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Space weather disrupts nocturnal bird migration, study finds

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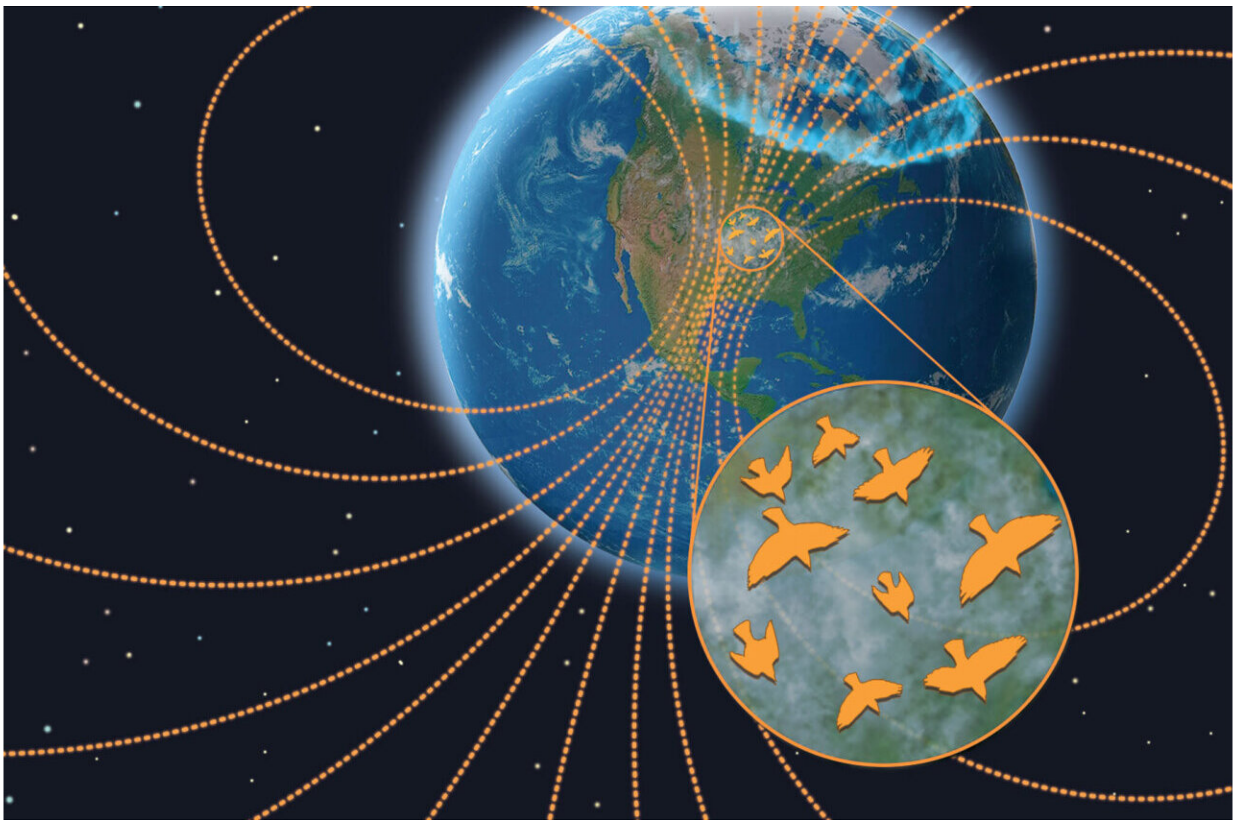


Conceptual and geographic layout of the study system. Space weather from the sun, such as coronal mass ejections, disturb Earth's magnetic field, causing the auroras and potentially decreasing the magnetic field's reliability for migrating birds. Credit: John Megahan, University of Michigan, from Gulson-Castillo et al. in PNAS, October 2023. DOI:10.1073/pnas.2306317120

It's well-known that birds and other animals rely on Earth's magnetic field for long-distance navigation during seasonal migrations.

But how do periodic disruptions of the planet's magnetic field, caused by solar flares and other energetic outbursts, affect the reliability of those biological navigation systems?

University of Michigan researchers and their colleagues used massive, long-term datasets from networks of U.S. Doppler weather radar stations and ground-based magnetometers—devices that measure the intensity of local magnetic fields—to test for a possible link between geomagnetic disturbances and disruptions to nocturnal bird migration.

