EMIT's Onboard Data Analysis: Performance Assessment and Lessons Learned

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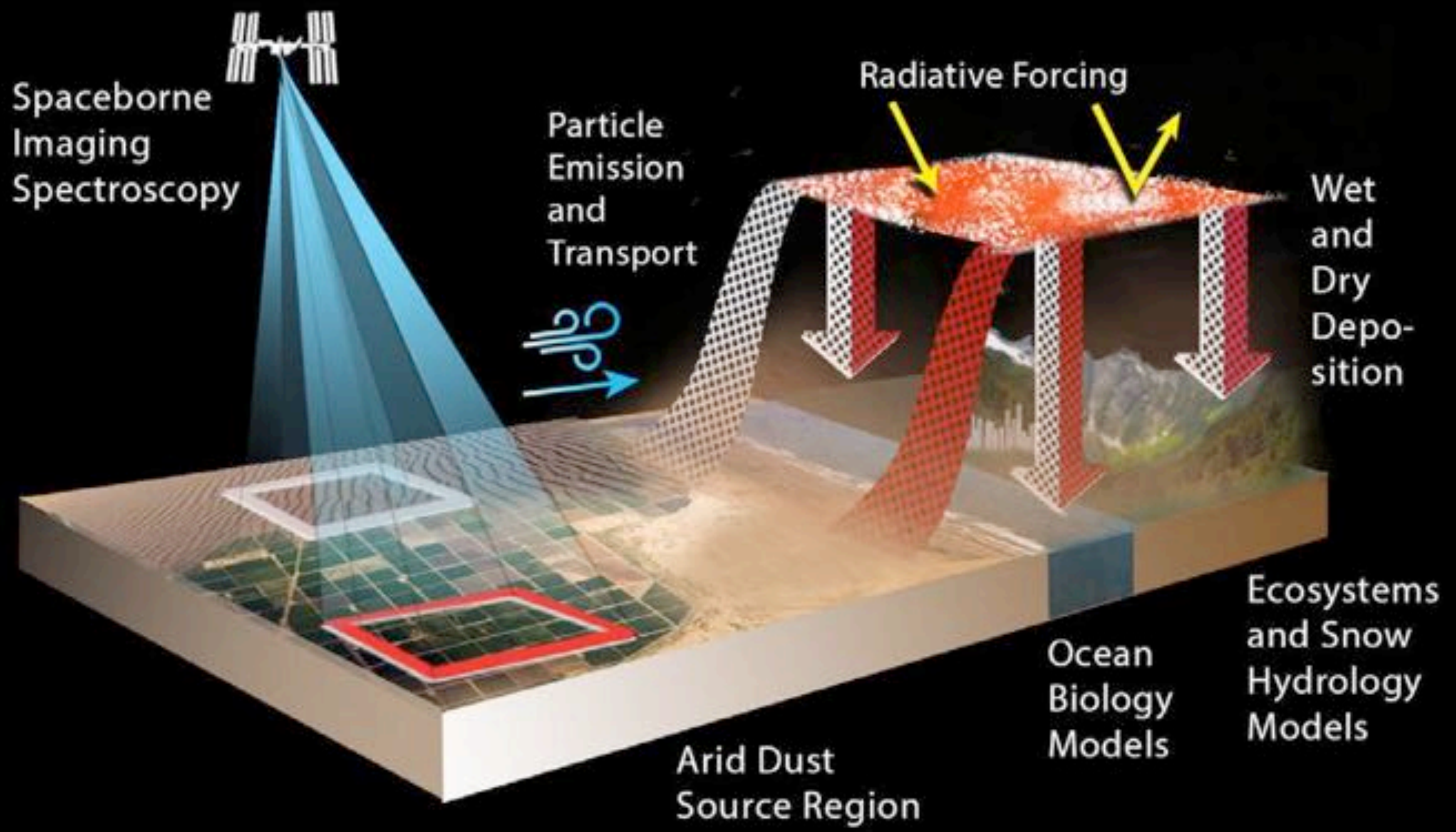
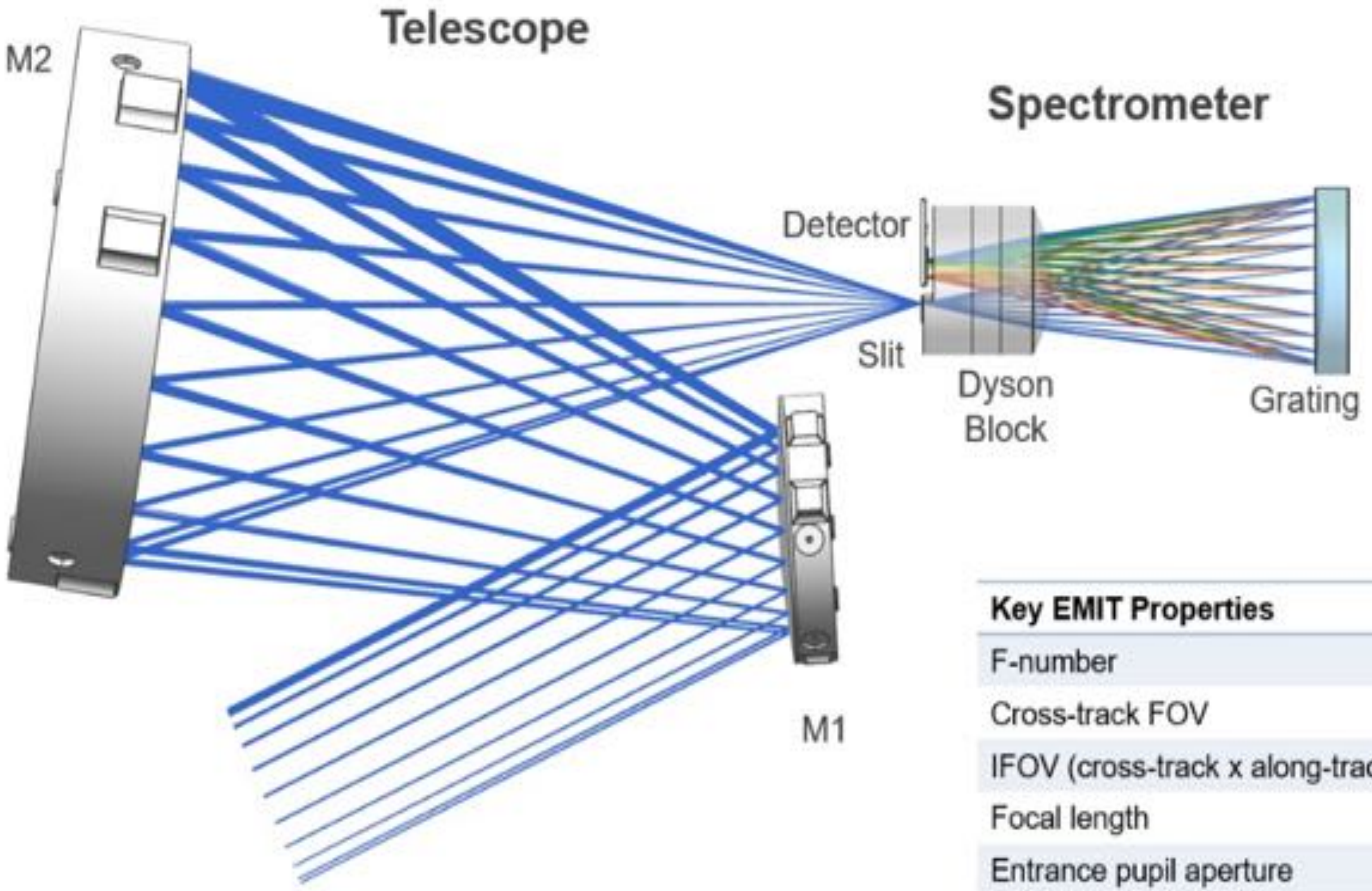
MODIS October 26, 2007. Credit: NASA

