Federal Service for Hydrometeorology
and Environmental Monitoring

VOEIKOV MAIN GEOPHYSICAL OBSERVATORY

Since 1849

Russian national system of the air quality forecasting and managing: present status and perspectives

E.Genikhovich, V.Kirillova, V.Nikolaev, I.Gracheva, A. Ryzhakova, D.Rumyantsev, K.Lazareva

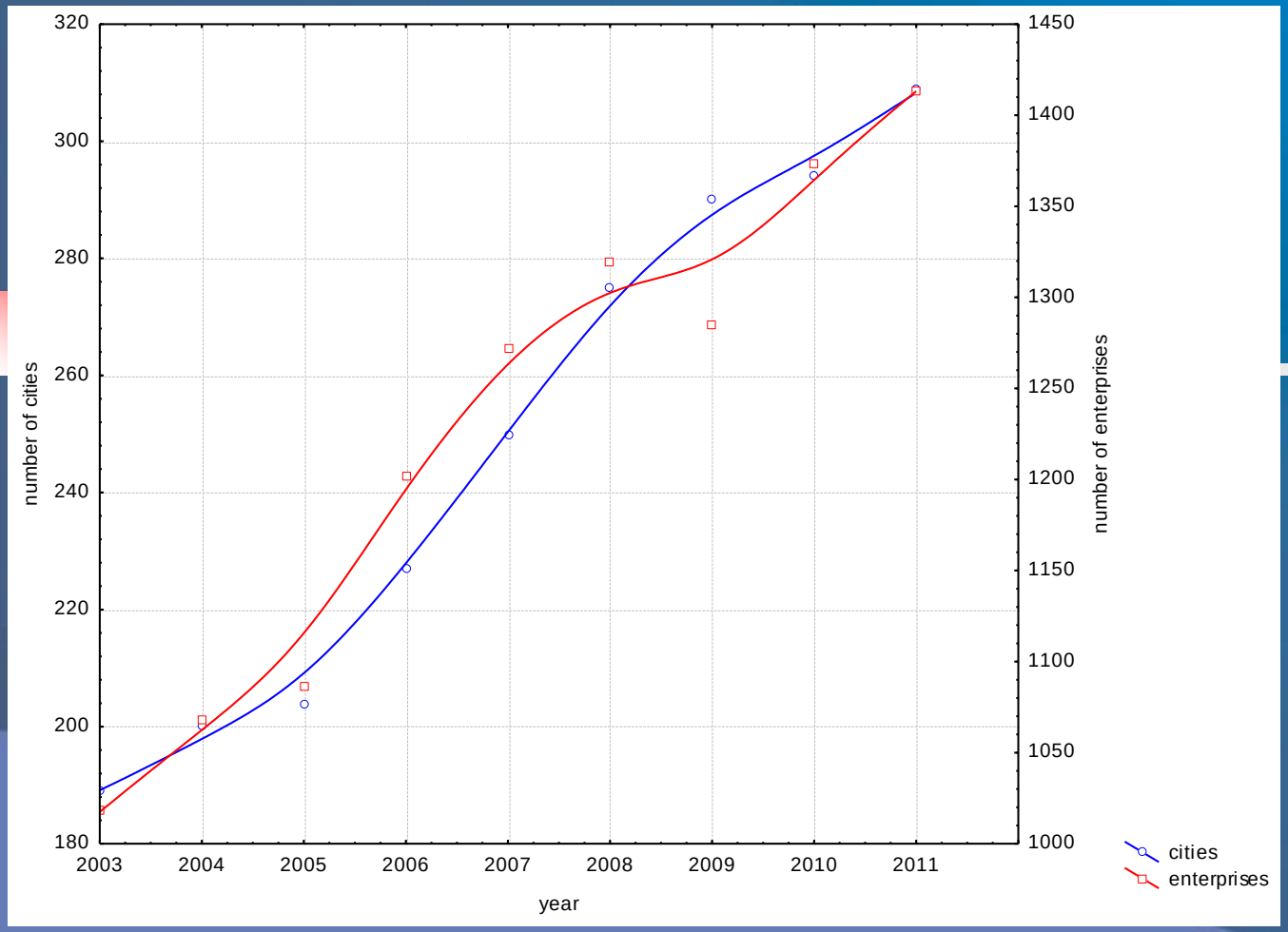
Voeikov Main Geophysical Observatory

St. Petersburg, Russia

Urban AQ forecasting is a part of the Russian national strategy of the AQ management

- Capital investments in the air pollution prevention, abatement strategies etc, are actually aimed in Russia to guarantee that the AAQSs are not exceeded during 98% of the year;
- During remaining 2% of the year, which correspond to the "anomalously unfavorable meteorological conditions" (UMCs), compliance with the AQ standards should result from short-term emission control measures (ECM) that have to be implemented at different enterprises in accordance with their preconceived action plans;
- Different ECM levels correspond to the different levels of warnings, which are provided daily to end-users by the local/regional met offices of the Russian Hydrometeorological Service depending on daily AQ forecasts, registered levels of the air pollution, duration of episodes etc.
- The met offices products include "general" forecasts" of urban UMCs, which are characterized by the relatively high frequencies P of exceeding of predetermined levels/percentiles of concentrations;
- In many cities these forecasts are supplemented with "concentration forecasts" as well as "targeted" forecasts for the sources of individual enterprises.

