Оценки антропогенных эмиссии CO_2 Санкт-Петербурга с помощью численного моделирования и дистанционных измерений

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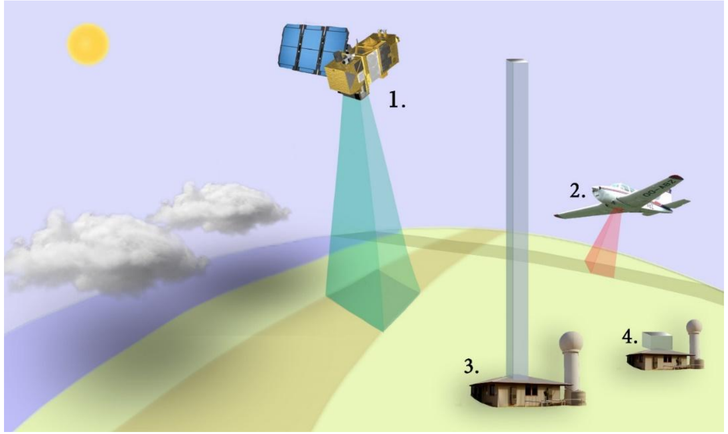
Two methods of CO_2 anthropogenic emission estimation

1. Inventorisation

- Using of CO_2 emission proxy information (amount of fossil fuel burned, location of power plants and industries, night city lights, etc.)
- Errors can reach 50% [1,2,3]



Main methods of atmospheric observations
(1 – satellite, 2 – airplane, 3 – remote ground-based, 4- in-situ)

2. Inverse modelling of atmospheric transport

Measurements of CO_2 content →
- In situ
- Remote

+

Modelling of CO_2 transport in the atmosphere →
- 3D Eulear models
- Dispersion models
- Box models
- Others

+

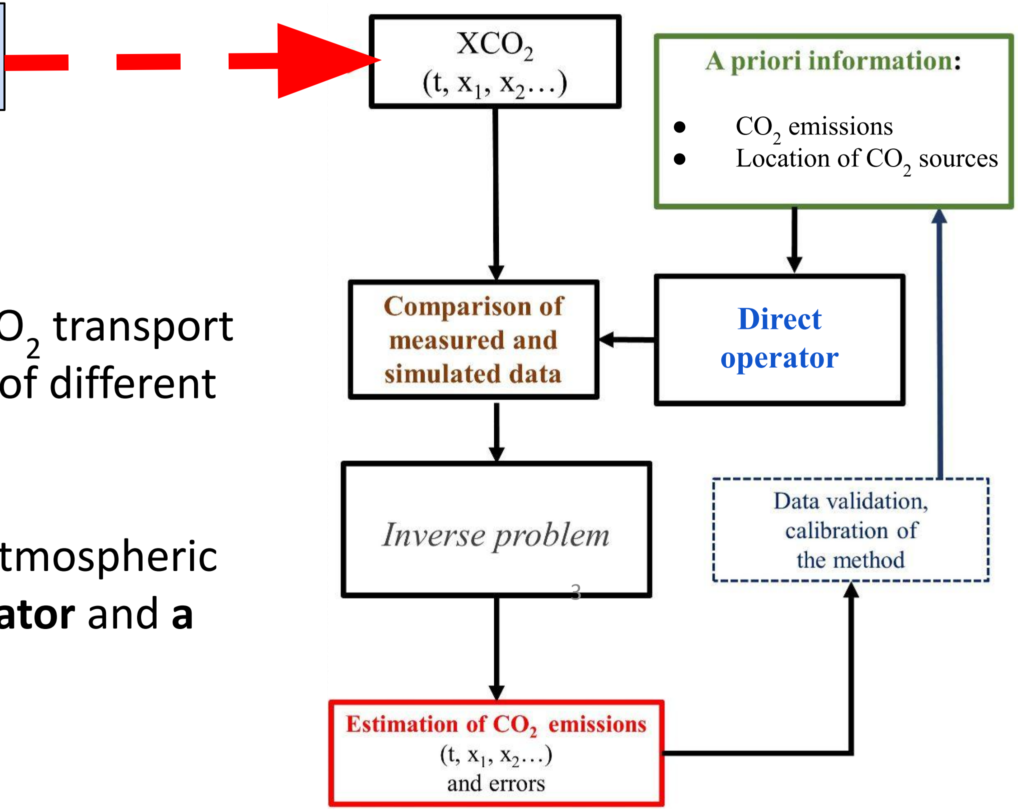
A priori data →
- Emissions of CO_2
- Location of CO_2 sources
- Boundary conditions
- Others

