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Peer Review File

Climate change reduces the wind chill hazard across Alaska

Corresponding Author: Dr Gabriele Villarini

This file contains all editorial decision letters in order by version, followed by all author rebuttals in order by version.

Version 0:

Decision Letter:

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Dear Dr Villarini,

Please allow us to apologise for the delay in sending a decision on your manuscript titled "Climate Change Reduces the Wind Chill Hazard Across Alaska". It has now been seen by 2 reviewers, and we include their comments at the end of this message. They find your work of interest, but some important points are raised. We are interested in the possibility of publishing your study in Communications Earth & Environment, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.

Please submit your point-by-point responses as a separate file, distinct from your cover letter where you can add responses to the Editors' comments that you do not want to be made available to the reviewers. Word files are preferred. We recommend that any figures, tables or graphs that are included in the response to reviewers are also included in the main article or Supplementary Information.

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and the completed checklist:
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We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

Please do not hesitate to contact us if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Sylvia Sullivan, PhD
Editorial Board Member
Communications Earth & Environment

Joe Aslin
Deputy Editor
Communications Earth & Environment

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REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The article addresses an relevant, interesting and current topic in a region impacted substantially by climate change. There are a few important items in the article that I think are necessary to address by the authors since they are relevant to their interpretation of the results comparing the CTL and PGW simulations.

1. Line 83; page 4. The authors acknowledge that "A downside of the PGW method is that it only partly captures systematic changes in the large-scale circulation." I see this as a substantial issue and limitation to the study since the local wind speed

and temperature conditions being examined for WCT changes across Alaska are dependent on large-scale circulations. The authors should meaningfully address this limitation and describe how this will directly impact the results presented in their study.

2. Line 130, page 6 and lines 138-140; page 7. The authors first state that "This experimental design is possible due to the similarity in day-to-day weather in the control and PGW simulations.", but then state "Our conclusion is therefore conditional on similar day-to-day weather variability in the future."

First, it is not clear why the authors assume similarity in day-to-day weather in the control and PGW simulations. They provide no evidence to support this statement, especially since the wind speed and temperature conditions are clearly different between the control and PGW simulations.

Second, the authors need to address the validity of this assumption for future climate scenarios since it seems to be something entirely setup by the approach and methodology of their study. This assumption puts significant limitations on the interpretation of their results when comparing the control to the PGW simulation.

3. paragraph of lines 187-195, page 9. The authors need to more robustly and thoroughly describe the negative impacts of a warming climate for this regions. While they acknowledge they are "far more serious" compared to the positive impacts, they seem to under emphasize the negative impacts. Also, it is not clear the meaning and purpose of the summary last sentence of the paragraph. What is the "lesson" the authors reference? Why is "highlighting a positive aspect of warming" a starting point for adaptation to climate changes?

Reviewer #2 (Remarks to the Author):

“Climate Change Reduces the Wind Chill Hazard across Alaska” by Kim et al uses a WRF modeling approach to evaluate future changes (2071-2100 versus 1976-2005) in the magnitude and timing of extreme wind chill days (EWCD, identified where surface air temperatures are less than -34.4 degrees Celsius). This is an important topic to delve into as such weather extremes have diverse impacts including on human health, energy, and ecosystems amongst other areas as noted by the authors. Key findings include that the largest relative EWCD changes (43 fewer days) are anticipated in low elevation (<=100 m) areas along the state’s northern and western coasts where ~60% of state’s population resides. The WRF model simulations suggest that air temperature warming, rather than wind speed reduction, is a main reason why fewer ECWDs are projected moving forward.

The paper is very well written and key findings are clearly presented. This is an informative study that will likely be of broad interest to Alaskans, various stakeholders, and those that research Arctic weather/climate extremes. That said, I think to build up the study’s relevance and motivations, it would be a good idea if the authors expanded the background text in the introductory paragraphs around human health impacts. This may include the addition of statistics (if available) on extreme wind chill temperature-related effects on morbidity and mortality of Alaskan residents. Otherwise, just a couple of minor suggestions are offered below by line (L) number in the submitted manuscript.

L66: “…eventually leading to weakened wind speeds…” is confusing given the previous statements on cold (warm) season strengthening (weakening). Suggest clarifying or removing this phrase.

L199: In the WRF data and simulations section, it would be a good idea to note why the older ERA-Interim products and CMIP5 archive are used in this study (as opposed to ERA5 and CMIP6).

