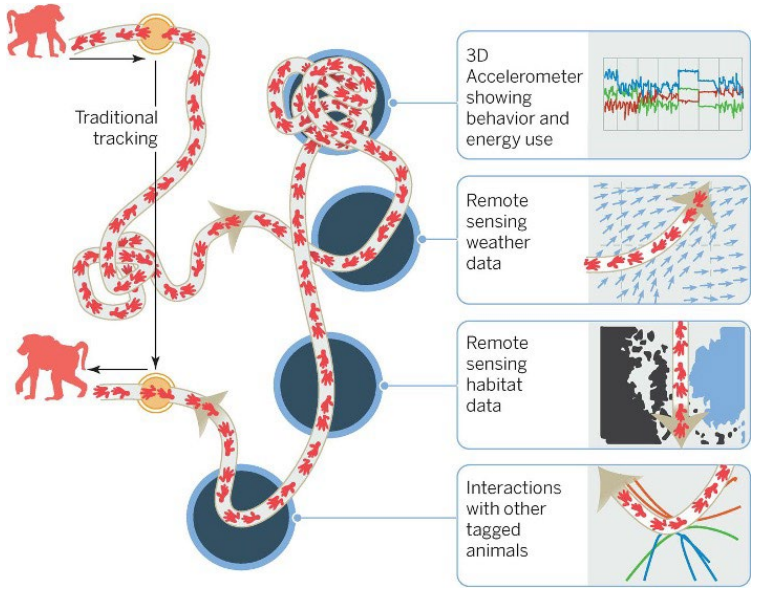
BioSpace25 - Biodiversity insight from Space
10 - 14 February 2025 | ESA-ESRIN | Frascati - Italy

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

BEGIN
BELL EDWARDS GEOGRAPHIC DATA INSTITUTE

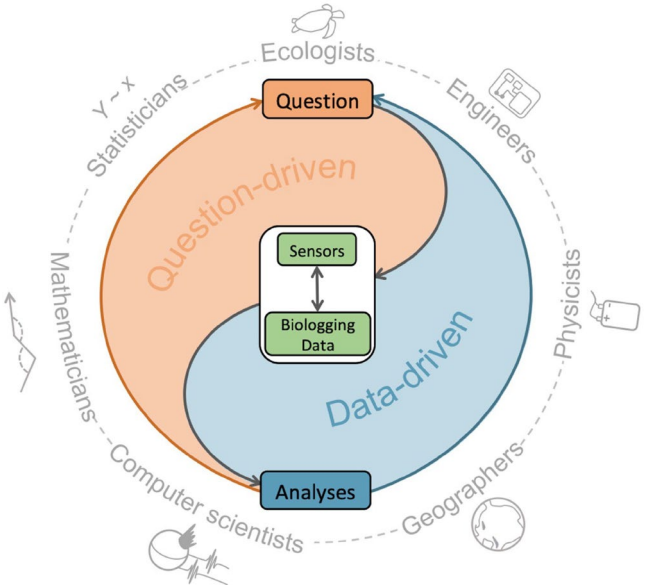
Fernando Benitez-Paez (University of St Andrews), Vanessa da Silva Brum-Bastos, Ciarán D. Beggan, Jed A. Long & Urška Demšar

Internet of Animals



Kays et al. 2015 Science 348(6240)

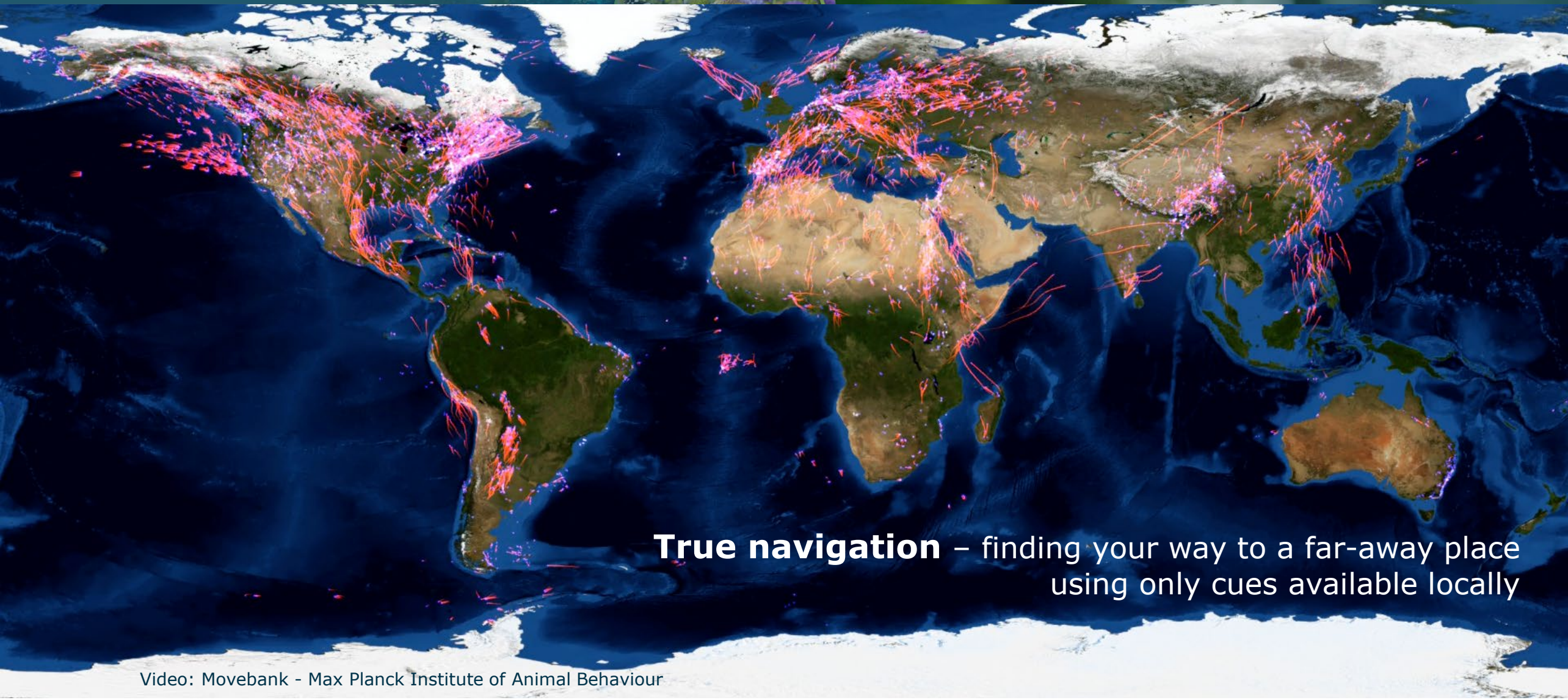
Big data animal tracking as an eye on life and planet



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?



