18.3

CLIMATE AND ATMOSPHERIC CIRCULATION CHANGES IN SOUTHERN AFRICA DURING THE LAST 100 YEARS

Joachim Rathmann*, Jucundus Jacobeit
University of Wuerzburg, Institute of Geography, Wuerzburg

1. INTRODUCTION

This study intents to contribute to the understanding of inter-annual, inter-decadal and multidecadal variations in the climate of southern Africa.

Thus, main features of climate and circulation variability in southern Africa are identified, described and discussed including interactions with sea surface temperatures (SST).

A 98 year record of gridded data covering Africa south of the equator was used to document the spatial patterns of climate variability and long-term changes during the 20th century.

2. DATA AND METHODS

The data used in this study are the monthly Global Sea-Ice and Sea-Surface Temperature (GISST2.3b), the Kaplan SST anomalies, the Global Mean Sea Level Pressure (GMSLP2.1f), the following HadSLP1 data and gridded temperature and precipitation data, obtained from the Climatic Research Unit (Norwich). These data have been improved and corrected within the PIK (Potsdam Institute for Climate Impact Research).

The major modes of SST, SLP, temperature and precipitation variability have been derived by both t- and s-mode principal component analyses with Varimax rotation. Canonical correlation analyses have further been applied, in order to investigate the coupling of different climate elements with one another.

A further step analyses the available data for trend detection by means of linear regressions, a commonly used method where the trend is determined as the difference of the ordinate values at the ending and beginning points of linear regression lines (Jacobeit, 2000). These regressions have been calculated for each of the 3530 gridboxes being interpolated afterwards.

All methods have been applied on a monthly and annual time scale to avoid the difficulties in determining adequate seasons and season lengths.

3. CIRCULATION CHANGES

First results of the PCAs show a strengthening of the Southern Ocean Anticyclones within the study period. These results are confirmed by trend analyses, showing a significantly decreasing pressure south of southern Africa, whereas the oceanic Anticyclones are strengthening. These trends mostly exceed the standard deviations.

The resulting time coefficients of the PCAs have been further submitted to canonical correlation analyses in order to investigate the influence of the Atlantic and Indian Oceans on the climate of southern Africa. Associations between SSTs and southern African rainfall are evident. The influence of SLP on African temperatures can be shown in Fig. 1: A strong positive coupling of the Mascarene High with air temperature in the south-eastern part of the continent, whereas negative couplings prevail in central southern Africa.

Time coefficients of this pattern show positive values since the mid-20th century. This might be due to both increasing SLP and temperature in areas with highest correlations.

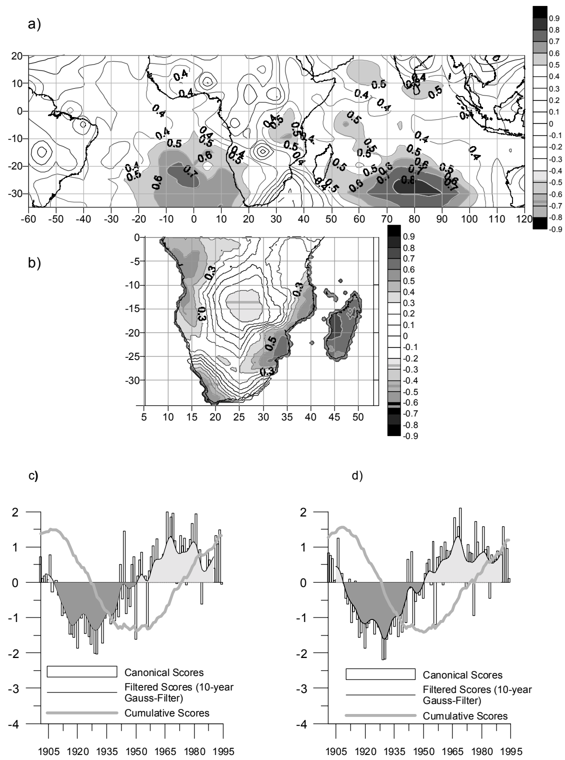

Fig. 1: First pair of canonical patterns for gridded SLP (a) and temperature data (b) for January 1901-1994 . The explained variances are 6,3 % and 8,2 %, respectively. The canonical correlation coefficient is 0,86. Time series (canonical scores) are shown in sections c (for the SLP pattern) and d (for the temperature pattern).

4. TRENDANALYSES

Trend analyses confirm the well known warming with strongest temperature increase in the central interior of southern Africa and the region of Angola (cf. Hulme et al., 2001). A curious cooling trend in the southwestern Part of southern Africa is probably

*corresponding author address:
Joachim Rathmann, Univ. of Wuerzburg, Institute of Geography, Am Hubland, D-97074 Wuerzburg, Germany;
e-mail: joachim.rathmann@mail.uni-wuerzburg.de

due to inhomogeneities of the CRU Data. These trend patterns are consistent for all months as well as for the annual mean.

