Understanding Surface Temperatures in Southern Africa's coastal and shelf waters

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MARINE ENVIRONMENTAL RESEARCH

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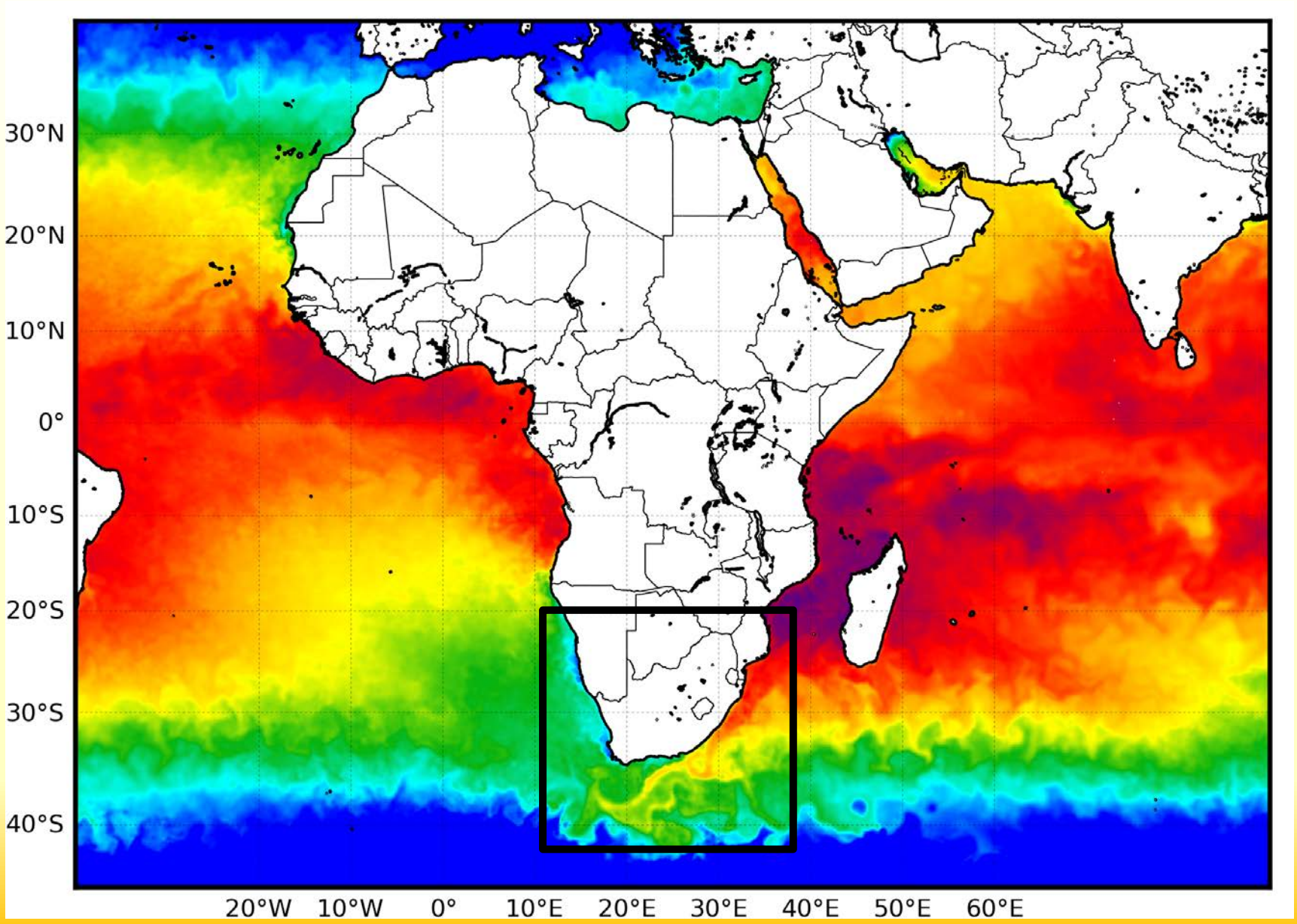
SPES BONA

1. Marine regions
2. Drivers of SST variability
3. Some challenges
4. What next ?


30°N
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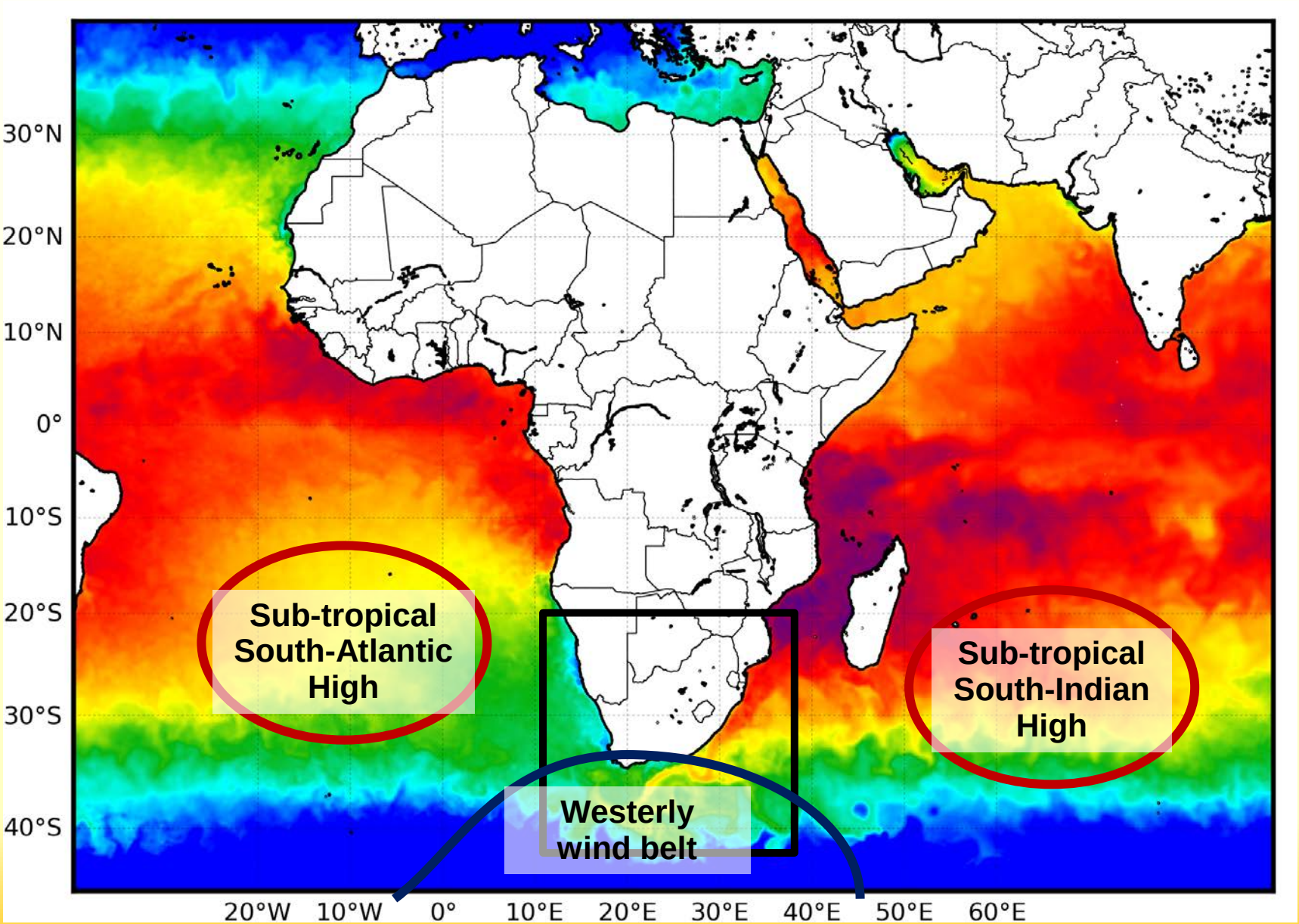
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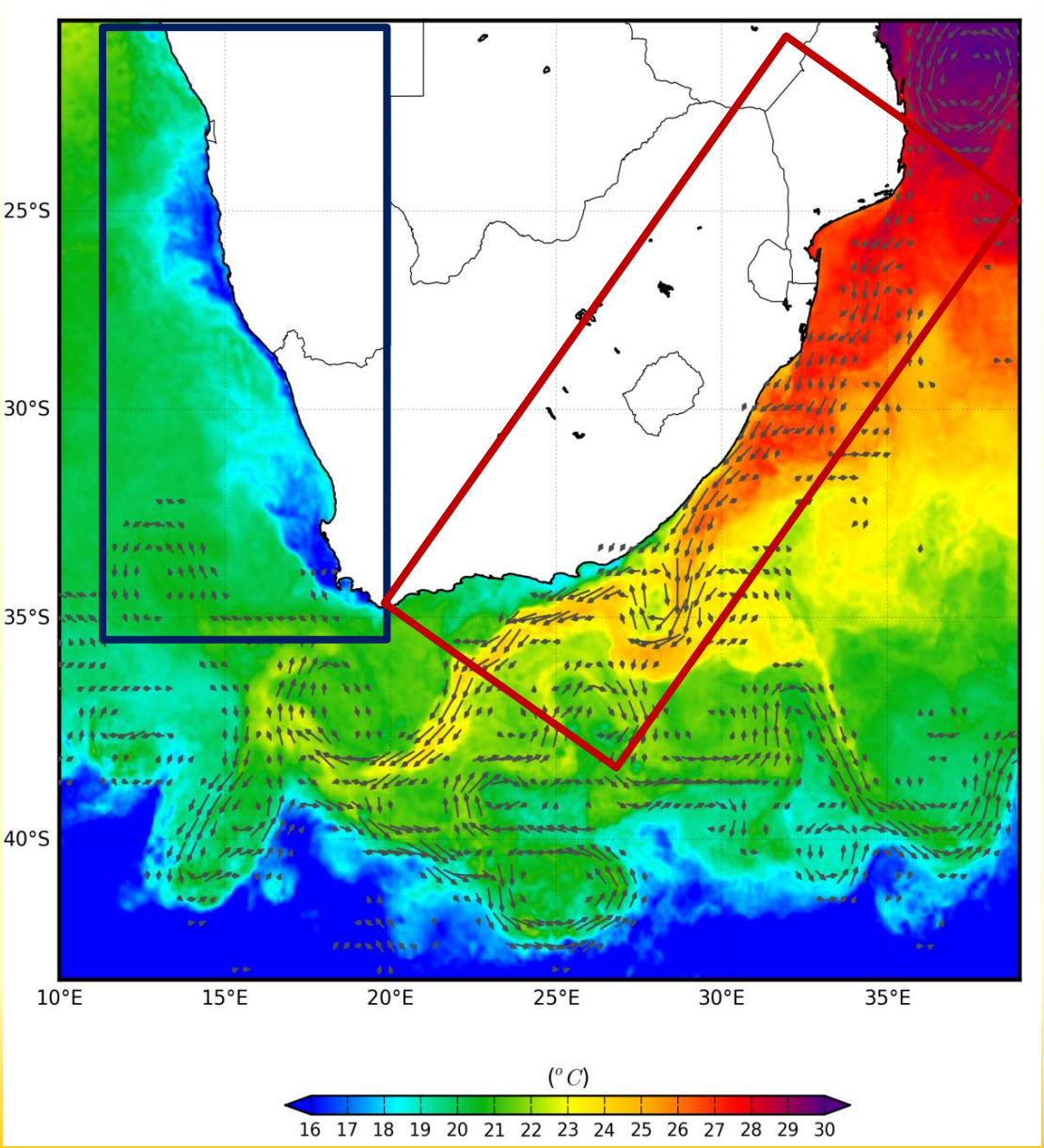
Sub-tropical South-Atlantic High
Sub-tropical South-Indian High
Westerly wind belt

Two contrasting marine systems



The Benguela:

- Strongest coastal upwelling system in the world
- Cold
- Wind-driven
- Supports a rich fishery with catches of rock lobster, cods, hakes and haddock, sardines and anchovies of over a million tons per year

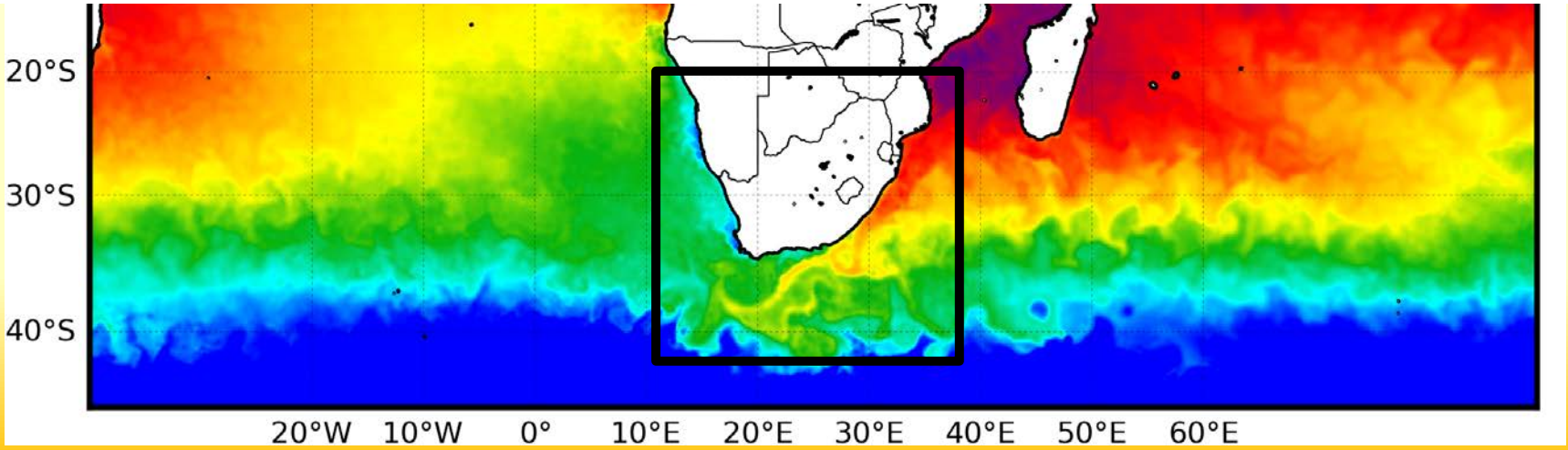
The Agulhas:

