NASA Carbon Monitoring Scoping Study

Draft whitepaper to motivate and guide July 2010 workshop

1. Background & Motivation

The IPCC assessments consistently point to accelerating growth in anthropogenic emissions of greenhouse gases (GHGs) as the primary driver of recent climate change. Of particular concern are the carbon-based gases, since CO2 and CH4 represent over 90% of the 100 year global warming potential. Hence anthropogenic perturbation to the natural carbon cycle represents a central threat. Policies are being considered by the US and international community with the goal of stabilizing GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The potential policies include multilateral treaties under the United Nation's Framework Convention on Climate Change (UNFCCC) and/or bilateral agreements, the EPA's Greenhouse Gas Reporting Rule (now being implemented), and draft US climate and/or energy legislation (with and without cap and trade provisions). In addition to policies imposed by governments, voluntary carbon trading and/or offset programs are also being implemented on various scales. Effective design and implementation of all of these policies is contingent on reliable information about carbon stocks and fluxes with varying requirements on accuracy and spatio-temporal resolution.

Incomplete GHG and carbon data on policy-relevant spatio-temporal scales represents a barrier to scientific and public understanding, policy formulation, and successful policy implementation. Sustained and accurate "top-down" monitoring of atmospheric GHG concentrations has been available for decades (for a total-earth assessment) but the existing network is not optimized to monitor anthropogenic emissions on regional scales. While bottom-up estimates of country-level CO2 emissions carry reported uncertainties ranging from ±5% to greater than ±20%, the total annual accumulation of CO2 in the atmosphere varies by up to 100% due to natural variability in the carbon cycle. To balance the carbon budget, up to 50% of anthropogenic emissions have to be absorbed by the terrestrial biosphere, but the location of this "missing sink" cannot be constrained with current data at scales smaller than continents. Some critics of GHG stabilization policies have cited this uncertainty as reason to doubt the attribution of accelerating emissions to anthropogenic activity. This issue of scientific and public understanding represents a proximate threat to establishing stabilization policies. Additionally, the incompleteness of geospatially-explicit data in key regions hampers diagnostic and prognostic efforts to design policies tailored to the unique challenges of individual countries. For example, the emissions of the US, Russia, China, India and Brazil are each driven by different economic and technical factors and represent distinct monitoring challenges. Without better geospatially-explicit data on GHG emissions and carbon stocks, evaluation of the efficacy of policy implementation is at risk – including prompt diagnosis and correction of policy failures to achieve the end goal of stabilization. Finally, unless scientifically robust information can be generated in an open, accessible, and policy-relevant format it will not be actionable or embraced by decision-makers.

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2. Monitoring challenges

Efforts to define requirements for policy-relevant GHG monitoring are challenged by three overarching issues:

1. Lack of well-posed, policy-relevant questions
2. Gaps in scientific understanding
3. Limited examples of existing policy-relevant products

Since GHG stabilization policies are still evolving, well-posed questions from end-users are not readily available. In fact, there is currently no focused or sustained forum or process for enabling this dialogue between policy/decision-makers and scientists. Efforts are underway to address this issue but the current approach is limited to periodic workshops and ad hoc peer-to-peer efforts. Scientific understanding of GHGs and the carbon cycle is evolving rapidly but there are significant questions associated with process models for the atmosphere, land, and oceans – which correspond to uncertainties in the community's ability to offer independent tests of self-reported emissions and/or carbon sequestration. Fortunately, the US Carbon Cycle Science Program represents a sustained effort to identify and address gaps in scientific understanding and has devoted some attention to decision support (e.g., SOCCR, 2007). There are, however, few existing examples of policy-relevant GHG/carbon products beyond the self-reported emission inventories. Therefore it's difficult to exercise the usual "push-pull" process used in defining applied-science requirements (where scientists share current capabilities with decision-makers who respond with requests for additional information). All of the above factors suggest that efforts to define requirements for policy-relevant GHG/carbon monitoring will need to be iterative and might benefit from exploratory pilot projects.

Despite the recognized challenges to defining GHG/carbon monitoring requirements, efforts have been underway to identify priorities for improvement. The results of the various efforts suggest a common set of themes.

