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# Assessment of UAV image quality in terms of optical resolution

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Evaluate the quality of images  
from different UAV sensors in  
terms of their optical resolution



# Motivation

1



UAVs have  
successfully  
become part of  
modern  
photogrammetry  
and remote sensing



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4

Image sharpness vary  
with altitude and  
environmental  
conditions



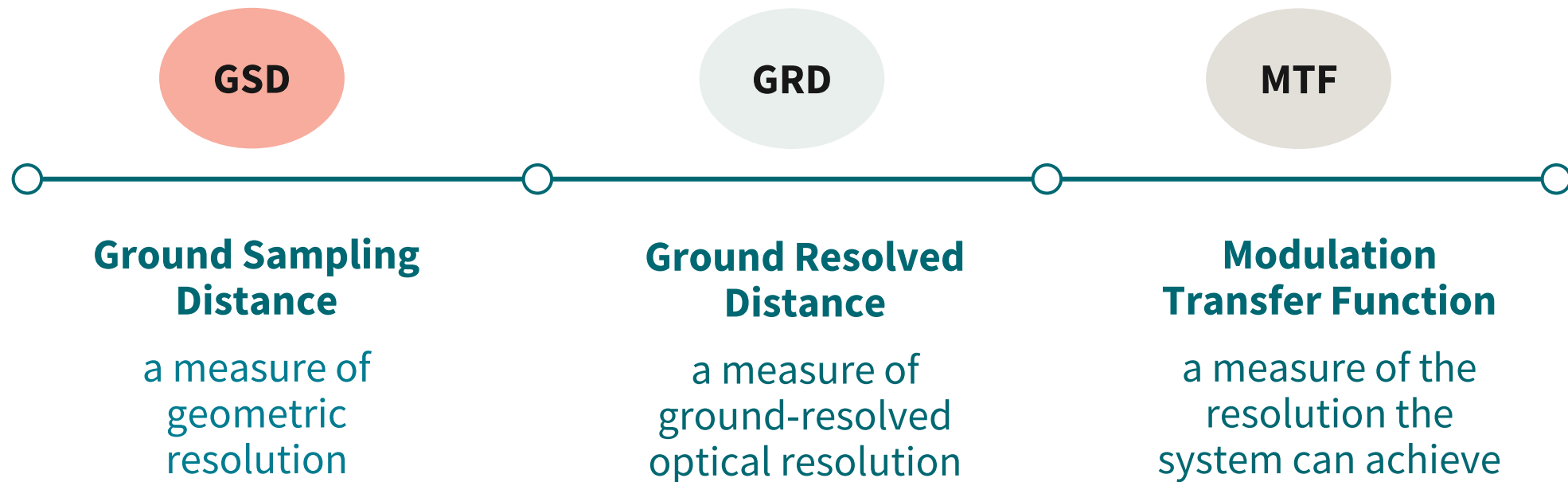
# Assessment of radiometric image quality

- Sharpness
- Contrast
- Resolution

The main indicators of image quality are the signal-to-noise ratio and the radiometric accuracy and stability of the sensor.



# Assessment of radiometric image quality - measures







# Cameras



Mavic 3E



Matrice 4E



Phantom 4 RTK



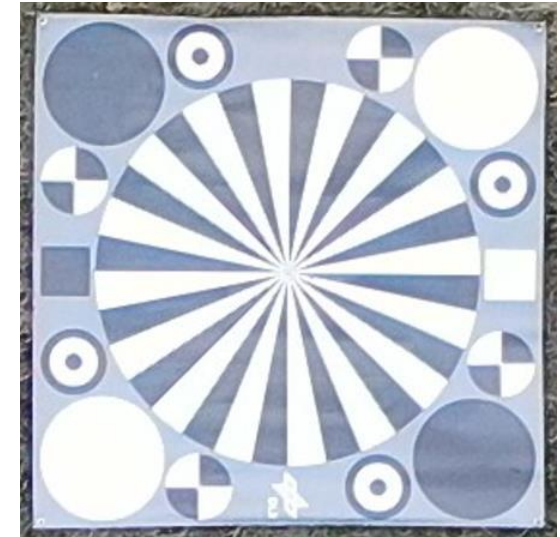
Zenmuse P1

| Camera       | Mavic 3E           | Matrice 4E        | Phantom 4 RTK     | Zenmuse P1        |
|--------------|--------------------|-------------------|-------------------|-------------------|
| Pixel size   | 3.3 $\mu\text{m}$  | 3.3 $\mu\text{m}$ | 2.4 $\mu\text{m}$ | 4.4 $\mu\text{m}$ |
| Focal length | 12.29 mm           | 12.29 mm          | 8.8 mm            | 35 mm             |
| FOV          | 84°                | 84°               | 84°               | 63.3°             |
| Resolution   | 5280×3956          |                   | 5472×3648         | 8192×5460         |
| Shutter type | Mechanical shutter |                   |                   |                   |



# Experiments

- tests with Siemens star
- test field for UAVs in Józefosław near Warsaw
- four different sensors
- flight in various lighting and weather conditions, and at different altitudes
- evaluation of the optical resolution using the software ResolvingPower developed by The German Aerospace Center (DLR)