- Strongest western boundary current in southern hemisphere
- Warm, narrow and fast (>2m/s)
- Meso-scale variability linked to forcing from source regions
- Higher fish diversity

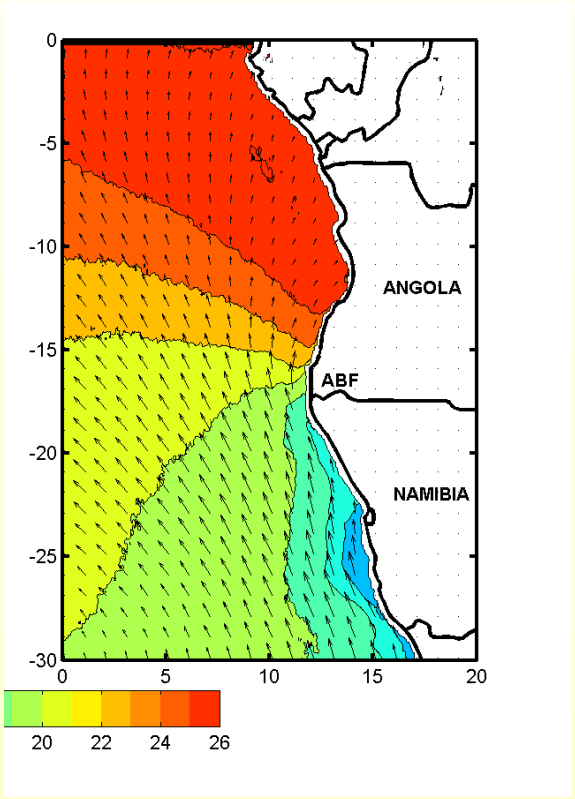
Vigaud et al. 2012 (Climate Dynamics):
Oceanic surface conditions prevailing over the Agulhas current regions of the South West Indian Ocean (SWIO) influence Tropical Temporal Trough persistence for regional experiments with an oceanic mixed layer, warmer sea surface temperatures being associated with increased moisture advection from the SWIO where latent heat release is enhanced, favoring baroclinic instability and thus sustaining convection activity locally.

Rouault et al. 2012 (International Journal of Climatology):
The diurnal cycle of precipitation over South Africa during summer is strongest over the interior and along the east coast of South Africa, explaining up to 70% of the variance. The presence of the warm Agulhas Current play an important role in the diurnal cycle of the rainfall over South Africa.

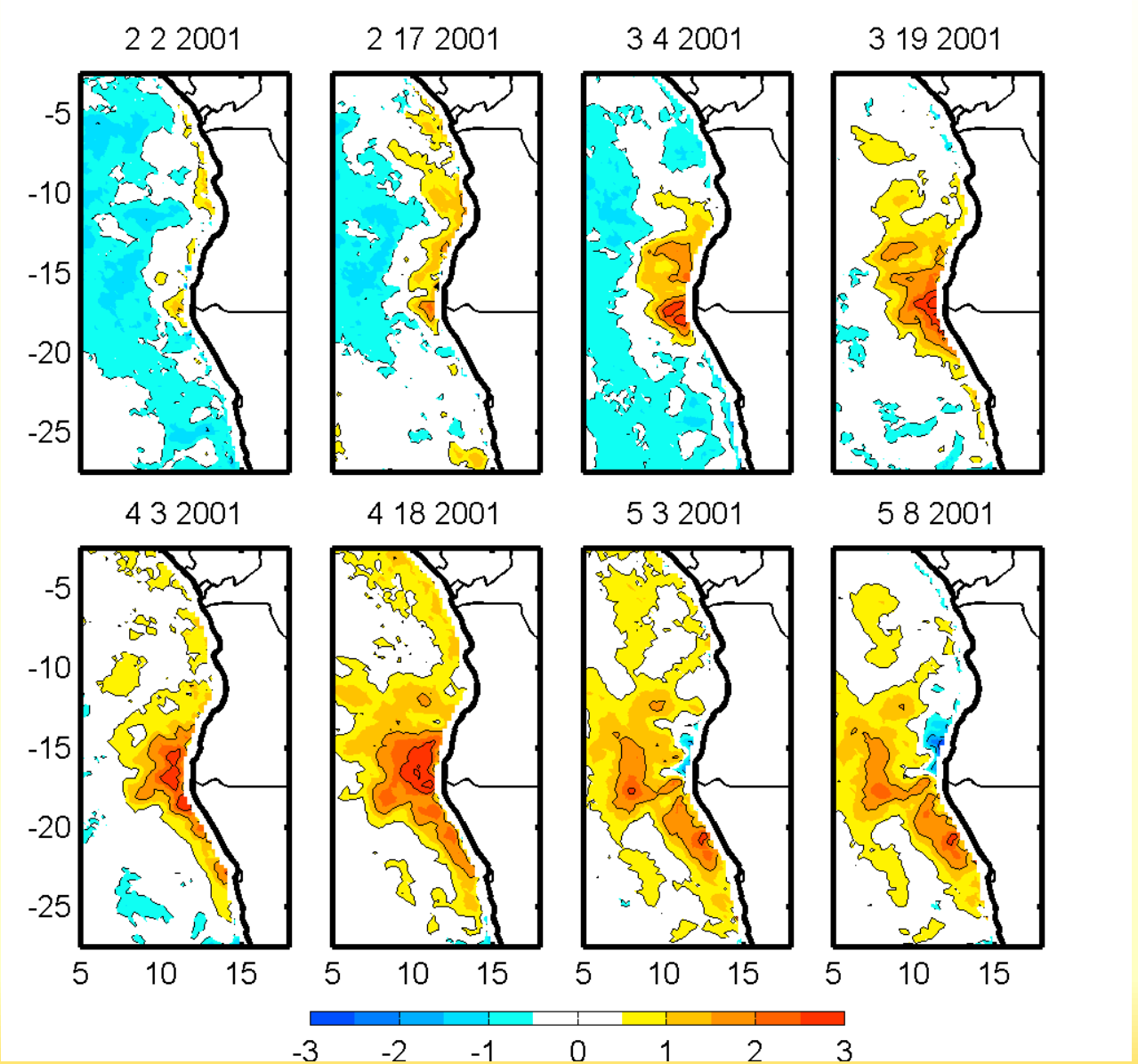
Dupont et al, 2011 (Journal of Geography):
Inferred vegetation changes for the Late Miocene south-western African coast consistent with a marine-driven climate change in south-western Africa triggering substantial radiation in the terrestrial flora, especially in the Aizoaceae.



Benguela Ninos



Rouault et al. 2007



TRMM SST Monthly anomaly centered on the date of interrest from February 2001 to May 2001

Distribution shifts observed in

- **Kelp**

Kelp has moved 70 km eastwards between 2006 and 2011 after being "stationary" for the previous 70 years

- **Small pelagic (Anchovy, Sardine)**

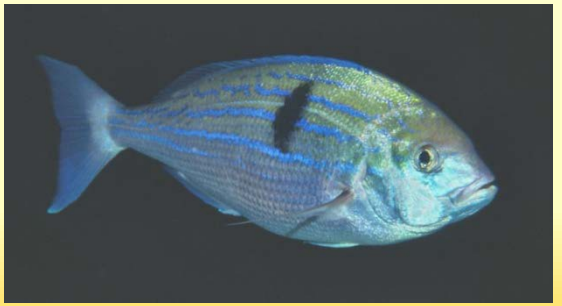
Eastward shift since 1990s

- **West coast rock lobster**

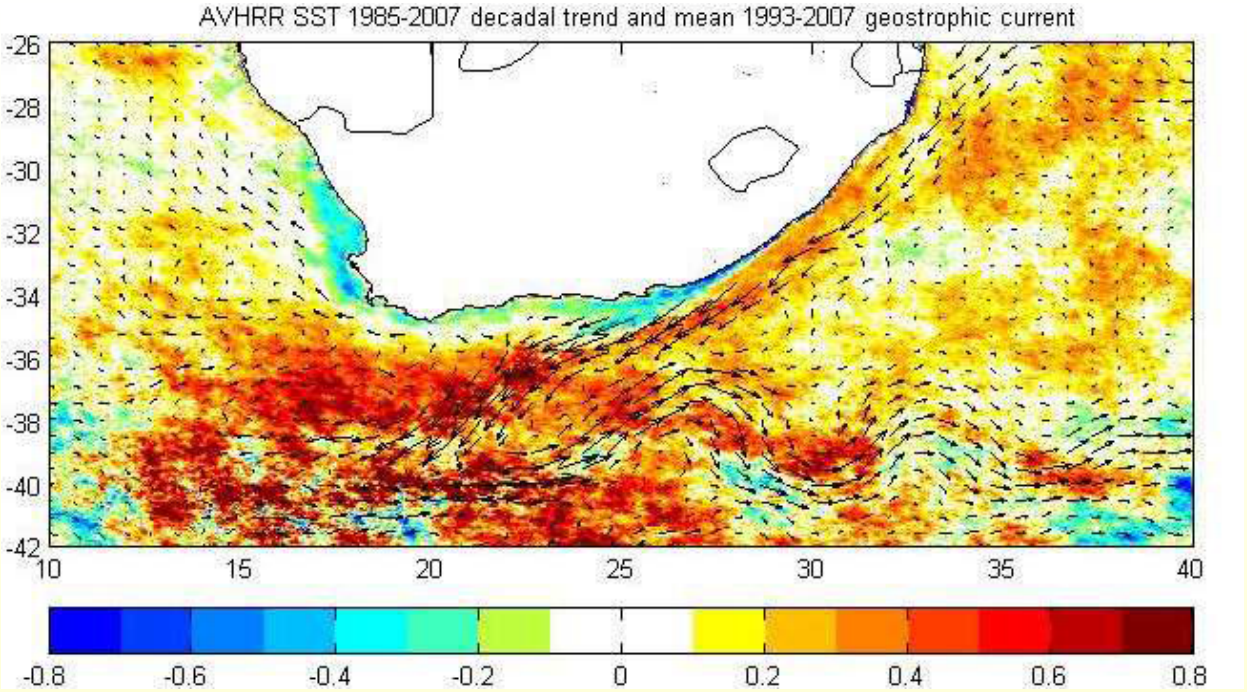
Shift in catches of west coast rock lobster from west coast to southern coast during 1990s

- **Kwazulu-Natal Linefish**

Change in fish species community composition at sub-tidal reefs off Durban between 1989-97 and 2002-07. Fewer temperate and more tropical species

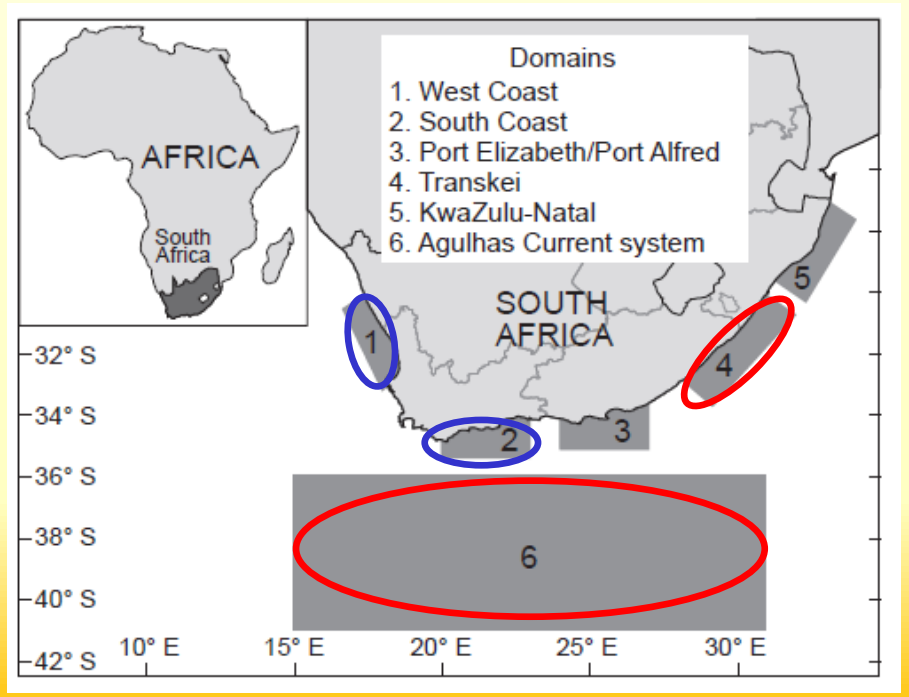


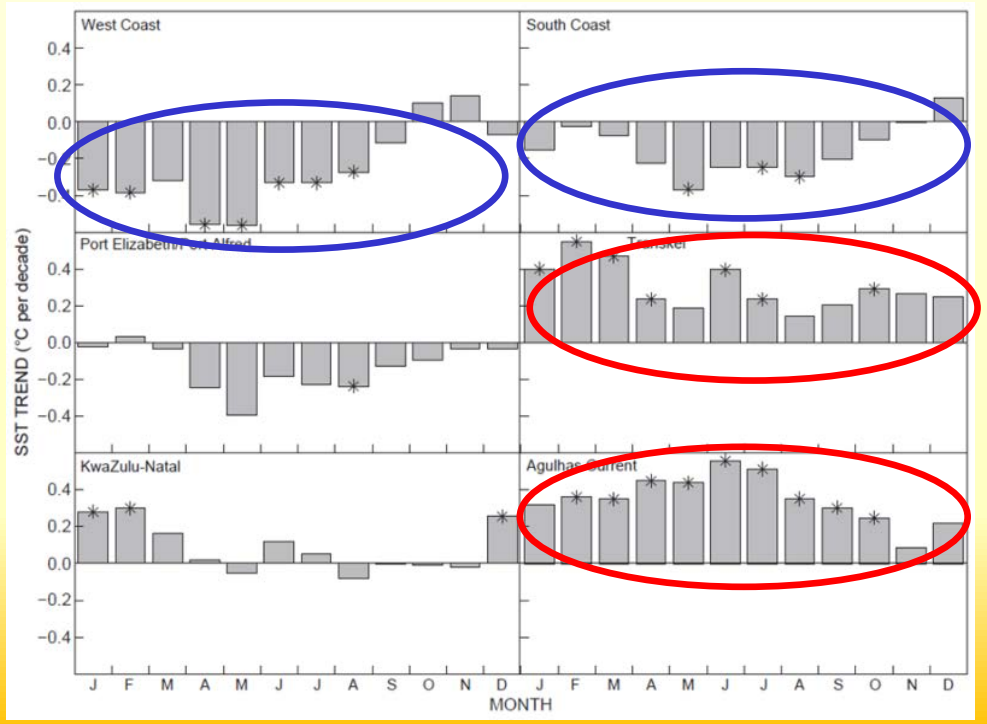
(van der Lingen et al. 2006; Cockcroft et al. 2008)



