From a Swarm of satellites to a flock of birds

Ciaran Beggan[1], Urška Demšar[2], Fernando Benitez[2], Jed Long[3]

[1] British Geological Survey, UK, [2] University of St. Andrews, UK, [3] Western University, Canada

Animal Navigation

Animal movement - from birds to bees to bats to baleen whales - has been a source of scientific study for centuries. The use of the geomagnetic field has long been postulated as a primary or secondary mechanism for long distance navigation in addition to the Sun, stars, visual landmarks, sound, smell or ocean salinity.

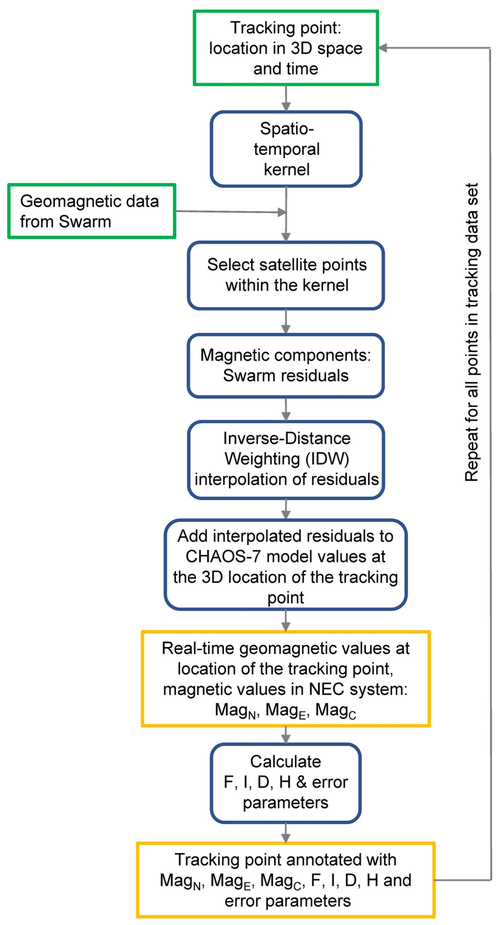
The development of small tracking devices since the 1990s has allowed location and orientation data to be collected from a range of different animals. The MoveBank.org database is an online platform where scientists worldwide manage, share, analyse and archive animal tracking and other sensor measurements. To date, there are billions of locations from thousands of taxa available.

Can we use tracking data to test if external magnetic field variation affects animal movement or migration?

Left: Stork with tracking tag including GPS, magnetic sensor, temperature and satellite data transmitter (from movebank.org)

Using Swarm and models to infer the local magnetic field variation

As there are so few geomagnetic observatories in remote locations, a key problem is to infer the magnetic field experienced by an animal at a particular time and location. We developed a new data fusion software tool *for non-geophysicists* to collate Swarm models and overpass data together to estimate the local magnetic conditions. The Python package called **MagGeo** [1] makes use of **vires-client** to collect Swarm measurements and append them to the MoveBank data. This allows researchers to make inferences on animal behaviour.



MagGeo

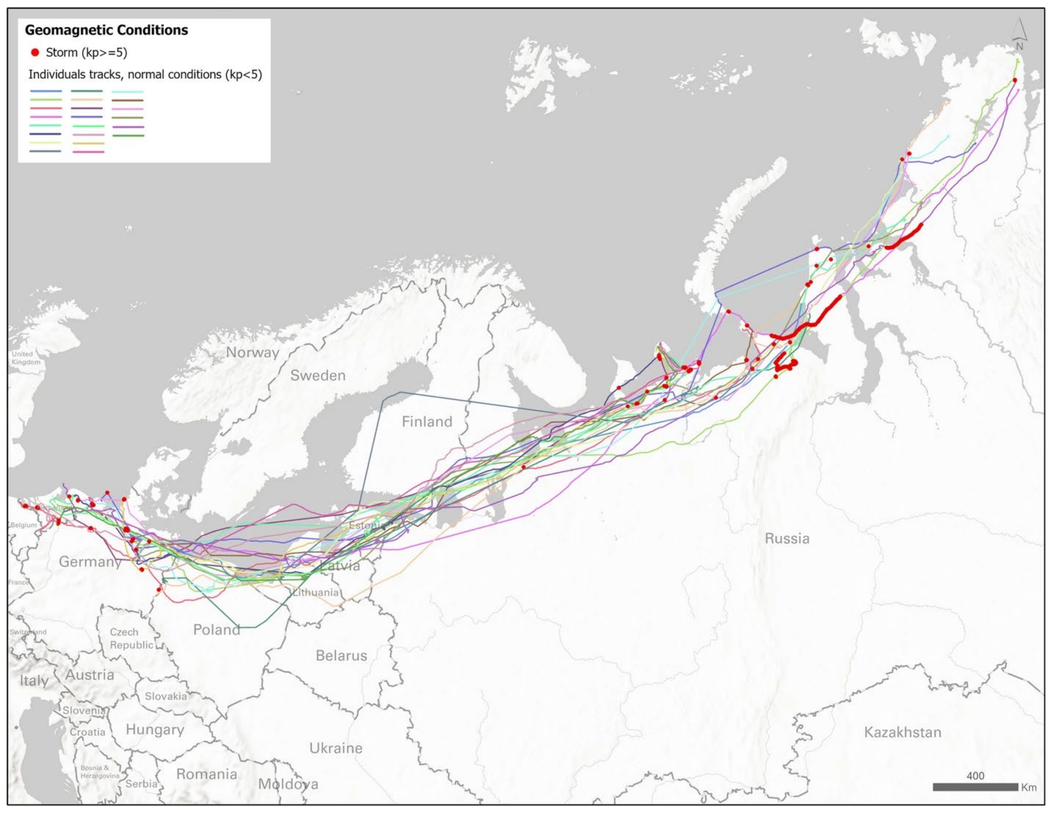
A general outline of the magnetic annotation method is shown. Green boxes show data inputs, blue boxes calculation steps and yellow boxes outputs. The workflow uses the CHAOS model of main and crustal field to isolate the external field (ionospheric and magnetospheric) within a certain time/distance kernel before appending it to the animal location data. Indices like Kp can be attached too.