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Version 1:

Decision Letter:

** Please ensure you delete the link to your author home page in this e-mail if you wish to forward it to your coauthors **

Dear Dr Villarini,

Your manuscript titled "Climate Change Reduces the Wind Chill Hazard Across Alaska" has now been seen by our reviewers, whose comments appear below. In light of their advice we are delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment.

We therefore invite you to edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

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We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Sylvia Sullivan, PhD
Editorial Board Member
Communications Earth & Environment

Joe Aslin
Deputy Editor,
Communications Earth & Environment
https://www.nature.com/commsenv/
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REVIEWERS' COMMENTS:

Reviewer #2 (Remarks to the Author):

The authors have considered and addressed reviewer concerns in their revised manuscript. I recommend acceptance of the paper in its present form.

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General comment from the Reviewer 1:

The article addresses an relevant, interesting and current topic in a region impacted substantially by climate change. There are a few important items in the article that I think are necessary to address by the authors since they are relevant to their interpretation of the results comparing the CTL and PGW simulations.

Response: Thank you for the review and comments. We have revised the manuscript according to your comments, and this has led to a much-improved paper. We have addressed all comments point-by-point below.

Comment #1. Line 83; page 4. The authors acknowledge that "A downside of the PGW method is that it only partly captures systematic changes in the large-scale circulation." I see this as a substantial issue and limitation to the study since the local wind speed and temperature conditions being examined for WCT changes across Alaska are dependent on large-scale circulations. The authors should meaningfully address this limitation and describe how this will directly impact the results presented in their study.

Response: We appreciate this concern and agree that the PGW method has some limitations besides having several advantages. The overarching goal of our study is to understand climate change impacts on WCT. We do so by using published datasets of current and future climate where the future climate is constructed using the PGW method. The specific implementation of PGW applies spatial climate changes (i.e., the deltas) to thermodynamic variables and to U and V winds. This means that forced changes in the mean-state circulation are included in our study. Forced changes in mean-state circulation are small, however, compared to forced thermodynamic change (as reported elsewhere, e.g., Deser et al. (2012); see also Figures 2 and 3 in Liu et al. (2017)), noting that these are not the exact deltas used in this study, but useful to see how small the forced mean-state circulation changes are). Forced mean-state circulation changes—such as shifts in mean jet stream position—are also more uncertain than forced thermodynamic change (Shepherd 2019).

The main limitation of PGW is that it does not allow for the possibility of forced changes in circulation anomalies (i.e., changes in synoptic-scale circulation variability: sometimes referred to as the eddy dynamic component). We therefore do not expect PGW to capture changes in WCT associated with changes in synoptic circulation variability (by design of PGW, the synoptic-scale sequence is the same in current and future climate. This allows us to quantify change without it being masked by variability). The importance of changes in circulation anomalies, however, varies regionally and there is evidence that for our focus region of Alaska in winter, eddy-dynamic contributions to the total forced change are small (Hall et al. 2024). Quantifying the role of forced change in circulation anomalies

for WCT demands large ensemble climate simulations to overcome sampling issues (Deser et al. 2012) that are currently unfeasible with km-scale models.

In the revised manuscript, we better state this limitation of PGW in that it misses any contributions to changed WCT from changed synoptic-scale variability but there is evidence from Hall et al. (2024) that contributions may be small during the cold season in Alaska. This more accurate description of what PGW does and does not consider allows for more accurate interpretation of our results. Please refer to the revised manuscript.

"A downside of the PGW method is that it only partly captures forced circulation change[27]. While mean-state circulation change is included, any forced change in circulation anomalies (i.e., changes in synoptic-scale circulation variability) is not considered. The importance of changes in circulation anomalies, however, varies regionally and there is evidence that for wintertime in Alaska contributions from circulation anomalies may be small[27]."

"We interpret this conclusion within the limitation of the PGW approach in not allowing for the possibility of forced changes in synoptic circulation variability. Quantifying the role of forced change in circulation anomalies for EWCDs demands large ensemble climate simulations to overcome sampling issues[36] that are currently unfeasible with km-scale models. Our conclusion is therefore based on the assumption that synoptic eddy contributions to EWCDs are small compared to contributions from mean-state changes."

References

Deser, C., Knutti, R., Solomon, S., & Phillips, A. S. (2012). Communication of the role of natural variability in future North American climate. *Nature Climate Change*, *2*(11), 775-779.

