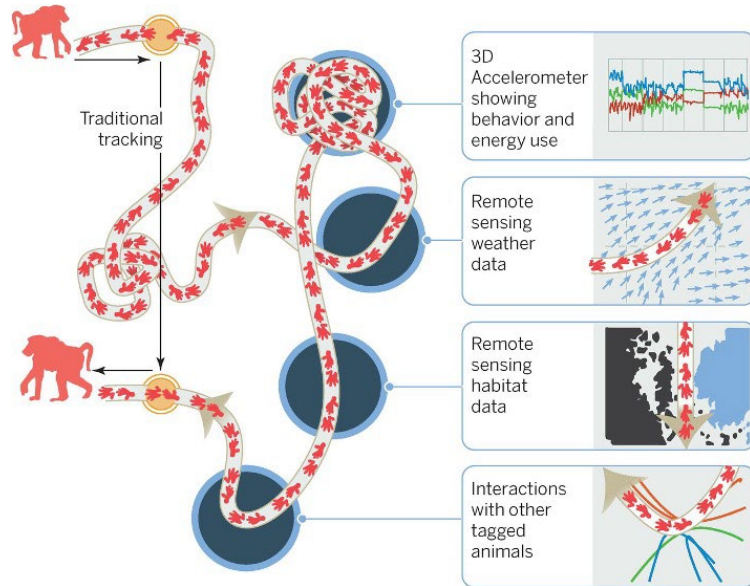


BioSpace25 - Biodiversity insight from Space
10 - 14 February 2025 | ESA-ESRIN | Frascati - Italy

MagGeo – A data fusion tool to link Earth's magnetic data from Swarm Mission to Wildlife GPS trajectories

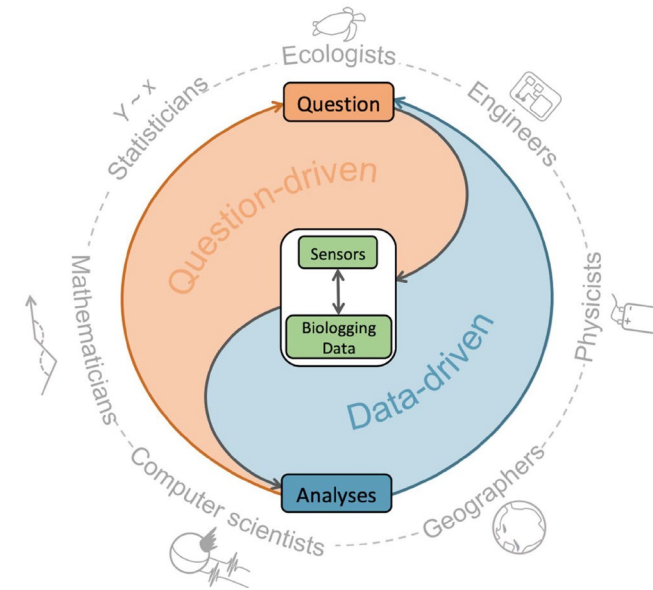


Fernando Benitez-Paez (University of St Andrews), Vanessa da Silva Brum-Bastos, Ciarán D. Beggan, Jed A. Long & Urška Demšar



Kays et al. 2015 Science 348(6240)

Big data animal tracking as an eye on life and planet



Williams et al. 2019 Journal of Animal Ecology 89(1)

The Integrated Biologging Framework (IBF) for movement ecology

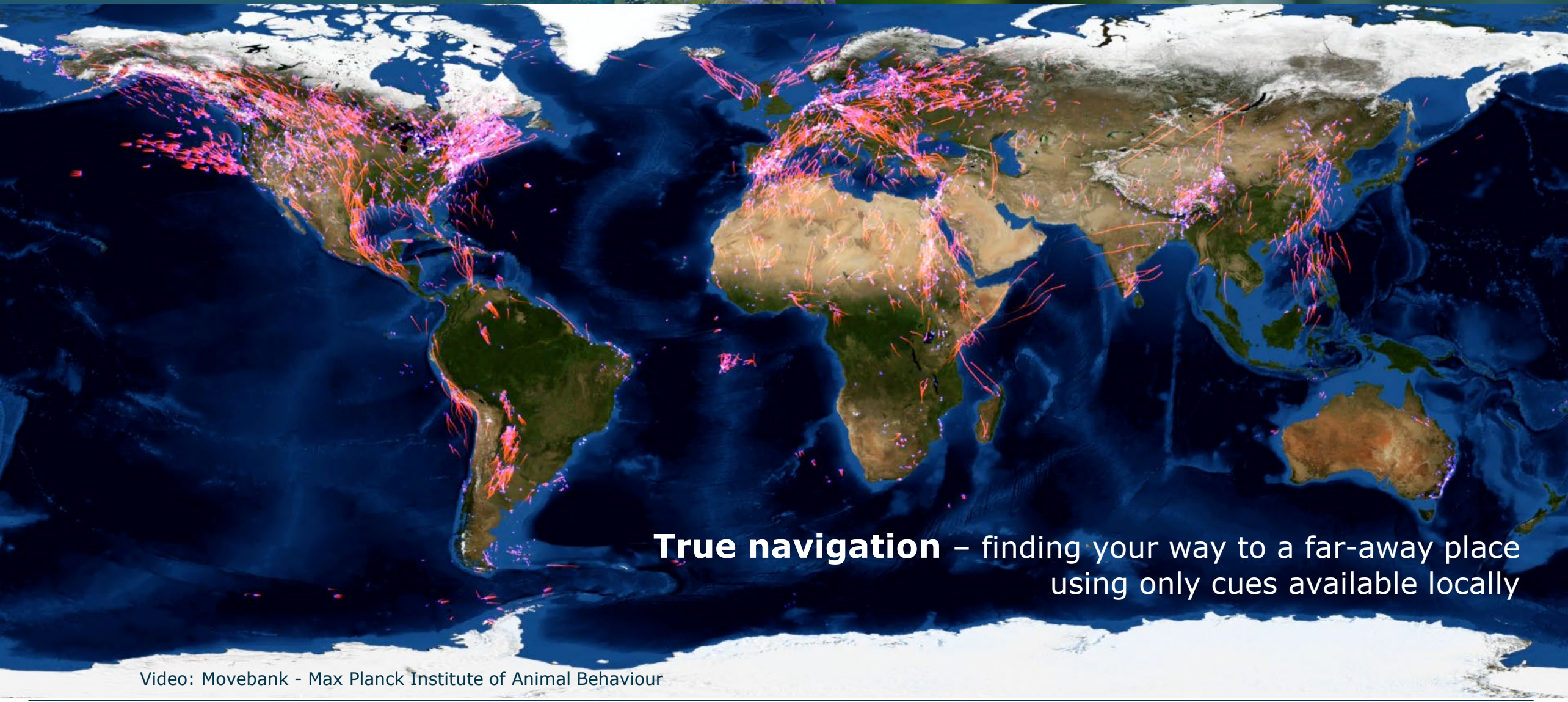
How are animals able to perform true navigation?



