Remote sensing at night: The EULE mission concept

GFZ Helmholtz Centre for Geosciences

RUB

AK Fernerkundung

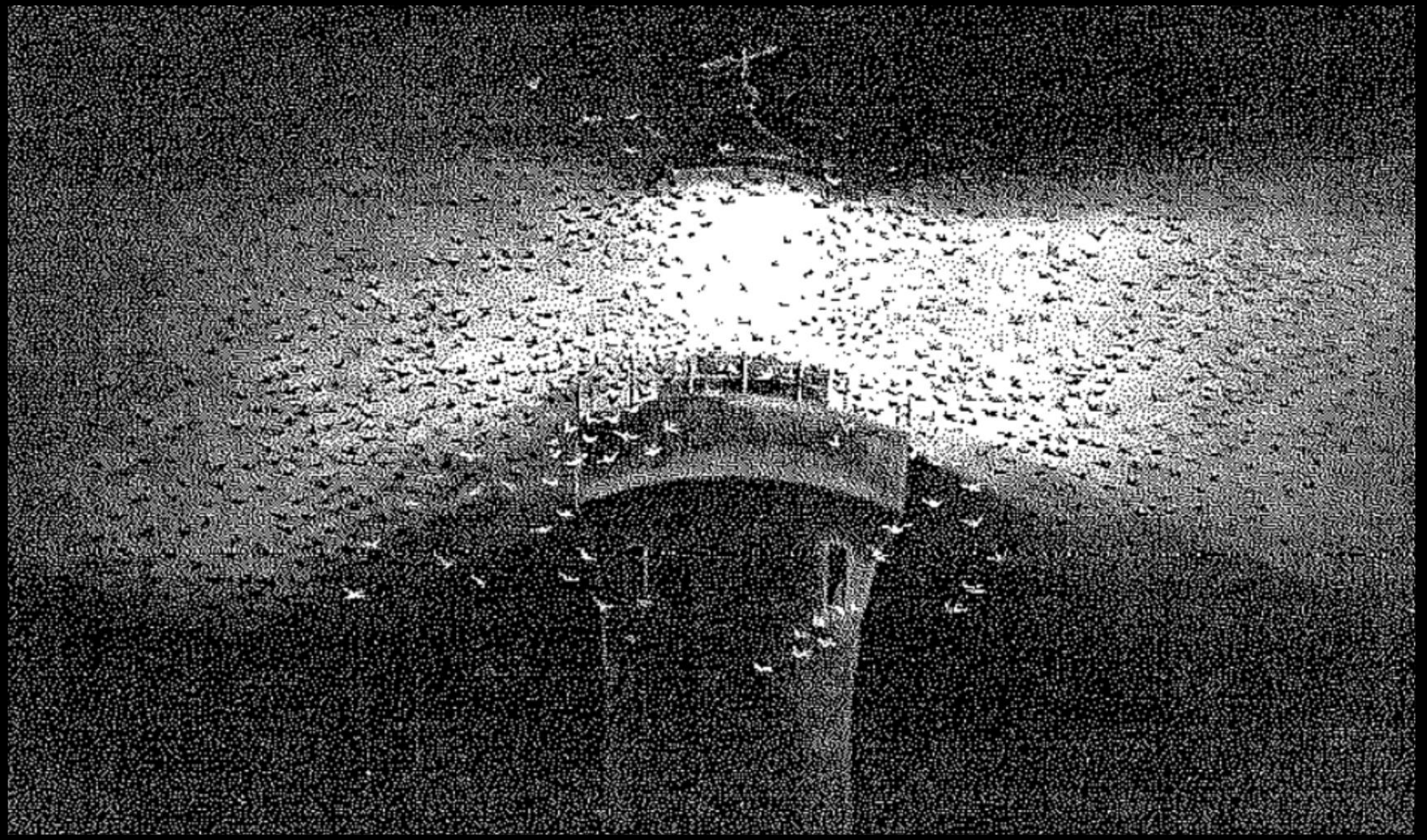
Christopher Kyba

September 29, 2025

Urban - Rural interaction:
Navigating through tipping points in coupled human-environment systems

Could there be a tipping point for light pollution?

Illustration of the Eddystone Lighthouse
M.E. Clarke (1912)



From “on the Destruction of Birds by Light-houses” (1880)

St. Augustine Fla (1877):

…as far as could be seen by the beam of light, the air appeared to be a solid mass of birds. Each morning the keepers raked up more than two bushels of dead birds. The ground in the vicinity of the light was covered with dead and wounded birds. “I can hardly give a correct idea of the number, but there must have been more than a million. The air was so thick with birds on these nights that I had to protect my face with my hat to keep them from blinding me.”

From “on the Destruction of Birds by Light-houses” (1880)

Cape Cod (1877):

“Now no sea birds fly against the light, as was the case in former years, except..."

“The great rush of birds on the night of March 29th-30th as observed in Ireland (1911)

“Where there was any light in a window they were dashing against it.”

“The streets were practically littered in the morning with the bodies of dead birds.”

“I looked towards one of the gas lamps at 11pm and the whole air seemed one mass of small birds”

“…the birds kept hovering over towns where gas lamps were lighted. There are no gas lamps at Cappoquin, and no birds were observed there.”

“A Lapland Longspur Tragedy” (Roberts, 1907)

“on the fateful night there was an immense migratory movement of Lapland Longspurs… they were attracted by the lights of the towns and congregated in great numbers over and about these places.”

“…taking the reasonably accurate basis of calculation furnished by the lake surfaces, it would seem that certainly not far short of a million and a half birds were killed.”

“A Lapland Longspur Tragedy” (Roberts, 1907)

“Electric light captures” (Hamilton, 1880)

“The reputed rarity of an insect is frequently owing to its ability to conceal itself … whereas it may be really abundant. This is exemplified in the instances of *Calosoma scrutator* and *C. willcoxi*. During near twenty years of collecting here I only took a single living specimen of each.”

“Electric light captures” (Hamilton, 1880)

“[Powerful electric lights were suspended in the corners of one of our parks in the city.] During one hour I picked up 120 *Calosoma scrutator* and 136 *C. willcoxi*.”

“The number of coleoptera and insects of all orders that are attracted to the electric lights in these cities is beyond computation.”

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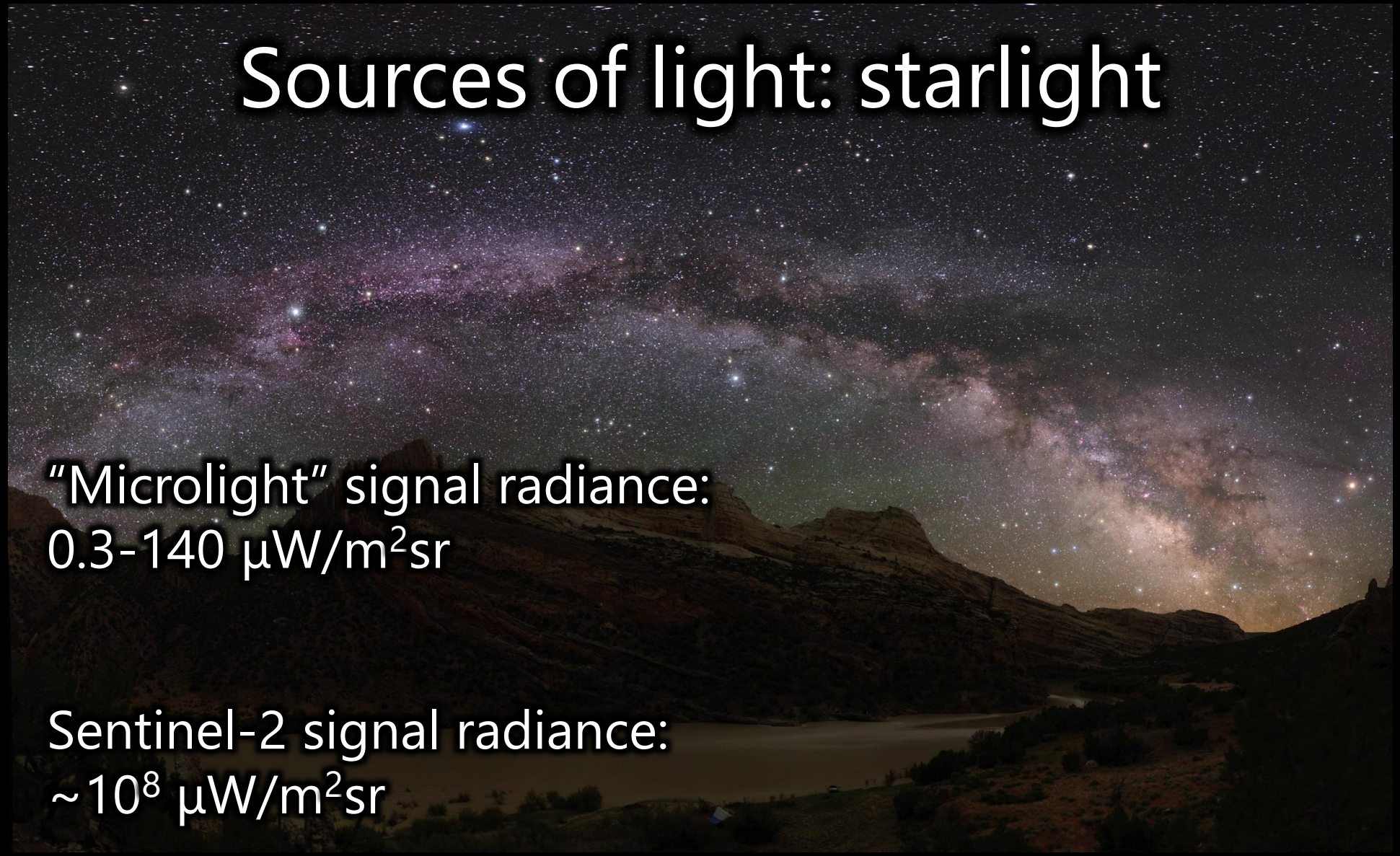
Visible band light at night?

NASA MESSENGER, August 2, 2005

Sources of light: starlight



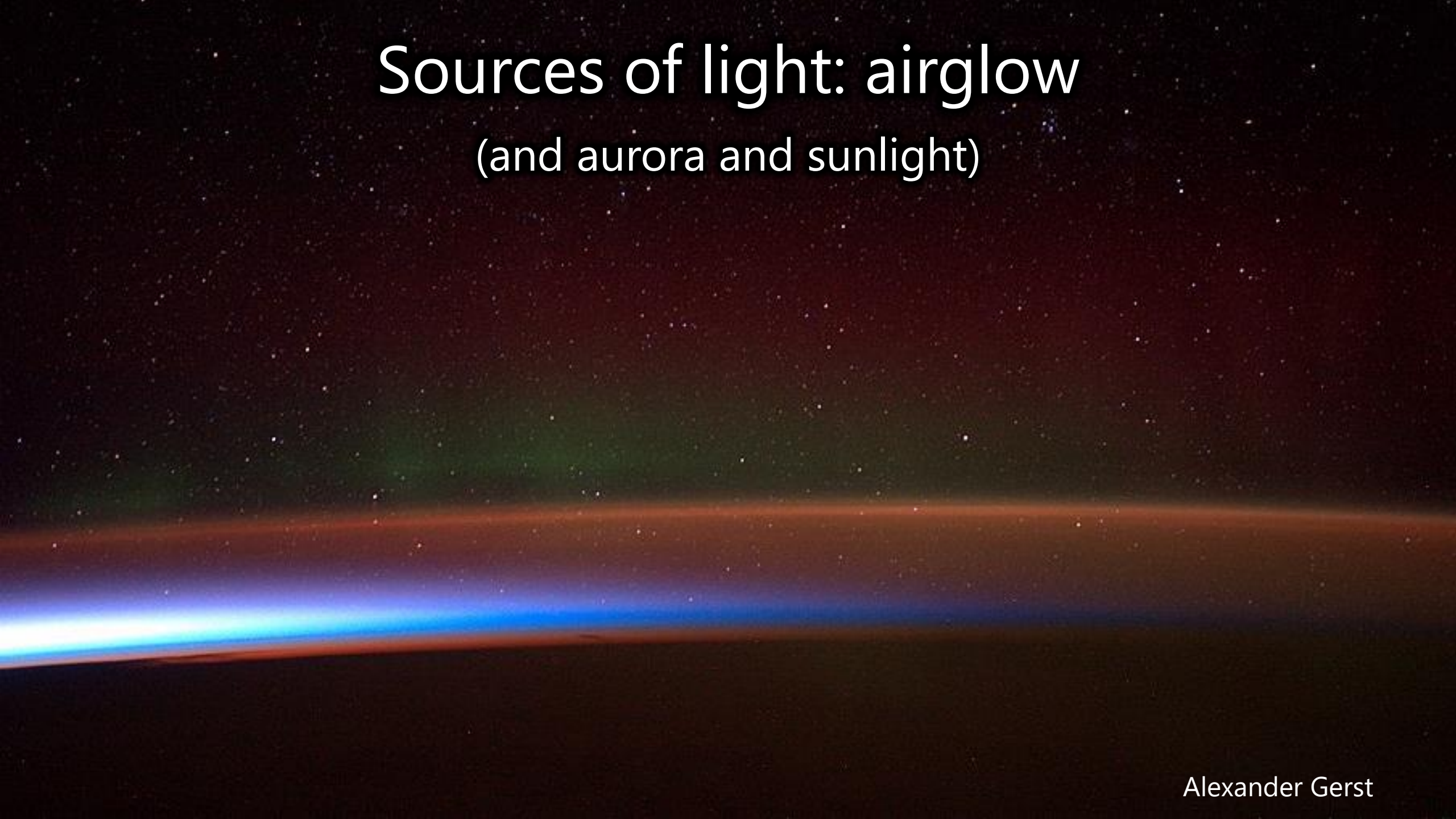
"Microlight" signal radiance:
0.3-140 $\mu W/m^2sr$

