NASA Earth Science

Earth Science Advisory Committee

March 10-11, 2020
Washington, DC

MEETING MINUTES

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J. Marshall Shepherd, Chair

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Lucia S. Tsaoussi, Executive Secretary

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Prepared by Elizabeth Sheley
Electrosoft

Wednesday, March 10, 2020

Call to Order, Opening Remarks

Dr. Lucia Tsaoussi, Executive Secretary, of NASA's Earth Science Advisory Committee (ESAC), opened the meeting. Members were participating both in person and by phone. Dr. Tsaoussi took roll, then explained that this was a Federal Advisory Committee Act (FACA) meeting. As such, only Committee members were allowed to speak, aside from a public comment session. The first presentation was the annual ethics briefing required of members. This was not part of the public meeting.

Meeting Charge

After the briefing, Dr. J. Marshall Shepherd, ESAC Chair, re-opened the meeting by stating that it would be good to get a sense of where NASA's Earth Science Division (ESD) is going, especially with the new Decadal Survey (DS). Dr. Thomas Herring, ESAC Vice Chair, agreed, and noted that ESAC would present to the NASA Advisory Council (NAC), which was to meet soon.

Earth Science Division Update

Ms. Sandra Cauffman, Acting Director for ESD, welcomed ESAC. Dr. Michael Freilich retired as ESD Director about a year ago. The announcement for the position went out in November and closed in February. NASA was still in the selection process, but should have a permanent director soon.

Moving into the future, data systems are growing in importance and funding, especially with some of the upcoming missions. Ms. Cauffman then provided an organizational chart for ESD and the NASA Science Mission Directorate (SMD). NASA renamed the Sentinel 6A spacecraft the "Sentinel 6 Michael Freilich." The Earth Science Technology Office (ESTO) supports a strong cubesat program; cubesats are capturing amazing data and the program is very productive.

Ms. Cauffman noted ESD's orbital missions and instruments. The Division increasingly thinks in terms of observing missions, not satellites. ESD works closely with partners, including international, internal, and commercial. There are nontraditional partnerships with Google, Microsoft, Conservation International (CI), and Mercy Corps.

The Fiscal Year 2021 (FY21) President's Budget Request (PBR) recommends cancellation of two Earth science missions, Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) and Climate Absolute Radiance and Refractivity Observatory PathFinder (CLARREO-PF). Congress has continued funding of these missions despite their having been cancelled in two previous PBRs. Orbiting Carbon Observatory-3 (OCO-3) went up. There are new Earth science instruments on the International Space Station (ISS). Landsat continues: the Agency hopes to launch Landsat-9 in 2021, and there are continuing studies for the next generation of Landsat, to launch in 2027. ESD will soon provide recommendations to the SMD Associate Administrator, Dr. Thomas Zurbuchen, and will proceed to the mission concept phase, Phase A, in the first quarter of FY21.

For NASA overall, FY21 is a strong year. Ms. Cauffman noted the Artemis campaign, along with lunar and Mars work. The FY21 PBR funds the first Earth science Designated Observables (DO) mission, as well. Ms. Cauffman showed SMD PBRs versus enacted budgets from 2013 to 2020. For ESD, the FY20 appropriation is $1.972 billion, which partly addresses the 2017 DS recommendations. However, there is no funding to begin the Earth Science Explorers. This recommended program cannot start until 2023 at the earliest due to the funding profile. The FY20 PBR also selected the Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR) instrument for the Earth Venture Instrument (EVI) program. Ms. Cauffman showed the PBR history for ESD from FY12-25.

Accomplishments for FY19-20 include continued implementation of the DS, which was received in January, 2018. NASA launched OCO-3 last year, as well as the Hyper-Angular Rainbow Polarimeter (HARP; Ms. Cauffman later said this was in commissioning) and Compact Infrared Radiometer in Space (CIRiS), which are In-Space Validation of Earth Science Technologies (InVEST) program cubesats. HARP was initially an airborne instrument. The Division confirmed the Geostationary Carbon Observatory (GeoCarb), PACE, and CLARREO-PF missions to enter Phase C/implementation. There were seven launches in the airborne campaign and Landsat 9 continues moving to its late 2021 launch date. Dr. Jack Kaye explained that GLIMR will focus on the western hemisphere.

Planned accomplishments for FY20-21 include selection of the first EV-Continuity (EVC) mission, focused on the radiation budget. Some suborbital campaigns have been postponed due to travel concerns about the coronavirus. The Sentinel-6 Michael Freilich, Landsat 9, and Tropospheric Emissions: Monitoring of Pollution (TEMPO) will launch this year. ESD will select the next Health and Air Quality Applied Sciences Team (HAQAST), and the first SERVIR Amazonia hub will begin operations.

The International Space Applications challenges for 2019-20 is a hackathon that pairs NASA data with problem-solvers. From the previous round, ESD found that some of the teams were quite young. There were over 29,000 registrations, and 37.5 percent of volunteer event leads were women. The next one will be in October, 2020; participants must register.

Dr. Kaye explained that ESD had been through a busy suborbital period, but also deferred three of the five EV suborbitals selected in the last year. He described the current projects, noting that travel issues have affected field work. Smaller things may need waivers to delay or continue.

Decadal Survey Implementation Strategy

Ms. Cauffman presented a high-level snapshot of NASA's response to the DS, which includes the entire ESD program of record and endorses the existing balances of the ESD portfolio. Unlike the 2007 DS, it is not specific in recommending missions, but rather prioritizes observations and thus allows implementation flexibility. There is also an emphasis on competition and international partnerships. Another recommendation is to have a "continuity measurement" strand as part of the Earth Venture (EV) program. The DS identified five DO areas for mandatory acquisition, and introduced a new, competed Explorer line within a set of DOs. It called for a Decadal Incubation Program to mature technologies for important measurements. As noted, ESD will not be able to implement the Explorer line before 2023. Two of the five mandatory DOs were combined, resulting in the following:

- Combined: Aerosols-Clouds, Convection and Precipitation
- Mass Change
- Surface Biology and Geology
- Surface Deformation and Change

For the new EVC area, ESD released an Announcement of Opportunity (AO), selecting the Libera mission in February. Decadal Incubation selected study teams to determine what ESD will need to do to mature the technologies. Dr. Sara Tucker thought the study teams were also awarded augmentation funding, but Ms. Cauffman said that that is separate. The study is to identify activities, not hardware. ESD is issuing contracts on the DOs. Dr. Kaye explained that there were some augmentations to existing tasks, but those were completely different tasks with separate budgets.

The EVC initiative follows a DS recommendation to find innovative and cost-effective ways to continue existing measurements. A solicitation targeting radiation budget measurements was released in late 2018, and Libera was selected a few weeks ago. Dr. Herring asked how well space-qualified the mission's nanotubes are. Ms. Cauffman replied that while there is some risk, it is not so far out as to be considered

speculative. Dr. Andrew Dessler was concerned about the mission being cancelled; the continuity is essential. He asked what ESD had considered in the event of cost overruns. Ms. Cauffman said that ESD expects the mission to be on or under budget. The proposal was less than the $150 million cost cap. As ESD did the selection, they chose innovation over continuity to see if they could get this done in a reasonable way. The Division will work with the team, and is looking at current missions to see when and how Libera can launch. The risk is not considered high. Dr. Dessler said that losing continuity of the energy balance measurement would be disastrous, and suggested that NASA be ready to contribute additional funds should Libera go over budget. Ms. Cauffman said that this is a new strand, and ESD will adjust as needed, watching it closely. It will be the first mission out of the new DS.

For the DS Incubation initiative, two science teams have been selected, one on Planetary Boundary Layer, and the other on Surface Topography and Vegetation. As noted, Explorer implementation is on hold, but Atmospheric Winds is eligible for this and has been removed from the incubator list. When its Explorer program does start, ESD will use a two-step process in the AO. Once the Explorer line is funded, the Division will start a program office at one of the NASA centers. In September, the DO study teams presented their year-one activities to ESD. The teams have developed Science and Applications Traceability Matrices (SATMs), begun work on architectures, started soliciting industry and international partners, and are prepared to update their plans. ESD recently held a meeting for the teams in order to select final architectures.

Part of responding to this DS involves determining how to best implement the DOs with international partners. There is broad interest, with the European Space Agency (ESA) being most closely aligned thus far. Every DO team involves multiple centers, which has been a good way to pull in the best resources of NASA. Ms. Cauffman reviewed the Aerosol and Clouds, Convection, and Precipitation (ACCP) science and science objectives. There will be many applications in this area. A review of the study status and timeline showed that at the end of this year, ESD will do the final down-selection. The final report will be due in September, 2021, after which NASA will move to the formulation phase.