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True navigation – finding your way to a far-away place using only cues available locally

Video: Movebank - Max Planck Institute of Animal Behaviour



→ THE EUROPEAN SPACE AGENCY

Map Navigation

Visual landmarks

Olfactory environment

Earth's magnetic field

Geographic Positioning

Where am I?

Compass Navigation

The Sun

The Stars

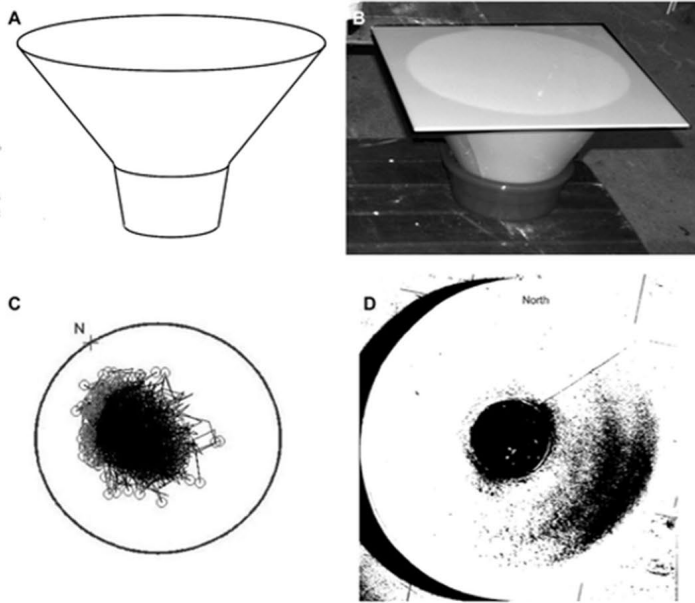
Polarised Light

Earth's magnetic field

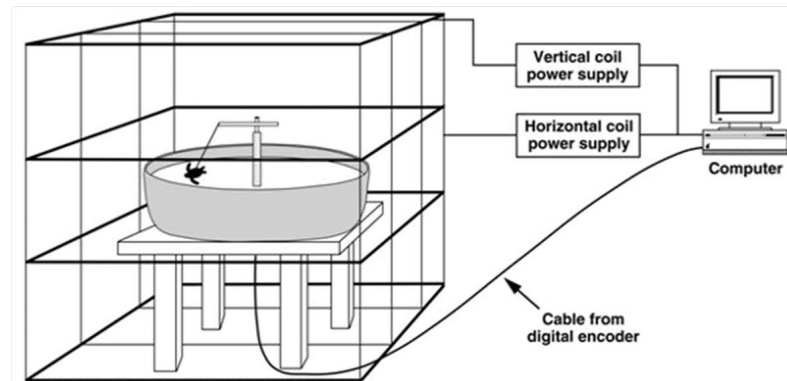
Identifying the direction of movement

Which way to go?

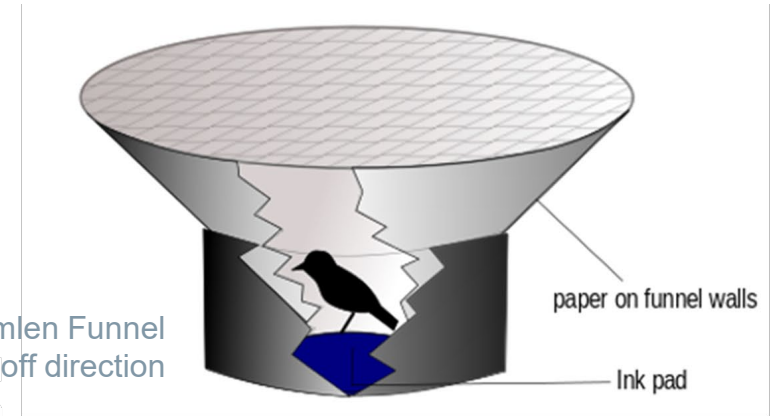
Lab experiments



Mark E. Deutschlander, 2014

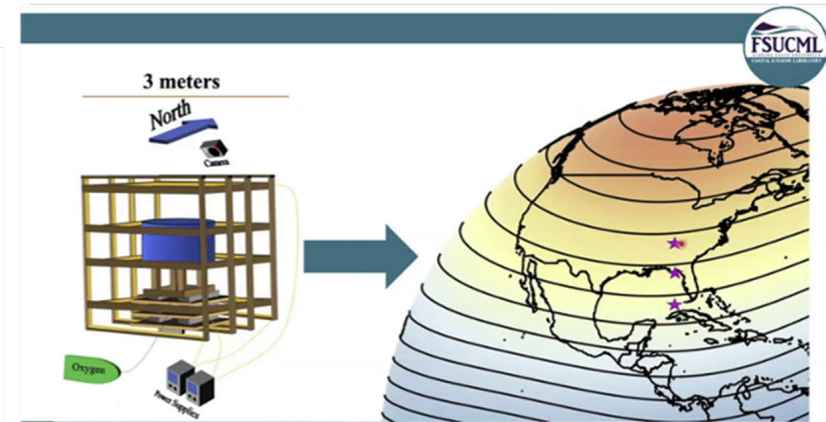


Lohmann, Kenneth & Lohmann, Catherine. (2006)



