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# Climate variability at the southern boundaries of the Namib (southwestern Africa) and Atacama (northern Chile) coastal deserts during the last 120,000 yr

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**Abstract**

In this study, we present grain-size distributions of the terrigenous fraction of two deep-sea sediment cores from the SE Atlantic (offshore Namibia) and from the SE Pacific (offshore northern Chile), which we 'unmix' into subpopulations and which are interpreted as coarse eolian dust, fine eolian dust, and fluvial mud. The downcore ratios of the proportions of eolian dust and fluvial mud subsequently represent paleocontinental aridity records of southwestern Africa and northern Chile for the last 120,000 yr. The two records show a relatively wet Last Glacial Maximum (LGM) compared to a relatively dry Holocene, but different orbital variability on longer time scales. Generally, the northern Chilean aridity record shows higher-frequency changes, which are closely related to precessional variation in solar insolation, compared to the southwestern African aridity record, which shows a remarkable resemblance to the global ice-volume record. We relate the changes in continental aridity in southwestern Africa and northern Chile to changes in the latitudinal position of the moisture-bearing Southern Westerlies, potentially driven by the sea-ice extent around Antarctica and overprinted by tropical forcing in the equatorial Pacific Ocean.


*Keywords:* Late Quaternary; Chile; Atacama Desert; southwestern Africa; Namib Desert; Aridity; Grain size; End-member modeling; Southern Westerlies

## Introduction

Most ice-core, terrestrial, and marine records of continental aridity indicate much drier conditions during the Last Glacial Maximum (LGM; approximately 21,000 cal yr B.P.) compared to the Holocene (e.g., Kohfeld and Harrison, 2001, and references therein). LGM aridity particularly increased in high latitudes (to up to 20 times higher "dustiness") but a moderate increase has also been estimated for low- to mid-latitudes (Kohfeld and Harrison, 2001). Aridity records from the low-latitude Northern Hemisphere primarily reflect reduced monsoonal rainfall during the LGM induced by the Northern Hemisphere summer insolation minimum (e.g., deMenocal et al., 1993; Jansen et al., 1989; Matthewson et al., 1995).

Comparatively little is known about late Quaternary aridity in the Southern Hemisphere, although several arid environments are present in South America (e.g., Atacama Desert and Patagonia), in Africa (e.g., Namib Desert and Kalahari savannah), and in the continental interior of Australia. Terrestrial paleoclimate records suggest that, similar to the Northern Hemisphere, most regions of the Southern Hemisphere were apparently much drier during glacial intervals. This is particularly true for Patagonia (Clapperton, 1993; Iriondo, 1999) and Australia (Hesse and McTainsh, 2003; Hesse et al., 2003, 2004; Markgraf et al., 1992), and also suggested, although less clear, for South Africa (Thomas and Shaw, 2002). No consistency exists for LGM aridity in low-latitude Southern Hemisphere regions

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affected by monsoonal summer rains; conditions on the Bolivian altiplano in tropical South America were wetter (Baker et al., 2001; Thompson et al., 1998), whereas relatively arid conditions prevailed in the summer rainfall region of South Africa (Johnson et al., 2002; Partridge et al., 1997), as well as in the western part of southwestern Africa (Lancaster, 2002, and references therein), although some studies indicate wetter conditions in the winter-rainfall area of southwestern Africa (Dupont and Wyputta, 2003; Meadows and Baxter, 1999). The nature of late Quaternary climate variability in Southern Africa seems to cause even more discussion due to the complex pattern of atmospheric circulation over this part of the continent (e.g., Cockroft et al., 1988; Nicholson, 2000; Tyson, 1986).

Here we focus on an intercontinental comparison of aridity records based on the evaluation of grain-size data from marine sediment cores off southwestern Africa (ca. 20°S) and subtropical South America (ca. 27°S). The particle size and composition of the terrigenous fraction of marine sediments provide a unique record of continental environments preserved within a robust stratigraphic framework based on AMS $^{14}$C dating and marine oxygen-isotope stratigraphy. In contrast to the lower-latitude Northern Hemisphere (e.g., Guerzoni et al., 1996; Kiefert et al., 1996; Schütz and Jänicke, 1980), only a few such records have been published from the Southern Hemisphere (e.g., Hesse and McTainsh, 1999, 2003; Lamy et al., 1998a; Stuut et al., 2002b).

