Vision: Workshop will formulate recommendations, conclusions, in the CPSICC Nexus and foster partnerships among experts from different nations. By the end of the workshop, we will identify R&D gaps within this nexus and set an agenda for filling these gaps.

https://cpsiccnexusworkshop2024.org/

Monday	Tuesday	Wednesday	Thursday	Next Steps
• Introductory Remarks • Introduction to 'serious games' • Future Scenarios • Plenary Talks	• Talks on Nexus components and their interactions • More on games • Mixer and lightning talks	▪ Detailed Scenarios ▪ Gameplay in 2030 ▪ Synthesis and iteration ▪ Short talks, banquet and 'Ted' talks	▪ Jump to 2050 for scenarios and gameplay ▪ SWOT analysis and identification of R&D gaps and strategies for filling them	▪ Workshop summary report ▪ Summarize and synthesize in white paper (NATO) ▪ Option for NATO Workshop Book ▪ Option for special journal issue or broad interest perspectives pieces ▪ Website dissemination

We have many scientific and research subject matter expert and support staff to help. Feel free to reach out to them

An exhortation to action at the CPSICC Nexus—A case study from heat stress

Matthew Huber
David E. Ross Director of the Institute for a Sustainable Future
Purdue University

July 30, 2024

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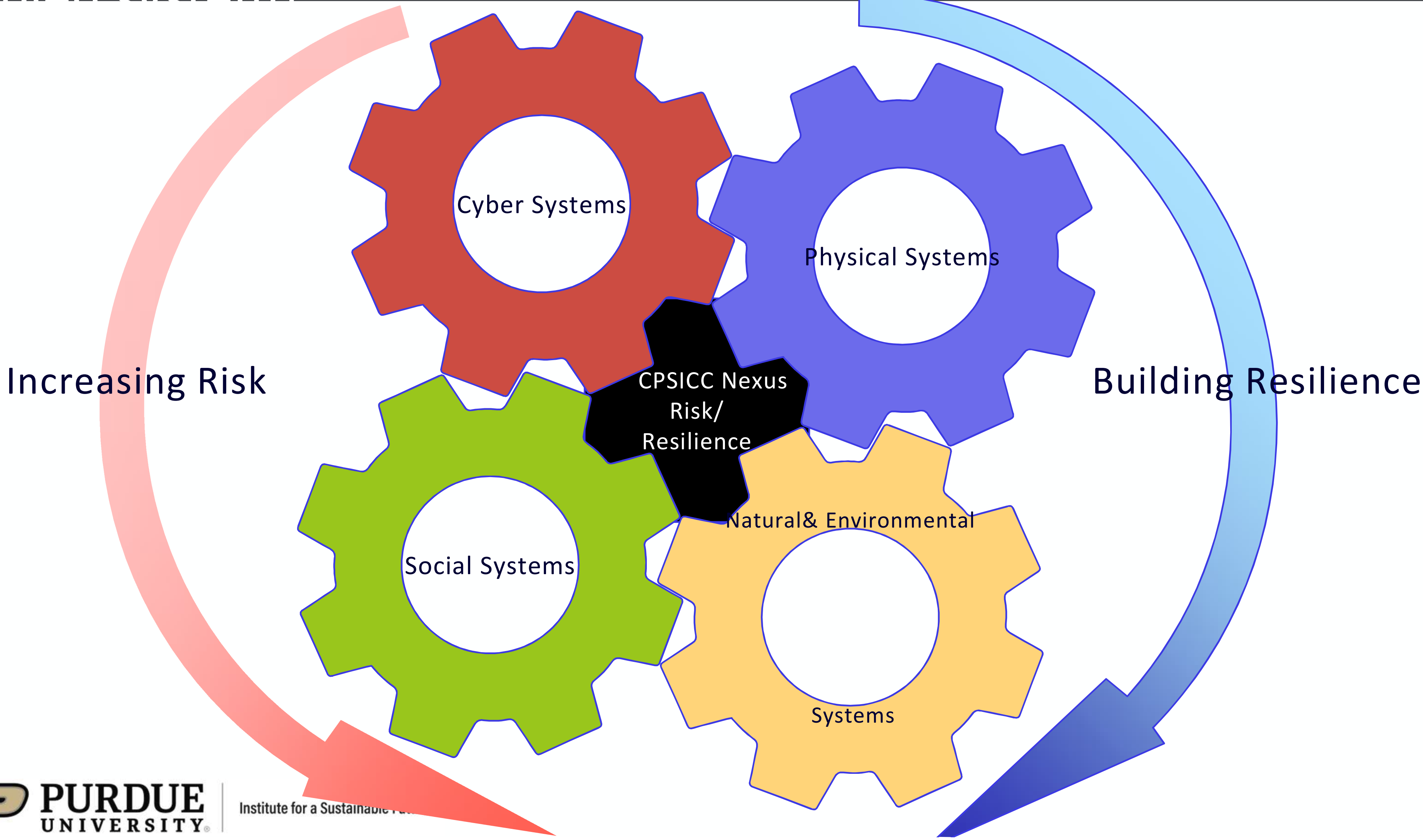
What interactions and controls remain to be identified for the coupled system?



A hotter world kills people

Revealed: 6,500 migrant workers have died in Qatar since World Cup awarded

Guardian analysis indicates shocking figure over the past decade likely to be an underestimate

- **What we know about the human cost of the 2022 World Cup**

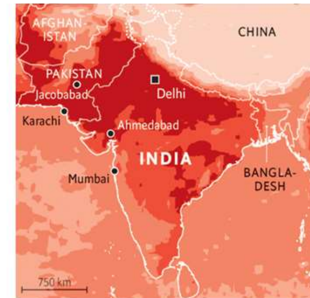
Latha Bollapally, with her son Rajesh Goud, holds a picture of her husband, Madhu Bollapally, 43, a migrant worker who died in Qatar. Photograph: Kailash Nirmal

The Guardian, 2021

Asia | Wet bulb hot

India's deadly heatwaves are getting even hotter

The consequences of climate change will be horrific for the Indo-Gangetic



Maximum "feels-like" temperature*, 1980-2021, °C 26 32 38 46 50

*Universal thermal climate index, describing the physiological comfort of the environment, based on temperature, wind, humidity and radiation Sources: Copernicus; European Commission

The Economist

Apr 2nd 2023 | DELHI AND JACOBABAD

Share

IN THE OPENING scenes of "The Ministry for the Future", the American novelist Kim Stanley Robinson imagines what happens to a small Indian town hit by a heatwave. Streets empty as normal activity becomes impossible. Air-conditioned rooms fill with silent fugitives from the heat. Rooftops are littered with the corpses of people sleeping outside in search of a non-existent breath of wind. The electricity grid, then law and order, break down. Like a medieval vision of hell, the local lake fills with half-poached bodies. Across north India, 20m die in a week.

https://www.economist.com/asia/2023/04/02/global-warming-is-killing-indians-and-pakistanis?frsc=dg|e

The Deadly Combination of Heat and Humidity

By ROBERT KOPP, JONATHAN BUZAN and MATTHEW HUBER
JUNE 6, 2015

THE most deadly weather-related disasters aren't necessarily caused by floods, droughts or hurricanes. They can be caused by heat waves, like the sweltering blanket that's taken over 2,500 lives in India in recent weeks.

Temperatures broke 118 degrees in parts of the country. The death toll is still being tallied, and many heat-related deaths will be recognized only after the fact. Yet it's already the deadliest heat wave to hit India since at least 1998 and, by some accounts, the fourth- or fifth-deadliest worldwide since 1900.

These heat waves will only become more common as the planet continues to warm.

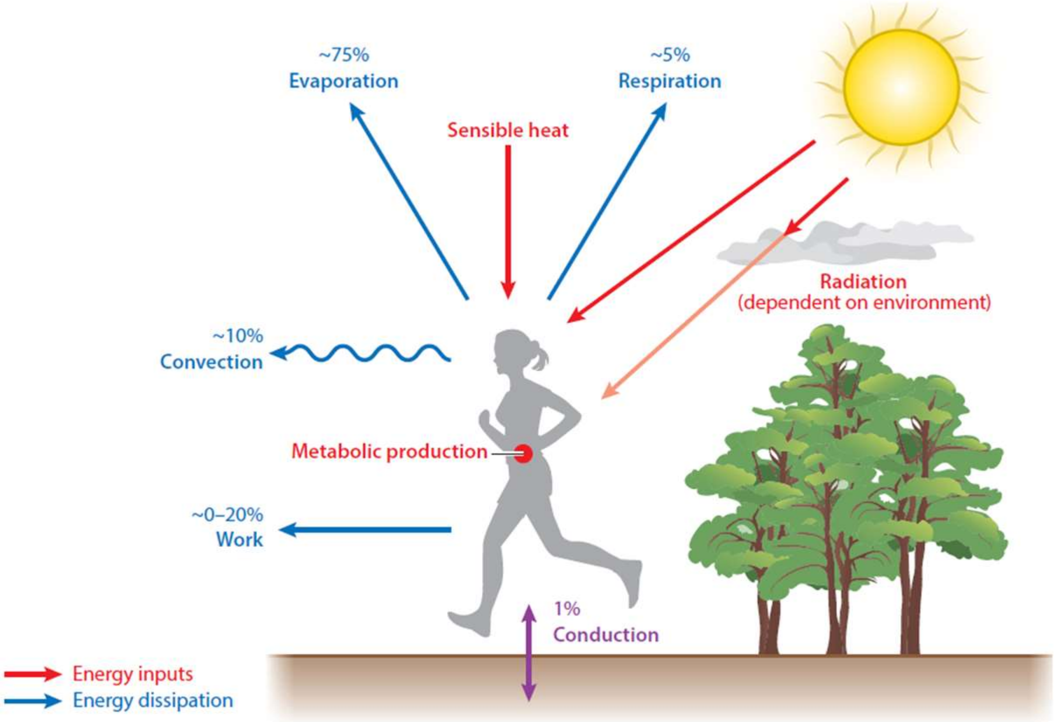
They don't just affect tropical, developing countries; they're a threat throughout the world. The July 1995 heat wave in the Midwest caused over 700 deaths in Chicago. The August 2003 heat wave in western Europe led to about 45,000 deaths. The July-August 2010 heat wave in western Russia killed about 54,000 people.

But as anyone who's spent a summer in the eastern United States knows, it's not just the heat; it's also the humidity. Together, they can be lethal, even if the heat doesn't seem quite so extreme.

New York Times SundayReview | OPINION

Heat stress arises when humans cannot dissipate internally generated energy

This arises under:
- **High temperatures**
- **Humid conditions**
- **High solar radiation**
- **Manual labor**



Buzan and Huber, *Annual Review of Earth and Planetary Sciences*, 2020

Haldane 1905

THE INFLUENCE OF HIGH AIR TEMPERATURES.
No. I.

By J. S. HALDANE, M.D., F.R.S.,
Fellow of New College and University Lecturer in Physiology, Oxford.

The aim of the following investigations was to ascertain the limits within which men can continue to exist normally, and to work, when the air temperature is abnormally high: also to study the abnormal phenomena which are produced when these limits are exceeded.

The subject is one of wide interest, not only in connection with the effects of very warm weather or tropical climates, but also because there are many industrial occupations in which men or women have to work daily in very warm air. My attention was first drawn to the subject in connection with the conditions of work in mines and in the cotton and flax textile industries. There are, however, many other occupations, such as work in the stoke-holds and engine-rooms of steamers, in drawing the ovens used for firing pottery, in the drying of salt, etc., where men are exposed to high temperatures; and the effects of even ordinary warm summer weather in producing heat-stroke, especially among soldiers, are well known.

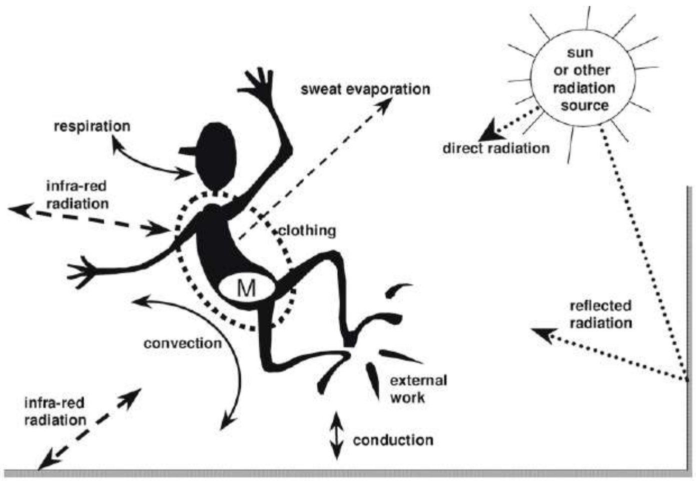
There are many observations showing that men can remain with impunity in temperatures considerably above the body temperature. In tropical countries, for instance, the shade temperature may, if the air be dry, rise to 120° F. (49° C.) without causing much inconvenience. The experiments made by Blagden and Forsyth and by Dobson in 1775[1] prove definitely that for short periods far higher air temperatures can be borne. These observers found that they could remain for a few minutes in a room at about 250° F. (121° C.) without serious inconvenience or marked rise of body temperature, although beef-steaks exposed in the room at the same time and place could be cooked within

- “The experiments made by Blagden and Forsyth and by Dobson in 1775 prove definitely that for short period far higher air temperatures [than 49°C] can be borne. These observers found that they could remain for a few minutes in a room at about 121C) without serious inconvenience…although beefsteaks in the room at the time and place could be cooked within 13 minutes.”

- “The bearing of these experiments on the question as to the rise in temperature allowable on economic or humanitarian grounds in places where persons have to work continuously will be sufficiently evident.”