Operational urban AQ forecasts in Russia

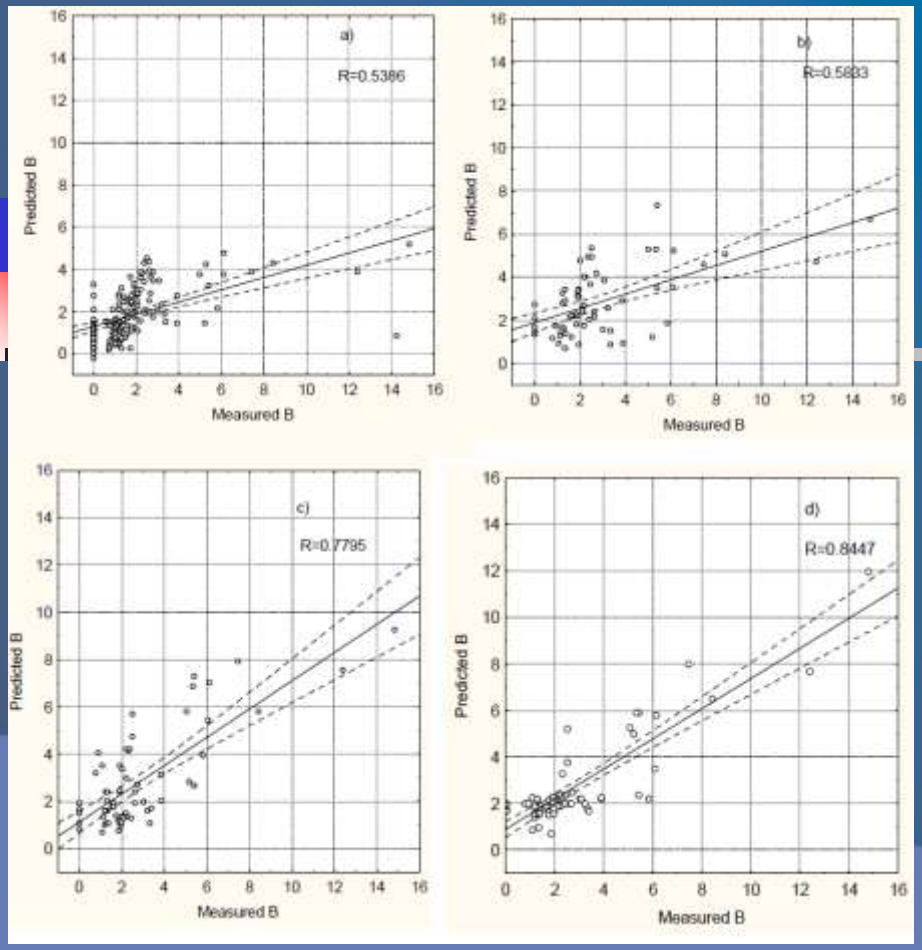


- In 2011 operational AQ forecasts are provided for 310 cities
- In 2011 targeted forecasts are routinely prepared for 1420 major polluting enterprises

MGO Statistical Forecasting Model (SFM_MGO)

- The “initial” list of predictors (some of them will be excluded as a result of the consequent step-wise regression) accounts for quantitaitve and qualitative indicators including measured concentrations, met parameters, “synoptical predictor” etc.;
- The stage of “education” starts with linearization of relationships based on initial nonlinear transformations of predictors;
- It includes also censoring and normalizing of predictors and uses the step-wise regression to construct the final expression (“model”) depending only on “significant” predictors;
- On the stage of “application”, the resulting model is used in the operational mode;

Dimensionless maximum daily CS2 concentrations in Krasnoyarsk, Siberia (warm season)



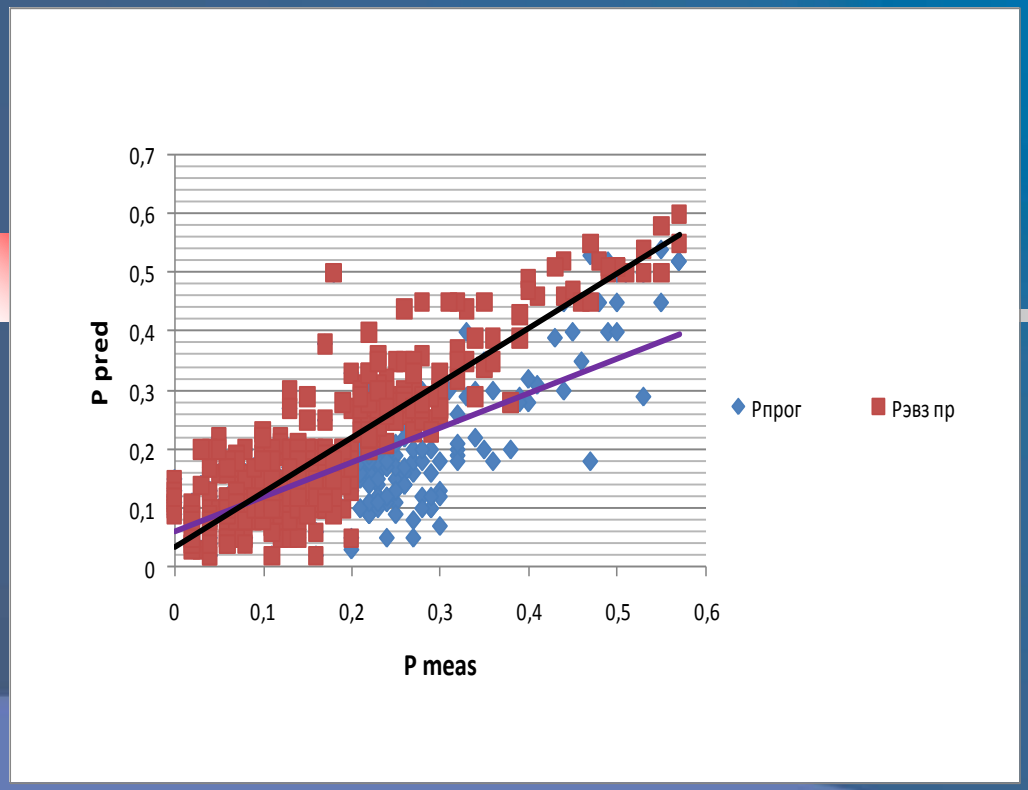
a) No predictor transformation;

b) Censoring of predictors;

c) Censoring plus linearization;

d) Censoring plus linearization plus normalization

“Standard” and “specialized” forecast of episodes of extremely high air pollution for the Urals Region



Trendlines

- Standard forecast:

$Y = 0.59\ X + 0.06$

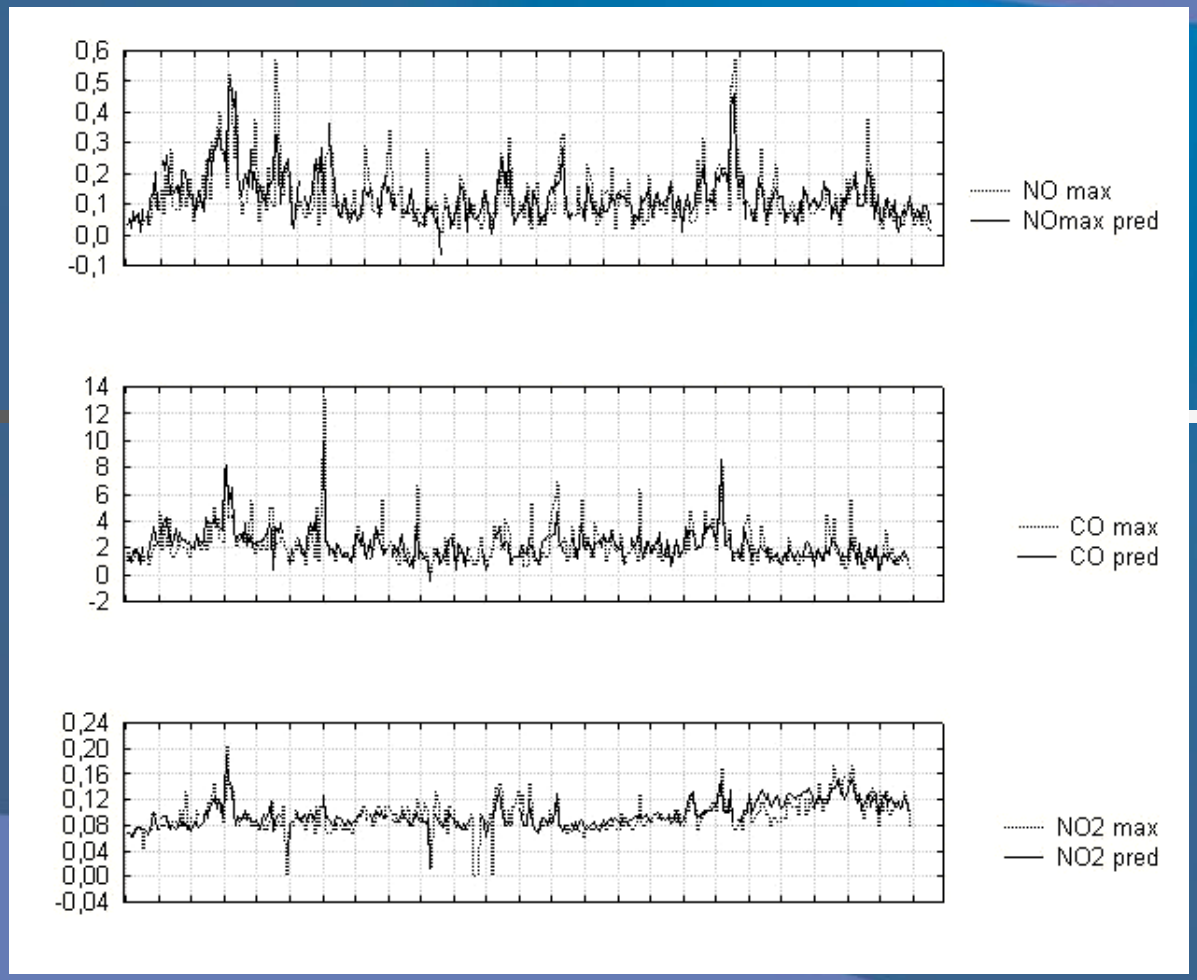
$R^2 = 0.50$

- Specialized forecast:

$Y = 0.93\ X + 0.03$

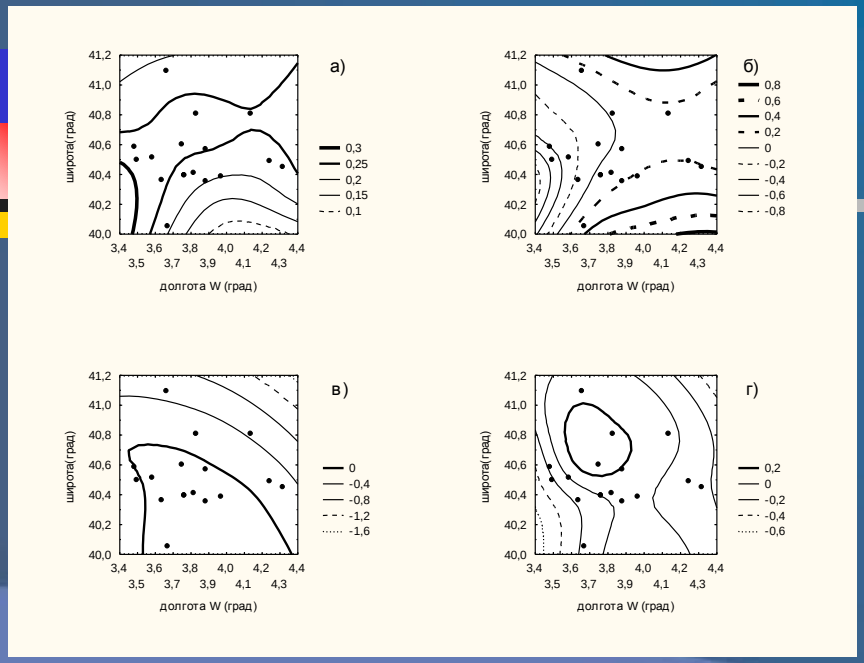
$R^2 = 0.76$

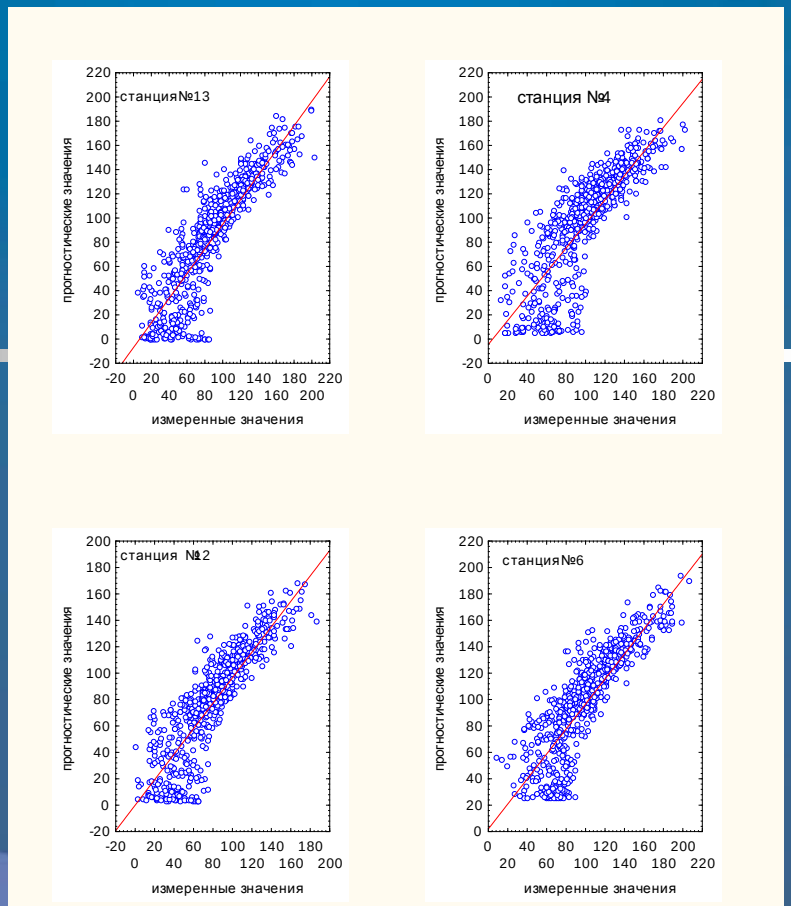
Measured and predicted winter daily maxima of NO, CO and NO2 concentrations in Sochi (Russia)