A recently completed report by the National Research Council (NRC) - Verifying Greenhouse Gas Emissions: Methods to Support International Climate Agreements (Pacala et al., 2010) – highlighted the following key needs:

- Strengthen national GHG emission inventories
- Improve ability to independently and remotely estimate national fossil fuel CO2 Emissions
- Validated area emissions estimates through measurement of "urban domes"
- Accurately estimate national emissions and removals from sinks from Agriculture, Forestry, and Other Land Use (AFOLU) and independently check self-reported estimates of CO2 emissions from deforestation, reforestation, and forest degradation.

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Additional, specific recommendations from that panel included:

- Prompt action to avoid critical data gaps (e.g., OCO replacement mission and others)
- Optimization of observing strategies for remote-sensing platforms to address specific topics such as urban domes
- Augment atmospheric observations to include ^{14}C to help disentangle the contributions of fossil fuel combustion from terrestrial ecosystem processes

Other study efforts reported similar findings (2nd Greenhouse Gas Information System workshop, 2009) and additionally, called for:

- Accounting for carbon sequestered and released in coastal oceans and general ocean carbon processes[1]
- Executing a set of focused coordinated pilot projects or case studies to help identify user needs and system requirements and ensure relevance of the products.
- A prototype data/model integration system to leverage existing assets with standard units, metadata, and protocols for model and data intercomparison.
- Open and transparent information products to ensure acceptance by the international community.

Finally, recent efforts to increase collaboration between the "bottom-up" and "top-down" communities towards reducing uncertainty in national emission inventories are leading to similar recommendations (IPCC Expert Meeting on Inventories, 2010).

In summary, while there remain barriers to deriving precise requirements for GHG/carbon monitoring for policy support, there is a growing convergence on key themes that may warrant priority attention.

3. Scope of NASA Carbon Monitoring System activity

Independent of the recent interagency efforts to address GHG/carbon monitoring for policy support, NASA has an established Earth science program devoted to the study of fundamental biological and physical processes that impact life on Earth. NASA's Earth science program regularly collects, archives, processes and distributes Earth observations that provide critical information for decision makers. Past examples of sustained observations for policy support include NASA's satellite observations of upper atmospheric ozone; AGAGE observations of CFCs with relevance to the Montreal Protocol; and satellite observations of deforestation and land cover – land use change NASA's Earth science research program also includes climate change, climate modeling and carbon cycle science as key research areas. NASA participates in existing interagency efforts to coordinate US and international response in these areas including: the US Carbon Cycle Science Program

[1] Ocean carbon fluxes are currently not included in most GHG stabilization policies. However, given the existence of large gradients in CO2 upwelling in some coastal waters and estuaries, coastal fluxes may become important in the future, depending on spatial scale and point of regulation issues. Additionally, the oceans will exert some degree of remote influence on inverse model based flux estimates over land.

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and North American Carbon Program (NACP) and the Group on Earth Observations (GEO) including the Committee on Earth Observation Satellites (CEOS).

While the aforementioned GHG/carbon monitoring studies were underway, the FY10 Congressional Omnibus Bill was released in December 2009 with new direction and funding for NASA for "pre-phase A and pilot initiatives for the development of a carbon monitoring system. Any pilot developed shall replicate state and national carbon and biomass inventory processes that provide statistical precision and accuracy with geospatially explicit associated attribute data for aggregation at the project, county, state and federal level using a common dataset with complete market transparency, including extraction algorythms[*sic*] and correlation modeling".

After an initial planning effort in early 2010, NASA responded to the new congressional direction by establishing two pilot projects: a global CO2 flux estimation project and a US biomass estimation project. Both projects will include experimental intercomparison of top-down and bottom-up estimates. Additionally, NASA established a Scoping Study effort intended to provide a coordinated input to agency strategy development on the topic of carbon monitoring.

Several NASA Earth Science program areas offer capabilities relevant to GHG/carbon monitoring including: Research & Analysis (e.g. Carbon-Cycle and Ecology)), Applied Science(e.g. Agriculture/Forestry, Ecology, and Climate), Technology(e.g. Sensor development), Missions (e.g. EOS, the Decadal Survey, OCO-2, JPSS).

This Scoping Study is intended to provide input to agency strategic development. No assessments or recommendations from this study including any report generated by it will constitute an agency decision or policy.

Finally, the Scoping Study is intentionally focused on potential roles for NASA in supporting GHG/carbon monitoring efforts by the US and/or international community. The description of overarching challenges and priorities described in this whitepaper are intended to offer context and background, not propose new directions for NASA.