Sentinel-2 signal radiance:
~10^8 $\mu W/m^2sr$

Dinosaur National Park
Dan Duriscoe
US NPS

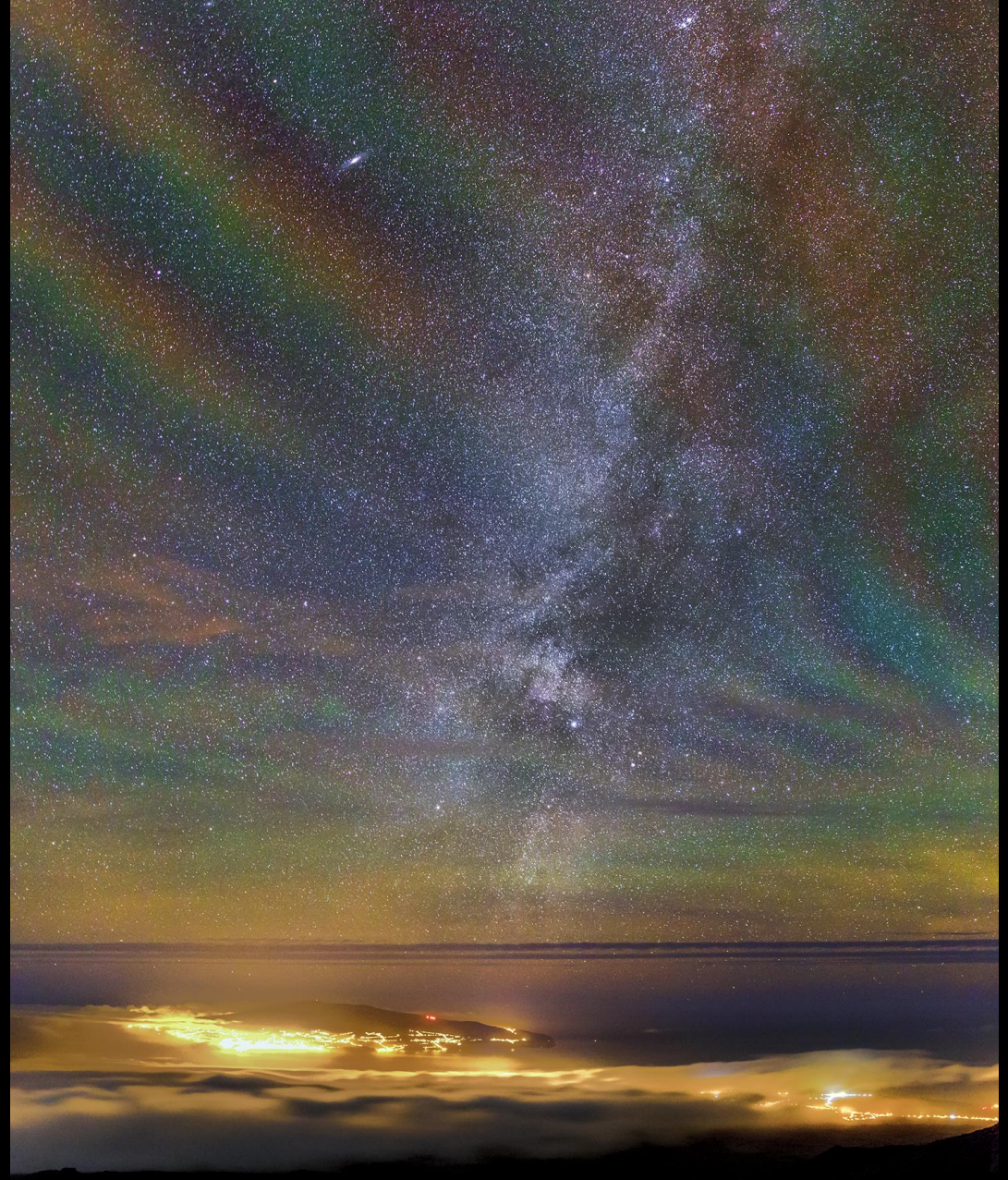
Sources of light: airglow

(and aurora and sunlight)



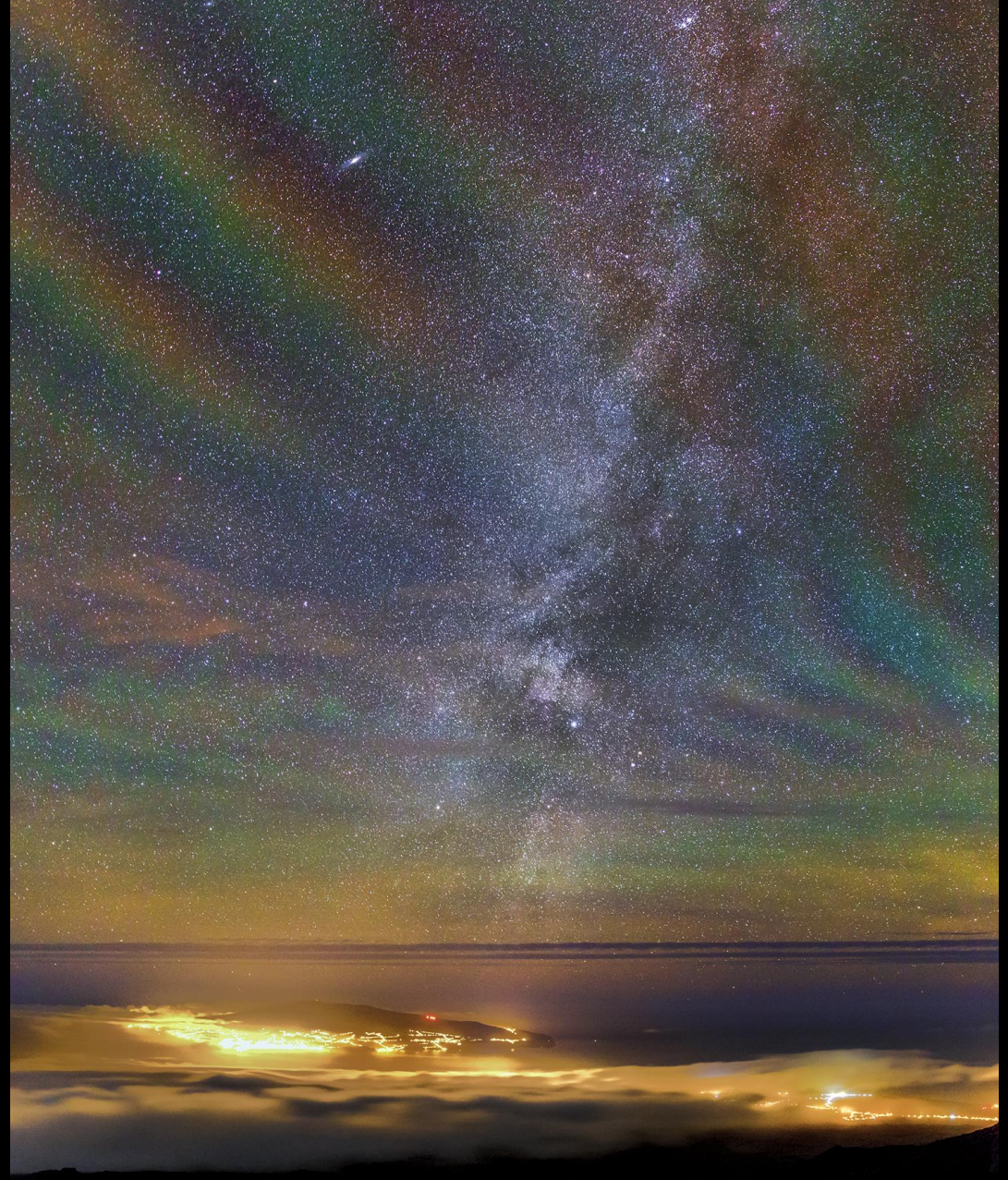
Alexander Gerst

Gravity waves



@miguel_claro

https://www.miguelclaro.com/wp/portfolio/rainbow-bands-of-airglow-in-gravity-waves-above-pico-island/

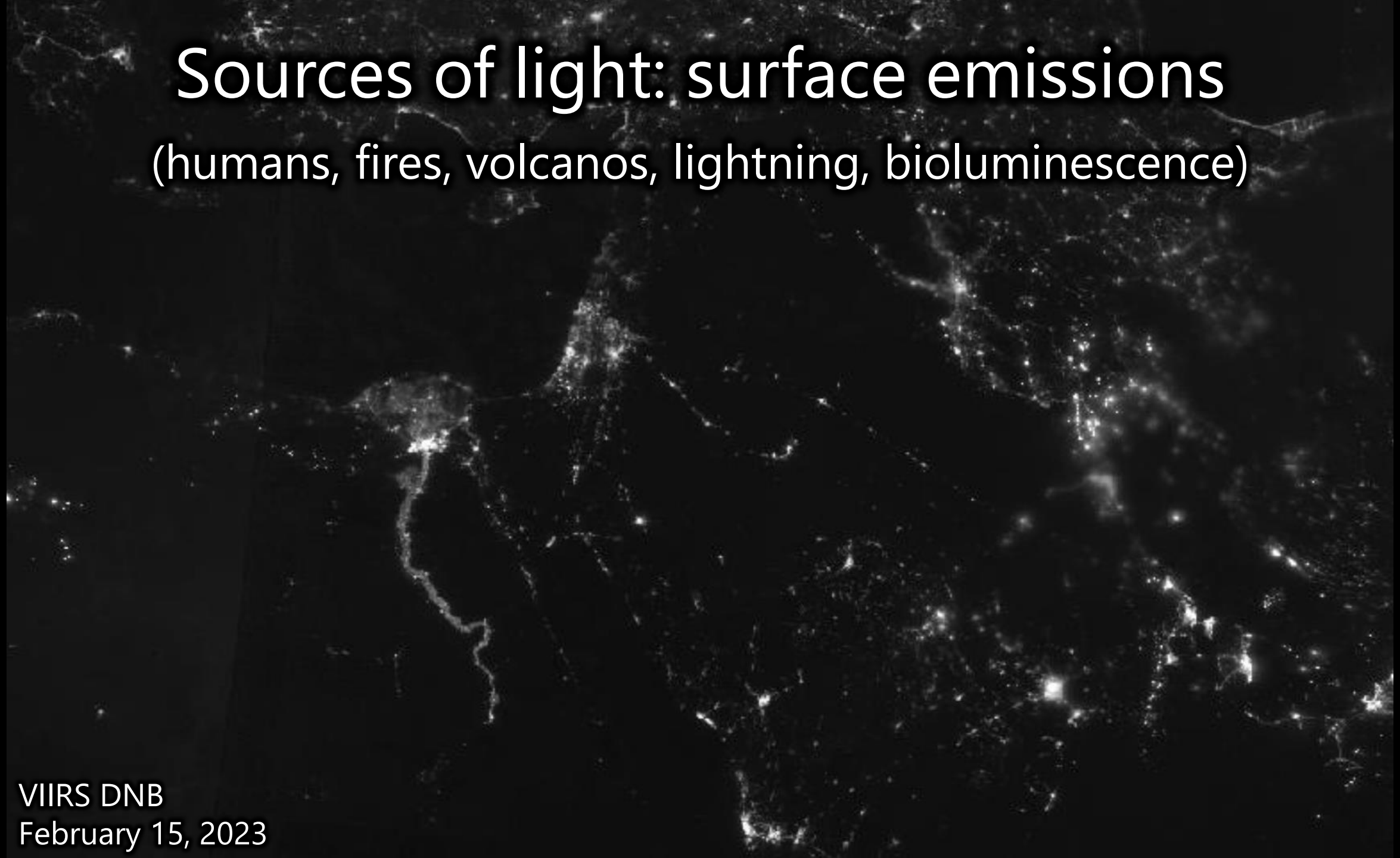


@miguel_claro

https://www.miguelclaro.com/wp/portfolio/rainbow-bands-of-airglow-in-gravity-waves-above-pico-island/

Sources of light: surface emissions

(humans, fires, volcanos, lightning, bioluminescence)



VIIRS DNB
February 15, 2023

Aotearoa (New Zealand) by starlight and airglow

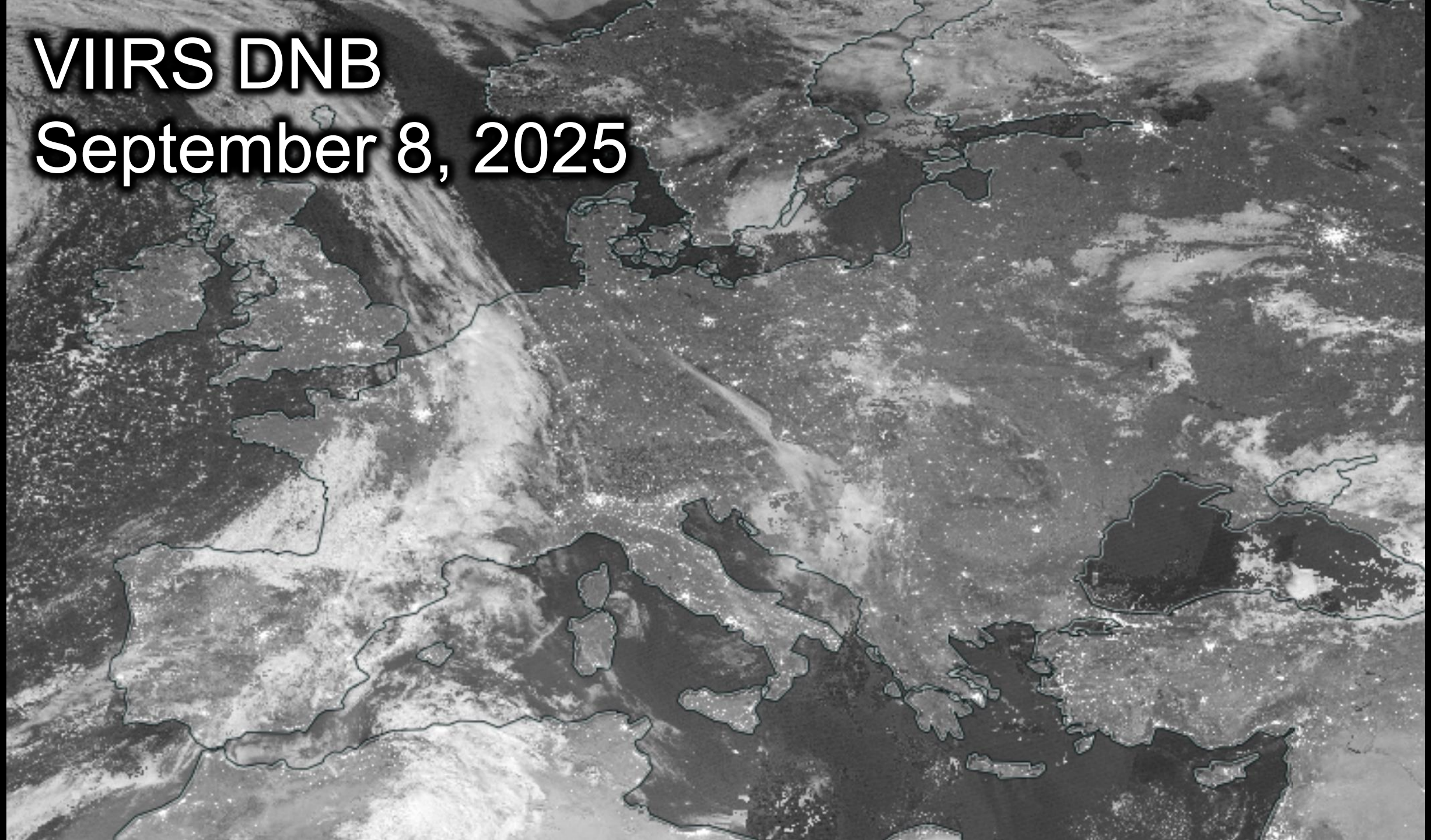
7 years cloud-free, moon-free data
From VIIRS DNB