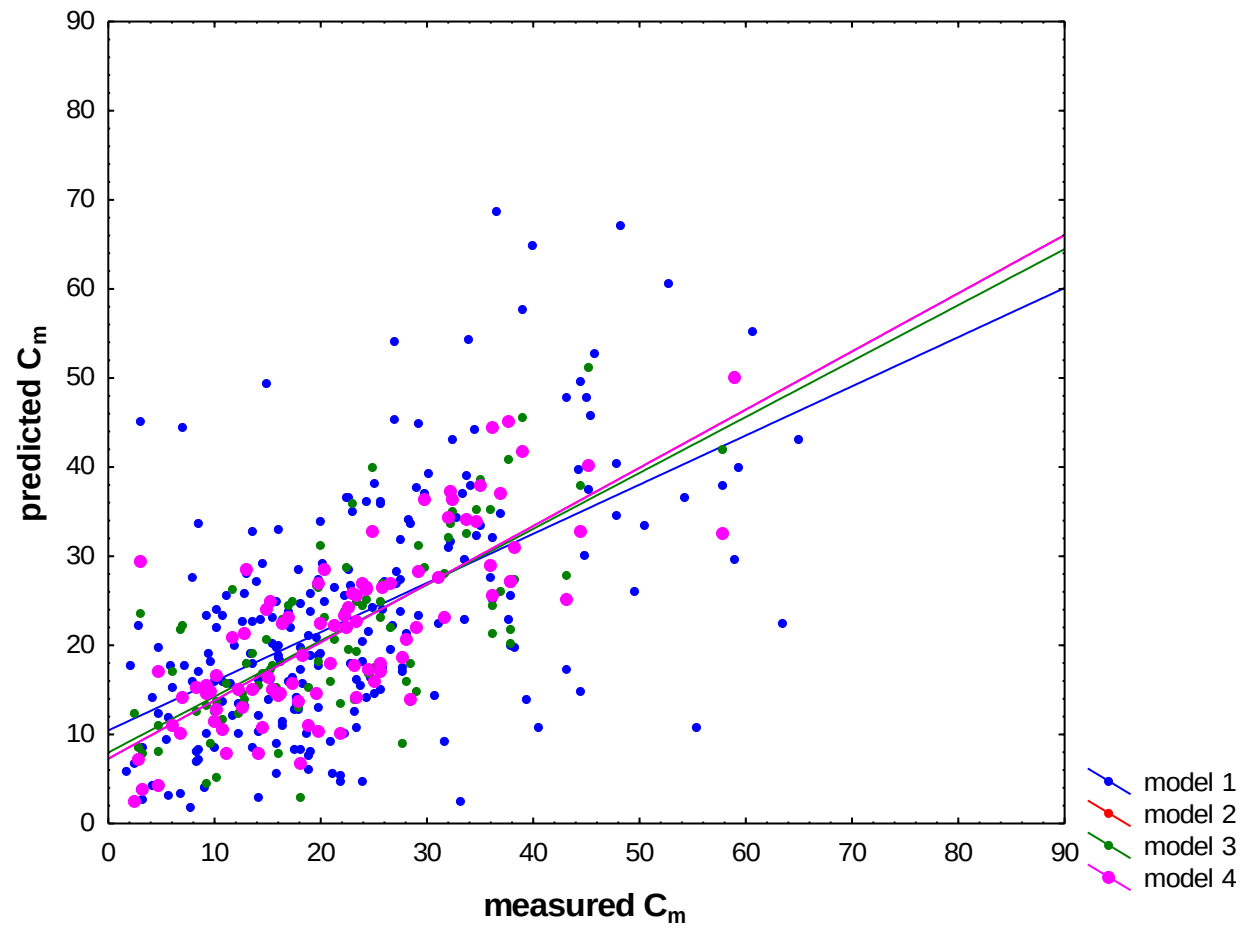
Correlation coefficient R > 0.8

Natural orthogonal functions and daily O3 maxima for Madrid, Spain

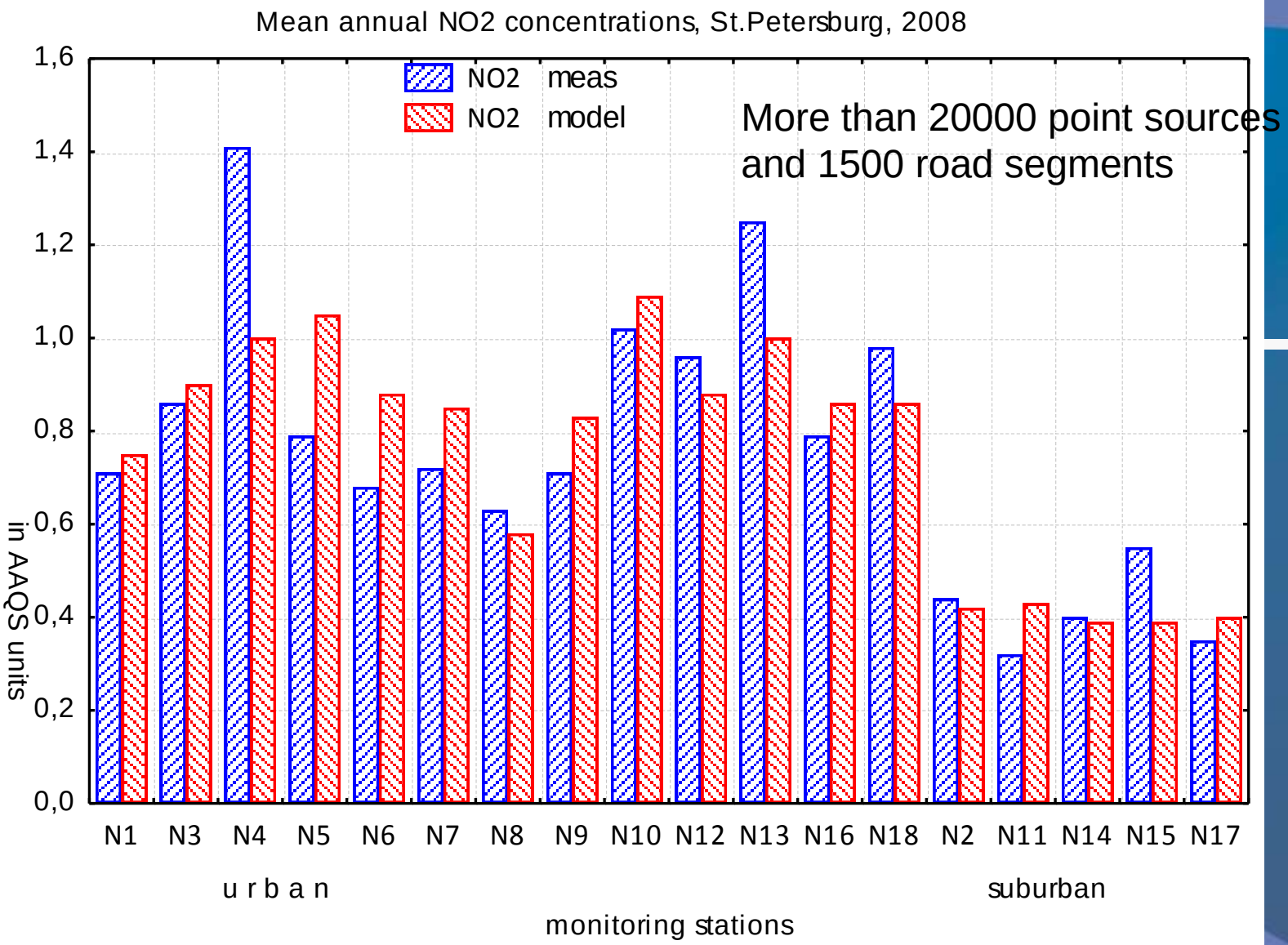




Daily O3 maxima for Shanghai, China



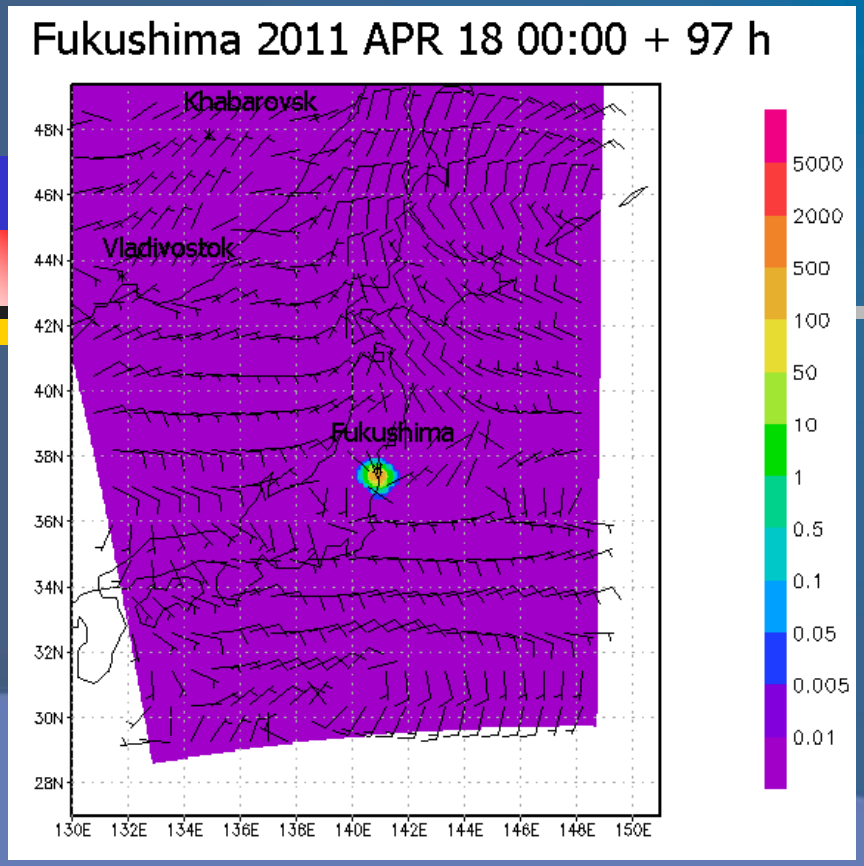
Dispersion modeling, St. Petersburg, Russia

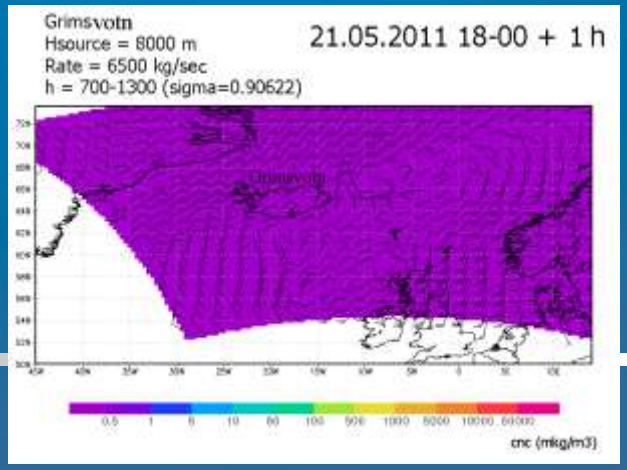


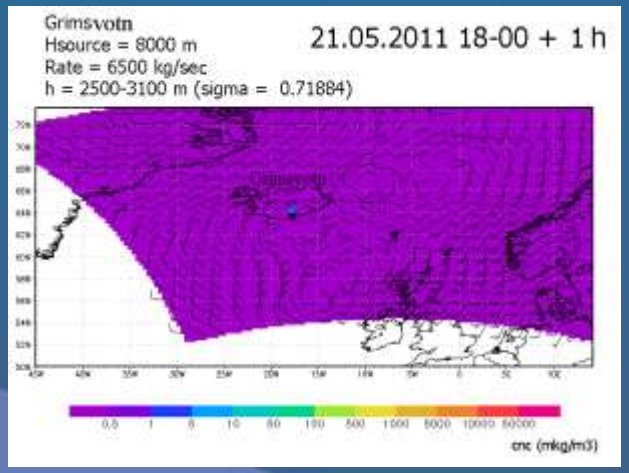
