A review of the Cape Town "Day Zero" Drought

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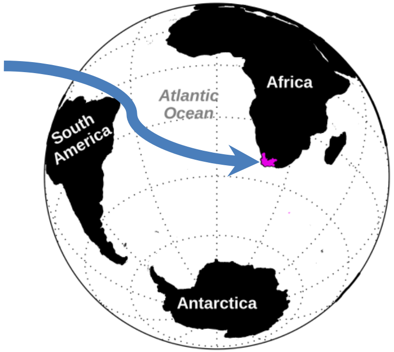
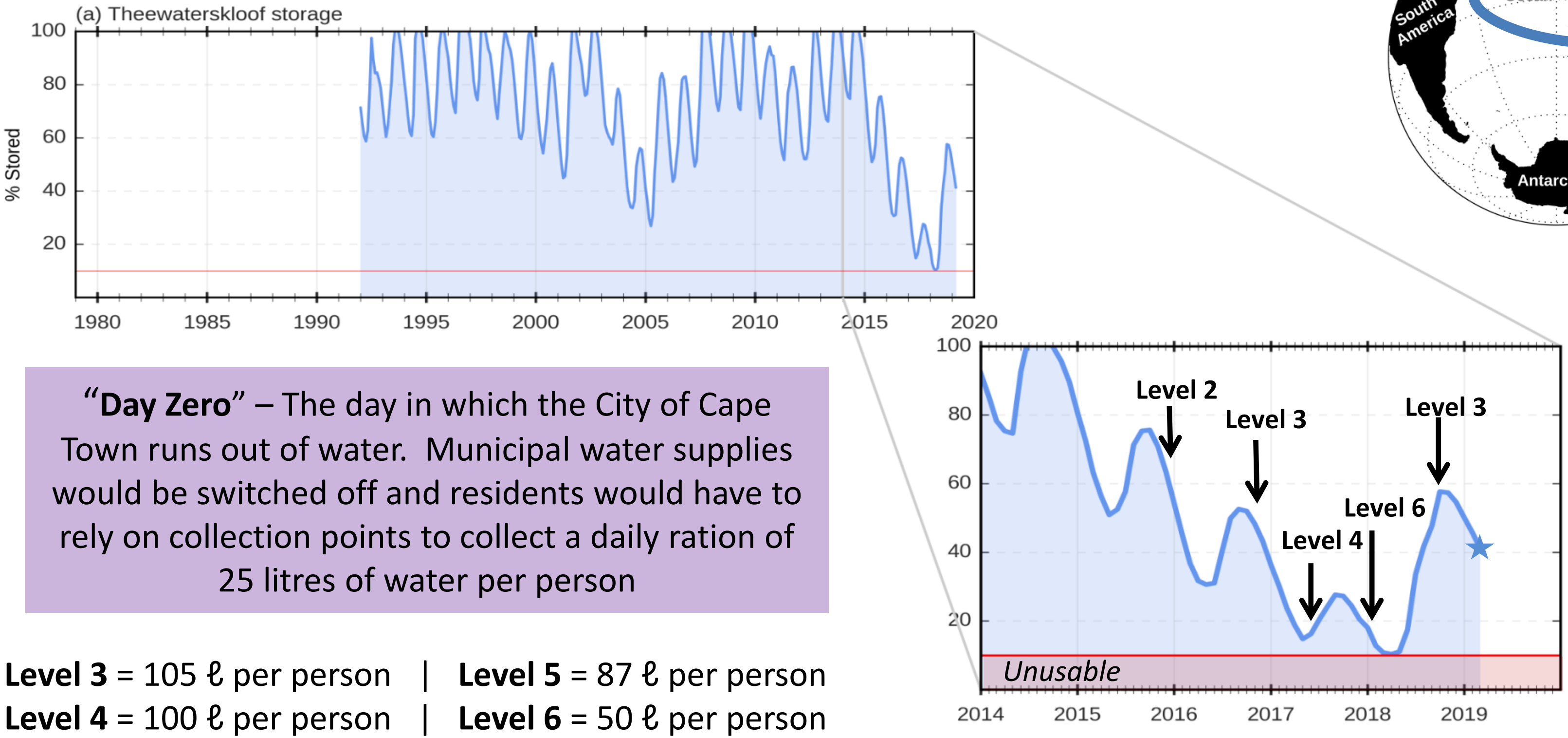
Background:

The Western Cape (WC) Province in South Africa





"Day Zero" – The day in which the City of Cape Town runs out of water. Municipal water supplies would be switched off and residents would have to rely on collection points to collect a daily ration of 25 litres of water per person

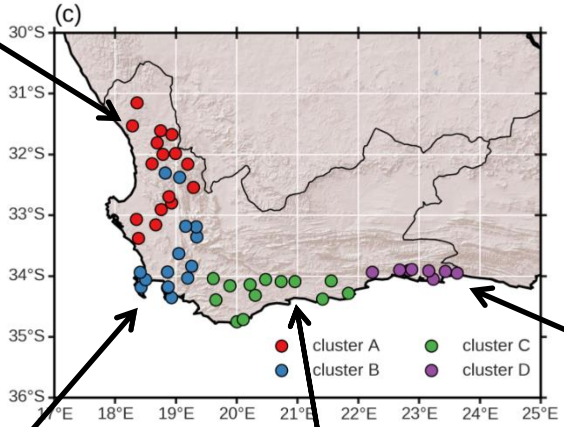
Level 3 = 105 ℓ per person | **Level 5** = 87 ℓ per person
Level 4 = 100 ℓ per person | **Level 6** = 50 ℓ per person

Avg. = 201 ℓ per person per day (2004/05 to 2015/16)

The rainfall regime of the Western Cape:

(Clusters based on annual totals and winter rainfall contribution)

Winter rainfall (**Apr-Sep**), but generally dry (< 200 mm)



All year round rainfall and wet (> 1000 mm)

Core winter rainfall region and generally wet (> 1000 mm)

Transition zone between winter rainfall and all year round rainfall --- mostly dry (< 500 mm)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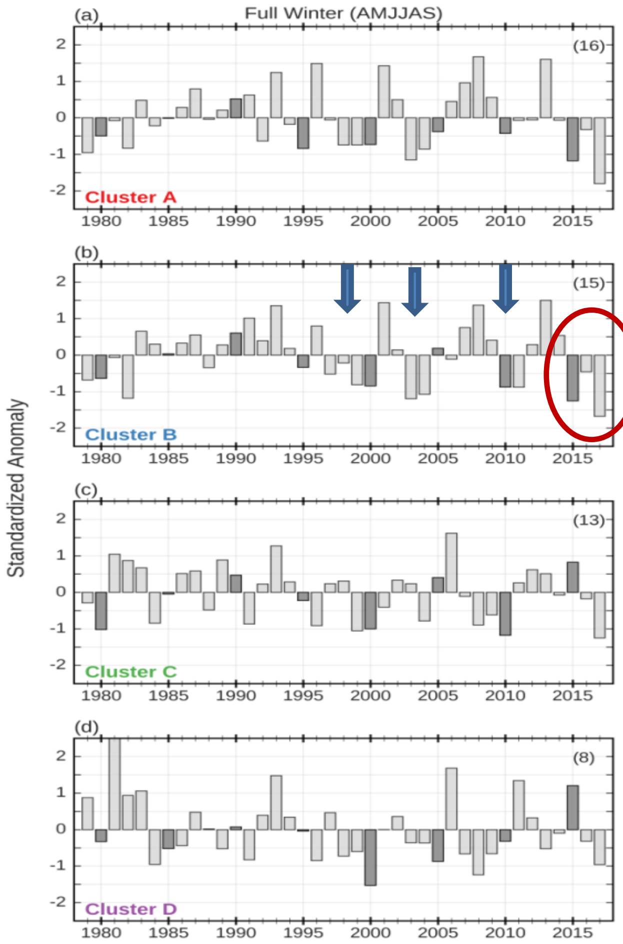
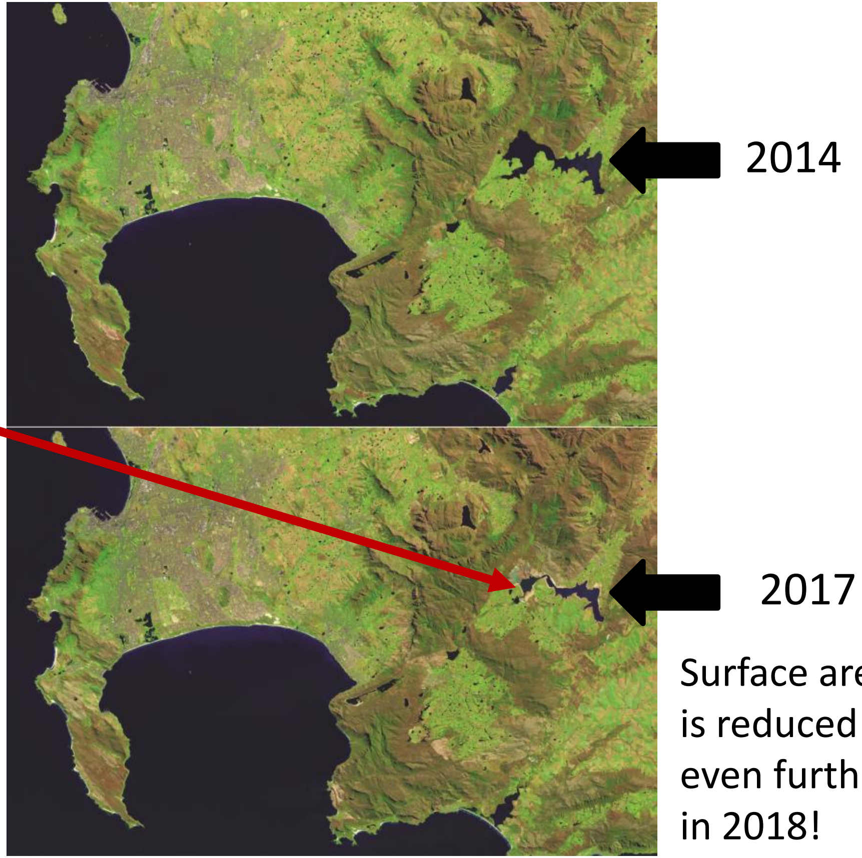
Landsat – Shuttle Radar Topography Mission (SRTM) – NASA/JPL/NIMA

