

# **GROUND-BASED CLASSIFICATION METHOD FOR DIRECT NORMAL AND GLOBAL HORIZONTAL IRRADIANCE**

**EMS Conference, Barcelona, 06.09.2024**

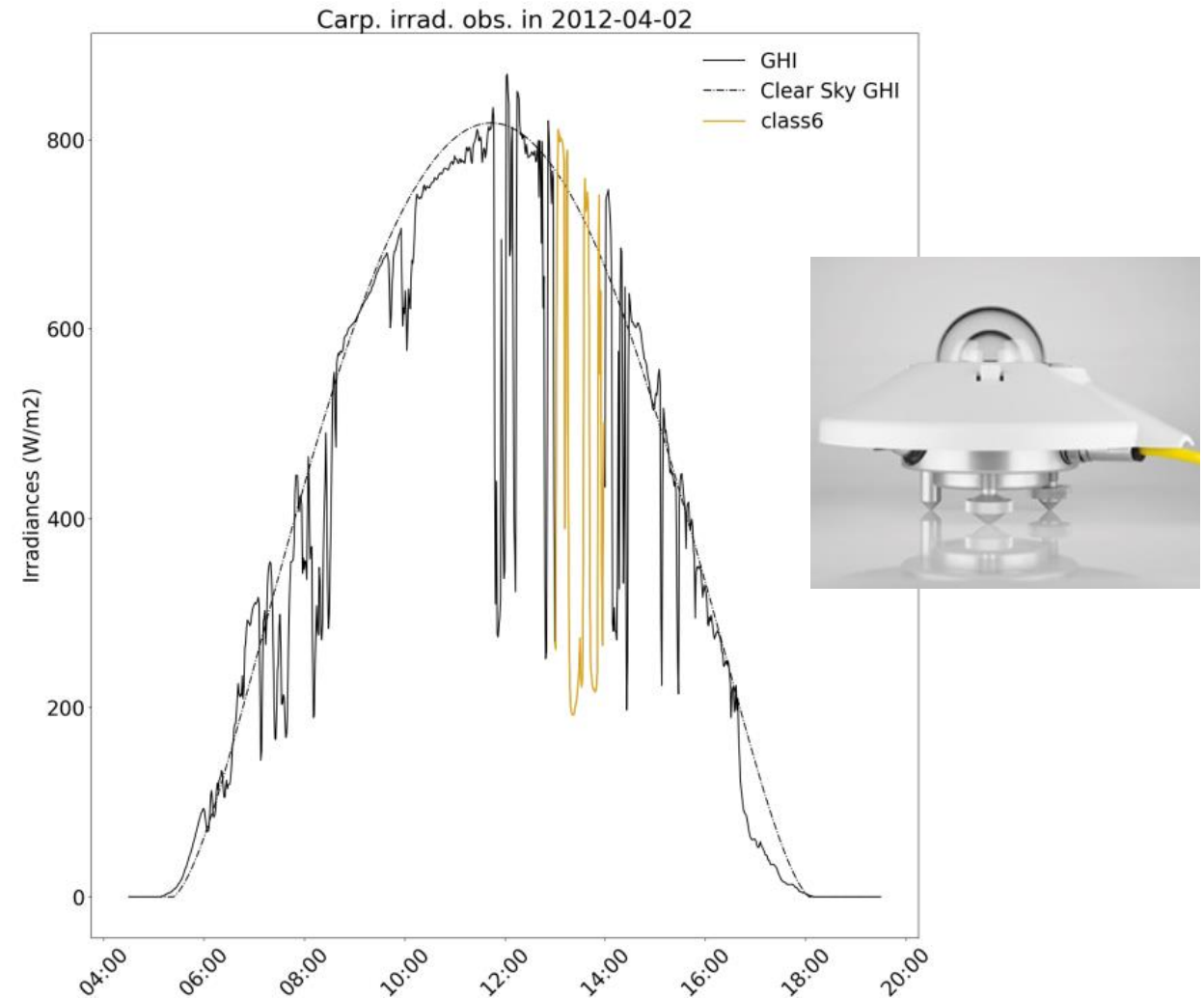
**Diego Miranda, Faiza Azam, Jorge Lezaca, Marion Schroedter-Homscheidt**

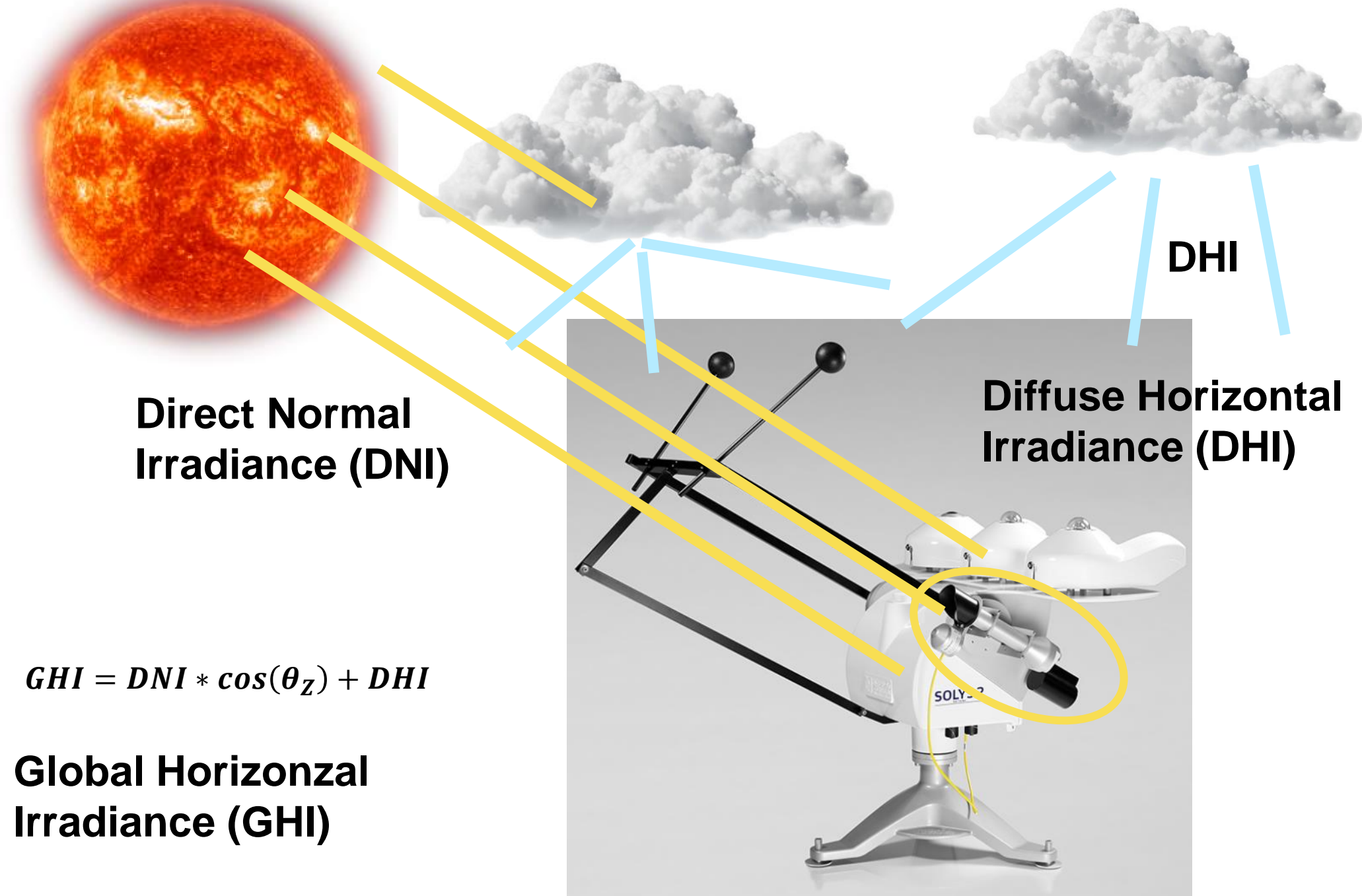
**German Aerospace Center (DLR), Institute of Networked Energy Systems, Oldenburg**



# Motivation

- **Clouds and aerosols: main factors influencing the solar irradiance variability.**
- Clouds can cause strong variation on times scales as short as 1-min
- Identifying short-term variability is **relevant for solar power systems operation, irradiance models, forecasting services, etc.**





**Direct Normal  
Irradiance (DNI)**

**Diffuse Horizontal  
Irradiance (DHI)**

$$GHI = DNI * \cos(\theta_z) + DHI$$

**Global Horizontal  
Irradiance (GHI)**

# Reference Database – Carpentras, year 2012



- BSRN-Carpentras, 2012 (south of France). 1-min data, 280 hours manually classified as:

Class 1 – Clear sky

Class 2 – Close to clear sky (e.g. thin cirrus and aerosols)

Class 3 – Sky with medium variability, close to the clear sky (e.g. cirrus clouds)

Class 4 – Variable sky with large variability, close to the clear sky in some intervals

Class 5 – Sky with medium variability

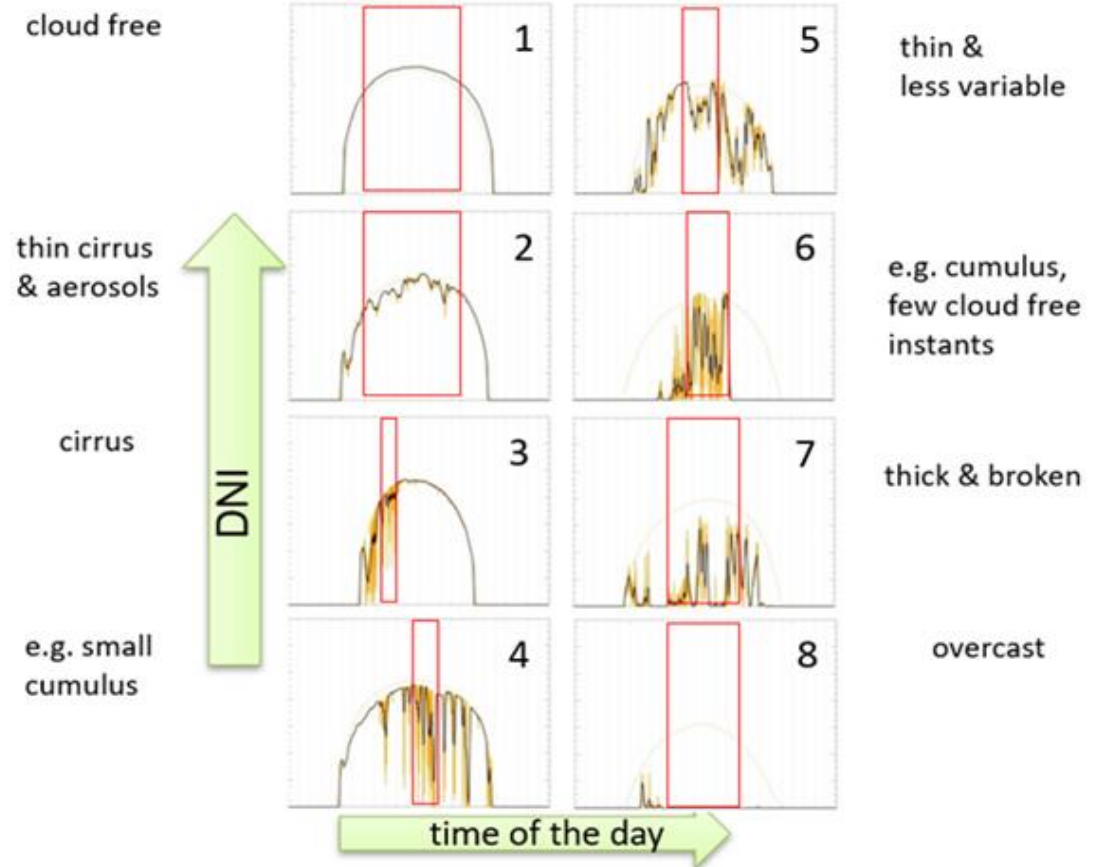
Class 6 – Thick/broken clouds with large variability

Class 7 – Partly overcast sky

Class 8 – Overcast sky

Time-window for classification: 1 hour (using 1-min data)

