# Climassay Climate Risk Scoring

Methodology & Data Sources

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A complete technical reference for real estate investors, acquisitions analysts, ESG officers, and risk teams evaluating Climassay's property-level climate risk assessments.

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|---|---|
| **Version** | 1.1 |
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## Contents

# 1. Executive Summary

Climassay delivers property-level climate risk scores by integrating authoritative federal data sources — FEMA, NOAA, EPA, USDA, and Census — directly at the parcel level where available, with transparent state and county-level fallbacks where parcel data is unavailable. Risk scores are transparent, auditable, and mapped to quantitative valuation adjustments through a scenario-based model grounded in real estate fundamentals.

The platform is designed to meet the analytical standards of institutional real estate investors, including requirements emerging from TCFD, SEC climate disclosure rules, SFDR Article 8/9 fund reporting, and GRESB ESG benchmarking. Every score includes full source attribution and confidence indicators.

Version 1.1 introduces a concentration-aware composite scoring model that prevents a single extreme hazard from being diluted by low scores in other categories — addressing a systematic bias in additive risk models identified by Painter (2020) and Smull et al. (2023).

| Principle | Implementation |
|---|---|
| Parcel-first data | FEMA NFHL, USDA WUI, NOAA SPC, EPA EJScreen queried at property coordinates before any fallback |
| Transparent sourcing | Every hazard score tagged with originating data source and confidence tier |
| Auditable math | Valuation adjustments derived from explicit NOI model — no black-box ML |
| Conservative defaults | When data is unavailable, scores default to state or county baseline — never zero |
| Concentration-aware | Peak hazard floors and concentration penalties prevent single-hazard dilution |

## 2. Composite Risk Score — Concentration-Aware Model

The composite climate risk score combines four hazard scores (each 0–100) using a three-layer model that preserves the actuarial weighting of a traditional weighted average while adding concentration sensitivity.

### Layer 1 — Weighted Average Baseline

Four hazard weights reflect their relative actuarial impact on property insurance, operating costs, and long-term value in the US real estate market.

```
Baseline = (Flood x 0.40) + (Storm x 0.30) + (Heat x 0.20) + (Wildfire x 0.10)
```

| Hazard | Weight | Rationale |
|---|---|---|
| Flood | 40% | Highest single-peril insured loss driver in US residential/commercial RE |
| Storm / Wind | 30% | Second-largest loss driver; tornado, hurricane, and severe convective storm exposure |
| Extreme Heat | 20% | Growing driver of HVAC opex, vacancy in Sun Belt markets, and habitability risk |
| Wildfire | 10% | Material in WUI and western markets; now property-level via USDA WUI + USFS WHP |

### Layer 2 — Concentration Penalty

If the peak hazard exceeds the average of the other three by more than 40 points, a concentration bonus is added. This catches properties where risk is dominated by a single hazard — coastal flood zones, WUI wildfire corridors, tornado alley cores — that a simple weighted average would understate.

```
Bonus = max(0, (Peak − Others_Avg − 40) x 0.3)
```

### Layer 3 — Peak Hazard Floor

The composite can never fall more than one risk bucket below the highest individual hazard. A property with a 95 wildfire score cannot score "Low" overall regardless of what the other hazards read.

| Peak Hazard Score | Composite Floor |
|---|---|
| 90+ | 60 (High) |
| 75–89 | 45 (Moderate) |
| 60–74 | 35 (Moderate) |
| Below 60 | No floor applied |

```
Final Composite = max(Baseline + Bonus, Floor), capped at 100
```

### Academic Basis

Painter (2020, Journal of Financial Economics) found that markets price concentrated climate exposure differently than diversified exposure for long-duration securities. Smull et al. (2023, PLOS ONE) showed that additive risk models systematically underprice concentrated climate exposure. The concentration penalty directly addresses this documented bias.

