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Potential Operational, Infrastructure, and Strategic Implications of Changes In Heat and Humidity (Poster)

Jennifer L. Bewley
R. Abraham Holland
Sara C. Runkel
Todd D. Ringler

November 2021

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IDA Document NS D-32882

Log: H 21-000439

INSTITUTE FOR DEFENSE ANALYSES
4850 Mark Center Drive
Alexandria, Virginia 22311-1882



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About This Publication

This work was conducted by the Institute for Defense Analyses Central Research Program, Project C2265 “IDA Climate Security Initiative - Phase II.” The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

For More Information

Jennifer L. Bewley, Project Leader
jbewley@ida.org, 703-845-2390

Leonard J. Buckley, Director, Science and Technology Division
lbuckley@ida.org, 703-578-2800

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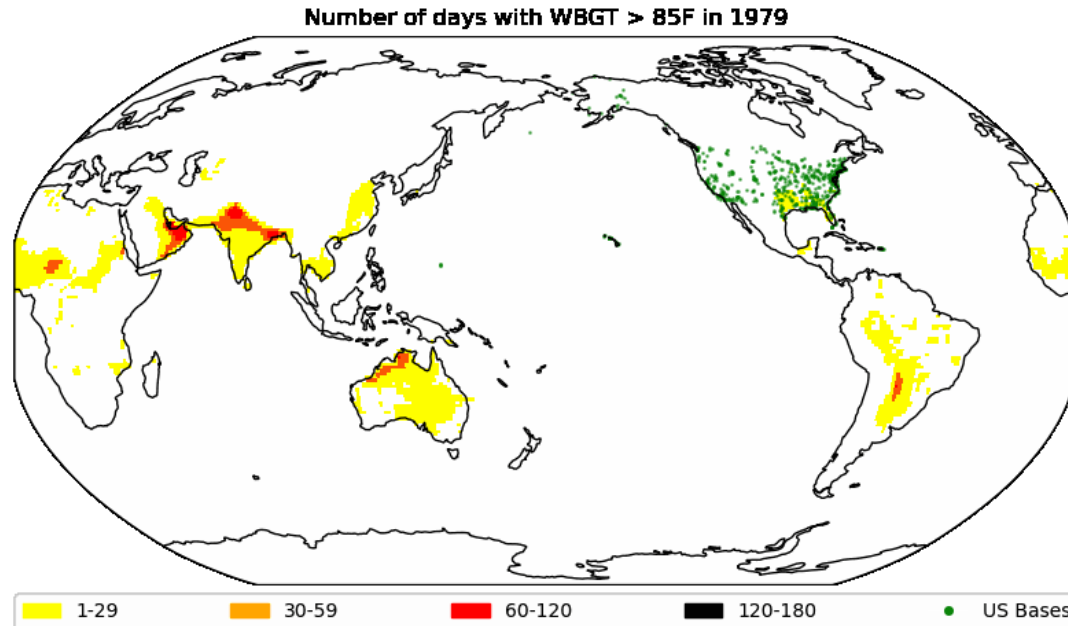
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Executive Summary

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) Resource Conservation and Resiliency program area has supported a broad portfolio of infrastructure-focused research intended to help maximize the number of available training days and mission readiness. This analysis takes the first steps at connecting installation-level climatic risks and the other critical input into mission readiness: our people. Over time, we believe this approach can help further SERDP-ESTCP's mission by supporting more efficient and integrated identification of investments that yield the largest gains in available training days and readiness. In 2019, the Institute for Defense Analyses began developing an internally funded interdisciplinary climate security capability within its cadre of research personnel. One of the first results of this effort is a demonstration analysis mapping global changes in an estimated Wet Bulb Globe Temperature (WBGT) Index derived from the most recent ensemble of Community Earth System Models to a publicly available dataset of the DoD's current installation infrastructure. We then estimate the anticipated activity limitations for personnel expected to wear body armor on these installations using common work/rest restriction policies. We find that several global regions, as well as important military training installations, are likely to experience increased WBGT levels that could impose meaningful operational limitations. For commanders seeking to avoid these limitations, innovating new cooling technologies and infrastructure, inventing operational concepts that lower the expected physical strain on body armored servicemembers, reducing operational limitations by removing body armor, or simply accepting operational gaps created by these changes may be their only options.