Equivalent exposure ~ 1s
Processing by Helga Kuechly

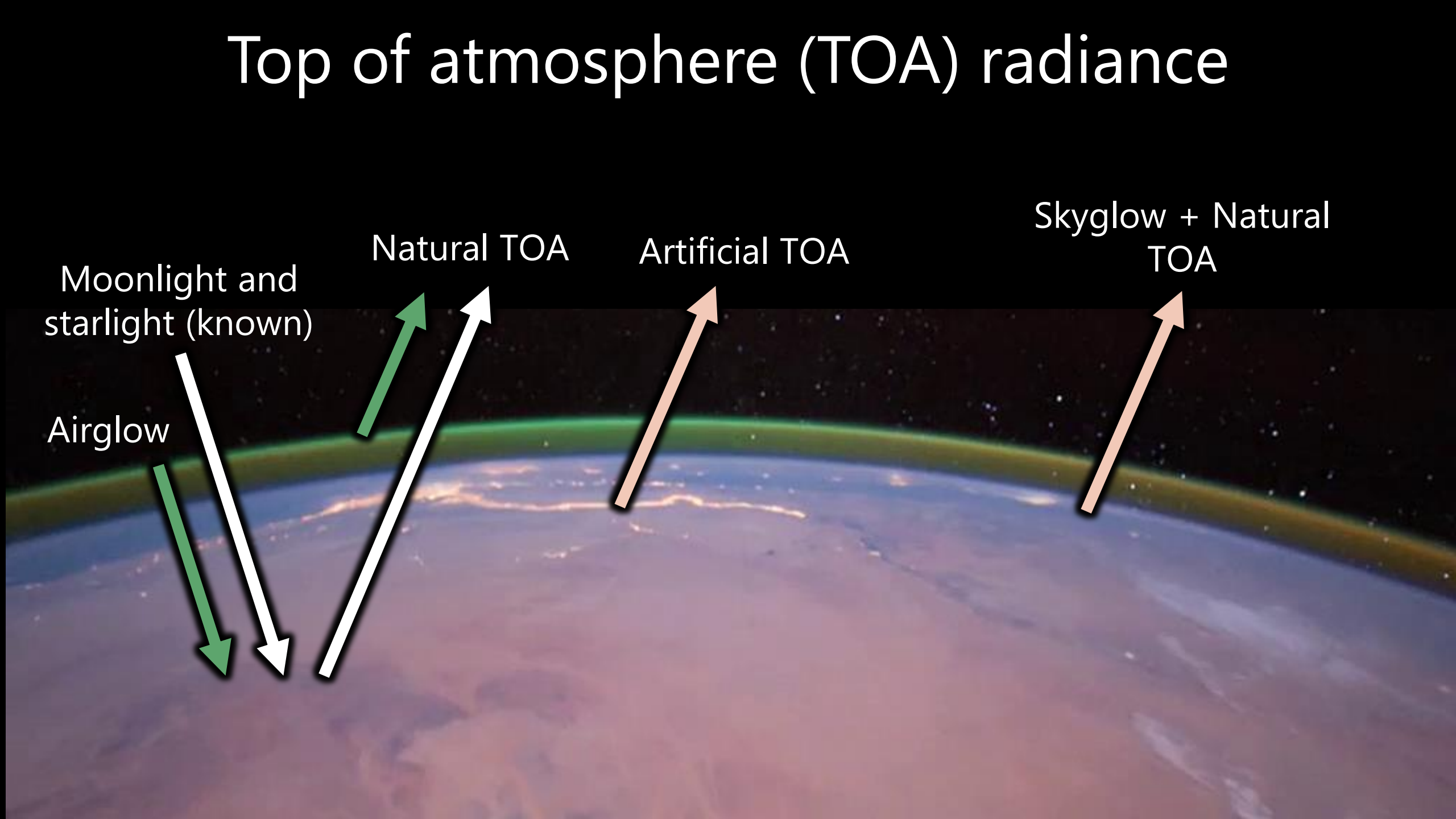
Sources of light: moonlight

Bettymaya Foott
Darksky International

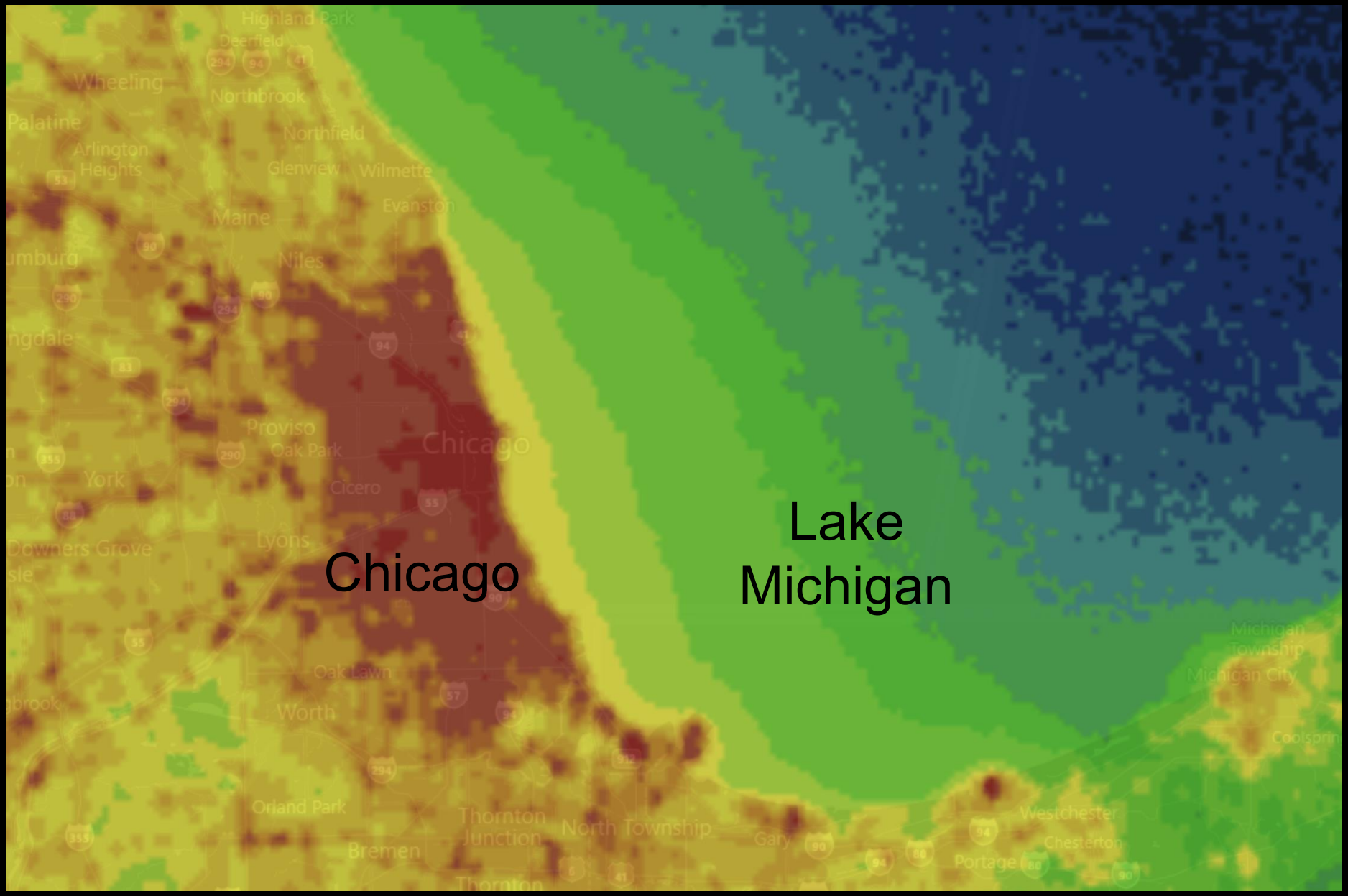

VIIRS DNB
September 27, 2025


VIIRS DNB
September 8, 2025

Top of atmosphere (TOA) radiance



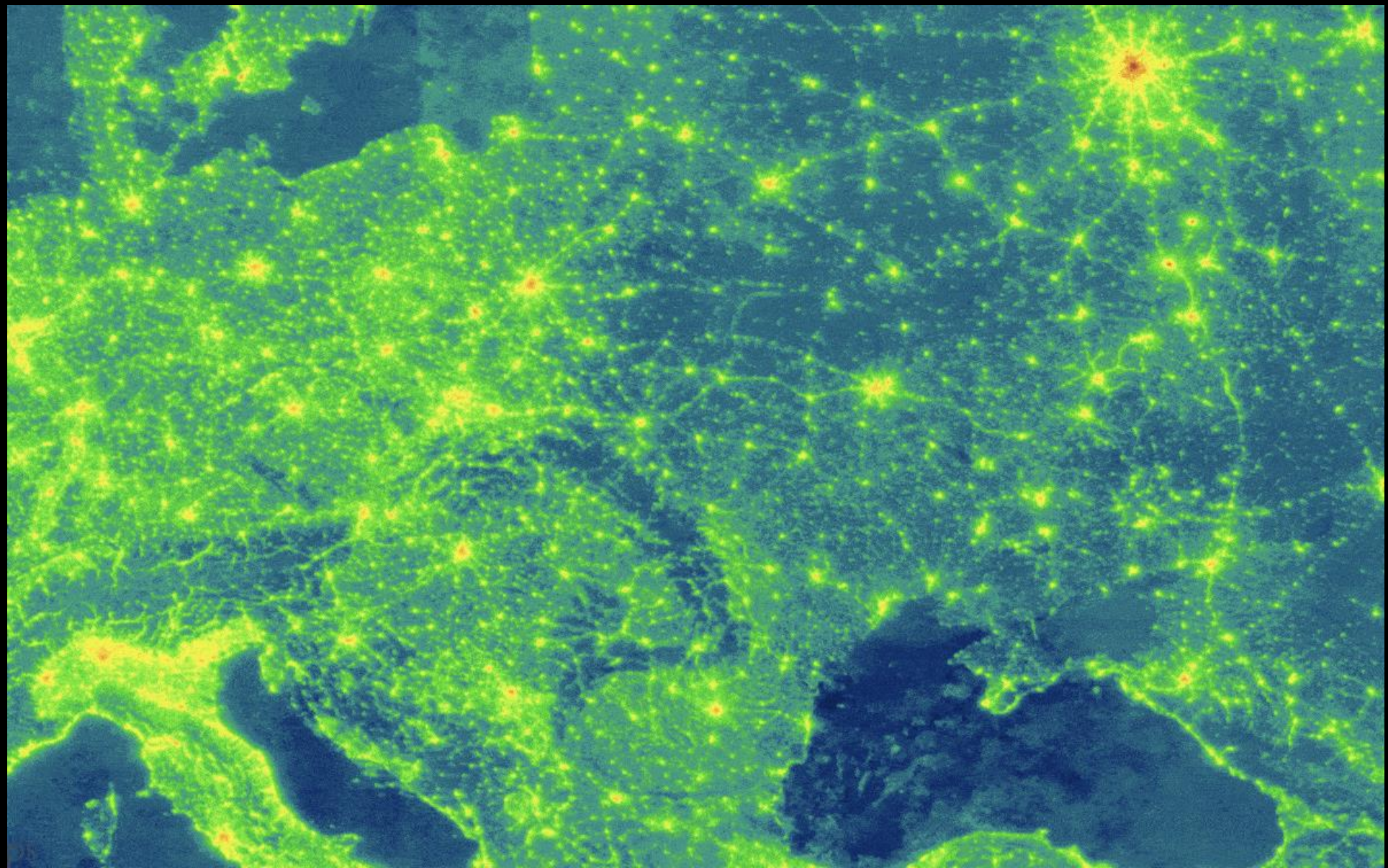
Skyglow



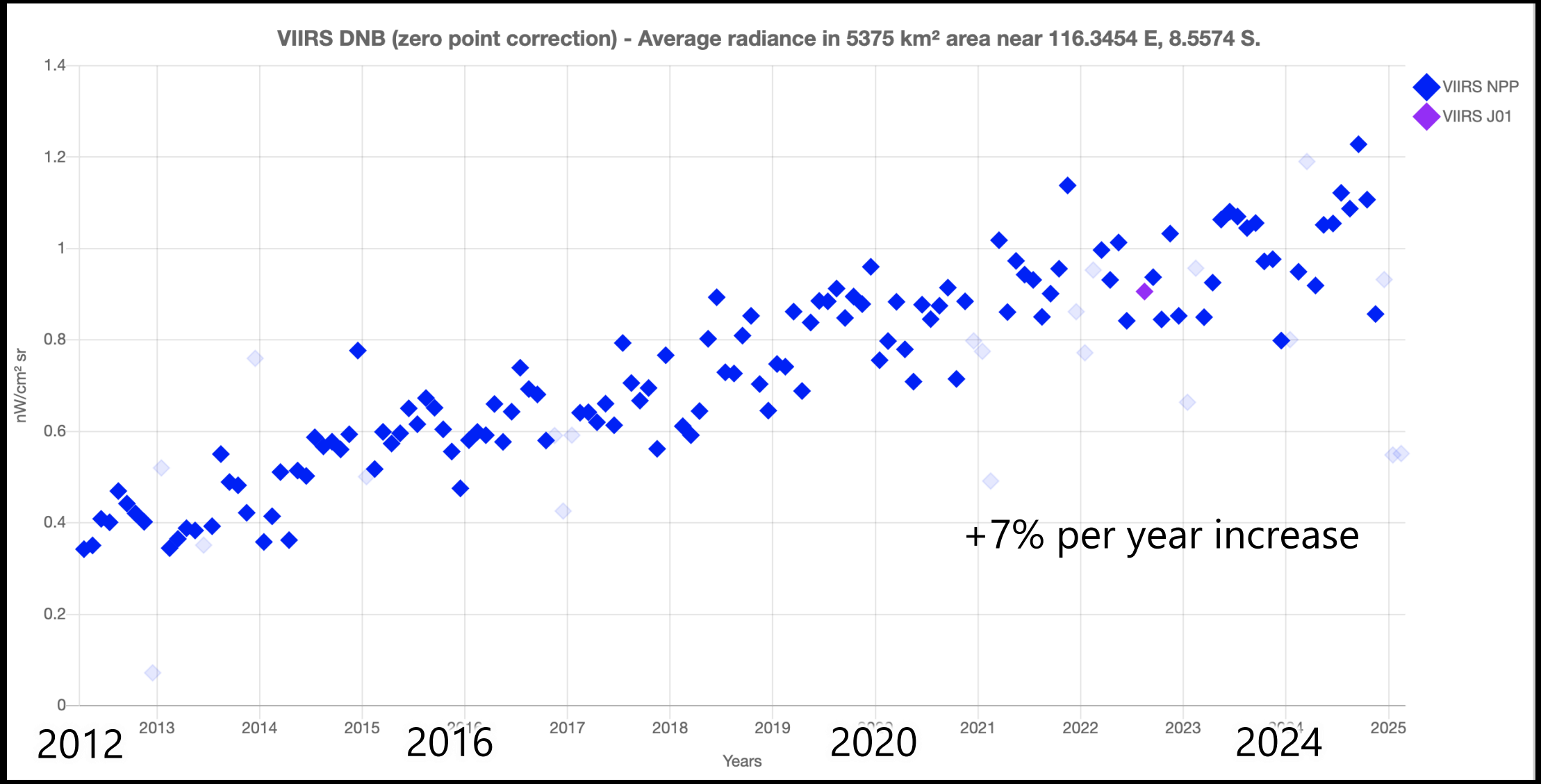
Current missions

- VIIRS DNB:
  - Daily view of most of Earth
  - Poor resolution, no spectral information, terrible radiometric stability
- SDGSAT-1:
  - Resolution 10m (pan), 40m (RGB)
  - Issues with access/rights/information
  - Sensitivity too low for atmospheric applications

