



IMAD23ALM MAD: The etiopathological basis of gait derangement in Parkinson's disease: decoding locomotor network dynamics

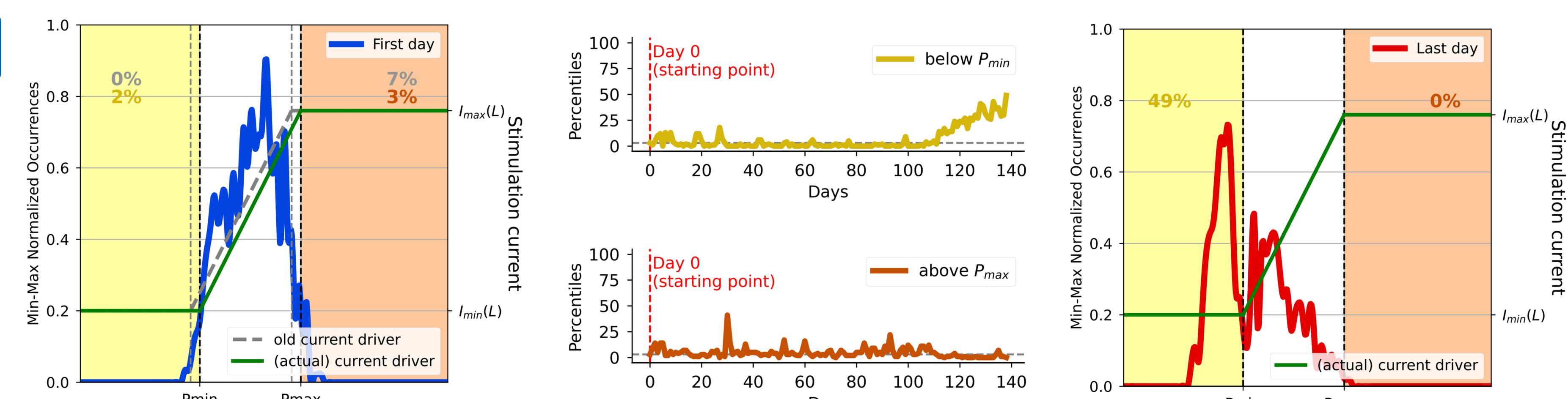
LAURA: Transformer-based Long-Term Deep Brain Activity Predictor

S. Falciglia^{1,4}, L. Caffi^{1,2,3,4}, C. Baiata^{2,3}, C. Palmisano^{2,3}, I.U. Isaias^{2,3}, A. Mazzoni^{1,4}

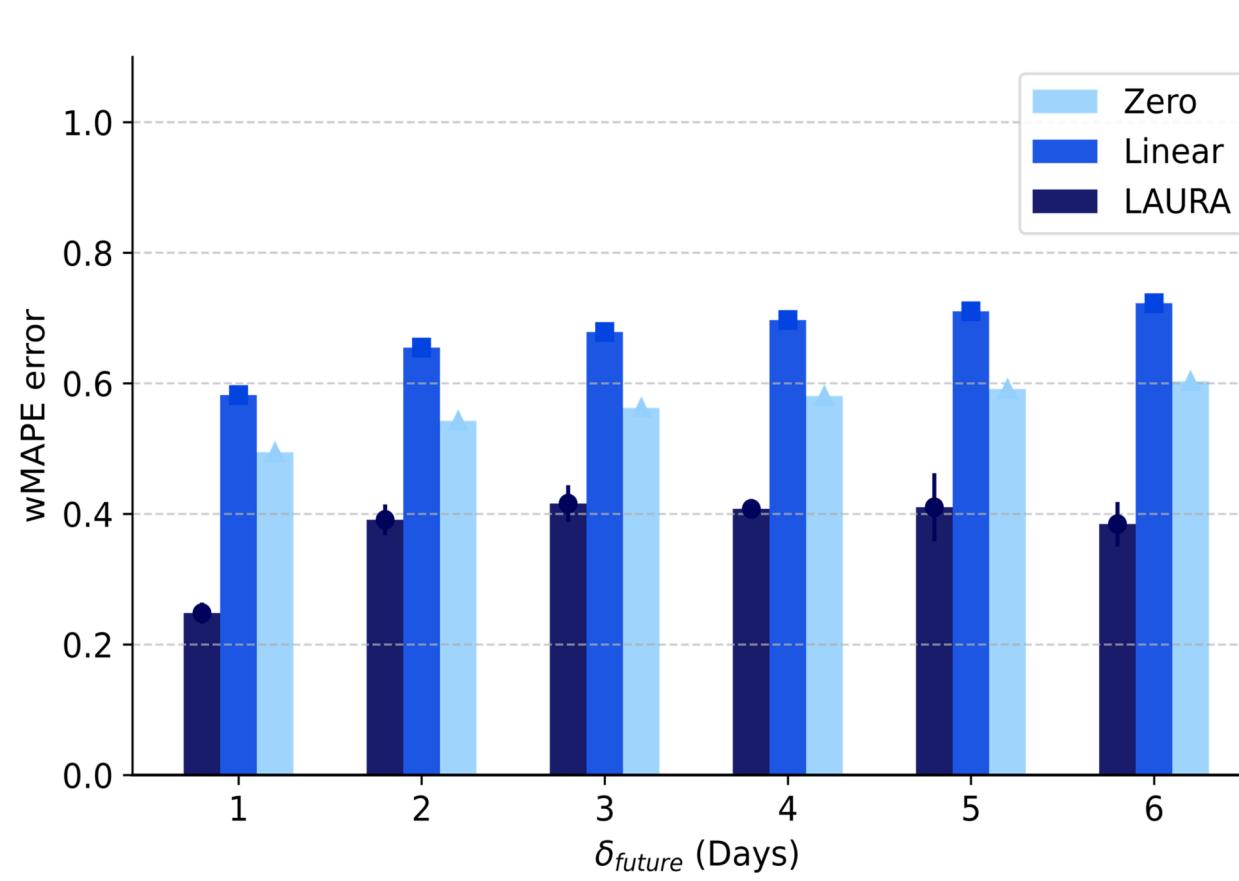
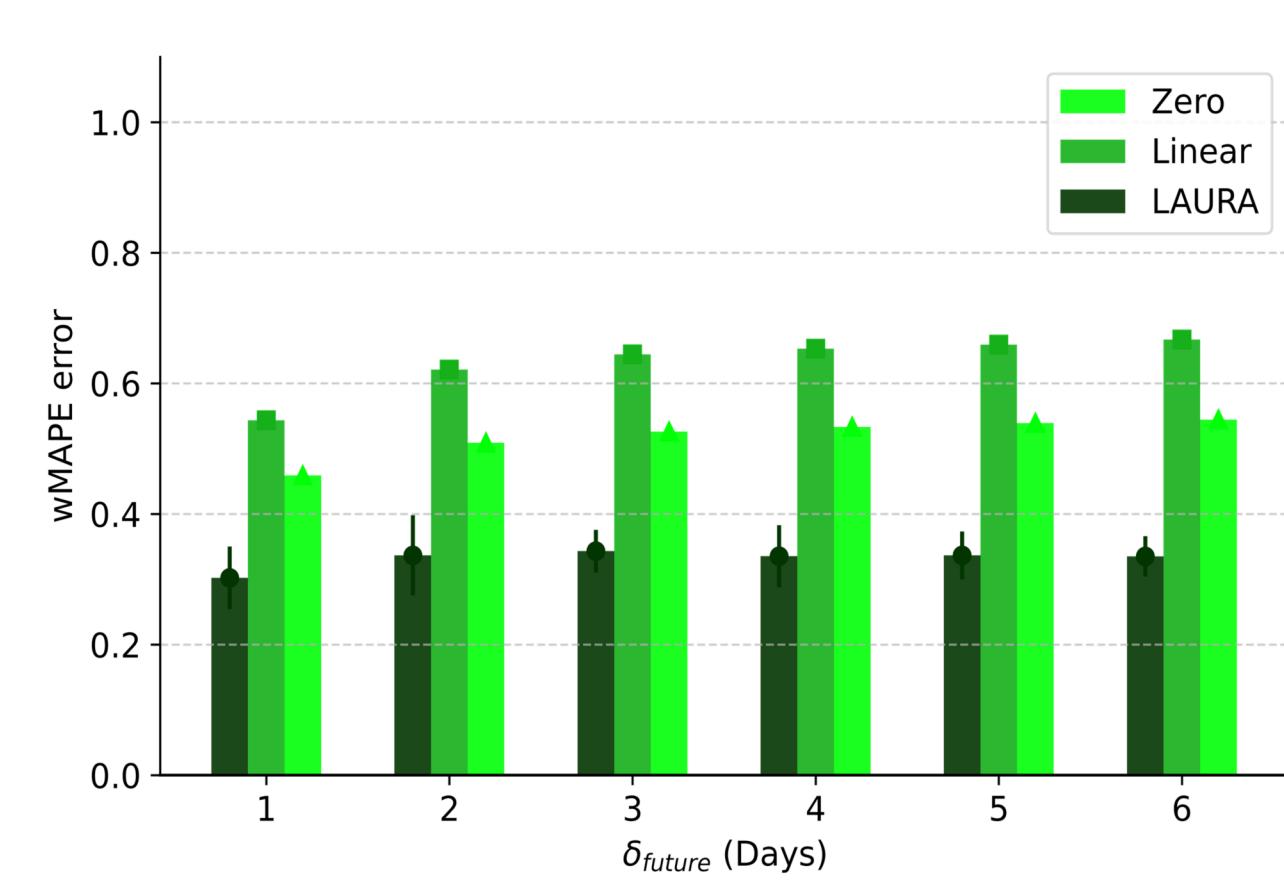
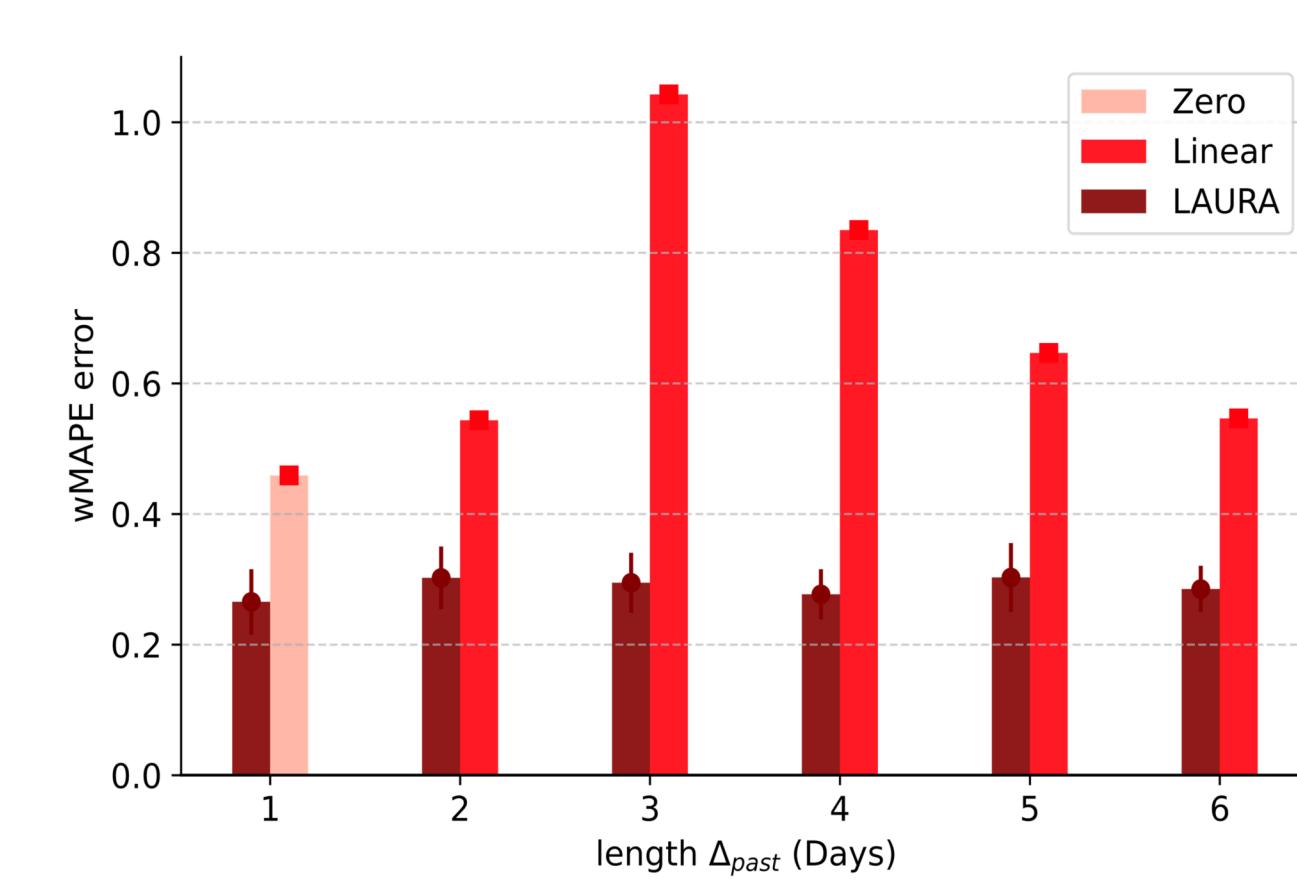
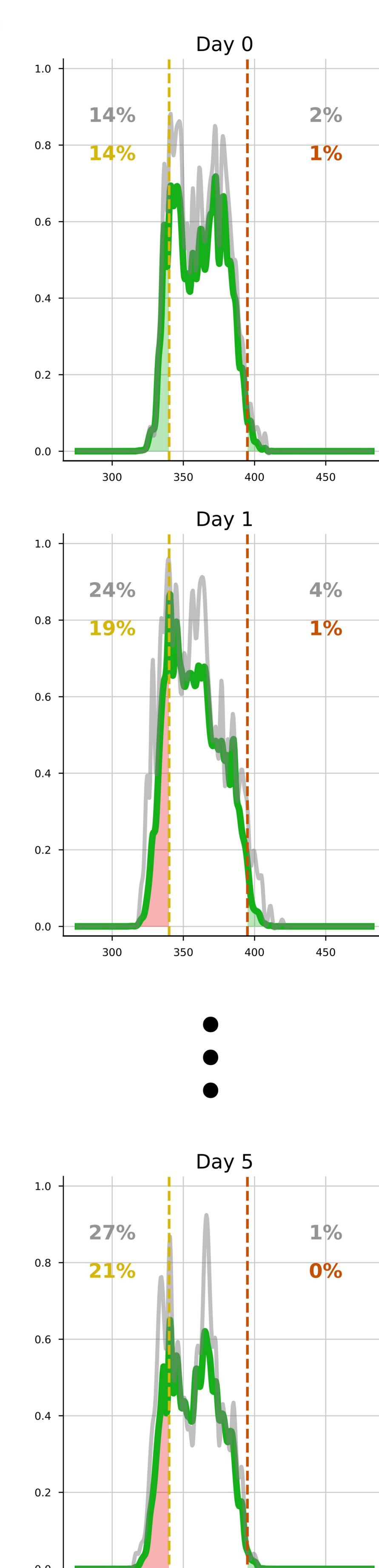
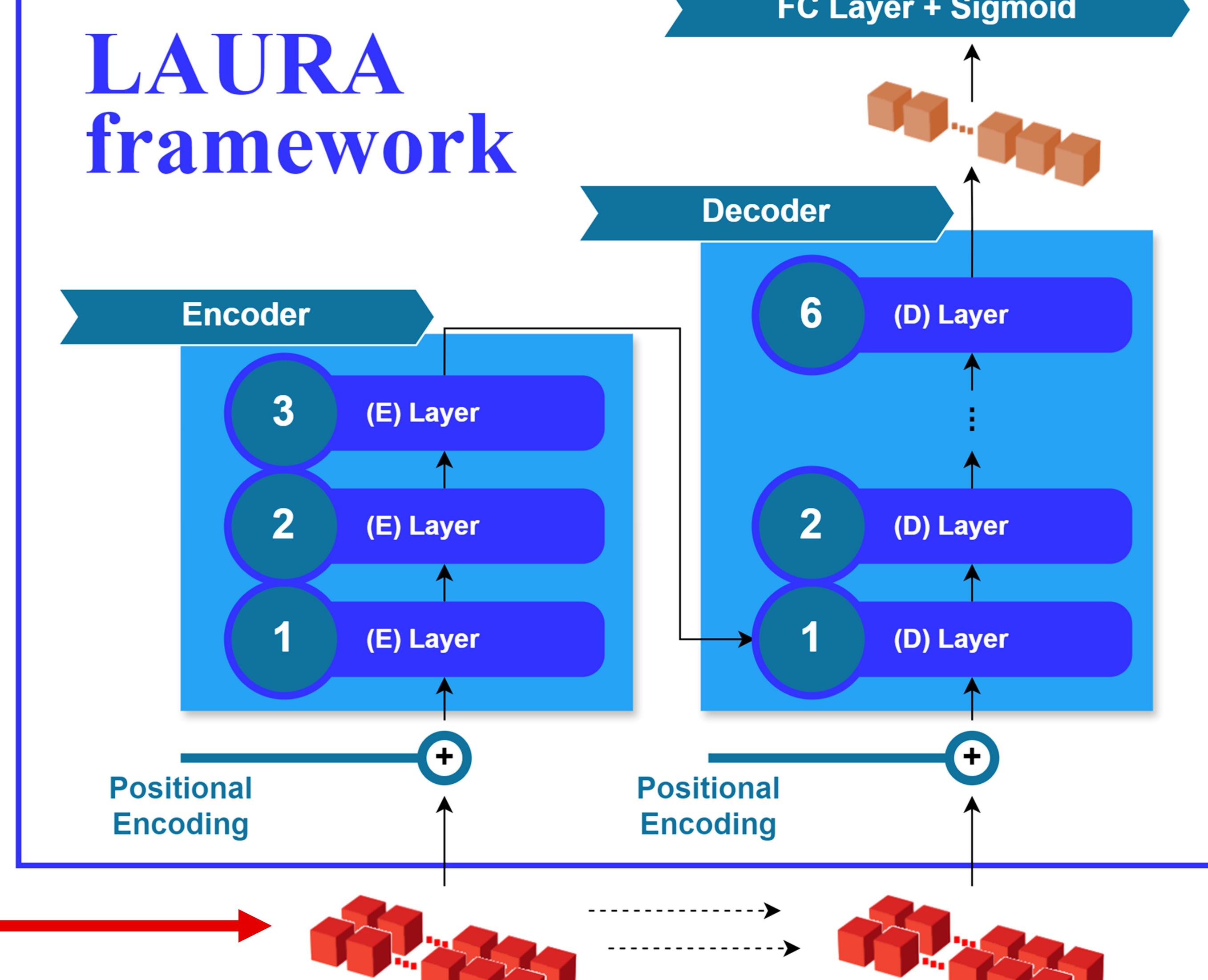
