



ENMAP DATA PRODUCT VALIDATION: INITIAL STEPS TOWARDS DATA HOMOGENIZATION AND INTEROPERABILITY

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M. A. Soppa ⁽³⁾, A. Bracher ⁽³⁾, M. Bachmann ⁽⁴⁾, R. Kokaly ⁽⁵⁾, C. Ong ⁽⁶⁾, J. F. Moreno ⁽⁷⁾, F. Gascon ⁽⁸⁾, R. O. Green ⁽⁹⁾, E. Carmona ⁽⁴⁾, M. Pato ⁽⁴⁾,
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⁽⁵⁾ US Geological Survey (USGS), Boulder Colorado, United States of America

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⁽¹⁰⁾ Space Agency, German Aerospace Center (DLR), Bonn, Germany

LPVE 2023

EnVAL: validation of EnMAP products (GFZ)

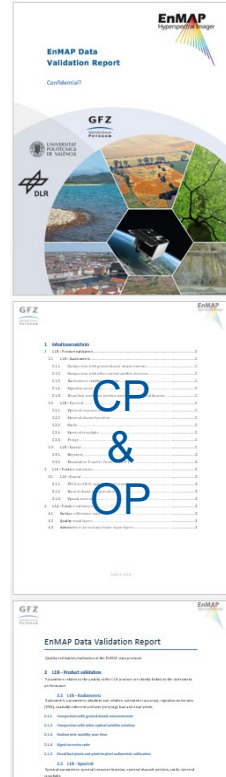
Image based



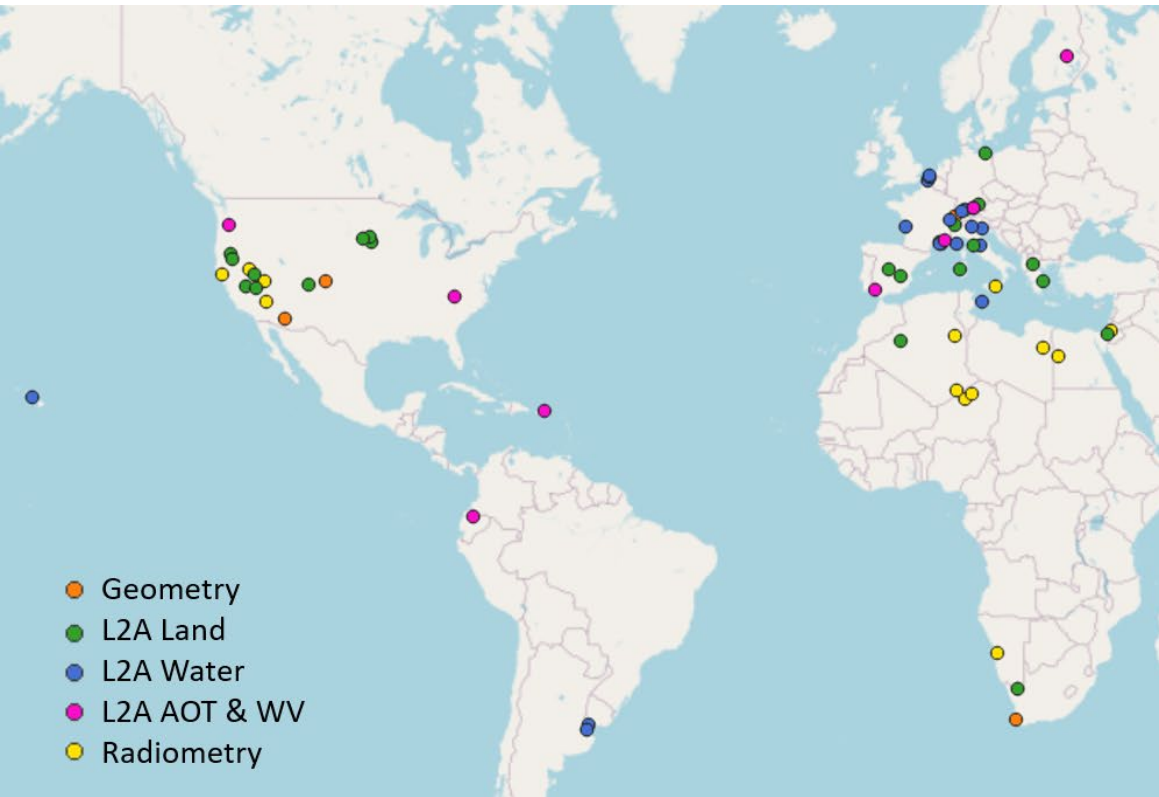
| Data product | Field-, Image-, Model based validation | | | |
|--------------|--|--|--|--|
| | Radiance | Reflectance | Geometry | Quality |
| L1B | <ul style="list-style-type: none"> - Vicarious: <ul style="list-style-type: none"> • Inter. Sites • RadCalNet - Stability: <ul style="list-style-type: none"> • PICS • Moon • SNR - Scene based: <ul style="list-style-type: none"> • Dead/bad • Striping | | <ul style="list-style-type: none"> • Keystone • MTF | <ul style="list-style-type: none"> • SRF/Smile • Anomalies |
| L1C | <ul style="list-style-type: none"> • Cross-Validation (PRISMA, S2, EMIT, ...) | | <ul style="list-style-type: none"> • Absolute • Band-to-Band • VNIR-to-SWIR | <ul style="list-style-type: none"> • Anomalies |
| L2A | | <ul style="list-style-type: none"> • Ground & Water • Quality mask • Aerosol & WV | | <ul style="list-style-type: none"> • Anomalies |

Field based

In-situ/
Reference data



EnVAL: validation of EnMAP products (GFZ)



Planned for CP:

- Potential ~100 sites
 - Fulfil certain requirements regarding:
 - Altitude & global distribution
 - Atmospheric conditions
 - Site characteristic
- Well balanced

EnVAL: validation of EnMAP products (GFZ)

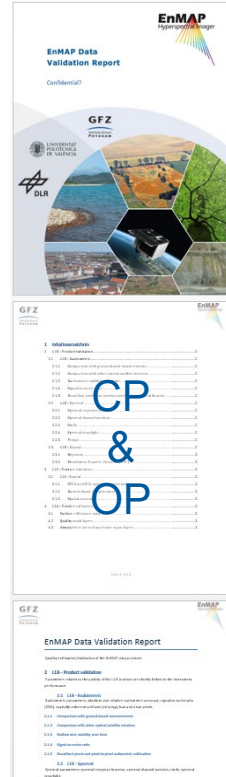
Image based



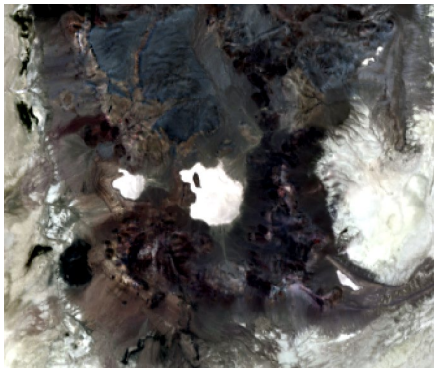
| Data product | Field-, Image-, Model based validation | | | |
|--|--|-------------|----------|---------|
| | Radiance | Reflectance | Geometry | Quality |
| <p>In-situ/Reference data</p> <p>L1B</p> <ul style="list-style-type: none"> Core sites <ul style="list-style-type: none"> Demmin/Camarena (agriculture, soils; S. Chabrillat) → REF Lake Constance (water; A. Bracher) → REF Munich North Isar (agriculture; T. Hank) → REF Makhtesh Ramon (geology; E. Ben-Dor) → REF Plateau_Rosa (snow; R. Colombo) → REF International sites <ul style="list-style-type: none"> Ivanpah Playa (USA ; R. O. Green) → RAD Pinnacles (Australia; C. Ong) → RAD Amiaz Playa (Israel; E. Ben-Dor) → RAD Networks/others <ul style="list-style-type: none"> RadCalNet (Railroad Valley, USA; Gobabeb, Namibia) → RAD, REF Hypernet → REF AERONET/AERONET-OC → REF PICS (Libya4 & Algeria3) → RAD, REF S2 Geographic Reference Image → GEO | | | | |
| | L1C | | | |
| | L2A | | | |

