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[KSxAOV1I-22] From Ocean Data to Maritime Intelligence: Colombia's Path toward Operational Digital Twins

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Colombia is developing a maritime intelligence ecosystem that demonstrates how digital technologies can transform oceanographic and meteorological information into practical, high-resolution services for maritime safety. The SIPSEM (Integrated Forecasting System for Maritime Safety) climate services ecosystem, led by the Colombian Maritime Authority (DIMAR), constitutes an innovative South American approach that connects observation, high-level modeling, predictive intelligence, and interoperability to support operational decision-making.

The system addresses a fundamental coastal challenge: global models and heterogeneous observations are often fragmented, siloed, or lack the resolution required for tactical maritime applications. SIPSEM responds through a multi-layer architecture that integrates Colombia's oceanographic and marine-meteorological observations with nested numerical models, data-driven intelligence, and digital dissemination.

At its modeling core, SIPSEM uses a cascading approach that links global atmospheric forcing with regional, coastal, and local configurations, progressively increasing spatial resolution from about 27 km to 750–150 m in critical port environments. This architecture enables high-resolution simulations, operational forecasting, and scenario-based analysis, linking large-scale environmental dynamics with the local conditions necessary for navigation, port operations, coastal protection, and emergency response.

A key innovation is its open, interoperable digital architecture. ERDDAP provides a flexible data integration and dissemination layer, connecting heterogeneous sources and formats via standardized services such as WMS and interoperable interfaces. This architecture facilitates access to reusable data, geospatial integration, and the scalable delivery of environmental information across diverse platforms and user groups.

Through SIPSEM, Colombia demonstrates how a maritime authority can evolve from isolated datasets and models toward an operational, scalable ecosystem of digital twins. Port-scale modeling at the Port of Barranquilla illustrates how high-level numerical modeling, AI-driven predictive intelligence, and open digital infrastructure can combine to strengthen Colombia's maritime security, climate resilience, and emerging ocean intelligence capabilities.

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