Namibian Rainfall and the 1933/34 Benguela Niño

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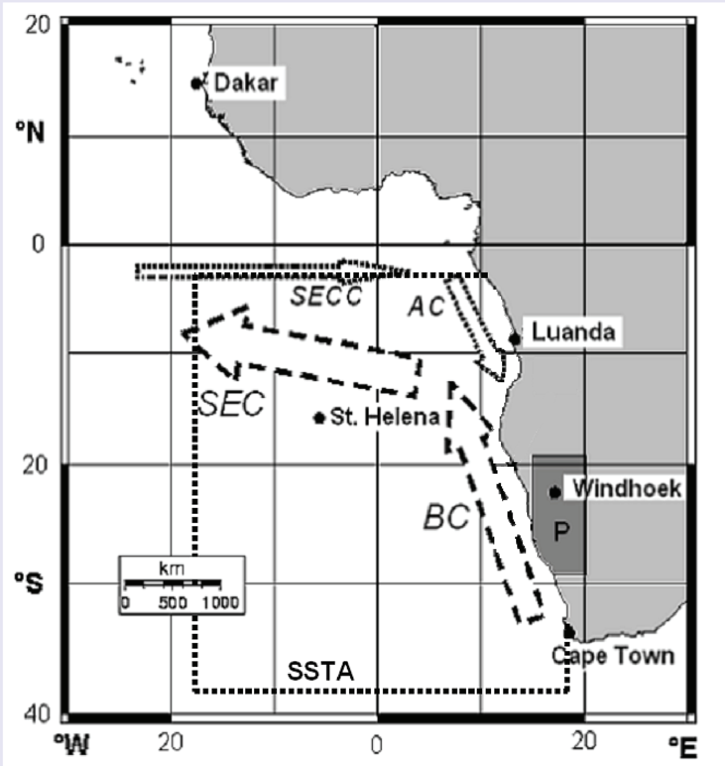


Fig.1: Precipitation study area (P) of GELLERT (1955) (dark grey box) and the selected SSTA area (dotted box); arrows represent the eastward South Equatorial Counter Current (SECC), the southward Angola Current (AC), the north-westward Benguela Current (BC), and the more westward South Equatorial Current (SEC).

Introduction:

In the predominantly arid- to semi-arid Namibia the farmers are naturally/ intensely interested in year-to-year rainfall variations, both in terms of the spatial distribution of the rain as well as quasi-cycles between 'dry-years' and 'wet-years', and they have always tended to keep rainfall records. With the result that the earliest continuous observation series for Namibia were derived from farms distributed irregularly over the hinterland and one of the earliest of such series was compiled by GELLERT (1955) for the area P (see Fig.1) - the data set this paper is mainly based on.

Exceptionally good rainy seasons occur in the interiors of Angola and Namibia when unusually warm surface water occupies the tropical/ subtropical South-East Atlantic. Such events were termed 'Atlantic Niños' by HISARD (1980) and 'Benguela Niños' by SHANNON et al. (1986). For the case of relaxed south-east trade winds, the so-called South Equatorial Counter Current (SECC) transports more equatorial near-surface waters eastward into the Gulf of Guinea, Fig.1. Off Angolan and Namibian coasts, such abnormal warm near-surface waters feed the accelerated Angola Current (AC) as far as about 26°S. Here, an oceanic frontal system is established. It separates cold near-coastal waters in the south from warmed waters in the north where the sea surface temperature (SST) reaches peak values exceeding the climatic mean by 3-6°C.

Warm coastal waters, however, reduce the thermal contrast between water temperatures of the near-coastal zone and the air temperature of the Namibian interior. Thus, such 'Benguela Niño' events reduce on-offshore gradients in the sea level air pressure and weaken the equatorward (geostrophic) component of the south-east trade wind. In other words, such a Niño-like situation leads to dryer coastal zones and wetter areas of the Namibian hinterland. The frequency of Namibian 'dry/ wet years' was already studied by ROUAULT et al. (2003) and they concluded that 'wet years' primarily attribute to positive anomalies in the SST of the western Indian Ocean. Reanalysing historical data of the matured 'Benguela Niño' 1933/ 34, we like to show that extreme 'wet years' in the Namibian hinterland also depend on thermal conditions in near-surface layers of the South-East Atlantic Ocean.