The Mass Change (MC) DO study also identified eight science objectives. The team has been holding community forums and providing updates. Ms. Cauffman showed the study milestones and schedule. ESD wants to start implementation with Surface Biology and Geology (SBG), then AACP, MC, and Surface Deformation and Change (SDC). Ms. Cauffman described SBG and listed the science objectives identified thus far. The U.S. Geological Survey (USGS) is very interested in this. The selected architecture is likely to be super-spectral first, to be compatible with Landsat, but will move to hyper-spectral. A graph of the study status and key dates indicates that there will be a mission concept review in September, 2021. SDC, which will be the last, will look at the whole solid Earth, ideally taking advantage of data from other missions, such as the NASA-ISRO Synthetic Aperture Radar (NISAR) mission. SDC is in the second year of a 5-year study. The question is whether to pursue the most promising option or keep the team together for the long haul, as the first mission will not likely start until 2027.

Dr. Shepherd asked why the Explorer program has not been viewed with much favor. Ms. Cauffman explained that it is just a budget issue. ESD has not gotten what the Division would need to start it. The National Academy of Sciences (NAS) made some assumptions when they issued the DS, and the realities do not match. Dr. Tucker noted that the decision rules for the budget state that large mission delays are the best way to manage lower budgets. Those rules also state that there should be competitions. Ms. Cauffman replied that there will be competition on the DOs, and ESD has the budget for them now. It is not possible to do both the DOs and Explorers at this time. Dr. Herring asked how she handles the budget uncertainty, given that while Congress appropriates more than the PBR, that might not always occur. Ms. Cauffman said that it is a risk, and constitutes one of the reasons NASA needs to work with stakeholders. When a budget is cut, the cut applies to missions, and the rest of the program remains intact and healthy. ESD has to impress on its stakeholders that it works this way. It is a yearly battle. The Division requests

what it thinks is necessary for a healthy program. It is better to do it like this than for Congress to give ESD unfunded mandates that cannot be met.

Discussion

Dr. Herring observed that there seemed to be two concerns from the morning's presentations: the Explorer line and the radiation budget. For the latter, it was not clear if they were going down a risky path, but there was to be a briefing on it that afternoon. Dr. Anastasia Romanou said that there should also be contingency plans for ocean chemistry. Ms. Cauffman said that the Joint Polar Satellite System (JPSS) will launch in 2027, and NASA has to work with the National Oceanic and Atmospheric Administration (NOAA) in the interim. Dr. Tucker noted that there were risks associated with that launch date as well. Ms. Cauffman said that NASA looked at all of the options when ESD selected the mission. They also looked at the option of JPSS 3 launching early. The Division has multiple contingencies because they know the criticality of the data. There are multiple instruments, which ESAC would hear about. Dr. Kaye elaborated, citing the Total and Spectral Solar Irradiance Sensor 1 (TSIS-1) on ISS, and NISAR. The next JPSS launch may lead to issues on downlinks, which could challenge NOAA. Terra has fuel to go to 2025-26 but will have to exit the A Train in 2023. ESD has solicited input from the project scientists, who preferred having some funds for final archiving and analysis, if possible.

Dr. Ian Joughin asked about the mandatory aspect of the DOs. Ms. Cauffman said that ESD has to do all five, but only three of the six Explorers. They are working to stick with budget targets and determine the actual numbers. ESD needs to see what the teams come up with. There was no pushback on combining the aerosols and precipitation DOs. The combined DO has a larger budget target as a result. Regarding the PBR zeroing out PACE and CLARREO-PF, the teams keep working. ESD will see what happens, as Congress keeps funding them. It was noted that NASA prefers the Office of Management and Budget (OMB) to cut specific missions rather than remove chunks of funding. NASA is used to this. If Congress said to take $200 million from the budget, ESD would have to cancel something to keep everything else healthy. Dr. Joughin observed that it seems easier to ask for the missions back than the money.

Dr. Kaye said that the suborbital program finished the deployment phase of Operation IceBridge, and Ice, Cloud and land Elevation Satellite 2 (ICESat-2) is now up. It was a major use of the G5, which is a platform SMD shares with the Human Exploration and Operations Mission Directorate (HEOMD). Looking ahead, ESD is working with ESA on a wind lidar campaign, and looking at launch vehicles. They have had a solicitation and selected a team. There are now concerns about the travel associated with field work. Shipping may start months in advance of the campaign, so those are risk elements. Does NASA want to ship instrumentation for campaigns that might not happen?

The DC-8 has had engine problems but the team expects it to be back up and go to 2025. This is a 60-year-old aircraft with good range and implementation options, and it is a big part of a lot of campaigns. ESD has contracted with the National Science Foundation (NSF) to study the roles of large aircraft and integrated satellite modeling studies. The DC-8 can hold about 40 instruments and around 30 people. It is very versatile, and therefore popular with much of the community. ESD has looked at other aircraft. Instruments are getting smaller, but people are not, and new planes would require modifications that could be difficult. There are purchase, operations, and maintenance to consider in terms of cost and time and versatility. The safety features might affect where the planes are flown and their ranges. The atmospheric chemists prefer planes with engines on wings and other characteristics that affect air flow. A NAS study will examine this, and Dr. Kaye will make sure ESAC receives the report.

Designated Observable Studies

The ESD program scientists for the DO studies described their work.

ACCP

Dr. Scott Braun began the presentation by showing the components of the study team, which included multiple NASA centers, some universities, and other Federal agencies. The study was approved to start October, 2018, and the report will come out in the fall of 2021. As this is the study combining Aerosol with CCP, there are two funding elements. Dr. Braun listed the eight science objectives, four for CCP and four for Aerosol, with the linkages between them. He then listed the applications objectives, based on lessons learned from a variety of missions. This area seems to have a good likelihood of connecting to the applications community.

The study approach starts with the SATMs, leading to the architecture study and the science and applications activities. The study team did workshops to develop the architectures, then held an evaluation workshop to score the qualitative science to determine what was most promising. Next, the team applied the framework and did assessments to determine if they met the objectives for science and applications. All of this fed into the value framework. The team is currently on Version F of the SATM. They held a workshop in Pasadena in April 2019 to get feedback, and invited international partners to participate. The resulting input from about 250 participants allowed them to build a range of 41 candidate architectures. A graph showed the construction status of these. The cost numbers are very preliminary and done for relativistic assessments. The team hopes to study multiple mission implementations associated with three science implementations.

The community is very excited about this. The team is currently studying how to implement the Japanese Space Agency (JAXA) radar, and looking at smaller building blocks using cubesats. Dr. Braun presented several different architectures under study. Among the elements studied are time differences. There might need to be some creativity to make them fit within the budget. He provided lessons learned from Architecture 8G, in terms of architecture construction, programmatic constraints and the impact on science, and current science benefit scoring that focuses on instrument performance.

The value framework includes five core elements, which were not weighted in the presentation. The team has developed eight attributes for applications, and is organizing information in a “baseball card” format. The near-term schedule has begun shifting to virtual interactions. The team is looking at a JAXA study and smallsats. The intent is to downselect to three observing systems for further study, with a goal of a single observing system selection by the end of FY22.

Dr. Shepherd asked how a DO concept fits into mission continuity. Dr. Braun said the team is looking at continuity of observations, ideally with enhanced capabilities. It will depend on the affordability of radar and other elements. They are trying to continue Global Precipitation Measurement (GPM) -like measurements. Dr. Romanou asked about the level of industry participation envisioned with the smallsat configurations, and how that might affect the cost cap. Dr. Braun replied that some instruments are from NASA centers, and some from industry. They are still working to cost out more fully. For some, there might not be industry sources, but the team wants to involve industry to the extent possible.

Mass Change

Dr. Tsaoussi described MC, which is determined by measuring gravitational changes over set time periods. It allows scientists to relate components of the Earth system to one another and provides continuity of the Gravity Recovery and Climate Experiment (GRACE) measurement record, which is long and contributed significant science advances. The study team is led by the Jet Propulsion Lab (JPL) with participation from the Ames Research Center (ARC), Langley Research Center and Goddard Space Flight Center (GSFC). Challenges include: translating the science objectives to gravity observations; measurement capability and relevant analytical framework (e.g. models); and, continuity. NASA does not want to interrupt some of the trends that have been established. GRACE was the first mission of its kind, with two gravity measurements and multiple satellites. Information from GRACE and the Follow-On

(FO) show how complicated MC measurement is regarding gravity; lots of manipulation of the data must occur. In order to do simulations, investigators need to know all the factors that must be considered.

