

Supporting Information (SI)

The entire lifetime of a distinct double-diffusive staircase in crater Lake Nyos, Cameroon

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The Supporting Information consists of three figures, Fig. SI-1 to Fig. SI-3, as well as eight tables, Table SI-1 to Table SI-8, listing the characteristics of the identified DD layers for the eight dates of CTD profiling used in this study. There are two formats:

- (i) Table SI-1, Table SI-7 and Table SI-8 concern the profiles before and after the quasi-steady expansion phase of the DD zone. These are the build-up and the decay phases with limited information as the interfaces were not identifiable;
- (ii) Table SI-2 to Table SI-6 concern the profiles of the quasi-steady expansion phase of the DD zone. They include information on the interfaces, the T-steps between layers and the upward heat fluxes.

See the footnotes of the tables for more details.

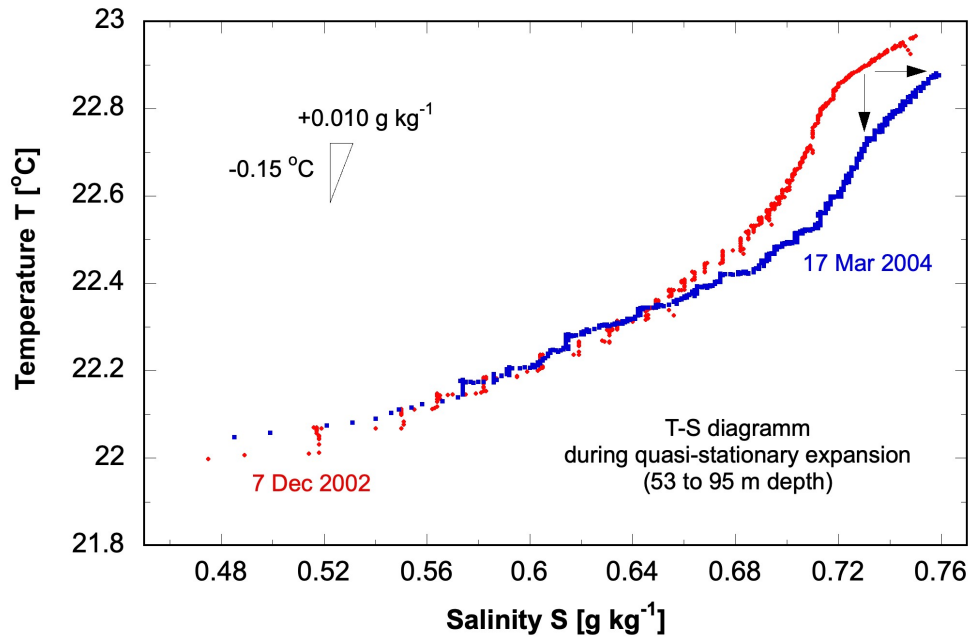


Figure SI-1 T-S diagram for the period of the quasi-stationary expansion from Dec 2002 (red) to Mar 2004 (blue). Upper right shows the lower end of the DD zone (95 m depth), indicating very small changes in S of $\sim 0.010 \text{ g kg}^{-1}$, while temperature decreased by $\sim 0.15 \text{ K}$ over the 466 days. The lower left shows the upper end of the DD zone (53 m depth) with negligible changes of temperature as the effect of cooling due to subduction compensates the effect of warming from the heat flux from below.

