

Machine Learning based Prediction of Astronomical Seeing using All-Sky Camera and Cloud Sensor Data

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Background – Astronomical Seeing

Definition:

- Blurring and twinkling of celestial objects caused by turbulence in the Earth's atmosphere.

Cause:

- Temperature variations create turbulent air layers

Measurement:

- Measured using Full Width at Half Maximum of a star image
- **Units: arcseconds (")**

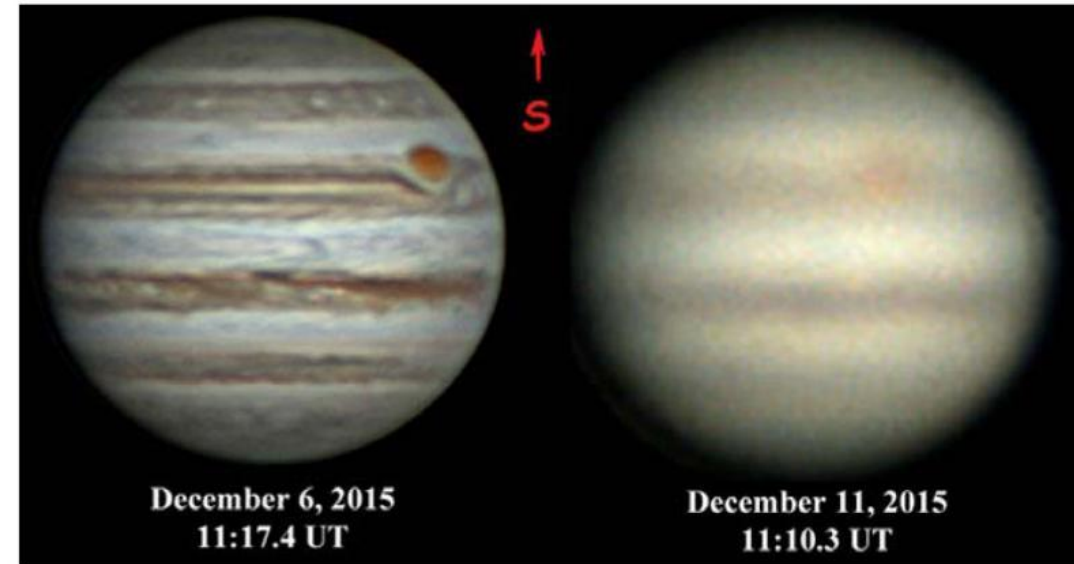
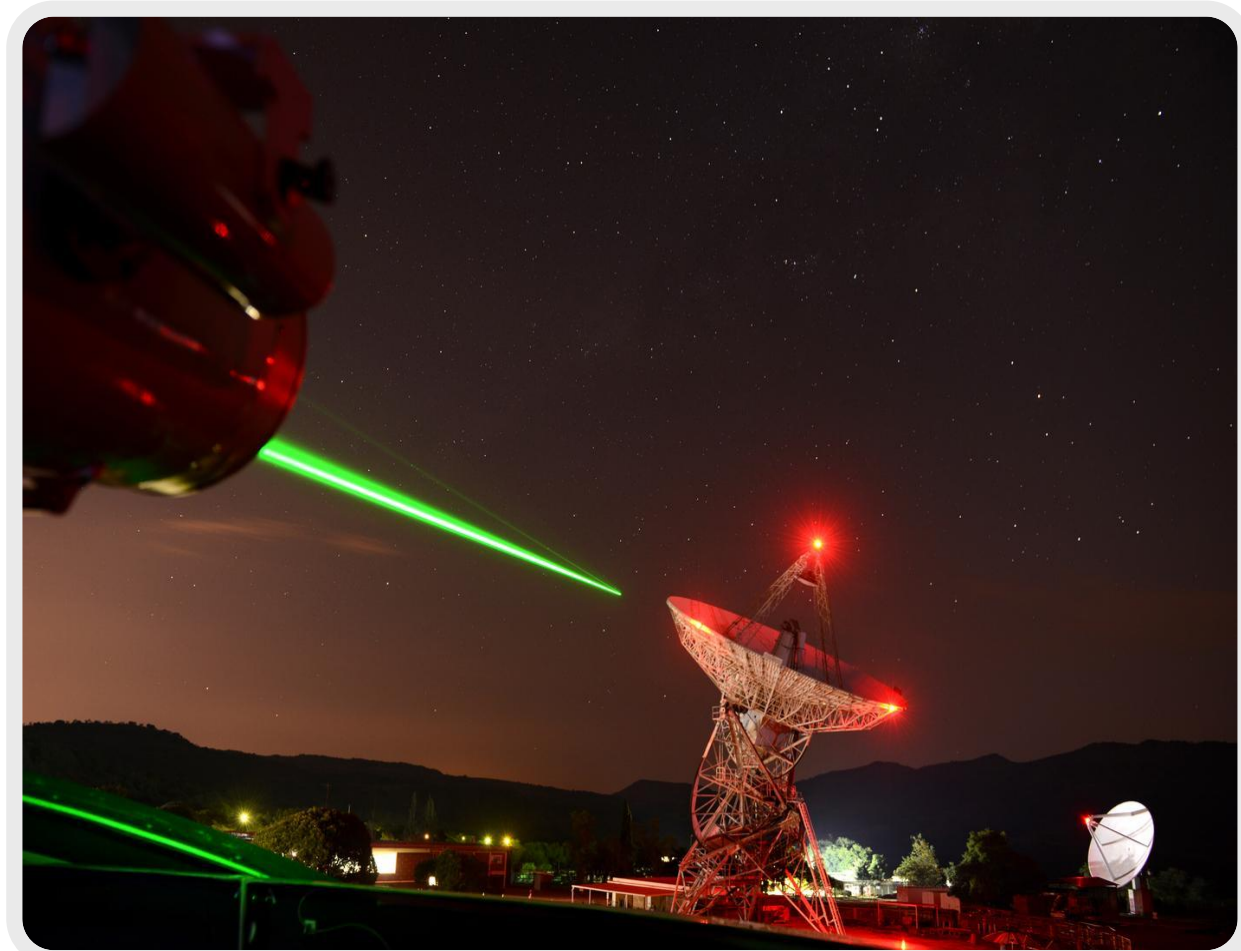


