Earth Science Subcommittee
of the
NASA Advisory Council Science Committee

May 11-12, 2011
NASA Headquarters
Washington, D.C.

MEETING MINUTES

Byron Tapley, Chair

Lucia Tsaoussi, Executive Secretary

Table of Contents

Prepared by Elizabeth Sheley
Zantech Corp.

Subcommittee Members Present
Byron Tapley, ESS Chair
John Christy
Judith Curry
Efi Foufoula-Georgiou
Raymond Hoff (May 12 only)
Gregory Jenkins
William Large (via teleconference)
Patrick McCormick
Jean-Bernard Minster (via teleconference)
Mahta Moghaddam
Steve Running (via teleconference)
Robert Schutz
Mark Simons

Introduction and Announcements
Dr. Byron Tapley, Chair of the Earth Sciences Subcommittee (ESS), opened the meeting. After a discussion of program status, budget implications, launch vehicle issues, and the delay of Tier One missions, specifically Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) and Climate Absolute Radiance and Refractivity Observatory (CLARREO), much of the meeting was to be devoted to topic of modeling and assimilation.

Among the main issues concerning ESS have been the Joint Polar Satellite System (JPSS), which will be the topic of a future briefing. Additional issues include international collaboration and the Global Geodetic Observing System. A great deal of data is being collected, but a particular interest to earth scientists is whether these data are being fully utilized. Another topic of concern is the Fiscal Year (FY) 2012 budget, which includes a significant reduction in the 5-year run-out of the NASA Earth and Space Science Program. The FY12 budget affects the goals of the Decadal Survey goals and creates a situation in which small and medium missions are increasingly less affordable. Finally, there is an ongoing problem with the availability of suitable, affordable, and reliable launch vehicles (LVs). Left unaddressed, this will affect the Earth Science Department (ESD) missions in terms of both the amount and quality of science the Department can conduct.

Earth Science Division Update
Dr. Michael Freilich, Director of ESD, presented an overview of Department activities, including updates on the FY11 and FY12 budgets, the missions, the launches and access, and the Glory launch vehicle failure.

While NASA continues to fly the preeminent constellation of space satellites, all of the missions are old. Age crops up in various ways. The Solar Radiation and Climate Experiment (SORCE), Gravity Recovery and Climate Experiment (GRACE), and CloudSat satellites all have significant battery issues. CloudSat is not taking data at present, although improvements are being implemented. SORCE and GRACE have several fall-back positions. All three are going well beyond the design life and guarantee. But in general, the constellation continues driving science forward. Dr. Freilich expects all of the missions to continue following the current senior review.

In discussing budget issues, Dr. Freilich noted that the proposed and actual budgets under the current Administration have been notably larger than those of the previous Administration, which had a downward trend. The FY11 budget was not finalized until April 2011, and resulted in $1.628 billion, which was less than what the President proposed, more than what ESD expected from Congress, and above the FY10 budget. While it is true that some important things are not being done under this budget, there is much that is being done, and that should be the focus of external discussions: ESD is making significant progress with significant funding.

The Obama Administration also provided guidance on priorities, which do not completely match those of the 2007 Decadal Survey. The combination of priorities and budgetary constraints results in a plan that is realistic and responds to the community and the budgeters. ESD's work is viewed as societally important, with policy implications. The climate initiative was developed by ESD, reviewed, and signed off by the Office of Management and Budget (OMB) as a closed plan. Because the Administration told ESD to take some things out of the plan, those activities have been deferred.

This year, ESD had scheduled three launches: GLORY, which had problems with its March launch; Aquarius, to measure sea surface salinity, and currently scheduled for June; and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP), planned for October. There have been problems associated with GLORY's Argentine collaboration and lawsuits filed in that country. Aquarius also has challenges but is moving along well, as is NPP. Other scheduled launches go from 2012 through 2015.

After a series of failed launches, NASA has suspended the Taurus contract and is trying to determine how to go forward on the OCO-2 launch. The earthquake in Japan has affected the Japanese Aerospace Exploration Agency's (JAXA's) ability to go forward with the Global Precipitation Mission (GPM); there will be more concrete information available on this at the next meeting. The delay will likely be months, not years.

Venture Class Update

Venture Class is a Tier-I, Decadal Survey recommendation. It is science-driven, principal investigator (PI) led, competitively selected, cost- and schedule-constrained, regularly solicited, and orbital and suborbital. The Venture Class investigations complement the systematic missions identified in the Decadal Survey, and provide flexibility to accommodate scientific advances and new implementation approaches. The program has three strands: EV-1 for suborbital/airborne investigations; EV-2 for small, complete missions; and, EV-Instrument for spaceborne instruments for flight on Missions of Opportunity (MoO).

EV-1 is going very well and flights are beginning for the five selected investigations that were solicited in FY09. The final Announcement of Opportunity (AO) was planned for May 2011. EV-1 and EV-2 will solicit on 4-year intervals, staggered so there is an AO every 2 years. EV-Instrument will issue AOs annually. Each of these Class D missions complements the program's strategic missions and will lead to a robust, nimble slate of programs.

Other Projects

Dr. Freilich gave brief updates of projects under the Earth Venture-1 program. These included Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS); Airborne Tropical Tropopause Experiment (ATTREX); Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE); Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ); and Hurricane and Severe Storm Sentinel (HS3).

The Earth Science Technology Office (ESTO) is receiving additional funding. ESTO is known for spreading its resources in a focused way. The Applied Sciences Program also complements these areas, with an emphasis on four application areas: health (air quality), water resources, disasters, and ecosystems.

ESD sequestered some of the new funds into nonflight areas such as research and application (R&A), technology, and applied sciences. A key is that this is all synergistic. ESD chose the program components to ensure the Department could integrate and gain benefit from each component. The result is an integrated, multi-disciplinary program that covers the whole field. ESD is targeting a reduction in its liability for uncosted funds, which can be a liability when dealing with Congress.

Collaborations

International collaboration is part of the U.S. national space policy. To that end, NASA continues to move forward with formal bilateral frameworks with the European Space Agency (ESA). This has stepped up due to a change in ESA's data policy, which is now more open and therefore acceptable to NASA.

In addition, NASA is collaborating with the India Space Agency (ISRO), on a project involving a scatterometer. The French space agency, CNES, is working with NASA on the Surface Water and Ocean Topography (SWOT) project, and a polarimeter project is under discussion. Additional collaborations involve the space agencies of Canada, Japan, and Argentina. Talks are ongoing with NASA's German counterparts. The Agency had been discussing a collaboration with Brazil, but that is not budgetarily possible now.

In addition, there are many interagency collaborations. Dr. Freilich made special mention of the U.S. Global Change Research Project (USGCRP), and a Landsat project with the U.S. Geological Survey (USGS) and Department of Interior (DOI).

Launch Vehicles (LVs)

Dr. Freilich said that in the aftermath of the GLORY failure, NASA has no plans to do a carbon-copy mission, as some of the GLORY missions were relatively old. The Total Irradiance Monitor (TIM) will likely be flown on SORC and Active Cavity Radiometer Irradiance Monitor (ACRIMSAT) missions through 2016. NASA and the National Oceanic and Atmospheric Administration (NOAA) are already working on a next-generation instrument. The other instrument was the Aerosol Polarmetriv Sensor (APS), which is being re-examined for relevancy. ESD does not want to put other parts of its program on hold to fund the GLORY recovery and is wary of treating it as a higher priority than it is.

Regarding the LV crisis, ESD does not currently have the right capacity for its missions. The commercial LV industry is not creating reliable, affordable products that ESD can use. The reliability and availability problems are affecting ESD now and will have greater impacts on Earth and space science programs in the coming decade. Dr. Freilich detailed the issues with the various LVs currently up for consideration. Some of the upcoming missions occurring as soon as 2013 do not yet have LVs lined up.

<u>The Role of Modeling in NASA ESD</u>

Dr. Jack A. Kaye, Associate Director for Research in ESD, presented an overview of the Department's use of modeling. Modeling contributes to each of ESD's six major activities. The programmatic roles of modeling include quantitative tests of understanding Earth system processes and behavior; predictive capability; use in producing observation-model hybrid products; and, use in developing future observing systems.

The key is observationally driven modeling, which allows researchers to aggressively incorporate their observations. Modeling helps in making decisions where there are competitions for funding, as well as in special cases of directed funding where NASA leadership and commitment is crucial. Active engagement with the interagency modeling community, through USGCRP, helps NASA provide leadership through the comparisons and assessments.

Overview of NASA ESD Modeling Capability

David Considine, Manager of ESD's Modeling, Analysis, and Prediction (MAP) Program, presented an overview of modeling in the Department. ESD's modeling effort focuses on presenting Earth as a complete, dynamic system. ESD modeling is observation-driven, with a scope from sub-kilometer to global, and a scale ranging from minute to centennial. The capabilities were developed heterogeneously. There are ongoing efforts to interconnect modeling groups and software, with open codes. Some NASA investigators use externally developed modeling capabilities, which are considered part of the NASA ESD modeling capability. NASA policy directive governs the release of NASA software by category, ranging from relatively free to restricted. There are controlling authorities, but the big modeling codes are downloadable.

The goal of observation-driven modeling is to maximize the utility of NASA observations to achieve ESD goals in a synergistic manner, attempting to develop realistic representation of the Earth's system and its processes. Observations are used for model development, constraining parameters, evaluation, initialization, and boundary conditions, as well as filling data gaps.

Dr. Considine provided a list of some of the larger NASA modeling assets. The modeling efforts involve collaboration with external partners. These include other agencies and universities, as well as Federally Funded Research and Development Centers (FFRDCs) and multiagency consortia, all of which expand ESD's modeling capabilities.

