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Supplementary Materials for

Nonrainfall water origins and formation mechanisms

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Supplementary Materials

note S1. Site description.

This study was conducted in the central Namib Desert at the Gobabeb Research and Training Centre (lat. –23.55^0, long. 15.04^0 and elv. 405 m a.s.l.). The centre is located about 60 km from the Atlantic Ocean on the outer edge of the Namib fog-zone, annual precipitation < 20 mm. The fog zone is an area of the most visible impacts of advective fog characteristic of the Namib coast (*49*) although there are suggestions that other types of fog could occur regularly in the Namib (*7*). The centre is surrounded by three distinct ecosystems: to the north and east the gravel plains (91% sand, 0.6% clay and 8.4% silt), to the west and south the sand dune sea (74.8% sand, 5.5% clay, 19.7% silt) and the ephemeral Kuiseb river (91.5% sand, 2.1% clay, 6.4% silt) lies south of the centre separating the gravel plains and sand dune sea. The Kuiseb river is one of the largest ephemeral rivers (~560 km) in Namibia, draining the western Great Escarpment with a 420 km long catchment area of approximately 15 500 km^2 (*61*). It drains the high plateau (~2000 m a.s.l) westward through the escarpment to the Atlantic Ocean near Walvis Bay. Mean annual rainfall at the headwater is > 300 mm yr^{-1} and decreases to less than 20 mm yr^{-1} in the low lands (*62*). The Kuiseb river has flowed past Gobabeb at least once a year for an average of 12 day yr^{-1} with a maximum of 33 days in 1997 (*62*). Rainfall and groundwater availability are often the primary determinants of species distribution in the Namib Desert (*31*) with large trees confined to the eastern edge of the desert and along ephemeral watercourses (*63*) where they access the shallow alluvial aquifers (*64*). The ephemeral vegetation at Gobabeb Research and Training Centre is dominated by four species: *Faiderbia albida*, *Acacia erioloba*, *Euclea pseudobenus* and *Tamarix usneoides* (*61*).

note S2. Supplementary methods.

Precipitation, groundwater, fog and dew sampling

All samples were collected within the vicinity of the Gobabeb Research and Training Centre from January 2014 – January 2015. Groundwater samples were collected during field campaigns from two boreholes located in the Kuiseb River (Table 1). The river water sample was obtained on the 23rd December 2013 when the river flowed for two days. Precipitation was collected immediately after a rain event to minimise evaporation effects at the centre. Despite our best efforts, we captured about half of the precipitation events during this period for isotopic analysis (Table 1, fig. S1). Fog samples were collected from fog collectors designed after Schemenauer and Cereceda (*65*), 1 m^2 metal frames covered by a polyethylene mesh raised 2 m from the ground surface and oriented in the direction of the dominant fog bearing wind. The mesh intercepts fog droplets which coalesce and flow into a collecting trough directing the flow to an outlet pipe and into a container where samples were collected daily at 08:00 hrs. Dew was collected from a dew collector, which was made of 1 m^2 metal sheet overlain by a glass plate at a 30^0 angle raised to 0.5 m from the soil surface. The glass plate is able to achieve or go below the ambient dew point temperature facilitating dew formation which collects in a trough placed at the end of the collector. Attached to the trough is a collecting pipe which directs this flow into a container. Dew samples were obtained opportunistically during field campaigns at 06:00 hrs to minimise evaporation. All samples were then transferred into 15 ml Qorpak clear french square bottles with black phenolic polycone lined caps, labelled appropriately with the sample type, location and date and stored at Gobabeb Research and Training Centre until shipment to the Indiana University-Purdue University Indianapolis (IUPUI) Ecohydrology Lab for isotope analysis. HYSPLIT (*60*) was used to track the origin of the five precipitation events captured during the study period (fig. S1).

Practical considerations for dew and fog water collection

The major difference between fog and dew formation is the dependence of dew formation on the receiving substrate surface attaining or falling below ambient dew point temperature while fog formation is independent of the receiving substrate surface. The receiving surface of the dew collector has a high thermal conductivity, which facilitates dew condensation on the dew collector compared to the fog collector using polyethylene mesh. Therefore when water was collected in the dew collector and absent from the fog collector this input was classified as dew. Because interception by objects projecting into the fog droplet stream is the dominant avenue for fog deposition onto a surface, it is possible to collect appreciable amounts of fog in the dew collector. However, fog collectors are more efficient in harvesting this input, collecting significantly more fog water compared to dew collectors during fog events. Furthermore, fog water collected in the dew collector easily exceeds the theoretical dew maximum yield of 0.8 mm per night (*66*). Therefore when water was collected in both the dew and fog collectors and the dew collector had significantly more than 0.8 mm of input we classified this as fog and discarded the sample and collected that in the fog collector.

note S3. Wind direction and speed measurements.

Automatic wind measurements started in November 2015 therefore we made use of manual observations made three times daily at 08:00hrs, 14:00hrs and 20:00hrs. Kaseke *et al*. (*50*) shows that fog and dew moisture advected to the site lags behind that of a site (Kleinberg) west of Gobabeb Research and

Training Centre. Based on this, we made the assumption that relatively high wind speeds with a general westerly wind direction at 20:00hrs should give a general indication of the source of advective fog and dew observed at the study site. Kaseke *et al*. (*50*) also shows that dew formation at the site generally occurs between 04:00 – 07:00hrs, therefore we made the assumption that wind direction at 08:00hrs generally reflects the source of locally derived fog and dew and that the speed would be generally low. Because mixed fog is a combination of both the advected and local moisture we made the assumption that both observations at 20:00hrs and 08:00hrs were equally important thus we averaged the two (table S2). We acknowledge the uncertainty of the wind data due to lack of automatic instrumentation; however, we present this data as an additional line of evidence to verify our fog and dew classification (methods).

In general advective fog originated from the south-west (median 230°), mixed fog from west-south-west (median 260°) while radiation fog originated from south (median 180°) of the site. This data is generally consistent with expectations indicating advective and mixed fog have westerly origins (Atlantic Ocean) while radiation fog originates from a southerly direction consistent with the position of the river at the study site. Wind speeds attributed to advective fog (4.0 m/s) were higher than both those for mixed (3.8 m/s) and radiation fog, which is also consistent with expectation. In general, advective dew originated from the south-west (median 205°) while the locally derived dew originated from the south-east (median 166°) (table S2). We expected higher wind speeds would transport moisture to the site resulting in advective dew formation while locally generated dew would have slower speeds or calm conditions. The data generally supports this, 6.5 m/s vs 2.1 m/s for advective dew and locally generated dew, respectively (table S2).

table S1. Isotopic composition and d-excess of individual precipitation events captured during 2014–2015.

Sample ID	Date	$\delta^{18}O$ ‰	$\delta^{2}H$ ‰	$\delta^{17}O$ ‰	*d* ‰
Rain 1	11/02/2014	3.41	30.04	2.62	2.79
Rain 2	13/02/2014	5.28	43.79	3.26	1.58
Rain 3	03/01/2014	1.72	12.05	0.88	-1.72
Rain 4	04/01/2014	-2.63	-32.63	-4.11	-11.57
Rain 5	24/09/2014	3.05	10.37	1.49	-14.02

table S2. Isotopic composition and classification of individual fog, dew, groundwater, and river samples captured between 2014 and 2015. The wind direction (azimuth degrees) and speed (m/s) that may have influenced formation (note 3) are also shown.

ID	$\delta^{18}O$ ‰	$\delta^{2}H$ ‰	$\delta^{17}O$ ‰	Classification	Wind direction	Wind speed (m/s)	Date
F1	-1.5	-2.14	-0.62	Advective fog	130°	3.0	21-Sep-14
F2	-1.04	-1.12	-0.24	Advective fog	270°	4.0	2-Jan-14
F3	-0.52	+3.01	+0.03	Advective fog	230°	5.0	25-Nov-14
F4	0.00	+10.79	+0.25	Advective fog	180°	5.0	24-Oct-14
F5	-0.07	+7.69	+0.22	Advective fog	270°	3.0	4-Oct-14
F6	-0.49	+4.41	-0.08	Advective fog	180°	5.0	24-Oct-14
F7	-1.94	-7.34	-1.23	Advective fog	230°	5.0	23-Oct-14
F8	-0.94	-0.74	-0.69	Advective fog	230°	2.0	3-Oct-14
F9	-0.98	-0.78	-0.52	Advective fog	130°	6.0	9-Sep-14
F10	-0.33	+5.19	+0.41	Advective fog	230°	2.0	3-Oct-14
F11	-1.08	-2.61	-0.06	Advective fog	180°	6.0	29-Dec-14
F12	-0.97	-0.32	-0.43	Advective fog			
F13	-0.72	+1.04	+0.08	Advective fog	230°	4.0	12-Sep-14
F14	-0.94	-1.11	-0.56	Advective fog	230°	3.0	5-Mar-14
F15	+0.45	+10.42	+0.51	Advective fog			

F16	-0.84	-4.18	-0.81	Mixed fog	180°	3.5	10-Sep-14
F17	-0.43	-0.77	-0.27	Mixed fog	270°	4.5	11-Jan-15
F18	-0.02	+3.35	+0.12	Mixed fog	315°	4.5	7-Jan-15
F19	+0.09	+2.63	+0.08	Mixed fog	335°	6.5	25-Aug-14
F20	+0.54	+9.60	+0.45	Mixed fog	230°	3.5	23-Sep-14
F21	+0.25	+6.00	+0.42	Mixed fog	270°	4.0	23-Mar-14
F22	-1.47	-7.36	-0.86	Mixed fog	140°	3.0	4-Mar-14
F23	-0.82	-2.63	-0.26	Mixed fog	250°	3.0	1-Apr-14
F24	-0.55	-1.35	-0.40	Mixed fog	180°	4.5	25-Jun-14
F25	-1.01	-5.19	-0.80	Mixed fog	270°	3.5	22-Feb-14
F26	+3.89	+22.16	+1.10	Radiation fog (rain)	310°	3.0	29-Sep-14
F27	+3.20	+19.14	+1.84	Radiation fog (rain)	310°	5.0	18-Aug-14
F28	+4.26	+26.54	+2.30	Radiation fog (rain)			
F29	+0.88	+5.56	+1.08	Radiation fog (groundwater)			
F30	+0.98	+7.23	+0.81	Radiation fog (groundwater)	50°	3.0	6-Mar-14
F31	+0.14	+0.15	+0.39	Radiation fog (groundwater)	50°	0.0	22-Jan-14
F32	-0.78	-4.70	-0.21	Radiation fog (groundwater)	360°	4.0	21-Feb-14
F33	-1.31	-10.66	-1.10	Radiation fog (groundwater)	90°	2.0	4-Aug-14
F34	+6.98	+34.05	+3.56	*Radiation fog (groundwater)	130°	2.0	20-Jan-14

F35	+11.42	+56.28	+6.51	*Radiation fog (groundwater)	310°	3.0	29-Nov-14
F36	+10.99	+55.19	+6.16	*Radiation fog (groundwater)	360°	7.0	16-Dec-14
F37	+4.32	+22.67	+2.29	*Radiation fog (groundwater)			
F38	+9.64	+57.90	+4.74	*Radiation fog (groundwater)			
D1	-1.74	-10.73	-1.65	Groundwater sourced dew			28-Dec-13
D2	-2.9	-13.93	-2.07	Groundwater sourced dew	130°	3.0	31-Jul-14
D3	+0.30	+3.20	-0.33	Groundwater sourced dew	50°	2.0	10-Dec-14
D4	-6.76	-28.19	-4.11	Groundwater sourced dew	360°	2.0	16-Oct-14
D5	-3.34	-14.16	-2.10	Groundwater sourced dew	180°	2.0	30-Jul-15
D6	+0.34	+3.08	-0.24	Groundwater sourced dew	130°	2.0	4-Aug-15
D7	+0.88	-10.06	-0.23	Shallow soil sourced dew	230°	2.0	2-Aug-14
D8	+1.75	+1.38	+0.43	Shallow soil sourced dew	90°	2.0	4-Aug-14
D9	+2.24	+1.06	+0.51	Shallow soil sourced dew	130°	2.0	5-Aug-14
D10	-5.51	-37.21	-3.32	Shallow soil sourced dew	230°	1.0	7-Aug-14
D11	-1.17	-19.36	-1.13	Shallow soil sourced dew			
D12	+3.13	+5.60	+1.19	Shallow soil sourced dew	130°	3.0	31-Jul-15
D13	+0.04	+6.68	-0.91	Advective dew	180°	6.0	25-Jul-14
D14	-0.07	+8.72	-0.68	Advective dew	230°	7.0	26-Jul-14
D15	-6.01	-15.62	-3.71	Advective dew			

