



**World  
Meteorological  
Organization**

Weather • Climate • Water

# Introduction to heatwave indices

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defining and measuring heat waves

# What We Know

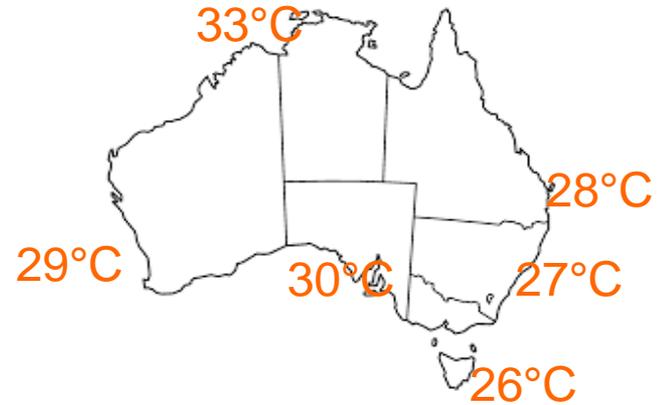
## General Findings



Heat waves

- More intense
- Longer in duration
- Earlier within the summer season

## Temperature Thresholds



## Heat & Human Health

### Lag Effects

Heat effects are not often immediate  
(LAG OF 1-3 DAYS)



DAY OF EXPOSURE



DAY 1 - 3

### Vulnerable Populations



ELDERLY



YOUNG



ILL



URBAN



OUTDOOR WORKERS



INDIGENOUS PERSONS



LOW INCOME

Temperature  
(Exposure)

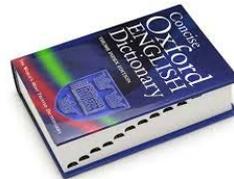


Human Health  
(Outcome)



There is no consistent and methodical approach to defining temperature extremes in public health studies

What is the Importance of Definitions?



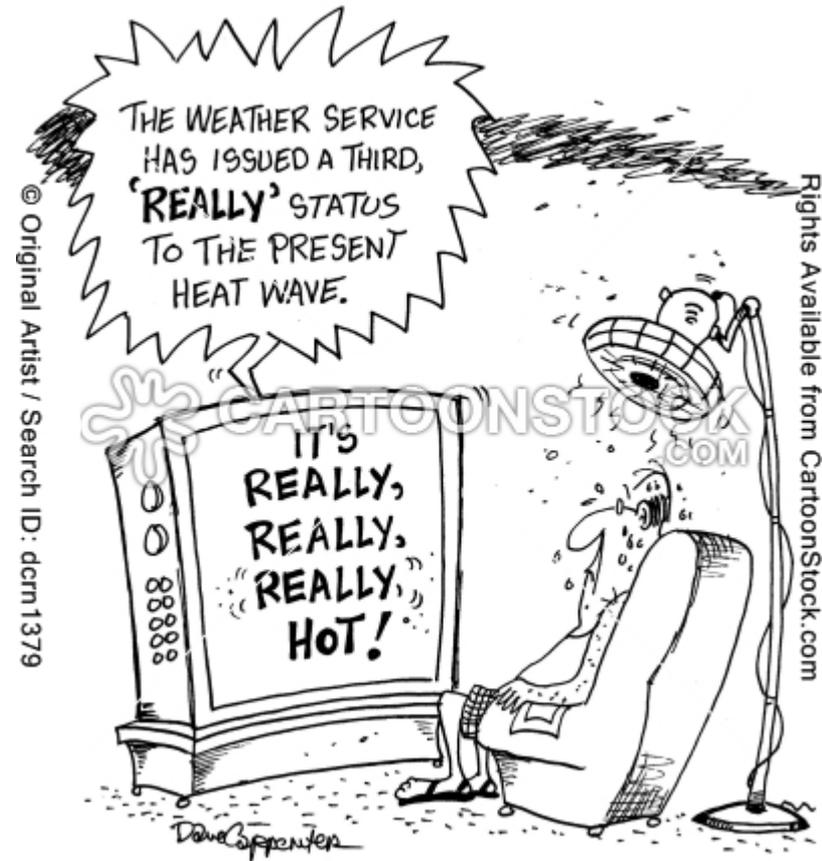
What impact, if any, does the manner in which an extreme day is defined have on the association between extreme heat and health outcomes?

# The problem:

- Impacts of heat waves are extensive
- No universal way of measuring them – many different indices
- So how did ET-SCI decide on which ones to use?

