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SCIENTIFIC PROGRAM

Wednesday (10.05) – **Geostatistics today** – pre-conference short course by **János Geiger**

Thursday (11.05) –

09:00- **Registration**

11:00-11:30 **Opening ceremony** with speeches by:

Ferenc Fedor - President of the Geomathematical & Informatics Section of the HGC
Tamás Síkfői - President of the Chamber of Commerce and Industry of Pécs-Baranya
Zoltán Unger - Associate President of the Hungarian Geological Society

11:30-12:00 **Opening lecture** by **János Geiger** - **Statistical Process Control in The Evaluation of Geostatistical Simulations**

13:00-14:30 **Climate modelling past and future –** chair: István G. Hatvani

- Keynote speaker: **Gabriella Szépszó - Climate adaptation in Hungary: from the climate model outputs to the end-users**

- **Dániel Topál** Detecting breakpoints in annual $\delta^{18}O$ ice core records from North Greenland
- **Csaba Ilyés** Examination of 110 year long Rainfall Data using Spectral and Wavelet Analysis
- **Tímea Kalmár** Regional climate modelling with special focus on the precipitation-related fine scale processes
- **Péter Szabó** Sources of uncertainties in climate model results

15:00-17:30 (with break) **Big data in geoscience –** chair: Zoltán Nagy

- Keynote speaker: **Balázs Székely - Big data in geoscience – are we big enough to use and to understand that properly?**

- **Zoltan Nagy** The Repository Information Model
- **Éva Farics** Determination of sedimentological processes of a coarse-grained deposits in Buda Hills applying combined cluster and discriminant analysis
- **László Sőrés** How to Document Scientific Work? Preserving Memories for the Semantic Web
- **László G. Somos** Statistic evaluation of digitized geophysical well logs data. (Digitized logs, Statistical evaluation, Multi-correlation)
- **Gyula Mező** Use of Sequential Gaussian Simulation for modelling groundwater pathlines and travel times near an underground radioactive waste repository
- **Tamás Miklovicz** Application of 3D geological modelling and grade tonnage calculations on Recsk ore complex
- **Ágnes Krupa** "Data-Mine" software: Complex earth scientific documentation of excavations with a uniform, real 3D background

Friday (12.05) –

08:30-10:30 (with break) **Mathematical aspects of reservoir geology –** chair: János Geiger

- Keynote speaker: **Marko Cvetković - Geomathematical aspects of reservoir and exploration geology**

- **István Nemes** From Russia with love – On production since 1947
- **Szabolcs Borka** Handling a mature clastic HC reservoir without seismic – trends, facies proportions and depositional zones
- **János Blahó** Permeability problematics in modelling of highly heterogeneous reservoirs
- **Ivona Emanović** Variogram analysis of well derived lithofacies data in Eastern part of Drava Depression
- **Zsolt Kovács** Evaluation of the trends of hydrocarbon migration processes based on oil density - reservoir depths relationship in Hungary

11:00-12:15 **Geomathematics in water quality protection –** chair: Balázs Trásy

- Keynote speaker: **József Kovács - Determining Water-Bodies Using Multivariate Data Analysis Methods**

- **Zsuzsanna Szabó** A reactive transport model of CO_2 and brine inflow to a fresh water aquifer
- **István G. Hatvani** Estimation of chlorophyll-a in rivers, on the example of the River Danube and Tisza
- **Péter Tanos** Combined Cluster and Discriminant Analysis on the River Raab's Austrian and Hungarian sections

13:30-15:00 **Data analysis in engineering geology –** chair: László Kovács

- Keynote speaker: **Ákos Török - Geomathematical aspects of engineering geology**

- **Balázs Czinder** Statistical analyses of strength parameters and aggregate properties of andesites from Hungary
- **Nikoletta R.-Boissinot** Evaluation of curve characteristics of shear strength along discontinuities using state-of-the-art breakpoint detection methods
- **Alina Vattai** Effect of JRC value on shear strength along discontinuities of Hungarian sandstones
- **Dániel Borbély** Permeability of rock mass around a radioactive waste repository tunnel

15:30-17:15 **System theory, future of geology & geoinformatics –** chair: Péter Tanos