They found a 9–17% reduction in the number of migrating birds, in both spring and fall, during severe space weather events. And the birds that chose to migrate during such events seemed to experience more difficulty navigating, especially under overcast conditions in autumn.

The new findings published in *Proceedings of the National Academy of Sciences*, provide correlational evidence for previously unknown relationships between nocturnal bird migration dynamics and geomagnetic disturbances, according to the researchers.

"Our findings highlight how animal decisions are dependent on environmental conditions—including those that we as humans cannot perceive, such as geomagnetic disturbances—and that these behaviors influence population-level patterns of animal movement," said study lead author Eric Gulson-Castillo, a doctoral student in the U-M Department of Ecology and Evolutionary Biology.

Earth's magnetic field is regularly impacted by solar outbursts that can trigger colorful auroras and that sometimes disrupt satellite communications, human navigation systems and power grids.

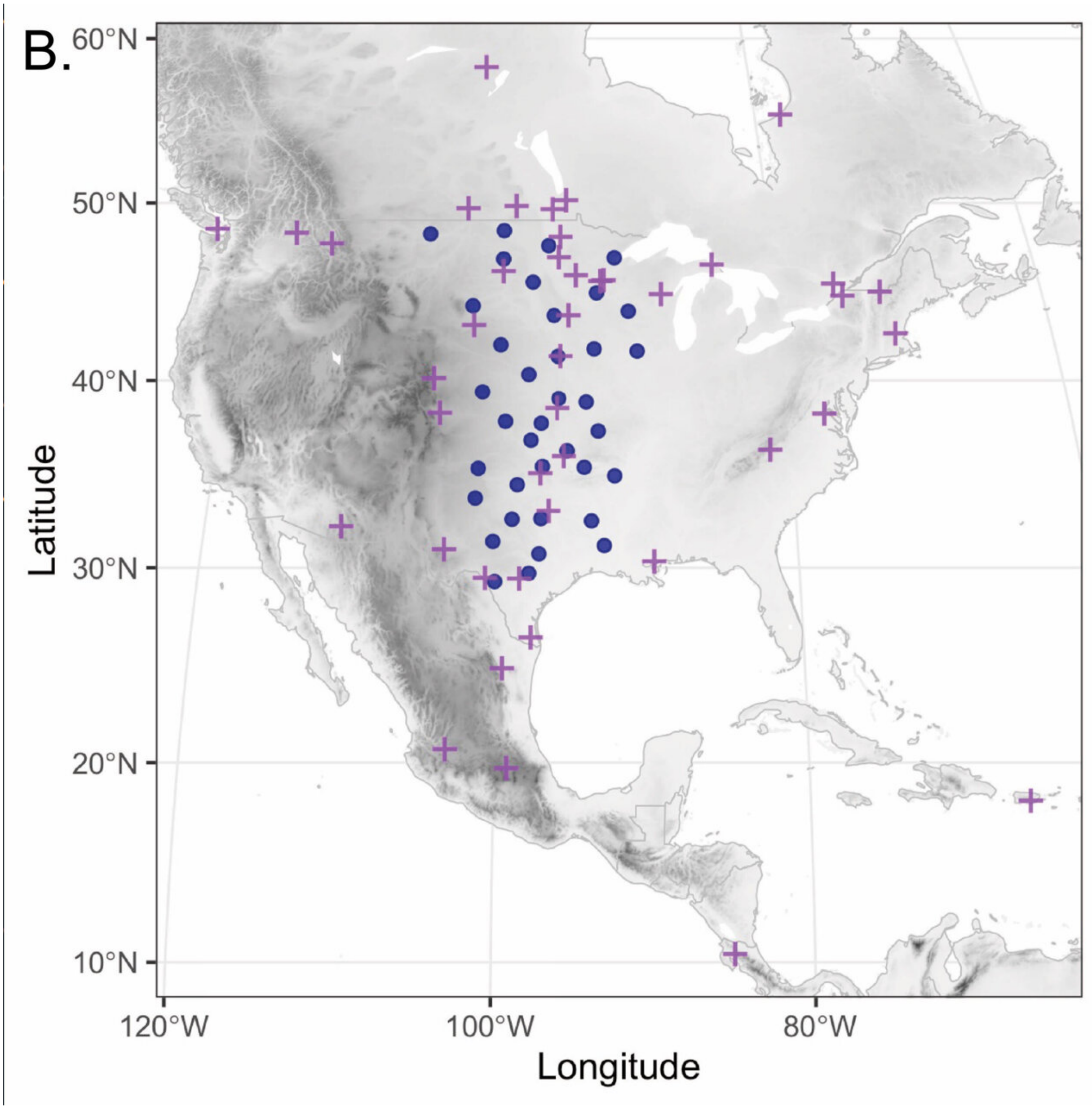
But little is known about how those disturbances affect animals that depend on Earth's magnetic field for migratory orientation and navigation. Previous experimental studies over several decades provide strong evidence that birds, sea turtles and other organisms key into small changes in magnetic inclination, intensity and declination when making orientation decisions and developing navigational maps.

