ASEN 6080 HW 3

– Ian Faber, 108577813

1. b. Use the filters with SNC to process the data from HW2 with J_3 in the dynamics, but not the filter model. Characterize the performance of the filters over the range $\sigma \in [10^{-15}, 10^{-2}]$ km/s^2.

i. Plot the post-fit RMS of the measurements as a function of σ

See PDF

ii. Plot the 3D position + velocity RMS vs. σ

– See PDF

iii. What is the optimal value of σ to use? Why?

I found that the optimal value of σ to use was

$\sigma = 10^{-8}$ km/s^2,

as it balances postfit RMS as close to 1 as possible while also minimizing 3D RMS. In fact, 10^{-8} km/s^2 results in postfit RMS's of 1.0006 for LKF and 1.0021 for EKF, with respective 3D RMS's of 0.155044 and 0.281466.

iv. Show the filter performance with the optimal σ by plotting the time history of the state errors with covariance bounds, as well as the postfit residuals.

See PDF.

c. Define Q in the RIC frame and discuss its performance relative to Q in the ECI frame.

See PDF for plots.

Defining Q in the RIC frame as diagonal with the same σ as in ECI didn't affect the performance at all. This makes sense, as defining Q as diagonal with all identical entries essentially defines the initial covariance ellipse as a sphere, which is symmetrical in every orientation. Thus, rotation doesn't have any effect.

d. How else could $\Gamma(t_i, t_{i-1})$ be evaluated other than analytically?

We could numerically integrate Γ instead. In fact, this is very easy to do based on how I've implemented my filters.

we know that

$$\Gamma'(t_i, t_{i-1}) = \int_{t_{i-1}}^{t_i} \Phi(t_i, \tau) B(\tau)\, d\tau,$$

where $B = [0_{3\times3}, I_{3\times3}]^T$. I here,

$$\Gamma'(t_i, t_{i-1}) = \int_{t_{i-1}}^{t_i} \Phi(t_i, \tau)\, d\tau \cdot B$$

Since I already integrate Φ in my filters from t_{i-1} to t_i, all I have to do is multiply the result by B and I get the numerically integrated Γ'!

ASEN 6080 HW 3 Problem 1 Main Script

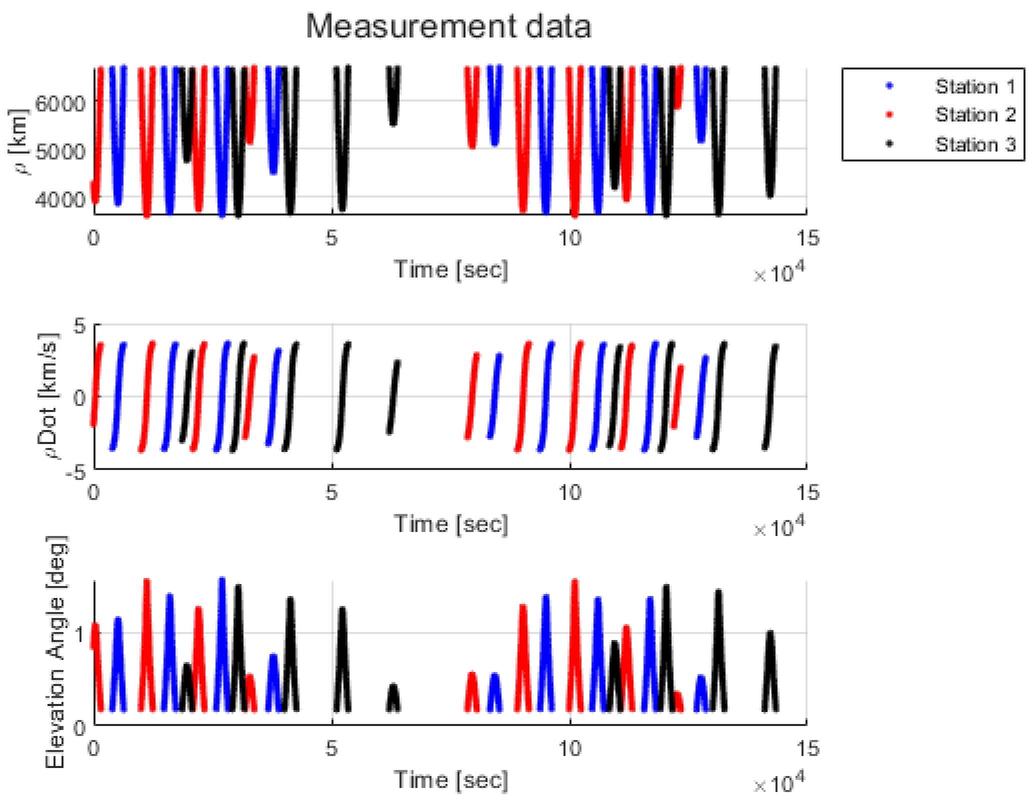
Table of Contents

By: Ian Faber

Housekeeping

Setup

Load Truth Data

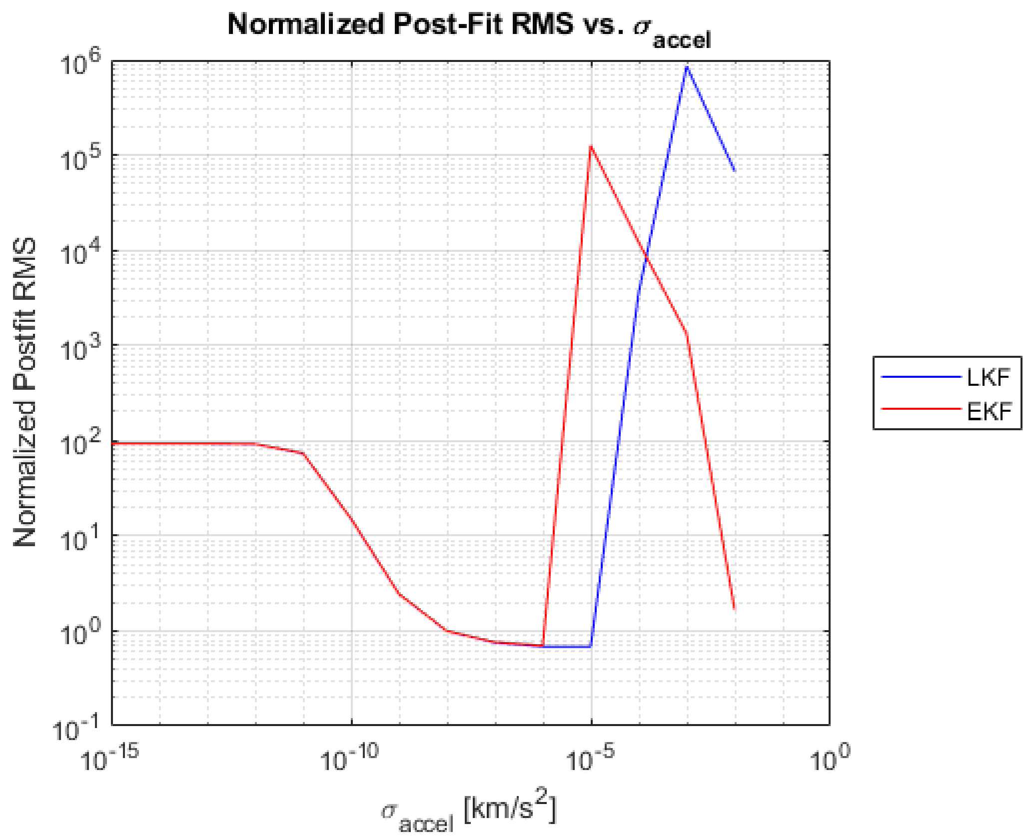


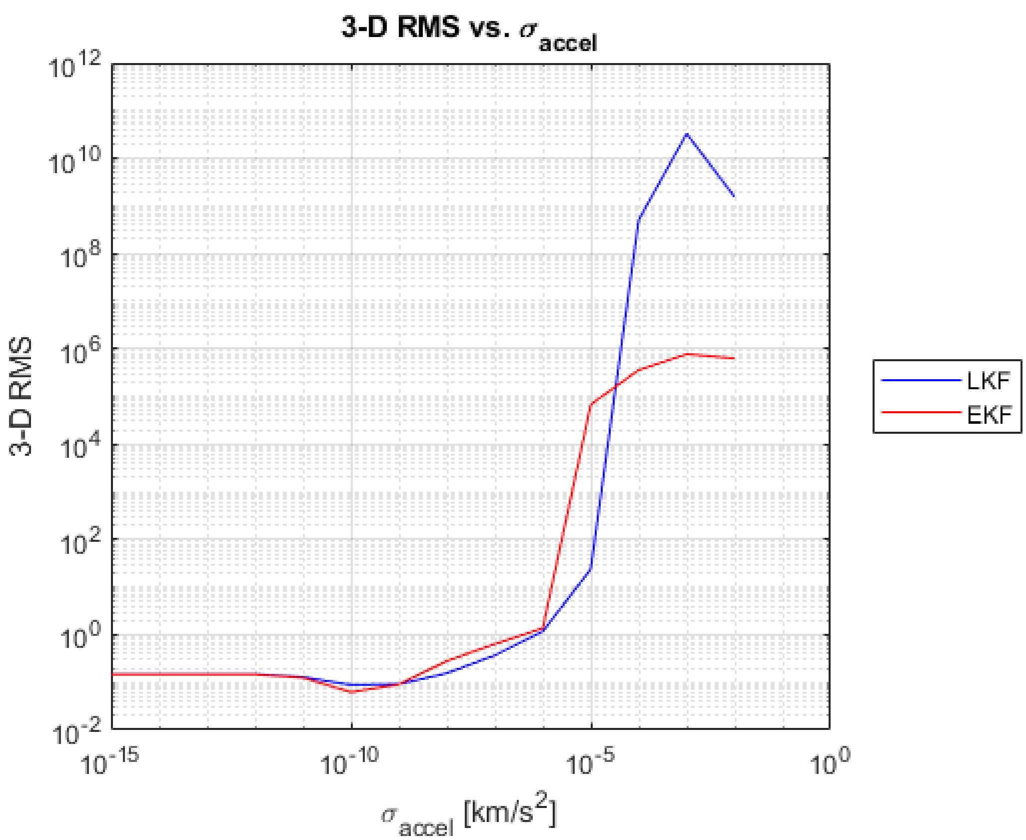
Problem 1b: Filter setup

Problem 1b: Run filters once per sigma

Problem 1b: Plot results vs. sigma

Plotting SNC filter results vs. sigma

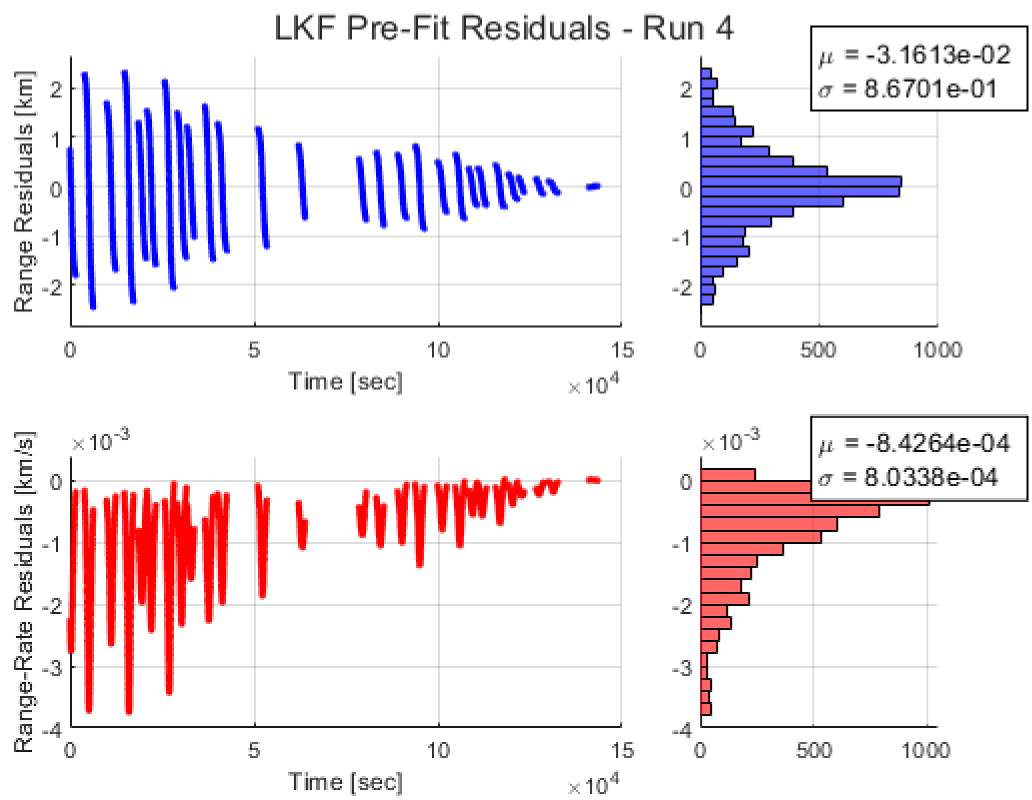

Normalized Post-Fit RMS vs. σ_{accel}
Normalized Postfit RMS
σ_{accel} [km/s^2]
LKF
EKF

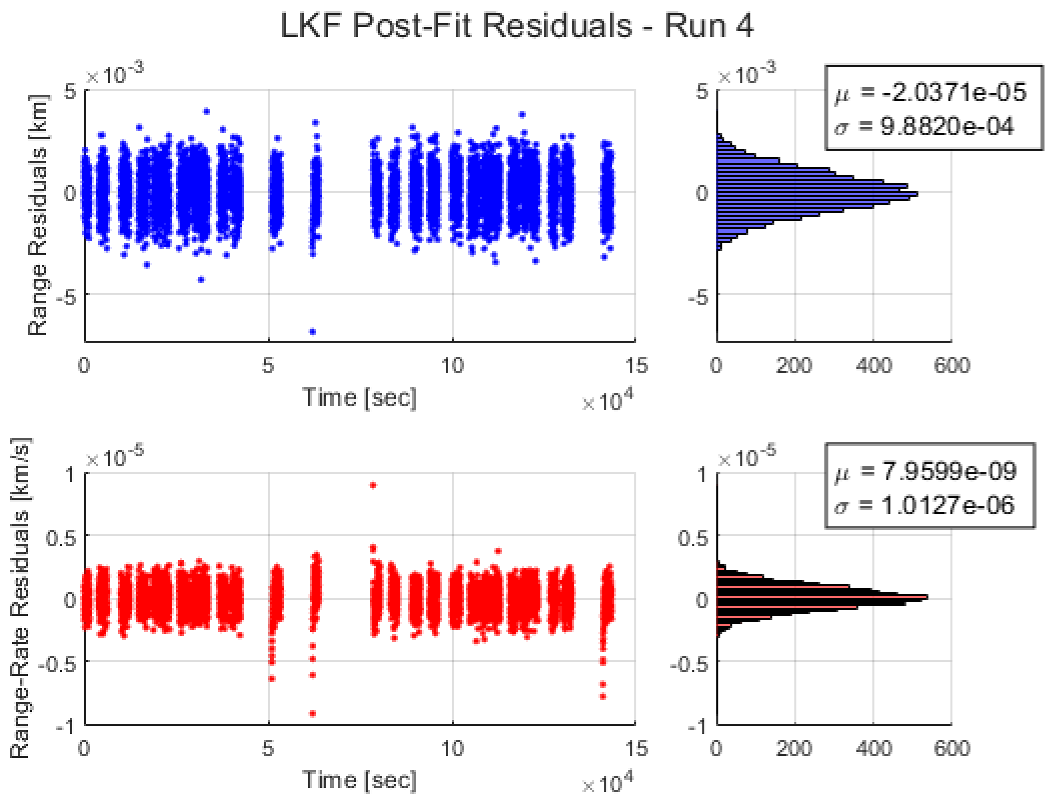

3-D RMS vs. σ_{accel}
3-D RMS
σ_{accel} [km/s^2]
LKF
EKF

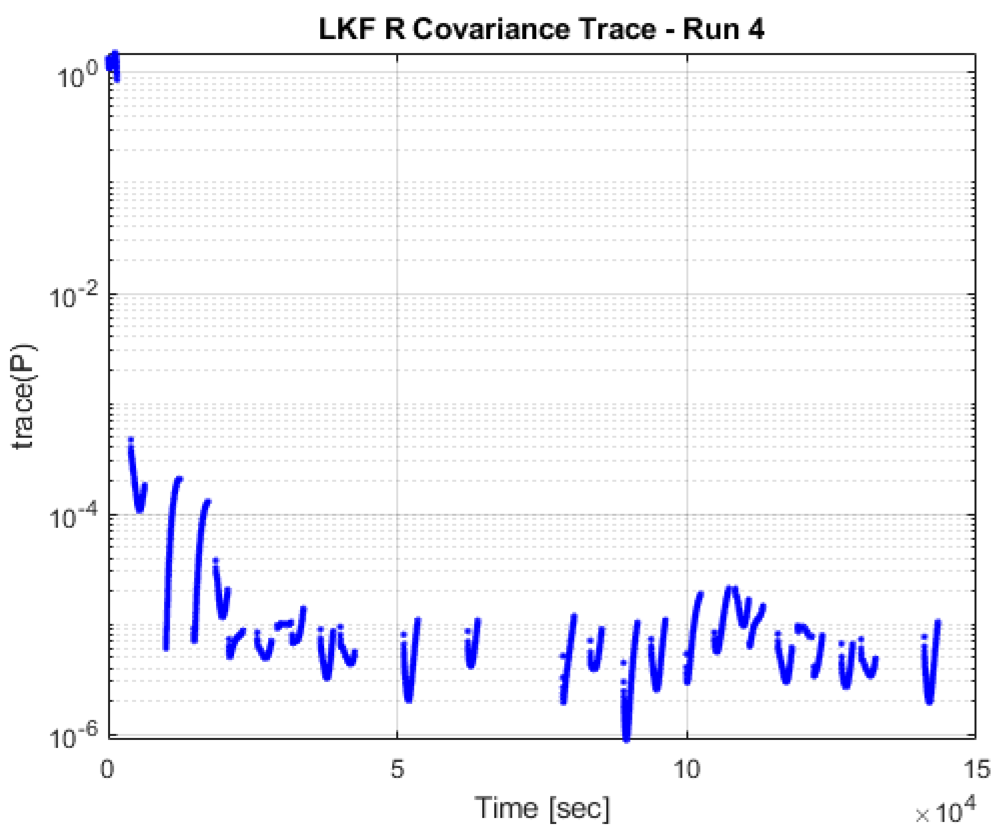
Problem 1b: Choose optimal sigma and show state errors