Focusing on specific systems, Dr. Considine noted that there are two systems for modeling Earth's global climate: the Global Earth Observing System-5 (GEOS-5) and the Goddard Institute for Space Studies (GISS) Model E. The two systems have different regimes in terms of length and time scales. The GISS is used mostly on decadal scale and longer-term studies, while the GEOS-5 is shorter-term and more immediate.

The Earth System Modeling Framework (ESMF) is a NASA effort, initiated by the Agency, that is now a multiagency collaboration with most funding coming from outside NASA. ESMF provides an environment for assembling geophysical components into applications, as well as a toolkit that can increase interoperability, improve performance, offer portability, and reuse common utility code. There have been efforts to involve external users. One possibility in that area is offering software as a service, as the idea of running these large models in single facilities becomes less viable.

Overview of GISS Earth System Modeling

Dr. Ronald L. Miller discussed the GISS Model E, which encompasses a range of models, including two ocean models to compare representations: the Russell Ocean and HYCom Ocean. GISS also includes models for vegetation, land surface, sea ice, and ocean biology, with work being done on an ice sheets model. Half of the funding comes from a block grant to GISS, with the other half coming from competitive proposals. The model uses everything from satellite data to paleo-climate data. To show how the GISS approach works, Dr. Miller presented graphics related to the Pinatubo volcano eruption, in which GISS found novel connections between stratospheric and surface wind patterns. Another example showed observations of the American Dust Bowl and Western Chinese dust storms compared to models. The model breaks out pure sulfate and sulfate-on-dust.

Dr. Considine explained the use of GISS modeling in Intergovernmental Panel on Climate Change (IPCC) AR4, which did a large number of forcing simulations. AR5 GISS modeling uses a cubed sphere, which offers a number of advantages such as better resolution. Simulations for the Coupled Model Intercomparison Project 5 (CMIP5) incorporate pre-industrial control runs and operate in three configurations: non-interactive, chemistry and aerosols with direct effect (CAD), and CAD plus indirect aerosol effect. NASA is giving some modeling results to the Environmental Protection Agency (EPA) for regional models. Mitigation exercises will involve making changes in constraints to see what results.

EPA will be doing the downscaling. In addition, code verification is left to individuals, who catch the obvious things. Quality control becomes a problem as the models become more complex. Dr. Jenkins asked about the status of AR4. Dr. Miller explained that the cubed sphere led to higher resolution, which is appealing and allows for more detail and confidence. There are many scientific reasons to go to a cubed sphere. GEOS-5 is interacting with GISS. The program is a few million. There is an advisory board that provides a great deal of feedback.

Global Modeling & Data Assimilation for Weather & Short-term Climate

Dr. Michele Reinecker, of the Global Modeling and Assimilation Office (GMAO), explained that assimilation is at the heart of modeling. GMAO's observation-driven model suite brings models and observations together through data assimilation spanning many timescales and modeling all components of the Earth in order to develop an integrated Earth system analysis. GMAO contributes to Decadal Survey missions, and recently implemented a repository for GEOS-5. GMAO runs simulations daily. Data assimilations bring together observations and models and maximize the utility of both while tamping down their biases.

As an example of what GMAO does, Dr. Reinecker explained how the atmospheric assimilation shows a mixture of operations, research, and operational/research systems. A great deal of data goes into current modeling, as much as 30 million data points, about one-third of which are assimilated daily. More than 90 percent of these data are satellite data. Many of the applications are run out of Langley.

One of the field campaigns is the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS). Observing system science can isolate individual data points to determine the impact. The Modern Era Retrospective Analysis for Research and Applications (MERRA) program does atmospheric reanalysis of comparable quality to the ERA-Interim system. A comparison of the zonal mean correlation between MERRA and ERA-Interim shows variability in the tropics but not otherwise. MERRA is also used for ocean reanalyses. Where there is less observation, there is more variability. Carbon species, aerosols, ocean biology, and land surface fields analyses are underway. The next steps are tighter coupling and feedback between systems.

GMAO contributes seasonal forecasts to NOAA, with observations that have validated the NOAA forecasts. Now GMAO is embarking on IPCC/AR5 modeling. As systems have matured, the Office continues updating the models, increasing resolution to address observations better and make comparisons more accurate. This improves forecasts of extreme weather, and the ability to compare with satellite observations and assimilate high resolution data.

GMAO is always trying to find independent data to validate its findings, looking at data from coding, regression testing, and other methods. GMAO initializes and can make changes as it goes, but also values the predictability angle. As yet, there have been no direct comparisons with the GISS model, although they are working toward common elements.

Discussion with Dr. Freilich

As Dr. Freilich was unable to stay for discussion following his earlier briefing, the Subcommittee spoke with him following Dr. Reinecker's presentation.

Dr. Efi Foufoula-Georgiou asked about NASA's role in an initiative between the United States and Europe to model sustainability. Dr. Freilich was not familiar with the initiative, but noted that, through USGCRP, NASA engages with other agencies on sustainability issues. NASA has enabled sustainability science to go forward, but the Agency does not have a large direct sustainability effort. Dr. Kaye added that NASA is trying to be involved in the global change efforts. Observations are critical to the future evolving community. The data and support NASA can provide puts the Agency at the core of the international community, where there is now a big push to integrate certain activities with the social sciences. However, the latter are not NASA's thrust.

Dr. John Christy observed that NASA has requirements to monitor ozone and other substances. Regarding some of the observations, are the requirements for NASA specifically? Dr. Freilich said that NASA seeks to make long-term measurements, and there is now a program to bring in these data. The Particles, Atmosphere, and Chemistry Experiment (PACE) mission is a contribution while the Agency learns what develops in other programs. However, there is no mandate to do these measurements forever.

Dr. Mahta Moghaddam asked about the possibility of using Minotaur 4 as a launch vehicle. Dr. Freilich said that it is being considered, but the Minotaur is a government program and the preference is for commercially developed LVs. Still, the Minotaur is being used for some programs. Not all of the missions currently in need of a launch vehicle can fit on Minotaur 4. NASA is not allowed to be in the LV business, and the Science Mission Directorate (SMD) cannot independently analyze the LVs. They are pursuing products within and outside the Agency to better define the issue and show possible actions to be taken. The decisions on this are made way above the level of ESD, and any assistance the Subcommittee could add to that would help.

Dr. Mark Simons asked if there is possibly a systemic failure in how these missions are shepherded through NASA. He is concerned about the natural hazard activities, and it is not clear that the Administration understands what NASA can bring to natural hazards. He is very concerned with the priorities and the representation of natural hazards in light of their impact on society. It does not fall within the standard rubric of climate change. The community is concerned that these things are not being done for some negative reason. Dr. Freilich replied that there is no question that solid earth processes have had some progress within NASA. However, ESD has been historically unsuccessful in getting a free flying space mission to make solid earth measurements, and that is also true of other countries. NASA wants to fly the best, most capable system possible, but tends to price itself out of the market. Dr. Freilich wonders if flying less capable, more affordable missions might build credibility through the innovative research and be a better long-term strategy. As for DESDynI, it was growing larger and larger. ESD pushed as hard as possible but could not overcome the budget decision. In 2009, he was asked to explain to the White House, through a climate lens, the missions that ESD was pursuing. He tried to define climate up front. The Administration characterized DESDynI as an earthquake mission, while he gave it a broader definition. ESD has to set its sights realistically and go for missions that can be done, to build credibility for the future. In addition, the Department must be careful about chasing the disaster of the moment. ESD cannot be ambulance-chasing on missions that take 5-7 years to develop. He shares the frustration, and feels he has to figure out how to sell a solid earth and natural hazard mission. He is not sure that that expertise is in many places.

Dr. Foufoula-Georgiou said that natural hazards fall within climate inputs and the differences in topography should be a factor. Dr. Simons added that DESDynI was a science mission, and natural disasters were part of it. Dr. Freilich said that it might be possible to shift focus, perhaps beginning with something small that people value so that they ask for more of that kind of input.

<u>Discussion with SMD Associate Administrator Ed Weiler</u>

Dr. Tapley noted that the Subcommittee had been discussing some higher level questions, like the LV issue and the problems it creates. Dr. Weiler explained that the lack of a reliable LV is a broad failure. NASA will have to recertify Taurus XL due to its failures, and Atlas 5s are unaffordable. Costs have gone up dramatically and have led NASA to renegotiate collaborations. The situation has created a loss of science instruments and is affecting all of the missions. SMD is looking at all other kinds of options. SMD is a customer, and has to find a way to get reliable, affordable LVs. He does not care which one it is. SMD has raised this issue to the Administrator and Congress repeatedly. At the core, NASA is the space agency and requires LVs. NASA is thinking about block buys; Deltas are on the table. Everything should be on table, though NASA cannot buy foreign launch vehicles. Dr. Freilich added that the baseline launch scenario for one of the upcoming launches is a joint launch. The risk of putting two major spacecraft on one launch is substantial, but they have to consider it.

Dr. Christy asked about whether earth science is supported by both parties in Congress. Dr. Weiler said that there are those who maintain that earth science is not a core function of NASA. This is not true – earth science is a core part of NASA's mission. This stance that it is not is worrisome. The NOAA budget is not getting passed and some of its work is being affected, like the polar weather satellite. By getting a raise in funding, ESD could also be a target by virtue of standing out. It is frustrating, especially when people in Congress attack climate satellites. The country needs these data.

Dr. Simons wondered about the amount of effort required for an ensemble of nations to take a view of a constellation. Dr. Weiler said that this is essentially the Mars program. However, neither NASA nor the European space agencies have the funds to do the science they want to do. They all have the same science goals and know they have to work together. Earth science is becoming increasingly international. Dr. Freilich added that when ESD put together its climate initiative, the Department used the criteria that the likely international contributors would need. There are various Earth-observing collaborations that NASA will be chairing and dealing with for the long term. There are elements that will always be led or done entirely by individual nations. But there is a lot of harmonization and collaboration.

