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Innovations in information management and access for assessments

Anne M. Waple¹, Sarah M. Champion², Kenneth E. Kunkel², and Curt Tilmes³

¹Second Nature, Boston, MA, USA

²Cooperative Institute for Climate and Satellites-NC, North Carolina State U/NOAA's National Centers for Environmental Information, Asheville, NC, USA

³NASA Goddard Space Flight Center, Greenbelt, MD, USA

Abstract

The third National Climate Assessment (NCA3) included goals for becoming a more timely, inclusive, rigorous, and sustained process, and for serving a wider variety of decision makers. In order to accomplish these goals, it was necessary to deliberately design an information management strategy that could serve multiple stakeholders and manage different types of information - from highly mature government-supported climate science data, to isolated practitioner-generated case study information - and to do so in ways that are consistent and appropriate for a highly influential assessment. Meeting the information management challenge for NCA3 meant balancing relevance and authority, complexity and accessibility, inclusivity and rigor. Increasing traceability of data behind figures and graphics, designing a public-facing website, managing hundreds of technical inputs to the NCA, and producing guidance for over 300 participants on meeting the Information Quality Act were all aspects of a deliberate, multi-faceted, and strategic information management approach that nonetheless attempted to be practical and usable for a variety of participants and stakeholders.

1 Introduction

The quality, objectivity and credibility of climate assessment reports are pillars of trust for the development of large-scale policy. The International Panel on Climate Change (IPCC) as well as the first two US National Climate Assessments (NCAs) had significant impact on national and international policy-related discussions. These assessments have provided critical 'state of the science' summaries, and the major conclusions of these reports have been well-vetted during the assessment process in addition to resting on peer-reviewed academic literature. The information base for these assessments necessarily emphasizes mature datasets and high confidence information. It is a time-consuming, expert-dependent approach and results in an exceptionally rigorous suite of information.

This paper focuses on the development of an information system for the Third NCA (NCA3) in the context of a broader information system for the US Global Change Research Program

(USGCRP). One of the key conclusions of the effort is that success lies not only in the quality of the data and analysis itself, but in a human-centered (not just technical) approach to information management, access, communication, and technical support.

1.1 Background

The first two NCA processes as well as most IPCC assessments can be termed ‘summative’ assessments, aiming to summarize our current collective understanding by examining both the breadth and depth of existing scientific analysis to take a “snapshot” of what is known at a particular point in time. This ‘state of the science’ is rigorous and designed to support policy decisions and identify gaps in scientific understanding that can inform research agendas and funding priorities.

Developing a rigorous understanding of what we know is involved and time-consuming. One explicit goal of the NCA3 was to improve the ability of the USGCRP (the interagency program responsible for developing the NCA) to meet the legal requirement to produce a U.S. climate assessment every four years.¹ Meeting this deadline has proved difficult given the enormous effort involved and in order to facilitate timely NCA reporting, a sustained assessment process was developed as part of the NCA3 process (see Buizer et al. 2015). A more rigorous, accessible and well-managed information management approach was needed to support this ongoing effort. In addition to enhancing the efficiency and documentation of the assessment process, this system needed to support the deliberations of the authors as they developed drafts, provide traceability and verification of information sources, and build infrastructure to facilitate current and future assessments.

Additionally, the NCA3 process was designed to serve a wider array of stakeholders. With this in mind, a complementary approach to summative assessment, is a ‘formative’ style of assessment that allows a more integrated and iterative cycle of information development - from input to usability. Following a distinction used in educational assessment language (e.g. GWAEA 2010), a formative assessment approach allows continual feedback and adjustment, in conjunction with the student, to improve learning outcomes. When applied to scientific assessment, this approach involves stakeholders in the information development process (not just the end-use of information), includes a wider variety of information sources, and an accessible and non-expert interface for contribution and retrieval of the information. While the NCA itself was not designed to provide high-resolution information tailored to all decision-makers, by designing a more inclusive and iterative assessment process, the types of questions being asked, and therefore the types of information brought into the assessment, can be more informative to a wider array of stakeholders. Additionally, the information system used to support such a process, should then link from a national assessment process to datasets of increasing resolution housed in the agencies and beyond, including in other portals such as the Climate Data Initiative and climate.data.gov.

