

ESS Jan 7-8, 2009

January 7, 2009

### Introductory remarks

Dr. Daniel Jacob, Chair of the Earth Science Subcommittee (ESS), opened the meeting and detailed the charge to the committee. Executive Secretary of the ESS, Dr. Lucia Tsaoussi introduced new ESS members Drs. Hoff, Running, Schutz, McCormick, and Vorosmarty. Dr. Jacob reviewed items of particular importance, namely the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and the Earth Sciences (ES) research program. He noted that the incoming Administration may make quite a difference for the Earth Sciences Division (ESD), as will changes in the NAC Chair and Science Committee Chairs, which will result in more subcommittee participation. The next NAC meeting will include all subcommittees in a “jamboree” format in the third week in April, and will be combined with a formal ESS meeting.

### Earth Science Division Update

Dr. Michael Freilich, Director of ESD, provided an overview of recent division activities and programmatic status. The ESD now has a total of 60 people, about half its previous size, and the scope of work has not decreased, however it does have 5 recruitments in place despite hiring freezes. Divided into Research, Flight Programs, Applied Sciences, and the ES Technology Office, the division is running 1700 grants and a variety of flight missions with a very thin support staff. The budgetary allocation is about 55/45 between flight missions and “science,” respectively. Applied Sciences is important in a structural sense, but covers only about \$35-50M in funding, and Research is in a similar situation. Based on recommendations from the Len Fisk committee, ESD has responded to the call for more staff, obtaining 2 program executives and program scientists; the division has been relying more on detailees and is trying to attract competent people regardless of classification.

ESD’s overarching goal is to advance ES science and applications, through spaceborne data acquisition, research and analysis (R&A), and predictive models. Data analysis (DA) and the vantage point of space are important, but the division is also doing science. The six major activities of the division are comprised of Earth-Observing (EO) satellites with interagency and international partners, high-quality science products, research in 6 focus areas, Applied Science, improving EO technologies, and Education and Public Outreach (E/PO).

The 6 thematic focus areas of research are: atmospheric composition, carbon cycle and ecosystem, physical climate, weather, water and energy cycle, and earth surface and interior. Examples include have long-time series of measurements of sea level, which continues to

uncover ever-increasing time scales of ocean change; sea level change has been found to be non-uniform. There is now a record of several decades in ozone measurement. Satellite measurements can now be used in novel ways, such as measuring polar ice thickness with IceSat. This knowledge is obtainable only with good, consistent measurements over long periods of time. A recent example includes the measurement of NO<sub>2</sub> column concentrations in Shanghai and Beijing over three years; observers saw dramatic decreases in Beijing, perhaps as a result of policy change before the Beijing Olympics.

Suborbital platforms include aircraft, within the Airborne Science program. Field campaigns provide vertical and horizontal resolution not obtainable from satellites, which in turn helps to synthesize data. Applied Sciences is a small portion of funding, but it has been effective. A notable example is a NASA/National Park Service collaboration (Inventory and Monitoring Program) on determining habitat values, connectivity, and inter-area traverse corridors from multiple moderate-resolution satellite imagery products. The collaboration has shown how development affects wildlife traverse. The program acts as a bridge between technical and nontechnical users of the information.

Program accomplishments include the successful launch of Jason-2 in June 2008, which has subsequently undergone a 6-month calibration/validation period. On January 26<sup>th</sup>, Jason-1 will move into an interleaved orbit with Jason-2. A number of NASA operating missions are coming to the end of their design lifetimes and will be the subject of a Spring 2009 Senior Review. Eight missions in development include the Orbiting Carbon Observatory OCO, which will monitor CO<sub>2</sub> mixing ratios (February 23 launch date), and Glory, which will measure aerosol properties and distribution, scattering, total solar irradiance. Glory seems to be on track for a late 2009 launch. AQUARIUS, which will measure ocean salinity, is an Argentine space agency collaboration due for a May 2010 launch. The NPOESS Preparatory Project (NPP) is possibly slated for June 2010 to late 2010 as part of the NPOESS tri-agency effort with the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DOD). NASA has successfully integrated the desired instruments Clouds and the Earth's Radiant Energy System (CERES) and Ozone Mapping and Profiler Suite (OMPS-Limb) into NPP. The Landsat Data Continuity Mission (LDCM) is well along in its development cycle and is scheduled for a December 2012 launch. The baseline LandSat mission does not have requirement or budget for thermal infrared (IR) instruments, while ESD recognizes that there is utility for these measurements for monitoring irrigation and groundwater. However ESD has done nothing to preclude their development and is spending real money in response to the community interest, including an investment in multispectral resolution. This effort can be maintained until May. If additional budget is not forthcoming, however, that option will be turned off.

Global Precipitation Measurement (GPM) is a multispacecraft microradiometer JAXA/NASA mission which will be able to characterize and calibrate other instruments, enabling synthesis of other measurements. It is scheduled for 2013/14. ESD has also started Decadal Survey (DS) missions Soil Moisture Active and Passive (SMAP) (phase A was initiated in September 2008)

and IceSat II. Community workshops have been held for Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) and Climate Absolute Radiance and Refractivity Observatory (CLARREO).

Dr. Freilich reported that ESD is following the establishment and tiering of the Survey's 15 prioritized missions. Dr. Jacob commented in this context that there is no way to practically deliver these missions by 2019. There have also been a number of developments in NPOESS that may require a revisit of the Decadal Survey. Dr. Freilich noted that a mid-term review of the Survey has been requested by Congress, however, he felt that the division could not change priorities on a year-to-year basis; there must be some credibility to the priorities. He was loath to rapidly embark on a reevaluation despite the understanding that the science has changed in some ways, as this will ruin community consensus. In that light, ESD has chosen to head aggressively into the future despite the state of the budget. Dr. Jacob cautioned against slavish adherence to the DS, which may cause problem as ideas grow old and as missions that will start in 2020 begin to be considered. The mid-term review is critically needed. Dr. Freilich agreed, but questioned how the division might, in the interim, both manage the long-term program while using the DS only as a consensus builder and a community education prop.

