# The state of the union: air-sea interactions during coastal marine heatwaves


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**Abstract**



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## 1. Introduction

Documentation on the negative impacts of changing climates due to anthropogenically forced warming on both marine and terrestrial ecosystems has grown rapidly over the last few decades. The primary focus of which tends towards the measuring of linear increases in mean temperatures in distinct regions. Whereas these long term changes are important and are already effecting a myriad of systems identified as critically important (Stocker et al., 2013), the major impacts on humans and ecosystems in the present are due to extreme events (Easterling et al., 2000). Often unpredictable, cyclones, floods, heatwaves and cold-spells may begin and end before any warning systems may be of use. It is for this reason, and others, that more focus in climate change research is now being applied to the study of these extreme events (Jentsch et al., 2007).

Due to the currently sparse occurrence of such extreme events in time and space, very few have impacted areas in which long term ecological data were being sampled *a priori*. Two well documented exceptions to this trend are the 2003 heatwave in the Mediterranean and the 2011 heatwave off the west coast of Australia. The 2003 Mediterranean heatwave has been documented to have negatively impacted as much as 80% of the Gorgonian fan colonies there (Garrabou et al., 2009), and the 2011 Western Australia heatwave is now known to have caused a permanent 100 km range contraction of the ecosystem forming kelp species *Ecklonia radiata* in favour of the tropicalisation of reef fishes and seaweed turfs (Wernberg et al., 2016).

Both of these seawater temperature anomalies are classified as 'marine heatwaves' (MHWs), which differ slightly from the traditional definition of a heatwave that was originally developed for atmospheric events (Perkins and Alexander, 2013). Here we make use of the definition for marine heatwaves given


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in Hobday et al. (2016) as “a prolonged discrete anomalously warm water event that can be described by its duration, intensity, rate of evolution, and spatial extent.” The characterization of these events in this manner allows investigators from anywhere in the world to compare and classify events using common statistical properties.

In addition to the use of these common statistics for comparing events, it is necessary to identify the possible range of physical causes so as to be able to compare similar ’types’ of events as well. It is hypothesised that MHWs should either be caused by oceanic forcing, atmospheric forcing, or a combination of the two. For example, the transport of warm water onto the coast of Western Australia is responsible for the large scale MHW that occurred there in 2011 (Feng et al., 2013; Benthuysen et al., 2014). However, recent research into the development of a mechanistic understanding between local- *vs.* broad-scale influences on the formation of extreme events at coastal localities has revealed that meso-scale forcing from offshore onto the nearshore (<400 m from the coast) occurs far less than hypothesized (Schlegel and Smit, 2016). It is therefore necessary to consider additional mechanisms that may be responsible for these events.

Air-sea interactions have been a focus of study for decades (Frankignoul, 1985), with mixed results. Whereas interactions are often detectable at high latitudes, mid latitude relationships between air and sea are much more tenuous (Krishnamurti et al., 1988). Equation 1 in Deser et al. (2010) shows the process through which the upper mixed layer in the open ocean is effected by atmospheric and oceanic process. Unfortunately this process does not appear to apply to the coastal regions of the world, of which little is yet understood of the mechanistic processes driving the extreme events observed there. In certain special instances, such as the 2003 heatwave over the Mediterranean described in Garrabou et al. (2009) a clear connection may be drawn between the air and sea. This is however an exception to the norm as most bodies of water are not subject to static atmospheric and oceanic conditions. One reason given for the lack of apparent air-sea interactions at mid-latitudes is that the coupling of these two media drives an increase in the variability of both, inhibiting heat flux from one to the other (Barsugli and Battisti, 1998).

An earlier version of this manuscript sought to compare the co-occurrence of MHWs and atmospheric heatwaves (AHWs), both measured *in situ*, along the coastline of South Africa via the same methodology outlined in Schlegel and Smit (2016). The rates of co-occurrence for extreme events between these media were found to be lower than those found for nearshore and offshore seawater. It was therefore decided to create an index of synoptic figures of the mean air-sea state during the occurrence of coastal MHWs. The temperature dataset used for the calculation of the MHWs consisted of daily temperature records collected *in situ* at dozens of locations. The state of the sea, both SST and surface currents, was determined with BRAN. The state of the air temperature and wind were determined with ERA-Interim. The aim of the application of these datasets to this investigations was to visually search for broadscale patterns in the air and/ or sea that occur at similar times to MHWs at coastal localities. We hypothesized that i) similarities in the synoptic view of air and sea would reveal similarities between the largest MHWs detected in the dataset; ii) these similarities would be greater for the sea than the air; and iii) these observed similarities would aid in the development of a broader mechanistic understanding of the relationship between coastal MHWs and air-sea interactions.

## 2. Methods

### *2.1. Data*

## 3. Results

## 4. Discussion

## 5. Conclusion


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