"White Paper" Summary of the MODIS/VIIRS Science Team Meeting

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Introduction

The Moderate Resolution Imaging Spectroradiometer (MODIS)–Visible Infrared Imaging Radiometer Suite (VIIRS) Science Team Meeting (STM) took place October 15-18, 2018, at the Sheraton Silver Spring Hotel in Silver Spring, MD.

The three-day meeting agenda included programmatic updates from representatives of NASA Headquarters (HQ) on the overall Earth Science Program, and then on MODIS and VIIRS specifically; reports on the status of the MODIS and VIIRS instruments and their respective data products; and several sessions that were used to review algorithm development and science investigations in the Atmosphere, Land, and Ocean Disciplines. There were also opportunities for discipline-specific discussion for Atmosphere and Land,[1] including how to overcome remaining challenges in transitioning from MODIS to VIIRS.

After the STM ended, there was a MODIS Calibration Workshop held on the afternoon of October 18 and a VIIRS Calibration Workshop held the morning of October 19, which focused on the operation and measurement performance of each instrument. The first (Thursday afternoon) session focused on MODIS Calibration while the second (Friday morning) session focused on VIIRS Calibration. To learn more see *Summary of the MODIS–VIIRS Calibration Workshop* on page 27.

The agenda for the week (i.e., the STM and calibration workshops), presentations, and posters can be accessed online at *https://modis.gsfc.nasa.gov/sci_team/meetings/201810*.

Day One

The first day featured an Opening Plenary Session in the morning, followed by a session on data products for MODIS and VIIRS early in the afternoon. Later in the afternoon, the focus narrowed to the Atmosphere Discipline, with emphasis on science analysis and results.

Opening Session

Michael King [University of Colorado—*MODIS Science Team Leader*] opened the meeting by welcoming the participants and reviewing the agenda.

Sandra Cauffman [NASA Headquarters (HQ)—*Deputy Director of the Earth Science Division (ESD)*] gave an opening presentation that helped place the activities of MODIS and VIIRS in the

[1] Note that, for reasons that are explained in the introduction to the *MODIS/VIIRS Ocean Algorithms and Science Analysis* session on page 20, the Ocean Discipline chose not to have a separate Breakout Session at this meeting.

broader context of NASA's Earth Science program. She provided an overview of NASA's Earth Science program, including an update on the status of ESD FY18 and FY19 appropriations. She noted that funding is substantial and is expected to remain at a high level for FY19 and beyond. Cauffman briefly discussed NASA Earth Science missions planned through 2023, and mentioned recent and upcoming flight program events. Recent updates included the end of several missions (QuikSCAT, CATS on ISS, GRACE), the launch of new missions (TSIS-1; NOAA's JPSS-1 (or NOAA-20); ICECube, MIRATA Cubesats; TEMPEST-D, RainCube, and CubeRRT to the ISS; GRACE-FO; ECOSTRESS; ICESat-2), and EVI selections (EMIT and PREFIRE).[2]

Cauffman then provided an overview of NASA's private sector small-satellite constellation pilot project. She explained that NASA has entered into contracts with three private companies (Planet, DigitalGlobe, and Spire)[3] to buy existing data products related to *essential climate variables* (ECVs)[4], derived from private sector-funded small-satellite constellations, for evaluation by NASA researchers to determine the value for advancing NASA research and applications activities and objectives. She added that NASA has identified a broad set of ESD-funded researchers who will be supported to assess the value of the geophysical information in the data products for advancing NASA research and applications objectives. Cauffman also spoke about the importance of NASA's Earth Science partnerships, which currently include Google, Mercy Corps, Microsoft, and Conservation International. These partnerships allow NASA to amplify our work to understand the Earth as an integrated system and enable societal benefit. In closing, Cauffman provided a snapshot of the 2017 Earth Science Decadal Survey,[5] stating that the report identifies the key questions and challenges for Earth System Science, provides emphasis on competition as a cost-control method, explicitly allows implementation

[2] The extensive list of acronyms in this sentence are all misson, instrument, or CubeSat names, which can readily be found online.

[3] DigitalGlobe, a Maxar Technologies company headquartered in Westminster, CO, has five very high-resolution Earth imaging satellites (GeoEye-1, WorldView-1, WorldView-2, WorldView-3, WorldView-4) capable of collecting 30-centimeter resolution imagery. Planet, headquartered in San Francisco, CA, has three satellite constellations (SkySat, Dove, RapidEye) with more than 150 satellites supplying imagery and derived products over the entire Earth at medium and high resolution with high repeat frequencies. SPIRE, headquartered in San Francisco, operates a constellation of over 60 satellites collecting radio occultation soundings, aircraft location information and ship reports. GPS radio occultation measurements can be used to sound the atmosphere for temperature, water vapor, and atmospheric pressure.

[4] Climate Data Records (CDRs), are time-series observational data of sufficient length, consistency, and continuity to record effects of climate change. Examples of CDRs include calibrated radiances, surface reflectance, and surface temperature. Essential Climate Variables (ECVs) are derived in part from CDRs, and address the following terrestrial categories: River Discharge; Water Use; Groundwater; Lake and Reservoir Levels and Volumes; Snow Cover; Glaciers and Ice Caps; Permafrost; Land Surface Albedo; Land Cover; Absorbed Photosynthetically Active Radiation; Leaf Area Index, Biomass; and Fire Disturbance. CDRs and Terrestrial ECVs are parameters derived from systematic long-term measurements collected by satellite and aircraft platforms as well as in situ observation networks.

[5] To learn more see *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space*, which can be viewed and downloaded from https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth.

flexibility, explicitly encourages international partnerships, and endorses existing balances in the ESD portfolio.

Following up on Cauffman's opening overview, **Paula Bontempi** [NASA HQ—*MODIS and Suomi NPP Program Scientist*] provided the NASA HQ perspective on MODIS and Suomi NPP. Bontempi provided an overview of the algorithm maintenance proposals received for the 2017 Earth Science Senior Review [6] of MODIS on both Terra and Aqua (henceforth referred to as MODIS Maintenance). There were 21 proposals received for Terra and 26 received for Aqua.

Focusing in on Senior Review, Bontempi explained that one issue that came up was that some Principal Investigators (PIs) were confused if they were working on a *standard product* or other product. She reminded the participants of the process by which a "new" or "provisional" approach/algorithm is transitioned to a standard data product (which historically has involved development of a formal Algorithm Theoretical Basis Document, or ATBD, which is then peer reviewed), and the difference between an operational data product and algorithm refinements in "research mode."

Bontempi then discussed the details of the most recent Terra/Aqua/Suomi-NPP ROSES (TASNPP) call.[7] She showed the Earth Observing System (EOS) standard land data products recommended for Suomi NPP, ocean products for Suomi NPP, atmosphere data products (from MODIS) recommended for Suomi NPP, atmosphere data products (from Aura's OMI and MLS) recommended for Suomi NPP, and sounder data products recommended for Suomi NPP—as identified in the TASNPP call. She stated that to support accurate estimation of data system capacity to produce and archive products selected through this solicitation, all proposers had to categorize their proposal as either one that continues the generation of existing products; or one that seeks to develop new products or substantially modify existing products.

Bontempi then discussed the selection process for the TASNPP call, specifically with regard to the fact that some products are now *orphaned*, i.e., the Principal Investigator (PI) of a given product was not selected to continue that product. Bontempi said that the science panels were tasked with selecting the strongest proposals and there are no guarantees that a given team will be funded indefinitely. The fact that a given product may be orphaned is not new, but if a product is used by other teams, further discussion is warranted by each of the Disciplines to mitigate the impact. More detailed discussion of this comes up in both the Atmosphere and Land Breakout Session summaries that follow, as well as in the Discipline Summaries at the end.

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[6] Historically, every two years (since 2007) NASA's Earth Science Division has conducted a review of its missions that are in *extended operations*—meaning they have completed their specified prime mission—to assess their operating status, success in achieving mission goals, and merit for continued operation. Moving forward such reviews will be taking place every three years.

