OVERVIEW OF RESEARCH OUTPUT FROM THE HEAT-SHIELD PROJECT

Andreas D. Flouris

FAME Lab, University of Thessaly, Greece

FAME LAB

- **Mission**: to address the negative impacts of workplace heat stress on the health and productivity of workers in strategic European industries

HEAT SHIELD

European Commission | Horizon 2020 European Union funding for Research & Innovation

Funded by the EU Horizon 2020 research and innovation programme (no.668786)

THE HEAT-SHIELD PROJECT

20 partners | 11 countries

- University of Copenhagen
- University of Ljubljana
- University of Thessaly
- University of Wolverhampton
- University of Florence
- Swiss Federal Laboratories for Materials Science and Technology
- Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek
- Lund University
- Federal Office of Meteorology and Climatology MeteoSwiss
- Loughborough University
- Institute Josef Stefan
- Tuscany Centre of Injuries & Occupational Diseases
- Age UK
- University of Porto
- Dutch National Health Service
- Center for Technology Research and Innovation Ltd.
- Karditsa Travel
- ACCIONA Co.
- University of Nicosia
- Odelo Slovenia d.o.o.

ILO METHODOLOGY TO ADDRESS OCCUPATIONAL CHALLENGES

- Assess needs
  - hazards assessment
  - profile of the target population
  - background on the social context
- Gain support
  - identify and involve key actors that provide ongoing advice, support, networking
- Establish education objectives and content
  - identify specific learning objectives to create an activist workforce that will advocate effectively for a healthier work environment
- Select education methods
  - select methods based on objectives, content areas and the profile of the workforce
- Implementing an education program
  - carry out the plan
- Evaluate and follow up
  - allow lerners to judge the progress toward new knowledge, skills, attitudes or actions
  - allow educators to judge the effectiveness of the training and what has been accomplished

International Labour Organization

FIELD STUDIES ACROSS EUROPE

- **HEAT-SHIELD mission:** to address the negative impacts of workplace heat stress on the health and productivity of workers in strategic European industries

tourism	agriculture	manufacturing	construction	transportation
				
GREECE CYPRUS	CYPRUS ITALY GREECE SLOVENIA	SLOVENIA DENMARK	SPAIN ITALY	SWITZERLAND PORTUGAL GREECE

FIELD STUDIES ACROSS EUROPE – METHODOLOGY

Metabolic Rate

second by second time-motion analysis or real-time analysis

Heart Rate

beat by beat heart rate data using heart rate monitors

Core Temperature

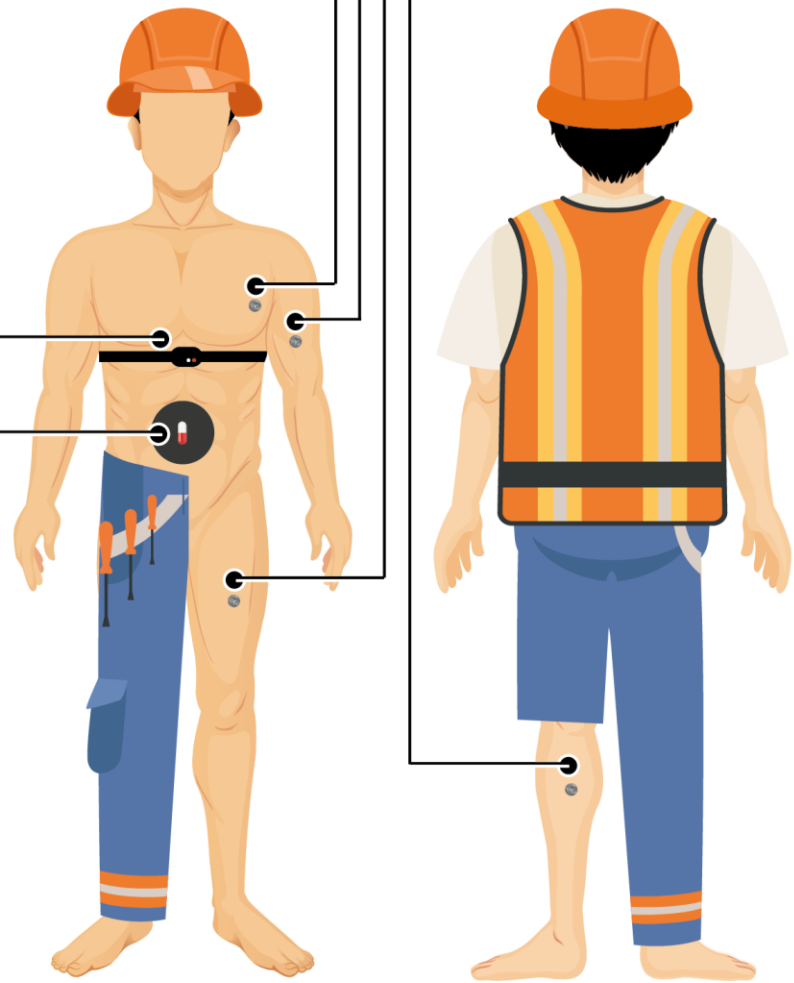
continuous core temperature data using telemetric capsules

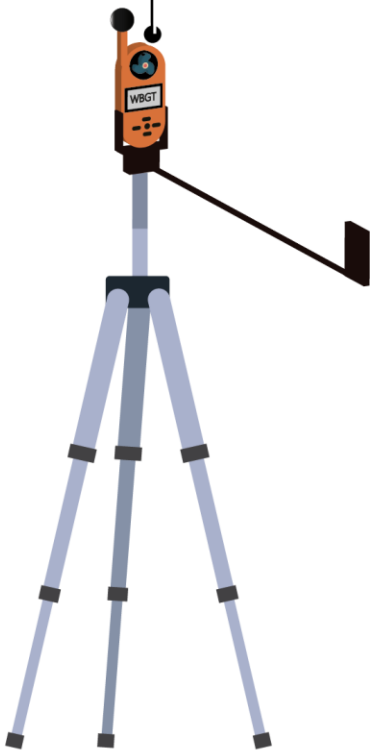
Mean Skin Temperature

continuous skin temperature from four sites using wireless thermistors

Occupational Heat Stress

continuous environmental data using a portable weather station





Ioannou et al., 2021, Int J Env Res Public Health

FIELD STUDIES ACROSS EUROPE – MITIGATION

- Personalized warning system
- Adaptation strategies

work-rest ratios

hydration

mechanization

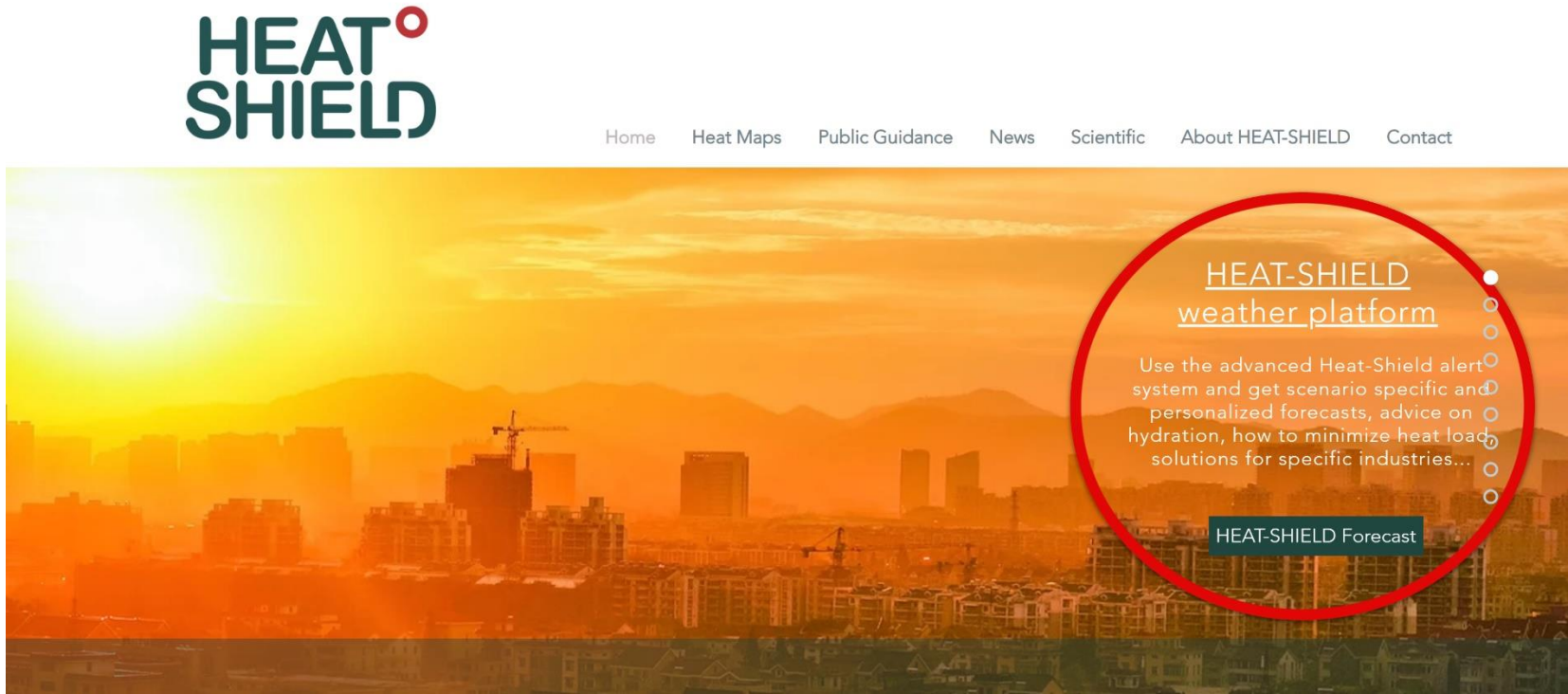
clothing

- Vulnerable workers

ALL PROJECT OUTPUTS ARE SHOWN IN OUR WEBPAGE

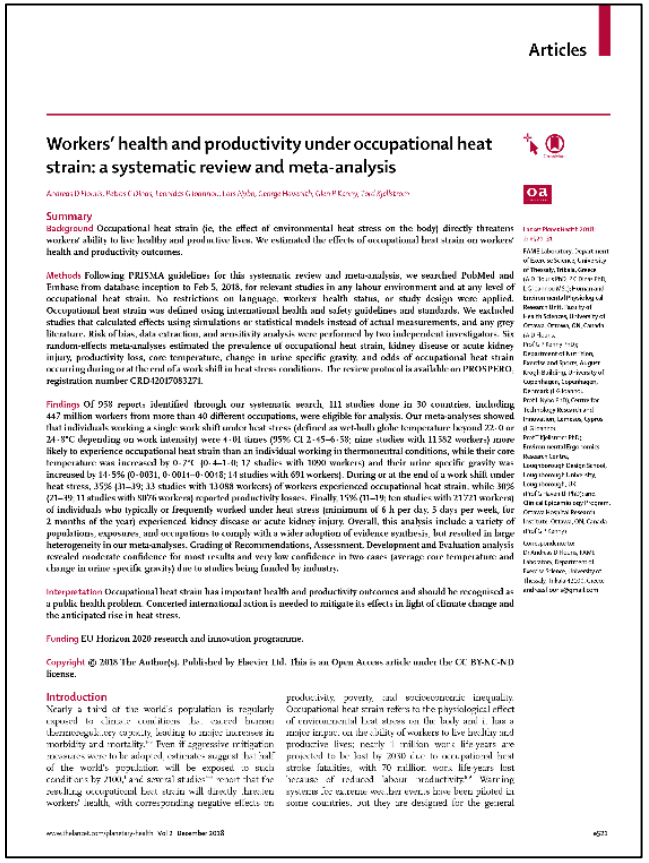
- Outputs to date:
  - guidance documents
  - 52 scientific articles
  - >40 conference presentations
  - 6 videos
  - 9 infographics
  - …

- **www.heat-shield.eu**



HEALTH IMPACT OF OCCUPATIONAL HEAT

- During or at the end of a single work shift under heat stress
  - **35%** of workers experience symptoms of occupational heat strain



Articles

Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis

Summary

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Methods Following PRISMA guidelines for this systematic review and meta-analysis, we searched PubMed and Embase from database inception to Feb 5, 2018, for relevant studies in any labour environment and at any level of occupational heat strain. No restrictions on language, workers' health status, or study design were applied. Occupational heat strain was defined using international health and safety guidelines and standards. We excluded studies that calculated effects using simulations or statistical models instead of actual measurements, and any grey literature. Risk of bias, data extraction, and sensitivity analysis were performed by two independent investigators. Six random-effects meta-analyses estimated the prevalence of occupational heat strain, kidney disease or acute kidney injury, productivity loss, core temperature, change in urine specific gravity, and odds of occupational heat strain occurring during or at the end of a work shift in heat stress conditions. The review protocol is available on PROSPERO, registration number CRD42017083271.

Findings Of 958 reports identified through our systematic search, 111 studies done in 30 countries, including 447 million workers from more than 40 different occupations, were eligible for analysis. Our meta-analyses showed that individuals working a single work shift under heat stress (defined as wet-bulb globe temperature beyond 22·0 or 24·8°C depending on work intensity) were 4·01 times (95% CI 2·45–6·58; nine studies with 11 582 workers) more likely to experience occupational heat strain than an individual working in thermoneutral conditions, while their core temperature was increased by 0·7°C (0·4–1·0; 17 studies with 1090 workers) and their urine specific gravity was increased by 14·5% (0·0031, 0·0014–0·0048; 14 studies with 691 workers). During or at the end of a work shift under heat stress, 35% (31–39; 13 studies with 13 088 workers) of workers experienced occupational heat strain, while 30% (27–33; 11 studies with 8076 workers) reported productivity losses. Finally, 19% (11–29; ten studies with 21 771 workers) of individuals who typically or frequently worked under heat stress (minimum of 6 h per day, 5 days per week, for 2 months of the year) experienced kidney disease or acute kidney injury. Overall, this analysis include a variety of populations, exposures, and occupations to comply with a wider adoption of evidence synthesis, but resulted in large heterogeneity in our meta-analyses. Grading of Recommendations, Assessment, Development and Evaluation analysis revealed moderate confidence for most results and very low confidence in two cases (average core temperature and change in urine specific gravity) due to studies being funded by industry.

