RESOLVING URBAN LIGHTING TYPE MIXTURES FROM ENMAP NIGHTTIME HYPERSPECTRAL DATA: LAS VEGAS AT NIGHT

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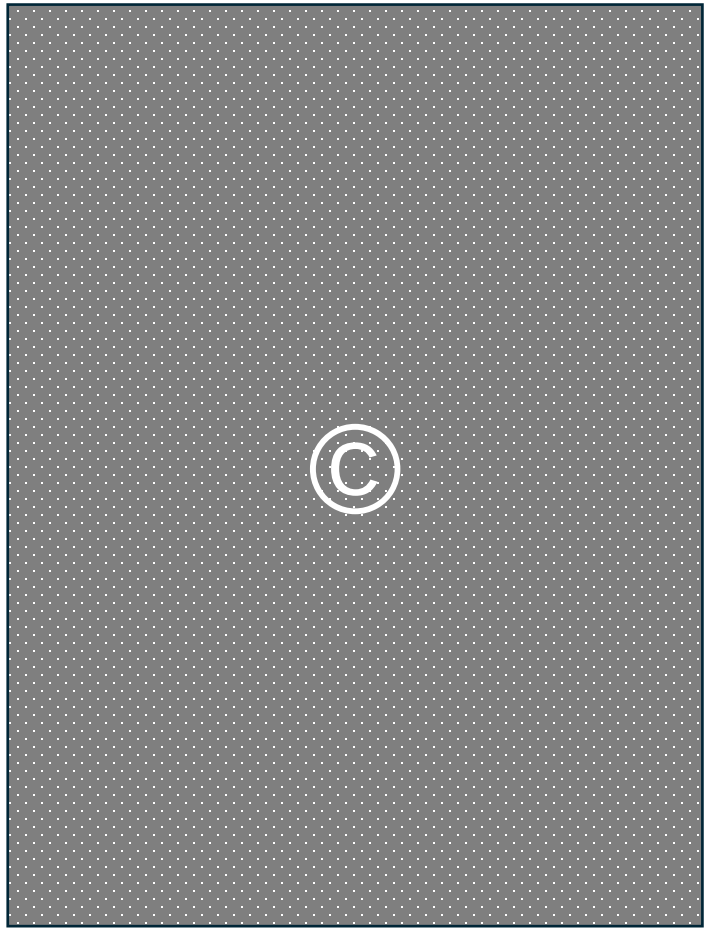
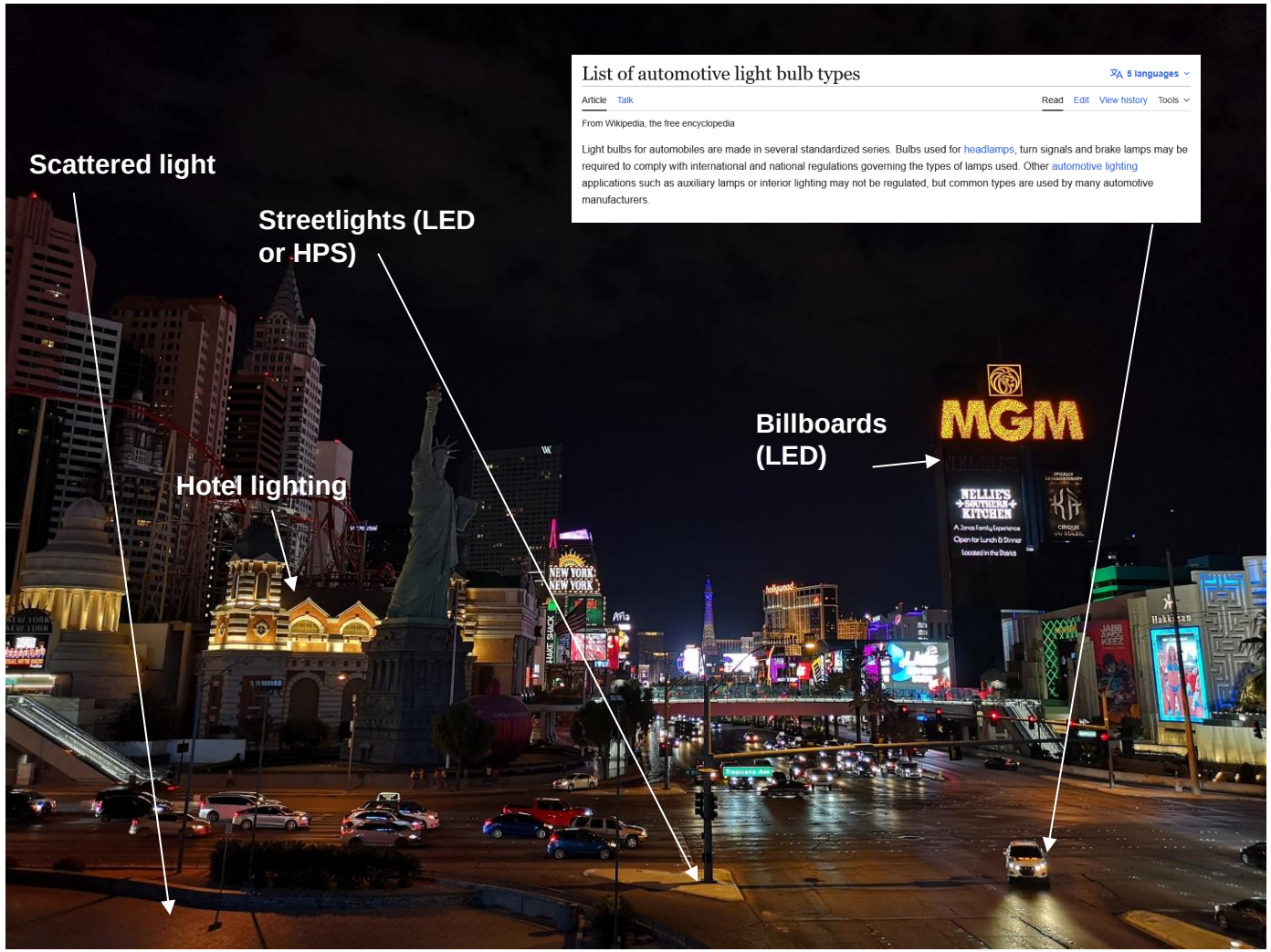
Why YOU should be interested in nighttime remote sensing and detecting lighting types

- In general, it is night half of the time...
- Nighttime light as unique indicator of human activity
- Lighting type (ie LEDs, HPS etc.) of special relevance
  - Energy consumption
  - Modernisation & rebuilding efforts
- Problem: No dedicated nighttime mission
  - **Existing systems (VIIRS, SDGSAT) lack spectral resolution**
  - **State of the art: mapping dominant lighting type only**



Nature Volume 652 Issue 8109, 9 April 2026

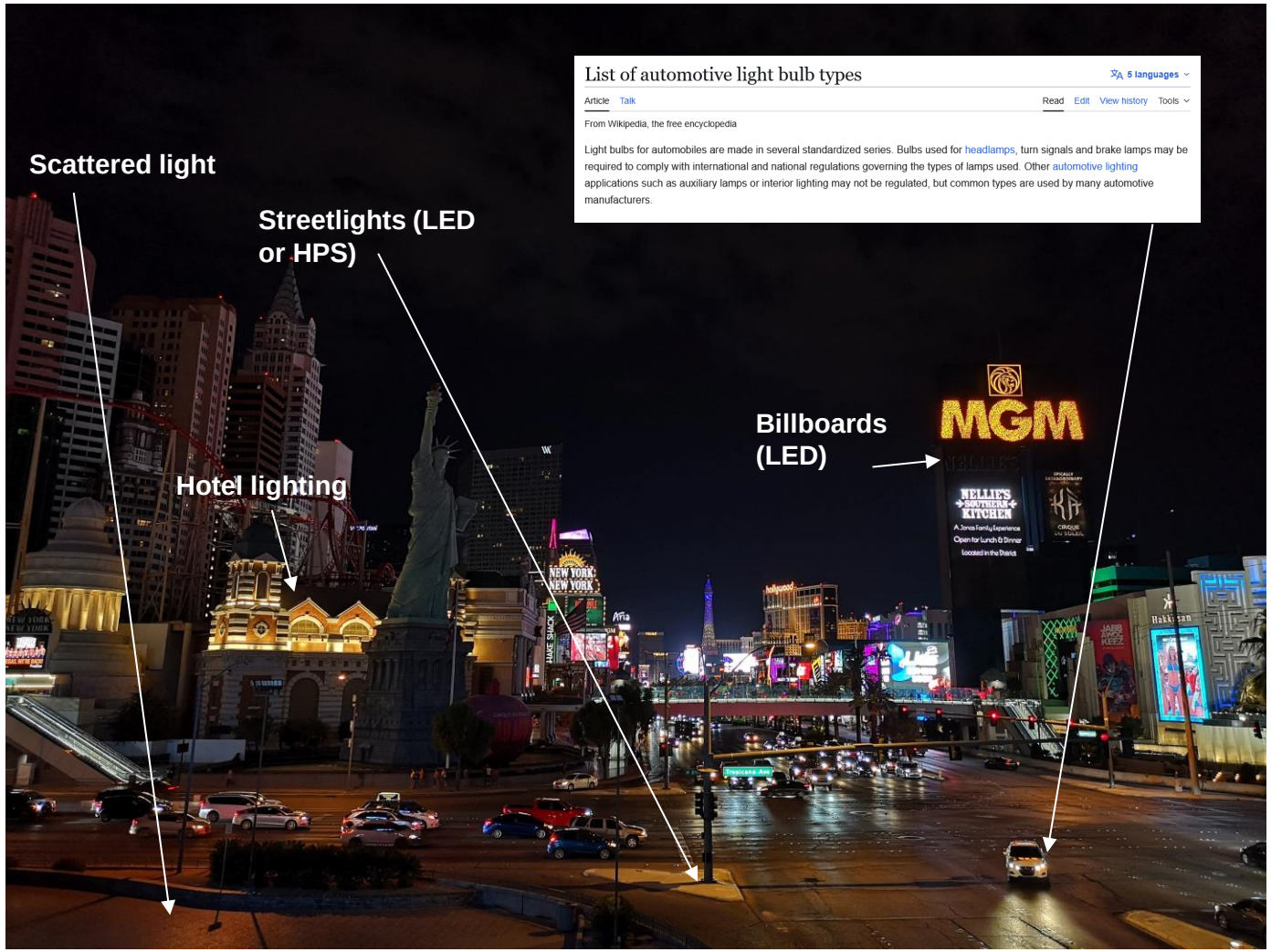
Problem: Urban lighting is more complex than this



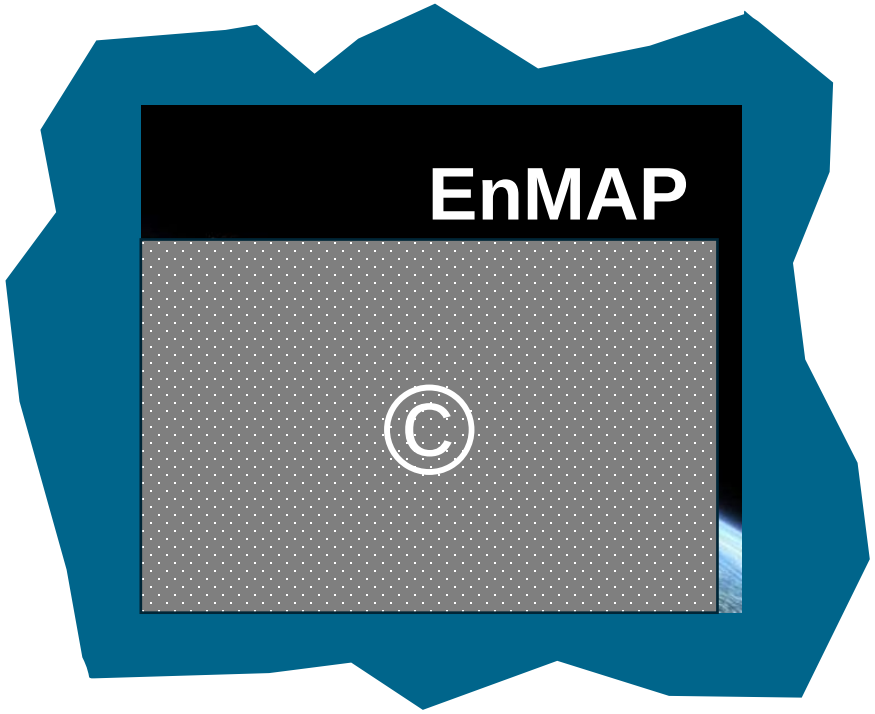
Las Vegas at night 2022 (Own image taken for “research” purposes)

If only there were hyperspectral nighttime data... 🤔

EnMAP



Las Vegas at night 2022 (Own image taken for “research” purposes)