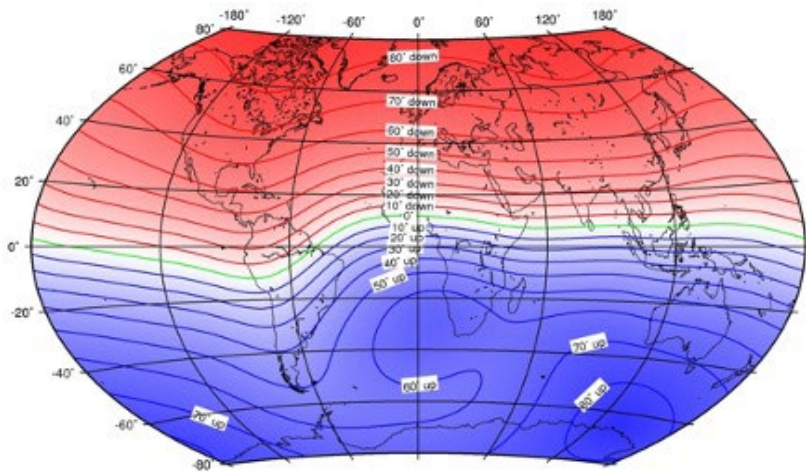
Emlen Funnel
Take-off direction

Bianco et al. 2019, J Exp Biol

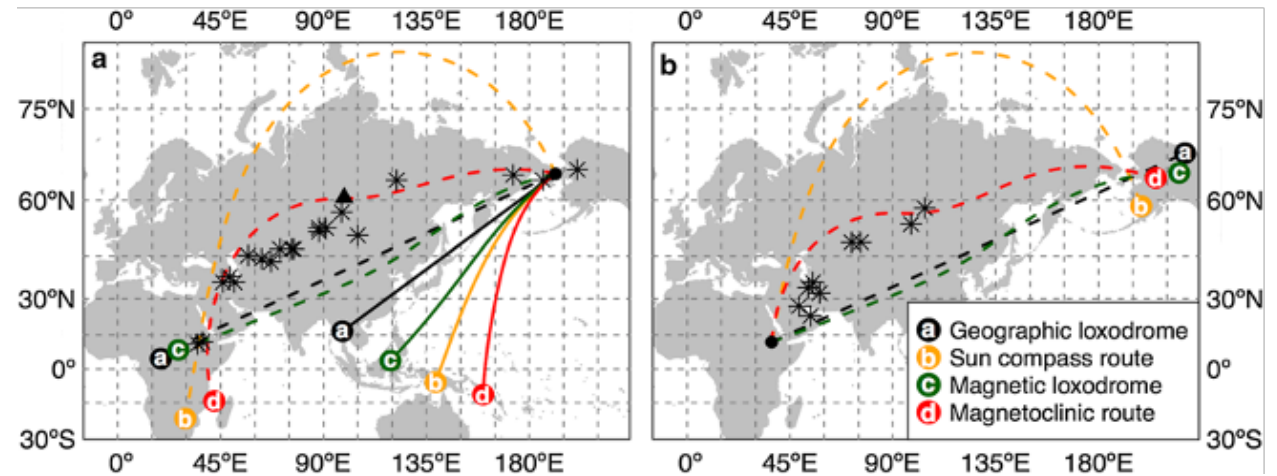


Bryan A. Keller et al., 2021

Magnetic field changes only across space



BGS 2019



Åkesson & Bianco 2017 J Comp Physiol A

Questions we have been looking at:

Data fusion of satellite geomagnetic and tracking data?

Are migration flights affected by geomagnetic storms?

Benitez-Paez et al. *Movement Ecology* (2021) 9:31
<https://doi.org/10.1186/s40462-021-00268-4>

Movement Ecology

METHODOLOGY ARTICLE **Open Access**

Fusion of wildlife tracking and satellite geomagnetic data for the study of animal migration

Fernando Benitez-Paez^{1,2}, Vanessa da Silva Brum-Bastos¹, Ciarán D. Beggan³, Jed A. Long^{1,4} and Urška Demšar¹

Zein et al. *Mov Ecol* (2021) 9:46
<https://doi.org/10.1186/s40462-021-00283-5>

Movement Ecology

RESEARCH **Open Access**

Simulation experiment to test strategies of geomagnetic navigation during long-distance bird migration

Beate Zein^{1*}, Jed A. Long^{1,2}, Kamran Safi^{3,4}, Andrea Kölzsch^{3,4,6}, Martin Wikelski^{3,4,5}, Helmut Kruckenberg⁶ and Urška Demšar¹

Explore what happens **in the wild**, when birds are on the move



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Open tracking data from individuals and species

