# April-May Southern Hemisphere subtropical zonal wave-4 exerts significant influence on South Africa's Winter Rainfall Zone

## Advancing Subtropical Climate Dynamics

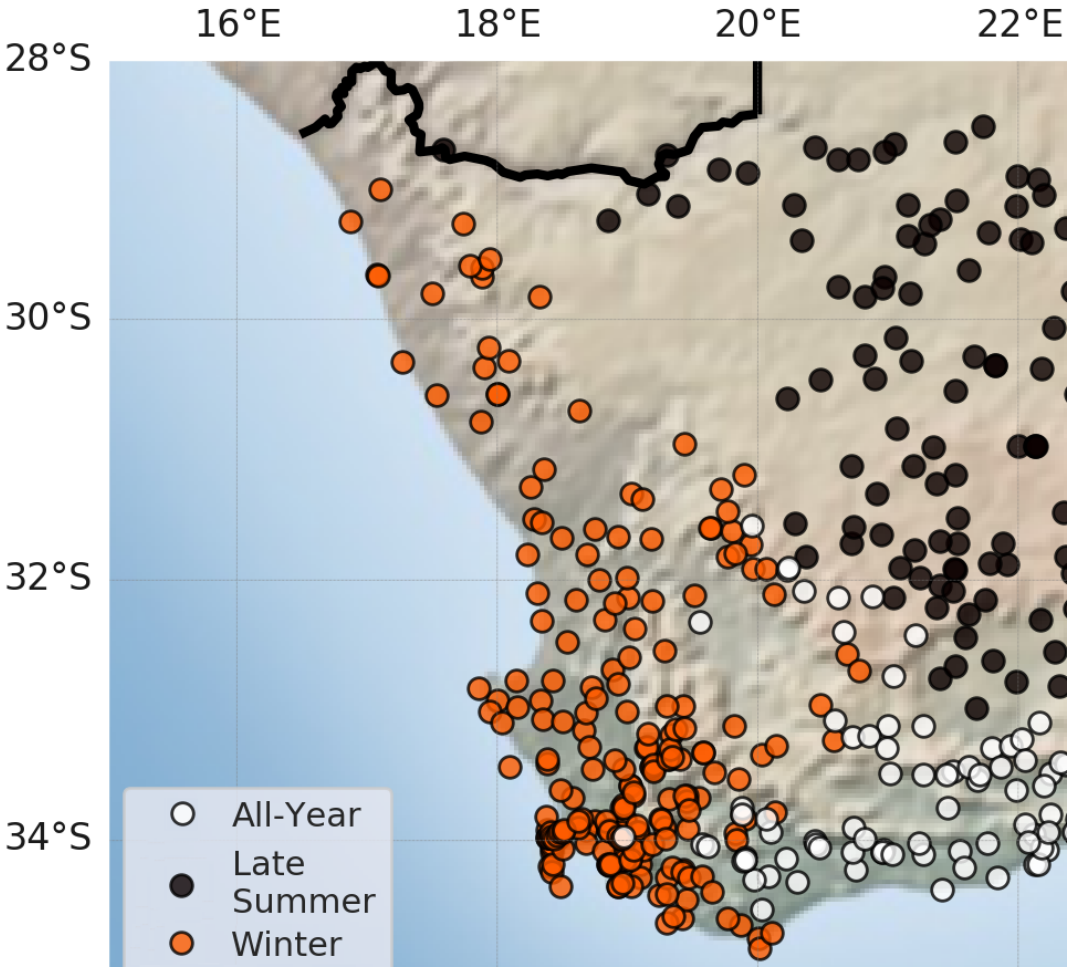
Stefaan Conradie (stefaan@csag.uct.ac.za)
supervisors: Prof. Bruce Hewitson, Dr. Piotr Wolski

Climate System Analysis Group (CSAG), University of Cape Town (UCT)

2 August 2022

# Framework

- Relating standing AM ZW4 to rain-bearing synoptic systems & winds around western South Africa

