Global Greenhouse Gas Information System

Workshop on Policy Needs & Current Capabilities

October 15-16, 2008
Caltech

WORKSHOP REPORT

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1. EXECUTIVE SUMMARY

A Global Greenhouse Gas (GHG) Information System offering actionable knowledge on GHG sources and sinks and their links to anthropogenic activities could be a critical component of any successful effort to address the impacts of climate change by limiting atmospheric concentrations of greenhouse gases. A workshop hosted by the Jet Propulsion Laboratory (JPL) and RAND was held at the California Institute of Technology in Pasadena, California on October 15 and 16, 2008 to examine the potential information needs and options for deploying such a system.

The Workshop focused on systematically identifying the gaps between policy-information needs and current GHG tracking and attribution capabilities. The Workshop engaged a diverse community of policy information users and information providers from the Earth Science and Energy sectors. The Workshop consisted of interactive topical presentations in plenary session and breakout sessions for brainstorming.

The workshop produced the following key findings:

I. Policy makers could derive significant value from a GHG Information System that offered reliable information on anthropogenic GHG sink-source fluxes (distinct from natural contributions) over an appropriate range of spatio-temporal scales. In particular, such a system could supplement data on emissions from fossil fuel combustion currently derived largely from self-reported data on energy and fuel use, could enable better management of emissions from and sequestration into bio-physical systems, and could reduce the potential for unreported leakage from any greenhouse gas emissions control regime.

II. Currently operating and planned systems, if properly integrated, offer some of the necessary capabilities a future Global GHG Information System should provide.

III. Most policy mechanisms under consideration to limit atmospheric GHGs would require additional and/or improved data sources and significant interaction with potential information providers and end users in order to provide actionable knowledge. Key needs include sustained capability for better space-based observations, significant increases in the number of ground based sensors, measurements of trace gases to help link measured GHG concentrations to sources of combustion of particular fossil fuels, and improved data assimilation, distribution, and analysis systems.

IV. Extracting policy-relevant information from current and future data sources requires expanded synthesis, analysis, and modeling efforts, spanning multiple disciplines and agencies, which can be facilitated through applying a coordinated, interdisciplinary approach. A continuation of this activity is recommended to systematically identify user needs and assess gaps relative to current capabilities by mid-2009 in order to guide the requirements, design, and potential deployment of a future GHG information system.

The first day focused on the GHG information needs of policy- and decision-makers to support or enable various efforts, including: International Treaties to Reduce GHG Emissions, Carbon Markets, Transparent Reporting, and Natural Resource Management. On the second day, current and expected near-term GHG observation capabilities were discussed and participants began to consider potential gaps between these capabilities and potential needs.

This report describes the workshop approach, agenda, discussion topics, and key themes as well as a proposed outline for future work[1].

2. WORKSHOP BACKGROUND

2.1 Motivation

A Global GHG Information System will prove a critical component of any successful effort to address the impacts of climate change by limiting atmospheric concentrations of greenhouse gases. It will provide the information needed to implement and assess actions to reduce emissions, influence land use change, and sequester carbon. The information from such a system will also be subject to intense scrutiny. Therefore, an effective system must openly and transparently produce data of unassailable quality and at the same time be accessible to policy makers, regulators, scientific community, and the general public.

2.2 Objectives & Scope

The information system will likely require a combination of space-based assets, ground-based assets, self-reporting, carbon cycle modeling, fossil-fuel inventories, energy data, and meta-analysis to transform the data into actionable knowledge for policy makers. The specific requirements on such a system would be shaped by the degree of international cooperation it enjoyed and the needs of the policy regime it aimed to support, which might range from verifying treaty obligations, to certifying the tradable permits and offsets underlying a market in greenhouse gas emission reductions, to providing a comprehensive inventory of high and low emitters that could be used by NGO's and other international actors. Some technical studies have examined particular components of such a system in single scenarios. But there remains a need for a comprehensive survey of the range of potential requirements, options, and strategies for such a monitoring system. Fulfilling this need, either singly or collaboratively, will provide an opportunity for U.S. leadership in creating part of the infrastructure necessary for global reductions in greenhouse gas emissions.

Specifically, the workshop objectives included addressing the following broad questions:

1. What are the information needs of different policy purposes?

[1] Questions on this report may be addressed to the Synthesis Committee: Riley Duren (JPL), Robert Lempert (RAND), James Butler (NOAA), Michael Ebinger (LANL), Scott Doney (WHOI), and Stacey Boland (JPL).