Interpretation Occupational heat strain has important health and productivity outcomes and should be recognised as a public health problem. Concerted international action is needed to mitigate its effects in light of climate change and the anticipated rise in heat stress.

Funding EU Horizon 2020 research and innovation programme.

Introduction

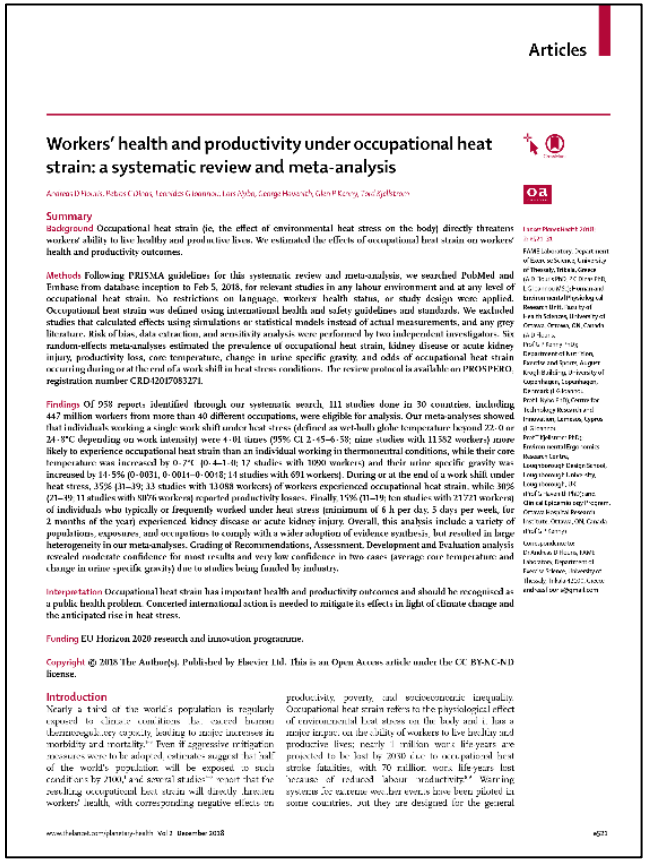
Nearly a third of the world's population is regularly exposed to climate conditions [illegible] increased human thermoregulatory capacity, leading to major increases in morbidity and mortality.[1,2] Even if aggressive mitigation measures were to be adopted, estimates suggest that half of the world's population will be exposed to such conditions by 2100,[3] and several studies[4–7] report that the overlying occupational heat strain will directly [illegible] workers' health, with corresponding negative effects on productivity, poverty, and socioeconomic inequality. Occupational heat strain refers to the physiological effect of environmental heat stress on the body and it has a major impact on the ability of workers to live healthy and productive lives; nearly 1 million work-life years are projected to be lost by 2030 due to occupational heat stroke fatalities, with 70 million work-life years lost because of reduced labour productivity.[8,9] Warning systems for extreme weather events have been piloted in some countries, but they are designed for the general

www.thelancet.com/planetary-health Vol 2 December 2018 e521

Flouris et al., 2018, Lancet Plan Health

HEALTH IMPACT OF OCCUPATIONAL HEAT

- Those who frequently work in the heat experience
  - **4-fold** increase in the likelihood of having heat strain
  - **0.7°C** higher body temperature
  - **14.5%** increase in urine specific gravity
  - **15%** risk for kidney disease / acute kidney injury



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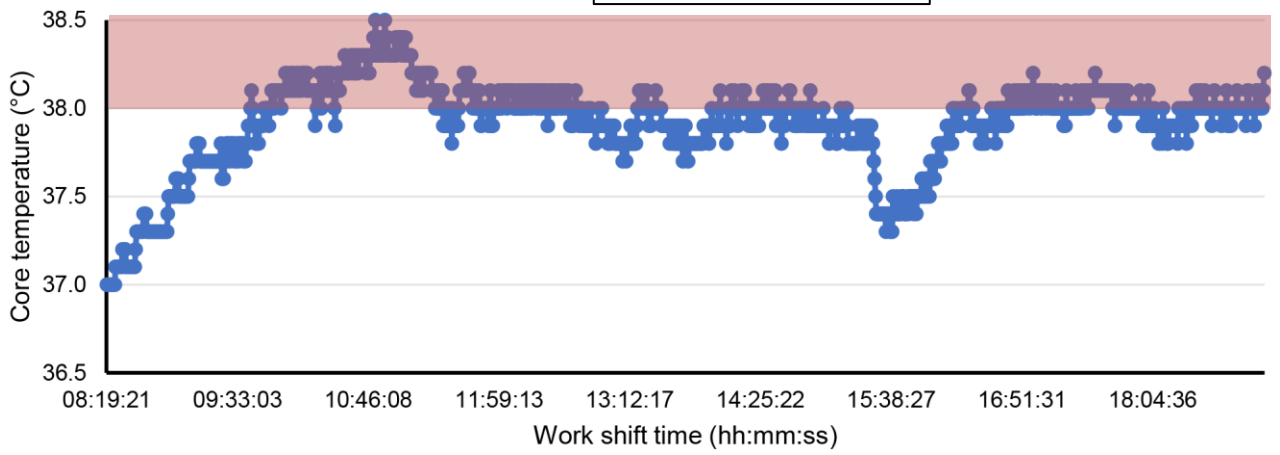
Flouris et al., 2018, Lancet Plan Health

HEAT IN THE WORKPLACE

Construction



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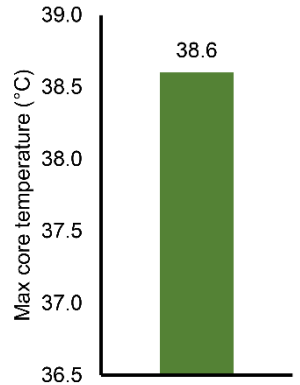
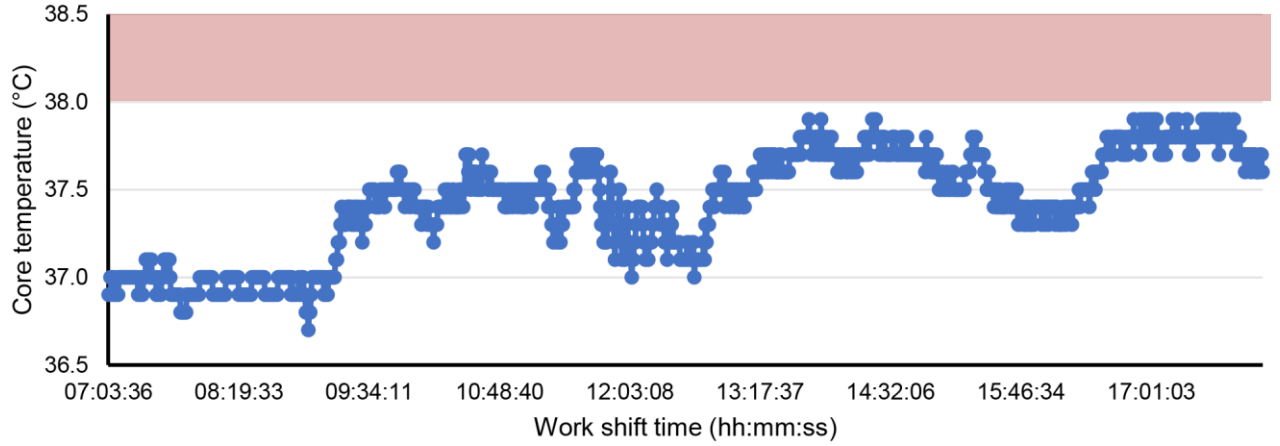


Agriculture



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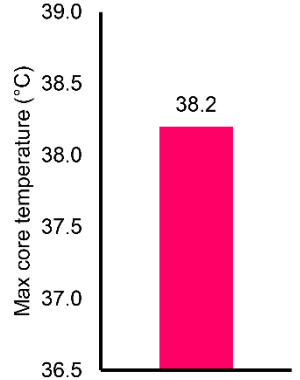
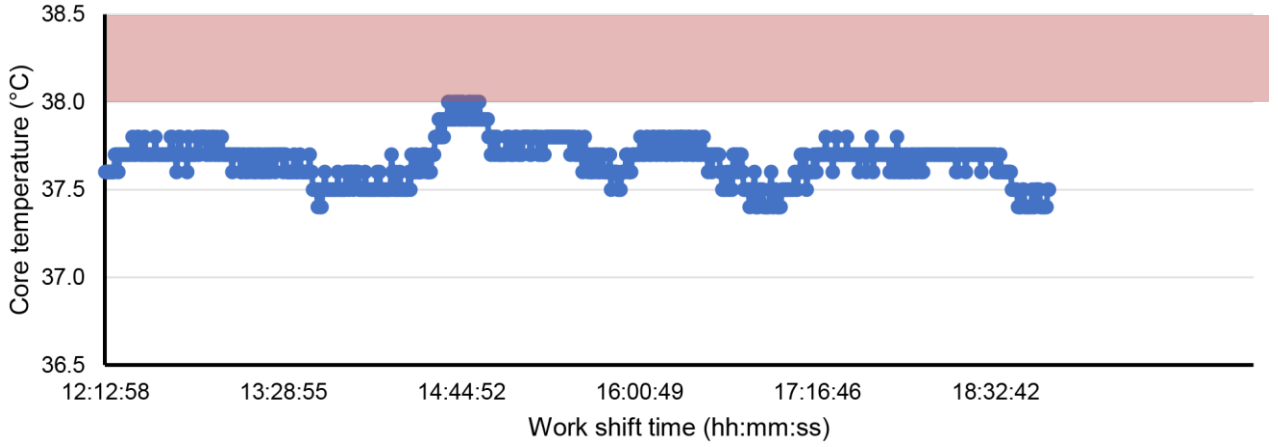
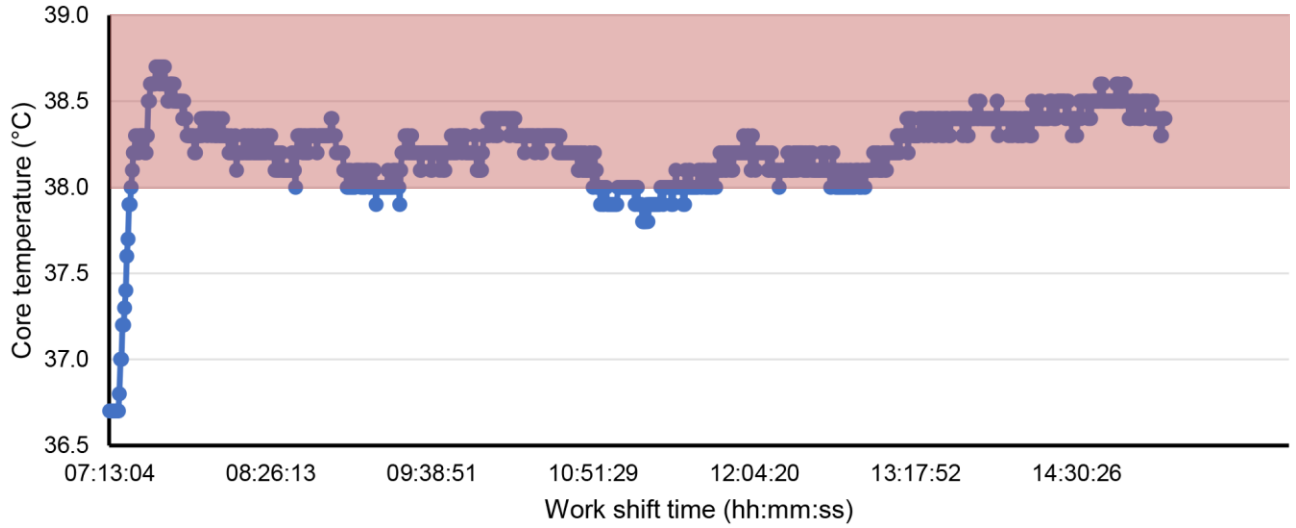