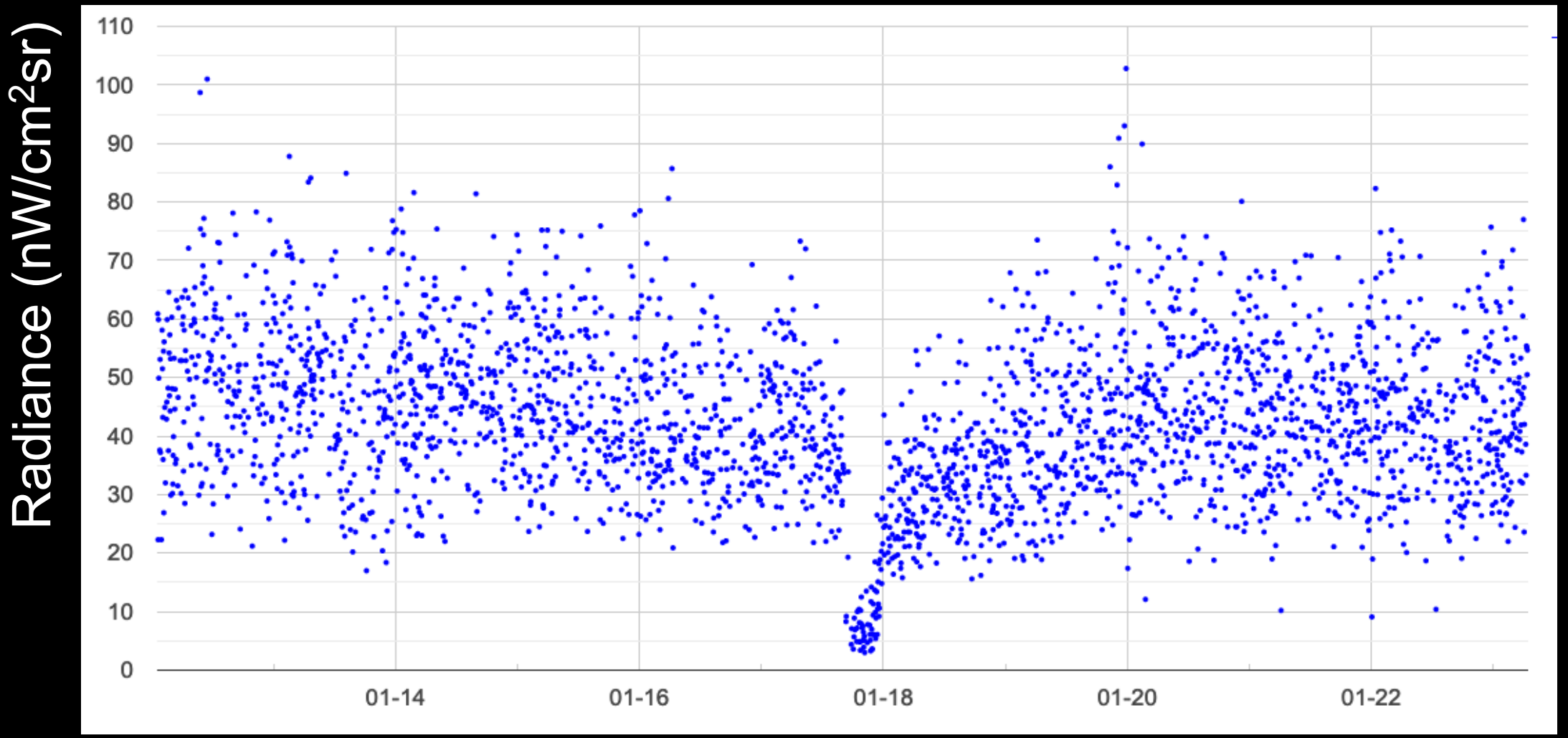
October 2021 – October 2022 (DNB)



Lombok, Indonesia (DNB)



Radiance for single DNB pixel
San Juan, Puerto Rico



Observation angle & radiometric stability

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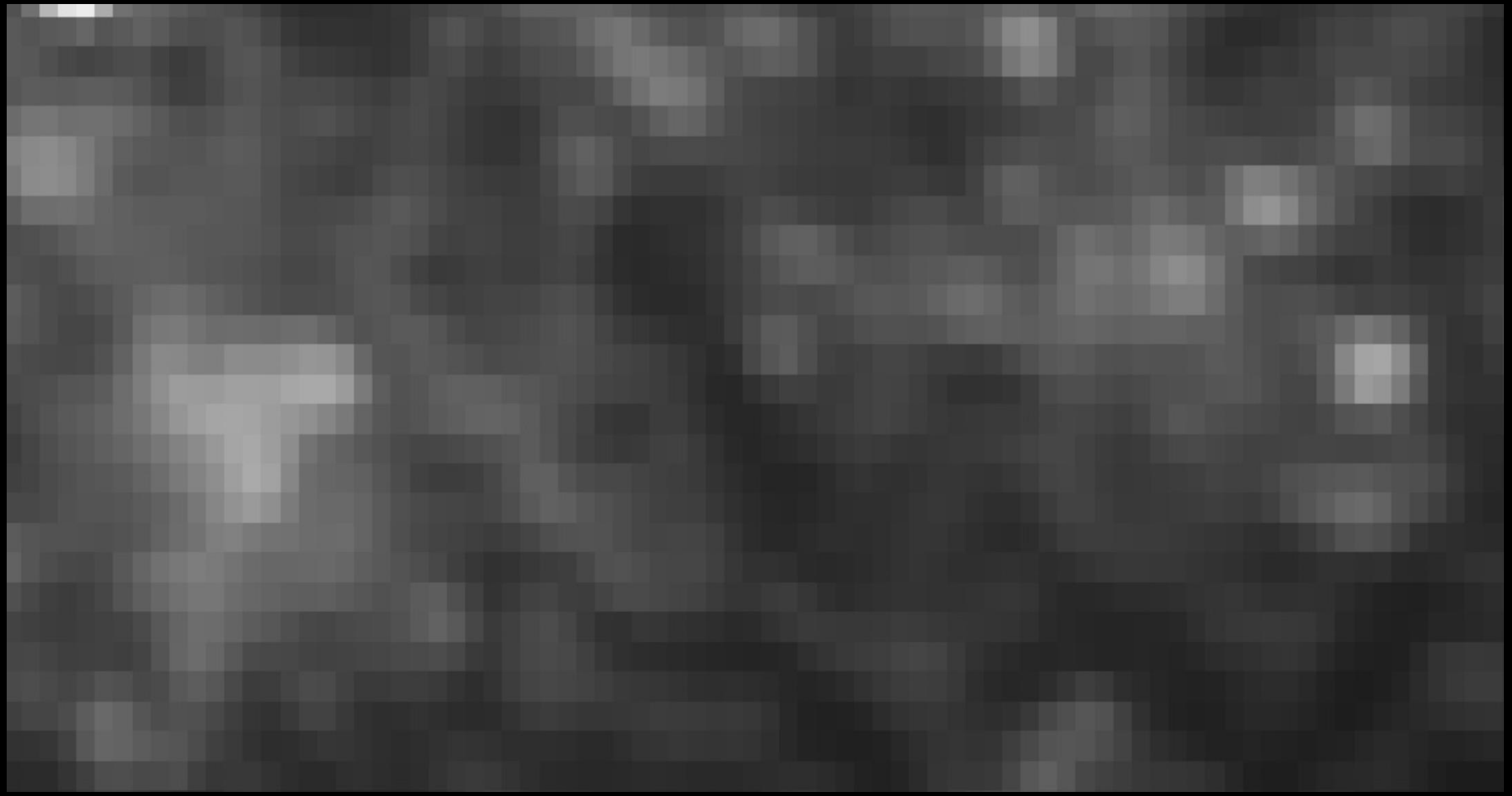
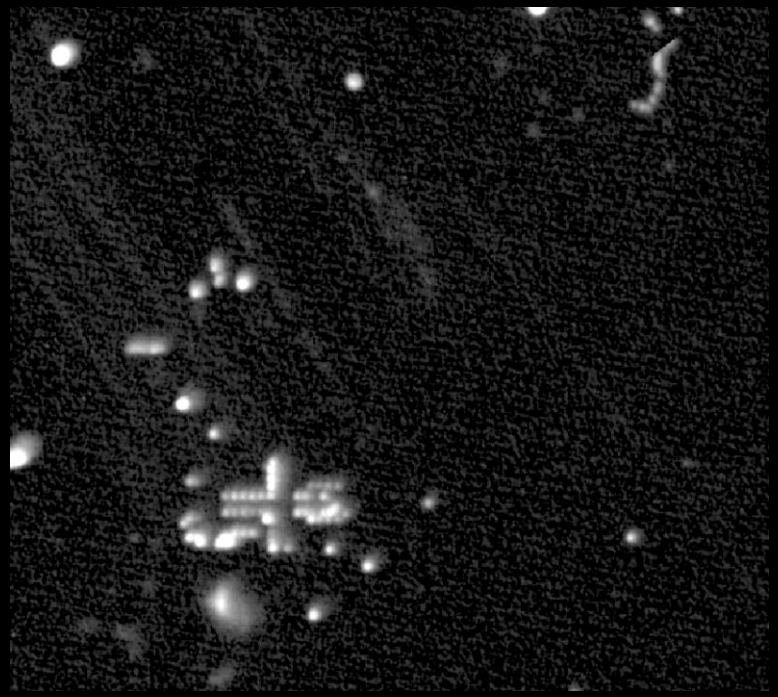
Essen & Bochum – VIIRS DNB



Essen & Bochum – SDGSat 1

Spectral information

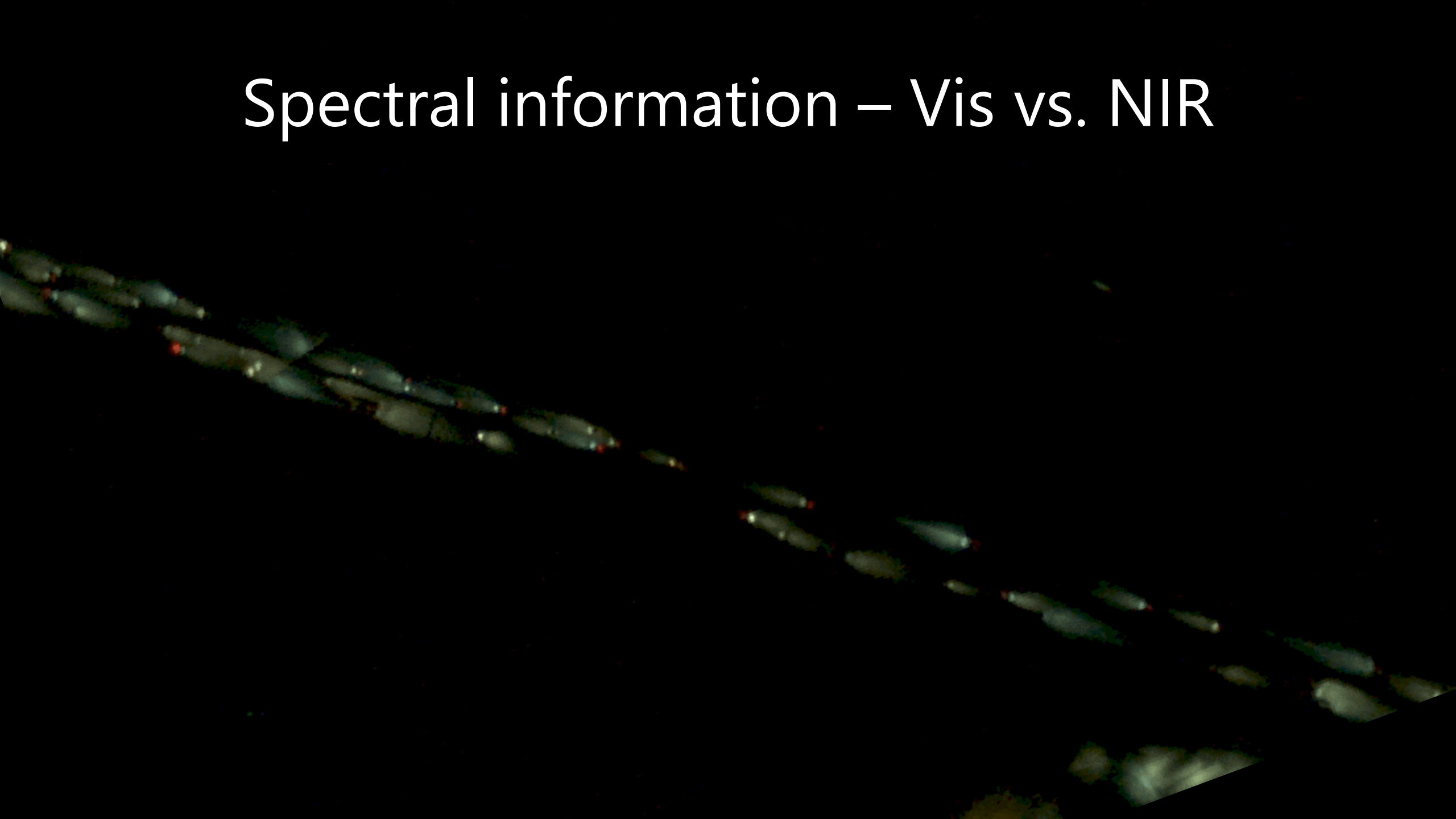
UV



Visible (RGB)

NIR

Spectral information – Vis vs. NIR




Köln – SDGSat 1

Köln – Aerial photos

EULE – European Urban Light Explorer

Earth Explorer 12
Proposal

EULE
Scientific Objectives & Aims

- Assessing electricity access & stability
- Measurement of the (physical) power of artificial light in the atmosphere

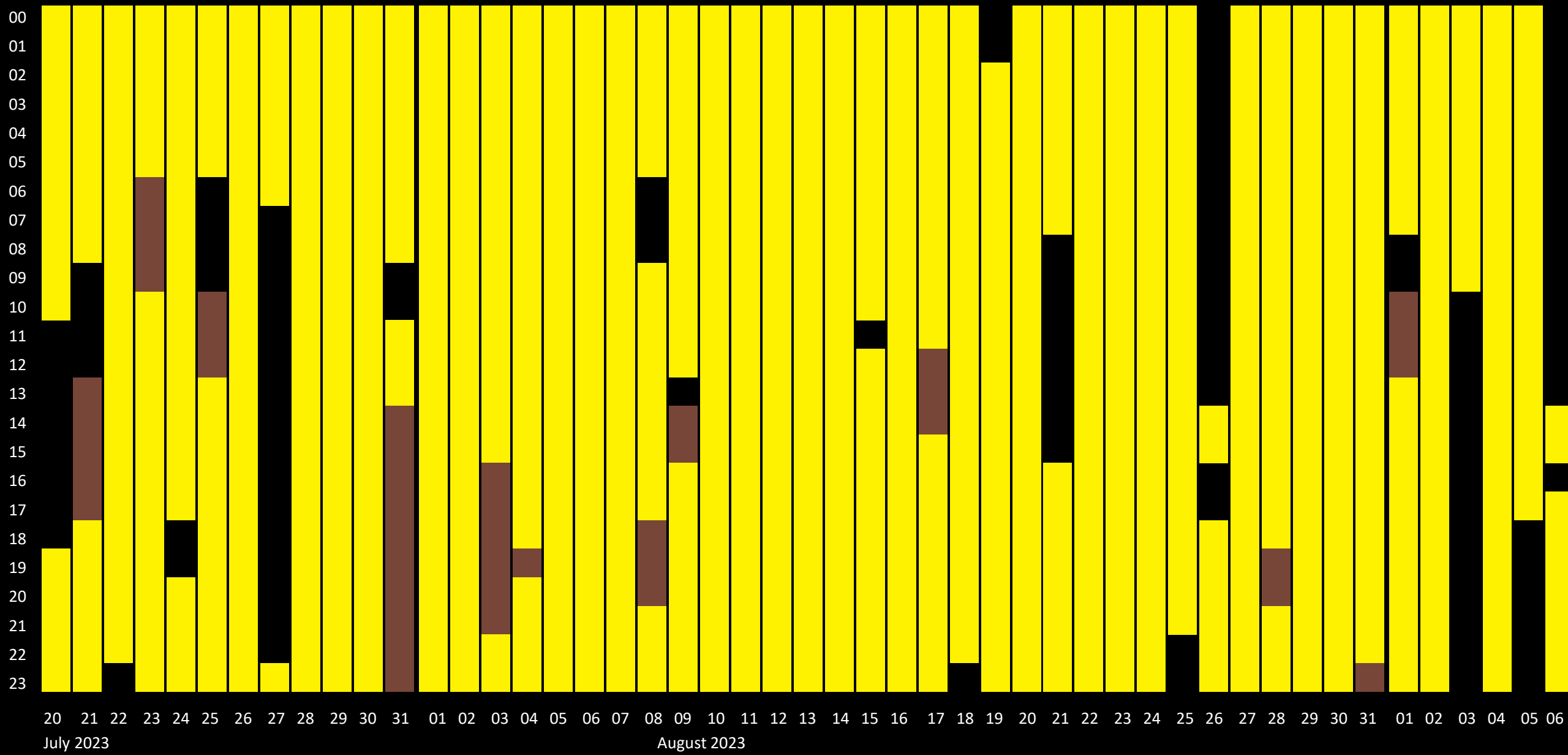
Observations in 5+ spectral bands

- RGB+NIR (20 m) & Pan (10 m)
- High sensitivity (microlight) mode (200 m)

Kibera slum,
Nairobi, Kenya.