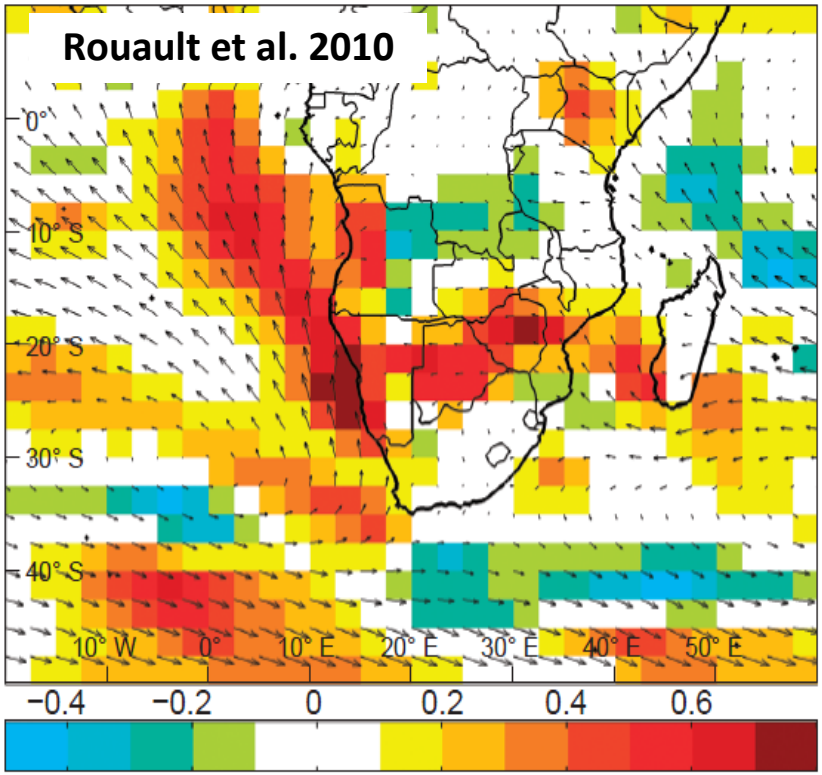
Changes in SST around SA in recent decades (1985-2007; AVHRR SST)

Cooling off inshore west and south coast but warming off east coast and in Agulhas Current



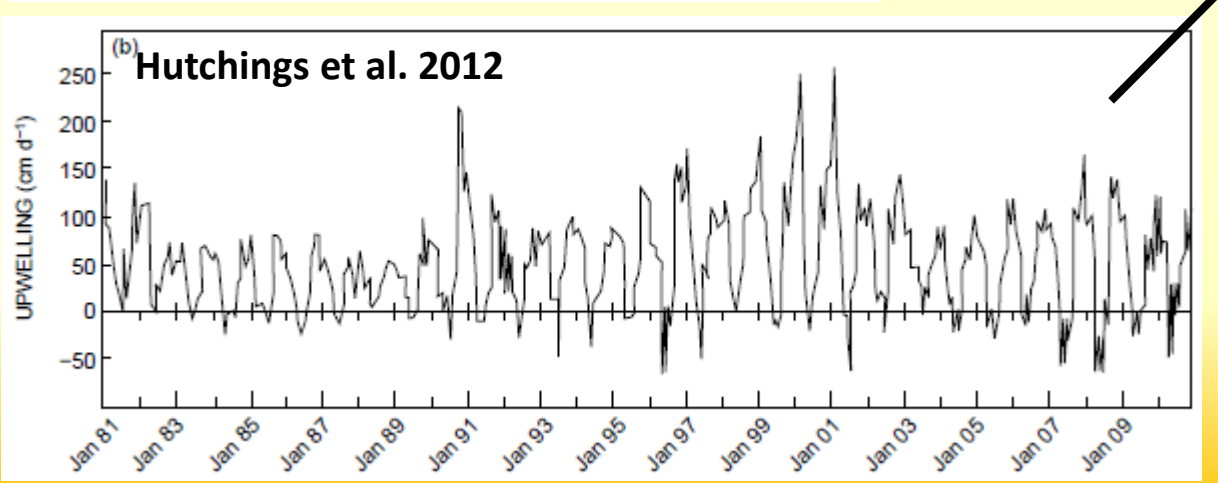


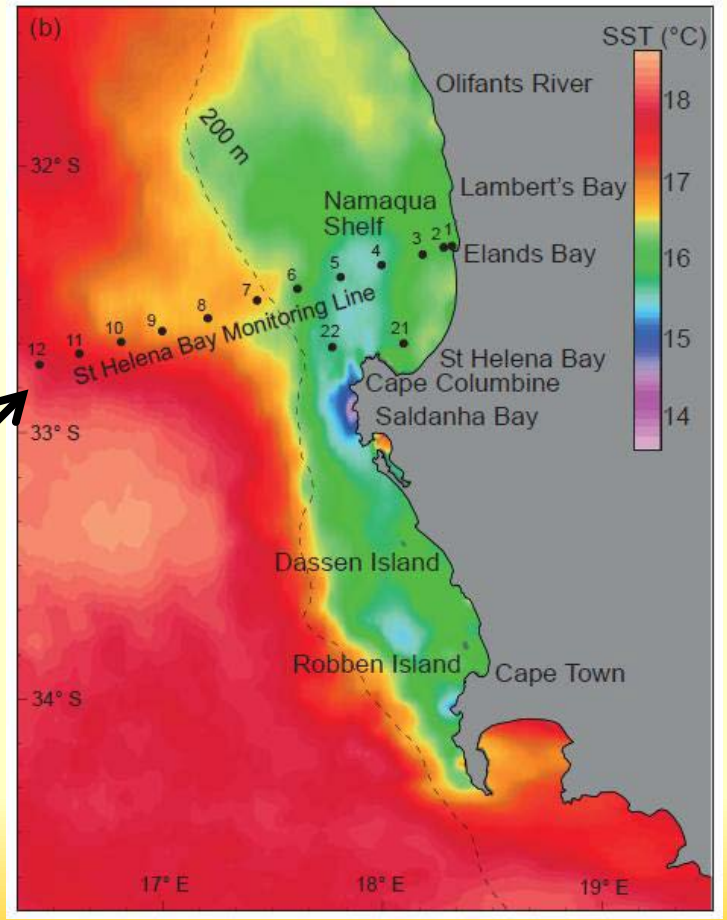
Rouault et al. 2010



Increase in southerly winds off west coast over the period 1982-2009

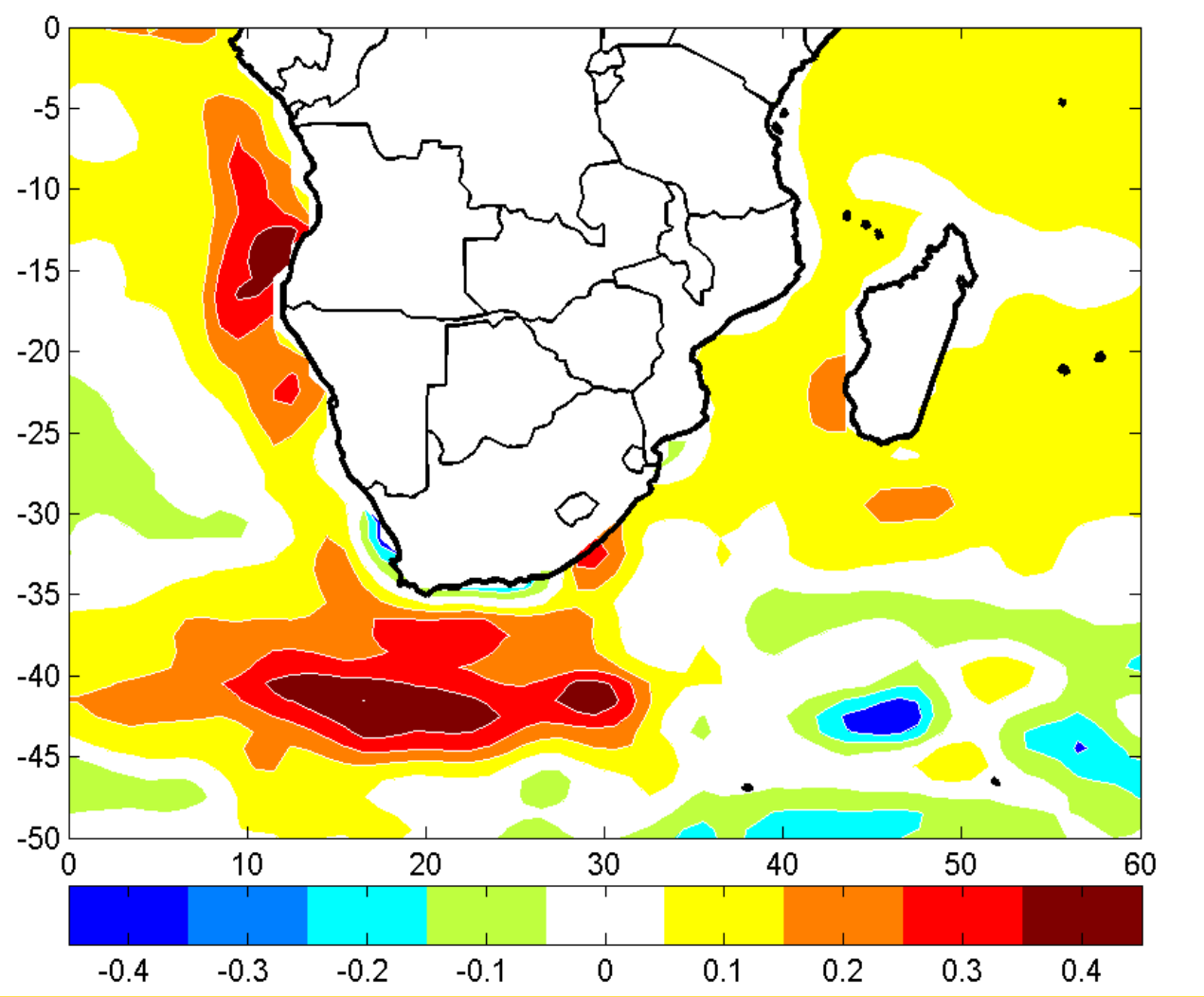
Increased upwelling in St Helena Bay from early 1990s





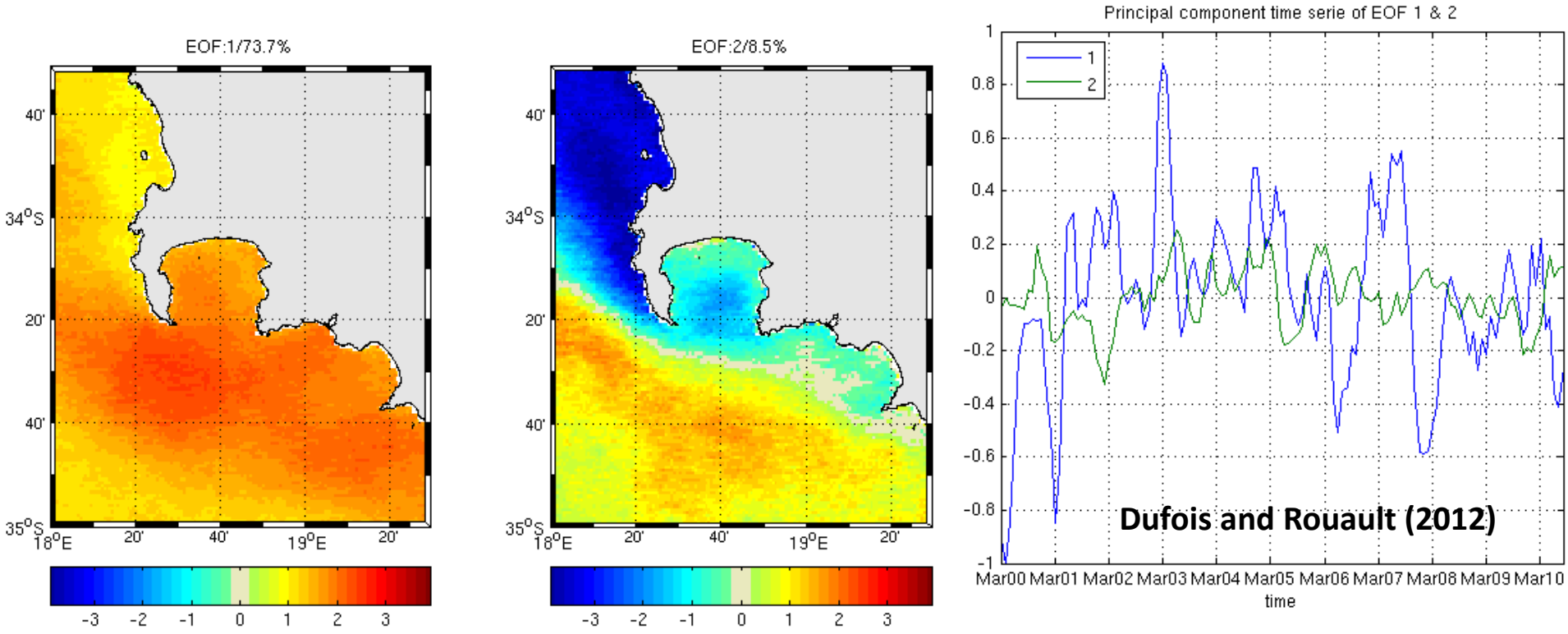
Slide adapted from C. van der Lingen

Hypothesis (Dr. F. Marsac) that warming in Equatorial Indian ocean resulted in large volume increase in tropical fishes which are then migrating south through the “Agulhas Current highway”.



