Klaipėdos Universitetas

Use of ANN models for port air pollution management

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- Growing amount of waterborne transport increases shipping emissions.
- Increasingly focusing on air quality in cities and ports more effective ways to evaluate emissions are sought.
- There are different problems in estimating port air pollution including missing data as well as no way for direct statistical emission estimation model and environmental impact of estimation.

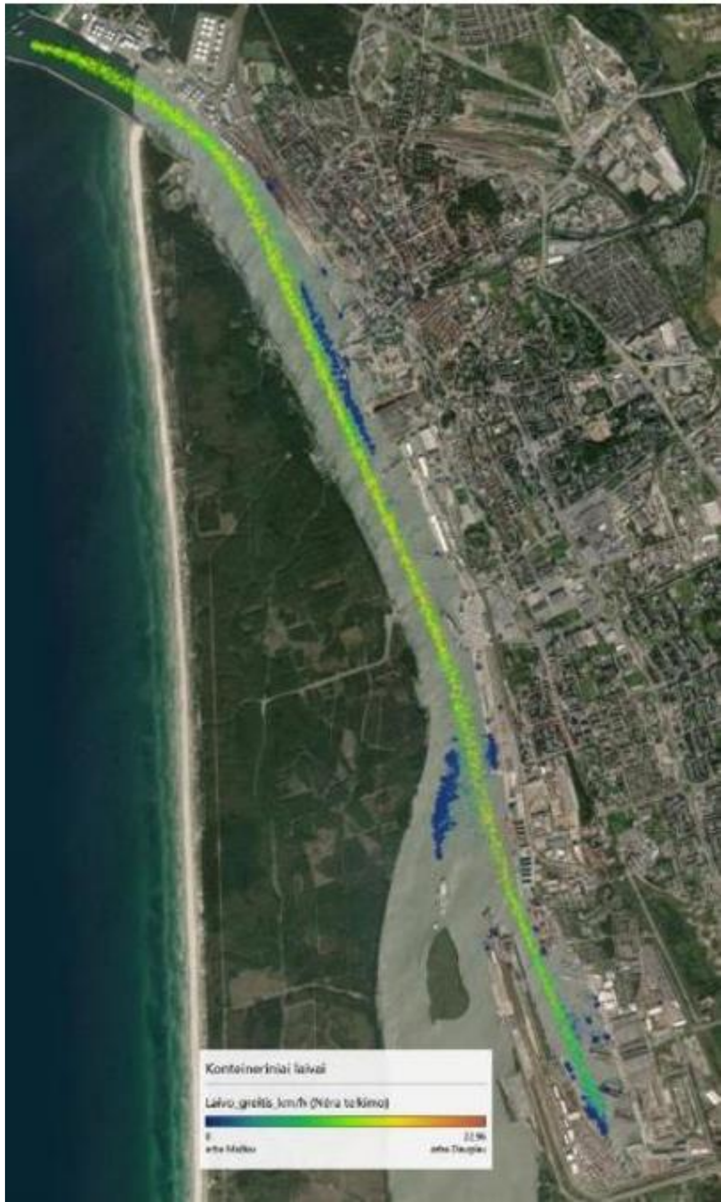
- Currently, to evaluate air pollutant emissions in port and their influence on environment three methods are being employed:
  - Statistical estimation models (example EMEP/EEA navigation model).
  - Direct air pollutants measurement.
  - Usage of air quality evaluation models.

  With each method certain limitations exists that can be improved by applications of ANN models.

STATISTICAL ESTIMATION MODELS

Statistical models have a number of benefits:

- They are easily scalable to any vessel traffic intensity.
- Can be easily integrated into automated port systems.
- Have acceptable accuracy, if enough accurate data on ships is available.