2. What information can be made available in the near-and mid-term?

3. What are the gaps between information needs and availability?

4. What actions should the U.S., either alone or in collaboration with others, take now to begin to fill these gaps?

2.3 Approach

This interactive workshop engaged members of diverse policy communities with technical experts experienced in the design of similar information systems. The workshop examined the potential needs posed by a range of different policy mechanisms, current observational and modeling capabilities, and provided a first-cut analysis of gaps between the two.

The agenda topics were selected to address four categories of needs that might be supplied by a GHG Information System. Specifically, these are to:

Support treaty verification: Provide independent verification of international treaties intended to limit greenhouse gas emissions.

Support carbon markets: Provide objective constraints on quantity of emissions or effectiveness of claimed emission reductions.

Support transparency: Provide unassailable, freely-available, and widely-trusted public information on GHG emissions to incentivize emissions reductions.

Support natural resource management: Provide input to resource managers seeking to make adaptation decisions associated with impacts of increased levels of GHGs.

It was recognized these four needs involve distinct sets of end-users, and thus vary considerably in terms of data and information requirements. Participants discussed the degree to which end-user needs do and do not overlap between the different categories, recognizing that information system requirements will depend heavily upon the specific policy mechanisms it is designed to support.

3. SYNOPSIS OF DISCUSSIONS

A listing of plenary presentations with speaker names and affiliations is provided below in the form of an abbreviated agenda. The full agenda is provided in Appendix B. This section provides a brief overview of the topics discussed at the workshop. The presentation materials were made available to participants after the workshop.

Day 1

- *Welcome & Context* – Paul Dimotakis (JPL/Caltech)
- *The Grand Challenge* – Charles (Chip) Miller (JPL)
- *Workshop Concept & Objectives* – Robert Lempert (RAND)
- *The Global Carbon Cycle* – Scott Doney (WHOI)
- *The Human Contribution (fossil fuels)* – Gregg Marland (DOE/ORNL)
- *Treaties & Regulation* – Phil DeCola (OSTP)
- *Carbon Markets* – Joe Nation (ENVIRON/Stanford)
- *Registries and Self-Reporting* – Diane Wittenberg (The Climate Registry)
- *Fossil Fuel Resources (Coal)* – Dave Rutledge (Caltech)
- *Decision Support (Natural Resources, Energy, Geoengineering)* – Riley Duren (JPL)
- *Breakout Session #1 – Identify Key Needs (split into 3 groups, same charter)*

Day 2

- *Summaries from Breakout Session #1 by group*
- *Survey of Past/Concurrent Efforts* – Nick Burger (RAND)
- *Spaceborne Observing Capabilities* – Charles Miller/Mike Gunson (JPL)
- *Ground Sensing Capabilities* – Jim Butler (NOAA/ESRL)
- *Integrated Products (Data to Knowledge)* – Stacey Boland (JPL)
- *Breakout Session #2 – Identify Key Gaps (split into 3 groups, same charter)*
- *Summaries from Breakout Session #2 by group*
- *Discussion of Future Plans*

3.1 Day 1 Synopsis

To open the workshop, Paul Dimotakis of JPL and Caltech gave a high-level overview of the connections between anthropogenic greenhouse gas emissions and climate change. He then described ongoing efforts at JPL targeted at improving our scientific understanding of the potential impacts of climate change, considering the role of international agreements in reducing greenhouse gas emissions, and exploring the technology options for achieving large reductions in anthropogenic emissions of greenhouse gases.

Charles Miller of JPL then shared the scientific motivation behind the concept of a Global GHG Information System, citing data that indicate actual anthropogenic carbon emissions since 2005 have exceeded the worst-case emission scenario (A1FI) described by the Intergovernmental Panel on Climate Change. He also noted the likely economic motivations of the private sector in their desire for establishment of a cap and trade system – at current carbon market values, world emissions of 10 Gigatons Carbon (GtC) suggest a potential $1 trillion dollars annual market.

Robert Lempert of RAND described the workshop concept, objectives, and methodology. He offered three additional points motivating establishment of a Global GHG Information System:

- Addressing climate change has become a national and global imperative
- A global greenhouse gas information system would provide a crucial piece of infrastructure needed to meet this challenge
- Building such a system provides an opportunity for U.S. leadership

He also pointed out that such systems should reflect the key principles of effective decision support: the system should be built from users' needs, identified collaboratively between information providers and users, with an emphasis on decision processes over information products. In order to design an information system and products to enable decision support processes, he noted a multidisciplinary and multi-organization approach is needed.