A discussion ensued regarding the nature of the mid-term review, which was explicitly to avoid changing DS priorities. Dr. Freilich noted that the top tier of late-term missions, as currently envisioned by the DS, had a zero probability of launching before 2020. Based on concept studies, ESD would need about \$13B to launch these missions, signifying a need to triple the budget in the peak year. The community is aware of these probabilities. However, ESD is already making early technology investments to embrace the idea that this is an ensemble program. A committee member commented that this approach seems incompatible, and asked whether mission costs could be lowered. Dr. Freilich noted that ESD is not embarking on studies of different mission architectures; the aim is to get the missions started. The DS already did the studies. He also felt that positive change is underway with the new administration. That said, Dr. Freilich invited the committee to be vocal about specific disagreement with this approach. Dr. Jacob agreed with the overall strategy as laid out by Dr. Freilich, but urged that the communities supporting the Tier 2 and Tier 3 missions be informed of budget realities so they could redirect themselves. Dr. Jacob also pointed out that ESS has recommended that second and third tier missions should not be excluded from Venture-class missions. Dr. Freilich noted that every effort is being made to prepare for this, but that there is at present no budget.

Dr. Freilich reported on the CY08 ESD Airborne Missions, which posted a 60% increase in flight hours over 2007 through a multi-agency and multi-mission effort. ESD purchased two Global Hawks that will play a role in suborbital Venture-class missions. The division remains dedicated to flying a suite of missions, using the R&A program to synthesize data. The budget has included an increase of \$570M over several years' time, specifically aimed at DS missions. ESD expects a supplemental after the Continuing Resolution as well as a regular 2010 budget, and is positioning itself internally. Dr. Jacob noted that past presentations have had much

enthusiasm for Venture class mission. Dr. Freilich averred that enthusiasm remains, but that Congress must act to provide a mechanism. A discussion ensued about driving down mission costs, after which Dr. Freilich directed the committee's attention to a presentation on mission cost drivers, to be given the next day. He added that climate change would be a major factor in the characterization of the ESD budget. Some committee members felt that scientific expertise in understanding global change has been oversold and urged caution in relying on this factor, focusing instead on the need to acquire more information on climate parameters.

#### *NPOESS Update*

Requirements for NPOESS have changed, wherein DOD would like to drop back to 1980-type requirements for their short-term needs. An Integrated Operations Requirements Document is in place to help uphold mission standards. NASA has tried to make NPP as good a mission as possible by putting on instruments for continuity. However, OMPS-Limb, Aerosol Polarimetry Sensor (APS) and the altimeter remain demanifested from NPOESS. The mission is in the middle of a vigorous tri-agency discussion. Visible Infrared Scanner (VIRS) instrument delays are pacing the entire mission. NASA has taken the position that NPP is a critical NASA research mission. NOAA and NASA have been collaborating well. January 2013 is the nominal launch date, but Dr. Freilich regarded this date as unlikely. NPP will be playing a critical role if N-prime ends up having any substantial difficulties.

#### Research and Analysis Program Update

Dr. Jack Kaye presented a status report on the R&A program, and the scope of the ROSES call, which covers the entire program: R&A, Applied Sciences, Technology Program and E/PO. Programs vary from year to year. Annual calls are put out for some focused subjects, or periodic calls for areas such as mission science teams. The ROSES release is usually held in mid-February, thereby providing guidance to community early in the year, and also providing a way to tailor solicitations each year. ROSES generates over 1000 proposals per year, not including student fellowships. NASA has made a specific push to accelerate selection times, and means and medians have been decreasing accordingly. Success rates of proposals can vary enormously. NASA has made limited use of two-step approach to reduce the number of full proposals. In response to a question as to how time was reduced so significantly (mean of 290 to 129 days), Dr Kaye responded that the time is an easily quantifiable metric that can be added to staff performance plans. There has been no discernible change in the mix of large vs. small proposals. The community is provided information on the available budget, and not everyone proposes to the largest number. However, the program has been seeing proposals from universities that have not proposed before.

New program elements in 2007 were geodetic imaging, airborne instrument technology transition, accelerating operational use of research data, and space archaeology (primarily at centers). In 2008, ROSES included its first focused call on biodiversity, remote sensing of water

quality, an ocean salinity science team, science definition teams for SMAP and ICESat II, Earth Science for decision-making, and Applied Science Feasibility Studies.

Within Airborne Science, several missions were carried out, including Antarctic Peninsula flights, with a total of 1667 hours in many smaller missions. Plans for FY10 include a major hurricane campaign using Global Hawk aircraft, and an atmospheric physics/chemistry campaign for FY11. NASA also carried out some ship-based work with NOAA (Southern Ocean GasEx). The Airborne Instrument Technology Transition solicited in 2007 is expected to lead to significant new capability. NASA contributed to interagency activities, such as the Committees on Solar and Space Physics (CSSP) Synthesis and Assessment reports, the Ocean Research Priorities Plan and Implementation Strategy, and many others. Several changes in staffing are expected over the coming year, including the departure of IPAs. Education and Public Outreach activities include a five-year review of the international program, **Global Learning and Observations to Benefit the Environment (GLOBE)**. The University of North Dakota will be holding an airborne science summer school with a DC-8 in California, and significant IPY and Climate Change Education programs were included in the FY08 Appropriation Bill. Asked about data storage plans, Dr. Freilich reported that NASA is exploring different venues for long-term data archiving, such as the National Archives, but continues to support data analysis and storage in the meantime.