Dr. Tapley asked if there might be a way of working the non-Agency community into the planning and strategy. Dr. Weiler responded by asking whether, provided the communities really accept the fact that everyone has tighter budget, it is time to get the science community together to develop an international set of priorities. This has to be approached very carefully due to differences among the various countries – it will not be easy, but it does make scientific sense.

Dr. Gregory Jenkins asked about the long-range situation, as in how ESD will explain its programs in 2018, beyond budget issues. Dr. Weiler said that a number of the programs will have been launched at that time. There will be some new satellites operating. Dr. Freilich added that ESD will have a constellation the same size as the one now, and it will be a bit younger, measuring a range of variables. Dr. Tapley noted that the Academy is looking primarily at planetary exploration. Dr. Weiler said that ESD has monthly meetings with the Academy to talk about the issues. It might be possible to have them come in and talk to the Subcommittee.

Dr. Robert Schutz observed that new technology for sensors, etc., will be limited by the LV situation. Dr. Weiler agreed, saying that that is why it is the primary issue. He is a bit more optimistic than a few months ago because the Agency is looking at multiple directions. Dr. Tapley noted that there was language in the Authorization precluding outreach, but Dr. Weiler said that that did not apply to ESD. Dr. Freilich explained that ESD has an education program, and SMD has an education element. Dr. Kaye noted that the education element may be different from one topic to another. The Administration is looking for duplication in order to make cuts. This calls for an effort to demonstrate the uniqueness of certain programs. Dr. Weiler said that this situation is not as bad as that of 2005-2008. The budget is going up, and the first priority is to sell the importance of the program. Dr. Freilich said that ESD spends a lot of time looking at the space between the budget lines to see what is not getting done. However, the program has plans to launch seven new missions in next 5 years, five of those within the next 2 years. There is a need to point out what the Department is doing, not what they are not doing.

Dr. William Large asked about GLORY and if the whole idea of Venture class instruments might get in soon enough for these discussions. Dr. Freilich thought that this was a good question, as the timing is right. The EV2 AO will go out within 2 weeks, and will launch in 2017. Under the circumstances of LV failures, overlap is no longer something to be avoided.

Dr. Moghaddam asked about the strategy on the launch vehicle situation. Dr. Freilich replied that the EV2 AO opens up the opportunity for U.S. PIs to procure launch vehicles. Dr. Weiler added that there are many opportunities for ride-sharing and international collaboration, though NASA funds cannot be used to buy a foreign LV. Dr. Freilich said that NASA will indemnify on a Pegasus vehicle. The budget for applied science is going up. Dr. Kaye added that there is support for the national climate assessment, and joint implementation with the applied science program.

Dr. Tapley thanked Dr. Weiler for his participation.

In further discussion, Dr. Simons asked about the last letter and the discussion about the Applied Sciences Advisory Group (ASAG). Dr. Tapley said that this was mentioned, and that the letter also noted the lack of officially designated leadership. Dr. Judity Curry said that the broader point is important. They should be talking about water, earthquakes, ecosystems, etc., which are the things that sell. Dr. Freilich agreed. Applied science is growing without the non-flight areas. What they do is important, and the missions influence every person in the country. If Dr. Curry and others would like to recommend that ESD refocus more resources on another area, it would help him if they would also suggest areas of focus to cut back on. That is his dilemma. Dr. Foufoula-Georgiou said they should emphasize that to get a return on the investment, there must be a demonstration of value. NASA's value is often the value of the data that will come in the future. Dr. Freilich agreed, stating that there must be balance. Dr. Tapley said they can emphasize key points, which are availability and the additional abilities to deal with the data they do get.

Dr. Simons asked for more detail about the concept that NASA does not do analysis. Dr. Freilich explained that there are liabilities to NASA, as a science organization, also being known as an agency that provides certain information. For example, thermal infrared was to continue on Landsat. The western states can use it and the western state governors pushed it. NASA is not precluded from doing what it needs to for science, but the Agency cannot become NOAA in absentia.

<u>Terrestrial Carbon Cycles Predicted from Modeling and Satellite Data from 2000 to 2010</u>

Dr. Christopher Potter described the NASA Carbon Monitoring System (CMS) Pilot Project. This is a large, multi-center effort that must demonstrate the capability to form the science for a global carbon monitoring system. The Project's goals are to understand and predict the evolution of global carbon sources and sinks, and to establish the scientific credibility for use of such information to support policy and regulator activities.

Dr. Potter showed a diagram including the various elements under study. The carbon cycle is the least-well-constrained part of what is observed, as it is not observed directly. Instead, the observations are of proxies for carbon. Policymakers would prefer more direct measurements, but the science and monitoring for that are still in development.

Dr. Potter explained that studies of satellite data from 1982 to 1998 were not consistent; two different models gave very different results. One model was sensitive to drought, the other was not. Trends in the southern hemisphere have proven particularly difficult to confirm. The Amazon droughts of recent years have been used to compare the accuracy of the models.

The modeling has raised questions about whether warming temperatures explain NPP patterns in the northern boreal and tundra ecosystems, the impact of land use changes in China, the role of precipitation in western and central Africa, and more.

Dr. Moghaddam asked about heterogeneity. Dr. Potter said that systems are needed to determine it. The Amazon has been difficult to specify, and the situation could be due to a number of things. Some models depend on high frequency observations. Soil moisture and processes contribute to the uncertainty, as they are not amenable to satellite imaging, especially where there is a forest canopy.

Dr. Schutz asked how the different observations resulted when both Goddard and Ames ran the same model. Dr. Potter explained that it was the same model run by different observations. This shows uncertainty in remote sensing inputs. The team is doing all they can to close up the gaps.

Atmospheric Chemistry Models: Contributions to the 2010 WMO/UNEP Ozone Assessment

Dr. Anne Douglass, of Goddard's Atmospheric Chemistry and Dynamics (ACD) Branch, explained that the GEOS Chemistry Climate Model (CCM) is a collaboration between GMAS and ACD. The focus is on reproducing observed behavior. The Global Modeling Initiative (GMI) combination was a chemical mechanism used with assimilated fields in many applications. The approach here is to focus on the interactions between the physical and chemical processes in the CCM. A second part of the approach is to remove the dependence on reproducing exact observations.

An example of the focus on interactions is shown in the strategy to interpret the ozone increase in the summertime Antarctic strategy. The ozone hole does not appear in uncoupled models, but coupled models do show the ozone hole, which changes the dynamic. Dr. Douglass showed an example of the second part of the approach, regarding the atmospheric lifetimes of chlorofluorocarbons (CFCs). The project determined mean age, which was estimated to be 56 years, substantially longer than the 45 years being presented elsewhere. Dr. Douglass also discussed the El Nino/Southern Oscillation (ENSO) Forced Upper Troposphere Lower Stratosphere (UTLS) ozone variations. There is good agreement between the Microwave Limb Sounder (MLS) and the simulated sensitivity.

The GEOS CCM team approach to NASA data and ozone assessment found that model results may converge over time. Between 2002 and 2006, models became better synchronized but some were not as useful as they could have been. For example, some tracked observations better than others. The data let the team identify which models are more realistic. The team learned that they need to change focus, with the goal of using information from evaluation to establish uncertainty. The team wants to be able to explain why the models show their particular biases.

Aerosol Modeling at GSFC

Dr. William Lau explained that aerosol modeling at Goddard grew out of the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model, which was developed in the late 1990s with support from NASA and is now widely used by many different organizations. Dr. Lau explained the basic elements of the aerosol model. These include simulation of major atmospheric aerosol species; a range of sources; the atmospheric processes of aerosols; calculations of mass concentration, optical properties, and radiative effects; and, a range of applications. Dr. Lau noted the long-term variations of aerosols and their effects on global dimming and brightening. The various models give each other credibility. The team has determined that the best way to look at regional problems is to ensure that the observations are integrated.

The team is also interested in how to best use the different models to determine impact. As an example, Dr. Lau showed an example of how monsoon circulation has changed due to aerosol content and dust. GOCART improves air quality forecasts by NOAA and the National Center for Environmental Prediction (NCEP). The model is more accurate when the aerosol data are included.

Facilitating the Use of Satellite Observations for Evaluating CMIP5/IPCC Simulations

Dr. Duane Waliser explained that this modeling project is a collaboration between NASA and the Department of Energy (DOE). NASA, NOAA, and the Department of Defense (DOD) have produced observations of precipitation, column water vapor, and cloud frequency, leading to relatively good models and agreement. When observations are akin to modeled variables, the models will be used by the modeling community. The idea is to link them together.

The modeling centers are busy. They develop observations and Program on Climate Modeling Diagnostics and Intercomparison (PCMDI) archives, then analyze the data and disseminate them to the community. PCMDI and others develop and apply the model diagnostics for evaluation. The weak link is making sure that the observations are in a form useful for the model; NASA is working on this, and the model evaluations will be delivered this summer. NASA has funded prototypes for a limited number of satellite data sets.

The project has three primary goals: to provide the research community with access to analogous sets of satellite data; to carry out Coupled Model Intercomparison Project 5 (CMIP5) simulations in close coordination with the corresponding entities and activities; and, to directly engage the observational science teams to facilitate production of the corresponding data sets and documentation.

Dr. Waliser reviewed the main tasks for CMIP5. These tasks address simulation protocol guides, identification of data sets, production of a technical document, transformation of satellite observations into netcdf CF-compliant format, providing access paralleling model data archive and delivery, and advertising the availability of the observations for use in CMIP5 analyses. Dr. Waliser provided examples of the technical documentation that would be available for every data point.

DOE developed the Earth System Grid (ESG) to provide climate researchers worldwide with access to the tools and information they need in order to work with enormous climate simulation datasets. NASA is ready to receive the data sets, the first of which have been delivered and are undergoing quality control. NASA is also working with PCMDI to finalize metadata conventions.

