Federal Service for Hydrometeorology
and Environmental Monitoring

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Modelling of extreme concentrations of atmospheric pollutants, their forecast and practical applications in Russia

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Concentrations of urban atmospheric pollutants are noisy and the noise should be filtered out

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- Concentrations of urban atmospheric pollutants are of highly stochastic nature varying in space and time.
- It is understood that plume meandering, resulting from the turbulent nature of the wind flow, is the major physical reason of this noise.
- Filtering out the noise is a pre-requisite for success of attempts to model and/or predict the concentrations.
- Standard techniques of noise filtering like usage of either averaged or robust mean values are not too effective due to high noise intensity and its broadband spectrum.
- In the ensemble modelling, there is no guarantee that properties of the scattering in modelled concentrations are similar to those in the real atmosphere.

Plume meandering depends on the thermal stratification of the atmosphere

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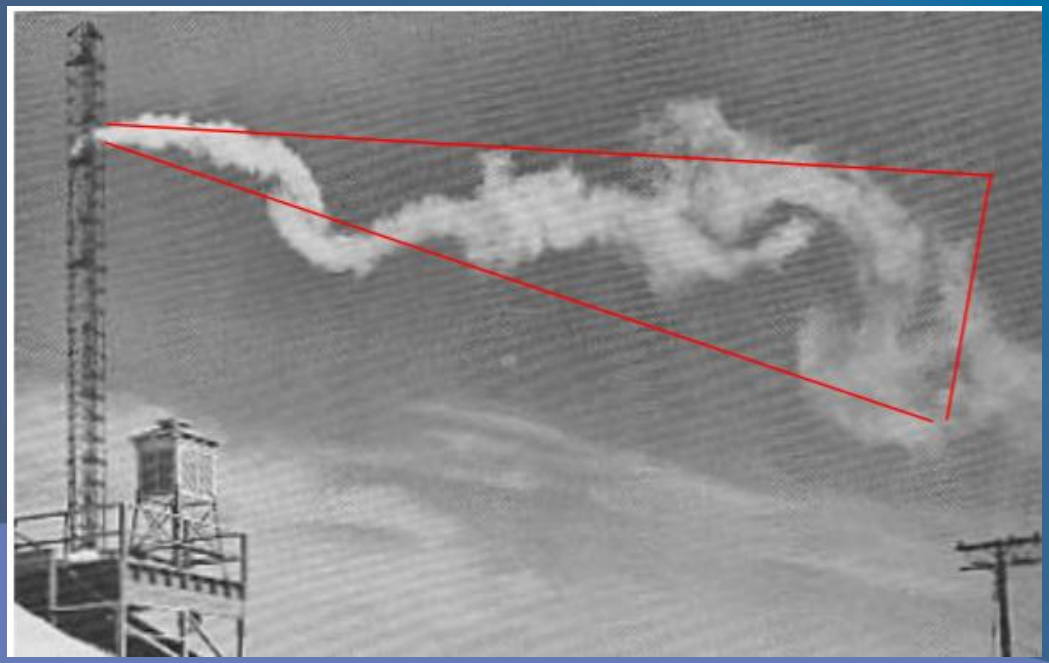
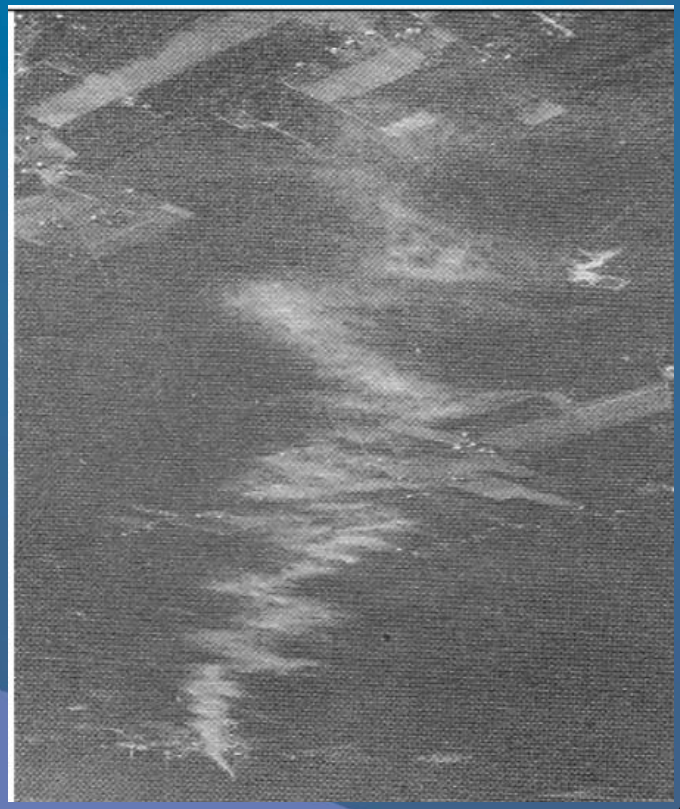
Strong instability



Strong stability



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Majorant concentration filtering

Tracer experiment

Wildfire (Australia, 18/11/2019)

- Results of the averaging depend on probability of the plume missing the receptor point due to the plume meandering;
- The highest average concentrations are measured when the plume axis hits the receptor point;
- Measured/calculated extremes (upper percentiles) are more robust characteristics of concentration fields than mean values.