# Some examples of heatwave definitions

- ETCCDI: 5 or more days that are above 90<sup>th</sup> percentile average T
- Some regions use fixed indices (5 days > 35°C, 3 days >40°C)
- Some definitions include humidity as well as temperature
- Others include spatial extent; cumulative heat
- Difficult to make consistent statements, both now and future projections
- What about non-summer excess heat events?? Are they heatwaves too?



# “Universal” Definition of a heatwave

**A prolonged period of excessive heat**

What defines prolonged?

What defines excessive?

Why should it matter?

What else should we consider?



# What makes a good heatwave index?

- Relative threshold (based on climate of the region)
- Consecutive days (although individual hot days can be important too)
- Be based (at least) on temperature
- Consider all aspects of heat waves (intensity, frequency, duration, timing, spatial extent?)
- Simplicity - be user friendly
- Have impact

Is it possible to have one universal index? **NO!**

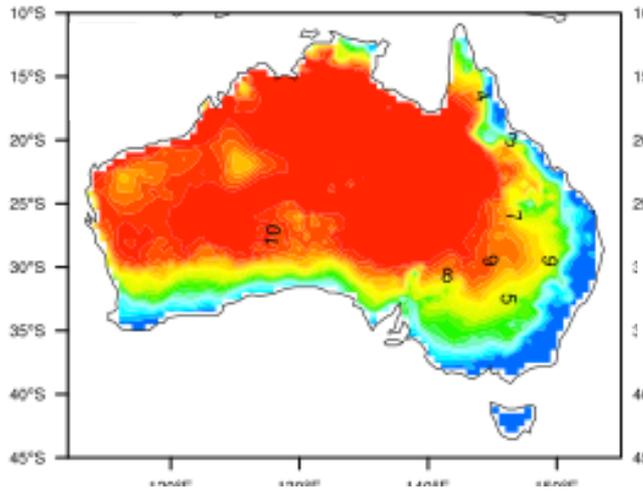
Metric	Description	Reference
TX90P	% days where $T_{\max} >$ calendar day 90 <sup>th</sup> percentile, based on a 5-day window, for the entire time period	ETCCDI ( <a href="http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml">http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml</a> ); Alexander et al. (2006)
TN90P	% days were $T_{\min} >$ calendar day 90 <sup>th</sup> percentile, based on a 5-day window, for 1961-1990	ETCCDI ( <a href="http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml">http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml</a> ); Alexander et al. (2006)
WSDI (warm spell duration index)	Annual count of days with at least 6 consecutive days when $T_{\max} >$ 90 <sup>th</sup> percentile, based on a 5-day window, for 1961-1990	ETCCDI ( <a href="http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml">http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml</a> ); Alexander et al. (2006)
HWDI (heatwave duration index)	Annual count of days with at least 6 consecutive days when $T_{\max} >$ mean( $T_{\max}$ )+5°C	ETCCDI ( <a href="http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml">http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml</a> ); Alexander et al. (2006)
SU (summer days)	Annual count of days when $T_{\max} >$ 25°C.	ETCCDI ( <a href="http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml">http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml</a> ); Alexander et al. (2006)
TR (tropical nights)	Annual count of days when $T_{\min} >$ 20°C.	ETCCDI ( <a href="http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml">http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml</a> ); Alexander et al. (2006)
CHT (combined hot days and tropical nights)	Average number of days with $T_{\max} >$ 35°C and $T_{\min} >$ 20°C	Fischer and Schär, (2010)
AT105F	Average number of days where $T_a >$ 40.6°C (105°F)	Fischer and Schär, (2010)
Deo_Ta index	Highest 3-day running mean of $T_a$	Deo et al. (2007)
Multiple threshold index	Longest period of consecutive days where: $T_{\max}$ must be above T1 for at least 3 days, mean( $T_{\max}$ ) of event is above T1; and $T_{\max}$ is T2 for every day of the event. T1=97.5 <sup>th</sup> percentile of $T_{\max}$ ; T2=81 <sup>st</sup> percentile of $T_{\max}$	Meehl and Tebaldi (2004)
Hot days/events	Frequency of $T_{\max} \geq 35^\circ\text{C}$ / Frequency of 3-5 consecutive days of $T_{\max} \geq 35^\circ\text{C}$	Collins et al. (2000)
Hot nights/events	Frequency of $T_{\min} \geq 20^\circ\text{C}$ / Frequency of 3-5 consecutive days of $T_{\min} \geq 20^\circ\text{C}$	Collins et al. (2000)
Warm days/events	Frequency of $T_{\max}$ anomalies $\geq$ 95th percentile/ Frequency of 3-5 consecutive days of $T_{\max} \geq$ 90th percentile	Collins et al. (2000)
Warm nights/events	Frequency of $T_{\min}$ anomalies $\geq$ 95th percentile/ Frequency of 3-5 consecutive days of $T_{\min} \geq$ 90th percentile	Collins et al. (2000)