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

Video: Movebank - Max Planck Institute of Animal Behaviour

Migratory Navigation

Map Navigation

Visual landmarks

Olfactory environment

Earth's magnetic field

Compass Navigation

The Sun

The Starts

Polarised Light

Earth's magnetic field

Geographic Positioning

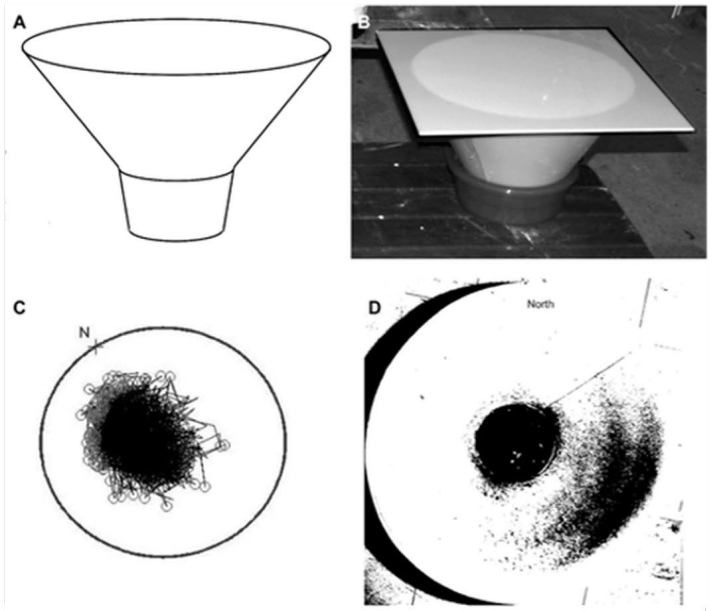
Where am I?

Identifying the direction of movement

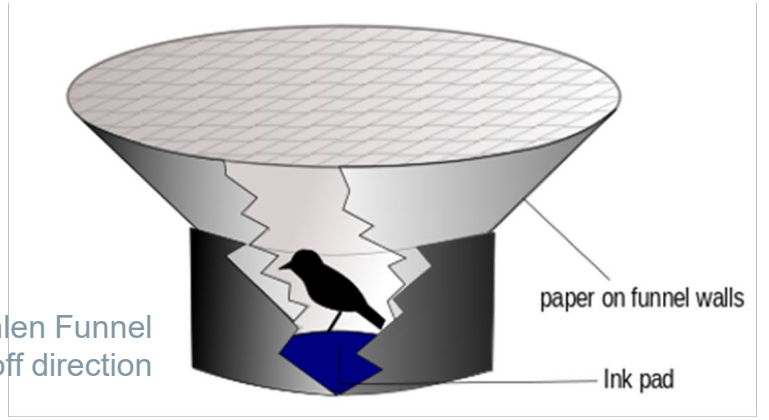
Which way to go?

Traditional Navigation Studies

Lab experiments

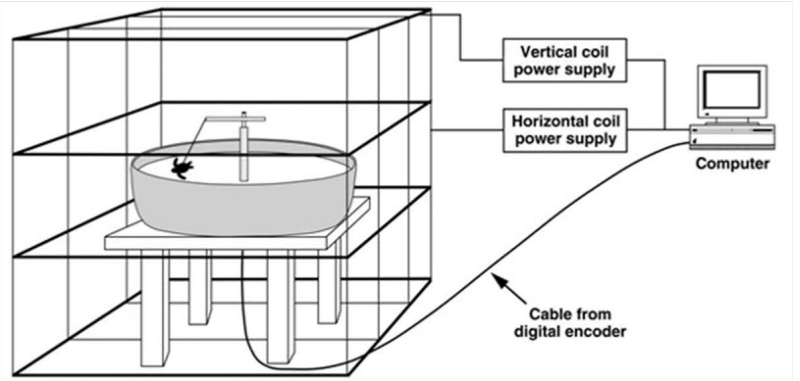


Mark E. Deutschlander, 2014

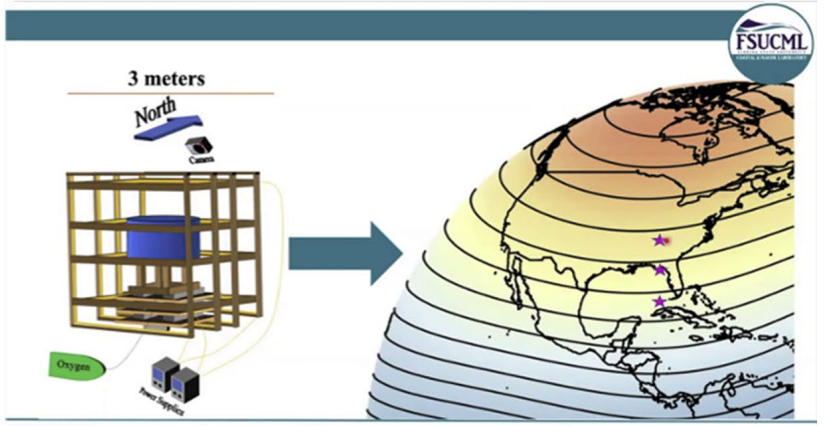


Emlen Funnel
Take-off direction

Bianco et al. 2019, J Exp Biol



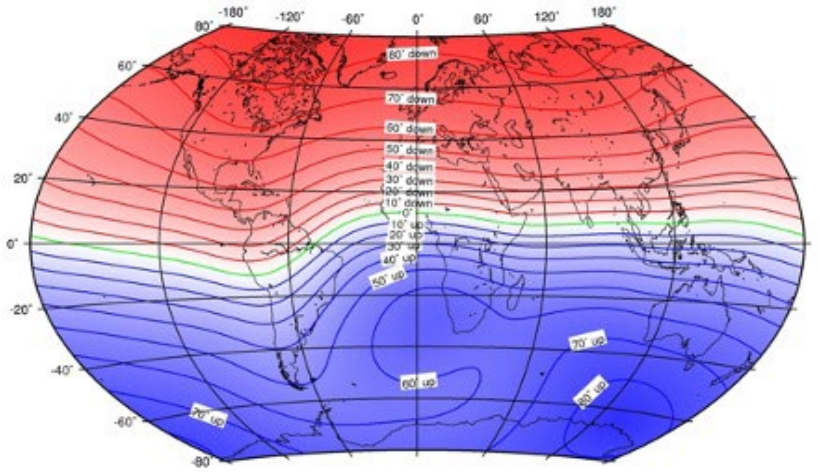
Lohmann, Kenneth & Lohmann, Catherine. (2006)



