'Fermi Solar Flare Observations' GI Program Progress Report, 28-January-2010

We present here a review of the current state of the various tasks we are undertaking for this GI program. The GBM solar flare catalog and quicklook products discussed below, and all of our research results will be available online through our Fermi Solar Flare Observations web site at http://hesperia.gsfc.nasa.gov/fermi_solar. The IDL software used to analyze Fermi solar data will be available online in the SolarSoftWare (SSW) repository (http://www.lmsal.com/solarsoft/).

Task 1. Develop a solar flare identification strategy for GBM data

Now that solar activity is picking up, we have begun to retrieve the files from the GBM archive, examine the data, and plan our flare identification strategy. The basis of our flare identification scheme is as follows. Using the daily CTIME file provided at the GBM archive, we will construct a measure of the net solar signal by 1) subtracting the summed rates in the anti-sunward detectors from the summed rates in the sunward detectors for two energy bands, 2) smoothing these two rates with a square wave to produce a value sensitive to solar flares and multiplying them together, and 3) multiplying that value by the short wavelength (0.5 – 4 Å) flux seen with the GOES soft X-ray sensor. Time intervals with this measure of the solar flux above some threshold most probably identify solar flares. Figure 1 shows an example of this method applied to the data from 2010 January 19. We have tested this method over several days of recent flare activity, and find that a threshold of ~1.0 identifies flares of sufficient size without being too numerous. We will need to fine-tune the algorithm as we get more data, but it is a good start.

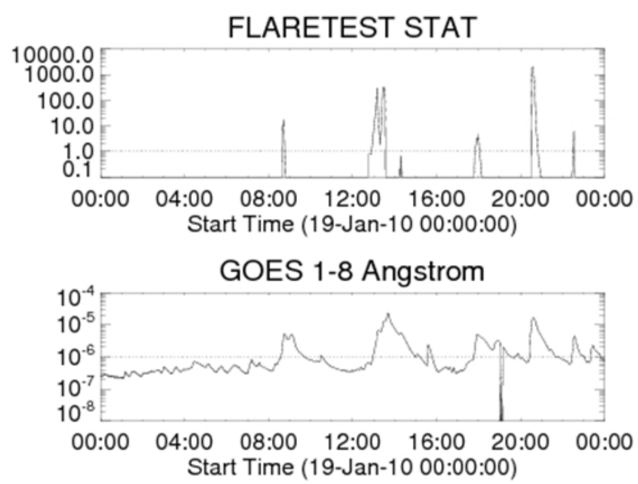

Figure 1 An example of the flare-finding algorithm applied to 2010 January 19 data. The top plot is the flaretest statistic - the result of combining information from GBM sunward and anti-sunward detectors, and GOES .5-4 Å data. The bottom plot is the time profile for the GOES 1-8 Å channel. A threshold in the flaretest statistic of ~1.0 (the dotted line in the top plot) identifies all of the larger (> C class, the dotted line in the bottom plot) flares shown in the GOES trace.

Task 2. Prepare a GBM solar flare catalog

We plan to include in the catalog all events identified as solar flares using the flare identification strategy outlined above. In the catalog, we will name flares by a number constructed from the time of the flare (YYMMDDHHMM). We will include the start, peak, and end time of each flare, an indication of the size of the flare and quality of the data, and the associated GBM trigger number, if any. We will provide an HTML-formatted version of the catalog online which will contain links to the location of the daily and trigger data files for each flare.

Task 3. Quicklook Products

All GBM data are publicly available on http://heasarc.gsfc.nasa.gov/FTP/fermi/data/gbm/, both as complete daily files and smaller files containing a short time interval for each triggered event. The daily and trigger files are available separately for each of the 14 detectors, and in high time resolution and high energy resolution formats. For

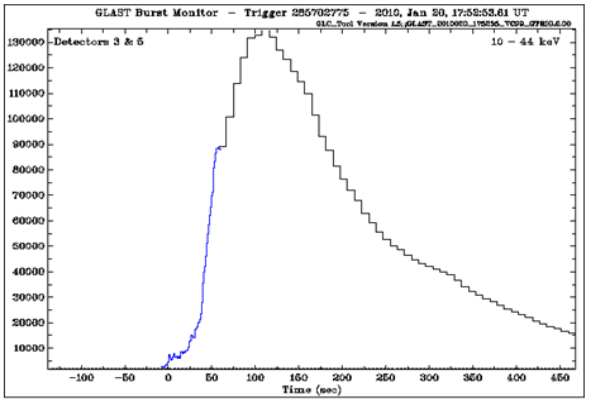

Figure 2. Example of quicklook plots available for the GBM flare trigger that occurred on 2010 January 20 at 17:50 UT: Low-resolution time profile in the 10 - 44 keV energy band.

each triggered event, a collection of quicklook plots showing light curves at various resolutions and energy bands is also available (see Figure 2).