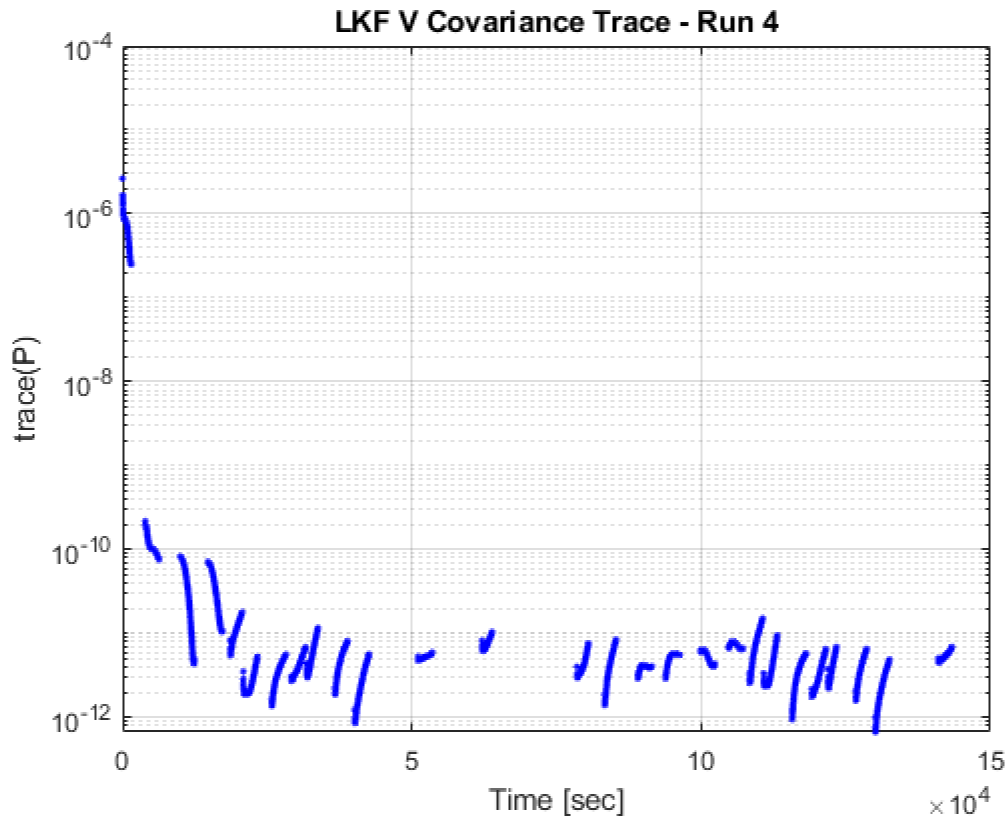
Based on plots, sigma = 1e-8 balances both postfit and 3D RMS

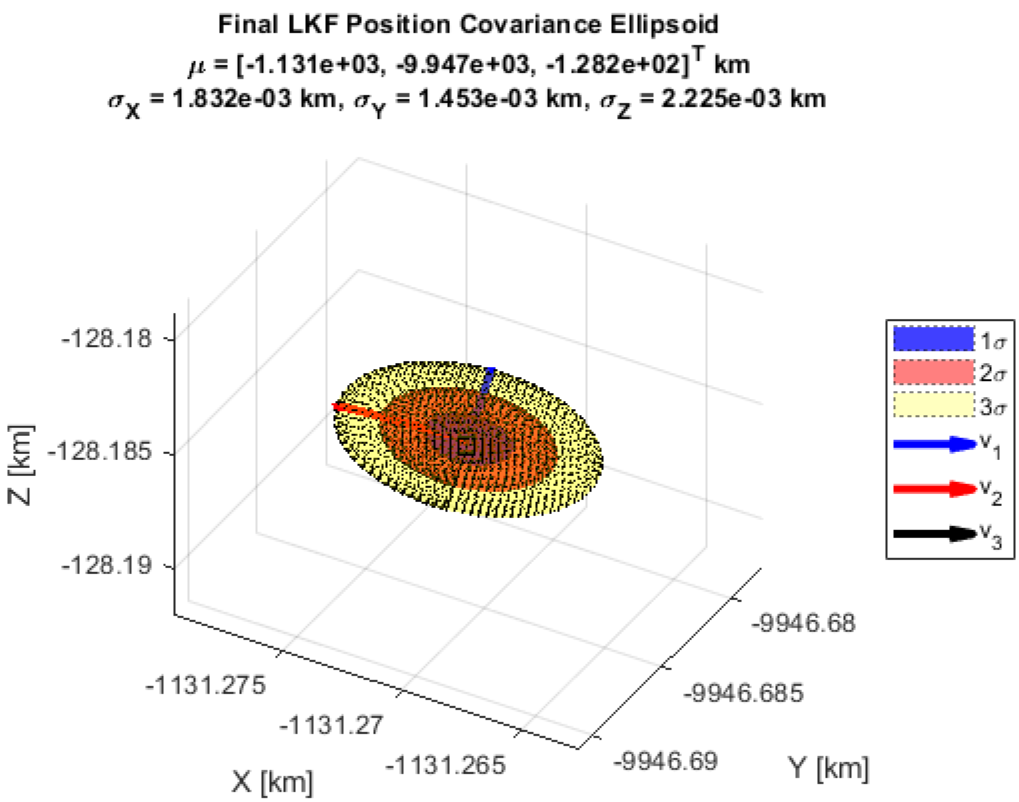
```
Plotting state errors vs. time for sigma = 1.000e-08 km/s^2

    Running LKF:
Prefit RMS: 9534.1497, Postfit RMS: 2.6087. Iterating LKF. Runs so far: 1
Prefit RMS: 8138.3783, Postfit RMS: 1.9022. Iterating LKF. Runs so far: 2
Prefit RMS: 3573.5092, Postfit RMS: 1.0638. Iterating LKF. Runs so far: 3
Prefit RMS: 1152.3100, Postfit RMS: 1.0010. Iterating LKF. Runs so far: 4
Final prefit RMS: 1026.6296. Converged after 4 runs
Final postfit RMS: 1.0006. Converged after 4 runs

    Running EKF:
Prefit RMS: 1.0021
Postfit RMS: 1.0021
```

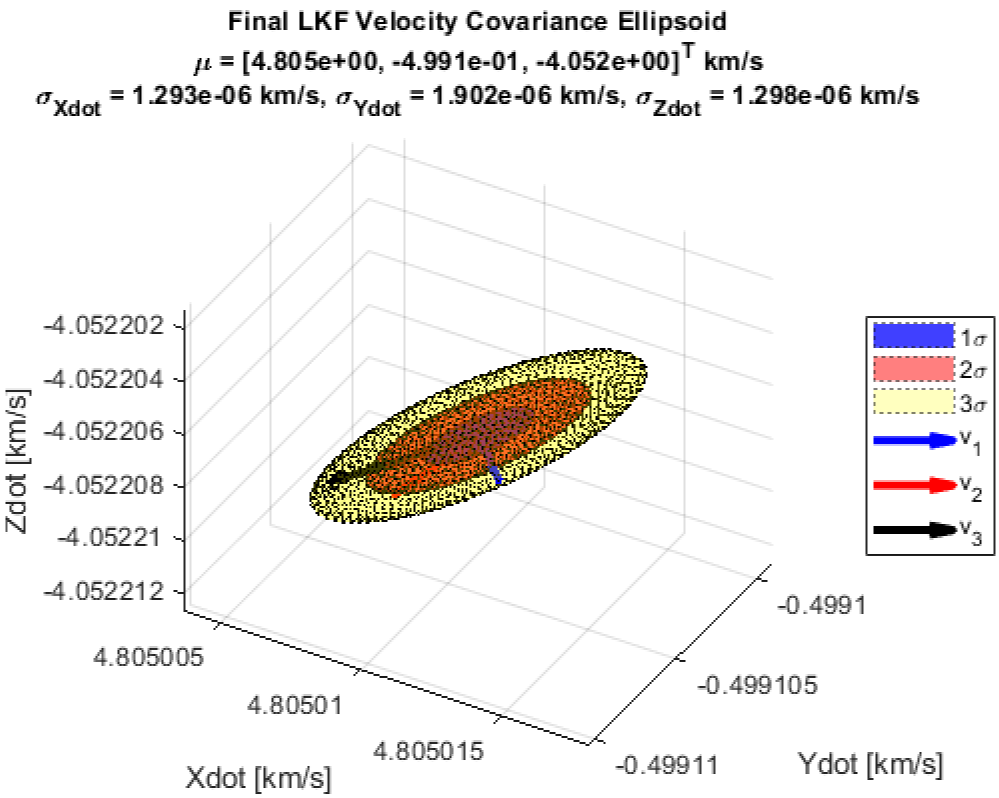


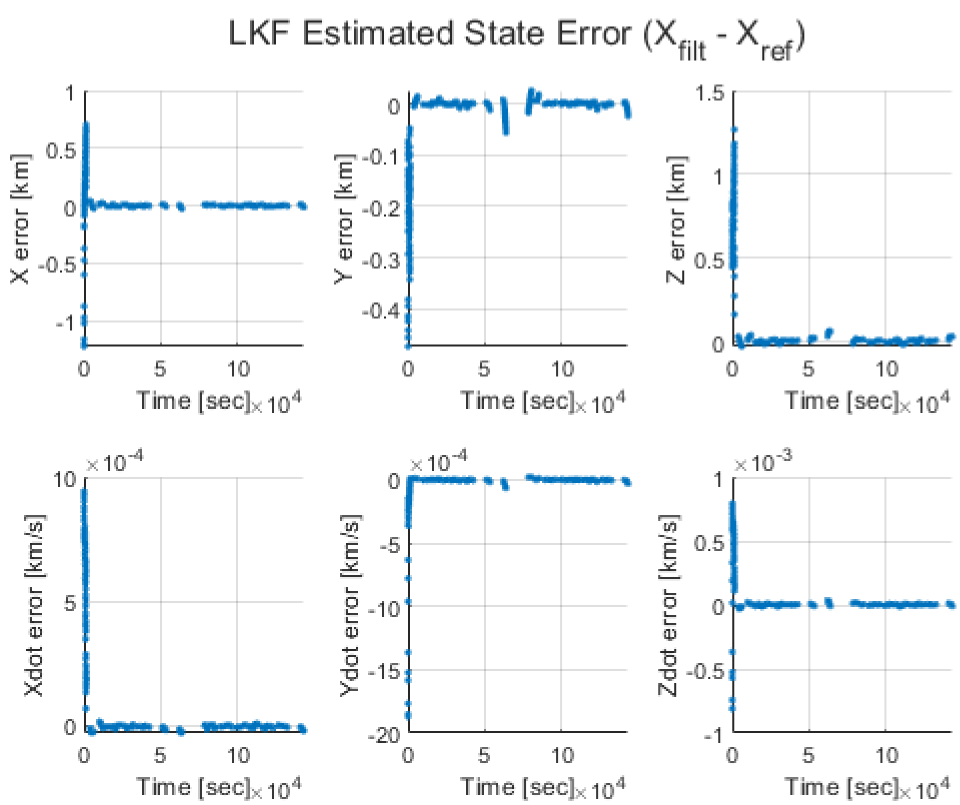

LKF Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = -2.0371e-05
σ = 9.8820e-04
Range-Rate Residuals [km/s]
Time [sec]
μ = 7.9599e-09
σ = 1.0127e-06

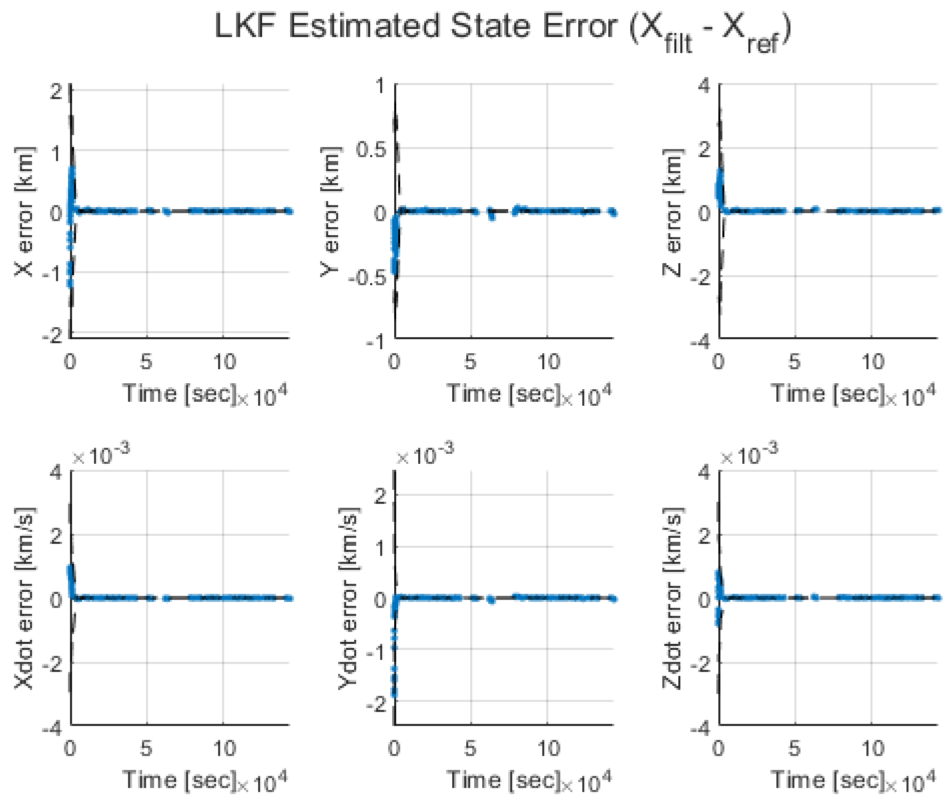

LKF R Covariance Trace - Run 4
trace(P)
Time [sec]

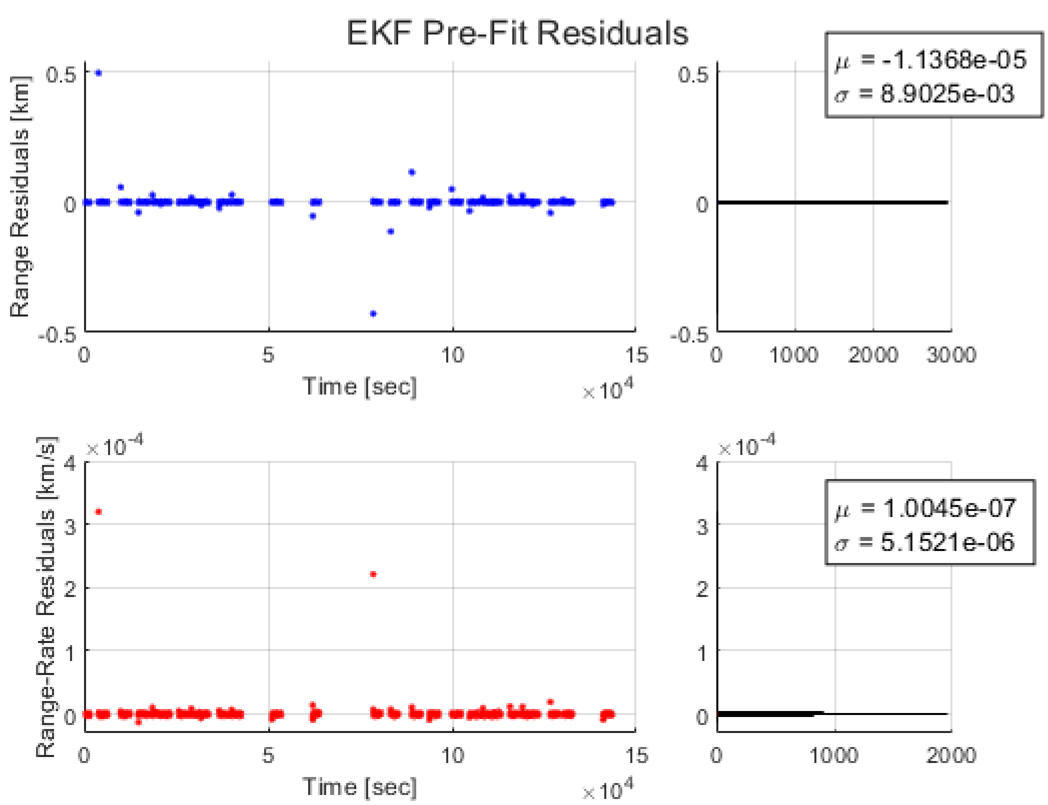

LKF V Covariance Trace - Run 4
trace(P)
Time [sec]
$\times 10^4$

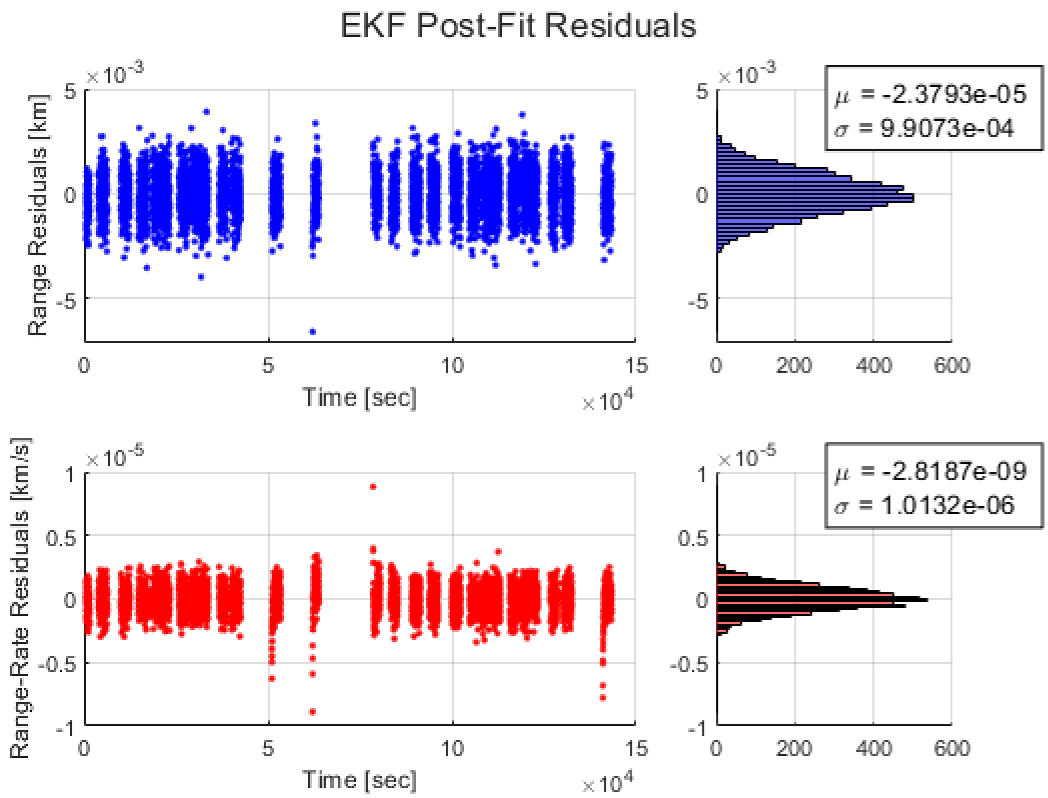

Final LKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σ_X = 1.832e-03 km, σ_Y = 1.453e-03 km, σ_Z = 2.225e-03 km
Z [km]
X [km]
Y [km]
1σ
2σ
3σ
v_1
v_2
v_3

