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Towards a simple and robust probabilistic solar variability analysis based on transition probability between variability classes of sky state



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Context & Objective

- Solar **variability** is the main cause to create instability of electrical grid when creating a **hybrid (PV/Diesel) power plant**. To mitigate the solar variability, several options are possible, such as using **storage system**, **solar forecasting and/or dedicated Power Management System (PMS)**, etc. In order to properly size the hybrid system, a **study about solar variability** is necessary.
- This work aims at **characterizing the solar variability and predictability** of certain zone primarily to find out the most suitable solution and the potentiality of building a hybrid power plant.

Approach

- To achieve the objective of this work, a 10-year **solar irradiation data in tropical area of West Africa** downloaded from SoDa-pro CAMS services is used as an example for this analysis.
- Distribution of monthly basis different percentiles **solar irradiation level** (figure 1) shows important solar variability in summer. For a better understanding of solar variability, a further study of transition between different levels is proceeded.
- In order to simplify the process, the sky-state of each timestep (1-min) is classified in four types (**clear sky, slightly cloudy, cloudy and variable**) by using the method proposed by Tina et al. (2012). Then, they are grouped by 5 x [1-min], regardless the order of minute within block, 56 combinations maximum in theory and after **filtering rare cases** with occurrence less than 0.5% of all combinations, only 6 combinations left for **August** data, as shown in figure 2.1.

- As a result of variability analysis, the **transition matrix-P** (figure 2.2) provides us the transition probability between different combinations. We assumed that solar variability follows the Markovian properties, with the help of **Markov chain method of order 1**, an N-step forecasting could be achieved by multiplying the transition matrix itself to generate new transition matrix P^N .