STATISTICAL ESTIMATION MODELS

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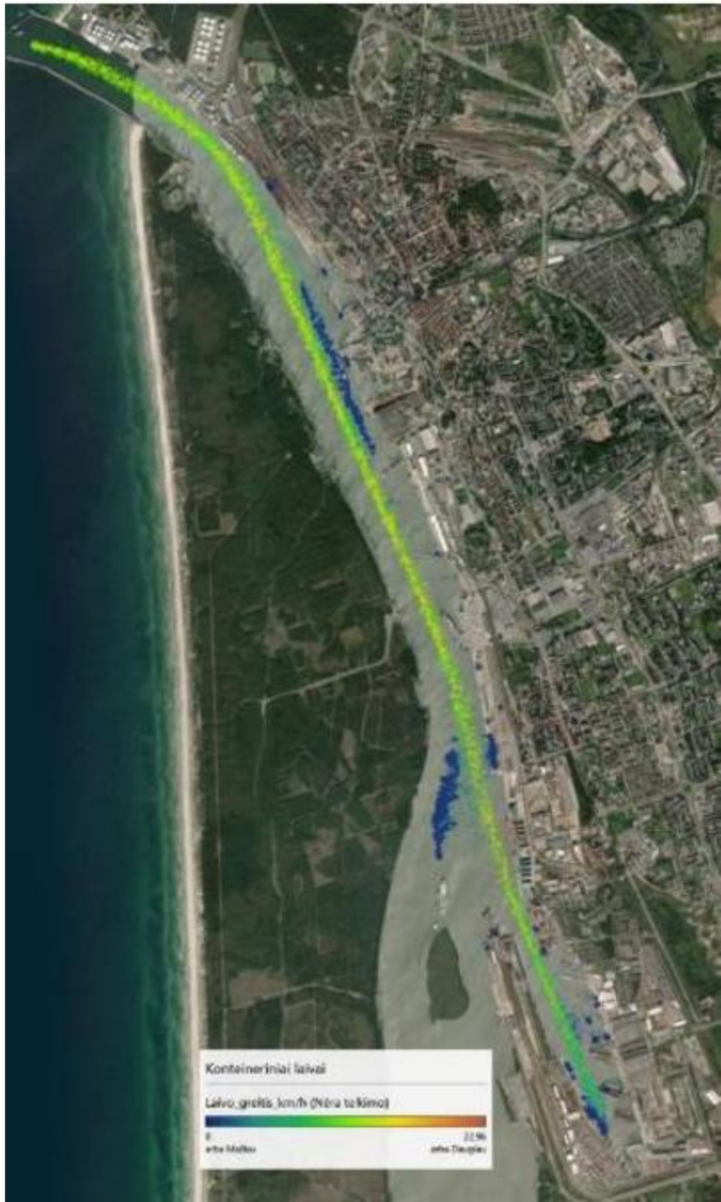
- Have acceptable accuracy, if enough accurate data on ships is available.
- For example EMEP/EEA Navigation pollutant emission from ship estimation model has 3 tiers of estimation. With the third one requiring data such as ship engine power, engine type and engine speed, as well as other data regarding movement and type of ship.
- Data on ship engines is not always available in databases, especially such as ship engine speed. Making use of Tier 3 difficult.



