# Assessing health risks in Croatia for cases of severe weather via UTCI and PET

Ines Muić, Iris Odak Plenković, Lidija Srnec, Kristian Horvath
Croatian Meteorological and Hydrological Service

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## Motivation

- Relationship of humans to thermal component of atmospheric environment is self-evident
- Everybody's daily experience: thermal comfort, discomfort and its impacts to ones health
- With increase in frequency of extreme events it is imperative to perfect the warnins for dangerous weather for the public
- We are exploring the potential of the Universal Thermal Climate Index (UTCI) and Potential Equivalent Temperature (PET) as severe weather-related mortality indicators in Croatia

# UTCI - Universal Thermal Climate Index

- UTCI equivalent temperature for a given combination of **wind speed, radiation, humidity and air temperature** is the air temperature of the reference environment providing the same physiological response of reference person as the actual environment
- Calculated by multi-node model of human thermoregulation, integrated with an adaptive clothing model - model simulations costly and complex

# UTCI - Universal Thermal Climate Index

- UTCI values are expressed in °C, interpreted in categories of physiological stress (assesment scale)
- Applicable to human strain under a wide range of climatic condition
- Simplified regression function (Bröde et al., 2011) for operational use

# Assesment scale

| UTCI (℃) range | Stress category |
|---|---|
| Above +46 | Extreme heat stress |
| +38 to +46 | Very strong heat stress |
| +32 to +38 | Strong heat stress |
| +26 to +32 | Moderate heat stress |
| +9 to +26 | No thermal stress |
| +9 to 0 | Slight cold stress |
| 0 to −13 | Moderate cold stress |
| −13 to −27 | Strong cold stress |
| −27 to −40 | Very strong cold stress |
| Below −40 | Extreme cold stress |

# PET – Physiological Equivalent temperature

- PET is defined as the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed
- PET is based on the Munich Energy-balance Model for Individuals (MEMI), which models the thermal conditions of the human body in a physiologically relevant way
- PET values are expressed in °C, interpreted in categories of thermal comfort

# Assesment scale

| PET (°C) | Thermal perception | Grade of physiological stress |
|---|---|---|
| <4.1 | Very cold | Extreme cold stress |
| 4.1–8.0 | Cold | Strong cold stress |
| 8.1–13.0 | Cool | Moderate cold stress |
| 13.1–18.0 | Slightly cool | Slight cold stress |
| 18.1–23.0 | Comfortable | No thermal stress |
| 23.1–29.0 | Slightly warm | Slight heat stress |
| 29.1–35.0 | Warm | Moderate heat stress |
| 35.1–41.0 | Hot | Strong heat stress |
| >41.0 | Very hot | Extreme heat stress |

[a] Values hold only for an internal heat production of 80 W and a heat transfer resistance of clothing of 0.9 clo (after Matzarakis and Mayer 1996)

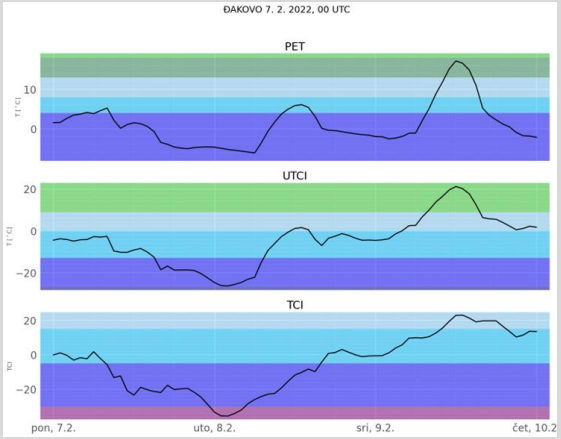
# Comparison of UTCI and PET forecasts over Croatian domain

- The meteorological data used for the calculation of UTCI - hourly model values of **air temperature**, **relative humidity**, **wind speed** and **mean radiant temperature** from **ALADIN-HR** (4 km, 73 levels, ALARO-1 phys.; CANARI+3D-Var with 3h cycle; 72h fcst.; LBCs: IFS-3h; 4 runs per day)

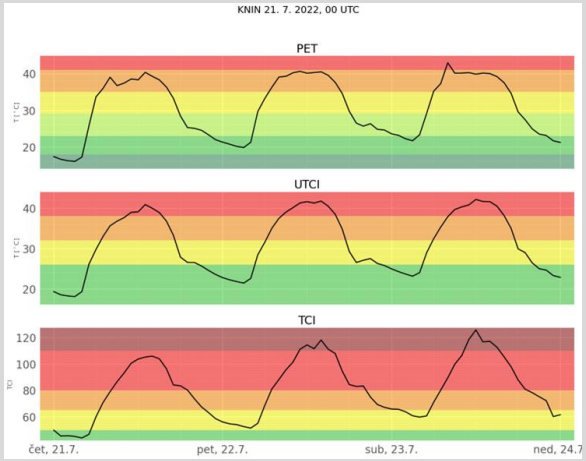
- Analysis of forecasted UTCI values for cases of strong local bora and jugo wind, heat wave and cold wave

- Comparison of heat stress/thermal comfort categories to which UTCI, PET and Thermal comfort index values correspond to shows good agreement between indices – UTCI is not in last coldest/hottest category when in comparison to PET and TCI for all cases

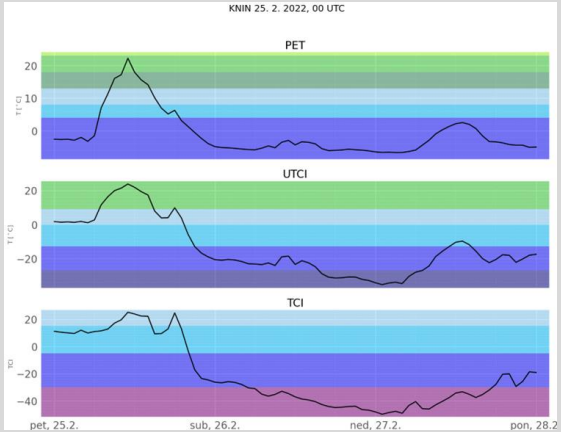
Cold wave
7.-9.2.2022.