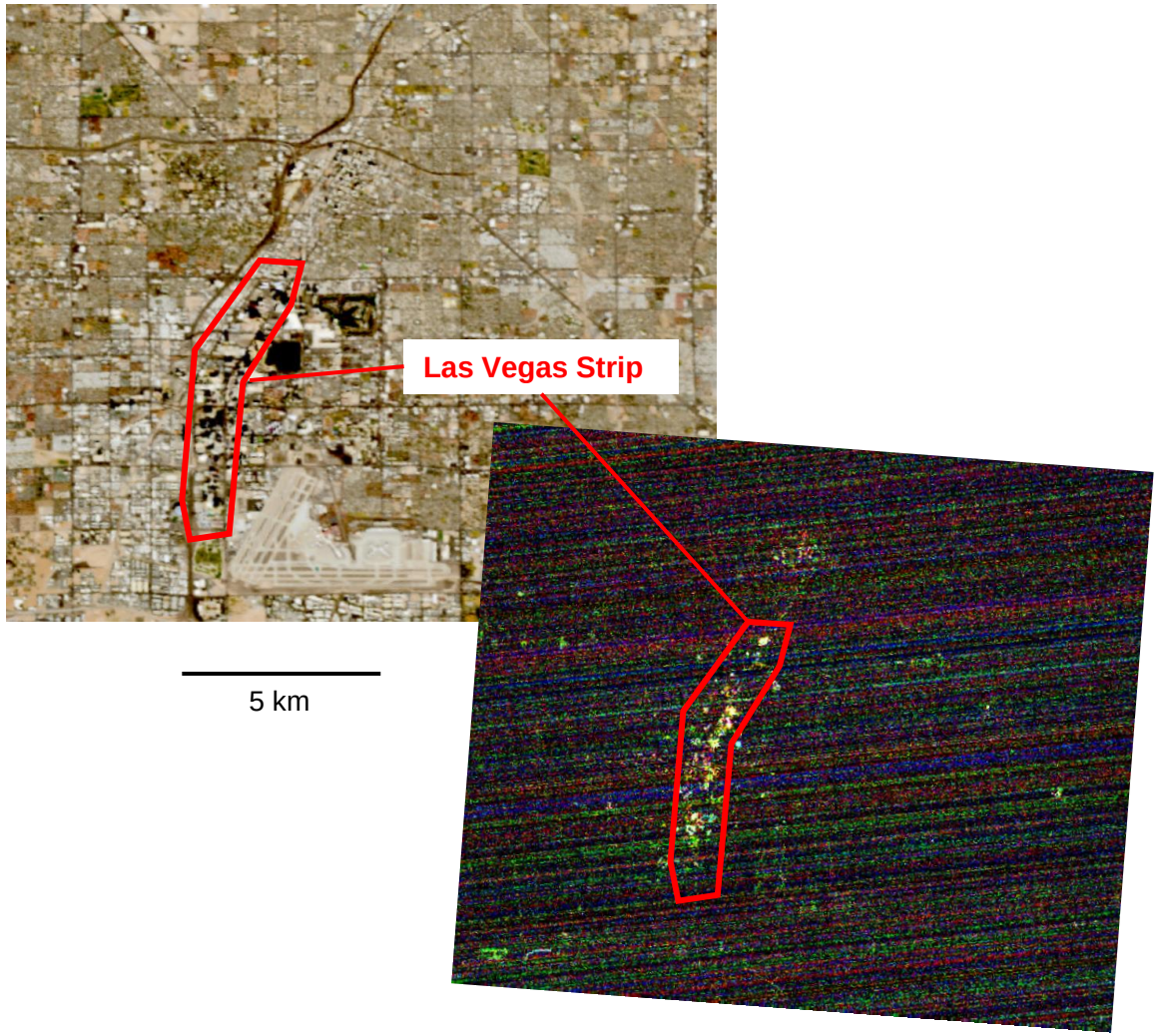


- Since 2022 by DLR
- 224 bands (VNIR – SWIR)
- 30m spatial resolution
- Nighttime capable on ascending orbits

EnMAP is not a nighttime mission...

- **Nighttime light several orders of magnitude below “expected” daytime radiance**
- Atmosphere correction algorithms do not transfer well to nighttime
- No cloud masking
- But still: operable at night with 224 bands!

Daytime EnMAP image of Las Vegas



Nighttime EnMAP image of Las Vegas (B48/30/16, minmax stretch)

Spectral unmixing at night

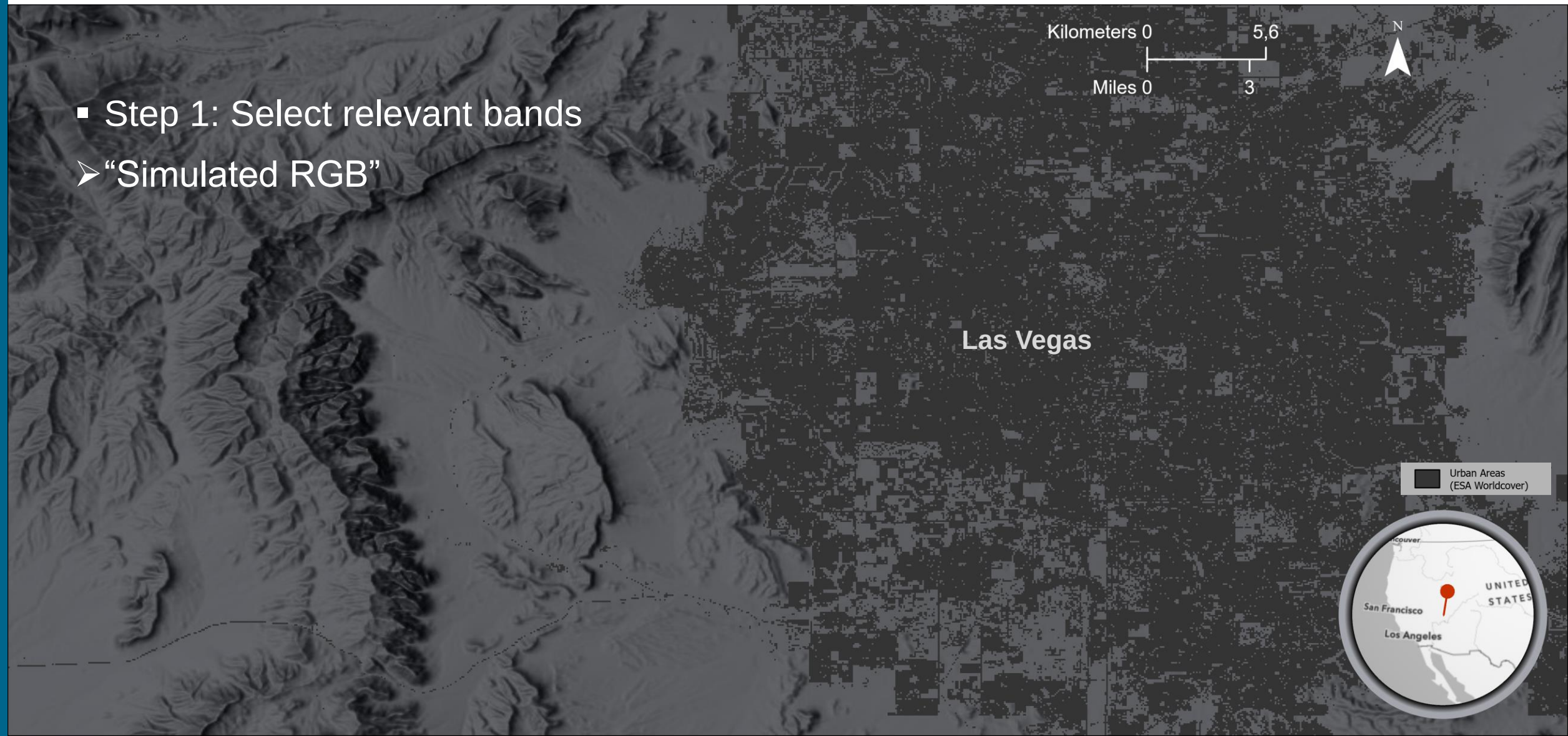
- Spectral Unmixing aims at decomposing a pixel spectrum - reflectance - in the percentages of materials occupying it
  - example: 50% water, 30% grass, 20% trees
- At night: Most of the pixel does not contribute to emissions
  - Radiance instead of reflectance
  - Same lighting types have different emission strengths (in watts)

➢ "Absolute" percentages physically meaningless

➢ Focus instead on finding different lighting types

Methodology: Sim-RGB image

- Step 1: Select relevant bands
  - ➢ “Simulated RGB”