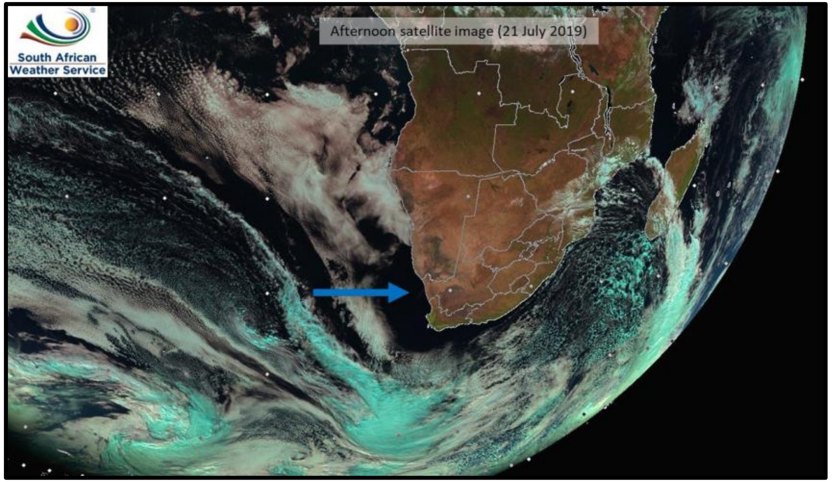


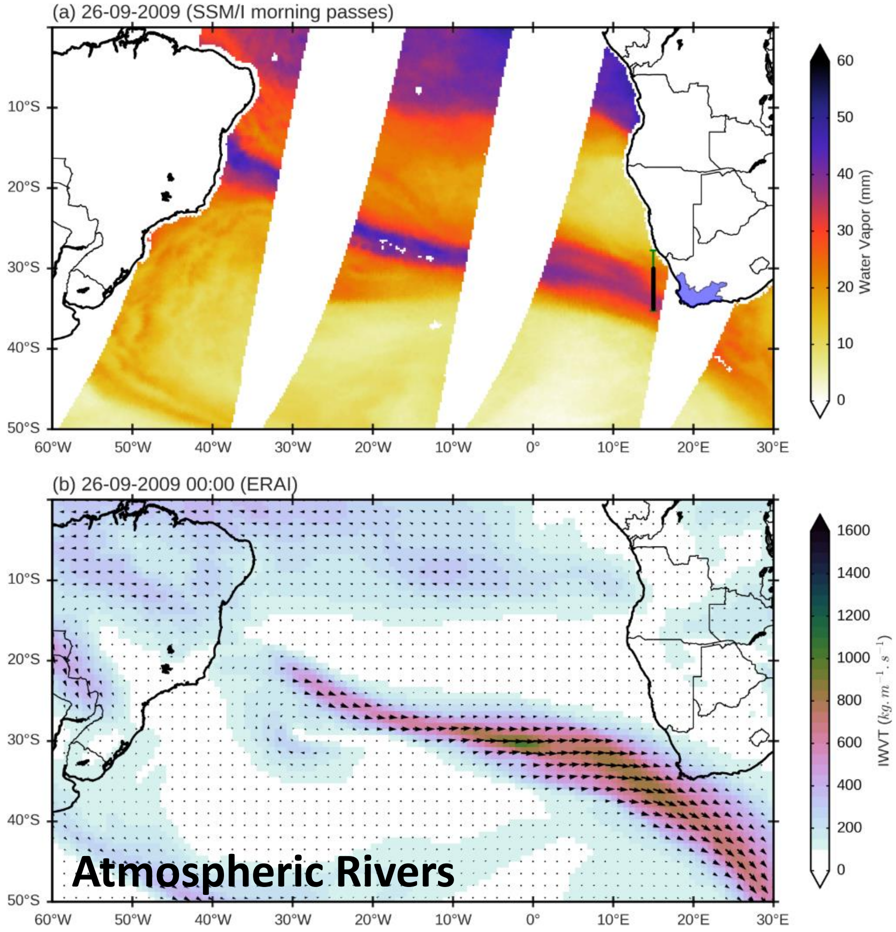


Surface area is reduced even further in 2018!

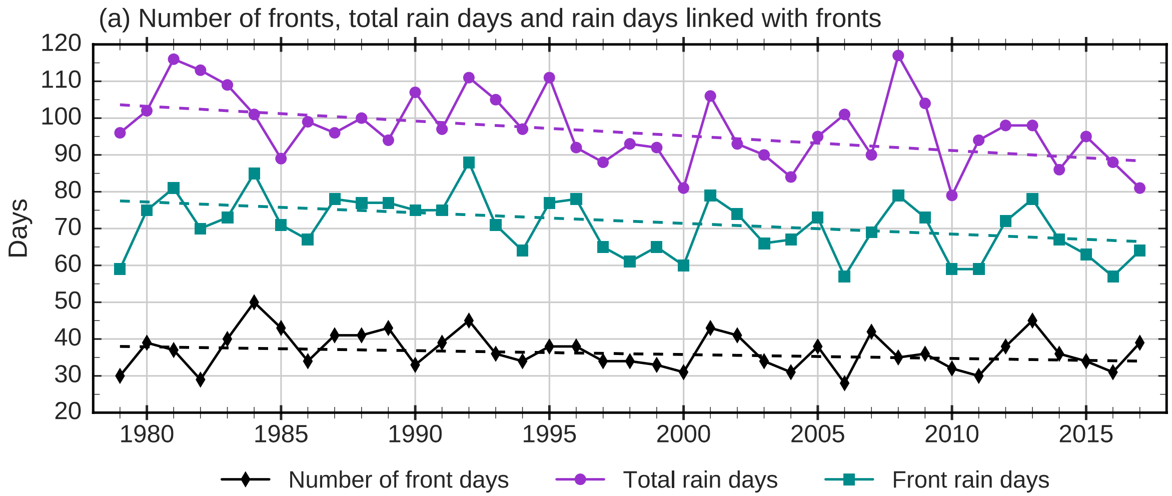
https://earthobservatory.nasa.gov/images/91217/water-shortage-in-western-cape

Given that on average just under **90% of winter rainfall** is brought to the Cape Town region predominantly by **mid-latitude frontal systems**, one hypothesis is the observed decline in rainfall might **be due to a decline in the number of fronts reaching Cape Town**…



