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Health and Environment International Trust
Mapua, Nelson, New Zealand

In collaboration with:
United Nations University, International Institute of Global Health, Kuala Lumpur, Malaysia
and
Lund University, Umea University, Sweden
Australian National University, Australia
University College London, United Kingdom
Nelson-Marlborough Institute of Technology, New Zealand

Technical report 2014:1

Hothaps Program Update,

June 2014 :

Progress report on a program for assessment and prevention of impacts of climate conditions and climate change on working people

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THE "Hothaps" Program Update, June, 2014

Hothaps = High Occupational Temperature: Health and Productivity Suppression

Aims

This program is designed to carry out and facilitate research and analysis on effects of heat exposure on working people (including gender aspects and effects on pregnant women and on children), to quantify climate change-related increases in workplace heat exposures and the impact this will have on human health and productivity in different locations around the world, and to identify feasible ways to prevent or reduce such exposures and effects. Impacts of increasing heat on health equity and associated links to economic development and human rights will also be assessed. The ultimate aim is to improve the understanding of the potential working life consequences of climate change and to promote effective prevention..

Overview

This program includes studies that:

- Develop better methods for assessing human heat exposure and heat stress using a variety of heat stress indexes
- Measure and model current and future heat exposures in different parts of the world
- Describe the history and local cultural aspects of heat impacts on working people
- Link to other bio-meteorological research on the biological mechanisms and clinical consequences of heat exposure.
- Test methods to measure effects of heat on human health and performance (particularly physical activity and work capacity)
- Apply such methods in Hothaps field studies in different parts of the world, focusing on workplaces in already hot locations (includes heat waves and continuous hot climates)
- Quantify the exposure-response relationships for direct heat effects and other workplace related effects of climate conditions
- Analyse the age- and gender-specific impacts of heat stress, including studies of pregnant women, working children, school children, elderly workers and other vulnerable groups
- Use climate change model outputs from internationally agreed models to estimate future trends of heat and cold exposures and the likely impacts on health and human performance of working people at local, national, regional and global level (using globally gridded data)
- Estimate the "burden of disease and injury" due to heat exposure
- Estimate the social and economic consequences of these Hothaps impacts

The Hothaps program welcomes independent research and analysis on any of these topics as it is not "possessive" of its' methods and results. The emerging evidence about the "Hothaps effect" is a "public good" that should be shared freely in order to facilitate and encourage preventive actions in any location. Background information, analysis methods and Hothaps study results will be provided and regularly updated on the website www.ClimateCHIP.org and on websites of the collaborating institutions.

Background

The recent global assessment of climate change impacts on human health has, however, brought the broader health and well-being impacts of heat on working people to a higher visibility (IPCC, 2014). The increasing *heat exposure* due to climate change during the hottest parts of the day in the hottest seasons will affect the productivity of people who have to work in the ambient climate, and the impacts on economic output is likely to be very large (DARA, 2012). In many tropical and sub-tropical countries the loss of labor productivity due to workplace heat will increase by billions of US dollars each year (DARA, 2012). Workplace heat will affect outdoor workers and many indoor workers in factories or other workplaces (even offices) without air conditioning (ISO, 1989; Parsons, 2014). Because physical work activities add surplus heat production inside the human body to the accumulated heat load, *heat stress* becomes a particular problem for working people when heat exposure from outside the body is high. If the ambient air temperature is higher than 37 °C, heat transfer goes into the body, and only evaporation of sweat can reduce body heat (Parsons, 2014). However, such evaporation is less and less effective as the humidity level goes up, and at 100% relative humidity sweating continues but it creates no body heat loss via evaporation.

Because of these well known physiological conditions, working people in non-cooled workplace environments are particularly vulnerable to *heat strain* in the form of clinical health effects or reduced physical performance (includes work capacity or productivity) as climate change causes temperatures to increase in most areas of the world (Kjellstrom et al., 2009a; Kjellstrom et al., 2013). The Hothaps program was designed and started to meet the need for analysis of increasing heat exposure as a problem in different parts of the world, and to identify effective heat prevention methods that can be integrated into future developments of working environments (indoors and outdoors) in agriculture, construction, manufacturing and services (Kjellstrom et al., 2009b; Kjellstrom et al., 2014). Heat is of course also a problem for clinical health effects, including heat wave mortality, which are described and quantified in a number of studies and reviews (e.g. McMichael et al., 1996, 2003; Costello et al., 2009). The heat effects on daily activities, work tasks and leisure sports are however generally ignored (as they are not considered "health effects") and the Hothaps program is aiming at filling the evidence gap.

