Onboard Instrument Processing Concepts for the HyspIRI Mission

Steve Chien, Dorothy Silverman, and Ashley Davies,

Jet Propulsion Laboratory, California Institute of Technology

Daniel Mandl, NASA Goddard Space Flight Center

Correspondence author: steve.chien@jpl.nasa.gov

S6 – Sensors and Platforms, Passive Optical and Hyperspectral Sensors

Future NASA missions will have instruments that generate enormous amounts of data. This abstract describes an onboard processing mission concept for a possible Direct Broadcast capability for the HyspIRI mission – a Hyperspectral remote sensing mission under consideration for launch in the next decade. In the HyspIRI mission, the visible to short wave infrared (VSWIR) and thermal infrared (TIR) instruments will produce 1.5 x 10^6 pixels for 10^9 bits per second of data. However the spacecraft will have only a 15 x 10^6 bit per second - band direct broadcast downlink capability, allowing only 1/60th of the data to be rapidly downlinked.

This abstract describes a concept under development to intelligently, onboard the spacecraft, in context spectrally and spatially subsamples the data as well as generates science products onboard to enable return of key rapid response science and applications information despite limited downlink bandwidth. This rapid data delivery concept focuses on wildfires and volcanoes as primary applications but also has applications to vegetation, coastal, flooding, dust, and snow/ice applications.

HyspIRI Mission

HyspIRI [HyspIRI] is a proposed mission that would carry a VSWIR hyperspectral instrument with 220 bands from 0.5 to 2.4 microns at 60m/pixel resolution and a TIR instrument with 8 bands in the 4 to 12 micron range, also with 60m/pixel resolution. With a VSWIR instrument swath of approximately 150 km and TIR swath of approximately 600 km these instruments will have a 15 and 9 day repeat coverage. The data acquisition rate is 1 gigabit per second. The normal data downlink path is to downlink at a high data rate when overlying polar ground stations with complete data processing and delivery in a 1-2 week timeframe. To enable more rapid data delivery, the mission is studying an option of including an X-band direct broadcast using heritage equipment providing continuous 15 x 10^6 bit per second downlink.

Operationally, the HyspIRI team would define a set of spatial regions of interest where specific algorithms would be executed [Chien et al. 2009a]. For example, known coastal areas would have certain products or bands downlinked, ocean areas might have other bands downlinked, and during fire seasons other areas would be processed for active fire detections. Ground operations would automatically generate the mission plans specifying the highest priority masks executable within onboard computation, setup, and data downlink constraints.

Rapid Delivery Science and Applications

In the remainder of this abstract we briefly survey some of the products that are being evaluated for rapid data delivery. In our studies we are focusing on three baselines: (1) downlink the MODIS bands (to leverage strong heritage in MODIS analysis algorithms), (2) downlink spectral bands needed to produce a larger set of science products, or (3) product science products onboard (including spatial sub-sampling via onboard detection for small targets such as volcanoes or wildfires). For each discipline we are evaluating the bands needed as well as the ancillary data needed to produce end science products.

Wildfires - One of the highest priority rapid data delivery applications is wildfires. The thermal bands of the TIR instrument can accurately detect the thermal signature of fires and send down alerts as well as the thermal and VSWIR data corresponding to the active fires [Justice et al. 2002]. For day overflights the VSWIR data can also provide useful data for burn scar evaluation [van Wagtendonk et al. 2004]. Thermal detections can be easily performed onboard and have been routinely performed onboard Earth Observing-1 (EO-1) [Davies et al. 2006] using algorithms processing data in the 0.4 to 2.4 micron range, and allows tremendous downlink savings as the spatial areas for even large fires (the areas currently burning, or hot) are a small fraction of total pixels acquired (1.5 x 10^6 pixels/s) . While burn scars are larger areas they still represent a small fraction of overflown landmass and only require a small fraction of the spectral information (typically only two bands).

Volcanism – Active volcanism also produces a distinctive thermal signature that can be detected onboard to enable spatial sub-sampling (a large eruption may cover 100 pixels compared to $1.5x10^6$ pixels/s acquired). Onboard algorithms [Davies et al. 2006] and ground-based algorithms suitable for onboard deployment [Wright et al. 2003, 2004, Harris et al. 2000] are mature: the latter examples use TIR bands. On HyspIRI, the algorithm would perform a table-driven temperature inversion from several spectral TIR bands and then trigger downlink of the entire spectrum for each of the hot pixels identified.