The Earth surface Mineral dust source InvesTigation (EMIT)

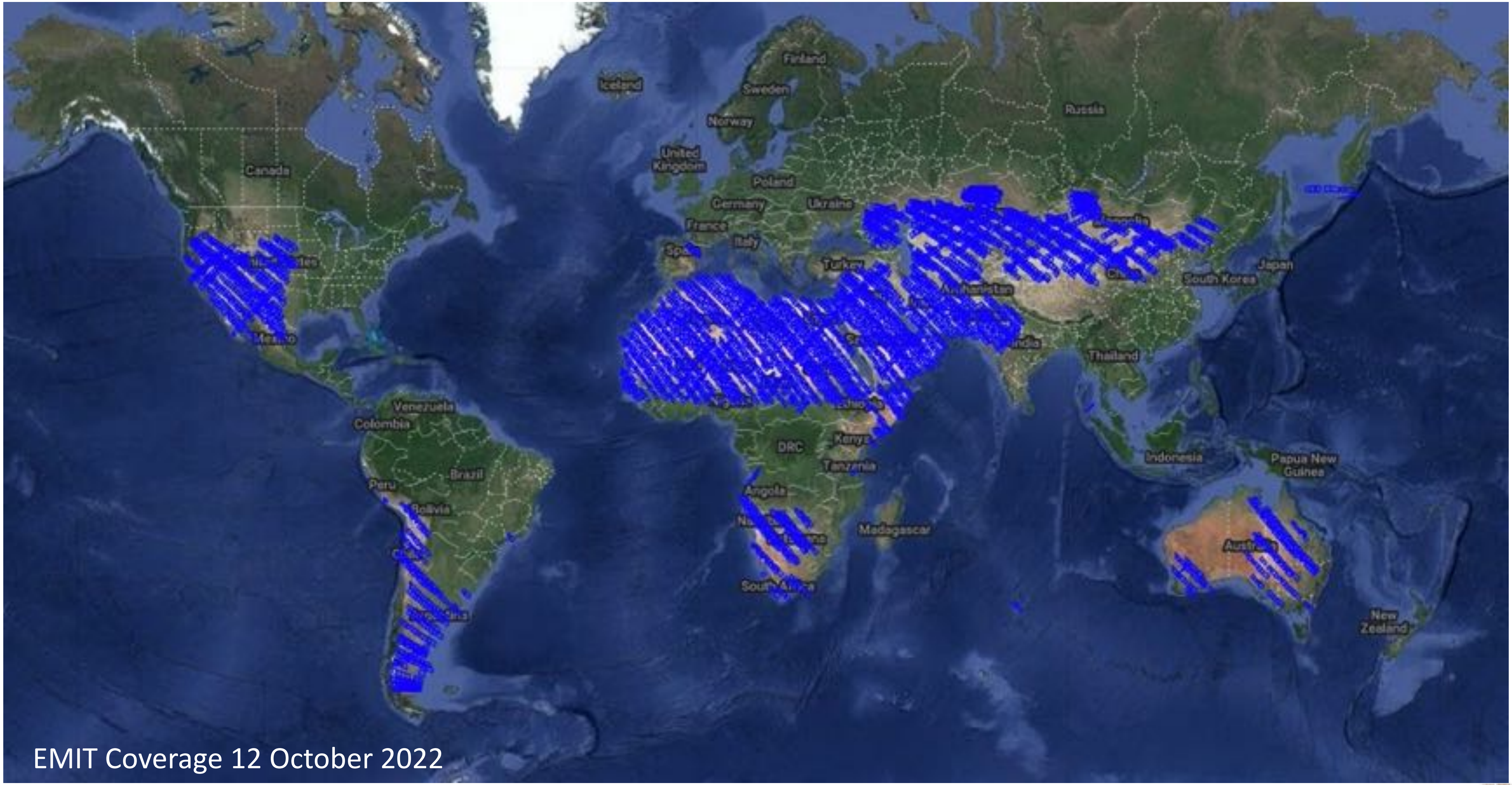




EMIT Imaging Spectrometer Elements

- **Two-mirror Telescope**
  - M1 (y-decentered, asphere)
  - M2 (y-decentered, asphere)
- **Dyson spectrometer**
  - Dyson block: CaF_2 lens with step
  - Slit (30 µm width, 37.2 mm length)
  - Diffraction grating (structured blaze)
- **FPA Assembly**
  - Order sorting filter (three zone)
  - Detector (HgMgTe)
    - 1280 x 480 pixel format
    - 30 µm pixel size

Key EMIT Properties	
F-number	F/1.8
Cross-track FOV	11°
IFOV (cross-track x along-track)	155 x 171 µrad
Focal length	193.5 mm
Entrance pupil aperture	110 mm
Spectral Range	380 – 2500 nm
Spectral Sampling	7.4 nm



EMIT Coverage 12 October 2022

Challenge

- Fixed ISS bandwidth limits
- Need to complete mission as fast as possible for risk reduction

