NASA Carbon Monitoring System Briefing:
Characterizing Flux Uncertainty

Wednesday, 11 January 2012
8:30 am to 1:15 pm
Resources for the Future (RFF)
7th Floor Conference Room
1616 P Street NW
Washington, DC 20036

Report by Molly E Brown, NASA GSFC and Vanessa Escobar, Sigma Space/GSFC

The Fiscal Year 2010 NASA Appropriation funded NASA to begin work on a Carbon Monitoring System (CMS). The NASA CMS will develop pilot studies to provide information across a range of spatial scales, consider carbon storage in biomass, and improve measures of the atmospheric distribution of carbon dioxide. NASA has initiated this work by building on its global measurement capability for carbon.[1] Other agencies and organizations are undertaking related activities to support national policy objectives and resource management.

This briefing provided an overview of the status of the NASA CMS flux pilot and data products under development and ascertained how to better characterize uncertainty in order to meet the needs of other agencies and organizations engaged in flux measurement and monitoring. This information will further enable NASA to generate better overall products in support of agency needs.

Summary of Discussion

During the meeting, we focused on the following topics:
- Policies that a mature NASA Carbon Monitoring System flux product might inform
- Use in the IPCC Greenhouse Gas Emission inventories of top-down CMS flux model outputs

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[1] *More information about the CMS and other elements of the NASA plan for responding to the challenge of climate and environmental change can be found in NASA's "Plan for a Climate Centric Architecture for Earth Observations and Applications from Space" at http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf*

- Products that will enable carbon mitigation policy evaluation at the local, city and state level
- Improvements to quantify the sensitivity of the climate to carbon dioxide for better estimates of the social cost of carbon
- Improvements in understanding of how land, ocean and atmosphere modeling components work together to improve climate model projections
- The uncertainty in both measurements of carbon dioxide and in the emissions inventories, and how CMS flux might improve these uncertainties

Proposed Action Items/Follow up

1. CMS Flux Pilot teams will continue to investigate potential opportunities for flux product policy applications by supporting and contributing to a discussion between policy makers, stakeholders and CMS scientists.
2. CMS Applications will follow up with CMS Pilot teams to present information on uncertainties from the policy perspective.
3. CMS Applications will plan another policy brief and build on the discussion points from this brief for both Biomass and Flux groups.
4. CMS Applications will hold individual follow-up meetings with specific partners within the group.

Attendees

Kevin Bowman, NASA JPL
Molly Brown, NASA GSFC
Jim Collatz, NASA GSFC
Roger Cooke, Resources for the Future
Lucien Cox, NASA Headquarters
Riley Duran, JPL/NASA
Vanessa Escobar, Sigma/NASA GSFC
Mahmud Farooque, Consortium for Science and Policy Outcomes (CSPO)
Peter Griffith, NACP/NASA GSFC
Michael Gunson, JPL NASA
Leif Hockstad, US EPA
Joanne Howl, Sigma Space
Kenneth Jucks, NASA Headquarters
Randy Kawa, NASA
Allison Leidner, AAAS/NASA HQ
Molly Macauley, Resources for the Future
Elizabeth Malone, Pacific Northwest National Laboratory
Cassandra Nunez, AAAS Fellow/NASA HQ
Steven Pawson, NASA GSFC
Stephanie Race, Earth Analytics Group
Tristram West, Department of Energy/JGCRI
James Whetsone, NIST

Detailed Notes

Molly M – The President of RFF, former Congressman Phil Sharp, would give the introduction, but cannot make it due to personal reasons today. Molly is very committed to this project, and through CMS has had the opportunity to work with the best scientists and engineers in the country. This is the second meeting in the series, the first was last fall focused on biomass. We hope to have another later this year.

Ken – The US Congress created an earmark directing NASA to create a Carbon Monitoring System, without a lot of specific language specifying what was to be done. We decided to go forward with doing what NASA does best – using measurements in combination with models to understand carbon flux. We started two CMS pilot projects, with the CMS Flux pilot we are talking about today focused on the Orbiting Carbon Observatory mission as a base. GOSAT data will also be a focus and will be used in validating model output. Ken is a scientist, and is very interested in using observations to make decisions. Also joining the meeting from NASA Headquarters were Allison Leidner, Cassandra Nunez, and Lucien Cox.

Peter – CMS fits into the North American Carbon Program (NACP) because the NACP is a loose configuration of the carbon work being done by many different US Agencies, including NOAA, NASA, USGS, USEPA, DOE and others. The goal is to understand sources and sinks of carbon variations in North America. NASA is to pilot projects for the NACP, and the CMS will make a big contribution towards the broader objectives of NACP.

Molly B – I've been reading the US Carbon Cycle plan, which focuses on real time observations from point to grid and to test policies as they are put onto place. CMS is one of the first programs with a goal that will try meet the objectives of the NACP. However there are several issues with communication. Where should science focus its efforts? Time domain or resolution? So please contribute and we will discuss your response as we move along.

