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Prof. dr hab. Joanna Wibig
Department of Meteorology and Climatology
University of Lodz, Poland

Review of the Habilitation Dissertation of Dr. Jiří Mikšovský

This review was prepared at the request of prof. Jan Trlifaj, Vice- Dean of the Faculty of Mathematics and Physics of the Charles University in Prague. It was based on Habilitation Thesis titled "Spatiotemporal links and variability in climate time series" published by Faculty of Mathematics and Physics of Charles University in Prague, a set of nine articles constituting an inherent part of the dissertation, the output of a plagiarism check by the *Turnitin* systém and selected other papers authored and/or coauthored by Dr. Jiří Mikšovský. Before starting the review, I got acquainted with the Act on Higher Education Institutions, the part on habilitation theses.

The reviewed thesis has been created as summary, amalgamation and evolution of materials published in nine papers co-authored by Dr. Jiří Mikšovský between 2005 and 2019.

Mikšovský, J. and A. Raidl (2006), Testing for nonlinearity in European climatic time series by the method of surrogate data, Theoretical and Applied Climatology, 83(1-4), 21-33, doi:10.1007/s00704-005-0130-7.

Mikšovský, J., P. Pišoft and A. Raidl (2008), Global Patterns of Nonlinearity in Real and GCM-Simulated Atmospheric Data, in: Nonlinear Time Series Analysis in the Geosciences: Applications in Climatology, Geodynamics and Solar-Terrestrial Physics (Eds.: Donner, R. V., and S. M. Barbosa), Lecture Notes in Earth Sciences, 112, 17-34, doi:10.1007/978-3-540-78938-3_2.

Mikšovský, J. and A. Raidl (2005), Testing the performance of three nonlinear methods of time series analysis for prediction and downscaling of European daily temperatures, Nonlinear Processes in Geophysics, 12(6), 979-991, doi:10.5194/npg-12-979-2005.

Huth, R., J. Mikšovský, P. Štěpánek, M. Belda, A. Farda, Z. Chládová and P.Pišoft (2015), Comparative validation of statistical and dynamical downscaling models on a dense grid in central Europe: temperature, Theoretical and Applied Climatology, 120(3-4), 533-553, doi:10.1007/s00704-014-1190-3.

Mikšovský, J., R. Brázdil, P. Štěpánek, P. Zahradníček and P. Pišoft (2014), Long-term variability of temperature and precipitation in the Czech Lands: an attribution analysis, Climatic Change, 125(2), 253-264, doi:10.1007/s10584-014-1147-7.

Brázdil, R., M. Trnka, J. Mikšovský, L. Řezníčková and P. Dobrovolný (2015B), Spring-summer droughts in the Czech Land in 1805-2012 and their forcings, International Journal of Climatology, 35, 1405-1421, doi:10.1002/joc.4065.

Mikšovský, J., E. Holtanová and P. Pišoft (2016A), Imprints of climate forcings in global gridded temperature data, Earth System Dynamics, 7, 231-249, doi:10.5194/esd-7-231-2016.

Brázdil, R., J. Mikšovský, P. Štěpánek, P. Zahradníček, L. Řezníčková and P. Dobrovolný (2019), Forcings and projections of past and future wind speed over the Czech Republic, Climate Research, 77, 1-21, doi:10.3354/cr01540.

Mikšovský, J., R. Brázdil, M. Trnka and P. Pišoft (2019), Long-term variability of drought indices in the Czech Lands and effects of external forcings and large-scale climate variability modes, Climate of the Past, 15, 827-847, doi:10.5194/cp-15-827-2019.

All papers included in the dissertation are multi-author works. Two publications have two authors each, two more three authors each, and the remaining four to seven authors. Dr. Jiří Mikšovský is the first author of six publications from the attached set.

Two papers were published in Theoretical and Applied Climatology, one in Nonlinear Processes in Geophysics, Climatic Change, International Jounal of Climatology, Earth System Dynamics, Climate Research and Climate in the Past. One work was published as a chapter in the book Nonlinear Time Series Analysis in the Geosciences: Applications in Climatology, Geodynamics and Solar-Terrestrial Physics. In summary, all articles were published in leading journals in the field.

Dr. Jiří Mikšovský is the author or co-author of 59 publications referred to in the Scopus database. He was cited 323 times (without autocitations) and has a Hirsch index 11. 52 his publications are referred to in the Web of Science database. He was cited 410 times (without autocitations) and has a Hirsch index 12 in this base.