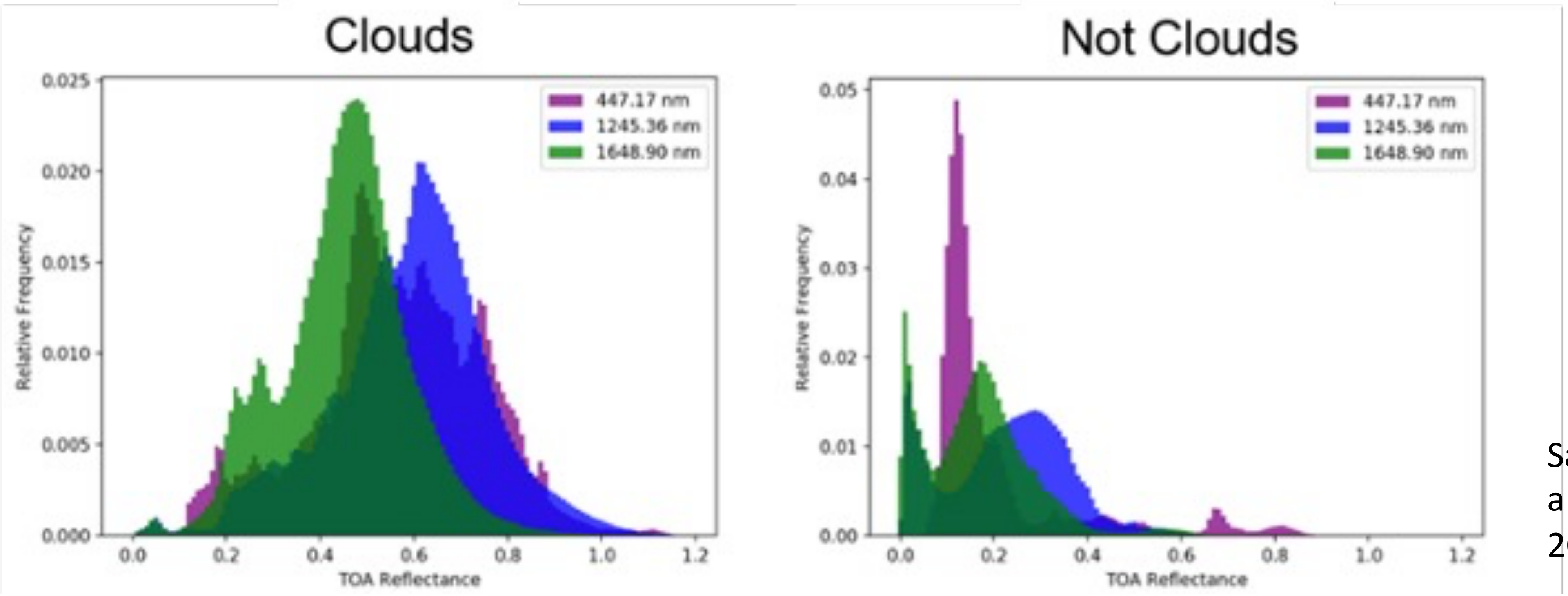
The EMIT Solution

- Clouds cover approximately half of Earth's land mass
- Screen out obvious clouds in real time, at the sensor
- More thorough screening on the ground for product accuracy

Three channel threshold of top of atmosphere reflectance

Setting	450 nm	1250 nm	1650 nm
conservative	0.51	0.56	0.29
moderate	0.31	0.51	0.22
aggressive	0.28	0.46	0.22

(must exceed threshold in all channels simultaneously)



Sandford et al., AMT 2020

Relationship between Radiance, DN and ρ

Gain

Dark level

$$L_i = g_i\,[DN_i - d_i]$$

Relationship between Radiance, DN and ρ

Gain ↓ g_i; Dark level ↓ d_i; Solar irradiance ↓ F_i; Solar zenith ↓ θ_s

$$L_i = g_i \left[DN_i - d_i \right] = \frac{F_i \rho_i \cos \theta_s}{\pi}$$

