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

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The concept

Today's earth's magnetic field (EMF) can be described through satellite measurement derived field models (Figure 1). By choosing appropriate magnetic elements observed at a given locality (we use Z and H), 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:

- The EMF varies in a broad range of time-scales. Here, only short time variations are important (Figure 3). Registered magnetic element-readings must hence be corrected for these variations prior to comparison with the IGRF. 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. Here we use Z and H, which are "suitable" off the coast of northern Norway / Barents Sea, but less so off the western coast of Norway (see Figure 1).

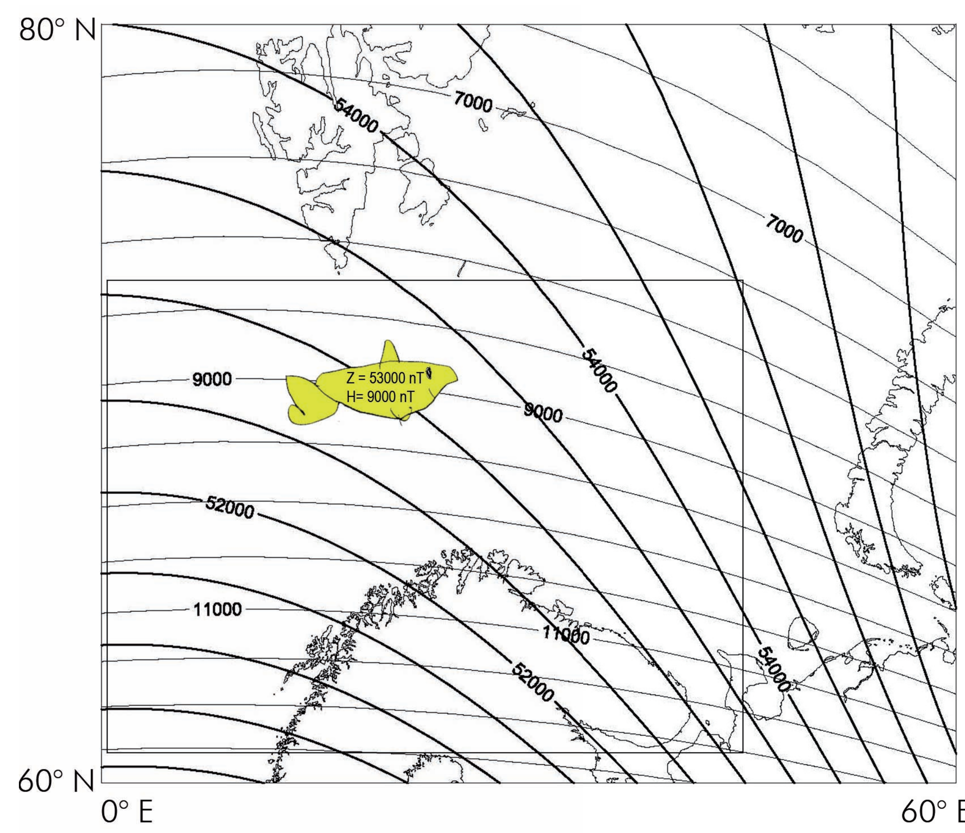


Figure 1: vertical component Z of the earth's magnetic field (bold lines) and horizontal component H (thin lines). Values for field model IGRF 2000 (IGRF - International Geomagnetic Reference Field). Units are nanoteslas. A data registration tag attached to the fish would measure Z = 53000 nT, H = 9000nT. For definition of magnetic elements, see Figure 2. The rectangle marks the limits of the area depicted in Figure 8.

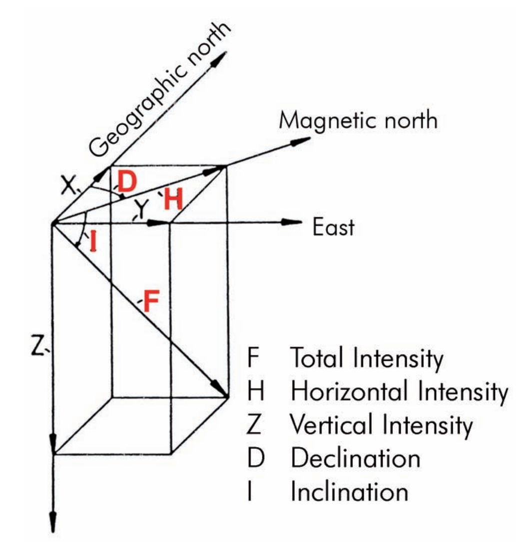


Figure 2: elements of the earth's magnetic field vector.