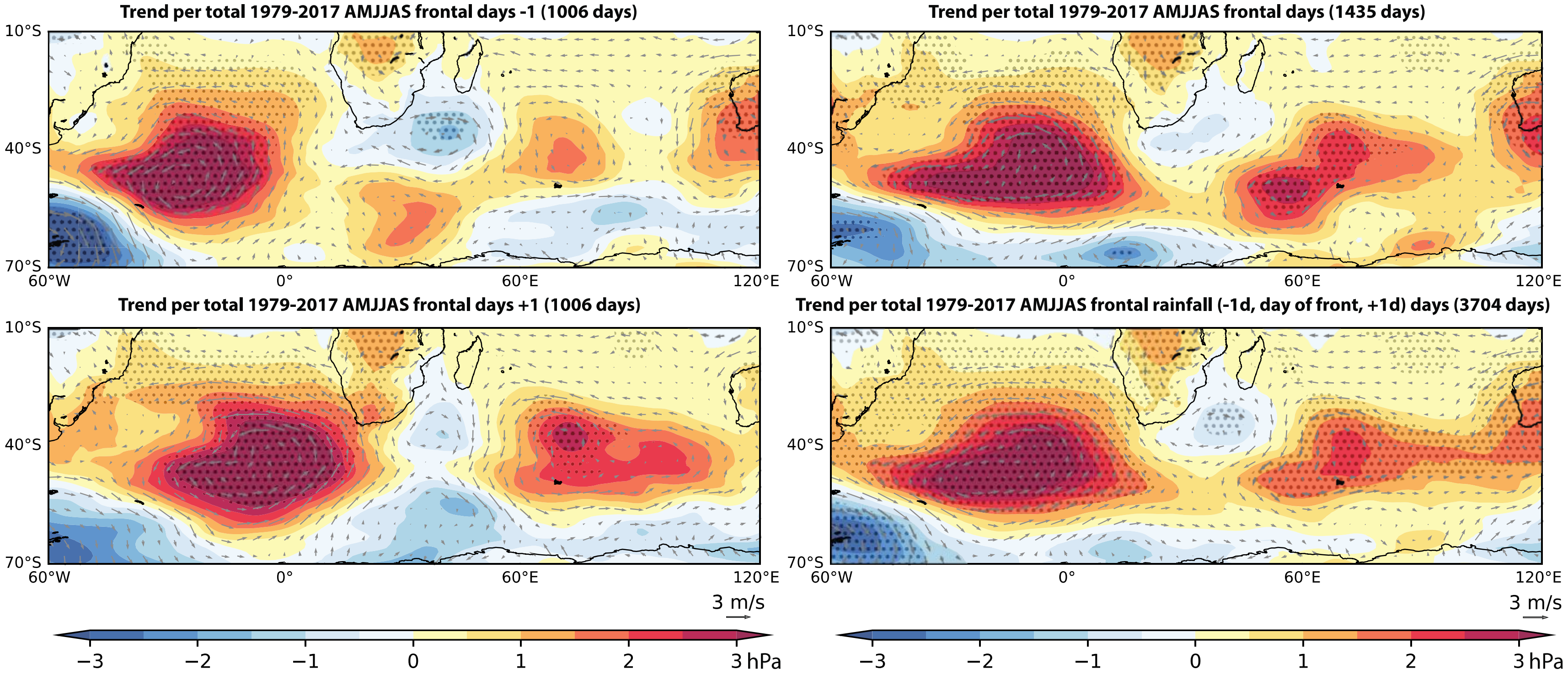


The number of fronts making landfall over the WC (see Burls et al. 2019)



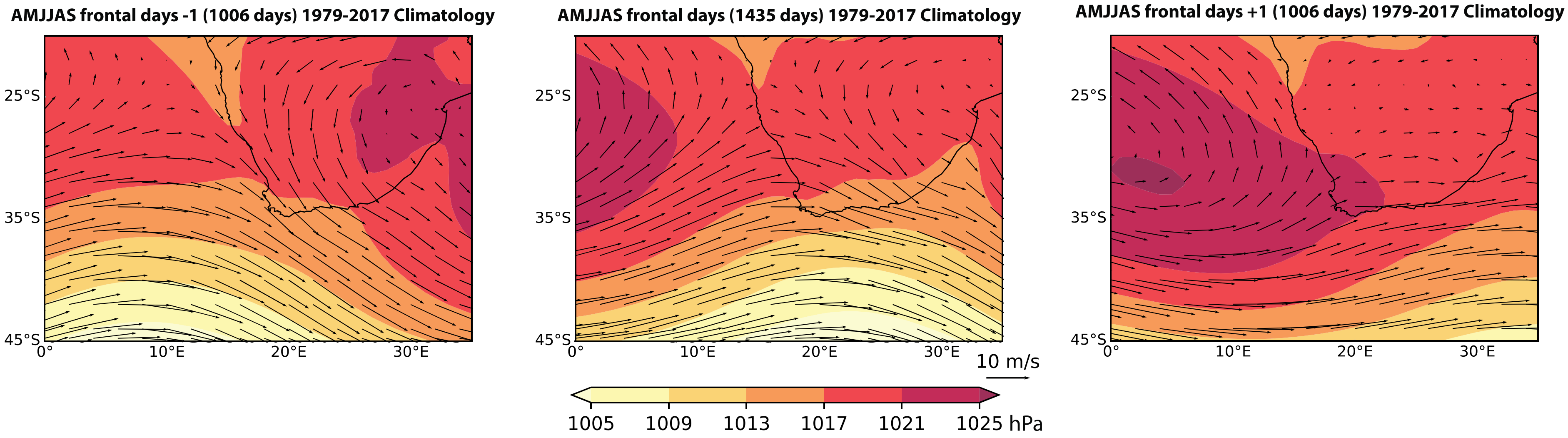
- The hypothesis was that the observed decline in rainfall days (**purple**) might be due to a decline in the number of fronts (**black**) reaching Cape Town. The **analysis shows no robust regional trend** in the number of fronts reaching Cape Town

- Instead, the **number of rainfall days** associated with fronts (**teal**) has declined, impacting not only the number of short 2–3-day rainfall spells but also the number of longer 5–10-day spells



Decline in the number of rainfall days associated with a front appears to be due to an **increase in the intensity of post-frontal ridging high** conditions

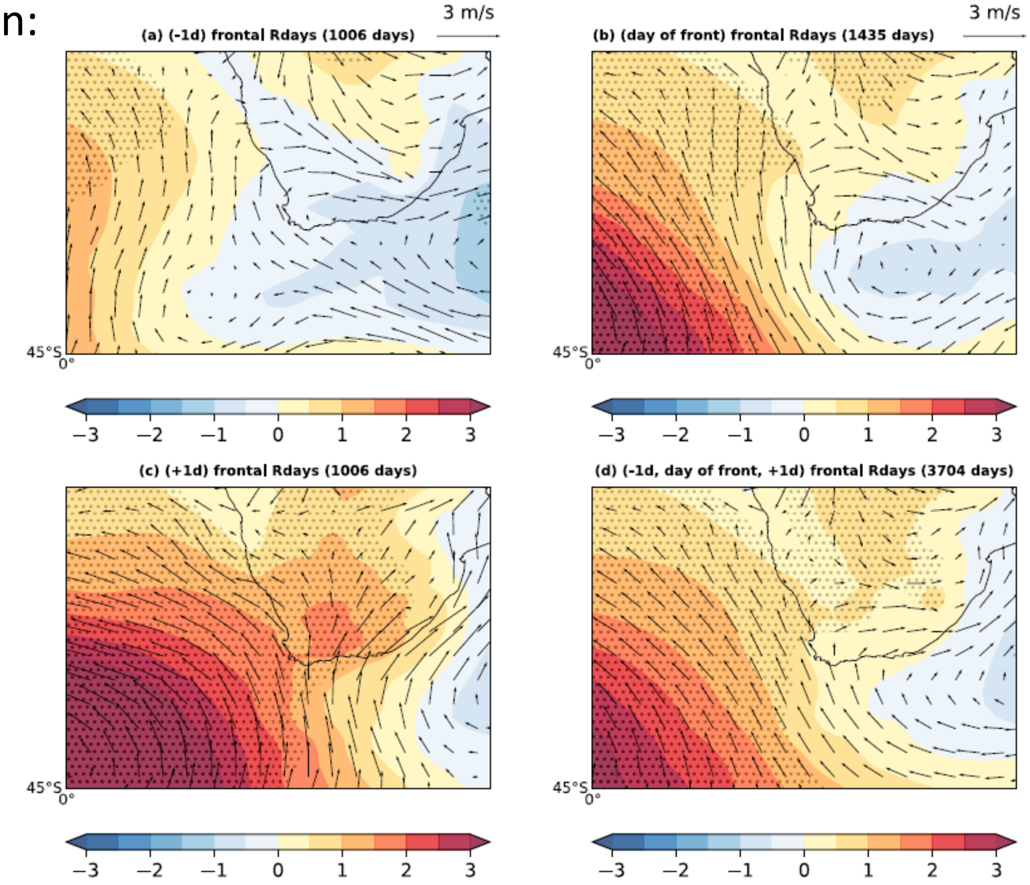
The average synoptic conditions typical of a frontal passage during the winter months.



