September 2009 Changes to the SSCWeb Cluster Database

Following a detailed analysis of the current values the SPDF has been supplying for the Cluster orbit positions, we have discovered and corrected multiple software problems that were contributing to errors in those values. Such errors are generally small and would be negligible except in a close formation constellation of spacecraft like Cluster. The largest relative errors in separations and relative positions among the Cluster spacecraft are typically near perigee and when operating in their closest configuration.

DETAILED ANALYSIS

The following analysis characterizes these errors in detail using over 4.4 million position vectors, covering 2000/222 through 2008/366 for each Cluster spacecraft.

 (1) Figure 1 below is a histogram of how much spacecraft-spacecraft separations are changed between the original SSCWeb data and the corrected Cluster orbits now being served.
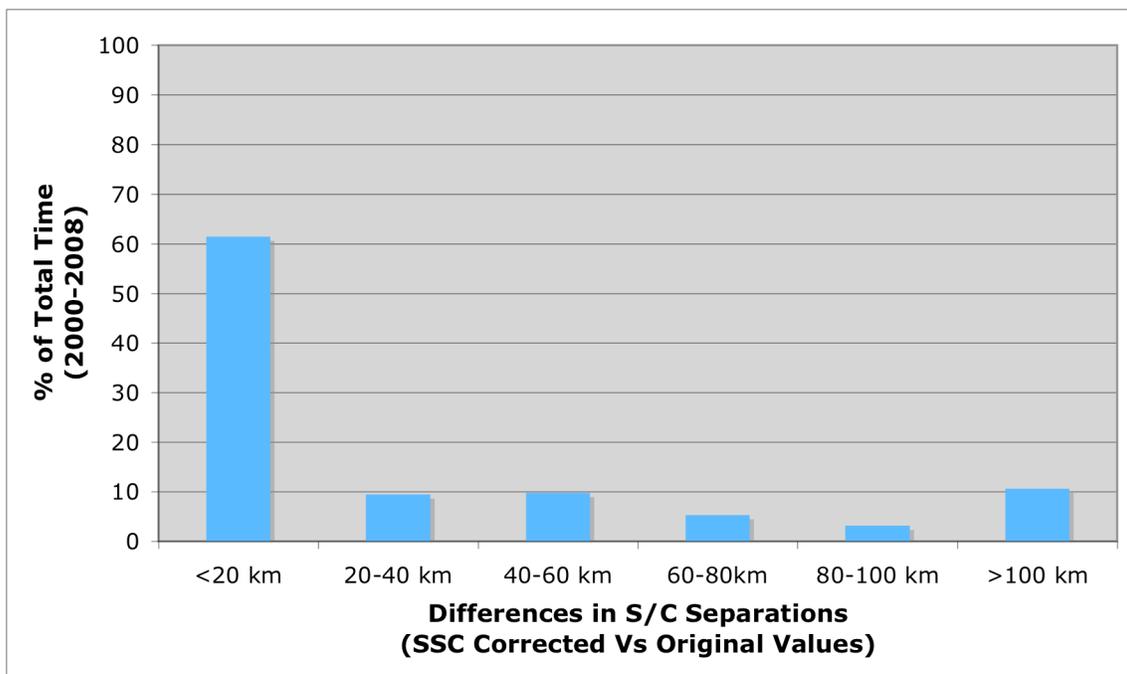
Figure 1

60% of the absolute separation distances (Cluster1 from Cluster2, C1 from C3, C1 from C4, C2 from C3, C2 from C4 and C3 from C4) change by <20 km but some 10% of the separations change by >100 km.

