High-Speed FLAASH Atmospheric Correction for NASA Spectral Imagery
SBIR Phase I Program

Tim Perkins and Steve Adler-Golden
Spectral Sciences, Inc., Burlington, MA 01803

Pat Cappelaere
Vightel Corp., Ellicott City, MD

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SBIR Program Objectives

• Problem
  – High duty cycle of upcoming missions such as HyspIRI will require high accuracy, fully automated, low latency, near real-time atmospheric correction (AC) processing
  – NASA’s current AC algorithms are, or will soon be, outdated in both the science and the coding

• Solution
  – Transition NASA’s current and future (HyspIRI) AC processing to a fast version of the C++ language FLAASH code

• Objectives
  – Port FLAASH to the Elastic Cloud or IAAS
  – Develop look-up tables (LUT) for near-real-time FLAASH processing
  – Phase II: port to prototype flight hardware

• Team: SSI + Vightel
  – Thanks to Dan Mandl, Technical Monitor
Processing Concept

- **Ground-based system:**
  - Will support Hyperion, Landsat, ALI, MODIS, ASTER

- **On-board system:**
  - For direct broadcast of products from HyspIRI, LDCM in near real-time
FLAASH Overview

• Development
  – Code developed by SSI with primary support from AFRL, additional support from NGA, NASA, SSI
  – ENVI commercial product developed from original IDL code
  – FLAASH-C developed for NGA parallel processing system; latest version approved for public release May 2011

• Science/Features
  – MODTRAN radiative transfer; pixel-by-pixel water retrieval; scene visibility retrieval; adjacency effect and spectral smile compensation; spectral polishing; wavelength self-calibration

• Operating Modes
  – Interactive (IDL) or batch (FLAASH-C)
  – High-speed MODTRAN LUT option (ongoing development)

• Demonstrated Sensor Support
  – AISA-ES, ALI, ARTEMIS, ASAS, ASTER, AVHRR, AVIRIS, CASI, Compass, GeoEye-1, HYDICE, HyMap, Hyperion, IKONOS, Landsat, LASH, MaRS, MASTER, MODIS, MTI, Probe-1, QuickBird, RapidEye, SPOT, TRWIS, WorldView-2
State-of-the-Art FLAASH Science

- **RT equation**
  \[ L^* = \frac{a \rho}{1 - \rho_e S} + \frac{b \rho_e}{1 - \rho_e S} + L_a^* \]
  MODTRAN-derived

- **Adjacency compensation improves accuracy**

- **Visibility retrieval from small dark areas**

Validation with Ground Truth

Chlorophyll Edge Contaminates Soil

Retrieved Meteorological Visibility (Urban Aerosol)
Technical Approach: Speedup via Look-up Tables (LUTs)

• Large pre-calculated LUTs replace the custom MODTRAN calculations in FLAAASH
  – Eliminates the Fortran module and around half the FLAASH run time

• Feasibility previously demonstrated (2000 Ph 1 program)
  – LUTs containing MODTRAN radiance spectra were built for nadir viewing from 3 km and 20 km (e.g. AVIRIS) altitudes

• LUTs have now been built for TOA nadir and off-nadir viewing
  – Utilize PCA compression to save storage
  – Current LUTs developed for rural aerosol model (5-300 km visibility)
    • Water vapor to 1.6xTropical, view angle to 30 deg off nadir, solar angle 0-70 deg, surface elevation 0-3.5 km
Phase I Accomplishments

- **Initial LUT Development**
  - Developed LUT for rural aerosol – ~ 1CPU-week of MODTRAN calculations
  - >100-fold compression with PCA (16 Gbytes → 100 Mbytes)

- **FLAASH-C Development**
  - Support compressed LUT files
  - Timing study: MODTRAN vs. LUT time comparison for MSI and HSI
  - New feature: atmospherically corrected radiance (shows blackbody source in “hot” pixels for characterizing fires, volcanoes, etc.)

- **Demonstrations:** EO-1 Data (Hyperion and ALI) - LUT and/or MODTRAN versions
  - On Elastic Cloud automatically processing new scenes
  - As a WCPS algorithm re-processing scenes on-demand as a
  - On IPM Telera (but not yet multicore)
LUT Evaluation

- LUT is a compressed spectral database supporting off-nadir viewing from the TOA
  - 145000 table entries, 350 – 2500 nm, 5 cm\(^{-1}\) resolution
  - After compression, roughly the size of a single Hyperion image

- Retrieved hyperspectral reflectance values agree closely with direct results from MODTRAN

Hyperion Reflectance Spectra
Data Product Generation

- Many data products could be generated from the atmospherically corrected data in near-real time
- Bringing the coding into FLAASH would avoid time- and memory-consuming cube I/O
- A prototype of a flood map product is shown here

New Mexico

Namibia

- Spectral Angle Mapper finds turbid water in two different ALI reflectance scenes
Phase II Plans

• Code Development
  – LUTs for standard aerosols/dusts (rural, maritime, urban, desert)
  – Extend to lower altitudes for aircraft (e.g. EMAS)
  – Parallelize for multiprocessor systems
  – Aerosol retrieval improvements, e.g. geographically dependent aerosol type, spatially varying AOD
  – Low-latency data product generation within FLAASH
    • Thermal IR data product(s) taking advantage of fusion with VNIR/SWIR
  – Radiance modeling for low-latency sensor calibration with cal/val sites

• Code Integration
  – Fully operational Sensor Web and IAAS data processing, distribution
  – Prototype HyspIRI flight system demo (Space Cube, Maestro)
  – Integrate with external data product codes

• Validation
  – Demonstrate accurate, automated atmospheric correction and data product generation across a variety of sensors, scenes, platforms