- “It is clear that in still and warm air what matters to the persons present is neither the temperature of the air, nor its relative saturation, nor the absolute percentage of aqueous vapour present, **but the temperature shown by the wet-bulb thermometer**. “

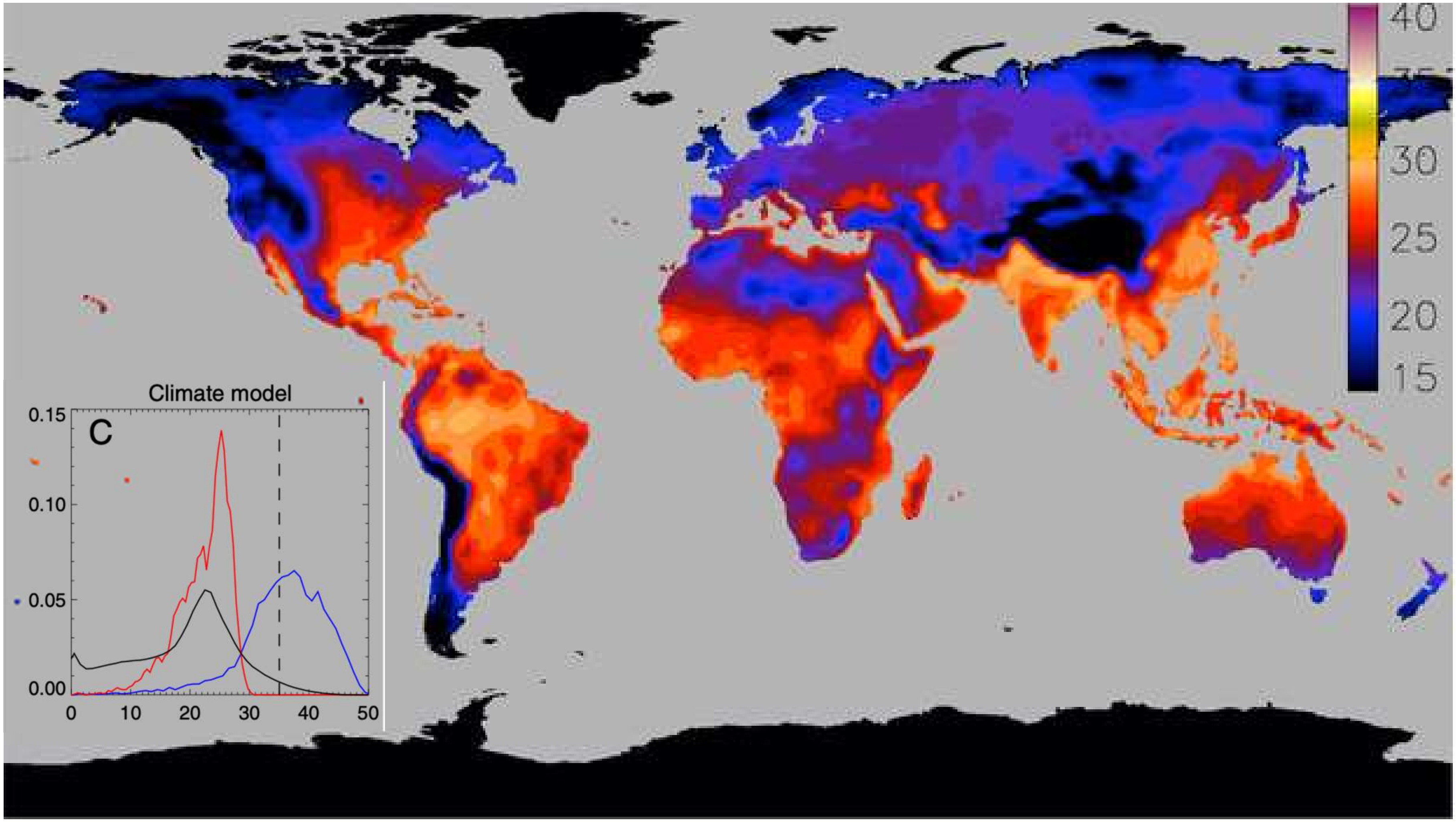
- “If this exceeds a certain point (about 78° F. or 25.5° C.) continuous hard work becomes impracticable; and beyond about 88° F. or 31° C. it becomes impracticable for ordinary persons even to stay for long periods in such air.”



Schematic representation of the pathways for heat loss from the body. M = metabolic heat production (reproduced with permission, Havenith, 1999)

Human Energy Balance

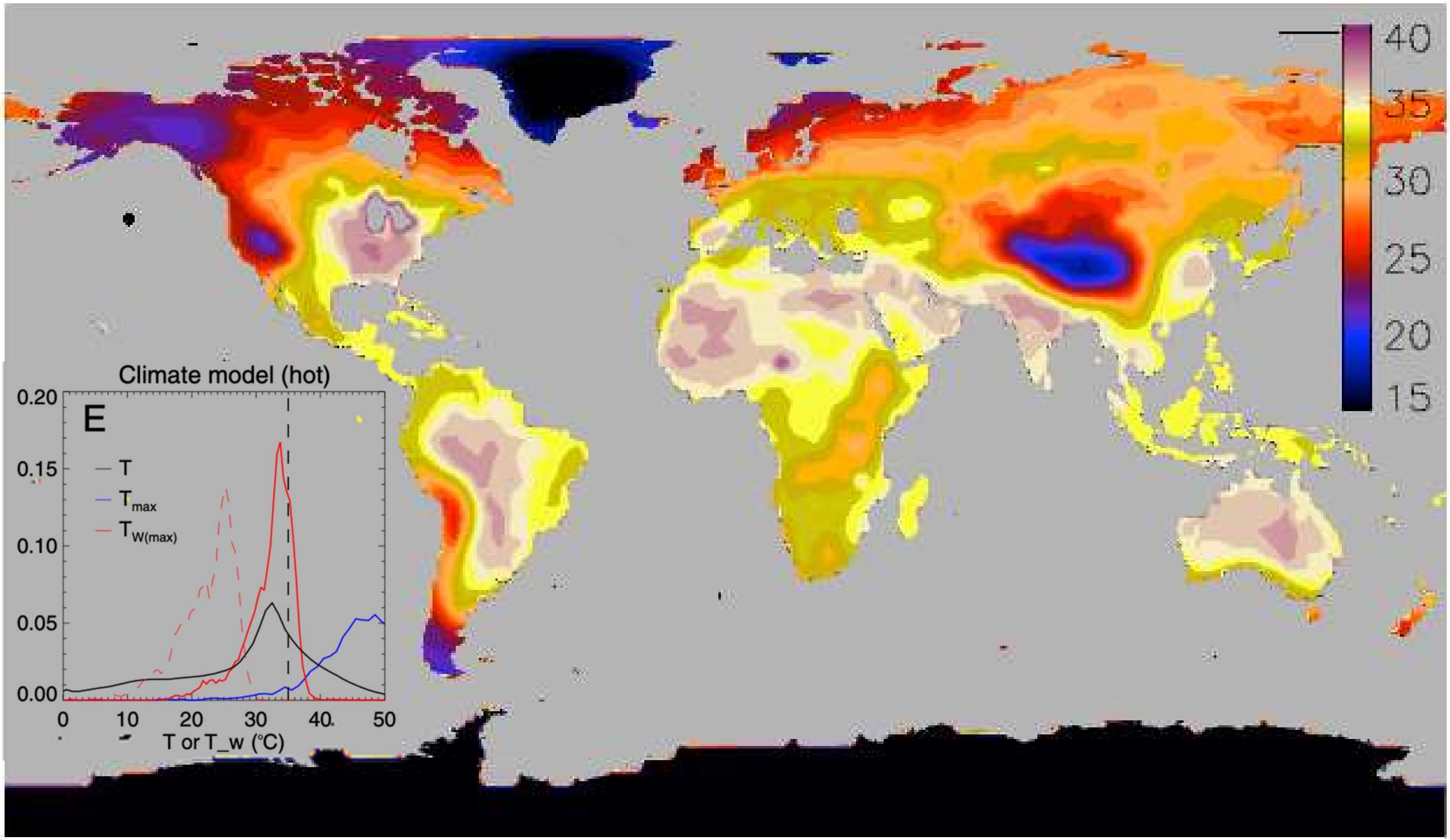
- A resting human body generates ~100 W of metabolic heat which (in addition to any absorbed solar heating) must be carried away via a combination of heat conduction, evaporative cooling, and net infrared radiative cooling. Conductive cooling is inhibited by high temperature, and evaporation by high relative humidity.
- Net (latent+sensible) cooling can occur only if an object is warmer than the environmental wet-bulb temperature T_W, measured by covering a standard thermometer bulb with a wetted cloth and fully ventilating it.
- The second law of thermodynamics does not allow an object to lose heat to an environment whose TW exceeds the object's temperature, no matter how wet or well-ventilated.



Modern maximum wetbulb temperature

Sherwood and Huber, 2010

(A) Histograms of 2-meter T (Black), T_{max} (Blue), and Tw_{max} (Red) on land from 60S–60N during the last decade (1999–2008). "Max" histograms are annual maxima accumulated over location and year, while the T histogram is accumulated over location and reanalysis time. Data are from the ERA-Interim reanalysis 4xdaily product. C and E: same but from modern climate simulation and simulation with 10x pre-industrial carbon dioxide concentration.



Future maximum wetbulb temperature

Sherwood and Huber, 2010

(A) Histograms of 2-meter T (Black), T_{max} (Blue), and Tw_{max} (Red) on land from 60S–60N during the last decade (1999–2008). “Max” histograms are annual maxima accumulated over location and year, while the T histogram is accumulated over location and reanalysis time. Data are from the ERA-Interim reanalysis 4xdaily product. C and E: same but from modern climate simulation and simulation with 10x pre-industrial carbon dioxide concentration.

Empirical Evidence for lower Wet-bulb limits

Hot hours definition: Tw thresholds conditional on Tdb

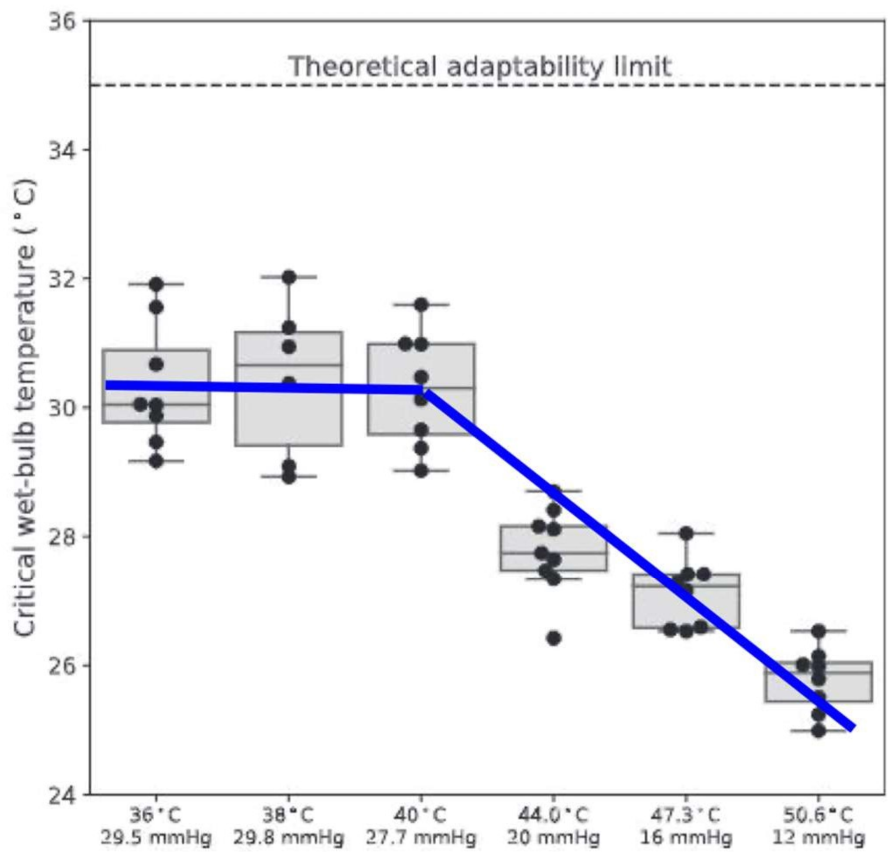
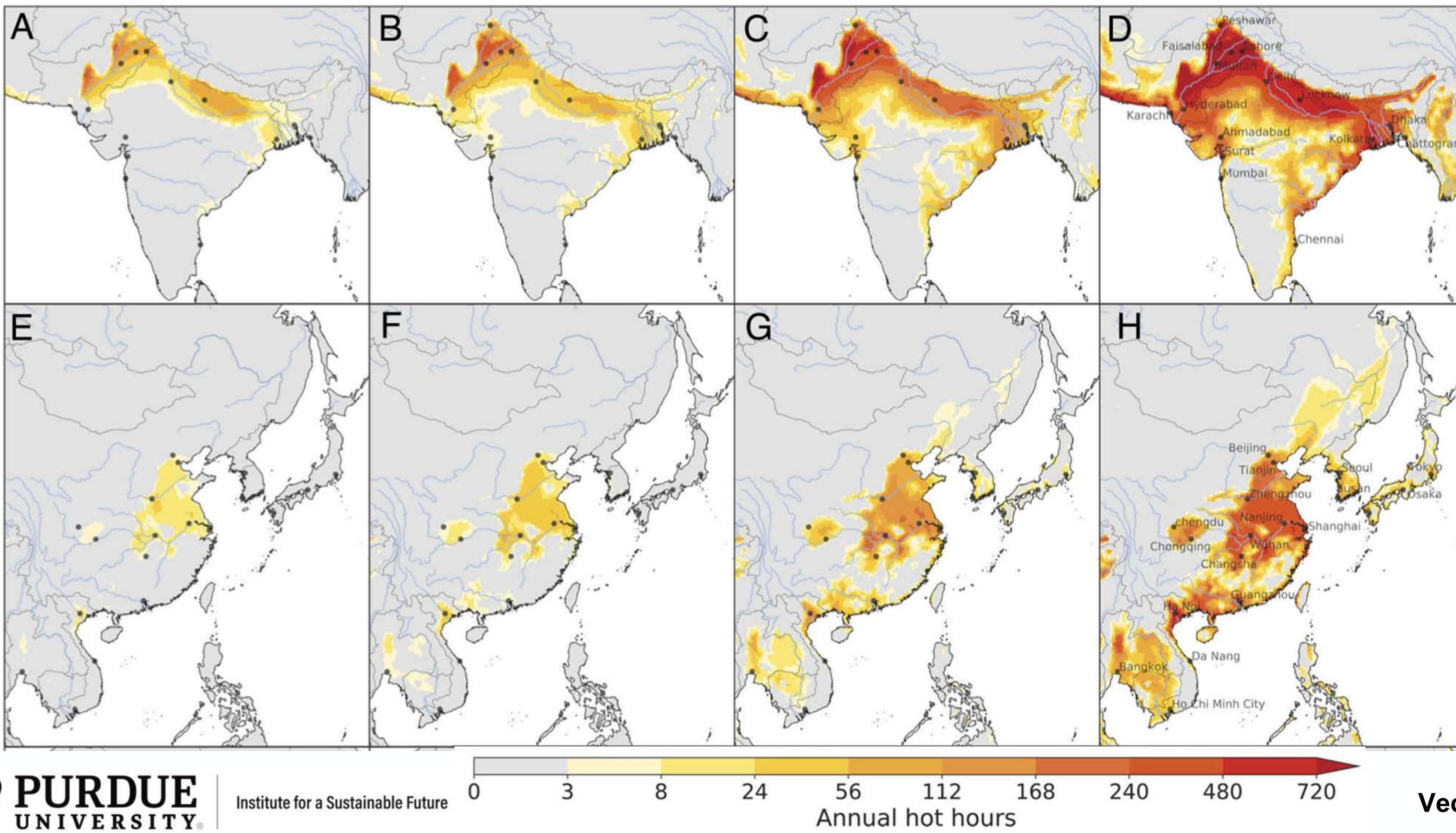


Figure 1. Critical wet-bulb temperature values for the study's six experimental protocols.