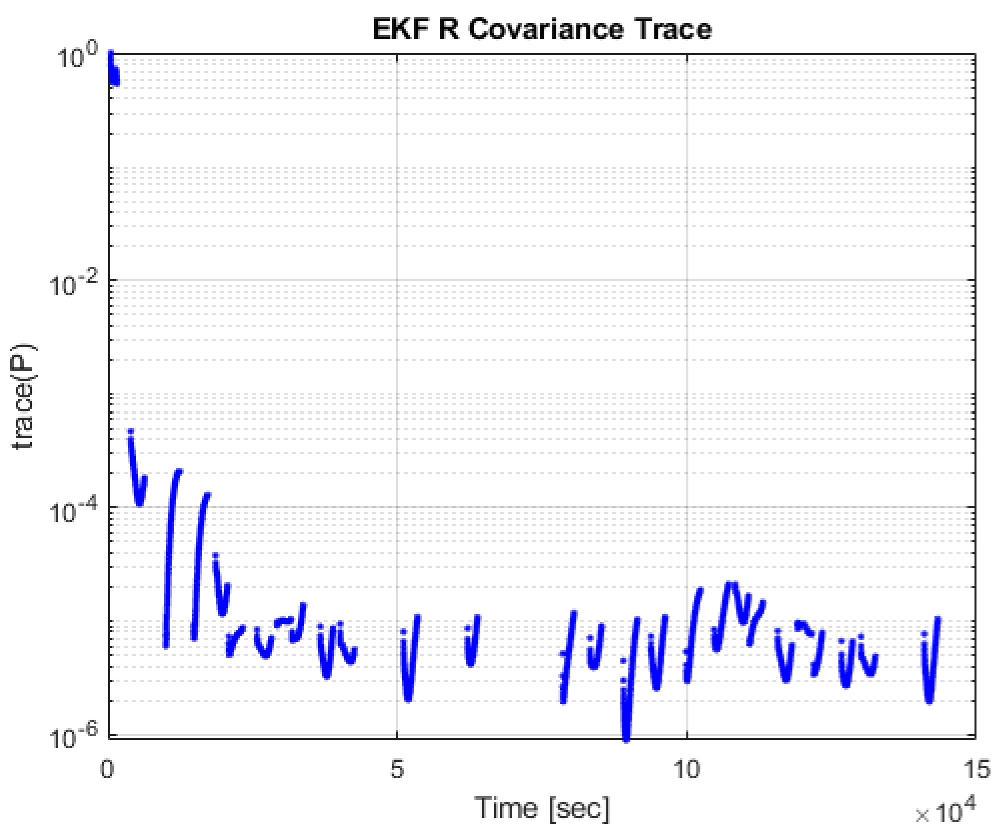

Final LKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]^T km/s
σ_{Xdot} = 1.293e-06 km/s, σ_{Ydot} = 1.902e-06 km/s, σ_{Zdot} = 1.298e-06 km/s
1σ
2σ
3σ
v_1
v_2
v_3
Zdot [km/s]
Xdot [km/s]
Ydot [km/s]

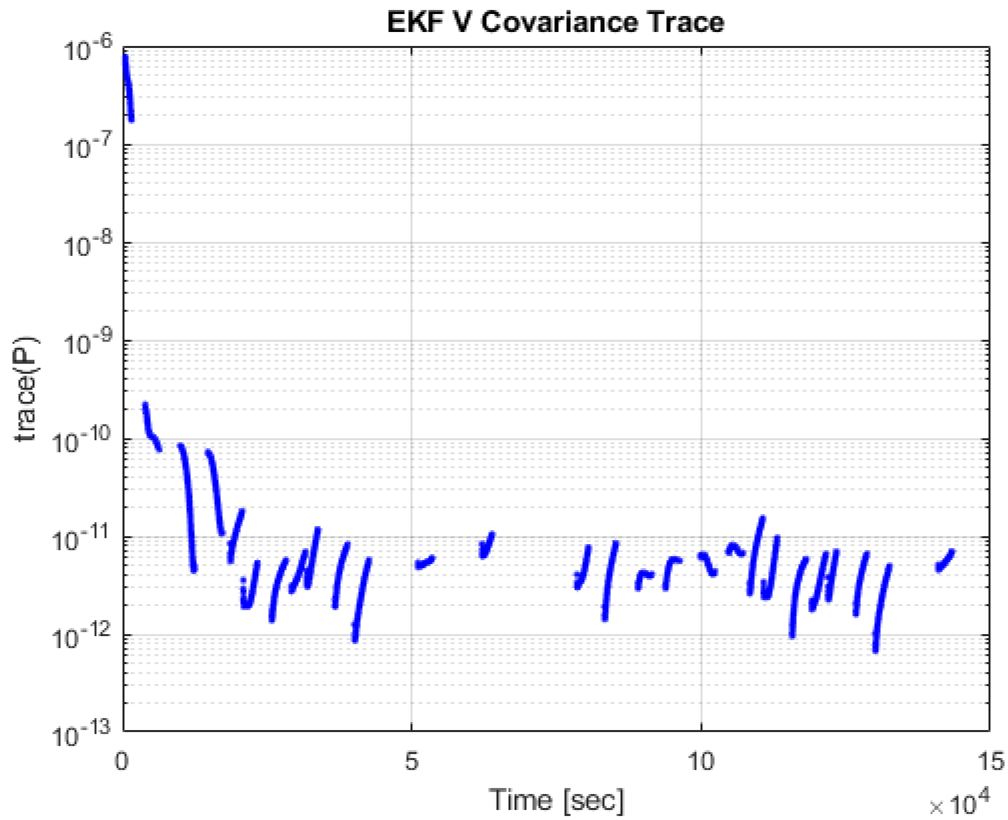

LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
$\times 10^4$

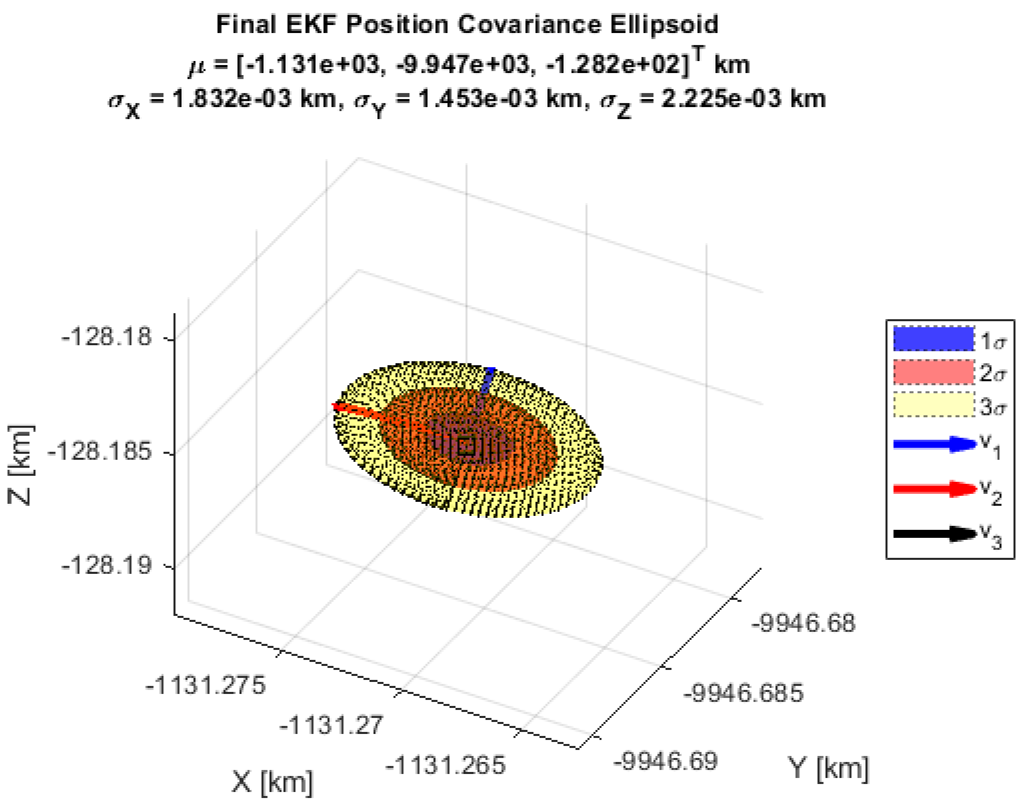

LKF Estimated State Error (Xfilt - Xref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3

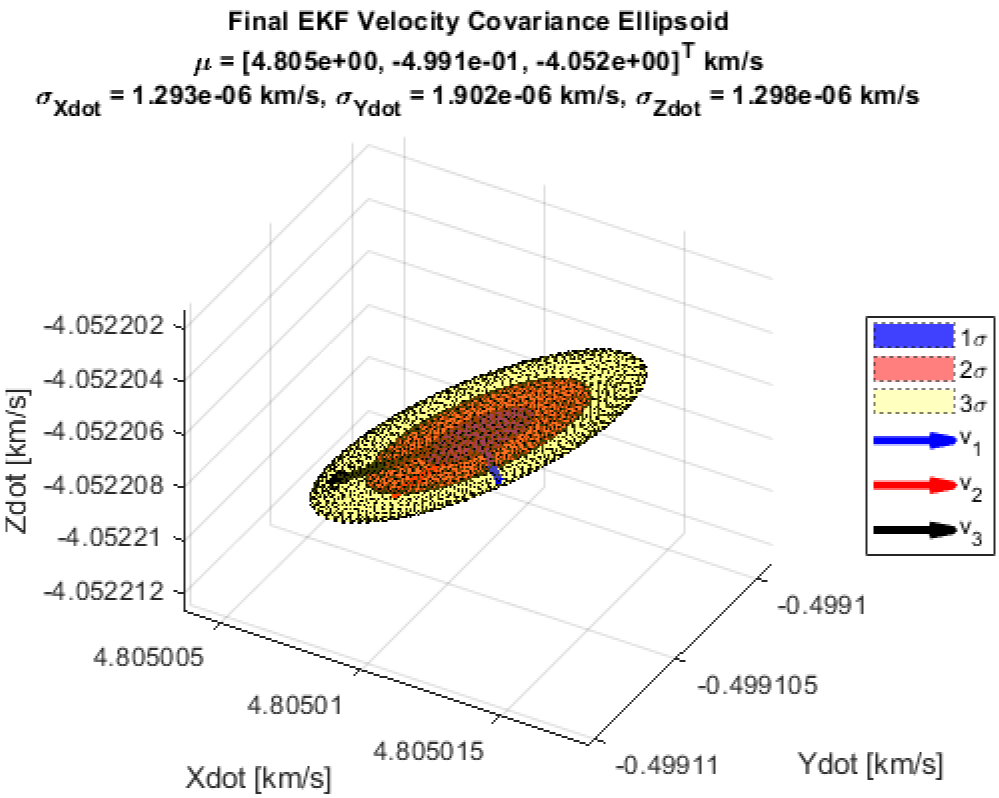

EKF Pre-Fit Residuals
Range Residuals [km]
μ = -1.1368e-05
σ = 8.9025e-03
Range-Rate Residuals [km/s]
μ = 1.0045e-07
σ = 5.1521e-06
Time [sec]
×10^4
×10^-4

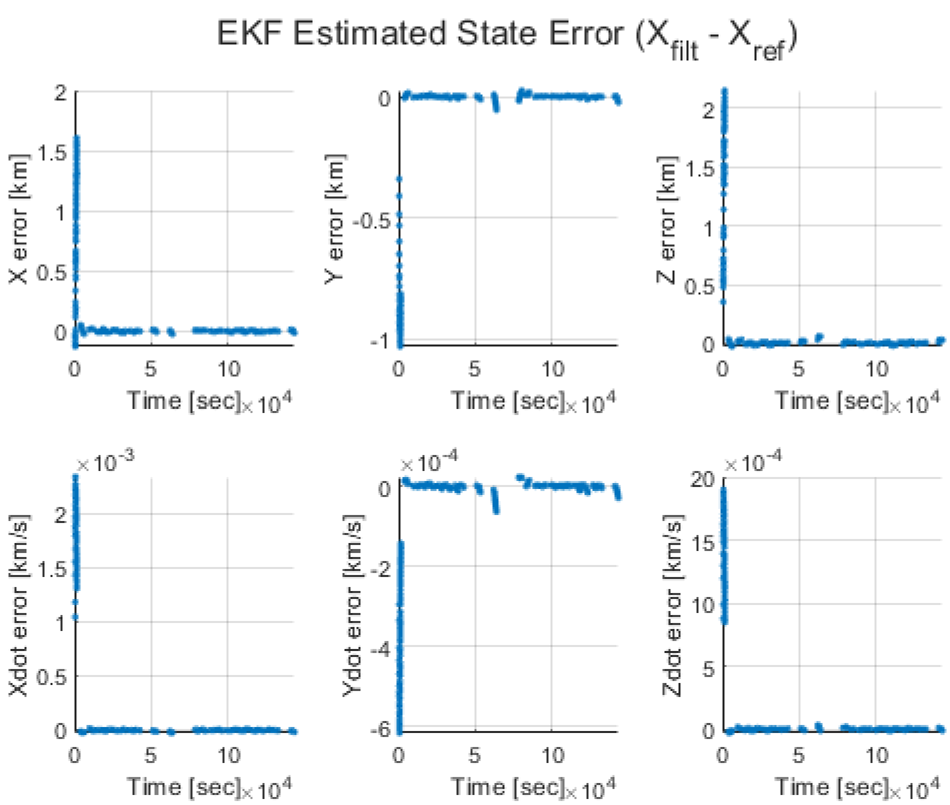

EKF Post-Fit Residuals
Range Residuals [km]
×10^-3
Time [sec]
×10^4
μ = -2.3793e-05
σ = 9.9073e-04
Range-Rate Residuals [km/s]
×10^-5
μ = -2.8187e-09
σ = 1.0132e-06

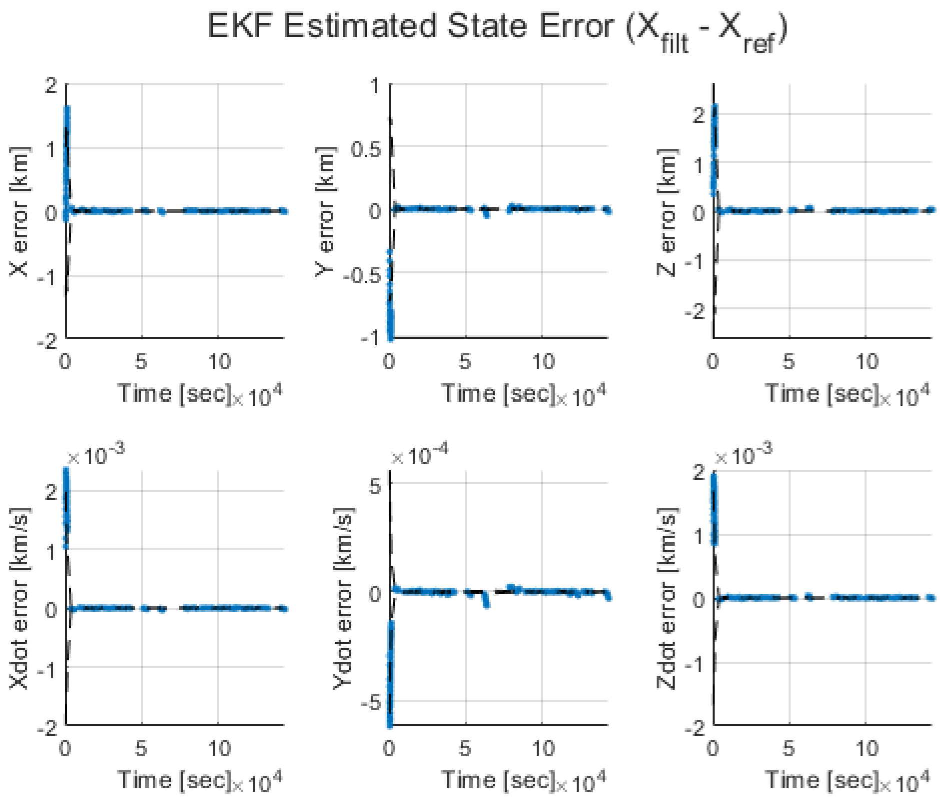

EKF R Covariance Trace
trace(P)
Time [sec]
×10^4


EKF V Covariance Trace
trace(P)
Time [sec]
$\times 10^4$


Final EKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σ_X = 1.832e-03 km, σ_Y = 1.453e-03 km, σ_Z = 2.225e-03 km
Z [km]
X [km]
Y [km]
1σ
2σ
3σ
v_1
v_2
v_3


Final EKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]T km/s
σXdot = 1.293e-06 km/s, σYdot = 1.902e-06 km/s, σZdot = 1.298e-06 km/s
Zdot [km/s]
-4.052202
-4.052204
-4.052206
-4.052208
-4.05221
-4.052212
4.805005
4.80501
4.805015
Xdot [km/s]
-0.4991
-0.499105
-0.49911
Ydot [km/s]
1σ
2σ
3σ
v1
v2
v3


EKF Estimated State Error (Xfilt - Xref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3
×10^-4



