CosmicTriad™ / PaleoIQ™

Orbital Signals and the Tilt-First Climate Hypothesis

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Date: July 2025

Abstract

Orbital parameters such as axial tilt (obliquity) are traditionally treated as slow, deterministic boundary conditions in paleoclimate and climate-dynamics studies. In this framework, obliquity influences climate primarily through long-term modulation of seasonal insolation, while shorter-timescale variability is attributed to internal atmosphere–ocean dynamics.

Here, we propose an alternative but compatible framing: that small, measurable variations in axial tilt, its rate of change, and associated meridional insolation gradients act as **continuous exogenous signals** that bias large-scale circulation regimes. We refer to this framework as the **Tilt-First Climate Hypothesis**.

The hypothesis is formulated to be explicitly testable and falsifiable using modern geodetic observations, cosmogenic isotope records, and statistical evaluation against established climate benchmarks. Rather than asserting dominance over known drivers such as sea-surface temperatures, this framework evaluates whether tilt-derived signals contribute *incremental predictive skill* to climate-regime forecasting and paleoclimate interpretation.

1. Introduction

Orbital theory has long provided a foundational explanation for glacial–interglacial climate variability, with obliquity recognised as a key driver of high-latitude seasonal insolation. In most contemporary applications, however, orbital parameters are treated as static or slowly varying external forcings, while climate variability on annual to decadal timescales is attributed to internal dynamics of the atmosphere–ocean system.

This separation has proven effective, yet persistent discrepancies remain between orbital forcing expectations and observed climate behaviour, particularly during periods of abrupt transition, delayed deglaciation, or asymmetric hemispheric response. These mismatches are typically resolved through feedback amplification or greenhouse gas attribution, often without revisiting assumptions about how orbital signals are *expressed* within the Earth system.

The present work does not challenge orbital mechanics or astronomical solutions. Instead, it asks a narrower and testable question:

Do small variations in axial tilt and related orbital signals act as continuous modulators of climate regimes, rather than merely as long-term boundary conditions?

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2. Plain-English Statement of the Hypothesis

We propose that small, measurable changes in Earth's axial tilt and short-timescale wobble gently bias the large-scale patterns that drive seasons and regional climate. These signals are subtle, but persistent.

Using satellite geodesy, isotope records, and modern statistical testing, we evaluate whether tilt-derived signals add real predictive skill to climate models. If they do, they are useful; if they do not, the hypothesis is rejected and reported as such.

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3. Formal Hypothesis

Let $\varepsilon(t)$ represent Earth's axial tilt as a function of time, with $d\varepsilon/dt$ denoting its rate of change. Let $\nabla I\phi$ represent meridional insolation gradients derived from orbital geometry.

Hypothesis:
Variations in $\varepsilon(t)$, $d\varepsilon/dt$, and derived insolation gradients act as exogenous predictors or modulators of atmosphere–ocean circulation regimes (e.g., ENSO state, jet-stream latitude, monsoon onset). Inclusion of tilt-derived features improves probabilistic forecast skill beyond persistence-only and SST-only baselines.

This hypothesis does not require tilt to be the dominant driver of climate variability, only that it contributes measurable, independent information.

"The specific derivation of these quantities is implementation-dependent and not discussed here."

4. Conceptual Mechanism (Non-Quantitative)

The proposed mechanism is intentionally high-level and agnostic to implementation:

Axial tilt and wobble

→ alter meridional insolation gradients and seasonal contrast
→ bias Hadley cell extent, jet-stream latitude, and storm-track position
→ influence wind stress, upwelling, and thermocline structure
→ affect ocean–atmosphere coupling strength
→ increase or decrease the probability of specific climate regimes

This chain does not imply deterministic outcomes, but probabilistic biasing of system states.

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5. Evaluation Strategy

The Tilt-First hypothesis is evaluated through comparative forecasting and hindcasting exercises, not through curve fitting to known outcomes.

5.1 Features

- Axial tilt $\varepsilon(t)$
- Rate of change $d\varepsilon/dt$
- Seasonal insolation contrasts
- Meridional insolation gradients by latitude band
- Optional angular-momentum or wobble proxies where available

5.2 Targets

- ENSO indices (e.g., Niño3.4, ONI)
- Jet-stream latitude indices
- Monsoon onset timing

- Regional precipitation and temperature extremes

5.3 Benchmarks

- Persistence models
- SST-only predictors
- Standard statistical and machine-learning baselines

5.4 Metrics

- Continuous forecasts: MAE, CRPS
- Classification tasks: Brier score, ROC/AUC
- Reliability diagrams and skill decomposition
- Formal model comparison using Diebold–Mariano tests

5.5 Validation

- Rolling-origin hindcasts
- Time-split cross-validation
- Hold-out decades
- Feature ablation to isolate tilt contribution

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6. Falsification Criteria

The hypothesis is rejected for a given region, timescale, or variable if:

- Tilt-derived features fail to produce statistically significant out-of-sample skill improvements over persistence and SST-only models, **and**
- Observed improvements disappear under ablation or robustness testing.

Negative results are considered valid outcomes and will be reported.

7. Relationship to Existing Climate Frameworks

The Tilt-First framework is complementary to established climate theory. It does not replace SST-driven dynamics, radiative forcing, or internal variability models.

Instead, it evaluates whether orbital-scale signals contribute *contextual bias* that improves regime identification, timing, or risk assessment when combined with existing predictors.

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8. Scope and IP Boundary

This paper defines the hypothesis, evaluation logic, and falsification criteria. It intentionally excludes:

- Reconstruction algorithms
- Isotopic transforms
- Signal weighting schemes
- Threshold logic
- Operational model architecture

These components are documented separately in technical and proprietary materials.

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9. Relationship to Companion Research

This paper establishes the conceptual and testable foundation for subsequent work, including:

- Analytical studies examining proxy-derived expressions of effective obliquity
- Reconstruction experiments investigating divergence between astronomical geometry and Earth-system response
- Applied forecasting systems integrating tilt-derived signals into operational climate products

10. Phase 1 Objectives and Deliverables

This research directly supports PaleoTech Phase 1 objectives:

- Operational testing of tilt-derived signals via CosmicTriad™ / PaleoIQ™, AxisPulse™, and ENSOLink™
- Demonstration of predictive skill in live or retrospective pilots
- Delivery of IP-safe validation packages for partners and funding bodies
- Transition from research hypothesis to operational climate intelligence where justified

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11. Concluding Statement

The Tilt-First Climate Hypothesis reframes axial tilt not as a distant boundary condition, but as a continuous signal interacting with Earth-system dynamics. By posing a falsifiable, metrics-driven question, this framework invites empirical evaluation rather than assumption.

Whether confirmed or rejected, the results provide a structured pathway for improving understanding of how orbital signals influence climate regimes across timescales.