Flouris et al., Unpublished Data

HEAT IN THE WORKPLACE

Tourism





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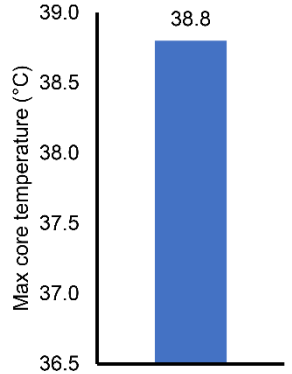
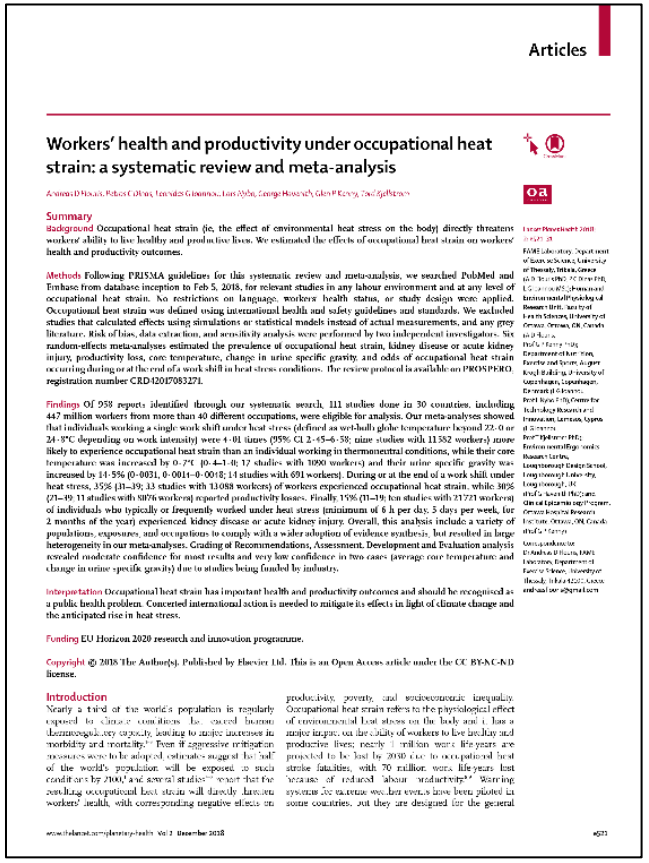


Flouris et al., Unpublished Data

PRODUCTIVITY IMPACT OF OCCUPATIONAL HEAT

- During or at the end of a single work shift under heat stress
  - **30%** of workers report productivity losses

- In most cases, the adopted units of labor reflected the total volume of output over **an hour** or **a day** recorded from **tens** or even **thousands** of workers **grouped together**



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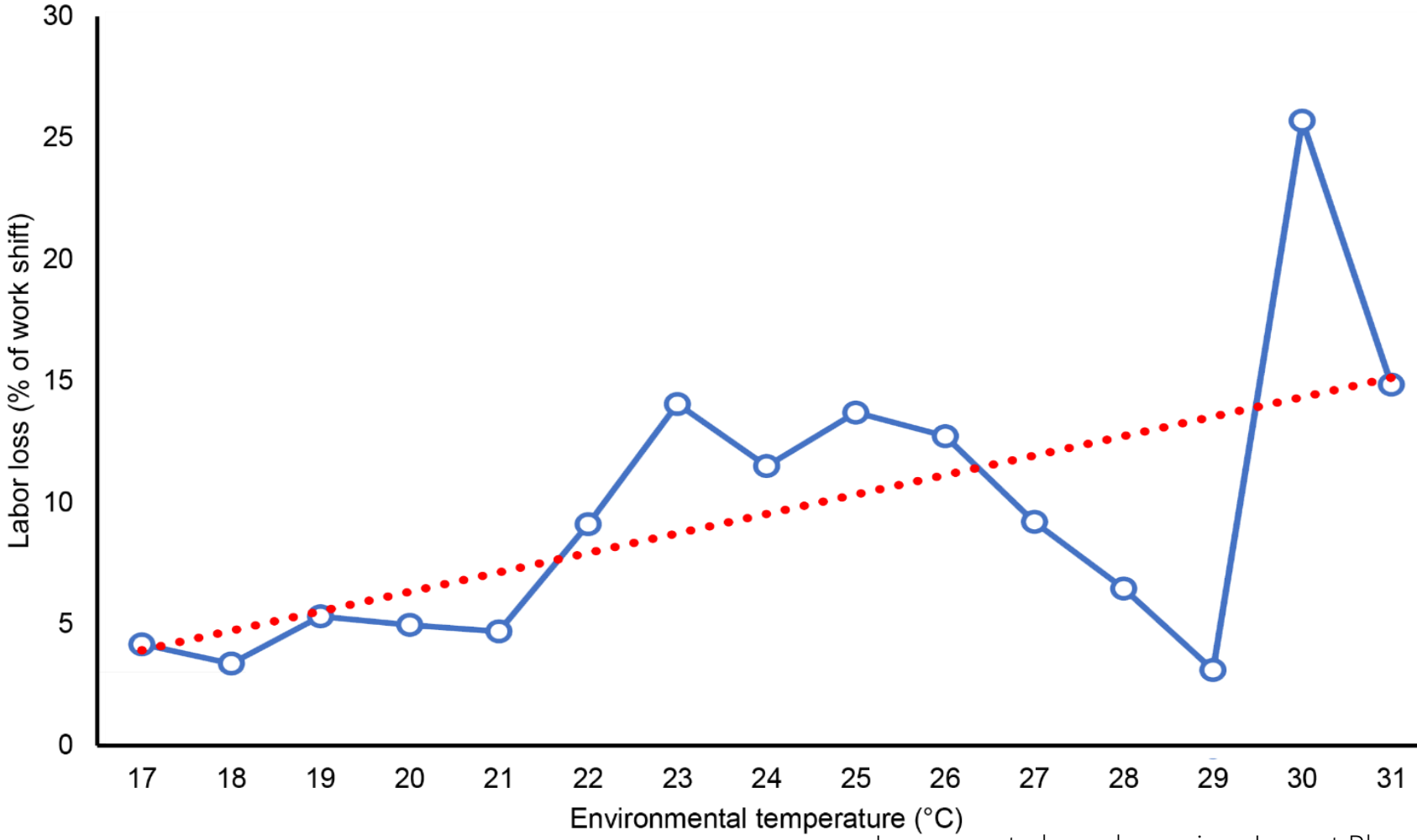
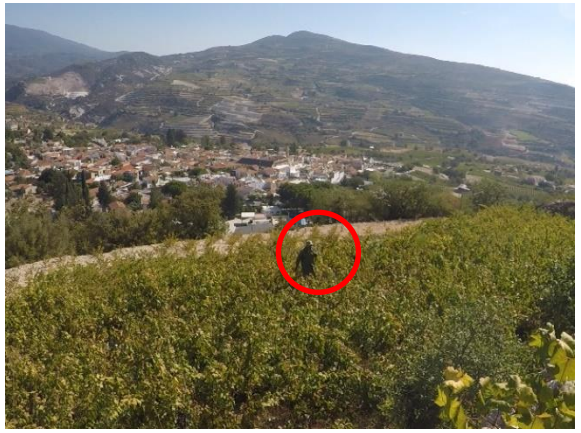
DO YOU THINK THE HEAT AFFECTS YOUR PRODUCTIVITY?

DO YOU THINK THE HEAT AFFECTS YOUR PRODUCTIVITY?

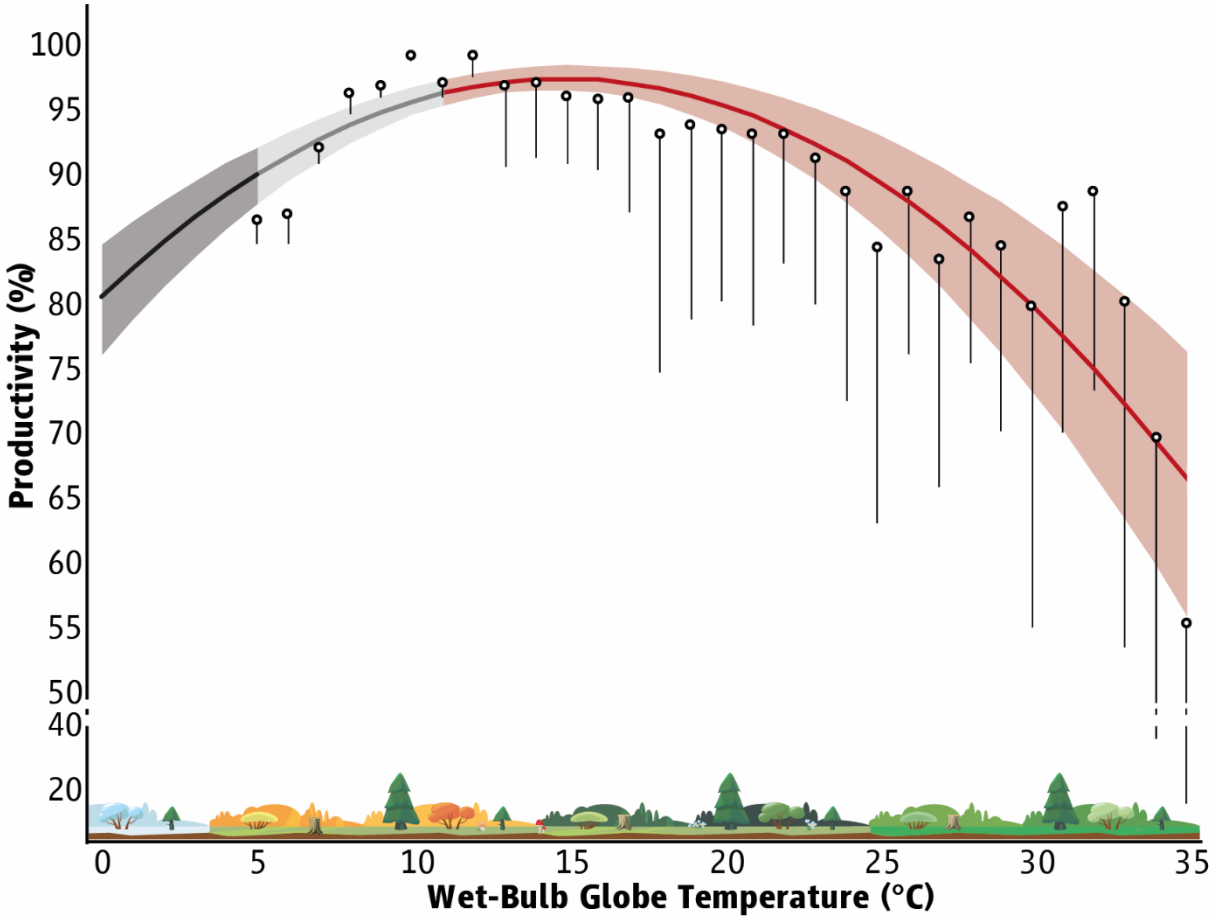
- Loss of **1%** of labor time for every 1°C increase in environmental temperature, for this worker

