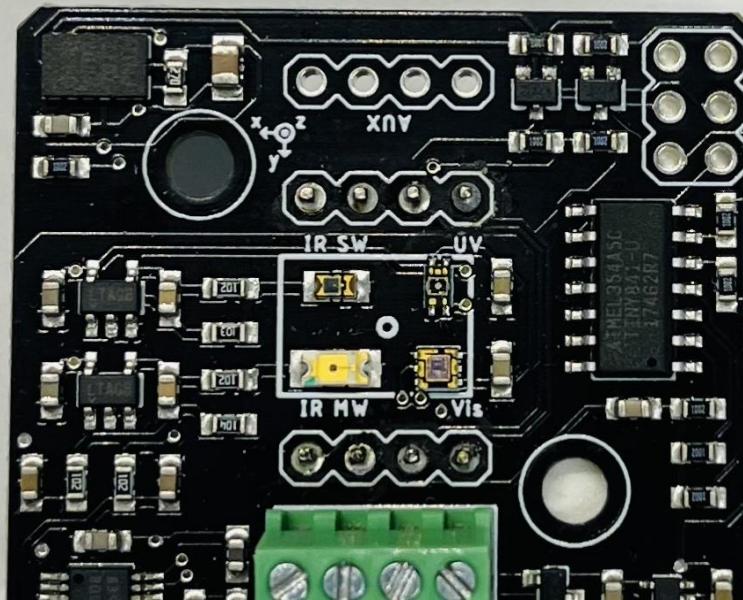




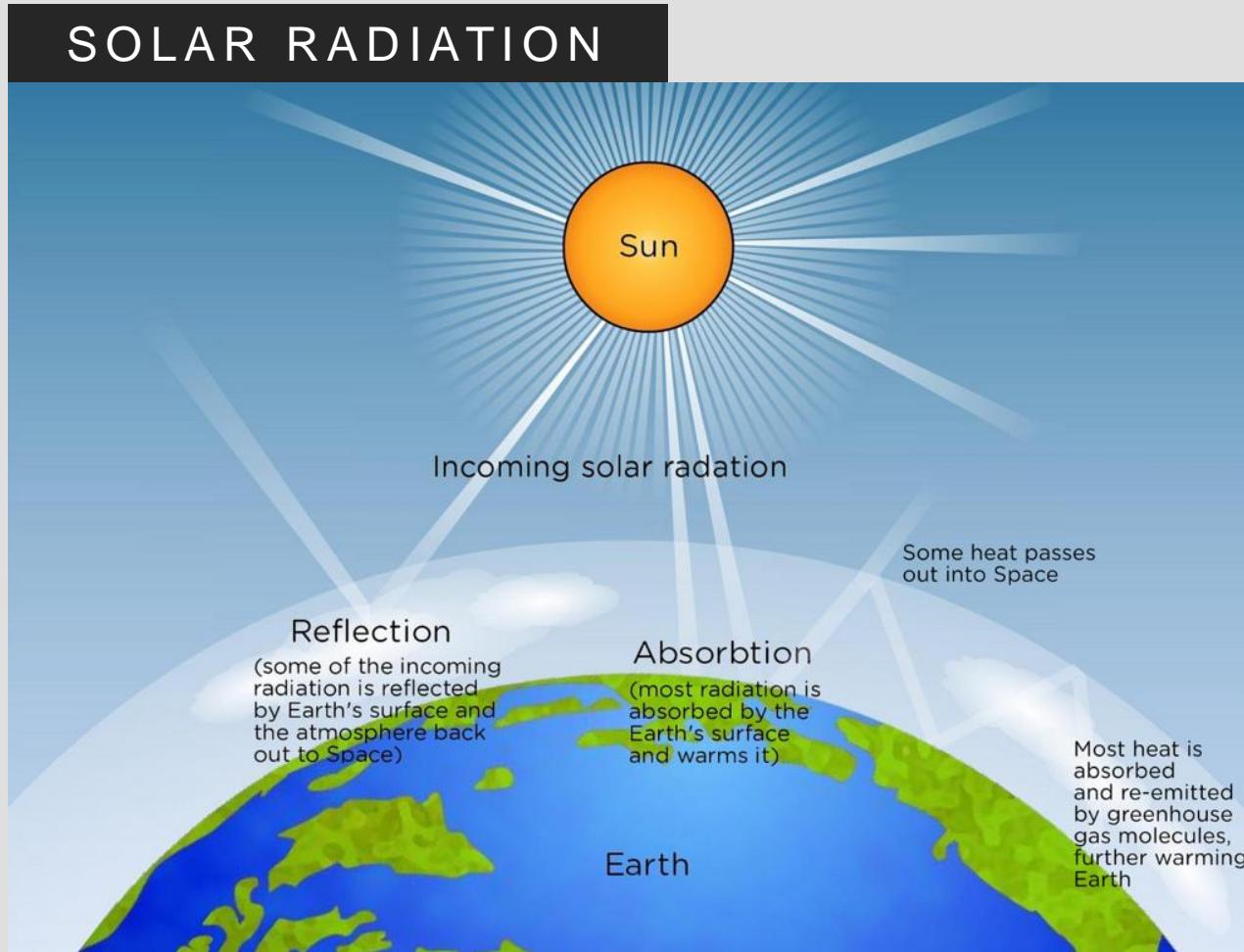
DEVELOPMENT OF A BETTER SOLAR RADIATION INSTRUMENT

MONARCH BOARD & ITS PHOTOSENSORS

Viet M Bui, Bobby Schulz, Tyler Fulghum & Andy Wickert

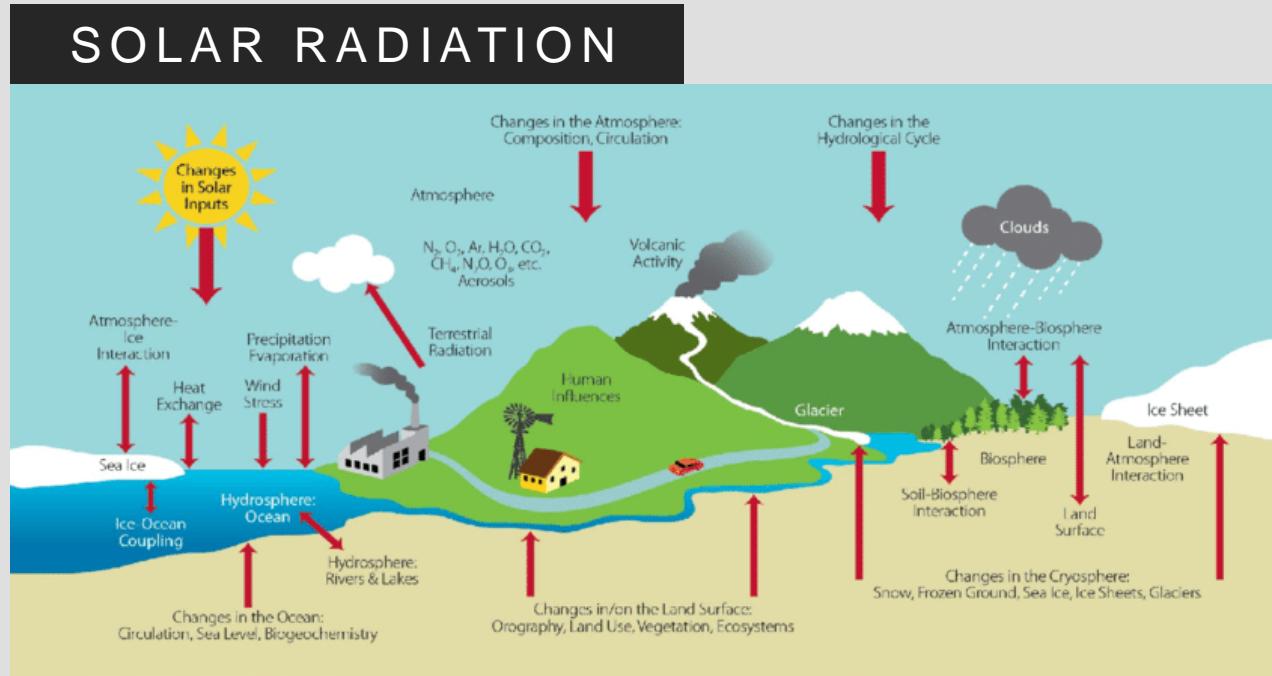


INTRODUCTION



- Sunlight
- Electromagnetic radiation emitted by the Sun
- Interact with our atmosphere
 - Absorbed
 - Scattered
 - Reflected

INTRODUCTION

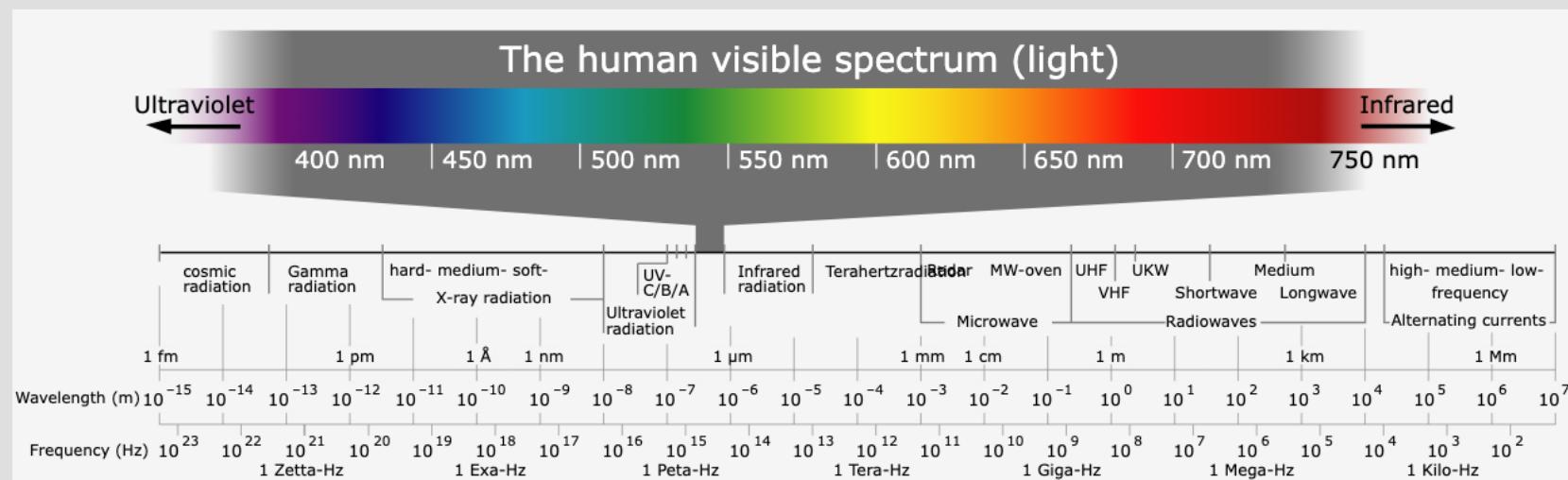


- Earth receives energy from solar radiation
 - Critical to climate system, water cycle, life, etc.

Bush, Elizabeth & Loder, John & James, Thomas & Mortsch, Linda & Cohen, Stewart. (2014). An Overview of Canada's Changing Climate.

INTRODUCTION

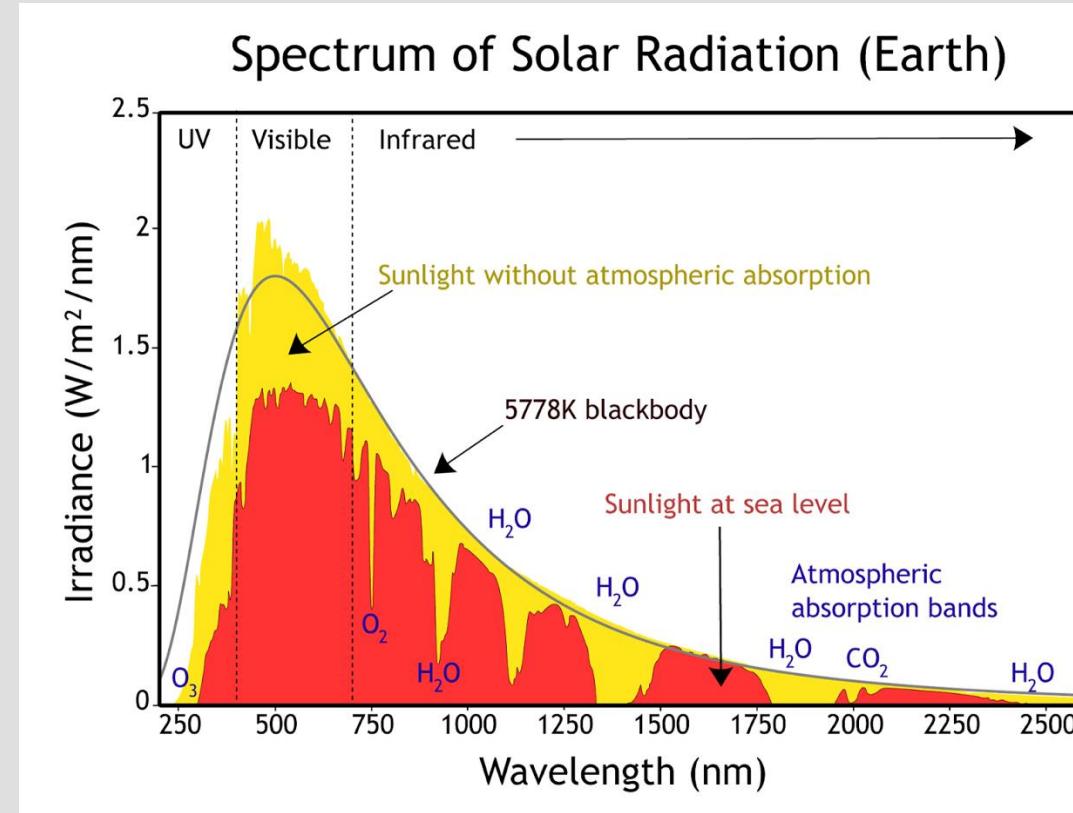
SPECTRUM



Electromagnetic Wave Spectrum by Horst Frank is licensed CC-BY-SA 4.0 International

- Want to capture a wide range of spectrum UV to IR regions
- Pyranometer is typically used to measure this range

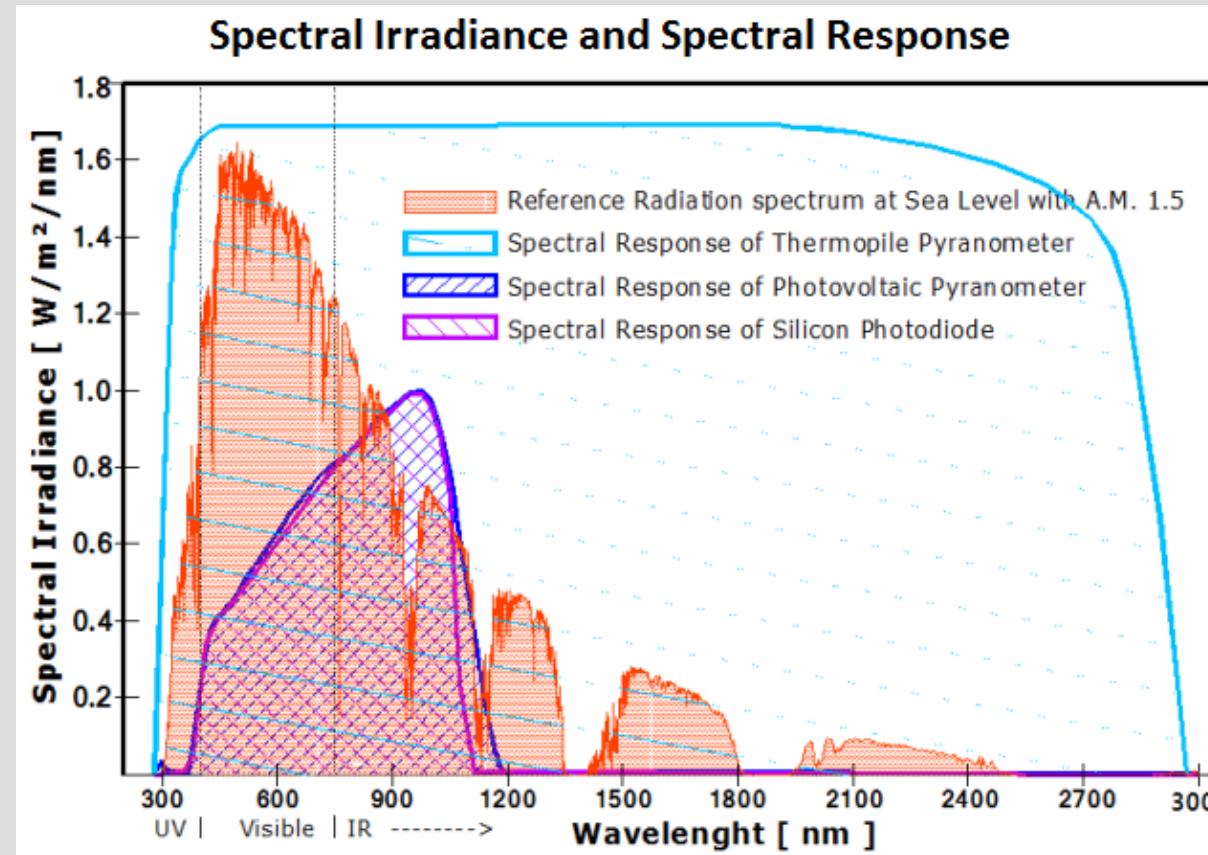
INTRODUCTION



Credit: Nick84 [CC BY-SA 3.0] via Wikimedia Commons

- We will use the blackbody as the comparison with the two devices that we are going to setup and measure.

