Automated Inlet Coordinate Verification Using Satellite Imagery and Vision AI

Eric Whyne
Data Machines
info@datamachines.com

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Abstract

The Geographic Names Information System (GNIS), maintained by the U.S. Geological Survey, provides coordinates for coastal inlets that systematically point to Intracoastal Waterway channel reference points rather than the actual ocean entrances where boats transit. Through development of Pelagic Insight, a nationwide coastal inlet intelligence platform covering 130+ tidal inlets, we discovered this positional bias (typically 0.3–1.0 nautical miles) and developed an automated verification methodology combining Mapbox satellite imagery with vision AI analysis. This approach detected coordinate discrepancies in 95 of 130 inlets (73%), with corrections ranging from 0.3 to 8.5 nautical miles, enabling systematic correction at a scale that would require weeks of manual cartographic review.

1 Introduction

Coastal inlets, the narrow passages connecting the open ocean to bays, sounds, and the Intracoastal Waterway, are among the most dangerous navigational features on the US coastline. When a boater enters "Shallotte Inlet" into a chart plotter or navigation app, they expect the coordinates to place them at the ocean mouth of the : the point where a vessel transitions from open ocean into the protected waterway.

They do not expect to be directed to a point on the Intracoastal Waterway, a half-mile or more inland from the actual ocean entrance.

Yet this is precisely what happens when applications source their inlet coordinates from the Geographic Names Information System, the federal government's authoritative database of geographic feature names and locations. For coastal inlets, these coordinates are systematically , not by random error, but by a consistent bias toward ICW channel reference points rather than ocean entrances.

2 Background

2.1 The Geographic Names Information System (GNIS)

GNIS is the official repository of domestic geographic names data maintained by the USGS Board on Geographic Names. It contains records for approximately 2.2 million features and serves as the federal standard consumed by NOAA, the US Coast Guard, the FAA, state and local GIS systems, and consumer mapping applications.

For each feature, GNIS provides a single coordinate pair. The database does not distinguish between different functional aspects of a ; for a coastal inlet, it provides one point, regardless of whether that point represents the ocean entrance, the ICW junction, or some midpoint along the channel.

2.2 The ICW vs. Ocean-Mouth Distinction

The Intracoastal Waterway is a 3,000-mile navigable waterway along the Atlantic and Gulf coasts. Many coastal inlets serve as junctions between the ICW and the open ocean, with channels extending from a few hundred yards to several miles. For navigational purposes, the ocean mouth is the operationally relevant : where vessels make the critical transition between protected and open water, where bar conditions pose the greatest danger, and where Coast Guard rescue operations focus.

2.3 How Inlet Coordinates Propagate

GNIS coordinates propagate through a chain of downstream consumers. When NOAA defines a marine weather forecast zone, it references GNIS. When a chart plotter manufacturer labels an inlet, the placement derives from GNIS. When a fishing app shows "nearby inlets," it queries coordinates that trace back to GNIS. A systematic error at the source propagates to every downstream application.

3 Problem Discovery

3.1 The Shallotte Inlet Anomaly

The coordinate bias was discovered during development of Pelagic Insight's depth sounding visualization. When testing with Shallotte Inlet, North Carolina, depth soundings rendered on the Intracoastal Waterway rather than at the ocean entrance. The reference coordinates (33.9043°N, 78.3811°W) corresponded to a point on the ICW approximately 0.5 nautical miles from the actual ocean mouth (approximately 33.915°N, 78.373°W).

3.2 Systematic Pattern Recognition

Manual spot-checks revealed the bias was not isolated. Inlet after inlet showed the same pattern: GNIS coordinates placed on or near the ICW, with the actual ocean entrance 0.2 to over 1.0 nautical miles away. The bias was consistent in direction, always toward the inland waterway, suggesting a systematic classification issue.

This is consistent with how GNIS classifies inlet features under the "Channel" feature class. The reference coordinate corresponds to the channel (the ICW segment) rather than the ocean terminus. The coordinates are not "wrong" in GNIS's internal logic, but they are wrong in the context of how downstream applications interpret "inlet location."

4 Solution Iteration

The path from discovery to solution involved four approaches, each building on the limitations of the previous one.

