In preparation for the follow-up breakouts we present:

**HyspIRI and the Art of Geo-Location**

*Dealing with substantial differences between the VSWIR and TIR measurement patterns*

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What I am going to present and why I am presenting it to you!

• The geometric properties of HyspIRI level-1 data.
• Exposing the myth of \textit{(defining limitations in)} achieving coincident individual observations between instruments and over time.
• Options for generating VSWIR, TIR and combined level-1 \textit{(calibrated)} products.
• \textbf{You} determine higher level product requirements needed to meet your research goals.
• Higher level products depend, both qualitatively and quantitatively, on the level-1 products from which they are generated.
Geometric Factors Influencing VSWIR/TIRS Combined Product Utility

- Final Satellite Orbit
- Satellite Pointing Accuracy
  - Attitude Control System (ACS)
  - Star Trackers
- Satellite Positioning Accuracy
  - GPS
- Instrument Models & Geometry
- **Science Users Geolocation Expectations??**
- Low-latency Product Geolocation Expectations!
Preliminary Geometric *Nominal* Parameters for the HyspIRI
The Satellite

- Platform: Sun-synchronous Circular Ground-track Repeat Orbit
- Altitude: 623 km (mean sea-level)
- Velocity: ~7 km/sec (ground speed)
- Repeat Cycle: 19 days
- 10:30 am MLT at Equator (descending node crossing)
The VSWIR Spectrometer

- Pushbroom Technology
- Revisit Cycle at Equator: 19 days
- Detectors/wavelength: 2*1280 (2 FPAs)
- Swath Width: 145 km
- Pixel size/GSD: 60 m
The TIR Instrument

- Whiskbroom (*2-sided rotating mirror*)
- Revisit Cycle at Equator: 5 days
- Detector Elements/band: 256
- Mirror Scan Frequency: 14.2 RPM
- Swath Width: 600 km
- Long-track Swath: 15.4 km at Nadir
- Nadir Pixel GSD: 60 m
Pushbroom Observing System

Cross Track Sample

Depiction
- Grids are the detectors
- Spots are the IFOV centers
- Colors are the wavelengths
Pushbroom Observing System
Pushbroom Observing System
Pushbroom Observing System
Pushbroom Observing System
HyspIRI TIR Scan Method

8 Thermal bands
Band to band co-registration: 0.2 pixels (12m)
Pointing Knowledge: 10 arcsec (0.5 pixels, 30m)
HyspIRI TIR Scan Method

Scan Angle

25.5  20  10  0  10  20  25.5

256 pixels  60mx60m
256 pixels  66mx74m
600km
HyspIRI TIR Scan Method

- Scan1
- Scan2
- Scan3

overlap & mis-registration opportunities

600km
HyspIRI TIR Scan Method

Odd numbered scans are acquired with scan mirror side 1
Even numbered scans are acquired with scan mirror side 2
The Bow-Tie effect is an artifact of the arrangement of sensors on the MODIS instrument.

An example of the bow-tie effect (near the right-hand edge of a 250 m band) :
How the VSWIR and TIR would image if HyspIRI were able to hover

Stationary View

TIR Detectors

VSWIR Detectors

TIR Scan Direction
Stationary View

TIR Detectors  VSWIR Detectors
Stationary View

TIR Detectors

VSWIR Detectors

Scan
Stationary View

TIR Detectors

VSWIR Detectors

Scan
Stationary View

TIR Detectors

VSWIR Detectors

Scan

0.2 s
Stationary View

TIR Detectors

VSWIR Detectors

Scan
Stationary View

TIR Detectors  VSWIR Detectors

0.6 s

Scan
Stationary View

TIR Detectors

VSWIR Detectors

Repeat: 2.2 s
With Spacecraft Forward Movement

How the VSWIR and TIR image when HyspIRI moves in orbit

t=0
With Spacecraft Forward Movement

TIR Detectors
d: 0 km

VSWIR Detectors
d: 5.6 km

Scan
Track

\( t = 0.8 \)
With Spacecraft Forward Movement

TIR Detectors
$\text{d: 200 km}$

VSWIR Detectors
$\text{d: 7 km}$
With Spacecraft Forward Movement

- TIR Detectors: d= 300 km
- VSWIR Detectors: d= 7.7 km

Scan

Track

\[ t = 1.1 \]
With Spacecraft Forward Movement

VSWIR Detectors
\( d: 8.4 \text{ km} \)

TIR Detectors
\( d: 400 \text{ km} \)

\( t=1.2 \)
With Spacecraft Forward Movement

TIR Detectors
d: 400 km

VSWIR Detectors
d: 9.8 km

Scan

Track

$\text{t}=1.4$

~2 km

~4.2 km
With Spacecraft Forward Movement

End of cycle and beginning of next period

t=2.2

TIR Detectors

VSWIR Detectors
d: 15.4 km

Scan

Track
VSWIR / TIR Alignment Correction?

