

TORCAST

How TorCAST Works

A Plain-Language Guide to the Tornado Potential Index

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TorCAST is not a probability map. It is a Maximum Potential Engine -- it tells you how dangerous conditions could get if severe storms form, and separately, how confident we are that storms will actually form. This document explains how that works in plain language.

1. THE CORE IDEA: POTENTIAL vs. CONFIDENCE

Most weather apps and outlooks show you a single number or category representing the chance of severe weather occurring in your area. That number bakes together two very different questions: *How bad could it get?* and *How likely is it to happen?*

TorCAST separates them. Consider two different days:

Massive instability, strong rotation, storms already firing. Tornado on the ground 30 miles away.	Equally massive instability and rotation, but a stubborn cap is holding. No storms yet -- but if the cap breaks, any storm that forms would be immediately violent.
Tornado probability: HIGH TorCAST Potential: HIGH TorCAST Confidence: HIGH	Tornado probability: LOW (cap may hold all day) TorCAST Potential: HIGH TorCAST Confidence: LOW -- CONDITIONAL

A classic probability approach treats Day B as low risk. TorCAST treats it as **high potential, conditional confidence** -- and displays it that way visually so emergency managers and storm chasers understand what they are dealing with. You see the full picture, not just the most likely outcome.

2. THE TORNADO POTENTIAL INDEX (TPI)

The TPI is a 0-10 score that represents how severe conditions could become if convective storms develop at a given location. It is calculated continuously across the contiguous United States and updated every model cycle.

TorCAST runs two parallel TPI calculations side by side:

Track	What It Measures	Update Cadence
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Live TPI	Uses real-time surface observations, active NWS warnings and watches, verified storm reports, and live radar-derived data to score what the atmosphere looks like right now.	Updated continuously
Predicted TPI	Uses short-range and extended-range computer model output to score what the atmosphere is expected to look like in the coming hours and days. Covers forecast windows from 1 hour to 3 days out.	Updated each model cycle (hourly / 6-hourly)

The two tracks are compared each cycle to generate a **trend** -- Rising, Steady, Falling, Rising Fast, Falling Fast -- that tells you at a glance whether conditions are improving or deteriorating.

3. WHAT GOES INTO THE TPI SCORE

TorCAST draws on a wide range of atmospheric parameters. None of them alone determines the score -- they are combined and weighted based on how strongly each one is associated with tornado-producing storms.

Atmospheric Ingredients TorCAST Evaluates

Atmospheric Parameter	Why It Matters for Tornado Potential
Surface Moisture (Dewpoint)	Warm, moist air near the surface is the raw fuel for severe storms. Higher dewpoints mean more energy is available for storm development and that any storms that form will be better organized and more intense.
Atmospheric Instability (CAPE)	CAPE -- Convective Available Potential Energy -- measures how much buoyancy energy is stored in the atmosphere. Think of it as how hard a storm can push air upward. The higher it is, the more powerful the updrafts.
Low-Level Wind Rotation (0-1 km SRH)	Storm-Relative Helicity in the lowest kilometer of the atmosphere is the single most important parameter for tornado potential. It measures how much spinning motion is available at the surface to be stretched into a tornado by a storm's updraft.
Deep-Layer Wind Rotation (0-3 km SRH)	Helicity measured through a deeper layer of the atmosphere supports the formation and persistence of mesocyclones -- the rotating cores of supercell thunderstorms that produce the vast majority of significant tornadoes.
Wind Shear (0-6 km)	The change in wind speed and direction from the surface to the upper atmosphere determines whether storms can organize into discrete supercells (the most tornado-capable storm type) or collapse into less-organized squall lines.
Cap Strength (CIN)	Convective Inhibition is the 'lid' on the atmosphere. A moderate cap can be beneficial -- it allows instability to build before storms fire. A very strong cap may hold all day, preventing any storms from forming regardless of how favorable everything else looks.
Cloud Base Height (LCL)	The Lifted Condensation Level is how high above the ground clouds form. Lower cloud bases mean the air near the surface is more humid, which helps tornado vortices survive the journey from the storm down to the ground.
Composite Tornado Parameter (STP)	A single number that combines instability, rotation, shear, and cloud base height into one discriminant. It has been shown in research to reliably distinguish 'significant tornado' environments from ordinary severe setups.