The two studied core sites are near the margins of coastal deserts, that is, the Namib and Atacama deserts, respectively, in very comparable climatological settings. Present-day aridity in both regions is induced by the sinking of air masses within the SE Atlantic and SE Pacific anticyclones, a process that is further stabilized by cold coastal waters within the Benguela and Peru–Chile eastern boundary current systems, respectively. More humid climate intervals during the late Quaternary as indicated by the long-term records at both sites have been interpreted to reflect an equatorward shift of the Southern Westerlies wind belt (Lamy et al., 1998a; Stuut et al., 2002b; Van Zinderen Bakker, 1976).

Here we present grain-size distribution data of the terrigenous sediment fraction collected off northern Chile. An end-member algorithm (Weltje, 1997) is applied to unmix the grain-size distributions (cf. Prins et al., 1999), which are then compared to downcore grain-size distribution data of sediments off Namibia (Stuut et al., 2002b). Based on the same approach—unmixing of grain-size distributions using an end-member algorithm—Stuut et al. (2002b) were able to make a distinction between wind-blown and fluvially derived sediment fractions in the SE Atlantic core (Fig. 1), and use their relative proportions in terms of paleoclimate proxies. The end-member model indicated that three end members produced the optimal balance between statistical description of the variance in the data set and complexity of mixture composition. The resulting three end members consisted of unimodal particle-size distributions that were consequently interpreted as 'coarse' eolian dust, 'fine' eolian dust, and fluvial mud. The interpretation that proximal eolian dust can be coarser grained than river-derived sediments was justified by the relatively short distance (few hundreds of km) to the source of the wind-blown sediments. In contrast, some studies dealing with relatively large source to sink distances (thousands of km) had shown that eolian dust can be finer than hemipelagic sediments (e.g., Boven and Rea, 1998; Rea and Hovan, 1995). To further support the interpretation, Stuut et al. (2002b) presented a present-day dust sample collected along a transect from the coast to the core site to demonstrate that the dust deposited on Walvis Ridge is silt sized. In studies offshore NW Africa (e.g., Koopmann, 1981; Sarnthein et al., 1981), the North Pacific (e.g., Rea and Hovan, 1995), and the Arabian Basin (e.g., Prins and Weltje, 1999), it was shown that hemipelagic sediments that spread through the water column on isopycnal layers can travel long distances and are usually clay–fine silt sized, hence supporting the interpretation of the hemipelagic mud end member on Walvis Ridge. Consequently, Stuut et al. (2002b) used the downcore proportions of the eolian and fluvial populations expressed in ratios to reconstruct the regional climate patterns in southwestern Africa during the last 300,000 yr. The ratio of coarse over fine eolian dust was used as a proxy for wind strength, which appeared to have varied on a glacial–interglacial scale with higher-frequency variability superimposed. Generally, glacial periods were characterized by stronger winds or increased atmospheric

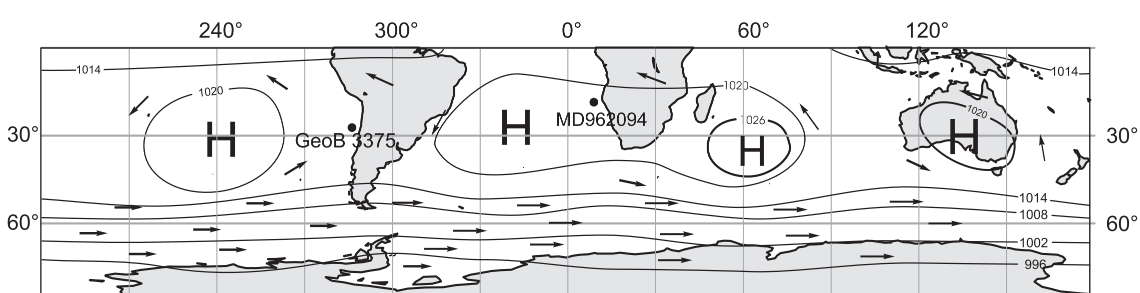


Figure 1. Schematic representation of the present-day position of high-pressure cells and general wind patterns on the Southern Hemisphere (modified after *Meteorology Today* by C. Donald Ahrens © 1994 West Publishing Company). Isobars are in millibars. Positions of discussed cores are indicated.

