Towards a constellation of thermal infrared sensors for wildfire detection:

Inter-calibration of FOREST-2 with Sentinel-3 SLSTR using the Moon

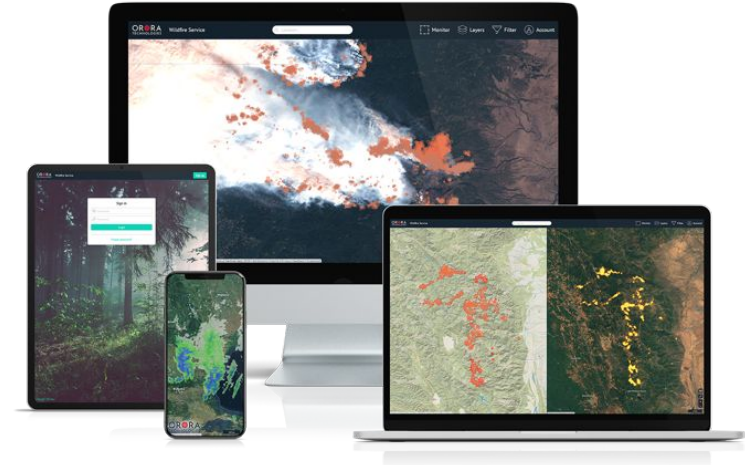2023-12-07

4th Lunar Calibration Workshop @EUMETSAT

OroraTech: intro

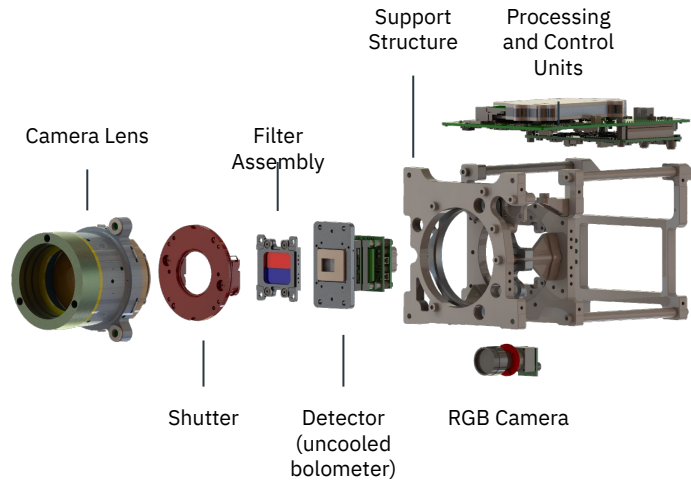**Thermal intelligence for a sustainable Earth**

- Munich-based startup with >90 employees
- Focus on wildfires & currently monitoring >160 Mio. ha of forest
- In-house development of Thermal IR imager → 2 in orbit, 8 more in production

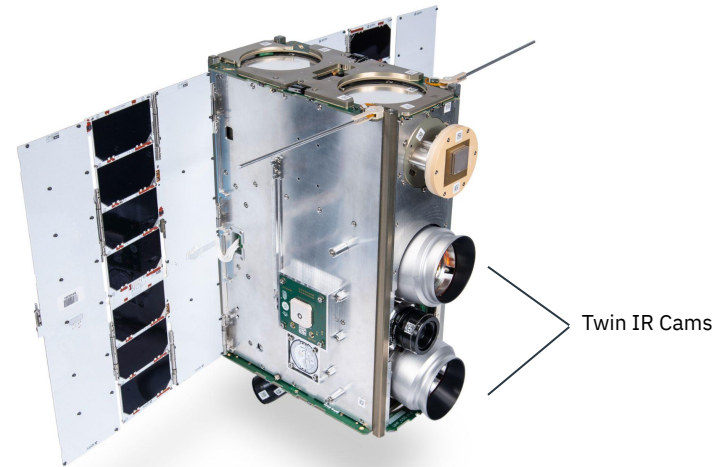**Goal**: achieve ~30min revisit (fast wildfire warning)

SAFIRE Payloads

SAFIRE Gen 1
Technology Demonstrator
(launched Jan 2022)

SAFIRE Gen 2
Production System
(launched June 2023)

Camera Lens

Filter Assembly

Support Structure

Processing and Control Units

Shutter

Detector (uncooled bolometer)

RGB Camera

Twin IR Cams

OT Missions

Mission	FOREST-1	FOREST-2	Constellation OTC-P1	Full Constellation
Satellites	1	1	8	~100
Payload	**SAFIRE Gen 1**	**SAFIRE Gen 2**		TBD
Status	**Operational** (Jan 22)	**Launched** (Jun 23)	**MAIT on-going** Launch 2024 Q4	Until 2027
GSD	250 m	200 m		TBD
Swath	160 km	410 km		TBD
Detector NEdT	<50mK	<50mK		TBD
Acquisition mode	Tasking	Continuous		TBD
Global revisit time	~ 14 days*	< weekly*	**twice daily**	**30 min**