Molly M – for social scientists in the room, the question is what the meaning of the products. The question is focused on 'so what'. We will write a report that will enable a discussion between policy makers and scientists. RFF has had a lot of experience in enabling policy interventions. An important part of the program is data to evaluate *ex post* – that is, how do we know if the policy is making a difference. The CMS effort will provide information on the underlying measures if the policy is working, and this is irrespective of whether the policy intervention requires voluntary or mandatory actions.

Ken – What about monitoring? Why is the word "monitoring" in the title? NASA has only the mandate to do pilots for what one might do. We might get the mandate as we have for ozone to actually monitor carbon. But for the moment, all NASA is doing now is demonstrating what could be done to address carbon problems.

Riley – To use the phrase "monitoring" does not mean that NASA takes on regulation, but to focus on sustained observations. Trends through time are needed to know if we are making a difference with our policies. Sustained observational monitoring is necessary for carbon. NASA is well positioned to do this task. No one else has this job.

Tris – DOE is more focused on "observation" than on "monitoring", although the two are grammatically synonymous. Some National Lab researchers in the past had pushed to develop a Carbon Management program, but this did not gain footing perhaps because "management" infers that you will be actively "managing" something instead of simply "observing". In fact, the reason we are discussing CMS is because we know that current "observations" themselves are not sufficient to understand the geographic location and attribution of current carbon sources and sinks across large areas (e.g., continents). Current observations alone are not sufficient to mitigate C emissions or adapt to global change. A network or observation/monitoring system could be developed to fully understand carbon sources and sinks. And with a more complete understanding, our estimates of fluxes will improve, and a system will be in place to inform policy and management. It is the research behind such a system that is needed.

Molly M – This nation has a tendency to regulate and to make legislation, but the required "data infrastructure" that is needed to determine if the regulations and laws are making a difference is usually forgotten. It is very difficult to fund because it is perceived as boring and unimportant, despite it being at the center of effective programs and policies.

Ken – We are building pilot projects for monitoring, and specifically for the use of remote sensing and earth science models.

Riley – Other agencies have monitoring tasks, but these are ground observations for flux, not remote sensing. Realities for the budget are that there are only a few agencies that are getting funding to do anything – NASA and NIST. We should not go too far on discussing monitoring since folks at NASA seem to be comfortable. These pilots are very focused on what remote sensing can do. This needs to be a much bigger program, one that involves multiple agencies.

Peter – What NASA does is the basic science that needs to be done before we can implement a monitoring program. Fragments of carbon monitoring are across the Carbon Cycle Interagency working Group – there is an awareness and interest in coordinating across agencies.

Tris – We have to do the research to get there.

Molly M – This is nothing new – it is the typical challenge for managing national and political resources. It has always been challenging to go across agencies.

Around the room introductions.
Kevin Bowman – JPL - he is in charge of inversion in the CMS program
Lucian Cox –NASA HQ - operations manager of applied science program, OCO missions
Jim Collatz – NASA GSFC - member of the CMS flux pilot team and does terrestrial carbon cycle modeling
Randy Kawa – NASA GSFC – on the CMS team – atmosphere guy does transport modeling and comparison to observations
Mike Gunson –JPL - OCO2 project scientist – making remote sensing observations of atmospheric constituents

Roger Cooke – RFF - mathematician by training – uncertainty analysis and risk analysis in the nuclear, aviation, deepwater drilling, and other sectors. New to this field but an area which has interested him. Works on the "Value of Information."
Liz Malone – PNNL - assessment modeling in various institutional and vulnerability analyses on the issue of climate change. Member of science steering committee for global carbon project – crosses social and physical
Tris West – PNNL - Ecologist by training, currently look at impacts of land management on terrestrial carbon cycle management – NACP carbon cycle in Midwest
Jan Meriz –RFF - senior policy advisor at RFF, works on a variety of carbon and climate change issues – work on the Montreal protocol with NASA and NOAA, was in White House at the time. Energy for 4 yrs, Commerce for 6 yrs
Joanne Howl – Sigma/GSFC – trained in biological sciences and medicine, is currently technical writer and bring story forward on website
Riley Duran – JPL - Systems engineer – Works on pilot program focused on trying to define what the requirements are for global monitoring systems for carbon. Pilot for systems design study, who are end users, what translate into a system. DOE and NOAA interagency work, Carbon community for earth observations
James Whetstone –NIST - Program manger for Carbon Green house gas climate science measurements. I have been managing the Influx experiment[2], whose focus is to develop standards that we think will be beneficial to communities interested in carbon and carbon inventories. Meteorological observations are used to verify emissions (measurable, reportable and verifiable mitigations) and identify the entity. Good targets are put in place for the performance capability for 1 kilometer for location and 20% of the emission strength itself.
Mahmud Farooque – ASU – observe and how we fit in – we do deal with outcomes based science policy and decision making under conditions of uncertainty. Reconciling supply and demand, and user in the policy domain.
Peter Griffith – Sigma/NASA GSFC - director of the North American Carbon Program (NACP)
Ken Jucks – NASA HQ – program manager for upper atmosphere research program
Steve Pawson – NASA GSFC - CMS lead for flux, space scientist by background. He works in the GMAO on bringing NASA'S big satellite observations into modeling
Allison Leider – AAAS/NASA HQ - earth science division AAAS fellow – to help connect some of the applications of CMS activity
Cassandra Nunez – AAAS/NASA – new with Applied sciences – discussing to implicitly incorporate research into REDD, carbon monitoring research arena
Vanessa Escobar – Sigma/GSFC – Works with Molly Brown on different fields of Applied Sciences. I facilitate between the scientist and the policy decision maker to