Scott Doney of the Woods Hole Oceanographic Institution then gave an overview of the Global Carbon Cycle to provide a summary of the bio-physical science associated with GHGs. The main anthropogenic sources of carbon are fossil fuel emission and deforestation, with the former about five times larger than the latter. The main natural sinks are ocean and the terrestrial biosphere with the remainder (about half) of the CO_2 emitted remaining in the atmosphere. There are large uncertainties in our measurements of both sources and sinks and net human perturbations of the carbon cycle exist on top of a large and variable natural background. In particular, our understanding of the sources and sinks from the terrestrial biosphere is based on calculating the relatively small differences between large daily and seasonal variations. Improving our ability to measure sources and sinks of carbon requires improving our understanding on a range of spatio-temporal scales (hours to centuries and smoke-stack to globe) , providing both a "top-down" view of the atmosphere and a "bottom-up" view of biophysical processes, and merging this information with improved atmospheric and oceanic transport models.

Gregg Marland of the Oak Ridge National Laboratory (ORNL) summarized the current state of the art in quantifying the human component of the carbon cycle based on emissions inventories. The current best estimates for fossil-fuel combustion carry uncertainties ranging from significant (10% for carbon dioxide (CO_2) and 30% for methane (CH_4) in the US and Europe) to extreme (unknown in other parts of the world). Of particular note is the possibility that some of these uncertainties are actually increasing with time. Other highlights:

- The 25 countries emitting the largest amounts of GHGs produce 80% of the problem suggesting that a reduction from those 25 nations would significantly improve the global situation
- Uncertainties associated with the output of these 25 largest emitters exceeds the combined output of all the other, smaller emitters
- ORNL experience based on quality control checks for data supplied by other entities suggests potentially large errors (factor of 20) between different estimating organizations for selected emission sources such as gas flaring and venting

- Certain gasses such as Carbon Monoxide (CO) and ^{14}C may serve as "tracers" of fossil-fuel activity and may be sufficient to reduce attribution uncertainties
- Current fossil-fuel inventories on a global level are based on a large, complex data sets, are considered under-funded, and exhibit large errors at the level of individual sovereign nations

Phil DeCola of the President's Office for Science and Technology Policy (OSTP) gave the first in a series of talks on policy needs by describing the role of treaties and regulation in reducing GHG emissions as well as an introduction to the challenges of carbon cap and trade schemes. An ensuing discussion focused on related topics including:

- Point of regulation: given the way GHGs are transported around the world following emissions, how and where should they be regulated – and what are the implications on related information systems?
- Effectiveness: while cap and trade systems can certainly be profitable, what ensures they actually meet the intent (of reducing GHG emissions)? This is of particular concern for the subject of "leakages". That is, based on the possibility for a "shell-game" type approach in which participants in a cap and trade program take advantage of exempted activities to avoid the costs of reducing emissions.

Joe Nation of the ENVIRON Foundation and Stanford University then offered a more in-depth treatment of the key cap and trade elements and provided some insights into plans underway in the State of California, including Assembly Bill 32 (AB32) which calls for a program to reduce state GHG emissions by 2020, with requirements on GHG monitoring and market-based approaches to achieving the reduction targets. The presentation triggered a key discussion about the challenge posed by "offsets." It is currently difficult to determine if offsets actually reduce total GHG emissions because the relative contributions of biomass carbon sources and anthropogenic activities to total atmospheric carbon are poorly understood. A subtle consideration arose: the real need may be for a carbon-cycle information system of which GHGs in the atmosphere are a part. This warrants further consideration.

Diane Wittenberg of the Climate Registry gave an overview of how carbon registries work. Some key aspects of this discussion included:

- The major barrier to increasing voluntary participation in carbon registries and/or enacting legislation is the <u>cost of verification</u>
- Current emission-reporting gaps include:
  - Fugitive emissions (wastewater treatment, landfills, natural gas transport)
  - Sequestration (geologic, forests, oceanic)
- The crucial role of 3rd party verification in ensuring reliable emissions data

This resulted in follow-up conversations regarding:

- The appropriate role of a GHG information system and decoupling it from an auditor organization and issues of liability
- The potential role for international collaboration in delivering and operating any Global GHG Information System in order to ensure "honest broker" status

David Rutledge of Caltech compared British coal reserve estimates based on geological studies to historical records of resources extraction. The latter suggests that the Earth's remaining recoverable reserves might be considerably smaller than currently believed. This highlighted the difficulties both in estimating fuel resources and predicting when "peak carbon" might occur.

