MAE 593I: GPS
HW5 Real Data Processing DGPS and PPP with NGS CORS Sites
Assigned: 11/16/14
Due: 12/2/14
You may work in groups of 2 to 3 people.

The objective of this assignment is to gain experience with the two precise GPS processing techniques that we discussed in class using real data. Along the way it will also:

1. Introduce you to available GNSS data repositories, such as the National Geodetic Survey's (NGS) Continuously Operating Reference Stations
2. Introduce to the free LAMBDA DGPS toolbox;
3. Introduce to freely available Precise Point Positioning (PPP) services;

To make the assignment more reasonable, I have packaged the GPS raw data from the standard file formats (ie RINEX) into MATLAB structures that are similar to the previous HWs. However, to provide additional information to those who are interested, I provide links to the original data repositories.

As mentioned in class, NGS CORS offers free GPS data that can be used to form DGPS solutions, to estimate tropospheric conditions for PPP, and for many geophysical applications.

This assignment uses NGS CORS data from Friday November 13, 2014 at the Morgantown, WV site, **WVMO**, which is located on our Agriculture Sciences Building and a Waynesburg, PA site, **PAGW**. These two sites are at approximately a 30 km baseline separation. The map below is taken from the NGS CORS Website.

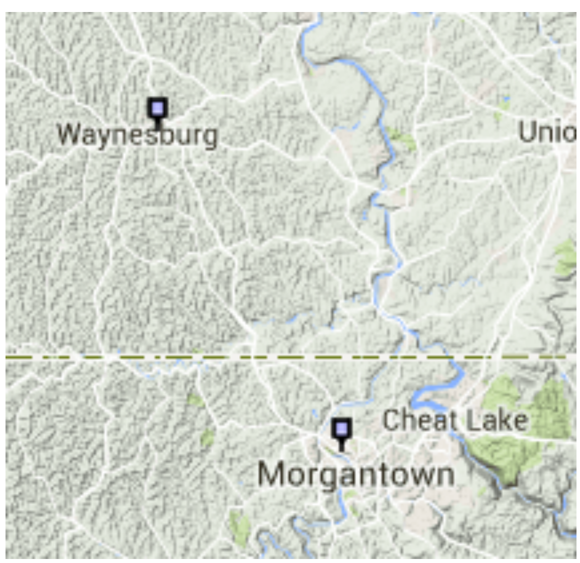

Figure 1: WVMO and PAGW locations (from NGS CORS Map)

In order to complete this assignment, you are provided the following files:

Raw files

- **wvmo_GPSOnly_5min_3180.14o** this is the RINEX file for WVMO on 11/13/14 (i.e. day 318 of 2014). Nominally, GPS and GLONASS data are available at 1 Hz. For this assignment, I have decimated the file to five-minute epochs and deleted all GLONASS data.
    - *wvmo3180.14o.gz is the file that is actually posted online and accessible through the following site http://www.ngs.noaa.gov/CORS/standard1.shtml*
- **pagw_GPSOnly_5min_3180.14o** this is the RINEX file for PAGW on 11/13/14 (i.e. day 318 of 2014). Nominally, GPS and GLONASS data are available at 1 Hz. For this assignment, I have decimated the file to five-minute epochs and deleted all GLONASS data.
    - *pagw3180.14o.gz is the file that is actually posted online and accessible through the following site http://www.ngs.noaa.gov/CORS/standard1.shtml*
- **brdc3180.14n** this is the broadcast GPS navigation data in the RINEX navigation data format.
    - **Total GPS broadcast ephemeris, merged from several tracking stations. Downloaded from http://cddis.gsfc.nasa.gov/Data_and_Derived_Products/GNSS/broadcast_ephemeris_data.html**