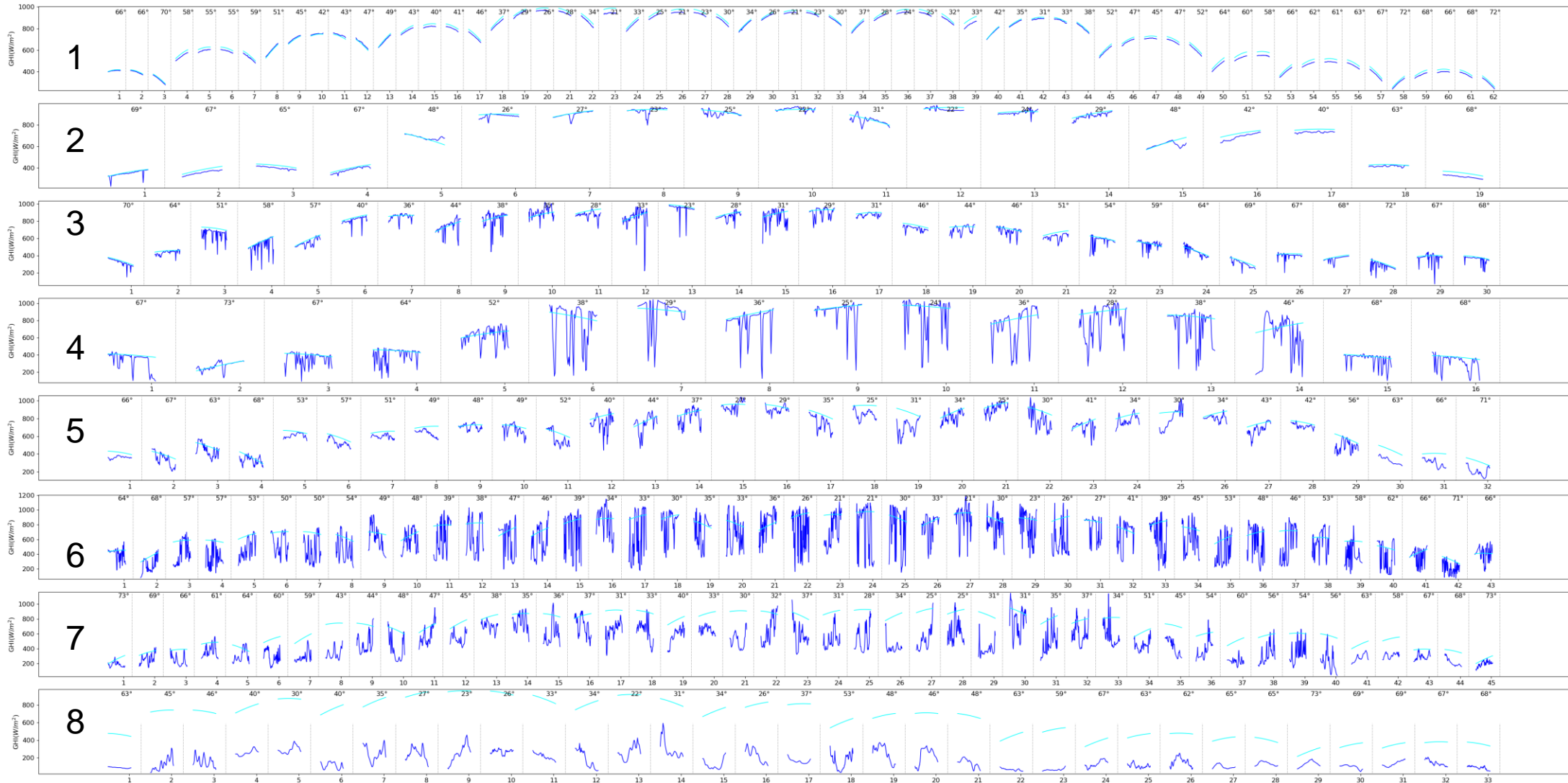
*Schroedter-Homscheidt et al. (2018)*



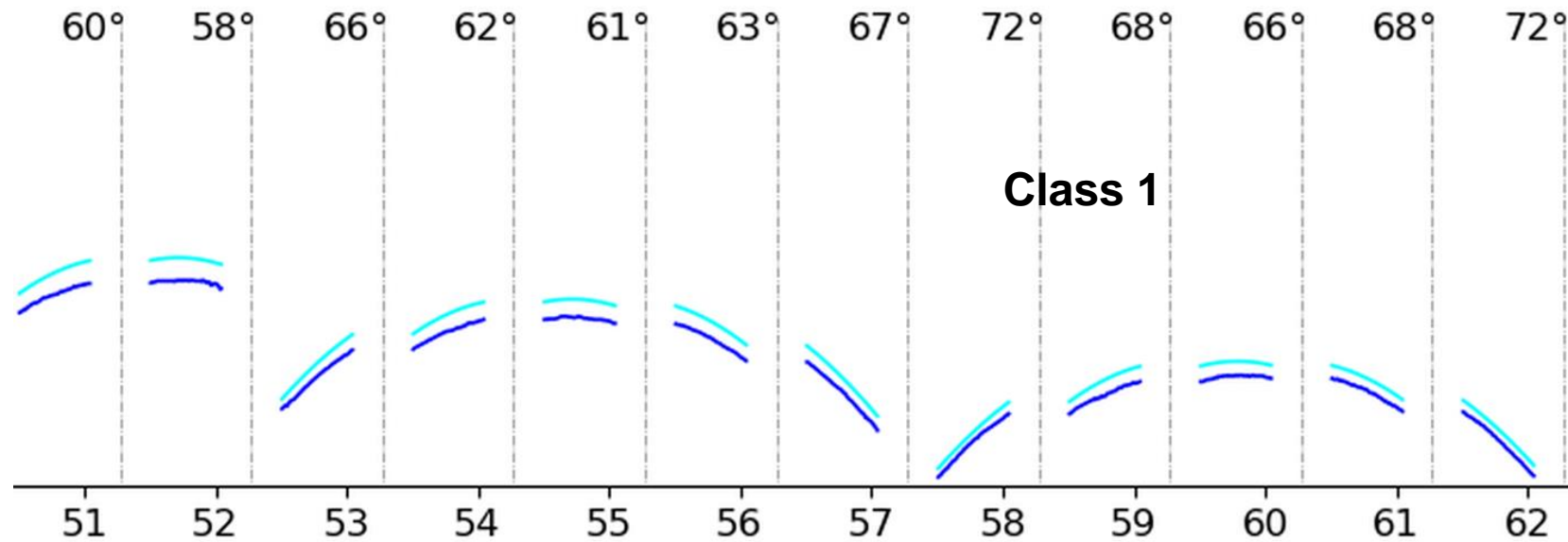
Example variability classes 1-8

Hours being classified, 1-min resolved data, 10 min moving average

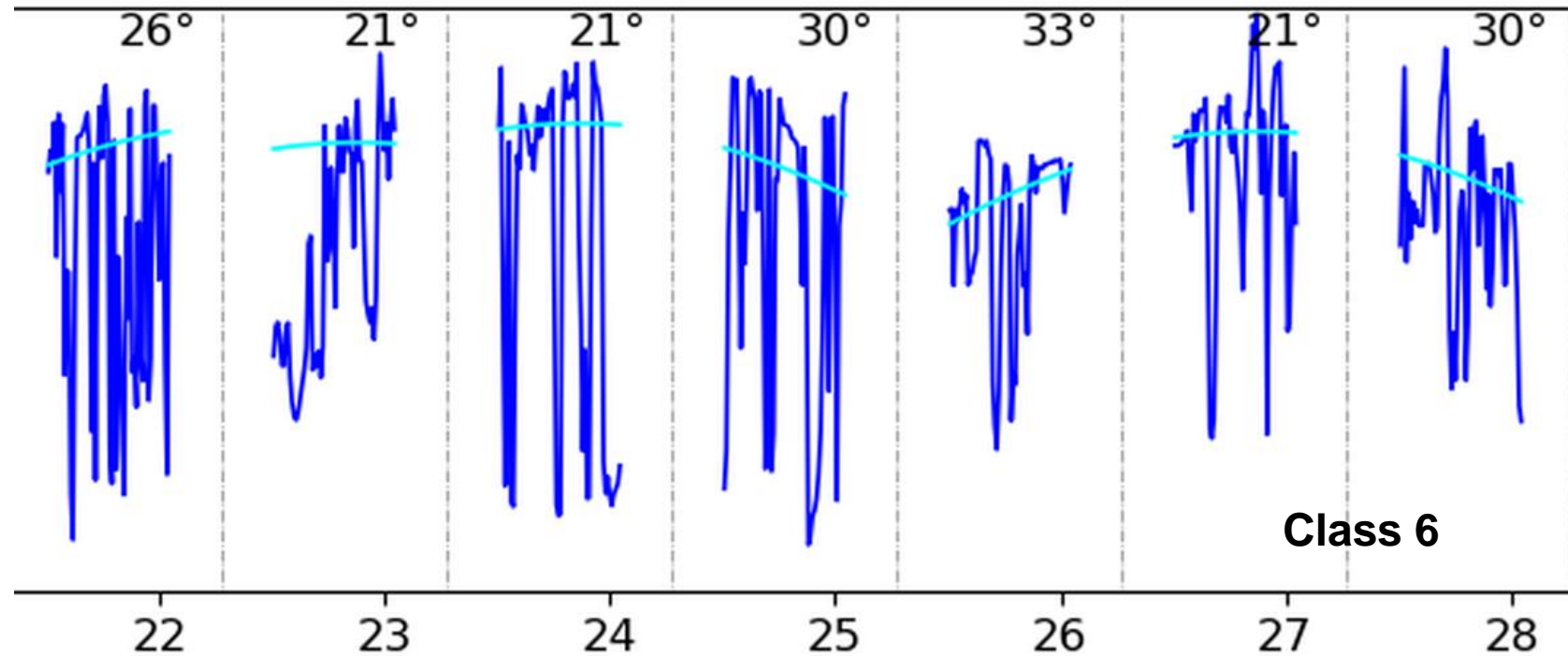
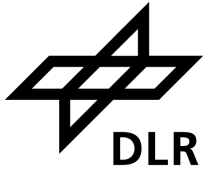
# Reference database for GHI-based classification



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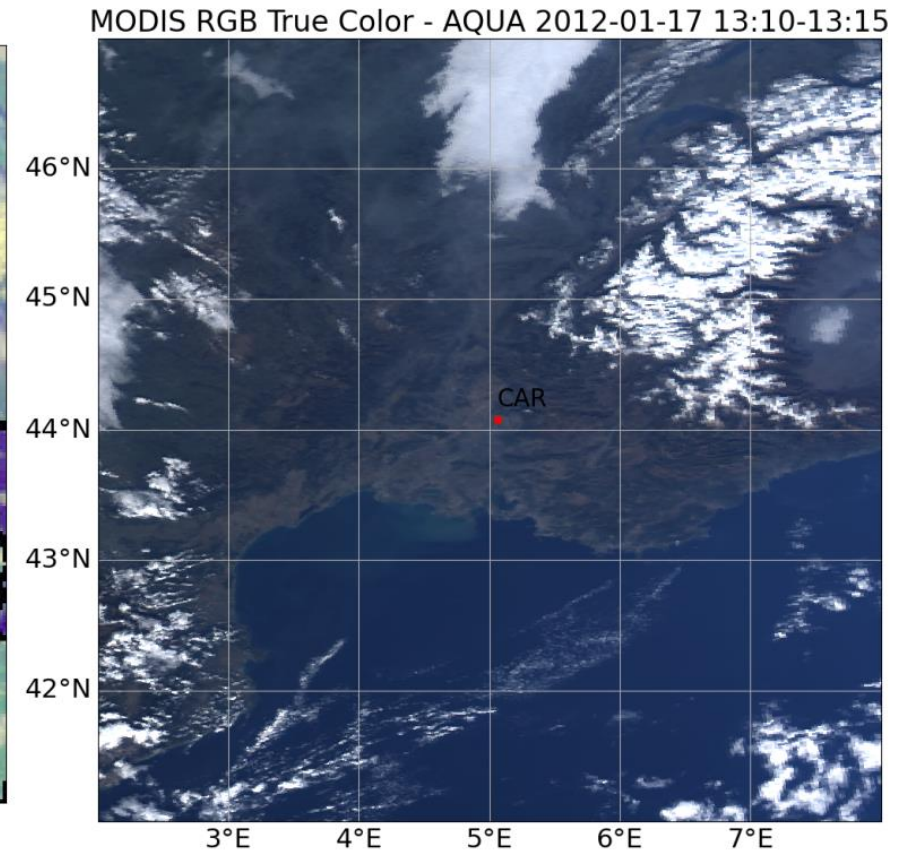
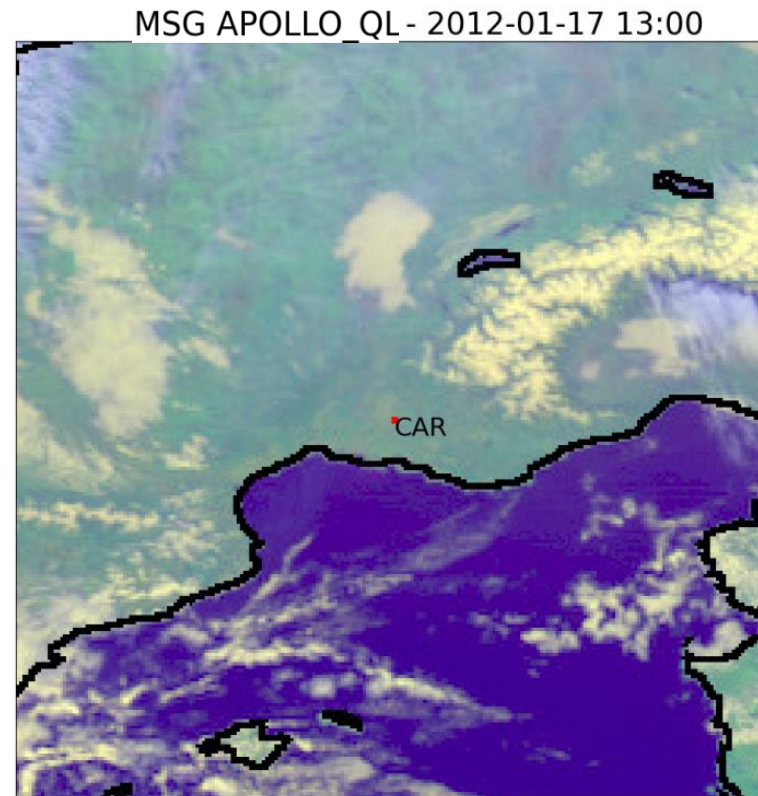
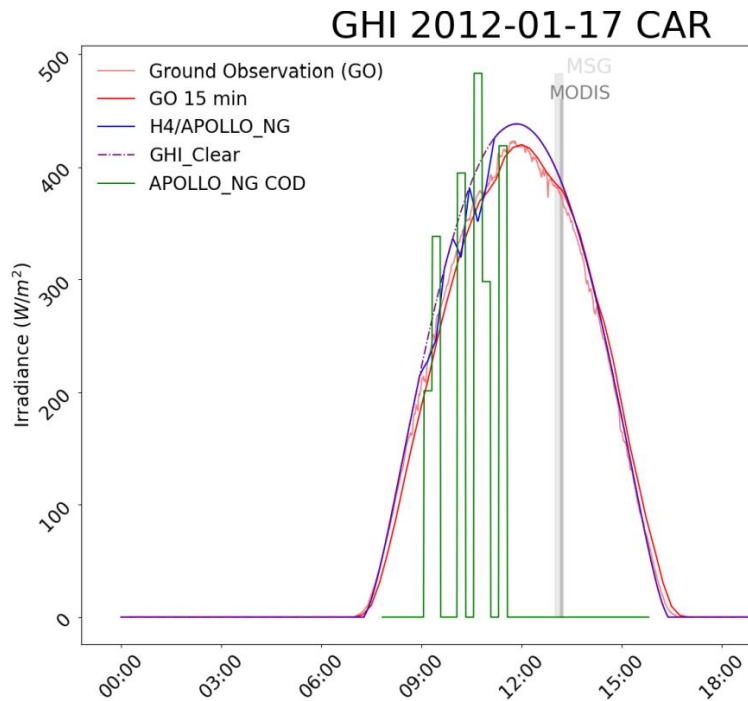


# Reference database for GHI-based classification



# Variability Indices (VIs)

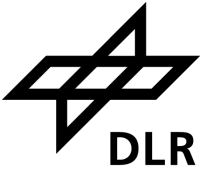
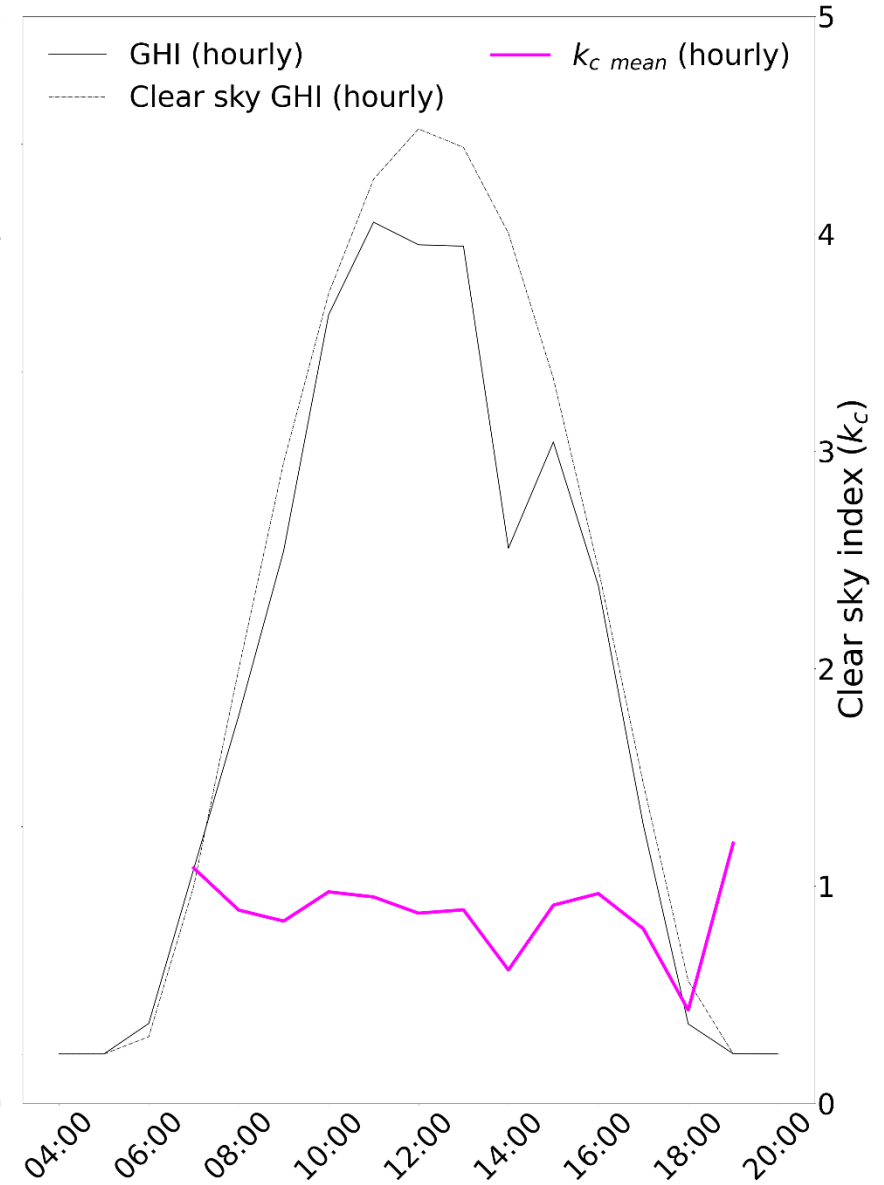
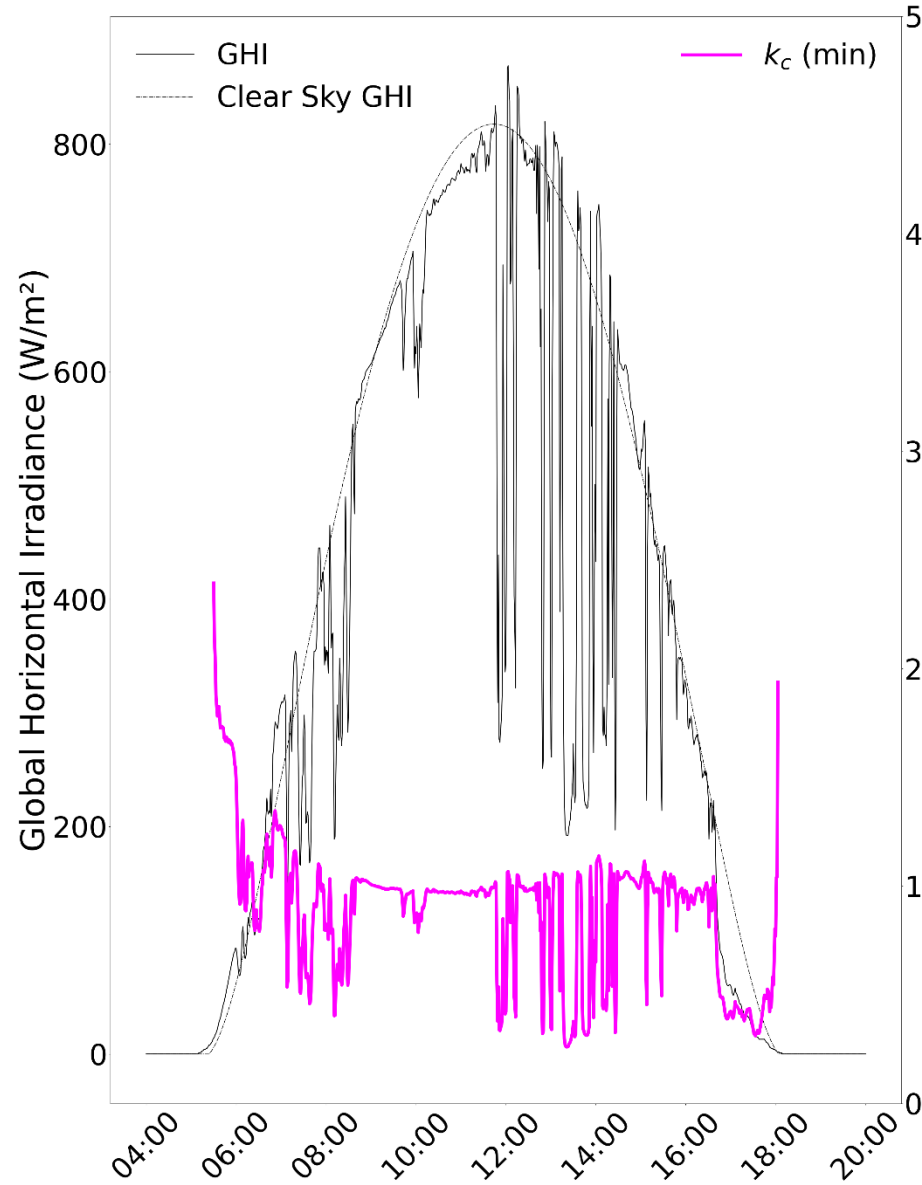
- Quantifies the variability information in the time window under study
- 13 different VIs are applied to classify hourly time-windows in one of the 8 classes



