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Stochastic investigation of temperature process for climatic variability identification

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1. Introduction

Lately, climate change has been the subject of intensive scientific research, due to the observed global changes in the temperature, precipitation, sea level, solar activity, etc. Although part of the scientific community attributes these changes to anthropogenic activities, others claim that they are a natural aftermath. In recent years, the main focus of the research is the investigation of the factors that mostly affect the climate dynamics trough the use of general circulation and/or stochastic models [1,2].

In this analysis, we use a dataset comprising hourly temperature and dew point records from meteorological stations in order to estimate the prediction interval (or error) of 30-year climatic periods. Dew point is the temperature at which air is saturated with water vapor, which is the gaseous state of water. A series of values, such as mean, standard deviation, maximum and minimum are estimated for each station individually. The reason why we chose to examine each station individually, is so as to minimize as much as possible the influence to our results from different climatic status. Subsequently, the climacogram (i.e., plot of variance or standard deviation of the mean-aggregated random variable of temperature and dew point versus scale) is also evaluated for various time periods. The justification for the use of the climacogram as a measure of statistical uncertainty can be seen in [3]. The main scientific interest of our work is to examine whether the examined processes have a Hurst - Kolmogorov behaviour, or else long term change (or dependence, persistence, clustering effect), as for example in [4]. The latter behaviour can be quantified through the Hurst coefficient, which varies from zero (0) to one (1). The overview of this analysis on the climatic variability at different scales aims towards the estimation of the uncertainty and irregularity of the Earth's climate dynamics.

Aim

The purpose of this analysis is to examine the climatic variability of temperature and dew point time series using the Hurst- Kolmogorov model. A poly-parametric model of high-complexity such as the climatic dynamics, is now approached by a three-parameter Hurst- Kolmogorov stochastic model just in terms of evaluation of prediction interval.

2. Methodology

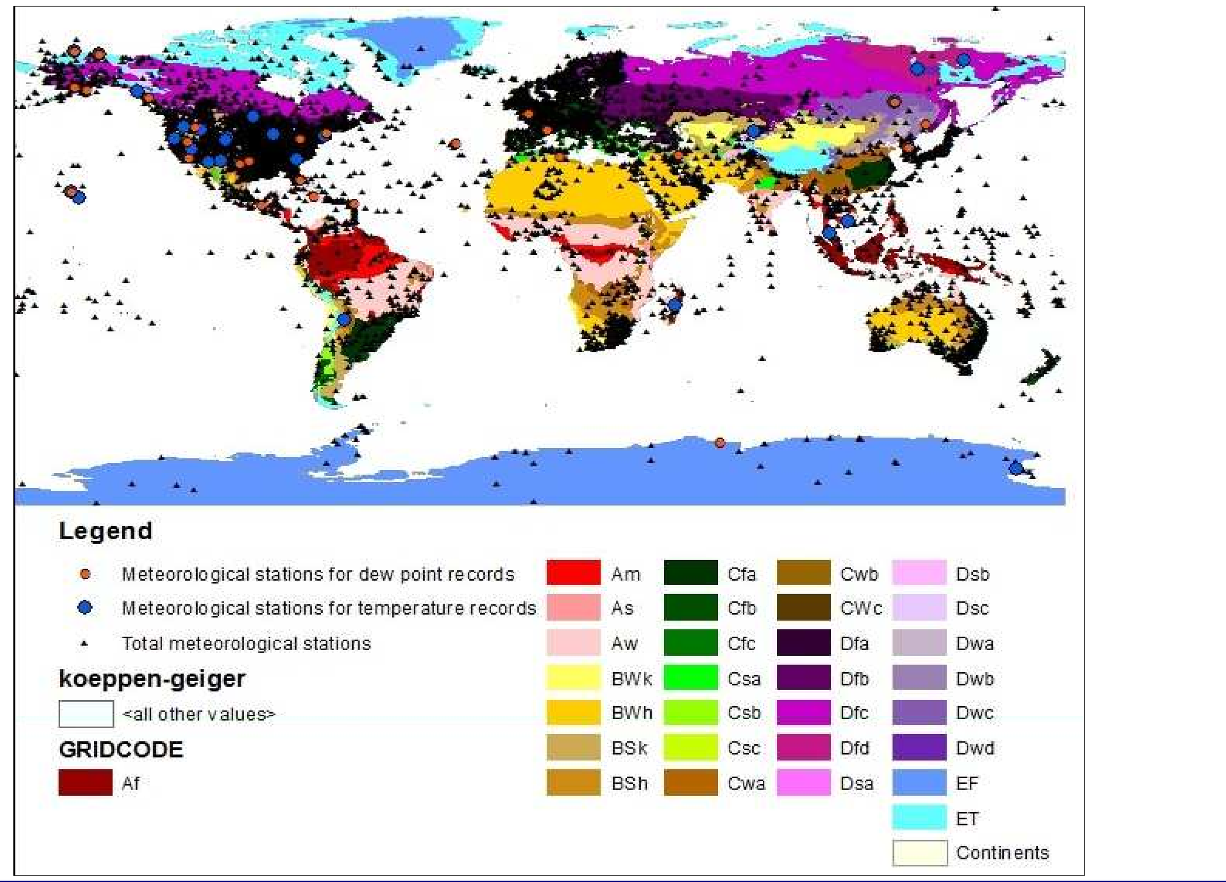
The statistical uncertainty enclosed within the surface and dew temperature process is quantified through a Monte Carlo approach. The analysis is based on the assumptions that the ratio of the annual mean temperature divided by the annual standard deviation is a stationary process, normally distributed and that it follows one of the most commonly used stochastic models in geophysics, i.e., Markov and HK (including the White Noise process for *H*=0.5). These assumptions are not only parsimonious, but also considered conservative, since any non-stationary approach would increase the complexity of the system and since the stochastic structure cannot be any less complex that the Markov and HK one-parameter models, which entail all exponential as well as a power-type behaviours. Furthermore, the analysis is applied for all climatic zones described in the Köppen system. Moreover, each mean annual value is considered valid when it is estimated from more than 1200 h, i.e. 4 measurements per day for at least 10 months. For the synthesis of the stochastic timeseries, we use the 3×AR(1) technique described in [4]:

$$\underline{\mathbf{x(i) = A(i) + B(i) + C(i)}}$$

<u>Autocorrelation coefficients for lag = 1</u>: $\varrho,A(1) = 1.52\ (H - 0.5)^{1.32}$, $\varrho,B(1) = 0.953 - 7.69\ (1 - H)^{3.85}$
$\varrho,\Gamma(1) = 0.932 + 0.087\ H,\ H \le 0.76$, or $\varrho,\Gamma(1) = 0.993 + 0.007\ H,\ H > 0.76$, where H is the Hurst-Kolmogorov coefficient.

Based on the Monte Carlo results, we estimate the prediction interval of each 30-year mean, standard deviation, minimum and maximum values. The prediction interval is actually a measurement ranging from zero to one that compares the 30-year values observed by each station with the ones predicted from the model. In this manner, we are able to capture any large, medium or low 30-year climatic variablity that occurred in approximately the last 100 years.

3. Map of spatial distribution of selected stations



4. Table of stations by Köppen–Geiger climatic classification

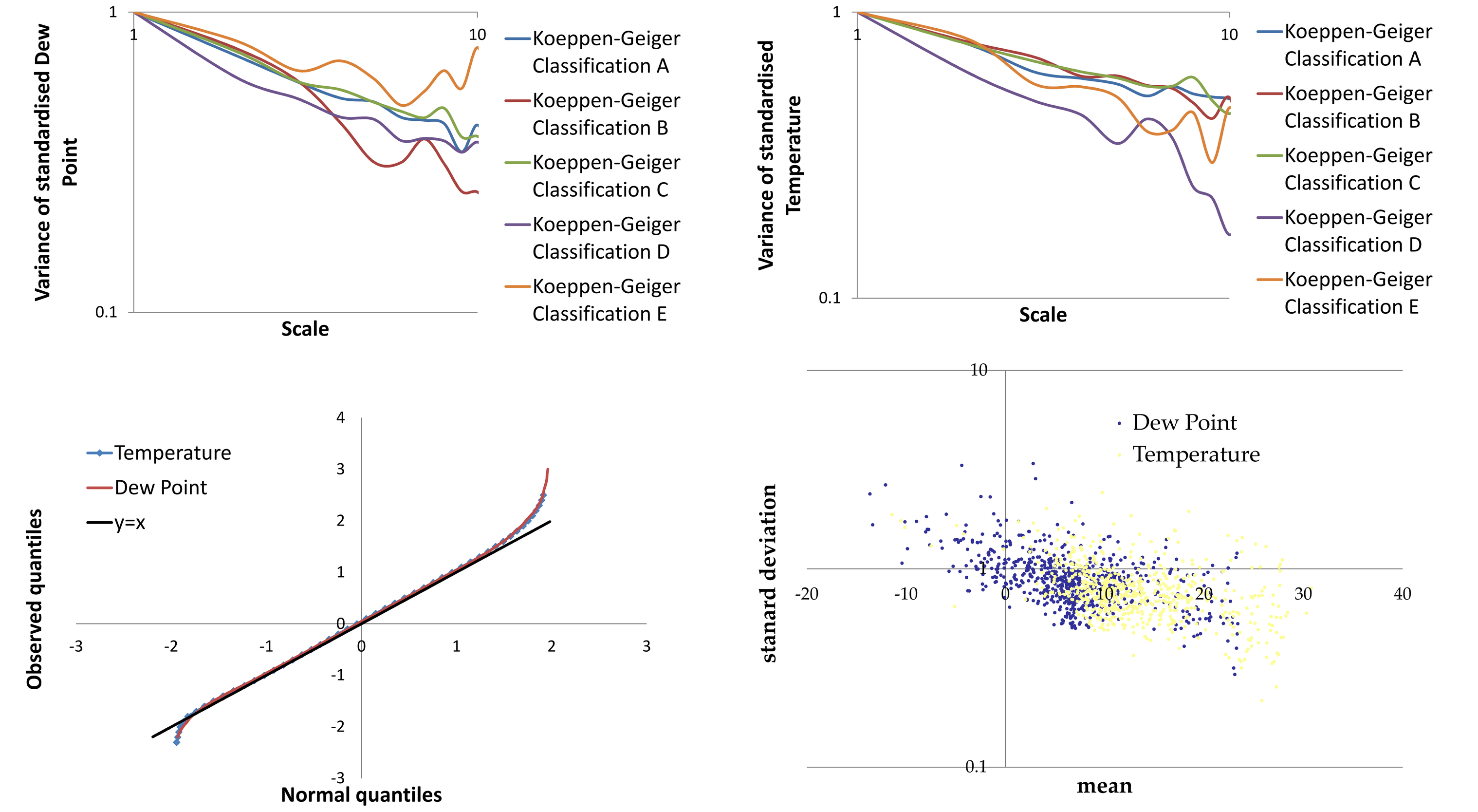
Köppen–Geiger climate classification	Syi D/T	Sye D/T	nSy D/T	maxS D/T	minS D/T	meanS D/T	Hurst coefficient D/T	Location D/T
Af	1973/1973	2014/2014	42/42	29,3/39	-11,7/-10	22,33/26,83	0,8/0,83	Parham, Antigua and Barbuda/Parham, Antigua and Barbuda
Am	1973/1973	2014/2014	42/42	28,9/36,7	-15,6/-13,8	19,2/24,68	0,77/0,74	Miami,USA/ Miami,USA
As	1939/1939	2014/2014	76/76	27,4/34,4	5/11,7	18,3/24,76	0,74/0,76	Honolulu,Hawaii/Honolulu,Hawaii
Aw	1945/1945	2014/2014	70/70	31,7/39,7	-6,1/1	20,82/26,59	0,83/0,88	Guantanamo,Cuba/Guantanamo,Cuba
Bwk	1973/1973	2014/2014	42/42	34,4/53,9	-34,4/-30	-1,83/13,2	0,61/0,80	Nevada,USA/Nevada,USA
Bwh	1973/1973	2014/2014	42/42	30/53	-14/-3	8,95/22,30	0,56/0,86	Tozeur,Tunisia/Tozeur,Tunisia
Bsk	1943/1943	2014/2014	72/72	28,3/42,2	-38,3/-15,6	10,72/17,11	0,8/0,77	Los Angeles,USA/San Diego,USA
Bsh	1948/1948	2014/2014	67/67	27,8/48,3	-27,8/-19,4	8,8/18,58	0,68/0,84	Texas,USA/Texas,USA