STATISTICAL ESTIMATION MODELS

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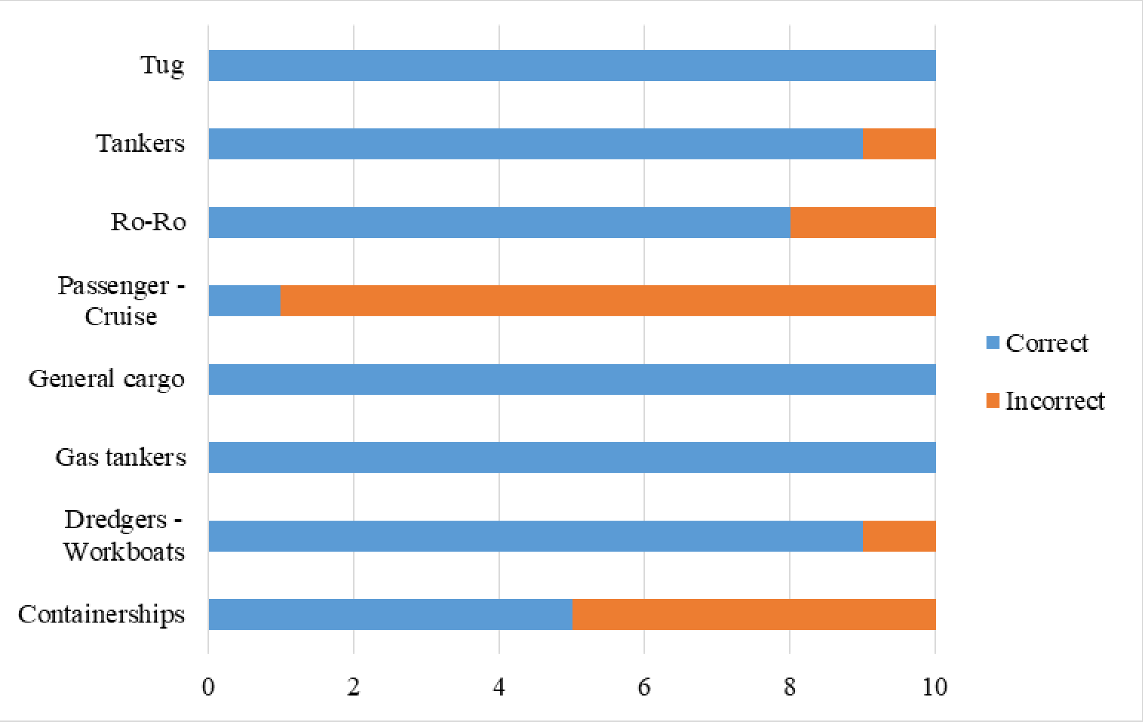
A solution can be use of ANN models for missing data prediction.

- A relatively simple ANN model, capable of predicting engine speed, based on ship type and engine power was developed.
- Model was trained on 89939 vessel data base, initial data consisted of vessel type, main engine power and number of engines and engine speed category according EMEP methodology (High, Medium, Slow).
- The resulting model can predict engine speed category for vessels that were not in original data base (with exceptions for certain vessel types – development still in progress).