Data Base and Methods:

I. Short-term Series

Seasonal precipitation records (mm) from the Namibian interior were published by GELLERT (1955), but unfortunately in a rather obscure German report-series. It covers ten rainy seasons (July 1928 – June 1938), which span the extreme Benguela Niño event of 1933/ 34 described in more detail by JANOWIAK (1988) and FEISTEL et al. (2003). The reanalysed precipitation series stem from 70 farms/ stations distributed irregularly in the Namibian hinterland between (19 – 29)°S and (15 – 20)°E. The enclosed area is labelled by P in Fig.1. Station positions are plotted over rough topographic contours and they show that most of them take place 1000 m above the sea level in the west of a Namibian mountain chain aligned roughly north-south, Fig.2 (left panel). Overall means from all 70 stations were computed for each recording year. The minimum of 153.4 mm/y was found for 1932/33 while the maximum of 782.7 mm/y was obtained for 1933/34. These two extreme rainfall years were excluded to obtain a more characteristic spatial pattern <P>, Fig.2 (right panel).

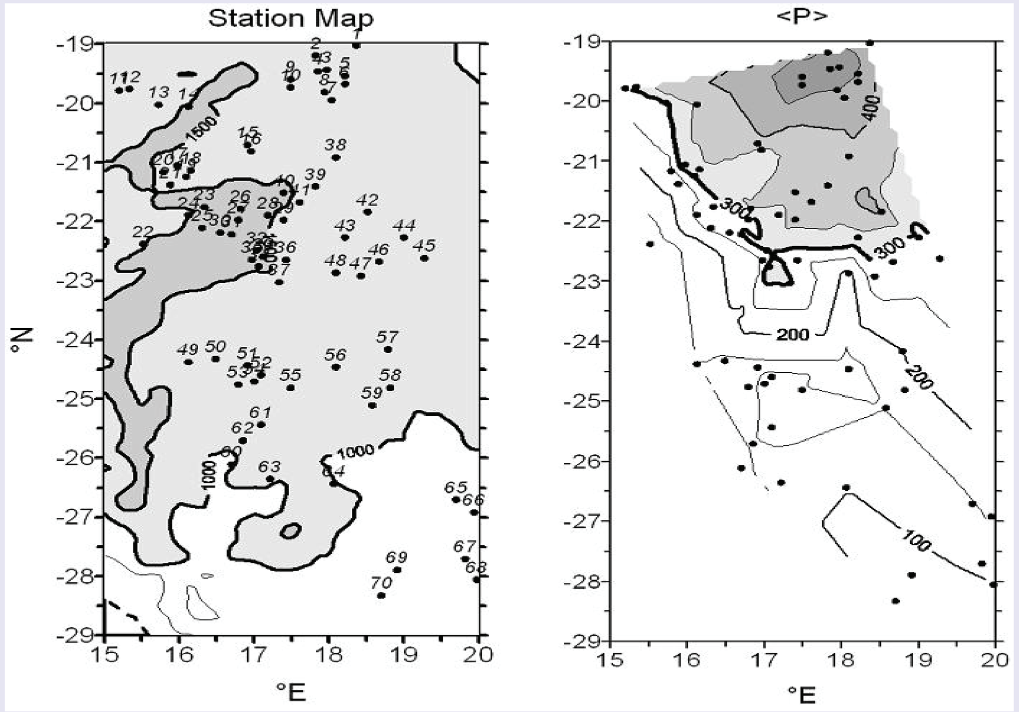


Fig.2: Station map (P) of 70 numbered rainfall-stations (dots) over rough topographic contours (m) of the Namibian hinterland (left panel); the rainfall time series started in July 1928 and ended in June 1938; the overall precipitation pattern <P> (mm) excludes the two extreme rainy seasons of Fig.3.

