Predictability estimates of foehnal events in Romania

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Abstract: The chaotic behavior of foehnal events from peri – Carpathical regions is evidenced by computing the error doubling time (via the Kolmogorav entropy) using the Grassberger-Procaccia algorithm. Real data of temperature and relative humidity were used in order to estimate the law predictability of these events and the obtained results are in good agreement with the daily forecasting skill.
Keywords: fractal dimension, Komogorov entropy

1. Introduction

The aim of this paper is to give some insight about the limits in the foehnal events prediction possibilities. Therefore, some specific parameters as the fractal dimension and Kolmogorov entropy must be estimated. Section 2 presents a short theoretical background in which the standard notations and interpretations of terms are used. In section 3 the processing of the data series is discussed.

The results are presented in section 4. Section 5 concludes with some physical interpretations of the results.

2. Theoretical background

The theoretical framework used in this study is, briefly, the following (Zeng X., Pielke R. A., and Eykholt R. (1990)):

Let $x_i = x(i\Delta t)$ (i = 1, 2, … N) represent the time series of temperature or humidity values, where N is the total number of observations and Δt = 1 hour is the time interval between measurements. A k-dimensional space is then constructed by forming the vectors

$$x_i = \left(x_i, x_{i+m}, \ldots x_{i+(k-1)m}\right)$$

(1)

where T = mΔt is the time delay, with the integer m chosen appropriately. The correlation function is given by (Grassberger and Procaccia, 1983a):

$$C(r) = \lim_{n \to \infty} \frac{i}{n^2} \sum_{i,j}^{n} \left(r - \left\| x_i - x_j \right\|\right)$$

(2)

where H is the Heaviside function, and the usual Euclidean norm is used. It can be shown that C(r) depends upon r as:

$$C(r) \approx r^{\nu}$$

(3)

For each embedding dimension k, this exponent ν can be obtained from the slope of the linear part of a plot of ln(r) versus ln(r). The correlation dimension ν_s is defined to be the saturation value of ν as k → ∞. For a fixed value of r, it can be argued that (Grassberger and Procaccia, 1983b):

$$C_k(r) \approx r^{\nu} e^{-k\tau K}$$

(4)

where K is the Kobnogorov entropy. When saturation is reached for sufficiently large k,

$$K = (1/m\tau)\ln\left(C_k(r)/C_{k+m}(r)\right)$$

(5)

The error-doubling time, as a measure of predictability, is computed from

T = ln2/K

(6)

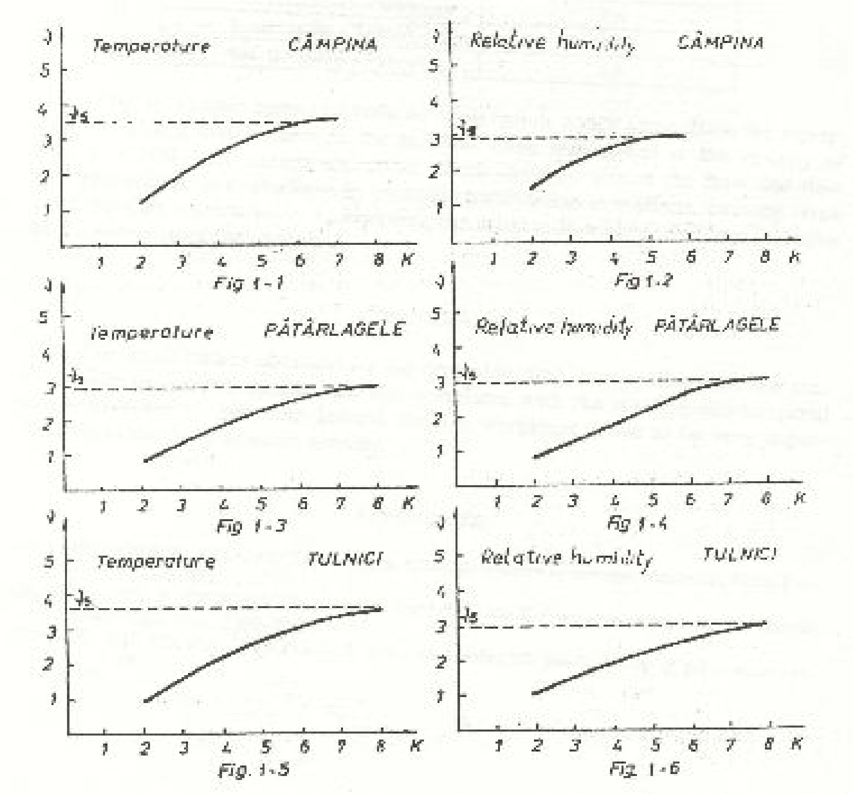
3. Data processing

Six series of 1428 data representing temperatures and relative humidities obtained from hourly measurements at three meteorological stations (Campina, Patarlagele and Tulnici) were used. Due to the noise, but especially to the shortness of the data series, the algorithm was applied to the deviations from the mean values, a standard method used when dealing with short series of low precision. The minimum values of the autocorrelation coefficient indicated a value of m belonging to the interval 8l-100. In order that the application of the procedure should be valid, the first and the last 20% of the correlation function C(r) values were eliminated, and the slope of the ln(C(r)) versus ln(r) plotting was computed using the L.M.S. method. Experimental tests showed that the selection of the interval for the values of r had a major impact on the results. Dealing with temperature values affected by an initial error of approximately 0.2^0 C, and with a horizontal extension of about 12°C, the best choice for r was estimated when ranging from 0.5 to 10. As for the relative humidity variables, the same arguments led to the interval 10-60 % for r. Error-doubling time computations were made with central values, namely 7^0 C for temperature and 30 % for relative humidity.

4. Results

The correlation dimension values ν_s for temperature and relative humidity at Campina, Patarlagele and Tulnici are shown in Figs. 1.1-1.6. When comparing Figs. 1.1,1.3, and 1.5 with Figs. 1.2, 1.4, and 1.6, we see that the correlation dimension for the temperature is greater than 3, whereas for the relative humidity it is less, indicating that a supplementary variable could be necessary to describe the evolution of temperature in time. Consequently, the temperature is less predictable as compared with the relative humidity. This result is enhanced by the

values of the error-doubling time, τ, which are displayed in Table I. The table shows that for each station, greater values of τ are obtained for the relative humidity (note, however, that even if there is a difference of unpredictability, both parameters are very unpredictable, due to the small values of τ).



Figs. 1.1-1.6: The correlation dimension for temperature and relative humidity at Campina, Patarlagele, and Tulnici.

Table 1
The error-doubling time values for temperature and relative humidity at Campina, Patarlagele and Tulnici

Parameter	τ (hours)
Temperature - Campina	2.3
Rel. Humidity - Campina	3.7
Temperature - Patarlagele	4.1
Rel. Humidity - Patarlagele	9.4
Temperature - Tulnici	4.3
Rel. Humidity - Tulnici	6.4

This difference seems to have an explanation which starts from the topographical characteristics around the stations. Each station lies in the vicinity of hills of a 700-1000 meters elevation, which strongly affects the flow and thus the temperature perturbations in suitable stratification conditions, causing large predictability uncertainties. Concerning the relative humidity, it is less sensitive to the presence of the mountain.

5. Conclusions

The small values obtained for the error-doubling time indicate the low predictability of foehnal events, and this correlates with the small spatio-temporal scales involved (-100 km). Indeed, foehnal warmings prove to be very unpredictable in the daily forecast activity.

References

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