Dr. Jacob commented that research in ESD was once Balkanized and asked whether this situation had been resolved. Dr. Kaye responded that while most research is competed, but there are center offices that perform some minor operations activities. Overall, the processes are the same. Dr. Jacob noted that ESS had made a recommendation that small fundamental science investigations should be funded. Dr. Kaye reported that ESD has responded to this recommendation in the FY09 call, using a thoughtful filter for the separation of fundamental science and high-risk, high-yield proposals. The selection rate for the New Investigator program is 1 in 4 or 5. Dr. Jacob felt this was low. Dr. Kaye felt that decreasing the cap would limit the work that could be accomplished under it. Dr. Jacob noted that \$125K per year is substantial for a young investigator, therefore it might be worthwhile to bring the selection rate to 30%. Asked about a trend toward 4-year proposals, Dr. Kaye replied that ROSES is trending toward 3-year, although some will stay at 4 (atmospheric studies, in particular). ESD now has the flexibility to pick the right period. There is seldom a period of no opportunity. Student fellowships have remained pretty stable, at about 50/year. In addition, program managers and scientists can provide more money at their discretion. ESS felt that student fellowships should be protected.

Dr. Jacob slated for later discussion the ROSES two-step process, and the impact and visibility of E/PO.

## Flight Program Update

Dr. Stephen Volz provided an overview of flight program activities, focusing on the responsibility for flight hardware, and the many missions moving forward in 2009, including ICESat II, GLORY, GPM, SMAP, OCO, and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO).

Operating missions Aura, CALIPSO, CloudSat, Aqua, Solar Radiation and Climate Experiment (SORCE), EO-1, Tropical Rainfall Measuring Mission (TRMM), Terra, ICESat, Jason-1, QuikSCAT, Gravity Recovery and Climate Experiment (GRACE), and Acrimsat will undergo a Senior Review in April 2009; Landsat and Ocean Surface Topography from Space Mission (OSTM/Jason-2) will not be reviewed. While science return and appropriate resources, plus the state of instrumentation, will determine the fate of missions, the default decision is to continue. Currently, most missions are green, except ICESat I, which has lost its third laser; the satellite has one more ice-mapping campaign in its lifetime. QuickScat and CALIPSO have had some issues, but are still green. In the history of Senior Reviews, Dr. Volz noted that missions terminated in 2006 had had replacement missions in the queue; and no terminations were made in 2007. ICESat I, however, will be terminated because of its laser failure. The Senior Review also will consider the likelihood of continued reliability for an extended period, for a given mission. Final mission budgets will be determined in September 2009.

Missions in formulation and development include OCO, GLORY, Aquarius, NPP, GPM, and LDCM. Added to this is SMAP (in phase A) and ICESat-II (which will be in formulation and development by the end of the year). The Cross-Track Infrared Sounder (CrIS) instrument is expected to deliver by February 2009, for NPP. VIRS has not gone through environmental testing yet. There are also programmatic and performance issues for NPP that must be addressed. GPM had a successful year, and completed a preliminary design review (PDR) in November 2008, and has a mission confirmation review scheduled for Spring 2009. GLORY is suffering from APS's program execution problems, although the instrument is working well so far; the mission is scheduled for a fourth-quarter 2009 launch. LDCM has completed the transition to phase B, has completed CDR on instruments and is on track for a December 2012 launch. ESD is continuing development of the TIRS instrument concept, so is still pushing for thermal channels. OCO is ready to fly in February 2009 and is simply lacking a launch vehicle. Aquarius is going through instrument level testing. SMAP went into phase A in September 08; launch vehicle access and partnership determination are the biggest issues. Launch vehicles continue to hamper the entire program- there are no Delta vehicles and no replacement is in sight. This is a national issue as well.

Programmatic implementation activities within SMD include the Earth Science Pathfinder Program (competitive) and Earth Systematic Missions (ESM) (directed, strategic). All named DS missions are housed in the ESM Program. ESD is in the process of revitalizing both offices with new program managers and staff, new Program Plans, etc. Both Program Offices will undergo a

thorough Program Implementation Review. ESD has also hired two Program Executives, while struggling to meet current obligations and DS development missions, and relying on Program Offices and other contractors on a case-by-case basis.

A brief discussion ensued on launch vehicle availability. Dr. Volz noted that it will be a particular problem in 2012-14; 2015 and beyond is not an issue. There are variable solutions ((Minotaur IV, e.g.). The only real problem for ESD is SMAP in 2013. The Atlas V may be a solution for some missions if a payload co-manifest can be accomplished.

#### Discussion with the Science Mission Directorate Associate Administrator

Science Mission Directorate Associate Administrator, Dr. Ed Weiler, conducted an informal discussion with ESS. Dr. Jacob raised the NPOESS problem and the commitment to long-term monitoring for Earth Science. Dr. Weiler had no easy answers as NASA has no control over NPOESS; it is an Air Force/NOAA effort primarily, and NASA only sits on an advisory group. NPP has provided lessons on NPOESS; there were too many variables, and the absence a good management structure. NASA has sent the message that NPOESS is not going to work and invited the community to provide support for a larger solution.

Addressing the escalating cost of ES missions as recommended by the Decadal Survey (DS), Dr. Weiler pointed out that the single biggest issue is access to space for mid-sized missions (i.e. those that fly on the old Delta II class). In addition, missions as costed by the DS were highly unrealistic and undercosted by at least a factor of two. Missions cost more in part because the price of an engineer has gone up. Costs do not decrease with experience because scientists want more, bigger, and newer capabilities. Where does one curtail that ambition in favor of making progress? Dr. Weiler reiterated the science sweet spot concept, describing a moderate cost cap wherein 95% of the science can be obtained, and asked for the community's help in determining this spot. Dr. Freilich suggested considering the synergy amongst missions and who perceives a stake in a low-cost or restrained-capability mission. Dr. Hoff cited the risk-averse nature of NASA and suggested that to cut costs, one must take higher risks. Dr. Weiler felt that Venture-class missions could achieve some DS science, but warned that even cheap failures require testimony on the Hill, but added his personal view was that a very plausible scenario for three budget changes exists, and ES is in the best position of all SMD.