[2] Influx is a top-down/bottom-up greenhouse gas quantification experiment in the city of Indianapolis. As part of the INFLUX project, CO2, CH4 and CO mixing ratios are measured using wavelength-scanned cavity ringdown spectroscopy (Picarro, Inc.) at two towers surrounding Indianapolis, IN, with expansion underway to a network of twelve sensors, including 14CO2 flask sampling.

help communicate (in English) the needs of user and policy communities back to NASA.
Molly Brown – NASA GSFC – Does both science and applications at the Biospheric Sciences Laboratory. Works to get everyone on board for solutions. We have a complex political field for the CMS and we need facts based on hard science to help us move forward. Make a difference in the political domain interesting relationship between the examples.

Steve's presentation begins

Steve Pawson – CO_2 balance of the atmosphere – fluxes from land, ocean to atmosphere will determine how CO_2 in atmosphere will grow. We need to understand processes – biological, physical and 'human' perspectives. Satellite data and models – how use together to better understand issues. Global perspective on problem instead of point data, CMS is a framework to bring things together.

CMS complements carbon tracker, as it uses satellite data instead of the NOAA ground observations.

Riley - CMS has a much more rigorous dataset globally, but carbon tracker is global but is based on much more sparse network of observations – 100 total, but with very high accuracy, calibrated, in situ sampling, continuous electronic sampling. NASA uses denser observations but far less precise. It is not that one is better than the other, but we need both.

Peter- carbon tracker also uses towers as well as electronic sampling, aircraft samples, and other observations.

Riley – An important point in both regimes is that the atmosphere stirs these gases around to invert back in time to see where emission started. Inversion model has enormous errors. By increasing observations we can beat down the errors in these models.

Peter – It is worth translating errors in transport model. Inverse models run weather forecasts backward to estimate where the CO_2 came from, and therefore all inverse models have the same errors as weather models.

James – Carbon tracker has the same resolution as CMS Flux - 1 degree latitude/longitude.

Jim – Carbon tracker nominally looks like one degree but really has a much lower resolution since it is aggregated into vegetation biomes – it is far less precise.

Riley – It is similar to the world trying to move from 1950s where we can measure at one half of a percent using observations to those using satellite data in order to get to space/time scales right. Cities, local governments and others need spatial scales at a few kilometers to get at where the action happens for policy makers.

James – A square kilometer is the focus of a lot of policies and is where the work is done. Would like to discriminate between one place or another, a power plant here vs there, supporting markets like would be set up with cap and trade programs and evaluating how our policies are working.

Riley – This meeting is about uncertainty and how we can develop data products for policy. We need to work on awareness and relevance – policy makers wonder if we should do anything in climate change policy. Right now we can't decide if a place is source/sink- we can't even agree on the sign because of how bad the models are. What are the current pieces of information that are relevant to policy makers? We need to describe what is the state of the art for remote sensing based model output in projects like CMS. More effort needs to be put into providing a 'Carbon science 101' for decision makers at the global, continental, region, state and local scales, and what does our understanding of the carbon cycle mean for policy. Right now we are talking entirely different languages.

Steve- We don't fully understand what scale we can make carbon information – bottom-up or top-down. We may be orders of magnitude off of what is actually needed by decision-makers.

Roger Cooke – Is this problem similar to dry deposition for aerosols?

Steve – Dry deposition is not similar because carbon has a weight and falls out of the atmosphere. For CO2, there is little natural long-term destruction and thus a long residence time in the atmosphere. In the summer we have the action of the plants, photosynthesizing and removing CO2 from the atmosphere, and in the nighttime CO2 is emitted.

Mike – There is no significant loss of CO2 in atmosphere, except for very small amounts, thus the anthropogenic addition through economic activity remains a problem.

Steve – Once we start getting to places that have no ground measurements, we get some representation of the vertical column in the atmosphere. This will help better constrain our models.

Steve goes back to the PPT – Scope of Flux project. Having multiple models give us some measure of uncertainty – not complete since there are only two for land and two for ocean, but better than nothing. We have a lot of entanglement of attribution, across land, ocean, and atmosphere.