Field based

**In-situ/
Reference data**



L1B TOA validation



Corresponding
AOI/pixel;
homogeneity check

+ HR georeference
+ Geolayer

BOA REF

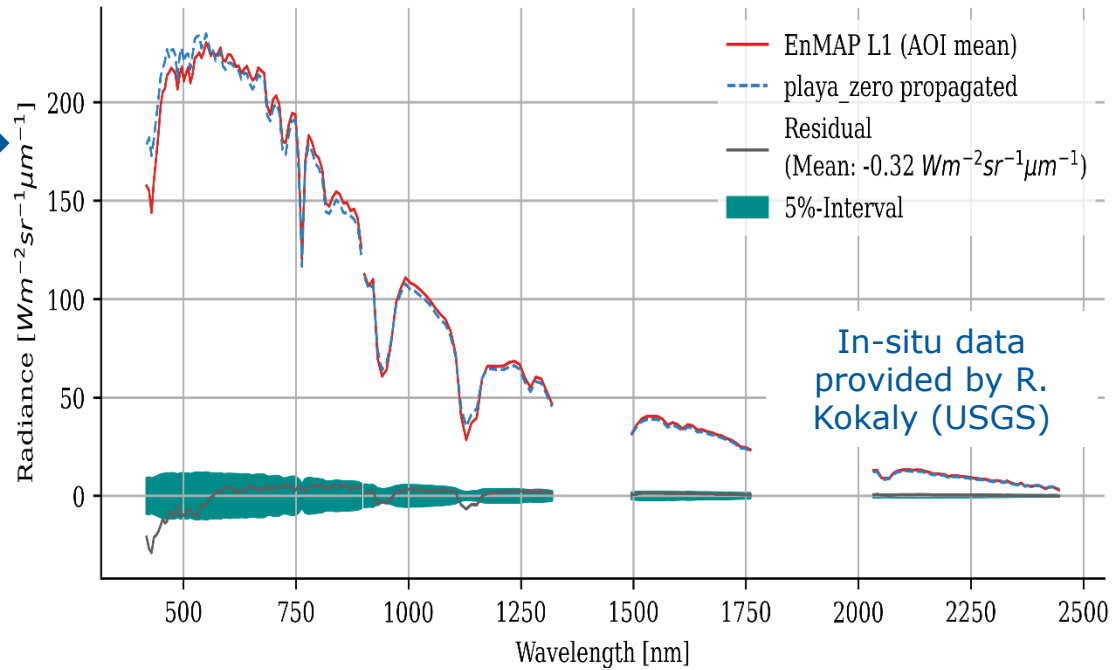
- RadCalNet
- In-situ spectra
- AOT & WV

Propagation →
(TOA RAD)

(Spectral;
temporal;
view & illum.;
AOT & WV
adjustment)

TOA Radiance Comparison playa_zero (06/28/2022)

Off-nadir across: 2.5; along: -0.2; delta AOT: -0.326, delta CWV: 1.217



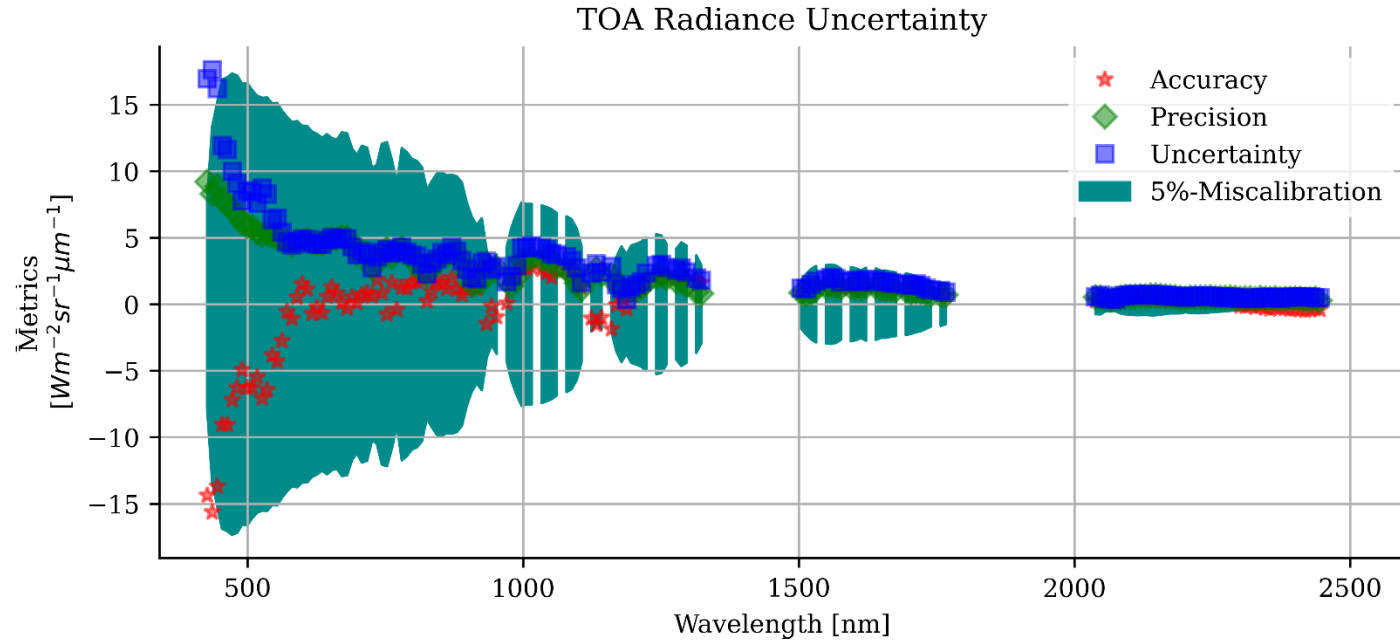
L1B TOA RAD validation

- 35 L1B potential validation matchups



- 23 valid matchups

(Railroad Valley (3), Gobabeb (10), Pinnacles (3), Amiaz Plain (1), Makhtesh Ramon (1), Playa Zero (2), TXL (1), Nansen Ice Shelf (2))