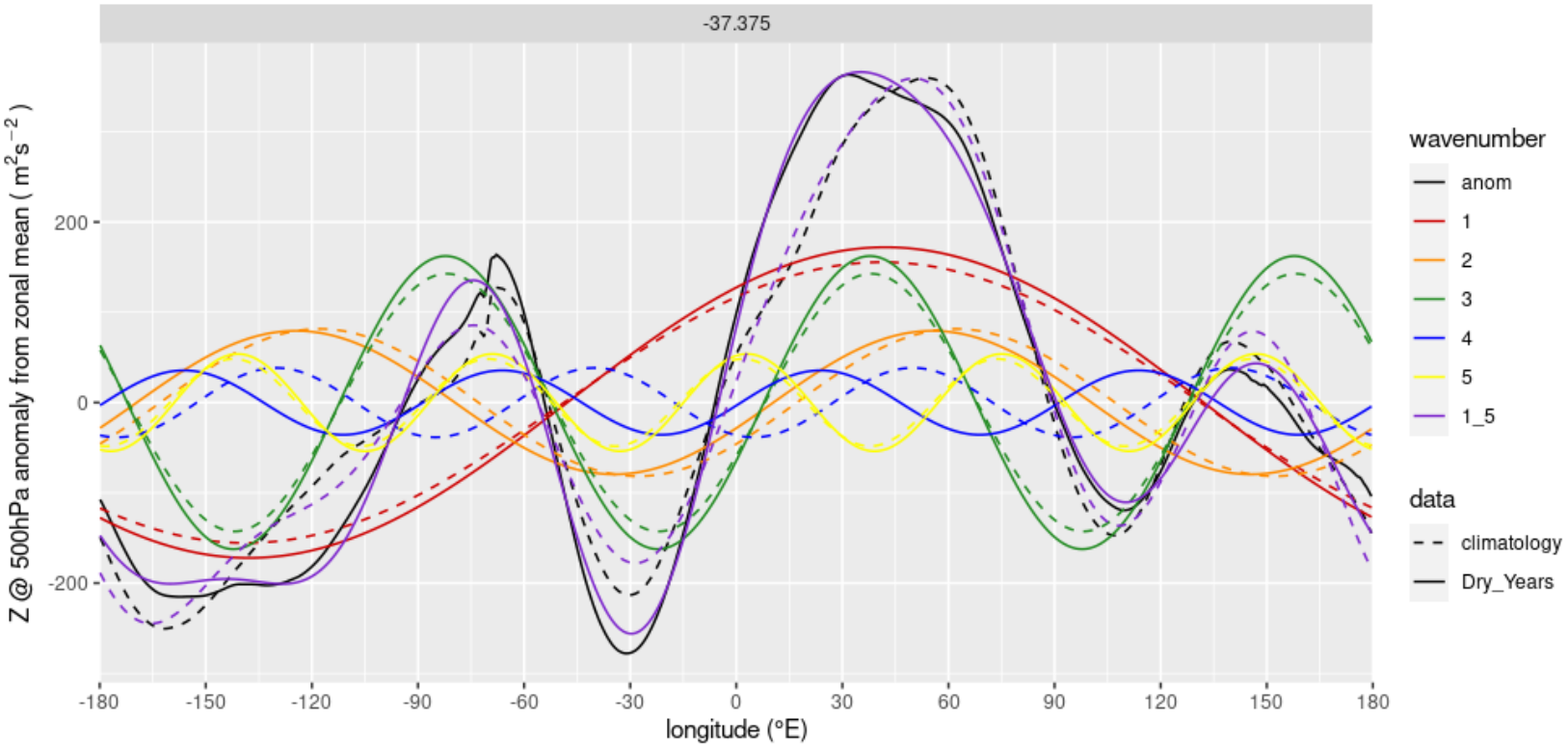


# Framework

- Relating standing AM ZW4 to rain-bearing synoptic systems & winds around western South Africa
- What do seasonal mean ZW states represent?
  - Are ZW4 patterns "real" modes? Or just mathematical/statistical constructs? And ZW1–3?
  - Background state or average of short events?
  - eliocamp.github.io/scrapbook/posts/2021-01-14-wave4/; also Goyal et al. (2022)

# Motivation: Why AM ZW4?

- Day Zero Drought (Ross Blamey's talk!) AM anomalies show ZW4 pattern (Mahlalela et al., 2019)



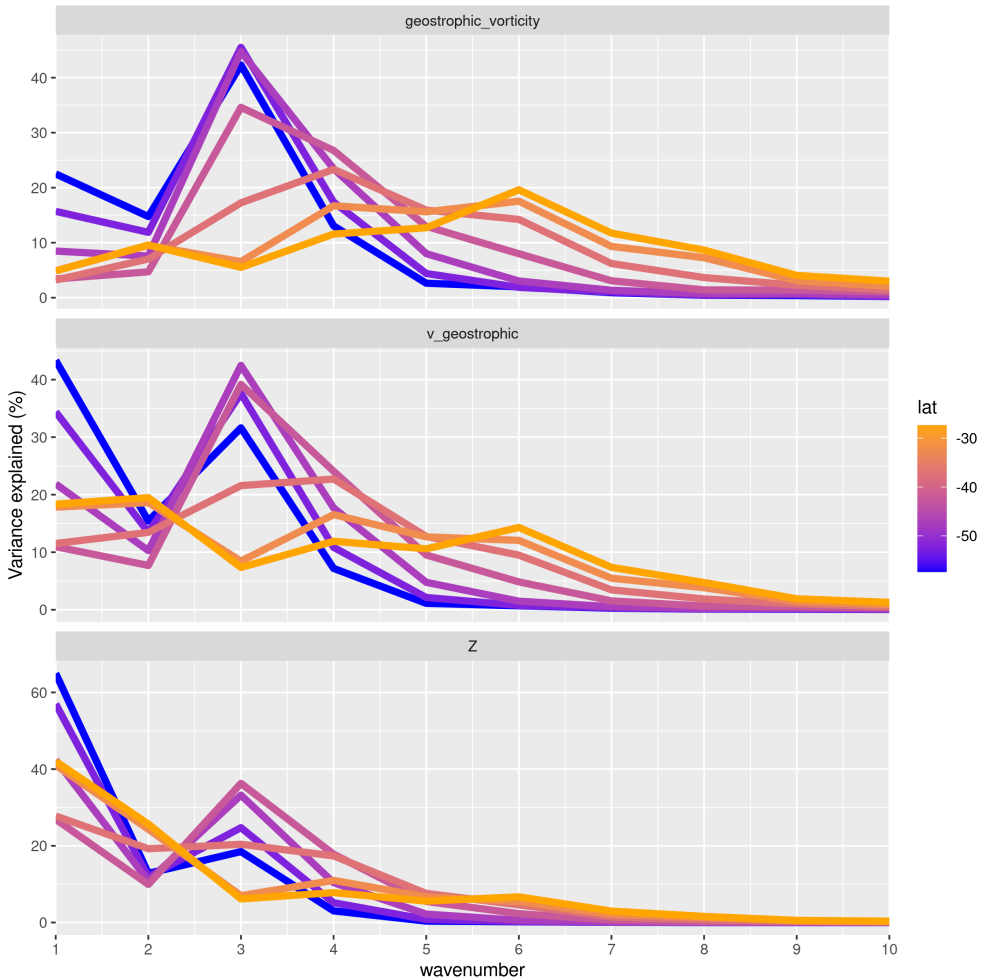
# Motivation: Why AM ZW4?