The SATM overview for the MC DO has a baseline observing system that supports the full science objectives. MC is not the only observable, and investigators must weigh the gravity factor with the rest. A lot of discussion by the team and vetting in the community must occur. A list of the entire set of measurements from the DS regarding MC was color-coded by importance. There was a community workshop to initiate the vetting process. Dr. Tsaoussi gave an example of the performance targets derived from community interpretation, including baseline and goal performance targets. The suggested measurement parameters for the baseline include five different weighting schemes; the goal measurement performance would require more funding, while bringing ESD closer to the DS objectives.

The team is linking architectures to science performance. Measurement performance for the various types of architectures will be populated in Phase 2, which is where the project is at the moment. A framework will be used to assess the performance of any architecture across a space-time continuum. Dr. Tsaoussi showed how it would be mapped, and how the team will determine the science value in Phase 2. Three primary architectures include Precise Orbit Determination (POD), Satellite-to-Satellite tracking (SST), and Gravity Gradiometer (GG). SST is the most promising at the moment. The team will later look at different parameters and the addition of multiple pairs.

Along with establishing international partnerships, the team had a number of discussions with ESA. All of these are at different maturity levels and schedules. There is a strong desire to have overlap with GRACE-FO, especially after the user community had to manage a nearly 1-year gap between it and GRACE. Dr. Tsaoussi showed a preliminary result from the study of the science value methodology, and listed lessons learned regarding the SATM, architectures, and technologies. She confirmed that both NOAA and USGS are involved.

SBG

Mr. Woody Turner explained that this topic evolved from recommendations in a prior DS. The DO study involves multiple centers, with strong academic participation. Four working groups (WGs) serve as entry points: Algorithms; Applications; Calibration and Validation; and, Modeling. Over 400 people are engaged from the community, and each WG has regular calls. The WGs feed the Research and Applications Committee, which flows to the architecture team. They are now in Phase 2, assessment, having identified over 60 candidate architectures. These are being clustered for a down-select, to result in one primary and two secondary architectures. The goal is to have a mission concept review in 2021.

Mr. Turner showed the SATM with the observational capabilities. The questions come from the DS, which are translated into parameters. This is version 30. The codes for evaluating science performance provide direction. This can be traced back from the DS question and the spatial and temporal spectra needed to satisfy it. That is the mechanism the team used to come up with a suite of potential architectures. SBG is primarily global mapping, though there is some capacity to look at events.

Next, Mr. Turner listed the trade space elements and noted the value framework process for Phase 2. Risk tracks to Technology Readiness Level (TRL), which can be graphed. The team began narrowing down the number of architectures by pulling out common requirements and elements, and focusing on feasibility. They will use the design centers at the NASA centers. The timeline included some upcoming workshops that may go virtual if necessary; the team is working on back-up plans. The key products from the Algorithm WG have been sorted. International collaborations include the Indian Space Research Organization (ISRO) and the Italian Space Agency (Agenzia Spaziale Italiana; ASI); the latter want to be

involved. In reviewing lessons learned, Mr. Turner noted that the community wants high spatial resolution with global sampling and the shortest possible revisit frequency.

Dr. Romanou pointed out that data management approaches vary by country, which could be a factor in international partnerships. Mr. Turner said that NASA seeks free and open data policies, though there have been issues in the past. It is becoming the trend internationally. Ms. Cauffman added that ESD is pursuing the data buy and want to find a common licensing agreement with all of the companies involved. It needs to be consistent so PIs can know what to expect. Discussions are ongoing.

SDC

Dr. Gerald Bawden explained that SDC, the fourth DO study, covers a number of different sciences. Over the 5 years of the study, it will identify potential satellite architectures for NASA's next synthetic aperture radar (SAR). The SAR phase allows detection of movement, and SAR backscatter provides information as well. The bands are important for bouncing signatures back to the satellite. The wavelength helps determine the type of science investigators end up with. The team is looking at all the other work that can be done within a measurement of SAR backscatter – there are some key trade spaces.

As with the other DO studies, multiple NASA centers are involved. This DO is moving more slowly than the others, however. NISAR will launch shortly, and this is for its successor, so the selection is being planned for 2023. NASA might want to leverage ESA's activities in this area, and an option is to use a model in which two satellites collect feedback bouncing back from a signal originating from one. In the mean time, ESD will leverage NISAR. The initial candidate architectures are essentially "NISAR-lite," smallsat constellations, Tandem-L, and ROSE-L (ESA). These can be combined, and the team is considering all of them. ROSE-L would occur sooner than optimal for the SDC timeline, which could create a funding issue. The plans for 2020 included a workshop for the next week. The first R&A workshop, with 65 participants in four areas, had good results, but there was not enough participants from the sea ice community. Next time, the team will communicate better beforehand. Dr. Bawden showed the coverage, sampling, data latency, and amplitude for each of the four areas.

Dr. Bawden described the NISAR mass and power allocations to indicate how they could apply to SDC, noting where the opportunities might come. There is a model for moving from a conventional technology paradigm to an integrated paradigm that reduces cost, mass, and heat. While the antennae offer no economies of scale, there are several. A number of antenna technologies are under review. NASA will take these technologies through the performance tools to determine the range of technologies that meet SDC needs. One example is a deformation model. A second satellite improves the measurement certainty. The team is also looking at smallsats, which are not necessarily cheap. The cost impact of including a radiometer is another consideration. Regarding complementarity of data, the X band is used heavily in the commercial sector and the L band on the science side.

<u>Earth Venture Missions</u>

Dr. Charles Webb listed the guiding documents for Earth Venture Missions (EVMs). The 2007 DS called out the Earth Venture class of missions in order to develop cost- and schedule-constrained missions for the community. The constraints protect the budget from the impacts of overruns. EVMs are for niche science not essential for the portfolio. These are standalone missions, more complex instruments flown as hosted payloads, or complex sets of instruments, further intended to be applications-driven. The mid-term DS assessment recommended a more frequent cadence, which would be hard for ESD. The Earth Systems Science Pathfinder (ESSP) Program is at the Langley Research Center (LaRC).

In addition to EVM and EVC, there are EV Suborbital (EVS) and EV Instrument (EVI). The latter has some overlap with EVM. EVC arose from the 2017 DS, to address the perceived need for continuity of measurement. This is long-term strategy for measuring some of these variables. Dr. Webb listed all the

EVs since the beginning of the program, including those in development. EVC and EVI alternate, so there is one every 18 months, and the other two have calls every 4 years. The cadence is still being revisited. It is believed that ESD needs to communicate the schedule to the community better.

Dr. Webb noted the ESSP portfolio structure, including GLIMR and the Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE). The latter uses cubesats to look at a little-studied area of the polar regions. The demand for cubesats is high, and NASA is trying to figure out how to ensure its missions have the access they need. The Agency is also looking into the mass production of certain buses. There is a smallsat coordination group working on this at the SMD level. One issue is the lack of restrictions and the multiple conjunctions that occur per day. The satellites maneuver autonomously, and NASA is trying to work through that while industry continues to launch thousands of these.

The goal of GLIMR was to bring in new PIs. However, some investigators lack the necessary institutional support in building their instruments. NASA is trying to figure out how to address that. The Multi-Angle Imager for Aerosols (MAIA) is a hosted payload that will look at pollution and involve coordination with health officials. The Timed-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) is in storage. It involves cubesats that will go into three different orbits. The challenge is finding a way to launch them at the desired inclination. The Earth Surface Mineral Dust Source Investigation (EMIT), which will look for the mineral composition of naturally occurring dust, will launch in 2022.

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) launched in 2018 and had some failures of the storage, but JPL was able to work around that. There was some degradation of quality, but the volume is quite high and it has become quite successful. The Cyclone Global Navigation Satellite System (CYGNSS) was the first EVM, with eight smallsats in a low inclination orbit. It was greatly successful and persevered through issues with GPS signal strength. The Global Ecosystem Dynamics Investigation Lidar (GEDI), on ISS, measures vegetation. Dr. Webb noted that there are discussions to extend ISS to 2030. ESD has six instruments on it and had stopped proposals for it, but is now competing with other SMD divisions for space on it.