- Keynote speaker: **Sándor Molnár- The qualitative assessment of structured systems**

- **Viktor Feurer** The 3rd/4th industrial revolution - Challenges for researchers –
- **Ferenc Fedor** How to automate a petrophysical laboratory? - challenges and solutions

- **Neven Trenc** Application of semi-automated GIS procedure for river terrace delineation on high resolution LiDAR data in Sava river valley west of Zagreb, Croatia – First results
- **Ana Brcković** Application of artificial neural networks for lithofacies determination in absence of sufficient well data
- **Nikolina Mijic** Quarry Surveying and Analysis Using Drone-mounted LiDAR & AutoCAD Civil 3D

Saturday (13.05) –

08:45-10:15 **Poster session –** chair: Marko Cvetković

- **Janina Horváth** Application of cluster vs. directional classification method to identify lithofacies and sedimentary elements
- **Tímea Kocsis** Comparison of parametric and non-parametric time-series analysis methods on a long-term meteorological dataset
- **Dániel Erdélyi** Variogram analysis of precipitation δ18O over the Iberian Peninsula on a monthly-, seasonal- and annual scale
- **Artúr Kőhler** Trends in contaminant concentration time series
- **Shwan O. Hussein** The geographical evolution of urban greenness in the city of Erbil based on Landsat imagery
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- **Zsuzsanna Szabó** A numerical model of Na-montmorillonite validated by batch experiments
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- **Sándor Gulyás** Data acquisition, pre-processing of 3D image data of artificially distorted skulls, archaeological artefacts, fossils for 3D geometric morphometric analysis using CT and laser scanning: a comparison

10:30-12:30 **Geomathematics in applied geosciences –** chair: Ferenc Fedor

- Keynote speaker: **Zoltán Unger - Fault Statistics and Fractal Geometry**

- **Dorottya Kovács** Image processing for fractal geometry-based Discrete Fracture Network modelling input data
- **Tamás Jaskó** Quantitative Determination of Standard Sphericity and Roundness
- **Noémi Jakab** Determining the sufficient number of stochastic realisations to represent spatial uncertainty
- **Mihály Apró** Spatial uncertainty quantification using distance-Kernel method
- **László Z.-Sebess** Geothermal potential estimation with Monte Carlo method
- **Mátyás Sanocki** Uncertainty of subsurface uncertainty analysis' – can we mitigate it?

12:30-13:00 **Closing ceremony –** István G. Hatvani – Ferenc Fedor – Marko Cvetković

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Note: In general, the content of proceedings book has not been proof read by a native English speaker, and that is why solely the authors are responsible for the quality of language usage. However, certain chapters marked with '*' have gone through English proof reading by Mr. Paul Thatcher; pt.64@live.co.uk .

Examination of 110 year long Rainfall Data using Spectral and Wavelet Analysis

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The aim of our research was, to better understand the precipitation part of the hydrological cycle, because through infiltration, this is the most important source of recharging the groundwater. To better understand the periodicity of these rainfalls we used monthly and annual rainfall data also. We examined 110 year long precipitation time series' from four different cities, across the Carpathian-basin, obtained from the Hungarian Meteorological Service. With Discrete Fourier-transformation (DFT) and Wavelet time series analysis, we defined local and country-wide cycles in the datasets.

Using DFT we calculated the time-period distributions (spectra) of monthly and annual rainfall data. Spectra shown 21 cycles in Budapest, 16 in Debrecen, 17 in Pécs and 20 in Szombathely from the annual rainfall data. The most dominant cycle was the 5 year long, with the most dominant relative amplitude in all four stations, and there were 12 other present in all four datasets. From the monthly datasets several other periodic components were calculated locally and nationwide also.

Using Wavelet-analysis the time dependence of the cycles was determined in the 110 year long dataset in case of two cities, Debrecen and Pécs.

The paper will present the mathematical algorithm of the spectral and wavelet analysis besides the numerical results.

