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The climate of Socotra Island (Yemen): A first-time assessment of the timing of the monsoon wind reversal and its influence on precipitation and vegetation patterns

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ABSTRACT

The climate of Socotra, influenced by the Indian Ocean Monsoon, is poorly known, hampering understanding of its paleoclimate and (endemic) biodiversity. Mean annual rainfall and temperature, measured in a network of meteorological stations from 2002 to 06, were 216 mm and 28.9 °C. Combined with cloud cover information from satellite images, this data provides clear ideas on inter- and intra-annual variability. Precipitation derived from the northeast (NE) winter monsoon influences especially the NE plateaus and windward side of the Haggeher Mountains because of orographic effects. The southwest (SW) summer monsoon concentrates at the southern half of the island and generally produces less rainfall. During the SW summer monsoon, clouds cover the highlands and plateaus south of the Haggeher Mountains, creating fog. Preliminary measurements suggest that at higher altitudes, fog-derived moisture may constitute up to two-thirds of total moisture, amounting up to 800 mm. The predominant SW aspect of the enigmatic dragonblood tree underlines the importance of fog. Long-term weather observations by Socotri put these short-term meteorological observations into a longer perspective. Socotri informants also described the drought years when livestock populations crashed, after which windows of opportunities for the regeneration of dragonblood and other grazing-sensitive trees may have occurred.

1. Introduction

1.1. General

Socotra Island, situated in the north-western (NW) Indian Ocean (Fig. 1) is known for its spectacular flora, including the dragonblood tree (*Dracaena cinnabari*), frankincense (*Boswellia* spp.) and aloe (*Aloe* spp.) that once dominated the world's economy. The island's large number of endemic plant species (320, or 37% rate of specific endemism) and numerous endemic animals, motivated its 2008 listing as natural World Heritage Site (UNESCO, 2008). The natural diversity has its background in the weather pattern that is characterised by large spatial, altitudinal, seasonal and inter-annual variability. The climate is influenced by the seasonally reversing monsoon wind system and ocean–atmospheric interactions such as the Indian Ocean Dipole (IOD) (Saji et al., 1999; Webster et al., 1999; Prasad and McClean, 2004) and the El Niño – Southern Oscillation (ENSO) (Neff et al., 2001; Abram et al., 2007). The description of the island's climate has, however, remained largely anecdotal (Wellsted, 1835; Popov, 1957; Mies and Beyhl, 1998), with only preliminary site-specific assessments (Mies, 2001; Culek et al., 2006).

Several paleoclimate reconstructions were inferred from speleothems since Socotra's location on the inter-tropical convergence zone (ITCZ) is ideal to study the migration of climate belts (Fleitmann et al., 2004, 2007; Shakun et al., 2007). The application of climate-speleothem proxy relations should be based on a detailed understanding of the present climate. Also ecological studies, like the ones on the lack of regeneration of the enigmatic dragonblood tree (Adolt and Pavlis, 2004; Attorre et al., 2007) with a generation time of several centuries, can only be interpreted based on a thorough understanding of climatic variability.

This paper contributes to this understanding by assessing the timing of the monsoon wind reversals and the relative importance

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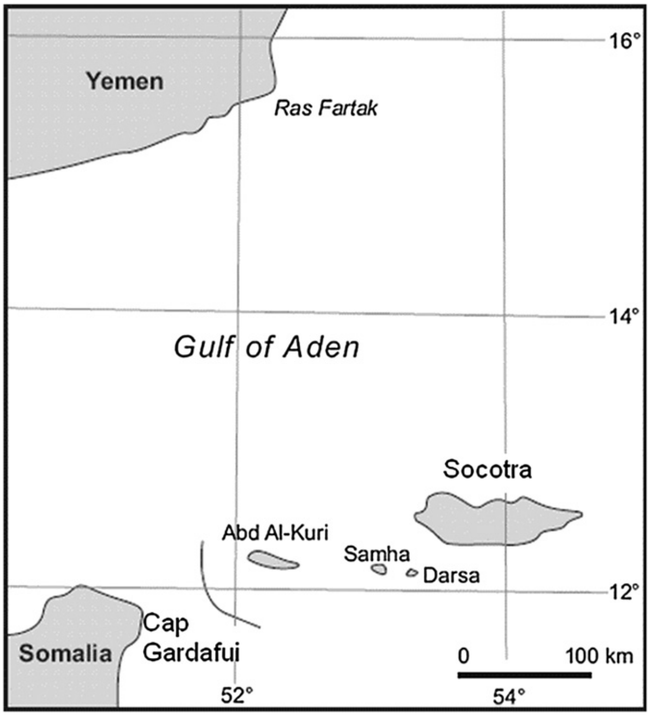

Fig. 1. Location of the Socotra Archipelago in the NW Indian Ocean (adapted after Kopp, 1999).

of the monsoon coupled rainfall periods originating from a north-eastern (NE) direction versus a south-western (SW) direction. It will assist in further understanding the unique botanic diversity of Socotra, especially in relation with projected climate change (Attorre et al., 2007). The presented Socotra's climate dataset may also contribute to the further understanding of the Indian Ocean Monsoon system that affects the lives of almost half of the world's population, whereas its response to global change is not fully understood (Leuschner and Sirocko, 2003).

1.2. The island's geography

The Socotra Archipelago, consisting of four islands, is situated between the Horn of Africa and the Arabian Peninsula (Fig. 1). Socotra, focus of this study, is the largest island with a surface area of 3625 km^2 (Cheung and DeVantier, 2006). Geological reconstructions place Socotra close to present-day Dhofar (Oman), (Fleitmann et al., 2004), whereas politically the Archipelago is part of Yemen.