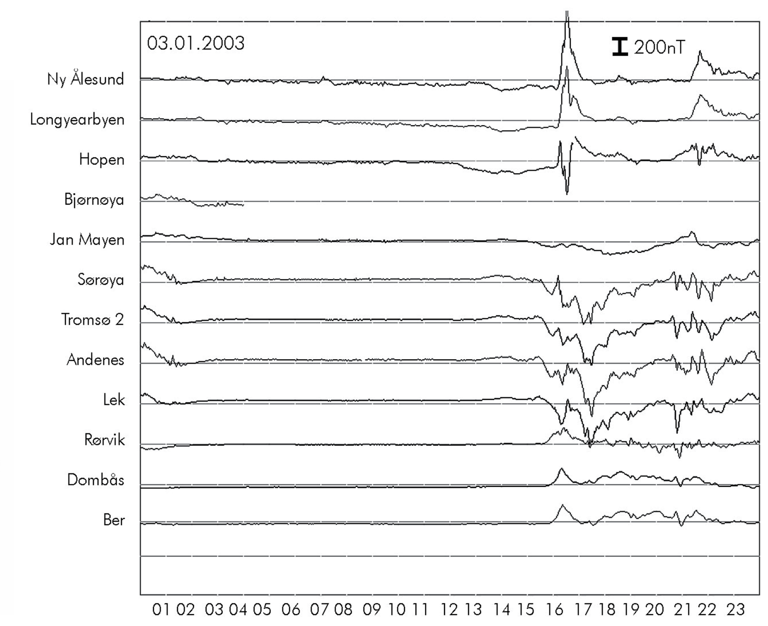


Figure 3: example for short period magnetic variations, here: Z component on 03.01.2003. Data from magnetic observatiories across Norway

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 (Figure 5), which produces a controlled magnetic environment to calibrate the registration tags. Magnetic elements were additionally measured with an Applied Physics 520 Fluxgate Magnetometer.

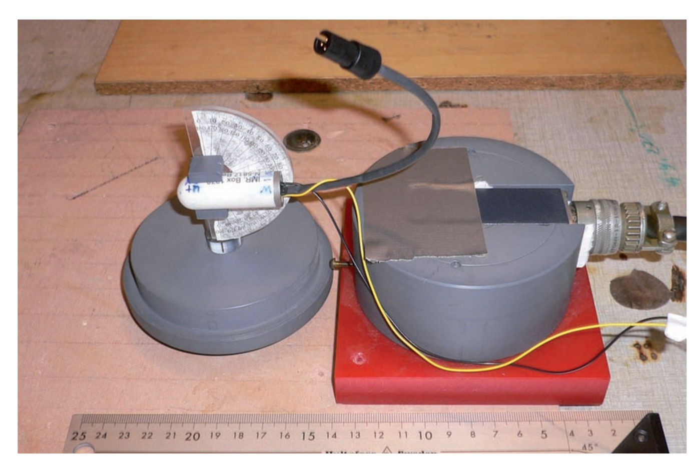
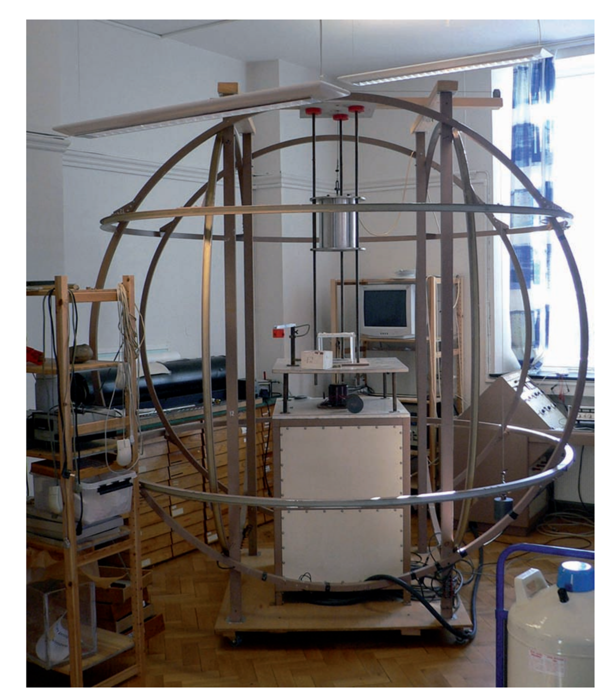


Figure 4: The data registration tag prototype (white cylinder to the left) and the fluxgate magnetometer probe (dark gray rectangular block to the right) during a measurement.

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



First results

Linearity

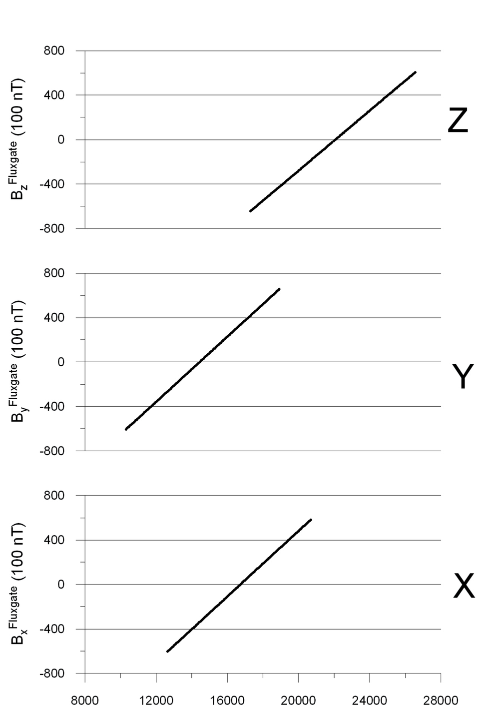


Figure 6: Uncalibrated magnetic components (x-axis) versus external coil-generated magnetic field (y-axes). The linearity is very good for all three components. Theoretical resolution (as deduced from the slope of the regression lines):

