Deep Learning-Based Solar Irradiance Prediction Model Using the FISM2 Dataset During the Solar Flare Events

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인공지능, 우주를 만나다 SpaceAI

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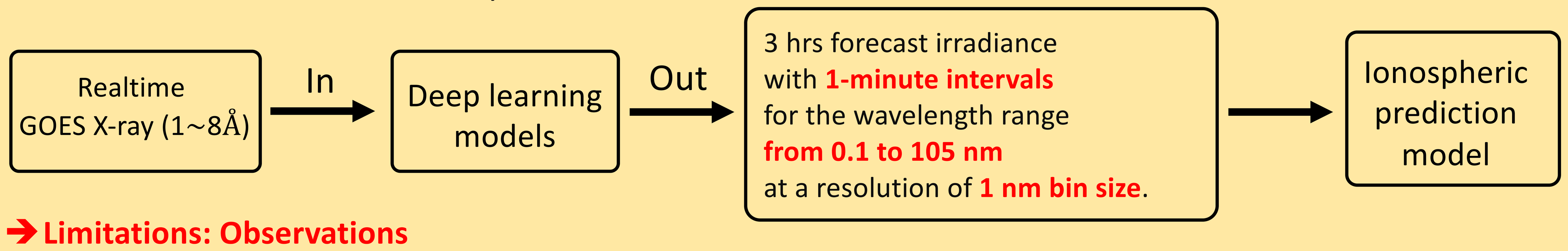
I. A Brief Introduction

- Currently, there is no tool available worldwide that can predict changes in solar irradiance when a solar flare occurs.
- In this study, we have developed a deep-learning model that can immediately predict changes in solar irradiance from the X-ray to the EUV, from the onset of a solar flare to three hours afterward.
- The deep learning model is trained on GOES X-ray and FISM2 model data, focusing on minute-by-minute details surrounding 964 M-class or stronger solar flare events from 2003 to the present.
- We have attempted predictions on only four wavelengths within the X-ray and EUV spectral 1nm bin range and have obtained meaningful results; in the future, we will expand our predictions to cover a broader range of wavelengths.

II. Key Points & Concepts

➔ **Ideal Goal:** The aim of this study is to forecast the solar irradiance after solar flare events.



➔ **Limitations: Observations**

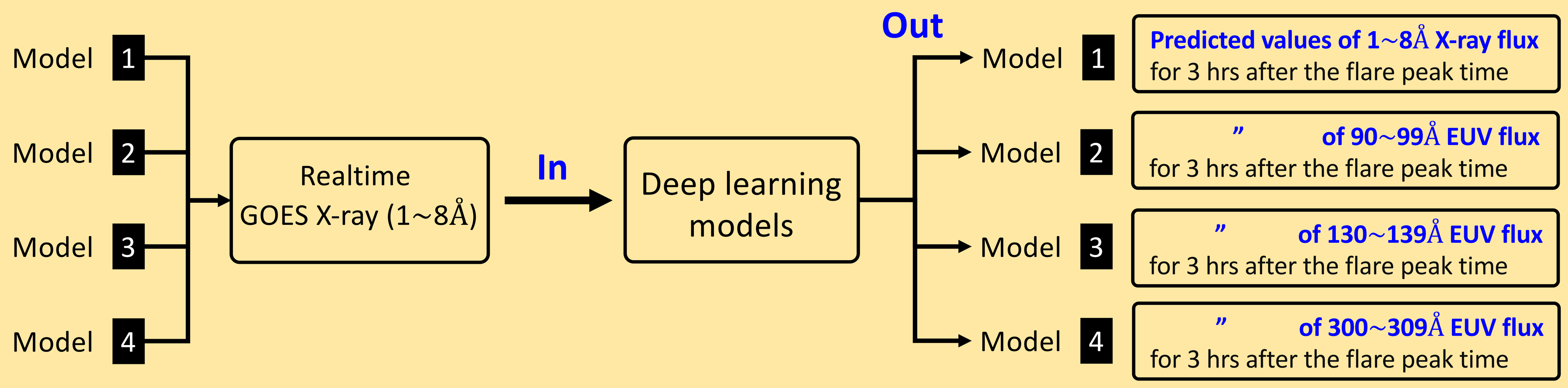
1. During solar flares, the only available data we have is the GOES X-ray data (1-8Å)
2. EUV observation is limited to certain wavelengths and is not viable. (SDO etc..)