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*Kjellstrom T, Lemke B, Otto M (2013) Mapping occupational heat exposure and effects in South-East Asia: Ongoing time trends 1980-2009 and future estimates to 2050. Indust Health 51: 56-67.

*Kjellstrom et al., (2014) Climate change impact on Occupational heat stress and related health and productivity effects. Technical report (in press on www.ClimateCHIP.org).

*Parsons K.(2014) Human thermal environments. The effects of hot, moderate and cold temperatures on human health, comfort and performance.3rd edition. London: Taylor & Francis; 2014.

Program development

The program started in 2008 and the progress and outputs have been presented in more than 90 publications (see Appendix). Further work is needed before it can be fully integrated into comprehensive assessments of the human health and well-being impacts of climate conditions and climate change. From the outset, method descriptions, guidance materials and proposed research protocols for Hothaps have been made freely available. This has stimulated new studies in different parts of the world. A website with relevant information and a Hothaps-Soft database and software have been developed (see: www.ClimateCHIP.org).

The program was initiated by the research group Health and Environment International Trust, Ltd, in New Zealand, and has received significant financial (via research grants) and other support during the first years of development from Australian National University, National Centre for Epidemiology and Population Health (NCEPH), Canberra, Australia (ANU), Umea University, Centre for Global Health Research, Umea, Sweden (UMU), University College London, Institute for Global Health, London, United Kingdom, and University of Tromso, Centre for International Health, Tromso, Norway. Links have also been made with Wellington School of Medicine and Health Sciences, University of Otago, Wellington, New Zealand, the Nelson-Marlborough Institute of Technology, Nelson, New Zealand, and a number of academic units in tropical cooperating countries.

In 2014 Hothaps was made a key component of the Environmental Health program of the United Nations University International Institute of Global Health (IIGH), Kuala Lumpur, Malaysia. It is also an important part of the interdisciplinary project on HEAT at the Pufendorf Institute, Lund University, Lund, Sweden. It contributes to the AVOID2 program at University of East Anglia, Norwich, United Kingdom, and the climate change and health research program at University of Wisconsin, Global Health Institute, Madison, Wisconsin, USA.

The program was developed by Professor Tord Kjellstrom who has been:

- Director, Office of Global and Integrated Environmental Health, WHO, Geneva, 1985-1997
- Professor of Environmental Health, University of Auckland, 1998-2002
- Director, Health and Environment International Trust, Mapua, New Zealand, 2000 - .....
- Visiting Fellow, Professor, ANU, NCEPH, Australia, 2002 - .....
- Senior Professor, Umeå University, Sweden, 2010-2013
- Honorary Professor, University College London, 2011 –
- Visiting Professor, United Nations University, IIGH, Malaysia, 2014 –
- Visiting Research Fellow, Lund University, Sweden, 2014 -

The **research team in New Zealand** includes: Tord Kjellstrom; and Bruno Lemke and Matthias Otto, Nelson-Marlborough Institute of Technology; Olivia Hyatt, Chris Freyberg, Dave Briggs, Anna Crosbie, Carolyn Hughes and Adrienne Taylor, consultant researchers, New Zealand

During the development the program has benefitted from important scientific and other input from a number of experienced scientist including:

Tony McMichael, Liz Hanna, Keith Dear, *National Centre for Epidemiology and Population Health, Australian National University*, **Australia**
Peter Byass, Rainer Sauerborn, Drs Joacim Rocklov, Maria Nilsson, Rebekah Lucas, *Centre for Global Health Research, Umeå University*, **Sweden**
Jon Oyvind Odland, *International Health, University of Tromsö*, **Norway**

