Impact of the Agulhas current on Southern African hydroclimate

Analysis of a high-resolution JRA55-driven CCLM hindcast simulation with spectral nudging

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Introduction

Motivation and Research goals

We investigate the impact of the Agulhas Current on the regional climate in Southern Africa, in particular on hydroclimate events, droughts and floods by a high-resolution CCLM hindcast simulation.
As the observational data coverage of the region is particularly scarce, this simulation fills the data gap for Southern Africa. Furthermore, this region has been witnessed serious droughts (in the Cape region) and heavy rainfall and storm events caused by tropical cyclones (in the south east) in the last years. Therefore, we simulate precipitation changes in a CCLM hindcast simulation driven by the reanalysis JRA-55 for the period 1958-2019 with the aim to detect variations and trends in precipitation on interannual to decadal timescales, and identify their drivers. A special focus lies on the impact of the Agulhas Current on hydroclimate changes.
The Agulhas Current causes near-coastal convection and is, thus, a key driver of precipitation in the southernmost eastern part of the African continent. Changes in the Southern Hemisphere westerlies drive changes in the position of the Agulhas Current. This, in turn, might cause precipitation changes by modulating the atmospheric humidity and temperature over the coastal region of south-eastern Africa.
The spatial high resolution of our simulation (16 km) enables us to study local precipitation changes. In addition, the hourly resolution helps to investigate extreme events in wind and precipitation and the use of spectral nudging for this simulation adds to, among others, a more realistic representation of the tracks of the tropical cyclones.
Precipitation in Southern Africa takes place in the austral summer season in the summer rainfall zone, which covers the whole study area, except for the Cape region in the south west where precipitation occurs in austral winter (winter rainfall zone).

Model setup:
- CCLM simulation 1958 - 2019
- Model version 5.0 clm10
- 10W - 55E, 0S - 55S (Fig. 1)
- 16 km horizontal resolution
- 36 vertical layers (up to 30000m)
- Hourly output
- Spectral nudging

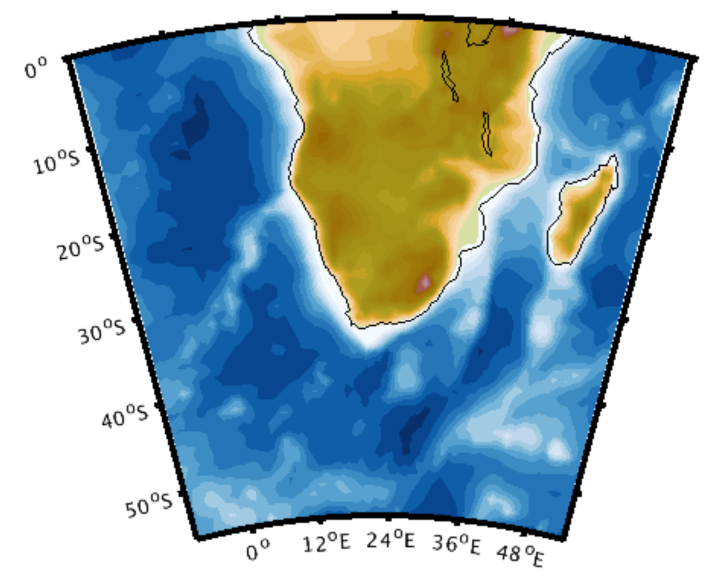

Figure 1 Model domain: of the CCLM simulation covers Southern Africa and the adjacent oceans. 10W - 55E, 0S - 55S.

Validation of model simulation

Comparison to gridded observation data sets

The mean precipitation over our research area (Fig. 2) shows a plausible pattern with higher rainfall over Madagascar and along the central south eastern coast. The annual cycle (Fig. 3) depicts clearly the differences between the two rainfall zones: the winter rainfall zone (WRZ) around the Cape of Good Hope (black both in Fig. 2) and the summer rainfall zone (SRZ) in the rest of the domain.