Socotra can be subdivided into three geomorphological zones: predominantly alluvial coastal and inland plains, limestone plateaus and the Haggeher Mountains. The island's diagnostic geographic feature and main watershed, the igneous Haggeher mountain range, reaches 1540 m. The southern coastal plain, measuring 70 by 5 km, is cut off by 300–400 m high escarpment cliffs of the limestone plateaus. In the north the coastal plain is narrower, interrupted by Wadi systems terminating in brackish pools separated from the sea by spits and bars. The arid Zahr basin dominates the western part of the island. The limestone plateaus, characterised by karstic features (De Geest, 2006), cover more than half of the island and are generally between 300 and 700 m asl, reaching 800 m at Ma'alah in the west and 1000 m at Diksam (Fig. 2). Wadi systems originating from the Haggeher Mountains are deeply cut-in these plateaus in especially the southern part of the island.

1.3. Monsoon climate

In winter, the atmospheric pressure gradient between the high-pressure cell over the Eurasian continent and the low pressure ITCZ over the southern Indian Ocean, results in moderate NE winds. In spring the northern tropical and subtropical landmasses warm-up, creating SW winds. In summer the ITCZ reaches its northernmost position resulting in a maximum intensity of the Indian Ocean Monsoon. In autumn the southward migration starts again and the strength of the monsoon diminishes (Fleitmann et al., 2004) (Fig. 3).

1.4. Limited meteorological data

The first measurements of temperature, wind directions and humidity with casual remarks on rainfall were made in the early 19th century (Kerr and Edin, 1811–1824; Wellsted, 1835; De Gray Birch, 1875; Forbes, 1903). During World War II, the British army installed a weather station at Mouri Airport (northern coastal plain) that functioned for three years (Popov, 1957). The timing of the reversal in the monsoonal wind pattern and the related rainfall periods drew most attention, as they were judged

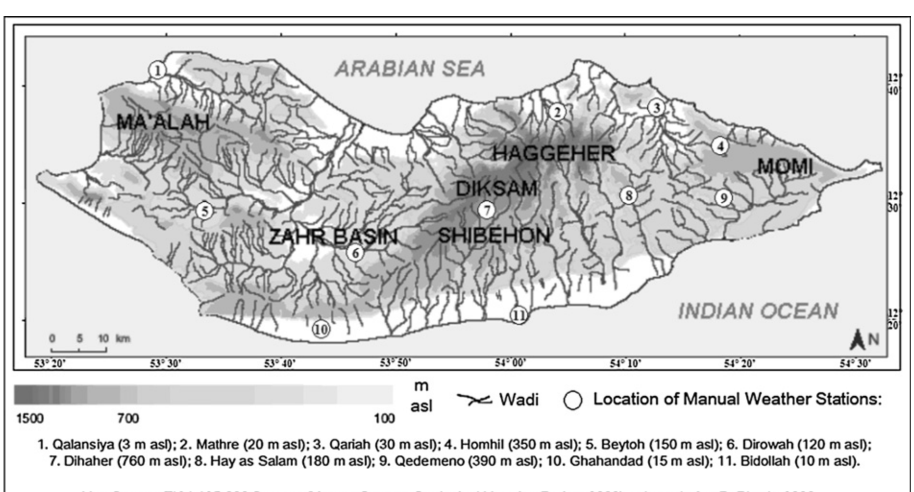

Fig. 2. Map of Socotra Island showing the location of the manual weather stations.

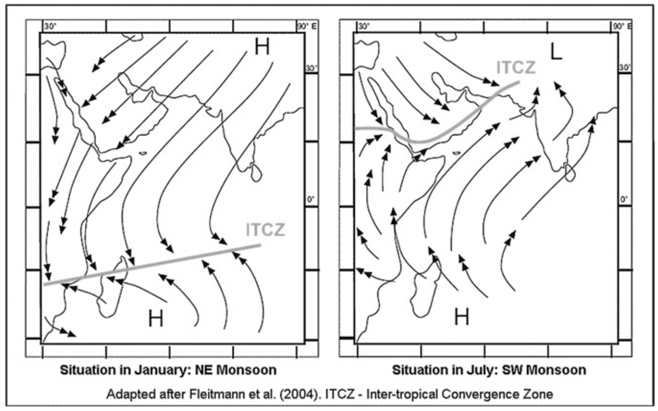

Fig. 3. ITCZ migration pathway and the Indian Ocean Monsoon winds.

differently to the extent of bringing precipitation by either the SW (Mies and Beyhl, 1998) or NE monsoon (Wranik, 2003; Miller and Morris, 2004). The complexity of Socotra's climate was further highlighted by Mies (2001) who, based on 24 h air humidity measurements in the lower Haggeher (800 m), postulated that half of the moisture in areas above 700 m may originate from fog. More recently an automated weather station was installed at Firmihin, at mid-elevation (440 m asl), providing five years site-specific meteorological data for this limestone plateau with dragonblood forest (Adolt and Pavlis, 2004) exposed to the summer SW monsoon (Kral, 2005; Culek et al., 2006).

2. Materials and methods

2.1. Weather station set-up and collection of meteorological data

In 2001, a network of 10 manual stations was set-up by the EPA to which Homhil station was added in 2003 (Fig. 2). Its selection was based on geometrical layout, geomorphological representation and operational feasibility. Elevation was only partly covered with no stations above 800 m. Each weather station was equipped with a thermometer and a rainfall collector (diameter 19 cm, depth 10 cm) with a millimetre gradual level indicator, shielded from direct sunlight and protected from harsh winds, humans and livestock. Since November 2001 and March 2002 respectively, rainfall (accuracy of 1 mm) and temperatures (min. and max. with accuracy of 0.1 °C) were daily registered by EPA officers. Data was cross-checked and monthly entered for analysis into Excel. An automatic solar powered Cumulus weather station (508–100 series) was placed at the Diksam plateau on 29 September 2003. Rainfall, air temperature and relative humidity were measured every hour till July 10, 2004. Wind direction and global radiation were registered until January 15, 2005.