TEMPO was the first EVI. It is in storage and will launch in 2022. GeoCarb had a lot of programmatic issues and ran up against the cost cap. It was given an extension at KDP-C, but after the extension there was a unanimous decision to terminate it. However, NASA Administrator Mr. James Bridenstine overrode the termination, allowing GeoCarb to move to GSFC from the University of Oklahoma, which was the PI's institution and which did not have the ability to support the mission. It is no longer an EV mission and is another part of the portfolio. Due to the coronavirus, some of the EVS investigations will be postponed. Dr. Colleen Mouw asked about the plan to assist inexperienced PIs. Dr. Kaye explained that SMD is concerned about this and is training PIs through the new PI Launchpad program. There is an active suborbital program with a broad distribution of investigators, but it has been tougher on the satellite side. Sometimes there needs to be a close partnership between a university person and a more experienced organization, though some universities can do space programs. Dr. Dessler asked why the GeoCarb cancellation was overruled. Dr. Webb said that two reasons have been suggested. First, the PI is at the University of Oklahoma, and the Administrator is from Oklahoma. Second, however, Mr. Bridenstine was uncomfortable with cancelling a carbon monitoring mission and did not want the fallout from Congress.

Dr. Dessler said that he remains concerned about continuity being "one and done." Ms. Cauffman explained that the purpose of EVC is not to implement continuity but to demonstrate that it is possible through new technology and innovation. It is development for missions to take from the EVC program. EVC will not be the measuring source. ESD is still determining the fall line. Dr. Kaye said that ECOSTRESS was a lower-cost mission that generated about 70 proposals, which ESD did not expect.

The demand is for the data, and it speaks well that the PI understood that people would want it. TEMPO was NASA's part of an international constellation of geostationary satellites. There is increased value in the coverage among the missions. It is part of what NASA does as part of the global constellation. ESD understands that success rates affect people writing proposals in areas they otherwise might not pursue. The Division makes it clear how much money there is.

Earth Venture Continuity 1

Dr. David Considine explained that the DS recommended implementation of the EVC as a program to demonstrate continuity measures. The goal is to identify means to maintain continuity of important measurements without undue impact on the ESD portfolio. The program assumes one year of operations, which NASA may opt to extend outside of the EVC program. EVC-1, the first of these missions, follows the 2018 cancellation of the Radiation Budget Instrument (RBI), and is focused on continuity of NASA's Earth Radiation Budget (ERB) measurements. There is a need to measure both incoming solar irradiance and outgoing reflected solar and infrared Earth-emitted radiation to quantify the ERB. The Clouds and the Earth's Radiant Energy System (CERES) instruments have made such measurements over the last 20 years, and it is necessary to maintain the measurements over a long period of time, often longer than a single instrument can last.

Dr. Considine showed an overview of the EVC-1 Program Element Appendix (PEA) and described the proposal criteria. This is a Class C instrument with a 5-year minimum baseline lifetime. NASA is responsible for higher level data products, while the PI is responsible for ensuring that the proposed observing system will enable continuity-preserving higher-level data products. The PI will also propose a science investigation. For EVC-1, ESD selected the Libera mission, which provides continuity of the CERES ERB measurements, with improved calibration and accuracy, in an affordable instrument. The science objectives are to: 1. Identify and quantify processes responsible for the instantaneous-to-decadal variability of ERB; 2. Develop Near-Infrared (NIR) and Visible (VIS) angular models and algorithms for shortwave (SW) scene identification using Libera's Wide Field-of-View (WFOV) camera radiances; and~~,~~ 3. Revolutionize our understanding of spatiotemporal variations in SW, VIS and NIR radiative fluxes.

JPSS-3 is the planned platform for Libera. The Terra and Aqua missions must terminate prior to the planned launch date of Libera because they will run out of propellant, and NASA will depend on the Suomi National Polar-orbiting Partnership (S-NPP) and JPSS-1 to bridge to JPSS-3. The estimated data gap risk could be as high as 0.5 by the end of the decade, but drops substantially if a commitment is made to maintain operations of both S-NPP and JPSS-1 until the JPSS-3 platform is launched. ESTO funded a pair of Instrument Incubator Program (IIP) investigations demonstrating technologies that could represent a real advance over that which was used in the CERES instruments, and could lead to more advanced instruments in the 2030s. It is not clear whether NASA would continue flying copies of Libera if the IIP investigations succeed. , as it is a demonstrator, with an option of continuing. At the present time maintaining continuity of the ERB record requires a substantial overlap period between successive ERB instruments for intercalibration, but an in-space intercalibration mission such as one based on the Climate Absolute Radiance and Refractivity Observatory (CLARREO) concept would eliminate this need.

Decadal Survey Incubation Studies

Mr. Robert Bauer described the DS Incubator, a new program element focused on investment in priority observation capabilities needing advancement prior to implementation. This risk-reduction program works closely with R&A and will do technology development, modeling, and small-scale pilots. The funding profile fluctuates. The Incubator is currently focused on two elements: the Planetary Boundary Layer (PBL), and Surface Topography and Vegetation (ST&V). Both observables list a multi-function

lidar for candidate measurement approach. The work started a year ago, with a study team for each area. There was a Research Opportunities in Space and Earth Science (ROSES) call in order to select a team for each area. The products will be white papers that will serve as a foundation for the next AOs in FY 21-22. Each study team is to work with their communities. The Incubator also made nine 1-year augmentations, which Mr. Bauer listed. He identified the PBL study team, which hopes to hold a workshop in May. The ST&V study team has planned a workshop for August. The Incubator expects to issue another ROSES call in about a year.

GeoCarb

Dr. Ken Jucks explained that this project passed the technology part of the Critical Design Review (CDR). NASA changed the management structure, which will be reviewed in a few months. The mission will have four channels, three of which are similar to OCO, and will do multiple revisits to a full mapping of the western hemisphere at roughly 5-10 km spatial resolution. It should get good observations on clear days. The single technical issue now has to do with error on pixels, and a potential solution looks promising. Ms. Cauffman said that when GeoCarb was confirmed by Mr. Bridenstine, ESD converted it to a directed mission out of GSFC, so it is no longer formally part of the EV line. NASA had to augment the budget to do this. GSFC will work with the PI, the host provider, and the launch provider. The CDR assessed the instrument but not the programmatics, which GSFC will address in July. The program office will be at LaRC. There is not currently a line for this in the PBR, but NASA will seek to move it in a future PBR as a directed mission. It will stay in the ESSP line.

Discussion

Ms. Cauffman explained that the RBI was cancelled because of significant cost overruns. Dr. Dessler said that what he finds troubling is that it seems like there is no plan for what do to after the EVC mission. Given the timelines for getting things launched, it seems problematic. Ms. Cauffman replied that there will be options. ESD has some serious hard work to do and is thinking through things rather than just waiting to launch Libera. This is very much in the forefront. Dr. Tucker asked about international opportunities. Dr. Considine replied that there are none with the capability to continue NASA's ERB measurements, and he is not aware of a solid plan for continuing the observations despite some related potential activities. Regarding CLARREO possibly covering the gap, nothing is clear about its status, and it is short-wave only. There is no other instrument using these carbon nanotubes, though there are some ESTO investments.

Ms. Cauffman noted that this measurement was given to NASA to do. Dr. Considine elaborated: in 2014, the responsibility was transferred from NOAA, which focused on weather measurements and subsequently divested a number of missions from their program, shifting some to NASA. Ms. Cauffman said that NASA has these measurements now and will do their best. ESD scientists want to continue the measurements. Some cubesats can gather these data. ESD is looking carefully, which is all they can do. Dr. Webb pointed out that the DS challenged NASA to find a more sustainable way to enable continuity, while being cost-effective and engaging technologies like smallsats that can be replenished. Dr. Kaye suggested looking at the history. This DS talked about continuity rather than one-offs. There is no across-the-board commitment to certain things. It is important to recognize that the number of areas the community wants to observe continually is beyond what any one agency can do, so NASA has to look internationally. The Agency cannot do everything itself and must pay attention to which things struggle. Ms. Cauffman said that ESD is trying to get synergy and do things better for less.

Dr. Joughin suggested there be a finding applauding international collaboration. Dr. Herring asked if there were any other observation and measurement losses to consider, such as ozone. Ms. Cauffman said that the JPSS series gets that and is good for now. Dr. Romanou noted that Landsat does not cover the open ocean. Dr. Marshall asked if it would help to have a recommendation or finding on how critical PACE is. ESD has not cancelled that mission, as Congress keeps appropriating the funds; the Division is

implementing the mission. This Committee advises NASA on what it is executing. If there were to be a finding on the current portfolio, it would be reasonable to mention multiple missions, and PACE could be one of them.

Dr. Shepherd suggested that the ESAC members reflect on what they discussed that day to see if any findings arise. They should email their thoughts to him and Dr. Herring for discussion the next day. Dr. Tsaoussi reminded the members that their discussions need to be in an open forum. They can wordsmith after the meeting but not add new statements or recommendations.

