The Atmosphere over the South Atlantic

A synopsis on mean state, recent trends and projected change

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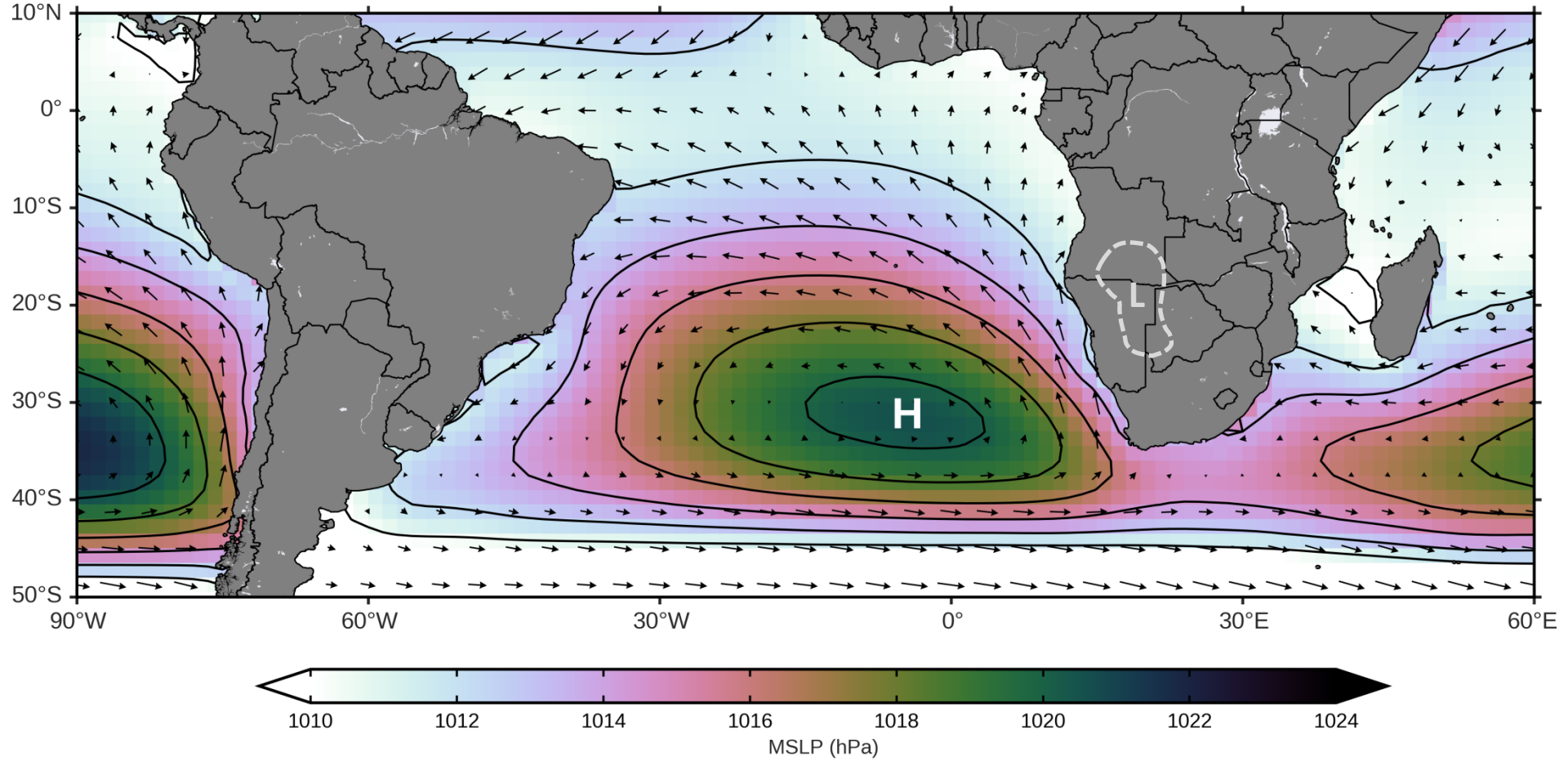
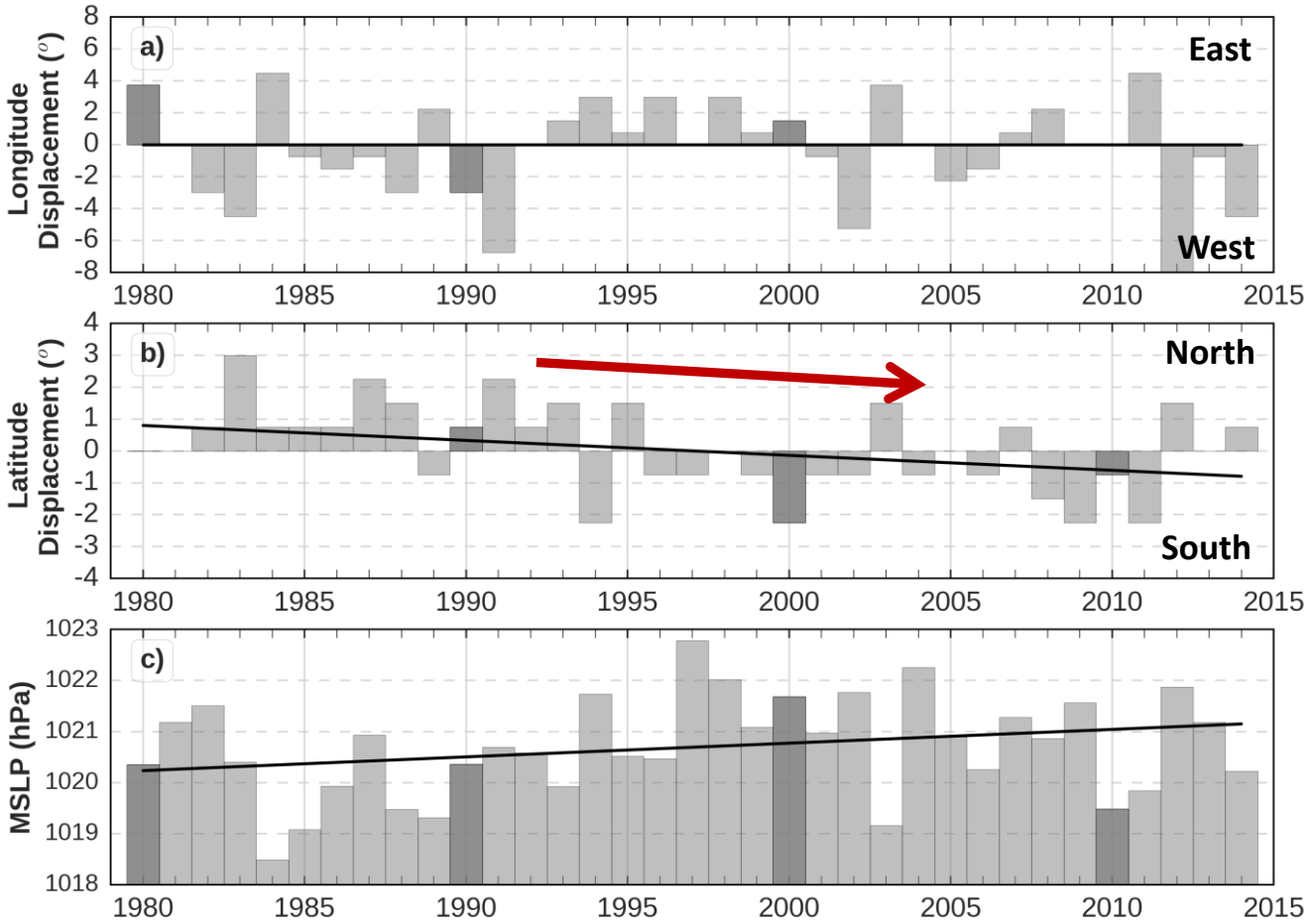
FUTURE CLIMATE FOR AFRICA

