Value of Data: Innovative Recommendations Report

Response Prepared for:

National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)
National Centers for Environmental Information (NCEI)

ST133017CQ0058 T1332KP19FNEEN0003 CLIN 2002 SubCLIN BE

August 11, 2020

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Purpose of Report

This Report was developed in response to Task Order #1332KP19FNEEN0003 for NCEI Science and Data Stewardship (SDS) support under Riverside PROTECH Satellite Prime Contract #ST-1330-17-CQ-0058. Specifically, NCEI directed the Contractor to "deliver a report documenting how it would innovate changes to the current Value of the Data understanding and success stories for user engagement, in the future."

This Report follows the methodology: "Start development of a report that provides context for a new framework of innovative approaches and methodologies to propel NCEI's current Value of the Data (VoD) model forward. The Report will provide an outline and plan of how best to execute future work including time and budget requirements, key literature and media sources, and propose opportunities, emerging technologies, and innovative presentation formats to leverage."

This Report provides eight key recommendations for implementing a new NCEI Value of Data model based on current research of climate services and models for value of data more broadly. The Report reviews initial conversations with key collaborators across federal, state, and local government. It suggests five goal-based model approaches to standardized economic impact of data across sectors and balances a sector approach with a problem-based approach.

Innovative Overview

Through the analysis of literature, close study of industry trends and National Oceanic and Atmospheric Administration (NOAA) resources, and our collective experience, CASE has compiled this Report to benefit NOAA's National Centers for Environmental Information (NCEI), the public, and industries that utilize climate, geophysical, and oceanic data. It presumes an NCEI-wide endeavor, which is particularly important for addressing grand compound challenges like coastal inundation, resource management, and resilience, and other areas in the near term such as health, environmental security, disaster risk reduction, and long-term planning of urban areas. While Section 4 details Approaches to Potential Future Goal-Based Models and specifies recommendations to move the Value of Data (VoD) model forward, CASE was particularly interested in highlighting New Innovative Methodologies as examined in Section 3; Section 5 presents resource requirements for each of these. These methods and their potential applications are detailed below and are noted here to provide insight and interest in the contents and later models and conclusions of the Report.

1) Create a standardized, NCEI-wide approach to assess value across domains and sectors and use it to set the priority of future sector engagement. Incorporate both assessments of economic value or potential value as well as social use or kinetic value.
2) Economic assessments must start with a standardized repeatable value for each sector rather than creating sector-values ad hoc when reports are updated. Specifically, start with statistics promulgated by the Department of Commerce (DOC) Bureau of Economic Analysis (BEA), the Office of the NOAA Chief Economist, and other authentic, referential economic sources.
3) Social use assessments should shift from a "point of sale" (access) of stories towards a "point of use" analysis. Rather than contracting with consultants for success stories, enable customer service representatives to become customer service researchers to conduct virtual case studies via meta-research on data use as defined by sectoral and social science literature.

4) Establish sustained relationships with professional societies and publish as a shared endeavor. When success stories come from professional practitioners rather than NCEI itself, they have more weight in the eyes of those judging investments in NCEI.
5) Place-based case studies and assessments are a central component of a VoD method. Changes in weather, climate, geophysical and oceanic states affect people, communities and businesses differently depending on location. A BEA study on the Ocean Economy, for example, shows the value of ocean data to travel and tourism and requires place-based assessments.
6) Expand on existing and new partnerships with other parts of NESDIS and other NOAA line organizations, other federal agencies, and regional groups including: Regional Climate Services Directors (RCSDs), the Regional Climate Centers (RCCs), State Geologists, Sea Grant College Programs, the Association of the State Climatologists (AASC), NOAA Oceanic and Atmospheric Research (OAR) Regional Integrated Science and Assessment (RISA) programs, Regional Fishery Management Councils, and others.
7) Improve VoD analysis by improving the engagement with users of data. Consider decentralizing user engagement by engaging through the Regional (and state) offices and partners.
8) Recognize the essential link between VoD efforts and sustained collaborative engagement with users of NCEI-stewarded data.
9) Design to eventually capture economic and social value in the Big Data Program of cloud service.

1.0 Introduction and Context

1.1 General Background Information

NOAA NCEI demonstrates the value of data that it stewards through use cases and success stories across a diverse range of the economy. Each success story focuses on a sector, showing data are used and the impacts of its application. NCEI also seeks to learn how users access the data, how user needs evolve over time, and how to improve access[1]. The purpose of this task order effort is to improve the current Value of Data model through innovative techniques.

The purpose of the VoD processes overall is two-fold. First, it communicates vertically up the chain of command to headquarters of NCEI, National Environmental Satellite, Data, and Information Service (NESDIS), and NOAA, to the Department of Commerce, and ultimately to Congress. In doing so, it gives feedback that helps support the budget process[2]. Second, the VoD process communicates laterally throughout NOAA and its stakeholders. VoD stories help data providers learn about data applications and ensure feedback for future data streams that may be required. That is, the process serves to inform additional potential practitioners about how to apply data, and it educates data scientists in ways that ultimately improve data stewardship.

1.2 Understanding the Context for a New NCEI VOD Framework

Stewarding one of "the most significant planetary data archives—spanning from the surface of the sun to the depths of the ocean, and from near real-time satellite imagery to ice core records that reveal atmospheric conditions from millions of years ago," NCEI authoritative data "feeds into maps, models,

[1] See Success Stories on User Engagement here: https://www.ncdc.noaa.gov/success/
[2] Eileen Shea, "The Federal Budget Process", Speaking of Climate Series. https://caseconsultantsinternational.com/community-service. May 2017.

and predictive analysis used every day by government officials, scientists, planners, and emergency responders."[3]

NCEI is looking to strengthen the present VoD model to identify innovative methods for both internal and external communication. To understand the value of retrospective data, from the basic archive to high level assessments, it is helpful to contrast real-time and retrospective data. While real-time data are used for operational decisions in the short term, retrospective data are used for design decisions in the long term, and other purposes. Real-time data apply to forecasts; retrospective data apply to projections and to improving forecasts.

While the present VoD model has yielded useful and interesting results, work for this Report is undertaken in the context of a One NOAA[4] headquarter approach, firmly aligned with NESDIS Reimagined[5], responsive to a broadened NCEI scope, consistent within the realm of the Department of Commerce, and most important, aware of both economic and social value.

1.2.1 One NOAA and NESDIS Reimagined

The One NOAA theme suggests NCEI fold its plans into the overall strategic guidance of NOAA headquarters. At the release of NOAA's new science and technology strategies for Cloud and Data plans, the NOAA Administrator stated "The value of NOAA's data depends on its quality, integrity, and the ability of users to access and use the data with modern, emerging, and innovative cloud-based services."[6] As NOAA's Data Strategy is subtitled Maximizing the Value of NOAA Data, its plans are an important input to this Report, particularly as it aims to "improve the management and overall value of NOAA's data . . . for the greater benefit to the agency." Similarly, NCEI must be mindful of NESDIS Reimagined, which prioritizes five strategic objectives to implement over the next five year (two of which are very pertinent to this Report: Provide consistent ongoing enterprise-wide user engagement to ensure timely response to user needs; Deliver integrated program development to provide a suite of products and services.)[7] NCEI serves over 400 products in the domains of oceans and coasts, geophysics, and weather and climate. Communicating value across all domains is needed.

1.2.2 Three Domains

As a use-based science organization, NCEI stewards data from the land, sea, and air. Its value is in serving needs across all domains. In 2015, NOAA NESDIS consolidated its data centers in an effort to increase efficiency, enable better discovery of environmental data, and develop integrated products and services across science disciplines (Redmon, 2016). This strategic merger positions NCEI to achieve its mission and service to the Nation, and at the same time presents an opportunity to showcase the quality and full breadth of its databases. NCEI's VoD model evolved over many years, some of which predates the combining of NOAA's former three data centers—the National Climatic Data Center (NCDC), the National Geophysical Data Center (NGDC), and the National Oceanographic Data Center (NODC) which includes the National Coastal Data Development Center (NCDDC) into a single enterprise

[3] Joe Pica, July 2020. Press announcement, NOAA Data Strategy. July 2020
[4] One NOAA was an effort begun by former Administrator Conrad Lautenbacher, which continues to this day. See various presentations by Louisa Koch, Director, NOAA Office of Education, One NOAA Science Seminars, and elsewhere.
[5] *NESDIS Reimagined* internal draft-in-progress
[6] Neil Jacobs, Press release NOAA 7 July 2020, https://www.noaa.gov/media-release/noaa-s-cloud-and-data-strategies-to-unleash-emerging-science-and-technology.
[7] Based on a draft presented to DOC about June 2020.

distributed across four geographic sites. VoD studies predating the NCEI merger concentrated primarily on the climate aspect of NCEI data and were not designed to service the geophysical and ocean domains. Furthermore, they emphasized surface in situ data and treads rather lightly on satellite data. On the one hand, there are many systems that deal with satellite data alone--Climate Data Records--in all three domains--Atmospheric, Oceanic, and Terrestrial, and the NSDIS user engagement efforts, especially for NOAA's Geostationary and Extended Orbits (GEO-XO) program. Yet, on the other hand in a NESDIS Reimagined context, incorporating Geostationary Orbiting Earth Satellite (GOES) and Polar Orbiting Earth Satellite (POES) data in a new VoD model is equally important to maximize data utility to the Nation. A new model is necessary to give coverage to all three domains or disciplines in the scope of NCEI--climatic, oceanic, and geophysical data, consistent with the context of the aspirational *NCEI Road Map*.[8]

1.2.3 Department of Commerce (DOC)

Department of Commerce relies on estimates of dollar figures that are consistent with the BEA. In the present model, estimates were sometimes derived from interviews and data gathered from selected sectors. Methods were more qualitative than quantitative, and less methodical than traditional economic analysis. The figures were not widely reviewed, and not subject to the scrutiny of peer review. Bad dollar numbers are worse than no numbers at all. Having said that, the present model resulted in numerous valuable storylines that generally resulted in clear understanding of the variety of ways data are used. The story telling is an effective means to communicate value up the chain and laterally.

1.2.4 Economic and Social

The last and most important consideration of this Report is the social context. VoD must be measured by how data are used. This effort aims to significantly broaden the recognition of NCEI as an authentic and authoritative source of climatic, geophysical, and oceanic data, products, and information. This Report aims to help NCEI remain the gold standard for environmental science data stewardship around the world. For data to have any value at all it must be credible, reliable, trustworthy, and salient to the people who need it. Well-stewarded data have potential value to be put into use in many ways. Potential value comes from high standards that NCEI applies in every step of data stewardship - Acquire, Analyze, Access, Archive, and Assess data (Owen, 2017; Kihn, 2017). An innovative valuation system accounts for the potential value that is inherent in the data sets and products in a sector. Further, the true value of information is manifested when data are put to use, a kinetic value. The potential and kinetic nature of the data's value exponentially increases through enhanced collaboration with strategic partners engaged in similar work throughout NESDIS, NOAA, other federal agencies, universities, and the private sector.

Important also, is to highlight efforts that are not part of this Report. This Report is not intended to suggest methods to estimate the economic VoD as a commodity. Given that the renowned World Economic Forum prints "there is no standard practice or formula set in place to assess the value of data" (Thirani), that would be beyond scope. Furthermore, there is no attempt to specify which economic model is best to assess value. Instead, this Report presents a range of possibilities.

[8] Mary Wohlgemuth, NCEI Five-Year Road Map: FY 2020–2025, released summer of 2020

This Report is intended to suggest methods to improve upon the existing VoD model. It endeavors to document, describe, adopt, modify, or use whatever means that can effectively move forward in serving the Nation's need for trusted and authoritative environmental information. The Report suggests means to "invent" new models by taking existing methods from other disciplines and molding them to NCEI's use.

2.0 Understanding a New Framework for VOD

The intention of this Report is to provide context, recommendations, and a launching point for VoD models for data, products, and analyses at NCEI. The Report seeks to create a forward thinking and well-informed approach that focuses on goal-driven methods, replicability with limited resources and alignment with the big data revolution. Goal-driven methods can exponentially increase the valuation of data and justification for continued support and increased resources and assets associated with NCEI.

This Report refers to two classes – or states – of value analogous to potential energy and kinetic energy. Potential value – like potential energy – is an intrinsic characteristic of data unrelated to its active applications. Potential VoD is thought of as a snapshot of possible value for a selected economic sector. The starting point for documenting the potential VoD begins with accepted economic assessments of the value of a given sector, such as those by the BEA. In this same context, kinetic value, like kinetic energy, represents data in motion supporting decisions in a variety of sectors, places, and decisions. Kinetic value can be estimated economically but is perhaps most usefully described through case studies and decision-support analyses.

First and foremost, a VoD model must start with the understanding that true value accrues only when data are used, to quote the late Molly McCauley, past Executive Director of Resources for the Future (Bernknopf, 2019). One implication of this perspective is that assessing value should include both social uses and economic uses. Snapshots of high-level economic value can serve as a tool in justifying investments in NCEI programs and captures a view of the potential value of NCEI. Additional analyses can help NCEI develop and document the more expansive kinetic value of planetary retrospective data at work.

Defining what value is and where potential value arises in a use chain is essential to valuation methodologies. Data does not innately have value, value is attained when data is accessed, used, and communicated. Data gains value when it is more accessible, when it is used more often, and when its utility is communicated more effectively.[9] The European Commission Open Data Directive identifies high value datasets based on one of the following indicators: potential to general social, economic, or environmental benefit; potential to generate innovative services; number of users; revenue they may help generate; potential for being combined with other datasets; and expected impact on the competitive situation of public undertakings (European Commission, 2011).

NCEI's existing VoD model relies heavily on a single sector approach to user engagement as told through success stories, factsheets, promotional videos, and counts of downloaded data types. Climate and weather data primarily remain the focal point of this effort and for good reason considering the extensive role they play in immediate and long-term decision making of both the individual and society

[9] The NCEI Road Map aspires to use its scientific and data expertise, to "provide science-based products and services that multiply the value of archived data and information." One easy step down that Road is to follow the path of NSIDC, who requires a formal citation as a condition of use of Scientific Data Sets.

as a whole. However, when trying to maximize public perception and garner financial support, it would be advantageous to increase promotional efforts that also emphasize value of NCEI's other two data domains.

NCEI's success stories and sectoral engagement factsheets do not accurately capture the weight and significance that geophysical data plays in day-to-day operations and institutional systems. The more public awareness around the ways in which geophysical data improves quality of life, the more value can be drawn from their applications. It is likely that those unfamiliar with geophysical processes will not recognize the value that such data have in coastal and resource management decisions, natural hazard risk reduction, and navigational systems.

This Report builds upon the successful sector approach but seeks balance between a single-sector and multi-sector, problem-based method of valuation.

Recognizing certain limitations of the existing valuation model and adjusting where needed can help to increase exposure of NCEI's services. Based on review of the current model, NCEI largely demonstrates the VoD through a single-sector approach, one that highlights datasets used by various organizations within a specific field or scope. For example, the success stories on user engagement target individual sector providers, including agriculture, aviation, natural resource management, retail and manufacturing, reinsurance, logistics and transportation, weather service providers, and fisheries. The same can be said for NOAA's sectoral engagement factsheets that focus on the areas of civil infrastructure, energy, health, construction, tourism, national security, litigation, and marine and coastal ecosystems. This Report builds upon the successful sector approach but seeks balance between a single sector and multi-sector, problem-based method of valuation.

This Report encourages a broad look at valuation that includes both economic value (dollars) and also social value (utilization). Economic models are essential to the former and success stories are essential to the latter. Though they are effective, case studies and storytelling only go so far, because the public do not seek out these stories out nor do they always have time to read them in full. A true measure of value requires a holistic approach, one that incorporates both innovative economic models and also social utilization approaches.

2.1 Potential Value – Economic Assessments Models

Much has been published about data's economic value, given the massive increase in shared data in the marketplace. Some financiers estimate that the global free flow of data generates more value than the flow of tangible goods. In a 2016 report, McKinsey estimates data flow value will surpass $11 trillion dollars by 2025, a figure that includes NOAA's climate data in the calculations of "some enormous publicly accessible topic databases" (Manyika, 2016); yet, that is "all" data—that are traded in the marketplace. (See *Box 1. Insights from the Private Sector*).

A source from a United Kingdom publication states that volume "is not the sole indicator of economic value. Most global data is unstructured, taking the form of pictures and videos, or the 'exhaust data' formed as a by-product of business. As long as such data is inaccessible for the purposes of analysis, or is unlinked and unaggregated, its potential value may remain unrealised" (HM Treasury, 2018).

While an analysis of data value will differ between open data and government data, these private sector insights can translate into a goal-driven, problem solving approach for NCEI's VoD model.

Box 1. Insights from the Private Sector

Insights from the Private Sector
Data as Intangible Assets

With 2.5 quintillion bytes of data generated per day in the world and 90% of all data produced in the last two years, organizations globally seek to value their data as assets and to use other organization's data to create their own value (PricewaterhouseCoopers, 2019). With this surge in data growth, the big data transformation has "enabled organizations to capture a broader, more granular and more real-time range of customer, production, operational and market interaction" (Schmarzo & Sidaoui, 2017). Valuations of data driven firms are higher than their peers in the same industry, as a federal environmental data hub. Although this Report does not recommend a method to do so, NCEI could align itself with the big data revolution by similarly quantifying the value of its data holdings as an asset and using the resulting facts to improve operational decision-making about data assets.

With the rise of technology companies over the last decade, intangible assets in the economy have vastly increased and efforts to value these assets in the private sector are abundant. In fact, economists estimate there could be more than $8 trillion in intangible assets in U.S. companies, representing nearly half the $17.9 trillion market capitalization of the S&P 500 index (Monga, 2016). At larger scales, one method to value intangible assets for public companies is to look at the company's stock market value and subtract the assets minus the liabilities with the difference serving as a proxy for the intangible assets (Monga, 2016).

But within companies, valuing data is a driver of analytics and data-driven decision making that can shape a company's performance, forecasting, model for competitive differentiation and the decisions that shape its future (Schmarzo & Sidaoui, 2017). They state organizations must create a framework that 1) identifies and prioritizes business use cases (e.g. acquiring more customers, improving customer satisfaction, reducing costs); 2) builds analytic profiles to facilitate analytics capture and re-use (i.e. an operational framework); and 3) identifies and prioritizes data sources for thoughtful data services.

2.2 Kinetic Value – Social Use Value Assessments

Financial institutions typically concentrate on the economic dollar value of assets as a traded good. Some financiers, as analyzed by the Bennett Institute at Cambridge University, deem that as data, can be used over and over again (unlike traded goods), assigning a dollar value is less fruitful than "highlighting data's contribution to the broad economic well-being of all society" (Coyle, 2020).[10]

Among other topics, the Bennett Institute explores which datasets the government should invest in maintaining and how should public sector data be put to use. Notably, they describe value from a data scientist construct (quality, temporal coverage, interoperability, etc.), what this paper calls a potential value, and value from the use construct, how people and organizations benefit from data, products and services that informs decisions, what this paper calls a kinetic value.

Valuing kinetic value is a difficult task. Financial institutions go about it by identifying investments and risks associated with actions in response to social needs.

In that vein, as early as 2008, the International Finance Corporation (IFC) (2010) of the World Bank reported on the impacts of natural stressors to humankind, issuing guidelines on financial risks of long-

[10] The Bennett Cambridge report defines Value of Data thusly: "People mean different things when they talk about the value of data. Some people think of it only in terms of monetary value. They might focus on how much organisations should be charged for data or what figure to include on a balance sheet. In this report 'value' refers to the economic concept of social welfare: the wellbeing of all society. Value arises from data when businesses create jobs or become more productive; when governments deliver more effective public services; when our environment is clean and diverse; and when people live happier and healthier lives."

term assets that Among other topics, the Bennett Institute explores which datasets the government should invest in maintaining and how should public sector data be put to use. Notably, they describe value from a data scientist construct (quality, temporal coverage, interoperability, etc.), what this paper calls a potential value, and value from the use construct, how people and organizations benefit from data, products and services that inform decisions, what this paper calls a kinetic value.

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In that vein, as early as 2008, the International Finance Corporation (IFC) of the World Bank reported on the impacts of natural stressors to humankind, issuing guidelines on financial risks of long-term assets that are vulnerable to climate change (IFC, 2010). As other financial institutions have done, IFC produced a remarkably detailed list of investments vulnerable to environmental conditions (*Box 2*). Each of these could be researched as a case study.

Box 2. Kinetic Value – Social Use Assessments by Financial Institutions

Insights from the Financial sector
Kinetic Value—Social Use Value Assessments

IFC guidelines reported on investments affected by the conditions measured and monitored in all three domains of data stewarded by NCEI—atmospheric, terrestrial, and oceanic. The assets discussion includes topics across those domains including:

- Areas vulnerable to water stress
- Change in ground runoff as a function of emissions Scenarios
- Merchandise trade as a function of climate change impacts
- Dramatic permafrost retreat affecting extractive business infrastructure
- Burden of diarrheal and cardiorespiratory diseases in developing countries
- Expanded growth seasons aggravating respiratory conditions and allergenic diseases
- Climate-change-induced changes in agricultural outputs for trading markets
- Managing business impacts of malaria
- Ecosystem services for climate resilience such as pest control, soil erosion, and watershed, river-flow, and wetlands for flood regulation
- Nonmarket benefits of natural pollinators
- Extreme weather events' impacts on livestock production
- Water requirements for energy production

Financial institutions point to inevitable grand challenges that are likely to revolve around health, environmental economic security, disaster risk reduction, and long-term planning of urban areas. NCEI would be well served to invest its VoD resources in these areas. These, as many societal grand challenges, are multidisciplinary by their very nature and obviously interconnected. Equally important, there is no end to the variety of use of data and no end to subdividing sectors into financially-viable investments. Selecting a few that rise to the top of society's concerns, would focus NCEI's efforts.

2.2.1 Methods to Measure Potential and Kinetic Value

As stated previously, a new framework for the VoD involves both potential value and kinetic value. It fames the potential value of data in economic or dollar terms and also frames the kinetic value of the data by how data are used.

There are endless ways that data provide value, and identifying all of them is impossible, particularly because they are constantly changing. The prioritization of case studies is subjective based on

intentional and unintentional circumstances. Administrative priorities or external natural events, (e.g. unforeseen events such as a tsunami or the COVID-19 pandemic) change the priority of sectors. Are case studies important for telling stories? Yes. Studies show[11] that stories are effective means for informing decisions. But objective analysis can strategically identify which stories would be the most impactful. Thus, a key recommendation is to continue the case study approach, but upgrade the methodology to allow for more analyses, that are more repeatable and operational, and are cost conservative.

In the following section, this Report lays out methods for measuring both potential and kinetic VoD, grounding the methods with examples in all three domains.

Potential value is measured based on three methods:

1) The overall impact of data within the enterprise,
2) New approaches for cloud-based data archives that are available for use in the marketplace, and
3) A proportionate share of value of the business sector.

The kinetic value of the data is framed in a social context based on how people use data. Kinetic value is measured based on two broad methods:

1) The social value of data as appraised within Financial and other Institutions, and
2) The value of science and data-driven decisions in the service of society.

