Significant Differences

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Introduction

Following on from the RDA analysis, we can now say which variables are more likely important in the determination of a relationship between an extreme event and wind variables. Therefore we can see if these variable are significantly different for all events within a time series and only those that co-occurred with other events. Happily, all of these co-occurring events have already been calculated and need only be loaded for us to begin this next analysis. For the purpose of simplicity I have limited all of these comparisons to the "tmean" statistic from the atmospheric data. The "tmin" and "tmax" values have all been calculate, but I find "tmean" to be a more relaistic indicator of temperature comparisons over a series of days. It is true however that different relationships will likely be found given the use of the different temeperature metrics. I have also limited this analysis to heat waves. Cold-spells may be included easily at a later date if this analysis is deemed useful.

Methods

Getting started all of the calculated events and co-occurring events were loaded.

```
# Marine
load("~/AHW/data/events/SACTN_events.Rdata")
# Atmosphere
load("~/AHW/data/events/SAWS_SACTN_events_tmean.Rdata")
# Co-occurring heat waves
load("~/AHW/data/cooccurrence/SACTN_SAWS_hw_tmean_CO.Rdata")
```

Once the events were loaded, it was then necessary to screen out only events that co-occurred with another event within 7 days. Note that this 7 day lag is in both directions, not just MHWs occurring before or after the AHWs. This is an important consideration as the results of this anlysis then do not show if the relationship between the events has a direction, simply that there may be a relationship. Also, I initially performed this analysis on a 2 day lag, as well as the 7 day lag shown here. I have omitted the 2 day lag data as often there are two few events to calculate a t.test. And the results were not much different than the 7 day lag results.

```
# Heat waves
SACTN_SAWS_hw_tmean_CO_7_day <- SACTN_SAWS_hw_tmean_CO[abs(SACTN_SAWS_hw_tmean_CO$latest) <= 7,]
```

After loading and screening everything I created a function (which may be seen in the .Rmd version of this file) that took two paired sites (the nearest SACTN to SAWS sites) and first checked for significant differences between the heat waves (marine and atmosphere) at those sites. The test used was a non-paired, two sided t.test that does not assume equal variance. The statistics compared were: `rate_decline` (the rate of decline of the temperature of the event back to the climatological average), `int_mean_abs` (the "absolute" mean temperature of the event, as explained in the RDA report), `int_max_abs` (the "absolute" maximum temperature of the event), `int_cum_abs` (the "absolute" cummulative intensity of the event, effectively the temperature over the threshold for each day of the event added together, this can become very large) amd `duration` (the length of the event in days). These variables were chosen as they appeared to have the best relationship with at least one of the wind variables from the RDA analysis.

Results

With all of that sorted, it was then time to have a peak at the results. And to see if anything interesting popped out.

```
event_sig <- ddply(SACTN_SAWS_nearest, .(index), event.sig, .parallel = T)
head(event_sig)
```

```
##   index        SACTN           SAWS distance    comparison         stat
## 1     1 Port Nolloth Cape Columbine 408.6757    MHW vs AHW rate_decline
## 2     1 Port Nolloth Cape Columbine 408.6757 MHW vs CO-MHW rate_decline
## 3     1 Port Nolloth Cape Columbine 408.6757 AHW vs CO-AHW rate_decline
## 4     1 Port Nolloth Cape Columbine 408.6757    MHW vs AHW int_mean_abs
## 5     1 Port Nolloth Cape Columbine 408.6757 MHW vs CO-MHW int_mean_abs
## 6     1 Port Nolloth Cape Columbine 408.6757 AHW vs CO-AHW int_mean_abs
##        p
## 1 0.0000
## 2 0.1457
## 3 0.8185
## 4 0.0000
## 5 0.0270
## 6 0.3855
```

Quickly scanning the results it does appear that in almost all instances, these flagship variables are significantly different between the MHWs and AHWs at each site. It also appears that MHWs that do not occur within 7 days of an AHWs are often significantly different from MHWs that do co-occur. This patern does not appear as clear with AHWs. With results this dense it can be difficult to effectively summarise them with one figure, but I have attempted to do so below.