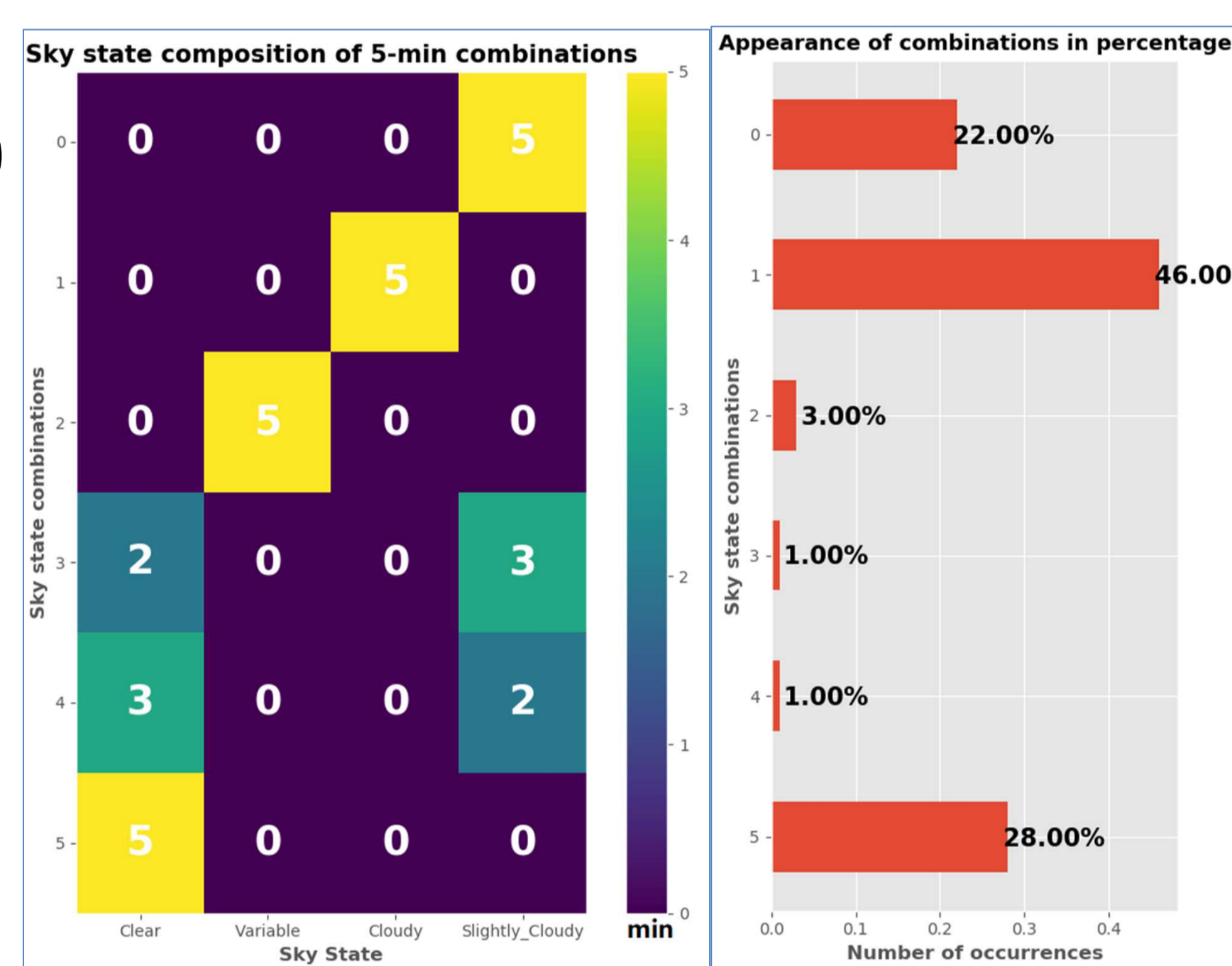


figure 2.1 : composition of filtered 5 min combinations and its occurrences