[7] This refers to Research Opportunities in Space and Earth Science (ROSES) program element *A.37*: The Science of Terra, Aqua, and Suomi NPP. The text of the proposal can be viewed at https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=553836/solicitationId=%7B40A081E0-D2A1-143D-2475-83DA93A7EC70%7D/viewSolicitationDocument=1/A.37%20TASNPP%20Amend%2010.pdf.

Bontempi added that a select number of the newly chosen Aqua and Suomi NPP PIs will work with NASA's Earth Science Data System Program and Earth Science Data and Information System (ESDIS) Project to develop accurate production and archival sizing estimates. PIs on selected proposals will then work with ESDIS and the Science Investigator-led Processing Systems (SIPS)[8] to implement the proposed products. Bontempi cautioned that algorithm refinements for Standard Products may be important, but they do not generate much excitement on the part of reviewers or program managers. She stated that to satisfy NASA Program Management and better serve the research community, we need to establish a new set of product documentation for the current standard product suite of MODIS and VIIRS, and maintain that level of documentation going forward. Lastly, Bontempi provided a list of discussion topics, encouraging participants to talk with their colleagues about these topics throughout the remainder of the week. These topics became a frequent point of reference throughout the meeting, particularly in the Atmosphere and Land Breakout Sessions discussions, and Discipline Summaries reported on below.

Jack Xiong [NASA's Goddard Space Flight Center (GSFC)] shared status updates on Terra and Aqua MODIS and the VIIRS instrument. He reported that the MODIS instruments on both Terra (nearly 19 years after launch) and Aqua (more than 16 years after launch) and their onboard calibrators (OBC) continue to operate and function normally, and both Suomi NPP (~7 years after launch) and NOAA-20 (~1 year after launch) VIIRS and their OBC continue to operate and function normally. He stated that challenging issues identified for both MODIS and VIIRS will be investigated and addressed for future calibration improvements in support of their data processing/reprocessing, and that more efforts are needed to better understand the calibration differences among sensors (Suomi NPP and NOAA-20 VIIRS; and Aqua MODIS) and to help generate consistent data products of high quality.

Kerry Meyer [GSFC] summarized the cloud team's assessment of relative shortwave radiometry between Suomi NPP VIIRS and Aqua MODIS. He noted that long-term climate data records require merging the observational records of multiple instruments (e.g., MODIS/VIIRS), and that for geophysical product continuity between sensors, relative radiometry (and radiometric stability) is particularly fundamental to the cloud team's physical retrievals. He pointed out that it is much more challenging for solar channels where the absolute reflectance specifications can be greater than the expected climate change signals, and that for cloud optical properties, relative radiometric offsets (even those within specified instrument uncertainties) can induce large non-linear inter-sensor retrieval differences. Then Meyer discussed a plan of action, being used by the Atmosphere Discipline cloud and aerosol algorithm teams, that adds radiometric adjustment factors into the Level-2 code to reconcile radiometric-induced retrieval differences.

[8] ESDIS supports data processing by providing SIPS for processing EOS standard products. Most SIPS are under the direct control of the instrument Principal Investigators/Team Leaders (PIs/TLs) or their designees, and typically collocated with the PIs/TLs' Scientific Computing Facilities (SCFs).

Bryan Baum [Science and Technology Corp. (STC)—*Suomi NPP Team Leader*] provided his perspective on achieving continuity from MODIS to VIIRS. He demonstrated the ability to construct infrared (IR) radiances for imagers based on imager–sounder data fusion, most recently the construction of Aqua MODIS-like channels for VIIRS. This methodology has been expanded to AVHRR+IASI and AVHRR+HIRS.[9] He also stressed the importance of moving from *instrument teams*, which were common 20 years ago, to *measurement teams*—because scientists need data continuity datasets in their research that extend beyond the lifetime of a single instrument. The priority of the Terra/Aqua/Suomi-NPP program is to achieve the best product continuity possible, and this may necessitate use of ancillary data from other polar-orbiting and geostationary (GEO) sensors.

Chris Barnet [STS—*Suomi NPP Sounder Team Leader*] discussed the Community Long-term Infrared & Microwave Coupled Atmospheric Product System (CLIMCAPS), which is a NASA continuity product system that is based on NOAA-Unique Combined Atmospheric Processing System (NUCAPS), and the use of AIRS/AMSU (on Aqua) and CrIS/ATMS (on Suomi NPP and NOAA-20) continuity products for cloud feedback studies.[10] CLIMCAPS uses the NASA GEOS-5[11] product for retrieval initialization. He described the work that has been done to create a hyperspectral sounding continuity product and showed examples of retrieval products that meet the needs of three communities: weather (e.g., extreme events), climate (e.g., processes, long-term trends), and composition (e.g., trace gases and air quality). He stated that NUCAPS is supporting real-time weather and air quality applications, and that the NASA continuity product will focus on developing a long-term (2002–2040) record for AIRS+AMSU and CrIS+ATMS. He concluded by stating that CLIMCAPS is designed to support community needs, asking participants how CLIMCAPS could support their research.

MODIS/VIIRS Data Products and Algorithms Status

Steve Platnick [GSFC—*MODIS Atmosphere Discipline Lead*] chaired this session. These presentations focused on determining aerosol optical properties and science using MODIS and/or VIIRS. The presentations are summarized on **Table 1** on page 5-6.

Table 1. Summary of presentations during *MODIS–VIIRS Data Products and Algorithm Status* session.

[9] Advanced Very High Resolution Radiometer (AVHRR) has flown on a series of NOAA, NASA, and international platforms since 1978; the last AVHRR launched in 2018 on the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT's) MetOp-C platform. IASI stands for Infrared Atmospheric Sounding Interferometer, which has flown on MetOp-A, -B, and -C. HIRS stands for High-resolution Infrared Radiation Sounder, which also flies on the MetOp series.

[10] AIRS stands for Advanced Infrared Sounder, and AMSU stands for Advanced Microwave Sounding Unit. CriS stands for Cross-track Infrared Sounder, and ATMS stands for Advanced Technology Microwave Sounder.

[11] GEOS-5 stands for Goddard Earth Observing System Model, Version 5, which is run by the Global Modeling and Assimilation Office at GSFC.

Presenter [Affiliation]	Topic	Summary
Rob Levy [GSFC]	Aerosol Optical Properties from MODIS: Dark Target (DT) Algorithm	Discussed MODIS aerosol optical depth (AOD) retrievals with the DT algorithm. Showed that DT on MODIS meets two out of five requirements for a Climate Data Record (CDR), with a possibility of meeting a third, and even a fourth and fifth using other sensors. The team continues to work on DT for VIIRS.
Christina Hsu [GSFC]	Status Update on Deep Blue (DB) Aerosol Algorithm for Constructing Consistent Long-Term Data Records From MODIS to VIIRS	Discussed recent progress on the DB algorithm for VIIRS. Showed new aerosol plume height products for VIIRS and MODIS, and the extension of Deep Blue aerosol products from cloud-free to cloudy regions.
Pawan Gupta [USRA/NASA's Marshall Space Flight Center]	Biomass Burning and Aerosol Characteristics in India	Showed how India is suffering from overwhelming particulate air pollution, which is creating significant radiative perturbations. Demonstrated how two decades of satellite aerosol and fire detection products can help with mitigation efforts.
Tamas Várnai [GSFC]	Aerosol Properties in Partly Cloudy Regions	Described efforts to advance our understanding of the effect of clouds and cloud-related processes on aerosol properties and aerosol radiative forcing.
Santiago Gassó [GSFC]	Aerosol Single Scattering Albedo and Layer Height using VIIRS and OMPS-NM (Nadir Mapper)	Explained that there is a need to improve global observations of aerosol absorption and height, which can be done using OMPS-NM and VIIRS data. Showed methodology for retrievals of aerosol optical depth (AOD), single scattering albedo (SSA), and layer height from near-UV to near-IR radiances.
Eric Wilcox [Desert Research Institute] and **Jun Wang** [University of Iowa]	Dynamics of Shallow Cumulus and Stratocumulus Clouds in the Presence of Black Carbon Aerosol	Showed that over the Southeast Atlantic, absorbing aerosols reduce turbulent entrainment in stratocumulus clouds. Similar results are seen over the North Indian Ocean.