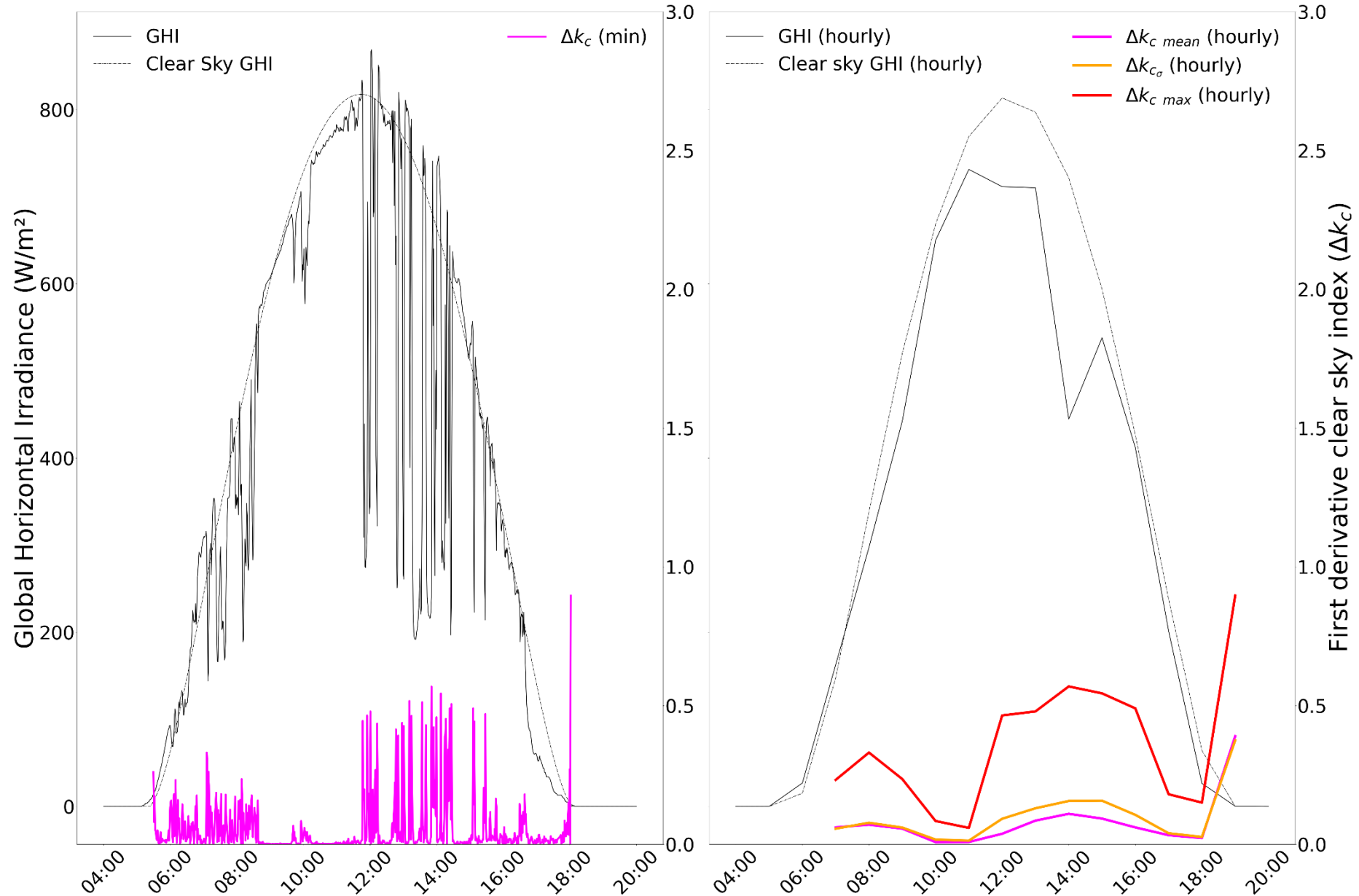


# VI. 1) $k_c$ mean

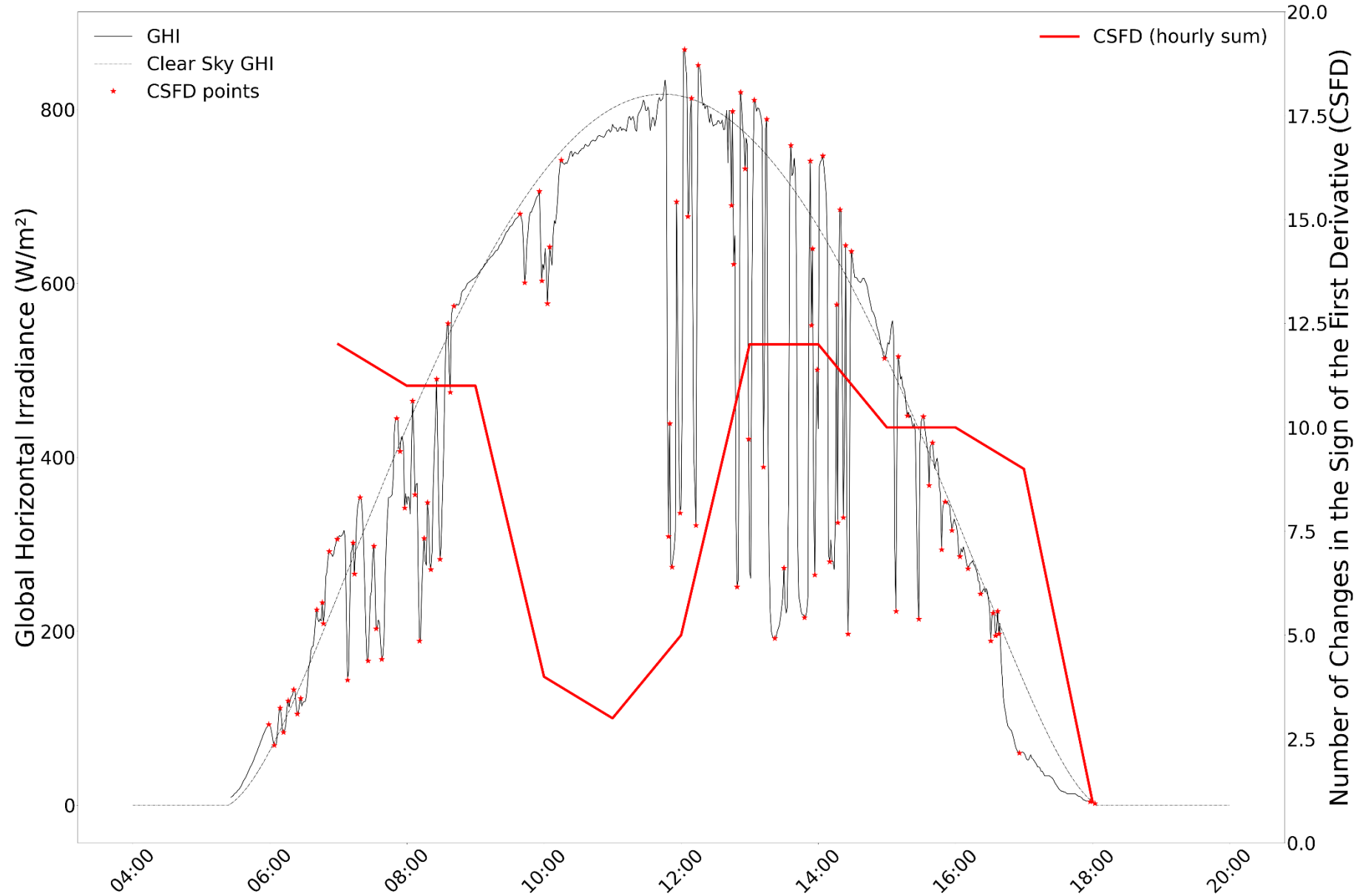
$$k_c = \frac{GHI}{GHI_{clear\ sky}}$$



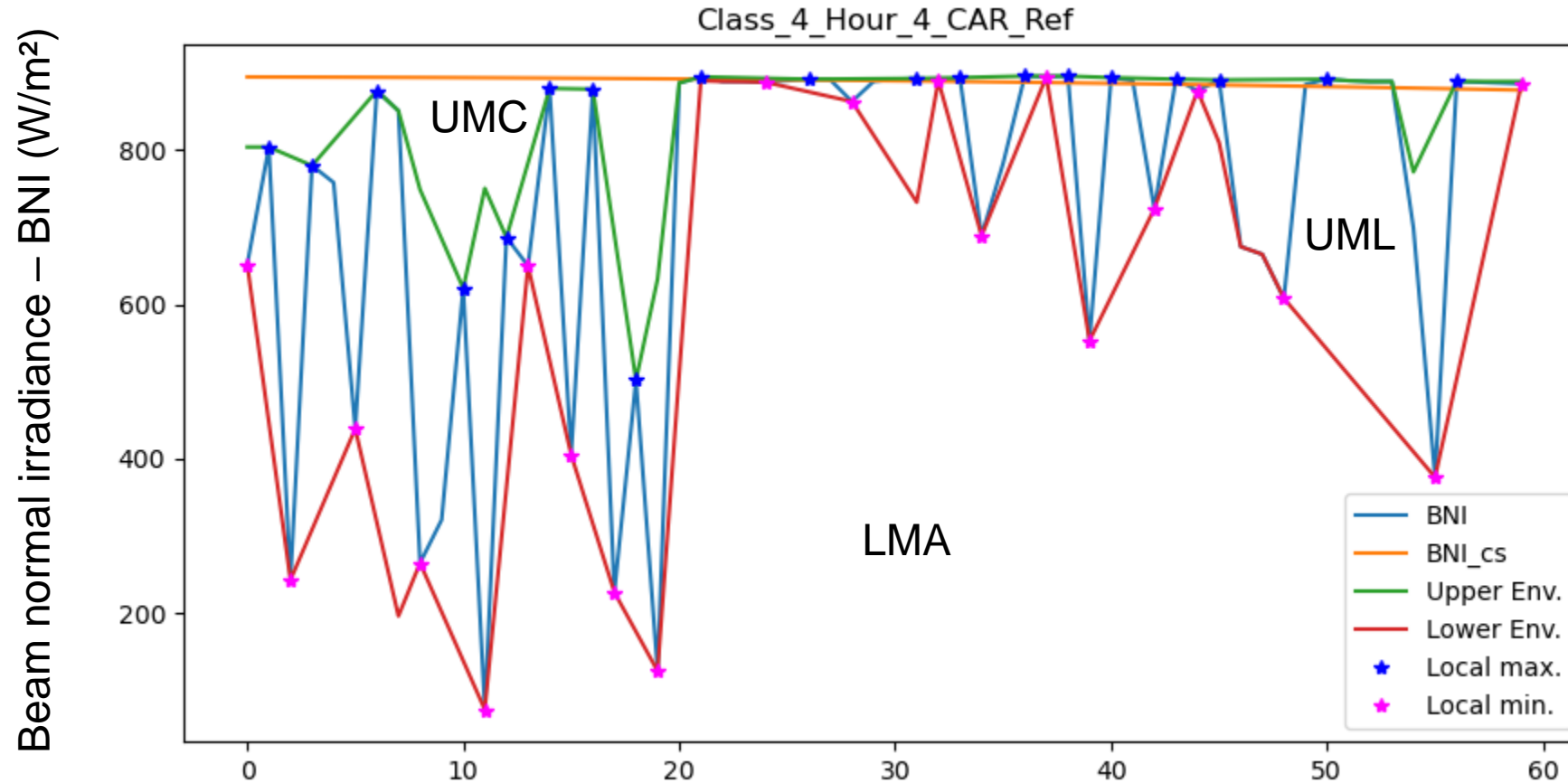
## VI. 2, 3, 4) $\Delta k_c$ mean, $\Delta k_c$ std and $\Delta k_c$ max



## VI. 5) Number of Changes in the Sign of the First Derivative (CSFD)



# VI. 6, 7, 8) Integral Methods: Upper Minus Clear (UMC), Upper Minus Lower (UML), Lowe Minus Abscissa (LMA)

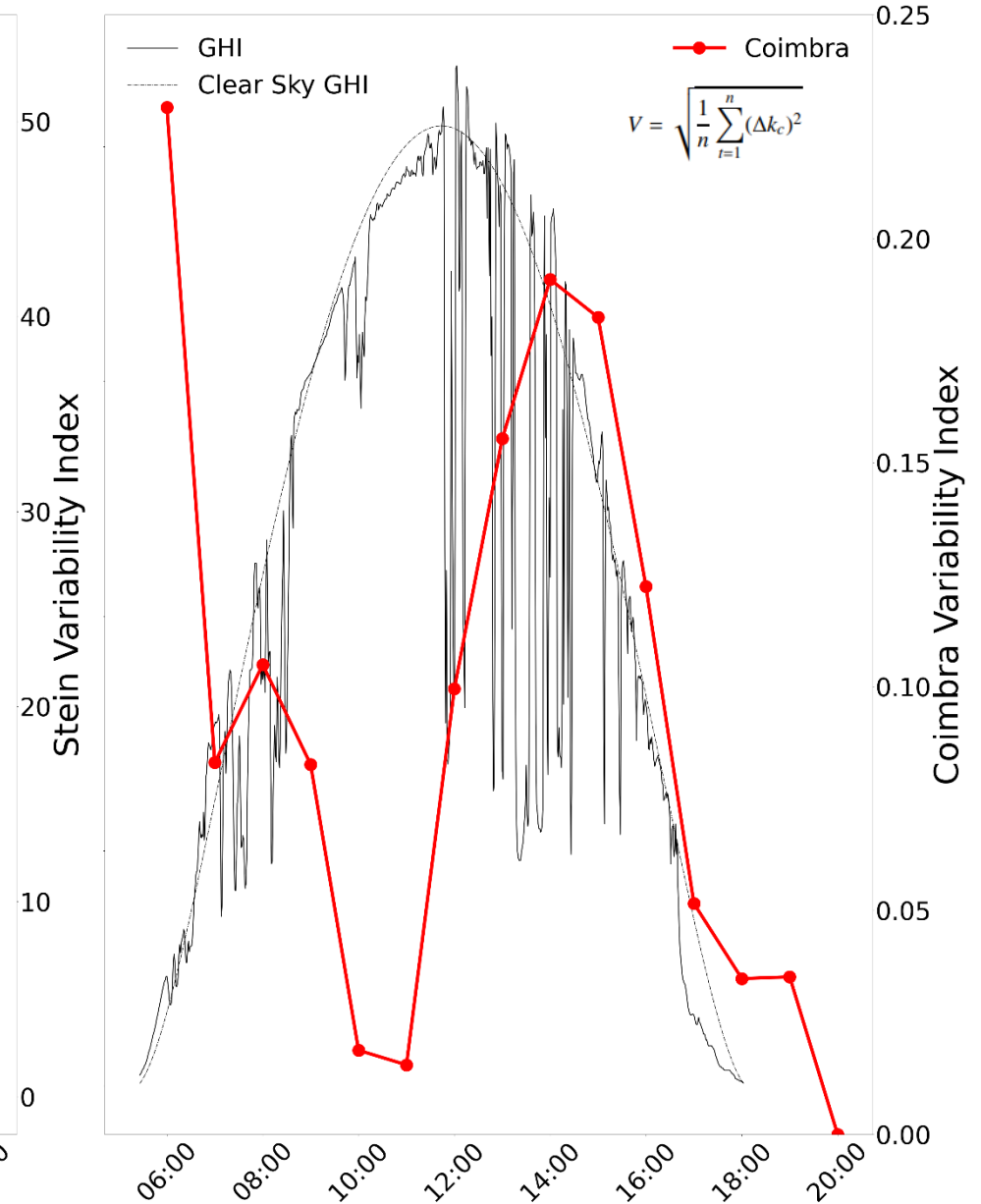
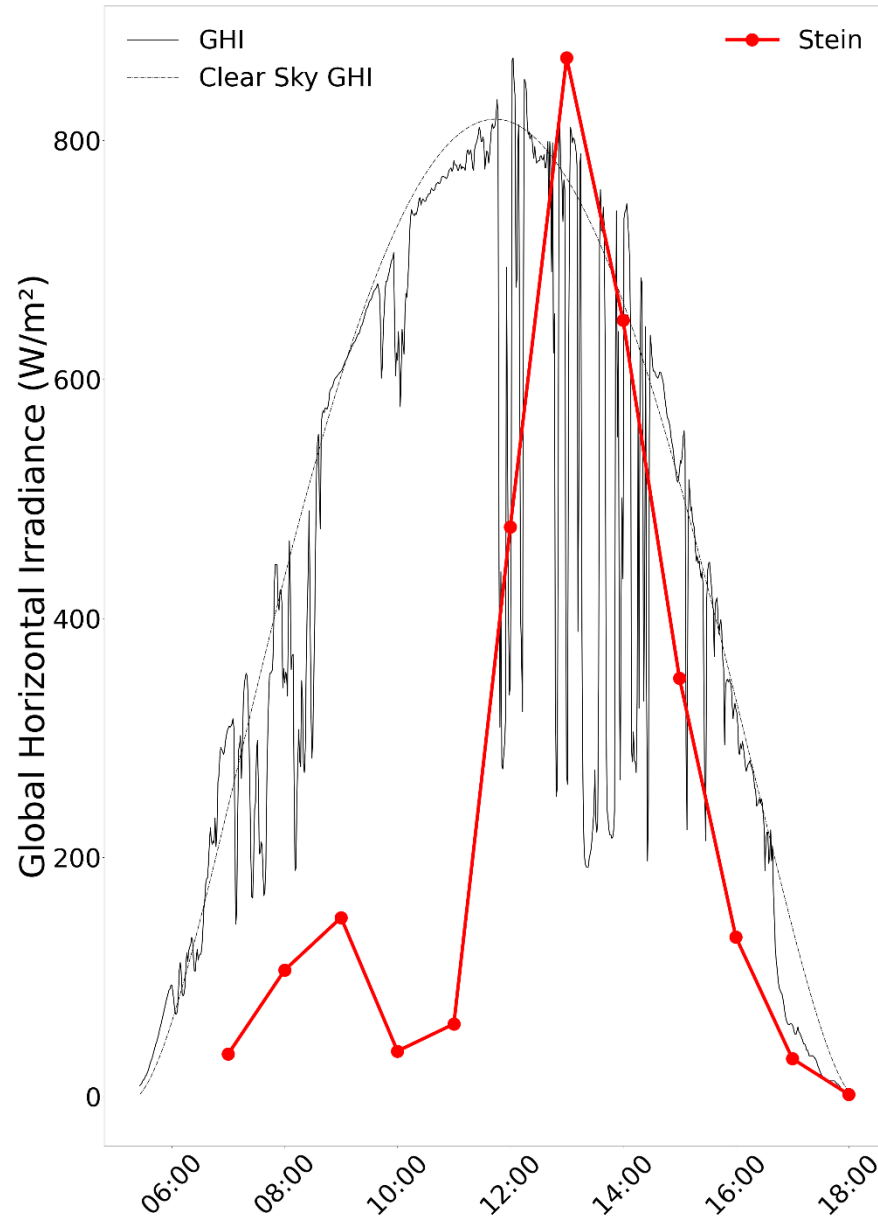