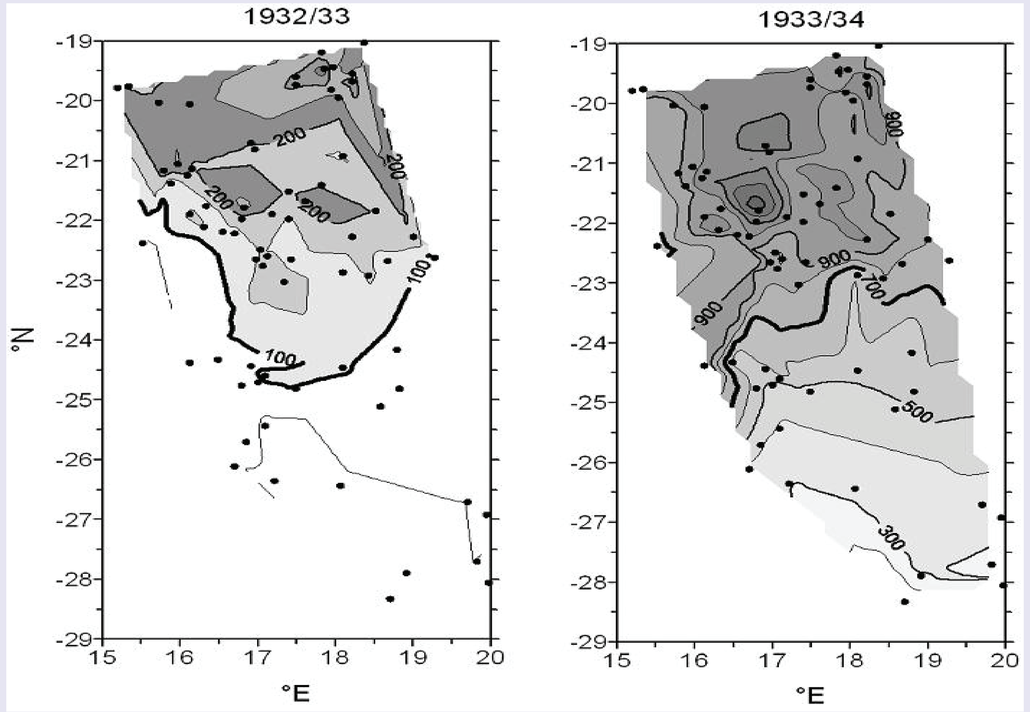


Fig.3: Rainfall pattern (mm) from the dry year (1932/33, left panel) and the wet year (1933/34, right panel).

