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Short-range forecast of atmospheric pollutants using non-linear prediction method

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During the last two decades, many studies of chaos that was applied to time series of atmospheric (environmental) pollutants are few in number, and their outcomes are ambiguous. For example, Lanfredi and Machhiato (1997) not concluded the presence of low-dimensional chaos in the time series of some air constituents; the PM10 concentrations that were predicted by Chelani (2005) are quite successful. In other words, the use of chaos theory and non-linear short-range forecast of atmospheric pollutants are in principle possible, but time series of air constituents are by no means always chaotic. Therefore, the present study is two-aimed: (1) to identify the chaos in the hourly time series of nitrogen dioxide (NO_2) and sulfurous anhydride (SO_2) at two sites in Gdansk (Poland) during the 2003, and (2) to forecast the concentrations of these pollutants using the non-linear prediction method. The length of series is 8760. To identify the chaos in the time series, the following methods are applied [1-4]: (1) To determine time delays, the concept of mutual information is used; (2) To determine attractor dimensions, we apply both the correlation integral method and the false nearest neighbours algorithm; (3) To refine the obtained results, we use surrogate data sets; (4) We evaluate Lyapunov exponents as the dynamic invariants of chaotic system. All these methods are in detail described in the review of Abarbanel et al. (1993) and are widely used.

The detailed data on the time delays (τ), attractor dimensions (d_A), embedding dimensions (d_E), first two Lyapunov exponents (λ_1, λ_2), Kaplan-York dimensions (d_L) and limits of predictability (Pr_{max}, hours) for NO_2 and SO_2 at several sites in Gdansk are presented. As example, below we give these data for NO_2:

τ	d_A	d_E	λ_1	λ_2	d_L	Pr_{max}
9	5.31	6	0.0184	0.0061	4.11	40

In spite of the fact that the correlation integral method provides the relatively small attractor dimensions, both the surrogate data method and the false nearest neighbours algorithm assert that the more reliable d_E for all datasets is 6. Such a value for the embedding dimension is comparatively large, but still indicates the presence of low-dimensional chaos in the studied time series. Also, two positive Lyapunov exponents validate the previous outcome.

The sum of positive Laypunov exponents is the Kolmogorov entropy which is in turn inversely proportional to the predictability limits. In our case, these limits vary from about three to four days. Using the results of previous analysis, we apply non-linear prediction method and compare the observed data and 12-hour forecast ones of studied pollutants concentrations at several sites in Gdansk. Our results can be considered as an example of quite satisfactory short-range forecast for the air pollutants in the industrial city.

References

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