MODIS/VIIRS Atmospheric Science Analysis

Steve Ackerman [University of Wisconsin–Madison—*VIIRS Atmosphere Discipline Lead*] chaired this session. The presentations emphasized clouds algorithms and science, though a variety of science topics related to the Atmosphere Discipline were discussed. The presentations are summarized in **Table 2** on pages 7-8.

Table 2. Summary of presentations during *MODIS–VIIRS Atmospheric Science* session.

Presenter [**Affiliation]**	**Topic**	**Summary**
Vince Realmuto [NASA/Jet Propulsion Laboratory]	Thermal Infrared (TIR)-Based Volcanic Sulfur Dioxide Products for Terra, Aqua, and Suomi NPP	Discussed the development of a prototype system for the automated detection and mapping of volcanic sulfur dioxide plumes based on multispectral TIR image data.
Bryan Baum [Science and Technology Corp. (STC)]	Construction of High Spatial Resolution Infrared (IR) Bands from Imager-Sounder Data Fusion	Discussed a construction of missing IR absorption-channel radiances for imagers based on imager-sounder data fusion. The team has provided simulated IR absorption bands similar to MODIS for VIIRS.
Steve Platnick [GSFC]	Cloud Detection, Height, and Optical Properties: Challenges in Extending MODIS to VIIRS	Quantified cloud data record continuity challenges due to calibration (shortwave and IR)—even for sister instruments (MODIS Aqua vs. Terra)—and forward model assumptions. The complexity increases as more sensors, such as VIIRS, are incorporated but progress is being made. Complimented the Atmosphere SIPS for their support.
Ping Yang [Texas A&M University]	Consistency of Ice Cloud Models in Forward Retrieval and Radiative Forcing Assessment	Discussed the scattering of light by nonspherical ice particles and explained that the same ice model must be consistently used in forward remote sensing implementation and downstream radiative forcing assessments.
Yu Gu [University of California, Los Angeles]	Type-Dependent Aerosol Impact on Ice Clouds from Satellite Retrievals	Discussed the impact of various aerosol types on the physical properties of two ice cloud types. Concluded that cloud fraction and

		optical thickness of convection-generated ice clouds increase with small-to-moderate aerosol loadings (<0.3 AOD) but decrease with heavy aerosol loads. For *in-situ* formed ice clouds, however, these cloud properties increase monotonically and more sharply with aerosol loading.
Gerald Mace [University of Utah]	Influence of Volcanic Sulfate Aerosol on Cloud Properties	Showed an analysis of collocated CloudSat radar and CALIPSO lidar data for Heard Island (volcano) to look at data both outside of and within a volcanic plume.

Day 2

The second day of the meeting began with three more presentations related to the Atmosphere Discipline. After that the focus moved to the Land Discipline for the remainder of the morning. The afternoon was dedicated to parallel breakout sessions held by the Land and Atmosphere Disciplines. (Note that, for reasons that are explained in the introduction to the *MODIS/VIIRS Ocean Algorithms and Science Analysis* session on page 16, the Ocean Discipline did not have a separate Breakout Session at this meeting.)

MODIS/VIIRS Atmospheric Science Analysis

Bryan Baum was the chair of this short session., which was really a continuation from Day 1. All presentations in this session describe efforts to incorporate data and products from multiple sensors for their investigations. The scientific studies are continuing to evolve from single- to multiple-sensor data fusion efforts. The presentations are summarized in **Table 3** on pages 8-9.

Table 3. Summary of presentations during *MODIS–VIIRS Atmospheric Science* session *[cont from Day 1]*.

Presenter [**Affiliation]**	**Topic**	**Summary**
Zhibo Zhang [University of Maryland-Baltimore County (UMBC)] and **Hongbin Yu** [GSFC]	Net Radiative Effects of Dust in the Tropical North Atlantic Based on Integrated Satellite Observations and *in situ* Measurements	Showed that observation-based dust radiative effects (DREs) can be derived for the dust aerosols in the Tropical northeast Atlantic from the combination of CALIOP-MODIS-CERES data.
Zhien Wang [University of Colorado]	Characterization of Polar Mixed-Phase Clouds and Tropical Convective	Explained how the synergy of MODIS, CloudSat, and CALIPSO measurements provide global

	Clouds with Multi-Sensor Data Fusion	retrievals of stratiform mixed-phase cloud properties to effectively constrain model simulations. Multi-sensor fusion offers a new potential to characterize tropical convective cloud variabilities.
Ivy Tan [UMBC]	Investigating the Extratropical Cloud Optical Depth Feedback with MODIS, AIRS, CERES, and AMSR	Explained that cloud feedbacks remain the largest source of uncertainty in climate sensitivity estimates, and showed that the CMIP5 models show a robustly negative extratropical cloud optical depth feedback. Further work is needed to determine the role of boundary layer decoupling.

*__Note on undefined acronyms in Table__: CALIOP stands for Cloud–Aerosol Lidar with Orthogonal Projection, which flies on the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission. CERES stands for Clouds and the Earth's Radiant Energy System, which flies on Terra and Aqua platforms. CMIP5 stands for Coupled Model Intercomparison Project, Phase 5, sponsored by the World Climate Research Programme.

MODIS/VIIRS Land Science Analysis

Chris Justice [University of Maryland—*MODIS–VIIRS Land Discipline Co-Lead*] was chair of this session (and the Land Breakout Discussion that followed in the afternoon of the second day). His opening remarks for this session focused on the MODIS to VIIRS transition, particularly as it applies to Land products. He started with some discussion of the heritage (history) of EOS MODIS Land observations. He stressed that Terra and Aqua now provide science quality morning (AM) and afternoon (PM) observations respectively. Terra has been collecting data for nearly 19 years as of this meeting (October 2018), and Aqua for more than 16, meaning we now have the basis for a long-term data record—which is essential for studying the impact of changes in climate—and the data are readily accessible through a variety of means. There have been a series of five or more reprocessings of the MODIS Land data, that provided systematic improvements with each successive reprocessing. Explicit quality assurance procedures have been developed and are routinely implemented at the Land SIPS.

As the Integrated Program Office developed VIIRS, they adopted many—but not all—of the best qualities of MODIS, and in many cases the VIIRS data products have been developed using the heritage algorithms from MODIS, with MODIS PIs heavily involved in the process. With that said, for a number of reasons the two instruments do not have an exact one-to-one matching in terms of algorithms and data products. As Paula Bontempi showed in her remarks in the Opening Session, some MODIS products, including several land products, have been orphaned (i.e., they will not continue with VIIRS). Justice went on to explain some of the reasons for those discrepancies.

The transition between these two instruments presents an opportunity for a Research to Operations (RtO) transition. Opportunities often come coupled to challenges; in this case the challenge is NASA and NOAA figuring out ways to work together for a smooth transition from RtO [i.e., from NASA MODIS (EOS) and Suomi NPP VIIRS to NOAA Joint Polar Satellite System (JPSS) series, e.g., NOAA-20]. The science community already has a long-term record from coarse resolution observations (with the previous transition from AVHRR to MODIS) but this time, with the operational VIIRS instrument also being a science quality instrument, the transition is from one science-quality instrument to another.

Justice then reviewed the MODIS proposals selected related to Land, showing those from the previous selection that were undertaking new science or developing new data products under the Science of Terra and Aqua 2014-2017. After that, he quickly ran through the ongoing projects (MODIS Maintenance) that are part of the recent Senior Review and gave an update on the status of each. He encouraged participants to visit the Poster Session to learn more.

Justice ended his remarks with a summary slide of the foci for the Land Team discussions during this afternoon's breakout session. The overarching theme of his bullet points was for the community to help develop a long-term strategy for NASA Land Products.

