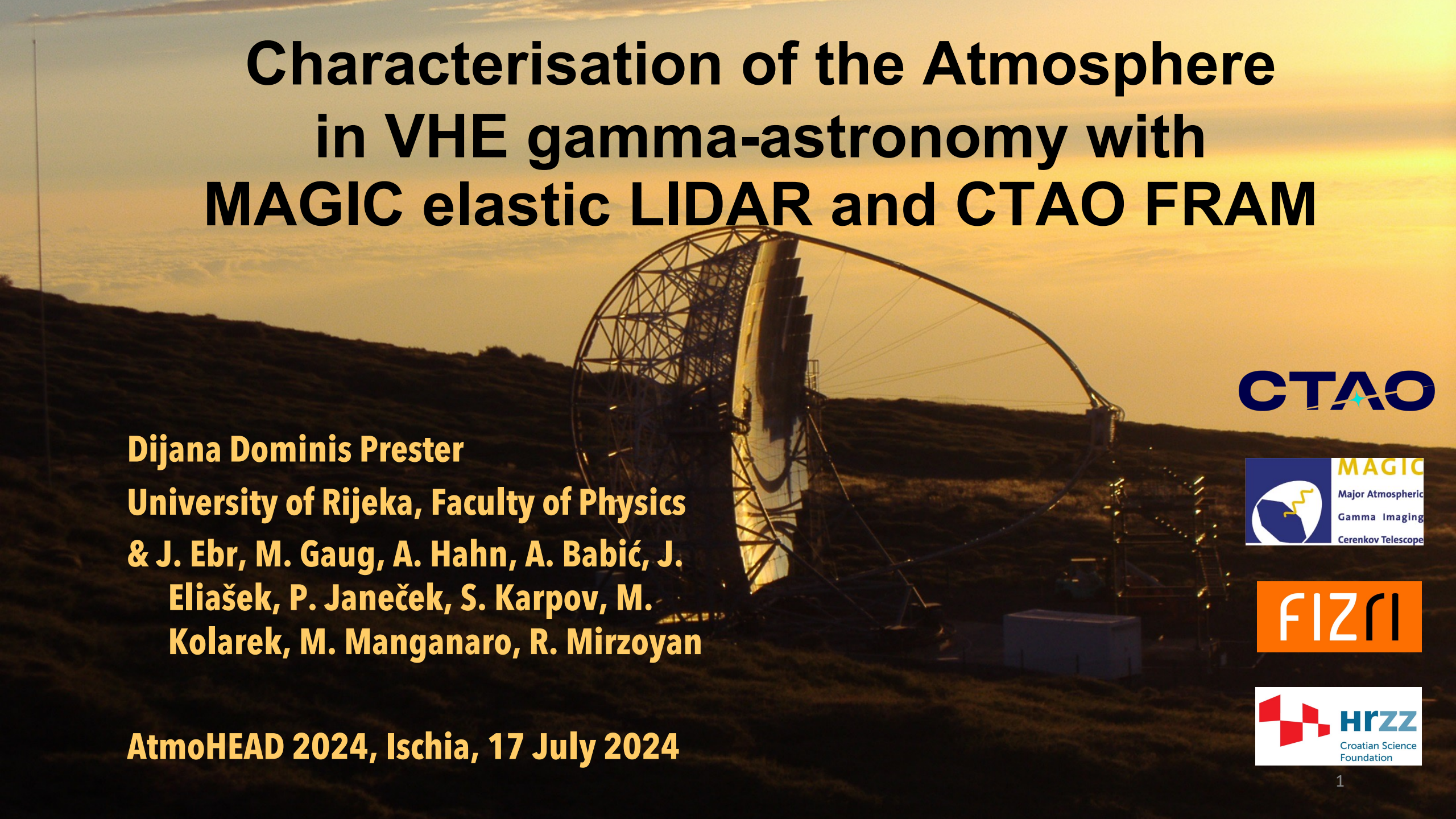
Characterisation of the Atmosphere in VHE gamma-astronomy with MAGIC elastic LIDAR and CTAO FRAM



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AtmoHEAD 2024, Ischia, 17 July 2024

Outline

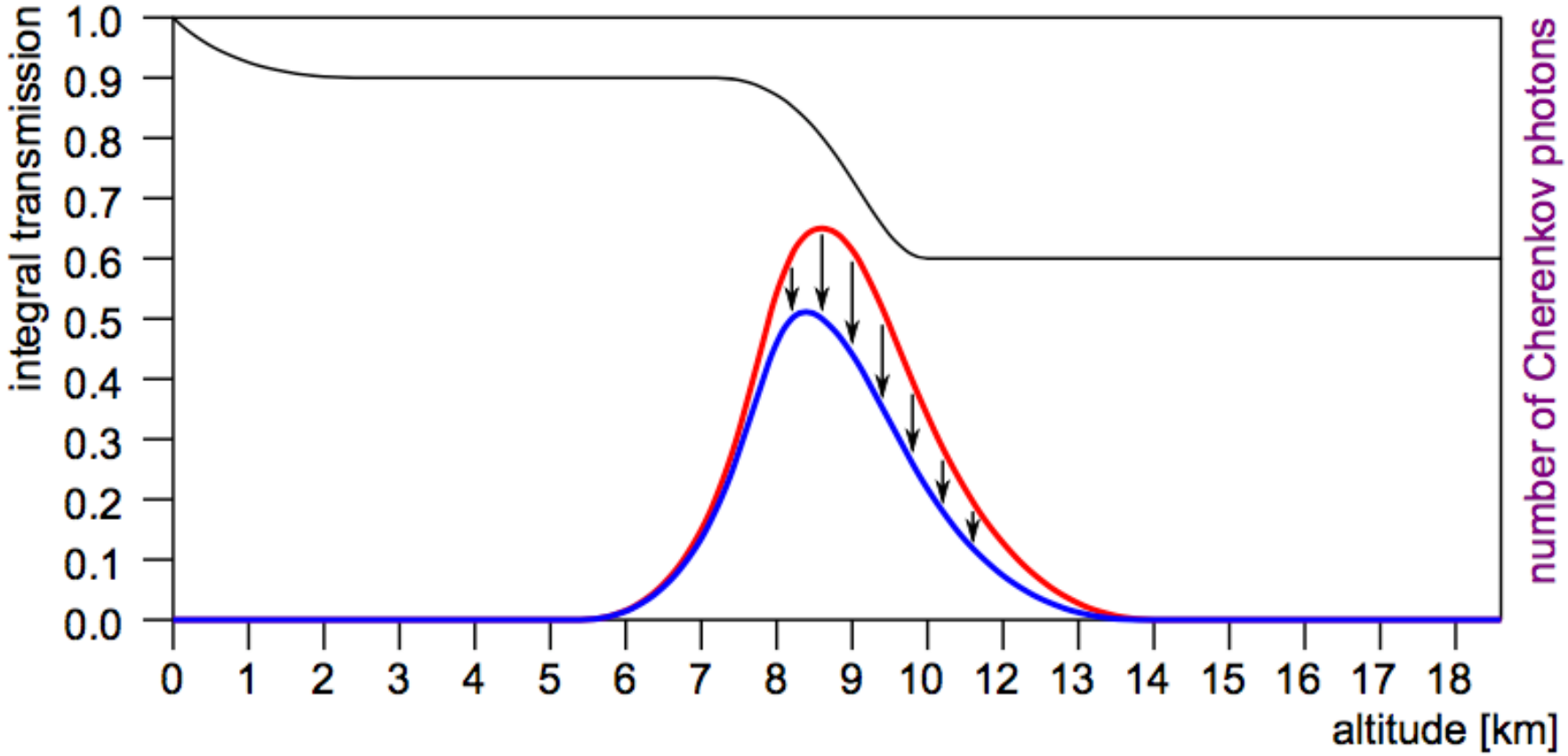
- - Adaptive Observation Scheduling for IACTs
- - Atmospheric aerosols transmission profiles (MAGIC LIDAR)
- - Aerosol optical depth maps (CTAO FRAM)
- - Correlation between MAGIC LIDAR and CTAO FRAM VAOD measurements

Atmosphere above La Palma

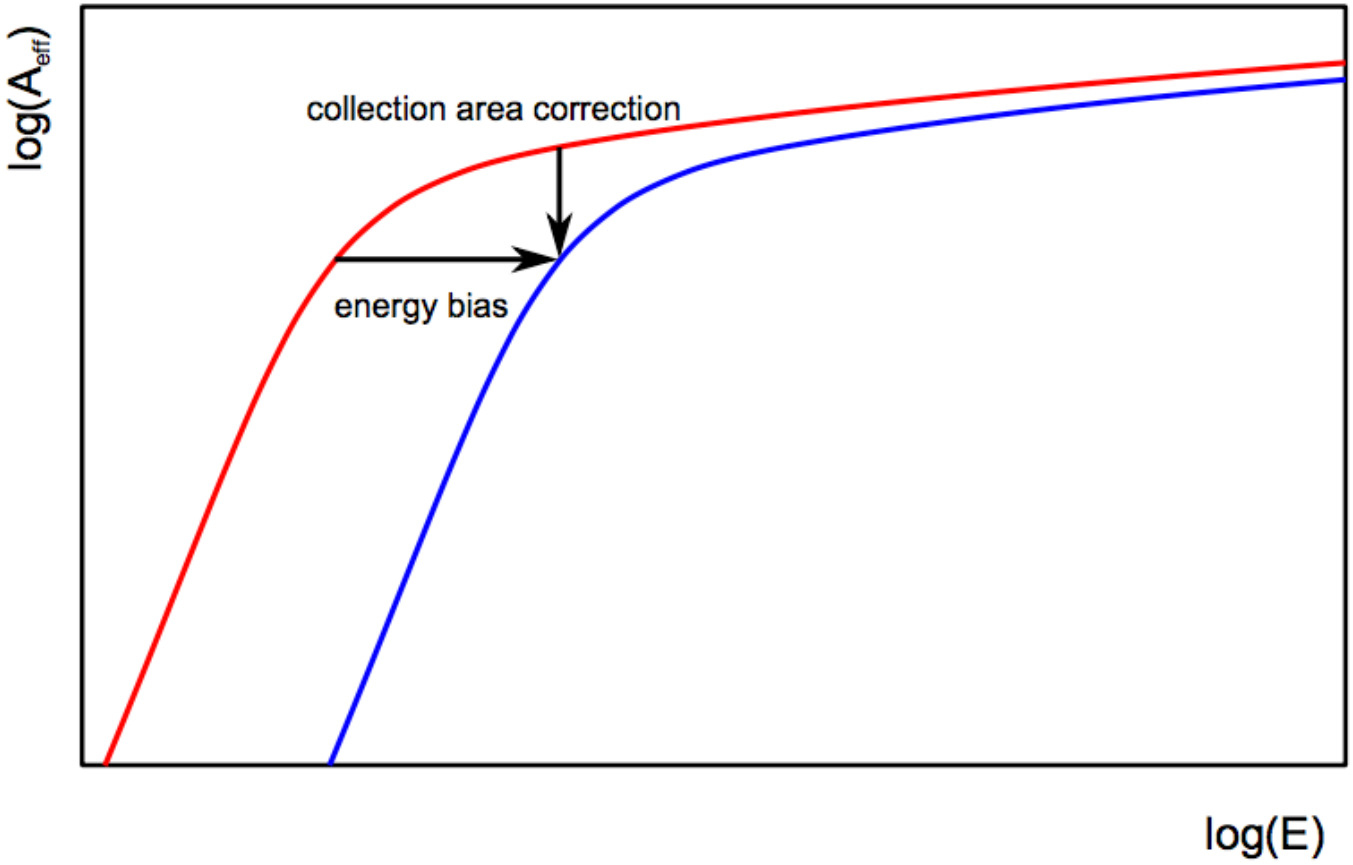
- Cirrus clouds
- Important for understanding the climate
- Altitude 5-20 km