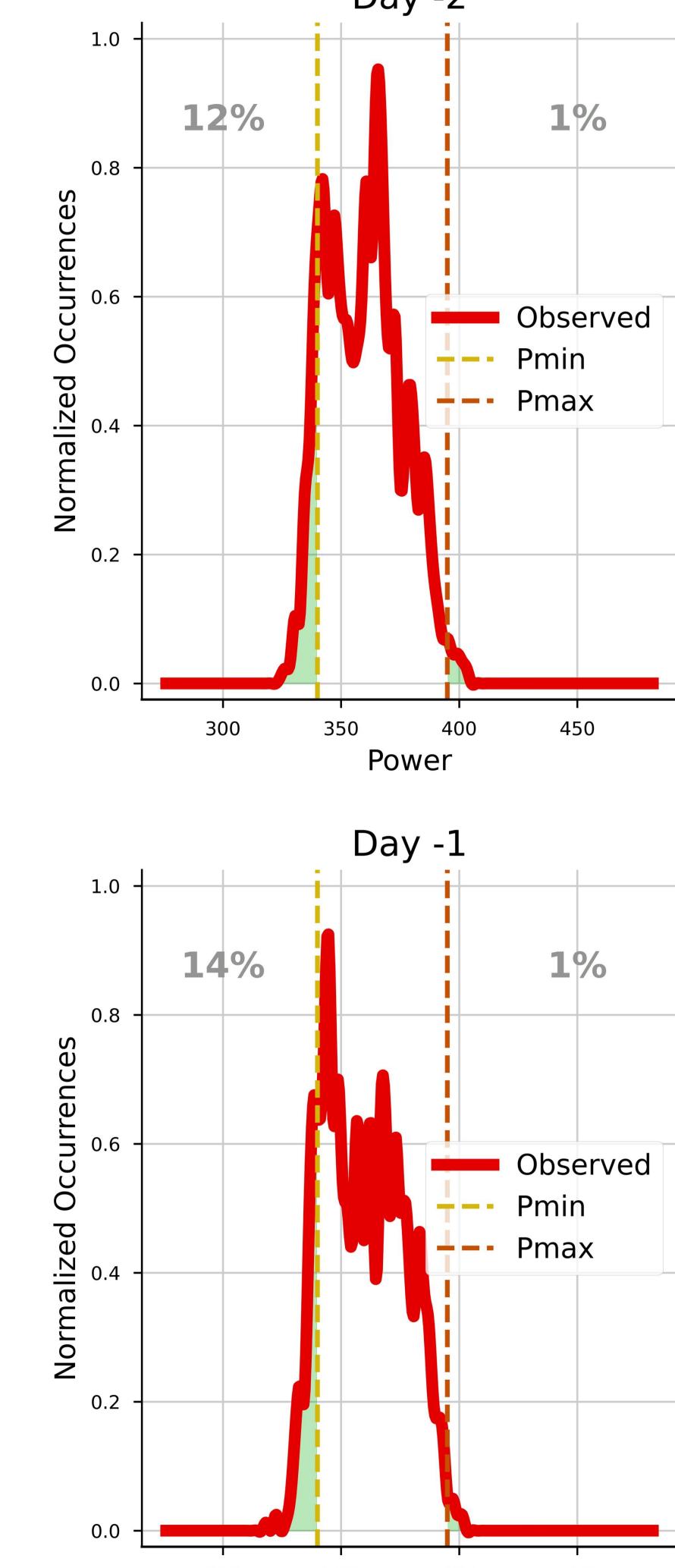
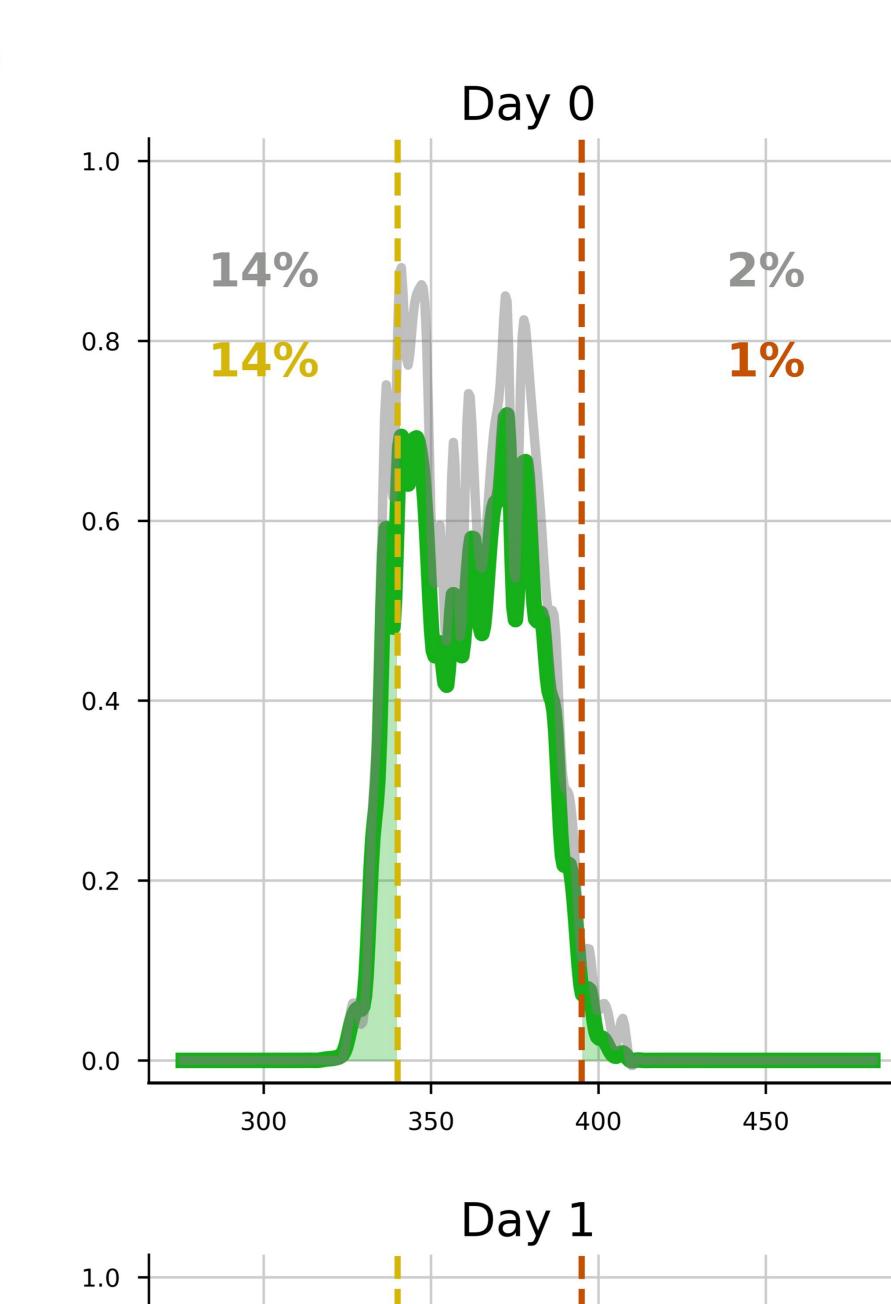
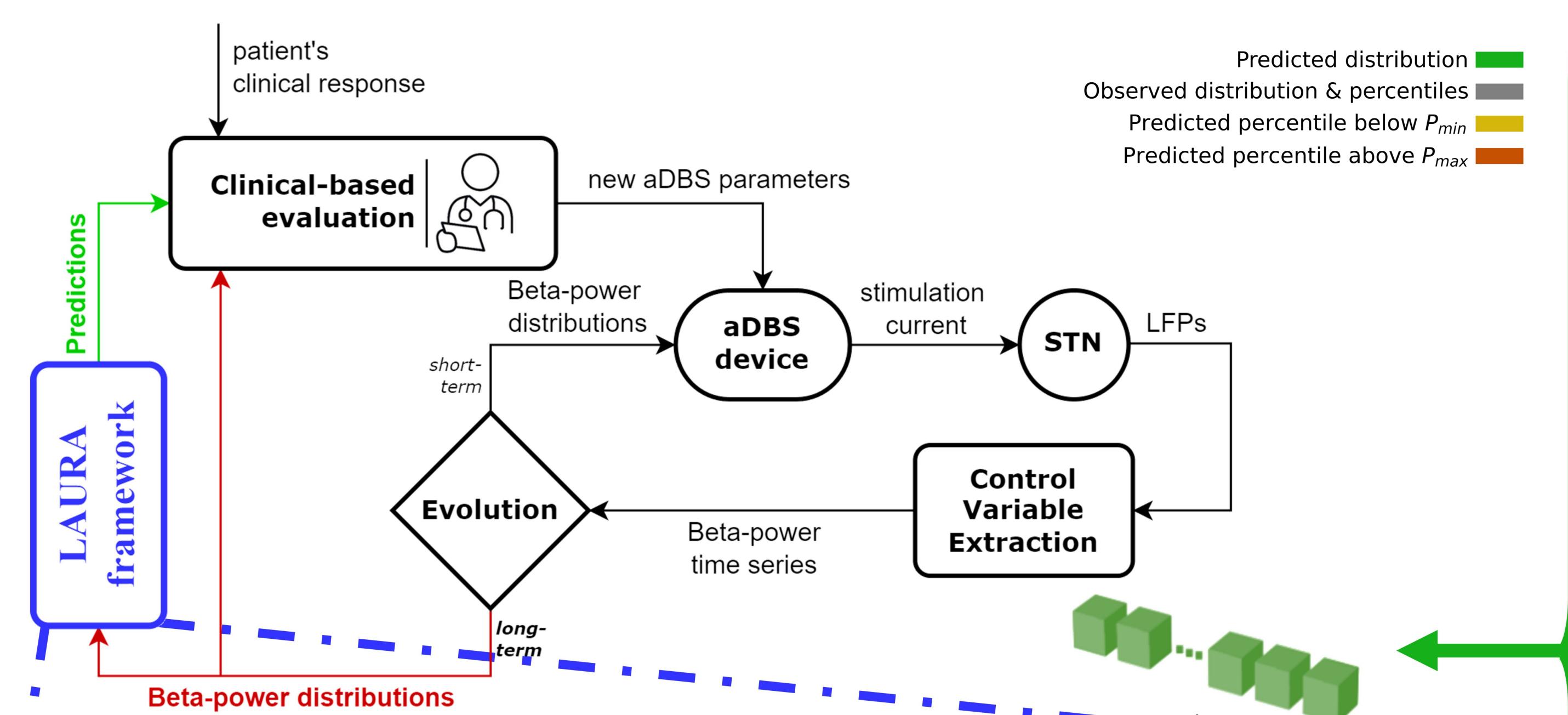
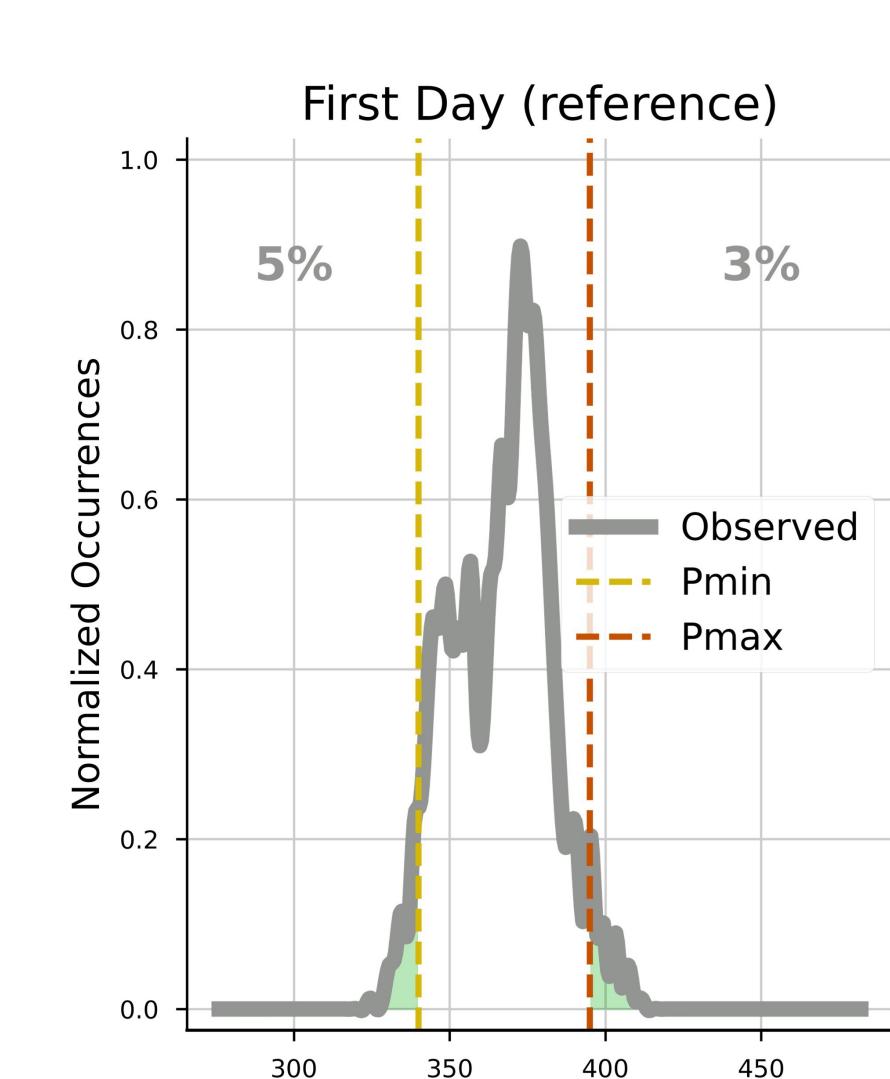
¹The BioRobotics Institute, Scuola Superiore Sant'Anna, 56025 Pisa, Italy - ²University Hospital Würzburg and Julius Maximilian University of Würzburg, 97080 Würzburg, Germany - ³Parkinson Institute Milan, ASST G. Pini-CTO, 20126 Milano, Italy - ⁴Department of Excellence in Robotics and AI, Scuola Superiore Sant'Anna, Pisa, Italy

ABSTRACT