Key words: *precipitation, spectral analysis, wavelet, cycles*

1. INTRODUCTION

On Earth approximately 400 000 km^3 volume of water is being transported annually in the water cycle, which is affected by the changing climate and the meteorological extremities present in recent years. In Hungary most of the drinking water is produced from groundwater aquifers, therefore the effects of a changing climate and even the slightest changes in the water cycle can have a strong effect to these aquifers. These changes in the behaviour of precipitation have an impact on the groundwater resources through the recharge, so we chose to investigate the precipitation. Several mathematical methods, such as the Lomb-Scargle periodogram (Nason et. al. 1999), the Wavelet Time Series Analysis (Kovács et. al. 2010), and the analytic version of the Discrete Fourier-transformation can be used to define periodicity. These were used before in several studies to examine precipitation in California (Sangdan 2004), at the Sanjiang Plain (Liu et al 2009) and in Gannan County, China (Zheng et al 2014), the Bükk and Mátra Mountains of Hungary (Kovács et. al. 2014) and in Central-America (Hastenrath 1964).

2. THEORETICAL BACKGROUND

The long term hydrometeorological datasets are considered to be time series, containing several of perioic components therefore we chose to examine it with spectral analysis, based on the Fourier-Transformation (Meskó 1984). Working with harmonic functions in the analytic Fourier Transformation, a complex Fourier-spectrum *F(f)* is obtained, which can be divided into a real and an imaginary part or can also be defined in an exponential form, by introduction two other real spectra.

The *A(f)* spectrum is called the amplitude, while the *Φ(f)* spectrum is called the phase spectrum. The amplitude spectrum gives the weight in the formation of the signal of the harmonic component falling into a frequency band unit around any frequency. The phase spectrum shows, what part of the period length the maximum of this harmonic component shifts in relation to the maximum of base function cos(2πft) (Ilyés et al, 2017).

Basically these meteorological processes are stochastic, but in this paper we searched for deterministic components in our datasets with the criteria, that the time series has no significant trend and the sampling rate is equidistant.

3. SPECTRAL ANALYSIS

To determine the cyclic parameters we used the data from the OMSZ (Hungarian Meteorological Service) online database (HMS 2015), which contains 110 years of meteorological parameters for five cities.

In this paper we present the results of Debrecen and Pécs, the two cities, which presented very different results, according to our measurements. After defining the cyclic parameters, the amplitude, the phase angle and the frequency, the cycles with the relative amplitude spectrum over 50 % were defined as major (dominant) cycles and cycles with relative amplitude spectrum between 20 % (in some cases 10 %) and 50 % were defined as additional (minor) cycles.

3.1 Annual precipitation

In this case, the registration period is 1901 – 2010, thus the length of the registration period, t_{reg}=110 years, the sampling rate is 1 year, and the numbers of samples are 110 from each city. The Nyquist frequency is 2 year (Meskó 1984). The Nyquist-frequency shows the minimal length of period of time that can be calculated correctly with this examination method.

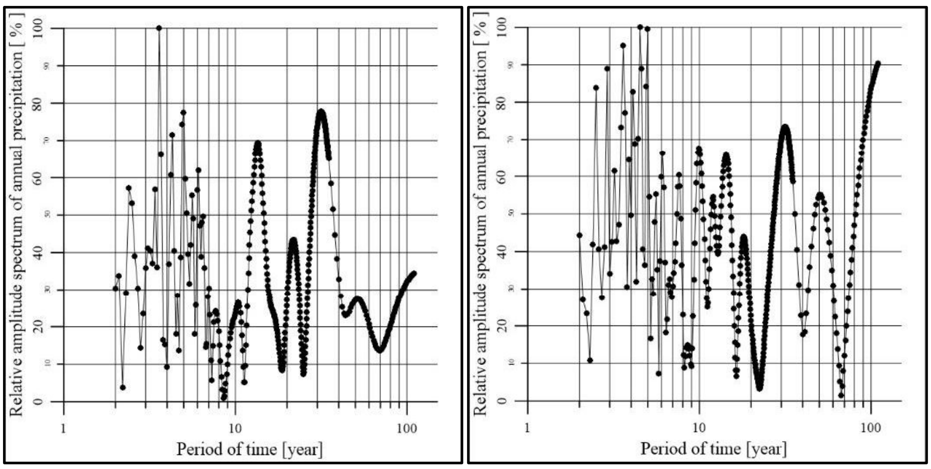

Figure 1: *Relative amplitude spectra of Debrecen (l) and Pécs (r) according to annual precipitation data*

In Debrecen 16 cycles were determined, 10 major cycles, and 6 additional cycles. In this city the 3.6 year long cycle was the most dominant, with 100 % relative amplitude, the other cycles amplitude spectra were between 27 – 77 % (**Figure 1**).