- Day Zero Drought (Ross Blamey's talk!) AM anomalies show ZW4 pattern (Mahlalela et al., 2019)
- Renewed focus on "waviness" and zonally asymmetric components of SH extra-tropical circulation – especially ZW3 (Irving and Simmonds, 2015; Campitelli et al., 2022; Goyal et al., 2021, 2022).
- ZW4 mode first EOF in austral summer $v_{250}$ & "ENSO-free" SST (Senapati et al., 2021a,b)
- Near orthogonal wave-4 pattern is leading mode of South Atlantic-Indian sector $v_{200}$ (Lin, 2019)

# Motivation: Why AM ZW4?

Higher wave numbers ($k \geq 4$):

- greater influence in subtropics & on variability
- ZW4: standing component in summer–early autumn
- explain more variance in $v_{g,k} \propto kZ_k$ & $\xi_{g,k} \sim \nabla^2 Z_k \sim k^2 Z_k$



# Data

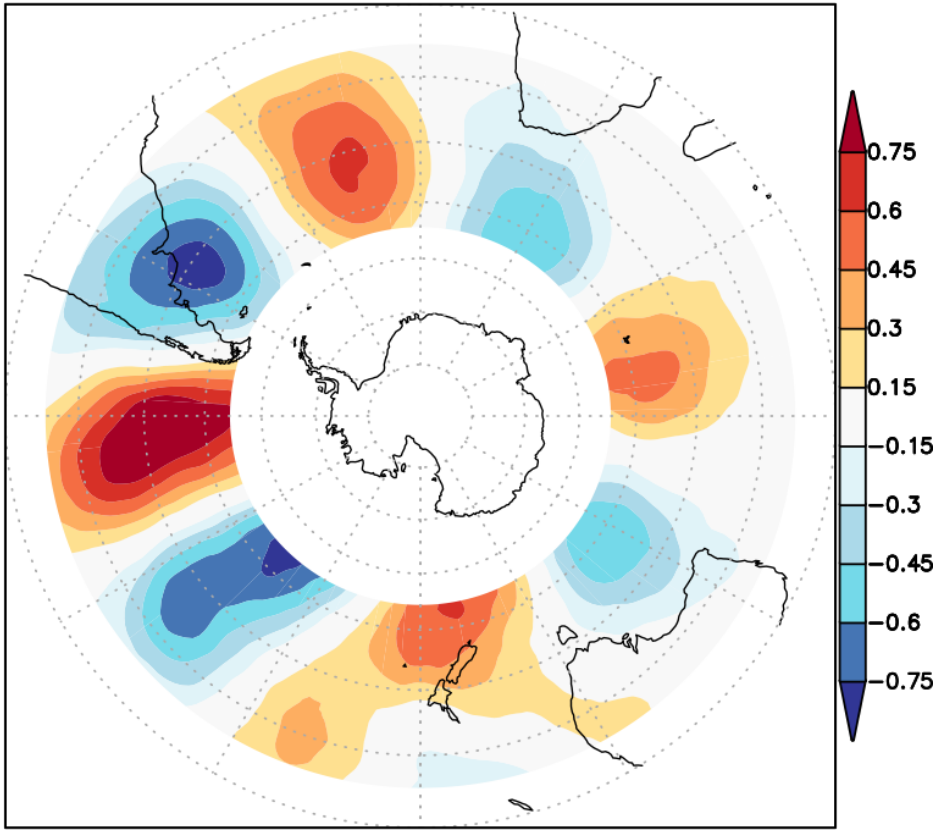
- Rainfall: SAWS, DWS, CoCT, GPCC
- $Z$, $v$: ERA-5