CO_2 emission estimation by inverse modelling (IM) of atmospheric transport

1. **IM of atmospheric optics**

2. IM of atmospheric transport

Estimates of CO_2 total content or XCO_2 from incoming solar radiation



- **Direct operator -** modelling of CO_2 transport from a priori sources by models of different complexity

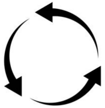
- Emission estimates depend on atmospheric CO_2 **measurements**, **direct operator** and **a priori** data

Scheme of CO_2 emission estimation by IM of atmospheric transport

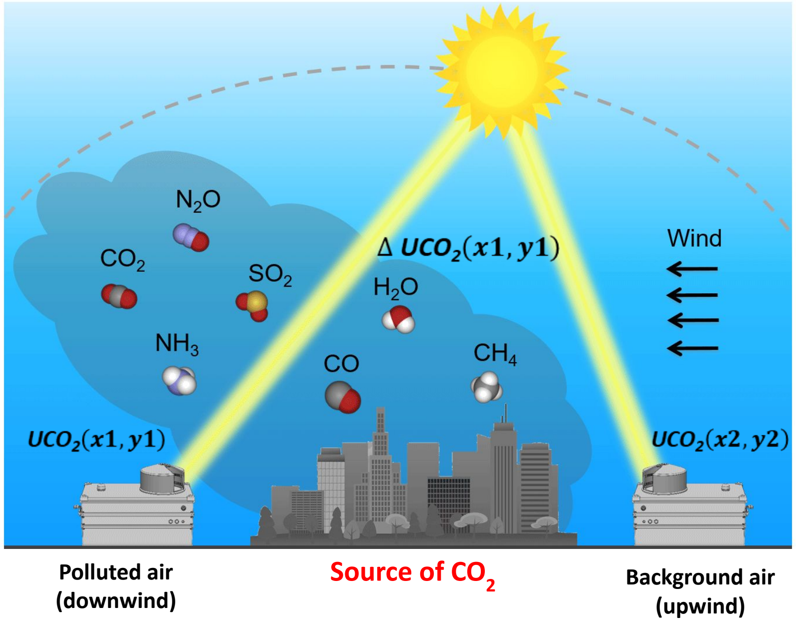
Principle of **differential spectroscopic (DS)** approach in estimating of anthropogenic CO_2 emissions of St Petersburg

1. **Estimation of city`s contribution (Δc)** to $TCCO_2$ using **parallel measurements** in background and polluted parts of St Petersburg

1. **Modelling of Δc_{mod}** by CO_2 atmospheric **transport models** and **a priori** CO_2 anthropogenic emissions



1. **Correction** of a priori CO_2 anthropogenic emissions by comparing Δc and Δc_{mod}

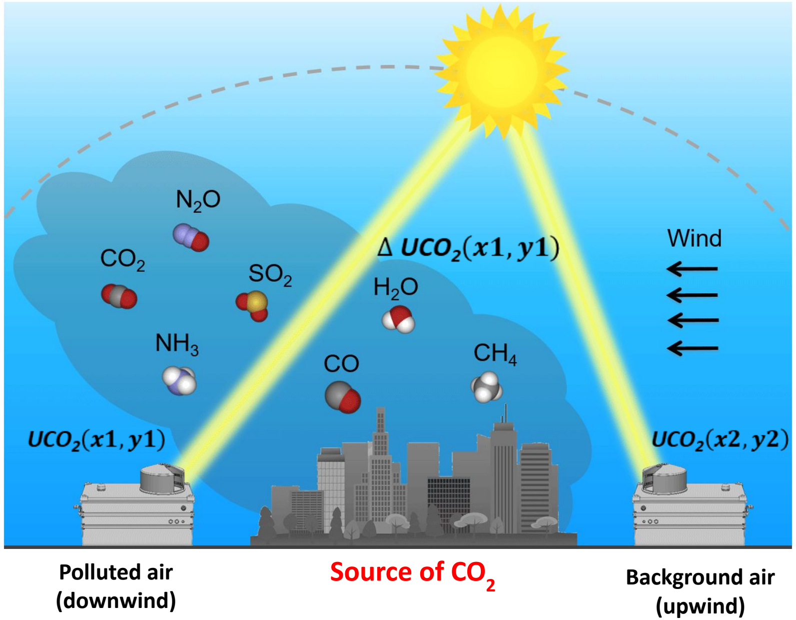


A scheme of the measurements of city`s anthropogenic contribution to gaseous content by **differential spectroscopic** approach