Riley Duren of JPL presented the potential carbon-information needs for other sectors. The impact of acidification on marine coastal resources, fisheries, forestry, and agriculture and the need to directly consider carbon concentrations in planning adaptation efforts was cited as a potential driver for a GHG information system. Additionally, the consideration of GHG information needs to support climate change mitigation options such as geoengineering and renewable energy was also discussed, although these were recognized as a secondary driver on GHG information system capabilities.

A breakout session was held to identify the key information needs associated with the policy regimes described earlier. Participants divided into three breakout groups each tasked with the same assignment but allowed flexibility on their approach. Each group was composed of both information users and providers and had a representative from each organization or sector to ensure cross-disciplinary representation. Following the two hour breakout session, the team reconvened for a quick summary of each group's findings.

3.2 Day 2 Synopsis

Prior to beginning the prepared talks on the second day, a more detailed discussion of the results of the previous day's breakout session was held based on each group's activity. Details on the first breakout session are contained in the presentation materials made available to the workshop participants, highlights of which are summarized in Box 3.1.

Nick Burger of RAND provided a survey of related efforts to enumerate the needs for GHG information systems. The consensus was further analysis is warranted on this front including the production of a matrix which includes:

- Title of activity
- Key players
- Level of maturity
- Official advocacy
- Ancillary data needs (beyond GHGs)
- Data to Knowledge needs

Mike Gunson of JPL then presented a review of current and near-term capabilities for space-based sensing of GHGs based on current and pending missions such as the

Orbiting Carbon Observatory (OCO), Atmospheric Infrared Sounder (AIRS), Greenhouse gas Observing Satellite (GOSAT), and Scanning Imaging Absorption SpectroMeter (SCIAMACHY). It was pointed out that there are currently no plans for a sustained capability for space-based observation of GHGs (all of the above missions are short-duration exploratory science missions). A key issue raised by the audience concerned the technological feasibility and desirability of observing emission point sources. While the technology exists to monitor point sources from space, the usefulness of such information varies with its spatial and temporal resolution and coverage capability. Depending on operational scenarios (e.g., cooperative vs. non-cooperative, whether nighttime observations are needed, etc) multiple technologies, instruments, platforms, and orbits could be required.

Jim Butler of NOAA's Earth Science Research Laboratory (ESRL) provided a description of the current state of the art for ground-based and in-situ carbon monitoring including an assessment of the various carbon networks and information tools such as NOAA's CarbonTracker. He highlighted the need for increased sampling (e.g., 10x more observations in North America, 20x world-wide), transport models with better resolution, and enhanced computing capacity. A significant challenge will be that of

Box 3.1 Breakout Session on Information Needs

The Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) initiative sponsored by the international Global Terrestrial Observing System (GTOS) program is proceeding in parallel with this effort and focuses on tracking forest/land use.

Key decision-support questions associated with GHG reduction include: are emission reduction efforts working? what information is needed to support audits of self-reported data? can we separate biological sources from fossil-fuel combustion? how do we address the relative costs and benefits of a GHG information system? what approach is needed for point-source monitoring (e.g., multiple sources within a "city grid cell")? how do we solve the "leakage" problem in cap and trade systems?

International Treaties will warrant resolution for GHG information sets to at least the size of sovereign nations (including very small nations). GHG reduction efforts should learn from the lessons of past successes (e.g., the Montreal Protocol for CFC reduction) – while recognizing the existence of key differences such as the Ozone problem involved a single sink, had no natural background, had a readily available solution, and benefited from robust modeling & solid scientific understanding.

Uncertainties in physical processes pose a major challenge to defining a useful GHG information system. There remain key unanswered "exploratory science" questions associated with the carbon cycle that must be resolved before we can completely define the requirements for such a system. This suggests the need for an incremental approach (near-term capability vs. long-term capability) and therefore a systematic roadmap for how and when to interleave the various efforts.

In addition to the 4 end-use regimes previously discussed, National Security is also a potential key user of a GHG information system. There were varying opinions as to whether National Security was more of a secondary user (i.e., impacted by Climate Change which is impacted by the carbon cycle).

Regarding the energy sector, it was recognized there is a need to combine information on GHG fluxes with data from fuel inventories and electrical power generation rates from utilities (i.e., data from SmartGrid and other sources) to help establish attribution of fossil-fuel combustion.

continued vigilance against the persistent threat of measurement and analysis biases. He also discussed the need to continue the incremental evolution in capability from exploratory research to operational (first in North America and then globally). Finally, he offered some thoughts on the topic of partnerships and socio-political challenges to implementing what will likely be a major system.

