This study aimed to investigate patterns occurring within upwelling events at various different spatial intervals from the coastline, as well as to test whether the same patterns are discernible in the various datasets. As seawater temperature is known to have a large influence on species distribution and productivity (Bolton 2010; Smit et al. 2013), thus it is important to understand not only how temperatures vary at different distances from the coastline but what contributing factors to ecosystem maintenance the intensity of these events have across these distance intervals from the coastline. Of particular interest to this study; the Benguela upwelling system, which is distinct in that it is one of four most productive regions in the world.

In this way, the proximal causes of environmental change might be understood in terms of its relevance in affecting these important regions. Sinnett and Feddesen (2014) expanded on this concept and illustrated that various environmental factors such as solar radiation, air temperature, humidity and wave energy are responsible for temperature variation within coastal regions. Here, however, we examine if the same upwelling patterns exist between the local and broader-scale SST fields given that various factors influence temperatures at different scales.

Results gathered during the course of this study clearly illustrate that upwelling events detected in different ocean sea surface temperature datasets showed variations with regards to duration and intensities across different time intervals. Noticeably, some patterns were dominant and persistent throughout the datasets; however, it was also observed that fewer upwelling events occurred at distances furthest away from the coastline. This was correlated in satellite datasets, where, often at distances of 10km and 20km from the coastline, similar upwelling events were apparent. This difference appears to be related to nature and the variability of physical oceanographic processes at both the broader and local scales; however, the potential involvement of other processes cannot be ruled out. These findings illustrate how dis-similar satellite data is from in situ collected datasets.

Often the differences noted between the in situ and satellite derived data were striking. Initially, it was anticipated a large degree of coupling within the datasets across the local and broader scales would be observed; instead the OISST satellite derived data yielded a more intense representation of events as compared to the SACTN collected data. The CMC dataset showed that events were moderate throughout the various sites and matched more closely with the in situ data observed. Information of events obtained from the OISST satellite data illustrated that these phenomena occurred more frequently and for longer durations.

Furthermore, it is now believed that the larger intensities witnessed within the in situ dataset may be in actuality an artefact of the inability of remotely sensed data to record the maximum and minimum temperatures that in situ instruments are capable of detecting (Smale and Wernberg, 2009). The in situ collected data shows very few events detected at Port Nolloth, similarly, the CMC and OISST dataset also shows fewer upwelling events recorded at a distance of 10km within this region. Upwelling events recorded in Sea Point match closely with the events detected in the OISST dataset at a distance of 10km.

Notably the CMC dataset showed large degrees of variance within detected events, however no major events were recorded. It is observed that the SACTN in situ collected temperature data shows similar patterns to the OISST dataset at a distance of 10km; with Saldanha Bay showing the highest frequency in upwelling events detected throughout the datasets. However, the in situ and OISST dataset at a distance of 10km once again showing similar detections as those recorded by the CMC dataset at the same distance from the coastline, and thus does not accurately represent these detected events. At a distance of 30km – 50km the in situ detected events differed greatly as those compared to what was observed within the satellite derived temperature data.

It should be noted that previous, similar studies have suggested that a longer, sampling time series, comprising of more data would have resulted in greater accuracy with regards to detecting subtle changes in temperature differences obtained from variable coastal regions such as the South African coastline. Schlegel and Smit (2016) suggested that having a time series of greater than 30 years for sites with a low variance results in increased ability to more accurately detect changes. They showed that high quality time series datasets have frequent measurements, with minimal missing (NA) values present. Furthermore, low quality datasets (i.e. those with more than 5% of NA values) have a higher chance of detecting variation where none exists.

We would be amiss to point out some weaknesses inherent in the SACTN dataset. Temperature

measurement along the South African coastline started in the 1970s, and has been inconsistent in

terms of the instruments used, the modifications to styles and methods, calibration, as well as site locations themselves (Smit et al. 2013; Schlegel and Smit 2016). Additionally, older records within some datasets, such as the SACTN dataset, may have been lost or are unreliable since the metadata for these are no longer available. These metadata are essential as their absence prevents the understanding of the influence regarding the utilised instruments on temperature recordings. It can thus be speculated that some measurements may not accurately represent well-validated temperature data due to the instrumentation used; however, we mitigated these effects by selecting only the most reliable and longest duration data, which other current and on-going studies, such as that by Williamson et al. have suggested are most suitable for the problem at hand.

Data in the SACTN are compiled from multiple sources, in addition to being acquired by various means, thus creating considerable heterogeneity; however, efforts are

currently underway to homogenise these datasets (Williamson et al., in progress). The underwater

temperature recorders (UTRs) used to collect data in the SACTN dataset expressed a lower number of NA values as compared to the data collected with hand thermometers. As such, this may have influenced the overall time series dataset (Schlegel and Smit, 2016). The level of precision at which data were collected also influenced the length of the time series needed. Time series in which temperature is collected at a precision of 0.5°C may require another 24 months of recordings to precisely detect long term variation (Schlegel and Smit, 2016). The average length of the thermometer time series component of the SACTN dataset was 346 months whereas the average length of UTR time series was less than half of that. With the extent of these differences in length being so severe, even once correcting for potential negative effects on the measurement precision of the thermometer collected time series, it was clear that thermometer data were more useful than that of UTRs. These influences may be expected to affect trend estimates of change derived from the data, however it is not anticipated that they have affected estimates of the variability in time and between sites in the way that they were used in this current study.

Irrespective, satellite-acquired SST records are useful to modern marine scientists. These data are often used to model and predict a wide range of oceanic and biological processes within open ocean ecosystems and habitats; however, these have only recently been used to study temperature variations influencing benthic organisms (Pearce, Faskel, and Hyndes, 2006). SST data acquired by satellites deviate from coastal in situ collected seawater temperatures for a variety of reasons (Smit et al. 2013). The SST data presented the broader-scale situation along the coast, therefore utilised here as a forcing boundary hypothesised here as influencing coastal temperatures. Analysis shows that the offshore SSTs (various sources) at a distance between 30km and 50km often do not match the detected events present within the in situ dataset along the west coast of South African.

EBUS, such at the Benguela upwelling system are known to be highly variable across a wide spectrum of spatial and temporal scales, in both the forcing and response of the system. In some cases, a climate event can force large, although temporary changes in the overall productivity and/or community composition; these effects were seen during the large 1997-98 El Niño event and the delayed upwelling in 2005 in the California Current. EBUS are therefore be characterized as both resilient (quick recovery from disturbances) and robust (maintenance of ecosystem function and relatively high productivity) to natural climate variability, maintaining an abundance of species of high commercial and conservation value. However, the scale of future responses to anthropogenic climate change may be beyond the historical scales of variability, thus making forecasting the response of EBUS to climate change difficult.

The importance of understanding the contributions of variation of upwelling on a local and broad scale relate to how productive these regions are but also indicated that upwelling found at a distance of 50km does not imply that the same upwelling events are present within the nearshore. Thus in order to detect coastal upwelling it is better to make use of coastal data. Within marine environments, coastal temperature variation allows for a varied spectrum in the spatial arrangements of marine biodiversity. Whilst wind and wave action may not be directly affecting ocean temperatures, Blamey and Branch (2009) have found that wave action has a profound influence on species distributions along the coastline. The presence or absence of marine species are determined by a variety of factors and whilst those factors may not be influencing each other as was the case here, they do however, collectively play an important role in affecting the marine life of the South African coastline; therefore, identifying those roles can aid in improving our understanding of nearshore dynamics, thereby providing greater knowledge base to be used for conservation efforts.