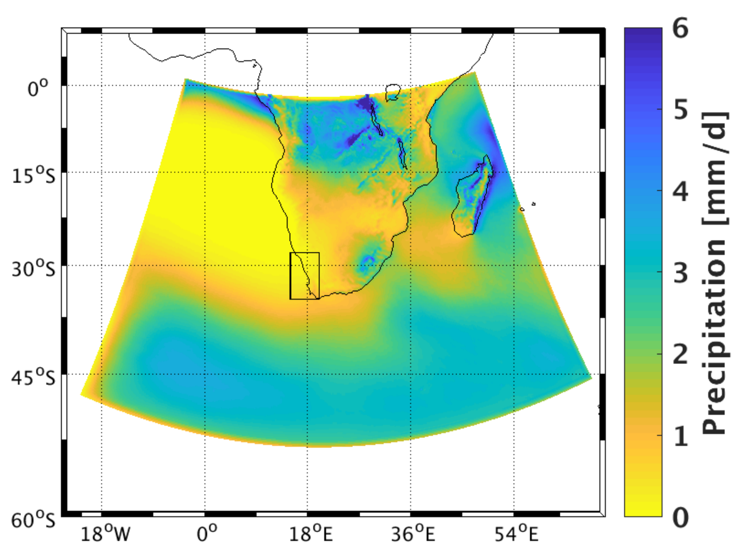

Figure 2 Mean precipitation: of CCLM 1958-04/2019 in [mm/day].

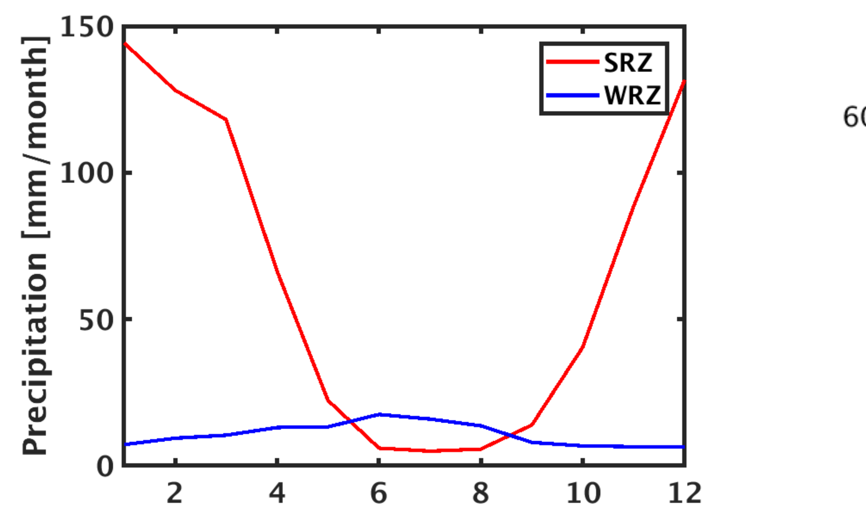

Figure 3 Annual cycle: of precipitation in the summer rainfall zone (SRZ) and the winter rainfall zone (WRZ) of CCLM in [mm/month] for the period 1958-04/2019.

