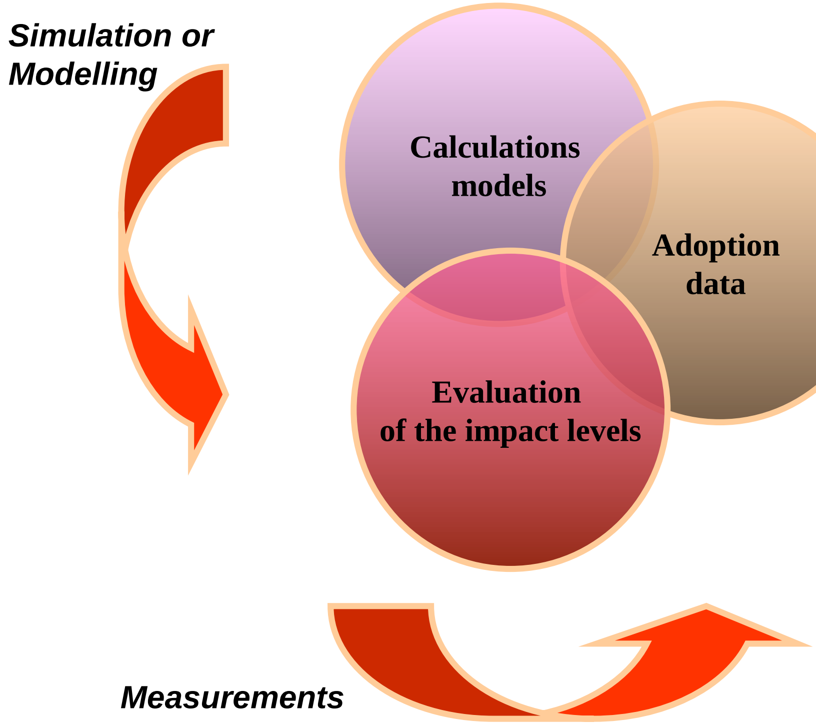
- **Stationary point sources**
- **Mobile sources**

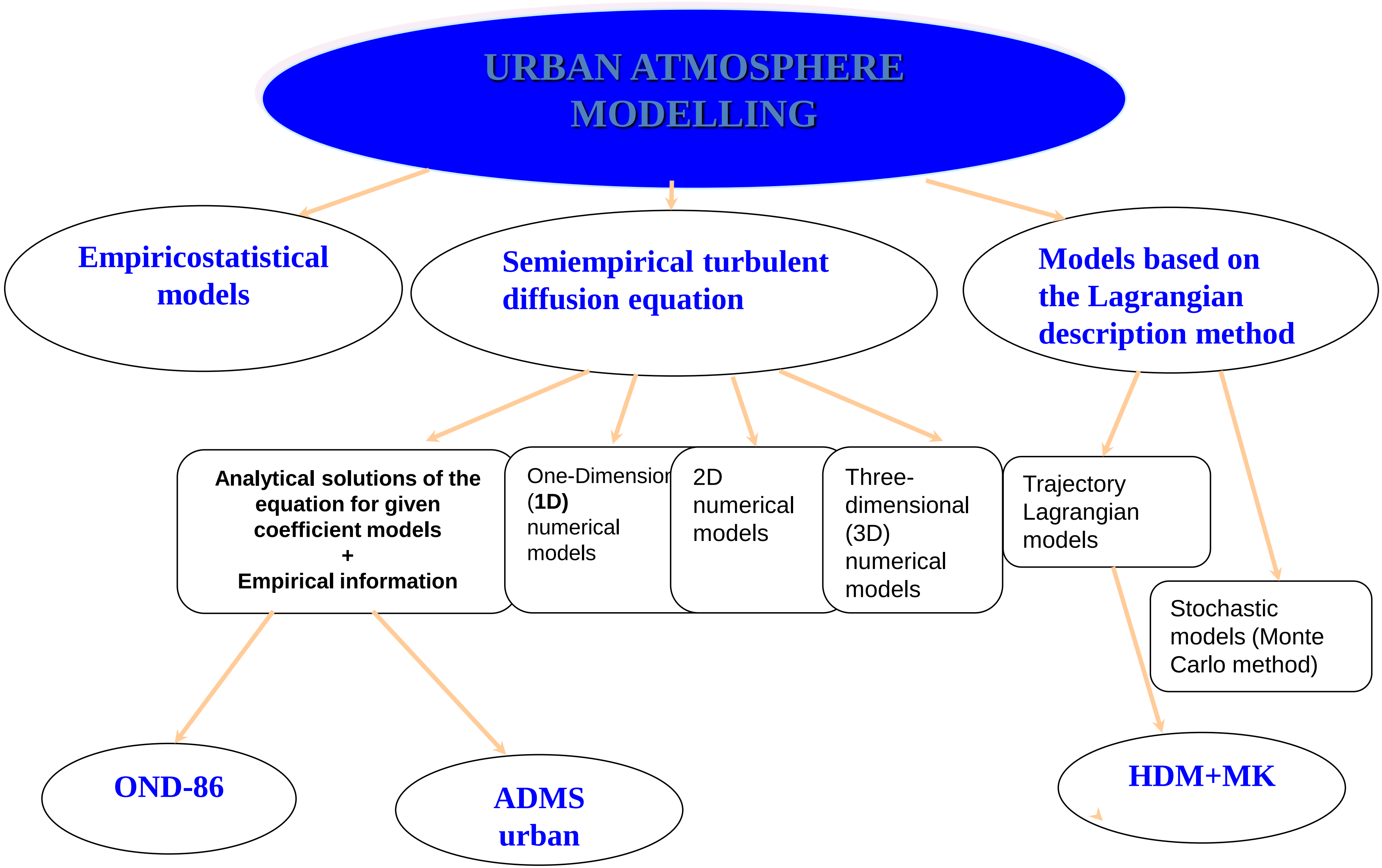
The four major groups of gaseous air pollutants by historical importance, concentration, and overall effects on plants and animals (including people), are sulphur dioxide (SO2), oxides of nitrogen (NOx: NO, NO2), carbon dioxide (CO2) and ozone (O3). Sulphur dioxide and nitric oxide (NO) are primary pollutants – they are emitted directly from sources.