II. Long-term Series

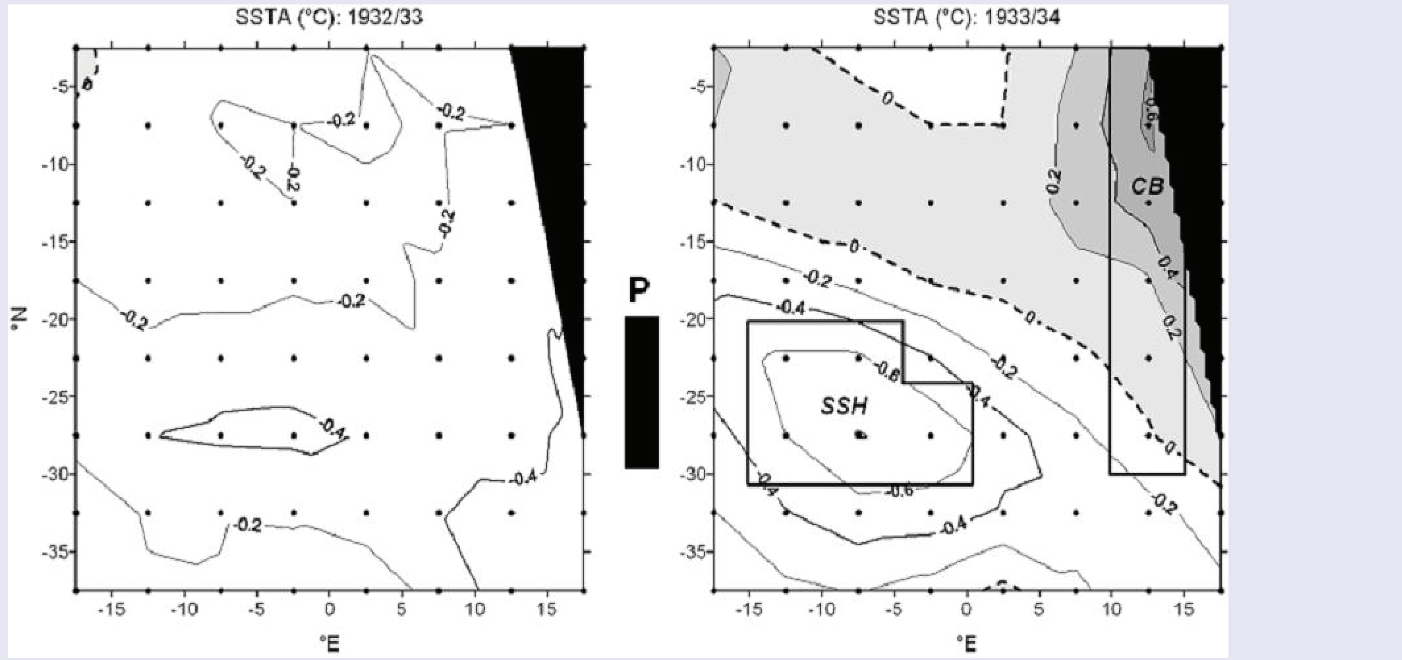
In addition, two long-term precipitation records were available. The first results from the farm 'Molkenhof' [21° 07'S, 15°44'E, not considered by GELLERT (1955)] and was kindly provided by the library in Swakopmund/ Namibia (1907 - 1969), while the second one results from the climatic data bank of the German Weather Service for the regular weather station Windhoek (1892 –1999). Both long-term series have been standardized (mean=0, standard deviation=1) for comparison with comparable long-term series of other quantities such as the air temperature of Luanda/ Angola, see Fig.1. Consequently, these standardized time series are expressed by multiples of the underlying standard deviation (STD). Because NICHOLSON (1986) reported quasi-cycles between two and three years for the rainfall variability over South-West Africa and we were interested in much longer quasi-cycles, all standardized series were additionally smoothed by three year running means (R.M.). Because the Benguela Niño event of 1933/34 was exceptionally strong (see TAUNTON-CLARK and SHANNON, 1988), all historical rainfall records from this period of time are seen to be potentially very useful for understanding the influence of such Niño-like events on the Namibian rainfall. However, it seems not to have been a component of previous studies and therefore worth further analysis, especially in context with the world-wide gridded SSTA data compiled for 5°× 5°-fields by KAPLAN et al. (1998). Its updated version was the base for yearly averages (July 1856 – June 2008) and is available via www.cdc.noaa.gov./cge-bin. The chosen study area (2.5°-37.5°S, 17.5°W-17.5°E) is shown in Fig.1. The German Weather Service provided monthly means of the dry air temperature of Luanda/ Angola (1901-1982). The resulting overall seasonal cycle was removed to obtain corresponding anomalies (T'). Thereafter, the positive trend of this temperature series has been removed (1.7°C/ 100 yrs) for comparison with the detrended block SSTA series described in the following.

RESULTS:

The area under consideration is characterized by arid conditions with values between <P> = 100 mm/y in the south and <P> = 400 mm/y in the north, while desert-like conditions dominate the south-easternmost region, Fig.2 (right panel). This spatial pattern changed dramatically during the dry season 1932/33, Fig.3 (left panel). Slight arid conditions (P>100 mm/y) are only found in the north of about 24°S while the rest of this region was dry. In contrast, the next rainy season (1933/34) shows semi-arid conditions (P>300 mm/y) for all southern regions, but humid conditions (P>700 mm/y) in areas in the north of about 24°S where the rainfall exceeds 1000 mm/y in central/ northernmost sub-areas. This abnormal rainfall pattern suggests that southward/ south-westward winds carried wet air masses against the northern and eastern flanks of the Namibian mountain chain to produce the detected south-westward orientated 'rainfall tongue'.