Problem 1c: Define Q in the RIC frame and run again

```
Running filters again with Q defined in RIC frame

    Running LKF:
Prefit RMS: 9534.1497, Postfit RMS: 2.6087. Iterating LKF. Runs so far: 1
Prefit RMS: 8138.3783, Postfit RMS: 1.9022. Iterating LKF. Runs so far: 2
Prefit RMS: 3573.5092, Postfit RMS: 1.0638. Iterating LKF. Runs so far: 3
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Final prefit RMS: 1026.6296. Converged after 4 runs
Final postfit RMS: 1.0006. Converged after 4 runs

    Running EKF:
Prefit RMS: 1.0021
Postfit RMS: 1.0021
```
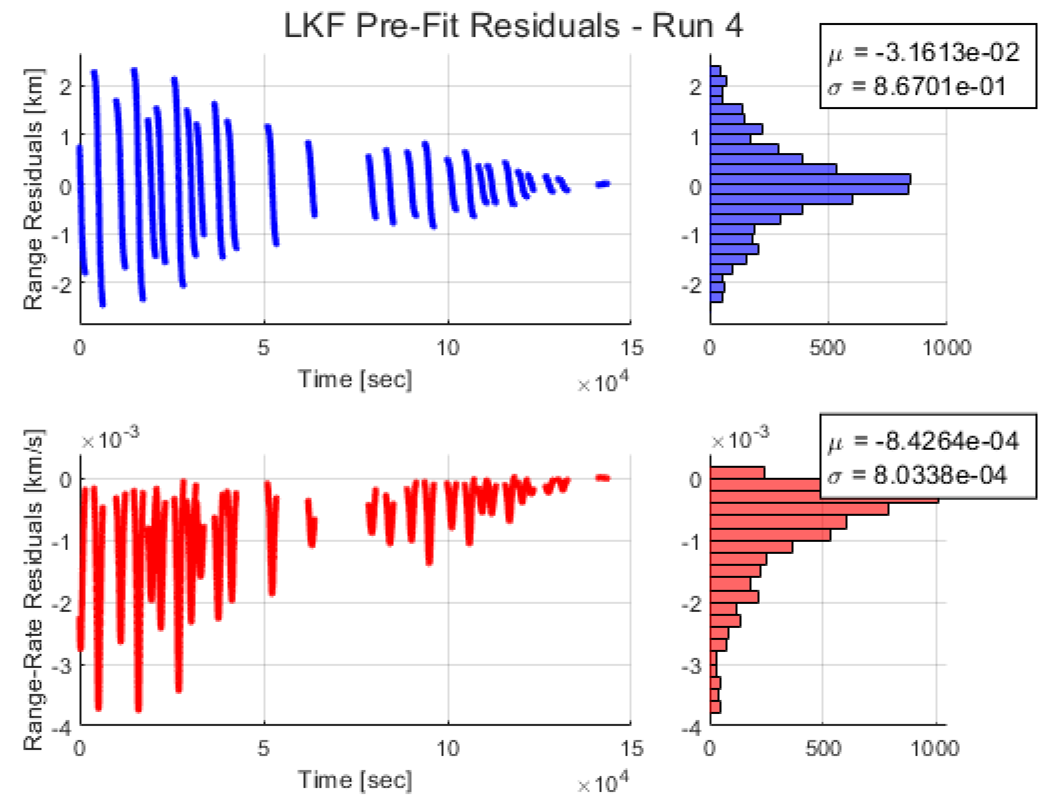
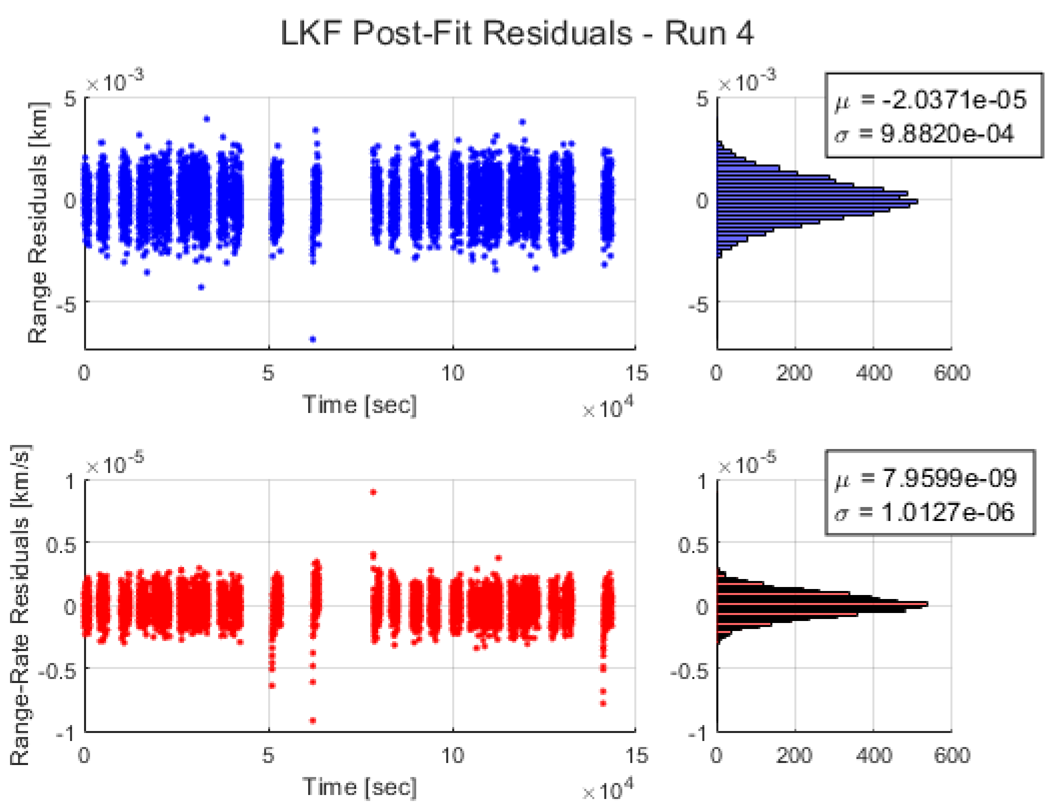
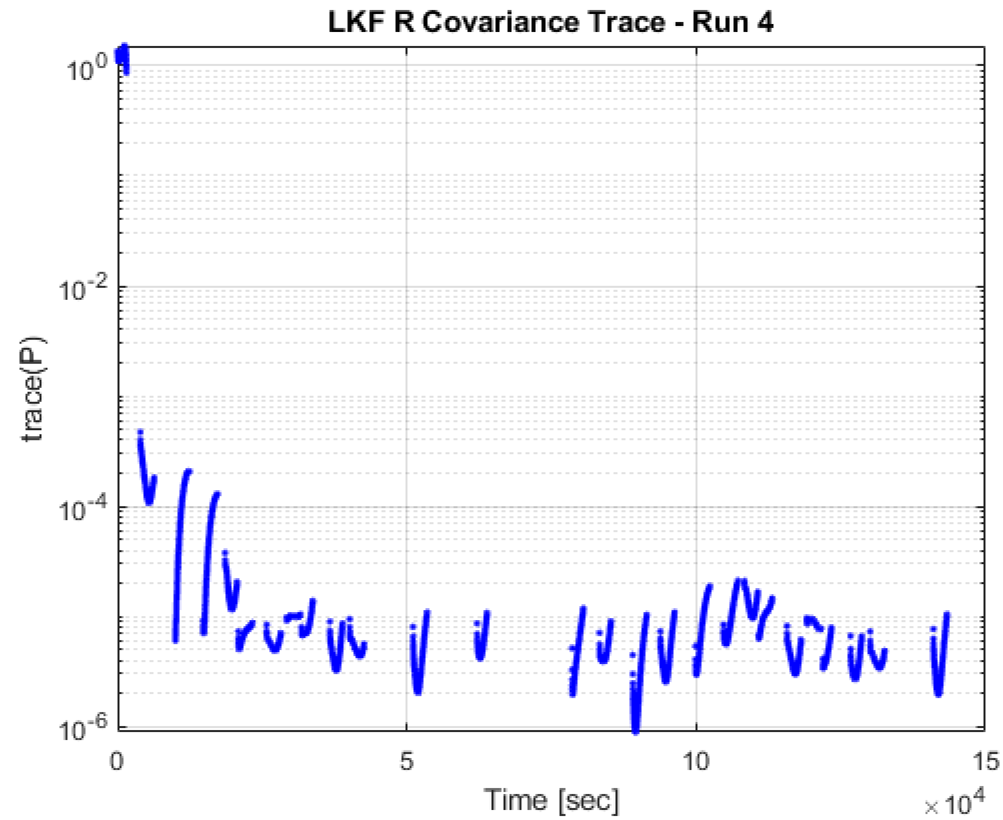
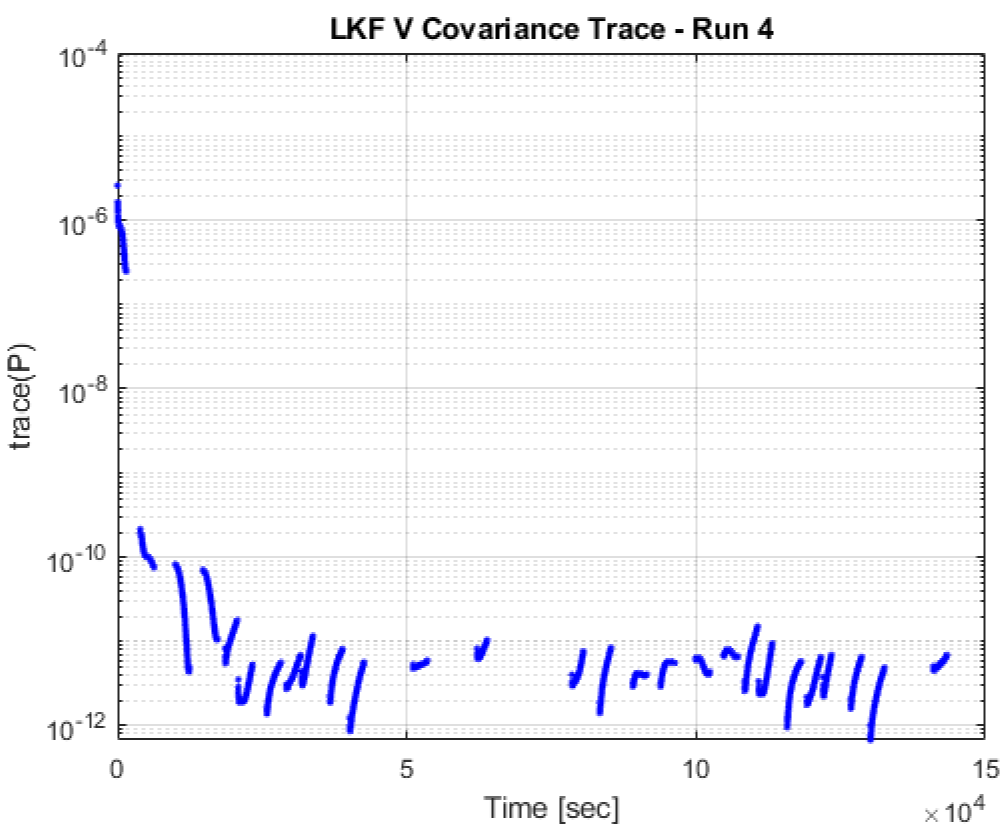
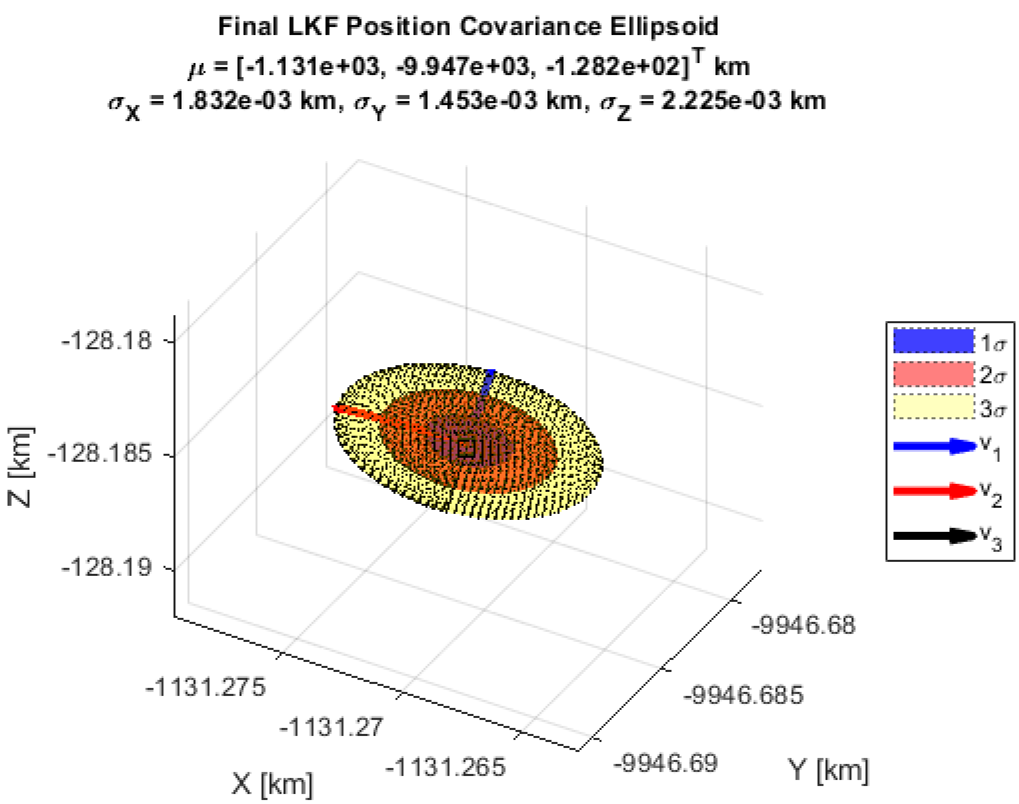
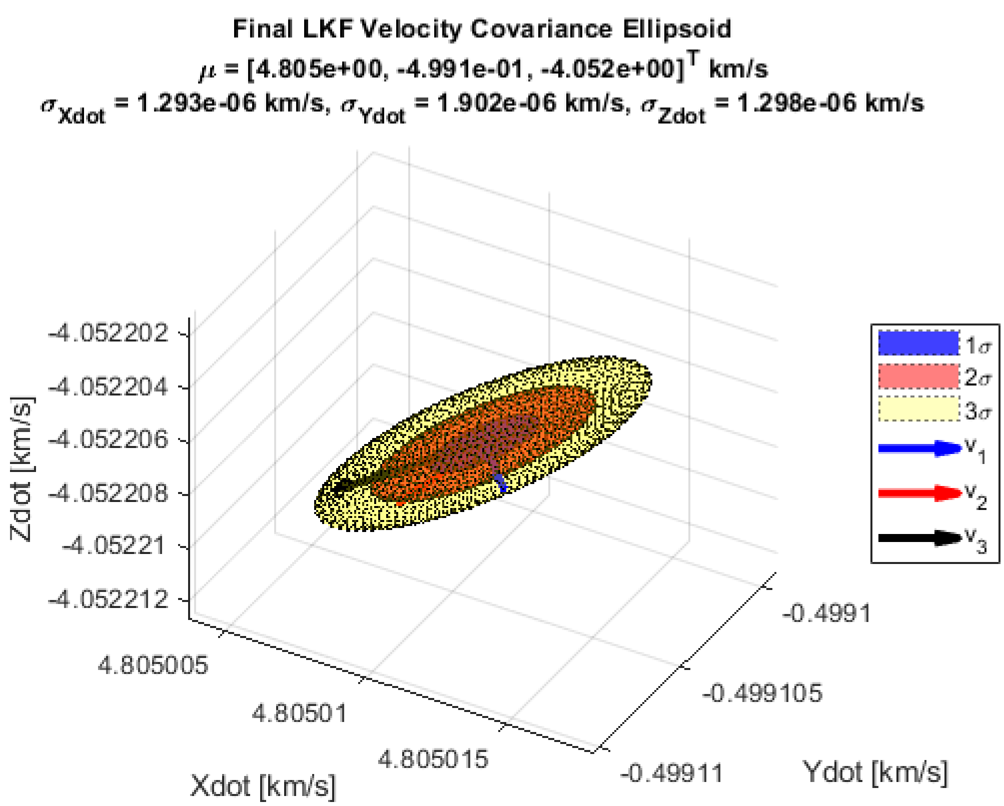


LKF Pre-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
$\times 10^4$
μ = -3.1613e-02
σ = 8.6701e-01
Range-Rate Residuals [km/s]
$\times 10^{-3}$
μ = -8.4264e-04
σ = 8.0338e-04

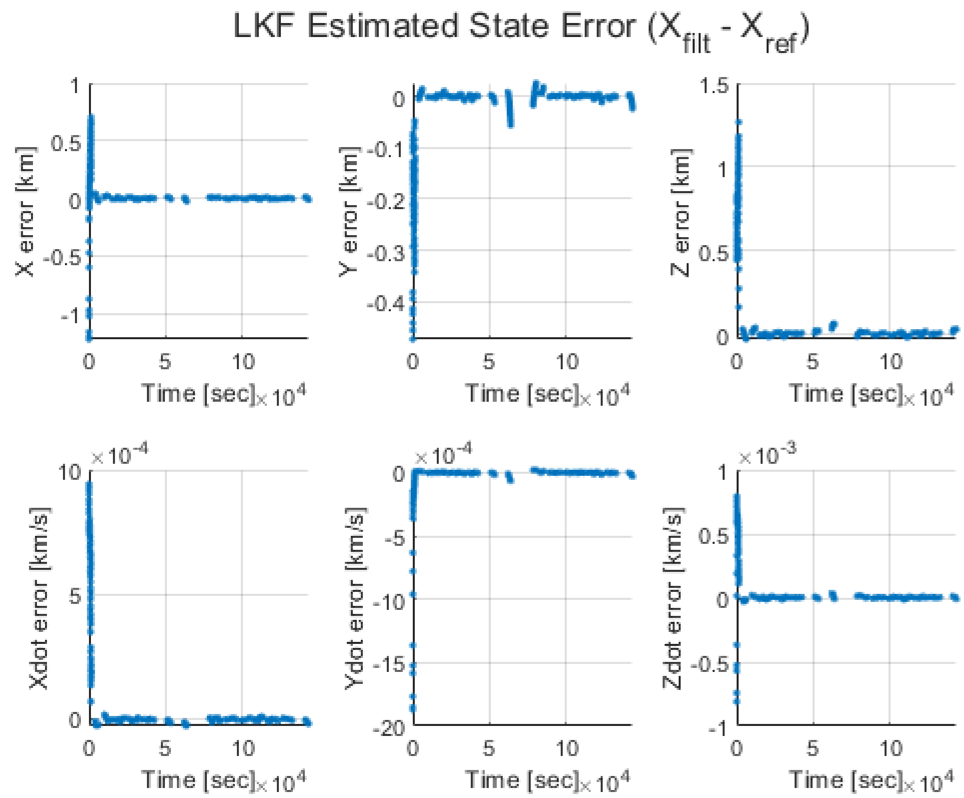

LKF Post-Fit Residuals - Run 4
Range Residuals [km]
$\times 10^{-3}$
Time [sec]
$\times 10^4$
μ = -2.0371e-05
σ = 9.8820e-04
Range-Rate Residuals [km/s]
$\times 10^{-5}$
μ = 7.9599e-09
σ = 1.0127e-06