MAJOR METEOROLOGICAL PROBLEMS

At no economically substantiated number of monitoring posts (up to several thousand on the territory of the megapolis) it is impossible to correctly solve the problem of spatial analysis of meteorological values and characteristics of air pollution.

Interpretation methods on rare observation networks are based on attracting spatially continuous data as additional information, though very inaccurate. For the city, first of all, they should include the results of calculations using mathematical modeling methods.

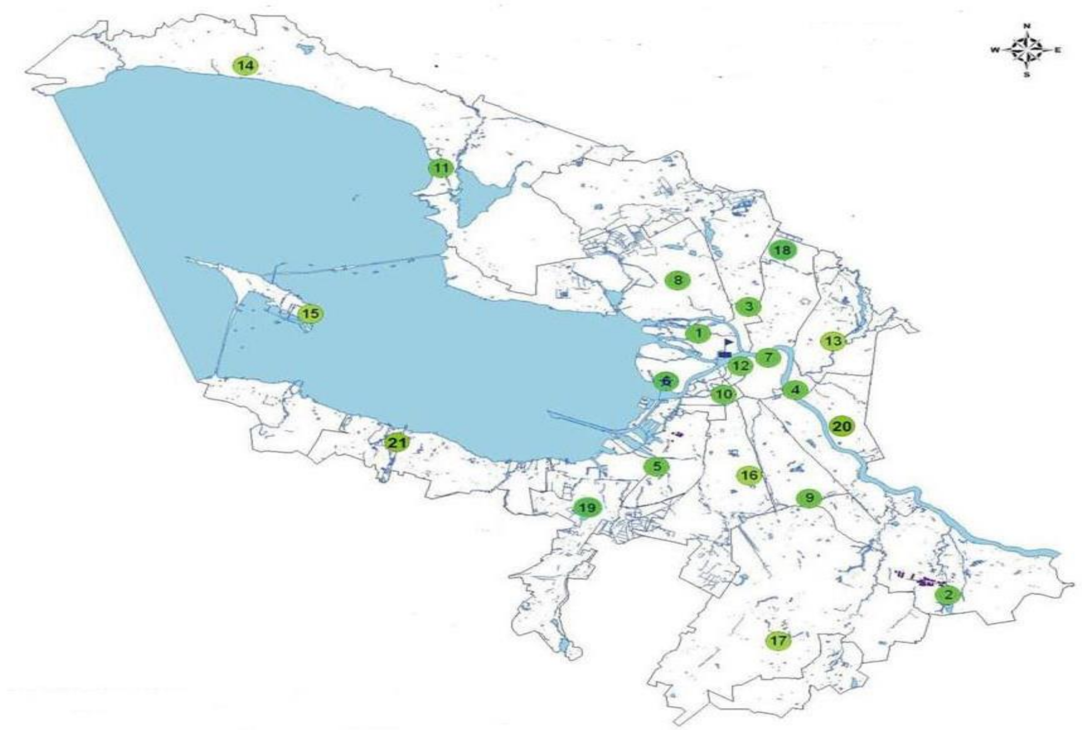




classification of mathematical models

PRACTICAL WORKS WITH STUDENTS:

- **Statistical processing of series of automatic gas analytical measurements.**



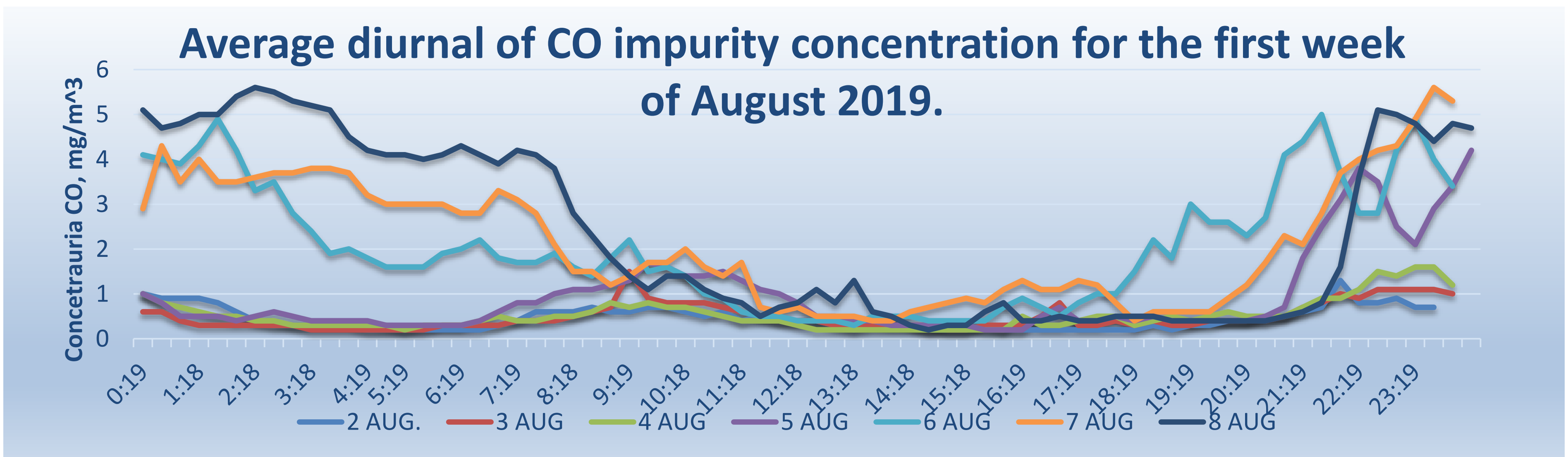
There are 20 automatic stations for monitoring atmospheric air pollution in St. Petersburg

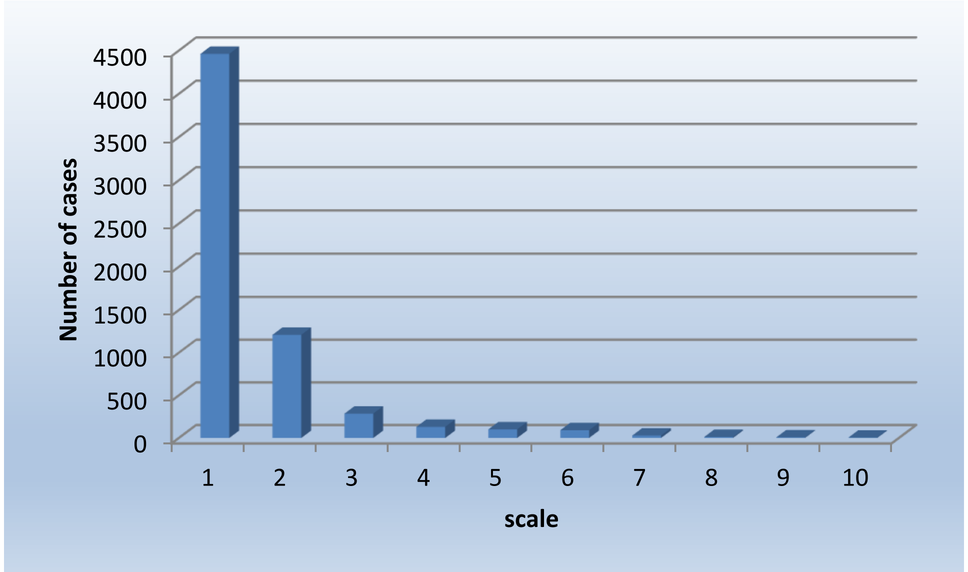
There is a series of observations of the concentration of one of the impurities (nitrogen oxide, nitrogen dioxide, carbon monoxide in mg/m3), obtained by automatic gas analyzer registration of 20-minute average values during 1-3 months (a total of 72 counts per day for 30-31 days, i.e. approximately 2160 values for each month).