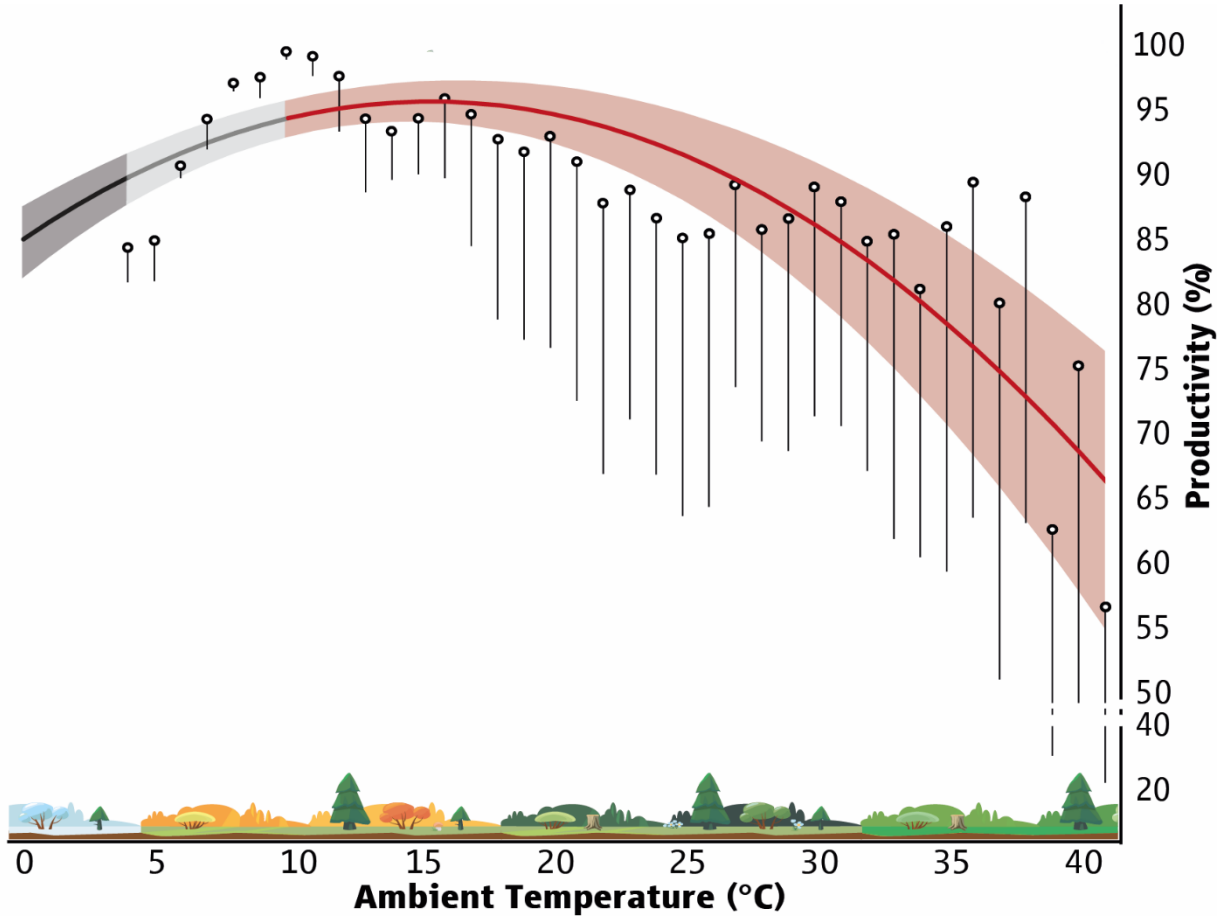




Ioannou et al., under review, Lancet Planet Health

IMPACT OF HEAT STRESS ON LABOUR PRODUCTIVITY



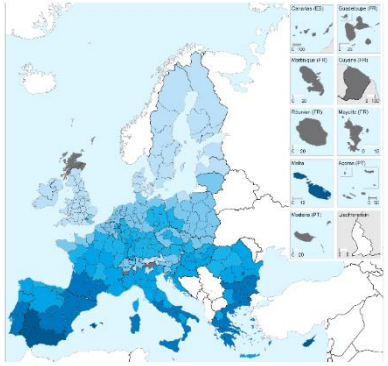


Ioannou et al., under review, Lancet Planet Health

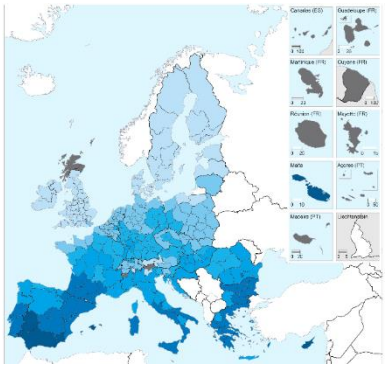
VULNERABILITY MAPS FOR EUROPE AT NUTS2

- Percentage of gross value added lost across Europe

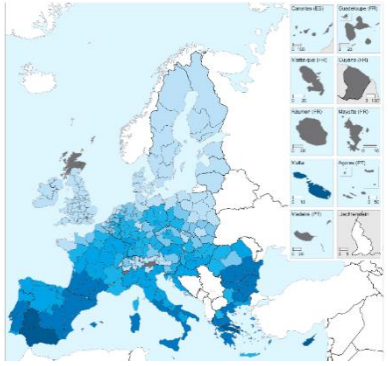
agriculture



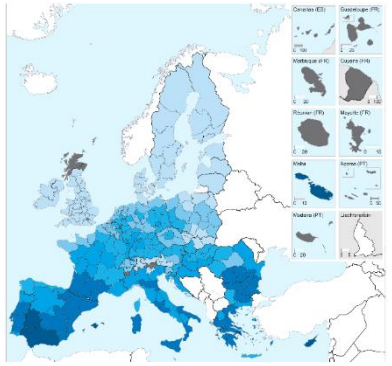
construction



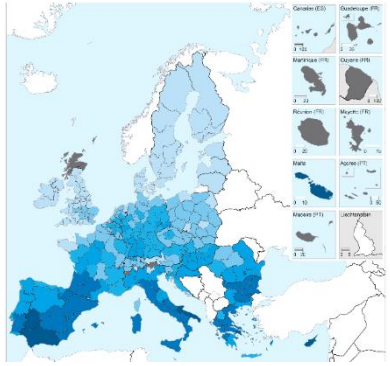
manufacturing

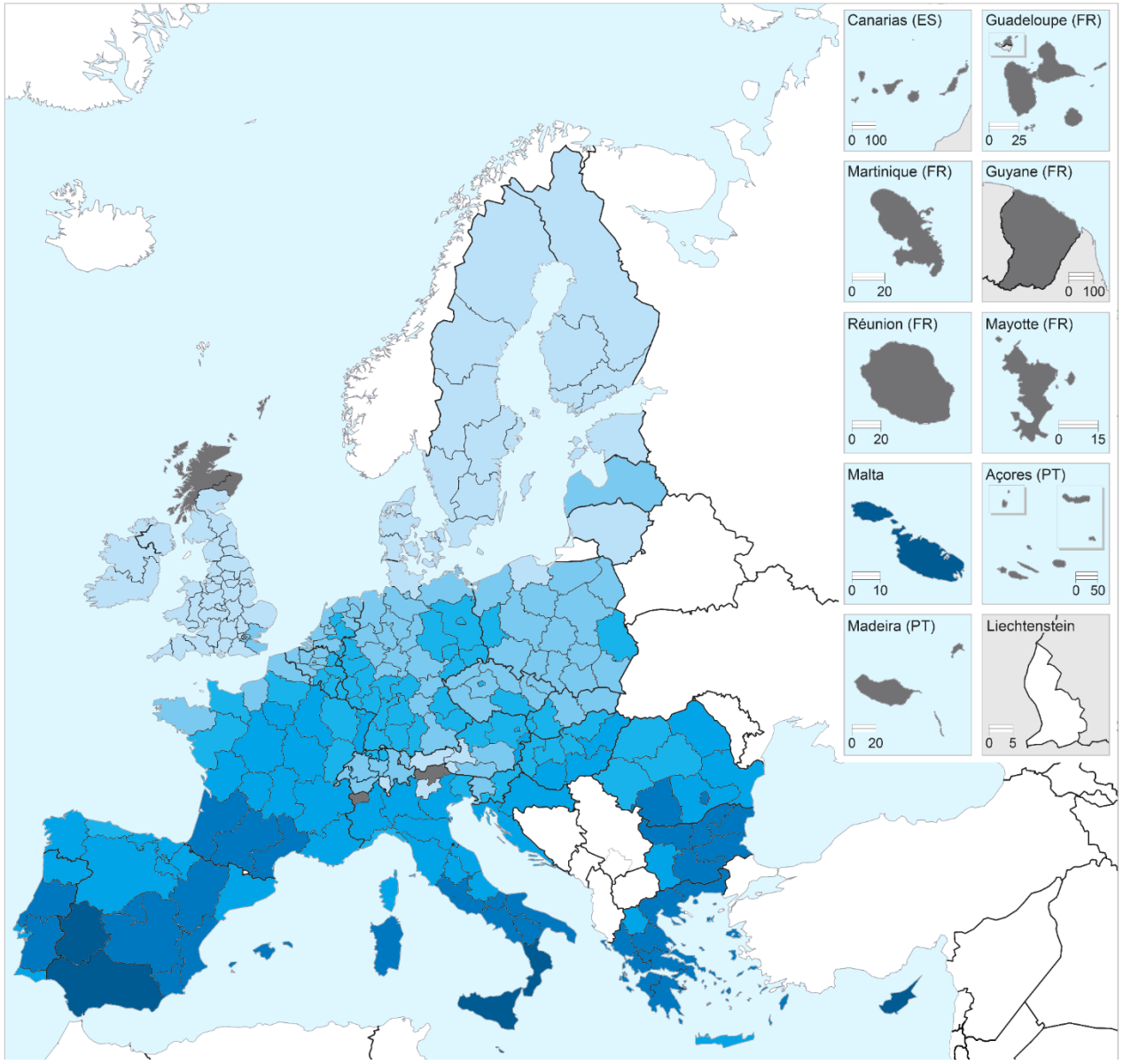


tourism



transportation

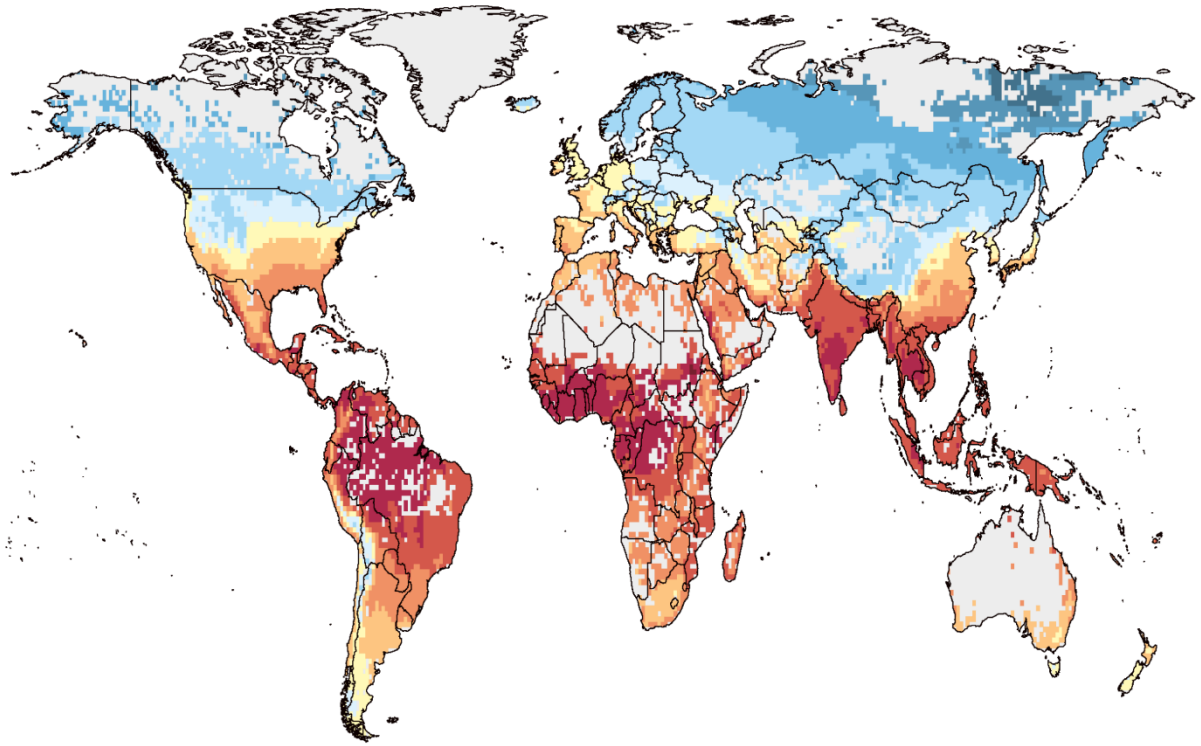




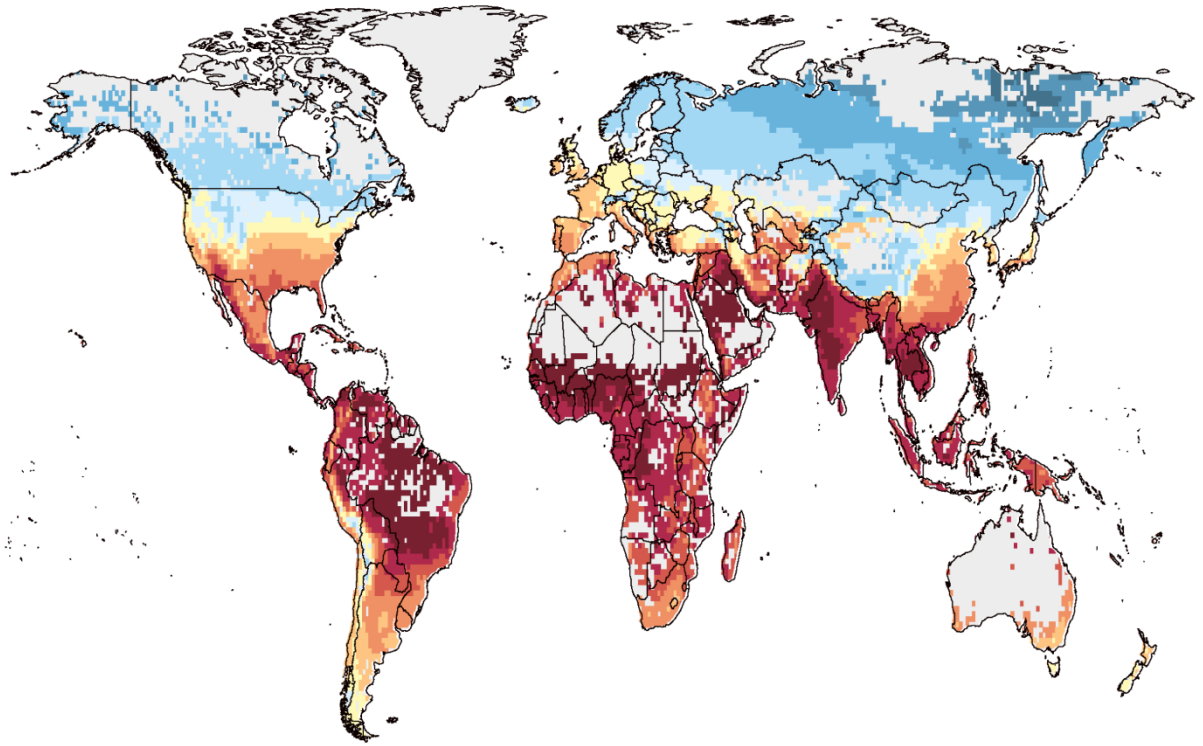
Flouris et al., Under Preparation

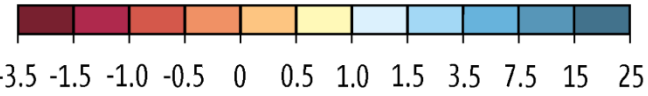
IMPACTS IN AGRICULTURE LABOUR PRODUCTIVITY

Wet-Bulb Globe Temperature



Ambient Temperature

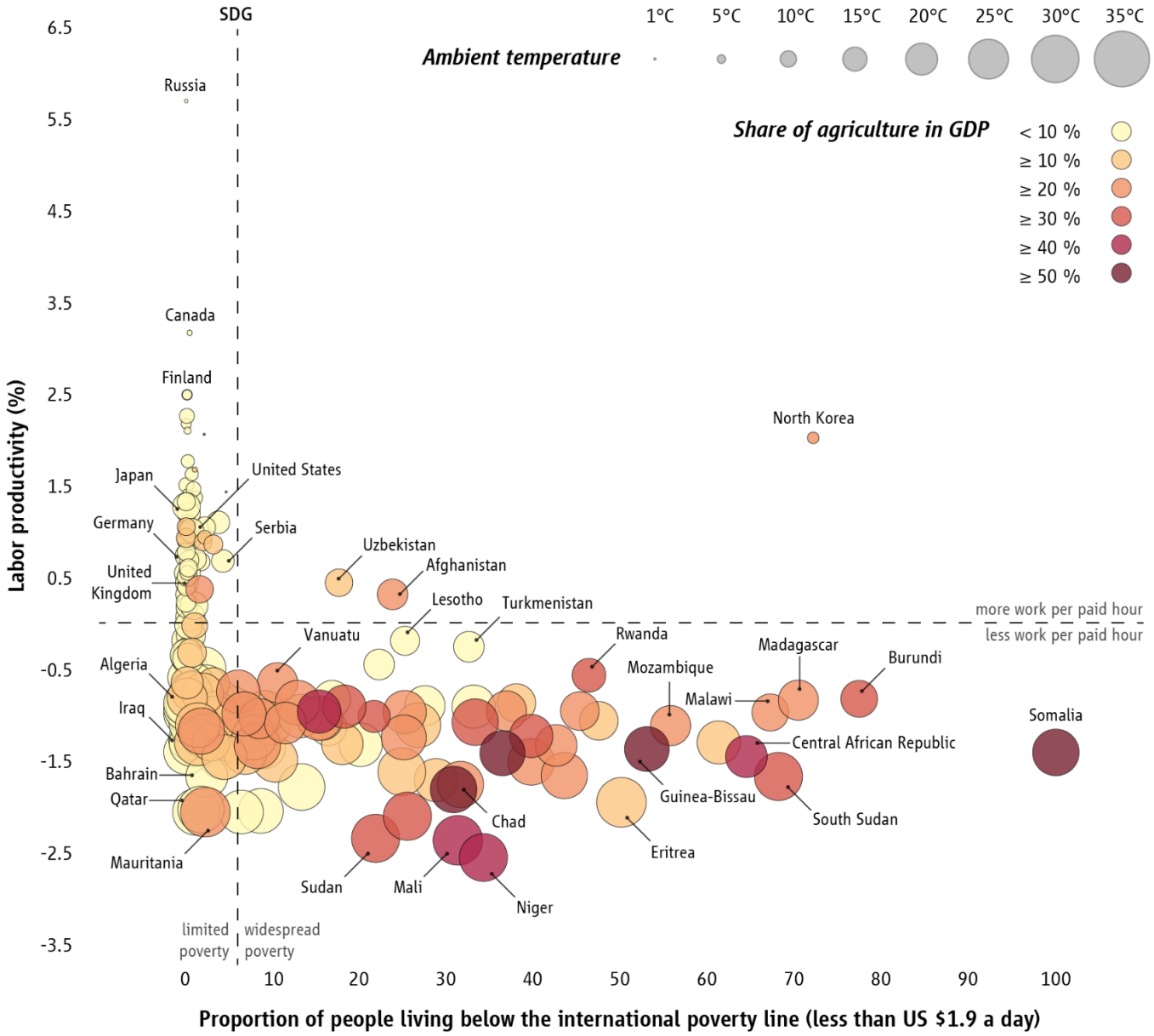




Net agricultural labor productivity change (%) between 2000 and 2040