➔ **Limitations: Models**

1. Empirical models of solar irradiance cannot represent changes due to real-time solar flare occurrences. (EUVAC, HEUVAC, NRLEUV2 etc..)
2. Even the FISM2 model does not provide real-time data.
3. Also, simultaneous prediction output for 105 wavelength bins is required, which is challenging.

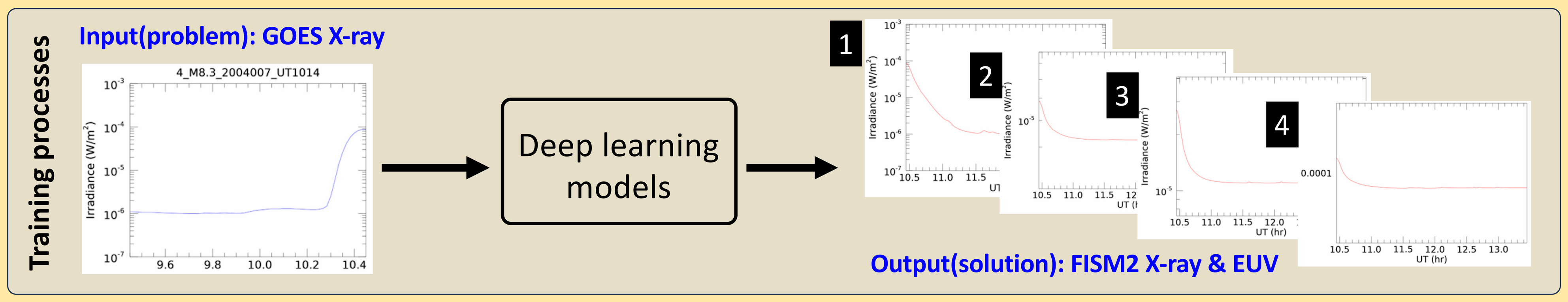
➔ **In this study,**

We developed a **4 test model to predict four wavelength ranges**, selecting **three EUV wavelength** ranges that respond sensitively to changes in X-rays after a flare occurrence.



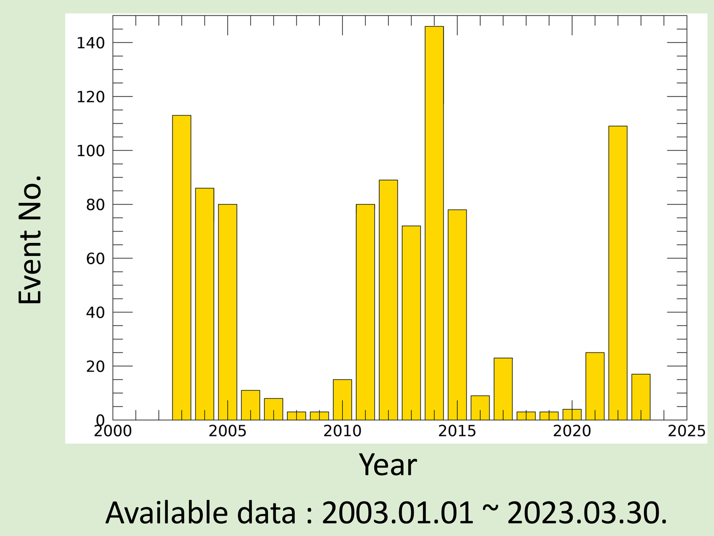
➔ **To collect training data for the deep learning model,**

1. **Firstly**, accurate and actual observed **input (problem) and output (solution) data are required**. We believe that the data from the **FISM2 model** *(Chamberlin et al., 2020)* meets this criterion.
2. **Secondly,** it involves **gathering flare events** that occurred during the available FISM2 model period. We have selected and collected flare events through the following process.