Potential operational, infrastructure, and strategic implications of changes in heat and humidity

Jennifer Bewley, Abraham Holland, Sara Runkel, Todd Ringler
(Institute for Defense Analyses)



The Wet Bulb Globe Temperature (WBGT) Index, an indicator of heat stress during exercise, was computed globally from 1979-2100 using temperature and relative humidity data from historical reanalysis data (NCEP) and a multi-ensemble climate model (CESM2).

The WBGT status at select U.S. bases was analyzed using location data from the Defense Installations Spatial Data Infrastructure (DISDI). The projected increase in the WBGT could have meaningful implications for how and when the DoD trains at select U.S. base locations

Heat category 'flag days' are used to assess heat stress on the human body by utilizing the WBGT index. Each flag condition indicates how to limit physical activity and increase hydration.

Work/Rest and Water Consumption Table

Applies to average sized, heat-acclimated soldier wearing BDU, hot weather. (See TB MED 507 for further guidance.)

| Easy Work | Moderate Work | Hard Work |
|---|--|--|
| <ul style="list-style-type: none"> • Weapon Maintenance • Walking Hard Surface at 2.5 mph, < 30 lb Load • Marksmanship Training • Drill and Ceremony • Manual of Arms | <ul style="list-style-type: none"> • Walking Loose Sand at 2.5 mph, No Load • Walking Hard Surface at 3.5 mph, < 40 lb Load • Calisthenics • Patrolling • Individual Movement Techniques, i.e., Low Crawl or High Crawl • Defensive Position Construction | <ul style="list-style-type: none"> • Walking Hard Surface at 3.5 mph, ≥ 40 lb Load • Walking Loose Sand at 2.5 mph with Load • Field Assaults |

| Heat Category | WBGT Index, F° | Easy Work | | Moderate Work | | Hard Work | |
|---------------|----------------|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|
| | | Work/Rest (min) | Water Intake (qt/hr) | Work/Rest (min) | Water Intake (qt/hr) | Work/Rest (min) | Water Intake (qt/hr) |
| 1 | 78° - 81.9° | NL | ½ | NL | ¾ | 40/20 min | ¾ |
| 2 (GREEN) | 82° - 84.9° | NL | ½ | 50/10 min | ¾ | 30/30 min | 1 |
| 3 (YELLOW) | 85° - 87.9° | NL | ¾ | 40/20 min | ¾ | 30/30 min | 1 |
| 4 (RED) | 88° - 89.9° | NL | ¾ | 30/30 min | ¾ | 20/40 min | 1 |
| 5 (BLACK) | > 90° | 50/10 min | 1 | 20/40 min | 1 | 10/50 min | 1 |

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For electronic versions, see <http://chppm-www.apgea.army.mil/heat>. Local reproduction is authorized.
June 2004

CP-033-0404

BDU = Battle Dress Uniform

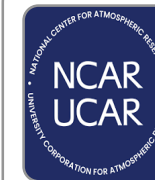
The number of days with a flag condition of yellow or higher was calculated using a combination of historical reanalysis data (NCEP) and climate model projections (CESM2) to provide global coverage from 1979-2100. A day was categorized as a Yellow+ flag day if any three-hour period during the day was categorized a yellow flag condition or higher.

- As air temperature increases, the body relies on sweat to dissipate heat, but as the humidity increases, it becomes harder to dissipate heat through sweat.
- The WBGT uses a combination of factors to estimate this relationship. Heat category 'flag days' are used to translate the measured WBGT index into concrete local guidance.
- When the flag condition is yellow or higher (WBGT > 85), it is dangerous to train outside while wearing body armor.