Therefore the NCA3 had to resolve a tension between serving the information needs of a rigorous and authoritative process designed for policymakers and scientists (and a legal

¹Legal reference: Global Change Research Act of 1990, 15 U.S.C. §§ 2921–2961: <http://www.gpo.gov/fdsys/pkg/USCODE-2011-title15/html/USCODE-2011-title15-chap56A.htm>

obligation for the NCA to meet the highest tier of the Information Quality Act [IQA]), and providing information that is more timely and relevant for decision makers. The NCA3 approach required a broad re-thinking of the way that information was managed both within the assessment process and “behind” it – a more accessible way to connect to the data that supported the conclusions. NCA3 coordination staff and agency program managers therefore designed several innovative solutions, including the development of a Global Change Information System, a foundation for data management and access.

2 New information management approaches: motivation and framing

2.1 Broad motivation for a federal climate information system

Over the past two decades there has been much discussion about creating a U.S. National Climate Service (NCS). An NCS has never emerged as a formal enterprise,² however, these discussions, along with emerging requests from stakeholders, have produced clear calls for access to climate related data and tools through organized federal efforts.

For example, congressional testimony of Deputy Oceanographer of the Navy Robert Winokur, on June 22nd, 2011 indicated:

“The Navy desires access to readily available, reliable and consistent data and information in an easily available and preferably consolidated location to move away from the current disparate method of locating and obtaining climate information...”

And at the National Climate Adaptation Summit, Dr. John Holdren, Director of the White House Office of Science and Technology Policy, issued “seven priorities for near-term action” in 2010, including:

“Creating a federal climate information portal. This would provide single-point access to data from all relevant federal agencies and programs and would evolve over time into a more ‘national’ portal with information about relevant non-federal efforts.”

Similarly, a recent analysis of stakeholder groups across three western states included a conclusion that “While sometimes conceptualized in different ways, a centralized location or source to obtain climate-related information was a prominent need...” (Dilling and Berggren 2014).

The problem being articulated above is not a lack of information, but rather a lack of accessible and ‘organized’ or curated information. For example, a coastal manager looking for information on sea level rise and associated impacts may find relevant information in as many as five or more agencies, all of whom have scientifically accurate information that is analyzed and presented differently (using different base periods, data sources, scales, analytical techniques etc), and not necessarily available in formats that are translatable for non-expert users.

²In lieu of a consolidated NCS, regional climate services have increased extensively in several USGCRP agencies

In response, and in the context of the development of the NCA3 and its associated data management needs, the USGCRP began to examine the possibilities for meeting the needs of stakeholders and scientists alike who wanted better access to data that was organized and usable.

2.2 NCA as catalyst and pilot

In 2010, stakeholder ‘listening sessions’ were held (USGCRP 2010a, b) that were designed to contribute to a new strategy for climate assessments. These sessions included a variety of what were considered ‘non-traditional’ assessment stakeholders (e.g. city sustainability leads, water managers, tribal representatives, private sector attendees) as well as many scientists and federal managers who would ultimately be engaged in supporting the NCA. During these initial workshops, there was considerable focus on how to incorporate non-federal and non-academic data and information into the assessment (e.g. tribal assessments, adaptation data from cities, specific case studies). An unequivocal workshop conclusion was that stakeholders must be part of the process and that there must be a solution that facilitates use of non-academic data and information while still meeting the IQA.

Other listening sessions throughout 2010 echoed similar themes and a specific ‘knowledge management’ (KM) workshop was held in September 2010 to address the potential solutions to these challenges (USGCRP 2010c). The workshop covered a wide range of topics and included participants from government, NGOs, private sector, and academia – both data experts and expected users. This workshop and its subsequent report were foundational in setting the strategy for information management in the NCA3. The report covered information needs and solutions ranging from how to manage the process of public comment, to considerations of web deployment of the NCA3, to peer review and data archiving. Without this workshop, the NCA3 would have been less well informed, but also its principal actors would have had much more difficulty in effectively communicating the needs to government leads; importantly, the workshop offered a ‘line of sight’ from the proposed NCA information management strategies to the community input that informed them.

Of note in this KM workshop was a request that the NCA3 ‘not forget about the authors’ in the process of managing information. The contention was that we should not only focus on the needs of the intended users, but also think about how to make the process and the information flow easier for the authors and contributors. This influenced NCA3 priorities on several fronts. For example, this request resulted in the design of a digital author workspace for each chapter team. A balance between employing ‘new’ collaborative technology and ensuring that it was straightforward to use for all authors (including those unfamiliar with online collaboration) proved absolutely essential and a key to its success. This online author space also served as an integral part of the end-to-end information flow that improved the capturing and tracking of sources and provenance of information and the progress of each team.