# Definitions 1 and 2: CTX90pct/CTN90pct

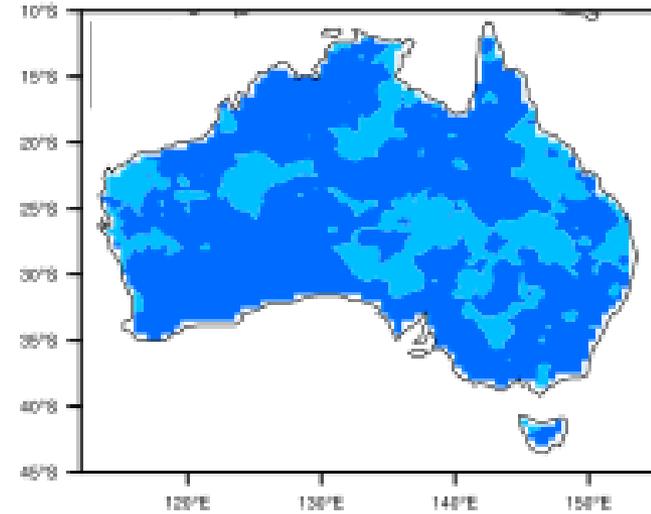
- Based on daily maximum (minimum) temperature
- Consecutive days exceeding the 90<sup>th</sup> percentile (15-day moving window)
- Detect out of season events (i.e. warm spells) and summer events
- Representing different peaks of the diurnal cycle
- Derived from ETCCDI indices....

# Why 90pct? Is it extreme enough?

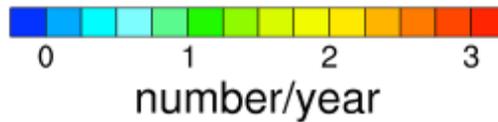
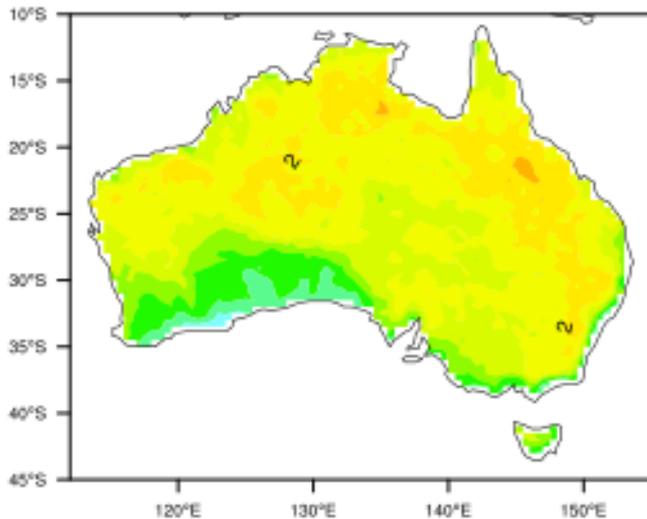
## 35°C Tmax



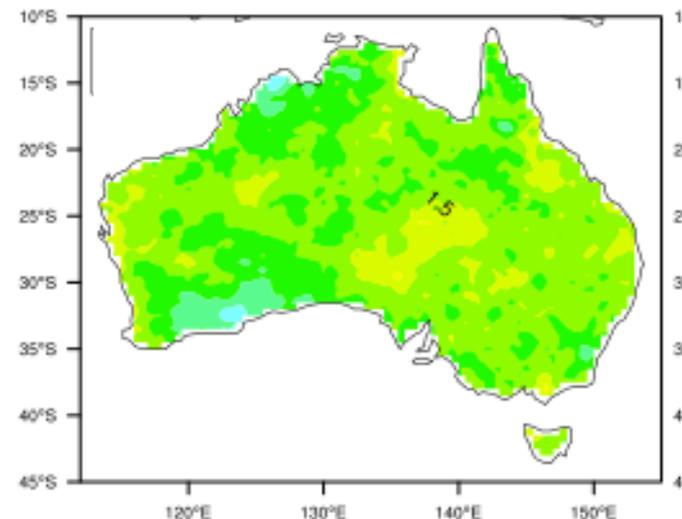
## 95pct Tmin



## 90pct Tmax



## 90pct Tmin



# Definition 3: EHF (excess heat factor)

- Considers daily Tmax AND Tmin:

$$T = (T_{max} + T_{min}) / 2$$

- Includes an acclimatization factor (monthly):

$$EHI(accl.) = (T_i + T_{i-1} + T_{i-2}) / 3 - (T_{i-3} + \dots + T_{i-32}) / 30$$

