SEASIDE BEACON

Sunrise Quality Prediction Algorithm v5.3

Chennai, India — Marina Beach, Elliot's Beach, Covelong Beach, Thiruvanmiyur Beach

Architecture Overview

Seaside Beacon predicts sunrise visual quality on a 0-100 scale using 9 weighted atmospheric factors, 2 minor adjustments, and multi-source data fusion. The algorithm is calibrated specifically for tropical coastal conditions at Chennai (13.08°N, 80.27°E), where baseline dawn humidity of 80-92% and persistent marine aerosols create a fundamentally different atmospheric regime than temperate-climate models assume.

The scoring system is grounded in Corfidi (NOAA SPC) sunrise color theory, SunsetWx/Alpenglow weight architecture research (Penn State), and Mie scattering physics for aerosol-wavelength interaction. All thresholds have been validated against photographic ground-truth from Chennai beaches.

Data Sources

Source	Type	Parameters Used
AccuWeather API	Hourly forecast	Cloud cover, humidity, wind, precipitation, visibility, ceiling, weather description, daily sunrise time, night hours of rain
Open-Meteo GFS	Hourly forecast (primary)	Cloud cover (total + high/mid/low layers), visibility, humidity, pressure MSL — preferred over AccuWeather when available
CAMS (Copernicus)	Atmospheric composition	Aerosol Optical Depth at 550nm (AOD) — via Open-Meteo air quality API

Data source priority: Open-Meteo GFS is preferred for cloud cover, visibility, and humidity based on a Feb 2026 ground-truth audit showing AccuWeather over-reports cloud (+35%), under-reports visibility (-75%), and over-reports humidity (+7%) for Chennai. AccuWeather remains the primary source for precipitation, wind, weather description, sunrise time, and night rain hours.

1. Weight Architecture

The 100-point base score is distributed across 9 factors. Two minor adjustments (post-rain bonus and seasonal solar angle) are additive on top, then clamped to 0-100.

Rank	Factor	Max Pts	Data Source	Scientific Basis
#1	Aerosol Optical Depth (AOD)	16	CAMS 550nm	Air clarity — highest single-variable predictor of color quality (R^2 ~0.65-0.70). No competitor uses this.
#2	Cloud Layer Distribution	20	Open-Meteo GFS	WHERE clouds sit (high/mid/low altitude). High cirrus = color canvas; low stratus = horizon blocker.
#3	Cloud Cover (total %)	18	Open-Meteo GFS	HOW MUCH cloud exists. 30-70% optimal (Corfidi). Subject to low-stratus discount.
#4	Humidity	15	Open-Meteo GFS	Mie scattering from water droplets. Chennai-calibrated: 80-88% is baseline, not penalty.
#5	Pressure Trend	11	Open-Meteo GFS	6-hour midnight-to-6AM pressure change. Clearing fronts (2-5 hPa fall) = dramatic skies.
#6	Visibility	5	Open-Meteo GFS	Coarse backup to AOD. Catches fog/mist that AOD might miss.
#7	Weather Conditions	5	AccuWeather	Go/no-go gate: active precipitation, thunderstorms, fog.
#8	Wind Speed	5	AccuWeather	Light breeze (8-20 km/h) optimal — structures clouds, clears boundary haze.
#9	Synergy	±4	Computed	Cross-factor interactions (e.g., low humidity + optimal cloud + good visibility).
—	Post-Rain Bonus	+8 max	AccuWeather daily	Night rain detected → crystal-clear post-rain air + broken cloud canvas.
—	Solar Angle	±2	Computed	Seasonal: Nov-Feb (low angle) bonus, May-Jul (steep angle) penalty at 13°N.

Base max = 16+20+18+15+11+5+5+5+4 = 99 pts (synergy max +4). With post-rain (+8) and solar (+2), theoretical max is 109, clamped to 100.

2. Factor Details

2.1 Aerosol Optical Depth — 16 pts (Factor #1)

Corfidi (NOAA SPC): "Clean air is the main ingredient common to brightly colored sunrises." AOD at 550nm measures total columnar aerosol loading. The scoring uses a Goldilocks curve based on Mie forward scattering physics: particles ~0.5 micron radius amplify red wavelengths at low solar elevation angles. Too-clean air (AOD <0.05) has insufficient scattering particles, producing pale yellows. Moderate aerosols (0.05-0.15) produce peak color. Heavy aerosols (>0.4) attenuate all wavelengths, washing out color.