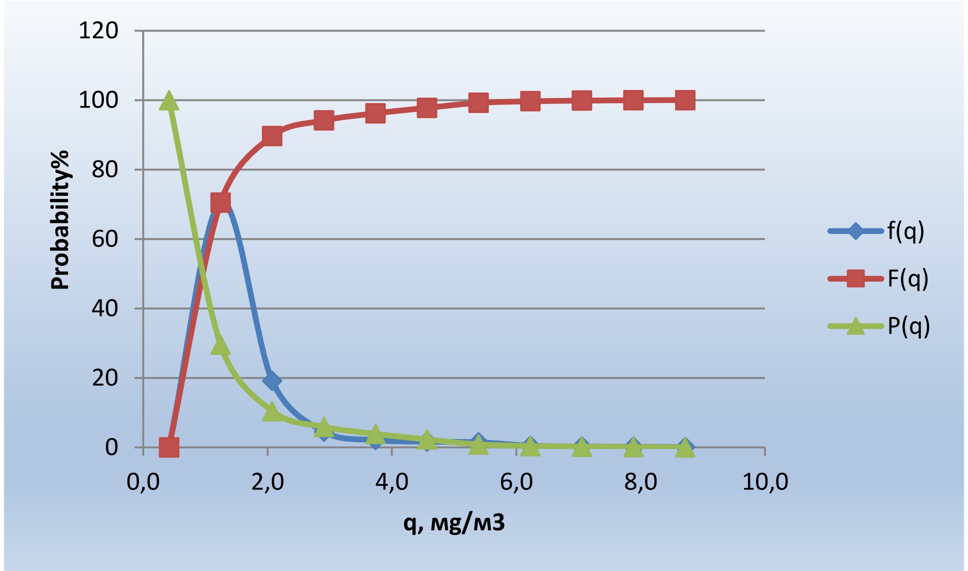
Elementary statistical processing is carried out. It includes obtaining a complete set of statistical characteristics of a number :

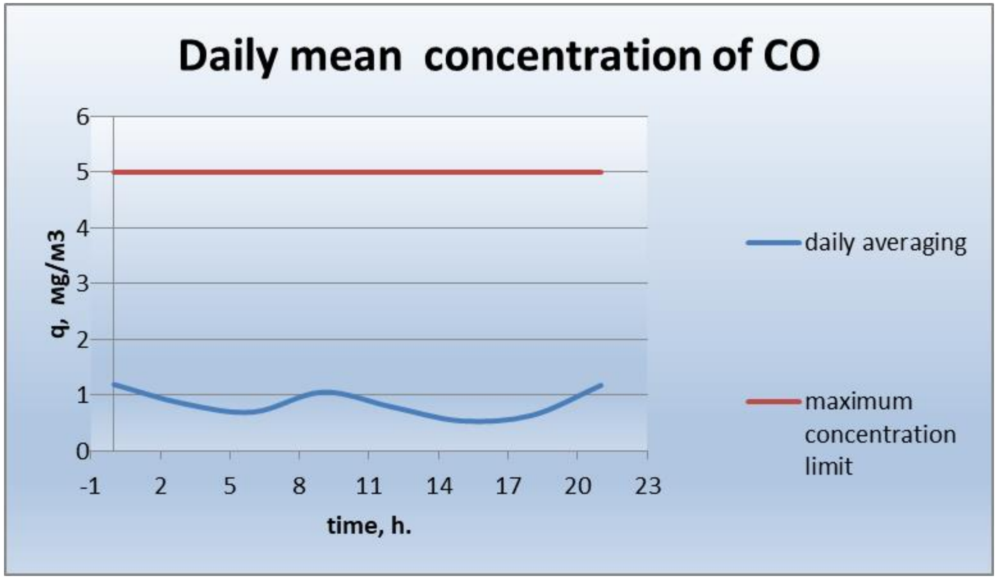
• Average, maximum values, standard deviations for sections of the series (decade, month):
• A histogram of the repeatability of concentration over sections of the series for each month;
• The probability density for sections of the series for each month;
• distribution function for the sections of the series for each month;
• Determination of concentration values exceeded in 10, 5, 2 and 1% of cases (percentiles) for the entire series.