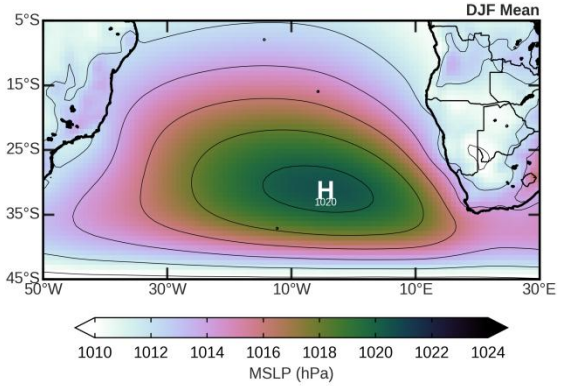
The summer months



Some key features: Warmer tropics / cooler extra-tropics, Land-sea temperature contrasts, Topography, Origin of convection (uplift and subsidence), adiabatic and diabatic heating, etc.

i) Is there evidence of changes in atmospheric ocean drivers that can be attributed to climate change?





Changes in the South Atlantic High Pressure

(Top) The east/west displacement of the SAHP during the summer months (DJF) for 1980-2014 (no change evident). **(Middle)** the north/south displacement with the solid line showing the downward trend of -0.4° per decade. **(Bottom)** The maximum pressure value at the centre of the SAHP (increasing trend of 0.24 hPa per decade).

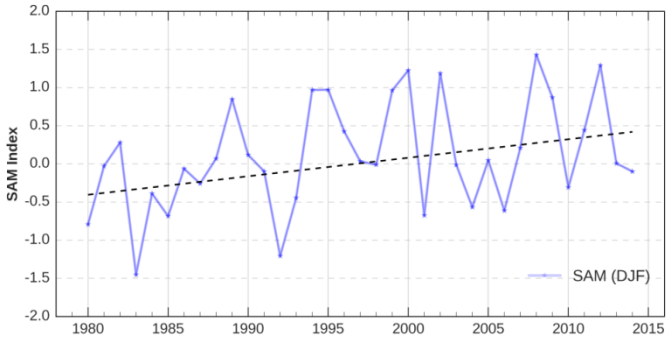
1. The role of the **Southern Annular Mode (SAM)**

(e.g. Santos et al. 2012)

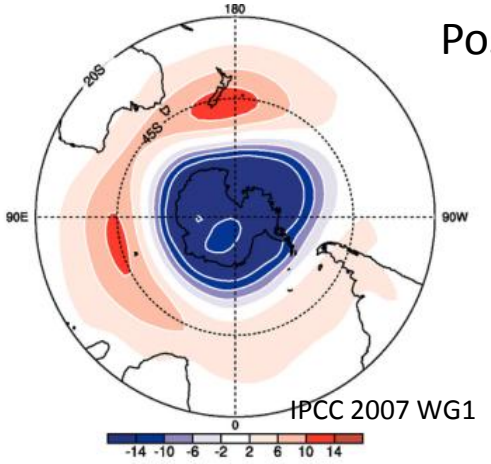
versus

2. **Hadley Cell** Expansion and Intensification

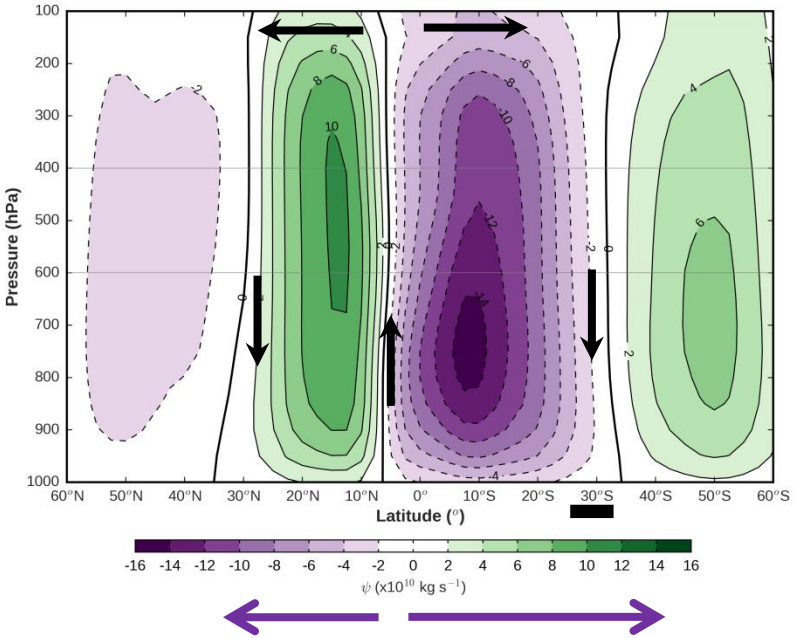
(e.g. Liu et al. 2012, Nguyen et al. 2013)