Overall, multiple elements of an end-to-end information system were considered and alternatives discussed within the staff, federal agencies, an interagency working group, and NCA advisory committee. Most of the development work was done within the NCA

Technical Support Unit at NOAA's National Climatic Data Center. The final elements of the information system included: 1) a portal with data quality and documentation guidance for external contributors, 2) more dynamic access to scenarios of climate and sea level, 3) an author collaboration platform, tracking evolving images and data, 4) a site for managing public comments and author responses, and 5) the NCA3 report itself as an electronic publication, including clickable access to data behind the report.

There were many lessons learned in the process and not all elements were equally successful in execution. However, systematically linking each piece of the information management challenge together and striving to make significant improvements in each piece was a valuable and generally successful effort requiring much new problem solving and innovative solutions.

Given the clear needs and goals of the NCA3, the breadth of data and information that would be incorporated, and the emerging plans for meeting those needs, the USGCRP decided to take advantage of the NCA3 to begin an effort to meet the broader information access challenges articulated in section 2.1. NCA3 became a pilot effort in the development of the Global Change Information System (GCIS), which would use lessons learned in the NCA3 process to build an interagency federal climate information management system. The NCA was ideal for this purpose especially given that it involved a subset of federal climate data, but broad-based enough that it would test out many components of the challenge. Initially, the GCIS was described broadly, encompassing all the components of the end-to-end system as outlined above. Over time, the GCIS came to mean a subset of the full information approach (specifically, the hidden 'back end' of the technical system dealing with traceability and the management of metadata). Lessons learned regarding the definition and communication of the GCIS can be found in section 4.3.

It should be noted that while the GCIS was a new effort and was focused initially on meeting emerging needs, especially associated with the NCA, it nonetheless built off a requirement in the GCRA to periodically recommend guidance for the integrated and accessible management of global change data (section §2934 (d)), and to provide integrated research information to international parties (through a Global Change Research Information Office; section §2953). Over the last two decades, there have been a variety of efforts to coordinate data across the USGCRP agencies in response to these requirements, but for a large number of reasons, it has been a continuing challenge. By focusing on the NCA in its initial phase, the GCIS sought to overcome some of the overwhelming scale issues and develop a sustainable system that could be flexibly built out over time. However, much important experience preceded and informed the GCIS.

In addition, in March of 2014, the Climate Data Initiative (CDI) was launched by the Obama Administration to provide a clearinghouse of climate decision-relevant data, especially to spur private sector innovation around developing climate-related resources from those data. It was followed by the Climate Resilience Toolkit (CRT) launch in November 2014 to provide access to data-driven tools, information and subject-matter expertise around resilience objectives. The CDI, CRT, and NCA are three complementary flagship products providing climate-related information, data and tools. The GCIS, building on the prototype

established to support the NCA is being used to integrate and link across those products and later, additional federal data and information.

3 Elements of the NCA-focused information system

3.1 Objectivity, integrity, and utility - the IQA

The Information Quality Act (IQA) (also known as the Data Quality Act) was adopted in 2001 as part of an appropriations bill. It directed the White House Office of Management and Budget (OMB) to guide federal agencies in ensuring that federal data and information is of maximum quality, objectivity, utility and integrity (OMB 2001, 2002; NOAA 2014). According to the criteria for applying the IQA, the NCA falls into a ‘highly influential’ category and must meet the most stringent IQA requirements.

Meeting IQA guidelines drove much of the conversation around how to guide authors, document processes, and evaluate appropriate use of the data, including non-traditional sources of data and information. The IQA also spurred guidance to authors – most of whom were not federal and not familiar with the IQA – on how to evaluate information on the basis of the four outcomes (quality, objectivity, utility, integrity [USGCRP, 2011]). This was particularly important as they considered information that did not have ‘built-in’ indicators of quality such as having passed through academic journal peer review.

As soon as the NCA Development and Advisory Committee (NCADAC; the federal advisory committee) was established in February 2011, several ad hoc Working Groups were formed to make some immediate recommendations for NCA processes. For example, Working Group 4 (WG4) was formed to examine “web deployment, peer review, and data management.” This was a critical initial working group - (previous federal advisory committees had not so explicitly addressed these issues) – and ensured that the NCADAC itself was an integral part of information management solutions. Initial recommendations from WG4 were informed, in part, by the listening session workshop reports and internal USGCRP discussions, and were submitted to the NCADAC and NCA staff in May 2011.