### Risk Buckets

| Score Range | Risk Tier | Interpretation |
|---|---|---|
| 0 – 30 | Low | Minimal expected impact on insurance or cap rates. Standard underwriting applies. |
| 31 – 60 | Moderate | Elevated exposure warrants climate-adjusted underwriting. Monitor for trend deterioration. |
| 61 – 100 | High | Significant climate exposure likely to materially affect insurance costs, cap rates, and exit value. |

## 3. Flood Risk — FEMA NFHL + NFIP Claims

Flood risk is assessed at the parcel level by querying the FEMA National Flood Hazard Layer for the specific property coordinates. The NFHL is the authoritative federal dataset used to set NFIP flood insurance requirements and constitutes the regulatory standard for flood zone disclosure in real estate transactions.

Version 1.1 blends NFHL zone scores with FEMA NFIP historical claims data at the county level (80% NFHL / 20% NFIP), adding a revealed-loss signal to the regulatory zone designation.

| FEMA Zone | Score | Description |
|---|---|---|
| X | 10 | Minimal flood hazard — outside 500-year floodplain |
| X500 | 25 | Moderate flood hazard — within 500-year floodplain |
| A | 75 | High risk — within 100-year floodplain, no BFE determined |
| AE | 80 | High risk — 100-year floodplain with Base Flood Elevation |
| V | 95 | Very high risk — coastal with wave action, no BFE |
| VE | 98 | Very high risk — coastal wave action with BFE (NFIP mandatory) |
| D | 40 | Undetermined risk — possible but not studied |

Confidence tier: Property-level. Source tags: fema_nfhl, fema_nfip_claims.

## 4. Storm Risk — NOAA SPC + IBTrACS Wind

Storm risk combines two property-level federal sources. Tornado risk uses the NOAA Storm Prediction Center's historical tornado database, querying events within a 50-mile radius. Hurricane/wind risk uses NOAA IBTrACS v04, which provides track-level wind speed data within 200 miles since 1970.

The tornado component scores frequency and peak magnitude (EF scale). The wind component scores peak severity (Saffir-Simpson thresholds) and frequency of tropical storm+ events. Zero tornadoes within 50 miles returns a score of 5.0, not zero, to account for data sparsity.

Confidence tier: Property-level. Source tags: noaa_spc, noaa_ibtracs_wind.

## 5. Heat Risk — EPA EJScreen + gridMET + CMIP6 Projections

Heat risk is scored using a cascade of sources at increasing granularity. The primary source is EPA EJScreen, which provides census tract-level heat percentile data. If unavailable, the system falls back to gridMET (4km resolution, University of Idaho/UC Merced), which counts days above 95°F from the most recent complete summer. Final fallback is NOAA 30-year climate normals at the state level.

Forward-looking heat projections are provided via the Open-Meteo Climate API, which delivers IPCC AR6 CMIP6 models downscaled to 10km resolution. The ensemble uses MRI_AGCM3_2_S (Japan Met Agency) and EC_Earth3P_HR (European Centre) models, reporting projected days above 95°F under SSP2-4.5 and SSP5-8.5 scenarios through 2050.

Confidence tier: Tract-level (EJScreen), 4km grid (gridMET), state-level (NOAA normals).

## 6. Wildfire Risk — USDA WUI + USFS WHP + CAL FIRE FRAP

Wildfire risk has been upgraded from county-level NRI data to a multi-source property-level cascade:

**CAL FIRE FRAP** (California only): The authoritative source for California wildfire perimeter history, maintained by the California Department of Forestry and Fire Protection. Queries fire perimeters since 1990 at the property coordinates. Scores frequency and largest fire acreage.

**USDA WUI**: The Wildland-Urban Interface classification from the USDA Forest Service, queried at property coordinates. Returns WUI class (Intermix High/Med/Low, Interface High/Med/Low, Non-WUI) mapped to 0–100 scores.

**USFS WHP 2023**: Wildfire Hazard Potential from USDA Forest Service Rocky Mountain Research Station, using LANDFIRE 2020 vegetation and FSim fire simulation at 270m resolution. Classified 1–5 (Very Low to Very High). CONUS coverage only.

**NIFC Fire Perimeters**: National Interagency Fire Center historical fire perimeters since 1995. Checks if the property falls within a previously burned area.

Fallback chain: CAL FIRE (CA only) → USDA WUI → NIFC → USFS WHP → State WUI index → NRI county.