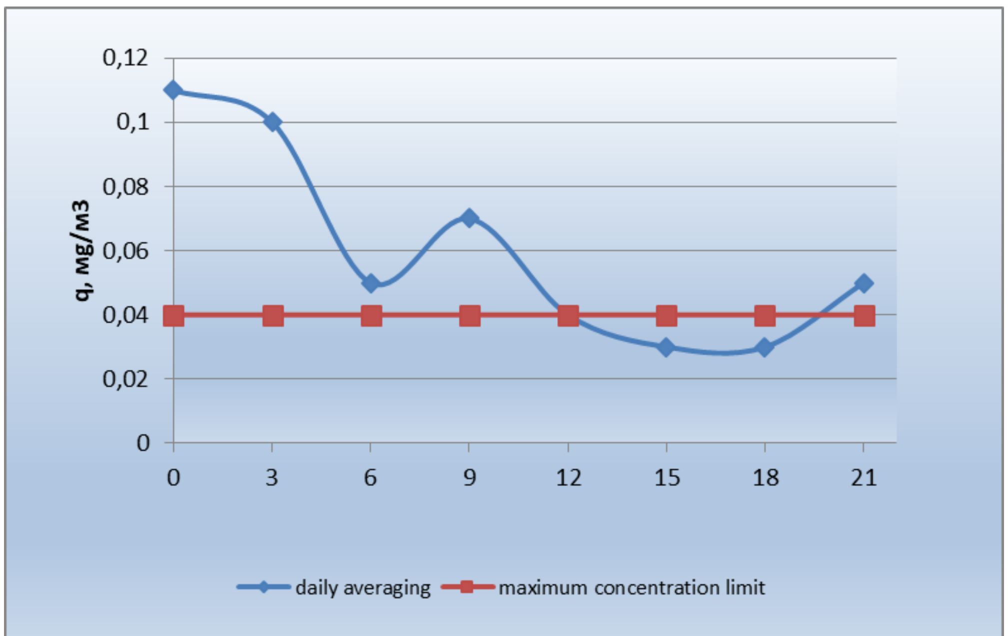
The results




4500
4000
3500
3000
2500
2000
1500
1000
500
0
Number of cases
1
2
3
4
5
6
7
8
9
10
scale


120
100
80
60
40
20
0
Probability%
0,0
2,0
4,0
6,0
8,0
10,0
q, мg/м3
f(q)
F(q)
P(q)


Daily mean concentration of CO
q, мg/м3
6
5
4
3
2
1
0
-1
2
5
8
11
14
17
20
23
time, h.
daily averaging
maximum concentration limit


q, мg/м3
0,12
0,1
0,08
0,06
0,04
0,02
0
0
3
6
9
12
15
18
21
daily averaging
maximum concentration limit

- ❖ The second task is to create a program to calculate the surface concentration values on the flare axis (for y=0). Investigate the effect of wind speed and source overheating on the shape of the dependence and the maximum concentration. Source power Q= 1 (g/c), source mouth radius R= 1 m, flow velocity w= 1 m/c. Calculation should be made up to the distance x=50h with discrete ***Δx***=0.2h, any (real) air temperature is taken. Perform calculations for all stability classes at:U=1,2,3,5,7,10 m/sec; Δ T=0,50,100,200 degrees; Take source h height equal (in meters)

In open terrain, a permanent source of power Q (g/c), height h (m) with radius of outlet R (m), initial velocity of the gas-air mixture w (m/c) and its overheating ***ΔT*** (°C). is considered. Wind speed at source level is U (m/s).

The axis x of the Cartesian system of coordinates is directed along the wind vector, the axis y is crosswise, and z is vertically upwards.

The surface concentration field is calculated by the formula:

$$q(x,y,0)=\frac{Q}{\pi\sigma_y(x)\sigma_z(x)}\exp\left[-\frac{y^2}{2\sigma_y^2(x)}\right]\exp\left[-\frac{h^2_{эфф}(x)}{2\sigma_z^2(x)}\right]$$

