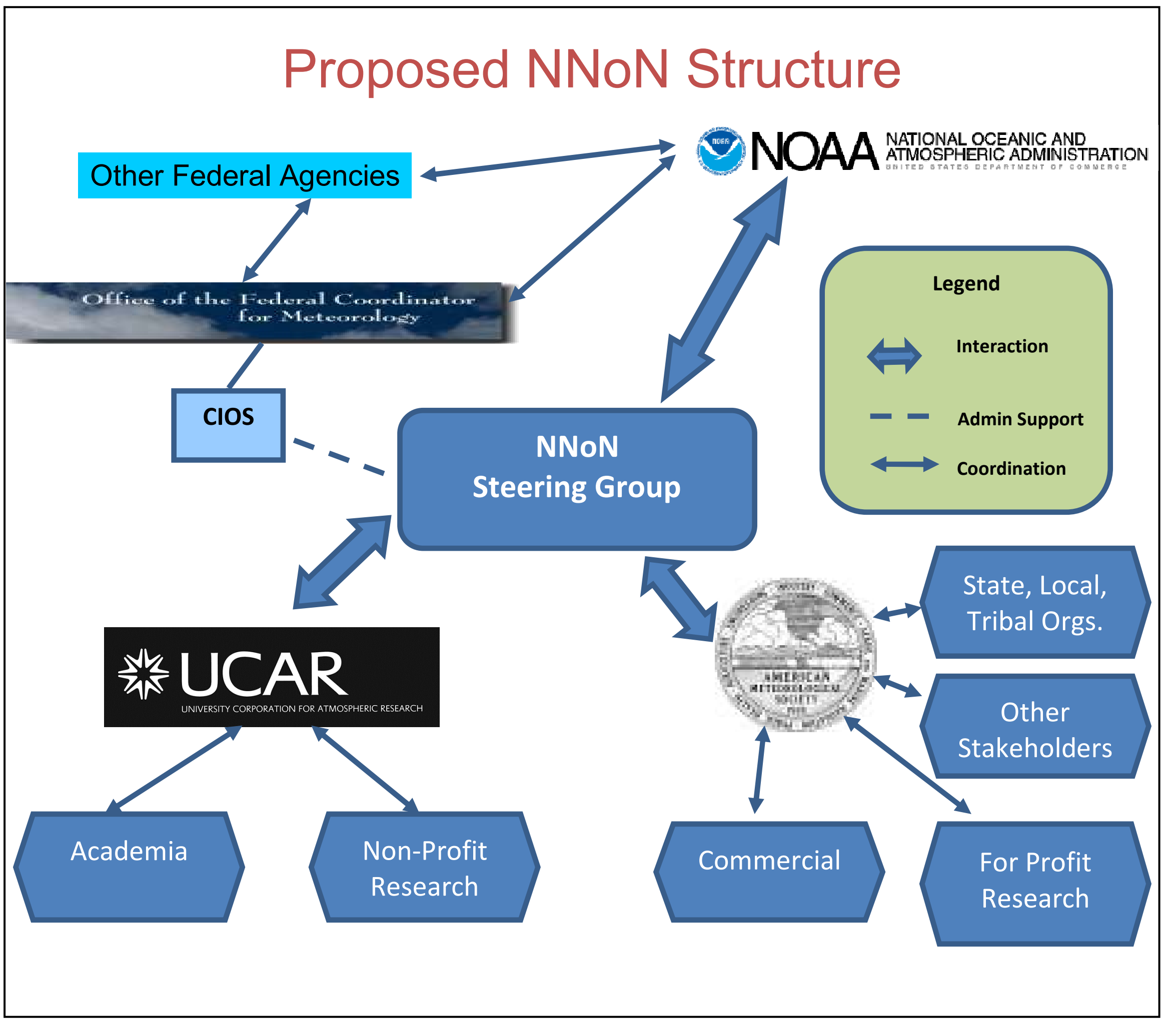
Final Report of the AMS ad hoc Committee on a Nationwide Network of Networks

June 2013



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Introduction

Summary of NRC Report.

In 2009 the National Research Council (NRC) published a report entitled "*Observing the Weather and Climate FROM THE GROUND UP: A Nationwide Network of Networks*". It summarized the work of a committee of the NRC's Board on Atmospheric Sciences and Climate charged with developing "…an overarching vision for an integrated, flexible, adaptive, and multipurpose mesoscale meteorological observation network…" In "… identifying specific steps…that meet(s) multiple national needs…" the committee was given five guidelines as follows:

- Characterize the current state of mesoscale observations and purposes;
- Compare the US mesoscale atmospheric observing system to other observing system benchmarks;
- Describe desirable attributes of an integrated national mesoscale observing system;
- Identify steps to enhance and extend mesoscale meteorological observing capabilities so they meet multiple national needs; and
- Recommend practical steps to transform and modernize current, limited mesoscale meteorological observing capabilities to better meet the needs of a broad range of users and improve cost effectiveness.

The committee was asked to concentrate on the planetary boundary layer extending from 2 meters below the surface to 2−3 kilometers above in the United States to include coastal zones. Forecast time scales of up to 48 hours were to be considered. It was asked to consider the roles of federal, state, and local governments as well as the private sector. The charge concluded that "…***the study will provide a framework and recommendations to engage the full range of weather-sensitive information providers and users in the development of an integrated, multi-purpose national mesoscale observation network.***

AMS Ad Hoc Committee Organization and Terms of Reference

In reaction to the NRC report the AMS decided to form an ad hoc committee under its Commission on the Weather and Climate Enterprise to address the report's recommendations and provide venues for community discussion and response. The list of committee members and the terms of reference appear in Appendix C. The committee held its first meeting in April 2009 and launched its effort at the AMS Community

Meeting held in Norman OK in August 2009. Subsequently, six working groups were formed and populated in the fall of 2009 with first meetings of these groups at the Annual AMS Meeting in Atlanta in January 2010. Since that time the working groups have been busy addressing the 15 recommendations in the NRC report.

Purpose of this Report

In preparation for the initial "Summit of Stakeholders" recommended in the NRC report, the ad hoc committee decided that options for organizing a nationwide network of networks needed to be written down along with other aspects needed to implement such a system in the United States. In so doing, it made sense to dissect the 15 recommendations, discuss them in context of present and future directions, identify options for implementation and recommend future courses of action, if any. The following sections are intended to do just that. Individual working group reports appear in appendix A and were used in part to formulate the responses in the main body of the report.

Executive Summary

The AMS ad hoc Committee on the Nationwide Network of Networks (NNoN) and its working groups have spent a year and a half at this writing (late 2010) going through the NRC report, discussing it in detail and developing options and recommended actions for responding to the 15 recommendations in the report. **The committee shares the vision of the NRC study that ultimately a "central authority" is required for the success of any nationwide network of networks**. A pathway to achieve this goal is recommended in the following sections. Traditional public−private−academic relationships will need to adjust to this new way of doing business — this will be a challenge for the entire community.

Other key recommendations include the following:

- A stakeholders summit should be convened at an early date to foment the NNoN initiative and continue the momentum achieved to date. Implementation plans should be a follow-on result of this summit.
- As funding for a NNoN will be a challenge, it is recommended that an implementation strategy be developed that prioritizes systems based on their economic benefits [e.g., it was evident that systems to improve observations of the earth's boundary layer would benefit multiple users (wind energy, aviation, forecasting onset of convective activity) and should be given a high priority].
- Ongoing R&D and treating all networks (new and old) as perennial testbeds will be essential to success in constantly assessing and improving the member

networks of the NNoN and developing new and innovative methods for observing Earth's boundary layer.

- That the **N**ationwide **N**etwork **o**f **N**etworks (NNoN) adopt the Unidata **L**ocal **D**ata **M**anager to provide the communications backbone for the NNoN.
- Metadata will be mandatory for applying data from the NNoN and an ISO and SensorML standard is recommended as schema to document data to enhance stakeholder usage of NNoN datasets.
- The human dimension must be considered when developing the NNoN and is key to engaging stakeholders and network operators as the market is developed. User assessments and education will be key parts of this effort.

Response to NRC Recommendations

Group A RECOMMENDATIONS: STEPS TO ENSURE PROGRESS

NRC Recommendation 1: Stakeholders, including all levels of government, various private-sector interests, and academia should collectively develop and implement a plan for achieving and sustaining a mesoscale observing system to meet multiple national needs.

Discussion

The NRC study group envisioned the development of an "…overarching national strategy to integrate disparate systems from which far greater benefit could be derived…" To do this a consensus-building process is needed to bring together the entire community of users, providers, and beneficiaries to collaborate on implementing a Nationwide Network of Networks.

Implementation Options

AMS formed an ad hoc committee to respond to the NRC report. One of its primary terms of reference (see appendix C) is "**A plan for a summit of stakeholders will be developed".** This report is a roadmap for planning such a summit. A number of activities should be planned leading up to it. These include identification and contact with most if not all of the stakeholder groups. Small meetings could be established with selected stakeholders and attendance at stakeholder conferences and meetings should be considered. The AMS is taking a leading role in this effort. The Commission on the Weather and Climate Enterprise, through its Board on Enterprise Communication, is planning a Stakeholders Summit at a future date.

Recommended Actions

The ad hoc committee recommends a Stakeholders Summit, as originally planned by the AMS, be held with active participation by a broad range of interested parties. Preparation for and promotion of the summit is extremely important, and it is vital that the information in this report is disseminated and understood by the potential attendees. Follow-on activities subsequent to the summit should initially include development of a detailed implementation plan. Plan developers should come from a cross section of all of the stakeholders and could operate under the joint oversight of AMS, OFCM and UCAR.

NRC Recommendation 2: To ensure progress, a centralized authority should be identified to provide or to enable essential core services for the network of networks.

Discussion.

While recognizing the importance of the function of each disparate network, the means of coming together to organize an overarching, Nationwide Network of Networks requires a centralized body to fulfill NNoN objectives. In the NRC Report this was referred to as a "Central Authority". Extensive discussion of this term has resulted in calling this entity a "NNoN Steering Group". Functions of a NNoN centralized authority or steering group are focused on the adoption of relevant technical standards for NNoN participants, coordination of NNoN activities and incentives among the major sectors (public, private, and academia), sustaining of efforts to fulfill NRC report recommendations, and developing broadly and deeply the market for mesoscale observations. When constituting a centralized authority or steering group, consideration should be given to broad inclusion of stakeholder interests and to scalability as the organizational structure moves toward maturity. Key to success will be an organization that facilitates the provision of essential core services such as identified in the NRC report. The "Central Authority" recommended in this report and elaborated upon in our response to NRC Recommendation 7 below should have the following functions and responsibilities as highlighted in the NRC report:

- Standards approval and repository control
- Metadata Definition
- Data Certification
- Routine Requirements Review
- Communications pathways definition and implementation
- Design and implementation of secure data systems for ready access by users
- Generation of value-added products
- Identification of pathways to sophisticated value-added products
- Identification of pathways to data providers
- Establishment of links to the National Climatic Data Center (NCDC)
- Development and provision of software tools for data searches, information mining and bulk data transmissions
- Development of limited sets of applications software for multiple purposes
- Provision of data quality checking services

The following illustration (Figure 1) represents the role of a central coordinating body to create and maintain a marketplace for data exchange.

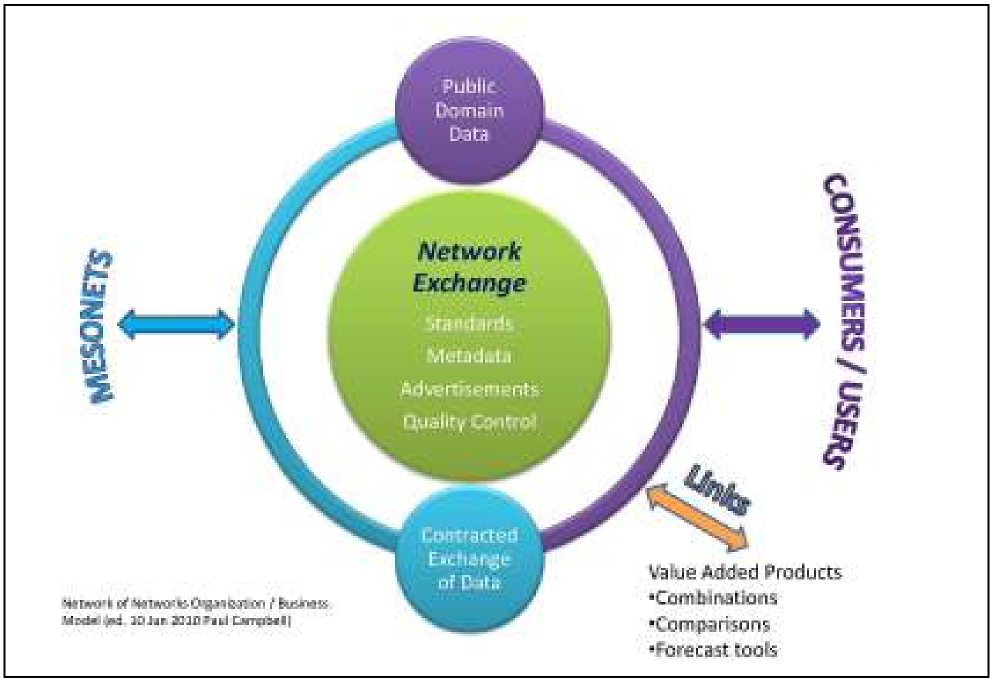

Figure 1. The Data Marketplace

Implementation Options

Initial working group discussions assessed the strengths and weaknesses of the various models discussed in Chapter 7 of the NRC report. The option of a viral model was seriously discussed as an initial phase during which stakeholders' interests could develop and emerge. The weakness of this model is that it lacks a centralized interface organization as a means of fulfilling the important functions mentioned above. Thus, we concluded that a strong central steering group should be the desired goal if the core services identified above are to ever be implemented. Figure 1 presents a straw-man organizational structure and figure 2 depicts a potential internal organization that provides the framework for executing and managing the essential core services. While the coordinating groups are not fleshed out in this report, their charter and ultimate structure should be a task for the implementing planning group that should be a follow-on activity to this review.

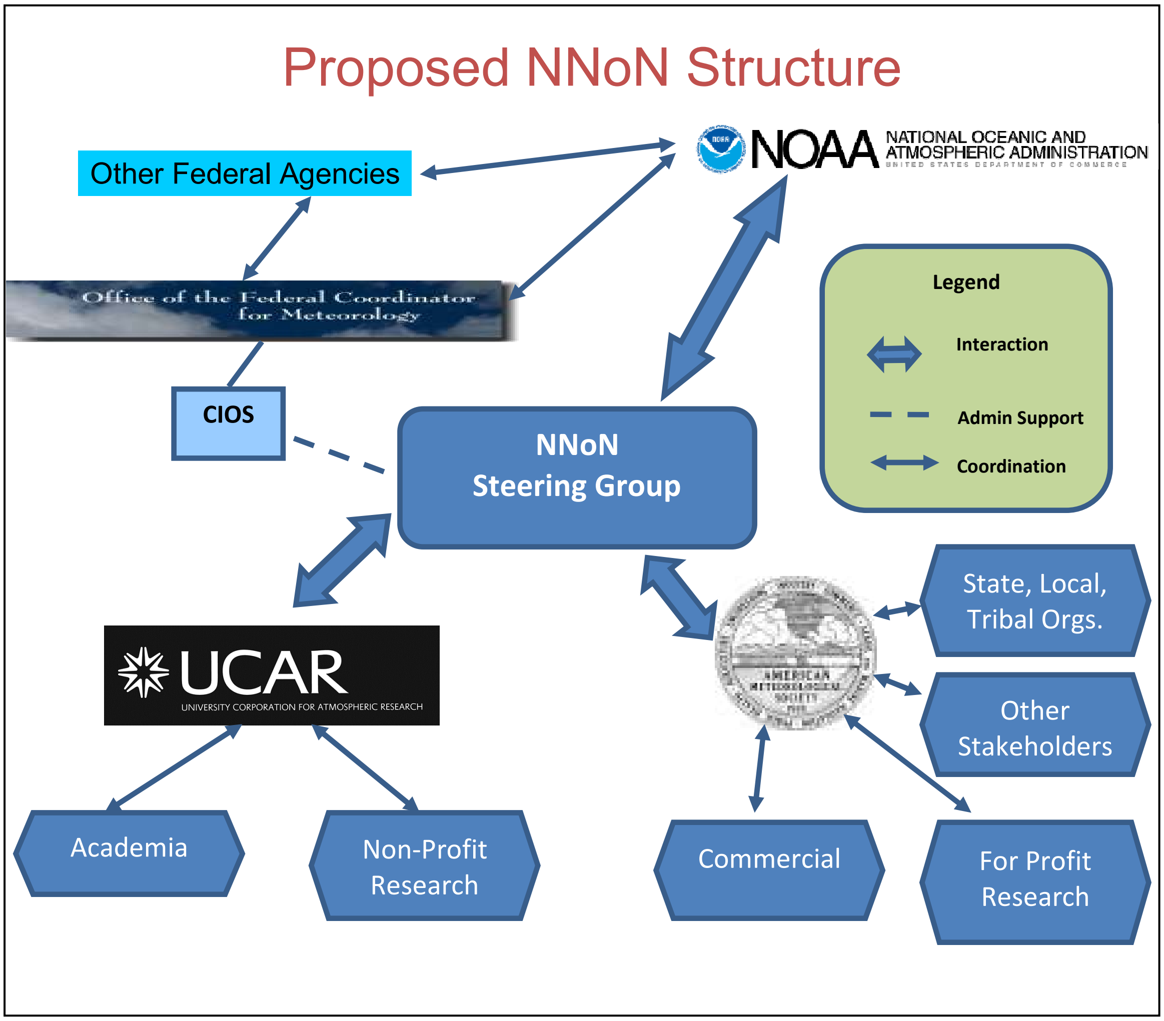

Figure 2. NNoN Central Authority/NNoN Steering Group Concept

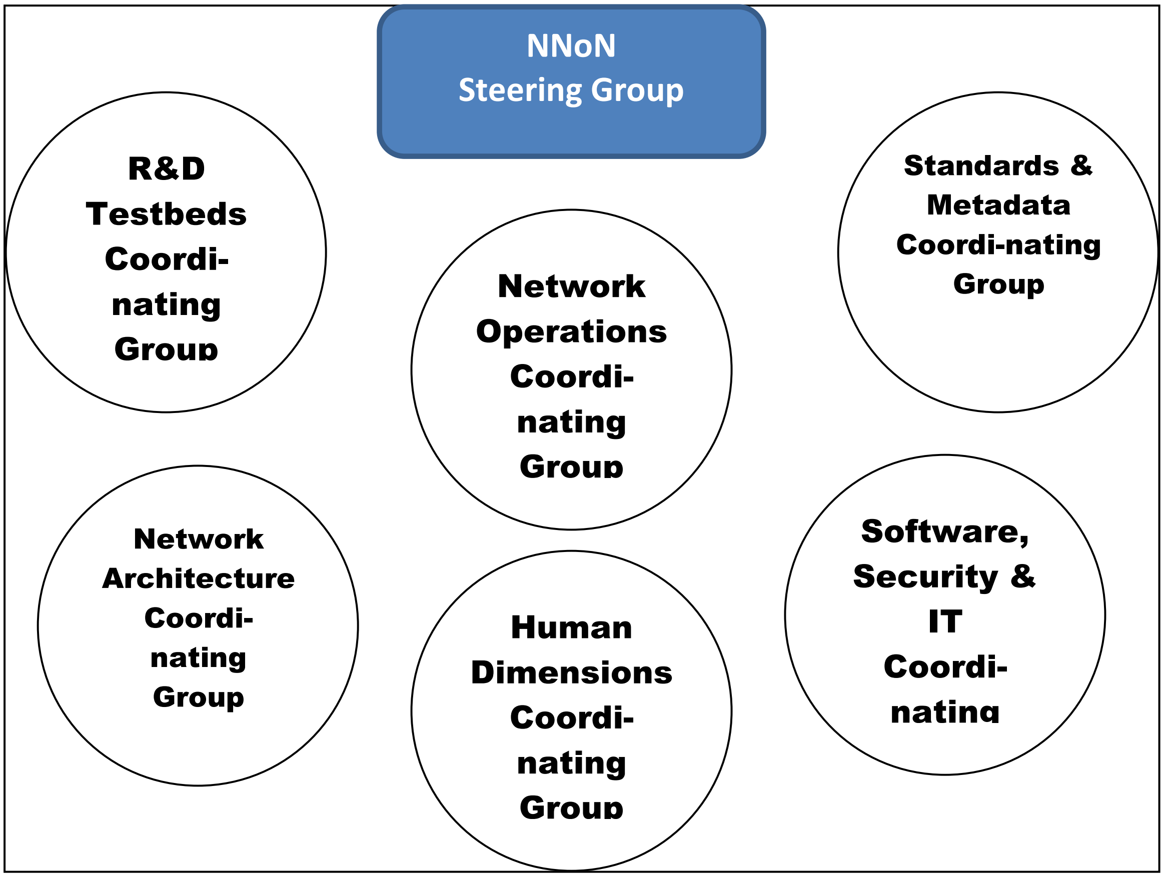

Figure 3. Central Steering Group and Potential Working Group Structure

Recommended Action

- Move forward with the creation of a centralized authority as further outlined in NRC Recommendation 7 below, whose purpose is to **"Meet societal needs by developing, maintaining, and expanding the market for mesoscale weather, climate, and** environmental observations in the United States."