Positive trend in SAM



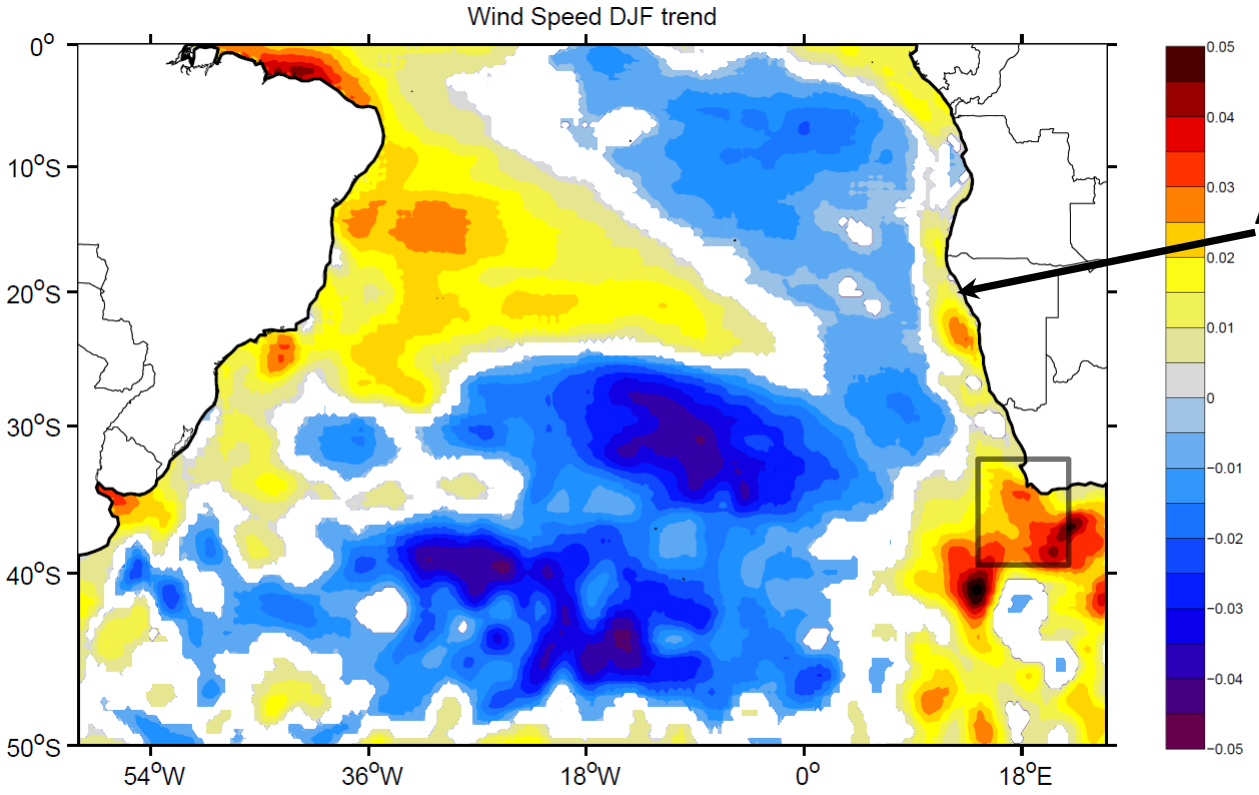
IPCC 2007 WG1



Expanding Hadley Circulation

Ozone depletion and GHGs

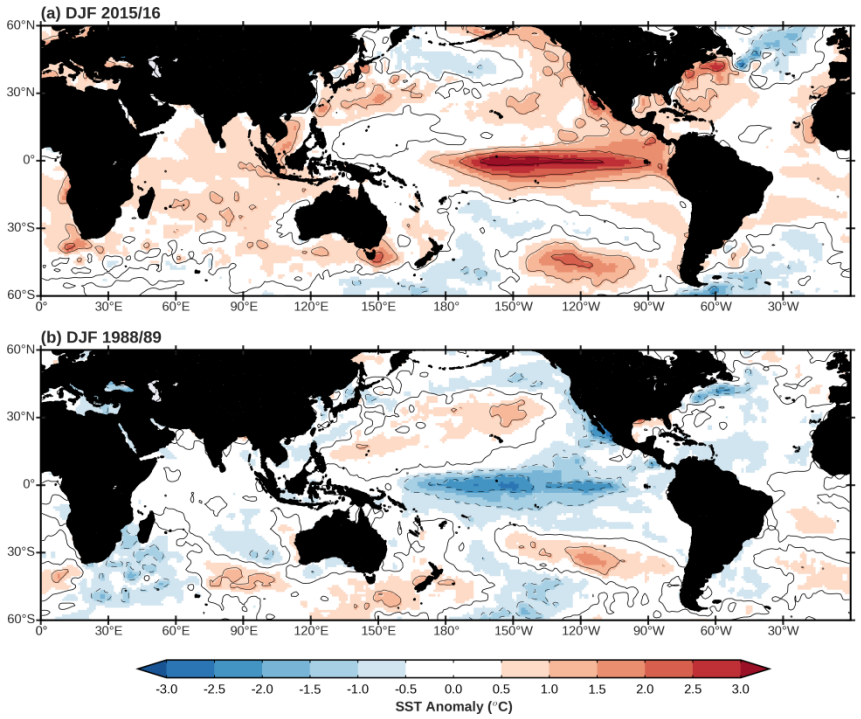
What does that mean for wind patterns along the West Coast?



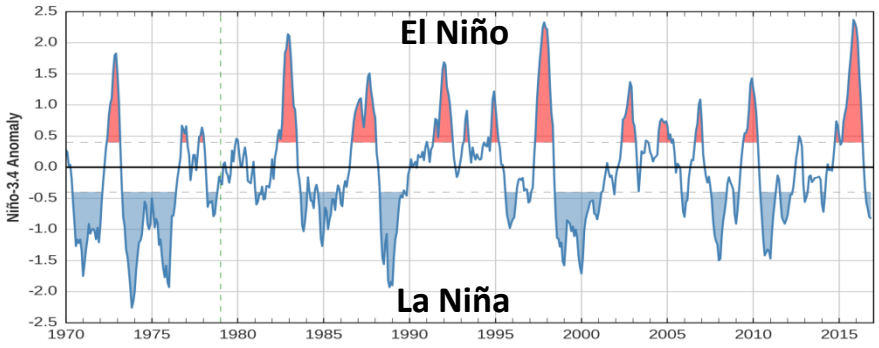
Summer wind speed trend over the South Atlantic derived from 20 years of satellite data

Implications for regional SSTs? – Coming up next in Mathieu's presentation

1.

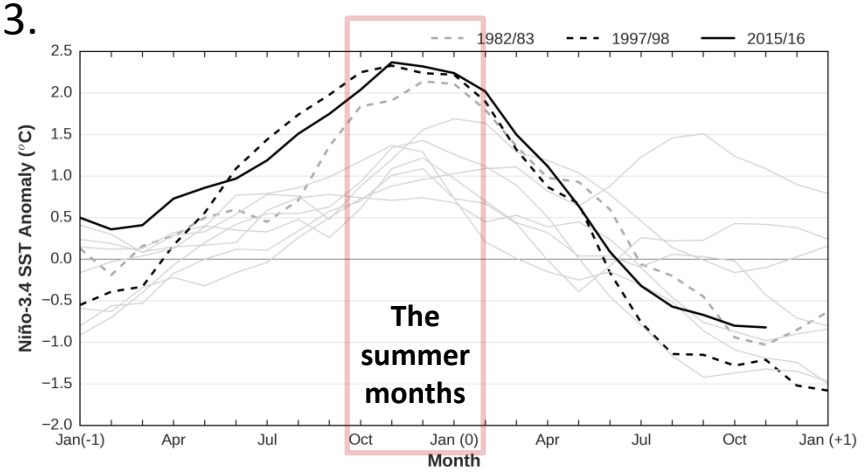


2.

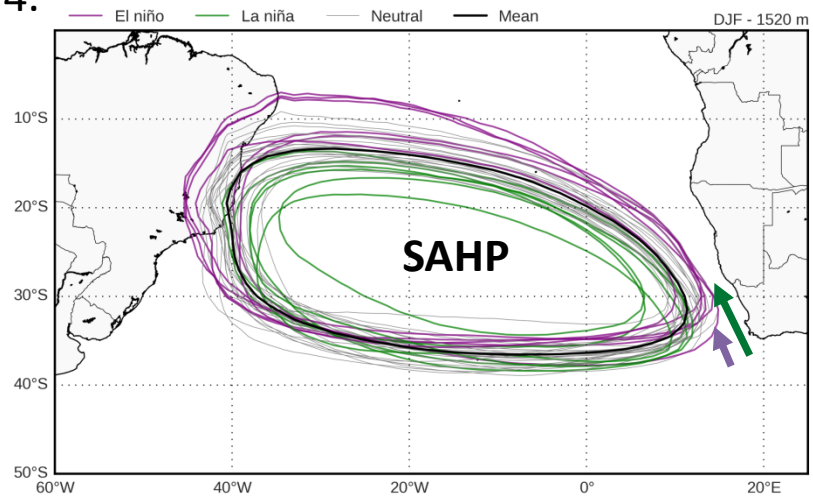


~ 4-7 year period

3.



4.



El Niño = weaker winds during the summer

La Niña = stronger winds during the summer

ii) What are known/projected changes in atmospheric ocean drivers due to long term changes in climate?