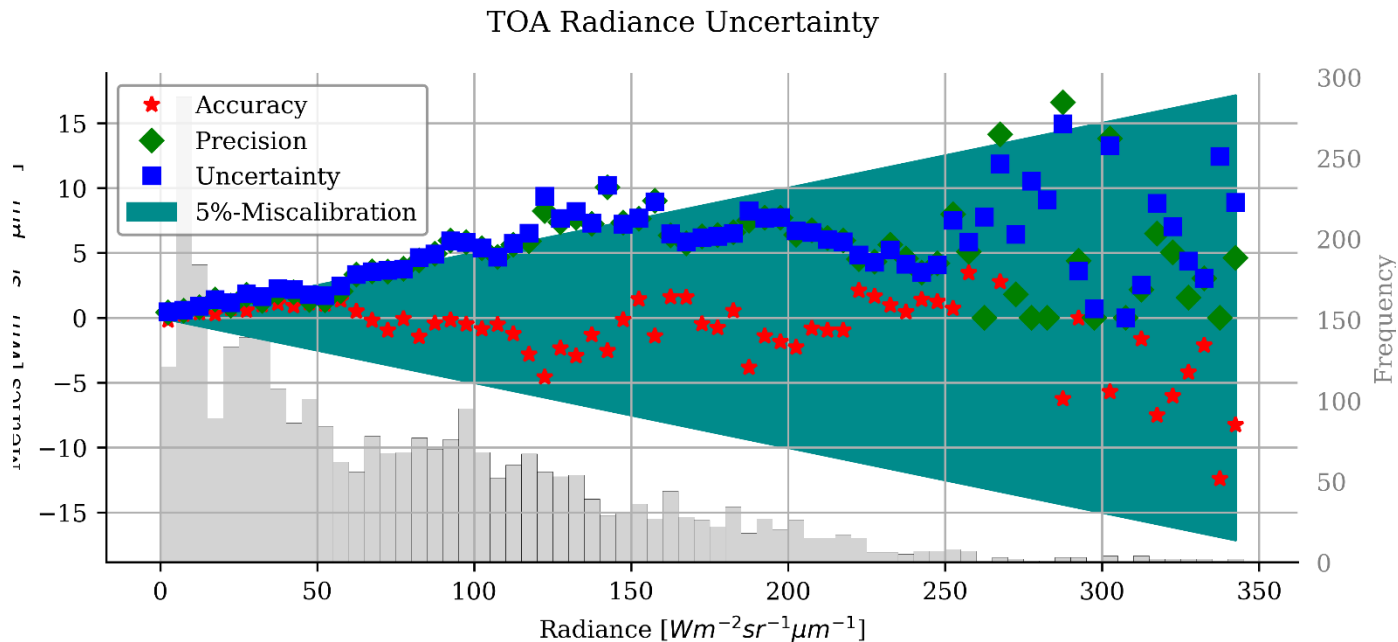
L1B TOA validation

- 35 L1B potential validation matchups



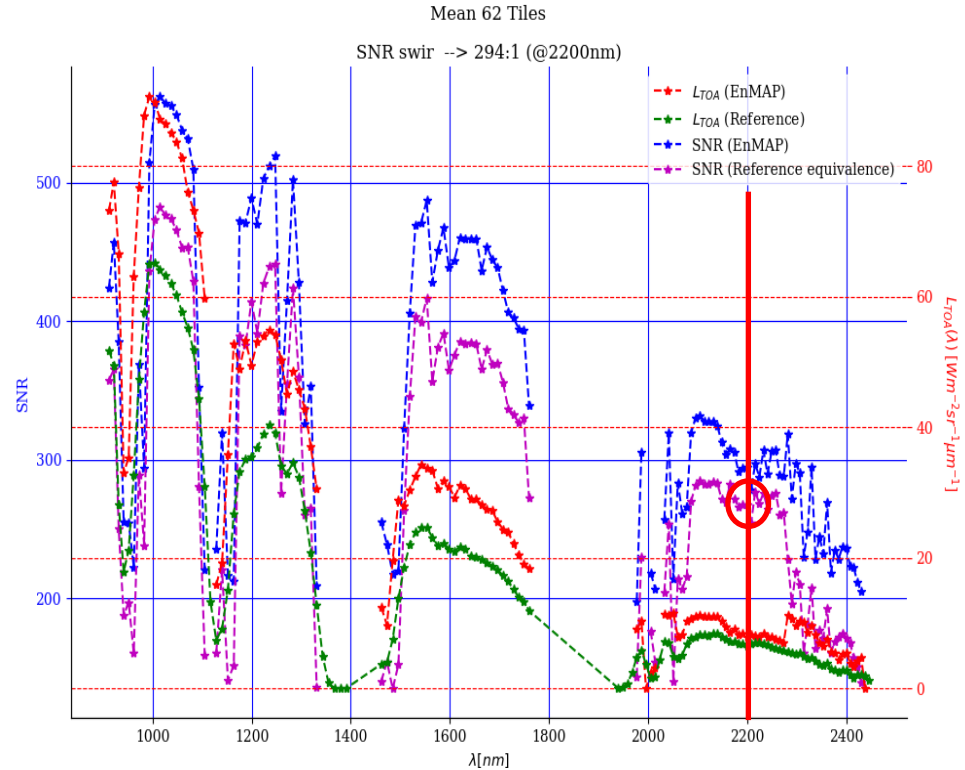
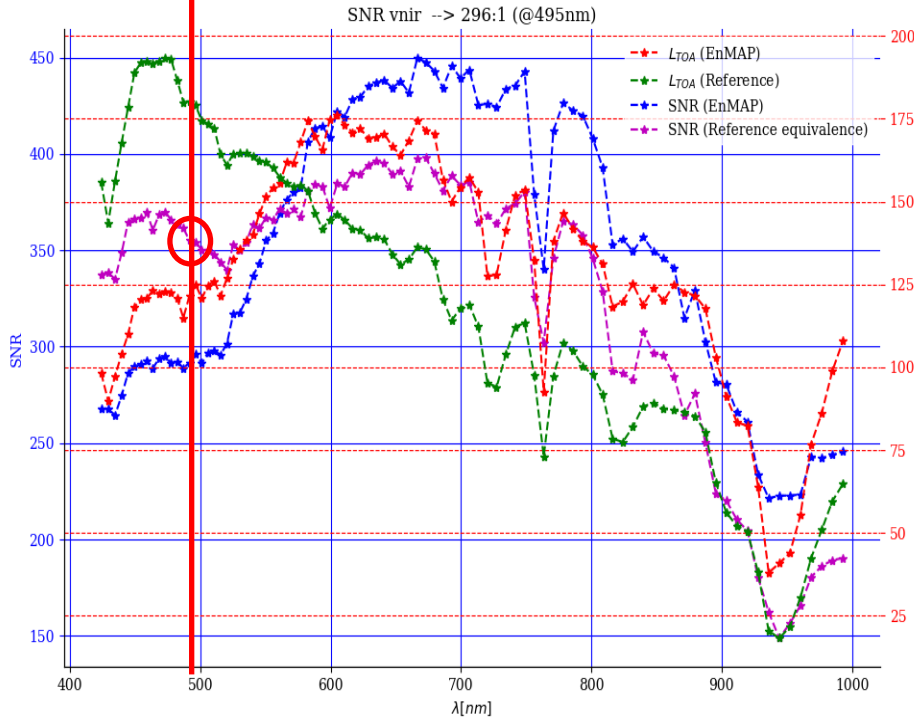
- 23 valid matchups

(Railroad Valley (3), Gobabeb (10), Pinnacles (3), Amiaz Plain (1), Makhtesh Ramon (1), Playa Zero (2), TXL (1), Nansen Ice Shelf (2))



L1B SNR

- Mean SNR calculated on the basis of 62 tiles
- DCT based; algorithm by J. Gorrone (UPV)

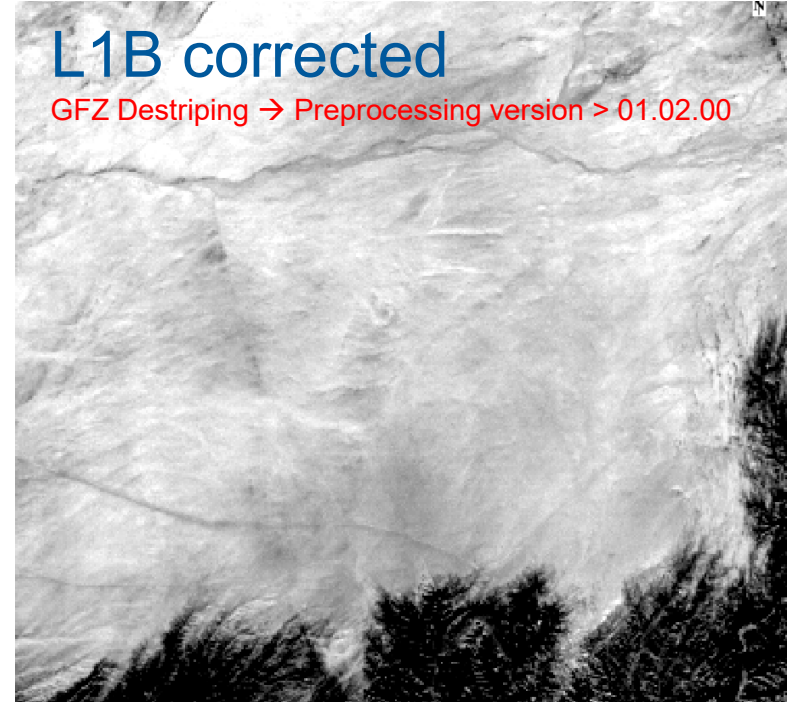
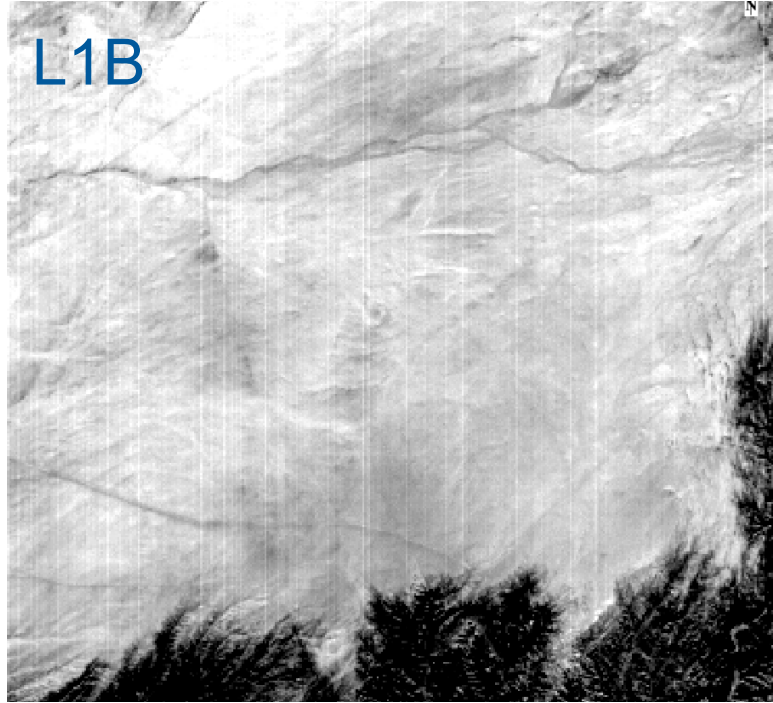