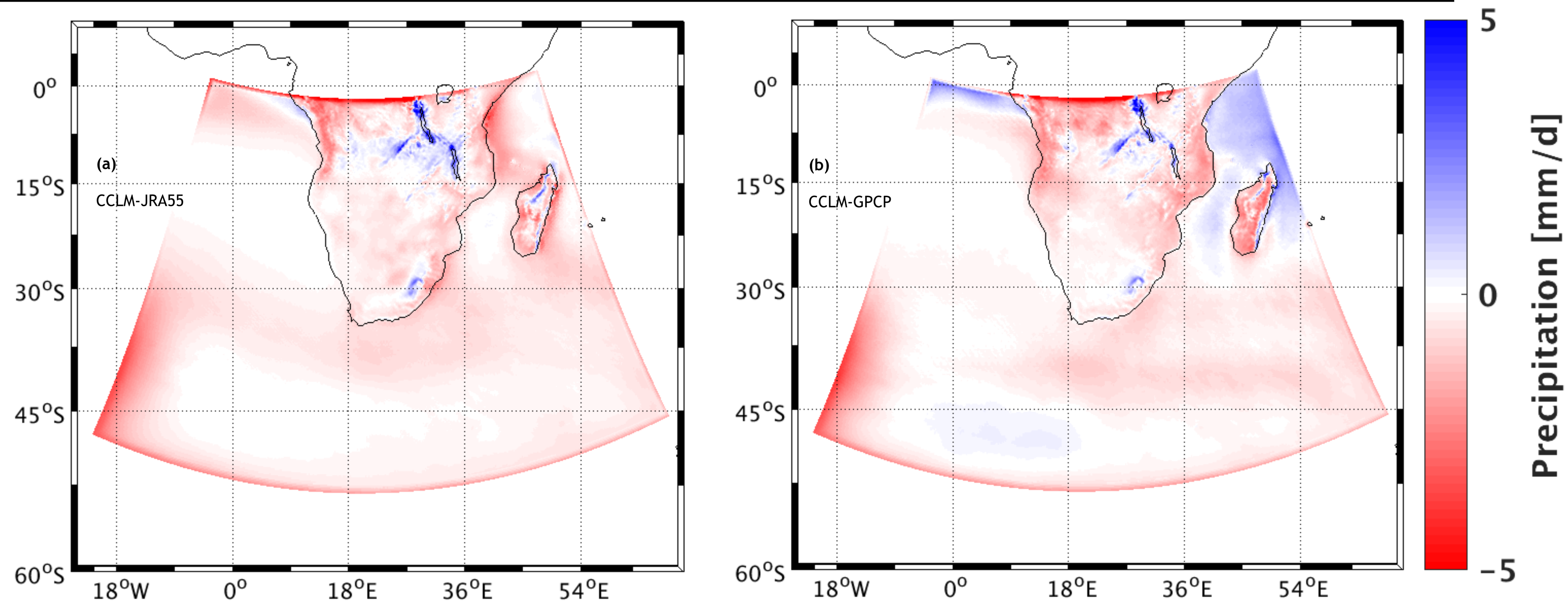

Figure 4 Bias in mean precipitation: subtracting precipitation of JRA-55 (a) and GPCP (b) from the on of CCLM in [mm/day] for the period 1958-04/2019 and 1996-2018, respectively.

In comparison to the driving reanalysis JRA-55 (~55 km resolution) (Fig. 4a) and the gridded combined observation and satellite data set GPCP (~100 km resolution) (Fig. 4b) differences are small in most of the coastal area. Deviations for Madagascar and the higher levels of the Drakensberg in the south east has to be further evaluated.

Impact of Agulhas Current on precipitation

Canonical Correlation Analysis

To detect the impact of the Agulhas Current and atmospheric variables (sea level pressure (SLP) and heat flux) we perform a canonical correlation analysis (CCA) with the precipitation in the SRZ and WRZ. Here we show exemplary the results for the SRZ. The Agulhas Current is represented by the sea surface temperature (SST).
The CCA patterns show that positive precipitation anomalies in the southern part of the SRZ occur when the south western Indian Ocean and Atlantic Ocean are warmer than usual and the west coast of southern Africa is cooler (Fig 5a and 5b). Furthermore, this SST pattern is linked to intensified and ridging of the subtropical highs in both Oceans (Fig. 5c). The same sign of SST and downward heat flux in most of the oceanic area shows that this precipitation pattern is driven by the atmosphere, and not by the ocean (Fig 5d), except for the region at the south east coast of South Africa where the Agulhas Current is located.