Forming WG4 was a critical step in the process of identifying priorities for NCA information management that cut across NCA staff, federal agencies, and the federal advisory committee. As a result of WG4’s recommendations, a more formal working group of the NCADAC was established in May, 2011 (WG6) for the purposes of evaluating and providing guidance on peer review, information standards and access.

There were several important outputs from WG6 including a Frequently Asked Questions document (FAQs)³ to help external contributors to the NCA determine how they can best ensure their input would be acceptable for use. Additionally, WG6 examined the likely types of data and information that might be received as part of the external submissions and provided a decision tool that the authors could use in the determination of *how* to use the input appropriately. (See Fig 1). For example, the tool helped determine when specific information could be used as supporting evidence for a key finding versus when it would

³<http://www.globalchange.gov/sites/globalchange/files/nca-info-quality-assurance-faq.pdf>

more appropriately be used only as an additional illustration of a point, but not as a primary source and not to support a key finding.

These tools and approaches gave the authors the ability to use a wider variety of inputs to the NCA without having to make potentially inconsistent judgment calls as to their value and quality, while still meeting the requirements of the IQA.

3.2 Managing external contributions and comments

As has been mentioned, a process to facilitate a greater degree of practitioner and non-academic information was called for in NCA3. After deliberation within the NCADAC, the USGCRP, and NCA staff, one approach to expanding access to this information for the NCA was a public 'Request for Information' (RFI), issued through a Federal Register Notice (FRN), and further publicized by participants and by the NCA website. This FRN solicited 'technical input' and provided timelines, guidelines (including webinars for those who intended to contribute), and contact information to facilitate follow-up.

This process generated over 200 individual contributions from NGOs, academic groups, federal agencies and others (over 500 documents total). Some of the inputs were extremely comprehensive and analytical involving dozens of team members, and others were brief workshop reports, data sets, or case studies. Because there were processes and tools to ensure appropriate use, many of these inputs were used to support the regional and sectoral content in the NCA3.

There were three major information management challenges associated with the technical input: the physical management of ingesting technical input in many different formats and organizing it in a way that was accessible for authors; gathering metadata about the technical input itself (contact person, title, copyright, etc.) without overburdening contributors; and ensuring traceability of images, statements, data etc. embedded in these technical inputs that were then used in the NCA3. The GCIS Interagency Working Group, (particularly a sub-group on data policy), was central for helping to determine different pathways for collecting and managing data for use in the NCA and to meet multi-agency requirements for stewarding data.

After examining multiple existing systems for managing public and technical input, it was determined that none quite met the criteria for simplicity of use, public accessibility, and organization of inputs for subsequent evaluation by the authors. Therefore a unique system was designed to facilitate the technical input management that was then linked to the authors' collaborative portal. For example, a simple web form allowed non-expert contributors to upload their input in a variety of common formats (MS Word, Excel, PDF, JPEG etc), and to provide required metadata elements about their submission. This very simple metadata collection allowed the (mostly) automatic organization of submissions so that submissions were tagged according to which section(s) of the draft NCA3 report outline they might be most relevant. This helped the authors manage the large quantity of information they had to review.

An additional requirement of the IQA for Highly Influential assessments is public review and comment. The NCA3 was available for public review for three months, and the information management challenges associated with this element were multiple: a) facilitate the easy download of a large draft report for the public and the upload and organization of comments, b) ensure accessibility for all members of the public while also providing digital security, c) require identifying information about the commenter so that comments could be released publicly with full transparency at the end of the process while initially providing anonymity to ensure absolute lack of bias (and perception of bias) as authors addressed comments, d) help author teams to respond only to the comments intended for their chapter and expertise, and e) ultimately make comments and responses public.

The NCA3 received over 4000 separate comments on the draft and every comment was addressed by the authors. The public comment process occurred with very few hiccups or flaws and a critical aspect was prior awareness of the likely spectrum of users, keeping the process as simple as possible while still functioning properly. It was also critical to have a dedicated and responsive team so that changes could be implemented in real time as challenges in the design and deployment arose.

3.3 NCA3 content and metadata

In an effort to better enable certification of IQA compliance, to continue to improve the authoritative nature of the NCA, and to better serve decision-makers, a significant effort was made in NCA3 to provide greater traceability to underlying data. This was possibly one of the most difficult challenges in the NCA3 information management process, in part due to the volume of datasets used, and in part because of their variety and sources. For example, as shown in Fig 2, it is sometimes the case that, even in just one figure, there can be multiple datasets, analyses, scales, and contributors.