# Western South Africa rainfall

- Both phase & amplitude explain ∼25% of southern WRZ AM rainfall variance
- Clear signal at 6-hourly time scale
- Also $R^2 > 0.25$ with $Z_{4,500}(37.5°\text{S}, 16°\text{E}) = A_4 \cos(4(16 - \varphi_4))|_{\phi=37.5°\text{S}}$
- Neither explains more than 5% in YRZ or LSRZ
- $Z_{4,500}(37.5°\text{S}, 16°\text{E})$ :
  - explains 50% of variance in SE Atlantic SOM trough node frequency
  - significantly correlated with 900-hPa synoptic westerly wind frequency.

# AM ZW4 modes

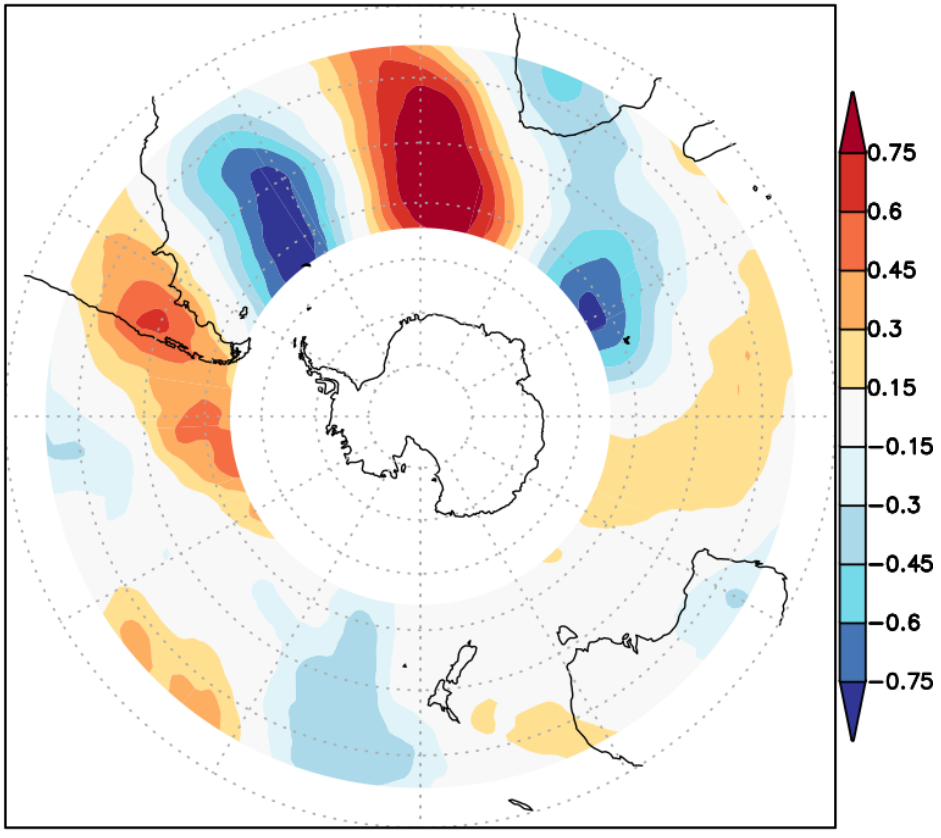
**AM** $v_{300}$ $25 - 55°\text{S}$ **EOF1:**




- Very similar to summer mode of Senapati et al. (2021b)
- shares 91% variance with $Z_{4,500}(37.5°\text{S}, 16°\text{E})$
- $R^2 \approx 0.2$ with rain in
  - south-western Cape
  - central Chile
  - far southern Brazil (Porto Alegre)