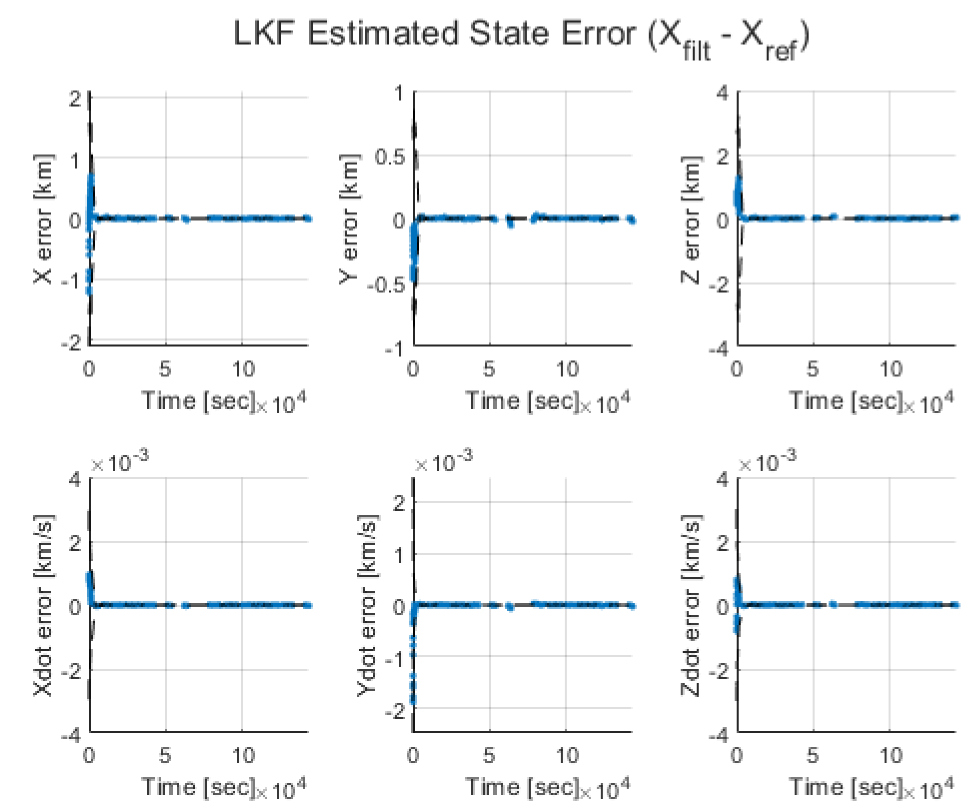

LKF R Covariance Trace - Run 4
trace(P)
10^{0}
10^{-2}
10^{-4}
10^{-6}
0
5
10
15
Time [sec]
$\times 10^{4}$

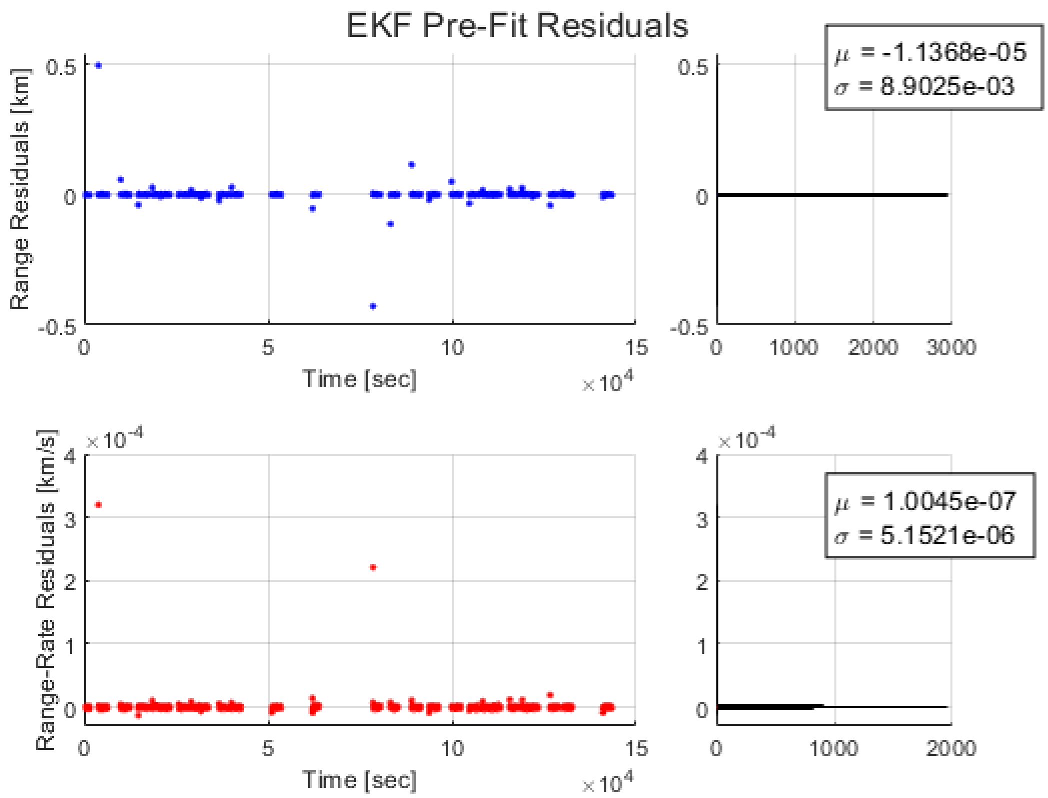

LKF V Covariance Trace - Run 4
trace(P)
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
0
5
10
15
Time [sec]
$\times 10^{4}$

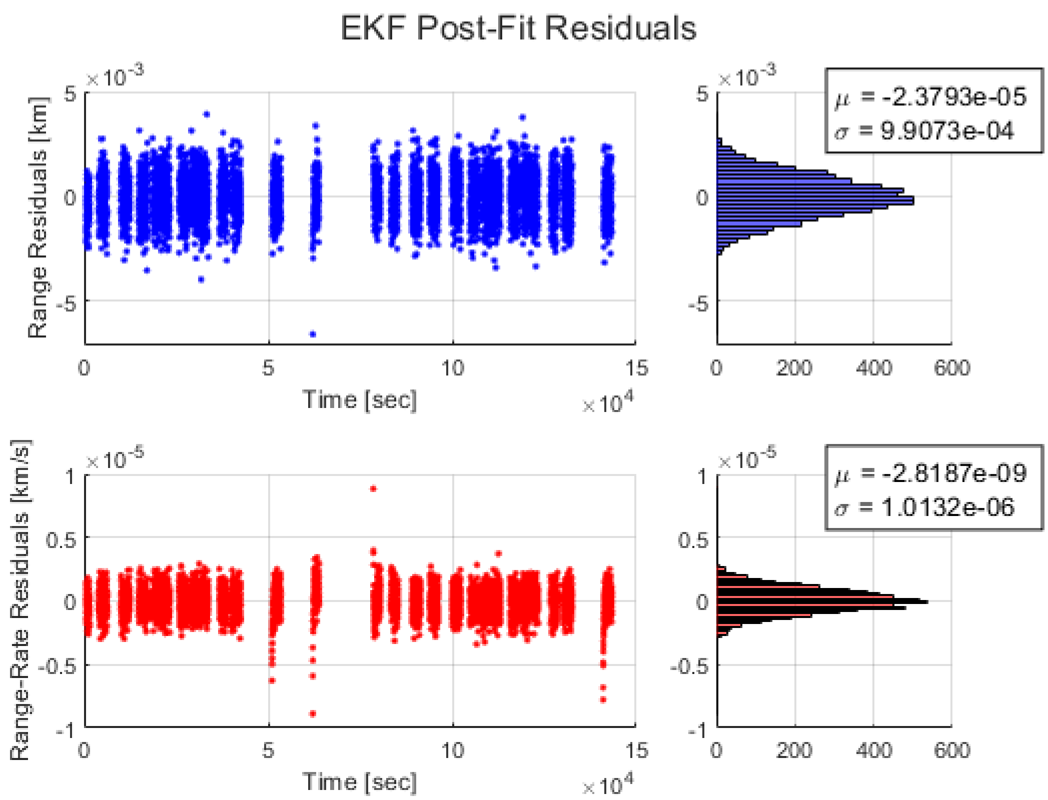

Final LKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σ_X = 1.832e-03 km, σ_Y = 1.453e-03 km, σ_Z = 2.225e-03 km
-128.18
-128.185
-128.19
Z [km]
-1131.275
-1131.27
-1131.265
X [km]
-9946.68
-9946.685
-9946.69
Y [km]
1σ
2σ
3σ
v1
v2
v3

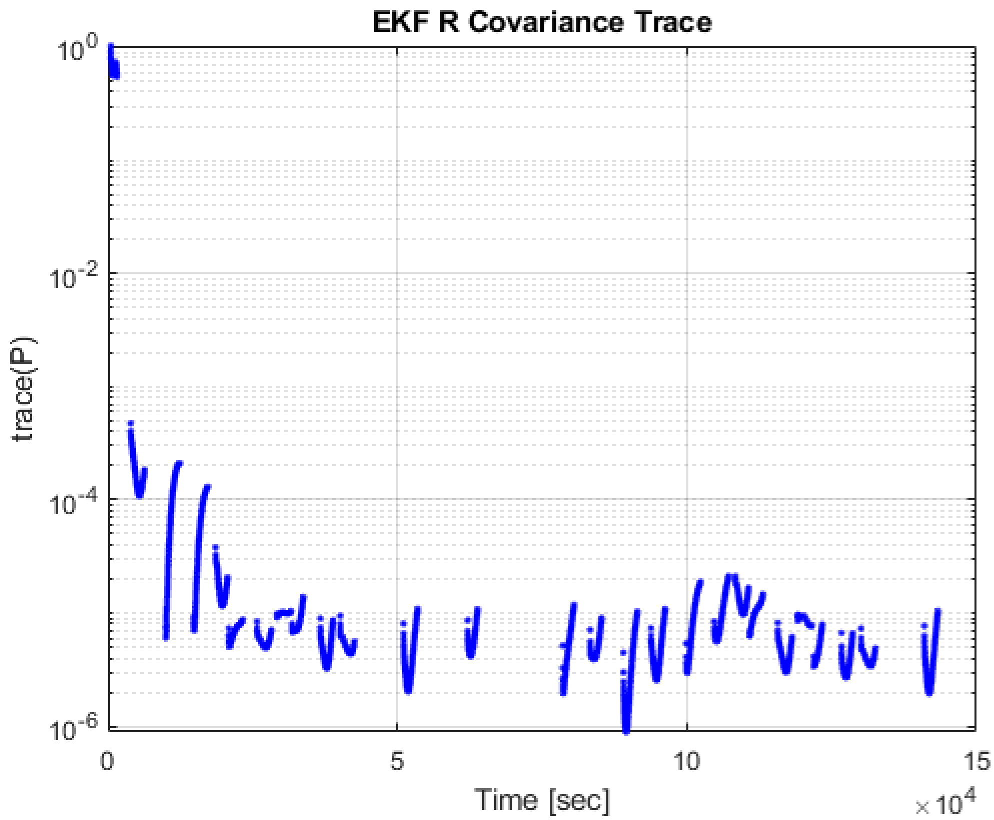

Final LKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]^T km/s
σ_Xdot = 1.293e-06 km/s, σ_Ydot = 1.902e-06 km/s, σ_Zdot = 1.298e-06 km/s
-4.052202
-4.052204
-4.052206
-4.052208
-4.05221
-4.052212
Zdot [km/s]
4.805005
4.80501
4.805015
Xdot [km/s]
-0.4991
-0.499105
-0.49911
Ydot [km/s]
1σ
2σ
3σ
v1
v2
v3

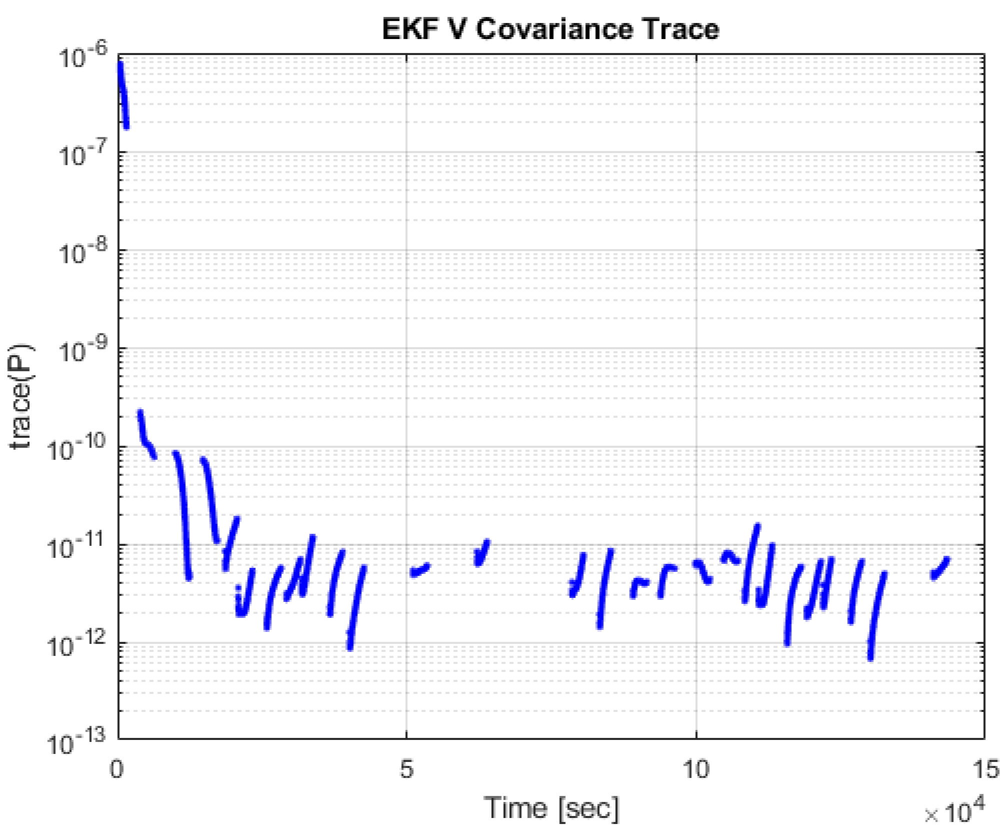

LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-4
×10^-3

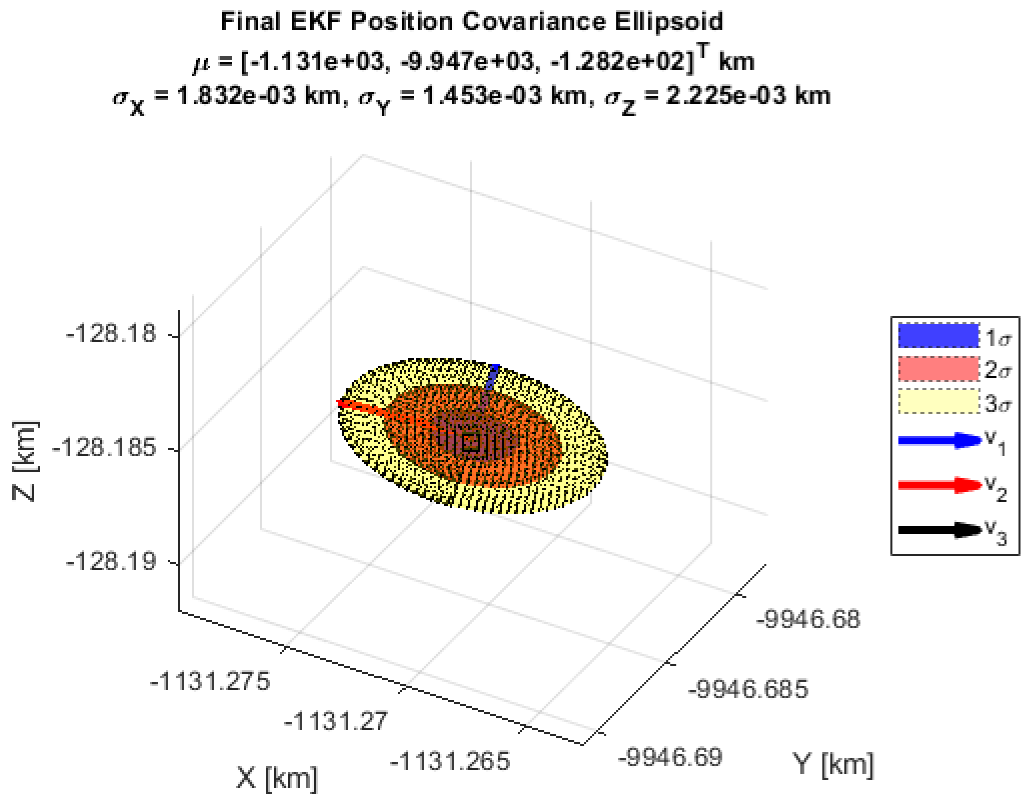

LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3

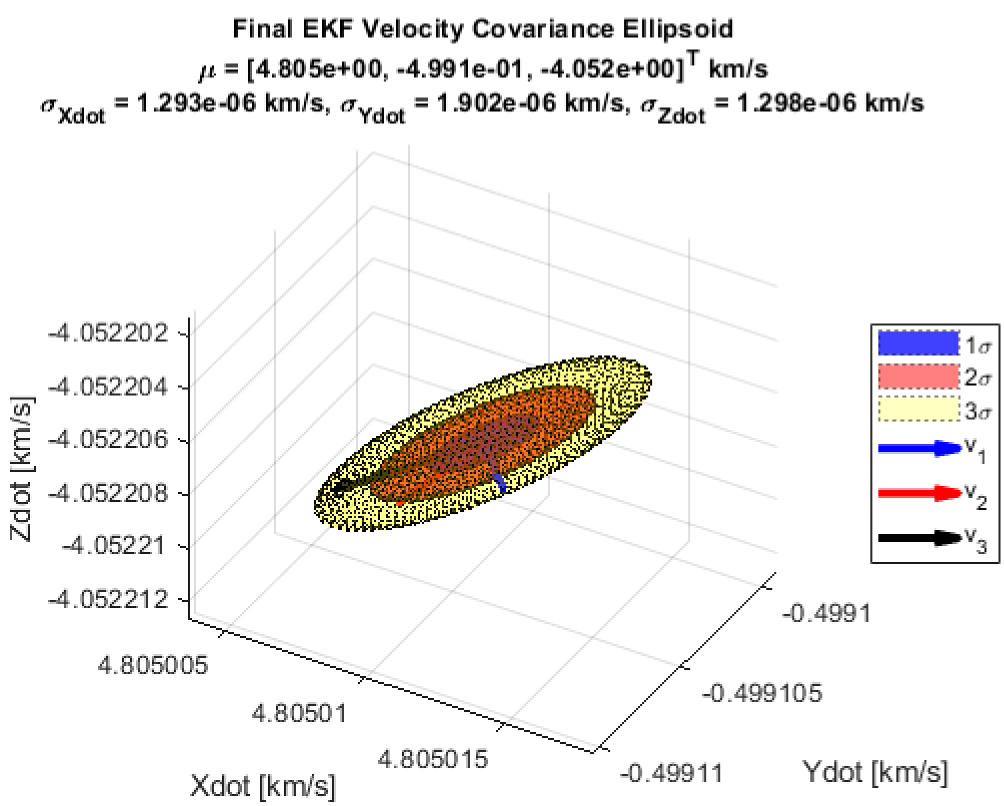

EKF Pre-Fit Residuals
Range Residuals [km]
Time [sec]
$\times 10^4$
μ = -1.1368e-05
σ = 8.9025e-03
Range-Rate Residuals [km/s]
$\times 10^{-4}$
μ = 1.0045e-07
σ = 5.1521e-06