NCEP Reanalysis Data

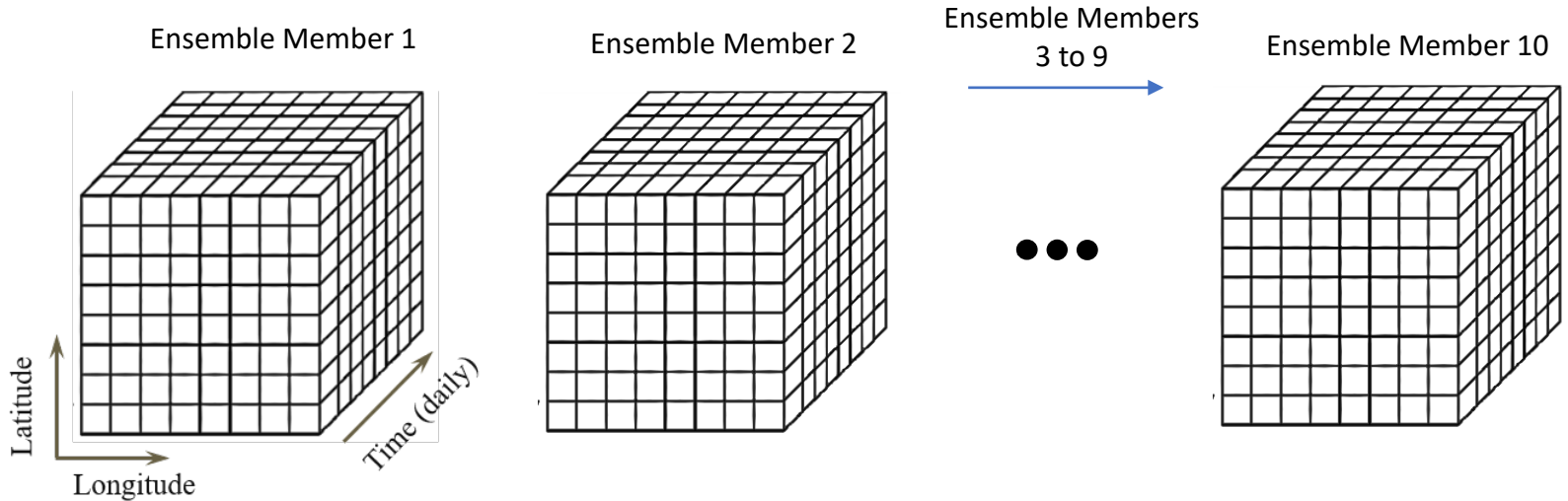
- Historical temperature and relative humidity data
- Global coverage from 1979 to present (daily)
- Publicly available US database: <https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.html>



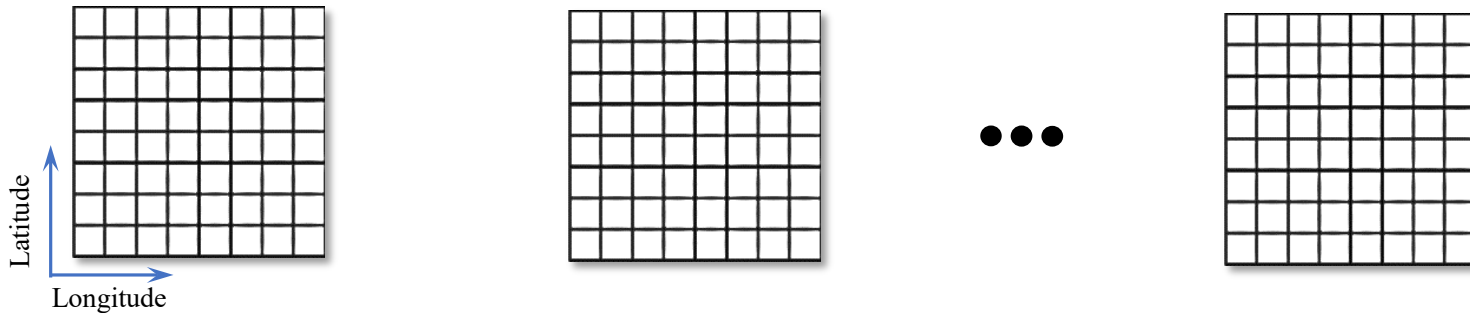
CESM2 Large Ensemble Dataset (CMIP6) 10 ensemble members

- Modeled temperature and relative humidity data
- Global coverage from 1980 to 2100 (3-hourly)
- Representative Concentration Pathway 8.5 (RCP 8.5)
- Publicly available US database: <https://www.cesm.ucar.edu/projects/community-projects/LENS2/>

Methodology Diagram

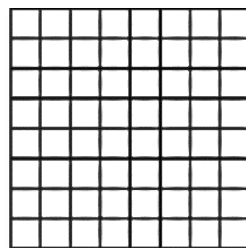


Calculate the **annual** number of days that can be categorized as a **yellow flag day or greater** for each ensemble member



Calculate the **median** number of days that can be categorized as a **yellow flag day or greater** across all ensemble members

The grid resolution is 1.25° (~140 km²)