Modelling the field of Majorant Concentrations (MCs)

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- ✓ MC is defined as the upper 98th percentile of the PDF of concentrations at the given receptor point (x,y,z) as well as, possibly, a given set of governing meteorological parameters ω = (U, dd, Ri,…);
- ✓ The 1st calculation technique for evaluation of MCs was developed at the Voeikov Main Geophysical Observatory (MGO) in 1960th. Based on this technique, several Russian national guidelines have been developed at MGO since that time. The most advanced one has been in effect since 2018;
- ✓ The models account for the initial plume rise, multiple sources, complex terrain, buildings and structures etc.
- ✓ The description of this approach was published in papers and monographs in Russian, English, German and Japan languages;
- ✓ The models were validated upon the field- and routine-monitoring measurements as well as upon data of the wind-tunnel experiments carried out in the former USSR and the USA;
- ✓ The models successfully participated at several international intercomparisons;

Experimental validation of the MGO model

error ~ 25%

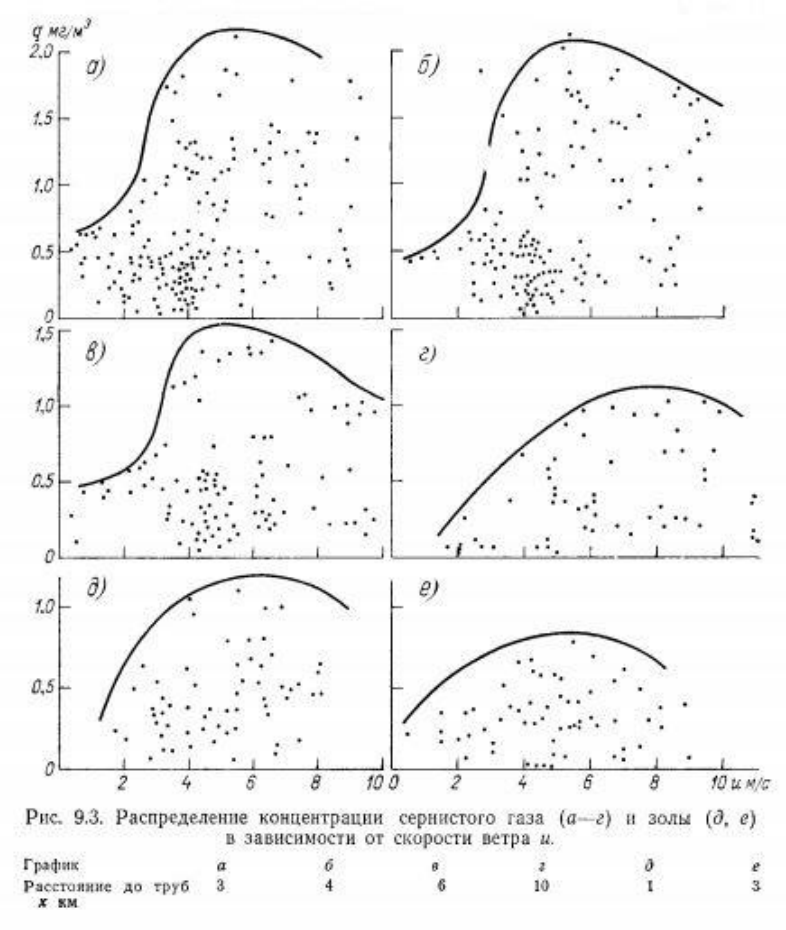
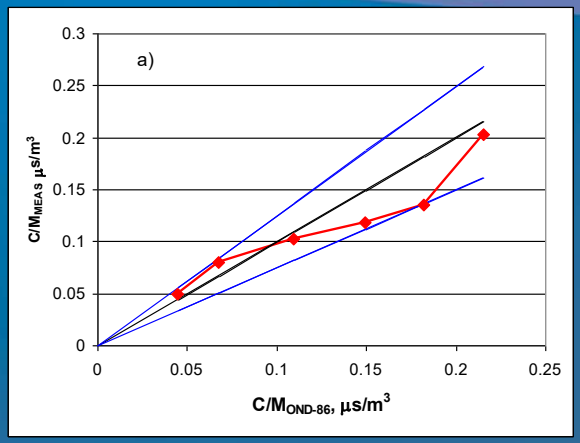
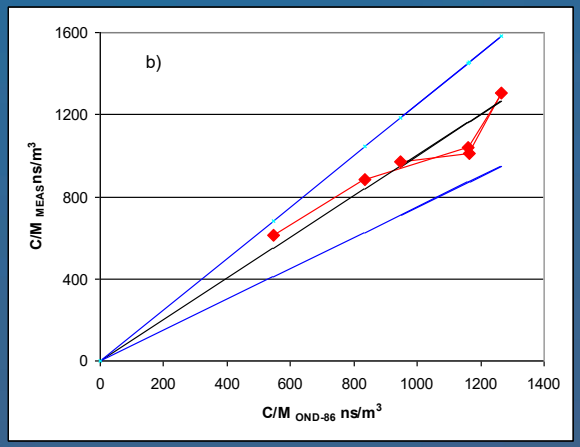