Providing traceability from key conclusions to the data that supports those conclusions requires adequate metadata (data about the data). Challenges in building an information system that accommodated this requirement included: (a) the actual development of the metadata (data sources, analysis methods, etc), and involvement of the report authors in providing and reviewing it, (b) documentation demonstrating that the metadata met federal requirements, and (c) development of tools to communicate the metadata to the readers of the report.

The task of managing the metadata included the efforts of a dozen personnel and took over two years from start to finish. It was necessary to translate the metadata into clear and correct documentation, which meant that the information had to be verified. The IQA guidelines require the ISO 19115 metadata documentation standard (NOAA National Coastal Data Development Center 2014). The metadata collection inputs included an effort to answer the “who”, “what”, “when”, “where”, and “why” of the NCA3 figures and datasets, and in a manner that also demonstrated transparency and reproducibility.

Initially, basic definitions for metadata inputs, such as “graphic”, “figure”, and “image”, were assigned, and a metadata repository was built within which to store the collected metadata and in the correct format. Using a web-based survey, first tier information about

the data was collected (e.g., “where did the data come from?”), by documenting whether a figure, image(s) were original for the report or cited from existing sources and then the specific figure, image and data source information (e.g., named individuals, URLs, publications, etc). In the same web-based survey, other information was collected such as dataset accessibility, dataset version identifiers, named analysis and visualization software and version identifiers, specific analysis and visualization methods, and intermediate products.

Storing and communicating the metadata occurred within the GCIS system (Tilmes et al. 2013, Ma et al. 2014), which was linked to the NCA3 web site and associated custom-built metadata viewer. The addition of these tools completed an end-to-end metadata collection process: originating with the web-based survey completed by an authoritative contributor, completed surveys were then extracted and ingested into the GCIS, while undergoing simultaneous and continuous quality assurance checks. Once met, the GCIS was used to populate the NCA3 website, where metadata is accessible through the metadata viewer (Fig 3).

There is natural resistance to providing this level of metadata since participants were not used to meeting such stringent requirements and did not always see the necessity. Not only are technical and timing improvements needed to make this a smoother process moving forward, but a communications challenge must be met in order for the authors to feel as though this is a valued aspect of the process (see lessons learned in section 4.3).

3.4 The external face of the NCA3

The NCA3 was the first major government report of its kind to be released primarily as a digital report and resource. The ongoing tension between serving policy and science audiences, and serving the public and decision-makers was strongly felt in this dissemination phase. For example, for some, the structure of the report (via the table of contents) historically has been the expected way of accessing the information. In contrast, experience shows that the majority of web-based readers prefer to jump to information by topics that most interest them, and access information in smaller “chunks.” In developing the interactive web-deployment for the NCA3, the reader is presented with an interconnected array of information; by clicking on links you can either go deeper into a subset of information (for example to download the data or metadata behind a figure) or away to other related but higher level information. The design in this case created a layered and more dynamic approach to finding and accessing the information while still giving readers the option of downloading a pdf.

Additionally, because the NCA3 information system was built on the premise of an ongoing or “sustained” assessment effort (see Buizer et al. 2015), it is assumed that information will be added to the site before the next periodic synthesis report is developed. Therefore the design has to accommodate the evolution of the information beyond the static format typically found in a downloadable report (developing interactive indicators for example) but also protect the highly vetted NCA3 contents from any subsequent, less-vetted data created for other purposes.

The design of the NCA site (nca2014.globalchange.gov) attempted to balance these priorities and allows users to organize the material by key findings (highest level summary), by region, by sector, by response options, and by a summary level of all sections, or a deeper discussion of the content (the full content of the report). It also allows word searches across the report, and uses the latest design principles to display the information. The highly aesthetic format of the website has been very well received, with positive comments received from a wide range of individuals – from authors, educators, Congressmen, and members of the public to the Chief of Staff in the White House. Readers can jump from highlights to deeper information at any point while browsing the information, and there is seamless connection to the metadata viewer for the rich information behind the figures and graphics.

