

The Ground Underneath the Map

Reference-Frame Modernization, Vertical Land Motion, and the Hidden Basis Risk in Insurance

END-2026

NSRS MODERNIZATION TARGET
(NATRF / NAPGD)

**-2 TO
-20**

NEW ORLEANS WEST-
BANK SUBSIDENCE, MM/
YR

**>10
MM/
YR**

GULF/SE COAST RSL
ACCELERATION,
2010-2022

EXECUTIVE DASHBOARD

Three things are happening at once. The vertical datum that anchors US flood maps and elevation certificates is being replaced. The ground in major coastal jurisdictions is moving at locally substantial rates. The ocean baseline along the US Southeast and Gulf coasts is accelerating. The cadence of revision in the reference architecture does not match the cadence of revision in the insurance products that depend on it.

THESIS

The geographic reference systems and physical-signal baselines under US flood maps, parametric triggers, and elevation-based insurance ratings are undergoing **simultaneous revision** while the ground itself moves locally fast and ocean baselines accelerate, leaving insurance products that treat geographic reference as static carrying an unmeasured form of basis risk in the transition window.

KEY STATISTICS

End-2026

NSRS modernization target (NATRF2022 / NAPGD2022)^{1, 2}

5 yrs

FEMA flood-map conversion window post-NAPGD release²²

-20 mm/yr

max New Orleans west-bank InSAR-measured subsidence³

12,000 km²

Houston-Galveston subsidence footprint 1906-2024⁵

85%

Houston flooded area where subsidence >5 mm/yr⁶

>10 mm/yr

US Southeast & Gulf RSL acceleration, 2010-2022^{4, 17}

5-10x

high-tide flood odds today vs. 50 years ago⁸

5M

NFIP policies referenced to NAVD 88 (all to convert)¹⁰

Scope & method. Public-source synthesis exclusively: NOAA, NASA, USGS, National Geodetic Survey, IERS, ITRF/IGN, FEMA, FHFA, and peer-reviewed geophysics and geodesy literature. No internal AEIG research is cited. Confidence and rationale carried on every judgment. Window: 2024 to early 2026. Timeliness: DURABLE, with a 6 to 18 month shelf life.

KEY JUDGMENTS

Six judgments anchor this assessment. Each is tied to public-source evidence (NOAA, NASA, USGS, NGS, FEMA, IERS, ITRF, FHFA, peer-reviewed literature) and carries an explicit confidence level.

- 1** **High** The NSRS transition from NAD 83 and NAVD 88 to NATRF2022 and NAPGD2022 is structurally consequential for any insurance product whose pricing or eligibility depends on elevation relative to a fixed datum.^{1, 2}
- 2** **High** Vertical land motion is locally large relative to insurance flood-map precision; New Orleans west-bank subsidence exceeds 20 mm/yr in places and Houston-Galveston subsidence affects 12,000 km².^{3, 5}
- 3** **High** US Southeast and Gulf Coast relative sea-level rise has accelerated to rates an order of magnitude above the historical baseline, driven by absolute rise, AMOC-response sterodynamic effect, and local subsidence.^{4, 7, 17}
- 4** **Moderate** Earth-orientation parameters and the global terrestrial reference frame are under active scientific revision; practical insurance impact is indirect but real through trigger-data dependencies.^{24, 25, 27}
- 5** **High** Parametric trigger structures built on modeled rather than directly observed data inherit the underlying source's model risk; basis-risk frameworks apply to reference-frame and trigger-data revisions.^{29, 30}

6

Moderate

The cadence mismatch between reference-frame revision, regulatory model approval, and event arrival is the structural exposure; carriers locked to a given datum vintage carry concentrated calibration risk in the transition window.^{10, 15, 21}

SECTION 01 · STRUCTURE

What Sits Beneath the Flood Map

Every US property flood-insurance rate is, structurally, a function of a Base Flood Elevation, the lowest insurable floor relative to that BFE, and rating tables that translate the delta into a premium. The architecture assumes the datum is stable.

