meeting/workshop summaries

HyspIRI Science Workshop Summary

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Approximately 180 scientists gathered from August 24–26, 2010, at the 3rd NASA Hyperspectral Infrared Imager (HyspIRI) Science Workshop held in Pasadena, CA. PDF versions of the presentations given at the meeting are available from the HyspIRI website (*hyspiri.jpl.nasa.gov*).

Introduction and Meeting Overview

The HyspIRI mission was recommended for implementation by the 2007 report from the U.S. National Research Council *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (also known as the Earth Science Decadal Survey or, simply, the Decadal Survey). The annual HyspIRI workshop provides an open forum to present the observational requirements for the mission and assess its anticipated impact on scientific and operational applications; the open forum also provides an opportunity to obtain feedback from the broader scientific community on the mission concept. This year's workshop had a greater emphasis on the science contribution from HyspIRI and, in particular, its contribution to climate science. There also was more emphasis on the potential contribution to science applications with recent examples from the oil spill in the Gulf and the volcanic eruption in Iceland. The morning of the first day focused on providing an overview of the mission. The afternoon of the first day focused on climate related talks. The second day was primarily science presentations, including discussion of the science questions that HyspIRI will address. The final day included discussions of related missions, partnership opportunities and plans for 2011 and beyond. Of particular interest was the discussion of a potential airborne campaign to acquire data for both science and algorithm testing beginning in the 2011-2012 timeframe. As at last year's meeting, there was a review of the Preliminary Level 1 mission requirements. This year there were over 25 posters which provided an excellent opportunity for more detailed discussions between talks. The workshop participants concluded that the HyspIRI mission would provide a significant new capability to study ecosystems and natural hazards at spatial scales relevant to human resource use. The participants felt the measurement requirements could be achieved with the reference instrument design concepts and be implemented through the use of current technology. The workshop participants endorsed the recommendation of the Decadal Survey itself, and reiterated the need for the HyspIRI mission; they felt the mission, as defined, would accomplish the intended science.

HyspIRI Science Workshop Participants

Woody Turner [NASA Headquarters (HQ)*—Co-Program Scientist for HyspIRI*] started the meeting by welcoming the participants and outlining the goals and objectives for this year's meeting. Turner noted that the science focus this year would be on climate but there would also be several key talks on the potential of using HyspIRI for applications research, and in particular, disaster response—illustrated by talks on the recent Gulf oil spill and volcanic eruption in Iceland. He noted that since the last workshop we have had a symposium at Goddard Space Flight Center (GSFC) that focused on higher level ecosystem products as well as largely completed two reports addressing certain critical aspects of the mission (i.e., sun glint and hot target saturation). Turner also highlighted the opportunities for international partnerships and welcomed the large number of international investigators present at the workshop. He closed by stating that the mission concept is clearly defined, utilizes mature technologies and is low cost, and is ready to go!

Jack Kaye [HQ—*Associate Director for Research and Analysis, Earth Science Division*] further emphasized the importance of climate observations. Kaye noted that there will be a National Climate Assessment in 2013 and NASA would play a key role. He discussed the possibility of the acquisition of a HyspIRI-like airborne dataset for NASA science and HyspIRI algorithm testing which also could contribute to the climate assessment.

HyspIRI will have three main payload elements, a Visible Shortwave Infrared imaging spectrometer (VSWIR), a multispectral thermal infrared (TIR) imager, and an Intelligent Payload Module (IPM). The next series of presentations gave details on these elements.

Rob Green [NASA/Jet Propulsion Laboratory (JPL)] identified how HyspIRI would provide critical climate observations and noted that the Decadal Survey had explicitly cited the need for HyspIRI for climate. He also summarized the instrument concept for the VSWIR. The VSWIR imaging spectrometer will obtain data covering the spectral range from 380–2500 nm with 10 nm sampling. VSWIR data will be acquired over the full terrestrial surface with a 19-day-revisit, including shallow water regions. The deep oceans and ice sheets also will be acquired with a 19-day-revisit but resampled to a spatial resolution of 1 km. Green presented examples of how the VSWIR data would be used for a range of science challenges, primarily focused on ecology, including mapping species and canopy chemistry. **The VSWIR system will provide the same level of spectrometer coverage in 1 year that it would take current and future full solar reflected range imaging spectrometers 100 years to provide.** The VSWIR instrument concept was shown to have design heritage from instruments such as the Moon Mineralogy Mapper (M3). This heritage has allowed the VSWIR instrument to be far smaller and use less power than earlier designs such as Hyperion on the Earth Observing-1 mission. In-flight, the instrument would be fully calibrated with an onboard solar panel, lunar looks, and ground calibration experiments. Green closed by reiterating that the VSWIR concept was mature and ready to go.

