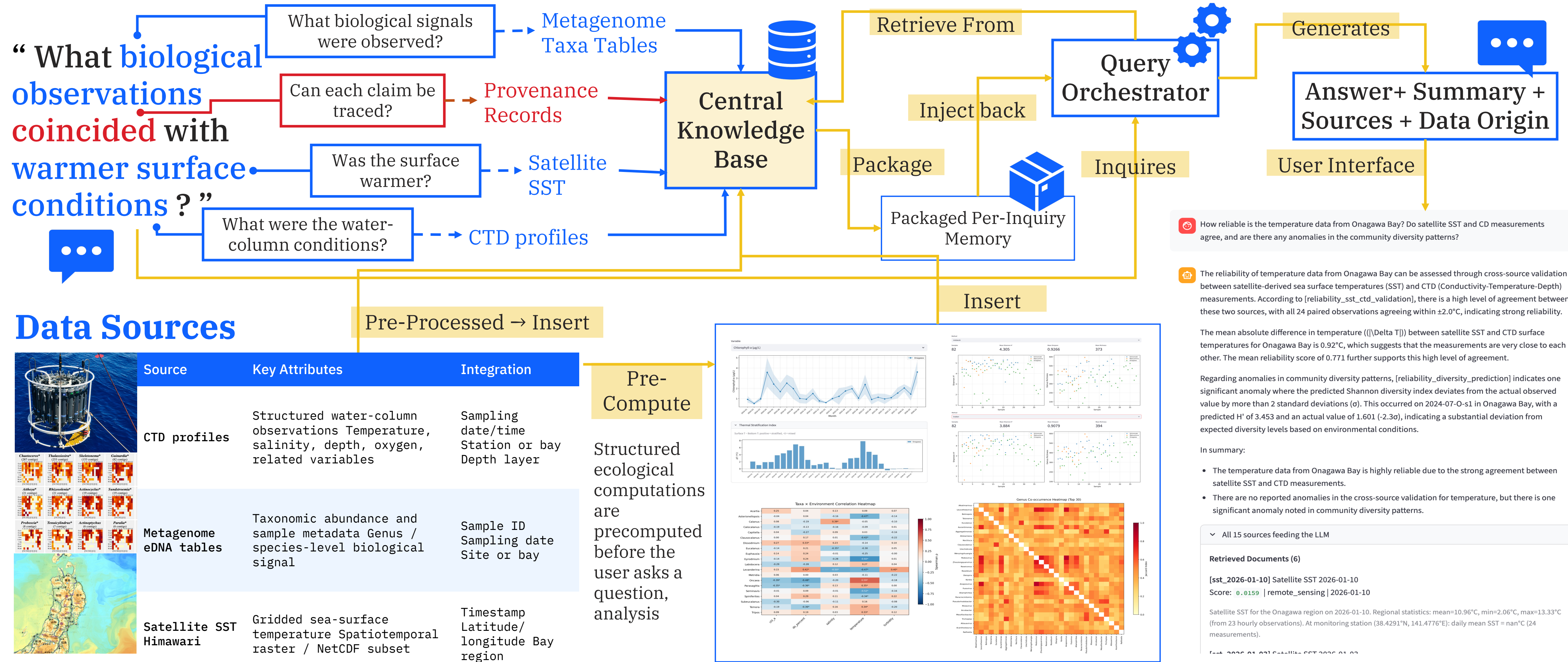


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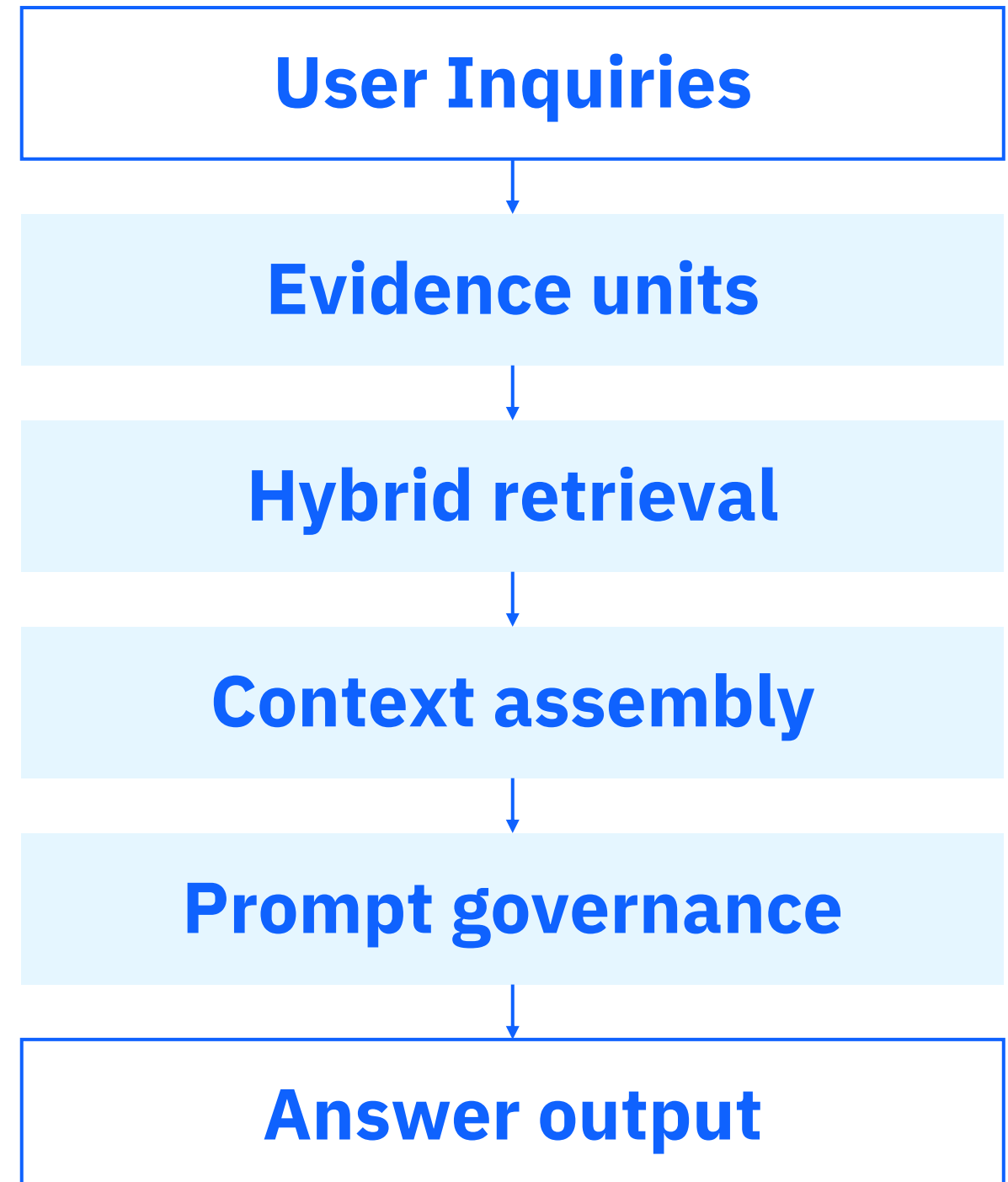
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I. The Subtle Complexity of a Simple Research Question And the Proposed Solution Pipeline



II. Framework Idea

A framework that converts heterogeneous ecosystem monitoring outputs data into source-specific, retrievable, citable, and auditable evidence units