- Calima
- Sahara dust
- Altitude around 3 km

Effect of a cloud on a Cherenkov air shower



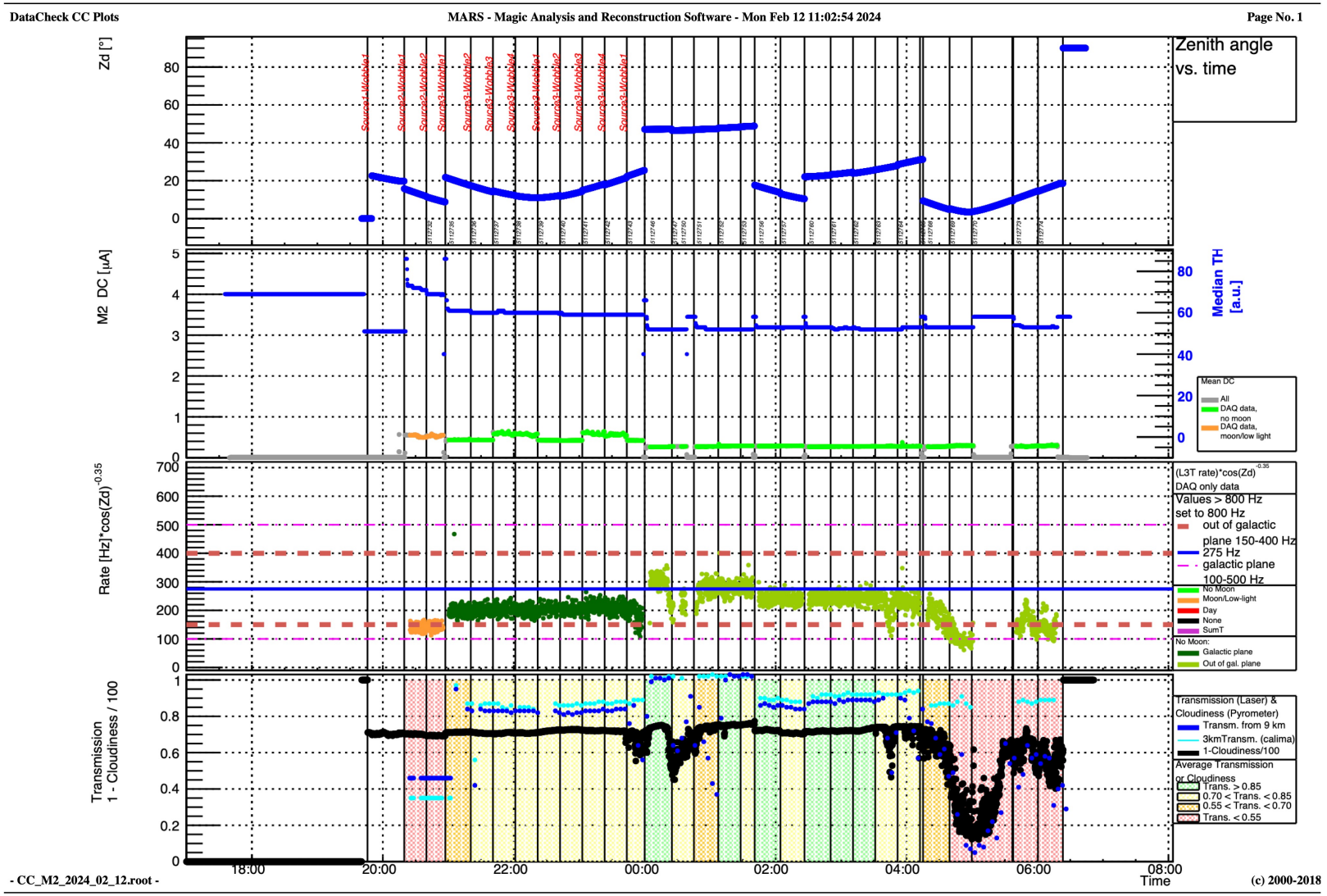
Energy threshold affected by a cloud



Adaptive Observation Scheduling

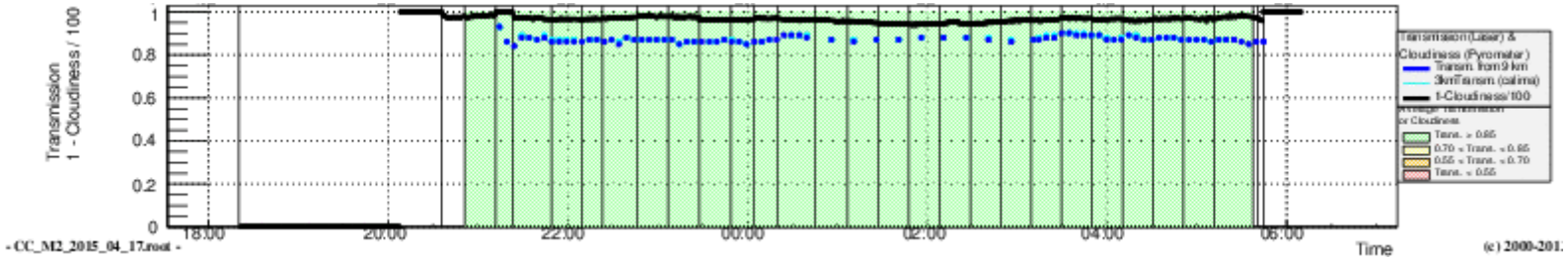
- 20-30% of the observational time at La Palma is affected by moderate atmospheric transmission levels that can be corrected using real-time VAOD measurements
- Observational time with IACTs MAGIC and CTAO is very expensive
- Observations of astrophysical sources and phenomena that emit softer gamma-ray spectra (GeV range energy thresholds) need high atmospheric trasmission (more than 0.85-0.90)
- Sources emitting harder gamma-ray spectra (TeV e.th.), including flaring and nearby AGNs, can be observed also during moderate atmospheric transmission (0.55-0.85) in order to allocate more observing time for sources that need observations with lower energy thresholds