Under NFIP Risk Rating 2.0, fully implemented April 2023, rating incorporates distance from water, type of flooding, flood frequency, foundation type, prior claims, and replacement cost. BFE remains the central elevation input. FEMA determines BFE through engineering studies combining hydrologic and hydraulic modeling with LiDAR terrain data.^{10, 11, 12}

BFE values on Flood Insurance Rate Maps are measured in feet above a vertical datum. Newer maps use NAVD 88; older maps use NGVD 29.^{13, 14} FEMA elevation guidance from November 2022 requires LiDAR compliance with USGS LiDAR Base Specification and that data from multiple sources be converted to a common vertical datum before use.¹⁵

This architecture assumes the vertical datum is stable. NAVD 88 has been the operative US vertical reference since 1991, defined by a single tide-gauge fixing in Father Point, Rimouski. Insurance rates, where elevation is required and not grandfathered, are based on BFEs from active DFIRMs. The dependency is concrete: a property's NFIP premium is a function of an elevation referenced to a datum set by mid-twentieth-century tide-gauge data and held constant in rating math.

ASSESSMENT · HIGH CONFIDENCE

The architecture has performed well across NFIP's maturing because the underlying physical reality (the position of the relevant points on the land surface) has been treated, for ratepaying purposes, as approximately static. The subsequent sections examine whether that approximation is still adequate.

Rationale: *At the precision of conventional flood-map rating tables, the static-datum assumption was fit for purpose throughout the 1990s and 2000s. The combination of NSRS modernization and locally accelerated vertical land motion now stresses it.*

SECTION 02 · MOTION

The Ground Is Moving Faster Than the Map

Three independent geophysical signals indicate that the approximately-static ground assumption is now stressed in particular geographies relevant to US property insurance.

Subsidence. A 2025 InSAR study documented Greater New Orleans west-bank areas distal from the Mississippi River losing elevation at rates between -2 and greater than -20 mm/yr.³ In the Greater Houston region, the most-cited century-scale dataset shows significant subsidence (greater than 0.3 m cumulative ground loss from 1906 to 2024) over approximately 12,000 km² covering nearly all of Harris and Galveston Counties.⁵ Within that dataset, 85 percent of flooded area in Houston-Galveston hurricane events occurred where subsidence rates exceeded 5 mm/yr.⁶

The implication is direct. If a property's underlying ground descends at 10 mm/yr (a measurable rate in parts of coastal Louisiana), the lowest-floor elevation captured in a 2018 elevation certificate over-states the property's elevation as of 2028 by approximately 4 inches relative to a fixed datum, before any datum revision. Over a thirty-year mortgage horizon the cumulative offset becomes a meter or more in the most rapidly subsiding zones.

Sea-level rise acceleration. Tide-gauge observations show US coastal sea-level rise has more than doubled across the past 125 years, from less than 2 mm/yr in 1900 to more than 4 mm/yr in 2024.⁷ Along the US Southeast and Gulf Coasts, recent peer-reviewed work documents an even sharper near-term acceleration: rates exceeded 10 mm/yr during 2010 to 2022, attributed to a delayed response to the 2009 to 2010 slowdown in the Atlantic

Meridional Overturning Circulation.⁴ GRL analysis identifies Southeast coast acceleration greater than 0.15 mm/yr².¹⁷

Tide-gauge sea-level trends are local relative-sea-level trends, integrating absolute rise and vertical land motion.¹⁸ NOAA tide gauges record high-tide flood probabilities five to ten times higher today than fifty years ago.⁸ The 2024 Journal of Geophysical Research paper concludes that millimeter-to-centimeter subsidence features can substantially increase hurricane-induced inundation and that passive flood mapping (maps that do not actively incorporate vertical-land-motion measurement) can lead to inaccurate flood-risk predictions.²⁰

ASSESSMENT · HIGH CONFIDENCE

Vertical land motion is now large enough at multiple US Gulf and Atlantic coastal locations to warrant explicit incorporation into the elevation-rating architecture. The 12,000-square-kilometer Houston subsidence footprint, the greater-than-20 mm/yr west-bank New Orleans rates, and the over-10 mm/yr Southeast tide-gauge acceleration are each, in isolation, large relative to the precision of NFIP rating tables.