Рис. 9.3. Распределение концентрации сернистого газа (*а—г*) и золы (*д, е*) в зависимости от скорости ветра *u*.

График	*а*	*б*	*в*	*г*	*д*	*е*
Расстояние до труб *x* км	3	4	6	10	1	3



Kincaid



Indianapolis

Measured C and their envelopes
Shchekino Power Plant (PP), Russia

Modelled vs meas 98% Q-Q plot
Kincaid PP / Indianapolis, USA

Russian regulatory policy on setting Permissible Emission Limits (PEL) and on emission control

1. The PEL values have to be set up for emission sources of certain enterprise categories on condition that their MC field, calculated with account for the background concentrations, should not exceed the corresponding Ambient Air Quality Standard (AAQS);
2. By definition, as soon as the PEL values have established, measured urban concentrations, on average, could exceed the corresponding AAQS values over the year for about 2% of the time, i.e., on the whole, 7 – 8 days, which correspond to anomalous Unfavorable Meteorological Conditions (UMC);
3. Meteorological offices have to provide local authorities and enterprises with routine UMC forecasts;
4. Depending on the class of the UMC forecasts, enterprises have to execute the emission control measures, which should be developed in advance and depend on the UMC class.

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Russian national network for forecasting the air pollution (in 2019)

- Number of prognostic centers – 76;
- Number of cities serviced – 529;
- Number of enterprises which ordered specialized forecasts (with account for specific parameters of their sources) – 1859;
- Methodological guidance - MGO
- Predictands - parameter P, daily maxima of concentrations at the monitoring stations etc.
- Models in use: stochastic, deterministic (NWP+CTM) **+** stochastic (fusion);
- Predictors in use: characteristics of the previous air pollution, meteorological, aerologic and synoptic information, synoptic predictor etc.

ATTN! DAILY MAXIMA = MAJORANT FILTERING

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Additional explanations

- The parameter P is estimated as a probability (frequency) for concentrations of all daily measured pollutants at all monitoring sites to exceed corresponding seasonal or annual averaged values multiplied by 1.5;
- The parameter Pi is estimated similarly to P but using only all daily measured concentrations of the pollutant No I;
- The synoptic predictor S, which allows for quantifying synoptic situations, is estimated as the mathematical expectation of P at the given types of this situation;
- The stepwise multiple linear regression is used to construct the stochastic model. The predictors in use could be transformed first using censoring, linearization, normalization etc.;
- When estimating P, censoring out the “not-high-enough” concentrations is an important first step in filtering out the noise, which, in a sense, is similar to the majorant filtering described above;

Observed vs predicted P for Krasnoyarsk

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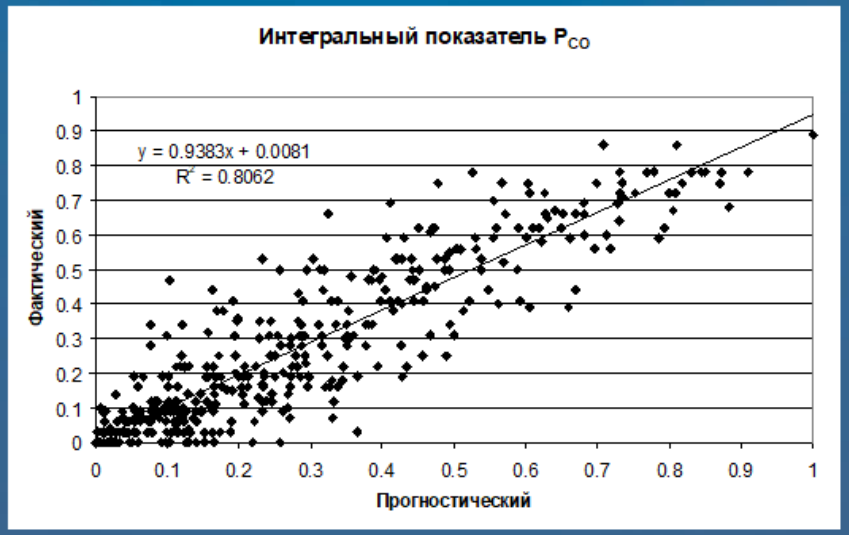
Hydrogen fluoride

