

## Global warming inputs in local climate changes of the Kherson region: current state and forecast of the air temperature

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The study is devoted to the global warming impact on the local climate in the Kherson region of Ukraine. Results of the study prove great impact of the global climate changes on the local climate conditions, especially, air temperature. Air temperature raise during the last years is considered to be the valuable factor of the global ecosystems changes. The short-term forecast of the air temperature by using the triple exponential smoothing Holt-Winters model showed a clear tendency to significant climate warming in the Kherson region till 2025. Average annual air temperature in 2025 probably would rise to +12.2°C, mainly at the expense of warming of the summer period. Climate changes will inevitably cause gradual changes in ecosystems of the different levels and impact greatly on human beings.

**Key words:** global warming, climate change, air temperature, Holt-Winters triple exponential smoothing, forecast.

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### Introduction

Global warming is an indisputable fact. It is projected that global average temperature will have been increased between 1.4 and 5.8°C till the end of this century (Patz et al., 2005). It is mentioned that the summer of 2003 was the hottest summer in Europe for the last 500 years: the average temperature was 3.5°C higher than normal (Schar et al., 2004). Human activities are supposed to be one of the main reasons of global warming (Kaur et al., 2017). Climate changes have great impact on all the biota, viz. microorganisms, plants, animals, humanity, etc. (Adams et al., 1998). There is no any biotic system on our planet which doesn't fall under the impact of climate changes. However, a few scientific researches have proved that climate changes perceptions of people depend on their beliefs in global warming (Howe and Leiserowitz, 2013). The goal of this study was to determine whether global warming had a considerable effect on the local climate conditions of the Kherson region of Ukraine during the period from 2010 to 2017, especially, on the air temperature. Also, the climate forecast for the nearest future (till 2025) was made.

### Materials and methods

To estimate an impact of global warming on the local climate conditions a comparison of the long-term meteorological data with the data of the studied period was conducted. The main comparison criterion was an average annual air temperature. The data used in comparison had been got from the Kherson hydro meteorological station (latitude 46°38'24"N, longitude 32°36'52"E, altitude 41 m) by using the stationary high-precision thermometers. The forecast was made by the means LibreOffice Calc 6.0 software application. Forecast was conducted by the triple exponential smoothing method of Holt-Winters (Hyndman et al., 2008), which is the most suitable for prediction of seasonal phenomena (Lewis, 1982; Billah et al., 2006; Gardner, 2006; Gelper et al., 2010; De Livera et al., 2011).

The time line with accordance to the method is presented as:  $y_1, \dots, y_t, y_t \in R$ . The task of the time line seasonal forecasting is as follows (formula 1-4):

$$y_{t+d} = a_t (\tau_t)^d \Omega_t + (d \bmod s) - s \quad (1)$$

$$a_t = a_1 \frac{y_t}{\Omega_{t-s}} + (1 - a_1) a_{t-1} \tau_{t-1} \quad (2)$$

$$\tau_t = a_3 \frac{a_t}{a_t - 1} + (1 - a_3) \tau_{t-1} \quad (3)$$

$$\Omega_t = a_2 \frac{y_t}{a_t} + (1 - a_2) \Omega_{t-s} \quad (4)$$

where  $s$  – seasonality,  $\Omega_t, i \in 0, \dots, s-1$  – season profile,  $T_t$  – trend parameter,  $a_t$  – forecast parameter without influence of the trend and seasonality.

## Results and discussion

It was established that the average annual air temperature during the last years had significantly rose comparatively to the long-term criterion value: from 0.6°C in 2011 to 1,9°C in 2010, 2012, 2013, 2015 and 2017 (Table 1).

**Table 1.** Air temperature values during the studied period (2010-2017) and forecasted ones for the period from 2018 to 2025

Year	January	February	March	April	May	June	July	August	September	October	November	December	Average/Sum
Air temperature (true values). °C													
2010	-4	2	3.4	10.7	17.6	22.5	24.7	26.1	17.7	7.8	10.5	1.6	11.7
2011	-2.7	-3.8	2.5	9.7	16.9	21.3	24.7	22.3	18.4	9.5	2.2	3.8	10.4
2012	-1.7	-7.3	2.6	13.2	20.8	23.3	26.5	23.7	19.1	14.6	6.6	-0.9	11.7
2013	-0.3	2.2	3.1	12	20.7	23	23.1	24.2	15.1	9.3	7.4	0.4	11.7
2014	-1.5	0	6.9	11.5	18	20.8	25	24.5	18.3	9.2	3.2	-0.2	11.3
2015	-0.2	0.8	5.2	9.3	17	20.9	23.4	24.1	20.9	9.4	7.3	2.2	11.7
2016	-3.6	4	6.3	12.7	16.2	22.1	24.4	24.6	18	8.4	4	-1.2	11.3
2017	-4.7	-0.7	7	9.3	16.3	22	23.4	25.4	19.9	11.3	5.4	5.9	11.7
Air temperature (forecasted values). °C													
2018	-1.8	2.8	10.4	10.8	15.9	19.7	24.3	25.8	20.0	8.5	1.5	0.3	11.5
2019	-3.4	1.7	9.4	8.3	12.7	19.2	23.3	24.3	21.8	8.1	-1.2	2.7	10.6
2020	-2.4	-1.8	9.5	11.8	16.6	21.2	25.1	25.8	22.5	13.2	3.2	-0.7	12.0
2021	-0.9	7.7	10.0	10.6	16.5	20.9	21.7	26.5	18.5	7.9	4.0	1.3	12.0
2022	-2.2	5.5	13.8	10.1	13.8	18.7	23.6	26.9	21.7	7.8	-0.2	0.7	11.7
2023	-3.7	4.5	12.9	7.6	10.5	18.1	22.6	25.4	23.5	7.3	-2.9	3.1	10.7
2024	-2.7	1.0	13.0	11.1	14.4	20.1	24.4	26.9	24.2	12.4	1.5	-0.3	12.2
2025	-1.3	10.5	13.5	9.9	14.3	19.8	21.0	27.6	20.2	7.1	2.3	1.8	12.2

The forecast has shown that global warming will have caused considerable increase of the air temperature in the region. The average annual temperature may reach + 12.2°C in 2025 at the expense of considerable raise of summer temperatures. However, cold season of the year may become colder. The next stage of the above-mentioned process should be a change of the regional climate type from the moderately-continental to continental or, that is less probable, to subtropical, as it is in the South of the Crimea.

## Conclusions

Results of the study have shown great impact of the global warming on the local climate conditions in the Kherson region of Ukraine. Considerable increase of the annual air temperature has been forecasted for the next 8 years. Global warming is considered to be a serious problem because of comprehensive negative effects on ecosystems and human beings' health (Bosello et al., 2006).

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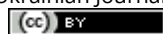
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