MAGIC: Datacheck for one observing night with variable atmosphere

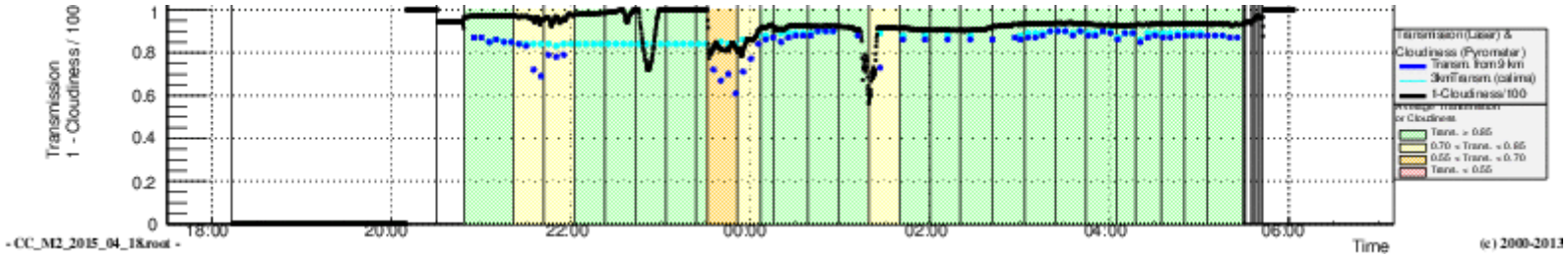


MAGIC: Different atmospheric conditions

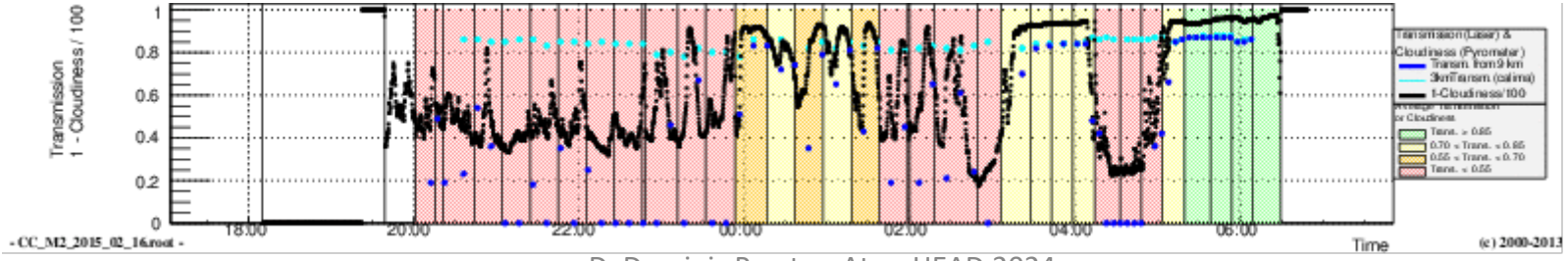
Perfect weather: no corrections



Easy corrections possible



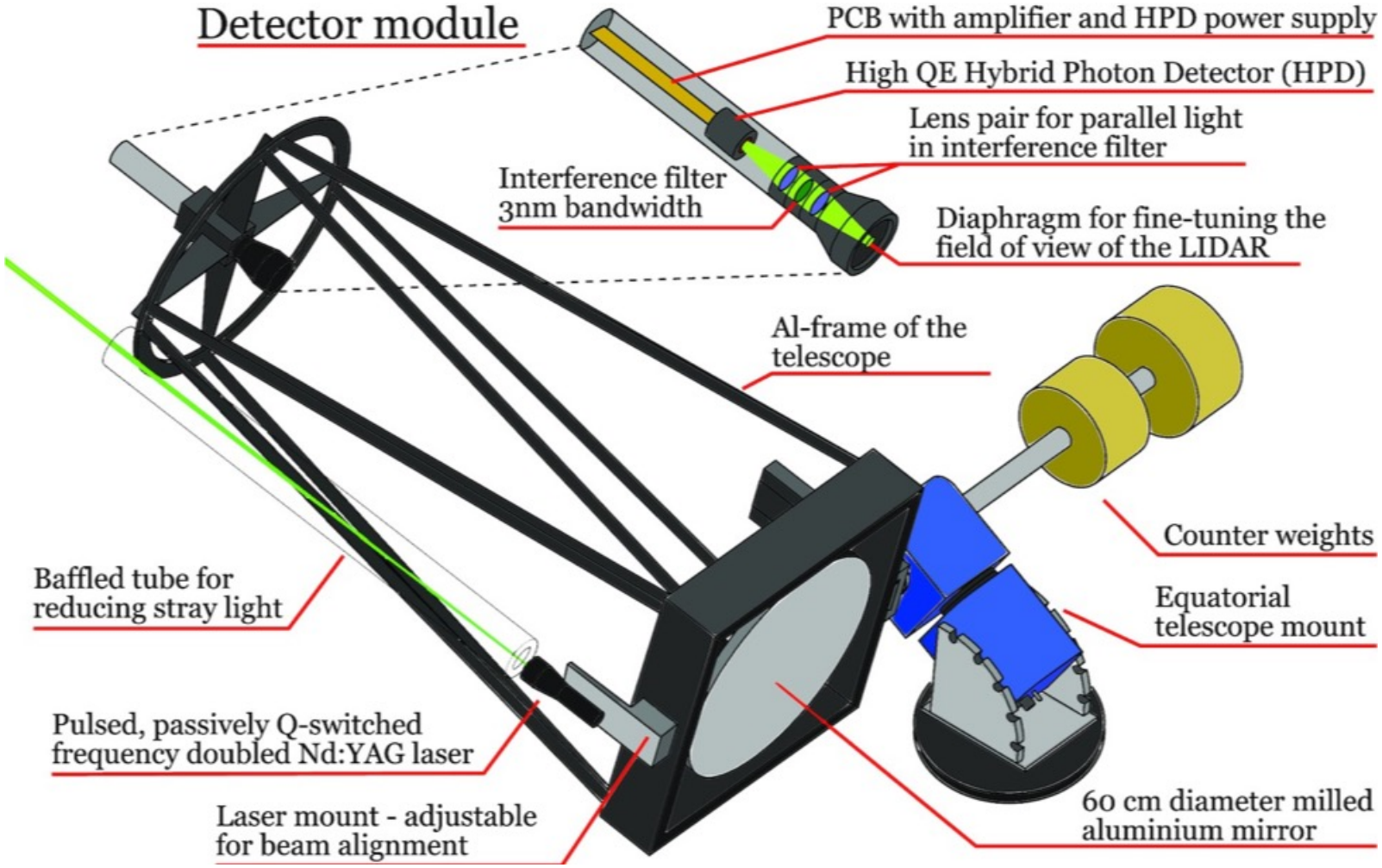
Very variable atmosphere



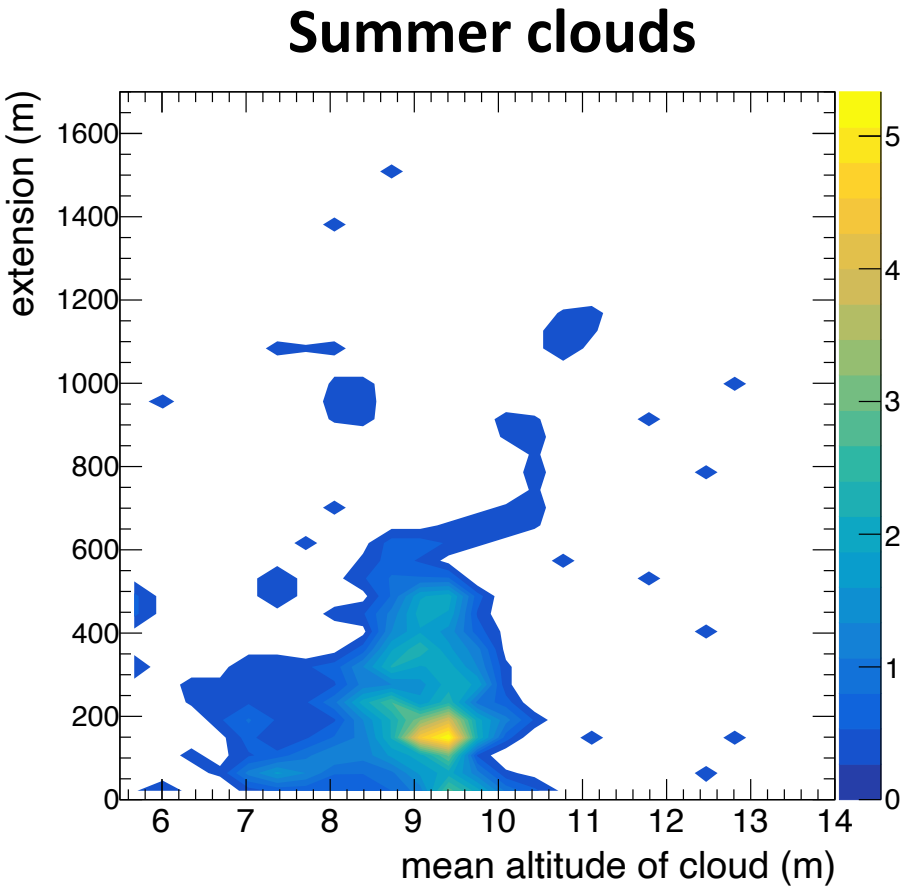
MAGIC Optical LIDAR

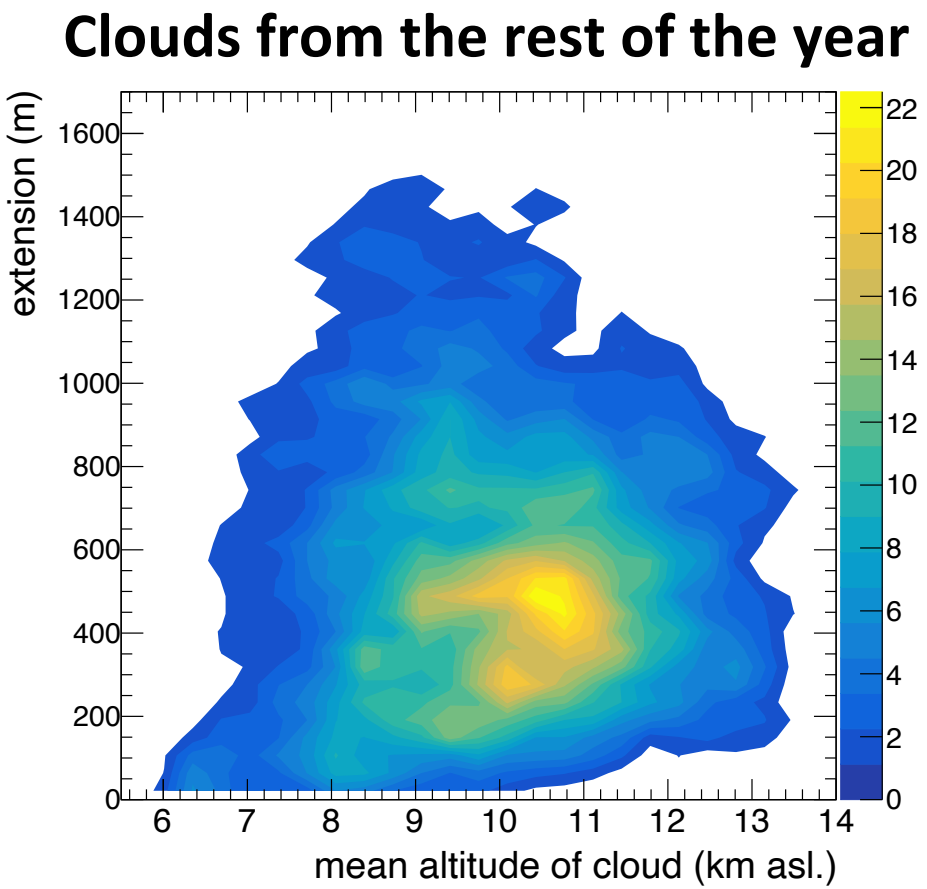
- LIght Detection And Ranging
- Pulsed optical laser at 532 nm

MAGIC Optical LIDAR

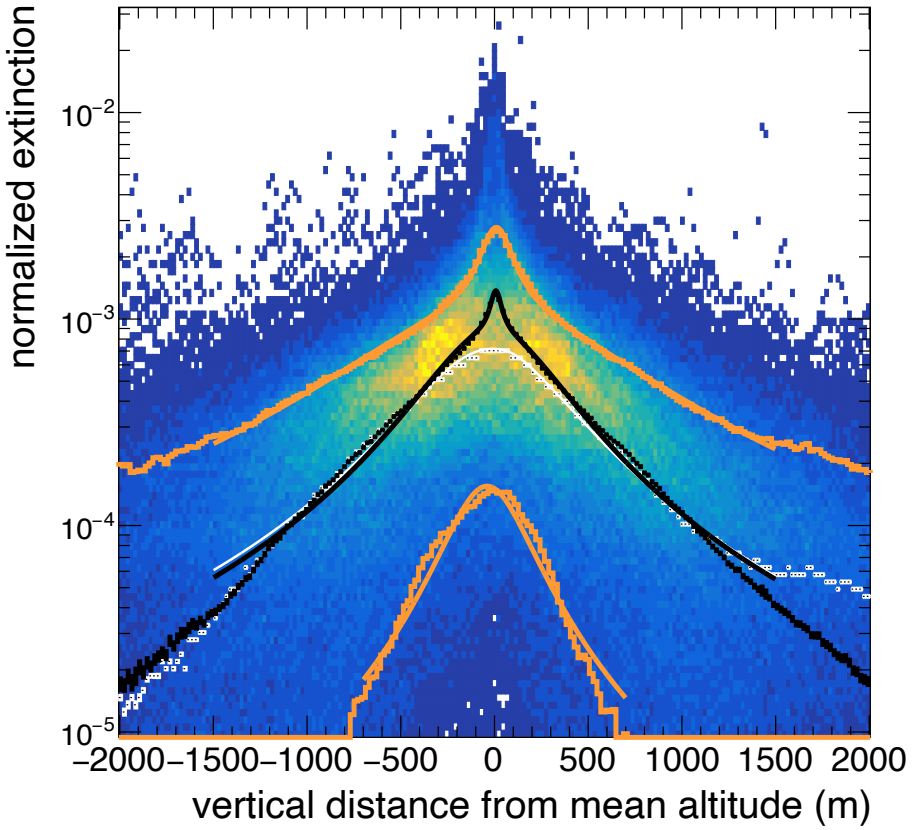


Vertical standard deviation of clouds ("extension") as a function of mean altitude

