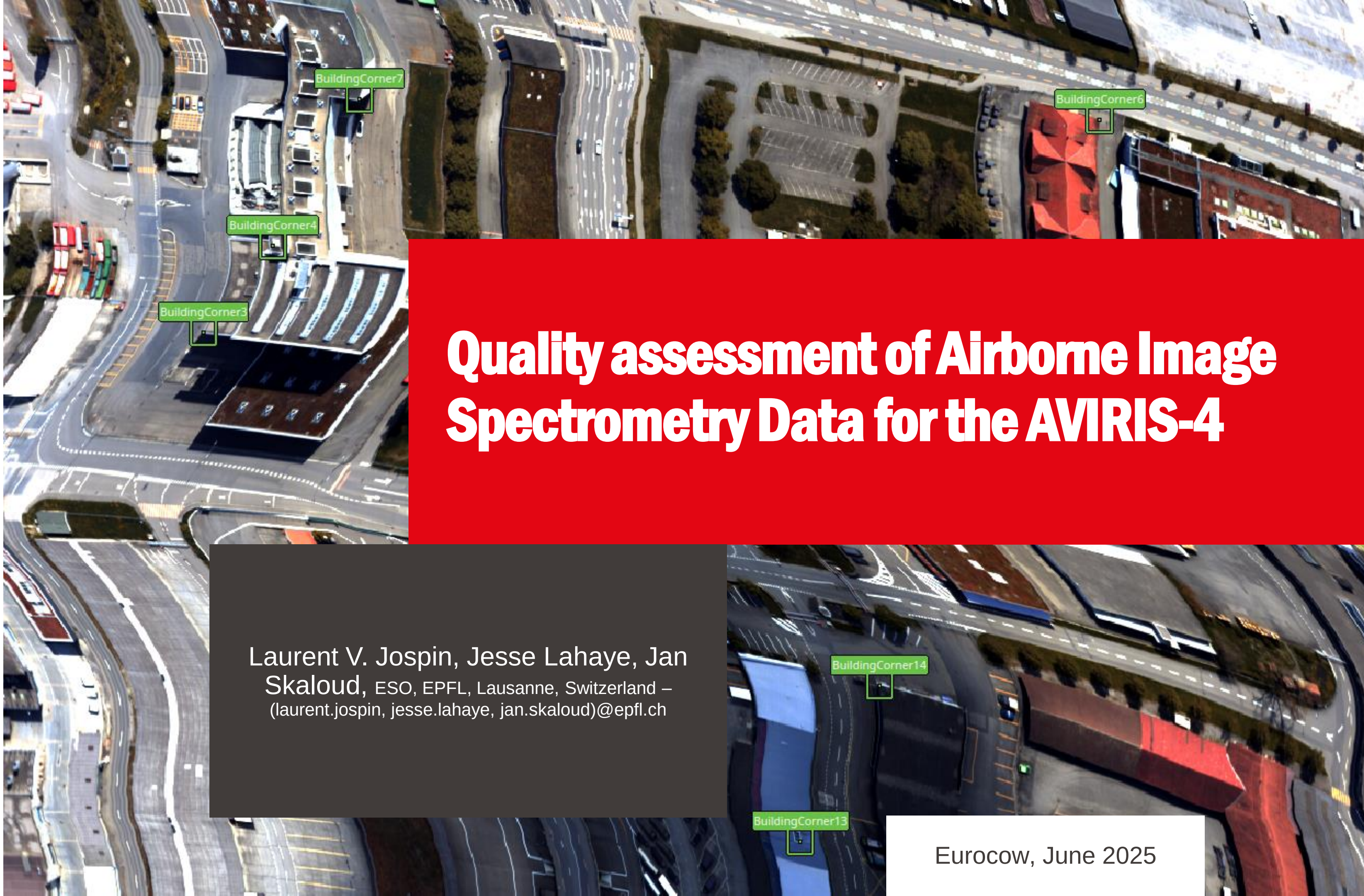

EPFL

Quality assessment of Airborne Image Spectrometry Data for the AVIRIS-4

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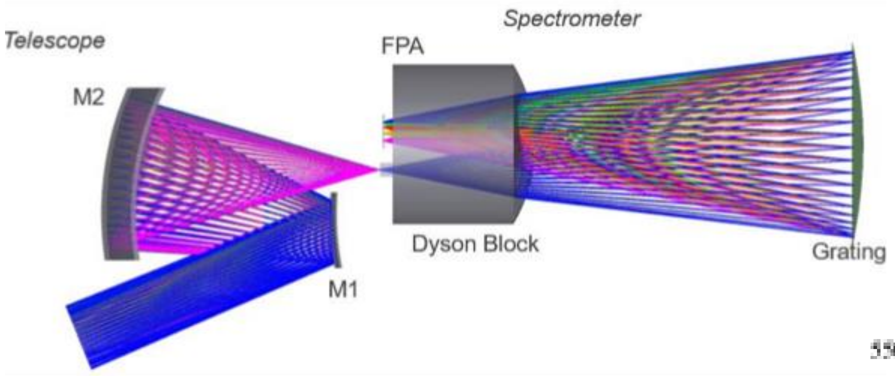
Eurocow, June 2025

EPFL

Agenda

- **Technology & applications**
- Geometrical challenges & QA
- The tool
- Some responses
- Perspective