# AM ZW4 modes

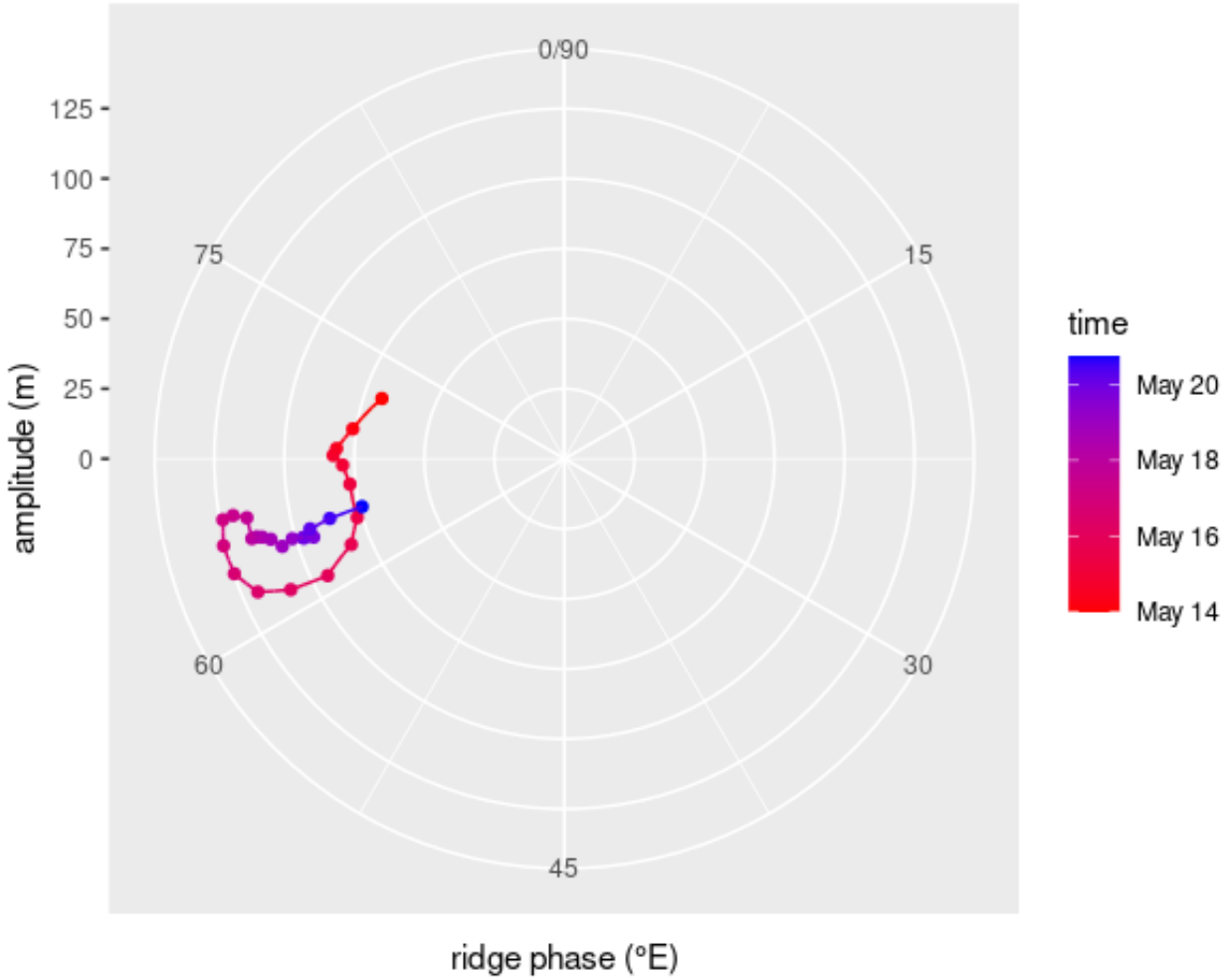
**AM** $v_{300}$ $25 - 55°\mathrm{S}$ **EOF4:**




- Very similar to summer mode of Lin (2019)
- Projects significantly onto phase of ZW3–6 over 35–40°S
- Correlations to rain in western SA:
  - $0.15 \leq R^2 \leq 0.2$ throughout WRZ
  - western LSRZ: $R^2 \approx 0.14$
  - Insignificant influence on YRZ ($p > 0.1; R^2 < 0.07$)