EKF Post-Fit Residuals
Range Residuals [km]
$\times 10^{-3}$
Time [sec]
$\times 10^4$
μ = -2.3793e-05
σ = 9.9073e-04
Range-Rate Residuals [km/s]
$\times 10^{-5}$
μ = -2.8187e-09
σ = 1.0132e-06


EKF R Covariance Trace
trace(P)
10^0
10^-2
10^-4
10^-6
0
5
10
15
Time [sec]
×10^4


EKF V Covariance Trace
trace(P)
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
0
5
10
15
Time [sec]
×10^4


Final EKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σ_X = 1.832e-03 km, σ_Y = 1.453e-03 km, σ_Z = 2.225e-03 km
-128.18
-128.185
-128.19
Z [km]
-1131.275
-1131.27
-1131.265
X [km]
-9946.68
-9946.685
-9946.69
Y [km]
1σ
2σ
3σ
v_1
v_2
v_3


Final EKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]^T km/s
σ_{Xdot} = 1.293e-06 km/s, σ_{Ydot} = 1.902e-06 km/s, σ_{Zdot} = 1.298e-06 km/s
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Zdot [km/s]
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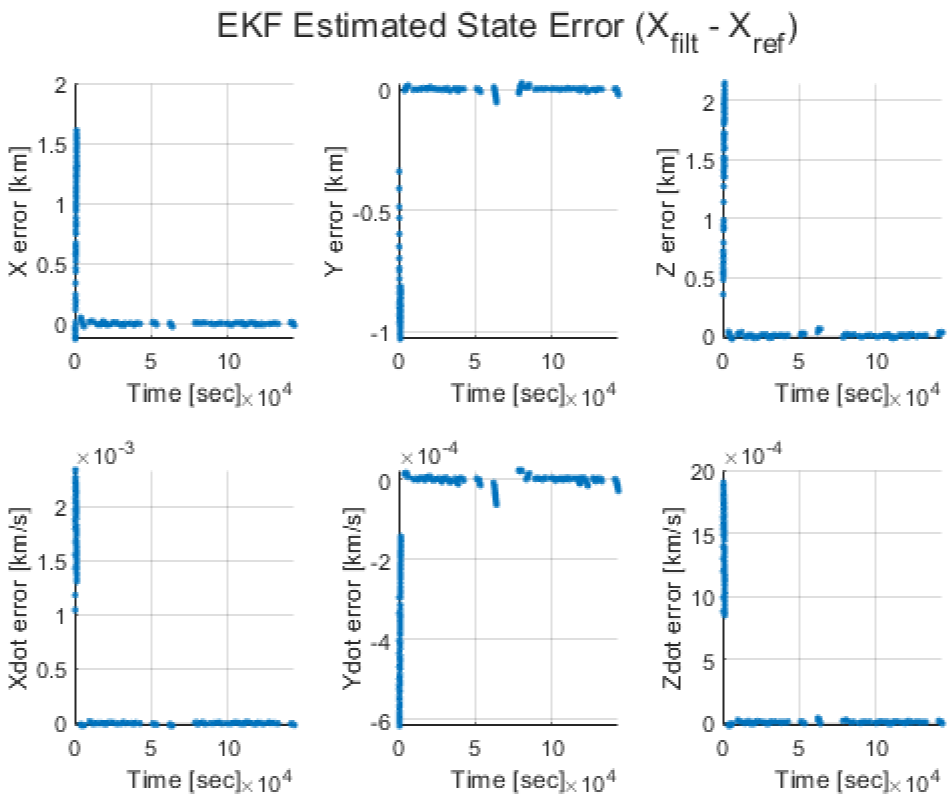
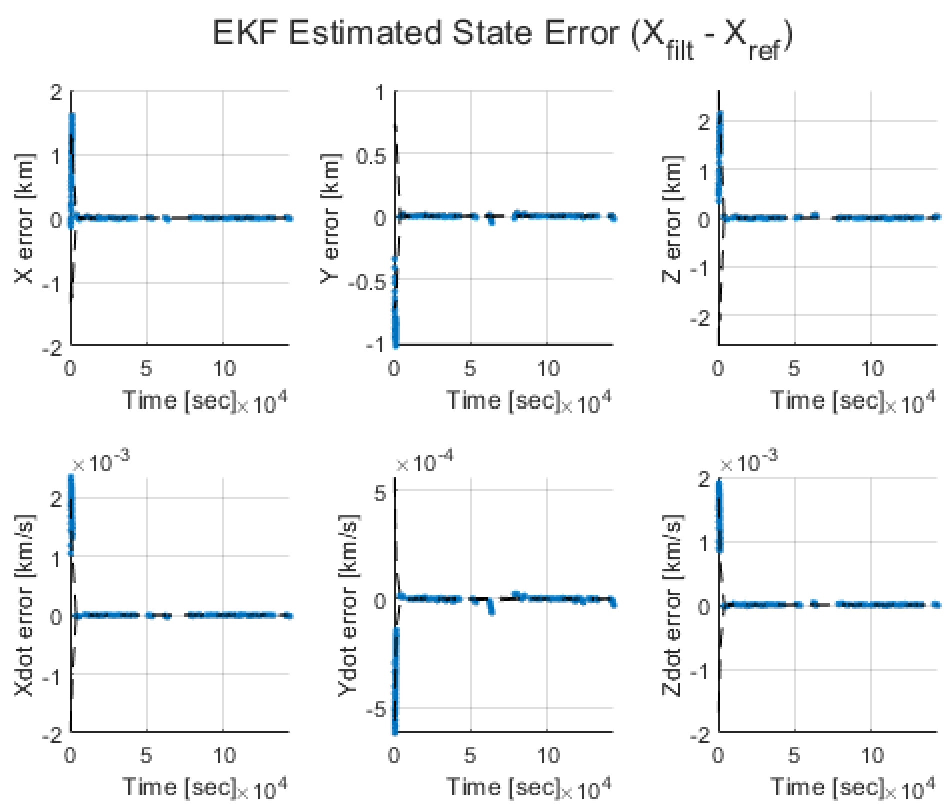
4.805015
Xdot [km/s]
-0.4991
-0.499105
-0.49911
Ydot [km/s]
1σ
2σ
3σ
v_1
v_2
v_3


EKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3
×10^-4
×10^-4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Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3
×10^-4
×10^-3

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2. Repeat problem 1 using DMC with $\bar{n}=0$ and $\tau = T/30$, where T is the orbit period in seconds

i. What is the optimal value for σ? Why?

I found that $\sigma = 1\times10^{-10}$ balanced the normalized postfit RMS near 1 while minimizing 3D RMS

ii. For the optimal σ, plot the J_3 accelerations and filter estimates vs. time, as well as their errors with covariance bounds. How well does the filter estimate the acceleration?

The LKF does a decent job at estimating the acceleration, while the EKF exhibits some serious deviations from the true J_3 acceleration. The deviations occur at the start of each measurement window, which makes sense as the exponential model we use is maximized at t_0, i.e. the start of each measurement window. This could be alleviated by reducing σ, but then postfit RMS suffers.

iii. Choose at least 1 different value for τ. How does this change the filter performance?

Changing τ_z from T/30 to T/600 doesn't affect the final estimates for R and V, but it causes w_z to no longer approximate the z component of J_3, instead approaching noise vs. a deterministic acceleration. Likewise, increasing τ results in a $\vec{w}$ that responds too slowly to the true J_3 acceleration.

c. Discuss how DMC could be used to account for an unknown maneuver.

An unknown maneuver would occur relatively quickly on the orbital timescale and at a specific time. Thus, to use DMC to account for a maneuver, I would use a small τ and only apply the Q from DMC at the probable maneuver times.

ASEN 6080 HW 3 Problem 2 Main Script

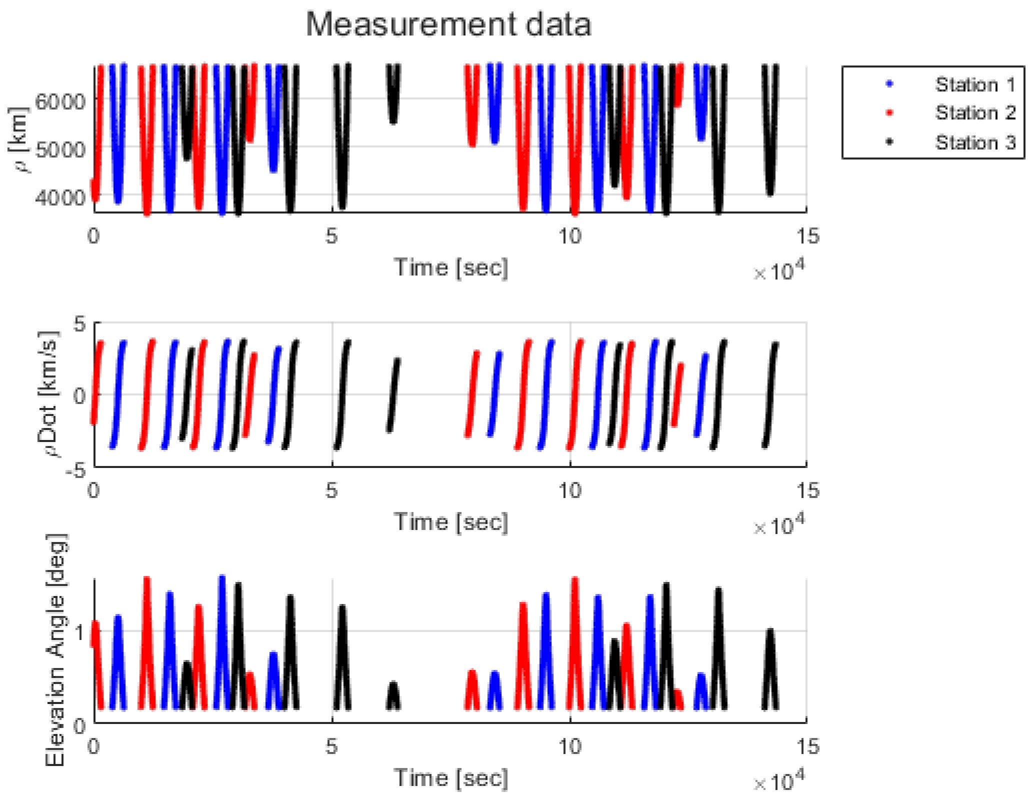
Table of Contents

By: Ian Faber

Housekeeping

Setup

Load Truth Data

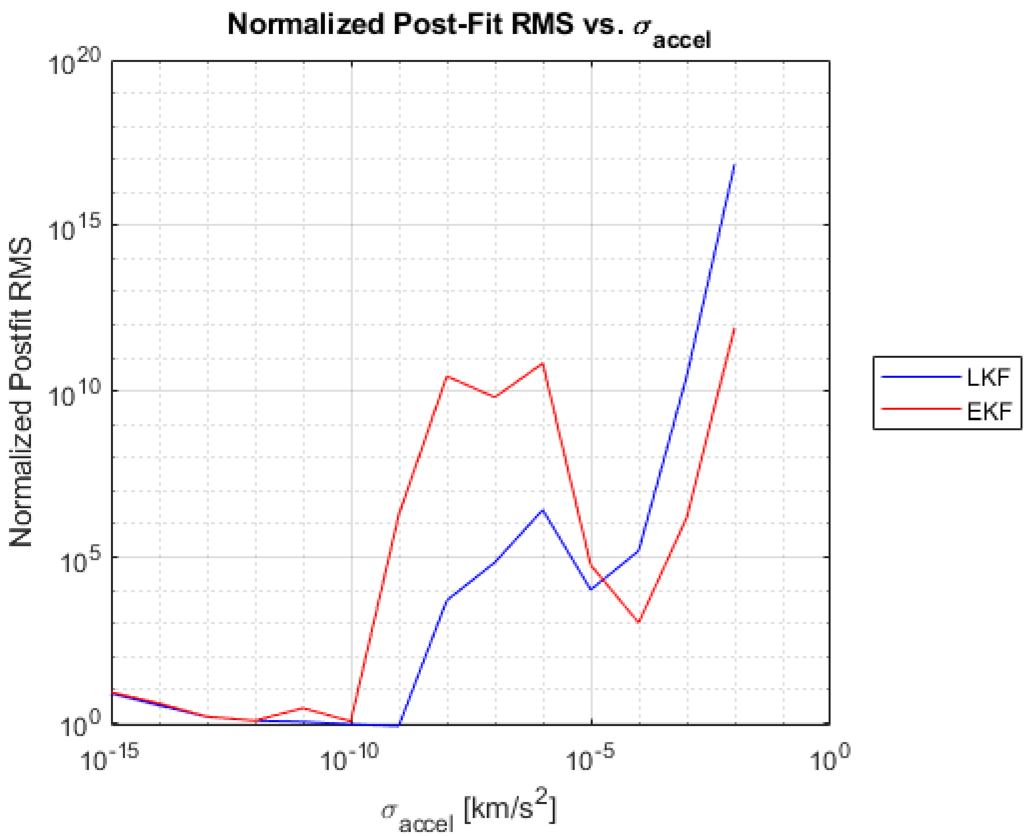


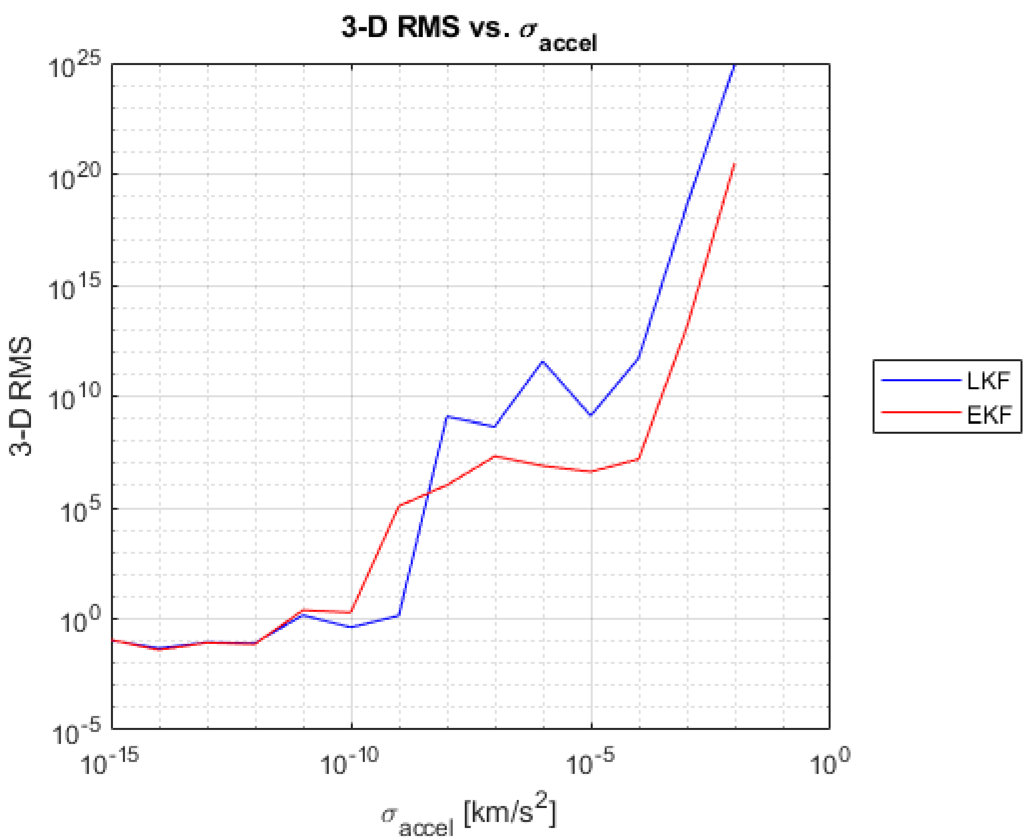
Problem 2b: Filter setup

Problem 2b: Test values of sigma

Problem 2b: Plot results vs. sigma

Plotting DMC filter results vs. sigma

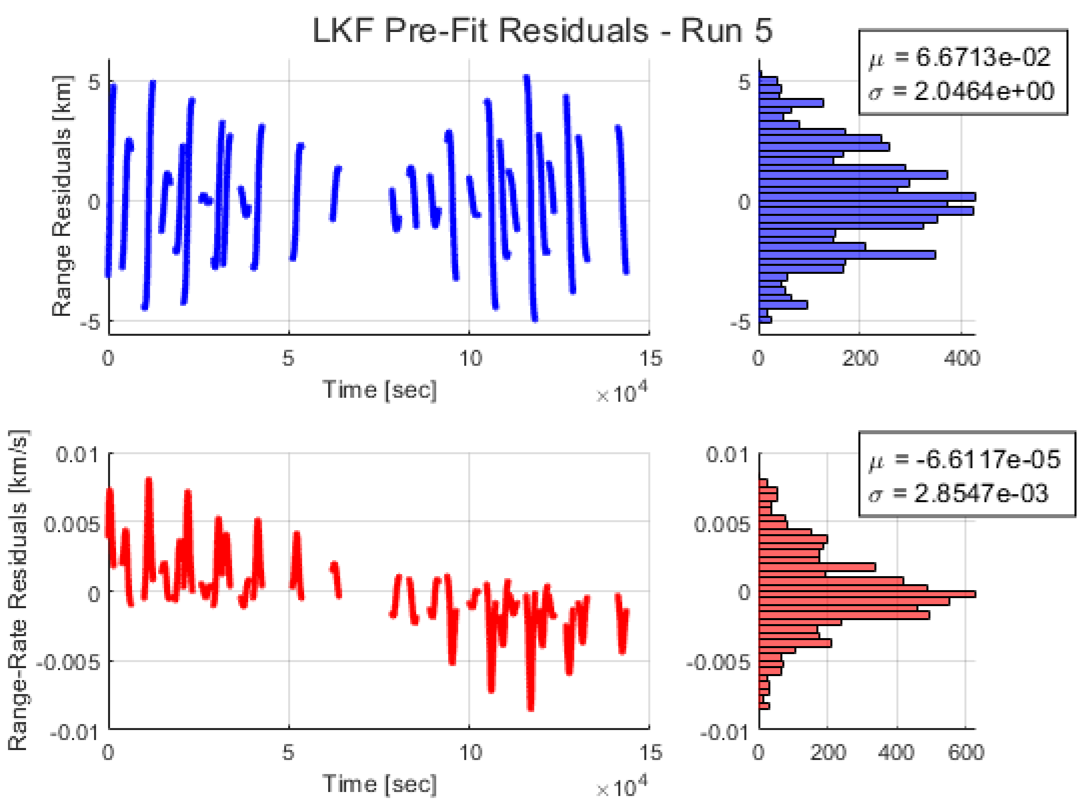

Normalized Post-Fit RMS vs. σ accel
Normalized Postfit RMS
σ accel [km/s2]
LKF
EKF