Methodology Sim-RGB image

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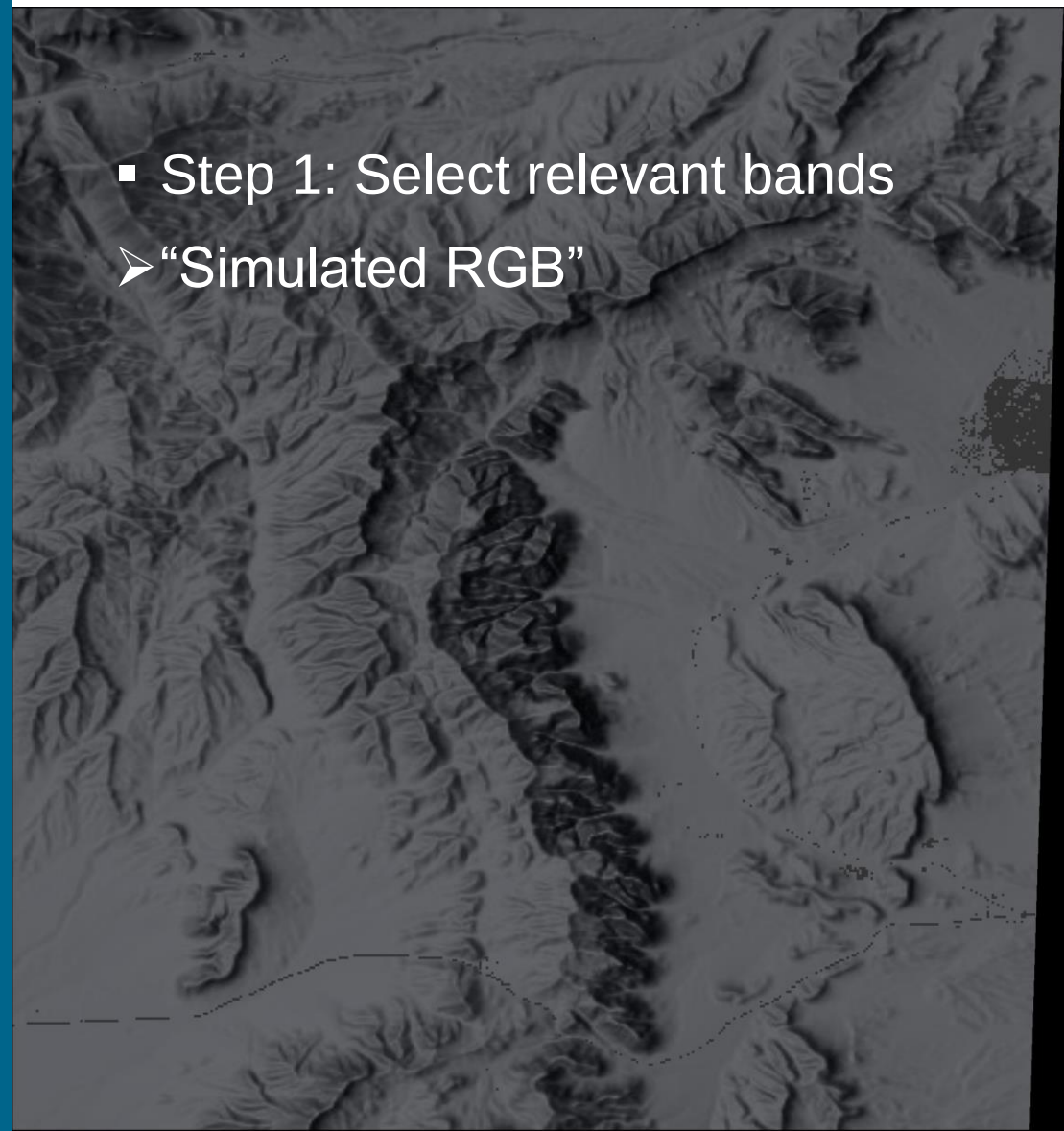
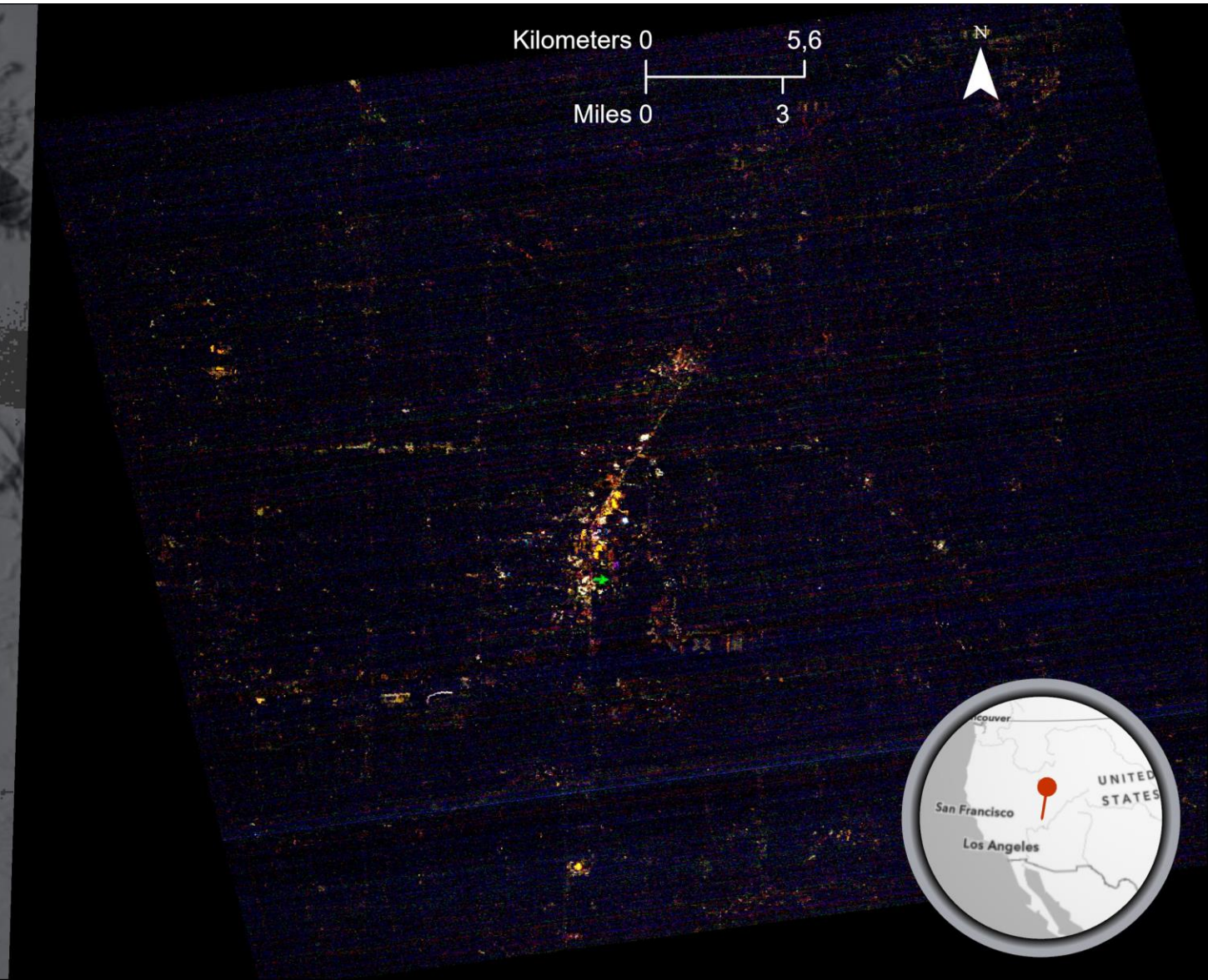
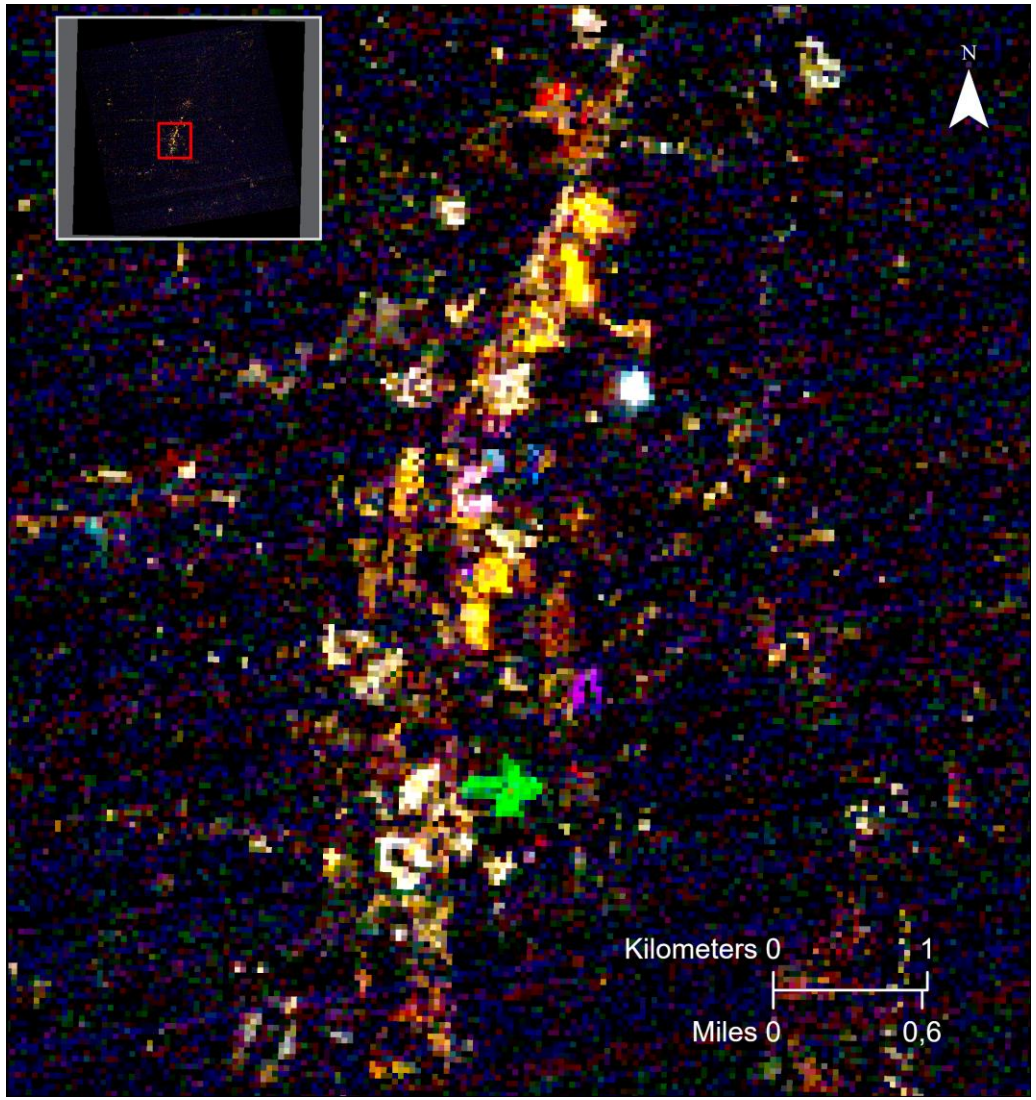




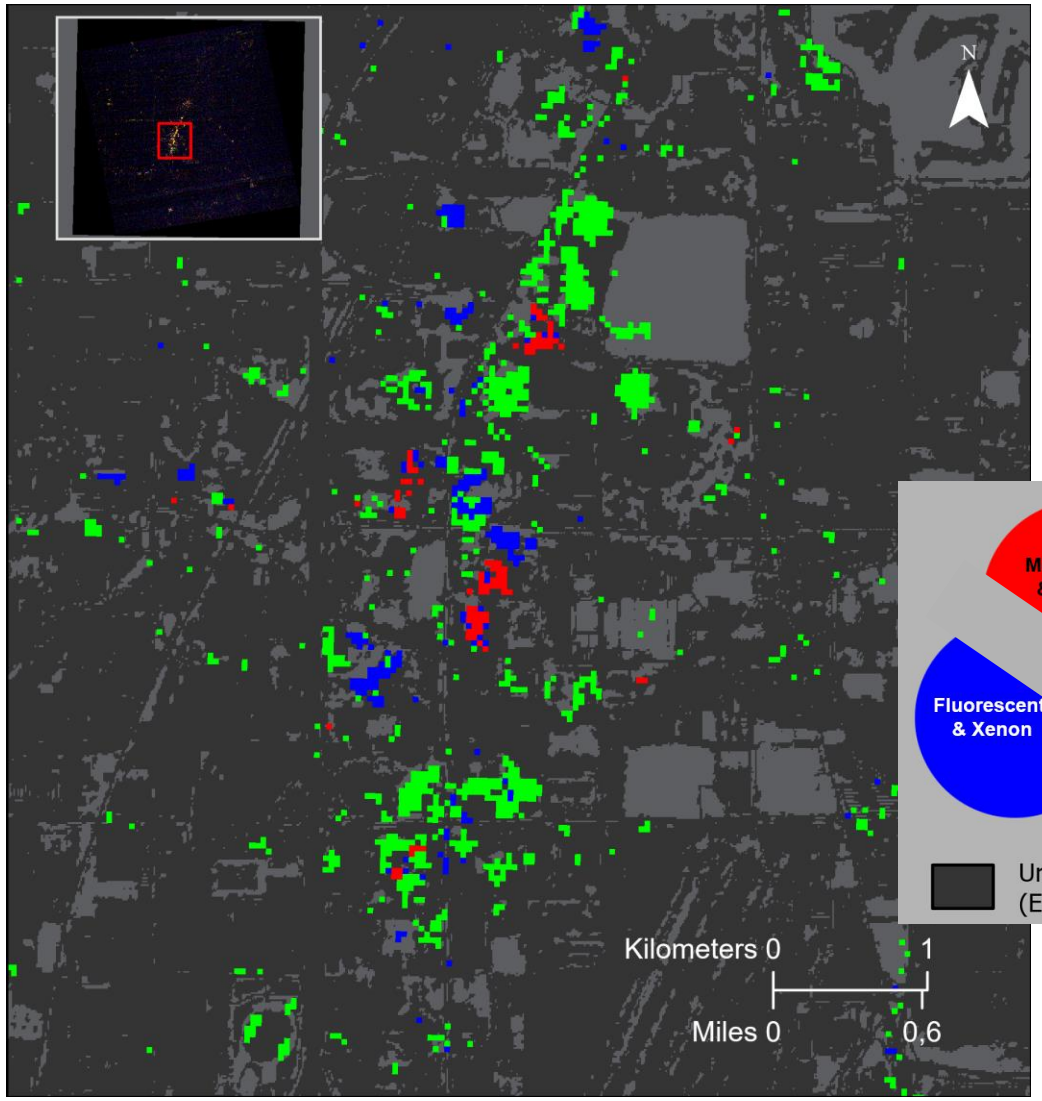
Methodology: Dominant lighting type

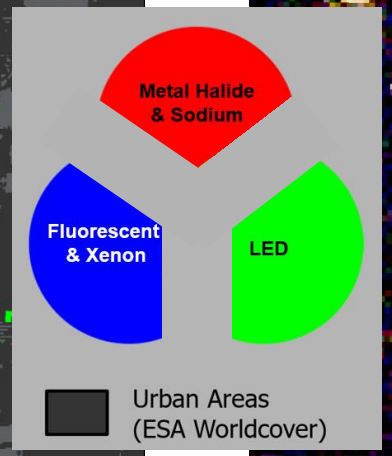
- Step 1: Select relevant bands (VNIR + SWIR)
  - ➢ “Simulated RGB”
- Step 2: prepare lighting spectra library
  - Convolve spectra using EnMAP spectral response function & standard atmosphere
  - ➢ “correct the targets, not the image”
- Step 3: Classify dominant lighting types using OLS