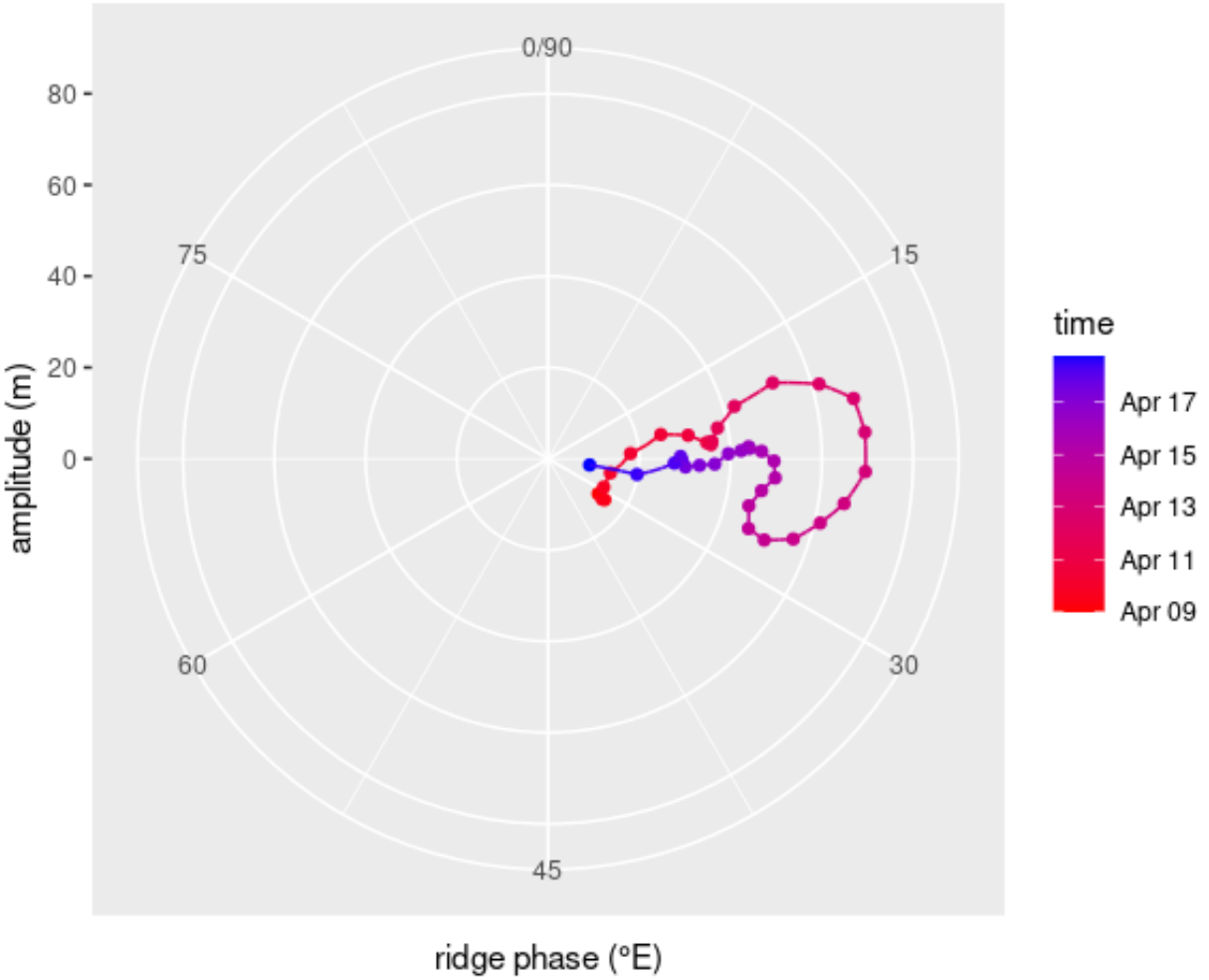
# Individual ZW4 events

May 1984 storm:



# Individual ZW4 events

UCT fire: April 2021 heat wave:



# Key References I

Campitelli, E., Díaz, L. B., and Vera, C.: Assessment of zonally symmetric and asymmetric components of the Southern Annular Mode using a novel approach, Climate Dynamics, 58, 161–178, doi:10.1007/s00382-021-05896-5, 2022.

Goyal, R., Jucker, M., Sen Gupta, A., Hendon, H. H., and England, M. H.: Zonal wave 3 pattern in the Southern Hemisphere generated by tropical convection, Nature Geoscience, 14, 732–738, doi:10.1038/s41561-021-00811-3, 2021.

Goyal, R., Jucker, M., Gupta, A. S., and England, M. H.: A new zonal wave 3 index for the Southern Hemisphere, Journal of Climate, 31, 1–25, doi:10.1175/JCLI-D-21-0927.1, 2022.

Irving, D. and Simmonds, I.: A novel approach to diagnosing Southern Hemisphere planetary wave activity and its influence on regional climate variability, J. Clim., 28, 9041–9057, doi:10.1175/JCLI-D-15-0287.1, 2015.

Lin, Z.: The South Atlantic–South Indian Ocean Pattern: a Zonally Oriented Teleconnection along the Southern Hemisphere Westerly Jet in Austral Summer, Atmosphere, 10, 259, doi:10.3390/ATMOS10050259, 2019.

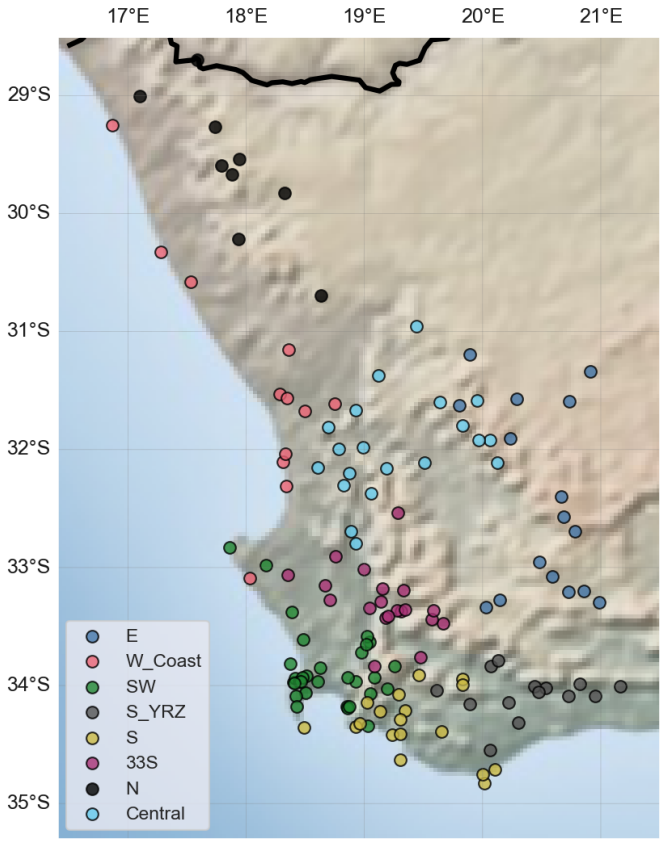
Mahlalela, P. T., Blamey, R. C., and Reason, C. J. C.: Mechanisms behind early winter rainfall variability in the southwestern Cape, South Africa, Clim. Dyn., 53, 21–39, doi:10.1007/s00382-018-4571-y, 2019.