This is timely activity for Assessment Report 5 (AR5) because the model scoring with observations involves weighting projections based on observation metrics. In addition, earth system modeling (coupled carbon-climate) has added complexity and greater freedom. Finally, decadal predictions involve downscaling Global Circulation Models (GCMs) with regional models. Systematic application of observations for regional models is less comprehensive than for global models.

The project is on course to deliver NASA satellite data sets for the evaluation of the CMIP5 climate model archive and impact the IPCC AR5. Dr. Waliser reviewed the project's future emphases and needs, which include identification of additional observation needs, development of additional capabilities, and facilitation of collaboration and accessible data.

Discussion

Dr. Kaye was concerned that the presentations might have been too much information. They were not trying to get in everything, and therefore left out many good pieces of information. They wanted to show the different levels of maturity. Dr. Tapley said that he was still not sure where ESD is with the ability to assimilate satellite data. There were examples, but not a discussion of the extent to which it is being converted to models. Dr. Kaye said he would like to characterize the partnerships better and specify the kind of assimilation discussed. Dr. Reinecker added that the timeliness of data is key to the operational side. The decadal work is in its infancy. Dr. Tapley noted that many of the results were atmospheric and he did not see evidence of using radio data. Dr. Reinecker explained that there is not much radio data, but it does exist.

Dr. Curry identified an overarching issue: verification and documentation, along with external oversight. It seems that GISS falls short of what happens with other projects. There is a lot of validation, but the verification of the documentation is not done. When these models are being used in assessments, there should be more scrutiny. Additional thought should be given to what is done in the way of more formal verification in order to make this a more robust model. The community should address this issue with the GISS model and perhaps GEOS, which require more systematic oversight and verification. Dr. Christy agreed, noting that there is the potential for litigation. Following a specific procedure would help protect against litigation. Dr. Tapley asked Dr. Curry to circulate what she had written on this.

Dr. Foufoula-Georgiou noted that verification is difficult for a model. She gave the example of hydrology, which must follow 30-year-old government procedures. Dr. Christy replied that a legal situation could be a nightmare. Dr. Kaye said that his group has been concerned with the Information Quality Act, especially at the interagency level. They need to look at the societal impacts, which is an enormous challenge. Dr. Tapley noted that they could get different results from the lack of verification. Dr. Lucia Tsaoussi said that there is also a matter of which entity enforces the standards. OMB enforces the Information Quality Act. Dr. Tapley added that if the team is going to put products out for use by everyone, they should have at least some subset that is quality controlled. Dr. Mogahaddam suggested that they initially think about a formal analysis program. It would be more in the Subcommittee's purview. Dr. Curry said that all of the uncertainties are a factor, like structural errors that are not detected by the comparisons with satellite data.

Dr. Kaye was not aware of any Memoranda of Understanding (MOUs) or other formal mechanisms being in place. Dr. Waliser added that there are a few models with many data points. There are 20 or so models worldwide, and more independence than one might guess. Dr. Miller noted that there are circumstances under which a researcher would pick different models. Dr. Considine explained that there are efforts underway to develop a package called "Earth System Curator" that would create standards. Goddard is doing something in-house as well. These efforts might go part of the way in satisfying the need for standards. Dr. Schutz cautioned that this concern goes beyond regulatory issues. Dr. Miller noted that one of the issues is a lack of resources for documenting models.

Dr. Freilich asked whether the burden is on those who produce the information products or those who use them. ESD does not want to have to educate every single practitioner on the legal system, but would like to focus on how to insulate against creeping requirements. Any recommendations ESS could make would be helpful. Dr. Curry wondered if this issue might be more appropriately addressed by another group. Dr. Miller said that the modelers should first find out what the Legal Department would need and want. Dr. Simons asked if it is sufficient for the community to do due diligence. Dr. Tsaoussi said that the lawyers and advisory committee at NOAA will make the assessment. A key issue is the literature.

Dr. Tapley encouraged the Subcommittee members to start formulating their thoughts. He adjourned the meeting for the day at 5:37 p.m.

<u>May 12, 2011</u>
Dr. Tapley opened the morning session with a session overview. The remaining background information on modeling was to be presented in the morning, with a focus on ocean and land. The Subcommittee was

to then assimilate their thoughts on observations and recommendations. The previous day included some interesting presentations and raised questions about compatibility and verification of models. Dr. Tapley asked the members to think about specific issues to discuss after lunch.

Ocean Modeling

Dr. Dimetris Menemenlis gave a presentation on the major ESD modeling assets with ocean components. It is important to have diversity in modeling for two reasons: first, different problems require different models and assimilation methodology; and, comparing different models helps modelers to fix possible fatal flaws. Dr. Menemenlis focused his talk on the Estimating the Circulation and Climate of the Ocean (ECCO) projects.

ECCO was developed in the 1990s, based on criteria identified in the 1970s and 1980s. Various projects have allowed NASA to differentiate the models and compare them to observations. There are questions about sensitivity, and there have been many gradient tests to ensure that everything makes sense – much of the information is non-linear. ECCO's current iterations are ECCO CLIVAR and ECCO3. ECCO3 will work with other MAP-funded models, the Ice Sheet System Model (ISSM) and GEOS-5. The team would like to couple GEOS-5 and another ocean component at some point, but they are now just experimenting with sensitivities and identifying the issues.

Dr. Jean-Bernard Minster asked if the technical problem with the compilers was being fixed. Dr. Menemenlis replied that there was a meeting at the Massachusetts Institute of Technology (MIT) at which it was agreed that they need to work on conversion of code. This has been done for one program, but there are remaining issues on another. He and Dr. Minster agreed to continue this conversation via e-mail.

NASA is launching ocean-observing satellites but needs to interpolate to the regions that are not observed, which can be done only with computer modeling. ECCO contributes to the CMS, which provides an evolving physical and biological environment for air-sea CO2 flux estimates. Another effort is in high latitude modeling, especially of sea ice. There has been much work done in trying to develop usable code for estimation methodology. The ECCO modeling team is looking at developing different types of sea ice mechanics and ice sheet/ocean interactions, including the ice shelf cavities, which are important oceanographically and as boundary measures. Dr. Menemenlis showed a simulation of a glacier changing. Dr. Simons asked about the "ground bumps" noted as having an impact in the simulation. Dr. Menemenlis said that there are still questions about them regarding the density of the sediment and other factors. There is not yet an ocean tide model; tides are currently included as mixing elements, but they will be included in ECCO3.

MITgcm is open source, with many contributors and checkers. Verification tests are run every night, and results are reported the next day. Those who contribute code must include a verification element. Anyone who wants to change the code must convince the others. In testing ocean physics, that is what data simulation and state estimation is all about. They are continually trying to understand and make adjustments. Dr. Large asked if the team had concluded their ocean work and was moving on to ice sheet research. He also wanted to know the long-term strategy. Dr. Menemenlis replied that they are not done. Researchers have been on this project for 30 years and there are many unresolved issues, with much work left to do. Dr. Large then asked if the ECCO project was expanding into regions and if the Sea-viewing Wide Field-of-view Sensor (SeaWIFS) is providing solutions. Dr. Menemenlis said that this was not the case, that they are providing information like velocity and salinity, and working on algorithms.

Regional Assessment Modeling Climate Adaptation Science Investigator (CASI) Working Group

Dr. Cynthia Rosenzweig discussed how the CASI working group is testing the use of model products in regional assessments. The NASA Office of Strategic Infrastructure asked them to help prepare the various

NASA Offices for a shifting climate. The Group is therefore actively working with the Centers to share model products. Some of this is based on work they did previously for New York City. The CASI mission is to advance and apply NASA's scientific expertise and products to develop climate adaptation strategies that support NASA's overall mission by minimizing risks to each center's operations, physical assets, and personnel. Models are imperfect, but scientists can still use them to understand the changing risks.

Dr. Rosenzweig discussed how the Group is downscaling Center-specific climate hazard information, and gave examples of probabilities, along with a range of model-based projections. They are holding regional workshops at the Centers, presenting an eight-step risk management framework. For downscaling techniques and products, the Group relies rely primarily on statistical downscaling, which produces finer-scale features than Global Climate Models (GCMs) using historical relationships between large and small spatial scales, and dynamical downscaling, which is achieved by running a climate model driven by GCM outputs at high resolution over a small spatial domain. At a recently workshop at NASA Ames, they showed likely changes in temperatures and precipitation. Stakeholders care most about the extreme events. The Working Group presents extreme temperature data, both current and projected, in terms of the number of days with high temperatures over 90 degrees, and the number of days with low temperatures below 40 degrees.

The arguments in favor of statistical downscaling are that it is inexpensive and encompasses a wide range of spatial scales. On the other hand, downscaling is limited by the quality of observed climate data, assumes that future statistical relationships will be the same as historical relationships, and relies on potentially challenging multivariate analyses.

Regional Climate Models (RCM) show annual precipitation. RCMs differ substantially from observations and from each other, however and are still more in research mode than of actual use. This is a factor in dynamical downscaling. The advantages of dynamical downscaling include that a wide range of variables can be analyzed together, and the physics/process-based future relationships are allowed to evolve as the climate system evolves. However, it is computationally expensive; the multi-decadal simulations are only available from a subset of GCMs, emissions scenarios, and time-slices; the results depend on the quality of driving GCM/boundary conditions; it can be challenging to discern the relative role of the GCM and RCM in producing a result; large-scale feedbacks may be missed; and, it is not possible to provide point data for impact models.