Units for integral methods:  $W/m^2 \cdot min$

Normalized by the Top of Atmosphere (TOA) irradiation

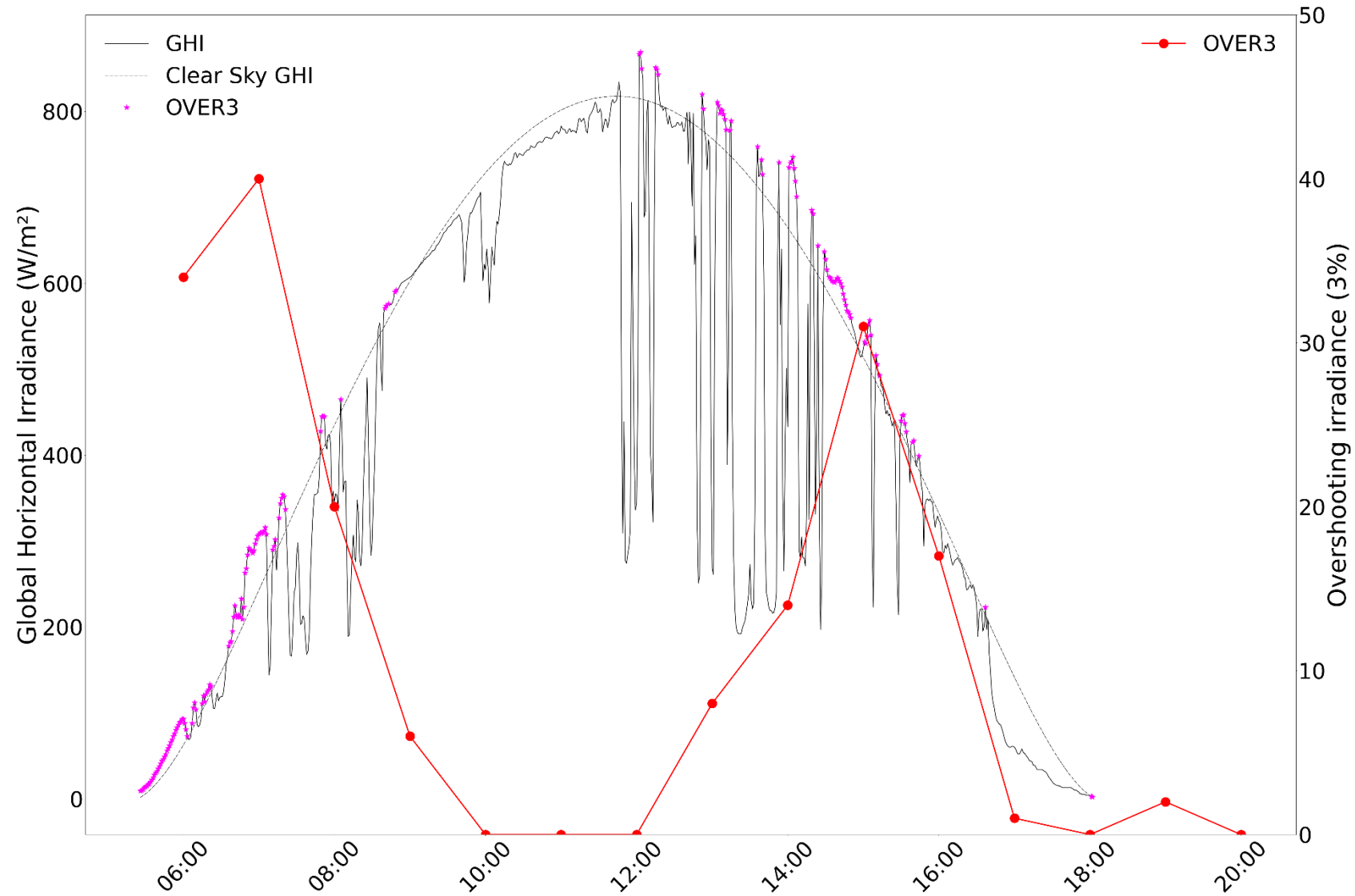
# VI. 9, 10) Stein and Coimbra

$$VI = \frac{\sum_{i=2}^n \sqrt{(GHI(i) - GHI(i-1))^2 + \Delta t^2}}{\sum_{i=2}^n \sqrt{(CSI(i) - CSI(i-1))^2 + \Delta t^2}}$$



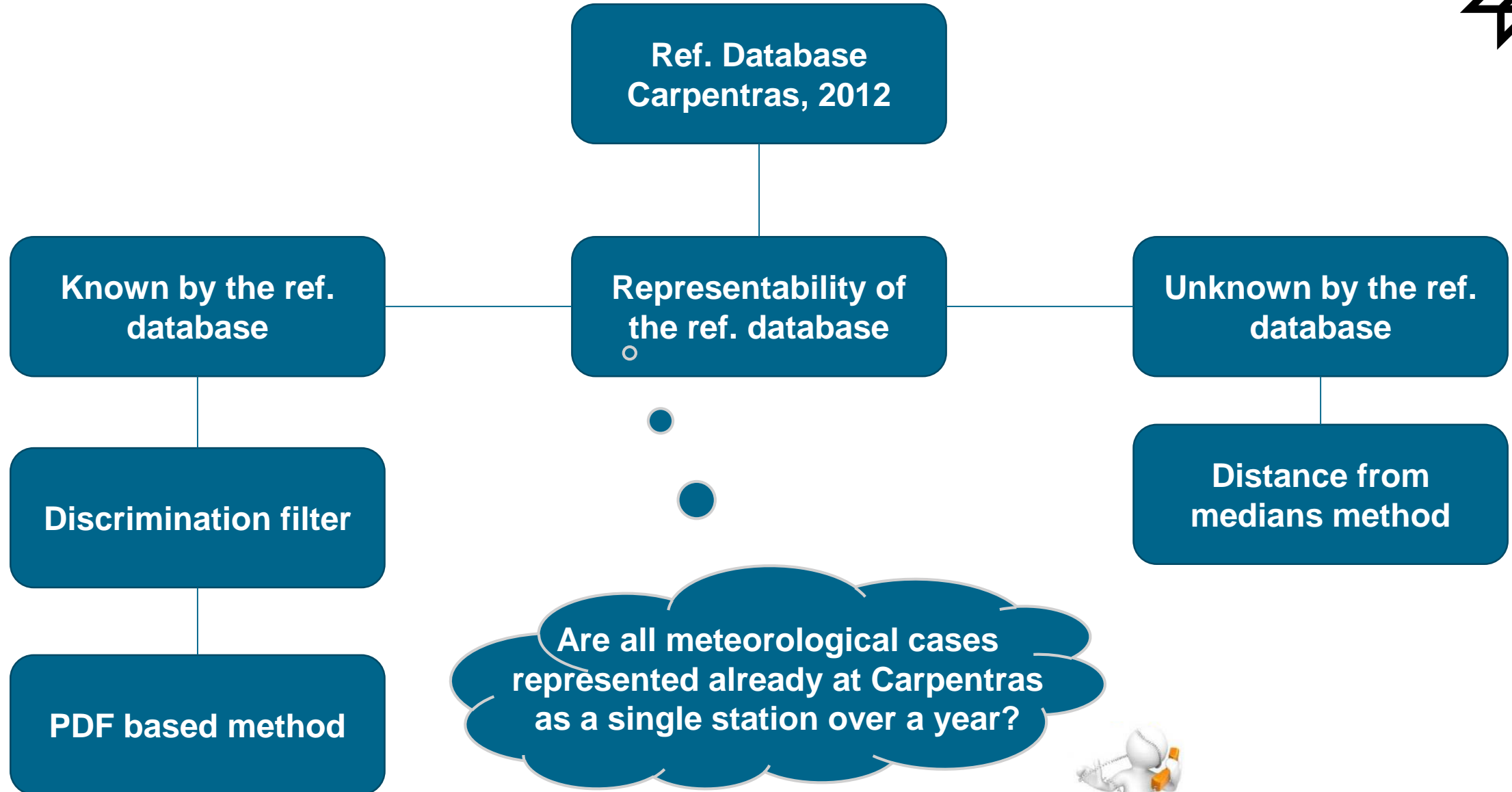
$$V = \sqrt{\frac{1}{n} \sum_{i=1}^n (\Delta k_c)^2}$$

## VI. 11, 12, 13) Over clear sky (3%, 5% and 10%)



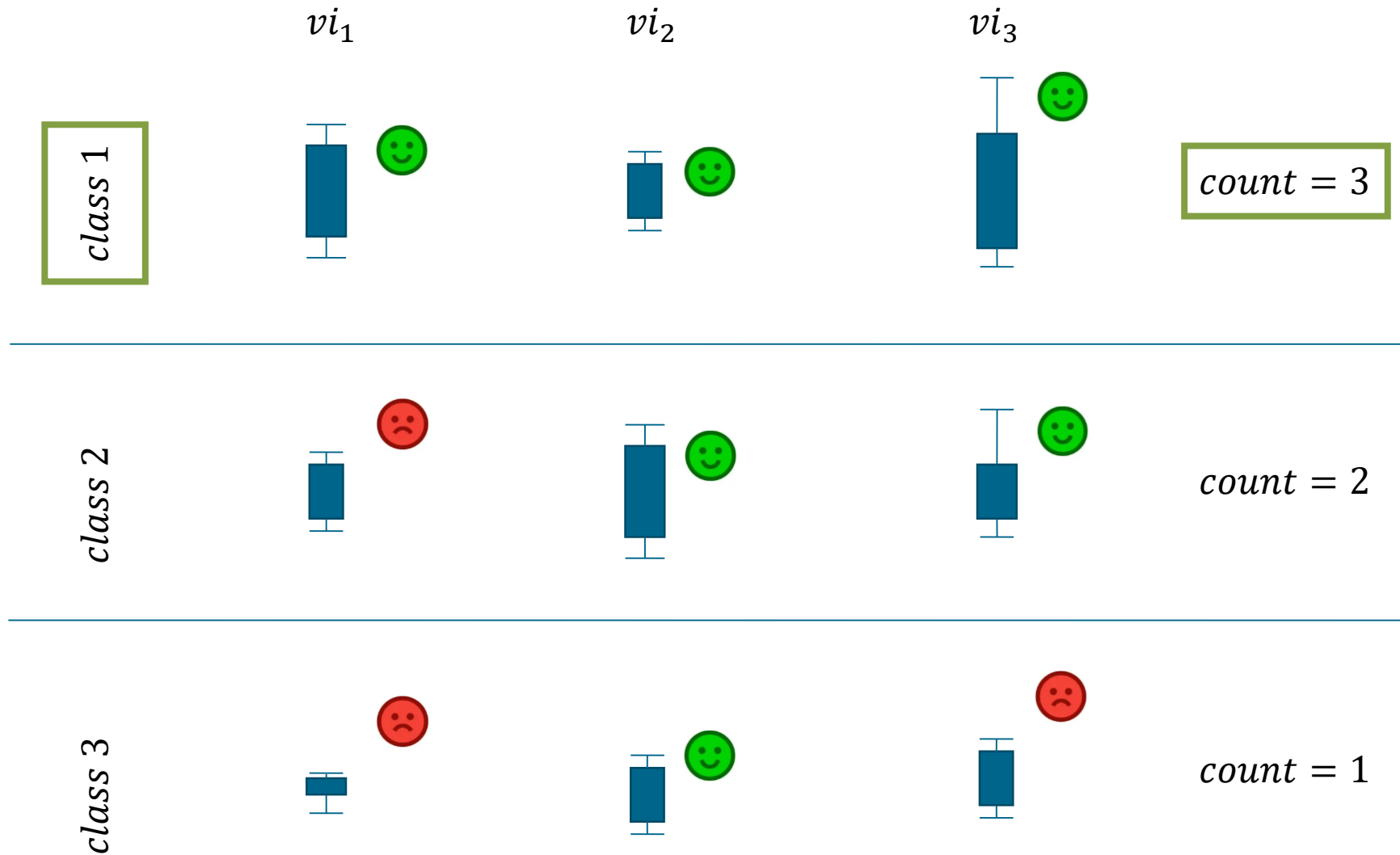
Similar plot for Over  
5% and 10%.

# Classification Algorithm



# Classification Algorithm – Discrimination filter

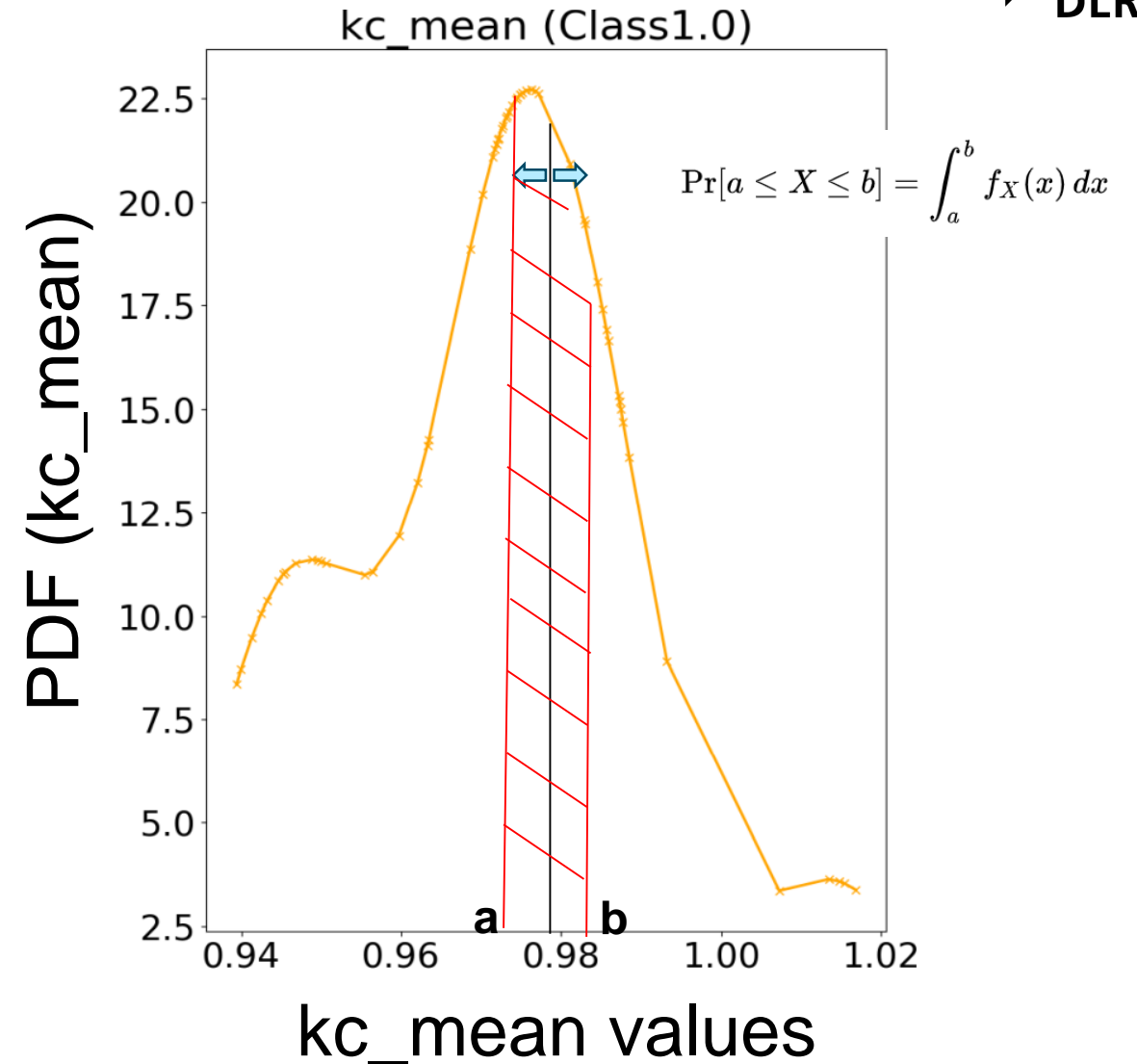
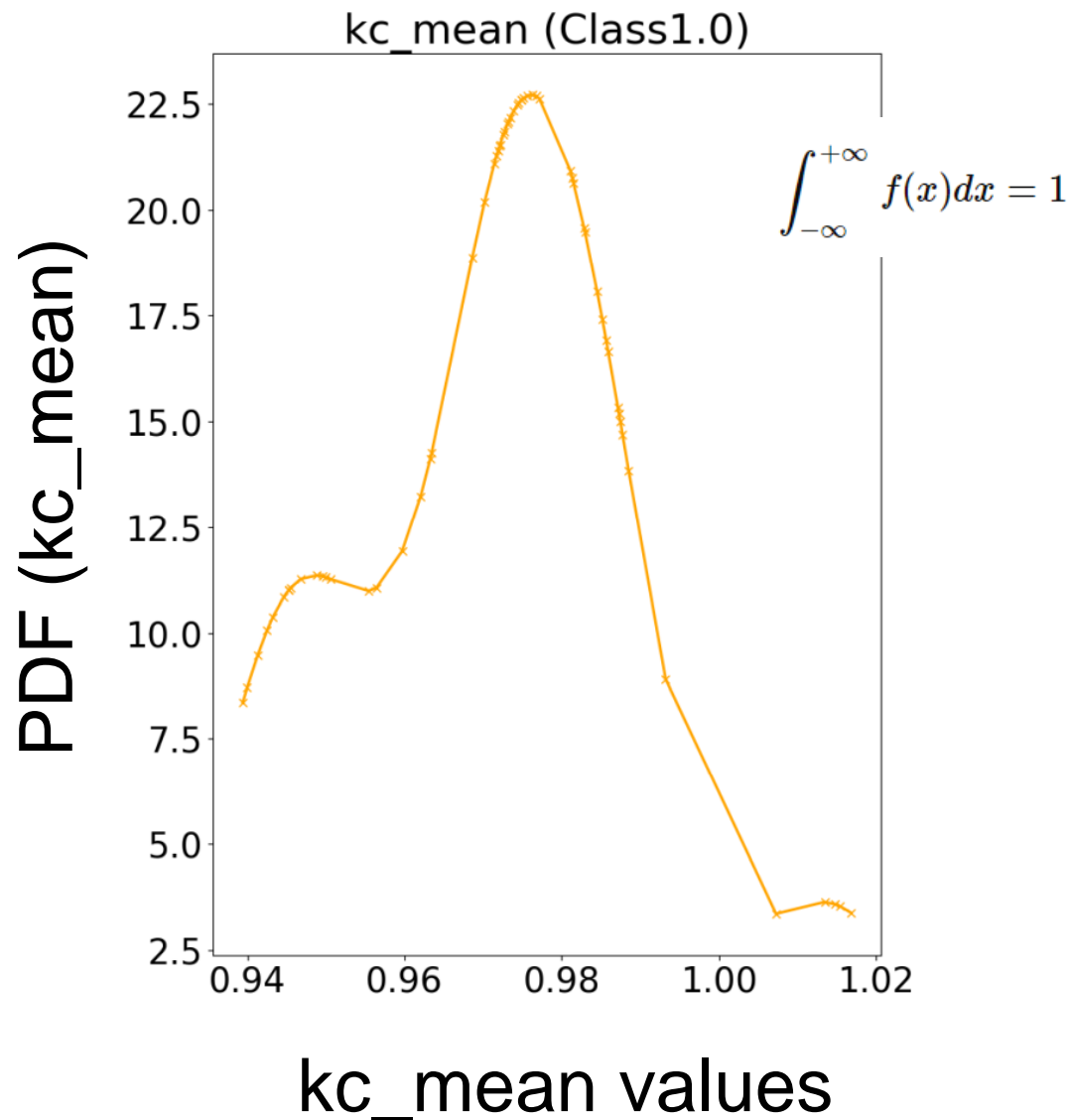
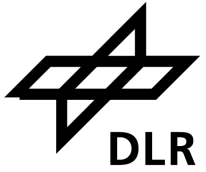
Solves about 70% of cases already