Stacey Boland of JPL then led a discussion on the topic of Integrated Products and the challenge of transforming carbon cycle data into actionable knowledge with relevance to decision makers. It is recognized that perhaps the least mature aspect of a putative GHG information system is the meta-analysis toolset which provides this critical transformation function. In order to derive requirements on these meta-analysis tools, we must first describe what the end-information set might look like – an effort perhaps best done through scenario or use-case analysis.

A final breakout session was held with the same three groups and approach but this time with a focus on identifying gaps between the perceived needs and current capabilities.

Box 3.2 Breakout Session on Capability Gaps

There are significant gaps between GHG information needs and current capabilities. To address the gap, participants suggested:

- *Increasing the number of high-accuracy surface (in-situ) network sampling stations*
- *Providing space-based CO_2 and CH_4 top-down column measurements to the earth's surface, traceable to the WMO standard with monthly temporal resolution, global coverage, and region spatial resolution*
- *Monitoring selected tracers such as ^{14}C, CO, S_2O, N_2O to improve carbon transport models and improve fossil-fuel combustion attribution - and use lessons learned obtained from other tracing other pollutants (e.g., metals)*

Additional needs warranting consideration in the development of a GHG Information System include:

- *Transparency: system must be designed with this in mind from the start*
- *Incremental development: system must allow data to be upgraded over time*
- *Understanding and implementing data serving needs*
- *Integrating social/economic data with measurements & models*
- *Improved quantification of uncertainty*
- *Continuity mechanism for sustained observations*
- *Atmospheric transport models*
- *Information products that satisfy user needs*
- *Mechanisms to assimilate new approaches & instruments*

A common recommendation was to continue this effort to identify actual user needs via follow-up engagement with other stake-holders. Additionally, identifying architectural options for a GHG information system in concert with the gap analysis could identify potential break-points in the design and support return on investment estimates.

Again, the detailed summaries of each group's findings for day 2 are contained in the respective presentation material distributed to the participants, highlights of which are in Box 3.2. The final workshop topic was a discussion of Future Plans. The team agreed there is value in publishing a peer-reviewed journal paper that addresses the driving informational needs, gap-analysis relative to capabilities, and a survey of the current landscape. Paul Dimotakis recommended we follow the National Academy process and solicit several independent experts to review the paper prior to submission. The expectation is that we will require several months to complete the gap analysis, followed by another workshop (in the spring 2009 timeframe), so the paper could reasonably be published by early Summer 2009. In the meantime, we agreed to release this Workshop Report in December 2008. A synthesis committee consisting of Riley Duren (JPL), Robert Lempert (RAND), Jim Butler (NOAA), Mike Ebinger (LANL), Scott Doney (WHOI), and Stacey Boland (JPL) was assigned the task of pulling together the Workshop Report before releasing it to the complete group for comments. Additionally, we discussed the possibility that those attending the Fall meeting of the American Geophysical Union in San Francisco the week of December 14 might participate in a follow up discussion on this effort. This concluded the workshop.

4. SUMMARY OF DRIVING THEMES

The following general, recurring themes emerged from the workshop:

1. The current uncertainties in observationally derived GHG concentrations and fluxes at various temporal-spatial resolutions limits the ability of GHG data to provide policy guidance for the different scenarios and they limit our ability to provide sufficient constraints on the carbon and climate models needed to accurately predict future changes.
2. There remain significant uncertainties in the magnitude of individual anthropogenic sources of GHGs, particularly in the attribution of fossil-fuel combustion based on economically derived inventories. These uncertainties represent a significant challenge to linking carbon data and models (knowledge) with responses (control).
3. Key physical processes including various carbon transport mechanisms and the relative contribution of natural and managed biological systems (versus fossil fuel contributions) are presently insufficiently understood to enable carbon and climate forecasting at the accuracies and resolution required to support policy implementation.
4. A crisp definition of key GHG information needs for the various policy users has not yet been undertaken in a systematic fashion nor has a gap-analysis between those needs and current capabilities been completed.
5. The data collection and analysis capabilities needed to support policy implementation can also inform the carbon and climate models needed to buttress policy formulation. The capability to convert scientific data into actionable societal knowledge warrants improvement, both in helping decision-makers form

well-posed questions and in bridging the earth sciences, engineering, and socio-economic communities to develop the necessary tools and methodologies.