INTRODUCTION



Graph by Arthurcala

- The Boxcar function = the response across spectrum

PROBLEM

- Industry standard (Kipp&Zonen CMP3) Thermopile Pyranometer
 - Calibrated by hand
 - Very expensive
 - Not easily scalable for mass production and accessibility beyond the PV industry
- We want to create an instrument
 - Using different sensors (photodiodes)
 - Photodiodes are mass produced with industrial purposes
 - Use it as the high-quality environmental sensors

INTRODUCTION

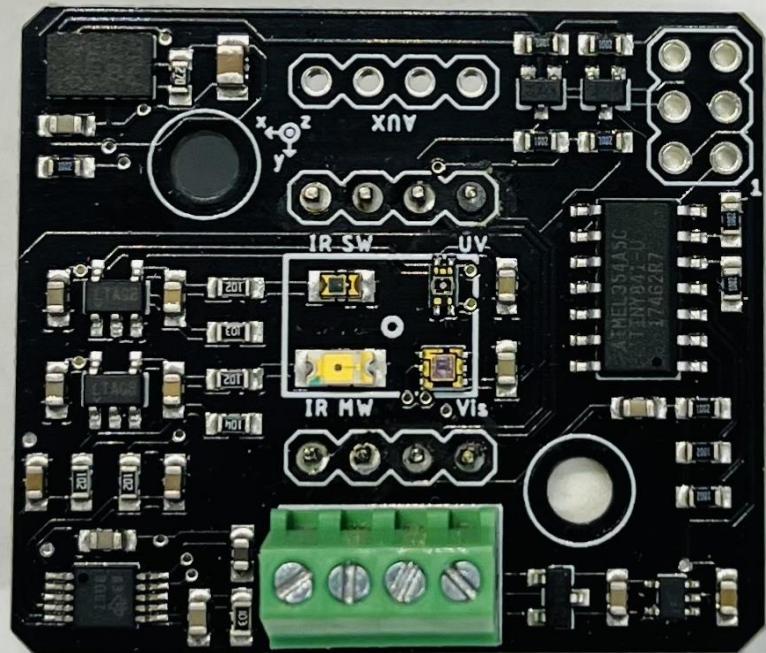
*Deployed station location near Perito Moreno Glacier,
Argentina*

APPLICATION

- To measure energy balance on glacier
- Photosynthetically active radiation
- General weather station

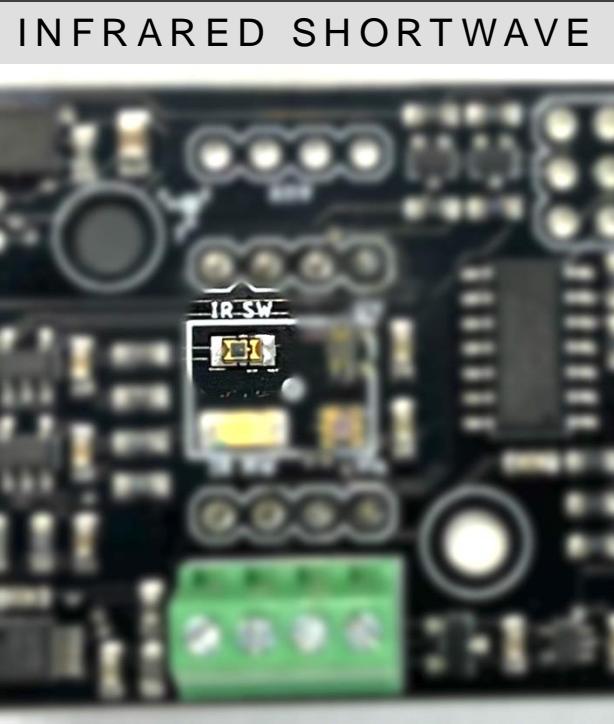


HARDWARE



Monarch Board next to a US quarter



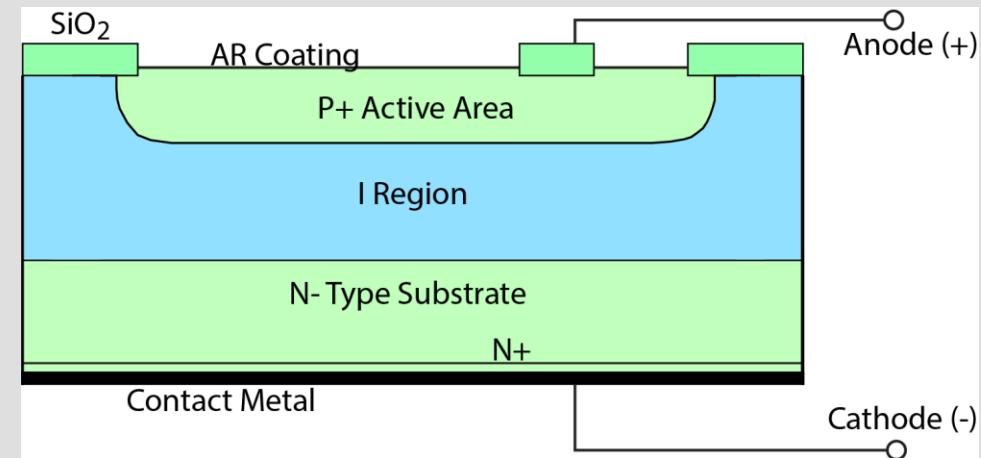


CODE NAME: IR_SW

DIGITKEY: VEMD1060X01CT-ND

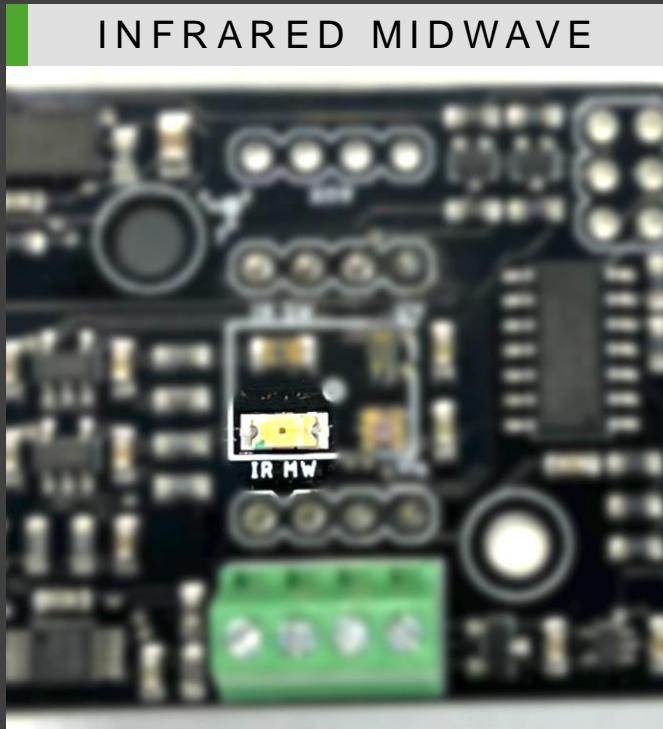
TYPE: PIN Photodiode

- Spectral bandwidth~: 350 -> 1070 nm



PIN photodiode cross-section, teamwavelength.com

INFRARED MIDWAVE

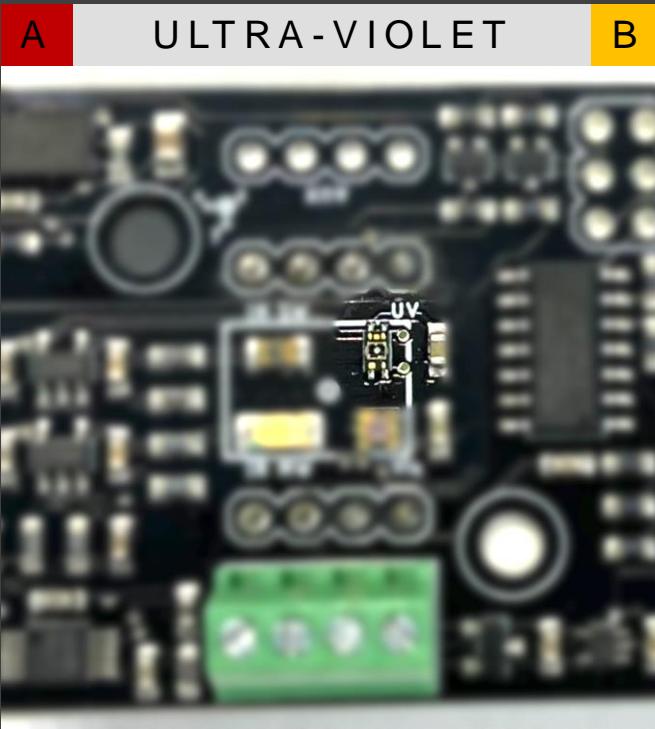


- Spectral bandwidth~: 800 -> 1700 nm
- Near IR detection because of different material
 - Indium Gallium Arsenide Photodiode
- Overlapping with IR_SW

CODE NAME: IR_MW

DIGITKEY: SD003-151-001CT-ND

TYPE: InGaAs Photodiode

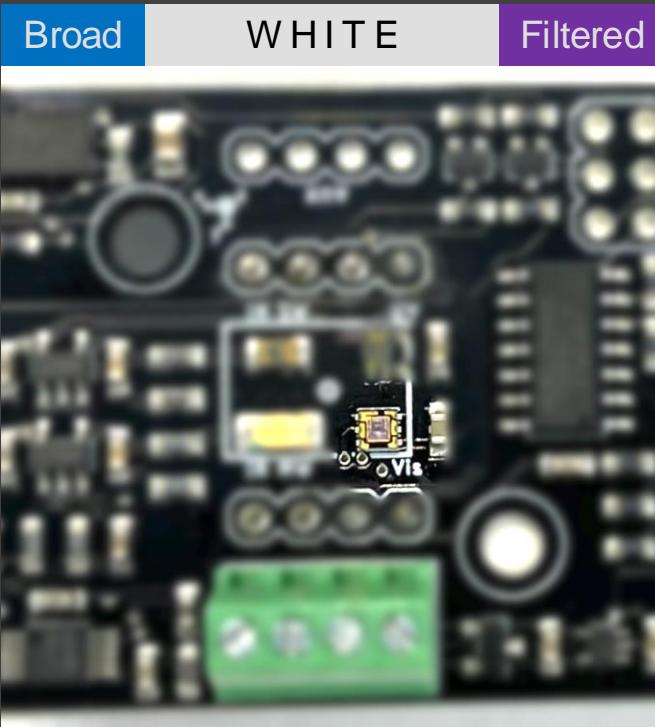


- Peak at 330 and 365 nm
- Compact digital circuit:
 - Photodiode
 - Amplifiers
 - Communication: I²C 16 bits

CODE NAME: UVA, UVB

DIGITKEY: VEML6075CT-ND

TYPE: ANALOG/DIGITAL CIRCUIT



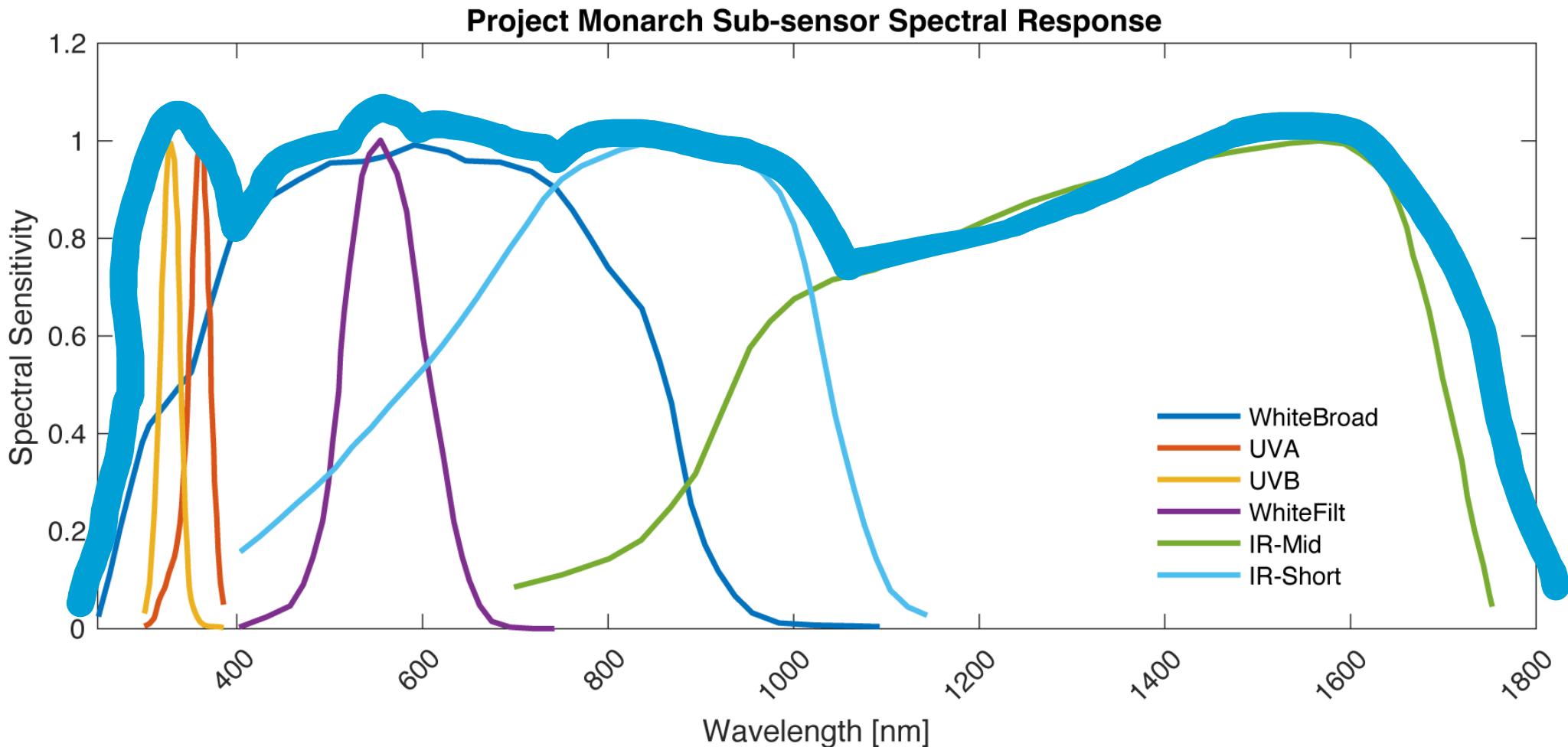
- Spectral bandwidth~: 400 -> 700 nm (filtered), 100 ->900 nm (broad)
- High accuracy ambient light sensor
- Measured in Lux
- Compact digital circuit:
 - Photodiode
 - Amplifiers
 - Communication: I²C 16 bits