In the end, using NASA Ames as an example, CASI allowed modelers to say that climate hazards for Ames include sea level rise, higher temperatures, and changes in droughts and floods. This knowledge in turn allows Ames to proceed with a number of adaptation steps today, though further planning activities will require regional coordination. NASA and CASI can play a leadership role in preparing for climate change by integrating activities within and across Centers, and coordinating regional efforts. Dr. Rosenzweig concluded by noting that the range of results associated with the downscaling technique is often smaller than other sources of uncertainty that influence decisions. Next steps include analysis of pre-conditions for extremes, further study of statistical products for downscaling, constructing analogues, developing localized approaches that meet stakeholders' specific needs, and stochastic approaches.

Dr. Christy asked about analogue methods. Some organizations find them more useful and like that they incorporate real data from past. Dr. Curry added that if an entity shows they have adapted over the past 100 years – which few have done – they can likely adapt to the coming years. Regional models tend to just give land and topography data, and sometimes the most useful information has not been presented. It is hard to oversell regional information, especially regarding confidence levels. Dr. Rosenzweig said that climate scientists need to work with decision-makers. Developing best practices and clear validation is a good idea. Case studies are useful up to a point, and most decisions are not made for the long term. Dr. Richard Hoff asked if the stakeholders really understand this material. Dr. Rosenzweig replied that in

New York, they showed model-based probability, which demonstrates the range. Stakeholders have said that scientists worry too much about uncertainty, which business people deal with all the time.

NASA Earth Exchange (NEX)

Dr. Rama Nemani discussed NEX, which is a collaborative supercomputing environment that provides direct access to data, models, analysis tools, and scientific results. The system is based on a NASA Ames platform that allows user communities to conduct sandbox prototyping. Once the process is done, they can go back to the data center, then return to the community. NEX is using various collaborative tools like the website, conferences, and various institutes, to generate interest. Participants put in the work flows they want to share, and the team can interact by running them through the system.

NEX has dealt with legal issues regarding firewalls, and has found that it is difficult to move large datasets. Public domain models are already in place. The community includes 154 members and 22 active research teams. NEX puts all science-funded projects on the systems and asks the PIs to participate. There are two climate models running, with a team from NOAA running GEOS-5 and a team from Stanford running another system.

This capacity was unimaginable a few years ago. NEX can process Landsat data in a matter of hours. Currently, the Exchange is trying to build virtual teams, but it not now distributing products or data. NEX is encouraging global, large-scale projects in which scientists can have complete control. The Exchange is leveraging past work, using workflows to look at droughts, for example. Prior to NEX, it took nearly 2 years to analyze the Amazon drought of 2005. For the 2010 Amazon drought, analysis took only a few weeks because NEX already had the workflow. Twelve teams are working on carbon modeling, NEX has its own modeling system on terrestrial observation, and a prediction system on ecological forecasting.

The platform is the ideal for the national climate assessment. Dr. Nemani listed some of the agency collaborations. He summarized by noting that NEX is trying to create a knowledge network, engaging a larger community by lowering the barrier of entry and capturing research through workflows and virtual machines to create the ability to build on past work. It is an enabling tool.

Dr. Hoff asked about the funding source. Dr. Nemani explained that NASA pays for most of it, with a small contribution from EPA. However, NEX will require additional contributions in the future. NEX was developed through American Recovery and Reinvestment Act of 2009 (ARRA) money and currently has four people staffing it. Dr. Simons asked about how much of the effort is actually used. Dr. Nemani explained that NEX is reusing a lot of technology from Ames and customizing more. It is all earth sciences, but the program is re-using the lunar science facilities.

Dr. Curry noted that turning this data into information and knowledge is difficult, and this work is crucial. It is also important for people outside the system who want to see what the connections are. This is key to documenting what earth scientists are doing and how their knowledge connects. Dr. Foufoula-Georgiou asked if this will become an entry point using cloud computing, and if there will be applications for models that anyone can use. Dr. Nemani said that NASA makes decisions on the resources and is looking at access issues. Foreign schools are currently excluded.

Dr. Tapley asked what satellite observations are being used. The answer was Moderate Resolution Imaging Spectroradiometer (MODIS), Landsat, Tropical Rainfall Measuring Mission (TRMM), and the Multi-angle Imaging SpectroRadiometer (MISR). Dr. Hoff asked about overlap with Giovanni. Dr. Nemani said that the main difference is that NEX is direct access with no downloading. Users employ their own computers and create what they want. Dr. Large said that NEX is assembling a wonderful dataset in one place and inviting people to come in. He wanted to know what value-added datasets were created that can go out. Dr. Nemani replied that datasets are made available to the modeling community. One of his colleagues (no identification; a man of Asian background) said that he calls it a playground, not a sandbox. Users bring their own sandboxes to the playground. It is an infrastructure allowing different components to interact together. Dr. Tapley asked if the datasets are resident and updated. They are. Much modeling is retrospective using satellite and weather data, so there is a 24-hour lag. Dr. Moghaddam asked for an example of a team bringing in its own models, and wanted to know how NEX is different from a Wiki. Dr. Nemani said that it is not that different. Users can save and archive. A one-off project is not the best match here.

Land Information System (LIS) as a Testbed for Agency Partners and Investigators

Dr. Christa Peters-Lidard explained that Goddard's Hydrology Branch set out to make code available to the community. LIS now has a mature team and is used at other agencies, most prominently the U.S. Air Force and NOAA. About half of the funding is from participating agencies. LIS is carried out at NASA to integrate observations with the models, which are mostly water and energy-balance models. LIS has been coupled to atmospheric models, like the Goddard Cumulus Ensemble (GCE), which is fully coupled. A goal is to have LIS coupled with estuary, coastal, and ocean models. The team spends has tried to make the code flexible. The keys are data assimilation, optimization, and uncertainty estimation.

LIS can be run in an uncoupled/analysis mode or a coupled/forecast mode. The former is based on past data. The NASA Unified Weather Research and Forecasting (NU-WRF) model consolidates NASA capabilities and tries to connect the model with satellite data. Any model run on LIS can be run with NU-WRF. Dr. Peters-Lidard gave examples of what can be done with LIS. Essentially, LIS is software, and people can request the code. The products are developed with two projects, the Global Land Data Assimilation System (GLDAS) and the North American Land Data Assimilation System (NLDAS), which run routinely at different resolutions. NLDAS is coordinated at NOAA and is also used by EPA.

The Air Force Weather Agency has used LIS to run the Agricultural Meteorology (AGRMET) modeling System. LIS also supports land analysis for NOAA's Climate Forecast System Reanalysis (CFSR) project. Dr. Peters-Lidard discussed multi-model soil moisture assimilation and the ways in which the physics of the model illustrates behavior. She also showed that the Catchment and Mosaic models work better for assimilation than the Noah model or the Common Land Model (CLM).

Snow is another active area, and in this area, the Noah model is the strongest. Dr. Peters-Lidard gave an example of soil parameter estimation, stating that soil databases globally are terrible. Her team wanted to be able to back out information about soil and soil moisture. After considerable work, the data and analysis are all in LIS. In addition, the team has coupled LIS to the Weather Research and Forecasting (WRF) model for a Florida soil moisture study.

The source code is available, but NASA has control of distribution. There are over 100 users, including international users, who help advance the work. The project has full documentation, archives, and discussion boards. The expectation is that users will run code wherever they want.

Dr. Tapley asked if land surface information is coupled to GEOS-5. Dr. Peters-Lidard said that LIS is not part of GEOS-5, but shares a component. The satellite assimilation is the same in both. That benefits the agencies the Branch works with, in that it allows the team to bring capability to them. Dr. Christy asked if the project was in contact with the private sector. Dr. Peters-Lidard explained that one company on the user list is Behren, and there is increased private sector interest. However, the LIS team has not pursued this. Dr. Foufoula-Georgiou asked about the level of difference seen with coupling. Dr. Peters-Lidard replied that there are some slight differences after 24 hours. The significant impact comes from analysis.

Dr. Foufoula-Georgiou observed that downscaling is statistical and dynamic. At the same time, the results for stakeholders are related to the extremes. There is a need to concentrate all historical data to understand cause and effect and the extremes, or to extend the analogy toward the extremes. The coupling will sometimes identify extremes. It is an important opportunity. Dr. Peters-Lidard agreed, adding that it is necessary to use models for dynamic understanding.

Transition from Research to Operations in the Joint Center for Satellite Data Assimilation

Dr. Lars-Peter Riishojgaard discussed research to operations (R2O) activities at the Joint Center for Satellite Data Assimilation (JCSDA). There have been several studies attributing economic value to weather modeling, but they are largely anecdotal. Dr. Riishojgaard's approach is more macroscopic. The Department of Commerce (DOC) says that 20 percent of the U.S. economy is weather sensitive. If half of this is forecast-sensitive, the projected affected amount comes to $75 billion/year, equal to 5 percent of the forecast-sensitive total. Assuming that the savings are distributed linearly over the achieved forecast range for the global Numerical Weather Prediction (NWP) system, a perfect forecast is useful over the entire range of predictability, and the atmosphere is predictable to 2 week range, this comes to 336 hours of useful forecast range, which could exceed $75 billion savings. It also implies $200 million per hour of forecast range per year in the U.S. economy.

Dr. Riishojgaard discussed the impact of various Global Observing Systems (GOS) components on 24-hour forecasting, along with their error contribution. Satellite data account for most of the skill and are growing in importance. R2O is therefore incredibly important. JCSDA began in 2001, triggered by concerns about U.S. leadership in research and R2O. At that time, most successful analysis was done by Europeans. To address this, NASA sought a balanced approach involving modeling, computing, and observational data. Dr. Riishojgaard listed the participating organizations, noted that they have come together to address the JCSDA mission and mission to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate, and environmental analysis and prediction models.

The overarching goal is to help the operational services improve the quality of their prediction products via improved and accelerated use of satellite data and related research. It is important to invest in these systems in order to obtain operational benefits as quickly as possible. Atmospheric composition is an area of strong interest to NASA, NOAA, and the military for different reasons, but the scientific issues are similar. JCSDA has two tracks of activities: internal, directed research; and, external research, responsibility for which rotates among the three partners. In addition, NOAA is spinning off a visiting scientist program.