In Pécs 17 cycles were calculated, 16 of them are major, and only 1 is additional cycle, which means, the periodicity is much more dominant in the precipitation time series in Pécs, than in Debrecen. We can describe the precipitation in Pécs with few, but dominant cycles. The most dominant 4.5 year long cycle followed by the 5 year long, with almost the same relative amplitude value, and the third is the 3.6 year long with more than 90% relative amplitude.

3.2 Monthly precipitation

The registration period is January 1901 – December 2010, the length of the registration period, t_{reg}=1320 months, the sampling rate is 1 month, and the numbers of samples are 1320 from each city, the Nyquist frequency is 2 months.

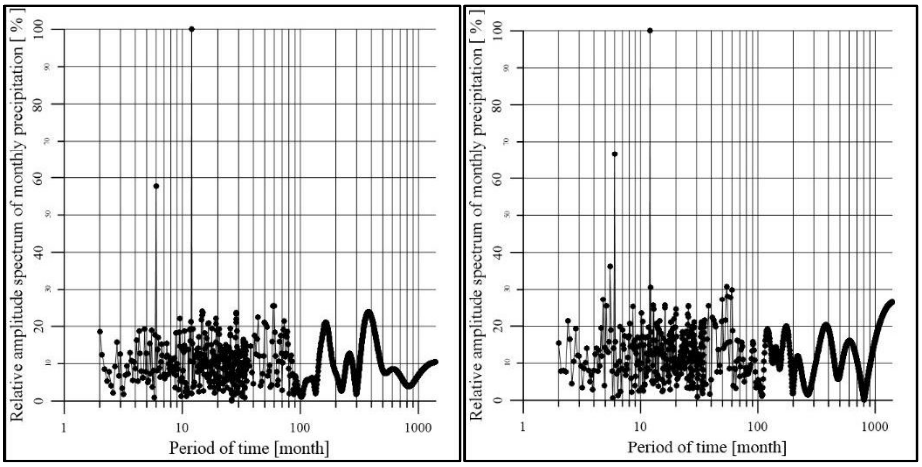

Figure 2: *Relative amplitude spectra of Debrecen (l) and Pécs (r) according to monthly precipitation data*

In Decrecen 43 cycles were detected, in Pécs 65 **(Figure 2)**. The similarities of this two stations are the following: The 1 year long cycles are the most dominant with 100 % relaitve amplitude - normalized to maximum amplitude value of the dataset - , and the second is the 0.5 year long with 57.64 % relative amplitude in Debrecen, and 66.53 % in Pécs. In Debrecen the other relaively dominant cycles are the 59, 14.7, 378 month long ones, most of the minor cycles have the relative amplitude range under the 20 % value, but were considered as important ones in the precipitation dataset. In Pécs, the dominant minor cycles are the 5.5, 54, 12.2, 60 month long ones.

3.3 Forecasting

With the *A(f)* amplitude spectra and the *Φ(f)* phase spectra, the original measured data can be recalculated, and with the major and minor cycles, and their period of time, amplitude and phase spectra values, the deterministic precipitation time series can be calculated (Eq. 1):

$$y(t)^{det} = \bar{Y} + \frac{2}{T_{reg}} \sum_{i=1}^{18} A_i \cos\left[\frac{2\pi}{T_i}(t-1901) + \Phi(T_i)\right] \qquad \text{(Eq 1)}$$

If we use the *t* parameter, with a value of t>2010, we can forecast to the future. In this paper we present the results of the 110 year long time series, calculated from the periodic components of the station of Debrecen from 1901 to 2010, and its correlation coefficient with the original measured data, with the forecast up to the year of 2030.