L1B TOA striping (across-track)

e.g. SWIR 2208 nm

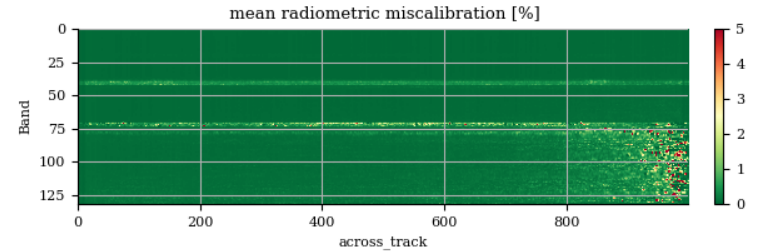
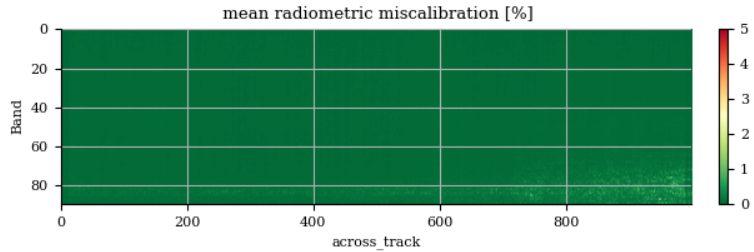
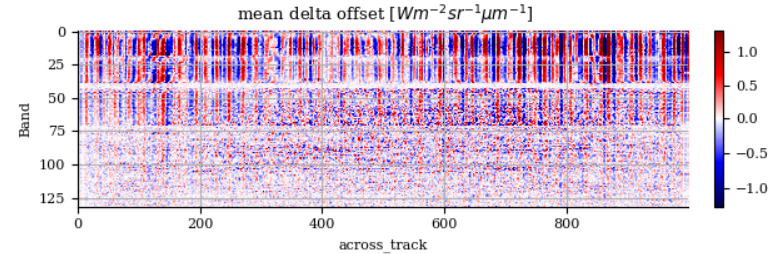
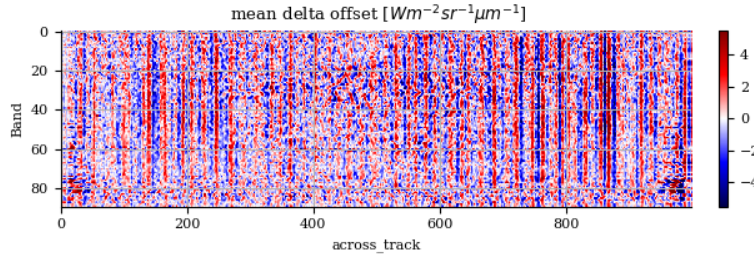
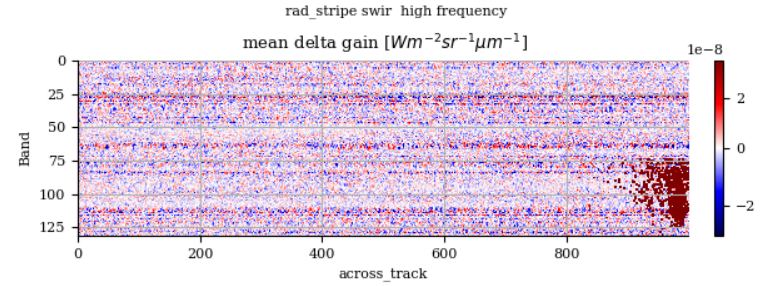
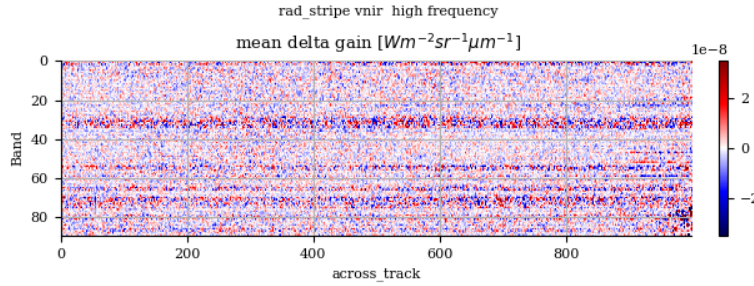
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Stretch: linear 5%



L1B TOA striping (across-track)

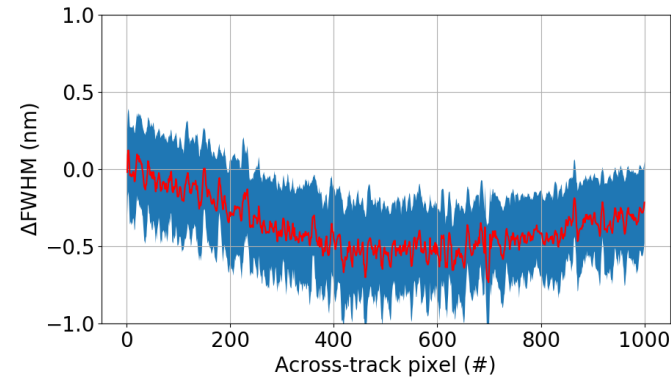
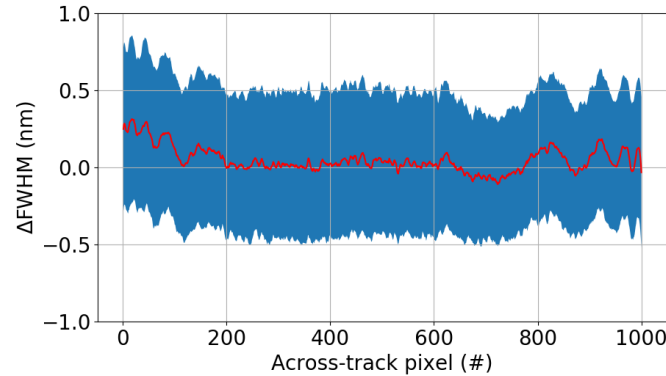
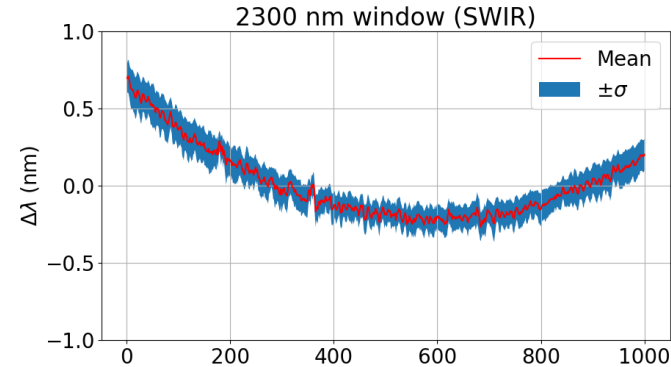
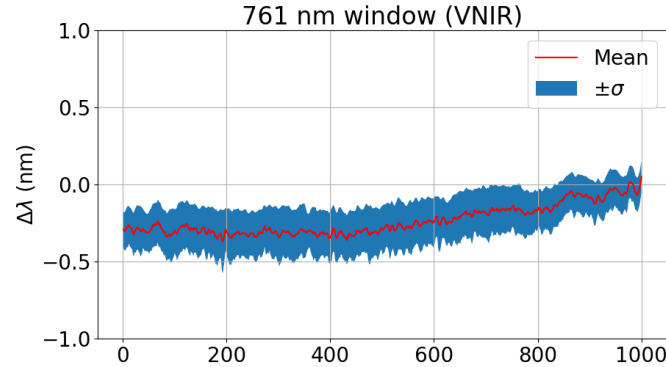
- VNIR & SWIR
- Based on 54 tiles
- High frequency
- No explicit criteria → 5%



L1B spectral validation



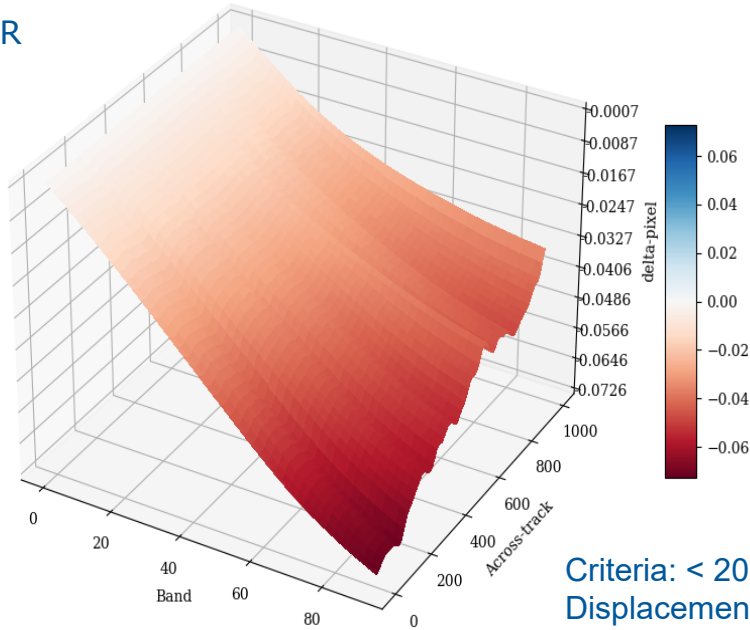
- Based on 7 tiles
- Validation performed by Luis Guanter (UPV)
- Criteria: < 20 % linear displacement of a detector element