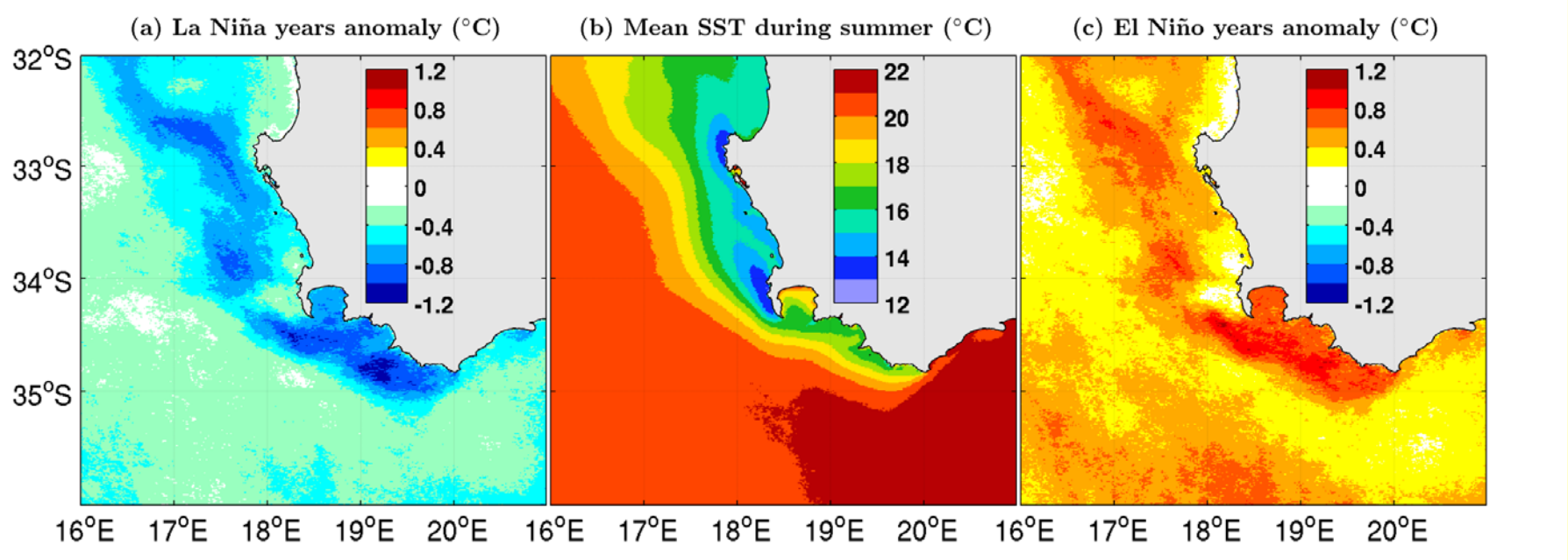
Linear trend Reynolds OI SST 1982-2012 in C per decade (Rouault et al, ??)

What are the dominant modes of this inter-annual variability?



- PC1 is correlated with Nino 3.4 (with a 4 month lag), mainly during austral summer months
- PC2 is correlated with SE monthly wind anomaly at Cape Town airport

SST anomalies during El Nino/La Nina years in January/February/March



Dufois and Rouault (2012)

What about the Agulhas Current ?

What we know

- Impact on regional and global climate
- Retroflection is one of the most intense region of air/sea interaction globally
- Recently observed annual cycle in Agulhas Current velocity (Krug and Tournadre, 2012)
- Seasonal variations in position of Agulhas Retroflection

What we don't know

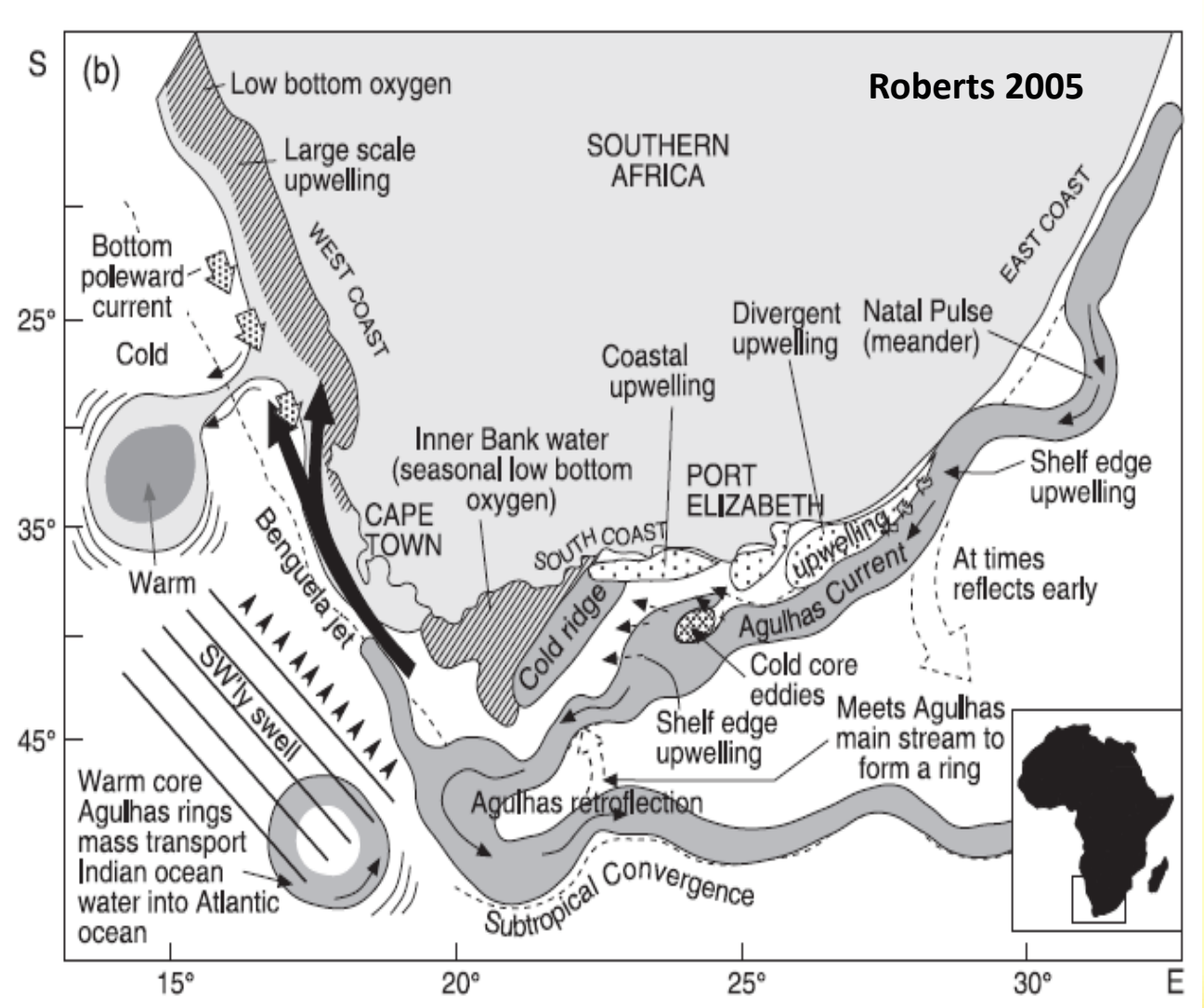
- Inter-annual variability of Agulhas Current unknown
- No idea of diurnal SST cycle in Agulhas Current

Proximity of Agulhas Current to the coast implies strong influence on coastal and shelf waters though:

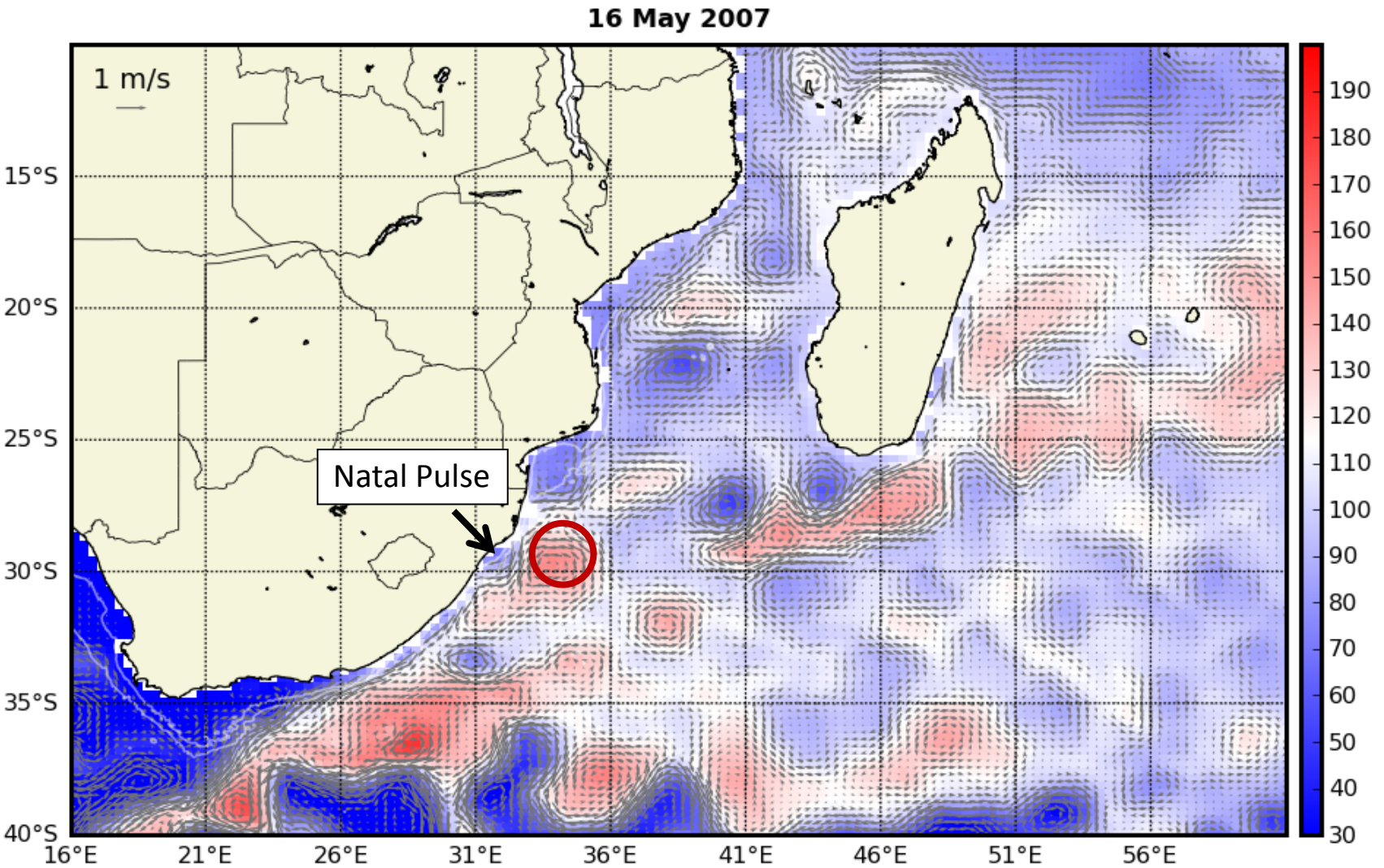
- Dynamical upwelling,
- Current intrusions,
- Meanders,
- Filaments,
- Shear edge eddies

(timescales of days to months, spatial scales of 100m to 200km)

Some of that variability is propagated from the Agulhas Current's source regions



Anti-cyclone propagating from Eastern Madagascar Retroflection region triggers a meander in the Agulhas Current. These meanders have been called Natal Pulse due to their region of origin in the Natal Bight.

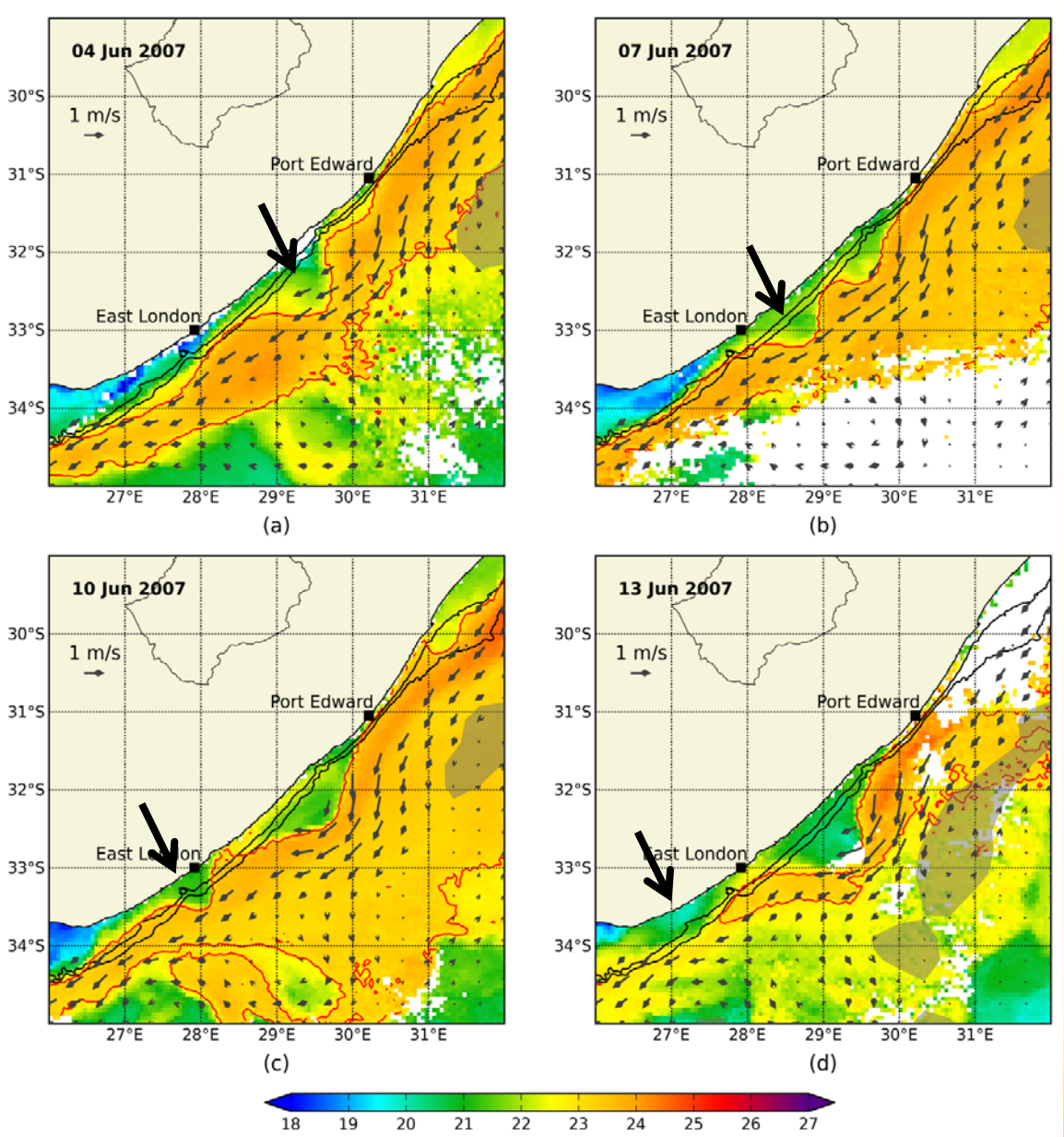


Interaction between Anticyclone and Agulhas Current generate a Natal Pulse (large cyclonic meander) in northern Agulhas Current.