Relationship between Radiance, DN and ρ

Gain
Dark level
Solar irradiance
Solar zenith

$$L_i = g_i\,[DN_i - d_i] = \frac{F_i \rho_i \cos\theta_s}{\pi}$$

Threshold in DNs:

TOA threshold from literature

$$T_i = \frac{F_i \alpha_i \cos\theta_s}{\pi g_i} + d_i$$

Further simplification:

$$b_i = \frac{F_i \alpha_i}{\pi g_i}$$

Onboard test:

$$T_i = d_i + b_i \cos(\theta_s)$$

Dark level

Brightness threshold at solar zenith zero

Actual solar zenith angle

Onboard calculation

- Test three channels for each pixel. Any pixel that exceeds all three thresholds is marked cloudy

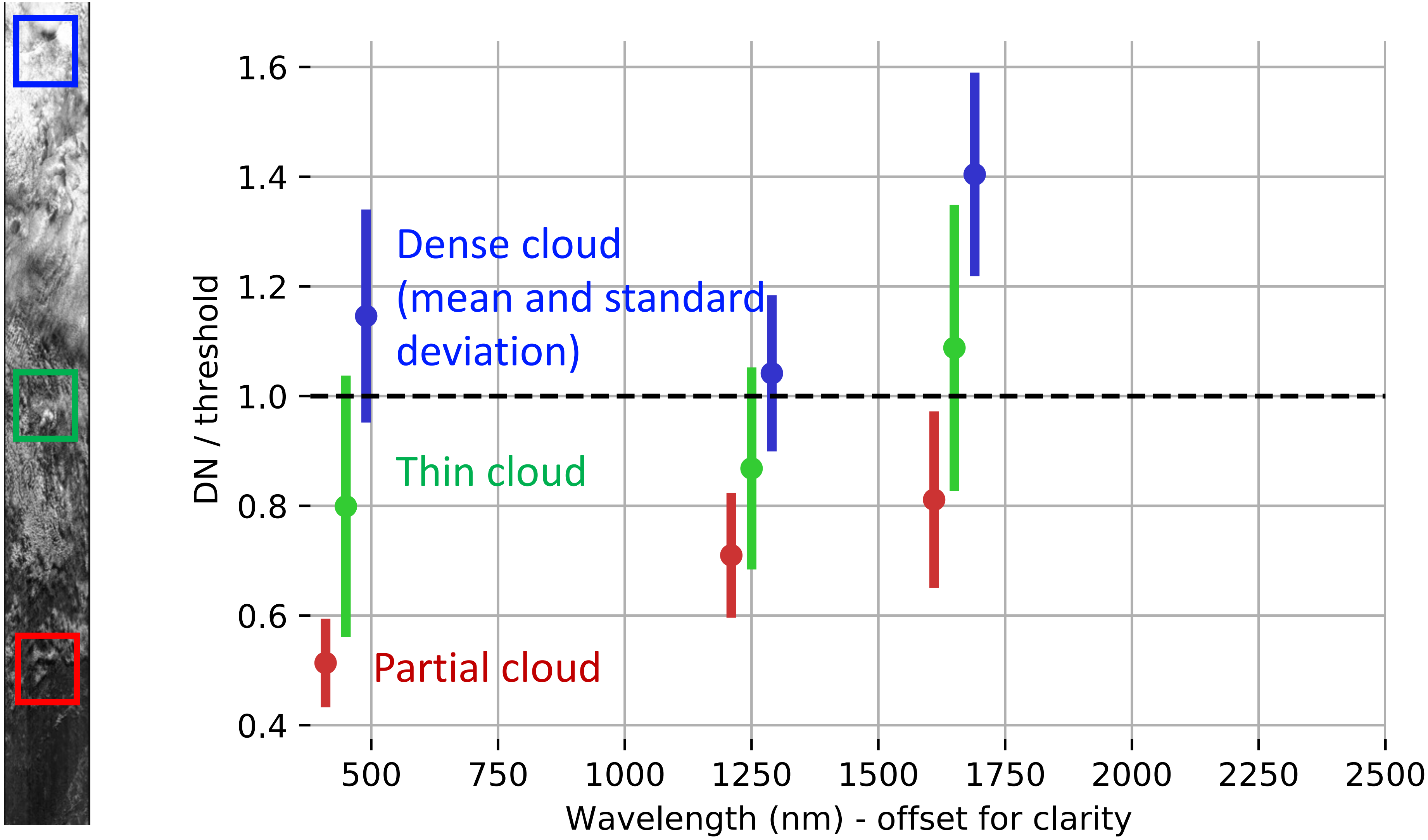
$$T_i = d_i + b_i \cos(\theta_s) \quad for \quad i \in \{1,2,3\}$$