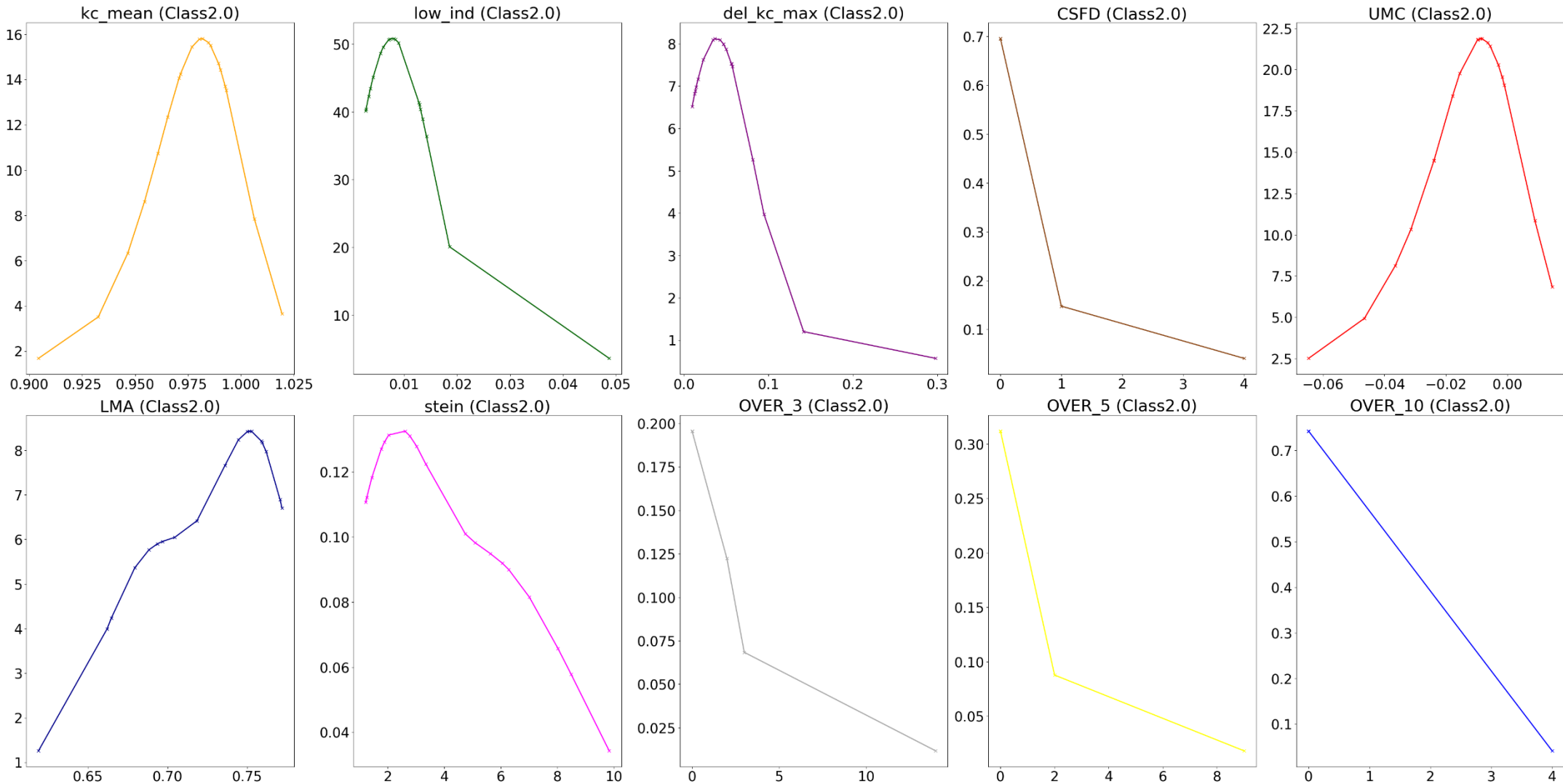


# Classification Algorithm – PDF based method

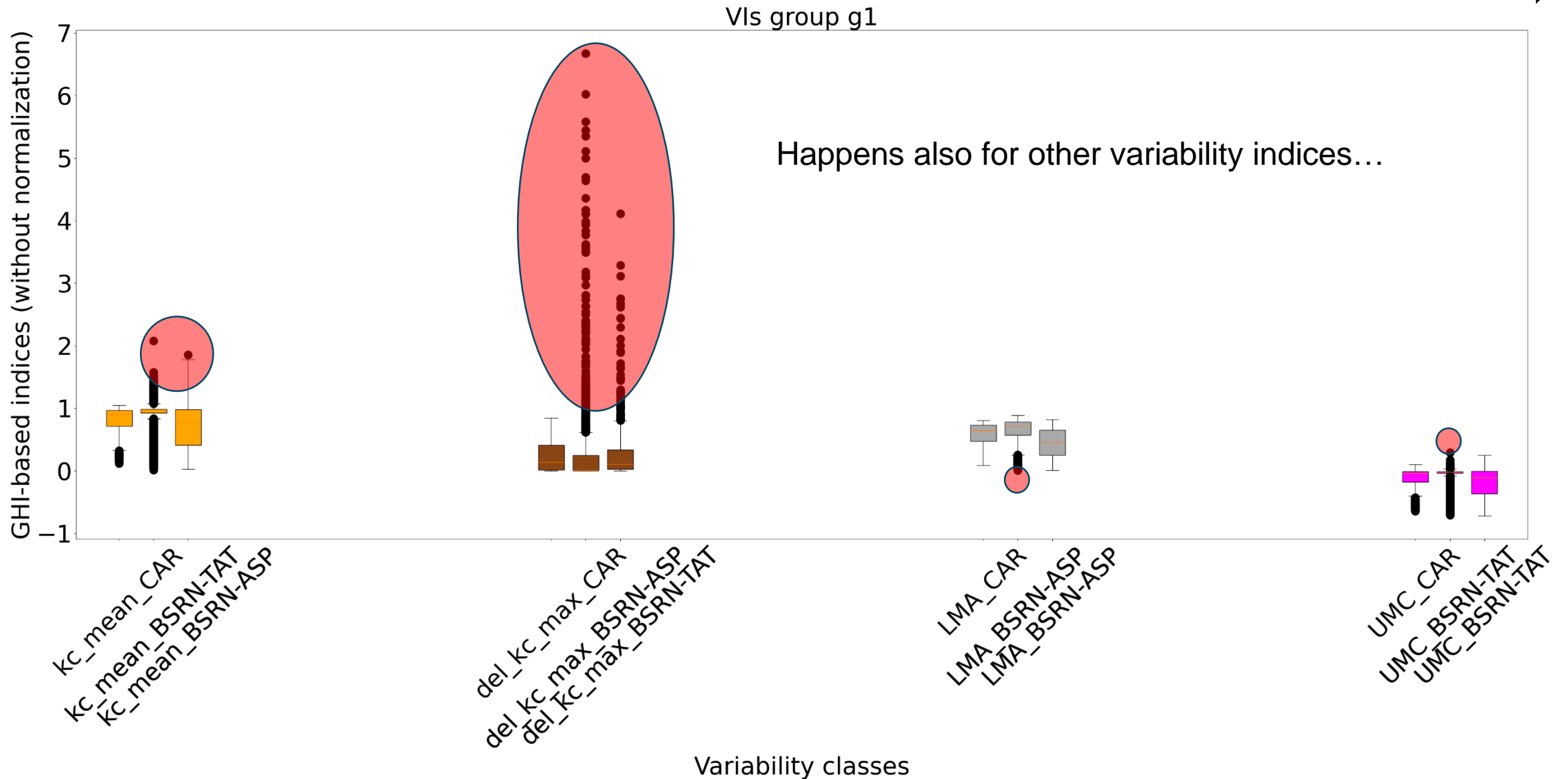
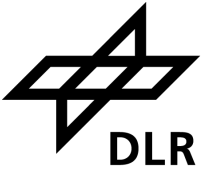
Solves about 20% of cases



# Classification Algorithm – PDF based method

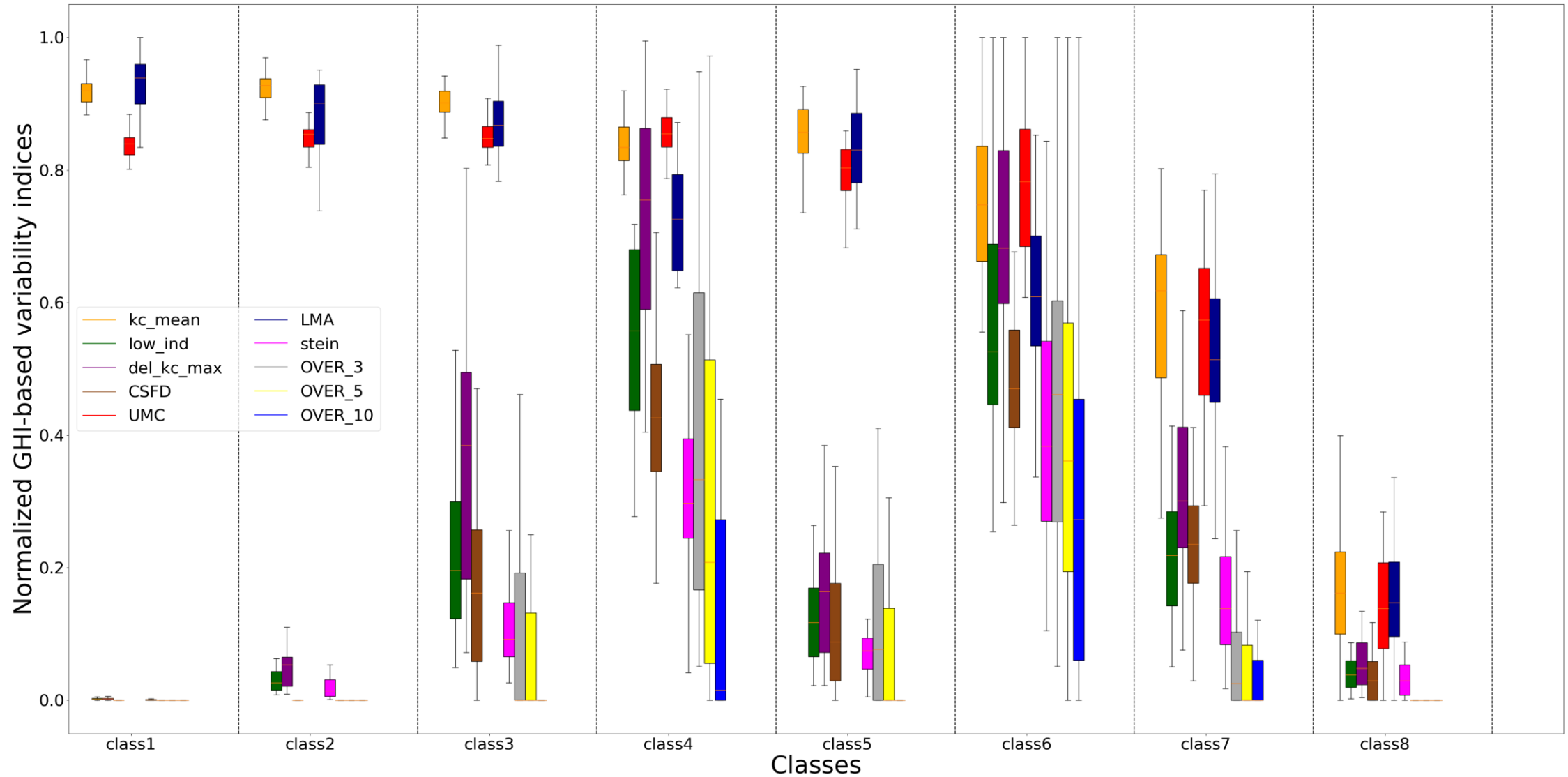


# Representability of the ref. database



# Classification Algorithm – Distance from median

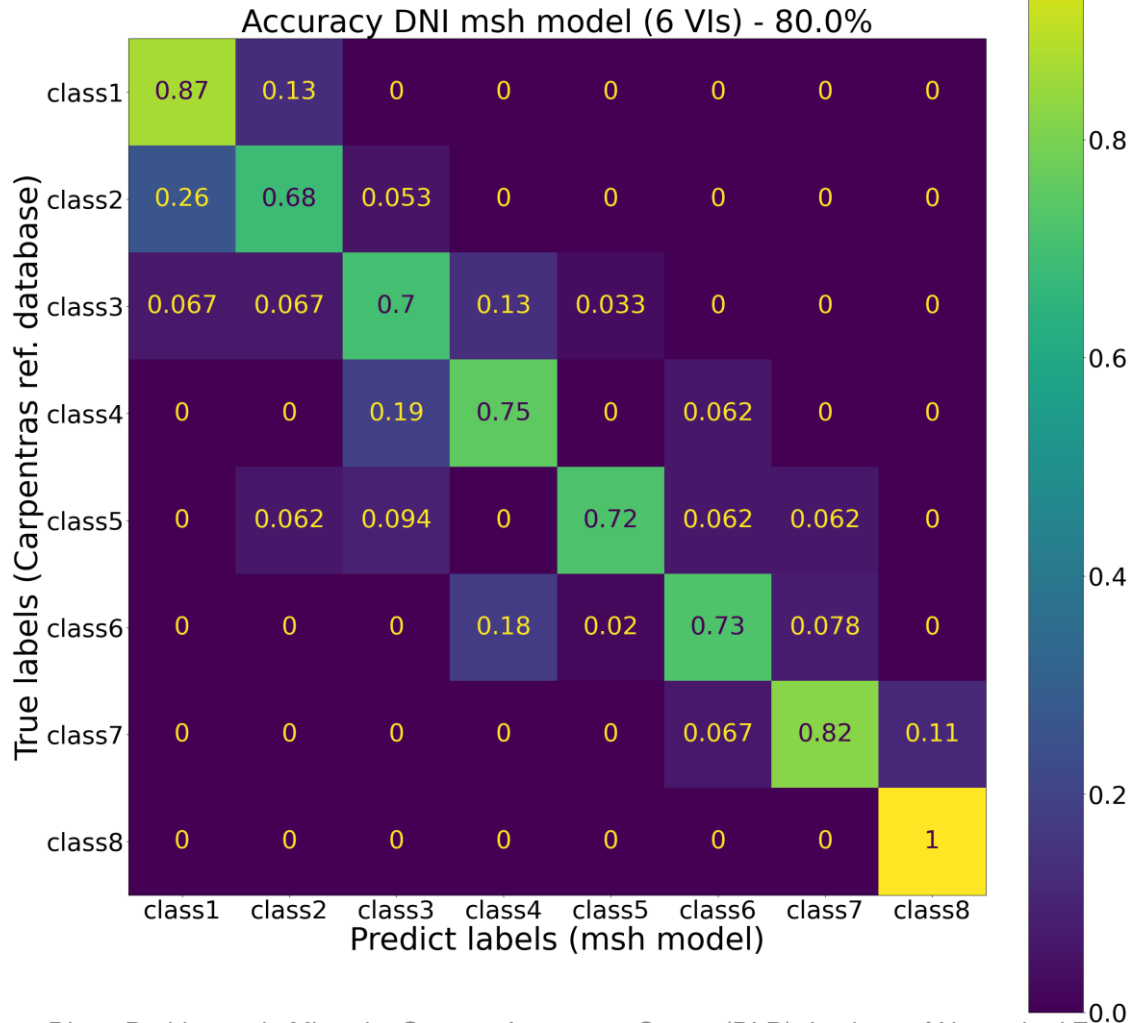
Applied only for remaining cases (10%)