MGO regional transport chemical model

- Advection: Galperin's scheme;
- Vertical transport: "inside" of the vertical diffusion;
- Diffusion: "effective coefficients";
- Dry deposition: WRF land use + Vd after Kousnetsov&Sofiev
- Transformations: CB IV
- Drivers: MM5, WRF
- Planned drivers: MGO Regional Climate Model, TVM

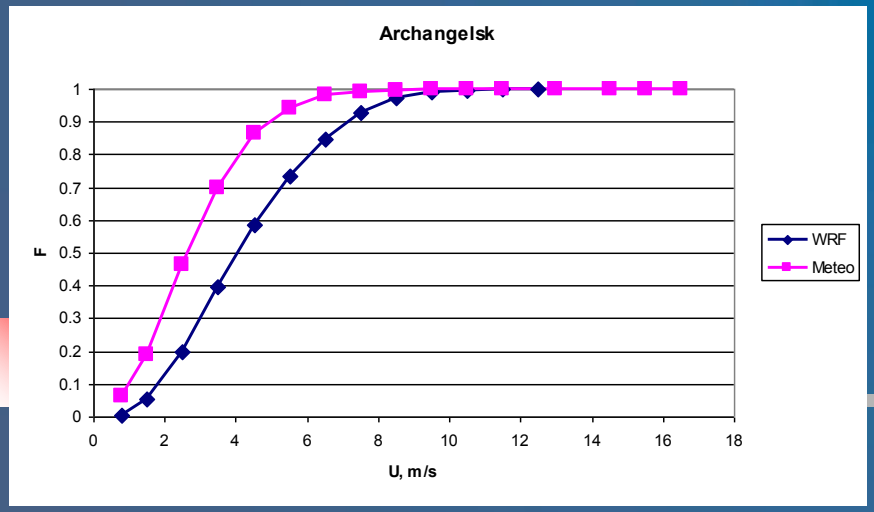
Fukushima accident and Grimsvotn eruption (relative units)

