VERIFYING PRECIPITATION EVENTS USING COMPOSITE STATISTICS

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ABSTRACT

Precipitation verification is difficult. The deterministic structures span many scales, some of which are finer than the available observations. Even with high-quality observations the errors are difficult to quantify due to the high natural variability. If specific aspects of the precipitation distribution are not isolated the error statistics can become diffuse and/or unrepresentative. Composite methods offer a relatively simple means of collecting focused statistics for specific events while maintaining statistical significance. Composites are collected based on the existence of events of interest, such as heavy precipitation, in the two fields being compared. Systematic errors are then evaluated as a difference in the composite samples.

In this study, statistical aspects of heavy precipitation events over Australia, as represented by the satellite observations and surface rain gauge analyses, are compared. The gauge analyses were kindly provided by Beth Ebert of the Australian Bureau of Meteorology Research Centre (BMRC) while the satellite data consisted of retrievals generated at the Naval Research Laboratory. Systematic biases in intensity and coverage will be investigated.

1. INTRODUCTION

The accuracy of satellite precipitation estimates can be assessed in many ways. Standard measures, such as the bias, equitable threat score (ETS), and the correlation coefficient provide information about algorithm performance over broad spatial scales. However, the ETS and the correlation are sensitive to small errors, and this sensitivity increases as the field variance increases. Baldwin (2004) showed that for complex fields, the ETS can drop rapidly with even small displacement errors. The bias on the other hand suffers the opposite problem in that it is not sensitive enough. Nachamkin (2004) discussed this effect in terms of the size of the grid over which the bias is calculated. Large positive and negative errors in spatially disparate areas partially cancel one another such that only the residual mean errors remain. Minor displacement errors essentially score the same as major errors if the fields have similar means. Limiting the size of the area over which the bias statistics are taken increases the sensitivity of the bias score. This is the main premise behind the composite method. By compositing samples taken over limited areas for a specific set of events, statistics specific to those types of events can be derived. Events are chosen based on size and intensity criteria, and are composited about the center of each event. Once the composites are derived, errors associated with specific types of events can be evaluated.

2. SATELLITE AND RAIN GAUGE DATA

Separate statistics were taken over Australia during the winter (dry) and summer (wet) seasons. The winter sample was taken for the period 2 June through 20 August 2003, while the summer sample was taken over the month of February 2004. Although the summer sample was over a relatively short time interval, multiple precipitation events were sampled. Far more events were sampled over the month of February than during the entire June through August period.

The BMRC rain gauge analysis (Ebert and McBride 2000) was used as the ground truth. The 2003 analyses included data from late-reporting cooperative observing stations and thus approximately 5000 stations around Australia contributed to these analyses. The 2004 analyses consisted of the preliminary synoptic stations alone, thus only 1000 stations were incorporated in these analyses. The 2004 analyses will thus be smoother than those in 2003, and some events may not be as well represented. In both cases, areas of low gauge density were not included in the analyses. These areas were mainly over the central western portion of the continent. No ocean-based measuring stations were included, thus the analysis is only valid over the land. The gauge data were analyzed onto a 0.25 degree grid using a three-pass successive correction (Barnes) technique. The analyses represented precipitation accumulated over the previous 24-hour period, and were all valid at 0000 UTC.

The satellite rainfall estimates were derived using the Naval Research Laboratory (NRL) blended satellite algorithm (Turk et al. 2002). Passive radiometric measurements from the SSM/I, TRMM-TMI, TRMM-PR and AMSU-B satellites were dynamically combined with data from the geostationary satellites GOES 9/10/12, and Meteosat 5/7 to create the final product. These estimates were output to a 0.25 degree grid covering Australia and the surrounding oceans. Like the BMRC gauge analyses, the satellite rain accumulations were valid at 0000 UTC, and represented the accumulated rainfall for the previous 24-hour period. For this study, both the satellite and rain gauge analyses were interpolated to a Lambert conformal grid with 5 km grid spacing. All of the composite statistics were performed on this grid.