(2) A more useful comparison is to consider the changes in absolute S/C-S/C separation distances (SSCWeb corrected vs original positions) as a fraction of the (correct) S/C-S/C separation distance. Small fractional changes should be generally less significant to analyses based on the original SSCWeb positions. Figure 2 below is such a histogram.
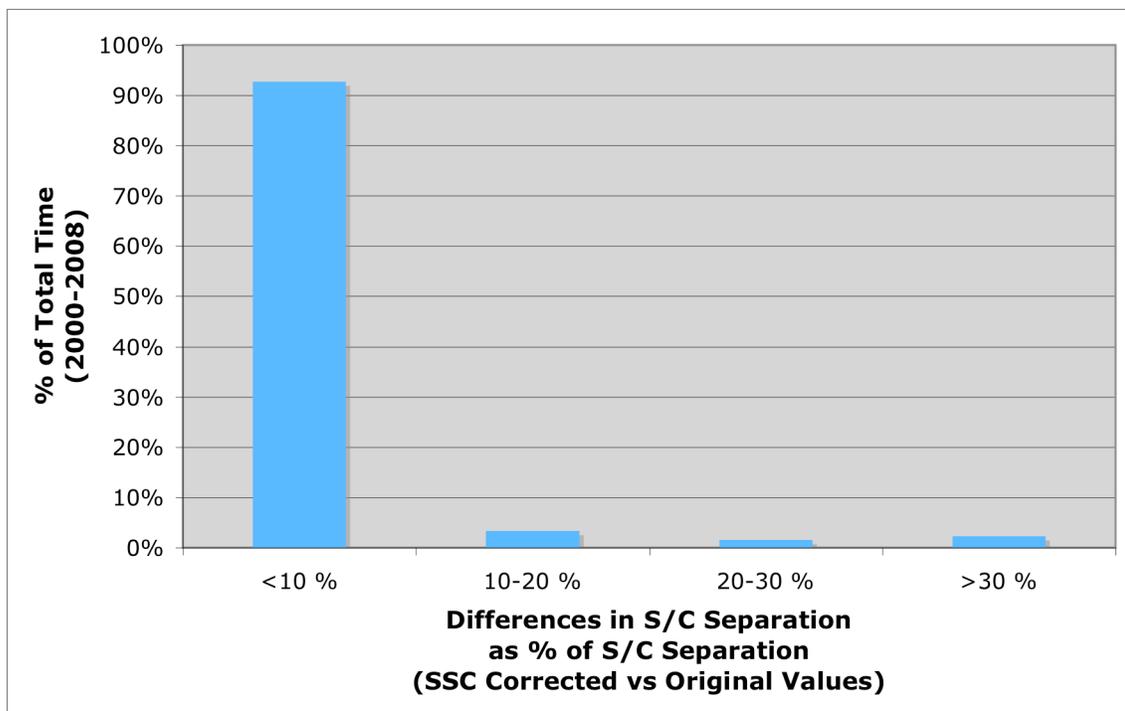
Figure 2.

From this histogram, we see that 92% of the separation changes are < 10% of the separation, although a small number (<2%) can be > 30%.