- **What is it?**

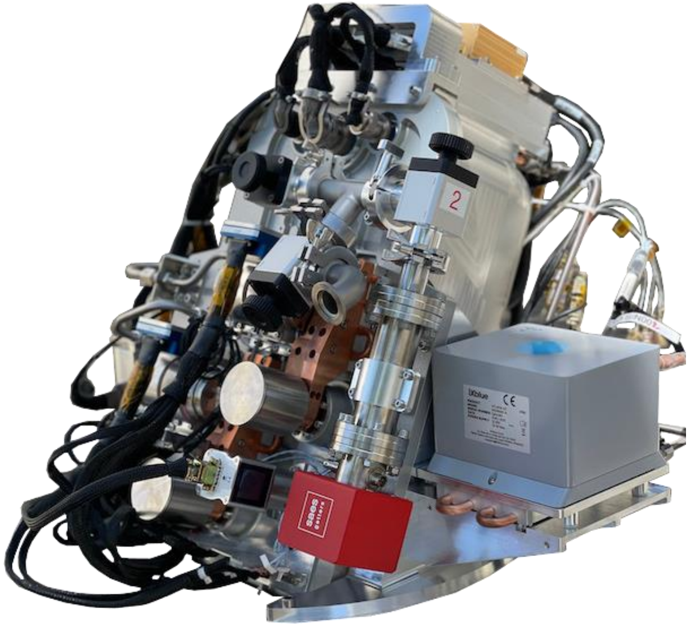


IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 22, 2025 5505705

The AVIRIS-4 Airborne Imaging Spectrometer

Andreas Hueni, *Member, IEEE*, Sven Geier, Marius Vögtli, Jesse LaHaye, Josquin Rosset, Dominic Berger, Luc J. Sierro, Laurent V. Jospin, David R. Thompson, *Senior Member, IEEE*, Daniel Schläpfer, *Member, IEEE*, Robert O. Green, Teddy Loeliger, *Member, IEEE*, Jan Skaloud, and Michael E. Schaepman, *Senior Member, IEEE*

The AVIRIS-4



- Background
  - NASA-JPL for i) Swiss-ARES consortium ii) ISS
  - Started in 2017 … delivered 2022/23, ISS(2022)
- SOTA in Europe
  - high SNR over ~300 spectral bands
  - spectral resolution (400 – 2’500 nm)
  - spatial resolution (0.30m GSD)
- Operations
  - from 2024 (standalone), from 2025 (together with ALS)
  - all data will be made open data
  - more info: https://doi.org/10.1109/LGRS.2025.3572349

Systems & platforms

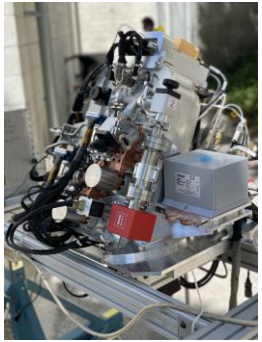
			
Payload	CWIS-II (AIS) and RIEGL-II (ALS) and PhaseOne (RGB)	Pika-L (AIS) and RIEGL- VQ (ALS) and 2 x PhaseOne (RGB)	Pika-L (AIS) **or** SODA (RGB)
Transect on slopes	✗	✓	✓
Spectral resolution	327 px (6.5 nm/px)	281 px (2.1 nm/px)	281 px (2.1 nm/px)
Spectral range	380 – 2500 nm	400 – 1000 nm	400 – 1000 nm
Spatial resolution AIS	$\geqslant$ 1 m/px	$\leqslant$ 0.2 m/px	$\leqslant$ 0.1 m/px
Spatial resolution ALS	~ 20 pt/m^2	~ 1000 pt/m^2	-
Spatial resolution RGB	$\geqslant$ 0.08 m/px	0.02 m/px	0.01 m/px
Coverage per one flight	500 km^2	10 km^2	1 km^2
Acq. zones (Tx/SA/ROI)	SA/ROI	Tx/SA	Tx