Based on Vecellio et al., 2022

Annualized hours over threshold wet-bulb

+1.5°C | +2°C | +3°C | +4°C



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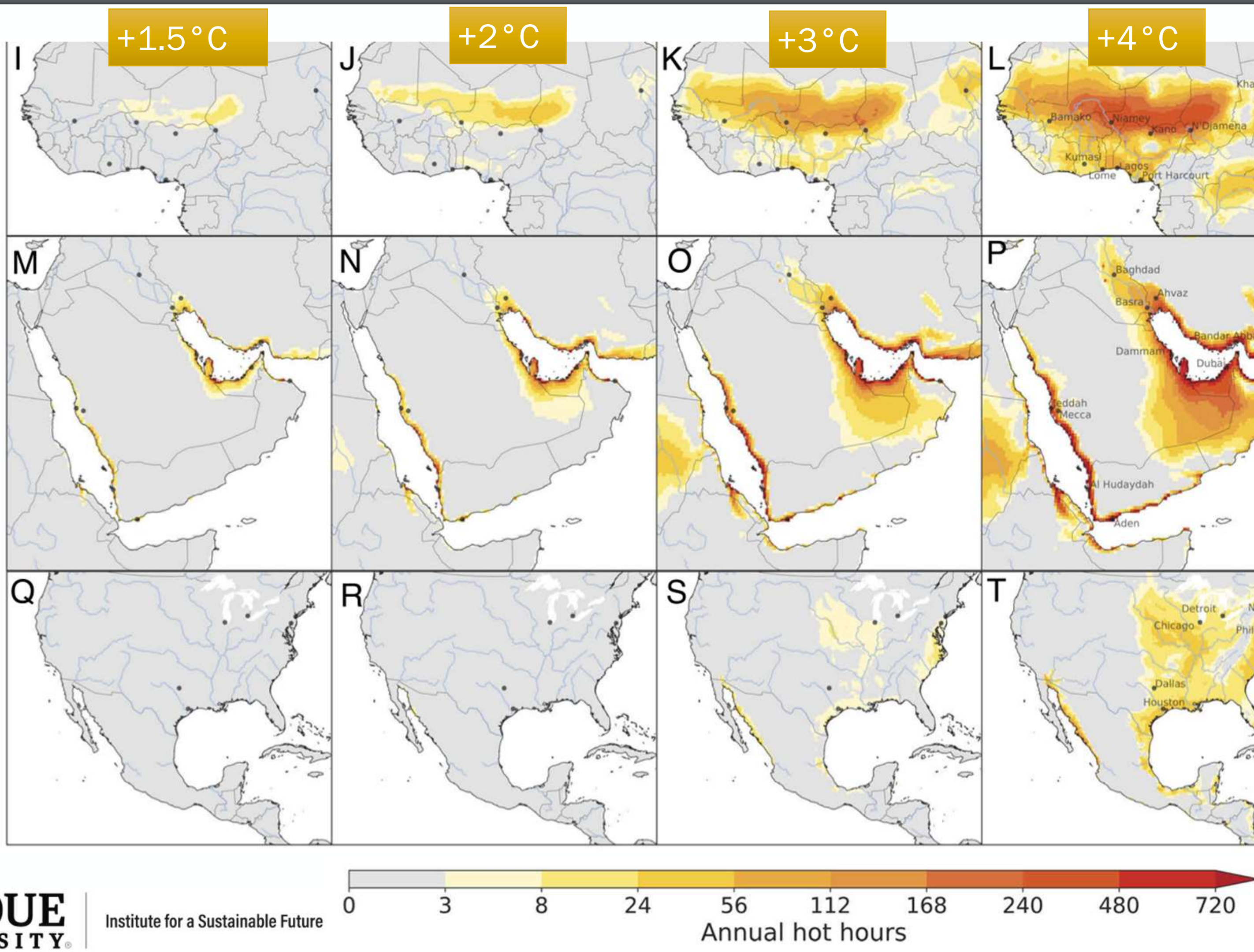
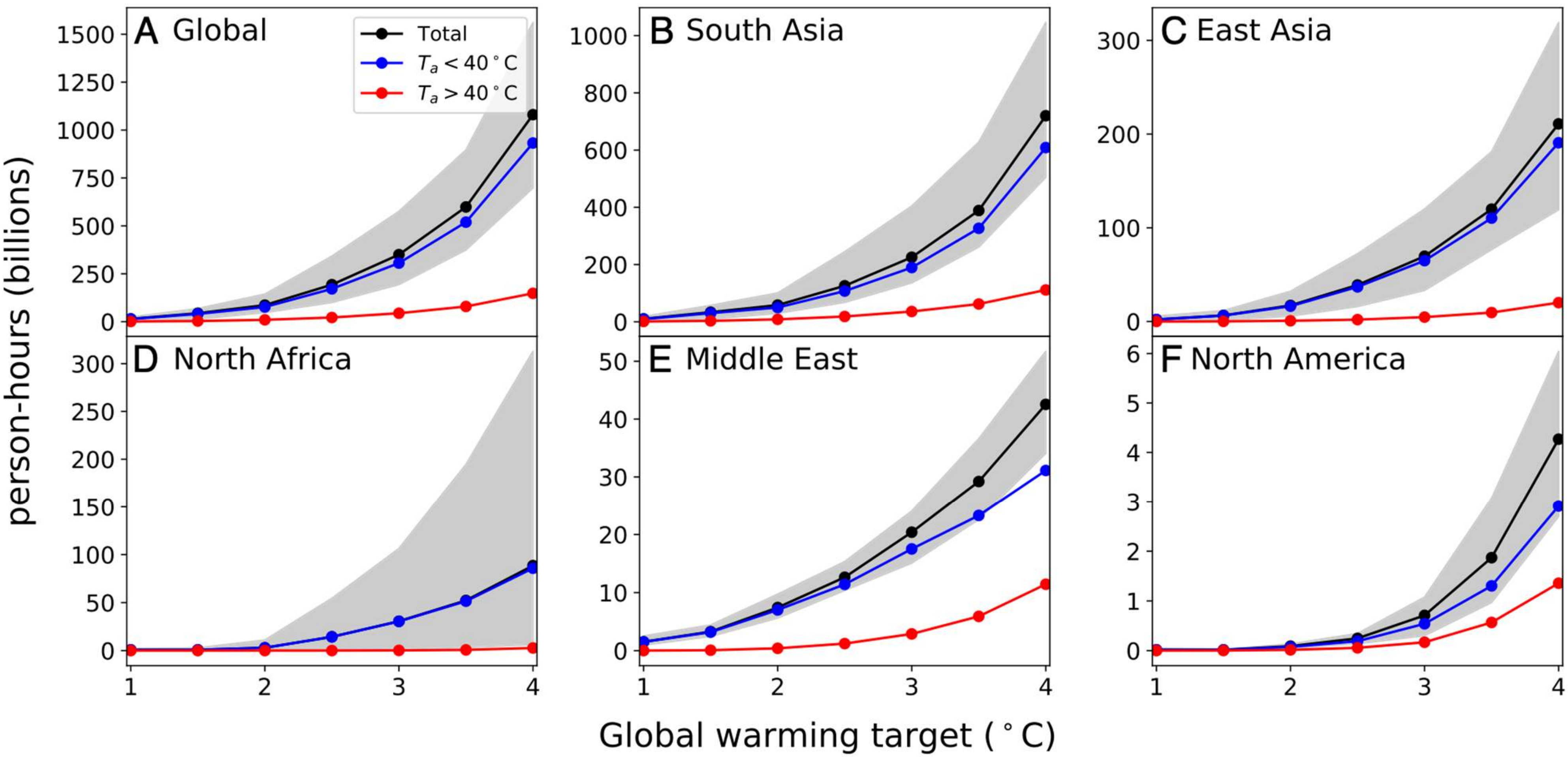
Vecellio et al., 2023

Annualized hours over threshold wet-bulb



Vecellio et al., 2023

Person-hours lost per year



Vecellio et al., 2023

Institute for a Sustainable Future

Irrigation can worsen heat stress

ARTICLES
https://doi.org/10.1038/s41561-020-00650-8
nature geoscience

Moist heat stress extremes in India enhanced by irrigation

Vimal Mishra[1,2], Anukesh Krishnankutty Ambika[2], Akarsh Asoka[2], Saran Aadhar[1], Jonathan Buzan[3], Rohini Kumar[4] and Matthew Huber[3]

Impact of Irrigation

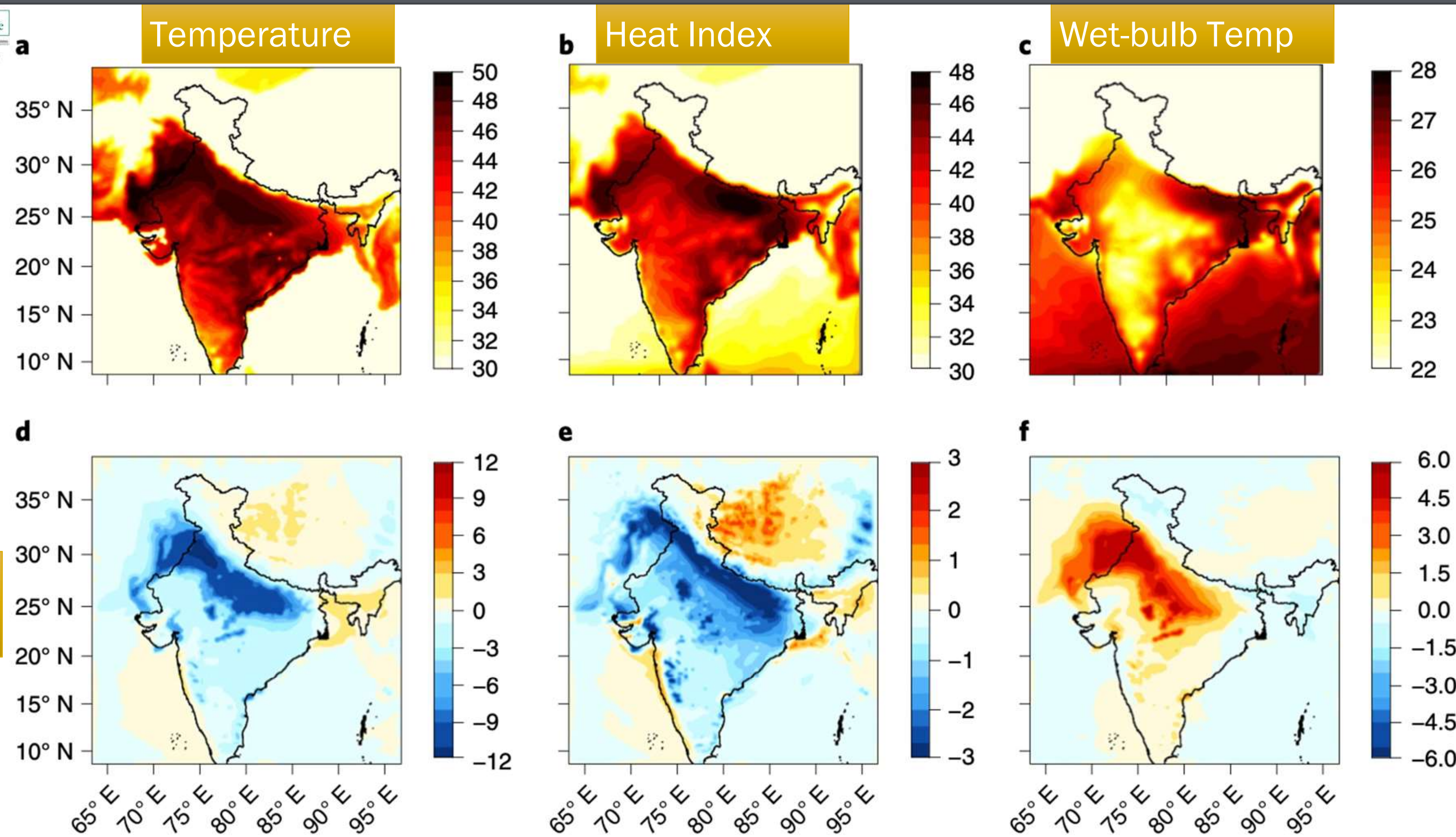


Fig. 4 | Influence of irrigation on dry and moist heat stress in India. a–c, 95th percentile of T_2 (°C) (**a**), HI (°C) (**b**) and T_W (°C) (**c**) for the summer (April–May) during 2000–2018 under the no-irrigation scenario. **d–f**, Difference (irrigation – no irrigation) in the 95th percentile of T_2 (°C) (**d**), HI (°C) (**e**) and T_W (°C) (**f**). Data for **a–f** are based on the WRF simulations with irrigation-on and irrigation-off scenarios for the 2000–2018 period.

What are the global impacts and local interactions?

GLOBAL HEAT WAVES ARE A PROPOSED SOCIETAL TIPPING POINT

HEAT STRESS REDUCES CAPACITY TO DO OUTDOOR LABOR

VALIDATED AND CALIBRATED MODEL

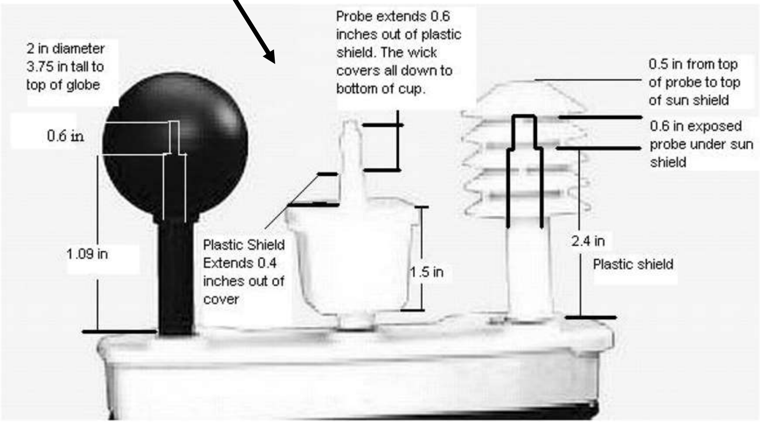
SECTOR-BY SECTOR ALLOWING FOR TRADE FLOWS, ENERGY FLOWS, POLICY INTERVENTIONS, AND INTERACTIONS BETWEEN ECONOMIES AND NATIONS

More sophisticated heat stress metrics

Wet Bulb Globe Temperature (WBGT) is used for assessing heat stress

WBGT factors in:

- **Temperature**
- **Humidity**
- **Wind speed**
- **Solar radiation**
- **Other radiation components**
- **Air pressure**



USARIEM (Natick Army Base)

Since we cannot conduct these experiments across the world, under future conditions, climate scientists run climate models and approximate these outcomes mathematically:

$$T_g^4 = \frac{1}{2}(1+\varepsilon_a)T_a^4 - \frac{h}{\varepsilon_g \sigma}(T_g - T_a) + \frac{S}{2\varepsilon_g \sigma}(1-\alpha_g)\left[1 + \left(\frac{1}{2\cos(\theta)} - 1\right) f_{dir} + \alpha_{sfc}\right]$$

Recent computational advances by our collaborators permit far more accurate approximations to WBGT

Building and Environment

Experimental study on physiological and psychological effects of heat acclimatization in extreme hot environments

Zhe Tian, Neng Zhu, Guozhong Zheng*, Huijiao Wei

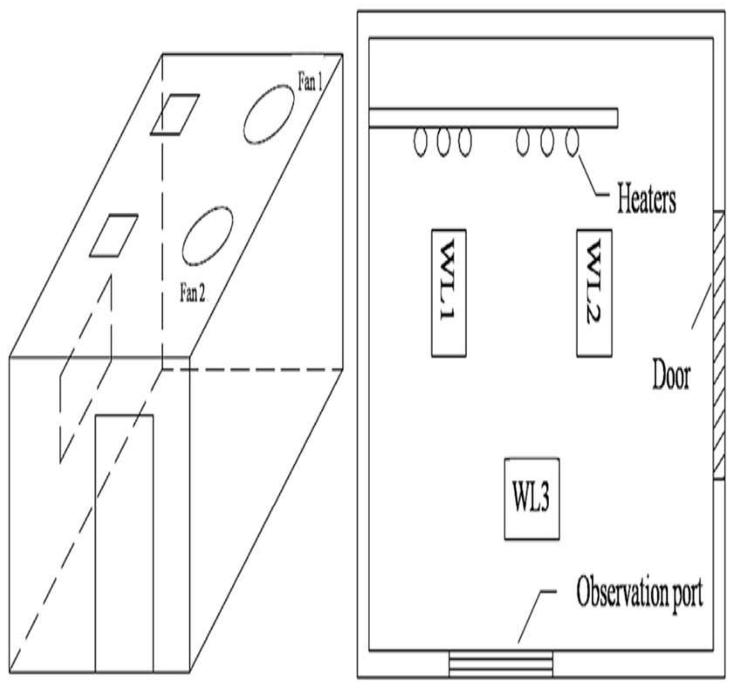


Fig. 1. The structure of this chamber and the arrangement of this experiment.