Dr. Riishojgaard presented a long list of program accomplishments and projects, noting the LIS-WRF coupling and explaining that GMAO is active in preparing for data from sensors that have not yet been used operationally. Ongoing improvement to the use of existing data is important. The intent is to stay on top of any given data type. Computing has been an issue, as data assimilation is a computer hog. However, it also drives generation of new capacity. Nonetheless, this becomes a resource issue, and JCSDA has therefore reviewed every funded project. The unsuccessful ones showed that the operations to research element was lacking, in that it did not allow researchers to contribute back. New resources have enabled greater capacity. The system is being expanded to 2700+ cores using NOAA funds. This could turn into an incredible success story.

Dr. Hoff asked how investigators obtain accounts. Dr. Riishojgaard replied that those who receive Joint Center funding will get access.

Computing for Models

Mr. Michael Little discussed IT support for the science community. Computing power is expensive, and there is always a need for more of it. Mr. Little explained what his High-End Computing Group does to help in this situation. The key is partnership. There have been many small investments that ultimately paid off. NASA is striving for a balanced approach, given the immense demand. He could spend NASA's entire budget meeting computing needs and there would still be requests for more.

Modeling requires computer support in order to do more science for the same funds; it is a matter of leverage. The High-End Computing Group runs its facilities as if operational support for science. Mr. Little spends a lot of time ensuring that this is being done the best way. He frequently checks with other supercomputing organizations and partners to learn best practices and how much of the need is being met. He has seen where better granularity improves the science directly. The relationship between observations and models requires very high speed data communications systems. The Group also offers access to specialized technical expertise in computing. Most climate scientists are not interested in also being experts in computer science. The High-End Computing Group provides that expertise for them.

Modeling is supported by IT investments. Mr. Little discussed the history of growth in capacity and speed. NASA turns over about one-third of its supercomputing hardware every year just to keep up, with the hardware that is taken off-line being put to use elsewhere in the Agency. High-performance computing has high maintenance costs, which makes it more cost-effective to replace the hardware. NASA tries to focus its investments, in part because it cannot compare to other Federal science organizations such as the National Institutes of Health (NIH) and the National Science Foundation (NSF). Therefore, NASA emphasizes the needs of its users. Anyone funded by NASA can submit a proposal for access to resources. New users are filtered rather than fully funded. NASA then reallocates resources as the need and justification become apparent. Most users are from academia and NASA, with some from industry, the FFRDCs, and other government sources. Potential users are turned down only very infrequently. Of the approximately 2200 users, about 40 percent are in the earth science fields.

User surveys provide anecdotal information on areas for improvement. As Mr. Little noted at the beginning, demand exceed capacity by 30 percent. He often talks to managers at other supercomputing centers, and has learned that the larger organizations have a greater capacity to schedule and group projects together for better efficiency. He also works with the modeling community to make sure they are being pragmatic. Using a supercomputer involves a steep learning curve, and Mr. Little's team has identified areas where they can help new users. There are programs to promote accessibility in modeling. One is a summer school, like the one run by National Center for Atmospheric Research (NCAR) to help modelers use systems more efficiently. NASA wants to infuse modeling and supercomputer use, which will be piloted at Ames. There is also a modelers' workbench, which makes it easier to use the modeling tools. The "climate in a box" concept is a suite of models requiring little infrastructure.

Dr. Patrick McCormick asked Mr. Little about the audience for the summer school. Mr. Little said that it will be juniors and seniors in college, graduate students, and post-doctoral fellows. "Climate in a box" is for those who have a climate modeling background but lack the resources to develop a model. Dr. Moghaddam asked about what happens to those whose applications are not approved. Mr. Little explained that almost all applications are approved, but new users receive a reduced allocation. His group monitors how they are using it, and talk to them and their sponsor to ensure that they are not wasting time. However, predicting use of a supercomputer is sometimes difficult. Over the last 20 years, demand has always been higher than resources. As a result, there are people who will not even seek access. If he had a budget sufficient to meet registered demand, more people would ask for time. DOD and NSF have the same issue. It is not that there is a problem, it is that supercomputing must work with a budget. Dr. Kaye added that demand will always outstrip supply, and NASA must therefore negotiate on the demand side. There is a continual dialogue with users so they understand what can be done. There is only so much NASA can do for computing.

Dr. Simons asked if there are plans to invest in hardware and general processing units (GPUs). Mr. Little replied that there are. This is a technology that his department decided had payoffs. The downside is that the modeling community has to understand how to use GPUs. The jury is out on the future utility of GPUs at this point. The Chinese have made huge investment in the technology but do not know what to do with it, for example. NASA is waiting to see how it is used by the community. Some codes will have to be completely re-engineered to run in that environment. He wonders if scientists want to spend their time converting code, and believes NASA will run a hybrid environment for quite some time. Some of the technologies that have developed in recent years will expand. Dr. Kaye added that the collective Agency investment at Ames and the substantial allocation of the Goddard investment to earth science work well together.

Wrap-up

Dr. Kaye returned to his slides and asked if there were remaining questions or specific questions based on new information. He said that the presentations showed how modeling permeates ESD activities and covered programmatic roles well. The philosophy of observation-driven modeling was presented – this is one of the aspects of NASA's program that is unique. There was not much talk about solicitation mechanisms, but this is an area that the Subcommittee members know well. Creating the illusion of competition where it does not exist is harmful to the community, so those programs and projects ESD has grown to depend on are likely to continue. Still, there is value in competition, which often comes up in the non-core efforts or the efforts associated with the core efforts. The presenters gave good examples of where they are engaged with others, such as NOAA and DOD. There was a lot about assessments, and about computing issues. Many products have been made available to the user community, and that was discussed as well.

Dr. Tapley said that the Subcommittee appreciated all of the presentations. There was much information, all of it excellent. The key is the observationally driven modeling. Dr. Schutz agreed. One thing that still ran through his mind was how it is all coordinated and by whom. Dr. Kaye said that he and Dr. Considine coordinate the programs. The program managers and scientists all have some responsibility for modeling. He is a generalist and expects others to know the specifics. His role is to make sure that the right conversations are happening. There are other issues where there must be coordination between goals and resources. Dr. Simons was also very impressed. He noted that the Earth Science program should go beyond what they had seen into the areas of earthquakes, volcanoes, and other phenomena.

Dr. Hoff asked how participation in USGCRP informs the decision-making process. Dr. Considine explained that it provides a forum for him and ESD to understand the goals of other agencies, how they approach modeling, and any commonalities. An interagency group was recently re-established. Knowing what their counterparts are doing will allow NASA to contribute to a national strategy and address the needs of the nation. Dr. Kaye added that there are other meetings occurring, and his group must navigate the interagency process. For NASA, it comes back to observations. Dr. Curry asked how Dr. Kaye would defend the GISS climate model's emphasis on 100-year time scales that does not use data assimilation. Dr. Kaye replied that GISS receives much attention and is part of an integrated whole. The GISS team is aggressive in incorporating observations. They were early users of satellite observations, which helps with the trends and deviations from long-term trends.

Findings and Recommendations

Dr. Tapley asked each member of the Subcommittee to present their high-level summary points. He thought that the presentations showed capabilities and accomplishments, while raising questions. Dr. Christy said that he appreciated the observation-based model development, and he has used some of the products. The more that is done, the more it helps earth scientists. There is an issue regarding the legal aspects of some things that could end up in court. He suggested that the Subcommittee issue a recommendation on those lines. These issues could result in NASA scientists having to testify, and he was not sure they were aware of everything that would go into that. Although there are questions about suing the U.S. government, the issue is that the product would be put on the stand and a NASA scientist would have to defend it. Dr. Foufoula-Georgiou said that even if there is a disclaimer, it can be questioned. Dr. Christy had already written a paragraph and will work with Dr. Curry, who had also written a piece on this topic. They will compile their material.

Dr. Moghaddam noted that she was new to ESS. She had two observations. First is the issue of connecting computational resources to modeling activities, which are expensive. She understood Dr. Kaye's point about resources driving more need, but she thought NASA's spending seemed disproportionate to that of NSF and NIH, which were much higher. The individual proposals do not allow PIs to ask for computational help. Second, the LV issue has affected ESD and will continue to do so in the future. Dr. Schutz observed that they had not heard much about solid earth, and he was concerned about the loss of DESDynI and the Synthetic Aperture Radar (SAR) mission. He does not want to leave this to the Europeans. He liked the modeling presentations, especially regarding the observation-driven element. He did have concerns about code verification and thought the complexity of all the models going into this suggests a need for a coordinator. When things get so complicated with so many contributors, who is coordinating? It does not have to be one person. The LVs remain an issue.

Dr. McCormick said that modeling has come a long way in the atmospheric area, thanks to the strong efforts of NOAA and NASA. Validation points, verification, and use of standard practices are important concerns. He liked the idea of Mr. Little's summer schools, which will create more linkages with the modeling community. Dr. Freilich said that there is another division in SMD doing the JPSS work. Regarding NPP, Dr. Hoff was concerned that there is pre-proprietary development, and now there is an issue about refusals to sign nondisclosure agreements. There are also procurement-related issues. These issues keep some parties from getting access. He added that this is anecdotal information. Dr. Freilich said that he was not aware of this issue with that specificity. It only applies to certain instruments, if it applies at all. Dr. Hoff said that it is an external procurement issue. Projects waste a lot of money if they are not ready to start work immediately. Dr. Tapley said that this is a critical issue and asked Dr. Hoff to draft a letter. Dr. Hoff added that when he has tried to use some of these data, the choices reflect constraints based on decisions that are not entirely clear. An indicator of success is other agencies starting to operationalize models, and he therefore congratulated Dr. Peters-Lidard, for the partners that her team works with are contributing like they should.