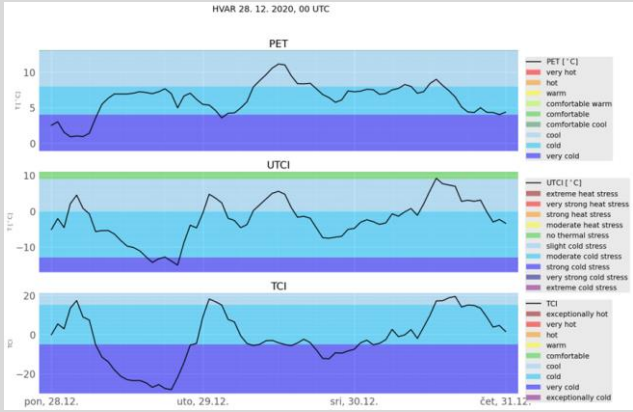

Heat wave
21.-23.7.2022.




Strong bora wind
25.-27.2.2022.




Moderate to strong jugo wind
28.-30.12.2020.



# UTCI and PET as inicators of increased mortality

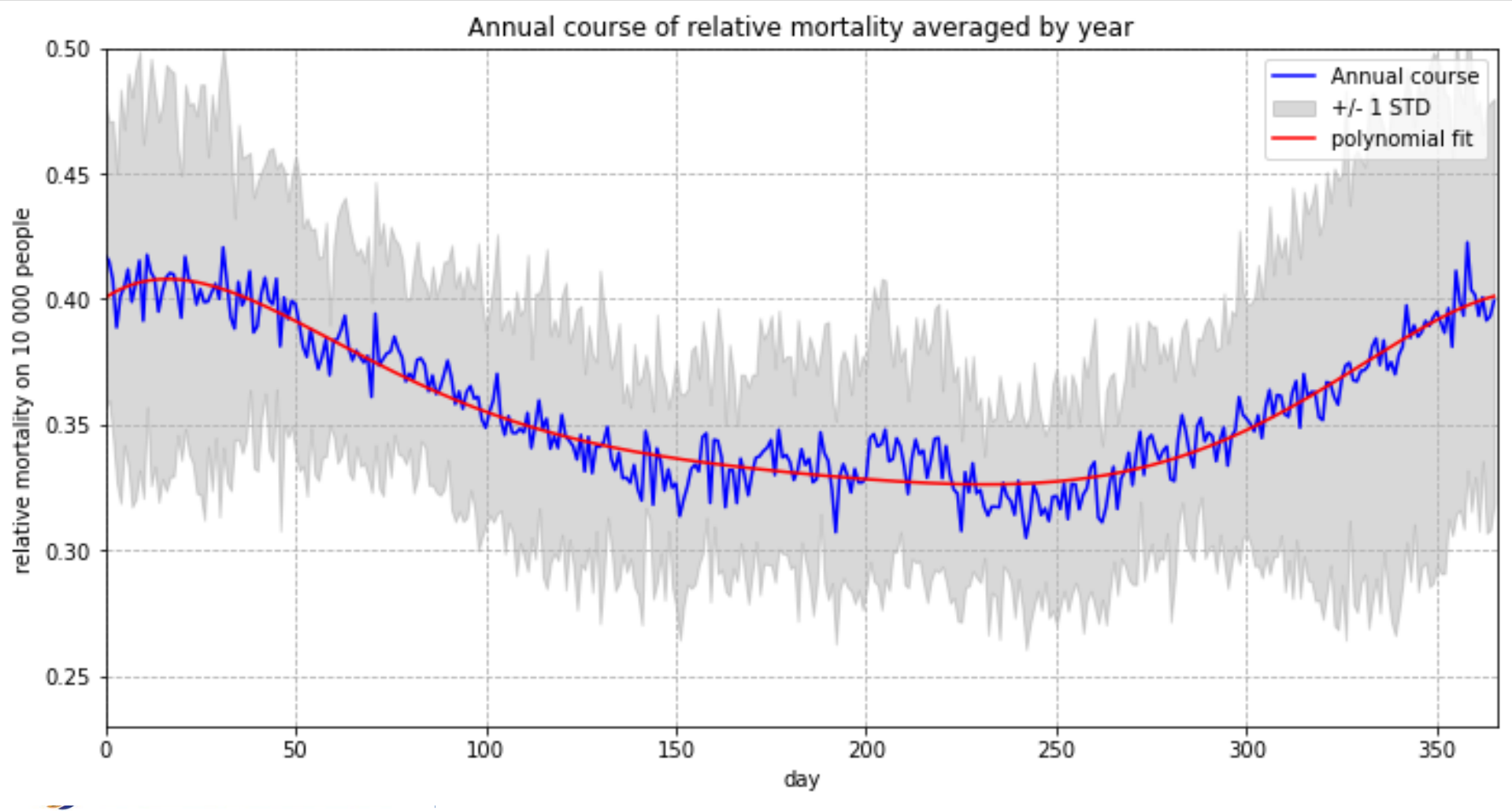
- The Croatian Public Authority for Health supplied us with mortality data for the time period 2006-2022.