Cfa	1943/1943	2014/2014	72/72	29,4/43,3	-27,7/-17,7	10,64/19,01	0,76/0,84	Dallas,USA/Dallas,USA
Cfb	1941/1941	2014/2014	74/74	24/33,3	-33,3/-19,8	4,5/7,77	0,82/0,66	Metlakatla,Canada/Metlakatla,Canada
Cfc	1945/1945	2014/2014	70/70	21,1/30	-36,1/-26,1	1,4/5,03	0,8/0,69	Kodiak Island bay,Alaska/Kodiak Island bay,Alaska
Csa	1973/1973	2014/2014	42/42	27/38	-26,9/-12	8,61/15,03	0,84/0,96	Montpellier,France/Montpellier,France
Csc	1947/1947	2014/2014	68/68	26,1/31,3	-3/0	13,5/17,48	0,81/0,74	Terceira Island,Portugal/Terceira Island,Portugal
Cwa	1973/1973	2014/2014	42/42	29/47	-38/-17,9	6,28/12,08	0,34/0,91	Incheon,South Korea/Incheon,South Korea
Cwb	1973/1973	2014/2014	42/42	33/50	-4,2/-3,1	17,95/23,96	0,88/0,92	Chiapas,Mexico/Chiapas,Mexico
Dfa	1945/1945	2014/2014	70/70	26/38,9	-37,8/-24,4	4,42/10,79	0,84/0,68	Boston,USA/Boston,USA
Dfb	1949/1949	2014/2014	66/66	26,8/38,9	-35/-29,4	4,68/10,59	0,82/0,72	Pittsburg,USA/Pittsburg,USA
Dfc	1942/1942	2014/2014	73/73	22,2/31,1	-51,7/-44,4	-2,24/1,31	0,88/0,77	King Salmon,Alaska/King Salmon,Alaska
Dsa	2001/2001	2013/2013	13/13	21,2/43,5	-33,7/-19,9	-0,44/13,24	0,86/0,8	Hamadan,Iran/Savay,Kyrgyzstan
Dsb	1998/1998	2014/2014	17/17	18/36	-33/-28	-2,24/2,93	0,7/0,87	Idaho,USA/Idaho,USA
Dsc	1983/1983	2014/2014	32/32	23,3/49	-51/-51	-11,56/-10,39	0,87/0,79	Prudhoe,Alaska/Prudhoe,Alaska
Dwb	1946/1946	2014/2014	69/69	30,2/42,3	-39/-21,6	6,34/1083	0,58/0,81	Seoul,South Korea/Khalkhgol,Mongolia
Dwc	1992/1992	2014/2014	23/23	26,3/39,4	-38/-47,4	-1,85/-0,12	0,33/0,56	Hulinzhen,China/Hanggu,North Korea
Dwd	1983/1983	2014/2014	32/32	28/43,2	-53/-46,7	-9,95/-3,32	0,62/0,65	Mageda Gagin Sijidao,near Mongolia and Russia/Turuun,Mongolia
EF	1991/1991	2014/2014	24/24	1,6/30	-52,1/,51	-19,15/-10,13	0,77/0,14	Antarctica/Antarctica
ET	1945/1945	2014/2014	70/70	17,2/28,3	-61/-49,2	-13,07/-10,98	0,93/0,88	Barrow,Alaska/Barrow,Alaska