Dark level (d_i)

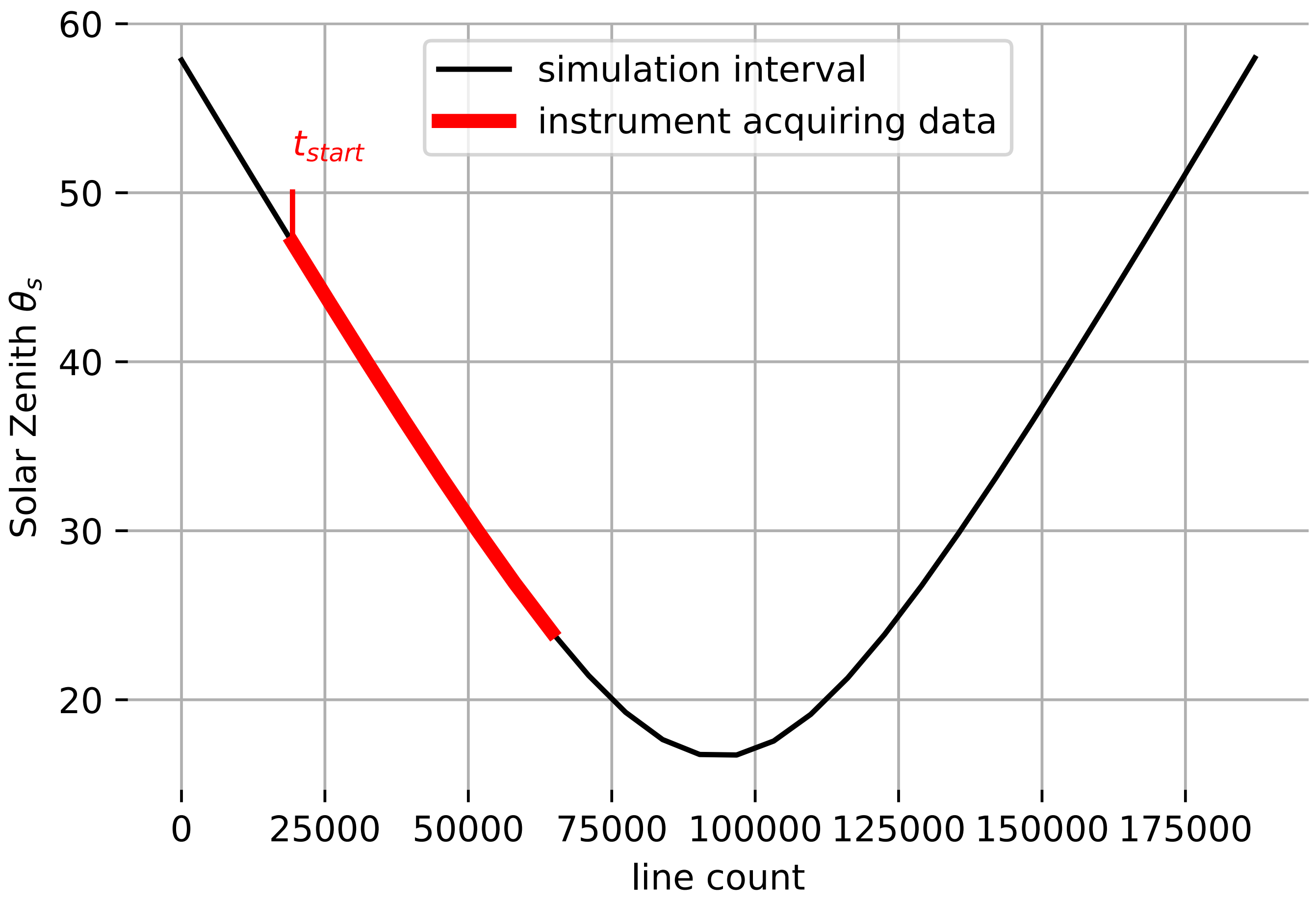
Brightness threshold at solar zenith zero (b_i)

Actual solar zenith angle (θ_s)

- Any segment with more than 25% clouds is excised.