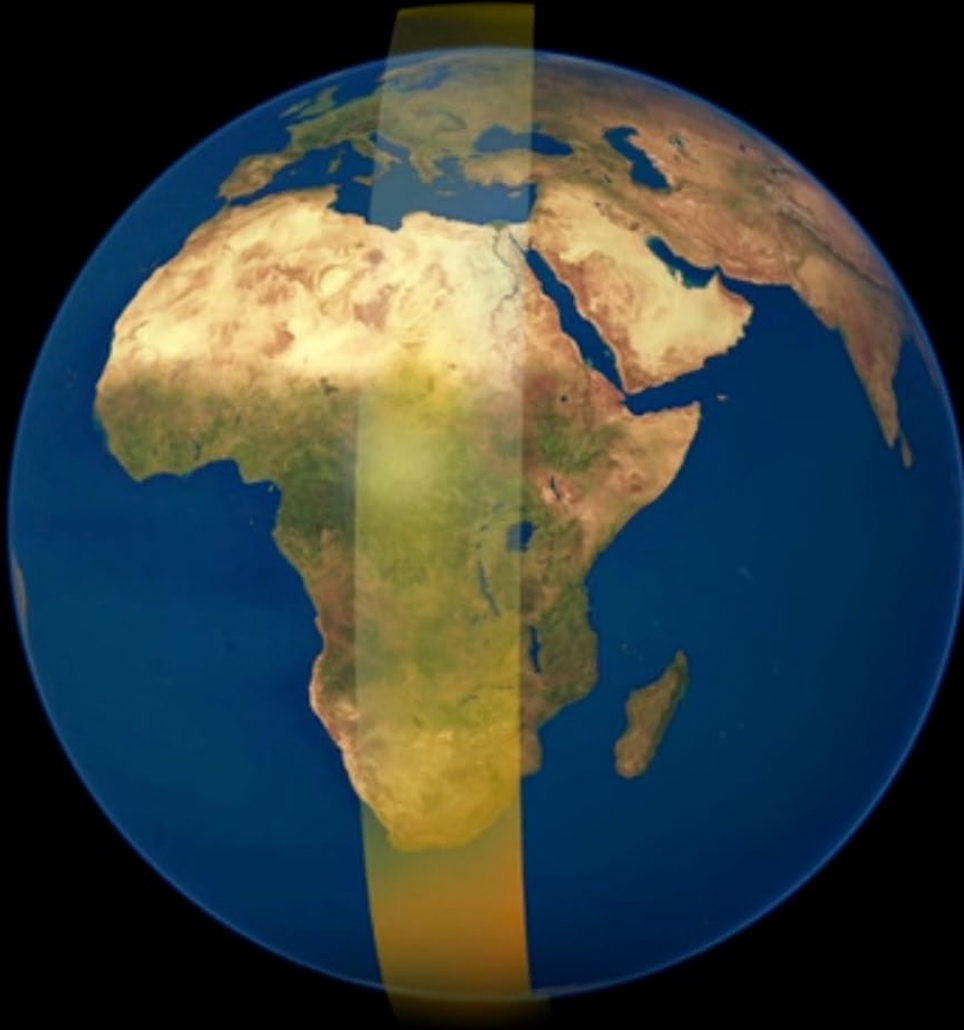


Open environmental geomagnetic data (EO)

The **geomagnetic field changes** in space and time
even small variations could matter, but what about more significant variations?