4.1 Manual Review

Effective for individual inlets but impractical at scale. With 130+ inlets, manual review would require 15–20 hours of focused cartographic work with reproducibility challenges.

4.2 GNIS Database Audit

Confirmed the systematic nature of the bias but provided no correction path. GNIS *is* the ground truth in the federal ; there is no alternative database to compare against.

4.3 Visual Audit via Satellite Map

Building a dedicated review interface overlaying coordinates on Mapbox satellite imagery was highly effective for human review but still required manual coordinate estimation and database updates.

4.4 Vision AI Audit

Using vision-capable large language models to analyze satellite imagery proved capable of auditing all 130+ inlets in approximately 10 minutes of compute time per pass. This approach, detailed in the following section, flagged 125 of 130 inlets initially, with 95 corrections confirmed and deployed after verification.

5 Methodology

5.1 Overview

The automated system operates in three stages: (1) satellite image acquisition, (2) vision AI analysis, and (3) validation.

5.2 Satellite Image Acquisition

For each inlet, a satellite image is retrieved using the Mapbox Static Images API:

- **Style:** `mapbox/satellite-v9` (no labels or overlays)
- **Zoom level:** Calibrated to show 2–3 nautical miles of coastline context
- **Dimensions:** 600×600 pixels
- **View:** North-up, nadir

Label-free imagery is deliberate: labels would bias the vision model, and the task requires analysis of physical coastal morphology.

5.3 Vision AI Analysis

Each image is submitted to a vision-capable AI model with prompts providing context (image center coordinates, scale), task specification (identify the ocean-mouth entrance), and output format (latitude/longitude with confidence assessment). Prompt engineering required iteration:

- Explicit instruction to find the "ocean-side entrance" rather than "the inlet location"
- Geographic reasoning guidance (center coordinates and scale for spatial estimation)
- Morphological cues (barrier island gaps, sand spits, jetty structures, wave-break patterns)

5.4 Coordinate Estimation

Two approaches were tested:

1. **Free-form geographic estimation (Pass 1):** The model estimates lat/lon directly from the image.
2. **Pixel-based estimation (Pass 2):** The model reports pixel coordinates (x, y) within the 600×600 image, which are converted to geographic coordinates via deterministic Mapbox tile , leveraging what vision models do well (spatial feature identification) while avoiding what they do poorly (coordinate estimation).

5.5 Validation Framework

AI-identified coordinates are validated through distance comparison (flagging >0.1 nm discrepancies), coastline proximity checks, human spot-checks, and cross-reference with previously corrected inlets.

6 Results

6.1 Pass 1: Grok-2-Vision

The initial audit used xAI's Grok-2-Vision model against all 130 inlets.

Table 1: Pass 1 audit results (Grok-2-Vision)

Result	Count
Flagged as needing correction	125
Marked correct	1
Uncertain / could not determine	4
Total inlets audited	130

The model flagged 125 of 130 inlets (96%) as needing correction. Initial developer reaction was ; a tool flagging nearly everything appeared to lack specificity. However, manual verification confirmed the AI was right.

The 2.18 nm pattern: A correction distance of 2.18 nautical miles appeared 12 times across different states, corresponding to ∼300 pixels of offset. While the *magnitude* was imprecise, the *direction* was consistently , always pointing from the inland ICW toward the actual ocean entrance.

The largest corrections: Biloxi, MS (8.54 nm); Apalachicola, FL (6.52 nm); Hilton Head, SC (5.32 nm); Wassaw Sound, GA (5.09 nm).

95 of 130 inlet coordinates were corrected and deployed to production based on the first pass. 35 inlets were confirmed as already correct (within 200 m of the ocean entrance).

6.2 Pass 2: Claude (Pixel-Based Refinement)

A second pass used Anthropic's Claude with the pixel-based methodology. Rather than estimating geographic coordinates directly, the model was asked: "Where in this 600×600 pixel image is the ocean inlet mouth? Report as pixel coordinates (x, y)."

Results: 120 inlets refined, 2 skipped (Ossabaw Sound and Tampa ; no distinct narrow inlet mouth visible). Corrections were deployed to production.