CODE NAME: WhiteBroad, WhiteFil

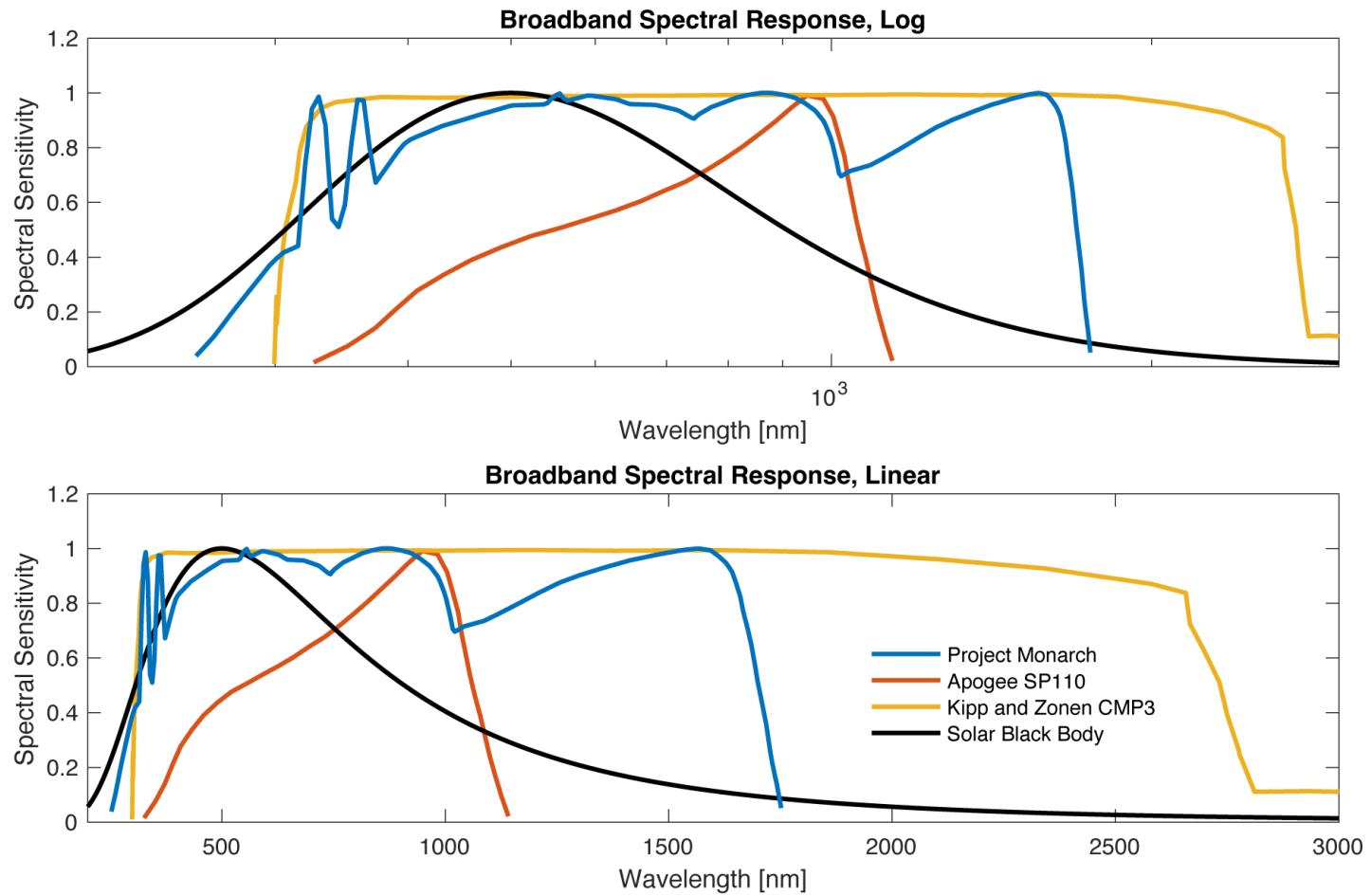
DIGITKEY: VEML6030-GS15CT-ND

TYPE: ANALOG/DIGITAL CIRCUIT

SPECTRAL RESPONSE



COMPARISON

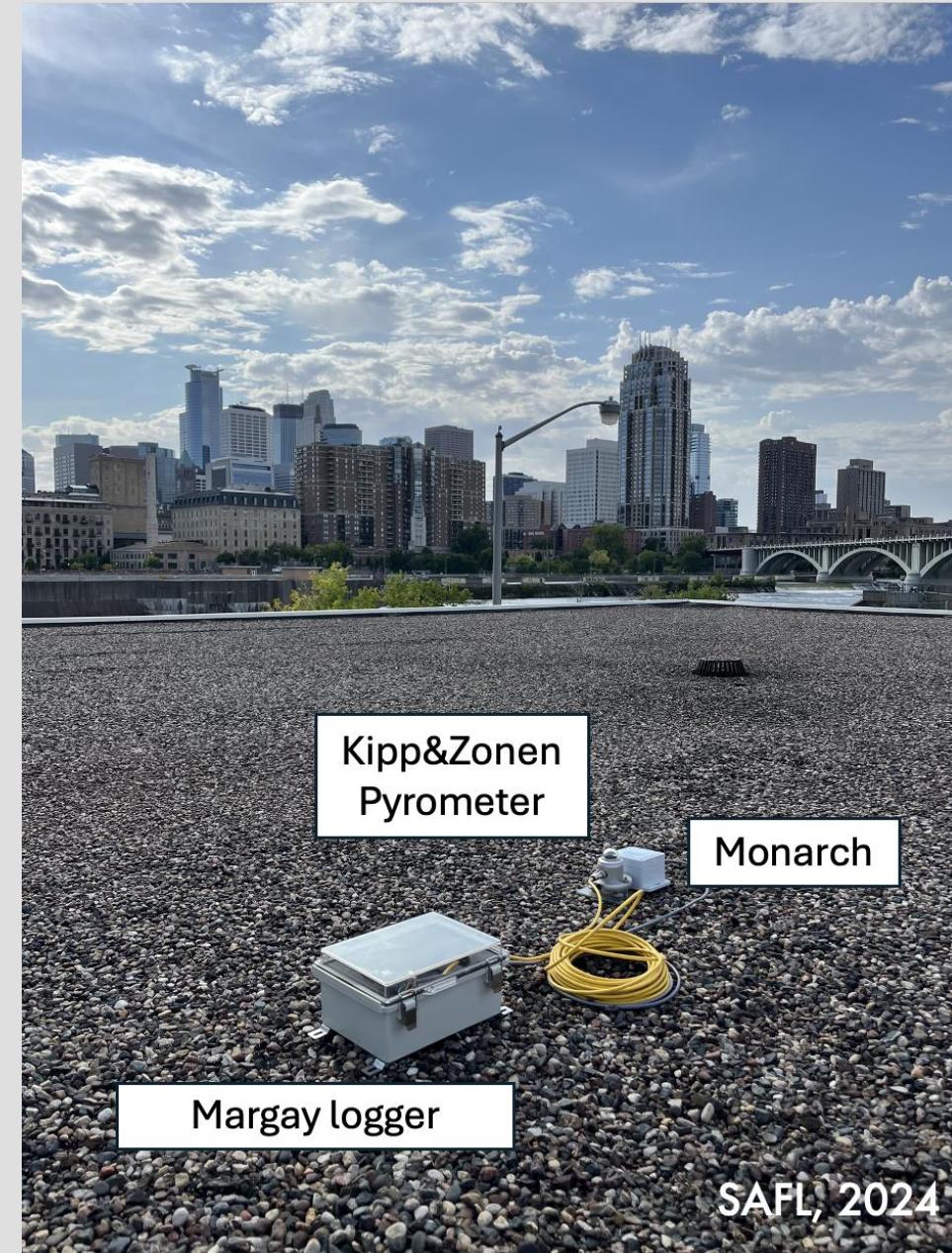


METHODOLOGY

- Using Zipp & Zonen CMP3 Pyranometer (industry standard) to compare how well Monarch board data correlate
- The linear correlation:
 - We are measuring numbers different from CMP3
 - See how well we approximate the broad-band thermopile radiometer and not just reproducing it.
- Could use the linear correlation to create transform function to output number to be as close to the industry standard