- 145km
- 15.4km
- ~14°
How the VSWIR and TIR would image if TIR bore sight were rotated by $\sim 14^\circ$
t = 0.8

TIR Detectors
\(d: 0 \text{ km}\)

VSWIR Detectors
\(d: 5.6 \text{ km}\)
t=1.0

TIR Detectors
d: 200 km

VSWIR Detectors
d: 7 km

Scan

Track
TIR Detectors
d: 300 km

VSWIR Detectors
d: 7.7 km

t=1.1
t=1.4

TIR Detectors
d: 400 km

VSWIR Detectors
d: 9.8 km

Scan

Track
t = 2.2

TIR Detectors

VSWIR Detectors
d: 15.4 km
What’s the problem with making level-1 VSWIR, TIR and combined products?

• By definition level-1 data must be entirely reversible back to the original level-0 data.
  – Geo-tag *radiometrically* corrected data.
  – Re-grid data using nearest neighbor values and geo-tag back to original pixel data positions (*need to deal with multiple values for the TIR*).

• VSWIR and TIR observations are inherently misaligned in a manner which is both geographically and temporally sensitive.
Issues with sun synchronous orbits which impact geo-location control

• The selected 19 day sun synchronous circular repeat cycle orbit is not truly synchronous.
  – All sun-sync orbits are designed *and must be maintained* to have a fixed precession rate which will exactly match the target MLT only 2X annually

• Many factors influence the position of the sub-satellite ground track and variations of several kilometers are tolerated even in high resolution platforms (e.g. Landsat)
Why a 19 day repeat cycle and how do we determine the satellite altitude?

• We want global coverage in the shortest amount of time commensurate with achievable FOVs within the mission’s cost constraints.

• There are a variety of altitudes which produce the same repeat cycle.
  
  – Orbital with period $T$ that divide into 19 days as an exact integer $N$ provide a perfect repeat cycle.
  
  – If $T$ is in minutes, then $N*T = 12360$ $(= 19*24*60)$

  – $N > 2\pi R_{\text{Earth}} / \text{Swath-width}$ ensures global coverage
Sun Sync Orbits for 19 Day Repeat

Incomplete Overlap at 140KM Swath Width
Incomplete Overlap at 145KM Swath Width
Sun Sync Orbits for 19 Day Repeat

Orbital Altitude (KM)

Total Number of Orbits Over Repeat Cycle

No Overlap above 268
150KM Swath Width
Can we have a shorter repeat cycle consistent with the current concept

• Maybe?
Maximum Altitude Ensuring Global Coverage (at Candidate Swath Widths & Repeat Cycles)
Maximum Altitude Ensuring Global Coverage
(at Candidate Swath Widths & Repeat Cycles)
Onboard Low Latency Products

- VSWIR, TIR, VSWIR / TIR Gridded?
- > 15.4km?
- Radiometric Correction
- Atmospheric Correction (VSWIR)
- AC TIR?
- DEM Corrected?
- VSWIR/TIR Co-Registration?
- Actual Product Generation (WCPS)
Finally!!

- The preceding descriptions are not merely a simplification --- they are an oversimplification.
- We need to take the effects of the Earth’s rotation into account.
  - The ground sampling distance (GSD) for each instrument and the VSWIR pixel shape vary with latitude.
  - The nadir TIR and VSWIR ground tracks will not be congruent because of acquisition time differences.
- Effects related to Earth’s shape and topography
- **In my opinion none of these effects need impede the scientific utility of the data provided that we use them intelligently.**
Maximum Altitude Ensuring Global Coverage

(at Candidate Swath Widths & Repeat Cycles)
Orbital Altitude (KM)

19 Day Sun Synchronous Repeat Orbits

Number of Orbits in Repeat Cycle

Orbital Altitude (KM)
Sun Sync Orbits for 19 Day Repeat

Orbital Altitude (KM)

Total Number of Orbits Over Repeat Cycle
All you need to know about spatial impact without going into way too much detail!

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