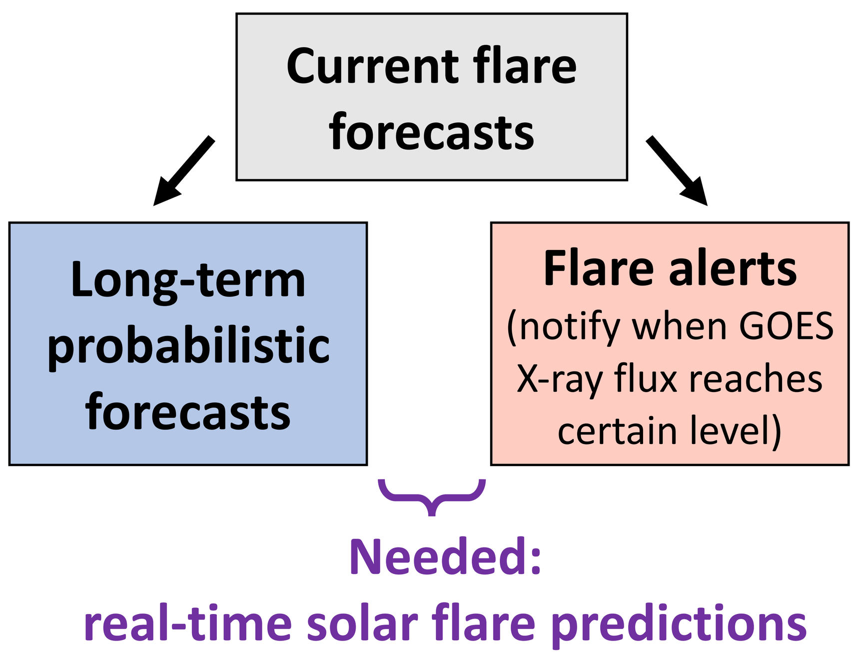
Concept for Real-Time Solar Flare Predictions Using Early Flare Signatures

Juliana T. Vievering[1] (Juliana.Vievering@jhuapl.edu), P. S. Athiray[2], J. C. Buitrago-Casas[3], P. Chamberlin[4], L. Glesener[5], S. Krucker[3], J. Machol[6], C. Peck[4], K. Reeves[7], S. Savage[8], B. Smith[1], A. Winebarger[8]; *(1) Johns Hopkins Applied Physics Laboratory, (2) University of Alabama Huntsville, (3) Space Sciences Laboratory at the University of California Berkeley, (4) Laboratory for Atmospheric and Space Physics at the University of Colorado Boulder, (5) University of Minnesota Twin Cities, (6) CIRES at the University of Colorado Boulder, (7) Harvard-Smithsonian Center for Astrophysics, (8) NASA Marshall Space Flight Center*

Introduction

- **Understanding when and where solar flares and eruptive events will occur** continues to be an important goal for the heliophysics community, from both fundamental science and space weather perspectives.
- For a wide variety of operations and research purposes, we need to invest in the development of **flare predictions** that are **more actionable** than long-term (e.g., 24-hour) forecasts and provide **earlier notice** than current flare alerts.
- To address this need, we seek to develop a tool using machine learning that **rapidly aggregates near-real-time signatures of flare onset**, including X-ray and EUV irradiance measurements, to provide **early prediction of the magnitude and duration of ensuing solar eruptive events**.



