The CT GRACE India Gujarat Aquifer Signal: Tubewell-Irrigated India Supply Overlay for Cotton

Why NASA GRACE satellite terrestrial water storage over the India Gujarat cotton belt delivers a 2.81 pp directional spread on Cotton forward 60-day returns via tubewell-irrigation yield-shock transmission.

David Stendahl · Market Lab Analytics · November 6, 2026

The signal with the limits stated upfront

Three things the reader must know before the rest of this brief lands.

First, the full-distribution daily Spearman information coefficient against Cotton forward 60-day returns is minus 0.065 at p-value 3.6e-7 on a sample of 6,089 daily observations spanning 2002 through 2026. Statistically significant on the 24-year GRACE window.

Second, Phase +1 (TWS High) delivers minus 0.74 percentage points below baseline across 2,359 trading days (38.7 percent of sample) and Phase −1 (TWS Low, aquifer stress) delivers plus 2.07 percentage points above baseline across 2,621 days (43.0 percent). 2.81 pp directional spread between the extremes.

Third, Phase 0 (On Trend) delivers minus 3.32 percentage points edge on an 18.2 percent middle bucket — stronger in absolute terms than either extreme. The pattern is non-monotone around Phase 0, and the non-overlap independence test is not independently significant at p-value 0.28.

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The thesis: tubewell-irrigated Gujarat aquifer stress

Gujarat is the second-largest Indian cotton-producing state after the Vidarbha region of Maharashtra. Unlike rain-fed Vidarbha, Gujarat cotton production relies more heavily on tubewell-pumped groundwater irrigation. Farmers extract water from shallow and deep aquifers to irrigate fields when monsoon rainfall is deficient; this makes Gujarat yields somewhat more buffered than Vidarbha but still vulnerable to sustained aquifer depletion.

The NASA GRACE satellite mission measures terrestrial water storage anomalies (groundwater plus soil moisture plus surface water) via gravity with monthly resolution. GRACE downturns over Gujarat

raise pumping cost (deeper wells, more energy), compress marginal acreage yields, and force marginal farmers out of production. The transmission to Cotton futures runs at 60-day horizons via Indian supply conditions.

The signal takes NASA GRACE monthly TWS anomaly over the India Gujarat cotton-belt bounding box, z-scores on a rolling window, and tanh-bounds. State thresholds plus or minus 0.2 (moderate) and plus or minus 0.5 (extreme). Phase +1 at composite above +0.3, phase −1 below −0.3. Target: ICE US Cotton No. 2 first-nearby back-adjusted close.

Historical window: NASA GRACE/GRACE-FO series from 2002; engine runs from 2002 onward with 504-bar warmup.

What the firings have actually done

Computed over 6,089 daily observations post-warmup from 2002 onward. The baseline Cotton forward 60-day return is mean plus 1.66 percent and median plus 0.15 percent across the live-window sample.

> **Baseline Cotton forward 60-day return:** mean plus 1.66 percent / median plus 0.15 percent across the live-window sample.
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> **Daily Spearman IC (fwd 60d):** minus 0.065, p-value 3.6e-7, N equals 6,089. Statistically significant.
>
> **Non-overlap IC (60-day step):** minus 0.108, p-value 0.28, N equals 102. Sign-consistent but not independently significant.
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> **Phase-conditional forward 60-day Cotton returns:** Phase +1 (TWS High, 2,359 days / 38.7 pct): plus 0.92 percent, edge minus 0.74 pp. Phase 0 (On Trend, 1,109 days / 18.2 pct): minus 1.66 percent, edge minus 3.32 pp. Phase −1 (TWS Low, Aquifer Stress, 2,621 days / 43.0 pct): plus 3.73 percent, edge plus 2.07 pp.
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> 2.81 pp directional spread between Phase +1 and Phase −1. Non-monotone around Phase 0.

Three findings. The daily IC is statistically significant on the 24-year GRACE window with contrarian polarity. The Phase −1 TWS Low tail delivers plus 2.07 pp edge with 43 percent sample share — a well-sampled bullish regime. Phase 0 delivers minus 3.32 pp edge on 18 percent share — the strongest absolute edge but non-monotone around the middle.

Three cases that frame how to read the signal

The canonical anchors are the 2022-2023 India dual-aquifer stress period, the 2015-2016 Indian drought year, and the 2010-2011 strong-monsoon aquifer recharge.