Original from: [5]

Emission Monitoring Mobile Experiment (EMME)

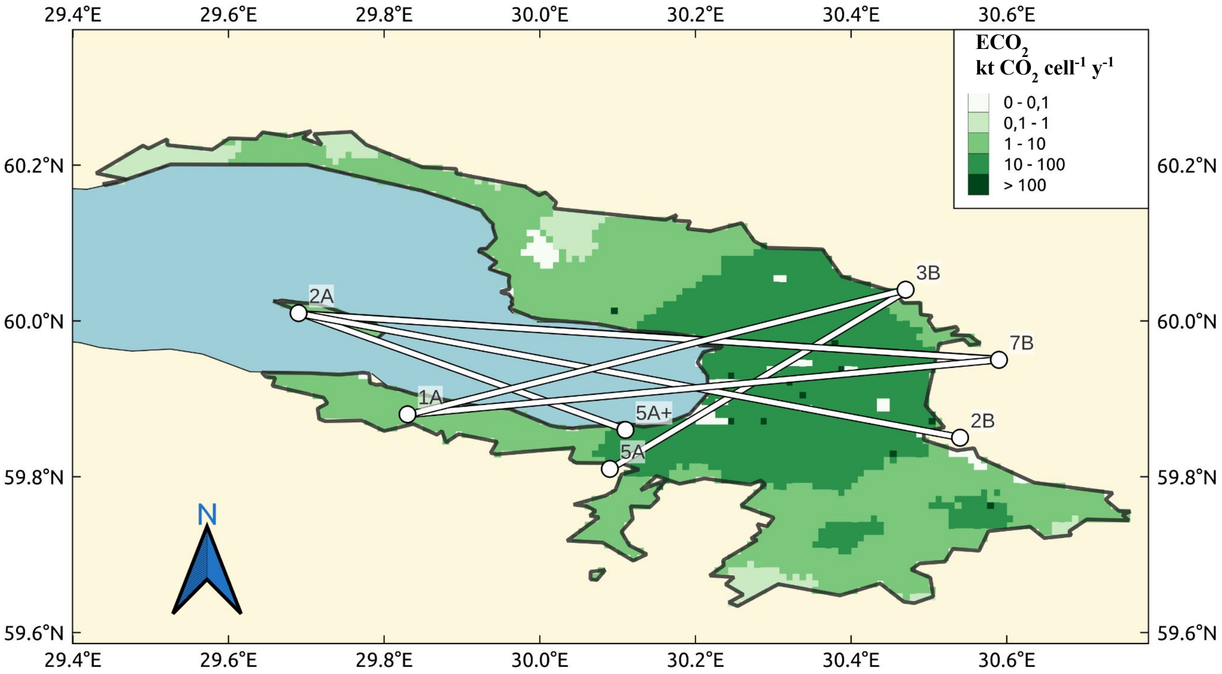
- **St Petersburg -** large industrial Russian city with over 5.5 million population
- In 2019-2020 **EMME** measurement campaign was carried out in St Petersburg by SPbU, Voeikovo observatory, University of Bremen and Karlsruhe Institute of Technology [Makarova et al., 2021]
- Two mobile **inter-calibrated** IR Fourier-spectrometers **Bruker EM27/SUN** with systematic error of ~0.02% were used in the EMME
- The **spectrometers** were used to carry out **parallel measurements** of **TCCO$_2$** and other gases in **polluted** and **background** locations of St Petersburg (see a scheme on the right)
- **11 days** of planned measurements in March-April 2019
- The **measurements** were used to estimate **St Petersburg** anthropogenic **emissions of CO$_2$**



A scheme of the measurements of city`s anthropogenic contribution to gaseous content by **differential spectroscopic** approach

Original from: [5]

Spatial coverage of St Petersburg by measurements of EMME campaign in Mar-Apr 2019 (simplified assumption)