Deep brain stimulation (DBS) of the subthalamic nucleus (STN) is an effective therapy for several Parkinson's Disease (PD) symptoms. Its adaptive approach (aDBS) further modulates the stimulation according to the power of the beta band [12-30 Hz] of STN local field potential (STN-LFP). However, long-term recordings revealed fluctuations in the STN LFP beta power distribution over timescales of days, necessitating regular clinician involvement for recalibration of the aDBS setting. Here we present a Transformer-based framework predicting the distribution of STN LFP beta power up to six days in advance. High accuracy (>93%) was achieved in four patients over a year of recordings, independently from stimulation settings. This paves the way for an autotuning strategy of aDBS control algorithm maintaining optimal stimulations levels independently from variations in patients conditions.



Explorative Data Analysis (EDA). STN beta power distributions of a patient show variability over time. (Left) The aDBS setting (i.e., P_{min} , P_{max} , $I_{min-left/right}$, $I_{max-left/right}$, F , PW) is imposed during the appointment patient-neurologist at day 0 by looking at the patient's past normalized daily distributions available (blue). Daily percentages below P_{min} and above P_{max} are shown for both the old (gray) and actual (dark yellow, dark orange) settings. (Middle) Variability profiles over time, assessed concerning the distributions' percentiles respectively below and above the two thresholds for beta power P_{min} (dark yellow) and P_{max} (dark orange) within the actual aDBS setting. (Right) STN