Jim – The global fluxes in and out of the atmosphere are ~9 petagrams of fossil fuels, ~1 petagrams from deforestation, ocean is a net sink of ~2.5, land taking up 2.5 and all the rest (~5) stays in the atmosphere. Half of total emissions increasing the atmospheric concentrations, half being absorbed by plants and ocean. There are big signals from the biosphere and ocean with the human component contributing a steady increase over time.

Riley – We must think about time scales. Signals to atmosphere – we must be able to remove biosphere from the activity of humans in order to be able to attribute CO2 to activity in particular locations.

Steve – The error bars are still big. GEOS-Chem adjoint is the inverse model that is being used – Kevin's work at JPL. GEOS5 constraints depend very strongly from long time series from NASA and NOAA satellites, surface winds, etc. Meteorological dataset that are heavily constrained by satellites.

Riley – Unlike most observations, CO2 reflects an entire earth ecosystem problem. Not just about CFC or Ozone like in other observations.

Jim – It is not just simply CO2 emissions from land, we have climate change effects, land use change, save the forests, lots of different management and processes. Natural and anthropogenic sources are conflated in the same atmospheric constituents, making it very hard to attribute the total CO2 in the atmosphere to a particular human activity. Controlling it from a policy level requires dealing with many different processes.

Riley – We have attribution with a big A and a little a – little a is human, big A is about how much of the carbon budget is due to humans, and how much due to larger changes in the climate system, the total system. Big A is the proximate barrier to action, the focus of many actors to do nothing. Little 'a' is what MRV is focused on.

Molly M – cost effectiveness of any intervention is correlated with how precise it is. Untangling the anthropogenic effects from broader carbon issues will have a big impact on the cost of mitigation.

James – If you engage in mitigation, you need to know how to measure the improvement. We need to have accurate observations to make that judgment that we are making a difference that it was worth the cost of the policy in the first place. That is what NIST would like to contribute.

Steve – back on NOBM and ECCO/Darwin Slide

Overall bias – NASA/CASA and ECCO Ocean, CASA-GFED land and NOBM ocean
We can't discriminate between the accuracies of the models, but we can discriminate between combinations of the models and how well they agree with observations. Inverse model serves a critical role in helping us determine which model works well.

Riley – I like to think of it like weather models – there will not be a 'good' model, it will be more likely to be a weather forecasting, model skill, ensemble of multiple models that are used together to get the right answer.

Molly M – With the weather comparison, what about the temporal domain? What is the spatial/temporal scale we will need for carbon model outputs?

Riley – We need knowledge of what is happening now, and what is happening over long term. Climate forecasts are effective over decades not days thus they are really projections not forecasts. From a climate model perspective, how can flux data inform improvements over decades? There are very different on requirements on carbon models than for weather models, so the analogy breaks down at some point.

Molly M – We could use the models to look back and to look forward to show the impact of a policy.

Riley – We need to help policy makers create a portfolio of options – land use management, fossil fuel, optimize and integrated assessments – climate models don't really help with this policy formation. One is evaluating policy compliance – reanalysis – and with CMS to help with creating the policy plan – that is the weather analogy.

Steve – And the same model components can be used for both.

Elizabeth – Do you see that as part of what we need to do to make projections, or contribute to projections?

Riley – At the NASA Ecosystem and Carbon Cycle meeting in September 2011, Scott Denning pointed out one major use of the CMS system was to improve how climate models deal with aspects of the ecosystem that are poorly constrained now. His point was, uncertainties in projections could be diagnosed using the kind of coupling of carbon cycle being implemented in CMS – use case scenario and diagnostics of carbon models.

Jim – A goal would be then to improve the climate models and their ability to project future carbon dynamics. Of course, CMS activities are not directly focused on predicting the carbon cycle in the future because we use observations and there are no observations of the future.

Kevin – If you had observations over a ten-year period, you could easily swamp out the benefit of 10% or 20% reduction over ten years which is the policy objective in many cases. The time scales over which policies are implemented are the same scale at which the climate response should be seen.

Riley – Thus this is the big A attribution – changing land and ocean fluxes vs anthropogenic stabilization policies are a very important tools. Not a direct application of CMS but important.

Roger – The are developing economic models that go out hundreds of years – what we are doing here will be used by them. These models need accurate climate information.

Riley – The analogy of weather breaks down when we start looking at decadal, seasonal to inter-annual, then get into projection space with ensemble models 100 years out. Different problems begin to drive the errors in the models that cannot be fixed using observations. The numerical weather prediction works very well for reanalysis to support decision-making in the short term – are you meeting your commitments – looking back. Multi-decadal projection model improvement is a secondary importance.

Steve – Observational constraints on vegetation should be an important part of how we can adjust what climate models are doing. When get into climate constraints, model themselves have biases. Uncertainty is non-trivial problem.

