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The earth's geomagnetic field and geolocation of fish: first results of a new approach

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The concept

Today's EMF can be described through satellite measurement derived field models (IGRF - International Geomagnetic Reference Field, Figure 1.) The EMF is described by the magnetic elements, visualized in Figure 2. By choosing appropriate elements observed at a given locality, it is in principle possible to determine the geographic position of this locality by comparing these values with the IGRF (see Figure 1). By measuring and storing magnetic element-readings from a registration tag attached to a fish, recovering the tag will potentially enable tracking the migration pattern. The earth is immersed in its EMF – consequently the proposed concept may be applied globally.

Limitations of the concept:

- The EMF varies in a broad range of time-scales. For the present purpose, only short time variations are important (Figure 3). Registered magnetic element-readings must hence be corrected for these variations. For the north Atlantic, time variations of magnetic elements can be obtained from numerous magnetic observatories (Iceland, Norway, etc).
- The proposed concept will only be applicable in regions where isolines of magnetic elements are close to orthogonal. We have used Z and H, which are "suitable" off the coast of northern Norway/Barents Sea, but less so off the western coast of Norway (Fig. 1).

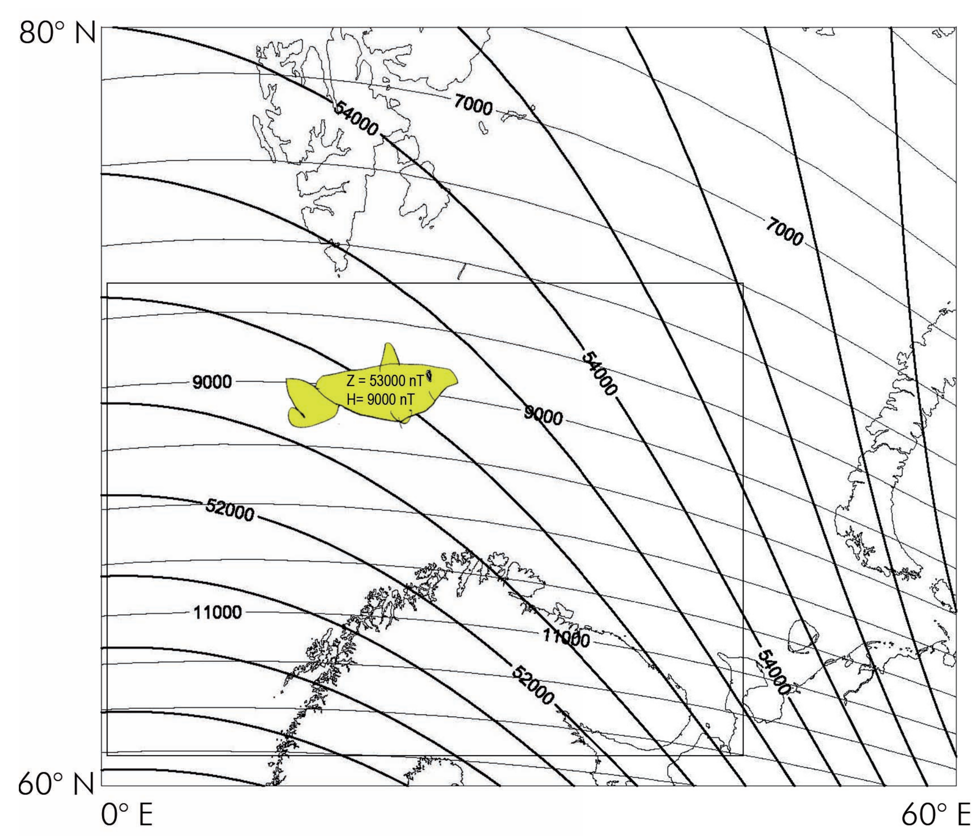


Figure 1: vertical component Z of the earth's magnetic field (bold lines) and horizontal component H (thin lines). Values for IGRF 2000. Units are nanoteslas. A data registration tag attached to the fish would measure Z = 53000 nT, H = 9000nT. The rectangle marks the limits of the area depicted in Figure 8.

