



Award Winner

Cross-Platform Climate Catastrophe Models: How LLM Translation Enables Actuarial Adoption

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INTRODUCTION

Climate change creates catastrophe scenarios that actuaries must continuously learn to model. When natural disasters strike, health system disruption follows a predictable pattern that generates correlated exposures across multiple insurance lines. Hurricane Maria's impact on Puerto Rico demonstrates this dynamic. The category four hurricane that struck in September 2017 produced cascading failures across healthcare, power, water, and transportation infrastructure that persisted for months (Cowan and Zavala, 2021). The initial impact involved immediate physical damage, but secondary effects proved equally consequential.

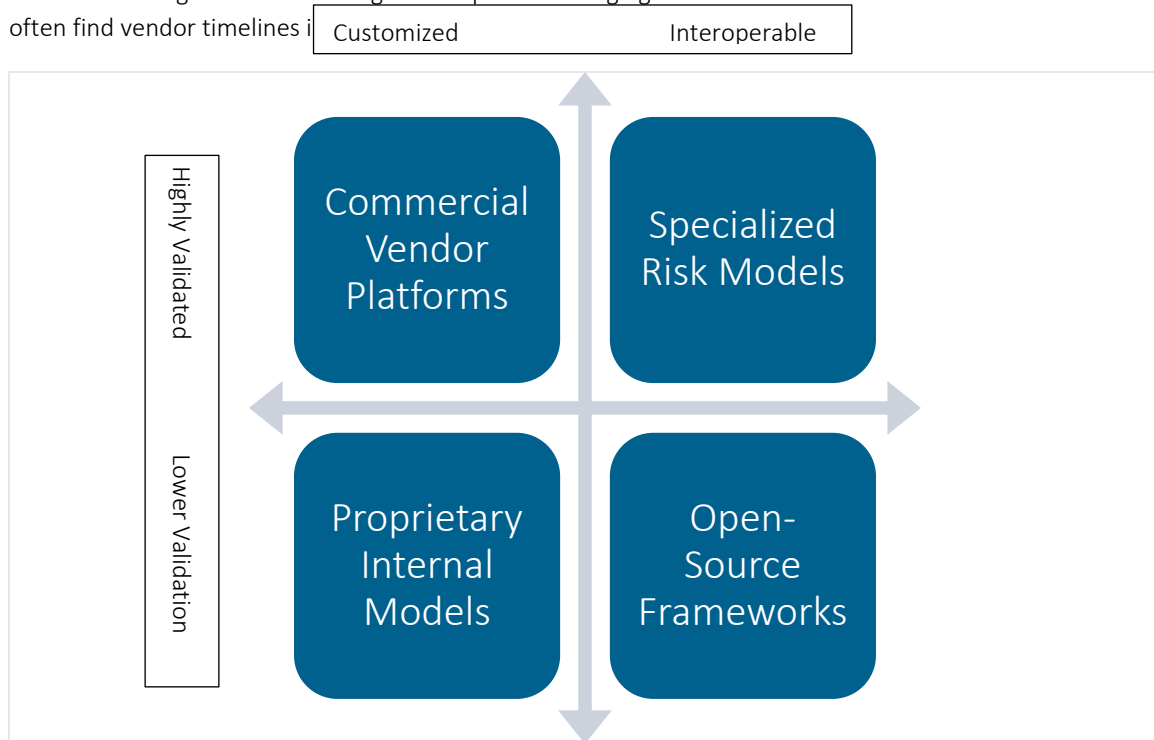
The global scale of climate-related health impacts extends far beyond individual catastrophic events. Non-optimal temperature exposure has been associated with 5 million deaths annually worldwide, with 9.43% of global deaths attributable to cold and hot temperatures (Zhao et al., 2021). Wildfire-related particulate matter presents another growing threat. Recent actuarial research quantifies how PM2.5 exposure during wildfire season affects prevalence of circulatory conditions, mental and behavioral disorders, neoplasms, and respiratory conditions (Yi et al., 2025). Complementary mortality analysis demonstrates that wildfire smoke impacts extend beyond immediate respiratory effects to include systemic inflammation and cardiovascular incidents (Titon et al., 2025). Cross-platform models, enabled by large language model (LLM) translation capabilities, preserve computational power while maintaining accessibility for broader actuarial adoption. This capability has value because climate risks require customization that varies by use case, line of business, and analytical need.

