Information on AP9 V1.20 issue affecting long mission duration Monte Carlo results
14 October 2015

We have identified an issue in AP9 V1.20 which leads to incorrect Monte Carlo results for very long mission runs (>3-4 years). There is no effect on AP9 mean and perturbed mean results, nor on any AE9 and SPM results. AP9 V1.20 (all versions) suffers from a numerical instability in the matrices that evolve the Monte Carlo dynamics. The original stability test gave a false pass due to numerical noise in a critical matrix calculation (eigenvalue estimation). We have instituted a more robust stability test that has allowed us to apply additional tapering of long lag correlations, as needed, to obtain a stable Monte Carlo simulation.

The problem results in unrealistic increases in the amplitude of Monte Carlo dynamics after 2-4 years of simulation, especially for protons of low energy (<1-10 MeV) and high energy (>100-200 MeV). As a result, Monte Carlo quantities (e.g. means, medians and percentiles) may increase unrealistically after multi-year mission periods.

Figure 1 below shows median AP9 monthly fluences from 40 Monte Carlo runs for V1.05 and V1.20. The changes in the V1.20 median after 2 years for energies less than ~6 MeV and greater than ~150 MeV result from the numerical instability. Note that initial medians are slightly different between V1.05 and V1.20 due to inclusion of new data and templates in V1.20.

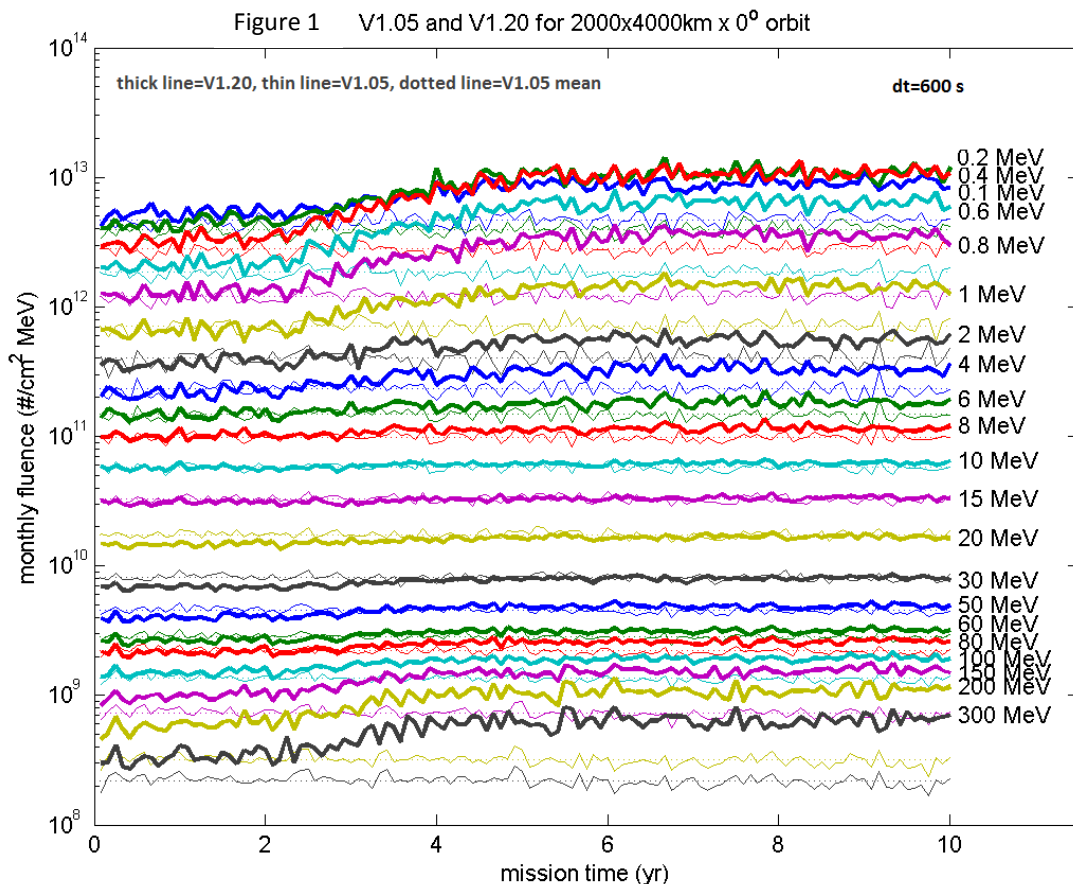Figure 1   V1.05 and V1.20 for 2000x4000km x 0° orbit