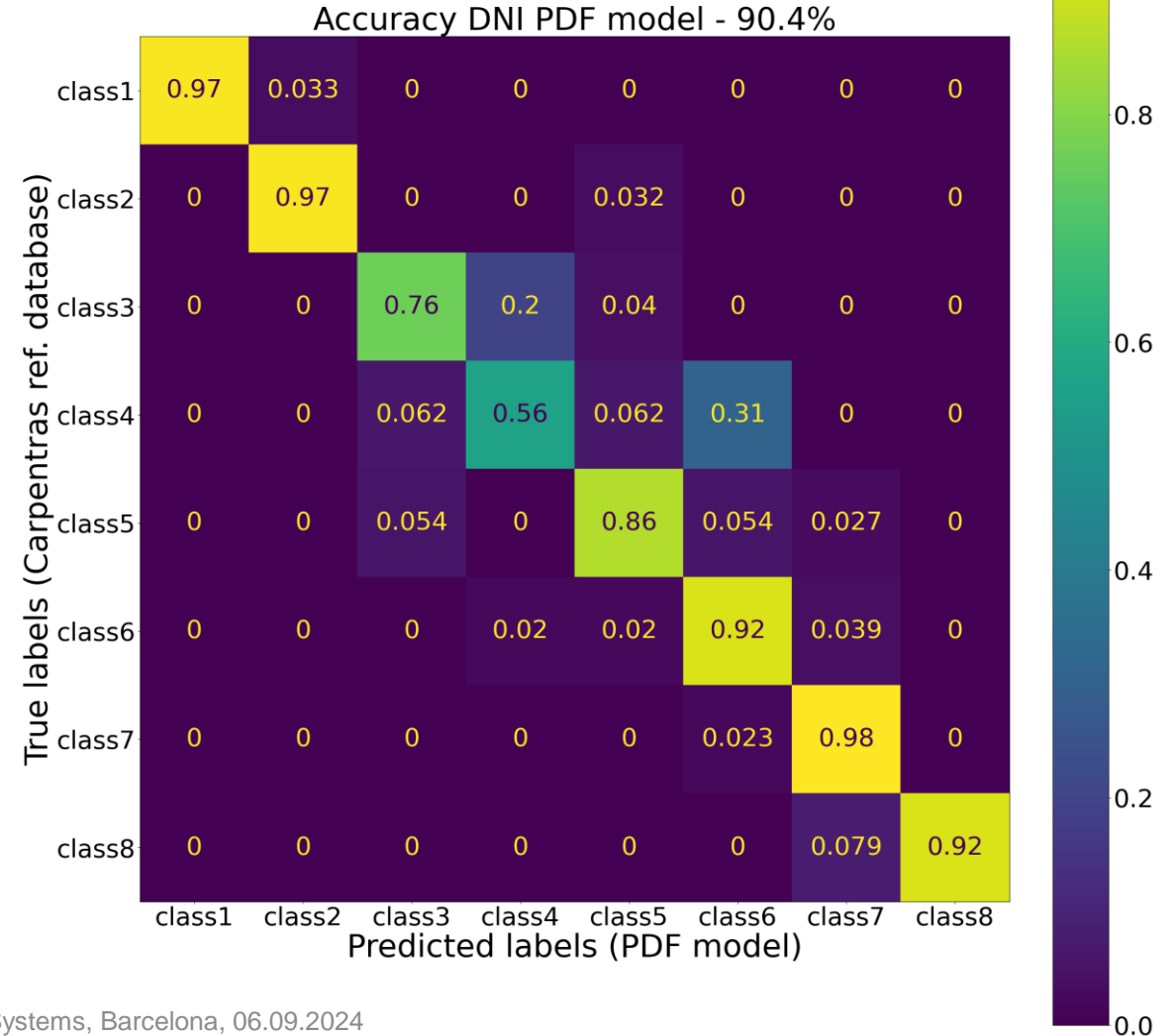
# Results for DNI – Carpentras Reference Database



**Previous model**  
Schroedter-Homscheidt et al. (2018)



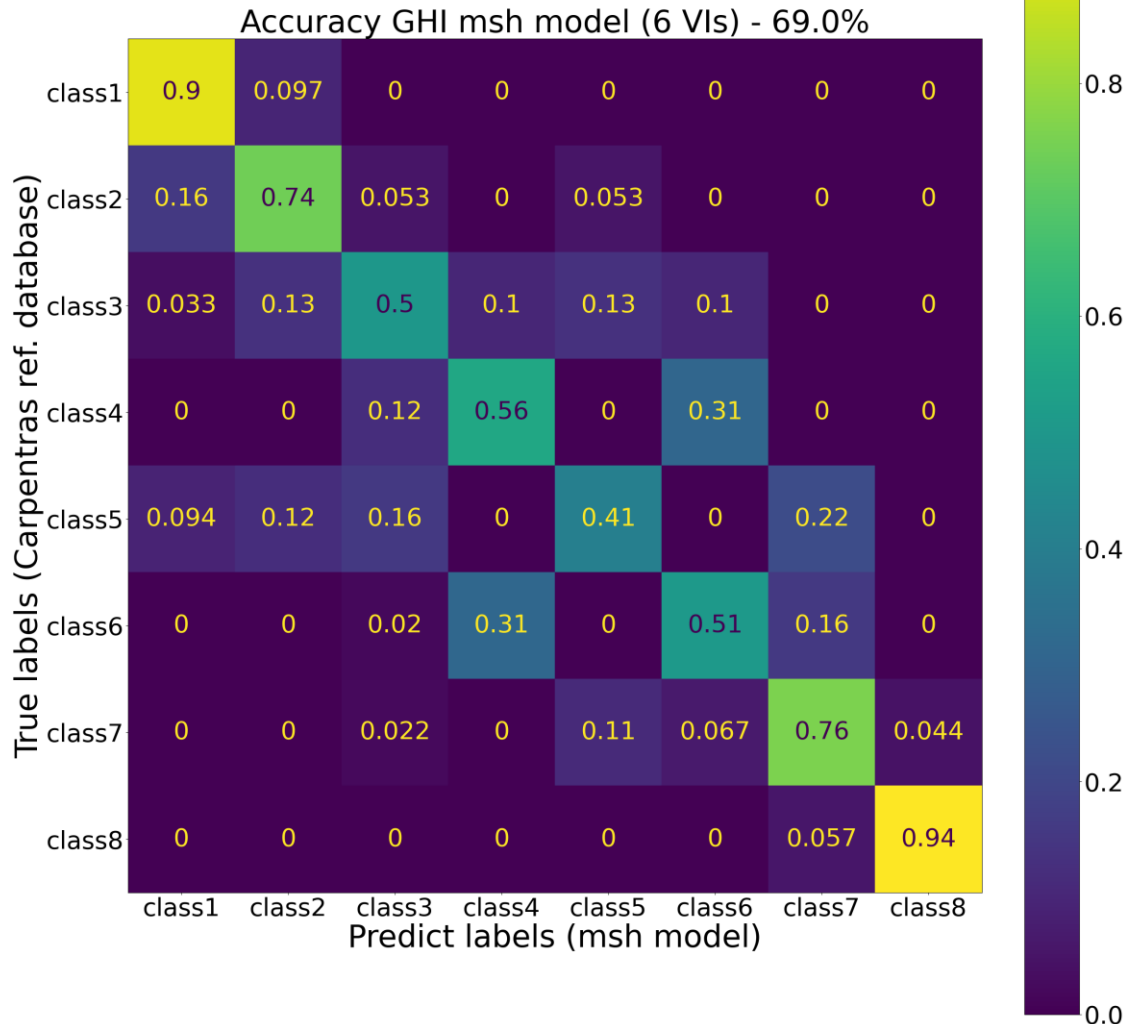
**New model**  
(discrimination filter + PDF approach)



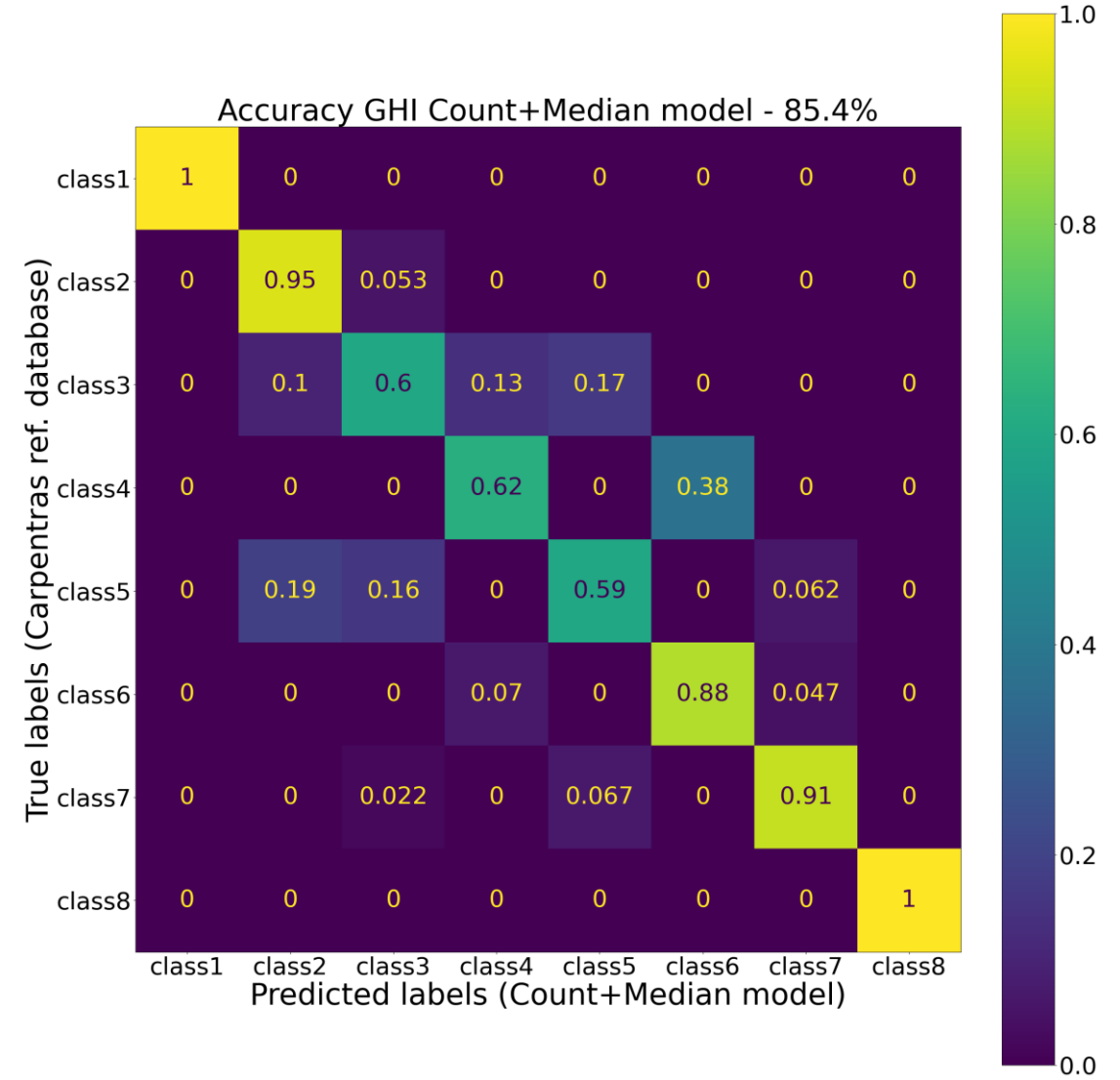
# Results for GHI – Carpentras Reference Database



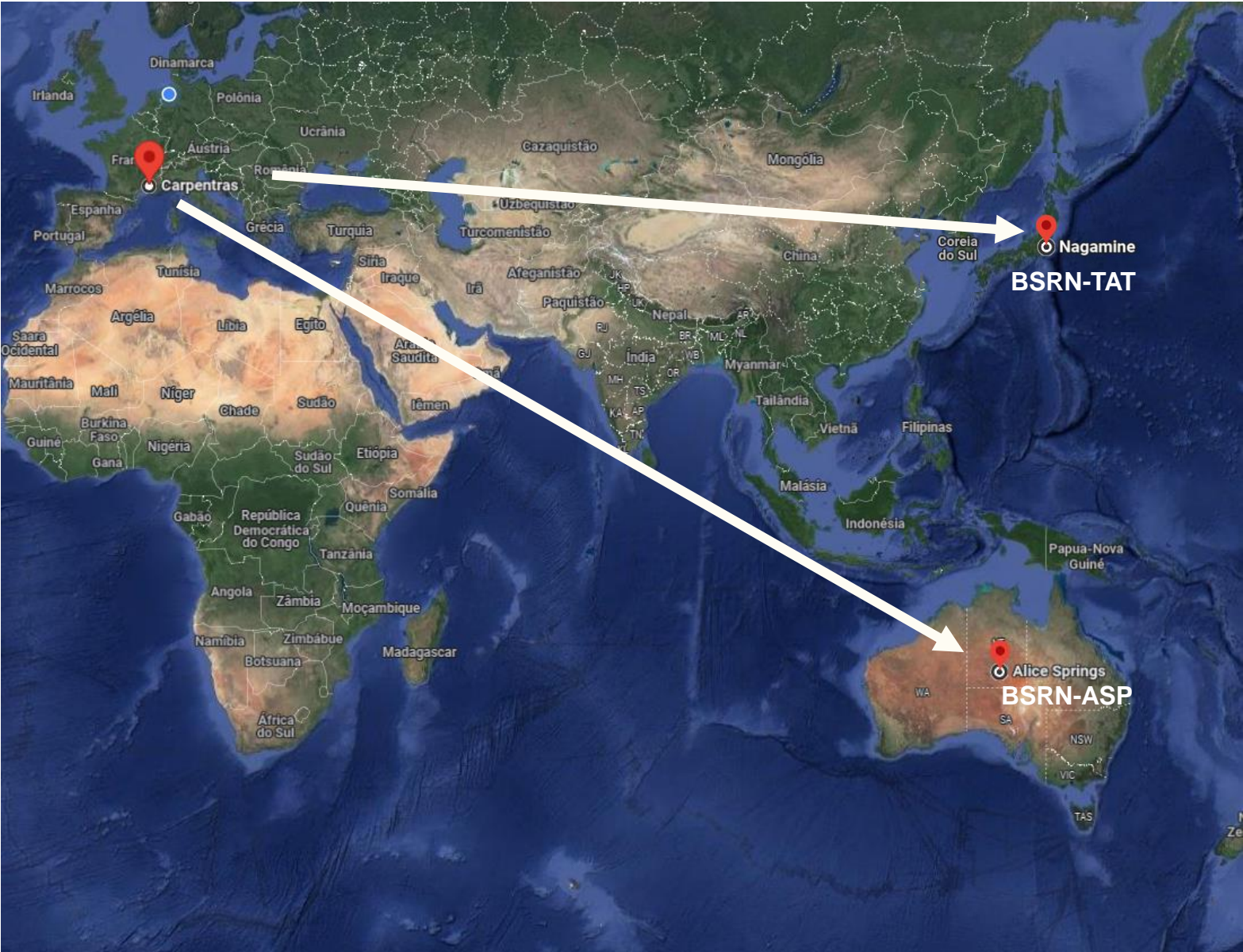
**Previous model**  
Schroedter-Homscheidt et al. (2018)