Miguel Román [GSFC] followed Justice with an overview of the land data products from Suomi NPP. He showed a flowchart of the NASA VIIRS Land Product Interdependencies. His emphasis was on the impact that the orphaned products from the most recent TASNPP call will have on the flow of data products. He said that as much as possible, MODIS-equivalent Collection 6 products will be used to mitigate effects of orphaned products.

Román then discussed the current status of the VIIRS Land Processing SIPS for Version 1.0 of the Suomi NPP VIIRS algorithm. He also looked ahead to plans for reprocessing efforts beyond Version 1.0, i.e., Version 2.0 for Suomi NPP and Versions 1.0 and 2.0 for NOAA 20 (a.k.a., J1) VIIRS. He then went on to show examples of VIIRS Land products in action. He emphasized the current continuity between MODIS and VIIRS. Several of them (e.g., active fires, cryosphere) show areas where using VIIRS data clearly improves over results obtained with MODIS. He then discussed validation activities for VIIRS.

The remainder of this session consisted of four presentations on selected VIIRS Land products, which are summarized in **Table 4** on pages 10-11.

Table 4. Summary of land product presentations during *MODIS/VIIRS Land Science Analysis* session.

Presenter [**Affiliation]**	**Product**	**Summary**
Dongdong Wang [University of Maryland]	Incident Downward Shortwave Radiation and Photosynthetically Active Radiation (PAR)	Discussed efforts to improve the current algorithm, which is based on limited spectral information and doesn't integrate surface reflectance.

		The work combines data from VIIRS, MODIS, and geostationary satellites.
Xiaoyang Zhang [South Dakota State University]	Land Surface Phenology	Described metrics of the Global Land Surface Phenology (GLSP) Product. Showed how incorporating VIIRS data improves the ability to track progress of growing season. Compared both MODIS and VIIRS data to ground-based datasets to validate results.
Miguel Román [GSFC]	NASA's Black Marble Standard Suite	Described the "Black Marble," a new standard product using VIIRS Day–Night Band (DNB) to detect night lights—but the goal is to do science using the lights. Discussed the algorithm and gave several examples, showing the product's versatility. Emphasized work done in Puerto Rico before and after Hurricane Maria.
Glynn Hulley [NASA/Jet Propulsion Laboratory]	VIIRS Land Surface Temperature and Emissivity (LST&E) Product	Discussed the status of the current algorithm and validation efforts. Showed data from three validation sites: Redwood National Forest, Lake Tahoe, Algodones Dunes (desert). Discussed applications including improved detection of impact of turf removal in CA and heatwave detection.

Breakout Sessions

The afternoon of the second day included parallel breakout sessions for the Atmosphere and Land disciplines.

Atmosphere

Steve Ackerman and **Steve Platnick** facilitated the Atmosphere Breakout discussion, which intentionally emphasized open discussion over a series of presentations on specific research topics. Discussion topics focused on how to efficiently and effectively produce useful EOS–Suomi NPP/JPSS continuity data products for science team investigators and the larger community. Ackerman and Platnick began with some opening remarks to set the tone for the discussion. Steve Ackerman reported that project summaries, represented as two-page slides,

were collected from all Atmosphere Science team PIs and will be distributed to the Atmosphere Team.[12]

At the request of the facilitators, **Kevin Murphy** [NASA HQ—*NASA Program Executive for Earth Science Data Systems*] clarified some questions that had come up during and/or after Paula Bontempi's remarks in the Opening Plenary concerning the status of orphaned products. He explained that if a product is supported only through Senior Review maintenance, MEaSUREs,[13] etc., the SIPS is still tasked with production as long as the PI can support the product. This includes archiving and delivery of the data through the Level-1 and Amosphere Data Distribution System (LAADS). On the other hand, if a PI is no longer funded, they need to indicate that the product is no longer supported (i.e., orphaned) and that SIPS can only continue to support orphaned products until it breaks, e.g., new production system. Murphy concluded by noting that some products that are currently orphaned may be supported as the schedule develops.

Liam Gumley [UWM] gave the only formal presentation during this breakout, focusing on the Atmosphere SIPS. Following on Murphy's comments, he noted that if an orphaned atmosphere product (e.g., Dark target aerosol, water vapor, cirrus reflectance) has sufficient resources to support product development, SIPS can support production and port to LAADS. An overview of the Atmosphere SIPS processing is summarized in **Table 5** on page 13. Gumley explained that the Deep Blue Aerosol (AERDB) products have been reprocessed four times in the past year, and showed an example using Worldview. He showed an example of the Cloud Mask (CLDMSK) products in Worldview, and also demonstrated the impact of the Cloud Top and Optical Properties (CLDPROP) product by showing comparison of Level-3 (L3) data processing versus swath width.

The group discussed the importance of stewardship and SIPS showed as an example of the CLDPROP flow chart, which is generated automatically.

The group supports the use of the NetCDF4 data format for continuity products and the intention is to transition to NetCDF4 for future MODIS collections.

Following Gumley's presentation, there was more discussion on product documentation and publications. Specifically, clarifying the definitions of and need for User Guides and ATBDs, along with the history. The consensus of the Atmosphere Team was to focus on User Guides, which often refer to previous ATBDs and published papers, but will accommodate additions to a User Guide. Continuity product User Guides have been written and are hosted at LAADS. Science team investigators asked to provide input on the documents.

[12] These summaries can be found at https://www.ssec.wisc.edu/mvac/october-2018-meeting. Note that some Team members had just received funding when the meeting took place , and thus did not have slides compiled.
[13] MEaSUREs stands for Making Earth Science Data Records for Use in Research Environments.

Product Description*	Product Short Names	Spatial resolution	Product PI(s)	SIPS Production and Delivery to LAADS
Cloud Mask (day/night)	CLDMSK_L2_VIIRS_SNPP CLDMSK_L2_MODIS_AQUA	0.75 km 1.0 km	Ackerman Holz	Completed May 2017
Deep Blue Aerosol (day)	AERDB_L2_VIIRS_SNPP AERDB_D3_VIIRS_SNPP AERDB_M3_VIIRS_SNPP	6.0 km 1° x 1°	Hsu	Completed Oct 2018
Cloud Top and Optical Properties (day/night)	CLDPROP_L2_VIIRS_SNPP CLDPROP_D3_VIIRS_SNPP CLDPROP_M3_VIIRS_SNPP CLDPROP_L2_MODIS_AQUA CLDPROP_D3_MODIS_AQUA CLDPROP_M3_MODIS_AQUA	0.75 km 1° x 1° 1° x 1° 1.0 km 1° x 1° 1° x 1°	Platnick Heidinger	Expected Oct 2018 Expected 2018

Next there was discussion of the status of the products and the schedule, focusing on some continuity challenges and remaining uncertainties.

Table 5. Overview of Atmosphere SIPS processing status. *[See next page.]*

*__Note__: Reprocessing Rates for Products in Table—*AERDB*, 1100x; *CLDMSK*, 2920x; and *CLDPROP*, 132x.

There was discussion about continuity challenges between MODIS and VIIRS, specifically how do the algorithm groups plan to demonstrate that products have continuity? There was an exchange between algorithm developers and science investigators, which suggested that acceptable continuity depends on product usage. Current foci of developers includes developing time series across large spatial regions, pixel-level intercomparisons (to the extent possible), and using other independent methods (e.g., ground-based networks).

With regard to uncertainty, the consensus was that there is no single/simple answer or methodology to determine product uncertainty, as it depends on part of the state space, and what datasets or combination of datasets are used. Approaches used by Atmosphere Algorithm developers include:

- Pixel-level for quantitative error sources that we understand (cloud optical and top datasets in CLDPROP have associated uncertainty datasets).

- Statistical approaches based on independent measurement techniques that cover some aspects of a product suite: e.g., Aerosol Robotic Network (AERONET, near global) and other ground-based assets (typically not extensive), field campaigns, independent satellite assessment (e.g., CALIOP for cloud mask and cloud-top).
- L3 data time/space aggregation uncertainties are more complicated since error source correlation on time/space scales needs to be understood.