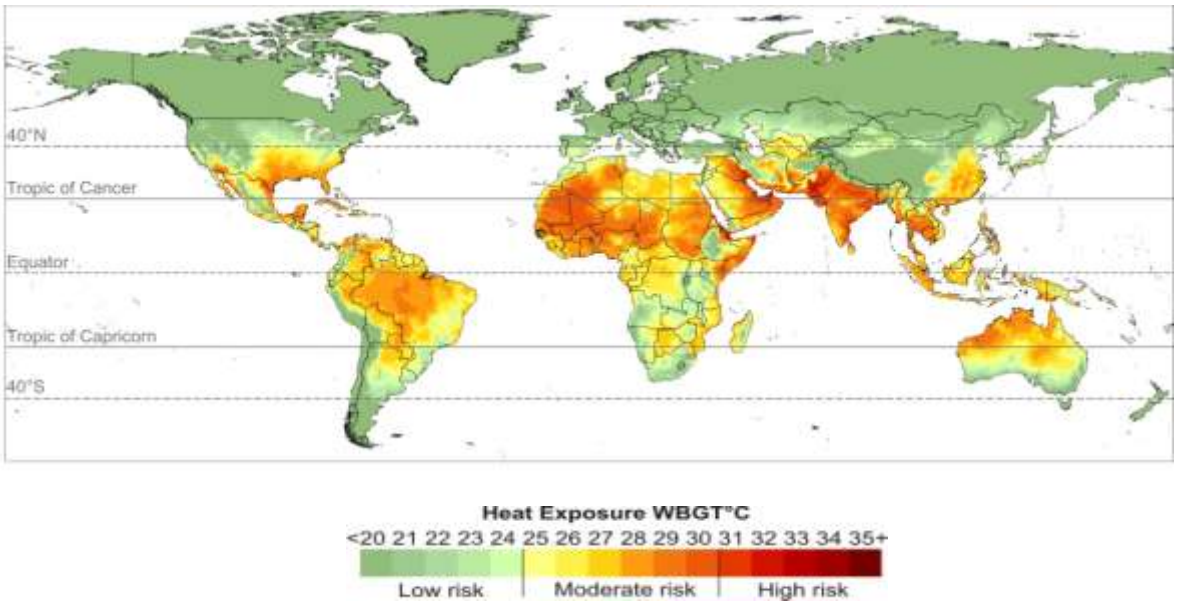
Anthony Costello, Michael Davies, Anna Mavrogianni, *University College London,* **United Kingdom**
Kalev Kuklane, Ingvar Holmer, Maria Albin, Kristina Jakobsson, *Lund University*, **Sweden**
Hannu Rintamaki, *Finnish Institute of Occupational Health*, **Finland**
Ken Parsons, *Loughborough University*, **United Kingdom**
Shin-ichi Sawada, *National Institute of Occupational Health,* **Japan**
Martin Manning, Ralph Chapman, *Victoria University*, **New Zealand**
Philippa Howden-Chapman, *Otago University*, **New Zealand**
Marc Schenker, *University of California, Davis*, **USA**

In addition, there are a number of scientists from specific countries who have been active contributors in published work to date. These include:
Juma Rahmna, **Bangladesh**, Jennifer Crowe, **Costa Rica,** Luis Blanco, **Nicaragua**
Ramon Antonio Garcia-Trabanino, **El Salvador** Hildaura A de Patino and Anabel Tatis, **Panama**
Angie Mathee, Joy Oba, Mark Collinson, Stephen Tollman, Jonny Myers, **South Africa**
Leonie Dapi, **Cameroon** Ahmed Balogun, **Nigeria**
Vidhya Venugopal, Pranab Nag, Anjira Nag, Kalpana Balakrishnan, Sushil K Dash, Subhashis Sahu, Wasundhara Joshi, **India**
Bandana Pradhan, **Nepal** Keith Dear, **China**
Benjawan Tawatsupa, Uma Langkulsen, Nuntavarn Vichit-Vadakan, Sasitorn Taptagaporn,**Thailand**
Nguyen Bich Diep, Duong Khanh Van, Nguyen Thu Ha, **Vietnam**
Steve Sherwood, Peng Bi, **Australia**
Sudhvir Singh, Alistair Woodward, Simon Hales, **New Zealand**
Marc Schenker, Jonathan Patz, Thoams Bernard, **USA** Christer Hogstedt, **Sweden**
….. *additional people have provided unpublished Hothaps input*