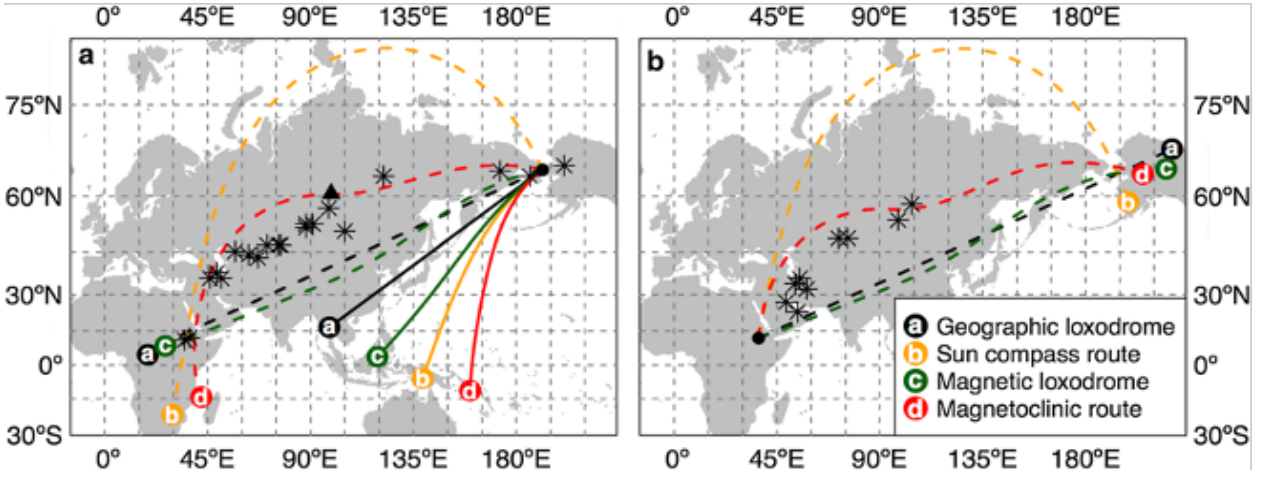
Bryan A. Keller et al., 2021

Traditional Navigation Studies

Magnetic field changes only across space



BGS 2019



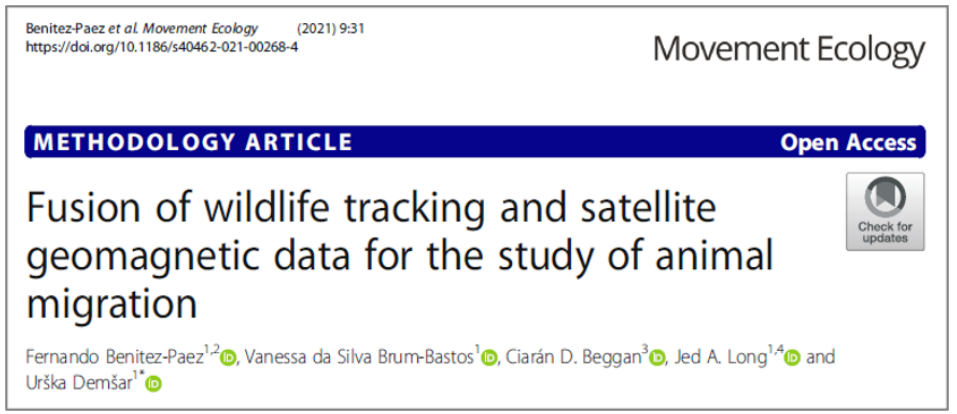
Åkesson & Bianco 2017 J Comp Physiol A

Our Approach - Spatial Data Science

Questions we have been looking at:

Data fusion of satellite geomagnetic and tracking data?

Are migration flights affected by geomagnetic storms?



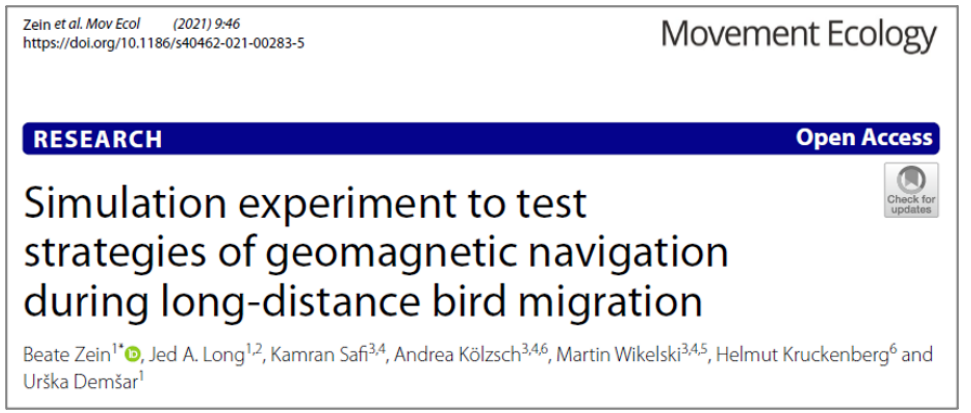
Benitez-Paez *et al. Movement Ecology* (2021) 9:31
https://doi.org/10.1186/s40462-021-00268-4

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-Bastos[1], Ciarán D. Beggan[3], Jed A. Long[1,4] and Urška Demšar[1*]



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

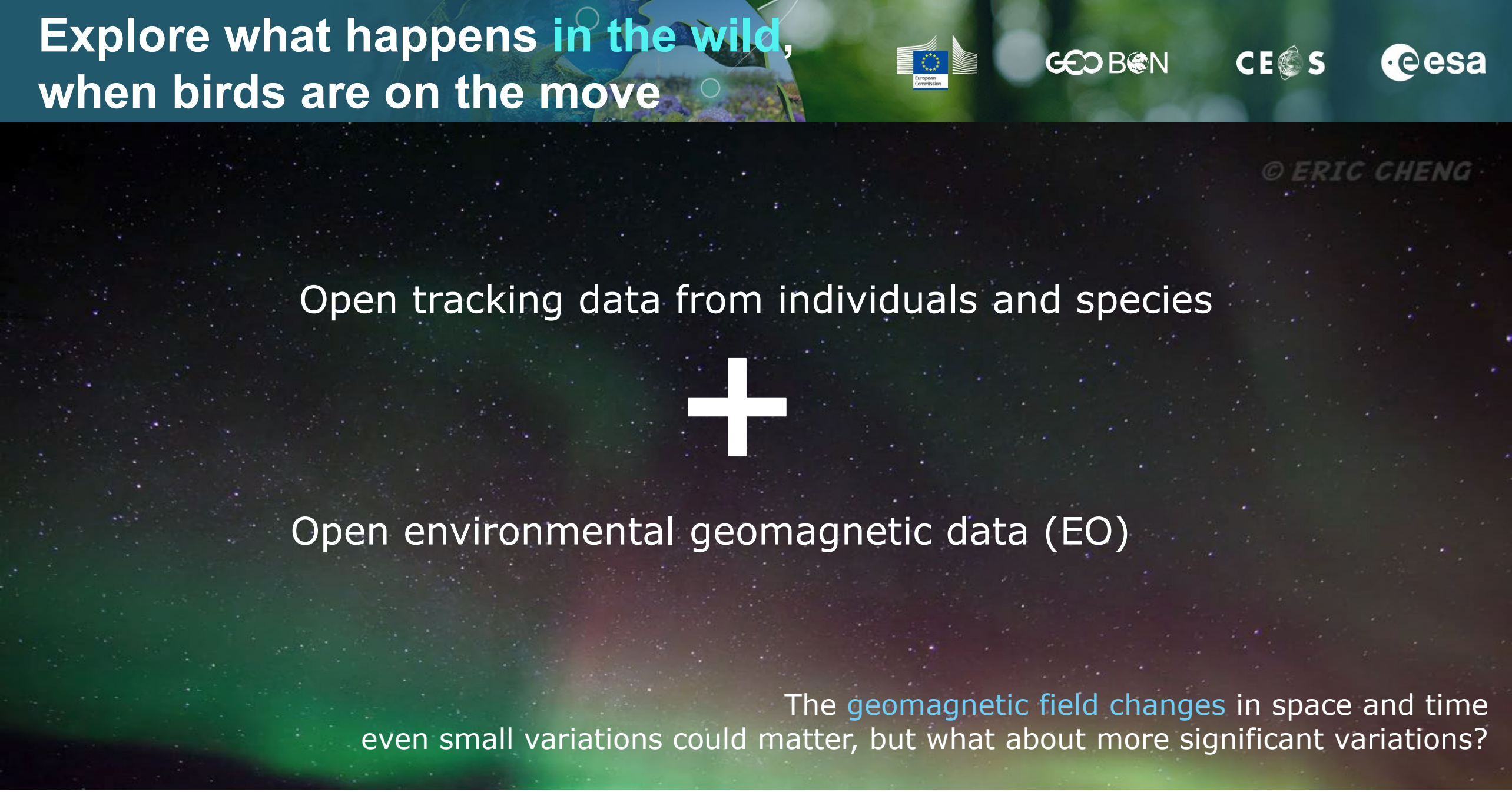
Movement Ecology

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 Kruckenberg[6] and Urška Demšar[1]