Resolving Power



# Experiments

**Influence of  
flight altitude  
on optical  
resolution**

**Influence of  
lighting  
conditions**

**Analysis of  
point clouds  
from dense  
image matching**



# Experiments

**Influence of  
flight altitude  
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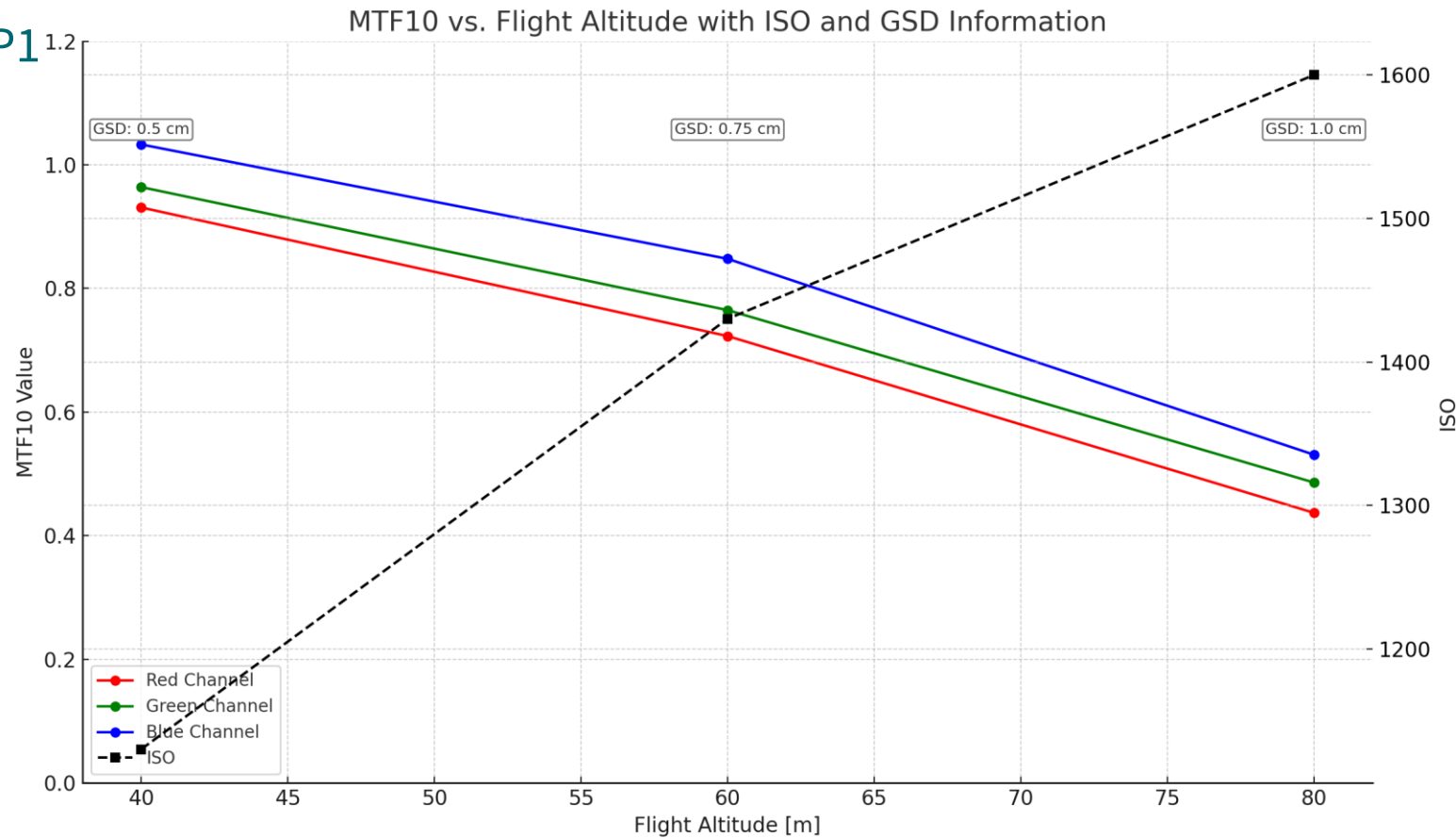
**Influence of  
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# Experiments

