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

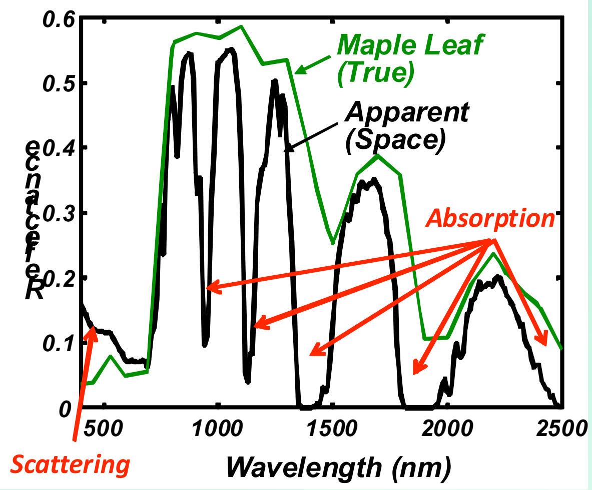
Vightel Corp., Ellicott City, MD

HyspIRI Science Workshop, Washington D.C.

25 August 2011

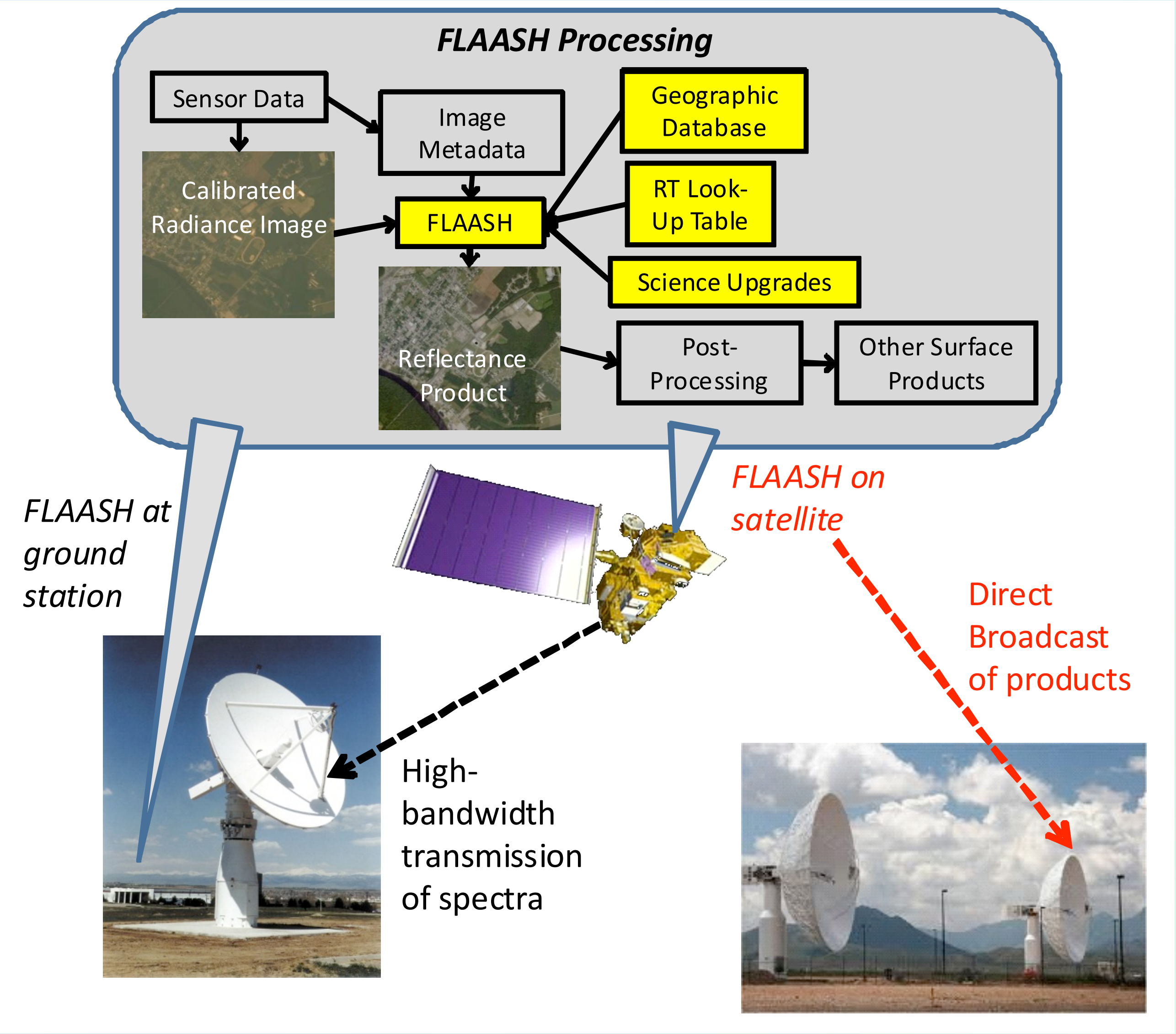
SBIR Program Objectives

- **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  - NASA's current AC algorithms are, or will soon be, outdated in both the science and the coding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