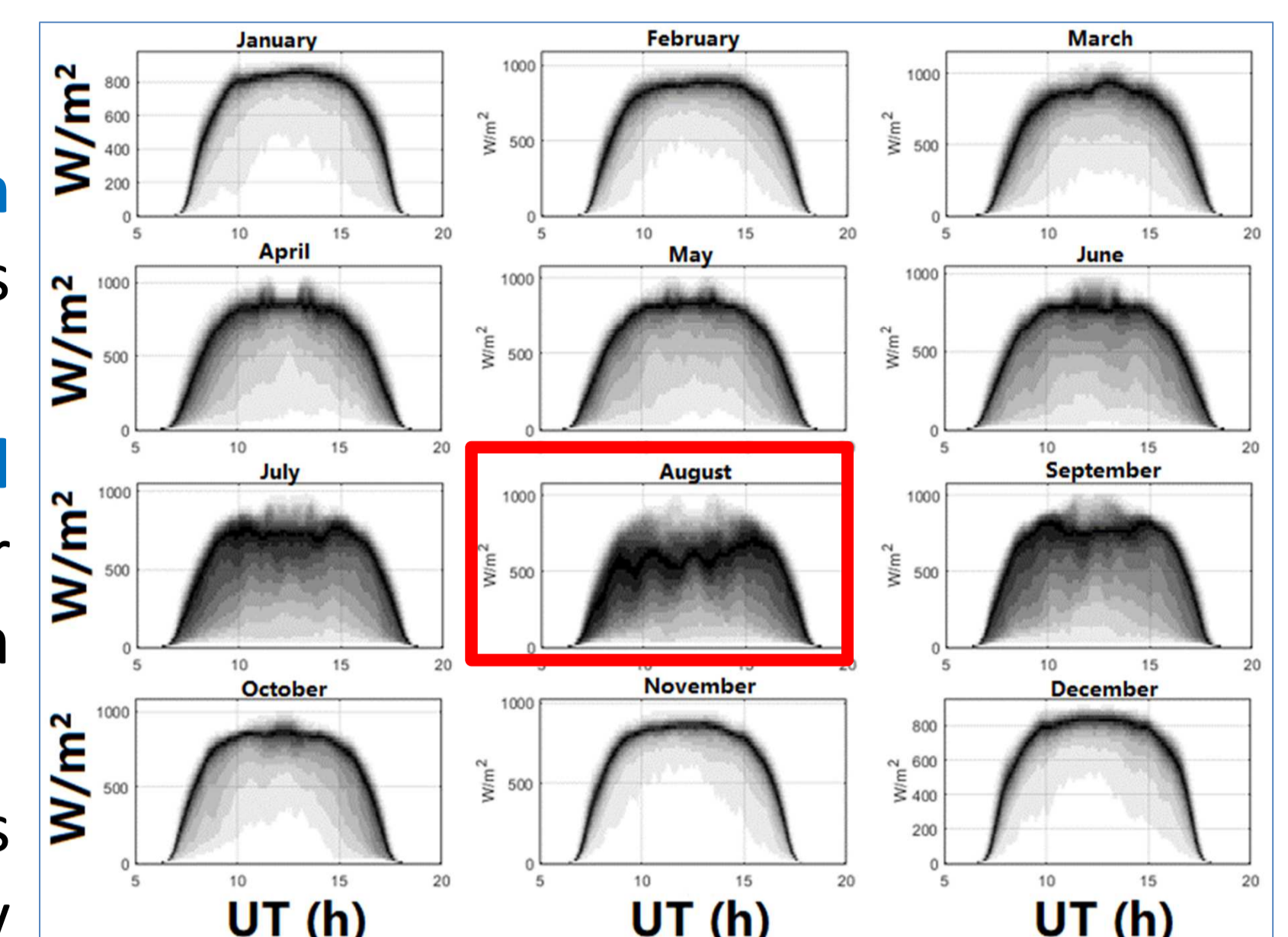


figure 1 : Monthly basis different percentiles irradiation level of 10 years data in West Africa