Upstream instabilities are triggered during the passage of Natal Pulses.

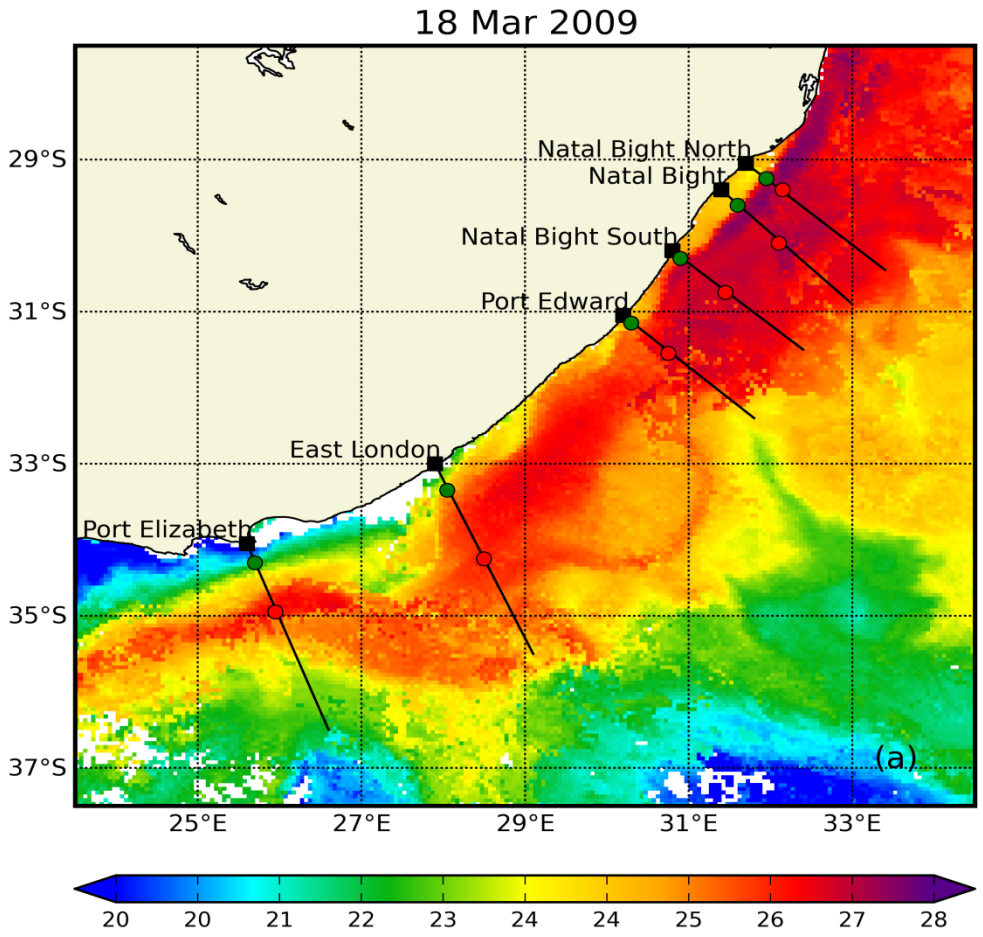
These instabilities show as meanders upstream of Natal Pulses.

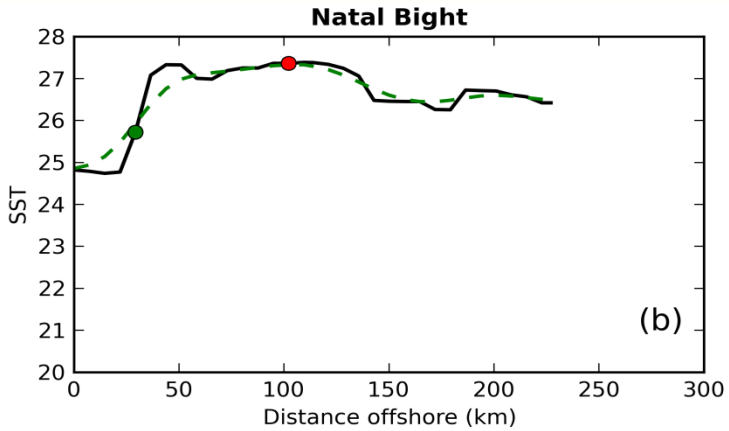
During their southward progression, meanders (including Natal Pulses) can evolve rapidly to **1) dissipate**, **2) merge** or in some rare occasion, **3) detach** from the Agulhas Current.

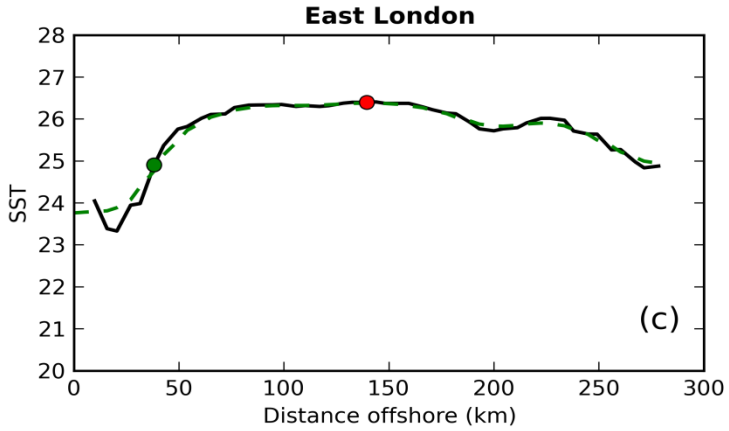


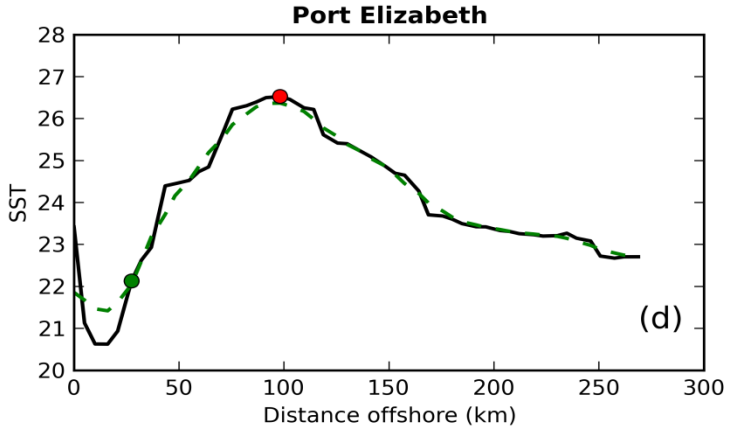
Rouault and Penven, 2011

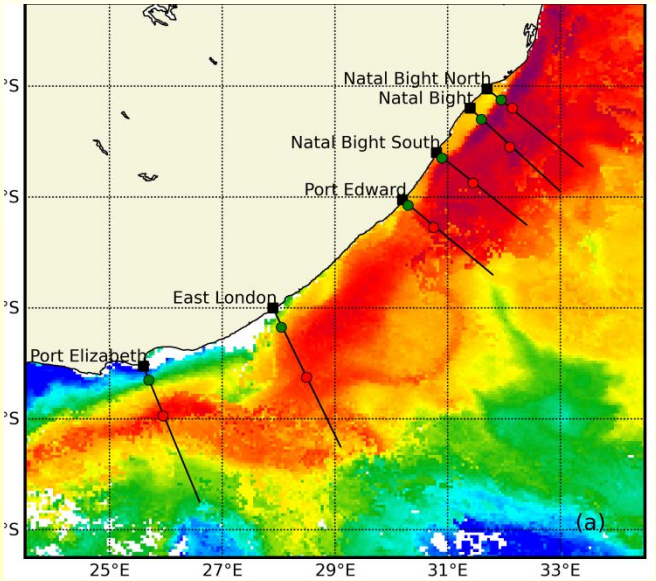
Attempt to track some of that variability using OSI-SAF hourly SST dataset (MSG2-SEVIRI)

