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Absolute humidity anomalies and the influenza onsets in Russia: a computational study

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Abstract

In the current work we use a computational approach to analyze the association between the anomalous drops of absolute humidity and the subsequent onset of influenza epidemics in Russia. The correlation between these two factors is searched relying on the data of acute respiratory infection incidence in Saint Petersburg, Moscow and Novosibirsk. The analysis results, along with the output from the same analysis for Ile-de-France region (Paris and its suburbs), were compared with those achieved by Dr. Jeffrey Shaman and his co-authors for the US states. We show that although the analysis results for Ile-de-France are in agreement with the conclusions of Dr. Shaman, it does not hold true for the case of Russia, where the relation between the low levels of absolute humidity and the influenza onset is proved to be statistically insignificant.

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1. Introduction

Influenza (or, shortly, flu) is one of the most common human infectious diseases. Being the most virulent among more than two hundred known seasonal acute respiratory infections (ARIs), it causes repetitive outbreaks resulting in high worker/school absenteeism and productivity losses. Also, if not treated properly, influenza leads to complications that may cause death of infected persons (the annual mortality rate is from 250 to 500 thousand individuals, according to WHO [12]).

To reduce the number of untreated cases of influenza it is crucial for the healthcare organs to be ready for the incoming epidemic. Although the seasonality of influenza outbreaks is acknowledged for a long time, its mechanism still does not have a satisfactory explanation. A lot of factors are named that may define the moment of an outbreak onset and its dynamics over time, but the extent of influence of one or another factor on the outbreak parameters is still arguable. Nevertheless, most of the researchers have come to terms with a fact that absolute humidity (AH)

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dynamics may be correlated with epidemic occurrence [10], [11]. This statement was supported, among the other works, by results of data analysis for flu outbreaks in Russia [3], [6]. The experiment performed by Shaman et al. demonstrated a hands-on biological justification showing that virus survival and transmission among guinea pigs increased monotonically with a decrease in AH [8]. In the subsequent paper the authors extend their previous findings to the human population level, showing that the onset of increased wintertime influenza-related mortality in the US is preceded by anomalously low absolute humidity levels [9]. As a result, the authors state that "AH is a major (and likely predominant) determinant of influenza seasonality". At the same time, they admitted that some of their experiment results contradicted this statement: particularly, the association between the AH drop and a subsequent influenza onset did not reach statistical significance in a big part of the Northwestern USA.

In this paper we aim to answer the question if the anomalous drops in AH may precede the influenza onsets in Russian Federation using the long-term ARI weekly incidence data in three cities (Moscow, Saint Petersburg and Novosibirsk) from 1986 to 2015. For this sake we adapt the idea of Shaman et al. to use it for our data, implement the corresponding computational algorithm and perform the data analysis. The experiment results contribute to understanding whether the anomalous drops in absolute humidity before the flu outbreaks is inherent in case of Russia as well as in the USA and, thus, whether this phenomenon could be used to increase the quality of by far not-so-accurate model predictions obtained by the authors for flu dynamics in Russia [4], [5]. To perform the data analysis we have reconstructed the algorithm which aims at representing the average AH dynamics before and after influenza onsets and assesses the statistical significance of potentially abnormal AH dynamics.

2. Algorithm structure

2.1. Assessing AH dynamics before and after an onset

First of all, we need to form a dataset of AH deviations before and after an onset. This is done according to the following sequence of operations:

- Form an array which contains all the days of influenza onsets corresponding to the selected year period and geographical locations (states, cities, countries) under consideration. These days may be taken from external sources or calculated by the algorithm itself based on a fixed influenza outbreak criterion. Let n be the overall number of onset days.
- For $i \in \overline{1, n}$:
  - Take a sample of AH values corresponding to continuous measurements during 6 weeks (42 days) before and 4 weeks (28 days) after the i-th onset for the corresponding year and a state (70 values in total).
  - Using the AH sample, form a dataset $Z^{(i)}$ which contains corresponding values of AH', local daily deviations of AH from its 31-year mean for each day (70 values in total).
- Let $Z^{(i)} = \{Z^{(i)}(-42), Z^{(i)}(-41), \ldots, Z^{(i)}(27)\}$, $i \in \overline{1, n}$, where $Z^{(i)}(0)$ corresponds to the value of AH' in the day of influenza onset. Form the averaged sample Z: $Z(j) := \frac{\sum_{i=1}^{n} Z^{(i)}(j)}{n}$, $j \in \overline{-42, 27}$.

The sample Z contains averages of AH' values which we are going to investigate further to find anomalous drops corresponding to extremely low values of AH'. The simplest way of doing it is to seek them visually on the AH' graphs. However, since the visual comparison of graphs is highly subjective and thus error-prone, it seems reasonable to assess the significance of the observed abnormal drops with the help of statistical tests.

2.2. Statistical testing

In order to determine statistical significance of an AH' deviation from the level $AH' = 0$, a bootstrapping using a Monte Carlo sampling procedure was used similar to the one used in [9]. Our aim was to accept or deny the null hypothesis: samples of AH' dynamics preceding the epidemic onset do not differ significantly from the randomly chosen arbitrary samples of AH' dynamics throughout the year.

To test this hypothesis two samples of AH' are generated. One consists of the averaged values of AH' throughout the wintertime seasons sampled randomly in time and space ("arbitrary sample"), another one is comprised of averaged

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