Figure 2. Jupiter, captured with the same equipment in good (left) and bad (right) seeing conditions. *Cliff Ashcraft, New Jersey, USA*

Motivation – Why Seeing Matters?

- Atmospheric turbulence degrades image quality in **ground-based astronomical observations**.
- The poor seeing reduces the accuracy of **astronomical and geodetic measurements**.
- Seeing monitors are **expensive** this limits continuous monitoring at many sites.
- Need for **alternative, lower-cost approaches to estimate or predict seeing conditions**.



Credit: Jacoline Schoonees - DIRCO

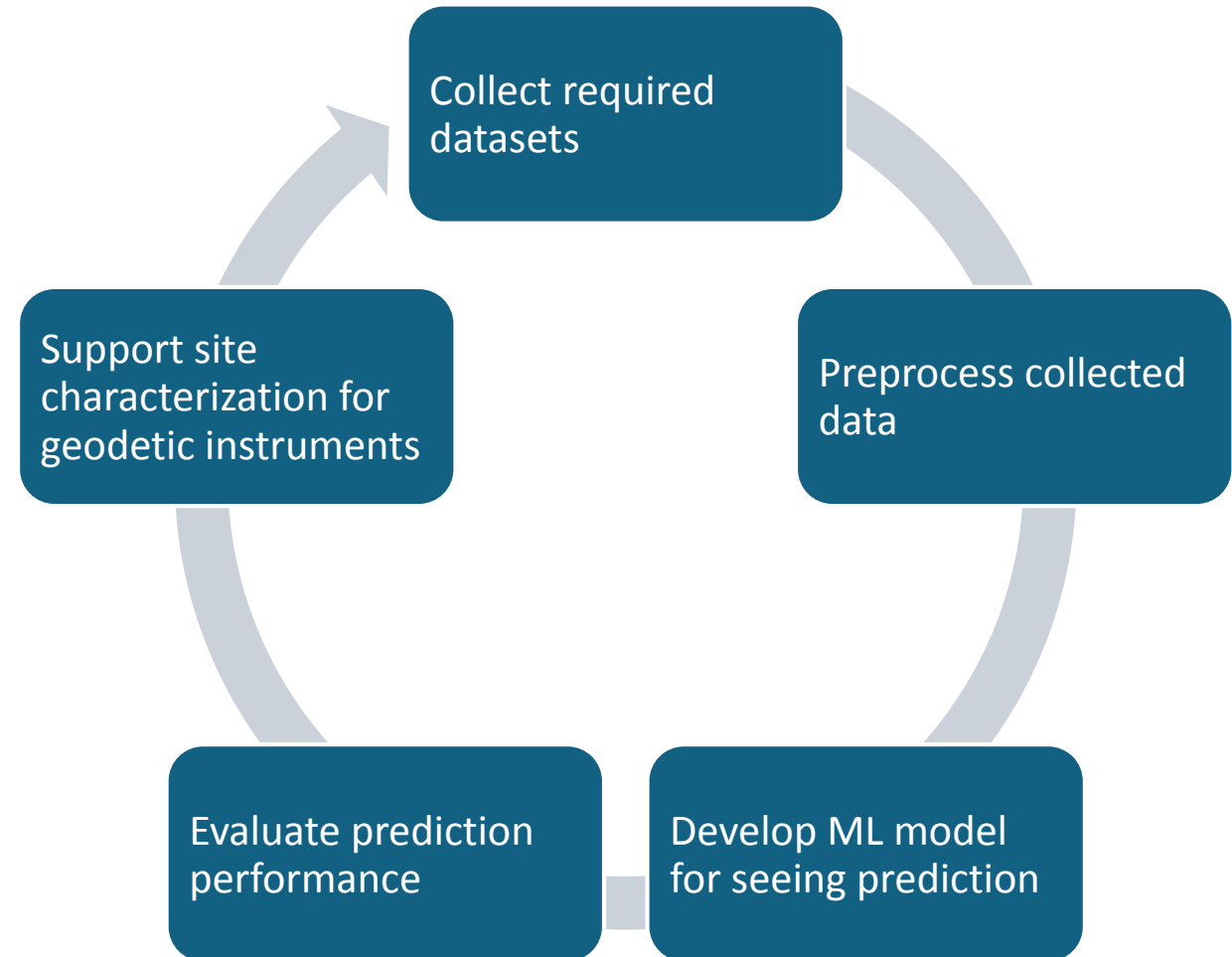
Research Question and Objectives

Question:

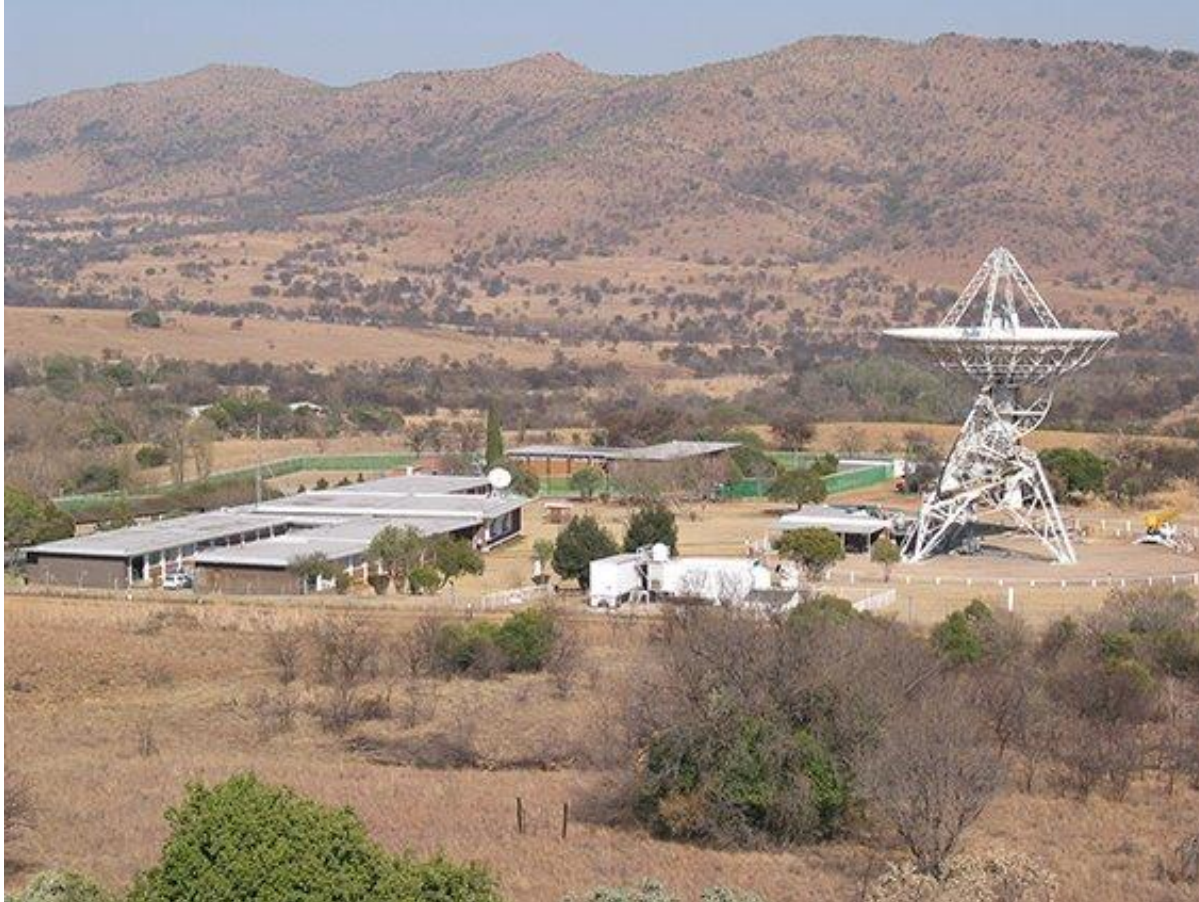
- How accurately can machine learning predict astronomical seeing using environmental data and all-sky camera images?