Vision comparison

- Humain
- 3 bands
- 480 and 700 nm

- Mantis shrimp
- 12 bands
- ~as human

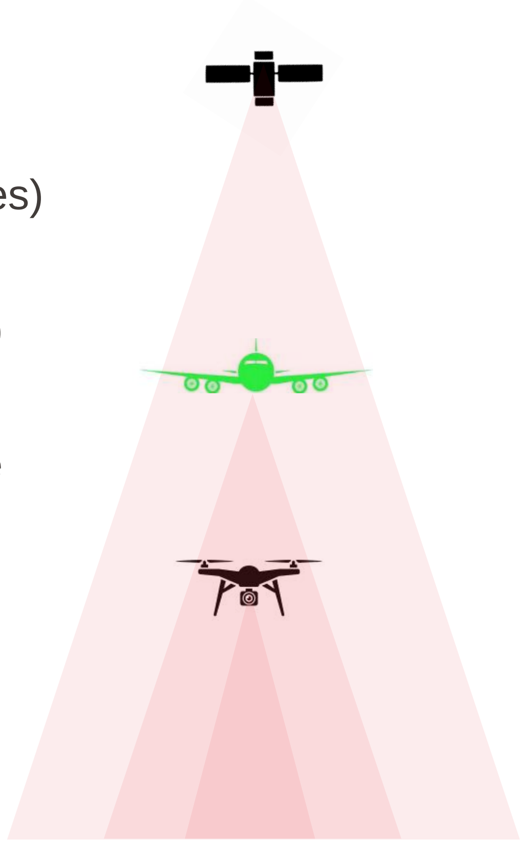
- Pika-L
- 281 bands
- 400-1000 nm



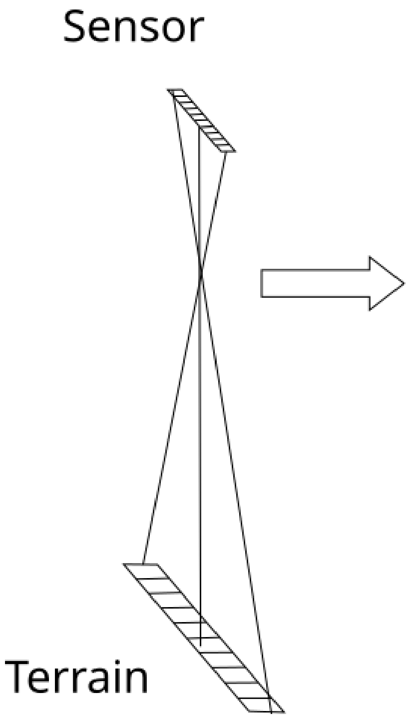
- AIVRIS-4
- 327 bands
- 380-2500 nm

Applications & challenges

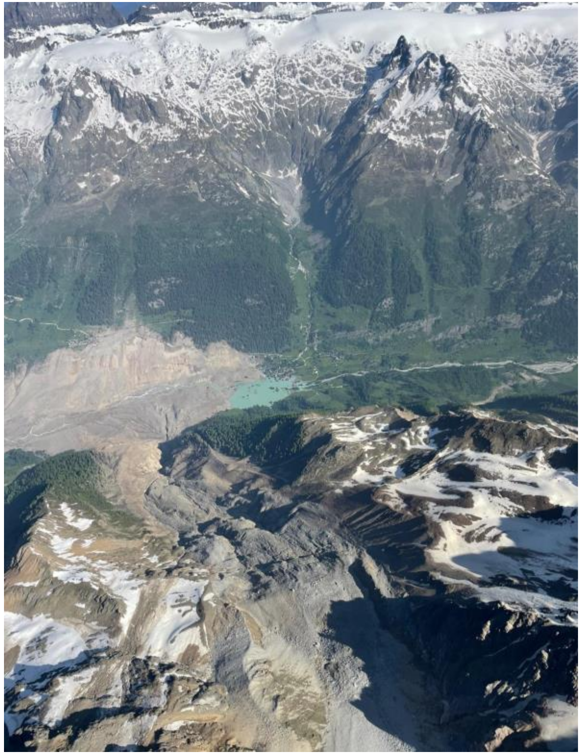
- Biodiversity (plant traits)
- Atmospheric (trace gases)
- Aquatic (algae blooms)
- Snow (water equivalent)
- Geological
- Soil, forestry, agriculture
- :
- ESA ground truth!



X scale open data



Multi-mode sensing challenge (natural disaster)



AIS/HS imagery data georeferencing, visualization
The need in open data & tools

- Data Quality Assessment
- Guarantee Interoperability
- FAIR principals (Findable, Accessible, Interoperable and Reusable)
- Ground truth – develop tool for tie-points in HS image (MALAHYD)

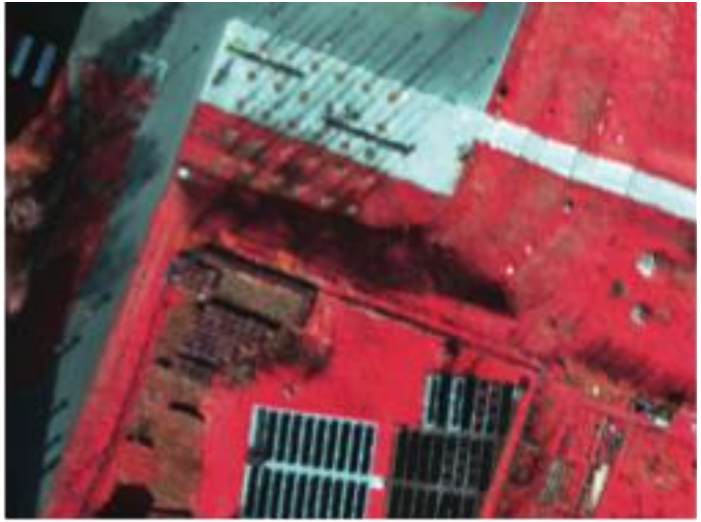
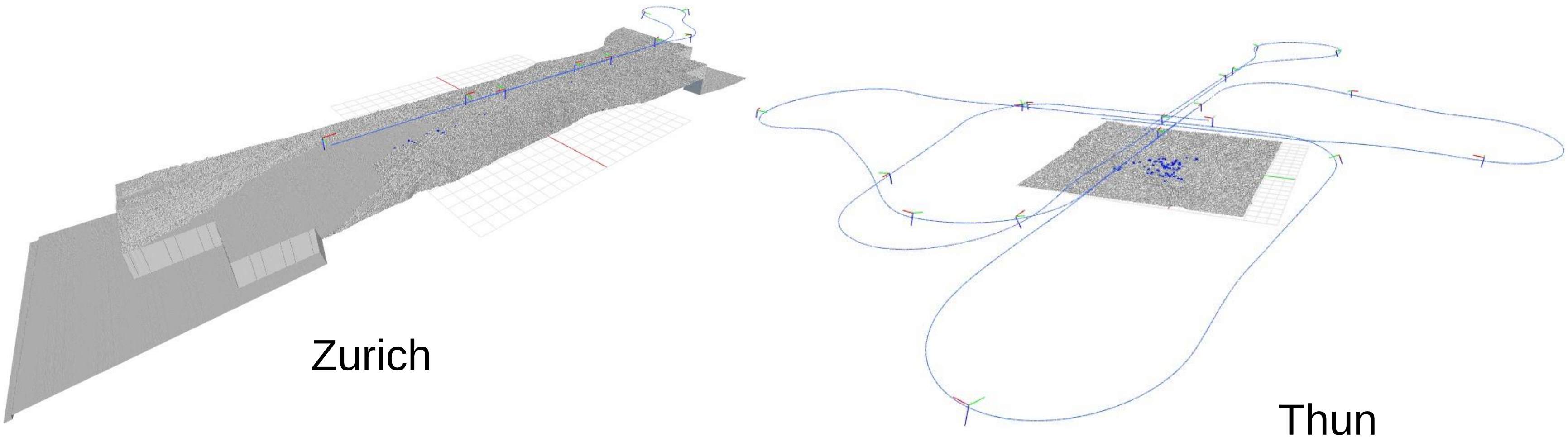


Fig. 2. Georeferenced AVIRIS-4 radiance data of a garden bed area at UZH Irchel campus in Zurich visualized as a false color near-infrared image. Band combination: $R = 850$ nm, $G = 650$ nm, and $B = 550$ nm.