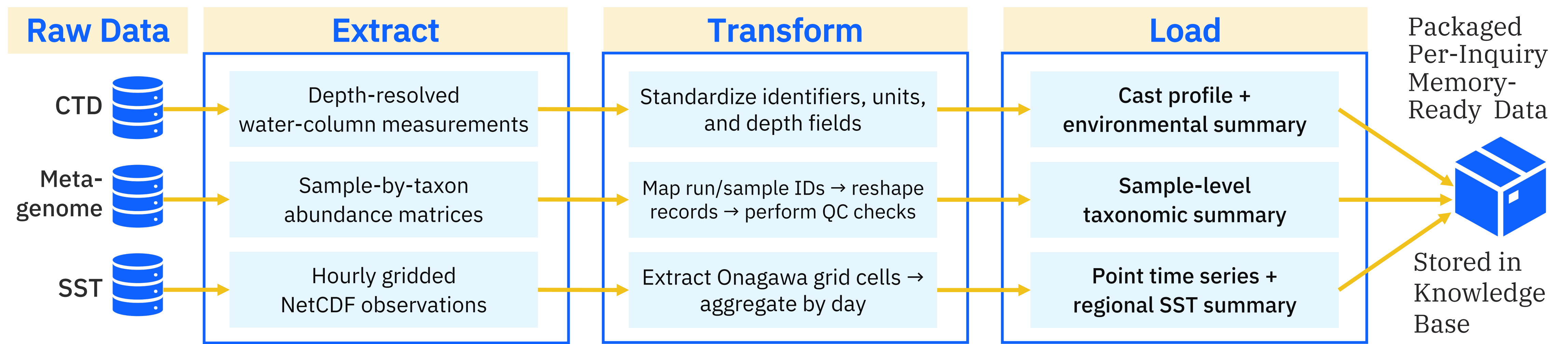
III. Onagawa Bay: Pilot Site

Natural Convergence

Observatory point where regional currents and biological responses meet.



IV. Each Modality of the Heterogeneous Data Sources Required Specific Preprocessing Methods



V. Pre-Computed Analysis Memory

Structured ecological computations are precomputed before the user asks a question, analysis such as:

CTD Monthly Trends	Taxa-Environment Corr.
Diversity Indices	Taxa Co-occurrence

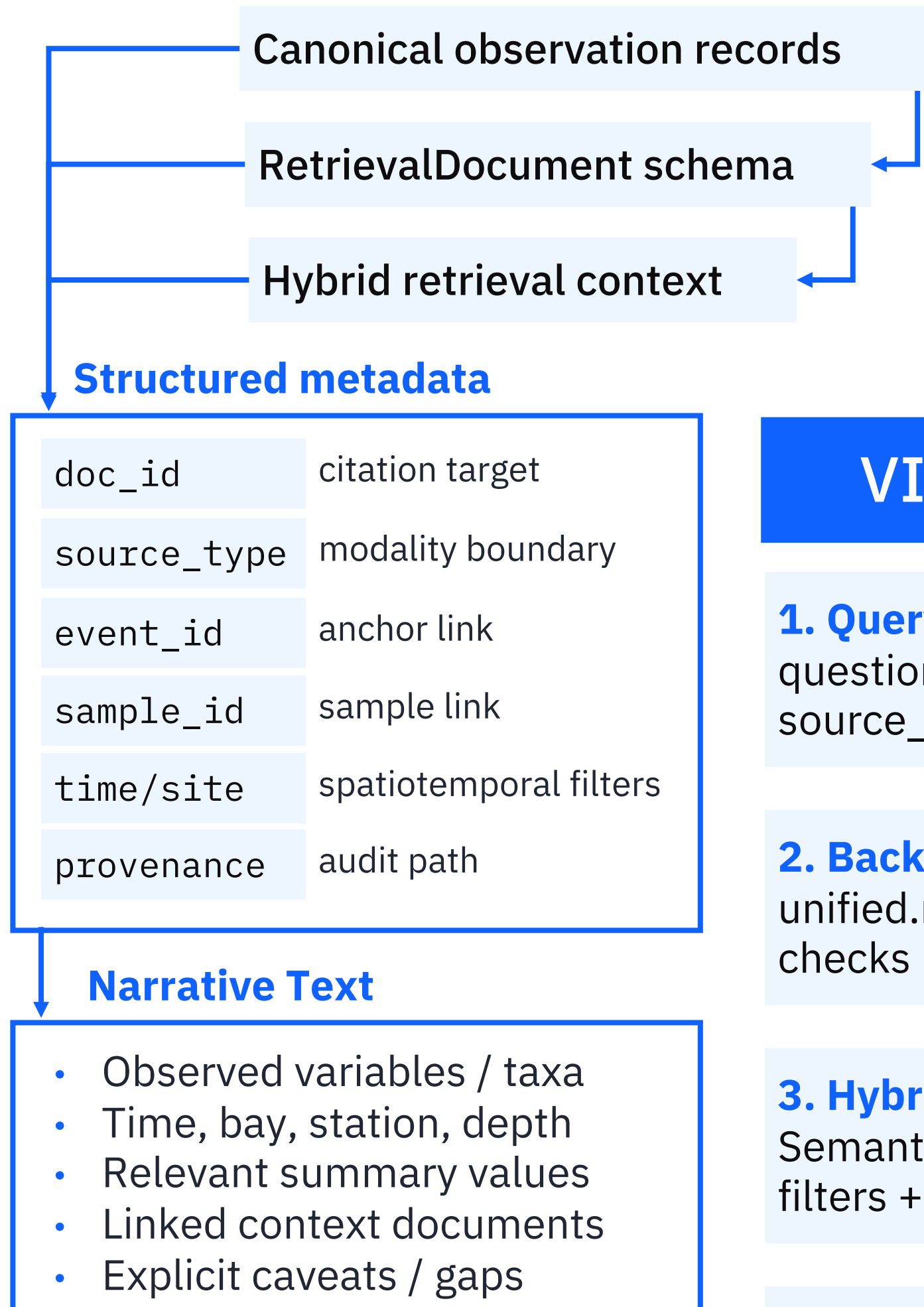
Pipeline Hands-off: typed Parquet + serving context → anchor events / links → retrieval documents → PostgreSQL + pgvector

VII. RAG System Evaluation Processes →

Benchmark the system with 15 questions across 5 categories. Supports the ablation study - across 7 system configurations varying source coverage (0–3), pre-analysis injection, and reliability injection.

System variant	Main comparison	Potential evaluation questions
LLM-only	Generation baseline	What might explain the unusual plankton signal we saw around Onagawa this season?
Single-source RAG	Isolated modality evidence	Can you summarize what the CTD observations suggest about the water conditions during that sampling period?
Two-source RAG	Partial cross-source linking	Do the biological samples line up with any noticeable water-column conditions?
Multi-source RAG	Full heterogeneous retrieval	Was there anything unusual in the physical environment around the time the community composition changed?
Multi-source + Analysis	Effect of analytical memory	Are there any recurring patterns between the environmental conditions and the taxa we observed?
Multi-source + Reliability	Effect of validation context	How confident should we be that the apparent temperature change is real and not just a data mismatch?
Full framework	Complete proposed framework	What is the most defensible explanation for the biological change, based on the available observations?