The quicklook products that we will provide include daily GOES time profiles overlaid with indicators of GBM observing times, as well as orbital light curves of combined detectors in several energy bands. We plan to make these available through the RHESSI quicklook browser tool available at http://sprg.ssl.berkeley.edu/~tohban/browser/. A sample page is shown in Figure 3.

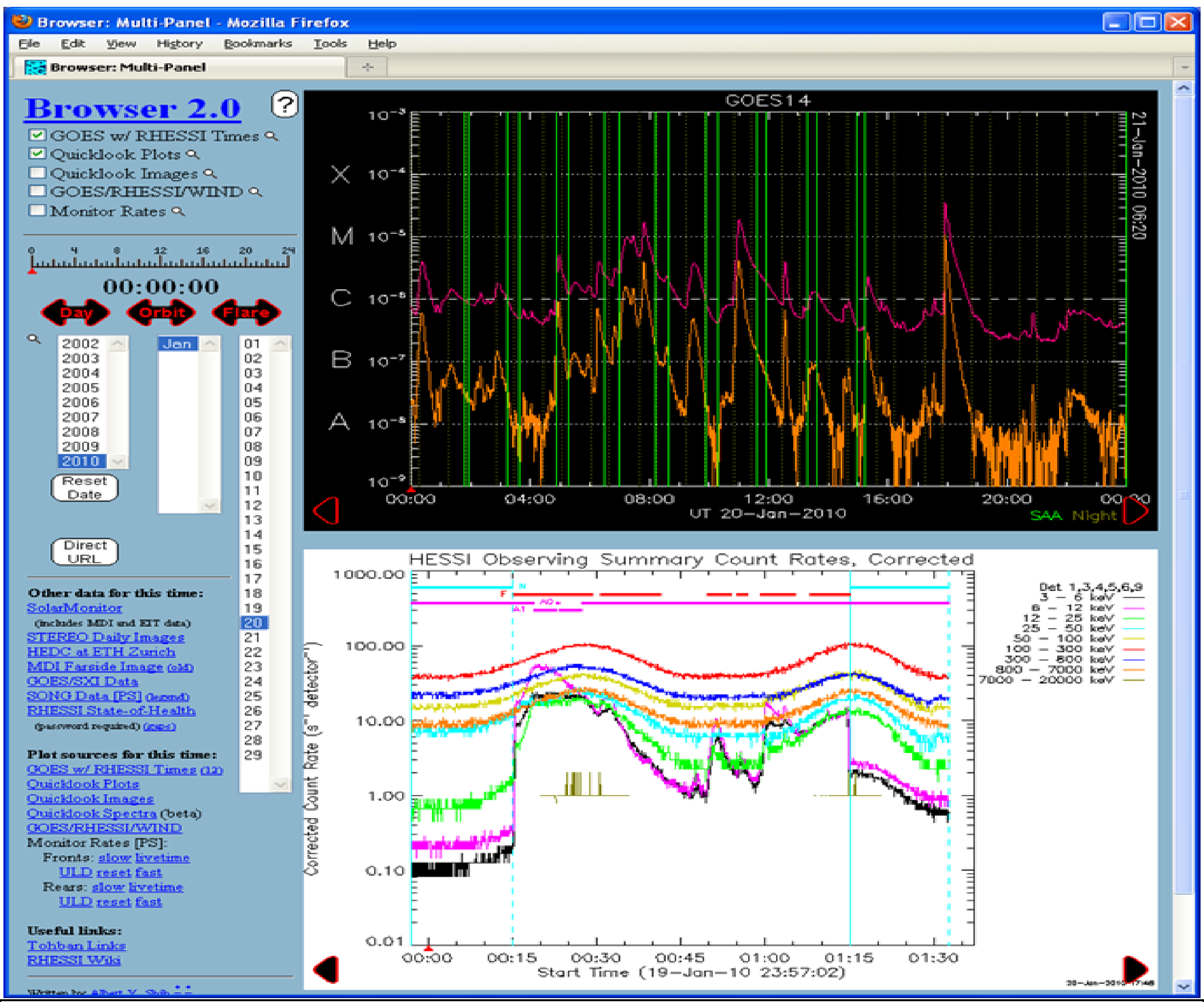

Figure 3. RHESSI quicklook browser page. Top plot shows the daily GOES two-channel X-ray light curves with RHESSI observing times overlaid; bottom plot shows RHESSI lightcurves in multiple energy bands for a single orbit showing the GOES M4 flare on 20 Jan. 2010. The options on the left allow the user to select the time interval and the plots to display. We will add GBM quicklook lightcurve displays to this interface.

Task 4. Spectral Analysis

Our OSPEX spectral analysis package has been extended to read the GBM data files. OSPEX can now read and plot time profiles and spectra from the GBM CSPEC and CTIME files (both daily and trigger files). Figure 4 shows an example of GOES, GBM and RHESSI light curves and count flux spectra generated with OSPEX for the 2010 January 20 solar flare..