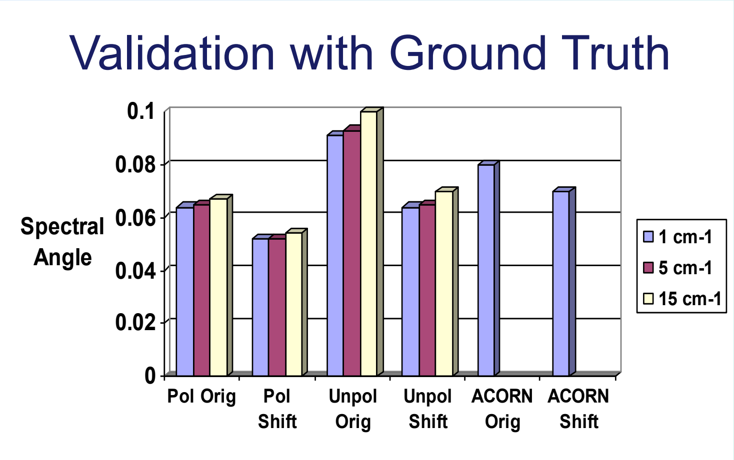
- **Development**
  - Code developed by SSI with primary support from AFRL, additional support from NGA, NASA, SSI
  - ENVI commercial product developed from original IDL code
  - FLAASH-C developed for NGA parallel processing system; latest version approved for public release May 2011
- **Science/Features**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

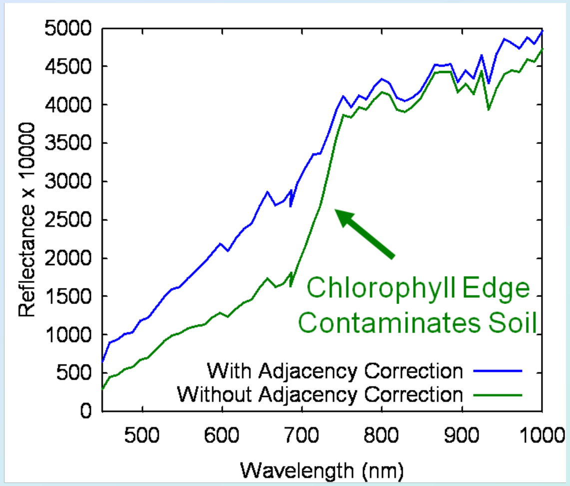
- RT equation

$$L^* = \frac{a\,\rho}{1-\rho_e S} + \frac{b\,\rho_e}{1-\rho_e S} + L_a^*$$

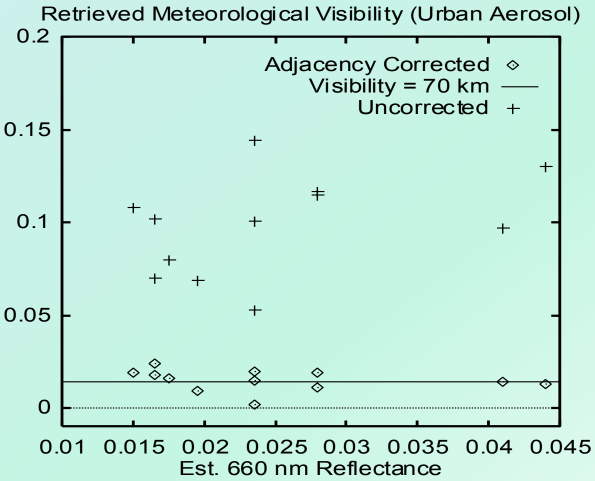
MODTRAN-derived



- Adjacency compensation improves accuracy



- Visibility retrieval from small dark areas

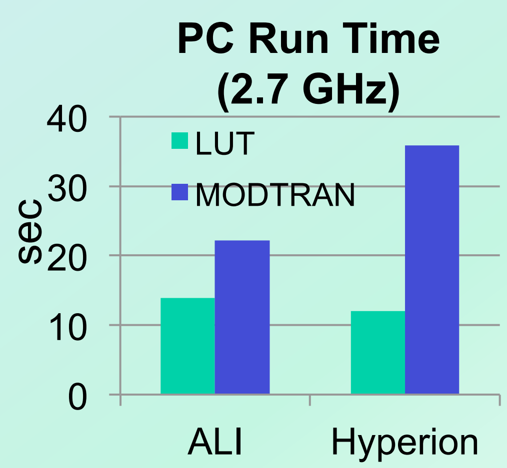


Technical Approach: Speedup via Look-up Tables (LUTs)