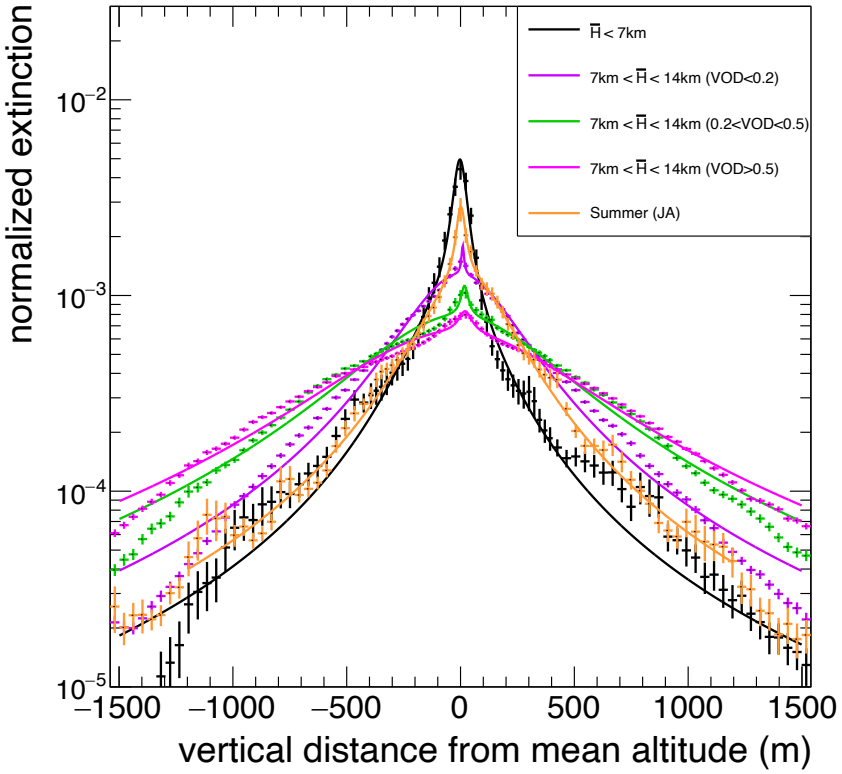




Distributions of normalized extinction vs. vertical distance from mean altitude

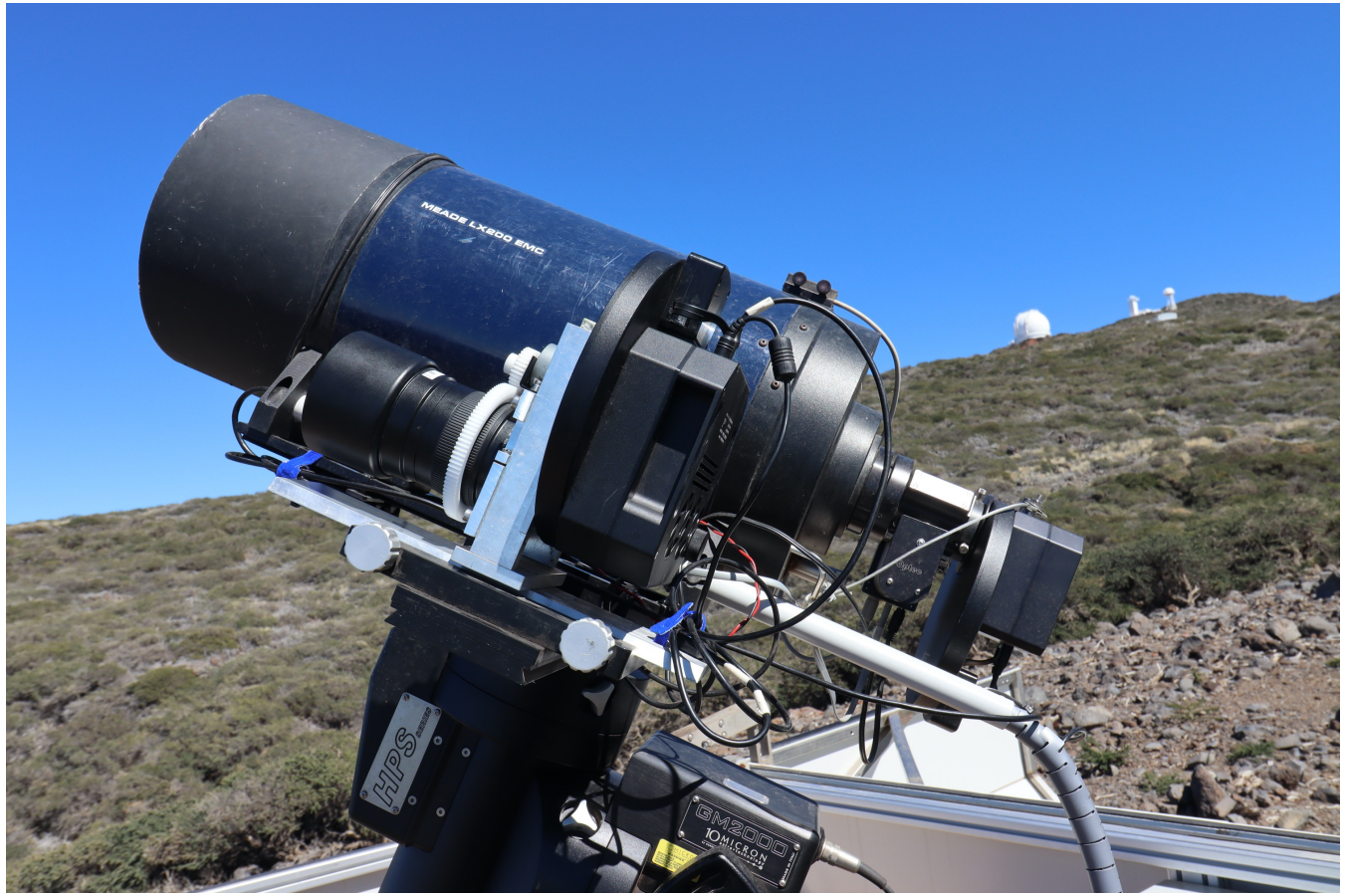


All extinction profiles (color map), with the bin-wise means (black), medians (white) and 10% and 90% quantiles (orange).



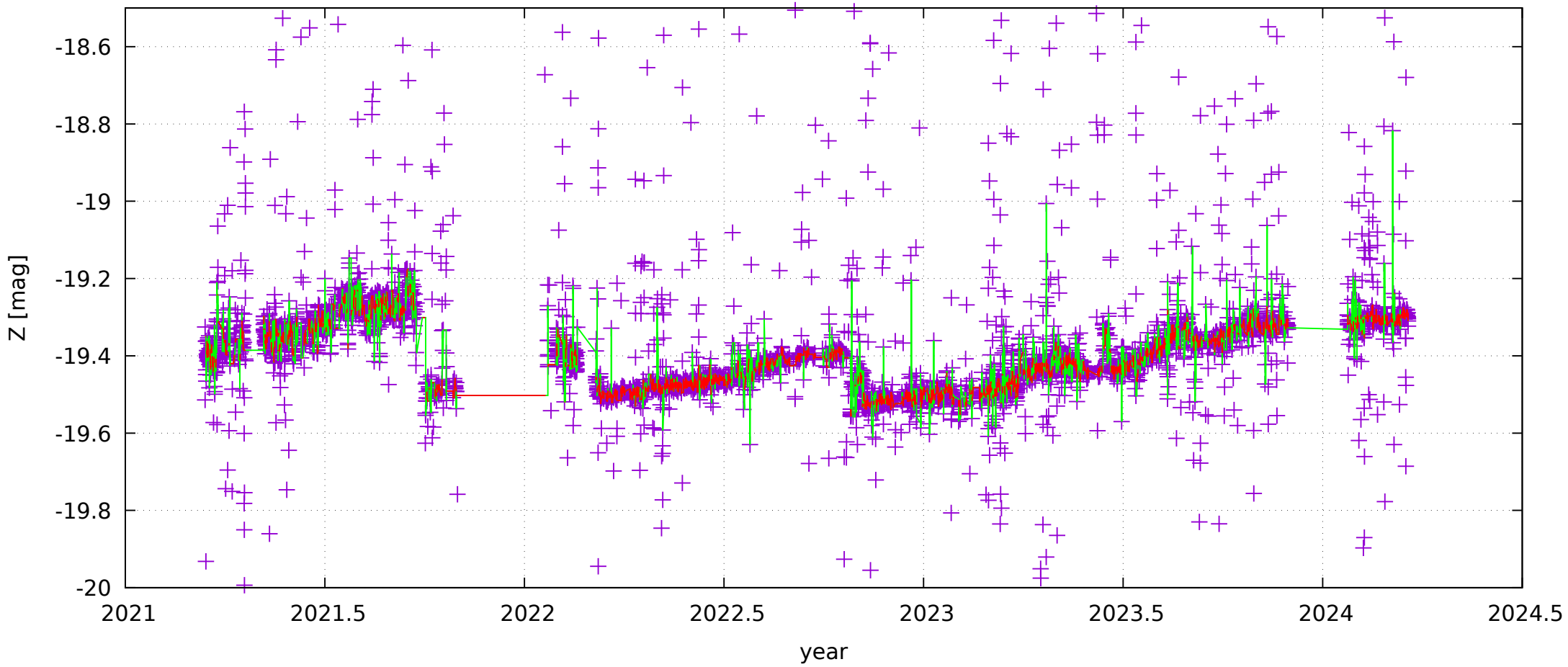
The mean extinction profiles for different cloud cases: low clouds (H < 7 km asl., black), medium altitude clouds (7 km asl. < H < 14 km asl.) for three different VOD ranges: VOD < 0.2 (lila), 0.2 < VOD < 0.5 (green) and VOD > 0.5 (pink), and Summer clouds (orange).

