January-March 1992 Activity
under
Contracts N00014-88-K-0711
and N00014-91-J-4158

Typhoon Monitoring Using Passive Microwave Observations

FINANCIAL SUMMARY

Through March 31, 1991 we have spent $98,350 of a total of $125,288 received under N00014-88-K-0711. We have spent $2568 of a total of $40,000 received under N00014-91-J-4158.

SCIENTIFIC SUMMARY

A major reorganization and upgrade of the physical retrieval code has been completed. New capabilities for performance analysis of the retrieval algorithm and simulation of sensors other than MSU have been added. The following features are now available:

1) Variable text output detail, ranging from display of all intermediate results for single cases to single-line output with an overall summary for multiple cases or multiple simulations of a single case.

2) Graphical output of retrieved tropical cyclone thermal structure and the locations and observed and predicted values of the thermal measurements.

3) Generalized navigation and scan geometry, so that any polar-orbiting sensor with axial (but not conical) scan geometry can be simulated. At present, only MSU orbital elements are available, but the antenna footprint patterns of other satellites can be approximated by varying the antenna response angle and the separation in time between scan lines and individual elements. These parameters are specified in a run-time data file rather than within the code, so additional sensors can be added without recompiling. SSM/T and AMSU have been added so far.

4) Standardized documentation and modular organization of source code, with one module per file and control of changes and recompilations using the Microsoft NMAKE utility. These changes have already made the code much easier to debug, maintain, and upgrade, and in the future they will make it easier for others to move the code into an operational environment.

The next major objective is a performance analysis of the algorithm for MSU and SSM/T using the various simulation modes. The following calculations will be made and analyzed over the next six months, and the results submitted for publication in the refereed literature:

1) Runs for the 1980-84 MSU development sample using archived MSU data, and verification against reconnaissance ground truth.

2) Simulations for MSU, SSM/T and AMSU using idealized structures and locations within the footprint pattern to analyze the differences in algorithm performance for these various sensors. Examples of these types of calculations and a preliminary result are attached and will be described below.

3) Simulations for MSU, SSM/T, and AMSU using the retrieved thermal structures from the 1980-84 MSU development sample (item 1) as input 'truth,' with estimates of anticipated performance of the algorithm on real data for these sensors.

An additional objective is modification of the code to use real SSM/T data. This objective, in part, guided the code upgrades and is not expected to be too difficult, but will probably not be undertaken in the next quarter.

PRELIMINARY RESULTS

The attached Figures illustrate some of the new capabilities of the retrieval code and some preliminary results obtained from it. This series of experiments were designed to test the effects of:

1) Tropical cyclone location relative to the footprint center, and

2) Tropical cyclone location within the data swath

on retrieval algorithm performance for MSU, SSM/T, and AMSU. The same 'truth' thermal structure was used for all. The six parameters which define the 'true' thermal anomaly structure were specified, and the same values used for the constraint (guess) on the retrieval algorithm. Uncertainties (variances and covariances) of the constraint were those used in real data applications with MSU. This is an optimum case, in which the guess is exactly correct (but uncertain). This situation is chosen to see:

1) if the algorithm adjusts the retrieved structure away from the guess (which would indicate problems), and

2) the estimated accuracy of the retrieval, as measured by the variance of maximum temperature anomaly (δT).

Four cases are established for each instrument type: the tropical cyclone is either centered within a footprint (C) or equidistant from four footprints (B for "bracketed"), and is either at nadir (N) or on the limb (L) of the data swath. The four experiments (C,N), (C,L), (B,N), and (B,L) are each repeated 100 times using simulated observations generated from the truth and perturbed by an assumed uncorrelated error of 0.5 °K to retrieve the structure for the constraint described above.

The results are tested for bias by computing the T statistic from the mean retrieved δT, its standard deviation, and the known truth. The accuracy test is applied by computing the mean value of the estimate of δT variance produced by the retrieval algorithm; note that this variance is larger than the square of the standard deviation of the 100 δTs, since the computed variance includes the specified uncertainty of the constraint as well as the simulated effects of observational error.

A bias T-statistic which is significant at the 95% level is found only for SSM/T (B,L). Additional experiments will be necessary to determine if this is a "false positive", which by definition is expected to occur by chance 5% of the time.