Matlab files

- **realDataMat** MATLAB binary file with broadcast GPS orbits, and data from WVMO and PAGW on 11/13/14. Using above files. Two structure variables are used to store the station GPS data ;
    - **pagw,wvmo**
        - **TOWSEC** {1x288}: seconds into GPS week. The GPS week for this data is 1818.
        - **C1** {32x288}: GPS pseudorange measurements in **meters** on frequency L1. The row is the GPS PRN number and each column corresponds to the elements of the TOWSEC vector. A NaN means no valid observation for that PRN at that particular epoch.
        - **P2** {32x288}: GPS pseudorange measurements in **meters** on frequency L2. The row is the GPS PRN number and each column corresponds to the elements of the TOWSEC vector. A NaN means no valid observation for that PRN at that particular epoch.
        - **L1** {32x288}: carrier-phase measurements in **L1 Cycles**. The row is the GPS PRN number and each column corresponds to the elements of the TOWSEC vector. A NaN means no valid observation for that PRN at that particular epoch.
        - **L2** {32x288}: carrier-phase measurements in **L2 Cycles** The row is the GPS PRN number and each column corresponds to the elements of the TOWSEC vector. A NaN means no valid observation for that PRN at that particular epoch.
    - **satTOWSEC** {288x1} time vector for satellite obits in seconds into GPS week. The GPS week for this data is 1818.
    - **satsXYZ** {288x32x3} Orbit data for the GPS satellite. The first index corresponds to the elements of satTOWSEC vector, the second index is the PRN number of the GPS satellite, and the 3 values keyed at a time index and PRN are ECEF X, Y and Z. Orbit values are in **meters.**
        - For those who are interested, to get from navigation RINEX to ECEF coordinates, you must apply the algorithm that is in the GPS ICD: http://www.navipedia.net/index.php/GPS_and_Galileo_Satellite_Coordinates_Computation

Note: No GPS clock biases are provided for the HW. These will be canceled in DGPS, but if you want to try standard absolute positioning, these must be extracted from the navigation message.

Problem 1 [50 points]: Based on the KF equations we developed on the board in class, and the example UKF code posted on eCampus, formulate a carrier phase DGPS Kalman filter to estimate the 3D baseline from WVMO to PAGW.

- Hint when forming double differences. Because all epochs in which each site is not tracking a particular satellite are provided as **NaN**, and also because all observations are organized in a matrix in which the rows corresponds to PRN numbers, you can simplify your code by differencing entire matrix rows and monitoring validity of individual double differences with calls to **isnan()**
- Use WVMO as your reference station and obtain WVMO's coordinates from the CORS site for WVMO.
- In your selection of p. rocess noise covariance, **Q**, keep in mind that both stations are not moving.
- Use the LAMBDA method in a complimentary manner to your filter as is done on the dgpsKF UKF posted on eCampus
    - You can Obtain LAMBDA MATLAB toolbox here: http://gnss.curtin.edu.au/research/lambda.cfm

Determine both 'float' solution and 'fixed' solutions and compare your results with the baseline separation that is determined by simply subtracting the two site coordinates listed on each site NGS CORS webpage.

Problem 2 [50 points]: Use PPP to determine WVMO to PAGW baseline.

- Process the two station RINEX files using the JPL APPS service: http://apps.gdgps.net/ Click the "CA code" option. This is needed because the station data we are using tracks C1 (CA) data for pseudorange on L1
    - Process both stations are 'Static' mode. This will give you one position solution for the entire day and is analogous to the filters we've used in this class with process noise for position = 0.
        - The solution will be provided in a "JPL Time Dependent Parameters" File with the extension *tdp (this is just a text file that can be opened with any editor)
            - The format of a *tdp file is:

"Seconds past 2000" "Nominal" "Estimated" "Formal Error" "Parameter Name"

- We are interested only in the lines parameter names with 'STA X', 'STA Y' and 'STA Z'

    - Now process both station in "Kinematic" Mode. This estimates the station position at each 5-minute epoch and is analogous to filters we've designed in with class with process noise for position states to be set to a large value.

Compare the static PPP baseline to the baseline determined using the coordinates posted on the NGS CORS site for each station.

Plot a time history of the Kinematic solution vs. DGPS solutions (float and fixed) obtained in problem #1.