CORRELATION BETWEEN GPS ERROR SIGNALS AND GEOMAGNETIC ACTIVITY IN THE IONOSPHERE

SAHITHI ANKIREDDY RISE ONLINE STEM RESEARCH INSTITUTE

PURPOSE

- Learn more about the correlation between GPS errors and geomagnetic activity in the ionosphere.
- Investigate the specifics of this correlation, and find out exactly what values and measurements in the GPS system are affected and involved

HYPOTHESIS

- If the strength of geomagnetic activity increases, then number of GPS errors will also increase.

INTRODUCTION

- Geomagnetic activity is measured by the K-index, which is on a scale of 1-9. As the K-index gets higher, then it indicates that there is more geomagnetic activity in the ionosphere. The ionosphere is also where GPS signals are transmitted, thus geomagnetic activity can highly affect GPS systems and cause errors (Ionosphere, 2015).
- WAAS: Wide Area Augmentation System. WAAS (only spans over North America) is a correction system that was installed to supplement and correct the Global Positioning System (GPS) in hopes of improving accuracy, availability, and precision (Satellite Navigation-WAAS-How It Works, 2015).
- WAAS can be turned off and on in many GPS systems. Since, measurements with WAAS are more accurate, the difference from the measurements (elevation, latitude, longitude) taken with and without WAAS is the error signal.
- Geomagnetic activity is caused due to the behavior of the sun and the nature Earth's magnetic field.
- "As the sun approaches its solar maximum—the peak of intensity in the sun's cycle—solar flares and associated coronal mass ejections occur more frequently. These eruptions on the sun launch charged particles into space, called solar wind" (Geomagnetic Disturbances, n.d., [Online]).
- Solar flares are sudden events of increased brightness from the Sun and are giant bursts of X-ray energy (Redd., n.d).
- Solar flares occur more often than CMEs (coronal mass ejections) and it only takes 8 minutes to reach Earth because they travel at the speed of light in all directions. CMEs are bursts of solar wind and are not always associated with solar flares (Redd., n.d).
- The Earth's magnetic field protects the Earth and the satellites, such as the GPS systems, from the solar wind and solar flares. Thus, when solar flares occur or when there is too much solar wind released, and when CME's occur, a temporary disturbance takes place. (Redd., n.d).

MATERIALS

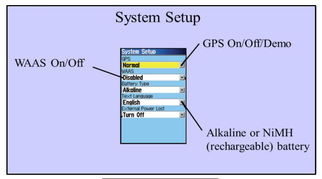
- GPS with capability of enabling WAAS on/off
- Internet in order to access K-index

IMPACT

- Aviation. Mining. Agriculture. Marine. Recreation. These are just a few of the industries that utilize GPS systems on a daily basis. GPS systems are very multi-purposeful and are vital to many industries. However, these systems get faulty from time to time.
- One of the sources of error could possibly be due to solar disturbances affecting the Earth's magnetic field, causing geomagnetic disturbance/storms in the ionosphere. Thus, knowing more about and the specifics of GPS errors and how they are caused is important for many of these industries.

METHODS

Buy a GPS with the feature in which WAAS can be enabled on/off, and find a permanent location to put GPS and take data.



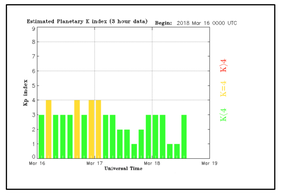
WAAS ON - WAAS OFF

Turn GPS on at 12am, and record elevation, latitude, and longitude with WAAS enabled. Turn WAAS off and record the same measurements with WAAS off.

Calculate the error signal between each measurement by subtracting the with WAAS measurement from the measurement without WAAS for elevation, latitude, and longitude.

METHODS

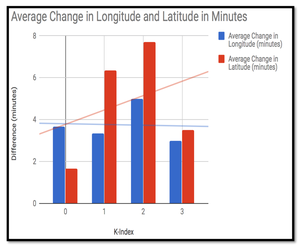
Immediately go online and record K-index value. Note any geomagnetic storms present.