4 Beyond NCA3: summary of lessons learned from the GCIS

As with any significant emerging project or effort, the specific pathway for design and outcomes are not well known at the outset and designing an information system with such high visibility required a leap of faith. The previous approaches to development and deployment of NCA reports had the advantage of being well described, conceptually clear, and technically proven. Building a new approach to information management increases uncertainty, leading to anxiety among government officials and participants, even though there was strong support for a more innovative, useful, and cost-effective product.

Multiple lessons that are informing the ongoing assessment process resulted from the challenges described above.

4.1 Risk and reward

Many concerns regarding the quality of NCA information sources, the integrity and security of the information systems, and the volume of data and information, stemmed from the NCA3 commitment to an open and inclusive process. As with all inclusive processes, there is risk. Facilitating external contributions was viewed as necessary not only to improve the quality of the assessment, but also to enhance its utility for decision-makers (see Jacobs and Buizer 2015). But it also could have opened the process to an array of negative consequences, including “hacking” from external parties or inadvertent inclusion of information that did not meet IQA standards, among other concerns. Therefore, some of the preparation and implementation for the NCA3 information management system included significant attention to ensuring that the system itself was robust, and that the contributions relied on were of high quality. In reality, the NCA3 process received very little information that was deemed unusable (though not all of it was ultimately used) and there was no evidence of anyone engaging with harmful intent. However, preparation for this possibility was essential to the process (and will be for future assessments). Managing the risks of an open process requires pro-active caution and attention and innovative management from staff and technicians as the systems are assembled. It also requires clear and frequent communication to decision makers in the federal process so that the concerns about and perception of risk did not exceed actual vulnerability (see also section 4.3 below regarding lessons around communication). In reality this can include much more time and energy

interpersonally than it does technologically, and budgeting for this aspect of the effort is essential.

4.2 Guidance and training

One of the main lessons from the NCA information management process was that where guidance and training was provided to authors and contributors early and clearly, the process was much more streamlined and ultimately more successful. For example, while guidance for technical input contributors was as comprehensive as it could be at the time, there is still room for improvement in many areas, including in better defining requirements for metadata documentation associated with technical input. There were many other areas where guidance existed but was provided too late to be widely used by contributors, as in the instructions on how to use climate and sea level scenarios (see Kunkel et al. 2015). In still other instances, for example, guidance related to documenting levels of certainty (see Moss 2015) the guidance changed over time (in response to feedback), which authors found confusing.

With the scenarios guidance, timing was the primary issue – the scenarios were not available at the time that the request for technical input was released and so technical input contributors did not have the benefit of consistent future scenarios in their submissions. This also became problematic for integrating information from multiple technical input sources. In terms of the metadata associated with technical input, lessons learned through the process allowed us to better understand how, and importantly *when*, to ask for metadata in future iterations. For example, it is challenging to know early in the process which graphics will be used as support for major conclusions. However, the identification of key graphics (and datasets) and the process of requiring appropriate metadata requires further discussion prior to initiating metadata collection for the next synthesis report.

Unfortunately, most of the metadata for the NCA3 was requested after the report content was mostly assembled. This was at the height of last minute revisions and reviews and the all-volunteer army of authors did not always have the capacity at that time to chase down details of figures and datasets. Two improvements have already been suggested in this regard. The revised process separates the collection of the required metadata information into two tiers. Tier 1 information collects graphic source information (e.g., “Who is responsible for this graphic, and where did it come from?”) and is a required first step of report production. Tier 2 information collects reproducibility-level inputs on dataset(s), tools, and analysis methods; this tier is required if there is data and/or analysis included in the visualized results. Metadata collected in the Tier 1 and Tier 2 surveys will be required before a report can proceed to government review. This revised process is already being applied to a special report on climate change and human health that is under development. And to assist in the execution of this new approach, communication is key, especially to those participants who are not familiar with federal data requirements. As part of the revised metadata process, the staff is emphasizing early and often the importance of metadata as not only a Federal requirement, but a “best-practice” throughout the community of climate data production and use.

Where relatively comprehensive guidance was produced (e.g. the IQA source information decision tree), these help clarify processes, risks or questions, and actions. Though these

tools took us a long way down a path of facilitating the use of new data and the participation of new stakeholders and still ensuring a robust and rigorous process, it is not clear that many authors internalized this guidance in the array of other guidance that they received. A possible next step with the source information decision tree may be to make it a more interactive digital evaluation tool. This may make the evaluation process of new kinds of information a little smoother and quicker.