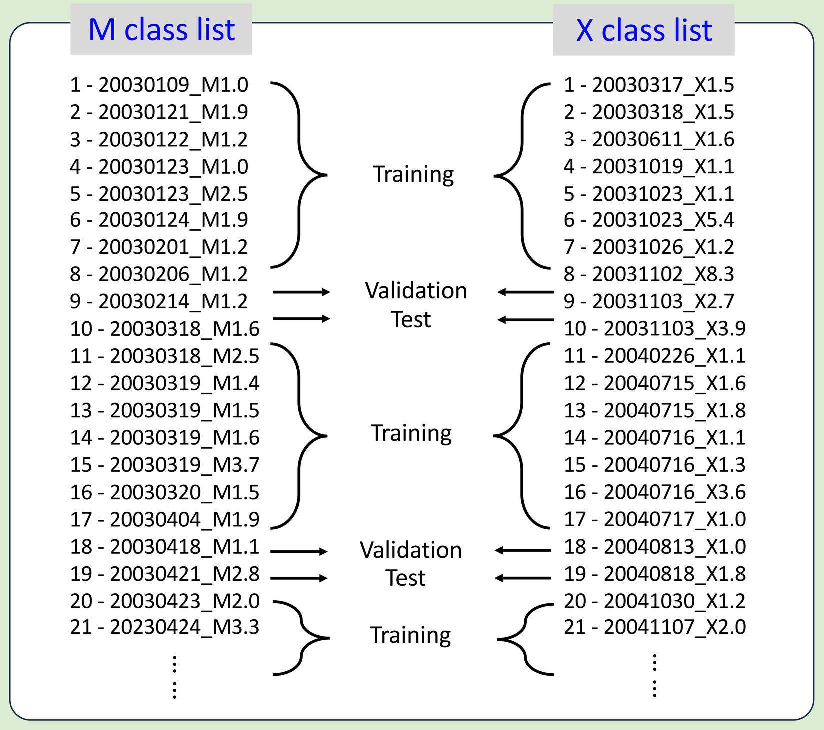
III. Flare Events Selection & Classification

- To generate training data for the FISM2 model, it's necessary to understand the data range provided by the FISM2 model. The **available FISM2 data spans from 1 January 2003 to 30 March 2023**.
- For selecting flare events, **we chose flares of class M1 and above**. Through these criteria, we have secured a total of 964 flare events.



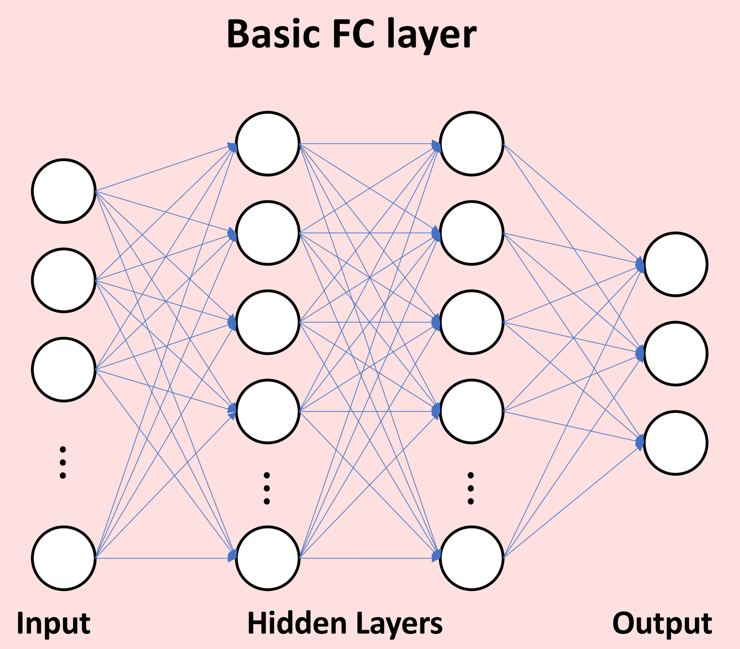
Available data : 2003.01.01 ~ 2023.03.30.

