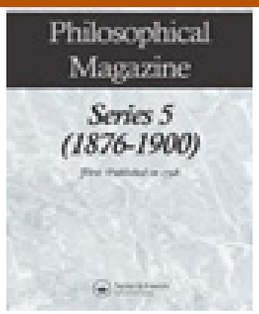

Philosophical Magazine Series 5

ISSN: 1941-5982 (Print) 1941-5990 (Online) Journal homepage: http://www.tandfonline.com/loi/tphm16

XXXV. On the motion of glaciers

R.H. Koch & Fr. Klocke

To cite this article: R.H. Koch & Fr. Klocke (1880) XXXV. On the motion of glaciers , Philosophical Magazine Series 5, 9:56, 274-277, DOI: 10.1080/14786448008626838

To link to this article: http://dx.doi.org/10.1080/14786448008626838

Published online: 28 Apr 2009.

XXXV. *On the Motion of Glaciers.*
By R. H. Koch *and* Fr. Klocke*.

THE measurements hitherto made upon glacier-motion have either been only approximative determinations of the annual or daily *mean* velocity, or have been executed for the purpose of showing that the motion of glaciers corresponds with that of liquids; while investigations upon the actual course of this downward motion are wanting—whether, namely, it proceeds continuously in the same direction, or whether it is discontinuous, stoppages or even reversals of the motion taking place. From the observations made by M. Pfaff on the névé† the latter is probable even for the motion of glaciers.

Our investigations were limited to the observation of a point of the surface in a vertical plane parallel to the longitudinal direction of the glacier; the measuring of the lateral motion, and the motion of the deeper layers of the glacier, as well as observations during the night, were for the time excluded. Nevertheless, from the facts which have up to the present time been observed, it can already be concluded that the motion of a glacier is not at all uniform; for one and the same point may now move toward the mountain, now toward the valley, now ascend, now descend. It was further found that two points of the surface, distant from 50 to 60 metres from one another, can move in different, nay, in opposite directions.

The method chosen for the observations was that employed by M. Pfaff, and already used for other purposes. Two scales, one perpendicular to the other, were fixed upon the glacier so that the one was vertical and the other horizontal; their movements were observed on the cross-threads of a firmly placed telescope. The number of scale-divisions travelled over by the cross-threads gave then directly the horizontal and vertical components of the motion‡.

The examinations were made in the days from the 28th of August to the 6th of September, on the west side of the Morteratsch glacier. The observing-station was about 1½ kilometre distant from the lower principal extremity of the glacier. This situation was selected on account of the firm ground

* Translated from a separate impression, communicated by the authors, from Wiedemann's *Annalen*, 1879, vol. viii. pp. 661–666.

† *Abh. d. math.-phys. Classe der k. bayer. Akademie der Wissenschaften*, xii. Abth. 2, p. 105 *seqq.* 1876.

‡ The telescopes and tripod stands were kindly intrusted to us by the Director of the Freiburg Mathematical Cabinet, Prof. Lindemann, and by the Director of the Physical Institute, Prof. Warburg.

which it presented for the setting-up of the instrument (a condition not everywhere fulfilled), and also because at this spot the glacier formed a tolerably continuous mass, without any longitudinal, transverse, or marginal fissures worth mentioning; here, too, was the best prospect of being free from accidental anomalies of the motion.

In setting up the scales we proceeded in the following manner. The stake on which the scales were fixed was sunk into the ice to the depth of half a metre, and a mound of ice 30 centims. in height raised around it, in order as much as possible to prevent melting away of the ice at this spot. The mound was covered with earth and stones; so that the whole resembled one of the well-known earth-mounds. A stake thus planted was perfectly stable and could be employed for the observations for about four days. The reading-telescopes were set up firmly on the bank, and sufficiently sheltered from the action of the sun. The readings were nearly always executed by both of us, each independently of the other. The scales were graduated in half-centims.; millimetres were estimated. The uncertainty of the estimation amounted, with unfavourable illumination or with trembling of the image in consequence of unequal heating of the intervening air, to about 0·1 centim.; but it sometimes rose to 0·2 centim.; in normal circumstances, however, the readings of both observers were perfectly concordant.

In order to convince ourselves that the motions observed on the scales were not motions of the scales themselves, but really indicated the motion of the point in question of the glacier, near one of the signals a second was fixed in the ice, and so close to the first that both appeared in the field of the telescope. With this arrangement the observations showed that both pairs of scales moved in close conformity to one another.

We select as evidence for our above-expressed assertion the observations of the 3rd and 4th of September, because on those days the motions of the glacier took place under different conditions: the 3rd was all bright and cloudless, while the sky during the forenoon of the 4th (the time of the greatest motion) was covered with cumulus clouds and the glacier was only at times exposed to the sunshine.

The times in the following Table are reckoned from midday to midday. The numbers give the horizontal and vertical motions in centimetres. + denotes a downward motion, — a motion upward (uphill). The readings took place halfhourly during the period from 6 A.M. to 6 P.M.