Dr. Jacob expressed his frustration with limited data sharing within international partnerships. Dr. Weiler pledged to do what he could, and agreed that this is now the time for ESA-NASA missions. On the data side, he felt that ESA, at least in space science, had not been a major problem, noting however that while ESA has not developed the advanced algorithms and data sets, they do have the sensors. Dr. Freilich felt that ESA has restrictive data policies that have been difficult to change at the policy level, but that there is now indeed a commitment to change behavior at a lower management level, and reported improved efforts at getting data released. Dr.

Minster urged NASA to share its unique technology and know-how in data analysis and management.

Asked how NASA could increase collaboration with international partners for missions, Dr. Weiler felt that the best collaborations tend to bubble up from the community, not from the top down. Venture-class missions will hopefully provide opportunities for more international partnerships. ES seems to have been assigned a preponderance of strategic missions, which can be shared with international partners. Dr. Freilich observed that both NASA and ESA responded to the DS with very similar scopes, and that international collaboration leads to decreased cost on either side, however it doesn't make them happen faster, and the missions must be managed to schedule. The capabilities on either side must be equivalent, and sampling issues are also a concern. Dr. Weiler welcomed ideas and expressed his desire to facilitate matters where possible.

### Applied Sciences Update

Dr. Teresa Fryberger described the Applied Sciences Program (ASP) as a leveraging tool for the applications of ES, such as in crop monitoring and firefighting. APS acts as a bridge from ESD to the decision makers in forecasting, response and recovery, resource management, and policy, in eight ES focus areas. The ASP budget has been at \$33M for several years, and has recently moved to competitively selected projects through ROSES. ASP is working in 31 states, and maintains partnerships with many government agencies and international regional groups. ASP has participated in public health efforts, in one instance using satellite imagery to support pandemic prediction in partnership with the US Centers for Disease Control (CDC). ASP has also worked with the Atlanta-based HELIX system group on measuring particulate concentrations in the air, and correlating these measurements to office visit data for asthma treatment. Knowledge of particulate concentration has been found to lead to better patient management in response to changing environmental conditions. Some HELIX results have been validated, and CDC would like to expand the program.

Future directions for ASP will include a focus on the impact of climate change on humans; and applications of ES generally to secure benefits for mankind. The National Research Council (NRC) 2007 Assessment of Applied Sciences has also endorsed the notion that ASP participate in new mission design. The program is now seeking to have two-way communication, giving feedback to the ES community and strengthening the connection to the ESD and the R&A program. ASP has established an Applied Science Analysis Group (ASAG), which will constitute an advisory committee, per the NASA 2005 Authorization Act. The ASAG will report up to ESS. ESS member Raymond Hoff is Chair of the ASAG. A kickoff meeting was held on January 5-6<sup>th</sup>, and the ASAG will report formally to ESS by Summer 2009. Dr. Fryberger observed that there is a great hunger in the end-user community-at-large for what remote sensing can provide, and that NASA should manage expectations in this area.

Committee members discussed implications of intellectual property (IP) ownership and creating mechanisms to determine the value of leveraged program efforts. Dr. Hoff noted that IP rights reside with the public if the government pays for the research behind the IP. Dr. Minster that IP issues could be a handicap to working with the private sector. Asked how AS input to the science community might be envisioned, Dr. Fryberger replied that ASP must work closely with the division to ensure that the end-user is being heard adequately. She did not fear an inundation of requirements on either side. Dr. Simons suggested that repeat time can be one area in which applied sciences can play a role in determining societal relevance. Asked to explain the origins of ASP's 8 focus areas, Dr. Fryberger responded that they were based on needs and where ES has a capability, and also along the lines of DS findings on applied sciences. Dr. Vorosmarty suggested the ASAG craft a mission statement in order to focus priorities. Dr. Jacob asked for successful examples in the utility of science data to operations? Dr. Fryberger cited SURVEAR, a Central American geospatial information effort, in which USAID has been footing most of the bill. Dr. Jacob applauded ASP's efforts in underscoring the consequences of climate change. Asked to assess the difficulty in finding other agencies to use this data, Dr. Fryberger thought it would be difficult to compete. One issue is in shoring up decision support for sustained land use. However, the climate change community is chaotic at the moment. Disaster response and agriculture are the oldest and most well established efforts, as well as fire fighting. Air quality and public health projects have been awarded at about \$3M a year.

### Modeling and Assimilation Program

Dr. Don Anderson provided a status of the ES Modeling and Assimilation Program (MAP). Michele Reinecker partnered in the presentation. The Modeling Analysis and Prediction Program spans many activities in modeling land, ocean, and atmospheric phenomena, with some components of geodesy. Elements include next-generation activities such as sea-ice and land ice sheet models, and the Observational System Simulation Experiment (OSSE) for model input to planning Decadal Survey missions, including identifying measurement requirements, and the Integrated Earth System Analysis activity, for consistent analyses of Earth system components for weather/climate prediction. In terms of budget coverage, in-house vs. competitive grants run about 60-40 in favor of NASA.

