LAB 3 - IMU Data Collection and Analysis

Purpose:

To collect the IMU data and analyze it while stationary for 10 min and 5hr to measure the actual sensor error.

Methodology:

In order to collect the linear acceleration, angular velocity, orientation and magnetic field a Vectornav VN-100 IMU sensor is used. A ros node is written for reading the IMU data and publishing it has /imu and /magnetometer topics and save it as a bag file.

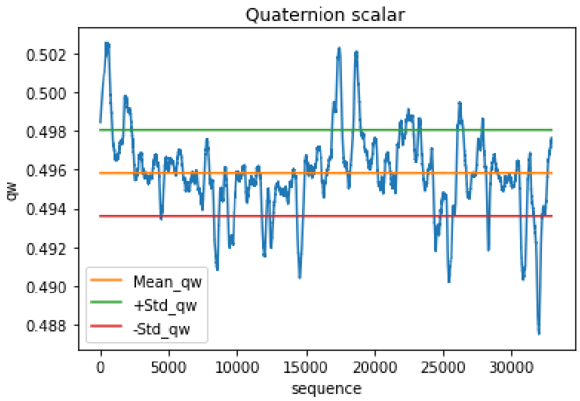
Data Collection:

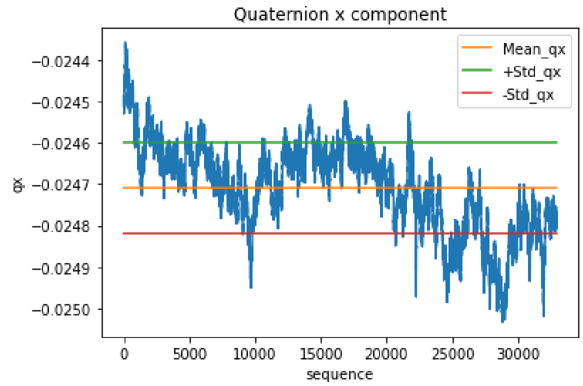
Data is collected for 10 min and 5hr and parameters which are collected are

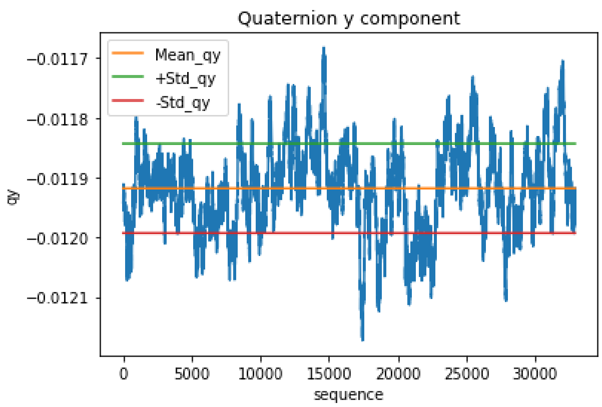
1. Orientation (quaternion x,y,z,w) - deg
2. Angular Velocity (wx,wy,wz) - rad/s
3. Linear Acceleration (ax,ay,az) - m/s^2
4. Magnetic Field (mx,my,mz) - Gauss

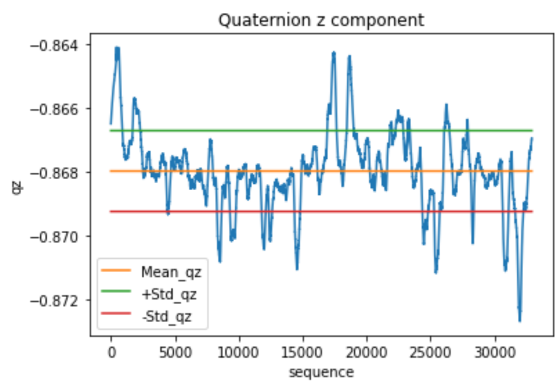
15 Min IMU Data Analysis:

1. Quaternions:



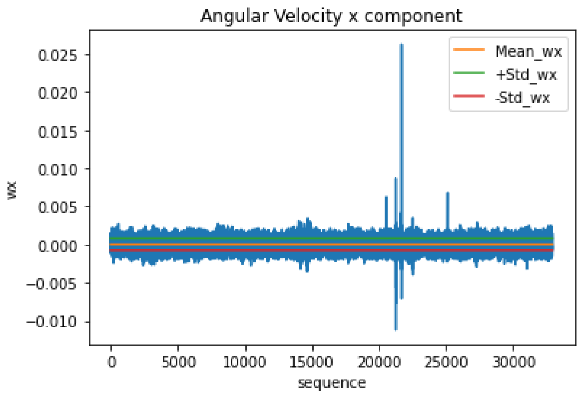


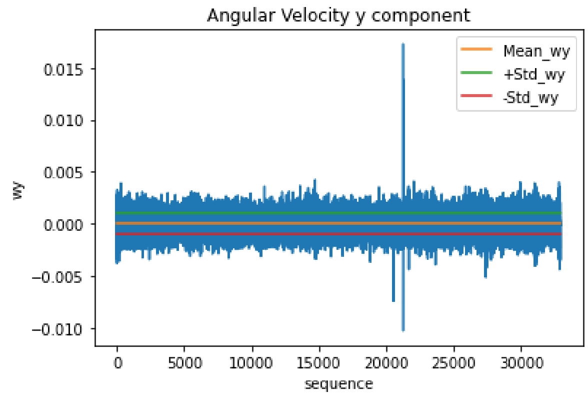


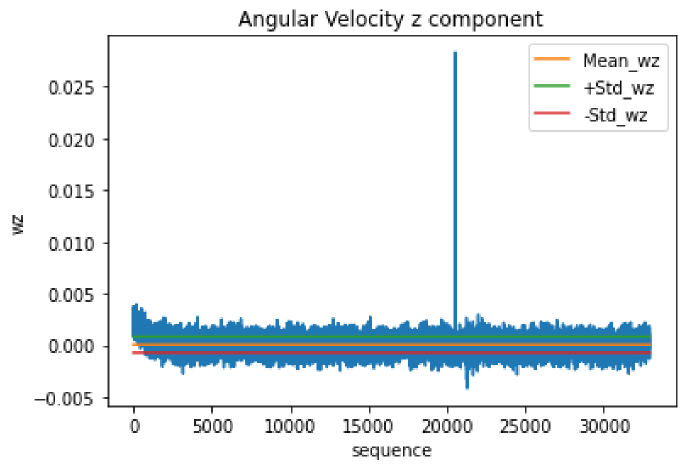


index	orientation.w	orientation.x	orientation.y	orientation.z
count	32932.00000	32932.00000	32932.00000	32932.00000
mean	0.49582	-0.02471	-0.01192	-0.86799
std	0.00222	0.00011	0.00007	0.00127
min	0.48748	-0.02503	-0.01217	-0.87270
25%	0.49491	-0.02478	-0.01197	-0.86851
50%	0.49577	-0.02469	-0.01192	-0.86802
75%	0.49682	-0.02463	-0.01187	-0.86742
max	0.50257	-0.02436	-0.01168	-0.86411

2. Angular Velocity :

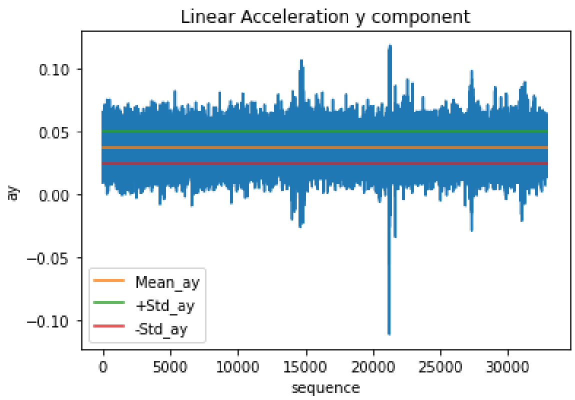


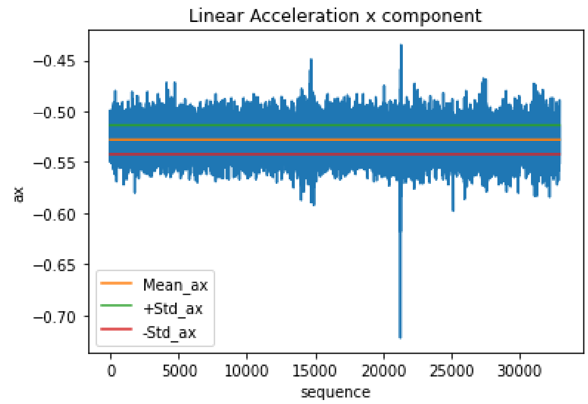


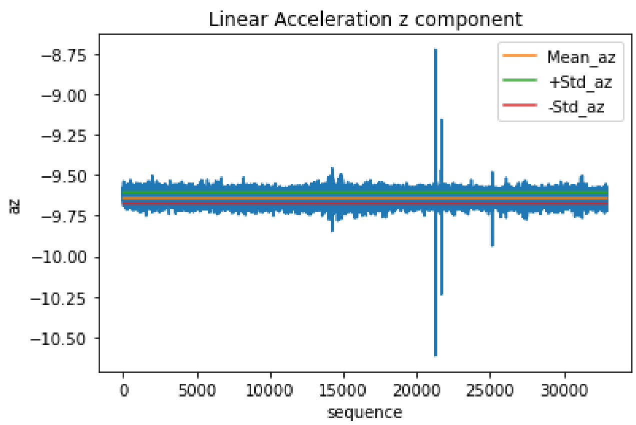


index	angular_velocity.x	angular_velocity.y	angular_velocity.z
count	32932.00000	32932.00000	32932.00000
mean	0.00002	-0.00001	0.00006
std	0.00077	0.00100	0.00078
min	-0.01121	-0.01031	-0.00416
25%	-0.00048	-0.00066	-0.00045
50%	0.00002	-0.00001	0.00004
75%	0.00052	0.00063	0.00054
max	0.02627	0.01730	0.02831