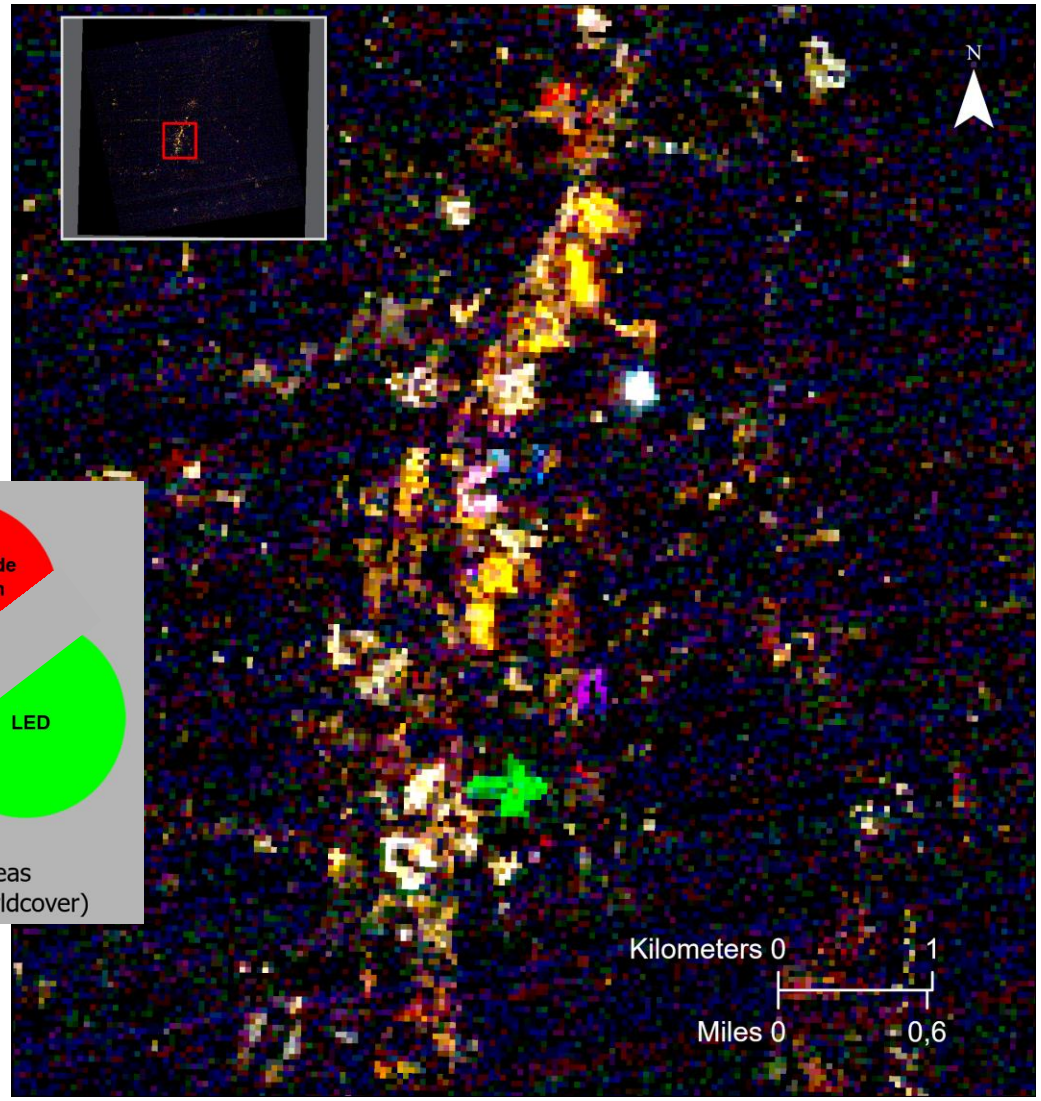


EnMAP Sim-RGB of the Las Vegas Strip

Dominant lighting type



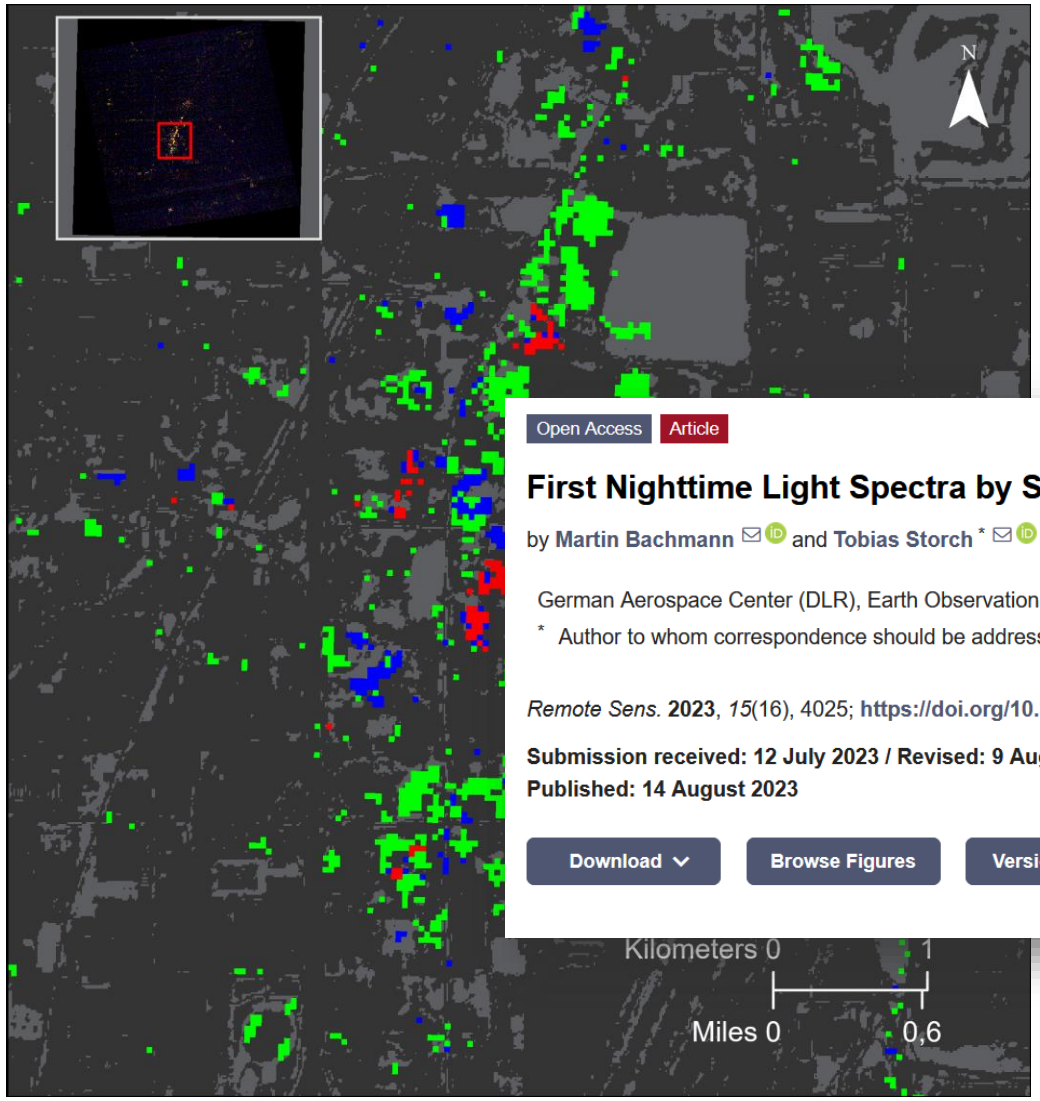




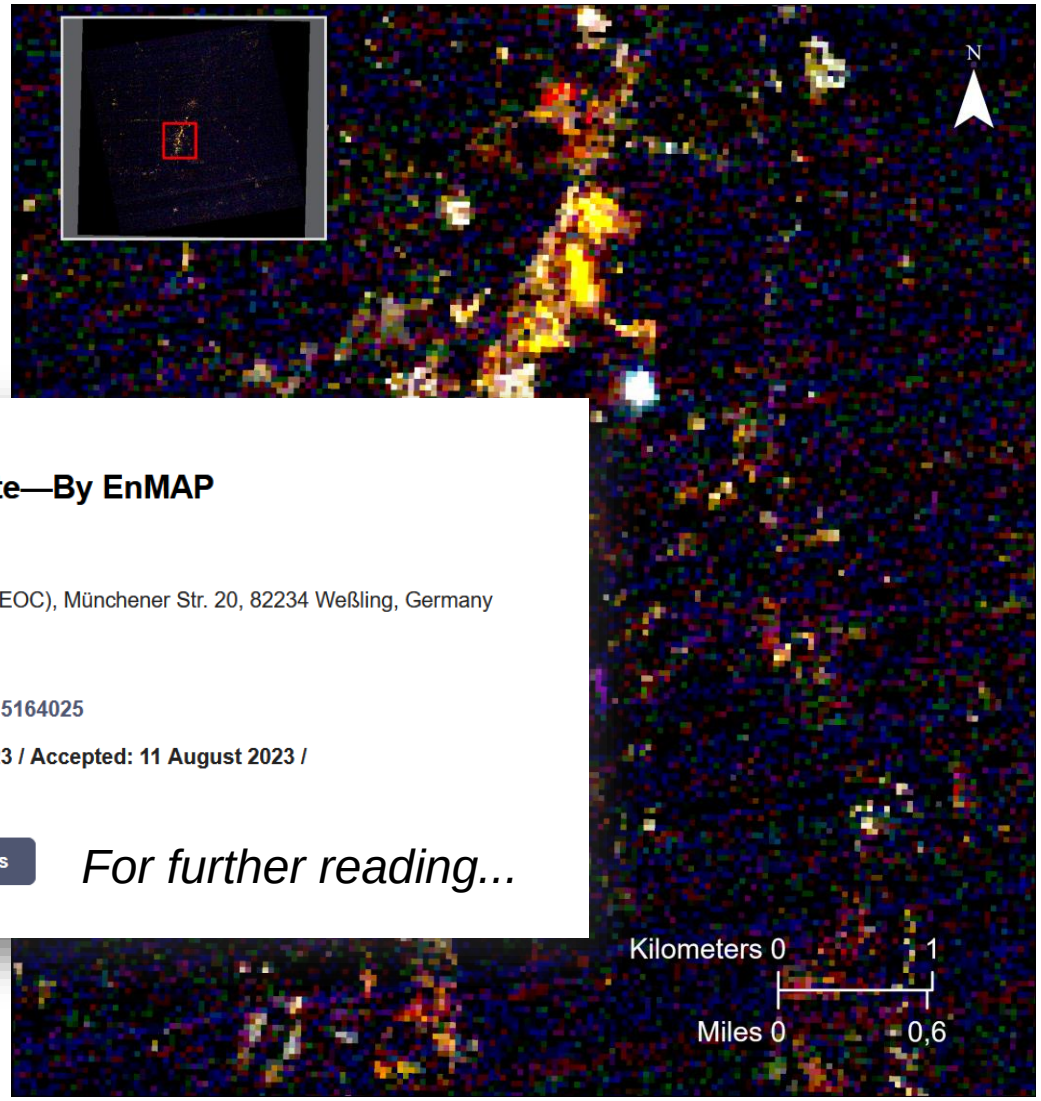
EnMAP Dominant lighting type classification of the Las Vegas Strip

EnMAP Sim-RGB of the Las Vegas Strip

Dominant lighting type



EnMAP Dominant lighting type classification of the Las Vegas Strip



EnMAP Sim-RGB of the Las Vegas Strip

Open Access Article

First Nighttime Light Spectra by Satellite—By EnMAP

by **Martin Bachmann** and **Tobias Storch** *

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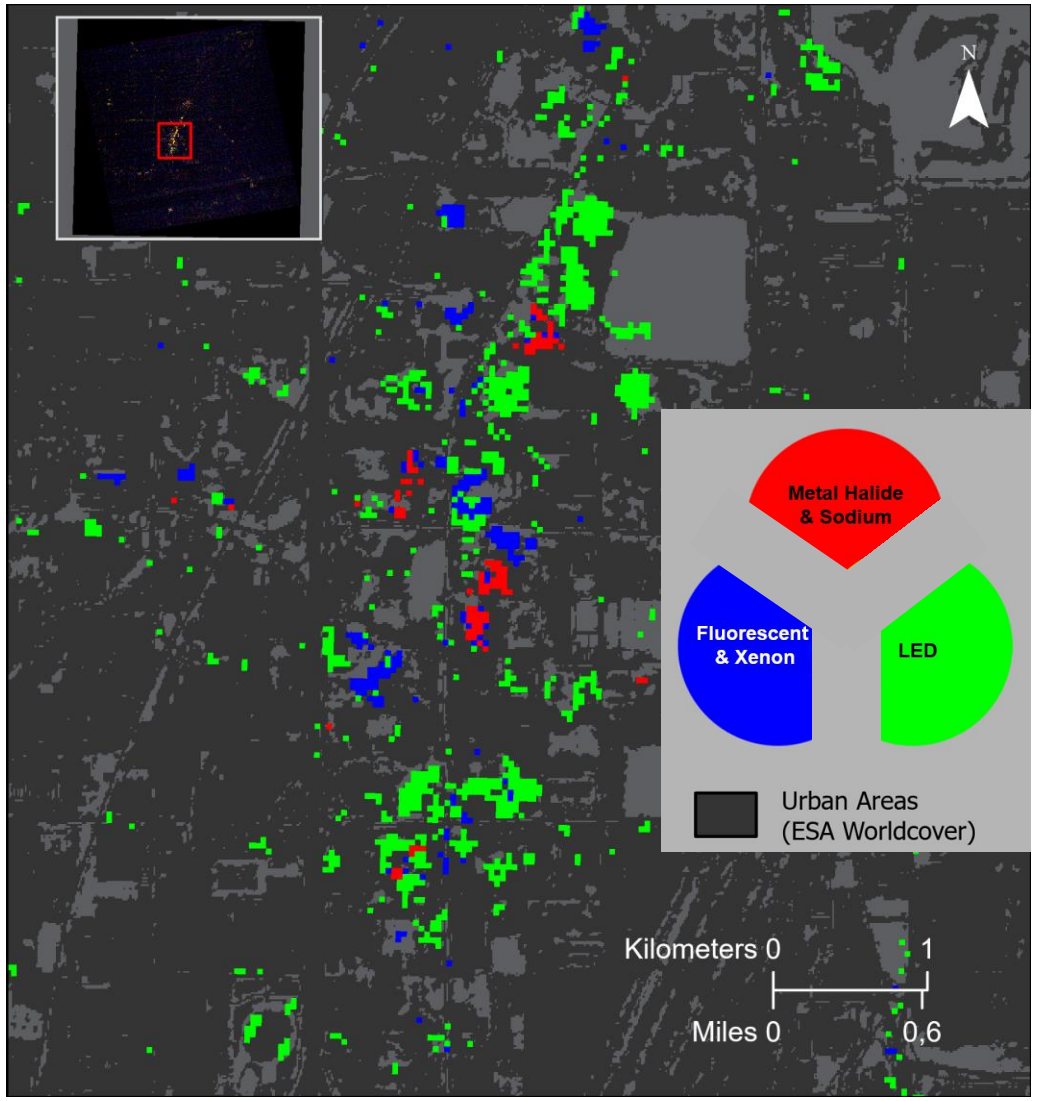
For further reading...