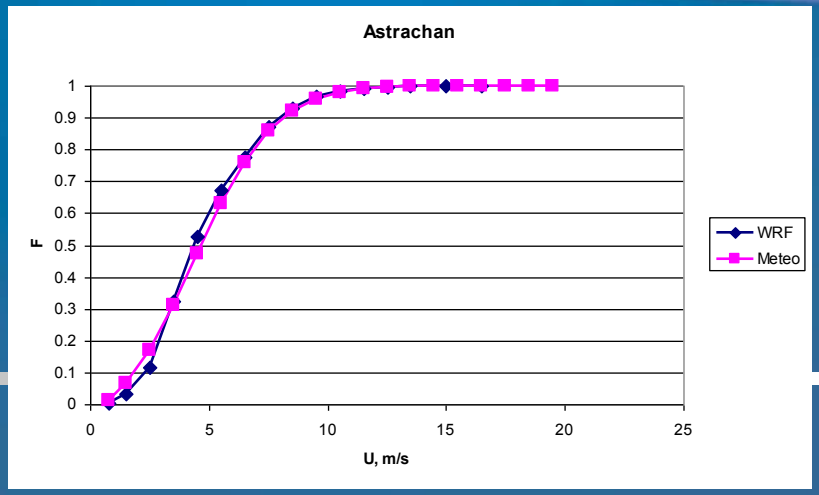


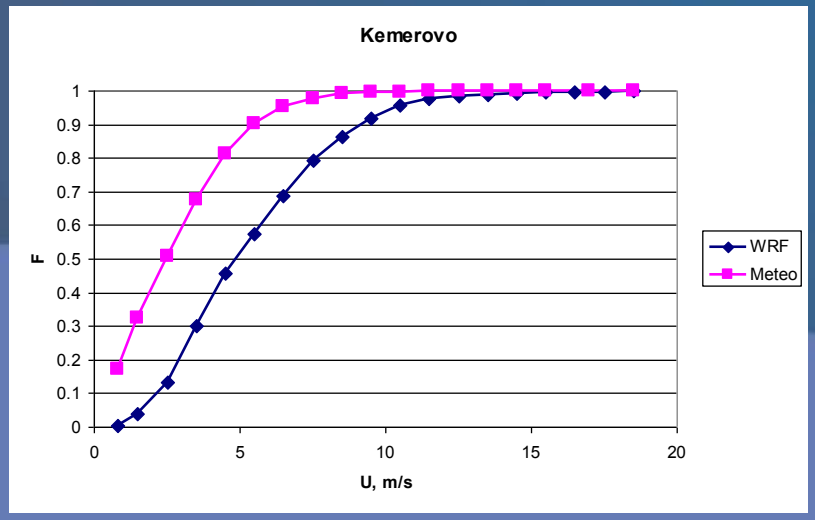


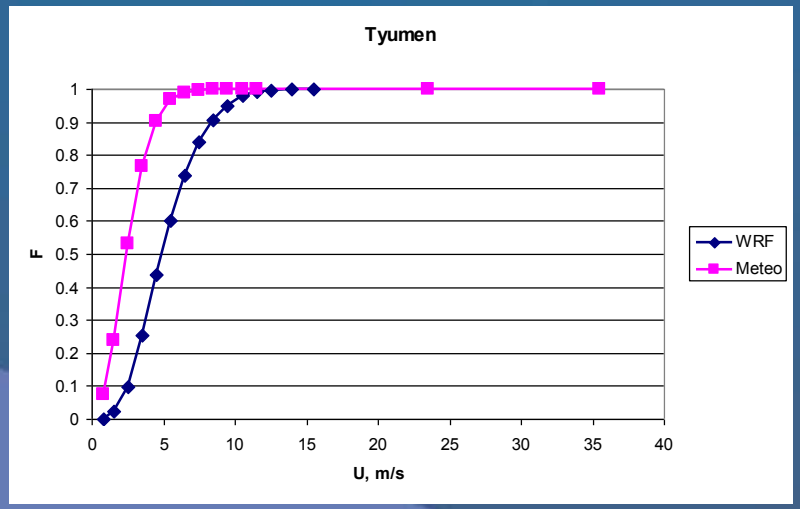


Wind-speed regime modeling with WRF

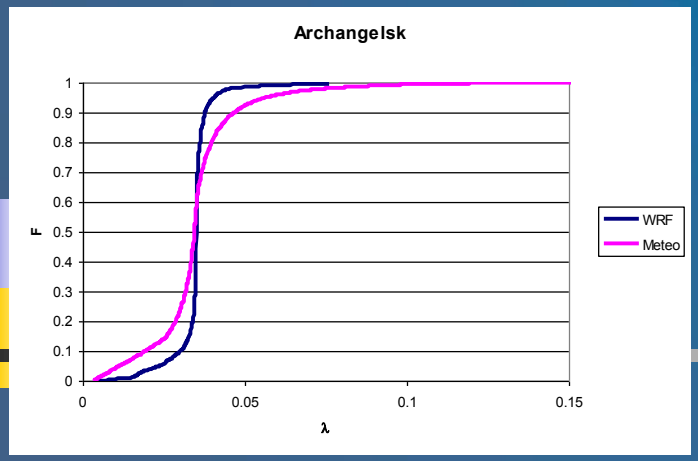


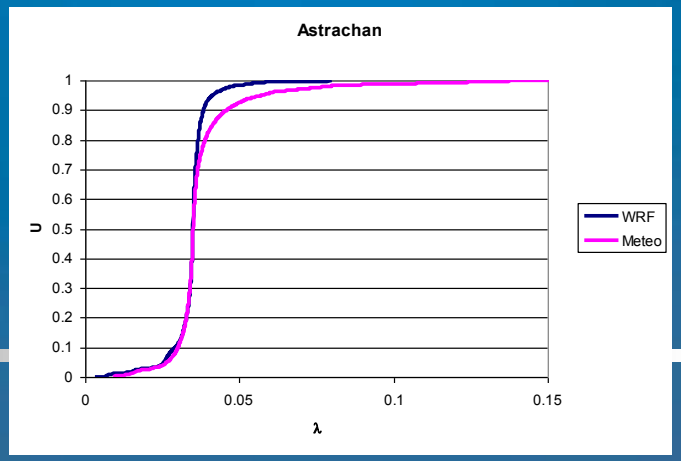


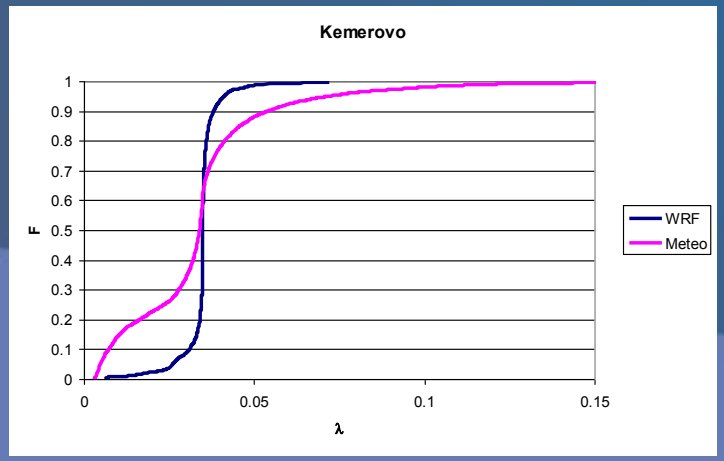


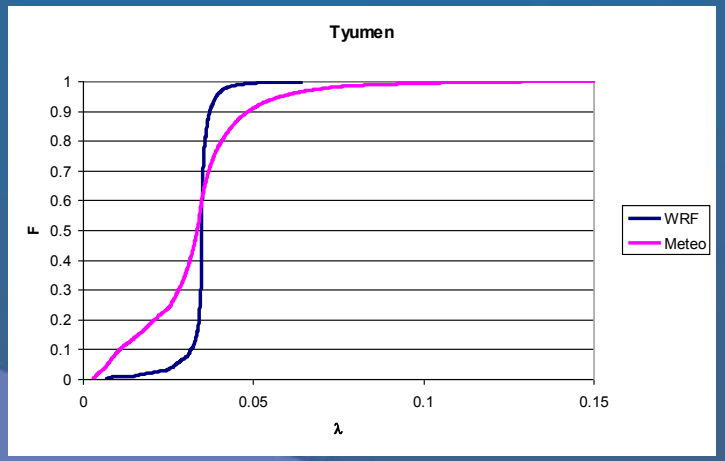


Turbulent regime modeling with WRF: $\lambda = (K/zU)_{z=z1}$

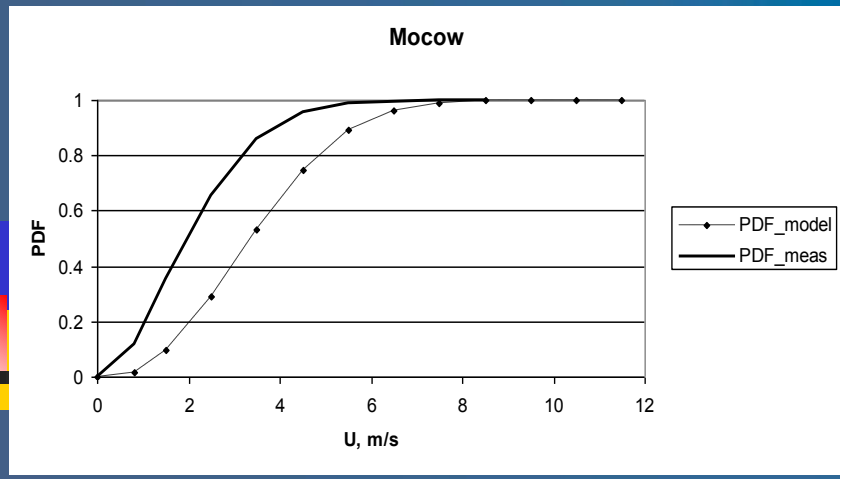


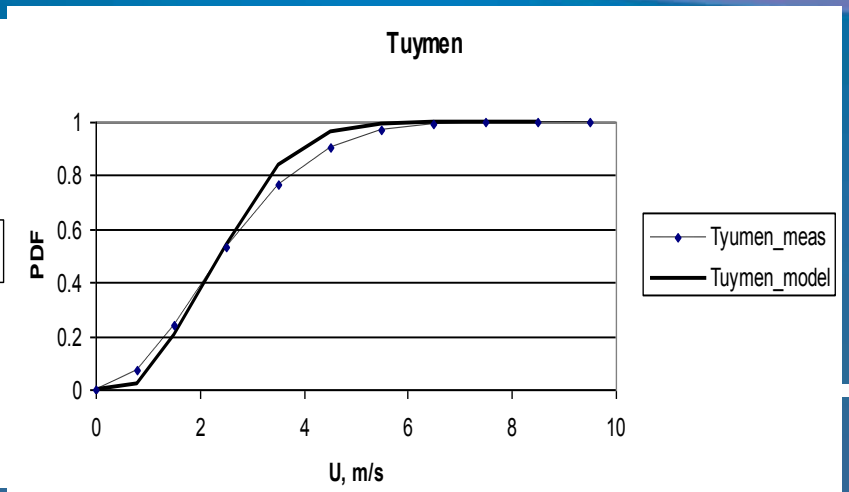


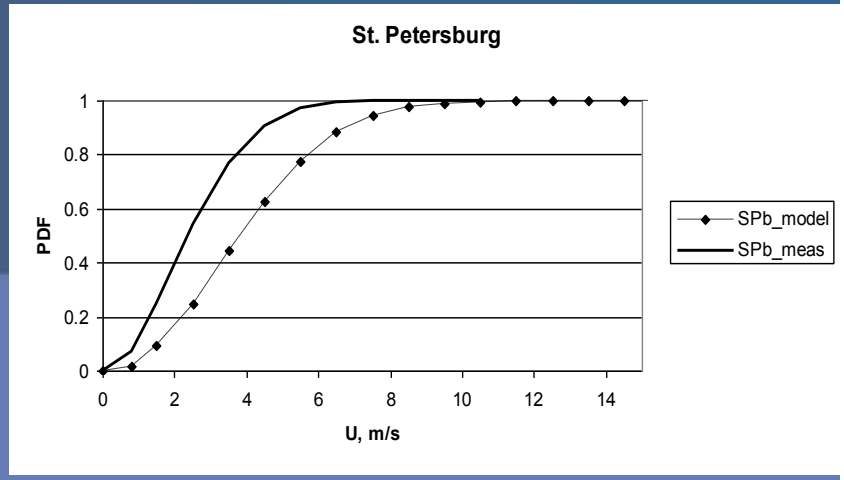


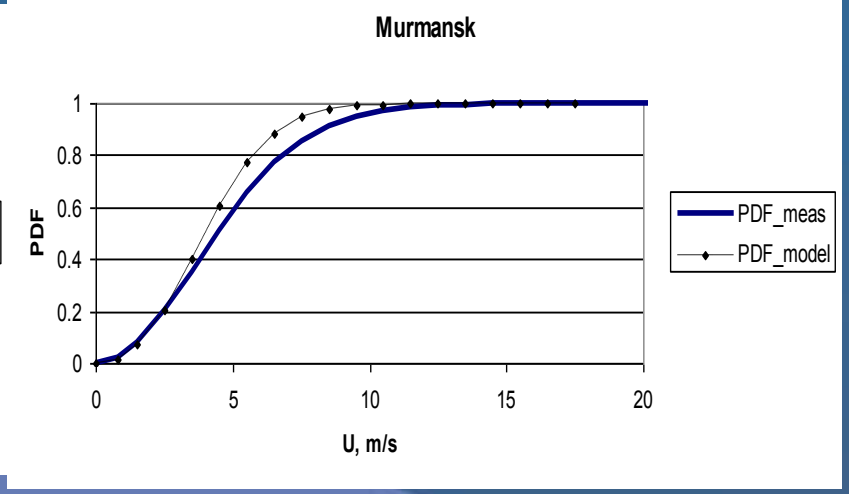


Wind-speed regime modeling using MGO Regional Climate Model



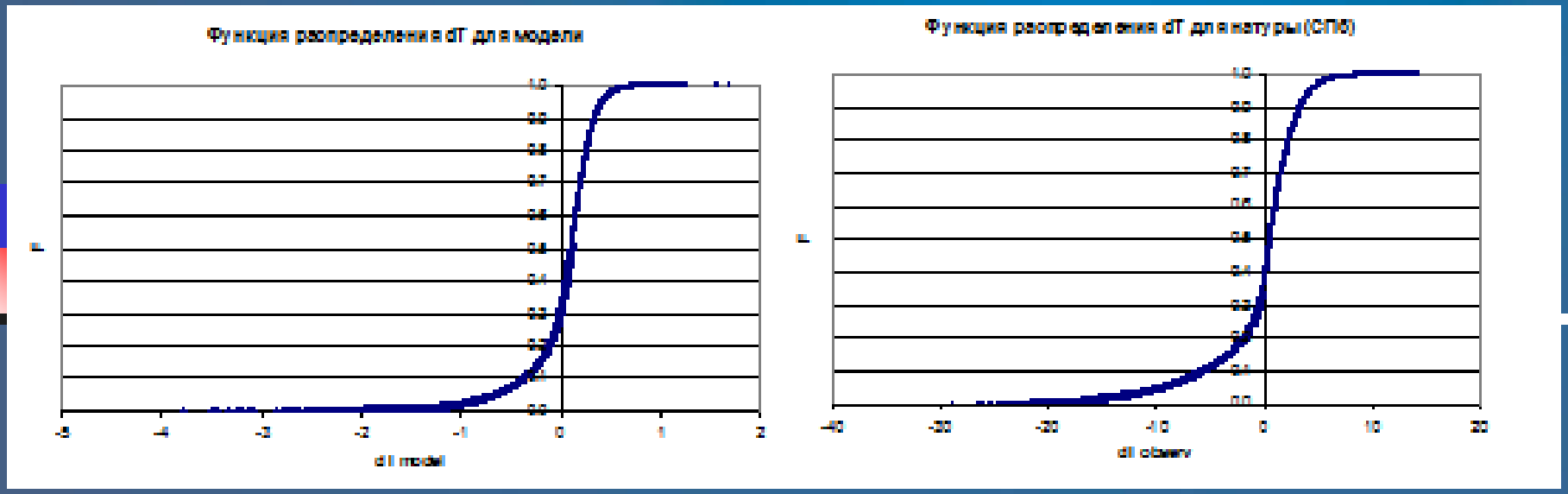






Solid lines – observations, dashed lines – modeling results

PDF of ΔT "underlying surface-air" for St. Petersburg, Russia



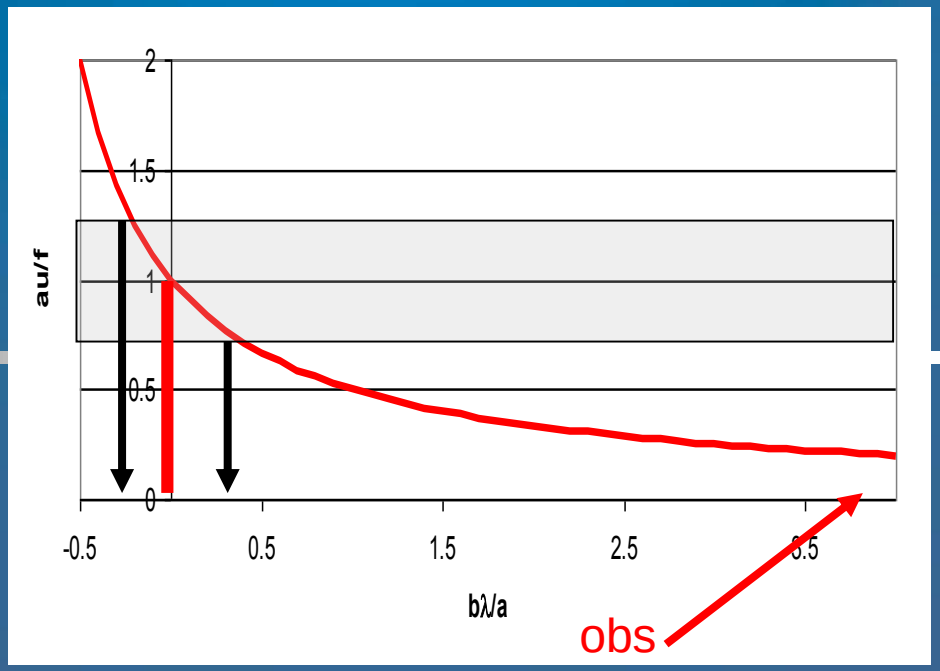
MGO_RCM

Observations

This model underestimates temperature gradients in the surface layer and, therefore, thermally induced turbulence

Data-assimilation: 0D example