Swarm Mission - ESA



Video: esa

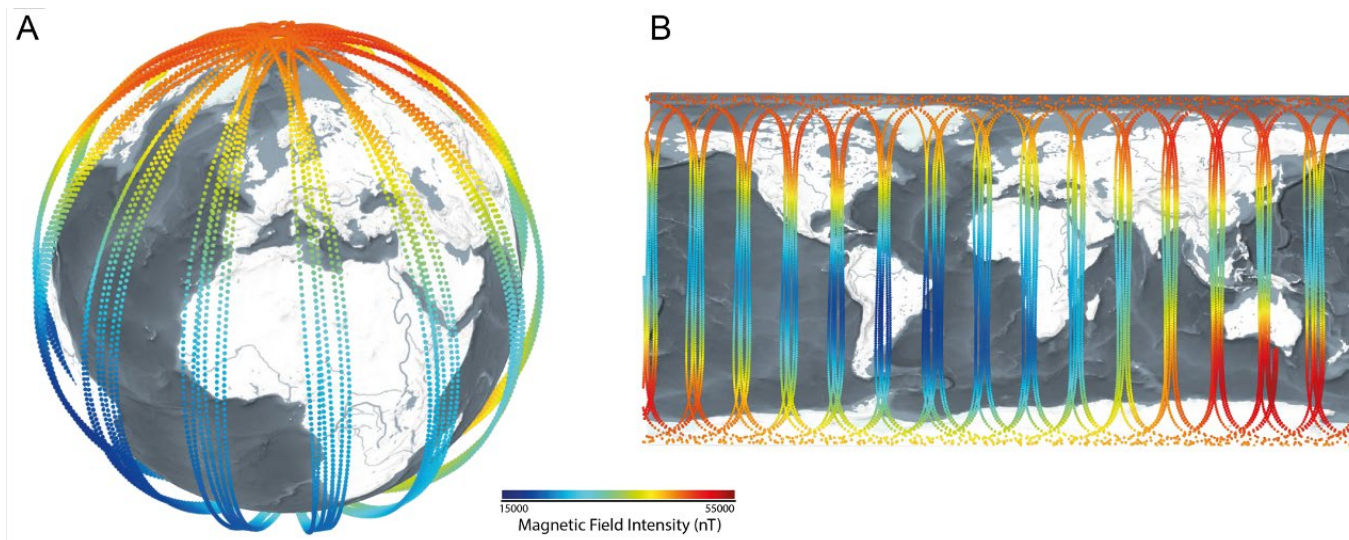
0:03 / 1:16



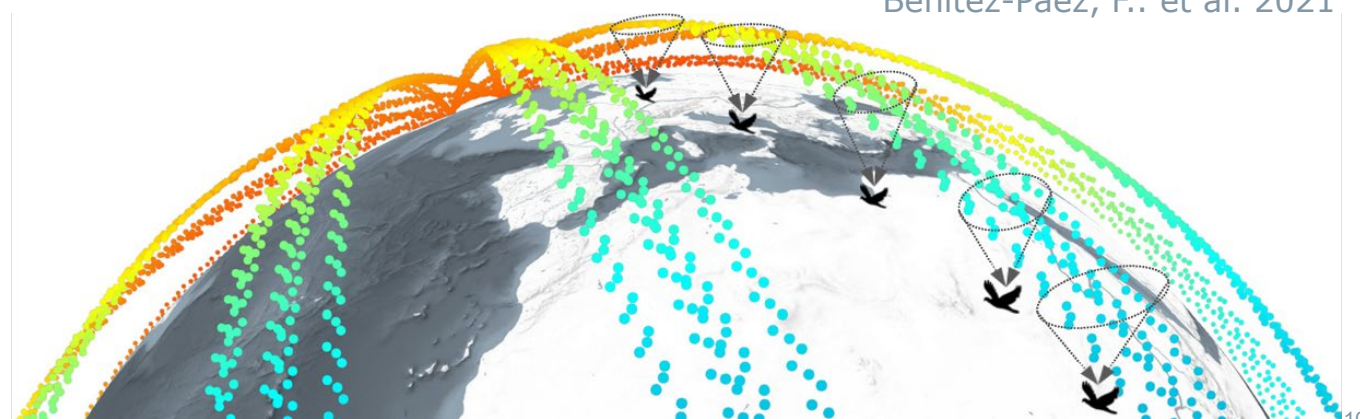
...is not than simple



3 Satellites, reporting geomagnetic variations every second



Benitez-Paez, F. et al. 2021

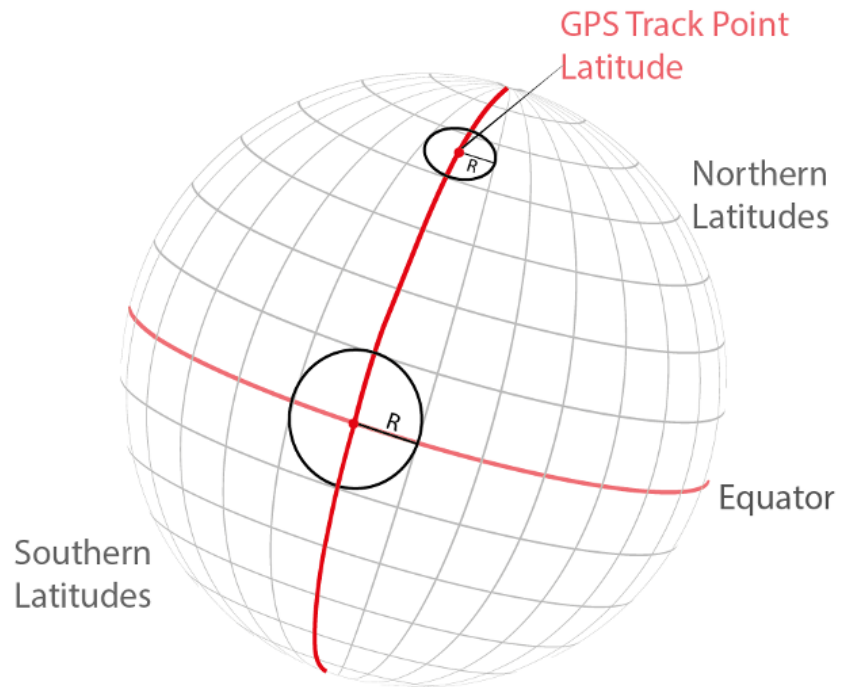


Data fusion method



For each tracking point:

A



Define spatial neighborhood based on Swarm orbits

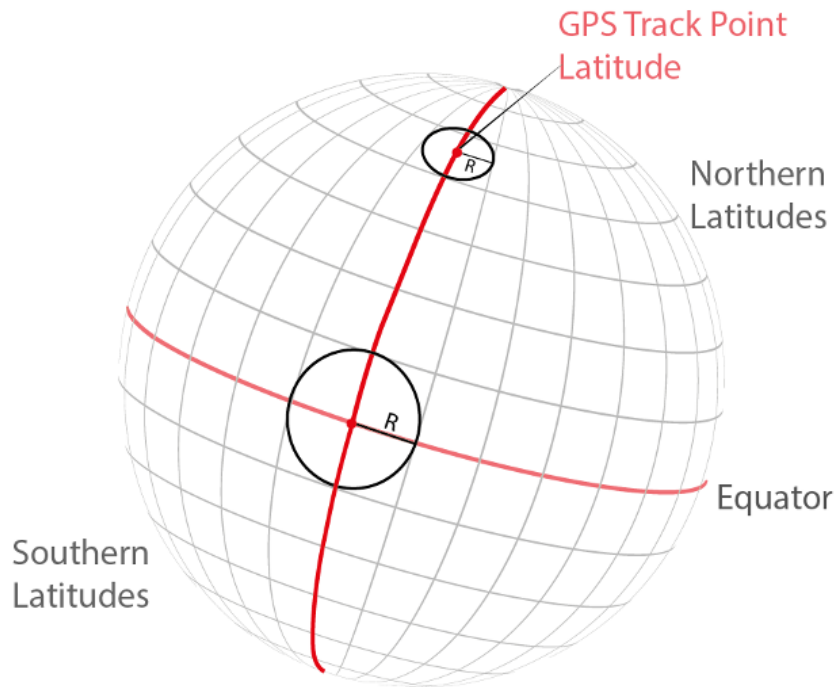


Data fusion method



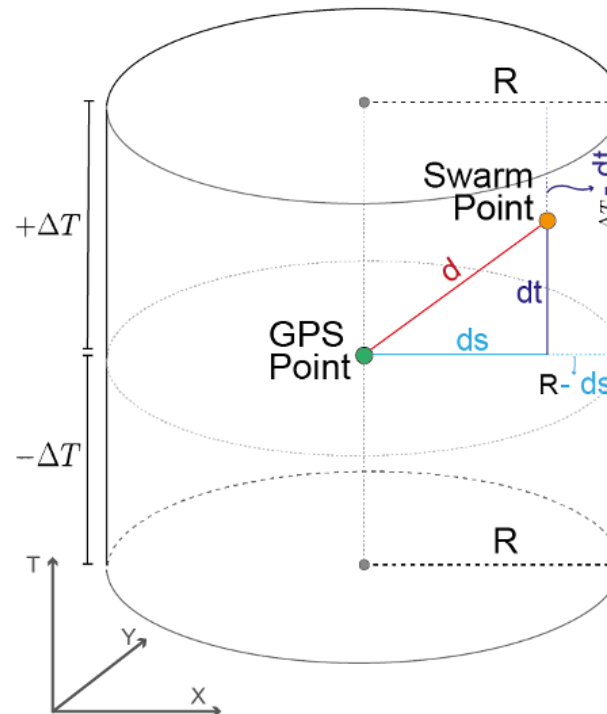
For each tracking point:

A



Define spatial neighborhood based on Swarm orbits

B



Define spatiotemporal kernel and weighting

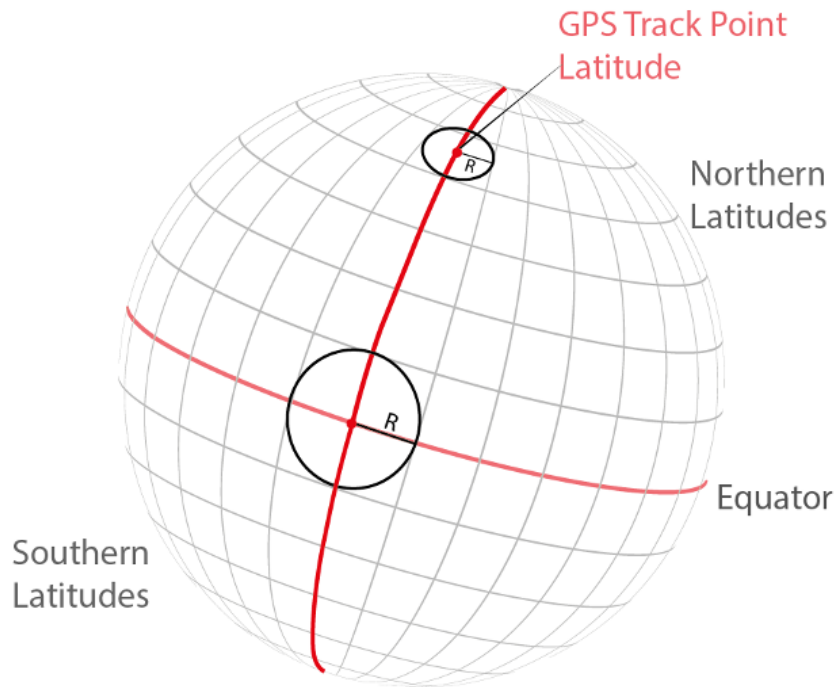


Data fusion method



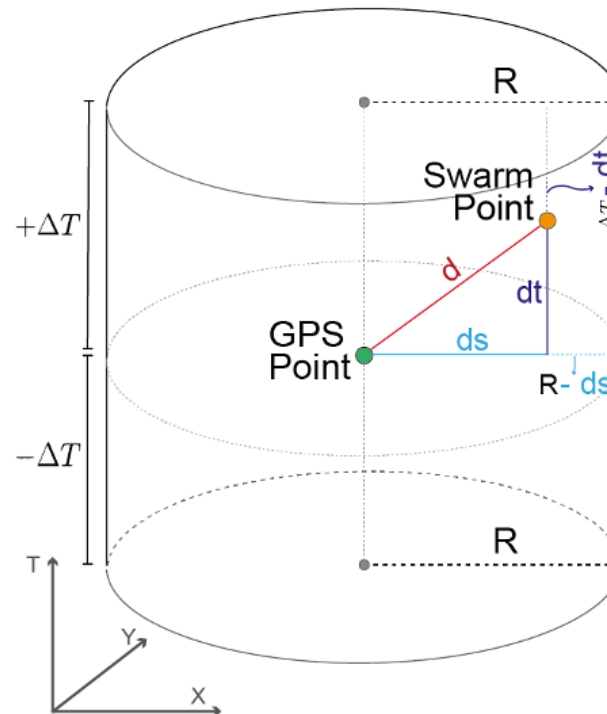
For each tracking point:

A



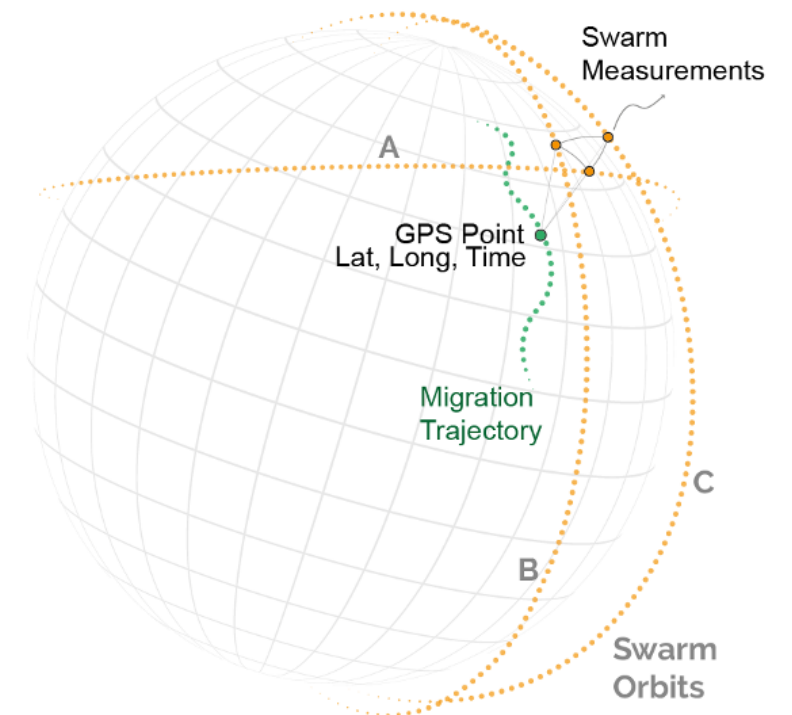
Define spatial neighborhood based on Swarm orbits

B



Define spatiotemporal kernel and weighting

C



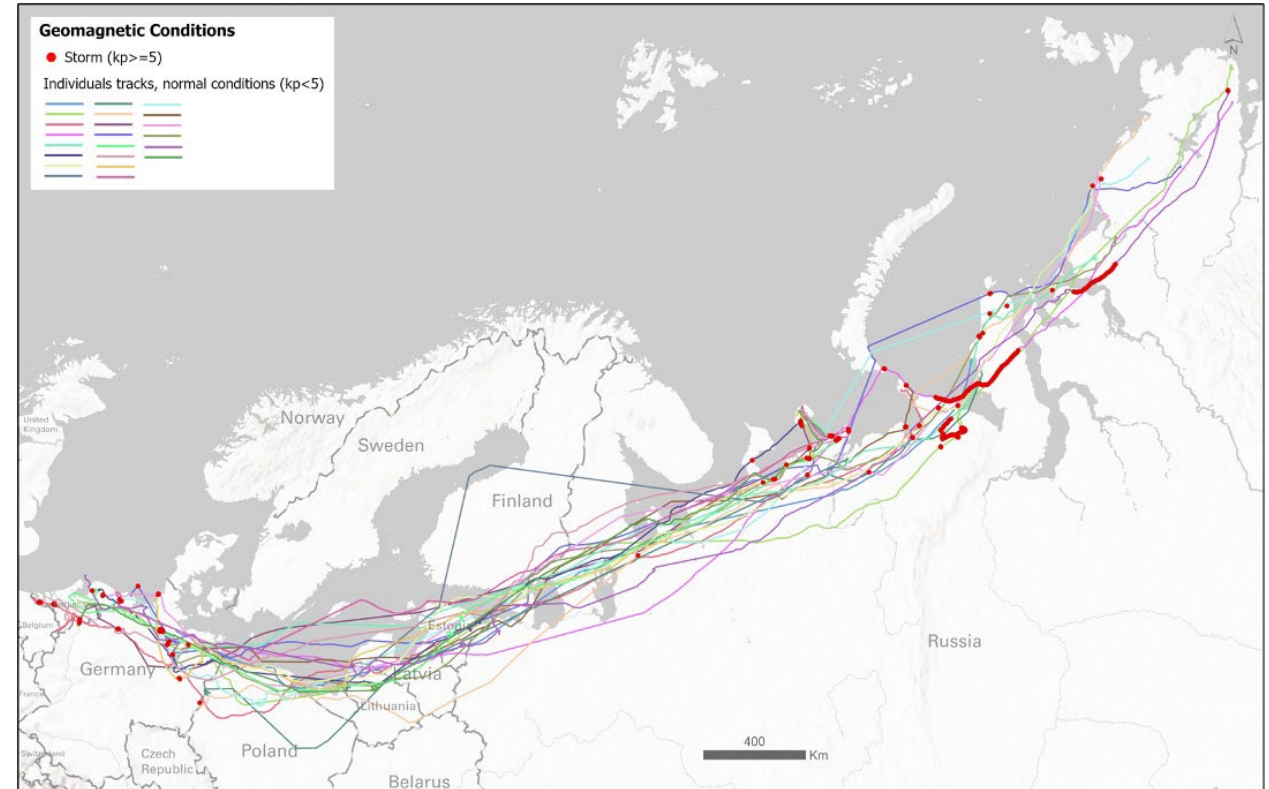
Interpolate residuals and add to the model at the location and time of the tracking point