Carbon monoxide



Presented data correspond to 2008 – 2012
when the system of the emission control has not been in effect yet

Statistical characteristics of P forecasts, Krasnoyarsk

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Pollutant	Season	Number of forecasts	Pearson correlation coefficient	
			Training sample	Independent sample
All measured	Warm	690	0,82	0,77
	Cold	638	0,86	0,84
HF	Warm	647	0,70	0,68
	Cold	599	0,70	0,69
CO	Warm	685	0.86	0.88
	Cold	596	0.90	0.92

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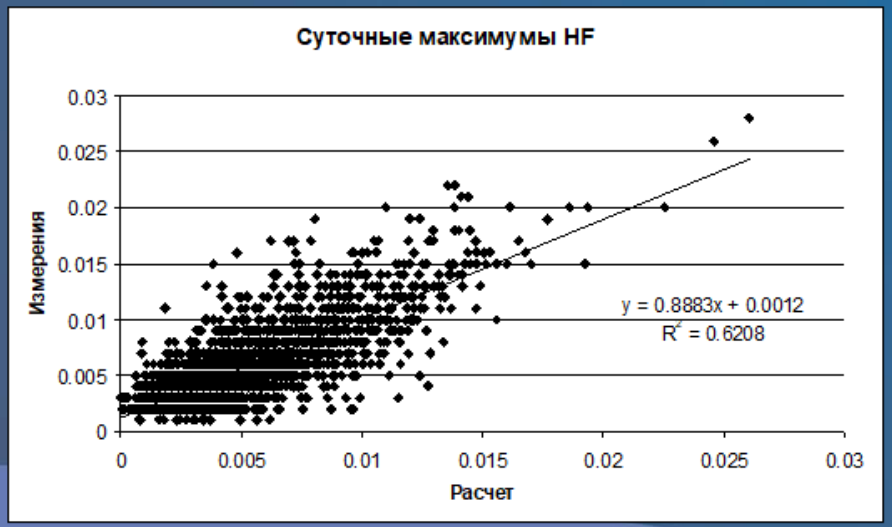
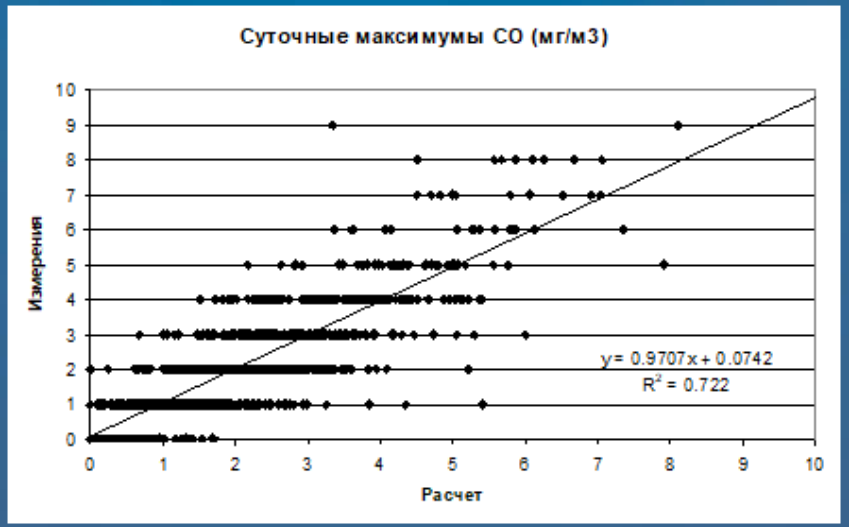
Observed vs predicted daily concentration maxima for Krasnoyarsk

Hydrogen fluoride



Carbon monoxide



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Conclusions

1) Models for simulation and prediction of majorant urban concentrations seem to be performing better than “standard” models which are supposed to generate the concentrations corresponding to the given values of time and governing meteorological parameters;
2) One could speculate that it could be attributed to the fact that the limit distributions of majorant concentrations are small-parametric, which is not true for the actual concentrations;
3) Majorant models are most efficient when they are used for the decision-making triggering certain action, for example, emission control measures.
4) They are simple enough to be used in the Russian regulatory practice and air quality management for more than half a century.

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Thank you!