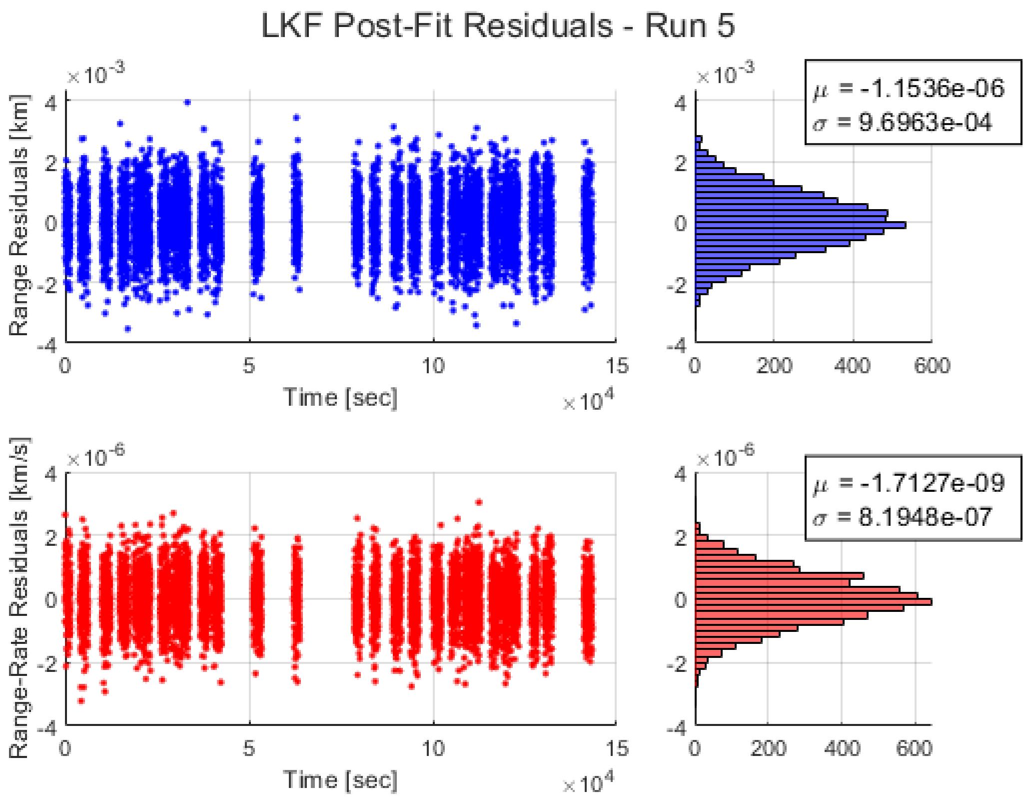

3-D RMS vs. σ accel
3-D RMS
σ accel [km/s2]
LKF
EKF

Problem 2b: Choose optimal sigma

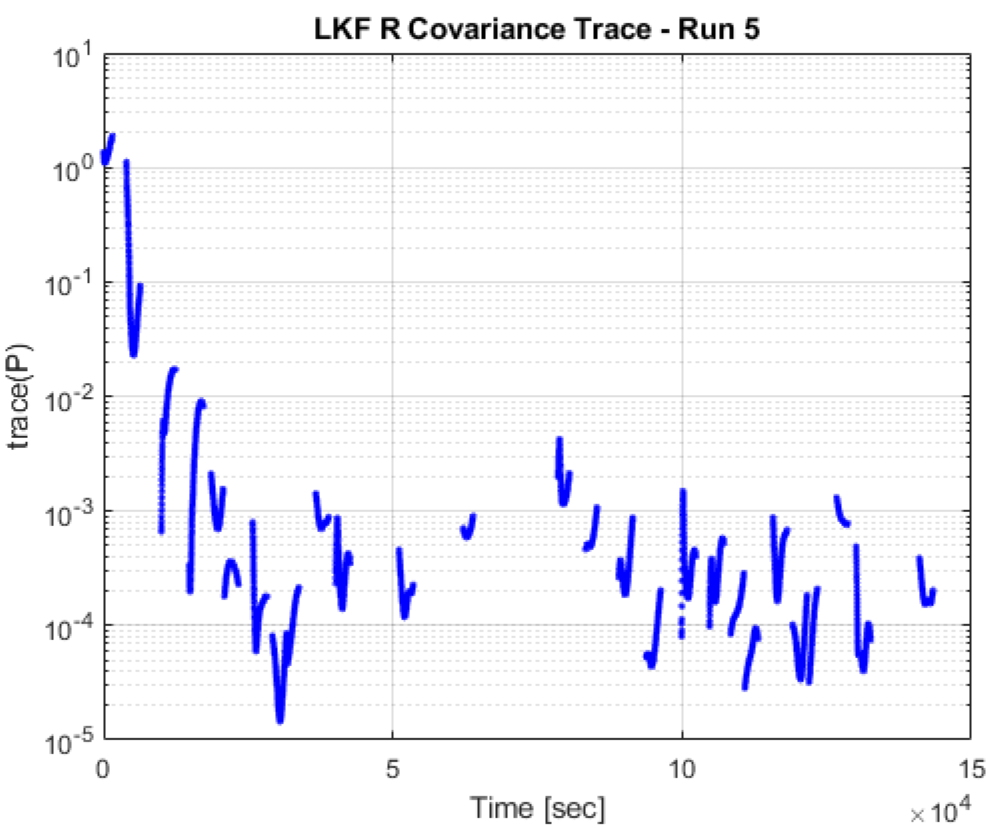
Based on plots, sigma = 1e-10 balances both postfit and 3D RMS

```
Plotting state errors vs. time for sigma = 1.000e-10 km/s^2

    Running LKF:
Prefit RMS: 9534.1497, Postfit RMS: 0.9366. Iterating LKF. Runs so far: 1
Prefit RMS: 5479.2712, Postfit RMS: 0.9244. Iterating LKF. Runs so far: 2
Prefit RMS: 3992.5455, Postfit RMS: 0.9218. Iterating LKF. Runs so far: 3
Prefit RMS: 2550.0405, Postfit RMS: 0.8967. Iterating LKF. Runs so far: 4
Prefit RMS: 2484.3232, Postfit RMS: 0.8976. Hit max LKF iterations. Runs so
far: 5
Final prefit RMS: 2484.3232. Hit maximum number of 5 runs
Final postfit RMS: 0.8976. Hit maximum number of 5 runs

    Running EKF:
Prefit RMS: 0.8933
Postfit RMS: 0.8933
```

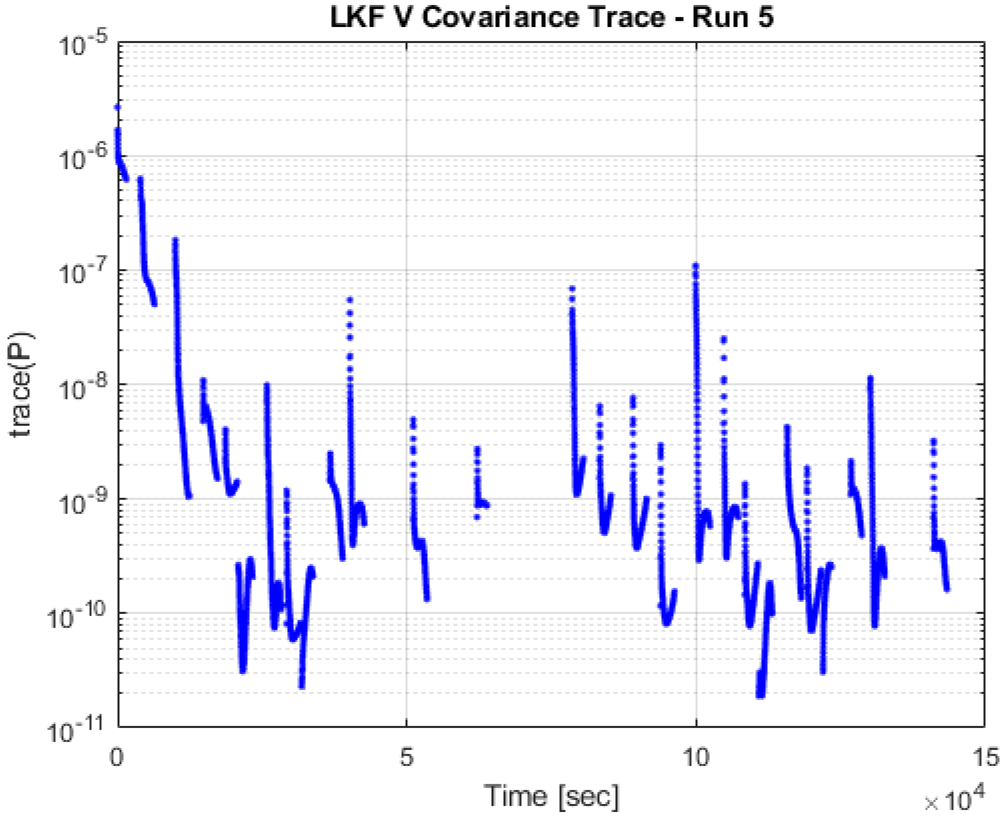


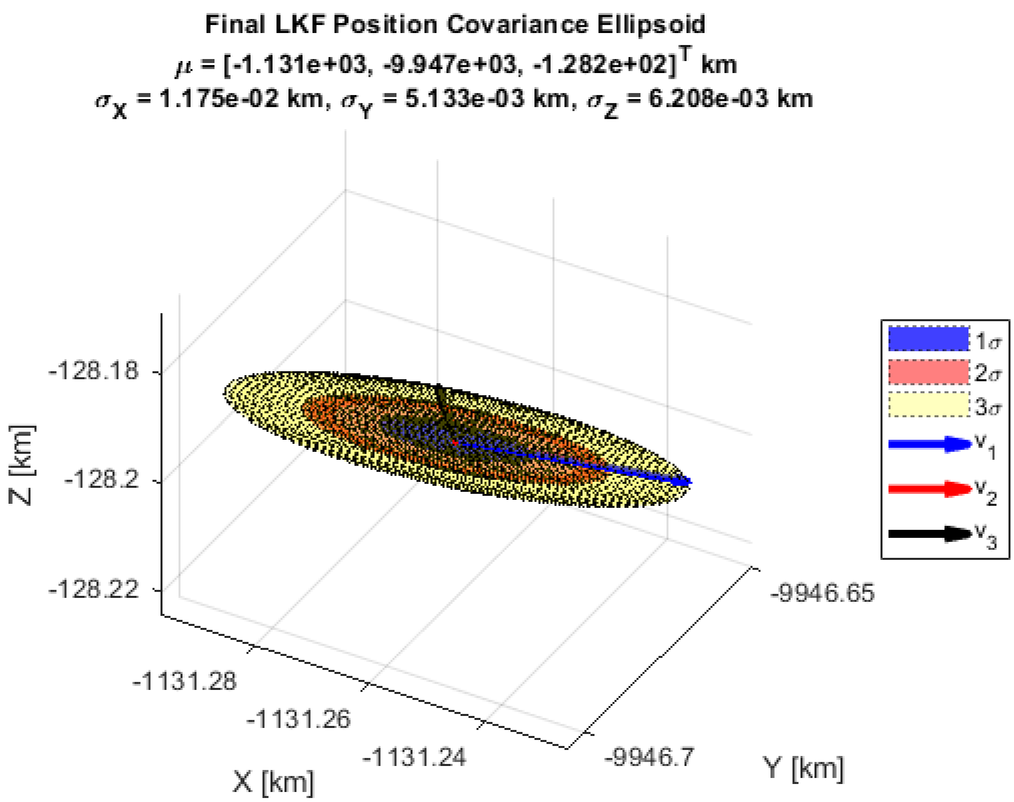


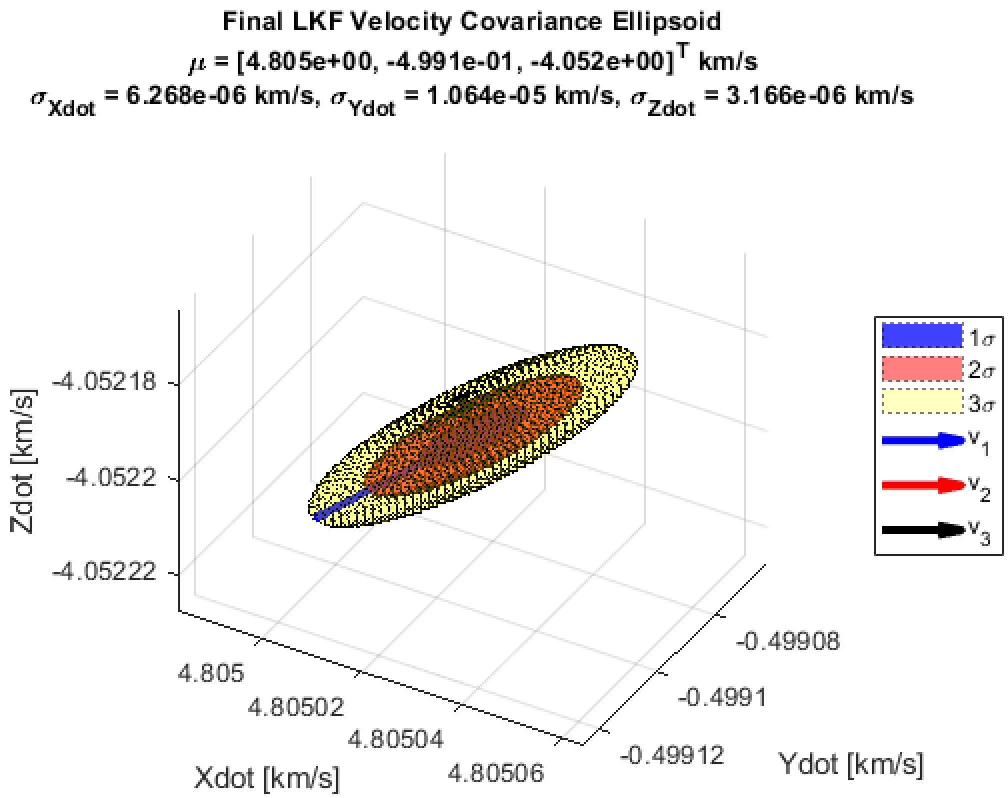
LKF Post-Fit Residuals - Run 5
Range Residuals [km]
Time [sec]
μ = -1.1536e-06
σ = 9.6963e-04
Range-Rate Residuals [km/s]
Time [sec]
μ = -1.7127e-09
σ = 8.1948e-07

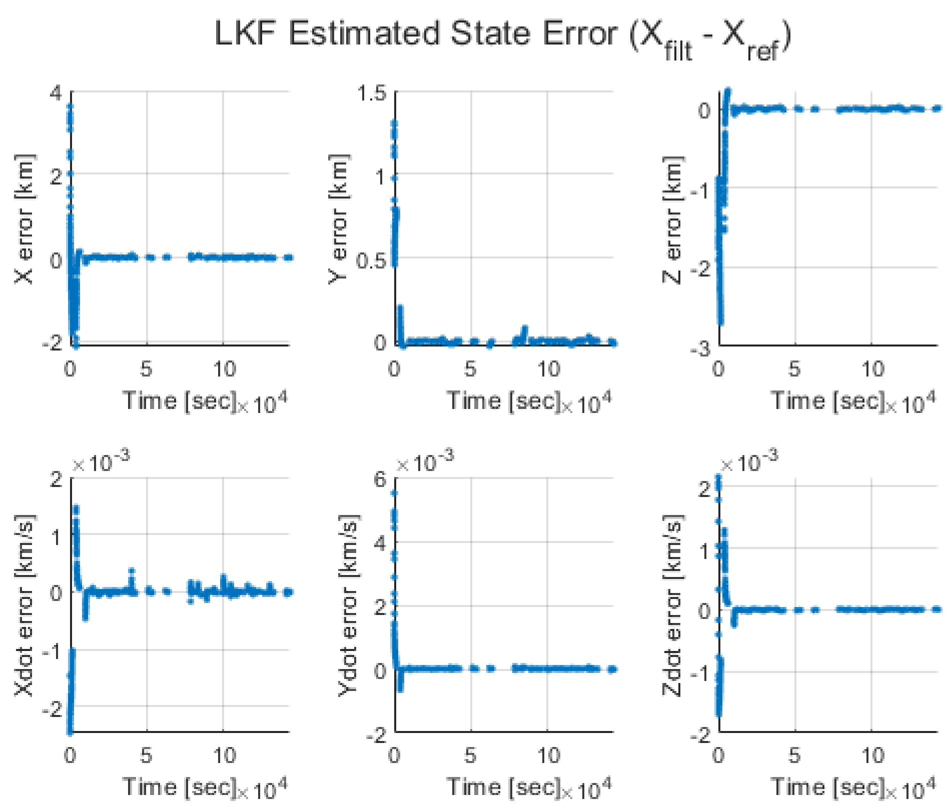


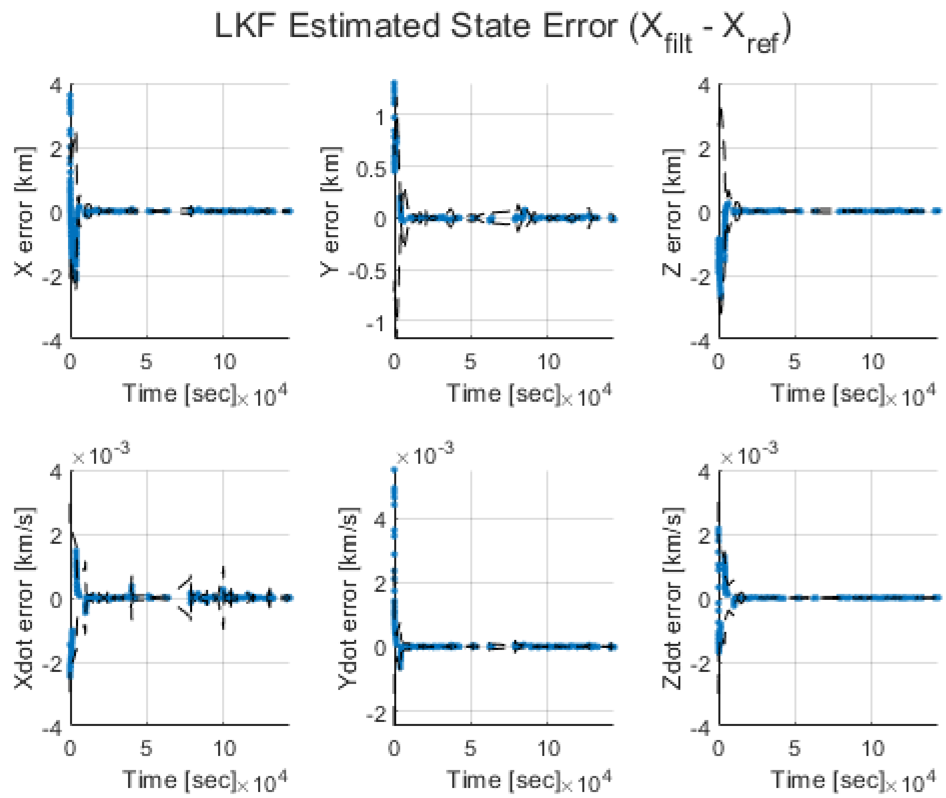
LKF R Covariance Trace - Run 5
trace(P)
Time [sec]