Focusing on actual computational requirements for answering science questions, modeling requires a systems engineering approach on some levels. MAPP has made a heavy investment in designing common interfaces for purposes of element interaction, and in shared software for a flexible system. DOD has borrowed the infrastructure and has adopted ESMF (Earth System Modeling Framework) compliance standards. MAPP has responded to a community call for a common framework, committed to the software infrastructure, however the framework is designed so that it can evolve to accommodate new structures and new ideas. NASA is not being prescriptive- the community has been working together to evolve the infrastructure, and NASA is now just one of the participants. Dr. Jacob felt that contrary to some assertions, that ESMF is

neither user-friendly nor mature. ESMF is also a moving target. Dr. Anderson conceded the point, but reiterated the evolutionary nature of the ESMF.

Dr. Reinecker, chair of the National Center for Atmospheric Research (NCAR) Advisory Board, continued the presentation and detailed components of the system across the Goddard Earth-Observing System (GEOS) framework. GEOS-5 is an atmospheric model with a data assimilation component that has the capability of modeling historical data. Modeling earth systems requires different resolutions and timescales, and the goal is to move toward a seamless model framework. As one moves to higher resolutions, one increases realism in terms of variability. The intensity of carbon emissions can be determined much better at higher resolution, for example, as well as the characterization of chemistry transport features. In preparation for an assessment of the Intergovernmental Panel on Climate Change (IPCC/AR5), MAPP is starting to look at decadal predictability in regional impacts. The main challenge is the distribution of data to the community. Each model is committed to over 6000 years of runs.

Goddard Institute for Space Studies (GISS) modeling plans for AR5 include improved models for clouds, sea ice, new dynamical core options, fully active aerosol and chemistry data, indirect effects, and the carbon cycle. Dr. Minster asked about the coupling of hyperbolic and elliptical data. Dr. Reinecker replied that this is understood, and efforts are just starting to address the land-ice model. The timeline for AR5 was briefly reviewed- the system will be finalized in 2009, and will have runs finished by the end of 2010. Dr. Reinecker showed an example of model behavior in the demonstration of dynamic feedback in the Antarctic ozone hole. Coupling ozone to climate model shows a summertime ozone increase; however the decoupled model does not show an increase. Thus the coupled model agrees with historical data.

Another example was a GEOS-5 on-line atmospheric chemistry model, dubbed AEROCHM, which can test for simulations of the combined troposphere and atmospheric chemistry, yielding realistic distributions and concentrations. Most runs have specified emissions, such as isoprene, which is still a challenging parameter. Dr. Reinecker provided details of the Modern Era Retrospective Analysis for Research and Applications (MERRA), the focus of which is the hydrological cycle. The analysis is 50% complete, with processing expected to be complete to the year 2007 by August 2009. The effort represents the Global Modeling and Assimilation Office's (GMAO) reanalysis using GEOS-5. In response to a concern about noisy data, Dr. Reinecker agreed that the analysis is based on derived data. MERRA does yield ancillary products, and will be distributed on-line, open to the community. Aside from supporting instrument teams and field campaigns, MAPP is also undertaking the observation of system data, for observation impact assessments, and contributing to 24-hour forecast error reduction.

Future directions for MAPP include continuing collaboration with National Centers for Environmental Prediction Environmental Modeling Center (NCEP/EMC), with a complementary development focus and common architecture. The program is also working on land data assimilation at the NASA GMAO, preparing for the SNAP mission, and ocean data assimilation

for altimetry and surface chlorophyll, for input into seasonal forecast systems. In terms of subseasonal variability- the ocean provides an important memory to the system.

MERRA and GEOS-5 tools will provide a capability to initiate an IESA (Integrated Earth System Analysis). MAP is starting to interface with missions, to try to bring models to bear on DS planning. Most DS missions are not focused on numerical weather prediction (NWP), so models must be developed in part by using adjoint tools to calibrate synthetic observations for OSSE. For non-NWP models, MAPP is developing infrastructure by using ACE Multi-Beam Lidar (MBL) as a test case. MBL provides 3-day global coverage and is more likely to capture important aerosol transport events. Early model tests show some encouraging results.

In the push toward seamless models, MAPP is trying use satellite data better in data assimilation systems by considering impact from other components in the earth system). However much data is omitted due to cloud and rain effects, therefore modeling efforts will need continued interaction and collaboration in the community. MAPP is also supporting national efforts in dynamical cores and the Cubed-Sphere concept, introducing it to graduate students.

Emerging collaborations in the MAP program will be bringing models and satellite observations together, which can contribute eventually to an assimilated product for Earth's energy budget analyses. The GEOS System Roadmap, leading ultimately to GEOS-6 2011, includes non-hydrostatic capable models, physics for hi-resolution measurements, chemical assimilation, 4D-Var weak constraint parameters, weather-climate coupling, and chem-climate interactions. Teamwork will be necessary for convergence of software suites, to distribute it to the university community, and to have a controlled development environment. Improving the realism of models will require data-driven models, increased complexity and increased resolution, and continued interagency partnerships.

### *Discussion*

Dr. Minster commented that in earthquake modeling, it is difficult to assess epistemic (bias) uncertainties. Dr. Reinecker replied that atmospheric simulation has a capability for bias corrections, but it can inflict also bias inappropriately, therefore an independent evaluation is needed to assess and compare biases. Dr. Anderson addressed the balance of resources between NASA and the community, noting that while resources have not increased over the last 5 years, there has been a drive for collaboration between communities and centers. In response to a concern, Dr. Anderson stated that NASA strategically views the MERRA analysis as ongoing, with a continual national effort in reanalysis. Historical analysis will be built into the process. There is no equally large competing activity of this sort in the US. There is discussion of a new agency to develop this model, but Dr. Anderson felt that such an agency would not necessary, and that NASA should take advantage of the opportunity to lead the effort. Internationally, there is an equivalent style of frameworks, and they have all signed up to the ICD. Dr. Anderson added

that MAP is providing the opportunity, at \$25-50K per year, for graduate students to analyze the runs; the return to GISS for this funding activity has been enormous.