## DJI Zenmuse P1

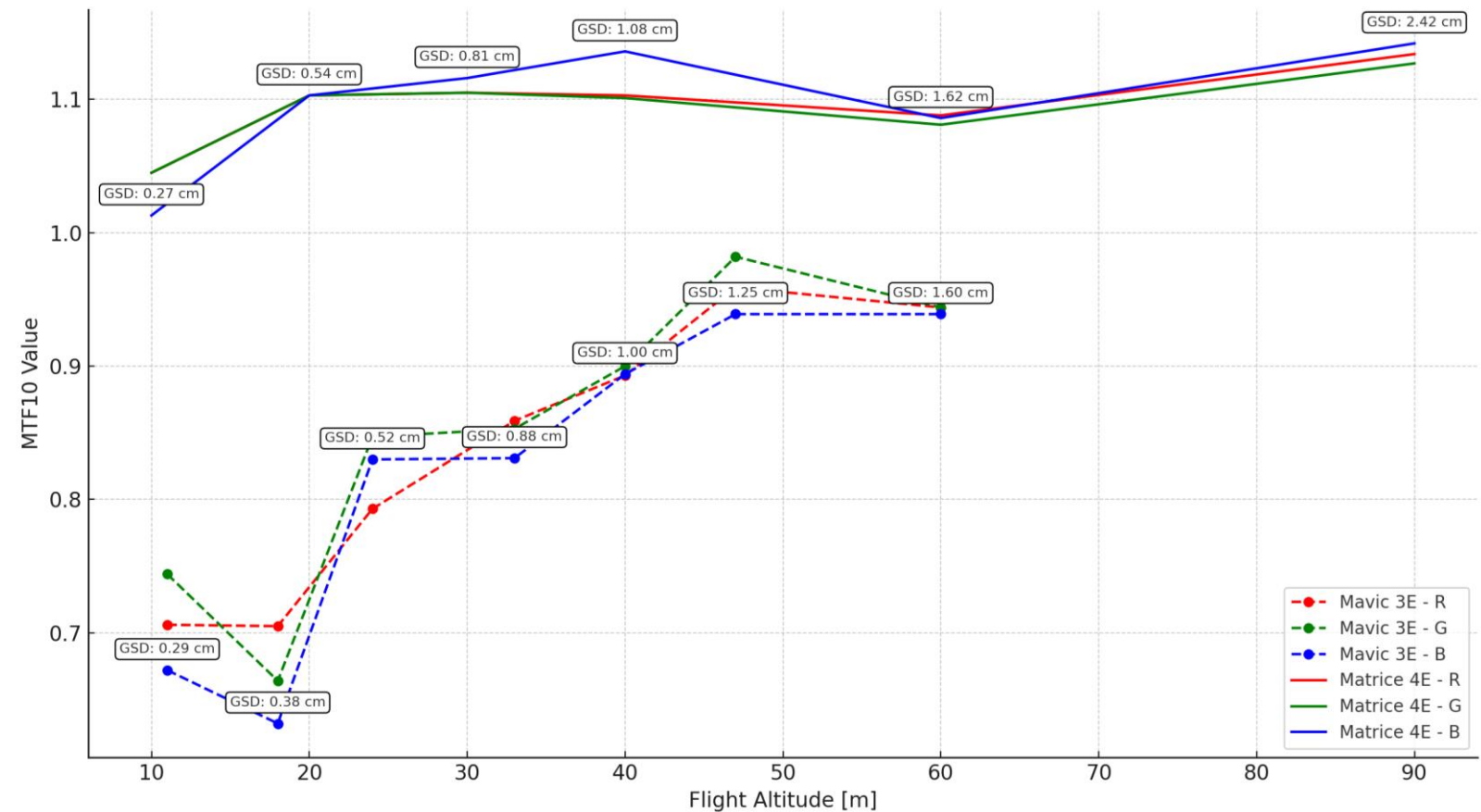


Dependence of MTF10 value on flight altitude and ISO parameter



# Experiments

## Mavic 3E and Matrice 4E

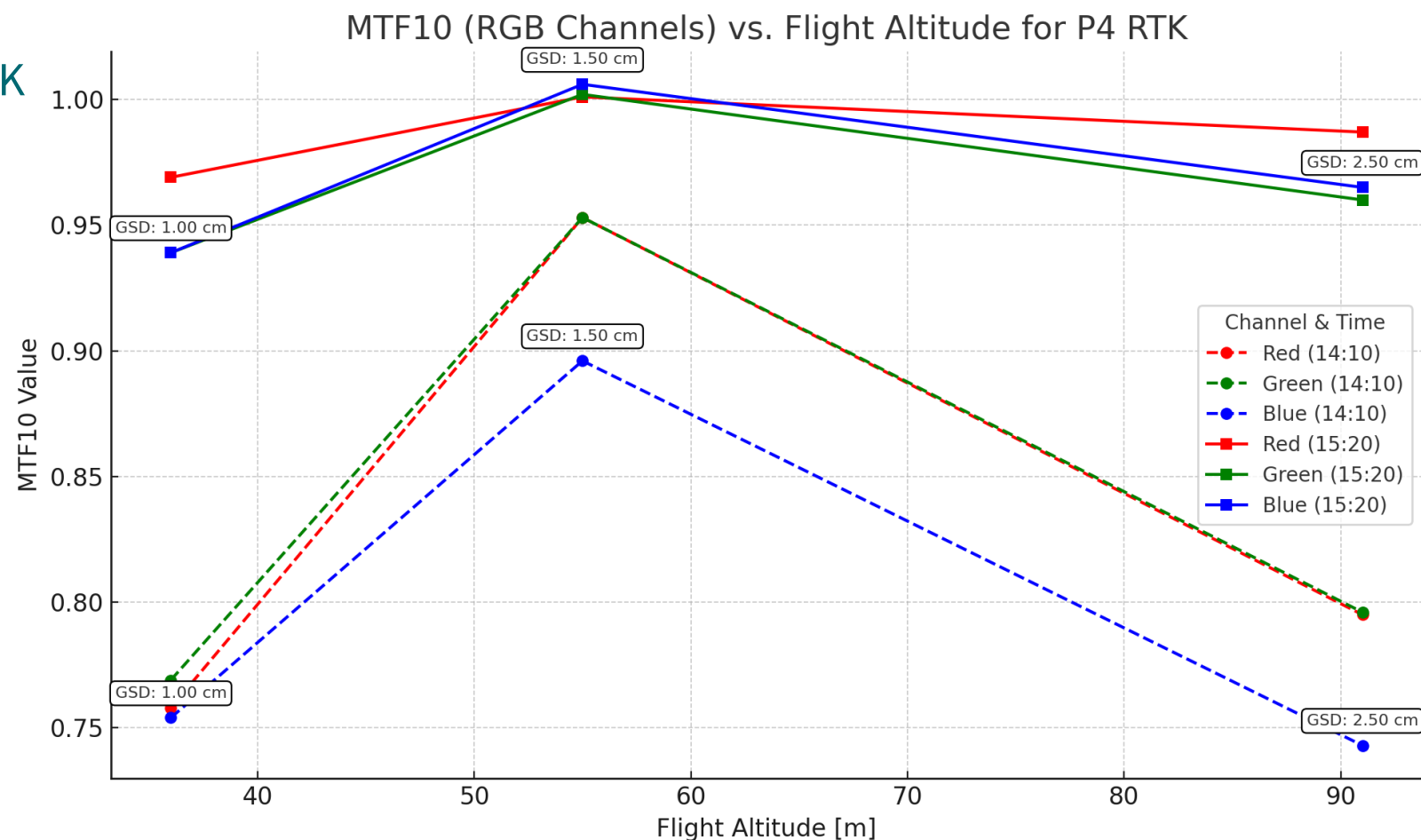


The values of MTF10 for Mavic 3E and Matrice 4E in relation to the flight altitudes