From this general introduction of potential and kinetic value, this Report next explores several methodologies to measure both potential and kinetic value of data.

3.0 New Innovative Methodologies

Whether for potential or kinetic value, this Report suggests that NCEI should begin with a goal-driven approach to select a VoD model.

Identifying the highest-level goal is the essential first step to creating a strategic approach for which successes and failures can be critically and quantitatively evaluated. Models are created in order to solve problems and different models can be employed depending on their utility to solve that problem and reach a goal, whether it is for potential or kinetic value. The potential data and metrics are presented as examples, and do not represent the full scope of possibilities. Identifying these metrics should be part of the process. Many of the metrics would depend on increased resolution of customers.

First, define a goal. A VoD model should be built upon the goal for which it seeks to achieve. (See more about Goal-based Models in Section 4). For example, the following goals would strongly dictate different VoD models and subsequent engagement processes (Stubbs, 2016).

- Increase public support for federal open data initiatives
- Increase congressional support and connecting big data with federal actions, of increasing interest to federal policy makers
- Better serve stakeholders and their data needs
- Better incorporate data into administration goals and key initiatives of the government
- Prioritize investments and to a support a data-driven budgetary process

[11] See numerous works by Newell, Slovic, Twersky, Kahan, Leiserowitz, used in The Psychology of Decision Making in Climate Change, MLA studies, UNC Asheville, including the 6 Americas.

Second, identify organizations currently engaged in data valuations. Within the last few years, major organizations are completing their own data valuations, including data as an information asset. For organizations willing to share this information, this offers low hanging fruit to estimate the contribution of federal data and a proxy of its value.

- Data gains value when it provides actionable information. Value can be mapped through sectors and the decisions they make to create profit, or through key cross-sector government-driven initiatives and value data provides them.
- If a sector-based approach is chosen, start with an analysis of data intensive sectors, using a similar, but more in-depth approach, to that of the Government Data Intensive Sector (GDIS) by the Department of Commerce Economics and Statistics Administration.
- Extraction and integration of government data are becoming less ad hoc and more streamlined, linking through application program interfaces and cloud-based tools could offer opportunities for the government to identify who is using data and when. This advancement in technology also means government data are now leveraged for even greater value across many different industries.

How the data are valued depends on the goal. Using the example of coastal data, *Box 3* illustrates a goal-driven approach, or method, to selecting the type of model that would be useful.

Box 3. Goal-driven approach method to select type of model for Value of Data.

Method to Select Type of Value of Data Model Based on Goal-Driven Approach			
Potential Goal	**Potential Operational Strategy**	**Potential Data and Metrics**	**Potential Data Valuation**
Improve NCEI's assets to increase customer access to Data.	Increase the use of Data.	Data download frequency, data download volumes, counts of Application Programming Interface (API) use, measures of diversity and abundance of domains.	As an asset.
Improve the resiliency of coastal communities to rising sea levels.	Expand use of NCEI assets that inform coastal resiliency by ensuring regional partners are utilizing them.	Counts of coastal resiliency managers using Data, counts of .gov addresses from coastal communities, number of resiliency plans that include the use of NCEI products, or use of NCEI products to fulfill resiliency readiness as outlined by the Federal Emergency Management Agency (FEMA) and OCM.	As a benefit to society and the environment.
	Calculate cost savings from utilizing Data to inform coastal policy decisions.	Cost reduction of economic losses following storms for resiliency managers pre and post NCEI product use.	As informing policy.
Maintain or improve funding for NCEI and data assets.	Identify the issues that matter most to policy makers.		
	Identify the cost savings of using Data for specific events.		As cost avoidance.

	Identify key users to serve as allies based on customer value to the economy.	revenue from companies using data, revenue with a value of data applied metric, number of congressional hill visits by NCEI customers.	As value to key users.
	Increase the financial value of Data to the private sector.	Number of companies using Data, number of sectors using data, revenue from companies using data, revenue with a value of data applied metric, competitors of current data users, trade associations of current data users, market research of how users and competitors receive information.	As revenue.

The method to identify use cases must be updated to ensure repeatability and goal orientation by removing subjective selection and collection. There will always be intangible value from NCEI stewarded data and infinite possibilities to define and measure this value for the benefit of the environment and society, but it is important to focus on the use cases and types of value that will serve NCEI goals and operational strategies.

3.1 Extract Potential Economic Value from Validated Studies

In all methods, it is important to use validated numbers, based on peer or industry reviewed numbers that can withstand the scrutiny of quantitative objective analysis. Numbers cannot be based on casual interviews. Just as NCEI is the authoritative source of environmental data, NCEI must use authoritative sources of economic measurement of its stewarded data.

As stated previously, this Report recommends three methods for measuring potential value:

1) The overall impact of data within the **enterprise**,
2) New approaches for **cloud-based data** archives emerging in the marketplace, and
3) A proportionate share of value of the **business sector**.

3.1.1 Economic Proportionate Value of Data within the Enterprise

Many efforts have been undertaken to assess data value such as: *NOAA by the Numbers*[12] by the Chief Economist and *Assessing the Economic and Social Benefit of NOAA Data Online*, a chapter in a National Research Council workshop summary. However, these were general in nature, based on reports from line offices. As they state, there were no attempts to replicate or put it to peer review the numbers in the studies. A more sector specific study *Economic Values of Selected NOAA Products within the Railroad Sector*[13] provided more solid numbers, and good methods for case studies. Arriving at economic dollar values has not been a straightforward task, even for the NOAA Chief Economist. Aligning numbers among NCEI, NOAA, and BEA can be achieved by careful use of validated studies.

The Economic Value of the Weather, Water and Climate Enterprise, as a subset of the marketplace of data, was the subject of the American Meteorological Society's (AMS) 2013 Washington Forum. Estimates of annual economic impacts of weather events presented were as much as $485 billion (Lazo,

[12] NOAA by the Numbers: NOAA's Value to the Nation, https://www.performance.noaa.gov/wp-content/uploads/NOAA-by-the-Numbers-Accessible-Version-Corrected-17-JUL-18.pdf.
[13] Economic values of selected NOAA products within the railroad sector, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.192.3456&rep=rep1&type=pdf.

2011). Reducing those impacts through better forecasts, through Disaster Risk Reduction programs, are in turn dependent upon the three domains of data stewarded by NCEI.

3.1.1.1 Percent of Forecast Value

Forecast data are used in the operational decisions. The data value in forecasts is evident in the costs and savings in avoiding disruption in services, or loss of revenue. Yet, often overlooked, archived data are used to improve forecasts. Data denial studies, Observing System Simulation Experiments (OSSE)[14] and other techniques, rely on the storage of retrospective data used to improve models. Therefore, the value of forecasts themselves could be counted as part of the value of archived data. Or, in other words, NCEI may formulate a number based on Lazo's $485 billion.

> ***NCEI could estimate a proportional share of forecast value as being due to retrospective data.***

As a simple suggestion, NCEI could estimate a proportional share of forecast value due to retrospective data. By rating archived data as contributing 1%, for example, to the value of forecasts, NCEI-stewarded data products would be estimated to contribute $4.8 billion to the economy.

3.1.1.2 The Four to One Ratio

One of the top referenced articles on the subject, the WMO's *Economic Assessment of Meteorological and Hydrological Services* (WMO, 2015) assessed the benefit cost ratios of services worldwide. Improvements that reduced disaster losses in the world ranged from 36 to 1 in developing countries to 4 to 1 for the U.S.

> ***Four dollars are realized by every dollar spent, to roughly scale the value of data archived by NCEI as being roughly four times the annual budget of the center.***

That is, for every U.S. dollar spent, four times the benefit was realized at a minimum. This exhaustive review of nearly 300 pages, judged the economic benefit on expected outcome of decisions that were based on reliable scientific data as opposed to decisions not based on data (p 48). Incremental costs, benefits, economic efficiency, willingness to pay, and all the usual measures of econometrics were used to understand the types of actions that would be taken by those who had and did not have access to NCEI stewarded data.

The study, funded by the World Bank and the United States Agency for International Development (USAID), among others, dived into case studies and provided examples of economic benefits of data. Two examples worth citing are 1) the heat watch and warning forecast product that benefits from the archive of normal temperatures and humidity, and the improvements in Global Circulation Models, which benefits from the analysis of archives of gridded model data.

As a simple suggestion, NCEI leverage the widely cited WMO report conclusion that four dollars are realized by every dollar spent to roughly scale the value of NCEI archived data to roughly four times the Centers' annual budget.

[14] OSSEs are commonly used in both Office of Oceanic and Atmospheric Research (OAR) and NESDIS line offices that use archived, gridded model data as well as other data resources.

3.1.1.3 User Engaged Values

An NCEI VoD project engaged consultants[15] to interview energy, reinsurance, agriculture, logistics and transportation, weather service providers, retail and manufacturing, fisheries, and coral reefs industry representatives, resulting in a modest amount of useful dollar estimated value. For example, 20-30 energy companies in the U.S. provided dollar values derived from use of temperature data. From this effort, the consultants created infographics that are used in posters and brochures, highlighted case studies, customer analytics, unique success stories that demonstrate the value and breadth of data uses, and at key engagement symposia; full distribution of these materials is unknown.

A 2017 American Meteorological Society (AMS) Annual Meeting presentation[16] demonstrated the "nuts and bolts" of NCEI's recently established Customer Relationship Management solution, Salesforce-Customer Engagement Requirements Exchange (CEREx) (personal communication Brewer, 2017). Brewer remarks that the solution does not yet provide substantial information about requirements against specific outputs, as it lacks sufficient input. Howsoever it represents "a concerted effort to understand the uses of its data, the benefit the data provides to customers, and who exactly those customers are."

Another NCEI funded group[17], noting that end-user engagement can be "time and resource intensive", proposing a web-based facility to evaluate the use of data. Based upon the decades-long cumulative experience of services in climate data, they proposed variations of formal evaluation techniques (formative, summative, and situation recognition) which are encapsulated in a system called SCENIC (VanderMolen, 2019).

The US Geological Survey (USGS) undertook a value methodology within the "enterprise" that may provide a useful method for NCEI (Pearlman et al., 2019). Prepared in coordination with NOAA, the study, 'Demonstrating the Value of Earth Observations—Methods, Practical Applications', was a workshop summary that described development of a value chain schema, particularly for satellite data, and is a beneficial resource for deliberate value method comparisons.

3.1.1.4 Coastal Value Methods

Along with the NOAA Office of the Chief Economist, the NOAA Office for Coastal Management (OCM) has pursued many different approaches to valuing data products.[18] Two stand out: the Digital Coast value method and the NOAA Fleet study.

The Digital Coast Value Method is an innovative tool that policy-makers can utilize to capture risk exposure, especially under dynamic environments such as those in coastal areas. To economically value the OCM Digital Coast product, NOAA collected a benefit estimate from a survey of 1,000 users and subtracted the cost of the product to yield a total return on investment. OCM borrowed an approach by National Aeronautics and Space Administration (NASA) that identifies an issue, uses a policy decision as a key indicator of benefit, and then calculates value as a function of how it informed the policy (promoting the solution, not the data). OCM tried to implement this approach but found calculations

[15] Acclimatise, a consultancy firm from the UK was engaged for this project.
[16] See recorded presentation https://ams.confex.com/ams/97Annual/webprogram/Paper305637.html.
[17] Specialists with the NCEI Regional Climate Centers (RCC) and OAR/CPO Regional (RISA) offices jointly proposed tools to measure value. See VanderMolen.
[18] Kate Quigley, OCM Economist, Interview

challenging given the diversity of partners that contribute data to the Digital Coast product and the inability to discern the direct contribution of OCM to the policy decisions which invariably result (See *Box 4. Digital Coast and LIDAR Data Value*). OCM also explored methods expressing product value in time savings as well as data science methods that use Internet Protocol (IP) addresses as a starting point. Much of their research focused on information, product, or services value, though there is methodological overlap with valuing data. The NOAA Fleet Study is one case in point.

Box 4. Digital Coast and LIDAR Data Value

Example Value Digital Coast LiDar

Of course, NCEI's role in Digital Coast is as the long term archive for coastal Light Detection and Ranging (LiDAR) data which it distributes. Communities use LiDAR high resolution data for topographic or bathymetric analyses, to understand the level of risks of potential flooding. For example, researchers used LiDAR to map land changes along the Outer Banks caused by Hurricane Isabel, which struck the barrier island chain in 2003. The data collected provided a visualization of where breaches occurred as a result of the storm and can inform planners and policy makers on the process and location of future inlet formation and shoreline change (Dunbar, 2004). Additionally, LiDAR was used to map potential flooding scenarios from storm surges in New Bern, NC. It demonstrates the flexibility of the tool and its capability to scale from the regional level down to the street or household level (Montgomery, 2014). Such extensive data are valuable for their use by state and local governments to inform policy decisions. This will be critical for an uncertain climate future and the variability of sea level rise and associated impacts and costs.

The NOAA Fleet Value Study, performed by Abt Associates & Corona Environmental Consulting in 2018, offered not only valuation methodologies but also a systematic process to tackle a larger question through strategic selection of a subset of products used in valuations: 600 fleet-dependent NOAA products were collated, 12 products were assessed for qualitative value chains, and 5 were further studied to provide monetized benefits through product-specific methodologies (contingent valuation-willingness to pay, market-based, and economic impact analysis). The second part specifically assessed the cost-effectiveness of NOAA ships and contract vessels as a substitute for data collection efforts. Such questions can center and drive the value methodologies selected.

3.1.1.5 Discussion within the Enterprise

Valuing NCEI *products and information* often requires untethering from valuing the data, there is opportunity to critically assess the many lessons learned through their approaches and an opportunity to create a cohesive approach within NOAA given the many entities currently exploring this question.

Discussions with interviewees about ocean data led to a mixed response about the importance of untying the value of data from the value of data collection, data products, and value of information. Kate Quigley, OCM, stated that valuation methodologies using cost savings and time savings for the Digital Coast product were hindered by the diversity of data suppliers in the product, hence extrapolating NOAA's contribution was challenging (*personal communication*). Robert McGuinn, Gulf Coast Institute, NOAA Deep Sea Coral Research and Technology Program, echoed Kate's concerns that issues could arise [within NOAA] when the value NCEI provides, including data infrastructure and hosting, is extrapolated to include value of the data collected by other line offices (*personal communication*). Jeff Adkins, NOAA Chief Economist Office, was less concerned with this hindrance, pointing out the large increase in value that comes through providing access, i.e. through the Digital

Coast portal (*personal communication*). These dynamics should be considered and managed in valuation methodologies.

3.1.2 Economic Value of Data in the Cloud

The present VoD approach predates the NOAA Big Data Program, announced in December 2019, geared to expand no-cost access to NOAA data through partnering commercial Cloud Service Providers (CSPs): Amazon Web Services (AWS), Google Cloud, and Microsoft. NOAA states that the CSPs "clearly understand the value of NOAA's data to their customers and to the Nation's economy" (NOAA News, December 2019). How that understanding would transfer to NOAA is unknown. That is, user authentication is not clear. NCEI is not the direct data provider through this agreement, instead, it is a marketplace of service providers who will presumably represent and report on the value the customer assigns to the data. NCEI cooperative institute known as the Cooperative Institute for Satellite Earth System Studies (CISESS) acts as the "data broker" between NOAA and the Cloud Service Providers.[19]

It is crucial that NCEI consider their access to this customer information and value-added products at these early stages of cloud strategy implementation, noting that the 2020-2025 NCEI Road Map aims for 100% cloud accessibility. All VoD methodologies need to develop a cloud strategy lens, incorporating the imminent changes to NCEI's internal capacity to identify, understand, and engage customers given the shift to the cloud. The consequences of movement to the cloud in identifying customers and use cases could go either way: one way in which information is now lost because the information only exists within the cloud provider or another in which a partnership could provide better access to this information than had it existed on a government platform.

3.1.2.1 The Big Data Program

The recently released NOAA Cloud Strategy[20] "provides a common vision and guide for future cloud initiatives. It "seeks to accelerate innovation in areas such as Artificial Intelligence (AI) and 'Omics[21] through rapid adoption of cloud services, ensure a smart transition to the cloud, promote broad and secure access to NOAA's data." It sets a goal — a Transformative Technology Outcome — that "100% of NCEI's data is accessible through the Cloud to enable a truly integrated digital understanding of our Earth's environment." Lessons from private industry help guide ways to derive value (see *Box 5. Industry Perspective on Big Data Value Method*). Ideally, VoD models would align with NOAA's new strategies in emerging science and technology including those newly put forth by the NOAA Research Council for the Cloud and Artificial Intelligence, the NOAA Big Data Program, and the Federal Data Strategy: Leveraging Data as a Strategic Asset.

Box 5. Industry Perspective on Big Data Value Method

Dell Technologies: Value of data in improved decision making

Approaches to valuate data in the private sector are quickly evolving, some directly correlate the value of data with the subsequent value of business outcomes (Akred and Samani, 2018). The Chief Technical Officer of Dell EMC Global Services, Bill Schmarzo, outlined strategies to derive the value of data based on the extent that it can

[19] https://www.noaa.gov/big-data-project-frequently-asked-questions
[20] NOAA Cloud Strategy: Maximizing the Value of NOAA's Cloud Services: https://nrc.noaa.gov/Portals/0/Final Cloud Strategy.pdf
[21] 'Omics: refers to a field of scientific study ending in '-omics', such as genomics, transcriptomics, proteomics, or metabolomics.

advance key business initiatives. When specific business strategies are assigned a financial value, it is straightforward to assign a value to the data that supports those strategies. Schmarzo provides the following process for data economic valuation to establish "prudent value:"

1. Determine financial value of the targeted business initiative
2. Identify business decisions that support targeted business initiative
3. Quantify value of individual decisions with respect to the overall initiative
4. Assess value of each data source to each decision as a rough order of magnitude value
5. Aggregate economical value for each data source

Like all methods, the results will not be exact, but the process can drive "thoughtful data investment decisions."

As big data has become big business, the conversation about how to define the VoD has rapidly expanded. In 2016 the Congressional Research Service released the report "Big Data in Agriculture", that mapped the big data ecosystem of U.S. agriculture (Stubbs, 2016). In much the same way that NCEI presented sector-focused success stories, the report documents key players in collection, management and uses and the benefits and challenges of using public big data. The report also reviews the same for private data. While discussed separately, it could be useful to differentiate the role of public and private data to further identify the role government agencies have in sector use cases or decision trees.

Shift from tracking point-of-sale data downloads to tracking the point-of-use.

As a cost savings, with cloud technology, NCEI will relax significant cost investment currently it has in no in data storage media migration.[22] As the NOAA Big Data Program progress, however, NCEI will have less direct customer contact. More and more data will be utilized within the Cloud, rather than downloaded from NCEI data servers, and NCEI would likely not have full access to the IP addresses of customers.[23] NCEI would move from supporting direct or retail sales, of large and small quantities, to becoming wholesale distributors of data.

NCEI will need to shift from tracking point-of-sale data downloads to tracking the point-of-use. In effect, NCEI will need to use the marketplace of applications, where people use the data, to track back to the types of data used, however can continue using the CEREx-Salesforce Customer Relations Management (CRM) as Brewer describes it, "to track errors and system troubles, and to track retail sales."

As the Big Data Program evolves, NCEI will have the opportunity to use the same methodologies as large forward-thinking companies to provide financial value to data as an asset so that it feeds directly into business models and market based strategies. The method would derive concrete numbers to value data on the open data market on the same playing field as the increasing number of private sector companies.

The NOAA Cloud Strategy provides a common vision and guide for future cloud initiatives. It "seeks to accelerate innovation in areas such as AI and 'Omics through rapid adoption of cloud services, ensure a smart transition to the cloud, and promote broad and secure access to NOAA's data." The Cloud

[22] In this author's span with NOAA, data were migrated from paper, Hollerith punch cards, microfiche, FosDic film, reel tape, 6250bpi magnetic tape, robot cassette, magnetic disk, and to the virtual cloud—which itself is generally speaking hard media in storage in trailers in data farms with inexpensive energy sources, such as along the Columbia River.

[23] Interviewees noted the challenges that NOAA faces in their interpretation of the Paperwork Reduction Act and how this interpretation compares to other government agencies such as NASA. While it is out of scope to review the terminology of this Act in this report, interviewees noted the importance of customer information to best serve users of tax-payer funded assets and suggested NCEI could have a role revisiting this interpretation with the Office of the Chief Information Officer.

Strategy was recently made public, but efforts to value data at NCEI must be consistent with the strategy as it continues to evolve.

As the NCEI domains will be relevant far into the future with or without the cloud, the recommendations in this Report are relevant mainly to the organizational structure that exists at NCEI now. However, NCEI needs to be aware and cognizant of emerging topics relevant to the Cloud such as: *Open data: Unlocking Innovation and performance with liquid information*[24] (McKinsey, 2013) and *The economic value of data*[25] (HM Treasury, 2018) and *The rise of the data economy*[26] (Economist, April 2020), the latter of which is a private sector perspective on monetizing open source data.

During AMS's webinar on the NOAA Big Data Project and Cloud Service Provider Toolsets, Google's Public Data Program Manager, Shane Glass, noted that data is not inherently valuable until it can be applied and application capabilities rapidly expand when data exist in a machine learning capable cloud. During an interview, Glass expressed the opinion that the best way forward given these constraints will likely be a combined strategy. Data-driven backend methods for broad valuation assessments can also be used to identify key sectors and users followed by an in depth case study or engagement approach to evaluate the key users, the decisions they make and the value they place on the data [and their ability to serve as an NCEI ally]. He says that proposing a backend, data-driven approach is a huge step in the right direction, while noting its challenges given legal constraints on collecting user information. There may be workarounds by applying optional data input requests like NASA, but he felt they are often at the line or maybe over it.

Glass suggested that NCEI's benefit is ultimately dollars saved for taxpayers. While the cost savings on data migration to various storage technologies alone is significant, the cloud also allows NCEI to scale the business model. For example, rather than share a data set that is, 5 gigabytes to 10 users (50 gigabytes total), NCEI only uploads it to the cloud (5 gigabytes), saving 45 gigabytes total. There may be however a difference in data of commercial value hosted by a cloud service provider and data with scientific value hosted on NCEI servers (*personal communication*).

3.1.3 Economic Value within the Sector

The potential value of data for any sector can be estimated by some fraction of the entire value of that sector of the economy.

The potential value of data for any sector can be estimated by some fraction of the entire value of that sector of the economy. Economic institutions have varying methods to define sectors. The Office of Management and Budget devised a system in the 1970's to define economic sectors by a code called North American Industry Classification System (NAICS)[27] (See *Box 6. NAICS Codes Explained*). These divisions of Sectors are quite different from the

[24] See https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Open%20data%20Unlocking%20innovation%20and%20performance%20with%20liquid%20information/MGI_Open_data_FullReport_Oct2013

[25] See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/731349/20180730_HMT_Discussion_Paper_-_The_Economic_Value_of_Data.pdf

[26] https://www.ibm.com/downloads/cas/4JROLDQ7

[27] The US Census Bureau maintains the government references for NAICS codes. See https://www.census.gov/eos/www/naics/

Sectors that NCEI has traditionally used as its customer types. (See *Box 10. Sample List of Sector Resources*). However, it is somewhat possible to identify businesses that use data from NCEI servers, identify their NAICS codes, and then assign a value of that data as a proportionate share of that sector's total economy.