A TYPOLOGY OF CLIMATE CATASTROPHE MODELING

Climate catastrophe models can be categorized along two dimensions: validation maturity and customization flexibility. This framework helps actuaries select appropriate tools for different organizational contexts and risk questions.

Commercial vendor platforms occupy the high-validation, low-customization quadrant. These platforms provide extensively validated models for a wide range of hazards. They benefit from substantial development resources, industry acceptance, and refinement informed by user experience. Many vendors now offer climate-conditioned catalogs enabling scenario analysis under different warming pathways. The primary limitation involves customization constraints imposed by vendor development cycles and licensing

frameworks. Organizations seeking to incorporate emerging climate science or test novel risk scenarios often find vendor timelines i



Specialized frameworks represent a different approach. Recent actuarial research has developed climate-adjusted models that incorporate pollution variables and temperature effects into stochastic mortality projections. For wildfire impacts specifically, these frameworks separate baseline mortality from climate-sensitive components, enabling projections under alternative pollution scenarios while preserving familiar actuarial structures (Titon et al., 2025). However, broader deployment may require translation into spreadsheet formats or other internal tools for stakeholder review, creating a barrier to adoption across organizational hierarchies.

Proprietary internal models occupy the low-validation, low-customization quadrant. Organizations may develop catastrophe estimates using internally maintained spreadsheets with limited external validation or peer review. These models offer familiarity and ease of inspection but lack computational scalability for complex climate scenarios involving correlated exposures, time-varying parameters, or high-dimensional uncertainty. The limited interoperability means insights remain locked within specific organizational workflows, making it difficult to incorporate external research or compare results across industry frameworks.

Open-source frameworks represent an emerging category in the high-customization, low-validation quadrant. Recent work demonstrates how modular, auditable methodologies can be implemented with cross-platform accessibility (e.g., Lieberthal et al., in progress). A useful design pattern develops both code implementation (for computation) and spreadsheet implementation (for transparency), intended to be mathematically equivalent. This dual-platform approach supports and facilitates internal model approval and aligns with expectations for clear documentation. These approaches enable rapid incorporation of emerging research and customization for organization-specific portfolios, though validation quality may vary by implementation and requires careful implementation.

LLM TRANSLATION AS AN INTEROPERABILITY LAYER

Large language models now make it feasible to translate actuarial calculations between platforms while preserving mathematical logic. From an economic perspective, this development addresses a market friction that has historically limited catastrophe modeling accessibility. The friction involves a coordination problem between technical and business stakeholders. Risk committees and boards may prefer examining explicit spreadsheet formulas, while actuarial and data science teams require computational efficiency for Monte Carlo simulation, reverse sensitivity analysis, or portfolio-level aggregation.

Actuaries developing loss allocation algorithms in R and Python can generate equivalent formulas via a combination of LLM translation and open-source packages (Gazoni and Clark, 2024; Barbone et al., 2026). The work then primarily involves verifying that both platforms produce equivalent results within numerical tolerances. This cross-platform translation effectively turns the LLM into an interoperability layer that bridges code-centric and spreadsheet-centric environments. The same underlying logic becomes both high-performance and highly inspectable, depending on the audience.

An open research question concerns which programming languages produce more accurate translations. R's statistical orientation and relatively standardized syntax for common actuarial operations may produce more consistent translations for advanced modeling constructs.¹ Python's broader adoption across industries may increase the volume and diversity of training data, potentially improving translation performance for general modeling patterns and data-handling workflows. Systematic evaluation of translation accuracy across languages represents an important research direction, particularly for complex operations like credibility weighting, mixture distributions, correlation structures, and time-varying hazard intensities that are central to climate catastrophe risk estimates.