Goal:

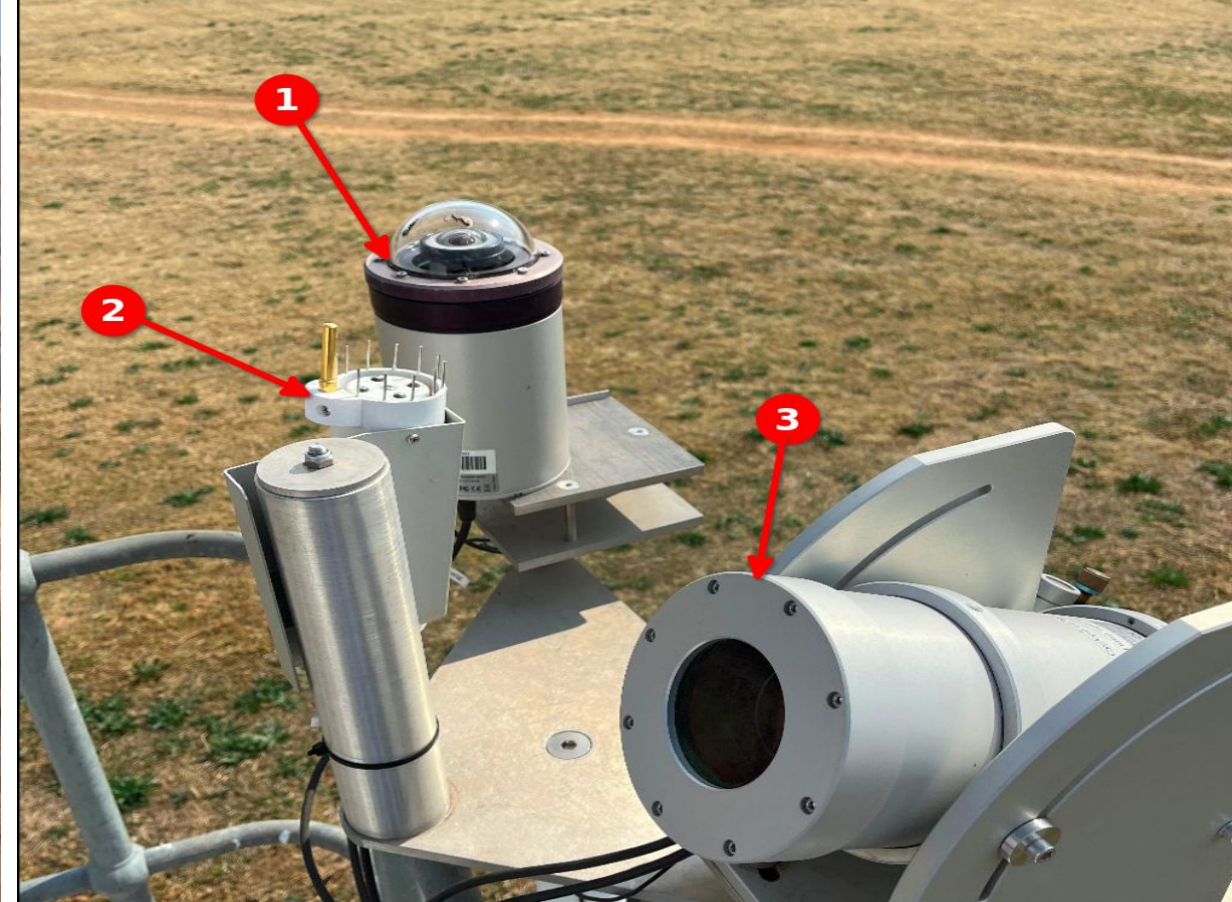
- Support **site characterization for geodetic instruments**