Simon Hook [JPL] summarized the instrument concept for the thermal infrared (TIR) multispectral imager on HyspIRI. The TIR imager will obtain data in eight spectral channels; one of the channels is located at 4 μm and the other seven channels are located between 7–12 μm. TIR data will be acquired over the full terrestrial surface with a 5-day-revisit, including shallow water regions. The deep oceans and ice sheets also will be acquired with a 5-day-revisit but resampled to a spatial resolution of 1 km. Hook presented examples of how the TIR data would be used for a broad range of science and applications with particular emphasis on volcanoes, wildfires, and water use and availability. For each area, Hook provided examples of how the instrument concept was designed to address critical questions in that area. The TIR instrument operates continuously, providing both a daytime and nighttime scene for the entire Earth every five days at the equator. He showed how the revisit will be greater at higher latitudes and used an example from the recent Iceland eruption to highlight how the TIR would have been able to provide daily information on the composition and chemistry of the volcanic plume—of particular importance for aeronautics. The TIR instrument concept has design heritage from instruments such as the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Moderate Resolution Imaging Spectroradiometer (MODIS) and is a mature concept that can be built and launched in the same timeframe as the VSWIR instrument. In-flight, the instrument will be calibrated with a two-point calibration, obtained by viewing an onboard blackbody and deep space every scan. There also will be lunar looks and ground calibration using automated validation sites. Hook closed by restating that the TIR will provide essential data for reducing the uncertainties in land carbon flux together with data for a range of applications from volcano monitoring to wildfires.

Carl Bruce [JPL] provided more detail on the VSWIR reference design concept. Bruce stated that this year's effort had focused on checking the mass and power requirements and confirming the instrument met certain key requirements. This included numerical modeling of the signal to noise and uniformity. He noted the VSWIR system will be a high data rate system with no new technology needing to be developed as the critical parts are at Technology Readiness Level (TRL) 6. Antecedent data are available from the MARS instrument, a similar design to the VSWIR instrument, and together with data from the upcoming Airborne Visible/Infra-

red Imaging Spectrometer–Next Generation (AVIRIS-NG) will provide valuable information on the nominal design concept. Current plans call for ground control points in order to meet the 30-m geolocation accuracy requirement. There are some differences between the HyspIRI concept and the M3; for example, the VSWIR instrument will use two identical spectrometers, have a larger radiator and use four detectors compared to a single detector in M3. These differences will not impact the reference design concept which continues to be optimized. The VSWIR instrument is possible because of several key technologies that have been developed over the last decade such as curved electron-beam fabricated gratings and uniform slits which enable a highly uniform imaging spectrometer to be built.

Marc Foote [JPL] then provided more information on the TIR reference design concept. The TIR instrument will be a whiskbroom scanner with a 51° total field of view and ground resolution of 60 m. The data will be collected with a two-sided scan mirror. The dwell time for any given pixel will be 32 microseconds. The system will use a Mercury Cadmium Telluride detector and the focal plane will be cooled to 60 K with an active cooler. The scan mirror will use a lower resolution controller combined with a higher resolution interferometric encoder for high pointing knowledge. A two point calibration (viewing a blackbody and deep space) will be performed every two seconds. The system will use a Cassegrain telescope with radiation from the instrument baffled away from the detector. There will be a single detector array, having 32 readout ports, with 256 x 16 pixels in each of the eight spectral channels. The system will use time delay and integration with each channel using four columns from the array—since each channel has extra columns, the best four columns can be used. Current testing of a prototype read-out integrated circuit indicates compliance with noise and power specifications, and the instrument noise-equivalent temperature difference should be less than 0.2 K in the seven thermal infrared channels, with ample signal from hot targets for the mid-infrared channel. Various commercial cryocoolers are being studied with several available that meet the design requirement.

Dan Mandl [NASA/Goddard Space Flight Center (GSFC)] described the Intelligent Payload Module (IPM) that will provide low-latency data, which can be used for a wide range of applications such as near-real-time (NRT) monitoring of fires or floods. There will be two data streams on the spacecraft; one is downloaded through the normal route while a second identical stream goes to the IPM. The IPM will be able to subset and process this second stream and download the data in NRT via a direct-broadcast antenna. The NRT data will be available over the internet. Work is currently underway on benchmarking the Computer Processing Unit for IPM and developing delay tolerant network communication connectivity to handle any network disruption. The web coverage service will be used to automatically load algorithms so a custom algorithm can be loaded for a particular task or application and the data downloaded in NRT such as during a fire or flood. An IPM testbed for HyspIRI has been developed and is being used for testing algorithms such as automated atmospheric correction using existing Hyperion data.