Rationale: *The combination of measurement-grade GPS, InSAR, and tide-gauge data triangulates the same conclusion across independent observation modes. The mitigation paths (more frequent LiDAR collection, continuous-GPS and InSAR integration into flood-map updates, rate-table subsidence allowances) are known and slow.*

SECTION 03 · FRAME

The Reference Frame Is Also Moving

While the ground moves, the reference system used to describe the ground is being revised. The NSRS modernization is scheduled to complete by end-2026.

The National Geodetic Survey is implementing a modernized National Spatial Reference System replacing NAD 83 (in use since 1986) and NAVD 88 (in use since 1991) with four new terrestrial reference frames (NATRF2022, PATRF2022, CATRF2022, MATRF2022) and one new geopotential datum (NAPGD2022).^{1, 21, 22} NGS published an updated implementation timeline in the Federal Register on 2024-10-09; rollout target is end-2026.²

NAPGD2022 is the operative replacement for NAVD 88 for flood mapping and elevation rating. It is built on satellite-gravity data, including NASA GRACE-FO mission inputs, and reflects the geoid rather than a single fixed tide-gauge reference. NGS completed a pilot project with FEMA in 2010 on the new geopotential datum's floodplain-mapping impact; further coordination is planned closer to rollout, with tools and services scheduled within five years post-modernization.²²

The implication is concrete. Every BFE on every DFIRM is currently referenced to NAVD 88 (or NGVD 29). On NAPGD2022 rollout, every BFE will have a value in the new datum that differs by a position-dependent offset from its NAVD 88 value. Where the two surfaces diverge by several centimeters, an elevation certificate's lowest floor could fall on the wrong side of a flood-rating threshold in the new datum without any physical change.

At global level, ITRF2020 was released in 2022 with horizontal site velocities at formal error less than 1 mm/yr, explicit modeling of post-seismic deformation and nonlinear seasonal motion. The ITRF2020 Plate Motion Model was published in GRL in 2023.^{24, 25} Adjacent to reference-frame revision, NASA Loomis et al. 2024 combined GRACE-FO with satellite laser ranging to refine the J2 oblateness time series, revising polar-ice-loss estimates upward by 15.4 Gt/yr for Antarctica and 3.5 Gt/yr for Greenland.²⁷

ASSESSMENT · HIGH CONFIDENCE

The structural issue is three out-of-phase cadences: reference-frame revision on five- to ten-year cycles, flood-map and model approval on multi-year cycles, event arrival annual or sub-annual. During the transition window between formal NAPGD2022 release and full FEMA flood-map conversion (an estimated five years), properties will be rated, surveyed, and elevation-certified under mixed datum vintages with conversion offsets handled jurisdiction-by-jurisdiction. This is the concentrated calibration-risk window.

Rationale: *NGS publication, FEMA pilot scope, and ITRF2020 release dates align on the 2025 to 2031 window. The systemic load is small per property but nonzero in aggregate across the entire US flood-mapped inventory.*

SECTION 04 · PARAMETRIC

Parametric Inherits the Model

The basis-risk framework developed for parametric insurance applies directly to the reference-frame and physical-signal questions. Where the trigger is a derived rather than directly observed quantity, the carrier inherits the source's model risk.