Box 6. NAICS Codes Explained

NAICS Codes Explained

Originally developed for comparing business statistics among Canada, Mexico, and the United States, the North American Industry Classification System (NAICS) is used by Federal statistical agencies to classify businesses. Each business or industry is assigned a NAICS code. The Bureau of Economic Statistics uses the NAICS to collect, analyze, and publish statistical data related to the U.S. economy. For example, the NAICS code and related small business size standard for NOAA contract support domains are shown below[28]:

NOAA NAICS Codes ProTech Contract		
Domain	**NAICS Code**	**Size Standard**
Fisheries	541990	$15M
Oceans	541620	$15M
Weather	541330	$15M
Satellites	541712	1,000 Employees
Enterprise Operations	541611	$15M

Under the general sector code 54, titled Professional, Scientific, and Technical Services are establishments that specialize in performing professional, scientific, and technical activities for others. It lumps together "legal services, accounting, bookkeeping, architectural, engineering, computer services; advertising, photographic services; translation and interpretation services; veterinary services; and other professional, scientific, and technical services." Furthering the example, the NAICS Code 541620 is titled Environmental Consulting Services. It includes specialties such as wetland and ecological restoration and well as sanitation services. Code 541712, the NESDIS ProTech Satellites NAICS code, is Research and Development Physical, Engineering, and Life Sciences.

3.1.3.1 DOC Proportionate Share of Sector Economic Value

The Department of Commerce Economics and Statistics Administration released a report in July 2014 entitled "Fostering Innovation, Creating Jobs, Driving Better Decisions: The Value of Government Data" (Department of Commerce, 2014). The methods outlined in the Department of Commerce (DOC) analysis focused on defining the ecosystems of firms reliant on federal data as a key contributor to their production processes and estimating the size of this Government data-intensive sector (GDIS). In the value chain, the report includes analysts, bench-markers, data brokers, and value-added re-packagers as the primary components of the GDIS. They note that ideally, an estimate of the commercial value of government data to GDIS firms would come from identifying how much lower the market value of GDIS firms would be without government data but counterfactual estimates are challenging and market valuations were not available from privately held firms. Instead, the authors relied on estimates of the revenue size of the GDIS sector as a proxy for the value of data provided to this sector.

[28] https://www.protechservices.noaa.gov/industry.php

First, authors conferred with agency staff to develop a list of companies known to use government data and then added to this list the competitors cited in their 10-K filings or annual reports when publicly traded. They used the revenues from these firms as the lower bound estimate of GDIS revenues. To generate the upper bound, they used the NAICS codes from these firms and the associated total revenue of the industry from the U.S. Census Bureau. Though this method only provides a high-level estimate of the VoD, it could be a valuable first step in identifying key sectors that can be further evaluated for use cases and included in engagement strategies.

NCEI could estimate the percentage of that overall value affected by environmental (ocean atmosphere, geophysical) conditions.

This Report suggests that the well-established sectoral estimates provided by the BEA are the most reliable starting point for determining potential value of any given sector (see *Box 7*).

Box 7. Bureau of Economic Analysis Insights

Insights from Department of Commerce Bureau of Economic Analysis

As described in "The Value of U.S. Government Data to US Business Decisions", another method to gauge the use of federal data through a broad lens is with the Bureau of Economic Analysis's input-output (I-O) accounts (Hughes-Cromwick, 2019). The report's tables show how industries interact with each other, showing the supply of goods and services and how these goods and services are used. It cited a total output of $189 billion in 2016 for I-O account514, which includes data processing and other information services, up 26.4 percent compared to 2012. The input-output tables can be broken down to their NAICs codes to provide further resolution and insights into sectors utilizing federal data.

Through research and dialogue with a given sector, NCEI could estimate the percentage of that overall value affected by environmental (ocean atmosphere, geophysical) conditions.

The BEA provides clear repeatable methods and metrics as they relate to the NCEI's contribution to the U.S. gross domestic product (GDP) (Nicolls et al., 2020). Though NOAA derived economic statistics separately, the products derived from the partnership with BEA are consistent with the accounting framework for the entire U.S. economy. Keeping within this framework gives weight to the metrics relevant to the audience NCEI seeks to engage.

3.1.3.2 Measuring the Ocean Economy

The BEA, in partnership with NOAA, released a report entitled "Defining and Measuring the U.S. Ocean Economy" that reviews prototype statistics to measure the NCEI's ocean domain's contribution to the U.S. GDP in 2018 (BEA, 2020). It highlights the coastal travel and tourism sector as the major contributor to the ocean economy. It is likely to be a major contributor to the vitality of individual coastal states and regions, requiring the valuation of ocean data to travel and tourism involve place-based assessments. The largest contributors were as follows:

As ocean economy statistics are refined to further detail NAICS codes, data-driven approaches to value date and subsequent engagement strategies can be refined and improved.

1) Tourism and recreation, coastal and offshore ($142.8 billion)
2) National defense and public administration ($124.4 billion, primarily defense)
3) Minerals, offshore ($48.7 billion, primarily oil and gas)

4) Transportation and warehousing, marine ($25.3 billion, primarily freight)

The prototype statistics in the BEA report are at the three-digit NAICS industry level for gross output, value added, compensation and employment. In the data as an asset approach, NAICS codes derived from customers using NCEI products could be cross analyzed with NAICS codes from the BEA study to prioritize detailed models and engagement strategies. As ocean economy statistics are refined to further detail NAICS codes, data-driven approaches to value data and subsequent engagement strategies can be refined and improved.[29]

3.2 Extract Kinetic Social Value from the Marketplace

Developing a new NCEI VoD model requires analysis of past experiences in valuing data, data products, and information across NOAA, other government programs and the private sector. Attempts to critically assess and communicate NOAA's contributions to its mission through the value of products and data are not new. It benefits NCEI to learn from the methods employed by other institutions, both within and outside NOAA, as it seeks to employ a new model. Many of these strategies' focus on the value of products or the value of information, but these previous attempts are useful to inform value of data models.

The present VoD model may fail to capture substantiable Success Stories[30] and associated reliable analyses that are relatable to DOC, One-NOAA, and NESDIS Reimagined. Moving the NCEI model from one-by-one success stories to a broader view of impact may increase audience resonance, meeting the NCEI goal of increased user engagement.

Instead of counting the downloads, count the lowdowns.

This Report suggests that NCEI move forward from an analysis at the point-of-sale to an analysis at the point of use to assess value. Instead of counting the downloads, count the lowdowns. NCEI should develop methodologies to collect metrics on where and how the data are being used.

As stated previously, the kinetic value of the data is framed in a social context based on how people use data. Kinetic value is measured based on two broad methods:

1) The social value of data as appraised within f**inancial and other institutions**, and
2) The value of science and data-driven **decisions in the service of society**.

COVID-19 has taught private enterprise anything in the United States, it is that corporate innovation can be rapid and at low cost (The Economist, April 2020). Numerous companies put aside seeking advice from elite consultants with its inherent "analysis paralysis" and turned inwards instead to existing staff to spur innovation. Many companies make money "by selling services and software to help others process digital information". As many companies have done, NCEI has an opportunity to empower its staff to turn to meta-analysis of data use studies. American corporations learned more by testing than by months spent with endless analysis and meetings, and moved from the doldrums of design by discussion, to the jet stream of rapid prototyping, all done virtually and remotely.

[29] The non-profit and public sector frequently defines a "Blue Economy" using a three legged approach that includes environmental sustainability, economic growth, and social equity driven by integrated governance and technological innovation (Keen et al.)

[30] See Success Stories on User Engagement https://www.ncdc.noaa.gov/success.

Corporate lessons-learned can be applied to extracting the kinetic value of data from the marketplace in several ways. NCEI could evaluate its value of data by their use in key initiatives and administration goals. This process could be completed in a historical context, to assess the value-added where the presence of data affected an outcome that can be measured in economic terms, such as cost savings, or the value lost when either data was not used or it was not available and there was an economic loss. An example by USGS gives some insight (see *Box 8*).

Box 8. U.S. Geological Survey Value of Earth Observations

USGS Case study Demonstrating the Value of Earth Observations

USGS, NOAA, and other European agencies recently hosted a workshop on assessing the value of earth observation data (Pearlman et al., 2019). Workshop attendees discussed value chains and decision trees as to methods to apply value to earth observation data. Value chains included the value-added products incorporated into decision-support systems that would subsequently lead to actions. The participants suggested starting in reverse order, starting with the users, and assessing the value chain in reverse order. A decision tree evaluates the demand side of the value chain and considers the different types of decisions made using information provided by the data. As one example, it is possible to assess outcomes of decision trees with and without data and monetize the marginal benefit of outcomes. Workshop experts discussed three approaches:

- Product value chains/decision trees (analyzing the impact of a single information product),
- Thematic value chains/decision trees (analyzing the impact in a thematic area [for example, flooding] from a suite of products), and
- Market value chains/decision trees (analyzing the impact of products within the context of the market sectors within which they are used).

The workshop was co-hosted by GeoValue Community; an entity dedicated to "understanding benefits from geospatial and environmental information for complex socioeconomic decisions." This community could offer resources, insights and lessons learned as NCEI explores new VOD models.

3.2.1 Social Value Appraised by Financial and Other Institutions

There are many financial institutions that approach environmental data as an influence on market value. Reading financial reports (something members of Congress have much experience) reveals the impacts of environmental conditions on an industry. Financial institutions like IFC (*Box 2. Kinetic Value – Social Use Assessments by Financial Institutions*) can provide validated indicators that NCEI can use for the VoD. It would be important for NCEI to connect the data used in the asset discussions (e.g. connect permafrost retreat to the soil and air temperature in situ data and in the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite monitors). Many other such reports make those connections. The Intergovernmental Panel on Climate Change (IPCC) report, Managing the risks of extreme events and disasters to advance climate change adaptation (IPCC, 2012), USB Financial Report Climate Change: Beyond Whether (USB,2007), and the World Economic Forum Global Risks annual reports[31] are cases in point. They calculate and estimate the costs of social impacts from environmental conditions. A portion of those costs can be abated by better forecasts, better science, and better data stewardship, as the WMO weighty study attests (WMO, 2015).

Financial institutions…can provide validated indicators that NCEI can use for the Value of Data.

[31] The World Economic Forum releases some studies publicly here: https://www.weforum.org/

3.2.1.1 Appraise by Virtual Case Studies

The current VoD model relies on case studies. Case studies, through story-telling, can be powerful means to communicate value. However, developing case studies can be a lengthy and expensive process, and defining users is an important and difficult task. In most private sector data valuation models, identifying the customer and how they use data are foundational, even as customers leave "digital fingerprints all over the internet" (Schmarzo, 2013). Corporate lessons can apply to methods that yield quick and useful results. This Report suggests rapid prototyping of virtual case studies.

Case Studies are valuable tools to learn who is doing what with data. A short comparison of two techniques of deriving case studies is shown in *Box 9*. The first study engaged consultants. The second engaged a methodology. The first study took approximately 9 months while the second study took approximately 9 days. Clearly virtual case studies are an innovative option to the present model. Both yield results, however the traditional case study required 18 staff versus 1 staff for the virtual case study, gathered 110 versus 2,500 surveys, and analyzed 41 versus 48 examples of data uses.

Box 9. Comparison of Case Study Methods

Comparing Case Studies Methods—the present model vs Virtual Case Study

One recent VoD case study was *NCEI Climate Products and Services Market Analysis: Power Sector* (Global Science & Technology, Inc, 2016)[32]. An excellent analysis, the study strove to identify data used by the energy sector. The study involved 18 staff who produced or distributed climate data products and services to the sector, at NCEI and with RCC, RCSD, SCO, CICS-NC partners. They identified 110 interviewees (chosen from utilities, regulators, regional energy bodies, academic institutions, trade associations, and sector groups). In total, 69 individuals were interviewed for the study (see survey purpose[33]). The survey tallied 80% or 41 people who used Data. Further analysis of these 41 use cases gleaned information on the types of data used and qualitative information on the economic impact in their industry of the data use.

A 2016 virtual case study was carried out under contract, "*NCEI Climate Products and Services Market Analysis: Health Sector Engagement*" (McGuirk, 2016). The study involved one staff person who produced or distributed climate data products to the health Sector. The study identified 3,780 "interviewees" (choosing the population of the attendees at the AMS 2016 Annual conference). In total, 2,500 presenters were surveyed virtually (all conference technical presentations and the poster sessions). The survey tallied 2% or 48 people who used data topics on climate and health. Further analysis of these 48 use cases gleaned information on the types of data used and the impact of the data on public health. Multi-domain data, gridded model data, *in situ*, and remotely sensed (NOAA Atmospheric Infrared Sounder and other sensors), were the primary data types. Areas of use included heat stress, vector borne diseases, respiratory health, psychology, and severe weather injury disaster risk reduction (in order of frequency).

[32] Internal NCEI report, web published https://ncics.org/ncics/pdfs/events/energy-sector-resilience/Acclimatise_NCEI_Jan8.pdf
[33] "2016 Climate & Weather Data Market Assessment. The purpose of this activity is to assess the market value of climate and weather data and products from NOAA's National Centers for Environmental Information (NCEI) (formerly known as the National Climatic Data Center, NCDC) as well as data products provided by other meteorological service providers. Your detailed responses will help NCEI better understand the demand for climate and weather data, and help prioritize product and services development."

3.2.1.2 Library Reviews – Customer Service Researchers

Identifying the users of data can be a research-intensive process. Even though virtual case studies can be quickly performed, a caution about case studies was provided by Google Cloud Public Dataset Program Manager, Shane Glass. He noted that case studies do little to expand users (if that is the goal) because they focus on existing people or organizations that have found or used data (*personal communication*). Focusing only on cases that have successfully expanded users provides little context about how to expand to those that have not. Literary review can provide virtual case studies. NCEI can provide the means to discover new uses of data by performing meta-research.

Use existing bodies of work to reveal and surmise the uses of the data – and go from there to model its value.

Different ways to rapidly reveal use cases can be undertaken by NCEI staff, regional centers, interns, or by contest. Consider customer service representatives as customer service researchers. One methodology is to perform literature searches. The names of sectors change with time, and the priority given to each sector changes with administration politics, but essentially the commonly used ten sectors based on the NCEI Sector Fact Sheets have remained relatively unchanged.[34] For each sector of the economy, it is possible to identify the corresponding professional society, and their publications, trade journals, and magazines. In each of those publications, a researcher can easily discover ways that data are used in that profession. Student intern Buckner[35] with CASE Consultants International was tasked with that goal. The sectors, professional societies, and a couple of publications for each are listed below (see *Box 10*).

Short study identified some sectors, their professional societies, the literature in which they publish, and cited articles in which authors referenced data that are stewarded by NCEI.

Box 10. Sample List of Sector Resources

Traditional List of Sectors, Sample Societies, and Publications	
1. Agriculture and Food Security, Forestry Society of American Foresters (SAF) *Journal of Forestry, Forest Science*	6. Health National Environmental Health Association (NEHA) *Journal of Environmental Health*
2. Coastal American Fisheries Society (AFS) *North American Journal of Fisheries Management, Fisheries Magazine*	7. Planning: Urban and Rural American Planning Association (APA) *JAPA, Planning Magazine*
3. Disaster Risk Reduction Risk Management Society (RIMS) *Risk Management Magazine*	8. Tourism National Recreation and Park Association (NRPA) *Parks and Recreation Magazine, Journal of Leisure Research, SCHOLE*

[34] Historical footnote, from the early days of the Customer Service Representative in the 1960s, each interaction with the public was recorded on a Hollerith punch card. There was one column to identify the Sector, and with the limitation of 0-9 digital encoding, ten was the maximum number of Sectors that could be tabulated. Tabulating customer sector continues to this day, mostly self-reported.

[35] Hadley Buckner, Student Intern, NCSU, Environmental Studies

4. Environmental Security, Public Policy Association for Public Policy Analysis & Management (APPAM) *JPAM, APPAM Annual Reports*	9. Transportation American Public Transportation Association (APTA) *Passenger Transport*
5. Association of Energy Services Professionals (AESP) *AESP Magazine*	10. Waste Resources Air & Waste Management Association (A&WMA) *Environmental Management, JA&WMA*

NCEI can use existing bodies of work to reveal and surmise the uses of the data – and go from there to model its value and learn by testing different approaches. It is possible to quantify use cases quickly in each sector and visualize trends from year to year. For example, the virtual case study above on health (see *Box 9. Comparison of Case Study Methods*), was repeated for a different year, in which the top use of climate data for health was not heat but Psychology. The intern's short study identified some sectors, their professional societies, the literature in which they publish, and cited articles in which authors referenced data that are stewarded by NCEI. A couple of results from the Sector-Society-Publication method for the forestry and fishery sectors appears in *Box 11*.

Box 11. Literature Searches by Sector Society

Sample Literature Searches—Forestry and Fishery

The Society of American Foresters publishes in the Journal of Forestry and in Forest Science. A brief literature search in these two publications yielded multiple examples of the use of data, as described in this brief excerpt from the student intern's report:

Over the last five years, The Journal of Forestry has published numerous articles detailing forestry in America in which NCEI-stewarded data are found to support research results and inform conservation strategies. Data were used as evidence for climatic changes that affect forest health, to develop effective forestry management practices, to evaluate the health effect of management practice, such as prescribed burns and pine beetle infestations, and used to formulate new management techniques in response to changing forest ecosystems.[36]

As another example, the American Fisheries Society journal publishes many articles that involve environmental data. An article describing an updated mitigation strategy for an invasive species of carp, compared migratory paths of both species to assess the overlap of their migration and drew conclusions about the best times and practices for addressing the issue of an invasive carp species.[37] *The article referenced precipitation data obtained from NCDC for two watersheds in Minnesota. This data was then used to plot the number of fish compared to precipitation, water depth, and temperature. The data were used to evaluate fish migratory patterns in relation to weather and climate in the Minnesota watersheds, and to determine patterns in data through a table constructed with data from NCEI and other sources.*

[36] Buckner, Hadley. The Use of National Centers for Environmental Information data in Trade Publications. July 6, 2020. Student Intern, NCSU, Environmental Studies.

[37] The student intern read many articles to learn about the SOTC use, and specifically summarized Chizinski, Christopher J. et. al. Different Migratory Strategies of Invasive Common Carp and Native Northern Pike in the American Midwest Suggest an Opportunity for Selective Management Strategies, Journal of Forestry. North American Journal of Fisheries Management, Vol. 36, Issue 4, August 2016.

It is possible to use the metadata metrics of simple library science methodology to see who uses data and for what purpose. Over 22 case studies were identified in peer-reviewed publications, each of which quantified the kinetic social value of the data used in the study. The intern study was performed over a period of 6 weeks for a total of 20 hours. Utilizing customer service representatives as customer service researchers is certainly one methodology that can be repeated, made routine, and meet the needs of the SDS task order.[38]

Use the metadata metrics of simple library science methodology to see who uses data and for what purpose.

3.2.2 Social Value from Data-driven Decisions in Service to Society

Value is both relative and conceptual, so its scope and interpretation vary depending on the user. Data can only be as valuable as they are applied (i.e. how are data being utilized, at what scale and scope, and governed by what rules and conventions). When optimizing supply chains, value of data has been traditionally viewed from a supply side, as opposed to viewing it from the demand perspective. However, measuring value strictly through an economic lens minimizes potential, which is why it is important to utilize non-market-based valuations (Ada Lovelace Institute, 2020; The Bennett Institute and ODI, 2020). It is important, as the NCEI Road Map states "to collaborate with users to understand, document, and share their needs for existing and future products and service throughout the full life cycle."[39]

What are some methods to gain the information on use of data and products that can aid NCEI in furthering their data stewardship? There are several methods to determine data and products that use NCEI data. Identifying outlets that source NCEI stewarded data validates and improves NCEI efforts. A guiding principle is to derive value from existing sources, for example, trade magazines as well as peer-reviewed science journals, cases that show an overlap between a sector of the economy and the planetary data stewarded by NCEI. Determine the groups (e.g. professional organizations) that routinely use the data. Identify how NCEI can use their resources to report vertically and laterally about the importance of NCEI-stewarded data. One method is written in the preceding section, a short study by a student intern on the sectors, professional societies, literature used, and citing data that are stewarded by NCEI (see Box 10 Sample List of Sector Resources). Another technique is to extract the information from the outcomes of long-term decisions.

3.2.2.1 Recovery and Revitalization

A good example of the kinetic value of data is disaster recovery and rebuilding programs. Policy makers rely on climate, ocean, and geophysical data to make informed decisions on where and how to rebuild. Billions of federal taxpayer dollars are spent on disaster recovery efforts. NCEI has a role, through its data assessment studies, in helping those dollars be well spent. NCEI's role in that process needs to be acknowledged.

[38] An excerpt from the NCEI SDS task order says "The Contractor shall develop case studies and success stories for user engagement that can be used to highlight its benefit to staff across NCEI, and externally for senior-level talks highlighting NCEI's growing understanding of user needs and value"
[39] NCEI Road Map

Funding is more than an economic recovery tool, it contributes to fewer school days missed, decreased mental health strain on the community, reduced future loss of lives and property, and many other aspects of Disaster Risk Reduction (Smith et. al, 2011).

For every dollar expended on natural hazard mitigation, six dollars are subsequently saved.

For every dollar expended on natural hazard mitigation, six dollars are subsequently saved; in 2005, that ratio was only 1:4 (FEMA, 2018). Such mitigation activities include, but are not limited to, structural retrofits and floodwalls, enforcement of zoning and land use plans, forest management and wetland restoration projects, and elevating or even removing structures out of harm's way, all of which rely on geophysical data to some capacity.

Long-term planning and policy decisions are made every day based upon the planetary data stored at NCEI. The value of these decisions can be extracted from the marketplace and used to fundamentally meet the goals of any VoD study, as evidenced in this disaster recovery example.

A case study on recovery and revitalization demonstrates VoD in more than just monetary terms is, The New Alexander Theater in St. Croix, Virgin Islands, illustrates a mitigation project that revitalized a destroyed theatre (see *Box 12*).

Box 12. Coastal Data and Revitalization

Coastal Data and Civic-led Disaster Recovery and Revitalization

Built in 1954, the Alexander Theatre located on St. Croix in the Virgin Islands once stood as the center of economic activity for the island town of Christiansted. At the turn of the century, however, the theatre and surrounding properties experienced blight and stood in disrepair for the last two decades. When Hurricane Maria hit the Caribbean in 2017, rather than just rebuild the old theatre to its pre-event condition, the community collaborated with emergency managers and local non-profits to revitalize the property for multi-use purposes. Through a hazard mitigation grant from FEMA, the New Alexander Theatre will be transformed into the island's first indoor performing arts center that will also serve as the downtown region's only emergency shelter in times of need (St. Croix Foundation, 2019). The retrofitted building will serve as a cultural, economic, and public safety hub for the community, and in doing so, contribute to reduced fatalities by sheltering evacuees, reduced lost days from school, reduced emotional toll and mental health stress on survivors, and training and support for economic development initiatives.