- Consider the linear problem au=f in the variational formulation: J = (au,u)-2(f,u) = min;
- Account for the observational data in the form G = (bu,u) = min;
- Data assimilation means minimization of the functional J + λG;
- In 0D case, a,b,f are constants; and it is a math. analysis problem, which has a simple solution (red curve on the right figure);
- The grey strip there indicated the relative error of the equation solution due to uncertainties in the coefficients of the initial equation;
- Param. λ couldn't be varied outside the interval indicated by black arrows – it means that the results of this "data assimilation" strongly depend on unknown errors in the coefficients of the governing equations.



The red vertical bar corresponds to the exact solution of the governing equation, black arrows indicate boundaries of the interval of possible variations of λ that are "in agreement" with errors in this solution.

Arbitrarily varying λ one can provide any "quantitative agreement" with observations!

Conclusion

- Nation-wide system of the air pollution forecast efficiently works in Russian cities as a part of the general AQ management connected to emission control and regulation;
- For several regions it has already been "expanded" to the regional scale but should be supplemented there by deterministic forecasts;
- "General-purpose" NWP drivers are not effectively adapted to the requirements of the AQ modeling (they are "fitted" to observations using mean-square metrics rather than module-maximum one);
- Wind-speed and turbulent regimes are modeled by NWP with significant errors which can "distort" concentration fields; in particular, at some locations WRF overestimates wind speeds and does not generate enough non-neutral thermal stratifications;
- There is a danger that data assimilation adjustment just artificially passes these errors on corrections of emission rates, violation of basic conservation laws and so on;

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Thank you!