Image products from the new hyperspectral sensor DESIS

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JACIE - 14 April 2016
Forth Worth, Texas, USA

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² DLR – Optical Systems
Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Agency

• Aeronautics, Space, Transportation, Energy and Security

• 16 sites in Germany, ~8000 employees

• 45 Institutes
  • Optical Space Systems (Berlin)
  • Earth Observation Center (Oberpfaffenhofen)

Washington DC, Brussels, Tokyo, Paris
Competences: Hyperspectral Image Processing

• Spaceborne:
  • The Environmental Mapping and Analysis Program (EnMAP)
  • Biodiversity, climate & ecosystem change, natural resources

• Airborne:
  • HySpex (VNIR&SWIR, operated by DLR)
  • Calibrated & characterised at DLR

• Micro aerial vehicles:
  • Cubert 450-950nm (Frame camera, ~0.5kg)
Consortium: DLR & TBE Data Processing

**TBE**
- Teledyne Mission Control
- Data Storage
  - DESIS data + Auxiliary data
- Data Transcription
  - ToA
  - Orthoimage
  - Reflectance
- Commercial Partners

**DLR-GS**
- DLR DESIS Data Management System
  - Data Storage
    - DESIS data + Auxiliary data
  - L1a processor
    - ToA
    - Orthoimage
    - Reflectance
- Scientific Partners

Flow:
- Tasking Raw image data + auxiliary data
- Request Data
- Data download (Polling)
- Share Calibration
- Share Validation
Processing Chain

Level 1A Processor
Transcription

Level 1B Processor
Systematic and Radiometric Correction

Level 1C Processor
Orthorectification

Level 2A Processor
Atmospheric Correction

Earth datatakes
Experimental datatakes
Calibration measurements

Orbit and Attitude Products
Auxiliary Data

In-flight Calibration Process (offline)

Update Cal Tables

Calibration & Reference Products

Long Term Archive L1A Data

L1A
- Data from different data streams: Image data, calibration data, AOCS, prepared for long term data storage.
- Not delivered to the user.

L1B
- L1A data + applied systematic and radiometric corrections (housekeeping and AOCS data appended).
- TOA radiance.

L1C
- Orthorectified and resampled L1B data
- Direct georeferencing, DEM.

L2A
- Atmospheric corrections

DEM Database
REF Database

Atmospheric LUT

Auxilary Data

Raw Data
Earth datatakes
Experimental datatakes
Calibration measurements

Orbit and Attitude Products
Auxiliary Data

Screening

L1A Data

Publish Cal Measurements

Update Cal Tables

Calibration & Reference Products

L2A Product

L1C Product

L1B Product
Level 1A Processor

- Raw DESIS Data
- Earth Data Take
- Screening
- DC Extraction
- L1A Dark Current Product
- Tiling
- Dead Pixel Mask
- QL Generation (requires some functionality of L1B Processor)
- L1A Earth Product
- Archive

Earth Data Take

- darkNumberBefore x 1024
- 1024 x N
- 1024 pixels (spatial)

Dead Pixel Mask

- 1024 pixels (spatial)
- 235 pixels (spectral)

Archive

- 1024 pixels (spatial)
- 8

Tiles

- 1024 pixels (spatial)
- 235 pixels (spectral)
Geometric Correction Processor L1C: Overview

**Geometric Correction of L1B Product** for sensor, satellite motion and terrain related geometric distortions:

- Sensor Model (including laboratory calibration & in-flight boresight angles)
- Sensor Model refinement by automatic GCP extraction from references
  - Different image matching methods
  - Several outlier detection and removal mechanisms
- Resampling by accounting for the rolling shutter
- Geometric performance targets
  - 0.5 pixel (15 m) w.r.t. Landsat-8 orthos (linear RMSE)
  - 95% achievement
How to improve the geometric accuracy? within an operational environment

How to improve the geometric accuracy? within an operational environment

Original image

Metadata
- GPS
- STS&IMU
- Camera Cal.
- Time sync
- In-flight Cal.