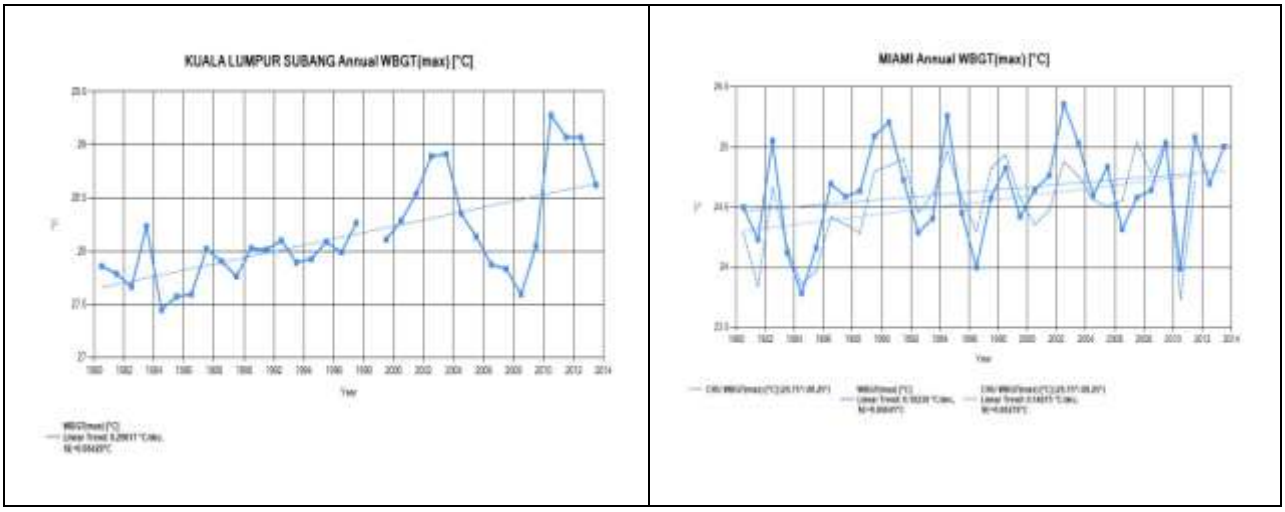
Descriptions of current and likely future workplace heat exposure around the world

Hothaps has accumulated grid cell (0.5 x 0.5 degrees) data for the whole world on monthly climate variables, which can be used to calculate the occupational heat stress index WBGT (Wet Bulb Globe Temperature), or any other heat index, in any part of the world and any month. The map below shows the example of 30-year average (1980-2009) of monthly average WBGT in the afternoons indoors or in full shade for the hottest month in each part of the world (e.g. hottest summer days are August in the USA and Egypt; April in India; January in Australia).

The seven hottest days each month can be estimated at 2-3 °C higher levels than those in the map, and the three hottest days may be up to 5 °C hotter than the levels in the map. The WBGT heat level outdoors in the sun in the afternoons is usually 2-3 °C hotter than the indoor or full shade values. It is clear that moderate or high risk of heat stress in outdoor or non-cooled indoor environments is an important problem for many countries in the tropical and sub-tropical zones. The Hothaps website www.ClimateCHIP.org includes heat analysis tools for this type of gridded data available for each place on Earth. This map was included in the IPCC (2014) health impact chapter. The heat exposure intensity scale below the map (shown as different colors on the map) is based on the international standard for prevention of workplace heat effects (ISO, 1989). When WBGT reaches 25 or 26 °C, the heat stress on people carrying out very intensive labor is so high that frequent rest periods are recommended. The higher the WBGT, the more rest is needed.



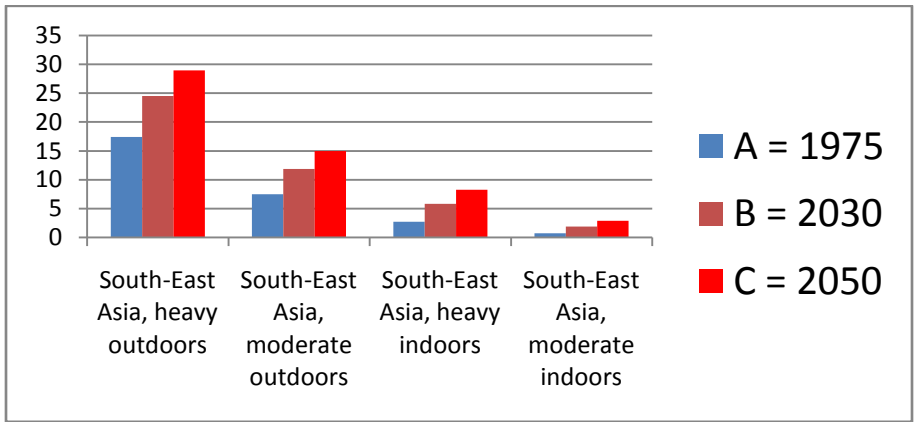
Another Hothaps analysis tool is the Hothaps-Soft software and database with daily data from thousands of weather stations around the world. In a few seconds the actual measured climate data as well as calculated WBGT, UTCI (Universal Thermal Climate Index), and other heat stress relevant variables can be presented in graphics like the two below for the airports in Kuala Lumpur (Malaysia) and Miami (USA). The time trends for 1980-2013 can be calculated and data for the same grid cell (CRU = Climate Research Unit) as where the weather station is located can be shown (as shown for Miami below). The annual trends for average WBGTmax (afternoon values) are 0.3 °C per decade in Kuala Lumpur and 0.1 – 0.15 °C per decade in Miami.