Confidence tier: Property-level (WUI, CAL FIRE, NIFC), 270m grid (USFS WHP).

## 7. Supplemental Hazards — Drought + Wind

Two supplemental hazard scores are computed but do not contribute to the composite score. They are displayed separately and used in the hazard-specific discount calculation.

**Drought**: US Drought Monitor county-level data (NDMC/NOAA/USDA). Queries the past 52 weeks of drought severity statistics, weighting D0–D4 categories by severity. Fallback: NOAA CPC Palmer Drought Severity Index 30-year climatology.

**Wind**: NOAA IBTrACS v04 hurricane track and wind speed data within 200 miles. Scores peak wind severity (Saffir-Simpson thresholds) and frequency of tropical storm+ events since 1970. Fallback: state-level wind exposure baseline.

## 8. Valuation Adjustment Model

Climassay supports two valuation modes. When financial inputs are provided (monthly rent, vacancy, operating expense ratio, insurance, and cap rate), a full NOI model computes base and climate-adjusted values. When only a purchase price is provided, a hazard-specific discount is applied directly.

### NOI Model

```
EGI = monthly_rent x 12 x (1 - vacancy_rate)
```

```
NOI = EGI - (EGI x opex_ratio) - annual_insurance
```

```
Base Value = NOI / cap_rate
```

### Hazard-Specific Price Discounts

When a purchase price is provided without full financials, discounts are applied based on the risk bucket, anchored to peer-reviewed transaction data:

| Tier | Discount | Source |
|---|---|---|
| Low | –3% | Beltran, Maddison & Elliott (2018) — Journal of Urban Economics |
| Moderate | –11% | Ortega & Taspinar (2018) — First Street Foundation (2022) |
| High | –24% | Keys & Mulder (2020) — Ouazad & Kahn (2022) — NBER |

Commercial discounts vary by asset class (multifamily lowest, hospitality highest) and lease type (NNN passes ~60% of climate cost increases to tenants).

## 9. Scenario Analysis Framework

Scenario analysis presents the expected property value under three climate risk regimes, enabling sensitivity testing regardless of the property's current assigned bucket.

| Scenario | Insurance Mult. | Cap Rate Add. | Vacancy Add. | OpEx Add. |
|---|---|---|---|---|
| Low | +8% | +0.15% | +0.2% | +0.5% |
| Moderate | +45% | +0.75% | +1.2% | +2.0% |

| | | | | |
|---|---|---|---|---|
| High | +120% | +1.80% | +3.5% | +5.5% |

Scenario assumptions are calibrated against Swiss Re (2023 US climate insurance gap report), Green Street Advisors climate risk premium study, NCREIF, and FEMA actuarial publications. Sources: Low = First Street Foundation minimal-exposure tier; Moderate = CoreLogic/RMS median observed discounts 2019–2023; High = Miami Beach AE zone / CA WUI post-Camp Fire / Houston post-Harvey observed outcomes.

## 10. Lens Metrics — HA-LTV, CIGR, PCDR

The Lens module provides three proprietary climate-finance ratios that translate hazard scores into metrics familiar to lenders and investors.

### HA-LTV — Hazard-Adjusted Loan-to-Value

Adjusts conventional LTV downward based on composite climate risk. Higher composite score = greater risk penalty = lower safe leverage.

```
HA-LTV = LTV x (1 - composite/100 x 0.15)
```

### CIGR — Climate Insurance Gap Ratio

Measures the share of total insurance burden attributable to unpriced climate risk. Derived from the scenario insurance surge for the property's risk bucket.

```
CIGR = insurance_surge / (1 + insurance_surge)
```

### PCDR — Property Climate Drift Rate

Annual rate of change in a property's climate risk profile. Higher PCDR indicates accelerating risk exposure.

```
PCDR = comp^2 x 0.04 + comp x 0.002 + seed x 0.002 + hazard bumps above 0.6
```

Thresholds are user-adjustable in the Lens tab. Default LTV is 80%.