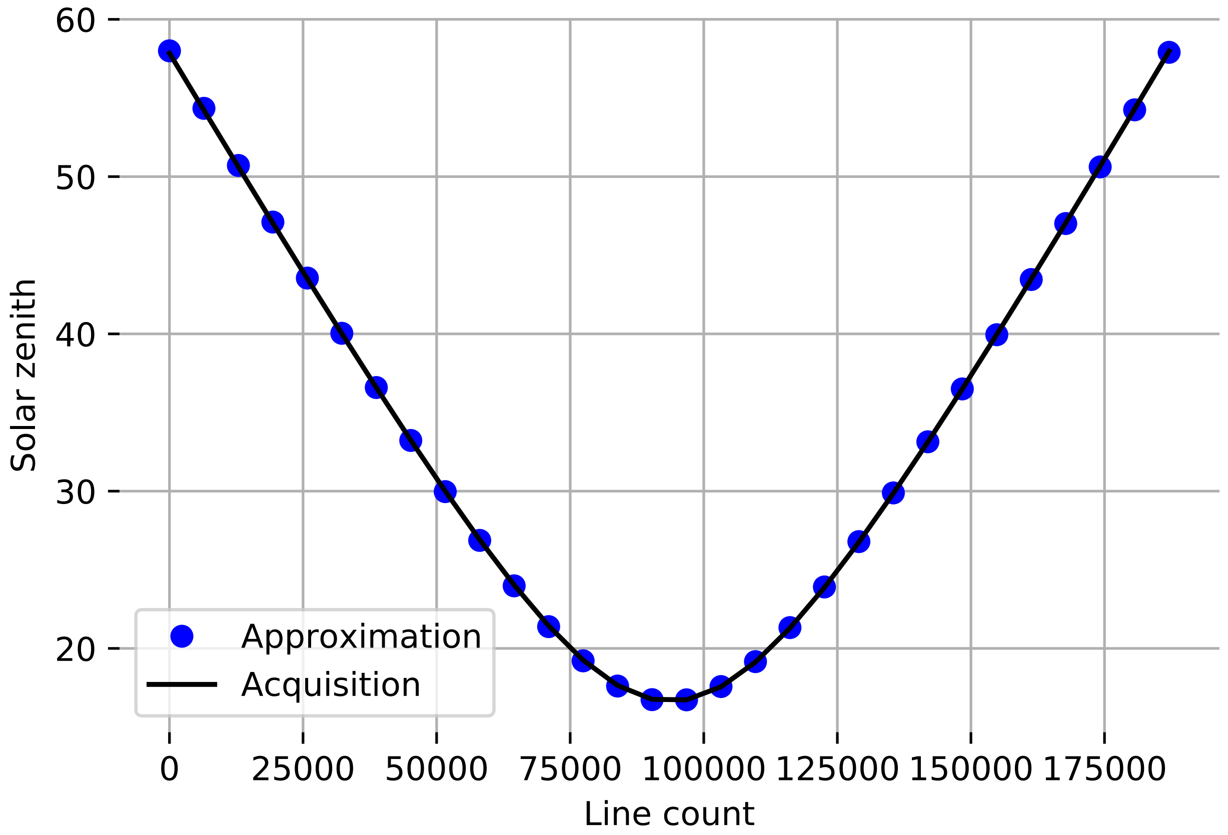

Dense cloud
(mean and standard
deviation)
Thin cloud
Partial cloud
DN / threshold
1.6
1.4
1.2
1.0
0.8
0.6
0.4
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm) - offset for clarity