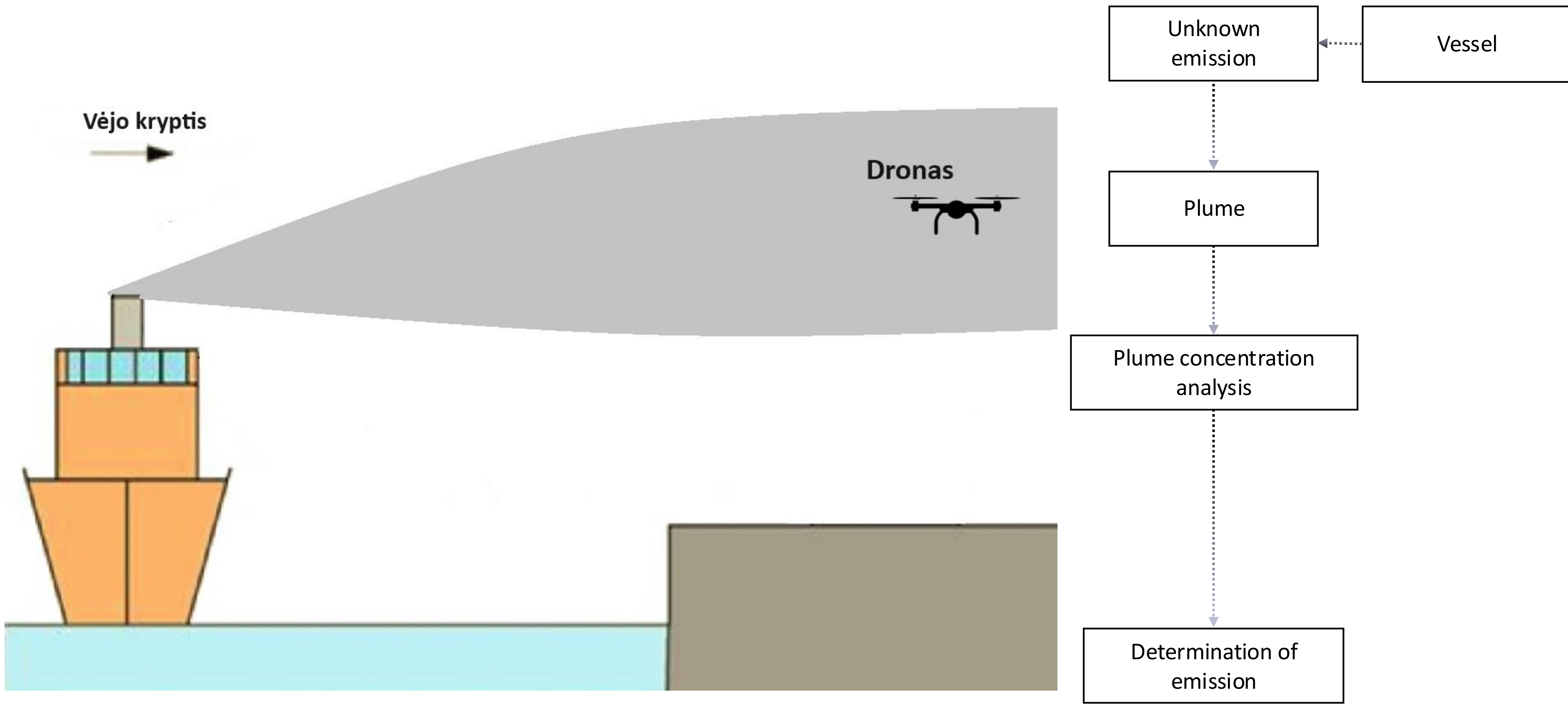


DIRECT AIR POLLUTANTS MEASUREMENT

- Direct air pollutant emission measurement is by far the most accurate way to determine air pollutant emissions from a vessel.
- Requires to get a lot of data from a vessel, including fuel consumption.
- Does not scale on port level, where vessel traffic is high.
- Needs qualified personnel and time to implement.

DIRECT AIR POLLUTANTS MEASUREMENT

- A more modern solution is to apply UAV’s with pollutant measurement equipment.
- Can be perfectly used for fuel sulfur content control by CO2/SO2 ratio control.
- Has limited to no capability to determine pollutant emission in units of mass.
- The capabilities of UAV’s can be improved with NN, by development of methodology for estimation of emission, based on plume measurement.



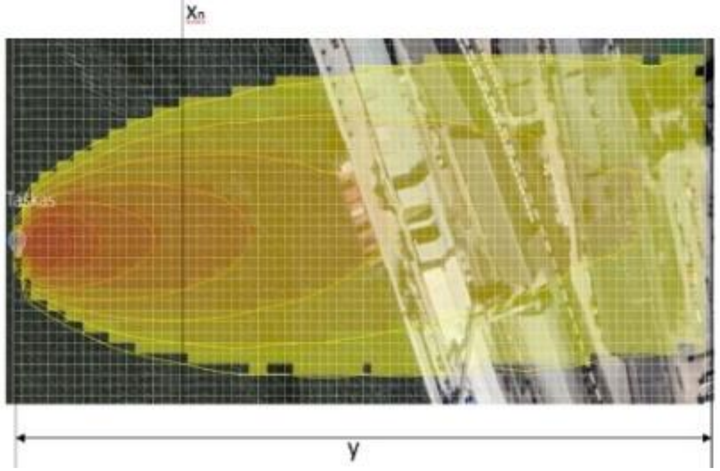
Vėjo kryptis
Dronas
Unknown emission
Vessel
Plume
Plume concentration analysis
Determination of emission

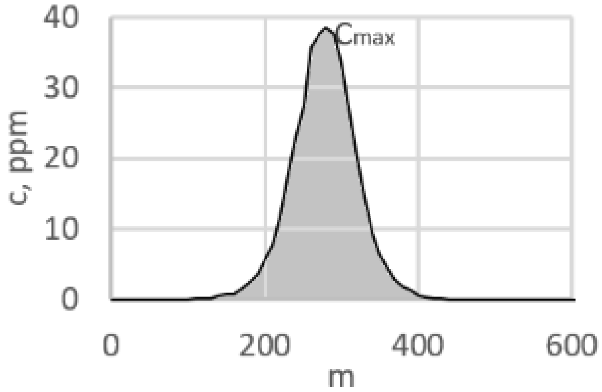
DIRECT AIR POLLUTANTS MEASUREMENT

Four parameters were used for training the neural network:

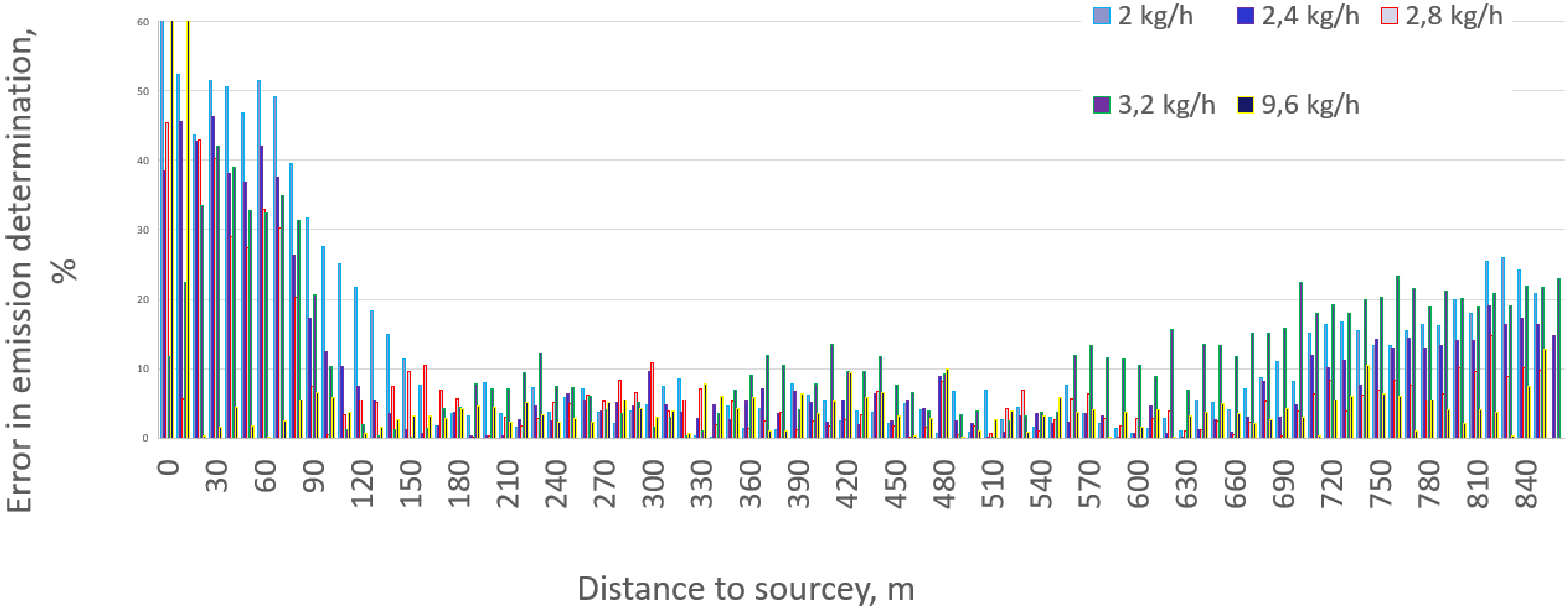
- Maximum concentration at each plume step (x) Cmax, ppm
- Concentration integral at each y step $\int c\,(x)dx$
- Distance y from the pollution source, m
- Emission rate for plume generation in each simulation case, E, kg/h."

The vessel exhaust gas plume was modeled with Lagrangian plume model (left – horizontal dispersion of the exhaust gas plume, right – example of the integrated LID plume cross-section at distance x, with the maximum concentration Cmax marked)."





DIRECT AIR POLLUTANTS MEASUREMENT



Model's average error at different distances and emission rates from the source

AIR QUALITY EVALUATION MODELS

- In order to evaluate the effects of shipping emissions on the environment a pollutant dispersion estimation is necessary.
- The process can be quite time consuming, require a lot if initial data that can not be gathered quickly or in automated way.
- To make process more manageable, NN model was developed that allows to circumvent many of the initial data, and rely on limited data.