The average difference in seasonal rainfall between the northern (stations 1-47) - and southern sub-areas (stations 48-70), over this 10-year record, was (221±36) mm/y, but during the extreme wet year 1933/34 this difference increased roughly by the factor of two. Concerning both subsequent extreme Namibian rainfall years, the sea surface temperature anomaly (SSTA) of the South-East Atlantic shows slight negative values for the dry season 1932/33, Fig.4 (left panel). During the wet year 1933/34, however, there is a significant dipole between enhanced negative SSTA's in the south-west and positive anomalies in the north-east of the study area, Fig.4 (right panel).

Fig.4: Contoured isolines of averaged monthly anomalies of the sea surface temperature (SSTA) for the dry rainfall year 1932/33 (left panel) and the wet year 1933/34 (right panel) shown in Fig.3; the latitude range of the precipitation study area (P) is marked in between both panels (dark rectangle) while the land surface is given by a black triangle; the 5°×5° SSTA-boxes with strong negative anomalies (SSH) in the south-west and those of exceptional positive anomalies (CB) in the north-east are enclosed by bold lines (filled dark grey for SSTA > 0.4°C); resulting time series of both blocks were used to compute that of the dipole difference (CB-SSH).



Positive SSTA's attribute to a pronounced southward spreading of exceptional warm waters to reach the latitude of about 26°S in near-coastal zones. Therefore, spatial means of the coastal SSTA-block (CB, 2.5° -27.5°S, 12.5°E) were separately computed as well as for the offshore SSTA-block in the south of the St. Helena Island (SSH). The latter is identified by closed isotherms (SSTA ≤ -0.4°C) around the position 27.5°S, 7.5°W. The resulting difference series CB (warm) – SSH (cold) describes temporal changes of this regionally fixed SSTA-dipole. It shows that monthly SSTA's of the near-coastal zone (CB) reached their absolute peak value (~ 2°C) during the 1933/34 Benguela Niño and that this peak coincides with that observed in the corresponding anomaly of the air temperature (~3°C) in Luanda/Angola (not shown). Further positive peaks sufficiently coincide with those of the two long-term precipitation records (<P>), Fig.6. This is confirmed by peaks in the unsmoothed dipole SSTA series (CB-SSH) exceeding the value of +0.5°C labelled by 'Benguela Niño' years reported in the quoted literature, Fig.6.

Fig. 5: Tree year running means (3 y R.M.) of standardized annual series (mean=0, standard deviation=1) of the SSTA-dipole (CB-SSH, dots/ bold line, positive values greyed) and corresponding precipitation series (<P>) from the two stations Windhoek (open circles) and Molkenhof (dots); the thin upward arrow marks absolute peak values for the wet year 1933/34 and superimposed changes in periodicity/ intensity of the quasi-14 year cycle are seen quite clear.