AOD Range	Score	Description
< 0.05	13	Crystal clear — vivid but slightly pale (insufficient Mie scattering)
0.05 - 0.10	16	Goldilocks low end — near-perfect clarity + optimal scattering

AOD Range	Score	Description
0.10 - 0.15	16	Goldilocks peak — optimal forward Mie scattering
0.15 - 0.20	14	Very clean — excellent colors
0.20 - 0.30	12	Clean — vivid, slight softening
0.30 - 0.40	9	Mild haze — colors present but noticeably muted
0.40 - 0.50	6	Moderate haze — colors substantially reduced
0.50 - 0.70	4	Heavy haze — colors faint
0.70 - 1.00	2	Very heavy haze — minimal color
> 1.00	0	Dust/pollution event — no color visible
No data	8	Neutral default — assume moderate

Source: CAMS (Copernicus Atmosphere Monitoring Service) via Open-Meteo air quality API. AOD550 forecast for 6 AM IST at beach coordinates.

2.2 Cloud Layer Distribution — 20 pts (Factor #2)

Corfidi (NOAA): "High clouds intercept unadulterated sunlight" — cloud altitude is the #2 predictor of sunrise color quality. WHERE clouds sit matters more than HOW MUCH cloud exists. High cirrus (>6000m) catches pre-sunrise light as a vivid orange/red canvas. Mid clouds (2000-6000m) provide moderate canvas. Low clouds (<2000m, stratus) block the horizon and turn everything grey.

Cloud Layer Condition	Score	Interpretation
High >= 30%, Low < 40%, Mid < 30%	20	Pure high cloud canvas — ideal for vivid sunrise
High >= 30%, Low < 40%, Mid 30-60%	17	High + some mid — still great
High >= 30%, Low < 40%, Mid >= 60%	14	High + heavy mid — good but less contrast
High >= 30%, Low 40-55%	11	Mixed layers — some light gets through gaps
High >= 30%, Low 55-75%	9	Heavy low under high — significant horizon blockage
High >= 30%, Low >= 75%	6	High clouds exist but horizon mostly blocked
High < 30%, Low >= 75%	1	Thick low stratus, no canvas above — worst case
High < 30%, Low 65-75%	3	Heavy low cover, limited ceiling view
High < 30%, Low 50-65%	5	Moderate low band — gaps likely, some light through
High < 30%, Mid >= 50%	9	Mid clouds provide some canvas
High < 30%, Low < 50%, Mid < 50%	6	Mostly clear — no canvas, no blockage
No layer data (ceiling fallback)	2-17	Estimated from AccuWeather ceiling height + cloud %
No data at all	10	Neutral default

2.3 Cloud Cover (Total %) — 18 pts (Factor #3)

Corfidi: "Without clouds, you won't get spectacular reds, pinks, oranges." 30-70% coverage is optimal — clouds act as a canvas for reflected sunrise light. Peak drama at 45%. This factor measures total amount only; altitude is scored separately in Factor #2.

The scoring uses a peaked curve centered at 45% with smooth dropoffs in both directions. Clear skies (<15%) produce pleasant glow but lack dramatic canvas. Heavy overcast (>90%) blocks nearly all light.

Cloud Cover	Score Range	Description
0 - 15%	5-7	Clear sky — pleasant glow, no dramatic canvas
15 - 25%	7-10	Scattered clouds — limited canvas for color
25 - 30%	10-15	Approaching optimal — decent potential
30 - 60%	15-18	OPTIMAL — peak drama at 45% (Corfidi). Clouds as color canvas.
60 - 75%	10-15	Decent but increasingly blocked light
75 - 90%	3-10	Heavy overcast — most light blocked
90 - 100%	0-3	Total overcast — almost no light gets through

Low-Stratus Discount (v5.3)

When cloud layer data shows predominantly low cloud (low > 40%) with minimal elevated canvas (high + mid < 15%), the cloud cover score is discounted by 50%. This corrects the assumption that "optimal amount" of cloud is beneficial regardless of altitude — 50% low stratus is grey, not colorful. The discount only applies when multi-level data confirms the all-low-stratus condition.

2.4 Humidity — 15 pts (Factor #4)

Atmospheric Chemistry and Physics (2013): scattering enhancement f(RH) = 1.28-3.41 at 85% RH — the relationship is exponential, not linear. High humidity causes hygroscopic aerosol growth, expanding particles and increasing light scattering. This is partially redundant with AOD (which already measures the scattering result), so the weight was reduced from 20 to 15 in v5.2.

Critical Chennai calibration: tropical coastal dawn humidity of 80-88% is BASELINE, not a penalty condition. Colors survive in this range (confirmed by photographic ground-truth). Penalties only fire in extreme conditions (>93% = near-fog territory). Previous versions penalized >85%, which punished every single Chennai morning.