A very simplified explanation presented by Bakun (1990)…

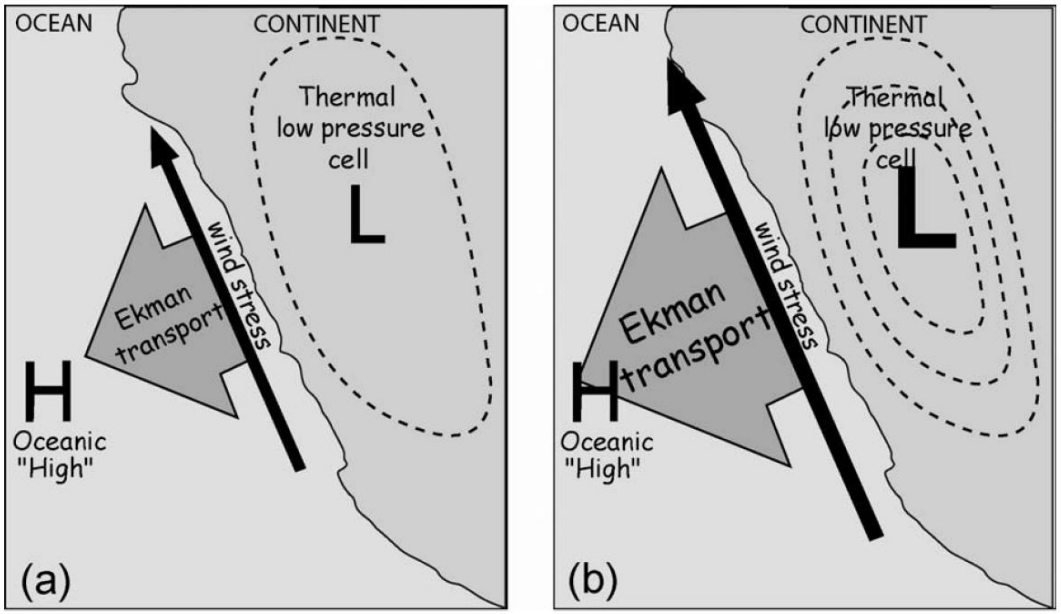
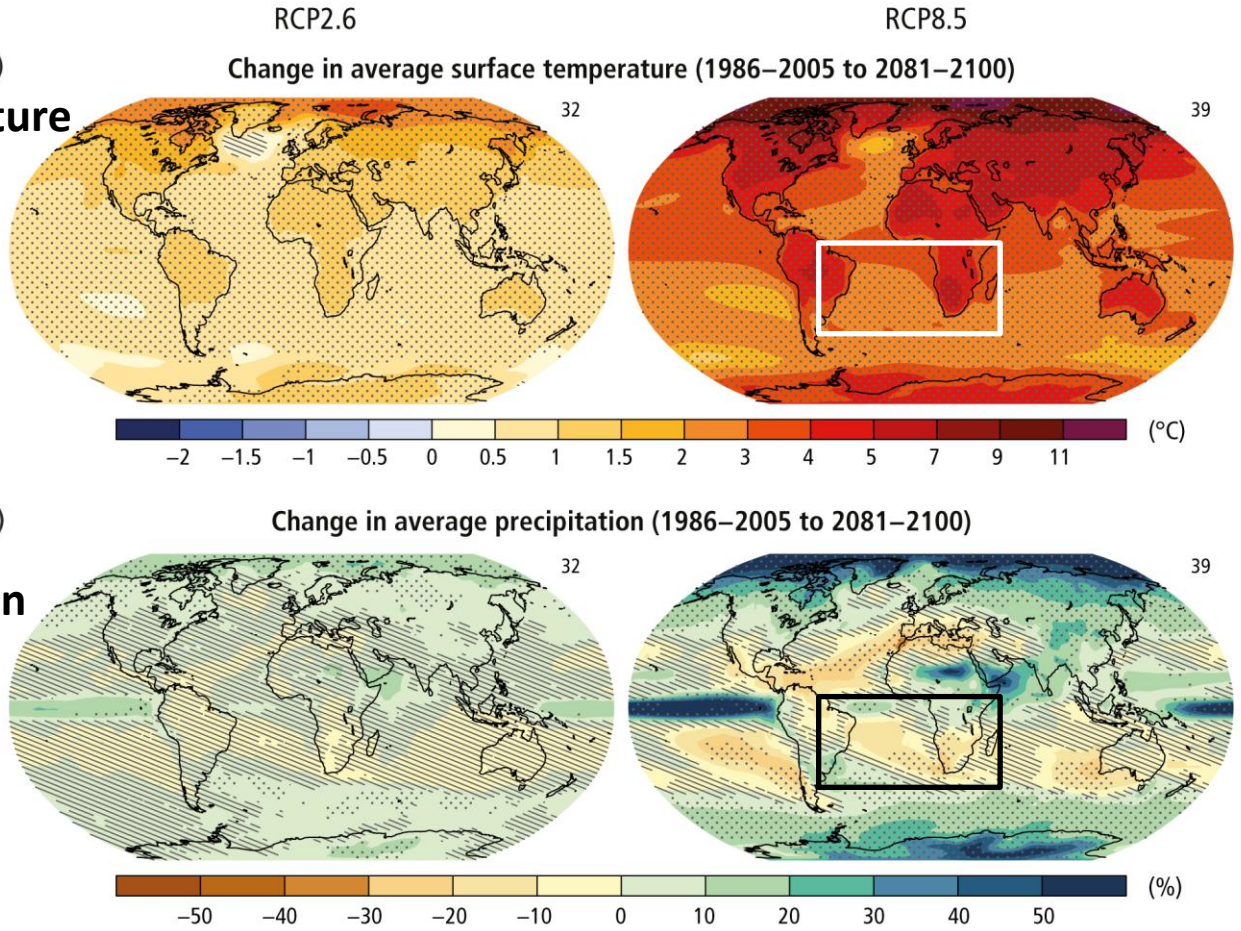


Fig. 4. Diagram of upwelling intensification mechanism: (a) a "thermal" low-pressure cell builds up over the coastal landmass due to heating of the continental surface relative to the more slowly heating ocean, exerting equatorward geostrophic wind stress on the sea surface that, in turn, drives offshore-directed Ekman transport of ocean surface water and corresponding upwelling of deeper waters required to replace the surface waters transported offshore; (b) buildup of greenhouse gases in the atmosphere inhibits nighttime cooling of the heated coastlands, increasing average intensity of the coastal low-pressure cell and associated upwelling-favorable wind, which in terms drives quadratic (or greater) increases in offshore surface transport and resulting upwelling.

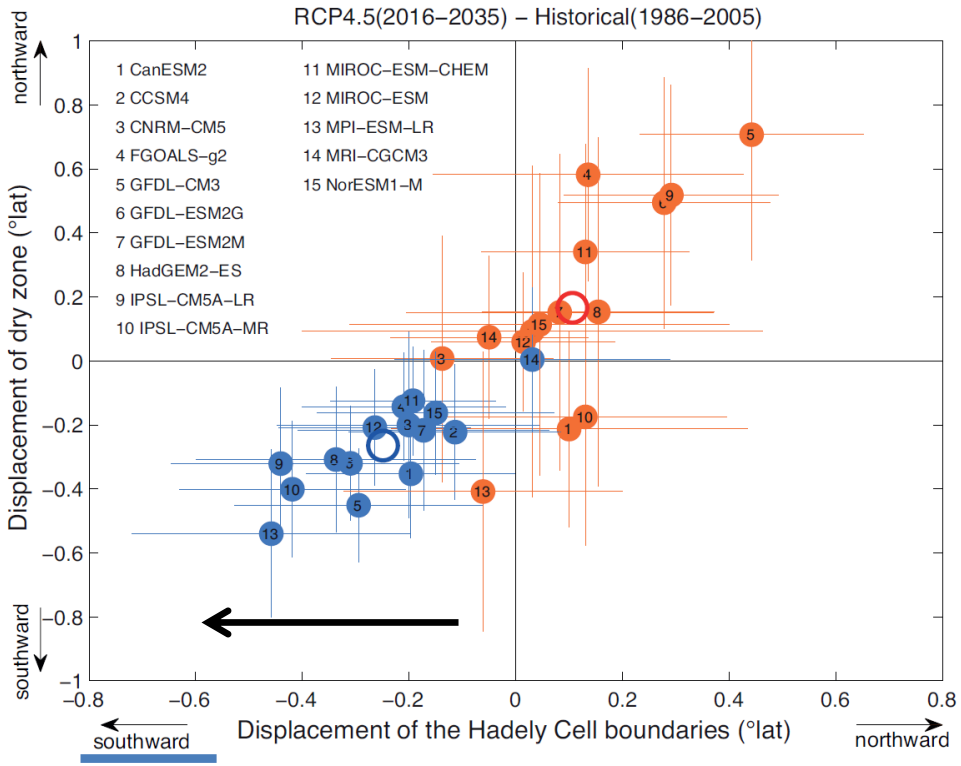
Bakun and Weeks (2008)