CTAO FRAM



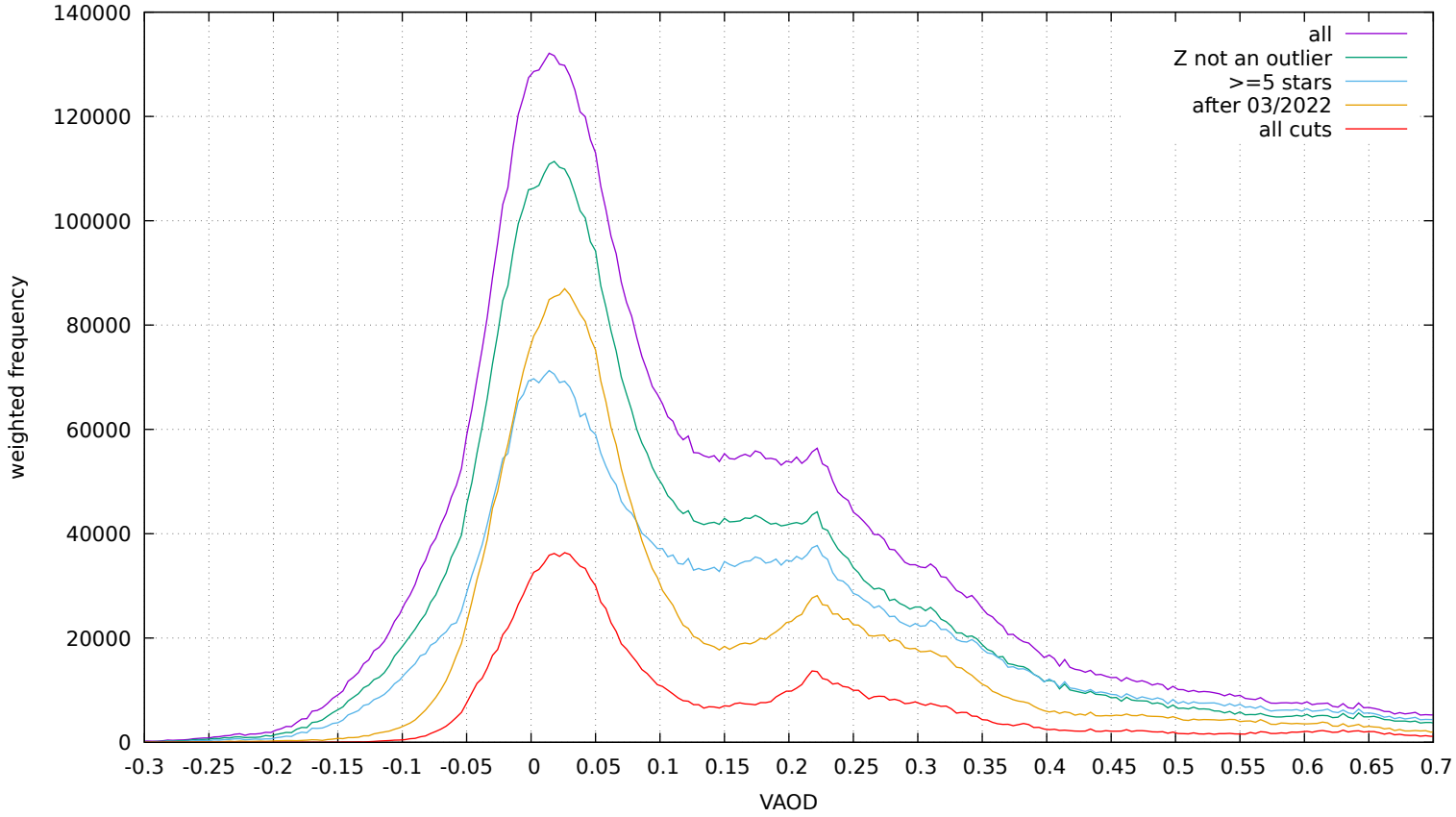
F/Photometric Robotic Telescope

CTAO FRAM time series of zeropoints from scans

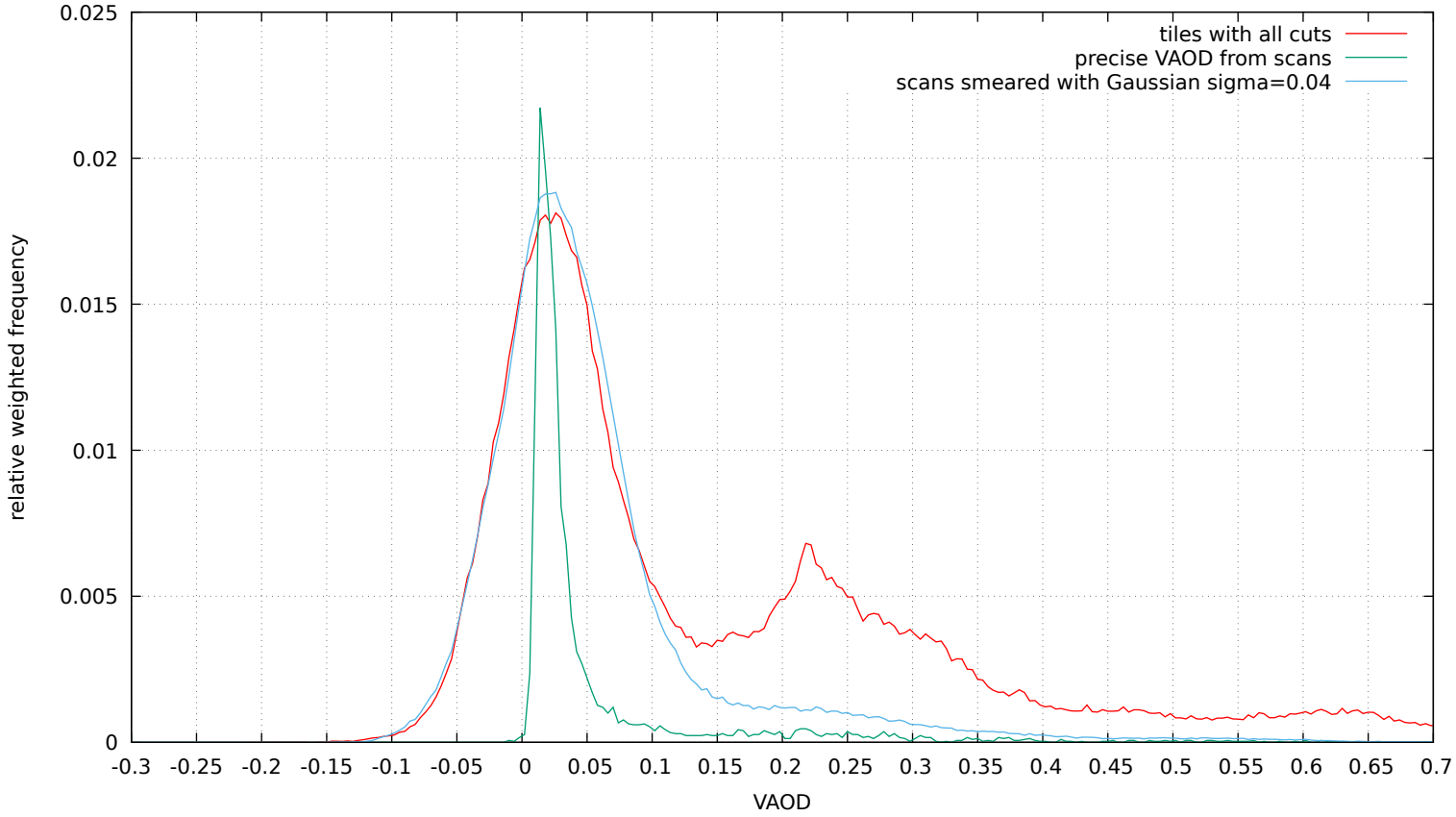


Green line - values accepted during real-time processing. Red line - values excluding outliers.

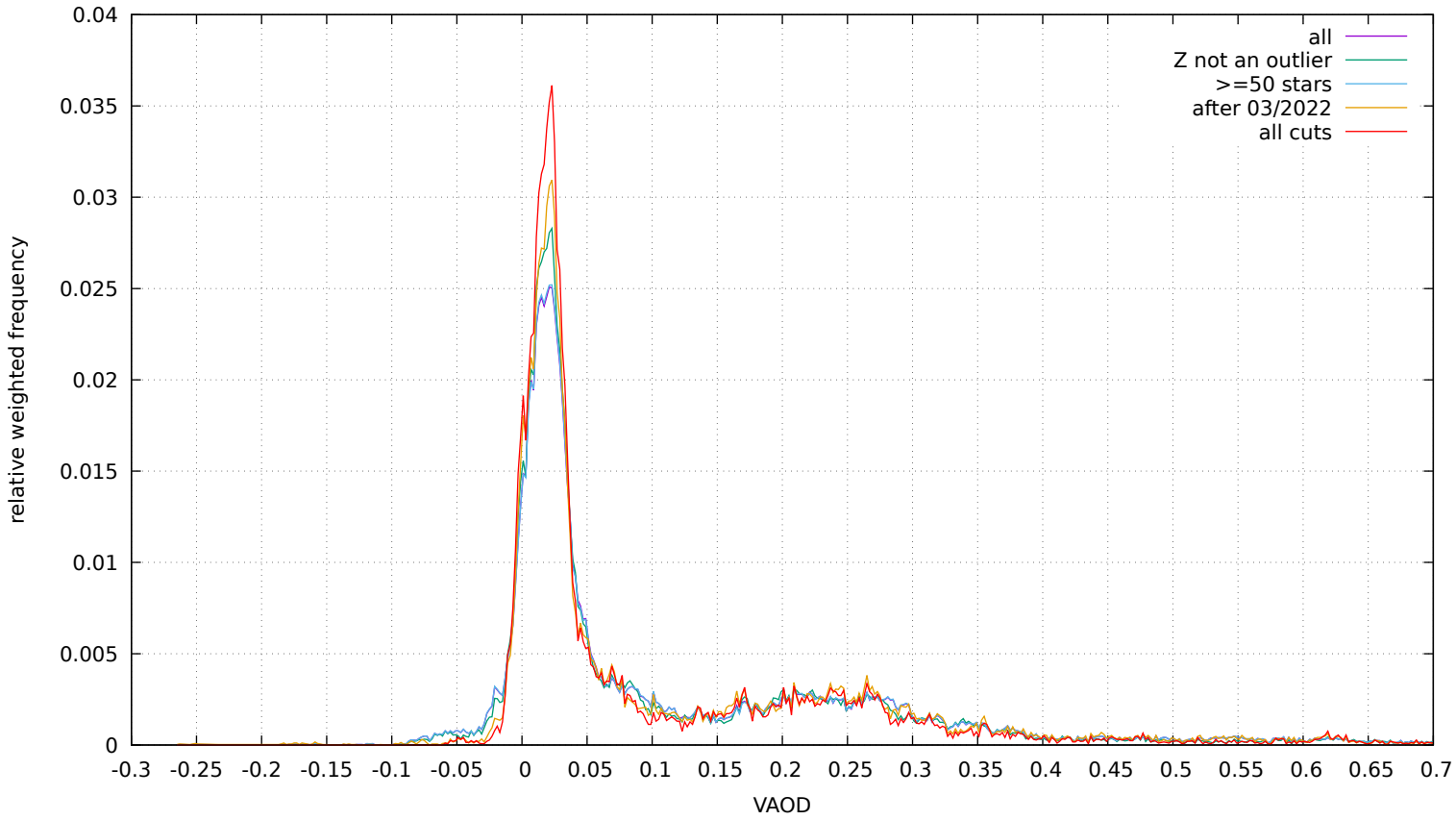
Distribution of VAOD values measured by CTAO FRAM in tiles with different cuts applied



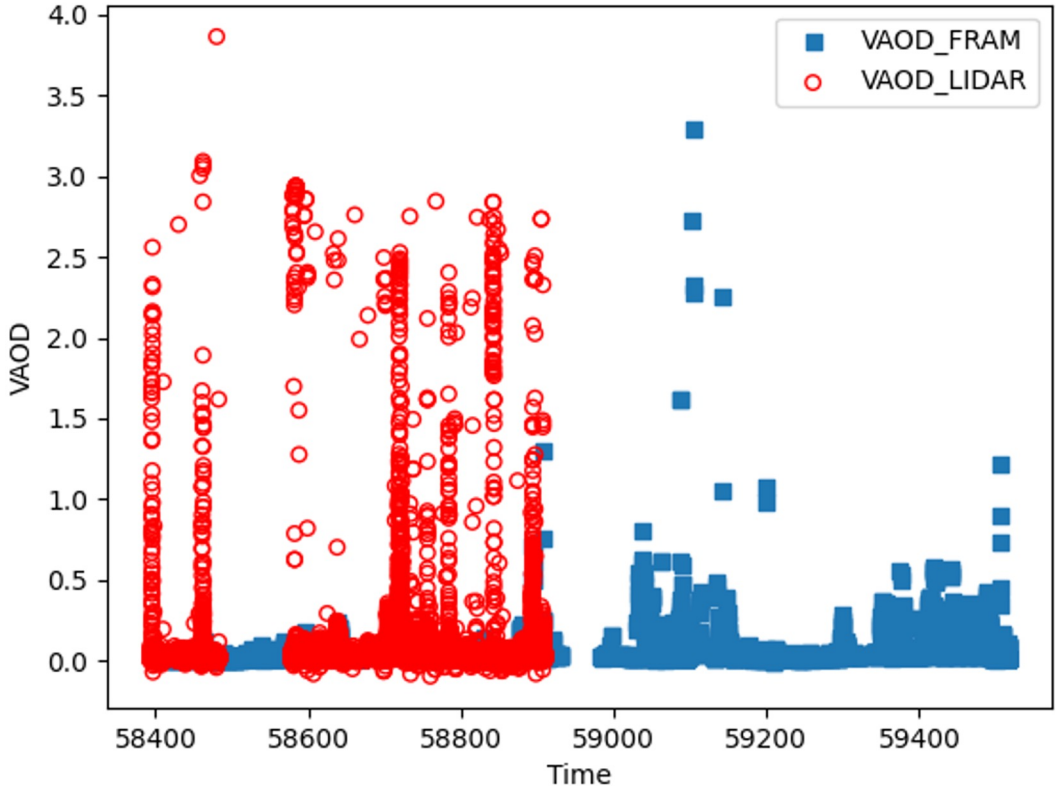
Distribution of VAOD values measured by CTAO FRAM in tiles after all cuts compared with the distribution of the precise VAOD measurements from scans without and with a smearing with a Gaussian with σ = 0.04