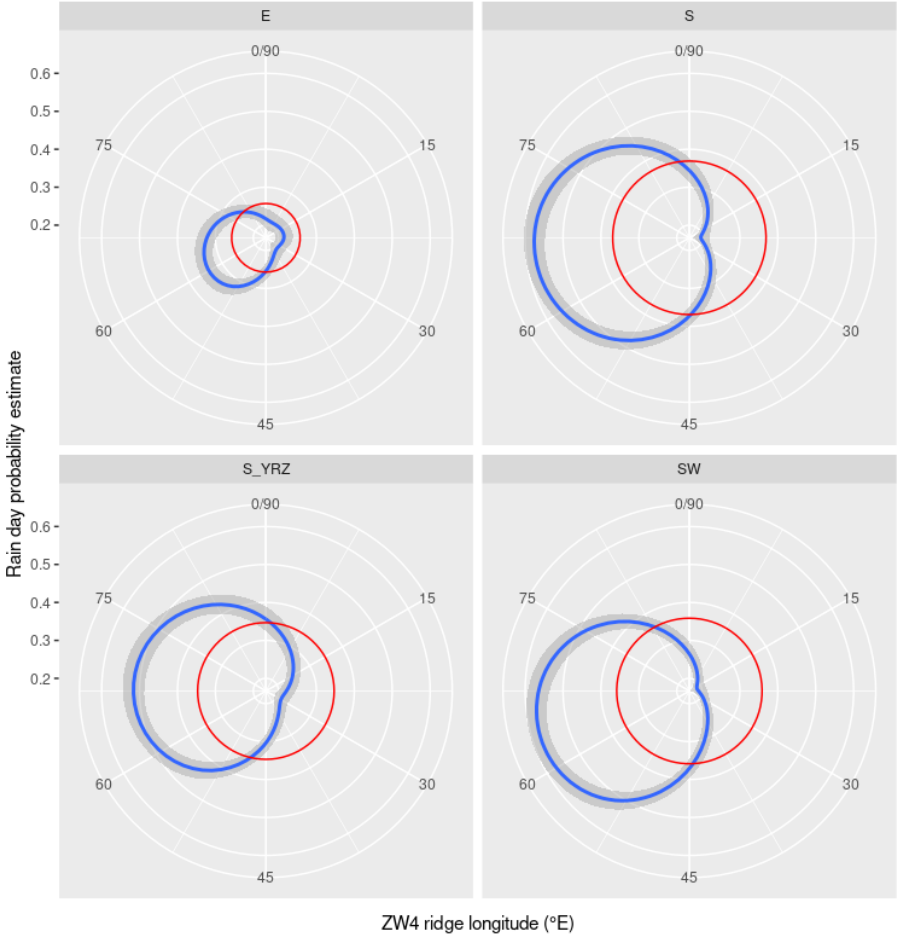
# Key References II

Senapati, B., Dash, M. K., and Behera, S. K.: Global wave number-4 pattern in the southern subtropical sea surface temperature, Scientific Reports 2021 11:1, 11, 1–12, doi:10.1038/s41598-020-80492-x, 2021a.

Senapati, B., Deb, P., Dash, M. K., and Behera, S. K.: Origin and dynamics of global atmospheric wavenumber-4 in the Southern mid-latitude during austral summer, Clim. Dyn., doi:10.1007/s00382-021-06040-z, doi:10.1007/S00382-021-06040-Z/FIGURES/7, 2021b.

