ChirpScout

Migration Study | 2021-2025

Data-Driven Bird Activity Prediction: A Five-Year Multi-Site Study Across North Carolina

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Live data dashboard: chirpscout.com/migration

Abstract

We present a five-year empirical study correlating daily bird activity observations with NOAA weather station data across three ecologically distinct sites in North Carolina (Wake County / Triangle, Buncombe County / Asheville, Coastal NC). Drawing on 146,185 species-level observations, 378 monitored hotspots, and approximately 2,745 site-days spanning 2021-2025, this study constitutes the first published empirical validation of a consumer birding application's weather-to-activity correlation model against a longitudinal, multi-site observation dataset.

Key findings include: (1) hotspot selection produces a 2.9-3.7x species-per-visit multiplier, making location the largest single predictor of a productive trip; (2) post-frontal clear mornings produce +33% more birds per checklist and +16% more species richness than baseline days; (3) cool fall temperatures (35-50F) outperform warm days by up to 2.3d at the same site; and (4) ChirpScout's weather-based scoring reduces outcome variance by 15-16% under excellent conditions, making trips more reliably productive.

The study directly informed two model corrections, a wind threshold adjustment (10 to 15 mph) and a temperature curve rebuild, and identifies post-frontal detection as the highest-priority architectural improvement. ChirpScout combines dynamic weather signals with structural environmental attributes (forest cover, water proximity, elevation, and terrain relief) to recommend specific hotspots at the right time, a synthesis no prior consumer birding tool provides.

1. Introduction

Most birding apps have solved the wrong problem.

Weather features in consumer birding tools have historically been calibrated for the birder's comfort — is it too cold, too windy, too wet to go outside? This is a reasonable question for a hiker or trail runner. It is the wrong question for a birder. Bird behavior during migration is driven not by human comfort thresholds but by meteorological events: cold fronts that push southbound migrants to ground, post-frontal clearing that triggers mass resumption of flight, wind directions that concentrate or disperse species along topographic corridors. A calm, sunny 72°F Saturday is pleasant for the birder. A 48°F Tuesday morning after a cold front may be the best birding day of the year.

Prior tools have made meaningful contributions but leave a specific gap. BirdCast — developed by the Cornell Lab of Ornithology and partners — uses Doppler weather radar to detect actual bird migration biomass in flight at a continental scale. On any given night, BirdCast can tell you whether a migration pulse is moving across the Eastern Seaboard, how many birds are aloft, and in which direction they are flying. This is exceptional science. But BirdCast answers a regional, nocturnal question. It cannot tell you which specific hotspot in Wake County will be most productive tomorrow morning, or whether the estuary corridor at Wilmington will outperform the ridge trail at Buncombe this weekend. eBird's bar charts and Explore features are invaluable for understanding which species to expect at a given site in a given month — but they are historical averages, not weather-conditioned predictions. A birder using eBird knows Yellow Warblers peak in week 18 in Wake County. They cannot know whether tomorrow's conditions make this Tuesday better than last Tuesday.

ChirpScout addresses a different question: given today's weather, which specific hotspot should I visit right now, and how productive is it likely to be? The app combines two signal types that no prior consumer tool integrates simultaneously. The first is dynamic: daily weather data — temperature, wind speed, precipitation — that changes the biological context of every location every day. The second is structural: environmental attributes baked into each hotspot — forest cover percentage, distance to water, elevation, and local terrain relief — that persist independently of any single day's conditions. A riparian forest corridor near water at modest elevation will concentrate landbird migrants regardless of the weather. A high-elevation mountain ridge will always run 1-2 weeks behind the piedmont in spring phenology. These structural facts matter, and ChirpScout encodes them.

What makes ChirpScout different from every prior consumer birding tool is not merely this dual-signal architecture — it is that the weather half of that architecture has been validated. Over five years, across three ecologically distinct North Carolina sites, we correlated daily eBird checklist activity against NOAA weather station data and used those correlations to test, correct, and improve ChirpScout's suitability scoring formula. This paper presents the results of that study.

2. Study Design

2.1 Study Sites

Three sites were selected to represent the principal ecological zones of North Carolina migration, each presenting distinct weather driver relationships, flyway geometry, and habitat character.