From Sept. 2, 23h 30m to	Scale I. Distance from the margin of the glacier 35 m. Distance from the telescope 93 m. Horizontal motion.	Scale I. Vertical motion.	Scale II. Distance from the margin of the glacier 90 m. Distance from the telescope 148 m. Horizontal motion.	Scale II. Vertical motion.	State of the sky.
Sept 3 0h	±0·0	+0·2	+1·0	−0·1	Sept. 3 clear.
0h —m to 0h 30m	+1·0	+0·6	+0·6	+0·2	
0 30 „ 1 —	−0·2	±0·0	+0·5	+0·3	
1 — „ 1 30	+0·1	±0·0	+0·5	+0·2	
1 30 „ 2 —	+0·2	+0·3	+0·6	+0·3	
2 — „ 3 —	+0·1	+0·5	+0·9	+0·6	
3 — „ 4 —*	+0·1	−0·1	+0·3	+0·0	
4 — „ 5 —	−0·4	+0·2	±0·0	±0·0	
5 — „ 6 —	+0·8	+0·1	−0·3	±0·0	
6 — „ 18 —	+2·3	−1·0	−6·2	−1·0	
18 — „ 19 —†	+1·1	−0·1	−0·1	+0·3	
19 — „ 19 30	+0·6	+0·7	−2·1	+0·2	
19 30 „ 20 —	−0·7	−0·3	+1·3	+0·8	
20 — „ 20 30	+2·3	+0·2	+2·1	−3·3	
20 30 „ 21 —	+0·7	−0·3	+1·7	+3·5	
21 — „ 21 30	−1·6	+1·2	+0·4	+0·8	
21 30 „ 22 —	−0·1	+1·1	+1·6	+1·0	
22 — „ 22 30	+0·7	+0·8	+2·3	+0·3	
22 30 „ 23 —	+1·8	−0·4	−0·9	−1·0	Cumuli, occasional glimpses of sunshine.
23 — „ 23 30	−0·8	−0·2	+0·6	−0·2	
23 30 „ 24 —	−0·5	+0·2	+0·8	+0·4	
Sept. 4					
0 — „ 0 30	−0·3	±0·0	+0·2	±0·0	Sept. 4 clear.
0 30 „ 1 —	−0·2	±0·0	+0·3	±0·0	
1 — „ 1 30	±0·0	+0·1	+0·8	+0·2	
1 30 „ 2 —	±0·0	−0·1	±0·0	−0·1	
2 — „ 3 —‡	±0·0	+0·4	+0·7	+0·4	
3 — „ 4 —	−0·2	+0·3	+0·2	+0·1	
4 — „ 5 —	.....	.....	−0·2	±0·0	
5 — „ 6 —	.....	.....	−0·2	±0·0	
6 — „ 18 —	+2·1	−2·2	−6·9	+0·3	
18 — „ 18 30§	+0·6	+0·2	−0·3	+0·1	
18 30 „ 19 —	+0·8	−0·3	−0·5	−0·1	
19 — „ 19 30	+0·9	−0·1	+3·3	+0·7	
19 30 „ 20 —	+0·6	−0·2	−2·5	+0·5	
20 — „ 20 30	+0·4	+0·4	+0·9	+0·5	
20 30 „ 21 —	+0·2	+0·8	+0·6	+0·2	
21 — „ 21 30	+0·1	+0·3	+0·8	+0·1	
21 30 „ 22 —	−0·1	+0·4	+1·1	+0·7	
22 — „ 22 30	−0·3	+1·3	+0·6	+0·4	
22 30 „ 23 —	−0·2	−0·2	+0·8	+0·2	
23 — „ 23 30	−0·6	−0·1	+0·4	−0·3	
23 30 „ 24 —	±0·0	+0·2	+0·6	−0·2	

* Shortly before 4 h. the scales enter the shadow of the mountains; about 4 h. 30 m. the entire glacier lies in the shadow.

† Shortly before 19 h. the irradiation of the glacier by the sun commences.

‡ Shortly before 4 h. the scales enter the shadow of the mountains; about 4 h. 30 m. the whole of the glacier lies in the shadow.

§ Shortly before 19 h. the irradiation of the glacier by the sun commences.

Let us first consider the motion of scale I. (distant about 35 metres from the margin of the glacier). During the afternoon the point moves but little, horizontally as well as vertically, and that in the positive direction. In the later hours P.M. this motion constantly diminishes, and at last entirely ceases. After this, during the night (6^h–18^h), the point moved vertically upwards, and horizontally towards the valley. As soon as the sun's irradiation commences (about 19^h), absolutely irregular motions take place, which last till noon; then (from 0^h onward) again commence the slow downward movements, and all is repeated in like manner.

With Scale II. (more towards the middle of the glacier) the course of the movements is similar. During the afternoon a tolerably uniform motion takes place both horizontally and vertically, in the positive direction; at about 4^h the glacier comes to a stand. But in the night, in the horizontal direction a considerable retrograde movement came in (the opposite of what took place with Scale I.), possibly amounting to 9·9 centims., while the vertical motion almost always remained but feeble. Then, as in the case of Scale I., with the commencement of the solar irradiation begin the irregular movements, which last on till midday, and thereupon pass over again into the regular downward motion.

Even at a point situated about 1 kilometre further up the glacier similar movements of the ice were ascertained. Briefly, at all points observed by us the maximum of the variations of the motions falls in the forenoon, commencing with the irradiation of the glacier by the sun. Thus, everywhere (at least on the west side of the glacier) the sum of the motions during the night was a going back toward the mountain.

The observations of the 4th of September, finally, show that with a less intense irradiation the motions of the glacier become correspondingly less considerable. The motion of the glacier was similar on the other days of observation.

From the observations which have at present been made it is not yet possible to perceive which of the more or less probable hypotheses would explain the actual motion of the ice. We intend to continue these labours on a larger scale at the commencement of the coming summer.

Freiburg im Breisgau, Sept. 17, 1879.