USGS ShakeMap, the standard parametric earthquake trigger source in the United States, does not reflect the actual distribution of shaking intensity after an event according to USGS's own characterization. It is not equivalent to an instrumental network, and in regions without dense seismic monitoring it is more model than observation. Guy Carpenter cites this property explicitly when documenting ShakeMap use for parametric earthquake transactions.²⁹

The 2024 Vanuatu earthquake parametric paid out, but Vanuatu has no strong ground-motion instruments within 250 km of the epicenter, so the ShakeMap basis was primarily a model derivation rather than direct measurement.³⁰ The same structural property applies to tide-gauge series used as triggers for parametric coastal-flood policies, which integrate accelerated vertical-land-motion, and to satellite-derived precipitation indices used as triggers for parametric agricultural and infrastructure policies, which depend on retrieval algorithms that change with sensor generation.

Where the trigger is a derived rather than directly observed quantity, parametric is most accurately described as transferring loss-allocation logic to a model output rather than to a physical signal. The product still functions; the basis-risk surface is just different from what indemnity carries.

The reference-frame transition adds a specific new category to the basis-risk taxonomy: datum-transition basis risk. A parametric coastal-flood policy that pays on a tide-gauge threshold expressed in NAVD 88 has a clear trigger today. The same policy in NAPGD2022 has a different specific threshold value for the same physical sea surface. Mid-policy datum conversion creates a window where the contractual trigger and physical signal diverge by the conversion offset.

ASSESSMENT · MODERATE CONFIDENCE

Parametric policy language issued during the 2026 to 2031 NSRS transition window will need to specify which datum applies, with formal conversion provisions, or contractual triggers will drift from physical signals by the conversion offset. We expect this to become a standard policy-language addition by 2027.

Rationale: *The pattern is observable in past datum transitions at the regional level and in industry guidance from PwC, WTW, and NAIC on parametric basis-risk treatment. The judgment is moderate because the magnitudes per policy are small but the cumulative volume is large.*

SECTION 05 · EXPOSURE

What Carriers and Federal Programs Carry

Aggregate calibration exposure from reference-frame and physical-signal drift is distributed unevenly across the property-insurance system. NFIP carries the most direct exposure.

NFIP has approximately 5 million policies outstanding nationally; every policy is rated under Risk Rating 2.0 with elevation as a key input; every elevation is currently referenced to NAVD 88; every NAVD 88 elevation will require explicit or implicit conversion to NAPGD2022 over the transition window.^{10, 11} NFIP lapsed on 2025-09-30 pending congressional reauthorization, with bridge legislation forcing immediate full-risk-rate transition for lapsed policies on reauthorization.³¹

State-backed flood and property insurers in coastal high-exposure states carry the same exposure indirectly through their rating dependence on FEMA flood maps and state-jurisdiction surveying standards. Private parametric carriers and ILS structures with US flood, hurricane storm-surge, or earthquake triggers carry both the data-source basis risk and the new datum-transition basis risk where contractual triggers are expressed in elevation terms.

The mortgage-finance system is exposed via FHFA's increasing attention to climate risk. FHFA issued two Advisory Bulletins on climate-related risk management in 2024 to Fannie Mae, Freddie Mac, and Common Securitization Solutions, and released a Mortgage Loan and Natural Disaster Dashboard mapping climate-hazard exposure to GSE-backed loans by census tract.^{32, 33} The reference-frame transition is not currently identified by FHFA as a distinct risk category; the underlying physical-signal acceleration is.

The strategic question for the 2026 to 2030 horizon is whether reference-frame revision is treated explicitly within the model-approval and rating-cycle architecture of NFIP, state-backed insurers, and parametric structures, or whether it is left to absorb implicitly across the jurisdiction-by-jurisdiction map-update cycle.

ASSESSMENT · MODERATE CONFIDENCE

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Rationale: *The question is open at the federal regulator level as of early 2026 and the public record contains no explicit policy guidance. Confidence is moderate because the regulatory direction will not be visible until the first NGS/FEMA joint advisory post-NAPGD2022 release.*

SECTION 06 · OUTLOOK

Three Scenarios, 12 to 36 Months

Construction confidence reflects analytical quality, not probability. The structural argument is anchored to multi-year reference-frame and oceanographic baselines.

