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The Evolution of Positioning Accuracy and Linear vs. Non-linear Motions of the Earth

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The precision and accuracy of GPS/GNSS positioning has improved by considerably more than an order of magnitude over the course of my career, and the amount of data readily available (GNSS sites) has increased by several orders of magnitude. Over the last 40 years, geodesists have exploited this dramatic (and still continuing) increase in measurement capability to discover and study an ever-increasing set of phenomena. In the 1980s and early 1990s, the GPS satellite constellation was incomplete and there was only a sparse global tracking network. As a result, measurement noise limited rate accuracy to a few to several mm/yr, whereas today we are approaching accuracies of a few tenths of 1 mm/yr for long-term rates, and likely approaching the limit at which variability in surface loading makes motions fundamentally non-linear.

In this talk I will take a historical perspective, highlighting the improvement in measurement capabilities and our understanding of tectonic and other earth processes. At the beginning of my career, we focused on estimating rates of steady processes like rigid plate motions, the distribution of strain across rapidly-deforming plate boundary zones, or the displacements due to large earthquakes. We thought that over most of the Earth, motion and deformation mostly occurred linearly with time. The noise level in position solutions at that time was very high, and most non-linear variations in observed time series were considered to be noise either due to positioning error or to unstable geodetic monuments. While the deformation due to changing surface loads was recognized as a physical signal, knowledge of the changing loads was rudimentary and the signal was below the noise level in most cases. Today we recognize a wide variety of signals that produce a mix of linear and non-linear motions of the Earth, and positioning geodesy has become the essential tool for studying most of them. I have had the good fortune to work on measuring and understanding many of these processes, and I will discuss some of the highlights of the evolutionary path of positioning geodesy along with future perspectives. We have reached, or nearly reached, the point at which the approximation of linear motion breaks down because the measurement precision is now comparable to or smaller than the non-linear surface loading deformation over most of the planet. The coming years should see more exciting discoveries, but we must think broadly about the full range of geophysical signals that are contained within our data.