It is difficult to see the site names in the following figure due to the limiting page size, but they are given in geographical order from the Namibian border to the Mozambiquan border, as shown in the following table.

```
##                 SACTN               SAWS    distance index
## 1        Port Nolloth     Cape Columbine 408.6756544     1
## 2           Sea Point Cape Town DF Malan  21.2259985     2
## 3           Oudekraal Cape Town DF Malan  23.4083949     3
## 4            Hout Bay Cape Town DF Malan  24.3521821     4
## 5           Kommetjie         Cape Point  28.5712688     5
## 6            Bordjies         Cape Point   4.8650202     6
## 7       Bordjies Deep         Cape Point   5.4316356     7
## 8           Fish Hoek Cape Town DF Malan  22.9456655     8
## 9         Muizenberg Cape Town DF Malan  17.4649221     9
## 10        Gordons Bay        Jonkershoek  22.4773270    10
## 11        Betty's Bay         Cape Point  38.7896219    11
## 12           Hermanus        Jonkershoek  57.7677766    12
## 13           Stilbaai     Cape St Blaize  69.0456068    13
## 14      Ystervarkpunt     Cape St Blaize  45.1027213    14
## 15         Mossel Bay     Cape St Blaize   0.5906963    15
## 16             Knysna     Cape St Blaize  85.0866015    16
## 17   Tsitsikamma West    Cape St Francis 129.5546924    17
## 18 Storms River Mouth    Cape St Francis 106.4126650    18
## 19   Tsitsikamma East    Cape St Francis 105.4009495    19
## 20      Pollock Beach     Port Elizabeth   7.2891691    20
```

```
## 21           Humewood     Port Elizabeth   4.4134245    21
## 22            Hamburg        East London  39.9356484    22
## 23     Eastern Beach        East London  27.3516529    23
## 24      Orient Beach        East London  27.0507950    24
## 25      Nahoon Beach        East London  29.3474430    25
## 26            Sodwana      Cape St Lucia 123.9661298    26
```

