Preventive measures or, what can be done

The exact effect of the warming of the ocean on South Africa's weather and climate is not yet certain. That there is going to be an effect can readily be seen at Marion Island where the vegetation is changing due to climate change, where the locations of certain ecosystems are in flux and where alien species are more invasive than before.

So what preventative measures can we take to counteract the effects of ocean warming? Firstly, efforts should be aimed at increasing our understanding of the changes in the ocean currents and surface temperatures that can be expected. This can be achieved with appropriate sophisticated modelling and by studying how the oceans have changed in the past. However, many of the most elementary mechanisms that play a role in the oceans' ameliorating effect on climate change are still not perfectly understood. Without proper knowledge of the ocean systems, much of our prognostication is going to remain in the realm of speculation.

Second, it is clear that where long records of regular observations have been kept, much was learned about climate changes and how the terrestrial environment reacted to such changes. Wider networks of observation locations, aimed at persistent and long-term monitoring, will be a boon to understanding how the inevitably growing effects of global climate change is going to affect South Africa.

On the recent warming of the Agulhas Current

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The Agulhas Current is an energetic current driven by the wind field over the Indian Ocean. It has a profound effect on the climate and the coastal ecosystem of South Africa and plays a key role in the global ocean circulation. The current carries warm and salty water from the tropics polewards and controls the exchange of heat and salt between the Indian and Atlantic Oceans. Since the 1980s, the sea surface temperature of the Agulhas Current system has increased significantly. This is due to an increase of its transport in response to an augmentation in wind stress curl in the South Indian Ocean. This causes an intensification of the Agulhas Current system and leads to an increased flux of salt and heat into the Atlantic Ocean. There is also an augmentation in the transfer of energy from the Agulhas Current to the atmosphere due to increased evaporation. These observed changes could have far-reaching consequences over and above their potential regional impacts on ecosystems and climate.

Introduction

The Agulhas Current (Figure 4.90) flows along the east coast of South Africa before moving offshore near latitude 34°S and subsequently retroflecting back into the mid-latitude South West Indian Ocean. It creates a coastal dynamic upwelling in the vicinity of Port Alfred and Port Elizabeth bringing nutrient rich water to the surface [1, 2]. High evaporation rates and associated turbulent latent and sensible heat fluxes occur above the Agulhas Current throughout the year due to an important sea surface temperature contrast between the Agulhas Current and its surroundings. Measurements in the Agulhas Current have shown substantial transfers of water vapour in the marine boundary layer, a deepening of the marine boundary layer due to intense mixing, and unstable atmospheric stability created by the advection of colder and drier air above the current [1, 2]. The intensity of mixing in the local boundary layer is such that cloud lines can often be observed above the current [3]. Rouault *et al.* [4] have provided evidence of the influence of the Agulhas Current on the evolution of a severe convective storm over southern South Africa. That particular storm, in December 1998, led to severe flooding and a tornado in Umtata that nearly killed President Nelson Mandela when the winds in the town caused a building to collapse. On the global scale, Agulhas water leakage around South Africa controls the exchange of heat and salt between the Indian and Atlantic Oceans and has a role in the Atlantic meridional overturning circulation [5].

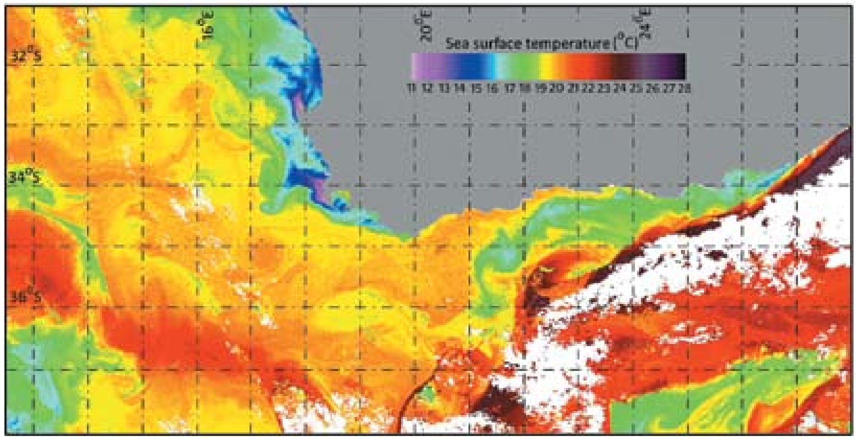

Figure 4.90 A composite satellite image of sea surface temperatures near South Africa for 14-19 December 1998. The information was gathered by the AVHRR on board the NOAA-14 satellite. Colours show the sea surface temperatures and clouds appear white. The core of the Agulhas Current has temperature of 21 to 25 °C. [AMS]

Mean sea surface temperatures

Figure 4.91, an image obtained using 4 × 4 km resolution Advanced Very High Resolution Radar Sea Surface Temperature imagery (AVHRR SST) [6], shows the 1985-2007 mean sea surface temperature around South Africa. The mean absolute geostrophic ocean current vector derived from merged altimetry [7] is superimposed on the image, which shows the major elements of the Agulhas Current system. The main loop is found south of the continent. The Retroflection is located in the domain delimited by 10˚E to 20˚E and 37˚S to 42˚S. Eddies shed from the Agulhas Current can be found as far as latitude 50˚S but most of them are usually formed in the Retroflection and move northwestwards towards Brazil. The Agulhas Return Current flows eastwards and meanders from 37˚S to 42˚S. A coastal upwelling of cold water is evident from Cape Agulhas to Namibia and is the result of strong seasonal southerly wind. This is in contrast to the Port Alfred upwelling cell that is triggered by the Agulhas Current itself. Sporadic wind-driven upwelling also occurs to the east of Cape Agulhas.