The geophysical data in the form of coastal DEMs and floodplain layers that will be used for the site review and reconstruction process therefore supports more than just the income generated from the new theatre, it will also "impact the economic vitality and the social fabric of historic downtown Christiansted" (McKay, 2020).

Clearly in service to society, environmental data value is illustrated in decisions made every day.

3.2.2.2 Geophysical Data

Geophysical data are critical to sustained public safety and productivity. Geophysical data are an evolving and dynamic system, requiring a nuanced approach to account for complexity and absolute value. This approach must involve systems thinking and account for uncertainty, feedback loops, and externalities. While geophysical data have significant potential to improve safety and longevity, they are underutilized. Geophysical disasters have accounted for the majority (53%) of disaster-related fatalities over the last 20 years (UNDRR and CRED, 2018). Geophysical data have the potential to preserve human lives, public infrastructure, and private property. These risk reductions correspond to reductions of financial risk and real dollar applications.

Two examples that illustrate the social value from decisions in the service of society highlight the importance of geophysical data in transportation and navigation (see *Box 13*).

Box 13. Decisions in Transportation Illustrate Value

Geomagnetism data value on Transportation and Navigation Sectors

The geophysical domain informs the actions of societal agents, institutions, and infrastructure systems. Geomagnetic data informs Global Positioning Systems (GPS) and polarity readings, which are crucial for navigation systems in commercial aviation, defense missiles, and personal travel and transit lines. Recent magnetic pole wanderings have necessitated the release of a new and updated version of the World Magnetic Model (WMM) released in 2020, which is relied on for air traffic management, surveys and mapping, and smartphone and consumer electronic applications (CIRES, 2020).

Geophysical data drive the science of navigation, allowing commercial and energy companies to pivot and adapt during periods of disruption. In recent events related to the impacts of COVID-19, the United States temporarily closed its borders to international shipping traffic. Subsequently, in one month, the number of commercial ships anchored off ports on the west coast were triple the number normally seen there (Northam, 2020 April 27). These cruise and cargo ships were forced to either anchor or take alternate routes due to COVID-19's disruption in the supply chain, and in doing so, were dependent on geophysical data to make the necessary navigational adjustments.

Value of solar data is illustrated in many beneficial areas to society. Solar event impacts on communication infrastructure and space travel have been well studied. But how often are the impact stories tied back to the value of NCEI or related to the efforts to acquire, analyze, access, assess, and archive the data?

3.2.2.3 Disaster Recovery Land Use Planners

Geophysical data are used to support decision-making across a wide range of issues, including policies regarding exploration of natural resources, tsunami early warning systems, and resource deployment in wildfire management efforts. The value and influence, however, of NCEI's data domain on long-term community planning and natural hazard mitigation projects remains undetermined.

The ability to capture both economic returns on investment and losses avoided over extended periods of time may have significant congressional budget interests considering the amount of funding that goes into managing disaster-related activities, from pre-event planning efforts, to post-event response, and recovery operations.

No economic data exists for 63% of disasters recorded.

According to a 2018 report published by the United Nations Office of Disaster Risk Reduction (UNDRR), in collaboration with the Centre for Research on Epidemiology of Disasters (CRED), no economic data exists for 63 percent of disasters recorded from 1998 through 2017. Likewise, social kinetic value data is neither collected nor analyzed (UNDRR and CRED, 2018).

Geophysical, climate, and extreme weather events will continue to occur in the future, and efforts to manage these threats and reduce future risk require the best available data to inform decision making across all levels of governance. Geophysical data are used to support decisions communities make in how they plan, shape, construct, and in the event of a disaster, rebuild. Capturing the value of these long-term economic returns that accumulate over time substantiates the investment of funding to

mitigate the damage and expense that would otherwise be incurred. Through noting and promoting the use of geophysical data in decision-making, its value is confirmed and reinforced.

3.2.2.4 Natural Hazard Mitigation

Data informed decisions on land use practices illustrate the value of NCEI-stewarded data, sometimes in unexpected ways. For example, a study performed by researchers at Resources for the Future (RFF) highlights the cost-effectiveness of satellite imagery used in post-wildfire response efforts (*Box 14*).

Box 14. Wildfires Illustrate Value of Data

RFF and Wildfires

Using imagery from Landsat and commercial satellites to assess wildfire burn areas and prioritize response measures, federal agencies can save up to $7.7 million per year in post-fire costs (Bernknopf et al., 2019). Satellite data are also being used to capture nocturnal luminosity in countries such as North Korea, in an attempt to shed light on the state of their economy and GDP (Economist, May 2019).

There are many examples of data products and services that incorporate the contributions and serve the needs of the diverse stakeholder community; consider the Coastal Data Development (CDD) Program, Gulf of Mexico Restoration, Coastal Ecosystems Sustainability, Tourism, and the RESTORE Act Science Program. In general, data across specialties (oceanography, marine fisheries science, marine biology and ecology, marine climatology, marine geospatial analysis, socio-economics, ecosystem services, among others) have value in land use planning and development practices (*Box 15*).[40]

Box 15. Land Use Planning

Three land use planning examples

First, to minimize damages in future floods, the Resilience Office in Miami-Dade, Florida is focused on concentrating future development projects in higher lying areas located near existing transit lines. To do so, they rely on accurate hydrology and coastal digital elevation models. Second, in the coastal town of Charleston, South Carolina, a large-scale infrastructure project geared toward risk reduction to sea level rise is currently being discussed. The U.S. Army Corps of Engineers (USACE) recently delivered a report proposing an 8-mile perimeter seawall that would stretch around the city's historic peninsula. The project is estimated to cost $1.75 billion dollars and is expected to hold off water for 50 years (Johnson, 2020). Third, consider the general example in the area of property acquisition and relocation. Homes are often a family's largest asset and represent a significant amount of both economic and social capital for an individual. If a housing structure is significantly damaged in a disaster, and analysis demonstrates that it is more cost effective to relocate to a less hazard prone area, then families may opt to have their property bought out to reduce future damages incurred by that homeowner. Geophysical and climate information used to support floodplain mapping and insurance rate maps helps to identify disaster risk reduction areas and opportunities for implementing the acquisition process. All of these coastal management decisions rely on a comprehensive understanding of geophysical processes.

To summarize, this section of the Report suggests that NCEI seek out data-driven decisions from the marketplace and use them to illustrate the kinetic value of data. One way to have those decisions revealed to NCEI is through professional fellowships.

[40] Excerpt Riverside SDS Proposal

3.3 Promote Professional Fellowships

Through professional groups, NCEI can learn not only how, why, and when private and public entities use data but also how NCEI enhances society by protecting the health and vitality of communities and economies. Value is achieved when data – and derived information – are used, not just provided. Through fellowships, professional "ambassadors" of data can mainstream their newly-gained knowledge about NCEI into the practices of their professional society, as in the example of the American Planning Association (APA) (see *Box 16. NCEI Fellowship with APA*). Professional fellowships also help gather and create sector value studies.

the whole is greater than the sum of its parts
– Aristotle

Private-Public-Partnerships will launch new initiatives in shared efforts to explore that value of data. AMS launched new efforts into Partnerships with the weather, water, and climate enterprise. For example, a Panel on Professional Societies held at the AMS Annual Conference (AMS, 2019), encouraged cross-collaboration between the providers of scientific information and those who apply the knowledge professionally. The panel represented the American Fisheries Society, Water Utility Climate Alliance, APA, and Urban Land Institute. Each expert presented needs. American Fisheries, for example state:

> *In general, the marine system has been under-studied, and ocean parameters have not been well-addressed. Downscaling and other tools over oceans do not supply enough detail to support short term local decisions, nor the broader fisher's market. Better detailed mapping and higher resolution is needed for factors that drive productivity and food supply, Anomalous high temperature pools (such as the northeast pacific ocean "blob" heat wave) needs to be better understood, as many species' distribution is restricted by temperature tolerances.*

The water alliance further suggested benefits of close collaboration:

> *It is difficult to incorporate new data unless it clearly provides for better decisions, and is worth the effort to incorporate it. Better resolution and lead times does not add to the operations or planning if water utilities cannot process the information into the systems they use. In future, water utilities can be better prepared with adaptation plans that include scenario planning, future outlook analysis, and different outcomes. Table top exercises help alliance members appreciate data and incorporate it into operations.*

Promoting professional partnerships is one mechanism for capitalizing on the power of externality. Partnerships drive innovation which thereby enhances value. NCEI's current model for assessing the VoD focuses on a limited partnership network, one that is focused heavily on showcasing collaborative efforts across federal agencies and academic institutions. Adding regional and local actors to the existing federal framework will help capture the true value of a product, whether that product is a specific NCEI dataset or a data tool.

3.3.1 Example – American Planning Association

Private-Public Partnerships can expand the circulation and use of data, thereby increasing its value. By collaborating with professional societies, data providers can inform decisions through shared knowledge about the state of the science. One case-in-point is the work NOAA undertook with APA, a Professional society numbering around 50,000 U.S. members. The effort resulted in methods to apply climate data and science in all the planning work the members do. How did the effort come about? See the example of how climate data can be introduced and embraced by professional associations across the nation (*Box 16. NCEI Fellowship with APA*). Climate change mitigation and adaptation are now a major focus for professional planners and the APA. The value of local, regional, and state governments and agencies involved in planning for future climate change cannot be calculated. The planning profession has embraced climate change data and has become a critical ally in the development of plans, programs, and projects designed to mitigate or adapt to the effects of climate change.

Box 16. NCEI Fellowship with APA

Mainstreaming Science into Professional Practice thru fellowship

When the IPCC Fourth Assessment Report (FAR) was released in 2007, NOAAs National Climatic Data Center (NCDC; now the National Centers for Environmental Information's Center for Weather and Climate) initiated a program to disseminate this Important climate information to a variety of professional associations. Marjorie McGuirk, with the NCDC Director's Office, contacted Scott Shuford, then the Planning Director for the City of Asheville, NC, to discuss how professional planners might utilize the climate data found in the FAR.

Several months after meeting with McGuirk on this matter, Shuford proposed a project that would result in a handbook on climate change for professional planners. This project was accepted by NOAA and was jointly executed through an Intergovernmental Program Act (IPA) exchange involving the University of North Carolina (UNC)Asheville's National Environmental Modeling and Analysis Center (NEMAC).

Shuford was embedded in the Asheville NCDC office where he had access to cutting-edge climate scientists stationed there, as well as the climate data housed within NCDC. While developing the handbook, he contacted the APA about his work with NOAA and NEMAC. This resulted in an invitation to speak at the Rocky Mountain Land Use Institute's Annual Conference in Denver, CO in March of 2008 where he delivered a presentation entitled "The Role of Urban and Rural Area Planners in Helping Mitigate and Communicate Climate Change." That same month, he was also invited to speak at the American Meteorological Society's *What About Water Forum* in Washington, DC on the topic of "What Urban Planners Want to Know about Climate Change and Water Resources."

In April 2008, Shuford presented at the APA National Conference in Las Vegas, NV on the topic of "The Science of Climate Change," the first of six consecutive presentations at APA national conferences he made on the subject of climate change. When Shuford first began presenting at APA national conferences, there were only a small number of presentations on the subject of climate change at these conferences. Now, more than 20 climate change-related sessions are conducted at the APA national conference every year.

The APA also holds sessions on the ways in which cities are augmenting and contextualizing datasets for optimal resource utilization, strategic stakeholder engagement, and equitable public investment opportunities. For example, city planners utilized satellite and GPS data to better understand retail dynamics and economic trends within the commercial sector as well as opportunistic sites for future development (APA, 2020).

With the consent of NOAA, Shuford consolidated the research for the climate change handbook for planners into a APA Planning Advisory Service Report (Number 558) entitled *Planning for a New Energy and Climate Future* (co-authored with Suzanne Rynne and Jan Mueller), published by APA in February 2010. A forward was included by then NCDC Director Tom Karl and copies were distributed widely. The following year, Shuford was the primary author of the APA's Climate Change Policy Guide.

3.4 Update Distribution Channels to Generate New VoD Supply

Corporations adjusted their methods of distribution of products and built entirely new supply chains and billings systems in record time in response to the COVID-19 crisis. No existing policy or mechanism currently forces new distribution channels for NCEI data and products in response to crises, yet, new distribution channels can provide automated means of measuring the use of the products distribution. This section suggests modifying regular user engagement techniques so that the VoD can be assessed through the marketplace of existing platforms.

3.4.1 Distribute Products through Key Media Sources

Sharing the content of NCEI derived products through broadcast media or other arenas would help spread the use of data in all domains. Regularly scheduled products on broadcast media would greatly expand the reach, and thus the utility of the products. Each distribution media could in turn monitor and report on the participation.[41]

Importantly, a timely response can have more impact than a comprehensive approach to value. Prioritizing timely responses to hot button issues goes hand in hand with strategies to communicate them, especially done within the increasingly small timeframes that people absorb and act on information. Use pointed tactics to communicate value with the methods and within the timeframe people need it most.

Timeliness is something most Broadcast Meteorologists are keenly aware. An effort by Yale University and AMS concluded that broadcast meteorologists are ideally positioned to educate Americans, . . . have tremendous reach, are trusted sources of climate information, and are highly skilled science communicators . . .but easily available, high quality content with localized impact was lacking (Maibach, 2017). To that end, partners in NASA, NOAA, George Mason University and Climate Central developed a nation-wide program, *Climate Matters*, which aired in hundreds of markets with a library of broadcast quality videos.[42] Work continues at AMS for methods to expand on-air programs for the whole enterprise of air, sea, and land domains.

Two nearly shovel-ready examples of NCEI products that would be good candidates for wider distribution are the Regional Climate Summaries and the National State of the Climate (SotC) Report.

3.4.1.1 Example Regional Climate Summaries

For example, the Southeast Regional Climate Summary brings together many partners: the National Weather Service (NWS) River Forecast Centers, the National Centers for Environmental Prediction (NCEP), RCCs, RISAs,, the National Integrated Drought Information System (NIDIS), and State Climate Offices (SCO), among them. In one brief hour-long session, experts explain the state of the regional weather, water, climate, and earth science for that month. They offer both a retrospective analysis, and a near-term future projection. Here, all the data domains are well integrated into products and summaries that are useful for many sectors. Some of the highlights include analysis of gridded data using NOAA's Applied Climate Information System (ACIS) database[43], which includes mesonets and many

[41] Through the Neilson ratings, among others.
[42] ClimateCentral library https://medialibrary.climatecentral.org/
[43] ACIS is a gridded database of weather and climate observations from multiple state, federal, local, and private mesonets coordinated by State Climate Offices and Regional Climate Centers. See Umplett.

observational platforms; drought outlooks, which include satellite-derived soil moisture, analysis of rainfall, and projected outlooks; as well as NOAA's Local Three-Month Temperature Outlook, (known as the L3MTO). These seminars and webinars are meaningful to a wide audience. For example, ACIS products provide planning instruments to reduce heat exposure. Each session attracts, however, only around one hundred participants or so. Distribution of the announcement is limited to One-NOAA Science Seminar mail lists, and to persons registered through the usual parties, such as the AASC. Broader distribution through media, such as local broadcast meteorology, would exponentially expand the generation of new VoD evidence.

3.4.1.2 Example TV Meteorologists – State of the Climate Report

The SotC Report, both the U.S. and Global monthly editions, are the most used and widely distributed analysis that NCEI produces. Yet more can be done to distribute the product and entrain in more people who would use it to benefit their economic sector. This Report recommends that the NCEI SotC be prepared for broadcast using Storm Center's GeoCollaborate®[44] or other means.

One of the first uses of GeoCollaborate® technology was in broadcasting weather forecasts. Leaders in the field (Dave Jones in particular) worked to create processes by which NWS products could be integrated into the systems used by TV meteorologists that analyze and display weather forecasts. A similar approach could be effective in a retrospective data environment, using it for the SotC.

Sometimes the SOTC Report is not well attributed. For example, in its story "Winter is Not Coming", the Economist attributed much of the SotC to NASA, even though it fairly much copied the press lead line from NOAA. The Economist printed sections of the SotC in their exclusive section on international economic trends, which indicates the importance of climate variability and change to the international commodities market. Some six million people subscribe to this highly influential international weekly newspaper.

As a sort of VoD survey effort, CASE Consultants International suggested (via a post on LinkedIn) that this routinely produced NOAA NCEI product be packaged into a mainstream media broadcast. Hundreds of people responded positively to this post which said:

> *"I'd like to see this monthly report reconditioned into a packaged product that TV meteorologists could easily routinely broadcast. The State of the Climate reports (national and global editions) are produced by the Asheville office of NOAA: National Oceanic & Atmospheric Administration. Packaged along with NCEP 3-month outlook, it would be viewed - and used - by millions. How do you measure the Value of Data? By how it's used."*

Clearly, this product is highly anticipated and well distributed within the Weather and Climate Enterprise. By creating the means to have the report routinely broadcast, almost automatically, NOAA could gain quantitative information about the product's reach. This Report suggests broadcasting the SotC as one innovative approach to assessing the VoD.

[44] http://geocollaborate.com/

CASE engaged student intern Kehrer[45], to assess the spread and use of the SotC product. The findings in her full report noted that the use of the product on federal websites had dropped substantially beginning in 2016. Many federal websites that used to echo NCEI's report, ceased to post it. State government websites continued to use the report, as indicated in *Box 17*.

Box 17. Use of the State of the Climate Report

Customers using the State of the Climate Report

Each of the 50 states has a State Agricultural Extension Office associated with a state university that provides agricultural climate data for that specific state. A few uses of the SOTC product follow:

- Alaska uses air temperature data to create their own graphs
- Arizona provides monthly climate outlooks
- Florida creates an informational PowerPoint
- Maryland used data and graphics from both the National and Global Report on their "Climate Change and Basic Evidence" page
- Midwest states – Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri, Minnesota, Ohio, and Wisconsin – use data to create their own articles and graphs.

The Energy Bulletin writes weekly updates on anything and everything related to the energy industry. In each of their weekly releases, there is a "Climate Change" section in which data from the SOTC is often used. Corporations like BASF, YARA, Syngenta, John Deer, Bayer AP and Nestle Water, all strong advocates of sustainability, produce numerous articles about climate works but seem to source their data more recently from the IPCC.

3.4.1.3 Connect Data Stewardship to the Hot Topics

NOAA's guidance to maximize the VoD gives NCEI permission to promote, or better yet, pitch, their value during periods of high public engagement regarding a relevant issue or recent event. When a hurricane is about to make landfall or an astronaut is preparing to launch into space, there is an upsurge in attention being paid to such an occurrence, often in the form of increased broadcast coverage, social media trends, scientific research, and financial backing. NCEI should seize these windows of potential engagement and promulgate the value of their data.

Current "hot topics" can be connected to the products and analysis that NCEI creates. For example, news on the Space X launch connects to NCEI as geophysical data were used in the design of the heat shields. Making that connection takes a wide breadth of readership. But with practice, connections can be made, as in this brief example on Space Weather (see *Box 18*). An article in the June 2020 Economist about low probability high impact events described the space weather center--the NCEI office in Boulder--and highlighted the National Space Weather Strategy and Action Plan, and the value of the DSCOVR satellite.

[45] Kehrer, Brittany (2020). State of the Climate Analysis, Unpublished Manuscript, Student Intern, George Mason University with CASE Consultants International.

Box 18. Space Weather News Connects to NCEI Data

Space Weather

Among other data types, data about the sun are stewarded by NCEI. Solar flares, sunspots, magnetic field, and coronal mass ejections, have widespread impacts on many sectors of society. Perhaps the best known is the Carrington event of 1859 where a massive ejection fried what was then the electronic communication of the day, the telegraph systems all over the U.S. and Europe. The value of these data can be ascertained in discrete studies about power grids, radio, and communication lines. Generally speaking, archived data are used in design decisions of such infrastructure. Solar data were used, for example, to design the heat shield of the European Space Agency Solar Orbiter, launched in February 2020.

Communication science guides effective messaging. The many studies of human heuristics (Newell, Slovic, Twersky, Kahan, Leiserowitz) advise a means to communicate most effectively; one way is to take advantage of current affairs.

Each time there is a news story on an environmental event, link that story to data stewardship.

Each time there is a news story on an environmental event, there is an opportunity to link that story to data stewardship. Demonstrate NCEI's value by showcasing how data supports "hot" or relevant topics. Ocean monitoring products can have widespread teleconnections, such as with phenomena associated with sea surface temperatures; phenomena such as the El Niño Southern Oscillation (ENSO) or the Indian Ocean Dipole, fuels decisions as far ranging as rainfall in East Africa and wildfires in California and Australia.[46]

For example, the great Australian Bushfires and the torrential rains in East Africa were two sides of the linked Indian Ocean Dipole (IOD) in December 2019, the counterpart to El Niño. Ocean data stewarded by NCEI, in cooperation with the World Oceanographic Commission, yielded the facts and figures that revealed the linkages between these wide-spread, death-causing extreme events. The importance of ocean data to early warnings of wildfires is widely known to East Asia forecasters. But the value of ocean data to disaster risks reduction efforts is less known. Ocean data are only now being discovered by the media. Had any broadcast effectively linked the bushfires to NOAA-observed data, it would have generated a new VoD source.

The WMO provided an animated short explanation of wildfires and how the data system from satellites to in situ monitors on land, air and at sea were used to help monitor and control wildfires.[47] These sorts of animations supplied to broadcast outlets can expand product awareness.

Following the Mount St. Helens eruption in 1980, the collection and absorption of volcanic information from researchers, media personnel, and the general public skyrocketed. Not only was there a surge in public attention being paid to the unfolding of the disaster, but the event is responsible, in part, for the proliferation of ground and space-based monitoring data. Some argue that it was “a turning point for volcanic science, sparking a huge influx of money and people into a field and setting the stage for rapid improvements in understanding” (Palmer, 2020). Events like these grasp the attention of those that may otherwise not explore geophysical science or consider the impact it has on quality of life. Harnessing

[46] See any of numerous references to ENSO, MJO, IOD, and other ocean phenomena such as this one https://www.bbc.com/news/science-environment-50602971.
[47] See wmo.int/environment

these periods of intense focus where there is a desire for knowledge saturation can bring about unexpected publicity and funding.

This Report recommends that NCEI review similar instances not only in the natural hazards discipline, but also those of scientific exploration and technological innovation, and assess whether perception of the value of their data shifted and where improved engagement is possible. Was VoD somehow collected from recent events of the massive Sahara Desert dust plume that was captured by the GOES-East satellite (NOAA, 2020)? What about SpaceX's 2019 Falcon Heavy rocket that carried COSMIC-2 satellites intended to improve climate and space weather forecasts (NOAA and SpaceX, 2019)?

Another example that demonstrates VoD, for which the public could be made more aware, is in community investment for disaster risk reduction. A significant amount of federal funding right now is being used to develop and reconstruct projects aimed at risk-reduction and disaster-management. In 2018, the Department of Housing and Urban Development (HUD) awarded a record $28 billion to nine states, Puerto Rico, and the Virgin Islands to help support long term disaster recovery efforts. Of that total, $16 billion was earmarked for hazard mitigation activities alone (HUD, 2018). Now taking into account the investments made by other federal, state, and local entities for recovery and risk reduction purposes, it is clearly apparent that a significant amount of expenditures is allocated towards lessening the threat of natural hazards in order to ensure the safety, security, and well-being of the Nation. This presents a unique opportunity for NCEI to leverage its existing data and expertise in such a way that capitalizes on the attention and resources being invested into communities. NCEI should promote the value it can lend to these efforts.