Surface Temperature

Precipitation



IPCC AR 5 | Figure 2.2 | Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model mean projections (i.e., the average of the model projections available) for the 2081–2100 period under the RCP2.6 (left) and RCP8.5 (right) scenarios for (a) change in **annual mean surface temperature** and (b) change in **annual mean precipitation** (in percentages).



IPCC AR5 (Fig. 11.16)

It is likely that in the near term the **poleward expansion** of the descending southern branch of the Hadley Circulation and the SH mid-latitude westerlies in austral summer **will be less rapid than** in recent decades – IPCC AR5 2014

A key issue in projections of near-term SH extratropical circulation change is the extent to which changes driven by **stratospheric ozone recovery will counteract changes driven by increasing GHGs**

iii) What are the challenges in projecting/modelling long term changes in atmospheric ocean drivers at a local scale?

The Main Challenges

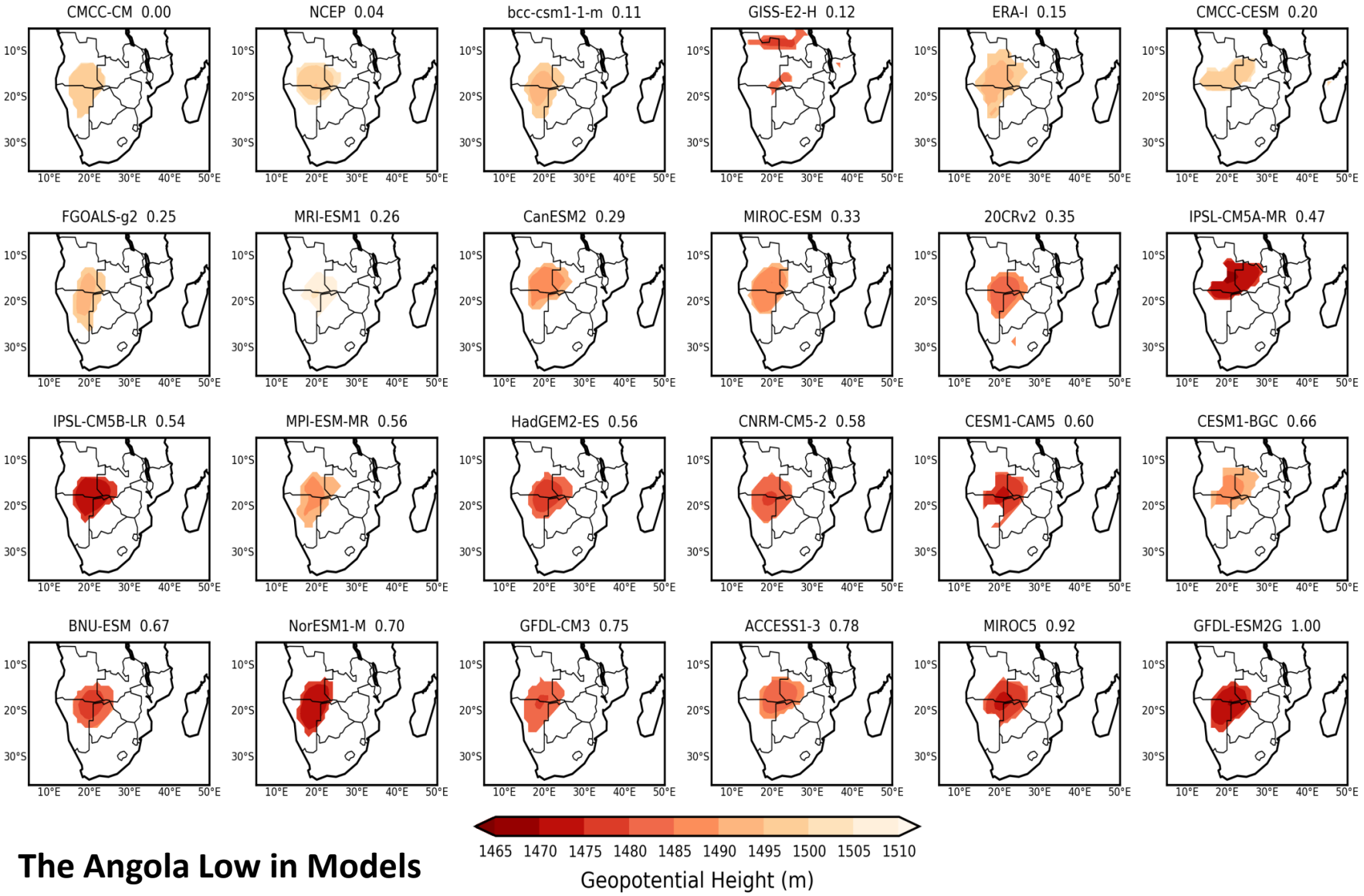
- The grid resolution of a model is around 100 to 200 km. At such **low resolution**, they are **unable to accurately represent the complexity** of an area like the west coast, but it can better resolve large-scale patterns.

- Models are at a resolution where they **cannot simulate all aspects of the environment**, which requires these sub-grid processes (e.g. such as cloud processes) to be parameterised. This introduces another level of uncertainty.

- The models also have **different strength and weaknesses**, with some features or processes represented well and others poorly (depending on the model).

- We do not yet know all the **tipping points or thresholds** associated to anthropogenic warming. For example, just how will ENSO respond? Will we get fewer events, but more extreme? Or just more events? How will the signal from the Pacific get to other parts of the world in the model?

- And, most of the uncertainty in the model projections are at **the regional scale**.



