Ecological Monitoring Network for the Gulf of Finland

Oksana Smirnova, Tatiana Popovich

(Oksana Smirnova, PhD, St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences (SPIIRAS), 39, 14 Linia VO, 199178, St. Petersburg, Russia, SPIIRAS - Hi Tech Research and Development Office Ltd, 7, 14 Liniya, 199178, St. Petersburg, Russia, sov@oogis.ru)

(Tatiana Popovich, research assistant, SPIIRAS - Hi Tech Research and Development Office Ltd, 7, 14 Liniya, 199178, St. Petersburg, Russia, PhD-student, the Bonch-Bruevich St. Petersburg State University of Telecommunications, 22 Prospekt Bolshevikov, St. Petersburg, 193232, t.popovich@oogis.ru)

1 ABSTRACT

Ecological situation in the Baltic region has notably worsened in the last 20 years. On the one hand, public organizations are bringing investments in order to build clear transport, green cities, to lower energy consumption in the region. On the other hand, construction of a new building of Leningrad Nuclear Power Plant not far from St. Petersburg is planned in the nearest future. In order to control the level of air pollution, to study the impact of pollution on the environment, to identify the most endangered regions, we would like to propose a new permanent ecological monitoring network for the Gulf of Finland. We hope this network will join together environmental specialists from different countries, which will allow to design a global ecological monitoring network. The major tasks for this network are the following: organization of ecological monitoring for the Baltic region and research of air pollution distribution along the Baltic sea; assessment of affects on the environment, health risks for atomic power plant staff and inhabitants of the nearest regions (North-West Russia, Estonia, Finland, Sweden); investigation of seasonal and daily changes of atmospheric temperature, pressure, humidity, wind and their effect on distribution of air pollution; creation of specialized social network for environmental scientists for data and research exchange. An example of ecological monitoring network operation in the Gulf of Finland along with description of means and results of monitoring are given in this paper.

Keywords: meteorology, measurement, ecology, monitoring network, GIS

2 INTRODUCTION

At present time, there are a lot of different atmospheric dispersion models designed by Environmental Agencies in different countries all over the world. One of the most widely-used and respected atmospheric dispersion models is called CALPUFF (Thongplang, 2016). It uses a meteorological model, a dispersion model and a post processing package as major inputs (Thongplang, 2016).

Among atmospheric dispersion models, we can distinguish ones that operate in the Baltic region, e.g. CMAQ (HZG), EMEP (IVL) and SILAM (FMI).

SILAM (System for Integrated Modelling of Atmospheric Composition) was developed in Finnish Meteorological Institute. It is used to predict consequences of emergency situations and contains record modules of dispersal of radionuclide, different-sized aerosols and natural allergens. For numerical modelling, SILAM either uses meteorological data bases (Sofiev et al., 2006) of the European Centre on Medium-Range Weather Forecast (ECMWF, http://www.ecmwf.int), or numerical prediction models in HIRLAM (Unden, 2002).

CMAQ (Community Multi-scale Air Quality) was released by US Environmental Protection Agency. It estimates deposition of ozone, particulates, toxics and acid (CMAQ). CMAQ combines meteorological models, emissions models and an air chemistry-transport model, which allows to use it for predicting the dispersal of multiple air pollutants and for generating air quality estimates (CMAQ).

EMEP (European Monitoring and Evaluation Programme) is a cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe. It relies on three main elements: collection of emission data, measurements of air and precipitation quality and modelling of atmospheric transport and deposition of air pollutions (EMEP). It provides assessment and regularly reports on emissions, concentrations and depositions of air pollutants, the quantity and significance of transboundary fluxes and related exceedances of critical loads and threshold levels (EMEP).

Input data for atmospheric dispersion models are usually the following:

- characteristics of emission source (concentration of pollutants, flow rate, temperature, height of emission source and etc.);
- meteorological characteristics (wind velocity, type of atmospheric stability, temperature and etc.);
- characteristics of terrain (city or village, relief, nearby buildings and their shape and etc.).