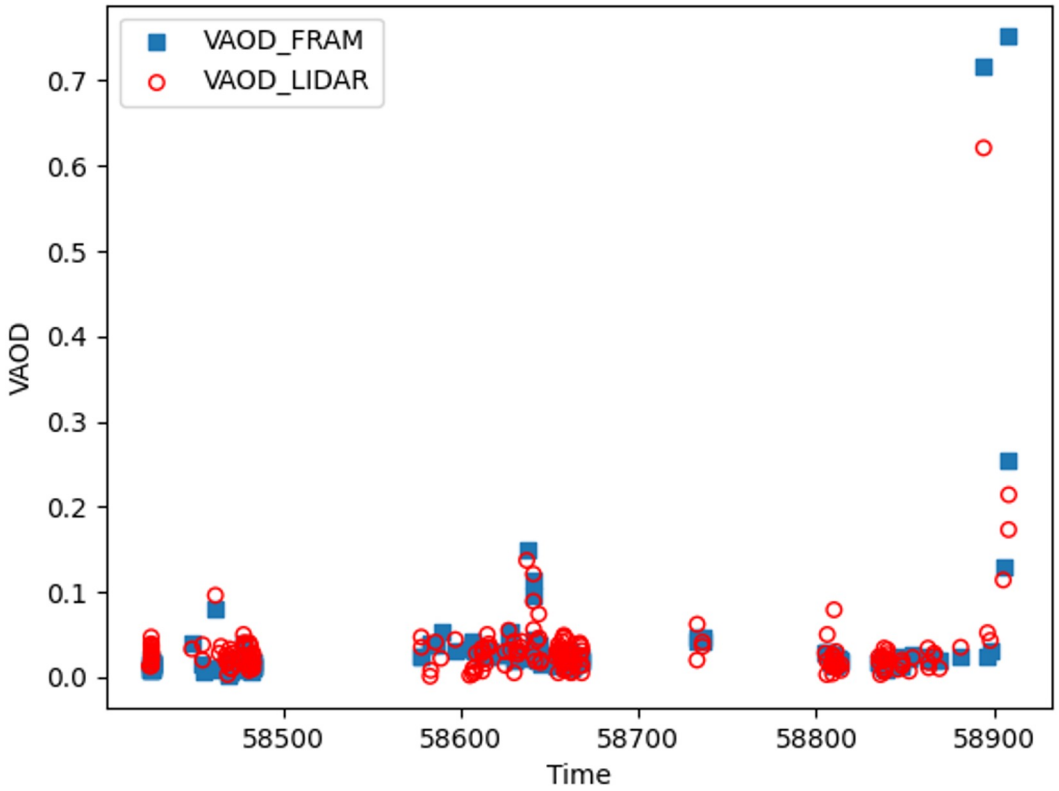


Distribution of VAOD values measured by CTAO FRAM in tiles with different cuts applied (normalised to the number of entires after each cut)

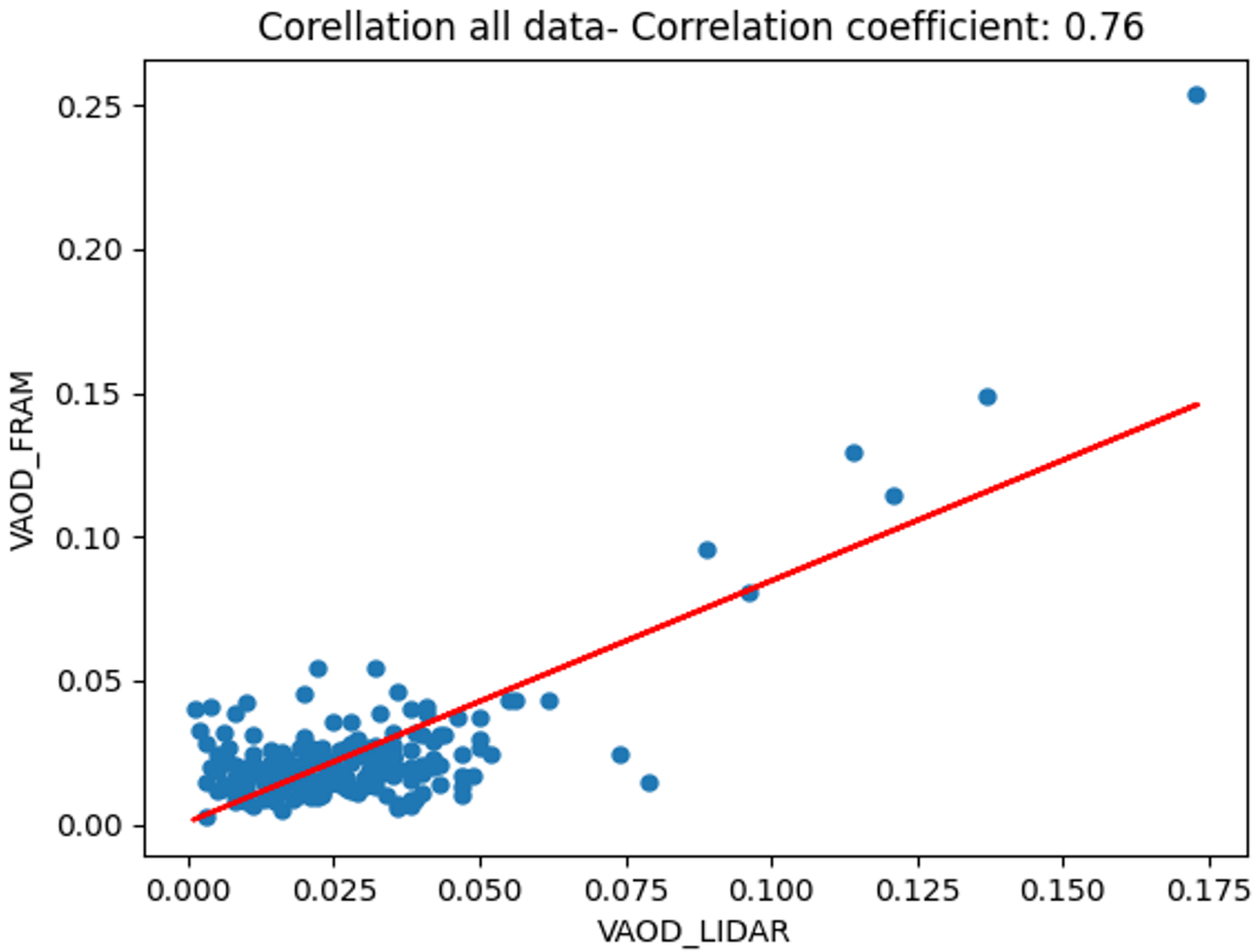


VAOD measured by MAGIC LIDAR and CTAO FRAM

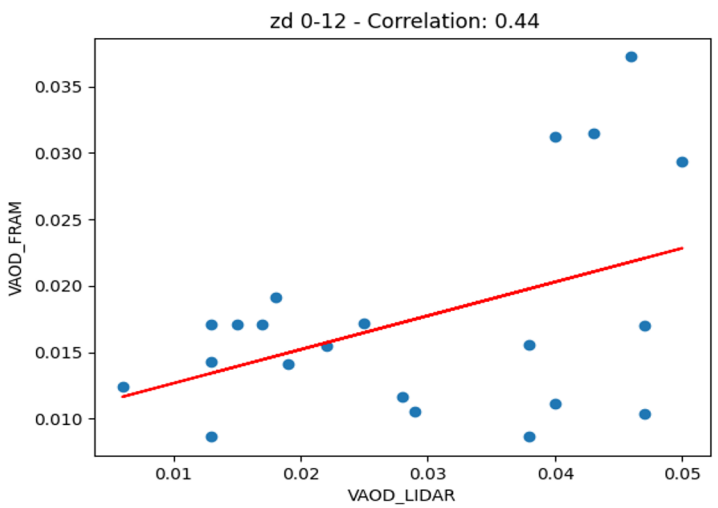


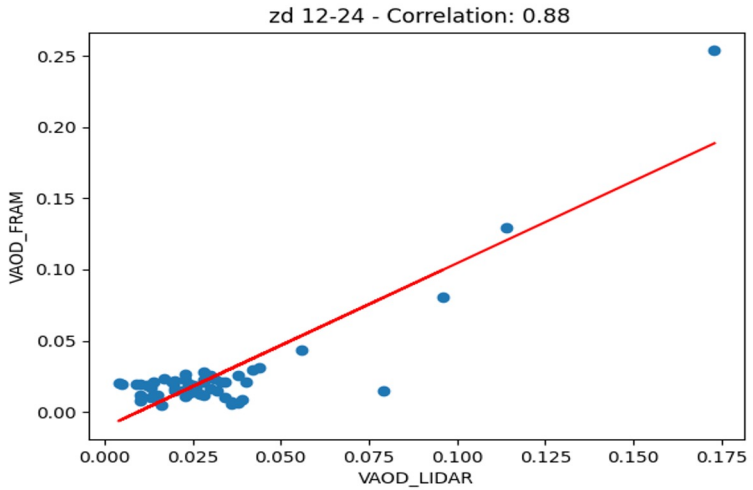


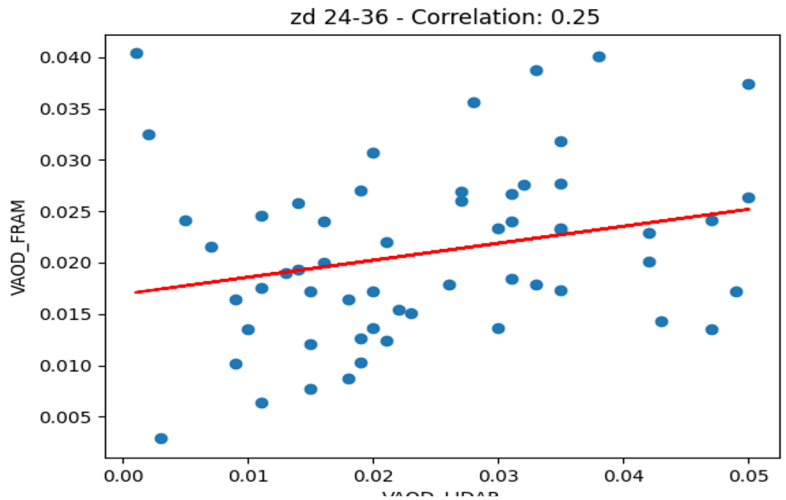
Correlation between MAGIC LIDAR and CTAO FRAM

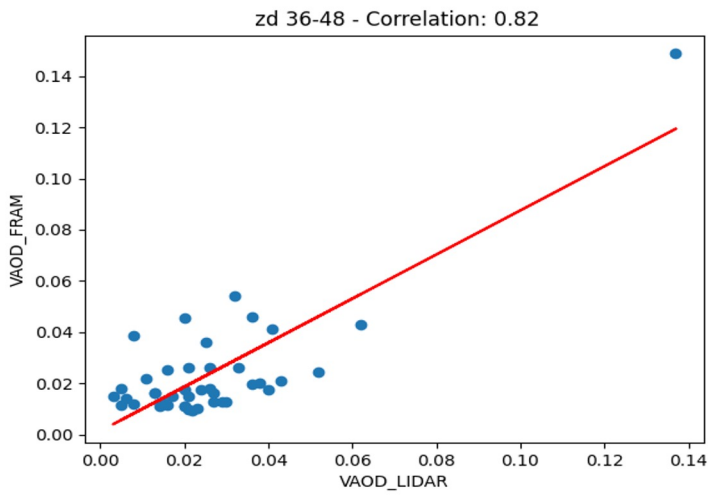


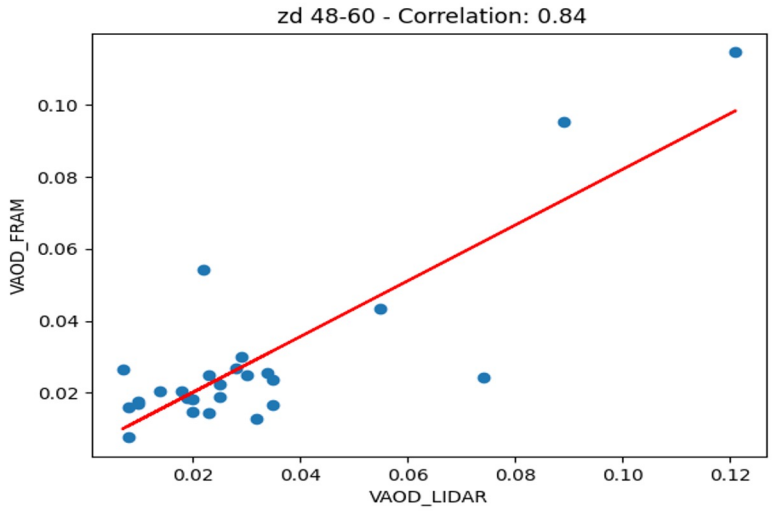
Correlation LIDAR/FRAM in dependence of the zenith angle