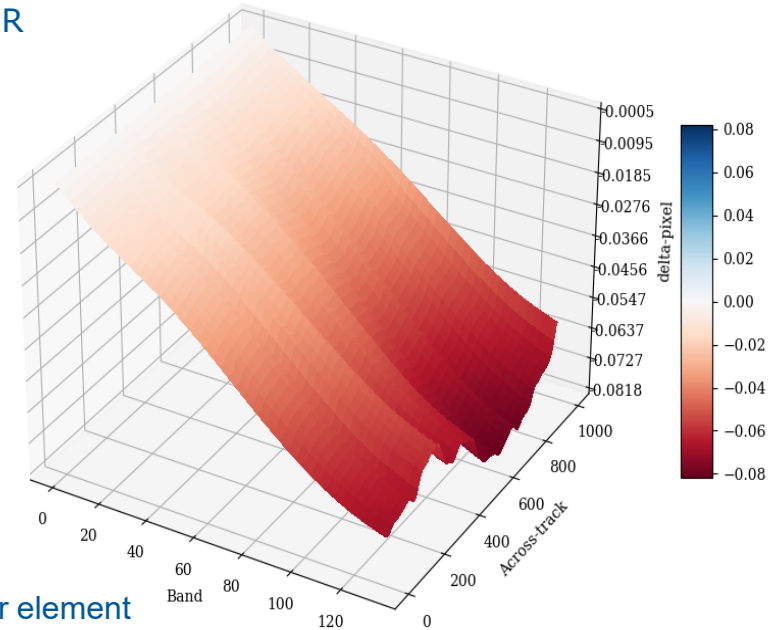
L1B keystone

- Mean keystone calculated based on 36 tiles
- Pixel-based cross-track distortion cumulated along bands

VNIR

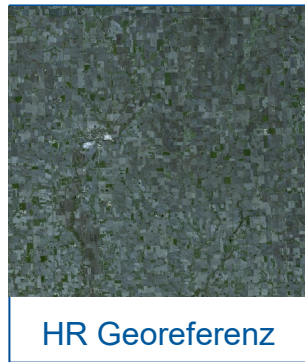
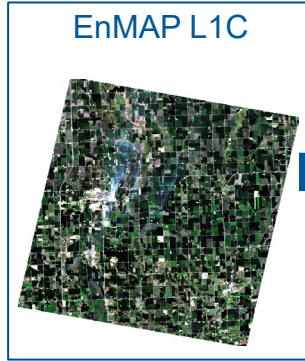


SWIR

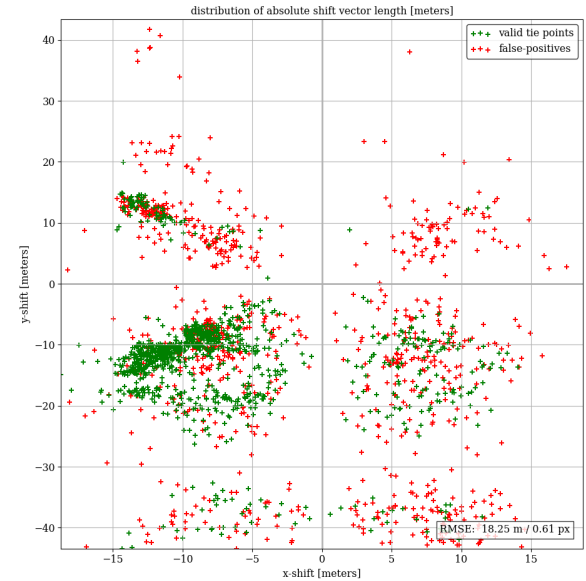
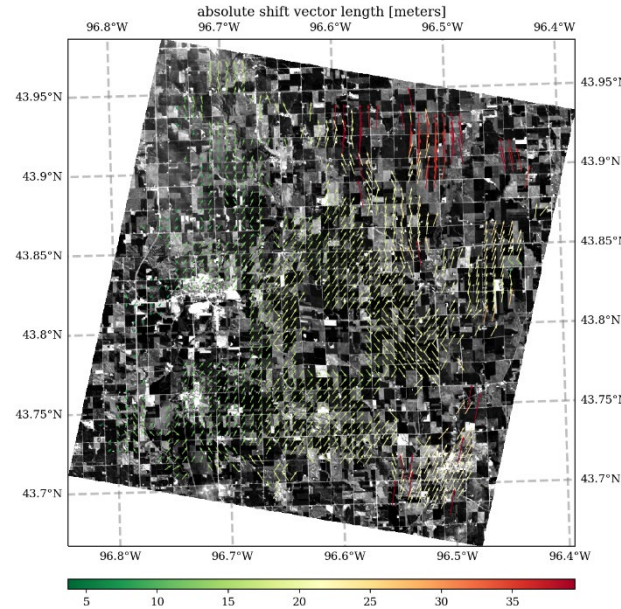


Criteria: < 20 % linear
Displacement of a detector element

L1C absolute geometric validation

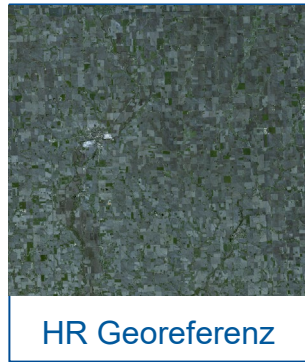
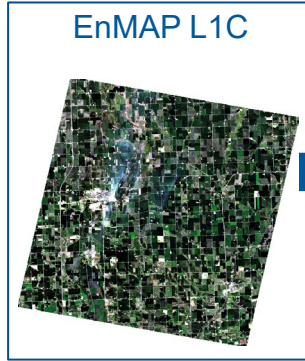


Spatial mis-registration



- Matching possible \rightarrow < 1 GSD (1 sigma)
- Matching not possible (due to clouds, snow, water etc.) \rightarrow < 100 m (1 sigma)

L1C absolute geometric validation

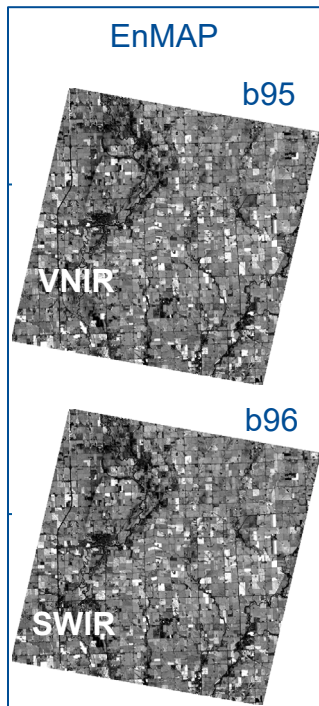


Aggregated geometric misregistration statistic

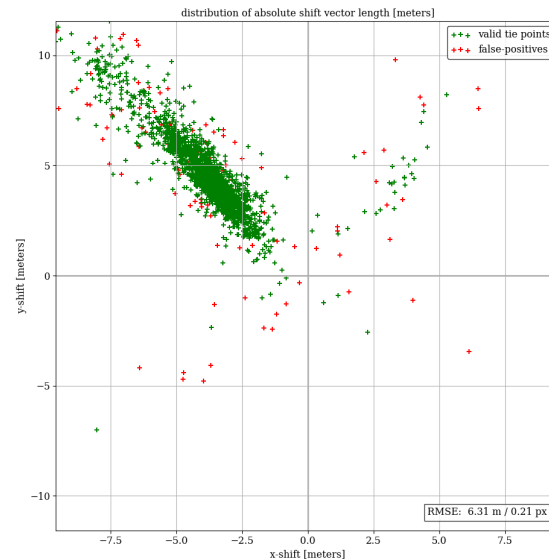
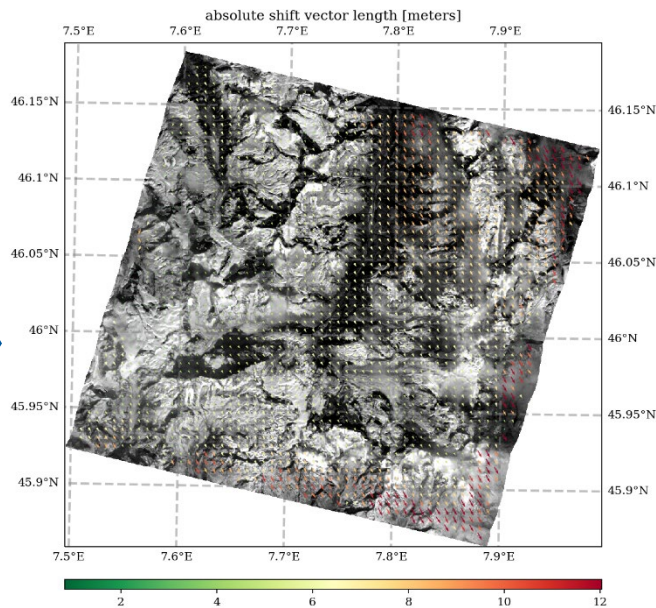
| METRIC [m] | VALUE [m] |
|------------|-----------|
| N_Tiles | 47 |
| RMSE | 29.05 |
| RMSE_X | 17.57 |
| RMSE_Y | 19.54 |
| MEAN_ABS | 33.09 |
| MEAN_X | -0.1 |
| MEAN_Y | -14.7 |
| STD_ABS | 5.3 |
| STD_X | 6.3 |
| STD_Y | 6.7 |

- Matching possible $\rightarrow < 1$ GSD (1 sigma)
- Matching not possible (due to clouds, snow, water etc.) $\rightarrow < 100$ m (1 sigma)