The table above illustrates some of the characteristics of the examined meteorological stations for dew point and temperature records, based on two criteria. First, a grading is estimated based on the Köppen–Geiger climate classification for each station. Then, the station of higher credibility for each Köppen–Geiger climate classification is selected, based on the criterion of at least 30 continuous years of observations (nSy).

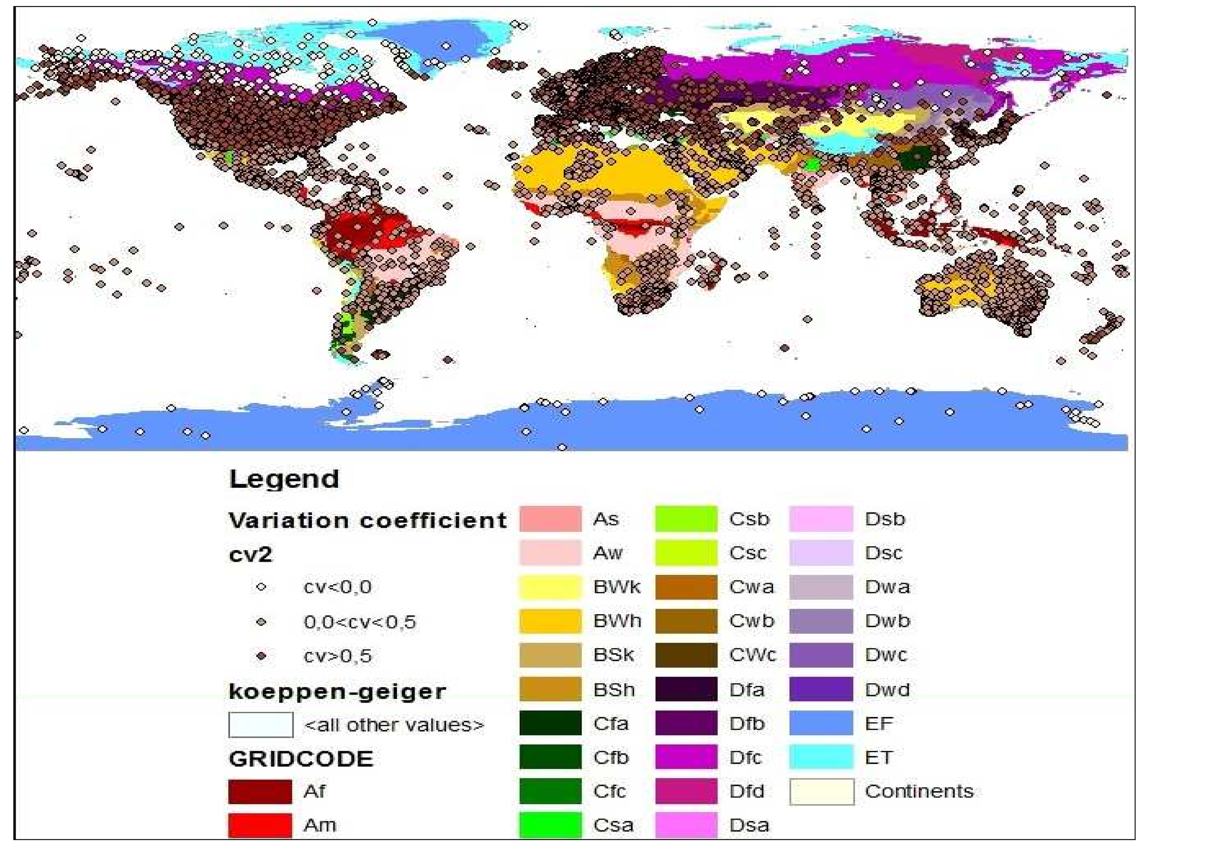
An important comment is that most of the reliable stations are found in the USA.

The orange cells indicate the meteorological stations for dew point and temperature records located at the same Köppen–Geiger climatic classification ,but in a different location.