3. Linear Acceleration:

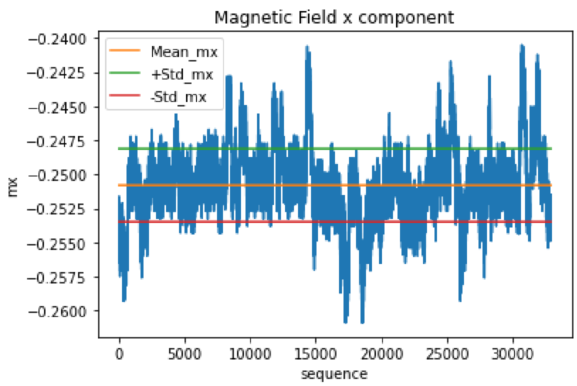


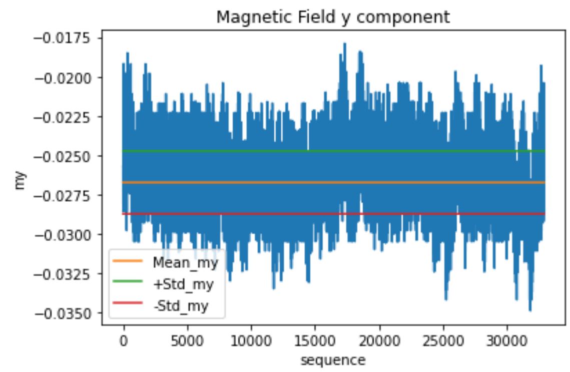


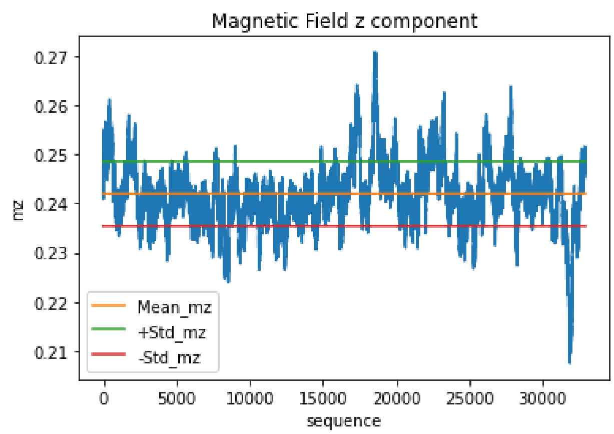


index	linear_acceleration.x	linear_acceleration.y	linear_acceleration.z
count	32932.000000	32932.000000	32932.000000
mean	-0.527939	0.037130	-9.640382
std	0.014091	0.012813	0.034178
min	-0.722000	-0.111000	-10.615000
25%	-0.537000	0.029000	-9.662000
50%	-0.528000	0.037000	-9.640000
75%	-0.519000	0.045000	-9.619000
max	-0.435000	0.118000	-8.724000

4. Magnetic Field:



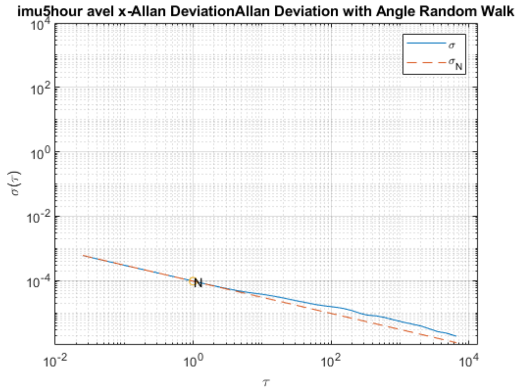


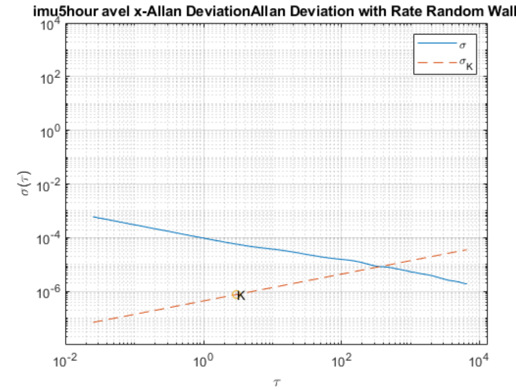


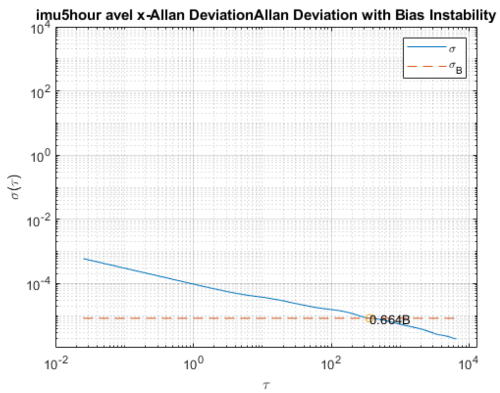
index	magnetic_field.x	magnetic_field.y	magnetic_field.z
count	32932.00000	32932.00000	32932.00000
mean	-0.25081	-0.02674	0.24195
std	0.00269	0.00200	0.00657
min	-0.26090	-0.03490	0.20740
25%	-0.25210	-0.02810	0.23840
50%	-0.25100	-0.02690	0.24160
75%	-0.24940	-0.02560	0.24540
max	-0.24050	-0.01790	0.27090