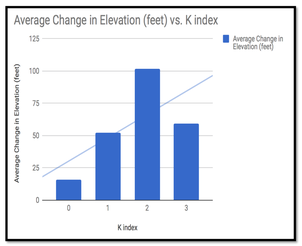


Come back at 6PM. Repeat the process. Record all the measurements with both WAAS off and on. Calculate differences between the WAAS on and the WAAS off measurement for each of the 3 types of measurements. Go online and record the K-index value.

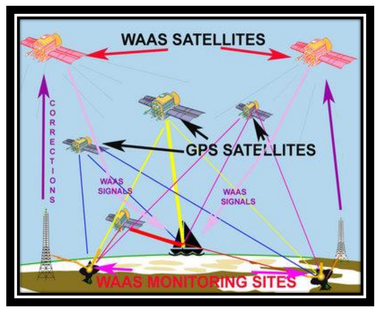
Repeat this entire process every day for at least 2 weeks.

RESULTS

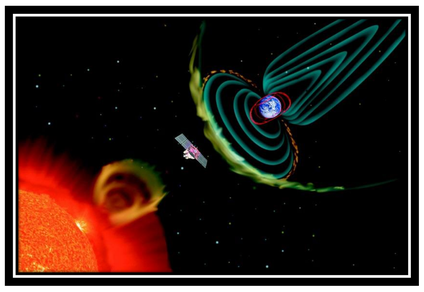




The average differences (error signals) in elevation, longitude, and latitude from the K-index values (measures geomagnetic activity; the higher the K-index value, the higher the geomagnetic disturbances /activity) present in this experiment, are shown above.



WAAS is a system of ground radio stations and satellites

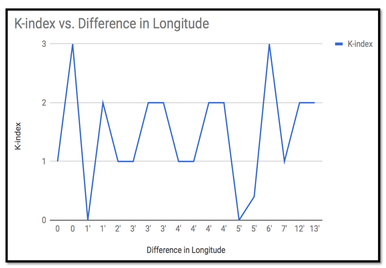


A depiction of an geomagnetic storm

RESULTS

The table below shows all of the differences or error signals from the data for each type of measurement and it's according K-index value.

Date	Time	Difference in Elevation (feet)	Difference in Longitude	Difference in Latitude	K-index Value
12/28/17	12:00 AM	90	3'	13'	1
12/28/17	6:00 PM	36	0	2'	1
12/29	12:00 AM	122	4'	10	2
12/29/17	6:00 PM	124	3'	5'	2
12/30/17	12:00 AM	3	4"	2'	1
12/30/17	6:00 PM	144	2'	2'	1
12/31/17	12:00 AM	110	3'	24"	2
12/31/17	9:30 PM	61	4'	3'	2
1/1/18	12:00 AM	98	6'	4'	3
1/1/18	11:00 PM	37	7"	5'	1
1/2/18	12:00 AM	86	12'	8'	2
1/8/18	12:00 AM	7	5'	3'	0.4
1/8/18	10:00 PM	72	8'	2'	2
1/9/18	12:00 AM	33	4'	1'	4
1/10/18	12:45 AM	115	13'	2'	2
1/17/18	1:00 AM	2	4"	14"	1
1/18/18	1:00 AM	31	5'	1'	0
1/20/18	3:00 AM	21	0	3'	1
1/24/18	12:00 AM	10	1"	1'	0
1/26/18	1:30 AM	23	1"	0'	2



The graph above compare the K-index value to the difference (error signal) in the longitude(feet).

CONCLUSION

- The hypothesis was partially supported. It was hypothesized that as the K-index increases, then the amount of GPS errors would increase as well.
- There is a linear correlation in GPS errors in elevation and latitude when the K-index increased from 1 to 2, but the correlation does not continue as the K-index increases to a value of 3.
- The most likely explanation for this lack in trend is that the sample size when the K-index was 3 is less than that at the K-index of 0-2.
- However, the hypothesis is not supported for longitude as there does not seem to be a correlation in the data.

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ABSTRACT/ SAFETY SHEET