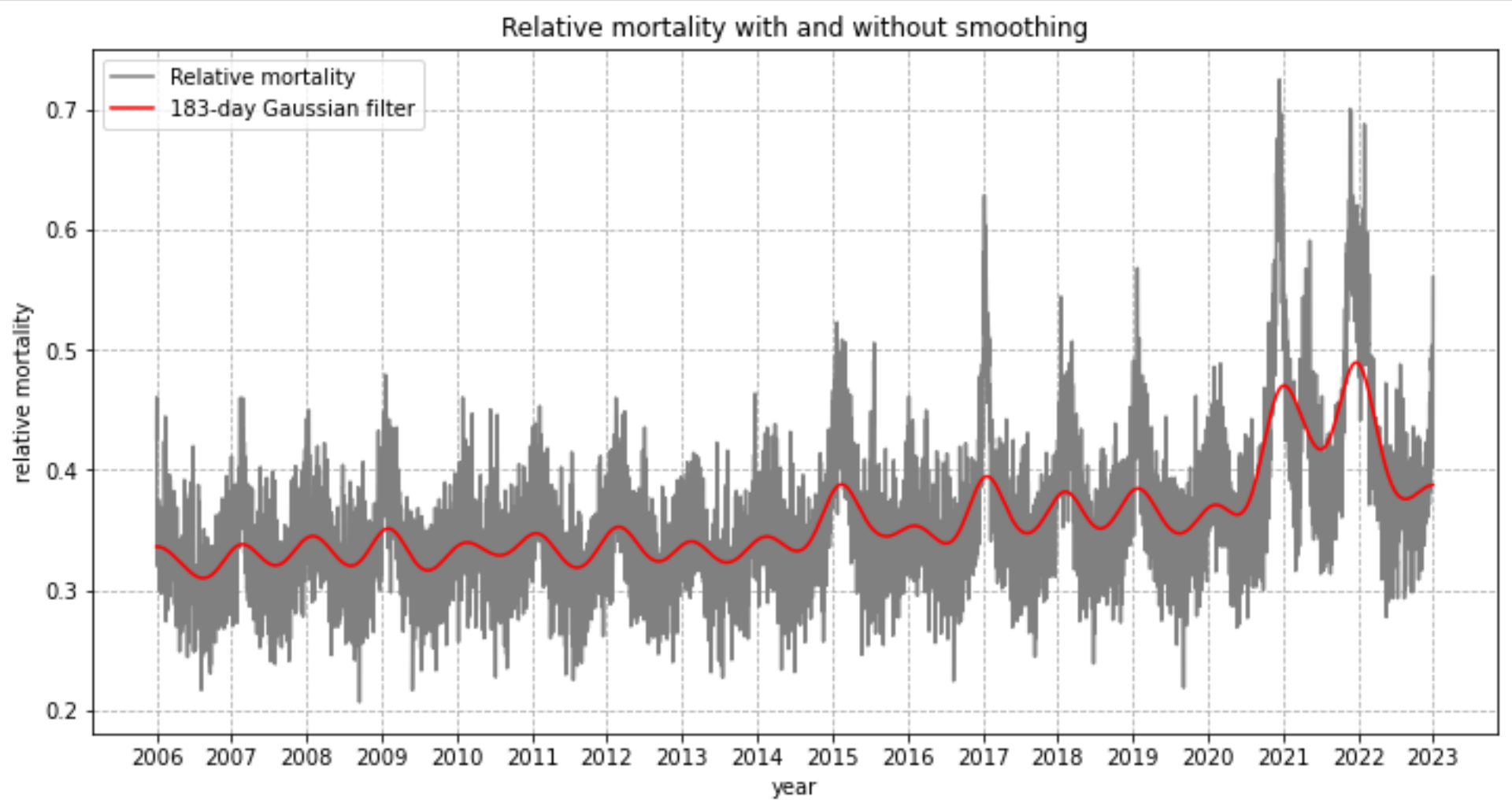
- For the same period, for continental, mountain and 2 maritime stations in Croatia UTCI and PET are calculated from measurements (air temperature, relative humidity, wind speed) -> exception is the mean radiant temperature which is estimated from the RayMan model from the measurements of global radiation, air temperature, and relative humidity – daily means of PET and UTCI were calculated

- We want to study the effects of cold and warm physiological stress on the population mortality

# UTCI and PET as inicators of increased mortality

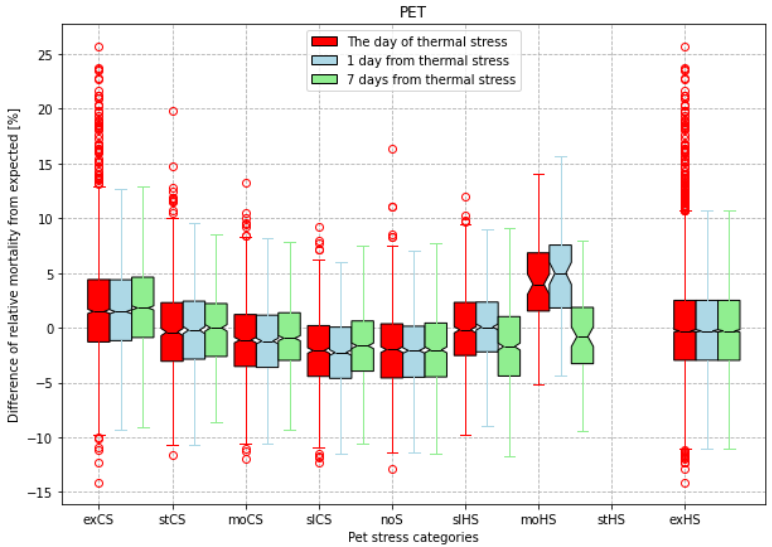
- We calculated relative mortality (by number of population), smoothed it with a Gauss filter (window size 183 day) which is used as an assessment of expected mortality.
- Annual course of relative mortality on 10 000 people show maximum in the cold part of year and minimum in the warm part of year
- The difference of relative mortality and expected mortality (ORSO for short) is then used in further analysis
- Difference in amplitude of expected relative mortality from year to year are noticed

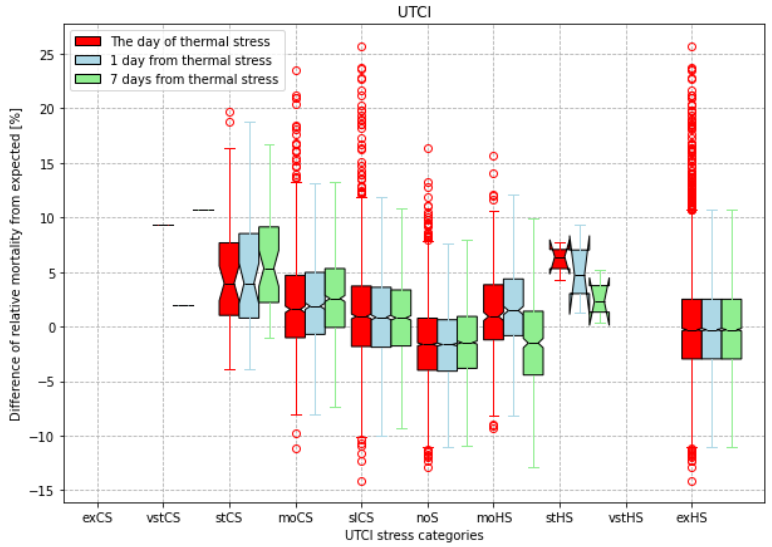

Annual course of relative mortality averaged by year
Annual course
+/- 1 STD
polynomial fit
relative mortality on 10 000 people
0.50
0.45
0.40
0.35
0.30
0.25
0
50
100
150
200
250
300
350
day


Relative mortality with and without smoothing
Relative mortality
183-day Gaussian filter
relative mortality
0.2
0.3
0.4
0.5
0.6
0.7
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
year

# Differennce of relative mortality from expected (ORSO)

- For every thermal comfort category for PET and stress category of UTCI we averaged ORSO on the day of the thermal strain, 1 and 7 days after thermal strain (example for Zagreb-Maksimir station)



# Differennce of relative mortality from expected (ORSO)

- For coldest categories of PET/UTCI – positive ORSO on the day of thermal strain, also for 1 and 7 days after

- For moderate/strong hot categories for PET/UTCI – positive ORSO on the day of thermal strain
  - 1 day after  ORSO is decreasing and drops 7 days after – „harvest effect”