Real-Time Solar Flare Predictions

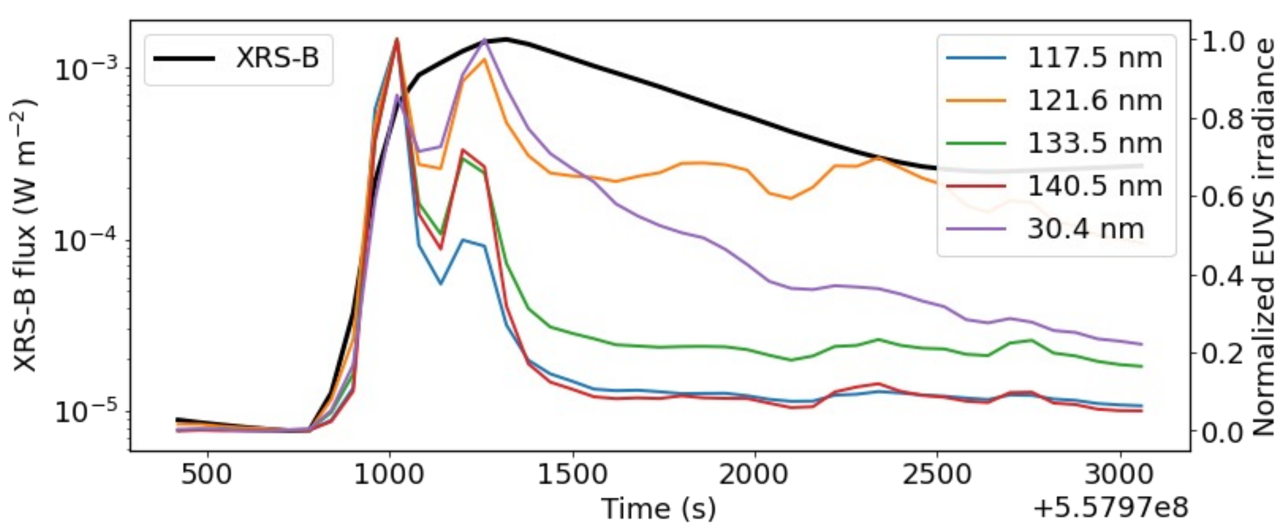
We propose developing a tool that **rapidly aggregates near-real-time signatures of flare onset** to provide **early prediction of the magnitude and duration** of ensuing solar eruptive events.

Multiple near-real-time data sets available:

- Solar irradiance (e.g., GOES/XRS, GOES/EUVS, SDO/EVE/ESP)
- Imaging (e.g., GOES/SUVI, SDO/AIA)

X-ray and EUV Irradiance

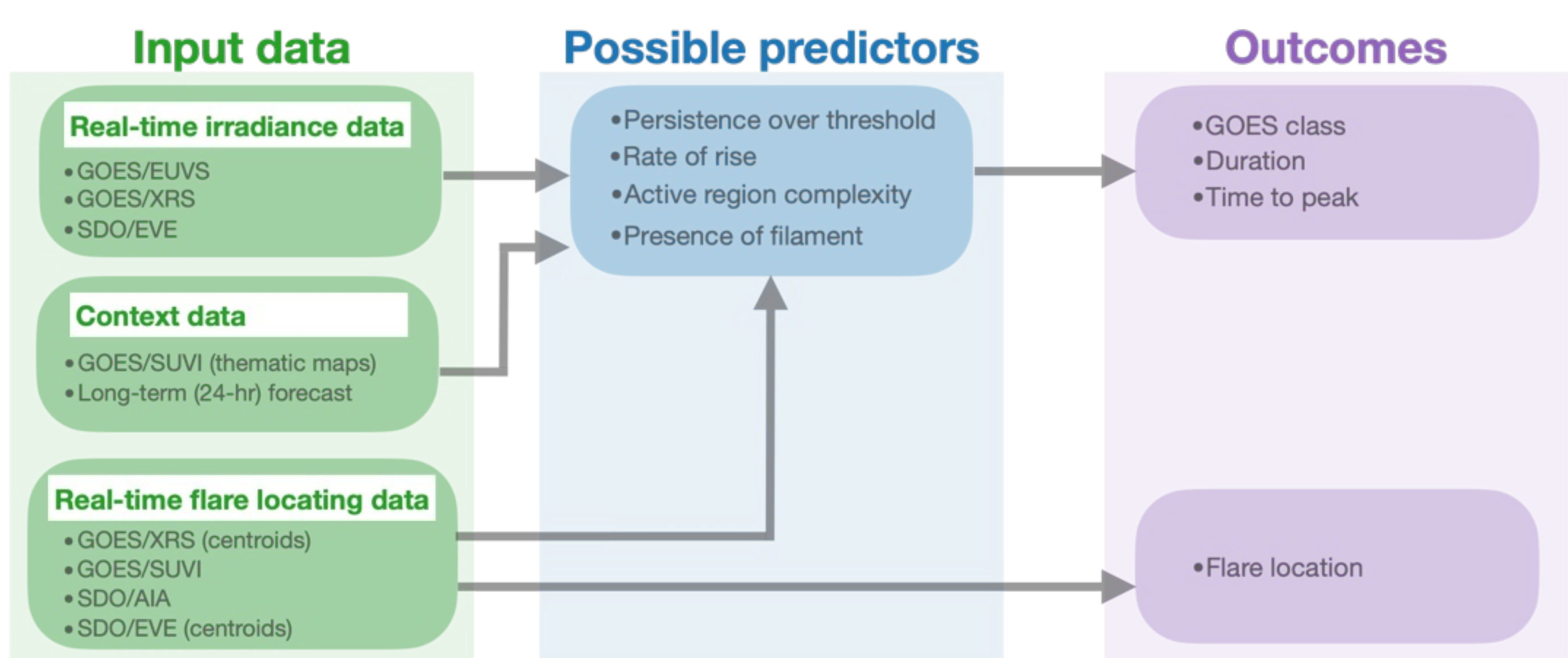
Example time series for the 6 Sep 2017 X-class flare from GOES/XRS-B and GOES/EUVS (subset of emission lines).