Among meteorological characteristics that influence pollution dispersion can be velocity and direction of wind and vertical temperature stratification. Air quality standards, e.g. annual average, are usually based on statistical data. Therefore, a vast volume of statistical data about meteorological characteristics taken over a lengthy time period is required. Also, sets of meteorological data should be representative for a given region, i.e. they should represent all regional peculiarities.

It should be noted that currently existing atmospheric dispersion models do not fully take into account all peculiarities of the atmosphere. Major meteorological parameter required for dispersion models is atmospheric mixing height (Seibert et al., 2000). The atmospheric mixing height is the layer adjacent to the ground over which pollutants or any constituents emitted within this layer or entrained into it become vertically dispersed by convective or mechanical turbulence within a time scale of about a hour (Stull, 1988; Seibert et al., 1998). Vertical profile of atmospheric mixing height depends on variation of air temperature, atmospheric pressure and wind velocity. Variation of air temperature depends on the type and parameters of underlying surface. Temperature can increase and decrease with altitude variation depending on the time of day and the season.

Monitoring of lower levels of the atmosphere is conducted with special means like radiosondes, wind profilers (Angevine et al., 1998), ceilometers (Eresmaa et al., 2006), remote sounding systems: lidars (Hennemuth and Lammert, 2006), sodars (Russell and Uthe, 1978) and etc. However, application of such means has a number of limitations connected with weather conditions, high costs of experiments, resolution and accuracy of measurements.

Successful implementation of said models for modelling of prevalence of pollution over the observation region and efficient estimation of air pollution depend, first of all, on the model of atmosphere and on meteorological information. We propose to create totally new ecological monitoring network, which will allow to monitor changes of meteorological parameters, radiation and others parameters in real time on different heights above the sea surface. For this network we propose to use a specialised measurement module that allows to measure basic meteorological parameters (air temperature, relative humidity, atmospheric pressure, direction and velocity of wind) in lower levels of the atmosphere with high vertical resolution. Also, these data can be used as initial data for numeric modelling of prevalence of pollution over the observation region.

3 ECOLOGICAL MONITORING NETWORK

Ecological monitoring network consists of two or more measurement modules connected to each other. Each module includes a set of meteorological and gamma-radiation sensors. Sensors are located vertically on the pole (Fig. 1) or other suitable vertical surface at the set distance from each other and provide measurements of the atmospheric and radiation parameters. Power can be provided from standard power unit or other electrical source with the range of 7-14 volt with the current of at least 2 ampere.

Each measurement module consists of:

- wind velocity and direction sensor;
- set of integrated sensors that measure relative humidity, atmospheric pressure and air temperature;
- gamma-ray radiation sensor;
- cross-connect equipment.

The major tasks of ecological monitoring network are the following:

- collection, processing, storage and visualisation of information about atmospheric and radiation parameters;
- data analysis for identification of the anomalous regions and regions that threaten the ecological safety;

- study and research of daily and seasonal changes of atmospheric and radiation parameters and their effect on distribution of air pollution;
- creation of regional model of the atmosphere;
- study of applicability of this atmosphere's regional model for prediction of distribution of radiation and air pollution above the sea surface and its other applications;
- creation of specialized social network for environmental scientists for data and research exchange.