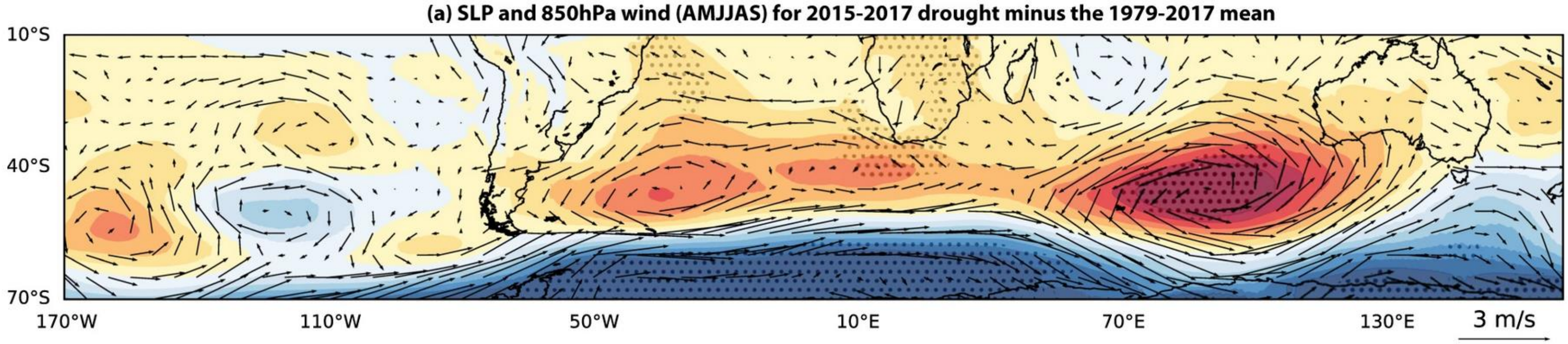
Important to note wind direction and ridging high-pressure

Zoomed in on the Cape Town region:

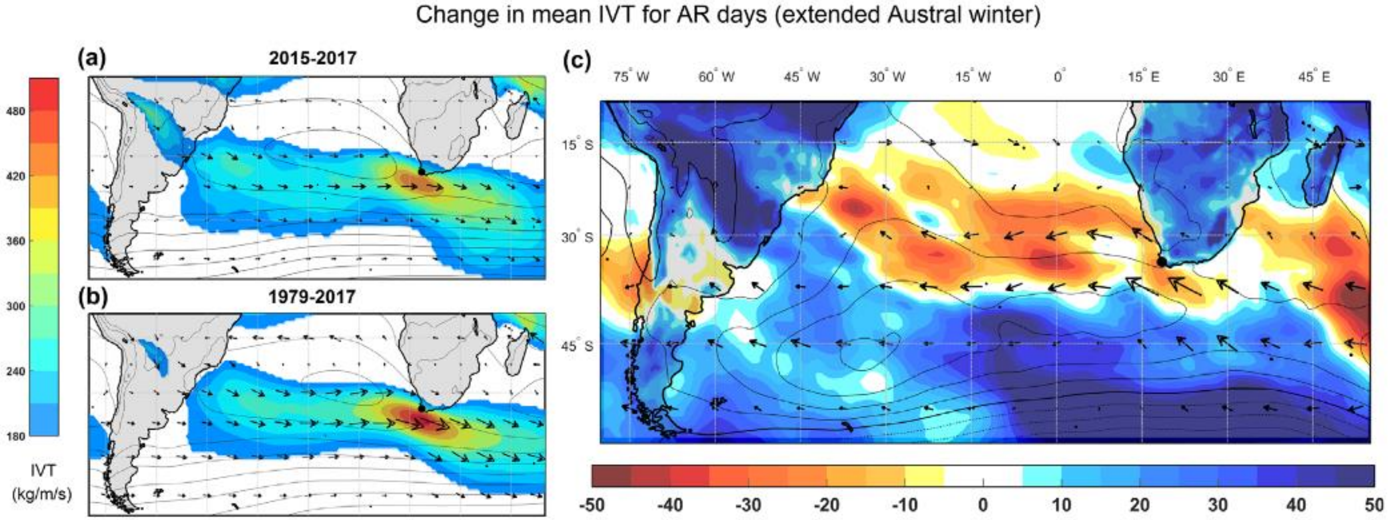
- **Trends towards more southerly and south-easterly wind conditions** during the passage of frontal systems and an **increase in the intensity of post-frontal ridging high** conditions are more visible.
- Possibly leading to a decline in the **occurrence of the onshore and upslope wind conditions** that promote orographic uplift during the passage of a frontal system



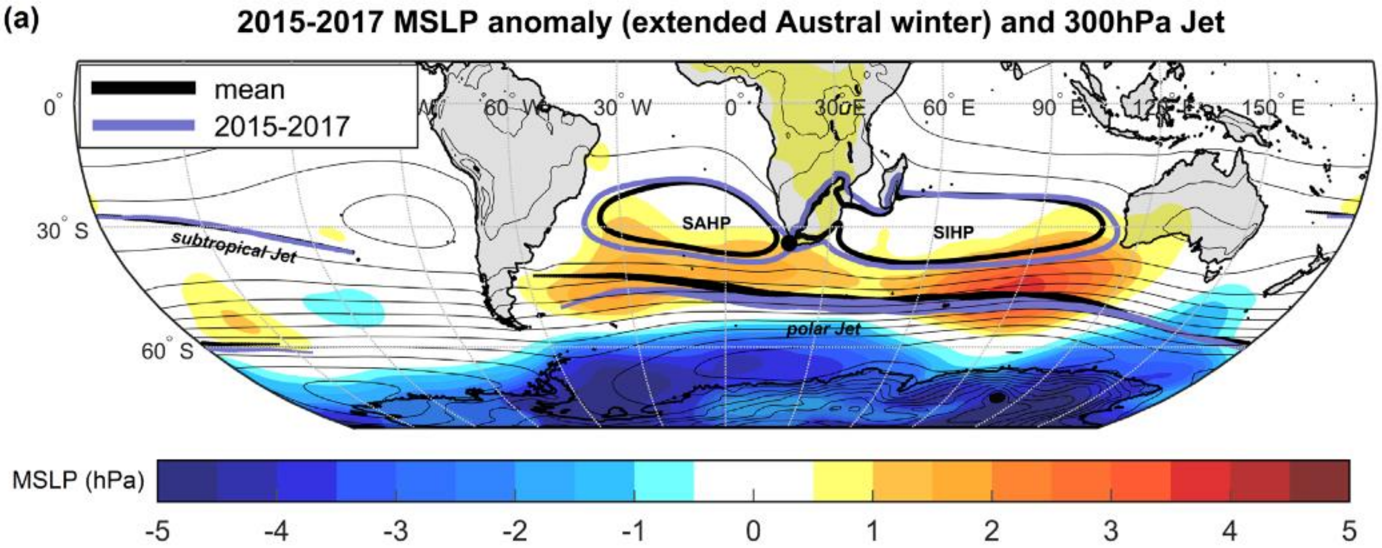
The 2015-2017 Drought



Anomalous conditions during the **2015–2017 drought display Hadley Cell expansion characteristics** with high-pressure anomalies on the southern edge of the subtropical high-pressure systems (anticyclones) within each ocean basin in the Southern Hemisphere

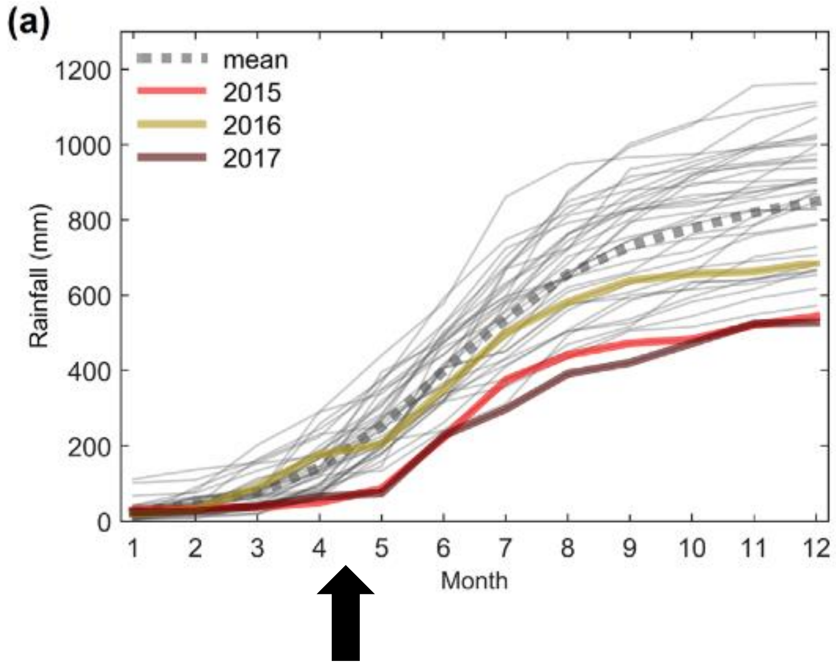


Sousa *et al. (*2018) also note a decrease in the intensity of ARs and of the zonal flow, as well as a deflection of the **maximum IVT corridors towards higher latitudes**, i.e. further away from the Cape Town area, occurred during 2015-2017



Sousa *et al. (*2018) suggest that the **expansion in SAHP and poleward shift in the jet streams** lead to the **poleward displacement of Atmospheric Rivers** for the 2015-2017 drought.