SETUP

- Margay Logger
- CMP3
- Monarch



RESULTS

JUNE 7-JULY 5, 2023, DATA

WILDFIRE SIGNATURE

OCT 10-13, 2024, DATA

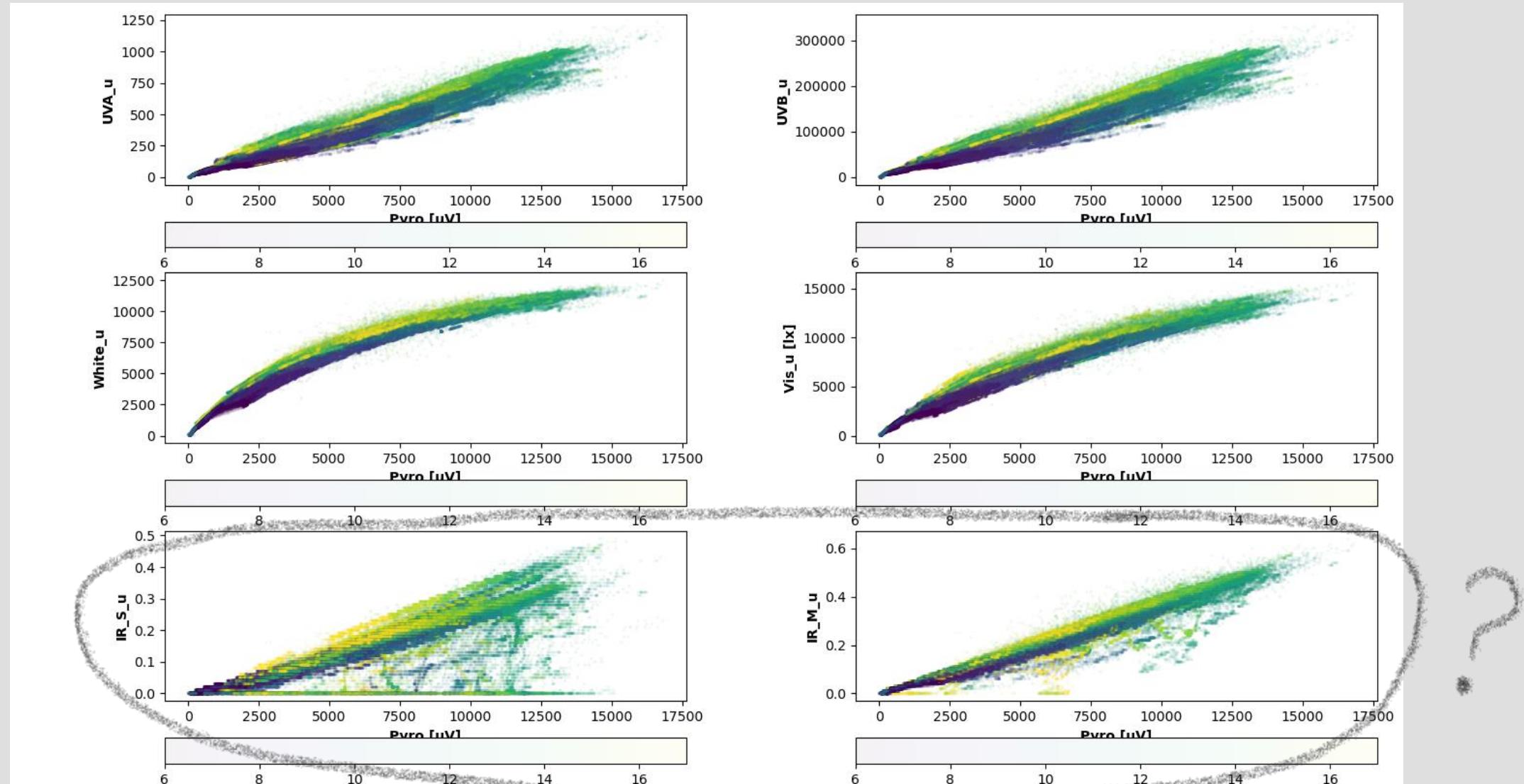
HARDWARE ISSUE

NOV, 2024, DATA

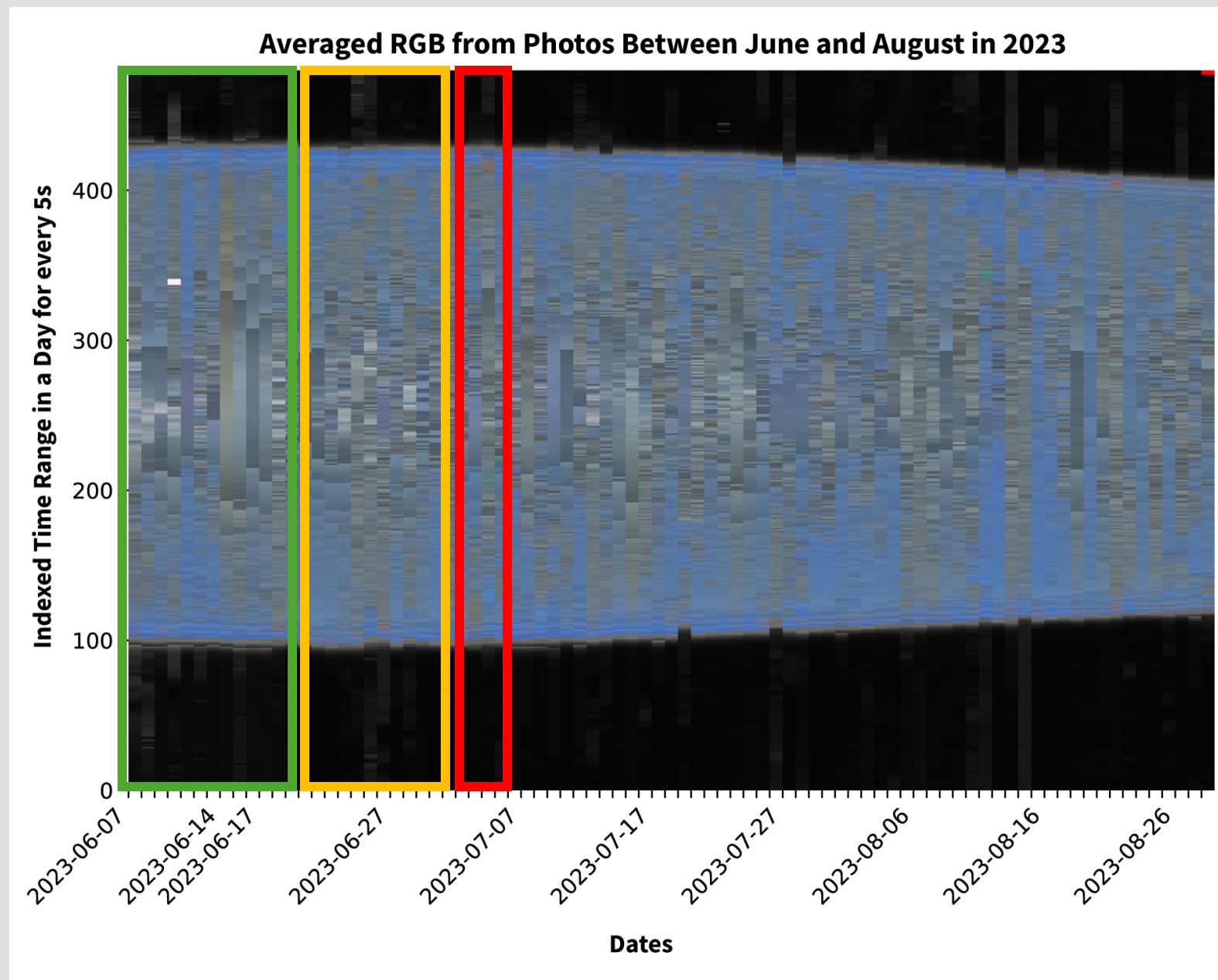
CONDENSATION

MONARCH HOUSING

RESULTS JUNE 7-JULY 5, 2023, DATA



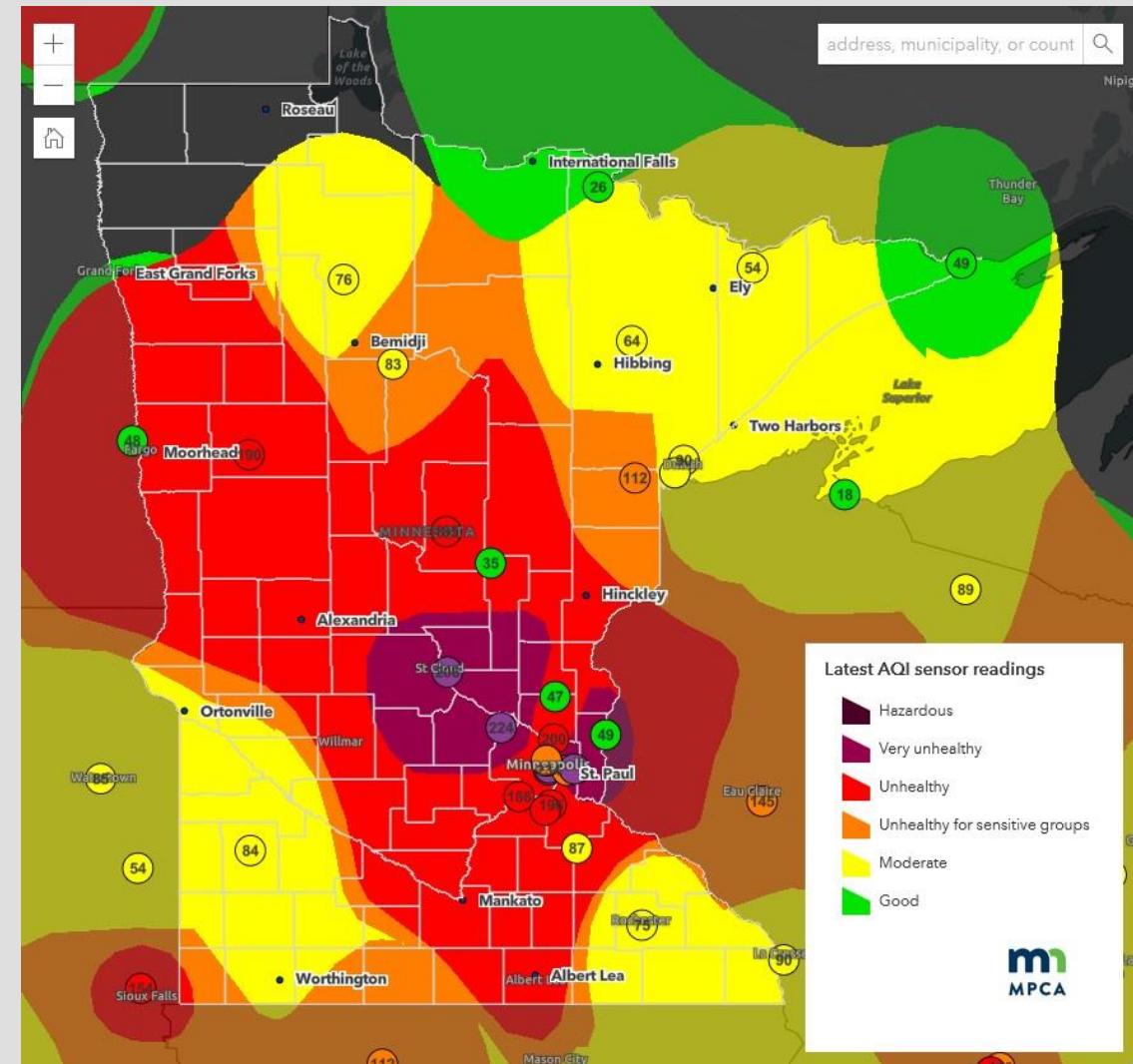
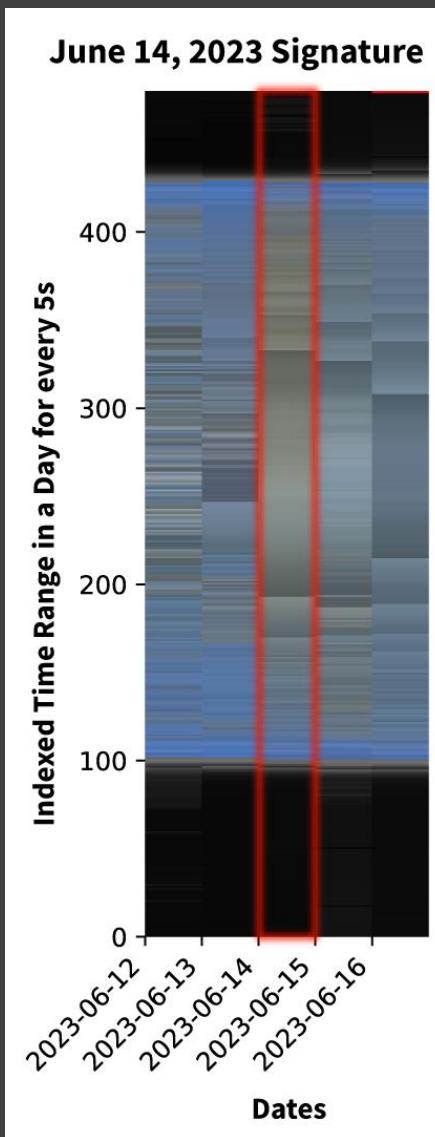
Data measured from Monarch Board plotted with Pyranometer value from CMP3 in x axis



WILDFIRE SIGNATURE

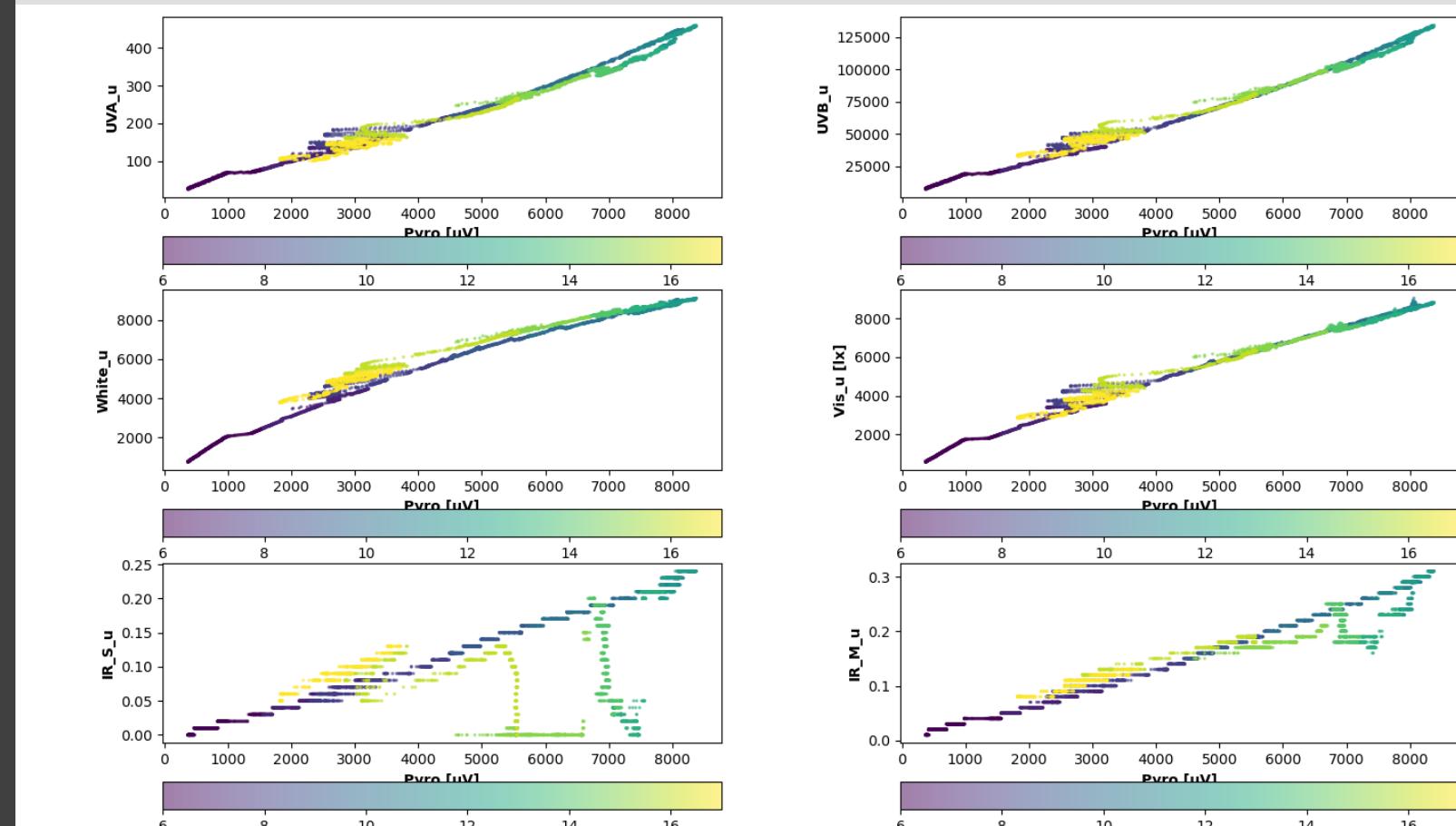
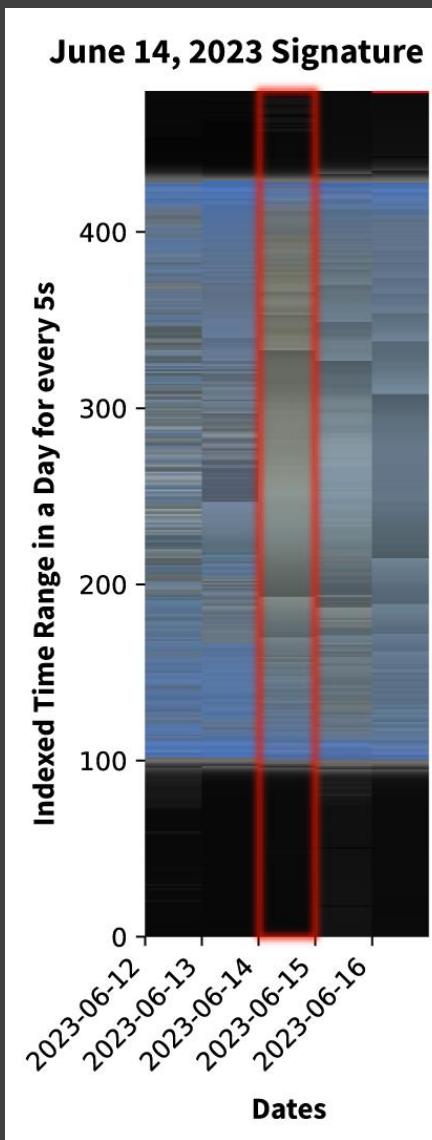
- Orange Hue of Minneapolis's skyline June 15
- What does this tell us about the event on June 14?

WILDFIRE SIGNATURE



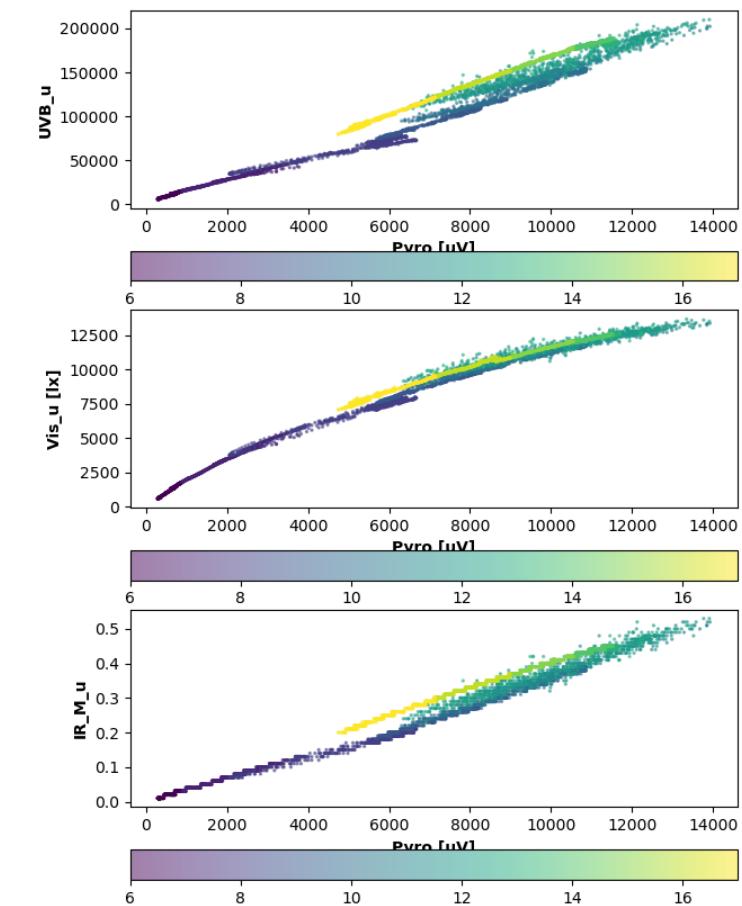
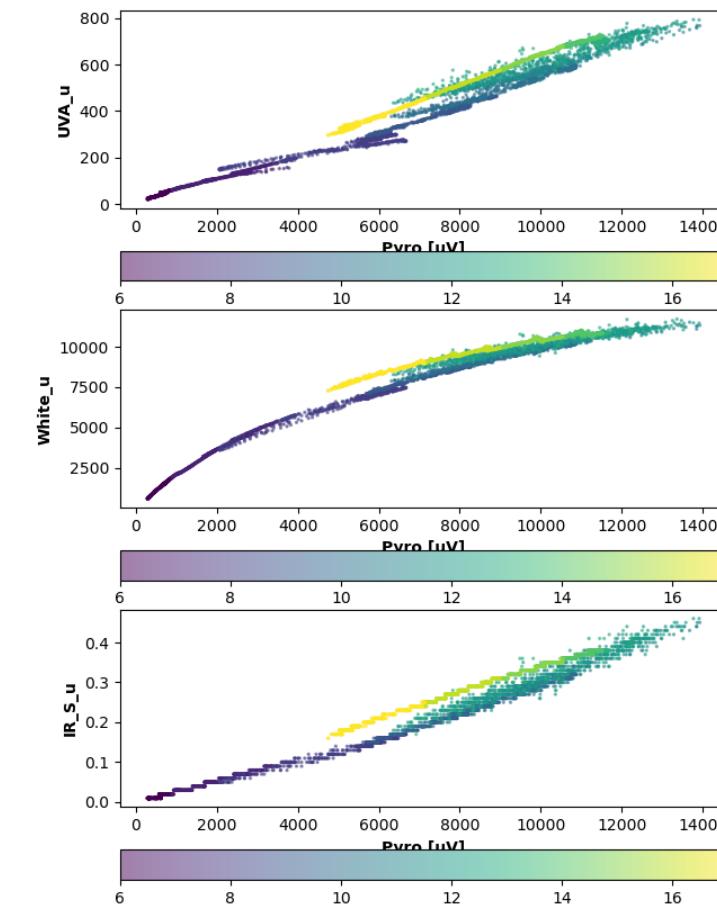
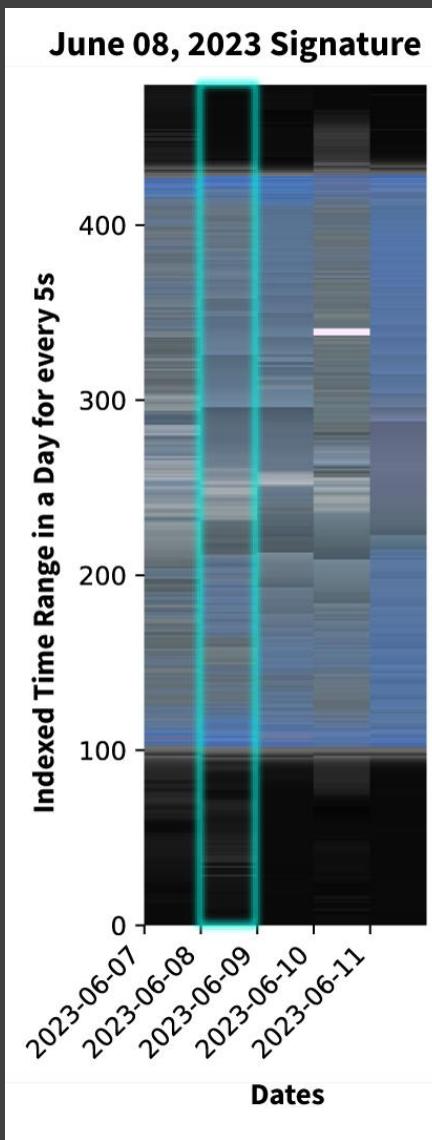
Smoke event of June 14 2023, reached "Very Unhealthy" in Air Quality Index, MN DNR