Data Sources



SARAO Hartebeesthoek site – aerial view (*Credit: M. Gaylard*)

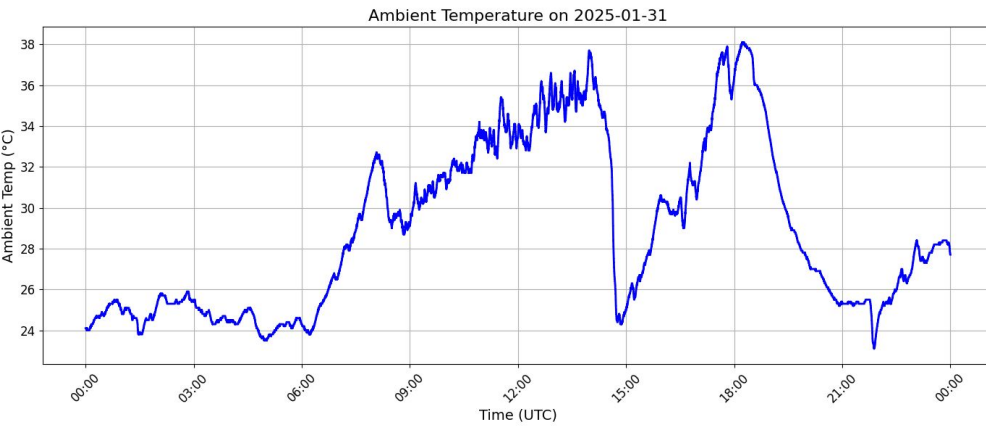


1. All sky Camera
2. Cloud Sensor
3. Seeing Monitor

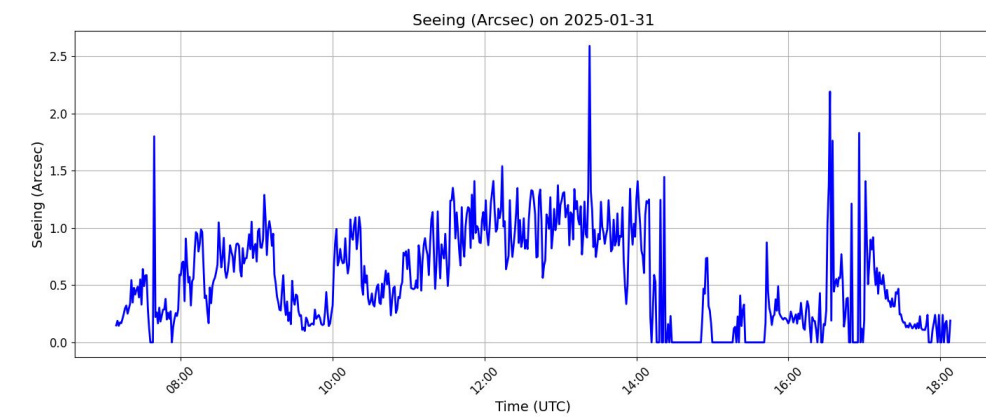
Data Samples

HartRAO AllSkyCam #3

All-sky camera image captured on 31 Jan 2025 at 12:00 UTC



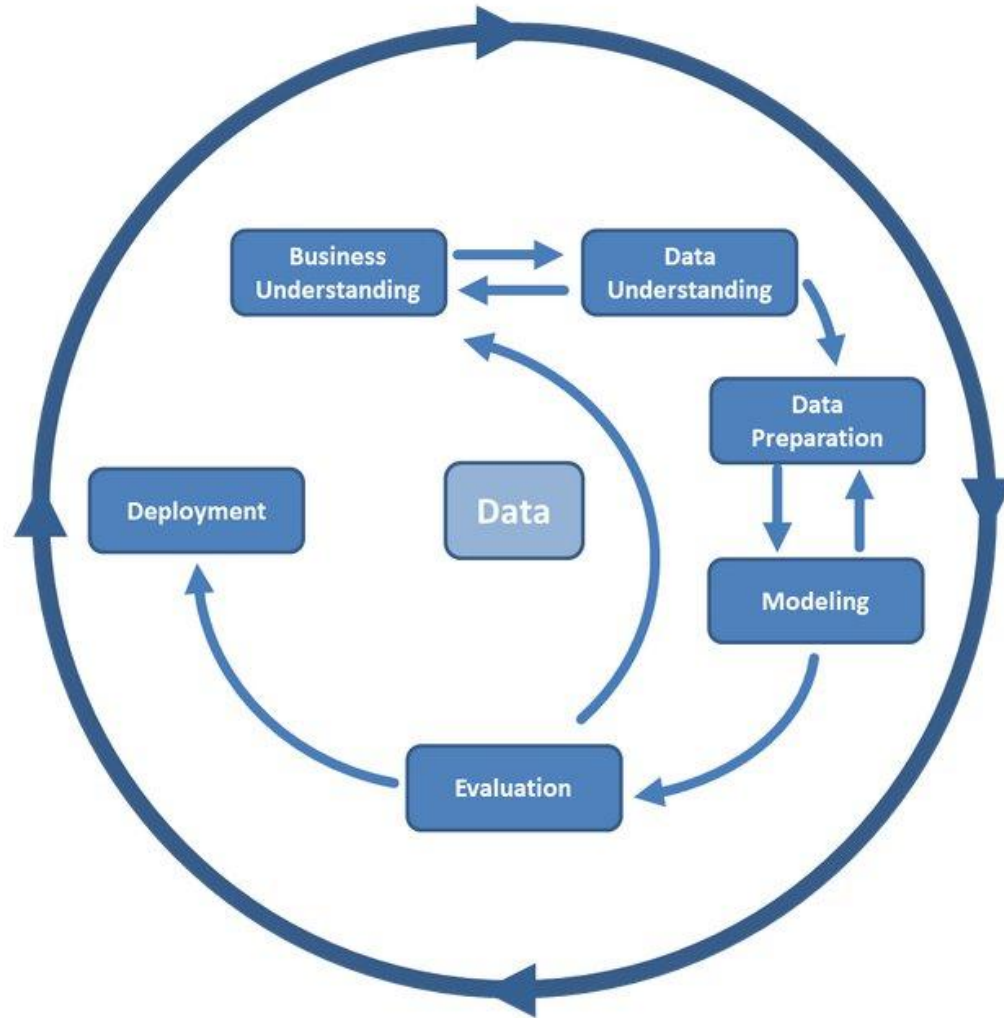
Ambient temperature from cloud sensor data (31 Jan 2025)



Astronomical seeing measurement on 31 Jan 2025



Methodology – CRISP DM



- define seeing prediction problem.
- collect data characteristics, data types.
- feature engineering and preprocessing, data alignment.
- ML models (RF, XGBoost, MLP)
- RMSE, MAE, R^2
- support site characterization

Methods and Models Explored

Pearson Correlation

Random Forest & XGBoost

MLP – simple feedforward neural network.

Chronological train/test split (80:20) to avoid leakage.