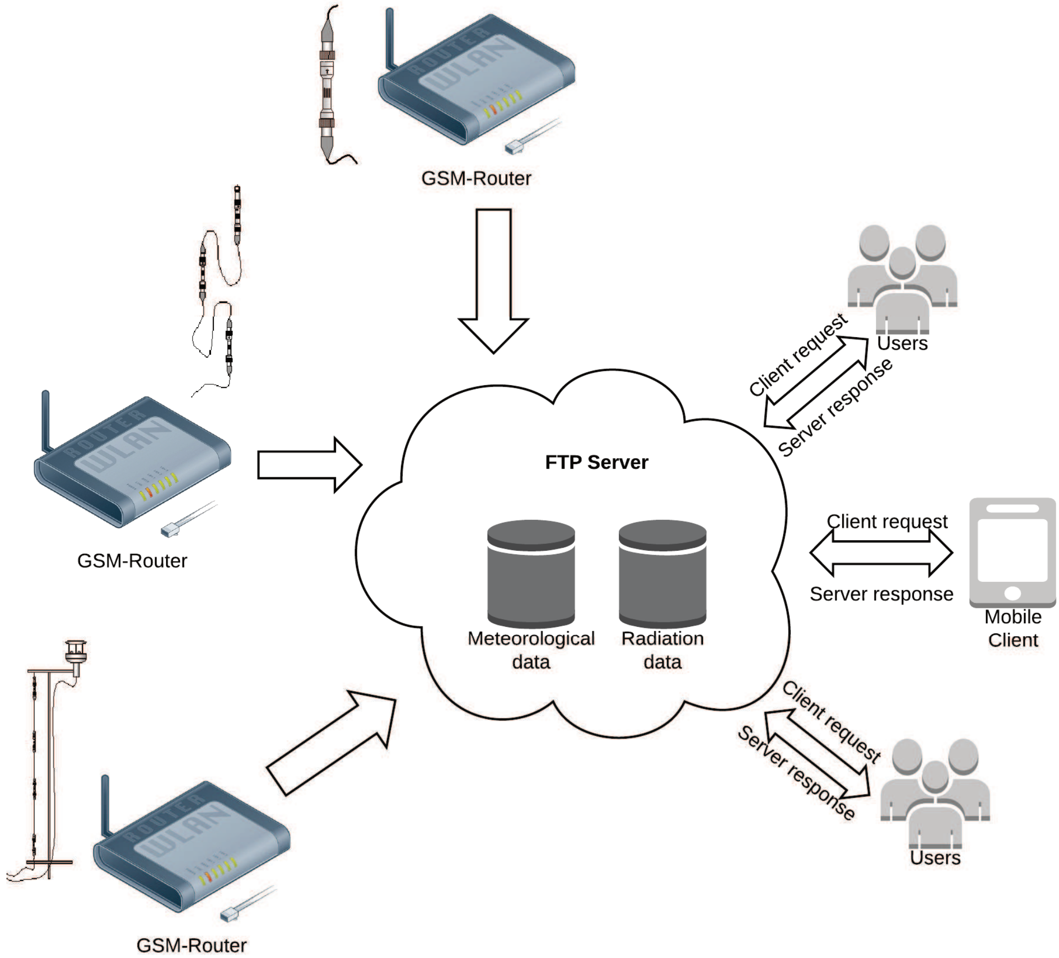

Fig. 1: Scheme of the ecological monitoring network.

The measurement module includes several meteorological multisensors which are located on the predetermined height from the earth surface. It collects the major meteorological data (air temperature, relative humidity, atmospheric pressure and wind velocity and direction) and radiation at intervals of every 5 minutes. Obtained data is transmitted to FTP-server through information channels. FTP-server is a special application for data storage and users' requests processing for the purpose of meteorological and radiation information retrieval under various search conditions. With the use of specially developed script, after every cycle of measurement, obtained data is converted into structured text files.

These files contain data about time of the beginning and the end of measurement process, size of measurements, description of measurements (data name, data type, variable's type: analogous or digital) and values of measured parameters. Structured text files are stored at FTP-server. With the use of developed application, contents of these files can be visualized in form of tables and graphics upon users' request.

4 CASE STUDY: EXAMPLE OF ECOLOGICAL MONITORING NETWORK IN THE GULF OF FINLAND

4.1 Description of proposed ecological monitoring network in the Gulf of Finland

At present time, ecological monitoring network is established along the route: Vasilievsky Island (Saint-Petersburg), Kronshtadt, Seskar Island, Moshchny Island, Gogland Island. It allows to take measurements of

ISBN 978-3-9504173-2-6 (CD), 978-3-9504173-3-3 (print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI, Clemens BEYER

meteorological parameters and of radiation in the region of about 30 000 square km. Data is transmitted to FTP-server in real time and are stored in form of structured text files.