WILDFIRE SIGNATURE



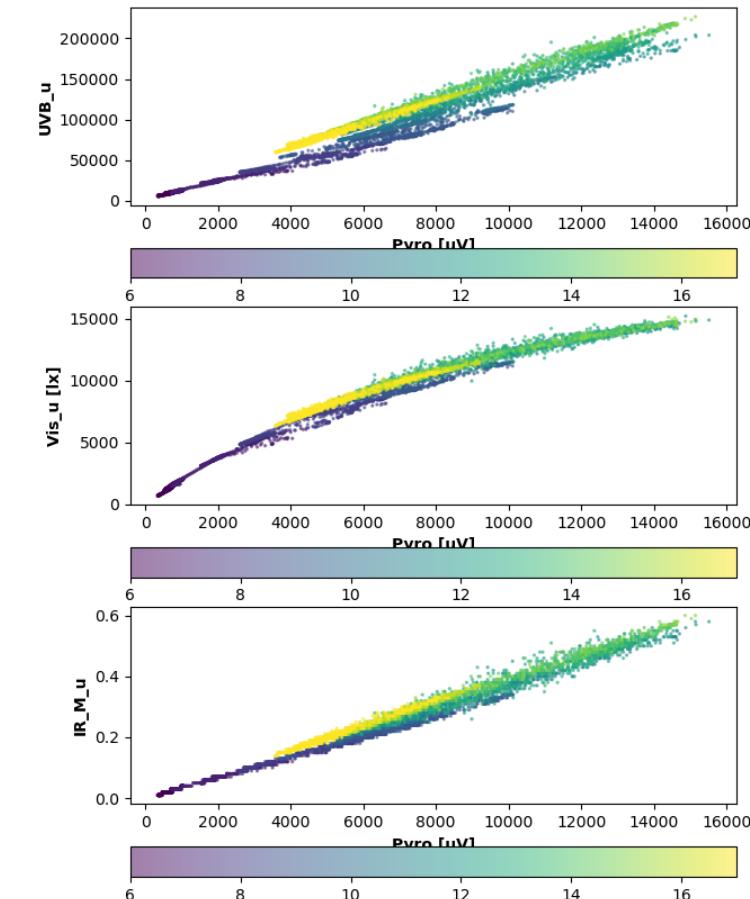
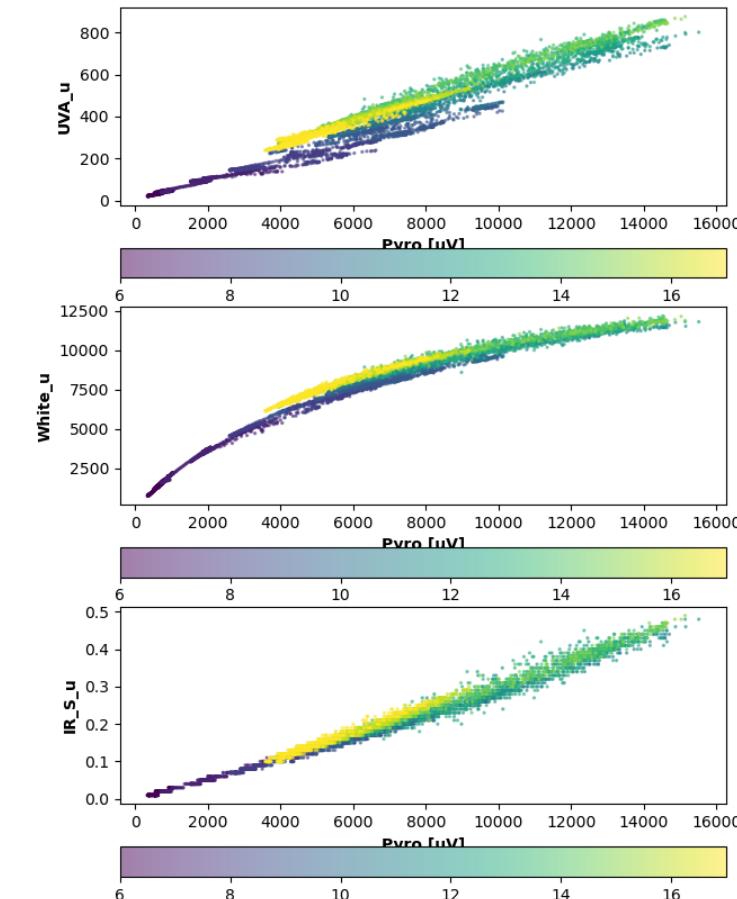
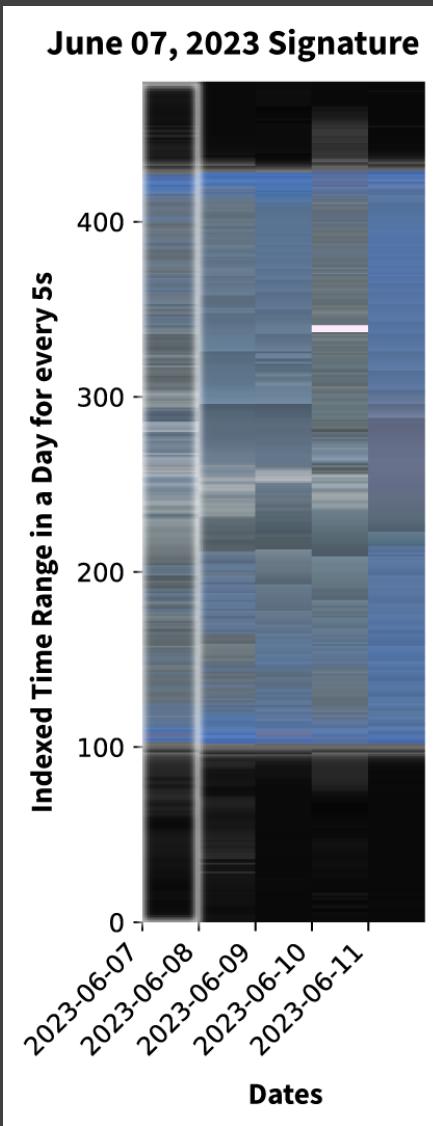
- IR_SW and IR_MW registered low numbers during mid day, could explain why the IR ranging so far down from the linear expectation correlated line?

WILDFIRE SIGNATURE



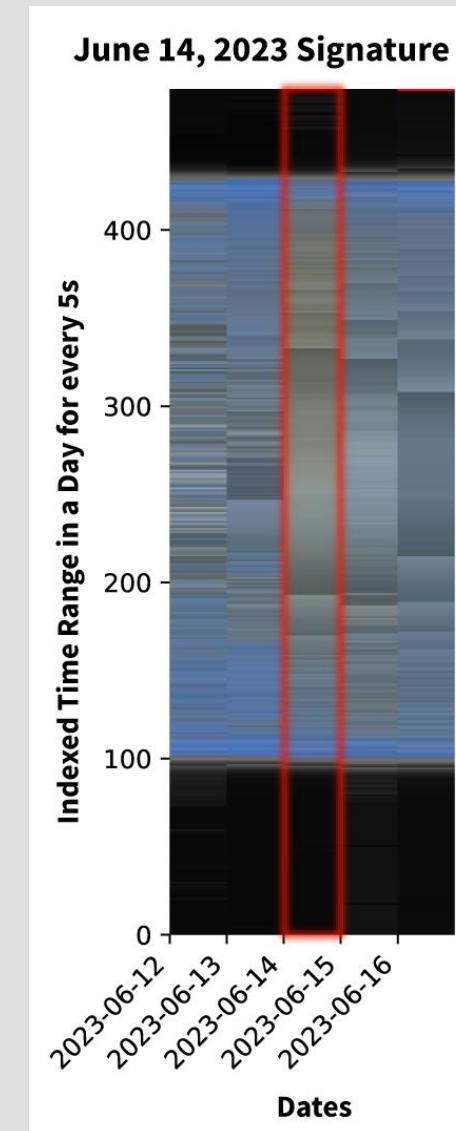
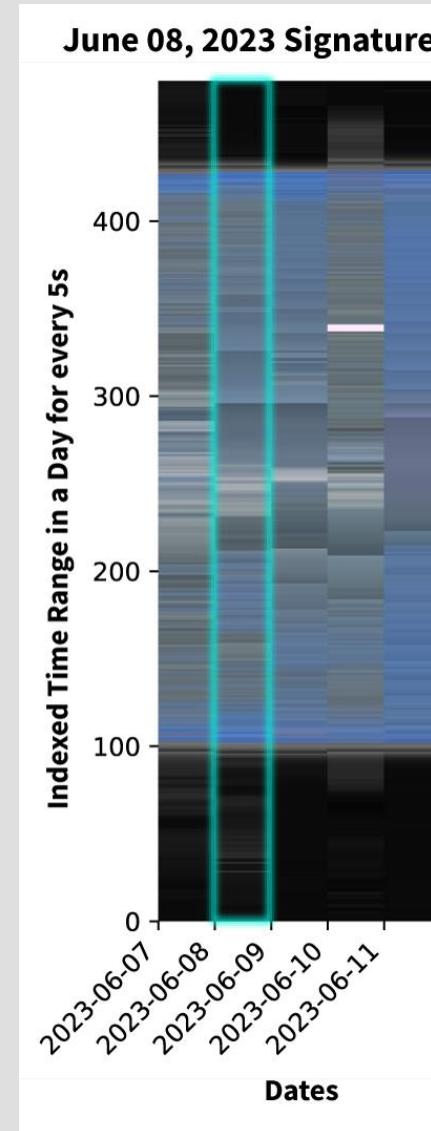
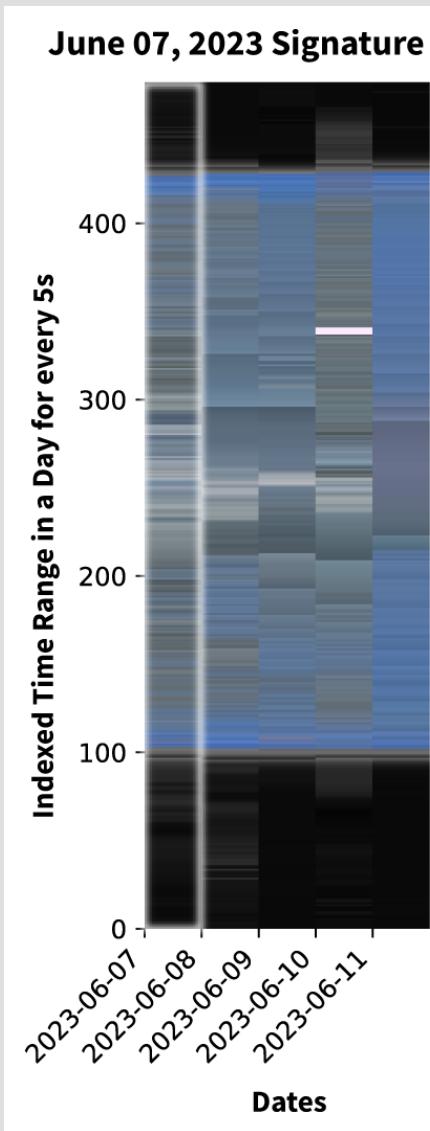
- Relatively sunny condition

WILDFIRE SIGNATURE



- A lot of overcast cloud

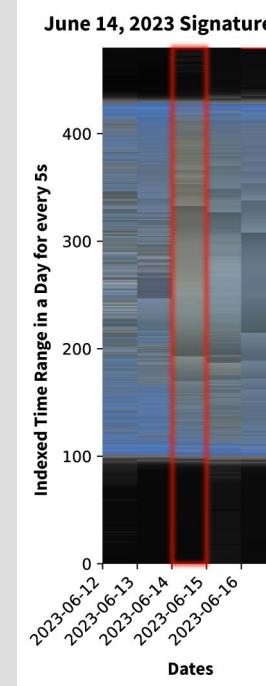
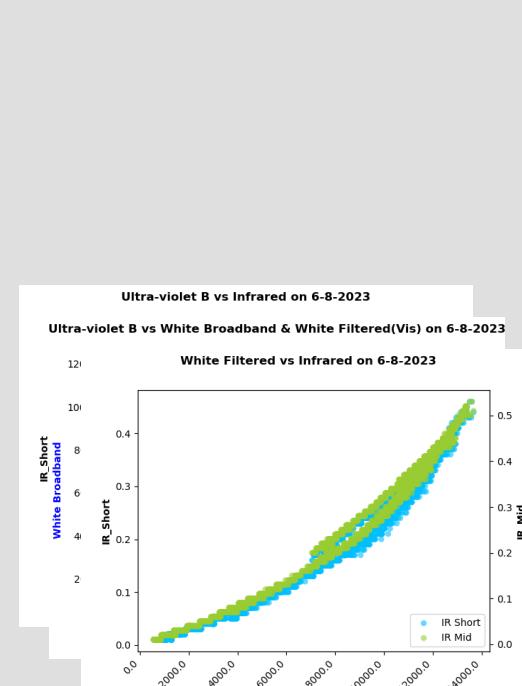
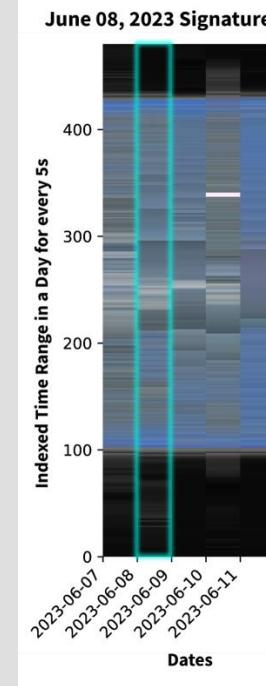
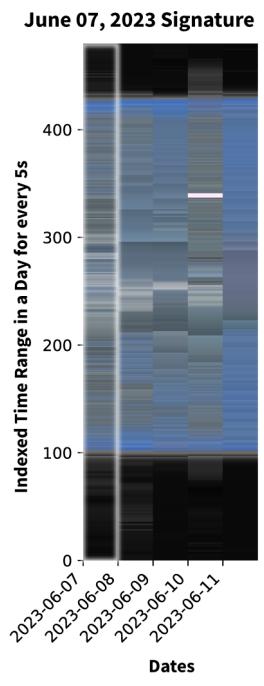
WILDFIRE SIGNATURE



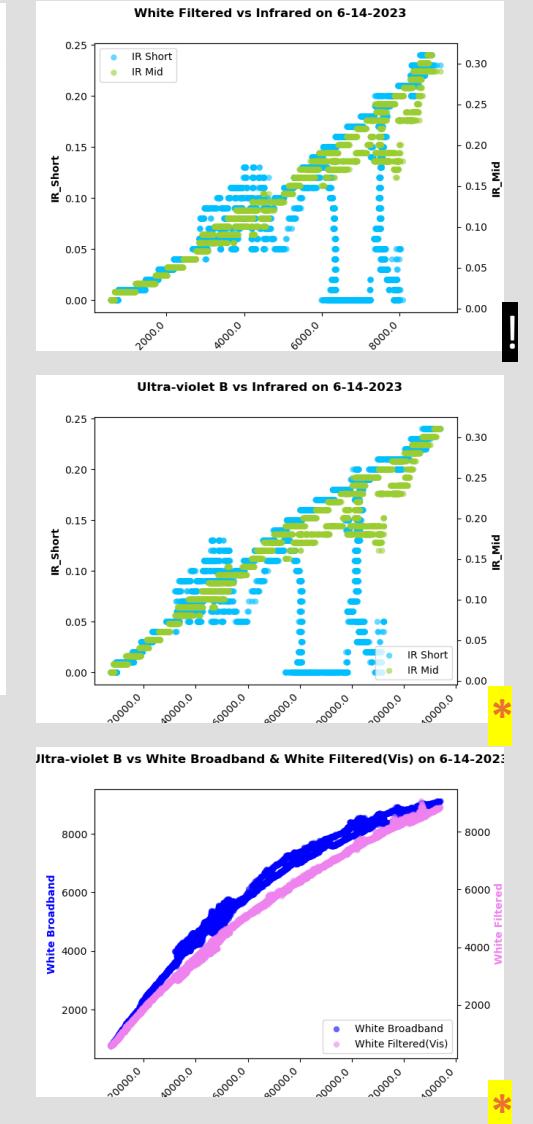
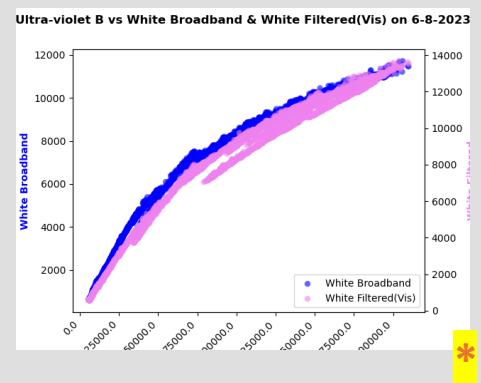
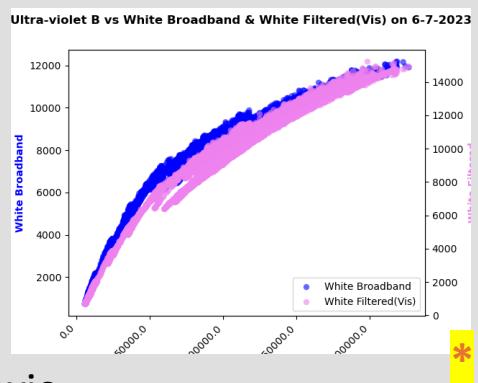
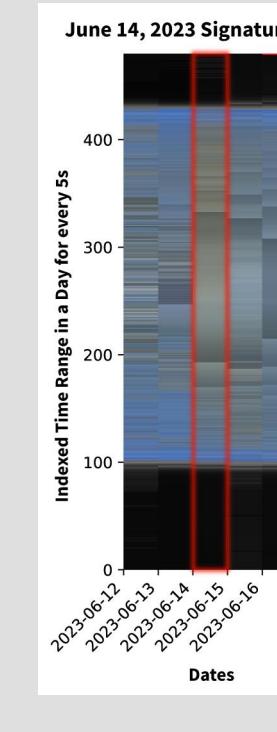
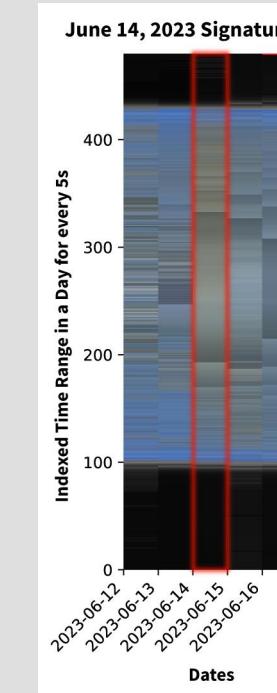
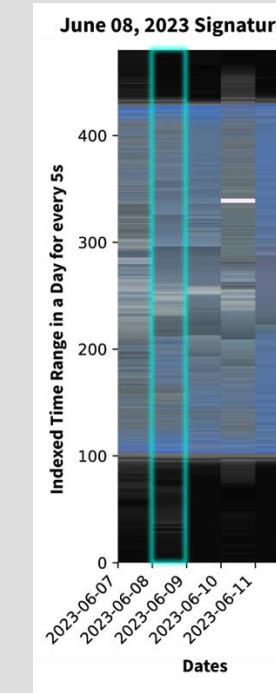
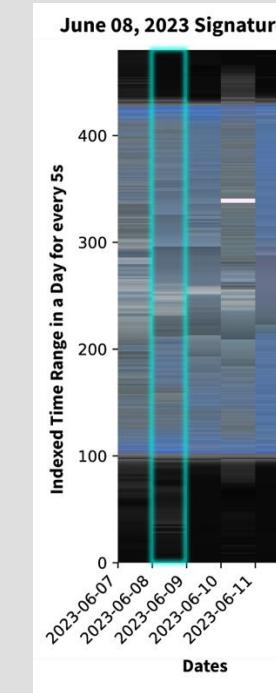
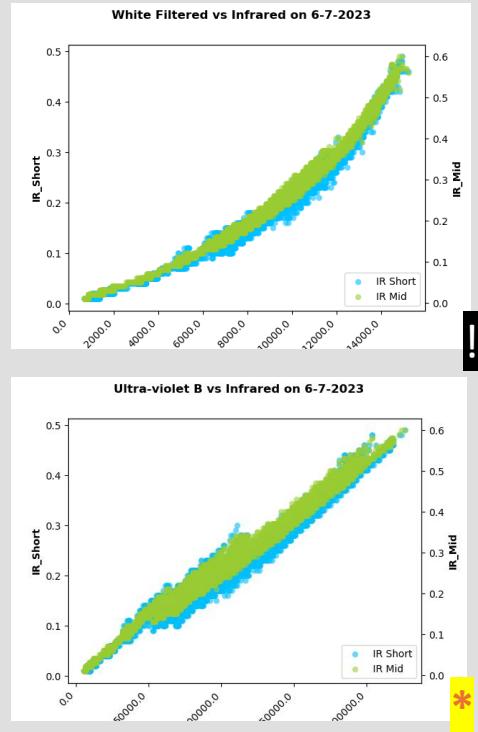
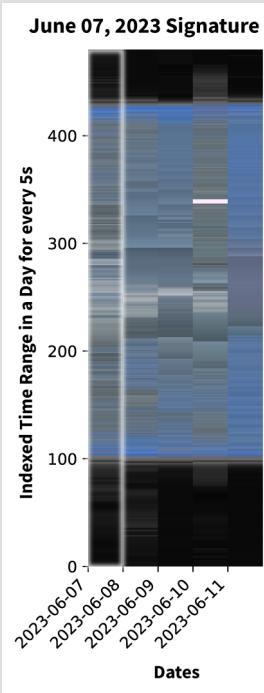
RESULTS