G1	**-9.12**	**-65.38**	**-4.89**	**Shallow groundwater**			**6-Aug-14**
G2	**-8.98**	**-61.05**	**-4.44**	**Shallow groundwater**			**24-Jul-14**
G3	**-9.62**	**-64.72**	**-4.44**	**Shallow groundwater**			**5-Aug-15**
G4	**-9.62**	**-64.73**	**-4.40**	**Shallow groundwater**			
G5	**-6.67**	**-46.37**	**-3.59**	**Deep groundwater**			**5-Aug-14**
G6	**-6.93**	**-45.40**	**-3.26**	**Deep groundwater**			**6-Aug-15**
R1	**-11.49**	**-85.11**	**-6.51**	**River water**			**23-Dec-13**

Note: 1. * refers to samples that show evidence of evaporative enrichment.

2. wind speed and direction are manual measurements

3. the river flowed for two days from the 23^{rd}–25^{th} December 2013

table S3. Monthly rainfall that could have influenced fog and dew formation at the Gobabeb Research and Training Centre during the observation period.

	Rainfall amount (mm)		
Month	**2013**	**2014**	**2015**
January	**0**	**2.16**	**4.93**
February	**0**	**7.92**	**0**
March	**21.70**	**0**	**0**
April	**0**	**2.69**	**0**
May	**0**	**0.36**	**0**
June	**0**	**0**	**0**
July	**0**	**0**	**0**
August	**0**	**4.4***	**0.44**
September	**17.97**	**0.64**	**0**
October	**0**	**0**	**0.17**
November	**0**	**0.13**	**0**
December	**1.71**	**0**	**8.66**

Note: *recorded in a weather station 13 km from the study site.

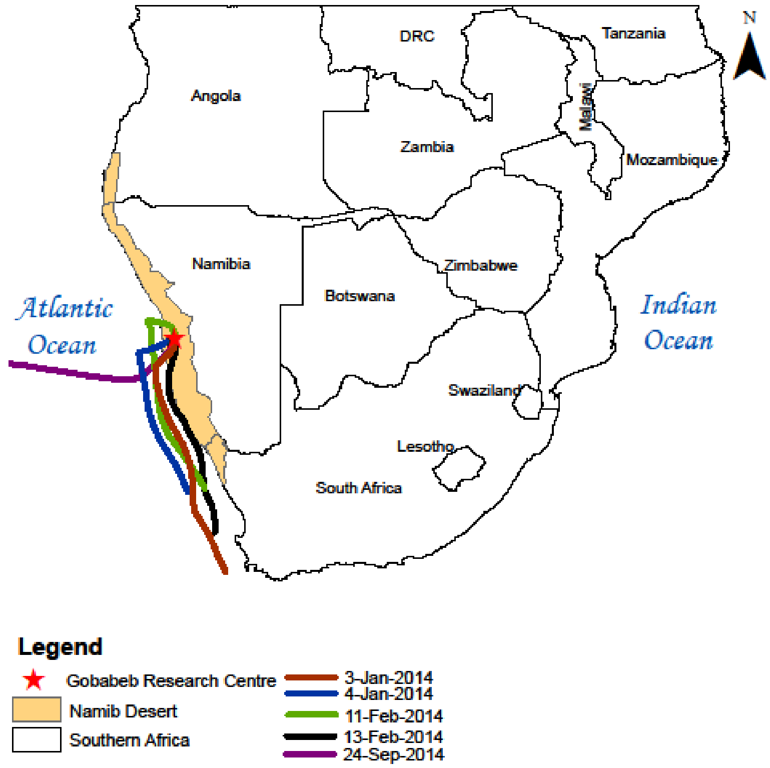

fig. S1. Hybrid Single-Particle Lagrangian Integrated Trajectory model (*60*) of 48-hour backward trajectory analysis of the five precipitation events captured at the Gobabeb Research and Training Centre during the observation period.