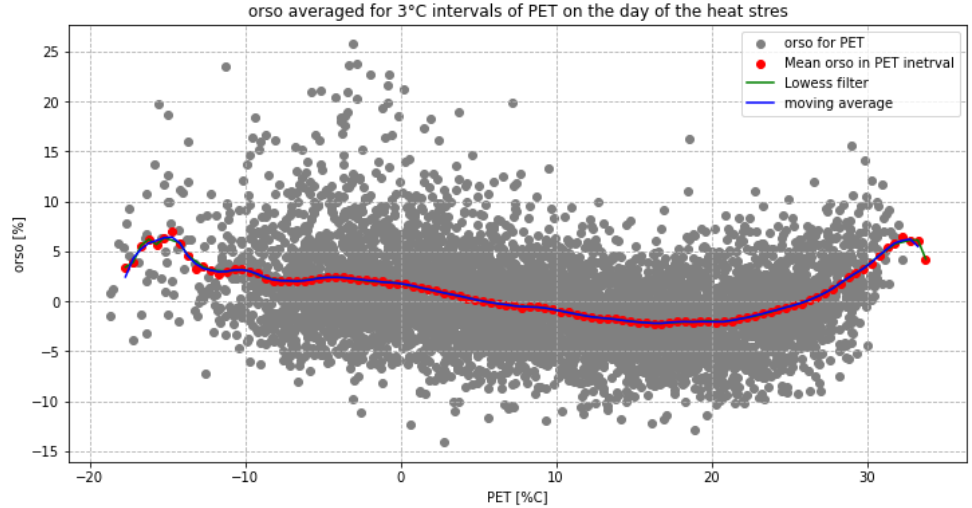
# Differennce of relative mortality from expected (ORSO)

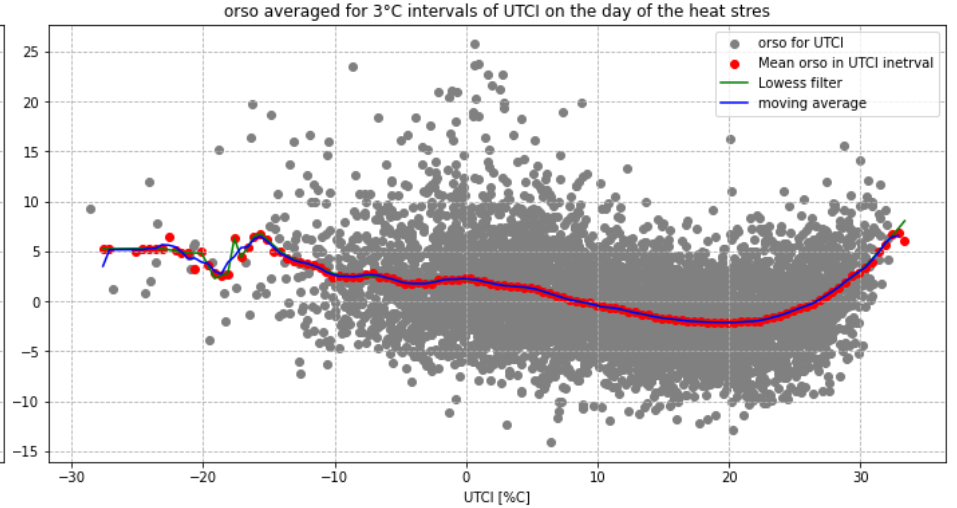
- We want to determine for what index value of PET and UTCI difference of relative mortality form expected (ORSO) will be statistically significant

- For the whole range of PET/UTCI values ORSO values are averaged in 3°C intervals (with a 0.5°C step) of PET/UTCI values – averaged ORSO is smoothed with moving average and locally weighted scatter plot smoothing (lowess)

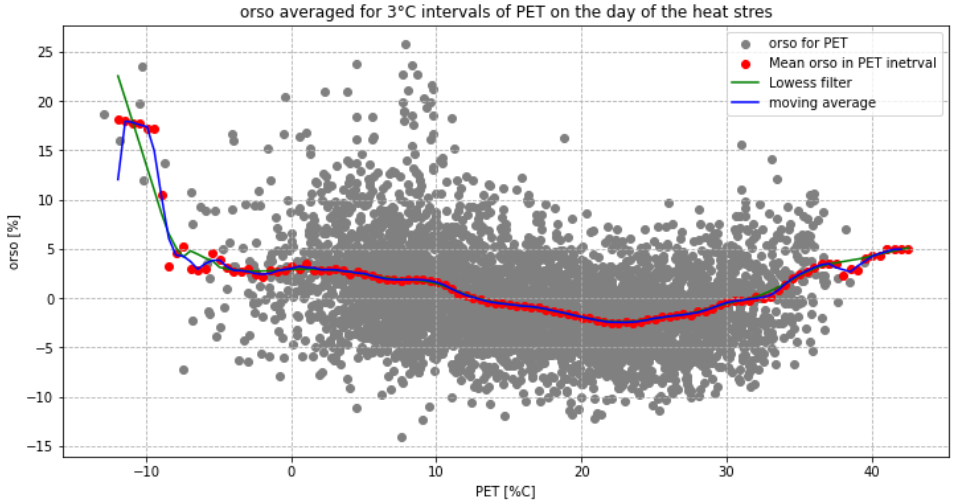
- Same was done for relationship PET/UTCI - cumulative ORSO for 3, 5, 10 days after thermal strain

