NIST Area of Critical National Need - Complex networks and complex systems

Development of Network to Assess Trends in Greenhouse Gas Emissions for

Climate Change Mitigation

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Statement of Need

Climate change mitigation efforts are a high priority for the new administration. There will be a broad suite of mitigation efforts to reduce greenhouse gas emissions (GHG), but there is not currently a measurement network of state-of-the-art instruments at an appropriate resolution to determine if policy actions are effective and to determine if we are in fact reducing GHG emissions at an acceptable rate.

There is a *critical national need* to develop a trace gas instrumentation and communications network to quantify and verify trends in greenhouse gas (GHG) emissions at a resolution appropriate for detecting trends at the state to regional and national level. It requires government action because of the size of the problem (global) and the urgency to reduce GHGs below levels that threaten humanity. As the U.S. considers setting GHG emissions reduction targets, and states have already established their own targets, there is a need to quantify and verify whether these targets are being met.

It requires linking the best in technology, science and policy with a goal of environmental improvement. It is appropriate for the Technology Innovation Program because it requires development and testing of a full suite of instruments, development of the communications network, and integration with atmospheric transport modeling to determine sources and sinks for GHGs. This is not in the venue of existing government programs, so it is essential for such a network to be developed and implemented quickly.

A network of carbon and non-carbon GHG instrumentation has to be designed to provide a pipeline of data at a high quality to be able to detect trends at this scale and to identify sources from landfills to urban areas versus the land-based sink (e.g. forests). The data need to be analyzed and archived in a network pipeline from remote sites to a central data system quickly enough to inform policy decisions. Although flask measurements are currently employed globally for resolving continental GHGs, particularly CO_2, a higher resolution network of instrumentation and communications is desperately needed.

Researchers at Oregon State University are developing a prototype system that includes atmospheric measurements, transport modeling, remote sensing data, and a computer cluster for data assimilation. A related prototype data management system is being developed in collaboration with software engineers. However, it needs to expand to include other critical GHGs and tracers, and the sheer number of the required measurement systems and computing resources are beyond the scope of any government agency funding program.

This is high risk because such a grand system does not exist at the level of precision and coverage of GHGs needed to meet the climate change reduction targets.

Background

As an example, the governors of the western states have committed themselves to the Western Climate Initiative through which they will reduce greenhouse gas (GHG) emissions. States have committed to

reducing GHG levels to e.g. 10% less than 1990 levels by 2020, and to 75% below 1990 levels by 2050. Lawmakers and the public will want policies to be effective at reducing GHG emissions while being consistent with other economic, social, and political objectives. Long term management of state's GHG emissions will thus require effective and transparent measurements, evaluation, and revision of existing GHG reduction policies. Thus it is essential to develop independent and effective measurement and modeling approaches, for tracking GHG emissions and decision-support tools that are powerful and flexible enough to supply state-of-the-art information for adaptive management strategies. All of this must be done in a way that provides clear communication of current conditions and probable outcomes of various policy decisions to State legislators.

To accomplish these goals, it requires a network of atmospheric GHG observation sites that measures atmospheric GHG concentrations and, via transport modeling, allows determination of spatial and temporal trends in the "sources." The suite of instruments would need to measure carbon and non-carbon GHGs, and tracers to identify sources (e.g. landfill methane versus wetland sources of methane).

Greater spatial resolution is required in the large metropolitan areas because they are the largest GHG emission sources. A network of sites will allow detailed characterization of trends in anthropogenic emissions, biogenic sources and sinks for CO_2 and feedbacks to climate, and the impact of policy measures to reduce GHG. It requires spearheading development of information technologies to serve as decision support for policymakers in the context of climate change mitigation. Distributing sites across the country requires establishment of a central data system and satellite communications to transmit data to the center for processing and dissemination.

Research technology to be developed

The research required is development of a prototype system that measures the appropriate atmospheric gases at each network site, model optimization of where to locate sites for effective spatial coverage, and research on a data system tailored to this prototype system such that the measurement, data management, and communications system has the capability of being expanded to the whole U.S.