- And a significance factor:

$$EHI(sig.) = (T_i + T_{i-1} + T_{i-2}) / 3 - T_{95(clim)}$$

$$EHI(sig.) = (T_i + T_{i-1} + T_{i-2}) / 3 - T_{90(cal)}$$

- Which are combined:

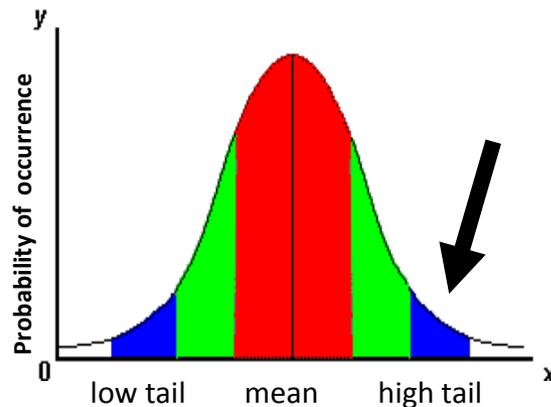
$$EHF = \max[1, EHI(accl.) \times EHI(sig.)]$$

- Interested in POSITIVE EHF values only
- Original calculation geared towards summer events

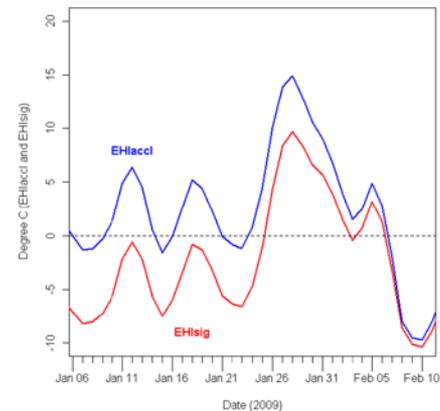
# Excess Heat and Heat Stress matter

Excess Heat Factor (EHF) developed by the Bureau of Meteorology<sup>1</sup>

$$\text{EHF} = \text{Excess Heat} \times \text{Heat Stress}$$



3 consecutive days where daily mean temperatures > 95<sup>th</sup> percentile

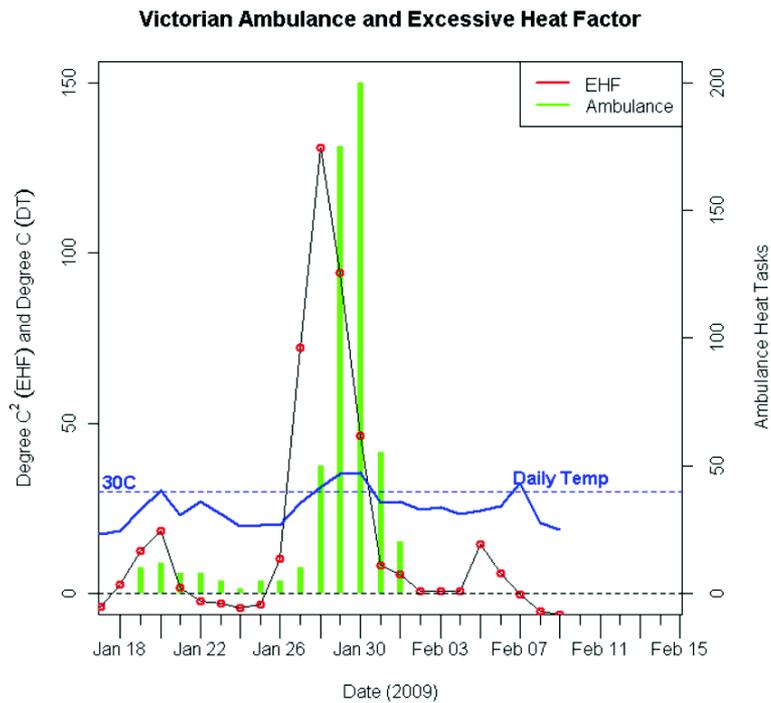


How hot were the preceding 30 days by comparison?