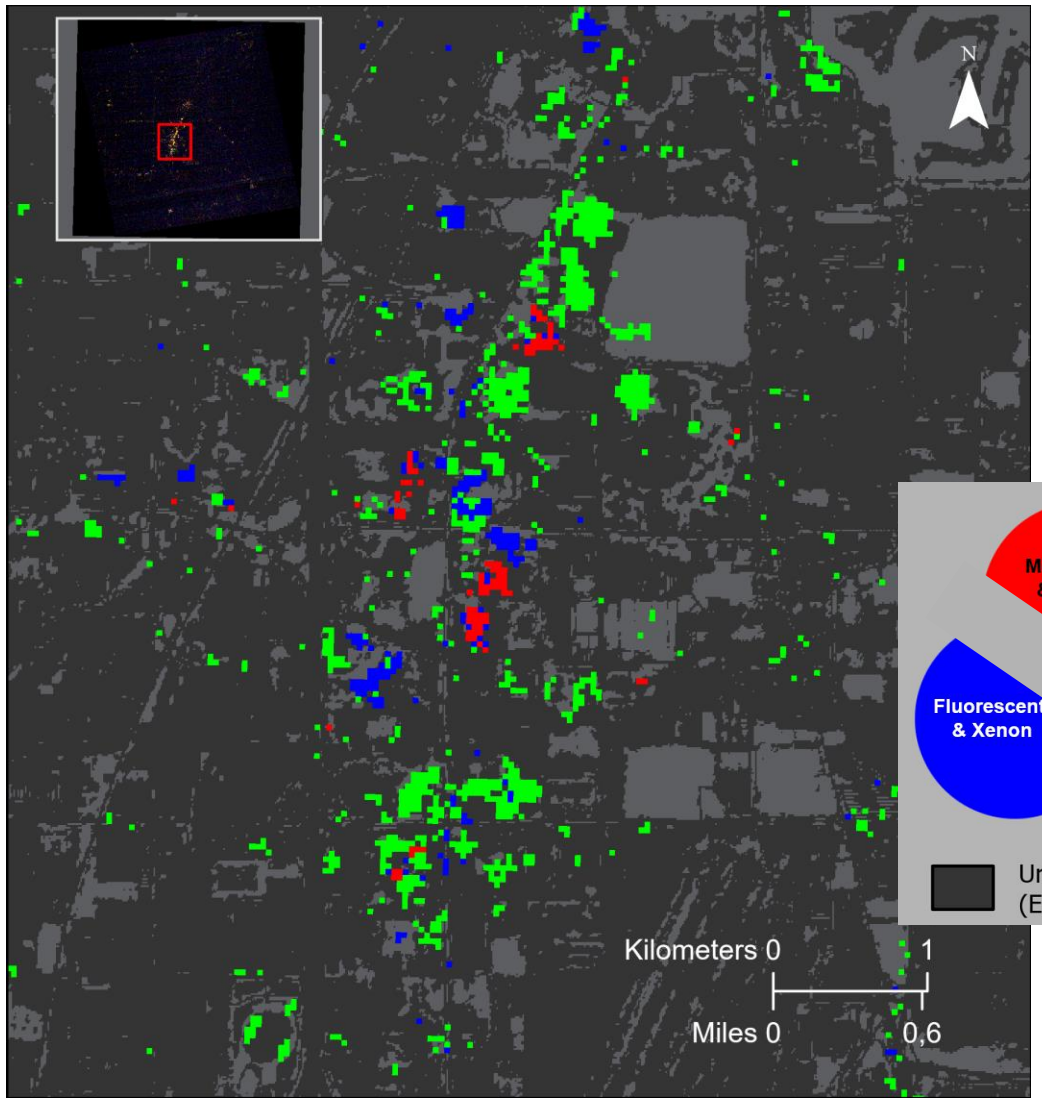
Lighting type complexity

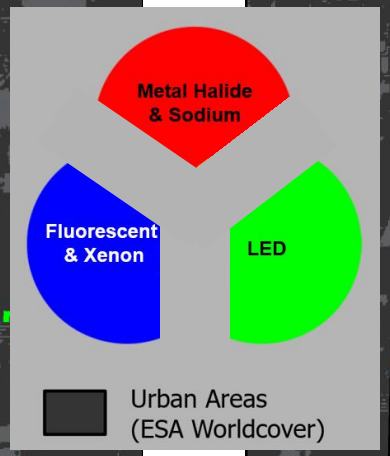


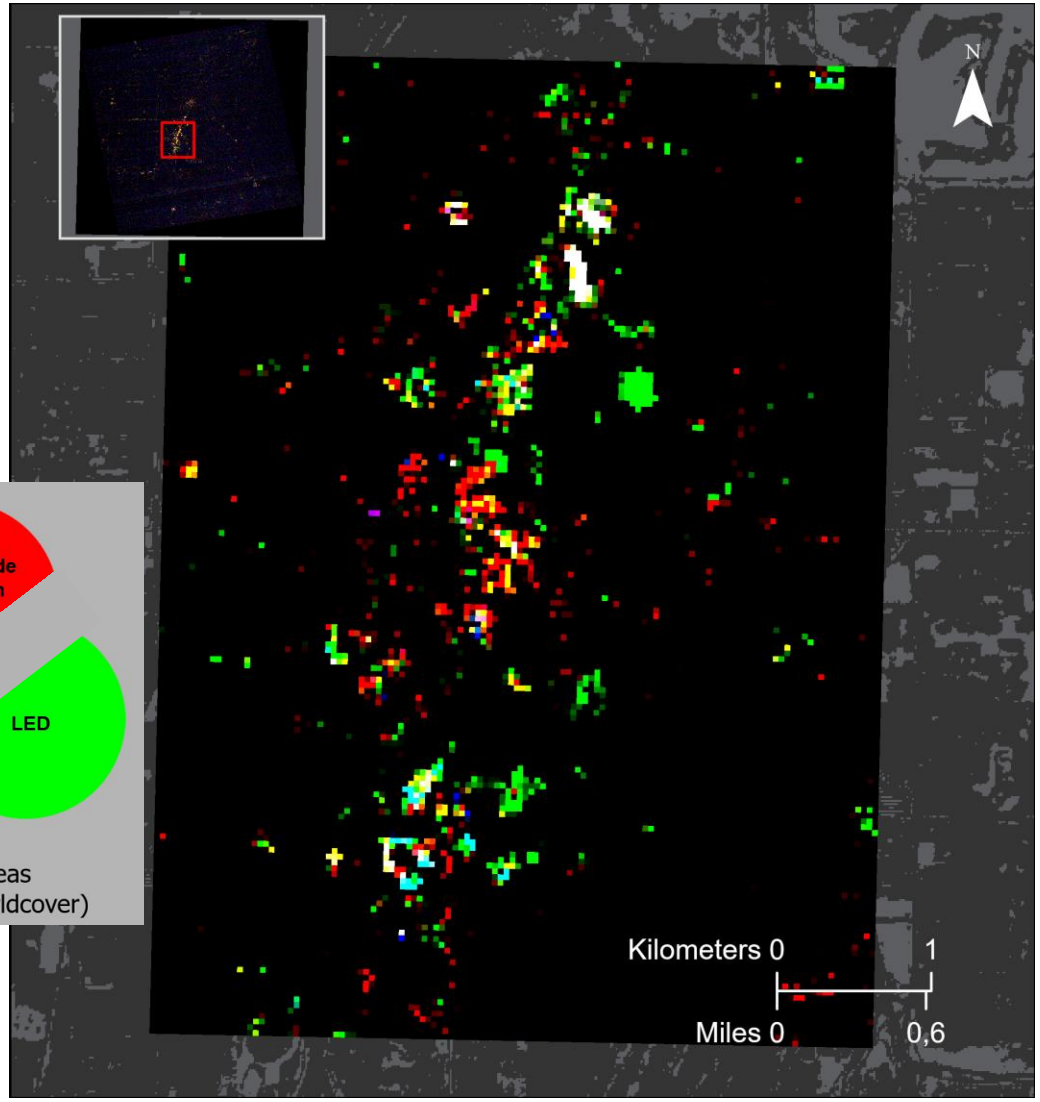
EnMAP Dominant lighting type classification of the Las Vegas Strip

- Step 3: **Run spectral unmixing**
  - Balanced mix of 12 spectra
  - Run spectral unmixing
  - For comparison: group spectra into three groups (same as dominant lighting type)

Lighting type complexity





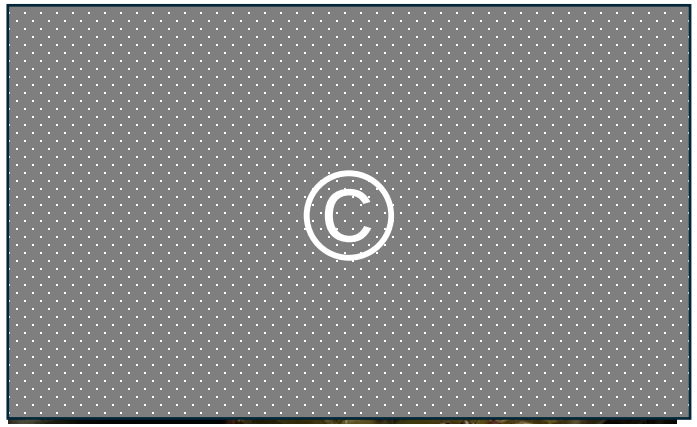


EnMAP Dominant lighting type classification of the Las Vegas Strip

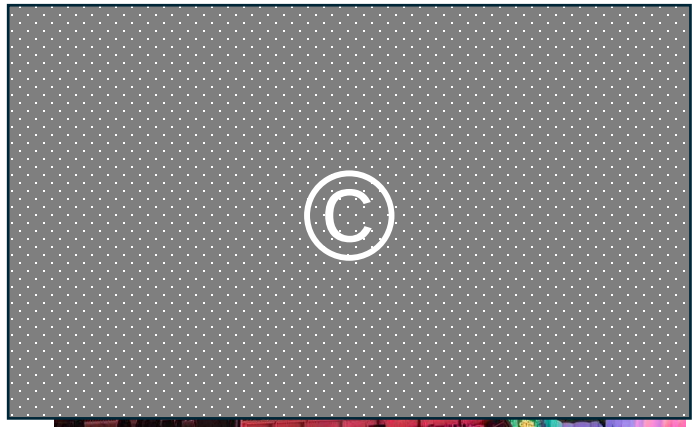
EnMAP Lighting type complexity of the Las Vegas Strip

Homogenous areas

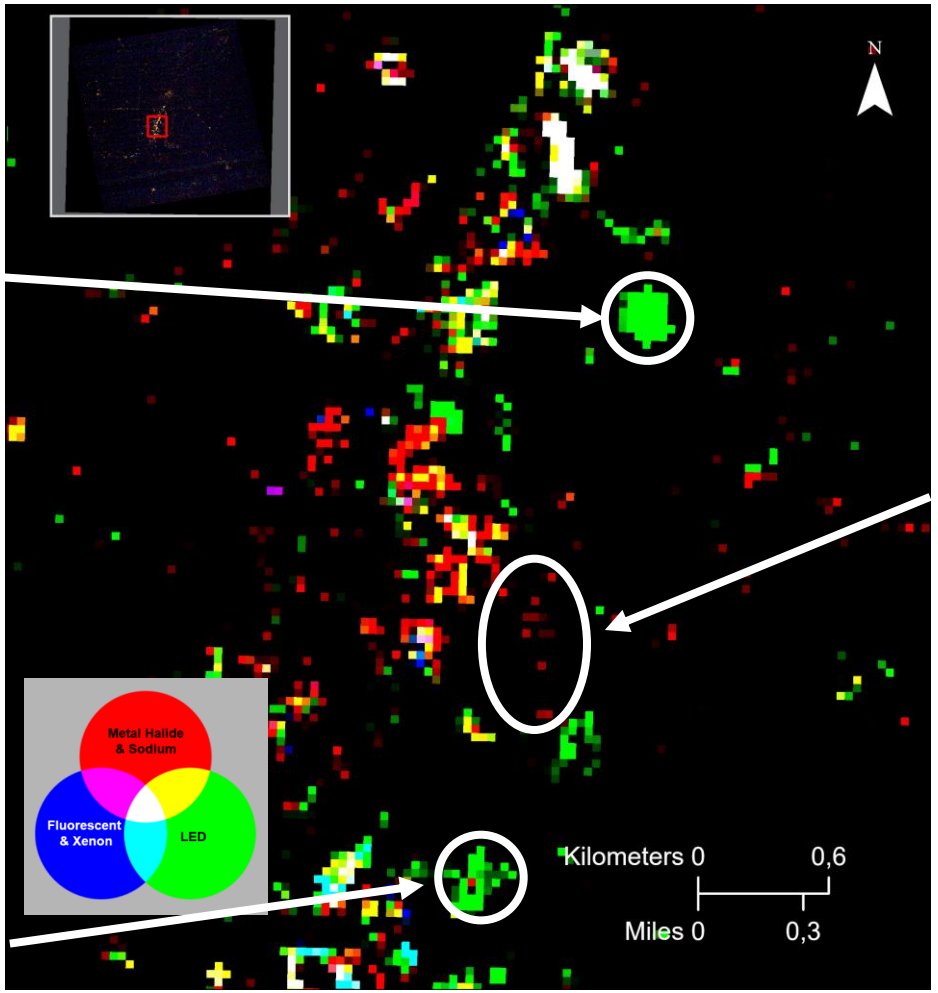
- Red/Green/Blue: one dominant lighting category
- Magenta/Cyan/Yellow: two dominant categories
- White: all three categories