Nonetheless, an important outcome of engaging in discussions of using ‘new’ sources of useful information, and particularly the level of detail with which this discussion was approached, has likely resulted in increased acceptability of using non-government, or non-academic data and information where appropriate. This is a marked shift from previous assessments. The NCADAC working groups played an enormous role in ensuring that this discussion was incorporated routinely into deliberations and approached systematically. The conclusions and guidance that were then generated ‘internally’ to the NCADAC became more acceptable and influential as a result.

4.3 Communication and scale

Delivering the NCA3 electronically was a major decision for the NCADAC and for the federal agencies, and it is likely to have lasting repercussions. This decision was made at the highest policy levels, following the broad expansion of information technology options and a commitment of the Obama administration to innovation in this area. Still, the volume of material involved and the challenges discussed in this paper made this a daunting effort. In the end, this would not have been accomplished without the support of external contractors in addition to extremely dedicated staff in both the USGCRP coordination office and the NOAA Technical Support Unit.

A key to successfully moving into electronic delivery was constant communication and clear articulation of benefits and risk. There remained a high demand for detailed information regarding the specifics of the NCA3 delivery throughout its development and although it was a time-consuming process to keep multiple groups apprised of possibilities, options, or decisions regarding information deployment, it was an essential element, particularly as there was no precedent.

However, the success in linking the online delivery of the NCA3 and the data and information support system behind it has not yet been fully realized (though is continually improving). There was some concern about the GCIS for a variety of reasons, resulting in two important lessons:

1. The GCIS initially was described to encompass a full system – from ‘front end’ web deployment of content and access, to the deep ‘back end’ servers and systems to manage and connect all the information. This full GCIS system was difficult to describe succinctly, and the scale was concerning to some officials whose support was critical to progress, but whose deep understanding of the system was inevitably limited. Over time, the specific description of the GCIS became constrained to the functions managing the traceability and metadata – the ‘hidden’ technical component. However, while it was easier to communicate to

non-experts about the system by focusing on only one or two specific components at any given time, the vision of a truly end-to-end approach that connects people and input all the way through to deployment, managing multiple strands of content, metadata, graphics, and more along the way, was still essential in developing a coherent *design*. This tension may always be present to some degree, and paying more attention to smart communication may be necessary as the program moves forward, and as it requires further decision-making.

2. The second challenge of the GCIS was that it was perceived as a ‘challenge’ to some individual agency-managed web or data responsibilities or opportunities. Although there was explicit communication that GCIS would not house any actual data (this would still happen in the agencies), and it would not seek to displace users of individual agency websites, building credibility and investment in a shared system was difficult, especially in an era of limited resources. More could have been done initially to bring agencies together to build common goals and shared commitment, and this will need to be an ongoing element of the GCIS build out, even as its value is increasingly recognized. An interagency GCIS working group was an important part of communication across the agencies, and further work to ensure this group can help to communicate at appropriate levels in their agencies would be very valuable.

4.4 Capacity and ownership

While this article has not discussed staffing in any detail, the bulk of the work was accomplished by the NCA Technical Support Unit (TSU), and by the NCA staff at the USGCRP, with important input from a multi-agency GCIS Interagency Working Group. These teams were heavily interconnected and much of the early development of the NCA information management strategy required daily interaction and strong core relationships between the teams.

It is essential for the success of USGCRP and NCA information management that there is collective investment (financially and professionally) in the process, and the opportunity to build long-term institutional memory and clear responsibility and accountability. While NOAA requested and received specific funding for the TSU, there must be an ongoing understanding of all of the agencies’ roles and a clear path of communication and responsibility to the NCA coordination office and NCA Director in the future in order to build from the current foundation to a fully functional information system and to more easily deploy future assessments.

5 Conclusion

The information management challenge for the NCA3 was significant. Not only did the process seek to improve the ability to meet the existing imperatives for the assessment, but also intended to serve new stakeholders and become a sustained (and sustainable) process. The electronic delivery of this report, along with data transparency and traceability, though

in retrospect among the most dramatic successes, was also a major cause of stress throughout the process.

It was essential to success that the goals of the NCA3 included the clear intent to become a long-term sustained process. Without this understanding and motivation, the scale of solutions would have been smaller, less mindful of multiple ongoing circumstances and users, and less designed for stability and re-use. The products and services for NCA3 information management were more robust as a result of understanding them to be part of a long term process and larger scale solutions.