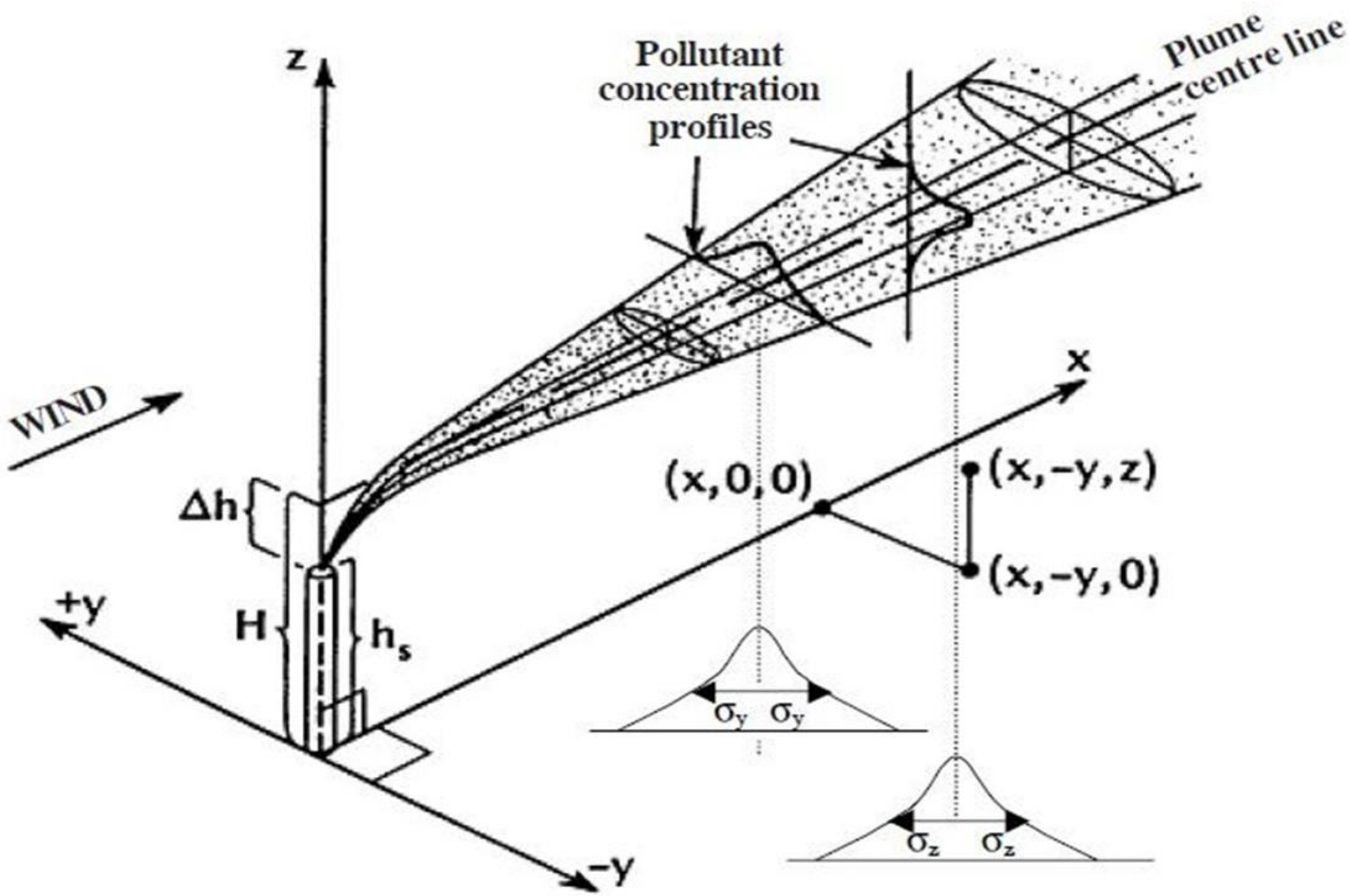
where

$$h_{эфф}(x)=h+\left(\frac{3}{\beta^2}\frac{M}{U^2}x+\frac{3}{2\beta^2}\frac{F}{U^3}x^2\right)^{1/3}$$