circulation relative to interglacial periods. These observations are supported by independent proxies for wind-driven upwelling in the same core (Stuut et al., 2002a) and in nearby cores on Walvis Ridge (Little et al., 1997) and Walvis Slope (West et al., 2004). Another climate proxy that Stuut et al. (2002b) derived from the end-member approach is the ratio of total dust (coarse + fine eolian dust) over fluvial mud, interpreted as a proxy for continental aridity. The paleocontinental aridity record of the last 300,000 yr showed a remarkable similarity to the global oxygen isotope record with increased aridity during interglacial periods relative to increased humidity during glacial periods. The increased glacial humidity was related to an equatorward displacement of the moisture-bearing Southern Westerlies that caused increased precipitation in the winter-rainfall region in southwestern Africa. This observation is supported by pollen studies that show a northward displacement of pollen types (*Restionaceae*) during the LGM (Shi et al., 2000), which are characteristic for the Fynbos vegetation of the winter-rainfall region of southwestern Africa (e.g., Cowling et al., 1997). The northward displacement of the Fynbos pollen during the LGM was related to a northward expansion of the winter-rainfall region (Dupont and Wyputta, 2003), probably caused by a northward displacement of the Southern Westerlies. The apparent contradiction between contemporaneous occurrences of coarser eolian dust, related to increased wind intensities, and increased proportions fluvial mud, related to increased humidity, can be explained by the increased thermal gradients between poles and equator during glacial times leading to increased atmospheric circulation, together with an equatorward displacement of the zone of moisture-bearing Southern Westerlies, which caused increased precipitation in the winter-rainfall region of southwestern Africa. In this paper, we compare the late Quaternary continental aridity variability in northern Chile to the one in southwestern Africa to see if these data gain insight in intercontinental timing of Southern Hemisphere aridity variations and help to assess low- versus high-latitude forcing mechanisms.

## Materials and methods

Gravity core GeoB 3375-1 was recovered from the upper continental margin off Chile at 27°28′ S/71°15′ W, at 1947-m water depth (Fig. 1) during the CHIPAL-Expedition of RV Sonne (Hebbeln et al., 1995). The dominant lithology of the core is clayey silt to silty clay with <20% $CaCO_3$. The terrigenous fraction of these sediments is of eolian origin coming from the dry part of northern Chile carried to the SE