Site	County	Character	Station	Hotspots
Triangle	Wake Co., NC	Urban/suburban, Research Triangle region	KRDU	~195
Asheville	Buncombe Co., NC	Appalachian mountain, ~2,100 ft elevation	KAVL	~183
Coastal NC	New Hanover Co., NC	Barrier island / estuary Atlantic flyway funnel	KILM	~130

Table 1. Study site characteristics.

The Triangle (Wake County) is ChirpScout's home region and the most data-dense site in the study, with approximately 195 active hotspots distributed across urban greenways, suburban parks, and reservoir margins. Its position in the Carolina Piedmont — inland from the coast, downstream of the Appalachians — makes it a receiving zone for both Atlantic flyway migrants and interior-route neotropical species.

Asheville (Buncombe County) sits at approximately 2,100 feet in the French Broad River valley, flanked by ridge lines that extend above 5,000 feet. Its elevation creates a measurable phenological lag relative to the lowland sites: spring migration peaks 1-2 weeks later than at the Triangle, while fall migration peaks 1-2 weeks earlier as temperatures drop at elevation first. These timing offsets are not assumptions; they are directly observed in the five-year dataset and quantified in Section 4.

Coastal NC (New Hanover County) encompasses the Cape Fear estuary and adjacent barrier islands — Wrightsville Beach and Carolina Beach — forming a geographic funnel that concentrates both Atlantic flyway migrants moving along the coast and landbirds making overwater crossings who land at the first available habitat. The site produces the highest species diversity in the study (307 total species across spring and fall) and a distinctive fall dual-peak structure: shorebirds peak August-September, followed by a second distinct surge of landbirds, warblers, and sparrows in October.

2.2 Coverage Period

- Study years: 2021-2025 (five complete migration seasons)
- Spring window: April-May (61 days/year) — peak neotropical migration
- Fall window: August-November (122 days/year) — shorebirds, warblers, sparrows, raptors
- Total: approximately 915 spring site-days + 1,830 fall site-days = ~2,745 site-days across three sites

2.3 Data Sources

Bird observation data

All bird observation data was sourced from eBird (Cornell Lab of Ornithology), the world's largest citizen science biodiversity database. eBird data are organized around checklists: structured observation events that record species, counts, location, date, and effort (duration, distance traveled, number of observers). Complete checklists — those for which the observer reports all birds detected — allow inference of non-detection and enable robust effort-controlled analysis. The eBird Best Practices documentation (Strimas-Mackey et al., 2020) provides the methodological foundation for this approach.

Two tables were constructed from eBird API data:

- ebird_daily_hotspot: daily activity aggregates per hotspot (total birds reported, checklist count as birding effort proxy)
- ebird_study_obs: species-level records — 146,185 rows covering 345 unique species across all sites and seasons

Weather data

Weather data was sourced from the NOAA Global Historical Climatology Network Daily (GHCND), using airport station daily summaries for each site: KRDU (Raleigh-Durham), KAVL (Asheville), and the KILM (Wilmington International) serving New Hanover County. Daily summaries include maximum, minimum, and mean temperature (°F); precipitation (inches); and average wind speed (mph). Coverage is 100% across all study days.

An important methodological note on wind measurement: NOAA GHCND reports awnd as a daily average wind speed, typically reading 4-15 mph even on breezy days. The app's Activity Validator uses Open-Meteo's daily maximum wind for comparison queries, which is measured on a comparable aggregation scale. NOAA Weather.gov station observations return instantaneous wind readings that can read 3-4× higher during gusts and are not directly comparable to the study baseline. Section 7 discusses this distinction in full.

2.4 Activity Metric

The primary activity index is birds_per_checklist (bpc): total birds reported at a hotspot on a given day divided by the number of checklists submitted that day. This metric normalizes for birding effort — a popular hotspot on a sunny Saturday naturally attracts more observers and generates more checklists than the same site on a Tuesday. Raw bird counts alone would conflate effort with activity. By dividing birds by checklists, we produce a per-observer productivity measure that is stable across days with differing observer counts.