GENERAL ASSUMPTIONS FOR MODEL DEVELOPMENT

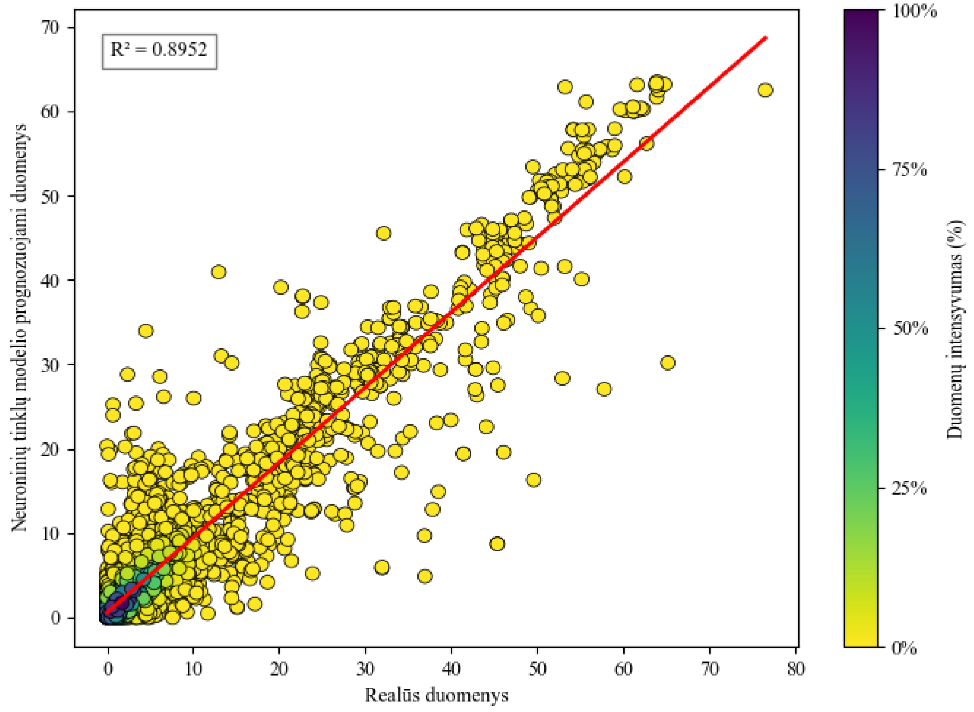
- The dispersion of solid particles depends on the technical parameters, position of the ship, emissions, and meteorological conditions.
- These parameters can also be evaluated directly, or through secondary parameters. The relationship between all these parameters is known, but the direct evaluation of each of them is difficult.
- The model is based on usage of AIS system data, the technical database of the ships, the ambient air measurement data, and the ambient air pollution of 1 µm, 2.5 µm, 10 µm (PM1, PM2.5, PM1) data.
- To distinguish the ambient air pollutant data from other sources, the data was selected when the wind direction was from 180 to 360 degrees.

AIR QUALITY EVALUATION MODELS

- To create and train neural network model, Neural Designer software were used.

- The training data consisted of real measurements of ambient air pollutant concentrations of particulate matter done in one minute intervals in port for 6 months.

- Data was divided for neural network training, selection and testing as follows: i) 60 % for training, ii) 20 % for selection, and iii) 20 % for testing.



- The trained neural network, using position, technical and meteorological data, predicted the concentrations of particulate matter at different distances from the vessel.
- The correlation coefficient amounted from 0.82 to 0.92 depending on pollutant.
- The best correlation is achieved with PM1, the smallest fraction measured solid particulate matter.