Bogdan Oaida [JPL] discussed the overall mission concept. HyspIRI is planned to be in a 626 km Sun-synchronous orbit with a 10:30 AM descending equatorial crossing time. Oaida showed there are several other potential orbits that could support the 19-and 5-day revisit of the VSWIR and TIR respectively, including an orbit around 705 km used by many other spacecraft—e.g., the A-Train. He outlined the operations concept for HyspIRI, which is very simple since both instruments are always turned on in order to provide global mapping. The VSWIR data are day-only data and currently planned to be acquired when the solar elevation is greater than 20°, however, this constraint may be relaxed to 10° to provide additional coverage in the polar regions. This year the results from the 2009 concept study were reviewed and the mass confirmed to meet the design principle for JPL. Multiple spacecraft solutions are available which would be modified to add power and an onboard recorder. Several launch vehicles are available which would meet the requirements. The ground systems and data management concept continues to mature. In a response to a Request For Information, Norway's Kongsberg Satellite Services (KSAT) has indicated they will have ample capacity to meet the downlink needs of HyspIRI with two polar downlink stations.

Rob Green and **Simon Hook** reviewed the Draft Level 1 Mission Requirements that serve as the top-level requirements for the HyspIRI mission and provide the basis for deriving the more detailed Level 2 requirements. These requirements were first presented at the 2008 Workshop and are reviewed at each workshop to make sure the community is fully aware of the data that HyspIRI will provide.

Greg Asner [Carnegie Institution for Science, Stanford University] then gave the first of two keynote presentations highlighting the key climate contributions of HyspIRI. Asner began by noting that biospheric and cryospheric feedbacks are two major uncertainties that need to be resolved to understand and predict climate change. Changes in greenhouse gas emissions are controlled by biospheric feedbacks, and although the different biospheric processes are known, we do not understand their relative contributions. For example, temperature changes can result in a large re-shuffling of plant functional types, including changes in invasive species and nitrogen fixing plants. This re-shuffling

results from drier and warmer conditions, which then leads to new feedbacks. Invasive species may grow faster but only if higher temperatures and light are available with sufficient nutrients and moisture. Invasive plants and other changes in plant functional types can result in significant changes in nitrogen cycling and thus levels of the greenhouse super-gas nitrous oxide. New plant functional types may store less carbon or have a different albedo which in turn can result in a new feedback. Studies have shown that by combining imaging spectrometer data with model data, e.g. the Carnegie Ames Stanford Approach (CASA), these fluxes can be obtained. This information cannot be obtained from current coarse spatial and spectral resolution measurements. Asner noted that the Intergovermental Panel on Climate Change (IPCC) is currently trying to determine whether a biospheric feedback is taking place in the Amazon, which in recent years has been getting ~1% drier every 3 years. A recent paper using MODIS data suggested the Amazon became greener during droughts but subsequent studies suggested this was an artifact in the MODIS data. HyspIRI will provide the measurements needed to observe and understand this shift in plant functional types that coarser spatial and spectral resolution instruments cannot provide. He also reported that HyspIRI will provide valuable information on albedo feedbacks, fire emissions, and evapotranspiration. Asner noted that current sensors are underestimating fire emissions since they do not resolve the contribution from many agricultural and forest fires that are typically smaller than large wildfires. The global mapping capability of HyspIRI is critical to fully understand these feedbacks. (Other missions provide detail on local processes but HyspIRI will provide the core measurements for understanding what is happening globally.) HyspIRI measurements would be even more powerful when coupled with data from other systems which provide plant structural information such as the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission. Finally, Asner emphasized that the IPCC needs this information as soon as possible to understand what changes are happening now and to better predict what will happen in the future.

Tom Painter [JPL] gave the second keynote presentation on albedo feedbacks associated with dust and black carbon (BC) in snow. As noted in the recent IPCC reports albedo changes can have a radical effect on climate, but at present our knowledge of albedo feedback is very limited. This lack of knowledge occurs because *in situ* radiation measurements are expensive and sparse, and quantitative retrievals from current remote-sensing technology are not possible. Information about changes in snow albedo is critical but more improved measurements are needed to understand the impact of BC and dust. A key area where such knowledge is important is the *down wasting*[1] of Himalayan glaciers due to increasing warming and a combination of BC and dust. We know that down wasting is taking place but do not understand how much of this down wasting comes from changes in climate and radiative forcing by BC and dust. Likewise, changes in snowmelt have a critical impact on water resources such as in the Southwest U.S. In the Upper Colorado River basin, point models indicate that increasing dust from land-use/land-cover change in the desert southwest has reduced snow cover by 28–50 days. Current data from coarse spectral resolution sensors such as MODIS does not provide information where the albedo differences are greatest and easiest to measure. The higher spatial and spectral resolution of HyspIRI allows the retrieval of radiative forcing by dust and black carbon, fractional snow cover, snow grain size, and albedo.