JUNE 7-JULY 5, 2023

WILDFIRE SIGNATURE



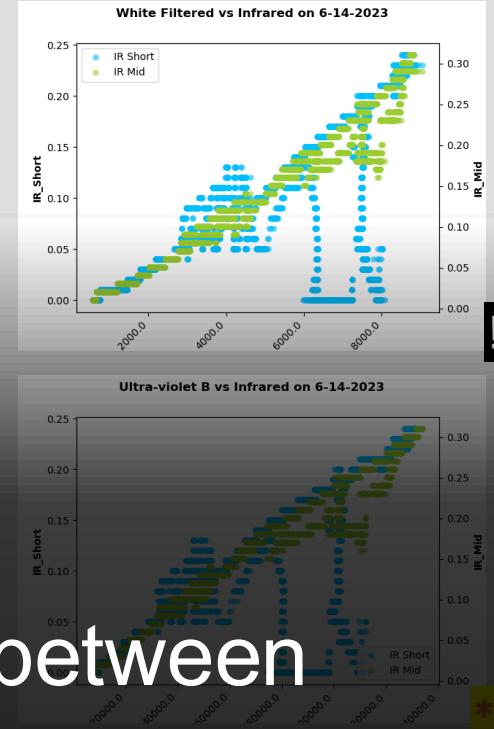
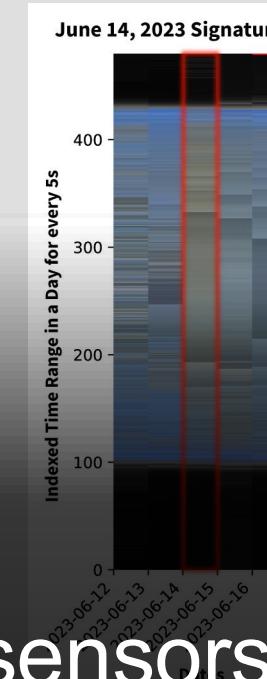
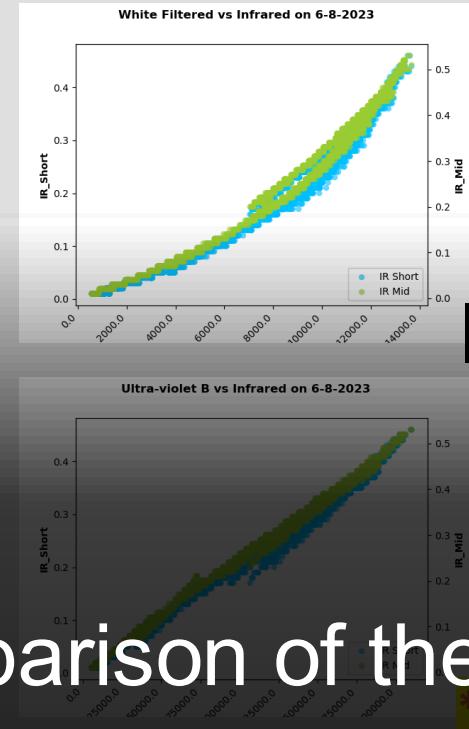
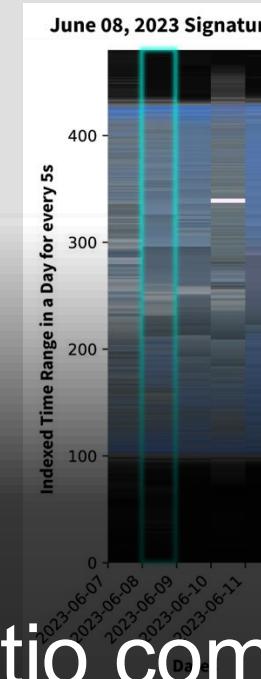
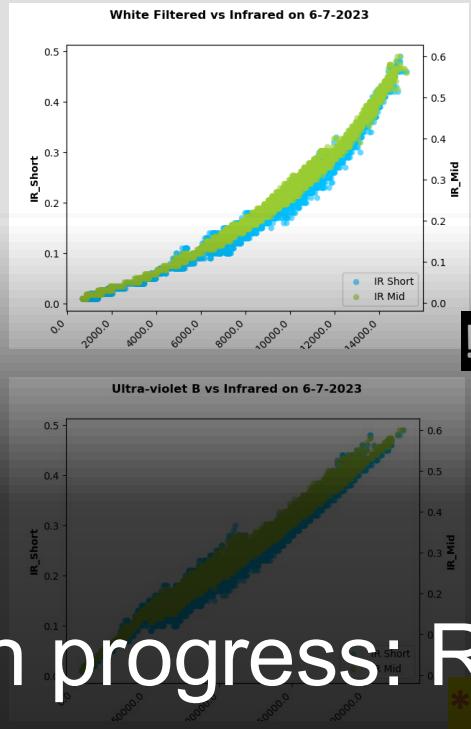
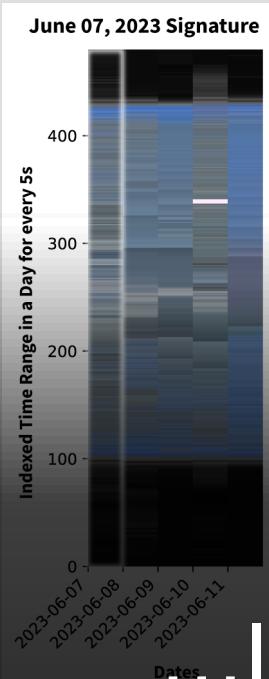
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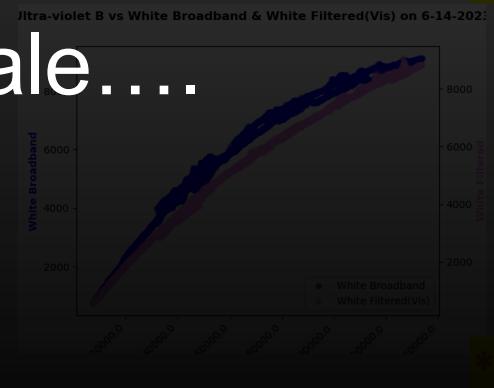
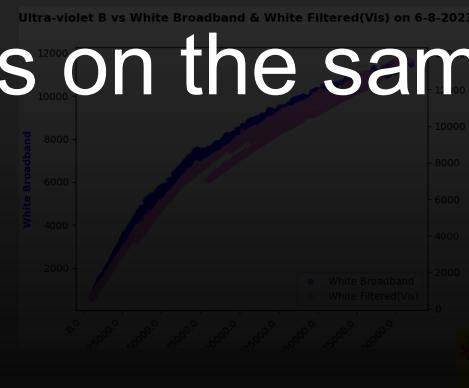
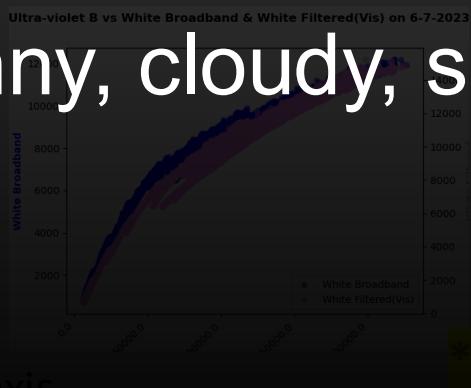
* UVB for x axis

! White Filtered for x axis

WILDFIRE SIGNATURE



...In progress: Ratio comparison of the sensors between sunny, cloudy, smoke plots on the same time scale....



* UVB for x axis

White Filtered for x axis

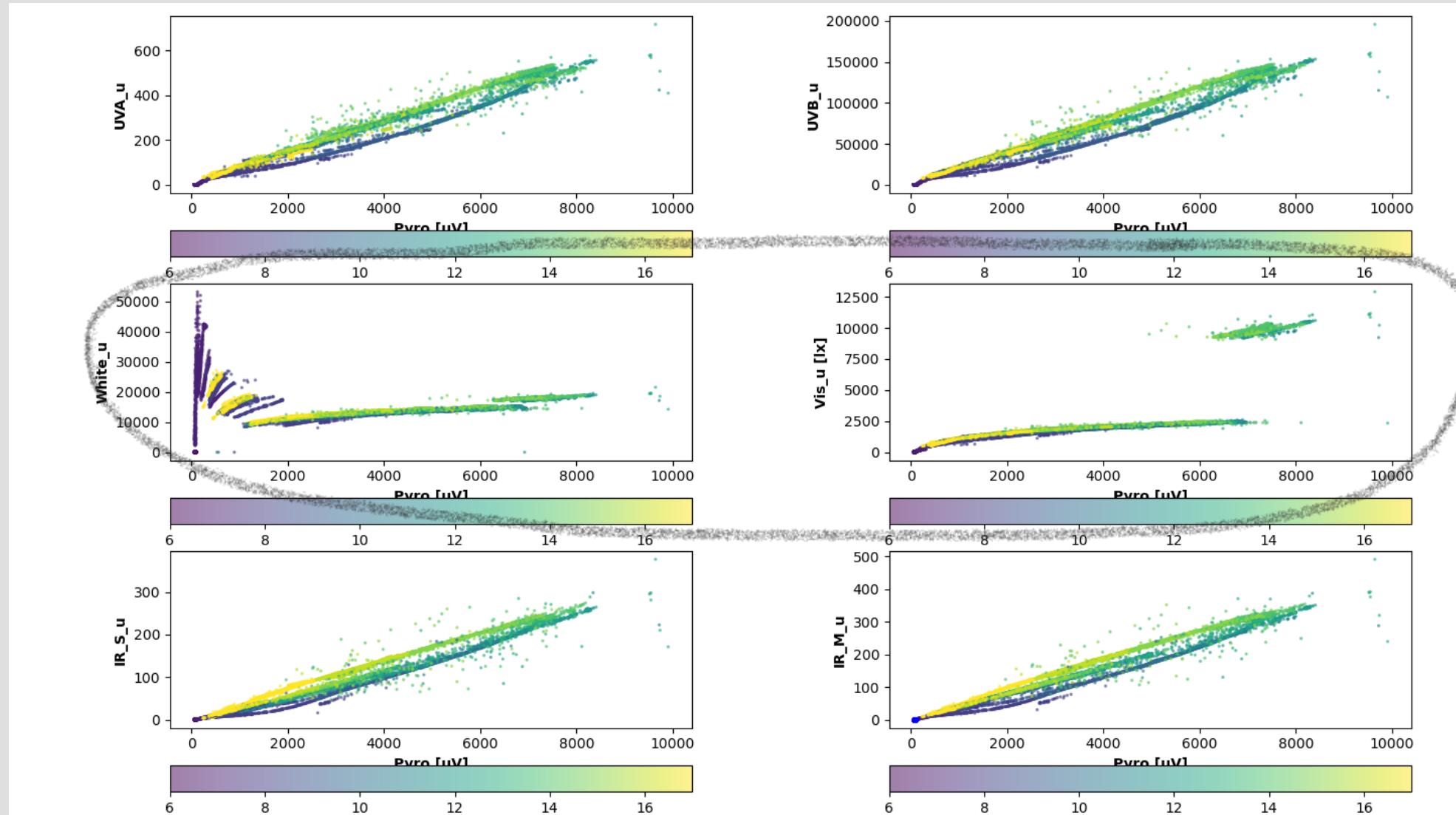
WILDFIRE SIGNATURE

- Not far after June 14 beginning on the 19th the battery level of the instrument reaching < 3.5V
- Margay logger operates \geq 3.5V
- Condensation happened → board corrosion
- Could not look further into the high-quality data beyond the 19th



OCT 10-13, 2024, DATA

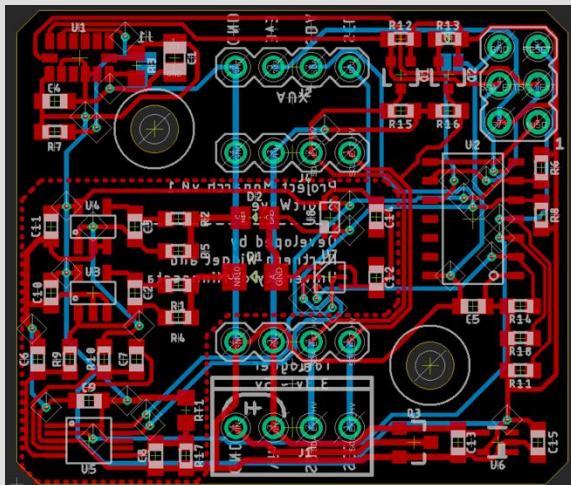
- Because the layer of Teflon that filter and protect the board was peeled off possibility from the winter to spring transition.
- The old board cannot be read and new board needed for the 2024 test.