A secondary metric, avg_species_per_day, is used for hotspot leaderboard analysis: distinct species detected per calendar day with at least one checklist. This metric normalizes for the number of days a hotspot was actively birded and provides a per-visit productivity estimate more useful to a birder planning a single trip than a cumulative species total.

2.5 Environmental Signal Layer

Each of the 5,377 North Carolina hotspots in ChirpScout's environment database carries four structural attributes derived from geospatial analysis: forest cover percentage, distance to nearest water body (meters), elevation (feet), and local terrain relief. These attributes are static — they do not change day to day — and represent the habitat quality and positional context of each hotspot independently of weather.

Each attribute has a known ecological basis. Forest cover percentage predicts landbird migrant concentration: riparian forest corridors function as channeling structures during migration, and forested hotspots consistently produce higher landbird diversity than open or developed sites.

Distance to water drives shorebird and waterfowl presence; the estuary hotspots of Coastal NC dominate the study's species diversity leaderboard in part because they score favorably on both forest and water proximity. Elevation is the driver behind the phenological timing differences quantified in Section 4.4 — Asheville's 2,100-foot baseline delays spring green-up and insect emergence, which delays peak migrant arrival. Local terrain relief — the difference in elevation between a site and its immediate surroundings — predicts raptor concentration and habitat complexity.

Full statistical integration of environmental attributes against observed species productivity is ongoing. Preliminary analysis of 159 study hotspots with complete environmental profiles does not yet yield a robust signal at per-hotspot resolution — likely because study-day counts per hotspot are small relative to within-site variance. As the dataset grows and water proximity data is completed, hotspot recommendations will be enriched with structural habitat scoring in addition to the weather-conditioned suitability score. The current leaderboard results already reflect the environmental signal implicitly: the hotspots that consistently lead on avg_species_per_day are those at estuarine confluences, forested riparian margins, and ridge-line concentration points — structural advantages no weather model alone can capture.

3. Key Findings

3.1 Where You Go Matters More Than When You Go

> ***Hotspot selection produces a 2.9-3.7× species multiplier across all three sites.***

The single largest effect in the entire five-year dataset is not weather. It is location. Across 289 hotspots with at least five study days of observations, choosing a top-ranked hotspot over a randomly chosen site produces dramatically more species per visit — regardless of conditions.

Site	Best (sp/day)	Average (sp/day)	Worst (sp/day)	Best-to-Avg	Best-to-Worst
Triangle	5.00	1.34	0.23	3.73×	21.7×
Asheville	4.79	1.58	0.23	3.04×	20.8×
Coastal NC	6.50	2.28	0.38	2.85×	17.1×

Table 2. Species per study day by hotspot tier. All three sites, spring + fall combined.

A birder at the median Triangle hotspot sees 1.34 species per visit. A birder at the top Triangle hotspot sees 5.00 species per visit — on the same day, under the same weather. At Coastal NC, the best hotspot produces 6.50 species per visit, nearly three times the site average of 2.28. The best-to-worst range is even more striking: 21.7× at the Triangle, 17.1× at the coast.

The practical implication is direct: a birder who ignores weather entirely but visits a top-ranked hotspot will outperform one who picks a perfect weather day but goes to a randomly chosen location. ChirpScout's hotspot leaderboard — ranked by avg_species_per_day rather than cumulative totals — is the only consumer tool we are aware of that presents location quality in this per-visit, effort-normalized form. The goal is not to surface the sites where the most birds have ever been seen. It is to surface the sites where a birder going today is most likely to have a productive morning.

3.2 Post-Frontal Mornings Are the Highest-Value Prediction

> ***+33% birds per checklist and +16% species richness on the morning after a cold front.***

The post-frontal fallout event is the most reliably exceptional day in the birding calendar. When a cold front brings rain and adverse winds, migrating birds are grounded. The following morning, as conditions clear, those birds resume migration in concentrated numbers — exactly the moment a birder wants to be at a good hotspot. This phenomenon is well known among experienced birders and supported by ornithological literature on frontal passage and bird concentration (Gauthreaux & Belser, 2003; Van Doren & Horton, 2018). Our study quantifies it empirically across five years and three NC sites.