# Experiments

Phantom 4 RTK

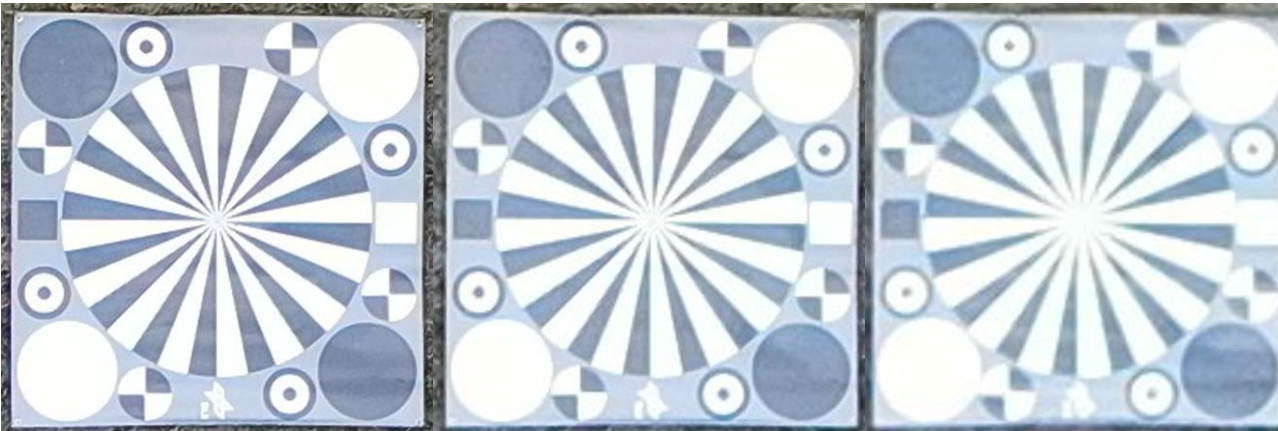


Dependence of MTF10 value on flight altitude and ISO parameter for DJI Zenmuse P1.





# Experiments



Example of Siemens star on images  
from P1 camera (40, 60 and 80 m AGL).

| Camera         | Flight Height | MTF10 (AVG) | GRD  | GSD [cm] | ISO  | Time       |
|----------------|---------------|-------------|------|----------|------|------------|
| DJI Zenmuse P1 | 40m           | 0,976       | 0,51 | 0,50     | 1130 | 03:30 p.m. |
| DJI Zenmuse P1 | 60m           | 0,779       | 0,96 | 0,75     | 1430 | 03:30 p.m. |
| DJI Zenmuse P1 | 80m           | 0,485       | 2,06 | 1,00     | 1600 | 03:30 p.m. |
| P4_RTK         | 36m           | 0,760       | 1,31 | 1,00     | 800  | 02:10 p.m. |
| P4_RTK         | 36m           | 0,949       | 1,05 | 1,00     | 800  | 03:20 p.m. |
| P4_RTK         | 55m           | 0,934       | 1,61 | 1,50     | 800  | 02:10 p.m. |
| P4_RTK         | 55m           | 1,003       | 1,50 | 1,50     | 800  | 03:20 p.m. |
| P4_RTK         | 91m           | 0,778       | 3,21 | 2,50     | 800  | 02:10 p.m. |
| P4_RTK         | 91m           | 0,971       | 2,58 | 2,50     | 800  | 03:20 p.m. |
| M3E            | 60m           | 0,944       | 1,70 | 1,60     | 100  | 11:30 a.m. |
| M3E            | 47m           | 0,959       | 1,30 | 1,25     | 100  | 11:30 a.m. |
| M3E            | 39m           | 0,897       | 1,17 | 1,05     | 100  | 11:30 a.m. |
| M3E            | 33m           | 0,859       | 1,02 | 0,88     | 100  | 11:30 a.m. |
| M3E            | 24m           | 0,806       | 0,79 | 0,64     | 100  | 11:30 a.m. |
| M3E            | 18m           | 0,667       | 0,72 | 0,48     | 100  | 11:30 a.m. |
| M3E            | 11m           | 0,706       | 0,41 | 0,29     | 100  | 11:30 a.m. |
| Matrice4       | 90m           | 1,134       | 2,14 | 2,42     | 120  | 9 a.m.     |
| Matrice4       | 80m           | 1,078       | 2,00 | 2,15     | 120  | 9 a.m.     |
| Matrice4       | 60m           | 1,112       | 1,45 | 1,61     | 120  | 9 a.m.     |
| Matrice4       | 40m           | 1,105       | 0,97 | 1,07     | 120  | 9 a.m.     |
| Matrice4       | 20m           | 1,098       | 0,49 | 0,54     | 120  | 9 a.m.     |
| Matrice4       | 10m           | 1,034       | 0,26 | 0,27     | 120  | 9 a.m.     |