AVIRIS-4 maiden (calibration) flights



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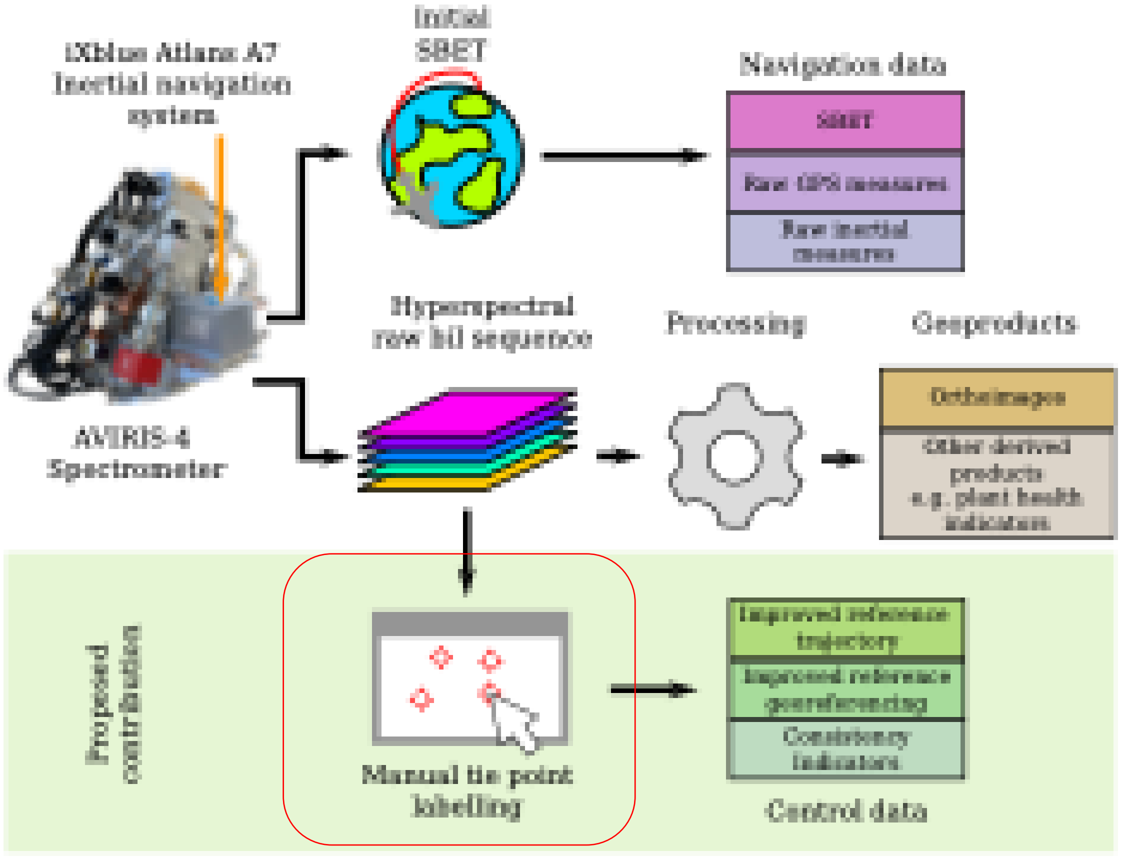
AIS geometric workflow