Figure 1 shows the estimates of δT standard deviation (square root of variance) for the twelve experiments. All fall between the "perfect" result of 0.5 °K (retrieved δT variance equals observational error) obtainable using an antenna of infinite horizontal resolution, and the "no information" result of 5.23 °K , which is the specified standard deviation of the constraint for δT. The accuracy of the retrievals systematically decreases with:

1) Antenna resolution (AMSU is best, SSM/T is worst),

2) Separation between tropical cyclone and footprint center, and

3) Separation between tropical cyclone and nadir (ground track).

These effects are listed in order of decreasing importance. Antenna resolution dominates; the AMSU at worst (B,L) is more accurate than the SSM/T at best (C,N), and a tropical cyclone which is on the limb but centered within a footprint (C,L) yields a more accurate result than one which is near the ground track but falls between footprints (B,N).

Figures 2-4 are examples of (C,N) for AMSU, (B,N) for MSU, and (B,L) for SSM/T, except that these are retrievals of a truth structure with a δT of 10.88 °K (constraint plus one standard deviation) instead of 5.65 °K as used for the bias and accuracy experiments.

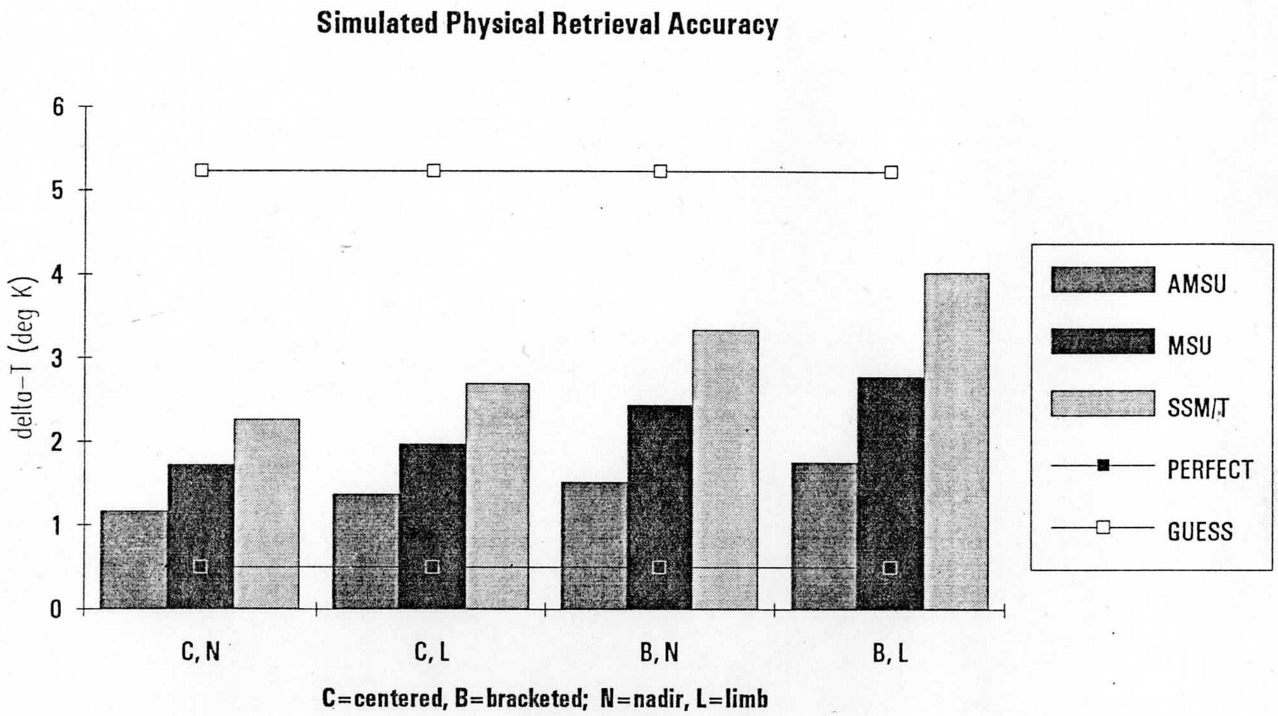

Fig. 1. Results of physical retrieval accuracy simulations. The vertical axis is the estimated standard error of the retrieved δT, in °K . The two horizontal lines indicate the standard error of a "perfect" retrieval (0.5 °K) and the standard error of a "no-information" retrieval (5.23 °K), which is equal to the standard deviation of the input constraint (guess) δT.