# 6-hourly ZW4 phase and rainfall by cluster

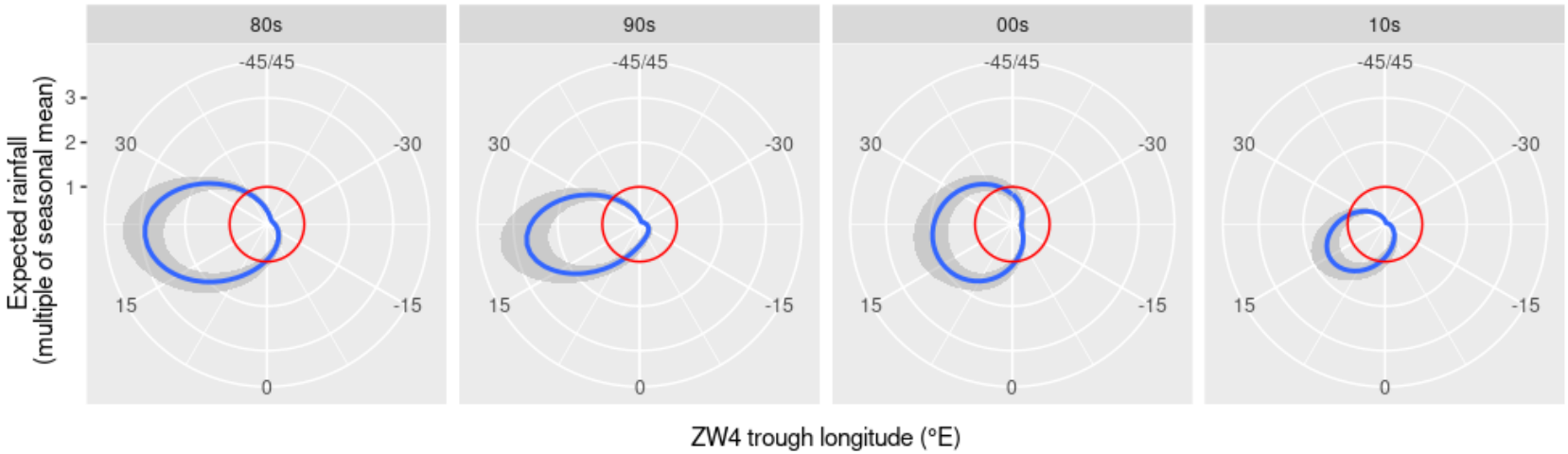


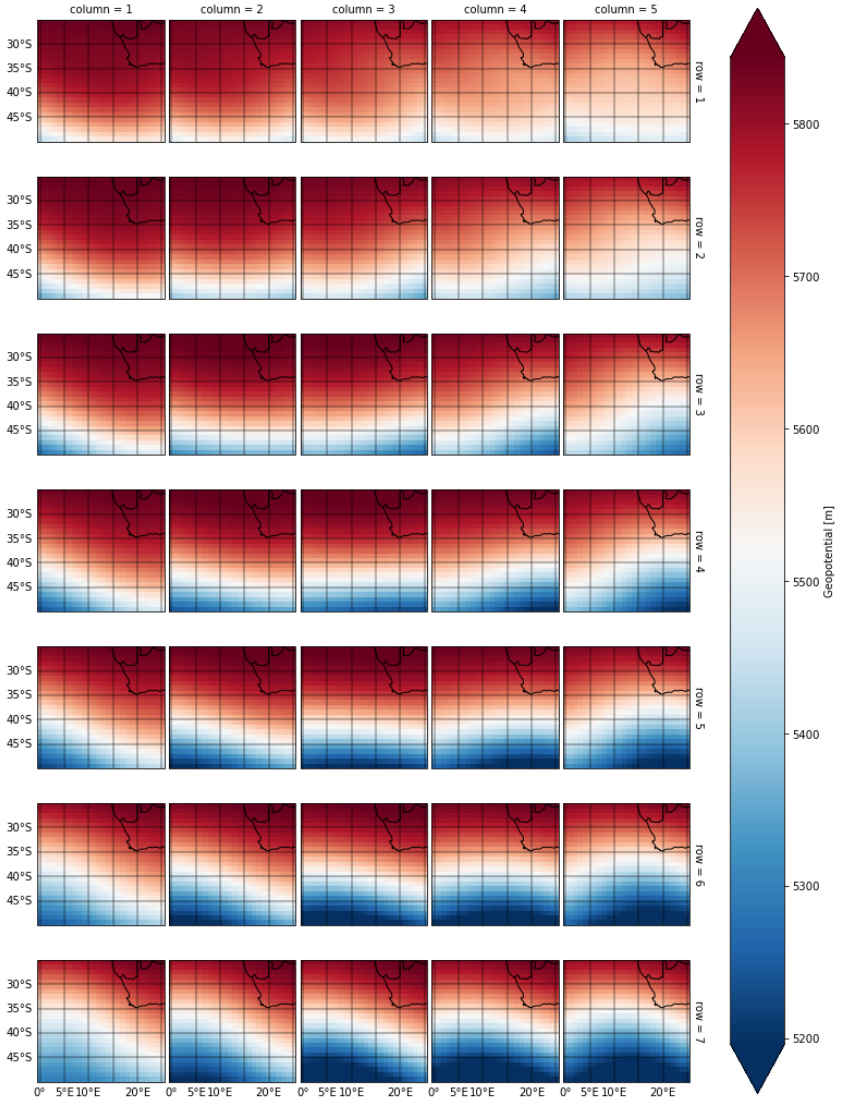
# Changes to rainfall-phase relationship over time

**Expected daily rainfall in 33S and SW clusters as a function of ZW4 trough position, by decade**

- considering only AM time steps with $A_4 > 50$m ($\sim 40\%$)



# The SOM


column = 1
column = 2
column = 3
column = 4
column = 5
row = 1
row = 2
row = 3
row = 4
row = 5
row = 6
row = 7
30°S
35°S
40°S
45°S
0°
5°E
10°E
20°E
Geopotential [m]
5800
5700
5600
5500
5400
5300
5200