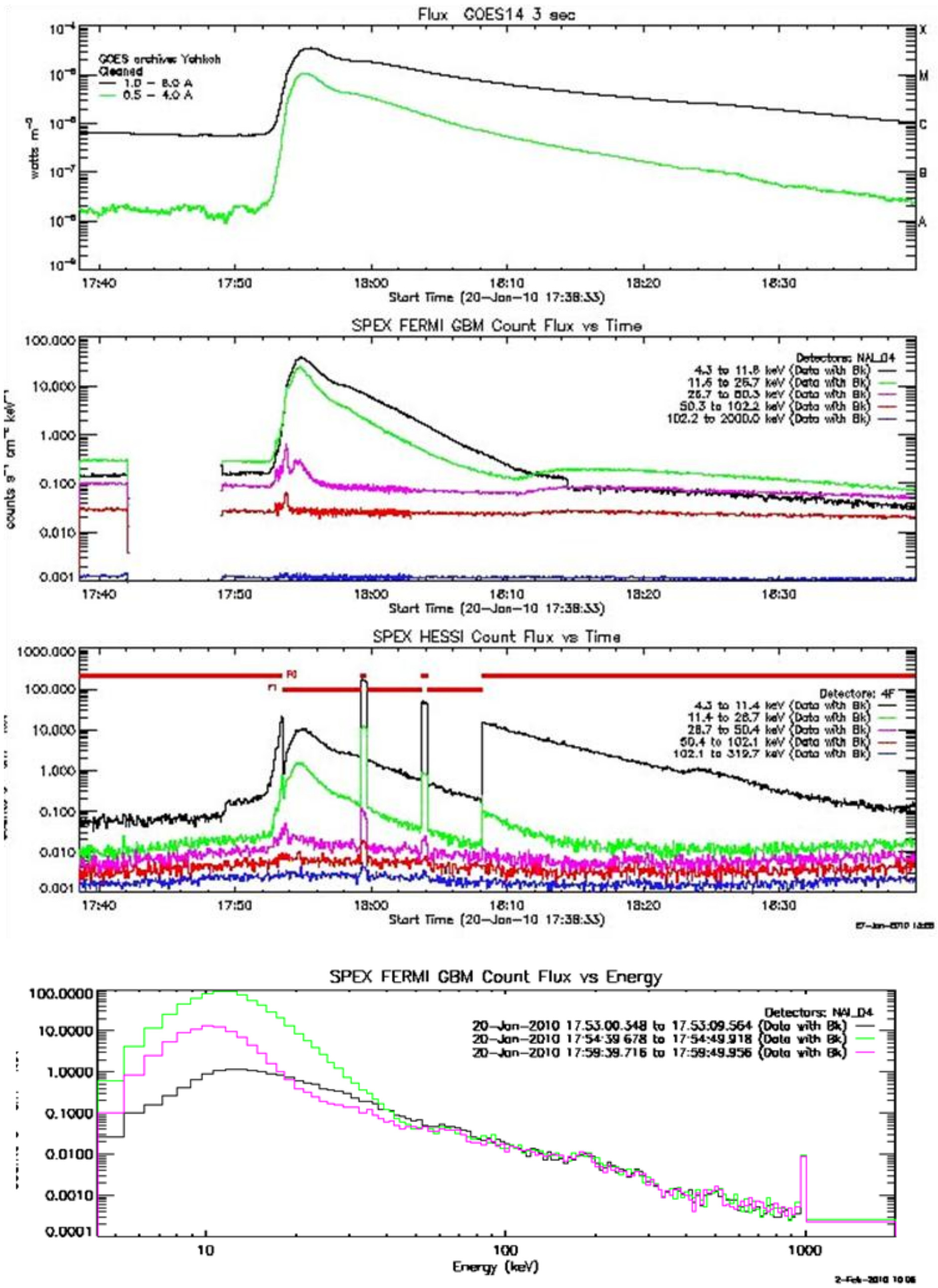

Figure 4. GOES (top), GBM NaI_04 detector (second), and RHESSI detector 4 (third) light curves plotted on the same time scale using OSPEX. The GBM and RHESSI count fluxes are plotted for the same four energy bands. The bottom plot is the GBM NaI_04 detector count flux spectrum for 10 seconds during the rise (black), peak(green), and decay (pink) of the 2010 January 20 M4 solar flare.

Task 5. Prepare to analyze GBM spectra

Efforts are currently underway to calculate the GBM response matrix for flare time intervals to enable the next step in OSPEX – detailed spectral analysis and cross-calibration with RHESSI and other solar instruments. We will install on our server the response matrix software developed at UAH, and generate response files for all flare time intervals. Required input to the response-generation software are the spacecraft position and orientation values, which we will extract from the daily POSHIST file provided in the GBM archive, and the position of the Sun at the time of the flare. The response files generated will be readable by OSPEX for spectral analysis.

Once these software pieces are in place and the flare catalog and response matrix database are created, we plan to facilitate OSPEX access to the GBM data. Rather than requiring the user to access the GBM archive and copy files manually, the user will be able to select the flare of interest from our GBM flare catalog and then OSPEX will transparently copy the required data files from the GBM archive and import the requested time interval and appropriate response matrix into OSPEX.

Task 6. Prepare for joint analysis of GBM and LAT spectra

In preparation for doing joint analysis of flares with the GBM and LAT data, we have been doing studies of flares observed by Yohkoh and RHESSI that have both nuclear-line and pion-decay emission. The 2005 January 20 flare is a good example of this. This flare exhibits what appears to be at least three stages of particle interaction at the Sun: 1) particles