There was also discussion about the status of L3 data products, which was not explicitly proposed in the TASNPP call—but not orphaned. Points included:

- An Atmosphere SIPS L3 capability for scalar statistics was initially pursued for QA purposes but evolved to support a production L3 infrastructure for interested teams.
    - The SIPS L3 infrastructure is referred to as the "Yori" tookit. Yori Configuration Files (aggregation rules and QA-filtering) are developed by/responsibility of algorithm team.
    - Currently being used for CLDMSK and CLDPROP VIIRS and MODIS streams. Will provide MOD08-equivalent datasets including all scalar, 1D and 2D histograms (daily, monthly).
- AERDB has separate SeaWiFS-like L3 product (daily, monthly); results similar to MOD08.
- Working toward defining if/how users can tailor their own aggregation needs for their studies.
- MODIS-like L3 browse imager and web site not yet developed. Will investigate leveraging MODIS-Atmosphere browse scripts.

There was also discussion about how to address relative calibration issues between VIIRS and MODIS. Adjustment factors have been developed by the Cloud and Aerosol Algorithm Teams. SIPS provides intersensor match files needed for calibration assessments and for monitoring of adjustment factors. DB Aerosol (AERDB) and CLDMSK/CLDPROP use different VNIR/SWIR adjustment factors, but very close in most bands. Adjustment factors are reported in L2 products provided in CLDPROP files. AERDB was requested to do so in their next release. SIPS reprocessing can be used for assessing time-dependent adjustments. AERDB has time-dependent linear adjustment (Sayer et al., 2017). Questions remain such as: How often do we need to change coefficients? How to keep science quality in forward stream? No decisions were made with regard to those questions.

Another issue that came up during the discussion was the need to add NOAA 20 (JPSS-1) to the calibration intercomparison infrastructure. This led to the broader question: *How will the SIPS continue to support calibration activities that need new satellites?*

The discussion wrap up included an Atmosphere Discipline priority to work with the new generation of GEO imagers (ABI, AHI), including Aerosol Dark Targets. All algorithms have been ported and had initial (limited) testing on these GEO imagers.

Land

Chris Justice facilitated the discussion, assisted by **Miguel Román**. Justice started by giving an overview of topics to be covered throughout the afternoon in freeform discussions and/or specific presentations. They included:

- Formulation of MODIS–VIIRS STM responses to Paula Bontempi's suggested topics for further discussion;
- Discussion of the status of MODIS Collections 6 and 6.1 (C6 and C6.1);
- Discussion of VIIRS delivery and related issues;
- Discussion of Land Processes Distributed Active Archive Center (LP.DAAC) and National Snow and Ice Data Center (NSIDC) data product distribution status and product use;
- Discussion of VIIRS and Sentinel-3 Surface Reflectance, and a broader conversation about the potential of having Sentinel-3 serve as a *de facto* "AM Platform" after Terra is turned off;
- Discussion of Suomi NPP and NOAA-20 Land Products; and
- Discussion of Land Product Synergy.

Justice then went back to some slides from **Paula Bontempi**'s overview presentation during the previous day's Opening Plenary, where she requested further discussion on a variety of topics. There was discussion of current land proposals and where they fit in terms of elements from the TASNPP call[14] and ensuring the Land SIPS has the information it needs in terms of product integration and generation planning. There was also discussion of VIIRS Land orphaned products, and how they will be managed by Land SIPS—following the example of the Ocean Team. **Glynn Hulley** [GSFC] noted that he wants to reduce the number of land surface temperature (LST) products currently being supported.

Kevin Murphy gave some HQ direction on orphaned products.[15]

There was then a discussion about the need for a continued science presence in Quality Assurance (QA) and that the SIPS has been stepping up to perform this task. The SIPS has also been increasingly involved in coding for some of the Land products. Justice enquired as to the current work load for MODIS maintenance, given that we will now have to maintain two algorithms: MODIS and VIIRS. The question is whether at the end of this funding cycle, VIIRS products will go into Senior Review?

Another question that came up was whether the Team is providing sufficient information for users to be able to easily access and use the products. The Land Team has, for a number of years, given emphasis to the User Guides rather than ATBDs, which were really intended for

[14] The elements were: *2.1* Sensor Fusion; *2.2* New Data Products; *2.3* Continuity Product Creation; *2.4* Near Real-Time (LANCE).

[15] See the Atmosphere Breakout report (page 11) for details. Murphy gave essentially the same remarks to both Breakouts.

reviewing whether a product would be suitable as a standard product. **Crystal Schaaf** [University of Massachusetts, Boston] voiced her strong opinion that User Guide updates really are key for users. People download a large document like an ATBD once, and don't do it again. Miguel Román stressed the importance of learning more about the makeup of our User Community. Many of our "users" are non-academics, and learning curve is steep.

Justice next reminded the participants that the Land SIPS Recompete is coming up. This will likely include non-NASA (international) data processing, e.g., Sentinel-3 (AM OLCHI, SLSTR) and perhaps GEO missions, in the framework of moving from a mission/instrument-focus to a measurement-focus. The questions for Land are: Where will these data be processed, and will there be higher level products and, if so, who will take care of their stewardship? The question was raised as to how NASA intends to implement a *missions to measurements* agenda. One suggestion was that this could be a new focus for their MeASUREs program.

Resources are being put into the MODIS Characterization Support Team (MCST) and VIIRS Characterization Support Team (VCST). Justice enquired whether their findings are getting back to the Team for the key products (e.g., surface reflectance, LST). There was also interest in understanding how the two MODIS Land calibration activities funded under the Senior Review contribute to the overall calibration efforts and the associated land products. For land product validation, given the limited funding PIs are encouraged to leverage the activities of the Committee on Earth Observation Satellites (CEOS) Land Product Validation (LPV) Working Group. Justice noted that NASA continues to take a lead role in CEOS LPV activities.

In her opening remarks, Paula Bontempi said: *"Algorithm developments for standard products may be important, but they do not generate much excitement on the part of reviewers or program managers."* The group had a discussion around this statement. Reviewers need better understanding in terms of what it takes to develop and generate the land products and which products the broader community sees as being important. The question was raised as to which land products the community desires? This topic will be the subject of a land workshop to be held in 2019.

After this conversation came four presentations on some of the specific topics Justice outlined at the beginning. These are described in **Table 6** on pages 16-17.

Table 6. Summary of presentations during the *Land Breakout* session.

Presenter [**Affiliation]**	**Topic**	**Summary**
Sadashiva Devadiga [GSFC]	MODIS C6 and C6.1	Discussed lessons learned from C6 processing and factors that necessitated reprocessing (i.e., C6.1). Explained calibration issues with Level-1B (L1B) as well as polarization correction. Went through the specific products that had changes from C6 to C6.1. Described the reprocessing plan

		for C6.1 and looked "beyond 6.1" to the eventual C7.
Miguel Román [GSFC]	VIIRS Delivery and Issues	Summarized VIIRS Suomi NPP product and Product Generation Executive (PGE) status. Discussed accessing VIIRS images in Global Imagery Browse Service (GIBS). Discussed plans for Suomi NPP Version 2 and J1 Version 1 reprocessing. Discussed maintenance and use of upstream products.
Kara Gergely [NSIDC] and **Tom Maiersperger** [LP.DAAC]	Updates on Data Product Use and Distributions	Each presented Land Product Distribution statistics and Issues at their respective organizations, gave background on use of products, and showed examples of data products being applied. The metrics of both LPDAAC and NSIDC are remarkably similar with regard to distribution of MODIS products.
Eric Vermote [GSFC]	VIIRS and Sentinel-3 Surface Reflectance	Discussed an effort to create long-term record of climate data—back to the AVHRR and work on a sensor agnostic solution for *atmospheric correction*. Ended with a comparison of the bands on instruments on Sentinel-3 and MODIS. Land Surface Reflectance Code (LaSRC) offers a mature pathway. Discussed Sentinel - 3 as a possible follow-on for the AM platform.
Ivan Csiszar [National Oceanic and Atmospheric Administration's NESDIS Center for Satellite Applications and Research (STAR)]	Suomi NPP and NOAA-20 VIIRS Products Update	Showed the plan for polar missions after NOAA-20. Gave updates on cal/val efforts for NOAA-20 and migration of Environmental Data Records from Interface Data Processing Segment (IDPS) to Enterprise Products. Showed a chart of Suomi NPP Enterprise Data Products. Ended with examples highlighting the value of having both Suomi NPP and NOAA-20 in orbit.