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

Noise

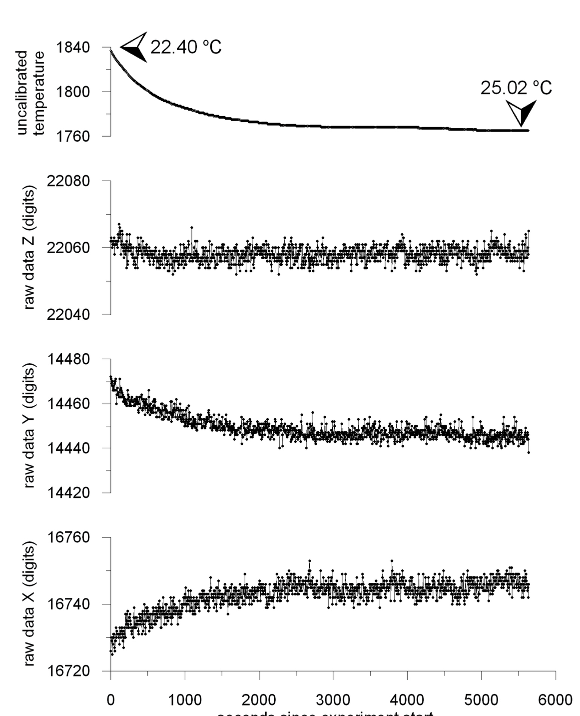


Figure 7: The noise level of the magnetic sensors is approximately ±5 digits for each component (corresponds to about ±75nT). Influence of thermal drift is apparent in the initial 2000 seconds of the experiment and shows that magnetic sensors are very sensitive to temperature changes. The temperature 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, location #1) and the Barents Sea (location #10), 10 geographic positions were chosen (open squares in Fig. 8).
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 (coloured dots in Fig. 8).

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 ambiguous where isolines of Z and H are close to parallel (southern part of the geographic region, cf. Fig. 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 locations #5 and #6 (275km) can be resolved with the method.
5. Order of magnitude example: the long axis of the ellipse around location #5 is about 465km.
6. A time series of possible candidate positions may further be filtered by making reasonable assumptions about fish swimming speed.

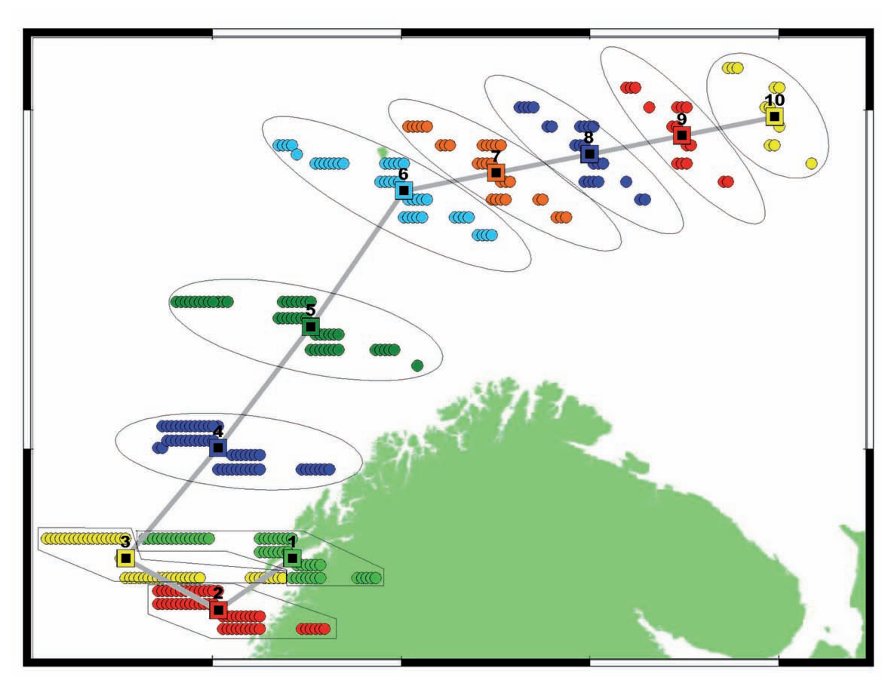


Figure 8: Results for a simulated fish migration between Vestfjord and the Barents Sea (for details, see text).

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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