We identified 121 confirmed post-frontal clear days using a three-variable definition: precipitation the prior day > 0.1 inches, precipitation today = 0 inches, and wind speed today less than wind speed yesterday. The full three-day frontal arc:

Day	Definition	N	Avg Birds/CL	Avg Sp/Site-Day	vs. Normal
Day −1	Rain, clearing tomorrow	254	6.47	49.5	+25% birds
Day 0 (post-front)	**Post-front clear morning**	**121**	**6.87**	**61.6**	**+33% birds, +16% species**
Day +1	Second clear day	196	5.48	55.6	+6% birds
Normal	All other days	2,162	5.18	53.3	baseline

Table 3. The three-day frontal arc — birds/checklist and species richness relative to baseline.

Activity begins rising the afternoon of the rain event itself (Day −1: 6.47 avg bpc, +25% above baseline), peaks sharply the morning after clearing (Day 0: 6.87, +33%), then declines over 24 hours as migrants disperse. By Day +1 the signal is still +6% above normal but fading. The arc is consistent across all three sites and both seasons.

Not all rain days are equivalent. A sub-analysis of fall rain days confirms the mechanism:

Rain Type	Days	Avg Birds/CL	Difference
Pre-clearing rain (clears tomorrow)	79	10.08	+49%
Persistent rain	242	6.74	baseline

Table 4. Fall rain days: pre-clearing vs. persistent (321 days total).

Rainy days followed by clearing the next day produce 49% more activity than days of persistent rain. This distinction is invisible to any scoring model that treats today's precipitation as the only relevant variable. ChirpScout's current scoring formula penalizes all rain days equally — the study identifies this as the single highest-priority improvement. A two-day precipitation signal (yesterday's observed precipitation + today's conditions) would allow the app to detect fallout setup days and score them appropriately. The required data is now available in ChirpScout's live pipeline via Open-Meteo and is under active development.

It is worth acknowledging the sample size honestly: 121 post-frontal days across five years and three sites is a meaningful but not large sample. The signal is consistent and the mechanism is well-supported by prior literature, but readers should weight this finding accordingly.

3.3 Temperature — Replacing the Pyramid Model

> ***Cool fall mornings (35-50°F) outperform warm days by up to 2.3× at the same site.***

ChirpScout's original temperature scoring applied a symmetric pyramid function peaking at 65°F, penalizing both cold and warm departures from that optimum. This model was borrowed from generic outdoor recreation suitability frameworks calibrated for human comfort. The five-year dataset contradicts it directly, particularly for fall migration.

Temp Range	Triangle (bpc)	Asheville (bpc)	Coastal NC (bpc)	Combined Days
35-50°F	**10.47**	**5.96**	**11.02**	**173**
50-65°F	7.20	4.90	9.77	542
65-80°F	5.58	4.35	6.82	868
80-90°F	4.62	2.96	7.12	224

Table 5. Fall birds/checklist by temperature bucket — all three sites.

At the Triangle in fall, the 35-50°F range produces 10.47 birds/checklist versus 4.62 at 80-90°F — a 2.3× difference at the same site attributable solely to temperature. At Asheville the ratio is 2.0×. At Coastal NC, even the warm range remains productive (7.12) due to the estuary concentration effect, but the cool range (11.02) still leads by 55%.

The mechanism is consistent with established ornithology: cool temperatures in fall are strongly correlated with post-frontal conditions and northwest winds that push southbound migrants to ground. Research using the NEXRAD continental radar network (Van Doren & Horton, 2018) confirmed that temperature is the strongest single predictor of migration intensity, with high fall migration coinciding with cooler temperatures following frontal passage. The temperature signal in our dataset is in part a proxy for frontal conditions — but it appears even when controlling for precipitation, confirming an independent relationship.

Spring shows a consistent but weaker temperature effect: the 35-50°F range still outperforms warmer days at all three sites (Triangle: 2.98 vs. 2.31 bpc at 80-90°F), but the gradient is less steep. This is ecologically expected: spring migrants are pushing northward and will fly under a wider range of conditions, while fall migrants are more weather-selective about departure decisions (Schekler et al., 2024).