Building and Environment 46 (2011) 2033–2041

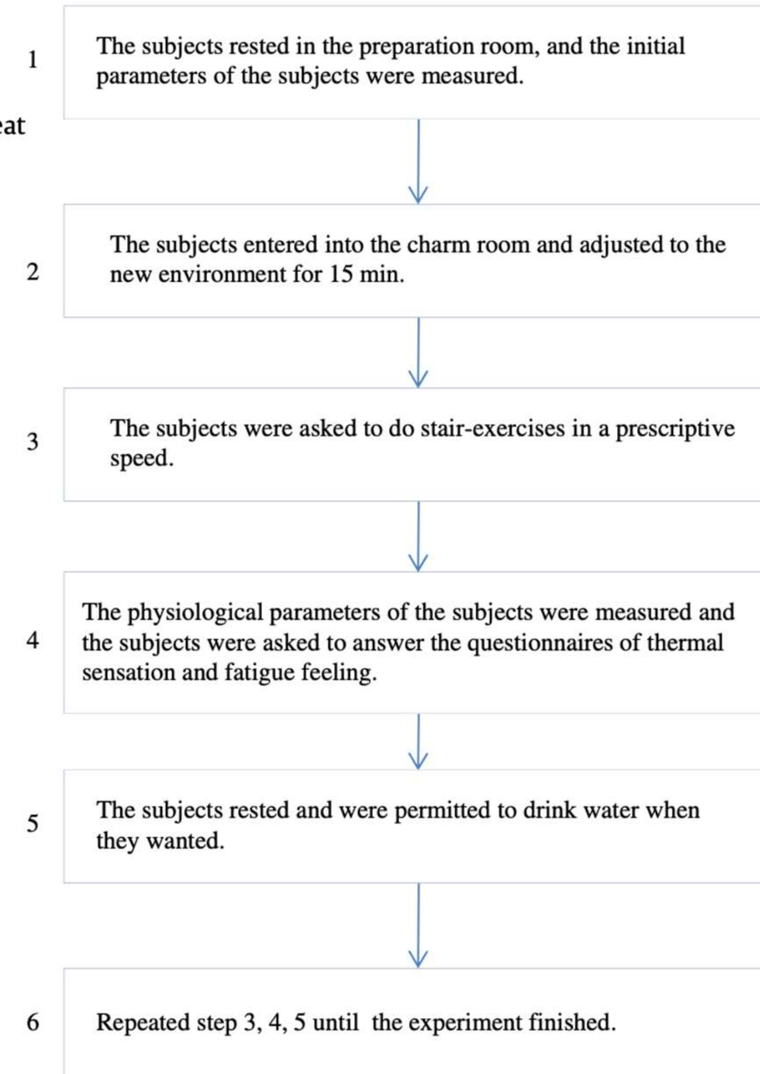


Fig. 2. Experiment process.

A new environmental heat stress index for indoor hot and humid environments based on Cox regression

Building and Environment 46 (2011) 2472–2479

Chuanzhi Liang, Guozhong Zheng, Neng Zhu, Zhe Tian*, Shilei Lu, Ying Chen

School of Environmental Science and Engineering, Tianjin University, Tianjin 300072, China

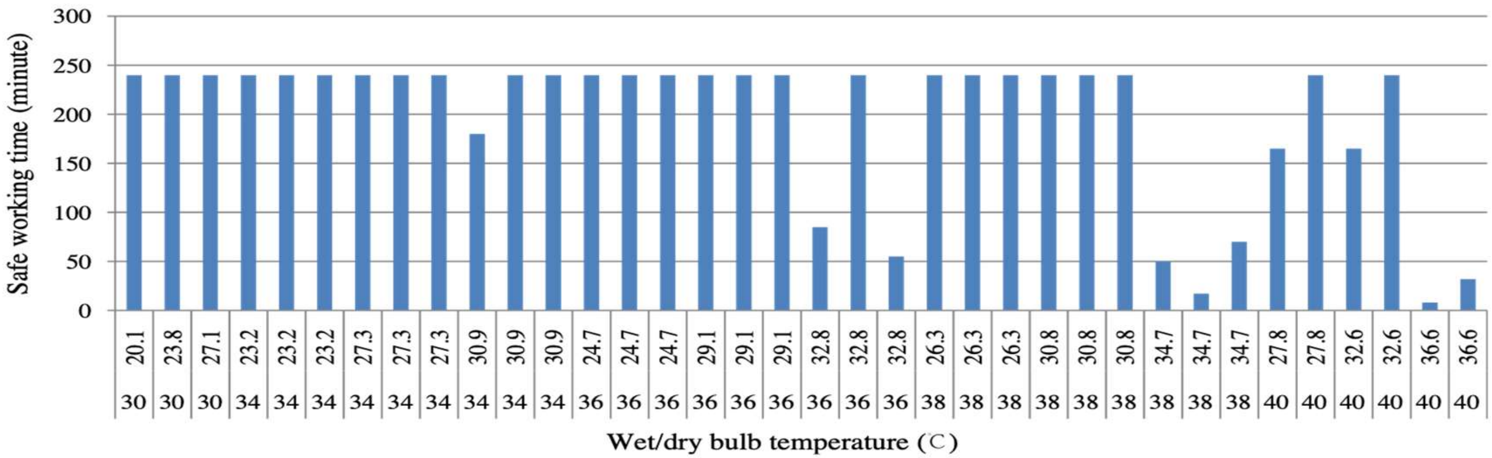


Fig. 3. The safe working time of light work in hot and humid environments.

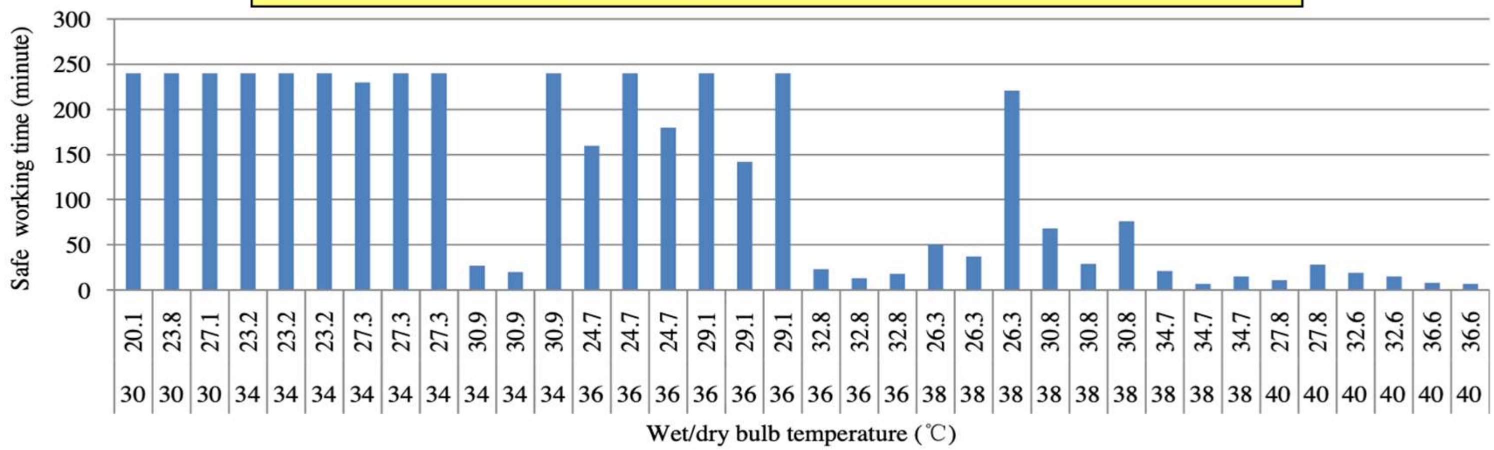
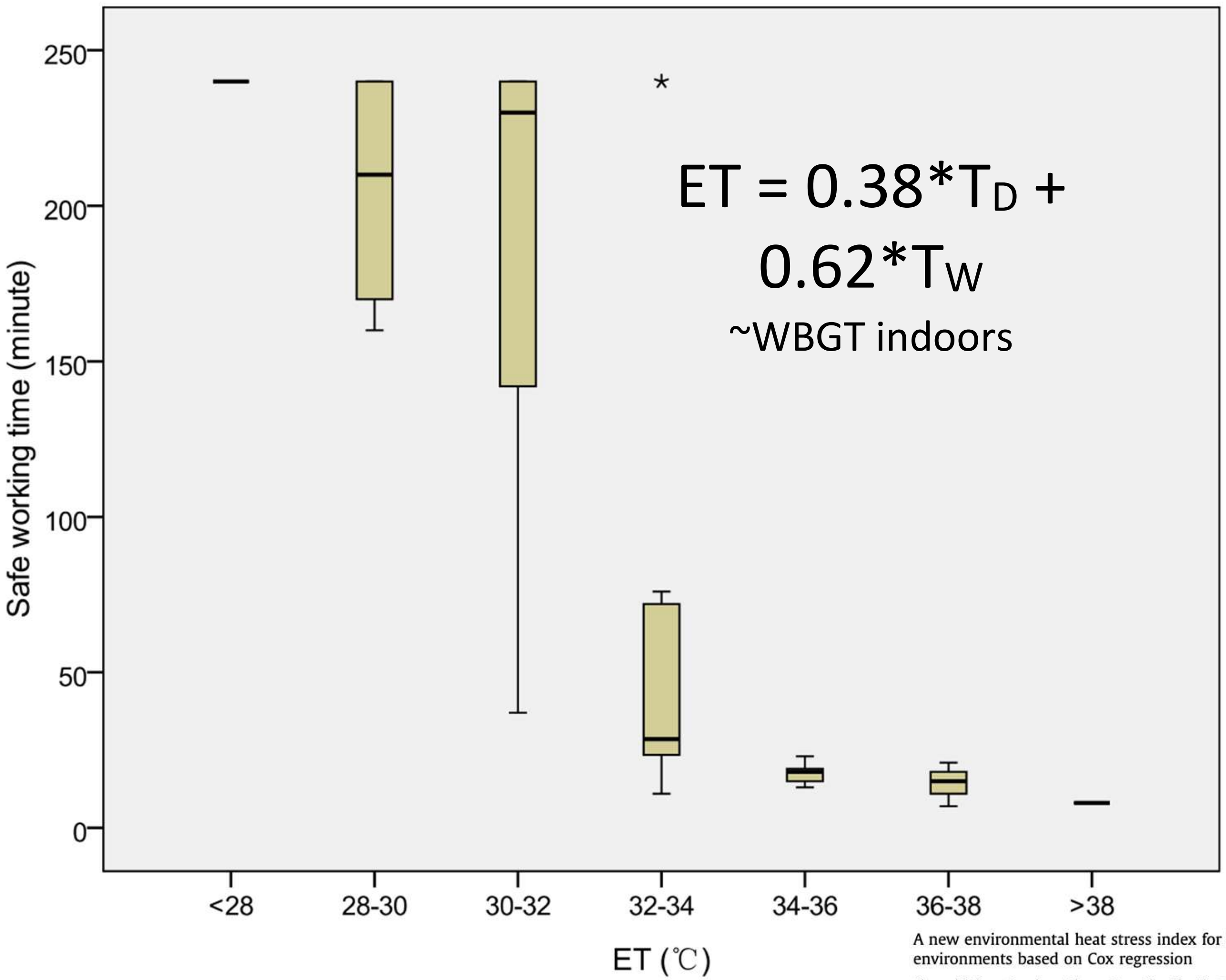


Fig. 1. The safe working time of heavy work in hot and humid environments.



A new environmental heat stress index for indoor hot and humid environments based on Cox regression

Chuanzhi Liang, Guozhong Zheng, Neng Zhu, Zhe Tian*, Shilei Lu, Ying Chen
School of Environmental Science and Engineering, Tianjin University, Tianjin 300072, China

Fig. 7. The boxplot of safe working time concerned with the ET (heavy work).

How ability to labor responds to WBGT

Heat stress causes labor productivity loss

- A body of scientific literature estimates this loss of productivity
  - Physiological methods; empirical methods
- We assess the economic implications of this loss of productivity:
  - We account for heterogeneity of labor types, their work intensity, and exposure to the sun within the same sector
  - Analysis at a disaggregated level: 65 sectors, 137 regions, 4 labor types
  - Also assess implications on poverty headcounts in a subset regions

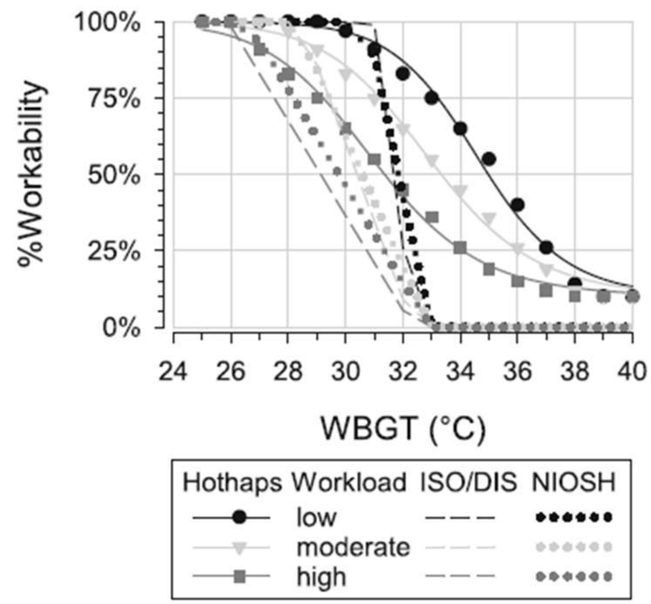
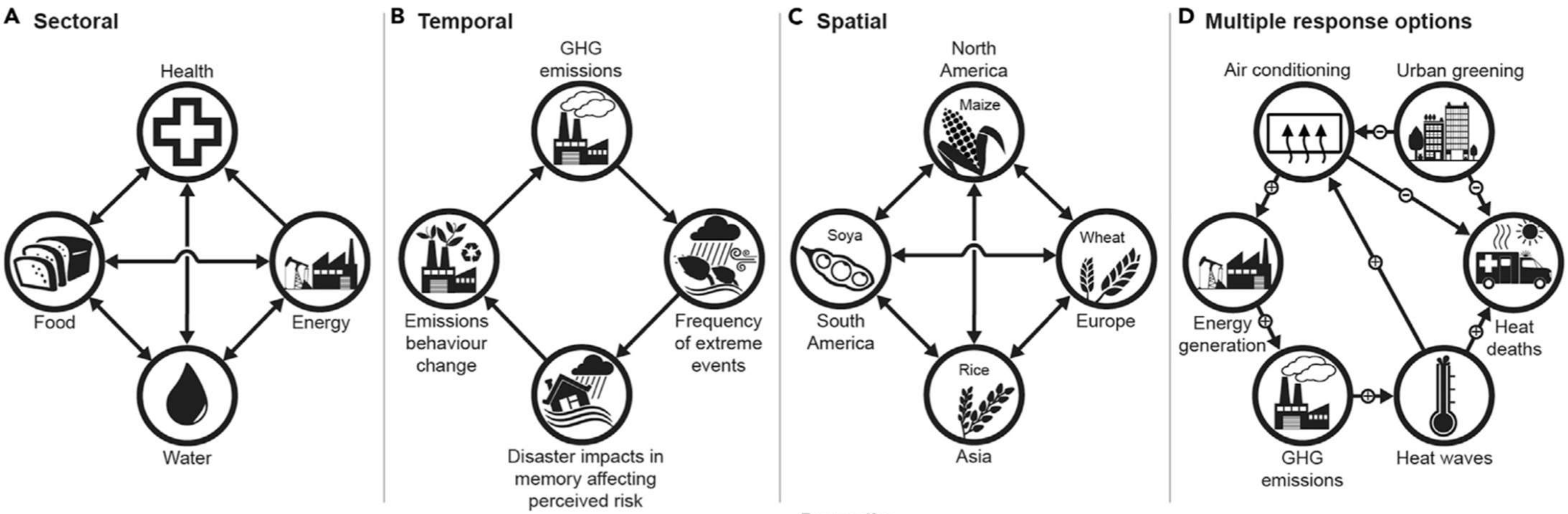