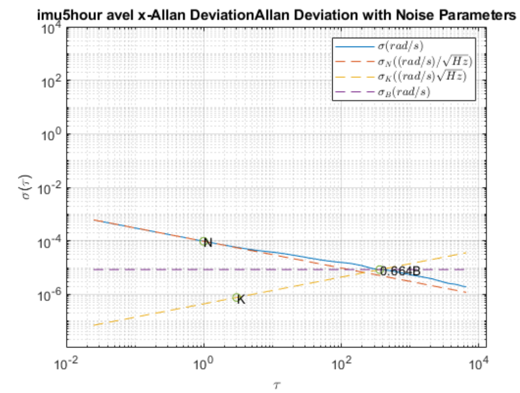
Allan Variance for 5hr Data:

Angular Velocity x:







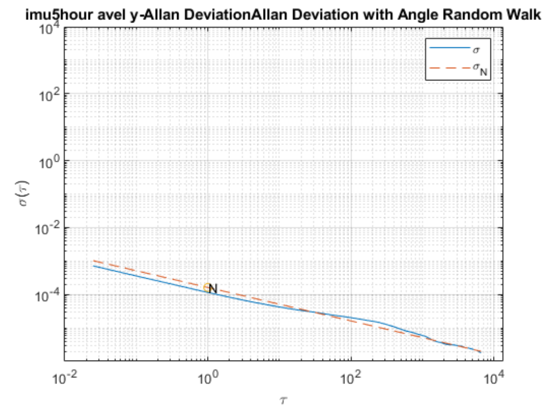


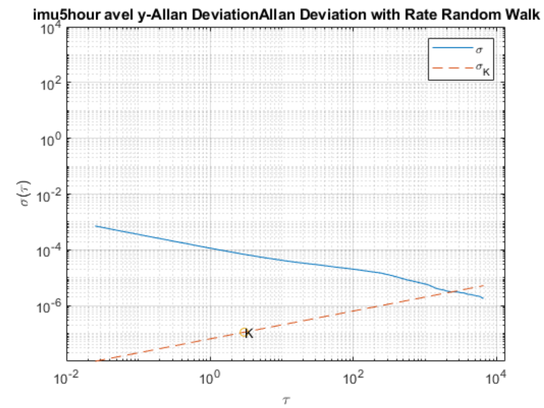
N = 9.5466e-05

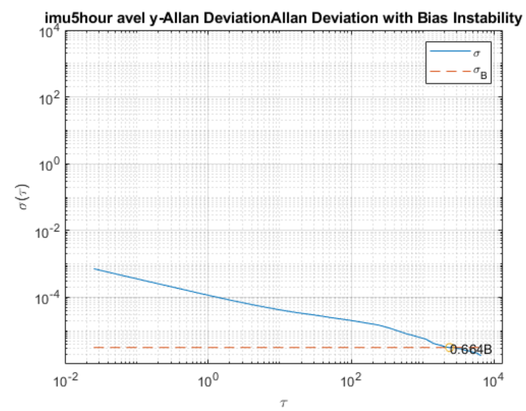
K = 7.5851e-07

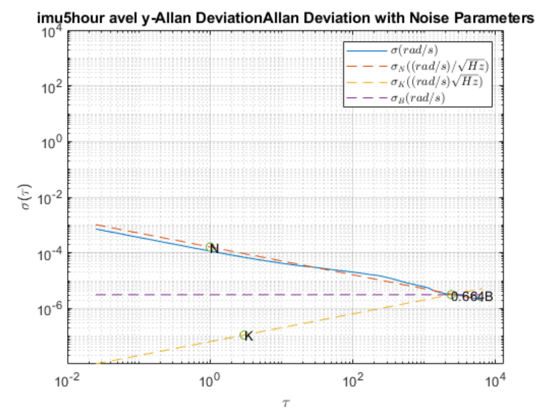
B = 1.2527e-05

Angular velocity y:







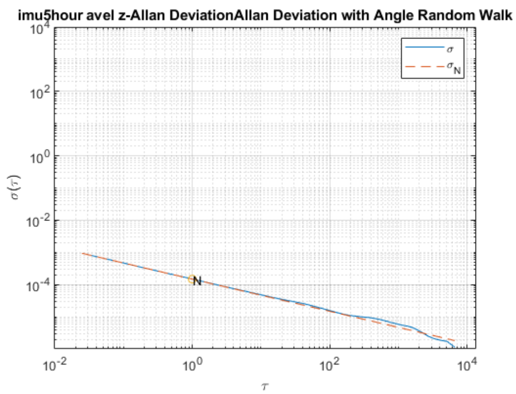


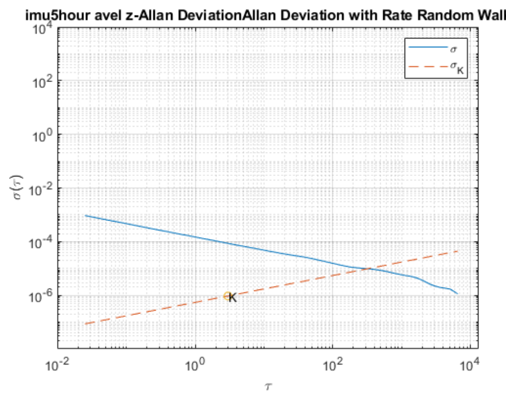
N =1.6150e-04

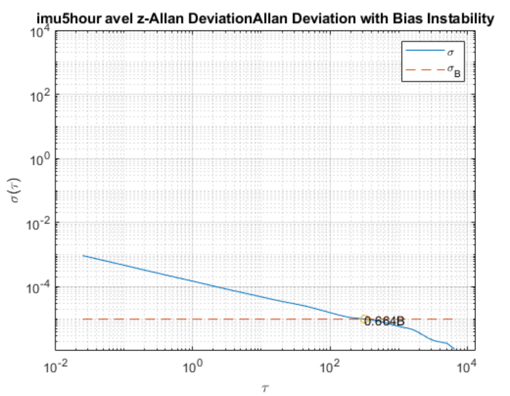
K =1.1057e-07

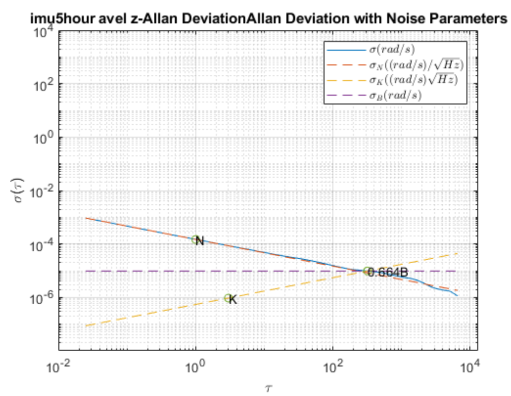
B =4.6995e-06

Angular Velocity Z:







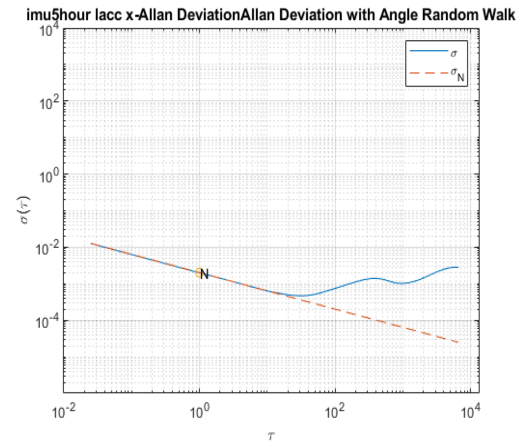


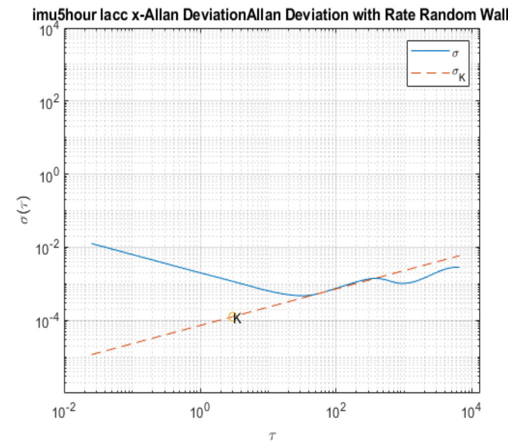
N =1.4754e-04

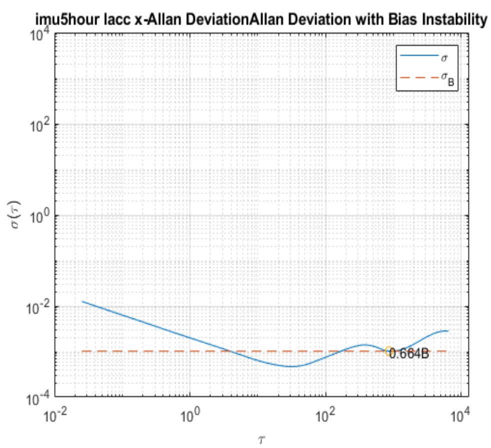
K =9.4467e-07

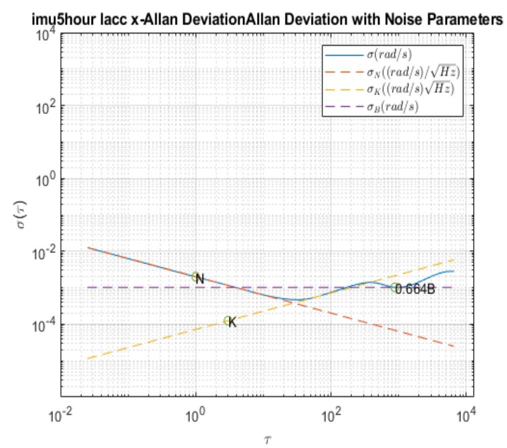
B =1.4649e-05

Linear Acceleration x :