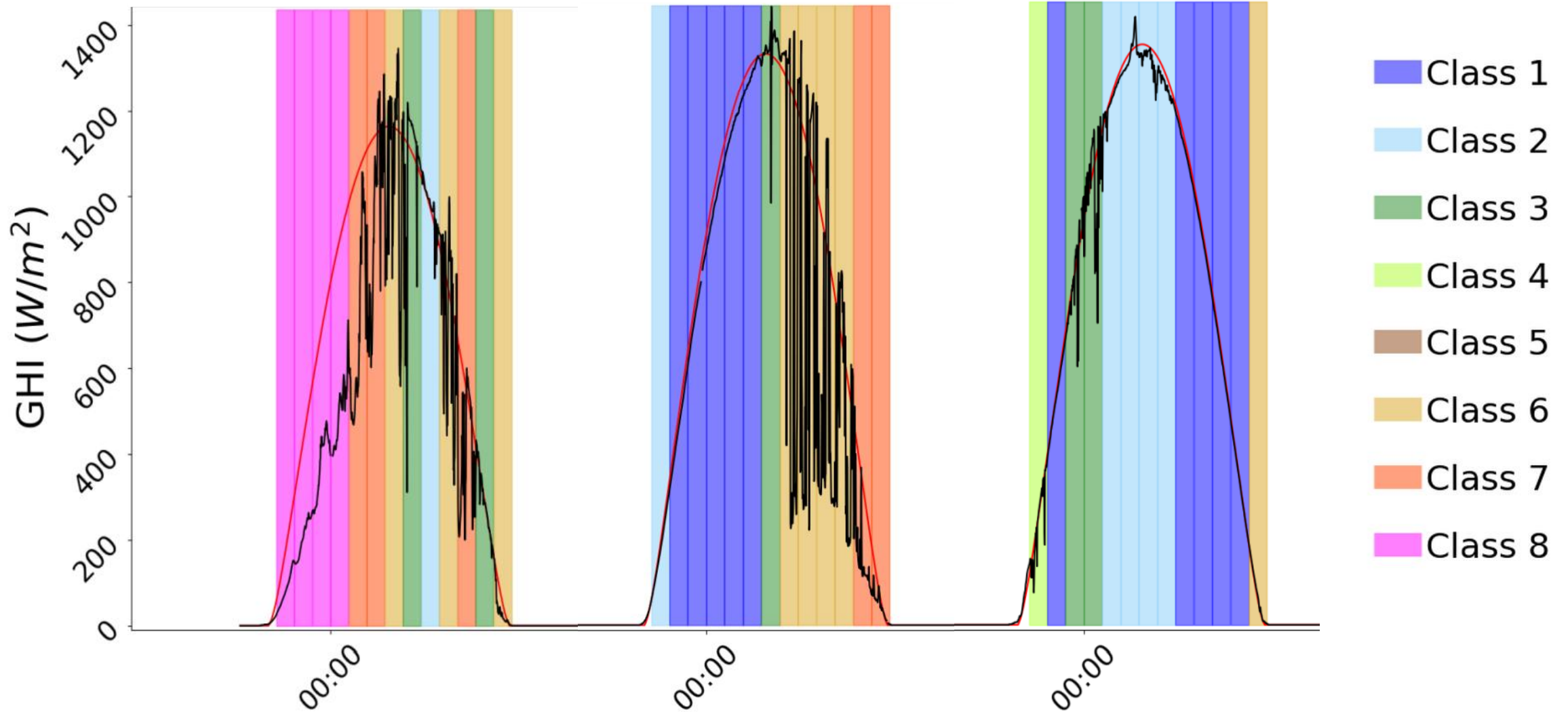
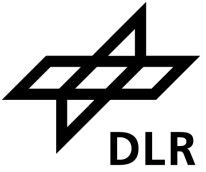
**New model**  
(discrimination filter + PDF approach)



# Running the model for other locations (application/operation of the model worldwide)



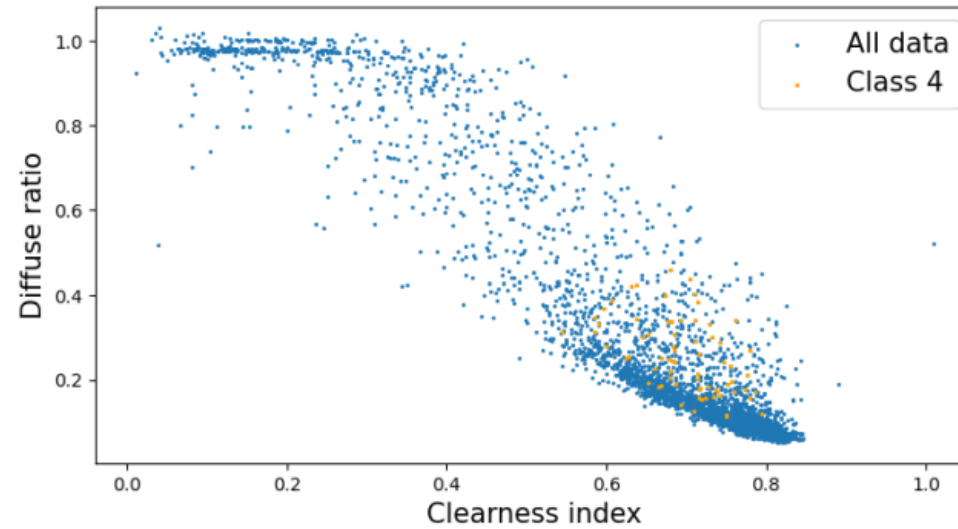
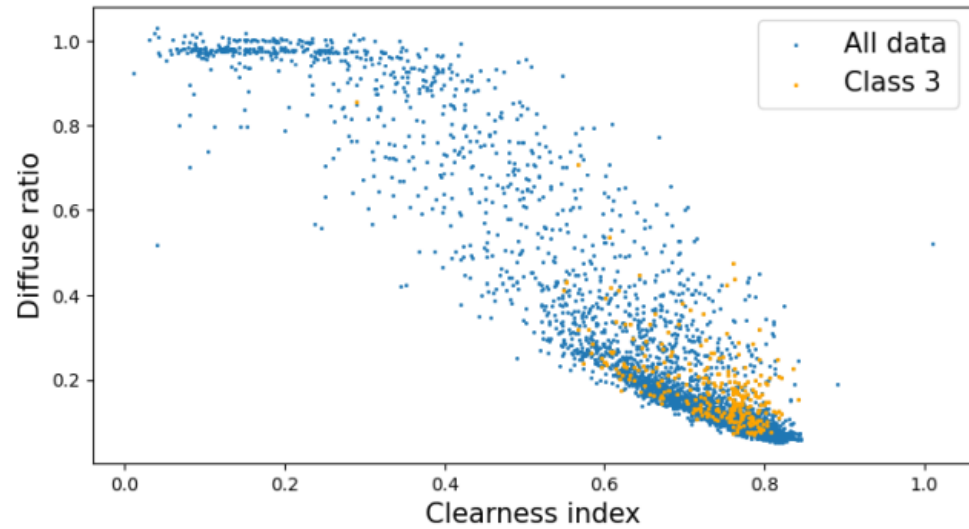
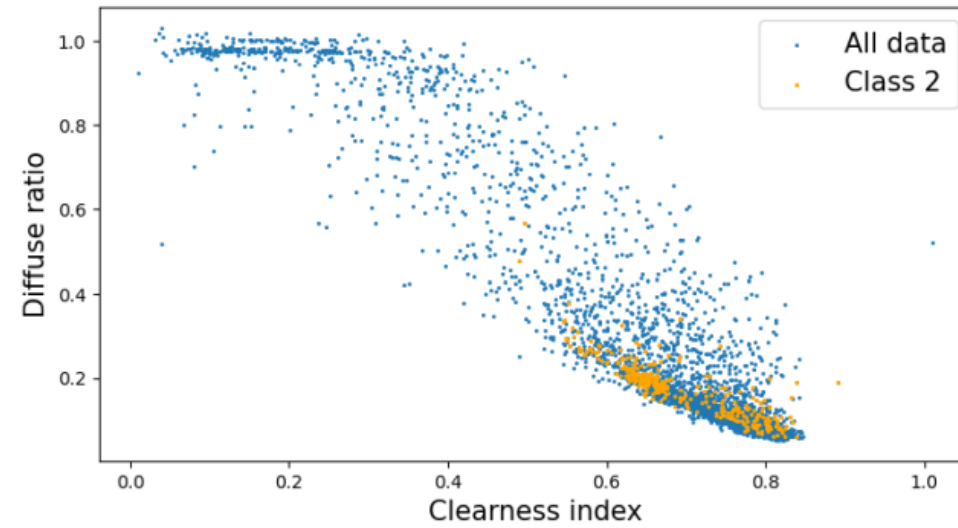
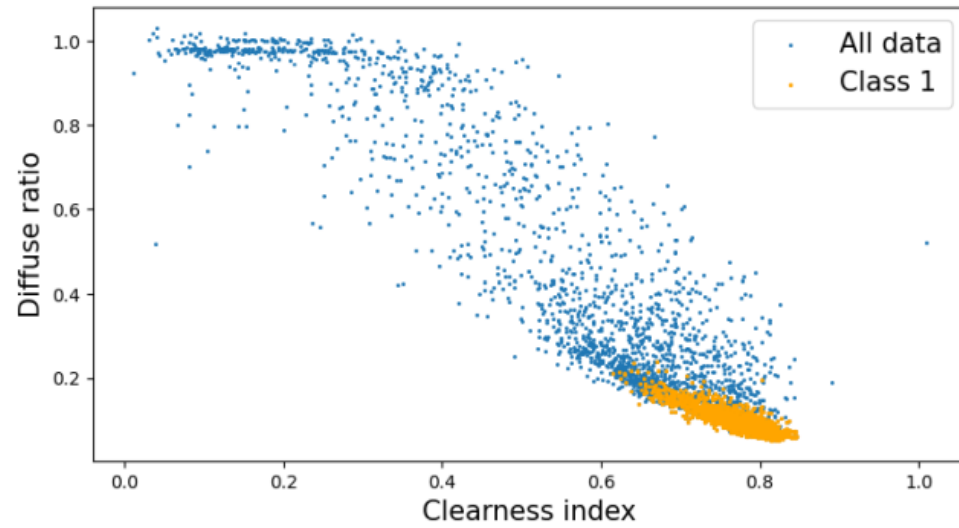
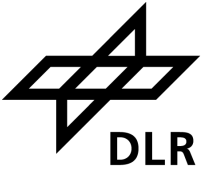
# Results for Alice Springs, Australia, 2018 (GHI model)





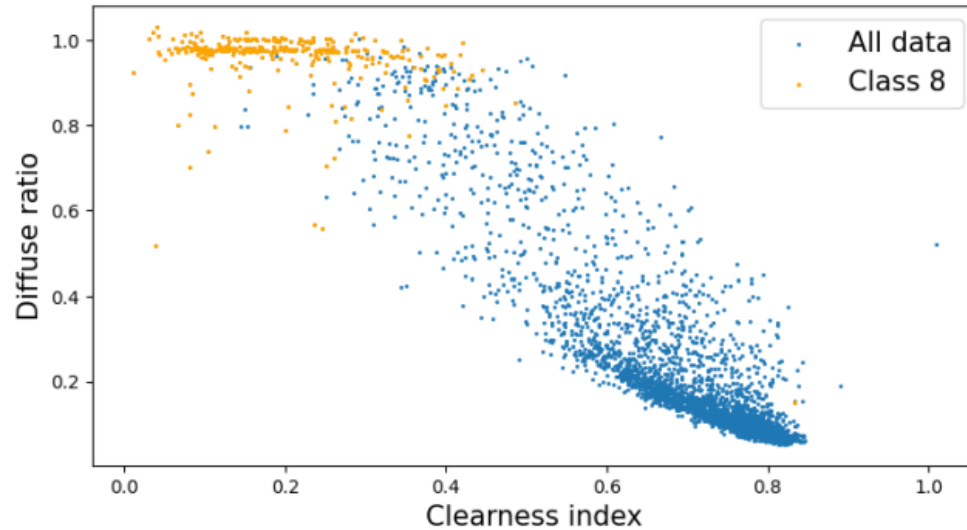
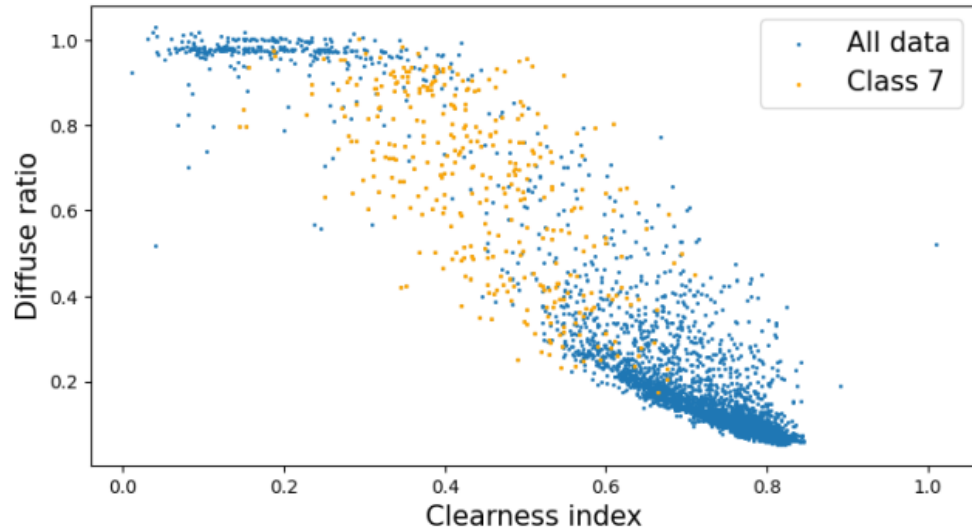
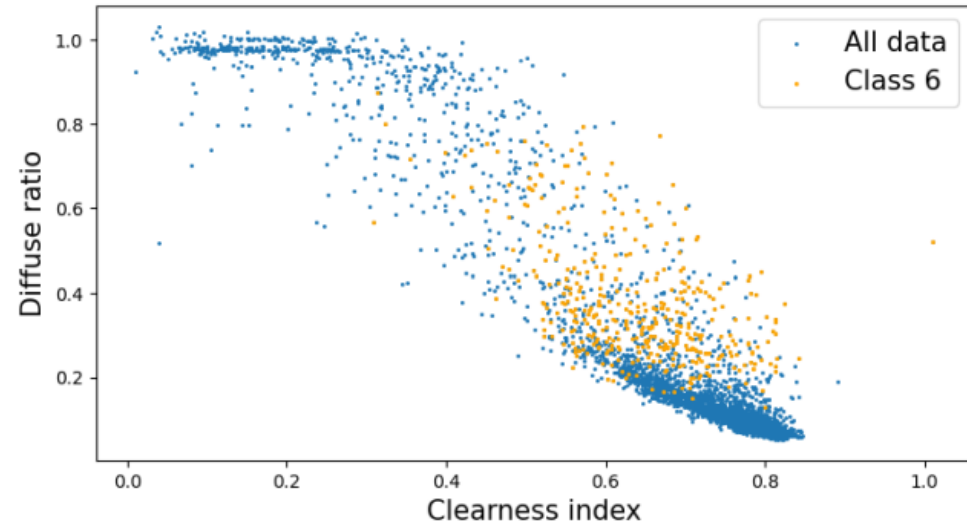
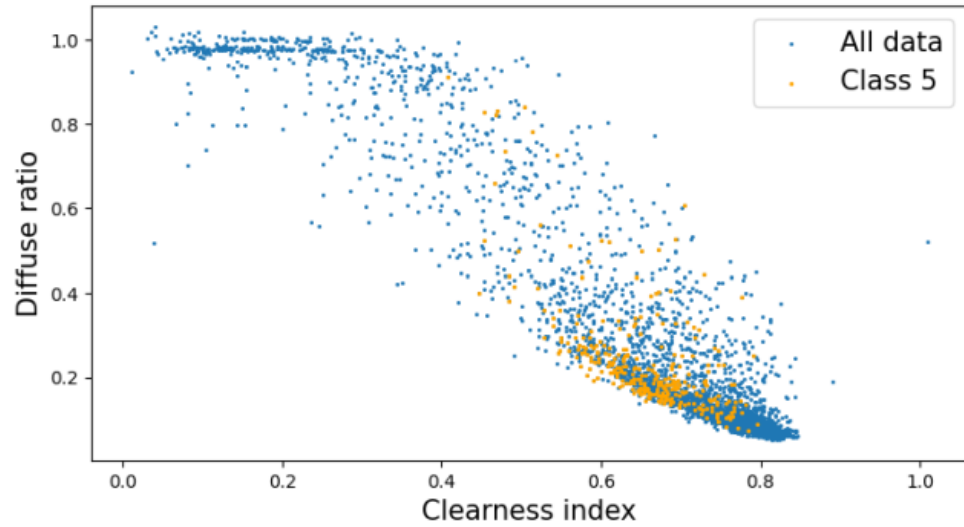
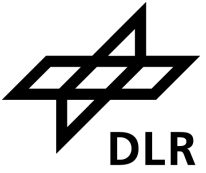
# Results for Alice Springs, Australia, 2018 (GHI model)

Check for plausibility (diffuse radiation vs. clearness index)