accelerated along closed loops exhibiting a delay between electron and ion impact; 2) down-stream particles (primarily ions) that appear to be from extreme shocks related to the CME producing the up-stream GLE protons with energies up to at least 10 GeV at Earth; 3) returning upstream particles after reflection beyond the Earth. Fermi is orders of magnitude more sensitive to pion-decay emission than RHESSI and will easily detect these three components, and combined with the nuclear line measurements from GBM and RHESSI, will provide a much clearer view of the three processes in less intense solar flares. To this end, OSPEX has been enhanced to use new nuclear-line and pion decay gamma-ray templates in preparation for analyzing GBM and LAT data.

Task 7. Improve pion-decay model

Another goal is to improve the theoretical modeling of the production of pion-decay gamma rays. We have calculated a combined gamma-ray line and pion-decay spectrum using the measured SEP spectrum for the 2001 April 15 event. We then used this spectrum to fit the Yohkoh gamma-ray data for the associated flare to determine if the SEP spectrum could explain the gamma-ray observation. The SEP spectrum did not provide an acceptable fit, indicating that the spectrum of protons at the Sun is significantly softer than those in space. Similar analyses will be performed in OSPEX using combined GBM and LAT solar flare data to obtain the spectrum of interacting particles at the Sun.

Task 8. Develop algorithm for autonomous solar pointing in response to a GBM trigger

We will study the first GBM solar flares and design an algorithm for the GBM Flight Software (FSW) to identify flares more likely to have a high-energy component worth following with the LAT via an ARR (Autonomous Repoint Request). Configuration Change Requests (CCRs) will be generated for the GBM FSW to implement this plan. Once the plan to modify the GBM FSW is approved by the Fermi Project Office, we hope that the changes to the GBM FSW will be implemented in the second year.