Dr. Jacob commented on MAP's ambitious agenda for future development and asked how its priorities are set. Dr. Anderson explained that they are set by interaction with community and by the requirements placed on MAP. The process forward will be guided by a MAP advisory board, with oversight and guidance, feedback to Headquarters and Goddard, and a science team function. Dr. Reinecker added that GMAO has a strategic management team, to which Dr. Jacob suggested that outside members should be included. Dr. Matrai recommended more user friendly options for non-modeler and reported finding the MAP website too complex. She felt an advisory committee could be a conduit to user input. Dr. Anderson replied that the model elements are not quite as Balkanized as NCAR's, and recommended that users approach leaders in the modeling community to obtain answers. He conceded however that there is no process in the website, as yet, to allow the conversation to be started. Dr. Anderson added that MAP was viewed as basic research with a focus. Dr. Reinecker felt that MAP should build a relationship with CCSM, but not replace it. In response to a question as to where the Joint Center for Satellite Data Assimilation (JSCDA) fits in the MAP process, Dr. Reinecker replied that it is not specifically part of the program, but NCEP physics is wrapped in one of MAP's models.

#### Public comment period

There were no comments in this period.

#### Discussion

ESS discussed how to balance research with science and technology development within ESD. Dr. Freilich did not see the two areas in conflict; regardless of funding sources, he felt AITT is the right approach for leveraging investment in technology. Dr. Hoff indicated that his experience has shown students dominated by analysis of instruments, and could not see where new instruments are emerging. Dr. Freilich asked ESS to state specific deficiencies in technology development. There was some concern in the committee about lack of competition, or that most awards are won by centers, despite the observation that center PIs also include the efforts of external center co-investigators. Dr. Matrai noted that many sensors for polar regions are simple sensors for temperate regions that fail in cold conditions. As a result, research teams tend to make them from scratch, costing more than necessary. What can ESS do to encourage this sort of work? Dr. Freilich asked ESS, assuming that no new money comes in, how it would advise on re-allocation of funds. Dr. Sarabandi noted that generating the (educational) pipeline is also important and of great concern. A participant recommended consulting one-pagers in the ESTO site ([esto.nasa.gov](http://esto.nasa.gov)), searching on relevant keywords, to result in a list of the PI and the collaborators for a given project. ESTO is looking at 28 different measurements, based on DS planning, and it also applies to aircraft and rocket opportunities. Dr. Kaye recommended using the student fellowship program for the same purpose. There is also money in the SBIR/STTR

program. Dr. Minster observed that NASA is in a good position to include as part of its extramural program, specific collaborations between scientists and engineers. Dr. Kaye regarded the AITT as a means of bridging the gap for instruments needed in field campaigns, and leveraging prior investments. Dr. Freilich offered to redirect portions of funding if overlaps between current programs are significant. Dr. Vorosmarty cited a revolution in small sensors that are low-cost and mass-produced, and recommended consulting a recent NRC report on multiscale sensors for hydrology. Dr. Matrai suggested that programs which support absolutely new instruments must have a scientist, engineer and modeler as part of the package. Other members recommended consideration of microsatellites and swarms of many small, more modest sensors. Dr. Freilich noted that DOD has some microsatellite plans, but with requirements that do not meet NASA needs. The new Venture Class program was also seen as a means of supporting technology development, as long as it could be kept from morphing into a strategic program.

January 8, 2009

Dr. Jacob opened the session and reviewed the agenda.

#### Decadal Survey Supplementation

Dr. Volz presented an update on the science and programmatic objectives of the Decadal Survey and how NASA is meeting its goals. Scientifically, the approach is integration of missions into the overall program and bringing in the community. Programmatically, the DS is attempting to anticipate change by focusing on a flexible, unified program that is not overly constrained. As integration progresses, supporting information for Tier 1 and 2 missions will be developed, to support a reasonable decision at the end of FY09. NASA has a flight project life cycle to adhere to, accompanied by a number of milestones, concept reviews, cost and schedule estimations, and this cycle requires a fair amount of detail at each step. Each step becomes more rigorous as the mission progresses. For all missions there is discussion of potential international partners at pre-phase A, in order to avoid duplication and to uncover cost benefits.

SMAP has finished requirements for pre-phase A, and ICESat II is progressing in pre-phase A. The DS mission development approach includes identification of Primary and backup Program Scientists, Program Executive, Data Systems staff, etc. For near-term Tier 1 missions, considerations will be made pending results of 2007 workshops, established science study and definition teams, and a Mission Concept Review by the end of FY09. Tier 2 missions are a step behind due to lack of upfront funding. Currently, NASA is conducting science workshops, has established ad hoc science study teams, mostly volunteer, to determine Tier 2 mission readiness to proceed to phase A. Late-term Tier 3 missions will be dependent on technology readiness and development and will utilize ESTO for calls for information. All named DS missions are strategic and directed. Elements of the mission will be competed, however; hardware will be built both in-house and with contractors in the industry. Possible competed

elements include SDTs, instruments, and spacecraft. All 15 named missions are directed, but the instruments may not be. The mission development teams will be tasked with identifying science traceability.

Mission requirements for completing phase A are: defining a mission concept, initiating technology development, and creating a notional instrument payload. Dr. Jacob suggested that as Tier 3 missions are not technology limited, it would be advisable to start creating a community of scientists to start thinking about these to prepare for the next DS, perhaps through the vehicle of a community workshop. Dr. Volz felt this to be a reasonable approach, but averred that ESD is in fact preparing for Tier 3 missions by already informally engaging in science definition, instrument readiness and technology activities. Dr. Freilich added that the community is responding through the R&A program, where appropriate, and also felt that a workshop would help to keep focus and tie scientific work to future opportunities.