NRC Recommendation 3: The centralized authority should require metadata of every component in an integrated, multiuse observing system.

Discussion

When few organizations operated networks, it was possible to contact technical experts with each organization to get information about *who* operated the network, *what* data were available, *where* and *when* the dataset extended, *why* the network was developed, *how* the data were quality assured, etc. Today, however, machine-to-machine information exchange is necessary to obtain data and metadata, use them appropriately for the application, and produce and deliver a product, all within seconds. In addition, decision makers across a range of important economic sectors are asking questions about climate variability and change that require extraordinary data and metadata stewardship. Metadata collection, maintenance, and archival according to interoperable standards is critical to that stewardship.

Implementation Options.

A host of options are available for sets of metadata elements, or "metadata schema," that describe environmental data. To enhance the exchange of metadata, user communities or oversight committees typically provide "crosswalks" that map the elements, semantics, and syntax of one metadata scheme to another. Examination of metadata standards used by weather and climate networks and integrated observing systems (e.g., Integrated Ocean Observing System, Global Earth Observation System of Systems) highlighted the convergence of environmental data communities toward ISO 19115-2 as a metadata content standard and SensorML as a metadata process standard. Crosswalks have been developed between these standards and others to enhance interoperability. In addition, the following organizations have adopted or endorsed ISO 19115: World Meteorological Organization, American National Standards Institute, Open Geospatial Consortium, European Commission's Infrastructure for Spatial Information in the European Community, and the Federal Geographic Data Committee. Education, best practices, and better tools are needed for the weather and climate enterprise to make best use of these metadata standards

Recommended Actions.

Recommendation #1: In coordination with other organizations within the broader atmospheric and oceanic sciences community, the AMS should provide opportunities for its members to become better educated on the nomenclature, structure, and implementation of metadata and the standards recommended below.

Recommendation #2: The AMS should adopt ISO 19115-2 and SensorML as the metadata standards for the Nationwide Network of Networks.

Recommendation #3: The AMS should establish a permanent committee to serve as a body of experts from academia, the private sector, nongovernmental organizations, and local, state, tribal, and federal governments to provide advice to organizations working to implement a Nationwide Network of Networks and to coordinate with the Federal Committee for Integrated Observing Systems.

NRC Recommendation 4: A national design team should develop a well-articulated architecture that integrates existing and new mesoscale networks into a national "network of networks."

Discussion

When there were only a few organizations operating networks, it was possible to make the appropriate technical contacts to gather enough information about a network's design, operation and construction to allow a new network to be effectively constructed. As soon as more than a few networks began to interoperate this informal method was no longer a cost-effective or reliable means to design, construct and operate a network. While recognizing the importance of the function of each disparate network, the knowledge developed by current network operators with regard to relevant technical standards cannot be ignored. In addition, the integration of reference stations that provide high-quality, long-term, and temporally dense observations across the U.S. are critical not only for the climate record, but also for comparison to other NNoN observations (e.g., temperature, precipitation, wind, soil moisture, atmospheric moisture) from in-situ and remote sensing systems. The experience developed over decades by existing climate and weather network operators provides a wealth of knowledge that the NNoN Steering Group, in cooperation with R&D/Testbed Coordinating Group, should tap to create a well-defined and articulated description of network instrumentation, construction, data structures and communications technologies.

Given this description of best practices, new networks can immediately take advantage of the hard-earned knowledge. Existing networks can then use this description of best practices to improve existing infrastructure

Implementation Options

Four specific tasks have been identified for the Architecture Coordinating Group. These tasks are: (1) Define, develop and refine the communications technology allowing meteorological data to pass between networks. (2) Define, develop, and refine data quality and availability standards. (3) Define, develop, and refine quality control procedures. (4) Define, develop, and refine data structures to effectively transfer data between networks, applications, and end users. The most critical activity is defining and refining the communications technology. Although existing networks use a wide variety of communications technologies to great advantage, none of these technologies are effective in network-to-network communications. The communication problem is compounded by the fact that the transfer of meteorological and climatological data will most likely be bi-directional, that is individual networks will offer data as well as request data. Thus the communications technology needs to be similar to popular peer-to-peer networks. The best candidate is the UNIDATA projects Local Data Manager (LDM), designed to allow data to be passed between cooperating sites. Although LDM is currently used in a tree-branch configuration, the underlying technology allows for sites to request as well as offer data. LDM requires consent between participating sites allowing an additional layer of security to the communications channels.

As noted above, existing climate or weather network operators have a wealth of information about the kinds of instrumentation that is most effective both for solving specific problems and for obtaining high-quality observations. By pooling this information with the R&D/Testbed group, NNoN Steering Group members can plan with their funding agencies for modernization and upgrade of their existing networks, knowing that much, if not all, of the testing, validation, and price/performance issues have been examined in detail. Given this base information about network instrumentation new networks will have means to justify instrumentation selection and costs to their funding agency.

A key component to the success of any network is a clear understanding of the quality of the data and its availability; this is crucial to the success of the NNON. Working in cooperation with the Metadata working group, the Architecture Working Group should provide the formal means to communicate the level of confidence attached to data from each network and its availability. New and operating networks have a specific set of objectives in terms of the variables measured and their spatial and temporal resolution. This information is crucial to any user of this data. To make informed decisions about how networks data can be used these factors must be clearly documented and understood. Because of the significant investment that public and private sector organizations make in their observing systems, it is desirable that all network operators attempt to obtain high-quality data and provide them in real-time to users to enhance data usage across a wide range of communities and users. Hence, quality standards for each measured variable should be established by the climate community, including the National Climatic Data Center (NCDC), state climatologists, and private sector companies with climate-quality data needs, and availability standards should be established jointly by the weather and climate communities, including the National Weather Service (NWS), NCDC, and private sector companies with real-time data needs. This description of the level of confidence and availability doesn't judge any existing or new network; it merely provides the users of the data from a network the means to understand how the data can be used. This information should be part of the metadata associated with any data from a network. Choosing the correct data structures (see task #3 above) would allow the metadata to be attached to each piece of data from a network, keeping all the information in a single file. Depending on the amount information contained in the metadata, there should little impact on the associated size and transfer rates.

A second component key to the success of the NNoN are the quality control procedures to flag questionable data. Although current networks employ homegrown Quality Control procedures that perform well given their very specific definitions, taking advantage of the lessons learned by existing climate and weather network operators to create best practices for both new and existing operators would improve the overall quality of the data from these networks. Although the National Weather Service has a very detailed description of the quality control standards for existing data sources, these standards are unlikely to be applicable to the spatial and temporal resolutions associated with mesoscale networks. A users group with members from university, National Weather Service, National Climatic Data Center, and privately run networks, along with members of Architecture and R&D/Testbed working groups, should be created to draft and maintain standards applicable to the NNoN.

As noted above the data structures need to be clearly defined in order for data to be transferred between networks. There are sufficient differences in computer hardware and communications technologies to make any form transfer (except in the form of ASCII characters) impossible. This is a well-known and understood problem in the meteorological community and existing data structures exist to allow efficient transfer. Currently GRIB, NETCDF, and HDF are commonly employed. There are several advantages to using NETCDF or HDF data structures as they are self-describing and allow metadata to be incorporated. New instrumentation developed by the R&D/Testbed may require modifications to these data structures in the future, but the existing forms are capable of handling a much wider range of instrumentation than commonly in use

Recommended Actions

- The Architecture Working Group should provide a formal means to communicate the level of confidence attached to data from each network and its availability, incorporating data quality standards of the climate community and data availability standards of both the weather and climate communities. The NNoN should integrate quality control procedures to flag questionable data. Recognized standards, such as the Global Climate Observing System (GCOS) Climate Monitoring Principles, are highly recommended.

- It is expected that as the implementation of the NNoN progresses, new tasks will become apparent and the need for further action on some of the four aforementioned tasks will no longer be necessary. Thus some structure within the NNoN Steering Group should be created to guide further actions by the Architecture Working Group. A structure similar to UNIDATA's users committee should be created to guide further and gain feedback on the effectiveness of the methods and documentation.

- It is recommended that the findings of the Architecture Working Group be regularly updated and published for ready access by all stakeholders.

- It is recommended that the Architecture working group help support educational, training and community outreach opportunities. Thus new networks would have a focal point to gather information.

NRC Recommendation 5: The national network architecture should be sufficiently flexible and open to accommodate

auxiliary research-motivated observations and educational needs, often for limited periods in limited regions.

Discussion

The Architecture Group addresses the aspect of the flexibility of the Nationwide Network of Networks (NNoN) as part of Recommendation 4, through the utilization of such tools as the Local Data Manager (LDM). Such tools will offer the flexibility to accommodate additional research-motivated measurement variables. The R&D/Testbeds Working Group addresses Recommendation 5, specifically from the standpoint of research-motivated observations, educational needs, etc. Operating networks have a specific set of objectives that determine the variables to be measured, along with the spatial extent, horizontal and vertical resolution, and temporal frequency with which they are measured. For example, the primary mission of climate reference networks is to obtain very accurate measurements of temperature and precipitation and their changes over time; hence, they may serve as geographically distributed locations for temperature and precipitation intercomparisons in a NNoN. If a network's measurements include variables that perhaps were motivated initially for research purposes (e.g., experimental field campaigns), these measurements should be evaluated by national laboratories, universities, and private companies with expertise on the specific instrumentation. In addition, these evaluation efforts to be conducted will be coordinated by an R&D/Testbeds Coordinating Group within the NNoN. If these additional variables are proven to be effective from the standpoints of mesoscale representativeness as well as cost, such variables will become part of the new measurement standards.

The R&D/Testbed Coordinating Group will work with the evaluating research entities in defining mesoscale representativeness from the standpoint of prevailing mesoscale processes, for example, in coastal, mountainous, urban areas, within and surrounding a network. The R&D/Testbeds Coordinating Group will also help disseminate these findings, with the help of the evaluating bodies, to all stakeholders through reports/publications.

In addition to coordinating with research teams around the country in evaluating the effectiveness of other additional variables for newer standards, the R&D/Testbeds Coordinating Group will offer educational, training, and community outreach opportunities from a research standpoint. If the NNoN is engaging in such educational, training, and community opportunities from other standpoints (e.g., Metadata group or Human Dimension group), then the R&D/Testbeds Coordinating Group will combine its efforts with the other NNoN groups to achieve the overall educational, training, and community outreach objectives of the NNoN.

Implementation Options

Four specific tasks have been identified for the R&D/Testbeds Coordinating Group. These tasks are: (1) developing definitions of mesoscale representativeness of every network, (2) constantly improving network mesoscale representativeness, (3) coordinating/evaluating efforts to standardize measurement of additional variables, and (4) developing manuals and procedural documents. These tasks are described in Appendix A.

Two seemingly viable options available to the Nationwide Network of Networks are outlined here briefly with respect to the R&D/Testbeds Coordinating Group tasks. The preferred option for the R&D /Testbeds Coordinating Group may be to engage in coordinating new research efforts with research entities and in utilizing existing research studies conducted by other research groups using measurements collected within networks. For example, the observing system simulation experiments (OSSEs) by NOAA will provide the basis for evaluating the impact of measurements of additional variables on the effectiveness of mesoscale observations, primarily for short-term (0-10 days) weather forecasting. As part of this option, the R&D/Testbeds Coordinating Group may engage other groups (e.g., Universities) to support the tasks of educational, training, and community outreach functions.

As the NNoN transitions into a more mature NGO over the coming years, the R&D/Testbeds Coordinating Group may recognize and develop some of the above-mentioned research and educational functions within the NGO itself. This option may be explored as the evolution of the NNoN creation of a NNoN Steering Group (centralized authority) takes place, a recommendation made in the NRC report.

Recommended Actions

- The R&D/Testbeds Coordinating Group should help facilitate newer "research" quality data collection efforts and incorporate some of this newer data output as part of standard network data output.
- The research findings of the research entities should be published for ready access by all stakeholders.
- The R&D/Testbeds Coordinating Group should help support educational, training and community outreach opportunities.

NRC Recommendation 6: Federal agencies and partners should employ testbeds for applied research and development to evaluate and integrate national mesoscale observing systems, networks thereof, and attendant data assimilation systems. Among other issues, testbeds should address the unique

requirements of urbanized areas, mountainous terrain, and coastal zones, which currently present especially formidable deficiencies and challenges.

Discussion

The stakeholders of the Nationwide Network of Networks (NNoN), managed by a Steering Group (Centralized Authority), are advised to evaluate the networks, via testbeds as necessary, for their mesoscale observational capabilities and effectiveness. The question, "How should these networks be characterized for their mesoscale observational capabilities and effectiveness before and after integrating them into the Network of Networks?" needs to be addressed by the NNoN Steering Group.

Mesoscale observational capabilities and effectiveness may be related to the density of the network measurement platforms and their strategic locations, length of the observational record, and the frequency of these measurements. Are different variables being measured by a network put into their proper contexts with respect to their spatial and temporal measurement frequency? For example, some variables (e.g., wind speed) may need to be measured more frequently, at higher spatial and vertical resolution and at multiple heights for boundary layer profiling than for other variables (e.g., soil moisture and temperature, atmospheric moisture). Also, how should the measurement strategy change with respect to the location of the network itself [i.e., whether the network resides in a simple terrain environment or in a complex terrain environment (e.g., a mountainous region, an urbanized location, a coastal zone)]?

These are some of the most important questions to be answered by the NNoN Steering Group. The R&D/Testbeds Working Group recognizes that many of these questions cannot be answered all at once or for all networks in the same manner. Nor can they be answered with regards to all of the variables measured by the networks that have already been built or will be built in pursuit of integration into the NNoN. In other words, considerable network-specific research, conducted over a period of time, will be necessary to perform this critical function. Currently available network-specific research knowledge, such as with existing weather and climate reference networks, should be applied to NNoN network architecture, including data quality and availability standards, while a continued research process on these (typically) core variables should be encouraged. The R&D/Testbeds Working Group recommends that an R&D/Testbeds Division be created within the Centralized Authority and the Architecture Group or Division closely works with the R&D/Testbeds Division, to receive the necessary research and guidance to successfully integrating these networks into the NNoN successfully.

To develop the necessary research and guidance, an R&D/Testbeds Coordinating Group will be established to coordinate testbed development efforts. The R&D/Testbeds Working Group recognized that there is no standard definition of what constitutes a testbed. In other words, testbeds are defined as those networks that offer the ability to test various aspects of measurement networks. For example, one can define sensor performance testbeds, network performance testbeds, forecast performance and impact testbeds, etc. Along these lines, testbeds may be defined to determine mesoscale representativeness, which clearly depends on the location of the network and the mesoscale processes prevalent within and surrounding the network. For example, in the context of climate-quality observations, the climate reference networks, overseen by NOAA, can serve as a geographically distributed testbed sites for many different mesoscale environments across the U.S. Since mesoscale representativeness is one of the least understood but one of the most critical aspects of the Network of Networks, a recommendation is made to consider every one of the networks that gets integrated into the NNoN an ongoing R&D testbed, with additional testbed attributes, such as sensor performance, forecast impacts, etc., as the case may be, other than mesoscale representativeness. In other words, the aspect being tested for considering every network a testbed is its mesoscale representativeness. As the mesoscale representativeness of a network evolves constantly over time, each network becomes a perennial testbed.

The R&D/Testbeds Coordinating Group will work with research laboratories, universities, and private companies, in evaluating current testbed attributes from mesoscale representativeness as well as others and recommending cost-effective augmentation to achieve increased measurement effectiveness.

Implementation Options

Four specific tasks have been identified for the R&D/Testbeds Coordinating Group. These tasks are: (1) developing definitions of mesoscale representativeness of every network, (2) constantly improving network mesoscale representativeness, (3) coordinating/evaluating efforts to standardize measurement of additional variables, and (4) developing manuals and procedural documents. These tasks are further described in Appendix A.