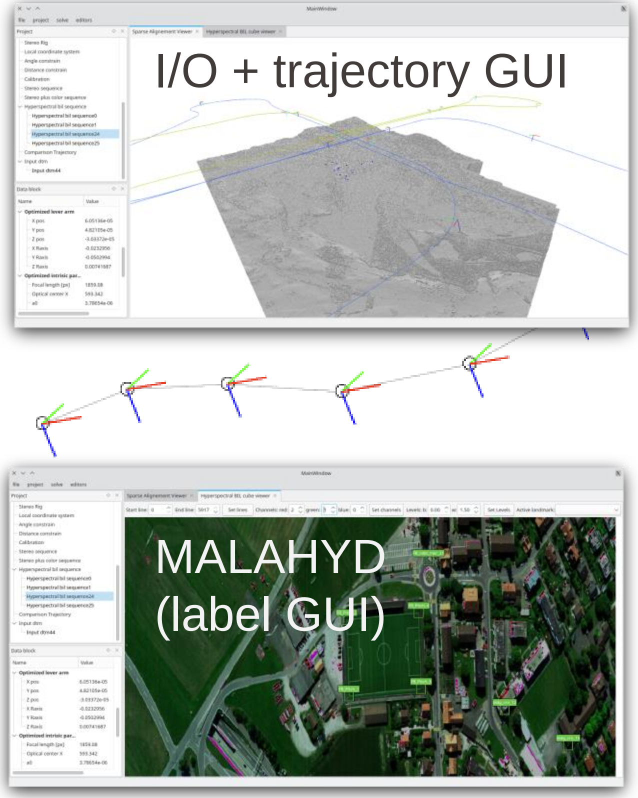


MALAHYD – GUI and related framework

sensors

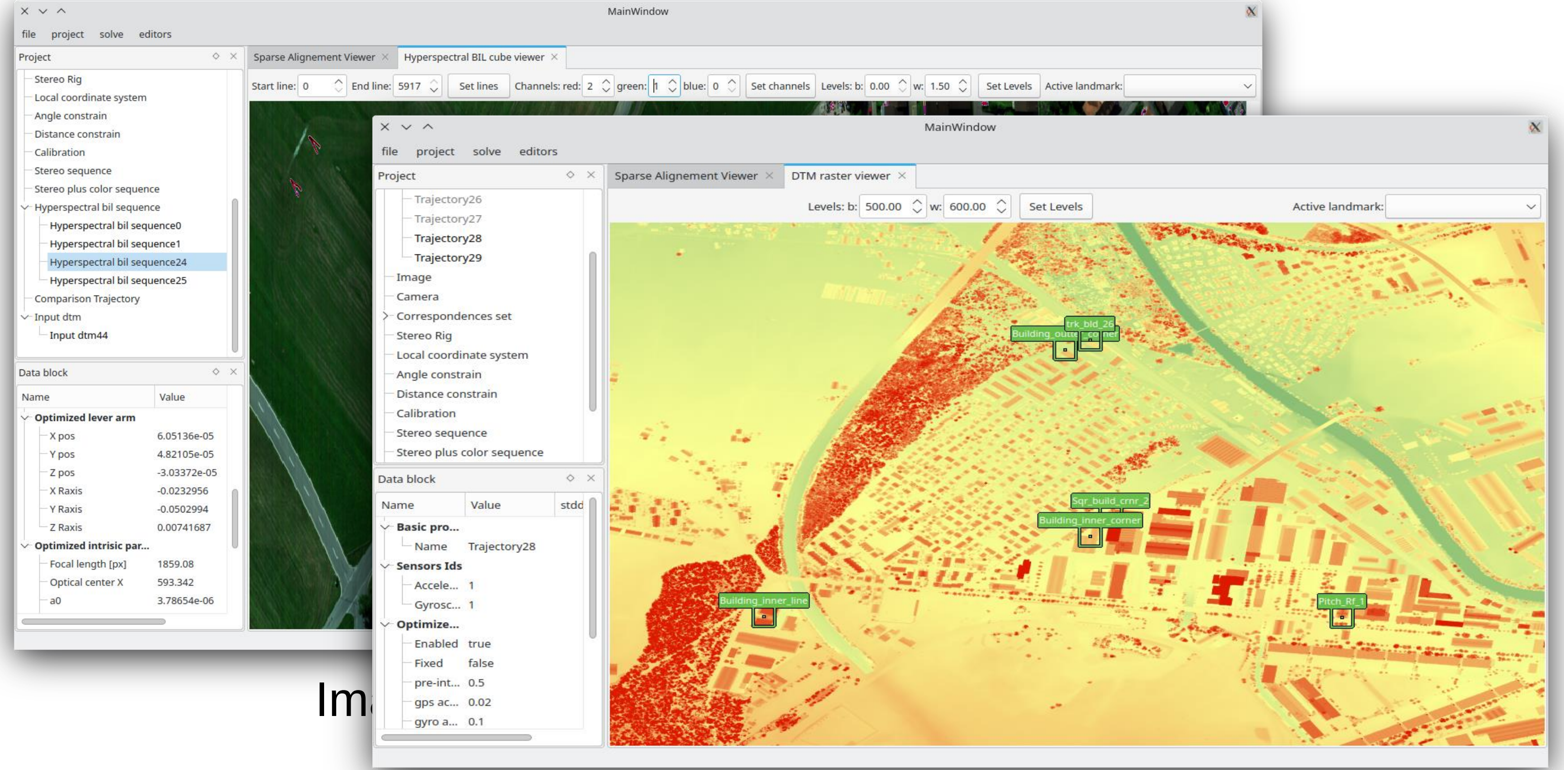
steviapp

Integrated optimization



- Part over larger & open CV/photo framework
- Manual labeling in AIS (.bil) files
- Basic evaluation (residuals)

MALAHYD – tie-point labelling module



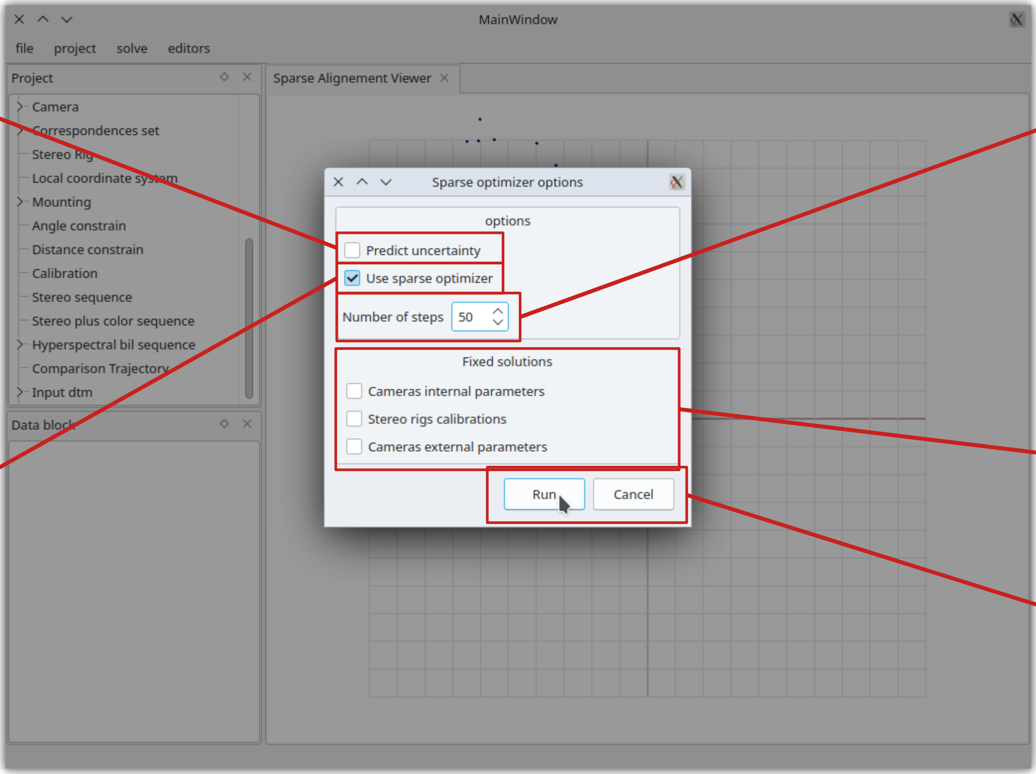
Ima

DSM tie points labeling

MALAHYD (steviapp) – optimization GUI

Predict uncertainty: estimate uncertainty of certain parameters. Uncheck by default (stability!)

Use sparse linear algebra: selected by default (memory!)



Number of iterations. Ceres back-end can interrupt the optimization earlier if it deems the problem converged