Moreover, from time to time, measurements of meteorological parameters are taken from the helicopter. On the 5-th September 2016 at 09:07:50 (MSK) offshore in the Gulf of Finland, an experiment was conducted with purpose of comparing theoretical and experimental data. Measurements were taken with the use of network of meteorological multisensors, constructed by “SPIIRAS-HTR&DO Ltd.”. This network was collecting measurements of tree major parameters: air temperature, relative humidity and atmospheric pressure. Measurements were taken from a helicopter Robinson R44 over a region size of about 50 square km.

In the Table 1, information about actual weather in the observation region from Russian Federal Service for Hydrometeorology and Environmental Monitoring [15] is given.

Parameter	Value
Atmospheric pressure on the station’s level, mm Hg	756
Air temperature, 0C	15.3
Minimal temperature, 0C	11.6
Relative humidity, %	81
Wind direction (At time of experiment, direction of wind changed multiple times)	S-W
Wind velocity, mps	2
General visibility, ball	4
Horizontal visibility, km	10
Atmospheric precipitation in 12 hours, mm	0
Water temperature in the Gulf of Finland, 0C	16

Table 1: Information About Actual Weather in the Observation Region

Measurement network consisted of two meteorological multisensors, attached to a conducting rope. Schematics of multisensors’ fixation on the helicopter and outside appearance of meteorological multisensor is shown in Fig. 2.


Fig. 2: Schematics of multisensors’ arrangement during the experiment and outside appearance of meteorological multisensor.

4.2 Observations and analysis

During the experiment, the following scheme of measurement taking was chosen. The helicopter followed previously developed and approved flight plan over the region of the Gulf of Finland. In the determined points of flight route, during the smooth decent of the helicopter, vertical measurements of meteorological parameters (air temperature, relative humidity and atmospheric pressure) were taken. Moreover, meteorological measurements were taken during horizontal flight from one point to another. Overall, 10 measurements were taken vertically and 4 – horizontally.

Documentation of obtained data was executed by specialised software. All data was later exported into structured text files. Vertical profiles of variation of air temperature, relative humidity and atmospheric pressure with dependence on height alteration obtained in the first point on route are shown in Fig. 3.

Obtained meteorological data, after proper processing, can be successfully used for numerical modelling of air pollution propagation over the Baltic Sea. Variability (volatility) of vertical profiles of meteorological parameters, that can be clearly seen on Fig. 3, significantly influences trajectories of air pollution propagation in lower levels of the atmosphere.

So, profiles of meteorological data are available to user at any time. Vertical resolution for measurements may change from a few centimetres up to ten meters.

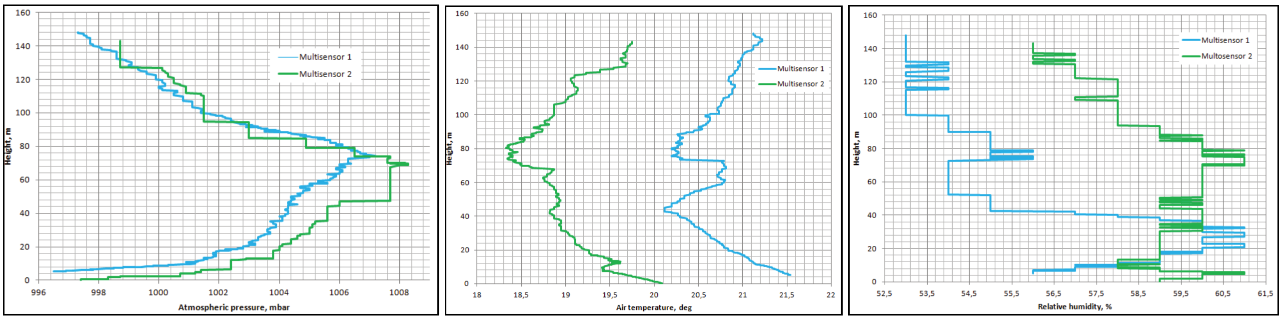

Fig. 3: Vertical profiles of atmospheric pressure, air temperature and relative humidity distribution in relation to height.