Are migration flights affected by geomagnetic storms?



22 individuals
151.156 GPS points total
13.697 points during migration



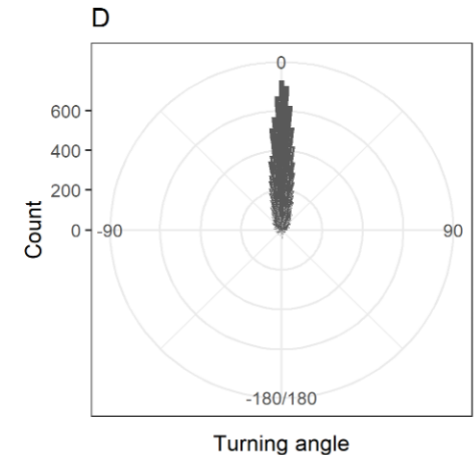
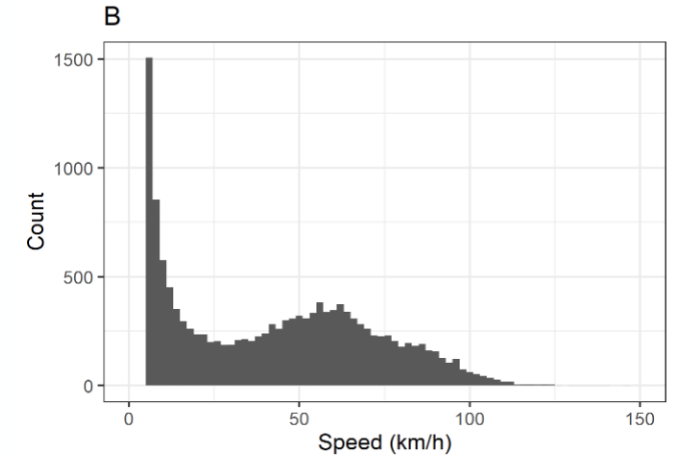
Autumn migration 2017 (1 Aug to 15 Nov 2017)
Large geomagnetic storm on 7-8 Sept 2017
Significant effects in the north of Russia

Are migration flights affected by geomagnetic storms?



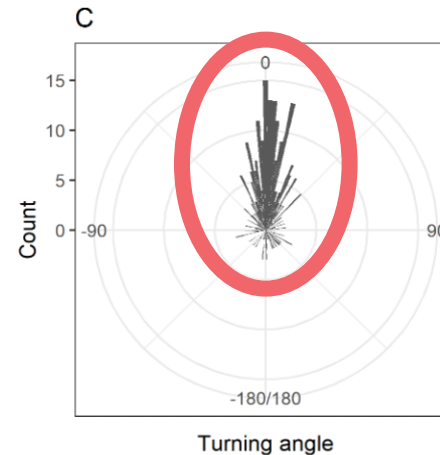
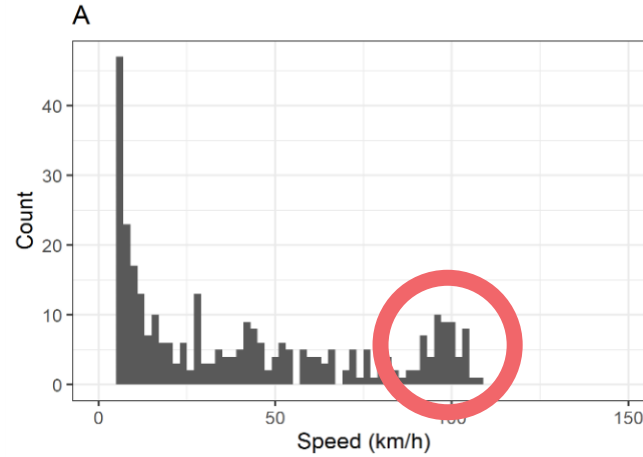
22 individuals
151.156 GPS points total
13.697 points during migration

No Geomagnetic Storm

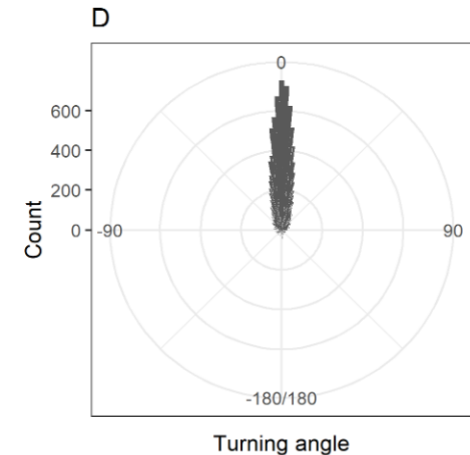
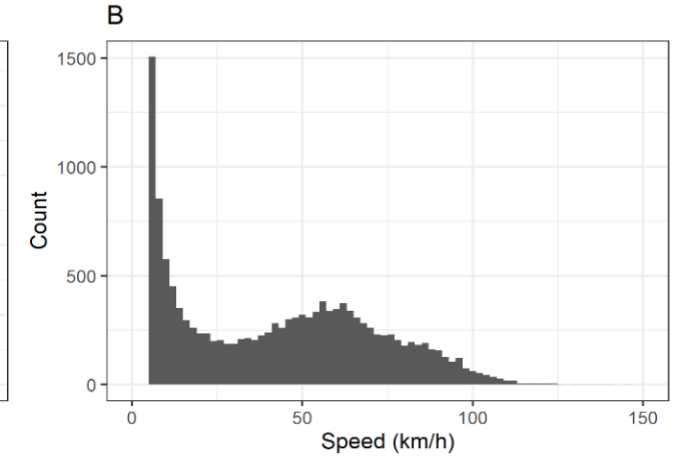


Are migration flights affected by geomagnetic storms?