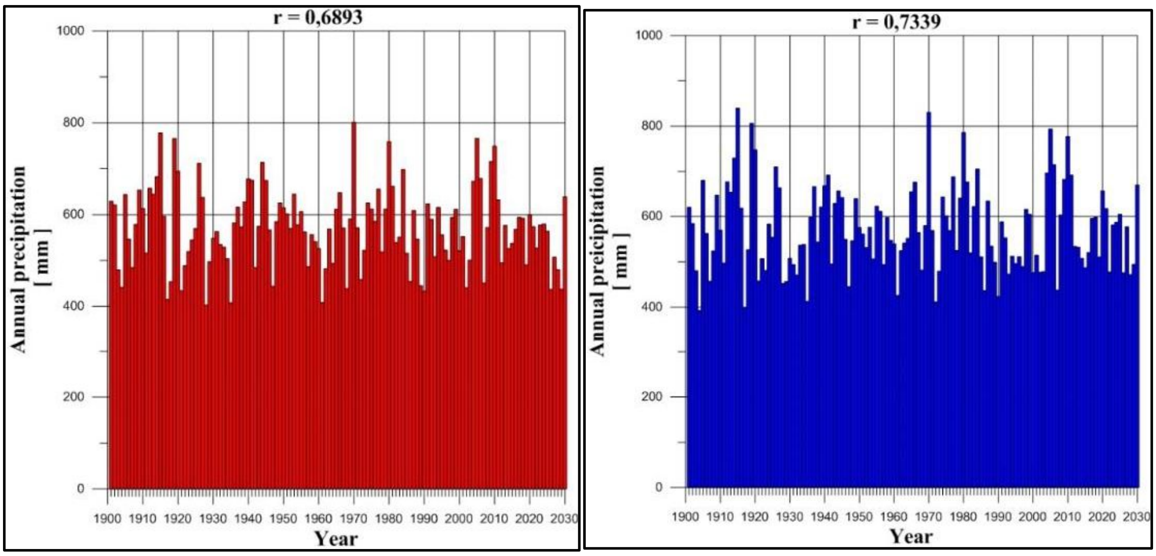

Figure 3: *Forecasting up to 2030 from the periodic components of the Debrecen dataset.*

The annual precipitation of Debrecen values range between 400 and 600 mm, with no year, when the 600 mm maximum would be exceeded (**Figure 3**). According to our calculations, large amount of precipitation within one year is not expected. The correlation coefficient between the original measured data and the calculated time series are 0.689 and 0.734 respectively.

4. WAVELET ANALYSIS

Wavelet time series analysis is a well-known method to investigate the time-dependence of a cycle within a time series. The periodic components from the previous examinations were used for this analysis.

The wave packet used for the calculation was a 1 year long period of time sine wave. The filtering has been derived by a cross-correlation function normalized to maximum value of the function. A discrete normalized cross-correlation matrix (Rxy) can be calculated from the cross-correlation functions of the wavelets (x) and the precipitation time series (y).

All of the 18 cycles from Debrecen were used for the wavelet analysis, and the results showed, that the cycles with period of time with a small value are less dominant in the 1910's, 30's and in the 70's.

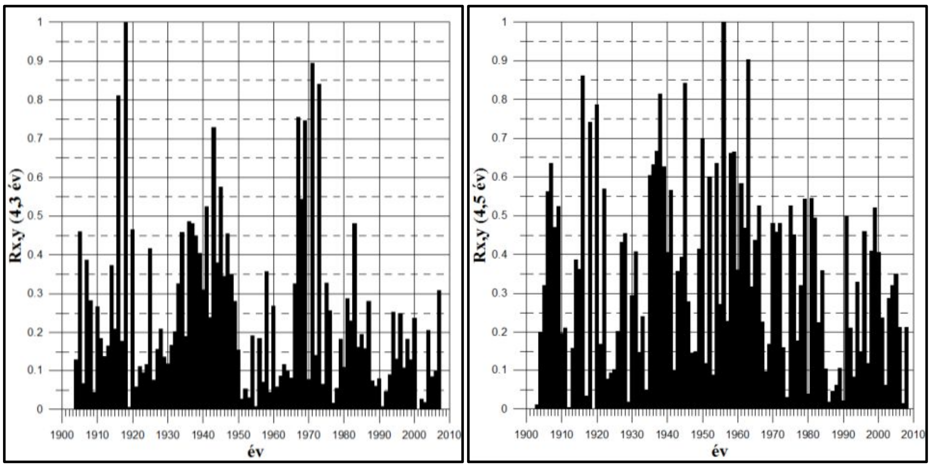

Figure 4: *Wavelet cross-correlation of the 4.3 year long cycle from Debrecen (l), and the 4.5 year long from Pécs (r).*