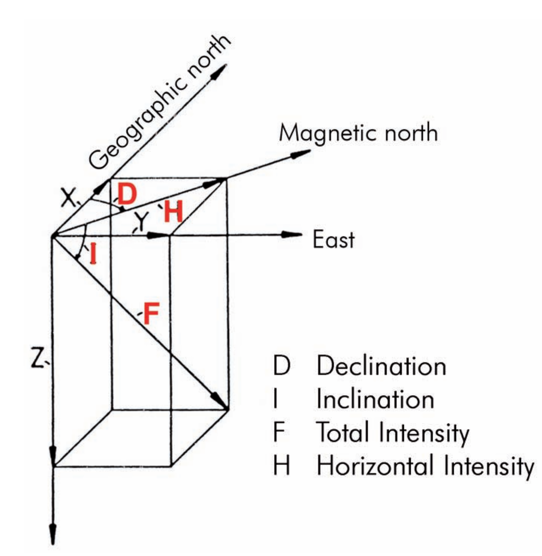


Figure 2: elements of the earth's magnetic field vector.

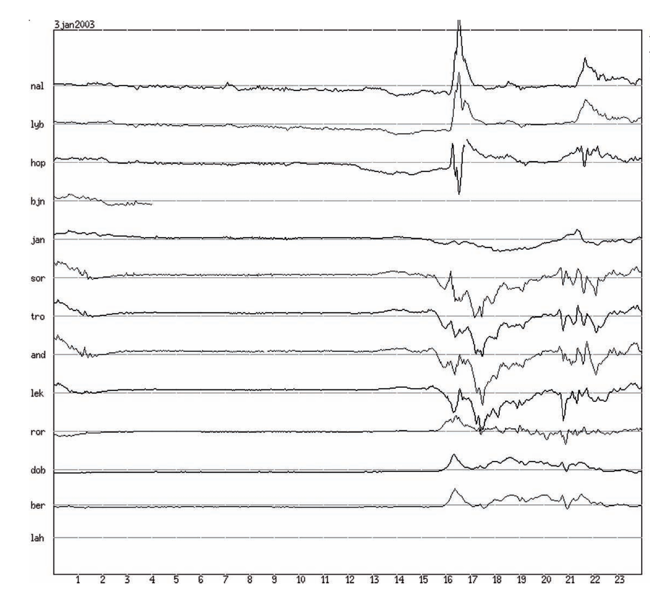


Figure 3: example for short period magnetic variations, here: Z component on 03.01.2003. Data from magnetic observatiories across Norway

Experimental work

Two prototypes of a newly developed data registration tag have been manufactured. The tags measure temperature, pressure, pitch and roll in three axes and the magnetic field in three axes. The analogue to digital converter resolution in the prototypes is 15 bit. Sensors are mounted in a cylindrical housing with 44mm length and 15mm diameter (see Figure 4)

Measurements were carried out inside at a dynamically auto-compensating three axes Helmholtz coil system at the Department of Earth Science (University of Bergen, see figure 5). The Helmholtz coil system produced a controlled magnetic environment to calibrate the tags. Magnetic elements were additionally measured with an Applied Physics 520 Fluxgate Magnetometer.

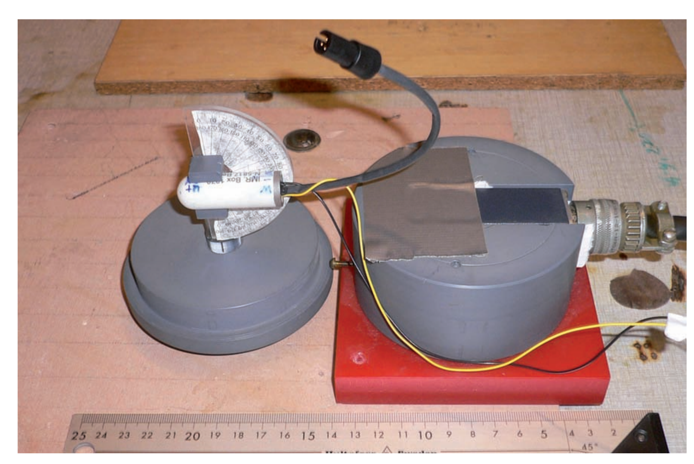
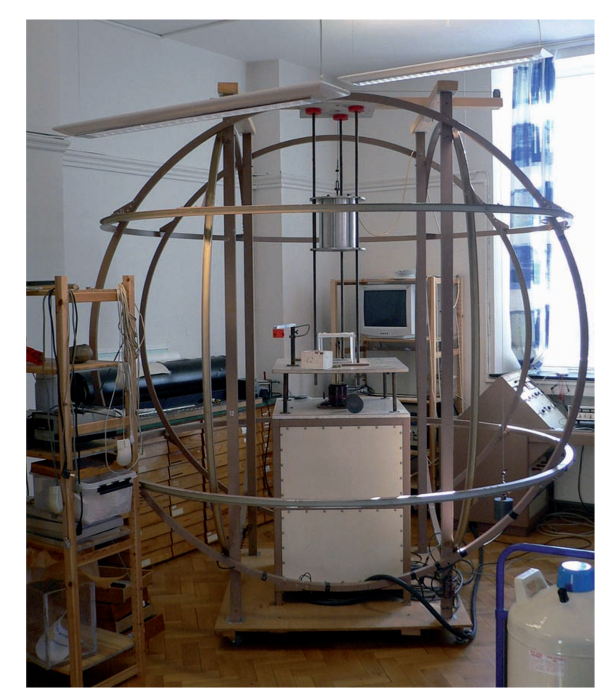