Global reference image database

Global DEM database

DEM

Matching

Tie points GCP / CP

Reference image

Improvement of Sensor Model

Generation of ortho image

Ortho image

Quality parameters derived from CPs
Tie points generation

Outliers: detect and remove
- By quality parameters of matching process
- By selection of only „best matches“ in a cell
- By consistency with Sensor Model
Level 1C Processor: ALOS/PRISM Example

- L1B image product: applied systematic and radiometric corrections
- TOA radiance

- L1C image product: Geometric correction
L2A Processor

- ATCOR – atmospheric correction accounting for elevation model

Radiation components flat terrain

\[ L = c_0 + c_1 \text{DN} \]

Radiation components rugged terrain

Surface reflectance

\[
\rho = \frac{\pi (L - L_1)}{\tau (E_{\text{dir}} \cos \theta_s + E_{\text{dif}})}
\]
L2A Processor

- ATCOR – atmospheric correction accounting for elevation model
- High geometric accuracy needed for topographic correction

- Atm + Topo corrected
- Geom. Acc. < 1 pixel
- Illumination map
- cos(local SZA)
- atm + topo corrected
- 3 pixel shift
Products

- Data Products:
  - L1A Earth
  - L1A Calibration
  - L1A Dark Current (DC)
  - L1A Experimental
  - L1B, L1C, L2A Products

- Calibration:
  - Pre-launch and onboard measurements
  - Geometric

- Reference Products:
  - Dark current
  - Dead pixels
  - Etc.
Quality Quicklooks

<table>
<thead>
<tr>
<th>Quality Layer (Geotiff)</th>
<th>L1B</th>
<th>L1C</th>
<th>L2A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead pixels</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Abnormal pixels</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Too high radiance level</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Too low radiance level</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shadow</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Land</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Haze over land</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Haze over water</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Cloud over land</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Cloud over water</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Aerosol optical thickness</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Perceptible water vapour</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Band cross-correlation</td>
<td></td>
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<tr>
<td>Bad columns</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bad lines</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Band-cross-correlation matrix
Quality Quicklooks

Haze / Cloud / Water / Land
Processor Performance Estimation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time/Size estimations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average. datatake/day</td>
<td>5.5 minutes or 2400 km (40 GBytes /day)</td>
</tr>
<tr>
<td>Tile size</td>
<td>30 × 30 km (482 Mbytes/tile)</td>
</tr>
<tr>
<td>Max. L1A image tiles / day</td>
<td>100</td>
</tr>
<tr>
<td>Processing time DESIS_HSI_L1A / tile</td>
<td>20 minutes</td>
</tr>
<tr>
<td>DESIS_HSI_L1A processing time / day</td>
<td>33.3 hours</td>
</tr>
<tr>
<td>Max. L2A tile orders / day</td>
<td>200 (assuming 1 order/tile)</td>
</tr>
<tr>
<td></td>
<td>GS-DLR Requirement</td>
</tr>
<tr>
<td>DESIS_HSI_L1B / tile</td>
<td>10 minutes</td>
</tr>
<tr>
<td>DESIS_HSI_L1C / tile</td>
<td>20-40 minutes</td>
</tr>
<tr>
<td>DESIS_HSI_L2A / tile</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Processing time DESIS_HSI_L2A / tile</td>
<td>45-65 minutes</td>
</tr>
</tbody>
</table>

The calculations are based on the following software (SW): CentOS 5.9, x86_64, 2.6.18-348.4.1.el5 and hardware (HW): AMD Opteron 63xx (8 cores). Time estimations for processing one tile are calculated using one core.
Conclusions

• Processors support
  • L1B, L1C, L2A product generation
  • Product with 4 different binnings
  • Earth data mode, and experimental modes: BRDF, continuous
  • On demand processing

• Same processors at TBE and DLR → Same product delivered to the users

• Close cooperation on outcomes of calibration and validation activities
Subsequent Presentations

Ray Perkins, Chief Engineer, MUSES Ground Segment, Teledyne Brown Engineering
“Teledyne’s Multi-User System for Earth Sensing (MUSES)’’

Janja Avbelj, PhD, DLR Remote Sensing Technology Institute
“Image products from the new hyperspectral sensor DESIS”

Lewis Graham, President & CTO, GeoCue Group
“Building High Performance Processing Systems in Amazon Web Services”

Ray Perkins, Chief Engineer, MUSES Ground Segment, Teledyne Brown Engineering
“Imaging Spectroscopy Applications Using the DESIS Hyperspectral Instrument on MUSES”