Ioannou et al., under review, Lancet Planet Health

IMPACTS IN AGRICULTURE – FUELING INEQUALITIES



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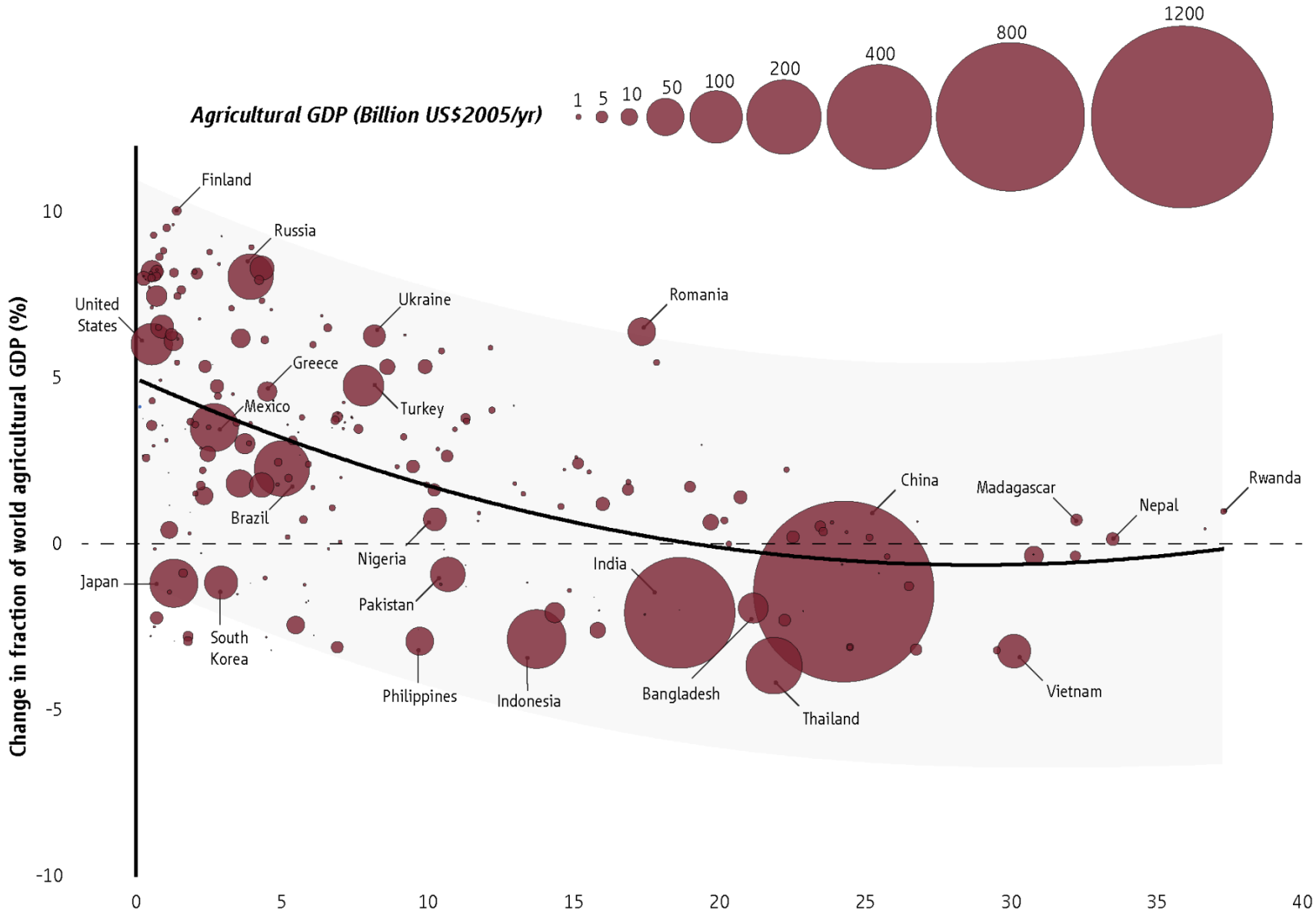


Ioannou et al., under review, Lancet Planet Health

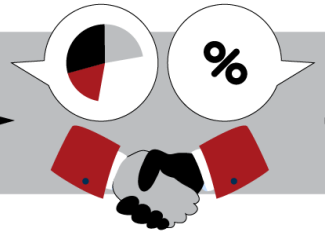
How well do thermal indicators quantify the magnitude of occupational heat strain?

THERMAL INDICATORS TO ASSESS OCCUP. HEAT STRESS

- Process to evaluate the efficacy of thermal indicators for assessing occupational heat stress and protecting workers

Part 1
Systematic review

Part 2
Delphi exercise



Part 3
Multi-country field evaluation

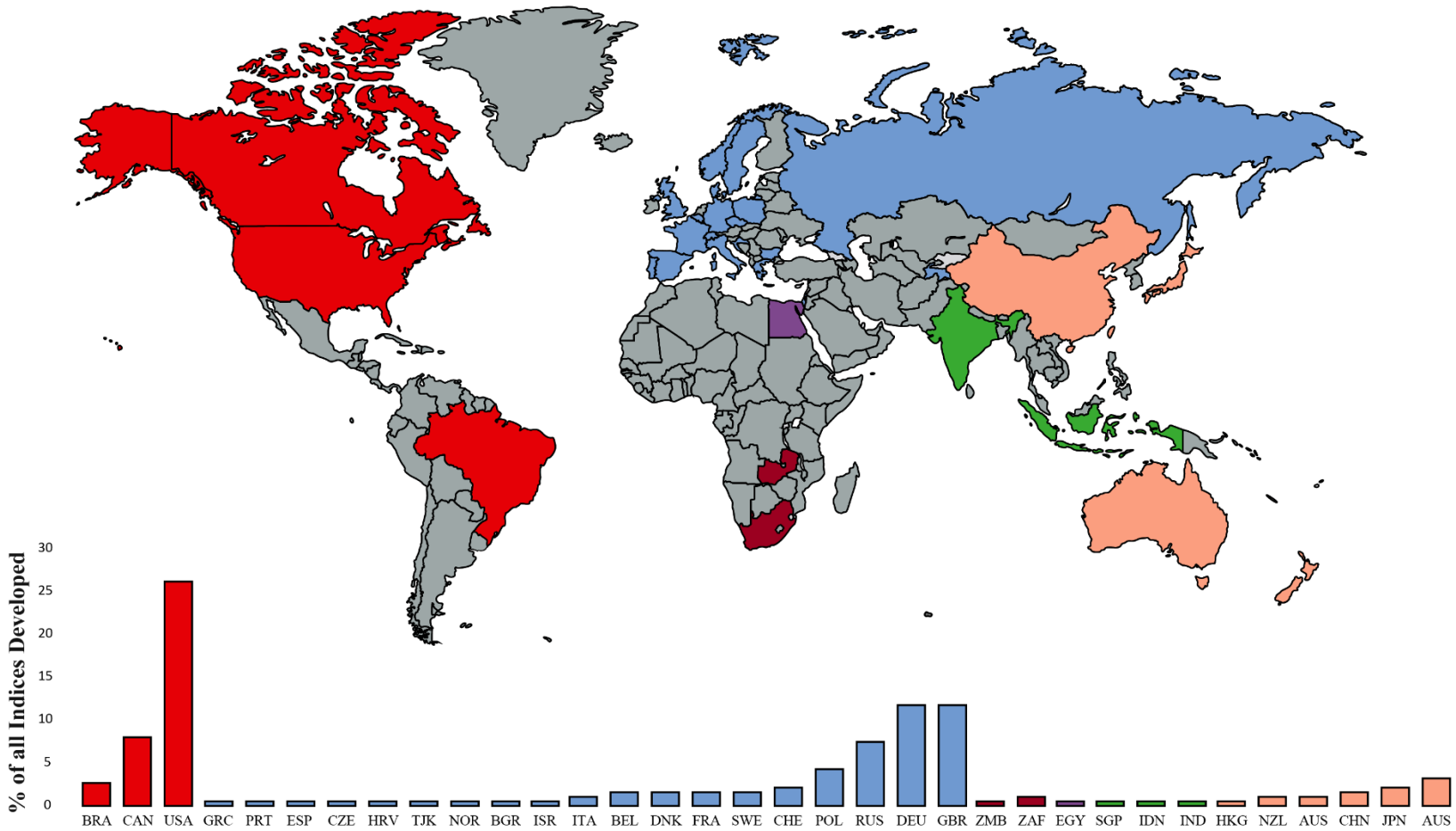
Part 4
Consensus recommendations

Ioannou et al., under review, Temperature

THERMAL INDICATORS TO ASSESS OCCUP. HEAT STRESS

- 232 publications (1905 – 2018)

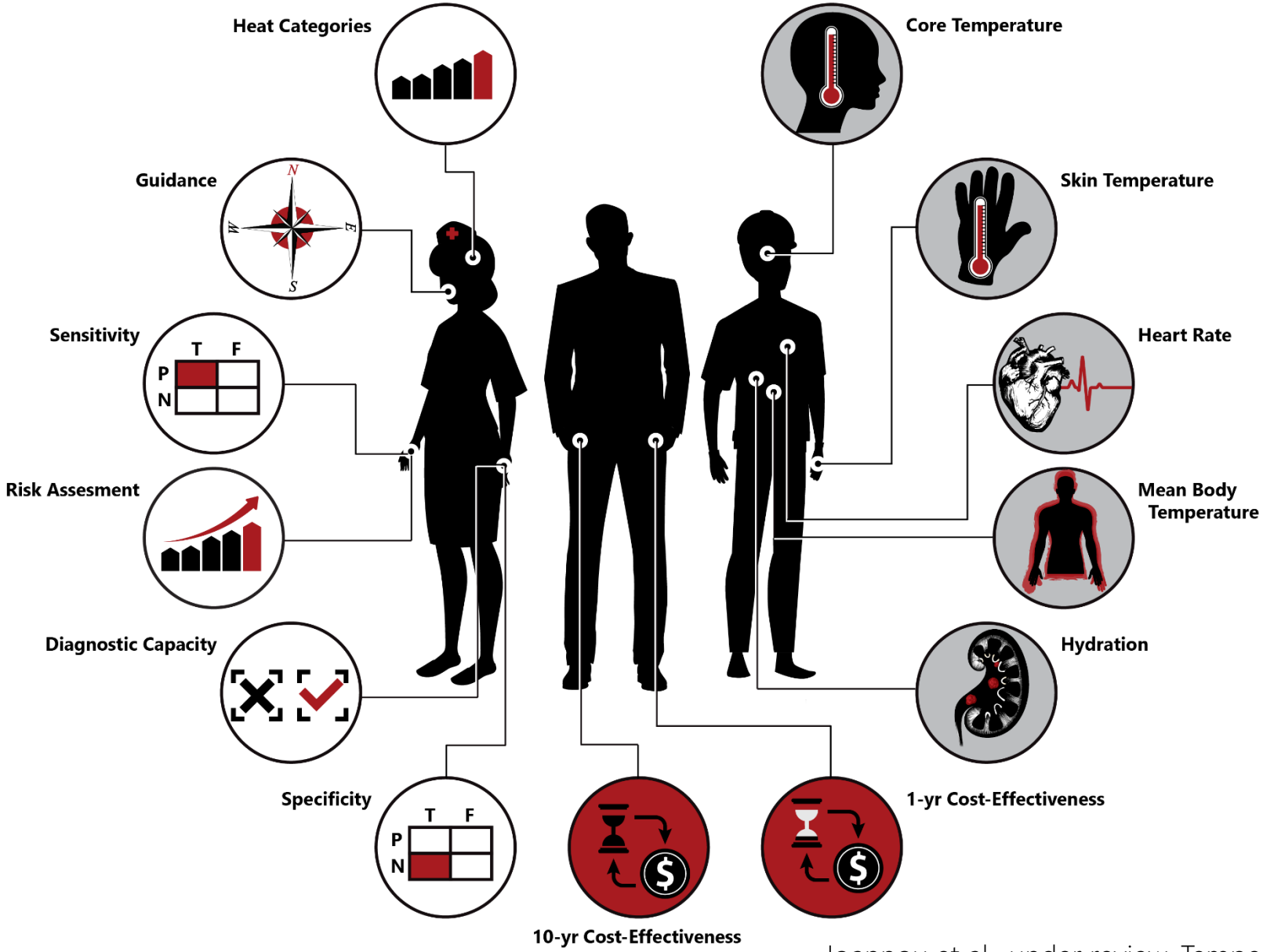
- **339 thermal indicators**
  - **187** calculated using meteorological data
    - **61** suitable for use in occupational settings