Figure 4: The data registration tag prototype (white cylinder to the left) and the fluxgate magnetometer probe (dark gray rectangular block to the right) during a measurement.

Figure 5: The Helmholtz coil system at the Department of Earth Science (University of Bergen). Coil diameter is 2.40m.



First results

Linearity

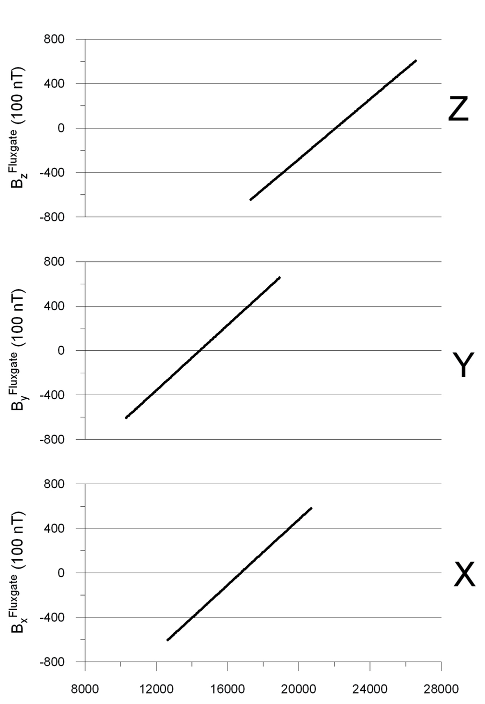


Figure 6: Measurement of the magnetic components (plotted along the x-axis) as exposed to the external coil-generated magnetic field (y-axes). Linearity is very good for all three components. Theoretical resolution (as deduced from the slope of the regression lines):

X: 14.74 nT / digit
Y: 14.64 nT / digit
Z: 13.90 nT / digit

Noise

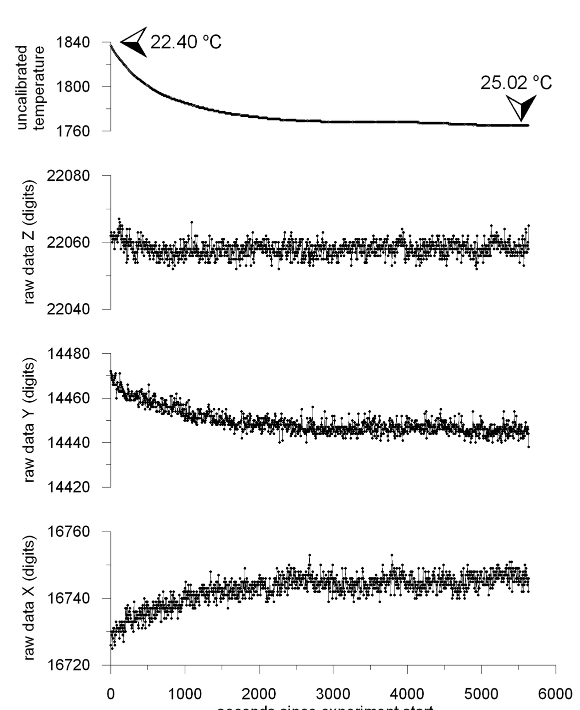


Figure 7: The noise level of the magnetic sensors lies in the range of about ±5 digits for each component, which corresponds to about ±75nT. The influence of thermal drift is apparent in the initial 2000 seconds of the experiment and shows that the magnetic sensors are very sensitive for temperature changes. The temperature dependency is linear (not shown here).

Accuracy in geolocation: a simulation.