There was more discussion following these presentations on a topic that continues to come up during the discussions. Namely, can NOAA and NASA find ways to effectively collaborate on products from the JPSS missions? Justice suggested that it would take "buy-in" from management of both organizations to do this over the long-term, with an intentional framework to get us where we want to go. Paula Bontempi indicated "there is currently no NASA money allocated for products from the JPSS series." However, **Jim Gleason** [GSFC—*Suomi NPP Project Scientist*] felt that to the extent we can show our products have value for answering critical Earth Science questions, we will continue to receive funding.

Justice then led an initial discussion on a Land Product Strategy during which the group returned to the Land Team Foci for this Meeting that Justice had shown in his morning presentation. During the conversation someone asked whether rapid advances in moderate-resolution and hyperspectral imagery capabilities will eventually render coarse-resolution products (e.g., MODIS and VIIRS) obsolete. Justice felt that while global scale products from Landsat/Sentinel are now feasible, we are a long way from a suite of standard products that would make coarse resolution products redundant.

Hank Margolis [NASA HQ—*Program Manager for Terrestrial Ecology Program*] closed out the breakout session with the "HQ Perspective" on these various topics. He showed the NASA Science Fleet diagram and remarked that NASA Administrator **Jim Bridenstine** has been quoted as saying "Earth is my favorite planet," and yet we heard earlier from Paula Bontempi that for Program Managers and Reviewers that "Algorithms are boring." There appears to be a gap between these two statements. How do we close this gap? Margolis felt that one key is to continue to produce groundbreaking science.

Margolis suggested that Team members can help with Peer Review panels for proposals. Also, when a publication is created, be sure to acknowledge NASA programs. (Vince Salomonson noted there are more Terra-related publications than Hubble Space Telescope-related publications.) Team members should also share new ideas with HQ, ideally via white papers. He ended by noting that the 2017 Earth Science Decadal Survey offers intriguing possibilities, particularly for Terrestrial Ecology.

Day Three

The morning of the third day was for the remaining Land Discipline presentations. Following that, the Ocean Discipline took center stage for the remainder of the day.

MODIS–VIIRS Land Science Analysis

Chris Justice chaired this session, which concludes the presentations that began on Day 2, and includes presentations from some of the "newly selected investigators." He also mentioned that the final presentation in this session was from a new NASA initiative—GEONEX focused on generating products from GEO data. These presentations are described in **Table 7** on pages 19-20.

Table 7. Summary of presentations during the *MODIS–VIIRS Land Science Analysis* session [*cont from Day 2]*.

Presenter [**Affiliation]**	**Topic**	**Summary**
Feng Gao [U.S. Department of Agriculture's Beltsville Agriculture Research Center (BARC)]	Phenology and Productivity in Agriculture	Discussed a prototype method for high-resolution measurements of evapotranspiration. Summarized proposed improvements and listed the measurements and satellite data that will be used. This activity shows the synergistic value of multiple sensors (including MODIS and VIIRS) for research and operational issues.
Fangni Lei [BARC**]** on behalf of **Wade Crowe** [BARC]	Integrating Multi-Platform Satellite Soil Moisture and Evapotranspiration Retrievals to Constrain Water and Energy Balance Coupling	Described work to assess whether current land surface models accurately characterize the relationship between soil moisture and evapotranspiration. MODIS data are input into the Atmosphere–Land Exchange Inverse (ALEXI) model and Noah as well as the Noah land surface model with multi-parameterization options (Noah-MP). Results reveal large discrepancies among existing land surface models.
Edward Bair [University of California, Santa Barbara]	Fusion of MODIS, VIIRS, and Landsat Snow Cover Data to Create Estimates of Snow Water Equivalent	Explained that snow cover in mountains varies dramatically, both spatially and temporally. Current satellites have high-temporal or high-spatial resolution—not both. Described Snow Water Equivalent (SWE) reconstruction technique using the Parallel Energy Balance (ParBal) model. Described a statistical method to fuse data at different spatial scales, e.g., MODIS, VIIRS (500 m) and Landsat (30 m) and showed some preliminary results.
Rob Wright [University of Hawaii]	Multi-Sensor Analysis of Global Volcanic Thermal Unrest	Described research to identify and characterize volcanic unrest using MODIS, called MODVOLC. Described plans to transition to VIIRS data using time-series analysis. Showed some initial results from Hawaii. Combined

		MODIS/VIIRS observations over volcanos correlate with other measurements and offer a means to predict eruptions from space.
Huilin Gao [Texas A&M University]	Developing a Long-term Global Reservoir Product Series by Fusing Multi-Satellite Observations	Discussed a Global Reservoir and Dam (GRanD) database and the challenges of getting reliable ET data over reservoirs. Satellite altimetry (e.g., ICESat) data have been used on large lakes and reservoirs (e.g., Lake Powell)—but coverage is limited. Incorporating data from MODIS and VIIRS into GRanD has overcome this limitation. Discussed plans to create a comprehensive, coherent, and long-term global reservoir product series: reservoir storage and reservoir evaporation.
Rama Nemani [NASA's Ames Research Center]	GEONEX: A NASA-NOAA Collaboration for Producing Land Surface Products from Geostationary Satellites	Described the GEONEX processing system (based on NASA Earth Exchange (NEX) framework), which is a collaborative effort for generating Land Surface products from new generation of GEO missions, which have resolutions comparable to MODIS and VIIRS. Described work to adapt Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm for use in GEONEX. Showed some preliminary products from GEONEX.

MODIS/VIIRS Ocean Algorithms and Science Analysis

Brian Franz [GSFC—*MODIS–VIIRS Ocean Discipline Co-Lead*] chaired this session. He began by mentioning that Ocean Discipline Team attendance is light due to another ocean-related meeting taking place this week.[16] Taking this into consideration, the Ocean Discipline opted ***not*** to have a separate Ocean Breakout at the MODIS–VIIRS STM. Franz reported that an Ocean Discipline Telecon—with complete attendance of all Ocean Discipline PIs—was held on July 16, 2018 and served as their "Breakout Session"—see *Ocean Discipline Summary Report* on page 24 for details on content of telecon. Given the conflict with the other meeting, the presentations

[16] This was the Ocean Optics XXIV meeting held October 7-12, 2018 in Dubrovnik, Croatia.

from the Ocean Discipline for this year largely emphasized new work and cross-disciplinary efforts, as summarized in **Table 8** on pages 21-23.

Table 8. Summary of presentations during *Ocean Algorithms and Science Analysis* session.

Presenter [**Affiliation]**	**Topic**	**Summary**
Bryan Franz [GSFC]	Continuity of MODIS & VIIRS Ocean Color Products	Reported that the ocean color time series was reprocessed in 2018 (which includes data from SeaWiFS, MODIS, and VIIRS). Discussed changes to the Marine Optical Buoy (MOBY) (global deep water) time series as well as updates on MODIS Aqua calibration. Showed 21-year Multimission Chlorophyll Timeseries. Discussed Atmospheric Correction algorithm refinement, and other areas for future development. Compared MODIS Aqua to MODIS Terra.
Kirk Knobelspiesse [GSFC]	Joint MISR/MODIS Ocean Color Atmospheric Correction with an Algorithm that Utilizes Reflected Sun Glint	Described MODIS Ocean Color with MISR Atmospheric Correction (MOCMAC), which uses Multi-angle Imaging SpectroRadiometer (MISR) data to benefit MODIS Terra atmospheric correction. Showed how multiangle observations in near infrared improve accuracy of aerosol modeling. Discussed efforts to refine reflected sun glint characterization using direct observations that "work with the glint"—as opposed to traditional approach that screen it out.
Irina Marinov [University of Pennsylvania]	Carbon-based Phytoplankton Size Classes using Multi-platform Ocean Color Observations	Explained that phytoplankton size groups (PSG) are a proxy for Phytoplankton Functional Types (PFTs). Described how PSG is calculated, showing examples from the Santa Barbara channel. Mie Scattering Theory links PSGs to optics and allows measurement from space. Showed global maps of pico, nano, and micro-plankton populations. Mentioned three applications detecting subtropical trends;