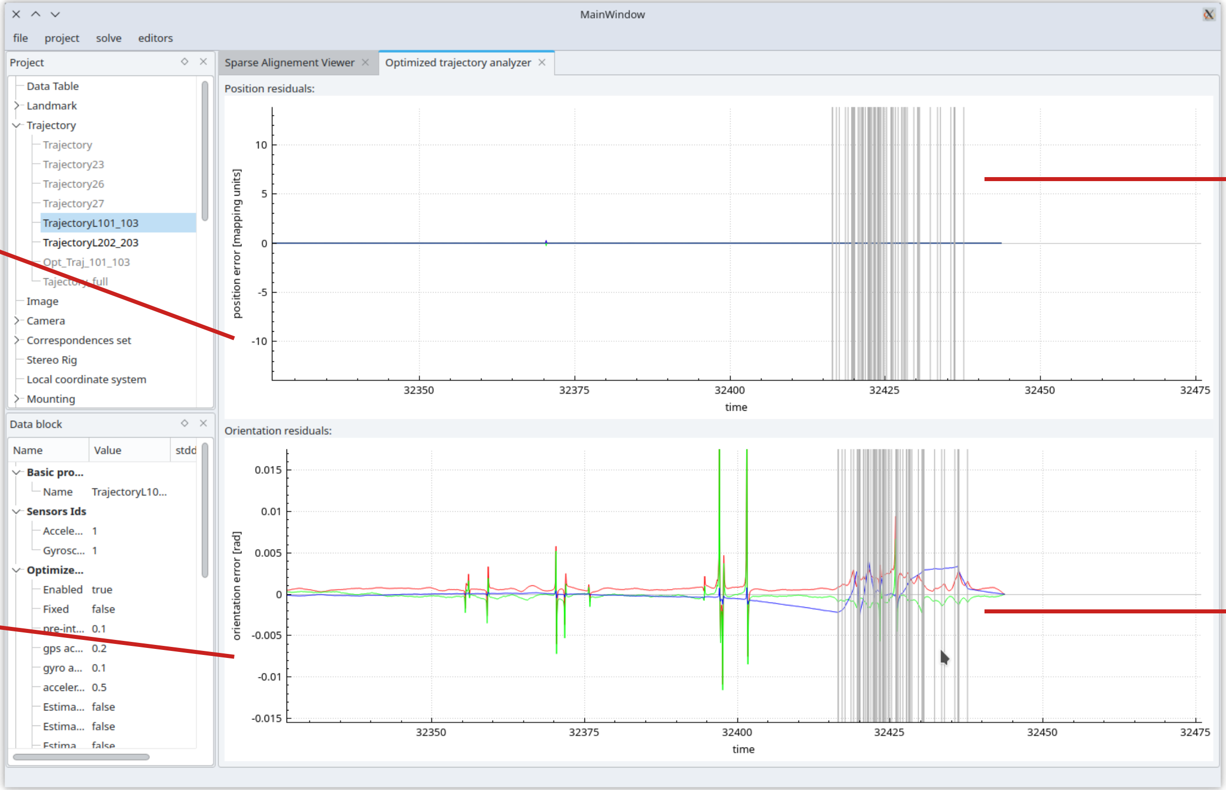
Quick override of certain *a priori* parameters.

Start / interrupt optimization

MALAHYD – Trajectory residuals analysis

Position residuals [mapping units]

Orientation residuals

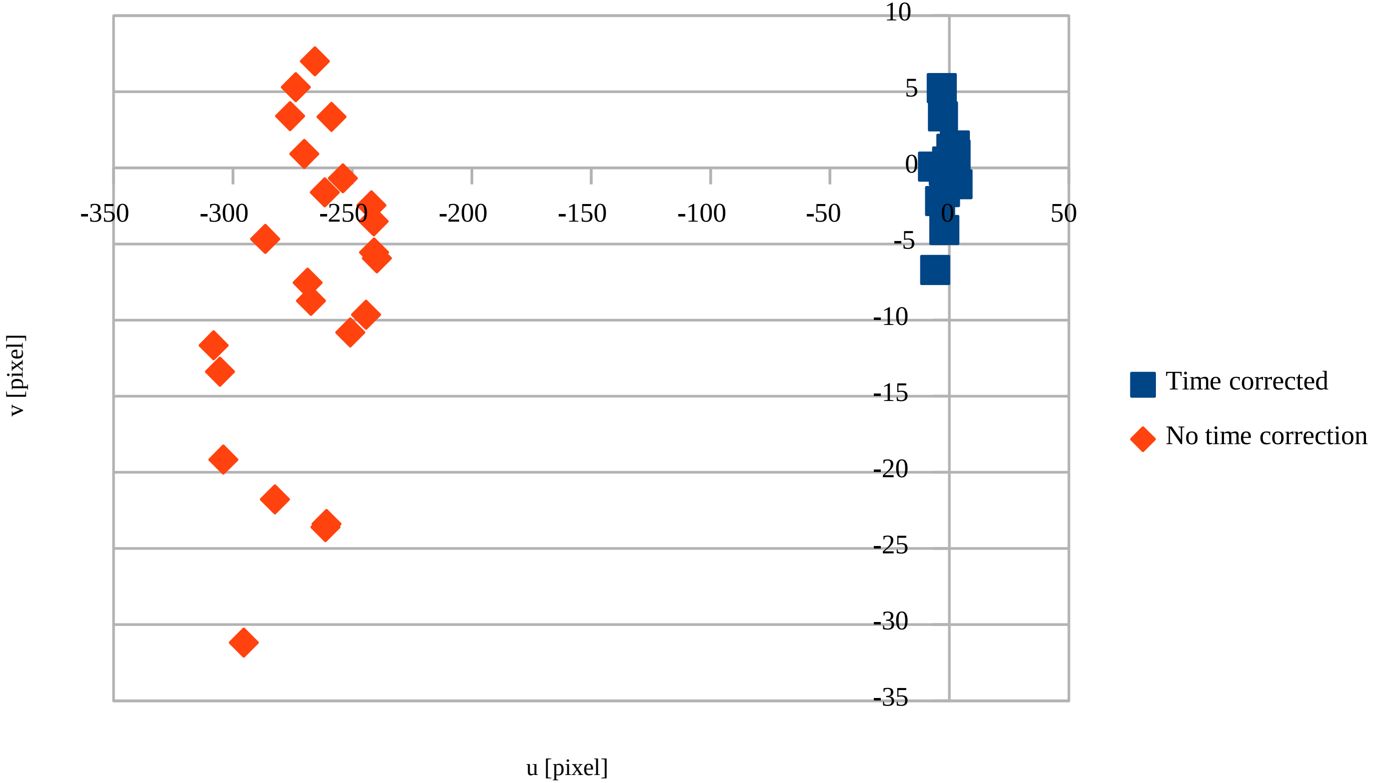


Vertical bars indicate time position of visual constraints (e.g. tie points)

Thun flight: residuals hints disagreement between trajectory vs. visual constraints