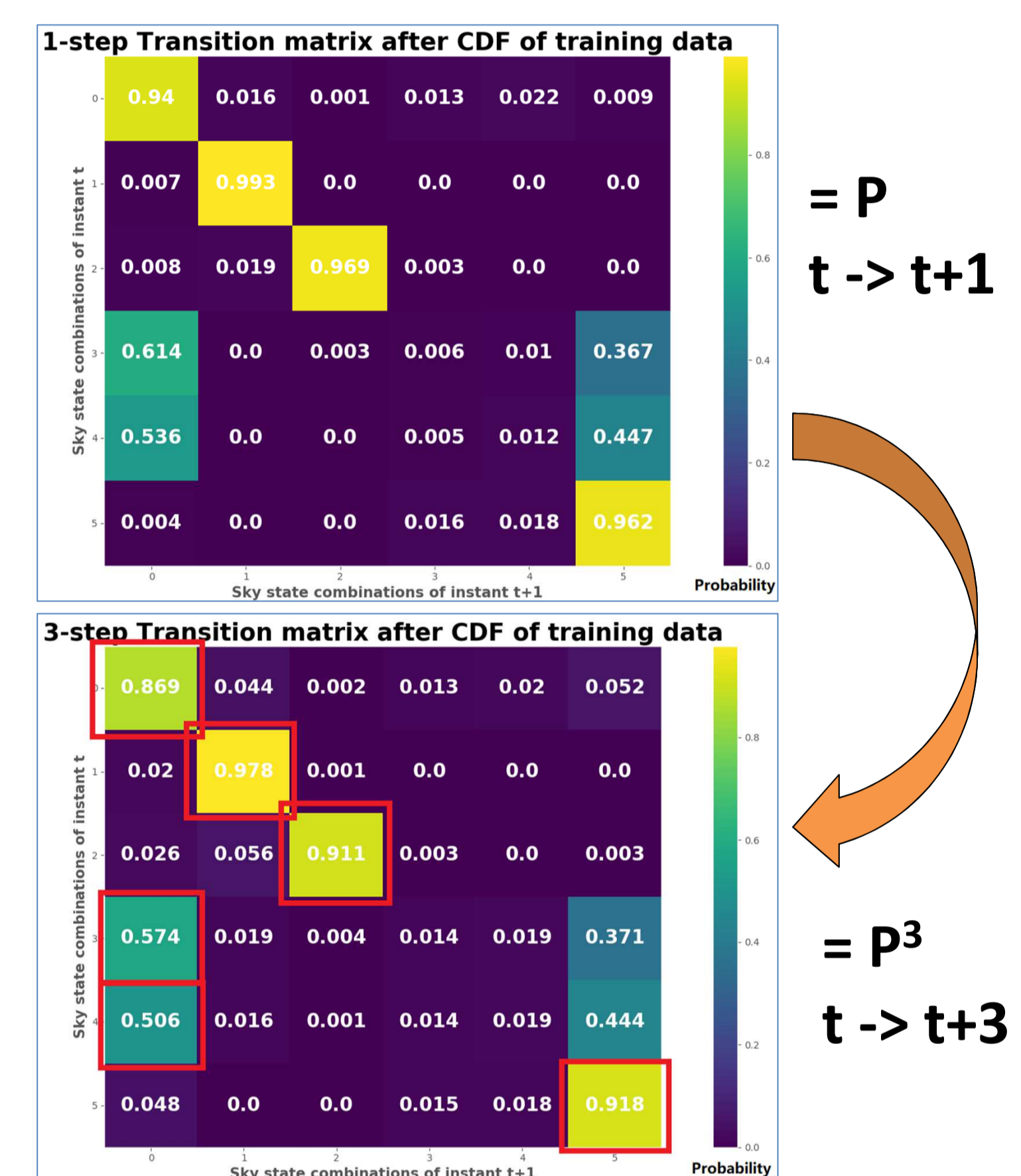


figure 2.2 : 1-step and 3-step Transition matrix between different combinations

Results & Discussions

- To evaluate the prediction performance, another 2-year data of same location is downloaded as test data. For the assessment, a comparison between test data and its prediction in red square, which is the most probable combination of N-step transition matrix, is proceeded. The **confusion matrix between prediction and test data** is used to give a direct view of the prediction accuracy.
- For August data, the result shows, excluding "Variable" case, all combinations with only 1 sky state during 5 min, the accuracy of 1-step transition > 93%, and for 3-step transition is > 69% (figure 3). And for January, the result of 3-step transition accuracy is > 77%. **Quantifying the predictability** from these results shows us that it is more predictable in January than in August.
- **Cohen's kappa coefficient** is also introduced to evaluate the model performance, but in this work, the agreement is between prediction and observation instead of using two observations. The score for combinations with only 1 sky state are all higher than 0.9, which are in "**almost perfect agreement**" range.