Back to PPT - 'top down' inverse slide to 'final thoughts' slide.

Riley –We can measure atmospheric concentrations at better than ½ percent at any particular place, but for carbon models such as the one Carbon Tracker uses, we have 100km resolution and can't even tell you the sign – we have 100% error. We have practically no knowledge at spatial scales, and on the order of a few percent at other scales (point data). Again, going back to the weather service analogy – if I was trying to do weather forecasts with 100 points instead of the tens of thousands of ground observations, 15 polar orbiting, many geostationary, 5 million observations every 6 hours, we'd have a similar kind of error structure in weather as we have in carbon now.

Molly M – Many economic analyses of the value of a better forecast to improve decision making to improve agricultural activities. Roger Cooke from RFF is one of the few scholars that I know that has written down information about climate and value of information. I think we need to do that for this community – similar to the value of information that has already been done for the weather forecast. The value of information for carbon may also be very large.

Roger – The social cost of carbon – there was an interagency initiative to establish a social cost of carbon that would result in a tax or surtax (called the Interagency Working Group on Social Cost of Carbon). This initiative used three carbon models, three different discount rates and decided that climate sensitivity is uncertain, and just estimated a fixed, arbitrary number about how sensitive the climate was. The decisions weren't sensible but they do create a uniform standard of measure that we can now use. If we have a CMS that could tell us the climate sensitivity that we would have in ten or twenty years, we could translate that into money. This is low hanging fruit and should be part of what CMS does.

Riley – cost thing – the best thing to do is to focus on climate models. Back in 2008 there was heavy discussions on MRV – council of economic advisors did a very simple analysis that assumes carbon trading, carbon uncertainty, etc. The bear that stopped us was the specific information to assess policy. Difference between MRV re- meeting commitments vs. assessing the impact of policies that are put into place.

Peter – MRV is auditing a process – codified etc.

Molly M – If we had better information about social cost of carbon, a dollar denominated measure if you know climate sensitivity, it would be really helpful. To be policy relevant, we can work on the climate sensitivity issue – Roger's problem is that there is no policy to act on at the moment.

Riley – The EPA said when we told them about CMS is that they already understood emissions using the inventory and bottom-up methods. They thought the CMS would only be useful for MRV and assessing the implications on the treaties, as we have all the information we need with our focus on activity data and factor data. Those things are in place, auditing mechanisms – why do I have to measure at all in the atmosphere, they asked. The thing that has no one has talked about is policy efficacy – nobody can say whether a policy is working unless you look at the atmosphere, no one has the mandate to do it.

Molly M – You are identifying at least three different policy strands. We want to start asking a different question, which is how to link up with what government has already done, and already has building on climate sensitivity parameters. The numbers are big for how much mitigation will cost.

Roger – The US government has taken a position in a sense, if you want to compute a cost of carbon you should use these models and these measures. A uniform measurement procedure has already been set into place and is usable by all government agencies. We should use that.

BREAK

Molly M – We have some new guests – please introduce yourselves.

Leif – I work at the EPA in the Climate change division where we work on international processes and MRV. Our focus is reporting inventories[3] to the IPCC national level emissions statistics.

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[3] See http://epa.gov/climatechange/emissions/index.html

Stephanie Race – Earth Analytics group is based in the San Francisco bay area – commercializing remote sensing of agricultural data. Working with NASA on airborne and satellite platforms. Informatics platform for growers and ranchers in private landowners – potatoes, wheat, etc. Models and calibration, remote sensing as input to crop and way calibrate models. Office in Bethesda, Alberta, NASA Ames, partners and JPL and Oregon state – biogeochemical modeling from a point of view – N2O emission measurements in crops, etc. research from science point of view.

Molly M – Leif, can you describe the IPCC inventories that you produce at the EPA? They are rather sophisticated, as they give a comprehensive picture of emissions over the given year.

Leif - The EPA does a great job working with interagency counterparts, meeting the commitment set upon the US under the IPCC agreements.

Molly M – Other agencies participate in discussions on uncertainties as reported in the tables in the Inventory document?

Leif – Resources are always tight – both for the US inventories and for other countries that report inventories. We produce an estimate of uncertainties, particularly for stationary sources. My colleague Brian Cook is releasing facility level point source data for 2010 today - power plants, facilities such as iron/steel plants, and their emissions within their fence line. All data coming out today is related to facility by facility data integrating depending on matching up information. 25,000 metric tons or more is the threshold over which all facilities must report to the EPA. The uncertainty of the data is -1 to +5 percent of the total.

We do have a few area sources where the fence line is a little less defined such as landfills that do report to EPA. These data are more uncertain because they have to rely on first-order decay models, and have +/- 20 percent uncertainty in their methane reporting, for example. We would appreciate another eye on methane from these sources outside of what we currently get from reports.

James – Thus the inventory numbers are based on models – methane generation of landfill?