Figure 2 below shows the 10 year fluence energy spectra based on 100 Monte Carlo runs from V1.05, V1.20, and a preliminary version of V1.30. The higher V1.20 fluences (compared to V1.05/V1.30), most noticable near 0.4 MeV and 300 MeV, result from the cumulative effect of the Monte Carlo issue over the 10 year mission run.   These V1.20 features are corrected in V1.30; V1.30 changes affect only Monte Carlo runs. The difference between V1.05 and V1.30 near 200 MeV represents the use of Van Allen Probe/RPS data-based templates first added in V1.20.
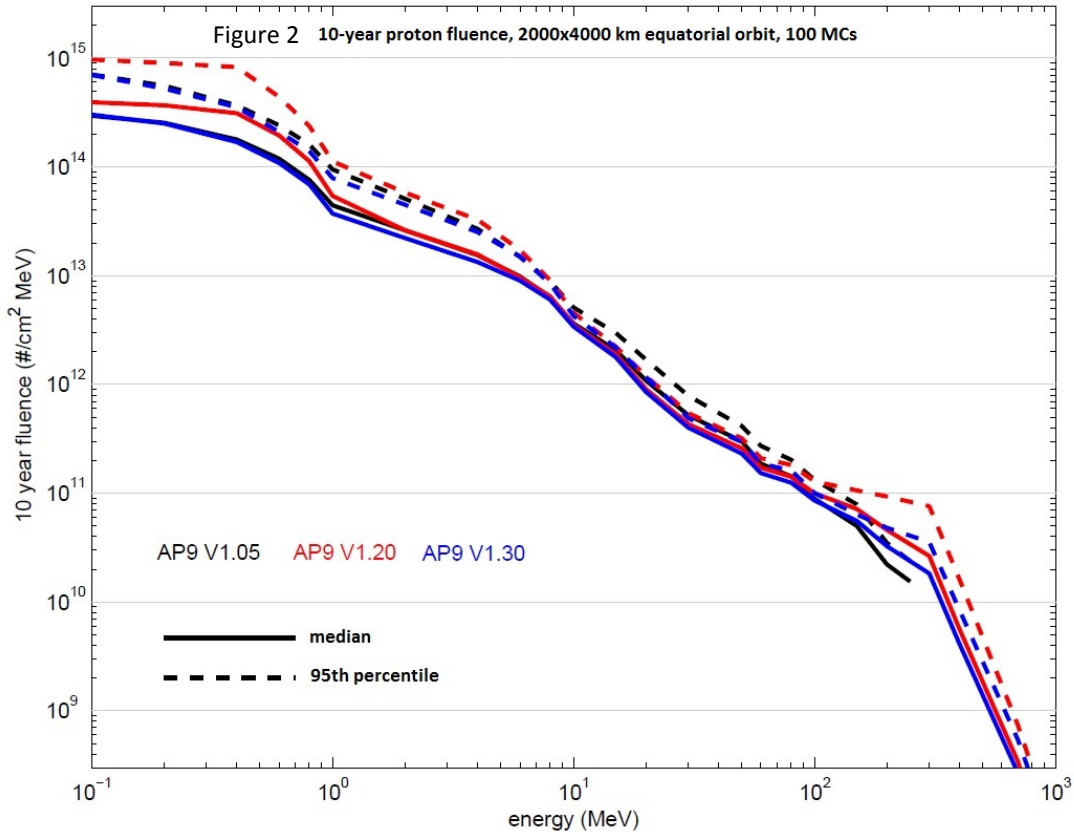
The forthcoming AP9 V1.30 release fixes the Monte Carlo problem, but leaves the mean and perturbed means unchanged from release V1.20.004.

We also note an error in TOR-2012(1237)-3 "Adding Multiple Time Lags to AE9/AP9 V1.0." Equation 17 was incorrect, and should be corrected as follows:

$$\left|\widetilde{\Lambda}_{jj}\right| < 1 \qquad\qquad (16, \text{correct})$$
$$\underline{\underline{\widetilde{G}}}\,\underline{\underline{\widetilde{G}}}^{T} = \underline{\underline{\widetilde{V}}}\,\underline{\underline{\widetilde{\Lambda}}}\,\underline{\underline{\widetilde{V}}}^{T} \qquad\qquad (17, \text{incorrect})$$
$$\underline{\underline{\widetilde{G}}} = \underline{\underline{\widetilde{V}}}\,\underline{\underline{\widetilde{\Lambda}}}\,\underline{\underline{\widetilde{V}}}^{T} \qquad\qquad (17, \text{correct})$$

The error was only in the tech report, not in the code that performs the test. This is the same test that gave a false pass due to numerical noise, and we noticed the error in the report during our investigation.

For additional information, please contact the AE9/AP9/SPM team.