Adjourn
The meeting adjourned for the day at 5:05 p.m.

Wednesday, March 11, 2020

Opening Remarks
Dr. Tsaoussi opened the second day of the meeting by taking roll. The first agenda item was public comment. As she had not received any requests for public comment, they would move on to the next agenda item. That afternoon, ESAC would frame its letter report to NASA.

Commercial Data Buy
Mr. Kevin Murphy discussed smallsat data acquisition and the 2017 pilot project to evaluate data from commercial smallsats to augment NASA observations. The project ended in January. Among other criteria, vendors need to be able to provide proven products when NASA purchases. Mr. Murphy reviewed the information vendors had to provide in order to demonstrate their operating capabilities and show they had smallsat constellations already in operation. Of the 11 vendors that responded to the RFI, 4 were selected to respond to an RFP. Three Blanket Purchase Agreements were awarded in October, 2018, to DigitalGlobe Inc., Planet Labs Inc., and Spire Global. Ultimately, the parties had to move to a more restrictive license regarding publication and data. They are still working out copyright and other issues. Dr. Joughin noted that commercial entities are producing competing products, which Mr. Murphy said he would address, as this has come up. It is an area where everyone is learning. There will have to be criteria addressing scientific use and openness, and it gets complicated, but the companies seem to be willing to provide exclusions for scientific use and derived products. Dr. Herring asked who assesses whether a science product could be used commercially, pointing out that this would be difficult to know in advance. Mr. Murphy said that there is potential for exposure, which has occurred with NOAA and public data. Dr. Herring noted the subtleties involved, and Mr. Murphy said that NASA will have to evaluate whether the commercial interests can help do NASA science, and how to negotiate the terms for open science while participating in a commercial marketplace that can provide new capabilities. This was a first try, and everyone will learn more as they go through this. It is in the interest of the government and industry both to understand this.

The approach to the evaluation was to look at ESD's six R&A areas and the four Applied Science program elements, as well as the Heliophysics Division (HPD) work on space weather. An independent assessment looked at calibration and geolocation, and NASA developed a summary report from the individual project reports for each vendor. Evaluation criteria include: accessibility of imagery and data; accuracy and completeness of metadata; quality of user support services; appropriateness of end user license agreement (EULA); utility of data and imagery for advancing Earth system science research and applications; and quality of vendor-supplied imagery and/or data. The projects fell into two groups: radio occultation and imagery. Bandwidth included some NIR. It varied by provider, some of which launched

new capabilities during the evaluation period. The data acquisitions were completely driven by the PIs' requests. ESD augmented existing grants with new funding for this.

The evaluation results for DigitalGlobe Inc. indicate that the data augmented and complemented NASA data. While of high quality, the products are snapshots. Long-term trends can be developed from the data. There were no issues with data access/download, documentation and metadata are sufficient, and user services are very good, but standard scientific collaboration is inhibited by license terms. The Planet Labs Inc. evaluation results were similar. This company has a different level of calibration among the sensors, of which they have many. The revisit frequency is excellent. It was hard to use the tools, however, and individual PIs interacting with the system had problems. PIs request access in advance but are not charged if conditions prevent it.

Spire Global, Inc. tracks ships and airplanes, so their first satellites were plentiful but did not have a lot of time with Global Navigation Satellite System (GNNS) radios compared to what they have now. Upon launch, the company showed that it does complement the bigger systems. The vertical information content was suitable for studying fine structures and seasonal variabilities, and the POD information was useful. Evaluation showed this company to be pretty good, supporting things that NASA did not know they would support. Spire Global also had capabilities for sea-level measurements that are difficult. However, it was hard to get their data, which NASA had to move over. Documentation and user services were good but, like the others, the standard scientific collaboration is inhibited by license terms. Dr. Tsaoussi added that they are engaged with ESD gravity mission work and have a lot of data, so there is work they could do with the Earth science community. They know ESD requirements fairly well.

Mr. Murphy said that all of these companies have technology development roadmaps. The pilot ended in January, and NASA is documenting it now in order to move to a sustained use program. The pilot was structured so that the data can be made available to a wider community of users. That should be in ROSES 20. Having transitioned from pilot project to sustained program, it is now called the Commercial Smallsat Data Acquisition Program (CSDAP). Objectives include: establishing a process for evaluating and bringing in new vendors; making purchased data available to a broad scientific audience; ensuring long-term data availability; and coordination with ESA. Ms. Cauffman pointed out that licensing is still problematic. Mr. Murphy agreed, though there is a distinction between operational and scientific use, with the latter being less expensive. The companies are based wherever they want to sell data. The legal frameworks are set up for that. Ms. Cauffman noted that NASA was not allowed to purchase from a couple of companies of Chinese origin.

Mr. Murphy then described activities for FY20 and beyond. The primary effort will be to continue monitoring development of companies and acquire relevant data. NASA will issue RFIs every 12-18 months. The Agency is trying to move to a standard scientific use license, which is complicated. There could be tiers of licenses. There has not yet been any pushback from universities, but ESD just put this in ROSES 20. Ultimately, NASA wants the evaluation teams to be made up of PIs selected through ROSES, though not right away. The Agency will ensure there is no double-buy and will make the data available through the standard scientific use license. There is a template NASA uses as a negotiation component. Most recent versions require that products published in a peer-reviewed journal are available for scientific use. The investigators will need a EULA on their derived product, but will not have to run it by the company now, though that was a requirement in the first round. NASA has been wrestling with the use issue nonstop. Ms. Cauffman agreed that it has been a struggle. While ESD wants to continue buying the data to augment its measurements, NASA can only afford so much. Mr. Lawrence Friedl noted that it would be great if the insurance companies were to go directly to the smallsat suppliers. If NASA is a conduit, that constitutes a success from the applications point of view.

Mr. Murphy explained that ESD was able to obtain some amazing information and gave some examples. Dr. Joughlin asked what kind of feedback he was getting from the companies. They are getting access to a creative community. Mr. Murphy replied that NASA has made that point to them, though it does not resolve the licensing question. Still, they recognize the value of the community. NASA is not putting up any barriers for science need at this point. Ms. Cauffman added that ESD has only done this once. Now that the Division is in the second cycle, new companies will enter the pilot, and the pilots from the first cycle will move into other agreements. The PIs only get input on the selected companies, not the prospective companies.

Dr. Tucker asked about continuity, because it is not certain that start-ups and other young companies will be around in 5 years. Mr. Murphy said that that is an unknown. It looks like a number of companies are coming into this market, so continuity may span multiple vendors. NASA already asks for long-term plans, which can be a window. ESD has determined that the products evaluated are of sufficient use that they justify purchase from Spire Global and Planet Labs, but from not DigitalGlobe, which has already sold to the government. An effort to move to a governmentwide license is getting major pushback.

Machine Learning- Artificial Intelligence

Mr. Murphy explained that this effort will span all ESD components. Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are the areas of study in this initiative. When ESD examined how people use AI in Earth science, they discovered that it goes across multiple data types, communities, and disciplines. There are eight focus areas for AI, and the building blocks are open data, open source, community building, research, and benchmark-labeled data sets. ESD has invested in AI/ML across the Division, and individual PIs may use it in their work.

Much of this work is through ESTO. Advanced Information Systems Technology (AIST) addresses the kind of ML that can go on satellites, and works to determine how to help PIs understand it. NASA can use AI through the entire value chain. Many different techniques are available. In the area of High-End Computing (HEC), the primary challenges are preparing the data and lowering the barrier to start that process. The Earth Science Data Systems (ESDS) program is working on open data sets and sharing AI techniques. There is also work on improving products from the commercial sector. There was a recent ESDS workshop on how to develop best practices in ML, and a report should be available in the next month or so. The growth in archival needs is steep.

A video on labeling data demonstrated some of the work that is being done. Typical processes involve the use of labels or key words to identify imagery. In AI, it is possible to take a label maker and digitize it via crowdsourcing. These are the bases for using future visual information and training models on how to identify similar phenomena. This shows the ability to create new training sets, and is a prototype effort for labeling data. Using that type of tool, investigators can begin to categorize imagery. One of NASA's problems is that people often have to look through catalogues of millions of items. Labels would enable identification of similar areas that might not be the first place a researcher goes to. Another video showed an imagery training labeler. This is identification, not analysis. The intent is to ultimately search pictures by label, using multi-frequency data. A lot of observations are needed, however. This technique will not provide answers, but it might reduce effort by narrowing down the data universe.