6. The definition and deployment of a Global GHG Information System will require an incremental approach with phased deliveries and iteration as scientific knowledge improves.
7. There is no systematic plan or roadmap at the national or international level describing how the community might go about defining, delivering, and operating a sustained GHG information system to address these gaps. Providing such a systematic plan is a useful service this team could provide to the community. To that end, engaging other stakeholders should be a priority.

To address the nascent gaps between information needs and current capabilities, participants identified the following (non-comprehensive) list of needs:

1. Better analysis of policy use-cases and scenarios to enumerate the driving information needs and complete the gap analysis.
2. Definition of “what a reasonable system could do” (capability assessment) to help indicate what policy needs could be met.
3. Increased surface (in-situ) CO_2 samples both in North America and globally with CarbonTracker-class accuracy and quality control.
4. Global coverage (space-based) measurements of surface CO_2 fields with OCO-class precision, improved spatio-temporal resolution, sustained over decades
5. Global coverage (space-based) measurements of surface CH_4 fields with appropriate precision, improved spatio-temporal resolution, sustained over decades
6. Continued and improved AIRS-like measurements of free troposphere CO_2 & CH_4 to address atmospheric transport
7. Measurement of key chemical “tracers” to improve understanding of atmospheric transport & fossil fuel combustion attribution (e.g., ^{14}C, CO, S_20, N_20)
8. Integration of power-generation “tracers” (e.g. lights and SmartGrid data) with GHG flux data to support combustion attribution.
9. Reduction of uncertainties in emission inventories (currently range from 10% to unknown for CO_2 and 30% for CH_4)
10. Improved data on renewable energy sources (and new figures of merit to capture relationship with carbon cycle)
11. Cross-validation of carbon flux-estimates based on economic data vs. estimates based on physical measurements
12. Improvements in computing capacity
13. New capabilities in converting data to actionable information
14. Improved ancillary data and models to break degeneracy between natural sources (e.g., biological) and anthropogenic (e.g., fossil-fuel combustion) sources (i.e., biomass/primary productivity, soil moisture, precipitation, surface winds.

The above list, though not comprehensive, can be used to jump-start follow-on efforts for comprehensively and systematically identifying gaps between policy needs and current and planned capabilities.

5. FUTURE PLANS

The following activities are proposed to continue the forward momentum with this effort. We expect further iteration of this plan following the December AGU meeting and ongoing road-mapping efforts.

1. In November, access to a private, shared website will be provided for all team members to share news and documents. The Workshop presentations have already been posted there.

2. A follow-up meeting with approximately 10 members of this team attending the Fall AGU meeting in San Francisco (and teleconference for off-site participants) will be held Sunday December 14 from 2-4pm at the San Francisco Marriott. Proposed meeting topics include: status and notes from each organization, roadmap for 2009 activities, potential dates for a Second Workshop, and identifying other potential stakeholders and participants.

3. To support capability assessments, a notional system point-design will be defined by early 2009 based on a straightforward evolution of the surface carbon sample network, space-based passive sensors, and data assimilation systems.

4. Additional stakeholders in the community (both information-users and producers) will be engaged in early 2009 to produce a series of "use-case" scenarios to better describe end-user needs.

5. A Second Workshop will be held in spring 2009 to bring together a collection of end-user needs and notional system design for reconciliation. Dates, venue, invitation list, and agenda will be defined in January 2009.

6. The outcome of the Second Workshop will result in a journal publication in the Proceedings of the National Academy of Sciences (PNAS) or equivalent venue by summer 2009 on the consensus assessment of needs, potential capabilities, and gaps.

Figures 1 and 2 provide a draft roadmap for activities through mid-2009 and process-flow for technical convergence, respectively.