Once pre-phase A is identified, science definition team is formally competed through ROSES. This is early planning work. At present, \$1.5M is budgeted for CLARREO and DESDynI, and \$400K for other Tier 2 missions in FY08. Dr. Volz noted that in the past, ESS had recommended that this type of research funding be competed. NASA welcomes community participation in the definition studies. Most meetings are open, and proceedings are made available on the mission websites. Very few meetings are closed, and meeting announcements are circulated widely on research lists. The Program Scientist is the primary POC for questions related to science, and the Program Executive for all mission implementation issues. Management and budget allocations are prioritized toward doing Tier 1 missions, first, while funding Tier 2 at lower but significant level, with equal funding for each of the five missions. FY10 funding will strongly influence priorities. Dr. Volz reiterated that the cost of all 15 missions is \$13B, exclusive of Venture Class and current operating missions, and that the Decadal Survey had underestimated the cost by roughly half.

In FY09, \$5M each has been allocated for CLARREO and DESDyNI, and \$2M each for the other 5 Tier 2 missions. The Venture Class mission line is looking for innovative ideas with potentially risky technology, new research avenues, and may include stand-alone orbital missions, MoOs, or complex instruments flown on a suborbital platform and can involve partnerships. A discussion ensued about availability to participants outside the Agency and the perceived NASA desire to keep instruments/payloads in-house; to some it appeared that the only opportunity for outsiders was in the Venture Class line, for which there is no current funding. Dr. Jacob observed that space missions seemed to reach out more to private industry? Dr. McCormick noted that planetary missions tended to use more university work. Dr. Volz cited technology readiness level (TRL) as a critical factor, but conceded the existence of an inherent bias to awarding known entities. He also called for an open process for identifying TRL readiness, and supported a broadening of the TRL panel so that it is transparent and defensible. Dr. Freilich noted that while the acquisition strategy meeting is chaired by the Administrator, the ESS should

make further recommendations in this vein to aid ESD in its efforts to be equitable. In the meantime, ESD is trying to prepare for Venture Class funding.

Of 14 missions, 9 are funded at \$125M for FY08 and FY09, a significant portion of which is competed. The Program Office is currently supporting cross-cutting mission and science studies, considering instruments for common approaches (LIDAR, e.g.), launch vehicle access, data standards and guidelines, and EOS ground system requirements. By October 1, 2009, SMAP will be in Phase B, ICESat II in phase A, and CLARREO and/or DESDynI will be ready to go into phase A. The science requirements are coupled, but the latter two are separate missions. Cross-cutting analysis will continue, and the Venture Class implementation approach will be completed. Dr. Volz felt the launch vehicle issues will be solved in part by flights on EELVs or co-manifested missions. Compatibility of orbit requirements is being studied; Delta IV has a re-vectoring capability to address this. (Some doubts were expressed regarding the placement of two spacecraft on one launch vehicle.) ESD is stressing that missions must be implementable, with independent cost estimates. At the end of phase A, must have an integrated baseline review that bring together all the reality checks, including de-scope plans. Uncertainties around some of the later launch dates are largely driven by current uncertainties in instrument development, etc., not budget or management.

### SAGE II Measurements

Dr. McCormick recused himself from this discussion and left the meeting room for its duration. Dr. James Hansen gave a brief overview of the lack of instruments on SAGE II that would allow quantification of stratospheric aerosol contents. Dr. Hansen argued that one cannot derive optical depth from the backscatter data provided by CALIPSO. There was some disagreement with this assertion, given the ability to derive extinction measurements from CALIPSO. Dr. Hansen cited SAGE III as an instrument on the shelf that can give very precise measurements of extinction at different wavelengths. Dr. Hansen averred that no one can determine how aerosols influence climate forcing, and presented some SAGE II measurements of optical depth at 1-micron, post-eruption of Mt. Pinatubo. He argued that CALIPSO would be unable to see the stratosphere as sensitively. Some contended that validation could be provided by MISER. A participant commented that during a recent Alaskan volcano eruption, one was able to see the ash cloud with CALIPSO a few days after eruption, but not the accompanying SO<sub>2</sub> cloud at a higher altitude; shorter wavelengths are needed to see the smaller particles.

Dr. Hansen contended that as the sun and stratospheric aerosols are major climate drivers, decadal records with precise and appropriate measurements will be needed to properly interpret decadal climate change. He recommended endorsing the Chemical and Aerosol Sounding Satellite (CASS), which would include the flight-ready SAGE III instrument, as a means to fulfill the Congressional mandate to monitor the stratospheric ozone layer. CASS would also provide upper tropospheric composition data in the post-Aura period, filling the gap before

GACM flies. There are no plans beyond 2015 for profile measurements, which is a concern. Dr. Jacob noted that the Europeans are not planning such measurements.

ESS discussed the ramifications of CASS, and assessed it against GLORY/APS fit in, which some felt was too crude by comparison, as well as occupying an inappropriate orbit. SAGE III also gives a good profile of the ozone change with very fine altitude resolution. Ozone is also climate forcing, correlated with solar changes, and is not as quantified as it could be. Some argued for the use of OMPS-Limb on NPP, which is designed to measure ozone profiles and aerosol extinction continuously. Dr. Hansen argued that OMPS-Limb is not measuring extinction but brightness, and not at sufficiently precise optical depth for aerosols. Dr. Freilich took note of the gap summary as presented, and contended that the ACE part of CASS will provide gas measurements, and could serve as the bridge between GACM and Aura. The Canadians are eager to launch ACE, and preliminary cost estimates have been done (\$120-200M). Dr. Jacob noted that this could be regarded as a strategic mission, as NASA is charged with monitoring the ozone layer, and therefore may call for a specific action.