I looked carefully through the long list of potential borrowings from other publications. According to the report of the *Turnitin* system, there are 143 such fragments. However there are mainly long names of institutions and databases, names of the variables or methods used in publications, references or internet addresses. In each case the coincidences relate to individual sentences or fragments thereof. I definitely don't see any symptoms of plagiarism here.

The presented set of publications concerns statistical climatology. The main aim of his research consists in extraction and interpretation of information recorded in the form of univariable or multivariable time series exploring various applications of time series analysis in meteorology and climatology. He analized the issue of nonlinearity in the climate data series trying to assess the magnitude of nonlinear behavior. He tested severeal linear and nonlinear regression models in their ability to identify various climate forcings and variability modes. He explored also the attribution issue, trying to identify factors shaping temporal variability of basic climate variables like temperature, precipitation, wind speed and other.

The first three papers in the list (and also in chronology) concern the issue of nonlinearity in climate records. In the first one (Mikšovský & Raidl, 2006), temperature and pressure records from Czech meteorological stations and NCEP/NCAR reanalysis were tested for for the presence of detectable nonlinearity in univariate and multivariate climatic time series. The surrogate data method was used for nonlinearity detection – results of nonlinear prediction for the original series were compared to the results for series whose nonlinear structure was randomized. In the univariate series none or very weak nonlinearity was found, whereas distinct nonlinearity was found in all tested multivariate systems. Pressure series generally exhibited stronger nonlinearity than series of temperature. Nonlinear behavior was generally more apparent in the longer records (30-year and 10-year-long datasets were tested). In the second paper (Mikšovský, Pišoft & Raidl, 2008) the global analysis of nonlinearity was performed. Series of daily values of relative topography (850/500) and monthly mean near-surface temperature from several gridded dataset with the global coverage . It was shown that the equivalent CO_2 concentration has a statistically significant effect on temperature but does not affect precipitation. That is why the equivalent CO_2 concentration affects all drought indices which take into account the influence of temperature, but not these which do not include temperature. The cooling effect of aerosols on temperature was found, but was relatively weak. The effect of natural forcings was statistically insignificant both on temperature and precipitation. Of the climate oscillations analyzed,only the impact of the NAO turned out to be statistically significant.

The very important part of these analyzes was comparison the results obtained using linear and nonlinear methods. It was shown that none of the employed nonlinear methods was able to provide significantly better approximation of the selected variables than simple linear regression. Authors state that it cannt be interpreted asa proof of an exlusively linear nature of links between predictors and predictand but suggest that the nonlinearity is too weak.

Because of these results attribution analysis in regard of wind speed and temperature gridded dataset with global coverage was provided using multiple linear regression models only. In the case of wind speed a significant link with NAO and CEZI was detected and in sme seasons also with ER WRP. The wind stilling formally correlate also with the equivalent CO_2 concentration index, however the physical mechanism was not presented. In the case of temperature in the gridded datasets the strong forcing of the equivalent CO_2 concentration index was confirmed. Connection to solar activity were weaker and mostly statistically insignificant. Connections of temperature to volcanic activity was found to be locally insignificant,in contrast to quite evident effect in global averages. The relations to the large scale oscillations was regionally and seasonally diverse.

All papers of the presented cycle concern detection, attribution and prediction of climate change. They are characterized by great care and attention to the quality of the results obtained. The data sets used are described in detail and tested in terms of quality. In many cases, various data sets are analyzed in parallel: ground observations, gridded datasets created from ground observations, reanalysis and model outputs. A detailed comparison of the results obtained for different sets of data enables reliable assessment of analyzed processes or phenomenas. A significant part of the work is devoted to the attribution of the detected changes. Predictors include both external factors and internal climatic oscillations. External factors include both anthropogenic and natural ones. The range of indices describing the internal oscillations of the climate system is very wide.

Great care is visible in the selection of methodology. Various forms of linear and nonlinear regression were applicated. Regression was used for prediction, assessment of spatial relations, trend estimation attribution issues linking the variations in selected climate variables with variables representing various external climate forcings and internal variability modes. Many interesting methods were used to test the linearity or non-linearity of many climatic processes. These include: the method of surrogate data and bootstrapping with moving-block modification employed for the monthly data. In the case of prediction different quantile mapping techniques were applied. It is worth emphasizing that the methodology is always carefully selected and described in detail.