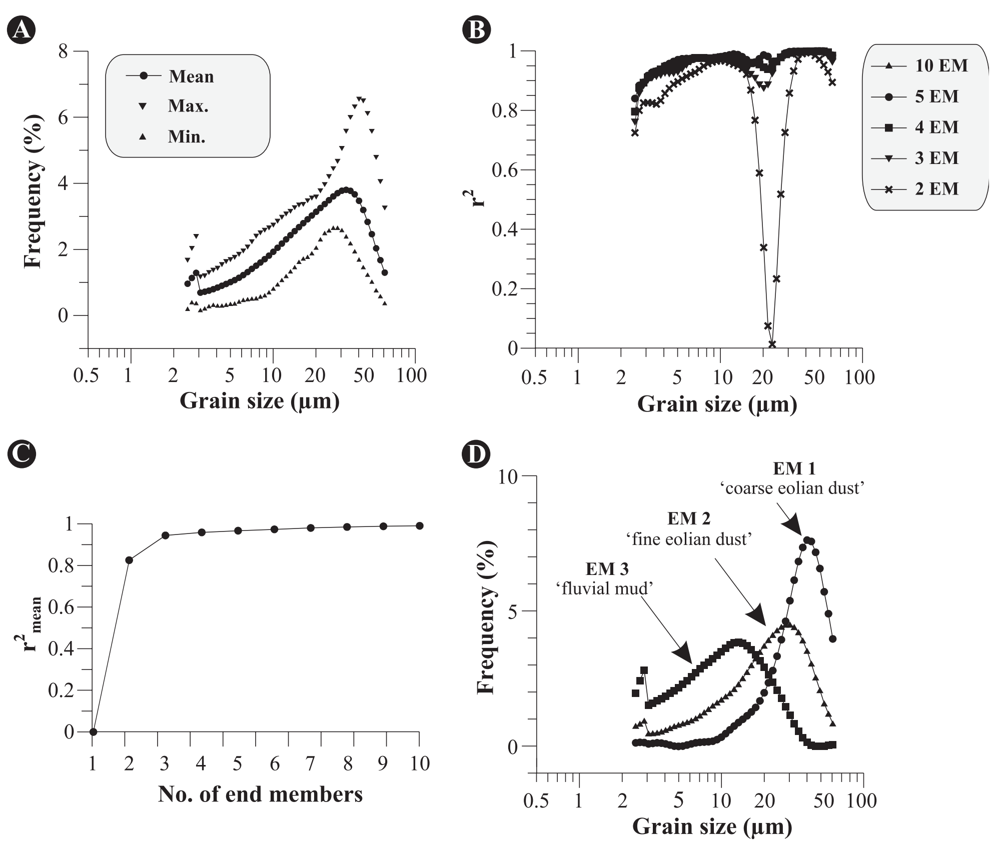


Figure 2. End-member modeling results of core GeoB 3375-1. (A) Summary statistics of input data (grain-size distributions, $n$ = 97); maximum, mean and minimum frequency recorded in each size class. (B) Coefficients of determination (r2) for each size class of models with 2–10 end members. (C) Mean coefficient of determination ($r^2$ mean) of all size classes for each end-member model. (D) Modeled end members of the terrigenous sediment fraction of sediments from offshore northern Chile.

Pacific by the Southeastern Trades and of hemipelagic origin carried to the SE Pacific by rivers (Lamy et al., 1998a). The age model slightly differs from the published data sets (Lamy et al., 1998a; 2000) as one additional AMS $^{14}C$ date has been added and the data were converted using the CalPal software (www.calpal.de). Grain-size distributions of the terrigenous fraction ($CaCO_3$ and $C_{org}$ -free; for methods, see Lamy et al., 1998a) were measured with a Micromeretics Sedigraph 5100, resulting in 51 size classes from 2 to 63 μm at a 5-cm (approximately 750-yr) downcore sampling interval.

## End-member model

In general, the terrigenous fraction of deep-sea sediments in the (sub)tropical ocean, that is not disturbed by post-depositional processes, can be considered a mixture of eolian and fluvial sediments. As was demonstrated in several studies (Arz et al., 2003; Frenz et al., 2003; Holz et al., in press; Moreno et al., 2002; Prins and Weltje, 1999; Stuut et al., 2002b; Weltje and Prins, 2003), grain-size distributions of deep-sea sediments can successfully be 'unmixed' into subpopulations or end members using an end-member algorithm (Weltje, 1997) and related to sediment transport mechanisms. Weltje's end-member algorithm was designed to describe the variance in any given data set based on covariant structures. The model's output is several end members, the number of which depends on the amount of variance explained. In contrast to other methods used to deconvolve mixtures like factor analysis (e.g., Davis, 1973), in the case of grain-size distributions, end members represent real size distributions, whereas factors or principal components can have negative values without any physical meaning. The minimum number of end members required for a satisfactory approximation of the data can be calculated from the goodness-of-fit statistics, represented by the coefficients of determination. The coefficient of determination represents the proportion of the variance of each grain-size class that can be reproduced by the approximated data. This proportion is equal to the squared correlation coefficient ($r^2$) of the input variables and their approximated values (Prins and Weltje, 1999; Weltje, 1997). Hence, the eventual outcome of the model is a statistically unique solution with end members that represent real particle-size distributions. The only prescription that is used during modeling is the fact that end members may not have negative grain sizes. No predefinitions are made regarding shape, sorting, or modal sizes of the end members (for more details of the application of the model to particle-size distributions, see Weltje and Prins, 2003).

The average grain-size distribution of the silt fraction in core GeoB 3375-1 ($N$ = 97) has a modal grain size near 29 μm (Fig. 2A). Figure 2B shows the coefficients of determination ($r^2$) plotted against grain size for models with two to ten end members. The mean coefficient of determination of the grain-size classes increases when the number of end members increases (Fig. 2C). The two end-member model ($r^2_{mean}$ = 0.83) shows low $r^2$ (<0.6) for the size range 18–27 μm. The three end-member model ($r^2_{mean}$ = 0.95) shows high $r^2$ (>0.86) for all size classes, except for the first one (<2 μm, $r^2$ = 0.76). The goodness-of-fit statistics thus demonstrate that the three-end-member model provides the best compromise between the number of end members and $r^2$. The grain-size distributions of the three end members are shown in Figure 2D. All end members have a clearly defined dominant mode. End-member EM1 has a modal grain size of approximately 40 μm, end-member EM2 of approximately 29 μm, and end-member EM3 has a modal grain size of approximately 12 μm.

