UNITED STATES MILITARY ACADEMY
WEST POINT

Introduction to Heat Wave Indices

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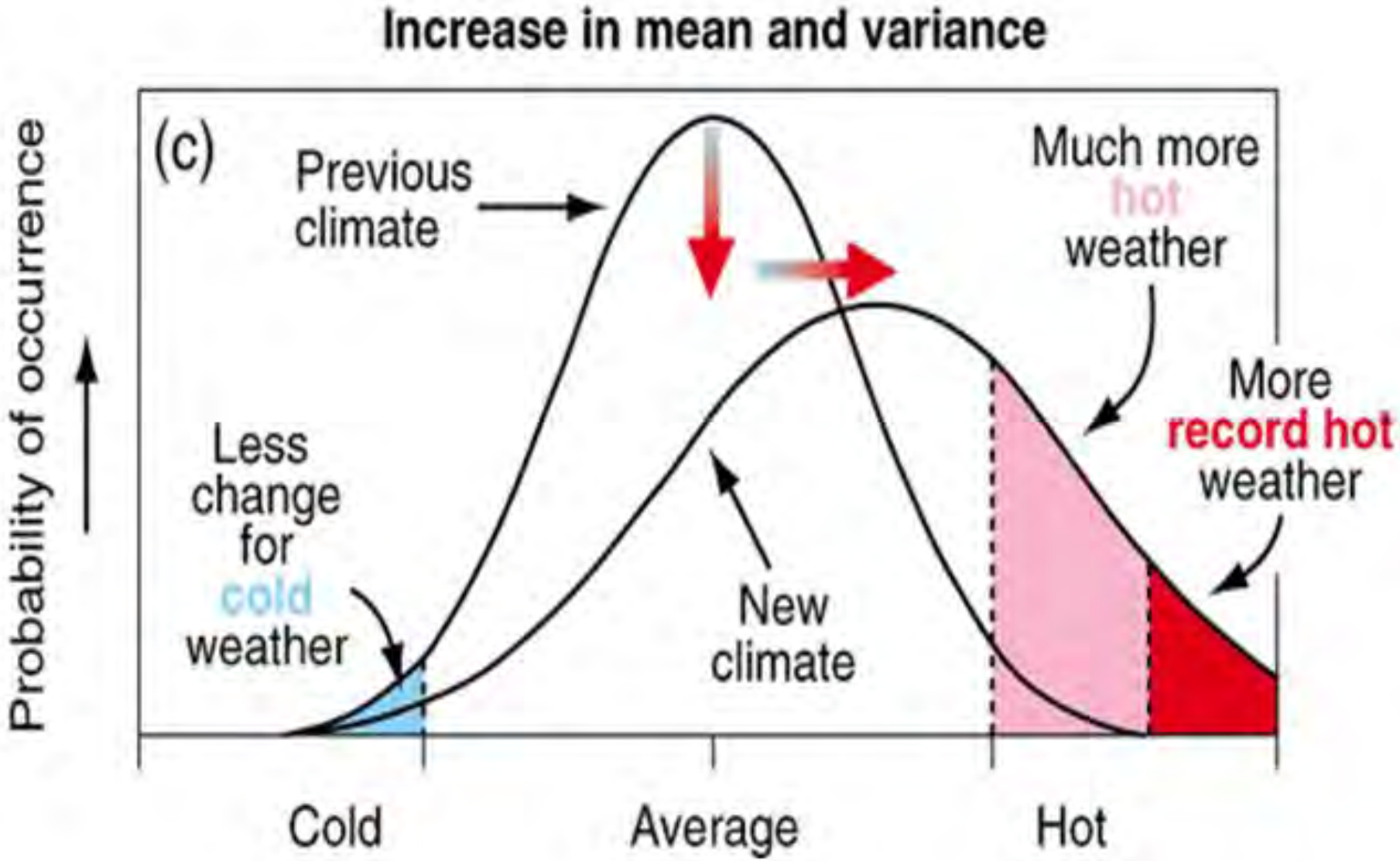
CLCRS

The dangers of excessive heat

- Heat is the leading weather-related killer in the United States
- Recent years have seen tens of thousands of people killed in Russia (2010) and Europe (2003)
- 2015 Indian heat wave


Increase in mean and variance
(c)
Previous climate
Much more hot weather
More record hot weather
Less change for cold weather
New climate
Probability of occurrence
Cold
Average
Hot

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?