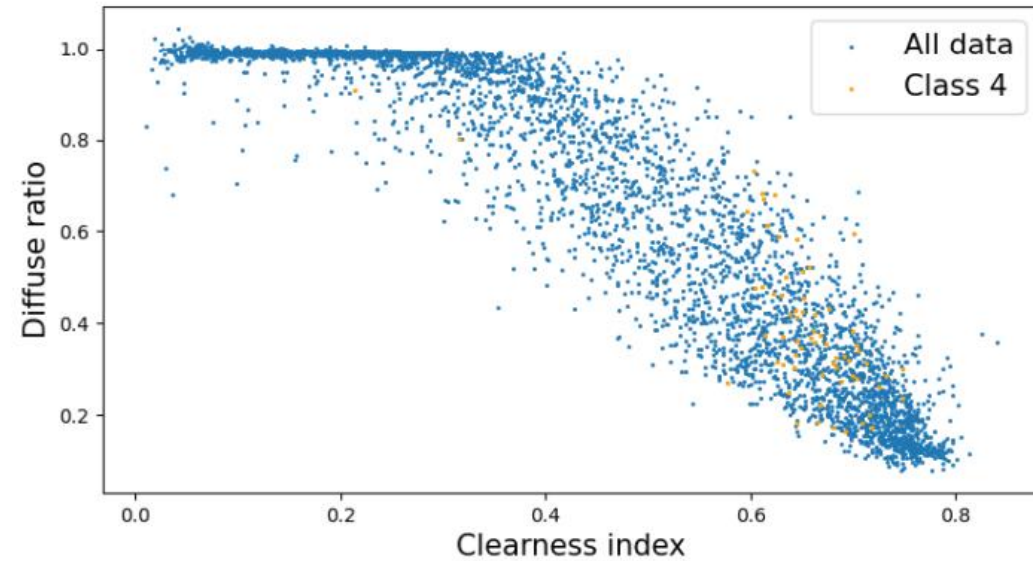
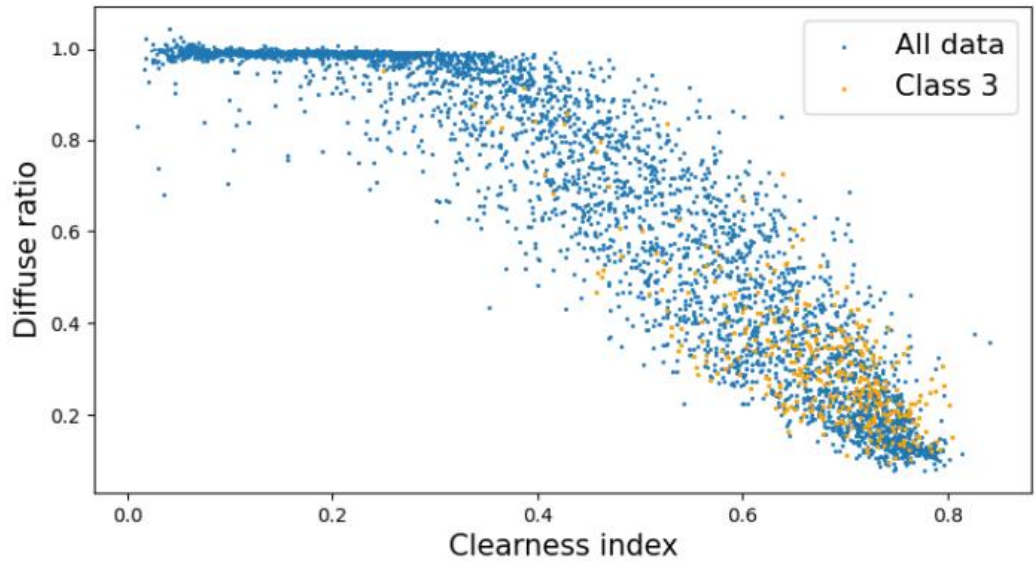
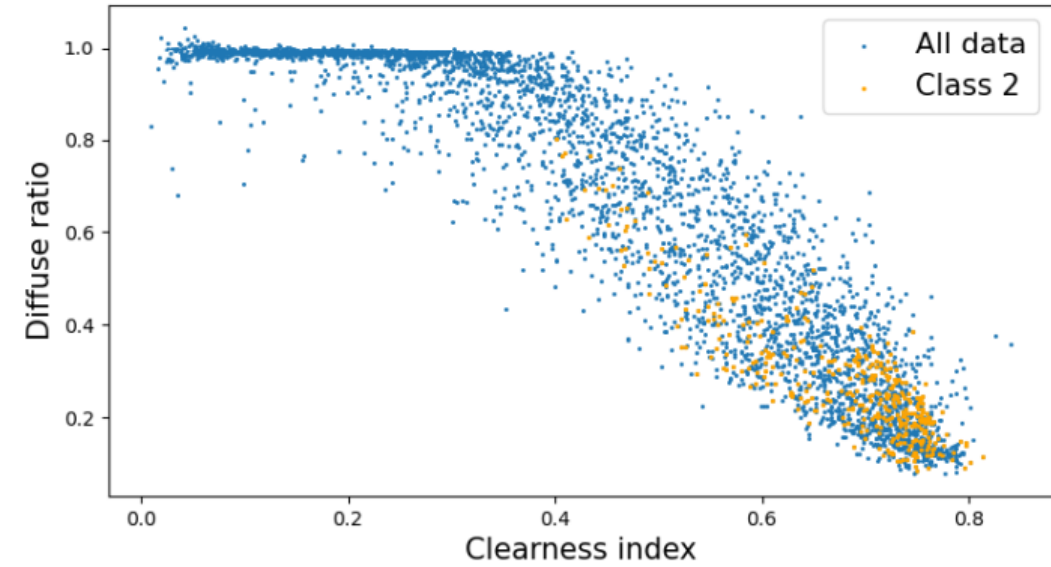
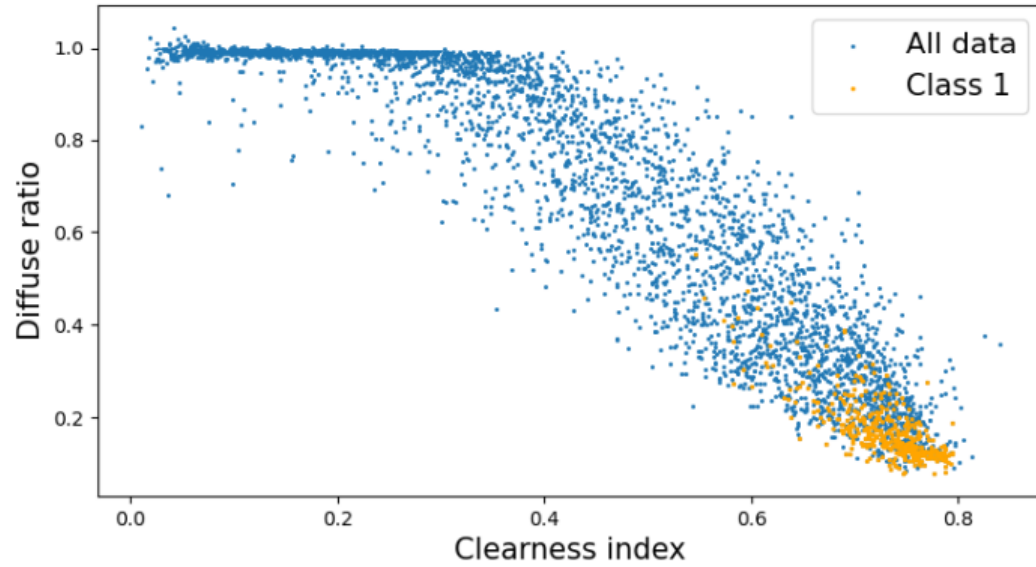
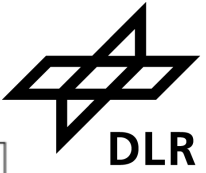
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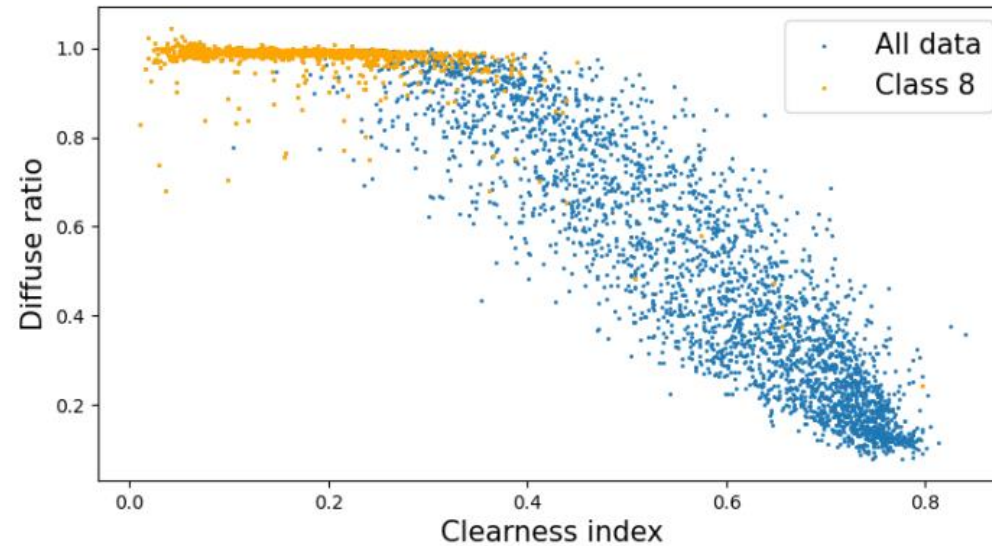
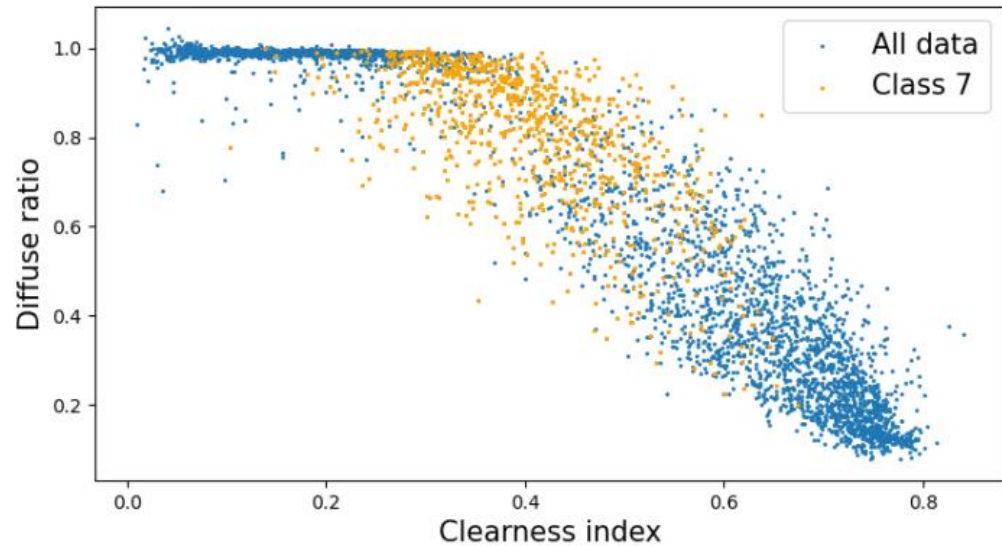
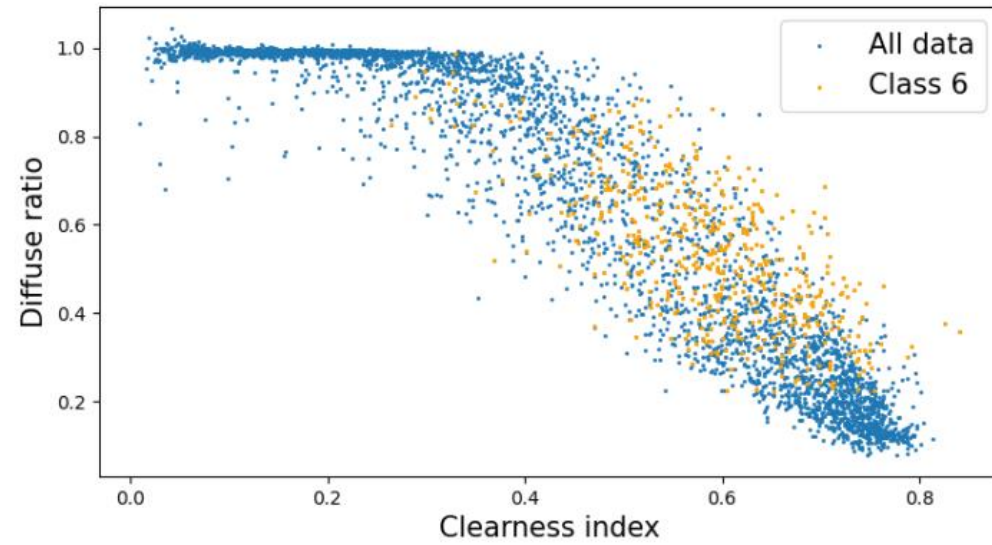
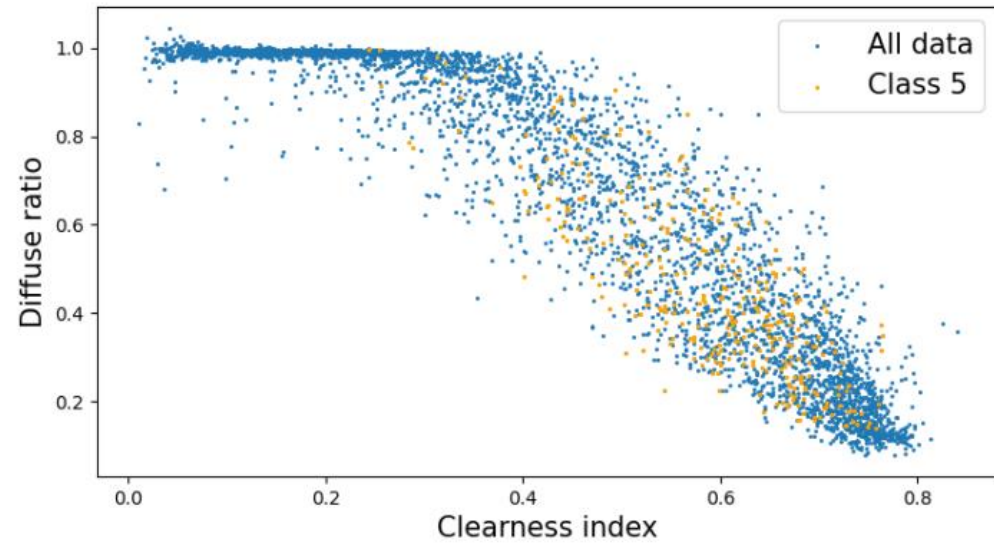
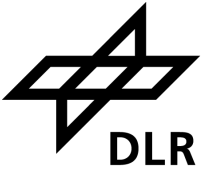
# Results for BSRN-TAT, Japan, 2018 (GHI model)

Check for plausibility (diffuse radiation vs. clearness index)



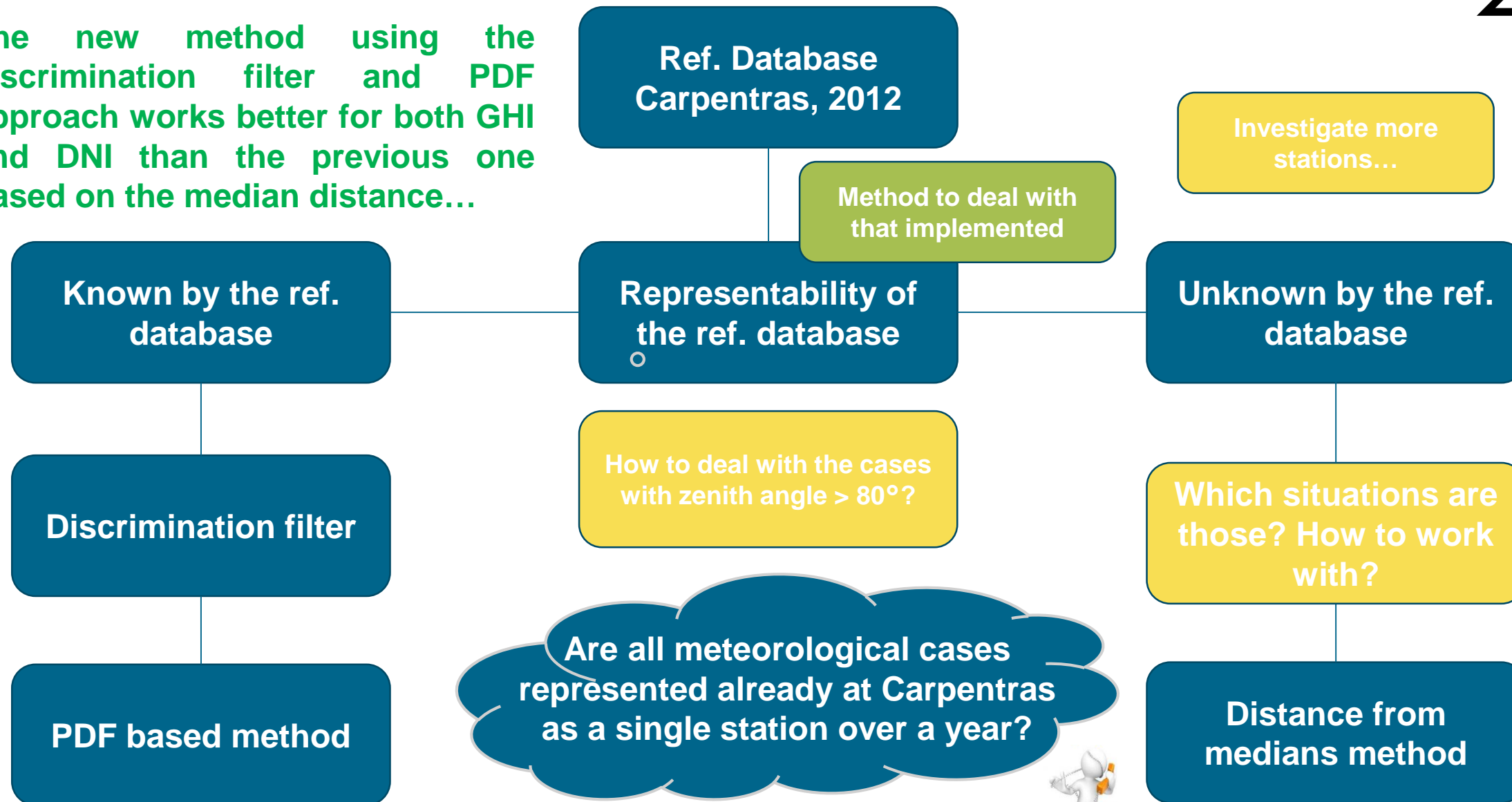
# Results for BSRN-TAT, Japan, 2018 (GHI model)

Check for plausibility (diffuse radiation vs. clearness index)



# Conclusions and next steps

The new method using the discrimination filter and PDF approach works better for both GHI and DNI than the previous one based on the median distance...



***Thank you for your attention!***  
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