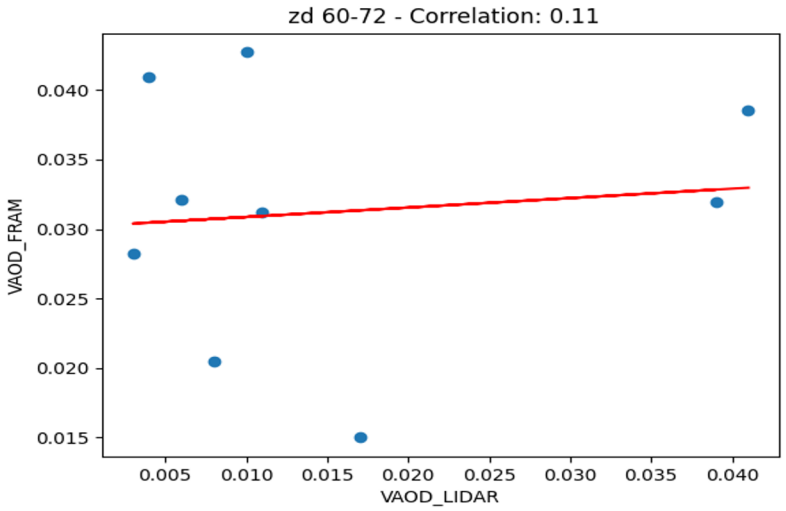






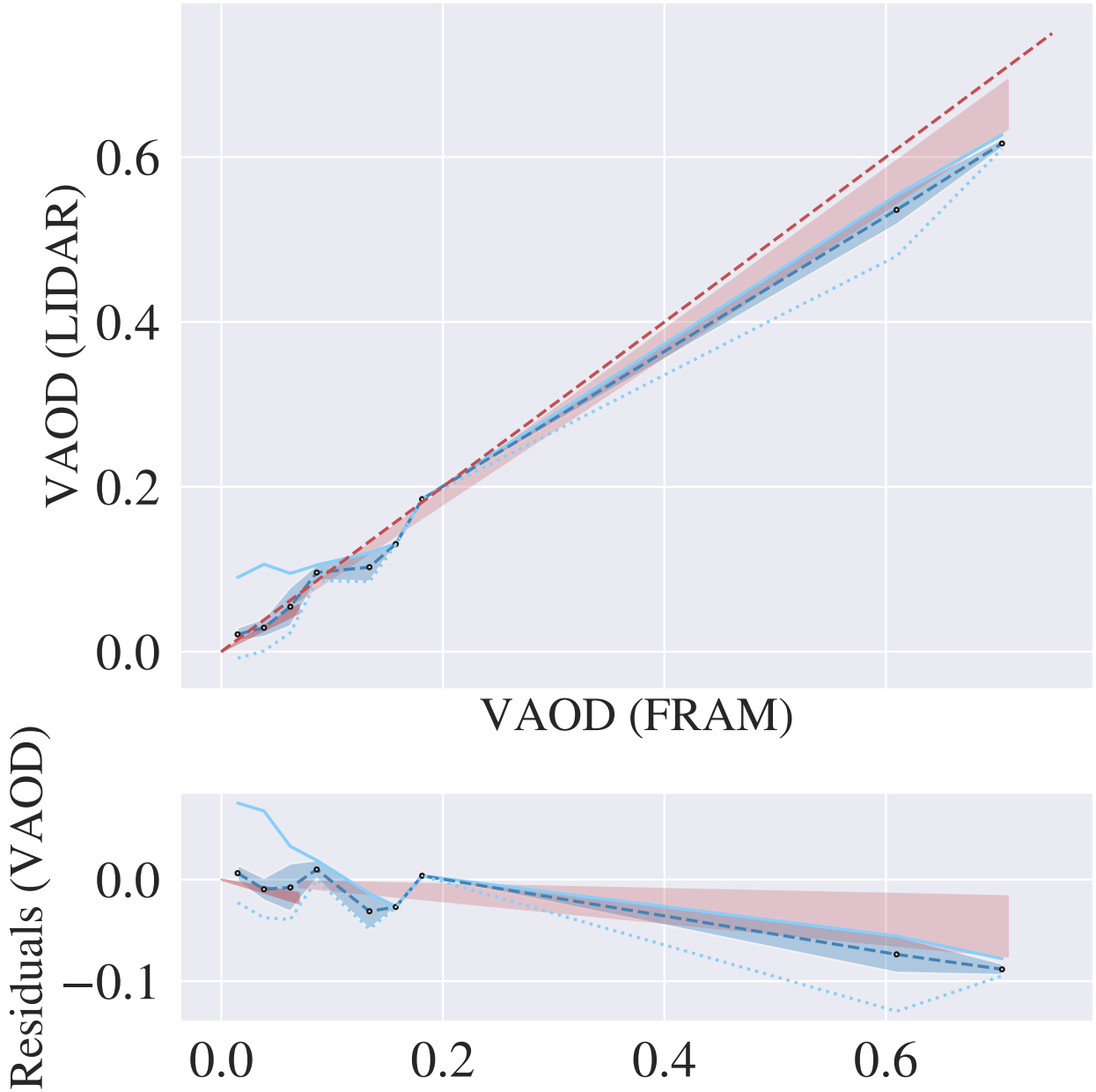






Correlation LIDAR/FRAM

- perfect correlation - red line
- the systematic unceratinties (Angstrom coeff., etc.) - ed shaded area
- the measurements showing medians – blue points
- 25-75 percentile - blue area
- extremes - light blue dashed lines



Conclusions and Future Perspectives

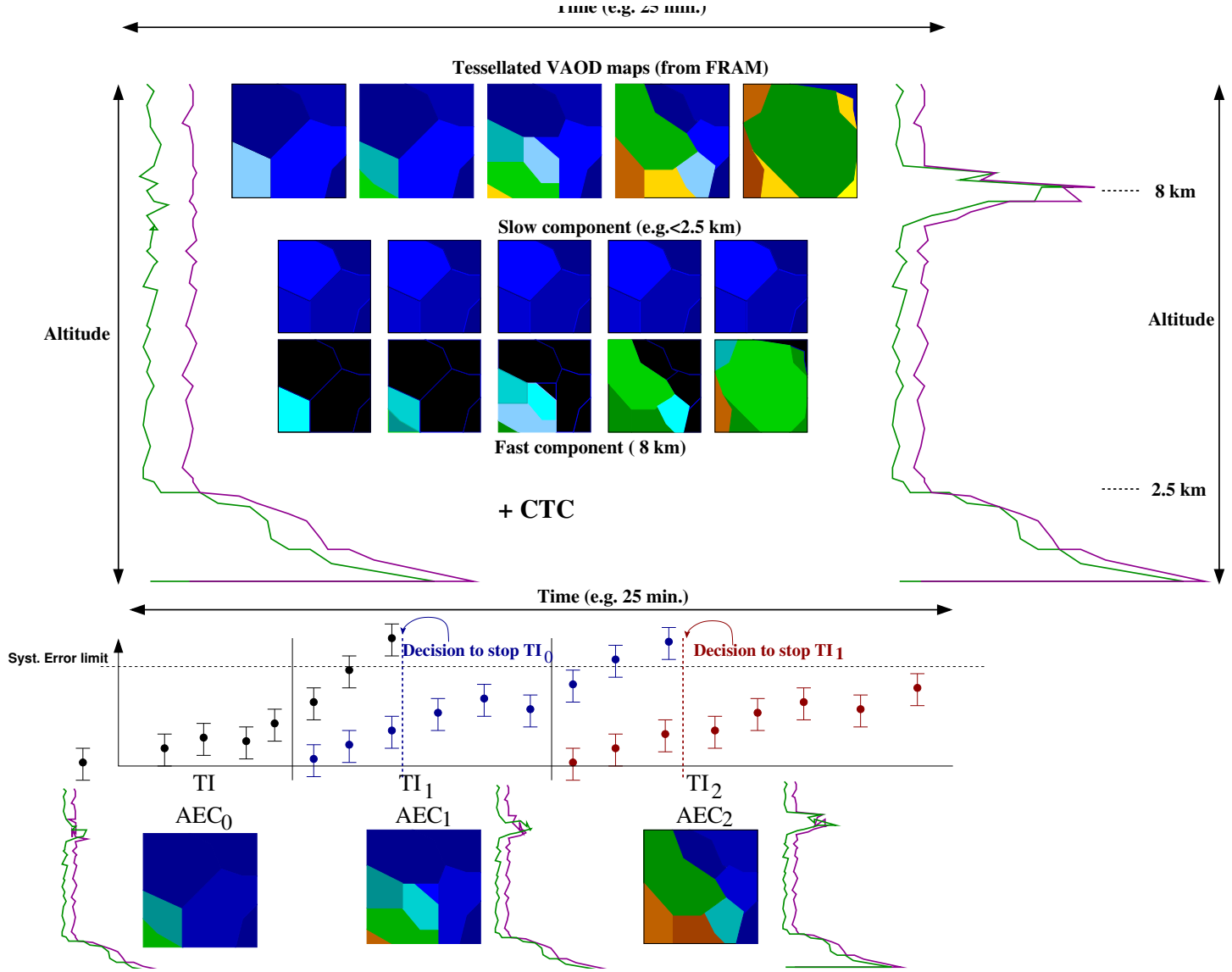
- Adaptive observation scheduling is important for optimisation of the available observational time of IACTs
- Different independent instruments for atmospheric characterisation used during the same time ensure a better strategy
- Correlation between MAGIC LIDAR and CTAO FRAM VAOD measurements is not perfect but satisfying, taken in account systematic uncertanities and small time overlap of our sample
- Possible applications for cases when one of the instruments is not working
- For the future, correlation studies including other instruments for atmospheric characterisation are planned


"I love the clouds
The clouds that pass up there
Up there the wonderful clouds!”
Charles Baudelaire: “The Stranger”

Backup slides

Scheme for the determination of new Stable Time Intervals (STIs) and new Monte Carlo (MC) simulated Instrument Response Functions (IRFs)