It was also important to consider the solutions as all being part of a coherent, linked end-to-end system beginning with user requirements as the driver. How *people* need to use the system was the critical first step and overarching consideration. The technological solution then could focus on the balance of maximizing simplicity with credibility, cost and utility considerations.

There are important lessons learned and continuing improvements that are already being made, including building on the successes with better training and guidance for participants, better timed collection of data, more interactive usability for tools that were valuable, and frequent and appropriate communication to a stakeholders and decision makers. However, an important conclusion of this process is that a tremendous amount of progress can be made in a relatively short period of time if there is stakeholder input from the beginning, there is an inclusive process for moving forward, a dedicated team of problem solvers that has support from leadership, and a laser-focus on the three primary end users of the system: the American public, on-the-ground managers and their elected representatives.

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References

- Buizer JL, Dow K, Black ME, Jacobs KL, Waple A, Moss RH, Moser S, Gustafson DI, Richmond TC, Hays SL, Field CB. Building a sustained climate assessment process. *Clim Chan*. 2015; doi: 10.1007/s10584-015-1501-4
- Dilling L, Berggren J. What do stakeholders need to manage for climate change and variability? A document-based analysis from three mountain states in the western USA. *Reg Environ Chang*. 2014; doi: 10.1007/s10113-014-0668-y
- Grant Wood Area Education Agency. Literature Review: Assessment for Learning (Formative Assessment). Grant Wood Area Education Agency. 2010. http://www.gwaea.org/iowacorecurriculum/docs/AssessmentForLearning_LitReviewFinal.pdf
- Jacobs KL, Buizer JL. Building community, credibility and knowledge: the third U.S. National Climate Assessment. *Clim Chang*. 2015; doi: 10.1007/s10584-015-1445-8

- Kunkel KE, Moss R, Parris A. Innovations in science and scenarios for assessment. *Clim Chang*. 2015; doi: 10.1007/s10584-015-1494-z
- National Oceanic and Atmospheric Administration. National Oceanic and Atmospheric Administration Information Quality Guidelines. 2014. revised. Available online at http://www.cio.noaa.gov/services_programs/info_quality.html
- NOAA National Coastal Data Development Center, cited. Metadata Standards. 2014. [Available online at <http://www.ncddc.noaa.gov/metadata-standards/>]
- Ma X, Fox P, Tilmes C, Jacobs K, Waple AM. Capturing provenance of global change information. *Nat Clim Chang*. 2014; 4:409–412.
- Moss RH. Assessing decision support systems and levels of confidence to narrow the climate information “usability gap”. *Clim Chang*. 2015; doi: 10.1007/s10584-015-1549-1
- Office of Management and Budget. Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies; 66 Federal Register 189 (28 September 2001). 2001. p. 49718-49725. <http://www.uspto.gov/products/catalog/infoqualityguide.jsp>
- Office of Management and Budget. Information Quality Act Final Guidelines. 2002. <http://www.whitehouse.gov/sites/default/files/omb/fedreg/reproducible2.pdf>
- Tilmes C, Fox P, Ma X, McGuinness D, Pinheiro-Privette A, Smith A, Waple AM, Zednik S, Zheng J. Provenance Representation for the National Climate Assessment in the Global Change Information System. *Trans on Geosci and Remote Sens*. 2013; 51(11):5160–5168. doi: 10.1109/TGRS.2013.2262179
- USGCRP. The United States national climate assessment NCA report series, vol. 1: Midwest Regional Workshop: Feb. 22–24, 2010. Chicago, Illinois: USGCRP; 2010a.
- USGCRP. The United States national climate assessment NCA report series, vol. 2: Strategic Planning Workshop. USGCRP; 2010b.
- USGCRP. The United States national climate assessment NCA report series, vol. 3: Knowledge Management Workshop. USGCRP; 2010c.
- USGCRP. Inf Qual Princ. 2011. at http://www.globalchange.gov/sites/globalchange/files/Information-Quality-Principles-Draft_2011-11-16.pdf

Fig. 1.
Decision Tree that was produced by WG6 to guide authors in using external data and information

Fig. 2.

From Fig. 2.7 in the NCA: 'Observed U.S. Temperature Change', this single figure has 11 images, 2 datasets used in multiple combinations across the 11 images, and nearly 300 metadata field inputs documenting this graphic

Fig. 3. A sample of the collected metadata for the NCA3 Fig. 2.7, via the NCA3 website metadata viewer. This view is in the “methods” tab of the viewer, where details of data analysis and visualization are provided. (Figure Source: CICS-NC)