## Results: northern Chilean and southwestern Africa aridity records

Differences in the temporal resolutions as well as uncertainties in the age models do not allow for a peak-to-peak correlation of the obtained aridity records. However, the general picture of aridity for the last 35,000 yr is very comparable in northern Chile and southwestern Africa (Fig. 3), and if the aridity records do indeed reflect general rainfall patterns, the two regions did exhibit comparable climates in terms of precipitation. The Chilean humidity record shows that before about 31,000 yr ago, conditions in northern Chile were relatively dry. After 31,000 yr ago, a humid phase commenced, which culminated about 27,000 yr ago and lasted until about 17,000 yr ago, with one drier interval at about 25,000 yr ago. From 17,000 to 11,000 yr ago, a drying phase started, and conditions were as dry after 11,000 yr ago as they were before 31,000 yr ago. Unfortunately, the core did not contain any late Holocene

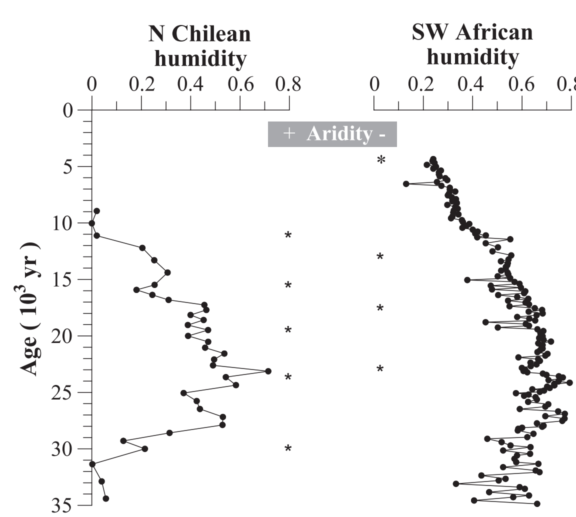


Figure 3. 35,000-yr paleoclimate time series. Continental-aridity records derived from the ratio of eolian and fluvial subpopulations for northern Chile and southwestern Africa. Symbols (*) indicate AMS-$^{14}C$ dating points.

