The Economics of Public Earth Observations and Environmental Information: Marginal Value, Interdependence, and Investment Under Uncertainty

Joseph Conran
American University[1] and National Oceanic and Atmospheric Administration[2]
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Motivation and Research Question

Governments invest substantial public resources in Earth-observing infrastructure to support weather forecasting, disaster preparedness, environmental management, and economic activity. Although these systems provide essential scientific information and obvious utility, estimating their economic value presents significant challenges. Observational systems, such as satellites or radar, rarely generate benefits directly. Instead, public and private institutions combine observations with other data, incorporate them into models and forecasts, and use the resulting information to make decisions. The economic value of an observation therefore depends on the decisions it influences, the availability of alternative information, and the resulting changes in societal welfare.

Electricity systems illustrate these challenges. Weather forecasts influence short-term electricity demand, renewable energy production, generation scheduling, and infrastructure protection. Space-weather observations also support grid reliability by providing advance warning of geomagnetic disturbances that may damage transformers or disrupt electrical service. At the same time, electrification, increasing reliance on weather-dependent generation, and changing climate risks may alter the economic consequences of forecast errors and infrastructure disruptions. Climate change is projected to affect the frequency and intensity of peak electricity demand, with implications for generation capacity and long-term infrastructure investment (Auffhammer et al., 2017).

The economic foundations of information valuation draw on Nordhaus and Popp (1997) and Macauley (2005). The Resources for the Future (RFF) and National Aeronautics and Space Administration (NASA) VALUABLES Consortium subsequently advanced decision-centered approaches connecting changes in information availability to behavioral responses and economic outcomes (Kuwayama, 2021). However, valuing information for an individual application differs from evaluating competing investments in the infrastructure that produces it. Observing systems share data, provide complementary measurements, and jointly support forecasting capabilities. Furthermore, uncertainty in projected benefits may not correspond to uncertainty in the preferred investment alternative. **This research will evaluate the robustness of public Earth-observation investment decisions by estimating the changes in uncertain economic and technical parameters required to alter the preferred alternative. The analysis will consider observational interdependencies and changing economic conditions, including energy demand, demographic trends, and the geographic distribution of climate-related risks, when evaluating these thresholds.**

Literature and Expected Contribution

Electricity-sector applications demonstrate both the strengths and limitations of this current valuation framework. Improved temperature forecasts may reduce electricity demand forecast errors, while space-weather observations allow grid operators to prepare for geomagnetic disturbances that threaten infrastructure. However, estimates of financial settlement exposure, avoided operational costs, and prevented infrastructure damages represent distinct economic outcomes that cannot necessarily be aggregated as equivalent societal benefits.

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[1] Primary affiliation (PhD Candidate, Department of Economics).
[2] Professional affiliation (Senior Economist, NOAA Chief Economist Team). The views expressed are solely those of the author and do not necessarily represent the official positions of NOAA, the Department of Commerce, or the U.S Government.
[3] Prepared exclusively for submission to this conference.

Existing studies emphasize immediate operational decisions and historical relationships among forecasts, behavior, and economic outcomes (e.g. severe storms, hurricanes, extreme heat). Longer-term climate and energy transitions introduce additional uncertainty. Changing temperatures may alter peak electricity demand, while greater reliance on wind and solar generation increases the importance of forecasting weather-dependent supply. More broadly, climate adaptation and infrastructure decisions may depend on information whose economic consequences unfold over decades (Moore & Sobel, 2025).

The proposed research will apply a common decision-analytic approach to selected Earth-observation investments using existing benefit-cost estimates and empirical parameters. The analysis will calculate the changes in key assumptions required to alter preferred investment alternatives and assess whether these thresholds fall within ranges supported by available evidence. Particular attention will be given to the treatment of uncertain forecast improvements, observational interdependencies, and the distinction between financial and societal benefits.