*Can be improved with tasking
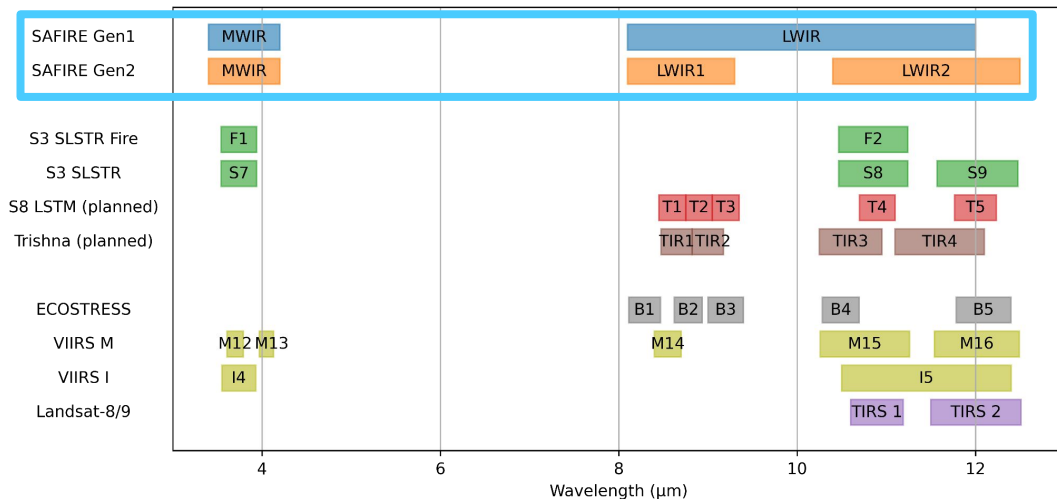
Thermal Infrared Bands

SAFIRE Gen 1:

- MWIR: fire detection
- LWIR: wide thermal infrared

SAFIRE Gen 2 - LWIR band split:

- LWIR1: "geological" / high contrast
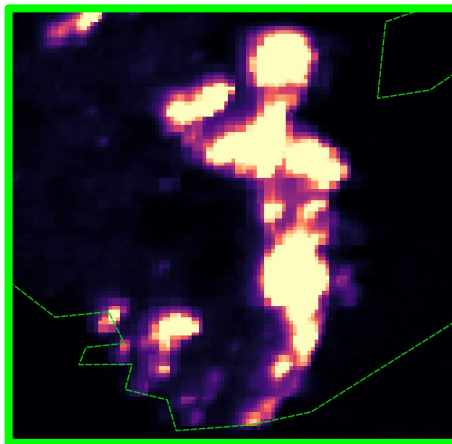- LWIR2: LST

Good overlap with VIIRS, SLSTR & others

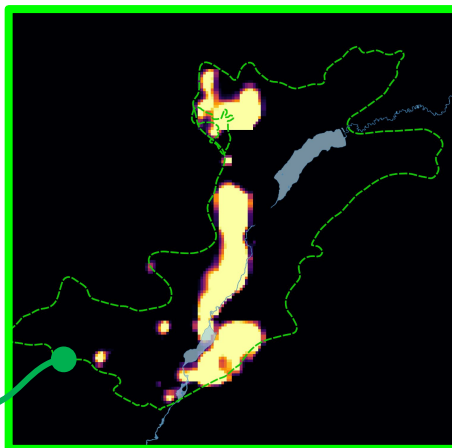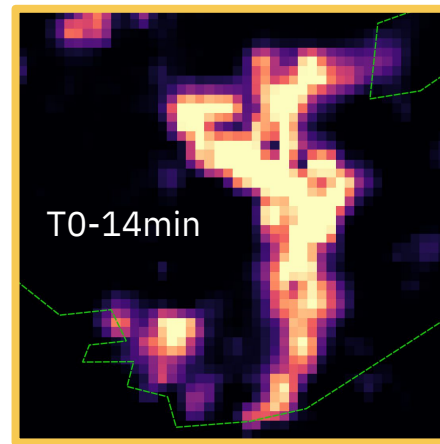Next iteration: further split of LWIR2 band

Active Fire Detection

Wildfires in Québec, Canada
August 2023

FOREST-2 MWIR

VIIRS I4

T0-14min
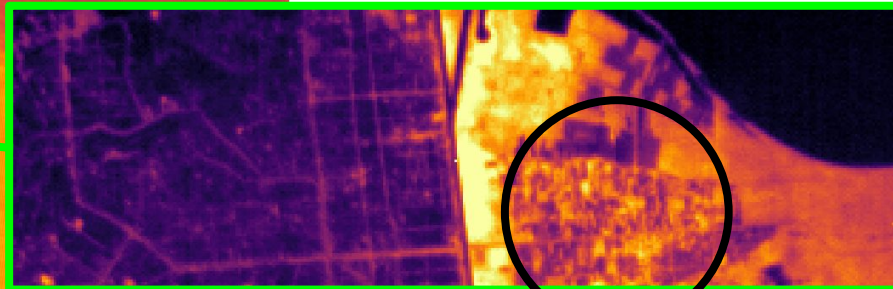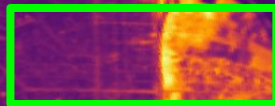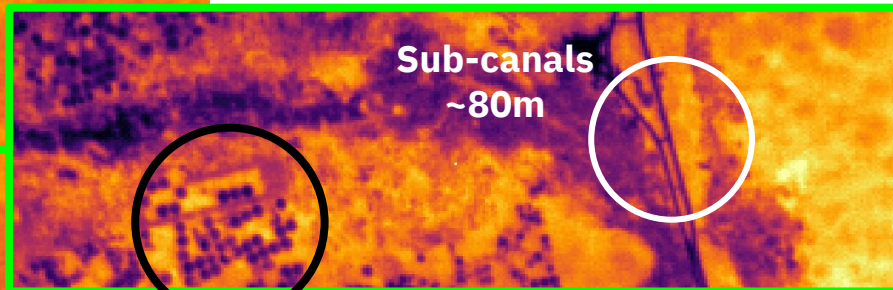
Final Wildfire
Perimeter