The wavelet of the 4.5 year long cycle shows 5 local maximum value (with more than 0.8 correlation coefficient), in the year 1956, 1963, 1916, 1945 and 1938.

The wavelet of the 4.3 cycle from Debrecen shows minimal similarities, with 4 maximum values, in the years: 1918, 1971, 1973 and 1916. The 1910's and the 1960-1970's decades have the more dominant values of the cycles in both cases, with much less dominance can be noticed after 2000 (**Figure 4**).

5. CONCLUSIONS

In recent years several studies explored the changes of the hydrological cycle. In this paper we examined the precipitation, to better understand the variability of it, with several mathematical methods based on DFT Fourier-transformation. According to our research, there are several different cycles in the rainfall datasets all over Hungary. We calculated 13 cycles which were present in all of the time series' and many others were calculated locally. We tested the forecasting method with the Debrecen precipitation records and it gave a strong correlation coefficient between the determined and the original measured data. Also the time-dependence of the cyclic parameters were determined with Wavelet analysis in case of two cities, Debrecen and Pécs. For further researches, the aim could be to better understand the nature of these periods, what are the main causes of it, and also to find a connection with the groundwater levels of the same time period.

ACKNOWLEDGEMENTS

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REFERENCES

HASTENRATH, S. L. (1967): Fourier Analysis of Central American Rainfall, Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie B, vol. 16. No. 1. 81-94.

HMS – Hungarian Meteorological Service Online Database, Available from: http://met.hu/eghajlat/magyarorszag_eghajlata/eghajlati_adatsorok/ [1. June 2015.]

ILYÉS, Cs., TURAI, E., SZŰCS, P., & ZSUGA, J. (2017): Examination of the cyclic properties of 110-year-long precipitation time series. Acta Montanistica Slovaca 22, 1-11

KOVÁCS, J., KISZELY-PERES, B., SZALAI, J. & KOVÁCSNÉ SZÉKELY, I. (2010): Periodicity in Shallow Groundwater Level Fluctuation Time Series on the Trans-Tisza Region, Hungary. Acta geographica ac geologica et meteorologica Debrecina vol. 4-5, 65-70

KOVÁCS, F. & TURAI, E. (2014): Cyclic Variation in the Precipitation conditions of the Mátra-Bükkalja Region and the Development of a Prognosis Method, ARPN Journal of Science and Technology, vol. 4. No.8. 526-540.

LIU, D., FU, Q., MA, Y. & SUN, A. (2009): Annual Precipitation Series Wavelet Analysis of Well-irrigation Area in Sanjiang Plain, IFIP International Federation for Information Processing, Volume 293, Computer and Computing Technologies in Agriculture II, 1, 563–572.

MESKÓ, A. (1984): Digital Filtering Applications in Geophysical Exploration for Oil, Akadémia Press, Budapest

NASON, G. P. & von SACHS, R. (1999): Wavelets in time-series analysis, Philosophical Transactions of the Royal Society A-mathematical Physical and Engineering Sciences, vol. 357, 2511-2526

SANGDAN Kim (2004): Wavelet Analysis of Precipitation Variability in Northern California, U.S.A., KSCE Journal of Civil Engineering, vol 8, No. 4. 471-477.

ZHENG, W., SHI, S. & GONG, Z. (2014): Evolution of Growing Season Precipitation Series in the West Region of Heilongjiang Province Based on Wavelet Analysis, Computer and Computing Technologies in Agriculture VII, Volume 419 of the series IFIP Advances in Information and Communication Technology 25-31.