Leif – Yes, we build in assumptions, what is the cover, what is the capture, a landfill-specific model. The next set of area sources such as natural gas production has an uncertainty of plus/minus 30-40% due to leakage, pipeline problems, etc. We have found that hydrologic fracturing processes greatly increases methane errors that apply on national basis. We use surveys, area sources, national estimates and facility level to help take some of our assumptions and clarify errors in our estimates.

The flux side of CO2 from forest land, soil carbon in the inventory has broad uncertainty ranges around estimates at present. The trick with those is separating the climate change influence from the anthropogenic piece of CO2 flux. Under the

MRV concepts the US has determined that all land is managed, thus all forests qualify as human influenced land, but other countries interpret what ‘human influence’ is in different ways. This means the inventories are not comparable between countries. What the anthropogenic part of the natural carbon cycle is has not yet been agreed upon.

Jim – We are using a version of CASA to model the US carbon cycle and include consideration of fire, harvest, and FIA data but not the influence of climate variability on ecosystems.

Peter – Brazil’s inventory might be a different story.

Molly M – Which between CO2 and methane does the US EPA worry most about?

Leif – We have probably more worries on the methane side because there is more regulatory authority – landfills and natural gas – under the clean air act as its policy base for the examination and mandated reductions of those emissions. Carbon dioxide is more problematic and therefore the forest service is probably going to be charged with policy side. We worry more about it from emission authority – mitigation as provided for under the clean air act.

Stephanie – In the inventories, do you distinguish between landfills and other sources – wetlands, farms, etc?

Leif – The estimates of wetlands and methane from them will be under the IPCC in the coming year after the regulations are developed. We do have livestock and agriculture methane sources included in the inventory. We get the information from the USDA.

Molly M. – You have been producing these inventories since 2007?

Leif - No we are doing it since 1994

Molly M – To what purpose have you put the time series of data? Not really a natural connection there?

Leif – We are working with economic colleagues who are always asking for pieces of the time series. What has the inventory been used for? Technically we have to provide the annual inventory to the IPCC. The new administration has been very interested in working to understand what policy interventions could be applied to affect the emissions – what part of the emissions is sensitive to changes in policy. However, the spatial scale is missing completely missing. We can’t tell you about cement plants in Ohio, only in the US as a whole.

Molly M – What policies have been made based on inventory?

Leif - The Supreme Court decision that the EPA was involved with that said green house gases endangered human health. We used the inventory to help support the lawsuit and the US Government in the suit, concluding that these emission sources are contributing climate change and that this is important. National level emissions, trend line and time period – it has helped the US government to take action on climate change.

A specific example is the new MSRP rules in 2020 for cars – light duty vehicles – how much of the national emissions are you affecting, trend lines, etc what does that do with US fleet.

There have also been some proposals to reduce emissions is always based on percent of info – the inventory is becoming the policy bible.

Molly M – What about integrated assessments, Tris?

Tris – My organization develops integrated assessments[4] which are global and thus primarily use data from the FAO statistics database. There are smaller, higher resolution models that use data and economic trends over the United States, including agricultural data, FIA data and other inventory information. This is where I have seen integrated assessment models going, where researchers are trying to get higher resolution, regional data for each country and use it in combination with remote sensing data products and land use.

Jim - We are familiar with EPA inventories at NASA. Could an atmospheric analysis be called an inventory? Is there room in the report to use the products that we produce, perhaps to evaluate their uncertainty?

Leif – On the sink side, ideally it would be nice to resolve bottom-up to top-down and thus we would want to see the accounting. But the inventory is defined by what the IPCC says is anthropogenic, and a source thus what is going on in the atmosphere is not important.

In the US we have determined that almost all forest is determined to be managed land. By managed it is subject by human influence. As part of the UN side of things, everyone reads this differently at the country level. The USDA is still trying to determine if the forests in Alaska are managed or not.

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[4]An assessment is integrated when it presents a broader set of information than is normally derived from a standard research activity. Because integrated assessments bring together and summarize information from diverse fields of study, they are often used as tools to help decision makers understand very complex environmental problems. In assessment of climate change, integrated assessment refers to that activity that considers the social and economic factors that drive the emission of greenhouse gases, the biogeochemical cycles and atmospheric chemistry that determines the fate of those emissions, and the resultant effect of greenhouse gas emissions on climate and human welfare.

Jim – Thus sinks are only relevant if they are part of managed land.

Tris – If you had a climate impact that released CO2 would it not be in the inventory?

Leif – Most of lands that are not managed are not considered part of anthropogenic emissions. For example in Australia, they have trouble because they are seeing huge amount of climate change and droughts resulting in large CO2 emissions from fires. Technically at this point the US puts everything in. But when something happens, do we want to be responsible for these emissions in the long run? How do we assess policies, particularly if the circumstances are beyond their control. Much is left to be determined.

Tris – Active management that impacts carbon emissions are currently included in the inventory – but you are saying that the US is considering putting other things that are non-anthropogenic?.