Active Storm Reports & Warnings	Live NWS tornado warnings, severe thunderstorm warnings and watches, and confirmed storm reports from spotters and storm chasers directly influence the Live TPI when active events are occurring nearby.
Radar-Derived Storm Rotation	When available, TorCAST ingests live radar rotation data (azimuthal shear) and per-cell tornado probability from NWS ProbSevere to directly detect rotating storms, providing the highest-quality real-time severe weather signal.

No single parameter makes or breaks the score. TorCAST requires multiple ingredients to be elevated simultaneously -- the same way meteorologists think about severe weather: you need moisture, instability, shear, and a trigger all working together.

Storm Mode: Supercells vs. Squall Lines

Not all severe thunderstorms are equally tornado-capable. A discrete supercell -- a single, organized rotating storm -- is far more likely to produce a significant tornado than a squall line or bow echo. TorCAST evaluates the atmospheric wind profile and model output to estimate which storm type is most likely to develop, and adjusts the TPI accordingly. Environments that favor linear storm modes carry a reduction in the tornado potential score even if raw instability is high.

4. THE CONFIDENCE LAYER: WILL STORMS ACTUALLY FORM?

Alongside the TPI, TorCAST displays a Confidence/Realization indicator that communicates how likely it is that the potential shown on the map will actually be realized. This is displayed visually using fill patterns on the map overlay:

Confidence Level	Map Display	What It Means
High Confidence	Solid fill	The cap is weak or absent, a trigger mechanism is in place, moisture is deep, and the timing is right. Storms are likely to form and the TPI potential shown is expected to be realized.
Conditional	Diagonal hatching	The environment is loaded, but storm formation depends on a trigger -- a passing short-wave, an outflow boundary, sufficient afternoon heating. The potential is real, but it requires something to set it off.
Low Confidence	Dotted pattern	A strong cap, moisture deficit, or unfavorable timing makes storm formation unlikely despite an otherwise favorable environment. The potential is shown so you understand what is at stake -- but the atmosphere is unlikely to release it today.

Confidence is driven primarily by cap strength (how strong the atmospheric lid is), the presence or absence of synoptic-scale forcing (jet stream dynamics, approaching fronts), surface moisture quality, and the time of day -- since most severe weather in the central and eastern US fires during the afternoon heating hours and tapers overnight.

5. THE TPI SCALE

The TPI runs from 0 to 10 and maps to six operational risk categories. These thresholds have been calibrated against real historical events -- they are not arbitrary round numbers.

TPI	Level	What It Means
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0 - 2	Very Low	No meaningful severe weather potential. Clear, cold, or post-frontal conditions.
2 - 3.5	Low	Typical spring background environment. No active trigger present. No action warranted.
3.5 - 5	Guarded	Atmosphere is primed but not yet active. A trigger is needed for storms to develop. Worth monitoring -- especially if confidence is moderate or rising.
5 - 6.5	Elevated	Multiple severe weather ingredients are in place. Isolated significant storms are possible. Active weather awareness appropriate.
6.5 - 8	High	Significant tornado risk. Multi-cell or supercell storm mode expected. A regional severe weather outbreak is possible.
8 - 10	Extreme	Major outbreak conditions. Long-track, violent tornadoes possible. Immediate protective action may be warranted in highlighted areas.

6. DATA SOURCES

TorCAST combines multiple real-time and model data streams. All sources are government-operated or publicly accessible scientific data feeds:

Source	Operator	How TorCAST Uses It
HRRR (High-Resolution Rapid Refresh)	NOAA / NCEP	The primary high-resolution forecast model for the US. Updated hourly. Provides the detailed atmospheric parameter data that drives TorCAST's short-range (0-18 hour) potential scoring.
GFS (Global Forecast System)	NOAA / NCEP	The US global forecast model, updated four times daily. Provides extended-range (Day 1-3) potential scoring beyond HRRR's range.
Surface Observations (ASOS / METAR)	NWS / FAA	Automated weather stations at airports and other facilities across the country report surface conditions continuously, providing real-time dewpoint, temperature, and wind data.
NWS Warnings & Watches	National Weather Service	Active tornado warnings, severe thunderstorm warnings, and watches issued by local NWS offices are processed in real time and factored directly into the Live TPI.
Local Storm Reports (LSR)	NWS / IEM	Verified reports of tornadoes, large hail, and damaging winds from NWS spotters and emergency managers, archived by the Iowa Environmental Mesonet and used for both live scoring and model improvement.
NWS ProbSevere	National Weather Service	A real-time radar-based system that tracks individual storm cells and provides continuously updated per-storm tornado, hail, and wind probabilities. The highest-quality live severe weather signal available.
NWS Area Forecast Discussions (AFD)	National Weather Service	Official forecast discussions written by local NWS meteorologists are analyzed to extract qualitative severe weather context that complements the quantitative model data.