Fig. 2 Percentage workability determined by WBGT using limit values calculated according to ISO/DIS 7243 (2015) or NIOSH (Jacklitsch et al. 2016) or using the empirical relationship from Hothaps (Kjellstrom et al. 2014)

Risk and Resilience Feedback Networks

interactions can dampen or amplify risks



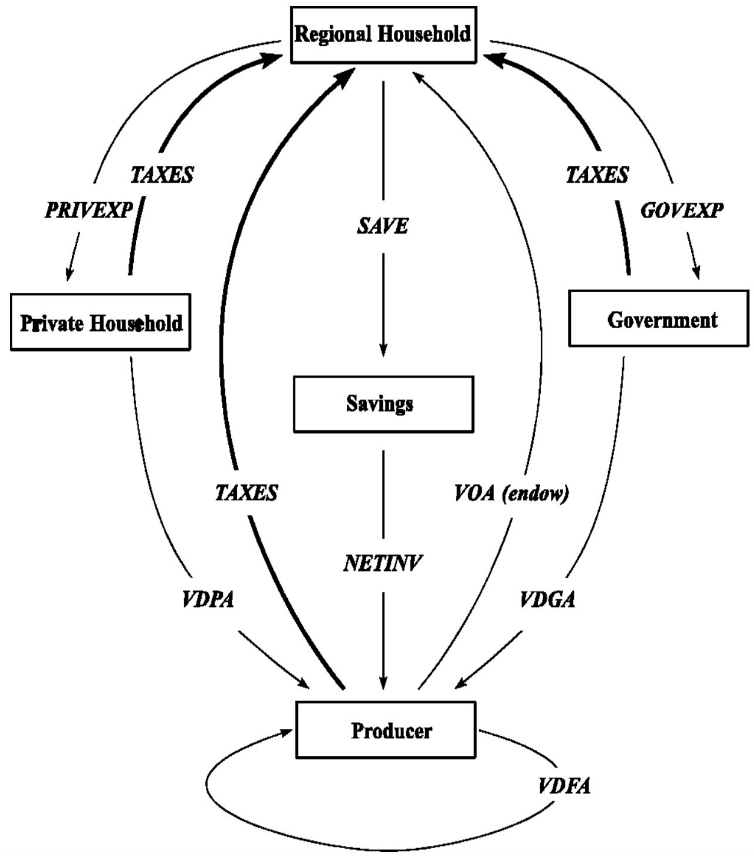
Perspective

A framework for complex climate change risk assessment

Nicholas P. Simpson,[1,*] Katharine J. Mach,[2] Andrew Constable,[3] Jeremy Hess,[4] Ryan Hogarth,[5] Mark Howden,[6] Judy Lawrence,[7] Robert J. Lempert,[8] Veruska Muccione,[9] Brendan Mackey,[10] Mark G. New,[1] Brian O'Neill,[11] Friederike Otto,[12] Hans-O. Pörtner,[13] Andy Reisinger,[6] Debra Roberts,[14] Daniela N. Schmidt,[15] Sonia Seneviratne,[16] Steven Strongin,[17] Maarten van Aalst,[18,19,20] Edmond Totin,[21] and Christopher H. Trisos[1,22,*]

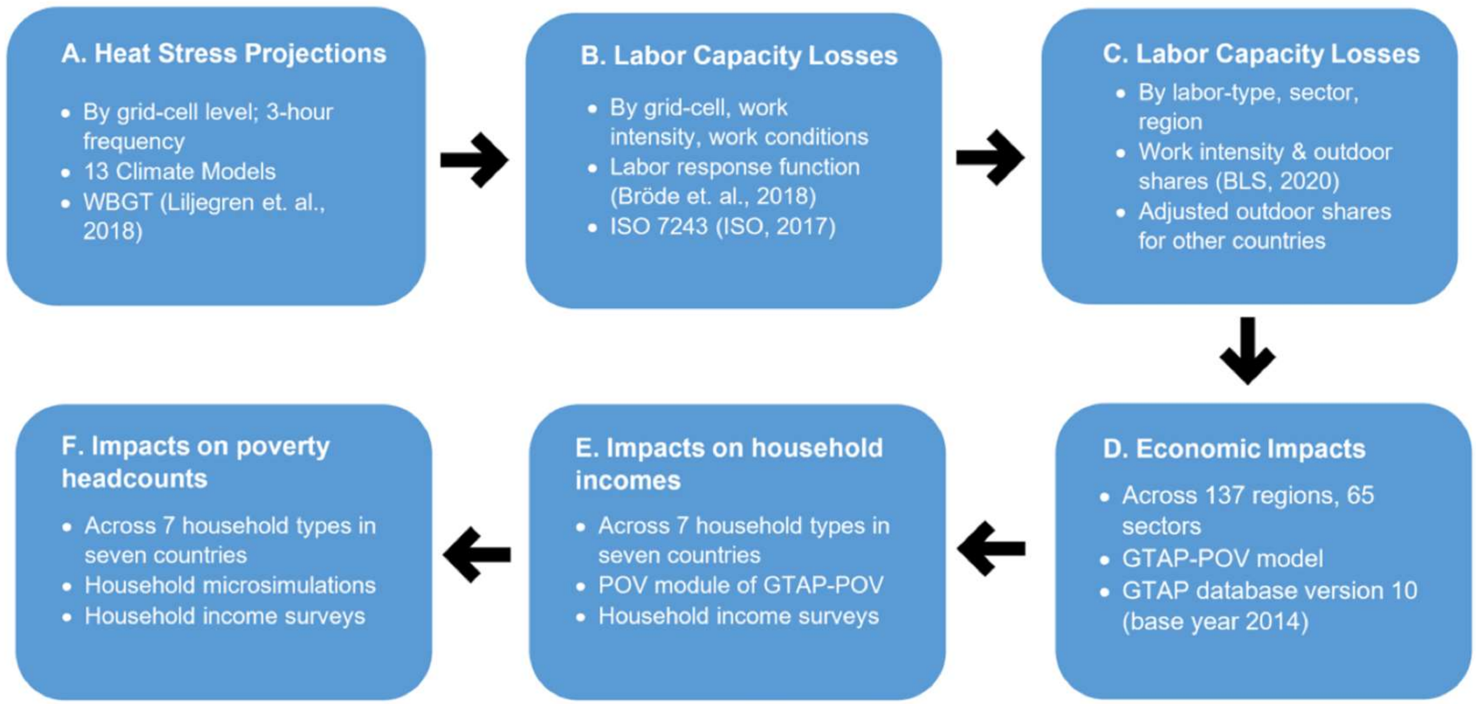
https://doi.org/10.1016/j.oneear.2021.03.005

Let Climate Shocks Interact within a Comprehensive Trade/Economic Model



- This effort utilizes GTAP (Global Trade Analysis Project) as its underlying framework
- Widely used global economic model
- Computable General Equilibrium Model written in GAMS which allows for explicit computation of factor decomposition and sensitivity to parameters/processes
- Highly validated against historical data
- Includes entire economy sectors; inter-sector linkages
- Can include migration
- Bilateral trade permits assessment of how geography of trade distributes economic impacts

Climate-Severe Weather-Agriculture- Economics-Poverty Linkage



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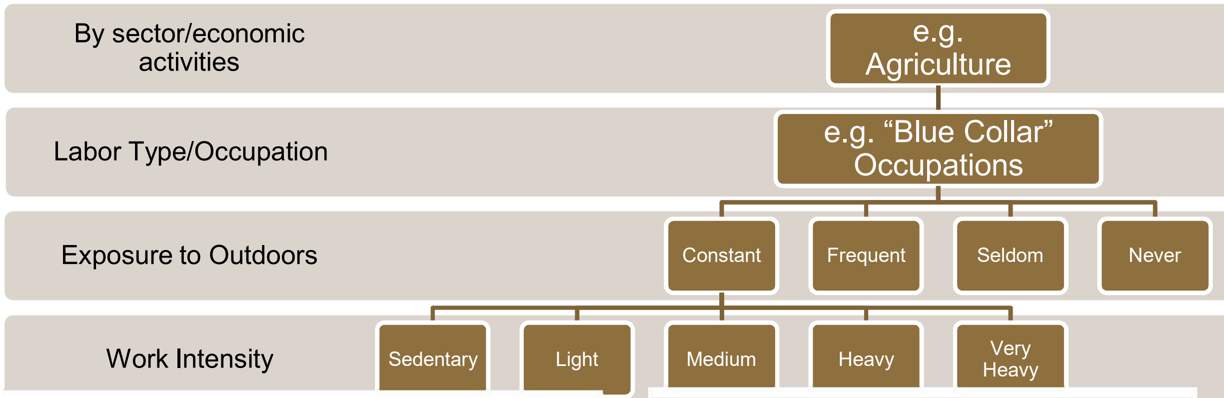
PURDUE UNIVERSITY GLASS Global to Local Analysis of Systems Sustainability

Detailed Sector by Sector and Country by Country Interactions



BLS Data

	BLS Economic activities
1	Agriculture and related
2	Mining, quarrying, and oil and gas extraction
3	Construction
4	Manufacturing
5	Wholesale and retail trade
6	Transportation and utilities
7	Information
8	Financial activities
9	Professional and business services
10	Education and health services
11	Leisure and hospitality
12	Other services
13	Public administration

BLS occupations	
Management Occupations	
Business & Financial Operations Occupations	"White Collar" workers
Office & Admin. Support Occupations	
Computer & Mathematical Occupations	
Architecture & Engineering Occupations	
Life, Physical, & Social Science Occupations	"Purple collar" – Technical and Professional Workers
Community & Social Service Occupations	
Education, Training, & Library Occupations	
Arts, Design, Entertainment, Sports, & Media	
Healthcare Practitioners & Technical Occupations	
Healthcare Support Occupations	
Protective Service Occupations	
Food Prep. and Serving Related Occupations	"Pink collar" – Service Workers
Building & Grounds; Cleaning & Maintenance	
Personal Care and Service Occupations	
Sales and Related Occupations	
Farming, Fishing, and Forestry Occupations	
Construction and Extraction Occupations	
Installation, Maintenance, & Repair Occupations	"Blue Collar" workers
Production Occupations	
Transportation and Material Moving Occupations	

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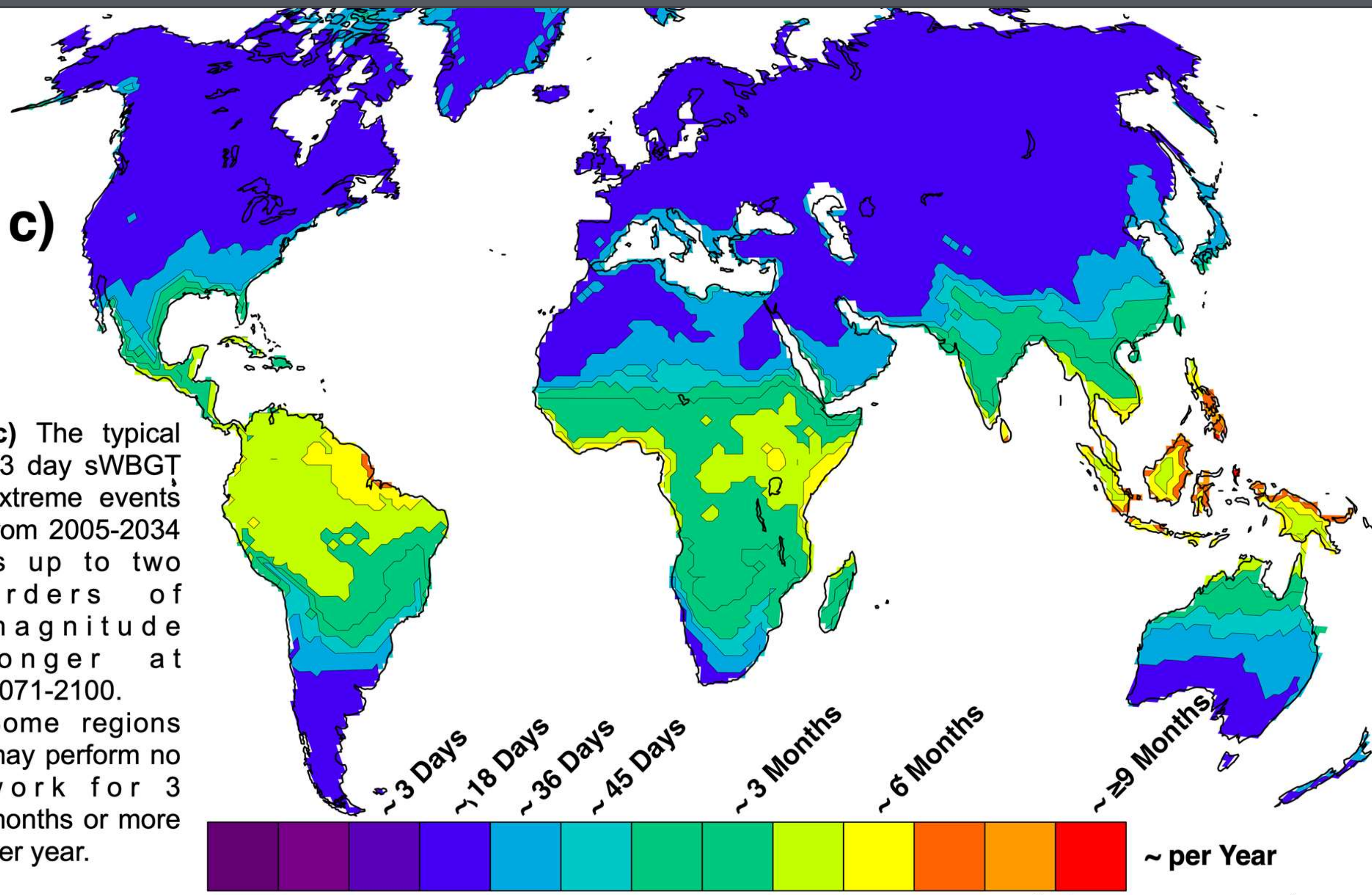
GLASS Global to Local Analysis of Systems Sustainability

Fraction of year in 2071-2100 as hot as highest 3 days recorded in 2020s



- **(c)** The typical ~3 day sWBGT extreme events from 2005-2034 is up to two orders of magnitude longer at 2071-2100.
- Some regions may perform no work for 3 months or more per year.