Hall, A., Rahimi, S., Norris, J., Ban, N., Siler, N., Leung, L. R., ... & Qian, Y. (2024). An evaluation of dynamical downscaling methods used to project regional climate change. *Journal of Geophysical Research: Atmospheres*, *129*(24), e2023JD040591.

Liu, C., Ikeda, K., Rasmussen, R., Barlage, M., Newman, A. J., Prein, A. F., ... & Yates, D. (2017). Continental-scale convection-permitting modeling of the current and future climate of North America. *Climate Dynamics*, *49*, 71-95.

Shepherd, T. G. (2019). Storyline approach to the construction of regional climate change information. *Proceedings of the Royal Society A*, *475*(2225), 20190013.

Comment #2. Line 130, page 6 and lines 138-140; page 7. The authors first state that "This experimental design is possible due to the similarity in day-to-day weather in the

control and PGW simulations.", but then state "Our conclusion is therefore conditional on similar day-to-day weather variability in the future."

First, it is not clear why the authors assume similarity in day-to-day weather in the control and PGW simulations. They provide no evidence to support this statement, especially since the wind speed and temperature conditions are clearly different between the control and PGW simulations.

Second, the authors need to address the validity of this assumption for future climate scenarios since it seems to be something entirely setup by the approach and methodology of their study. This assumption puts significant limitations on the interpretation of their results when comparing the control to the PGW simulation.

Response: Thank you for the comment. The similarity between the CTRL and PGW simulation is due to the experimental design of the PGW experiment. Both simulations are forced by the weather (short term fluctuations) provided by ERA-Interim with the exception that the PGW simulation has a smooth added delta for state variables that varies on monthly time scales. This results in very similar time series at regional scales as shown in Figure R1 since large variations in wind and temperature are driven by synoptic scale features (e.g., low pressure systems), which are similar in the PGW and CTRL simulations besides systematic shifts that stem from the forced climate change response (e.g., Hall et al. 2024).

Determining the forced changes in weather sequences (eddy dynamic component) would require large ensemble km-scale simulations which are currently not possible. The key advantage of the PGW approach, then, is to control for the sequence of synoptic weather and examine the forced change given the same synoptic weather.