T0-17min

FOREST-2 LWIR2

First Light

Suez Canal, Egypt
August 2023
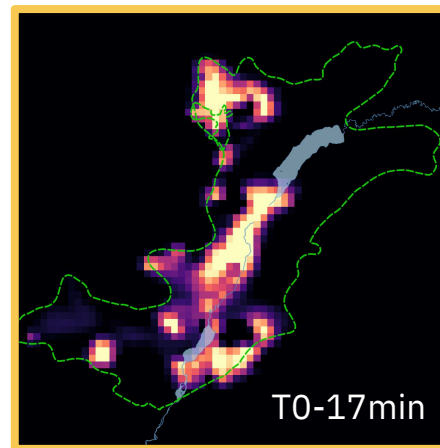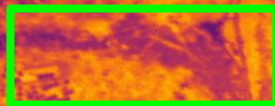
Agriculture

Sub-canals
~80m

Agriculture

7

Radiometric Calibration

- Thorough on-ground calibration campaign
- Challenges in-flight
  - No on-board black-body (complexity, volume)
  - MWIR difficult vicarious cal. (target variability)
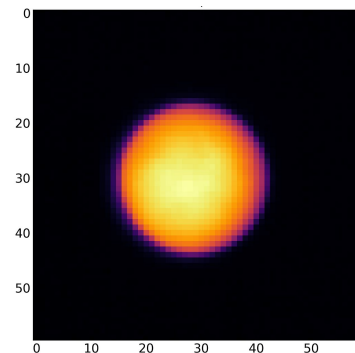
In-flight calibration strategy

- Radiometric offset: deep space imaging
- Radiometric gain: lunar inter-calibration with Sentinel 3A/B SLSTR

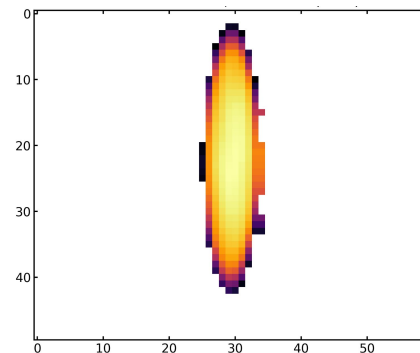→ Sentinel 3A/B SLSTR observes Moon **monthly** (~6.5deg)

→ Excellent SNR in SAFIRE Gen 2 (eg. MWIR)

→ Approach **suitable for a large constellation**

SAFIRE Gen 2 LWIR2 (single frame)

Sentinel 3 SLSTR F2

Inter-calibration with SLSTR

- SLSTR **Fire** F1/F2 channels used for calibration of SAFIRE Gen 2 MWIR/LWIR2

- Comparison of **lunar integrated radiances**
    - For SAFIRE Gen 2, oversampling = 1 ("staring" mode, int time ~12ms)
    - Compensation of SLSTR oversampling with accurate telemetry (validated with ellipse fitting)
    - Conversion from SLSTR BT to radiance using look-up tables
    - Compensation for different band SRFs

preliminary

Calibration Factor
$$\bar{g} = \frac{1/\gamma_{OS} \sum_{ij} L_{ij}^{SLSTR} \Omega_{ij}^{SLSTR}}{\sum_{ij} L_{ij}^{F2} \Omega_{ij}^{F2}}$$