Perhaps something stands out about the early winter (April-May)?

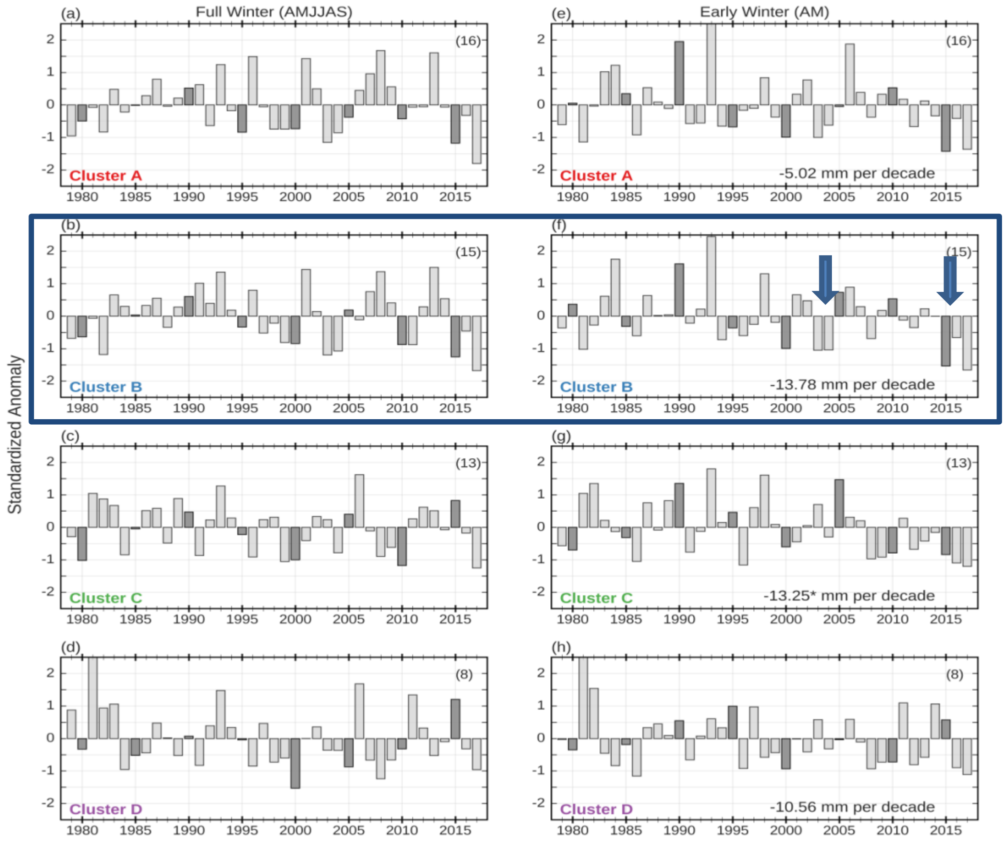


Cumulative rainfall for each year with the 2015-2017 years in colour

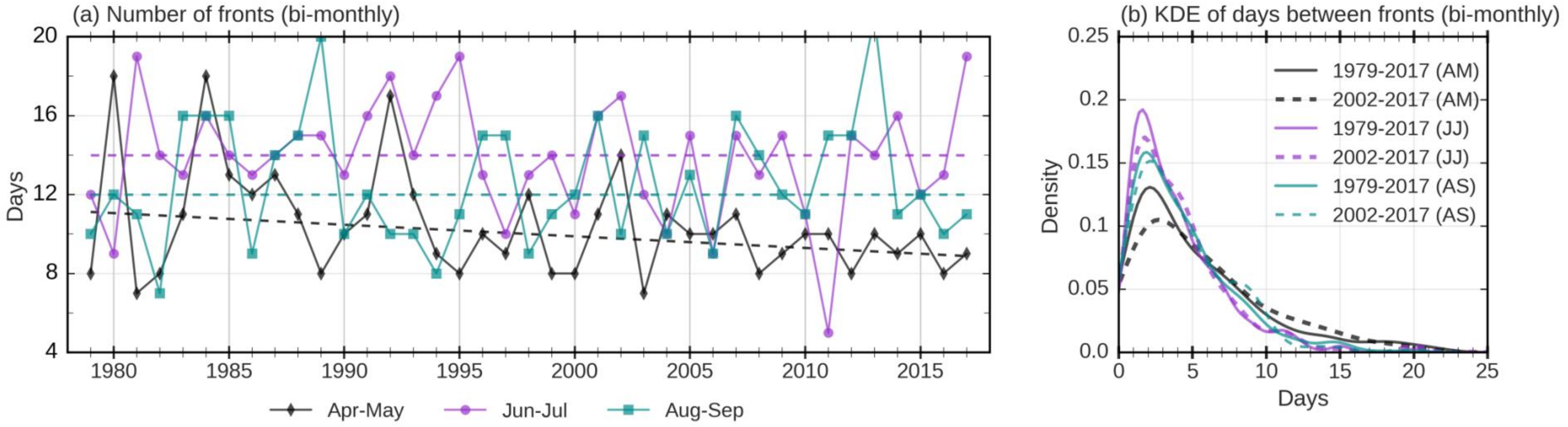
The lack of appreciable rainfall was most notable during the transition seasons

Leading to a **drastic shortening and delay of the rainy season**, strongly contributing to the unprecedented drought

Having a very dry early winter this year

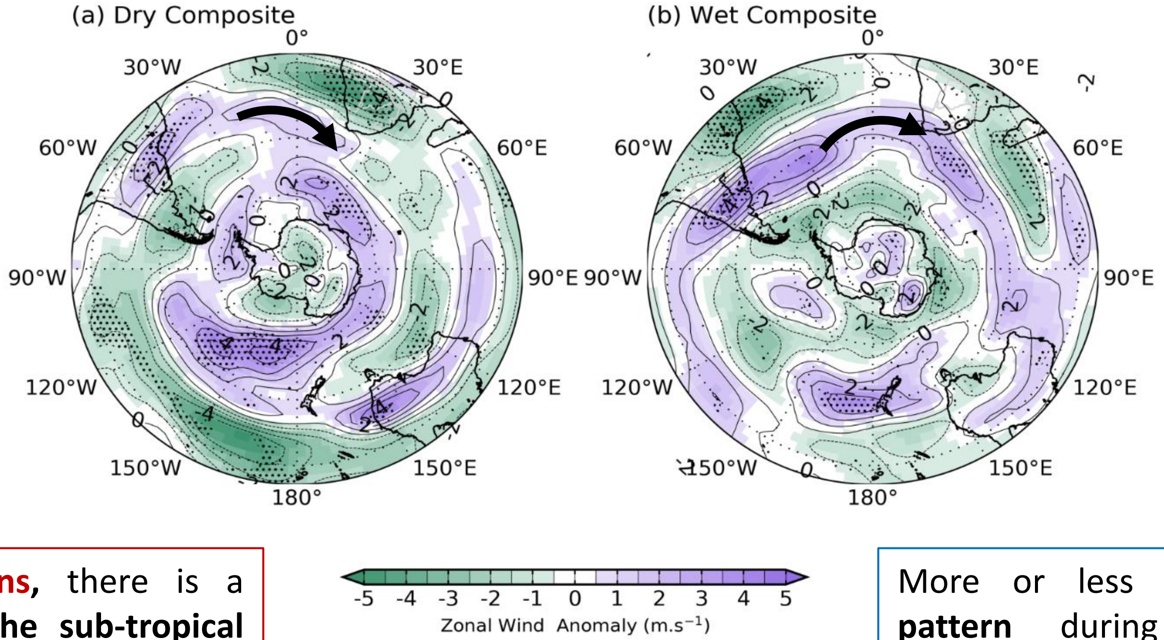


- A key characteristic of the **2015–2017 drought** is that the dry conditions are found to be **particularly severe during the early winter**
- Most **intense dry early winters occurred in the second half of the analysis period**
- Most **wet early winters** occur before the year 2000
- A trend analysis of the early winter rainfall reveals that **all clusters show a decreasing trend**, which vary in magnitude