3. VERIFICATION TECHNIQUE

Two separate composites were collected, one based on the existence of an event in the satellite estimates and the other contingent on an event in the gauge analysis. Heavy rain events were defined as contiguous precipitation areas anywhere over the Australian continent containing 24-hr rain amounts of 25 mm (~ 1 inch) or greater. Only those events containing 100-1000 grid points on the 5 km grid were selected. This was done to ensure well-defined composites representative of specific types of events. Overly broad event criteria lead to ill-defined composites while very narrow criteria lead to composites containing too few events to be statistically significant.

Figure 1 illustrates how each composite was collected. In this example, the composites are being generated based on the events in the satellite estimates. Once an event is identified, all surrounding data are composited on a 31X31 point (155X155 km) grid. The centriods of the satellite-estimated events act as the center of the composite. As multiple events are collected, all available satellite and gauge analysis data are composited about the center of the satellite estimated events. If the satellite and gauge events resemble one another on average, then the composites of both fields will also be quite similar. Note again that this composite process was performed twice: First for all satellite-based events as depicted in Figure 1, and then for all gauge-based events.

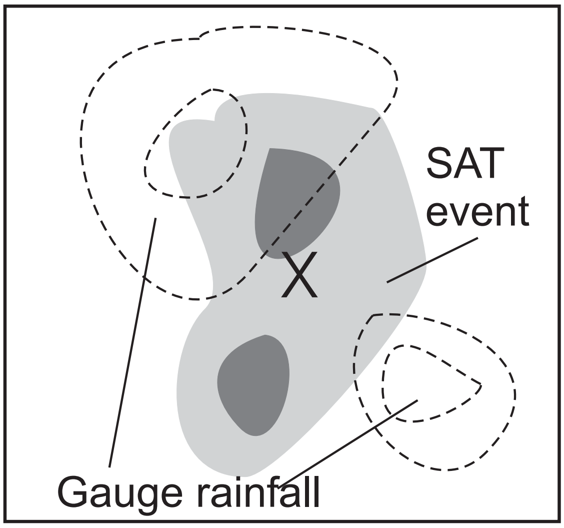

Figure 1. Conceptual example demonstrating the composite collection method. The shading represents a rain event identified in the satellite analysis. Dashed lines represent precipitation corresponding to the gauge analysis. The composite grid is centered with respect to the centroid of the satellite-based event.

In all of the composites, the data were templated by the available observations. If missing data existed in either the satellite or gauge analyses then data from both fields were set to missing. Ebert and McBride (2000) noted that the existence of voids within the data lead to errors in determining the full extent of a given event. The composites contingent on the satellite events were less affected by this due to the data coverage over the ocean. The gauge-based composites were more prone to these errors since partially observed events near the coast led to errors in the location of the event center. These errors effectively increased the variance in the gauge-based composites because the observed events were not all directly superimposed. In the data-mining sense, the data structures were less coherent and features like systematic phase errors were less apparent. Ebert and McBride (2000) noted that the phase error, and thus event position, was among the least sensitive parameters to the data boundary errors. In a Monte-Carlo experiment, they noted standard displacement errors on the order of two grid points or less for most events.

4. RESULTS

The results for the Jun-Aug period indicate that the satellite algorithm considerably underestimated the amounts in the gauge analysis. Figure 2 shows the composite based on the existence of an event in the gauge analysis. The shaded precipitation field represents the composite distribution of precipitation associated with the average event in the BMRC analyses, while the contours represent the average satellite-observed precipitation associated with those events. Note that the satellite rainfall amounts are considerably below those from the gauge analysis, and that the fields are poorly correlated. Figure 3 shows the composite based on the existence of an event in the satellite analysis. In this case the contoured field represents the composite average precipitation distribution in the satellite-based events, while the shaded field represents the gauge-based precipitation corresponding to the satellite-based events. In this case, the fields are better correlated, indicating that the satellite algorithm was able to detect a few events. However, maximum values in the satellite-based field were only about half those in the gauge data. Summarizing the results from Figures 2 and 3, the satellite algorithm often completely missed rain events that were detected by the gauge network. However, those events that are captured by the satellite also appear in the gauge analysis. Even in these cases, the satellite estimates are lower than the gauges. Visual inspection of the data indicated that most of the satellite-based events occurred near the coast.