The ongoing work for Hothaps will include calculations from risk functions of different health effects of climate conditions as well as the potentially related social and economic impacts. The resulting "Heat exposure health impact assessments" can also be presented as maps and trend graphs. The maps and graphics tools are made available for local analysis, and they will create new opportunities for health

authorities, educational institutions (including high schools), and other interested organizations to make their own analysis and develop training and information on local climate change impacts on health and well-being.

This analysis makes it possible also to estimate the percentage of annual daylight work hours lost because it is too hot to work, indicating the work capacity and labor productivity loss (as for SE Asia below, included in a recent report, Kjellstrom et al., 2014).



The work capacity loss and health impact data can also be presented in maps and the website www.ClimateCHIP.org makes it possible to zoom in directly on specific sites.

Completed Hothaps activities

Methods development for heat stress indicators measurement and calculation

- Publication of initial risk assessment based on reviews of available reports
- Field studies and reports from Taiwan, Thailand, India, Vietnam, Australia, New Zealand, Nigeria, Cameroon, South Africa, Costa Rica, and Nicaragua.
- Development of heat mapping methods and publications for selected regions, including Africa and South-East Asia
- Development of Hothaps-Soft software and database for local heat analysis
- Downloading of RCP modeled data by 0.5 x 0.5 degree grid cells
- Estimating global and regional impact of heat on working people, health and social effects, and economic outcomes as a part of the Comparative Risk Assessment carried out for the WHO global impact analysis
- Establishing the website www.ClimateCHIP.org for information and sharing of tools, data and new analysis

Ongoing Hothaps activities

- Special studies of heat stress and prevention in India, and communication and promotion of results (funded by Sida, Sweden)
- Field studies of core body temperature increase in young working women due to ambient heat and continuous physically active work in order to assess risk for impacts on pregnancy (United Nations University)

- Nationwide study of workers in Australia, including dehydration analysis (funded by NHMRC, Australia)
- Heat effects on agricultural workers in California (funded by NIOSH, USA)
- Publication of reports on Hothaps-Soft software development and other methods development
- Global mapping of heat stress and cold stress, and health risks and productivity losses, as well as links to air conditioning use
- Cooperation with Central American and USA scientists in assessing chronic kidney disease epidemic and its relationship to heat exposure and dehydration
- Analysis of architectural design and urban design impacts on local heat exposures in buildings
- Further development of ClimateCHIP website
- Producing ClimateCHIPs (Climate Change Health Impacts and Prevention profiles) for selected countries and regions.
- Analyzing the economic impacts of different climate change effects on health and well-being
- Producing short notes for websites on Hothaps issues and the emerging research and analysis results.
- Facilitating inter-disciplinary cooperation via new links between climatologists, health scientists, social scientists, economists, architects/engineers, etc.
- Strengthening Hothaps networking and communication for climate change policy development at national and international level

Potential planned Hothaps activities

- Further field studies in countries (plans on track for Egypt, Ghana, Ethiopia, India, Nepal, Bangladesh, Thailand, China, Colombia, Brazil and USA)
- Effect of heat on agricultural workers productivity and impacts on local food production in low income areas
- Effects of indoor classroom heat on school children's learning ability
- Establishing heat and cold exposure response relationships and definition of a "Livable climate"
- Defining thresholds for need for cooling systems in residential and workplace buildings
- Identifying eco-friendly cooling systems for workplaces and schools
- Global mapping of need for air cooling in workplaces analyzing potential for renewable energy solutions

Appendix.

Publications list for Hothaps reports, 2000-2014 (Chronological order); updated to 25 June 2014.

Peer reviewed journal articles

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