Ioannou et al., under review, Temperature

THERMAL INDICATORS TO ASSESS OCCUP. HEAT STRESS

- Criteria to consider when adopting a thermal indicator

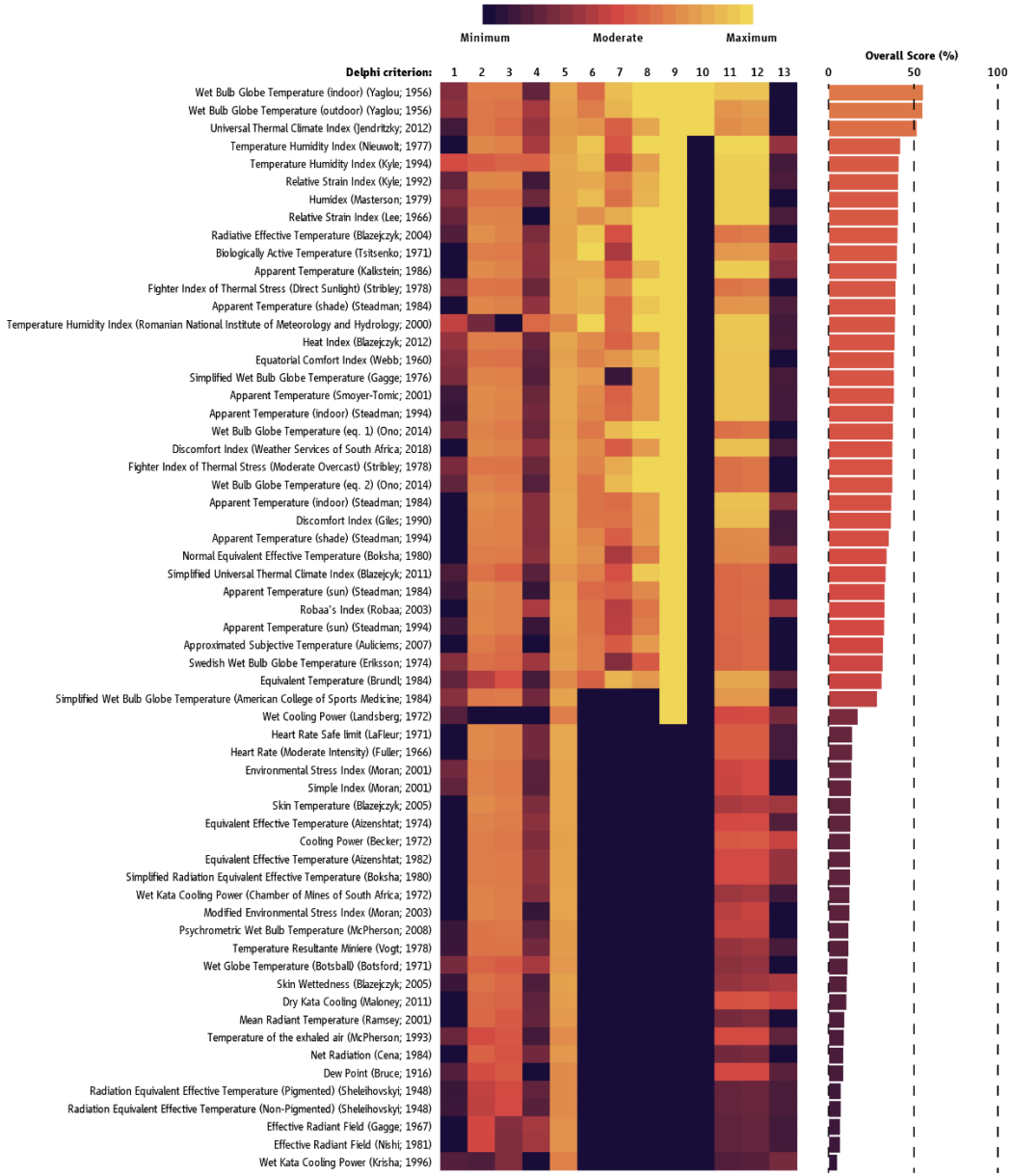


Ioannou et al., under review, Temperature

THERMAL INDICATORS TO ASSESS OCCUP. HEAT STRESS

- Field experiments evaluating the efficacy of 61 meteorology-based indicators for occupational settings to quantify the physiological strain experienced by those who work in the heat
  - **9** countries (Australia, Cyprus, Canada, Denmark, Greece, Qatar, Slovenia, Spain, and USA)
  - **372** experienced and acclimatized workers
  - **1 to 5** work shifts per worker

    - core body temperature
    - mean skin temperature
    - heart rate
    - urine specific gravity

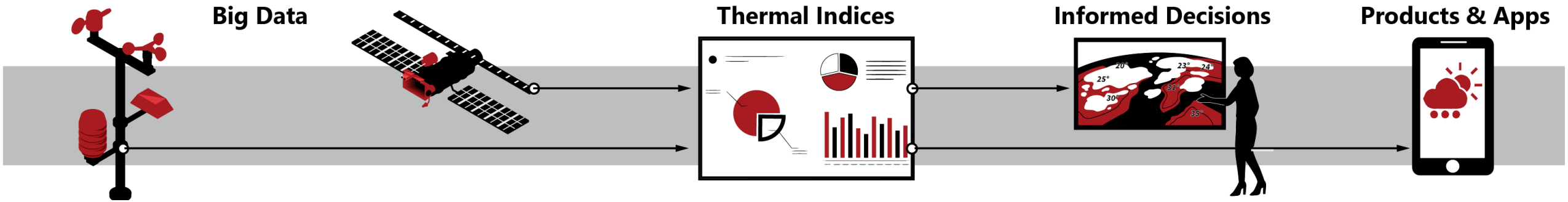


Ioannou et al., under review, Temperature

THERMAL INDICATORS TO ASSESS OCCUP. HEAT STRESS

- Simply measuring one or more meteorological parameters (air temperature, humidity, wind, solar radiation) does not adequately reflect the physiological heat strain experienced by working individuals

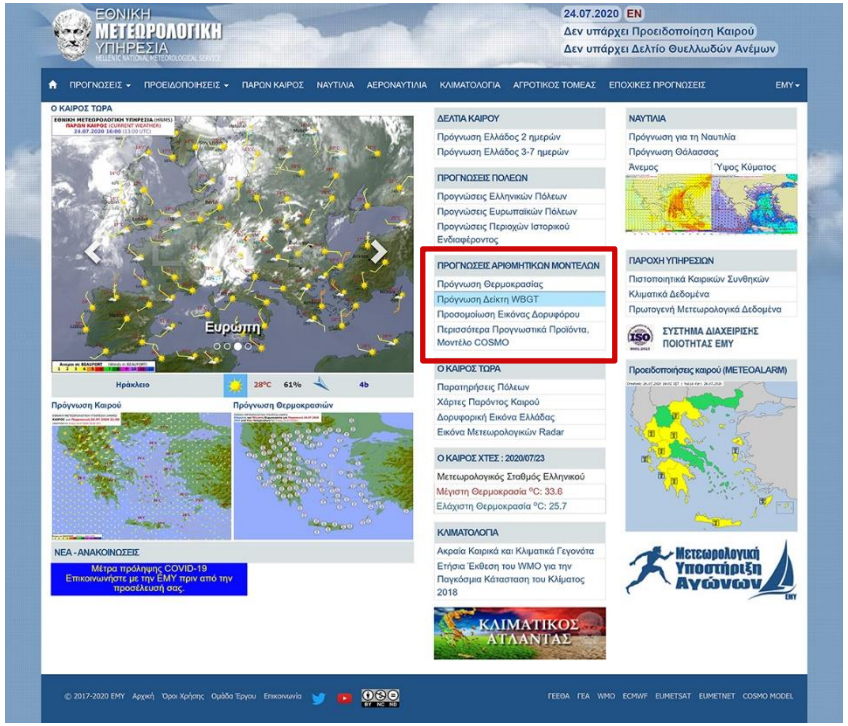
- The indoor and outdoor **Wet-Bulb Globe Temperature** (WBGT) as well as the **Universal Thermal Climate Index** (UTCI) emerge as the most efficacious meteo-based indicators for quantifying the physiological strain experienced by workers in different occupational settings



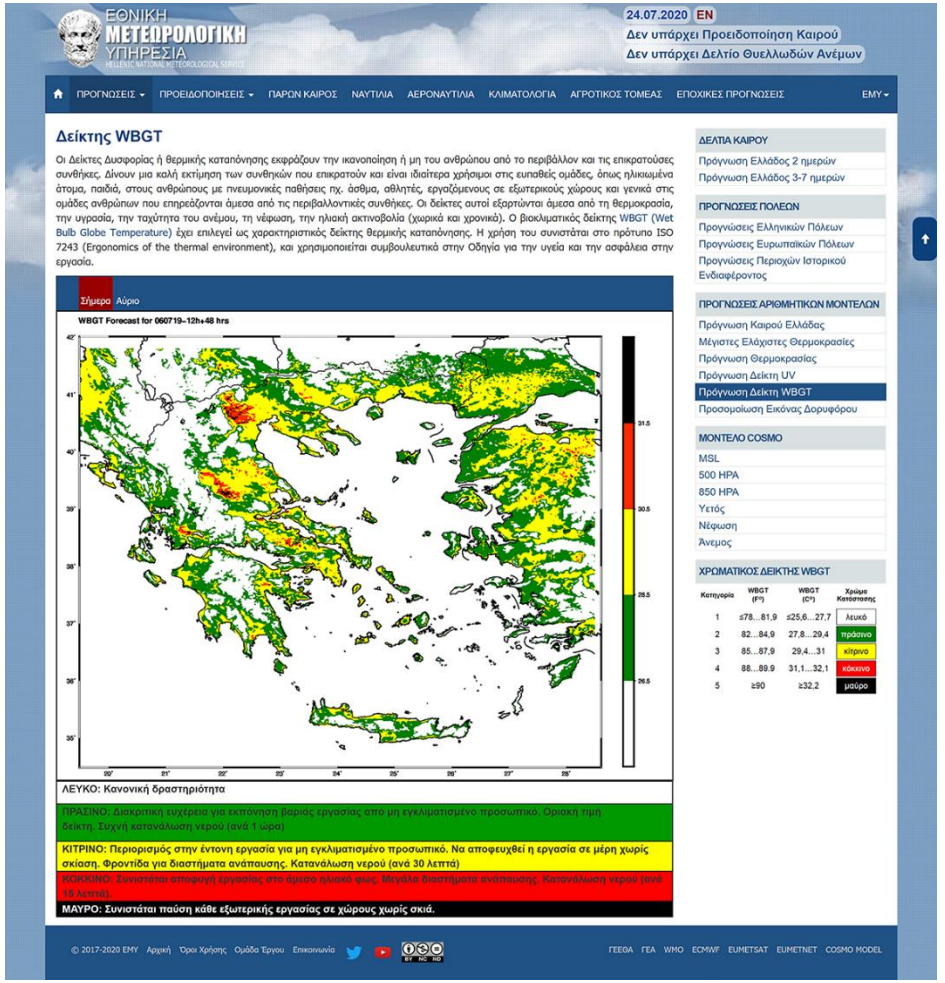
Ioannou et al., under review, Temperature