Case 1: The 2022-2023 India dual-aquifer stress

TWS Low firing anchored the 2022-2023 Indian cotton supply tightening as NASA GRACE showed concurrent Gujarat plus Vidarbha aquifer depletion through consecutive deficit monsoon periods. Composite held in Phase −1 territory. Cotton rallied materially through 2022 consistent with the Phase

−1 edge; the dual-India aquifer-stress signal compounded with the Texas megadrought on the US side. Stacking the Gujarat and Vidarbha signals gave multi-region confirmation of the Indian supply regime.

Case 2: The 2015-2016 Indian drought year

TWS Low firing through 2015-2016 as back-to-back El Nino-driven monsoon deficits depleted Gujarat groundwater (alongside Vidarbha). Composite held in Phase −1 territory through the 2015-16 drought. Cotton rallied through 2016 consistent with the Phase −1 edge; Gujarat and Vidarbha both contributed to the Indian supply shock during this canonical El Nino drought episode.

Case 3: The 2010-2011 strong monsoon aquifer recharge

TWS High firing through 2010-2011 as above-normal monsoon rainfall recharged the Gujarat aquifer. Composite held in Phase +1 territory consistent with sub-baseline Cotton forward returns through the recharge regime. Healthy aquifer carry supports Gujarat yields and softens the global supply balance.

How to use this signal today

Composite is currently reading minus 0.197 in the On Trend band. The Neutral phase began October 2026, 24 trading days ago. NASA GRACE terrestrial water storage over India Gujarat is running near the rolling z-score mean through 2026 as the composite transitions from the Phase −1 aquifer-stress regime that dominated 2022-25.

Pair with the following for stacked conviction: India Vidarbha GRACE (Z32312, rain-fed cotton companion), US Cotton Belt DSCI (Z100008, US supply), Xinjiang CHIRPS (Z3414, China supply), USDA WASDE stocks-to-use (systemic balance), CFTC positioning (Z32350), and apparel-demand signals (Z100400). This Gujarat signal gives the tubewell-irrigated Indian supply lens; Vidarbha gives the rain-fed companion.

Reader rule: TWS Low firings flag bullish supply-shock setups via Indian Gujarat yield compression. TWS High firings flag bearish regimes where aquifer support stabilizes production.

Methodology

Data source: NASA GRACE/GRACE-FO satellite mission monthly terrestrial water storage anomaly product aggregated over the India Gujarat cotton belt bounding box covering the state of Gujarat in western India. Computation: TWS anomaly z-scored on a rolling window, tanh-bounded. State thresholds plus or minus 0.2 (moderate) and plus or minus 0.5 (extreme). Phase +1 at composite above +0.3, phase −1 below −0.3. Target: ICE US Cotton No. 2 first-nearby back-adjusted close.

Historical window: NASA GRACE mission from April 2002; GRACE-FO follow-on from June 2018 with 11-month gap in 2017-2018; engine runs from 2002 onward with a 504-bar warmup for the rolling z-score.

Validation computed on 6,089 post-warmup daily observations. Daily Spearman IC minus 0.065 at p-value 3.6e-7 across 6,089 observations, statistically significant on 24-year sample. Phase +1 per-day forward return plus 0.92 percent (minus 0.74 pp below plus 1.66 percent baseline). Phase −1 per-day forward return plus 3.73 percent (plus 2.07 pp above baseline). 2.81 pp directional spread. Non-overlap IC at 60-day sampling minus 0.108 at p-value 0.28 across 102 samples, sign-consistent but not independently significant.

Note on polarity. The empirical pattern shows low TWS (aquifer stress) precedes Cotton strength via Indian yield compression. The brief frames the signal on this empirical direction.

What this signal does not cover

The signal does not cover rain-fed Vidarbha (see Z32312). It does not cover other Indian cotton states (Maharashtra non-Vidarbha, Telangana, Madhya Pradesh). It does not capture Pakistan or Chinese cotton supply. It does not capture realized yield response (that comes through USDA PSD India cotton and India MoAFW reports). GRACE monthly cadence plus 2-3 month data-processing lag limit short-horizon use.

Disclaimer

This brief and the signal it describes are for informational purposes only and do not constitute investment, legal, tax, or trading advice. Hypothetical or simulated performance results have certain inherent limitations. Unlike an actual performance record, simulated results do not represent actual trading. Also, since the trades have not been executed, the results may have under- or over-compensated for the impact, if any, of certain market factors, such as lack of liquidity. Simulated trading programs in general are also subject to the fact that they are designed with the benefit of hindsight. No representation is being made that any account will or is likely to achieve profits or losses similar to those shown. The phase-conditional forward-return stats reported above are a full-sample unconditional measurement. Readers should consult a licensed financial professional before taking any trading action.

References

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ICE Futures US, Cotton No. 2 first-nearby back-adjusted continuous contract (ticker CT), end-of-day settlement.