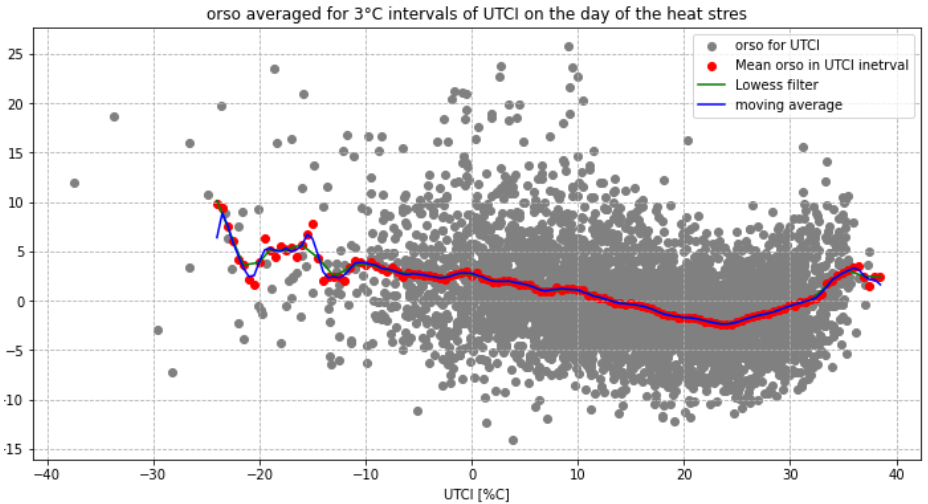
# Zagreb-Maksimir station



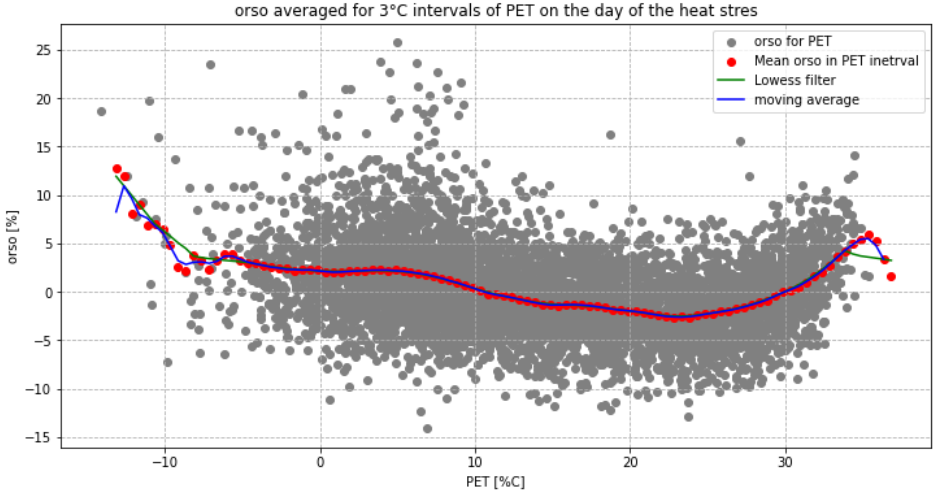



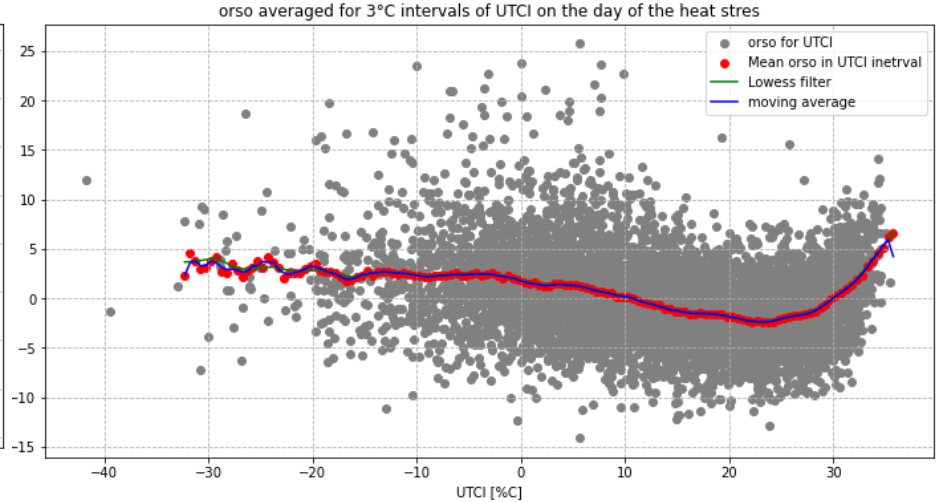
# Dubrovnik station



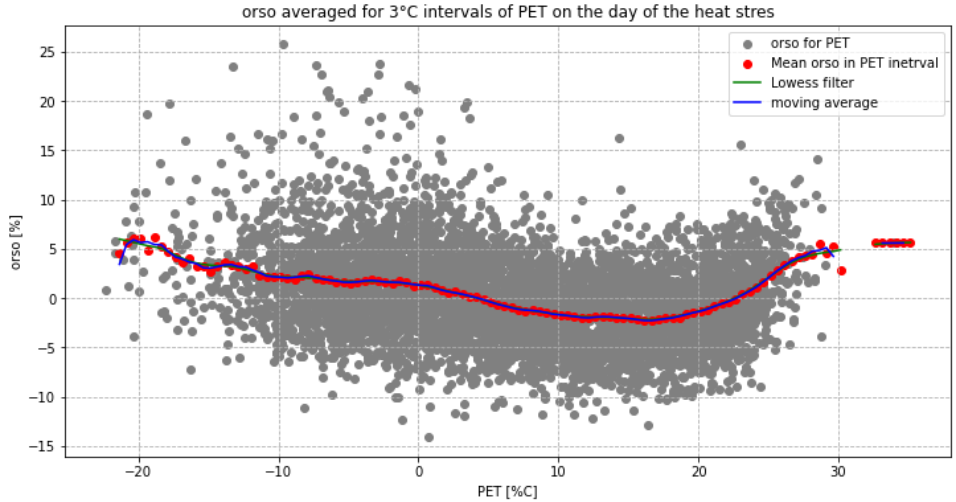



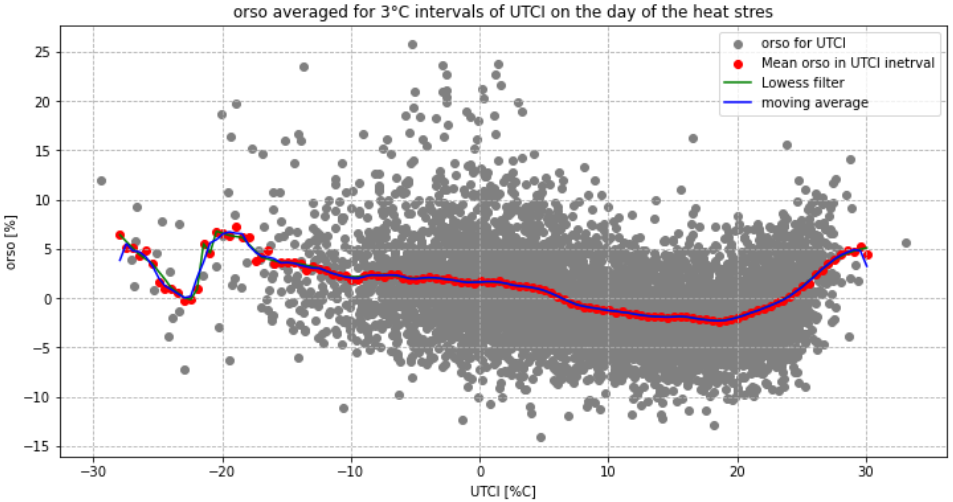
# Split-Marjan station



# Gospić station



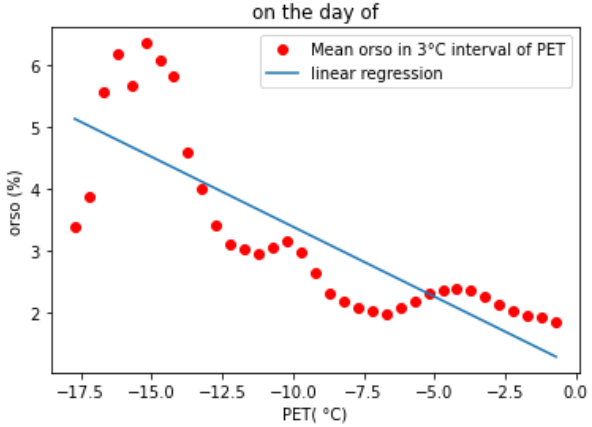
# Cold Cut Point (CCP) and Hot Cut Point (HCP)

