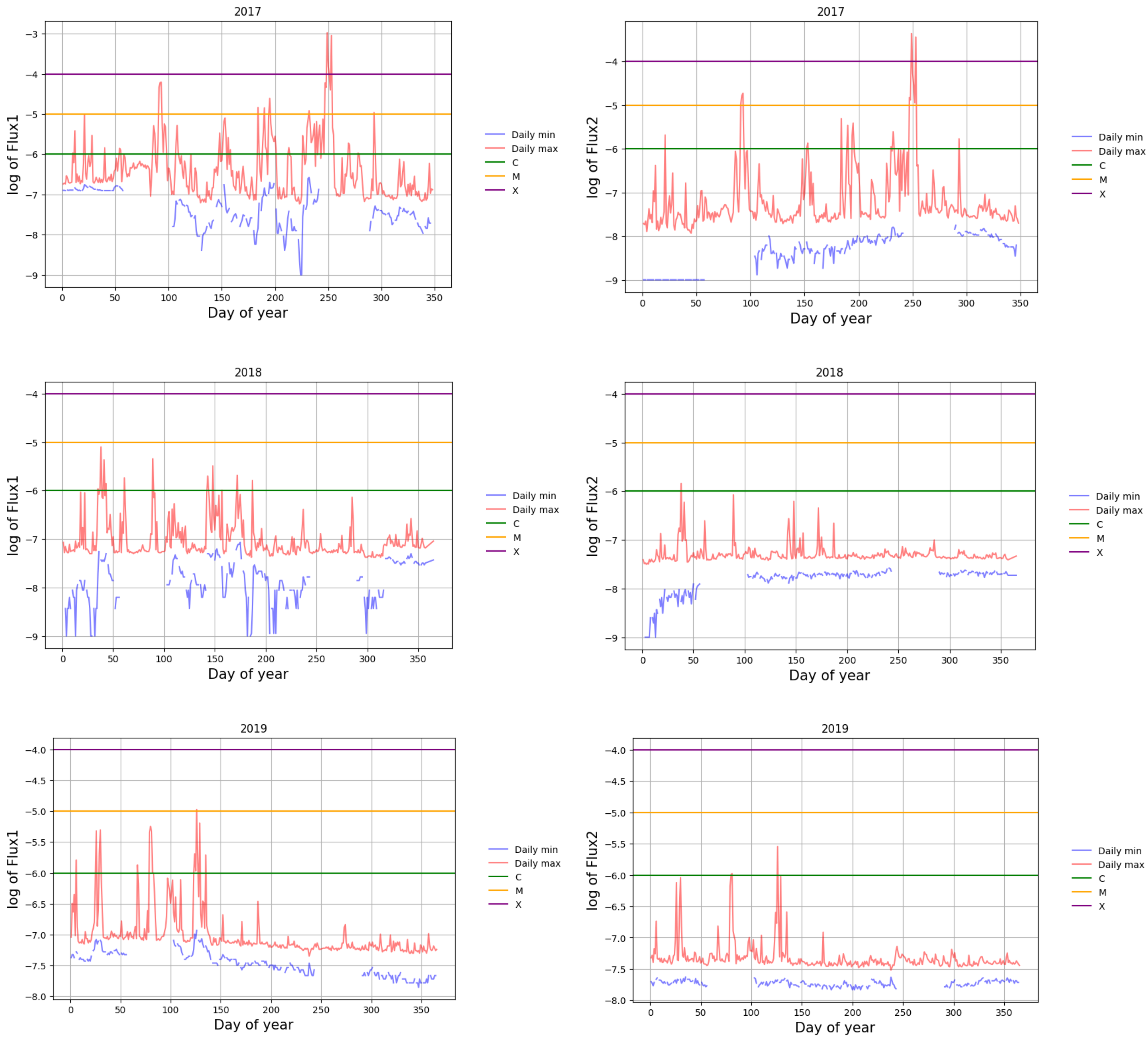
Youngjun Woo
UMID: yjwoo
April 18th, 2023

Analysis of changes in tail distribution of X-ray flux

We aim to analyze changes in tail distribution of the X-ray flux using the GOES data. GOES is a X-ray flux time series data measured at approximately a two-second sampling rate. There are flux-1 and flux-2 variables related to X-ray flux and Year, Month, Day, and Time variables related to the measurement time. Both flux-1 and flux-2 are measured in watts per square meter. A strong X-ray flux event is called a "flare", and flares can be classified in B, C, M and X class flares based on the following thresholds:

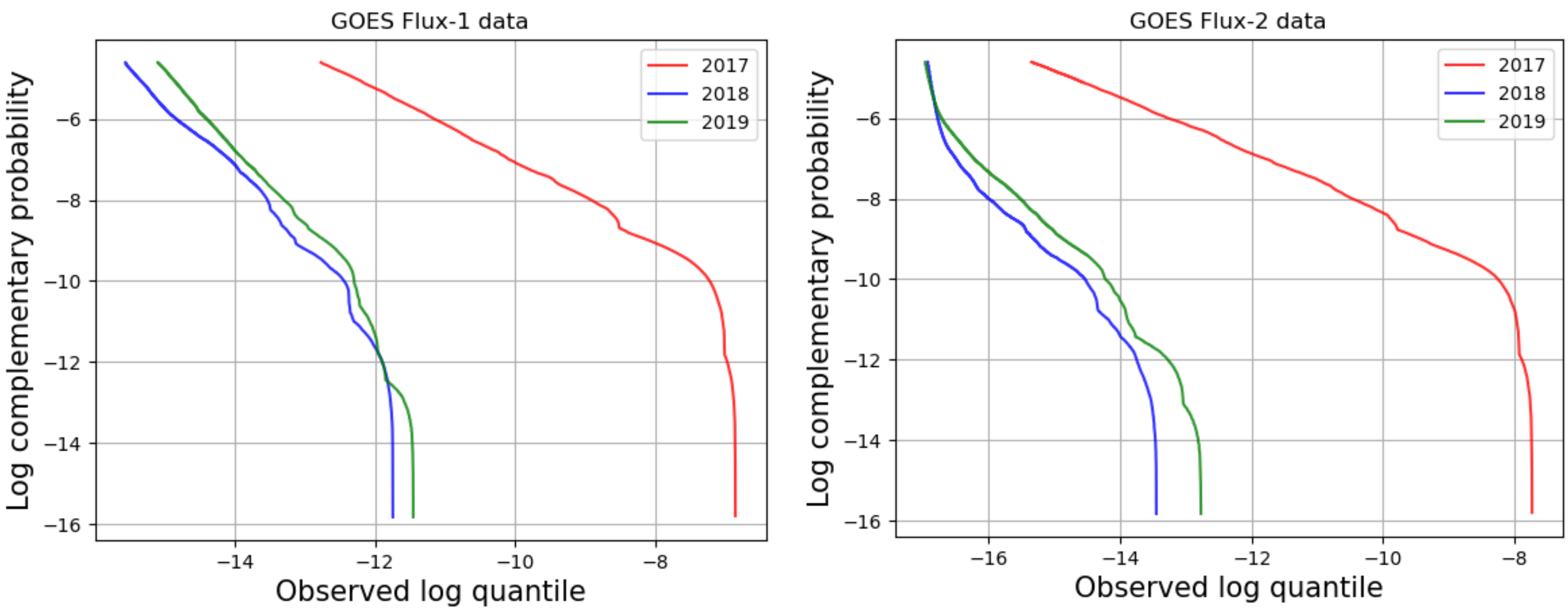
Class	Strength	What can they do to Earth
B	$I < 10e\text{-}6$	Too small to harm Earth
C	$10e\text{-}6 \leq I < 10e\text{-}5$	Small with few noticeable consequences on Earth
M	$10e\text{-}5 \leq I < 10e\text{-}4$	Can cause brief radio blackouts that affect Earth's polar regions and minor radiation storms.
X	$10e\text{-}4 \leq I$	Can trigger planet-wide radio blackouts and long-lasting radiation storms

Full data exists from 1981 to March 2020, but we only analyze data from 2017 to 2019, the last three years when data for all years exist. For each year, 14,590,631 X-ray fluxes were measured in 2017, 14,982,271 in 2018, and 14,974,694 in 2019. Plot 1 shows the time series plot of the log transformed Flux 1 and Flux 2 for each year. We can see that the distribution of X-ray flux varies by year. In 2017, X and M class flux also appeared frequently, but in 2018 and 2019, most of the flux were weaker than C class. In other words, the tail distribution of the flux in 2017 and the flux in 2918 and 2019 show slightly different behaviors.



Plot 1: Time series plots of the log transformed Flux 1 and Flux 2 for each year

More specifically, to analyze the behavior of the tail distribution of flux by year, we use the pareto tail plot, which plots $log(1 - j/n)$ against $logX_{(j)}$. If tail distribution follows $P(X > x) = c/x^{\alpha}$, then we have $log\, P(X > x) = log\, c - \alpha \cdot log\, x$ by the log transformation. Therefore, we can guess the tail distribution parameter alpha using the pareto tail plot. Plot 2 below shows Pareto tail plots of upper 1% fluxes for each year. We can see that the tail distribution of 2017 and that of 2018 and 2019 show different behaviors. The plot shows a slope of about 1 in 2017 and about 2 in 2018 and 2019. That is, tail of the X-ray flux in 2017 behaves like $P(X > x) = c/x$ and the tail of the X-ray in 2018 and 2019 behave like $P(X > x) = c/x^2$. It means that 2017 has a heavier tail distribution compared to 2018 and 2019.



Plot 2: Pareto tail plots of upper 1% fluxes for each year.