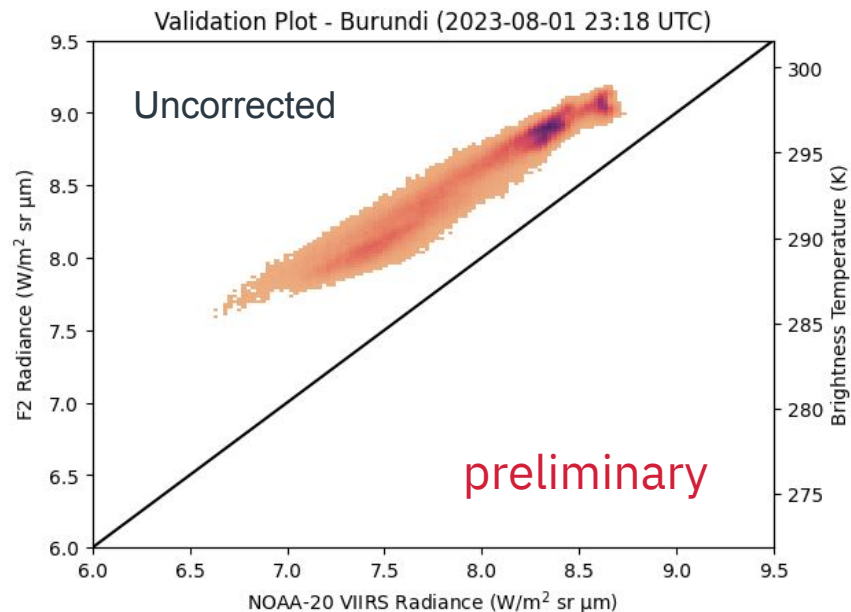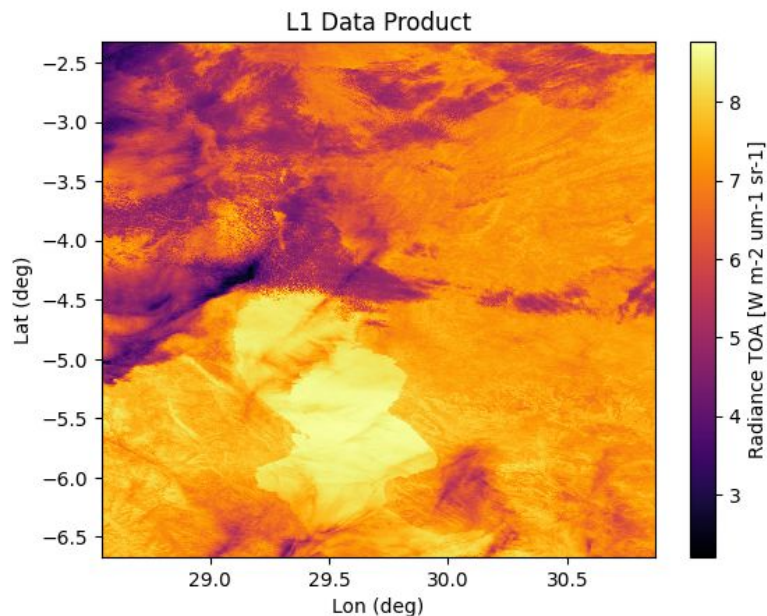| Band	g	u(g)
MWIR	2.27	0.03
LWIR2	1.43	0.06

