Active Regions

- 11-year solar activity cycle
- Active regions
  - Seen as sunspots on white light images
  - Areas of strong magnetic flux concentration
  - Sources of flares and CMEs

Image courtesy of ESA
How Flares Occur

Magnetic Reconnection

Image courtesy of University of California Berkeley
Flare Outputs

- Emits radiation over full EM spectrum
- Flare magnitude determined from peak X-ray flux
- Accelerates charged particles

<table>
<thead>
<tr>
<th>Flare Class</th>
<th>Peak Flux in 0.1-0.8 nm range (W m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td>B</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>C</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>M</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>X</td>
<td>$10^{-4}$</td>
</tr>
</tbody>
</table>
Space Weather Effects

Operations affected by space weather:

- Satellites
- Astronauts
- Aviation
- GPS Navigation
- Telecommunications
Detection Methods

● Current Method (NOAA/SWPC)
  ○ Four consecutive minutes of increasing X-ray flux that surpasses threshold (GOES/XRS)

● The new DEFT method
  ○ Intensity histograms of images taken by the GOES Solar UltraViolet Imager (SUVI) in 6 wavelengths – significant signal above threshold
Advantages of DEFT Forecasting

- Identifying solar flare locations
- Distinguishing concurrent EUV signatures
Flare Precursor Detection

- An unexpected discovery!
- Detected in the majority of cases
- Occurs many minutes before the start of the main stage flare
Method Comparison

Start of increasing X-ray flux: 2017 Sep 06 0857 UTC

SWPC Flare Alert Log

Space Weather Message Code: ALTXMF
Serial Number: 268
**Issue Time**: 2017 Sep 06 0912 UTC
**ALERT**: X-Ray Flux exceeded M5
**Threshold Reached**: 2017 Sep 06 0904 UTC
**NOAA Scale**: R2 – Moderate

DEFT Flare Alert

Space Weather Message Code: SUMX01
Serial Number: 114
**Issue Time**: 2017 Sep 06 1008 UTC
**SUMMARY**: X-ray Event exceeded X1
**Begin Time**: 2017 Sep 06 06 0848 UTC
**Maximum Time**: 2017 Sep 06 0910 UTC
**End Time**: 2017 Sep 06 0959 UTC
**X-ray Class**: X2.2
**Optical Class**: 2b
**Location**: S08W33
**NOAA Scale**: R3 - Strong

26 min early!

Space Weather Message Code: ALTXMF
Serial Number: 268
**Issue Time**: 2017 Sep 06 0912 UTC
**ALERT**: X-Ray Flux exceeded M5
**Threshold Reached**: 2017 Sep 06 0904 UTC
**NOAA Scale**: R2 – Moderate

15 min late

Space Weather Message Code: SUMX01
Serial Number: 114
**Issue Time**: 2017 Sep 06 1008 UTC
**SUMMARY**: X-ray Event exceeded X1
**Begin Time**: 2017 Sep 06 06 0848 UTC
**Maximum Time**: 2017 Sep 06 0910 UTC
**End Time**: 2017 Sep 06 0959 UTC
**X-ray Class**: X2.2
**Optical Class**: 2b
**Location**: S08W33
**NOAA Scale**: R3 - Strong

26 min early!
Results

- We have determined the best EUV intensity thresholds for each SUVI wavelength
- Examined flares between July and October 2017
- Instances where a flare/precursor was not detected were omitted from the mean

<table>
<thead>
<tr>
<th>Main Stage Flare Signatures</th>
<th>C Class (11)</th>
<th>M Class (13)</th>
<th>X Class (3)</th>
<th>All (27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean advantage over SWPC [mins]</td>
<td>-1.46</td>
<td>0.88</td>
<td>-1.50</td>
<td>-0.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flare Precursor Signatures</th>
<th>C Class (11)</th>
<th>M Class (13)</th>
<th>X Class (3)</th>
<th>All (27)</th>
</tr>
</thead>
</table>
### Most Successful Wavelengths – 195 and 304 Å

#### 304 Å

<table>
<thead>
<tr>
<th><strong>304 Å Precursor</strong></th>
<th>C Class (11)</th>
<th>M Class (13)</th>
<th>X Class (3)</th>
<th>All (27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean advantage over SWPC [mins]</td>
<td>-44.78</td>
<td>-25.78</td>
<td>-43</td>
<td>-36.05</td>
</tr>
<tr>
<td>Success rate of finding precursors</td>
<td>82%</td>
<td>69%</td>
<td>67%</td>
<td>74%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>304 Å Flare</strong></th>
<th>C Class (11)</th>
<th>M Class (13)</th>
<th>X Class (3)</th>
<th>All (27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean advantage over SWPC [mins]</td>
<td>-2.60</td>
<td>-3.00</td>
<td>-2.33</td>
<td>-2.77</td>
</tr>
<tr>
<td>Success rate of improving on SWPC's detection time</td>
<td>82%</td>
<td>85%</td>
<td>100%</td>
<td>85%</td>
</tr>
</tbody>
</table>
Future Plans

- **Ultimate forecast goal:**
  - Identify signatures up to or over an hour in advance
  - Forecast the flare magnitude
- Expand the number of ARs studied
- Apply our method to data with no flares and do blind tests
- Determine success rate depending on limb distance
- Investigate flare lifetimes (helps separate consecutive flares)
- Automate DEFT
Questions?