Agriculture accounts for largest share of losses

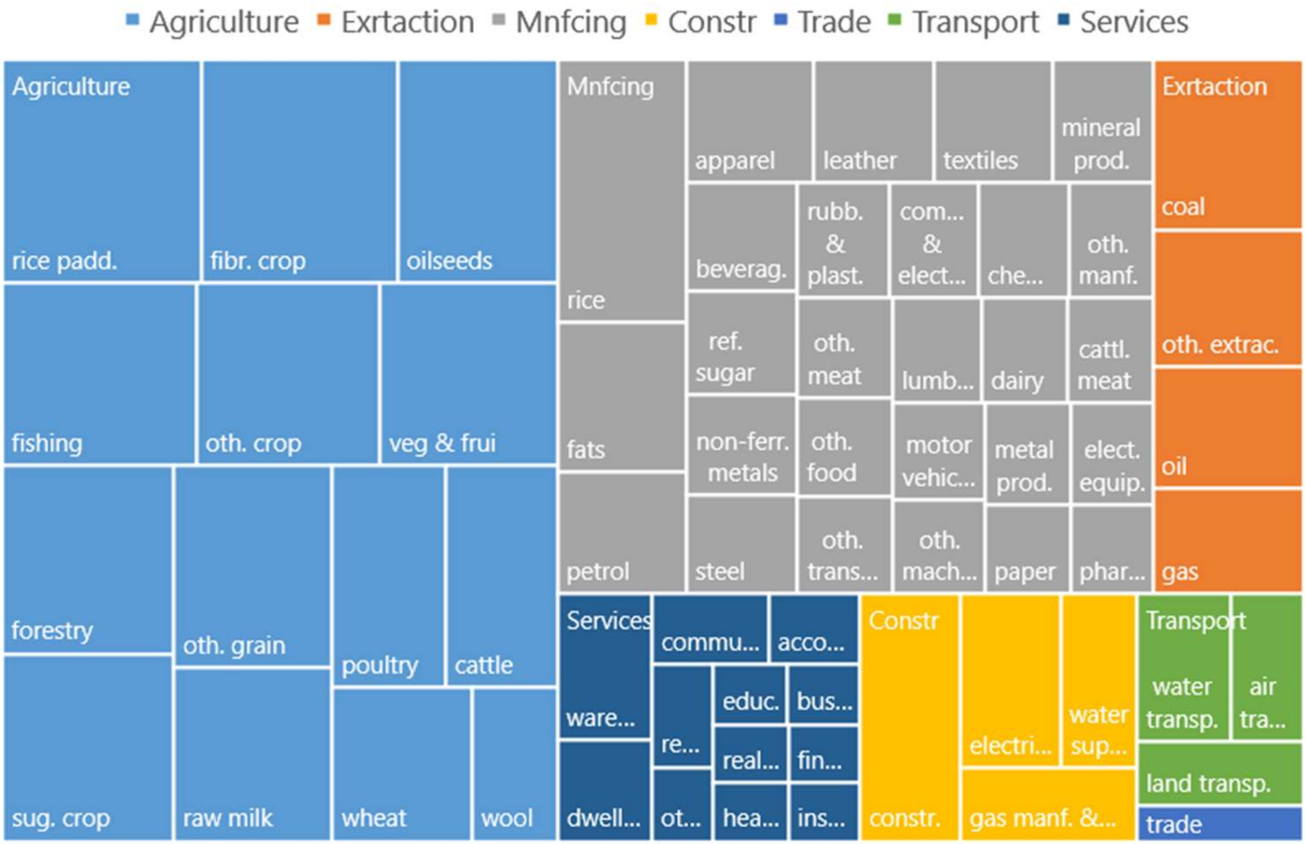
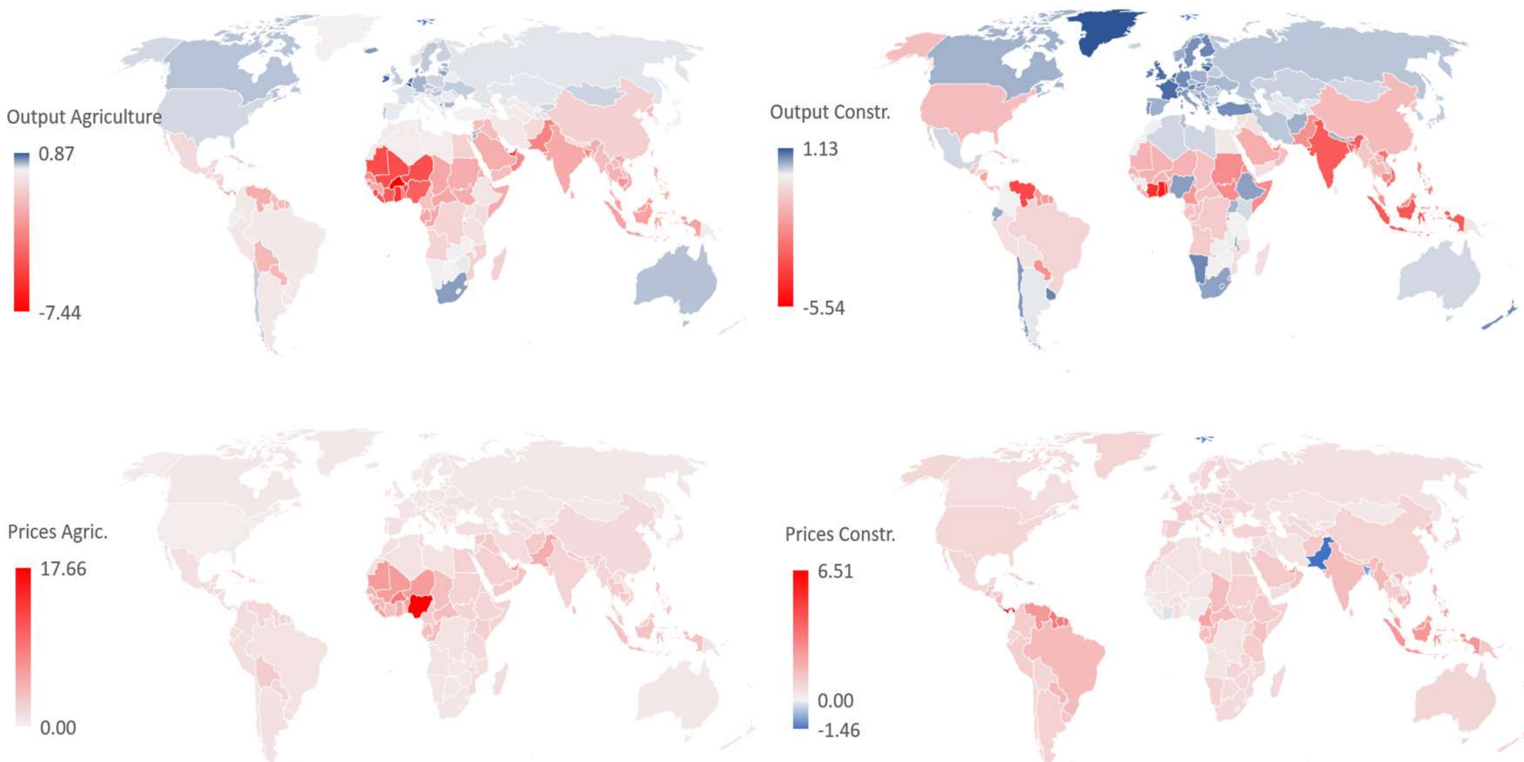


Figure shows loss of labor productivity by sector; box sizes reflect sizes of $ loss

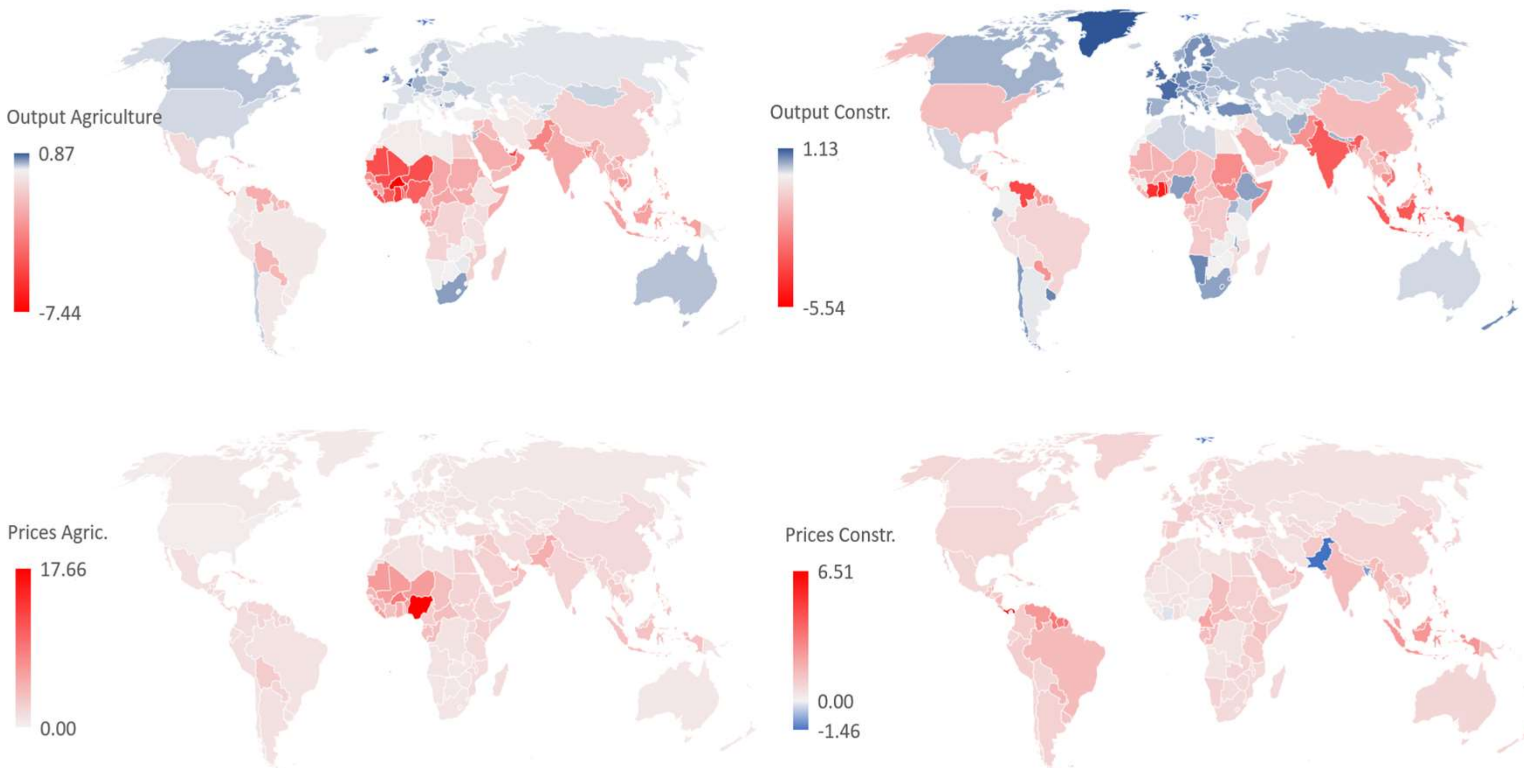
Across the tropics, output in agriculture and construction declines; prices increase at +3°C

Agriculture | Construction

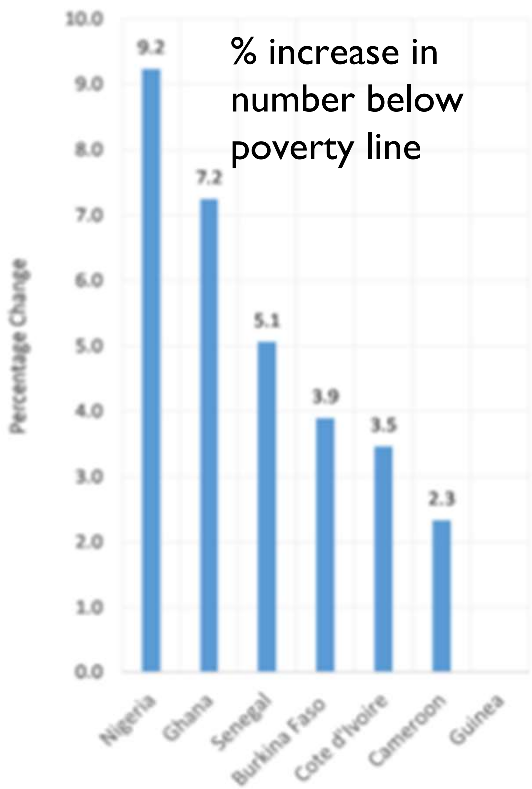


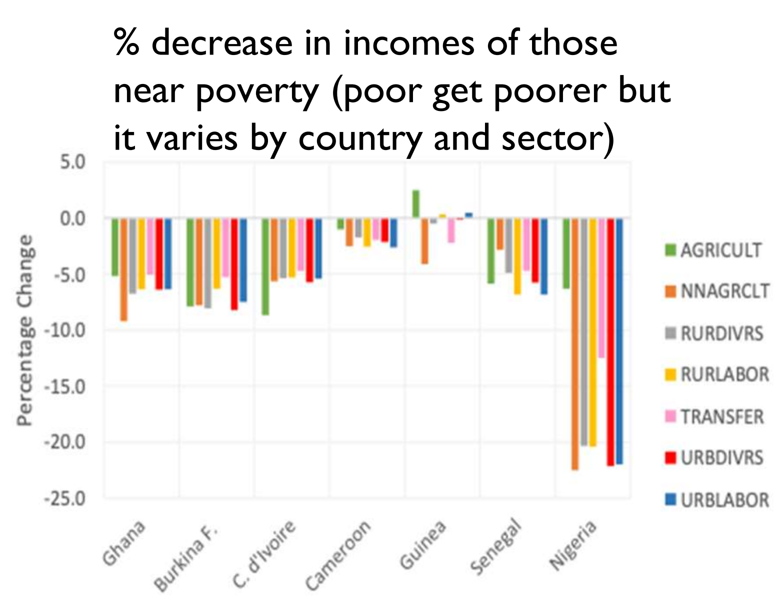
Across the tropics, output in agriculture and construction declines; prices increase at +3 °C

Agriculture | Construction



Large increases in poverty West Africa, but there are trade-offs and this favors U.S. ag production
Results have major implications for economic policy and also for migration that can be inferred
Results are fully attributable to the factors that cause them





Real Incomes near the Poverty Line, by Household Stratum and Country

Disproportionate Impacts Require Adaptation Solutions or May Drive Migration & Cascading Risks

