Metta Nicholson #28

Data Table

Control Data

Kp-0: November 3, 2012

First 10 data points:

no WAAS time (hhmmss)	Altitude (meter)	WAAS time (hhmmss)	Altitude (meter)	Time of data sample (UTC)	Error (meter)
10000	224.1	10000	225.3	1:00:00 AM	-1.2
10001	224.1	10001	225.3	1:00:01 AM	-1.2
10002	224	10002	225.4	1:00:02 AM	-1.4
10003	224	10003	225.4	1:00:03 AM	-1.4
10004	223.9	10004	225.4	1:00:04 AM	-1.5
10005	223.9	10005	225.4	1:00:05 AM	-1.5
10006	223.9	10006	225.3	1:00:06 AM	-1.4
10007	223.8	10007	225.3	1:00:07 AM	-1.5
10008	223.8	10008	225.2	1:00:08 AM	-1.4
. . . (continues for 19,910 points)	. . .	. . .	. . .	. . .	. . .

Kp-6 Data: September 3, 2012

First 10 data points:

no WAAS time (hhmmss)	Altitude (meter)	WAAS time (hhmmss)	Altitude (meter)	Time of data sample (UTC)	Error (meter)
10000	224.1	10000	225.3	1:00:00 AM	-1.2
10001	224.1	10001	225.3	1:00:01 AM	-1.2
10002	224	10002	225.4	1:00:02 AM	-1.4
10003	224	10003	225.4	1:00:03 AM	-1.4
10004	223.9	10004	225.4	1:00:04 AM	-1.5
10005	223.9	10005	225.4	1:00:05 AM	-1.5
10006	223.9	10006	225.3	1:00:06 AM	-1.4
10007	223.8	10007	225.3	1:00:07 AM	-1.5
10008	223.8	10008	225.2	1:00:08 AM	-1.4
. . . (continues for 5,148 points)	. . .	. . .	. . .	. . .	. . .

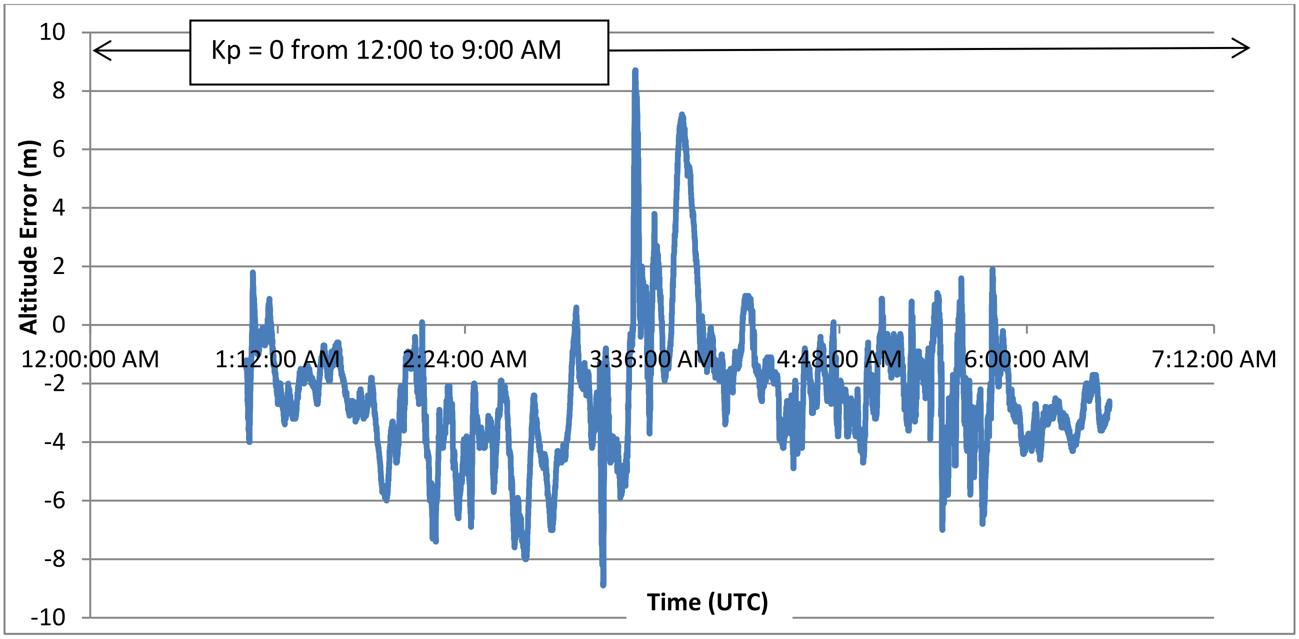
Kp-4 Data: November 20, 2012

First 10 data points:

no waas time (hhmmss)	Altitude (meter)	Waas time (hhmmss)	Altitude (meter)	Time (UTC)	Error (meter)
180000	233.1	180000	234.9	6:00:00 PM	-1.8
180001	233	180001	234.9	6:00:01 PM	-1.9
180002	233	180002	234.9	6:00:02 PM	-1.9
180003	233	180003	234.8	6:00:03 PM	-1.8
180004	233	180004	234.8	6:00:04 PM	-1.8
180005	232.9	180005	234.8	6:00:05 PM	-1.9
180006	232.9	180006	234.8	6:00:06 PM	-1.9
180007	233	180007	234.6	6:00:07 PM	-1.6
180008	233	180008	234.4	6:00:08 PM	-1.4
180009	233	180009	234.3	6:00:09 PM	-1.3
. . . (continues for 10,802 points)	. . .	. . .	. . .	. . .	. . .

Graphs

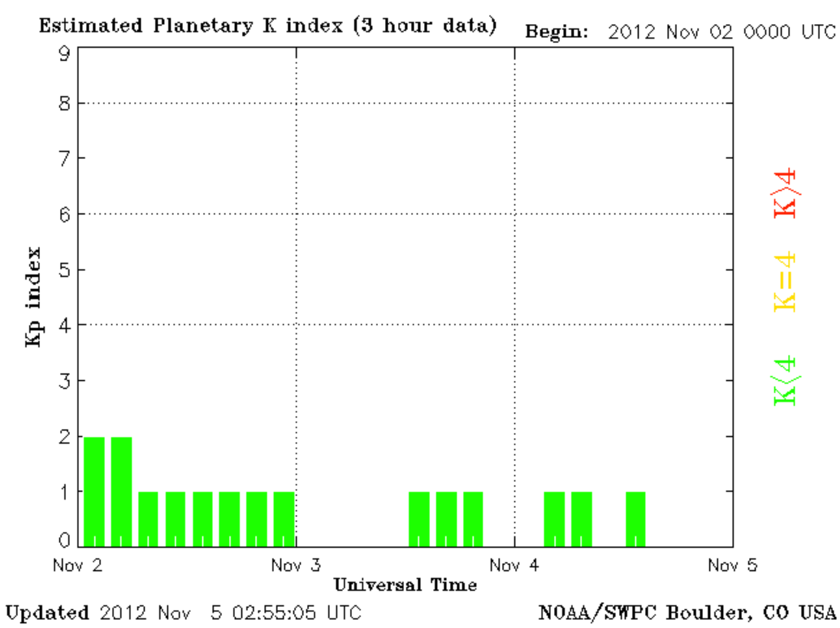
Graph of control data from Nov 3, 2012:



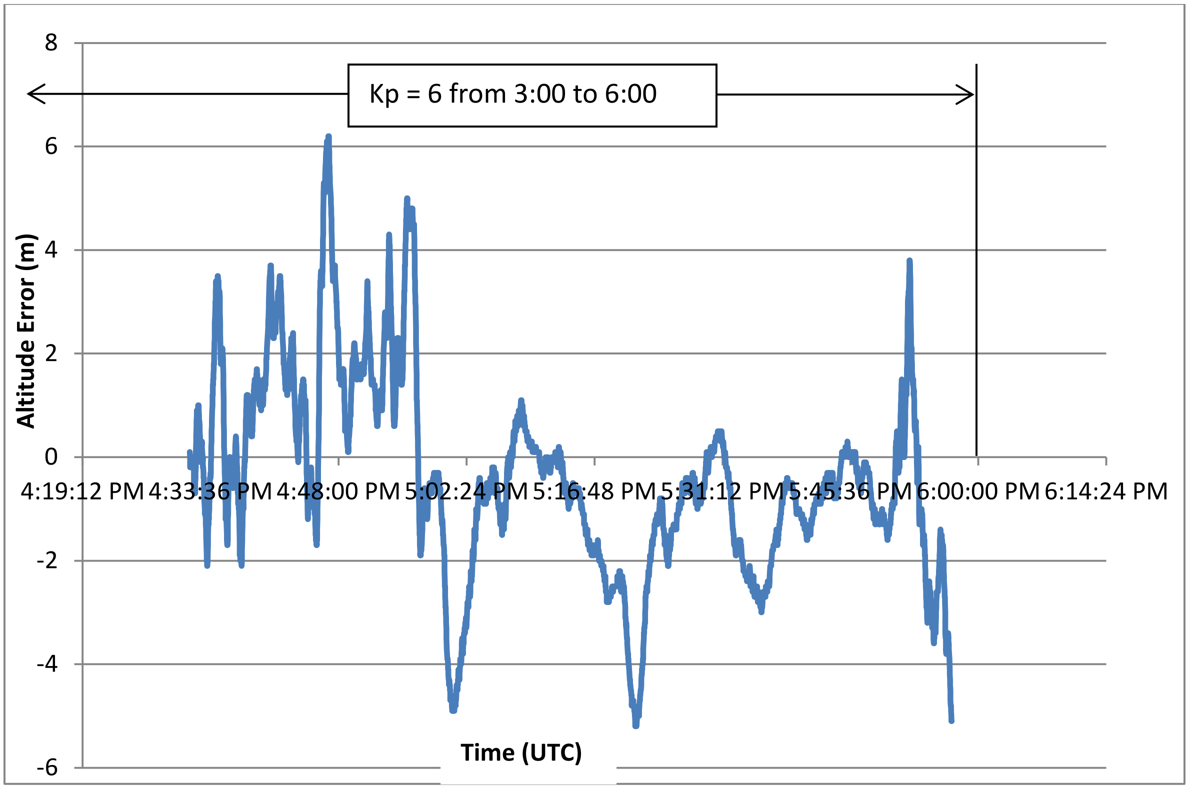
Number of data points: 19,910

Average error: -2.338 meters

Graph of Kp-indices for November 2 to 4



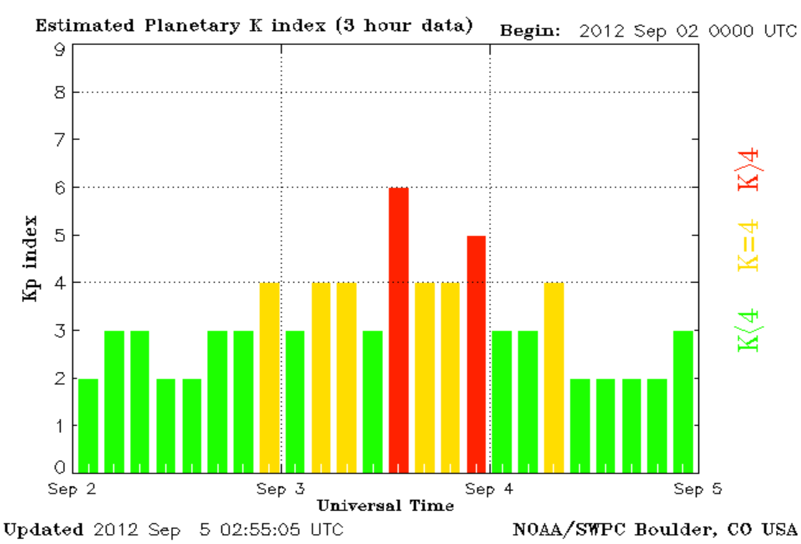
Graph of Kp-6 data Sep 3, 2012:



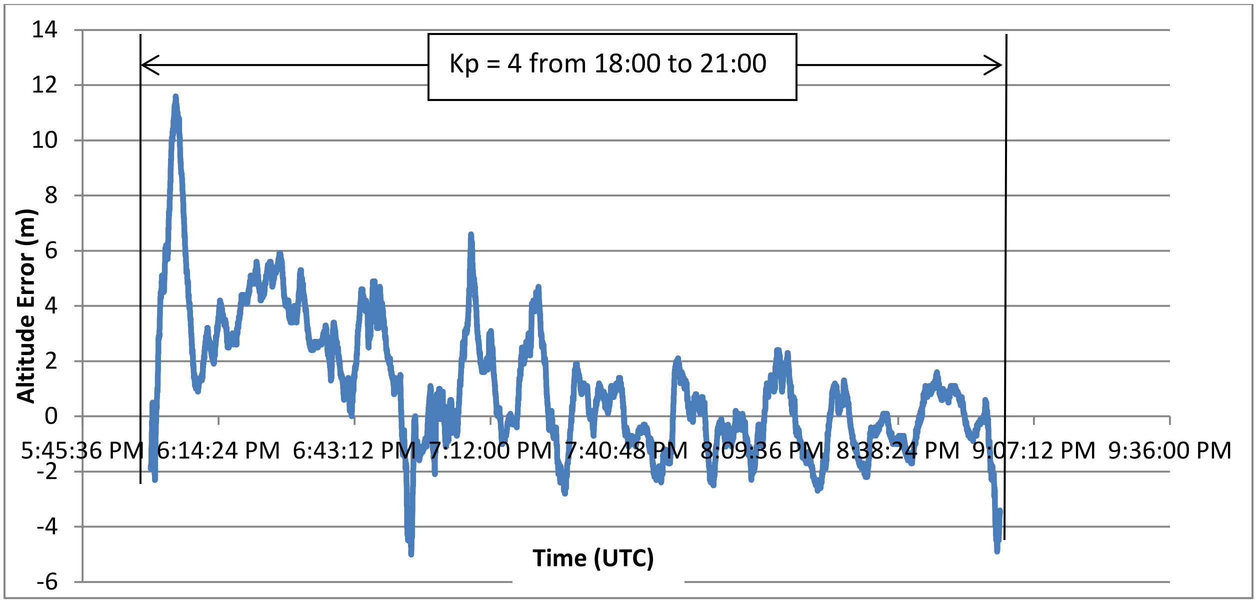
Number of data points: 5,148

Average error: -0.409 meters

Graph of Kp-indices for September 2 to 5



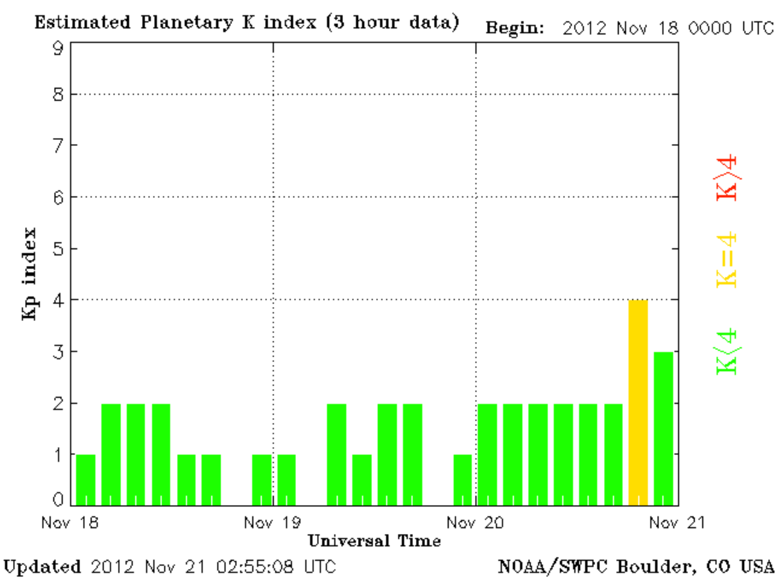
Graph of Kp-4 data Nov. 20, 2012:



Number of data points: 10,802

Average error: 1.053 meters

Graph of Kp-indices for November 18 to 21



Photographs

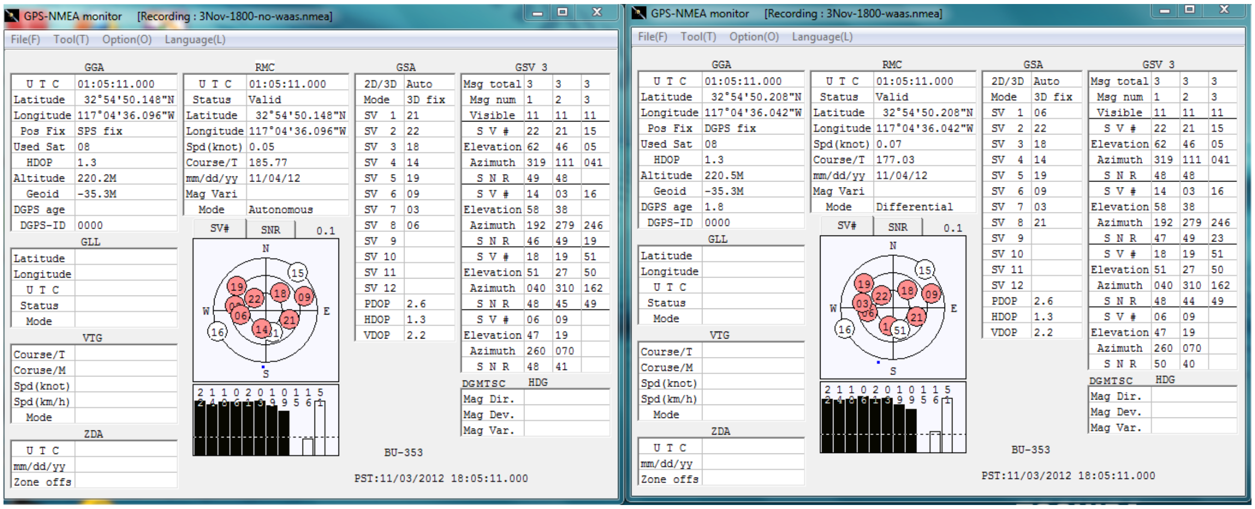


Figure 1: Screenshot of data recording in action- the window on the left is the no WAAS receiver, and the window on the right is the WAAS receiver