Error detection via tie points reprojection

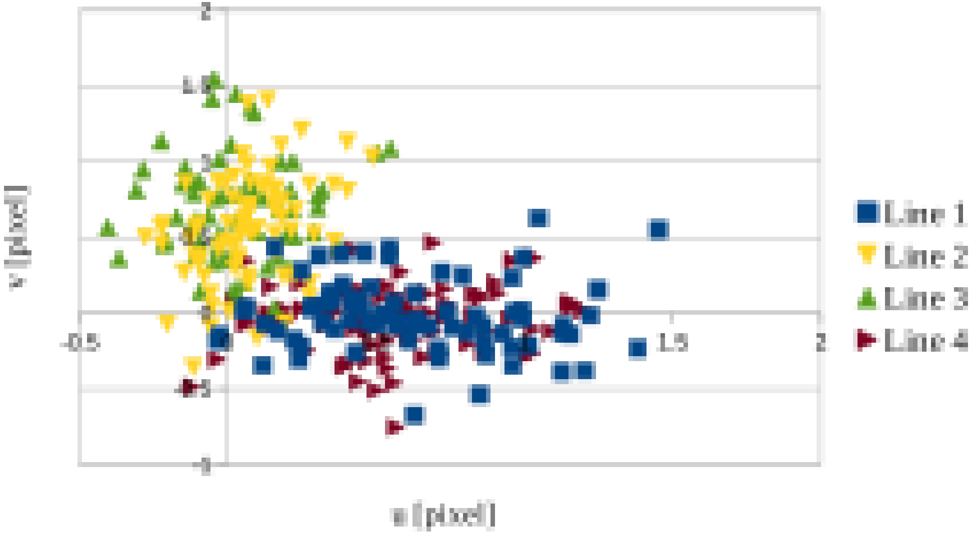
Zurich flight - time shift detection



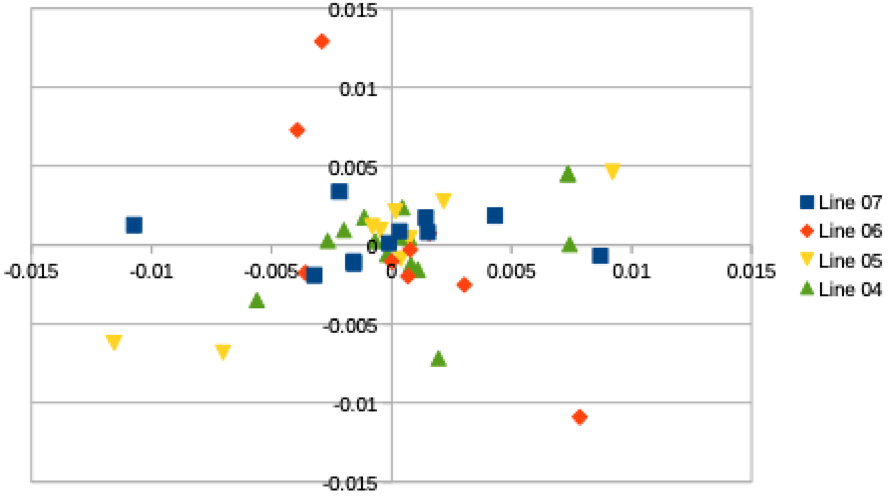
Error detection via tie points reprojection

Thun - orientation bias detection (platform stab.)

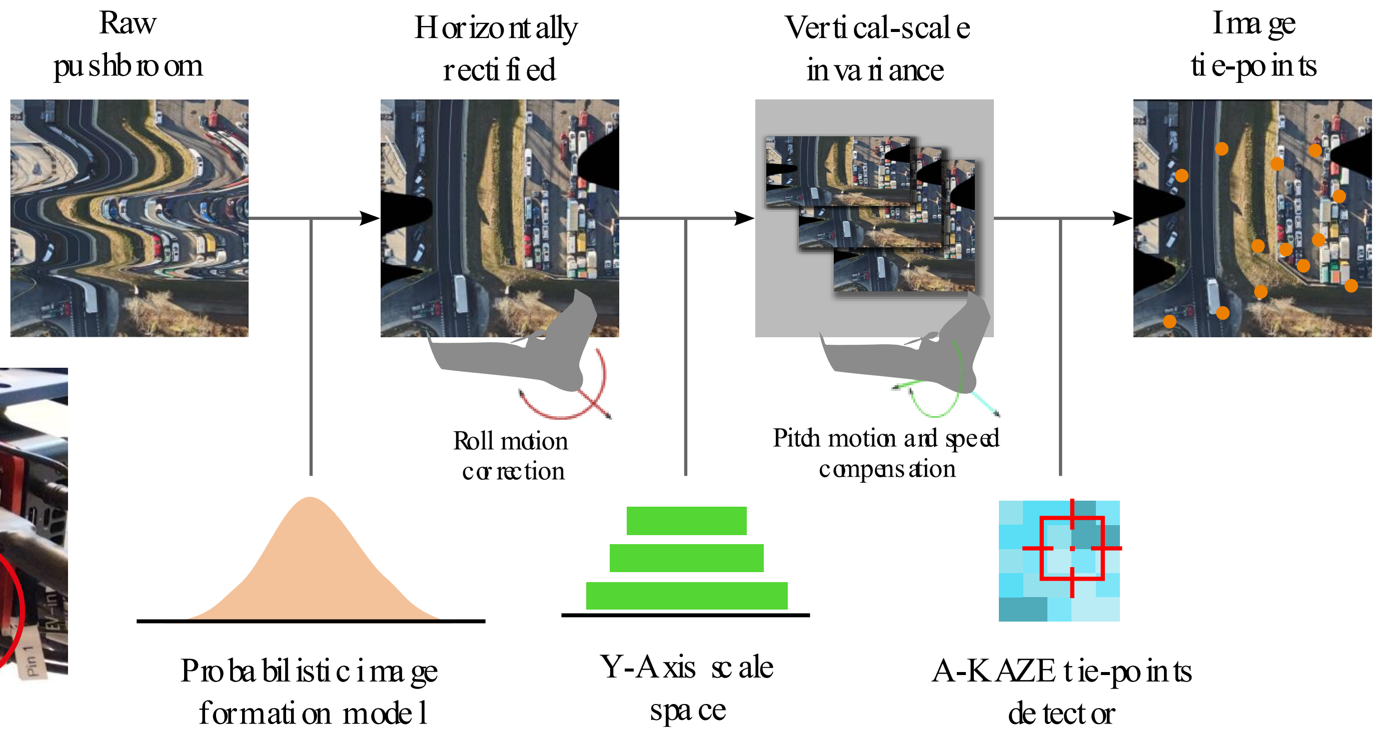
Before correction



After correction



Outlook - automatic tie points "without" IMU



Burkhard et. al (2025) Distortion invariant optical calibration for lightweight airborne imaging spectrometry
Accepted to ISPRS Annals (UAV-g, Finland, Sep. 10-12)