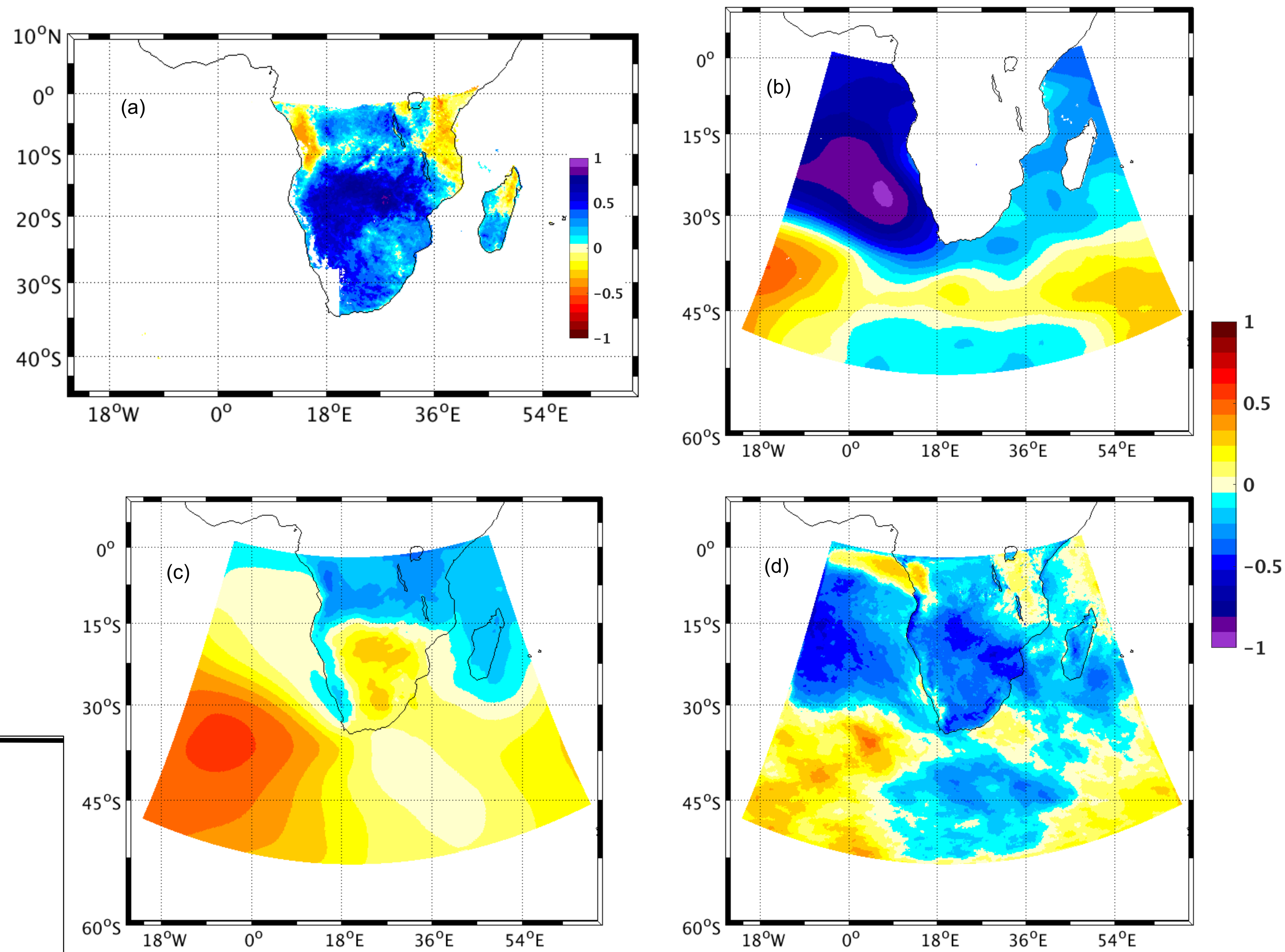

Figure 5 Canonical Correlation Analysis: (a) shows the CCA pattern of the precipitation related to the CCA pattern of SST (b). (c) and (d) show the regression pattern of SLP and downward heat flux with the SST, respectively. The first spatial loading is depicted here for each variable for the austral summer season December-February of 1958-2019.

Outlook:
The analysis will be further extent to study:
- the impact of the Agulhas Current by its position and strength
- trends and variability of precipitation over Southern Africa
- the recent drought in the Cape region
- recent tropical cyclones that made landfall at the south east coast

Acknowledgements: This investigation is part of the project CASISAC "Changes in the Agulhas System and its impacts on Southern African Coasts" within the "SPACES Program - Science Partnerships for the Adaptation of Complex Processes in the Earth System in the Region Southern Africa" in the BMBF Framework Program "Research for Sustainable Development" (FONA3).

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