Klimarealistene
Vollsveien 109
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ISSN: 2703-9072

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Vol. 4.1 (2024)
pp. 107-109

Will Climate Change Crush Air Quality by Boosting Temperature Inversions, or Not?

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Keywords: Temperature inversions; air quality; regional climatology.

Submitted 2024-04-09, Accepted 2024-04-14. https://doi.org/10.53234/scc202404/16

Commentary

Seventy-five years ago, in late 1948, 21 residents of Donora, Pennsylvania, US, and vicinity died from high concentrations of fumes emitted from the local heavy industry. This tragic event in Donora, a small town about twenty miles south of Pittsburgh, sparked the national air quality laws and regulations in the US.

The notorious incident was triggered by several days of stagnant air caused by persistent temperature inversions.

Temperature inversions have been a key component of some of the worst air pollution generated disasters in history, including in Europe in the 1950s. And interest in the impact of climate change on pollution-inducing temperature inversions is gaining traction.

What is a temperature inversion and why is it a challenge to good air quality?

A temperature inversion is an atmospheric condition where warm upper-level air rests above cool lower-level air. This is a stable situation because light air is floating above heavy air, keeping the air from circulating. When a temperature inversion exists at the earth's surface, the air becomes stagnant and air pollution levels can increase dramatically.

Notably, the number and strength of surface inversions can be altered depending on how climate changes, just like severe weather conditions such as tornadoes and hurricanes.

In 2022, I had a first-of-its-kind surface-inversion climatology report published in an environmental science journal (Sadar, 2022). The peer-reviewed research paper presented results from my assessment of 30 years (January 1991 through December 2020) of morning and evening upper-air measurements collected by the Pittsburgh National Weather Service.

Review and analysis of more than 21,000 observations revealed the amount and strength of surface inversions and their trends over the decades.

During the 30-year period, people in the Pittsburgh area awoke to significant surface inversions on nearly half of all mornings. Evening inversions occurred with a frequency of about 20 percent.

Interestingly, there was a discernable decline in both morning and evening inversion frequencies over the three-decade duration. However, while surface inversion strength in the morning was

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also generally on the decline, the evening inversion strength was increasing.

Consequently, like so much research, the hard data suggest some good and some bad outcomes from a warming climate during the 30-year record.

Comparison of my results with another recent 30-year investigation of surface inversion data from nearly 500 measurement stations throughout the world shows good agreement with such research results (Zeng et al., 2022). The trends in that recent work for the northeast US matched up well with the findings in my study.

Of course, as with all meticulous scientific studies, further investigation is needed to understand and corroborate these findings with observed atmospheric conditions, climate trends, and the climate system.

Investigation of the atmosphere just above the earth's surface relates directly to the understanding of climate change mechanics because changes to the trends in near-surface atmospheric temperature along with moisture content (both measured at least twice a day across the globe by launching weather balloons) have a profound effect on the earth's hydrologic (water) cycle.

In a just-released book, Climate and Energy: The Case for Realism edited by historian E. Calvin Beisner and climatologist David R. Legates (2024), the role of water in climate change is addressed in lucid detail. For instance, it's noted in a chapter by climatologist Roy Spencer that water vapor is "the strongest of Earth's greenhouse gases. Together with the clouds we see, water vapor accounts for about 75% of the greenhouse effect." In addition, "the processes that limit how much water vapor accumulates in the atmosphere - precipitation - are not known in enough detail to predict how the weak direct-warming effect of [carbon dioxide] will be either amplified or reduced by precipitation limits on water vapor" (pp. 157-159).

It is well known that the presence, strength, and duration of surface inversions affects the transport and transformation of atmospheric moisture, and vice versa, as water in the air impacts inversions. And as a direct link to air quality, more precipitation can help cleanse polluted air. In fact, rainfall helped to end the pollution episode in Donora, Pennsylvania.

So, surface inversions have a marked connection to complex climate change, clean air, and the water cycle.

Further evaluation of surface inversion conditions and trends is necessary to better understand a phenomenon that has such a critical influence on air quality and moisture. The discovery of additional correlations between changing surface inversion conditions and air quality levels and tendencies will help to expand understanding and subsequent mitigation of serious air pollution episodes in ever-changing climate conditions.

Nuanced science must advance regardless of political narratives that claim simplicity to the complexity of atmospheric dynamics. Research on temperature inversions, which focuses on the literal depth of atmospheric changes, is critical to further interpreting climate change and to fend off unhelpful politicking.

References

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   Note: Ref. 1 provides further details on surface-inversion conditions and the data set prepared from the University of Wyoming Department of Atmospheric Science website
   http://weather.uwyo.edu/upperair/sounding.html
   and for missing data when available, from the Plymouth State University website https://www.plymouth.edu/.

Ref. 1 also includes analysis of surface-inversion break times and monthly conditions. Contact the author for inquiries regarding the full dataset.

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