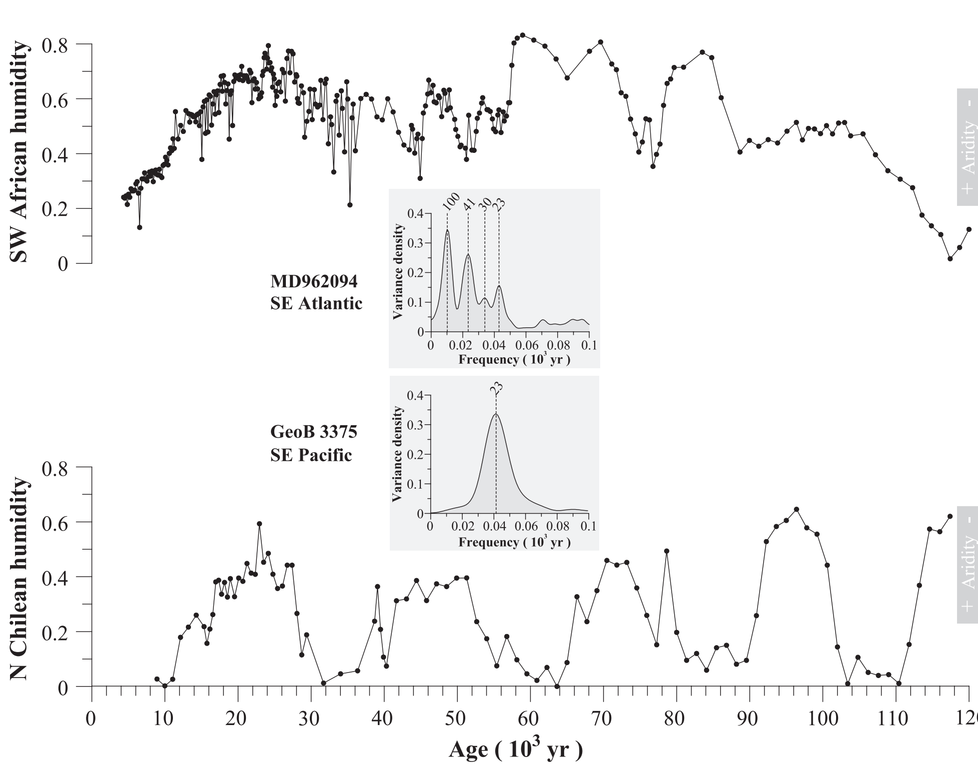


Figure 4. 120,000-yr continental aridity time series of cores GeoB 3375-1 (offshore N Chile) and MD962094 (offshore SW Africa). Inserts show the results of time-series analyses using the software package Analyseries (Paillard et al., 1996). Spectral analyses of core GeoB 3375-1 are based on 1000-yr linear interpolated time series for the time interval between 10,000 and 117,000 yr ago. We used a Parzen smoothing window with 87 lags, which resulted in a bandwidth of 0.021313. Lower and upper confidence limits at the 95% level are given by $0.379461 < P\ (95\%)/P < 6.6284$. Spectral analyses of core MD962094 were taken from Stuut (2001, chapter 7) for the complete (last 300,000 yr) aridity record.

sediments. The southwestern African humidity record shows a very comparable pattern although high-frequency variability seems to be superimposed on a general increasing humidity trend after 32,000 yr ago, which culminated about 27,000 yr ago. Apart from some short-lived slightly drier phases about 25,000 and 22,500 yr ago, conditions stayed relatively wet until about 18,000 yr ago when conditions tended to get drier. This drying trend continued until the top of the core, about 4000 yr ago.

On longer time scales (Fig. 4), there are clear apparent differences between the two humidity records; the Chilean record shows a pronounced approximately 20,000-yr variability with relatively wet phases about 100,000–91,000, 74,000–67,000, 50,000–39,000, and 27,000–17,000 yr ago, whereas the southwestern African record varies on all three Milankovitch periodicities, as illustrated in the time-series analysis diagrams.

## Interpretation and discussion

The terrigenous fraction of the deep-marine sediments offshore northern Chile consists of a mixture of eolian dust and hemipelagic mud (Lamy et al., 1998b), comparable to the terrigenous fraction of other coastal deserts (e.g., Koopmann, 1981; Prins and Weltje, 1999). In general, the downwind decrease in transporting capacity of a particular wind system can be recognized by the gradual decrease of the size of the eolian sediments it carries. A similar variation in the size of the eolian sediments is caused by fluctuations in the intensity of the wind system at a single location (Prins and Weltje, 1999; Stuut et al., 2002b). Given the sedimentation rates at core sites in both the eastern Pacific and Atlantic Oceans, which are in the order of a few centimeters per thousand years, each sample analyzed represents hundreds of years of accumulation and probably thousands of dust transport events, which have been mixed thoroughly together. Therefore, they can only be considered as a mixture. This mixture can be described with two end members, which represent the beginning and end process of a set of wind-depositional events with its accompanying downwind decrease in size of the wind-blown material, due to the downwind decrease in transporting capacity of the wind. Consequently, we interpret the coarsest two end members as the beginning and end process of eolian deposition and label them ‘coarse’ eolian dust and ‘fine’ eolian dust, with modal grain sizes of 40 and 29 μm, respectively (Fig. 2D). The modal sizes of the eolian end members compare very well to modal sizes of present-day dust that was collected offshore northwestern Africa (Stuut, unpublished data). The third end member is interpreted as fluvial mud with a modal grain size of 12 μm. The fact that in similar studies the fluvial fraction was much finer (approximately 8 μm in the Arabian Sea, (Prins and Weltje, 1999); approximately 4 μm in the SE Atlantic Ocean (Stuut et al., 2002b); approximately 4 μm in the equatorial Atlantic (Holz et al., in press)) might be explained by the fact that the clay fraction was separated from the Chilean sediments before grain-size analyses. The ratio of wind-blown versus fluvial sediments is taken as a proxy for northern Chilean continental aridity, which is compared to the southwestern African continental aridity record for the last 35,000 and 120,000 yr (Figs. 3 and 4, respectively). The fact that the sediments from the two cores that are compared here were analyzed with different particle-size analysis techniques (for a comparison of Sedigraph and Laser particle sizing see Konert and Vandenberghe, 1997) probably causes changes in the absolute values of the particle-size distributions (and hence their end-member compositions) but does not prevent a comparison of the downcore trends of end-member contributions observed in both cores.