# Experiments

**Influence of  
flight altitude  
on optical  
resolution**

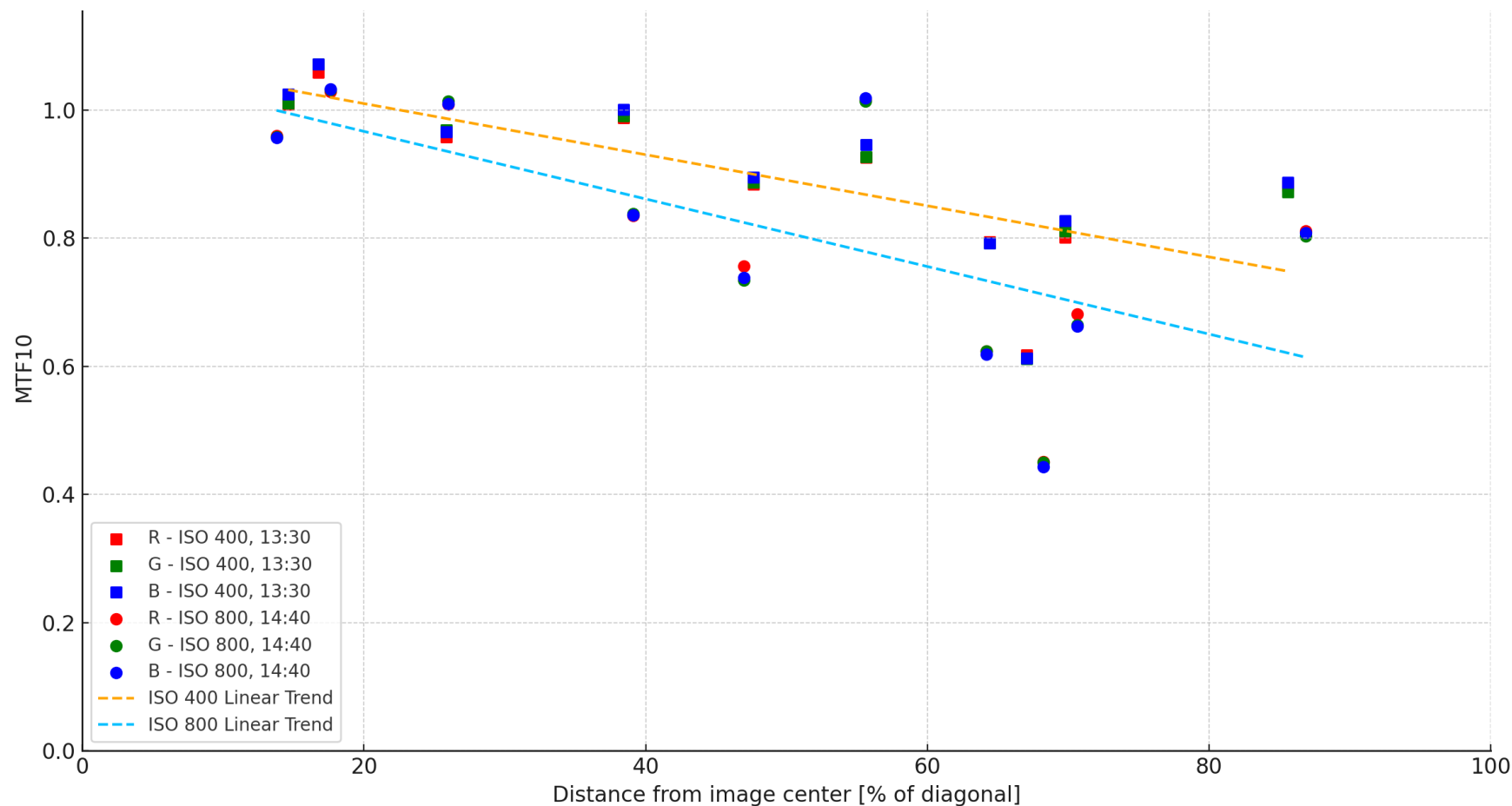
**Influence of  
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# Experiments

Mavic 3E

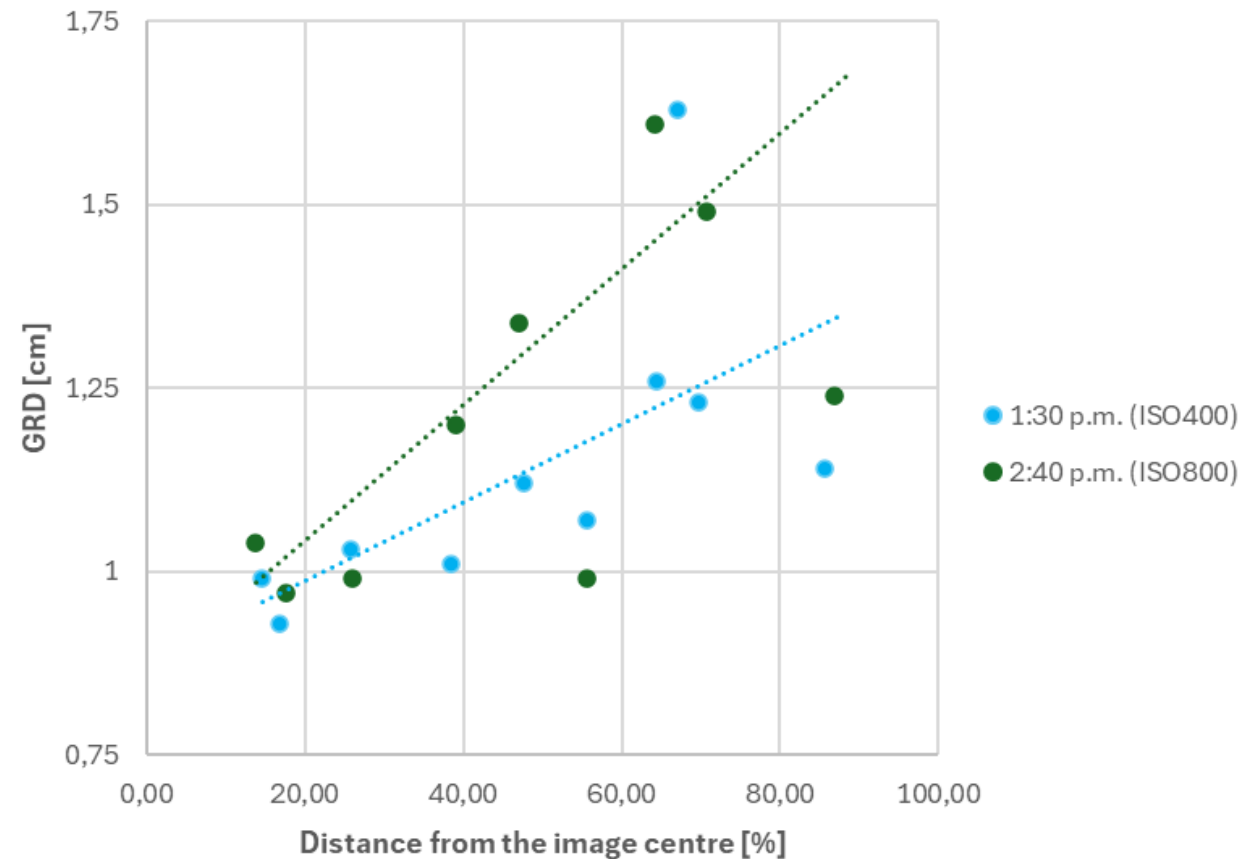


The values of **MTF10** in relation to the distance from the image centre for two flights performed at different times