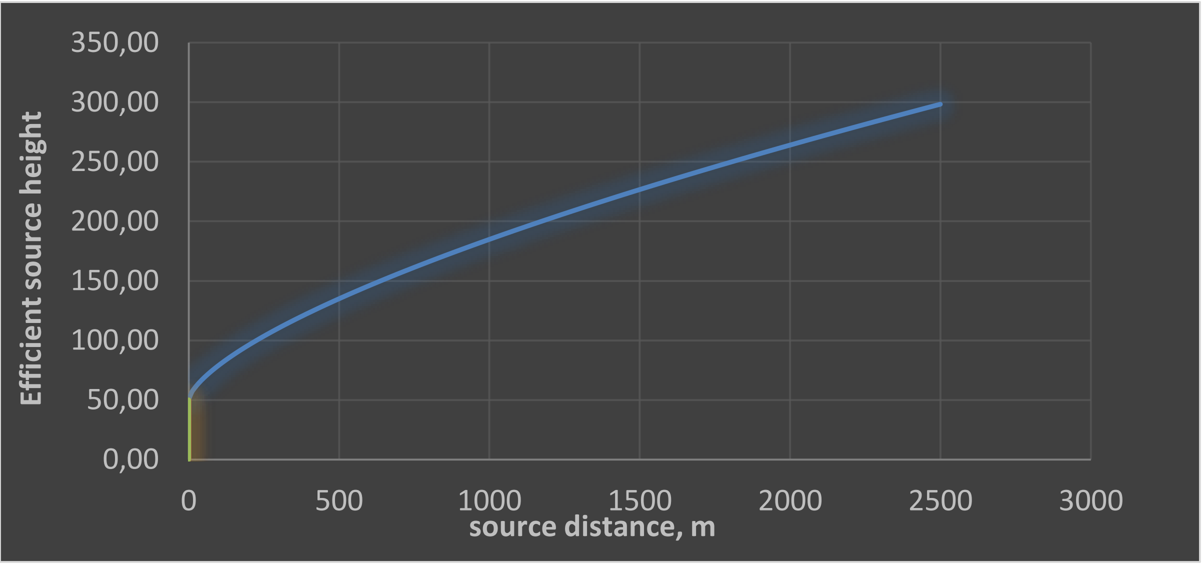
effective height of the source

$\sigma_y(x)$

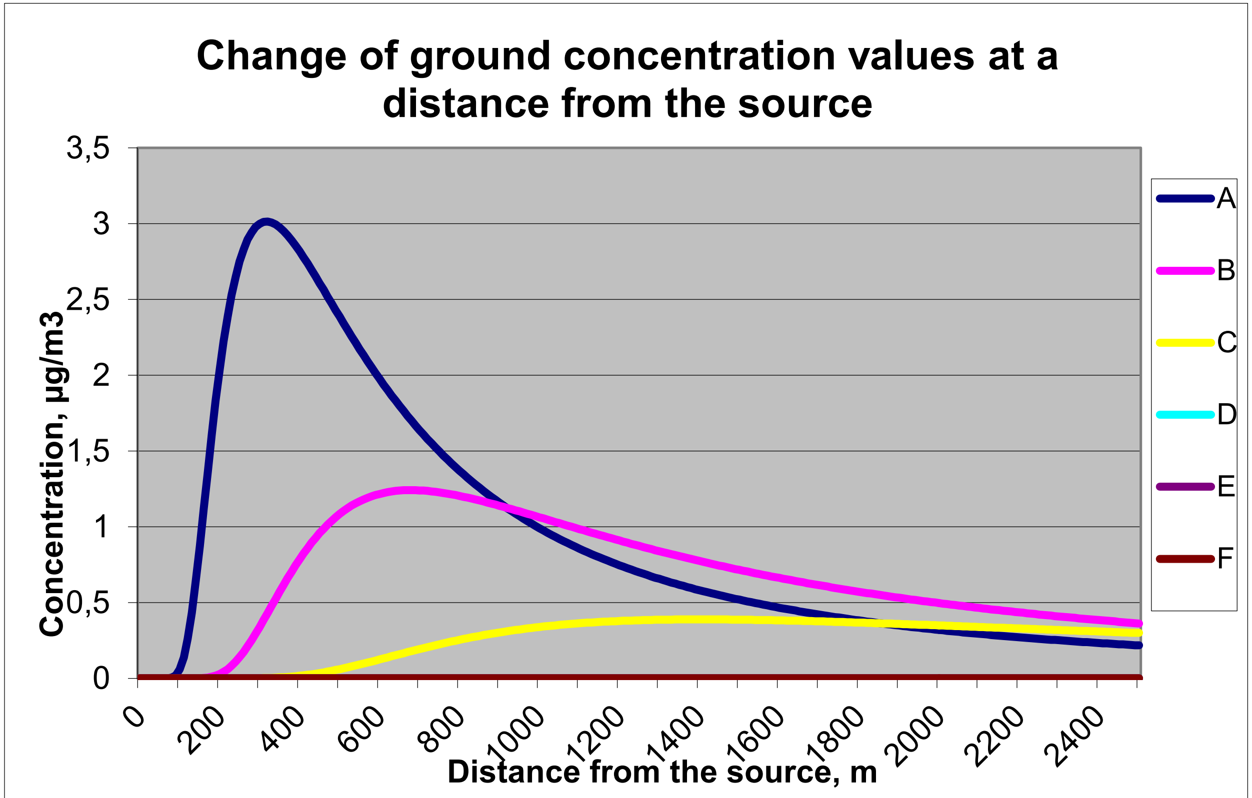
Stability Class	$\sigma_y(x)$	$\sigma_z(x)$
A	$0.22x(1+0.0001x)^{-1/2}$	$0.20x$
B	$0.16x(1+0.0001x)^{-1/2}$	$0.12x$
C	$0.11x(1+0.0001x)^{-1/2}$	$0.08x(1+0.0002x)^{-1/2}$
D	$0.08x(1+0.0001x)^{-1/2}$	$0.06x(1+0.0015x)^{-1}$
E	$0.06x(1+0.0001x)^{-1/2}$	$0.03x(1+0.0003x)^{-1}$
F	$0.04x(1+0.0001x)^{-1/2}$	$0.016x(1+0.0003x)^{-1}$