4. Approach for Scoping Study

The objective of this whitepaper is to motivate a broader discussion and assessment by the NASA community, including representatives from NASA HQ and the field centers, as well as our colleagues in academia, industry, and other US agencies with backgrounds in GHG and carbon observations, modeling, analysis, systems engineering, and/or policy-relevant applications of these capabilities. A workshop will be held July 13-14 in Boulder, Colorado to facilitate this discussion and initiate development of a Scoping Study Report.

The objectives of the Scoping Study Report (notionally, about 20 pages in length) include:

1. Assessment of current NASA capabilities relevant to GHG & carbon monitoring
2. Assessment of gaps in NASA capabilities relevant to GHG & carbon monitoring

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3. An integrated schema of carbon policy and carbon monitoring to enable an optimal vision of the use of agency capabilities through 2020
4. Extrapolate both near-term (3-5 year) and long-term (>5 years) issues.

The latter should offer insights on synergies among internal NASA programs, interagency collaborations, and private-public partnerships.

The workshop will identify an outline for the Scoping Study Report, key themes for elaboration, and section writing assignments for subsequent work after the workshop, leading to delivery of the 1st Version of the Report to NASA's Earth Science Division (ESD) in September 2010. The NASA Earth Science Division will provide additional venues for community input through ESD workshops, including a follow-on Scoping Study workshop in the Fall/Winter of 2010 which will solicit more feedback and comments on the Report.

Initial guidelines for the Scoping Study include:

- Be responsive to the congressional mandate for pilot projects
- Take initial steps toward addressing recommendations from the NRC panel
- Demonstrate efficacy of NASA & partner capabilities to address needs
- Work with end users to help derive well-posed questions to identify other needs
- Strive to build capacity in improved infrastructure, tools, processes, and people
- Provide an integrated, overarching view of related NASA efforts
- Be sensitive to the needs of other agencies and how to best facilitate partnering
- Provide open and inclusive opportunities for review and comment on the Report

To help focus the workshop discussion and offer initial framing of the Scoping Study Report, the following approach will be taken. Four "carbon monitoring scenarios" or "policy use-cases" will each be explored with an end-to-end perspective (i.e., notional driving questions, required observations, models, integration/synthesis, and decision support analysis):

I. GHG emissions from area sources of CO2, CH4, & N2O (country total & AFOLU)
II. GHG emissions from "atmospheric domes" (urban fossil-fuel emissions)
III. Terrestrial carbon stocks & stock-changes (forest & soil carbon offsets)
IV. Ocean carbon fluxes

Additionally, teams organized by the following areas will approach the same themes from a "discipline-centric" perspective:

1. Observations: priorities for measurements from space, air, and surface (and their attributes);
2. Modeling & Data Assimilation: model/data fusion including tracer transport inversion and contributing models (atmospheric transport, terrestrial ecosystem carbon, ocean carbon, etc); model intercomparison; error characterization & propagation;
3. Decision-Support: definition of policy-relevant information; analysis and tools to synthesize, compare and reconcile top-down and bottom-up emission estimates.

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This approach is intended to offer a notional framework to help organize the Scoping Study effort. Workshop participants will be given the opportunity to comment on the approach and suggest alternatives.

REFERENCES & RECOMMENDED READING

–US National Research Council (NRC): *Verifying GHG emissions: methods to support international climate agreements (2010)*
http://www.nap.edu/

–GHGIS Interagency Workshops on Needs and Capabilities (2008 & 2009)
http://climate.nasa.gov/Documents/

–The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle (2007)
http://www.globalchange.gov/publications/reports/scientific-assessments/

–RFF report on Forest measurement and monitoring (2010)
http://www.rff.org/Publications/

–US Carbon Cycle Science Program (ongoing)
http://www.carboncyclescience.gov/

–U.S. Climate Change Technology Program, Strategic Plan, Chapter 8 - Enhancing Capabilities to Measure and Monitor Greenhouse Gases (2006)
http://www.climatetechnology.gov/stratplan/final

–GEO Carbon Strategy (in review) – draft available (TBD)

- IPCC Task Force on Inventories – report from IPCC Expert Meeting on Inventory Uncertainties & Validation (March 2010) - TBD

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