		detecting flavors of ENSO in the tropics; and comparing PFT Algorithms and climate models.
Barney Balch [Bigelow Laboratory for Ocean Sciences]	Particulate Inorganic Carbon from MODIS	Gave a brief primer on the importance of *cocholithophores*, one-celled animals that are strong drivers of ocean biogeochemistry and optics and affect CO_2 balance. Discussed new *differencing algorithm* for Particle Inorganic Carbon (PIC). Described recent research, including participation in a seven-week cruise on the R/V *Endeavor* in July 2018 that coincided with the largest cocco bloom (in area) in 30 years!!
Jing Tan [Scripps Institution of Oceanography]	Estimating the Fraction of Photosynthetically Available Radiation Absorbed by Live Phytoplankton from MODIS and VIIRS Data	Discussed fraction of Absorbed Photosynthetically Available Radiation (APAR), which is related to chlorophyll concentrations. Discussed algorithm development and optimization and how uncertainties are assigned using linear combinations of marine reflectance. Showed some preliminary results. Concluded with comparison of DSCOVR EPIC and MODIS measurements of APAR.
Lorraine Remer [University of Maryland-Baltimore County]	Understanding Airborne Fertilization of Oceanic Ecosystems using MODIS, VIIRS and CALIPSO	Explained how adding iron directly to the ocean increases biomass, changes physiology, and cranks up carbon engine. Atmospheric aerosol often contains iron. Showed a flowchart to illustrate the challenge of detecting dust deposition from satellite over the oceans—and they did the same exercise over land. (This proposal was really a hybrid between Ocean and Atmosphere.)
Goshka Szczodrak [University of Miami]	MODIS and VIIRS SST: Validation of Continuity Products and Results from Alternative Algorithms	Discussed skin sea surface temperature (SST) validation work using two kinds of shipborne radiometers: Marine–Atmospheric Emitted Radiance Interferometer (M-AERI) and Infrared Sea Surface Temperature Autonomous

		Radiometers (ISARs). Showed comparison of M-AERI observations with MODIS data. Discussed planned SST algorithm improvements including new cloud mask based on Alternating Decision Trees and improved ability to correct for aerosol effects.
Prabhat Koner [University of Maryland, ESSIC]	Use of SWIR Channels for Daytime Sea Surface Temperature Retrieval"	Described a *physical deterministic s*ea surface temperature (PDSST) retrieval and contrasted it with *stochastic inverse* (i.e., regression) retrieval that is the basis for current satellite SST retrievals. Described how PDSST is computed and then summarized advantages of PDSST over traditional SST retrievals. Showed examples of current GOES-13 daytime SST retrievals. Conclusion is PDSST retrieval could retrieve at least twice as much information as traditional retrievals.

Day Four

The final morning of the meeting contained only one additional presentation on the Global Imagery Browse System (GIBS) and Worldview.[17] After that, there were plenary reports from each Discipline team (Land, Ocean, Atmosphere) on their deliberations over the course of the meeting, primarily focusing on the Breakout discussions, followed by a closing discussion. The afternoon and Friday morning were used for Calibration Workshops.

MODIS and VIIRS Data Access Through GIBS and Worldview

Matt Cechini [Science Systems and Applications, Inc. (SSAI)] and **Ryan Boller** [GSFC] discussed the availability of MODIS and VIIRS products via the GIBS/Worldview system. Cechini began with an overview of GIBS/Worldview. He noted that 83% of tile requests are for MODIS and VIIRS imagery. Boller covered Worldview, showing a demonstration of the application's capabilities, particularly as they are applied to viewing MODIS and VIIRS imagery.

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[17] Worldview is an application (which runs in GIBS) that enables interactive browsing of global satellite imagery within hours of it being acquired— https://worldview.earthdata.nasa.gov.

Land

Chris Justice began by saying that he feels the next three years will be critical for the future of land products for NASA Earth Science. A long-term goal of NASA Earth Science is the creation of Earth System Data Records—i.e., continuity. The Land Team is wrestling with how to make the transition from EOS to JPSS. Justice suggested now is the time to plan for change but also a time to look back assessing "lessons learned" from our past. He showed a photo of the MODIS Land Team from 2001. He estimated that 70% of the people in the photo are still in the room today. He payed tribute to Vince Salomonson and all those who helped build a strong foundation for the NASA land products and the associated science from MODIS and VIIRS. He summarized the content of Land breakout session discussions.

Steve Running [University of Montana] suggested having an *EOS Victory Lap* and a special session at the 2019 AGU (which is AGU's hundredth anniversary meeting) providing a chance to look back on the 30 years of EOS, and plan "the next 30 years". He agreed with Justice's earlier statement that the next three years are crucial in planning for the future of NASA Earth Science.[18]

Atmosphere

Steve Ackerman explained that this group had only one presentation (by Atmosphere SIPS), and the breakout was discussion focused. Ackerman summarized the discussions noted above, noting the following action items:

- DB Aerosol (AERDB) and CLDMSK/CLDPROP use different VNIR/SWIR adjustment factors, but adjustments are very close in most bands. Adjustment factors are reported in Level-2 (L2) products provided in CLDPROP files. AERDB was requested to do so in their next release. SIPS reprocessing can be used for assessing time-dependent adjustments.
- Atmosphere team members provided summary slides (2 slides each) which will be made available to the atmosphere team.
- Science team investigators asked to provide input on the User Guides.
- We continue to work towards defining how/if users can tailor their own aggregation needs for their studies.
- MODIS-like L3 browse imager and web site are not currently supported or developed. Leveraging MODIS-Atmosphere browse scripts is under investigation.

[18] Such an event was held in Washington, DC, in June 2009, to mark the twentieth anniversary of the EOS program. To read a summary, see "NASA Earth System Science at 20: A Symposium to Explore Accomplishments, Plans, and Challenges" in the September–October 2009 issue of *The Earth Observer* [**Volume 21**, **Issue 5**, pp. 18-30 & 39—https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/Sept_Oct09.pdf#page=18].

- Atmosphere team members are interested in and working with new generation of GEO imagers (ABI, AHI).[19] Algorithms have been ported/tested on these imagers.

Ocean

Bryan Franz discussed details of the Ocean Discipline Team's telecon on July 16, 2018, that served as their "Breakout Session." The telecon had full participation; the agenda included programmatic business, ocean team overview, organizational procedures and responsibilities, and discussed PI proposals. He also reported on the status of the Ocean proposals selected under the TASNPP call as well as the MODIS Senior Review Product Maintenance Proposals. [20]

He noted that the Ocean SIPS are producing Ocean Color and Sea Surface Temperature (SST) from MODIS (on both Terra and Aqua) and VIIRS (on Suomi NPP only). Franz showed a list of when each dataset (i.e., Ocean Color and SST for MODIS and VIIRS respectively) was reprocessed.

Franz then showed a list of Ocean standard products, pointed out the two *orphaned products* for the Ocean Discipline, and then showed four possible future standard products. Similar to the Atmosphere and Ocean Breakout Sesssion described in this article, there was more discussion at the telecon about: *When does a product become "standard?"* Franz showed the procedure the Ocean Discipline follows for a product to become standard. He noted that they are trying to develop a more modern approach.

The Ocean team also touched on another question with which all Disciplines are wrestling at the moment: *What constitutes sufficient documentation for a data product*? Franz said that an end user needs a product guide—and it needs to be kept up to date. The overwhelming consensus from all three Disciplines is that, after the initial ATBD is compiled at the beginning of a mission, a User Guide is preferred for updates. A User Guide is more practical and, at least theoretically, kept up to date. In place of a User's Guide and/or ATBD, the Ocean SIPS utilize *Product and Algorithm Description Documents* (PADD), which is a living document that includes: a brief description of the product and its purpose, a brief description of the algorithms with links to associated publications for more details; details of implementation differences for each sensor; direct (live) links to source code for even more details; and product validation results with live links.