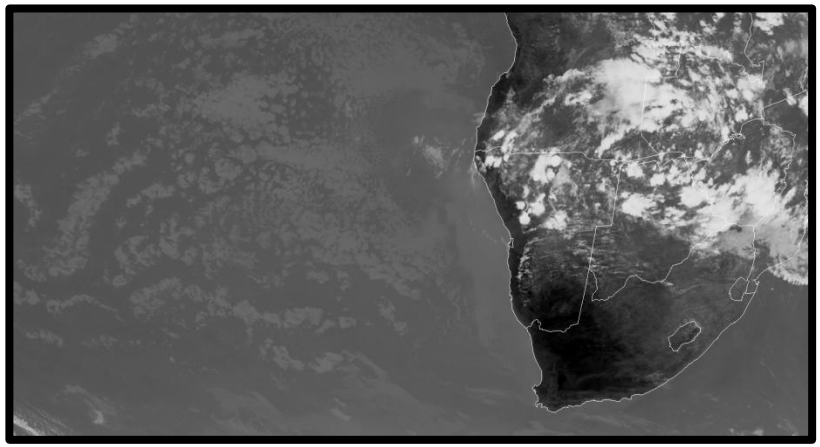
The Angola Low in Models

Munday and Washington (2017)

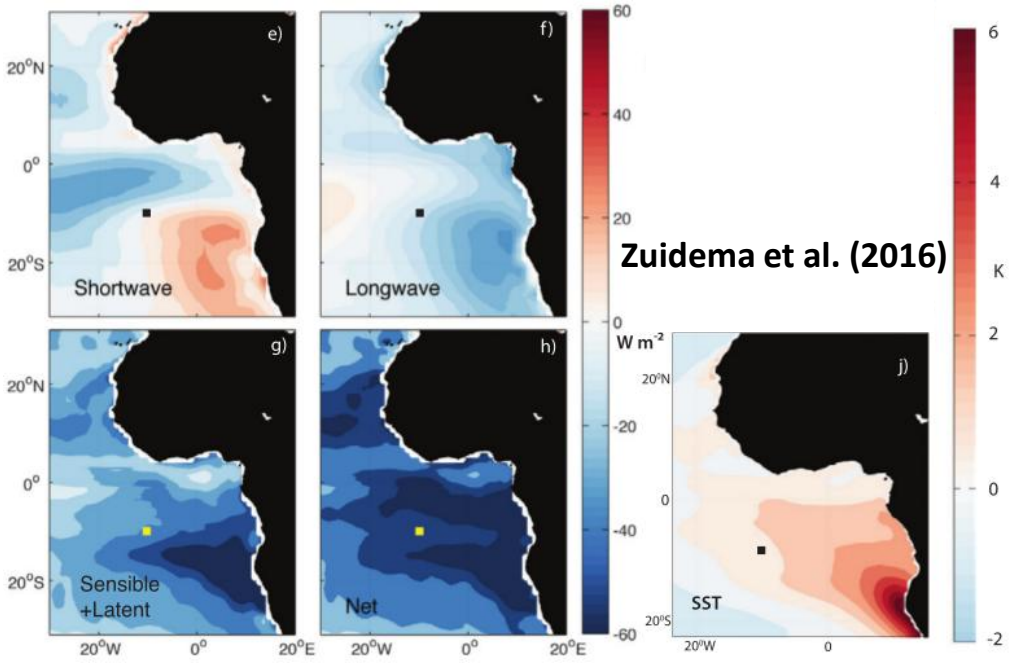
Coupled ocean-atmosphere global models, tend to **have systematic errors** in the eastern boundary regions, including a **warm bias in SST** and **too little cloud cover**.

The models tend to struggle to capture the low-level stratocumulus clouds, which then can alter wind patterns and SSTs. And this has a **large impact on surface heat fluxes as well as the radiation budget**.

More work, possibly through better observations, is required to **better understand and represent the coupled atmosphere–ocean processes** of the coastal upwelling region.

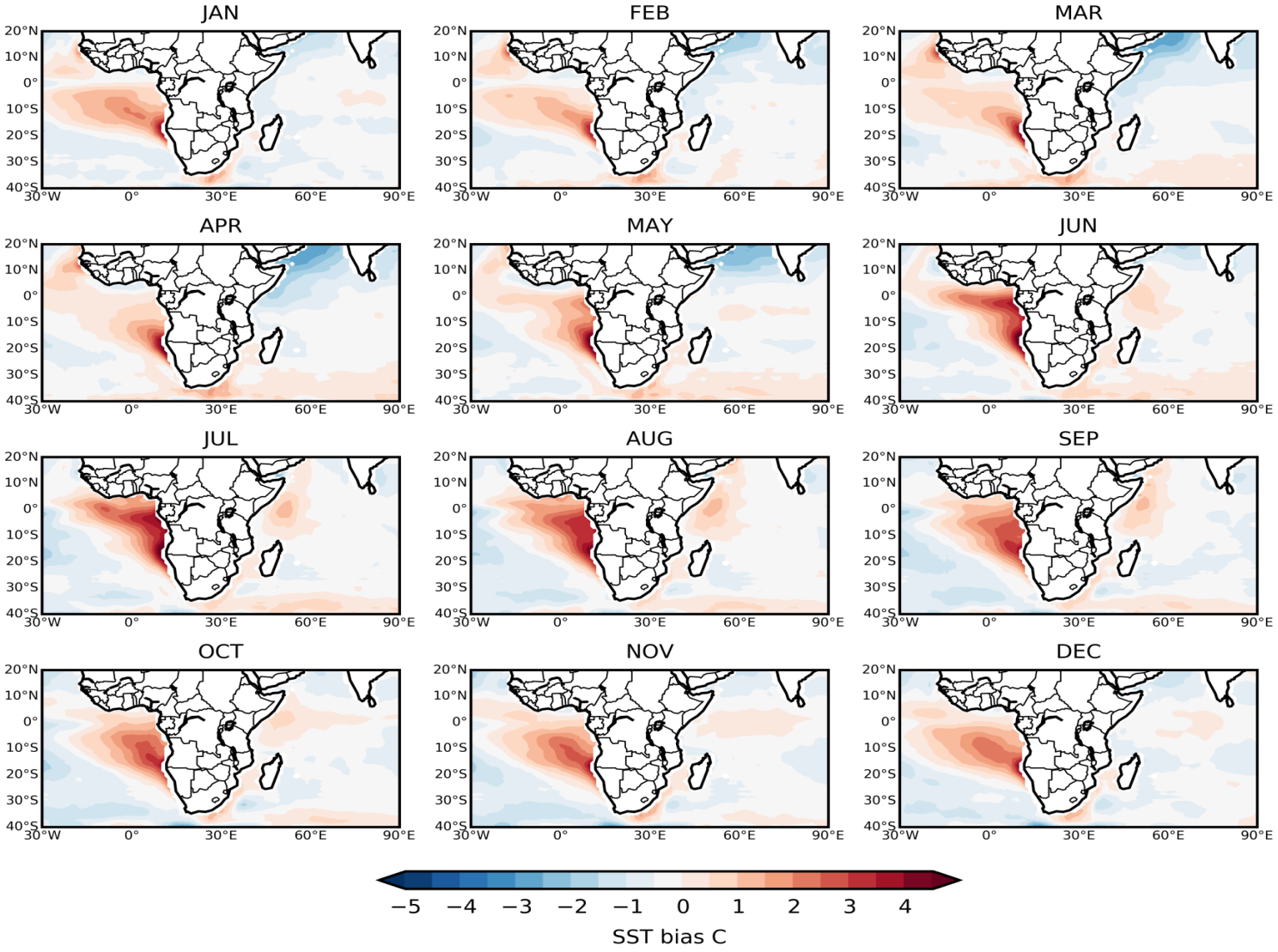


Marine stratocumulus clouds in the southeast Atlantic



Zuidema et al. (2016)

Ensemble mean SST biases in CMIP5 - Creese and Washington (2017)



A big problem in coupled atmosphere - ocean models

Take Away Messages:

- For the west coast of southern Africa – there has been a southward shift in the South Atlantic HP, resulting in an increase in wind speed in the southern part of the domain during the summer months.

- The difficulty in assessing change in upwelling systems is that results appear to be dependent on the data used, length of the time series available, the season of analysis (*are we seeing a shift in the seasons?*) and even the extent of the domain (e.g. northern vs southern Benguela).