Uncertainty Propagation
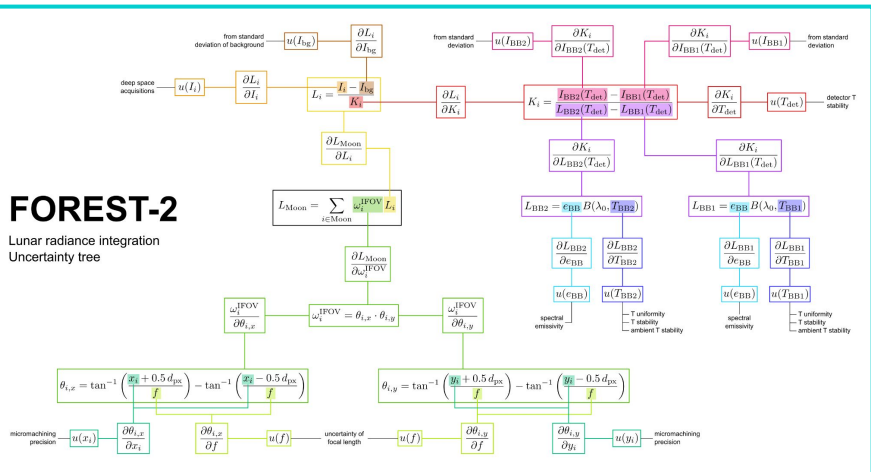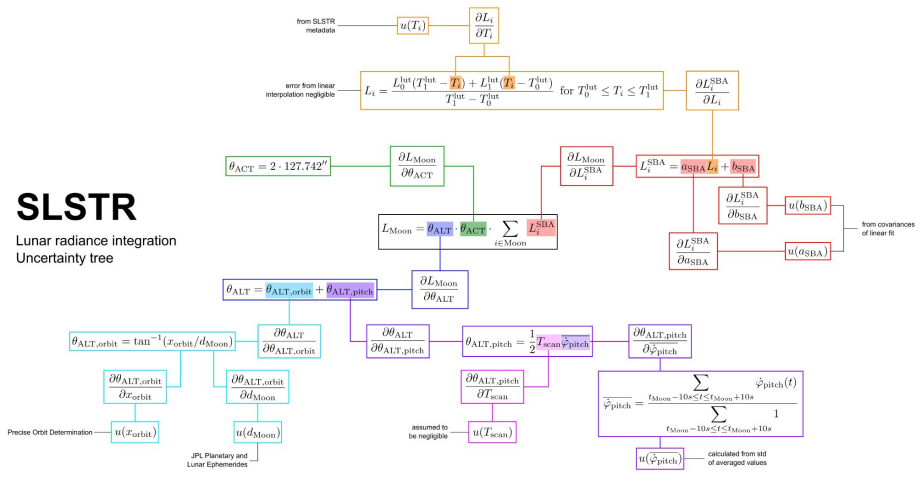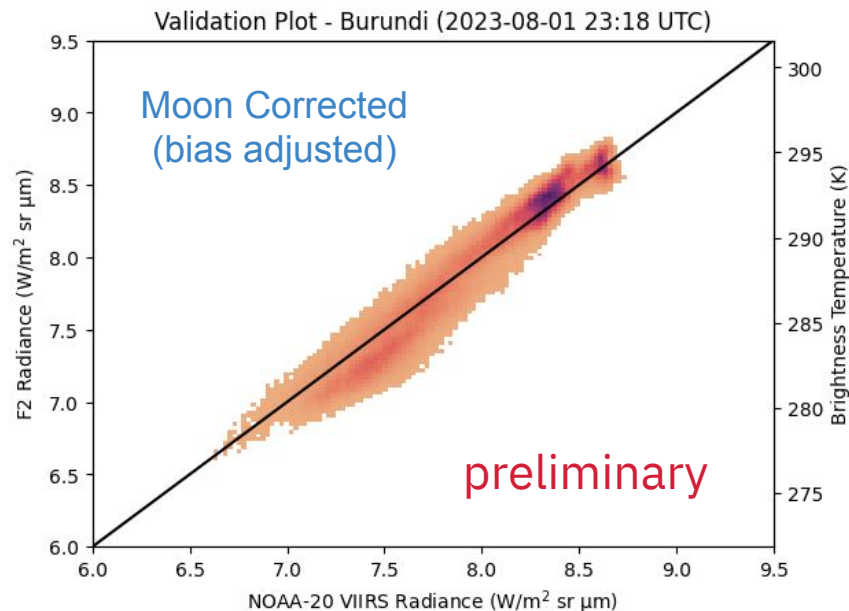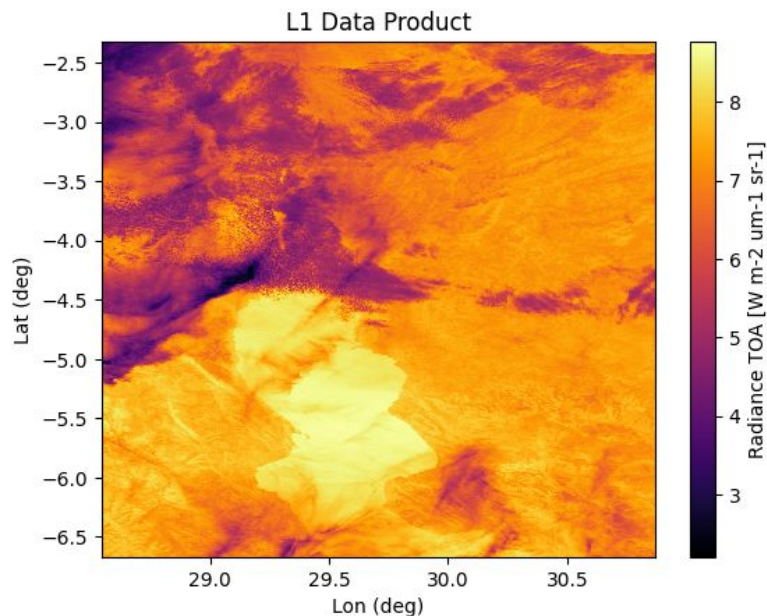
Radiometric Validation

- Method validation with **independent** sensor (VIIRS)

- Well-overlapping bands (VIIRS → SAFIRE Gen2)