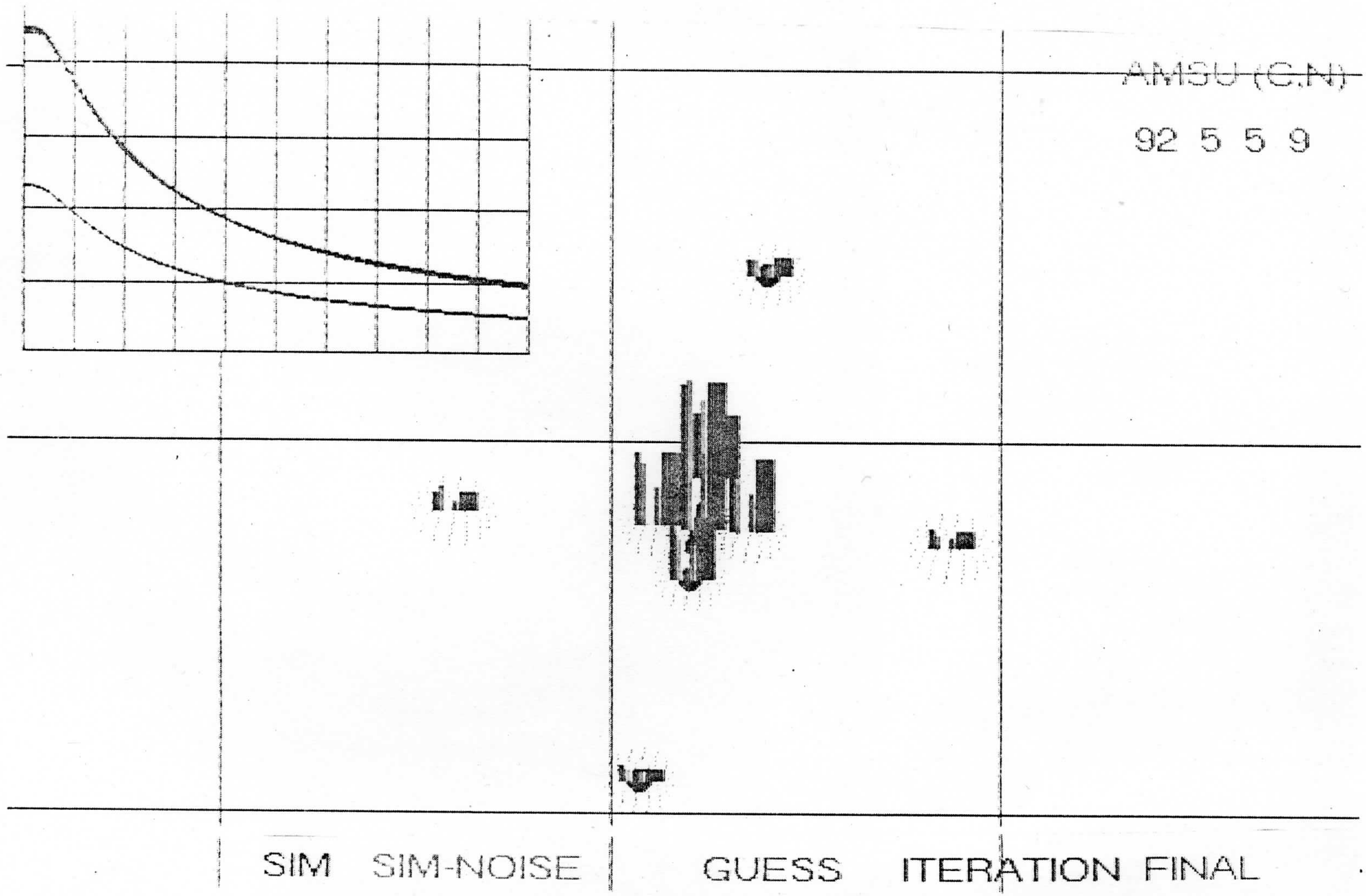

Fig. 2. Graphical display of a simulated retrieval using AMSU data for a tropical cyclone which is centered within a footprint at nadir (experiment C,N). The graph in the upper left shows the temperature as a function of radius. The bar graphs show the simulated observations with and without noise and the predicted observations based on the guess and iterated thermal structures. The retrieval algorithm works by adjusting the retrieved structure to minimize a weighted sum of differences between the retrieved and guess structure and between the predicted and actual (simulated) observations. The integration of the product of the antenna weight pattern for each footprint and the thermal structure is computed on a grid shown by the magenta dots. The distribution of these relative to the tropical cyclone center (red dot), the satellite ground track (gray dots), and the 5 ° latitude-longitude grid indicates the sizes and locations of the footprints used in the retrieval