Two viable options available to the Nationwide Network of Networks are outlined here briefly with respect to the R&D/Testbeds Coordinating Group tasks. The first and the preferred option, as part of Task1, is for the R&D/Testbeds Coordinating Group to work with other research groups (laboratories, universities, and private companies) in understanding mesoscale representativeness of networks and in defining levels of such representativeness through ongoing research. In other words, this effort may start out as an ad hoc approach, requiring minimal or no network specific research. The R&D/Testbeds Coordinating Group may rely on review panels to accomplish this task. To accomplish Task 2, the R&D/Testbeds Coordinating Group must resort to a period peer-review process to track improvements in network mesoscale representativeness.

With respect to Task 3, the R&D/Testbeds Coordinating Group may choose to engage research institutions such as universities, national laboratories, and private companies to receive the required research support with respect to collecting research quality data and using the existing networks as R&D testbeds and for educational purposes.

Instead of developing several procedural documents (manuals) itself, the NNoN would have an option to utilize documentation developed by a few of the successful network operators (e.g., the Oklahoma Mesonet, the Kentucky Mesonet, NOAA's Climate Reference Network, DOE's Atmospheric Radiation Measurement program).

Because of the expected uniformity and successful integration goals for all networks of the NNoN, as recommended in the NRC report, a second option may be considered in which some of these tasks may be accomplished within the R&D/Testbeds Coordinating Group.

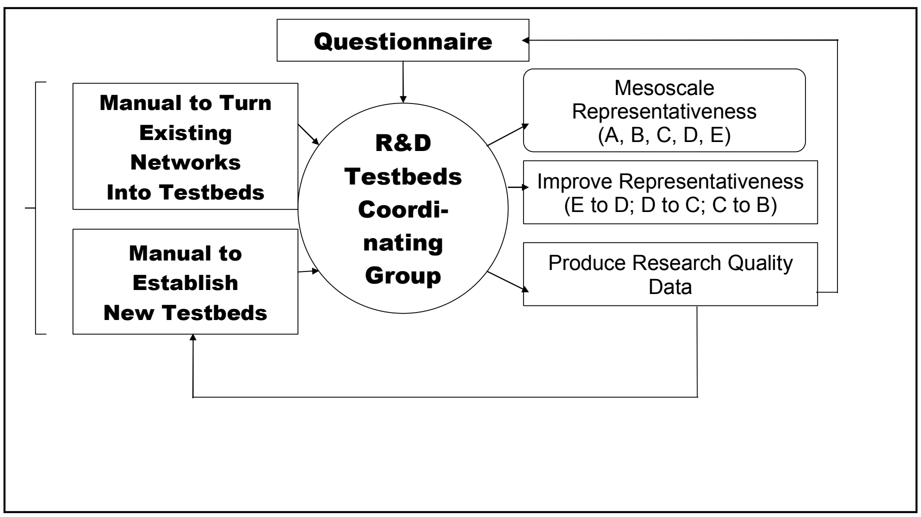

Figure 4. R&D Coordinating Group Tasks

Recommended Actions

- The importance of every network (existing or new) should be recognized as a perennial R&D testbed.

- An R&D/Testbeds Coordinating Group should be formed within a Centralized Authority. See Figure 3 for straw man tasks.

- Mesoscale representativeness must be recognized, established, and improved upon through ongoing research.

- The limitations of limited measurements should be recognized

NRC Recommendation 7: The United States should establish a robust and economically viable organizational structure to effect the national implementation of a multipurpose environmental observing network at the mesoscale. It may be preferable for this organization to take the form of a publicly chartered, private nonprofit corporation. A hybrid public–private organizational model would stimulate both public and private participation over a wide, dynamic range of investment and applications; maximize access to mesoscale data; and affect a synergism between the public good and proprietary interests.

Discussion and Implementation Options

A Nationwide Network of Networks involves a variety of interests spanning the public, private, and academic sectors. The NRC report recommendation to incorporate is a complex structure to initiate and to administer and relies on a substantial congressional mandate. Because of this lack of scalability, it is important to identify one or more alternatives in the near term that will bring interested parties to a common table, but allow independent development and initiative by the respective sectors. As stakeholders identify themselves and their roles, more sophisticated organizational structures can be considered to address emerging needs in the public sector and cultivate economic opportunities in the private sector. The first step to organize a NNoN governing body without incorporation still requires some sponsorship. Implementation is complicated by the scope of a NNoN extending to multiple societal sectors (public, private, and academic). If a single individual or entity in one sector acts without other entities, there are risks of inadequate resources being available and a lack of momentum that involves a critical mass of stakeholders. If one sector acts without other sectors, then a significant number of networks would be left on the sidelines. A preferred option would be for each sector to take an achievable step in coordination with the other sectors, and the step in each sector should be inclusive and inviting to potential stakeholders in the NNoN.

Recommended Actions

- Take the first step toward formal NNoN organization with a form of the Confederation of Federal Agencies alternative identified in the NRC report, with NOAA as the lead agency.
- Add to this alternative a NNoN advisory board (initially identified in this report as a NNoN Steering Group) able to provide input and direction from the stakeholder communities of regional, state, and local mesonets, private weather and climate reporters, forecasters, and consultants, and the related academic and research community.

- Encourage the formation of a thematic chapter of the AMS to develop the market for mesoscale climate and weather observations by supporting metadata standards adoption and a coordinated means of data discovery.
- Engage academia, including universities that operate mesoscale observation networks for state and local purposes, for research and education as well as exchange of available mesoscale observations.
- Let the NNoN related governing bodies in AMS and UCAR constitute nominees for a NNoN Steering Group.
- Maintain a policy of free and open availability of observations from all publicly owned assets.
    - Distinguish between core public data needs such as air traffic control, public safety, and emergency management, and supplemental public data needs such as industry independent forecast model improvement, general weather forecasts and climate predictions, and geographic in-fill for improved spatial resolution, consistent with related discussions among NOAA (including the NNoN Steering Group) and private weather and climate service providers.
    - Let the Federal Government further encourage the development of an open and competitive market for mesoscale observations by purchasing those data that fulfill some core and supplemental federal data needs as may be available on reasonable and competitive terms.
    - Let federal, state, and municipal government bodies equitably bear costs of shared networks that address mutual vital needs.
- Figure 4 graphically describes an organizational structure for coordinating the interests of the different sectors discussed above.

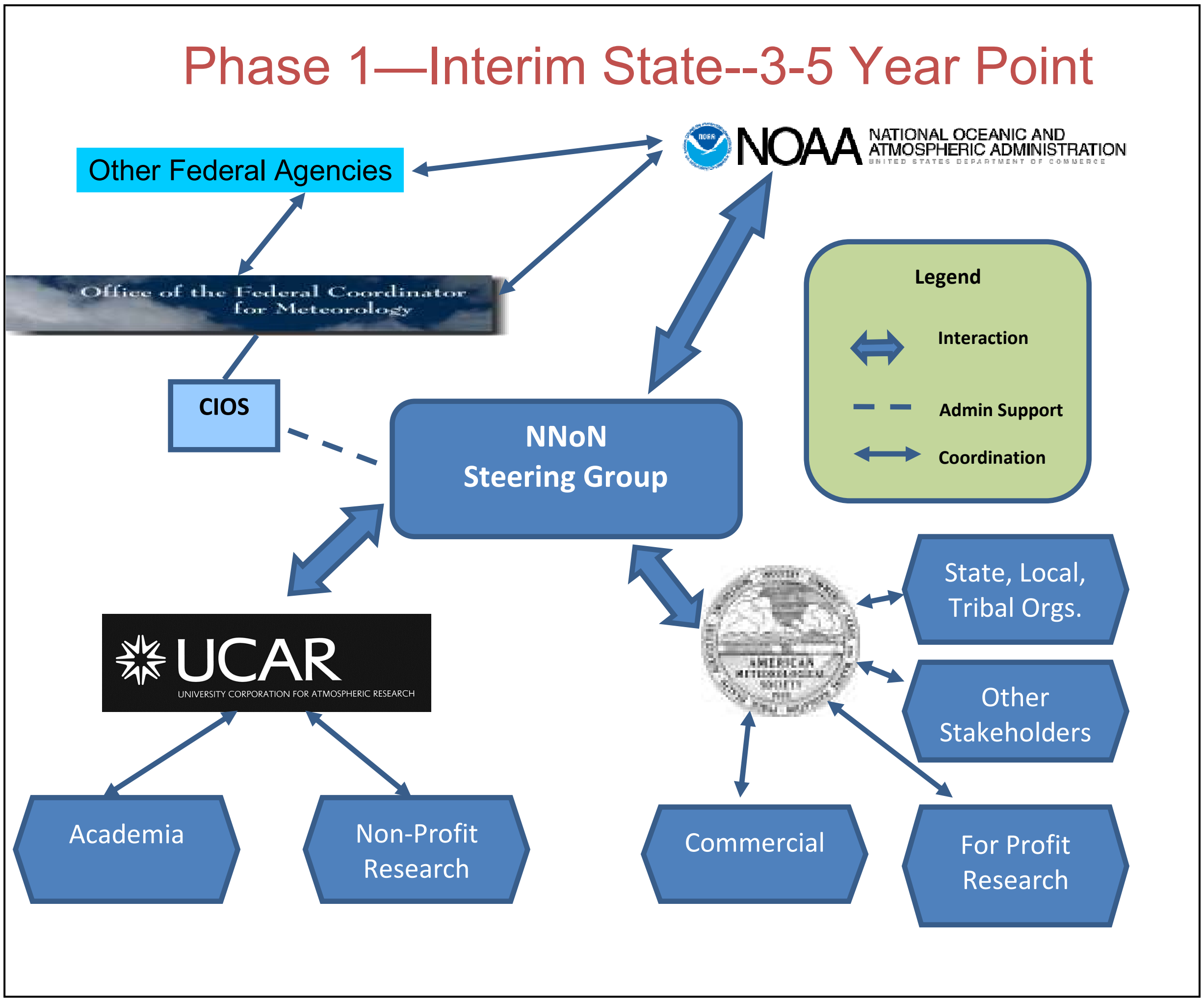

Figure 5. Proposed Interim NNoN Central Authority Organizational Option

In this initial state, the NNoN Steering Group will function as the "Centralized Authority" to adopt relevant technical standards for NNoN participants, coordinate NNoN activities and incentives among the major sectors (public, private, and academia), sustain efforts to fulfill NRC report recommendations, and develop broadly and deeply the market for mesoscale observations. At such time as sponsorship is available to incorporate, the NNoN Steering Group will become the initial Board of Directors of a private, nonprofit corporation. A notional final organizational structure is presented in Figure 5. Initial functions and responsibilities of each element are as follows:

Functions and Responsibilities of the elements of this structure are proposed as follows:

NNoN Steering Group

- Advisory Committee to help maximize value of public sector investment
- Management and execution of basic NNoN core services
- Implementation and refinement of the Business Model
- Liaison among three bodies

- Fulfillment of NRC report objectives

UCAR
- Open Source Development Host for data exchange software
- Advisory Committee nominations
- Research and education resource
- Research lead for academia

Federal Government
- NOAA
    - Lead Government Agency
    - Advisory Committee nominations
    - Research lead for federal agencies
    - Resource for climate and weather observing system guidance for networks
- OFCM
    - NNoN related Federal agency coordination through the Committee for Integrated Observing Systems (CIOS)
    - Administration of Advisory Committee under the Federal Advisory Committee Act (FACA)
    - Determining interagency needs and priorities and working to achieve them
    - Leveraging Federal agency's technology / capability
    - Coordinating and setting Federal agency standards, including data formats

AMS
- Sponsor of NNoN Chapter
    - Membership from private, academic, and public entities and individuals
    - Conduit for private sector, state, local governments, tribes, etc.
- Advisory Committee nominations
- Commercial and educational promotion
- Encourages use of Open Software for data exchange

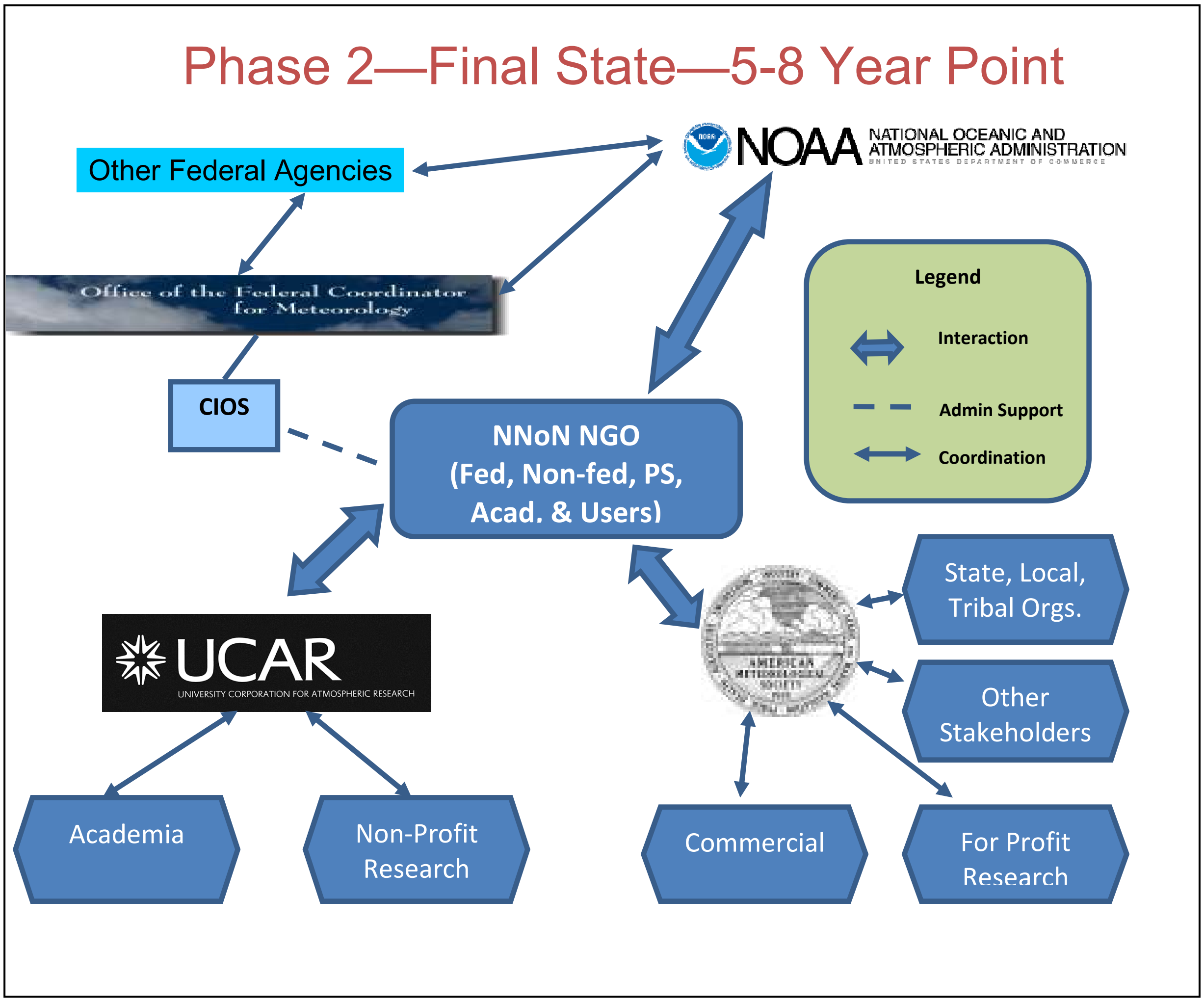

Figure 6. Proposed Final NNoN Central Authority Organizational Structure

The timeline to establish the NNoN NGO could be 5−8 years from inception. It will most likely require congressional action and will demand a solid business model for success. Interim states can take several pathways. The interim structure could become a FACA which may take 3−5 years from inception and there are many roadblocks to readily forming one. Other suggestions have included: 1). Forming a FFRDC-like organization (FFRDC=Federally Funded Research and Development Center); 2). Use of the National Research Council (NRC) and/or the National Academy of Public Administration (NAPA) as a startup core for the NNoN Steering Group; and 3). Using the AMS in this capacity until the NGO is up and running. The Stakeholders will need to consider various options as a pathway to the NGO during implementation planning.

Group B RECOMMENDATIONS: MEASUREMENTS AND INFRASTRUCTURE

[Group B provides individual responses to NRC Recommendation 8-14 below. However, no prioritization is provided for these new starts. Initial efforts should be directed towards the fundamental process of bringing existing elements together into a NNoN.]

NRC Recommendation 8: As a high infrastructure priority, federal agencies and their partners should deploy lidars and radio frequency profilers nationwide at approximately 400 sites to continually monitor lower tropospheric conditions

Discussion

The requirement for continuous monitoring of the lower tropospheric conditions, particularly the earth's boundary layer, is key for several sectors. Wind climatologies and real-time wind observations in the boundary layer are needed for improved siting and operation of wind farms in the renewable energy sector. The aviation sector requires better low-level wind information for detection of turbulence over airports. NOAA needs additional monitoring of low-level winds for improved prediction for the onset of convective activity. Current understanding of how to use radar wind profilers is based mostly on hourly data products – therefore use of these systems has been limited. New systems produce high-resolution products, but because this capability is not widely known, there is not much political will to fund more systems. NWS produced a well-received Cost and Operational Effectiveness Analysis completed several years ago. This was a document that actually helped save the NOAA Profiler Network from extinction. As a result, NWS is currently in the process of modernizing their profiler network, but current funding levels will only acquire 30−35 of the systems. This is a problem even with the results of a report to Congress in 2009, "Expanded National Profiler Network (NPN) Cost−Benefit", which recommended deployment of a 120-site network at a cost of $240 million, plus $24 million in annual operations and maintenance costs. The report's conservative estimate was that an expanded NPN would improve the $30 billion annual U.S. public benefit of weather forecasting by at least 10%.

Recommended Actions

An expanded NOAA Profiler Network would play a critical role in meeting the needs for higher resolution data in the lower atmosphere where severe weather originates and satellite sensing capability is currently limited. Based on the figures discussed above, the benefit-to-cost ratio would be 60 to 1 for the first 10 years of operation. With this proof of economic benefit, the Department of Commerce, through NOAA, should request and Congress should appropriate sufficient funds for deployment and operation of the full 120-site NOAA Profiler Network. Climate-quality observations of the surface atmosphere and soil need to be taken at these sites in conjunction with boundary layer observations.

NRC Recommendation 9: To meet national needs related to public health and safety, including the growing need for chemical weather forecasts, a core set of atmospheric pollutant composition parameters should be part of the mesoscale observing system. The core set should include carbon monoxide, sulfur dioxide, ozone, and particulate matter less than 2.5 microns in size at approximately 200 urban and rural sites (~175-km spacing).