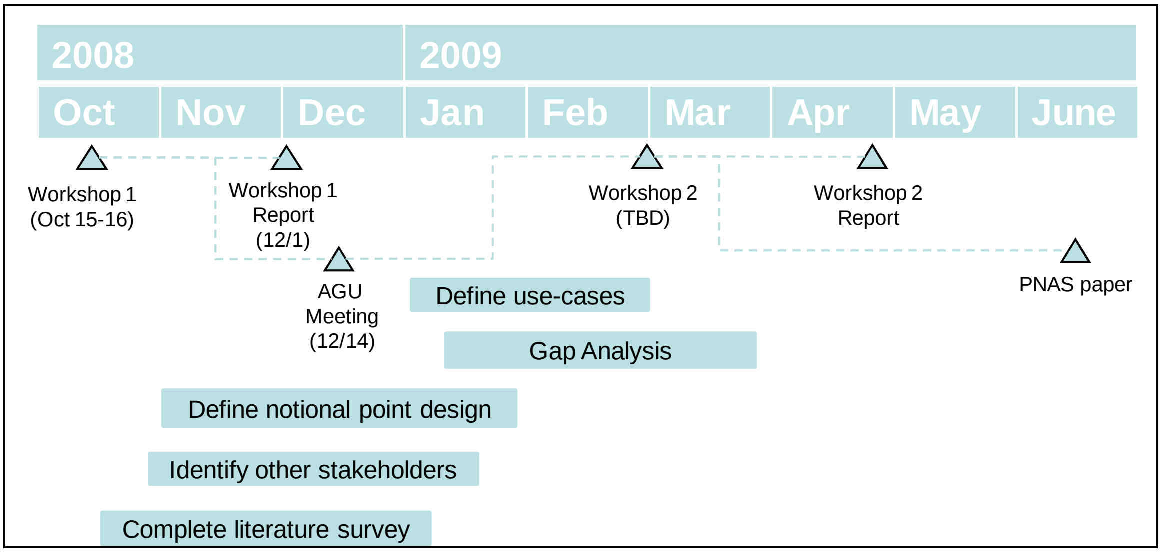

Figure 1 Roadmap for activities through mid-2009

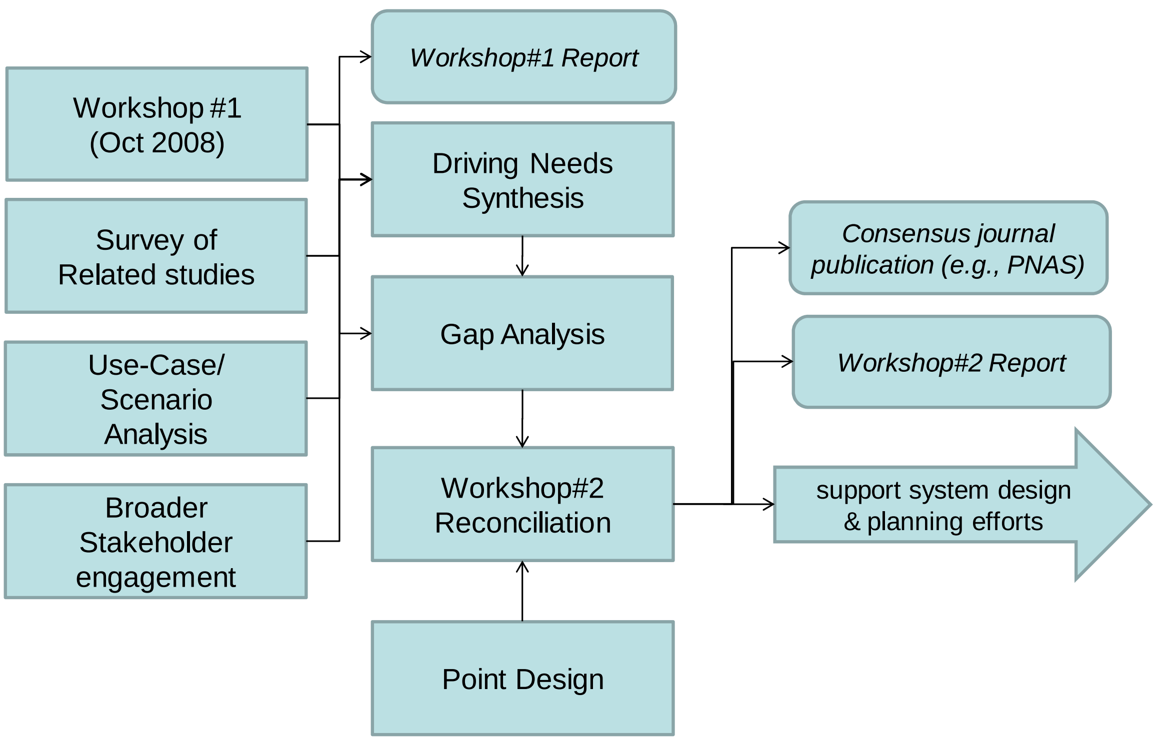

Figure 2 Process for technical convergence

Appendix A – Participant List

The color codes in the following table indicate mapping to the three parallel breakout sessions groups (green, blue, & yellow).