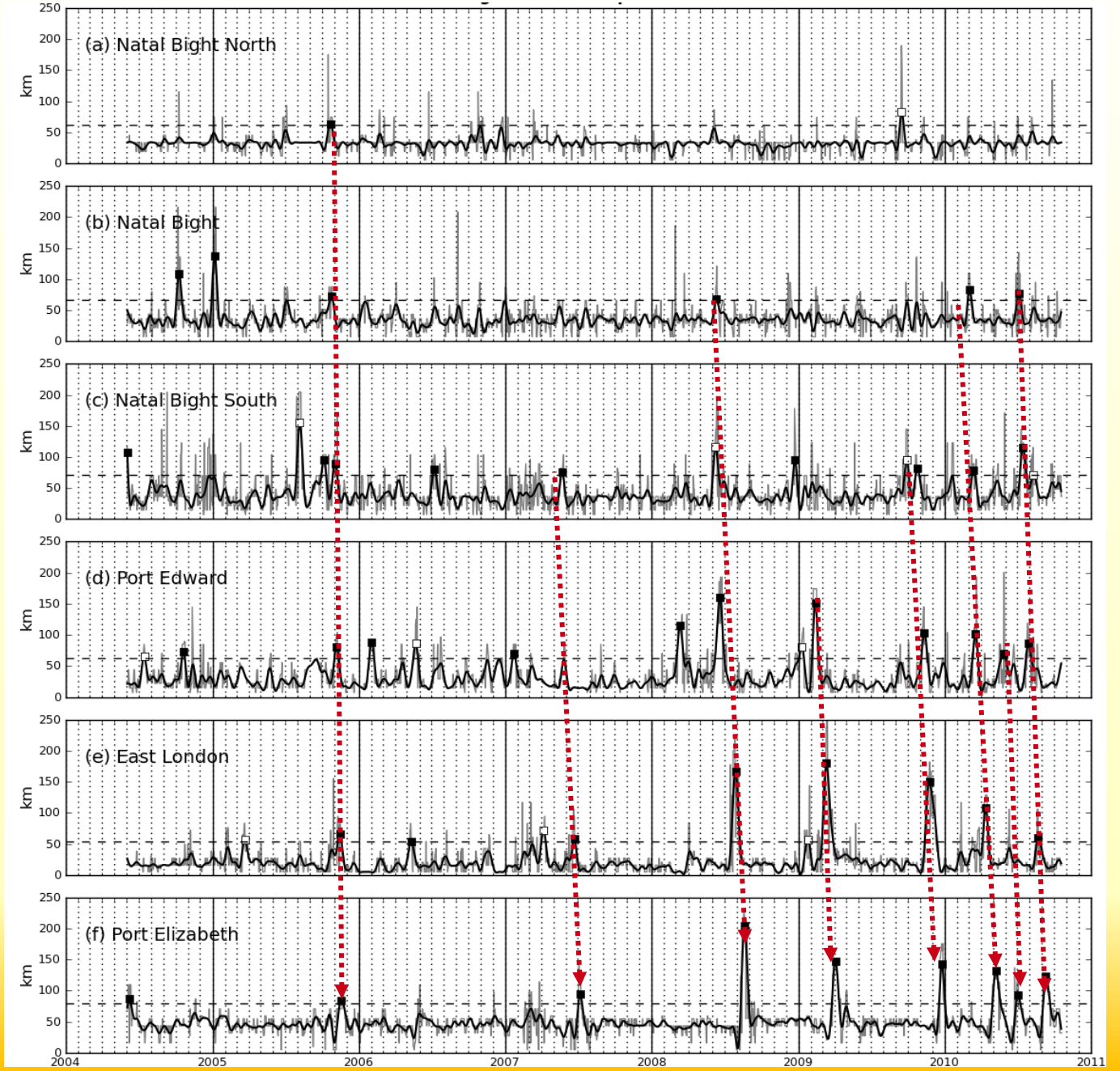






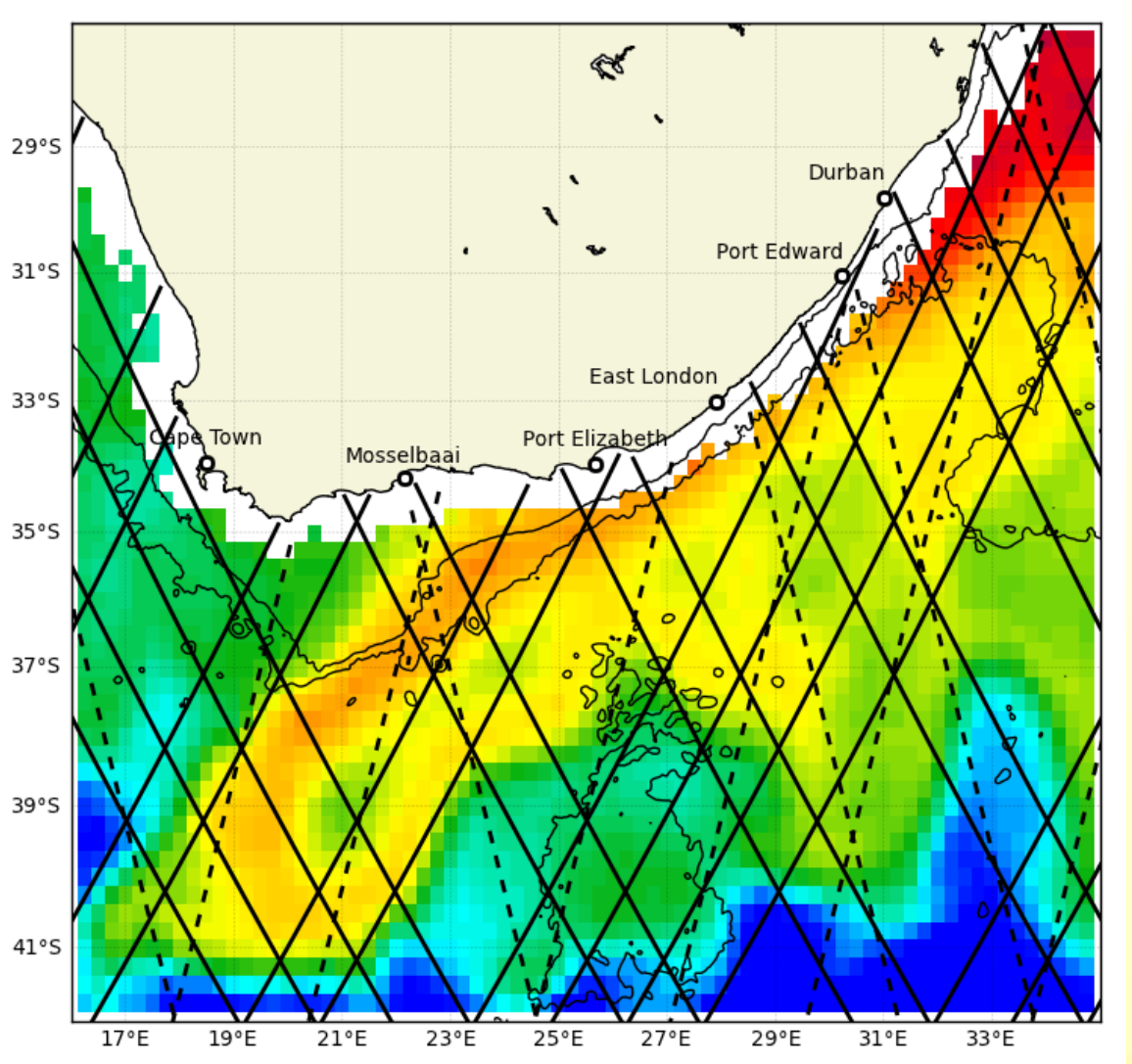



Natal Bight North
Natal Bight
Natal Bight South
Port Edward
East London
Port Elizabeth
(a)
25°E
27°E
29°E
31°E
33°E


(a) Natal Bight North
(b) Natal Bight
(c) Natal Bight South
(d) Port Edward
(e) East London
(f) Port Elizabeth
km
0
50
100
150
200
250
2004
2005
2006
2007
2008
2009
2010
2011

Microwave SST observations have low spatial resolutions and are not able to provide measurements near the coast.

This is a problem in northern Agulhas, where the current hugs the coastline.

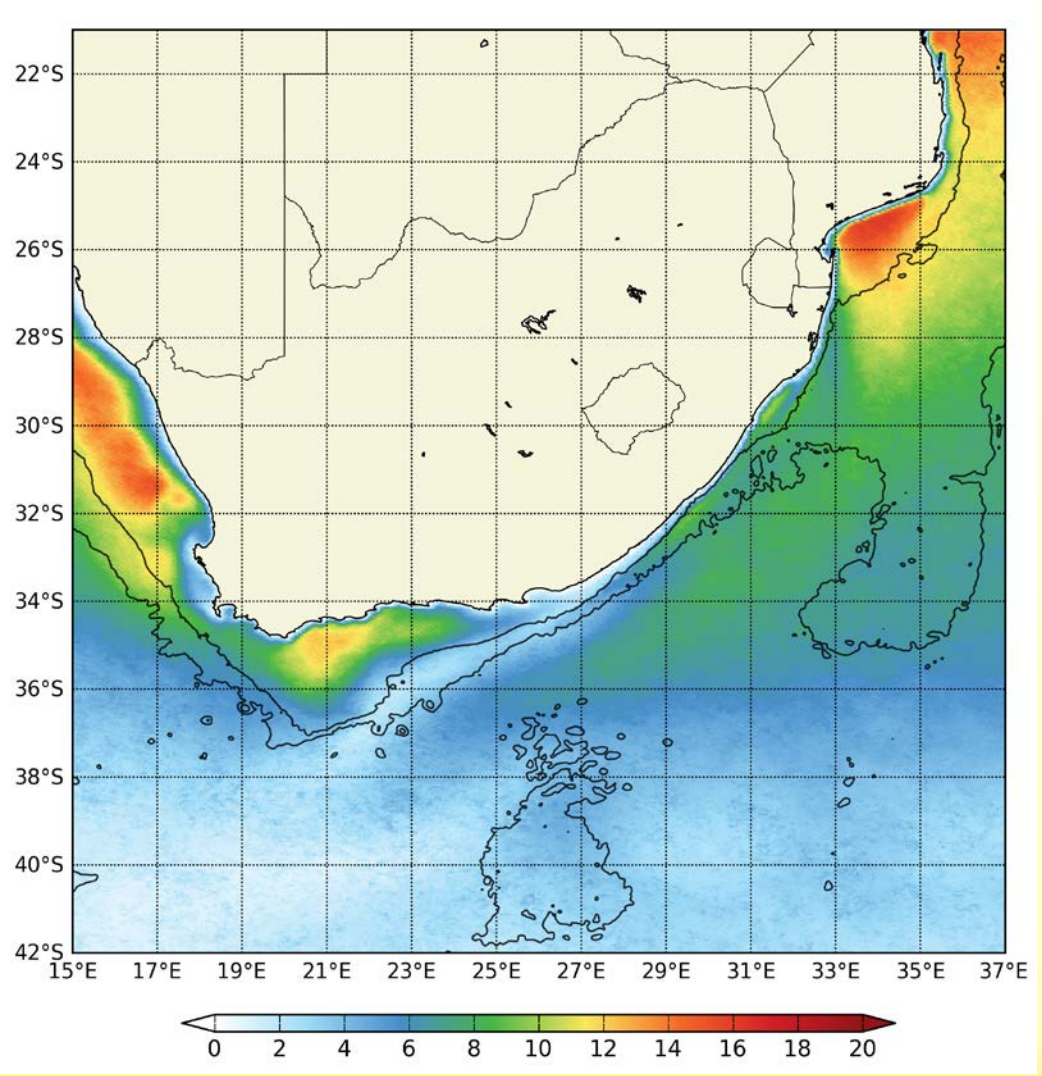


More than 30 years of IR SST observations from space are available, making SST one of the preferred variable to study climate change.

But cloud contamination in the region is a major problem

Over the Agulhas Current core, about 5 times as much water vapor is transferred to the atmosphere in comparions to neighboring waters (Rouault et al., 2010)

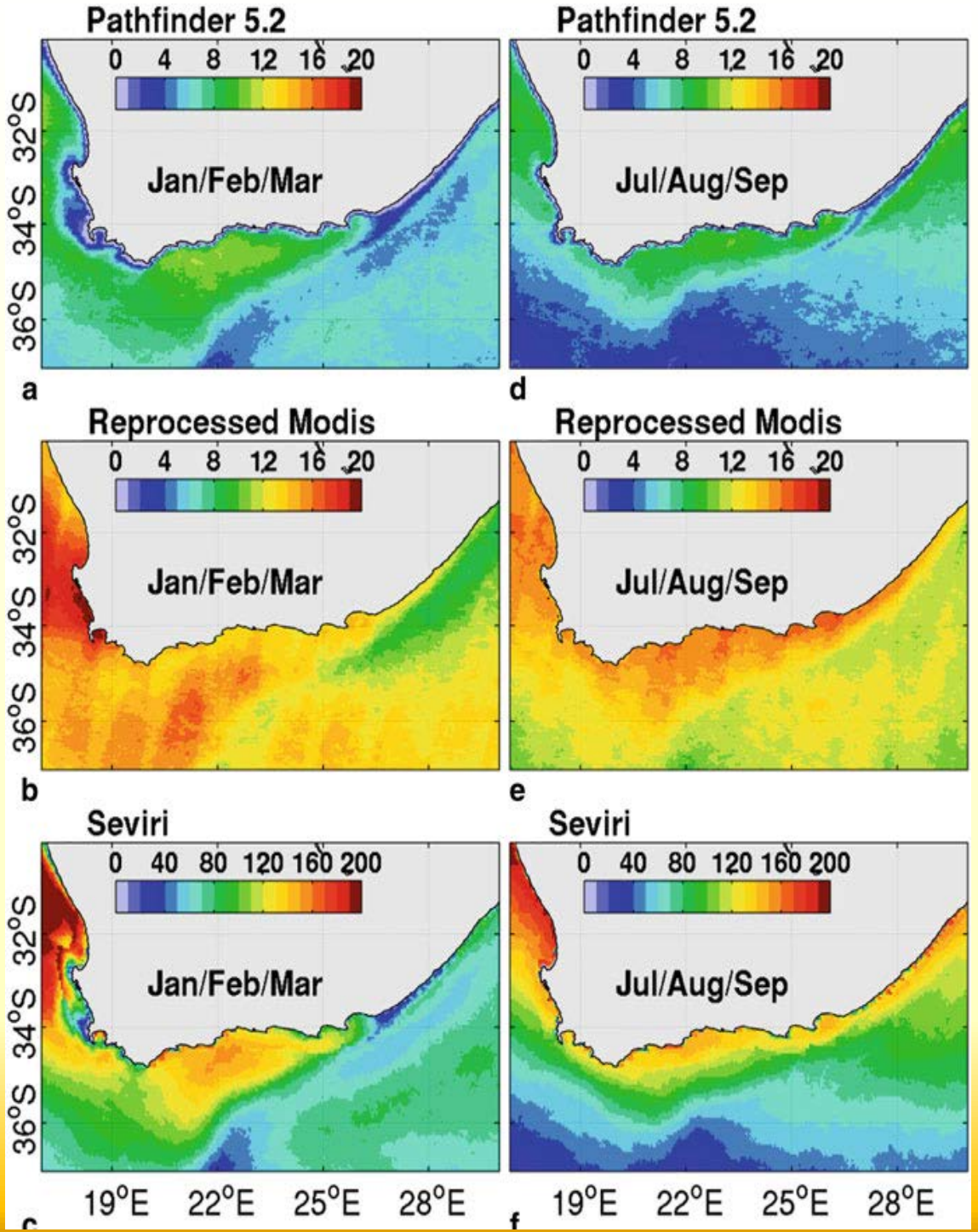
In regions of strong thermal gradients, automatic cloud screening procedures often result in the loss of good geophysical data. In some coastal regions such as Port Elizabeth (34S), dynamic upwelling induces strong temperature gradients between the Agulhas Current and the coastal and shelf waters.



Average number of monthly SST observations calculated over the 1985 to 2009 period from the NOAA Pathfinder de-clouded dataset (version 5)

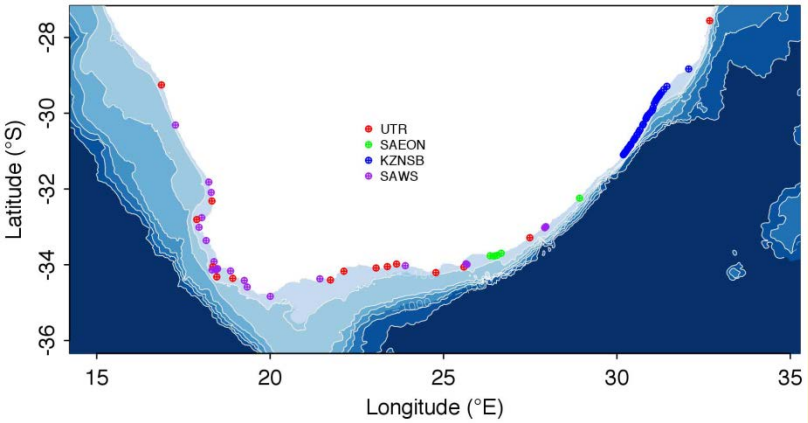
Our ability to observe coastal regions in southern Africa is dependent on:

- Sensor
- Cloud masking algorithms
- Season
- Local dynamics



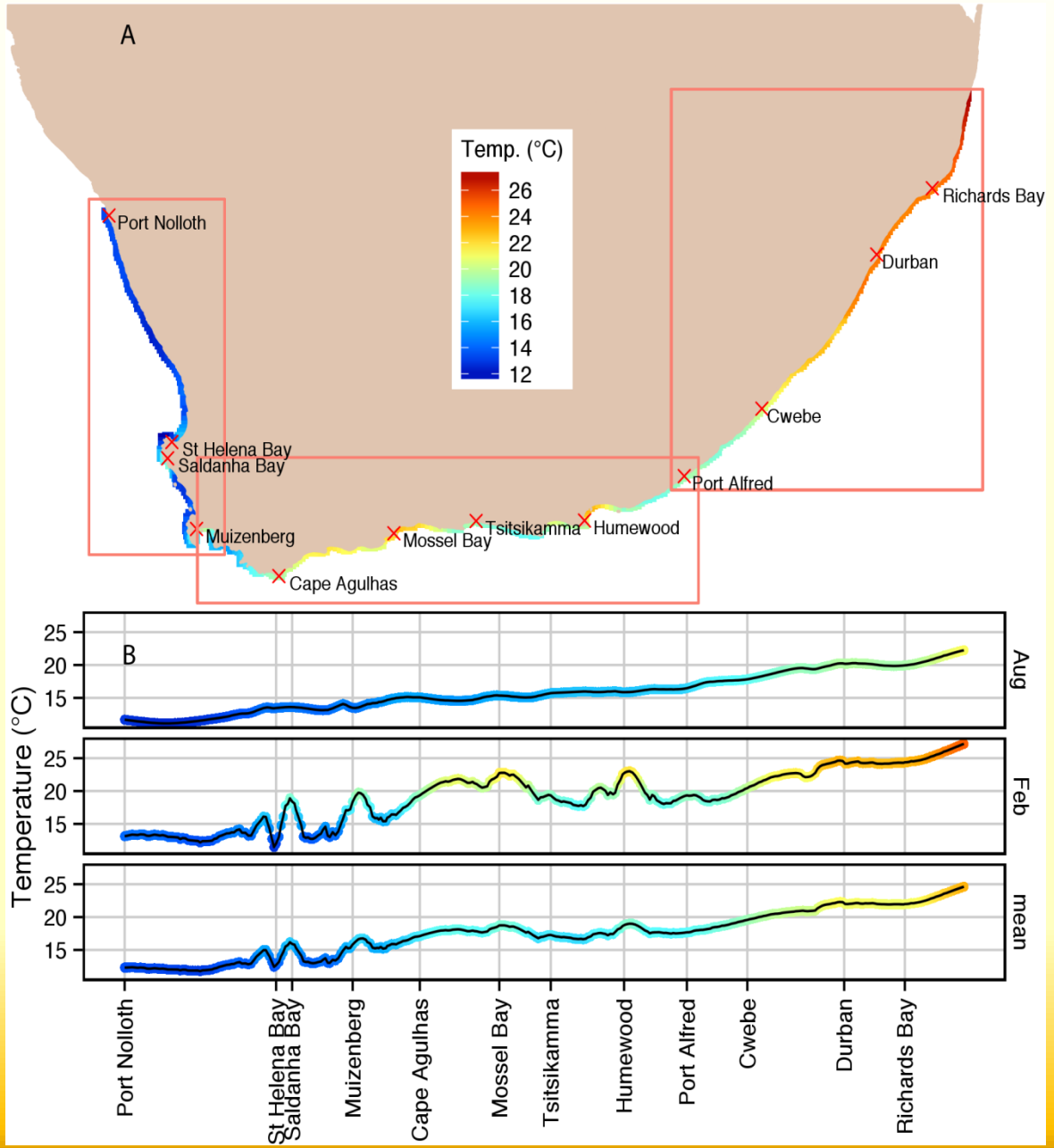
Number of good observations per month derived using the Pathfinder v5.2, MODIS TERRA and OSI-SAF hourly daytime SST

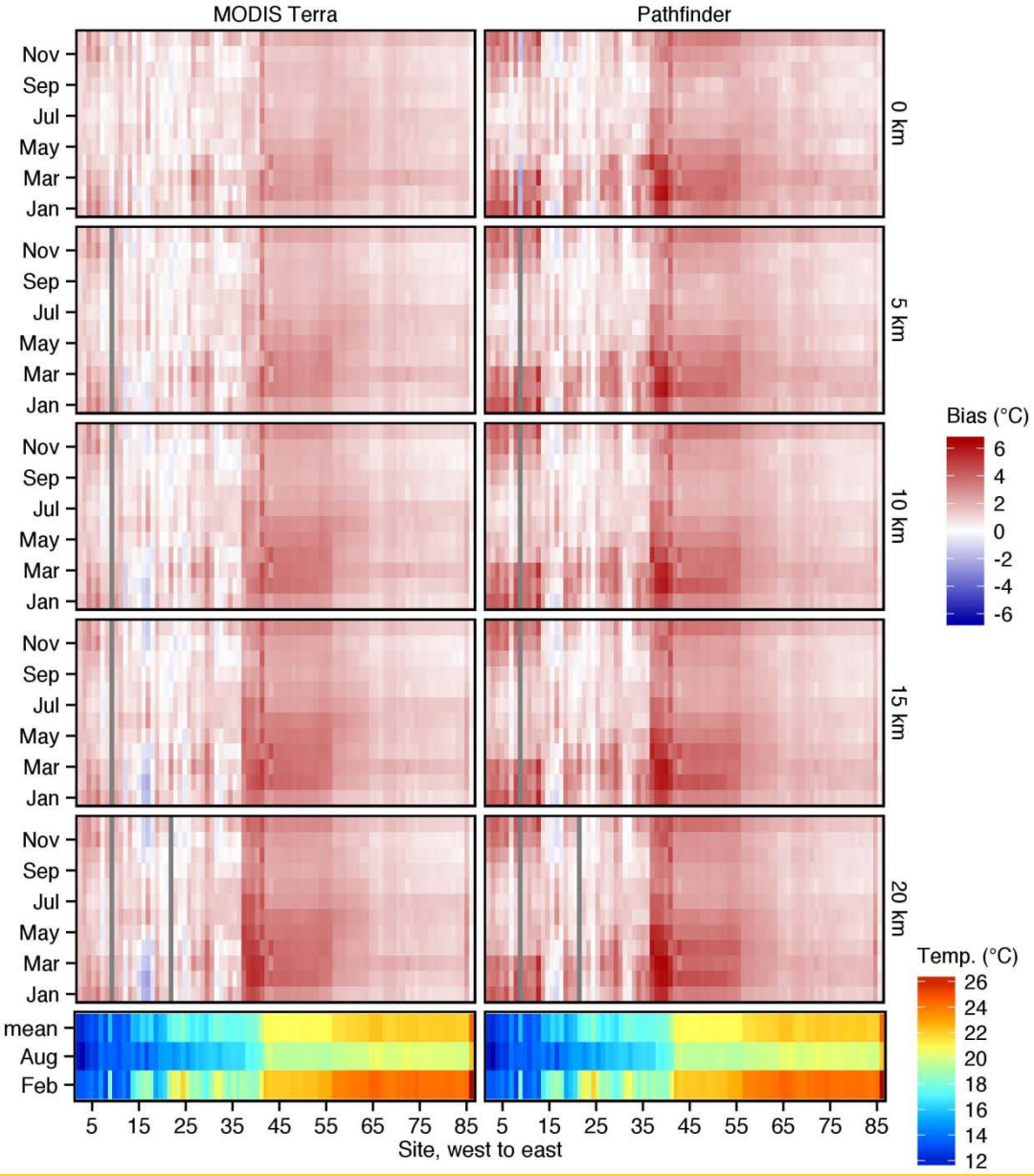
Krug et al. 2014



Interpolated summertime inshore in situ temperature data for the entire coast

A. J. Smit et al. (2013)

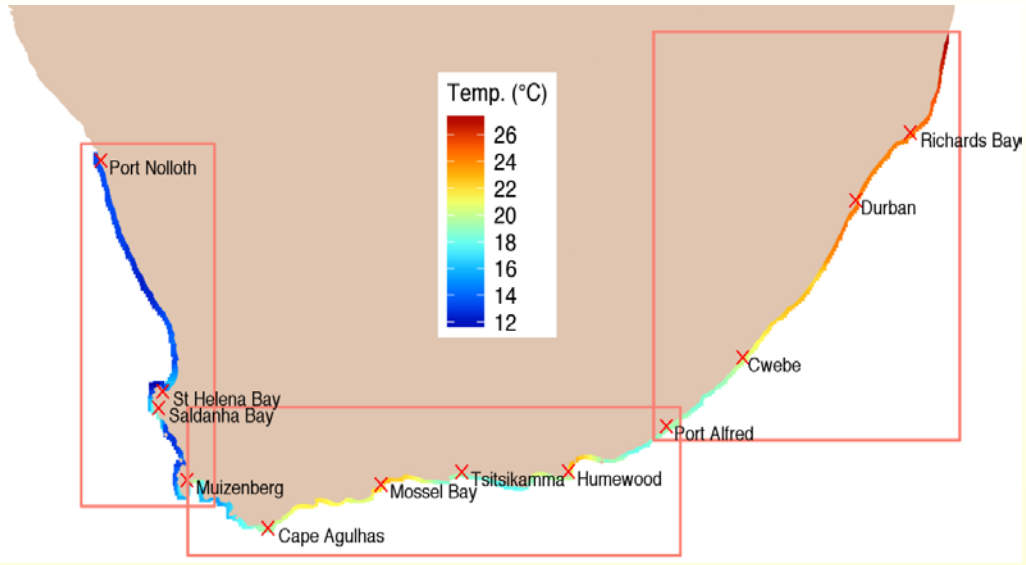




Smit et al. (2013)

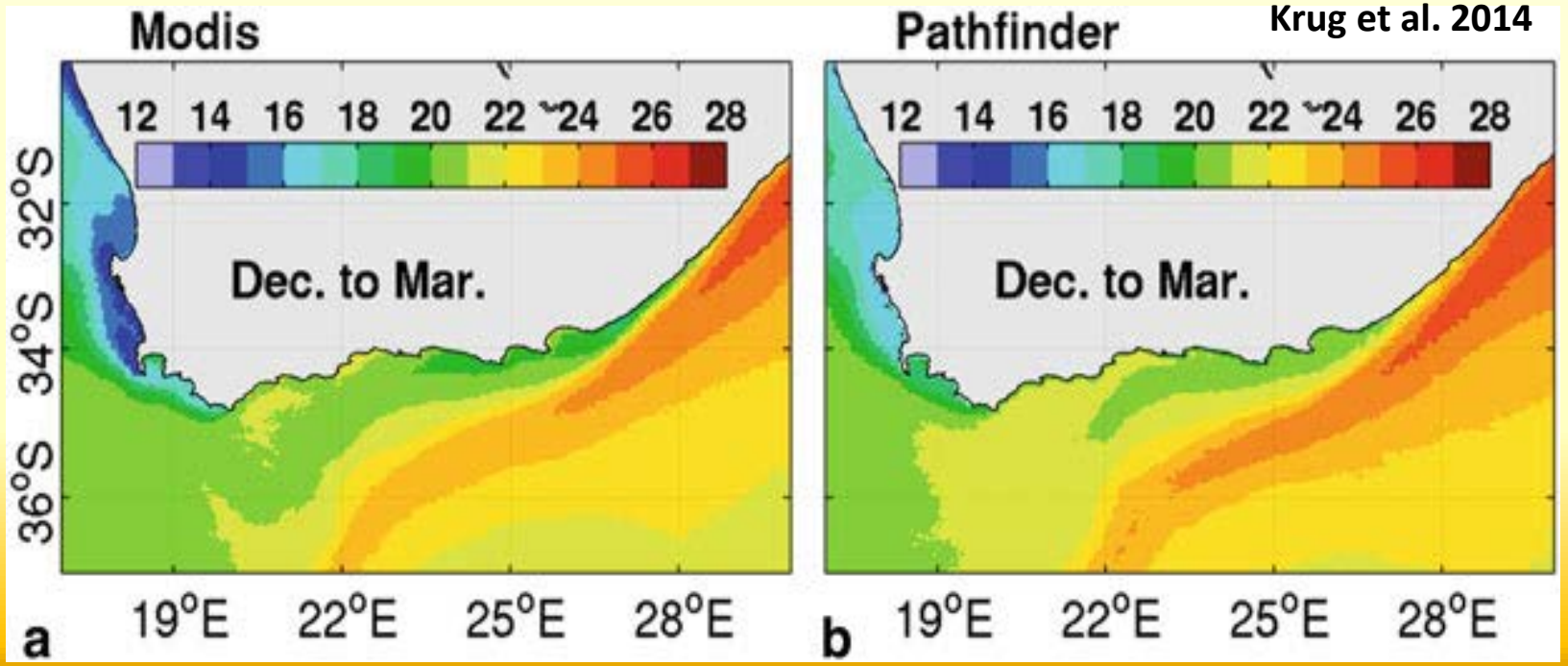
A raster image of MODIS Terra (left panels) and Pathfinder (right panels) biases with respect to in situ temperatures.