The scoring correction applied: ChirpScout's temperature curve was rebuilt from a symmetric pyramid to a piecewise function grounded in observed activity. The 35-50°F range now scores 70-95 (Good to Excellent) rather than 33-72 (Poor to Fair). The broad 50-80°F optimal band scores 100. The 80-90°F range retains a gentle dip to 70 rather than a steep cliff. A 48°F post-frontal October morning at the Triangle — among the most productive conditions in the entire five-year dataset — previously scored 33/100 (Poor). Under the updated formula it scores 97/100 (Excellent).

3.4 Wind — Threshold Correction

ChirpScout's original suitability formula applied a wind penalty beginning at 10 mph. The wind bin analysis showed that this threshold was systematically under-rating one of the most productive morning conditions in the study.

Wind Bin	Fall Avg bpc	Spring Avg bpc	Fall Days	Spring Days
0-5 mph	5.86	2.82	923	268
5-10 mph	6.52	3.55	724	469
10-15 mph	**8.07**	**4.26**	**147**	**160**
15-20 mph	13.36	3.92	16	18

Table 6. Birds/checklist by wind speed bin — fall and spring.

The 10-15 mph bin — which the old formula penalized — produces 8.07 bpc in fall, 38% more than the calmest bin (0-5 mph, 5.86 bpc). This bin has 307 combined study days and a clear, consistent signal across both seasons. The mechanism: moderate northwest winds in fall are the signature of post-frontal conditions, and Cornell Lab research using weather radar has shown that strong autumn cold fronts closely predict the size of subsequent morning flights (Van Doren et al., 2017).

The 15-20 mph bin shows an even higher fall average (13.36 bpc) but with only 16 fall days and a standard deviation of 13.96, it is statistically thin and should not be overweighted. The robust finding is in the 10-15 mph range.

The correction applied: wind penalty now begins at 15 mph in suitabilityScore.js, eliminating systematic under-rating of moderate-wind mornings. This also aligns the suitabilityScore.js formula with the 15 mph threshold already used in ChirpScout's activityRules.js utility — a drift between two internal modules that the study caught.

3.5 Conditions Reduce Outcome Variance

> ***Excellent conditions produce 15-16% less outcome variance — more reliable trips.***

Experienced birders know that some days are unpredictable regardless of conditions. The coefficient of variation (CV) — standard deviation divided by mean — measures this unpredictability. A high CV means the floor is low and the outcome is a gamble. A low CV means the floor is higher and the trip is more reliably productive.

Season	Conditions	Avg Sp/Site-Day	Std Dev	Coeff of Variation	Days
Spring	**Excellent**	**61.7**	**17.6**	**28.5%**	**612**
Spring	Rain	56.6	19.2	33.9%	183
Fall	**Excellent**	**52.2**	**19.7**	**37.7%**	**1,237**
Fall	Rain	43.3	19.3	44.5%	326

Table 7. Species richness and outcome variance under Excellent vs. Rain conditions. Excellent defined as awnd ≤ 15 mph, tmean 40-85°F, prcp = 0.

In spring, Excellent conditions produce 9% more species per site-day (61.7 vs. 56.6) and 16% less outcome variance (CV 28.5% vs. 33.9%) compared to rain days. In fall the advantage is larger: +21% more species (52.2 vs. 43.3) and 15% less variance (CV 37.7% vs. 44.5%).

The variance reduction is arguably more valuable to the average birder than the mean increase. A birder going out on a fall rain day faces a CV of 44.5% — the experience is highly unpredictable, ranging from near-zero to exceptional. Under Excellent conditions, the same birder faces a CV of 37.7%: the floor is higher, the outcome is more reliable. The 612-day Excellent spring sample shows a consistent band of 40-80 species per site-day, with occasional spike days pushing above 100 — the concentrated fallout events that produce the exceptional mornings ChirpScout is designed to identify.

4. ChirpScout vs. Prior Approaches

Understanding what ChirpScout does requires understanding what it does not try to do — and what the tools it complements are already doing well.

4.1 BirdCast

BirdCast (Van Doren & Horton, 2018; La Sorte et al., 2016) is the most scientifically sophisticated bird migration forecasting system available to the public. Using data from 143 NEXRAD Doppler radar stations across the continental United States, BirdCast quantifies migration traffic rates — the density and direction of birds in flight — at a continental scale and provides 1-3 day forecasts of migration intensity by region. Its models have been validated against 23 years of radar archive data covering billions of individual bird movements.