2.2. Satellite cloud cover images

A selection of 142 out of a total of 150 satellite images, freely available on the internet as previews (USGS-Earthexplorer, USGS-Glovis, NASA-Johnson Space Centre- The Gateway to Astronaut Photography of the Earth, see web references), encompassing all months of the year from 1962 to 2005, were used to assess cloud formation and prevailing wind direction (De Flou, 2006). Images were chronologically ordered, resulting in the representation of 6–17 satellite previews per month. By visually examining the cloud cover on each image, indications were obtained on cloud formation and the prevailing wind direction. Based on intra-monthly

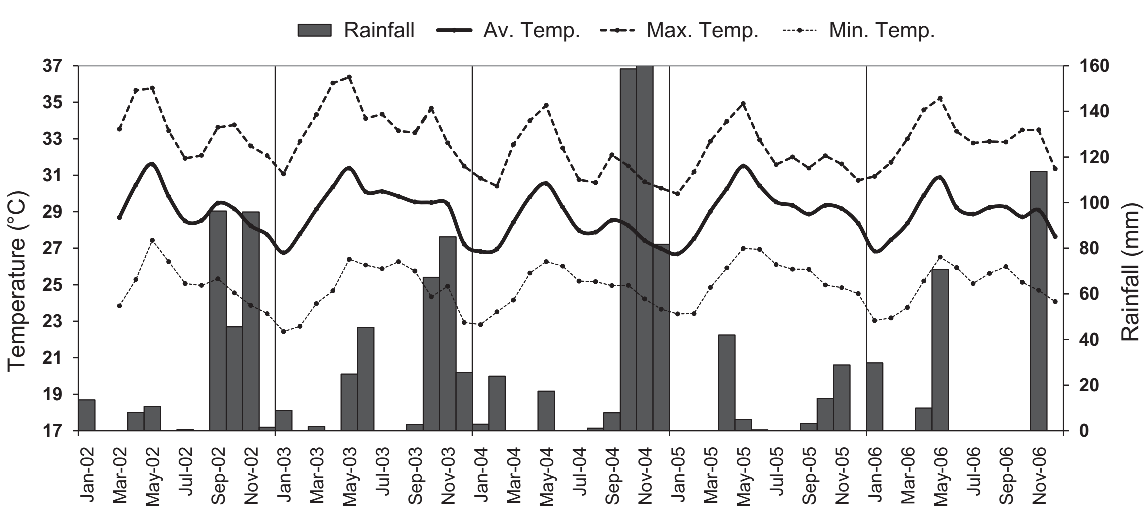

Fig. 4. Overview of mean monthly rainfall and temperature on Socotra (2002–2006) (mean annual temperature 272, 261, 569, 93, 224 mm respectively; mean annual temperature 29.2, 29.3, 28.2, 29.2, 28.8 °C respectively).

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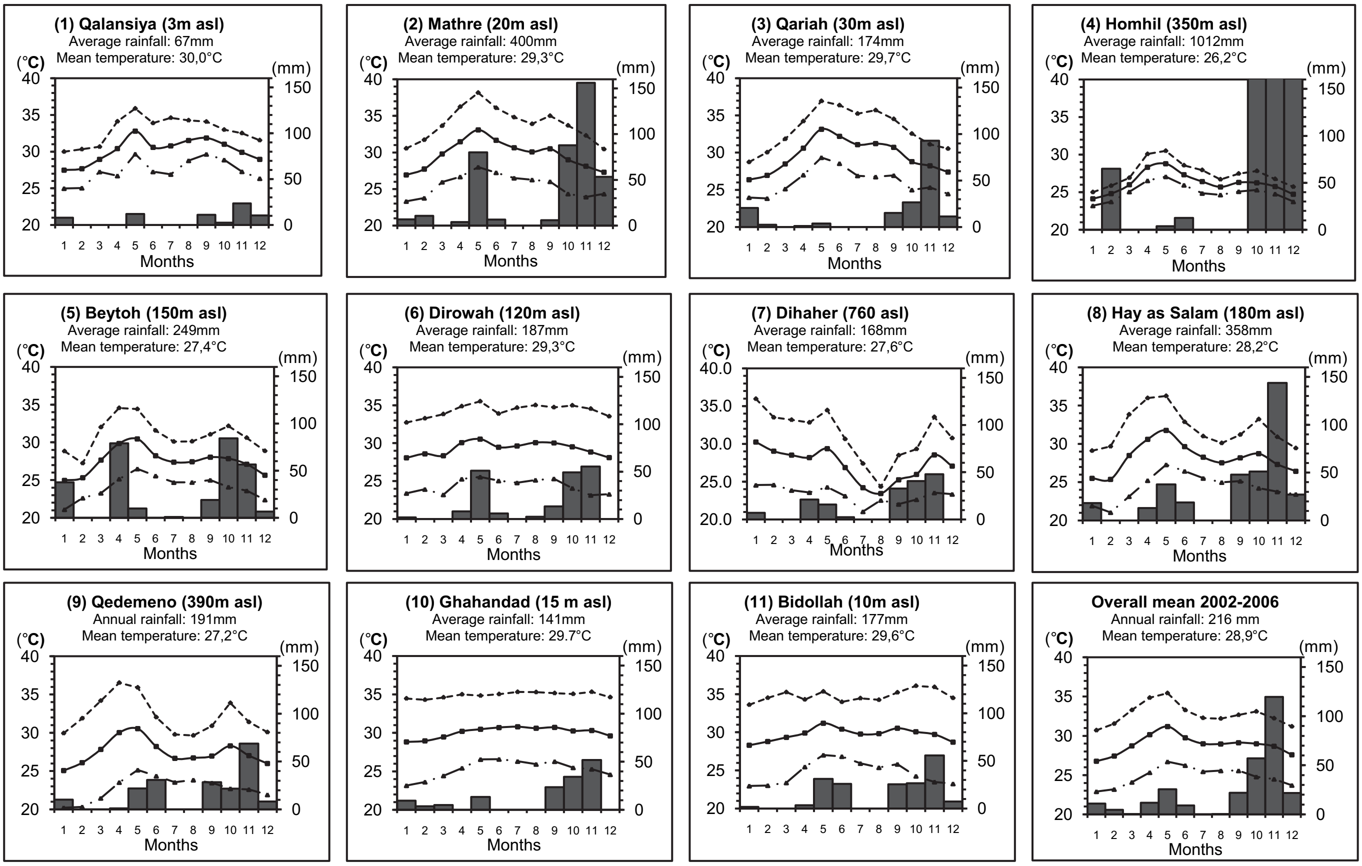