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



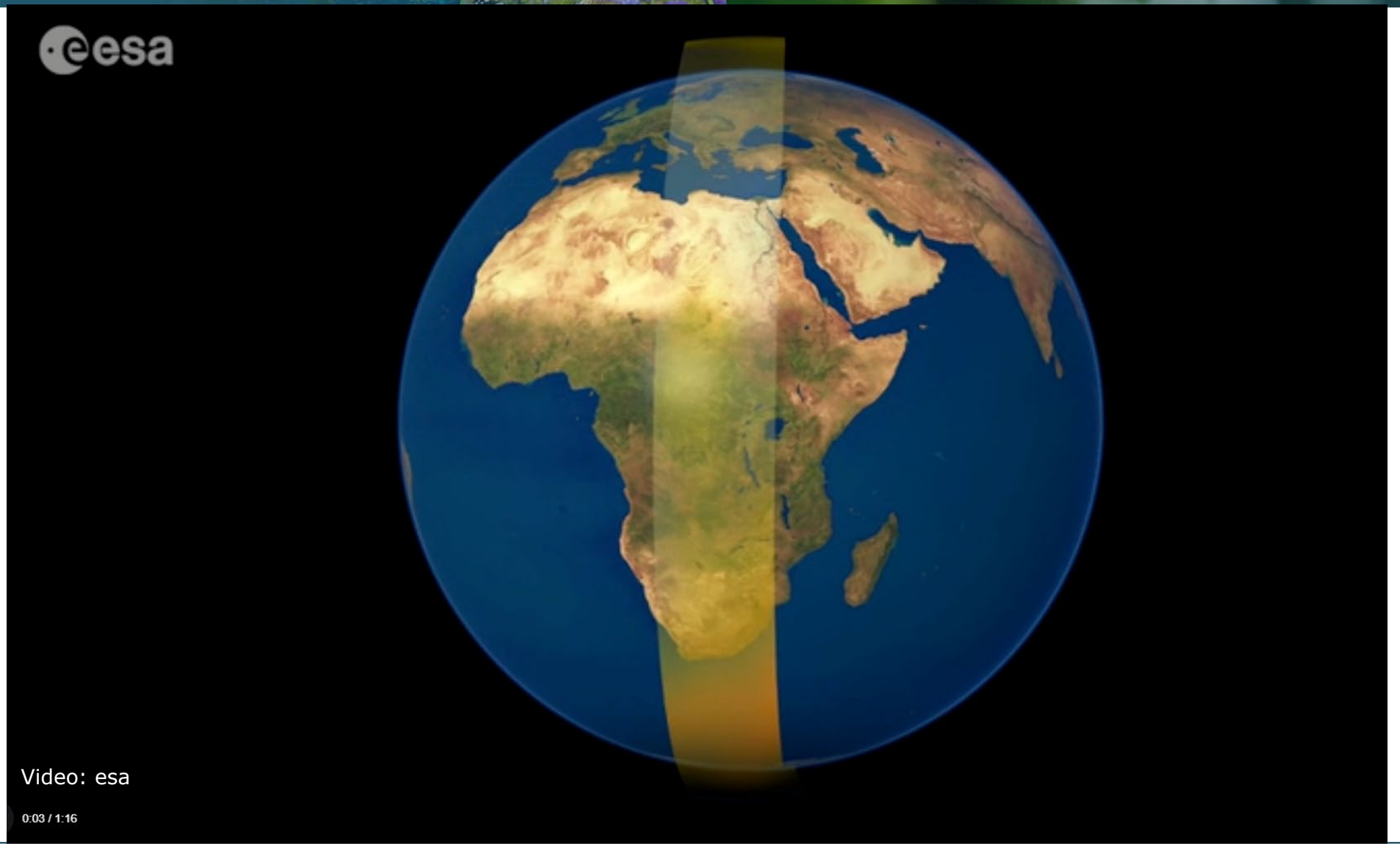
Open tracking data from individuals and species

+

Open environmental geomagnetic data (EO)

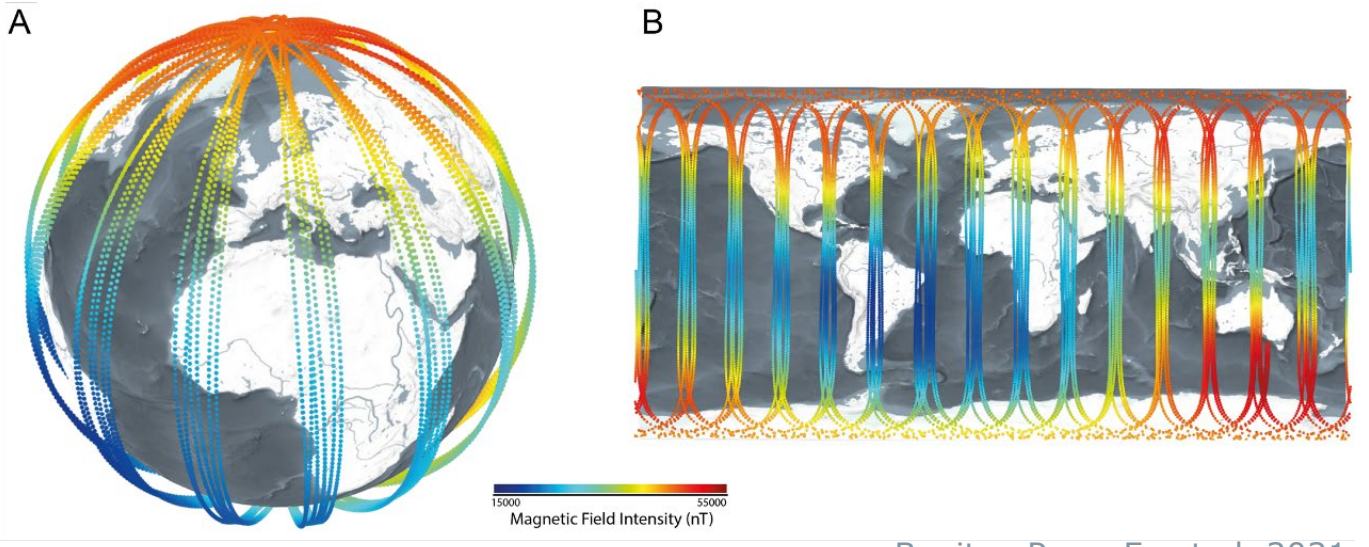
The geomagnetic field changes in space and time
even small variations could matter, but what about more significant variations?