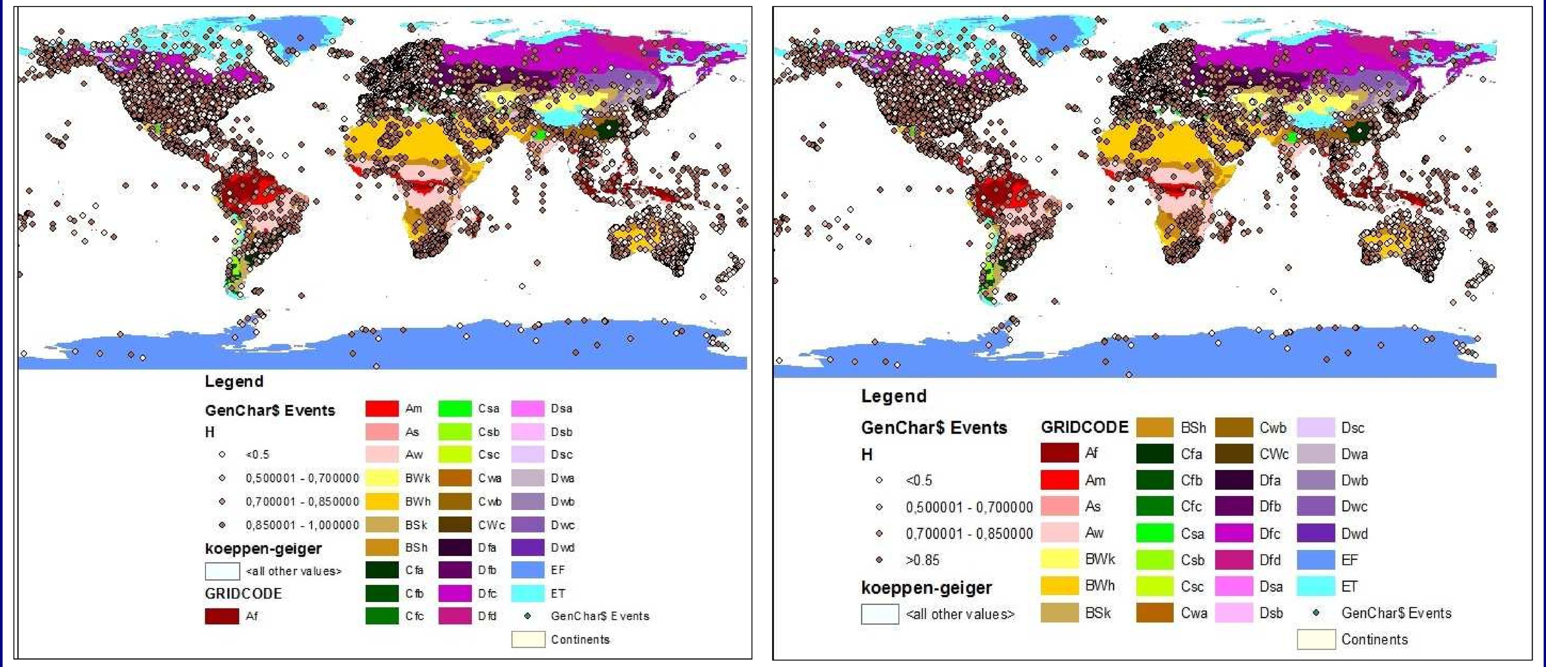
5. Several statistical features of high quality stations