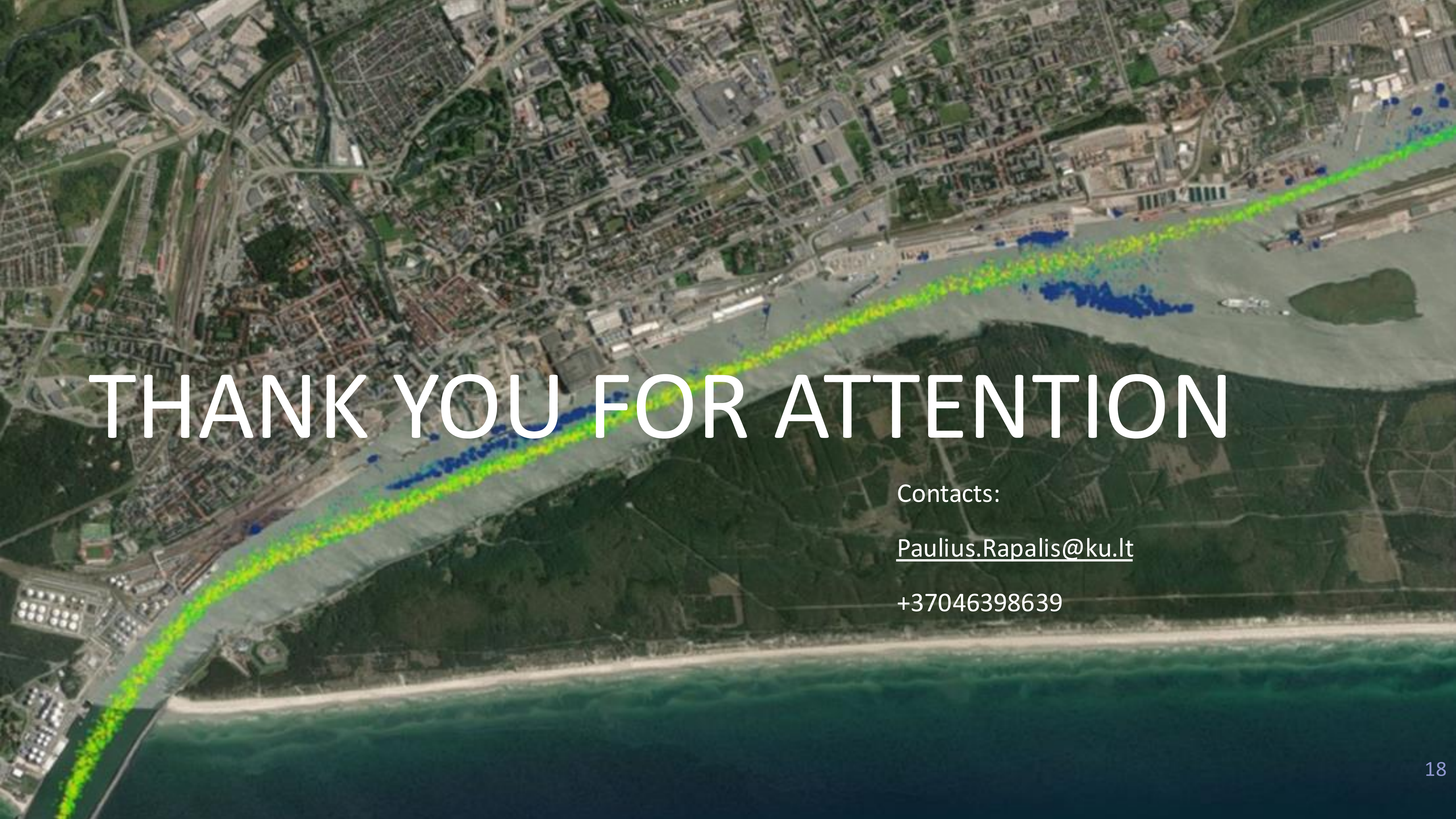
- The presented model allows the evaluation of dispersion of air pollutants from ship at real time.
- Model was able to find connection between all inputs and can adjust predictions if any of parameters change.
- Trained model can evaluate particulate matter dispersion as well as any other existing models like AERMOD or GRAL.
- This model could be included in other system to operate together with evaluation of other sources for a full picture of port environmental conditions.

CONCLUSIONS

In the port environment, the simplest way to estimate ship emissions is from statistical models. How ever the quality of the evaluation strongly depends on available technical data. ANN models can assist in accurately predicting missing data and ensuring accurate evaluation.

Measurement of exhaust gas emission is the most accurate way to determine emissions, but is close to impossible to implement on a larger scale. In port a combination of UAVs and NN models can be established to accurately evaluate emissions of selected vessels.

ANN's models are already used for air quality determination in cities. As it is shown in this study, neural networks can be trained based on real ship operation and pollutant concentration data to develop a model for online prediction of air pollutant plumes from ships in ports based only on data that is already available for port operators.



THANK YOU FOR ATTENTION

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