- The early winter months (**black line**) is the only period that appears to have experienced a decease (significant at 90% level) in the number of fronts reaching the WC

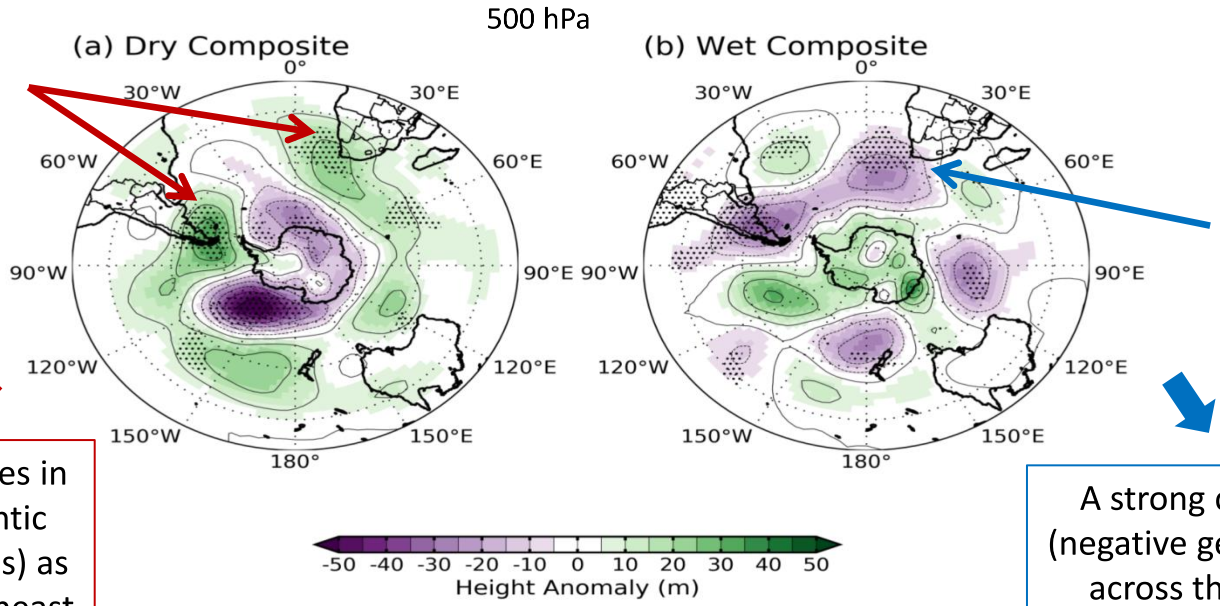
- As alluded to earlier - there is not a decrease in the number of fronts during the core winter months, these systems appear to track through the region quicker, producing less rainfall



Dry AM seasons, there is a **weakening of the sub-tropical jet** over southern Africa near 25°S and a strengthening of the polar jet near Antarctica

More or less the **reverse pattern** during the **wet composite**, but not as strong

Shifts in the jet stream already shown to impact on the track and intensity of fronts upstream of the Western Cape (e.g. Reason and Jagadheesha, 2005)



Anticyclonic anomalies in the southwest Atlantic (reduced cyclogenesis) as well as over the southeast Atlantic and South Africa

cold fronts would weaken and shift south on approaching the WC

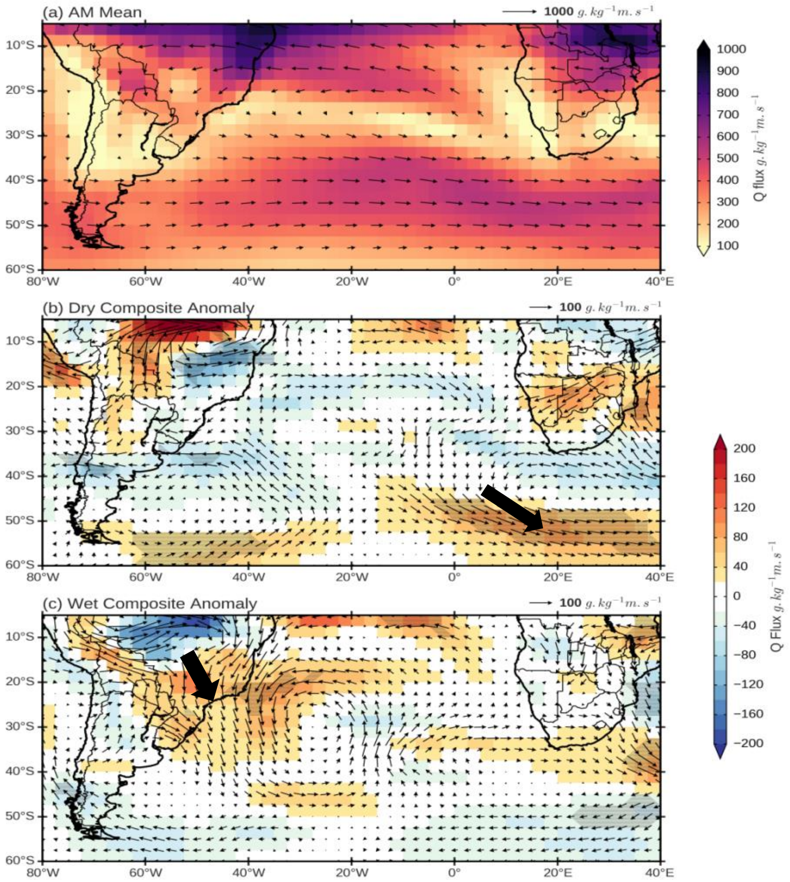
leading to reduced rainfall

A strong cyclonic anomaly (negative geopotential height) across the South Atlantic