3.5 Leverage Emerging Technology and Innovative Presentation Formats

Besides expanding the use of key products like the SotC report through mass media, increasing strategic use of social media will enhance provision of web stories and social media posts about new products, data releases, journal articles, engagement events and scientist profiles. Strategic methods to reach out to new audiences on these platforms[48] may entail working through the professional societies themselves.

In addition to distributing products through key media, authors of this Report identified ways that GeoCollaborate® could enable real-time collaboration between dispersed NCEI geographic teams who are working to develop retrospective data products:

> *"GeoCollaborate® is a shared secure environment for data stewardship and is compatible with GeoCONOPS (geographical concept of operations). . . GeoCollaborate® places data and products at the center of decision making, taking a use-case approach and placing all participants on the same map simultaneously. . .New products and services can evolve rapidly, and new ways to use and value NCEI data emerge collaboratively. . .Plus, the approach can deliver NOAA data to decision makers in a comprehensive, integrated way, which fosters value and trust. This trust will in turn increase user confidence, result in data-driven decision making, build use cases with new and established users, and grow cross-agency activities."*

[48] Excerpt from Riverside user engagement section of SDS proposal.

Furthermore, since much of NCEI's data offerings from all three domains can be visualized in a Geographic Information System (GIS) mapping environment, engaging people with web-based geospatial data sharing tool makes sense. It can be used to generate VoD examples, and enable "use-designed, use-developed and use-evaluated NCEI products and services." Generally, modifying user engagement processes through the use of an interactive tool would "put stakeholders in direct, continuous, and collaborative interactions to design, develop, and evaluate NCEI products and services," and would "facilitate interactive participation of users and stakeholders across the product and service lifecycle."[49] Most important, it would allow NCEI to "reach new prospective users, so that new data products can be delivered directly to decision makers, scientists, and educators so that they understand the relevance of NCEI data."

A good example of existing innovative visualization is a General Dynamics Information Technology (GDIT)[50]- led effort to design and develop the Office of Ocean Exploration and Research (OER) Video Portal. The project goals include: improve video annotation to support rich metadata; develop a process to automatically generate metadata records for thousands of video clips; archive both low- and high-resolution videos; and develop a search portal that allows users to quickly search for video clips and download low-resolution videos. A portal also allows users to request delivery of high-resolution videos. The project was honored with NCEI's Most Innovative Product Award in 2017.

3.5.1 Interoperability for Enhanced Value

Interoperability refers to the ability and ease at which data can be worked with and aggregated in order to reveal new insights and enhance value (Bennet Institute for Public Policy and Overseas Development Institute, 2020). Interoperable formats are necessary to ensure the delivery, digestion, and dissemination of data in such a way that is timely and meets the relevant needs and priorities of a community. According to Snowden et al., this elicits an important recognition in that the term is a characteristic of a relationship between systems, rather than a characteristic of a single file or dataset. Data is most valuable when in use, therefore, strategy and creativity are crucial when data are packaged and pitched for user engagement.

> *…NCEI is the Nation's leading authority of environmental information. These data are impressively heterogeneous in terms of platforms, instruments, formats, and user communities*
>
> *– Nancy Ritchey, NCEI's Archive Branch Chief*

Cognitive load and biases play a fundamental role in how people absorb information and respond accordingly. Data that are packaged to align with human behavior and psychology will inevitably be easier to absorb. The more it is absorbed and applied to practice, the more value data bring to both the consumers and providers. Leveraging the psychology of decision making will propel NCEI's current value of data model forward. Gestalt psychology is regarded as the foundation for the modern study of human perception. Its fundamental principle, the Law of Prägnanz, states that "individuals tend to order things

[49] Ibid
[50] GDIT is one of Riverside's Subcontractors under the NCEI SDS task order.

in their mind in a manner which is regular, orderly, symmetric, and simple" (Spruit and Lammertink, 2018, p. 248). Packaging data through visual design techniques alters how people perceive information and enhances the ability to apply it, as *Box 19* illustrates).

Box 19. Visual Effects

Visualization

Packaging data into visual effects is not a simple undertaking. Yet, museums, educators, and research institutions offer ready-made displays of Earth's geologic record, particularly to inform future scenarios of climate change. These (here unspecified) resources can be capsulated to heighten NCEI value in data stewardship, similar to how Science on a Sphere and the Smithsonian Ocean Exhibit, "advertises" NOAA. Should NCEI sponsor local or traveling geologic museum displays, it would engage more of the public constituency to the value of geophysical data.

In their 2011 report, the National Research Council highlights the value of paleoclimate records which "offer potential for a much improved understanding of the long-term equilibrium sensitivity of climate to increasing atmospheric CO2 and of the impact of global warming… Deep-time paleoclimate records uniquely offer the temporal continuity required to understand how both short-term (decades to centuries) and long-term (millennia to tens of millennia) climate system feedbacks have played out over the longer periods of time in Earth's history." (p. 6)

The value of paleoclimate data in the form of ice cores, tree rings, rocks, and sediment encapsulate the larger mission of NCEI stewardship for global environmental data: archiving such data for future comprehension and use. In years past, preliminary analysis of carbonate rock may not have revealed its full potential value. They are perhaps the only truly "visual" data that NCEI stewards. Much opportunity exists to promote their value.

Framing value through a sectoral lens increases comprehension of how data informs the world; however, does that engage an audience and pique their interest and curiosity enough to explore further? Out of the nine videos that cover success stories on user engagement, only three of them have been viewed on YouTube more than 350 times. This is due in part to the idea that data are utilized to support agendas and solve complex problems. So, in order to extract the most value out of data, it must align with a person's or a group's priorities and principles. Isolating user engagement by sectors does not achieve this fully because the sector alone is not enough to entice reader or viewer engagement. It may be more enticing to focus on a specific issue, policy, dilemma, or innovation that inevitably encompasses multiple sectors. The world operates in a system and utilizing a multi-sector approach offers a more accurate picture of the obstacles and tradeoffs that decision makers must consider, doing so will enhance value and reveal positive externalities that would otherwise go unseen.

Focus on a specific issue, policy, dilemma, or innovation that inevitably encompasses multiple sectors.

3.5.2 Improve Visualization Techniques

An expert in visualization, who was involved in the early efforts with climate.gov, performed a preliminary critical review of infographics used in one of the NCEI Success Stories produced by the present VoD model. (See Box 20). Although the drawings in the info graphics may be eye catching for a poster, the infographics were quite possibly less effective than intended. The information carried in the infographics may not translate to meaningful knowledge.

Box 20. Infographics Critique

Visualization expert comments on infographics: Adapt-N for Agriculture[51]

Visually:

- It is hard to tell where to look on these - there is no hierarchy of what is most important, and things just seem like random factoids.
- If all visuals are meant to support 'visual queries' then what is the query being answered here and how do you guide the user visually through the data? The eye jumps all over the images trying to figure out how things relate to each other.
- The 'pop' comparisons serve a purpose in the sense they might impress some readers, but they do not give any meaningful data. … "reefs can fit in the state of Nevada", "passenger miles is 63 round trips to Pluto", "27 million copies of Shakespeare's works". Would the average person know how big Nevada is? How far Pluto is? How many words are in Shakespeare's plays?
- Better comparisons I would try to relate things to numbers most people would relate to such as the distance to the moon instead of Pluto, or size of a football field, or something more relatable.

Information content:

There is a lack of context for some of the graphics:

- The change in annual average temperature does not indicate the year of the data or the reference period for the averages.
- The heavy precip chart does not indicate what 'heavy' means (what is the threshold?) and whether it qualifies due to a single event (say a 20" rainfall) or the total rainfall for the entire year.
- The pH axis is backwards on the ocean acidity chart, which makes sense given low pH means high acidity, but that is confusing and unexpected - surely there is a way to transform the pH to another value shows an increase along the axis,, and so on.

Just as there are standards in data stewardship, there are standards in data visualization. The prime contemporary standard is espoused by Yale University's Edward Tufte in his series of four classic books beginning with the standard bearer "The Visual Display of Quantitative Information." Several scientists at NCEI hold the four-volume set, which is included in the extensive Tufte training. It is important to convey information about data using the methods that meet standards of visualization, even if the information is only for "marketing" (e.g. pie graphs of numbers of customers by sector)[52]. These standards are developed cognizant of human heuristics, and the limitation of the visual field.

The display of information through graphs, charts, maps, and diagrams is in of itself a science. Certain methods of visualization work well because they correspond to how people see and think, for example, showing trends over time as a line. Eyes can easily follow a line and see a pattern, and it is best for displaying an interval scale, that is, a continuous range of numeric values divided into equal ranges such as dates. Visualization science helps meet NCEI's strategy to "improve communications and feedback mechanisms with customers" and "exploit new technology to assist users in using data efficiently".[53]

Stephen Few's book, Now You See it, Simple Visualization Techniques for Quantitative Analysis explains "pre-attentive factors" that enhance comprehending graphics, and visual "working memory limits factors" that detract from comprehending graphics His book "Show Me the Numbers Designing Tables and Graphs to Enlighten explains that humans can attend to only three to four visual details at a time.

[51] https://www.ncdc.noaa.gov/success/adapt-n-agriculture
[52] Tufte and others strongly discourage the use of Pie graphs.
[53] NCEI Road Map

So, if a line graph with three colored lines also contains a legend, the eye will not attend to and the brain will not interpret the legend unless the words of the legend are in the same color as the lines they represent. Works by neuropsychologist Stephen Kosslyn, who, using psychological principles of memory, attention, and visual perceptions, developed principles to improve PowerPoint presentations. In his book "Clear and to the Point: 8 Psychological Principles for Compelling PowerPoint Presentations", Kosslyn shows the "Eight Fold Way" of visualization, explaining the Principle of Appropriate Knowledge, Compatibility, Informative Changes, Perceptual Organization, Capacity Limitations, Discriminability, Relevance, and Salience. Colin Ware goes even further in cognitive recognition and the ability to derive meaning from visuals. This Report does not attempt to describe visualization theory, but suffice to say, for the most part, the present VoD model includes many graphs and other visuals that are not in keeping with the accepted contemporary standards of visualization.

There has been an effort to create consistent graphics across NCEI, especially with the work related to the National Climate Assessment. UNC Asheville's NEMAC announced:

> *"NEMAC worked with U.S. Global Change Research Program and North Carolina Institute for Climate Studies - NCICS to develop a consistent graphical style for climate indicators. This collaboration focused on how data should be represented in order to accurately and effectively communicate the message. Check out the website to learn more about each one (and see the graphics)!"*[54]

The graphics created for the National Climate Assessment were indeed aligned with the Tufte protocols.

The WMO has a series of short videos that explain the value of observation platforms, including many animations. For example, an animation titled "Ocean Buoys" was issued for World Oceans Day.[55] NCEI could rightfully claim to share a part of the WMO's media expenditures and say "NCEI makes buoy data available from all over the world." (Piggybacking on the products of WMO or other global partners can expand the value of NCEI 's voice to the value story.)

A key to cost effective media is to leverage the existing media of partner organizations to NCEI's own advantage.

3.6 Sustain and Enhance User Engagement

As stated in the NOAA Data Strategy: Maximizing the Value of NOAA Data, one goal is "Engage stakeholders and leverage partnerships to maximize the value of NOAA data to the Nation." Value studies can be generated through sustained engagement with private sector partners. In a general sense, the purpose of user engagement is "to understand information needs, identify use-inspired requirements, and document the use and value of NCEI products and services." Methods are needed for NCEI to work with others to ensure that the tale of value of NCEI and the data it stewards is told, and told, ideally, and most appropriately, by the users of the data in their decision-making frameworks. The present VoD model produces success stories told from NCEI's point-of-view, often saying "they use our

[54] April 20, 2020 NEMAC blog announcement https://www.globalchange.gov/indicators
[55] WMO Buoy animation states "Ocean buoys are crucial for coastal early warning systems and provide information to accurately forecast and predict severe maritime and coastal weather. . . New video highlights the importance of buoys for our safety and livelihoods." See additional WMO videos, such as one on ocean sea surface temperature here: https://www.linkedin.com/company/world-meteorological-organization/videos/

data." If there were one single step NCEI took from this Report it would be to eliminate the phrase "our data", as in this success story "The report, which compiles feedback from companies in these industries, demonstrates how our climate data products are used to understand the effect of . . . how weather is influencing their bottom lines" Instead, effort should be made to write from the point of view of "the user" and highlight the common good that arises from public data.

Methods are needed for NCEI to work with others to ensure that the tale of value of NCEI and the data it stewards is told, and told, ideally, and most appropriately, by the users of the data in their decision-making frameworks.

Value-added products are the purview of the private sector not NCEI or the Government and this Report does not suggest competition with private sector players, but rather cooperation within the public-private enterprise. To receive stakeholder feedback, NCEI recognized in the early 2000's that it was necessary to create a new culture of shared learning that values co-production of knowledge and promotes ongoing and sustained engagement with stakeholders.[56] Engagement enables NCEI users and stakeholders to develop a shared understanding of the value of data in meeting their needs and to participate collaboratively to ensure that NCEI products and services are use-inspired, use-designed, use-developed, and use-evaluated.[57] To that end, sectoral specialists should be identified who will engage with the sector by joining their user conferences, as opposed to NCEI holding user conferences. The sector specialists would describe data holdings and seek feedback on improved products, but most of all, listen and learn from the people engaged in delivering decision-ready products to their clients.

3.6.1 Engage to Create Value Stories

Extensive experience in planning and conducting events[58] that deal with the exploitation of data products in economic sectors, demonstrates that engagement creates value stories. Sectors like energy, planning, transportation, architecture, construction, and health, as well as coastal and marine resource managers and businesses, including the Coral Reef Conservation Program, have shared their economic and social VoD success stories.

To decide which sectors to include in a VoD model, naturally NCEI considers consequences or level of impact of value added products, pure economics, and willingness and known avenues to engage. Gathered experience shows that the key sectors to work with are those identified in the National Climate Assessment and the IPCC.[59]

The early sectors (see *Box 10. Sample List of Sector Resources*) were defined back when Hollerith punch cards were used to record every customer service interaction. Each card had ten rows, with only one column to record the type of sector (thus only 10 possible entries). The sectors have modified somewhat since the merging of the three domains into NCEI. The Bureau of Economic Analysis defines sectors quite differently as the Ocean Economy study shows (BEA, 2020). BEA defined these major activity groupings for the ocean economy:

[56] Scott Hausman, Deputy Director, NCDC, Climate Data: Value Added Opportunities, Responding to the Needs of Climate Science ad Service Users. July 2011.
[57] Riverside user engagement section of SDS Proposal.
[58] See the Climate and Grid forum, and other CASE Events: https://caseconsultantsinternational.com/events
[59] The Sector Fact-Sheets by NCDC/NCEI and also by WMO are widely available and provide useful explanations on how data are used in the key sectors.

1) Living resources, marine
2) Construction, coastal and marine
3) Research and education, marine
4) Transportation and warehousing, marine
5) Professional and technical services, coastal and marine
6) Minerals, offshore
7) Utilities, coastal
8) Ship and boat building, non-recreational
9) Tourism and recreation, coastal and offshore
10) National defense and public administration

How to connect these economic sectors to the types of ocean data stewarded by NCEI depends on understanding data sets such as the Toga array, buoys, sea surface temperature, wave heights, thermohaline currents, ocean indices (e.g. Madden-Julien Oscillation (MJO), IOD, ENSO, etc.), ocean heat blogs, salinity, pH, chlorophyll, deep sea coral, and data from programs such as the southeast coastal ocean observation network and the marine sanctuaries. In some cases, the expertise resides not within the data archivists, but within the network of collaborating partners.

3.6.2 Identify Some Key Strategic Partnerships

Promoting professional partnership is one mechanism for capitalizing on the power of an externality. Partnerships drive innovation which thereby enhances value. NCEI's current model for assessing the VoD focuses on a limited partnership network, one that is heavily centered on showcasing collaborative efforts across federal agencies and academic institutions. Adding regional, local, and commercial actors to the existing federal framework will help capture the true value of a product, whether that product is a specific dataset or a tool that uses it.

One key challenge to strategic partnerships involves coordinating with complementary efforts of other federal, state, local, and tribal agencies. Within the legacy NCEI circle these include NOAA line organizations, the Center for Coastal Management, National Marine Fisheries Science (NMFS) Centers, State Climatologists; Regional Climate Centers, RCSDs, and others. Within a wider circle, these include State Geologists, State Oceanographers (only 1 state has one so far), and State private information partnerships involved in key sectors. For the latter category, one example is the U.S. Department of Defense funded DANTE[60] project, which involves partnerships with USGS, NOAA, universities, and international organizations. Coastal zone managers, State Sea Grant programs; regional USDA hubs, the Department of the Interior (DOI), and others. An emerging opportunity is the new AMS Expanded Partnership Committee (see *Box 21*).

[60] The DANTE Project recognizes that environmental stresses (droughts, floods, storms, earthquakes, wildfires, pest infestations, volcanic eruptions, and infectious disease vectors) are often key contributing factors to defense interventions, including humanitarian response, counter insurgency, and border control. Early phase military planning activities need to incorporate systematic monitoring and forecasting of environmental stress and their impacts on security outcomes. ISciences, AMS Annual Conference, 2019.

Box 21. Opportunity – AMS Partnerships

AMS Partnership Opportunity

At the centennial meeting in early 2020, AMS formally created the AMS Partnering Committee, chaired by Eileen Shea. Responsibilities of this new Committee are: to establish and maintain an overall partnering strategy and to guide staff and volunteers in executing the strategy; to oversee the development and operation of technologies that enable partnering; to determine processes and guidelines for partnering; and to guide the prioritization of new partnerships in collaboration with other relevant AMS boards and committees. Emphasis is placed on partnerships with professional societies outside the atmospheric, oceanic, and geosciences. This committee can be extremely valuable to NCEI's effort to expand and sustain partnerships with sectoral professional societies and both NCEI and NCICS are represented on the committee. This new partnership opportunity could engender greater cross-NESDIS interaction, as with the GEOXO requirements gathering, among others.

Key partnerships are fully inline within the context of NOAA's Data Strategy. It expects that NCEI will "Establish partnerships to enable effective and wide scaling of access to NOAA's data, the provision of expertise that supports the wider understanding of those data, and the effective use of NOAA information products by all."[61]

A second key challenge is to strategize partnerships in establishing sufficient resources to support sustained engagement with partners and stakeholders. This requires that NCEI "builds trust and credibility, understands needs to inform product developments, and identifies gaps and opportunities to guide future investment in observations, research, and modeling."[62]

Strategize partnerships in establishing sufficient resources to support sustained engagement with partners and stakeholders.

The third final key challenge to strategic partnerships is in eliciting feedback on the needs of commercial businesses and local level decision makers, a necessary step toward enhancing the value. For example, feedback that the 30-year Climate Normals used for heating and cooling degree days was insufficient for utilities' use due to uncertainty associated with climate change. Utility groups continue to look at NCEI for leadership and guidance on navigating the decadal and other Normals products. Examples like this present continued opportunities for NCEI to provide direction and support for the commercial sector.

This leadership role is worth capitalizing on, as it carries considerable weight when demonstrating organizational value to Congress.

To design, develop, and evaluate NCEI products and services, it is necessary to engage with stakeholders in direct, continuous, and collaborative interactions. But more, to approach groups (such as ASHRAE[63]) in places and at events with which they are familiar. An outreach campaign to trade associations and professional societies is one method (e.g., infrastructure, construction, health, energy, transportation, water resources, insurance catastrophe modelers, tourism, and coastal developers, as well as coastal and marine resource managers). These tend to have a regional component, as in the example (Box 22).

[61] NOAA Data Strategy
[62] Scott Hausman, July 2011, presentation.
[63] ASHRAE is a professional association, previously known as the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Box 22. Regional Approach – Recurring Flood

Regional Approach Example Recurring Flood Monitoring and Forecasting

The goal of a Recurring Flood Model monitoring and forecasting system is to provide the entire nation meaningful information on a timely basis. However, a region by region approach to build it out is necessary to account for differences that exist among the regions in terms of information requests and in terms of processes that manifest as "recurring". In the Pacific for example, the region-wide ENSO signal and extra-tropical storms both generate elevated water levels along the shoreline (Marra, interview). Along the Gulf and Atlantic Coasts more localized effects, such as the speed of the Florida Current (Sweet, et al., 2016) as well as land-falling rain and inland flooding also need to be considered. A region by region approach to create and package a set of products is logical to articulate differences in the nature of flood forcings (and the level of understanding) and because regions serve as the locus for efforts that are currently underway.

3.6.2.1 Inter-Agency and International Partnerships

Partners that monitor, use, and steward environmental data are key in the continuum of data stewardship. Professional partners allow NCEI to tackle issues that are inherently multi-sector and involve a community of practice.

A fundamental precept of the NCEI engagement strategy is to develop and strengthen partnerships across the previously separated data centers. Sectoral and solution-focused engagement creates teams drawn from all three domains– ocean, climate, and geophysics – to tackle user challenges that call for combined expertise. Likewise, inter-NOAA and interagency partnerships, as with NESDIS The Center for Satellite Applications and Research (STAR), NWS Weather-Ready Nation, the Sea Grant offices, and the Coastal Zone Management program, as well as the USGCRP agencies provide for integrated data, products and services that help people approach complex issues, such as coastal inundation and development, and all the challenges in the National Climate Assessment.

International partnerships are also a key to maximizing the value of data.

Regional partnerships also need development. Delving into these inter-NOAA and interagency partners reveals that each agency involved in the USGCRP defines "region" differently, as each agency has its own boundaries. The USDA, DOI, USGS, Environmental Protection Agency (EPA), and so forth each has its own regional offices, which collect together State offices within those regions. NOAA has defined different regions for each of its Line Offices--NWS, NESDIS, National Ocean Service (NOS), OAR, NMFS. Probably the only region that is defined by natural boundaries is the NWS River Forecast Region, though the boundaries of the NCEI Regional Climate Centers come close. Therefore, the greatest common denominator of "region" is the state boundaries. See the reference[64] for a small collection of maps for the NOAA line offices and selected USGCRP agencies that act in partnership with NOAA in the enterprise domains, land, sea, and air. Inter-NOAA and inter-agency partnerships help NCEI deliver integrated information across the federal family.[65]

International partnerships are also a key to maximizing the value of data, such as with the WMO and the Intergovernmental Oceanographic Commission (IOC). Partnerships are important for marine data collection and management, through working groups, such as the WMO-IOC Joint Technical Commission

[64] See Regional map collection by Marjorie McGuirk and Rocky Bilotta, https://caseconsultantsinternational.com/projects.
[65] Excerpt from Riverside SDS proposal

for Oceanography and Marine Meteorology (JCOMM) Expert Team on Marine Climatology (ETMC) and with the International Comprehensive Ocean-Atmospheric Data Set (ICOADS), and United Nations Educational, Scientific and Cultural Organisation's (UNESCO) International Maritime Organization.