Swarm Mission - ESA

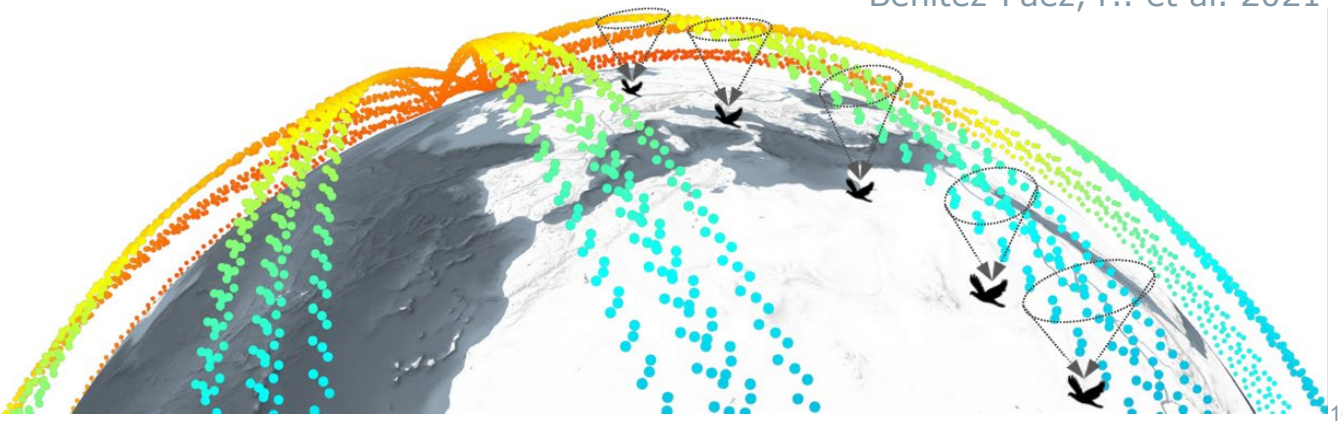


…is not than simple

3 Satellites, reporting geomagnetic variations every second

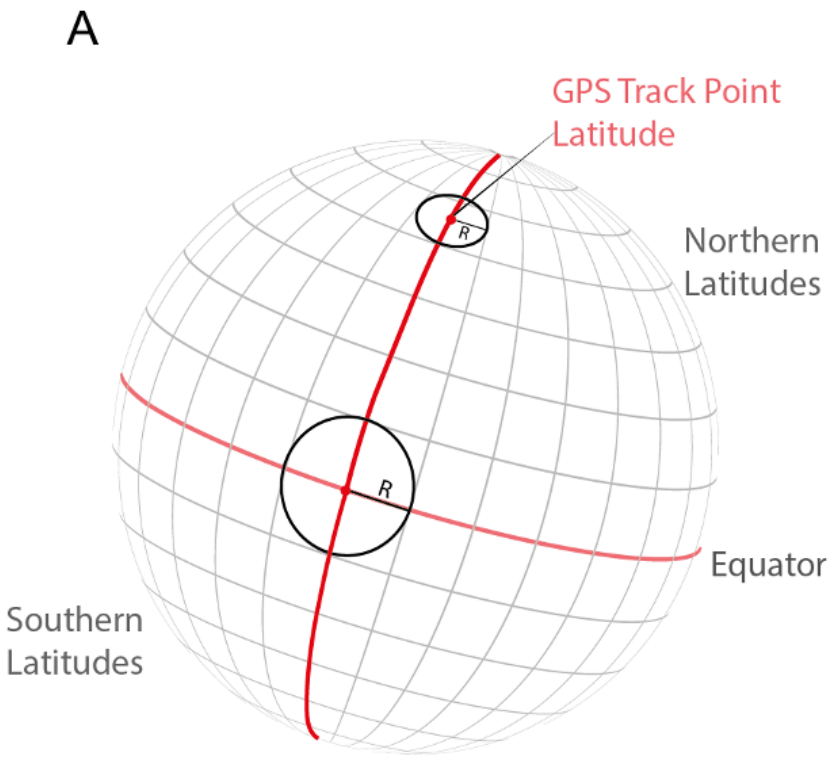


Benitez-Paez, F.. et al. 2021



Data fusion method

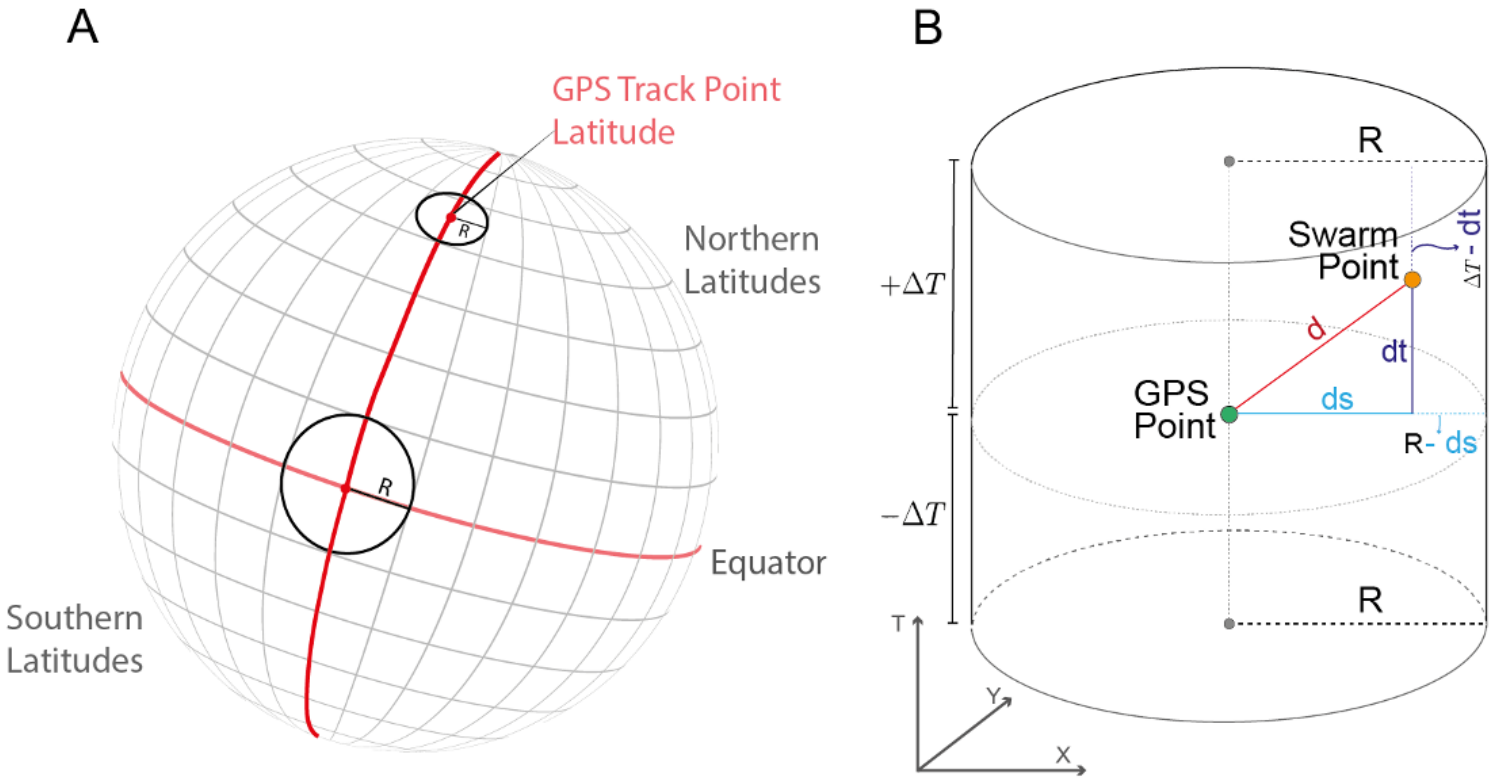
For **each** tracking point:



Define spatial neighborhood based on Swarm orbits

Data fusion method

For **each** tracking point:

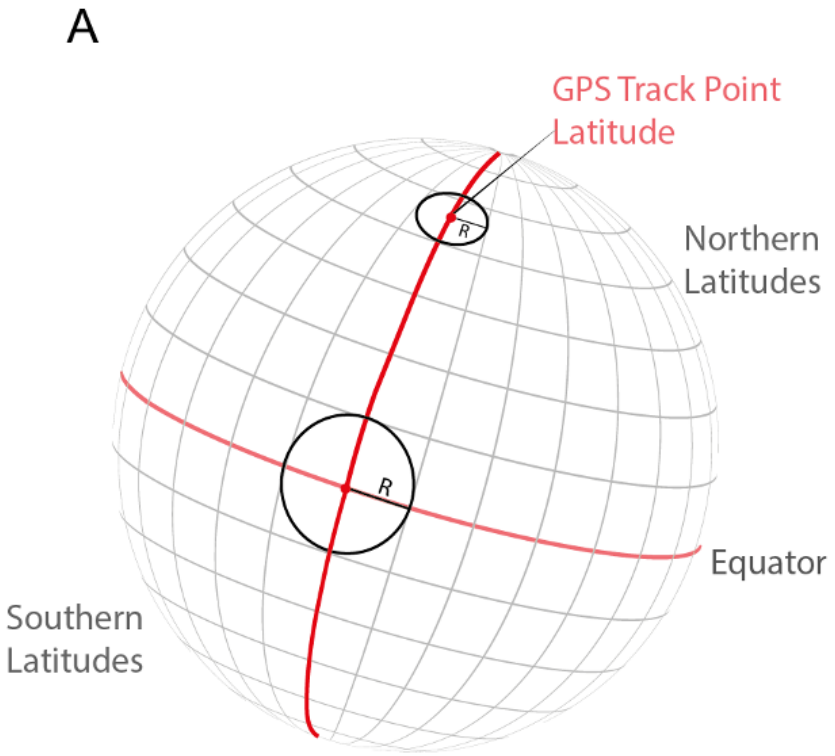


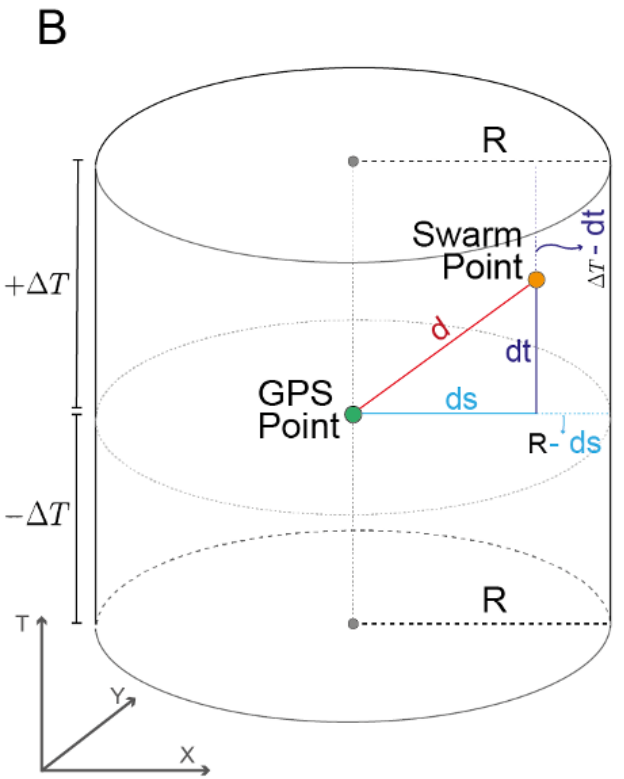
Define spatial neighborhood based on Swarm orbits

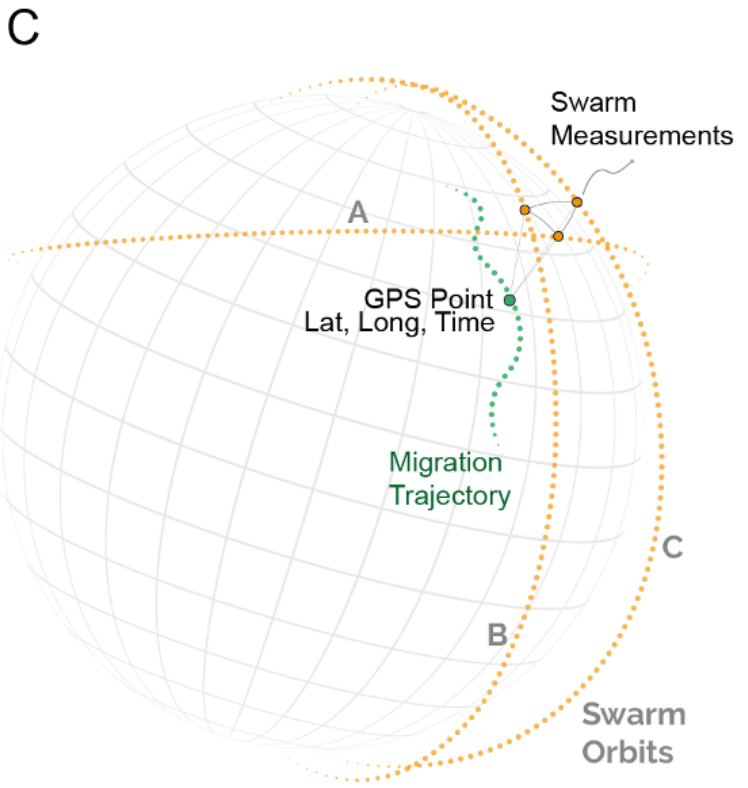
Define spatiotemporal kernel and weighting

Data fusion method

For **each** tracking point:







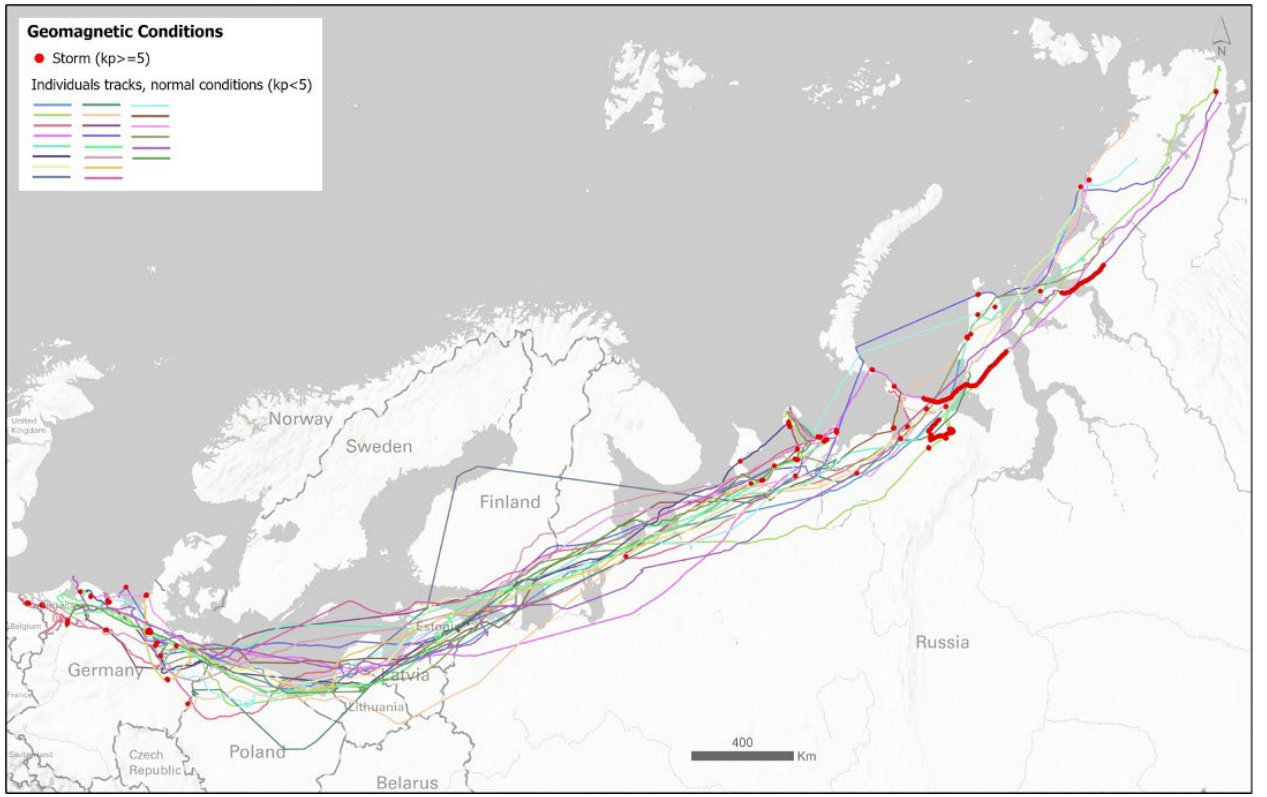
Define spatial neighborhood based on Swarm orbits