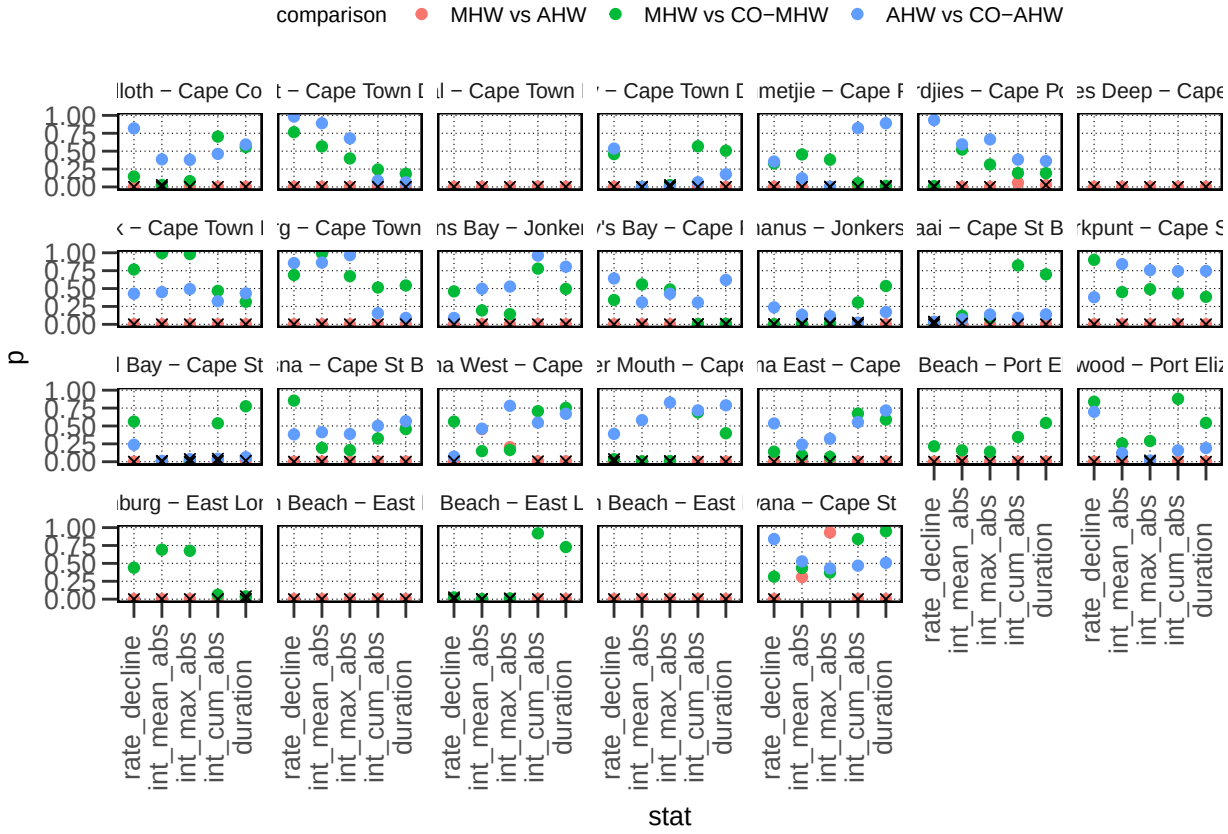

Figure 1: Dot plot showing p-value result of t.tests that compare the statistics seen on the x axis between various groups of events, which are shown in colour. Significant differences are highlighted with black 'x' shapes. Note that some panels only have peach dots. This is because there are fewer than 3 events co-occurring within 7 days of each other for the paired time series. Also note that some panels do not have blue dots, this is because the rate of decline for the AHWs is not always able to be calculated, therefore some site pairings do not have 3 or more complete AHWs co-occurring within 7 days of MHWs.

One may see that almost all of the peach dots are highlighted with black 'x's, meaning for most site pairings, these important variables are significantly different between MHWs and AHWs. This is not terribly surprising, but is important to note none the less. Additionally, while note often significantly different from one another, the non-co-occurrring MHWs do tend to be significantly different from the co-occurring MHWs more often than the non-co-occurring AHWs are significantly different form the co-occurring AHWs.

Discussion

That almost all of the important variables for MHWs are significantly different from the AHWs at almost all sites is an interesting result in that it shows that the variables that may be best linking these events to wind forcing are significantly different from one another. This implies that MHWs and AHWs must be responding

to wind forcing in intrinsically different ways. I'm sure this could be taken forward, but I can't quite think of how just now. There is likely something very complex going on, but I'll need to do more reading to get at what that may be. That being said, what reading I have done on this topic is not very reassuring, in that there may not be an answer out there. The interaction between air and sea at mid-latitudes is very poorly understood and some claim that a clear signal may not exist, as it does nearer the equator.

Besides significantly different MHWs and AHWs, we see that some sites show significant differences between co-occurring and non-co-occurring events. I was hoping that more of these results would be significant, as this would then imply that the events that are co-occurring with their air/ sea counterpart are different from the events that don't co-occur. Were this the case, then it would give us something to focus on when looking for that illusive signal. Some of these do however show significant difference and so a part of the keyt may be in there.

Next step

I've been at this for a bit now and am aware I'm starting to ramble. Like that sentence (and this one). If this avenue of research is deemed worthwhile then the next step will be to zero in on the sites that show significant difference between co-occurring and non-co-occurring events. The differences between these events may illucidate some driver as to the potential forcing occurring between these different systems. Though I am beginning to wonder, if it is this difficult to find a signal, does one really exist? Or will it be a product of deep fishing?