A commonly accepted and widely used proxy for continental aridity is the mass flux of eolian dust (e.g., Arimoto, 2001; Hesse, 1994; Pye, 1989). Dust flux and particle size are strongly related because the mass flux of dust via dry deposition can be controlled by a relatively small number of aerodynamically large particles (Arimoto et al., 1997). However, in some particular cases like, for example, carbonate-rich sedimentary environments, it is difficult to calculate the flux of individual terrigenous components because the accumulation rates are dominated by deposition and post-depositional alteration of the carbonate fraction. Because the two cores presented here are from highly-productive upwelling areas, post-depositional changes like carbonate dissolution are too high to calculate reliable flux estimations. However, because the relative size of the terrigenous sediment fraction is independent of the sedimentation rates, especially in these cases, we think the end-member approach provides a good alternative to reconstruct continental aridity.

The northern Chilean aridity record shows a pronounced variability on orbital time scales particularly in the precessional band, with increased relative humidity during precession maxima (e.g., the LGM), compared to relatively dry precession minima (e.g., late marine oxygen isotopic stage 3 and early Holocene). This is consistent with previously published sedimentological, mineralogical, and geochemical data from core GeoB 3375-1 (Lamy et al., 1998a, 2000) implying that not only the mode of sediment input varied on precessional frequencies but also continental weathering conditions and source areas. An important difference of the northern Chilean and the southwestern African records compared here is the relative importance of orbital frequencies in the long-term records. While the African record shows prominent obliquity (ca. 41,000-yr) cycles (Stuut, 2001, ch. 7), the Chilean record shows a very strong precessional (ca. 21,000-yr) signal (Lamy et al., 1998a, 2000, see Fig. 4). Owing to the different orbital frequencies on which the records seem to vary, the humidity records seem to be in antiphase during the older parts (>55,000 yr ago) of the records. The precessional signal, which is very strongly present in the Chilean record, implies that also the tropics played an important role in controlling latitudinal shifts of the Southern Westerlies in the southeastern Pacific but much less so in the southeastern Atlantic. In fact, modern climatological data suggest that the latitudinal position of the Southern Westerlies in southern South America is not only controlled by high-latitude conditions, that is, around Antarctica, but also substantially by changes in the tropics, especially the strength and position of the subtropical anticyclone in the southeastern Pacific sector (e.g., Markgraf, 1998). For the LGM, a reduced strength of the tropical Hadley-cell circulation has been invoked to explain more humid conditions on the Bolivian altiplano (Baker et al., 2001; Thompson et al., 1998), which likely influenced both the strength and position of the southeastern Pacific anticyclone and thus the position of the Southern Westerlies, a mechanism that has been used to explain Holocene shifts of the Westerlies (Lamy et al., 2001). During the LGM, this tropical forcing was in phase with the high-latitude control by sea ice.

Similar to northern Chile, in southwestern Africa, relatively humid conditions prevailed during the LGM compared to the Holocene (Dupont and Wyputta, 2003; Stuut et al., 2002b). Although the sediment core offshore southwestern Africa was retrieved from closer to the equator than compared to the Chilean core, the source areas of sediments for both cores are at comparable latitudes probably because the main fluvial source in southwestern Africa is the Orange River, which drains a large part of South Africa from about 24–32°S, next to several ephemeral rivers that drain the southwestern African coastal region. An increase in precipitation and runoff most likely leads to increased runoff of the Orange River as well as more continuous runoff of the smaller regional rivers that at present are ephemeral. The contemporaneous relatively humid conditions during the LGM point to a Southern Hemisphere-wide mechanism. At present, the Southern Westerlies are the source of moisture for both South America (e.g., Miller, 1976) and southwestern Africa (e.g., Tyson, 1986). An equatorward shift of the Southern Westerlies would explain the observed increase in precipitation during the LGM. Various papers have suggested latitudinal movements of the frontal zones in the Southern Ocean (e.g., Brathauer and Abelmann, 1999; Gersonde et al., 2003; Morley, 1989) and of the Southern Westerlies in particular (Heusser, 1989), which could explain the variability in the latitudinal position of the Southern Westerlies. However, there are also studies that argue for a fixed latitudinal position due to the confining Southern Ocean bathymetry (Matsumoto et al., 2001), and, more confusing, some global circulation models (GCMs) argue for a poleward shift (Anderson et al., 2002; Valdes, 2000) of the frontal zones in the Southern Ocean during glacial times.