Analytical Framework and Applications

The analysis will evaluate differences in expected net societal benefits between investment alternatives, conditional on uncertain economic parameters and the availability of other observational capabilities.

$$\Delta NB_{i,j}(\theta, S) = NB_i(\theta, S) - NB_j(\theta, S)$$

Where:

- $\Delta NB_{i,j}(\theta, S)$ = difference in expected net societal benefits between investment alternatives *i* and *j*.
- $NB_i(\theta, S)$= expected net societal benefit of investment alternative *i*, relative to a specified baseline.
- $NB_j(\theta, S)$ = expected net societal benefit of comparison alternative *j*, relative to the same baseline.
- θ = uncertain technical and economic parameters, including forecast improvements, behavioral responses, and unit benefit estimates.
- S = other available observational capabilities, including complementary and substitutable information sources (e.g. foreign partner assets, remote sensing vs in-situ sensors).
- i, j= mutually comparable investment alternatives within a defined decision problem.

Three National Oceanic and Atmospheric Administration (NOAA) assessments will provide the foundation for this analysis: the GeoXO Benefit Analysis (Adkins, 2022), Space Weather Next Cost-Benefit Analysis (NOAA, 2026a), and NEON Series-1 Microwave Sounder Benefit-Cost Analysis (NOAA, 2026b). GeoXO estimates benefits from improved electricity demand forecasting through a benefit-transfer approach. NEON extends this analysis using regional electricity-market and weather data to examine relationships among weather forecast errors, load forecast errors, and market settlement outcomes. These financial outcomes require additional economic justification before they can be classified as net societal benefits. Space Weather Next examines a different mechanism, estimating avoided outages, transformer damage, and operational costs associated with geomagnetic disturbances. EUMETSAT's assessment of European satellite investments will provide an additional prospective valuation example (Varley, 2023). USGS Landsat research (Loomis et al., 2024) and European Sentinel studies (Sawyer & Papadakis, 2024) will inform the discussion of observational substitution, complementarity, and international information sharing.

The quantitative analysis will use existing benefit-cost models, published empirical parameters, and reported sensitivity results to construct alternative investment scenarios. For each selected program, the research will calculate differences in net benefits among alternatives under common baseline assumptions. It will then vary selected parameters, including the realization of projected forecast improvements, downstream economic response estimates, and observational continuity or substitution assumptions where the available evidence supports such comparisons.

Break-even analyses will identify threshold values at which the preferred investment changes. These thresholds will be compared with uncertainty ranges supported by available evidence. Parameters with defensible probability distributions will support probabilistic sensitivity analysis, while structural assumptions will receive deterministic sensitivity testing.

For electricity-sector applications, the research will also consider alternative assumptions concerning future demand, weather-dependent generation, and exposure to extreme temperatures. These scenarios will evaluate the sensitivity of existing valuation relationships to changing energy-system conditions rather than estimate the full economic consequences of climate change.

Anticipated Results and Policy Implications

The central hypothesis is that parameters contributing substantially to uncertainty in aggregate benefits are not necessarily those most consequential for public investment decisions. Parameters shared across alternatives may affect projected benefits without changing their relative performance. Conversely, assumptions concerning observational substitutes, forecast realization, and future energy-system conditions, which are often assumed to be static, may alter the preferred investment.

The analysis will test this hypothesis using selected within-program comparisons and distinguish quantitatively supported findings from results dependent on structural assumptions. Benefits that cannot be credibly monetized will be characterized separately rather than assigned zero value.

The findings may inform public investment in environmental observing systems and electricity-sector resilience by identifying which sources of uncertainty are most consequential for resource allocation. The research will also identify limitations in historical, short-term valuation approaches for representing longer-term climate adaptation and structural economic change.

By connecting value-of-information theory with public investment decisions, the paper provides actionable empirical guidance for federal agencies and energy policy managers evaluating disaggregated, interconnected environmental infrastructure under changing economic and climate conditions

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