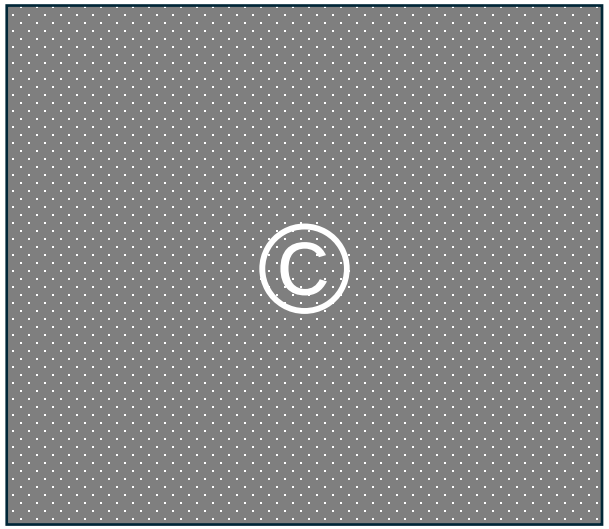


The sphere (dreamstime.com)



MGM Grand hotel (tripadvisor.com)

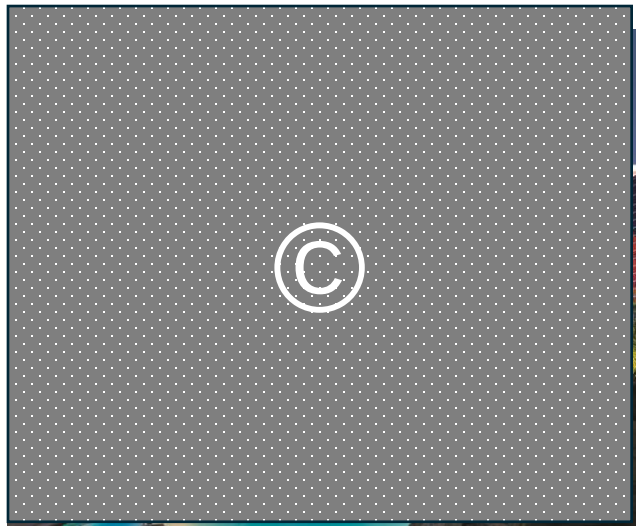




Large parking lot (Google street view)

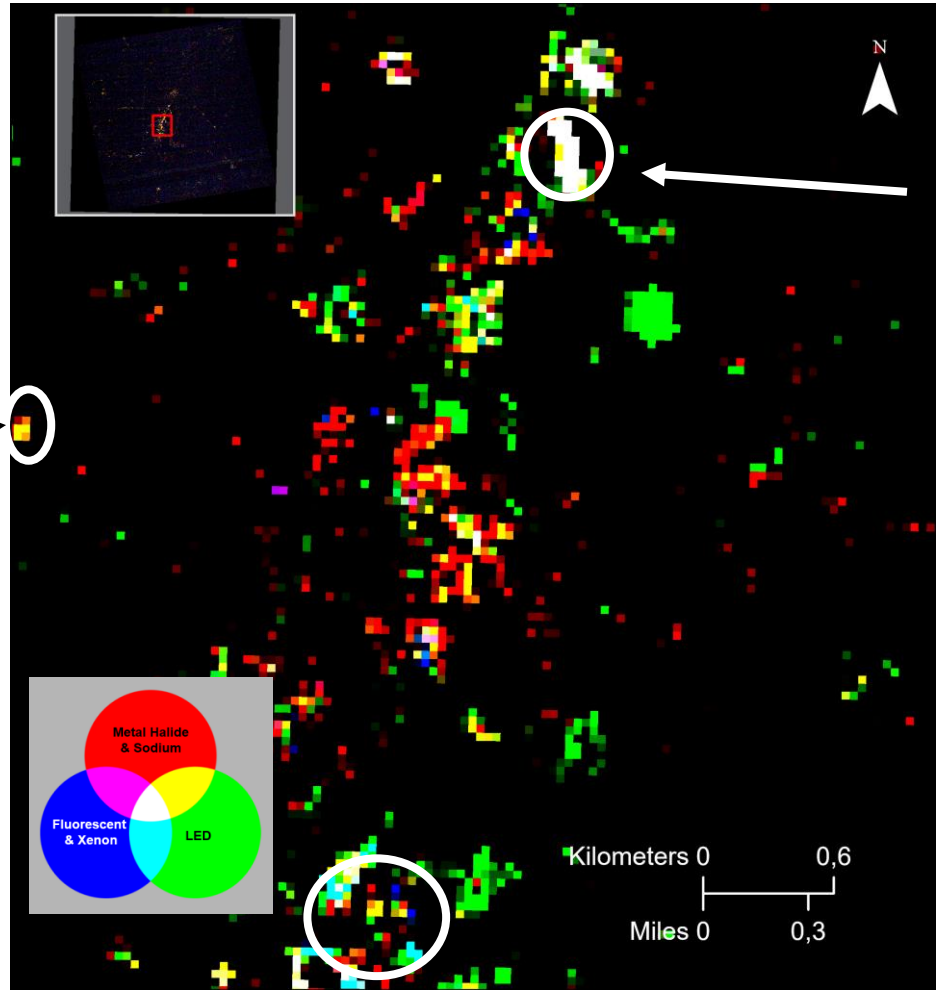
Heterogenous areas

- **Red/Green/Blue: one dominant lighting category**
- **Magenta/Cyan/Yellow: two dominant categories**
- **White: all three categories**

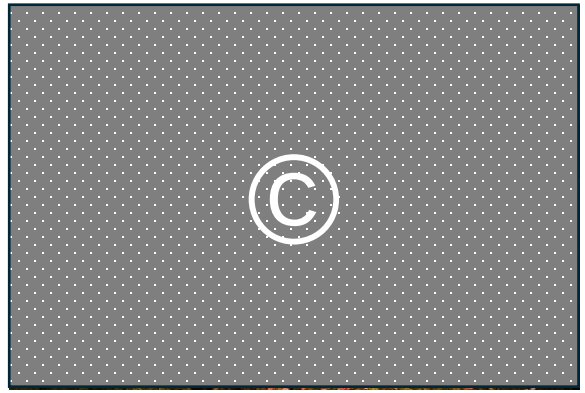


Rio Hotel (lasvegasconcierge.us)

- Mostly Sodium, but some LED

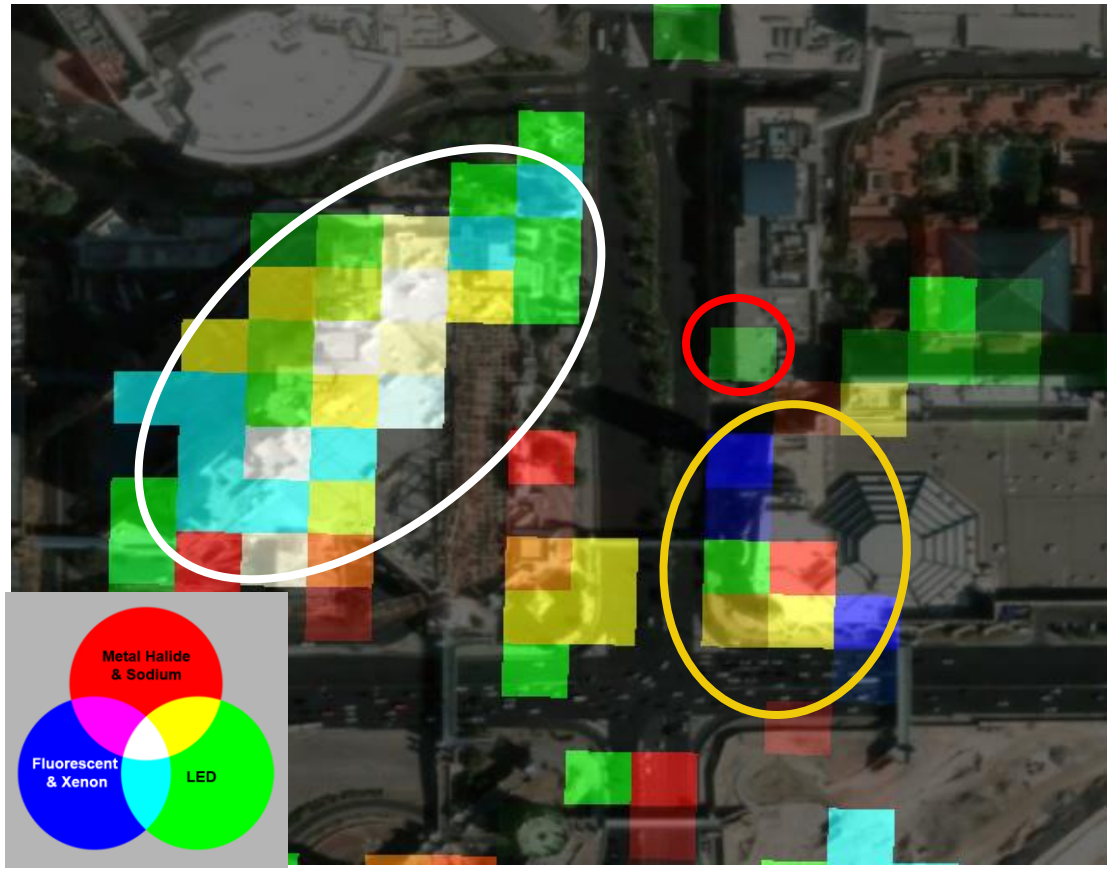


Wynn Hotel (stories.wynnlasvegas.wynnorigins.com)



- Mostly LED, but also Sodium and some Xenon

Heterogenous areas: remember this image?



Las Vegas at night 2022 (Own image taken for “research” purposes)

Discussion

Limits:

- Very weak signal increases unmixing uncertainty
- Las Vegas is a very bright city
- Most of these bright targets are large resorts with one dominant lighting type
- **no validation data (!)**
- EnMAP: detection limit at <0.03 W/m²/µm/sr
  - VIIRS: 2×10^{-7} W/m²/ µm/sr ...

Potential:

- Gradual changes in lighting type likely detectable
  - ➢ EnMAP nighttime spectral unmixing can provide valuable additional information...

... **for bright targets and under optimal conditions**

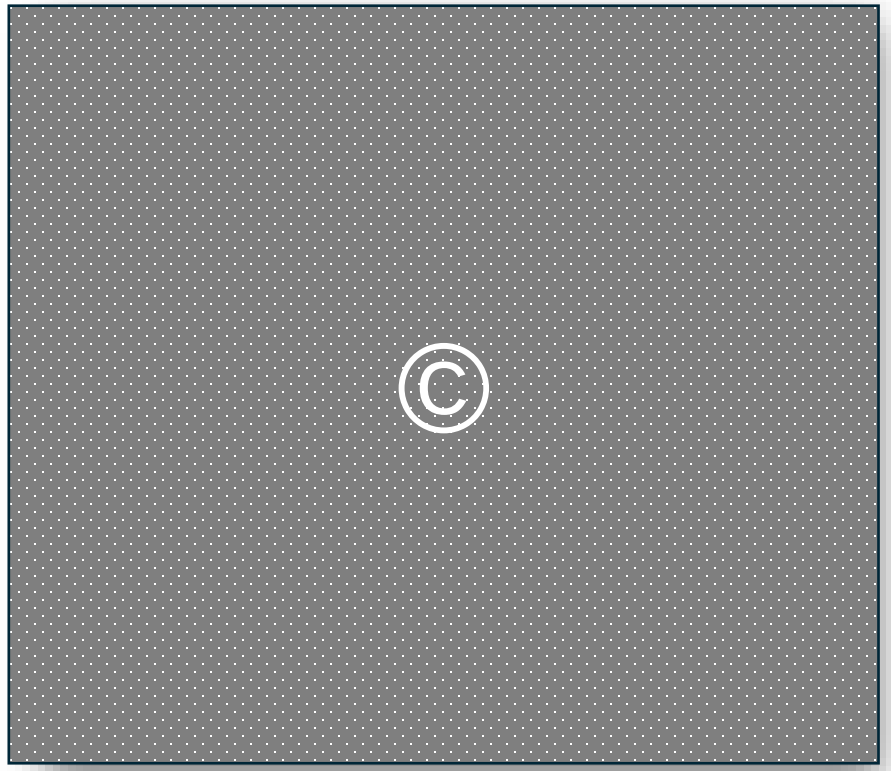
To summarize:

- Lighting type classification important, but spectral resolution of most sensors allows only for mapping dominant lighting type
- Used EnMAP spectral unmixing approach over Las Vegas to assess lighting type complexity
- **Conclusion:** EnMAP can add valuable spectral information to bright nighttime targets, but further validation required
- Make sure to also visit:

Mapping Artificial Lights using EnMAP – Results from Las Vegas, Riad and Tokyo

Martin Bachmann, Emiliano Carmona, Daniele Cerra, Merlijn Dingemanse, Miguel Pato, Tobias Storch