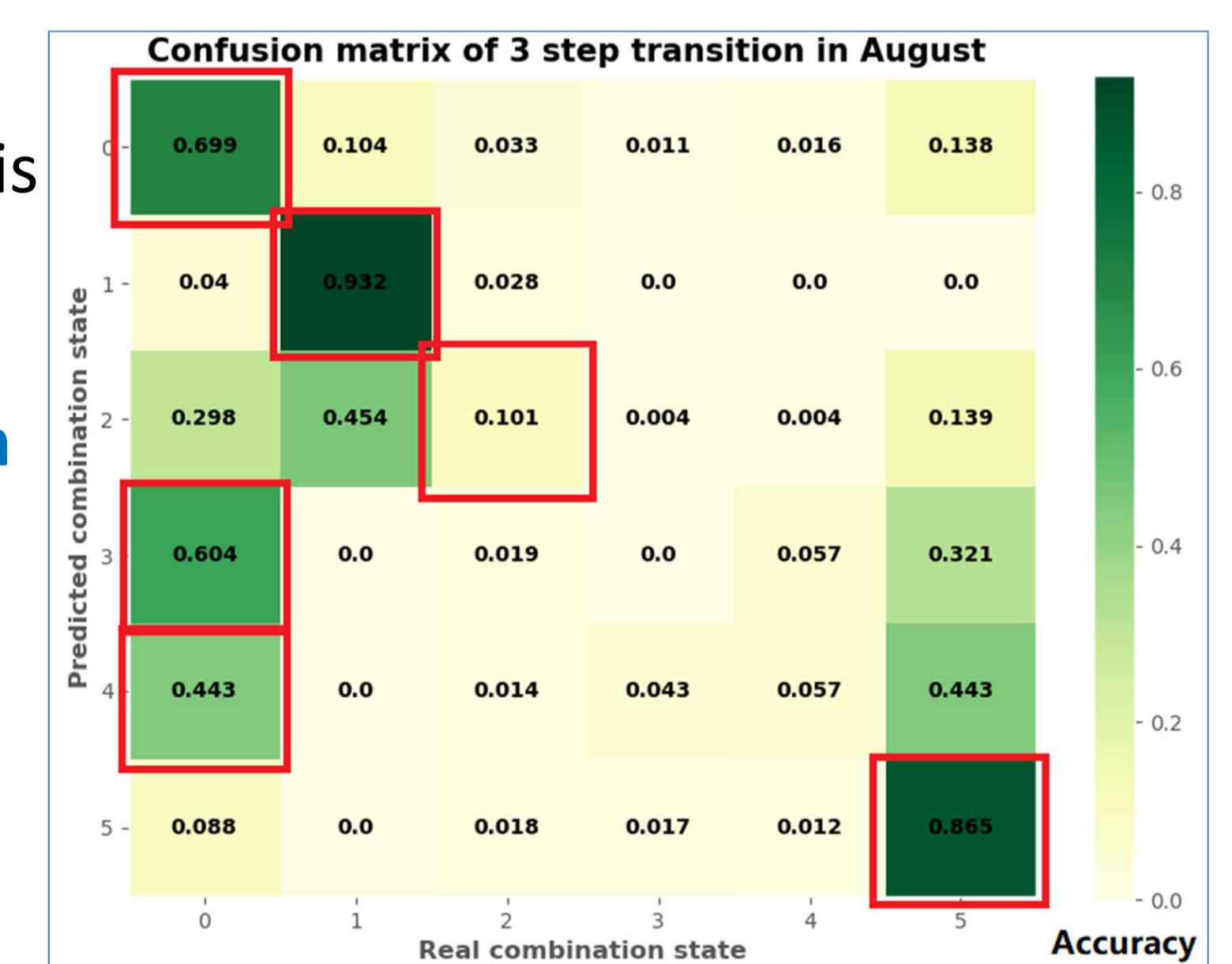


figure 3 : Confusion matrix between predicted and real data

Conclusions & Perspectives

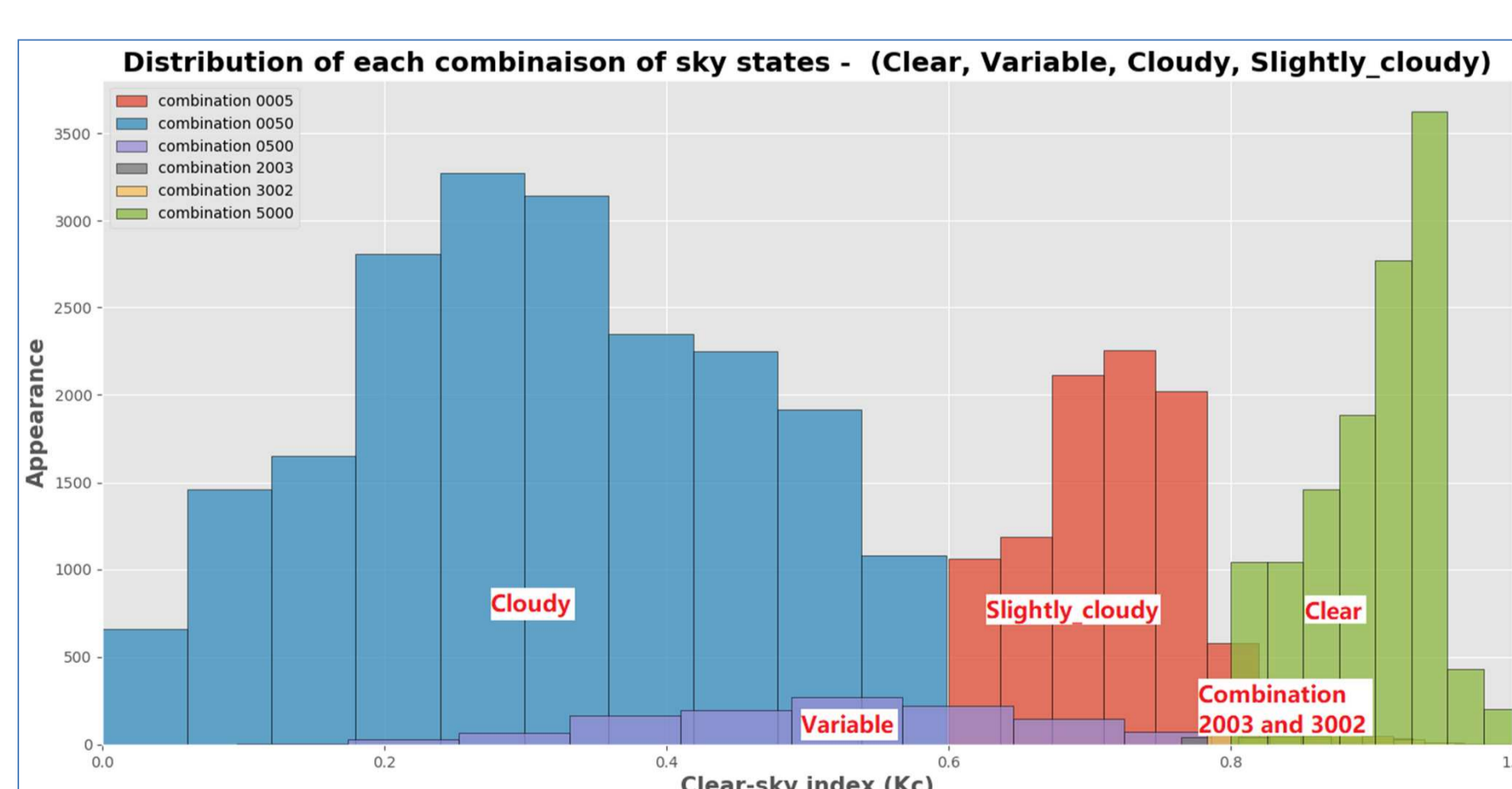


figure 4. Kc Distribution of each sky state combinations Excluding filtered rare combinations

Reference:

Tina, G. M., S. De Fiore, and C. Ventura. 2012. "Analysis of Forecast Errors for Irradiance on the Horizontal Plane." Energy Conversion and Management, IREC 2011, The International Renewable Energy Congress, 64 (December): 533-40. <https://doi.org/10.1016/j.enconman.2012.05.031>.

- This analysis is a **simple tool to evaluate the solar variability and predictability** of certain area to find out the best hybrid system design.
- Next step is to **characterize the typical and minimum clear sky index** of each combination (figure 4), it could be used with the **Clear-sky GHI** to provide irradiation information as a probabilistic solar forecasting.
- Our work could be used as a "**fallback**" procedure of PMS to maintain the stability of electrical grid in case of dysfunction of standard forecast.