7. MACHINE LEARNING & CONTINUOUS IMPROVEMENT

The physics-based scoring engine provides TorCAST's foundation -- it is interpretable, scientifically grounded, and produces defensible results on day one. On top of it, TorCAST applies a machine learning correction layer trained on real verified outcomes.

Every time a tornado, large hail event, or damaging wind report is confirmed in an area where TorCAST issued a score, that outcome is recorded. Over time, the system learns the difference between environments that look dangerous on paper but routinely bust (classic spring 'loaded gun' days in the Southeast), and environments where the physics engine may be underestimating risk due to regional patterns the hand-tuned formulas don't fully capture.

The ML layer learns *residual corrections* -- it does not replace the physics engine, it refines it. It is also aware of geography and time of day, allowing it to apply different calibrations to Tornado Alley supercell events versus Southeast US winter-tornado setups versus West Coast low-CAPE high-shear environments.

The model retrains automatically as new verified outcomes accumulate. TorCAST gets more accurate over time -- every real severe weather event makes the system smarter.

Uncertainty Quantification

The ML layer also produces calibrated uncertainty estimates for each forecast point. This means TorCAST can tell you not just what the TPI is, but how confident the model is in that number -- reflecting the spread of possible outcomes in a given atmospheric setup. High-uncertainty forecasts are displayed with wider confidence intervals on the platform.

8. REGIONAL CONSIDERATIONS

Severe weather is not one-size-fits-all, and TorCAST's scoring reflects that. The atmosphere behaves differently in different parts of the country, and the parameters that matter most for tornado potential vary by region.

Region	TorCAST Scoring Approach
Tornado Alley (KS, OK, TX, NE, IA)	The classic high-CAPE, high-shear supercell environment. Storm mode (discrete supercell vs. squall line) is the primary discriminator. Dryline position and forcing are weighted heavily.
Dixie Alley (AL, MS, TN, AR, LA)	High-shear, lower-CAPE environments, often with significant capping. Surface moisture quality and low-level jet strength are critical. The highest fatality risk from winter and spring tornado events.
Gulf Coast & Southeast (FL, GA, SC, NC)	Subtropical moisture and frequent storm initiation, but often organized in mixed-mode or linear setups. Environment quality and storm mode are assessed carefully to avoid overforecasting.
Northeast & Great Lakes (NY, PA, OH, MI)	Less frequent but high-impact events, often tied to strong synoptic forcing. Terrain interactions and lake-effect moisture influence local severe weather risk.
West Coast / Pacific (CA, OR, WA)	Low-CAPE / high-shear environments where standard severe weather indices like STP are unreliable. TorCAST uses a dedicated kinematic scoring regime that gives appropriate weight to rotation and shear over raw instability in these setups.

9. HOW TO READ TORCAST

A few principles for interpreting TorCAST output:

Principle	Explanation
Look at Potential AND Confidence together	A High TPI with Low Confidence is a conditional warning -- the environment is dangerous, but storms may not form. A Moderate TPI with High Confidence and storms already firing may be more immediately actionable.
Watch the trend	A rising TPI heading into the afternoon hours on a High Confidence day is a very different situation than a falling TPI after storms have peaked. The trend arrow is one of the most operationally important displays.
TorCAST is not a tornado track forecast	The TPI tells you about the environmental potential at a location -- it does not predict whether a specific tornado will touch down at a specific address. Always follow official NWS warnings for immediate life-safety decisions.
High TPI does not mean a tornado will occur	Many days with TPI scores of 7 or 8 produce severe weather but no tornadoes. TorCAST tells you the atmosphere is loaded -- what happens depends on whether storms initiate, how they evolve, and local factors the grid cannot fully resolve.
Extreme TPI (8+) should always be taken seriously	When TorCAST reaches Extreme levels, the atmospheric ingredients for a major outbreak are in place. These days are rare. On the days that TorCAST has verified at 8+, significant tornadoes have occurred.

TorCAST was built by weather enthusiasts and technologists who believe that the public deserves access to the same quality of atmospheric intelligence that professional meteorologists use -- presented clearly, honestly, and without hiding uncertainty behind a single oversimplified number.

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