Figure 2: Setup of GPS receivers

Results Discussion

The goal of this experiment was to study the impact of solar flares and other forms of solar activity on Global Positioning System (GPS) receivers. To achieve this, two GlobalSat BU-353 WAAS receivers were attached to a computer, allowing the computer to record one data point per second. It was discovered that with this experiment, it is difficult to isolate one variable to test. For example, the number of satellites the receivers acquired signals from differed from time to time. In this case, the two receivers occasionally used different numbers of satellites to form their calculations.

With each trial, the duration of time that the computer recorded data differed, due to the amount of time geomagnetic activity was active. It was soon learned, however, that one difficulty with this experiment is that predictions regarding geomagnetic storms are only occasionally accurate. Therefore, it was difficult to record data during solar storms, especially when storms occurred unexpectedly in the middle of the night. It was decided that a more efficient way to gather information was to record data continuously, in order to raise the chance of receiving data during a geomagnetic storm.

Each trial was completed using the same receivers in the same location. The same computer was used to record data. The data analysis was completed using the same procedures, making it easy to compare data. One slight modification to the procedures was the system used to complete the data analysis. After the first file was successfully analyzed and graphed, an additional copy of this file was made, to use as a rubric. The data from following trials was then pasted into this rubric, so that the difference between the altitudes was automatically calculated. In order to make a graph of altitude versus time, the “time” column had to be modified to improve clarity.

The time period with a Kp-index of 6 on September 3, 2012 was the product of a solar flare that happened 16 to 48 hours before the data was recorded. The solar flare resulted in a CME that impacted the Earth’s atmosphere, resulting in a geomagnetic storm. It takes 16 to 48 hours for a CME to reach Earth, so when the data was recorded, the solar flare had already decayed.

It is difficult to predict how much impact a CME will have on Earth, because there are many factors that may affect the CME’s impact. If Earth were directly in the line of fire, the impact could be very great. If the CME only slightly grazed Earth, however, the impact would be much less. A CME also has a magnetic field that could also have an effect on Earth. If the positively charged part of the CME's magnetic field lined up with Earth's negatively charged part, the CME's hit would be very powerful, because opposites attract. If the opposite were true, however, the CME's hit would not be very strong, because similarly charged particles repel. Therefore, different CMEs may have very different impacts on Earth and cause different strength geomagnetic storms.

For the purposes of this experiment, it was hoped that there would be several strong CME impacts. However, this was not the case. If there had been stronger flares and CMEs, then there may have been a more recognizable effect on the GPS receivers. Because this did not happen, the graphs did not show any particular trend.

Contrary to what was expected, the graph of the Kp-6 data had the least average error and smallest error range. The average error was about 0.409 meters, and the range was approximately 11 meters. Oddly, the Kp-0 data had the most average error (2.338 meters) and largest range (about 18 meters). The Kp-4 data was in between, with an average error of 1.053 meters and a range of around 16 meters. It is possible that this outcome is the result of other error sources, such as satellite geometry, signal multi-path, and number of satellites, which may have affected the GPS receivers. Therefore, any effect that the solar flares may have had on the receivers could have been covered up by all these other error sources.

Much data was recorded for periods of time with low geomagnetic activity. The graph from November 3, 2012 is an example of control data that was analyzed and graphed. For each three-hour time period, there were about 10,000 data points recorded, which means that there were 10,000 trials. Each of these trails alone, however, is not independent, because there is some correlation between data points recorded soon after each other. After about 100 seconds, this correlation is lost, so data separated by 100 seconds or more could be considered uncorrelated. Therefore, there is a large amount of uncorrelated data for each three-hour time period.

The hypothesis for this experiment was that a Kp-index of 6 or higher could cause an error of 20 meters. However, data for this experiment showed that the highest error caused by a Kp-index of 6 was 6 meters. This data was not significantly different from data received during time periods with lower Kp-indices, nor was there a significant difference in the average altitude errors.