"Universal" Definition of a Heat Wave

A prolonged period of excessive heat

What defines prolonged?

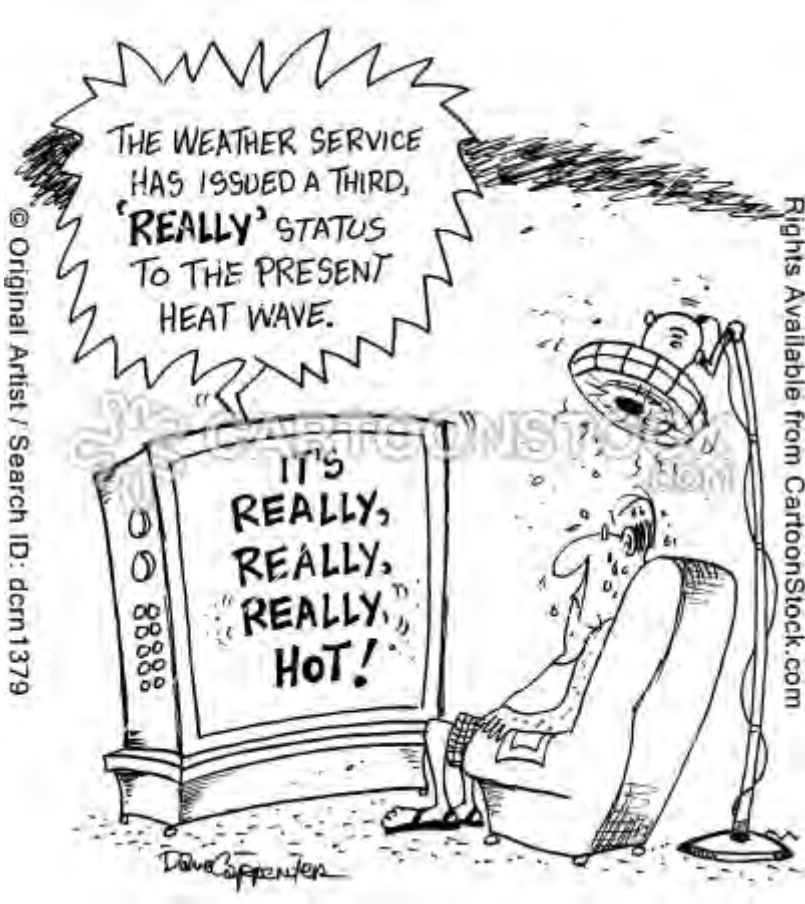
What defines excessive?

Why should it matter?

What else should we consider?

Some examples of heat wave definitions

- ETCCDI: 5 or more days that are above 90th percentile average T
- Some regions use fixed indices (5 days > 35^{o}C, 3 days >40^{o}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?



What makes a good heat wave index?

What makes a good heat wave 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