Thanks for your attention ☺



APPENDIX

About me

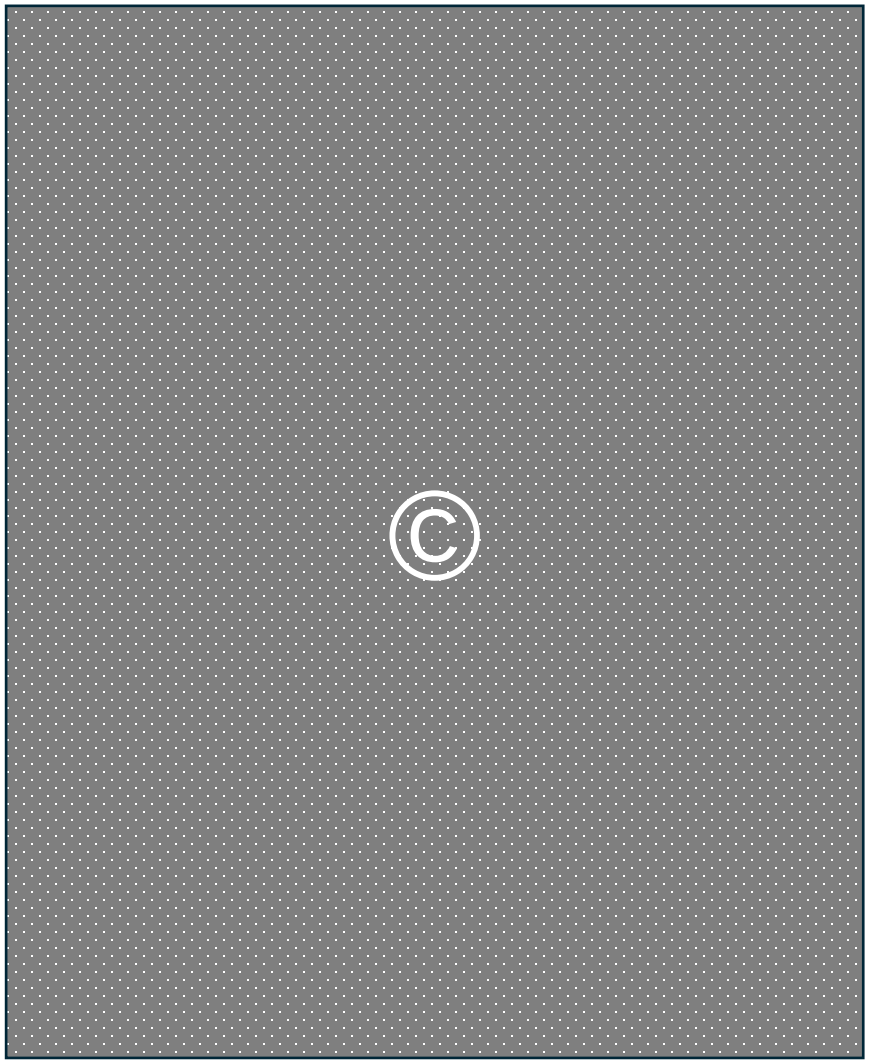
- MSc. Geomatics
- At EOCs Imaging Spectroscopy department since 12/2024

Topics:

- Nighttime light variability and light pollution
- Sentinel-2 (at night)
- Conflict monitoring using fire data (mostly at night)
- **EnMAP (at night)**

Detecting lighting types: State of the art

- Nighttime data lacks spectral resolution:
  - **VIIRS DNB**: panchromatic, so not capable of detecting lighting types, also 750m spatial resolution and high variability
  - **SDGSAT**: only 3 Bands at 40m -> can separate LED from other lighting using blue peak, not much else
  - **Others**: low number of bands and/or low detection limit
- **As such: Focus on detecting dominant lighting type only**

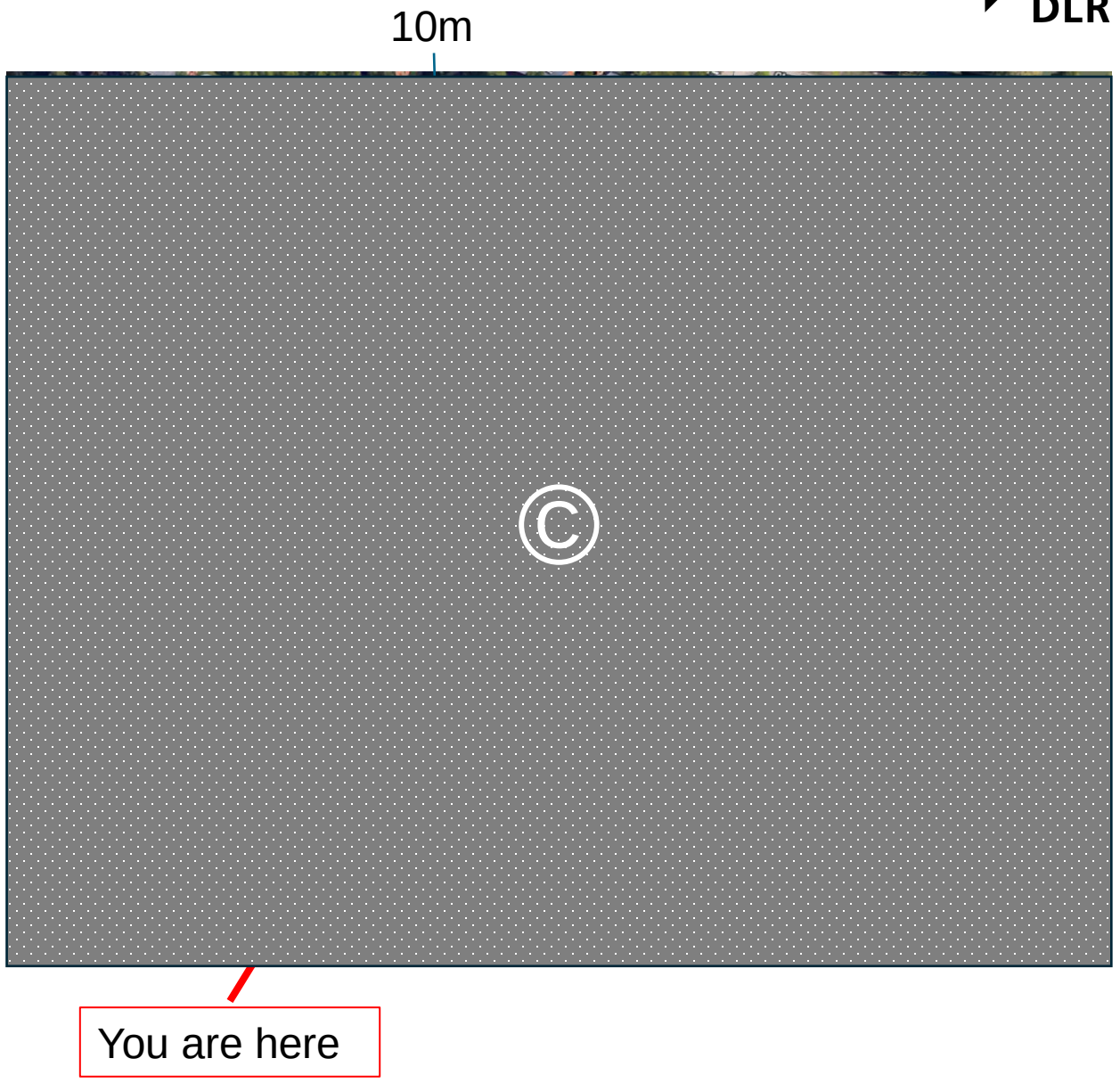


Jia et al. 2024, *https://doi.org/10.1016/j.rse.2024.114104*

Platforms

We make due with:

- **VIIRS (since 2012)**
  - PAN only at 750m, very good sensitivity
  - Daily overpasses
  - Problem: LED lamps not properly covered
- **SDGSAT-1 Glimmer (since 2022)**
  - RGB+PAN at 40m/10m with pretty good sensitivity
  - Tasking based
- Others (not as relevant): Landsat-8, S2, etc.

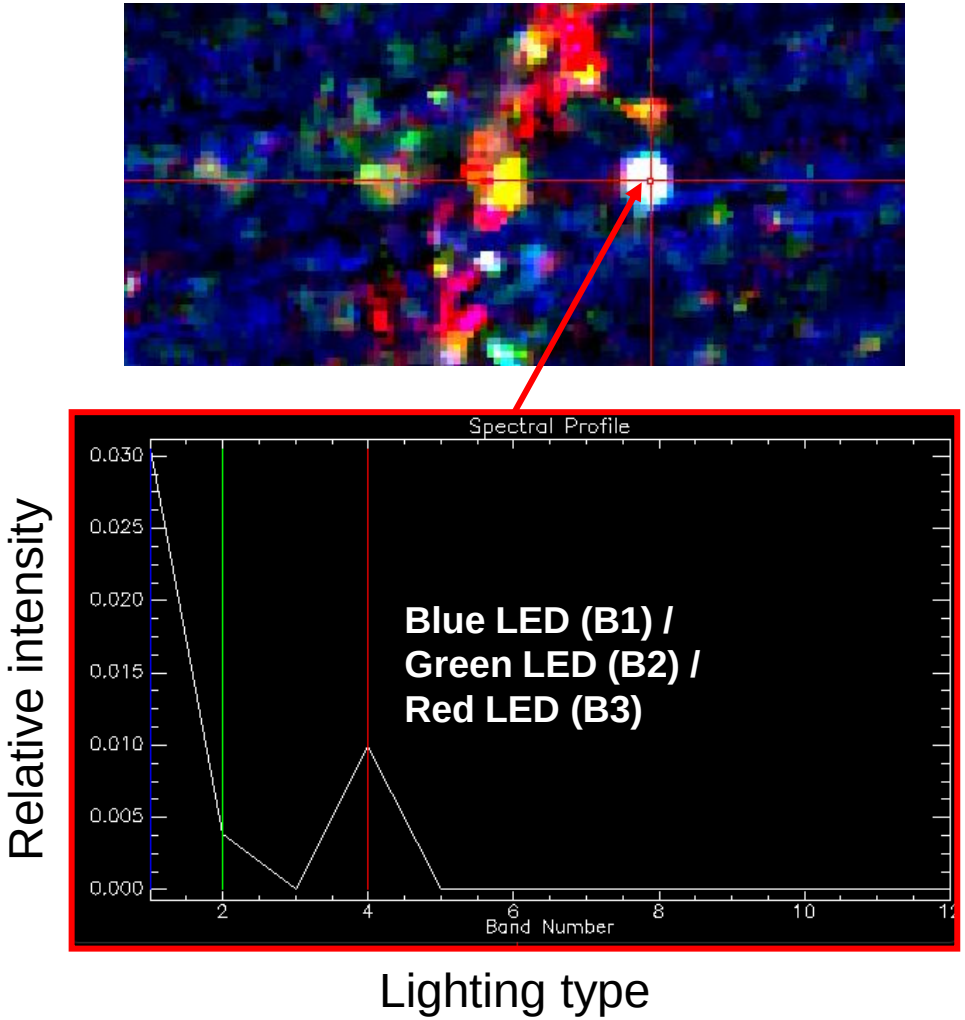


Spectral unmixing at night (with example image)

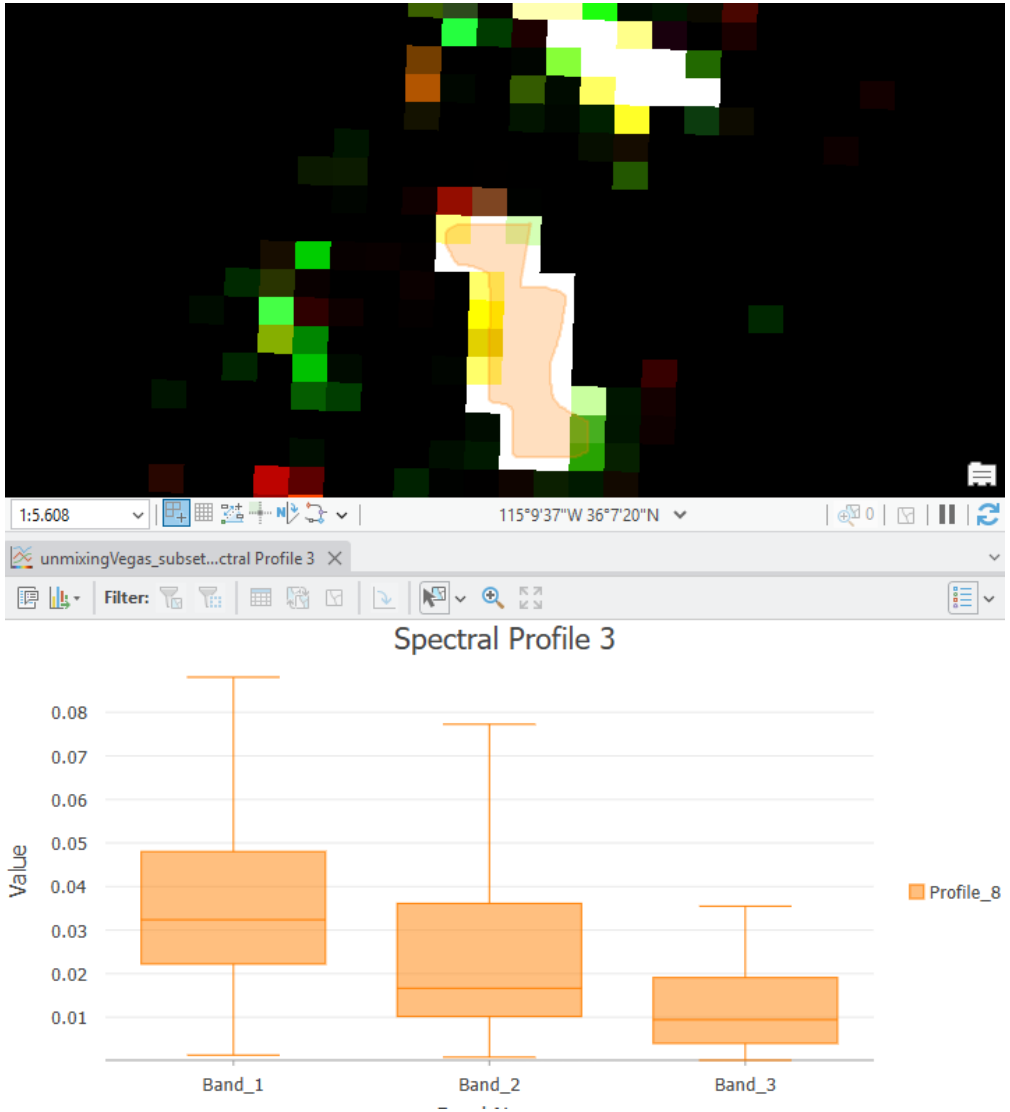
- Spectral Unmixing aims at decomposing a pixel spectrum - reflectance - in the percentages of materials occupying it
  - example: 50% water, 30% grass, 20% trees
- At night: Most of the (sub)pixel does not contribute to emissions
  - Radiance instead of reflectance
  - Same lighting types have different emission strengths (in watts)