  - I5 / M15 / M16 → L2

- Quasi-simultaneous acquisitions (~few min, bc similar orbit)
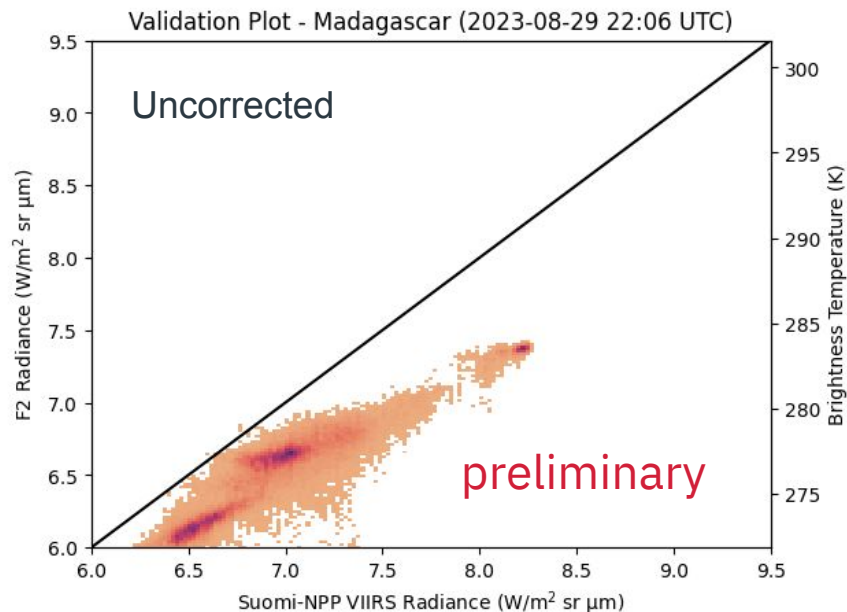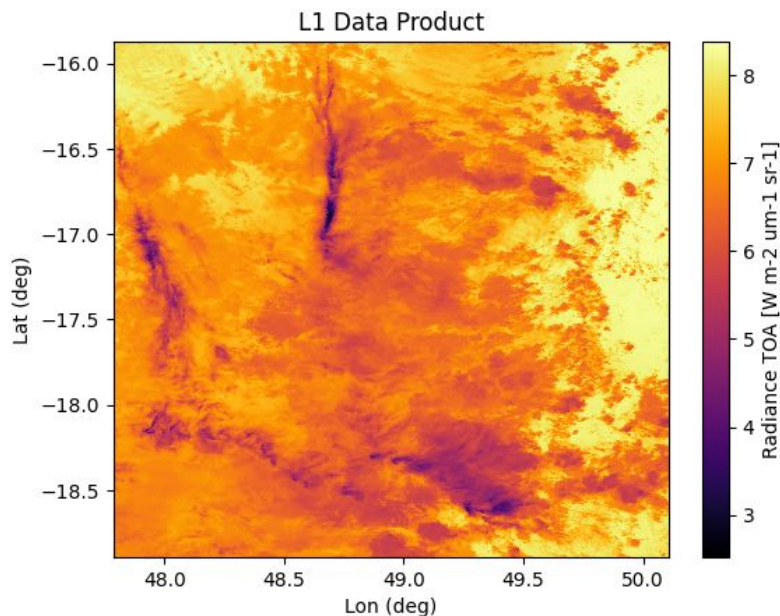
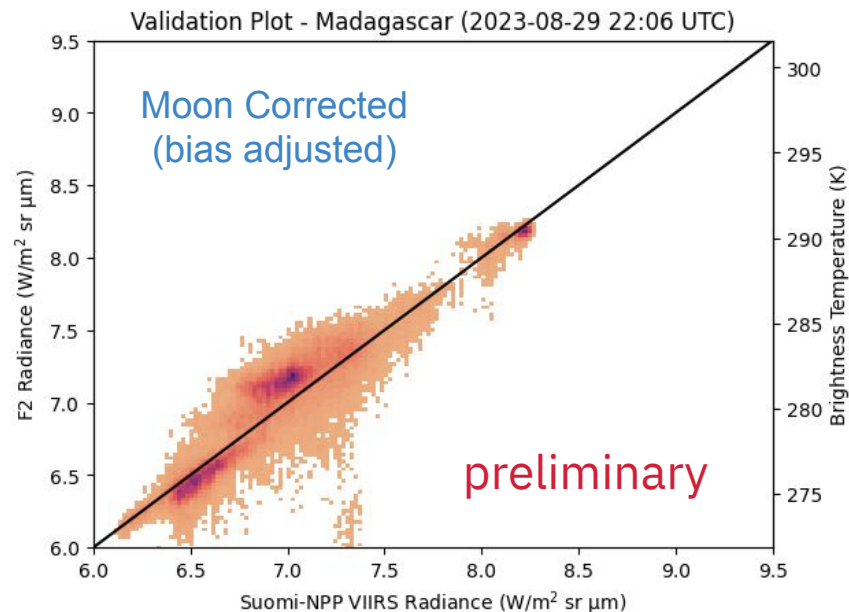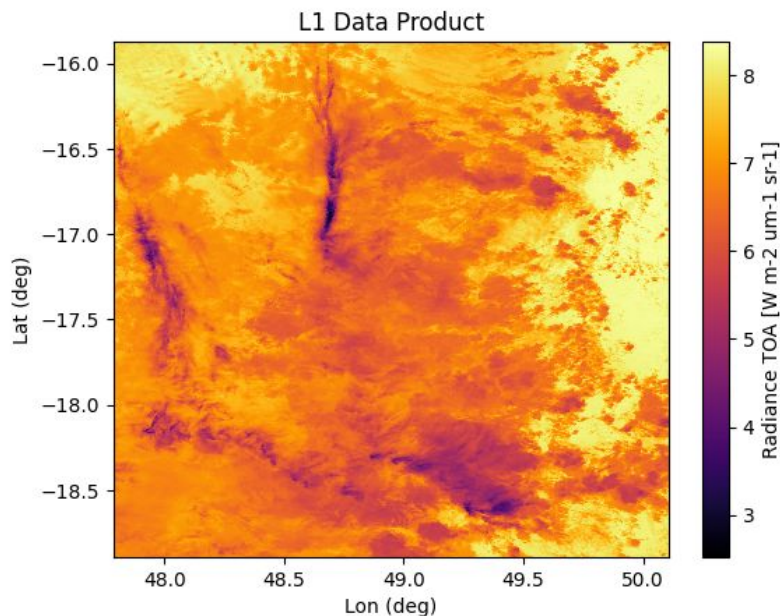- Clouds filtered with VIIRS mask
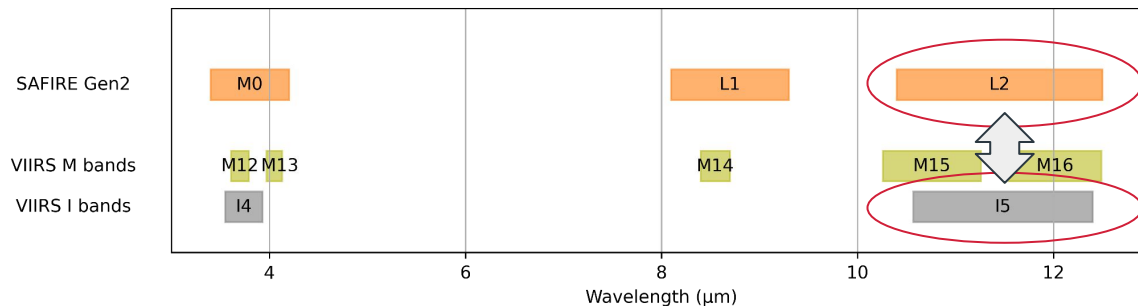
Validation with NOAA-20 VIIRS