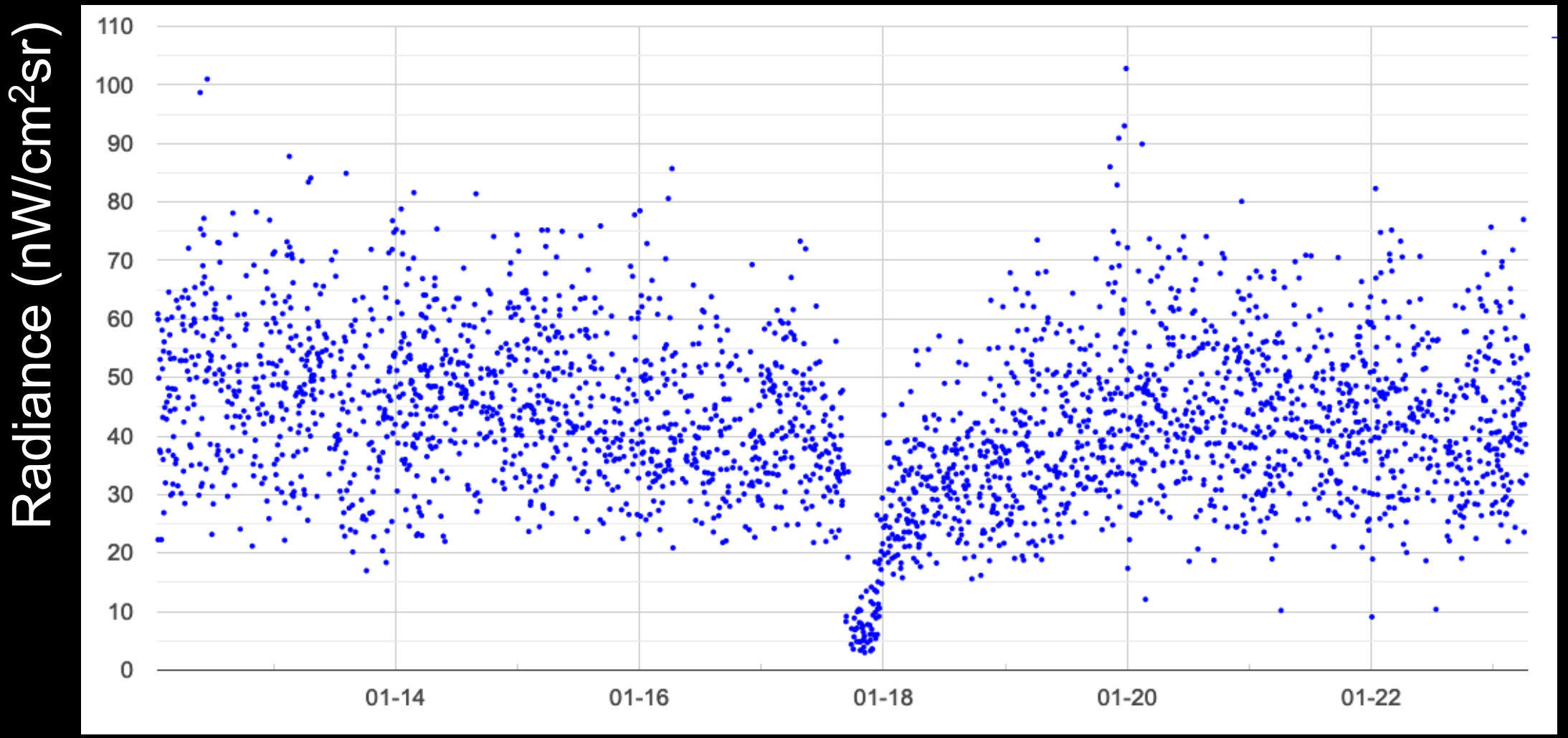
1 out of 2 days there is a power outage

Average duration of **3:15** hours/day without electricity

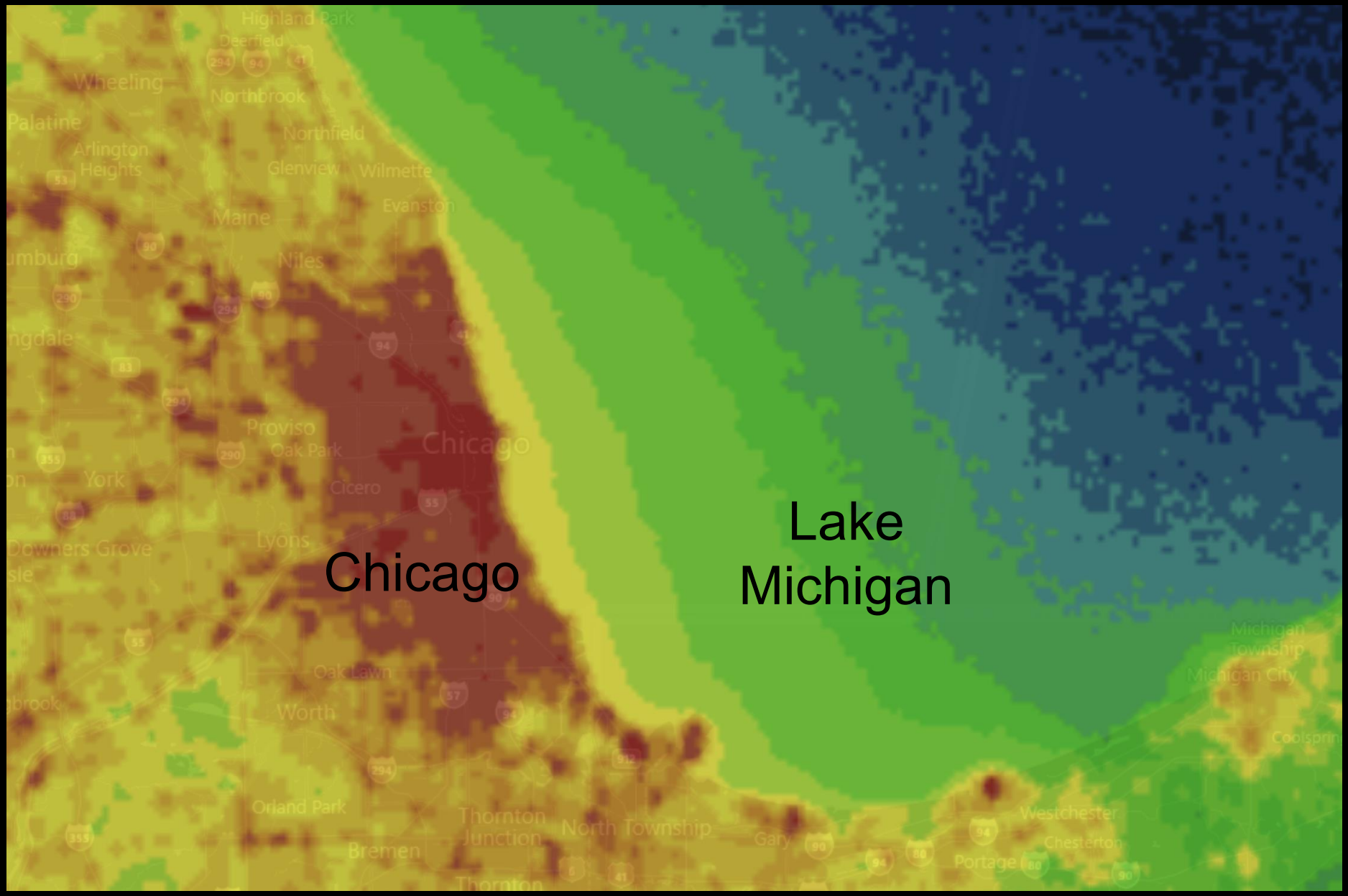


Lawrence Otieno Ouma

Radiance for single DNB pixel
San Juan, Puerto Rico



Skyglow



Skyglow

Andreas Jechow

Rate of change in light emissions

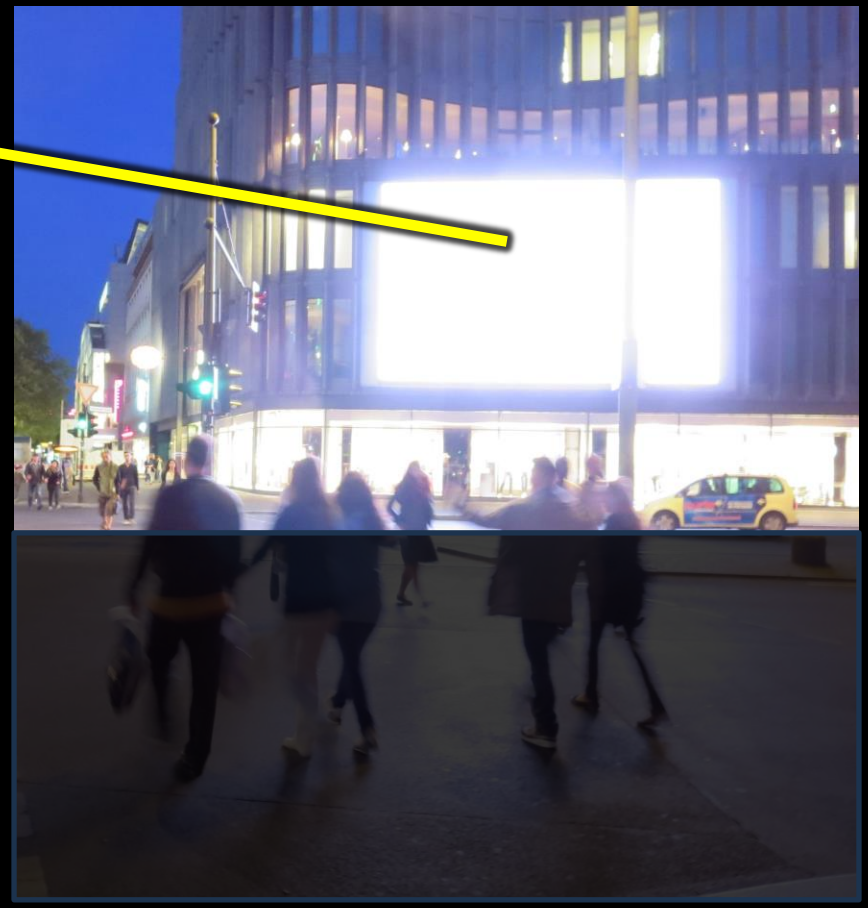
Looking down:
+2% / year

Kyba et al. Science Advances (2017)
Sanchez de Miguel et al. Remote Sens. (2021)

Looking up:
+7% to +10% / year

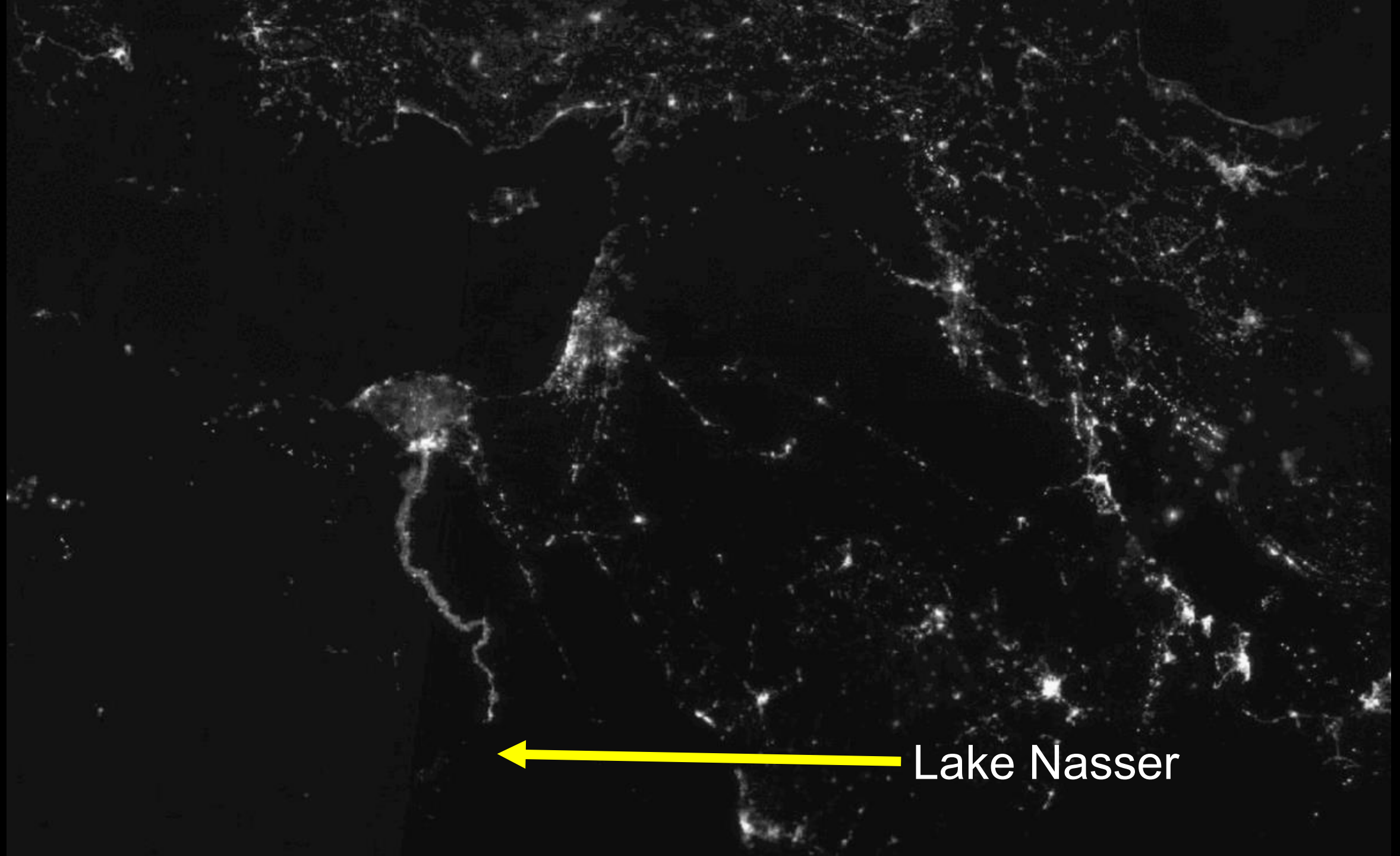
Kyba et al. Science (2023)