Baseline · Orderly transition

CONSTRUCTION CONFIDENCE: HIGH · VELOCITY: GRADUAL

NGS completes the modernized NSRS rollout by end-2026 on schedule. FEMA begins jurisdiction-by-jurisdiction flood-map updates to NAPGD2022 over a five-to-ten-year window; NFIP rates continue under existing DFIRMs with implicit grandfather provisions. Parametric policies and cat bonds renew with revised datum specifications. No major event coincides with the transition window.

SIGNAL TO WATCH: NGS OFFICIAL NAPGD2022 RELEASE PUBLICATION IN THE FEDERAL REGISTER

Deterioration · Event-during-transition

CONSTRUCTION CONFIDENCE: MODERATE · VELOCITY: RAPID

A major hurricane or atmospheric-river event hits a coastal jurisdiction during the active datum-transition window. Post-event analysis identifies elevation-rating ambiguity, datum-conversion errors, or InSAR-documented subsidence that materially exceeds the assumed BFE precision. NFIP claims processing slows; private-flood and parametric structures face documentation disputes; a class-action posture forms around rating-vintage versus event-time elevation reality.

SIGNAL TO WATCH: A MAJOR ATLANTIC-LANDFALL HURRICANE IN 2026 OR 2027 WHOSE POST-EVENT CLAIMS DOCUMENTATION INCLUDES VERTICAL-LAND-MOTION OR DATUM-CONVERSION ANALYSIS

Stabilization · Regulatory integration

CONSTRUCTION CONFIDENCE: MODERATE · VELOCITY: STRUCTURAL

Federal regulators (FEMA, FHFA, NAIC) and state insurance departments integrate reference-frame revision into model-approval and rating-cycle architecture. NFIP Risk Rating 2.0 evolves to incorporate continuous-GPS and InSAR vertical-velocity inputs at the property or block level. Parametric policy language standardizes datum specification and conversion provisions. The mortgage system formalizes elevation-rating uncertainty as a credit-risk consideration at the GSE level.

SIGNAL TO WATCH: FEMA OR FHFA PUBLIC GUIDANCE ADDRESSING REFERENCE-FRAME REVISION IN THE CONTEXT OF INSURANCE RATING OR GSE CREDIT-RISK POLICY

ASSESSMENT · HIGH CONFIDENCE

The 2026 to 2030 outlook hinges on whether the reference-frame transition is treated as a routine geodetic upgrade or as a moment to integrate the underlying physical-signal acceleration into insurance product architecture. Baseline is the most likely twelve-month path. Deterioration is possible if an event lands in a high-subsidence and high-RSL-rise jurisdiction during the transition window. Stabilization is the most likely two- to five-year outcome if regulators act on the available data, and the most expensive long-run outcome if they do not.

Rationale: *The available scientific signal is unambiguous (NSRS rollout, peer-reviewed subsidence rates, AMOC-driven RSL acceleration). The open question is whether US regulators move proactively or reactively; both paths lead toward stabilization on different cost curves.*

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Publishable Market Research

Timeliness: DURABLE. The structural argument is anchored to multi-year reference-frame and oceanographic baselines that change slowly relative to the analytical horizon. This assessment carries a six- to eighteen-month shelf life. Material updates may be required at NGS official NAPGD2022 release, at FEMA flood-map update milestones, and at any major US coastal landfall during the transition window.

Classification: PUBLIC. Prepared on open-source intelligence verified against allowlisted sources (NOAA, NASA, USGS, NGS, FEMA, IERS, ITRF/IGN, FHFA, peer-reviewed literature). Figures cited are drawn from public sources; analytic judgments are Aegean's.

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