Dr. Curry was very impressed by many of the presentations, especially those by Drs. Peters-Lidard, Reinecker, and Potter. She singled out Dr. Potter for his sense of unknowns and uncertainties, and for mapping out what his team needs. Two topics concerned her. The minor issue was impact assessment. The solution is not useful for extreme events or decadal timescales. The uncertainty management is of great concern, as it is not being done. She does not see what is being done that is NASA-specific. Refocusing to take it in a direction that is more observationally constrained and decadal will reflect NASA better. This is important, and the key in terms of quality will be huge in terms of national assessment. This needs to go to a higher level. There is an opportunity there to make a mark.

Her larger issue concerned GISS. Most of the important contributions could be done in another context, and she held that GISS is a second-tier effort. There is a general lack – the team does not seem to be accountable, there is no external advisory committee, there is no evident oversight or guidance, the project is not cutting edge modeling, and a lot of what GISS does can be developed outside of this framework. It matters because the climate model is one of NASA science's two public faces, with planetary research, and GISS does not put the best foot forward. A better case needs to be made. There needs to be oversight. The Geophysical Fluid Dynamics Laboratory (GFDL) and NCAR also do this kind of modeling, and they are in the top tier with climate dynamics and assessment. There is no rationale for choosing an ocean model in GISS. If they are going to do these assessments, it has to be defensible. The lack of oversight and lack of cutting edge work is cause for concern. The action is to recommend external review and maybe a standing advisory committee. The once every 5-year proposal is not enough. Dr. Reinecker has an advisory committee, and her group has been doing a better job as a result.

Dr. Tapley agreed that an external review would help. Dr. Simons said that he had a similar reaction. He has no feeling as an outsider as to where any of these things stood relative to comparable national and international activities – he wondered if they are unique, and he does not know their quality or whether they are related to the NASA mission. He felt there was insufficient information to make a judgment. He did not even feel he had enough information to tell Dr. Freilich what to do in this area. Dr. Curry added that Drs. Peters-Lidard and Reinecker presented that kind of information, but the others did not.

Dr. Freilich said that the comments were useful and thoughtful. He suggested that before making a recommendation for a review or oversight, the Subcommittee should ask for the programmatic oversight operation that is in place, which could be provided in writing or via telecom. There was a tight agenda and therefore the presenters did not discuss management. Dr. Tsaoussi wondered about making comparisons of GISS to other systems, as there is a different level of detail. Dr. Simons said that there is a statement being made on the order of magnitude of funding, and he wondered about the Subcommittee's role in that. At some point, the decision must be made about how much money goes where.

Dr. Kaye explained that GISS was structured as one of the big modeling efforts. His team saw GISS as important and did not look to have it compete. It is important to channel work to the right level of resources. If the project does not measure up, they need to know and address it. He wondered if this review should be a part of a larger review at Goddard.

Dr. Foufoula-Georgiou asked if there was a sense of a programmatic vision. She wanted to see how the pieces fit together. The ESD has mission to advance earth science through space-borne data. The pieces then fit together toward advancing system science. It is all there, but they are discussing the elements and uniqueness. There have to be some elements in place. NASA should ask if there are some better models, and how to develop synergy. She would like to see more interagency coordination beyond providing data to other organizations. NCAR is a good example of a group advancing a specific viewpoint and agenda. ESD might want to approach some of this in a more systematic way. There are some stovepipes within the system, and it might be worth integrating them better.

Dr. Jenkins said that the observation modeling perspective is good, though he did not hear much on tropospheric chemistry modeling, which is a key uncertainty in climate change that fits NASA's mission of satellite measurements. Dr. Tapley said that much of that is contracted out but very tightly linked through Goddard. Dr. Jenkins said that there should be more comparison and validation activities for model improvement and verification. There is a way to compare on decadal time scales. NASA needs to be a leader in long-term climate change and determine how to do this on decadal comparisons. He also wants to see how models can be improved from airborne campaigns and would like to see a direct comparison. Finally, NU-WRF is in development, and it is not clear where that is going. He would like to see it tested in field campaigns. He also wants to know the link between it and GEOS5 or GISS. No one is clear about whether the regional models are interpolators, nor is it clear how to do regional models.

Dr. Simons asked what the Subcommittee was supposed to have heard in this review. Dr. Kaye said that it was to have been as inclusive as possible within the time constraints. They tried to present a perspective of what others were doing and pick up parallels, though they did not try to be comprehensive. Dr. Simons said that, in that context, the solid earth and natural hazard activity was not represented. He does not want to see the continued attempts to advocate for natural hazard science result in it being pushed into environmental science. Only NASA can do this. NASA needs to strongly advocate at all times what it can do. There was little talk about the fact that there was a rearrangement of the Decadal Survey priorities. Dr. Simons said that they first need to establish a consensus order, and second, set priorities. The first part was very important. They are seeing degradation from the order that was developed. That may be a fiscal reality, but they should not let it go without having a discussion. He was impressed at how many things were applications. ESD should highlight this and find more support for a vigorous applications program. NASA needs a plan for disasters, both short- and long-term, that has a link to an applications program and operational activities. It is not easy, but they need to visit it. A longer discussion of response to all disasters is needed. It will develop a clientele and enthusiasm for what ESD does. Dr. Curry added that disaster in terms of societal interest is a better selling point than climate change. At a strategic level, ESD should recognize this. It is not an add-on, it is of equal importance and plays to NASA's strengths.

Dr. Minster said that most important to him is what NASA can do uniquely in entering into research that is beyond the capacity of others. NASA can examine not only pre-disaster situations but also at the most efficient ways to respond. There is little focus on that. Dr. Tapley noted that there is the Academy report, and he wanted to know if there was a recommendation. Dr. Freilich requested a clear written statement from the Subcommittee. Dr. Simons said that he and Dr. Minster would structure something that recognizes NASA's ability to respond. Dr. Freilich said that the task articulated is to enhance and focus ESD activities related to intermittent and unpredictable events and observations of those events. He wanted to know how to organize those activities. Dr. Tapley said that they also need to think about the way to use research related to disasters. Dr. Minster said that it is easy to see how NASA can complement the Federal Emergency Management Agency (FEMA) with hurricanes and get the right kinds of modeling and data. It is more difficult with an earthquake. If they are not ready for it, they can miss it. It requires action in the absence of urgency. NASA can do that. NASA has to be the agency people turn to for the data. Dr. Tapley suggested they separate the plan from action. ESS is going to recommend that the Director come up with a plan that they can later review. Drs. Minster and Simon will develop the recommendation.

Dr. Simons asked how ESS was to address questions about the Decadal Survey. Dr. Tapley replied that the Academy is doing a midcourse assessment that will be reported in 2012. They will be advising ESS, which means they do not have input. Dr. Minster said that it would not be a bad idea for those giving advice to hear from the advisees. Dr. Freilich suggested that Dr. Tapley, representing the Subcommittee, approach them to determine what is possible and desirable. Dr. Simons said that ESS must be very clear that the situation is not just that DESDynI is delayed. It no longer exists officially. However, it was 25 percent of the Tier 1 Decadal Survey activity. Dr. Tapley asked if ESS is compelled to defend it if the Academy does not. They might not. The budget issues on DESDynI are accompanied by measurement issues that were unknown at the time of the Decadal Survey, as were some technology issues. The measurement issues were a problem. The Decadal Survey recommendation was made in 2006. He would rather let the Academy determine if the reality is a reasonable response. Dr. Simons said that they are adding over a year of being silent on this. Dr. Tapley asked what ESS should recommend if the funds are not there – that NASA do none of the other activities? If there are funds left over, does ESD go down the queue, or do the next best science? If ESD cannot do DESDynI, should it do no science with that money?

Dr. Minster wondered what those in the solid earth community who are focused on natural disasters are doing wrong. He maintained that they must be doing something wrong, as they are spending a great deal of effort and still not convincing the Agency, the public, and other agencies. Dr. Moghaddam asked if ESS had been given a reason why this happened. Dr. Freilich observed that the Subcommittee was asking the Program for advice. The communication ESD received from the Administration when the budget came out made it clear that this was driven by budget and economic exigencies. The budget decisions were made for reasons of performance or benefit. It was clear that this was neither punitive nor judgmental on the merits of the missions, but driven to devise a program that fit.

Dr. Simons said that one proposal is to convey their concerns to the Academy. It is vital that, in the zero sum game, they find some way to implement this. It was a clear desire of the U.S. research community, it has gone through endless review, and NASA should find a way to do this. Dr. Tapley asked if it was only DESDynI or if there was a general budget issue. Dr. Simons replied that, in reading the language that came from the White House, it seemed like DESDynI had more life to it. The earth science community once said that DESDynI was extremely important and wanted it done. He thought that NASA must find a way to do this, and he wanted a recommendation of some sort. Dr. Tapley said that there were two other programs dropped, and ESS must decide if they want to focus on DESDynI or the whole earth science area. Dr. Simons said that the last time ESS met, they voted on this. Dr. Freilich said that the question put to ESS was whether the mission was scientifically viable. ESS was unequivocal on supporting DESDynI.

Dr. Minster said that earth scientists get confusing feedback from the review process, OMB, and NASA. He wanted to know where to go to talk with those who spend the money. It was not clear why they have to keep changing the scope. Dr. Freilich said that he understands the frustration. Time has passed, and the political, budgetary, and scientific environments are constantly evolving. They cannot assume that something that failed in the past will fail again. There are examples of programs with 20-year timeframes. He asked that Subcommittee members please check any statements about a program through Dr. Tsaoussi to prevent misstatements. Dr. Minster said that he and Dr. Simons will assimilate their thoughts, and that he would send a general essay on the telecom experience.