Discussion

In a January 2010 report, “Air Quality Observation Systems in the United States”, prepared by the Committee on Environmental and Natural Resources (CENR), Air Quality Research Subcommittee (AQRS), the study reported that “Several hundred million dollars are allocated annually by a number of federal agencies, together with state and local partners, to maintain and operate the nation’s fixed monitoring networks, short-term field studies, and satellite remote sensors. However, the full value of data from these efforts is not realized. Each type of observation has inherent limitations. Institutional barriers and resource limitations currently impede our ability to maintain observational capacity, synthesize observations of various types and from different agencies, and adapt current systems to meet observational needs as our understanding of air quality improves and the atmosphere changes”. In listing observational needs and issues, the same report stated that the success in monitoring of reductions of CO_2 emissions is insufficient due to pollutants not well characterized by existing observation systems. In addition the resolution of atmospheric pollutant observations is not sufficient to allow models to guide air quality decisions. Finally, federal budgeting practices do not adequately address long-term maintenance and updating of this observational infrastructure.

Implementation Options

- Satellite remote sensing of air quality and emissions is rapidly maturing in its capability for spatial and temporal coverage of pollutants. Sensors for monitoring emissions and pollutants could be included when planning next generation environmental satellites.
- The NOAA U.S. Climate Reference Network (USCRN) and U.S. Regional Climate Reference Network (USRCRN) have automated sensor platforms with extensible system architecture and potential capacity to accommodate additional CO, CO_2, O_3, and SO_2 sensors. Portions of a modernized COOP Network may also be designed and deployed with this capacity.

Recommended Actions

- Both of the options listed above should be pursued.
- Federal budgeting must adequately address long-term maintenance and upgrading of the atmospheric pollutant observational infrastructure.
- As recommended in the CENR-AQRS study referenced above, a multiagency task force made up of representatives from EPA, NOAA, NASA, USDA, DOE, and DOI should be formed to:
  - identify gaps and overlaps among programs,
  - achieve coordination and establish minimum standards for program design & implementation,
  - promote the use of common data formats and communication protocols, and
  - Jointly budget and fund development and deployment of new observational technology.

NRC Recommendation 10: A national, real-time network of soil moisture and soil temperature observations should be deployed nationwide at approximately 3000 sites.

Discussion

Existing soil temperature and moisture observations are disparate and frequently unrelated. They suffer from differing protocols and metadata standards. There is no ubiquitous quality assurance/quality control across network data, nor is there a consolidated repository for all data. Not all existing networks observe soil temperature; those that do don't measure it at the same depths. However, several prominent mesonet managers recognize the importance of measuring soil temperature and moisture and have documented the economic benefits they have for agricultural decisions. NOAA has also recognized the importance of these data, particularly in "agricultural sensitive areas" and has included plans for soil measurements in the COOP Network Modernization Plan.

Implementation Options

- Soil moisture/temperature instruments have been added to the U.S. Climate Reference Network in the conterminous U.S., and the USRCRN is also capable now of hosting soil moisture/temperature instruments with existing extensible system architecture.
- Adding soil moisture/temperature instruments to the NWS COOP Modernization is highly feasible at those sites currently receiving data loggers for enhanced Hourly Precipitation Data instruments. This would bring the total platforms to the recommended 3000 sites.

Recommended Actions

- Both implementation options are dependent upon COOP Modernization and USRCRN being funded for a national deployment, in addition to funds being provided for the soil probes and their maintenance for those networks and U.S. Regional Climate Reference Network (USRCRN).
- Use the results of a Klockow et al. (2010) on the economic benefits of the Oklahoma Mesonet (with soil measurement sensors) for crop producers to support funding of either option discussed above.
- Encourage the Department of Agriculture to assist NOAA in funding for the soil measurement sensors based on their proven benefits for agricultural decisions.

NRC Recommendation 11: Emerging technologies for distributed collaborative adaptive sensing should be employed by observing networks, especially scanning remote sensors such as radars and lidars.

Discussion

Distributed adaptive sensing is a new architectural approach for organizing resources in networks having multiple sensors and multiple users of sensor data. This approach has been developed by the NSF-funded CASA Engineering Research Center as a way to enable many small radars to collectively acquire data in response to changing weather and changing user needs. Below, we discuss this recommendation in the context of both the evolution of the national network of Doppler weather radars and the emerging NNoN.

Despite the improvements in radar applications that resulted from the deployment of the WSR-88D network, a generally acknowledged fundamental limitation of today's national network is its inability to observe the lower part of the atmosphere. This is due to the several hundred kilometer spacing of the radars and the effect of the Earth's curvature and terrain blockage. More than 70% of the troposphere below 1-km altitude above ground level (AGL) is not observed by today's network. The need for increased, high-resolution radar coverage of low altitudes for improved forecasts and detections of severe winds events, tornados and floods, has been identified by several National Research Council and OFCM reports.

The NSF CASA Engineering Research Center has proposed addressing this problem by deploying large numbers of small X-band radars that implement distributed, collaborative adaptive approaches to sampling the weather and feeding the data to the various groups of users who rely on the data for decision-making. NOAA's Joint Radar planning team's technology vision (presented to the NOAA Science Advisory Board) recommends (among other topics) continued studying of gap-filling radars such as envisioned by

CASA to increase coverage; also exploring multiple wavelength radars (10-cm, 5-cm, 3-cm); and prototyping use of numerical models assimilating radar data to demonstrate warn-on-forecast. NOAA's vision document identifies the CASA program as a collaborator in ongoing research on gap-filling radars. The concept of many small radars organized in a distributed adaptive network opens up new possibilities for owning, operating, and maintaining relatively low-cost radar networks, and for combining and sharing the data with other sensors, such as the WSR-88D radars. These are among some of the key themes of the NNoN.

CASA has operated an end-to-end radar network in southwest Oklahoma to field-demonstrate distributed adaptive sensing of the boundary layer and real-time information delivery to multiple user groups. The network operates using dual polarization and achieves multiple-Doppler coverage of the boundary layer with high spatial (average 250 m) and temporal resolution (1-minute updates between radar scans). Data are disseminated in real time to local NWS forecasters and Emergency Managers as well as research-users. During four Intensive Operations Periods (IOPs) from 2007−2010, the CASA team demonstrated improved characterization of small-scale circulations and damaging wind events, more accurate quantitative precipitation estimation, and improvements in numerical weather prediction forecasts for tornadic development, and increased confidence and accuracy of user decision making. CASA plans to launch a network in an urban zone using the equipment and resources.

Lidar is an emerging technology that has resided in the research arena for a number of years but is on the brink of achieving operational status. A number of systems have found their way into airport wind shear observation systems and others are in use for monitoring atmospheric pollution.

Recommended Actions

- Continue planned improvements to extend the lifetime of the WSR-88D radar network based on the recommendation of the Joint Radar Planning Team

- Accelerate on-going research related to small distributed collaborative radars and develop candidate architectures for integrating them with the WSR-88D radars; determine costs for alternate approaches to deploying such technologies to address gaps in the present nationwide network, and develop a deployment/implementation plan.

- Pursue the establishment of a NNoN test bed that integrates CASA boundary layer radar information and other sensors for evaluation by different user groups using distributed adaptive or other suitable architecture.

- Continue research and development of lidar systems and explore integration strategies to use them as a part of atmospheric boundary layer observing system.

NRC Recommendation 12: Ground-based observations should be complimented with space-based observations to further strengthen models and forecasts. As a high satellite instrument priority, the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), in cooperation with foreign space agencies, should seek to improve the quality of geostationary satellite water vapor and temperature soundings within continental atmospheric boundary layers, thus facilitating more skillful forecasts in otherwise data-sparse areas.

Discussion

Geostationary MetSats: GOES-R Advanced Baseline Imager will have the ability to provide near-real-time mesoscale images at good (0.5 km) resolution, thus meeting many of the report's recommendations. Its estimates of assimilation of radiances, cloud drift winds, and free troposphere water vapor will enable the initialization of global and mesoscale forecast models. However, there are no plans for an atmospheric profiler sounder for GOES-R or later platforms. With GOES-R, there will be 48 times more data than with current imagers. This amount of data, combined with data from other envisioned platforms such as phased-array radar, will threaten to overwhelm the existing communications infrastructure and overload the end users.

Polar Orbiting MetSats: Current imagers provide ability to monitor conditions over data-sparse, data-denied and hard to reach areas of the world. However, they do not provide a continuous view and data is rarely near real-time, usually stored on board and downloaded over readout stations. Their infrequent time domain sampling sensor data are well suited for climate statistics, but severely limit utility for monitoring or forecasting mesoscale events. Currently, approximately 70% of pixels on average are contaminated by clouds. Microwave imaging array technology offers a useful lower-resolution alternative for atmospheric profiles under cloud cover. Because of schedule delays and cost overruns, the U.S. polar orbiting program has been restructured, with NOAA/NASA and DOD now planning separate programs

Implementation Options

Geostationary MetSats: Infrared hyperspectral soundings and soundings from microwave synthetic thinned aperture arrays offer unique opportunities to improve mesoscale prediction.

Polar Orbiting MetSats: Hyperspectral sounders for greater accuracy and vertical resolution of atmospheric profiles; radio occultation from GPS (COSMIC) is all-weather and provides temperature and moisture soundings.

Recommended Actions:

1. Develop research-to-operations plan for current R&D MetSat platforms;

2. Resolve competition between climate and weather scientists for limited resources for funding sensors by heeding the recommendations found in the International Astronautical Federation March, 2010 report, "Space Sensors for Climate Monitoring". Among the report recommendations were: i) A global climate monitoring strategy is needed, ii) Requirements for space observations should be stabilized and managed, and iii) Leveraging existing and planned assets and resources is essential;

3. Use "Implementation Plan for Evolution of Space and Ground-based Subsystems of the GOS", which makes specific recommendations concerning the evolution of the space-based and surface-based subsystem of the GOS;

4. MetSat technologies need to be combined/tiered in their deployment in order to leverage the particular benefits of each platform; and

5. Insure that the communications and IT infrastructure is upgraded to handle the major increase in data resulting from deployment of additional MetSat sensor platforms.

6. Support existing high quality reference networks (e.g., USCRN, high-quality state mesonets) to provide in-situ observations for the independent validation and verification of remotely sensed weather and climate variables.

NRC Recommendation 13: Existing surface observations and observing platforms associated with road and rail transportation, as appropriate, should be augmented to include World Meteorological Organization (WMO)-standard meteorological parameters. Conversely, existing WMO-standard meteorological observing stations near highways and railways should be augmented, as appropriate, to meet the special needs of the transportation sector.

Discussion

The MIWG contacted both public and private sector experts in road and highway weather observing systems regarding this recommendation. The FHWA reports that they have metadata for the 2,161 sensor stations in 38 states with Environmental Sensor Stations (ESS). The FHWA has also published an ESS Siting Guide that gives guidance to mainly roadway operations regarding the installation of ESSs along roads and highways. There is also another document entitled, NTCIP 1202 – Object Definitions for Environmental Sensor Stations that provides information that defines those objects used to describe ambient condition and pavement conditions. However, both of these documents are advisory in nature and any organization (primarily state highway departments) that deploys ESS type equipment is not bound to comply with them. It was noted by the MIWG that FHWA is in the final stages of deploying its CLARUS project, which is a data management tool designed to collect, quality control, and disseminate ESS reports from all participating states. This is considered a major step in better management and application of the ESS network data.

Implementation Options

Options: 1) The study recommended augmenting ESS type systems to include WMO standard meteorological parameters. One option would be to upgrade the existing 2,161 ESS sites and privately-owned railway sites (primarily wind sensors) with additional sensors per the WMO standard. 2) Another option would be to accept the existing sites (that do have standardization documents for insuring representativeness of weather and pavement conditions) as providing sufficient and useful data.

Recommended Actions

Accept the existing networks as providing meaningful data, and strongly recommend that instead of upgrading them use any available funds to properly maintain existing sites, as well as increase the number of sites. In deployment of additional sites, it should be strongly recommended that they comply with the FHWA's Siting Guide and NTCIP 1204.

NRC Recommendation 14: The Department of Transportation should assess and eventually facilitate the deployment of high-density observations through the Vehicle Infrastructure Integration initiative. Similar concepts should be considered for general aviation and marine transportation vehicles.

Discussion

Use of vehicle data in weather-related applications and products is being discussed within several weather and transportation organizations. The potential for millions of weather observations from vehicles would definitely lead to improvements in the diagnosis and prediction of adverse weather and road conditions. The Department of Transportation (DOT) initiative called IntelliDrive (previously called the Vehicle Infrastructure Integration Initiative referenced above) is making progress developing the capabilities to gather weather data from vehicles. Beginning in 2008 and continuing beyond 2013, a series of demonstrations will take place to address a number of scientific and technical issues. The Federal Highway Administration, through DOT's Research and Innovative Technology Administration (RITA) is conducting research to evaluate and validate the viability of using vehicle-based sensor data to generate millions of new weather and pavement condition observations. FHWA and RITA have funded NCAR to conduct research under the IntelliDrive initiative to develop a prototype Vehicle Data Translator (VDT), which collects, quality-checks, and disseminates vehicle-based weather and road condition data. Meantime, the AMS recognized the need to engage the weather enterprise on this topic and in 2009 established the Committee on Mobile Observations. The committee is scheduled to complete its work on this topic in 2011. NOAA is also involved in funding mobile observation research and development. In late 2009 and continuing into 2010, the NWS has funded a project to build a Mobile Platform Environmental Data observation network (MoPED). The objective of MoPED is to demonstrate that vehicle data can support surface transportation weather applications, and, if successful, these data will be included as part of their National Mesonet System. In a recent report on their efforts, NCAR concluded that "In a fully realized mobile observation network, the sheer volume of the observations will present challenges in data handling."

Implementation Options

While much research and development work is ongoing, it would be premature to discuss the various options for deployment of mobile weather observing platforms. A significant amount of research will be required to understand the feasibility of using vehicle-based data, as the characteristics of the data will vary greatly between vehicle manufacturers, vehicle models of the same manufacturer, and sensor types and models.

Recommended Actions

As a NNoN organization emerges, it should closely monitor and integrate the applicable results of DOT, RITA, NOAA, and the AMS efforts. A resulting plan should consider the various options that will no doubt emerge and establish a deployment plan for a National Mobile Weather Observation System.

Group C RECOMMENDATION: THE HUMAN DIMENSION

NRC Recommendation 15: The stakeholders should commission an independent team of social and physical scientists to conduct an end-user assessment for selected sectors. The assessment should quantify further the current use and value of mesoscale data in decisionmaking and also should project future trends and the value associated with proposed new observations. Upon implementation and utilization of improved observations, periodic assessments should be conducted to quantify the change in mesoscale data use and its added societal impact and value.

The broad objectives of the survey should:

- **Identify priority areas where training and outreach can be developed to broaden the number and types of users and uses of network data;**

- **Develop ways to acknowledge and broaden the uses of environmental monitoring information beyond weather and climate to include examination of societal vulnerability and resilience to a broader range of hazards;**

- **Examine whether and how the partnership agreements and applications within one state, group, or region can be used elsewhere;**

- **Discover metrics that measure how well current initiatives meet the data needs of the citizenry, for example, teachers, students, hospital administrators, golfers, homeowners, and individuals of all ages; and**

- **Identify novel ways to build capacity for using environmental monitoring data in society.**

Discussion

NNoN seeks to provide mesoscale observations and forecasts "to promote the health, safety, and economic well-being of our nation." (NRC Report, p. 4). Since this goal is based on socioeconomic outcomes, it is important to address the human dimensions of environmental monitoring in conjunction with business models, R&D/test beds, measurements, and architecture. "Human dimensions" addresses linkages among weather, technology, and society and includes risk communication, decision-making, vulnerability analysis, economic value— how the different stakeholders receive, interpret, and respond to weather information. There is an extensive body of research on these topics that can be applied to NNoN activities; additional applied research is also likely to be necessary. Examples of how incorporating human dimension can enhance the effectiveness of mesoscale observations include:

- A recent storm-surge project sponsored by NOAA examines public perception of storm surge warning messages with the goal of creating products and processes that increase evacuation rates by the public (CI-FLOW website)
- CASA (Collaborative Adaptive Sensing of the Atmosphere) Engineering Research Center has integrated NWS forecaster and emergency managers needs for weather information into the design and operation of a boundary layer X-band radar system (CASA website); and
- A large pilot project conducted by social scientists at Argonne National Lab demonstrated improvement in emergency management decision making for chemical hazards when training and appropriate decision support products were developed. These products enabled emergency managers to interpret the complex plume and meteorological models to determine when the public should shelter in place and when they should evacuate. (Hewett 2010)

Implementation Options

The HD working group focused on three areas: 1) economic and noneconomic valuation that defines the value of the data in ways that are relevant to potential funders, 2) user assessment through focus groups and surveys to determine how mesoscale data can meet the decision making needs of different stakeholders based on their tasks, meteorological and climatological knowledge, technological access and organizational structures; and 3) user assessment through end-to-end test bed research evaluating the use of and response to new mesoscale information to maximize positive socioeconomic impacts.

The NNoN report highlighted six broad user groups/application that would most benefit from mesoscale data: i) weather and climate; ii) energy; iii) public health and safety; iv) transportation; v) water resources; and vi) food production. Some of these user groups, such as the energy, railroads, and airline industry (included in the transportation group) will utilize mesoscale data for private sector decision making for cost avoidance and operational efficiencies. Other users – within the climate and weather, public health and safety, and water resources and public transportation – have significant public safety/service missions and typically rely on public officials, such as emergency managers or road managers, to use weather information to elicit protective behavior from the public. Our assumption is that the sectors dominated by private companies have the resources and meteorological knowledge to translate their needs into new mesoscale weather products. Therefore, the HD group should focus the needs assessment and end to end-analysis on those user groups that have a significant public safety mission, or lack the meteorological knowledge to define products that meet their decision making needs.

Recommended Actions

1. Human dimensions expertise should be included in the NNoN Steering Group;

2. OFCM interaction with the NNoN Steering Group through CIOS should include coordination with a newly formed OFCM working group for integrating social science applications into meteorological operations. The social science working group complements CIOS activities. While the CIOS group is focused on the observational technology, this group is addressing risk communication, reaching vulnerable populations with hazard information, effective partnerships among stakeholders, and end-to-end analysis.

3. When an independent NNoN organization is formed a Human Dimensions group should be created within the organization.

4. Economic analysis:

- Short-Term Benefits Analysis ─ a benefits analysis of mesoscale networks should be compiled using existing results from mesonets for the six key user groups discussed in the study. This should be compiled with the goal of creating defining benefits for a NNoN.
- Long-term valuation study ─ in the long term methods should to be developed that link observing capabilities with socioeconomic outcomes.

5. User Assessment. Conduct focus groups and surveys with users within the weather and climate group, public safety, and food and water sectors to develop decision support requirements that in turn drive observational requirements of the system. The stakeholders should be encouraged to provide their own perspectives on the state of the current networks and the ways to value the data that are available. They need to know they are key players in directing the future of the Network of Networks to assure that a truly integrated system is developed. When the stakeholders discuss how they use the data they may show conflicting ideas of what temporal and spatial scales are best. The Network of Networks will benefit from listening, and changing the approaches to be flexible and interactive for as many stakeholder communities as possible.