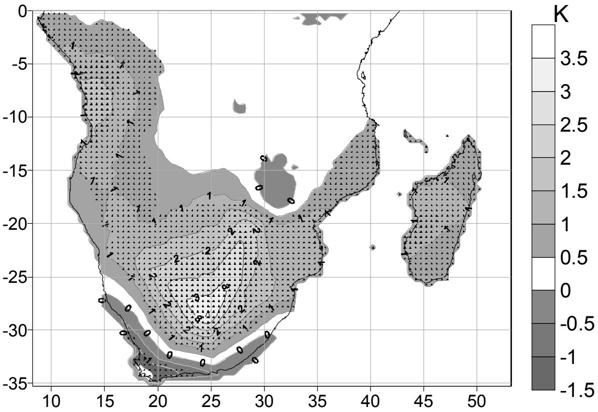

Fig 2: Linear trends of March temperature in southern Africa for the period 1901-1998. Grid boxes with trends exceeding the standard deviations, respectively, are marked by dots, enlarged circles indicate the 95% significance level.

Precipitation, however, does not show any significant trend pattern but a widespread variability. Little increasing trend can be detected within the region of East Africa.

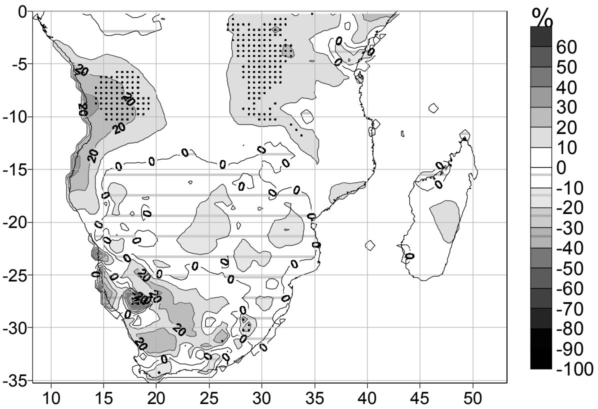

Fig 3: Relative linear trends of annual precipitation in southern Africa (deviation in % from the mean) for the interval 1901-1998. Grid boxes with trends exceeding the standard deviations, respectively, are marked by dots, enlarged circles indicate the 95% significance level.

A further part of this study tries to identify and separate external forcing factors on southern African climate. The most important ones are solar, volcanic and anthropogenic influences.

Solar-climate connections are still very controversial (Benestad, 2002). Nevertheless there has been special emphasis on discussions of recent climate change in terms of internal and external forcing factors. Statistical links between solar activity, indicated by the solar irradiance reconstruction of Lean (1998), and southern African climate could be substantiated by correlation and time series analyses. Solar-climatic relationships are difficult to proof, but highly significant correlations of surface air temperature and solar activity variations do suggest a physical link between the sun´s activity and regional climate. Highest correlations are found in regions showing the greatest warming during the 20th century.

30-year running correlations show high values in the first half of the 20th century. Thus, increasing surface air temperatures may partly be due to increasing solar activity.

Further investigations try to detect cumulative effects of volcanic eruptions on southern African climate. Heat rate anomalies, developed by Denhard et al. (1997), derived from the Volcanic Explosivity Index (VEI), are actually used. 30-year running means are applied to the heat rate anomalies, in order to get indices for cumulative, long-term volcanic influences on climate. Correlations with temperature data show highly negative values in regions, which have been shown to reveal the strongest warming trend within the last 100 years.

5. ACKNOWLEDGMENTS

The authors are grateful to Dr. H. Österle (Potsdam Institute for Climate Impact Research) for providing the corrections of the CRU temperature and precipitation data and to Dr. R. Allan (UK Hadley Centre) for providing the HadSLP data.

This study is part of the DFG-Post Graduate Research Program "Joint Geoscientific Research in Africa" at the Faculty of Earth Sciences / University of Wuerzburg.

6. REFERENCES

Benestad, R.E. (2002): Solar Activity and Earth´s Climate. Springer.

Denhard, M.; J. Grieser; M. Klein & C.-D. Schönwiese (1997): Statistische und deterministische Abschätzung vulkanischer Einflüsse auf das globale Klima. - Berichte d. Inst. für Meteorol. und Geophys. der Uni. Frankfurt/Main Nr. 101.

Hulme, M.; Doherty, R.; Ngara, T.; New, M. & Lister, D. (2001): African climate change:1900-2100. *Climate Research*, **17**, 145-168.

Jacobeit, J. (2000): Rezente Klimaentwicklung im Mittelmeerraum. *Petermanns Geogr. Mitt.*, **144**: 22-33.

Lean, J., J. Beer, and R. Bradley (1998): Reconstructed Solar Irradiance Data. IGBP PAGES/World Data Center-A for Paleoclimatology Data Contribution Series # 1998-028. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.