Remote sensing of horizontal emissions



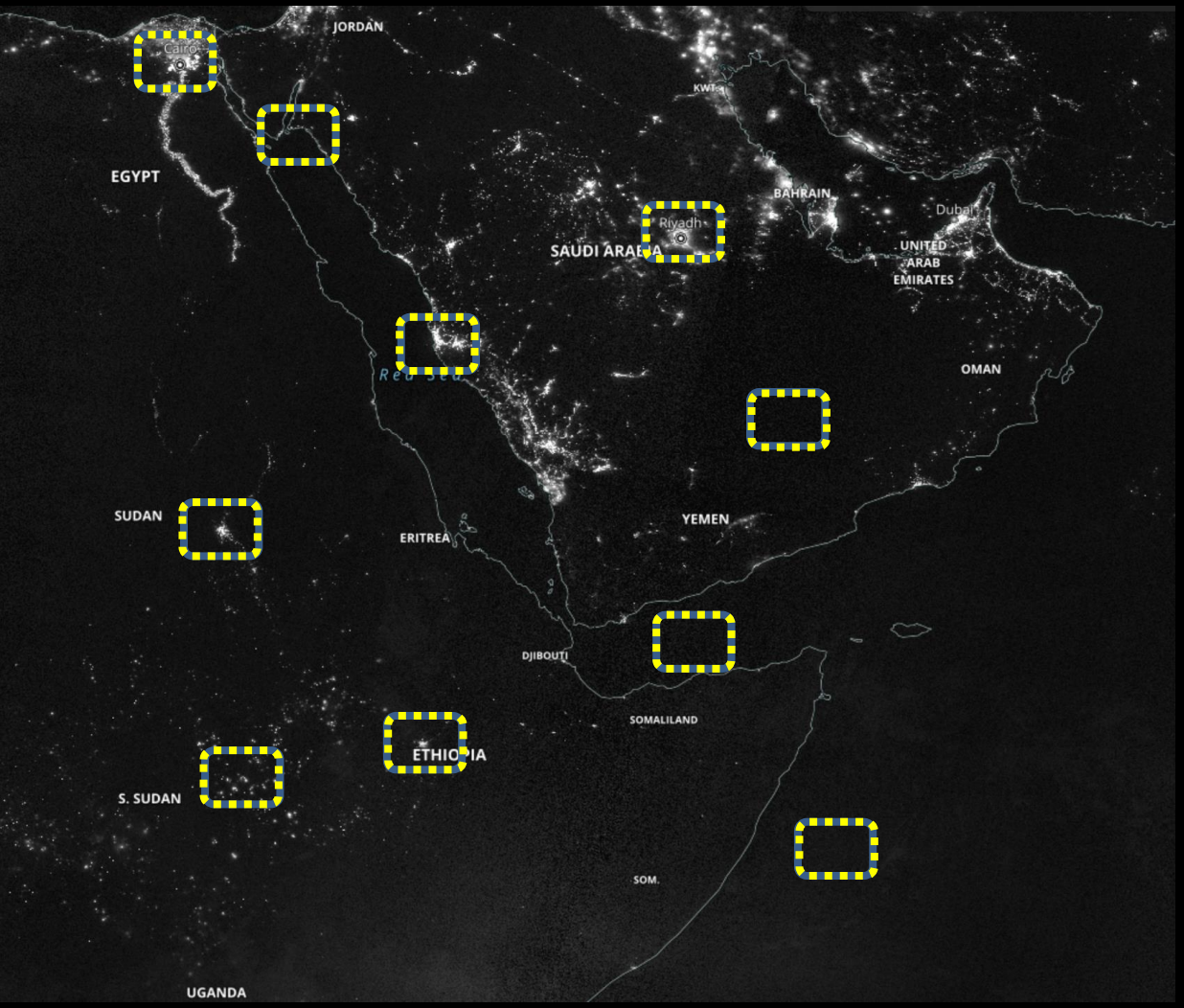
Extremely large dynamic range


February 15, 2023

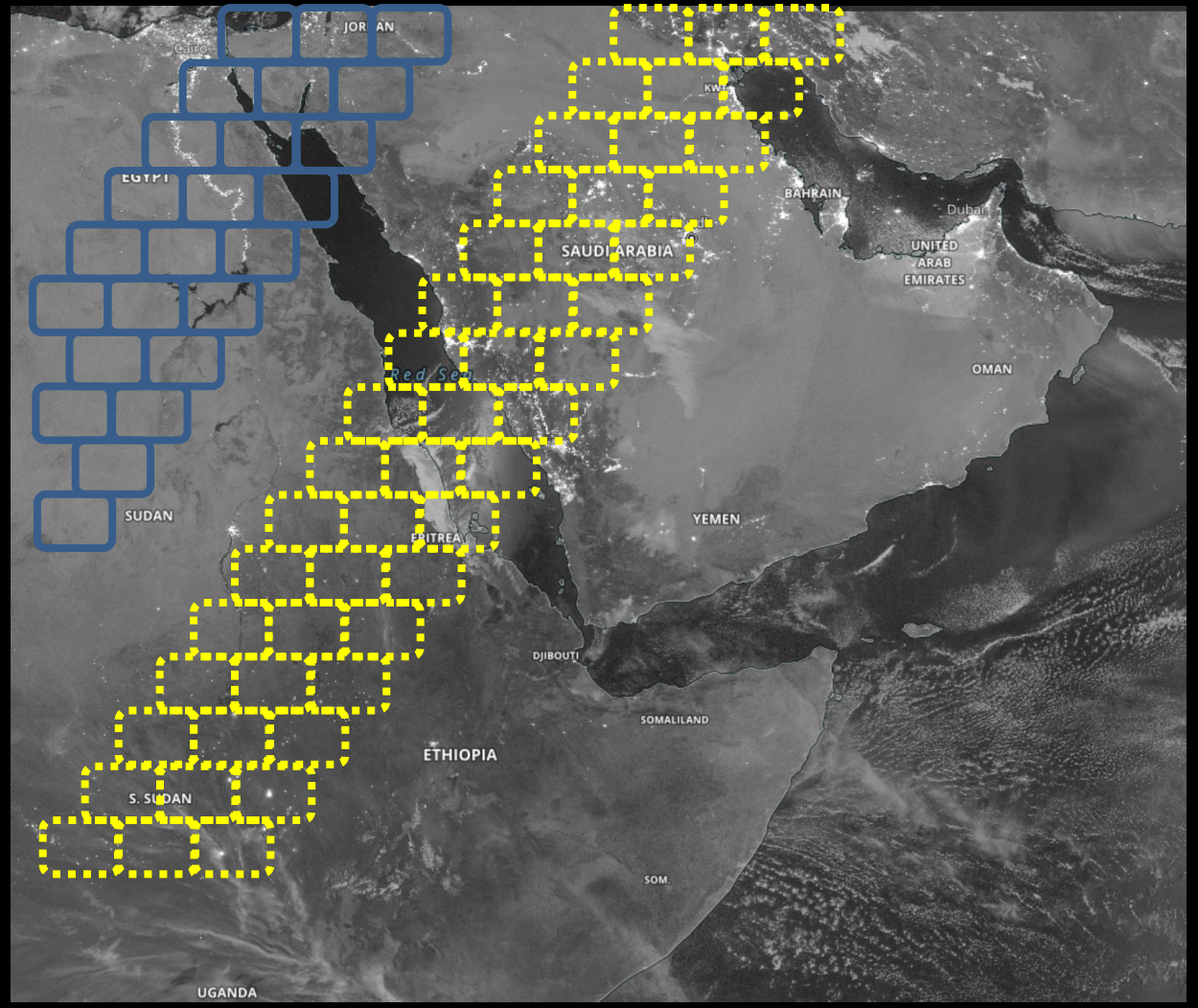

Lake Nasser

Variable operation mode

(conceptual diagram)

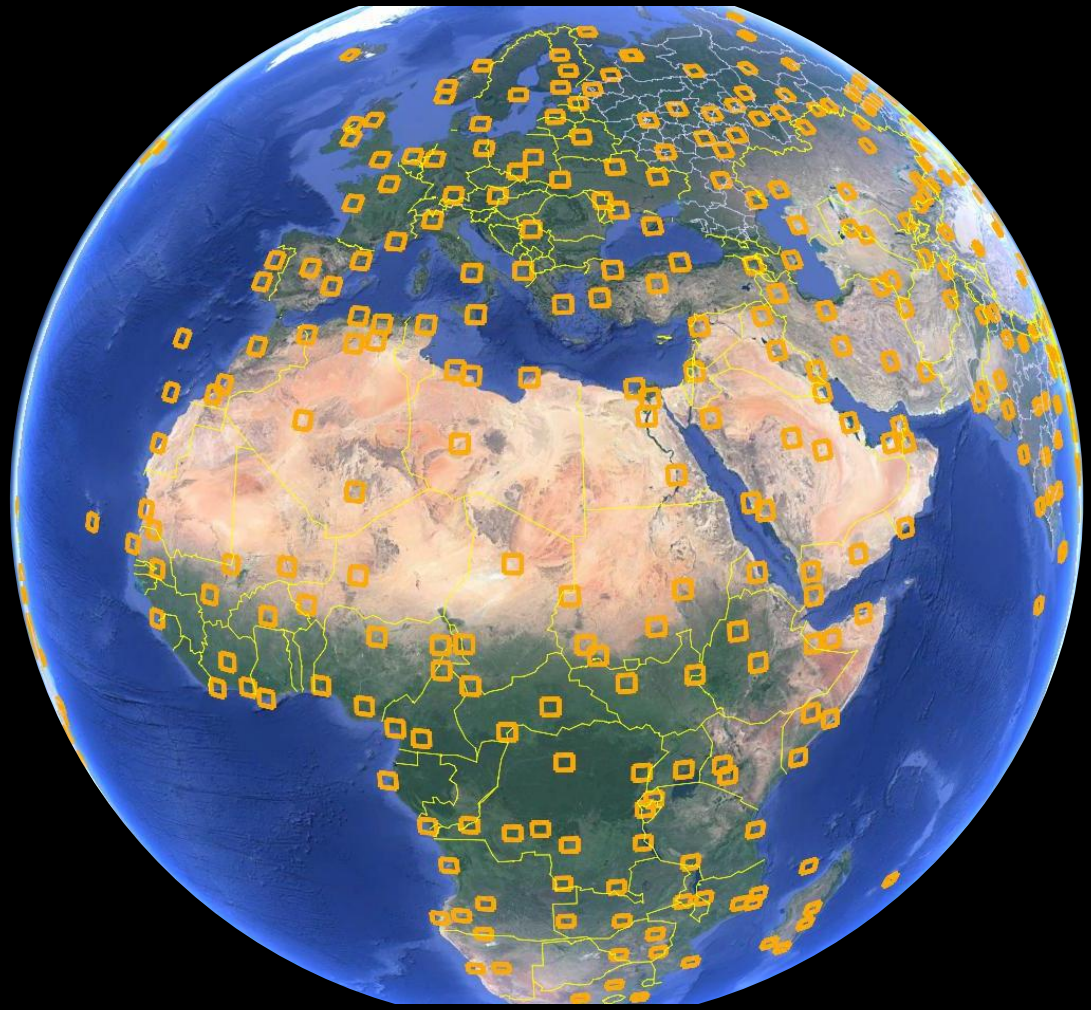


Moon free nights



Moonlit nights

Example mask during moon-free period



Tobias Storch

Some of the possible application areas

- Socioeconomic studies
  - Population
  - GDP
  - Material flows
  - Resource extraction / use
- Impervious surface / city boundary assessment
- Ecology & Health
- Atmospheric science & light pollution
- Earth surface properties

The world’s first microlight explorer

V3N0M V1V14N CC-SA 4.0

Catalano82 CC 2.0

What’s next?

Earth Explorer 13
Proposal

Nighttime Light Remote Sensing Webinar

- **October 6, 16:00**

  A geospatial perspective on electrification strategy in urbanizing Africa

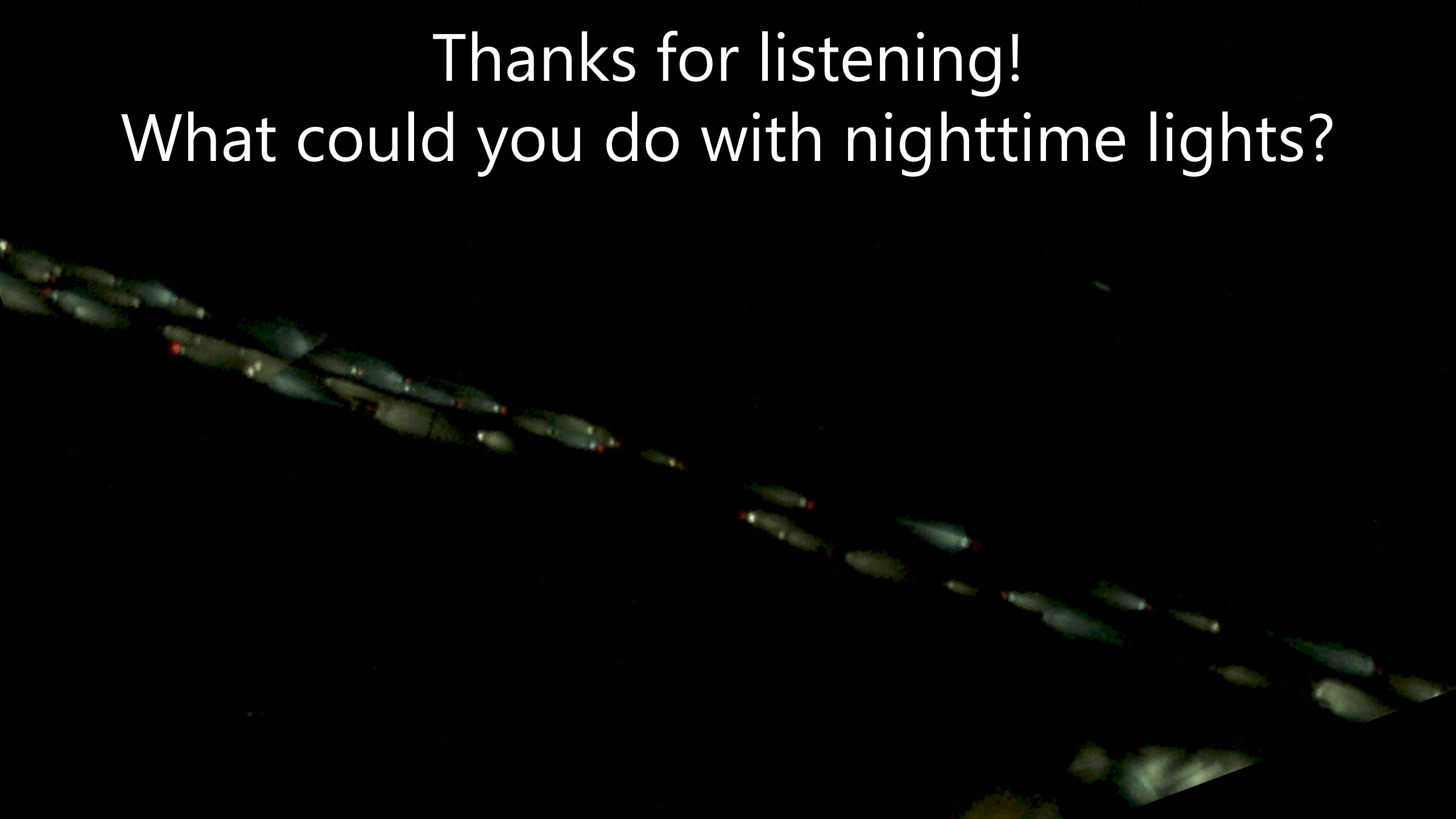
  Presented by Jessica Kersey (UC Berkeley), Sam Miles (Johns Hopkins), Vivek Sakhrani (AtlasAI)