Regarding configuration control key words, Mr. Murphy noted that there are hierarchies applied to data for searching, which is labor-intensive. This can be improved through ML. He demonstrated this by showing a smoke detection prototype using Geostationary Operational Environmental Satellite (GOES) 16 data. A hurricane intensity estimator that uses DL takes data every 15 minutes, then compares it to historical data in order to train the model. It matches up quite closely on the example of Hurricane Dorian. Some of the examples are the initial cut, and not everything lends itself to AI. The key to using it now and in the future is ensuring the availability of resources to the community. It takes a lot of work with

optimization and security. There is significant promise in some areas, but NASA still needs to evaluate accuracy and develop specific techniques for Earth science.

The hurricane track work was supported by his program, but it was a low level of effort. Dr. Shepherd noted that NOAA is extremely bullish on AI for forecasting, but intensity forecasting lags track forecasting. He asked if NOAA was involved in this effort. Mr. Murphy believed they were, adding that it is open-sourced. AIST and other groups have specific elements encouraging AI. Nothing inhibits other proposals from using AI, which has been done. However, it is expensive. Dr. Kaye said that PIs are free to bring a tool to something if they think it will help them. NASA does not need to approve it. Some AI/ML proposals do not always do that well in review because of concerns about correlation without insight. That is anecdotal. Perhaps advances in the technology will make that less critical.

Dr. Tsaoussi explained that the weather program funds some of this, as does remote sensing theory. They evaluate the proposals based on what they plan to accomplish. There are several cloud ML metrics being used by highly qualified science teams. Proposals that only focus on technique will not do well with a science panel that has science research questions to be addressed.

Research and Applications Cross-Benefits

Mr. Friedl explained that the cross-benefit of research and applications spans ESD and the broader community. In its eight-point strategy, the most recent DS designated the third point as "Amplify the Cross-Benefit of Science and Applications." Further, while science inspires those involved in applications, end-use needs can inspire research scientists and engineers. Embedding science in the applications process often uncovers questions driven by end uses that are new to research scientists. ESAC had asked for a review of the current approach as an opportunity to provide feedback and identify strategic opportunities. ESD would like ESAC, as representatives of the community, to let the Division know what they are hearing, and to take the message back to the community to get their further input.

NASA AOs have defined science to include research, applied research, and applications. Research is fundamental learning to explain phenomena and understand processes in the natural world. Mr. Friedl explained that applied research is more directed, and is the development of scientific knowledge directed to a particular result. The applications area involves working with non-research users to integrate research into their processes so that they can become sustained users of the data. He gave drought as an example, as applied to the three definitions, in which applied research derives three indicators that applications use in the U.S. Drought Monitor. Dr. Shepherd asked why the Drought Monitor did not have the NASA logo along with others. Mr. Friedl said that NASA provides one of many data sets, and is acknowledged on another page. Dr. Tsaoussi added that the Drought Monitor is a NOAA initiative that was developed by that agency. The NASA contribution is a specific one. Mr. Friedl noted that the Drought Monitor existed well before the GRACE data. Dr. Romanou observed that datasets are often at lower resolution than the users need, and asked who translates. Mr. Friedl said that that may occur within applied sciences or R&A, it depends on the specific user community. Often there are organizational barriers in addition to technology barriers.

He wanted to offer a sense of what NASA means by Earth science research and applications. Peer review literature is a primary output of scientific research. The applications side tries to understand such outputs to see what might be most applicable in improving their processes. The primary outputs are documented examples of adoption, and sustained use and impacts. While the applications side does encourage publication, it is not the primary metric. A comparison of the applications and research focus areas shows that Applications has five themes, plus capacity development, for six program elements. ESD R&A has six focus areas. The Division does not want to draw arrows indicating equivalencies across the two; instead, there are many connections. This approach reflects what users find most relevant and useful in

applications. ESD wants the applications side to be aware of the work coming from the research side, and the research side to be aware of applications user questions.

There is a lot of give and take between the two sides. An example comes from satellite mapping of evapotranspiration (ET). Many models were developed over time through research. As the models matured, they were adopted and integrated into decision-making. Discrepancies among ET estimates led to funding of a comparison effort that is still ongoing. Mr. Friedl listed some of the activities Applications has been doing within ESD, link applications and research. A highlight is the High Mountain Asia effort with the Chinese Academy of Sciences, which has been approved. Similarly, HAQAST is a mechanism that has researchers meet with state and local officials who can use the data. Once projects are identified, there is a separate pot of money to fund these efforts. The approach to further amplify the cross benefit starts with the data collection efforts and the products that go out to the community. There is also the question of how ESD considers the applications when developing missions. That line of thinking has been formally introduced via the DO Program, so that ESD now considers applications from the beginning in order to grow the applications uses and ensure the science is useful to society.

The ESAC meeting was to have examples from Air Quality, Disasters, and Conservation and Biodiversity. Mr. Friedl would like an initial discussion, with the goal of feedback. Dr. Kaye added that Mr. Friedl has presented assessments on both sides. A lot of the interactions with NOAA have data on the research side, sometimes enabling activities as well. It is important to understand that there are many areas where the boundary may be fuzzy. ESD has tried to make sure there is no "valley of death" by recognizing that some things sit firmly on both sides. In AIST, there are many technologies emerging that will make information more readily available. It is important to understand that ESD does not see firm walls around these areas.

Dr. Joughin said that NASA seems to have done a great job of bringing applications in through the Satellite Needs Working Group (SNWG). Dr. Herring asked about how the feedback mechanism operates across the program, citing the Drought Monitor. Mr. Friedl explained that the analyst using it has a chance to use a wide variety of sources. It could be that there needs to be better communication of the examples, which have not all been documented. Dr. Kaye said it can be challenging to get specific feedback, especially where things are "less well." Information comes back stated as a need for something to be done better. Specific items are more actionable. Mr. Friedl said that when the research and applications communities work together, they can get to the deeper levels. Dr. Joughin said that applications should be integrated into the science teams. It is tight-knit in NISAR.

Dr. Tucker observed that the DS recommended doing what ESD had already started to do. This is something to be proud of, and it has become important and valuable. There has long been an attitude in parts of ESD that they just do science and not applications. She sees the work Mr. Friedl has done in applications. Science is done for discovery and to better life. She asked where that is headed in ESD and NOAA. Dr. Kaye thought that everyone sees this differently. He does not think it is good to have a dichotomy between basic and usefulness. There may be a need to do fundamental work, but that is because science recognizes that there are fundamental uncertainties. ESD does not do a lot of purely curiosity-driven science. Rather, there is the expectation that new knowledge will inform, and maybe turn into, products and services. Mr. Friedl said that R&A has been in the research/applied research space, and applications has been trying to help users get and use data.

Dr. Lucy Hutyra said that this is an incredibly important direction. For HAQAST, the structure has been quite effective in bringing people together to define the science. The tiger team efforts have brought out novel, useful work, and she would like to see that expand. However, she sees some challenges with the teams. The members are not selected to do specific work but are instead selected for the team. She has

heard some grumbling in the community about that. Mr. Friedl said that ESD is making adjustments on the second HAQAST. He would like to hear what she is hearing, as well.

Dr. Romanou said that there is a group working on applications, using satellite data and NASA models. There is the issue of downscaling. Stakeholders have needs that NASA might not be addressing with satellite data or modeling. The groups need high-resolution data and do not have the capability to downscale. There is a prototype on climate projections, and it needs more variables. Dr. Kaye said that NASA has not been involved in downscaling. The NASA Earth Exchange (NEX) was initially oriented to providing satellite data to those who could not otherwise access it. NEX has been refocusing itself as a place for the research community to access the new generation of geostationary data. As NASA goes to higher resolution models, the Agency should look at the need for decrease. A separate set of DS recommendations addresses this, ESD has a group on it, and the Agency has been interacting with NOAA to figure it out. Mr. Friedl said that another goal is to expand beyond government agencies to the private sector, NGOs, states, nonprofits, indigenous, and many other groups that are ripe for opportunities.

The effort has international partnerships and is seeking more. There is a stronger focus on Federal agencies due to having established relationships with them, but it does not stop with them. For example, SERVIR, a partnership with the U.S. Agency for International Development (USAID), looks at use of satellite data. ESD has partnerships with NGOs such as CI and Mercy Corps. The Division is also doing more with the World Bank, which has a geospatial team. Other efforts seek to understand the mechanisms that philanthropies and foundations use. ESD should be able to give a status report in about 6 months. Ms. Cauffman added that Earth science data involve a world enterprise in which different entities all help each other view the Earth as a system. NASA will continue to look for collaboration opportunities. Mr. Friedl said they are also trying to get more into the private sector, though industry might not be open about their use, unlike government users. Getting private sector examples will present some interesting challenges.