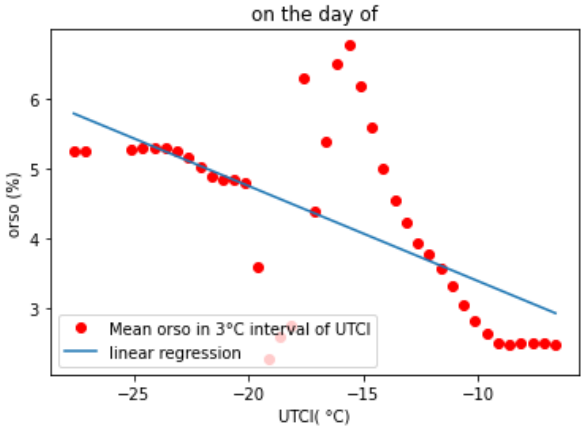
- CCP – value below which in cold conditions/cold stress categories ORSO is statistically significant
- HCP - value above which in hot conditions/hot stress categories ORSO is statistically significant

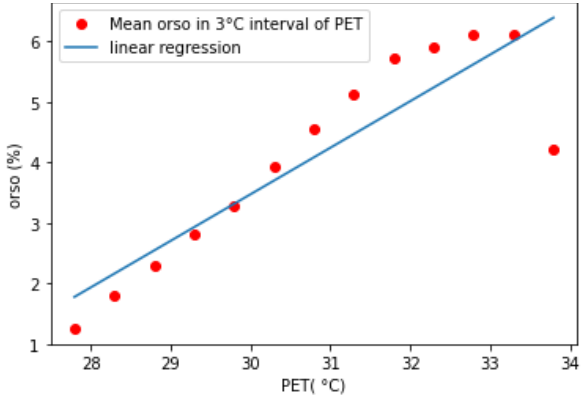
- CCP and HCP = averaged ORSO must be significantly higher from the mean of entire series and after that value there is an increase of ORSO

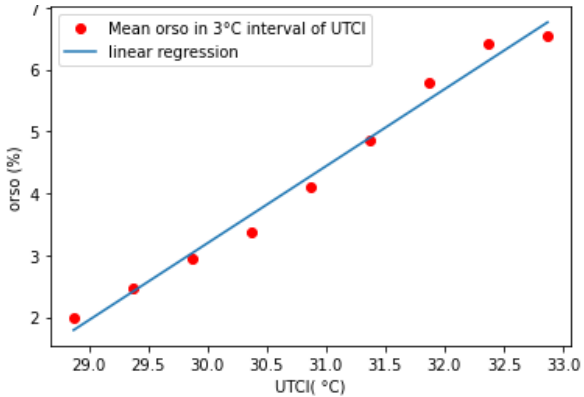
-> exceptions are data on the edge (very small number of data makes them not representable)

# Zagreb-Maksimir station



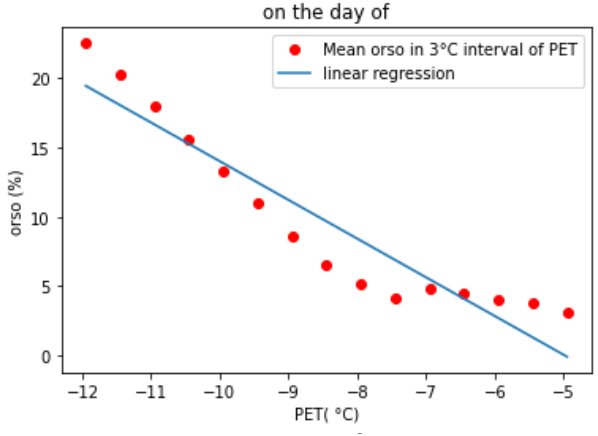



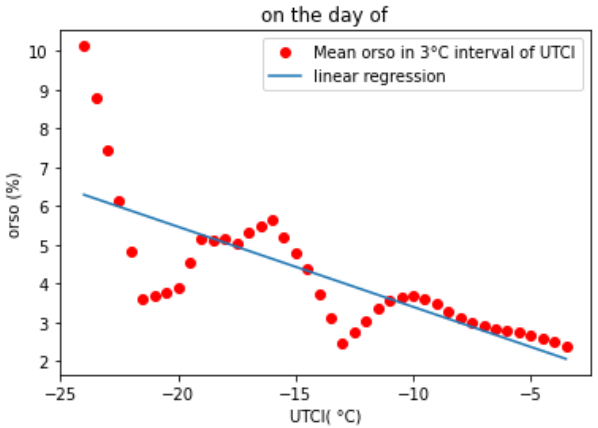

- For cold conditions UTCI/PET nad ORSO are negatively correlated and statically significant on a level of significance of 0.05
- For hot conditions UTCI/PET nad ORSO are positively correlated and statically significant on a level of significance of 0.05