TOA reflectance depends on solar zenith

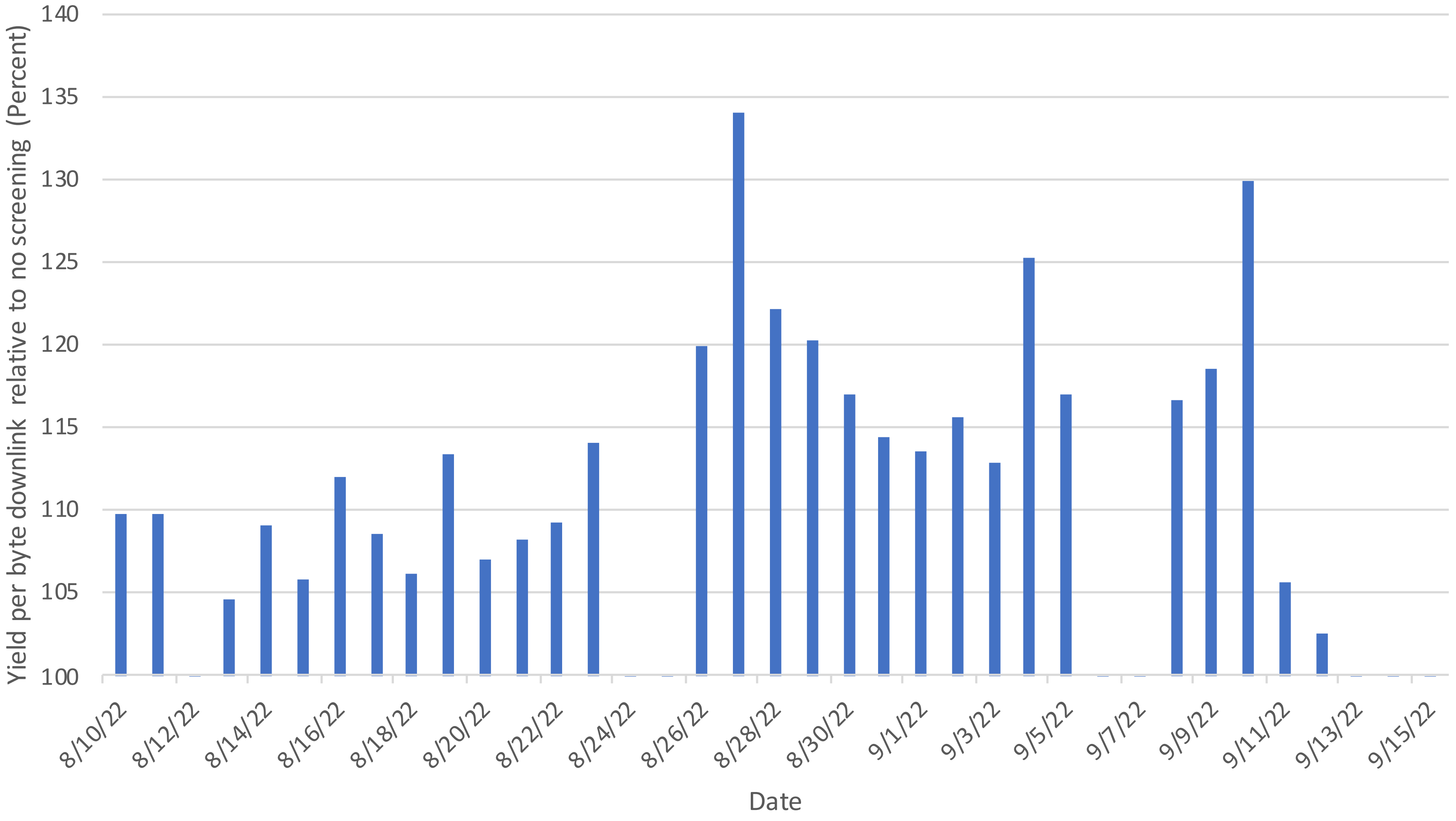


Solar zenith approximation

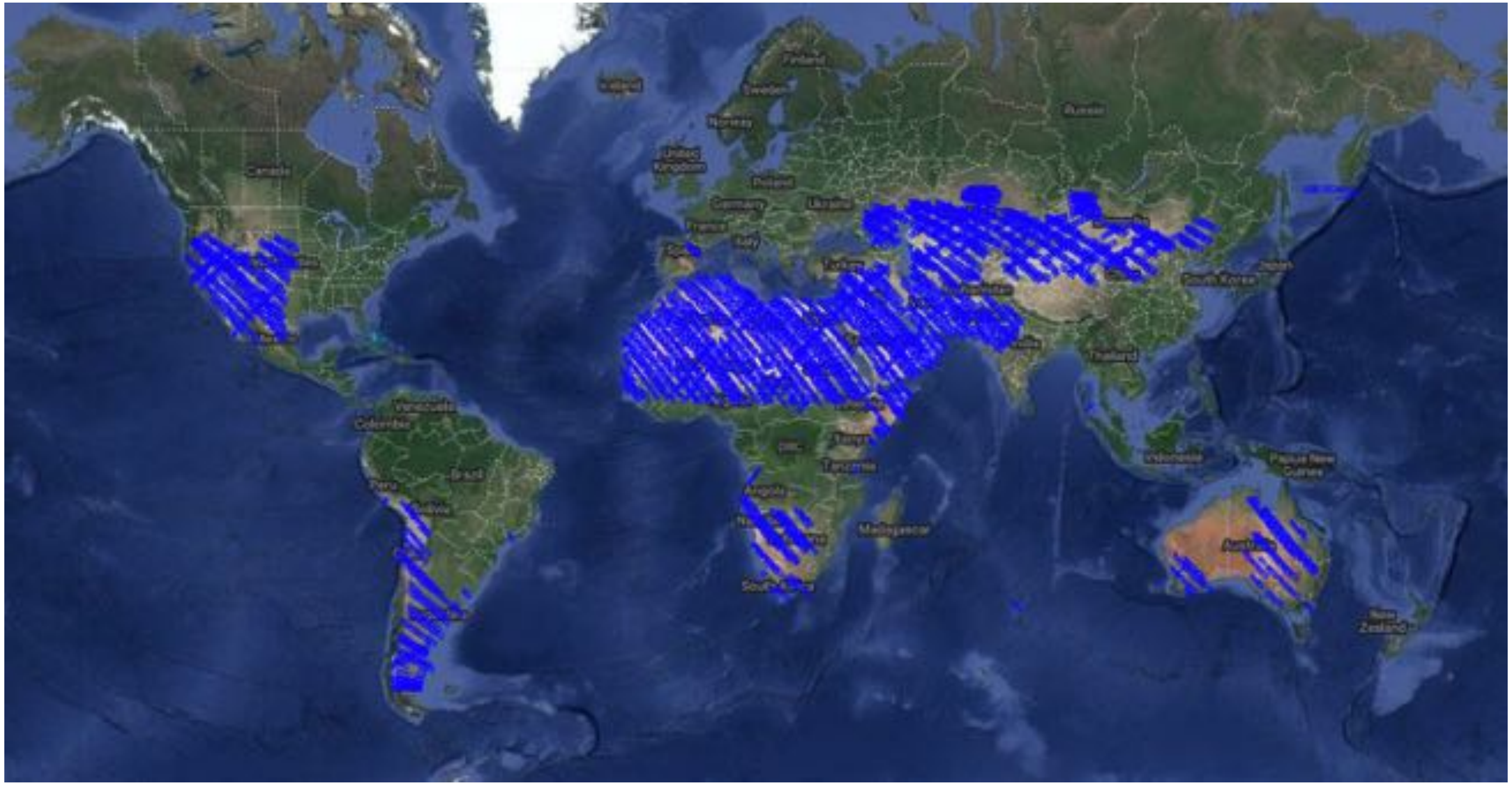
$$\theta_s = \sqrt{h_a + h_b\left(\frac{\ell + t_{start}}{t_n} + h_c\right)^2}$$