To assess the accuracy in geolocation the following simulation was carried out:

1. On a path between Vestfjord (Lofoten area) and the Barents Sea, 10 geographic positions were chosen (black squares in Figure 8, insert table shows longitude, latitude).
2. H and Z values for these 10 positions were calculated from the IGRF-model .
3. Noise levels of the registration tag were added to H and Z (cf. Fig. 7).
4. The modified Z, H-values were compared to the IGRF-model yielding possible geographic positions of registrations of the 10 ("unknown") positions.

Results:

1. The precision in determination of the geographic positions is a function of the inherent data-noise and "suitability" of the EMF in the region in question.
2. Position determinations are more difficult to obtain and also more ambiguous where isolines of Z and H are close to parallel (southern part of the geographic region, see also Figure 1).
3. It is not possible to calculate a precise estimate of a geographic position, because it depends on the properties of the EMF.
4. If the presented (synthetic) data had been obtained from a registration tag attached to a fish, they would have reflected the migration pattern of this fish over longer distances. Note that e.g. the distance between original position 5 and 6 in Fig.8 (275km) is possible to resolve with the method.
5. Order of magnitude example: the long axis of the ellipse around position 5 is abound 465km.
6. A time series of candidate positions may further be filtered by making reasonable assumptions about fish swimming speed.

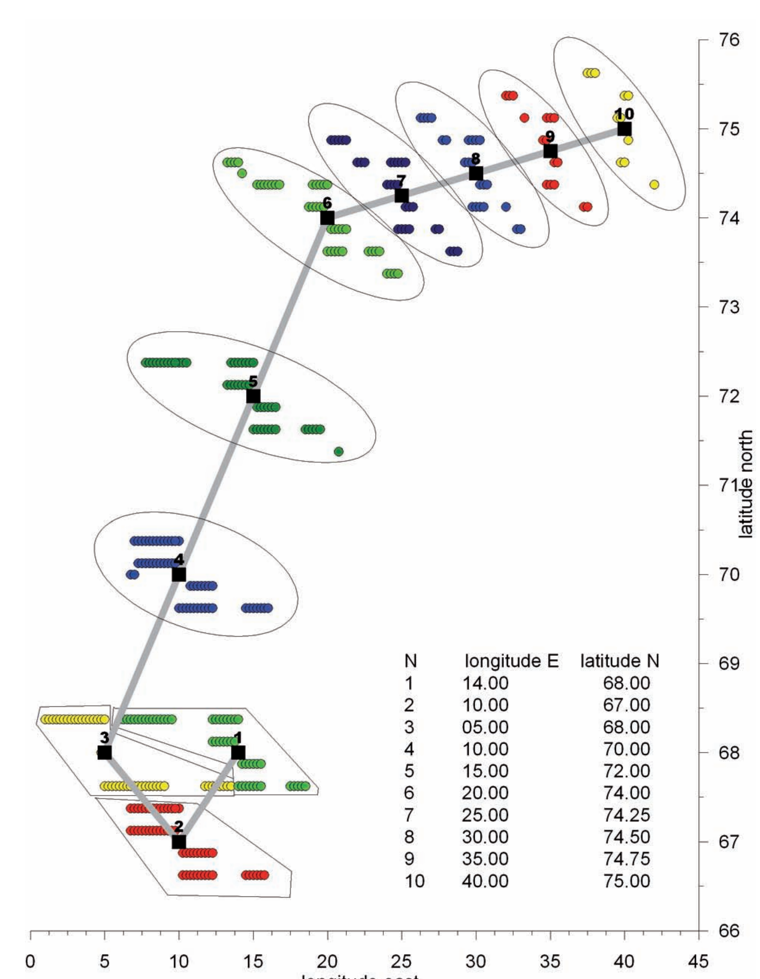


Figure 8: Results for a simulated fish migration between Vestfjord and the Barents Sea (for details, see text). Note that this is a plain longitude - latitude plot (no Mercator projection as in Figure 1).

Conclusion and future prospects

- The method can help to decipher broad scale migration in the geographic region chosen for this current study.
- For other geographic areas, other magnetic parameters than H and Z may be more suitable. Isoline maps of IGRF derived magnetic parameters will help to pick the best suited pair of magnetic parameters.
- Even though the method may eventually not work in your specific geographic region, magnetic data (e.g. total intensity F) may still help integrated models by including magnetic parameters as a new and valuable addition – note that we here perform a geolocation based on magnetic data alone.

Acknowledgements

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