Letter Writing/Next Meeting

Dr. Tapley summarized the discussion by noting that, in the presentations about modeling, the Subcommittee heard about excellent capability and a complex effort. However, it is not clear how the units interplay, and there was no organizational chart. The questions are: what are the goals, how do we go forward, and what is driving the primary objectives? There were two clear thrusts: observation, and the issue of validation and verification. There are also questions related to the difficulty of looking at the whole Earth, and how these efforts relate to NCAR. The interconnections were not clear, and there seemed to be potential for duplication, but that was not clear, either. Dr. Tapley was also interested in knowing whether some of these activities might be done more efficiently. There were probably good answers, but the meeting had time limitations.

Dr. Tsaoussi suggested that if the Subcommittee needs more information, it could be provided before the next meeting. Dr. Freilich recommended that the Subcommittee send a letter with specific questions. The questions will be answered at the next meeting or in another way that complies with the Federal Advisory Committee Act (FACA).

Dr. Hoff said that the question that nags him on the coupling is that it matters in some places and not in others. He wanted to know if there has been a strategy for the whole modeling framework on coupling, and when assimilation can be done. Dr. Curry agreed. Dr. Tapley suggested that ESS develop a consensus set of questions. The other issue is the review process. The Subcommittee needs to articulate the need for a natural disaster plan and push for it. Dr. Minster added that there are questions about how to do the things that are priorities. Dr. Kaye noted that had the presentations been structured differently, different questions would have arisen. There is some information his team can provide, like the strategy. They will also think about the issue of validation and verification, as well as the review process. Finally, they will be more explicit about the proposal process, as with GISS.

Dr. Tapley said that the assignments were determined. Drs. Christy and Curry will write a statement on verification of software, and Dr. Hoff will write a statement on the nondisclosure issue. Dr. Foufoula-Georgiou suggested that they emphasize the positive elements to make them more visible.

Closing Remarks /Adjourn

Dr. Tapley thanked Dr. Kaye and all of the presenters. Dr. Taoussi noted that the slides would remain in the drop box for another 8 to 10 days. She would also send the phone participants a short summary of the afternoon session.

Appendix A
Attendees

Committee members
Byron Tapley, ESS Chair, University of Texas
John Christy, University of Alabama, Huntsville
Judith Curry, Georgia Institute of Technology
Efi Foufoula-Georgiu, University of Michigan
Raymond Hoff, University of Maryland, Baltimore County
Gregory Jenkins, Howard University
William Large, National Center for Atmospheric Research (telecom)
Mahta Moghaddam, University of Michigan
Jean-Bernard Minster, University of California, San Diego (telecom)
Steve Running, University of Montana (telecom)
Robert Schutz, University of Texas
Mark Simons, California Institute of Technology
Lucia Tsaoussi, Executive Secretary, NASA Headquarters

NASA Attendees
Melody Avery, NASA Headquarters
Robert Bauer, NASA ESTO
Carol Carroll, NASA Headquarters
Steve Cole, NASA Headquarters
David Considine, NASA Headquarters
Bradley Doorn, NASA Headquarters
Anne Douglass, NASA GSFC
Mitra Dutta, NASA Headquarters
Richard Eckman, NASA Headquarters
Jared Entin, NASA Headquarters
T. Jens Feeley, NASA Headquarters
Robert Ferraro, NASA JPL
Michael Freilich, NASA Headquarters
Randall Friedl, NASA JPL
Barry Geldzahler, NASA Headquarters
Peter Hildebrand, NASA GSFC
Steve Hipskind, NASA Headquarters
Charles Icholeu (?), NASA Headquarters
Ramesh Kakar, NASA Headquarters
Jack Kaye, NASA Headquarters
John LaBreaque, NASA Headquarters
William Lau, NASA GSFC
Tsengdar Lee, NASA Headquarters
Allison Leidner, NASA Headquarters
Michael Little, NASA Headquarters
Hal Mariny (?), NASA Headquarters
Dimitris Menemenlis, NASA JPL
F. Mondo, NASA APL
Rama Nemani, NASA
Marian Norris, NASA Headquarters
Christa Peters-Lidard, NASA GSFC

Chris Potter, NASA Ames
Michele Rienecker, NASA GSFC
Lars P. Riishojgaard, NASA Headquarters
Mike Seablom, NASA Headquarters
Woody Turner, NASA Headquarters
Stephen Volz, NASA Headquarters
Duane Waliser, NASA JPL
Dan Warden, NASA Headquarters
M.Y. Wei, NASA Headquarters
Nicholas White, NASA GSFC
Diane Wrekland, NASA Headquarters

Non-NASA Attendees
Robert Boyd, McClatchy Newspapers
Dom Conte, General Dynamics
Jayla Kundu, OMB
Virginia Neale, UCAR
Amy Svitak, Space News

Appendix B
ESS Membership

Byron Tapley, ESS Chair
Director, Center for Space Research
University of Texas

John Christy
Earth System Science Center
University of Alabama, Huntsville

Judith Curry
School of Earth and Atmospheric Sciences
Georgia Institute of Technology

Efi Foufoula-Georgiou
St. Anthony Falls Laboratory
University of Minneapolis – Twin Cities

James Hansen
Goddard Institute of Space Studies
NASA

Raymond Hoff
Joint Center for Earth Systems Technology
University of Maryland, Baltimore County

Daniel Jacob, ESS Vice Chair
Department of Earth and Planetary Sciences
Harvard University

Gregory Jenkins
Department of Physics and Astronomy
Howard University

William Large
Oceanography Section
National Center for Atmospheric Research

Patrick McCormick
Co-Director, Center for Atmospheric Sciences
Hampton University

Anna Michalak
Department of Atmospheric, Oceanic and Space Sciences
University of Michigan

Jean-Bernard Minster
Institute of Geophysics and Planetary Physics
University of California, San Diego

Mahta Moghaddam
Radiation Laboratory, Electrical Engineering and Computer Science Department
University of Michigan

Steve Running
Department of Ecosystem and Conservation Science
University of Montana

Robert Schutz
Center for Space Research
University of Texas

Hank Shugart
Department of Environmental Sciences
University of Virginia

David A. Siegel
Department of Geography/Institute for Computational Earth System Science
University of California, Santa Barbara

Mark Simons
Division of Geological and Planetary Sciences
California Institute of Technology

Konrad Steffen
Cooperative Institute for Research in Environmental Science
University of Colorado, Boulder

Appendix C
Presentations

1. *Earth Science Division Update,* Michael Freilich
2. *The Role of Modeling in NASA ESD*, Jack A. Kaye
3. *Overview of NASA ESD Modeling Capability,* David Considine
4. *Overview of GISS Earth System Modeling,* R. Miller
5. *Global Modeling & Data Assimilation for Weather & Short-term Climate,* Michele Rienecker
6. *Terrestrial Carbon Cycles Predicted from Modeling and Satellite Data from 2000 to 2010,* Christopher Potter
7. *Atmospheric Chemistry Models: Contributions to the 2010 WMO/UNEP Ozone Assessment,* Anne Douglass
8. *Aerosol Modeling at GSFC,* William K. M. Lau
9. *Facilitating the Use of Satellite Observations for Evaluating CMIP5/IPCC Simulations,* D. Waliser
10. *Ocean Modeling,* Dimitris Menemenlis
11. *Regional Assessment Modeling Climate Adaptation Science Investigator (CASI) Working Group,* Cynthia Rosenzweig
12. *NASA Earth Exchange (NEX),* Rama Nemani
13. *NASA's Land Information System as a Testbed for Agency Partners and Investigators,* Christa D. Peters-Lidard
14. *Transition from Research to Operations in the Joint Center for Satellite Data Assimilation*, Lars Peter Riishojgaard
15. *Computing For Models,* Michael M. Little

Appendix D
Agenda

NAC Earth Science Subcommittee

NASA Headquarters
300 E Street SW, Washington, DC.

Wednesday, May 11, 2011

8:30-8:35 Opening remarks	L. Tsaoussi
8:35-8:45 Meeting charge	B. Tapley
8:45-10:50 Earth Science Division Update	M. Freilich
10:50-11:00 Coffee Break	
11:00-11:10 Role of Modeling in ESD Research	J. Kaye
11:10-11:30 Overview of Modeling Capability	D. Considine
11:30-12:00 Global Modeling - Assessment	R. Miller
12:00-1:00 Lunch	
1:00-1:30 Global Modeling – Data Assimilation	M. Reinecker
1:30-2:00 Discussion	All
2:00-3:00 Q&A with SMD Associate Administrator	E. Weiler
3:00-3:10 Coffee Break	
3:10-3:35 Carbon Modeling	C. Potter
3:35-4:00 Atmospheric Chemistry Modeling	A. Douglass
4:00-4:25 Aerosol Modeling	W. Lau
4:25-4:50 Observational Data for Model Comparison	D. Waliser
4:50-5:30 Discussion	All
5:30 Adjourn	

Thursday, May 12, 2011

8:30-8:40 Session Overview	B. Tapley
8:40-9:00 Ocean Modeling	D. Menemenlis
9:00-9:20 Regional Assessment Modeling	C. Rosenzweig
9:20-9:40 NASA Earth Exchange	R. Nemani
9:40-10:00 Land Information System	C. Peters-Lidard
10:00-10:30 Discussion	All
10:30-10:45 Coffee Break	
10:45-11:10 Operational Connection	L. P. Riishjogaard
11:10-11:30 Computing-Modeling Tie	M. Little
11:30-11:45 Discussion	All
11:45-12:00 Wrap-up	J. Kaye / D. Considine
12:00-12:50 Lunch	
12:50-2:00 Findings & Recommendations	ESS Members
2:00-3:00 Letter writing/next meeting	ESS Members
3:15 Closing remarks / Adjourn	