Data yield improvements

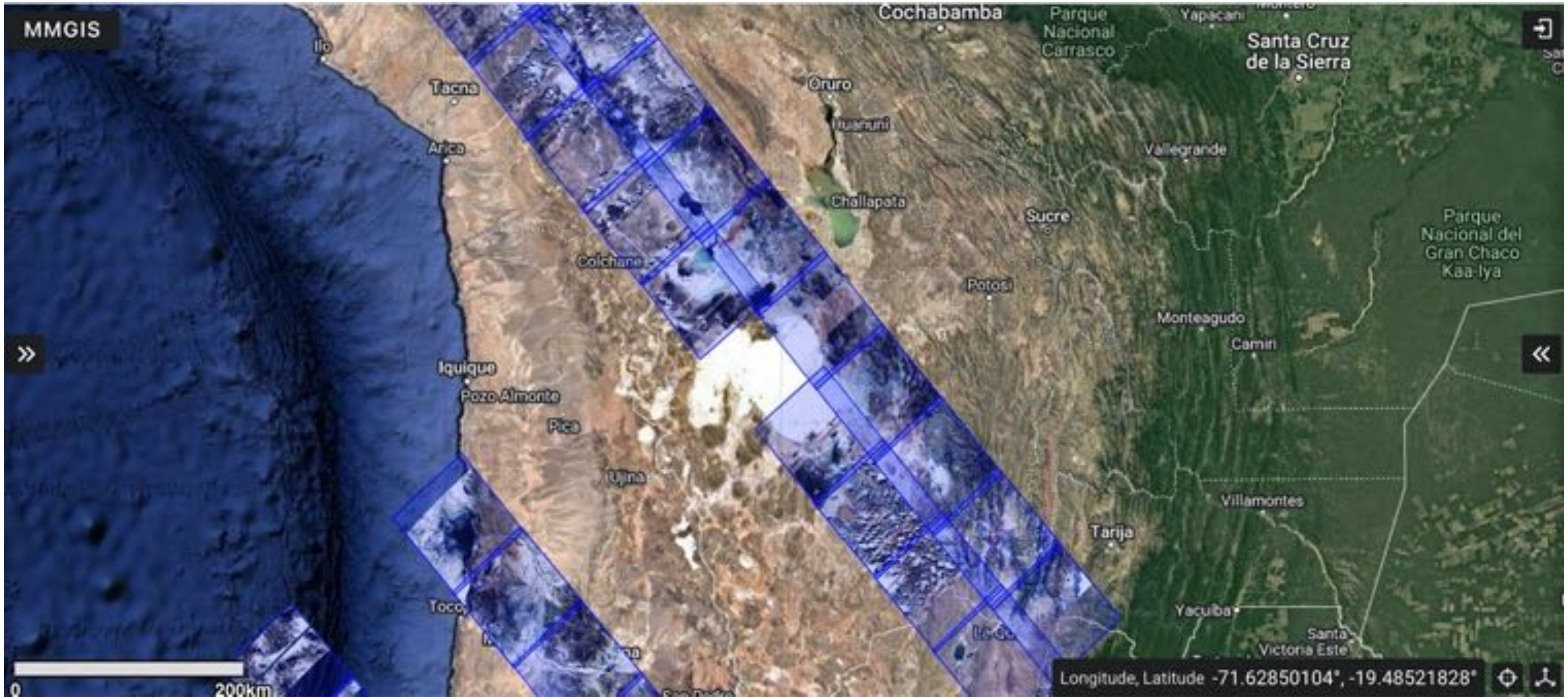


Challenge: arid lands



Challenge: popcorn clouds

One false positive



Future improvements?

- Cirrus channel at 1380 (requires an “or” operator)
- Different spatial aggregation or partial-swath screening