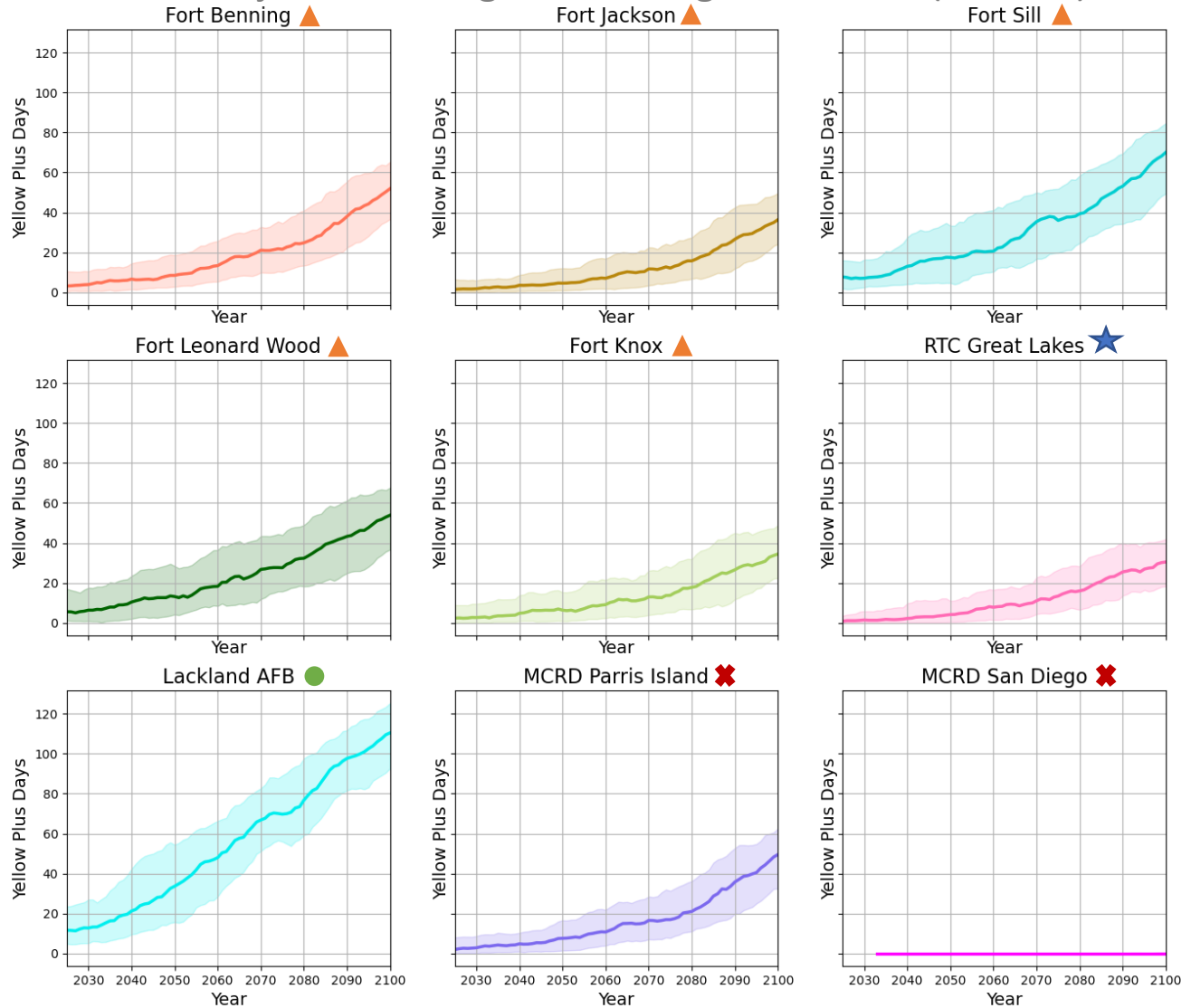


Number of Yellow+ Days at U.S. Training Bases

WBGT Projections using CESM2 Large Ensemble (RCP 8.5)

US Basic Training Bases:

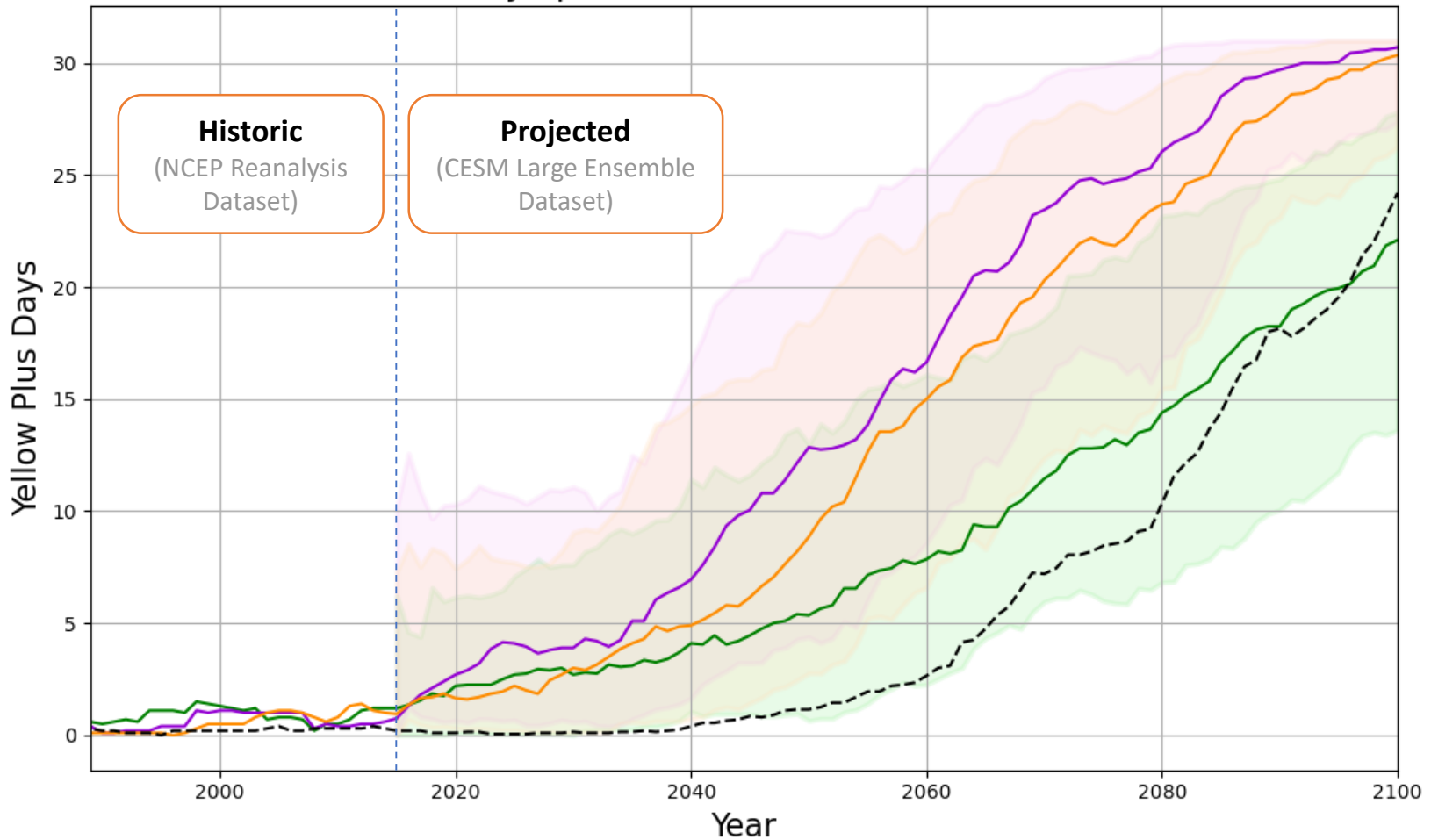
- Plots show number of days with yellow flag or greater and a confidence interval based on 10 ensemble members
- Heat and humidity restrictions will affect every Services' training pipeline
- Under the RCP8.5 Scenario, Lackland AFB is predicted to have **38** days of Yellow+ restrictions by 2050, and **114** days by 2100



Military Branch
 ▲ Army ● Air Force
 ★ Navy ✖ Marine Corps

Monthly Breakdown of Yellow+ days at Lackland AFB

Number of Yellow+ days per month at Lackland AFB from 1989 to 2100

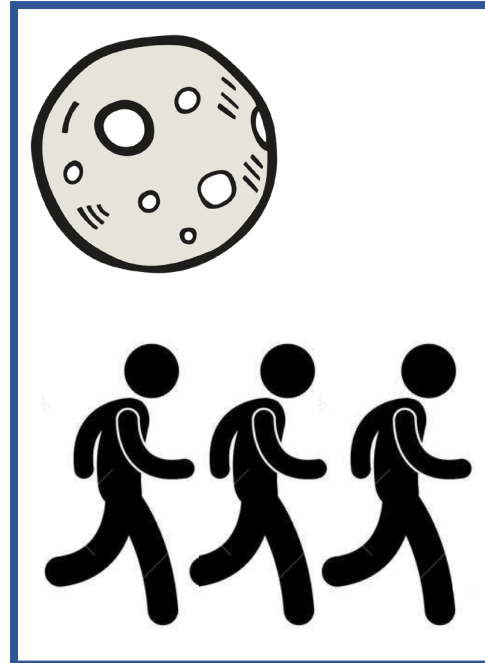


■ June ensemble median ■ July ensemble median ■ August ensemble median - - - Other months total