One recent study examined millions of bird banding records and found that geomagnetic disturbances were associated with increased incidence of migratory bird "vagrancy," that is, birds becoming lost during migration.

But most previous studies were narrowly focused in geographic extent, duration and the number of species examined. The newly published study, in contrast, uses a 23-year dataset of bird migration across the U.S. Great Plains to provide new insights at population and landscape levels.

The researchers used images collected at 37 NEXRAD radar stations in the central flyway of the U.S. Great Plains, a major migratory corridor. The flyway spans more than 1,000 miles in the U.S., from Texas to North Dakota.

The research team selected this relatively flat region to minimize influences from mountainous topography or oceanic and Great Lakes coastlines. Their final datasets included 1.7 million radar scans from the fall and 1.4 million from the spring.



Distribution of NEXRAD radar stations (dark blue circles) and SuperMAG inventory magnetometer stations (purple crosses) used in the study in relation to topography (grayscale). Researchers used the three closest and active magnetometer stations surrounding each radar station to interpolate ΔBmax, or maximum change in the magnetic field from quiet conditions, every hour. From Gulson-Castillo et al *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2306317120

The community of nocturnally migrating birds in this region is primarily composed of a diverse set of perching birds (Passeriformes, 73% of species) such as thrushes and warblers; shorebirds (Charadriiformes, 12%) such as sandpipers and plovers; and waterfowl (Anseriformes, 9%) such as ducks, geese and swans.

The NEXRAD radar scans detect groups of hundreds to thousands of migrating birds. Migration intensity—meaning the number of birds in each cluster—can be estimated and direction of flight can be measured.

Concurrent geomagnetic measurements were accessed through superMAG, a worldwide collection of geomagnetic ground stations. Data were collected from magnetometer stations near weather radar sites.

The researchers matched data from each radar station with a customized, spatiotemporally explicit index of geomagnetic disturbance that represents the maximum hourly change from background magnetic conditions.

U-M space scientist Daniel Welling and former University of Texas at Arlington undergraduate Michelle Bui compiled the space weather data and designed the geomagnetic disturbance index. Welling and Bui are co-authors of the new study.

"The biggest challenge was trying to distill such a large dataset—years and years of ground magnetic field observations—into a geomagnetic disturbance index for each radar site," said Welling, assistant professor in the Department of Climate and Space Sciences and Engineering at the U-M College of Engineering. "There was a lot of heavy lifting in terms of assessing data quality and validating our final data product to ensure that it was appropriate for this study."

The data trove was fed into two complementary statistical models to measure the putative effects of magnetic disturbances on bird migration. The models controlled for the known effects of weather, temporal variables such as time of night and geographic variables such as longitude and latitude.

"We found broad support that migration intensity decreases under high geomagnetic disturbance," said study senior author Ben Winger, assistant professor in the U-M Department of Ecology and Evolutionary Biology and a curator of birds at the U-M Museum of Zoology.

"Our results provide ecological context for decades of research on the mechanisms of animal magnetoreception by demonstrating community-wide impacts of space weather on migration dynamics."

The researchers also found that migrating birds appear to drift with the wind more frequently during geomagnetic disturbances in the fall, instead of expending great effort to battle crosswinds.

"Effort flying" against the wind was reduced by 25% under cloudy skies during strong solar storms in the fall, suggesting that a combination of obscured celestial cues and magnetic disruption may hinder navigation.

"Our results suggest that fewer birds migrate during strong geomagnetic disturbances and that migrating birds may experience more difficulty navigating, especially under overcast conditions in autumn," said Gulson-Castillo, who conducted the study as part of his doctoral dissertation. "As a result, they may spend less effort actively navigating in flight and consequently fly in greater alignment with the wind."

More information: Space weather disrupts nocturnal bird migration, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2306317120. doi.org/10.1073/pnas.2306317120

Provided by University of Michigan

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