daily distribution during the last day with the actual aDBS setting, when a recalibration of the device, with the definition of a new setting, is needed.



LAURA's patient-dependent performance. We trained LAURA as a personalized system on data from four patients. Here we show LAURA's performance on one patient assessed by monitoring the weighted mean average percentage error (wMAPE) between the observed and predicted distributions. LAURA outperforms both zero and first-order regressors. (Left) One-step-ahead prediction over a single aDBS setting. The prediction error is monitored for six different length (from 1 to 6 daily distributions) of the input sequence. (Middle) Multi-step-ahead prediction over a single aDBS setting. The wMAPE is monitored on predictions from 1 up to 6 days ahead, based on the patient's history sequence of optimal length N^* (=2 days, for this one patient) found experimentally. (Right) Multi-step-ahead prediction over multiple aDBS settings.

CONCLUSIONS

We presented LAURA, a personalised Deep Learning (DL) framework forecasting STN beta power distributions up to six days in advance, based on chronic home-monitoring recordings. The clinician-in-the-loop approach represents today the optimal strategy for interpreting LAURA's neurophysiological predictions, enhancing current long-term aDBS therapy for PD. Our framework leads to the development of a comprehensive, explainable DL architecture capable of combining neural data with chronic informative data pertaining to the clinic state of the patient, with the aim of an auto-tuning strategy within the aDBS workflow.