Leif – The bark beetle forest deaths are an example – is it anthropogenic or not?

Riley – Can you give some examples of bigger exclusions in the country, how would you use the top- down estimates. Known exclusions to IPCC guidelines, and things vary from country to country.

Leif – Wetlands are missing from IPCC and they are working on that now. Biggest one – biofuels also are being worked. Another example is international transport for planes and ships. Emissions from this sector are part of inventory but not reported in national totals, and not in the other countries either. Known memo items in inventory but doesn't get rolled up into totals. In EU it is a big deal since the countries are all so small.

Within the inventory structure, there is no clear role for top-down assessments from IPCC, but they have begun to discuss how top-down can be used as an outside dataset to improve the inventory. How do we improve our estimates from these remote-sensing based products?

Kevin – Would you see a role in which top-down estimates are produced, but the numbers that show that specific regions' inventories are inconsistent with atmosphere observations coming from region. Perhaps more effort or more specific numbers would be needed. Thus the model estimates provide detection of conditions that are different than expected, that do not equate with inventory numbers.

Leif – Well, the inventories are a broad-brush estimate and there is no framework for the IPCC to respond.

Riley – A few years ago there were a series of expert meetings[5] and a report on how remote sensing could help to improve inventories and activity data, for example Landsat helps with forest inventories and wetland extent. The other question is how can remote sensing help with the problems of emission factors. Sector by sector – methane from wetlands, fermentation, land fills, CO2 from non-fossil fuel sources.

Leif – The next step could be regional examination of the impact of remote sensing on activity data and emission factors. Africa, for example, we have a general understanding from particular agriculture activities, but are they accurate? Little is known because of weaknesses in the reporting structure. Although some countries have improved their inventories, developing countries have not shown not the same rate of improvement.

Stephanie – What about national ecological assessment? Has there been any systematic comparison of top down remote sensing with bottom- up assessment?

Leif – Validation activities are all controlled by international MRV assessments and rules, centering on questions of did you use the reasonable dataset to begin with. All done through international bodies who do not use or know much about remote sensing.

James – That is all verification – did you perform the recipe correctly, an audit not an assessment.

Riley – Many folks have done independent assessments in an ad hoc way, top-down burst data. Ron Prin and company has shown that it is much easier to test methane and other estimates than CO2.

Kevin – Of course CMS is not using methane as part of its charter, but it would not take a lot of effort to include it. At global scale, we don't understand the processes that drive the acceleration of methane emissions. It was stable for a long time and now it has increased.

---- Lunch ----

Tris – What is carbon monitoring and what can it contribute to what we have already? There are three places where I see CMS can make a big contribution. First, remote sensing can update, revise, or replace current datasets used to report

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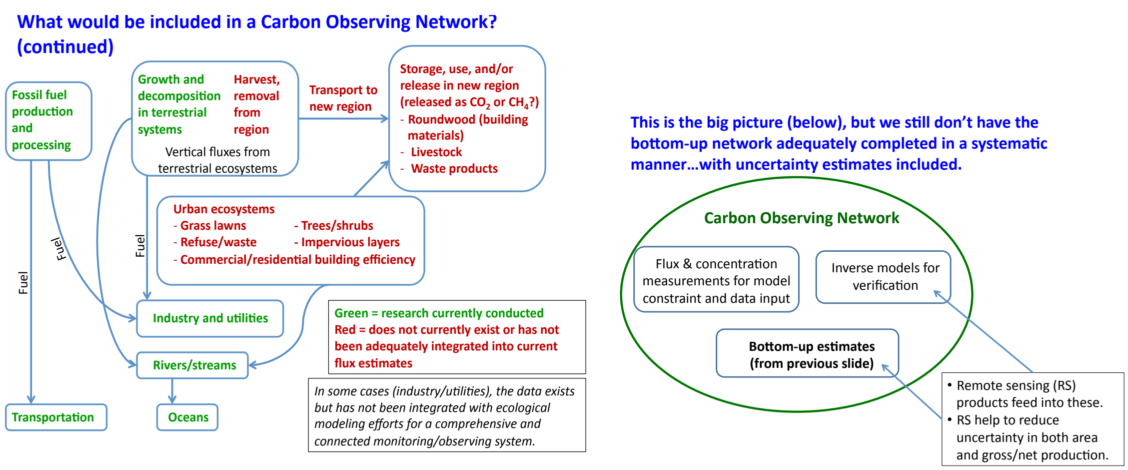
[5] IPCC Expert Meeting on Uncertainty and Validation of Emission Inventories (http://www.ipcc-nggip.iges.or.jp/meeting/meeting.html). The overall finding was that "while remote sensing, ambient measurement and inverse modeling techniques have been successfully demonstrated they are currently not sufficiently developed to provide comprehensive verification at the required accuracy, much is to be gained from working together, to improve verification techniques as well as gain better understanding of inventory estimates, and of natural emissions and removals." This highlights both the challenges and desire to do better – with Table 1 offering some guidance on focus areas (from an inventory perspective).

national sources and sinks IF they are better than the current datasets.. For example the cropland data layer – why don't we use it instead of the NASS data? It is because it is not obvious that it is much better than current statistics. Remote sensing has to provide products or enhanced products that are better than current inventory estimates, and do so on an annual basis.