Fig. 5. Overview of mean monthly rainfall and temperature (Max./Mean/Min.) for each manual weather station (2002–2006) (1–11) and the combined overall mean for Socotra.

variations, the frequency of changes was visualised, allowing the assessment of wind reversal within a month.

2.3. Fog collection

The Environmental Protection Authority (EPA), in collaboration with CARE-Yemen, carried out an experiment to test if water needs for isolated mountain communities could be met with fog collection. Four mist nets, ranging in size from 1 to 12 m^2, were used to collect fog in three locations on Diksam and one location on Momi plateau from July to September 2004. Applying widely used net types, these measurements allow comparisons with the well-studied fog oasis of Dhofar, Oman (Hildebrandt and Eltahir, 2006; Abdul-Wahab et al., 2007).

2.4. Oral history

We tapped Socotra's long oral tradition, base of daily survival, as a complementary source of climatic information through informal interviews that we held amongst the EPA community liaison officers. Indicated years should, however, be taken with some caution as written records to triangulate this information are lacking.

3. Results

3.1. Weather station records

Mean annual rainfall, measured at the 11 manual stations from 2002 to 2006, was 284 mm, or 216 mm when excluding the abnormal Homhil records, with important inter-annual variability (Fig. 4). Maximum rainfall was reached in November, with an average of 120 mm or 42% of the mean average rainfall. In March, July and August there was generally no rain.

The mean annual rainfall at individual stations showed considerable variation (Fig. 5). At Mathre, Qariah, Hay as Salam, Qedemeno and especially Homhil, the amount of rainfall at the end of the year (winter rains) was higher than from April to June (summer rains).

May was the hottest month with an average recorded temperature of 31.2 °C whereas a second pronounced warm period occurred in September–October with mean values of 29.1–29.0 °C respectively. This trend was observed in all stations, except Ghahandad at the southern coast (Fig. 2:10) where the temperature remained virtually constant throughout the year (Fig. 5). The amplitude between the mean annual minima and maxima, representing differences between day and night temperatures, ranged between 10.0 °C and 2.6 °C. The mean annual temperature was 28.9 °C ± 0.3 °C, with 28.2 °C in the wet year 2004 (Fig. 4). Popov (1957) observed a nocturnal minimum temperature of 13.5 °C in the Haggeher Mountains in January; we measured a minimum temperature of 8.7 °C during the early morning of January 15, 2006 at the summit. Herders told us it does get even colder, but no frosts have ever been recorded in oral traditions during the period of habitation of several millennia.

Precipitation and temperature data of the Diksam automated station can be correlated with data from nearby Dihaher manual station. The relative humidity data showed not only a high value (>95%) during periods of rainfall, but also during cloudy months. Late September the mean relative

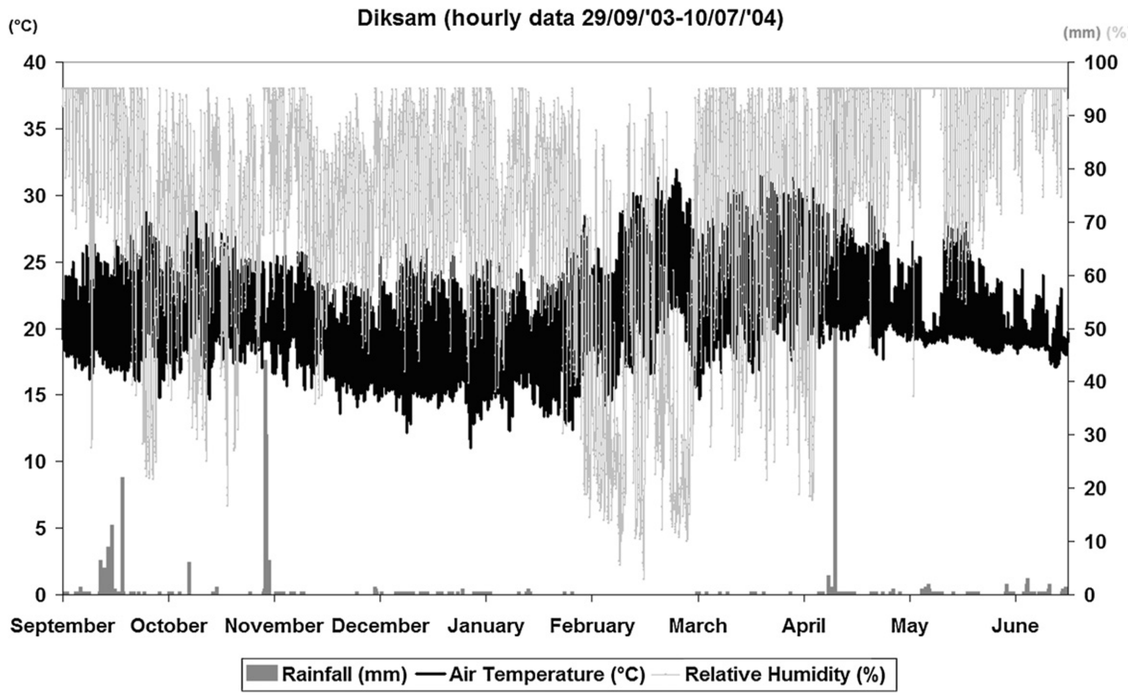

Fig. 6. Rainfall, Temperature and Relative Humidity at Diksam station (Sept. 2003–July 2004).