There are several instruments in development that could be combined or modified to provide the best suite of measurements at each site. Each site of the network should be equipped for continuous measurements of GHG (CO_2, CH_4, N_2O), and carbon monoxide (CO) and ^{222}R (with CO and ^{222}Rn providing information on the source of emissions and atmospheric mixing respectively). In some regions, methane (CH_4) may be the largest source of non-CO_2 greenhouse gas; it is mostly emitted by microbial processes associated with livestock and landfills. A subset of the network sites should include periodic flask measurements of a broad suite of GHGs (CO_2, CO, CH_4, SF_6, H_2, and halo carbons). ^{14}C isotope measurements should also be made to isolate the fossil fuel component of observed CO_2 anomalies. Other chemical tracers can be correlated with the ^{14}C depletion of CO_2. This will require collaboration with a research and engineering staff at companies for whom we have beta tested instruments.

Optimization is based on computer modeling of atmospheric transport and footprint modeling, and remote sensing data, and assimilation of data from the instrument network. The framework should be designed to be easily incorporated into a global GHG tracking system.

Pathway to achieving goals (matched to all three critical national need selection criteria)

Modeling would be done with some existing measurements to optimize the locations of the new measurement systems for best coverage at a sufficient density. The state-of-the-art instruments have to be field deployable and provide continuous real time monitoring of ambient atmospheric trace gas concentrations. The sites would need to be equipped with remote link connections to enable data download via satellite for real-time data analysis and display. The instruments and communications need to be

adapted for state-wide to national network design that links to the global framework of existing non-continuous GHG observations. The measurement and data-streaming systems would be installed and maintained while model setup is underway. A central data server for processing, storage and backup would be installed. Modeling with atmospheric transport models would distribute the GHG in the atmosphere spatially and temporally, which requires cluster computing or supercomputing, an SQL server, and ample data storage capabilities.

Results over a target region (e.g. a state) would be provided with uncertainty bounds on the estimates. This information would be reported for administrative use (e.g. Our Changing Planet, an annual supplement to the President's Budget).

Expected new outcomes and capabilities

This network will provide a decision-support tool for U.S. and state policymakers to determine progress in meeting climate change targets, locate areas for improvement, and to increase public awareness of this important issue.

Maps to Administrative Guidance

The Administration has prioritized climate change mitigation. With multiple efforts to reduce GHG emissions, it will require independent quantification and verification of progress towards reducing emissions. The proposed measurement and modeling system would provide a prototype to meet those needs at the national to state level of resolution.

This project would provide results for inclusion in 'Our Changing Planet: A Supplement to the President's Budget,' an annual report of the U.S. Climate Change Science Program, the periodic synthesis and assessment reports of the Carbon Cycle Science Program, and other reports of the OSTP.

Justification for Government Attention

Climate change is an urgent issue that is global in nature, and countries have set forth plans to reduce GHG emissions before dire consequences ensue. Climate change is an important agenda of the new administration and of states. Timing is critical for having a quantification and verification system in place quickly. The National Academy of Science National Research Council (NRC) has a 2009 committee that is assigned to determine the state of the science and research needs in quantifying and verifying GHG emissions, indicating the level if importance of this topic. *Likely proposers* include research groups at universities and research institutions who are conducting research in support of the US Climate Change Science Program.

Essential for TIP Funding

Meets a timely need that is not met by others: This is essential for TIP funding because other federal agencies are not addressing this need. NIST is a member of the U.S. Carbon Cycle Science Program, but has not played a large role to date and this would be an excellent opportunity to fill a critical national gap in climate change research. NOAA's focus is on some major GHGs at global to continental scales, too crude for assessing progress towards state, regional and national GHG emissions targets. DOE is focused on climate modeling and terrestrial ecosystem carbon studies, and does not support long-term observations or monitoring systems. EPA R&D also does not support long-term atmospheric network observation systems that measure all GHG constituents, coupled with modeling. This is a huge gap that desperately needs to be filled.

Potential for impacts and transformations: This prototype design will provide the blueprint for developing a national GHG observation/modeling/data assimilation system to inform policy makers in a timely manner for effective actions to be taken.