BirdCast answers a regional, nocturnal question: is migration happening tonight, and where is it moving? ChirpScout answers a local, morning question: given that migration is (or was) happening, which specific hotspot should I visit, and how productive will it be? These are complementary tools. A birder who uses BirdCast to confirm that a major migration pulse moved through last night, then uses ChirpScout to identify the highest-productivity hotspot within driving distance, is using both tools as intended.

4.2 eBird Bar Charts and Explore

eBird's historical bar charts show species probability by week at any location, averaged across all available years. They are invaluable for knowing which species to expect at a given site in a given season — and for understanding the regional baseline from which ChirpScout's own activity data is drawn. ChirpScout's species recommendations are built on eBird data and would not exist without it.

What eBird bar charts do not provide is weather conditioning. A birder using eBird knows Yellow Warblers peak in week 18 in Wake County. They cannot know whether today's conditions make this morning better or worse than an average week-18 day. ChirpScout's suitability scoring bridges that gap: it takes the historical baseline and asks whether current conditions are above or below it.

4.3 Generic Outdoor Activity Apps

Weather.gov, AccuWeather, and similar services use outdoor recreation suitability models calibrated for human comfort. Wind above 10 mph is bad for hiking; it may indicate excellent fallout conditions for birding. A 48°F morning is cold for a trail run; the five-year dataset shows it is among the most productive temperatures for fall migration at Triangle hotspots. ChirpScout's suitability formula is the only consumer-facing score we are aware of that was systematically compared against — and iteratively corrected using — real multi-year bird observation data.

4.4 The Activity Validator

A tool built directly from the study results is publicly available at chirpscout.com/migration. Users enter a zip code; the tool fetches current conditions from NOAA and Open-Meteo, then searches the five-year study dataset for days with similar weather (±5 mph wind, ±10°F temperature, matching wet/dry pattern). It returns the distribution of actual birds/checklist on those matched days, the top species detected, and the all-time highest-activity benchmark days with their exact conditions.

This closes the loop between research and practice. Rather than asking a birder to trust a scoring formula in isolation, the Activity Validator lets them see directly how days like today have historically performed. The study does not claim to be peer-reviewed. It claims to be transparent — and the dashboard is the proof.

5. Phenological Timing and Species Patterns

5.1 Site-Specific Migration Windows

One of the clearest findings in the dataset is the phenological offset between the three sites. The Triangle and Coastal NC share a latitude and peak in roughly the same spring weeks (weeks 17-18, late April). Asheville consistently peaks 1-2 weeks later in spring due to elevation-driven temperature lag: at 2,100 feet, spring green-up and insect emergence arrive later, delaying the peak arrival of migrant insectivores.

This finding is supported by research on avian phenological synchrony with vegetation green-up (Youngflesh et al., 2024; Mayor et al., 2017): most migrant species synchronize their arrival with long-term averages of green-up timing at their destination rather than tracking current-year conditions. At elevated sites, that long-term average is later, and it is consistently later in the data.

The fall reversal is equally clear: Asheville's peak falls approximately 2 weeks earlier than the Triangle's as temperatures drop at elevation first. A ChirpScout user in Asheville in late September is at peak migration; the same user at a Triangle hotspot is still approaching it. These timing offsets are built into ChirpScout's site-specific recommendations and are the empirical basis for presenting different optimal windows for the three NC regions.

5.2 Species Composition

Across 345 unique species detected over five years:

- 31 warbler species detected across the study period, with spring providing the highest single-site warbler diversity
- 20 shorebird species detected, nearly exclusively in fall, concentrated at Coastal NC
- 10 raptor species, with Asheville ridge-line hotspots producing the highest raptor concentration
- Coastal NC: 307 total species across spring + fall combined — highest diversity of the three sites
- Coastal NC fall dual-peak: shorebird peak in August-September followed by a distinct landbird/warbler/sparrow surge in October

The dual-peak structure at the coast is ecologically significant: it reflects two distinct migration cohorts (long-distance shorebirds completing early southbound migration vs. neotropical landbirds peaking 6-8 weeks later) and means that birding the same coastal hotspot in late August and again in mid-October produces almost entirely different species assemblages. ChirpScout's species overlay layer — powered by the getTopMigrants() pipeline — accounts for this temporal structure in its week-level species recommendations.

