Environmental Computational Science and Earth Observation Laboratory

Project subject

Range shift of migratory butterflies under climate change

Context

Understanding the interaction between climate and the diversity of life is essential to inform and optimize conservation strategies that aim to slow and potentially reverse the pervasive decline in biodiversity[1], as well as the associated destructive consequences for human wellbeing.To this end, Species Distribution Models (SDMs) are key mathematical tools to map the current geographic distributions of species and predicting their future shifts under climate change. These models work by correlating observations of species occurrence with recorded environmental variables biotic (e.g. symbiosis, trophism) and abiotic (e.g. environmental, climatic) conditions[2,3]. Deep learning has emerged as a promising tool for SDMs, leveraging the vast and growing volumes of data generated by citizen science and environmental data[4,5] and modelling multiple species at the same time[6].

Given the incredibly large number of species on Earth, it is essential to focus on sentinel species which can reflect the response of ecosystem health to environmental changes. Migratory species play a key role in ecological networks, by transporting nutrients and impacting trophic webs, providing important ecological services along their migratory route[7]. Whether driven by survival or reproduction, migrations are an adaptive response to specific environmental conditions and, in turn, highly impacted by environmental changes. More specifically, butterflies play a key ecological role, contributing to pollination, having a significant part in food webs[8], and hosting a great taxonomic diversity[9]. Butterflies are historically one of the most studied insects[10] and the recent involvement of the general public through citizen science initiatives[11] has generated a large number of observations worldwide. Migratory butterflies are extremely sensitive to environmental changes[12–14] and global warming has already been associated to a decrease in butterfly diversity[15] with a drastic expected contraction of the suitable habitats for most species[16,17].

Project

This project aims to predict the range shifts of migratory butterflies under climate change. The project will consist in two main parts:

• Migratory butterfly observations worldwide from the Global Biodiversity Information Facility (GBIF, https://www.gbif.org/, with more than 145 millions of Lepidoptera observations) and global climatic repositories will be used to train and validate a seasonal concatenated species

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distribution model (Multilayer Perceptron), which has been previously developed by the ECEO lab for the Monarch butterfly (Figure 1). Specifically, the model considers monthly climatic predictors (e.g. temperature humidity, evaporation) and the estimated probability of occurrence of the previous season as inputs. The model architecture would need to be adjusted to model multiple species at the same time.

• The model will then be used to make future projections of seasonal species shifts under climate change scenarios at the global scale.

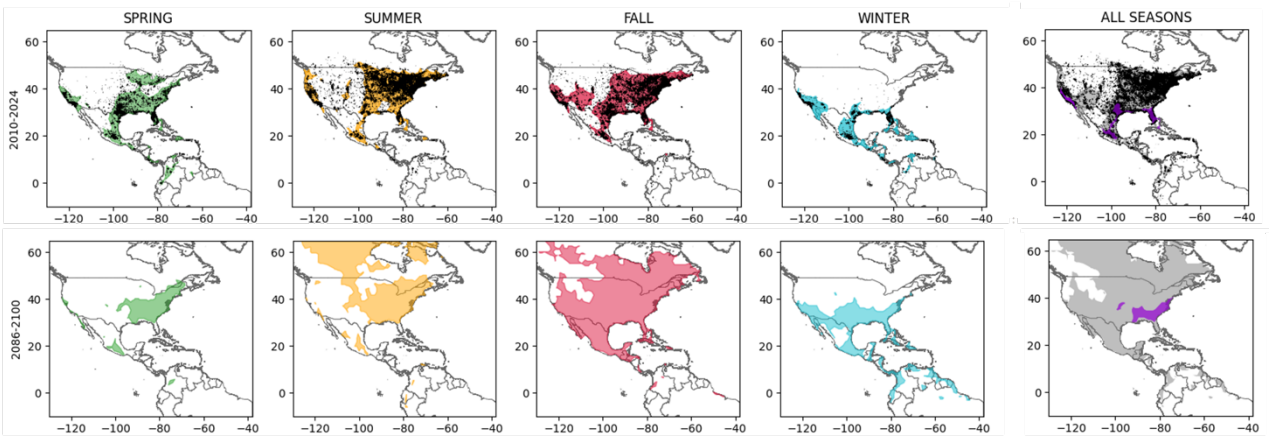

Figure 1. Estimated seasonal and global niches of the Monarch butterfly (spring in green, summer in orange, fall in red, winter in cyan, any season in grey and year-round in purple) with Monarch observations in black in the recent past (2010-2024, top row) and at the end of the century (2086-2100, bottom row under the SSP5-8.5 climate change scenario).

The project will primarily involve georeferenced data processing, environmental covariate extraction and output visualization. Ultimately, migratory butterflies represent pivotal species to monitor climate change impacts and biodiversity loss, and their study can generate crucial insights to identify biodiversity hotspots, minimize the extinction risk under climate change and promote science-informed biodiversity conservation.

Requirements

- Experience or strong interest in big data and climate-driven modelling.
- Proficiency in Python and relevant libraries (e.g., pytorch, numpy, matplotlib).
- Strong willingness to learn and ability to work independently and interest in contributing to projects with ecological impact.

Literature

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