Geomagnetic Storm



No Geomagnetic Storm

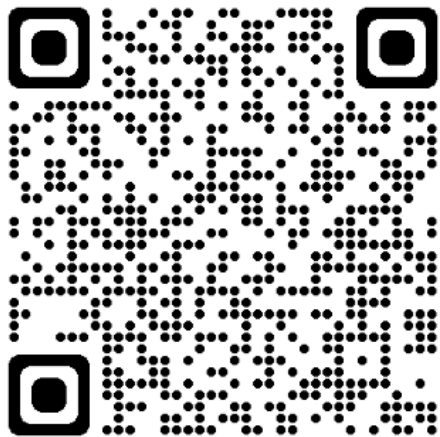


22 individuals
151.156 GPS points total
13.697 points during migration

MagGeo – Open-Source Software



Sequential and Parallel mode
Entirely built in Python (soon in R)
A documented tool
Step by step for **no python**
ecologists



MagGeo - Sequential Mode

Authors | Fernando Benitez-Paez, Urška Demšar, Jed Long, Ciaran Beggan

Contact | Fernando.Benitez@st-andrews.ac.uk, ud2@st-andrews.ac.uk, jed.long@uwo.ca, ciar@bgs.ac.uk

Keywords | Bird migration, data fusion, Earth's magnetic field, Swarm, GPS tracking

Overview

This Jupyter Notebook will guide you through the required steps to annotate your GPS tracking data with the earth's magnetic field data from Swarm (European Space Agency). This version is called Sequential Mode, alternatively you can use Parallel Mode to take advantage of parallelized computing if required. More information about the Swarm satellites can be found in the Main Document on the MagGeo github repository. This script will use a sequential loop to run the annotation process for each GPS Point (row) from your data.

To execute the code, you can go through each cell (pressing `Ctrl+Enter`), you will also find inner comments `##` to describe each particular step. If you are not familiar with using Jupyter Notebooks, you might want to take some time to learn how first, for example take a look at the `notebook-basics.ipynb` Notebook inside MagGeo.

Data requirements

Your trajectory must be in a csv format:

There are three columns that must be included in your GPS trajectory. Make sure your GPS trajectory includes **Latitude**, **Longitude** and **timestamp**. We suggest that the Timestamp column follow the day/month/year Hour:Minute (`dd/mm/yyyy HH:MM:SS`) format, Latitude and Longitude should be in decimal degrees (WGS84). Optionally an altitude column can be used providing altitude (the altitude must be in **km**). Other Columns will be ignored. Here it is an example of how your GPS track should look:

timestamp	location-long	location-lat	altitude	individual_id
08/09/2014 05:54	68.307333	70.854717	0	1
08/09/2014 06:10	67.97505	70.8303	0.406	1
08/09/2014 06:26	67.752417	70.761717	0.498	1
08/09/2014 06:42	67.561983	70.686517	0.787	1
08/09/2014 07:14	67.548317	70.68545	0.337	1
08/09/2014 07:30	67.549433	70.68575	0.026	1
08/09/2014 07:46	67.530983	70.690333	0.026	1

For this example we are reading the `BirdGPSTrajectory.csv` file. If you want to run the method using your own csv file, make sure you store your the file in the `./data` folder. For more information about the dataset we used in this example go to the Main Notebook.

What are we currently working on?



Ali Moayed



Big Data Analysis of Animal Migration Using ML techniques

Meixuan Liu



Better understanding of **the impact of olfactory cues** in animal migration studies using ML

Next Challenges

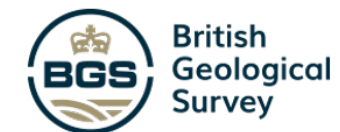
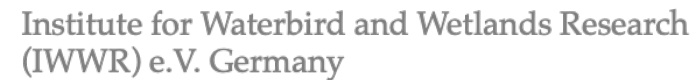
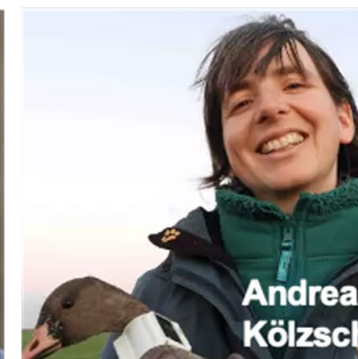
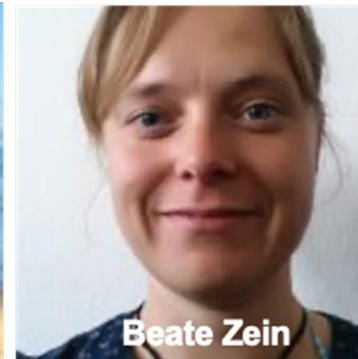
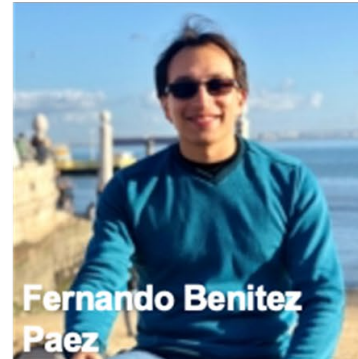
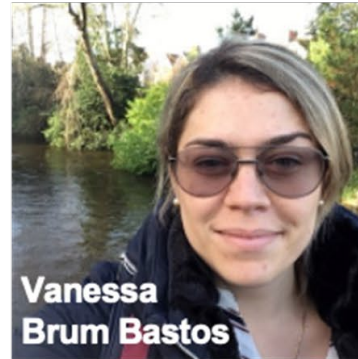
Expand MagGeo – More species (e.g. Marine mammals & Fish)

Similar methods for species that cannot be tracked – **Majority of migratory species**

New environmental conditions (radio telemetry, e.g. songbirds, Bats or Insects) – Other type of Satellite data

Indeed, there are many exciting new opportunities for EO and animal movement researchers.

...of course, it isn't just me



BioSpace25 - Biodiversity insight from Space
10 - 14 February 2025 | ESA-ESRIN | Frascati - Italy



Thank you for listening

Fernando Benitez-Paez



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