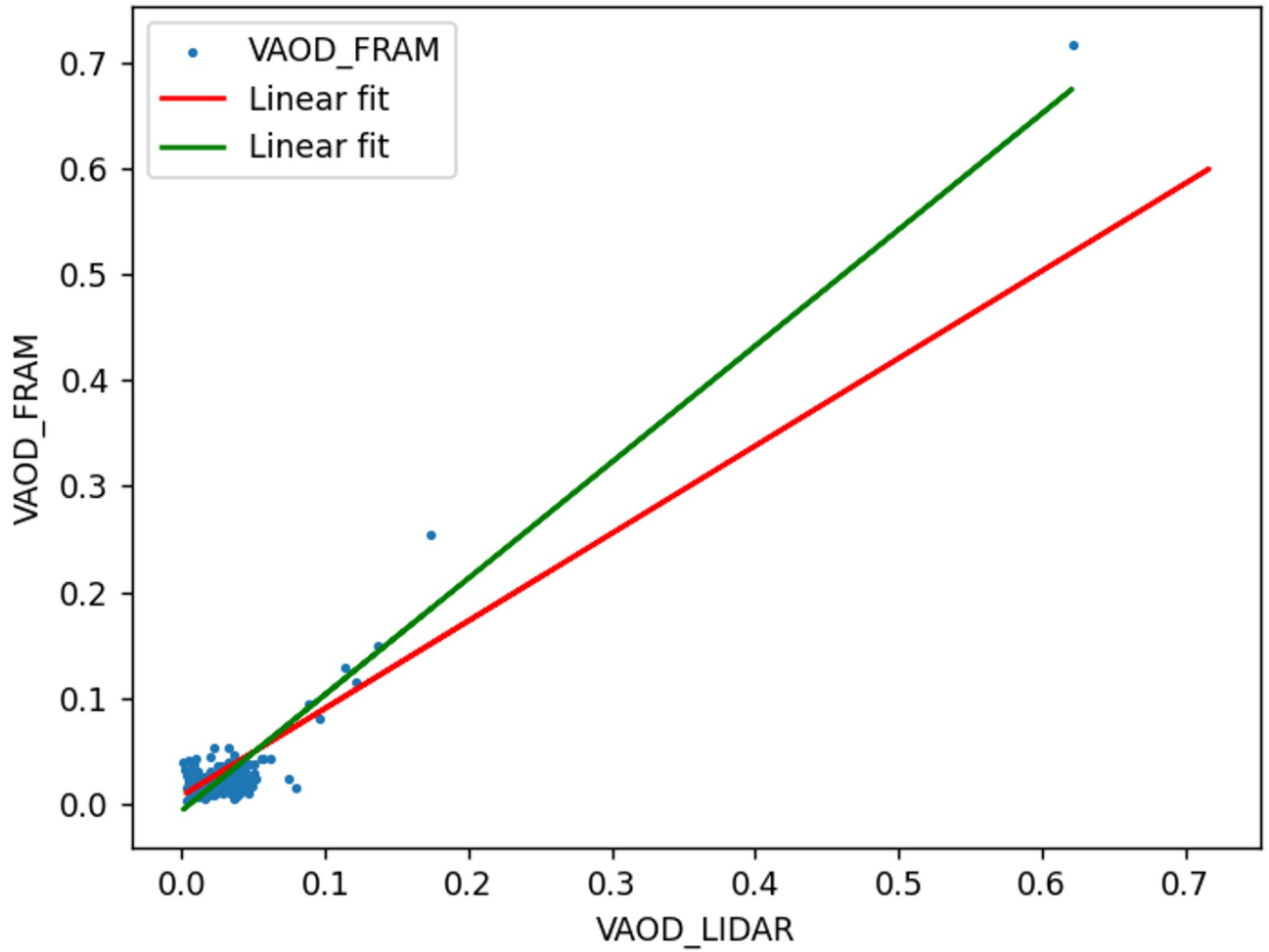
Procedure for obtaining average instrument response 114 functions over a time interval within which the systematic error due to simplifications of 115 the profile remains acceptable.

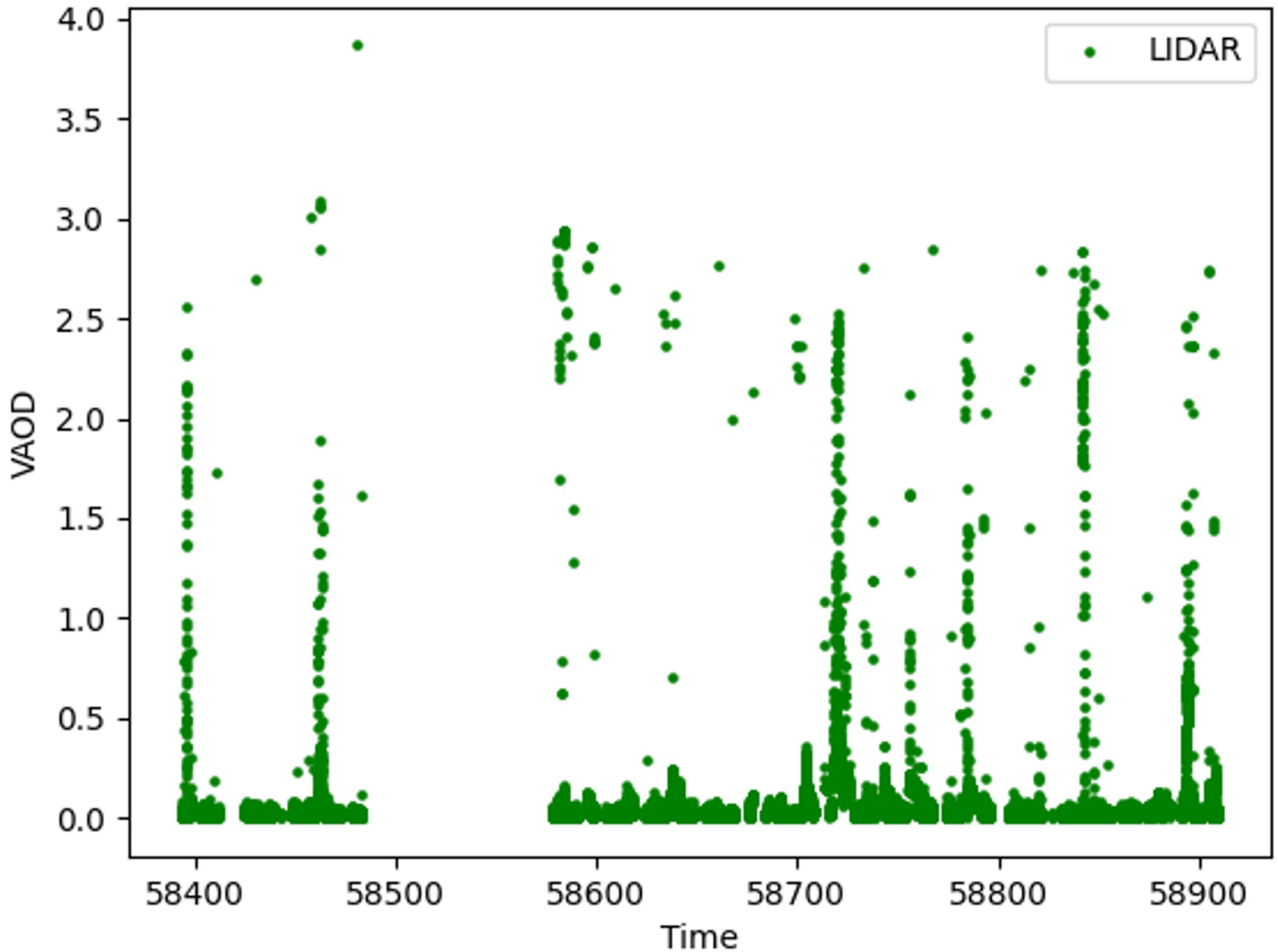


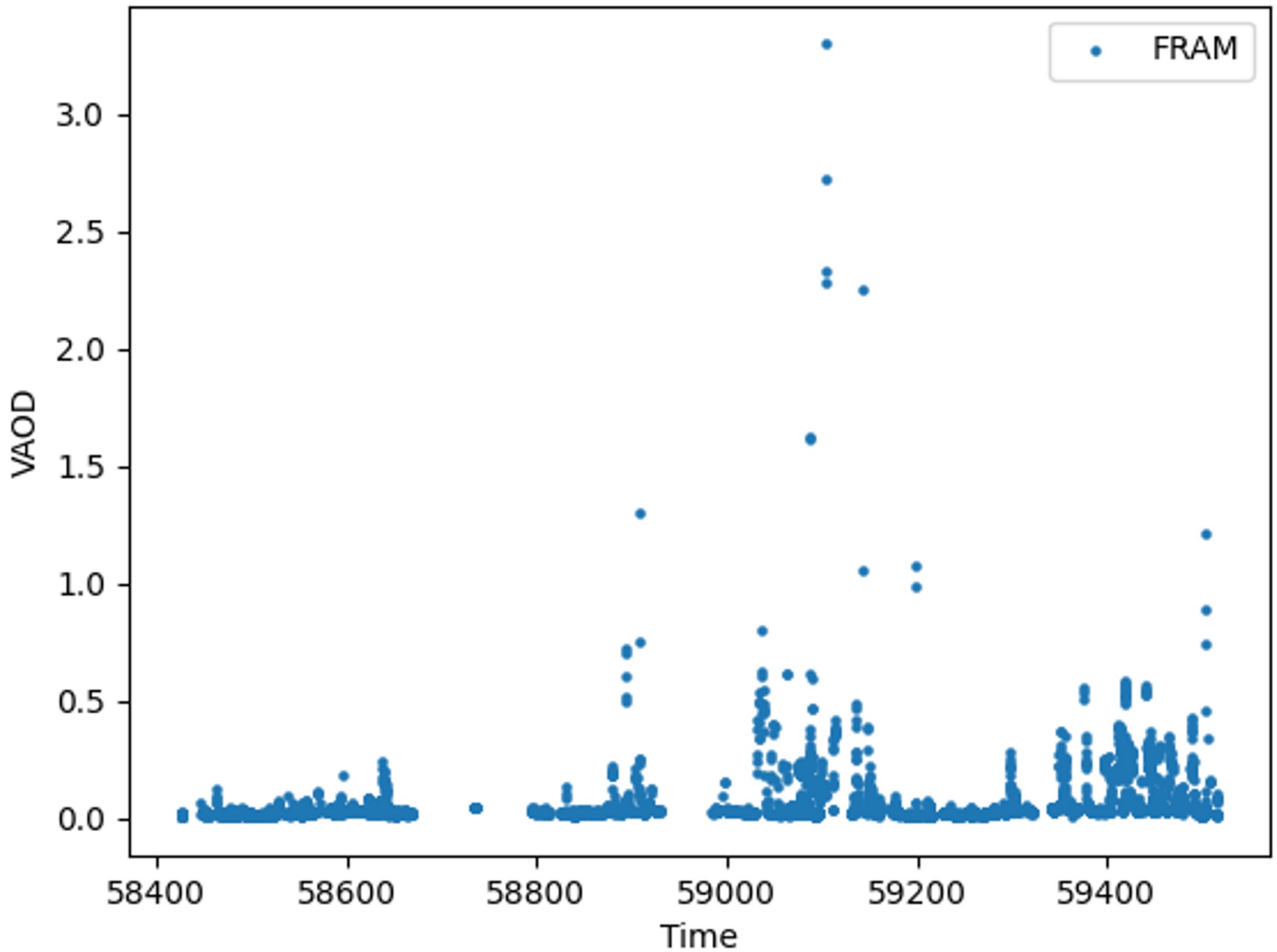
Data quality classes (MAGIC 2 year statistics)

Data quality class	LIDAR T (9 km)	Without calima cut (% of time)	With calima cut
1. (no corrections)	1.00-0.85	69	85
2. (corrections)	0.85-0.70	17	9
3. (corrections)	0.70-0.55	6	2
4. (“garbage”)	0.55-0.00	8	4

Standard correlation fit vs. robust fit




LIDAR
VAOD
Time
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
58400
58500
58600
58700
58800
58900


FRAM
VAOD
3.0
2.5
2.0
1.5
1.0
0.5
0.0
58400
58600
58800
59000
59200
59400
Time