ESS discussed the abilities of SAGE III, and contended that climate change was a weaker argument than stratospheric ozone issue, which by contrast is unassailable, and considered a recommendation that resources be found to fly CASS in partnership with Canada. Dr. Freilich asked where these resources would be found, or what should be given up or delayed in order to provide them. ACE was dismissed as providing insufficient optical depth, and a nadir-looking system. Dr. Volz was tasked to determine the steps necessary to support CASS. Dr. Kaye felt that NOAA has been firm about retaining climate measurements in NPP, and was prepared to invest in some elements of the stratosphere. In this context, a participant commented that the limb instrument for NPOESS has a third tier priority (lowest), and expressed concern about the disconnect between operational expectations and reality.

#### Comparison of Earth and Space Science Missions

Dr. Margaret Luce presented preliminary results of a study that was initiated in response to a NAC Science Committee recommendation to analyze cost drivers for ES. The study was undertaken to address the perception that ES instruments are intrinsically more expensive than comparable instruments in other division. Although the study is not finished, a large database has been assembled that will continue to be useful.

Characteristics of instruments were of particular interest in this study, with an eye to development of a specific metric. Cost analysts from Aerospace Corporation and SAIC examined costs from the WBS level up. The study is also collecting cadre data on technical costs and schedule at milestones. Much of this data was collected *ex post facto*, thus caution is suggested in interpretation. The database contains >130 instruments with 40 data fields, and 30 missions with 100 data fields, including acquisition mode (competed or in-house, university, industry). The study examined the science rationale and how science requirements drive the level

of difficulty. Missions under consideration have both complete and incomplete life cycles, and were launched within the past decade. Eight ES, 8 Solar, 5 AP and 9 Planetary missions were analyzed. The study team held a midterm review in October 2008, at which time it issued some recommendations, added other missions and instruments, and completed data collection. A draft final report is due to the NAC Science Committee by February 2009.

The database addresses questions as to whether there is a systemic cost difference, depending on vendor source or instrument complexity, and phase BCD cost vs. mission complexity by division. Complexity ranges from small missions (20%) to the Flagship missions (highest), and ES was found not to be out of family with these. For Aqua and Terra, however, algorithm development costs may have accounted for an overstatement of cost. The large number of people that use the data may also drive this cost.

The impact of acquisition method was also considered, judging whether development cost of directed missions is greater than AO-acquired. ES missions by this measure are larger in scale, but for a given complexity they are in family with the other divisions. The algorithm costs for Aqua and Terra were given a similar treatment as in the previous category.

In considering Phase BCD cost vs. mission complexity by mission mode, the study found greater cost and complexity values associated with directed missions. There were correlations among instrument cost, schedule and performance metrics, with instruments grouped by spectrometer, imager, in situ, and lidar/radar categories, taking into account differences among imagers. Instruments were also assessed by contract type (industry, NASA, university, JPL/APL, and contributed). In this area, ES instruments tended to be at a higher level of difficulty.

In the category of instrument cost vs. level of difficulty, ES instruments (cost/kg one of the lowest), tended to have the highest levels of difficulty and complexity, and were therefore more expensive, as well as heavy. Dr. Freilich commented that higher mass may be due to either requirements or lack of restraint. In terms of instrument schedule vs. level of difficulty, it was found that even low-end instruments can take a long time to develop. ES stands out in this category.

There was also a strong correlation between mass and power, and mass and cost. Cost vs. mass for each division, for Astrophysics instruments, is not the best indicator. Astrophysics had the lowest cost/kg, but the average mass was much higher. The low-hanging fruit is off the tree for ES, by this measure.

Key findings are that Earth Science missions do not show a systemic difference in cost or cost growth compared to other divisions; missions from all 4 SMD divisions experience cost growth similarly. Mission cost and schedule growth correlate with payload cost and schedule growth. Instrument complement, not the spacecraft, is the typical driver of cost. Longer-lived missions (design life) were also included in the complexity measure. Dr. Minster commented that in his experience proposing radar missions, the worst criticism each time was that they were too cheap

(\$200-400M); and complexity was low. Dr. Luce shared his frustration, but noted that there is a big emphasis on not overrunning; with NASA probably more conservative than it needs to be.

Dr. McCormick noted the impact on mission cost of such anomalies as launch vehicle staff strikes, etc. ESS considered calling for another study to separate real from anecdotal effects, or a synthesis of the success or failure stories. Dr. Luce reported discussions with the instrument developers and project managers on determining whether this is a desirable thing to do in the future.

Considering the mass/power relationship as most persuasive, the committee pondered whether this might argue for a swarm of instruments/satellites with lower mass, fully utilize a launch vehicle's capacity with a tailored payload. Dr. Freilich noted that small also tends to mean a short lifetime. Dr. Luce expressed a bias toward Aura, which was extremely cost effective, and essentially a big dumb bus with power stability and long lifetime; however different missions will require different things. Systems engineers will be needed to evaluate them. Dr. Hoff noted that small size breeds opportunities for the outside community to bid on missions, and may help improve access. However, acquisition seems to be irrelevant to the costs. ES is dominated by the architecture adopted by EOS 15 years ago.

### Wrap-up

Dr. Minster recommended a finding on DACS regarding the issue of very long-term data curation; the use of the National Archives seems unsuitable. Dr. Freilich agreed the concern is valid, but contended that there is no evidence that NASA plans to discard or diminish its data holdings. As is, the NASA system can handle a lot more data and bandwidth, and those efforts will continue in EOS/DIS (at \$150M per year). Dr. Minster commented that GEOS is going to need help. Dr. Hoff added that NOAA is not retaining a lot of data, thus data archiving is not just a NASA problem. Dr. Jacob tasked himself with a draft letter, to be circulated and finalized. The next meeting was scheduled for April 14-16, tentatively. Dr. Jacob adjourned the meeting at roughly noon.