6) End-to-End Test Bed Analysis. The R&D/Test Bed effort should integrate users and human dimension issues in all the test beds. This will facilitate the development of economic models and effective products.

Summary

Recommended Action

Creation of a "Central Authority" (initially NNoN Steering Group) is the key action needed to implement the recommended actions in both the NRC report and as further explored in this document.

Next Steps

Plan for Summit

- **BEC Planning effort**
- **Stakeholder identification and contact**

Brief key sectors/groups to achieve buy-in of major concepts

- **UCAR**
- **OFCM & NOAA (including NWS and NESDIS)**
- **AMS**
- **Selected Private Sector groups**

Conduct Town Hall Meeting at Annual Meetings

- **Brief Draft Report**
- **OFCM Briefing on CIOS Status**

Participate in AMS Washington Forum—April each year

Publish this report

- **Full committee including working groups review and comment on draft—Nov 2010**
- **Post on AMS website for comment—Dec 2010**
- **Print/Post draft version for Seattle meeting—Jan 2011**
- **Print/Post final version in Fall 2011 (Note: This was delayed until Spring 2012 and report remained in draft until the Spring of 2013 at which time all reviews were complete and report was ready for publication in final form)**

Follow-on Steps

- **Hold NNoN-Themed AMS Summer Community Meeting—TBD**

- **Establish Implementation Planning Groups**
    - **AMS Thematic Chapter Establishment**
    - **Stakeholder engagement**
    - **Data management**
    - **Business Model development**
    - **Others as required**

- **Hold Stakeholders Summit—TBD**

- **Standup Interim “Central Authority/NNoN Steering Group”**

- **Establish NGO**

Appendixes

Appendix A

Working Group Reports

Organization and Business Models

Summary of Working Group Participation and Activity

In November 2009 the Organization and Business Models Working Group (WG) was initiated based on volunteers with an expressed interest in Nationwide Network of Networks (NNoN) participation. Our first assignment was to study the National Research Council (NRC) report, Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks (2009) in preparation for a WG meeting held in Atlanta, GA during the American Meteorological Society (AMS) conference in January, 2010. Members of the WG are: Paul Campbell, Campbell Scientific; Richard Pyle, Vaisala; Marisa Patrizi, Raytheon; Jim Giraytys, CCM; Bob Plante, Oklahoma University; Brian Bell, Global Science & Technology; Carlton Bjerkaas, SAIC; Chris Hill, Mixon Hill; Curtis Marshall, NWS; John Doherty, Weatherbug; Steve Woll, Weatherflow; Kevin Schrab, NWS; Maria Pirone, Harris Corp.; and Apoorva Bajaj, CASA. Initial WG discussions were centered on creating a marketplace for data exchange. Alternative forms of organization as suggested in Chapter 7 of the NRC report were considered by subgroups of the WG. We adopted the following mission statement: "Meet societal needs by developing, maintaining, and expanding the market for mesoscale weather, climate, and environmental observations in the United States." Participation in NNoN panel discussions were made at the Public Private Partnership Forum in Washington, DC in April, 2010, and at the AMS Summer Meeting in State College, PA in August, 2010.

Findings

The NRC report, Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks (2009) recommended forming a federally chartered, private non-profit corporation. While this alternative will remain a possibility, it is a complex structure to initiate and to administer and relies on a substantial congressional mandate. Because of this lack of scalability, it is important to identify one or more alternatives in the near term that provide coordination between public and private sectors, but allow independent development and initiative by these sectors. As stakeholders identify themselves and their roles, more sophisticated organizational structures can be considered to address emerging needs in the public sector and cultivate economic opportunities in the private sector.

Recommended Actions

1. Take the first step toward formal NNoN organization with a form of the Confederation of Federal Agencies alternative identified in the NRC report, with NOAA as the lead agency.
2. Add to this alternative a NNoN advisory board or committee able to provide input and direction from the stakeholder communities of regional, state, and local mesonets, private weather and climate reporters, forecasters, and consultants, and the related academic and research community.
3. Encourage the formation of a thematic chapter of the AMS to develop the market for mesoscale weather observations by supporting metadata standards adoption and a coordinated means of data discovery.
4. Engage academia, including universities that operate mesoscale observation networks for state and local purposes, for research and education as well as exchange of available mesoscale observations.
5. Maintain a policy of free and open availability of observations from all publicly owned assets.
    a. Distinguish between core public data needs such as air traffic control, public safety, and emergency management, and supplemental public data needs such as industry independent forecast model improvement, general weather and climate forecasts, and geographic in-fill for improved spatial resolution, consistent with related discussions among NOAA (including the NNoN advisory board) and private weather and climate service providers.
    b. Let the Federal Government further encourage the development of an open and competitive market for mesoscale observations by purchasing those data that fulfill some core and supplemental federal data needs as may be available on reasonable and competitive terms.
6. Figure A.1 graphically describes this structure.

7.

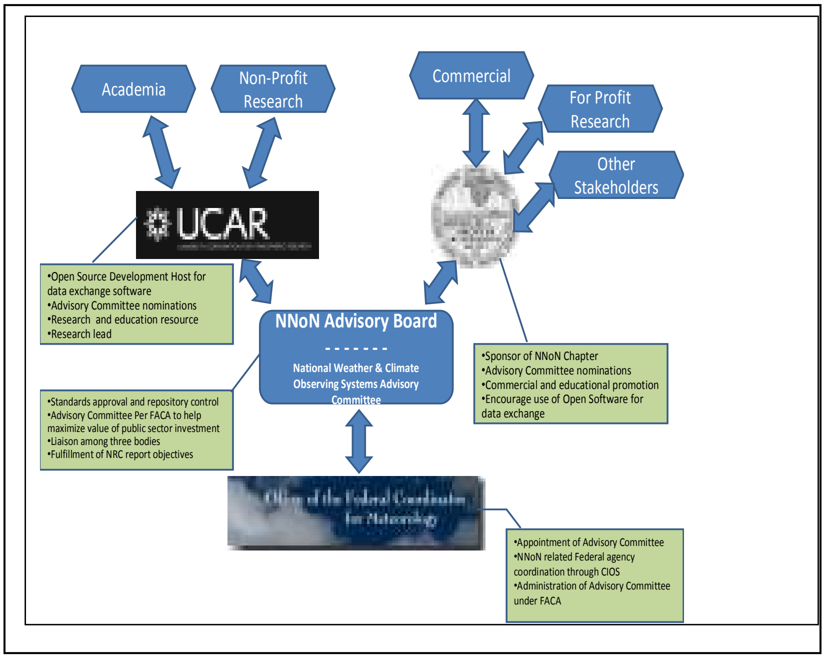

Figure 7. Org/Bus Model WG Proposed Interim NNoN Central Authority Organizational Structure

NNoN Management Structure - Concept of Operations

Federal Government

- Whereas there are various Federal Government agencies that require weather and climate observations to fulfill their operating requirements, such as air traffic control, public safety, climate adaptation, and emergency response; and
- Whereas there are many and varied uses for weather and climate observations to improve and facilitate private sector weather reporting and forecasting, as well as economic interests ranging from optimization of renewable energy resources to surface transportation planning and use; and
- Whereas the common interests of public and private sectors can benefit from improved and expanded mesoscale observations as outlined in the 2009 National Research Council report, Observing Weather and Climate From the Ground Up: A Nationwide Network of Networks; and
- Whereas many weather and climate observations are being made in various public and private networks; therefore,
- It is proposed that there be formed a Nationwide Network of Networks (NNoN) Advisory Committee administered under the Office of the Federal Coordinator for Meteorology (OFCM) and directly associated to the Committee for Integrated Observing Systems (CIOS).

- Be it further proposed that OFCM invite state, academic, and private sector input by forming an advisory committee under the Federal Advisory Committee Act (5 U.S.C. App.) (FACA) as follows:
  - Seven to 15 members
  - Committee members nominated by the American Meteorological Society(AMS) or University Corporation for Atmospheric Research(UCAR) as allowed by FACA, and appointed by the Secretary of Commerce
  - The advisory committee or their appointees will determine reasonable guidelines for term of office to provide for new input while maintaining continuity of direction
  - Advisory committee members shall be appointed to broadly represent weather and climate interests
  - Herein called the Weather and Climate Observing Systems Advisory Committee (WCOSAC) to CIOS
    - Weather and Climate Observing Systems Advisory Committee (WCOSAC) Charter Statement: Advise CIOS with input on observation standards, data exchange, coordination with related observing and data exchange activities and interests outside of Federal operations, and direction to achieve objectives and benefits for the public good outlined in National Research Council reports: Observing Weather and Climate From the Ground Up (2009), Fair Weather: Effective Partnerships in Weather and Climate Services (2003), and related studies.
  - Also referred to as the NNoN Advisory Board for AMS and UCAR.

Private Sector

- Whereas there are individuals and entities interested in the organizational development of a Nationwide Network of Networks (NNoN), and
- Whereas many organized interests around NNoN are represented in the Ad Hoc Committee on Network of Networks under the Commission on the Weather and Climate Enterprise of the AMS, and
- Whereas the organizational structure of the AMS lends itself to promoting broad weather and climate community interests and the Constitution of the AMS states: "The objective of this Society is to advance the atmospheric and related sciences, technologies, applications, and services for the benefit of society," therefore…
- It is proposed that a Chapter of the AMS be established as a sub-set of AMS members with a specific interest in NNoN, and
- It is proposed that an additional chapter membership dues be set by AMS to cover the expenses of the Chapter, and
- It is proposed that a NNoN Advisory Board be appointed by AMS with a selection of NNoN Advisory Board members as nominees to advise the Office of Federal Coordinator for Meteorology (OFCM) in a manner consistent with the

duties and responsibilities prescribed in the Federal Advisory Committee Act (5 U.S.C. App.), and

- It is proposed that the activities of the Chapter shall be conducted for the benefit of its members consistent with the broader interests of the AMS and the NNoN initiative and shall include:
    - Establishing and maintaining standards for metadata and observations that support broad use of mesonet data.
    - Providing to Chapter members a NNoN web page with links to their own web sites along with other commercial market development initiatives.
    - Promoting to the private sector the existence, and mission of the NNoN initiative.
    - Promoting the expansion of the scientific exploration and use of NNoN data.
    - Promoting the commercial success of the NNoN on behalf of Chapter members.
    - Creating an environment where software tools and capabilities can be developed under the Open Source Initiative (OSI) guidelines and made available for use by Chapter Members under the Open Source Definition (OSD) suite of licenses in coordination with academia and government interests in NNoN.
    - Encouraging awareness, education, and serve as a repository of knowledge on the data available under the NNoN.
    - Encouraging the exchange of NNoN data between Chapter members.

Academic and Research Interests

- Whereas there are academic and research entities interested in the organizational development of a Nationwide Network of Networks (NNoN), and
- Whereas many organized interests around NNoN are represented by the University Corporation for Atmospheric Research (UCAR), and
- Whereas the organizational structure of UCAR lends itself to promoting academic and research community weather and climate interests, therefore……..
- It is proposed that a steering committee within UCAR be established as a sub-set of the UCAR organization with a specific interest in NNoN, and
- It is proposed that UCAR shall select members of the steering committee as nominees to advise the Office of Federal Coordinator for Meteorology (OFCM) in a manner consistent with the duties and responsibilities prescribed in the Federal Advisory Committee Act (5 U.S.C. App.), and
- It is proposed that the activities of the UCAR NNoN steering committee shall be conducted for the benefit of UCAR members consistent with the broader interests of UCAR and the NNoN initiative and shall include:
    - Participation with the NNoN Advisory Board and any other standards committees concerning data exchanges and metadata definition under the auspices of the NNoN.
    - Promotion to the academic and research community of the existence, and mission of the NNoN initiative.

- Promotion of the expansion of the scientific exploration and use of NNoN data.
- Promotion of the commercial success of the NNoN on behalf of participating UCAR members.
- Hosting a repository of software tools and capabilities can be developed under the Open Source Initiative (OSI) guidelines and made available for use by Chapter Members under the Open Source Definition (OSD) suite of licenses in coordination with private sector and government interests in NNoN.
- Facilitation of the utilization of NNoN data for UCAR members.
- Fulfillment of education needs relating to NNoN in coordination with AMS.

Architecture

Tasks

The Architecture Working Group includes the following members: Pat Guinan, Rich Kramer, Andres Orrego, Bill Callahan, Christopher Fiebrich, David Helms, Garry Schaefer, John Horel, Jonathan Porter, Ken Hubbard, Mike Grogan, Paul Heppner, and Tom Stoffel. The original chairman of the working group, John Horel (University of Utah), began discussions among the members of the working group via several teleconferences. Due to other commitments, John Horel turned over the his chairmanship to Bob Pasken (Saint Louis University) The primary goal of the committee was to describe the data collection and communications protocols, create the network catalog, deal with database and archive issues, determine how data would be accessed in real time, maintain network security, impose quality control, and determine how to handle the problems associated with proprietary data. As the committee member several changes were made to explore these issues the original mandates were made as new information and the working group members made suggestions. Although there is overlap with the instrumentation working group, the architecture working group provides interested participants with information about solutions that have proven themselves in other mesonets. The group provides best practices to existing mesonets to improve the data quality from these existing mesonets and provides a means and method for mesonets to take advantage of new technologies as they become available.

Overall NNoN Architecture Options

- **Data Collection/Communication**
- **Network Catalog**
- **Database and archive issues**
- **Real-time access procedures**
- **Online data availability**
- **Network Security**

Quality Control

Proprietary Data handling

Findings

During the discussions among the working group members and the chairman of the other working groups, it became apparent that by using existing well-tested technologies and tools a central database would not be required or needed. The UCAR Unidata project's Local Data Manager (LDM) provided a means of providing access to the data and archiving without a formal database and archiving. LDM is a collection of cooperating programs that select, capture, manage, and distribute arbitrary data products. The system is designed for event-driven data distribution, and is currently used in the Unidata

Internet Data Distribution (IDD) project. The LDM system includes network client and server programs and their shared protocols. An important characteristic of the LDM is its support for flexible, site-specific configuration. LDM acquires data and shares them with other networked computers. Each data product is treated as an opaque unit, thus nearly any data can be relayed.

An important advantage of LDM is that data can either be ingested directly from a local data source such as data from a mesonet, or the LDM can talk to other LDM servers to either receive or send data. Thus each member mesonet can scan the data stream being passed between LDM sites, determine and extract any data needed locally, add data to the stream from local sources, or pass the existing data stream on to other LDM servers.

Since LDM provides a means of adding requests for data to the product queue, there is no longer a need for central database as the data can be requested in the data stream. Data captured on one machine can be stored on other machines on a network providing a mean for the archival of data.

Further, LDM does not require significant new computer resources to operate. Existing computer resources can typically be retasked to act as an LDM node.

Since LDM uses peer-to-peer communications protocols, security issues are also minimized, as LDM allows a connection **ONLY** if both peers agree to a connection. Only if the managers of both LDM servers agree to pass data **AND** only after each mesonet operator makes the changes to allow requests for data can data pass between LDM sites. Thus, without express acknowledgment by both sites no data will flow.

LDM also allows for a tiered approach to the construction of the data-sharing network. LDM can be configured as a hierarchical, or fan-out, network scheme. Thus mesonets that are well connected and well funded are able to relay the data streams to a fixed number of others, reducing the burden on mesonets without as many resources. The design is flexible enough that as new data products become available they can be introduced from any node in the system and passed to all other nodes. In this model a network catalog is built as the data passes from leaf to branch to root nodes. This network catalog of data is also self-correcting as new data sources become available and other data sources become unavailable.

The importance of the quality of the observations from existing mesonets was also discussed at length. Although there was some discussion on how individual mesonets would become part of a larger regional/national mesonet, it was very clear that the issue of data quality and reliability is crucial to the success of a Nationwide Network of Networks. The committee suggested adopting a set of application dependent standards, including instrument siting, communications, and data quality. The details of these application-dependent standards will need to be determined by the stakeholders and the operators. Thus the committee members felt that there should be several indicators of the quality of mesonet observations and that these indicators should strongly reflect the siting quality, maintenance, and quality of observation. The indicators of the siting, maintenance, and data quality should be part of the description of the mesonet data, mesoscale representativeness, and data quality as described in the metadata. This approach doesn't prevent a mesonet from participating in the Nationwide Network of Networks, but provides data users with a level of confidence. The description on the metadata of the mesonet would provide means for mesonet operators to request additional funding to upgrade their mesonet to improve the quality of their data and to provide a means of quantifying the impact of the mesonet for their funding agency and users. The use of LDM would also provide an additional source of Quality Control on data being passed between sites as data being passed from a leaf to branch node will have additional quality control tags attached to the data. The members of the committee also felt that guidance for best practices should be developed to capitalize on the knowledge and strengths that existing mesonet operators have created. The American Association of State Climatologists could provide useful guidelines for the development of these

The AMS recommends that individual mesonets use LDM to pass their data upstream from their mesonet to a nearby aggregator. Additional quality control checks to data being passed from the local mesonets would be performed by the aggregating site. There was discussion as to whether the recommendation should be one aggregating site per state or whether regional aggregating sites would be preferable. Each of these sites would then pass the data from the local mesonets upstream to a larger more robust aggregator and then finally to a single master site. The recommendation of the committee was that NCAR would be the single master site.

Recommended Actions

- The AMS recommends that the Nationwide Network of Networks (NNoN) adopt the Unidata Local Data Manager to provide the communications backbone for the NNoN.
- The AMS recommends that the leaf-branch-root configuration of the LDM be implemented with each mesonet as a leaf with either regional or state-level branch nodes and that NCAR provide the root node for this network configuration.
- The AMS notes that adopting the LDM as the communications methodology removes the need for a central database and network catalog. Further security issues are minimized due to the peer-to-peer nature of the communications.
- The AMS recommends that the Quality Control Standards be described in the metadata structure according to metadata standards described in section 2.4.
- The AMS recommends that an application be developed that allows users to conduct data discovery on the NNoN metadata.
- The AMS recommends that application specific quality control standards be developed in cooperation between the users of the mesonet data and mesonet operators.
- An architecture that ensures the expeditious availability of highly perishable data for short range forecasting must be developed.