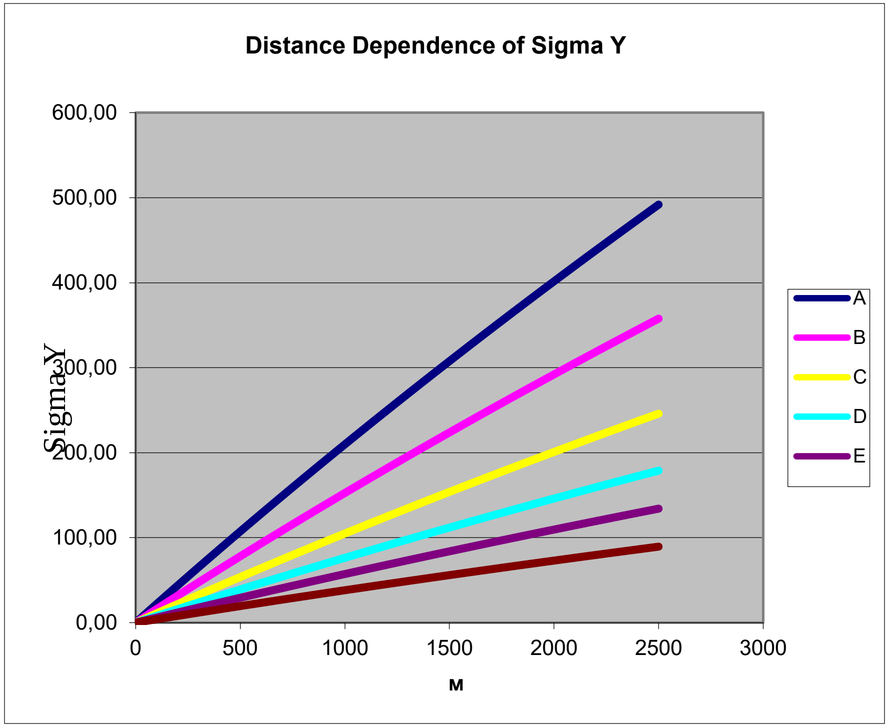
The results

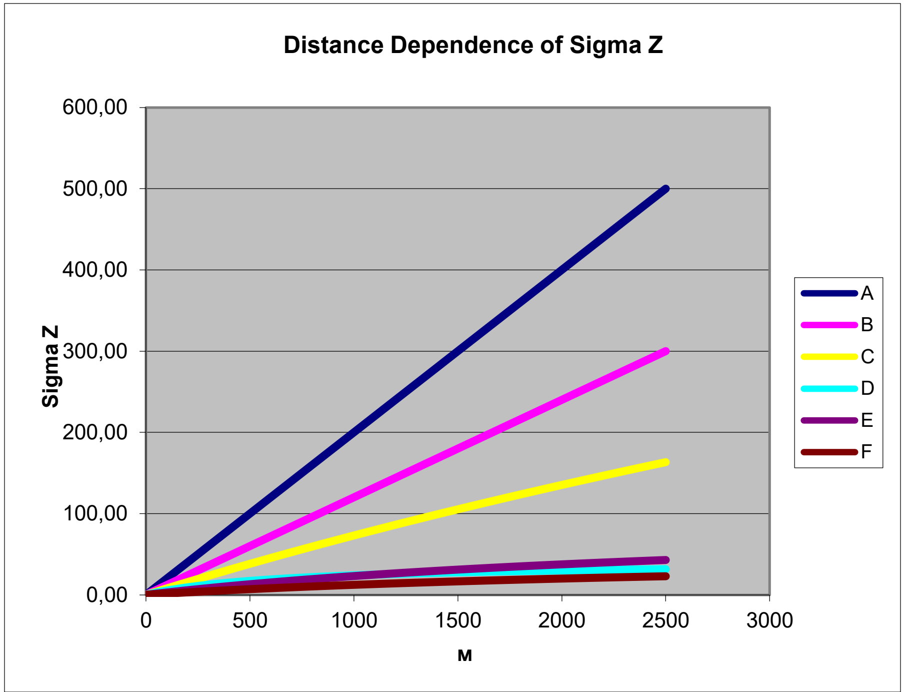


350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
Efficient source height
0
500
1000
1500
2000
2500
3000
source distance, m



Change of ground concentration values at a distance from the source
3,5
3
2,5
2
1,5
1
0,5
0
Concentration, µg/m3
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Distance from the source, m
A
B
C
D
E
F


Distance Dependence of Sigma Y
600,00
500,00
400,00
300,00
200,00
100,00
0,00
Sigma Y
0
500
1000
1500
2000
2500
3000
M
A
B
C
D
E


Distance Dependence of Sigma Z
600,00
500,00
400,00
300,00
200,00
100,00
0,00
Sigma Z
0
500
1000
1500
2000
2500
3000
M
A
B
C
D
E
F


THANK YOU!!
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