Among the achievements of the presented set of works, one of the most important is the assessment of nonlinear behaviour in climate system. Areas with the strongest manifestations of nonlinearity were identified in the higher latitudes and linked to the atmospheric zones with the most intensive synoptic activity. The analysis confirmed presence geopotential height of 850 hPa level from the NCEP/NCAR reanalysis and the outputs of the global climate model HadCM3 of the Hadley Center were analyzed. Authors investigated the spatial and seasonal variations of nonlinearity in the data comparing the predictions by multiple linear regression and by the method of local linear models, complemented by tests using surrogate data. They have shown that basic patterns of nonlinearity seem to be identical for both the reanalysis and the model outputs with the tendency to slightly stronger nonlinearity in the model outputs than in the reanalysis data. They found the distinct contrast between weak nonlinearity in the equatorial area and stronger nonlinearity in higher latitudes. The also found generally stronger nonlinearity in the colder season. In the third paper (Mikšovský & Raidl, 2005) three nonlinear (local linear models (LLM), multilayer perceptron neural network (MLP NN) and radial basis function neural network (RBF NN)) and one linear (multiple linear regression (MLR)) methods were compared in their ability for the construction of temporal and spatial transfer functions between different meteorological quantities for the short-term prediction of daily mean temperatures and for the downscaling of NCEP/NCAR reanalysis data. As predictands series of daily mean, minimum and maximum temperatures from 25 European stations were used. All nonlinear techniques proved to be better than linear regression in the majority of the cases. None of the tested nonlinear methods was recognized to be distinctly superior, however the MLP method performed slightly worse than two others. Geographical and seasonal variations of the performance of different methods was also analysed and it was shown that nonlinear character of relations between climate variables is well apparent over most of Europe, in contrast to rather weak nonlinearity in the Mediterranean and North Africa. Nonlinearity also seemed to be noticeably stronger in winter than in summer in most locations.

One paper presents the comparative validation of statistical and dynamical downscaling models on a dense grid in central Europe. Two regional downscaling models and five statistical models were taken into account. Among statistical models there were one linear and four nonlinear ones. Several characteristic of minimum and maximum temperature distribution were analyzed: spatial and temporal autocorrelations, extreme quantiles, skewness and kurtosis. It was shown that the fit of modeling values toobservations in short time scales is equally dgood for statisticaland dynamical models in witer, whereas during summer statistical models are slightly better. On long time scales statistical models do not outperform the dynamical ones and the nonlinear statistical models do not outperform the linear ones.

Five remaining papers concern the attribution issue. The forcing factors of long-term variability of selected climatological variables are sought. Among the predictors are natural forcings like solar activity and explosive volcanism, anthropogenic factors expressed by the effect of the greenhouse gases (GHGs), described by the annual mean CO_2 –equivalent concentrations, and the effect by the sulphate aerosols, described by SO_2 emissions. Aside from external forcing factors the large scale oscillations in climate system were considered. As the potentially most important were selected the North Atlantic Oscillation (NAO), the Arctic Oscillation Index (AOI), the Atlantic Multidecadal Oscillation (AMO), the Southern Oscillation (SO), the Pacific Decadal Oscillation (PDO), East Atlantic/Western Russia Pattern,CentralEurope ZonalIndex (CEZI) and Trans Polar Index. A multivariate approach was applied to reveal, sometimes weak, however statistically significant links among multiple variables in a robust way. Linear analysis represented by multiple linear regression (MLR) method was compared with nonlinear mapping represented by local linear models (LLM) and neural networks in the form of multilayer perceptron (MLP). Among the variables were temperature, precipitation and wind speed in Czech Republic, several drought indices, of distinct seasonal variations of the results, with nonlinearity typically intensified during the cold part of the year in the extratropical regions. The question was asked how strong is the actual improvement achieved by application of a specific nonlinear method over its linear counterpart? It was shown that in many applications linear methods give results that do not differ significantly from those obtained by non-linear methods. At the same time it was confirmed, on the ezample of NCEP/NCAR reanalysis and HadCM3 climate model, that the climate models are capable of reproducing the basic character of the observed nonlinearity patterns.

Another important achievements of Dr. Jiří Mikšovský are results on the estimation of the extent to which various external and internal factors are responsible for climate change in relation to the climate system.

In summary, I think that Dr. Jiří Mikšovský is an experienced researcher. His works are characterized by great care for robustness. They are well cited and Dr. Jiří Mikšovský is a recognized researcher in Europe. In my opinion the scientific quality of the Dissertation of Dr. Jiří Mikšovský is very high. I fully support his efforts to obtain the Habilitation degree.

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