Real-time chromospheric and transition region UV measurements from EUVS and EVE provide a **direct measure of impulsive phase heating and energy deposition in the low solar atmosphere**, which provides early indication of flare onset.

Concept for Real-Time Solar Flare Predictions Tool

Using real-time data sets and machine learning techniques, we aim to identify the strongest predictors of flaring activity and how these predictors relate to the resulting flare magnitude and duration.



Acknowledgements

We acknowledge JHU/APL for support to develop this concept.

Contact

Have additional ideas for a real-time flare prediction tool and/or applications? Interested in this concept? Please reach out!

Email: Juliana.Vievering@jhuapl.edu

References

Frissell, N. A., et al. 2019, Space Weather, 17, 118

Early Flare Signatures with GOES/EUVS

In preliminary work, we investigate the utility of **real-time EUV irradiance data** from GOES/EUVS for **early predictions** of solar flare characteristics.

	Measurement	Region
EUVS	C II (**133.5 nm**)	chromosphere
EUVS	C III (**117.5 nm**)	chromosphere
EUVS	Mg II (280 nm)	chromosphere
EUVS	H I Ly-α (**121.6 nm**)	chromosphere, TR
EUVS	Si IV / O IV (**140.5 nm**)	transition region (TR)
EUVS	He II (25.6, **30.4 nm**)	transition region (TR)
EUVS	Fe XV (28.4 nm)	corona
XRS	0.05 - 0.4 nm (XRS-A)	corona/flare
XRS	0.1 - 0.8 nm (XRS-B)	corona/flare