5 CONCLUSION AND FUTURE WORK

In this paper, we have proposed a new permanent ecological monitoring network for the Gulf of Finland, that will allow to organise the ecological monitoring for Baltic region and to assess effects of air pollution on the environment. In the future, we plan to use obtained experimental results to advance and modernise algorithms of modelling and predicting of air pollution propagation in inhomogeneous environment above the sea surface. Also, we intend to conduct further experiments in order to study the influence of variation of meteorological characteristics in circadian and seasonal cycles over the sea surface. For this, we suggest to establish an ecological monitoring network along the route: Vasilievsky Island (Saint-Petersburg), Kronshtadt, Seskar Island, Moshchny Island, Gogland Island, Helsinki and Stockholm. This network will help to predict distribution of harmful emissions, influence of technological companies' operation (thermal and atomic power stations, integral emissions in the atmosphere of large and small megalopolis and etc.) on environmental conditions. Our company is interested in international collaboration with all countries of the Baltic region (Estonia, Lithuania, Latvia, Finland, Sweden), national and international businesses for the sake of production of suitable measurement devices and hardware, production, placement, exploitation and maintenance of specialised monitoring systems. We are also keen to share informational resources of the proposed network with any interested users (science, business and government).

6 REFERENCES

ANGEVINE et al., 1998: Angevine Wayne M., Bakwin Peter S. and Davis Kenneth J. Wind profiler and RASS measurements compared with measurements from a 450-m tall tower // J. Atmos. Oceanic Technol. – 1998. – 15. – p. 818–825.

CMAQ: United States Enviromental Protection Agency, URL: https://www.epa.gov/air-research/community-multi-scale-air-quality-cmaq-modeling-system-air-quality-management

ECMWF, European Centre on Medium-Range Weather Forecast, URL: http://www.ecmwf.int (accepted on 05.06.2017)

EMEP: URL: http://emep.int/models.html

ERESMAA et al., 2006: Eresmaa, N., Karppinen, A., Joffre, S. M., Räsänen, J., and Talvitie, H.: Mixing height determination by ceilometer // Atmos. Chem. Phys. – 2006. – 6. – p. 1485-1493.

HENNEMUTH AND LAMMERT, 2006: Hennemuth B. and Lammert A. Determination of the atmospheric boundary layer height from radiosonde and lidar backscatter // Bound.-Layer Meteorol. – 2006. – 1. – p. 181–200.

RUSSELL AND UTHE, 1978: Russell Philip B. and Uthe Edward E. Regional patterns of mixing depth and stability: Sodar network measurements for input to air quality models // Bull.Am. Meteor. Soc. – 1978. – 59. – p.1275–1287.

SEIBERT et al., 1998: Seibert P., Beyrich F., Gryning S.E., Joffre S., Rasmussen A. and Tercier P., 1998. Mixing layer depth determination for dispersion modeling. In: COST Action 710 Final Report (Eds by B.E.A. Fisher, J.J. Erbrink, S. Finardi, P. Jeannet, S. Joffre, M.G. Morselli, U. Pechinger, P. Seibert and D.J. Thomson). Harmonization of the pre-processing of meteorological data for tmospheric dispersion models. L-2985 Luxembourg: European Commission.

SEIBERT et al., 2000: Seibert P., Beyrich F., Gryning Sven-Erik, Joffre S., Rasmussen A., Tercier P. Review and intercomparison of operational methods for the determination of the mixing height // Atmospheric Environment. – 2000. – 34(7). – p. 1001-1027.

SOFIEV et al., 2006: Sofiev M.: A dispersion modeling system SILAM and its evalution against ETEX data/ M. Sofiev, P. Siljamo, I. Valkama, M. Ilvonen, J. Kukkonen // Atmospheric Environment. – 2006. - №40. – p.674-685.

STULL, 1988: Stull R. B., 1988. An introduction to boundary layer meteorology. Kluwer Academic Publishers, Dordrecht.

THONGPLANG, 2016: Thongplang J. Air pollution modelling: what is it and what can it tell us? Aeroqual, August 11, 2016. http://www.aeroqual.com/air-pollution-modelling

UNDEN, 2002: Unden P. (Ed.) HIRLAM-5 Scientific Documentation. HIRLAM Project, SMHI, S-601 76, 2002, Norrkoping, Sweden.