The UNDRR with the International Science Council (ISC) new global Hazard Framework[66] is developing a new global hazards framework that provides a scientific set of 300+ Hazard Information Profiles, for hazards encompassed by the Sendai Framework, the UN Sustainable Development Goals (SDGs) and the Paris Climate Agreement. NCEI expert Adam Smith is also contributing to the upcoming WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970-2019) with a section on the U.S. Billion-dollar Weather and Climate Disasters Report. When these international bodies view the work of NCEI scientists, NCEI, NESDIS, and NOAA maximize the value of data that feeds these reports, through increased exposure and use.

NCEI has gained from and contributed to opportunities to lead, design, produce, develop, and implement many relevant international programs (in light of NCEI World Data Center role in producing the Annual State of the Global Climate, the IPCC, and the European Centre for Medium-Range Weather Forecasts (ECMWF) Copernicus project). Over the decades, NCEI has joined with the exceptional body of experts at WMO as leaders in the provision of scientific services. WMO programs and reports inform critical decisions and help society prepare a future dominated by a changing climate. The 2021-2030 UN Decade of Ocean Science for Sustainable Development brings even more opportunity for NCEI to connect.

3.7 Base Customer Service on Place

Why does place matter? To reach the people who are making decisions. The NOAA Data Strategy strives to provide "quality data and information required for decision makers." For a deeper understanding of how, why, and when practitioners apply data and derived information, a local approach is helpful, a regional approach is essential, and close collaboration with resource management agencies in and outside of NOAA is mandatory for knowing who the decision-makers are.

3.7.1 Social Value Chain

In a place-based engagement, an iterative process steps down the data to information product development and delivery chain, again to support the full realization of value. Data 'generators, transformers, transmitters frame 'useful, usable, used' construct of data value. This process has to be driven from the user not the provider side, as the following example in coastal inundation shows.

Box 23. Generating Value from Place-based Method

Generate value from Place-Based Projects - Coastal Inundation

Place-Based Value of NCEI-stewarded-data, is illustrated in the highly successful Coastal Inundation project, which involved key sector partners in a trusted and credible relation that built over time (Marra, 2007).

In Marine Technology Society Journal paper entitled *An Integrating Architecture for Coastal Inundation and Erosion Program Planning and Product Development*, the authors laid out a conceptual framework that supports program planning and product development toward hazard-resilient communities. That framework recognizes the importance of understanding both the physical and social systems that shape coastal inundation risk and resilience.

[66] Communication with Adam Smith, See https://council.science/what-we-do/our-work-at-the-un/disaster-risk-reduction/.

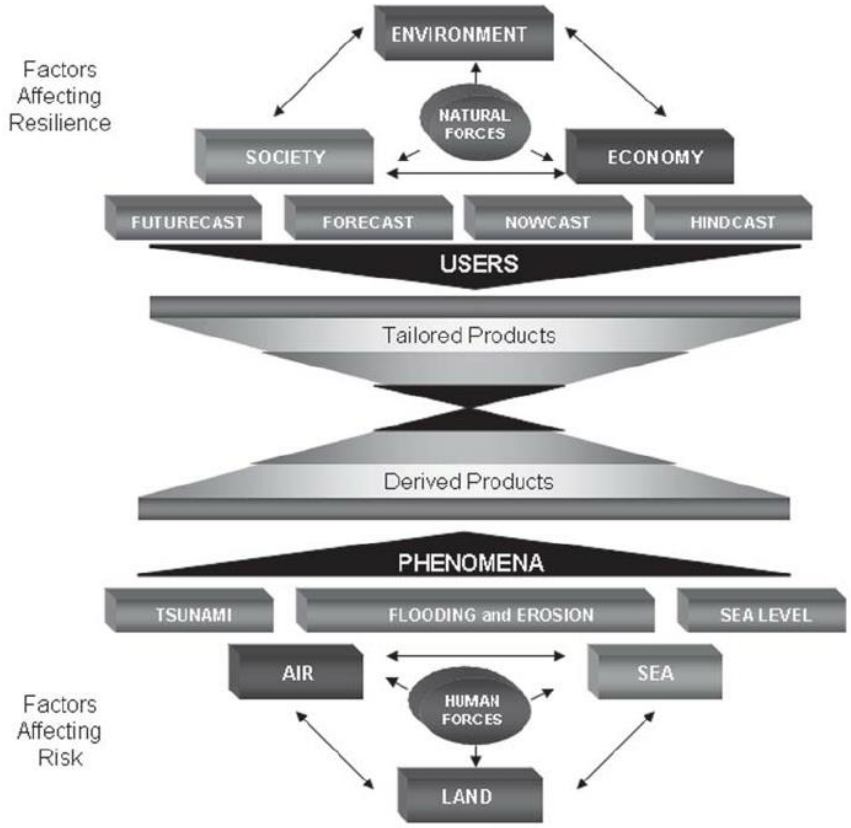
In addition to providing a conceptual architecture for a successful coastal inundation scientific program, it also points to the various programmatic stages at which data and information products from NCEI and other sources provide value. Archived observations of air, sea, and land conditions provide valuable insight into core earth information phenomena like tsunamis, flooding and erosion, and sea level rise. NCEI's historical archives provide both scientists and decision-makers with information about how these phenomena operated in the past. That information also supports the creation of derived data and information products that provide value to those who monitor current conditions as well as provide future projections. In parallel, public, and private sector decision-makers are provided with similar information on the social and economic conditions that affect the vulnerability and resilience of coastal communities.

There is value at each stage throughout this contextual framework as physical earth system data and information are combined with socio-economic information to support the emergence of more resilient coastal communities.

An estimate of the full value of data for coastal inundation requires a combination of economic and decision-support value (data in context). Economic assessments and case studies of decision-support are essential to maximize the value of data in terms of these place-based risk and resilience efforts.

Key components of the NOAA Data Strategy involve "Stewarding and preserving valuable data assets, funded by U.S. taxpayers, for use by future generations;" and "Aligning the value chain from observations through prediction and services, with sound data management principles and practices." The value chain from observations through services is illustrated in the Value Chain Hour Glass (*Box 24*) created for Coastal Inundation projects (Marra, 2007).

Box 24. Hourglass Value Chain



Full value is realized by going completely through the chain. The cascade of products down the value chain includes the transition from raw data to derived data products, to tailored information products. The dialog process that must accompany this process has to be driven from the user not the provider side; and the tailoring required at various places along the way must account for regional as well as sectoral variability.

3.7.2 Distribute (Decentralize) Customer Service

NOAA's Data Strategy commits to "Engage with NOAA's stakeholders to ensure that NOAA receives ongoing expert and timely feedback on NOAA's data practices, especially as they relate to the use of NOAA's data in the research and commercial sectors."[67] Broadly speaking, state and regional partners (e.g. the AASC) can help NCEI provide data services to and collect timely feedback from its stakeholders. Better engagement can also help NCEI collect user requirements and collect quality data nationwide (e.g. Storm Data reports, Drought Monitoring data). Presently, NCEI's Customer Engagement Branch in Asheville processes weather and climate data requests most frequently and geophysical and oceanic data less frequently. Extend their reach by several methods: (1) Incorporate the other two disciplines. (2) Expand the services that go through the existing RCCs and SCOs. (3) Filtering phone calls by zip code and route the requests to the State offices. (4) Advertise the regional and state offices as the "first stop" for Regional, State, or local scale data online. (5) Enhance the ability of NCEI service personnel to provide for national-and international data-scale delivery. (6) Enable customer service personnel to become customer researchers. To do this may require a sustained budget managed by the RCSDs for the RCCs and SCOs to handle customer requests and to collect the unique and significant reports that form the basis of the stories that are submitted monthly to NESDIS headquarters. Solidify a structure in place (such as ACIS, or SharePoint) for reporting up the chain of command on what they are seeing as data successes and limitations.

In an NCEI-Road Map aspirational context, NCEI's regional offices and affiliated State offices could continue the "last mile" of retail services[68]. These offices are enabled to provide the more intimate close contact between providers of data and users of data and do many individualized services as part of their state and university mission. From these retail outlets, NCEI could encourage the story lines for the videos that are so popular on Climate.gov from the retail vendors. A decentralized Regional approach can be leveraged for efficiency and efficacy.

3.7.3 Support a Multi-Sector Approach

Data-informed decisions illustrate the kinetic value of NCEI-stewarded data sometimes in unexpected ways, as in this multi-sector example in land management (*Box 25*). With all the complexities of land management, measuring the value of precipitation data, as in the Global Historical Climatology Network (GHCN) data housed at NCEI, is difficult. The life-preserving decisions taken by Jakarta exemplify the effect of data used for ordinances.

[67] NOAA Data Strategy

[68] The NOAA Data Strategy calls for "Create a reporting and coordination structure throughout NOAA line and staff offices to effectively and collectively steward NOAA's data assets. Such a reporting structure could be analogous to the established intra-organizational means used to steward NOAA's financial or workforce assets. Former NOAA Director Vice-admiral Lautenbacher set a "last mile of service" policy, which espoused helping citizens use NOAA products and services, as opposed to "loading dock stove piped" data delivery.

Box 25. Multi-sector Data-decision in Land Management

Multi-sector data-decision in Land Management

Rainfall data, along with international monitoring and analysis of extreme rainfall records, for example, led to decisions to protect and plant forests on coastal areas, revamp the city's water supply, and improve wastewater treatment (The Economist, Jan 2020). The basis of action was the knowledge that extreme precipitation would continue with climate change, a conclusion drawn from the base of data stewarded by NOAA, along with WMO, through International and National Climate Assessments. Although Jakarta Indonesia's record rainfall of December 2019, was a "precipitating event," it was compounded by a sewer system whose maintenance has not kept pace with the city's expansion, plus the residents want to extract water from wells, which makes the whole city sink. Pumps built to carry flood waters out of the city central area broke as the ground sunk further below sea level. Worse, land management practices that burn forests to make way for palm oil plantations, dry out peat bogs, make wildfires more likely and further uses the water supply.

Data are not, and never have been, neutral. Data practices have social practices 'baked in', so when we talk about data we are also talking about the socio technical structures around data capture. How data has been gathered, interpreted, and sued reflects accepted social norms

– Ada Lovelace Institute (2020, p.4)

Socio-ecological phenomena do not operate within a vacuum; therefore, the true value of anything cannot be extracted by analyzing only the individual parts. Data operate in a similar manner. Data have the potential to generate externalities when linked or aggregated with other datasets (see sample in Box 26). Doing so can enhance and reveal new insights that may otherwise go unseen (HM Treasury, 2018; Bennett Institute and ODI, 2020). The idea of *economies of scope*[69] applies to the potential value of NCEI's three data domains, whereby the act of merging complementary information on environmental, institutional, and infrastructural systems elicits positive externalities worth capturing.

Box 26. Multi-Sector Approach for U.S. Army Corps of Engineers

Multi-Sector Example Chronic Water Stress

ISciences has developed integrated datasets for monitoring and forecasting surface water anomalies on time scales of minutes to decades; for assessing chronic water stress (demand as a fraction of renewable supply) in time scales from months to decades; and for assessing the impact of surface water anomalies on agricultural production, electricity production, and municipal drinking water supplies. These efforts have all required thoughtful integration of disparate datasets on the bio-geophysics of water, and human geography (e.g., water infrastructure, cultivation areas, and electricity generation).

This work, supported by USACE, is a construct for new integrated products, as it defines design characteristics that make dataset integration easier and less costly.[70]

[69] The economies of scope concept is that the unit cost to produce a product will decline as the variety of products increases, with economies, as in cost savings, are formed by variety, not volume, and scope, as in broadening production or services, is expanded through diversified products.
[70] Excerpt from Riverside SDS Proposal

Many uses of data require an interdisciplinary approach, and many involve examining changes in environmental measurements and indicators over time. These data can be used to predict desirable or undesirable socioeconomic or environmental outcomes, find and characterize patterns and anomalies in data that would not otherwise be apparent, and detect critical environmental thresholds that when crossed result in a significant and irreversible change of state. For example, ISciences integrated data from Landsat and MODIS to improve estimates of evapotranspiration and provide early warning of drought, and to examine the role of surface water anomalies (both drought and flood) in the onset of political violence and refugee flows.[71]

As another multi-sector example, combining satellite imagery with additional geophysical and climate datasets, such as wind, humidity, precipitation, and drought data, provides wildfire managers and response teams the ability to estimate wildfire risk from space (Dooley et al., 2017). The same can be said for assessing a region's risk of malaria transmission, which relies on soil moisture, surface air temperature, precipitation, and humidity data, combined with social vulnerability indicators (World Meteorological Organization, 2014).

a TV meteorologist would say "there are 3 million people affected by this line of thunderstorms" NCEI could say, there were 3 million people positively affected by decisions taken informed by retrospective environmental data.

There are subject matter experts who are engaged in valuation work, particularly at NOS. Over the years, they have been proponents of developing measures that can help describe the value of NOAA efforts that are known to provide value but are hard to quantify and communicate. For example, the value of engagement and the application of new data. Recently, there was a concerted effort to develop quantifiable valuation measures for a series of projects funded by NOAA resilience grants.[72]

The value of the decisions that are made based upon data is not diminished by a lack of quantifiable economic dollar values. Instead of dollar values, the number of people positively affected by the decision could be used to describe the importance of the work NCEI undertakes. Just as, for example, a TV meteorologist would say "there are 3 million people affected by this line of thunderstorms", NCEI could say, there were 3 million people positively affected by decisions taken informed by retrospective environmental data in this place and time. A place-based approach grounds an economics of scope method for VoD in a kinetic sense.

3.8 Engage a Community of Practice

Lessons on value can be drawn from a community of practice approach, such as in the fields of natural hazards planning and risk management. As a number of scholars suggest, inter-organizational coordination is a critical component of hazard mitigation, disaster recovery, and adaptation planning (See three Berke references and also Smith). This includes vertical (local, state, regional, and federal actors) and horizontal (across sectors and jurisdictions) integration. (See *Box 27. Declared Disasters and NCEI Value*). The ability to effectively coordinate information and resources across networks and

[71] Excerpt from Riverside SDS Proposal
[72] Adam Stein, personal communication, July 2020.

different organizational cultures not only demonstrates the effectiveness and efficiency of such organizations, but these partnerships add value that extends beyond the data itself.

Box 27. Declared Disasters and NCEI Value

Federally Declared Disasters

Housing recovery operations following a federally declared disaster require coordination efforts that span a whole community approach. Numerous agencies and institutions at the federal, state, and local level are working together to rehome displaced families. Under the FEMA Direct Housing Mission, manufactured housing units (commonly referred to as FEMA trailers) are used to temporarily house survivors who experience significant damage to their homes. The site selection process and placement of these manufactured housing units requires extensive coordination from groups outside of FEMA, including USACE, state and local emergency managers, utility companies, city councils, local departments of social services, etc. Geophysical data in the form of Digital Elevation Models (DEMs) is relied on for assessing the feasibility of these site locations, and whether elevation requirements and local permitting regulations are required.

Seeing the need for engaging a community of practice, NOAA Climate Program Office is turning to "collaborative approaches involving subject matter experts from different professional domains."[73] It is "piloting a strategic effort to enhance its investments and improve the nation's resilience with user-driven solutions." Four efforts focus on increased flooding, warming ocean temperatures, fluctuating lake levels, and more frequent heat waves—all of which impacts communities in every region and economic sector. For another example of a success story on community of practice, consider NCEI's involvement on drought and livestock (*Box 28*).

Box 28. Drought Community

U.S. Drought Monitor

The U.S. Drought Monitor has received widespread recognition for the invaluable impact it has on operational decision making for livestock producers, prospectors, and traders, as well as policy makers at both the state and federal level. While the NCEI Drought and Livestock Success Story identifies ample horizontal collaboration exchange (i.e. across a broad range of federal agencies, (NCEI, NCEP, USDA), improvement can be made on vertical information sharing from federal to regional to local entities. The Drought Monitor remains a powerful and effective tool for policy decision-makers and program administrators. Additional value can be garnered from local USDA agencies, and state drought councils to help meet the needs at the community level, tapping into the network of already existing Food Service Agencies and food councils across the country. This has a two-fold benefit. first, it provides members of the local food system another tool for their arsenal, and second, it fosters dialog that can result in the improvement or enhancement of the tool; this forms a community of practice.

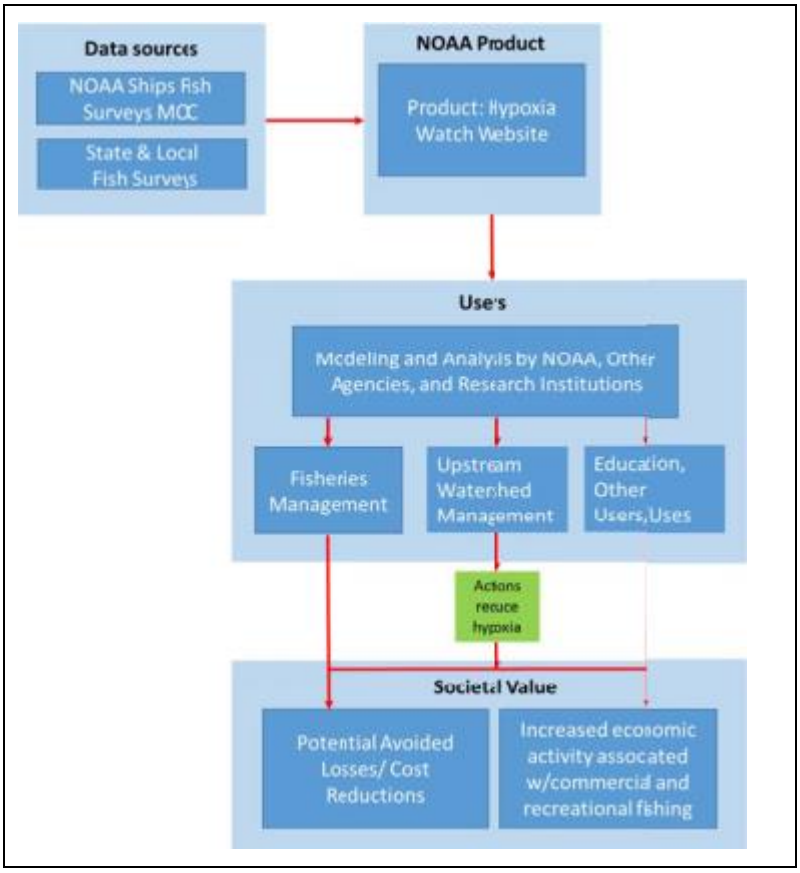
4.0 Approaches to Potential Future Goal-based Models

Whether for potential or kinetic value, this Report (as previously explained in Section 3.0), suggests using a goal-driven approach to select a model for valuing data. First, identify the goal and then compare models that could inform them. This section explores five methods or strategies for modeling how data is valued: as an asset, as informing policy, as providing a societal benefit, as revenue to the private sector, or as utility for a key ally.

[73] NOAA's Climate Program Office launches Climate Risk Areas Initiative, CPO News, July 2020

To examine the five goal-driven models, this section uses the example of hypoxia and the Hypoxia Watch product. The NOAA Fleet study created a value chain for Hypoxia products (Box 29 Value Chain Hypoxia). NOAA Fisheries, through their Southeast Area Monitoring and Assessment Program (SEAMAP), provides data for the Hypoxia Watch.

Box 29. Value Chain Hypoxia



Hypoxia, or the lack of oxygen, is a common issue in coastal areas as a consequence of nutrient pollution. Nutrient runoff causes overgrowth in algae that consume oxygen as they decompose and sink to the seafloor. The Gulf of Mexico and the Chesapeake Bay are two hotspots of hypoxic zones, where the lack of oxygen can kill aquatic species and disrupt the food web with impacts and economic losses for the fishing industry and coastal communities driven by this industry. In the most recent *Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2017 Report to Congress* (EPA, 2017) the Hypoxia Watch product is described as generated products "that form the basis for summertime advisories on anoxia and hypoxia conditions in the north-central Gulf of Mexico."

VoD models should be defined within the scope of the goal NCEI seeks to achieve. When NCEI creates clear goals with measurable successes, and identifies which operational strategies can be achieved, then VoD models can be applied that fit the goals.

What follows is a summary of a five model approach using the example of Hypoxia.

4.1 Model 1: Data as an Asset

***Goal**: Improve the Hypoxia Watch product to reach more end users.*

***Value Chain Starts With**: The NCEI data product.*

***Value Chain Seeks to Understand**: The total value of the asset.*

While data should be viewed in a larger context than just an asset to NCEI, this is a first step in a data-driven means to determine impacts of data on society and the economy at large. This approach starts by identifying the product[74] and continues with analytical methods (to align with NOAA's Big Data Program and eventually with NOAA's Artificial Intelligence strategies). The next step in this model is to identify the users. This method would rely heavily on a CRM solution as well as a database of on-line users given the likeliness that end users may not be captured at the data download contact point.

For example, key users of the Hypoxia Watch product are the Mississippi River/Gulf of Mexico Hypoxia Task Force. A value chain user web database could populate stakeholders of the task force, such as the Louisiana Hypoxia Working Group, the Ouachita River Valley Association, the Louisiana Wildlife & Fisheries Commission, or the Louisiana Shrimp Task Force.

Next, through publicly available information or direct engagement, it is possible to map the decisions made as a consequence of the Hypoxia Watch product. The decisions in themselves create value to the data, though additional mapping efforts could be completed to include economic losses or cost avoidance. While this exercise is not new, the focus is on creating a data-focused strategy that provides a foundation for repeatable metrics. Creating a database of use case analytics has the potential to improve efficiency in demonstrating value and opportunity for repeatability that could outweigh the benefits from detailed narratives.

4.2 Model 2: Data as a Societal Benefit

***Goal**: Decrease the Gulf of Mexico hypoxic deadzone.*

***Value Chain Starts With**: The environmental issue.*

***Value Chain Seeks to Understand**: The total value of NCEI products to ongoing societal or environmental issues.*

This approach requires that NCEI prioritize societal and environmental benefits that they seek to achieve or issues they seek to solve. Value is measured as a function of data product contributions to achieving a solution. This prioritization schema of a societal goal should be replicable and based on criteria designed by NCEI. Priority could be based on an implementation matrix (i.e. what can be solved within logistical and resource constraints), the blue economy, timeliness, or NOAA strategic plans. This model has potential to crossover with the NOAA's Technology, Planning, and Integration for Observation (TPIO) portfolio analysis. TPIO has utilized multiple data-driven frameworks for constructing value trees for investment portfolio analysis and decision support, e.g. the NOAA Observing System Integration Analysis (NOSIA)-II), which have included tools such as CasaNOSA (Yapur and Miller, 2008) and PALMA (Yapur and Reining, 2015). The value trees include NOAA's long term goals, the supporting NOAA assets, and key products and then used subject matter experts to create reusable metrics for performance measures.

[74] A common NOAA strategy for valuing data begins with the product, interview, Jeffrey Adkins

Starting with a large scale societal or environmental goal, key operational initiatives can be identified, and then the NCEI assets and programs that support those initiatives critically assessed. These portfolio analyses could be constructed in advance and deployed at key timepoints or "marketing flash points" where public concern is highest.