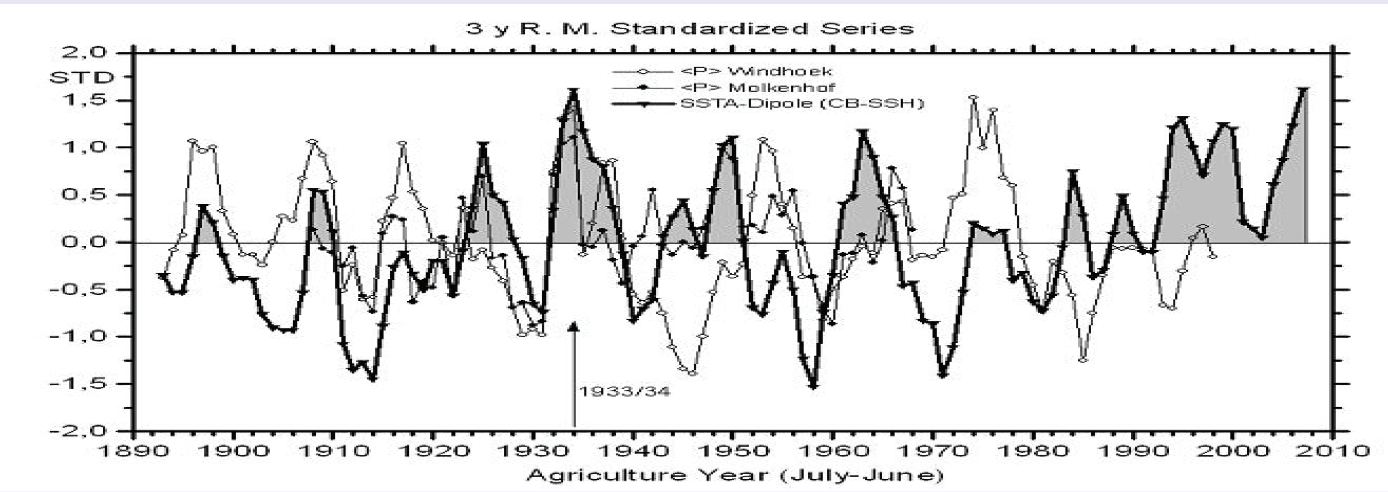
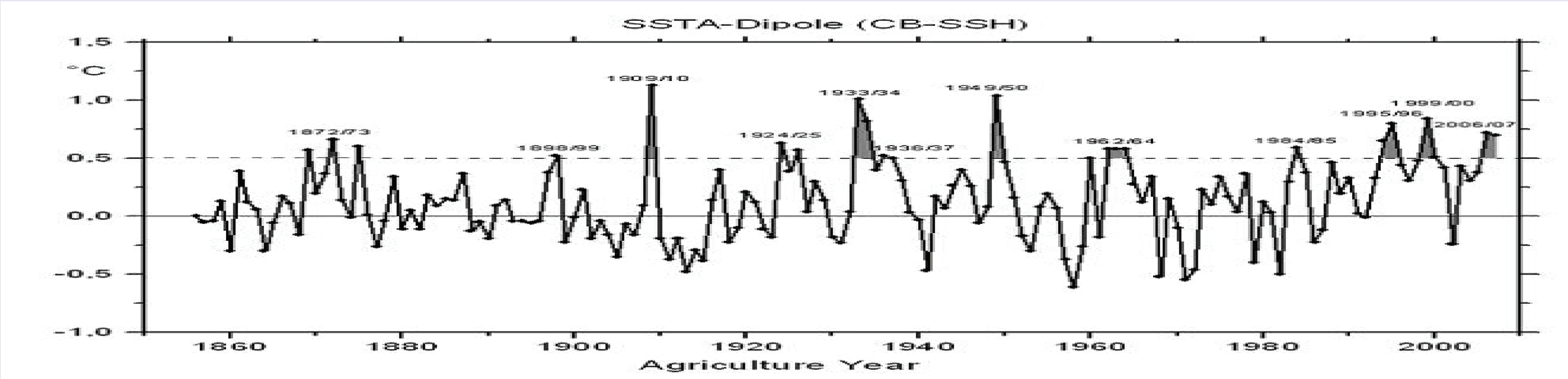


Fig.6: Annual series of the SSTA-dipole (CB-SHH, right panel, Fig.4); positive peak values exceeding the value of 0.5°C (grey above dotted line) are labelled by Benguela Niño events reported in the literature.



Discussion and Conclusions:

While both the ocean and the atmosphere exhibit vertical convection in reaction to regional unstable stratification, the heating at the air-sea interface tends to make the air more instable and this releases upward fluxes of heat and moisture. Concerning year-to-year changes in the Namibian rainfall, which reach peak values in the austral summer, (JAEGER, 1976), it is widely accepted that the associated moisture flux mainly results from air masses originating in the western Indian Ocean, ROUAULT et al. (2003). This is implied by typical wind-arrows for January redrawn from NICHOLSON (2000), Fig.7. However, others authors, e.g. HIRST and HASTENRATH (1983) and NICHOLSON and ENTEKHABI (1986), reported some evidence that the Namibian rainfall should be modulated frequently by positive SSTA's in the sub-tropical East Atlantic. Other studies suggest that changes in the SSTA of the western Equatorial Atlantic play a substantial role in rainfall variability over West Africa. Following FLORENCHIE et al. (2003), it seems to be that relaxed easterlies over the tropical West Atlantic explain about 23% of the SSTA-variability off Angolan coasts, whereas local winds only control about 9%. Furthermore, the eastward propagating equatorial counter current (SECC) involves this 'wind-information'. It triggers, with a certain time lag, corresponding changes in the SSTA of the Gulf of Guinea. The St. Helena Island Climate Index (HIX) proposed by FEISTEL et al. (2003) has turned out to be an effective index to describe such changes over the tropical/ subtropical South-East Atlantic on the interannual time scale.