6.3 Combined Results

Table 2: Combined results across both audit passes

Metric	Pass 1	Pass 2
Inlets audited	130	122
Corrections deployed	95	120 refined
Processing time	∼10 min	∼10 min
Largest correction	8.54 nm	∼3 km
Approach	Free-form lat/lon	Pixel → geographic

Table 3: Overall processing summary

Metric	Value
Inlets audited	130
Total coordinates corrected	95 (73%)
Total coordinates refined (Pass 2)	120
Processing time (per pass)	∼10 minutes
Compute cost (per pass)	∼$5–10
Largest correction	8.54 nm (Biloxi, MS)
Inlets confirmed correct	35 (within 200 m)
Inlets skipped (ambiguous)	2

7 Discussion

7.1 Vision AI Geographic Reasoning

Vision models demonstrated strong satellite image interpretation, correctly identifying barrier islands, tidal channels, wave patterns, and man-made structures. They reliably distinguished between ocean entrances and ICW junctions without specialized training. The pixel-based approach (Pass 2) proved significantly more precise than free-form coordinate estimation.

7.2 The Human Skepticism Bottleneck

The most significant finding may not be technical but procedural. When the initial audit flagged 96% of inputs, the development team's first instinct was to dismiss the results as hallucination. The tool was built to find a known systematic , and it found that bias consistently. Manual verification proved the AI correct.

This suggests that the primary barrier to adopting AI-assisted geographic data verification is not model accuracy but institutional trust. Organizations accustomed to treating federal databases as authoritative may resist AI findings that challenge that , even when the findings are correct and verifiable.

7.3 Comparison to Manual Review

Table 4: Vision AI vs. manual review for 130 inlets

Factor	**Manual**	**Pass 1**	**Pass 2 (pixel)**
Time	3–4 hours	$\sim$10 min	$\sim$10 min
Reproducibility	Varies	Deterministic	Deterministic
Scalability	Linear	Parallelizable	Parallelizable
Cost	Analyst labor	$\sim$\$5–10	$\sim$\$5–10
Corrections	95 (extensive)	95 (w/ skepticism)	120 refined

7.4 Limitations

1. **Coordinate precision:** ±50–150 meters, sufficient for feature identification but not precision charting.
2. **Ambiguous morphology:** 2 of 130 inlets required human judgment.
3. **Temporal variability:** Satellite imagery is a point in time; highly dynamic inlets may shift over months.
4. **Image quality:** Cloud cover and resolution affect accuracy.

8 Implications

8.1 GNIS Data Quality

We recommend: (1) GNIS should distinguish between ocean-entrance and ICW-junction coordinates for inlet features; (2) the USGS Board on Geographic Names should conduct a systematic review of coastal inlet coordinates; (3) GNIS records should include metadata indicating what aspect of the feature the coordinates represent.

8.2 Impact on Downstream Systems

The coordinate bias propagates to NOAA marine weather forecasts, Coast Guard search-and-rescue references, electronic chart systems, and every third-party application sourcing inlet coordinates from federal databases.

8.3 The Case for a Verified Inlet Coordinate Dataset

No federal database currently provides verified ocean-entrance coordinates for US coastal inlets. We propose creation of an open dataset covering all navigable tidal inlets, explicitly defined as ocean-entrance points, verified through documented satellite imagery analysis, maintained annually, and distributed through federal data portals and API access.

8.4 Vision AI as a Geographic Data Quality Tool

This methodology has applications beyond inlet coordinates: verification of bridge, dam, and lock coordinates; detection of migrated geographic features; quality assurance for crowdsourced data; and rapid post-disaster damage assessment.

9 Conclusion

Federal geographic databases are foundational infrastructure. The GNIS coordinate bias documented , consistent, systematic, and affecting 73% of US coastal inlets, propagates silently through every downstream application. In approximately 10 minutes per pass and at negligible cost, the automated vision AI system audited 130+ inlet coordinates, identified 95 requiring correction, and refined 120 positions.

We recommend three actions: (1) the USGS should review and update GNIS coordinates for coastal inlets using this methodology; (2) a verified ocean-entrance coordinate dataset should be established as open data; (3) federal agencies should adopt vision AI as a routine geographic data quality assurance tool.

Accurate coordinates save lives. When a recreational boater navigates to an inlet in deteriorating conditions, the difference between the ocean mouth and a point on the ICW is not ; it is the difference between entering the inlet safely and searching for it in breaking seas.