Measurements and Infrastructure

Tasks

- **Identify current capability**
- **Identify requirements**
- **Identify Gaps between current capability and requirements**
    - **Lower troposphere (boundary layer)**
    - **Atmospheric pollutants**
    - **Soil Moisture and Subsurface temperatures**
    - **Scanning remote sensors**
    - **Metsats**
    - **Road weather**
    - **Ocean, Marine, Coastal**
- **Recommend path forward**

Findings

See body of report

Recommended Actions

See body of report

Metadata Policy

The Metadata Policy Working Group includes the following members: Jeff Arnfield (NOAA National Climatic Data Center), Richard Berler (KGNS-TV, Laredo, TX), Brenda Boyce (Mixon/Hill, Inc.), Jerry Brotzge (University of Oklahoma), Joshua Campbell (Campbell Scientific, Inc.), Gerry Creager (Texas A&M), Eric Floehr (ForecastWatch), Carroll Hood (Raytheon), Sytske Kimball (University of South Alabama), Anthony Lupo (University of Missouri), Alex McCombs (Oklahoma Climatological Survey), Renee McPherson (Working Group Chair, Oklahoma Climatological Survey), David Morris (Weatherflow, Inc), Jim O'Sullivan (NOAA National Weather Service), Mohan Ramamurthy (Unidata/UCAR), Bob Scott (Illinois State Water Survey), Jay Titlow (Weatherflow, Inc.), and Loren White (Jackson State University).

Valuable input for and assistance to the Working Group has been provided by George Frederick (AMS NNoN Committee Chair; Falcon Consultants), Ted Habermann (NOAA National Geophysical Data Center), Curtis Marshall (NOAA National Weather Service), Paul Pisano (Federal Highway Administration), Gary Rasmussen (American Meteorological Society), and Judson Stailey (Office of the Federal Coordinator of Meteorology).
The Working Group met regularly, typically by conference call. The conference call dates (and locations, when not a conference call) were as follows:
December 4, 2009
January 19, 2010 (Atlanta, GA; AMS Annual Meeting)
February 12, 2010
March 12, 2010
April 9, 2010
May 14, 2010
June 22, 2010 (Unidata webcast of Ted Habermann seminar)
July 9, 2010
August 10, 2010 (State College, PA; lunch discussion with a few members; AMS Summer Community Meeting)
August 13, 2010
September 24, 2010

An invitation was also extended to the Chair of the working group to act as a subject matter expert at the Office of the Federal Coordinator of Meteorology's (OFCM) Metadata Joint Action Group (JAG), the federal counterpart to the AMS NNoN Metadata Working Group, and to participate in the design review meeting of the National Mesonet Pilot Project (NMPP), overseen by NOAA's National Weather Service (NWS). Similarly, the OFCM Metadata JAG Chair, Judson Stailey, was invited and able to participate in our AMS working group meetings (beginning on May 14, 2010) and National Mesonet Program Manager Curtis Marshall was able to participate in several of the OFCM Metadata JAG meetings. In this manner, we ensured that each group was aware of each other's directions, concerns, and points of decision with the intention of finding an optimal and coordinated solution.

During the process, our AMS working group became aware of a significant expert, Ted Habermann, at NOAA's National Geophysical Data Center, who answered all questions posed by our group and, in a timely coincidence, provided a June 2010 seminar on ISO Metadata Standards and Interoperability at Unidata that was webcast for our members, the OFCM Metadata JAG, and others. As of September 2010, an archived version of this webcast was available at http://www.unidata.ucar.edu/community/seminars/.

Tasks

- **Metadata Template**
- **Standards Recommended for**
    - **Surface Data Networks**
    - **Subsurface Data Networks**
    - **Upper Air Data Networks**
    - **Ocean, Marine, Coastal Data Networks**

Findings

Overview

The original tasks were modified slightly by the working group, with approval of AMS Task Force Chair Frederick, at a face-to-face meeting during the 2010 AMS Annual Meeting in Atlanta, GA. The primary goal of the committee was to describe a metadata framework & its elements that characterize measurements such that the framework is useable for future generations. This goal included a subgoal to list the metadata elements that are mandatory for specific observing systems.

The first step for the working group was to follow due diligence to update ourselves on current standards, including those of the International Standards Organization (ISO), Federal Geographic Data Committee (FGDC), and Open Geospatial Consortium (OGC). Standards used by several national and international atmospheric, oceanographic, hydrologic, or other environmental observing systems or programs, including the Global Earth Observing System (GEOS), U.S. Integrated Ocean Observing System (IOOS), the Clarus Initiative, and the National Mesonet Pilot Project (NMPP), were examined.

Although most metadata standards were implemented by federal or international agencies or programs, the working group kept mindful of the fact that many of the networks that would provide data and metadata to the Nationwide Network of Networks (NNoN) would be relatively small state-owned networks with minimal budgets; small to large privately owned networks that needed to operate efficiently for profit maximization; or networks of the future that may evolve differently from today's observing systems. Hence, the ability of metadata standards to be implemented by these and other networks in the future would depend upon accessibility to tools (both development and operational), ease of implementation and maintenance, interoperability of the standard(s) with other standards (e.g., data formats), and value added to the network for obtaining, maintaining, and updating metadata for the NNoN.

The working group was also mindful of the need for the user community to easily discover networks, stations, or observations that were useful for their specific needs by accessing metadata from this wide variety of NNoN data providers. The metadata standard(s) would need to be flexible and extensible, with an identified process to update the standard as technologies and users' needs evolved. A standardized core dictionary (i.e., ontology) would be necessary for a consistent vocabulary between different types of data providers and their wide range of users. Appendix B outlines data dictionary, in this case for a road weather information system, as an example of the type of information that will have to be developed in the future to implement standardized metadata practices.

Other important decisions of the working group included items that we specifically chose *not* to do: (1) we would not establish a tiered structure that would "rank" the observations or stations of a network and (2) we would not implement any recommended metadata standards. Regarding the former, the working group members were aware of ongoing efforts by organizations or user groups to establish "tiers" of observations or data quality (e.g., "gold," "silver," "bronze") and decided that those decisions were best made by the organizations and users themselves. Our working group would recommend a minimal set of mandatory metadata, but not become involved in other policy decisions. Related to the latter item, the working group realized that implementation of the standards would require extensive resources that could not be provided by the AMS. Hence, we provide recommendations for a path forward, and encourage other ideas for implementation.

Background and Nomenclature

One early finding of the working group was that many network operators, especially those with traditional meteorology pedigrees, do not have extensive education or experience with metadata as it is described and used in the broader environmental community. For example, in geographic information science (GIS), latitude and longitude are considered *data* whereas they are considered *metadata* in the meteorological community. Terms such as "discovery metadata," "process metadata," "UML," "schema," and "crosswalk" are unfamiliar to many professionals who do not regularly engage in the details of database development, geoinformatics, software engineering, and related fields. The communication difficulties within the working group and between group members and outside experts were understandable and, we believe, representative of the broader AMS community. As a result, we provide **Recommendation #1** (see section A.4.3) to encourage the AMS to host short courses, establish working groups, and contribute to learning materials that educate data providers and data users on necessary vocabulary and concepts associated with metadata standards.

For this report, the following nomenclature is used:

Metadata ─ information about the data
Geospatial metadata ─metadata about data collected at specific geographic locations
Metadata standard ─ a description of the content required to describe data (a content standard) in a way that facilitates independent understanding of the data by users. These standards are generally conceptual models that describe content required to answer questions like who, when, where, and how were the data collected and processed and where can they be obtained.

Process standard ─ a description of the content required to describe a process in a way that facilitates independent understanding and reproduction of the process by users. These standards are usually developed to serve a particular community of data producers or users.

Profile ─ a collection of implementation rules and extensions to a metadata standard (e.g., guidance on specific elements, new elements) developed to serve the needs of a specific community. They can include specific guidance regarding particular metadata elements and new elements required to serve specific community needs.

Why Do We Need Metadata and Metadata Standards?

Technological developments in sensors and sensor networks over the past couple of decades have allowed many individuals and organizations to measure the atmosphere, cryosphere, hydrosphere, and lithosphere relatively simply and cost effectively. Although expensive sensors and expansive networks still form the foundation of our knowledge of the environment, the rapid proliferation of local and regional surface mesonets, television station radars, community and cooperative observers, lightning detection networks, and other sensing systems has complicated the task of *knowing* what data are available, *understanding* what information is in these datasets, *determining* the quality of the data, and *accessing* the data for specific uses that may not even have been conceived by the sensor or network operator. In particular, our vibrant private sector community is developing products, services, tools, and knowledge that support and expand the U.S. economy; many of these client-driven outputs require input of real-time or archived environmental data from a variety of sources.

When few organizations operated networks, it was possible to contact technical experts with each organization to get information about *who* operated the network, *what* data were available, *where* and *when* the dataset extended, *why* the network was developed, *how* the data were quality assured, etc. Today, however, machine-to-machine information exchange is necessary to obtain data and metadata, use them appropriately for the application, and produce and deliver a product, all within seconds. In addition, decision makers across a range of important economic sectors are asking questions about climate variability and change that require extraordinary data and metadata stewardship. Metadata collection, maintenance, and archival according to interoperable standards is critical to that stewardship.

Geographic information — Metadata, ISO 19115 and ISO 19115-2

The International Organization for Standardization (ISO), a federation of standards institutes from 145 countries, has developed and adopted ISO 19115 as the metadata standard for geographic datasets. ISO 19115 provides information about the identification, extent, quality, spatial and temporal schema, spatial reference, and distribution of digital geographic data. Included in this standard are 19 topic categories, including the following areas relevant to the AMS community: climatology, meteorology, and atmosphere; environment; inland waters, oceans, transportation; biota; and health. ISO 19115 is a content standard, so it defines elements but does not detail a format. This is done for the standard XML format in ISO 19139.

In 2009, ISO 19115-2 was adopted as an extension of ISO 19115 that includes elements relevant to imagery (e.g., satellite images) and gridded data (e.g., numerical model output). This extension includes metadata that describes the derivation of geographic information from raw data (e.g., instrumentation, numerical methods and computational procedures used).

In the 14th session of its Commission for Basic Systems, the World Meteorological Organization (WMO) endorsed Version 1.1 of a profile of ISO 19115 to be used in the WMO Information System. WMO Global Information System Centres (GISC) or Data Collection or Production Centres (DCPC) are implementing Version 1.1, and these centers raised questions concerning its implementation. The sixth session of the Inter-Commission Coordination Group on *WMO* Information System (WIS); held in Seoul in February 2010) invited the Inter-Programme Expert Team on Metadata and Data Interoperability (IPET-MDI) to provide guidance, including samples and templates, on metadata for authors and to clearly define a specification for minimum metadata requirements.

In addition to the WMO, the following organizations have adopted ISO 19115: American National Standards Institute (ANSI); adopted December 2003), Open Geospatial Consortium (adopted June 2001), and the European Commission's Infrastructure for Spatial Information in the European Community (INSPIRE). Many geospatial software developers, such as Esri, have implemented support for ISO 19115 (and ISO 19139). Other users of 19115-2 include the U.S. Geological Survey, NextGen, and GOES-R. As an ISO copyrighted publication, ISO 19115 and ISO 19115-2 must be purchased.

Content Standard for Digital Geospatial Metadata

The Content Standard for Digital Geospatial Metadata (CSDGM) from the Federal Geographic Data Committee (FGDC) is the current U.S. Federal Metadata Standard, originally adopted in 1994 and revised in 1998. According to Executive Order 12096, all Federal agencies must use this standard to document geospatial data created as of January 1995. Many local, tribal, and state governments have adopted or use CSDGM.

The standard was developed from the perspective of identifying what information a user would need to determine the following: (1) the availability of a set of geospatial data, (2) the fitness of the dataset for an intended use, (3) the process to access the dataset, and (4) how to successfully transfer the dataset. Hence, the standard establishes the names and definitions of data elements to be used for these purposes as well as information about the values that are to be provided for the data elements. The standard does not specify a data file format or how the data are transmitted, communicated, or presented to the user.

Recently, the U.S. and Canada have seen the importance of using an internationally recognized standard to facilitate data sharing across borders. As a member of ISO, the U.S. helped to develop ISO 19115 and has coordinated with Canada to develop the *North American Profile (NAP) of ISO 19115: Geographic Information - Metadata*. This profile was adopted by ANSI in June 2009, and it continues to be revised to better integrate with ISO 19115 and its updates. As an ANSI copyrighted publication, the NAP of ISO 19115 must be purchased. Details of CSDGM and the NAP of ISO 19115 can be found at http://www.fgdc.gov/metadata/geospatial-metadata-standards.

Sensor Model Language

Whereas ISO 19115, ISO 19115-2, and CSDGM are metadata *content* standards, Sensor Model Language (SensorML) is a *process* and *instrument description* standard. Originally developed at the University of Alabama in Huntsville, SensorML was adopted in 2007 by the Open Geospatial Consortium (OGC) and is part of OGC's Sensor Web Enablement standards. SensorML provides standard models and an XML encoding to describe any process, including the process of measurement by sensors, data quality assurance procedures, and instructions for deriving higher-level information from observations. Hence, SensorML can provide a complete and unambiguous description of the lineage of an observation.

SensorML provides a rich collection of metadata that can be mined and used for discovery of sensor systems and observation processes. These metadata include identifiers, classifiers, constraints (e.g., time, legal, and security), capabilities, characteristics, contacts, and references, in addition to inputs, outputs, parameters, and system location.

Users of SensorML include the National Aeronautics and Space Administration, National Data Buoy Center, National Weather Service, National Ocean Service, and IOOS. As an OGC standard, SensorML is publicly available (see http://www.opengeospatial.org/standards/sensorml).

Choosing Metadata Standards to Recommend for the Nationwide Network of Networks

After considering these and other available standards, the AMS NNoN Metadata Policy Working Group became aware that there is considerable convergence by providers of geospatial datasets toward ISO 19115-2 as a metadata content standard, especially with the endorsement of ISO 19115-2 by the WMO. In addition, SensorML provides considerable value to our community as a process standard and is interoperable with ISO 19115-2. In fact, the interoperability of ISO 19115-2, as diagrammed below, enhanced its value in the minds of our working group.

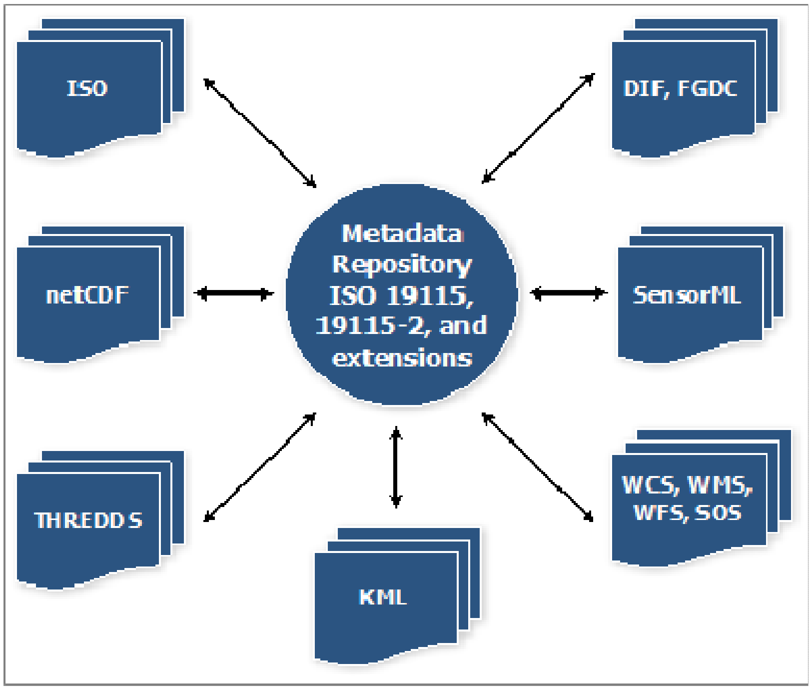

Figure 8. Metadata Interoperability using ISO19115-2

Example of the interoperability of ISO 19115-5 with SensorML and other commonly used standards in the meteorology, climatology, and oceanography communities. Diagram courtesy of Ted Habermann, NGDC.

As a result of extensive discussions within our working group and with our federal colleagues in OFCM's Metadata JAG and NWS's National Mesonet Pilot Program, we provide **Recommendation #2** to adopt ISO 19115-2 and SensorML as the metadata standards for the Nationwide Network of Networks.

Implementing the Metadata Standards for the Nationwide Network of Networks

Success of the Nationwide Network of Networks will be closely tied to successful implementation of the recommended metadata standards. In particular, the details of these standards are complicated and require extensive knowledge and experience that may not be financially feasible for some networks with valuable data. Without a doubt, the Federal government will provide expertise, tools, and perhaps even financial resources that can aid nonfederal networks. The AMS, however, can encourage a more extensive and collaborative environment to aid adoption by (1) hosting short courses that describe these standards and related implementation strategies and tools (see **Recommendation #1,** below); (2) developing workshops that bring together scientists, software developers, data providers and users, and program managers to discuss best practices, policy issues, and implementation details (see **Recommendation #1**); and (3) establish a permanent committee to serve as a body of experts to provide advice to organizations working to implement a Nationwide Network of Networks and to coordinate with the Federal government (see **Recommendation #3**).

Recommended Actions

Recommendation #1 – In coordination with other organizations within the broader atmospheric and oceanic sciences community, the AMS should provide opportunities for its members to become better educated on the nomenclature, structure, and implementation of metadata and the standards recommended below.

Recommendation #2 – The AMS should adopt ISO 19115-2 and SensorML as the metadata standards for the Nationwide Network of Networks.

Recommendation #3 – The AMS should establish a permanent committee to serve as a body of experts from academia, the private sector, nongovernmental organizations, and local, state, tribal, and federal governments to provide advice to organizations working to implement a Nationwide Network of Networks and to coordinate with the Federal Committee for Integrated Observing Systems (CIOS).

R&D and Testbeds

The R&D/Testbeds Working Group consists of eight (8) group members and Chair. The group membership consists of a good cross section of the three sectors involved. The Government sector is represented by Marc Schwartz of NREL, Allan Eustis of NIST, Michael Grogan of NCDC, and David Stensrud of NSSL. The Academia sector is represented by Jason Allard of University of Georgia. The Private sector is represented by Alan Hinckley of Campbell Scientific, Wes Perkins of MetOne, Earle Buckley of Buckley Environmental Consulting, and James Stalker (Chair) of RESPR, Inc.

The R&D/Testbeds Working Group focused mainly on Recommendation 6 provided in the NRC report. It also focused on Recommendation 5, related to research-motivated observations and educational needs of the stakeholders.

According to Recommendation 6, all stakeholders of the Network of Networks, managed by a Centralized Authority, should evaluate the networks, via testbeds as necessary, for their mesoscale observational capabilities and effectiveness. The question, "How should these networks be characterized for their mesoscale observational capabilities and effectiveness before and after integrating them into the Network of Networks?" needs to be addressed by the Centralized Authority.