VI. Data Integration Strategy

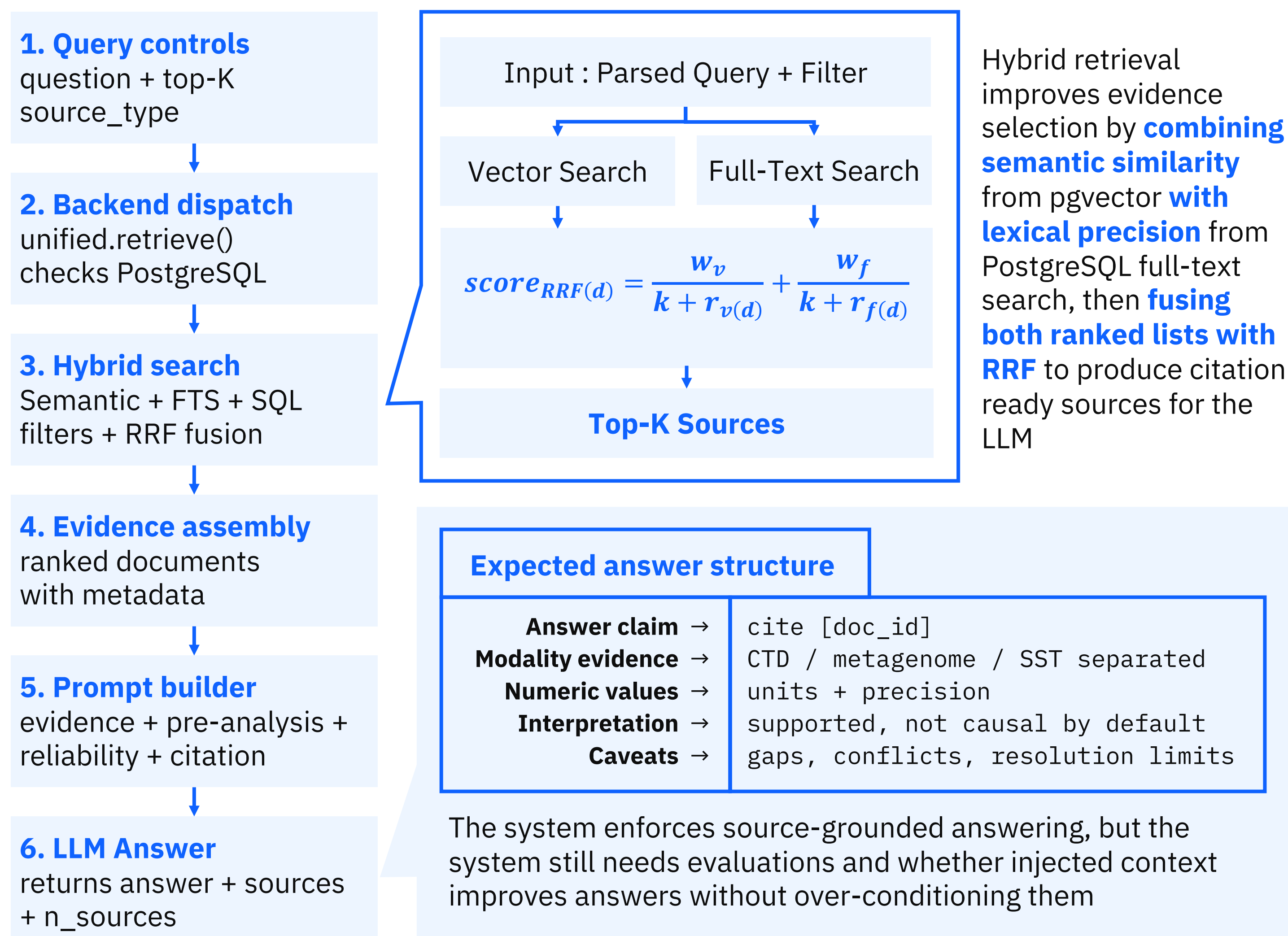


The LLM sees readable evidence → the system keeps structure to filter, rank, join, and audit it.