Science Presentations

After the two keynote presentations the remainder of the first day, all of the second day, and part of the third day were devoted to science talks. There were over 40 talks and the presentations associated with these talks are available from the HyspIRI website listed earlier. The talks covered a wide range in topics and included updates from the studies funded by NASA solicitations as well as updates on the key science questions that HyspIRI will address. The science questions were developed in conjunction with the Science Study Group, a group of scientists appointed by NASA to help guide the mission and ensure the measurements are of maximum benefit. The science talks included multiple presentations related to the application of the science data, in particular, recent results from the Gulf oil spill. HyspIRI-like imaging spectrometer data from the Gulf oil spill were obtained with the AVIRIS instrument. These data were used to determine the surface oil thickness and oil-to-water ratio, a new technique that greatly aided the response because to date there have been no technologies to derive oil slick thickness other than human observation and measurement. Thus, coarse spatial and spectral resolution sensors and Synthetic Aperture Radar (SAR) sensors can determine the presence of oil on the surface but are unable to determine if a thin film (i.e., sub-micron) is present or a thick (i.e., cm-scale) oil layer. The high spectral resolution of AVIRIS and HyspIRI will allow quantification of the amount of oil to guide response efforts, and to improve predictive capabilities. AVIRIS data also were acquired over the coastal wetlands for the entire Gulf region both before oil washed onshore and afterwards. These data will be used in ongoing studies to better understand the impact of the oil spill and remediation techniques on the fauna and flora of the wetlands around the Gulf.

[1] *Down wasting* is the stationary thinning of the glacial ice.

The third and final day of the workshop began with a short report on the recent HyspIRI Symposium arranged by **Betsy Middleton** [GSFC] and colleagues. The focus of the symposium was the higher-level data products, especially those related to ecosystem studies. Middleton highlighted the plethora of products that HyspIRI could potentially produce and noted such products will be critical in understanding the carbon budget. She also identified that more frequent revisits in the northern latitudes will be particularly advantageous given these regions are undergoing rapid change.

Middleton's presentation preceded a series of talks from our international colleagues and included presentations from Germany, Italy, Japan, Argentina, and Australia, each of which highlighted the capabilities within each country and how their respective efforts would dovetail with the unique HyspIRI global mapping mission. These included downlink opportunities as well as joint calibration and validation experiments.

The remainder of the morning and early part of the afternoon included a mixture of science and engineering presentations. These included more detailed presentations on the orbits, coverage, and downlink procedures. For example, **Bob Knox** [GSFC] discussed the benefit of the increased number of opportunities with latitude and noted how the TIR sensor would provide daily coverage in the northern latitudes. **Alexander Berk** [Spectral Sciences, Inc.] described updates to the MODTRAN®[2] radiative transfer model and how these would benefit the HyspIRI mission. For example a recent update for modeling gas plumes could be used for modeling volcanic eruption plumes. **Susan Ustin** [University of California Davis] gave a short presentation on a small workshop she is organizing on developing global HyspIRI data products.

Review of the Workshop and Next Steps

The final presentation reviewed the progress since the last meeting and future activities. Excellent progress has been made since the last meeting with additional reports such as the sunglint and hot target saturation reports that provide invaluable feedback on the measurement requirements for the instruments. Participants noted the large number of posters displayed at the meeting and asked that future meetings included an evening session dedicated to the posters. Of particular interest with the community was the possibility of an airborne campaign in California using the AVIRIS and the MODIS/ASTER Airborne Simulator (MASTER) sensors to acquire HyspIRI-like datasets for both science and algorithm development. Potential flight corridors were discussed together with how to ensure the necessary field measurements were made to maximize the usefulness of the data.

In summary, the participants felt that the HyspIRI Level 1 Mission would provide a significant new capability to study ecosystems and natural hazards at spatial scales relevant to human resource use. The participants confirmed the Draft Preliminary HyspIRI Mission Level 1 Requirements were achievable with the mission concept presented and would provide the data necessary to address the science questions identified for the mission.

[2] MODTRAN computer software is a registered trademark owned by the United States Government as represented by the Secretary of the Air Force.