Validation with NOAA-20 VIIRS

Validation with SNPP-VIIRS

L1 Data Product

Validation Plot - Madagascar (2023-08-29 22:06 UTC)

Uncorrected

preliminary

Validation with SNPP-VIIRS

L1 Data Product

Validation Plot - Madagascar (2023-08-29 22:06 UTC)

Moon Corrected
(bias adjusted)

preliminary

Next steps

- Gathering match-up data (long term trend)
- Mature the lunar processing (eg. SLSTR understanding)
  - Support from ESA OPT-MPC via Copernicus Contributing Missions program
- Comparison with lunar thermal models
- Multi-sensor calibration: from 1 (2023) to 20 cameras (2024) and beyond!

Normalized calibration factor
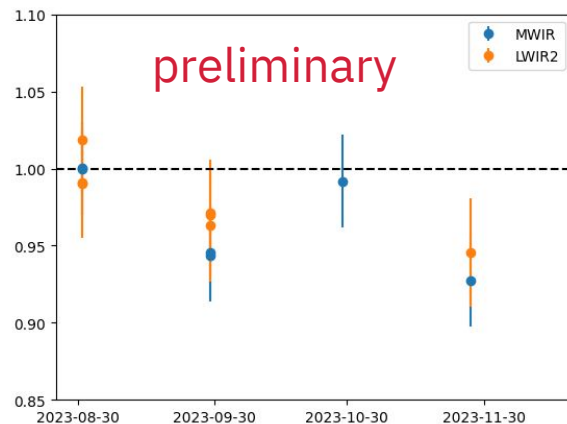
2023-12-06T18:56:04Z (LWIR2)
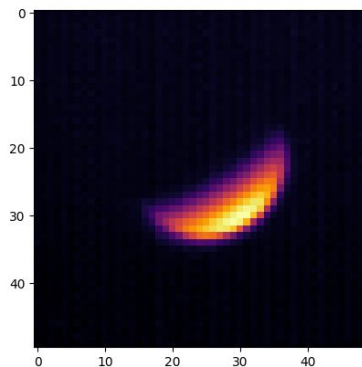
Diogo Rio Fernandes

Lead Optics Engineer

diogo.rio.fernandes@ororatech.com

"Detect every wildfire in 30 minutes, deliver it within minutes."

We're hiring: https://ororatech.com/careers/

ORORA
TECHNOLOGIES

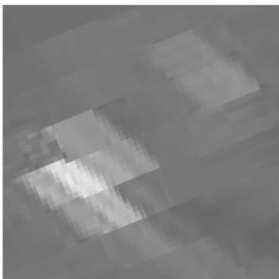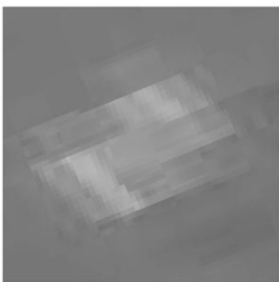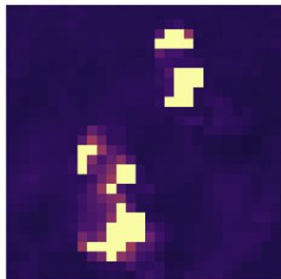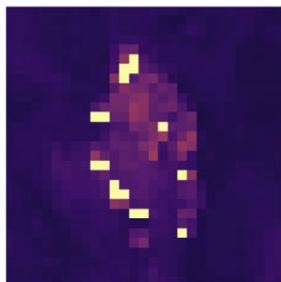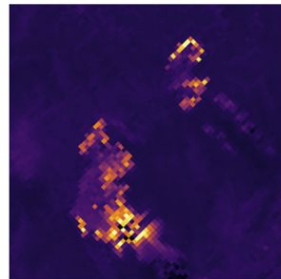# Backups
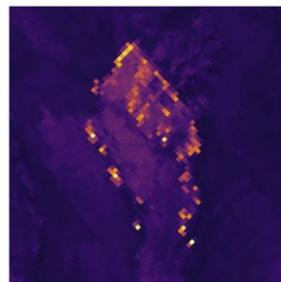
Fire Detection