Humidity Range	Score	Description
<= 55%	15	Exceptional — rare at dawn, vivid crisp colors
55 - 65%	12-15	Excellent — very clean, sharp colors
65 - 75%	9-12	Very good — slight softening
75 - 82%	7-9	Good — Chennai "dry" dawn
82 - 88%	4-6	Chennai baseline — pastels visible, horizon hazy
88 - 93%	2-4	High — sea-salt aerosols heavily swollen, color muting
93 - 97%	1-2	Very high — near-fog, significant washout
> 97%	0-1	Near-saturation — minimal color

2.5 Pressure Trend — 11 pts (Factor #5)

SunsetWx's #2 factor. Input: array of 7 hourly pressure_msl values from midnight to 6 AM IST (Open-Meteo GFS). The trend is calculated as last minus first value. Falling pressure (2-5 hPa/6hr) signals an approaching front with cloud breakup patterns — one of the most reliable predictors of dramatic sunrises (NOAA, SunsetWx). Normal diurnal fluctuation is +/-1-2 hPa/6hr, so thresholds are set above this noise floor.

Pressure Change (6hr)	Score	Description
< -5 hPa	2	Rapidly falling — severe weather/storm risk
-5 to -2 hPa	11	TRUE CLEARING FRONT — dramatic skies (best scenario)
-2 to -1 hPa	8	Moderate fall — possible weak front, some instability
-1 to -0.5 hPa	6	Slight fall — within normal diurnal range
-0.5 to +0.5 hPa	5	Stable — high pressure, predictable
+0.5 to +2 hPa	4	Rising — very stable, less dramatic
> +2 hPa	3	Rapidly rising — strong high pressure, clear but boring
No data	5	Neutral default — assume stable

2.6 Visibility — 5 pts (Factor #6)

Largely redundant with AOD (JGR 2018: PM2.5 explains 50% of visibility variance, RH explains most of the rest). Kept as a coarse backup that catches fog/mist scenarios AOD might miss. Reduced from 10 to 5 in v5.2.

Visibility	Score
>= 15 km	5
>= 10 km	4
>= 6 km	3
>= 3 km	2
>= 1 km	1
< 1 km (fog)	0

2.7 Weather Conditions — 5 pts (Factor #7)

Binary go/no-go gate. Starts at 5 points, deducted based on: precipitation probability (>15% = -1, >30% = -2, >50% = -3, >70% = -4), active precipitation (-2), thunderstorm/storm description (-2), fog/mist (-2), haze (-1). Sunny/clear description gives +1. Clamped to 0-5.

2.8 Wind Speed — 5 pts (Factor #8)

Penn State METEO 300: light breeze (8-20 km/h) is optimal, not calm. Dead calm (<5 km/h) traps boundary-layer haze. Light breeze structures clouds into ripples/billows that catch light. Strong wind (>25 km/h) disperses aerosol layers and clouds vertically.

Wind Speed	Score	Description
8-20 km/h	5	Optimal — structures clouds, clears low haze

Wind Speed	Score	Description
5-8 km/h	4	Light — good
20-25 km/h	4	Moderate — still decent
< 5 km/h	3	Dead calm — traps boundary haze
25-35 km/h	2	Gusty — dispersing clouds
> 35 km/h	1	Strong — too disruptive

2.9 Synergy Adjustment — +/-4 pts (Factor #9)

Captures cross-factor interactions that independent scoring misses. Recalibrated in v5.1 for tropical coastal conditions after ground-truth audit revealed old temperate-climate thresholds permanently locked Chennai into -2 synergy.

Hard Overrides (fog/mist):

Visibility < 3 km: returns -4 (complete fog override, no bonuses possible). Visibility < 5 km: returns -3.

Penalties:

Condition	Adj	Rationale
Humidity > 93% + cloud < 25%	-2	Washed-out and boring — near-fog, sparse clouds
Cloud < 15% + humidity < 70%	-2	Vivid but boring — needs clouds for drama
Cloud < 15% + humidity >= 70%	-1	Clear + humid = bland
Humidity > 93% + cloud >= 30%	-2	Clouds exist but colors truly washed out at near-fog

Bonuses (require elevated canvas — high+mid >= 15%):

Condition	Adj	Rationale
Humidity < 80% + cloud 30-60%	+4	Unusually dry dawn + good elevated canvas = vivid
Humidity < 85% + cloud 25-65%	+3	Dry-ish dawn for Chennai + good canvas
Humidity < 90% + cloud 25-65%	+1	Normal Chennai dawn + good canvas = slight boost
Visibility >= 15 + cloud 25-65% + humidity < 90%	+2	Strong combo: clear air + canvas + reasonable moisture
Visibility >= 10 + cloud 20-70% + humidity < 92%	+1	Good combo

v5.3: Cloud synergy bonuses now require elevated canvas (high+mid cloud >= 15%). Without mid/high clouds, "optimal cloud amount" is just low stratus providing no color benefit.