Using hypoxia as an example, perhaps the highest-level goal of NOAA/NCEI is that the Gulf of Mexico dead zone is reduced overtime. Clearly this goal far exceeds the purview of NCEI exclusively, but it does not preclude NCEI tracking their contributions towards achieving it to engage stakeholders in the value of NCEI. NCEI would map the relevant operational strategies for reducing the dead zone for which NCEI could contribute data. For example, suppose one of these operational strategies is to adjust the timing of fertilizer application in floodplain restoration. NCEI could map the products that inform these operational strategies, which could include data on crop moisture stress index, precipitation, climatology data that inform decision support for fertilizer application. The utility of these management strategies can be measured using the Gulf of Mexico Data Atlas water quality nutrients in estuaries data, Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) data archiving, the Ocean Color Archive and Hypoxia Watch. Mapping each of these further to the utility they provide, via decision making to each of the operational strategies, for reducing the Gulf of Mexico dead zone would provide a measure of value based on societal/environmental benefit.

4.3 Model 3: Data to Inform Policy

***Goal**: Improve congressional support for NCEI through utility in policy.*

***Value Chain Starts With**: The associated policy making* surrounding a societal issue.*

***Value Chain Seeks to Understand**: NCEI's value contribution to new policy.*

This approach prioritizes critical policy issues with specific pressing issues, such as coastal resilience after a storm, Harmful Algal Blooms (HAB) that shut down tourism for the Florida Gulf Coast, large dead zones (hypoxia) in the Gulf of Mexico. Capitalizing on the sentiment during this time period will innately add more value to the data and products provided to support policy making around the issue (Rabotyagov et al., 2014).[75]

A search of the policy database LegiScan, yielded 18 results with the keyword "hypoxia" since 2019. The most recent of which House Concurrent Resolution 64 (HCR64), passed in the Louisiana state legislature, intended to "express support for the annual Gulf Hypoxia Mapping Cruise conducted by the Louisiana Universities Marine Consortium (LUMCON) and to memorialize congress to provide continued funding." The two principal organizations that store hypoxia data from LUMCON are NCEI and the Gulf Coast Ocean Observing System (GCOOS). A bill introduced to the U.S. House Committee on Science, Space, and Technology proposed that services related to the Harmful Algal Bloom Operational Forecasting System (HAB-OFS) are exempt during a lapse of appropriations. NCEI provides inputs to and outputs from the HAB-OFS, including processed satellite imagery and GIS files among other data. Ongoing tracking of these policies and product applications would provide a measure of value as reflected through policy.

[75] Coast avoidance if models from data (note increased secondary value from product and information) could better predict timing and locations of deadzones for ample adaptation time of fisheries as in the economics of dead zones: Causes, impacts, policy challenges, and a model of the Gulf of Mexico Hypoxic Zone (Rabotyagov et al., 2014).

4.4 Model 4: Data as Revenue (or Cost Avoidance) to the Private Sector

***Goal**: Improve congressional support for NCEI through utility in the private sector*

***Value Chain Starts With**: the NCEI data product as prioritized by the Blue Economy*

***Value chain Seeks to Understand**: Contributions to revenue within the private sector, GDP contributions within a sector.*

The goal of this approach is to increase support of NCEI (i.e. increase funding) by providing quantitative evidence that NCEI's assets support the economy. Equipped with this quantitative evidence, NCEI can strategically engage current and potential end users by considering revenue within sectors and by asset. Customer profiles can be built to assess key products and company decision points. Subject matter experts can provide metrics on the value of data value to customer business initiatives, adapted from (Schmarzo & Sidaoui, 2017) to (1) Determine financial value of targeted business initiatives, (2) Identify business decisions that support targeted business initiatives, (3) Quantify value of individual decisions with respect to the overall initiatives and (4) Assess value of each data source to each decision as a rough order of magnitude value (Schmarzo & Sidaoui, 2017).

The valuation model would only include endpoints that can be directly monetized (i.e. financial value of a company or targeted business initiative). Partnerships with private sector value-added professional societies would be essential to this model.

The initial signal in this case would be a priority issue combined with knowledge of key user impacts. For example, in 2017 the Gulf of Mexico dead zone was the largest ever measured. In the OCM CRM and utility analytics database, commercial fisheries in the Gulf of Mexico are tagged by sector, operations (e.g. active vessel fishery), business decisions, species harvested (e.g. menhaden, oysters), sales volume, and other information as described in the Data as an Asset approach. In an associated knowledge management solution, economic data and metrics can be repurposed and applied. For example, hypoxia is shown to impact shrimp prices and fuel use (Smith et. al, 2011), shift spatial dynamics of menhaden (Langseth, 2014) and fleet dynamics of shrimp fisheries (Purcel, 2017). Combined with HABs, NOAA suggests the cost to the U.S. seafood and tourism industries is approximately $82 million per year. NOAA's National Centers for Coastal Ocean Science (NCCOS) studies are currently identifying proactive and adaptive fishery strategies that rely on hypoxia forecasting.

The purpose of this approach is to build reusable value chains through a data focused lens: subject matter experts can create and apply metrics as to how data contributes to hypoxia forecasting, this forecasting is then traced through decision points within fisheries (e.g. fish or not fish, fuel cost to move fleet, switch to resilient species) and their customer profiles (e.g. Dean Blanchard Seafood, hypoxia-sensitive brown shrimp distributor) and then applied to their revenue streams ($25-$50 million, media reported) or of those for the entire sector ($165.4 million brown shrimp landings) in a specific location until analytics are built out. The goal is not to provide robust economic analyses each time, but instead it builds a reusable analytics approach with existing information ready to deploy at applicable times.

4.5 Model 5: Data as Value to Key Allies

***Goal**: Improve congressional support by identifying key allies.*

***Value Chain Starts With**: The NCEI data product as prioritized by the Blue Economy.*

***Value Chain Seeks to Understand**: Identification of the most powerful allies of NCEI product, revenue within the private sector, GDP contributions within a sector.*

Many of the previous methods can be used to identify key users from a CRM and utility analytics database, but the purpose of this approach is to recognize the value in the "loudest voice." Champion voices within the environmental sector are not new, but NCEI can seek to identify these users with a repeatable, data-driven approach that prioritizes them and identifies them based on download analytics, media mentions or other methods. Data are valued when accessed, used, and communicated. The perceived value from data can disproportionately grow when the value is communicated through a powerful ally.

4.6 Different Models Support Different Engagement Strategies

There is no one size fits all approach to how best engage stakeholders in the VoD. Each goal outlined by NCEI will prescribe a different VoD approach and a tailored engagement and communication strategy. Different valuation methodologies are based around different goals as they relate, for example, to hypoxia and the Hypoxia Watch product. (See *Box 30*).

Box 30. Model Types for Hypoxia

Method to Select Type of Model Based on Goals for Hypoxia Product			
Potential Goal	**Potential Operational Strategy**	**Potential Data and Metrics**	**Potential Data Valuation**
Improve the utility of Hypoxia Watch product for end users.	Increase utility through better access, awareness and function of Hypoxia Watch.	Data download frequency, data download volumes, counts of API use, number of users, measures of diversity and abundance of NAICS codes, media mentions and media reach, business decisions dependent on the product.	Model 1 As an asset.
Improve the resiliency of coastal communities to hypoxia.	Improve how Hypoxia Watch informs coastal decision makers to improve resiliency to future hypoxia.	Hypoxia forecasts using data, counts of hypoxia forecast information in news media, counts of .gov addresses from coastal communities, reduction of Gulf of Mexico hypoxia area, downward trend in economic losses, 20% reduction of nitrogen and phosphorous delivery to Gulf by 2025 (Task Force).	Model 2 As a benefit to society and the environment.
	Calculate cost savings from utilizing Hypoxia Watch to inform coastal policy decisions.	Adaptation plans utilizing models with data, cost saving reported in models that use data, before/after economic losses from dead zones.	Model 3 As informing policy.
Maintain or improve funding for Hypoxia Watch.	Identify the specific hypoxia events and locations where Hypoxia Watch informed policy.	Hypoxia or related policies that mention programs or products reliant on data, news media analytics around dead zones, policy maker media analytics.	

	Identify private sector end users of Hypoxia Watch most dependent on the product for their business.	Fisheries utilizing NCEI product, cost avoidance from utilizing product, financial value of key business decisions informed by data, fishery management strategies informed by data.	Model 4 As revenue or cost avoidance.
	Identify the Hypoxia Watch events and coastal policy makers most dependent on Hypoxia Watch.	Fishery associations or state groups disseminating forecasting tools reliant on NCEI hypoxia data, avoided costs for adaptation of fisheries, number of congressional hill visits by NCEI product user.	Model 5 As value to key allies.

5.0 Outline and Plan to Execute Future Workflow

The first step towards a new, sustainable VoD endeavor requires NCEI to identify the purposes and objectives of that goal. Once those decisions are made, this Report recommends that NCEI proceed in an iterative fashion and to gather input from NCEI staff across data domains (geophysical, ocean, and coastal) along the way. RCSDs and partners, and NOAA offices engaged in related work groups with whom NCEI and NOAA work closely are all essentially implementers who will propel NCEI's VoD plan forward (e.g., the Office of the Chief Economist, NOS OCM, NMFS, BEA, and other agencies).

5.1 Lessons from Previous Proposals

Although this present Report is not a cost proposal, there are proposed guidelines for the time and budget necessary to implement the recommendations. Over the past decade, NCEI has issued several requests for economic and social VoD proposals. Though not all were entirely acted upon, the information gathered through these requests can inform this effort, especially time and budget requirements. Two examples follow.

5.1.1 Operationalize a Balanced Portfolio of Socio-economic Indicators

In May 2011, NCEI asked a group of environmental economists at Appalachian State University to assess the value of data. They proposed to "develop and operationalize a balanced portfolio of socio-economic indicators." The indicators: would examine the impact and value of weather, climate, and geophysical data; include the operational capacity to evaluate the social and economic outcomes under different scenarios; would be scalable from local to regional to national levels. Importantly, the work presumed an on-going collaboration to identify and address a wide range of present and future needs. The proposal[76] gave a timeline of approximately three years to reach an operational model.

- Year 1- Research Leader, two Research Associates, one Research Assistant (Graduate Student)
  Deliverable-operational indicators developed, 1-2 operational per year
- Year 2-Research Leader, one Research Assistant.
  Deliverable-capacity to produce 2-5 analyses and reports per year
- Year 3- Research Leader, one Research Assistant

[76] "A Three Part Plan to Monitor and Assess Weather and Climate Events from a Socio-economic Perspective", John Pine, PhD, Todd Cherry, Ash Morgan, June 2011

Deliverable-model developed and 2-6 refined analysis per year.

Should NCEI resolve to create and operationalize a portfolio of socio-economic indicators for the VoD , it should expect a budget reflective of this scale of input. Approximately $300,000 for the first year, $250,000 for the second year, and $150,000 per year thereafter. Though the proposal price is, of course, no longer relevant, it gives a scale of time and effort required for such an effort.

5.1.2 Advance New Uses – Cost Proposal

At Riverside's direction in June of 2019, CASE Consultants International provided a cost proposal "to advance new uses of NCEI data and information services for economic growth, environmental security and successful adaptation to changing environmental conditions."[77] The cost proposal included time by consultant subject matter expert consultants (as opposed to employee staff labor hours) for the initial undertaking, in these personnel specialties:

- Senior Advisor on climate services
- Climatologist
- Professional Planner and liaison to professional societies
- Scientist and engagement manager
- Media producer and professional journalist
- Environmental Economist
- Data mining specialist and social scientist
- Professional writer and editor

Although the CASE proposal was not adopted, many components of it are reiterated in this Report and are useful for time and budget estimates. That June 2019 proposal had a development cost at approximately $130,000 and annual production costs of approximately $80,000 per year. The budget reflects the types of skills required to undertake the endeavor. Two immediate deliverables were a methodology report that describes innovative approaches to document the value of NCEI data, products, and services; and a report that describes a framework for the goal of producing a Thematic Event Economic Report.

5.1.3 Innovate through GeoCollaborate

This Report suggests broadcasting the SotC report as one innovative approach to assessing the VoD (See Recommendation #4). However, the same was suggested in 2019 within the User Engagement Subcategory of the Proposed Work Statement for the SDS task order submitted by the Riverside Team. More recently, StormCenter submitted a cost proposal to NCEI to do the same and reiterated additional innovative user engagements that can be realized through the GeoCollaborate® tool. Time and budget requirements to put that in effect should be sourced from StormCenter.

5.2 Opportunities

NCEI has opportunities under the SDS contract, restated here: "to increase NCEI's enterprise cost efficiencies without loss of effectiveness, to improve the economies of effort for its customers, and to drive down its life-cycle costs for products and services through many avenues." Avenues available to NCEI include: business innovations, resourceful subcontracting, exploiting NCEI's geographic locations

[77] "Cost Proposal NCEI Value of Data: Innovating the Model", Eileen Shea and Marjorie McGuirk, June 2019.

and work location flexibility for accessing high performance lower cost labor, efficiency gains through science data product supply chain management, astute use of apprenticeships and internships, and leveraging the capabilities and resources of NOAA and NCEI relationships including cooperative institutes, universities, and including public-private partners such as the "Big Data Partnership".[78] Some of these avenues are suggested in the recommendations, methodologies, and cost proposals.

5.3 Propelling the Present Model Forward – Cost Proposal

Given the previous proposals related to the VoD, this Report is keenly aware that NCEI may take an iterative "build a little, test a little" approach as moves to propel the current VoD model forward. Thus, this Report takes a high-level look at resource requirements for each of the methodologies described above in Section 3, as opposed to a detailed plan or cost proposal. The results are provided here as background for NCEI's internal decision-making.

This Report recommends that NCEI consider using a combination of all these approaches to accurately describe the value of NCEI's work. As resources are limited, NCEI should start with clearly articulating their objectives for a VoD initiative.

This report recommends that NCEI consider using a combination of all these approaches to accurately describe the value of NCEI's work.

The work conducted to complete this Report identified a number of possible approaches reflecting different objectives and fundamental principles important to an NCEI VoD program. These are folded into the recommendations and budget narrative.

Many of the activities required for each approach are already underway through the work of NCEI staff and contractors (e.g., sectoral engagement teams, RCSDs, RCCs, GeoCollaborate®.) but perhaps have not been recognized as being part of a VoD model. But importantly, some NCEI resources are already being applied to the methods this Report suggests. Some of these approaches can be realized through, as the Riverside proposal states, "via the use of non-employee individuals (e.g., professional services agreements with subject matter experts, consultants, temporary staff, interns, etc.) for limited duration special projects."[79]

Estimated annual level of effort is also indicated. This is not necessarily new money, but rather a re-focus of effort from current activities to the ones recommended in this Report. Numbers are annual operating expenses assuming mid-level career professionals fully loaded. These professionals can be either federal employees or contractors.

5.3.1 #1 Extract Potential Economic Value from Validated Studies

Recommendation #1, Methodology Section 3.1 $100-$250k

One to two economists, for one year, for each task.

1. Improve the current model through a focused look at high-level economic information of selected economic sectors, which is used primarily to inform budget justification for NCEI. NCEI sectoral value in a high-level economic context can involve ascribing a value to NCEI as a fractional percentage of the total economic value of the sector, or using a four to one ratio of value as compared to the costs of the

[78] Excerpt from Riverside SDS proposal

[79] Excerpt from Riverside SDS proposal

observational platforms, or a set value for the industry. Establish an economic dollar value, ensure some level of DOC or peer review, and use that number every time.

This is the potential value of data in a high-level economic context. Methods include at a minimum using peer reviewed, repeatable, validated collaborative studies with the Office of the NOAA Chief Economist and the DOC BEA that highlight NCEI in the context of NOAA-wide Department of Commerce efforts to define and inform national economic growth and opportunities.

2. Critically assess best practices in economic valuation (per NOAA Chief Economist) of data, considering, for example: value-added products and services, information products that drive economic decisions across sectors, observed events with and without data products; and downstream economic impacts of products and services.

5.3.2 #2 Extract Kinetic Social Value from the Marketplace

Recommendation #2, Methodology Section 3.2 $100-250k

Extract Kinetic social value from the marketplace with 1-2 social meta researchers, customer service researchers.

Perform quick virtual case studies as a method to gather stories told from the point-of-view of those using the data, the "kinetic value" of data in a high-level social context. (See Box 9 Comparison of Case Study Methods). Use numbers developed by financial institutions for specific applied areas, (such as merchandise trade as a function of climate change impacts, or dramatic permafrost retreat affecting extractive business infrastructure). Share the marketplace reports involving data and derived products about current affairs in an overall framework of decision-making. Utilize library searches of trade magazines and journals to evaluate the uses of data. Highlight regional perspectives. (See *Box 22. Regional Approach – Recurring Flood*, which shows that this will be most effective if done with the values reported by the marketplace.) Include collaboration with other NOAA partners (e.g., NESDIS, NOS and NMFS) as well as other agencies and partners engaged in addressing those issues. Near-term opportunities in this context include sea level rise and coastal inundation, fisheries and coral reef management, and other issues identified in NOAA's recent Ocean Economy report (NOAA, OCM, 2019).

5.3.3 #3 Offer Professional Fellowships

Recommendation #3, Methodology Section 3.3 $10k per Fellowship

Use Professional Fellowships to mainstream data into practice, with candidates from industry, using IPA or other means.

Invite professional practitioners from various sectors to enter into professional fellowships, working within the NCEI structure at any location, to learn about the science, data, and products and devise ways that their profession can better use them. Collaborate with a few selected professional societies in the geophysical, ocean, coastal, weather, water, and climate fields especially those actively engaged in utilizing environmental information in decision-making (See Box 16 NCEI Fellowship with APA). Note that the IPA allows shared costs of positions, notably for arrangements made between university employees and government employees (whether federal, state, or local). An IPA arrangement is a powerful bureaucratic tool for directors to use to supplement personnel needs and to create value for any program at any time.

5.3.4 #4 Update Distribution Channels

Recommendation #4, Methodology Section 3.4 $TBD[80]

Use advanced media and decision-support technology in all of the methods undertaken to advance the present VoD model (particularly section 3.4 and 3.5). CASE has been working with Storm Center, beginning with formulating the SDS contract, and understands that they have submitted a formal proposal to Riverside for implementing the product at NCEI. Thus, a cost estimate is excluded for this recommendation.

Expand public awareness of NCEI and the data and products it stewards by opening channels of distribution. Place key products such as the regional and nation SotC summaries into the standard TV meteorologists display software kits. Connect the hot topics of the day to the different types of observing systems and data stewardship records that are under the purview of NCEI.

5.3.5 #5 Leverage Emerging Technology

Recommendation #5, Methodology Section 3.5 $100-200k per year
Visualization scientist specialist

Identify and evaluate emerging technologies to discover and explore environmental data and information services in a decision-making context (e.g., GeoCollaborate®, Climate Adaptation Toolkit, ISciences DANTE), recognizing that NCEI data are often most valuable when integrated with other data that also affect the efficacy of decisions and policies.

Utilize scientific methods of the visual display for data, in presentations, infographics, and science publications, and communication materials. Create targeted lists of sources and sinks for sector related media stories and infographics by researching sectors, (e.g. energy, agriculture, insurance, health, shipping) e-zines, blogs, trade publications, and high internet traffic sector and related general science websites.

5.3.6 #6 Assign NCEI Specialists as Ambassadors to the Industry

Recommendation #6, Methodology Section 3.6 $500k per year
Travel, materials, conference fees for about 10 existing in-house staff.

Sustain user engagement with focused actions with sectoral professional societies that provides for shared learning. Focus on collaborative products developed jointly with partners. Jointly produce presentations and peer-reviewed publications describing how, why, when and to whom data have demonstrated value for businesses, communities, and resource managers. Instead of holding NCEI user conferences, send customer service sectoral specialists to the conferences held by the sectors.

Focused and sustained engagement with sectoral professional societies will significantly enhance NCEI's VoD efforts. An implication is that any assessment of the VoD should actively involve the users or environmental data in sustained, interactive partnerships that promote shared learning. This kind of engagement results in detailed discussions on what future data needs may be and useful suggestions for changes from the perspective of the user communities who rely on planetary data.

[80] NCEI has received a proposal from StormCenter that could be used to support this work.

Work closely with key partnerships, those in NOAA and DOC who have experience and expertise in economic value studies such as the NOS OCM and NMFS who understand how data are used and can be used in issues like coastal and marine resource management and coastal community resilience.

Frame focused engagement with sectoral professional societies and regional partners as well as expanded partnership initiatives of professional society boards and committees (e.g. AMS Enhanced Partnerships effort).

5.3.7 #7 Empower Place-based Multi-sector Approach

Recommendation #7, Methodology Section 3.7 $3M per year

Decentralize and distribute customer service to empower place-based multi-sector approach. Support the State and Regional offices.

It is important to have a continuing series of place-based descriptive case studies of NCEI-stewarded data at work-- supporting decisions and investments, and improving businesses, communities, and resource management at regional, state, and local levels. A regional approach is essential here, with close collaboration among resource management agencies in and outside of NOAA. In order to form a deeper understanding of why, when, and how practitioners apply data and derived information, decentralize, and distribute customer service representatives (retitled to Customer Service Researchers). In order to serve the public with data, information, and products from all domains under the NCEI banner, enable the SCOs and RCCs to work through the offices of the RCSDs (retitled Regional Environmental Services Directors). Together with their inter-agency networks of government, private sector, and community interests, who use data in all domains, they can inform essential place-based VoD studies. These regional and local actors work throughout the country and should be actively involved in helping to guide and implement an innovative VoD approach. Assume that AASC Recognized State Climate Offices (ARSCO) would be budgeted by NCEI to contribute to the Drought Monitor, the sustained assessment reports, and customer service in the state and regional offices.

5.3.8 #8 Engage a Community of Practice

Recommendation #8, Methodology Section 3.8 $150-$200k per year

Subject Matter Expert with focus on problem or issue being addressed.

NCEI has multiple communities of users including scientists (in academia, government, and the private sector), businesses in a variety of sectors, government agencies at all levels, nonprofits, and ultimately, the general public who benefit from how data are used. To understand, document, enhance, and maximize the VoD requires NCEI to engage businesses, governments, and communities throughout the country. Problem-focused issues such as disaster recovery, wildfires, and sea level rise,\ involve a community of practice, people trying to solve a problem. Recognizing this suggests that a successful VoD program at NCEI would benefit from both sectoral and place-based engagements and analyses. Akin to CPO's focus on four problematic areas (increased flooding, warming ocean temperatures, fluctuating lake levels, and more frequent heat waves), NCEI can use a strategy that is issue-focused to help a community of practice improve their resilience with user-driven solutions—using actionable planetary data information.

These stories about the kinetic value of NCEI data will be valuable in enhancing awareness of data and information products throughout the country and would be done in concert with the RCSDs, RCCs and

SCOs. Integrated case studies like these, which emanate from the users-point-of view, will help document the social value of data and services.

6.0 Key Literature Sources

Abt Associates, & Corona Environmental Consulting. (2018). *NOAA Fleet Societal Benefit Study*.

Ada Lovelace Institute. Nuffield Foundation, 2020, *Rethinking Data*, www.adalovelaceinstitute.org/our-work/rethinking-data/.