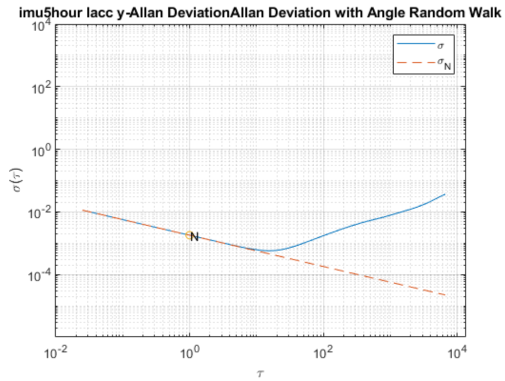


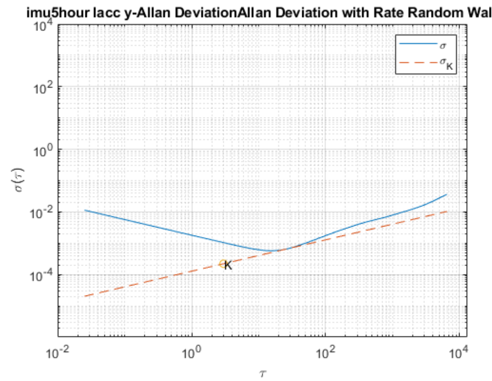
N =0.0020

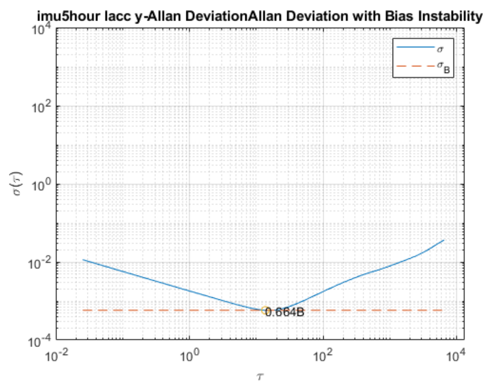
K =1.2492e-04

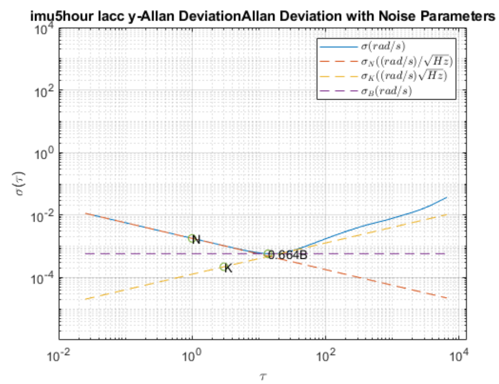
B =0.0015

Linear Acceleration Y:







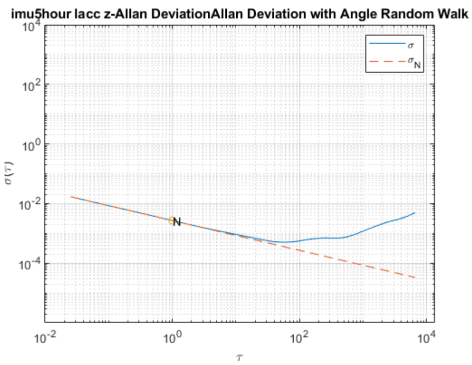


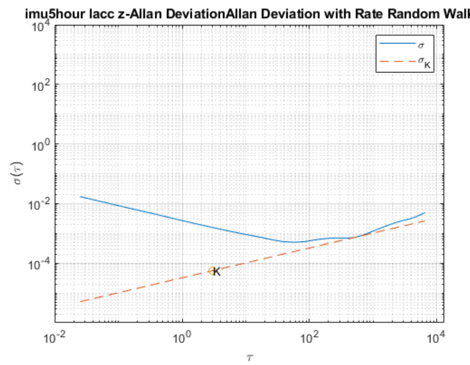
N =0.0018

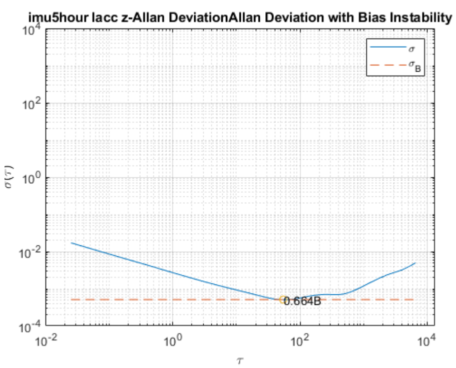
K =2.2125e-04

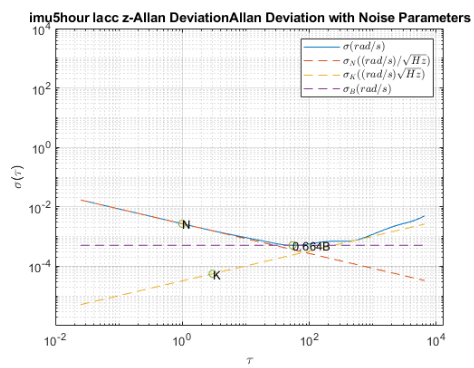
B =8.6861e-04

Linear Acceleration Z:









N =0.0027

K =5.6123e-05

B =7.6522e-04

1. What kind of errors/sources of noise are present?

Acceleration and gyro bias instability is the most important characteristic to consider when comparing gyro sensors. All gyro sensors, regardless of price or quality, will have measurement biases. Measurement bias is a constant measurement offset from true. Gyro biases will cause angle drift in time-integrated data. For example, When the gyro is switched on and remains stationary, the sensor will read a slight non-zero rate measurement. This bias is called turn-on bias.