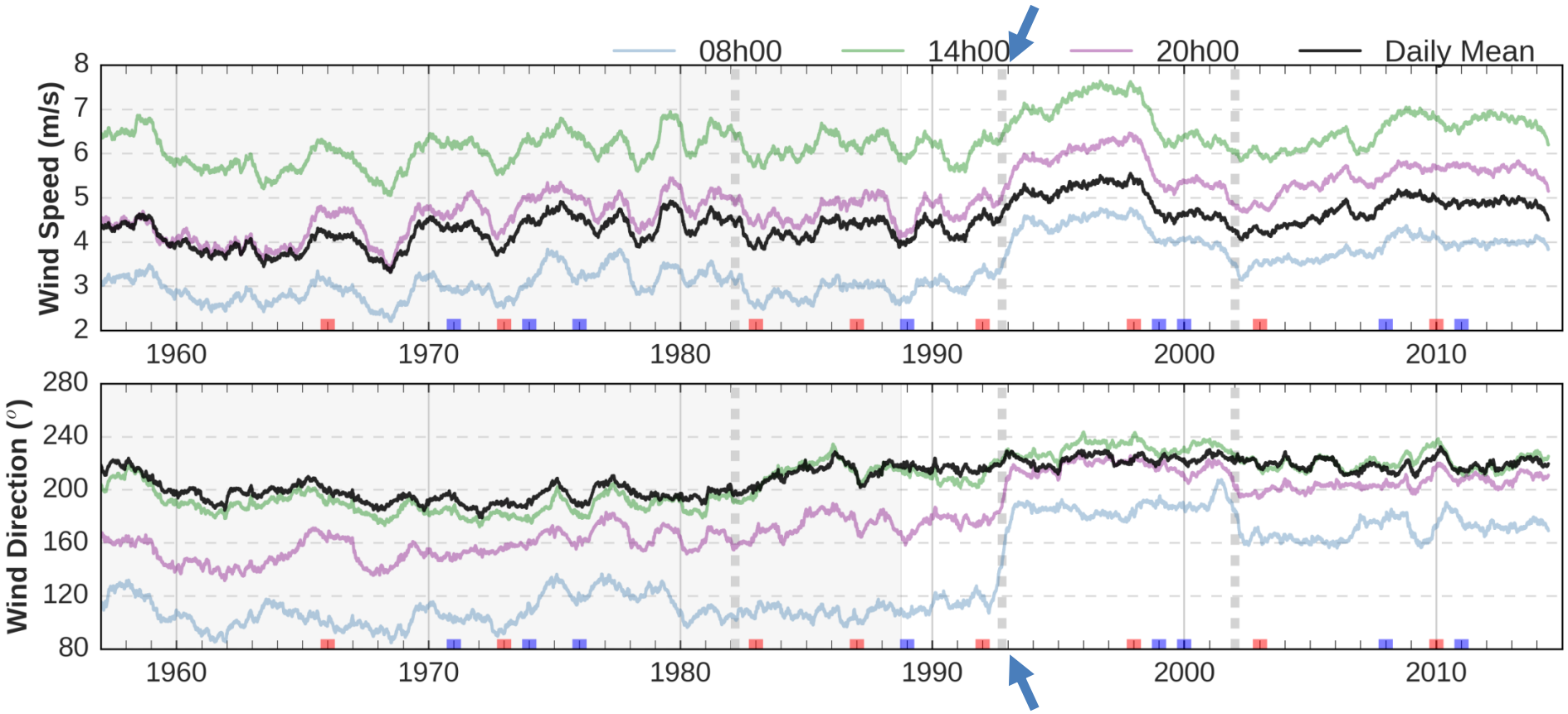
- In regions where there is a lot of climate variability it is extremely difficult to detect the climate change signal, which is often the case when focusing on shorter time scales (e.g. on a decadal time scale).

- It also comes down to the spatial scale. Most of the robust changes projected by the models are at the global scale, while the regional/local scale contains the most uncertainty.

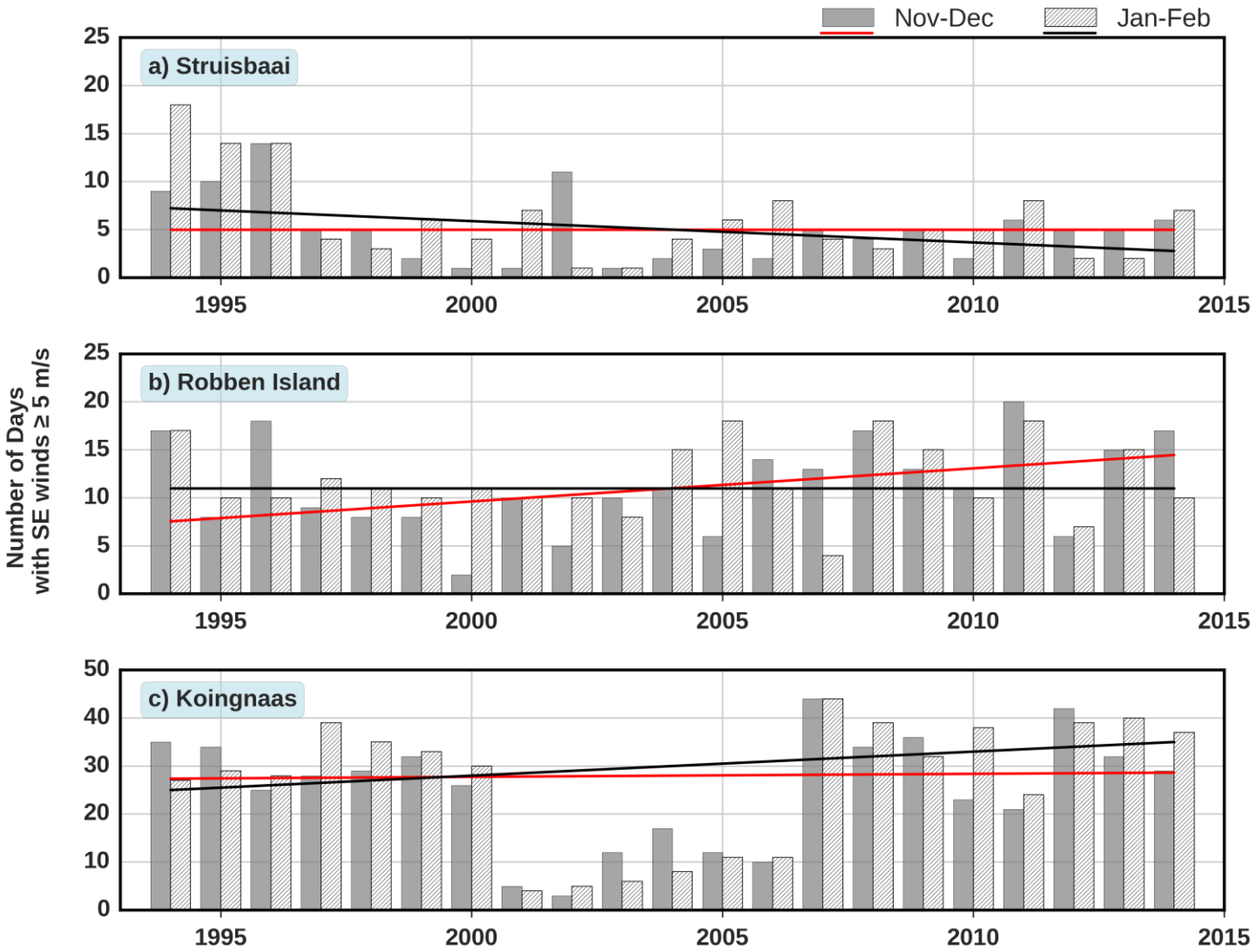
- More ocean and atmos-pheric observations will always be required to help improve the understanding of regional/local climate processes and to detect change.