Akred, J. and Samani, A. "Your Data is Worth More Than You Think." MIT Sloan Management Review. 18 January 2018. sloanreview.mit.edu/article/your-data-is-worth-more-than-you-think/. Accessed 8 October 2019.

AMS. "The Economic Value of the Weather, Water, and Climate Enterprise." American Meteorological Society Washington Forum, Washington, D.C, April, 2013.

—. AMS. Annual Conference 2019. Seventh Symposium on the Weather, Water, and Climate Enterprise Sectoral Panel, Symposium on Emerging Needs, Opportunities, and Careers in Climate Information Services, Board on Global Strategies, Austin, January 2019.

Bennett Institute for Public Policy, and Overseas Development Institute. 2020, *The Value of Data*, www.bennettinstitute.cam.ac.uk/publications/value-data-summary-report/.

Berke, Philip, and David Godschalk. "Searching for the Good Plan." *Journal of Planning Literature*, vol. 23, no. 3, 2009, pp. 227–240, doi:10.1177/0885412208327014.

—. and Gavin Smith. "Hazard Mitigation, Planning, and Disaster Resiliency: Challenges and Strategic Choices for the 21st Century." Building Safer Communities: Risk Governance, Spatial Planning and Responses to Natural Hazards, edited by Urbano Fra Paleo, IOS Press, 2009.

—. et al. *Urban Land Use Planning*. University of Illinois Press, 2006.

Bernknopf, Richard, et al. Resources for the Future, 2019, *The Cost-Effectiveness of Satellite Earth Observations to Inform a Post-Wildfire Response*, media.rff.org/documents/Valuables_Wildfires.pdf.

Bloudoff-Indelicato, Mollie. "Satellites Help Keep Communities Safe from Toxic Algal Blooms." *Resources for the Future*, 9 Oct. 2019, www.resourcesmag.org/archives/satellites-help-keep-communities-safe-toxic-algal-blooms/.

Brantley, Bill. "The Data Briefing: Four Steps to Becoming a Data-Driven Organization." 9 November 2019. https://digital.gov/2016/11/09/the-data-briefing-four-steps-to-becoming-a-data-driven-organization. Accessed 10 October 2019.

Brantley, Bill. "The Value of Federal Government Data." 14 March 2018. https://digital.gov/2018/03/14/data-briefing-value-federal-government-data. Accessed 10 October 2019.

Brewer, Michael, Ph.D., T. Owen, A. Hollingshead, and J. Dissen. "Customer Use Cases and Analytics for Climate Data at NOAA's National Centers for Environmental Information." 97th Annual Conference, American Meteorological Society. Ed. NCEI NOAA. Seattle: AMS, January 2017. https://ams.confex.com/ams/97Annual/webprogram/Paper305637.htm.

Bureau of Economic Analysis (BEA) https://www.bea.gov/system/files/2020-06/defining-and-measuring-the-united-states-ocean-economy.pdf.

Coyle, Diane, OBE. Valuing Data: Foundations for Public Policy, The Value of Data Summary Report. Cambridge: University of Cambridge and the Nuffield Foundation, 2020.

DeGaetano. Arthur T. Timothy J. Brown, et. Al. *Toward Regional Climate Services: The Role of NOAA's Regional Climate Centers*, Bulletin of the American Meteorological Society (2010) 91 (12): 1633–1644.

DOC, Fostering Innovation, Creating Jobs, Driving Better Decisions: The Value of Government Data, Office of Policy and Strategic Planning, July 2014.

Dooley, Kathy, et al. “Estimating Wildfire Risk from Space.” *Earthzine*, IEEE OES, 1 Aug. 2017, earthzine.org/estimating-wildfire-risk-from-space/. December 2010.

Dunbar, Brian. “LIDAR: In the Wake of the Storm.” *NASA*, NASA, 2004, www.nasa.gov/missions/earth/f_lidar.html.

Economist. "The incredible sinking city: Flooding in Jakarta is the worst for over a decade." The Economist 11 January 2020.

—. "Winter is not coming." The Economist 28 March 2020: 77.

—. "The data economy: Tear down this wall." The Economist 25 April 2020: 57-58.

—. Corporate Innovation: Crucible of creative disruption." The Economist 25 April 2020: 55-56.

—. "Satellite Data Shed New Light on North Korea’s Opaque Economy.” The Economist, 4 May 2019

—. “What’s the Worst that Could Happen?”, The Economist, 27 June, 2020.

European Commission, Proposal for a Directive of the European Parliament and of The Council Amending Directive 2003/98/ec on Re-use of Public Sector Information, 0430 19 (2011) (testimony of European Commission).

Federal Emergency Management Agency. 2018, *Natural Hazard Mitigation Interim Report*, www.fema.gov/media-library-data/1528732098546-c3116b4c12a0167c31b46ba09d02edfa/FEMA_MitSaves-Factsheet_508.pdf.

Few, Stephen. *Now You See it, Simple Visualization Techniques for Quantitative Analysis* . El Dorado Hills: Analytics Press, 2009.

Global Science & Technology, Inc. NCEI Climate Products and Services Market Analysis: Power Sector Engagement. Asheville, 11 Jan 2016. https://www.cicsnc.org/assets/pdfs/...sector.../Acclimatise_NCEI_Jan8.pdf.

Haydar Kurban, Ph.D. and J. Fuller, Ph.D. "Measuring the Economic Impact of Preparedness during Severe Weather Events." One NOAA Science Series. NOAA CPO, 2020.

HM Treasury. Crown, 2018, *The Economic Value of Data: Discussion Paper*, assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/731349/20180730_HMT_Discussion_Paper_-_The_Economic_Value_of_Data.pdf.

HUD Exchange. “HUD Awards $28 Billion in CDBG-DR Funds.” *Department of Housing and Urban Development*, 11 Apr. 2018, www.hudexchange.info/news/hud-awards-28-billion-in-cdbg-dr-funds/.

Hughes-Cromwick, E. and Coronado, J. 2019. “The Value of US Government Data to US Business Decisions,” Journal of Economic Perspective, 33 (1): 131-146.

International Finance Corporation. Climate Risk and Financial Institutions Challenges and Opportunities. Washington, D.C.: IFC, 2010.

IPCC, 2012 – Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.) Available from Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 8RU ENGLAND, 582 pp. Available from June 2012

Johnson, Chloe. “Charleston Faces an Existential Choice: Wall Off the Rising Ocean or Retreat to High Ground.” *The Post and Courier*, 20 May 2020.

Keen, M. R., Schwarz, A. M., & Wini-Simeon, L. (2018). Towards defining the Blue Economy: Practical lessons from pacific NCEI governance. *Marine Policy*, *88*, 333–341. https://doi.org/10.1016/j.marpol.2017.03.002

Johnson, Chloe. “Charleston Faces an Existential Choice: Wall Off the Rising Ocean or Retreat to High Ground.” The Post and Courier, 20 May 2020.

Kihn, Eric and Krisa M. Arzayus, *Stewarding NOAA’s Data: How NCEI Allocates Stewardship Resources*, NOAA, Presentation, Washington D.C., November 6, 2017

Kosslyn, Stephen M. *Clear and to the Point: 8 Psychological Principles for Compelling PowerPoint Presentations.* Cambridge. Oxford University Press. 2002.

Langseth, Brian J., et al. “Effect of Changes in Dissolved Oxygen Concentrations on the Spatial Dynamics of the Gulf Menhaden Fishery in the Northern Gulf of Mexico.” Marine and Coastal Fisheries, vol. 6, no. 1, 2014, pp. 223–34, doi:10.1080/19425120.2014.949017.

Lazo, Jeffrey K, M. Lawson, et. al. "U.S. Economic Sensitivity to Weather Variability." Bulletin of the American Meteorological Society June 2011: 709*720.

Maibach, E., and Coauthors, 2017: TV Weathercasters’ Views of Climate Change Appear to Be Rapidly Evolving. Bull. Amer. Meteor. Soc., 98, 2061–2064

Manyika, James, S. Lund, J. Bughin, et al. Promoting the free-flow of data: Digital globalization: The new era of global flows. New York: McKinsey Global Institute, March 2016.

Marra, J.J., Allen, T., Easterling, D., Fauver, S., Karl, T., Levinson, D., Marcy, D., Payne, J., Pietrafesa, L., Shea, E., Vaughan, L, An Integrating Architecture for Coastal Inundation and Erosion Program Planning and Product Development. Special Issue of the Marine Technology Society Journal Volume 41:1, Spring 2007.

McGuirk, Marjorie. "Climate Products and Services Market Analysis: Health Sector Engagement." 14th Climate Prediction Applications Science Workshop (CPASW). Burlington, 22-24 March, 2016.

McKay, Elisa. “New Alexander Theatre to Revitalize Christiansted’s

Monga, B. V. (2016). Accounting’s 21st Century Challenge: How to Value Intangible Assets. *Wall Street Journal*, 11–14. https://www.wsj.com/articles/accountings-21st-century-challenge-how-to-value-intangible-assets-1458605126.

Montgomery, Lori. “This new mapping technology will show whether global warming could

National Planning Conference 2020. American Planning Association, *Contextualizing Big Data*, 2020, www.planning.org/events/activity/9199180/.

National Research Council. *Understanding Earth's Deep Past Lessons for Our Climate Future*. National Academies Press, 2011.

—. Assessing the economic and social benefit of NOAA data online, National Research Council, The Socioeconomic Effects of Public Sector Information on line, Digital Networks: Toward a Better Understanding of Different Access and Reuse Policies: Workshop Summary: https://www.nap.edu/read/12687/chapter/13#49.

NCEI Communications. “World Magnetic Model 2020 Released.” *CIRES*, 10 Dec. 2019, cires.colorado.edu/news/world-magnetic-model-2020-released.

Nicolls, W., Franks, C., Gilmore, T., Goulder, R., Mendelsohn, L., Morgan, E., Adkins, J., Grasso, M., Quigly, K., Zhuang, J., & Colgan, C. (2020). *Defining and Measuring the U.S. Ocean Economy*.

NOAA News. Cloud platforms unleash full potential of NOAA’s environmental data: Easier accessibility promises scientific and economic benefits. Washington, DC, 29 December 2019.

—. NOAA, and SpaceX. “COSMIC-2 Launched!” *NOAA National Environmental Satellite, Data, and Information Service (NESDIS)*, 25 June 2019,

—. NOAA Satellite Tracking Dust and Sand Being Blown from Sahara Desert.” *NOAA National Environmental Satellite, Data, and Information Service (NESDIS)*, 18 June 2020,

NOAA Ocean Economy Report, OCM, Economic Benefits of NOAA OCM Resilience Grants, Final Economic Assessments and Methods, submitted to NOAA OCM by Eastern Research Group, Dec 2019.

Northam, Jackie. "Dozens of Oil Tankers Wait Off California's Coast as the Pandemic Dents Demand." NPR, 27 April 2020. https://www.npr.org/sections/coronavirus-live-updates/2020/04/27/845921122/dozens-of-oil-tankers-wait-off-californias-coast-as-the-pandemic-dents-demand.

Owen, T. (February 24-25, 2017). NCEI's Environmental Information: Resilient Places: Planning for Our Future. Asheville: American Planning Association.

Palmer, Jane. "The New Science of Volcanoes Harnesses AI, Satellites and Gas Sensors to Forecast Eruptions." *Nature News*, Nature Publishing Group, 18 May 2020, www.nature.com/articles/d41586-020-01445-y.

Pearlman, F., Lawrence, C.B., Pindilli, E.J., Geppi, D., Shapiro, C.D., Grasso, M., Pearlman, J., Adkins, J., Sawyer, G., and Tassa, A. (2019). Demonstrating the value of Earth observations—Methods, practical applications, and solutions—Group on Earth Observations side event proceedings: U.S. Geological Survey Open-File Report 2019–1033, 33 p., https://doi.org/10.3133/ofr20191033.

PricewaterhouseCoopers. (2019). Creating Value from Data Why you need to take a strategic approach to maximise the value of your data. In *Strategy&* (Issue February).

Purcell, Kevin M., et al. "Fleet Behavior Is Responsive to a Large-Scale Environmental Disturbance: Hypoxia Effects on the Spatial Dynamics of the Northern Gulf of Mexico Shrimp Fishery." PLoS ONE, vol. 12, no. 8, 2017, doi:10.1371/journal.pone.0183032.

Rabotyagov, S. S., Kling, C. L., Gassman, P. W., Rabalais, N. N., & Turner, R. E. (2014). The economics of dead zones: Causes, impacts, policy challenges, and a model of the Gulf of Mexico Hypoxic Zone. *Review of Environmental Economics and Policy*, *8*(1), 58–79. https://doi.org/10.1093/reep/ret024.

Redmon, Rob, and Eric Kihn. *World Data Service for Geophysics*, www.icsu-wds.org/publications/members-reports-posters/poster-presentations-2015-2016/2016-members-forum-posters/wds-geophysics.pdf.

Schmarzo, Bill. "Big Data: Understanding How Data Powers Big Business." *Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki*, 2013, p. 242. https://infocus.dellemc.com/wp-content/uploads/2017/04/USF_The_Economics_of_Data_and_Analytics-Final3.pdf.

Schmarzo, Bill, and Mouwafac Sidaoui. *Applying Economic Concepts to Big Data to Determine the Financial Value of the Organization's Data and Analytics, and Understanding the Ramifications on the Organizations' Financial Statements and It Operations and Business Strategies*. 2017, https://infocus.dellemc.com/wp-content/uploads/2017/04/USF_The_Economics_of_Data_and_Analytics-Final3.pdf.

Smith, Gavin. *Planning for Post-Disaster Recovery: Review of the United States Disaster Assistance Framework*. Public Entity Risk Institute, 2011.

Snowden, Derrick, et al. "Data Interoperability Between Elements of the Global Ocean Observing System." *Frontiers in Marine Science*, vol. 6, 2019, doi:10.3389/fmars.2019.00442.

Spruit, Marco, and Max Lammertink. "Effective and Efficient Business Intelligence Dashboard Design Gestalt Theory in Dutch Long-Term and Chronic Healthcare." *Applying Big Data Analytics in Bioinformatics and Medicine*, by Miltiadis Lytras and Paraskevi Papadopoulou, Medical Information Science Reference, 2018.

St. Croix Foundation. "The Alexander Theatre: Approved for Renovation and Retrofit." *St. Croix Foundation for Community Development*, 2019, www.stxfoundation.org/communitydevelopment/the-old-alexander-theatre/. Sunday Market Square." *The Virgin Islands Source*, 13 February 2020, https://stcroixsource.com/2020/02/13/new-alexander-theater-to-revitalize-christiansteds-sunday-market-square/.

Stubbs, Megan. "Big Data in U.S. Agriculture." Congressional Research Service, 2016, pp. 1–14

Thirani, Vasudha and A. Gupta. "The Value of Data." World Economic Forum 22 September 2017. https://www.weforum.org/agenda/2017/09/the-value-of-data/.

Tufte, Edward. *The Visual Display of Quantitative Information.* Cheshire. Graphics Press, 2001.

U.S. Department of Commerce Economics and Statistics Administration. (2014). *Fostering Innovation, Creating Jobs, Driving Better Decisions: The Value of Government Data*.

U.S. Department of Commerce Economics and Statistics Administration. Fostering Innovation, Creating Jobs, Driving Better Decision: the Value of Government Data. July 2014. https://www.commerce.gov/sites/default/files/migrated/reports/revisedfosteringinnovationcreatingjobsdrivingbetterdecisions-thevalueofgovernmentdata.pdf.

U.S. Environmental Protection Agency. Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2017 Report to Congress. August 2017.

https://www.epa.gov/sites/production/files/2017-11/documents/hypoxia_task_force_report_to_congress_2017_final.pdf

Umphlett, Natalie A. Warren Pettee, William Sorensen, Crystal J. Stiles Enhancing ACIS Maps: Increasing Usability through a GIS Portal, Bulletin of the American Meteorological Society (2020) 100 (12): 2417–2421. January 2020

United Nations Office of Disaster Risk Reduction (UNDRR), and Centre for Research on Epidemiology of Disasters (CRED). 2018, *Economic Losses, Poverty and Disasters 1998-2017*, www.preventionweb.net/files/61119_credeconomiclosses.pdf.

USB Financial Report Climate Change: Beyond Whether, Geneva. 2007

VanderMolen, Kristin, T. Wall, and B. Daudert. "A Call for the Evaluation of Web-based Climate Data and Analysis Tools." Bulletin of the American Meteorological Society February 2019: 257-268.

Venables, Mark. “Unlocking Value From Data Is Key to a Successful Digital Transformation.” Forbes Magazine, 28 March 2019. forbes.com/sites/markvenables/2019/03/28/unlocking-value-from-data-is-key-to-a-successful-digital-transformation. Accessed 12 October 2019.

Voyer, M., Quirk, G., McIlgorm, A., & Azmi, K. (2018). Shades of blue: what do competing interpretations of the Blue Economy mean for NCEIs governance? *Journal of Environmental Policy and Planning*, *20*(5), 595–616. https://doi.org/10.1080/1523908X.2018.1473153

Ware, Colin. *Information Visualization: Perception for Design.* Waltham. Elsevier, 2013.

World Meteorological Organization (WMO). Economic Assessment of Meteorological and Hydrological Services. Geneva: World Meteorological, 2015.

—. *Annex to the Implementation Plan of the Global Framework for Climate Services – Observations and Monitoring*, User Interface Platform, and Climate Services Information Systems Components. Geneva. 2014.

Yapur, Martin, and Eric Miller. “NOAA’s Integrated Observations and Data Management and Strategic Portfolio Tools.” *OCEANS 2008*, 2008, pp. 1–6, doi:10.1109/OCEANS.2008.5151991.

Yapur, Martin, and Robert Reining. “Constructing NOAA’s Value Tree: Representing Relationships between NOAA’s Organization, Services, and Observing Systems.” *10th Symposium on Societal Applications: Policy, Research and Practice*, 2015, https://ams.confex.com/ams/95Annual/webprogram/Paper264711.html.

Interviews and Conversations

Adkins, Jeff (Economist, NOAA Office of the Chief Economist). Personal interview. 16 June 2020.

Bateman, John and Leslie, John (Public Affairs Officers, NOAA NESDIS). Personal interview. 2 July 2020.

Glass, Shane (Program Manager, Google Cloud Public Dataset Program). Personal interview. 9 June 2020.

Gouldman, Carl (Director, NOAA IOOS) and Arzayus, Krisa (Deputy Director, NOAA IOOS). Personal interview. 2 July 2020.

Jiang, Liqing (Research Scientist and Data Manager, UMD Earth System Science Interdisciplinary Center/NCEI, Ocean Acidification Data Stewardship Project). Personal interview. 12 June 2020.

Marra, John (Regional Climate Services Director), June 2020.

MaMcGuinn, Robert (Project Manager, Northern Gulf Institute, Deep Sea Coral Research and Technology Program). Personal interview. 17 June 2020.

Schmarzo, Bill (Chief Innovation Officer, Hitachi Ventura). Digital interview. 15 June 2020.

Quigley, Kate (Economist, NOAA Office of Coastal Management). Personal interview. 12 June 2020. John Bateman and John Leslie, Public Affairs Officers, NOAA NESDIS

7.0 List of Acronyms

AASC	Association of the State Climatologists
ACIS	Applied Climate Information System
AESP	Association of Energy Services Professionals
AFS	American Fisheries Society
AI	Artificial Intelligence
AMS	American Meteorological Society
APA	American Planning Association
API	Application Programming Interface
APTA	American Public Transportation Association
APPAM	Association for Public Policy Analysis & Management
ARSCO	AASC Recognized State Climate Office
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
A&WMA	Air & Waste Management Association
AWS	Amazon Web Services
BEA	Bureau of Economic Analysis
CDD	Coastal Data Development
CERExx	Customer Engagement Requirements Exchange
CISESS	Cooperative Institute for Satellite Earth System Studies
CPO	Climate Program Office
CRED	Centre for Research on Epidemiology of Disasters
CRM	Customer Relations Management
CSP	Cloud Service Providers
DEM	Digital Elevation Model
DOI	Department of the Interior
DOC	Department of Commerce
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ETMC	Expert Team on Marine Climatology
FAR	Fourth Assessment Report
FEMA	Federal Emergency Management Agency

GCOOS	Gulf Coast Ocean Observing System
GDIS	Government Data Intensive Sector
GDIT	Geographic Information System
GDP	Gross Domestic Product
GIS	Geographic Information System
GEO-XO	Geostationary and Extended Orbits
GHCN	Global Historical Climatology Network
GOES	Geostationary Orbiting Earth Satellite
GPS	Global Positioning System
GRIIDC	Gulf of Mexico Research Initiative Information & Data Cooperative
HAB	Harmful Algal Bloom
HAB-OFS	Harmful Algal Bloom Operational Forecasting System
HUD	Housing and Urban Development
ICOADS	International Comprehensive Ocean-Atmospheric Data Set
IFC	International Finance Corporation
I-O	Bureau of Economic Analysis's Input-Output accounts
IPCC	Intergovernmental Panel on Climate Change
IOC	Intergovernmental Oceanographic Commission
IOD	Indian Ocean Dipole
IOOS	Integrated Ocean Observing System
IP	Internet Protocol
IPA	Intergovernmental Program Act
ISC	International Science Council
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
L3MTO	Local Three-Month Temperature Outlook
LiDAR	Light Detection and Ranging
LUMCON	Louisiana Universities Marine Consortium
MJO	Madden-Julien Oscillation
MODIS	Moderate Resolution Imaging Spectroradiometer
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NCCOS	National Centers for Coastal Ocean Science
NCDC	National Climate Data Center
NCDDC	National Coastal Data Development Center
NCEI	National Centers for Environmental Information
NCEP	National Centers for Environmental Prediction
NCICS	North Carolina Institute for Climate Studies
NEHA	National Environmental Health Association
NEMAC	National Environmental Modeling and Analysis Center
NGDC	National Geophysical Data Center
NIDIS	National Integrated Drought Information System
NMFS	National Marine Fisheries Services

NOAA	National Oceanic & Atmospheric Administration
NODC	National Oceanographic Data Center
NOS	National Ocean Service
NOSIA	NOAA Observing System Integration Analysis
NRPA	National Recreation and Park Association
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OCM	Office for Coastal Management
OER	Office of Ocean Exploration and Research
OSSE	Observing System Simulation Experiments
POES	Polar Orbiting Earth Satellite
PROTECH	Professional & Technical Service Solution
RCC	Regional Climate Center
RCSD	Regional Climate Services Directors
RFF	Resources for the Future
RIMS	Risk Management Society
RISA	Regional Integrated Science and Assessment
SAF	Society of American Foresters
SCO	State Climate Office
SEAMAP	Southeast Area Monitoring and Assessment Program
SDG	Sustainable Development Goals
SDS	Science and Data Stewardship
SotC	State of the Climate
STAR	The Center for Satellite Applications and Research
TPIO	Technology, Planning and Integration for Observation
UNC	University of North Carolina
UNDRR	United Nations Office of Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USACE	U.S. Army Corps of Engineers
USAID	United States Agency for International Development
USGCRP	U.S. Global Change Research Program
USGS	US Geological Survey
VoD	Value of the Data
WMM	World Magnetic Model
WMO	World Meteorological Organization