# Experiments

Mavic 3E

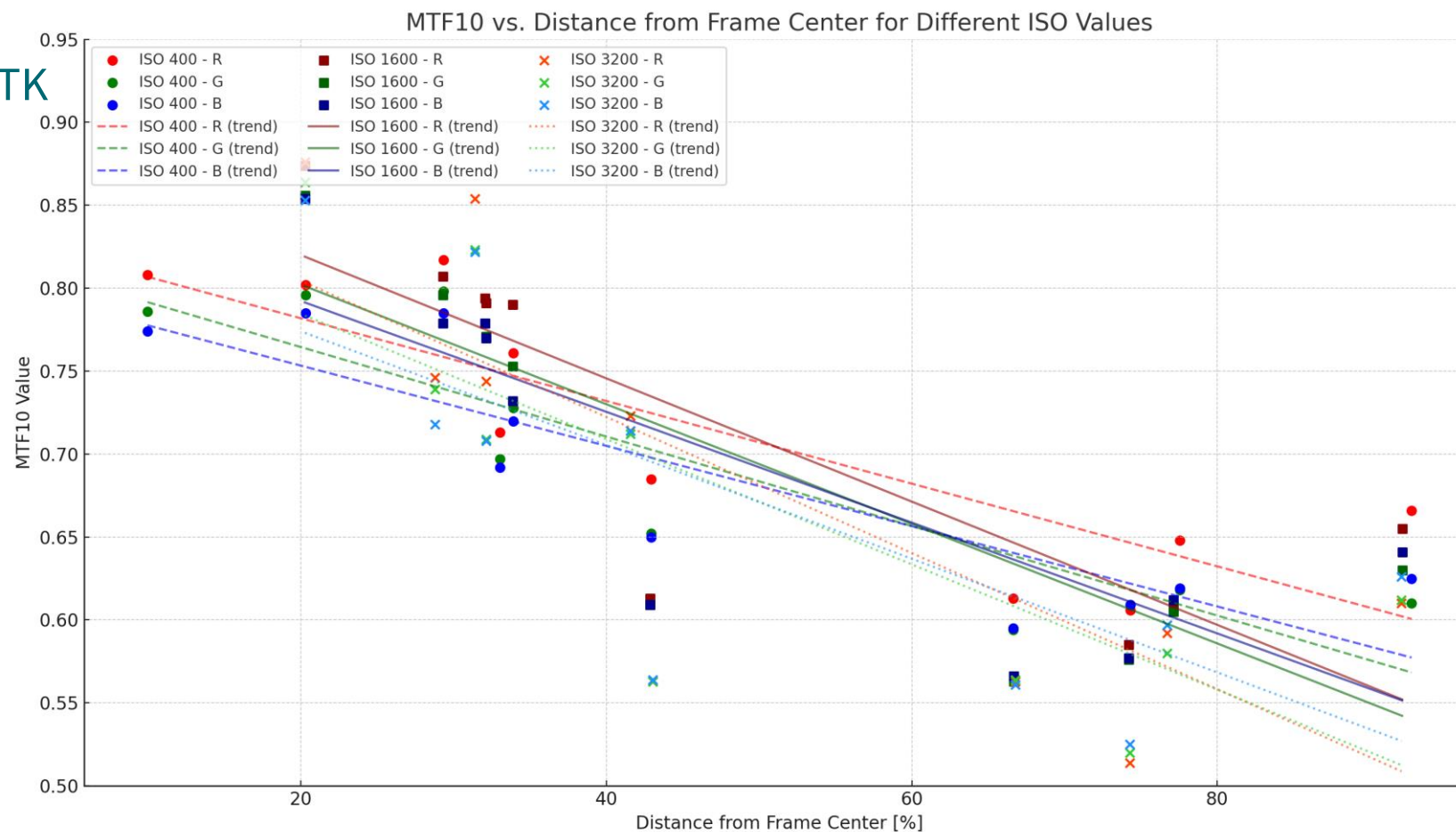


The values of **GRD** in relation to the distance from the image centre for two flights performed at different times