IMPROVING OCCUPATIONAL HEAT STRESS ASSESSMENT

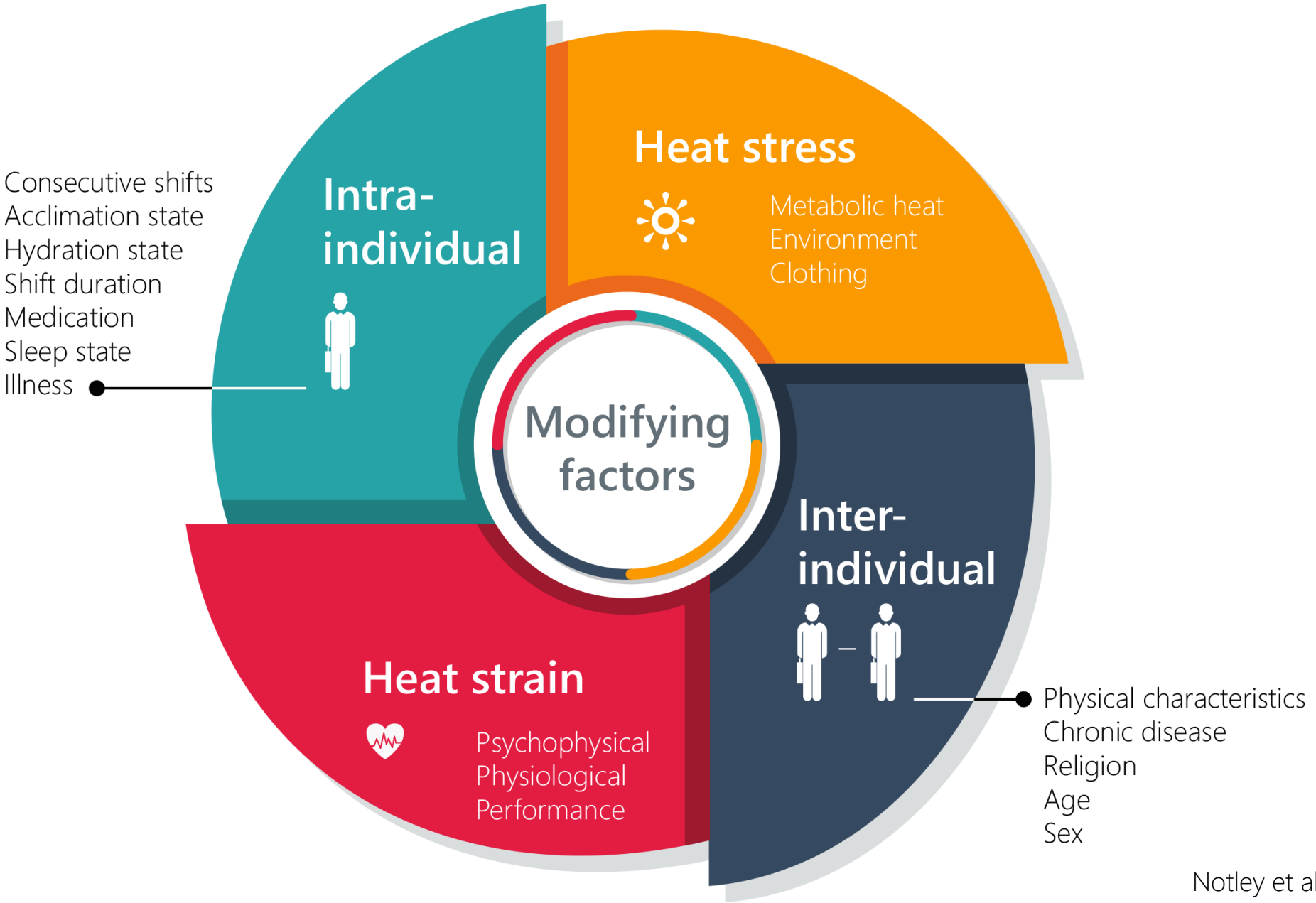
- Wet-Bulb Globe Temperature (**WBGT**) ---> largest evidence base for use in occupational settings
- **Popularize adoption** of WBGT for work settings



From the webpage of the Greek National Weather Service



FACTORS DETERMINING RESPONSE TO HEAT



Notley et al. 2019, Am J Ind Med

ADDRESSING HEAT EFFECTS ON OCCUPATIONAL HEALTH

- Assess needs
  - hazards assessment
  - profile of the target population
  - background on the social context
- Gain support
  - identify and involve key actors that provide ongoing advice, support, networking
- Establish education objectives and content
  - identify specific learning objectives to create an activist workforce that will advocate effectively for a healthier work environment
- Select education methods
  - select methods based on objectives, content areas and the profile of the workforce
- Implementing an education program
  - carry out the plan
- Evaluate and follow up
  - allow lerners to judge the progress toward new knowledge, skills, attitudes or actions
  - allow educators to judge the effectiveness of the training and what has been accomplished

International Labour Organization

COLLABORATION WITH KEY ACTORS

- Workshops with industry and worker stakeholders
  - Florence, Italy
  - Athens, Greece
  - Tønder, Denmark
  - Nicosia, Cyprus
  - Ljubljana, Slovenia
  - Loughborough, UK
  - Madrid, Spain
- Supporting European Trade Union Confederation
- Supporting Global Heat Health Information Network
- Meetings/Workshops with policy makers
  - WHO, Geneva
  - Honk Kong, China
  - Wellington, New Zealand
  - Doha, Qatar
  - Athens, Greece

CONTRIBUTION TO WHO, UNFCCC, AND GHHIN

ADDRESSING HEAT EFFECTS ON OCCUPATIONAL HEALTH

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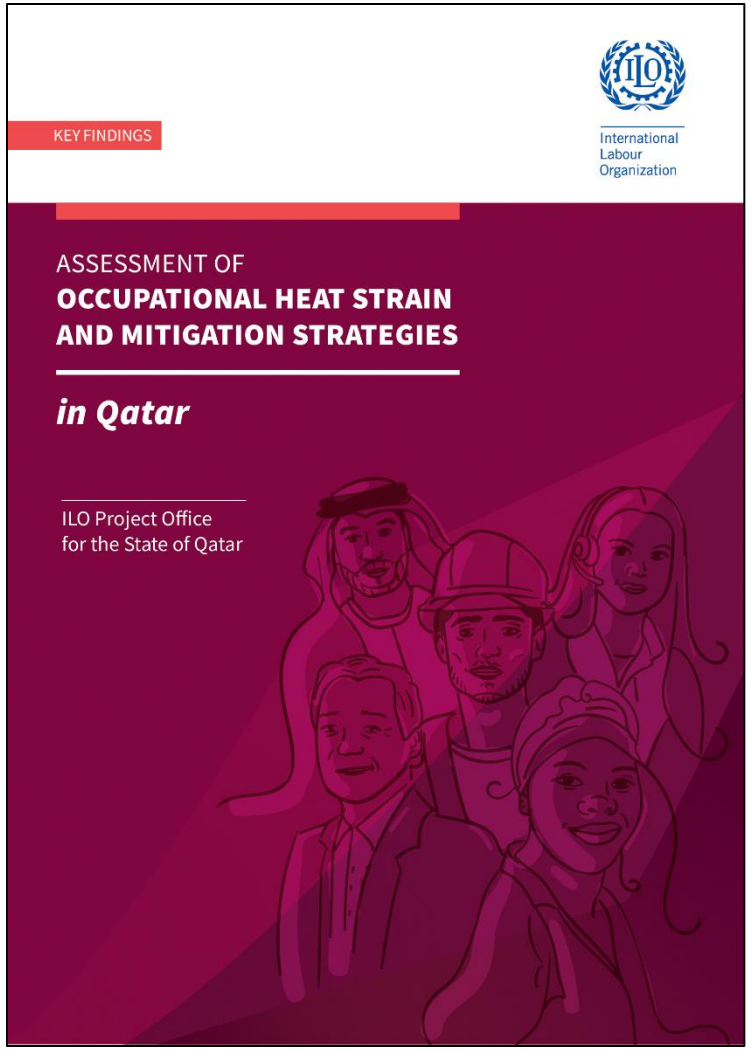
TECHNICAL REPORTS ON OCCUPATIONAL HEAT STRESS

Flouris et al., 2021



Flouris et al., 2019

WHO – WMO REPORT ON OCCUPATIONAL HEAT STRESS

- Technical report on occupational heat stress to be jointly published in 2021 by:

World Health Organization

WORLD METEOROLOGICAL ORGANIZATION

ADDRESSING HEAT EFFECTS ON OCCUPATIONAL HEALTH

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International Labour Organization

INFORMATION FOR WORKERS & EMPLOYERS

WORKING IN THE HEAT ?

Dehydration is a serious threat to your health

Hydration is about maintaining your body's water and electrolytes stores by ingesting fluid and salt to match the amounts you lose through sweating

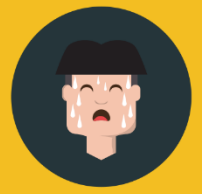
70%
OF EUROPEANS WORKING IN HIGH HEAT ARE DEHYDRATED

THIRST
DOES IT PROTECT ?
Thirst may not be sufficient to secure that you stay hydrated in hot conditions

WATER
AND SALT
Read these steps to secure adequate daily water and salt intake

HABITS
DAY-TO-DAY
It is not only about hydrating at work. Hydrating at home is equally important

BALANCE
Find your balance. Hydration needs vary from person to person



SWEAT LOSS
Your water needs may be high if you are a "heavy-sweater"

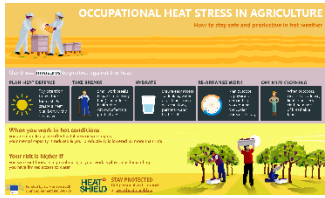
ELECTROLYTES
If your blood pressure is normal, extra salt to your meals may help

HEAT SHIELD

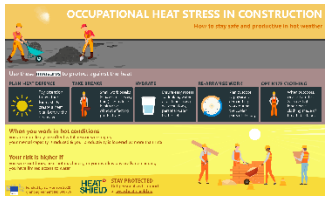
STAY PROTECTED
Get support personalized to your needs at www.heat-shield.eu

Funded by EU Horizon 2020 grant agreement No 668786

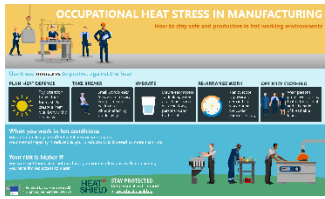
Agriculture



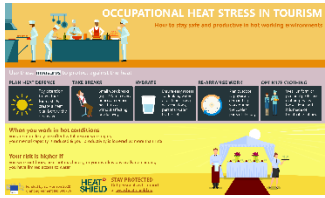
Construction



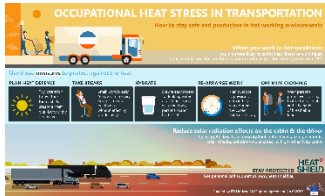
Manufacturing



Tourism



Transportation



INFORMATION FOR WORKERS, EMPLOYERS & OHS EXPERTS

HEAT AFFECTS YOUR HEALTH AND PRODUCTIVITY

HOT FACTs upon which you can ACT to minimize the detrimental effects on your organization's performance

ACCIDENTS - WORKERS' HEALTH - ORGANIZATION PERFORMANCE

Heat stress impairs physical and mental work capacity

Substantial productivity losses surpassing 15% on hot days

Heat increases work injuries, leads to accumulated fatigue & acute sickness

Frequent work in the heat causes chronic health hazards (e.g., doubled risk of kidney disease)

Request the development of a heat mitigation plan for your organization

Create a buddy system and take breaks (e.g., 2-5 min per hour) that protect health and maintain productivity

Ensure your work uniform is safe, comfortable, and made from breathable fabrics that reflect radiation

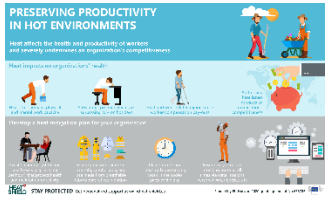
Plan outdoor and physically demanding work in the cooler parts of the day

Ensure easy access to drinking water at all times via water stations, personal water bottles, etc.