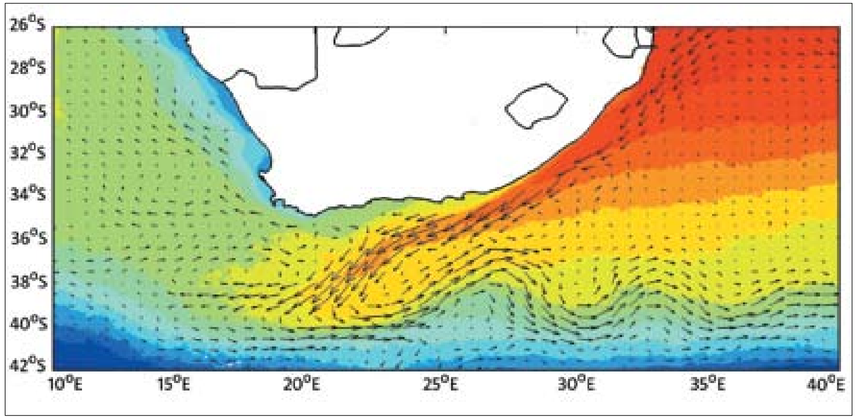

Figure 4.91 Mean 1985-2007 AVHRR SST. Mean 1993-2007 absolute geostrophic velocity vectors derived from combined altimeter is superimposed.

Changes in mean sea surface temperatures

Figure 4.92 (also obtained using 4 × 4 km resolution AVHRR SST) shows the linear trend in sea surface temperature from 1985 to 2007. The most important change is found in the Agulhas Current system, which has warmed by up to 1,5 °C since the 1980s. Rouault *et al.* [8] have shown that this warming was due to an intensification of the Agulhas Current system in response to an increase in trade wind and a poleward shift in the westerly wind in the South Indian Ocean leading to an overall increase in wind stress curl at relevant latitude. A numerical model that reproduces the observed SST relatively well showed that the transport of the Agulhas Current system had increased since the 1980s leading to the observed warming. This also led to substantial increase in evaporation rate of up to 1 mm per day per decade in the Agulhas Current system and a 50% increase in the leakage of Agulhas water into the South Atlantic. A cooling of up to 0,5 °C per decade occurs at the west coast. Another cooling occurs in the dynamic upwelling cell of Port Alfred and Port Elizabeth where it seems to spread into the Agulhas Current itself and to the west. Cold water seems to have propagated offshore and eastward from the Port Alfred dynamic upwelling cell. Upwelling favorable wind could have contributed to the cooling but an intensification of the Agulhas Current and concurrent intensifying of the dynamic upwelling could be the principal reason of the cooling in that region. The cooling in the west of the country, from Cape Agulhas to the Namibian border, is due to an increased southerly wind. The west coast cooling occurs mostly in autumn and winter [8]. The greatest warming is evident in the Agulhas Current system and the Transkei at all months of the year.

The origin of the cooling trends for the west and south coasts is found in an examination of the linear trend in European Center for Medium Range Weather Forecasts and National Centers for Environmental Prediction reanalysed surface wind speed in the region from 1982 to 2007 [8]. It shows that surface wind speed increased in the Southern Atlantic and Indian subtropics. This increased the wind stress curl in the South Indian Ocean and it is at the origin of the intensification of the Agulhas Current system [8]. The observed change in sea level pressure and wind speed is consistent with a poleward shift of the westerly wind in the Southern Hemisphere and an increase of the South Atlantic and South Indian Ocean high pressure systems due to intensification of the Hadley circulation and a trend towards a positive phase of the Antarctic Oscillation.

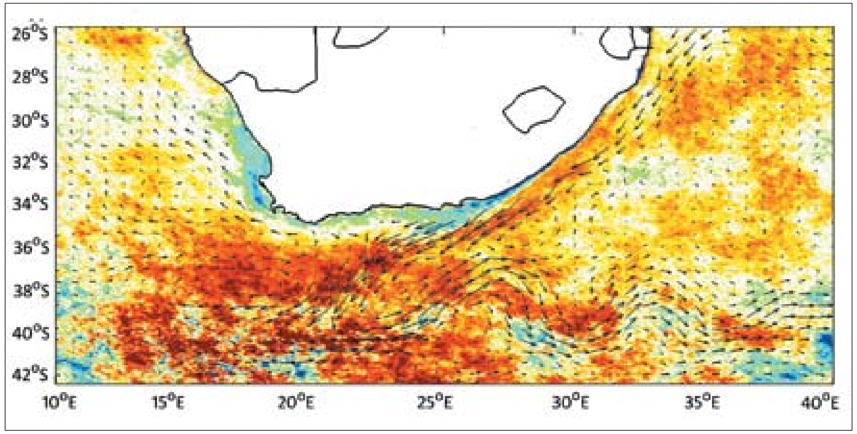

Figure 4.92 Linear trend of AVHRR SST from 1985 to 2007. Mean 1993-2007 absolute geostrophic velocity vectors derived from combined altimeter is superimposed.

Conclusion

In conclusion, it seems that the most important changes to the climate and coastal ecosystem in the region is an intensification of the Agulhas Current system since the 1980s. This caused a warming of the Agulhas Current system and a cooling of the Port Alfred upwelling cell. The west and south coast presents a cooling pattern from April to August. All those changes seem to have been triggered by an intensification of the high pressure system in the South Atlantic and South Indian Ocean and a poleward shift of the westerly system.

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