Many other rapid delivery applications exist. Rapid delivery data to feed vegetation and plant stress products would be of use in drought and crop tracking. These approaches can use plant color and are amenable to spatial snd spectral subsampling (e.g. [Perry & Roberts 2008] evaluation of 14 which require in total 22 VSWIR-range bands) and thermal models [Anderson and Kustas 2008] using TIR-band data. Ocean and coastal applications include sea surface temperature (using a small spectral subset of TIR (often only two bands) data but requiring considerable ancillary data) and ocean color applications to track biological activity such as harmful algal blooms. Measuring surface water extent to track flooding is another rapid response product leveraging VSWIR spectral information [Brakenridge and Anderson 2005, Carroll et al. 2009] which has been demonstrated onboard EO-1 [Ip et al 2006]. Again these only require the use of two spectral bands. Tracking of large-scale dust storms and cryosphere [Doggett et al. 2006] applications of snow and ice represent additional applications areas with small spatial area and require a small number of spectral bands.

References

M. Anderson and W. Kustas, "Thermal Remote Sensing of Drought and Evapotranspiration," Eos, Vol. 89, No. 26, 24 June 2008, pp. 233-234.

G.R. Brakenridge and E. Anderson, "MODIS-Based Flood Detection, Mapping, and Measurement: The Potential for Operational Hydrological Applications," Transboundary Floods, Proc. NATO Adv. Rsch Wkshp, Springer, 2005, pp. 1–12.

M. Carroll et al., "A New Global Raster Water Mask at 250 Meter Resolution," Int'l J. Digital Earth, vol. 2, no. 4, 2009.

S. Chien et al., Onboard Science Processing Concepts for the HyspIRI Mission, IEEE Intelilgent Systems, Nov/Dec 2009, pp. 12-19.

S. Chien and D. Silverman, Direct Broadcast Applications for HysPIRI, HyspIRI Mission Workshop, August 2009, hyspiri.jpl.nasa.gov

S. Chien et al., "Using Autonomy Flight Software to Improve Science Return on Earth Observing One," J. Aerospace Computing, Information, and Communication, vol. 2, no. 4, 2005, pp. 196–216.

S. Chien et al., "An Autonomous Earth- Observing Sensorweb," IEEE Intelligent Systems, vol. 20, no. 3, 2005, pp. 16–24.

A.G. Davies et al., "Monitoring Active Volcanism with the Autonomous Sciencecraft Experiment (ASE) on EO-1," Remote Sensing of Environment, vol. 101, no. 4, 2006, pp. 427–446.

T. Doggett et al., "Autonomous Detection of Cryospheric Change with Hyperion Onboard Earth- Observing 1," Remote Sensing Env, vol. 101, no. 4, 2006, pp. 447–462.

A. Harris et al., "Real-Time Satellite Monitoring of Volcanic Hot Spots,"Geophysical Monograph, vol. 116, 2000, pp. 139–159.

HyspIRI Mission Web site, hyspiri.jpl.nasa.gov

F. Ip et al., "Flood Detection and Monitoring with the Autonomous Sciencecraft Experiment Onboard EO-1," Remote Sensing of Env, v. 101, n. 4, 2006, pp. 463–481.

C.O. Justice et al., "The MODIS Fire Products," Remote Sensing of Environment, vol. 83, no. 1, 2002, pp. 244–262.

E. Perry and D. Roberts, "Sensitivity of Narrow-Band and Broad-Band Indices for Assessing Nitrogen Availability and Water Stress in an Annual Crop, Agronomy Journal, vol. 100 Issue 4, 2008, pp. 1211-1219.

van Wagtendonk, J.W., Root, R.R. & Key, C.H. (2004). Comparison of AVIRIS and Landsat ETM+ detection capabilities for burn severity. Remote Sensing of Environment, 92(3), 397-408.

R. Wright et al., "Automated Volcanic Eruption Detection Using MODIS," Remote Sensing of Environment, vol. 82, no. 1, 2003, pp. 135–155.

R. Wright et al., "MODVOLC: Near- Real-Time Thermal Monitoring of Global Volcanism," J. Volcanology & Geothermal Research, vol. 135, n. 1–2, 2004, pp. 29–49.