For over a decade, earthquake doublets have been scrutinized in hopes of revealing a differential rotation of the Earth's inner core. Conclusive evidence, however, depends on the acquisition of more waveform doublets, as current geographical coverage is minimal. We have designed a method to identify more doublets on a global scale by correlating pairs of events in the South Sandwich Islands and Tonga-Fiji using a number of stations world-wide. We have identified over ten new doublets as well as confirmed previously reported doublets for available data. By aligning on the phases not sensitive to the inner core, such as PKPbc or PKPab, we can observe temporal changes in the arrival times of the inner core phase PKPdf. Measurement of the differential residuals of the PKPbc-df phases yields an estimate of the differential rotation rate, assuming a spatial shift of the underlying velocity gradient in the inner core due to rotation about the spin axis. We choose to measure differential travel times based on the alignment of the PKPdf phase onset along with its cross-correlation as has been done in previous studies. The two methods produce significant and unsettling discrepancies between results, since relatively small travel time differences required to detect temporal changes in seismic waveforms sensitive to the Earth's core. When our data is combined with previous measurements, however, the resulting differential rotation rate agrees with more recent estimates. We find it impossible to fit a straight line to our differential residuals as a function of time lapse between events.