(3) Exploring time dependence of the separation differences, the next two figures below show (Figure 3) averaged Cluster separation distances in km and (Figure 4) the averaged differences in separation (SSCWeb original versus corrected) normalized by the corrected separation as a function of time from Cluster launch into early 2009.
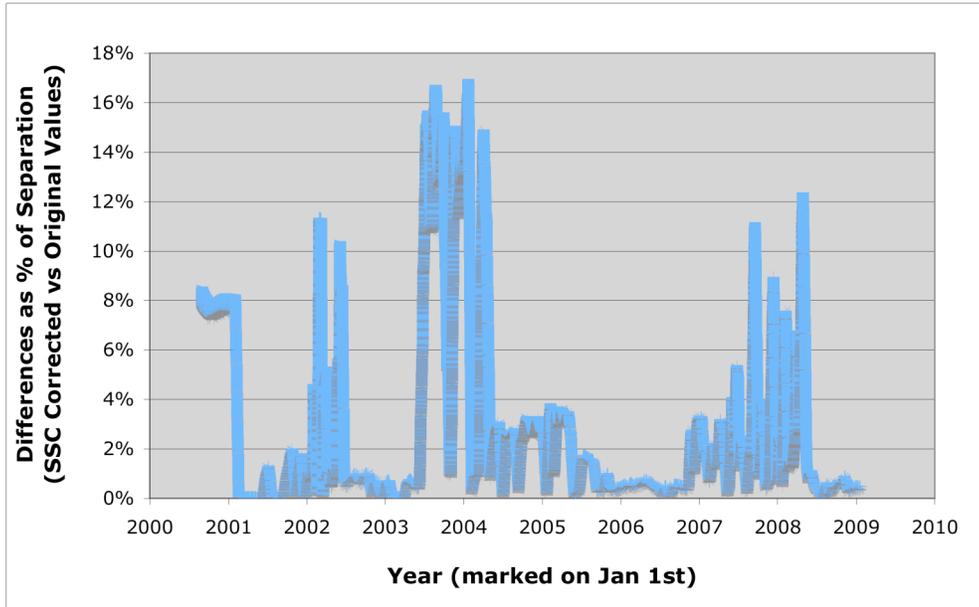
Figure 3
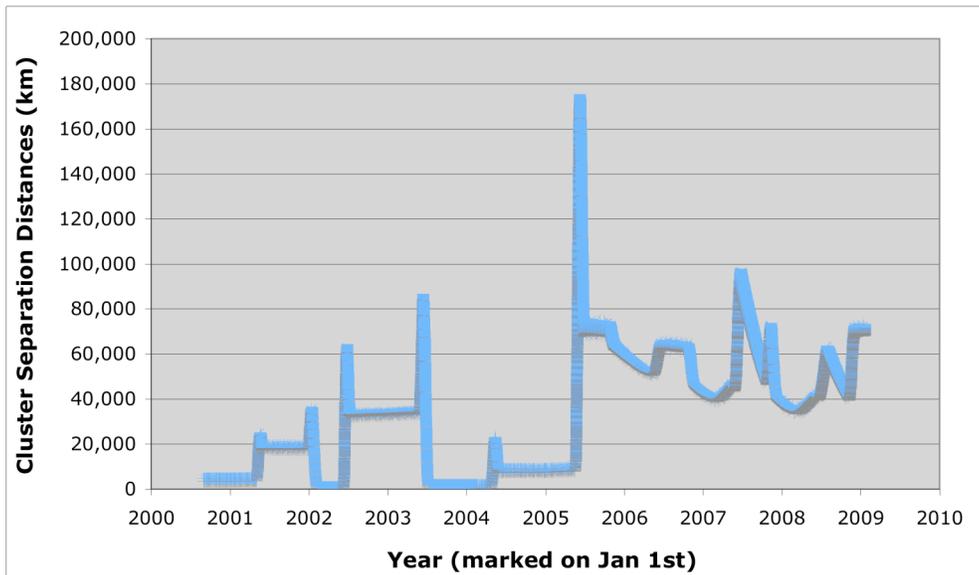
Figure 4

As can be seen comparing the first and second figure, the % difference in separation can be significant when spacecraft are closely spaced.

(4) To examine these worst case effects in more detail, Figure 5 shows a histogram of the % difference in separation for the specific period 2003 June 10 through 2003 October 27 when Cluster separations were small
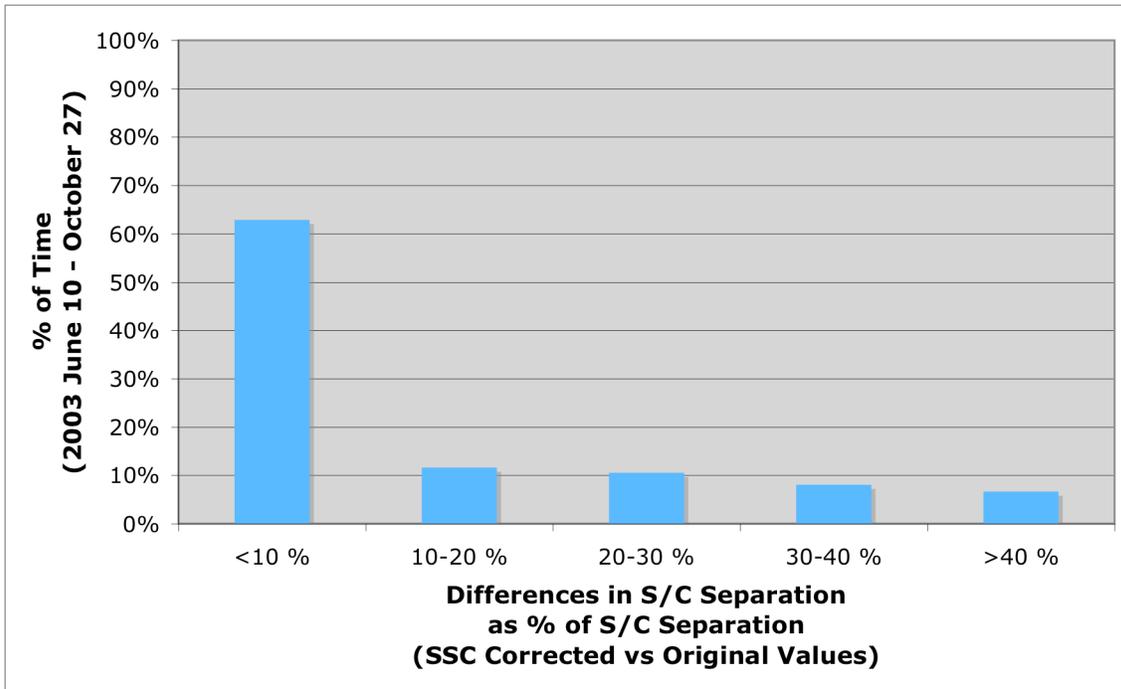
Figure 5