VNIR-SWIR co-registration validation



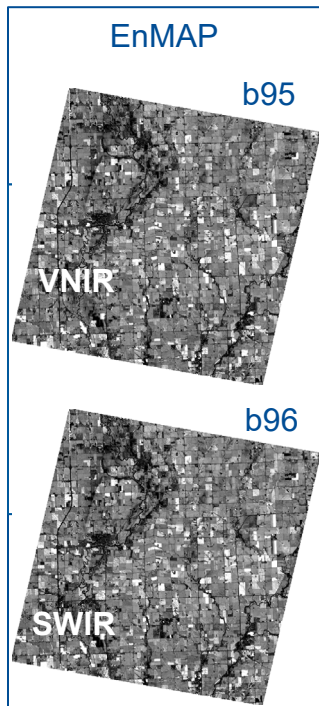
Spatial mis-registration



VNIR-SWIR co-registration validation

Aggregated geometric misregistration statistic

Only valid for acquisitions > 11.02.2023



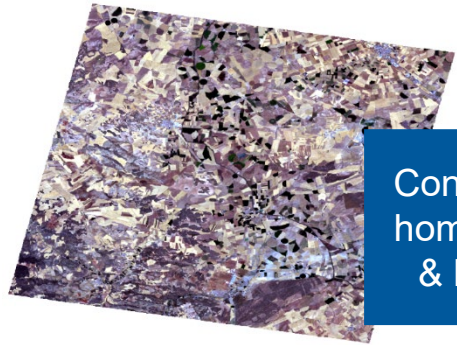
| METRIC [m] | VALUE |
|----------------|-------|
| N_Tiles | 31 |
| RMSE | 5.58 |
| RMSE_X | 3.8 |
| RMSE_Y | 4.0 |
| MEAN_ABS_SHIFT | 4.6 |
| MEAN_X_SHIFT | -3.0 |
| MEAN_Y_SHIFT | 3.2 |
| STD_ABS_SHIFT | 2.79 |
| STD_X_SHIFT | 2.08 |
| STD_Y_SHIFT | 2.18 |

Requirements: < 30 % of a pixel (1 sigma)

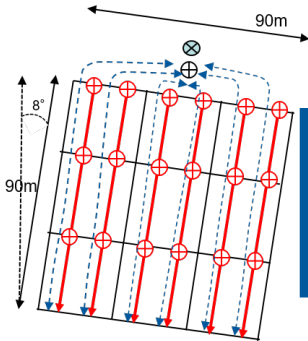
L2A BOA validation (land)

Spectral Comparison Barrax (07/18/2022)

Off-nadir across: 3.5; along: -0.2; AOT: 0.275, CWV: 1.627, DDV: 1.000

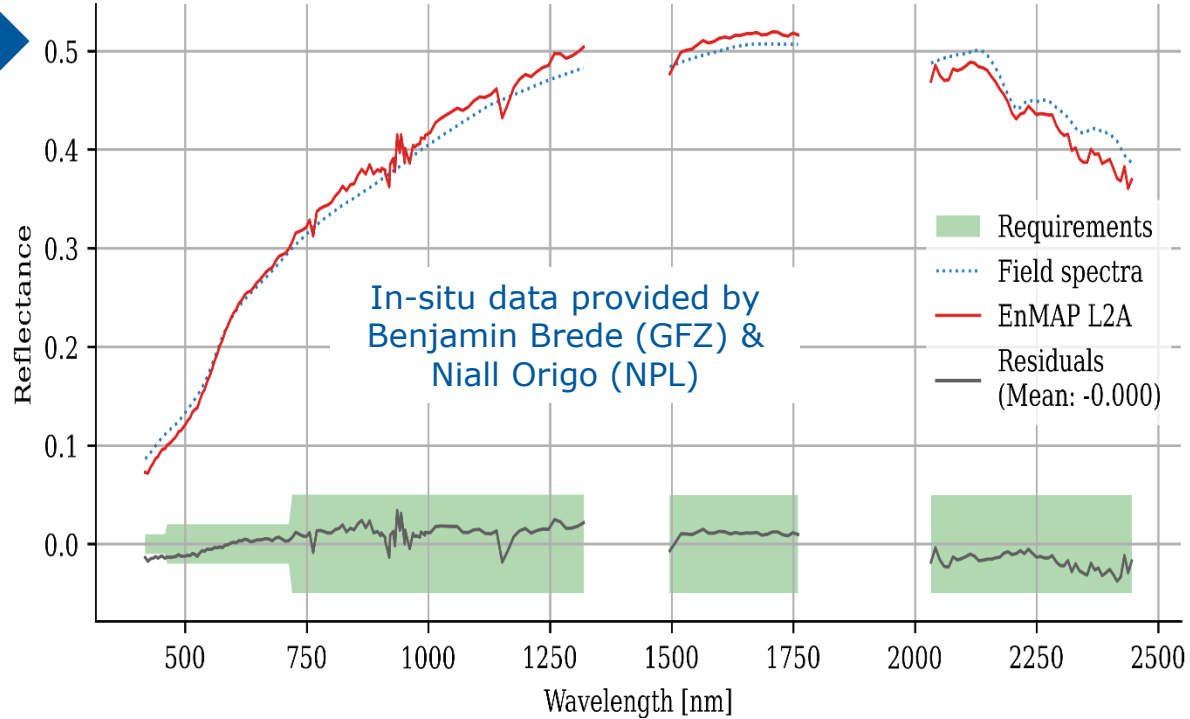


Consistency;
homogeneity
& location

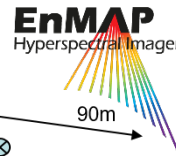


mean
spectra

ASD measurement + GPS

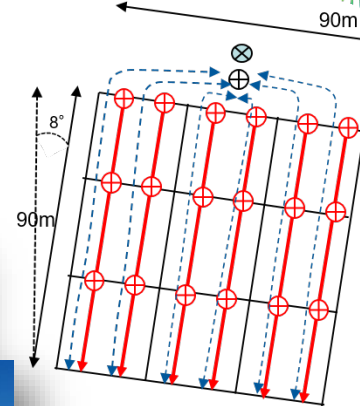


L2A BOA validation (land & water)



GFZ field activities (S. Chabrillat)

- Test measurements near P (05.07.2022)
- Kalkteiche Bernburg (Saale) (08.07.2022)
- Barrax (18.07.2022)
- Tegel (24. & 28.07.2022)
- Demmin (20.09.2022)



LMU field activities (T. Hank)

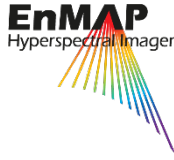
- MNI Field Campaign 2022



AWI field activities (M. Soppa)

- Lake Constance (2022)
- Tegus Estuary (2022)

L2A BOA validation (land)



In-Situ collaborators:

- R. Kokaly (USGS)
- B. Di Mauro (CNR)
- R. Colombo (UNIMIB)
- E. Ben-Dor & D. Heller (TAU)
- C. Anderson (USGS)
- C. Ong (CSIRO)
- R. O. Green (JPL)
- B. Brede (GFZ)
- Niall Origo (NPL)
- R. Milewski (GFZ)
- A. Bialek (NPL)
- C. Giardino (CNR- IREA)
- M. Saberioon (GFZ)
- V. Brando (CNR)
- T. Schröder (CSIRO)
- G. Kereszturi (Massey)
- T. Painter (UCLA)
- A. Kokhanovsky (GFZ)
- F. Buongiorno (ASI)
- ...

Great
community
success!

L2A BOA validation (land)