VALIDATION AND GOVERNANCE AS RESEARCH FRONTIERS

Automated validation presents a critical frontier for cross-platform climate modeling. Current practice relies on manual verification that spreadsheet and code implementations produce identical results for test cases, supplemented by spot checks and peer review. While effective for smaller models, manual approaches become burdensome for large-scale, multi-peril climate scenarios with complex dependencies. The economic cost of manual validation creates a barrier to model iteration, slowing the incorporation of emerging climate science into actuarial practice.

A next step involves developing systematic pipelines that audit spreadsheet formulas against reference code implementation, identify discrepancies, and track resolution. Such pipelines could integrate with version control systems, enabling continuous verification as models evolve and new climate research is incorporated. When combined with LLM translation, this suggests a model lifecycle process where updates are made in code, translated to spreadsheets, automatically regression-tested across platforms, and documented for governance and regulatory review.

Credibility theory provides conceptual tools for thinking about these validation pipelines. In many catastrophe and climate-related applications, parameter uncertainty dominates process uncertainty because observational histories are short, nonstationary, or incomplete relative to the tail events of interest (Guin, 2018; Jensen and Traeger, 2024). Explicitly integrating parameter-uncertainty diagnostics

¹ The author thanks an anonymous discussion with a colleague that included this point.

into cross-platform validation could make climate models more robust by stress-testing parameter sets or applying credibility-style weighting to alternative specifications.

PATH FORWARD: DEMOCRATIZING SOPHISTICATED CLIMATE RISK ANALYSIS

Climate catastrophe models benefit from flexibility because exposure patterns continually evolve as climate science advances. Actuarial organizations increasingly use multiple modeling approaches: vendor models for regulatory capital and well-established perils, specialized frameworks for mortality and morbidity projections, and open or exploratory tools for emerging exposures. The challenge involves ensuring that insights from these diverse tools are accessible, explainable, and auditable across the full range of stakeholders involved in risk management and governance.

Cross-platform capabilities enabled by LLM translation support this ecosystem by reducing barriers between computational environments and facilitating validation across technical backgrounds. For climate risks specifically, where parameter uncertainty, model risk, and deep uncertainty about future hazard pathways often outweigh the information in historical frequencies, this combination of analytical power and organizational accessibility is particularly valuable. Smaller insurers or pension funds without extensive data science teams can leverage shared frameworks and then translate results into formats suitable for boards, rating agencies, and regulators.

The emergence of LLM translation as an interoperability layer represents both opportunity and responsibility for the actuarial profession. Organizations previously constrained by tool limitations or expertise gaps can now access sophisticated modeling techniques while maintaining transparent validation processes. However, actuaries must help design standards, testing protocols and governance practices that ensure cross-platform models remain reliable as they are updated in response to new climate science and regulatory expectations.

In the context of climate risk, where impacts on mortality, morbidity, property, and assets are likely to intensify over the coming decades, the value of accessible and trustworthy models extends beyond technical sophistication. The documented health effects of temperature extremes, wildfire smoke, and compound disaster scenarios demonstrate the scale of risk that actuarial organizations must quantify and manage. Cross-platform climate catastrophe modeling, supported by LLM-enabled translation and robust validation, can help ensure that innovation in climate risk assessment reaches practitioners who need it, regardless of their preferred analytical environment. As climate scenarios continue evolving, this accessibility may prove as important as the analytical sophistication itself in supporting informed, forward-looking risk management decisions.

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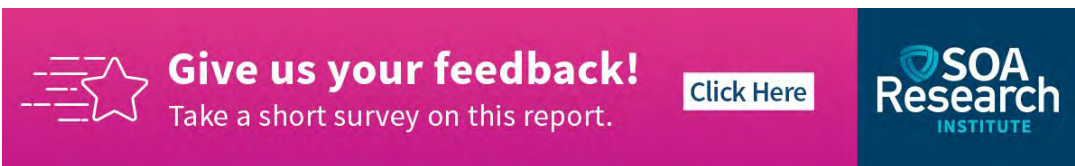
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