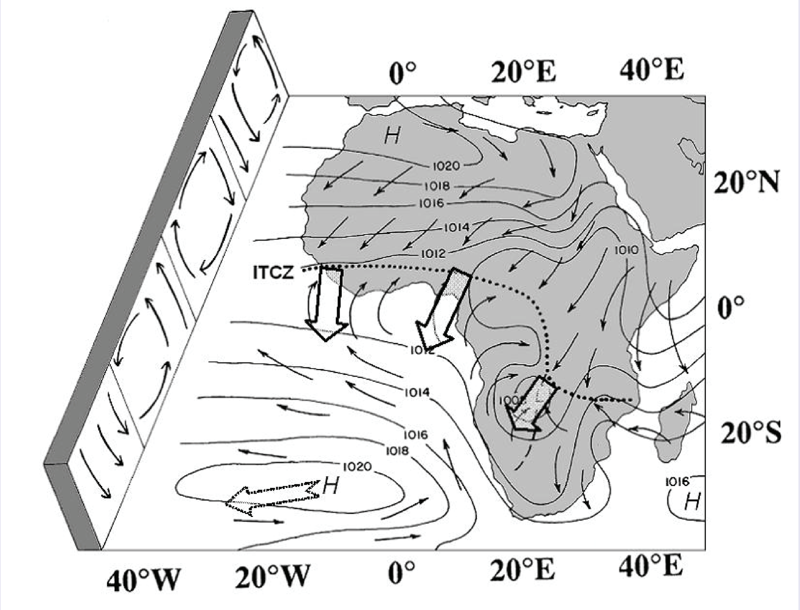


Fig.7: Characteristic winds (thin arrows) and isobars (hPa, H= High, L=Low) with the resulting axis of the Intertropical Convergence Zone (ITCZ, dotted line) over Africa during the austral summer (January) modified from NICHOLSON (2000); bold arrows indicate displacements of the ITCZ and the South Atlantic Anticyclone (H) during exceptional wet Namibian rainfall years, while the left box schematically shows meridionally distributed convection cells of the atmospheric circulation (arrows).

Gellert's data set shows that the matured Benguela Niño event of 1933/34 coincides with exceptionally heavy precipitation in the sub-area north of about 24 °S. Irrespective of the general division of the study area into a wet northern and a dry southern sub-area, it is concluded that prevailing southward and/ or south-westward winds, which are loaded sufficiently with humidity, produce such wet precipitation years over the Namibian hinterland. Such an exceptional situation obviously results from a significant south and/or south-westward displacement of the climatic axis of the Intertropical Convergence Zone (ITCZ) over southern Africa as already discussed by JANICOT (1998), Fig.7. This, however, favours positive SSTA's in coastal zones supported by the advection of equatorial waters from the Gulf of Guinea via the accelerated Angola Current to produce abnormal warm near-surface waters up to the latitude of about 26°S. This establishes/ strengthens the thermal contrast between positive SSTA's in the coastal belt (CB) and negative SSTA's in the south of St. Helena Island (SHH). Consequently, the difference series (CB-SSH) well describes extreme Namibian precipitation years and this suggests that associated moisture-fluxes from the South-East Atlantic essentially contribute to the so-called 'Namibian wet-years'.

In summary, our reanalyses of the strong Benguela Niño event of 1933/34 suggests that moisture fluxes and associated multi-year changes in the SSTA of the South-East Atlantic might be a more important factor in Namibian rainfall anomalies than previously thought and might even be of comparable importance to those originating in the West Indian Ocean, especially on the decadal scale!

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