*EUV channels in **bold** promising for this application

Data & Methods

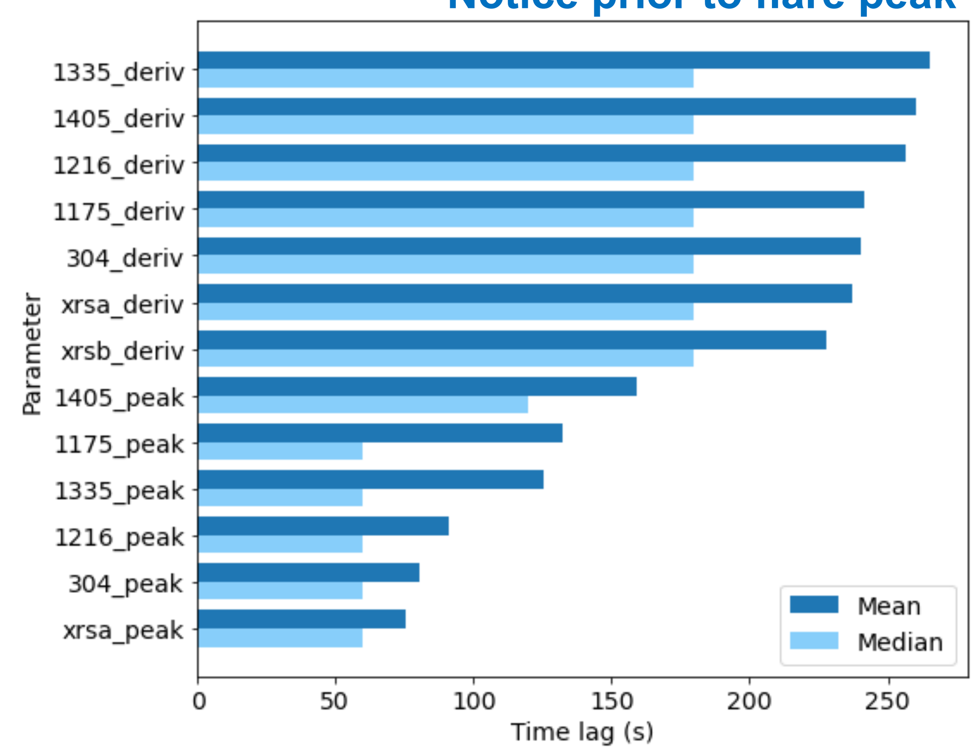
- GOES L2 science data (XRS, EUVS)
- 1-minute averages
- 2374 >C1 flares from 2017-2022
- For each X-ray and EUV channel, identified:
  - Peak intensity & time of peak
  - Max derivative & time of max derivative

Do parameters provide advanced notice?

We compute the time difference between the flare peak (XRS-B peak) and the predictor (peak intensity, max derivative).

EUVS irradiance measurements may provide **more advanced notice** of flares than XRS measurements alone.

