Project WORKLIMATE

https://www.worklimate.it/

In-depth analysis and limits of the WORKLIMATE forecasting system

The prototype forecasting system developed as part of the WORKLIMATE experimental activity, in its current form, includes three sections of forecasts:

1. Heat risk forecast for different worker profiles
2. Forecast of heat risk based on the "anti-heat" ordinance in force in some Italian regions
3. Forecast of areas where a maximum daily temperature of 35 °C may be exceeded.

The first two types of forecast use an indicator widely used in the employment sector at an international level for an initial assessment (first screening) of heat stress. The chosen indicator, the Wet Bulb Globe Temperature (WBGT), come out from a review of the literature whose results are available in a "Report" which can be consulted on the project website in the "Publications" section (https://www .worklimate.it/first-report-of-activity-on-revision-of-heat-warning-systems-and-selection-of-indicators-to-be-used-to-evaluate-the-impact-on-workers /).

The empirical measure called the WBGT (UNI EN ISO 7243:2017) was developed in the 1950s to monitor heat stress in US military training facilities. Later applications have made it possible to broaden its application, accounting for essential elements in the field of work, like personal protective equipment, in addition to the subject's degree of acclimation and the activity level (metabolic rate).
To date it represents the most common thermal stress indicator used in working environments to ensure that a worker's average body temperature does not exceed 38°C. .. The Physical Agents Portal (PAF) website (https://www.portaleagentifisici.it/fo_microclima_metodiche.php?lg=IT) has a thorough explanation of the indicator.

The WBGT was also chosen as an indicator in the prototype forecasting system (probabilistic forecasts with low spatial resolution and without any intra-day detail) dedicated to the employment sector, developed within the European project (H2020) HEAT-SHIELD (https ://www.heat-shield.eu/).

The WORKLIMATE forecasting prototype forecasts is based on the input meteorological parameters of the deterministic model BOLAM (http://www.lamma.rete.toscana.it/modelli/atmo/bolam-e-moloch-info-sui-modelli). The mesoscale model, which is a geographical dimension of meteorological systems that is between the synoptic scale and the microscale, was initially based on the global GFS (Global Forecasting System) model. It has an hourly temporal resolution with 120 hours and a spatial resolution of 7 km.

Higher resolution models were available, but for this phase and the first two forecast types created in WORKLIMATE, the BOLAM model was chosen because it offered a reasonable balance between a reasonably accurate forecast and comparatively easier operational chain management—a crucial component in this phase of chain testing. You may access the publication at https://www.mdpi.com/1660-4601/18/18/9940 for more information.

However, it should be remembered that weather forecasts (even more those automatic from meteorological models) are always affected, by their nature, by an intrinsic uncertainty and can be significantly different from the actual conditions observed; therefore the information obtained can be only considered as a support tool for the implementation of prevention and safety measures in the various operational contexts, to be provide during the risk assessment pursuant to the Legislative Decree. 81/08, which cannot ignore direct observation in the workplace.

A number of variables can affect the forecasts' uncertainty, including the quality (correspondence to real conditions) of the data used to initialise the mesoscale model ("initial conditions" derived from global models), the territory's characteristics, the weather, the season, the model's spatial resolution, the meteorological parameter, etc. The earth's surface and the atmosphere, which are both divided into more or less numerous vertical levels, are simplified in meteorological models. The earth's surface is further divided into grid points, which are regular points whose distances represent the horizontal resolution of the model (for example, in the case of a model with 7 km resolution, these points will be 7 km apart from each other). The spatial resolution directly influences the correct representation of surface characteristics such as the orography and morphology of the territory (altitude, coastline, etc.) or the use and characteristics of the land (forest use, agricultural use, urban use, soil humidity, type of soil, etc.) and as a result also the meteorological variables (temperature, wind, humidity, etc.)

Even though all other sources of forecast error may still exist, the forecast will be more accurate in describing the characteristics of the region if the spatial resolution is higher as well. Regardless of the model's resolution, events such as precipitation, winds, cloud cover, etc. that are not forecasted by the model may result in notable differences between the observed and forecasted values of other meteorological parameters on the ground (such as temperature, humidity, etc.); similarly, events that are forecasted by the model but do not occour may also cause these differences.

However, we have to consider that even in high resolution models (e.g. 2 km or or higher resolutions) the surface characteristics can never be as accurate as in reality; for example, in the case of altitude, in areas with complex orography the valleys will be at an altitude generally higher than the real one, while the mountains at a lower one, similar considerations on uncertainty can also be made for the other surface characteristics (also considering that land use and many soil characteristics are often described approximately, not updated and in any case averaged on the basis of horizontal resolution). The result is that, even in the case of a high-detail horizontal resolution, it will not be possible to predict the existence of local microclimates (in the context of the forecast for a given grid point the model does not allow you to distinguish if we are on a field, on a roof of a building, on an asphalt square, etc.).