Define spatiotemporal kernel and weighting

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

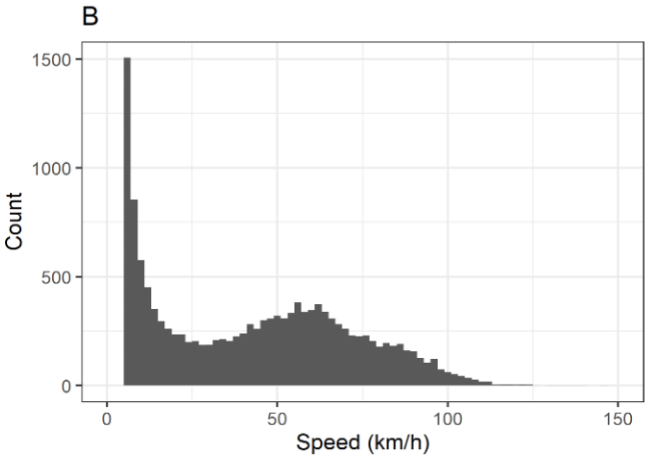


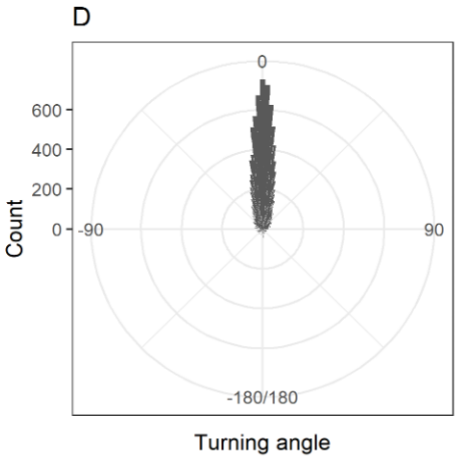
Autumn migration 2017 (1 Aug to 15 Nov 2017)
Large geomagnetic storm on 7-8 Sept 2017
Significant effects in the north of Russia

Are migration flights affected by geomagnetic storms?

22 individuals
151.156 GPS points total
13.697 points during migration

No Geomagnetic Storm





Benitez-Paez, F.. et al. 2021

Are migration flights affected by geomagnetic storms?

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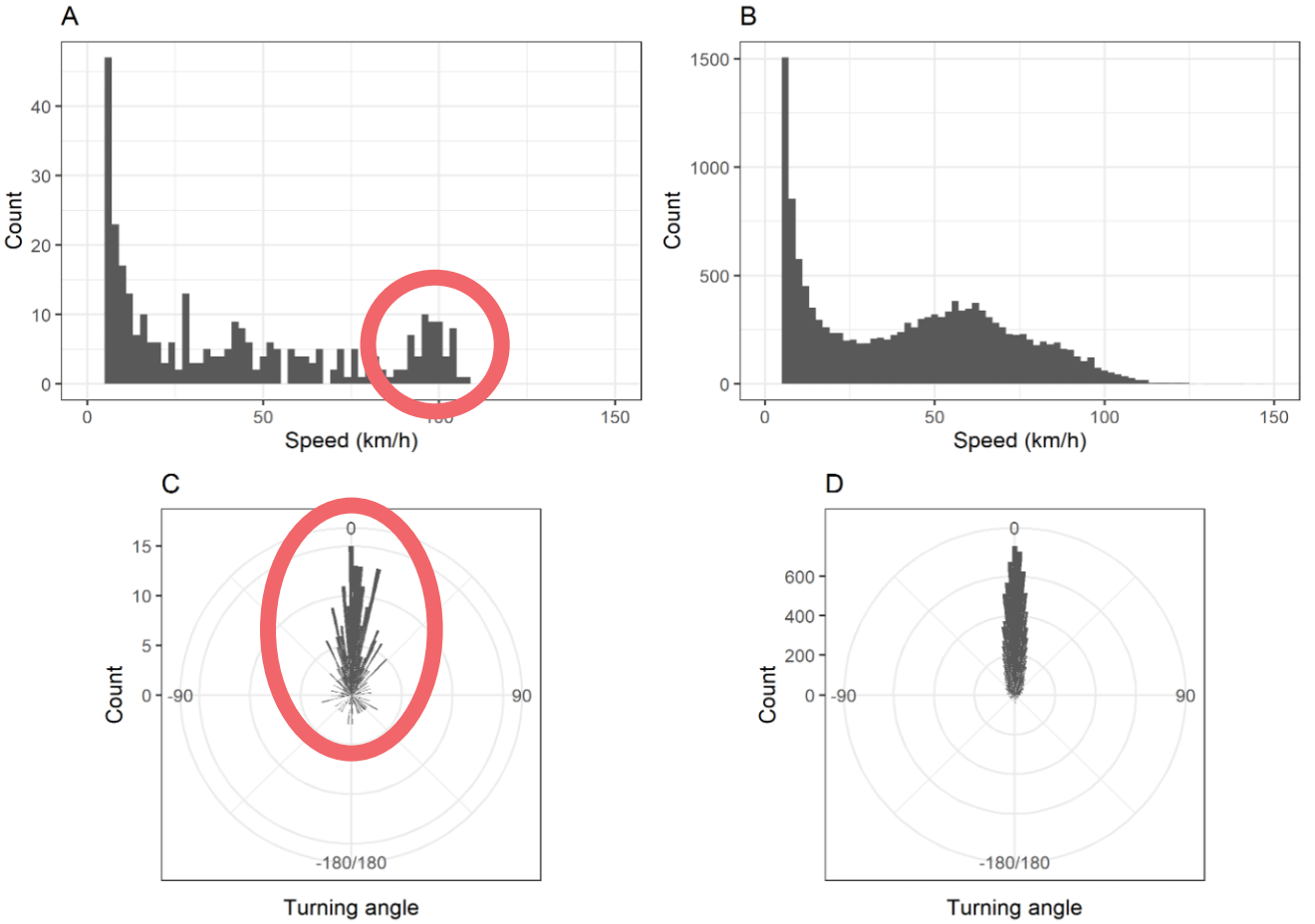
Geomagnetic Storm