Second, remote sensing based products and models can contribute to a top-down estimate that provides (a) international consistency in reporting, and (b) evaluation of current estimates.

Finally, it provides increased resolution to (a) estimate regional, as opposed to national, fluxes, and (b) provide attribution to sources and sinks. This is analogous to the recent mandatory reporting of fossil fuel emissions for entities that emit over 25,000 Mg CO_2 annually. This was put in place so that we know more about *who* is emitting *what*, and *where*. This is one compone that a CMS could offer. We will need similar resolution of data and activities related to land resources.



We have estimates for national fossil-fuel use and emissions and national land use. These are often based on county or state-level data. Some data are based on production; some on consumption. Datasets are not interconnected to allow for a systems perspective of C flux, storage, transport, use, etc.
We could use better information on where they occur and when in order to reconcile these estimates with other estimates (e.g., flux tower, tall tower concentration data, inverse modeling).
We need to know where forest and agricultural products are produced, consumed, and combusted/respired, in order to connect the movement of C and improve estimates of emissions. This significantly impacts estimates of regional emissions. We don't necessarily need to know this for national reporting. We need to know this in order to *ground-truth* national reporting **for regions**, to increase accuracy of national reporting, and to ensure that regional estimates sum to national estimates.

Leif – There are different approaches across all countries for dealing with transport, emissions, and other aspects of trade. It creates lack of comparability across all countries. A number is there but doesn't add to the totals and is computed differently. Missing components also include harvested wood products, which are poorly aligned with fluxes and emissions. Gaps are there.

Jim – Wood products are part of FIA data reported in the EPA reports as are estimates of wood imports, exports, and landfill emissions.

James – We are doing two things at NIST – we are improving standards and communities and other monitoring systems. We think that 40% of the totals are very uncertain – we are working to improve the capability of CO2 measurements. Where we spend our research dollars in areas where there is likely to be a measurement need sometime, but not tomorrow. We focus on five or ten years out. Influx experiment is one of these longer term projects. It largely utilizes expertise that is not found at NIST. Most is outside of NIST and other agencies. Many scientists are heavily involved in activity.

A critical question is that will the EPA use it to improve inventories if the experiment is successful. What I don't see is effective mechanisms in place to integrate measurement activities to policy activities. Mitigation activities and how it might be used in climate sensitivity, etc. How do the improvements help?

Molly M – How did you decide what questions to look at in designing your experiment?

James – We use meetings, and loose aggregation of agencies, like what we are doing now. NACP and the Climate Change Interagency Working Group (CCIWG) bear a lot of responsibility for improving our focus on these issues. Lot of good work has been done in these organizations.

Peter – The CCIWG is the only working group at USGRCP that has really kept going through three administrations. The others have not met in three years – specific people are responsible for this, both their involvement and their leadership.

James – The commitment has been there and they have been able to sell the commitment to their agencies.

Molly M – Can you give us an example of what you are working on now and how it will be helpful in the future.

James – Influx and other work that might contribute to better continuous emission monitoring (smoke stack monitoring) and the gas concentration point. The velocity piece is more uncertain – highly turbulent system using techniques – gas concentration is right but the velocity is not so the total emission statistics are off by 10-20%.

Area source monitoring based on Lidar estimates and other verification and area source emissions. NIST focuses on the standard side and delivers them to the regulatory agency. In the case of Influx, we will hand off the monitoring technology, develop and demonstrate the capability of the technology. But it is not clear who exactly will use the information.

How good is good enough? The customer has to tell us. Today it is a nebulous community that is bouncing around, and not well defined who would use the information. Knowing that we can estimate CO2 at an uncertainty of 5-10% is a good start, but we don't know if markets will be happy with it. In the natural gas sector, having a similar level of uncertainty in metering technology seemed to be ok – markets were still able to develop.

Yes, the markets may be unhappy with the current level of quantification, but as long as the results are randomly distributed around zero improvements won't be paid for by corporations.

Thus we assume the customer are carbon marketing people – if the customer is a politician – then their motivation is convincing stakeholders that it is in the common good to do this, working and paying off is different. If the error is larger than the expected signal of 10-20% change over time, then the error really makes a big difference.

Stephanie – Getting a good market going is going to take forever if don't work from the corporate side. We need to rethink our sourcing and be proactive.

Roger – By refocusing the efforts on climate sensitivity, we are able to get back to the feedbacks in the carbon system. When we talk about measuring the sensitivity the climate sensitivity, the economic models will let us know the impact of the climate change on the broader population.