These observational capabilities and their effectiveness may be related to the density of the network measurement platforms and their strategic locations and the frequency of these measurements. Are different variables being measured by a network put into their proper contexts with respect to their spatial and temporal measurement frequency effectiveness? For example, some variables (e.g., wind speed) may need to be measured more frequently, at higher spatial resolution and at multiple heights for boundary layer profiling than other variables (e.g., soil moisture and temperature, atmospheric moisture). Also, how should the measurement strategy change with respect to the location of the network itself [i.e., whether the network resides in a simple terrain environment or in a complex terrain environment (e.g., a mountainous region, an urbanized location, a coastal zone)]?

These are some of the most important questions to be answered by the Centralized Authority. According to the NRC report, it is suggested that these aspects be handled by the Architecture Group within the Centralized Authority (also recommended by the NRC report). The R&D/Testbeds Working Group recognizes that many of these questions cannot be answered all at once or for all networks in the same manner or with regards to all of the variables measured by the networks that have already been built or will be built to measure, in pursuit of integration into the Network of Networks. In other words, considerable network specific research, conducted over a period of time, will be necessary to perform this critical function. The R&D/Testbeds Working Group recommends that an R&D/Testbeds Coordinating Group be established within the Centralized Authority and that the Architecture Group closely work with the

R&D/Testbeds Coordinating Group, to receive the necessary research and guidance for integrating these networks into the NNoN successfully.

To develop the necessary research and guidance, the R&D/Testbeds Coordinating Group will consider every one of the networks that gets integrated into the Network of Networks an ongoing R&D testbed, similar to the Helsinki Mesoscale Testbed (Dabberdt, 2005). The R&D/Testbeds Coordinating Group will objectively work with other research group (national laboratories, universities, and private companies) to determine the current status of a network and recommend a course of action for the network to achieve increased effectiveness as a mesoscale network.

The R&D/Testbeds Coordinating Group will address the above issues and questions and many other related issues yet to be identified. The tools, to be adopted/developed and offered by other research groups in collaboration with the R&D/Testbeds Coordinating Group, will help the Group function successfully and undertake the four recommended major tasks. These four major tasks are discussed in the next section.

The approaches and systems to be recommended by the R&D/Testbeds Working Group should be equally applicable to existing networks as well as those that may be built in the future.

Tasks

- **Provide classification on mesoscale network representativeness**

As part of Task 1, the R&D/Testbeds Coordinating Group will identify other groups to determine the mesoscale representativeness of a network, using the procedural documents or manuals (to be developed by other groups that the R&D/Testbeds Coordinating Group will work with—Task 4). Through this task, the R&D/Testbeds Coordinating Group will engage other groups in evaluating whether or not a network has the required measurement platform density, strategic placement, temporal frequency, etc., to be classified as a mesoscale network. A network interested in joining the Network of Networks will complete a questionnaire to be submitted to the Central Authority (initially NNoN Steering Group) of the Network of Networks. This questionnaire may contain questions as shown below:

- Please briefly describe the primary purpose of your Mesonet work (e.g. weather observation and forecasting, air pollution, fire weather, agriculture, modeling, etc.)?

- Who are/will be the primary users and stakeholders of the Mesonet work data (e.g. public, emergency management, government agencies, industry, etc.)?

- Please provide a short historical narrative on the development of your Mesonet work. Is your Mesonet work similar to or supportive of other Mesonet works? If so, please elaborate.

- Is/ will your Mesonet data and metadata be publicly available? If so how? (e.g., hard copy, real time, internet etc.)

- Is/will your Mesonet work/operate as a short (1-3 years) or a longer term effort? Do you plan updates in your network? If possible, please provide relevant dates and potential upgrades.

- Does or will your Mesonet work instrumentation conform to current environmental siting and data gathering standards? (e.g., WMO, NWS, US Climate Reference Network, etc.)? Please elaborate.

Ultimately users will determine the relative value of data available from the NNoN. The R&D/Testbeds Coordinating Group can assist by offering independent assessments of the representativeness of data within a given region. Some legitimate concerns can be raised here as to how objective the process of determining mesoscale representativeness will be. The R&D/Testbeds Coordinating Group will have to be completely objective in this process and will not use this opportunity to alienate any networks or act in any way so the interested network operator does not feel left out. The R&D/Testbeds Coordinating Group should seek outside peer review to ensure this objectivity.

- **Provide ongoing input to improve network mesoscale representativeness**

Equally critical, if not more critical, is Task 2 for the R&D/Testbeds Coordinating Group. The initial letter designation of a network with respect to its mesoscale representativeness is really the starting point of a long-term interaction with the Network of Networks for any network operator. In other words, the R&D/Testbeds Coordinating Group will continually work with other research groups and with the network operator, to help the network achieve better mesoscale representativeness, etc. These improvements may result from cost-effective additions of newer and better measurement platforms (e.g., lidar systems), incorporation of newer platform placement strategies (e.g., through mesoscale model recommended locations), or inclusion of other key measured variables (e.g., trace chemical gases).

Through this task, the Centralized Authority will periodically redefine mesoscale network standards over a period of time such as every three (3) years. In other words, these improvements will lead to better mesoscale designations. The R&D/Testbeds Division will adjust the initial letter designations and future letter designations indicative of even further improvements, relative to the new mesoscale standards achieved over every three-year period. Such improvements in the mesoscale representativeness will be reflected in the procedural documents discussed as part of Task 4.

The R&D/Testbeds Division will use high-tech tools such as mesoscale atmospheric, oceanic, land, and other models to guide the network operator with this critical ongoing task. For example, no matter how dense our observational network becomes, the unobserved portion of the total observable space is going to be quite large, often in excess of 90%. Robust models can provide critical information within this large unobserved space, in addition to the sparse observations, leading to more comprehensive initial condition data sets to be used in our predictive/forecasting efforts. In other words, our predictive/forecasting success is only going to be as good as the initial conditions and their coverage and quality; having no observations and/or model derived variables within that 90+% unobserved space will severely restrict our ability to succeed.

The R&D/Testbeds Division will engage in this type of ongoing research, employing various models as necessary, to continually improve the mesoscale representativeness of all networks of the Network of Networks.

- **Guide research quality data collection process and promote education**

As a secondary but important benefit, the R&D/Testbeds Coordinating Group, along with its partnering research groups, should find ways to recommend to the network operator how their network may offer the opportunity to provide research quality data above and beyond their operational requirements as a mesoscale network. The R&D/Testbeds Coordinating Group may select different networks from the Network of Networks as research-motivated testbeds to evaluate the impacts of these additional research quality data. The selection process of networks may often be made by the research group interested in a particular location (mountainous, urban, and coastal) or in particular mesoscale phenomena (e.g., aircraft icing due to supercooled liquid water). In addition to these external funding sources, the R&D/Testbeds Coordinating Group will actively seek funding opportunities by working with other research groups to increase measured data output from these networks and incorporate the new variables (e.g., trace chemical gases) as part of standard mesoscale network output.

In addition to establishing the overall effectiveness of the research quality data on our ability to quantify mesoscale processes, the R&D/Testbeds Coordinating Group should work with its research groups to strive to understand cost considerations for the increased infrastructure requirements. In this regard, the R&D/Testbeds Coordinating Group should closely work with any external research program developers that have secured funding to engage in field campaigns and facilitate the process so the researchers and the network operator(s) in regions of planned field campaigns can coordinate their efforts effectively.

The R&D/Testbeds Coordinating Group should work with its research groups to publish their research findings in the form of reports and publications. The R&D/Testbeds Coordinating Group will participate in the community outreach efforts of the Centralized

Authority, especially in reaching out to research clusters around the country and elsewhere.

The R&D/Testbeds Coordinating Group will support the training activities of the Network of Networks by partnering with other research groups.

- **Develop and revise manuals to turn networks into perennial R&D testbeds**

The R&D/Testbeds Coordinating Group will work with a team of experts to develop procedural documents or manuals to be used to transform existing operating networks into perennial R&D testbeds at no or minimal additional infrastructure cost to the network operator. This effort may involve recommending additional measurement platforms, variables, or data collection frequencies to a network operator, not only to improve their network's mesoscale representativeness but also to achieve the broader national objectives of effective mesoscale observations and improved predictability.

Similarly, a different set of procedural documents will be developed for use with new networks to be built in the future. These procedural documents will likely be different from the first set of documents since new networks can be designed to operate as long-term R&D testbeds right from the start. For example, the R&D/Testbeds Coordinating Group, with support from other research groups, will be able to offer design specifications to the network operator as to where the measurement platforms should be located, in addition to recommending types of variables, data collection frequencies, etc.

The R&D/Testbeds Coordinating Group will utilize any existing procedural documents from other successful mesonet operators (e.g., the Oklahoma mesonet, the Kentucky mesonet or the Helsinki Mesoscale Testbed overseas) as much as possible. According to David Schultz (personal communication), the Helsinki Mesoscale Testbed does not have any procedural documents.

Such procedural documents may need to be developed based on sound research and open to accommodate differences in different networks and those who engage in the development of these documents may not resort to the paradigm of one-size-fits-all.

These procedural documents will also have to be continually updated based on further research and experiential knowledge gained from the efforts descried in Tasks 1, 2, and 3. In other words, a positive feedback approach must be established between various tasks recommended for the R&D/Testbeds Coordinating Group so existing procedural documents are used to guide such tasks and the research experience gained is used to guide the process of improving the manuals.

Implementation Options

Two viable options available to the Network of Networks are described here briefly with respect to the R&D/Testbeds Coordinating Group tasks. The first and preferred option for the Network of Networks is to form an R&D/Testbeds Coordinating Group. The R&D/Testbeds Coordinating Group will work closely with other research groups to define appropriate mesoscale representativeness measures for each participating network. This may initially be accomplished using an ad hoc approach to determine mesoscale representativeness with minimal or no research. For example, the R&D/Testbeds Coordinating Group may choose to form a review panel to determine the representative designation.

Similarly, Task 2 may be accomplished by periodically engaging other research groups to perform peer review and refining mesoscale representativeness designations.

With respect to Task 3, the Network of Networks may have an option to engage research institutions such as universities and national laboratories, instead of forming its own internal R&D/Testbeds Division, to receive the required research support with respect to collecting research-quality data and using the existing networks as R&D testbeds and for educational purposes.

Instead of developing several procedural documents (manuals) itself, the Network of Network would have an option to utilize documentation developed by a few of the successful network operators (e.g., the Oklahoma Mesonet, the Kentucky Mesonet).

As a second option, and as the Network of Networks evolves into a more mature NGO, the R&D/Testbeds Coordinating Group may choose develop some of the research and development functions internally.

Specific recommended actions are listed in the section below.

Recommended Actions

- The R&D/Testbeds Coordinating Group should help facilitate newer "research" quality data collection efforts and incorporate some of this newer data output as part of standard network data output.

- It is recommended that the research findings of the research entities be published for ready access by all stakeholders.

- It is recommended that the R&D/Testbeds Coordinating Group help support educational, training, and community outreach opportunities.

- It is recommended that the importance of every network (existing or new) be recognized as a perennial R&D testbed.

- An R&D/Testbeds Coordinating Group should be formed, which may eventually assume more research responsibilities within a Centralized Authority.

- It is recommended that mesoscale representativeness be recognized, established, and improved upon through ongoing research.

- It is recommended that the limitations of limited measurements be recognized.

Human Dimension

Tasks

- **Design methods for assessment and quantification of the economic value of NNoN data to users**
- **Develop methods to communicate this information to Congress, Government agencies and the public**
- **Identify Training and Outreach opportunities for current and new NNoN users**
- **Identify ways to broaden uses of data beyond traditional weather and climate users**

Findings and Recommended Actions

- **Recommendation 1. User Assessment--Designate Phase I II, III user groups (e.g. Water managers, Egg Farmers, Electric Utilities, Wind Energy Transportation Managers, Emergency Managers, Schools, Hospitals)**
    - **Designate Phase I, II, III Hazards**
    - **Collect existing metrics on types of usage of mesonet data as base data.**
    - **Develop decision based product metrics (thresholds, temporal, spatial scale, lead time, etc)**
    - **Conduct a current best practices/literature review**
    - **Conduct focus groups (conduct pilot work for AMS meeting to demo idea?)**
    - **Conduct a multi-attribute utility analysis**
    - **Address information dissemination and products in light of user met. knowledge, bandwidth, hardware, task**
    - **Twitter? Text Messages?**
    - **3D VAR**

- **Recommendation 2.—Economic Value**
    - **Phase I: literature review and best practices for agriculture, utilities, industries with "hard" costs/savings**
    - **Phase II: develop metrics for public safety. Look to NOAA for help in developing these metrics.**

- **Recommendation 3.-- End-to-End-to End Test Beds**
    - **Include economic assessment and user engagement as integral part of R&D/Test bed**
    - **Each R&D test bed should include user evaluation and impacts plan.**
    - **Over time standard user metrics can be developed across NNoNs.**
    - **Each R&D Test Bed should be connected to pilot user groups that receive data in real-time for feedback and evaluation.**

- **Designate 1 or 2 of the test bed for extensive user engagement and evaluation.**

- **Recommendation 4—Outreach**
  - **Rotating regional NNoN user meetings**
  - **Focus on high impact areas first**
  - **Look for interested universities to provide education programs for K-12**
  - **Outreach to Capitol Hill through NOAA and state locations.**
  - **Support Social Science JAG recently convened**

Appendix B

Sample Data Dictionary

Sample Data Dictionary

The following data dictionary is one example of the type of documentation that will be needed for a consistent vocabulary between different types of networks, data providers, and users. This sample is for road weather information systems and resulted from the U.S. Department of Transportation's Clarus Initiative, led by the Federal Highway Administration.

Ultimately, in accordance with **Recommendation #3** of the Metadata Policy Working Group, this or any other example data dictionary will have to be modified and approved by a permanent committee established to implement a Nationwide Network of Networks and to coordinate with the Federal Committee for Integrated Observing Systems (CIOS).

climate

This table contains human readable text descriptions of a particular region for which one or more climate records exist. A unique system identifier is assigned to each description. Both a regional description and the name of the entity contributing the climate records are included.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
regionDesc	varchar(50)	No	Description of Climate Region	
Source	varchar(50)	No	Source of climate region	

climaterecord

This table contains the actual climate record metadata used to perform climate record range quality checks. Each record is associated with a climate region described by the climate table. The climate record information is segmented by month and the observation type to which it applies. The minimum and maximum observed values are the limits within which an observed value must fall to pass the climate range quality check. The average observation value is calculated from multiple observations recorded over the specified time period and is not simply the mean of the minimum and maximum values, which could have been calculated on demand in lieu of a stored constant.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
climateId	int(11)	No	Unique record identifier from climate table	
period	int(11)	No	The month to which this climate record applies (1=Jan ... 12=Dec)	May = 5
obsTypeId	int(11)	No	Unique record identifier from obstype table	

Field Name	Data Type	Required	Description	Example
minObsRecord	float	No	The minimum observed value of this observation type for this period (month). Precision & bounds dependent on data type	Minimum Monthly Temp (in Deg C) = -2.9
maxObsRecord	float	No	The maximum observed value of this observation type for this period (month). Precision & bounds dependent on data type	Maximum Monthly Temp (in Deg C) = 38.2
avgObsRecord	float	No	The average observed value of this observation type over the period	

contact

The contact table contains basic information for communication with people who have an administrative relationship with a contributor. Commonly expected telephone, facsimile, postal, and email information is maintained.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
name	varchar(50)	Yes	Contact person	Mr. Fred Flintstone
title	varchar(50)	No	Contact person title	Owner of the Bedrock Mesonet
orgId	int(11)	Yes	Unique record identifier from organization table	
phonePrimary	char(10)	No	Contact phone (including area code)	2025551301 (no dashes)
phoneAlt	char(10)	No	Contact phone alternate (including area code)	2025551212 (no dashes)
phoneMobile	char(10)	No	Contact mobile phone number (including area code)	2025554444 (no dashes)
fax	char(10)	No	Contact phone fax (including area code)	2025553333 (no dashes)
pagerId	char(10)	No	Contact pager identifier	2025551111 (no dashes)
pager	char(10)	No	Contact pager number	556687
email	varchar(50)	No	Contact email address	Barney.Rubble@bedrock.com
radioUnit	varchar(50)	No	Contact radio unit identifier	2025555555 (no dashes)

Field Name	Data Type	Required	Description	Example
address1	varchar(50)	No	Contact mailing address line1	123 1st Street
address2	varchar(50)	No	Contact mailing address line2	Suite 450
city	varchar(50)	No	Contact mailing address city	Apple
state	char(2)	No	Contact mailing address state	OR
zip	char(10)	No	Contact mailing address zip	99999-4444
country	char(3)	No	Contact mailing address country	USA

contrib

The contrib table names a specific contributor of environmental observations and stores references to people who serve as contacts for that contributor. The display field is used to determine whether information from a contributor record can be presented to a user. This allows all required metadata to be completely entered for a contributor before users can begin requesting observation data provided by that contributor.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
orgId	int(11)	No	Unique record identifier from organization table	
name	varchar(50)	No	Name of the contributing agency or group within the agency providing observations	Bedrock Quarry Company
contactId	int(11)	No	Unique record identifier from contact table	
altContactId	int(11)	No	Unique record identifier from contact table as alternative contact	
metadataContactId	int(11)	No	Unique record identifier from contact table for metadata	
display	tinyint(1)	Yes	Boolean value that indicates this contributor record can be displayed on a user interface.	1
disclaimerLink	varchar(255)	No	Link to the contributor disclaimer	

distgroup

This table is a mechanism to track the description of a distribution group with an assigned identifier. This is used for administrative information purposes. For example, if a sensor belongs to distribution group identifier 3 then it would be possible to look up the description for that identifier to determine the group to which observation distribution is restricted.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	An index assigned to a particular distribution group	1
description	varchar(50)	Yes	A description of the group of people who will have access to a particular set of sensor information	public

image

The image table maintains a set of URL references to graphic files that are representative of a site where ESSs are deployed, along with a text description of the site.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
siteId	int(11)	No	Unique record identifier from site table	
description	varchar(50)	No	Description of image	The image represents the Cumberland Pass in southwest Virginia
linkURL	varchar(255)	No	Link to image	www.weatherpicture .com

obstype

This table keeps track of the types of observations currently recognized by the *Clarus* System. Standard NTCIP 1204 unit conversion constants are stored here for translating observation units when necessary. The active flag, similar to the contrib table display flag, indicates if the observation type can be presented to a user for querying observation records.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	A numeric value uniquely identifying an observation type and used for filtering observations	5733
obsType	varchar(50)	No	Type of observation collected by this sensor; based on NTCIP 1204 types	essAirTemperature
obs1204Units	varchar(50)	No	A label describing the NTCIP 1204 unit for this observation type	tenths of meters