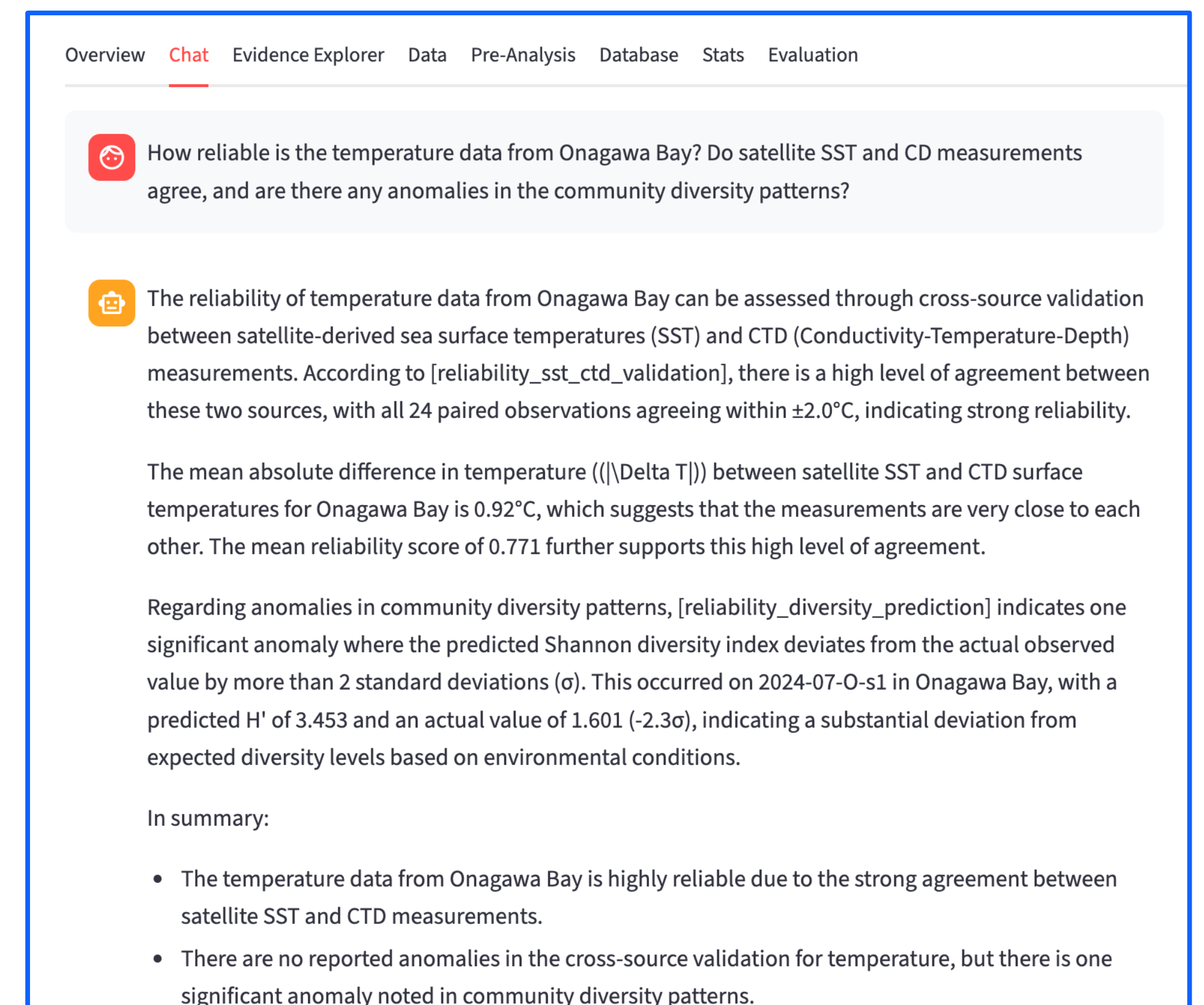
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VIII. Hybrid Evidence Retrieval and Large Language Models



IX. User-Facing Interfaces Prototype



Note on the usage of LLM: In this system, the LLMs was used locally to generate responses from retrieved ecosystem-monitoring evidence. Model inference was performed through a locally hosted model without internet access, cloud APIs, or external data-center computation. The environmental impact of each runtime was limited to electricity used by the local hardware in that session.