Conclusions

- New/open tool for manual TP in AIS
- QA – detection of important issues
    - Time tagging
    - Platform stabilization
- Manual – sure, but time consuming
- Future work will focus on automation.

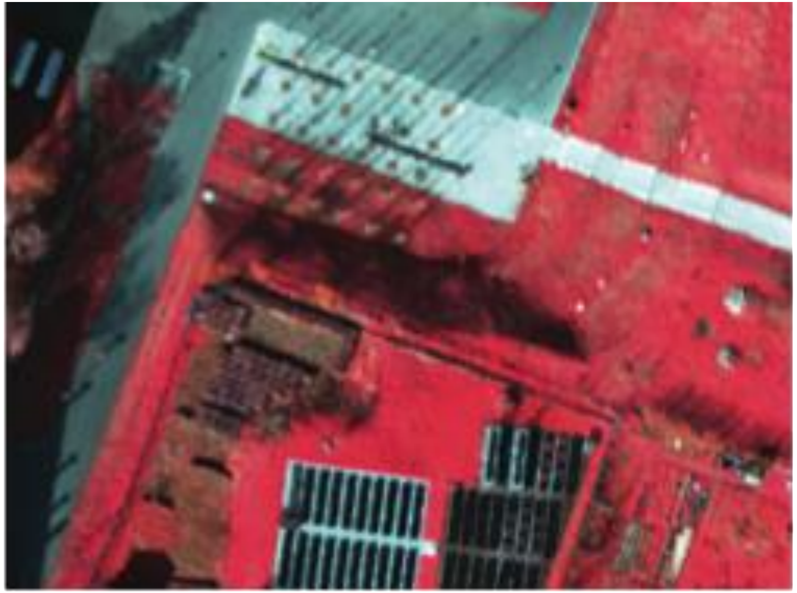


Fig. 2. Georeferenced AVIRIS-4 radiance data of a garden bed area at UZH Irchel campus in Zurich visualized as a false color near-infrared image. Band combination: $R = 850$ nm, $G = 650$ nm, and $B = 550$ nm.

Credit & links

AVIRIS-4

SteviApp

MALAHYD

Error detection via tie points reprojection

- A tie point pair (at position $\mathbf{t}_0$ and $\mathbf{t}_1$ with view direction $\mathbf{v}_0$ and $\mathbf{v}_1$) allows to check the orientation of the camera just by itself!
- Projected landmark position is estimated as:

$$\mathbf{V} = [\mathbf{v}_0 - \mathbf{v}_1]$$

$$\frac{1}{2}\left([\mathbf{v}_0\ \mathbf{v}_1]\left(\mathbf{V}^\top\mathbf{V}\right)^{-1}\mathbf{V}^\top(\mathbf{t}_1 - \mathbf{t}_0) + \mathbf{t}_0 + \mathbf{t}_1\right)$$

- Landmark is then reprojected on the image to get a projection error, in pixels.

Technical – under clouds operations?

TABLE I

COMPARISON OF KEY TECHNICAL SPECIFICATIONS BETWEEN APEX AND AVIRIS-4. THE VALUES FOR AVIRIS-4 ARE BASED ON THE FIRST CALIBRATION PERFORMED IN SPRING 2022 AT NASA JPL

Parameter	APEX	AVIRIS-4	Factor
Signal-to-noise ratio	650	> 2000	3
Frown [px]	< 0.16	< 0.03	5
Smile [px]	< 0.2	< 0.02	10
Sampling range [nm]	400 – 2498	375 – 2504	–
Spectral bands	299 (533)	287	–
VNIR spectral resolution [nm]	2.6 – 13.5	7.4	–
SWIR spectral resolution [nm]	5.6 – 9.9	7.4	–
Field of view	28°	40.2°	1.4
Across-track pixels	1000	1241	1.2
Ground sample distance [m]	≥ 1.7	≥ 0.3	6
Frames per second	30	213	7

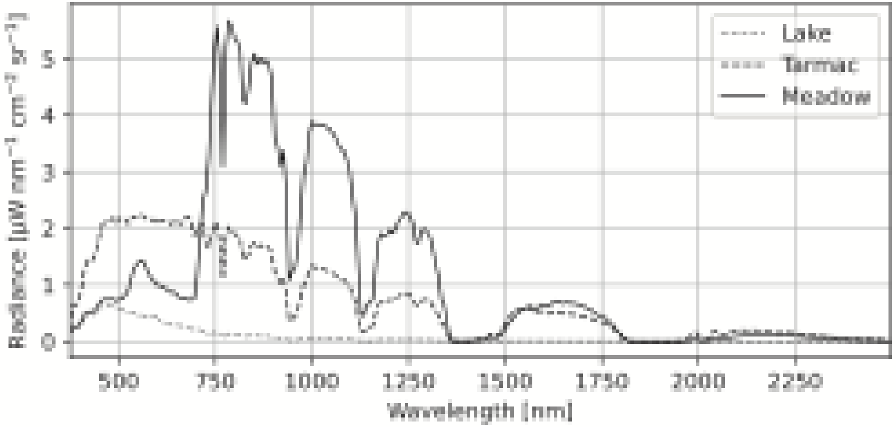


Fig. 3. AVIRIS-4 radiance spectra of various targets in the Zurich scene.

Hueni et. al (2025) Distortion invariant optical calibration for lightweight airborne imaging spectrometry
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