humidity dropped sharply to 50%, and rose again during (rainy) November. December and January were relative humid months with cold precipitation. February to April were dry months, until it started raining at the end of April or beginning of May. Humidity stayed high during the month of June (Fig. 6). The daily amplitude in global radiation was filtered out by taking the daily mean temperature, with a clear inverse relationship between the latter and relative humidity. The wind reversal periods were marked by the wind direction data (Fig. 7); at the end of April the wind shifted from a predominant NE direction towards a constant S or SE direction, lasting till late September.

3.2. *Relation cloud cover – wind direction*

Late June till late September was characterised by a well-developed SW-cloud cover type with orographic cloud formations over the southern cliffs, the elevated southern limestone plateaus and southern Haggeher Mountains, which all experienced fog formation, resulting in daily drizzles. The western part of the island was less covered by clouds, with the exceptions of Ma'alah and a small plateau further to the SW. The northern coastal regions remained cloudless (Fig. 8: f–i). The SW monsoon cloud cover was very stable, without exception over the years. In October both SW- and NE-cloud cover types were found (Fig. 9). All SW-cloud cover

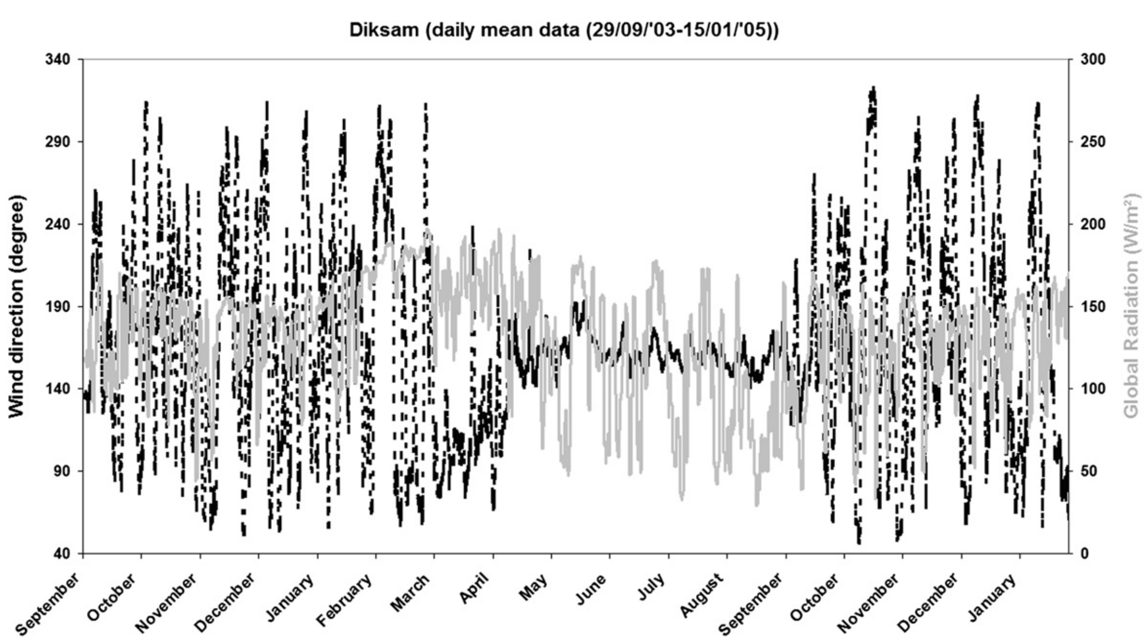

Fig. 7. Wind direction and Global Radiation, at Diksam station (Sept. 2003–Jan. 2005).