Data measured from Monarch Board plotted with Pyranometer value from CMP3 in x axis

OCT 10-13, 2024, DATA

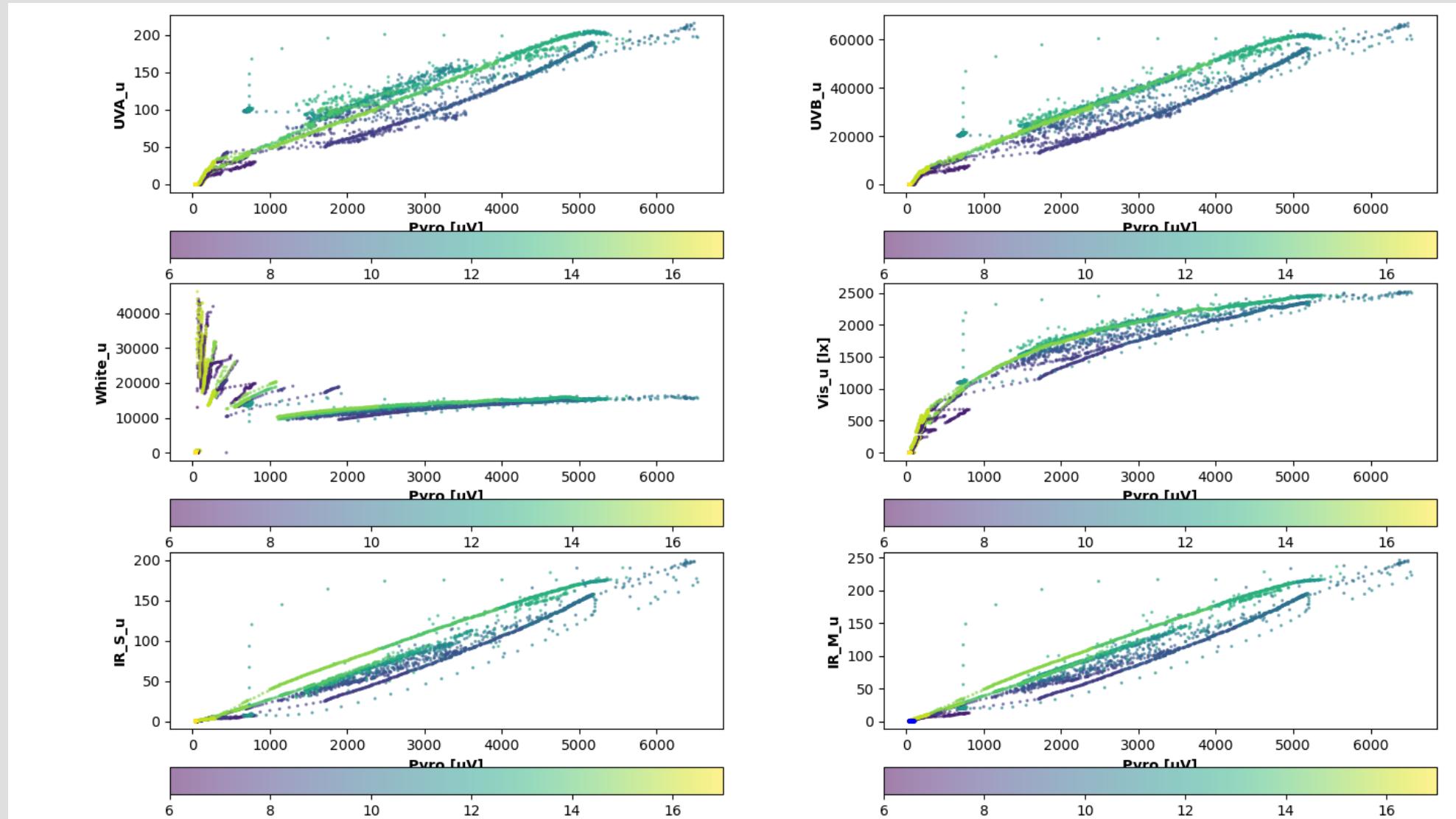
- 2 ways to look at this dataset
 1. Could be from the hardware itself where the I2C interface on the Vis board has problem in communication (bad soldering from the manufacture that we contracted?)
 2. Could coming from the container itself (Monarch's housing)



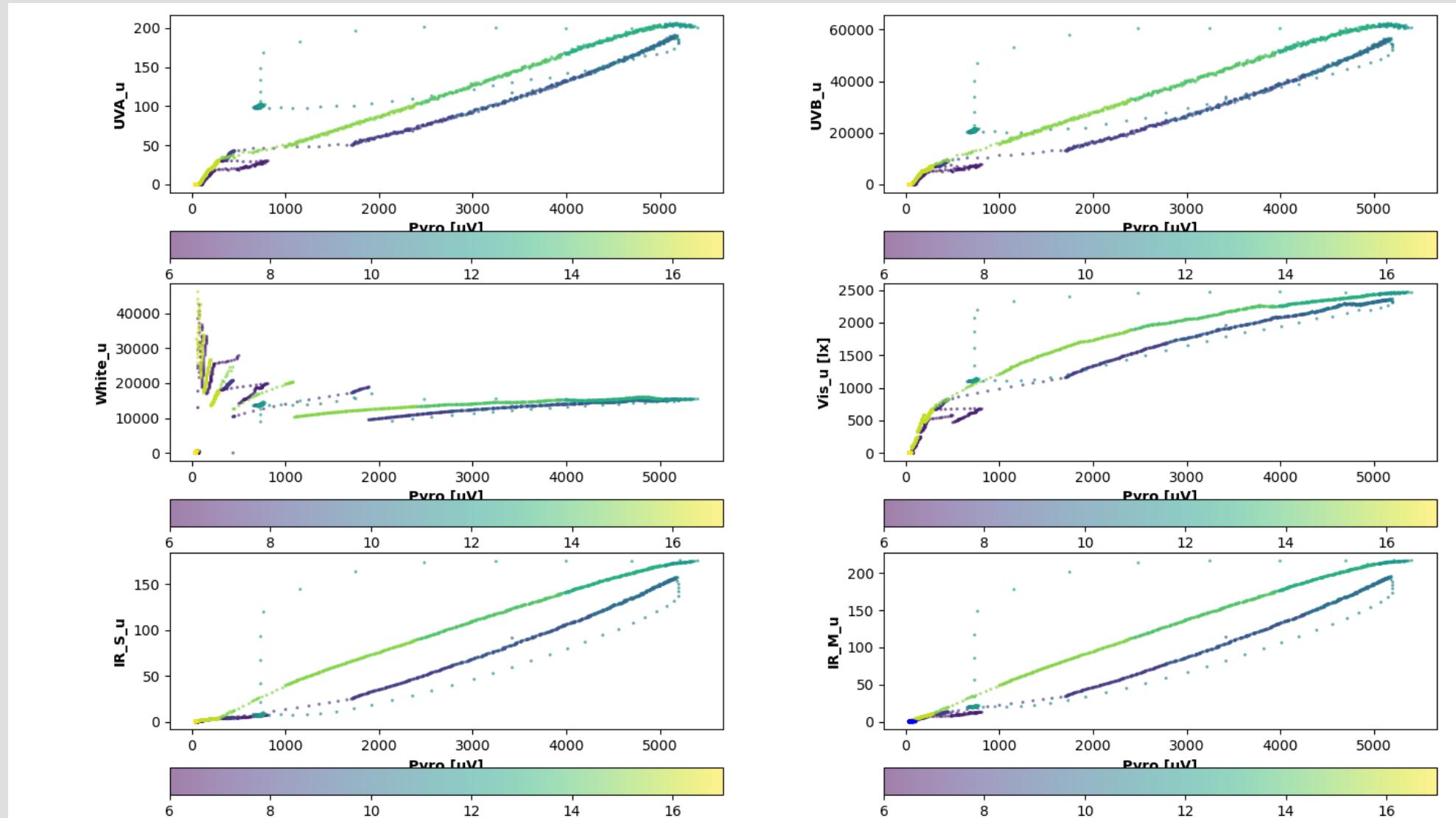
OCT 10-13, 2024, DATA

- Identified problem:
 - Whole batch of Monarch has issue with an I2C component was not securely soldered because it was a heat sink.
 - Did not fully reflow in oven
 - This issue will take longer to resolve.
- Solution: use the hand-soldered board used for the Ecuador project.

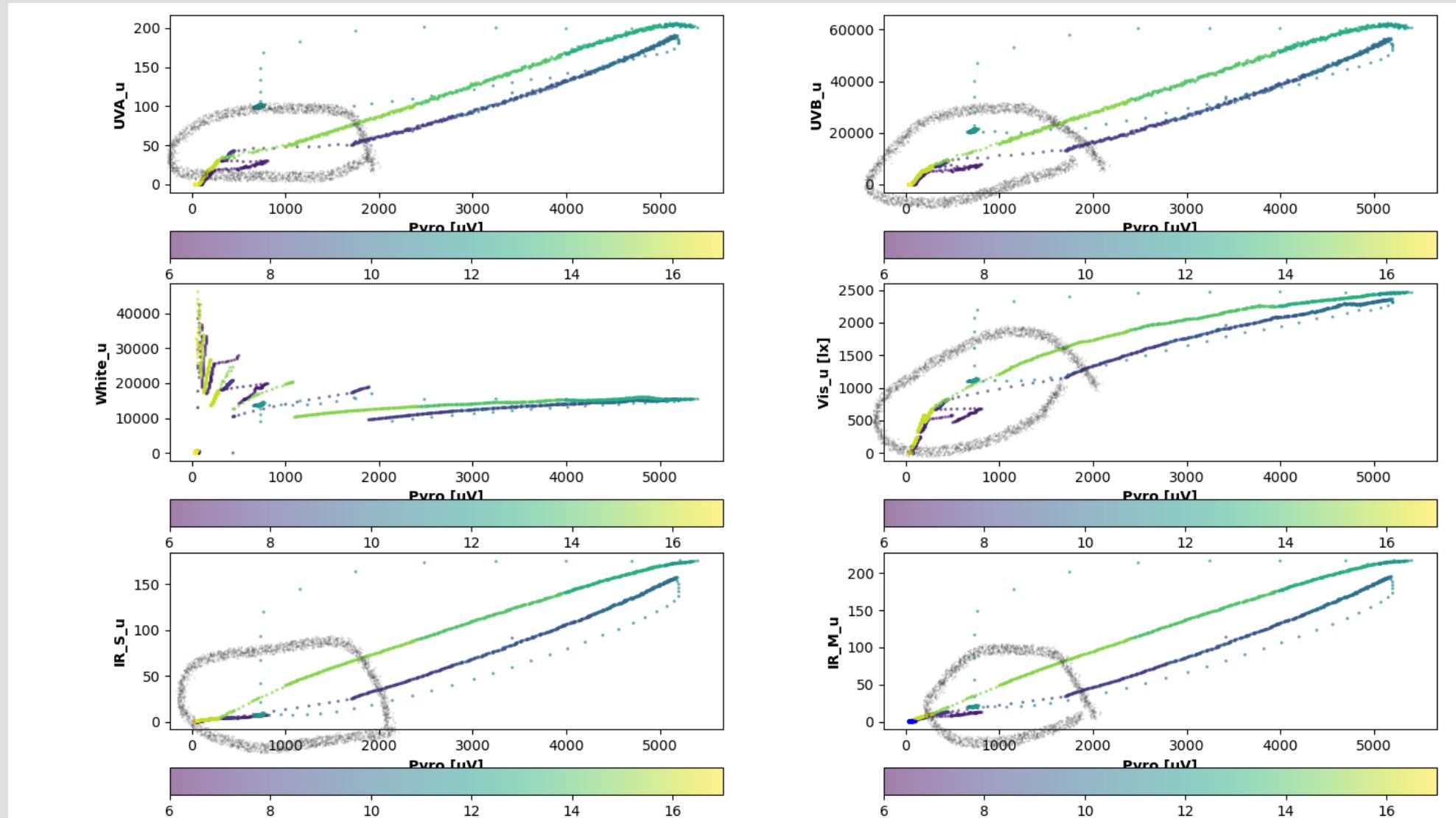




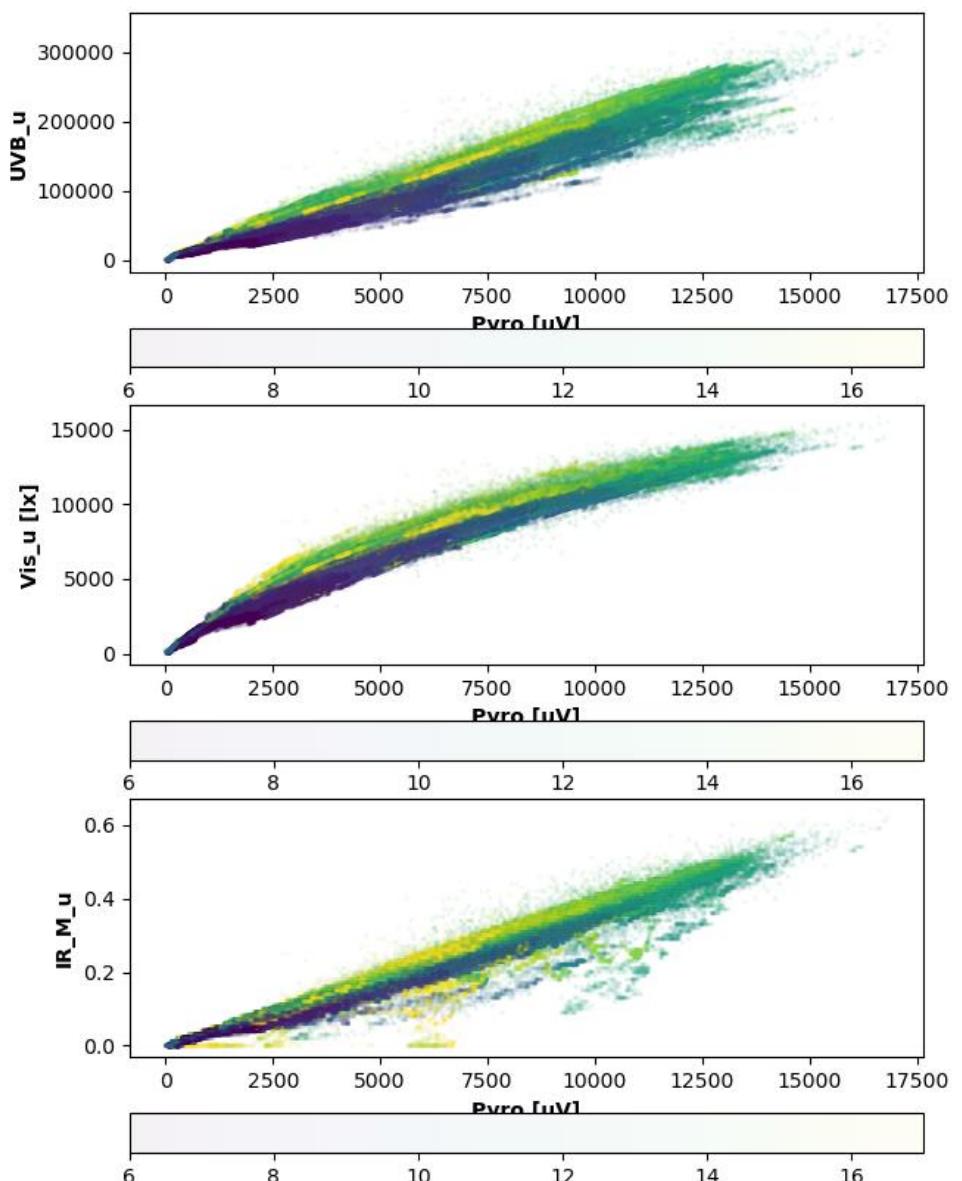
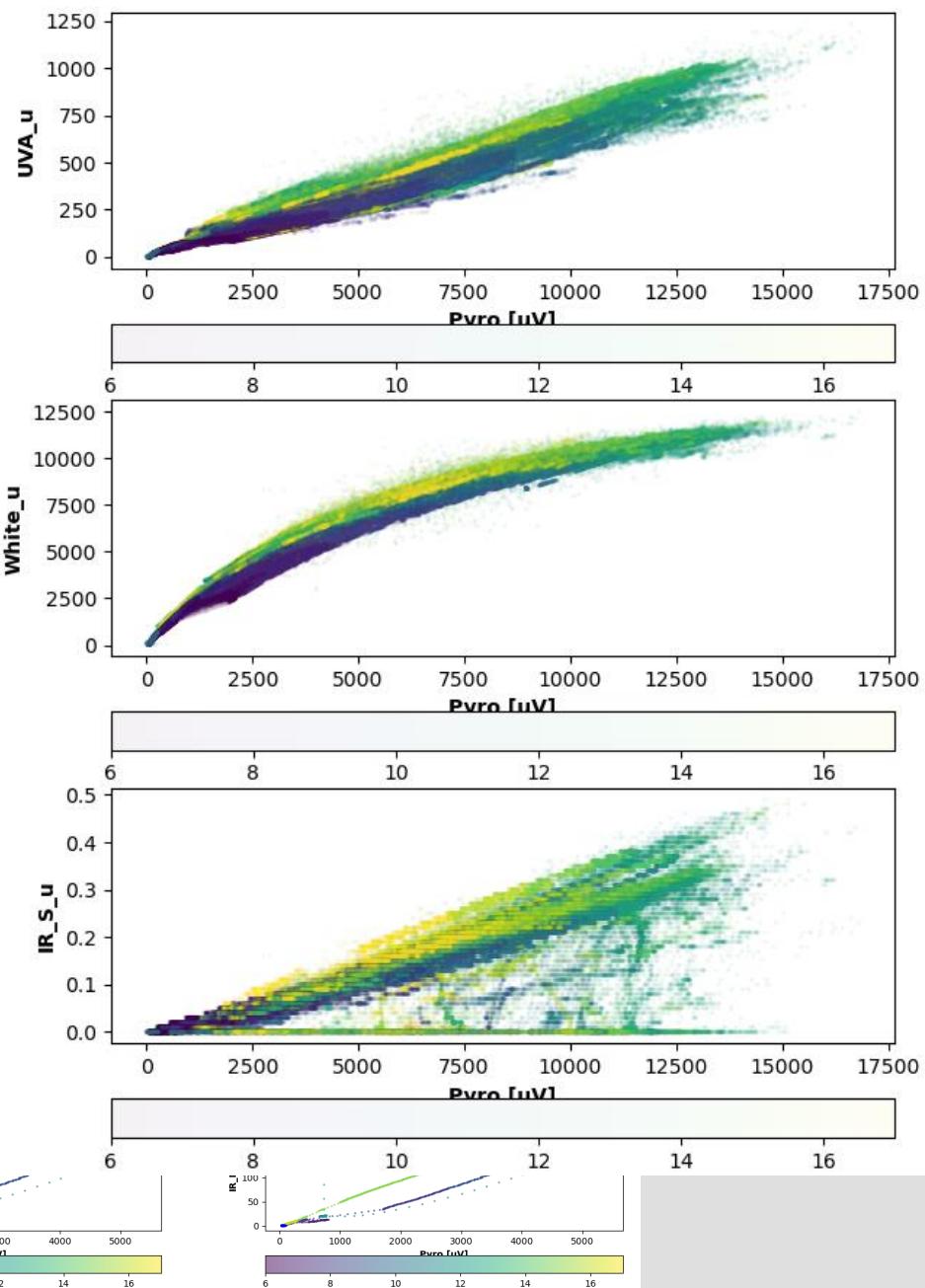
Data measured Between 16 and 17 November