enhanced cyclogenesis in the southwest Atlantic

Favourable conditions for the strengthening and track of frontal systems

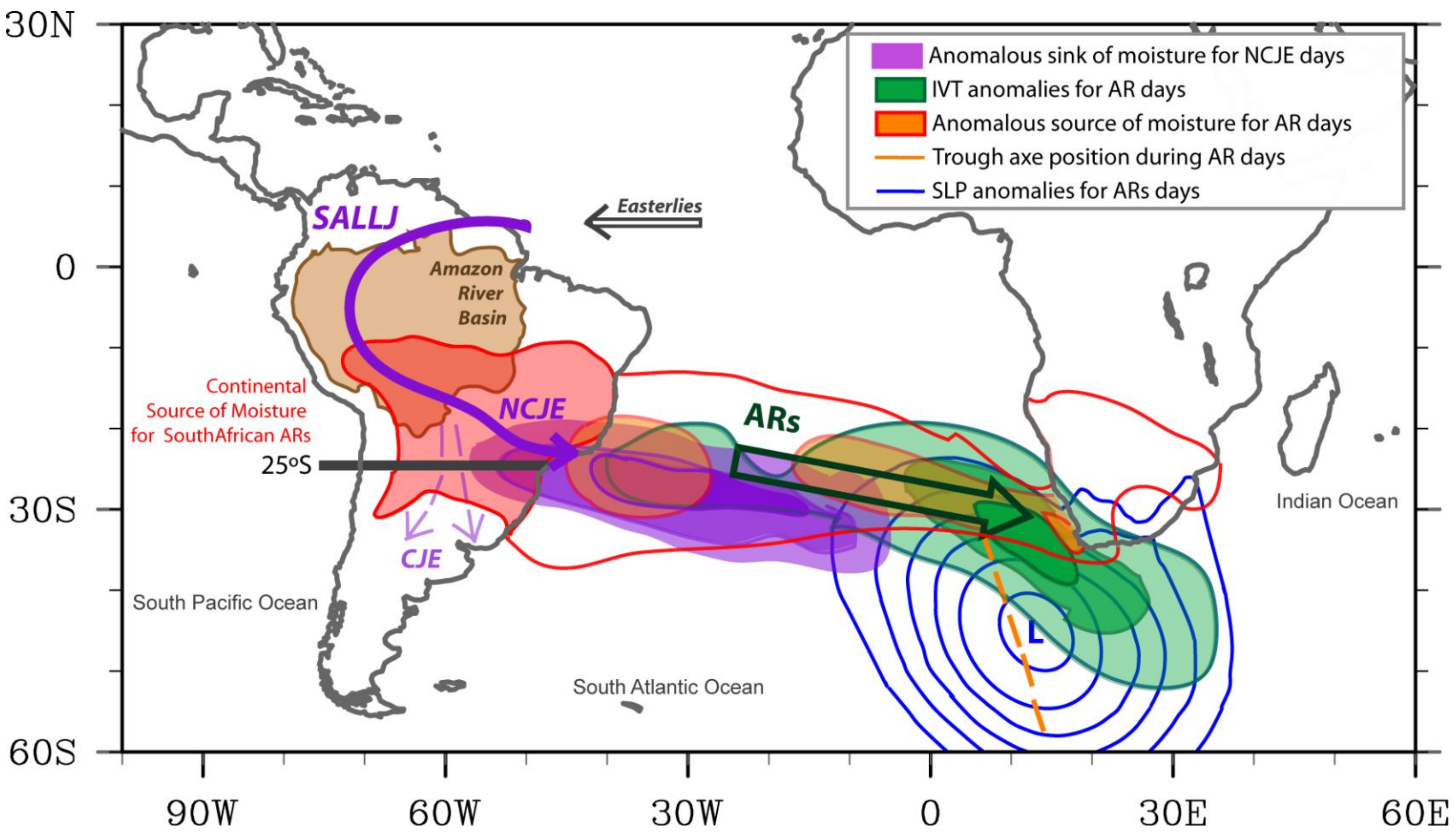
Moisture flux at 850 hPa



The maximum in **early winter moisture flux** in the lower levels is to the southwest of the WC as the westerlies transport moisture across the mid-latitude South Atlantic towards the region.

Dry early winters: anticyclonic anomalies develop over and south of South Africa leading to a clear **poleward shift** in the main moisture flux corridor to the south and southwest of the WC.

Wet early winters: cyclonic anomalies develop over and south of South Africa leading to a clear **equatorward shift** in the main moisture flux corridor to the south and southwest of the WC.



Ramos *et al.* (2018)

The future - should we be concerned?

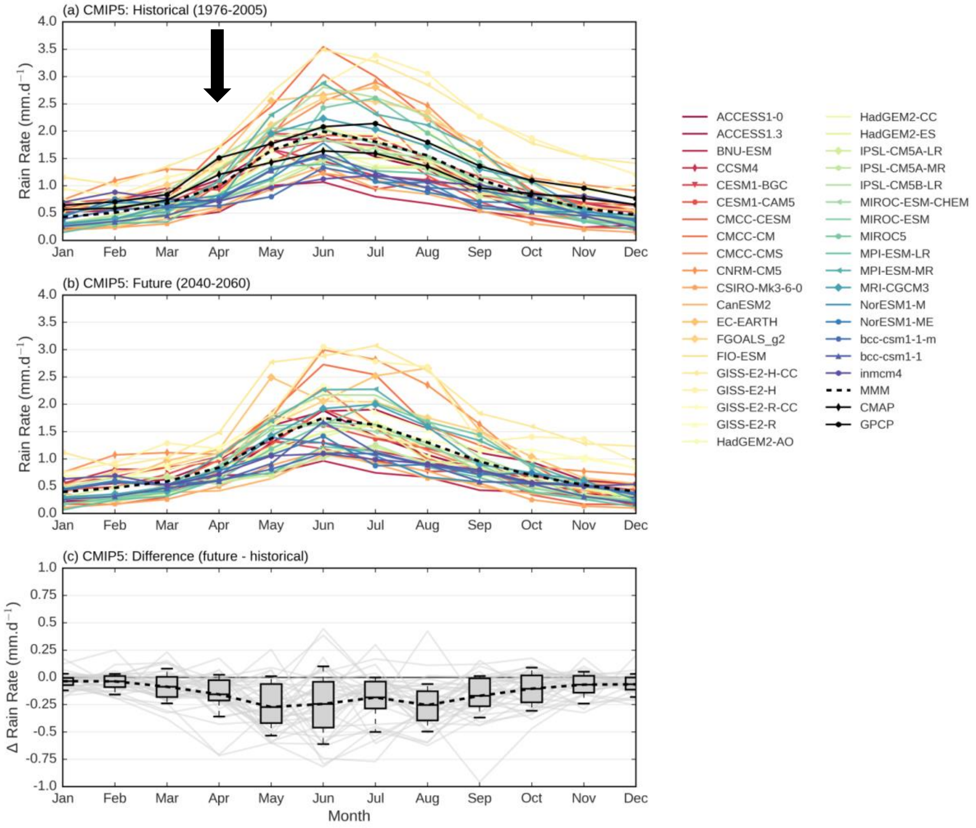
<u>The future - what it could look like</u>:

- **Early winter** period is likely **to get drier in the mid-twenty-first century**, with general agreement across the suite of CMIP5 models.

- The **drying is not restricted to just the early winter** period, with all winter months showing a decrease in rainfall in future projections

- Strongest magnitude in drying evident in **May-June**

- The **drying result is consistent with general projected Southern Hemisphere rainfall changes** in the midlatitudes (e.g. Purich *et al.* 2013; Lim *et al.* 2016, etc.)



Why we should we be worried…

Table 1: Provisional national water balance with and without critical interventions

Water use sectors	2030 water requirements projections (million m^3)		
	Without demand management interventions	With urban losses reduced from 35% to 15%	Reduce domestic demand from 237 l/c/d to 175 l/c/d
Agriculture (irrigation and livestock watering)	9 700	9 700	9 700
Municipal (industries, commerce, urban and rural domestic)	5 800	4 941	3 696
Strategic/Power generation	430	430	430
Mining and bulk industrial	1 017	1 017	1 017
International obligations	178	178	178
Afforestation	434	434	434
Total water requirements (2030)	**17 559**	**16 700**	**15 455**
Total water available (2015)	13 949		
Increased surface water yield	874		
Increased groundwater use	405		
Desalination (including treated AMD)	588		
Re-use	110		
Total water available (2030)	**15 926**	**15 926**	**15 926**
Deficit/surplus	-1 633	-763	527
Deficit/surplus	-10%	-5%	3%

RSA Department of Water and Sanitation: *National Water and Sanitation Master Plan* 2018

Some discussion points:

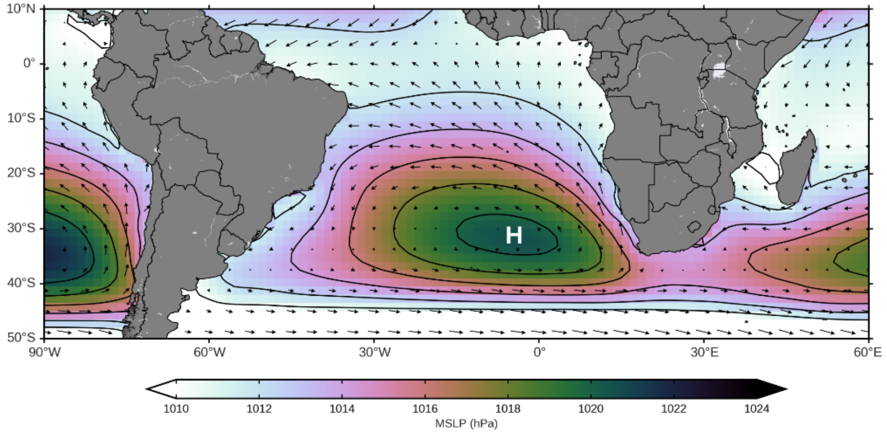
- Very regional focus but what about rest of Southern Hemisphere the past decade (e.g. The 2010-2018 “Mega-Drought” in Chile – Garreaud *et al.* 2019)

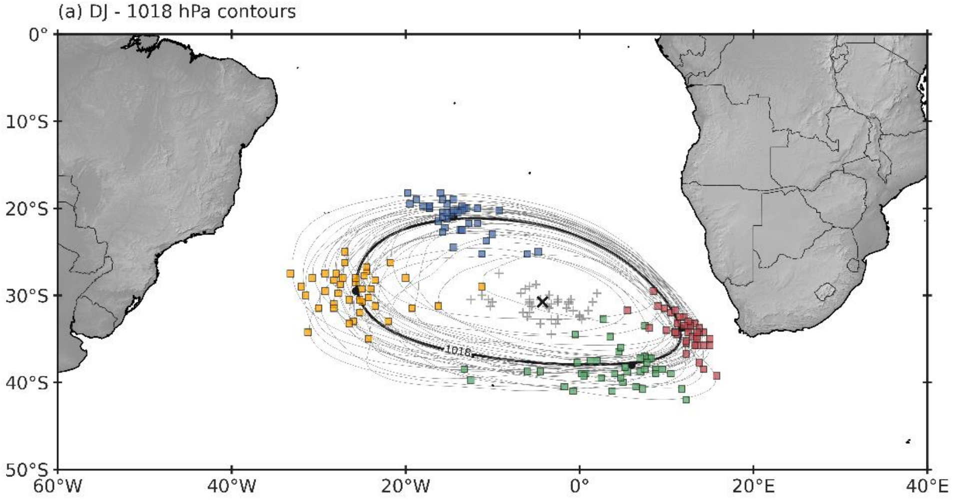
- Time scales - Modes of variability (e.g. SAM) vs Ozone Depletion / Recovery vs Climate Change fingerprints (Hadley Cell expansion)?