Franz then discussed the status of support for VIIRS on NOAA-20 (a.k.a., J1). The Ocean SIPS have been funded to acquire J1/VIIRS Level-0 data and produce Level-1B and Level-2 and -3 continuity products. However, the MODIS–VIIRS Science Team has **not** been funded to support J1/VIIRS. The Ocean Science Team is trying to offer support in whatever ways it can. In

[19] ABI stands for Advanced Baseline Imager, which flies on NOAA's GOES-R series (NOAA-16 and 17). AHI stands for Advanced Himawari Imager, which flies on Japan's Himawari geostsationaary satellites (Himawari-8 and -9).
[20] Note that, though not shown in his closing presentation, Brian Franz's *Power Point* also included overview slides on each of the Ocean proposals. There were presentations on several of these topics during the earlier *MODIS–VIIRS Ocean Algorithms and Science Analysis* session.

particular, Ocean Science Team is supporting generation of atmospheric correction look-up tables and performing vicarious calibration. Furthermore the OB.DAAC is currently distributing the J1/VIIRS L1B, L2, and L3 Ocean Color products produced by the Ocean SIPS (http://oceancolor.gsfc.nasa.gov).

Closing Discussion and Reflections on the Way Forward for the MODIS–VIIRS STM

Michael King [University of Colorado] opened up closing discussion with his own reflection on the meeting. He enjoyed the history, and thought there was value in continuing to offer this kind of gathering. He enjoyed the Plenaries where we get to hear from all disciplines.

On the issue of ATBDs that came up several times at this meeting, King is somewhat of an authority. He was responsible for five of them in his role as EOS Senior Project Scientist in the mid-1990s. At that time, ATBDs were written prior to coding of instrument algorithms. Although the last ATBD he authored was published in 1997 he noted that many publications have been based on the physics in those documents.

King also noted that he has been asked to do "accomplishments of each instrument" for Terra's 20th anniversary. Alan Ward reminded him that *The Earth Observer* newsletter published an article for Terra's fifteenth anniversary that listed 15 accomplishments broken down in terms of the five instruments onboard.

Steve Running another veteran of the EOS Program (Land), offered his perspective on the meeting format. He said that he actually did get inspiration for one of his investigations from an Ocean Discipline presentation at a MODIS STM. "Gee," he thought, "If sea level didn't rise, where did all that water go?" That became the impetus for research that led to a major publication.

Chris Justice mentioned that at one point, EOS Investigators Working Group (IWG) Meetings were a way to bring disciplines together. Those meetings were driven by interdisciplinary science (IDS), but they stopped happening in November 2002 for a variety of reasons. He suggested that maybe something akin to an IWG Meeting could be a way to reframe these STMs to make them more effective and aligned with the 'missions to measurements' agenda.

Vince Salomonson [University of Utah] has a long history with NASA Earth Science and offered some "big picture" words of wisdom. His assessment was that a restylization of the Earth Science program might be in order at this point. He noted that generational change is happening—and not just at NASA but everywhere in society. EOS was a brave new program in its day. Shelby Tilford and Francis Bretherten were "pioneers". NASA has always thrived on new technologies. EOS was that kind of thing at the time. We need that kind of innovation again. He even had a fun name to suggest: Global Observations for Sustainable Humanity, or GOSH. All kidding aside, he thought that most would agree that Earth has a survival issue. He believes NASA needs to be part of the solution.

Paula Bontempi said that she intends to take the input from these disciplinary summaries back to her colleagues. Her slides in the Opening Session were a conglomeration of issues. She used information from the last MODIS-VIIRS STM to come up with her slides for this meeting.

Taking a moment of personal privilege, Bontempi reflected that she might be one of the few people in the room today who will still be at NASA by the time the "third Decadal Survey" is conducted. We are leaving behind the "EOS era." She noted that our international partners have built their own programs. We are back to a pioneering era of sorts; we are back to "cutting metal." She said that Mike Freilich [NASA HQ—Director of Earth Science Division, *outgoing*] really wanted focus on Earth System Science in the second Decadal Survey. Leadership thinks "we're there" but proposals are lagging behind: e.g., still focusing on tweaking existing algorithms. She asked the Team to consider: If you had unlimited resources, what would you want to do?

Referring back to Salomonson's remarks, Bontempi added that, in her opinion, Decadal Surveys are open opportunities to submit white papers about "what the priorities for the next generation should be." Decadal Surveys have created new methods to have missions: e.g., the Earth Venture program. Funds may not be abundant as they once were, but she encouraged the Team to take advantage of the programs that do exist.

Summary of the MODIS–VIIRS Calibration Workshop

As a supplement to the MODIS–VIIRS STM, a Calibration Workshop was held in the afternoon of October 18 and the morning of October 19, focusing specifically on the calibration and characterization of the Terra and Aqua MODIS, and Suomi NPP and NOAA-20 VIIRS instruments. **Jack Xiong** and **Jim Butler** [both from GSFC] chaired the workshop, which included presentations from both the MODIS and VIIRS Characterization Support Teams (MCST/VCST) and from Atmosphere, Land, and Ocean Discipline representatives to the MODIS–VIIRS STM.

The first half-day session focused on the MODIS instruments, with presentations given by members of the MCST. These presentations outlined recent MODIS instrument performance and illustrated detailed results based on various in-orbit calibration activities. In addition, team members presented results from their investigations into improvements to calibration algorithms and mitigation of in-orbit issues. The MCST continues to calibrate and correct for the effects of aging instruments (over 18 and over 16 years for Terra and Aqua MODIS, respectively). The MODIS reflective solar band (RSB) gain performance has been relatively stable since the last STM in 2016. Recent improvements to the calibration include updating Aqua MODIS bands 1-4 response versus scan angle (RVS) using their response trending from both the on-board calibrators as well as the pseudo-invariant desert sites over a wide range of scan angles. The thermal emissive bands (TEB) have also shown excellent performance in recent years. Considerable effort was made to update the calibration of several longwave infrared (IR) bands that suffered from electronic crosstalk contamination from neighboring detectors, which affected Terra MODIS bands 27-30. The correction led to a new collection of data products, termed Collection 6.1.

The second half-day session focused on the VIIRS instruments, with presentations given by members of the VCST. Performance updates for and calibration insights into both Suomi NPP and NOAA-20 VIIRS were presented. With a few exceptions, the overall VIIRS instrument performance is more stable than MODIS.

Throughout the calibration workshop, several science team members presented their findings as they relate to the calibration efforts of these instruments. Two presentations covered various lunar calibration topics, and findings on cross-calibration between MODIS and VIIRS instruments were also presented, demonstrating the need and effort to be made to enable their calibration consistency. Also reported at the workshop was a brief overview of JPSS-2 VIIRS performance based on its prelaunch calibration and characterization. The direct interaction between science team members and the characterization support teams allowed multiple focus areas to be identified and discussed for improving MODIS and VIIRS science data products.

To see the full workshop agenda and download presentations, visit *https://modis.gsfc.nasa.gov/sci_team/meetings/201810/calibration.php*.

Conclusion

Overall the 2018 MODIS–VIIRS Science Team Meeting was highly successful. It was an opportunity for the community to engage in productive discussions on the ongoing quest for MODIS–VIIRS continuity, and to learn about the latest science results from MODIS and VIIRS across the Atmosphere, Land, and Ocean disciplines. There were programmatic and instrument updates, discussions about how to address barriers to continuity, e.g., orphaned products, as well as more general issues of data provenance, accessibility, and documentation for data products.

As of this writing, a date has not yet been set for the next STM. There was also discussion of a Land Discipline Workshop in 2019 to follow up on the topics discussed at this meeting, but no date has been set. Check the MODIS website (https://modis.gsfc.nasa.gov/sci_team/meetings) or "NASA Science Calendar" in *The Earth Observer* for updates.