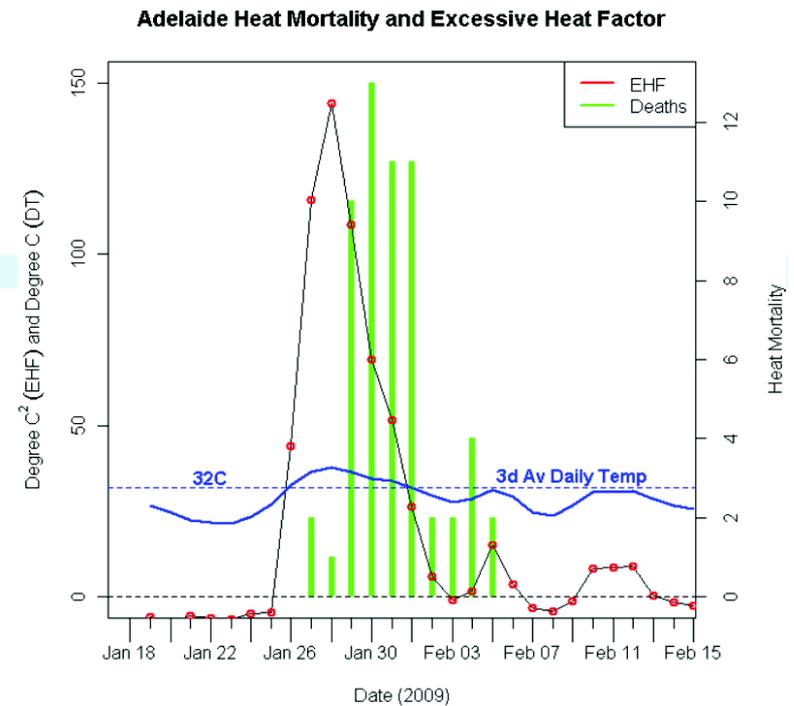
<sup>1</sup>Nairn and Fawcett (2013): Defining heatwaves: heatwave defined as a heat-impact event servicing all community and business sectors in Australia, CAWCR Technical Report 060

# EHF impacts

## Ambulance call outs



## Excess Mortality



**Based on the three definitions, a heat wave occurs when the threshold is exceeded/positive conditions occur for AT LEAST 3 consecutive days**

We have identified days where the:

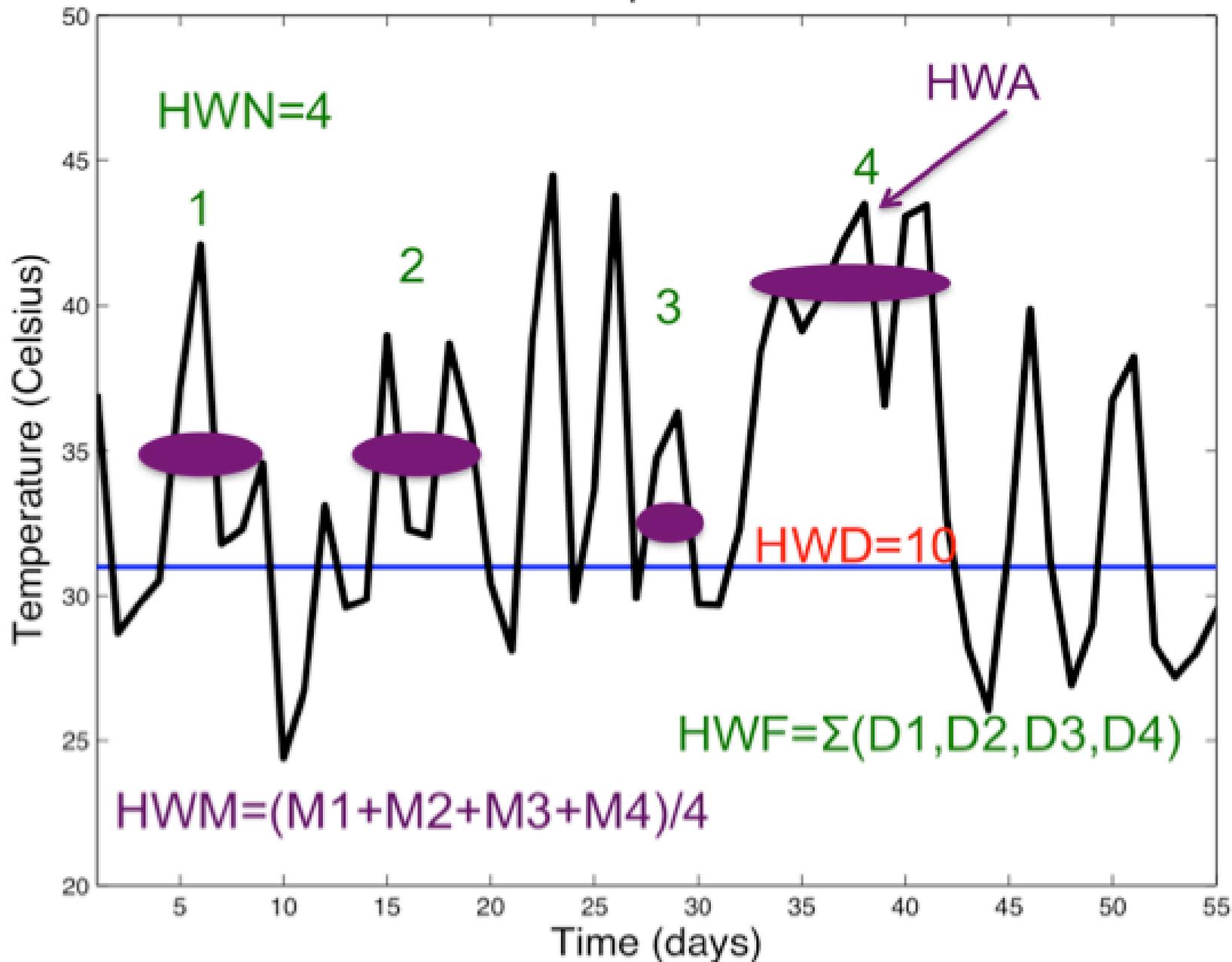
- Tmax/Tmin 90<sup>th</sup> percentile is exceeded
- Where EHF values (based on Tave) are positive

