Potential Improvements to GBM On-board Burst Locations
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1. Baseline Approach

The baseline approach for computing burst locations is to compare the relative detector count rates to a table of predictions for those rates over the sky. A grid of sky locations with ~5 degree separation was chosen. The rate table size is 1634 sky points X 12 detectors X 2 bytes = 39 kbyte, not significantly impacting our memory budget. The rate tables will include the effects of spacecraft and atmospheric scattering; these time-consuming calculations will be done in advance by ground software. The on-board software simply normalizes the detectors rates (above background) and exhaustively searches the rate table for the best match. The atmospheric scattering is computed assuming GLAST is zenith pointing and assumes a specific typical burst spectrum.

The primary contributors to the error in location are: 1) statistical errors, 2) variations in atmospheric scattering due to off-zenith pointing, 3) discreteness of the grid points on the sky, and 4) variations in burst spectra. These arrors were investigated by simulation using bursts with fluence of 10 photons/cm^2 and a distribution of spectral parameters as observed by BATSE. The simulation accounts for the effects of burst spectral variations only on the scattered flux, not on the directly observed flux. At this high fluence, statistical errors are only about 1.6 degrees so systematic effects dominate the total error. The simulation results are shown in Table 1, which shows the mean error, the 1 sigma error (68%), and 2 sigma error (95%) as a function of GLAST zenith angle. GBM easily meets the level 2 goal of on-board location error <15 degrees. At the nominal off-axis pointing of 35 degrees, the error is about 5 degrees.

Zenith angle (deg.)	Mean Error	1 Sigma Error (deg.)	2 Sigma Error (deg.)
0	3.1	3	6
15	3.4	3	7
30	4.5	4	10
35	4.7	5	11
45	6.2	6	14
60	8.9	7	21
75	11.6	9	29
90	14.2	13	40

Table 1: Location errors for the baseline approach.

The error at small zenith angles is easily explained by statistical errors and the systematic error due to the finite grid size. Atmospheric scattering errors are by definition zero (for a standard burst spectrum) at zenith pointing since those corrections are built into the rate tables. The increase in the error at large zenith angles is attributable to the growing error in the atmospheric scattering correction. Note that the spacecraft scattering does not

depend on the pointing and is assumed to be correctly calculated, for a standard burst spectrum, in the rate table.

These considerations lead to the conclusion that the locations might be significantly improved by adding additional information on atmospheric scattering for off-zenith pointing. The most straightforward way to do this is to construct a number of additional tables for other pointings and either select the most appropriate table or interpolate between them.

2. Five-table Approach

Once off-zenith pointing is considered, the problem becomes two-dimensional. The simplest extension of the baseline method is to add four more tables, each at a specific zenith angle and separated by 90 degrees of azimuth. The relative rates for a specific spacecraft pointing are determined by interpolating among the tables. We performed simulations using a range of values for the zenith angle of the additional tables, and determined that 60 degrees works well. The non-linearity of the error with zenith angle limits the usefulness of this approach. Table 2 summarizes the findings for the 5-table approach, with the additional 4 tables calculated at a zenith angle of 60 degrees.

Zenith angle (deg.)	Mean Error	1 Sigma Error (deg.)	2 Sigma Error (deg.)
0	3.1	3	6
15	3.2	3	7
30	3.6	4	8
35	3.6	4	8
45	3.7	4	8
60	3.8	4	9
75	4.8	4	13
90	7.8	5	35

Table 2: Location errors for the 5-table approach.

3. Spectral Variations

A major weakness of the present simulation is that it does not yet include the spectral response of the detectors, although it does include spectral variations in the flux scattered by the atmosphere. The spectral effects of the scattered flux were investigated by running the simulation without variations in the burst spectra to see if the accuracy improved significantly. Only a very small improvement was found.

4. Conclusions

1. A modest improvement in accuracy is obtained by increasing the number of tables from 1 to 5, particularly for zenith angles above 45 degrees. For the nominal mission profile of 35 degree offset pointing, the mean error improves from 4.7 degrees to 3.6 degrees.

2. Variations in the scattered flux due to variations in the burst spectra do not significantly affect the error.

3. Variations in the direct flux due to variations in the burst spectra may be important but have yet to be investigated. If this investigation determines that spectral variations lead to significantly larger location errors, then the most important improvement to the baseline approach will be to adding other tables for a range of burst spectra, rather than adding tables for other pointing directions.