No Geomagnetic Storm



Benitez-Paez, F.. et al. 2021

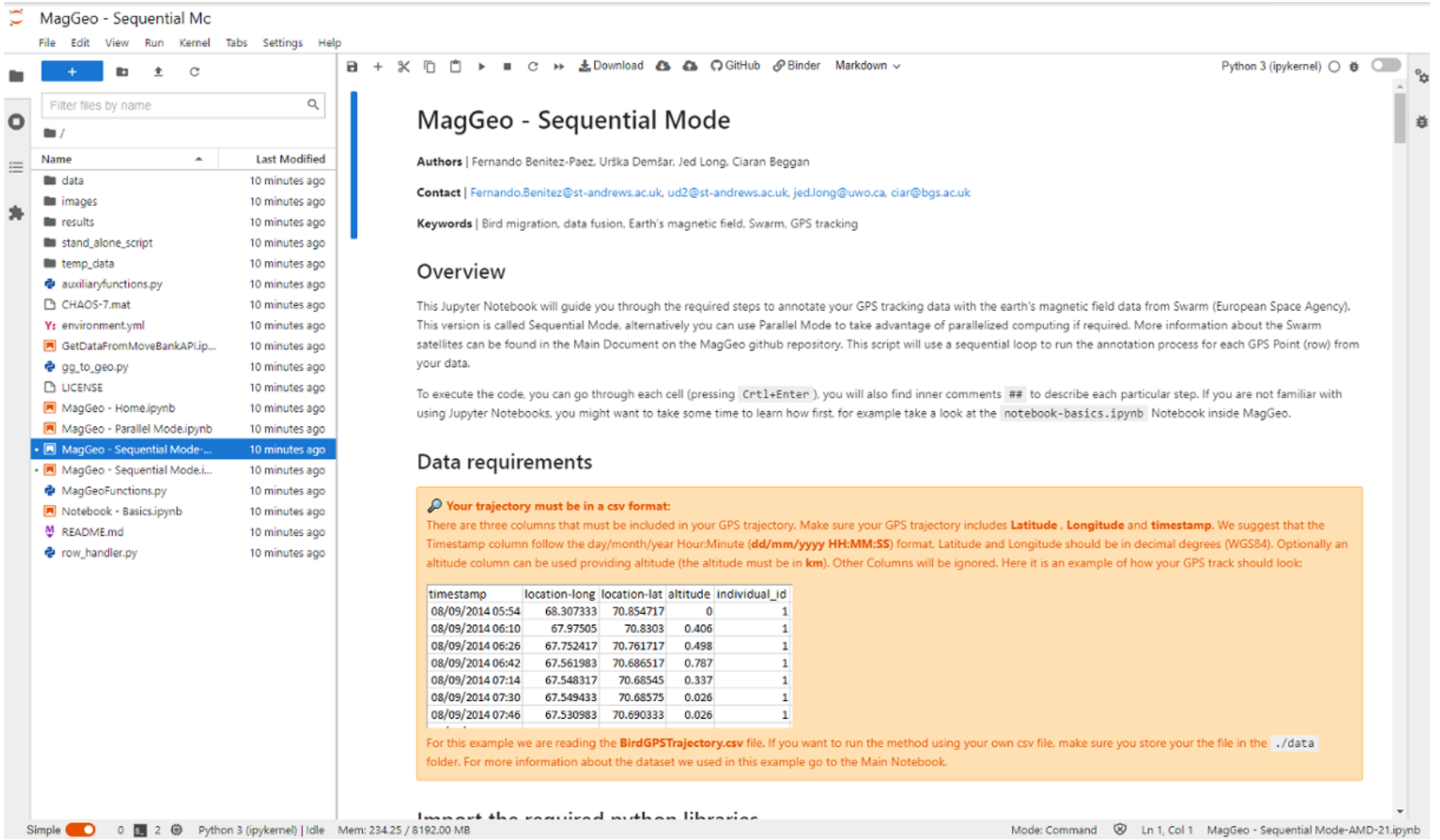
MagGeo – Open-Source Software

Sequential and Parallel mode

Entirely built in Python (soon in R)

A documented tool

Step by step for **no python** ecologists



What are we currently working on?

Ali Moayedi

Big Data Analysis of Animal Migration Using ML techniques

Meixiuan Liu

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

Next Challenges

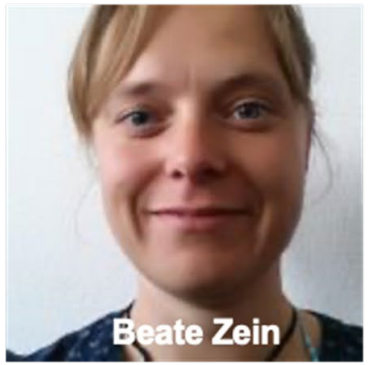
Expand MagGeo – More species (e.g. Marine mammals & Fish)

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



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MAX PLANCK INSTITUTE OF ANIMAL BEHAVIOR

BGS British Geological Survey

Western UNIVERSITY · CANADA

Institute for Waterbird and Wetlands Research (IWWR) e.V. Germany

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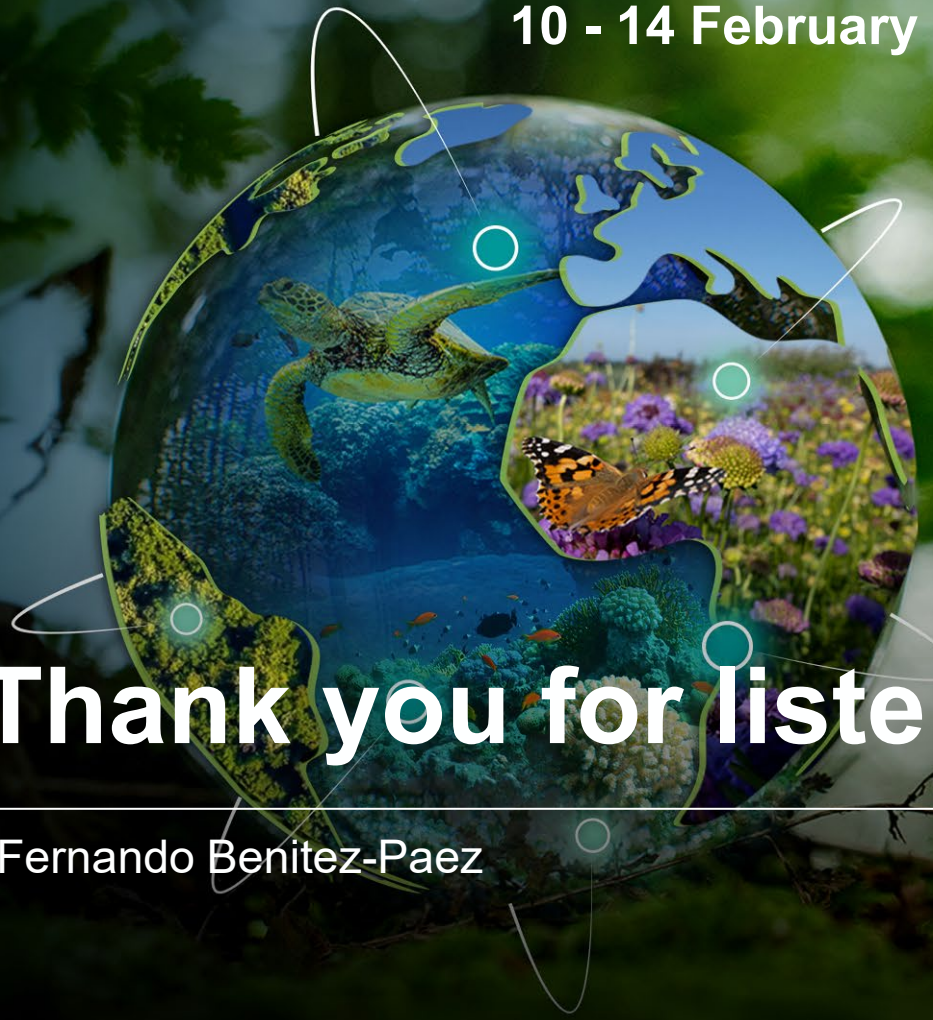

Thank you for listening

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