2. How do we model them? Where do we measure them? Can you relate your measurements to the datasheet for the VN100?

Noise Parameter Identification:

To obtain the noise parameters for the gyroscope, use the following relationship between the Allan variance and the two-sided power spectral density (PSD) of the noise parameters in the original data set Ω. The relationship is:

$$\sigma^2(\tau) = 4 \int_0^\infty S_\Omega(f) \frac{sin^4(\pi f \tau)}{(\pi f \tau)^2} df$$

Angle Random Walk:

The angle random walk is characterized by the white noise spectrum of the gyroscope output. The PSD is represented by:

N = angle random walk coefficient

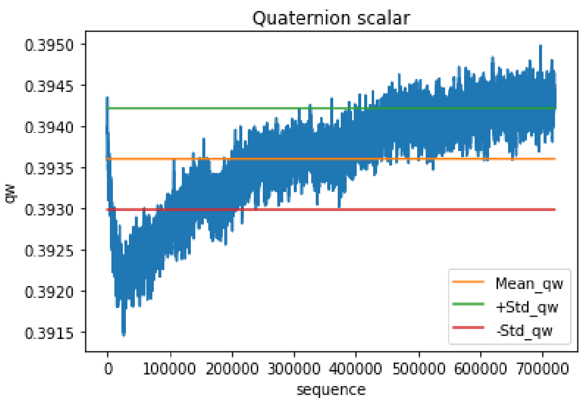
Substituting into the original PSD equation and performing integration yields:

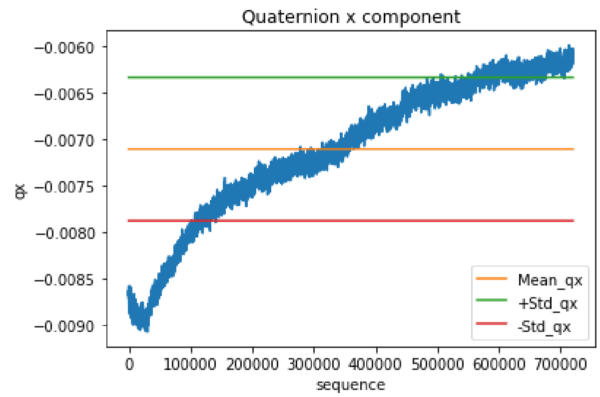
$$\sigma^2(\tau) = \frac{N^2}{\tau}$$

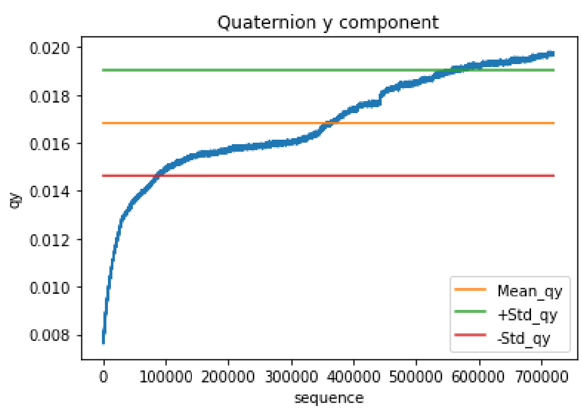
The above equation is a line with a slope of -1/2 when plotted on a log-log plot of $\sigma(\tau)$ versus τ. The value of *N* can be read directly off of this line at $\tau = 1$. The units of *N* are $(rad/s)/\sqrt{Hz}$.

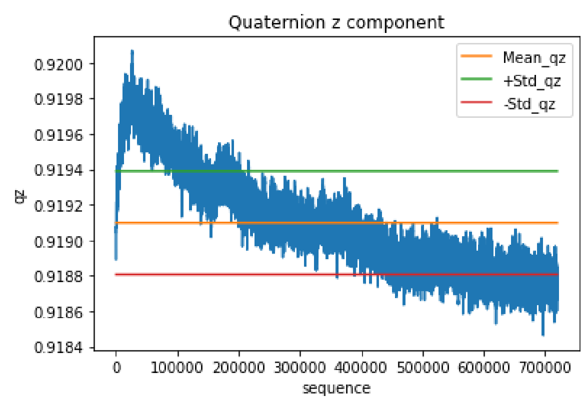
5hr IMU Data Analysis:

1. Quaternions:

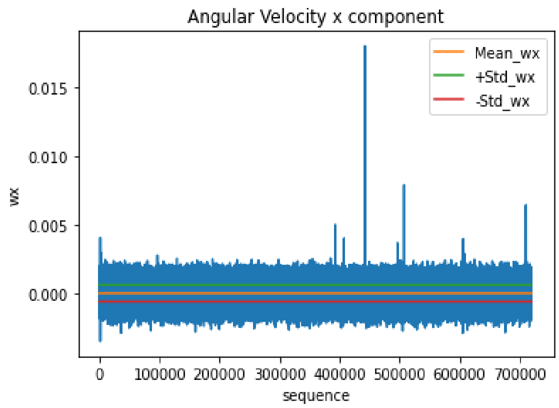


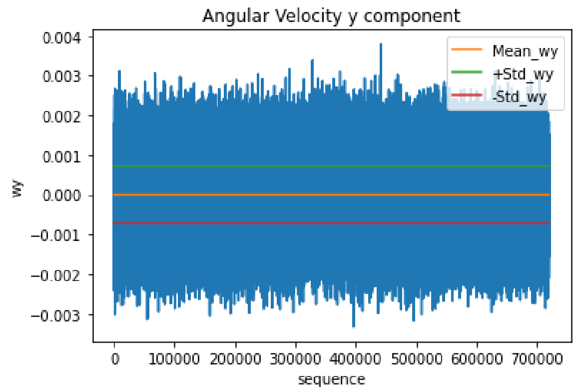


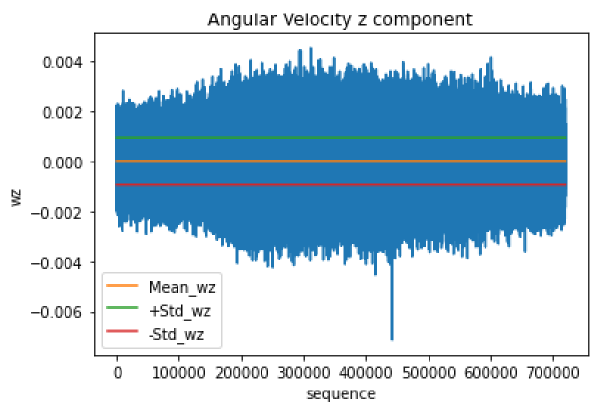




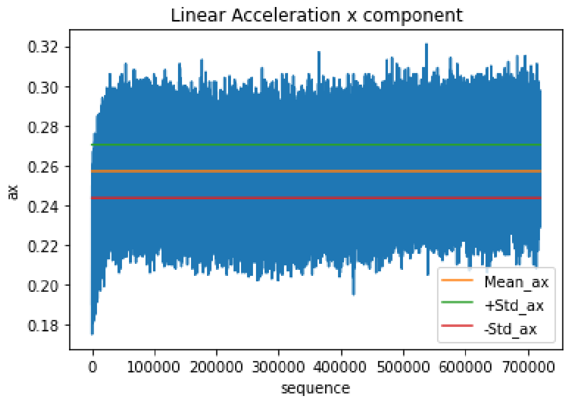
2. Angular Velocity:

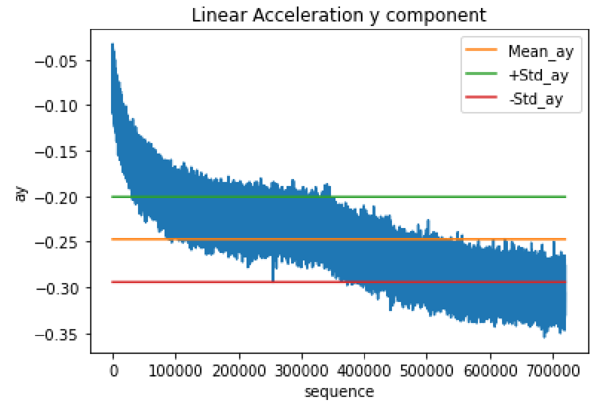


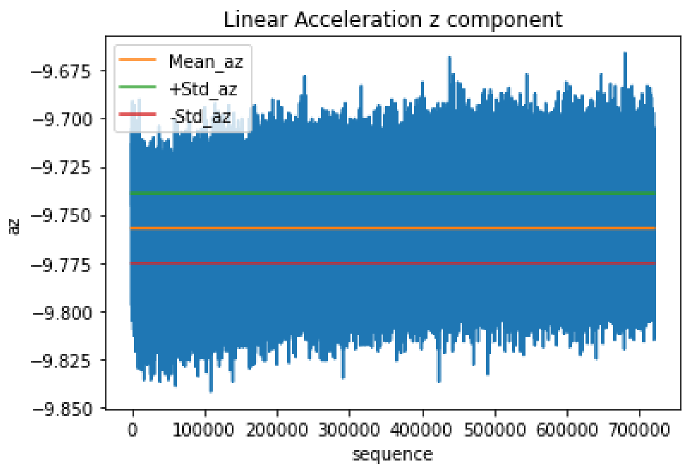




3. Linear Acceleration:







4. Magnetic Field: