VI. *On the anomaly in the variation of the magnetic needle as observed on ship-board. By* William Scoresby, *jun. Esq. Communicated by the Right Hon. Sir* Joseph Banks, *Bart. G. C. B. P. R. S.*

Read February 4, 1819.

THE anomalies discovered in magnetical observations conducted on ship-board, were usually attributed to the imperfection of the azimuth compass, until Captain FLINDERS, in his modest and enlightened paper on this subject, published in the Philosophical Transactions, suggested that they were probably owing to the concentration of the magnetic influence of the iron, made use of in the construction of the ship. The truth of this suggestion, and the accuracy of his observations, have since met with full confirmation, and his practical rules founded thereon have received additional support, from the "Essay" of Mr. BAIN "on the variation of the Compass," published last year.

As I have been materially anticipated by Mr. BAIN, in a series of observations on the variation of the compass,* which

* The azimuths contained in the following table were taken, either by the needle of a theodolite, or by a compass fitted up at sea, for the purpose, with a card made extremely light, and a bar fastened edgewise to it, by two brass screws, *a a*, as in the annexed sketch. The compass being small, the card light, and the needle very powerful, owing to the thickness of its ends, it performed considerably better than an expensive azimuth compass of larger dimensions, which indeed was so sluggish and erroneous in its indications, that I could make no good use of it.

I conducted on the coast of Spitzbergen, in the years 1815 and 1817, it will be unnecessary here to enter into the detail of these observations or enlarge upon the probable cause of the anomalies observed; it may be sufficient to give a table of the most accurate of my observations, and annex to it the few general inferences which were drawn from it, during the voyage in which most of the observations were made, together with such remarks on each inference as seemed to me calculated for its elucidation. I shall, however, just premise, that I am not unconscious of the great liability to error in observations of this kind, and of the variety of causes (arising out of the unequal distribution of iron in different ships, whereby numerous local attractions are formed) which contribute to the multiplication of those errors: it is, therefore, with the greatest deference that I submit these deductions, particularly as I conceive it will require observations to be made under a vast variety of circumstances, and in many different vessels, before *correct* and satisfactory conclusions can be drawn. It is *only* then as a step towards facilitating such general conclusions, the importance of which to our maritime concerns is so obvious, that I presume to offer these observations and remarks.

Table of Magnetical Observations, made on board of the ship Esk, in voyages to the Greenland or Spitzbergen Whale Fishery; with a view to investigate the laws by which the anomalies, or errors, discovered in the indications of the Mariner's Compass on ship-board, are regulated.

No.	Date.	Latitude.	Longitude.	Time. [*Ch.* Chronometer.] [*Ap.* Apparent.]	Sun's Azimuth. Observed.	Sun's Azimuth. True.	Variation. Apparent or observed.	Variation. Supposed true.	Errors produced in the observed variation by the attraction of the ship on compass needle. Errors attributed to the position of the ship's head. [Diff. of col. VIII. & IX.]	Differences produced by a change in position of the ship's head. [From col. VIII.]	Differences produced by a change in the position of the compass. [From col. VIII.]	Ship's head by binnacle compass.	Situation of the compass by which the Sun's azimuth was observed. [Col. VI.]
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	
	1815.												
1	June 30	77° 19′ N.	12° 15′ E.	*Ap.* Noon.	S. 7° W.	South.	7° W.	21° W.	14° 0′	- - -	31° 0′	S. by E.	Starboard side of the main deck.
2	- -	- -	- -	- -	38	South.	38	21	17 0			S. by E.	Larboard ditto.
3	- -	- -	- -	- -	21	South.	21	21	0 0	- -	17 0	S. by E.	Centre of main hatches.
	1817.												
4	June 6	77 56	0 15 W.	*Ch.* 6h 54′ P.M.	N. 36 W.	N. 73° W.	37	32.30	4 30	8° 15′	- -	W. ½ S. East.	On the binnacle amidships of the quarter-deck, 10 ft. from taffrail.
5	- -	- -	- -	7 28	35¾	64 30	28.45	32.30	3 45				
6	- -	- -	- -	7 28	45	64 30	19.30	32.30	13 0	- -	9 15	East.	Compass on a stand on the middle of the quarter-deck, 6 feet abaft capstern spindle.
7	- -	- -	- -	6 54	27½	73 0	45.30	32.30	13 0	26 0	- -	W. ½ S.	
8	- -	- -	- -	7 32	33	63 30	30.30	32.30	2 0	- -	- -	E. ½ S.	Starboard side of the main-deck.
9	- -	- -	- -	7 33	31	63 15	32.15	32.30	0 15	- -	1 45	E. ½ S.	Larboard side of the main-deck.
10	June 19	77 36	2 35 W.	*Ap.* 11 38	S. 25 W.	S. 5 30 E.	30.30	36. 0	5 30	- -	- -	E. by S.	On the binnacle, 10 ft. from taffrail.
11	- -	- -	- -	11 20	27	10 0	37. 0	36. 0	1 0	6 30	- -	N.	Ditto.
12	- -	- -	- -	12 3	34¾	S. 0 45 W.	34. 0	36. 0	2 0	3 0	- -	NE. ½ E.	Ditto.
13	—— 28	76 24	4 45 W.	*Ch.* 7 34	N. 46 W.	N. 68 11 W.	22.11	37. 0	14 49	- -	- -	NNE.	Starboard side of the main-deck.
14	- -	- -	- -	7 38	16½	67 11	50.41	37. 0	13 41	- -	28 30	NNE.	Larboard ditto.
15	July 16	76 6	0 30 W.	*Ch.* 6 33	60	79 54	19.54	33. 0	13 6	- -	-	South.	Starboard side of the main-deck.
16	- -	- -	- -	6 36	33	79 9	46. 9	33. 0	13 9	- -	26 15	South.	Larboard ditto.
17	- -	- -	- -	6 31	46	80 24	34.24	33. 0	1 24	- -	11 45	South.	Centre of main-hatches.
18	- -	- -	- -	6 44	53	77 9	24. 9	33. 0	8 51	- -	- -	South.	Centre of fore-hatches.
19	- -	- -	- -	6 43	41	77 24	36.24	33. 0	3 24	- -	12 15	South.	Larboard side fore-castle near the windlass end.
20	- -	- -	- -	6 41	70	77 54	7.54	33. 0	25 6	- -	28 30	South	Starboard ditto.

From these observations, and from the assistance afforded by the lucid remarks of Captain FLINDERS, the inferences which follow are deduced.

1. In the construction of every ship, a large quantity of iron being used, the portions thereof which have a perpendicular position, such as standard and hanging knees, the nails and bolts in the deck, the capstern spindle, flukes of the anchors (when at sea), chain-plates, iron stanchions and riders; the eye bolts, transom bolts, joint bolts, &c. of gun carriages, and possibly the upper surfaces of the guns themselves, &c. &c. have a tendency to become magnetical, the upper ends being *south* poles and the lower *north* poles, in this hemisphere, where the *north* end of the needle dips, but the contrary in the southern hemisphere, where the *south* end of the needle dips.

2. The combined influence of the iron distributed through all parts of the ship, seems to be concentred into a kind of magnetic *focus of attraction*, the principal south pole of which being upward in the northern hemisphere, is probably situated, in general, near the middle of the upper deck, but nearer to the stem than the stern.

Wrought iron having a much greater attraction for the magnetic needle than cast iron, the anchors, which usually lie about the bows, possess much more influence than guns; hence, the focus of attraction lies nearer to the bows than to the stern.

3. This focus of attraction so influences the compass needle, that it is subject to an *anomaly*, or variation from the true meridian, different from what is observed by a compass on shore; the north point of the compass being constantly drawn towards the focus of attraction, which appears to be a

south pole in north dip; and the south point being attracted in south dip, where the focus of attraction probably becomes a north pole.

The phenomenon of a ship appearing to lie nearer the wind when beating to the northward, with the wind at north, than when beating to the southward, with a southerly wind, was observed by my father at least 20 years ago, which phenomenon he attributed to the "attraction of the ship upon the compass;" and ever since the year 1805, I have been in the habit of allowing only 2 to $2\frac{1}{4}$ points variation on the passage outward to Greenland, with a northerly or north-easterly course, but generally 3 points variation on the homeward passage when the course steered was S. W. or S. W. b. W. Without this difference of allowance, a Greenland ship outward bound will be generally found to be to the eastward of the reckoning, and homeward bound will be even 4 or 5 degrees to the eastward of it.

4. This anomaly in the variation of the compass, occasioned by the attraction of the iron in the ship, is liable to change with every alteration in the dip of the needle, in the position of the compass, or in the direction of the ship's head.

If the intensity of the terrestrial magnetism be not equal in all parts of the globe, then the anomaly in the variation of the compass will be also liable to change with every alteration in the magnetic influence of the earth. This is a point of such importance, I conceive, in the science of magnetism, that I was very anxious to procure a dipping needle on my last voyage to Greenland, to ascertain whether the magnetism of the earth, by which the dipping needle is influenced, be not greater near the magnetic pole, than it is in England.

If it be equal, the oscillations of the same dipping needle would be performed, circumstances as to temperature and "local attraction" being the same, in equal spaces of time in both places; but if the magnetic power in either place be greater, the oscillations of the needle would there be quicker. The number of vibrations of a horizontal needle, performed in a certain space of time in Greenland, is to the number performed in an equal space of time in England as 5 to 6, each longer vibration in England being performed in 5 seconds, and in Greenland in 6. No alteration was observed in the time required for each vibration, whether the temperature was high or low, but I think in a low temperature the vibrations performed by the needle before it stopped were fewer.

5. The anomaly of variation bears a certain proportion to the dip of the needle, being greatest where the dip is greatest, diminishing as the dip decreases, and disappearing altogether on the magnetic equator.

Captain FLINDERS ascertained, that the medium error or anomaly for 8 points deviation of the Investigator's head, on either side of the magnetic meridian, was very nearly $\frac{1}{20}$ of the dip, .05 the decimal expression of which, he considered to be the common multiplier to the dip, for obtaining the radius of error at any situation in the southern hemisphere; and .053 to be the common multiplier, from England to the magnetic equator. This, however, can only be correct within certain limits, as on the magnetic pole, where the anomaly would probably be equal to the dip, or 90°, the decimal multiplier would require to be increased to 1.0. Hence it has been suggested, by an officer on board one of the vessels now in search of a north-west passage, that in those parts of the globe where the dip is 90°, the compass needle would pro-

bably always stand N. and S., by the attraction of the ship. This position clearly follows from the inference above, provided the compass be placed near the ship's stern in midships; but if placed as described in inference No. 8, the ship's head by the compass on the starboard side of the main deck, would always appear to be *east*, and on the larboard side *west*.

6. A compass placed near the stern, amidships of the quarter-deck, is subject to the greatest anomaly or deflection from the magnetical meridian, when the ship's course is about west or east; because the focus of attraction then operates at right angles to the position of the compass needle; but the anomaly disappears when the course is about north or south, because the focus of attraction is then in a line with, or parallel to, the compass needle, and consequently has no power to deflect it from its direct position. [See Observations, No. 4, 10, 11, and 12 of the prefixed table.]

This situation for the *binnacle* is deemed one of the best in the ship, and is very properly preferred. Being abaft the focus of attraction, the north point of the compass, in this magnetic hemisphere, is always attracted forward, and the errors at equal distances from the magnetic meridian, in the same dip, are alike in quantity both on easterly and westerly courses, and always towards the north; the correction, when applied to the apparent course, must therefore be towards the south, to give the true course steered. Thus in high northern latitudes, where the anomaly is great, (say 20°, or 10 degrees on each side of the magnetic meridian) a ship steering west by the compass 100 leagues, and then east 100 leagues, instead of coming to the place from whence she started, will be 104 miles to the southward of it.

7. The greatest anomaly with the compass in the position

last described, being ascertained by observation, the error on every other point of the compass may be easily calculated; the anomalies produced by the attraction of the iron in the ship, being found to be proportionate to the sines of the angles between the ship's head and the magnetic meridian.