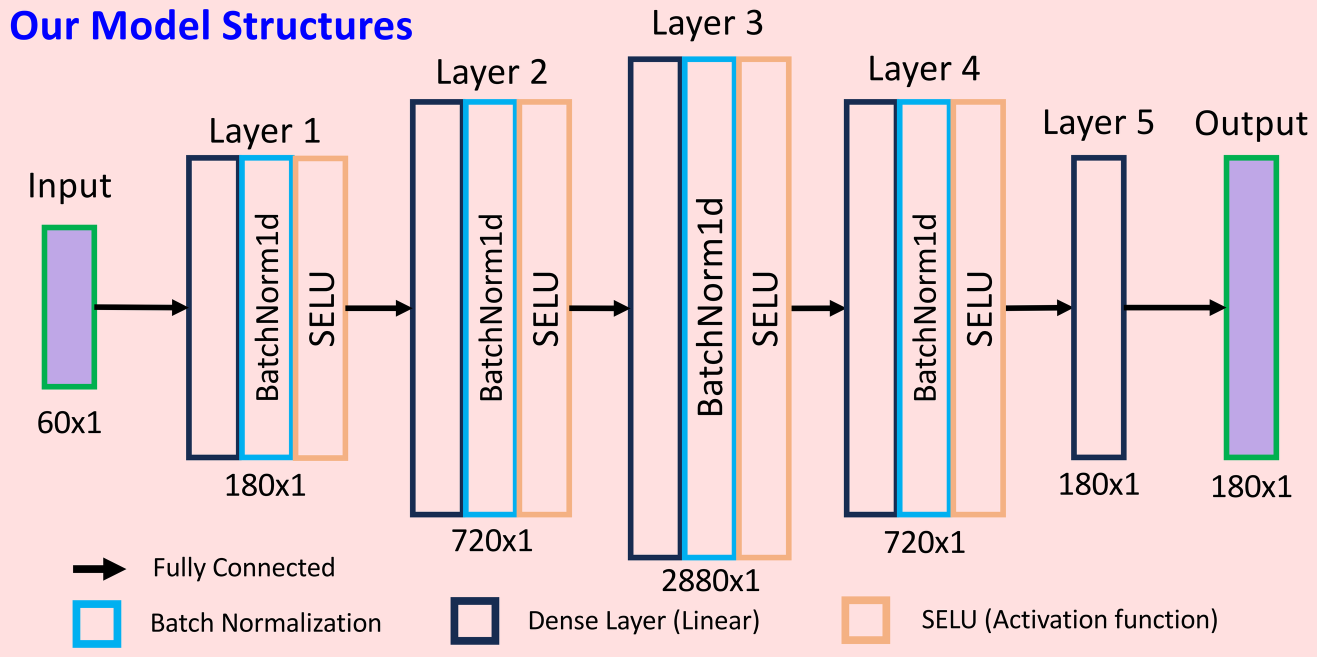
	X class	M class	Total
Event No.	84	880	964
Training (80%)	68	704	772
Validation (10%)	8	88	96
Test (10%)	8	88	96