- **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*

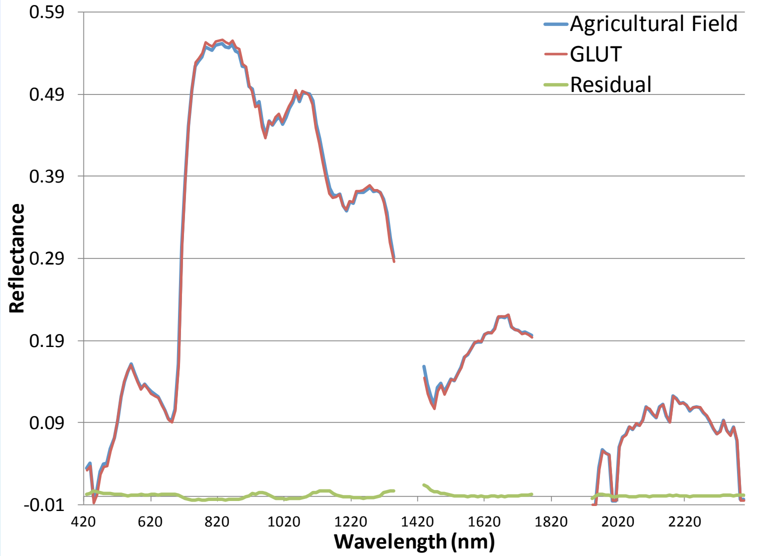
Phase I Accomplishments

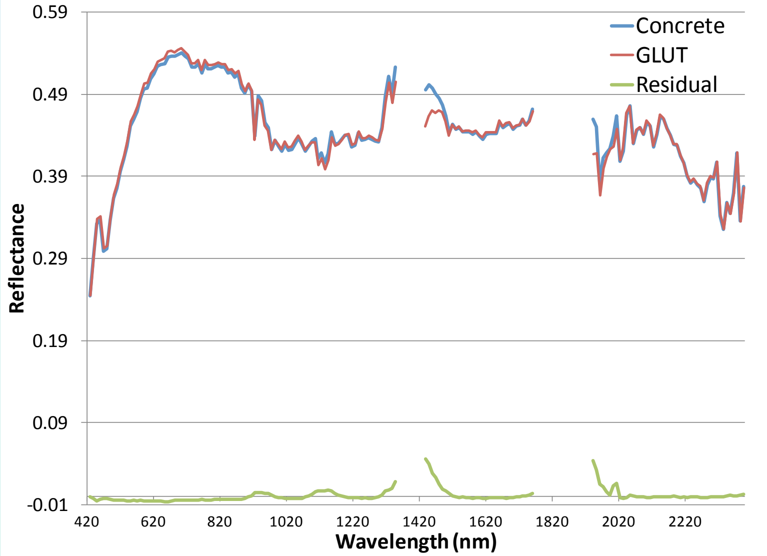
- **Initial LUT Development**
  - Developed LUT for rural aerosol – ~ 1CPU-week of MODTRAN calculations
  - >100-fold compression with PCA (16 Gbytes → 100 Mbytes)
- **FLAASH-C Development**
  - Support compressed LUT files
  - Timing study: MODTRAN vs. LUT time comparison for MSI and HSI
  - New feature: 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

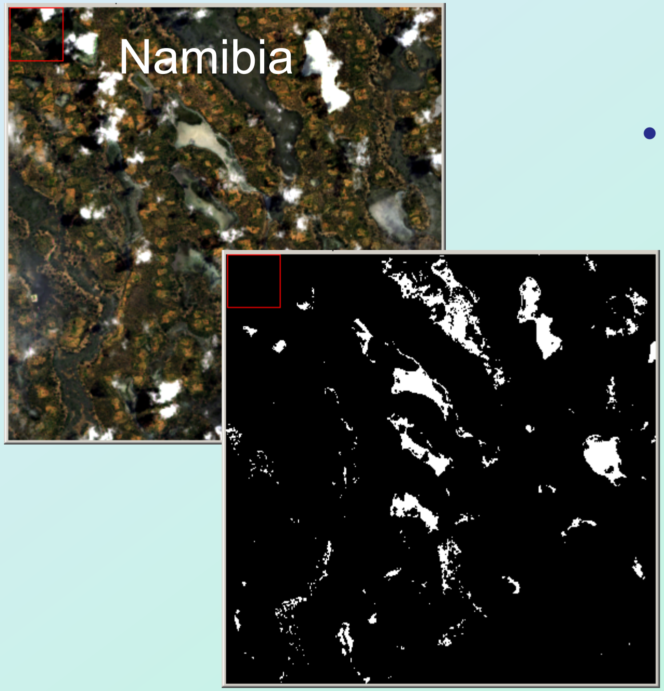




Hyperion Reflectance Spectra

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



- 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