## 11. Data Freshness & Update Cadence

| Data Source | Update Frequency | Climassay Refresh |
|---|---|---|
| FEMA NFHL Flood Zones | Ongoing (FIRM revisions) | Live API — real-time at query |
| FEMA NFIP Claims | Quarterly | Live API — real-time at query |
| NOAA SPC Tornado Database | Annual | Live API — real-time at query |
| NOAA IBTrACS Hurricanes | Annual | Live API — real-time at query |
| EPA EJScreen | Annual | Live API — real-time at query |
| gridMET 4km | Daily (used: annual summer) | Live API — real-time at query |
| USDA WUI Zones | Decennial | Live API — real-time at query |
| USFS WHP 2023 | ~5 years (LANDFIRE cycle) | Live API — real-time at query |
| CAL FIRE FRAP | Annual | Live API — real-time at query |
| NIFC Fire Perimeters | Annual | Live API — real-time at query |
| US Drought Monitor | Weekly | Live API — real-time at query |
| NOAA CO-OPS SLR | Annual projection update | Live API — real-time at query |
| Open-Meteo CMIP6 | Model runs updated periodically | Live API — real-time at query |

| | | |
|---|---|---|
| Census ACS 2022 | 5-year estimates (annual release) | Live API — real-time at query |
| US Census Geocoder | Continuous | Live API — real-time at query |

## 12. Limitations & Disclosures

1. Flood scores reflect current FEMA FIRM designation and NFIP claims history. Forward sea level rise projections are provided separately via NOAA CO-OPS but do not modify the flood score.

2. Heat projections (CMIP6) are supplemental and displayed alongside the current heat score. They do not modify the composite.

3. Storm scores are based on historical tornado tracks and hurricane wind data. They do not account for projected changes in severe convective storm frequency under climate change scenarios.

4. Wildfire scores are now property-level where USDA WUI and USFS WHP data are available. In areas without WUI coverage, state-level or NRI county fallbacks are used.

5. Valuation adjustments are illustrative scenarios based on published actuarial research and peer-reviewed transaction studies. They should be independently verified by a licensed appraiser.

6. Census ACS market data reflects 2018–2022 survey period with FHFA HPI appreciation applied. Actual current market values may differ.

7. Climassay does not provide investment advice. Scores should be used alongside traditional underwriting, local market knowledge, and professional judgment.

## 13. Academic References


• Beltran, Maddison & Elliott (2018). "Does flood risk affect property values?" Journal of Urban Economics. ~3% price discount in low flood-risk zones.

• Ortega & Taspinar (2018). "Rising sea levels and sinking property values." Journal of Urban Economics. 9–13% discount once buyers informed of flood zone status.

• Keys & Mulder (2020). "Neglected No More: Housing Markets, Mortgage Lending, and Sea Level Rise." NBER Working Paper 27019. 14.7–20% discounts in high-risk FEMA zones.

• Ouazad & Kahn (2022). "Mortgage Finance and Climate Change: Securitization Dynamics in the Aftermath of Natural Disasters." NBER Working Paper 26568. 20%+ discounts in uninsurable markets.

• Gourevitch et al. (2023). "Unpriced climate risk and the potential consequences of overvaluation in US housing markets." Nature Climate Change. $121–$237B overvaluation.

• Keenan, Hill & Gumber (2018). "Climate gentrification: from theory to empiricism in Miami-Dade County." Environmental Research Letters. Elevation premium emergence in coastal metros.

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• Smull et al. (2023). "Climate risk and municipal bond spreads." PLOS ONE / Duke Nicholas Institute. Additive risk models systematically underprice concentrated climate exposure.

• Swiss Re (2023). US Climate Insurance Gap Report. Insurance surge calibration for scenario parameters.

• Green Street Advisors (2024). Climate Risk Premium Study. Cap rate expansion data for commercial asset classes.

• First Street Foundation (2022). "The Cost of Climate." 9.4% average discount in moderate flood zones.

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• IPCC AR6 WG1 (2021). Climate model scenarios SSP2-4.5 and SSP5-8.5. Basis for heat projections.

• FEMA National Risk Index (2023). County-level hazard risk assessment. Fallback data source.

• Nature Cities (2025). Municipal debt and climate risk: $4.2 trillion market exposure analysis.

• Breckinridge Capital (2024). Municipal credit spreads and climate risk insensitivity. Practitioner research.