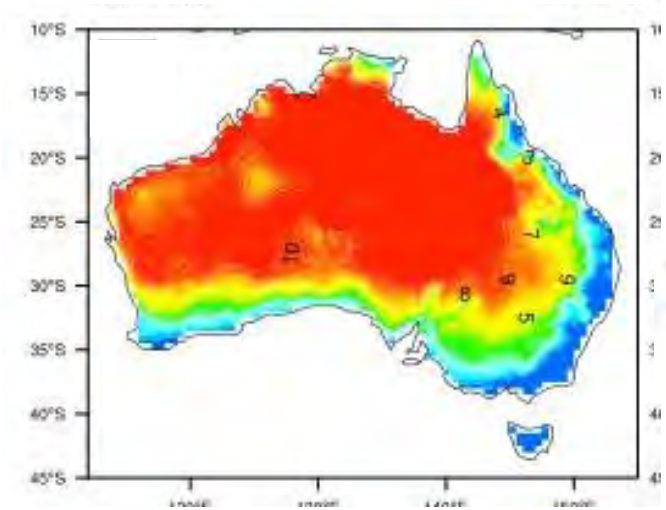
Is it possible to have one universal index? ***NO!***

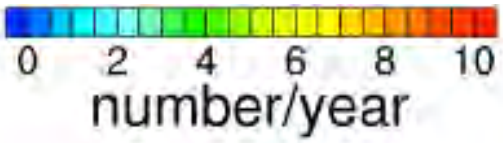
Definitions 1 and 2: CTX90pct/CTN90pct

- Based on daily maximum (minimum) temperature
- Consecutive days exceeding the 90th 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….

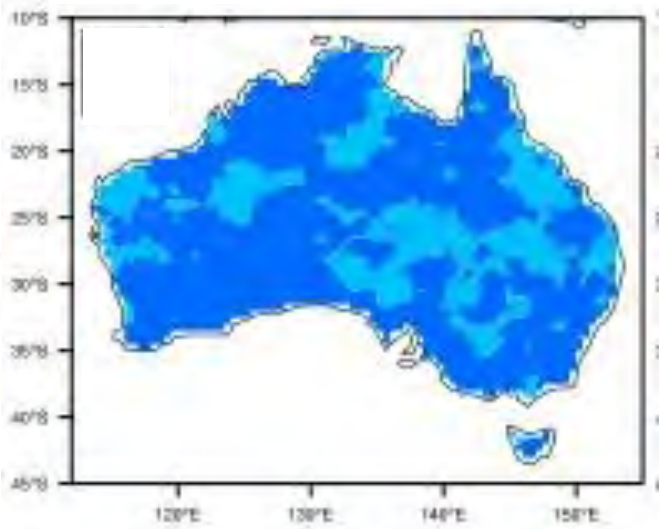
Why 90pct? Is it extreme enough?