Referring back to the example of uncertainty in the altitude representation, it can generally result in an increase in the probability of potential underestimates, even large ones, in the expected temperatures and risk levels (as in many valley bottoms, for example) or overestimates (as in some mountains, for example). Under some conditions, we may experience the opposite, with overestimations of the temperature in the deep valley, such as during temperature inversions, which are typical phenomenon of the winter season.

The problem described above is highlighted by observing the following figure (Fig. 1).

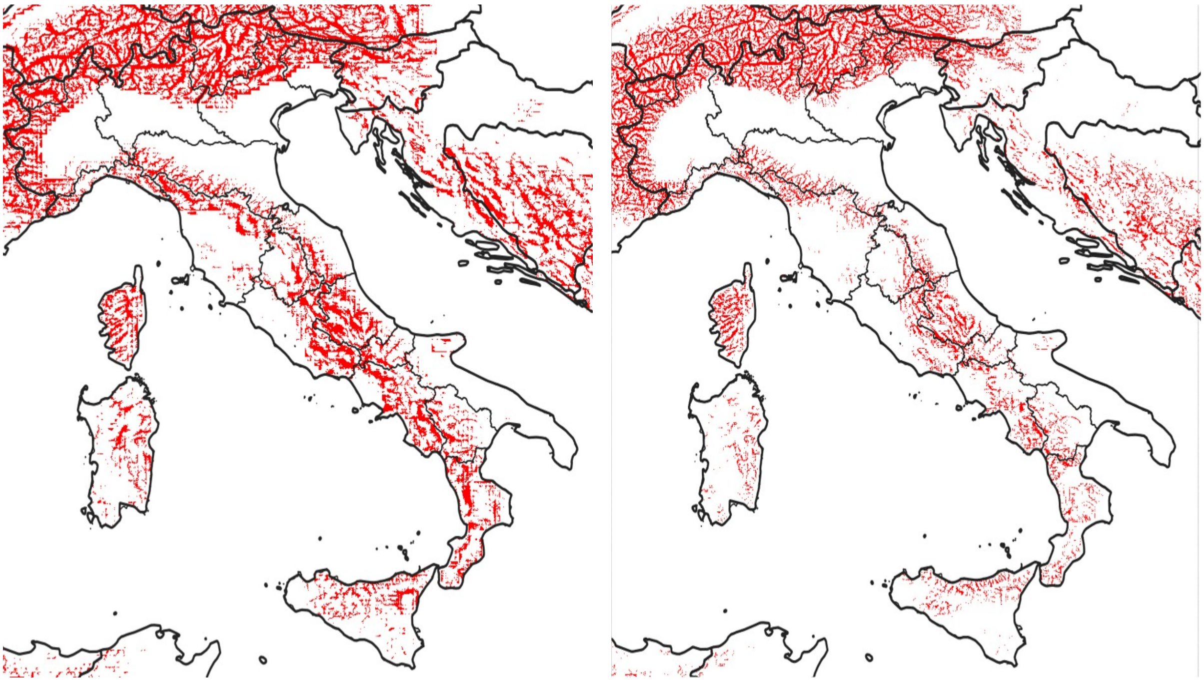

Figure 1: Difference in altitude between the DEM (Digital Elevation Model) of the BOLAM (7 km) and MOLOCH (2.5 km) meteorological models and the DEM at 90 m resolution (https://portal.opentopography.org/raster?opentopoID =OTSRTM.042013.4326.1). The areas in which the difference in altitude is greater than 200 m are indicated in red, i.e. those areas for which the BOLAM and MOLOCH models consider an altitude at least 200 m higher than the real one.

The areas in red in Fig. 1 (mainly deep valley in areas with complex orography) represent the areas where the altitude of the model's DTM is at least 200 meters higher than that of the high resolution DTM (90 m).

It is quite evident that going from a model at 7 km to one at 2.5 km the red areas are less large, demonstrating how much the model's DTM becomes more faithful to the real orography. Similar maps could be developed for the areas where the model altitude is lower than the real one (mainly ridges and areas above a certain altitude).

Even a wrong orographic and morphological depiction of the coastline could result in an underestimation of the daytime heat risk close to the shore, particularly if the model grid point is located at the interface between land and water. When interpreting and assessing the risk in light of the other indicated uncertainties, these are the kinds of situations that need to be taken seriously.