[1] Benitez-Paez, F, VS Brum-Bastos, CD Beggan, JA Long, U Demšar (2021), Fusion of wildlife tracking and satellite geomagnetic data for the study of animal migration, 9, 3, 10.1186/s40462-021-00268-41

Are greater white-fronted geese affected by geomagnetic storms?

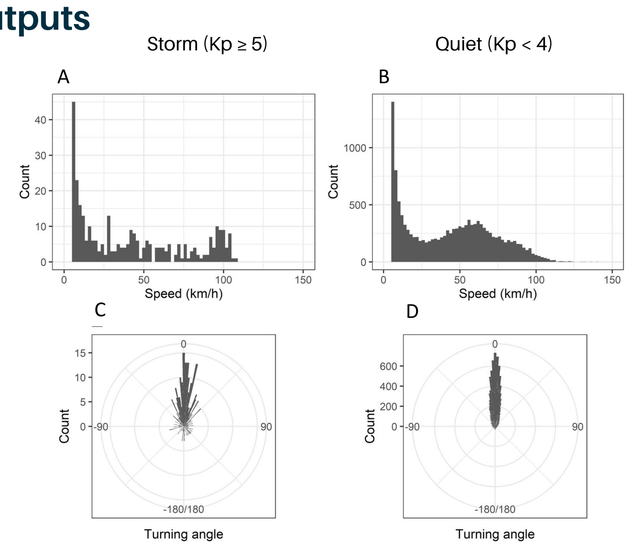
The North Sea population of the greater white-fronted geese (*Anser albifrons*) migrate between the Russian Arctic and northern Germany every Autumn. The hypothesis is that when geese encounter highly disturbed geomagnetic conditions (Kp ≥5) their movement is disturbed.

Data are from a single autumn migration (1 Aug 2017 to 15 November 2017) of 22 individuals with a total of 151,156 GPS locations, of which 13,697 points are of migratory movement (map below). We use tracks from individuals who migrated alone, to ensure independence. Serendipitously, a strong storm occurred on 7-8 Sept 2017, affecting northern Russia where the geese were situated at the same time. However, only 312 migratory measurements were made during the storm. Measurements where Kp ≥ 5 during flight are in red on the map.



Analysis using MagGeo outputs

Movement parameters during and outside of geomagnetic storms. Panels show the distribution of motion properties for storm (**left**) and quiet times (**right**). Panels **A** and **B** show distribution of speed during stormy conditions and during quiet conditions. Panels C and D show distributions of turning angle values during stormy and quiet conditions. In these two panels, the 0° reference is the bearing obtained from the previous and current GPS points.



There is some evidence of unusual movement/migratory behaviour during magnetic storms. Specifically, in (**A**) an increased rate of high-speed movements (~100 km/h) is observed and, even more interestingly, greater variation in turning angles (**C**) occur during high activity periods (Kp≥5) relative to quiet periods; this may indicate some level of disorientation.

Summary

- A new software tool (MagGeo) for animal movement researchers was created allowing access to Swarm data.
- During high geomagnetic activity, migratory geese were observed to fly more erratically and with more variable flight direction – albeit with a limited sample size.