46 L2A validation scenarios

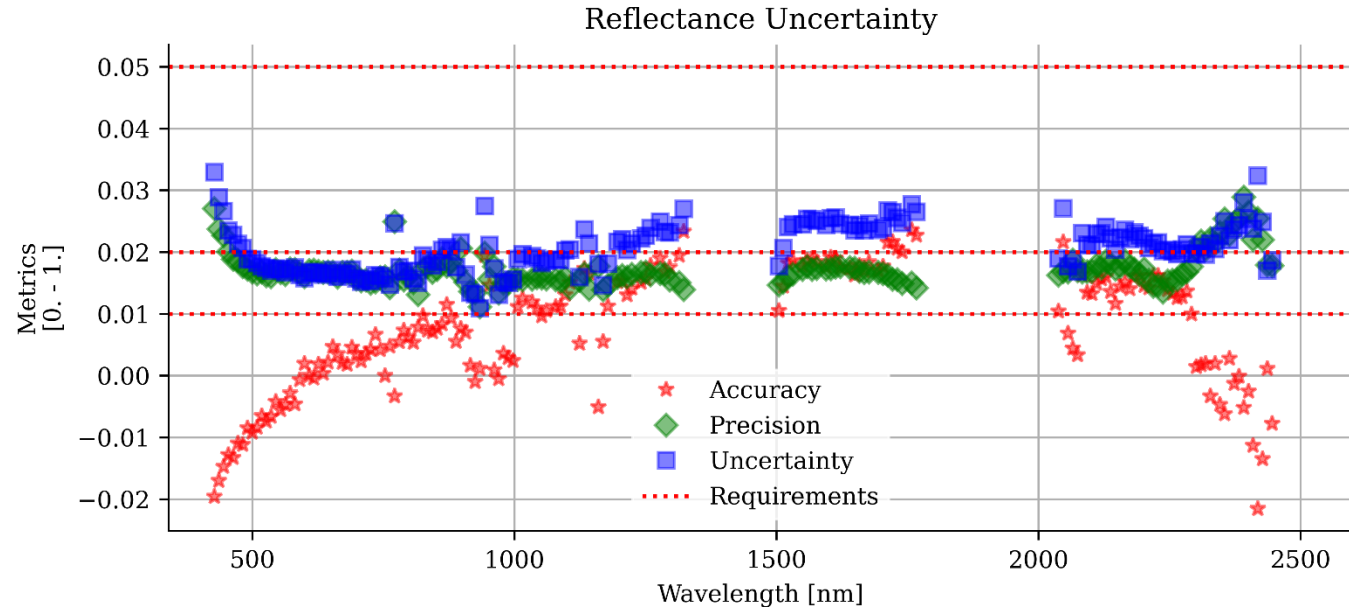


25 L2A validation scenarios
filters

(Pinnacles (3), Amiaz Plain (1),
Barrax (1), Munich-North-Isar (1),
Makhtesh Ramon (1), Camarena (1),
EROS (1), TXL (1), Playa Zero (2),
Gobabeb (10), Railroad Valley,
Nansen Ice Shelf (2))

Requirements: Uncertainty (RMSE)

< 0.01 for $\rho < 0.1$ and
< 0.02 for $0.1 \leq \rho < 0.3$ and
< 0.05 for $0.3 \leq \rho \leq 0.6$



L2A BOA validation (land)

46 L2A validation scenarios

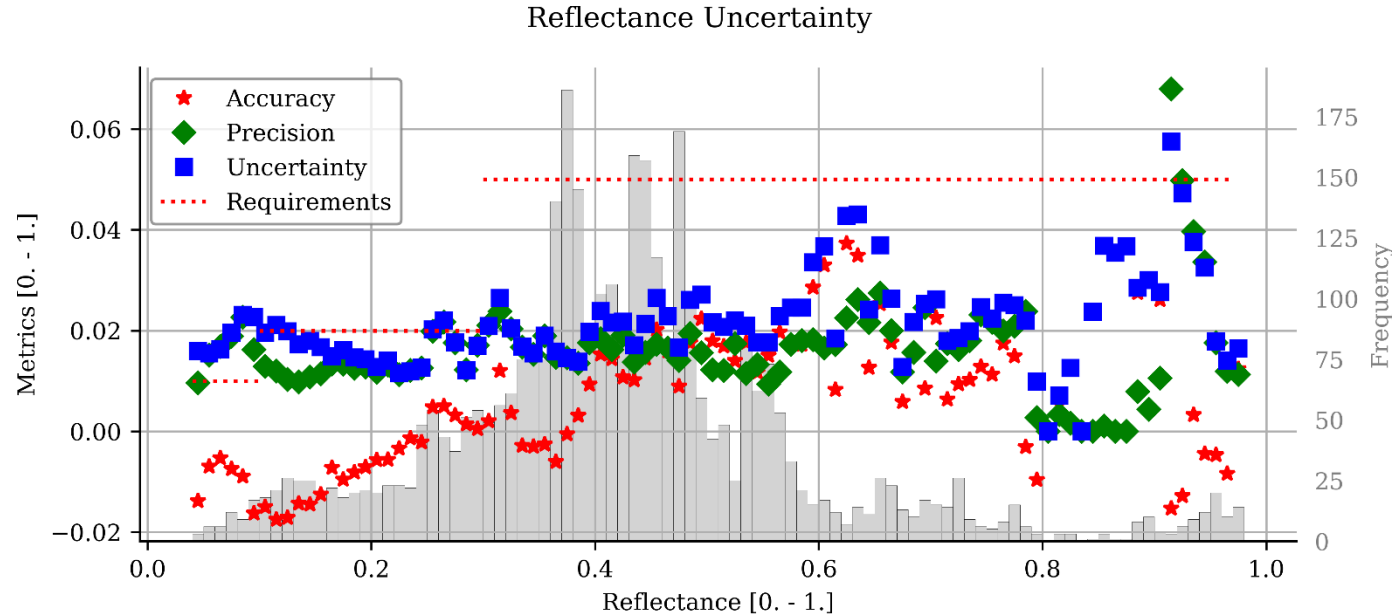


25 L2A validation scenarios
filters

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Requirements: Uncertainty (RMSE)

< 0.01 for $\rho < 0.1$ and
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< 0.05 for $0.3 \leq \rho \leq 0.6$



L2A BOA validation (water)

11 L2A validation scenarios

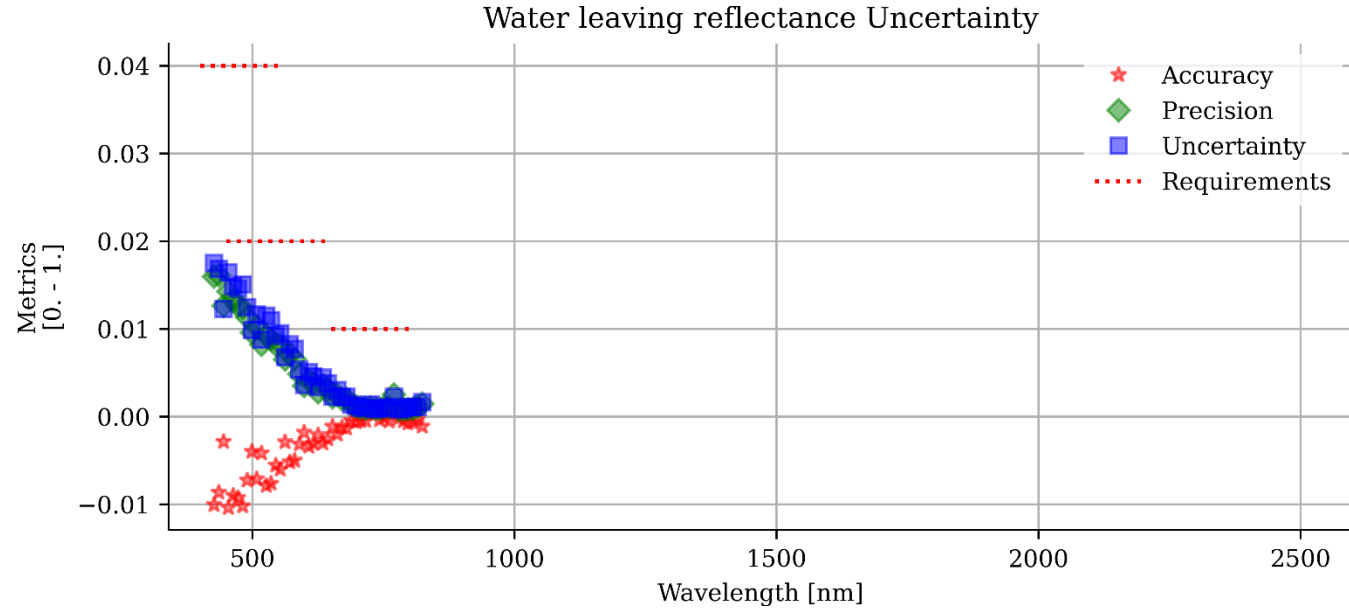


10 L2A validation scenarios
filters

(AAOT (4), Lucinda Jetty (2), Lake
Trasimeno (1),
San Marco (1), Lake Constance (2))

Requirements: Uncertainty (RMSE)

- < 0.04 for $\lambda < 550$ nm and
- < 0.02 for $550 \text{ nm} \leq \lambda < 650$ nm and
- < 0.05 for $650 \text{ nm} \leq \lambda \leq 800$ nm



L2A BOA validation (water)