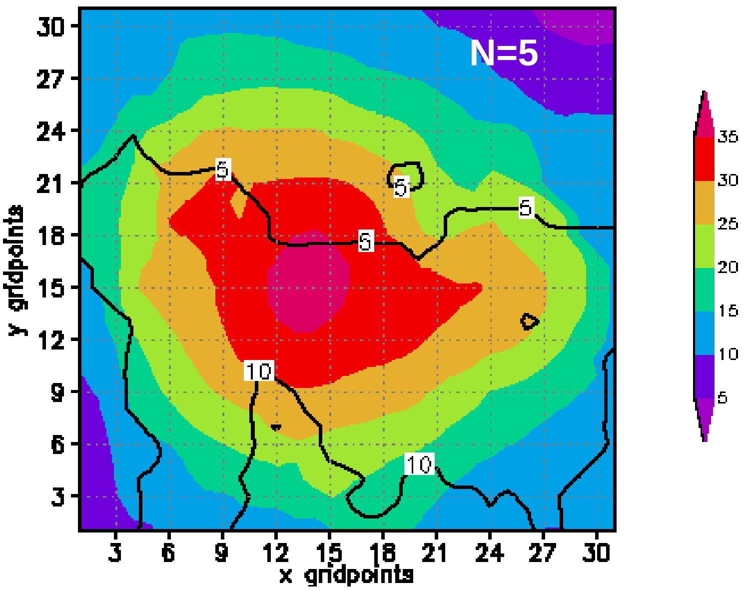

Figure 2. Winter precipitation composite based on the existence of events in the gauge analysis. The gauge-based precipitation is shaded in mm while the satellite-based precipitation is contoured in mm. The number of events in the composite is denoted by N.

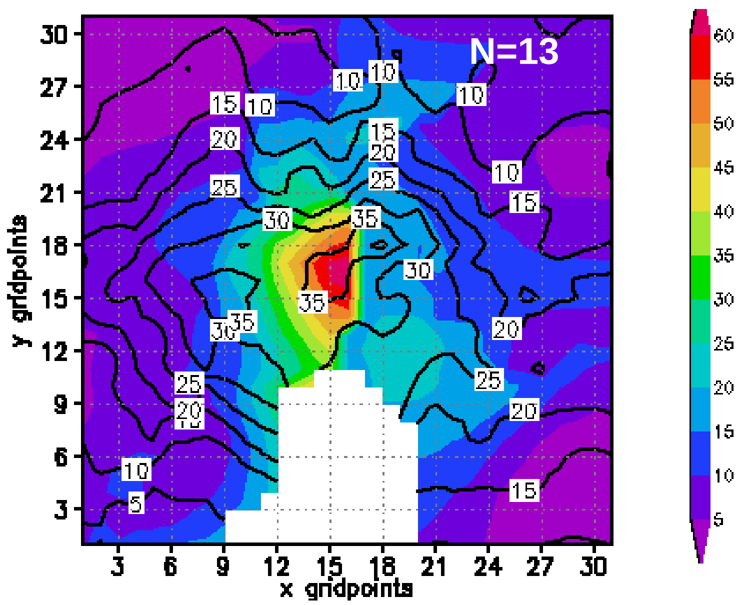

Figure 3. Same as Figure 2 except that the composite is based on the existence of an event in satellite-based analyses.