In this case, approximately 63% of the separations were still only changed by <10% but some 7% were changed by >40%.

(5) In this period and generally, the largest % differences in separation are correlated with radial distance of the spacecraft, with larger % differences concentrated near perigee as shown in the last two figures.

The first figure (Figure 6) below shows the % of total time 2003 June 10 – October 27 in several ranges of differences in separations normalized by separation,
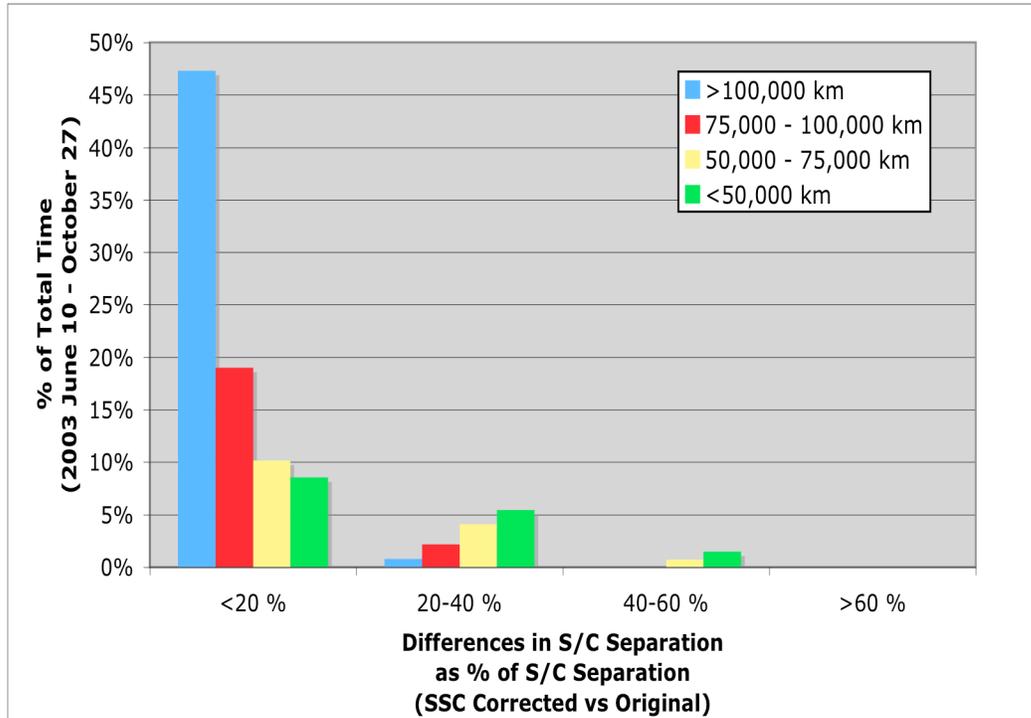
Figure 6

The large fractional differences in S/C-S/C separations are seen only at smaller radial distances, and the S/C spend relatively little time at these smaller radii.