35°C Tmax

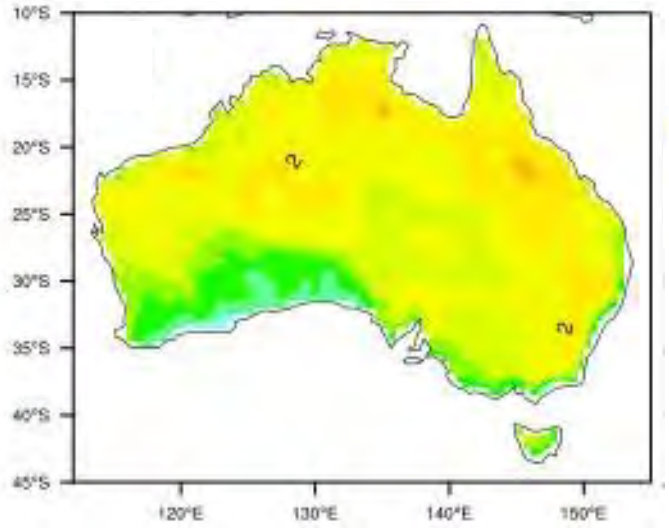




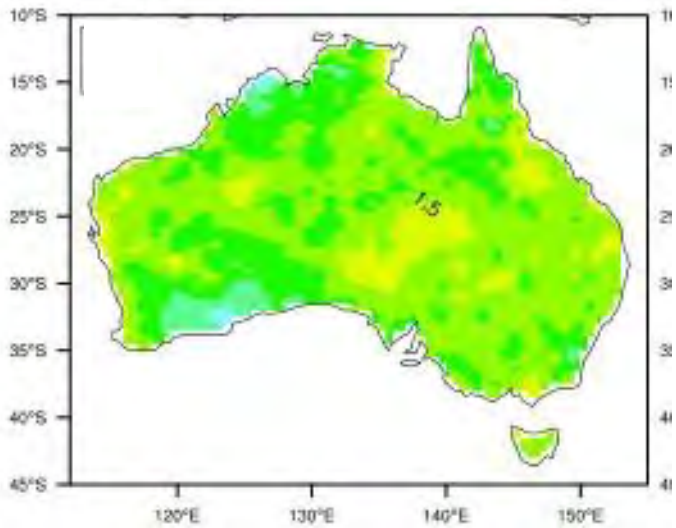
95pct Tmin



90pct Tmax



90pct Tmin



Definition 3: EHF (excess heat factor)

- Considers daily Tmax AND Tmin:

  $\boldsymbol{T}=(Tmax+Tmin)/2$

- Includes an acclimatization factor (monthly):

  $EHI(accl.) = (\boldsymbol{T}_i + \boldsymbol{T}_{i-1} + \boldsymbol{T}_{i-2})/3 - (\boldsymbol{T}_{i-3} + \ldots + \boldsymbol{T}_{i-32})/30$

- And a significance factor:

  $EHI(sig.) = (\boldsymbol{T}_i + \boldsymbol{T}_{i-1} + \boldsymbol{T}_{i-2})/3 - \boldsymbol{T}_{95(clim)}$

  $EHI(sig.) = (\boldsymbol{T}_i + \boldsymbol{T}_{i-1} + \boldsymbol{T}_{i-2})/3 - \boldsymbol{T}_{90(cal)}$

- Which are combined:

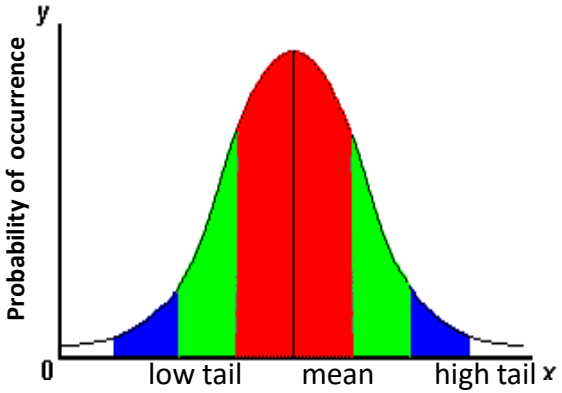
  $EHF = max[1, EHI(accl.) \times EHI(sig.)]$

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

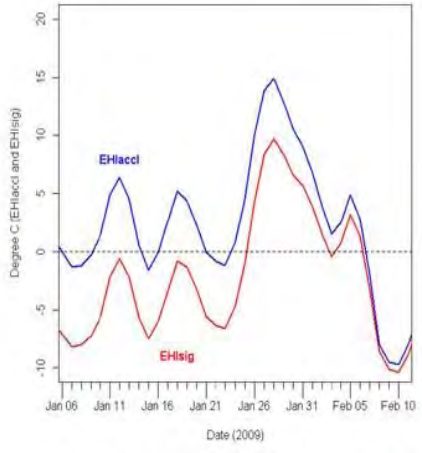
Excess Heat and Heat Stress matter

Excess Heat Factor (EHF) developed by the Bureau of Meteorology[1]