6. Map of variation coefficient spatial distribution

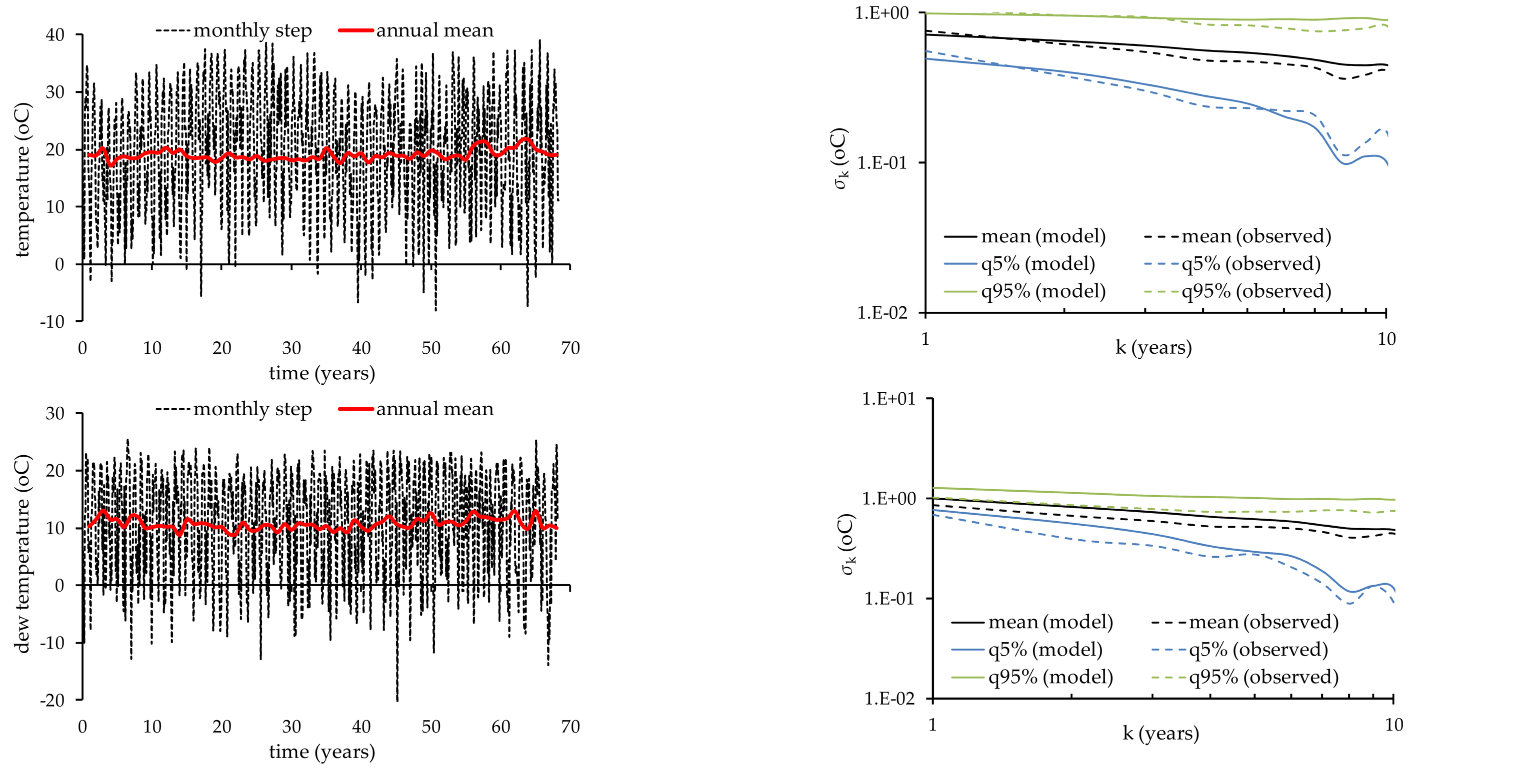


7. Map of Hurst coefficient spatial distribution

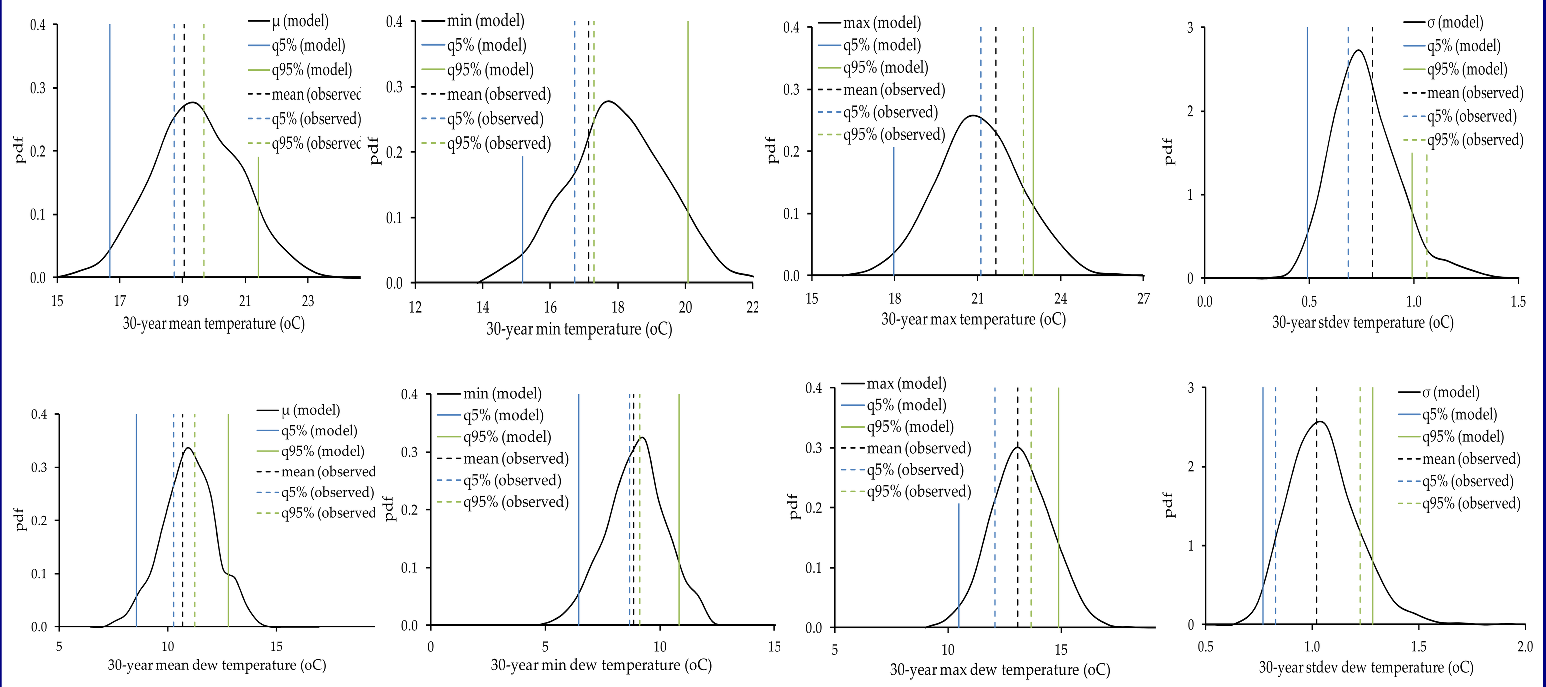


We observe that the Hurst coefficient is larger at the warm temperate zones, where the mean temperature and dew point records are higher. This may be explained that at these zones the clustering effect is more intense.