Name	Institution	Position
Gregg Marland	Oak Ridge National Laboratory	Distinguished Scientist
David Rutledge	Caltech	Kiyo & Eiko Tomiyasu Professor of Electrical Engineering
Robert Lempert	RAND	Director, Frederick S.Pardee Center for Longer Range Global Policy & the Future Human Condition
Nick Burger	RAND	Associate Economist
Kay Sullivan	Pardee RAND Graduate School	Graduate Fellow
Phil DeCola	Office of Science & Technology Policy (OSTP)	Senior Policy Analyst
James Butler	NOAA Earth Science Research Lab (ESRL)	Director Global Monitoring Division
Joe Nation*	ENVIRON International & Stanford University	Principal, ENVIRON; Lecturer, Stanford
Charles Miller*	JPL	Deputy PI, Orbiting Carbon Observatory (OCO)
Riley Duren	JPL	Chief Systems Engineer, Earth Science Directorate
Stacey Boland	JPL	Systems Engineer
Michael Gunson	JPL	Chief Scientist, Earth Science Directorate
Diane Wittenberg*	The Climate Registry	Director, The Climate Registry
Yuk Yung**	Caltech	Professor of Planetary Science
Doug Comstock**	NASA Headquarters	Director, Innovative Partnerships Program
Paul Dimotakis	JPL & Caltech	JPL Chief Technologist & John K. Northrop Professor of Aeronautics, Caltech
John Ledyard*	Caltech	Allen & Lenabelle Davis Professor of Economics and Social Sciences
Ken Masarie	NOAA ESRL	Research Scientist
Wahid Hermina	Sandia National Lab	Senior Manager, Sensor and Communications Microsystems
Mike Ebinger	Los Alamos National Lab	Research Scientist
Joe Pinto	EPA	Research Scientist
Scott Doney	Woods Hole Oceanographic Institute	Senior Scientist, Marine Chemistry & Geochemistry

*attended Day 1 only
**attended Day2 only

Appendix B – Agenda

DAY 1 (OCTOBER 15)

Time	Topic	Location
9:00 – 9:15 am	Welcome (P. Dimotakis)	Millikan Board Room
9:15 – 9:25 am	Introductions	Millikan Board Room
9:25 – 9:30 am	Logistics (R. Duren)	Millikan Board Room
9:30 – 9:40 am	A Grand Challenge (C. Miller)	Millikan Board Room
9:40 – 10:30 am	Workshop Concept, Goals, Agenda (R. Lempert)	Millikan Board Room
10:30 – 11:00 am	Global Carbon Cycles (S. Doney)	Millikan Board Room
11:00 – 11:30 am	GHG Sources (G. Marland)	Millikan Board Room
11:30 – Noon	Q&A/Discussion	Millikan Board Room
Noon – 1:00 pm	Lunch	Athenaeum East-West rm
1:00 – 3:00 pm	User Information Needs by Sector • Treaties & Regulation (P. DeCola) • Carbon markets (J. Nation) • Societal Incentives & Transparent Reporting (D. Wittenberg) • Natural resource management (R. Duren)	Millikan Board Room
3:00 – 5:00 pm	Breakout groups: basic information needs/questions, accuracies	Millikan Board Room & nearby venues
5:00 – 5:30 pm	Reconvene – quick breakout summaries	Millikan Board Room
5:30 – 6:00 pm	Break	
6:00 – 7:45 pm	Presidential Debate Viewing Party	Athenaeum East-West rm
7:45 – 9:00 pm	Dinner	Athenaeum East-West rm

DAY 2 (OCTOBER 16)

Time	Topic	Location
9:00 – 9:45 am	Recap & discussion of previous breakouts	Athenaeum Library
9:45 – 10:15 am	Survey of prior efforts (N. Burger)	Athenaeum Library
10:15 – Noon	Current & future capabilities • Remote Sensing (C. Miller) • In-situ Sensing (J. Butler) • Integrated Products (S. Boland) • Discussion	Athenaeum Library
Noon – 1:00 pm	Lunch	Athenaeum Library
1:00 – 3:00 pm	Breakout groups: gaps between current capabilities and needs (and how to close them)	Athenaeum Library & nearby venues
3:00 – 3:30 pm	Reconvene – quick breakout summaries	Athenaeum Library
3:30 – 4:30 pm	Synthesis	Athenaeum Library
4:30 – 4:50 pm	Future Plans & Roadmap (R. Duren)	Athenaeum Library
4:50 – 5:00 pm	Workshop Summary (R. Lempert)	Athenaeum Library