Captain FLINDERS's rule is—As the sine of eight points (or radius) is to the sine of the angle between the ship's head and the magnetic meridian (or sine of the course reckoned from south or north) so is the anomaly found at east or west by observation, to the anomaly on the course steered; or, the anomaly on any other course being found by observation, the error on that position of the ship's head "would be to the error at east or west, at the same dip, as the sine of the angle between the ship's head and the magnetic meridian, to the sine of eight points, or radius."

8. A compass placed on either side of the ship's deck, directly opposite to, or abreast of, the focus of attraction, gives a correct indication on an east or west course, but is subject to the greatest anomaly when the ship's head is north or south; and being here nearer the focus of attraction, the anomaly is much greater than that observed on an east or west course with the compass placed in the binnacle near the ship's stern.

This inference is founded on observations, No. 1, 2, 3, 8, 9, 13, 14, 15, 16, and 17, of the prefixed table. The latter part of the inference, namely, that the greatest anomaly occurs here when the ship's head is north or south, is fully and uniformly established; but the former part rests only on the authority of observations No. 8 and 9, though it derived

additional support from several observations which I have excluded, because neither the sun, nor any other distant object, calculated for proving the accuracy of the observations and determining the clear effect of the "local attraction," was visible.

9. A compass placed within six or eight feet of a capstern spindle, or anchor, or other large mass of wrought iron, foregoes, in a great measure, the influence of the focus of attraction, and submits to that of the nearer body of iron.

The effect of this is various, according to the relative position of the compass and the iron. When the compass is placed directly *abaft* the body of iron, the influence is similar to, but greater than, that of the focus of attraction on a compass placed near the stern, as described in inference No. 6. [See Table of observations prefixed, No. 6 and 7.] When placed directly *before* it, the anomaly is similar in quantity, but has its sign reversed; and when placed on either side of the mass of iron, the influence corresponds more nearly with that of the focus of attraction on a compass placed in the sides of the ship opposite to it, as described in inference No. 8. A compass placed upon the *drum head* of the capstern, any where out of the centre, will have its north point so forcibly attracted by the upper end or south pole of the spindle, that the ship's head may be made to appear to be directed to any point whatever, at the pleasure of the experimenter. I have sometimes excited the astonishment of my officers by taking the binnacle compass and so placing it on the capstern head, that the ship has appeared to be steering a course directly contrary to that intended.

10. When the iron in a ship is pretty equally distributed

throughout both sides, so that the focus of attraction occurs in midships, a compass placed on the midship line of the deck (drawn longitudinally) will be free from any anomaly from one end of the ship to the other, when the course is north or south; but on every other course an anomaly will generally appear, increasing as the angle between the ship's head and the magnetic meridian increases, until the error is at a maximum, when the course is east or west.

The unequal distribution of iron in the ship, on board of which I made all my experiments, prevented the above effect from being realized. A blacksmith's shop was situated between decks, on the larboard side of the fore hatchway. It was lined with sheet iron, and besides the armourer's forge, vice, &c. contained a large quantity of other iron. The effect of this, together with the anchors, windlass necks, and other iron, was very remarkable on a compass placed in different parts of the deck near the foremast. [See Observations, 18, 19, and 20 of the prefixed table.]

11. As a compass placed on the midship line of the deck is subject to no anomaly fore and aft, in certain ships, on a north or south course [Inference No. 10], and as a compass in either side of the ship, opposite to the focus of attraction, shows no anomaly on a west or east course [Inference No. 8], the intersection of the line joining the two situations in opposite sides of the ship with the midship line traced fore and aft, will probably point out a situation directly over the top of the focus of attraction, where no anomaly on any course whatever will appear.

The Esk, in which I made my magnetical observations, had, as above stated, an armourer's forge near the larboard bow,

which with the varying position of large quantities of iron work, composing our whale fishing apparatus, contributed to vary this point where no anomaly is supposed to exist, and prevented me from ascertaining satisfactorily, at any time, its precise situation. I made indeed but very few observations with this view, and these I find neither establish nor refute the inference.

12. The anomaly of variation is probably the greatest in men of war, and in ships which contain large quantities of iron; but it exists in a very considerable degree also in merchantmen, where iron forms no part of the cargo, especially in high latitudes, where the dip of the needle is great.

WILLIAM SCORESBY, Jun.

Whitby, 3d November, 1818.