# Experiments

Phantom 4 RTK

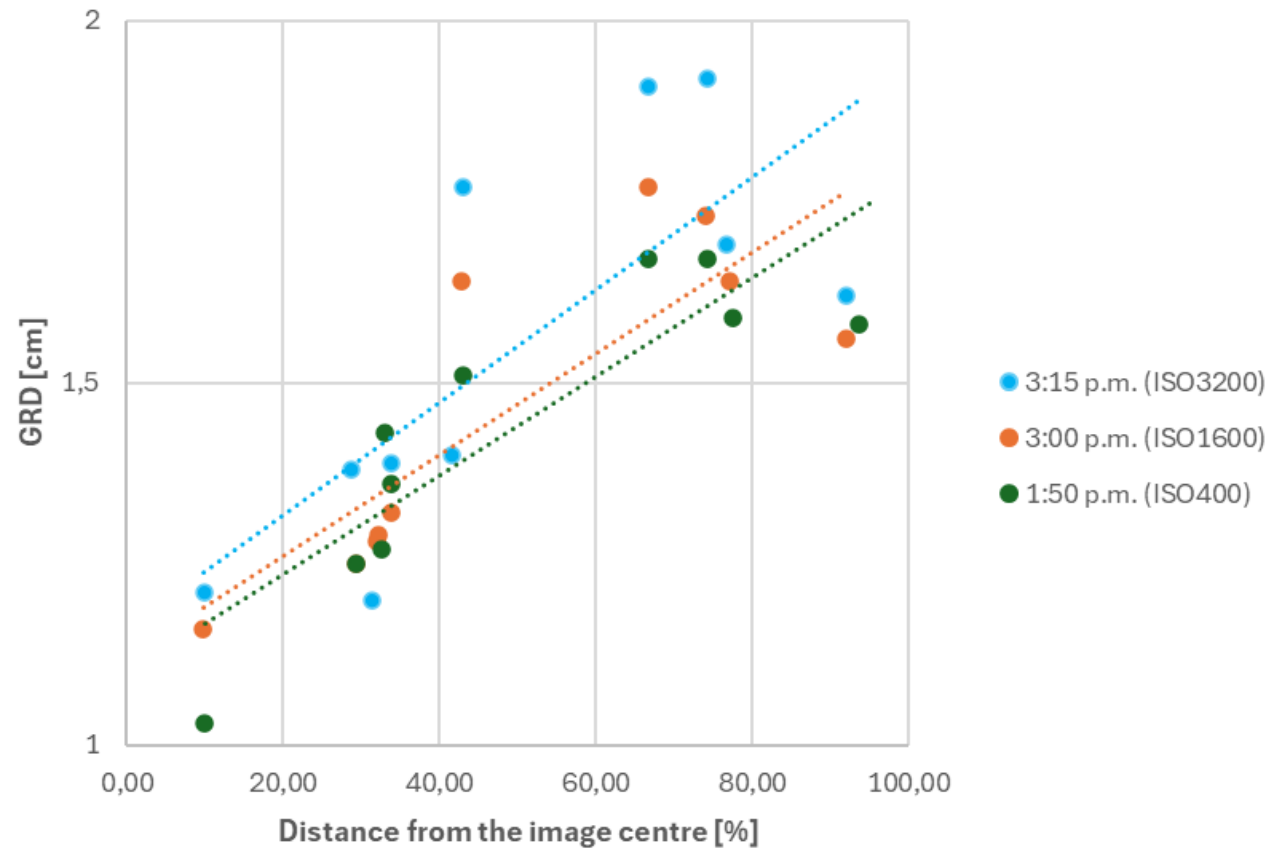


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# Experiments

Phantom 4 RTK

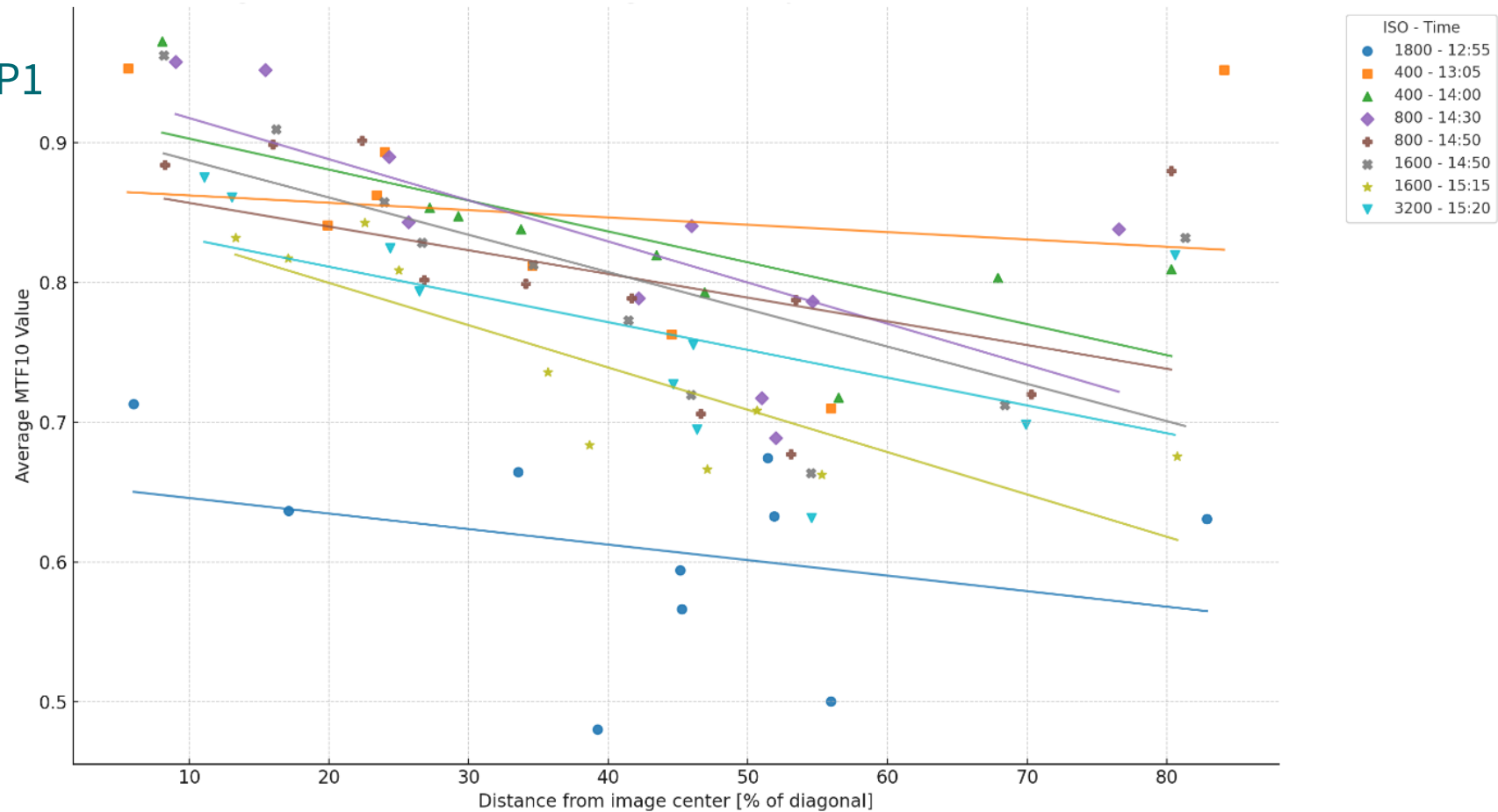


The values of **GRD** in relation to the distance from the image centre for flights performed