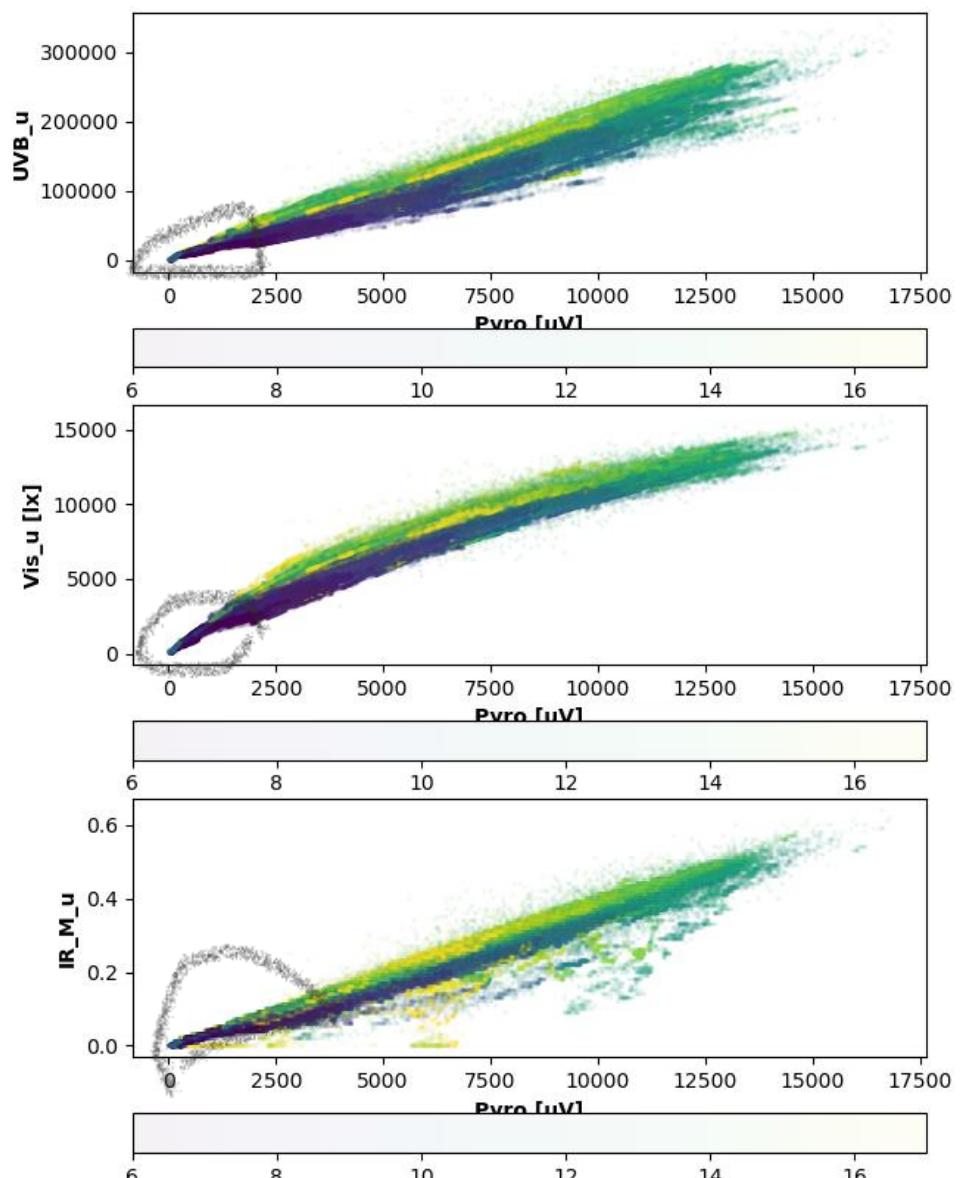
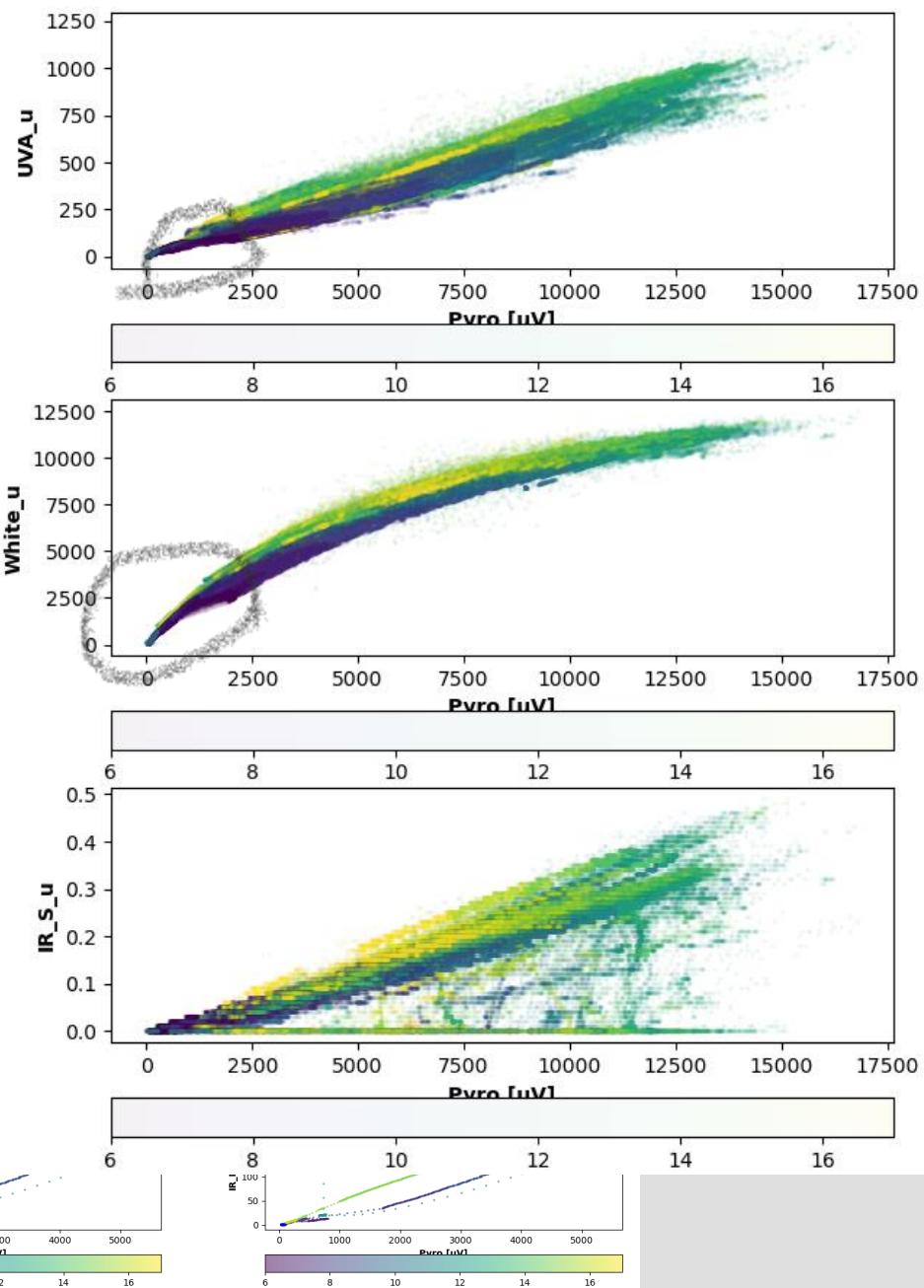
Data measured on 17 November because it is with sunny condition



Data measured on 17 November because it is with sunny condition



2023 Data



2023 Data

CONDENSATION

- Humidity and condensation inside the housing resolved by new batch of desiccant

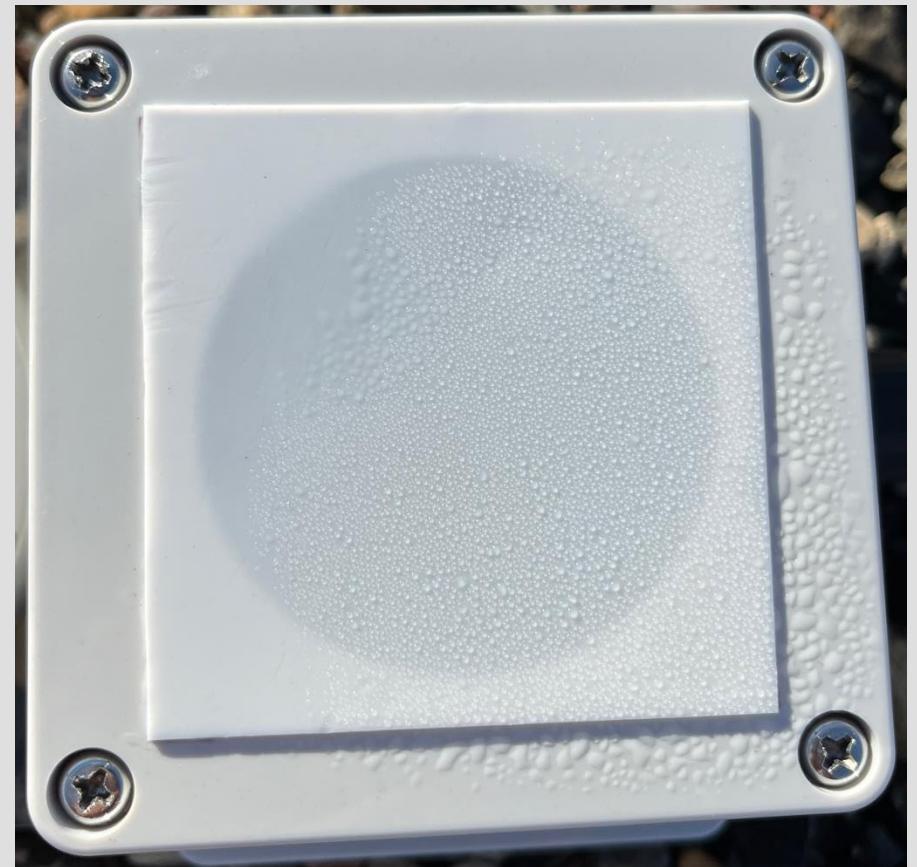


Desiccant inside Margay Housing



Desiccant inside Monarch Housing

- Exterior remains the same issue with condensation in early mornings



MONARCH HOUSING

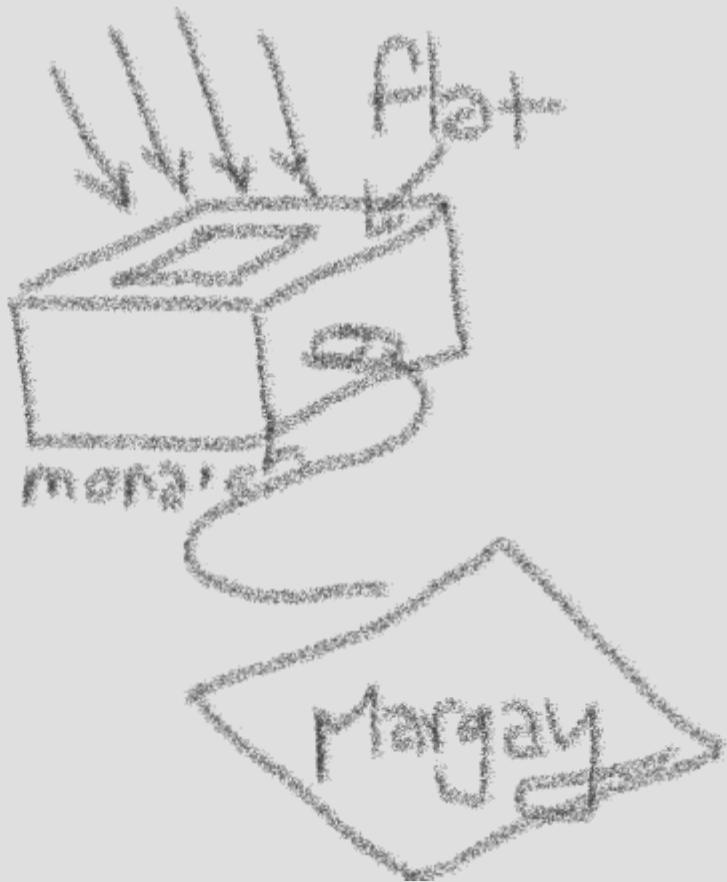
- More control environment with the housing is needed
- Redesign the flat top cover

NEXT STEP

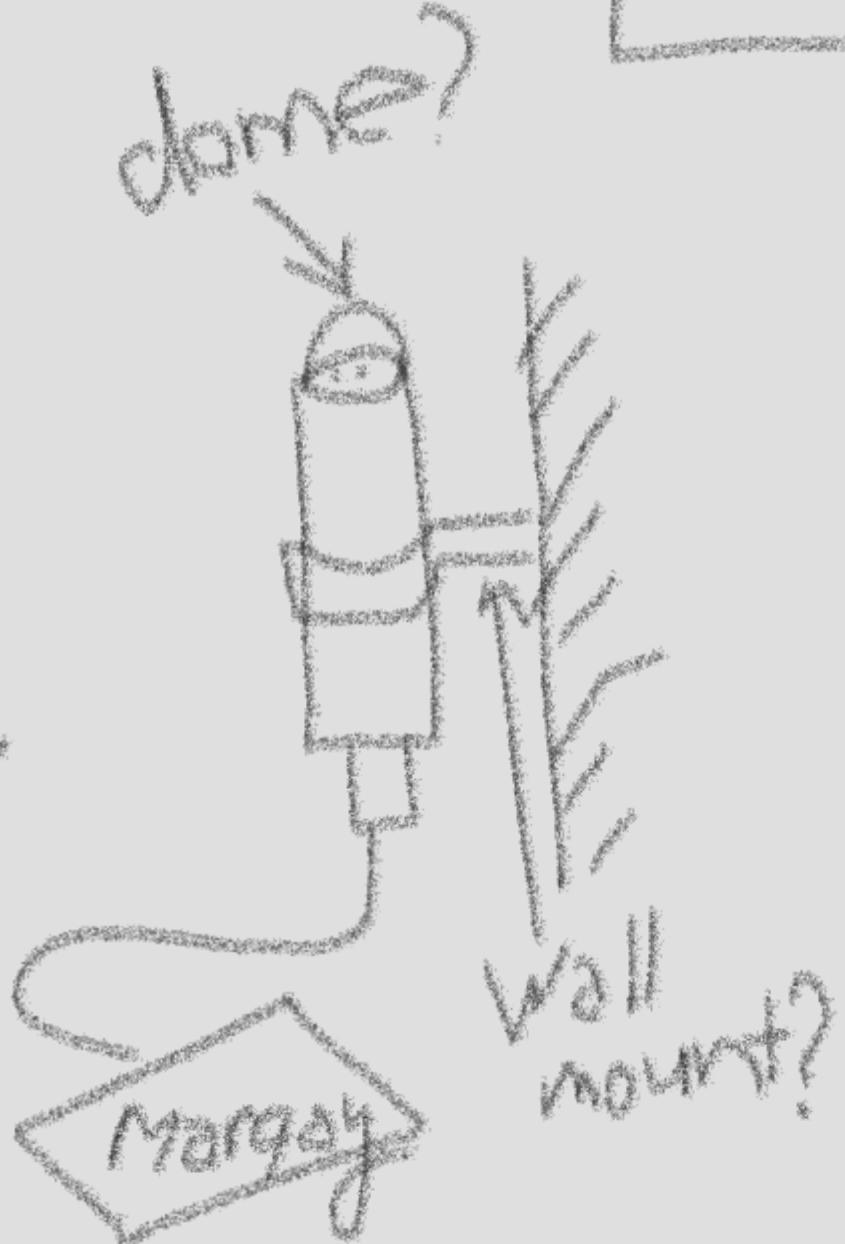
- Continue looking at the new set of data from the hand soldered board
- Averaging RGB values from the set of photos taken by the camera for Nov data
- Redesign and Improve the housing for Monarch...
 - Host engineering design event: Senior design team in MechE

NEXT STEP

CURRENT



NEW?



OPEN



FOR THE DEVELOPMENT OF A BETTER SOLAR RADIATION INSTRUMENT

QUESTION?

Thanks a million, to Bobby Schulz, Uma Arshani and Andy Wickert