Cross-Benefits - Air Quality

Mr. John Haynes said that ESD's Air Quality Research and Applications program has two major efforts: the Health and Air Quality Applications Program (Applied Sciences), and Tropospheric Composition (R&A). ESD has almost 30 active grants in this portfolio, which looks at how Earth observations can promote implementation of air quality standards, policies, and regulations. Partners come from various types of organizations. HAQAST is the crown jewel, connecting NASA data and tools with health and air quality stakeholders. It operates via tiger teams, with lots of cross-pollination with the community and other projects, and a great deal of leveraging with R&A as well. The tiger teams run for 4 years at a time, and ESD is now on the second iteration. HAQAST operates out of four quadrants: direct collaboration, support for advanced users, support for novice users, and broad dissemination. There are remote attendance options for meetings.

Mr. Haynes described the dissemination strategy, which has led to 217 papers published in journals by HAQAST team members. Examples of their work include the Wyoming Exceptional Event Demonstration. In order to avoid Environmental Protection Agency (EPA) penalties, the state of Wyoming sought to determine the cause of a large ozone occurrence. HAQAST was able to show that it came from the jet stream, and EPA gave the state a waiver, the first based on remote sensing data. A graph of Washington, DC, data shows how air quality has improved since 2005, with stricter environmental regulations resulting in a 50 percent decrease in nitrogen dioxide. EPA needs to be able to show that their efforts are succeeding despite increasing populations. The U.S. Forest Service (USFS) has developed smoke forecasters linked to air quality, which the public can see online to get the outlook for their areas. HAQAST is currently being recompeted through ROSES. ESAC should expect a team of similar size, to start in October.

Dr. Barry Lefer showed a depiction of the integrated observing system for air quality. The satellites cannot do this by themselves; there is a need for computer models, air quality monitors, field campaigns, and more. A campaign over the Gulf of Mexico took measurements that provided information on the impact of the oil and gas activities off the shore. Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) is a joint venture between NOAA and NASA, using satellites to find fires. Models do not know the intensity of the fires or how high the smoke goes. Smoldering fires have a different chemistry than flaming fires, which is another factor. Dr. Lefer showed the coordinated FIREX-AQ activities in 2019, which also brought in NSF. There were two phases: western wildfires, and smaller and agricultural fires.

Next is the ROSES call, proposing data analysis from field campaigns. The Tracking Aerosol Convection Interactions Experiment (TRACER) Air Quality and Health (AQH) will coordinate with the Department of Energy (DOE) TRACER work in Houston. The Airborne and Satellite Investigation of Asian Air Quality and Health (ASIA-AQH) is planned for 2024, to take place in several Asian megacities. Mr. Haynes said that TEMPO and MAIA are coming up, to launch in 2022. The DO closest to this is ACCP, which is engaging on the applied science side.

Dr. Shepherd noted the number of publications from the science team. He asked what the metrics for success are in applied science, and whether they should differ from R&A. Mr. Haynes said that his point was that doing applications does not necessarily reduce publishing, which matters to many scientists. He noted the stakeholders who come to these meetings and begin working with PIs to start solving problems. There are webinars among stakeholders, like the American Lung Association, which wants to be involved in air quality. Participants improve each others' metrics through collaboration.

Cross-Benefits - Disasters

Dr. Bawden explained that Dr. David Green is the NASA point person for natural disasters. Through NISAR, they have held nine workshops on applications. NASA's radar program typically responds to disasters, as in the example of the eruption of the Kilauea volcano in Hawaii. This is done to gain knowledge about the specific disaster, which helps to reduce risk and build resilience. The Disasters program has six focus areas covering a range of types of disasters. The data needs are the same as those of R&A for characterizing and understanding events, but how people use data can be different. Timelines differ between R&A and applied science. Understanding and addressing disasters are complementary. Both provide situational awareness and actionable science during events. Data help to better understand and characterize the events. Both applied science and R&A want to produce predictive models, but applied science uses more empirical models, while R&A is more concerned with the physics.

Dr. Bawden described cross-cutting disaster science outcomes. The real-time GNSS-Tsunami Early Warning (TEW) was a model created following the 2004 Sumatra earthquake. Over the last 5 to 6 years, NASA has worked with NOAA, the UN, and others to provide tsunami early warnings. This is now part of NOAA and provides science data that can save lives. Another example is Advanced Rapid Imaging and Analysis (ARIA). ESTO has invested in this project, which is fundamental research on tectonic processes. Last year, it showed ground movement, which was not actionable. However, some of this information can be used in damage response and mitigation. In addition, it is now possible to see tsunamis earlier in the ionosphere, and even observe the front moving across the ocean. The user community needs simple products, and the challenge now is moving them to a higher level while making the products more accessible.

Cross-Benefits - Conservation

Dr. Keith Gaddis explained that Biological Diversity and Ecological Forecasting is run as cohesive program in ESD, integrating R&A and applied science. The Program advances use of NASA observations to understand biological diversity through 36 active projects. Remote sensing is used to map numerous

taxonomic groups. Ecological forecasting, with 29 active projects, seeks to put that into the hands of decision-makers, and has end users on the teams. Examples of projects include documentation of landcover change in national parks. A migratory trajectory uses millions of user observations to create stopovers for migratory species. A project using Landsat tracked penguin guano, which is pink, and discovered many penguin colonies that were previously unknown. This has also been used for other birds in the southern hemisphere. The results have been used to change protected status areas. Management as joint programs enables a seamless transition from research to applications, as well as joint solicitations. Team meetings of PIs help to build a community that learns from each other. The Program provides training to show people how to accomplish these projects and use these tool sets.

An example is a partnership between NASA and CI, which will amplify ESD's work and community findings on biodiversity to stakeholders. CI will tell NASA what the user needs are, while also providing a planetary perspective. This international organization helps legitimize NASA's work in this area. For example, the Gaborone Declaration for Sustainability in Africa (GDSA) needs data, which NASA can provide. At the same time, CI knows how they use the data. This ties the benefit back to research, in that there are world experts involved from the CI side who help NASA improve its ability to map ecosystem changes. This helps move the end use forward while improving NASA's work and offering opportunities to increase the impact. The effort demonstrates the benefit of the Program's science work through innovation while validating the applications work. It pushes cross-disciplinary initiatives to achieve the objectives of users. This area had 150 publications in the last year, and while they measure success according to uptake by end users, the rate of publication is equal for applied science and research. In answer to a question, Dr. Gaddis added that they work in countries with their local scientists and agencies.

Discussion

Dr. Mouw asked about the strategic plan for communication. Mr. Friedl explained that there is a communications manager for R&A, and another for applications. The positions are writing-oriented, and try to show breadth across both research and applications. Ms. Cauffman added that in 2019, they published a story on how this work affected every state in the country. ESD is trying to build on that and wants to add more stories. Dr. Mouw observed that this puts the onus on NASA to produce stories. She wondered if they might be built into the awards. Mr. Friedl said that one goal is to re-release the applied science website, which will encourage user contributions. There is an effort to pull out the pathways that allow the applications. They also want to highlight the research questions and how research led to an application, and what the new research directions might be based on user needs. Ms. Cauffman noted that ESD is working with Google on this. Mr. Friedl further explained that each element within ESD has communications efforts, and each center has its own communications apparatus. Ms. Cauffman explained that the people within the Division are helping to develop content. Dissemination is an issue; they need outreach to the communities at large.

Dr. Kaye added that there are lots of opportunities, so that ESD becomes a great nucleating force and people want to come in with them. There are areas of struggle, of course. Some of the results need to arrive in a more reasonable and consistent way so ESD can see what is there and distinguish whether they are learning about the Earth or about techniques for learning. The latter may be interesting to a technical audience but not others. There is a need to determine which stories ESD tells. When they work with another agency, whose story is it? The various agencies tend to highlight what they themselves do. Often, the scientists are working together and have no problem with sharing, but feeding information up the chain makes them work harder. Mr. Friedl asked if Dr. Mouw was hearing from the community that the applications area is not doing enough or should do something differently. She replied it was more that she confronts issues of training PIs to understand where their impact will be. There is so much emphasis on research, so maybe there needs to be reconsideration of how information is shared and encouraged.