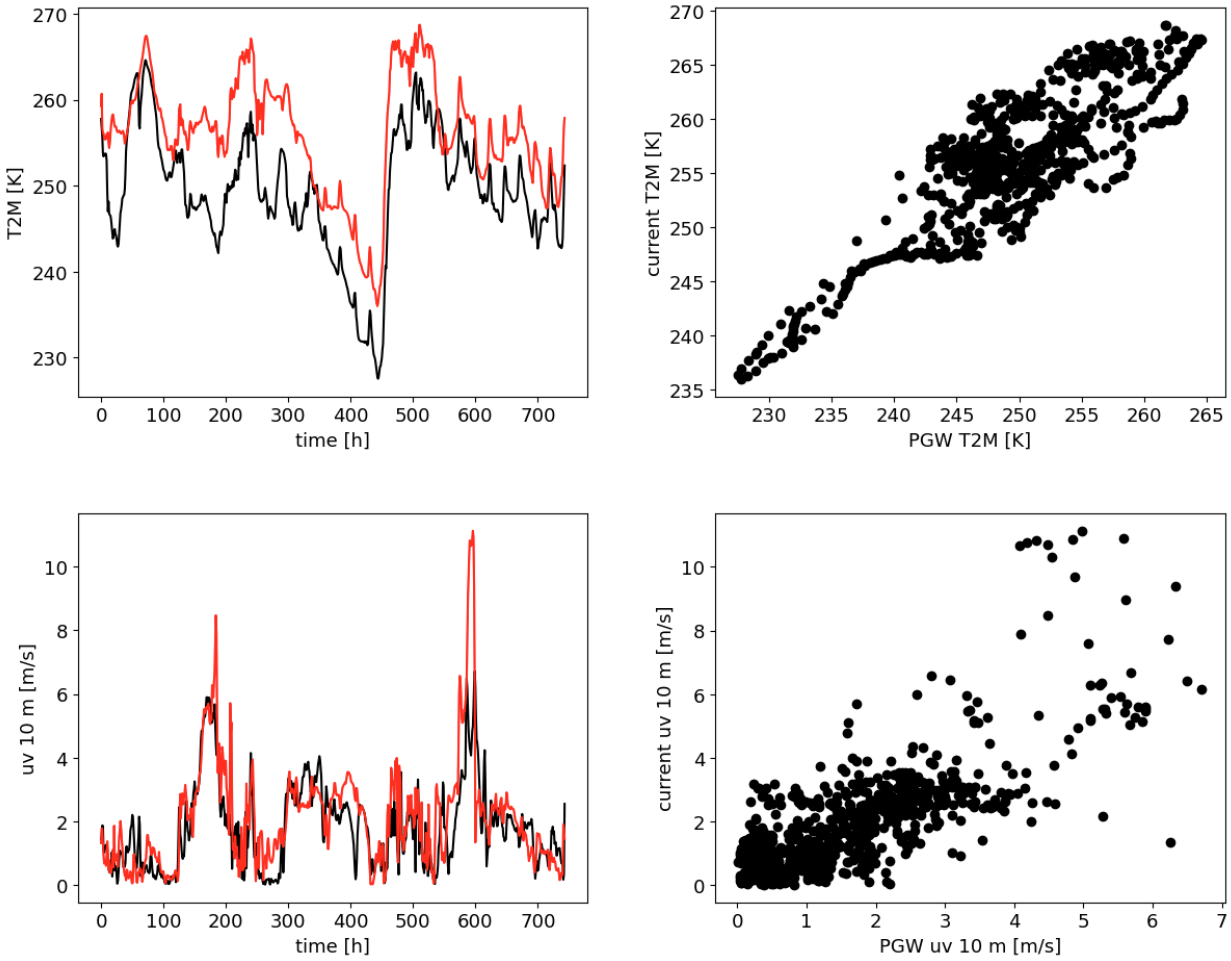

Figure R1. Time series of 2-meter temperature (T2M; top left) and 10 m wind speed (uv 10; bottom left) in the CTRL (black) and PGW (red) simulation at 63.83° latitude and -152.36° longitude during August 2016. The scatterplots on the right show the relationship of hourly T2M and uv 10 between the CTRL and PGW simulation.

Comment #3. paragraph of lines 187-195, page 9. The authors need to more robustly and thoroughly describe the negative impacts of a warming climate for this regions. While they acknowledge they are "far more serious" compared to the positive impacts, they seem to under emphasize the negative impacts. Also, it is not clear the meaning and purpose of the summary last sentence of the paragraph. What is the "lesson" the authors reference? Why is "highlighting a positive aspect of warming" a starting point for adaptation to climate changes?

Response: Thank you for the comment. We have revised the discussion to emphasize the negative impacts of warming in Alaska (e.g., permafrost thawing). Also, we here use the 'lesson' to emphasize the idea that proactive climate adaptation, viewing both the upsides and downsides of a warming climate as opportunities, rather than just avoiding

the negative aspects as stated by Bierbaum et al. (2013). They provided examples of proactive climate adaptations in the United States, and we aim to draw from it in our discussion. Ultimately, our goal is to encourage readers to recognize the potential benefits of a warming climate, rather than treating it as 'inevitable and impossible to manage,' by highlighting a positive aspect of warming despite the many negative effects of climate change. To better communicate our intentions and findings, we have revised the sentences. Please refer to the revised manuscript.

"One of the most serious impacts on both people and the environment in Alaska is permafrost thawing[40]. This degradation can cause land surface instability and subsidence, leading not only to infrastructure damage (e.g., the collapse of buildings and bridges)[41], but also to the emergence of diseases due to melting in Arctic (e.g., bacterial activation and exposure to accumulated hazardous chemicals)[42,43]. In short, theses environmental threats are linked to the fact that Alaska faces a range of anticipated hazards, including natural threats such as floods, erosion, and wildfires[44] as well as public health risks like the spread of infectious diseases[45].Therefore, it is not surprising these environmental changes threaten community infrastructure. However, there are compelling examples of proactive climate adaptation underway to manage inevitable changes. These efforts have been made with a comprehensive understanding of the risks and opportunities of climate change, addressing regional concerns such as sea level rise, flooding, water distribution, and transportation systems in several states of the United States[46]. Furthermore, clear information about the magnitude and timing of climate change can help foster better coordination, communication, and knowledge sharing in the decision-making process. Taking this as a lesson, we believe that our findings, which highlight a positive aspect of warming and investigate changes in magnitude and timing of extreme hazards, can be a starting point for adapting to the challenges of climate change within Alaskan communities."

