Continental patterns of bird migration linked to climate variability

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GEO Health Community of Practice
November 30, 2021

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Also acknowledging: other members of the NASA’s GMAO NCA group, Randal Koster, Allison Collow, Young-Kwon Lim, Natalie Thomas, and Anthony DeAngelis for their constructive comments.

Funding Support:
- Global Modeling and Assimilation Office (GMAO) Core funding, provided under NASA’s Modeling, Analysis and Prediction (MAP) program.
- GMAO National Climate Assessment (NCA) enabling tools funded by NASA.
For ~100 years, for management purposes, the continental patterns of avian migration in North America have been described in the context of three or four primary flyways.

This spatial approach fails to reflect a critical characterization of migration — phenology.

Phenology: seasonal timing of key life cycle events.
The shortcoming was due to the lack of reliable continental-scale data.

This gap is filled by analyzing unique radar-based data (NEXRAD) to quantify migration phenology.

A new spatial concept for migration is introduced.

Large-scale climatic mechanisms controlling the new spatial variability are explored.
Data

- **Bird migration:**
  - Developed from NOAA’s Next Generation Radar (NEXRAD) network, consisting of 143 stations across the U.S., using neural network algorithms (Lin et al. 2019).
  - Median migration date (q50), defined as the date by which 50% of the cumulative passage occurred at each radar station

- **Meteorological data:**
  - Temperature, geopotential height, and winds from NASA’s MERRA-2 Reanalysis.

- **Normalized Difference Vegetation Index (NDVI):**
  - NASA’s Moderate Resolution Imaging Spectroradiometer (MODIS) collection 6

- **Sea Surface Temperature (SST)**
  - OISST (NOAA Optimum Interpolation SST V2)

- **Climate indices:**
  - NOAA’s Physical Science Laboratory
Two regions are identified: each is homogeneous with a specific interannual variability.

Two-region pattern is intrinsically different from the previous three- and four-flyway strategies, both in how it has been achieved and its applications.
Two regions are identified: each is homogeneous with a specific interannual variability.

Two-region pattern is intrinsically different from the previous three- and four-flyway strategies, both in how it has been achieved and its applications.
Enables us to identify the region-specific drivers of interannual variability (e.g., climatic phenomena) of bird migration at the continental scale.

Detects years with opposite anomalies and investigates why.

Identifies large-scale temporal characteristics, e.g., std. deviation: 2.4 days in West vs. 1.7 days in East
Rossby waves control the avian migration

- Patterns of GHT (300 hPa) & temperature for 2005 minus 2010 identify atmospheric Rossby wave.

- Using GHT & meridional wind, Rossby wave train is traced back to the Pacific.
- Negative correlation ($R = -0.79$, $p < 0.00005$) between temperature and arrival date of migratory birds over the western U.S.
- Warmer temperature → earlier arrival in spring
Similar spatial variability for bird migration & temperature

- Climate regions obtained objectively based on similarity in interannual variability of Mar-Apr-May temperature.
- Open-source R package, HiClimR, is used (Badr et al. 2015).
- Consistent with two-region pattern from bird migration variability.
**Correlation between regional mean q50 and climate indices**

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<tr>
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<td>W</td>
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<td>-.50 (.1015)*</td>
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<td></td>
<td>E</td>
<td>.49 (.1115)</td>
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</table>


- Time-series of seasonal (March-April-May) means are used for climate indices are.
- Note difference between western and eastern regions.
Role of climate modes in avian migration: Eastern U.S.

- Pattern correlations between migration arrival date & SST (top) and GHT (bottom):
  - Patterns associated with the East Pacific-North Pacific (EP/NP) and North Tropical Atlantic (NTA) stand out.
  - Impact of SST is likely reflected through Rossby waves that are excited over the tropical Pacific.
The role of climate modes in avian migration: Western U.S.

- Generally weaker and more spatially limited (than eastern region) link to large-scale climatic feature like Rossby waves.

- High correlations with adjacent waters, which likely affect the region through temperature advection.
Conclusions & Future Work

- CONUS is divided into two regions based on interannual variability of bird migration.
- The new approach is conceptually different from traditional three- and four-flyway strategies.
- Western and eastern regions show different links to climate variability.
- Eastern U.S. shows significant relationships with several climate modes of variability consistent with atmospheric Rossby wave patterns.
- Western U.S. shows a strong link to regional temperature and adjacent waters.

Future directions:
- Using CMIP6 model outputs to investigate potential changes in bird migration patterns driven by future changes of climate phenomena.


THANK YOU!