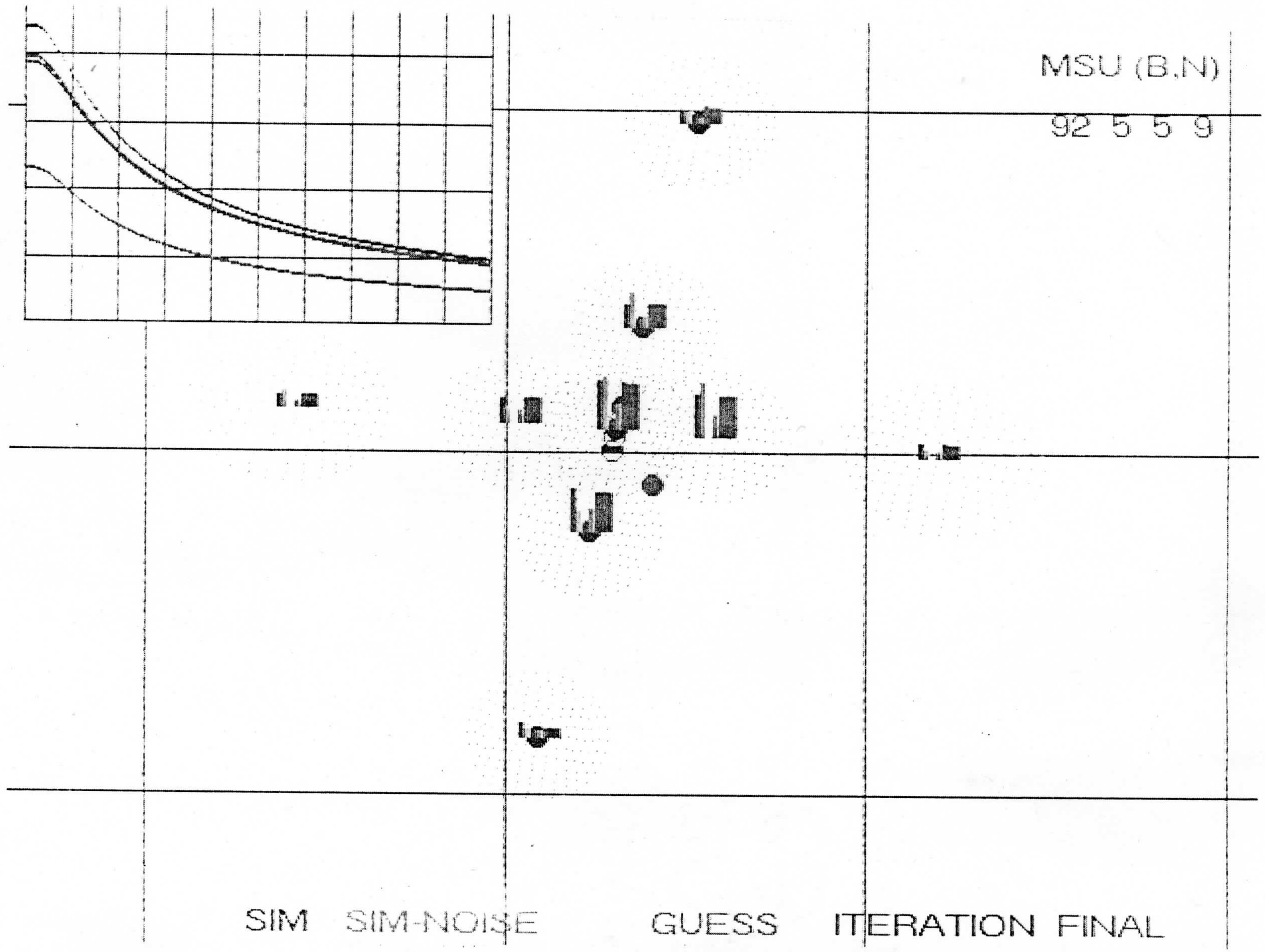

Fig. 3. Same as Fig. 2 except for MSU data, with the tropical cyclone near nadir but bracketed by four footprints (B,N).