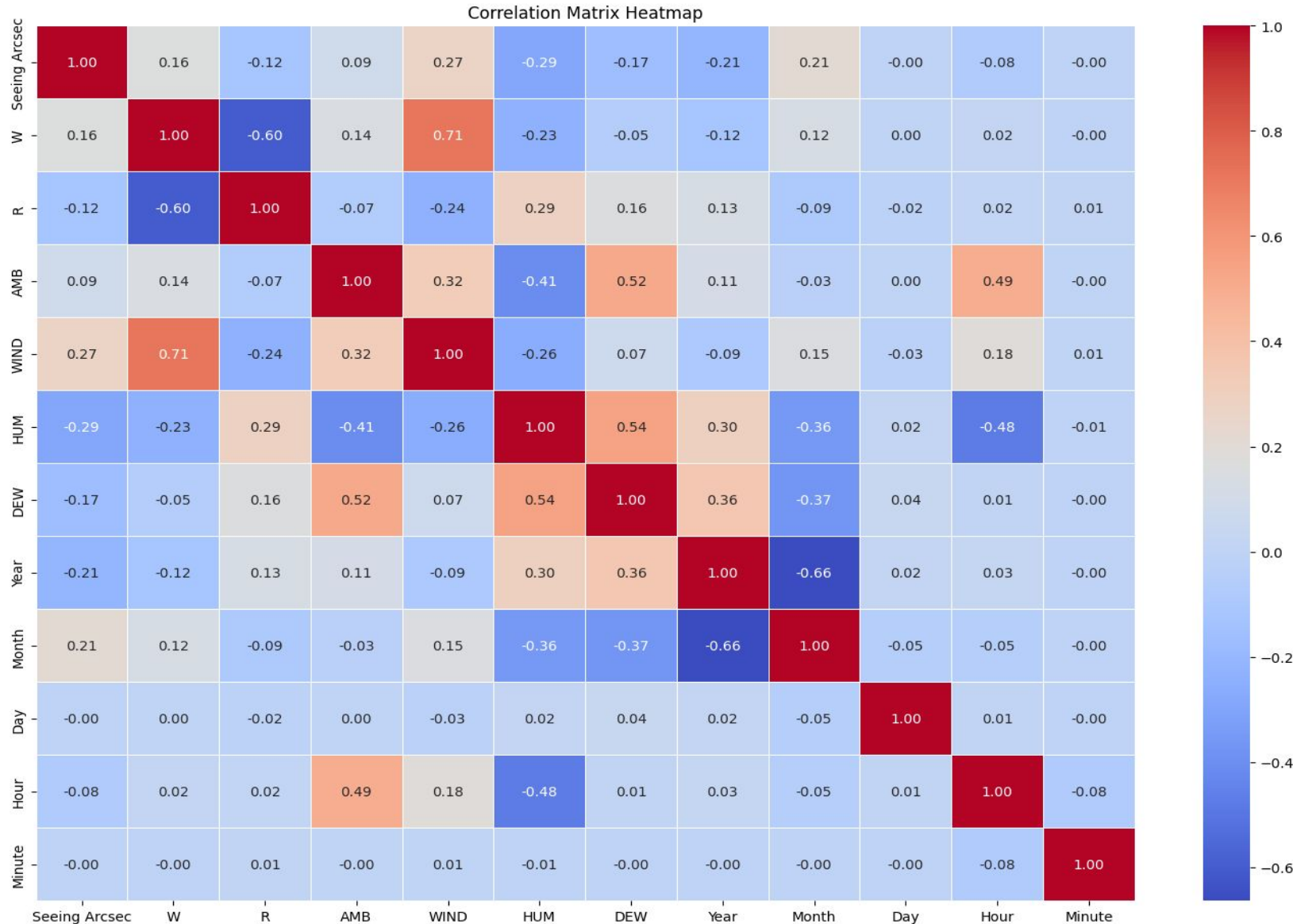
Evaluation Metrics

1.
$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2}$$

2.
$$\text{MAE} = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i|$$

3.
$$R^2 = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2}$$

Preliminary Results



| Model | RMSE | MAE | R ² |
|---------------|--------------|--------------|----------------|
| XGBoost | <u>0.272</u> | <u>0.189</u> | <u>0.521</u> |
| Random Forest | 0.276 | 0.193 | 0.506 |
| MLP | 0.316 | 0.221 | 0.369 |

Impact/Contributions

If successful:

-Terrestrial Laser data links

Cost-effective for site characterization

Supports observatory planning

Improves observation scheduling

Applications in:

- Astronomical observations
- Geodetic techniques (SLR / LLR)
- Terrestrial Laser Data Links
- Site characterization



Credit: Jacoline Schoonees - DIRCO

Conclusion

- Machine learning can support prediction of astronomical seeing
- Combines low-cost sensors with advanced analytics
- Enables data-driven site evaluation
- **Future Work:**
 - Integrate all-sky camera images
 - Expand model development.
 - Comparison of results with other datasets.

References

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THANK YOU!

Q&A

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