Variations in Antarctic sea ice were suggested as a possible cause for the latitudinal movements of the

Southern Westerlies (Simmonds, 1981; Stuut, 2001, in press). During periods of increased Antarctic sea ice, an enhanced polar vortex and increased thermal gradients between the poles and the equator would force the oceanic and atmospheric frontal zones to move equatorward, whereas during warmer periods, these frontal zones would move poleward due to decreased sea-ice extents. Sea ice appeared and disappeared in less than thousand years (Shemesh et al., 2002), confirming the high reactivity of this parameter as shown by modeling studies (Gildor and Tziperman, 2000, 2001). Antarctic sea ice and resulting latitudinal shifts of the Antarctic Circumpolar Current (ACC) and the Southern Westerlies would explain the observed humidity changes in northern Chile and southwestern Africa. Off southern Chile, Lamy et al. (2001, 2002) showed that during the Holocene long-term latitudinal shifts of the Southern Westerlies and the ACC were indeed in phase with sea-ice and temperature changes around Antarctica.

Additional tropical forcing that is unique to the SE Pacific and that might have affected rainfall in northern Chile are long-term changes within the El Niño/Southern Oscillation (ENSO). During the LGM, reconstructions of sea surface temperatures in the eastern tropical Pacific imply comparably little cooling within the eastern tropical Pacific cold tongue, indicating reduced Walker circulation during the LGM, a pattern that strongly resembles modern El Niño events (Koutavas et al., 2002). A tendency toward more El Niño-like conditions would be consistent with more humid conditions in northern Chile, as at present, within the northern winter rain belt of Chile, strong positive rainfall anomalies occur during El Niño events induced by a northward shift of the Southern Westerlies due to a weakening and northward displacement of the SE Pacific anticyclone (Ruttland and Fuenzalida, 1991). An additional support for a role of long-term ENSO changes in controlling the rainfall changes in northern Chile comes from modeling studies suggesting a strong sensitivity of long-term ENSO dynamics to precessional insolation changes (Clement and Cane, 1999).

Interestingly, also within the monsoonal system, important differences are evident between South America and eastern South Africa. Whereas monsoonal South America was clearly wetter during the LGM, consistent with the Southern Hemisphere insolation maximum, the eastern part of South Africa was apparently relatively dry in spite of maximum insolation (Johnson et al., 2002; Partridge et al., 1997). Baker (2002) speculated that this difference might be caused by the dominant control of glacial boundary conditions over insolation forcing in southern Africa.

## Conclusions

End-member modeling of the terrigenous silt fraction of core GeoB 3375-1 (offshore northern Chile) results in three end members that are interpreted as coarse eolian dust, fine eolian dust, and fluvial mud. These results are very similar to those from core MD962094 (offshore southwestern Africa).

The ratio of the proportions fluvial mud and eolian dust during the last ca. 120,000 yr is interpreted as a paleocontinental humidity record of northern Chile, which shows pronounced variability in the precessional band with more humid conditions during precession maxima (including the LGM) and more arid climates during precession minima (e.g., the early Holocene). Likewise, the humidity record from southwestern Africa also clearly shows a LGM increase in precipitation, which we attribute to a hemisphere-wide equatorward shift of the Southern Westerlies.

However, the long-term records of our two sites imply that also important zonal differences are evident between southwestern Africa and northern Chile. The strong precessional signal in northern Chile shows that tropical insolation changes, probably involving long-term changes in ENSO, have a strong influence on the latitudinal shifts of the northern margin of the Southern Westerlies in the SE Pacific but not in the SE Atlantic, which apparently responds predominantly to high-latitude forcing.

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