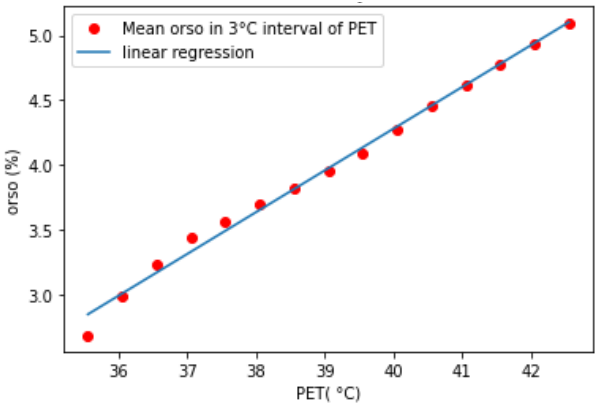
# Zagreb-Maksimir station

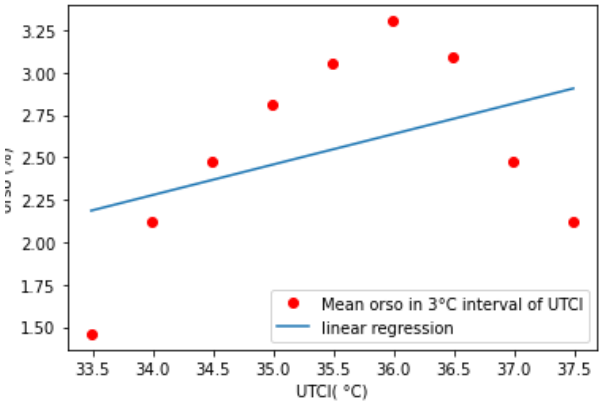
| | PET | | | | UTCI | | | |
|---|---|---|---|---|---|---|---|---|
| | CCP [°C] | signif. | HCP[°C] | signif. | CCP[°C] | signif. | HCP[°C] | signif. |
| ORSO | -0.71 | Yes | 28.79 | Yes | - 6.63 | Yes | 29.37 | Yes |
| ORSO3 | -1.21 | Yes | 28.29 | Yes | -9.13 | Yes | 29.87 | Yes |
| ORSO5 | -0.71 | Yes | 28.79 | Yes | -6.63 | Yes | 30.37 | Yes |
| ORSO10 | -5.63 | Yes | 32.37 | Yes | -6.63 | Yes | 32.37 | Yes |
| Stress category | Extreme cold | | Slight/moderate heat | | Moderate cold | | Moderate heat | |

# Dubrovnik station



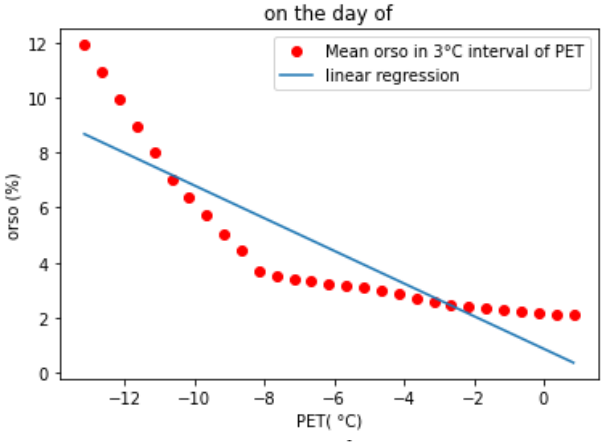



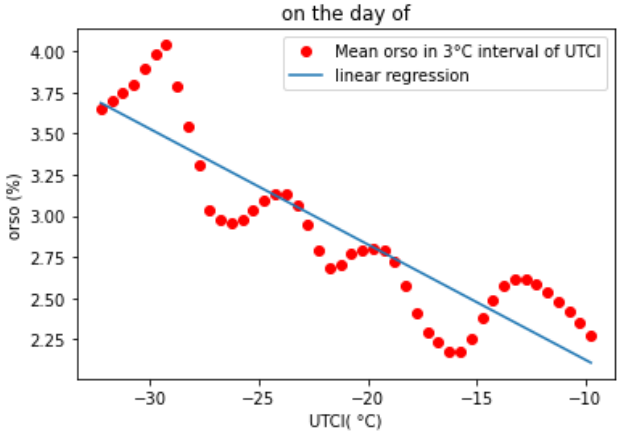

- For cold conditions UTCI/PET nad ORSO are negatively correlated and statically significant on a level of significance of 0.05
- For hot conditions UTCI/PET nad ORSO are positively correlated and statically significant on a level of significance of 0.05

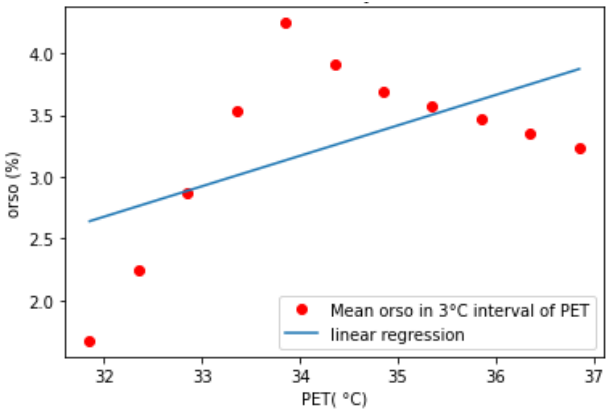
# Dubrovnik station

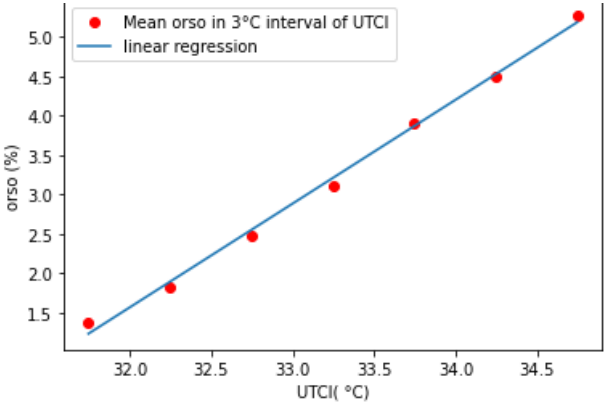
| | PET | | | | UTCI | | | |
|---|---|---|---|---|---|---|---|---|
| | CCP [°C] | signif. | HCP[°C] | signif. | CCP[°C] | signif. | HCP[°C] | signif. |
| ORSO | -4.95 | Yes | 36.05 | Yes | -3.51 | Yes | 33.99 | Yes |
| ORSO3 | 2.55 | Yes | 38.55 | Yes | -3.51 | Yes | 34.49 | Yes |
| ORSO5 | 3.05 | Yes | 40.05 | Yes | -3.51 | Yes | 36.99 | Yes |
| ORSO10 | 4.05 | Yes | NaN | No | -3.51 | Yes | NaN | No |
| Stress category | Extreme/ strong cold | | Strong heat | | Moderate cold | | Strong heat | |