EHF = Excess Heat x Heat Stress



3 consecutive days where daily mean temperatures > 95th percentile

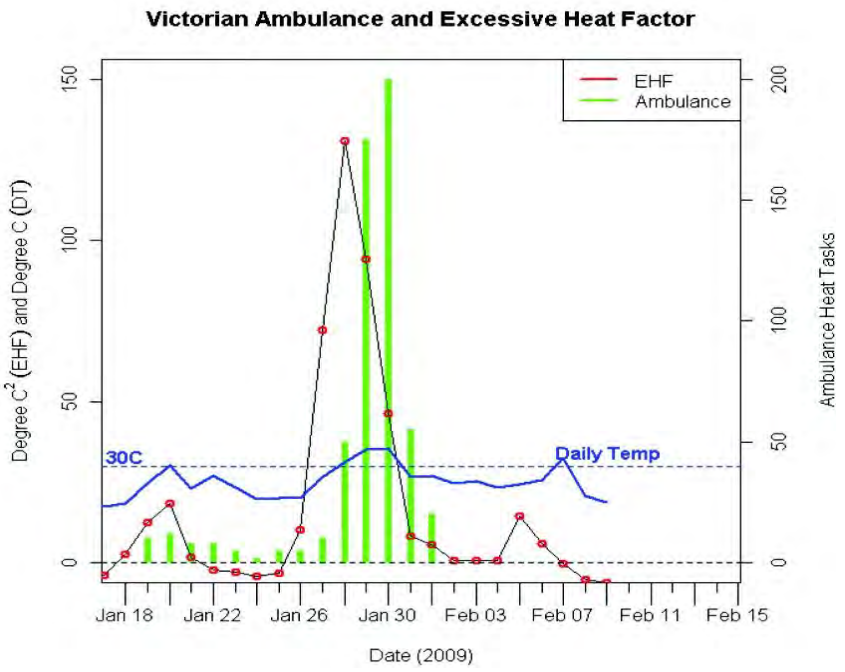


How hot were the preceding 30 days by comparison?

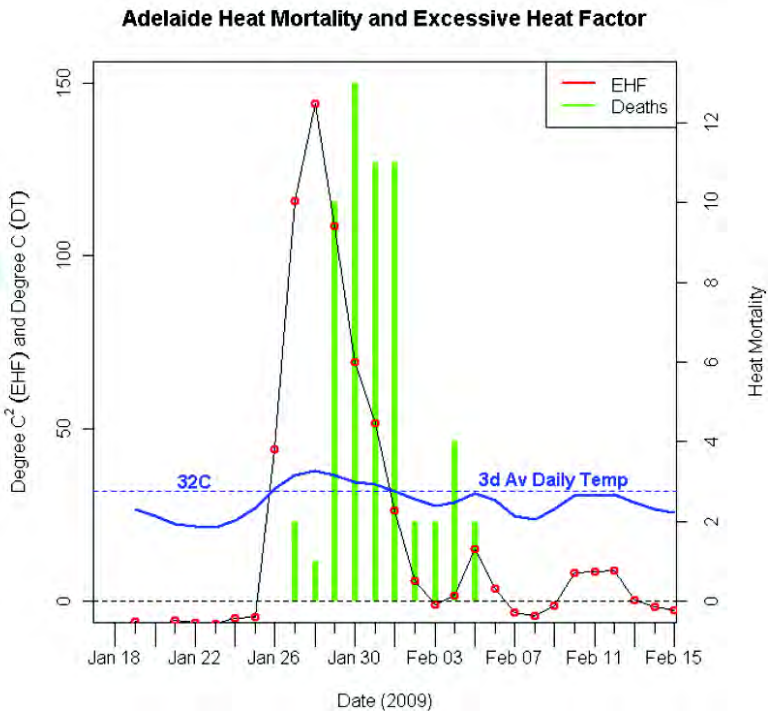
[1]Nairn and Fawcett (2013): Defining heatwaves: heatwave defined as a heat-impact event servicing all community and business sectors in Australia, CAWCR Technical Report 060

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 90th 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

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	ºC ($°C^2$ 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	ºC ($°C^2$ EHF)	N	H, AFS, WRH
40	nTX_bnTN_b	User-defined consecutive number of cold days and nights	Annual count of *n* consecutive days where both TX < 5th percentile and TN < 5th percentile where n >=2 and n <=10?	Number of events	N	H, AFS