IV. Deep Learning Model

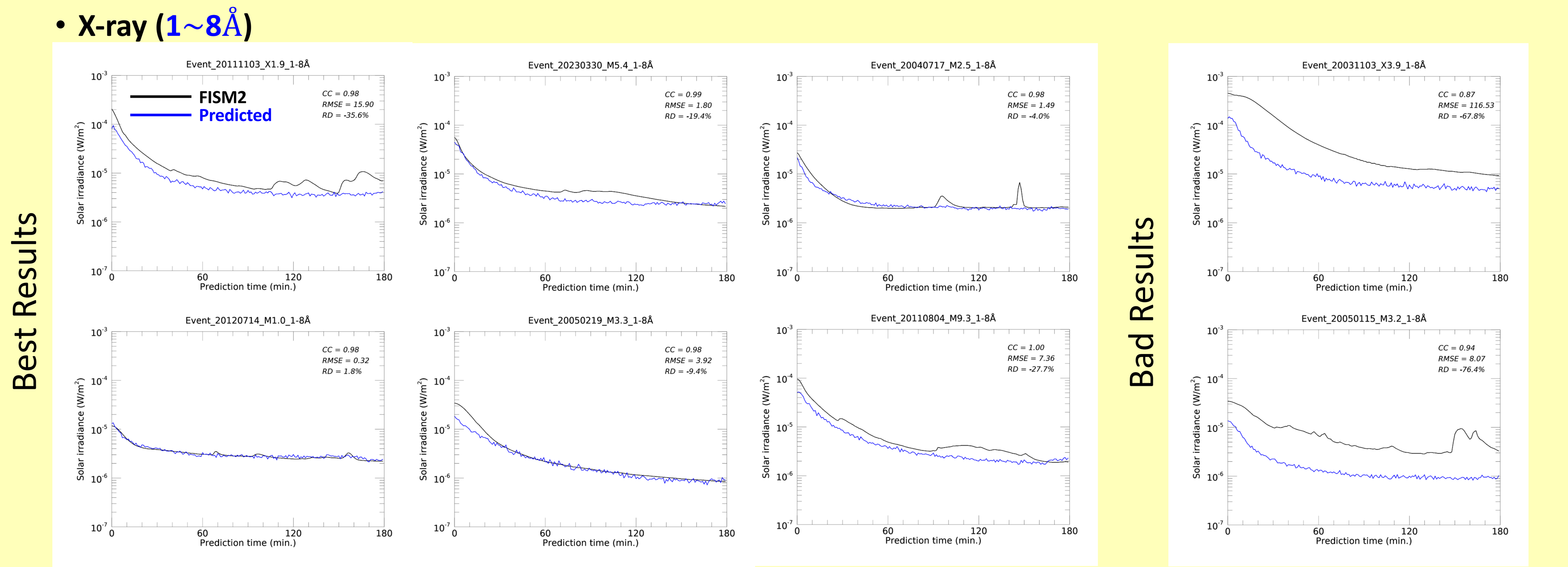
- The **Fully Connected Layer** (FC Layer), also known as **Multi-Layer Perceptron (MLP)**, is a simple model characterized by densely interconnected neurons, where each neuron in the previous layer is **connected** to every neuron in the next layer.