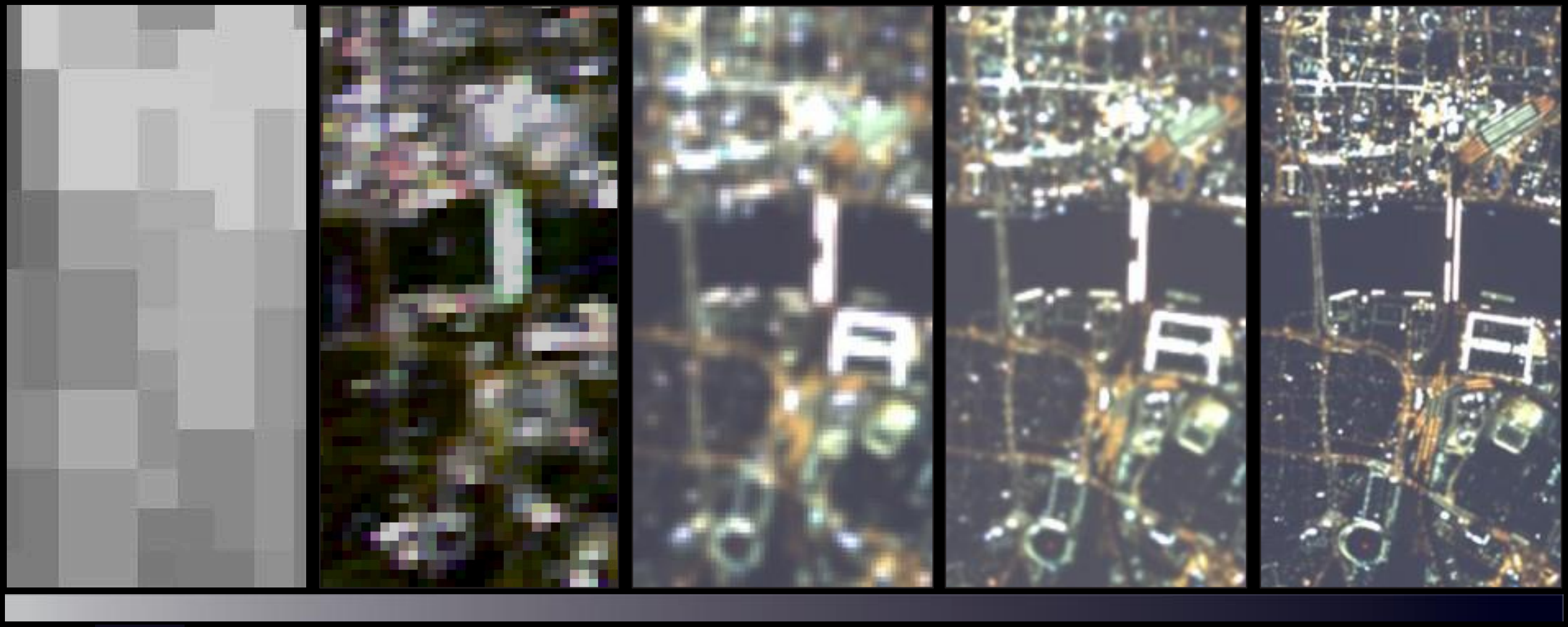
- **December 3, 10:00**

  Night lights from space: potential of SDGSAT-1 for ecological applications

  Presented by Dominique Weber (Swiss Federal Institute for Forest, Snow and Landscape Research WSL)

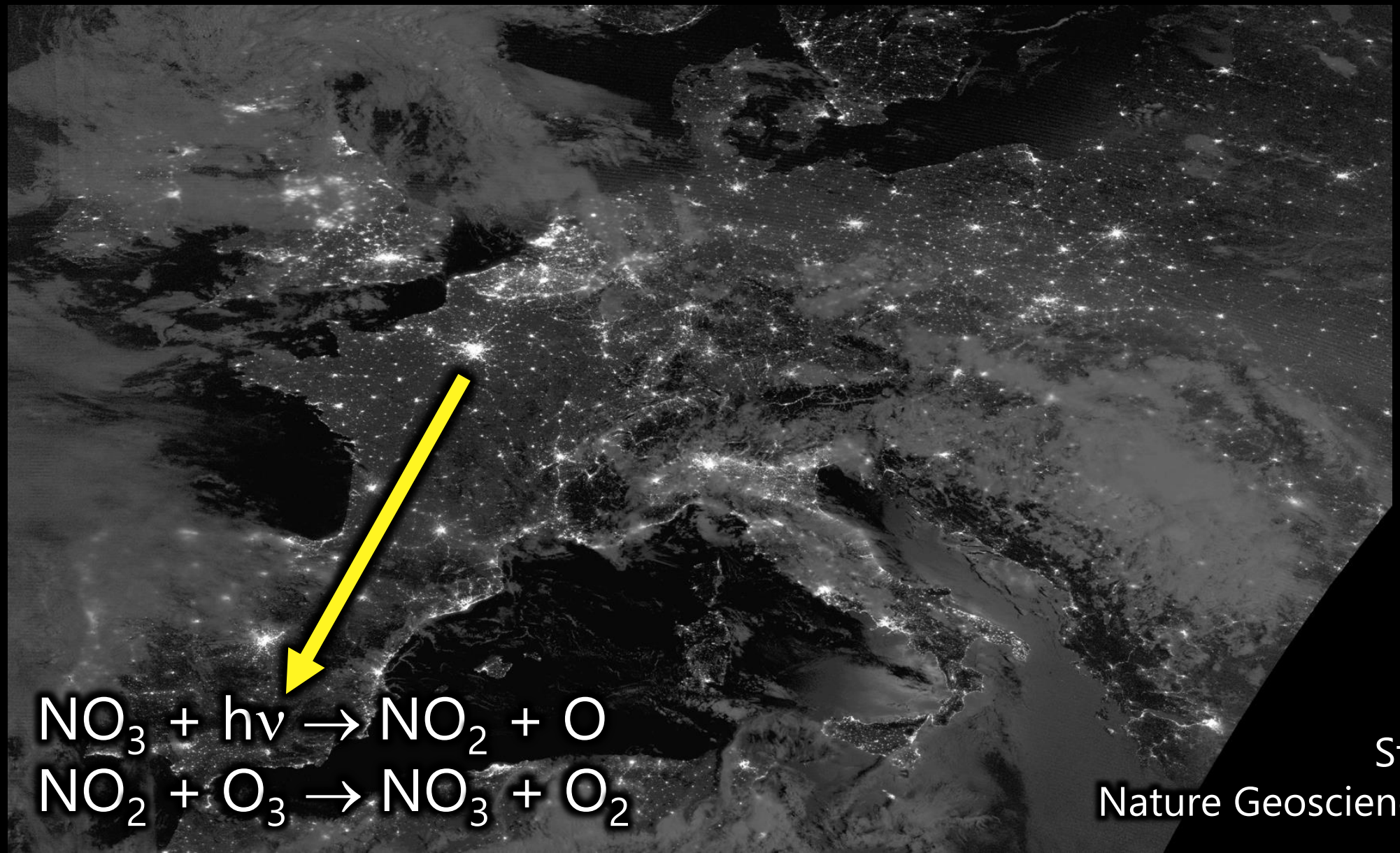
Thanks for listening!
What could you do with nighttime lights?




VIIRS DNB
(2022)
750 m
SDGSat-1
(2022)
40 m
20 m
Aerial observations
(2021)
10 m
5 m
0%
<5%
15%
25%
40%
“Dark” Fraction

Night Watch Team

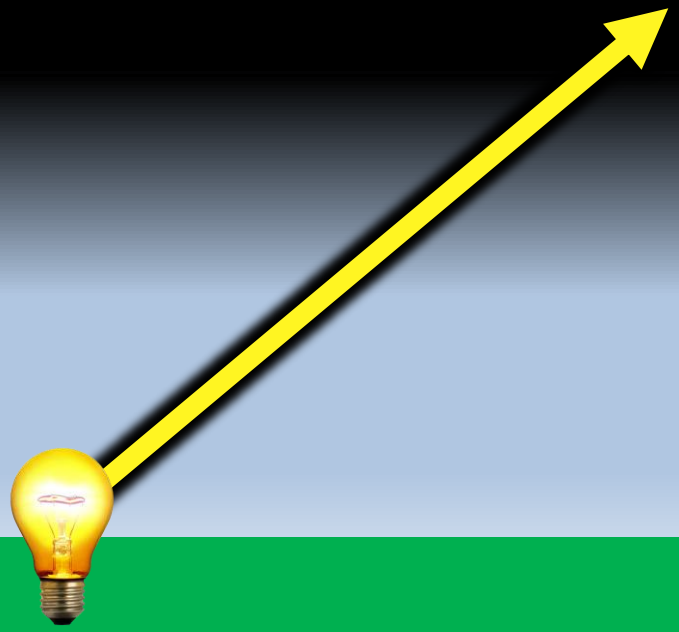
NO_x / air quality



Stark et al.
Nature Geoscience (2011)

Aerosol properties

- Observation of attenuation of direct beam from individual lights
- Observation of scattered light from areas without light sources



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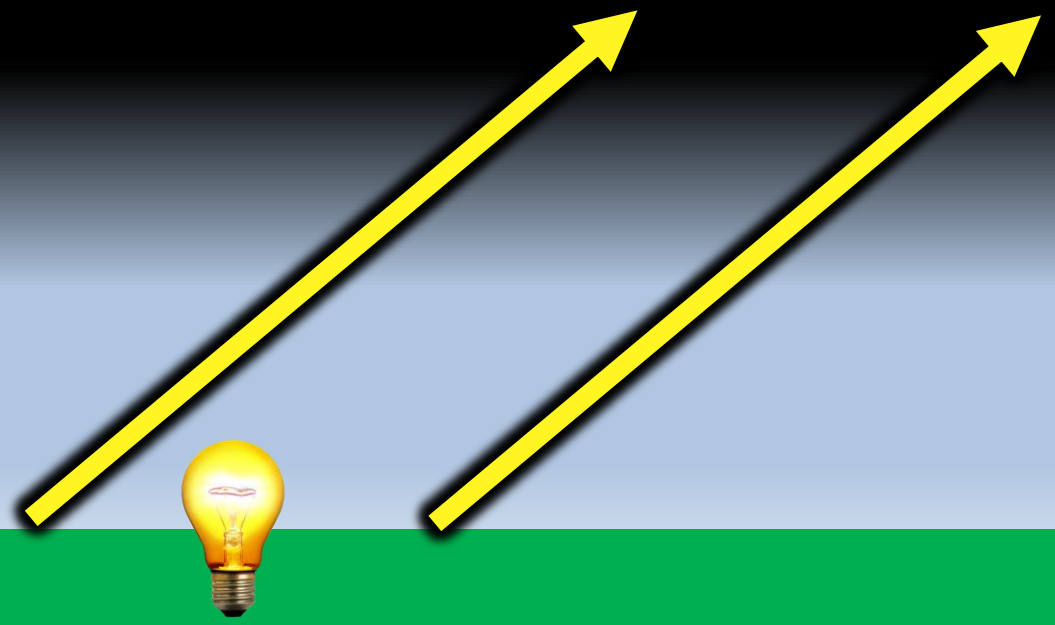