8. Estimation of the prediction interval for a station of high credibility

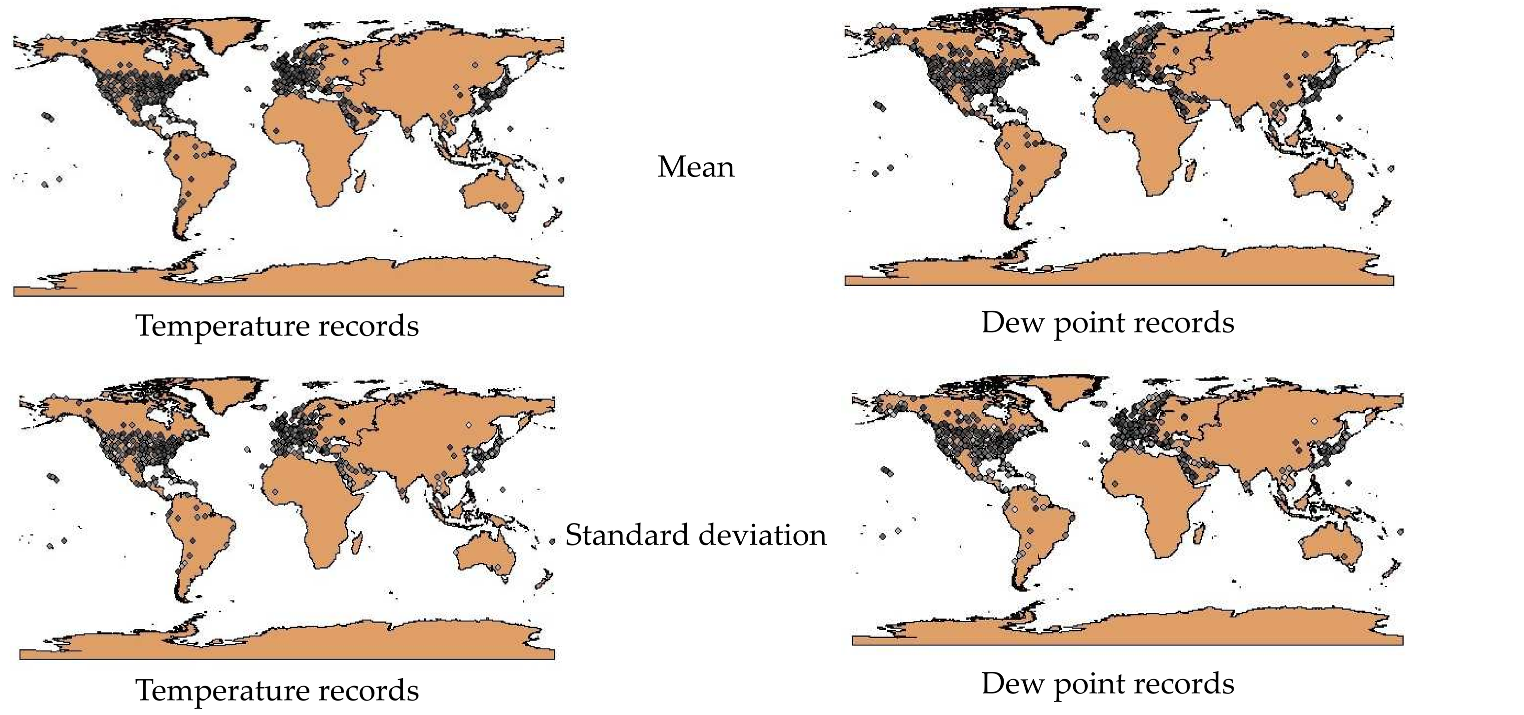


9. Estimation of the prediction interval for a high credibility station (cont.)



It seems that the Fractal Gaussian Noise model we are using has an adequate prediction interval.