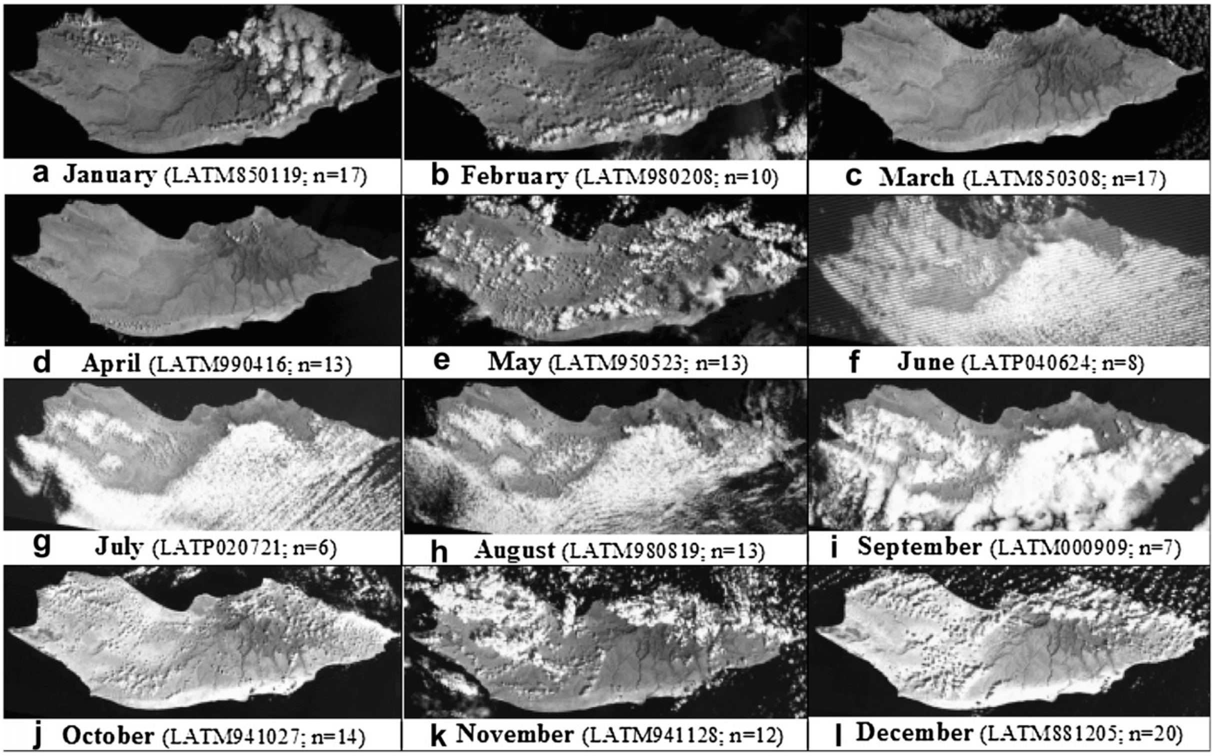

Fig. 8. Cloud cover of Socotra, as indicated by a monthly selection of the most characteristic previews.

types occurred before October 16; three out of four NE-cloud cover types occurred after October 26, indicating a quick wind reversal during October. November and December showed a clear NE cloud cover type with orographic cloud formations over the NE limestone plateaus (Momi), the area north of the Haggeher Mountains and the western part of the island at the elevated coastal cliffs and north of Ma'alah. There was also an important cloud intrusion following the NE-SW limestone range west of Shibehon penetrating the island to the northern parts of the southern limestone cliffs (Fig. 8: k and l). The NE cloud cover type was stable during November and December in respectively 75% and 85% of the images (Fig. 9). January and especially February showed less cloud cover. In January, most of the time clouds covered the northern flanks of the Haggeher which was less consistent in February when the first clouds at the southern coastal cliffs were observed (Fig. 8: a and b). Images with a clear NE cloud cover type were limited to the first half of February, which suggests the beginning of the spring-inter monsoon by the end of February (Fig. 9). In March and April, there was limited cloud cover with no clear wind direction component, characteristic for the inter monsoon (Fig. 8: a–d). From March till April, SW-cloud cover types increased from 20% to almost 50% of the images (Fig. 9). Yet in April, the SW-pattern was very variable and sometimes clouds only formed along the NE-SW limestone range west of Shibehon and along the southern coastal cliffs (Fig. 8: d). About half of the April-images were without pattern, indicating that April starts with the end of the inter-monsoon and ends with the beginning of the SW monsoon. In May the SW-cloud cover component developed further, with the building-up of the characteristic SW-cloud cover type in June (Figs. 8:e, f and 9).

3.3. *Quantities of fog harvested with nets*

Fog harvested with mist nets during the summer monsoon reached up to the equivalent of 10 mm of rain per day. The variation

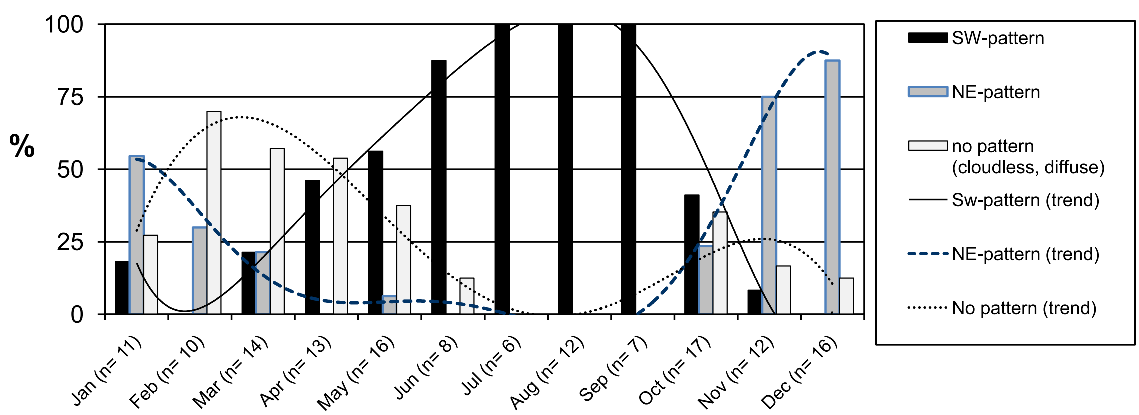

Fig. 9. Classification of cloud patterns on 142 satellite images of Socotra (see text).

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Table 1
Fog measurements during the SW monsoon, Socotra island (July–Sept. 2004), see Fig. 2 for areas.

Location	Area	Altitude (m asl)	Collector Size (m^2)	Trial duration (days)	Days with fog and no rain	Total water collected (l)	Water collected ($l\ m^{-2}\ day^{-1}$)
Shibhan	Diksam	500	1	63	60	639	10.14
Dimenhen	Diksam	500	2	66	48	1187	8.99
Difre-ahten	Diksam	700	12	89	80	4135	3.87
Dihof	Momi	500	6	74	19	80	0.18

in collected quantities underlines the importance of location and aspect.

3.4. Local climatic knowledge

We reviewed oral knowledge, passed on through generations (Morris, 2002), for a long-term understanding of the Socotra climate (Socotri word in between [ ]). The NE Monsoon from late October to February is called [*serb*], during which a cooling, much appreciated N wind [*serbihi*] brings rains. The [*serb*] winter rains are plentiful and prolonged, especially at the high NE and central plateaus and the interior valleys followed by the Central Highlands. The northern parts of the Haggeher Mountains and Momi Plateau can be covered in cloud and mist and experience some drizzle interspersed with rainfall. Mid-February, a transition period begins, known as the short summer [*qeyat*] lasting until April. In the lowlands, it is generally uncomfortably hot. The [*qeyat*] rains are unpredictable in time and space. The short period of intense heat and stillness in April is called [*minqeyat*], towards the end of which clouds begin to gather. The transitional pre-monsoon season [*doti*], running from the second half of April to the end of May or early June, is a period with possible rain again. In years when the [*doti*] rains are light or fail, the SW monsoon season [*horf*] from June to late September, will be very hard. When [*doti*] rains fail it is said that the next [*serb*] rains have a tendency to fail too. Normally though during the [*horf*] the mountains, and to some extent the high limestone plateaus, are covered in mist, with a constant drizzle. [*Zerebhen*] is the transition period in late September–October, as the SW Monsoon winds decline and shift to the NE Monsoon. The first day is marked by a short period with no winds, after which the winds start to shift and clouds pile up and disperse repeatedly, accompanied in many areas by heavy dewfall.

Linked with the survival of livestock, the island's interior economic base, droughts are well remembered and named. Most droughts are the consequence of failing [*doti*] summer rains, followed by poor [*serb*] winter rains. Especially 1844 [*Difareten*]:'hearing the nails clapping', 1942–1943 [*Dimindah*]: 'when the vultures where eating corpses' and 1954 were reported as severe droughts and the island was subsequently de-populated (Morris, 2002). Droughts also occurred in 1972, 1976 and 1981 when summer rains failed. Even the winter rains failed in 1978–1979 and 1980–1981. The summer rains of 1984–1985 and 1987 were very light, causing considerable livestock losses. Summer rains generally failed in 1993 and were completely absent in 1994. In 1999 with failing summer rains, cattle in the Haggeher Mountains died, and the number of goats and sheep dropped with 40% (Scholte et al., 2008). Even more disastrous than these droughts are severe winter floods after failing summer rainfall, as weakened cattle die from cold and houses are destroyed. Socotri on the central limestone plateaus thus remember 1999 [*enoh di mewaat*]: 'year of the dead', as subsequent floods were followed by a measles epidemic (Morris, 2002).

4. Discussion and conclusions

4.1. General weather pattern

The annual weather pattern on Socotra consists of the winter and summer monsoon, separated by autumn and spring transition periods. The autumn transition period lasts from early till late October. Wind changes from an SW towards NE direction, although with high variability. Relative humidity decreases and temperature rises towards the end of the period, when the first rains may fall. During the winter monsoon, from late October to early February, winds blow from NE direction bringing the largest annual rainfall in November. It affects the entire island, although the northern regions are more influenced due to orographic rainfall. The subsequent spring transition period, from mid-February until the first half of April, is generally dry, hot, rather cloudless while the general wind direction changes from the NE towards the SW with less variability. The summer monsoon starts with increasing wind speed, bringing rainfall in the second half of April, sometimes lasting till early June, influencing the southern regions of the island and only sporadically reaching the northern regions (Culek et al., 2006). From July until mid-August harsh winds generally blow from a western direction creating cloud cover above the southern coastal and especially higher altitude plateaus. Late August – early September, the SW wind generates high humidity.

Rainfall peaks around November, sometimes starting at the end of September and generally lasting till early February (NE derived winter rains) (Fig. 5). The second period of rainfall with (less) precipitation is April–May, which sometimes start in March and may last until June (SW derived summer rains). Both rainy seasons are alternated by dry periods, occurring in March and July–August. Comparing both rainy seasons from 2002 to 2006, we notice that they did not develop during the same periods and were not always equal in duration (1–5 months). At the manual stations of Qalansiya, Beytoh, Dirowah, Dihaher, Ghahandad and Bidollah, the differences were less pronounced, although also in these places winter precipitation dominated (Fig. 5). The annual rainfall registered at Homhil, with exceptional annual maxima well over 1000 mm in both 2003 and 2004 (Fig. 5), suggests errors in registration. Excluding Homhil, the mean annual rainfall registered on Socotra in 2002–2006 was 216 mm.

The NE continental winds of the winter monsoon take up moisture while passing over the warm Arabian Sea, explaining the wet winter monsoon on Socotra. The 400–600 m high limestone cliffs at the northern and southern coast and elevated plateaus around the Haggeher Mountains cause orographic uplifts. Consequently, two cloud cover types can be distinguished: an SW monsoon type, with cloud formations especially in the southern parts of the island and an NE monsoon cloud cover type with cloud formations especially above the northern parts of the island. Our analysis of 142 preview satellite images showed the inter-monsoon wind reversal periods to be rather constant in timing over the last 40 years.

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4.2. Importance of fog

Vegetation, in particular tree species such as dragonblood, is able to capture cloud water ('fog') by their canopies, producing so-called horizontal precipitation (Hildebrandt and Eltahir, 2006). Observed quantities of horizontal precipitation are comparable with measurements in the fog oasis of Dhofar (Oman) where, with similar green shade filters, 11.5 l m^{-2} day^{-1} was collected in July–September 2005 (Abdul-Wahab et al., 2007). The Diksam fog measurements, close to the Dihaher weather station (Fig. 5:7) with an annual average rainfall of 168 mm, suggest that during the SW monsoon, locally quantities of moisture received through fog are in the range of 357–567 mm, i.e. 68–77% of total moisture. This is inline with measurements in Dhofar where Hildebrandt and Eltahir (2006) found total moisture three times as high as rainfall. This results in a strikingly well-wooded vegetation surrounded by shrublands characteristic of much drier areas (Miller and Morris, 2004; Hildebrandt and Eltahir, 2006). The lack of fog at Momi (Table 1) showed its localised nature, making it difficult to extrapolate results over larger areas. The area south of the Haggeher generally experiences a dense cloud cover, while Momi and the northern shores are situated in the 'fog shadow' of the SW monsoon (Fig. 8).