The second (and last) figure (Figure 7) illustrates the relative importance of the differences between SSCWeb original and corrected separations in each of four bands of radial distance (appropriate to the demonstration interval in 2003). In this figure, we show how the total time when spacecraft are in each of the four distance bands divides among the differences in separations normalized by the S/C-S/C separations.
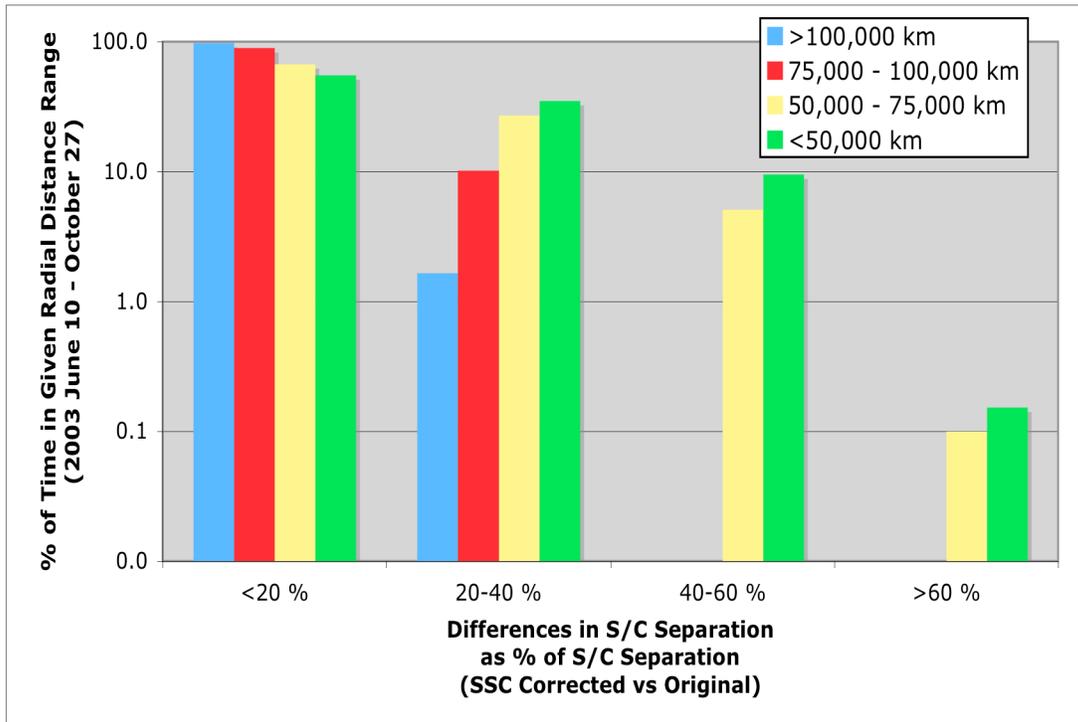
Figure 7

This figure (now on a logarithmic scale to show very small frequencies of occurrence) illustrates again that the largest changes in separation are highly concentrated at times nearer perigee.

DATABASE CORRECTIONS AND ADDITIONAL RESOURCES

We have corrected the Cluster database values as of September 4, 2009. The original (incorrect) values have been retained online as "superceded" orbits for users who need to do detailed comparisons of prior versus corrected data.

For reference, the sources for SSCWeb definitive and predictive data are now the following:

- Definitive orbits are taken from the Cluster Auxiliary Parameters produced by the Cluster Hungarian Data Center in Budapest, which are now the primary orbit product supplied to users by the Cluster Active Archive. These Auxiliary Parameters are typically made available 2-4 months behind the current date.

- Predictive orbits are derived from the "Super-LTOF" files produced by the Cluster Joint Science Operations Centre (JSOC) at Rutherford Appleton Laboratory in the UK. The STOF and LTOF files from which the Super-LTOF files are produced are products of the European Space Operations Center (ESOC) in Darmstadt Germany.

We would like to acknowledge the assistance of Ivar Christopher at the University of Iowa. His questions about apparent inconsistencies between SSCWeb and his calculations triggered our efforts to confirm and then correct the sources of these data inconsistencies.