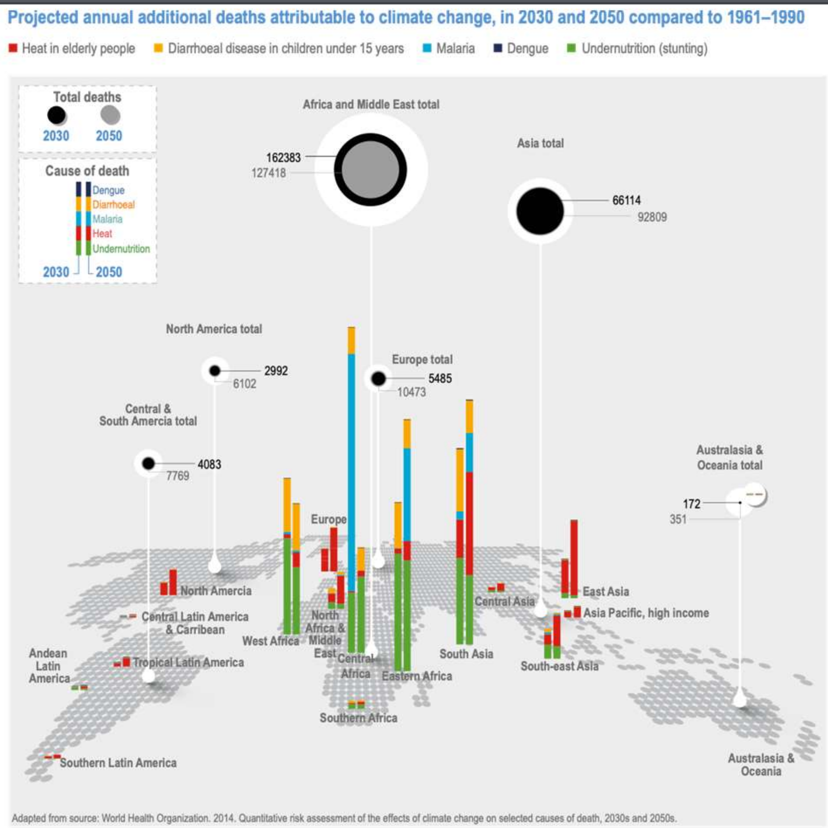
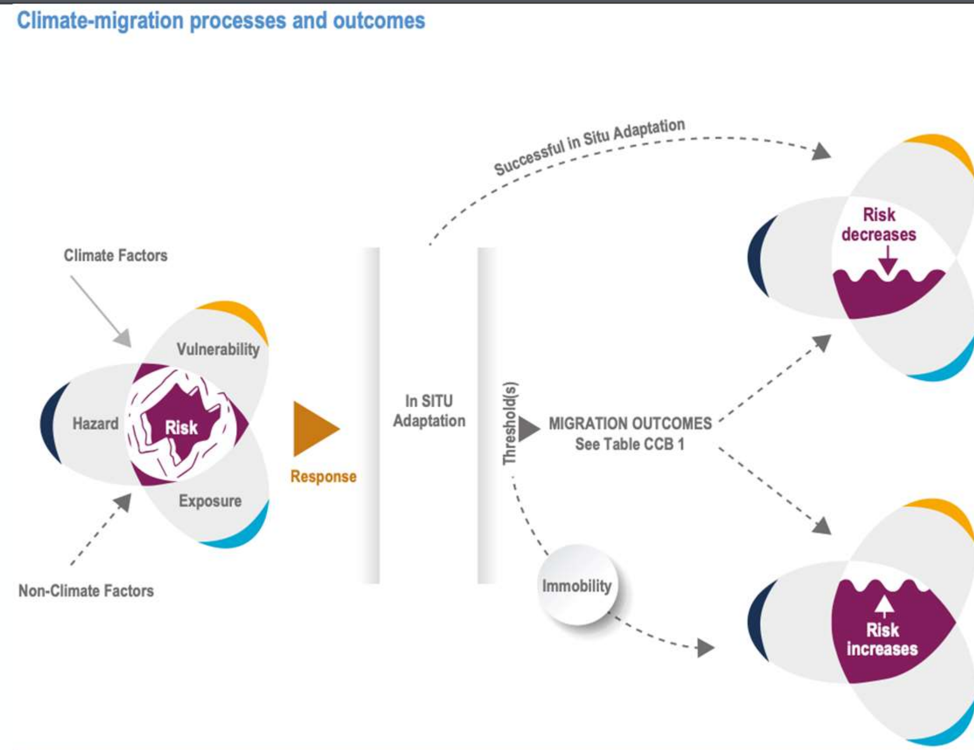


Figure 7.8 | Projected additional annual deaths attributable to climate change in 2030 and 2050 compared to 1961–1990 (WHO, 2014).



General interactions between climatic and non-climatic processes, adaptation, potential migration outcomes and implications for future risk. Adapted from McLeman et al. (2021).

Cissé, G., R. McLeman, H. Adams, P. Aldunce, K. Bowen, D. Campbell-Lendrum, S. Clayton, K.L. Ebi, J. Hess, C. Huang,
Q. Liu, G. McGregor, J. Semenza, and M.C. Tirado, 2022: Health, Wellbeing, and the Changing Structure of Communities.
In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment

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Table 1. Complex risk terms with and without an IPCC definition

Types of complex risk with IPCC definition	
Compound risk	compound risks arise from the interaction of hazards, which can be characterized by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors[28]
Emergent risk	a risk that arises from the interaction of phenomena in a complex system; for example, the risk caused when geographic shifts in human population in response to climate change lead to increased vulnerability and exposure of populations in the receiving region[29]
Types of complex risk with no IPCC definition	
Aggregate risk	the accumulation of independent determinants of risk[35]
Amplified risk	the substantial enhancement of background risk through combination or concentrations of determinants of risk in time or space[36]
Cascading risk	one event or trend triggering others; interactions can be one way (e.g., domino or contagion effects) but can also have feedbacks; cascading risk is often associated with the vulnerability component of risk, such as critical infrastructure[1,22,37,38]
Interacting risk	the combinations of hazards and their reciprocal influences between different factors and coincidences among environmental drivers[38]
Interconnected risk	the complex interactions among human, environment, and technological systems with physical interdependencies that are closely linked with interconnected social interactions[38]
Interdependent risk	complex systems involve interactions and interdependencies that cannot be separated and lead to a range of unforeseeable risks[39]
Multi-risk	the whole risk from several hazards, taking into account possible hazards and vulnerability interactions entailing both multi-hazard and multi-vulnerability perspectives[40]
Systemic risk	systemic risk results from connections between risks (networked risks), where localized initial failure could have disastrous effects and cause, at its most extreme, unbounded damage[4]

One Earth

Gold Standard
1 ton of CO_2 offset
CellPress
OPEN ACCESS

Perspective

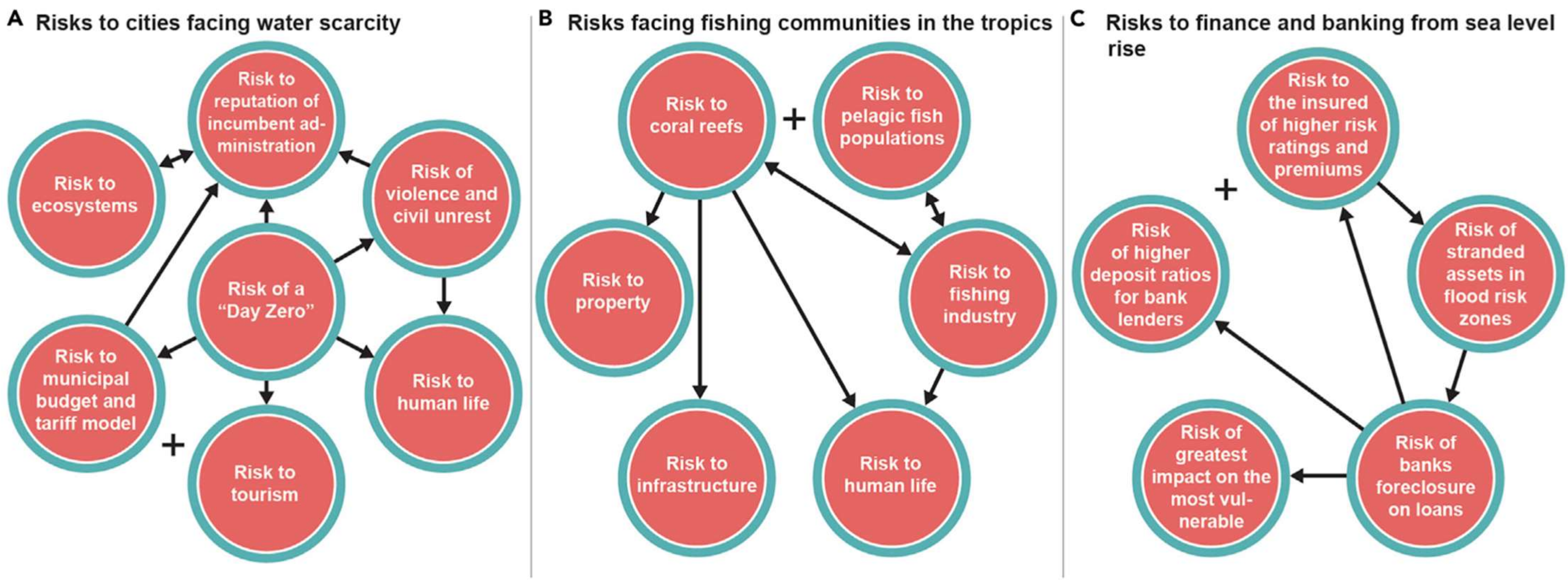
A framework for complex climate change risk assessment

Nicholas P. Simpson,[1,*] Katharine J. Mach,[2] Andrew Constable,[3] Jeremy Hess,[4] Ryan Hogarth,[5] Mark Howden,[6] Judy Lawrence,[7] Robert J. Lempert,[8] Veruska Muccione,[9] Brendan Mackey,[10] Mark G. New,[1] Brian O'Neill,[11] Friederike Otto,[12] Hans-O. Pörtner,[13] Andy Reisinger,[6] Debra Roberts,[14] Daniela N. Schmidt,[15] Sonia Seneviratne,[16] Steven Strongin,[17] Maarten van Aalst,[18,19,20] Edmond Totin,[21] and Christopher H. Trisos[1,22,*]

https://doi.org/10.1016/j.oneear.2021.03.005

Risk and Resilience Feedback Networks

interactions can dampen or amplify risks/resilience



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Welcome to the The Cyber-Physical-Social Infrastructure Climate Change (CPSICC) Nexus Workshop

Vision: Workshop will formulate recommendations, conclusions, in the CPSICC Nexus and foster partnerships among experts from different nations. By the end of the workshop, we will identify R&D gaps within this nexus and set an agenda for filling these gaps.

- Co-convened by Matthew Huber, Director of Purdue University's Institute for a Sustainable Future and Surya Nepal, Senior Principal Research Scientist at Australia's CSIRO, this NATO Advanced Research Workshop is sponsored by NATO's Science for Peace and Security Program and has been co-funded by the U.S. Department of Homeland Security's Science & Technology Directorate. Representatives from Nato SPS (Eyüp Turmuş) and DHS S&T (David Alexander) are here. Workshop partners include U.S. DOE Sandia National Laboratories, Purdue's Purdue Center for Education and Research in Information Assurance and Security and Policy Research Institute. Venus is American Geophysical Union Headquarters
- The CPSICC Nexus Workshop represents a collaborative effort to address the critical convergence of climate change, cybersecurity, and essential infrastructure, which includes social-economic-political institutions. As our global challenges grow in complexity, understanding the intricate interplay between these domains becomes paramount in order to prepare for the future. Given the multifaceted threats posed by climate change and cyber-physical-social security, we actively seek input from experts across diverse fields.

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Workshop Structure

Overview of Activities and Deliverables

https://cpsiccnexusworkshop2024.org/

Monday	Tuesday	Wednesday	Thursday	Next Steps
• Introductory Remarks • Introduction to 'serious games' • Future Scenarios • Plenary Talks	• Talks on Nexus components and their interactions • More on games • Mixer and lightning talks	▪ Detailed Scenarios ▪ Gameplay in 2030 ▪ Synthesis and iteration ▪ Short talks, banquet and 'Ted' talks	▪ Jump to 2050 for scenarios and gameplay ▪ SWOT analysis and identification of R&D gaps and strategies for filling them	▪ Workshop summary report ▪ Summarize and synthesize in white paper (NATO) ▪ Option for NATO Workshop Book ▪ Option for special journal issue or broad interest perspectives pieces ▪ Website dissemination

We have many scientific and research subject matter expert and support staff to help. Feel free to reach out to them

Institute for a Sustainable Future

We are a transdisciplinary research institute with >300 faculty, operating within Purdue Discovery Park District.

Our goal is to fulfill Purdue’s land-grant mission while supporting research and partnerships to accelerate the transition to a sustainable, resilient, prosperous future by envisioning and developing solutions to global challenges in sustainability including environment, climate, food-energy-water security, human and biosphere health.

Thank You

Contact Matthew Huber, Director ISF: huberm@purdue.edu

Follow us on Twitter: @purdueISF

Reach us at: purdueisf@purdue.edu

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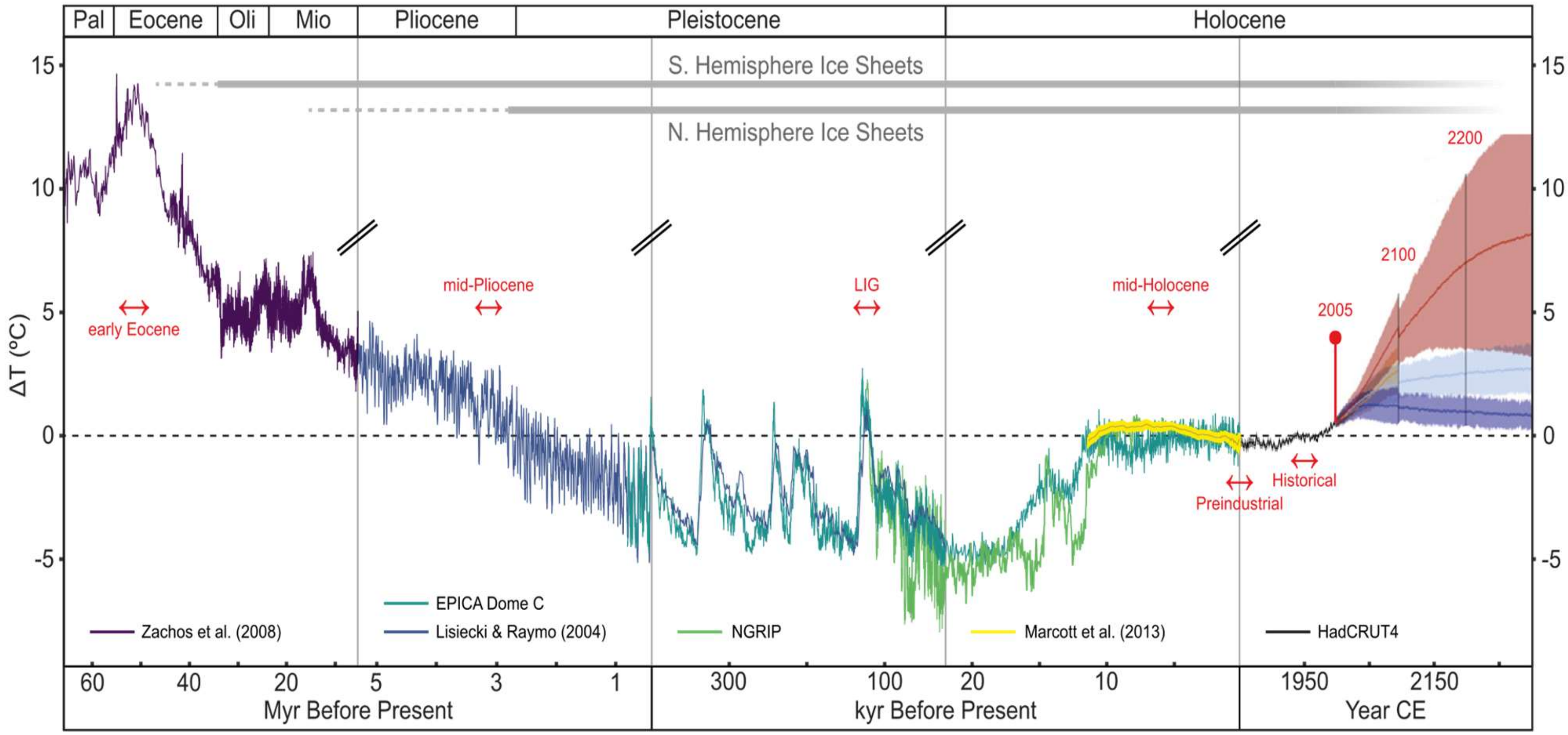
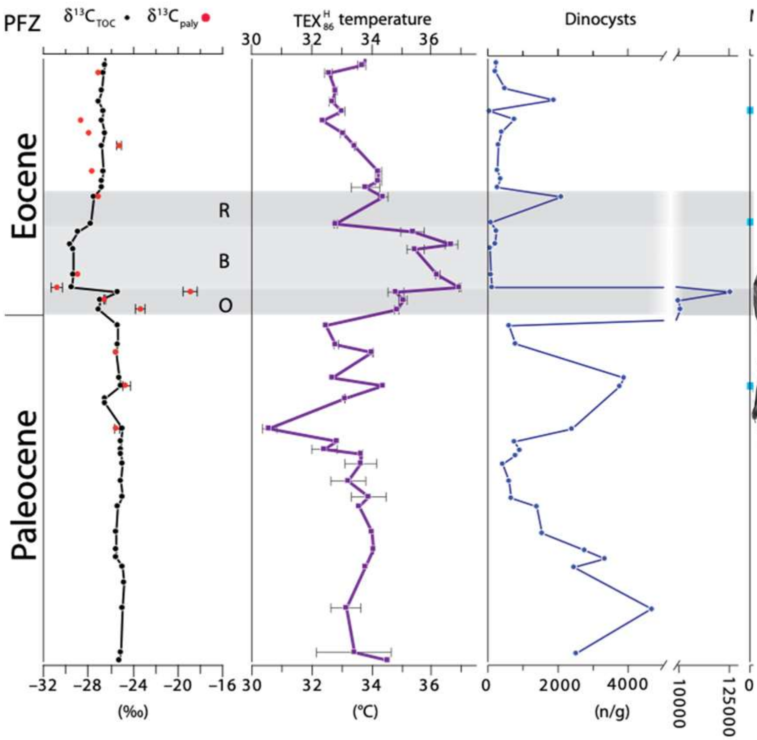