11 L2A validation scenarios

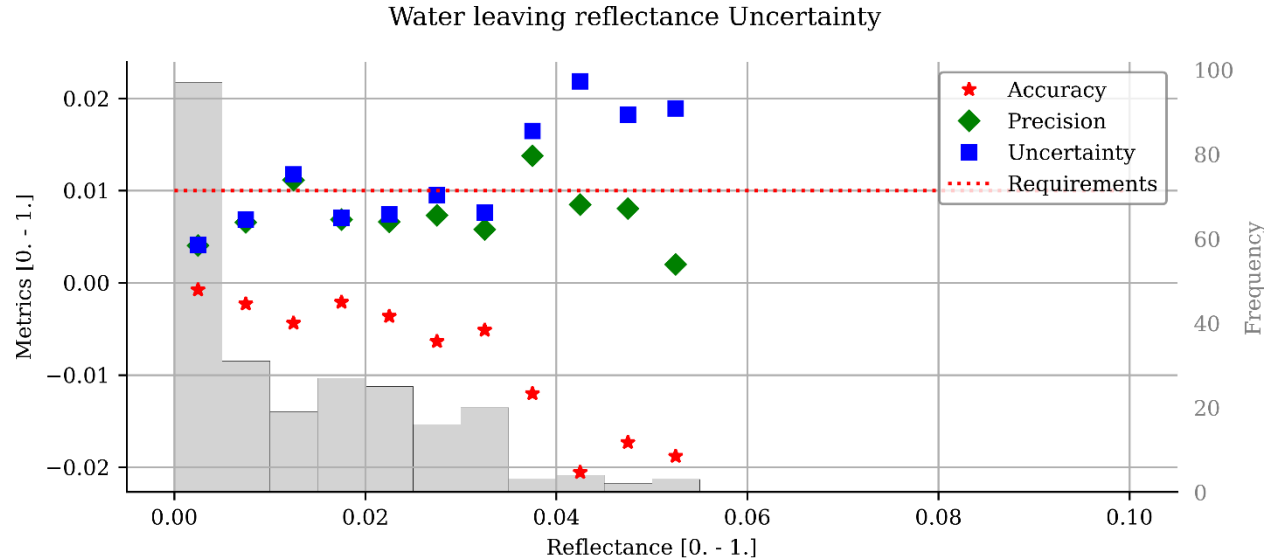


10 L2A validation scenarios
filters

(AAOT (4), Lucinda Jetty (2), Lake
Trasimeno (1),
San Marco (1), Lake Constance (2))

Requirements: Uncertainty (RMSE)

- < 0.04 for $\lambda < 550$ nm and
- < 0.02 for $550 \text{ nm} \leq \lambda < 650$ nm and
- < 0.05 for $650 \text{ nm} \leq \lambda \leq 800$ nm



EnVAL: interpretation of L1B validations

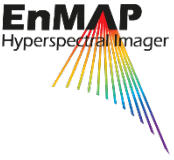
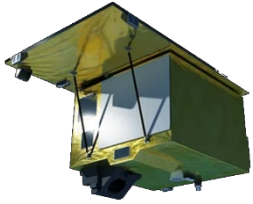


Image based



Field based

In-situ/
Reference data

| Data product | Field-, Image-, Model based validation | | | |
|--------------|--|--|--|--|
| | Radiance | Reflectance | Geometry | Quality |
| L1B | <ul style="list-style-type: none"> - Vicarious: <ul style="list-style-type: none"> • Inter. Sites • RadCalNet - Stability: <ul style="list-style-type: none"> • PICS • Moon • SNR - Scene based: <ul style="list-style-type: none"> • Dead/bad • Striping | | <ul style="list-style-type: none"> • Keystone • MTF | <ul style="list-style-type: none"> • SRF/Smile • Anomalies |
| L1C | <ul style="list-style-type: none"> • Cross-Validation (PRISMA, S2, EMIT, ...) | | <ul style="list-style-type: none"> • Absolute • Band-to-Band • VNIR-to-SWIR | <ul style="list-style-type: none"> • Anomalies |
| L2A | | <ul style="list-style-type: none"> • Ground & Water • Quality mask • Aerosol & WV | | <ul style="list-style-type: none"> • Anomalies |



EnVAL: validation of EnMAP products (GFZ)

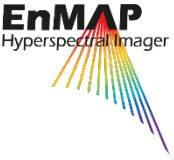


Image based



Field based

**In-situ/
Reference data**

| Data product | Field-, Image-, Model based validation | | | |
|--------------|---|-------------|----------|---------|
| | Radiance | Reflectance | Geometry | Quality |
| L1B | <p>Several issues were addressed/supported:</p> <ul style="list-style-type: none"> • Across-track striping • Along-track striping • Water-leaving reflectance • VNIR-SWIR co-alignment • Absolute geometric accuracy • Cirrus-correction over snow • Acquisition pointing issue • Masked/not transferred bands • Several minor issues | | | |
| L1C | | | | |
| L2A | | | | |



EnVAL conclusions:



- All important validation scenarios fulfil the mission requirements
- The independent validation identified and confirmed non-conformities, ensuring high product quality.
- Holistic validation forms the basis for homogenization and interoperability between missions
- Encourage to submit a proposal to the AO #00003: EnMAP product quality monitoring

EnVAL Operational Phase (OP): Goal

From „single“ site validation towards
global monitoring

Full uncertainty propagation

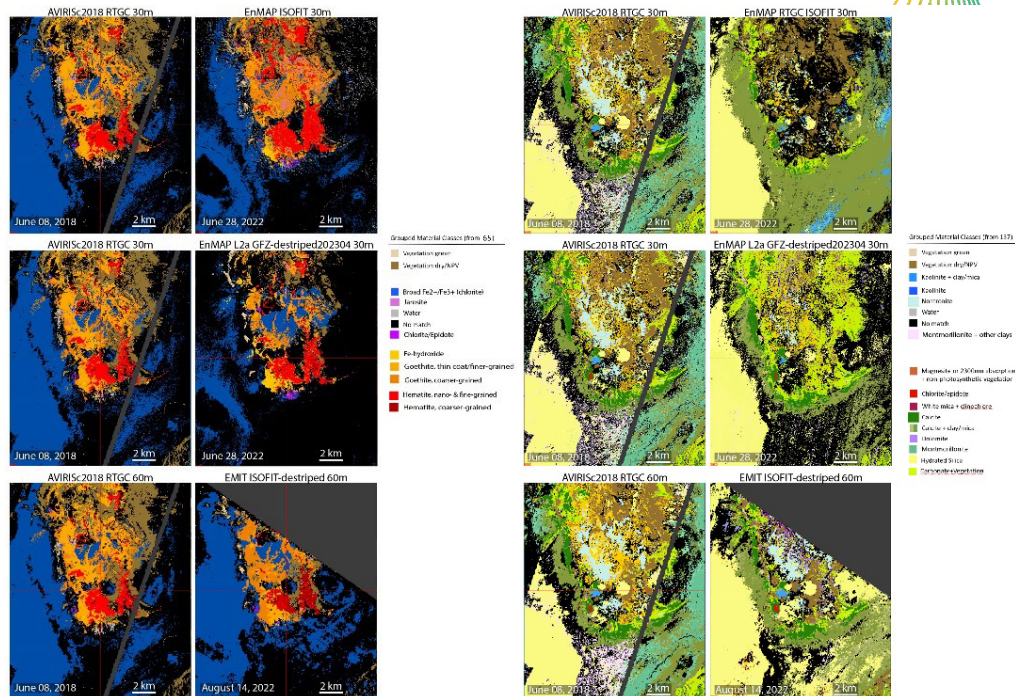
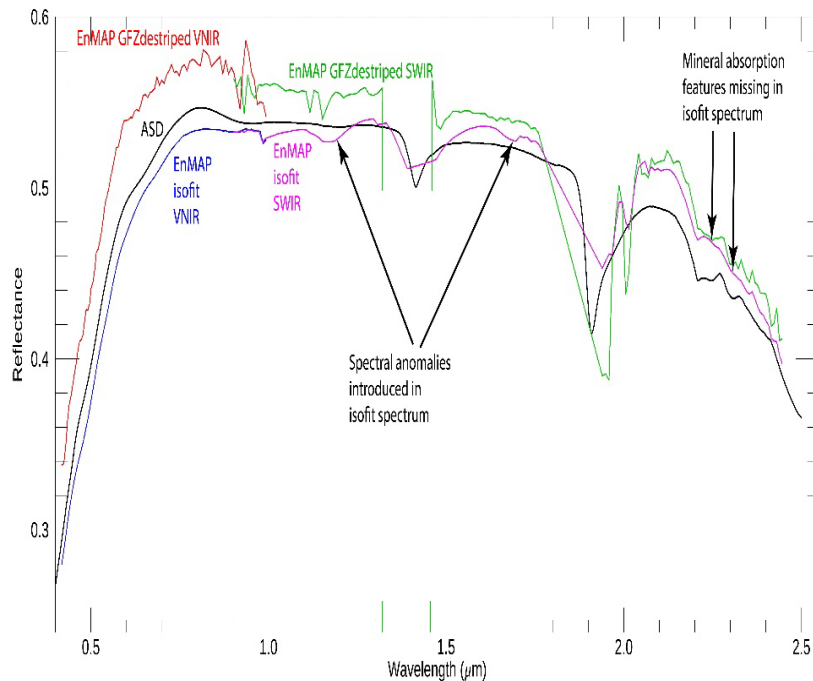
Homogenization & Interoperability

- Geometry
- L2A Land
- L2A Water
- L2A AOT & WV
- Radiometry

Planned for OP:

- Potential ~100 sites
 - Fulfil certain requirements regarding:
 - Altitude & global distribution
 - Atmospheric conditions
 - Site characteristic
- Well balanced

Homogenization & Interoperability



Attribute to Kokaly et al., at USGS; preliminary results; not for citation
 EnMAP corrected with ISOFIT provided by GFZ (Karl Segl)

ENMAP DATA PRODUCT VALIDATION: INITIAL STEPS TOWARDS DATA HOMOGENIZATION AND INTEROPERABILITY

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