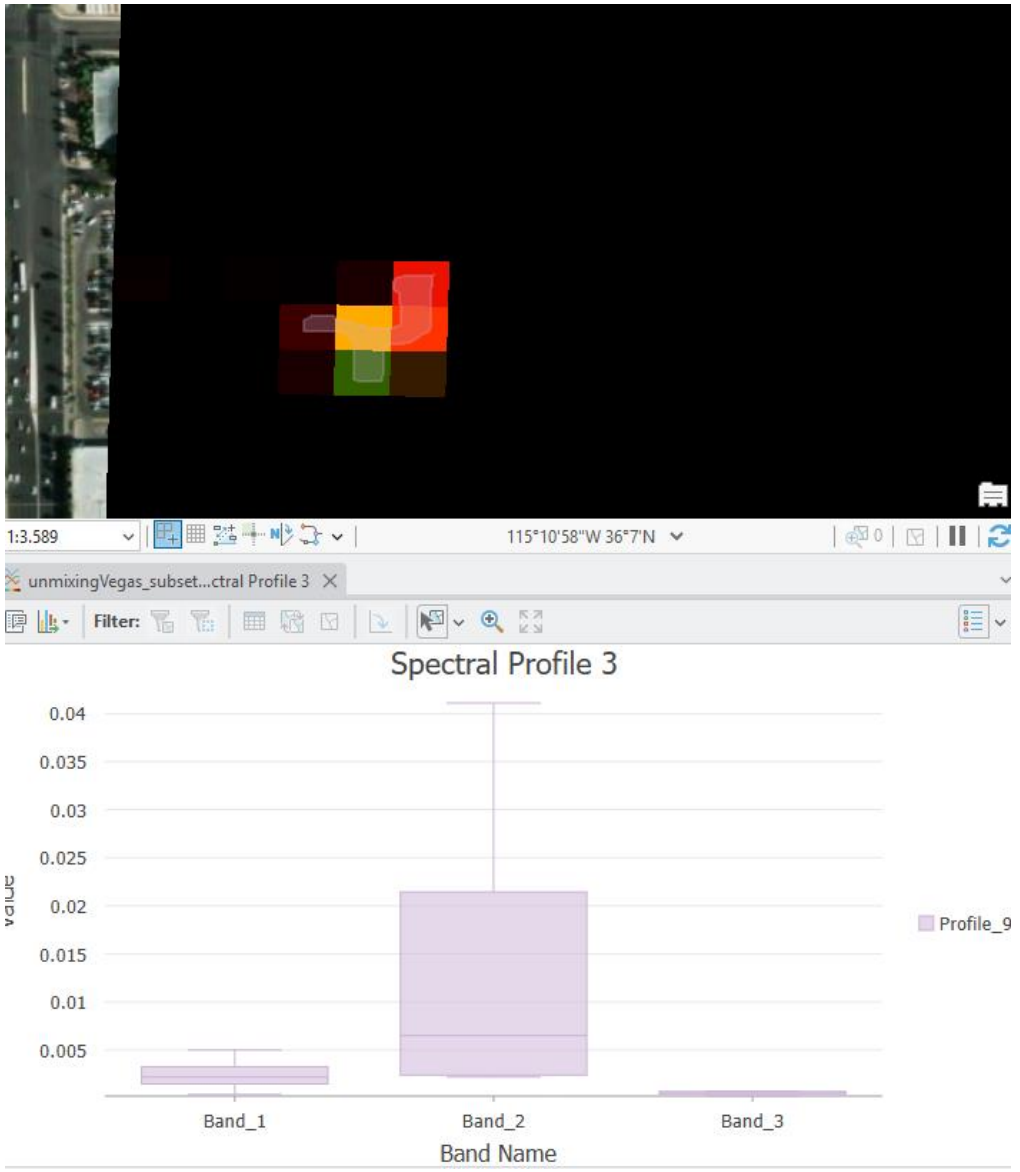
➢ “Absolute” percentages physically meaningless

➢ Focus instead on finding different lighting types

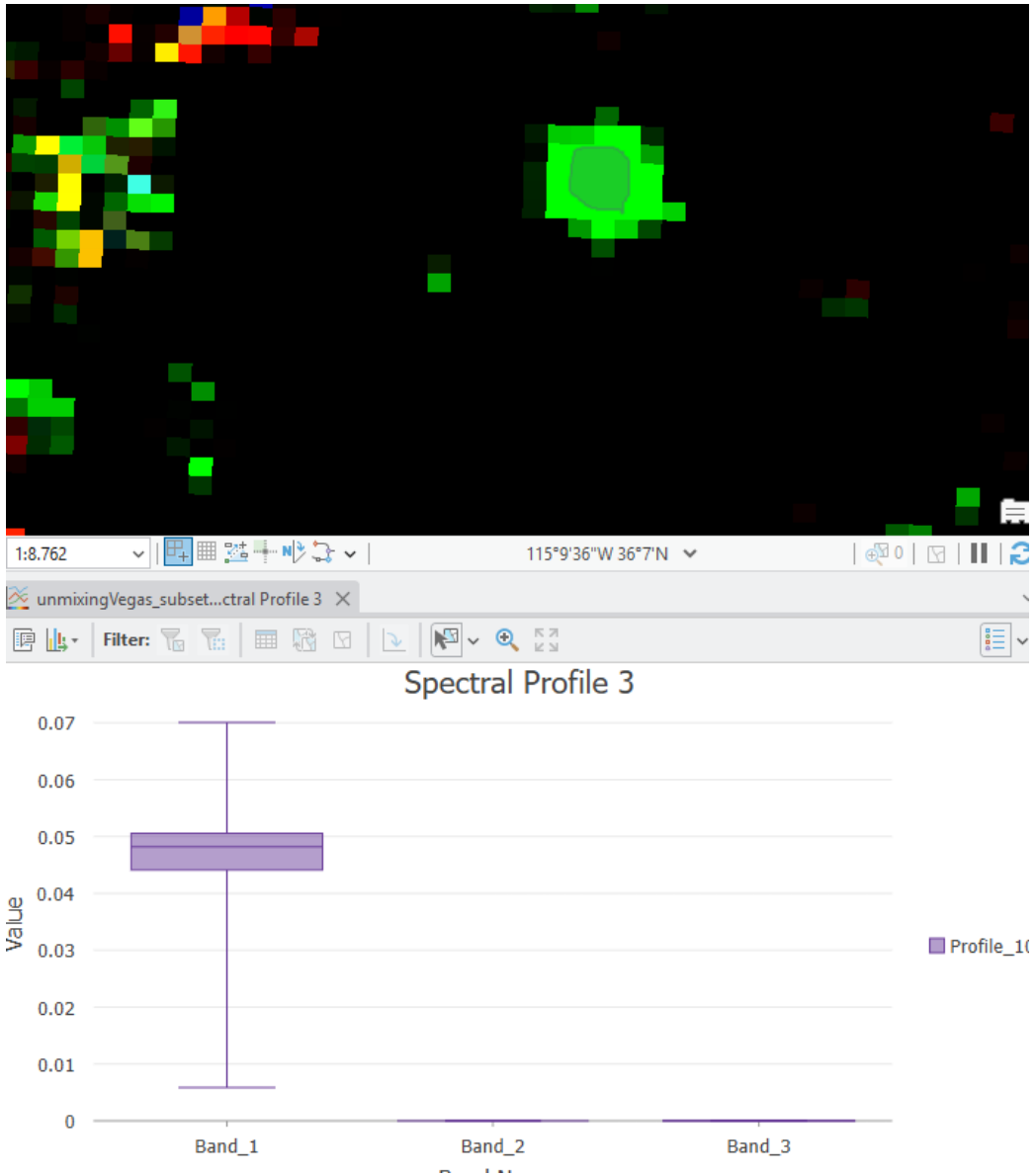


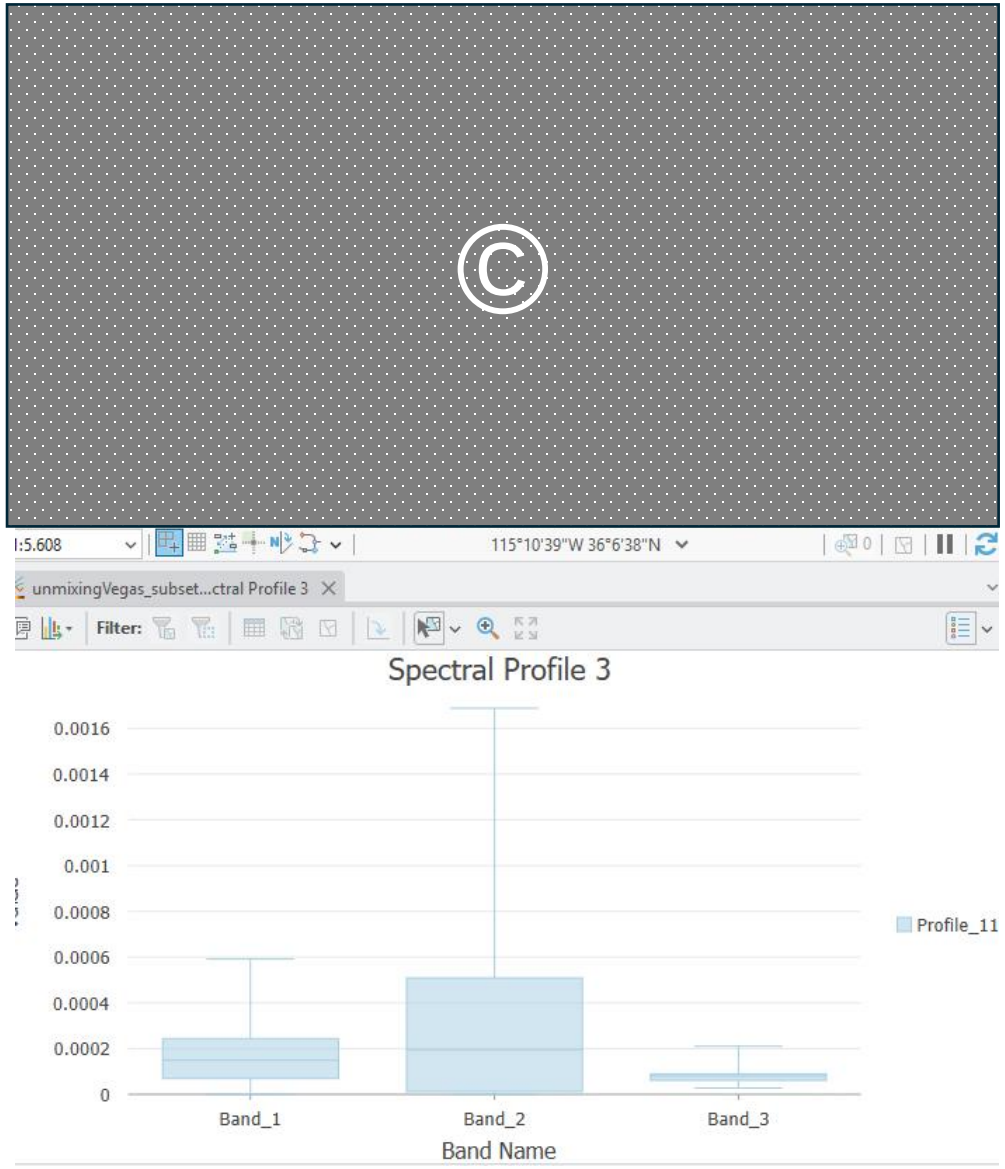
Spectral profiles: Wynn (L) and Rio (R)





Spectral profiles: Sphere (L) and parking lot (R)





Imprint

Topic:	**Resolving Urban Lighting Type Mixtures from EnMAP Nighttime Hyperspectral Data:** Las Vegas at night
Date:	2026-06-02
Author:	Merlijn Dingemanse
Institute:	Remote Sensing Technology institute (IMF)
Image sources:	All images “DLR (CC BY-NC-ND 3.0)” unless otherwise stated