# Split-Marjan station



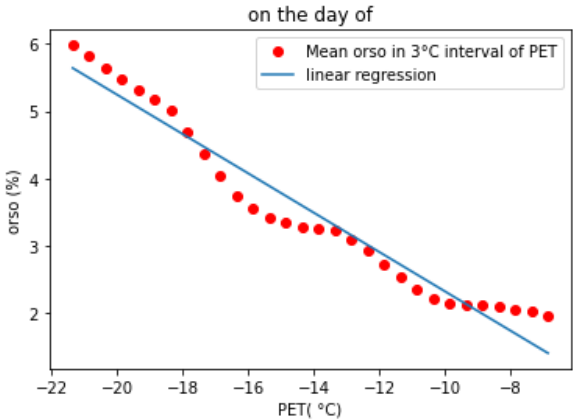



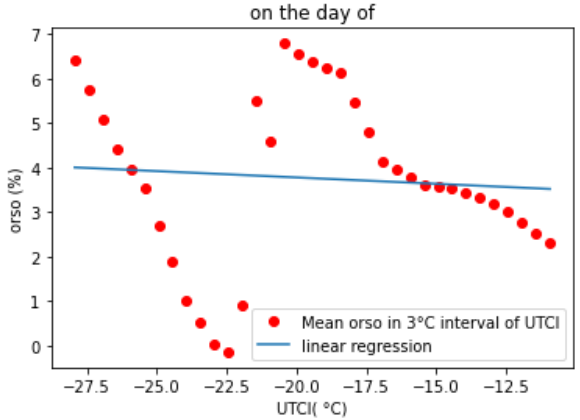

- For cold conditions UTCI/PET nad ORSO are negatively correlated and statically significant on a level of significance of 0.05
- For hot conditions UTCI/PET nad ORSO are positively correlated and statically significant on a level of significance of 0.05

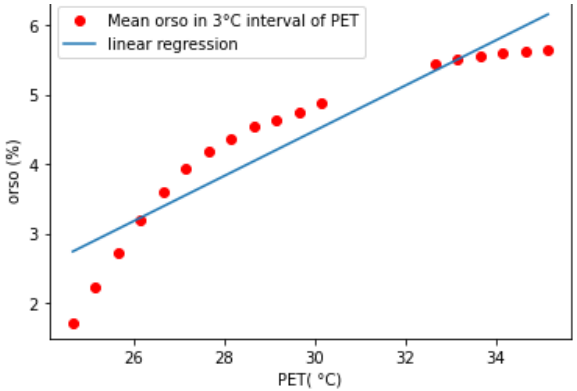
# Split-Marjan station

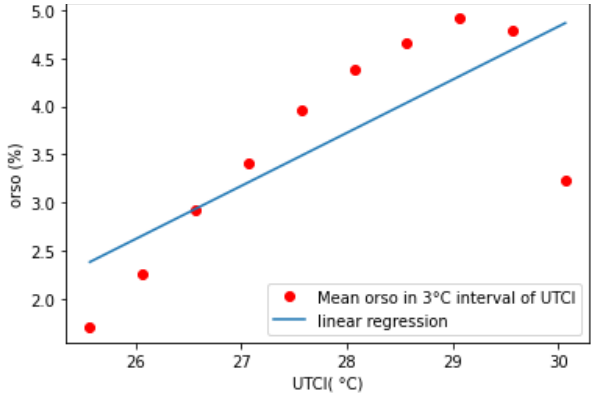
| | PET | | | | UTCI | | | |
|---|---|---|---|---|---|---|---|---|
| | CCP [°C] | signif. | HCP[°C] | signif. | CCP[°C] | signif. | HCP[°C] | signif. |
| ORSO | 0.85 | Yes | 32.35 | Yes | -9.75 | Yes | 32.25 | Yes |
| ORSO3 | 0.35 | Yes | 32.85 | Yes | -9.75 | Yes | 32.25 | Yes |
| ORSO5 | 3.35 | Yes | 33.35 | Yes | -9.75 | Yes | 32.75 | Yes |
| ORSO10 | 3.35 | Yes | 33.35 | Yes | -9.75 | Yes | 34.75 | Yes |
| Stress category | Extreme cold | | Moderate heat | | Moderate cold | | Strong heat | |

# Gospić station




- For cold conditions UTCI/PET nad ORSO are negatively correlated and statically significant on a level of significance of 0.05
- For hot conditions UTCI/PET nad ORSO are positively correlated and statically significant on a level of significance of 0.05

# Gospić station

| | PET | | | | UTCI | | | |
|---|---|---|---|---|---|---|---|---|
| | CCP [°C] | signif. | HCP[°C] | signif. | CCP[°C] | signif. | HCP[°C] | signif. |
| ORSO | -6.85 | Yes | 25.14 | Yes | -10.93 | Yes | 26.07 | Yes |
| ORSO3 | -5.85 | Yes | 25.14 | Yes | -10.43 | Yes | 26.07 | Yes |
| ORSO5 | -2.85 | Yes | 25.65 | Yes | -8.93 | Yes | 26.57 | Yes |
| ORSO10 | -2.85 | Yes | 27.65 | Yes | -8.93 | Yes | Nan | No |
| Stress category | Extreme cold | | Slight heat | | Moderate cold | | Moderate heat | |

## UTCI

- CCP is in moderate stress category for all stations – lowest values for mountain station Gospić, highest for maritime stations Dubrovnik
- HCP is in strong heat category for maritime stations Dubrovnik (highest values) and Split-Marjan and in moderate stress categories for continentak station Zagreb-Maksimir and mountain Gospić (lowest values)

PET

- CCP is in extreme stress category for all stations – lowest values for mountain station Gospić, highest for maritime stations Dubrovnik
- HCP is in strong heat category for maritime stations Dubrovnik (highest values) moderate heath for Split-Marjan and in slight heath stress categories for continental station Zagreb-Maksimir and mountain Gospić (lowest values)

# To sum up...

- From NWP ALADIN model (4 km hor. res.) omparison of heat stress/thermal comfort categories to which UTCI, PET index values correspond to shows good agreement between indices – UTCI is not in last coldest/hottest category when in comparison toPET for cases of strong wind, heat and cold wave
- For time period 2006-2022 relationship between mortality data and UTCI and PET indices calculated from measurements on 4 stations in Croatia is analysed
- The difference of relative mortality form expected (ORSO) was averaged in 3°C intervals for whole range of UTCI and PET values – to define CCP/HCP temperatures below/above which ORSO is statistically significant

# To sum up...

- For cold/hot conditions UTCI,PET and ORSO are negatively/positively correlated and statically significant on a level of significance of 0.05
- Temperatures of CCP correspond to different stress caregories for UTCI (moderate cold) and PET (extreme) – but are both lowest for mountain station and highest for maritime
- Similar for HCP - UTCI (strong/moderate heath) and PET (strong-slight heath) – but are both lowest for mountain station and highest for maritime
- For period of 3,5,10 days after very cold/hot thermal strain cumulative sums of ORSO are increasing
- CCP and HCP need to be defined for each region or county separately because of specific orography and climate diversity of Croatia