Most Yellow+ Days occur in Summer months (June, July, August)

Lessons Learned and Next Steps

- Heat and humidity projections indicate some U.S. bases within the basic training pipeline may have to cope with months of elevated activity restrictions each year.
- A richer and more detailed analysis can be done to identify adaptation strategies (e.g., day vs. night-time training, synthetic training, surging training during cool months)
- The existing analysis is a first pass, a number of empirical improvements could be made with existing data sources:
 - Confidence intervals could be improved by including more ensemble members from the CESM2 large ensemble dataset.
 - The RCP8.5 scenario is used for the analysis and assumes that no action will be taken to reduce emissions; additional scenarios could be analyzed to evaluate the range of possible outcomes.
 - Current analysis uses a simplified WBGT but a more robust study could be done to incorporate solar radiation and windspeed.



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Contact Information

Jennifer Bewley: jbewley@ida.org

Abraham Holland: rholland@ida.org

Sara Runkel: srunkel@ida.org

Todd Ringler: tringler@ida.org

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

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| | | | | | |
|---|-------------------|-------------------------|----------------------------|---|---|
| 1. REPORT DATE November 2021 | | 2. REPORT TYPE FINAL | | 3. DATES COVERED (From-To) | |
| 4. TITLE AND SUBTITLE Potential Operational, Infrastructure, and Strategic Implications of Changes In Heat and Humidity (Poster) | | | | 5a. CONTRACT NUMBER HQ0034-14-D-0001 | |
| | | | | 5b. GRANT NUMBER | |
| | | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) Bewley, Jennifer L. Holland, R. Abraham Runkel, Sara C. Ringler, Todd D. | | | | 5d. PROJECT NUMBER CRP 2265 | |
| | | | | 5e. TASK NUMBER | |
| | | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses Systems and Analyses Center 4850 Mark Center Drive Alexandria, VA 22311-1882 | | | | 8. PERFORMING ORGANIZATION REPORT NUMBER IDA Document NS D-32882 | |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Institute for Defense Analyses Systems and Analyses Center 4850 Mark Center Drive Alexandria, VA 22311-1882 | | | | 10. SPONSOR/MONITOR'S ACRONYM(S) IDA | |
| | | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited (12 November 2021). | | | | | |
| 13. SUPPLEMENTARY NOTES | | | | | |
| 14. ABSTRACT The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) Resource Conservation and Resiliency program area has supported a broad portfolio of infrastructure-focused research intended to help maximize the number of available training days and mission readiness. This analysis takes the first steps at connecting installation-level climatic risks and the other critical input into mission readiness: our people. Over time, we believe this approach can help further SERDP-ESTCP's mission by supporting more efficient and integrated identification of investments that yield the largest gains in available training days and readiness. In 2019, the Institute for Defense Analyses began developing an internally funded interdisciplinary climate security capability within its cadre of research personnel. One of the first results of this effort is a demonstration analysis mapping global changes in an estimated Wet Bulb Globe Temperature (WBGT) Index derived from the most recent ensemble of Community Earth System Models to a publicly available dataset of the DoD's current installation infrastructure. We then estimate the anticipated activity limitations for personnel expected to wear body armor on these installations using common work/rest restriction policies. We find that several global regions, as well as important military training installations, are likely to experience increased WBGT levels that could impose meaningful operational limitations. For commanders seeking to avoid these limitations, innovating new cooling technologies and infrastructure, inventing operational concepts that lower the expected physical strain on body armored servicemembers, reducing operational limitations by removing body armor, or simply accepting operational gaps created by these changes may be their only options. | | | | | |
| 15. SUBJECT TERMS changing climate; Climate Change; climate change assessments; Climate Security; extreme weather; Heat and Humidity; Military Installations; military training; Wet Bulb Globe Temperature (WBGT) | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT Uncl. | b. ABSTRACT Uncl. | c. THIS PAGE Uncl. | | | Buckley, Leonard J. |
| | | | SAR | 10 | 19b. TELEPHONE NUMBER (include area code) (703) 578-2800 |