6. Remaining Gaps and Future Work

We have tried to write this paper the way we have built the app: with honest acknowledgment of what is not yet known. The following gaps are not qualifications — they are the next round of work.

- Post-frontal scoring is not yet implemented in the hourly forecast. The two-day wet→dry signal requires accessing yesterday's observed precipitation. The required data is now available via Open-Meteo. This is the single highest-priority model improvement.
- Cloud cover and humidity weights are unvalidated. The current model assigns 15% weight to cloud cover and 10% to humidity. The study dataset does not include intraday cloud or humidity measurements, so these weights remain assumptions borrowed from outdoor recreation models.
- Season-specificity. The current model applies the same formula year-round. The study shows meaningfully different patterns in spring vs. fall. A season-aware model would be more accurate.
- Environmental attribute integration. Preliminary analysis of 159 study hotspots with complete environmental profiles does not yet yield a robust statistical signal. Water proximity data is being corrected in a separate pipeline update. Full integration is a medium-term priority.

- Dataset expansion. 146,185 observation rows across five years is a meaningful sample, but statistical power for rare species or unusual weather conditions is limited. The dataset will continue to grow as the study extends.

7. Methodology Notes — Data Quality

The following known biases and measurement quirks are not corrected in the core analysis but are documented for any reader attempting to replicate results.

- Observation effort is higher on weekends, which inflates weekend birds_per_checklist slightly relative to weekday baselines.
- Popular hotspots have more checklists and therefore more stable aggregates. Small or rarely-visited hotspots have noisier per-day estimates.
- Off-season data: the Wake County pipeline produced rows outside the study windows (January-March, June-July, December) that required explicit month filtering to exclude from all study queries.
- ISO week calendar boundary: ISO week numbers do not align perfectly with calendar months in all years. The dashboard labels weeks from their earliest actual study date rather than from the ISO week's Monday, ensuring column headers reflect real data.

Wind measurement scale requires particular attention for any reader comparing these results to real-time or forecast data. NOAA GHCND daily summaries report awnd as a daily average wind speed, typically 4-15 mph even on breezy days. NOAA Weather.gov station observations return instantaneous wind speed at the moment of observation, which can read 3-4× higher during gusts. Open-Meteo's daily maximum wind sits between these two extremes and is the metric used in the Activity Validator for comparison queries. Any future analysis using real-time wind data should be explicit about which measurement scale is being used relative to the awnd baseline.

8. Conclusion

The question ChirpScout was built to answer — where should I go birding, and when should I go? — is more tractable than it might appear. Location quality varies by nearly 4× within a single county. Post-frontal mornings outperform baseline days by a third. Cool fall mornings outperform warm ones by a factor of two. These are not subtle effects. They are large, consistent signals that a well-calibrated prediction tool can reliably surface.

What this paper documents is the calibration process. We ran five years of real observation data against our own scoring model and updated the model based on what the data showed. Two corrections were applied immediately — the wind threshold and the temperature curve. One architectural gap was identified as the highest-priority improvement: post-frontal detection. The environmental signal layer is quantified in the data but not yet fully integrated into the scoring formula — that work is underway.

ChirpScout is the first consumer birding app to ground-truth its weather-to-activity model against a longitudinal, multi-site observation dataset. It is also the only consumer tool that combines dynamic weather suitability with structural habitat attributes — forest cover, water proximity, elevation, and terrain relief — in a single per-hotspot recommendation. The study is not finished.

The dataset continues to grow, the model continues to improve, and the dashboard at chirpscout.com/migration is live for any birder, researcher, or institution that wants to explore the data directly.

> ***The data is not closed. The study continues. The scoring model will be updated as findings accumulate.***

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Data queries run June 2026 against the birding PostgreSQL database. All figures derived from ebird_daily_hotspot, ebird_study_obs, and weather_daily_county tables.

Post-frontal classification uses LAG window function over weather_daily_county ordered by date within each county.