Satellite-derived SST data show a warm bias along the whole coastline

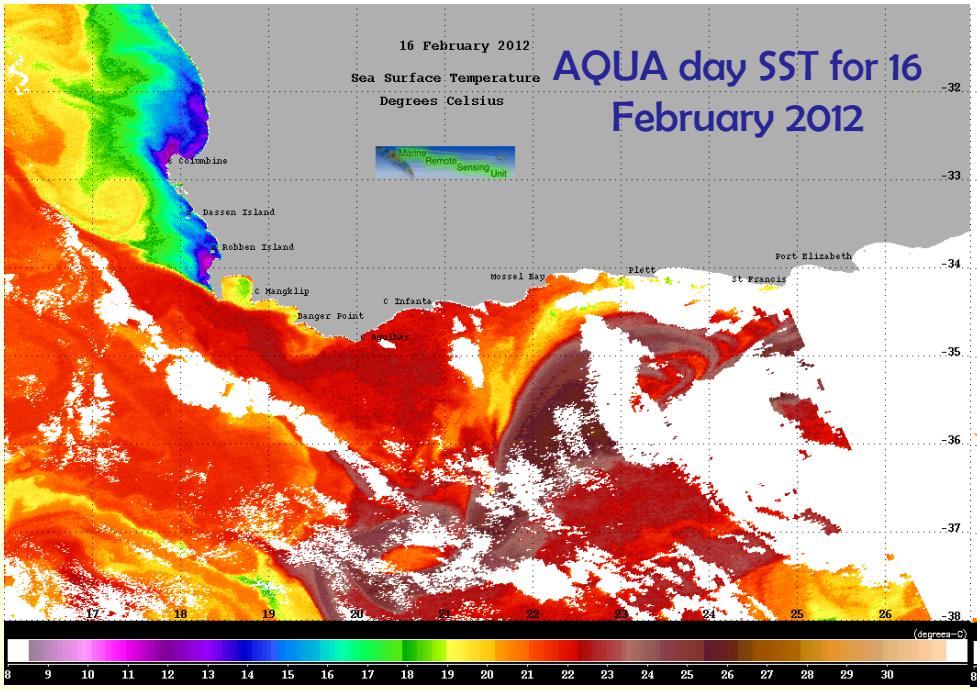


Conclusion from Smit et al. (2013):

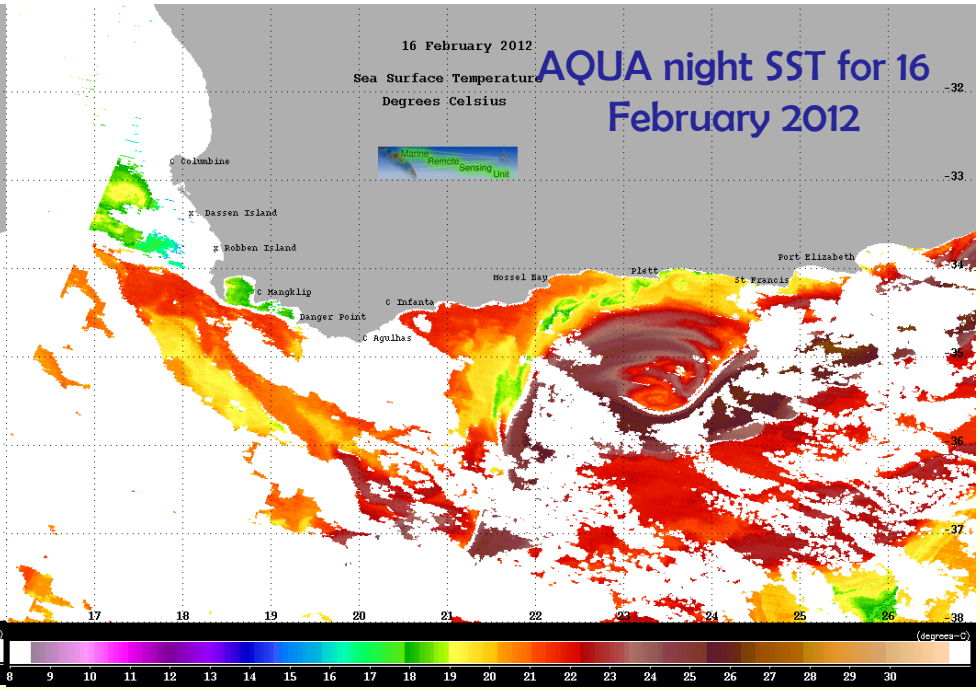
Temperature changes at major biogeographic breaks, e.g. Cape Point, are of such a magnitude that they can certainly be picked up by SST data, and particularly the summer (February) monthly mean SST pattern around the coastline clearly reveals the major biogeographical breaks between west, south and east coasts, despite the biases.



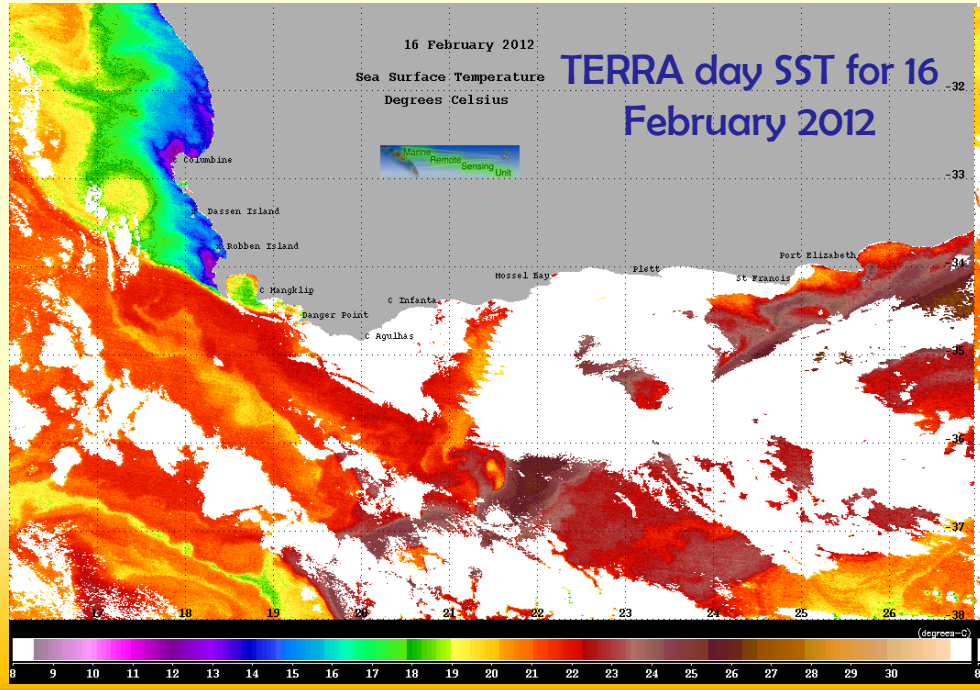
Krug et al. 2014



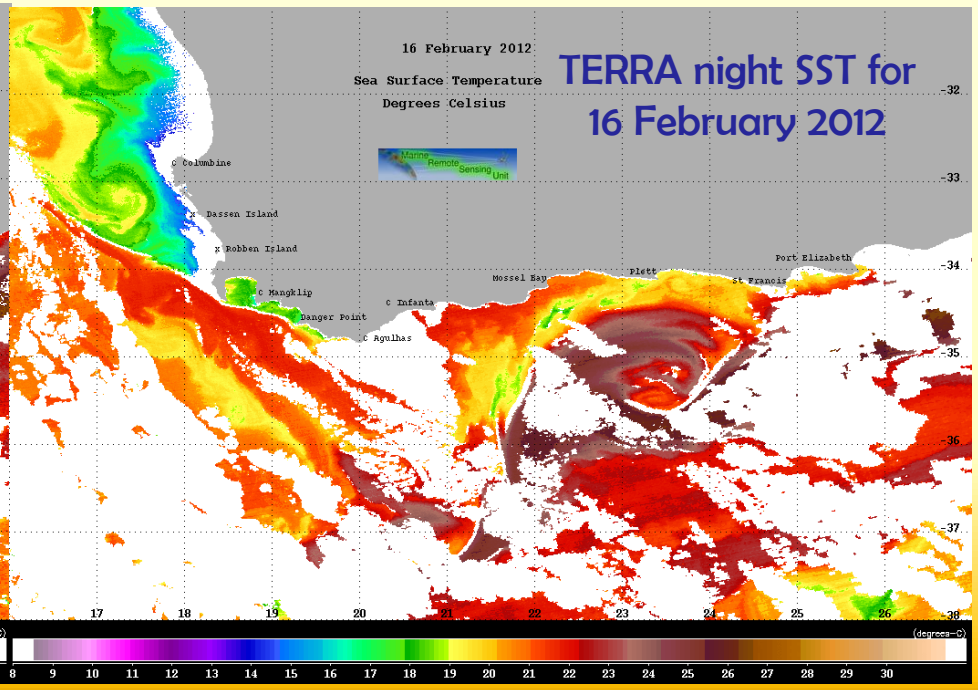
AQUA day SST for 16 February 2012



AQUA night SST for 16 February 2012

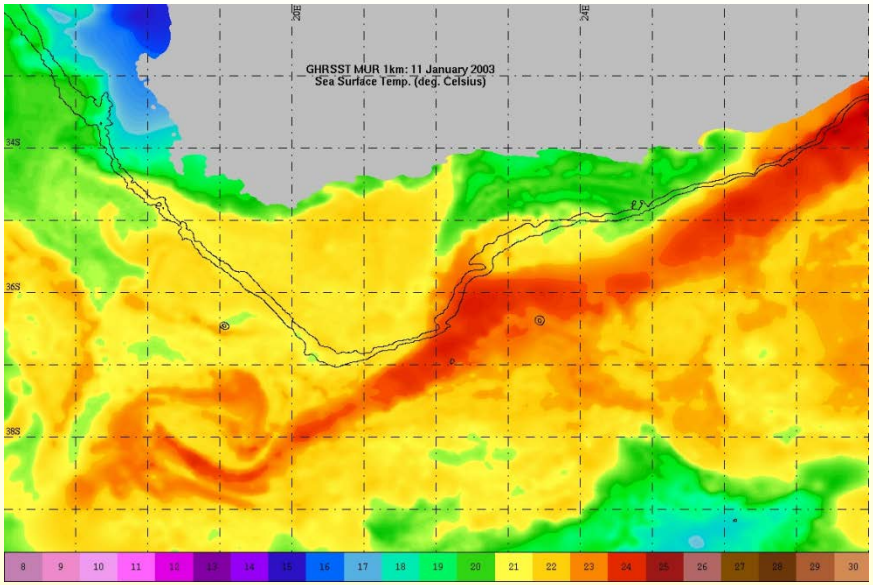


TERRA day SST for 16 February 2012

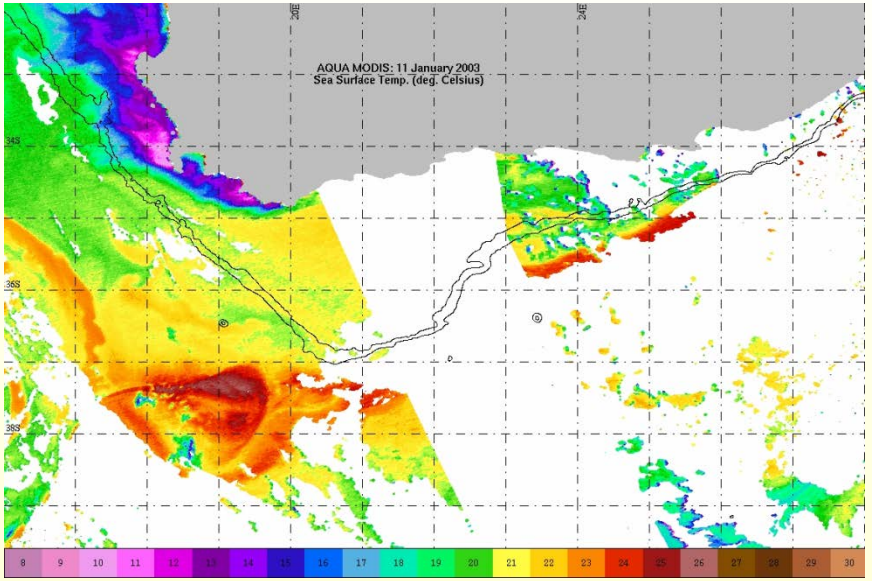


TERRA night SST for 16 February 2012

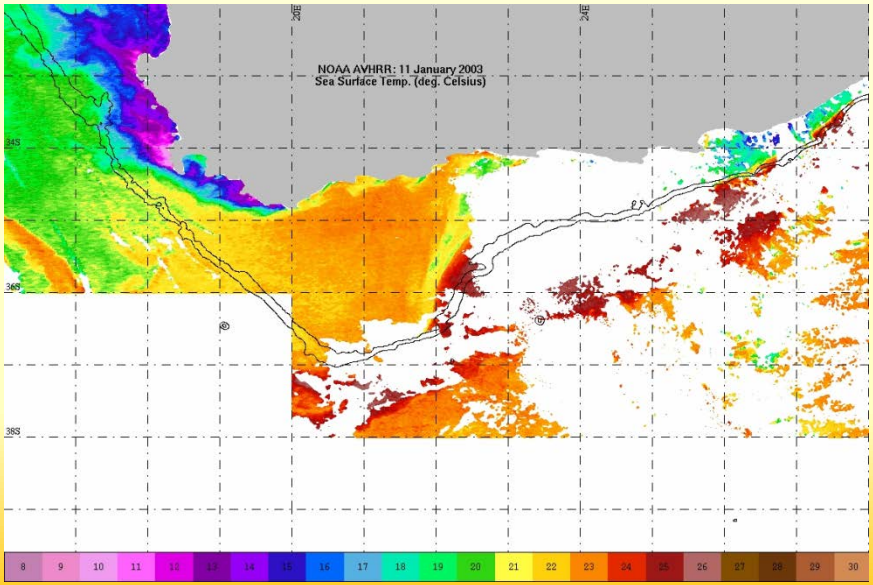
11 January 2003



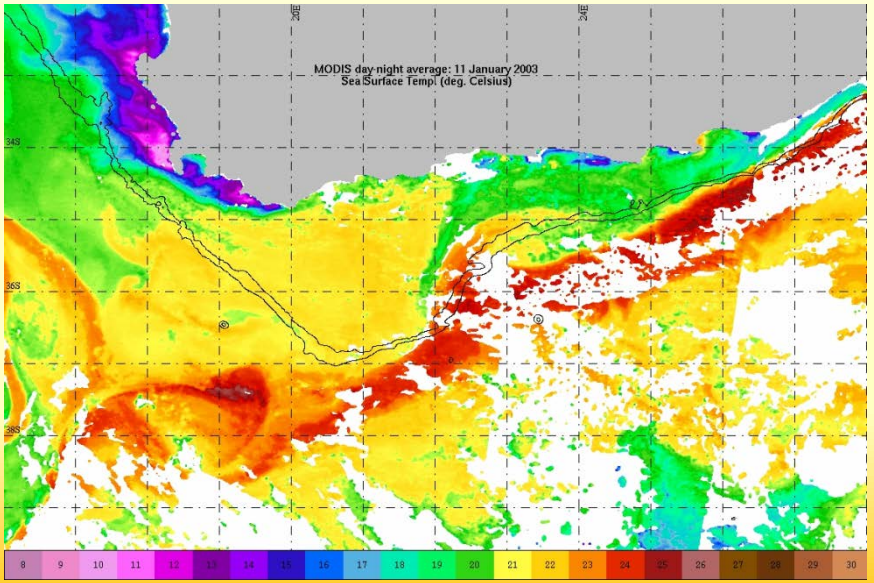
GHRSST MUR



Aqua MODIS



NOAA AVHRR



Blended Aqua/Terra MODIS