The importance of fog as a source of moisture on Socotra has been neglected, and has, for example, not been integrated in palaeoclimatic models of the Indian Ocean Monsoon System (Fleitmann pers.comm. 2007). Little is known about its evolution in times of increased aridification.

4.3. Climate and vegetation

The climate of the Socotra lowlands is comparable with surrounding Arabian and African continents, with mean annual temperatures approaching 30 °C and rainfall generally confined to the winter (Le Houerou, 2003). Yet with a locally higher mean annual rainfall (up to 200 mm), lowland vegetation on Socotra is more diverse than its continental counterparts. Halophytes are confined to the driest sea-ward oriented areas in Socotra whereas elsewhere *Croton socotranus* shrubland dominates (Mies, 2001).

The midlands of Socotra with their various exposures to either the SW or NE monsoon harbour a diversified vegetation dominated by succulent shrubland (Mies, 2001; Miller and Morris, 2004). The spectacular appearance of the bottle trees desert rose *Adenium obsesum* and cucumber tree *Dendrosycios socotranum* contests Le Houerou (2003)'s statement that midlands in the Eritreo-Arabian Domain 'lack originality'. Striking in the midlands are also the cliffs with fog catching microhabitats where frankincense trees, also being sheltered from grazing, regenerate. Here they may find an evolutionary refuge in times of aridification. The predominant winter precipitation makes the midlands more comparable to their counterparts on the African continent (Eritrea, Djibouti, Somaliland) than on the Arabian Peninsula as illustrated by the dominant *Buxanthus hildebrandtii* evergreen shrub that Socotra's midlands share with these areas. The differences with the seasonal cloud forest vegetation in Dhofar and Hawf (Oman, Yemen) may be linked to the occurrence of fog during the summer (Miller and Morris, 1988; Hildebrandt and Eltahir, 2006), whereas on Socotra fog bridges the dry season and winter rainy season.

Kral (2005) and Culek et al. (2006) showed that the montane vegetation south of Haggeher is influenced by moisture arriving with the SW monsoon in the form of a fine drizzle or fog. This corresponds to the predominant SW aspect of seven out of nine main areas where the island's flagship species, dragonblood trees, can be found (Attorre et al., 2007). The remaining two areas comprise Serahon (W-aspect) where dragonblood is of poor condition and Skand (SE) where, at the summit of the Haggeher Mountains and higher than the other areas, dragonblood has the greatest potential to survive periods of increased aridity (Attorre et al., 2007).

The lack of regeneration of dragonblood and frankincense trees has been the subject of much discussion if 'the goat or climate is to be blamed' (Mies, 2001; Adolt and Pavlis, 2004; Miller and Morris, 2004; Attorre et al., 2007; Scholte et al., 2008; Habrova et al., 2009). Increasing insight leads us to hypothesise that it is not the present (absolute) goat grazing pressure that causes the lack of regeneration, but increasingly reduced spatial and temporal grazing dynamics (Scholte et al., 2008). Reduced mobility is triggered by an increasingly sedentary pastoral lifestyle (Morris, 2002). Goat populations have historically fluctuated dramatically, mainly as a function of rainfall. The introduction of new management practises such as water provision, veterinary care, supplementary fodder and transport of animals by truck to other areas have, however, increased their survival during droughts (Scholte et al., 2008). Dragonblood and frankincense stands on Socotra are remarkably homogeneous (e.g. Habrova et al., 2009), and may have regenerated en masse in the aftermath of droughts when grazing pressure has remained low whereas rainfall re-established. There is an analogy to the homogenous *Acacia tortilis* woodlands in East Africa that can be traced back to the late 1880s when rinderpest ravaged cattle populations (Prins and Van der Jeugd, 1993). Follow-up research, assisted by the dragonblood age-assessments of Adolt and Pavlis (2004) and Habrova et al. (2009) may test this hypothesis, by investigating if tree stands can be traced to the above indicated drought years when goat populations crashed.

4.4. Perspectives

Socotra's plateaus and mountains should be considered as water towers of the island, providing fresh water that allows diverse life in an otherwise (semi-) arid environment. With the rapidly expanding human population and its demands, amongst other things expressed through increased (irrigated) agriculture, this dependence will become further pronounced. Climate change that has been projected to cause considerable aridification on Socotra (Attorre et al., 2007) is expected to put further pressure on the system. The maintenance and, where possible increase, of tree cover that intercepts fog will be of crucial importance for the hydrological balance of the island.

The increased insights offered by this study notwithstanding, a more quantitative understanding of the inter-annual variability of Socotra's weather, especially in relation to the expected climate change in the 21st century, can only be reached by continued data collection through an enlarged meteorological station network that includes Socotra's highlands. Of particular interest is the further understanding of the spatial importance of fog and its contribution to the hydrological balance of the island. Continuing the meteorological monitoring and linking it with the ecological monitoring and subsequent development of management guidelines should be a priority for the Environmental Protection Authority and its research and management partners.

Socotra's climate with its large spatial and temporal variation has shaped the evolution of its flora and fauna, resulting in its present outstanding biodiversity. Its continued survival in times of climate change and rapidly increasing human pressure will once again depend on it.

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