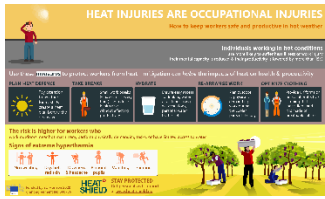
HEAT SHIELD **STAY PROTECTED** Get personalized support at www.heat-shield.eu

Funded by EU Horizon 2020 grant agreement No 668786

Employers

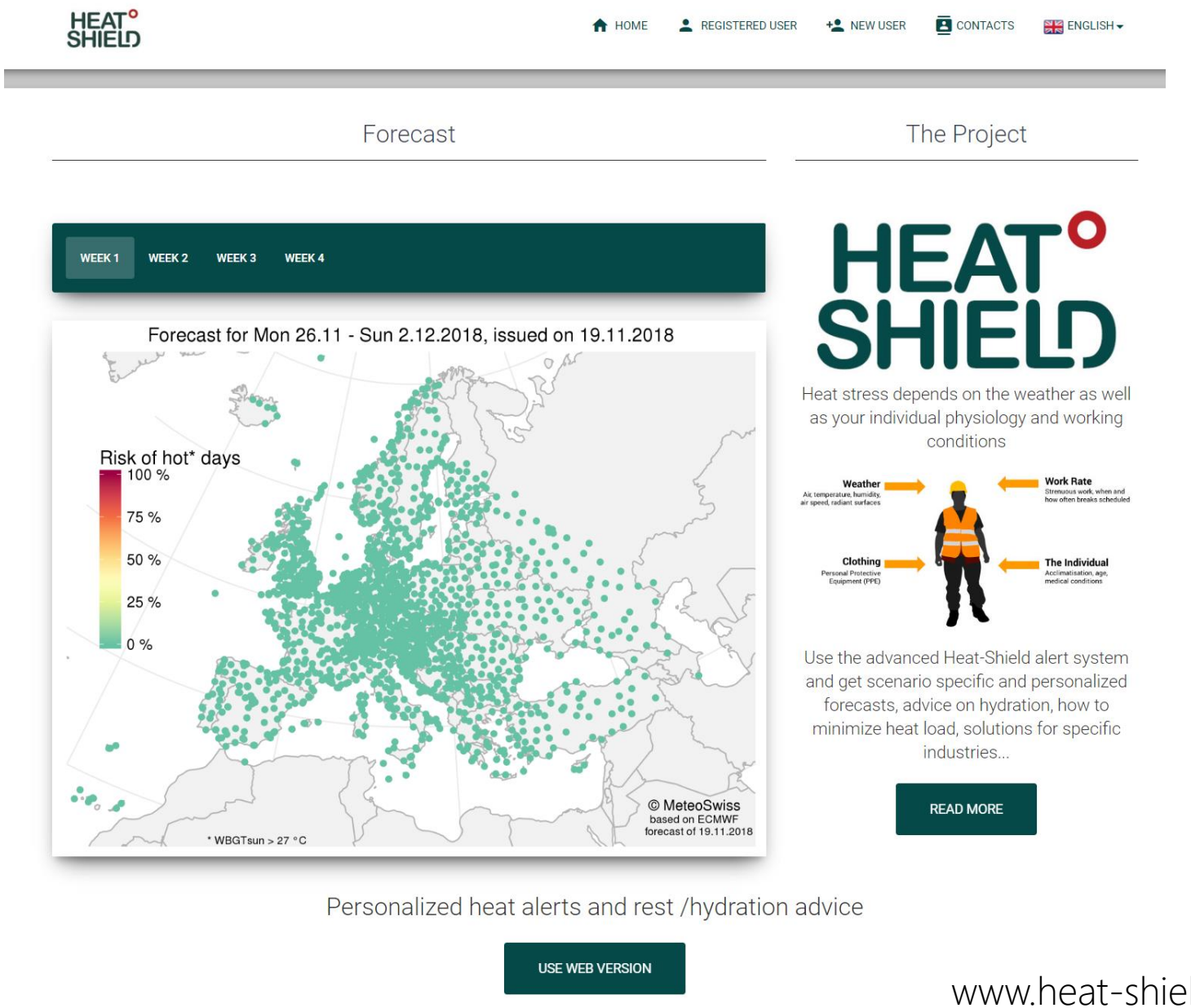


OHS experts



PERSONALIZED WARNING SYSTEM

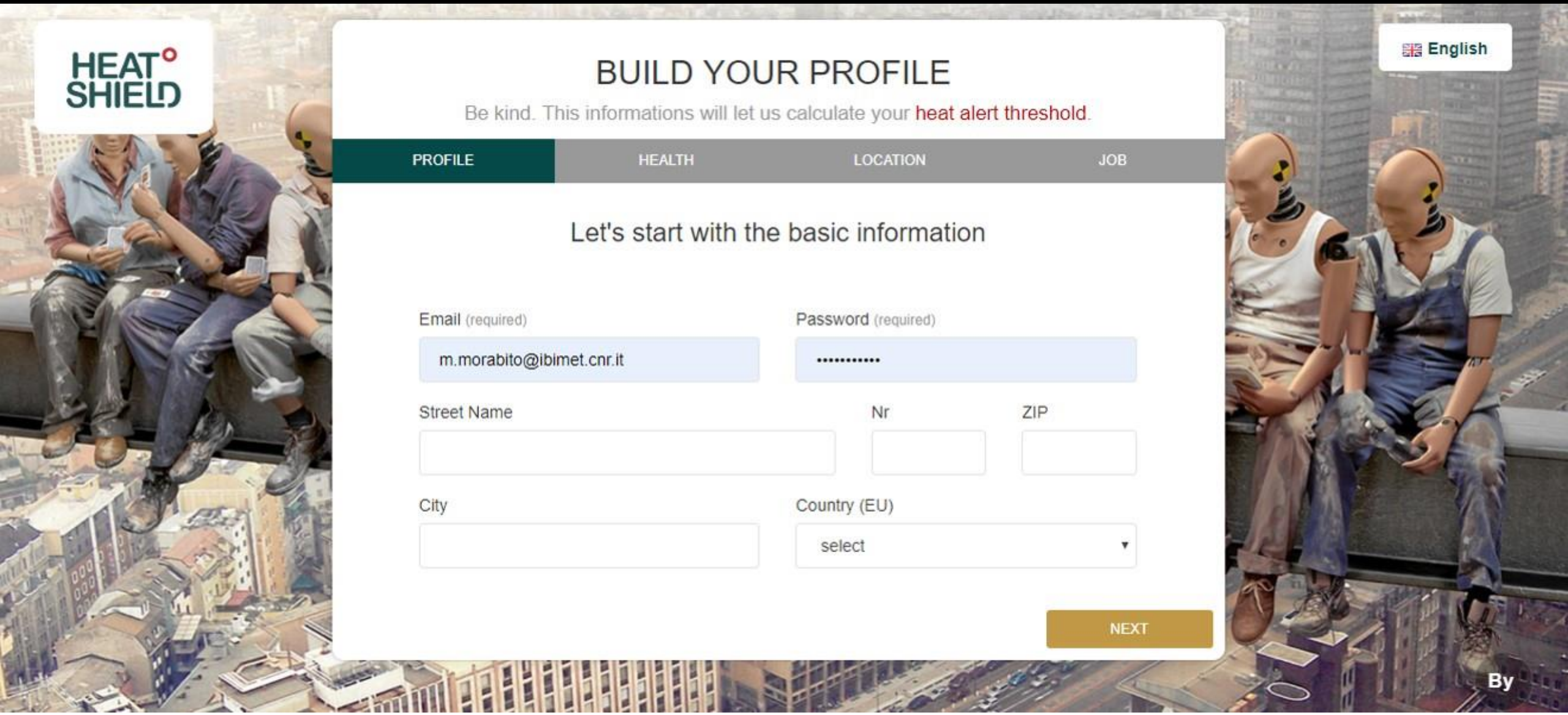
- Online platform providing forecasts and guidance **up to 30 days in advance**
- Designed for **workers** and **employers**



www.heat-shield.eu

PERSONALIZED WARNING SYSTEM

PERSONALIZED WARNING SYSTEM



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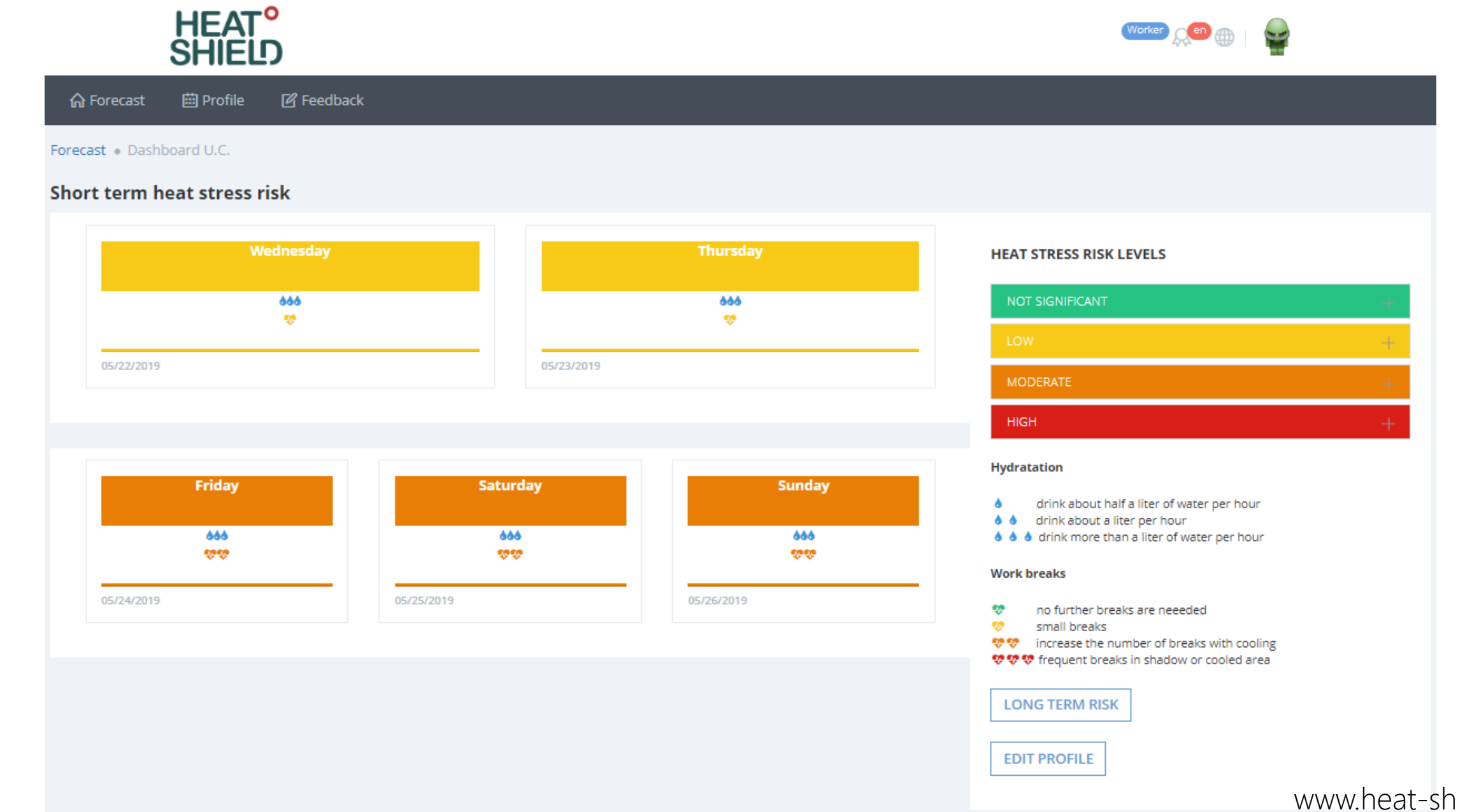

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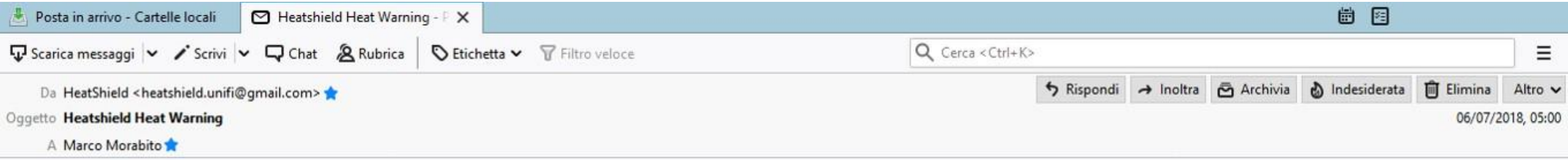

According to your profile's features, the heat stress threshold is expected to exceed in the next five days, in the area you selected

Please check the suggestions indicated in your profile

Heat Shield Staff

PERSONALIZED WARNING SYSTEM

HEAT SHIELD

Worker en

Forecast | Profile | Feedback

Forecast • Dashboard U.C.

Long term heat stress risk

Mon	Tue	Wed	Thu	Fri	Sat	Sun
05/27/2019	05/28/2019	05/29/2019	05/30/2019	05/31/2019	06/01/2019	06/02/2019
06/03/2019	06/04/2019	06/05/2019	06/06/2019	06/07/2019	06/08/2019	06/09/2019
06/10/2019	06/11/2019	06/12/2019	06/13/2019	06/14/2019	06/15/2019	06/16/2019
06/17/2019	06/18/2019	06/19/2019	06/20/2019	06/21/2019	06/22/2019	06/23/2019
06/24/2019	06/25/2019	06/26/2019	06/27/2019	06/28/2019	06/29/2019	06/30/2019
07/01/2019	07/02/2019					

HEAT STRESS RISK LEVELS

- NOT SIGNIFICANT
- LOW
- MODERATE
- HIGH

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OVERVIEW OF RESEARCH OUTPUT FROM THE HEAT-SHIELD PROJECT

Andreas D. Flouris

FAME Lab, University of Thessaly, Greece

Leonidas G. Ioannou,[1,2,3] Lydia Tsoutsoubi,[1,3] Paraskevi Gkiata,[1] Konstantinos Mantzios,[1] Maria Vliora,[1] Konstantinos Dallas,[1] Eleni Nintou,[1] Konstantina Poulianiti,[1] Giorgos Gkikas,[1] Gerasimos Agaliotis,[1] George Samoutis,[4] Lucka Kajfez Bogataj,[5] Marco Morabito,[6,7] Glen P. Kenny,[8] Igor Mekjavic,[9] George Havenith,[10] Chuansi Gao,[11] Tord Kjellstrom,[3] Lars Nybo[2]

[1]FAME Laboratory, School of Exercise Science, University of Thessaly, Greece
[2]Department of Nutrition, Exercise and Sports, August Krogh Building, University of Copenhagen, Denmark
[3]Centre for Technology Research and Innovation (CETRI), Limassol, Cyprus
[4]Medical School, University of Nicosia, Nicosia, Cyprus
[5]Biotehnical Faculty, University of Ljubljana, Slovenia
[6]Institute of Biometeorology, National Research Council, 50145 Florence, Italy
[7]Centre of Bioclimatology, University of Florence, 50121 Florence, Italy
[8]Human and Environmental Physiology Research Unit, School of Human Kinetics, University of Ottawa, Ottawa, ON, Canada
[9]Environmental Ergonomics Research Centre, Loughborough Design School, Loughborough University, Loughborough, United Kingdom
[10]Jozef Stefan Institute, Ljubljana, Slovenia
[10]Thermal Environment Laboratory, Department of Design Sciences, Faculty of Engineering, Lund University, Lund, Sweden