References

Bierbaum, R., Smith, J. B., Lee, A., Blair, M., Carter, L., Chapin, F. S., ... & Verduzco, L. (2013). A comprehensive review of climate adaptation in the United States: more than before, but less than needed. Mitigation and adaptation strategies for global change, 18, 361-406.

General comment from the Reviewer 2:

"Climate Change Reduces the Wind Chill Hazard across Alaska" by Kim et al uses a WRF modeling approach to evaluate future changes (2071-2100 versus 1976-2005) in the magnitude and timing of extreme wind chill days (EWCD, identified where surface air temperatures are less than -34.4 degrees Celsius). This is an important topic to delve into as such weather extremes have diverse impacts including on human health, energy, and ecosystems amongst other areas as noted by the authors. Key findings include that the largest relative EWCD changes (43 fewer days) are anticipated in low elevation (<=100 m) areas along the state's northern and western coasts where ~60% of state's population resides. The WRF model simulations suggest that air temperature warming, rather than wind speed reduction, is a main reason why fewer ECWDs are projected moving forward.

The paper is very well written and key findings are clearly presented. This is an informative study that will likely be of broad interest to Alaskans, various stakeholders, and those that research Arctic weather/climate extremes. That said, I think to build up the study's relevance and motivations, it would be a good idea if the authors expanded the background text in the introductory paragraphs around human health impacts. This may include the addition of statistics (if available) on extreme wind chill temperature-related effects on morbidity and mortality of Alaskan residents. Otherwise, just a couple of minor suggestions are offered below by line (L) number in the submitted manuscript.

Response: Thank you for your review and comments. We found a health statistics report (Berko 2014) showing that cold-related mortality in the United States was primarily attributed to excessive natural cold, which has a greater impact on human health than other weather-related factors. We have included this information in the revised manuscript along with a study (Young and Mäkinen 2010) specific to Arctic populations.

"One report showed that two-thirds of weather-related mortality among United States residents from 2006 to 2010 were attributed to excessive natural cold[8]. A study specifically of Arctic populations found associations between colder climate and a range of mortality, morbidity, and fertility indicators, indicating that risks are not restricted to areas less historically-adapted to cold weather[9]."

References

Berko, J. (2014). *Deaths attributed to heat, cold, and other weather events in the United States, 2006-2010* (No. 76). US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Young, T. K., & Mäkinen, T. M. (2010). The health of Arctic populations: Does cold matter?. *American Journal of Human Biology: The Official Journal of the Human Biology Association*, *22*(1), 129-133.

Comment #1. L66: "…eventually leading to weakened wind speeds…" is confusing given the previous statements on cold (warm) season strengthening (weakening). Suggest clarifying or removing this phrase.

Response: Thank you for your comment. We want to say that wind speeds in Alaska are expected to weaken overall due to rising temperatures, with Redilla et al (2019) indicating a decrease in wind speed during the warm season. We have revised the sentence for clarity.

"Over the same period, there is some evidence that wind speed may increase in the cold season and decrease in the warm season[17]. Given that the temperature is projected to increase, the wind speeds are eventually expected to weaken across the state[18]."

References

Redilla, K., Pearl, S. T., Bieniek, P. A., & Walsh, J. E. (2019). Wind climatology for Alaska: Historical and future.

comment #2. L199: In the WRF data and simulations section, it would be a good idea to note why the older ERA-Interim products and CMIP5 archive are used in this study (as opposed to ERA5 and CMIP6).

Response: Thank you for your comment. This study uses existing km-scale climate datasets produced before 2018 for historical and before 2021 for future. These datasets were produced before ERA5 and CMIP6 became fully available, hence the use of ERA-Interim and CMIP5. There may be some sensitivity of our results to these choices of datasets, particularly in the magnitude of the WCT response due to the stronger warming signal in CMIP6. The main findings of the directional change in WCT, importance of temperature over wind, and general spatial patterns of change relative to terrain will likely still hold. The computational expense needed to re-run these km-scale simulations and confirm this assumption is beyond our capacity. We address this issue in the revised manuscript.

"While there may be some sensitivity to our use of ERA-Interim and CMIP5 compared to the more recent ECMWF Reanalysis v5 and CMIP6, our main findings of the directional change in WCT,

relative importance of temperature versus wind, and general spatial patterns of change relative to terrain will likely not change."

Comments from the Reviewer 2:

The authors have considered and addressed reviewer concerns in their revised manuscript. I recommend acceptance of the paper in its present form.

Response: Thank you!