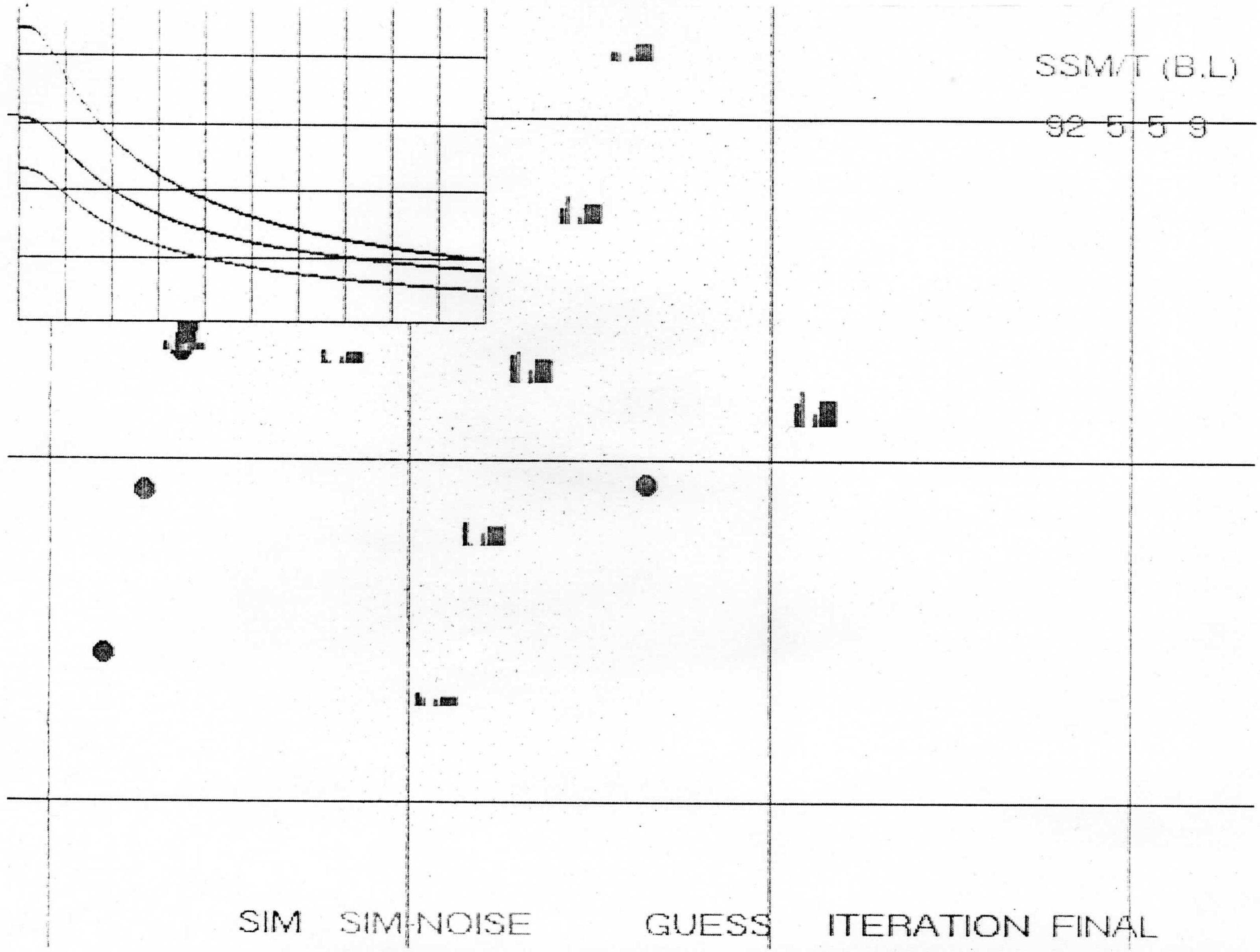

Fig. 4. Same as Fig. 2 except for SSM/T data, with the tropical cyclone bracketed by four footprints near the edge of the data swath (B,L). Notice the large sizes of the footprints relative to those nearer the ground track and to those of the AMSU and MSU.

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May 5, 1992

Mr. Mort Glass
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Dear Mr. Glass:

Enclosed is a summary of our activity under Contracts N00014-88-K-0711 and N00014-91-J-4158 from January 1 through March 31, 1992.

I have enclosed a somewhat longer report than usual because we have made considerable progress on the retrieval code and are now able to simulate retrievals for MSU, SSM/T, AMSU, and any hypothetical system with a cross track (rather than conical) scan geometry.

Please let me know if you would like material for presentations because by the time you have need I may well have additional simulation results and inferences. The ones presented in this report are very preliminary and are "examples" rather than results.

Sincerely,

Robert T. Merrill

Robert T. Merrill

Enclosure