# Experiments

## DJI Zenmuse P1

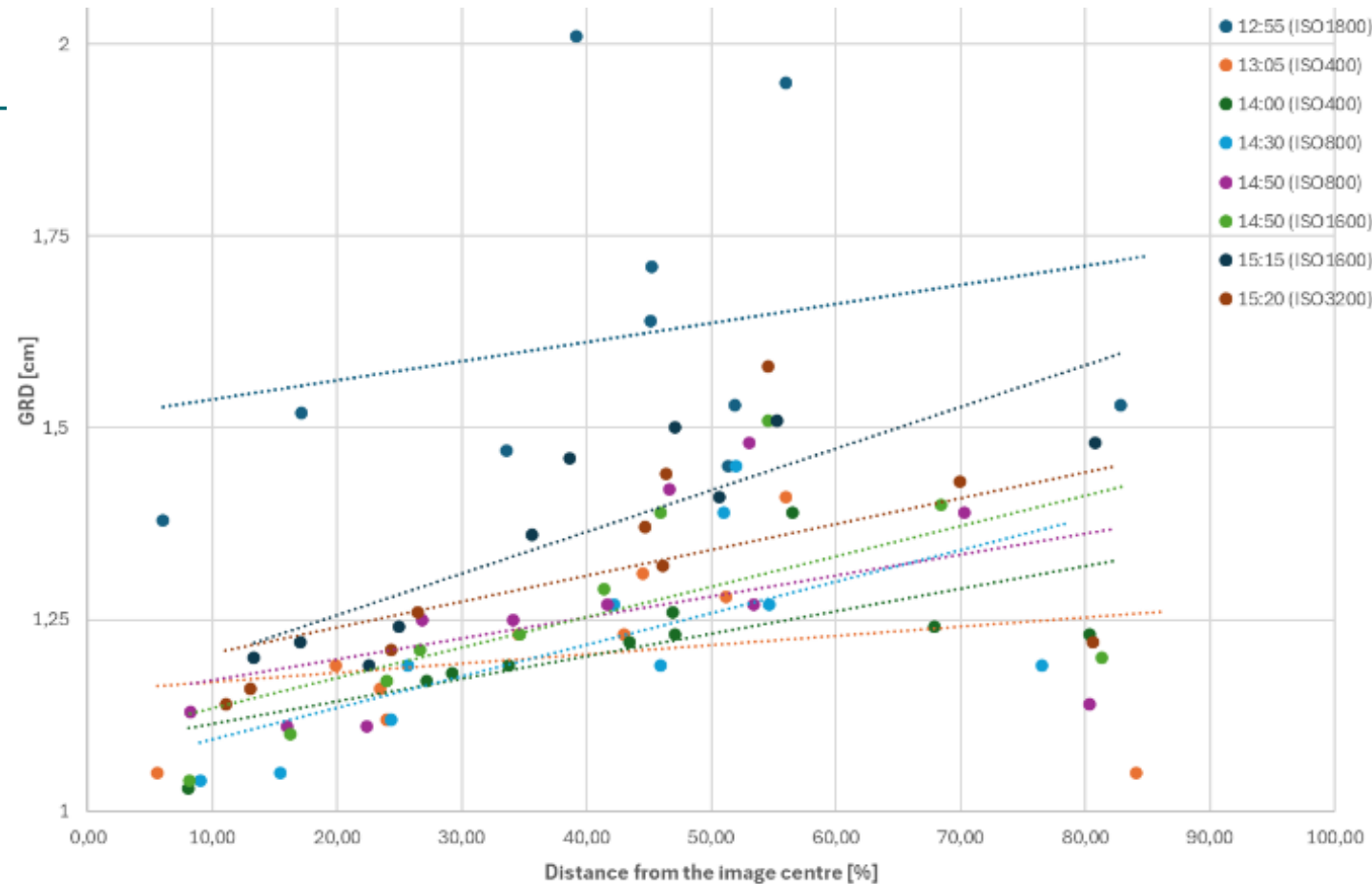


The values of **MTF10** in relation to the distance from the image centre for flights performed



# Experiments

DJI Zenmuse P1



The values of **GRD** in relation to the distance from the image centre for flights performed



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# Assessment of UAV image quality in terms of optical resolution



Warsaw University  
of Technology



ISPRS  
International Association  
of Photogrammetry and  
Remote Sensing



| Sensor  | ISO  | H     | GRD<br>avg | MTF<br>avg | Object 1 | Object 2 |
|---------|------|-------|------------|------------|----------|----------|
| M3E     | 400  | 13:30 | 1,14       | 0,897      |          |          |
| M3E     | 800  | 14:40 | 1,31       | 0,814      |          |          |
| P4 RTK  | 400  | 13:50 | 1,44       | 0,712      |          |          |
| P4 RTK  | 1600 | 15:00 | 1,46       | 0,699      |          |          |
| P4 RTK  | 3200 | 15:15 | 1,55       | 0,663      |          |          |
| M300 P1 | 1800 | 12:55 | 1,62       | 0,627      |          |          |

|         |      |       |      |       |  |  |
|---------|------|-------|------|-------|--|--|
| M300 P1 | 400  | 13:05 | 1,20 | 0,838 |  |  |
| M300_P1 | 400  | 14:00 | 1,21 | 0,803 |  |  |
| M300_P1 | 800  | 14:30 | 1,22 | 0,830 |  |  |
| M300_P1 | 800  | 14:50 | 1,26 | 0,804 |  |  |
| M300_P1 | 1600 | 14:50 | 1,25 | 0,807 |  |  |
| M300_P1 | 1600 | 15:15 | 1,36 | 0,744 |  |  |
| M300_P1 | 3200 | 15:20 | 1,31 | 0,768 |  |  |



## CONCLUSIONS

**A decrease in optical quality with distance from the camera's optical axis was observed for all sensors tested**

**MTF10 and GRD get worse the farther away from the center of the image**

**Results for Matrice 4E may suggest that some additional sharpening filter has been applied to the images by the camera on-board image processor**



## CONCLUSIONS

**Choosing the optimal photographic time has a huge impact on the optical resolution of the images**

**An increase in ISO leads to an increase in image graininess, which negatively affects MTF10 and GRD values**

**The image-derived 3D reconstruction deteriorates in quality as a result of increased image noise**



# Thank you!

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