Aerosol properties

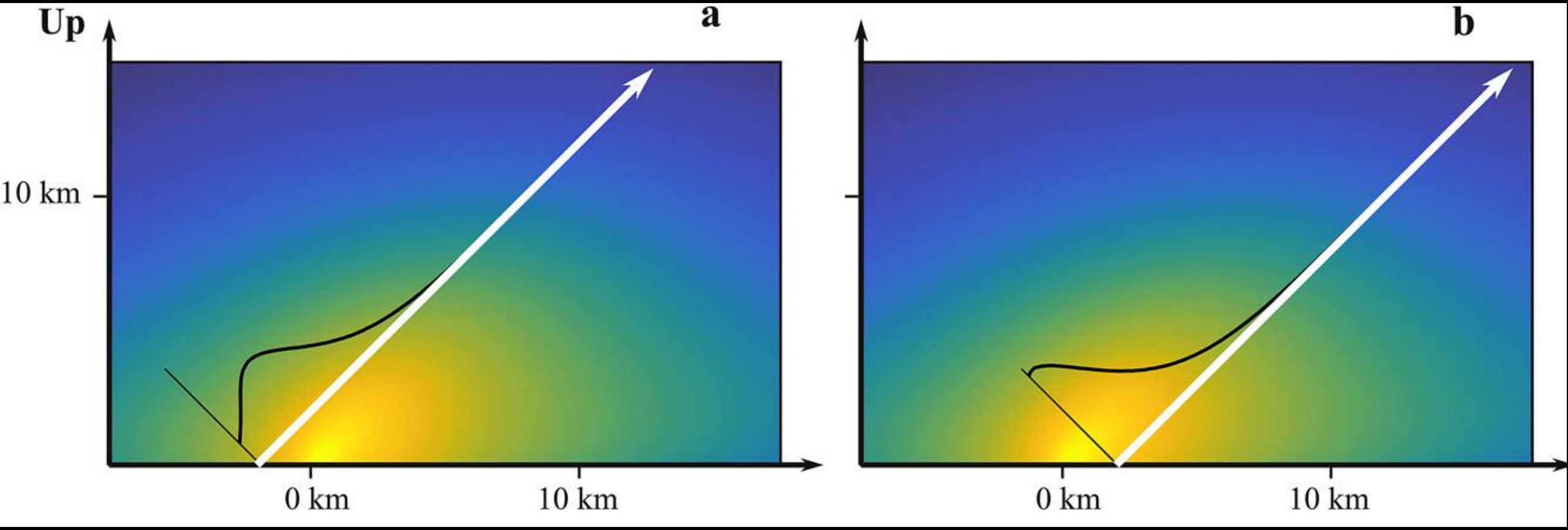
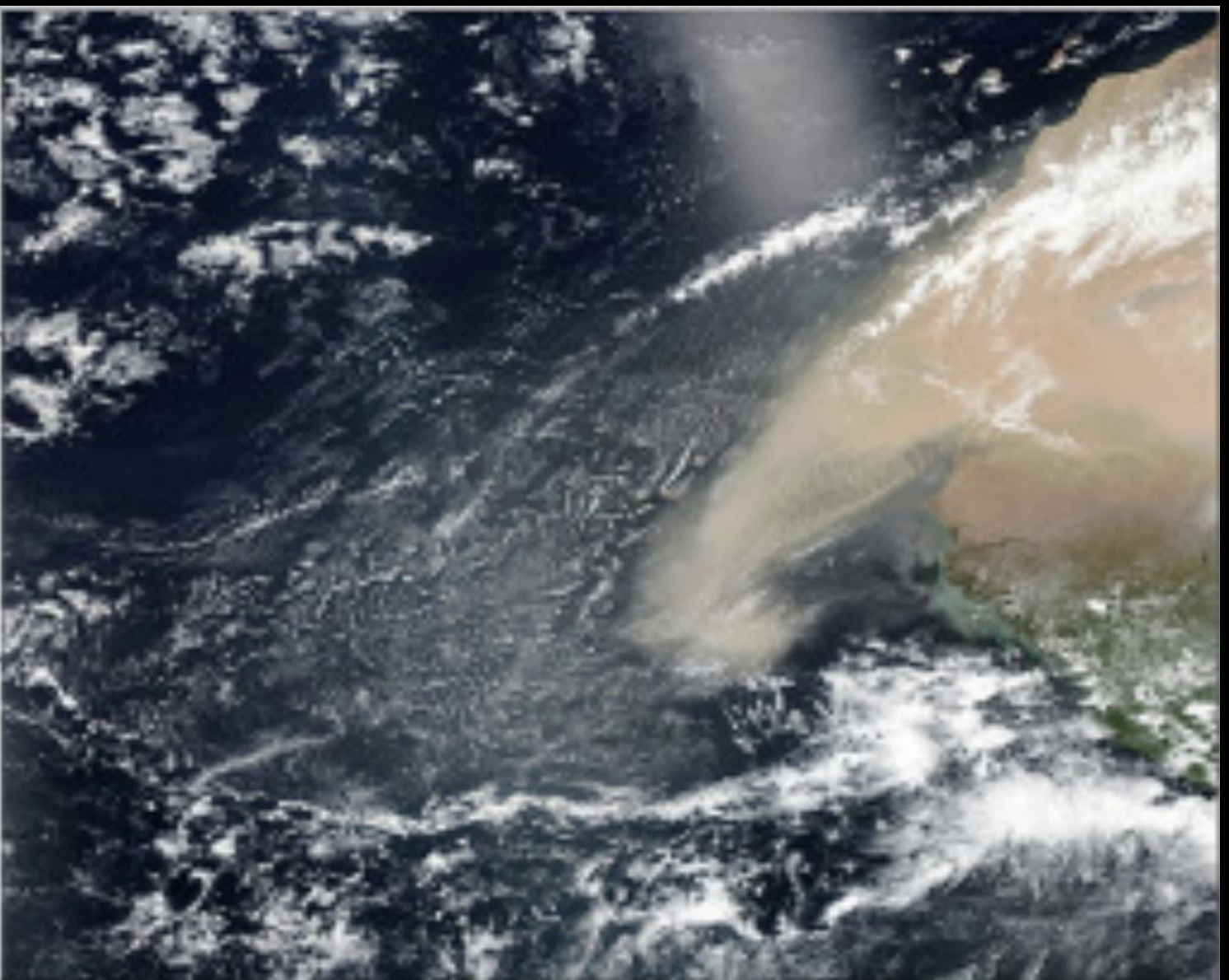


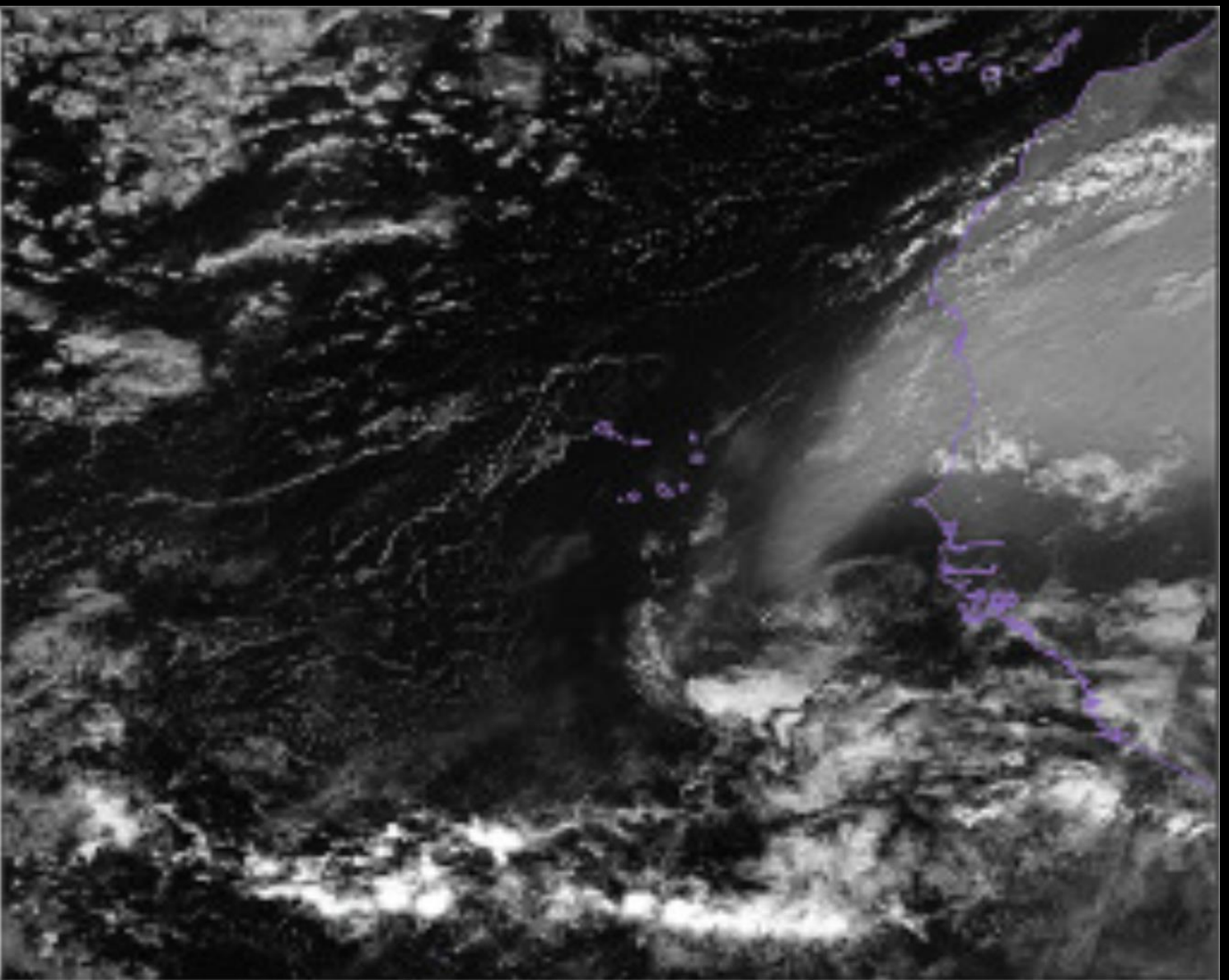
Figure: Zoltán Kolláth
Kyba et al. JGR: Atmospheres (2022)
See also Zhang et al. Atmospheric Measurement Techniques (2025)

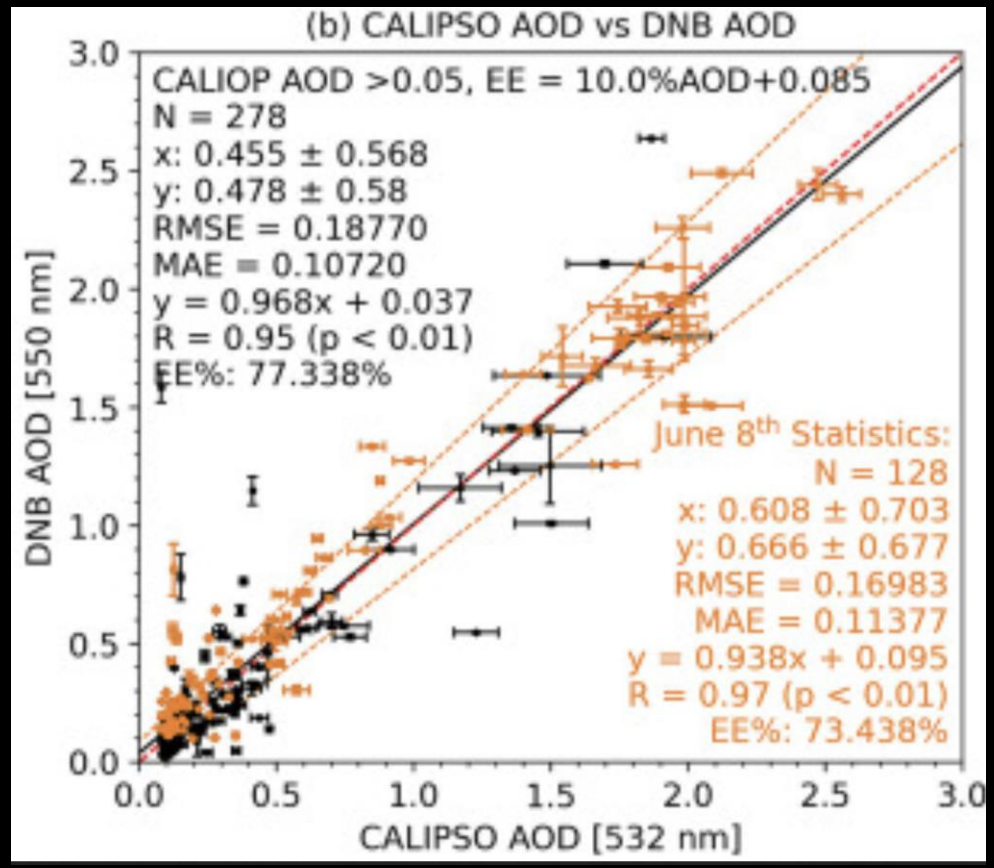
Aerosol optical depth with sunlight (dust)



Zhou et al. 2024
Remote Sensing of Environment

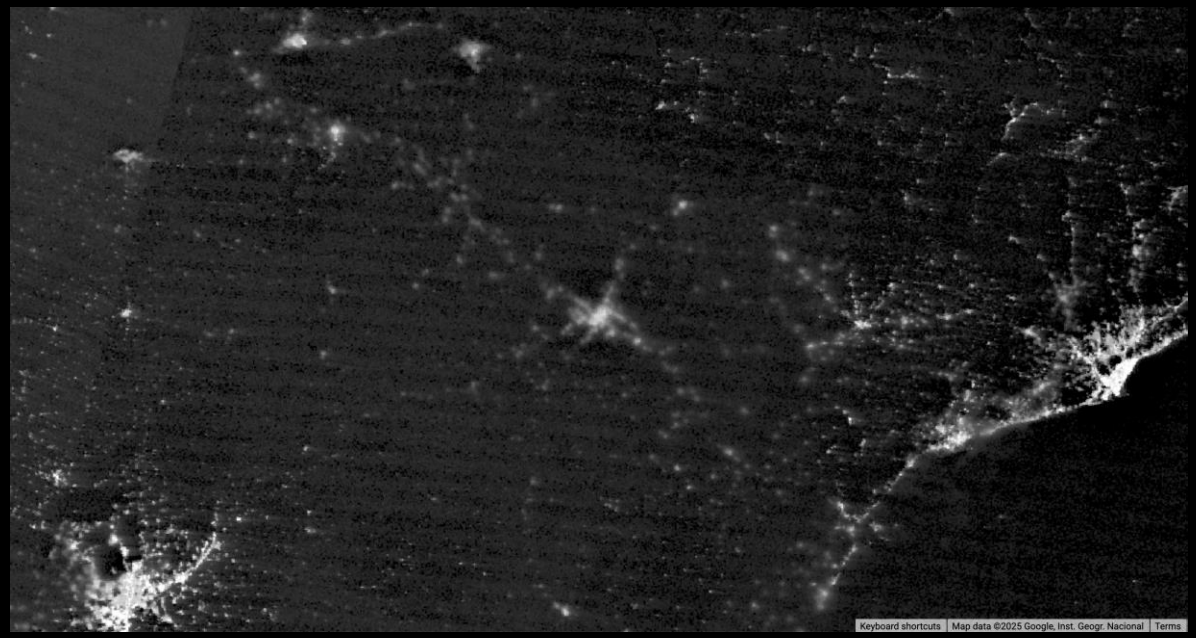
Aerosol optical depth with moonlight (dust)

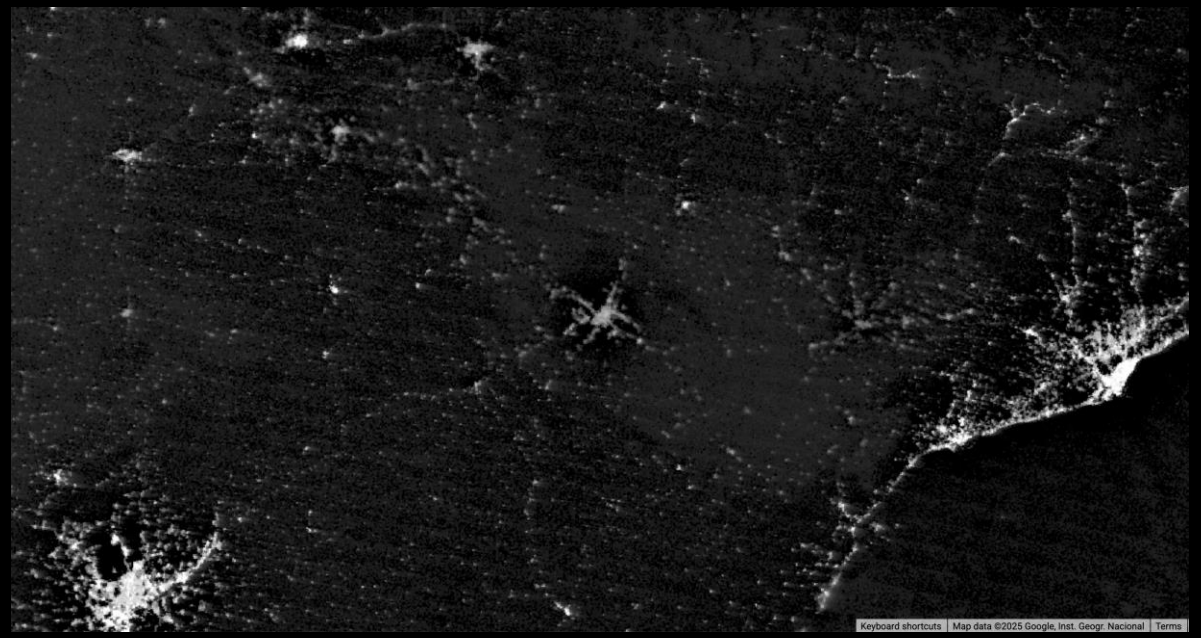




Zhou et al. 2024
Remote Sensing of Environment

Fog in Spain





Fog on December 27, 2024
Alejandro Sanchez de Miguel