Field Name	Data Type	Required	Description	Example
obsDesc	varchar(255)	No	A text description of this observation type	
obsInternalUnits	varchar(45)	No	A label describing the unit in which the observation type is stored for the *Clarus* System	m
active	tinyint(1)	Yes	A station value indicating if the observation type is currently in production	0
obsEnglishUnits	varchar(45)	No	English equivalent unit to the obsInternalUnits	ft

organization

The organization table maintains high-level information about an organization that can be composed of one or more contributors. There is a reference to an overall contact responsible for the contributors and identifying information used to communicate information about the organization.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
name	varchar(50)	No	Organization name	Loyal Order of Water Buffalo
location	varchar(50)	No	Organization location	MoDOT
purpose	varchar(50)	No	Organization purpose	To provide a world-class transportation experience that delights our customers and promotes a prosperous Missouri.
centerId	varchar(50)	No	Organization center identifier	4
centerName	varchar(50)	No	Organization center name	KC Scout
updateDate	datetime	No	Organization information last updated	10/23/2005 14:25
contactId	int(11)	No	Unique record identifier from contact table	

sensor

The sensor table contains specific information about a sensor's physical characteristics, such as location offset to the station on which it is attached, how it interprets observations of its surrounding environments, and when equipment maintenance will change expected performance. This information is used by quality checking software components to evaluate the effectiveness and accuracy of the reported observations.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
stationId	int(11)	Yes	Unique record identifier from station table	
sensorIndex	int(11)	Yes	The order of like sensors; used to distinguish one of a set of like sensors associated with a particular station	When multiple sensors are involved at one station: puck 0, puck 1, puck 2, puck 3
qchParmId	int(11)	Yes	Points to the record in the qchparm table that sets the quality checking parameters for this sensor	
distGroup	int(11)	No	Identifies distribution group to whom data from this sensor can be provided. Note: placing a one (1) in this field will not allow distribution of this observation and its associated quality checks to anyone including the contributor	1 = DON'T distribute, 2 = Distribute to everyone, etc
nsOffset	float	No	The north/south distance from the station reference location in meters	15.0 meters
ewOffset	float	No	The east/west distance from the station reference location in meters	8.0 meters
elevOffset	float	No	The vertical distance from the station reference location in meters	3.0 meters
surfaceOffset	float	No	The vertical distance from the pavement surface in meters	0.5 meters

Field Name	Data Type	Required	Description	Example
installDate	datetime	No	Initial installation date of sensor	2/8/2003 8:45
calibDate	datetime	No	Date the sensor was calibrated	
maintDate	datetime	No	Date maintenance was last performed	
maintBegin	datetime	No	Date sensor is taken out of service; sensors for which maintBegin < currentDate < maintEnd will not be checked for data quality. Use if sensor will be out of service for a significant period of time.	10/15/2006 14:15
maintEnd	datetime	No	Date sensor is put back into service; sensors for which maintBegin < currentDate < maintEnd will not be checked for data quality	10/15/2006 18:15
serial	varchar(50)	No	Sensor's serial id	
embeddedMaterial	varchar(100)	No	Description (including depth) of material sensor is embedded in	Rubber cement
sensorLocation	char(10)	No		

sensortype

This table groups a sensor's manufacturer and equipment model identifier into a unique combination. This arrangement supports quality checking observations by a set of nearly identical measuring instruments.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	17
mfr	varchar(50)	Yes	Manufacturer of sensor	Vaisala
model	varchar(50)	Yes	Manufacturer's model number of sensor	DSC111
outputAvgInterval	int(11)	No	Milliseconds used to describe average interval of observations	300,000 milliseconds = 5 minutes
outputIntervalUnits	varchar(8)	No	Internal units reported to data logger	Celsius
samplingInterval	decimal(18,9)	No	Interval time, in seconds, between consecutive sensor readings	15.0 seconds

qchparm

The qchparm table contains quality checking parameters for the associated sensor.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
sensorTypeId	int(11)	No	sensortype record identifier	
obsTypeId	int(11)	No	obstype record identifier	
isDefault	int(11)	Yes	Flags whether or not the record is the default	
minRange	float	No	Minimum value for sensor range (hardware) test, as defined by the sensor manufacturer or the instrument owner	Minimum sensor range temp = -160.0 Degrees or the minimum sensor range temp set by the operator = -100.00 (whichever is most restrictive)
maxRange	float	No	Maximum value for sensor range (hardware) test, as defined by the sensor manufacturer or the instrument owner	Maximum sensor range temp = 220.0 or maximum sensor range temp reporting = 150.0 (whichever is most restrictive)
resolution	float	No	The smallest increment or measurement that can be obtained from a particular sensor	tenths of degrees = .1
accuracy	float	No	The known potential variation of the observation	0.05
minDisplay	float	No	Minimum value for sensor display	-52.85
maxDisplay	float	No	Maximum value for sensor display	120.22
ratePos	decimal(18,9)	No	Maximum positive rate of change during the time period defined by rateInterval, and as used by step test	20.0 degrees

Field Name	Data Type	Required	Description	Example
rateNeg	decimal(18,9)	No	Maximum negative rate of change during the time period defined by rateInterval, and as used by step test; reported as a negative number	-20.0 degrees
rateInterval	decimal(18,9)	No	Interval of time, in seconds, over which ratePos & rateNeg apply in the step test	3600.0 seconds or 1 hour
persistInterval	decimal(18,9)	No	Amount of time, in seconds, that the observed value can remain constant (not change). Used for the persistence test	14,400.0 seconds or 4 hours
persistThreshold	decimal(18,9)	No	Smallest amount of change that is allowed between observations. Used for the persistence test	0.2 degrees
likeThreshold	decimal(18,9)	No	Largest observed difference that is permitted among like instruments. Used during the like instrument test	1.0 degree

site

The site table contains a set of textual descriptions that provide a variety of qualitative assessments for a region in which ESSs are deployed. A good portion of the information consists of the relationship between a road segment and the sensing station as well as access restriction data for maintenance personnel.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
stateSiteId	varchar(50)	Yes	Contributor's identifier for the site	stateSiteId = 315
contribId	int(11)	No	Unique record identifier from the contrib table	

Field Name	Data Type	Required	Description	Example
description	varchar(50)	No	Description of site, as used by the contributor (e.g., "Seward Highway @ Portage Glacier Road")	Fairfax County Parkway @ Reston Avenue
roadwayDesc	varchar(50)	No	Name/number of the highway nearest to the site (e.g., "Interstate 35," "U.S. Hwy 59," "State Hwy 81," "Haines Highway")	State Hwy 81
roadwayMilepost	int(11)	No	Nearest mile marker to the site	45
roadwayOffset	float	No	The distance, in meters, between the closest point on the center surface of the roadway to the site reference point (e.g., base of an RWIS station)	37.53 meters
roadwayHeight	float	No	The elevation difference, in meters, between the closest point on the center surface of the roadway to the site reference point (e.g., base of an RWIS station)	22.8 meters
county	varchar(100)	No	The county or jurisdictional name of the site location	Fairfax County or Centreville Township
state	char(2)	No	State of the site location (2 letter postal identifier)	VA
country	char(3)	No	The country of the site location (e.g., USA, CA, MX)	USA
accessDirections	varchar(50)	No	Directions to access the site from a major roadway	Turn left at the cow, proceed three miles to Joe's Grocery, turn right on State Hwy 81, go 3 miles, on left
climateId	int(11)	Yes	Unique record identifier from climaterecord table	

Field Name	Data Type	Required	Description	Example
representativeness	varchar(255)	No	Describe any unique meteorological or topographical feature(s).	Between 2 & 4 PM during the summer months, the ESS is shaded
obstructions	varchar(100)	No	Description of physical properties (e.g., trees, buildings) that might affect the accuracy of observations	Large outhouse parked on SW side of ESS
landscape	varchar(100)	No	Description of surrounding landscape	Sandy area except for obstruction of oak tree and outhouse
accessControlled	bit(1)	Yes	Ability for contributor to access the site (e.g., locked fence around site)	0 = no access, 1 = full access
terrainSlope	int(11)	No	The grade of the surrounding land, in whole degrees from horizontal	10 degrees
terrainSlopeDirection	int(11)	No	The direction of the grade, in degrees from North (e.g., slope down from west to east is noted as 270)	85 degrees
windRoughnessClass	int(11)	No	Roughness of the wind in four directions (expressed in whole percent)	24 percent
soilType	int(11)	No	The type of soil on which the site is located, as described by the USDA National Resource Conservation Service soil texture classification (e.g., sandy loam, silt) or by percent sand, silt, and clay	Full enumeration list is not yet available
stateSystemID	varchar(45)	No	Site identifier used by the state DOT (or other data contributor)	22

station

The station table contains records that describe the physical infrastructure onto which environmental sensors are attached. Each station record maintains the base geographical location for the sensors, historic deployment dates, and details about the remote processing unit (data logger) operational status that includes power and communication.

Field Name	Data Type	Required	Description	Example
id	int(11)	Yes	Unique record identifier	
stationCode	varchar(50)	Yes	The contributor's station identifier; this may be different than the stateSiteID to allow more than one station at a given site	stationCode = 48
category	char(1)	Yes	The category of station – "P" permanent, "T" transportable, "M" mobile, "O" other	P
description	varchar(100)	No	The description for the station	
type	int(11)	No	The type of station – "0" data collected electronically/ mechanically, "1" collected by humans, "3" unknown	
contribId	int(11)	No	Unique record identifier from station table	
siteId	int(11)	No	Unique record identifier from site table	
locBaseLat	decimal(18,9)	No	The latitude location of the base of the station tower or RPU stand, in decimal degrees (e.g., 34.567); positive values are North latitudes. Value can hold up to 9 digits of precision	37.4821
locBaseLong	decimal(18,9)	No	The longitude location of the base of the station tower or RPU stand, in decimal degrees (e.g., -123.456); negative values are West longitudes. Value can hold up to 9 digits of precision	-113.22

Field Name	Data Type	Required	Description	Example
locBaseElev	decimal(18,9)	No	The elevation location of the station base (tower or RPU stand) in meters from mean sea level	135.5
locBaseDatum	char(10)	No	The datum geocoordinate referencing model	WGS 1984
powerType	char(1)	No	The type of power for the station – "B" battery, "L" line	B
doorOpen	bit(1)	No	The status of the door (0=closed, 1=open)	0
batteryStatus	int(11)	No	The percentage of full charge of the battery (101 = error)	78
lineVolts	int(11)	No	The typical voltage for the power source (0 to 100)	12 volts
maintContactId	int(11)	No	Unique record identifier from contact table. The contact person for maintenance from contact table; is implemented in the database as a link to a contact person	Contact name for maintenance issues that is included in the contact list – the id of the contact name will be put here
maintArea	varchar(50)	No	The description of the maintenance group for this station (for the site maintenance personnel)	Substation 52
maintPrevFreq	varchar(50)	No	The description of preventative maintenance intervals	The station is serviced every year in the spring or when the station fails completely
maintCalibFreq	varchar(50)	No	The description of the calibration maintenance intervals	The station is calibrated every spring and fall
maintStatus	bit(1)	No	The maintenance status of the station – "0" out of service, "1" in service	0
maintInstallDate	datetime	No	The initial installation date of the station	3/8/2004 8:00
rpuNumCards	int(11)	No	The number of sensor interface devices	2
rpuCommType	int(11)	No	The communication type for the station – "1" phone, "2" IP address	2

Field Name	Data Type	Required	Description	Example
rpuPhoneNum	char(10)	No	The phone number to contact the rpu	2025555555
rpuIPAddress	char(15)	No	The IP address to contact the rpu	64.126.107.233
rpuMfr	varchar(50)	No	The manuafacturer of the rpu	XYZ Manufacturer
rpuUTCOffset	int(11)	No	The number of minutes offset from UTC for the remote processing unit (RPU). Areas in the U.S. (west of Greenwich) use negative values. Range from -720 to +720	-60
rpuDST	bit(1)	Yes	Does the RPU need adjustment for Daylight Savings Time (DST)? [0=no, 1=yes]	1
obsCollFreq	int(11)	No	The number of minutes between collection cycles (RPU to agency server)	2 minutes
obsCollOffset	int(11)	No	The number of minutes after UTC midnight that the first collection occurs	1 minute
obsTransFreq	int(11)	No	The number of minutes between transmission cycles	15 minutes
obsTransOffset	int(11)	No	The number of minutes after UTC midnight that the first transmission occurs	16 minutes
obsTransFormat	varchar(50)	No	The description of the transmission format from the station to the network data logger	The ESS will communicate with the data logger by way of remote control

Appendix C

AMS Ad Hoc Committee
on a
Nationwide Network of Networks

Committee Members

The committee membership appears below.

Ad Hoc Committee Member	Organization	Sector*
Steven Fine	NOAA/OAR	G
Paul Pisano	DoT/FHWA	G
Samuel P. Williamson	OFCM	G
Don Berchoff	NOAA/NWS	G
Scott Hausman	NOAA/NESDIS	G
Rich Scheffe	EPA	G
Walt Dabberdt	Vaisala	P
Bob Marshall	AWS	P
Joel Myers	AccuWeather	P
Jim Block	DTN	P
John Horel	Univ. of Utah	A
Fred Carr,	Univ. of Oklahoma	A
Rit Carbone	NCAR	A
Len Pietrafesa	NC State	A
George Frederick	Falcon Consultants	AMS/Chair
Gary Rasmussen	AMS	AMS/Support
Ex Officio Members – Commission Executive Committee and Working Group Chairs		
Pam Emch	BEED Chair	
Veronica Johnson	BEC Chair	
Tim Spangler	BEP Chair	
Joe Friday	Past Commissioner	
Matt Parker	Future Commissioner	
John Lasley	Measurements/Infrastructure WG Chair	
Bob Pasken	Architecture WG Chair	
Renee McPherson	Metadata Policy WG Chair	
Paul Campbell	Org/Business Models WG Chair	
James Stalker	R&D/Testbeds WG Chair	
Brenda Phillips	Human Dimension WG Chair	

Committee Charge

The terms of reference for the committee are as follows:

- **Ad Hoc committee with free and open discussion of the issues encouraged**
- **Committee resides under the Commissioner of the AMS Weather and Climate Enterprise Commission.**
- **Strategy development includes addressing potential business models, organizational structure and operating modes.**

- **A plan for a summit of stakeholders will be developed**
- **Other committees and/or working groups may be established to address specific aspects of the issue and to plan for implementation of the strategy developed.**
- **Life of the ad hoc committee indefinite but should be reviewed at least annually**

Appendix D

References,

Abbreviations

and

Acronyms

References, Abbreviations and Acronyms

References

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Abbreviations and Acronyms

3D VAR:	**Three-dimensional variational**
AGL:	**Above Ground Level**
AMS:	**American Meteorological Society**
ANSI:	**American National Standards Institute**
AQRS:	**Air Quality Research Subcommittee (of CENR)**
ASCII:	**American Standard Code for Information Interchange**
CASA:	**Collaborative Adaptive Sensing of the Atmosphere**
CENR:	**Committee on Environmental and Natural Resources**
CIOS:	**Committee for Integrated Observing Systems**
CLARUS:	**The *Clarus* (Latin for "clear") Initiative aims to deploy an integrated road weather observational network and data management system that is national in scope.**
COOP:	**Cooperative Observer Program**
COSMIC:	**Constellation Observing System for Meteorology Ionosphere & Climate**
CSDGM:	**Content Standard for Digital Geospatial Metadata**
CWCE:	**Commission on the Weather and Climate Enterprise**
DCPC:	**Data Collection or Production Centre**
DOC:	**Department of Commerce**
DOD:	**Department of Defense**
DOE:	**Department of Energy**
DOI:	**Department of the Interior**
DOT:	**Department of Transportation**
EPA:	**Environmental Protection Agency**
ESS:	**Environmental Sensor Stations**
FACA:	**Federal Advisory Committee Act**
FFRDC:	**Federally Funded Research and Development Center**
FGDC:	**Federal Geographic Data Committee**
FHWA:	**Federal Highway Administration**
GCOS:	**Global Climate Observing System**
GEOS:	**Global Earth Observing System**
GIS:	**Geographic information science**
GISC:	**Global Information System Centre**
GOES-R:	**Geostationary Operational Environmental Satellite—R**
GOS:	**Global Observing System**
GPS:	**Global Positioning System**
GRIB:	**Gridded Binary**
HCN-M:	**Historical Climate Network – Modernization**
HDF:	**Hierarchical Data Format**
IDD:	**Internet Data Distribution**
INSPIRE:	**Infrastructure for Spatial Information in the European Community**
IOOS:	**Integrated Ocean Observing System**
IOP:	**Intensive Operations Periods**

IPET-MDI:	**Inter-Programme Expert Team on Metadata and Data Interoperability**
ISO:	**International Standards Organization or International Organization for Standardization**
ITS:	**Intelligent Transportation System**
JAG:	**Joint Action Group**
LDM:	**Local Data Manager**
MetSat:	**Meteorological Satellite (also METSAT and Metsat)**
MIWG:	**Measurements and Interchange Working Group**
MoPED	**Mobile Platform Environmental Data observation network**
NMPP:	**National Mesonet Pilot Project**
NAB:	**NNoN Advisory Board**
NAP:	**North American Profile**
NAPA:	**National Academy of Public Administration**
NASA:	**National Aeronautics and Space Administration**
NCAR:	**National Center for Atmospheric Research**
NCDC:	**National Climatic Data Center**
NESDIS:	**National Environmental Satellite and Data Information Service**
NetCDF:	**Network Common Data Form**
NGO:	**Non-Governmental Organization**
NIST:	**National Institute of Standards and Technology**
NMWOS:	**National Mobile Weather Observation System**
NNoN:	**Nationwide Network of Networks**
NOAA:	**National Oceanic and Atmospheric Administration**
NPN:	**NOAA Profiler Network (formerly National Profiler Network)**
NREL:	**National Renewable Energy Laboratory**
NRC:	**National Research Council**
NTCIP:	**National Transportation Communications for ITS Protocol**
NSSL:	**National Severe Storms Laboratory**
NWS:	**National Weather Service**
OFCM:	**Office of the Federal Coordinator for Meteorology**
OGC:	**Open Geospatial Consortium**
OSD:	**Open Source Definition**
OSI:	**Open Source Initiative**
QA/QC:	**Quality Assurance/Quality Control**
R&D:	**Research and Development**
RITA:	**Research and Innovative Technology Administration**
RWIS:	**Road Weather Information System**
SensorML:	**Sensor Model Language**
UCAR:	**University Corporation for Atmospheric Research**
UML:	**Unified Modeling Language**
US:	**United States**
USCRN:	**US Climate Reference Network**
USDA:	**US Department of Agriculture**
USRCRN:	**US Regional Climate Reference Network**
VDT:	**Vehicle Data Translator**

WCOSAC: **Weather and Climate Observing Systems Advisory Committee**
WG: **Working Group**
WIS: ***WMO* Information System**
WMO: **World Meteorological Organization**
WSR-88D: **Weather Surveillance Radar-88 Doppler**
XML: **Extensible Markup Language**