Spatial distribution of CO_2 anthropogenic emissions in St Petersburg by ODIAC 2019 inventory database [6] for Mar 2019 and simple trajectories of air mass transport during EMME measurements

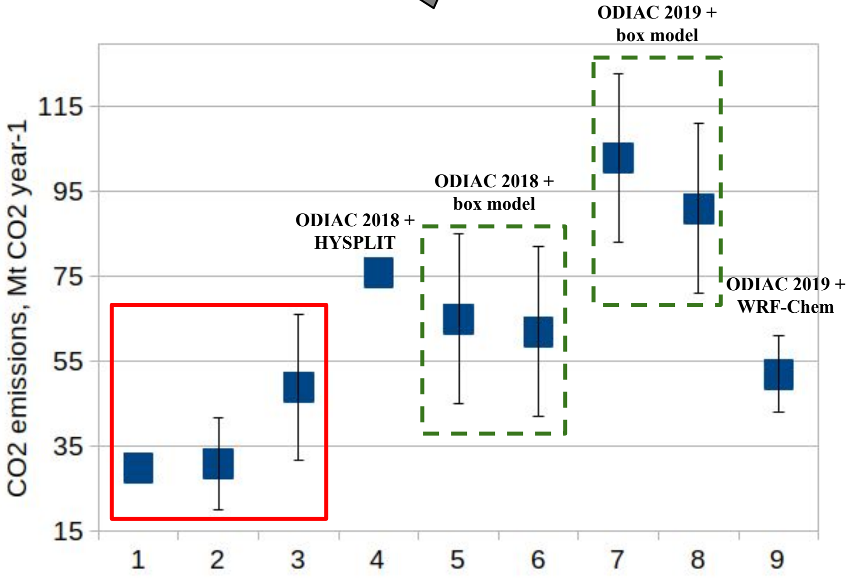
Methods used for St Petersburg anthropogenic emission estimation

N	Research	Atmospheric transport model	A priori data	Measurements
1	[Timofeev et al., 2020]	1D box model	ODIAC 2018	EMME 2019
2	[Timofeev et al., 2022]	1D box model/ STILT dispersion model	ODIAC 2018 ODIAC 2019	
3	[Ionov et al., 2021]	HYSPLIT - dispersion model	ODIAC 2018	
4	In progress	WRF-Chem - 3D numerical model of weather forecast and tropospheric composition	ODIAC 2019	

Estimates of St Petersburg CO_2 anthropogenic emissions

The same information

N	Method of CO_2 emission estimation	CO_2 anthropogenic emissions, Mt CO_2 year^{-1}	Error
1	St Petersburg official inventory [10]	30 (2015)	-
2	ODIAC 2018	31 (2018)	from ~35% [11]
3	ODIAC **2019**	49 (2019)	
4	EMME 2019 + dispersion model HYSPLIT + ODIAC 2018 [9]	76 (2019)	-
5	EMME 2019 + 1D box model + ODIAC 2018 [7]	65 (2019)	from ~20 Mt CO_2 year^{-1}
6	EMME 2019 + 1D box model + dispersion model STILT + ODIAC 2018 [8]	62 (2019)	
7	EMME 2019 + 1D box model + ODIAC **2019** [8]	103 (2019)	
8	EMME 2019 + 1D box model + dispersion model STILT + ODIAC **2019** [8]	91 (2019)	
9	EMME 2019 + WRF-Chem + ODIAC **2019**	52 (2019)	from ~9 Mt CO_2 year^{-1}



Red - inventories, green - inverse modelling method

Conclusions

1. The main factors influencing accuracy of integral CO_2 anthropogenic emissions of St Petersburg are the following

- spatial inhomogeneity of CO_2 sources on the territory of the city
- errors in a priori CO_2 emissions
- complexity of atmospheric transport models

1. The full available range of CO2 anthropogenic emissions of St Petersburg is 30-100 Mt CO_2

1. Using different a priori information and atmospheric transport models leads to the variations of emission estimates up to 50%

1. The estimates of St Petersburg anthropogenic CO2 emissions for 2019 according to inverse modelling are in a range ~50-100 Mt per 2019.

1. The most reliable estimates of St Petersburg anthropogenic CO_2 emission for 2019 according to our investigations is 52±8 Mt per year.

1. Emissions of such large cities as New-York, London, Toronto according to independent estimates constitute 92, 32, 16 Mt per 2019 respectively.

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Thank you for your attention!