What other information do we require?

# 5 characteristics:

- HWF - sum of days participating in an event
- HWN – frequency of events
- HWD – length of longest event
- HWA – Hottest day of hottest event (anomaly against seasonal mean)
- HWM – average magnitude of all events (anomaly against seasonal mean)
  
- Calculated for summer heatwaves and annual warm spells
- Separately for each definition

# Heatwave Aspects Schematic



35	HWN (EHF/CTN90pct/ CTX90pct)	Heat wave number	The annual number of summer (Nov-Mar in SH and May-Sep in NH) heat waves where conditions persist for at least 3 consecutive days per the definitions of EHF/CTN90pct/CTX90pct in Appendix B	Number of events	N	H, AFS, WRH
36	HWD (EHF/CTN90pct/ CTX90pct)	Heat wave duration	The length of the longest summer (Nov-Mar in SH and May-Sep in NH) heat wave where conditions persist for at least 3 consecutive days per definitions per the definitions of EHF/CTN90pct/CTX90pct in Appendix B	days	N	H, AFS, WRH
37	HWF (EHF/CTN90pct/ CTX90pct)	Heat wave day frequency	The total number of days each summer (Nov-Mar in SH and May-Sep in NH) that contribute to all heat waves where conditions persist for at least 3 consecutive days per definitions per the definitions of EHF/CTN90pct/CTX90pct in Appendix B	days	N	H, AFS, WRH
38	HWA (EHF/CTN90pct/ CTX90pct)	Heat wave amplitude	The hottest day of the hottest summer (Nov-Mar in SH and May-Sep in NH) heat wave where conditions persist for at least 3 consecutive days per definitions per the definitions of EHF/CTN90pct/CTX90pct in Appendix B	°C (°C <sup>2</sup> EHF)	N	H, AFS, WRH
39	HWM (EHF/CTN90pct/ CTX90pct)	Heat wave mean	Average magnitude of all heat wave days (Nov-Mar in SH and May-Sep in NH) heat wave where conditions persist for at least 3 consecutive days per definitions per the definitions of EHF/CTN90pct/CTX90pct in Appendix B	°C (°C <sup>2</sup> EHF)	N	H, AFS, WRH
40	nTX <sub>b</sub> nTN <sub>b</sub>	User-defined consecutive number of cold days and nights	Annual count of <i>n</i> consecutive days where both TX < 5 <sup>th</sup> percentile and TN < 5 <sup>th</sup> percentile where <i>n</i> >=2 and <i>n</i> <=10?	Number of events	N	H, AFS