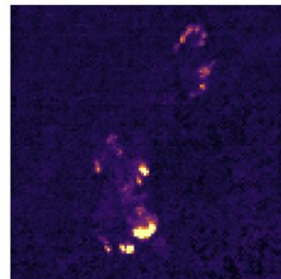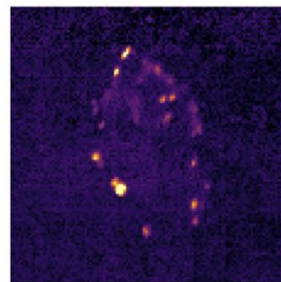Alaska - 01.07.2022 - 21:04 UTC
MWIR band

GOES-17 ABI (GEO)
21:04 UTC
GSD ~5km

Terra MODIS
21:40 UTC
GSD 1km

NOAA-20 VIIRS
21:30 UTC
GSD 375m

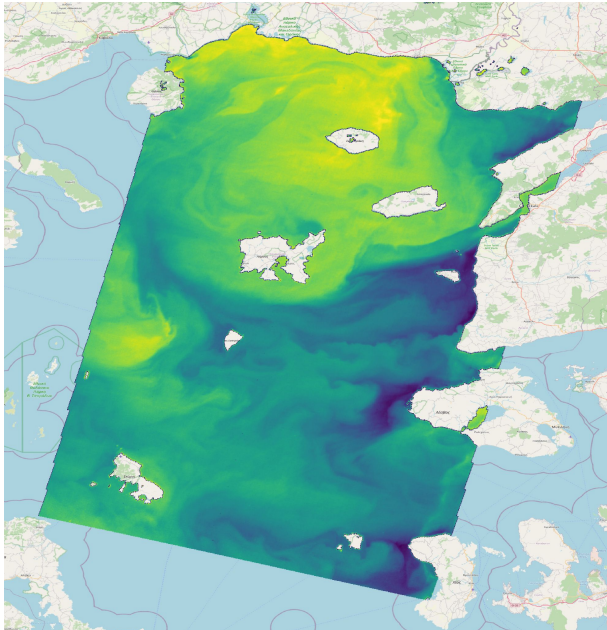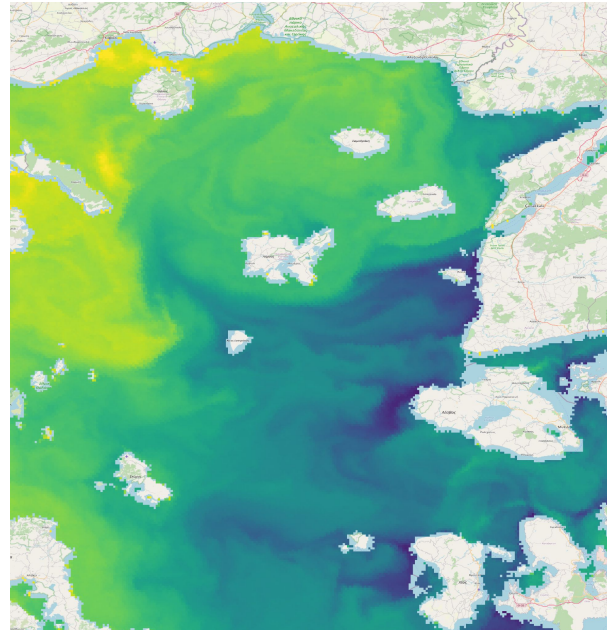FOREST-1 SAFIRE
21:04 UTC
GSD 250m

Sea Surface Temperature

Greece / Turkey - 15.07.2022 - 07:45 / 08:41 UTC
LWIR band
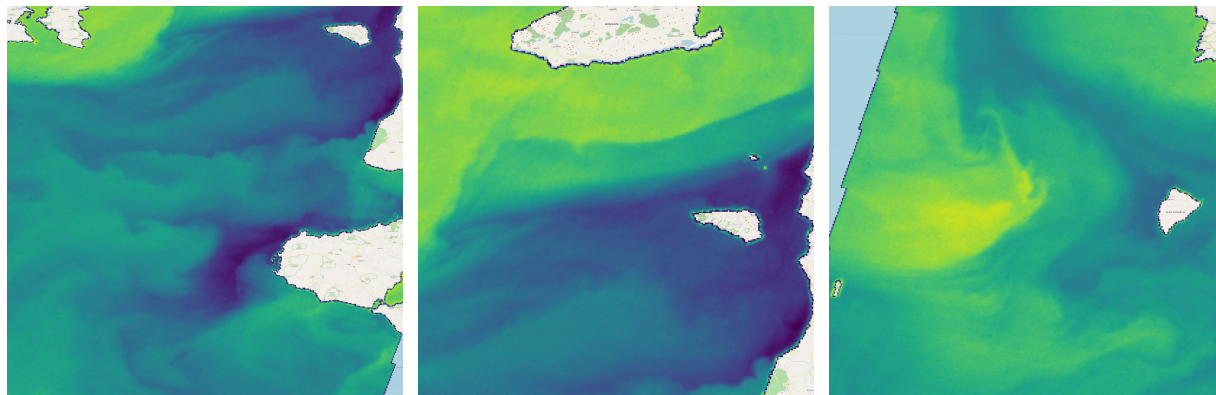
Here get slide from Martin

Forest-1 - raw data

Sentinel 3A - SST product

27°C

17°C

Forest-1 - raw data

Sentinel-3A SST