Findings and Recommendations

Dr. Shepherd said that he had captured a few things that could end up in the realm of recommendations or findings. First, a real concern is not losing the radiation budget measurement. He wondered if ESAC had a statement to make there. Second, there was the discussion of open data and data buys. Mr. Turner explained that ESD works with international partners and needs to retain the open data policy in NASA agreements with them. Next was GeoCarb and external challenges to NASA training. He wondered if there might be a need for training sessions to be online, or if there should be other support so that project management training is available. Ms. Cauffman said that SMD is having sessions to train new PIs, give them a picture of what they need to know and do, and help them understand what it means to be responsible for the entire effort. Dr. Shepherd said it sounded like SMD is on top of that. Dr. Tsaoussi reminded ESAC that they advise ESD, and their recommendations should be things that are actionable for ESD, not another NASA entity. However, they could make a statement about ESD furthering SMD efforts or something like that.

Dr. Shepherd mentioned the downscaling discussion in Mr. Friedl's presentation. Dr. Tsaoussi said that downscaling as part of a modeling effort is not directed to applied science. There is an effort to respond to the DS recommendations for modeling, and this could be strengthened through that. Not all downscaling is going to work. Dr. Herring said that he saw issues with the EV classes of missions, specifically EVM, which seems to call for very good PI training, as opposed to EVI. It would help to make the distinction between them. The EVC finding could support that. Dr. Joughin said there should be some criteria to evaluate who is doing what to ensure the PI is supported well. Ms. Cauffman explained that PIs need to pick a project management team that works with and supports them. That was not the case with GeoCarb, which made it tricky. Dr. Tucker said that she works at Ball Aerospace, which has projects throughout NASA. She thinks it is great that NASA is doing the training, but it would be good to identify the challenges and the specific training that are needed. Ms. Cauffman said that that is happening with EV. Dr. Joughin observed that it is hard to get a proposal through without a good team.

Dr. Herring mentioned the radiation budget. Ms. Cauffman said that ESD has a mission in that field, and some time. It was selected 2 weeks ago and will launch in 2027 on JPSS-3, in cooperation with NOAA. Dr. Dessler was concerned about what might happen if Libera goes over budget. Ms. Cauffman said the Agency will fund it all the way to the cap stated in the AO; the proposal was less than that. There is a significant margin for funding to the AO cap. JPSS-3 will be completed in 2024, then go into storage. The instrument will struggle to get there on time, but NASA puts things in storage all the time. The Agency tests after taking something out of storage.

Dr. Hutyra had sent two thoughts to Dr. Shepherd, which he read. First, she observed that they heard repeatedly the importance of coordinating with other agencies, especially NOAA, in a number of areas. Second, regarding applied science, the successes they heard about were astounding. These demonstrate good coordination of basic and applied research. Dr. Shepherd added that, regarding applied science, it is important to have a clear metrics as basic and applied research come closer together. Dr. Joughin suggested folding in the SNWG, which has brought in a lot of agencies. Dr. Tucker asked Mr. Friedl if he wanted ESAC to produce a certain volume of recommendations. He replied that that was a suggestion. Dr. Shepherd thought a future charge to ESAC might be to develop a more comprehensive assessment of Mr. Friedl's area.

Regarding the DO, Dr. Joughin thought it looked good and was comprehensive. Dr. Tsaoussi said that the primary charge to ESAC for this meeting was to assess the DO. That should flow through the letter, with findings and recommendations for each of those. She thought ESAC might want to list the importance of the missions of record. Dr. Joughin said it might be good to recommend that NASA seek as open a data policy as possible. Ms. Cauffman said the restrictions were on the data buy, a whole different area. It is a requirement everywhere else. The Italians have some missions they are trying to commercialize; NASA does not have an agreement with them. There was also an issue with JAXA, which is now opening up the

data. NASA's open data policy was the sticking point that prevented the Agency from securing an agreement with the Argentinians. NASA is working with ESA and other agencies on a global constellation. Dr. Joughin said that that might be a reason to commend ESD.

Dr. Tucker noted that the DOs seem to be in similar stages, but the presentations took different approaches. She would like something clearer about the differences. Dr. Tsaoussi replied that the science states and the observing systems are different, but they are using the same brief. Dr. Tucker said they came across differently. Dr. Joughin suggested having a chart at the beginning of each DO presentation to show where they are on the same timeline. Dr. Tucker liked that idea.

Closing Remarks

Dr. Tsaoussi said that there was a lot of material to digest. Dr. Herring quickly reviewed the above discussion, noting the following topics: DS progress, program of record, DOs, recommendation on open data policy on data buys, global constellation coordination with ESA and others, the Explorer line is on hold due to budget, the EVC and radiation budget is critical and should be monitored in case JPSS-2 fails, bringing in new PIs to EV is great and yet project management needs to be done well, recommendations on coordination, SNWG is useful, and applied science has had great success and the line is blurring between it and research. He would send the summary to ESAC members for editing.

Adjourn

The meeting adjourned at 3:01 pm.

Appendix A
Participants

Committee Members
James Marshall Shepherd, ESAC Chair, University of Georgia*
Andrew Dessler, Texas A&M*
Nancy Glenn, Boise State University*
Thomas Herring, Massachusetts Institute of Technology
Lucy Hutyra, Boston University*
Ian Joughin, University of Washington
Jasmeet Judge, University of Florida*
Colleen Mouw, University of Rhode Island
Ying Fan Reinfelder, Rutgers University*
Anastasia Romanou, Columbia University
Raymond Schmitt, Woods Hole Oceanographic Institute*
Sara Tucker, Ball Aerospace
Lucia Tsaoussi, Executive Secretary, NASA Headquarters

*via teleconference

Appendix B
ESAC Membership

James Marshall Shepherd, Chair
Department of Geography
University of Georgia

Lucia S. Tsaoussi, Executive Secretary
Earth Science Division
NASA

Roland Burgmann
Department of Earth and Planetary Science
University of California, Berkeley

Andrew Dessler
Department of Atmospheric Sciences
Texas A&M

Nancy Glenn
Department of Geosciences
Boise State University

Daven Henze
Mechanical Engineering Department
University of Colorado

Thomas Herring
Department of Earth, Atmospheric, and
Planetary Sciences
Massachusetts Institute of Technology

Lucy Hutyra
Department of Earth and Environment
Boston University

Ian Joughin
Polar Science Center, Applied Physics Lab
University of Washington

Jasmeet Judge
Department of Agricultural and Biological Engineering
Center for Remote Sensing
University of Florida

Colleen Mouw
Graduate School of Oceanography
University of Rhode Island

Ying Fan Reinfelder
Department of Earth and Planetary Sciences
Rutgers University

Anastasia Romanou
NASA Goddard Institute for Space Studies
Columbia University

Raymond W. Schmitt
Department of Physical Oceanography
Woods Hole Oceanographic Institute

Sara Tucker
Ball Aerospace & Technologies Corp.

Appendix C
Agenda

NASA Earth Science Advisory Committee
NASA Headquarters
300 E Street SW
Washington, DC 20546
March 10-11, 2020
Agenda

Tuesday, 10-March-2020
Conference Room 6H41

8:30	Call to Order, Opening remarks	L. Tsaoussi
8:40	SGE Ethics Training	C. Borland
9:40	Meeting Charge	M. Shepherd
9:50	Earth Science Division Update	S. Cauffman
10:30	*Coffee Break*	
10:45	Decadal Survey Implementation Strategy	S. Cauffman
11:45	Discussion	ESAC Members
12:00	*Lunch*	
1:00	Designated Observable Studies	ESD Program Scientists
	Aerosol and Cloud, Convection, and Precipitation	B. Lefer
	Mass Change	L. Tsaoussi
	Surface Biology and Geology	W. Turner
	Surface Deformation and Change	G. Bawden
2:00	Earth Venture Missions	C. Webb
2:45	Earth Venture Continuity 1	D. Considine
3:00	*Coffee Break*	
3:15	Decadal Survey Incubation Studies	R. Bauer
3:45	Discussion	ESAC Members
5:00	Adjourn	

Wednesday, 11-March-2020
Conference Room 5H41

8:30	Opening remarks	L. Tsaoussi/ M. Shepherd
8:35	Public Comment	
8:45	Commercial Data Buy	K. Murphy
9:15	Discussion	ESAC Members

9:30	Machine Learning- Artificial Intelligence	K. Murphy
10:00	Discussion	ESAC Members
10:15	*Coffee Break*	
10:30	Research and Applications Cross-Benefits	J. Kaye/L. Friedl
10:45	Discussion	ESAC Members
11:45	Lunch	
1:00	Cross-Benefits - Air Quality	J. Haynes/B. Lefer
1:15	Cross-Benefits - Disasters	D. Green/G. Bawden
1:30	Cross-Benefits - Conservation	K. Gaddis
1:45	Discussion	ESAC members
2:15	Findings & Recommendations	ESAC members
2:55	Closing Remarks	M. Shepherd/ L. Tsaoussi
3:00	Adjourn	