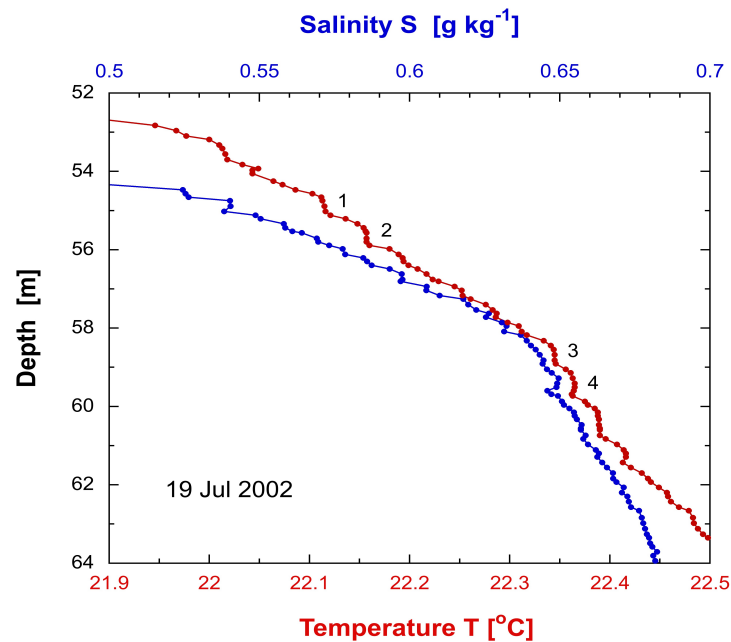


Figure SI-2 Profiles of temperature and salinity on 19 Jul 2002. Labelled are four not yet well-developed layers (Table SI-1) indicating the first signs of the up-coming establishment of the DD layering shown in Figs. 4 and 5.

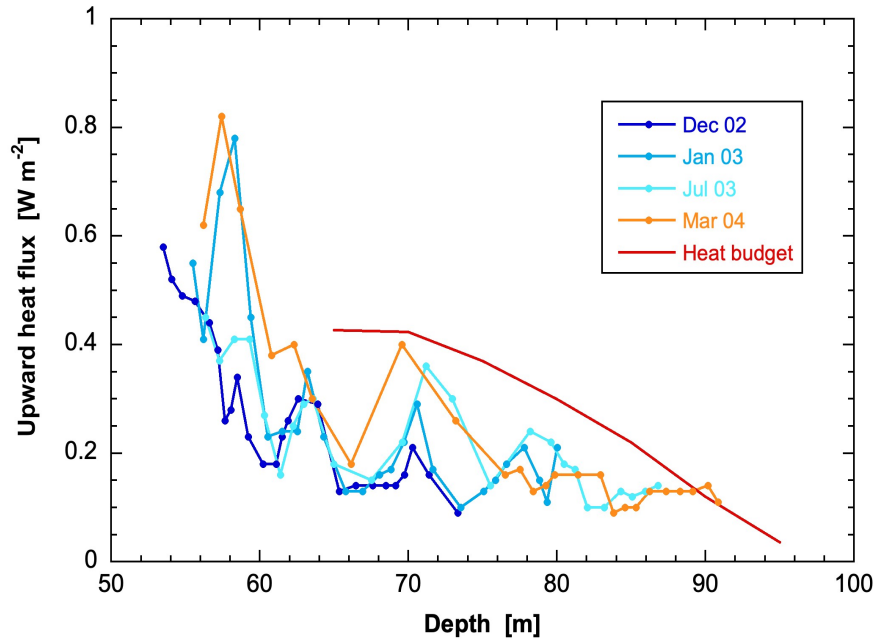


Figure SI-3 Upward heat flux within the DD zone for the period of quasi-steady expansion (Dec 2002 to Mar 2004). The four lines with dots represent the heat fluxes based on Eq. (6) (Tables SI-2 to SI-5) for the four CTD profiles taken during this period. The red full line, which results from the heat balance, shows the heat flux in the lower part of the DD zone for the same period. The uncertainty of the T trend, dT/dt , does not allow to calculate the heat flux accurate enough in the upper DD zone. The estimates mirror different expressions of the upward heat fluxes and are not expected to be equal (see text for explanations). The vertical divergence with weaker in-fluxes at the lower end of the DD zone and stronger out-fluxes at the upper end are characteristic for all five curves.

Table SI-1 Staircase characteristics for 19 Jul 2002

Layer number	Average depth (m)	Layer thickness H (m) ⁽¹⁾	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK)	Average S (g L ⁻¹)	Heat flux (W m ⁻²)	R_ρ (-) ⁽²⁾	Stability N ² (10 ⁻⁴ s ⁻²) ⁽²⁾
1	54.88	0.46	-	22.115	23	0.652			
2	55.65	0.45	-	22.157	21	0.690	-	1.98	1.13
3	59.42	0.68	-	22.362	10	0.706		1.86	0.91
4	60.44	0.78	-	22.389	10	0.706			

Footnote:

⁽¹⁾ Thickness of layers only, without interfaces (different definition in Table SI-2 to SI-5)

⁽²⁾ N² and R_ρ calculated from Eqs (4) and (5), based on gradients between layers (even when interfaces not identified).

Table SI-2 Staircase characteristics for 7 Dec 2002

Layer number	Average depth (m)	Layer thickness H (m) ⁽¹⁾	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK) ⁽²⁾	Average S (g L ⁻¹)	T-step ΔT (mK) ⁽³⁾	Heat flux (W m ⁻²) ⁽³⁾	R_ρ (-) ⁽³⁾	Stability N ² (10 ⁻⁴ s ⁻²) ⁽³⁾
1	53.01	0.19	0.15	21.999	0.1	0.475				
2	53.49	0.77	0.08	22.061	11	0.517	47	0.58		30
3	54.06	0.46	0.25	22.093	17	0.550	40	0.52	5.60	6.7
4	54.76	0.87	0.18	22.142	7	0.564	42	0.49	4.30	4.1
5	55.63	0.94	0.26	22.178	11	0.582	42	0.48	4.89	4.1
6	56.59	0.86	0.11	22.226	12	0.604	39	0.44	5.10	4.7
7	57.18	0.41	0.15	22.255	12	0.619	31	0.39	5.11	5.6
8	57.65	0.50	0.16	22.289	9	0.631	24	0.26	4.62	4.6
9	58.05	0.33	0.12	22.302	7	0.634	24	0.28	3.86	3.7
10	58.48	0.48	0.13	22.336	8	0.646	29	0.34	3.41	2.8
11	59.21	0.99	0.15	22.361	3	0.649	23	0.23	2.48	0.91
12	60.22	1.09	0.16	22.383	11	0.655	20	0.18	2.28	0.63
13	61.10	0.57	0.04	22.401	7	0.660	18	0.18	2.77	1.2
14	61.50	0.28	0.05	22.419	7	0.664	20	0.23	2.55	1.7
15	61.91	0.53	0.10	22.441	7	0.668	24	0.26	3.17	2.2
16	62.57	0.83	0.14	22.467	9	0.675	29	0.30	3.54	1.7
17	63.88	1.74	0.13	22.498	8	0.682	31	0.29	2.74	0.72
18	65.35	1.21	0.05	22.517	3	0.685	15	0.13	2.19	0.33
19	66.46	1.08	0.19	22.529	3	0.687	16	0.14	2.24	0.40
20	67.61	1.11	0.17	22.549	3	0.690	16	0.14	2.47	0.55
21	68.47	0.66	0.19	22.562	7	0.693	15	0.14	3.23	0.98
22	69.15	0.69	0.18	22.578	4	0.695	15	0.14	2.63	0.91
23	69.73	0.49	0.15	22.593	5	0.697	16	0.16	2.66	1.1
24	70.27	0.57	0.28	22.610	4	0.698	20	0.21	3.86	1.6
25	71.39	1.66	0.32	22.634	3	0.701	20	0.16	3.91	0.85
26	73.33	2.14	0.35	22.649	2	0.702	13	0.09	3.18	0.39
27	74.79	0.91		22.660	3	0.703				

Footnote:

¹⁾ Thickness H includes layer thickness H_L plus half of the interfaces H_I on both sides (except for the uppermost layer where only one interface is defined)

²⁾ T' is standard deviation within the mixed layer.

³⁾ ΔT = temperature difference between neighbouring layers. Upward heat flux based on Eq (6) using ΔT and H. R_ρ and N² (Eqs. 4, 5) based on interface gradients.

Table SI-3 Staircase characteristics for 9 Jan 2003

Layer number	Average depth (m)	Layer thickness H (m)	Interface thickness below layer (m) ⁽¹⁾	Average T (°C)	Fluctuations T' in layer (mK) ⁽¹⁾	Average S (g L ⁻¹)	T-step ΔT (mK)	Heat flux (W m ⁻²)	R_ρ (-)	Stability N ² (10 ⁻⁴ s ⁻²)
1	54.13	0.87	1.05	22.080	9.1	0.517				
2	55.49	1.03	0.34	22.152	1.0	0.579	48	0.55	6.34	5.7
3	56.19	0.87	0.71	22.175	3.3	0.593	37	0.41	4.79	3.5
4	57.32	1.17	0.62	22.226	2.5	0.620	57	0.68	4.18	4.0
5	58.30	0.89	0.74	22.290	7.0	0.649	61	0.78	3.34	3.2
6	59.39	1.19	0.43	22.348	1.5	0.667	42	0.45	2.55	1.3
7	60.54	1.13	0.52	22.373	1.5	0.673	24	0.23	2.20	0.63
8	61.51	0.92	0.64	22.397	3.4	0.678	24	0.24	2.86	1.0
9	62.52	0.96	0.44	22.421	1.6	0.685	25	0.24	2.79	1.2
10	63.21	0.50	0.31	22.446	9.0	0.693	30	0.35	2.60	1.2
11	64.29	1.75	0.88	22.481	1.5	0.700	26	0.23	2.35	0.63
12	65.76	1.07	0.56	22.498	0.8	0.703	15	0.13	1.91	0.24
13	66.93	1.36	0.38	22.511	1.3	0.705	16	0.13	1.52	0.17
14	68.06	0.87	0.48	22.530	1.6	0.707	18	0.16	2.10	0.48
15	68.83	0.65	0.63	22.547	1.4	0.710	18	0.17	2.23	0.61
16	69.70	1.16	0.70	22.565	0.6	0.712	23	0.22	2.13	0.68
17	70.59	0.59	0.51	22.593	4.7	0.716	26	0.29	2.36	0.84
18	71.64	1.565	0.69	22.618	0.5	0.719	20	0.17	2.26	0.41
19	73.51	2.11	0.58	22.634	0.4	0.720	14	0.10	2.37	0.25
20	75.07	0.98	0.43	22.645	0.9	0.721	15	0.13	2.11	0.33
21	75.85	0.63	0.45	22.664	1.7	0.723	15	0.15	1.76	0.35
22	76.59	0.89	0.92	22.676	1.2	0.727	19	0.18	2.19	0.54
23	77.79	1.49	0.55	22.703	3.9	0.726	23	0.21	2.44	0.69
24	78.82	0.55	0.75	22.722	1.4	0.727	16	0.15	2.28	0.60
25	79.33	0.40	0.31	22.734	3.6	0.728	11	0.11	2.65	0.72
26	80.02	1.49	1.50	22.745	5.8	0.729	24	0.21	2.23	0.53
27	81.85	1.47		22.782	3.8	0.731				

Footnote: Same footnotes as in Table SI-2.

⁽¹⁾ Interface thicknesses and T' fluctuations overestimated as CTD profile was collected at too low vertical resolution.

Table SI-4 Staircase characteristics for 16 Jul 2003

Layer number	Average depth (m)	Layer thickness H (m)	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK)	Average S (g L ⁻¹) ⁽¹⁾	T-step ΔT (mK)	Heat flux (W m ⁻²)	R_ρ (-)	Stability N ² (10 ⁻⁴ s ⁻²)
1	55.35	0.68	0.26	22.144	1.4					
2	56.35	1.12	0.19	22.196	2.3	-	41	0.45		19
3	57.27	0.84	0.26	22.226	2.2	-	33	0.37		9.1
4	58.27	1.09	0.29	22.263	1.9	-	38	0.41	7.83	5.9
5	59.30	0.96	0.30	22.302	1.8	-	37	0.41	6.79	4.9
6	60.32	1.05	0.50	22.337	1.4	-	27	0.27	7.20	3.7
7	61.37	1.14	0.40	22.356	1.3	-	18	0.16	7.28	2.8
8	62.24	0.53	0.22	22.374	1.2	-	23	0.25	4.45	2.3
9	62.95	0.89	0.20	22.402	1.0	-	28	0.29	3.34	2.2
10	63.58	0.50	0.43	22.430	0.9	-	26	0.30	4.54	2.1
11	64.98	2.15	0.31	22.455	0.8	-	22	0.18	6.83	1.5
12	67.51	2.94	0.26	22.474	0.7	-	19	0.15	4.89	0.76
13	69.59	1.28	0.35	22.494	0.7	-	23	0.22	2.57	0.46
14	71.18	1.89	0.45	22.521	0.8	-	37	0.36	2.78	0.90
15	72.94	1.51	0.21	22.567	2.2	-	31	0.30	3.30	0.75
16	75.52	3.74	0.18	22.583	0.9	-	20	0.14	4.00	0.52
17	78.21	1.71	0.37	22.607	1.1	-	27	0.24	2.22	0.37
18	79.60	0.96	0.27	22.637	0.6	-	23	0.22	2.02	0.48
19	80.47	0.82	0.24	22.653	1.0	-	19	0.18	2.24	0.65
20	81.22	0.66	0.38	22.674	0.6	-	18	0.17	2.64	0.84
21	82.05	0.96	0.09	22.689	1.1	-	12	0.10	3.81	0.78
22	83.18	1.39	0.29	22.698	0.9	-	13	0.10	2.80	0.47
23	84.28	0.78	0.19	22.714	0.7	-	15	0.13	1.34	0.12
24	85.06	0.80	0.21	22.727	0.9	-	13	0.12	1.82	0.30
25	85.95	0.96	0.27	22.741	3.5	-	15	0.13	1.76	0.31
26	86.80	0.71	0.26	22.758	1.3	-	15	0.14	2.37	0.61
27	87.50	0.72		22.771	3.3	-				

Footnote: Same footnotes as in Table SI-2.

⁽¹⁾ No absolute salinity S, as conductivity sensor malfunctioned.

Table SI-5 Staircase characteristics for 17 Mar 2004

Layer number	Average depth (m)	Layer thickness H (m)	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK)	Average S (g L ⁻¹)	T-step ΔT (mK)	Heat flux (W m ⁻²)	R_ρ (-)	Stability N ² (10 ⁻⁴ s ⁻²)
1	55.41	0.53	0.22	22.176	1.6	0.574				
2	56.20	1.07	0.48	22.205	1.8	0.592	52	0.62	2.56	1.9
3	57.42	1.35	0.69	22.280	1.2	0.615	67	0.82	3.11	2.7
4	58.68	1.21	0.95	22.340	6.1	0.643	55	0.65	4.29	2.5
5	60.78	2.51	0.40	22.391	0.9	0.665	40	0.38	3.84	1.5
6	62.29	1.02	0.66	22.421	2.2	0.674	37	0.40	3.86	1.8
7	63.53	1.04	0.18	22.465	1.3	0.692	29	0.30	4.25	1.1
8	66.15	4.62	0.62	22.479	0.9	0.695	25	0.18	2.71	0.32
9	69.57	2.00	0.37	22.514	1.0	0.704	41	0.40	3.30	0.61
10	73.18	5.18	0.20	22.561	1.3	0.713	33	0.26	4.13	0.68
11	76.51	1.55	0.23	22.580	0.6	0.715	19	0.16	2.50	0.30
12	77.53	0.51	0.16	22.598	0.7	0.717	17	0.17	3.16	0.89
13	78.40	1.21	0.40	22.614	1.8	0.721	16	0.13	2.53	0.63
14	79.26	0.56	0.17	22.630	1.5	0.722	15	0.14	2.32	0.61
15	79.85	0.65	0.25	22.643	3.3	0.724	16	0.16	2.93	0.67
16	81.42	2.47	0.27	22.663	2.0	0.725	20	0.16	2.49	0.44
17	82.94	0.60	0.19	22.683	0.9	0.727	16	0.16	2.46	0.46
18	83.80	1.03	0.14	22.695	1.1	0.728	12	0.09	2.16	0.38
19	84.57	0.60	0.17	22.706	0.7	0.729	11	0.10	1.94	0.31
20	85.31	0.85	0.24	22.717	1.4	0.730	12	0.10	2.52	0.50
21	86.24	1.02	0.16	22.730	1.7	0.732	15	0.13	2.78	0.60
22	87.35	1.17	0.16	22.747	0.8	0.734	16	0.13	3.30	0.82
23	88.29	0.76	0.16	22.762	1.8	0.737	14	0.13	3.43	0.89
24	89.14	0.96	0.33	22.776	2.1	0.739	15	0.13	3.06	0.76
25	90.16	0.91	0.20	22.792	1.0	0.742	15	0.14	3.22	0.92
26	90.85	0.63	0.11	22.807	0.6	0.744	12	0.11	2.80	0.76
27	91.47	0.51		22.816	1.9	0.746				

Footnote: Same footnotes as in Table SI-2.

Table SI-6 Staircase characteristics for 11 Aug 2004

Layer number	Average depth (m)	Layer thickness H (m)	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK)	Average S (g L ⁻¹)	T-step ΔT (mK)	Heat flux (W m ⁻²)	R_ρ (-)	Stability N ² (10 ⁻⁴ s ⁻²)
1	62.23	5.51	2.59	22.369	6.5	0.684	199			
2	67.35	6.75	4.30	22.475	3.8	0.731	97	0.95	3.25	7.4
3	75.82	7.51	0.63	22.562	2.9	0.753	54	0.45	2.43	0.32
4	80.01	0.85	0.65	22.598	0.5	0.757	17	0.16	2.67	0.41
5	81.06	1.10	0.52	22.619	0.8	0.758	18	0.16	2.67	0.69
6	81.98	1.12	1.20	22.633	0	0.760	24	0.23	3.06	0.71
7	84.33	2.80	0.41	22.667	1.1	0.766	21	0.16	3.86	0.74
8	86.49	0.55	0.24	22.684	0.7	0.768	9	0.07	2.38	0.29
9	87.06	0.67	0.49	22.692	0.3	0.769	10	0.08	2.83	0.58
10	87.88	0.85	0.49	22.703	0	0.771	13	0.11	2.89	0.64
11	88.77	0.97	0.50	22.718	0.9	0.772	17	0.15	2.54	0.61
12	89.78	0.98	0.33	22.736	1.1	0.774	17	0.16	2.16	0.51
13	90.61	0.76	0.40	22.752	0.5	0.776	16	0.14	3.06	0.83
14	94.15	0.55	0.15	22.813	0.4	0.787	7	0.05	4.50	

Footnote: Same footnotes as in Table SI-2.

Table SI-7 Staircase characteristics for 9 Mar 2005

Layer number	Average depth (m)	Layer thickness H (m)	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK)	Average S (g L ⁻¹)	Heat flux (W m ⁻²)	R_ρ (-)	Stability N ² (10 ⁻⁴ s ⁻²)
1	63.35	2.92	-	22.367	9	0.669	-		
2	68.64	7.17	-	22.471	6	0.699	-	4.47	1.3
3	75.35	4.84	-	22.564	2	0.716	-	4.16	0.93
4	83.74	3.78	-	22.666	2	0.728	-	3.61	

Footnote: Same footnotes as in Table SI-1.

Table SI-8 Staircase characteristics for 27 Oct 2005

Layer number	Average depth (m)	Layer thickness H (m)	Interface thickness below layer (m)	Average T (°C)	Fluctuations T' in layer (mK)	Average S (g L ⁻¹)	Heat flux (W m ⁻²)	R_ρ (-)	Stability N ² (10 ⁻⁴ s ⁻²)
1	71.43	6.18	-	22.462	3.6	0.734	-		1.8
2	78.73	6.91	-	22.559	7.9	0.758	-	5.93	1.7

Footnote: Same footnotes as in Table SI-1.