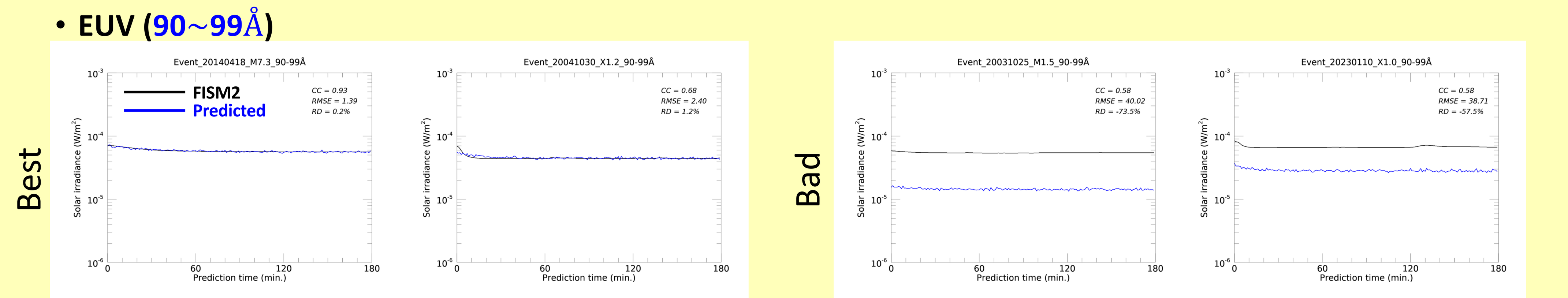


V. Prediction Results

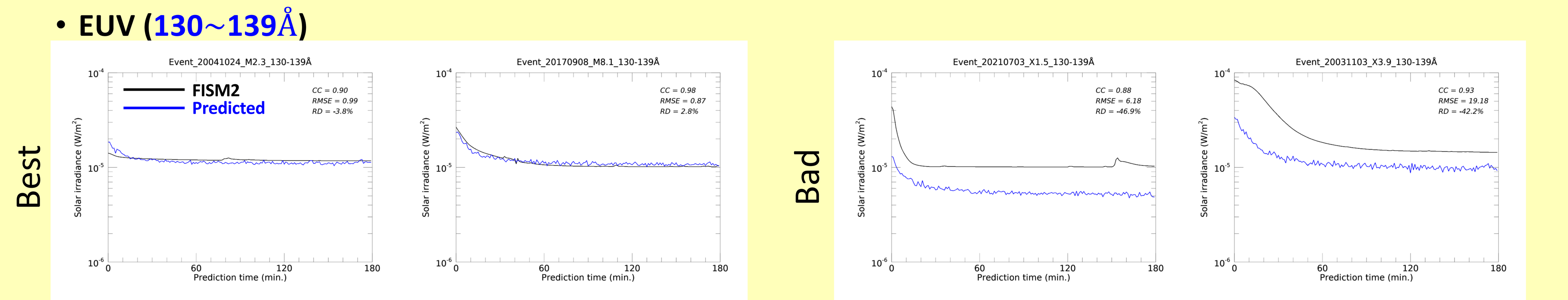
- **X-ray (1~8Å)**



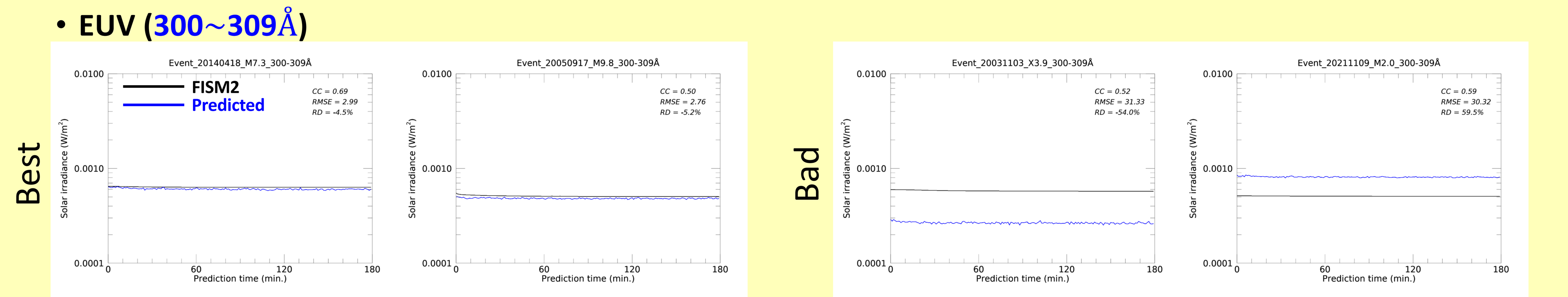
- **EUV (90~99Å)**



- **EUV (130~139Å)**



- **EUV (300~309Å)**



- For **X-rays**, the **correlation coefficient(CC)** was calculated as **0.91**, while for **EUV**, it was **0.65, 0.81, and 0.5**.
- In the case of **Mean Percentage Error(MPE)**, the values were **-24.3, -17.5, -20.8, and -5.6%**, indicating that, overall, the predictions were lower than the actual observed values.
- In future plans, we aim to refine areas where our model underpredicts relative to observations by tuning the deep learning model's hyperparameters.
- We also plan to expand the wavelength range to the full spectrum to better assess ionospheric responses, a step essential for enhancing our model's utility in ionospheric modeling.

VI. References & Acknowledgements

- The findings detailed in this document were made possible by utilizing the FISM2 model as delineated by Chamberlin et al. 2020, available at https://doi.org/10.1029/2020SW002588. We accessed these data through the LASP Interactive Solar Irradiance Datacenter (LISIRD), found at https://lasp.colorado.edu/lisird/.
- The GOES X-ray data and flare event information were obtained by referencing the information available at https://www.swpc.noaa.gov/products/goes-x-ray-flux.
- This project is a study supported by KASI's SpaceAI project. (https://spaceai.kasi.re.kr/)