10. Prediction measures of mean and standard deviation



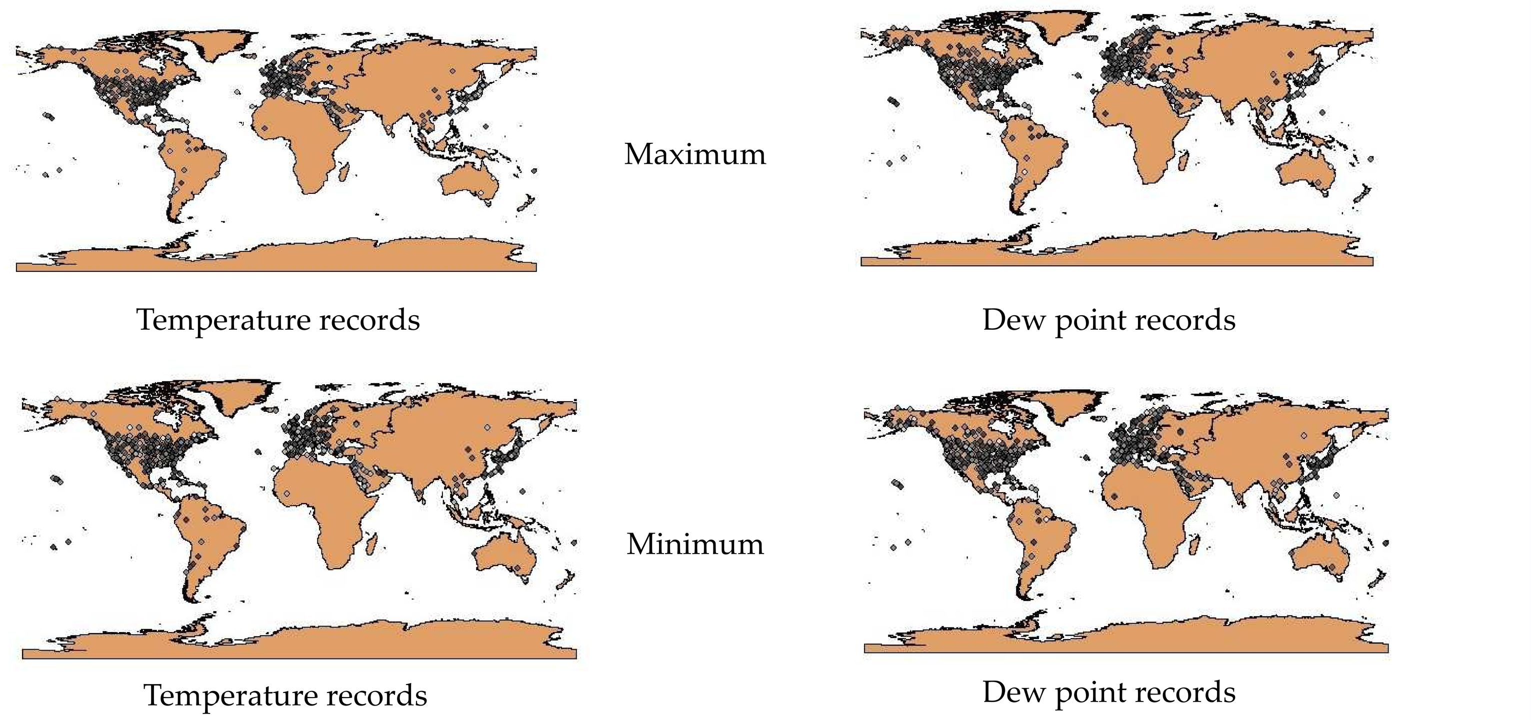
As the values increase from zero (0) to one (1), the dots turn from white, to grey and finally to black.

The mean temperature prediction intervals vary from 0.74 to 0.99, while the standard deviation prediction intervals from 0.09 to 0.99.

The mean dew point prediction intervals vary from 0.56 to 0.99, while the standard deviation ones from 0.07 to 0.99

For both temperature and dew point records, more than 50% of the standard deviation values are larger than 0.70.

11. Prediction measures of maximum and minimum values



As the prediction intervals increase, the dots turn from white (corresponds to zero prediction interval), to grey and finally to black (corresponds to prediction interval equal to 1). The maximum temperature prediction intervals vary from 0.08 to 0.99, while the minimum ones from 0 to 0.99.

The mean dew point records vary from 0.07 to 0.99, while the standard deviation ones from 0 to 0.99.

12. Conclusions

- The prediction intervals of the mean values of the temperature and dew point records are all larger than 0.8. Therefore, the HK model (or else Fractional Gaussian Noise) we adopt, can adequately predict the climatic variability of the examined processes.
- Prediction measures of the standard deviation, maximum and minimum values of both records, vary from 0.07 to 0.99, but the majority of them is larger than 0.65, as shown in the previous slides.
- We observe that as the mean value of temperature and dew point records increase, the corresponding value of the standard deviation decreases. This phenomenon mostly emerges at the warm temperate zones. Also, the Hurst coefficient at these zones was estimated higher than 0.85.

References

[1] P. Brohan, J. J. Kennedy, I. Harris, S. F. B. Tett, P. D. Jones, Uncertainty estimates in regional and global observed temperature changes: A new data set from 1850, doi: 10.1029/2005JD006548, 2006

[2] David R. Easterling, Briony Horton, Philip D. Jones, Thomas C. Peterson, Thomas R. Karl, David E. Parker, M. James Salinger, Vyacheslav Razuvayev, Neil Plummer, Paul Jamason, Christopher K. Folland, Maximum and Minimum Temperature Trends for the Globe, doi: 10.1126/science.277.5324.364, 1997.

[3] Dimitriadis, P., and D. Koutsoyiannis, Climacogram versus autocovariance and power spectrum in stochastic modelling for Markovian and Hurst–Kolmogorov processes, Stochastic Environmental Research & Risk Assessment, 29 (6), 1649–1669, doi:10.1007/s00477-015-1023-7, 2015.

[4] Markonis, Y., and D. Koutsoyiannis, Climatic variability over time scales spanning nine orders of magnitude: Connecting Milankovitch cycles with Hurst–Kolmogorov dynamics,Surveys in Geophysics, 34 (2), 181–207, 2013.

[5] D. Koutsoyiannis, The Hurst phenomenon and fractional Gaussian noise made easy, *Hydrological Sciences Journal, 47 (4), 573–595, 2002.*