The personalized risk calculation procedure used in the WORKLIMATE forecasting system starting from forecast meteorological data can be consulted in a 2019 publication (https://www.mdpi.com/1660-4601/16/16/2890). This phase can also be a source of further forecast uncertainty.

The standard worker profile (175 cm tall, 75 kg weight), who is not acclimated to the heat and engages in moderate to severe activities directly exposed to sunlight or shade, is used to customise the heat risk forecast. A typical worker doesn't wear personal protective equipment (PPE) or in any case wear clothing that does not cause a further increase in risk.
The percentage ratio between the forecasted WBGT and the above-discussed standard worker's customised WBGT defines the heat risk level forecast. The forecasted risk level will be null (green) if the forecasted WBGT is less than 80% of the personal customised WBGT; if it is between 80% and 100%, the heat risk level will be low (yellow). The heat risk level can be classified as moderate (between 100 and 120%, orange) or high (over 120%, red) if the forecasted WBGT exceeds the customised WBGT threshold.
Conditions classified as moderate or high heat risk involve WBGT values that are higher than the customized WBGT threshold and necessitate significant actions. These conditions will be taken into account in a preventive system designed to offer behavioural or organisational solutions to safeguard employees from the impacts of environmental heat.
It is crucial to keep in mind that even low heat risk conditions—which indicate

circumstances in which the forecast WBGT value is lower than the customized WBGT threshold—represent circumstances that should not be underestimated, particularly if they last for several hours or days or involve procedures that call for the use of bulky work clothes or waterproof personal protective equipment.
We must plan and execute ad hoc protective measures for workers who are thermally vulnerable, even in the presence of low risk areas (yellow areas).

Even the heat risk forecast provided on the basis of the "anti-heat" ordinance in force in some Italian regions is always based on the WBGT indicator calculated using the data provided by the BOLAM meteorological model. In this case the heat risk is calculated considering the situation expected at 12:00 based on the worker profile indicated in the regional ordinance, so this also in the case of a healthy worker (without individual conditions of thermal susceptibility), not acclimatised to the heat, exposed to sun at 12:00 and engaged in intense physical activity. Below are the regional "anti-heat" ordinances issued from 2021 based on the forecasts provided by the WORKLIMATE forecasting system:

- 2021
  - Regione Puglia, Ord. N. 182 del 26/06/2021
  - Regione Basilicata, Ord. N. 33 del 01/07/2021
  - Regione Calabria, Ord. N. 44 del 30/06/2021
  - Regione Molise, Ord. N. 38 del 29/06/2021
- 2022
  - Regione Puglia, Ord. N. 69 del 21/06/2022
  - Regione Basilicata, Ord. N. 28 del 23/06/2022
  - Regione Calabria, Ord. N. 11 del 13/07/2022
- 2023
  - Regione Puglia, Ord. N. 60 del 24/06/2023

- Regione Basilicata, Ord. 7 del 29/06/2023

An example of an "anti-heat" ordinance in force in 2023 in the Puglia region can be consulted at the following address (https://press.regione.puglia.it/documents/65725/0/ordine+258_caldo+agricoltura+2022_signed.pdf/ fba44af6-7ea2-3aab-8e2c-01a35eb6a7fa?t=1655813235905), while a project publication on health prevention policies for occupational exposure to heat implemented in Italy can be consulted at this address (https://oem.bmj. com/content/79/3/215).

The third section of the WORKLIMATE forecasting system prototype, therefore the forecast of the areas in which it is possible to exceed the maximum daily temperature of 35 °C, uses the forecast of the maximum daily air temperature forecasted on the basis of the MOLOCH meteorological model, with a 2.5 km resolution..

The legend of the three forecast maps (today, tomorrow and the day after tomorrow) indicates the possible exceeding (in red) or not exceeding (in white) of the maximum daily air temperature threshold of 35 °C. This information is provided in support of the joint INAIL-INPS press release (https://www.inps.it/content/dam/inps-site/it/scorporati/comunicati-stampa/ 2022/07/Allegati/3153_CS-Inps- Inail-.pdf) and which provides instructions for ordinary layoffs in the event of suspension or reduction of work activity due to high temperatures.

The WORKLIMATE forecasting system represents in this prototype phase a first orientation tool available to public health authorities and prevention operators: until today the prototype of the heat warning system that is available on the project website allows information to be displayed with a graphic detail at regional level and the extraction of some forecast information also at local (city) level. A Web App for the customized forecasting of various WORKLIMATE products is also being tested and is dedicated to the employment sector.