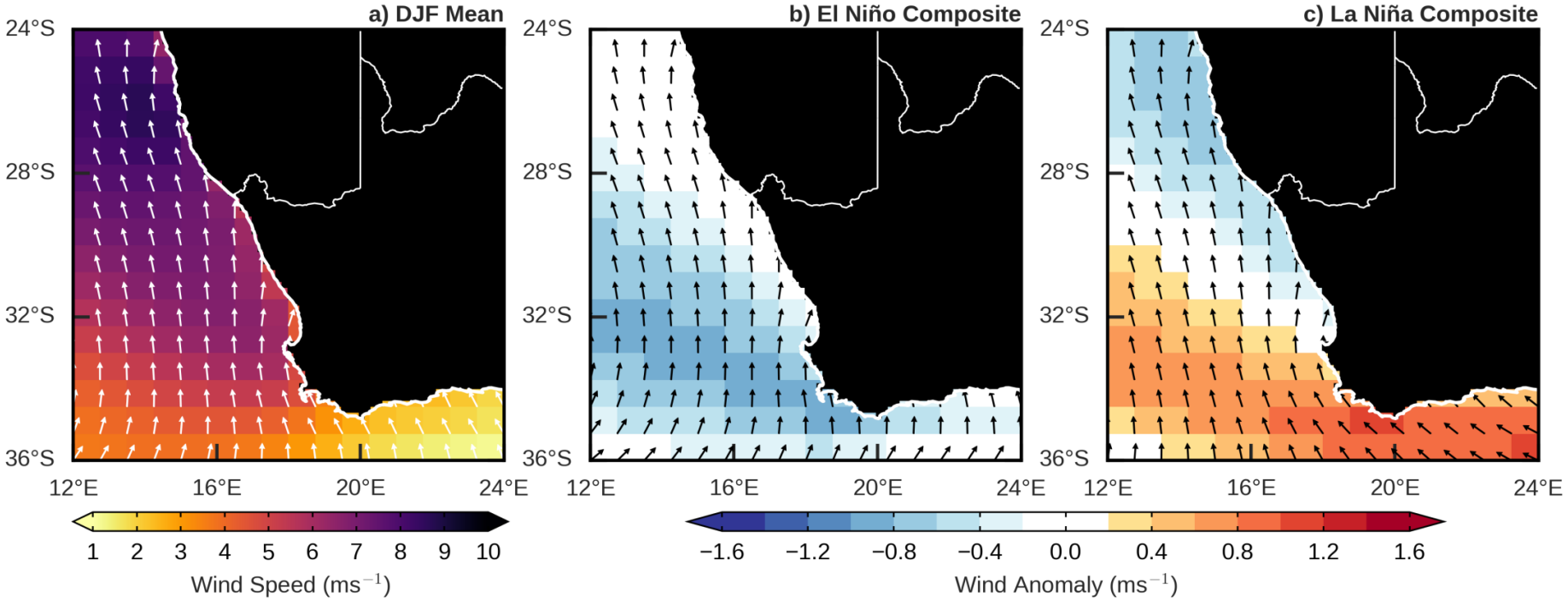
Additional slides if needed

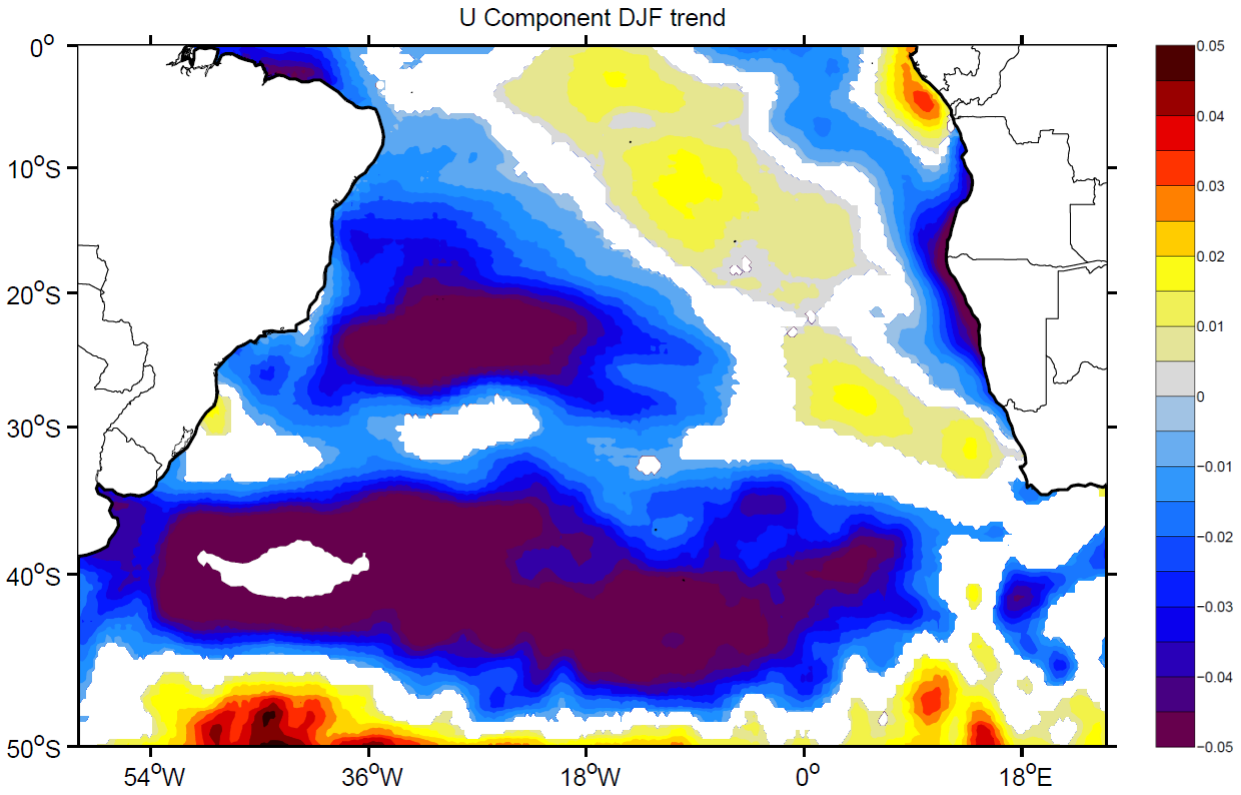
Why is it so hard to identify past trends?



Wind data (365-day running mean) from the CT Airport from 1957-2015. Grey vertical lines show when the station was changed (either instrument or location)


Nov-Dec
Jan-Feb
a) Struisbaai
b) Robben Island
c) Koingnaas
Number of Days
with SE winds ≥ 5 m/s
25
20
15
10
5
0
50
40
30
1995
2000
2005
2010
2015


a) DJF Mean
b) El Niño Composite
c) La Niña Composite
24°S
28°S
32°S
36°S
12°E
16°E
20°E
24°E
1 2 3 4 5 6 7 8 9 10
Wind Speed (ms^{-1})
−1.6 −1.2 −0.8 −0.4 0.0 0.4 0.8 1.2 1.6
Wind Anomaly (ms^{-1})



Changes in the U-component of winds over the South Atlantic