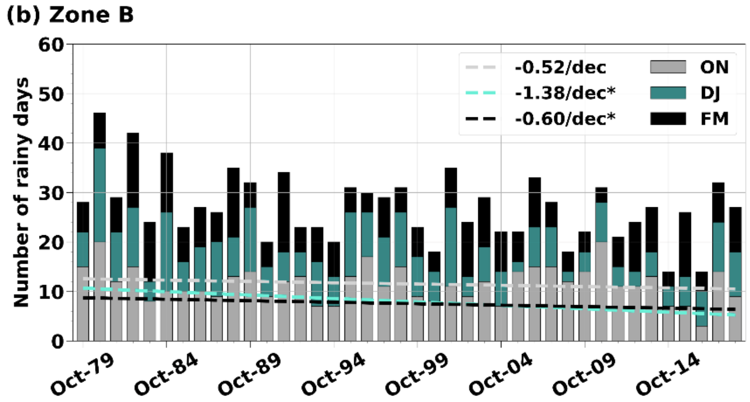
- Intraseasonal variability - early winter appears to be different to that of the core winter months. Could we be seeing a shift to a longer dry season and a shorter rainy season?

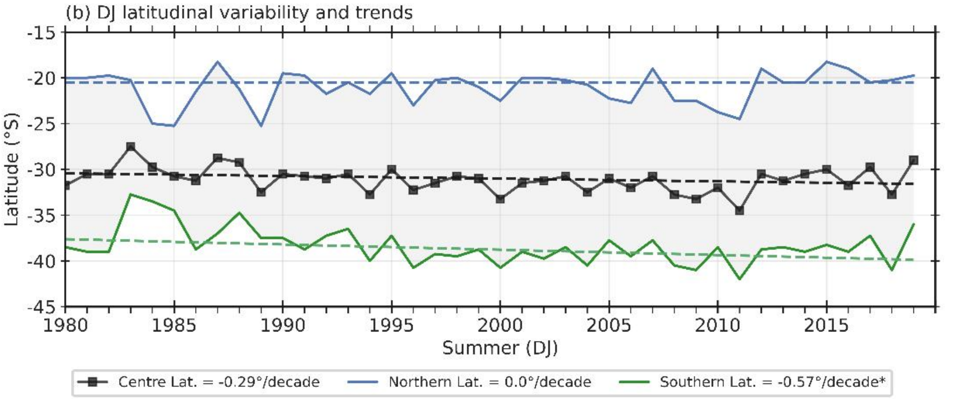
- There is consensus across nearly all the CMIP5 models projecting a general drying in the winter rainfall region during the mid-twenty-first century. But what if the models cannot capture the current rainfall seasonal cycle? Therefore, why we need to better understand mechanisms.

- Climate is one piece of the puzzle ----> Management of Water Resources(!)? (Climate Services)

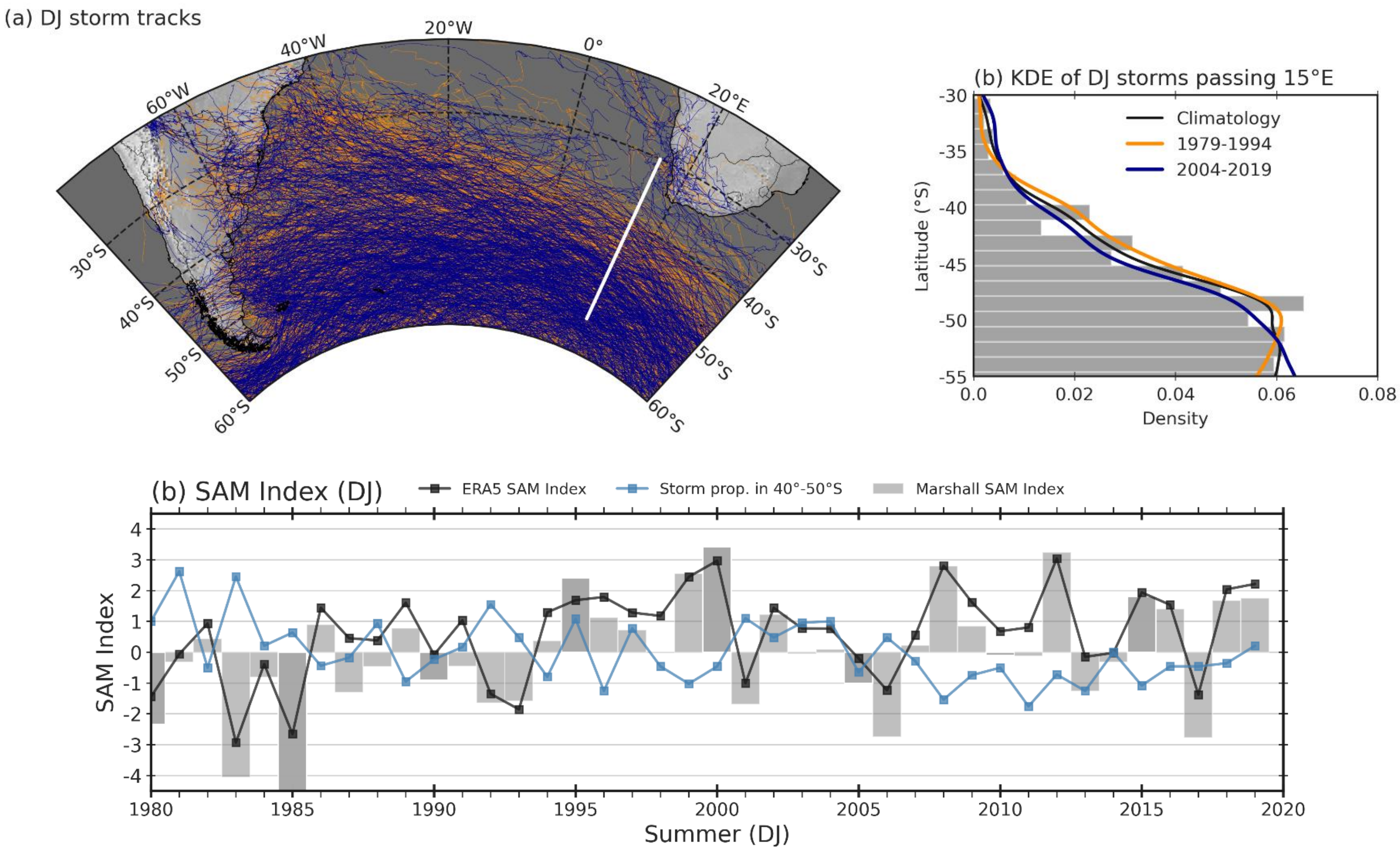








De Kock *et al.* (2022)



(a) DJ storm tracks
20°W
40°W
0°
60°W
20°E
30°S
40°S
50°S
60°S
(b) KDE of DJ storms passing 15°E
Climatology
1979-1994
2004-2019
Latitude (°S)
-30
-35
-40
-45
-50
-55
0.0
0.02
0.04
0.06
0.08
Density
(b) SAM Index (DJ)
ERA5 SAM Index
Storm prop. in 40°-50°S
Marshall SAM Index
SAM Index
4
3
2
1
0
-1
-2
-3
-4
1980
1985
1990
1995
2000
2005
2010
2015
2020
Summer (DJ)

More Information:

Blamey *et al.* 2018 (*J. Hydrometeor.*)
Sousa *et al.* 2018 (*Environ. Res. Lett.*)
Ramos *et al.* 2018 (*Ann. N.Y. Acad. Sci.*)
Burls *et al.* 2019 (*NPJ Clim. Atmos.*)
Mahlalela *et al.* 2019 (*Clim. Dyn.*)
De Kock *et al.* 2021 (*J. Hydrometeor.*)
De Kock *et al.* 2022 (*Clim. Dyn.*)

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