Notice prior to flare peak

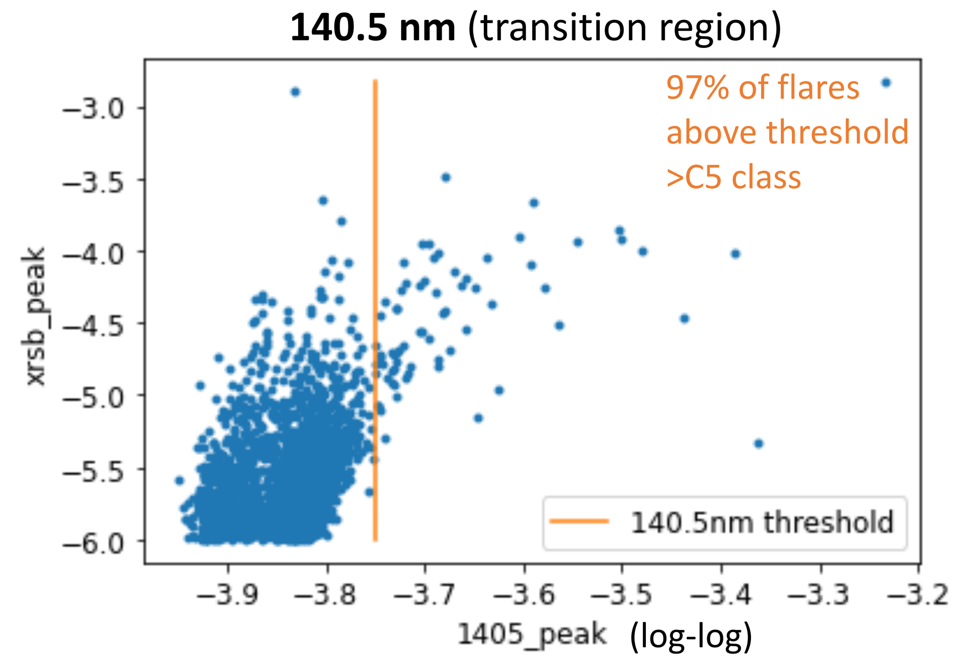


Are parameters predictive of flare characteristics?

We examine the relationship between flare peak (XRS-B peak) and the EUV predictor.

For several EUV lines, there are thresholds at which the peak intensity / max derivative is **strongly predictive of a large flare** (>C5 class).

140.5 nm (transition region)



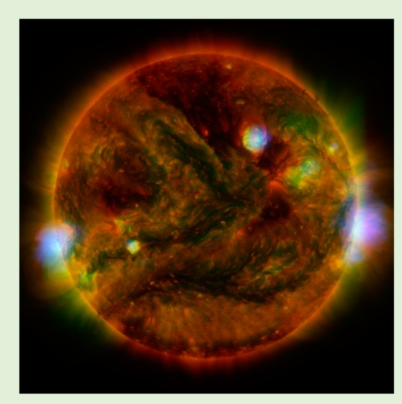
Next steps

- Identified thresholds will provide value in setting trigger thresholds for a future early flare alert system.
- Future studies should:
  - Examine earlier signatures (e.g., smaller preceding peaks)
  - Aggregate signatures using machine learning (e.g., random forest regressor)

Measurements/Missions That Will Benefit

Missions

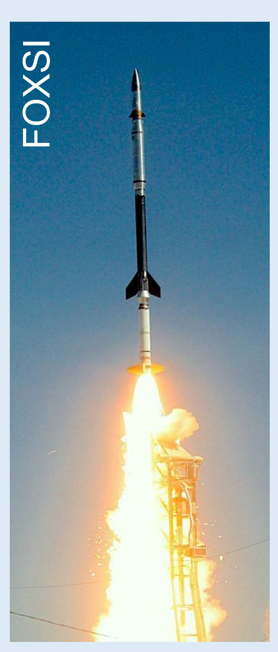
Improvements in near-term flare predictions are particularly important for observatories targeting flare physics that are restricted in field of view (e.g., IRIS, Hinode/SOT, Hinode/EIS, SOHO/CDS, SOHO/SUMER) and/or observing time (e.g., astrophysical observatories, CubeSats).



Credit: NASA/JPL-Caltech/GSFC/JAXA

Technology Development

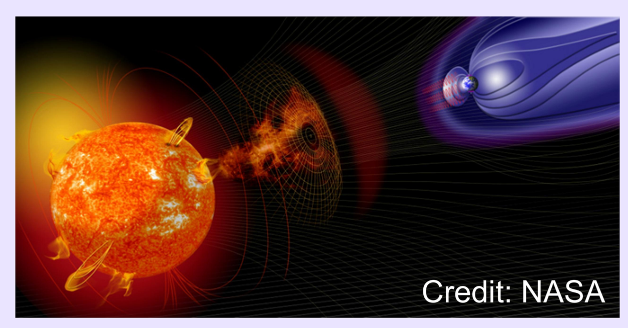
Sounding rocket flare campaigns



- Seek to perform a triggered launch to observe a large solar flare
- Important for developing novel instruments optimized for solar flare observations
- First solar flare campaign (2024) will feature FOXSI-4 (PI Glesener), Hi-C (PI Savage), and SNIFS (PI Chamberlin)

Space Weather

- The increase in SXR and UV irradiance from solar flares has an immediate impact on planetary atmospheres.
- Space weather impacts include satellite drag and radio blackouts (Frissell et al., 2019).



Credit: NASA