3. Minor Adjustments

3.1 Post-Rain Bonus — up to +8 pts

After rain: clearest air (15-20 km visibility), broken clouds remain at 30-60%. Two detection methods:

Primary (temporal): AccuWeather daily forecast reports nightHoursOfRain > 0 and 6 AM precipitation probability <= 20% = rain stopped, air washed clean. Awards +8.

Fallback (heuristic): When daily data unavailable, detects the data signature of post-rain conditions: visibility >= 15 km + cloud 25-65% + humidity 60-82% + precip probability <= 20%. This combination almost never occurs unless rain recently washed the air. Awards +8.

3.2 Seasonal Solar Angle — +/-2 pts

At Chennai (13.08°N), winter sun rises at a low angle = longer atmospheric path = more Rayleigh scattering = more vivid reds. Uses solar declination as proxy for sunrise elevation angle.

Condition	Adj	Description
Declination < -10° (Nov-Jan)	+2	Deep winter — best for reds
Declination -10° to 0° (Oct, Feb-Mar)	+1	Late autumn/early spring
Declination 0° to 10° (Mar-Apr, Aug-Sep)	0	Neutral
Declination 10° to 20° (Apr-May, Jul-Aug)	-1	Approaching summer
Declination > 20° (May-Jul)	-2	Peak summer — steepest angle, least scattering

4. Score Interpretation

Score Range	Verdict	Recommendation	Meaning
85 - 100	EXCELLENT	GO	Exceptional conditions — vivid, dramatic sunrise almost guaranteed
70 - 84	VERY GOOD	GO	Strong conditions — well worth the early alarm
55 - 69	GOOD	MAYBE+	Decent conditions — could go either way, likely pleasant
40 - 54	FAIR	MAYBE	Mixed conditions — subtle tones possible, not spectacular
25 - 39	POOR	SKIP	Muted sunrise likely — surprises happen but don't count on it
0 - 24	UNFAVORABLE	NO	Low expectations — heavy overcast, fog, or active weather

5. Golden Hour Calculation

Derived from actual AccuWeather sunrise time for the specific date. Three key times are provided to users:

Phase	Time	Description
Start (first color)	Sunrise - 20 minutes	First light touches high clouds, pre-sunrise glow begins
Peak (richest light)	Sunrise - 10 minutes	Maximum color saturation, sun below horizon illuminating cloud canvas
End (warm light fading)	Sunrise + 30 minutes	Direct sunlight transitioning from warm golden to neutral daylight

6. AI Description Layer

After the numerical score is computed, an AI layer generates natural-language descriptions of the expected sunrise experience. This is purely descriptive — the AI does not influence the score.

The AI receives all computed weather data (cloud layers, humidity, visibility, AOD, wind, score, breakdown) and generates: a greeting, sunrise experience description (what the sky, sun disc, and water reflection will look like), photography insight, beach-specific comparisons, and a "worth waking up" recommendation. Tone is calibrated per score tier — excited and vivid for high scores, honest and specific for low scores.

AI providers: 3-tier failover chain — Gemini 2.5 Flash (primary) -> Groq Llama 3.3 70B (fallback 1) -> Gemini 2.5 Flash-Lite (fallback 2) -> deterministic rule-based fallback (no AI). Max output: 3000 tokens. Response truncation is detected via finish_reason and triggers fallback to next provider.

7. Key Differentiators

Feature	Explanation
AOD as #1 factor (16/100 pts)	No known competitor uses Aerosol Optical Depth. SunsetWx uses moisture + cloud. Skyfire uses precip + cloud. Our use of CAMS AOD550 for Mie scattering physics is unique.
Multi-level cloud as #2 factor	Most competitors use total cloud %. We score WHERE clouds sit (high/mid/low altitude) as a 20-point factor separate from total coverage.
Tropical coastal calibration	Humidity thresholds, synergy bonuses, and baseline assumptions calibrated for Chennai 13°N tropical coastal conditions, not temperate-climate defaults.
Low-stratus discount	When detected, discounts the "optimal cloud amount" score by 50% — recognizing that 50% low stratus is grey, not the colorful canvas Corfidi describes.
Post-rain temporal detection	Uses AccuWeather's nightHoursOfRain for true temporal signal, not just heuristic data signatures.
Multi-source data fusion	Open-Meteo GFS (preferred) + AccuWeather (fallback) + CAMS aerosol data — cross-validated in Feb 2026 ground-truth audit.

Seaside Beacon v5.3 — February 2026 — Kevin T