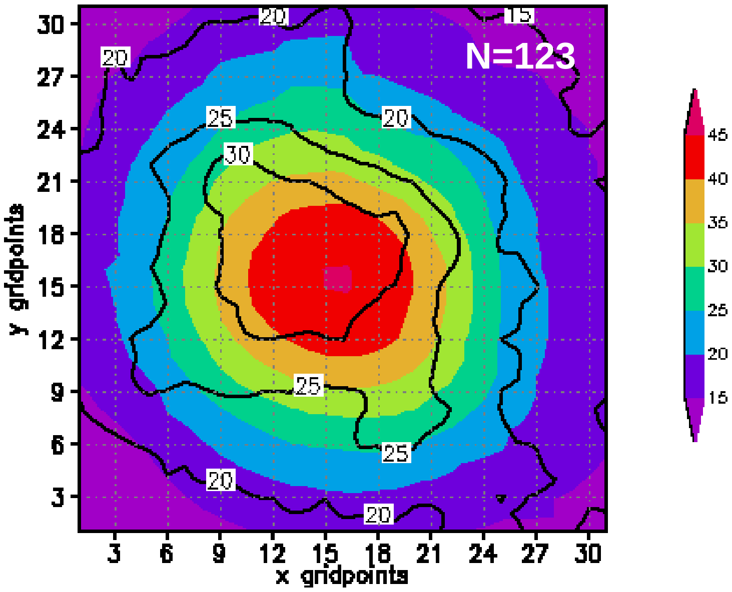

Figure 4. Summer precipitation composite based on the existence of events in the gauge analysis. The gauge-based precipitation is shaded in mm while the satellite-based precipitation is contoured in mm. The number of events in the composite is denoted by N

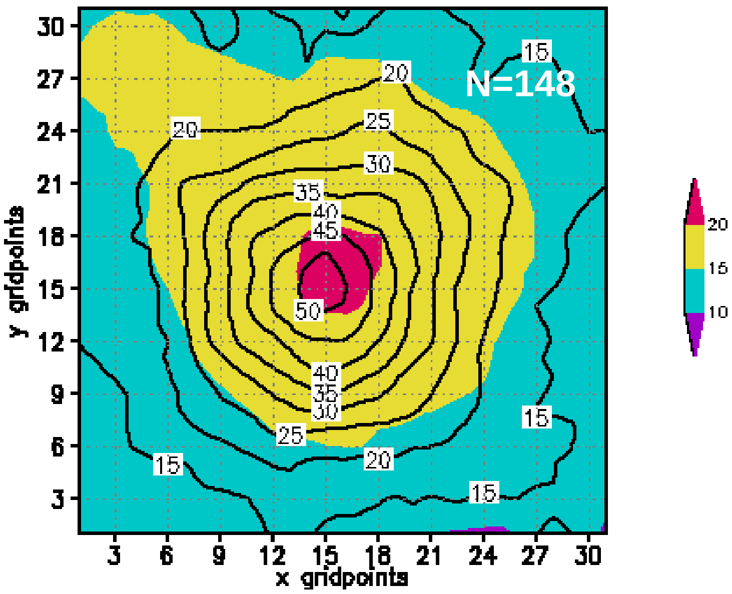

Figure 5. Same as Figure 4 except that the composite is based on the existence of an event in satellite-based analyses.

The results from February (Figs. 4, and 5) indicate somewhat better agreement between the two analyses, though the error characteristics are quite different from the dry season. Events that occurred in the gauge analysis were relatively well depicted by the corresponding satellite observations (Fig. 4). The patterns were well correlated, and although the gauge-based events contained more precipitation, the biases were not as severe as the dry season. However, for all events captured by the satellite algorithm (Fig. 5) the gauge amounts were typically far below those of the satellite. Part of this disparity may be due to the reduced number of gauge reports in the February data. Small events occurring in sparsely populated areas may have been missed by the gauge analysis. Summarizing, when an event was identified in the gauge analyses, the satellite analyses often contained similar precipitation amounts. However, the satellite analyses contained more small events with higher precipitation maxima than the gauge analyses, leading to a strong positive bias in the satellite-based event composite. Visual inspections of individual events indicated that the satellite analyses contained greater detail than the gauge analysis. This indicates that the reduced number of gauges may have resulted in the undersampling of some events.

5. CONCLUSIONS

Event-based composite statistics have been derived comparing satellite and gauge-based precipitation analyses over Australia. The results indicate considerable differences between the analyses. During the winter dry season the satellite analyses contained fewer events with less precipitation per event than the gauge analyses. During the summer wet season, the satellite analyses contained more small events with greater maxima than the gauge analyses. Some of these discrepancies may be due to differences in the representative scales inherent in each analysis. The low number of gauges in the summer analyses likely lead to the undersampling of some small convective events. However, this was not likely the case during the winter. Conducting this analysis with the updated summer gauge data, which include the late-reporting climate stations, would help separate the issues of data versus seasonal differences. Cloud properties, event duration, and precipitation type can all contribute to seasonal variations in the satellite estimates.

6. REFERENCES

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