Fig. 1. Temperature trends for the past 65 Ma and potential geohistorical analogs for future climates. Six geohistorical states (red arrows) of the climate system are analyzed as potential analogs for future climates. For context, they are situated next to a multi-timescale time series of global mean annual temperatures for the last 65 Ma. Major patterns include a long-term cooling trend, periodic fluctuations driven by changes in the Earth's orbit at periods of 10^4–10^5 y, and recent and projected warming trends. Temperature anomalies are relative to 1961–1990 global means and are composited from five proxy-based reconstructions, modern observations, and future temperature projections for four emissions pathways (*Materials and Methods*). Pal, Paleocene; Mio, Miocene; Oli, Oligocene.

Paleocene-Eocene Thermal Maximum 55 mya

Tropical Heat Death in Nigeria



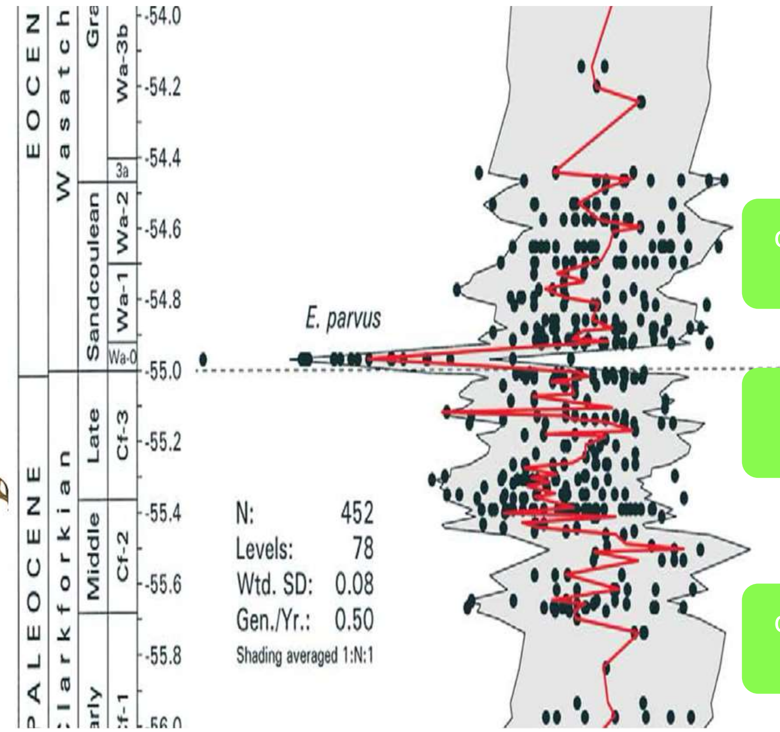
SCIENCE ADVANCES | RESEARCH ARTICLE

CLIMATOLOGY

Extreme warmth and heat-stressed plankton in the tropics during the Paleocene-Eocene Thermal Maximum

Joost Frieling,[1*] Holger Gebhardt,[2] Matthew Huber,[3] Olabisi A. Adekeye,[4] Samuel O. Akande,[4] Gert-Jan Reichart,[5,6] Jack J. Middelburg,[5] Stefan Schouten,[5,6] Appy Sluijs[1]

Transient Mammalia Dwarfing in Wyoming



dog-size horse

cat-size horse

dog-size horse

Gingerich, 2006

Food Engineering Reviews (2021) 13:92–103

https://doi.org/10.1007/s12393-020-09243-y

Food Supply Chains as Cyber-Physical Systems: a Path for More Sustainable Personalized Nutrition

Sergiy Smetana[1] & Kemal Aganovic[1] & Volker Heinz[1]

Received: 10 January 2020 / Accepted: 24 July 2020 / Published online: 22 August 2020

Abstract

Current food system evolved in a great degree because of the development of processing and food engineering technologies: people learned to bake bread long before the advent of agriculture; salting and smoking supported nomad lifestyles; canning allowed for longer military marches; etc. Food processing technologies went through evolution and significant optimization and currently rely on mino

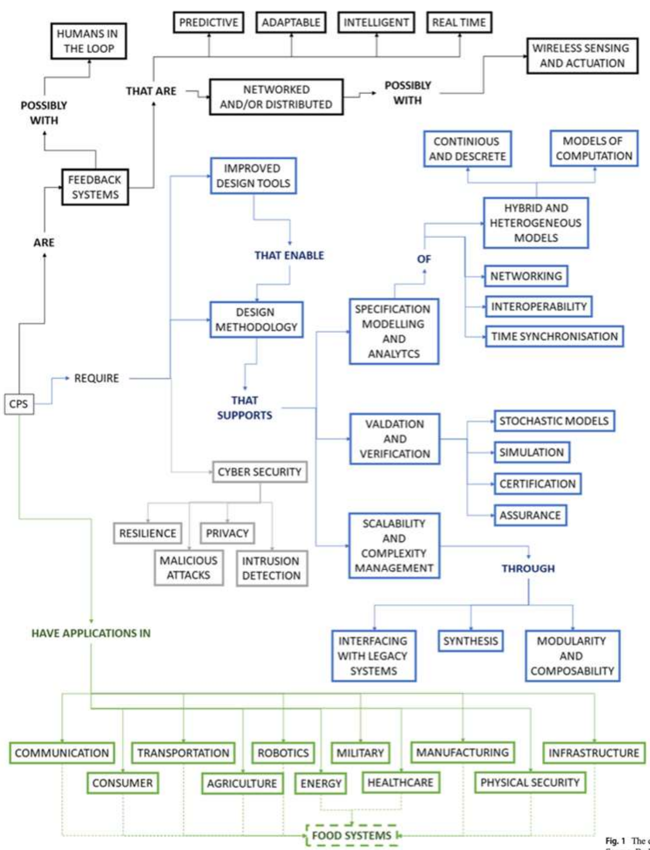
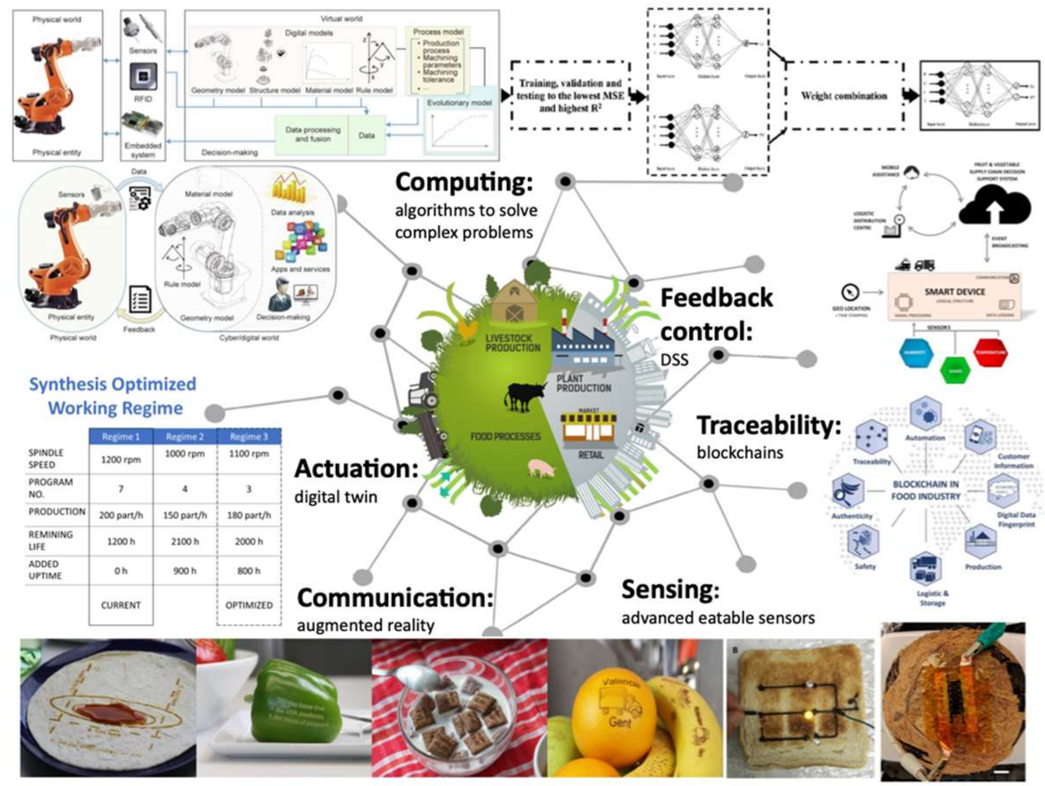
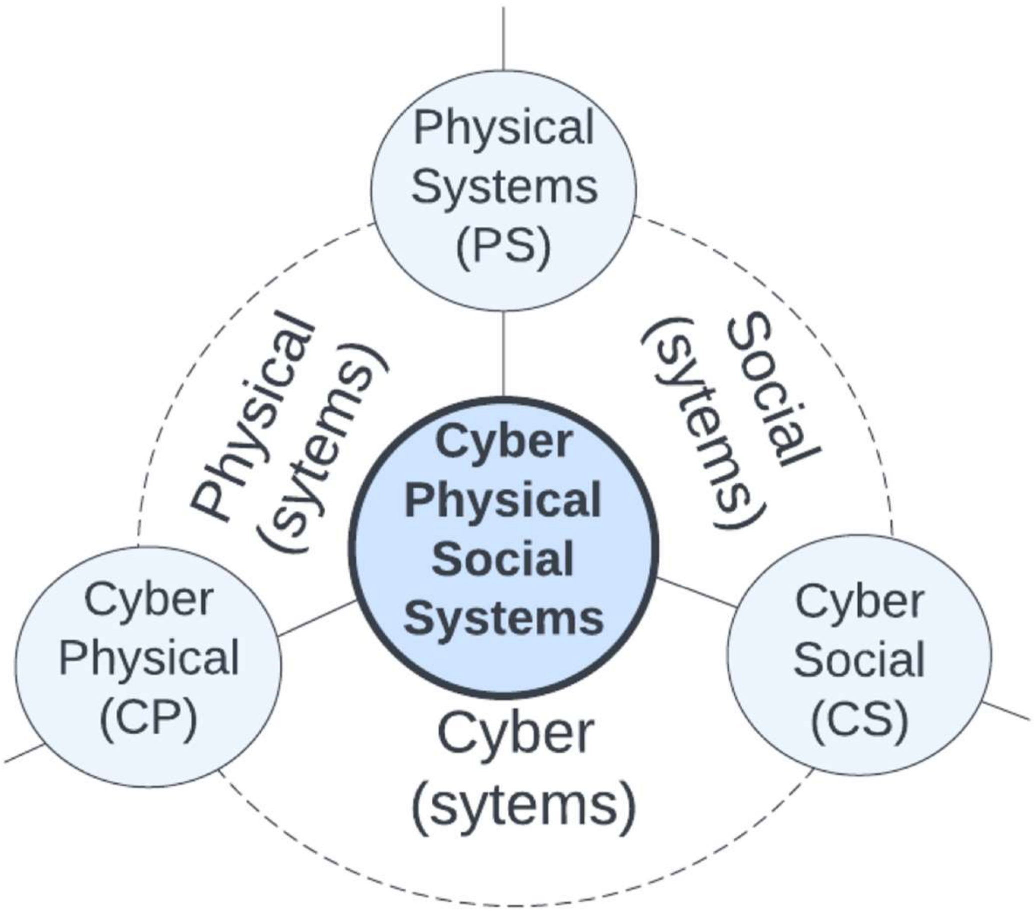


Fig. 1 The concept map of CPS. Source: Berkley University [16]



	Regime 1	Regime 2	Regime 3
SPINDLE SPEED	1200 rpm	1000 rpm	1100 rpm
PROGRAM NO.	7	4	3
PRODUCTION	200 part/h	150 part/h	180 part/h
REMINING LIFE	1200 h	2100 h	2000 h
ADDED UPTIME	0 h	900 h	800 h
	CURRENT		OPTIMIZED

Fig. 3 Overview of approaches, developed to fulfil main functions (in bold) of Food CPS ([7, 15, 29, 30, 48, 51, 68, 102]; http://www.agrocycle.eu/)



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Cyber-Physical-Social Systems: Taxonomy, Challenges, and Opportunities

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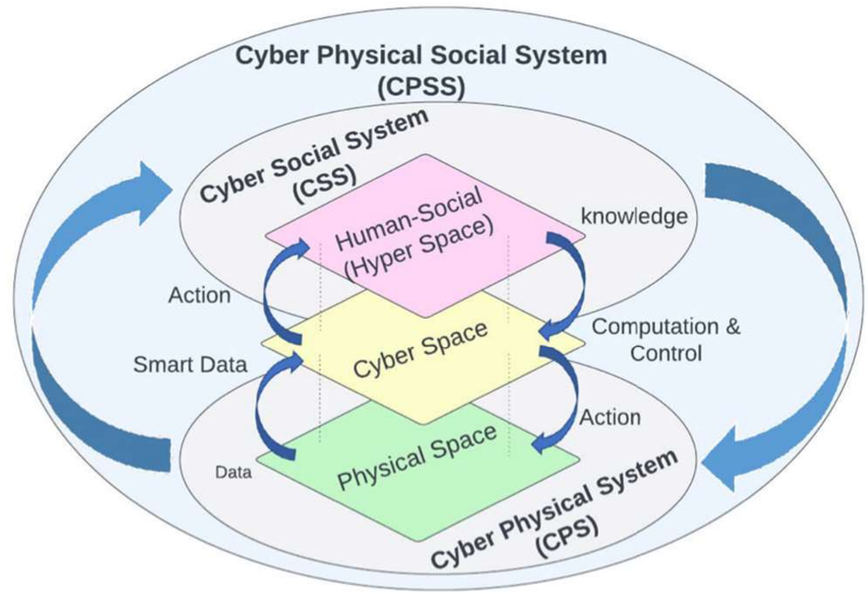

FIGURE 2. **The Cyber Physical Social System (CPSS) ecosystem.**