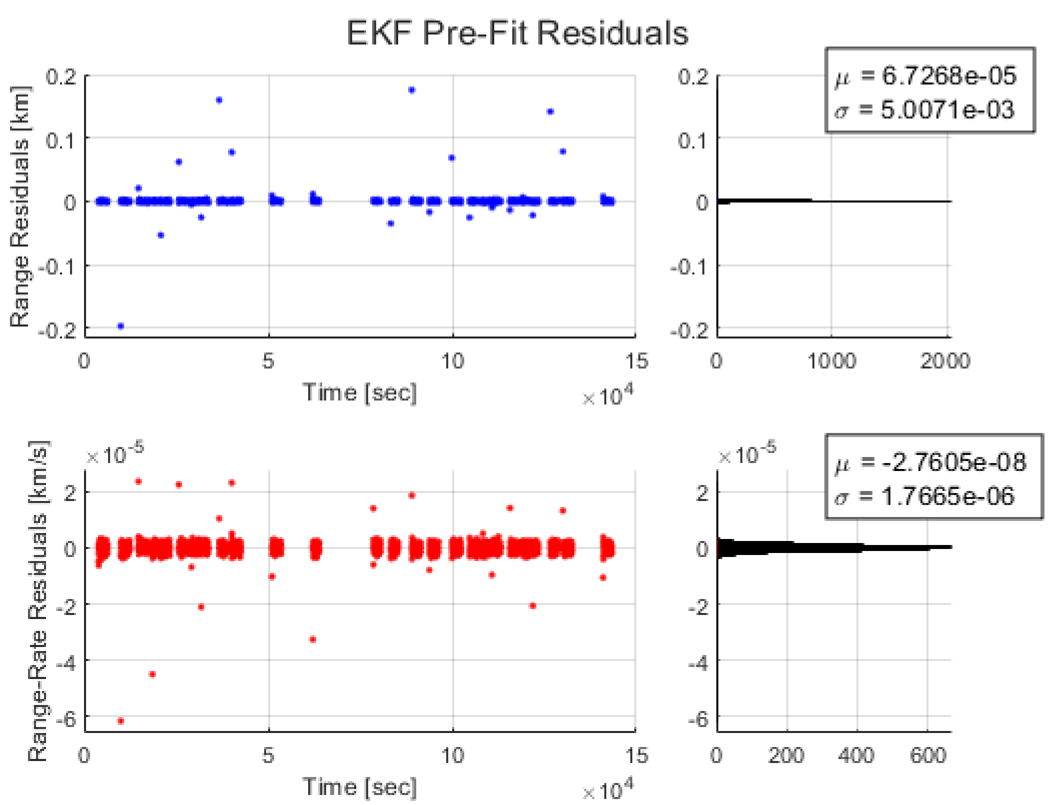

LKF V Covariance Trace - Run 5
trace(P)
Time [sec]
$\times 10^4$

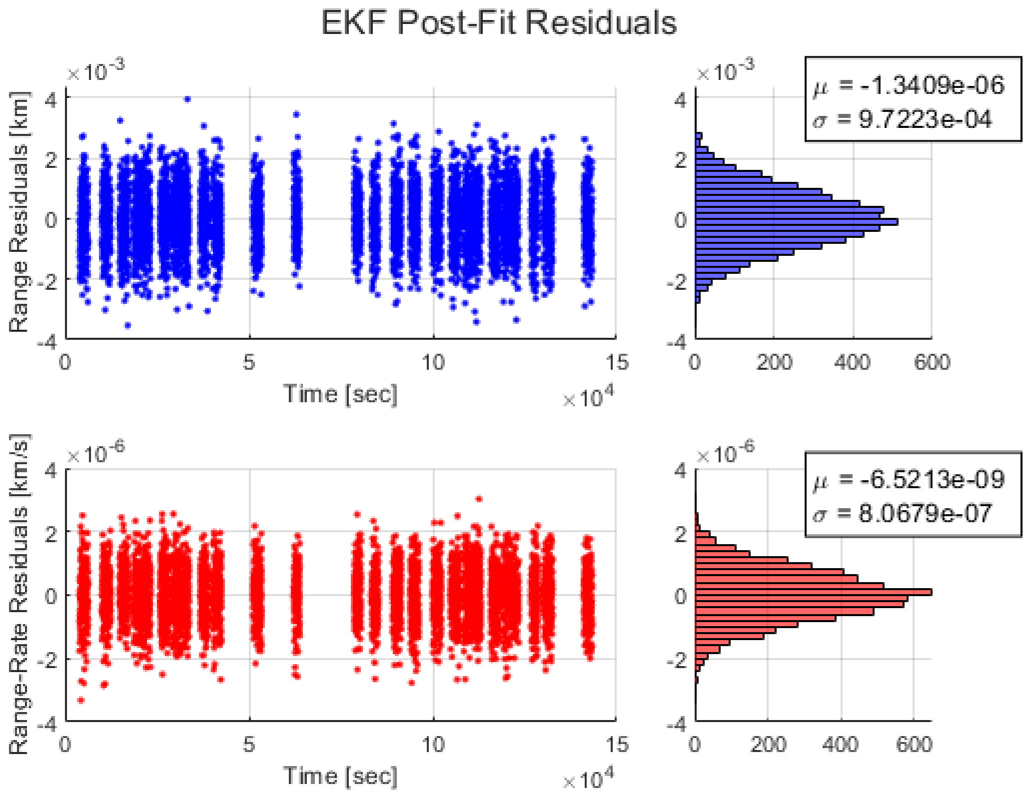

Final LKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σ_X = 1.175e-02 km, σ_Y = 5.133e-03 km, σ_Z = 6.208e-03 km
Z [km]
X [km]
Y [km]
1σ
2σ
3σ
v_1
v_2
v_3

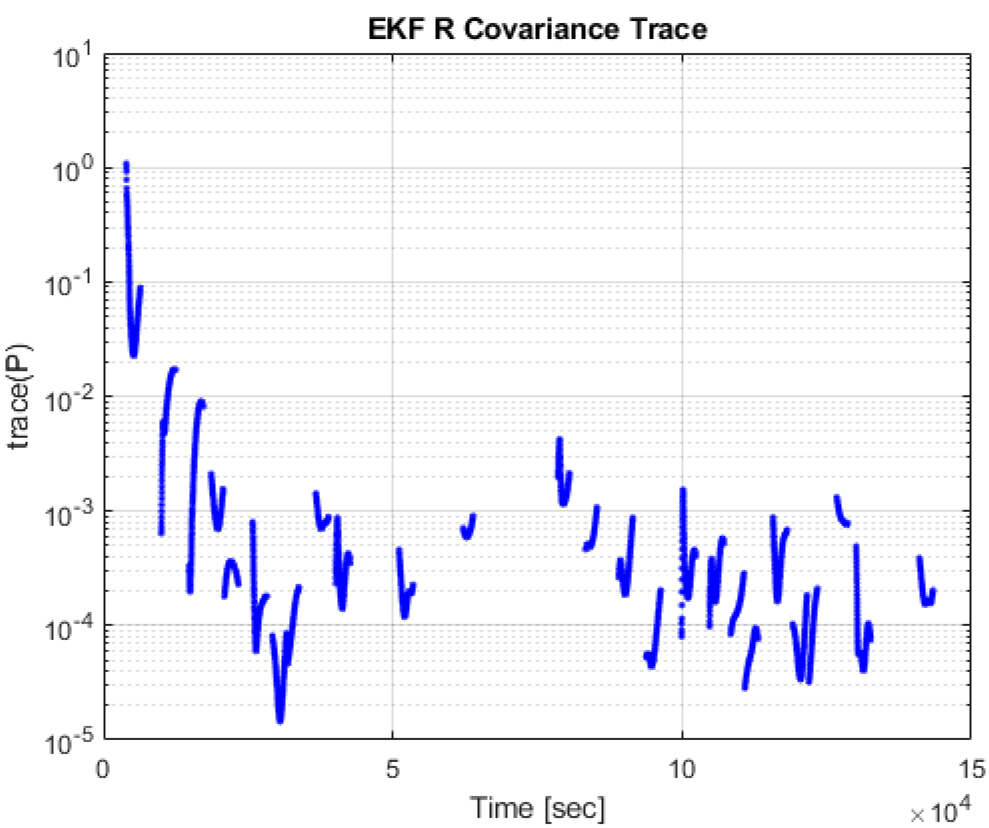

Final LKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]T km/s
σXdot = 6.268e-06 km/s, σYdot = 1.064e-05 km/s, σZdot = 3.166e-06 km/s
Zdot [km/s]
-4.05218
-4.0522
-4.05222
Xdot [km/s]
4.805
4.80502
4.80504
4.80506
Ydot [km/s]
-0.49908
-0.4991
-0.49912
1σ
2σ
3σ
v1
v2
v3

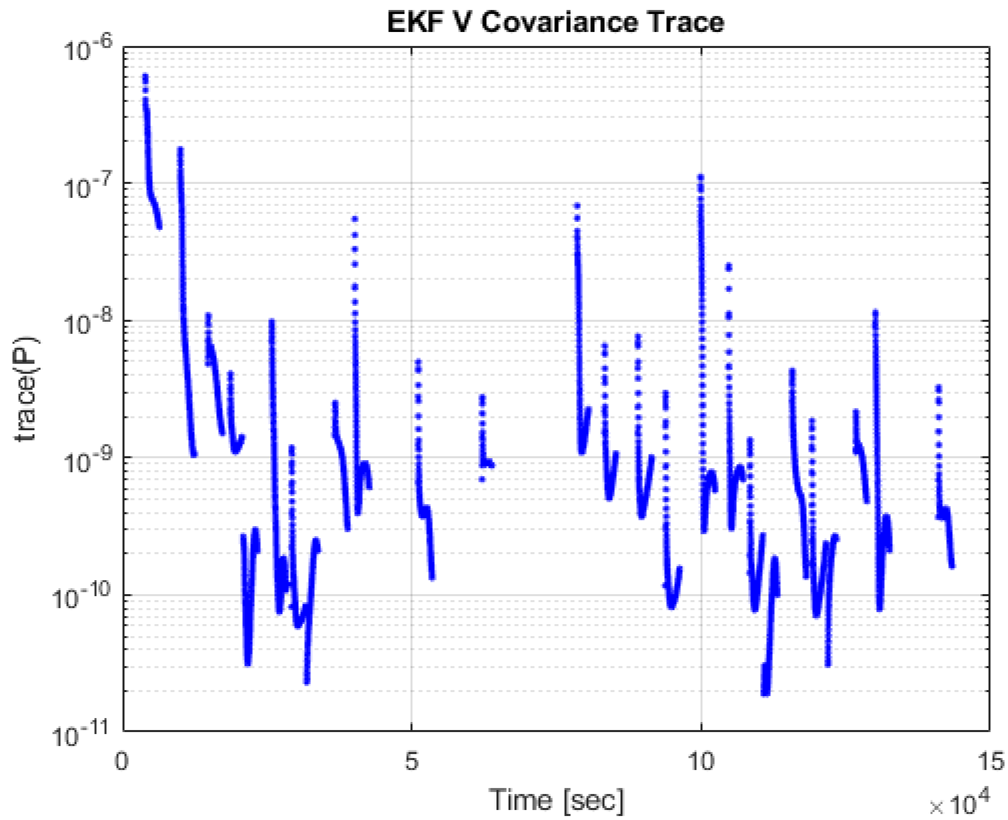

LKF Estimated State Error (Xfilt - Xref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
×10-3
Time [sec]×10^4

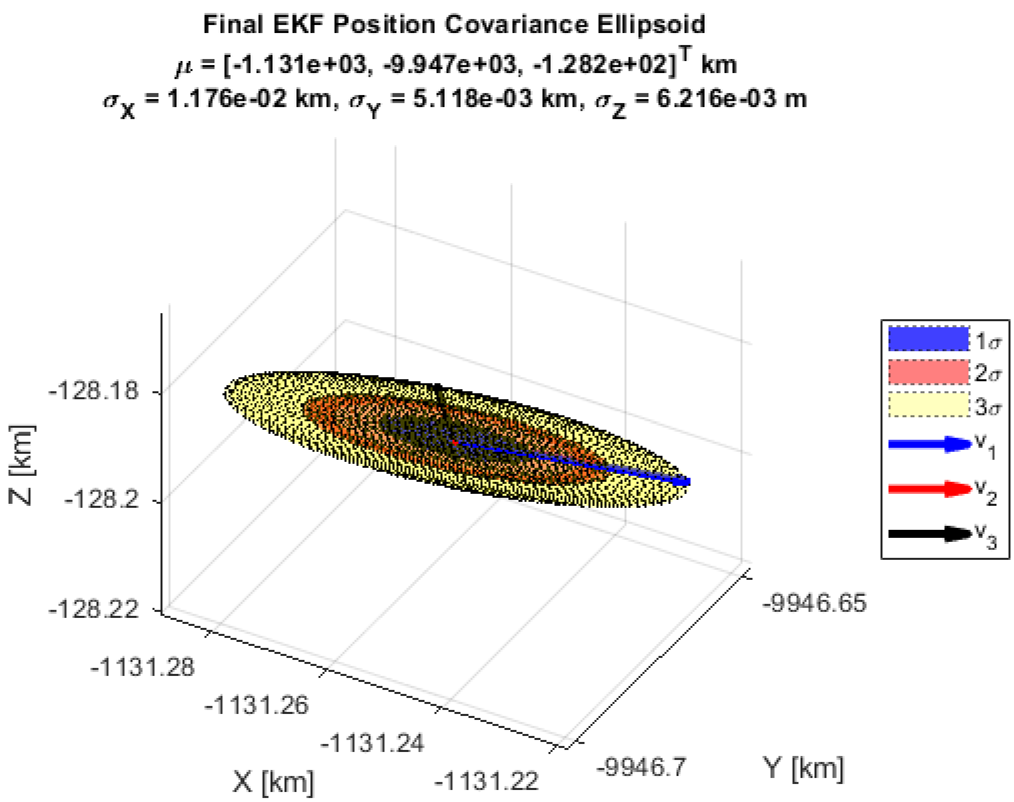

LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3

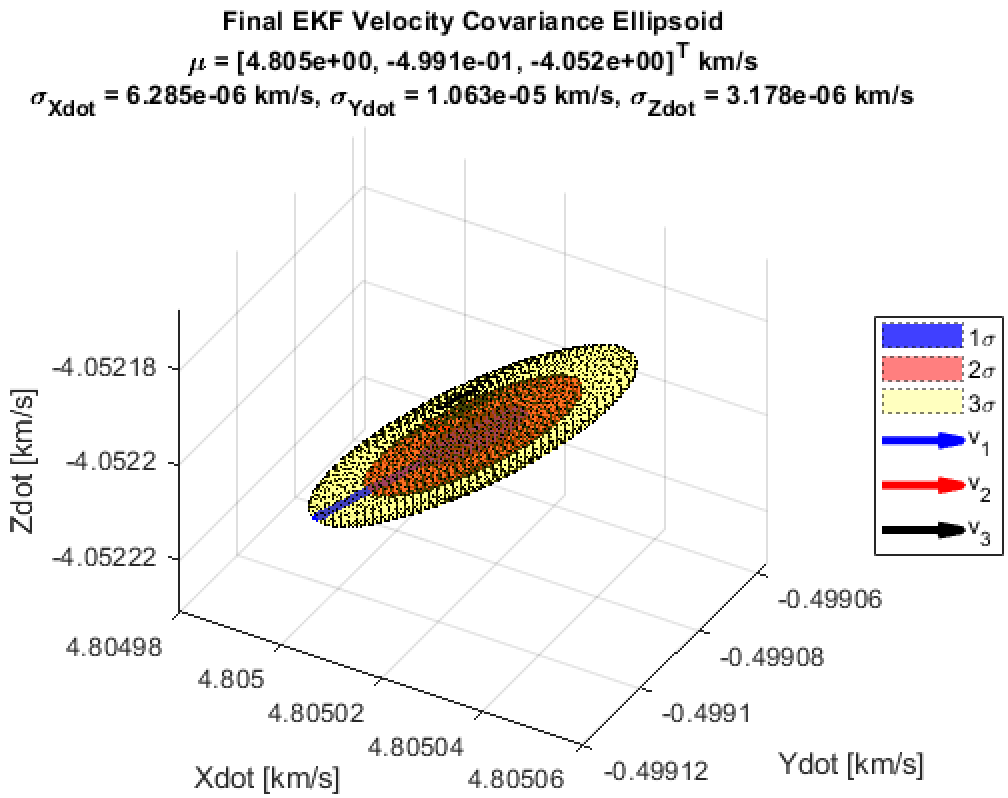

EKF Pre-Fit Residuals
Range Residuals [km]
Range-Rate Residuals [km/s]
Time [sec]
×10^4
×10^-5
μ = 6.7268e-05
σ = 5.0071e-03
μ = -2.7605e-08
σ = 1.7665e-06

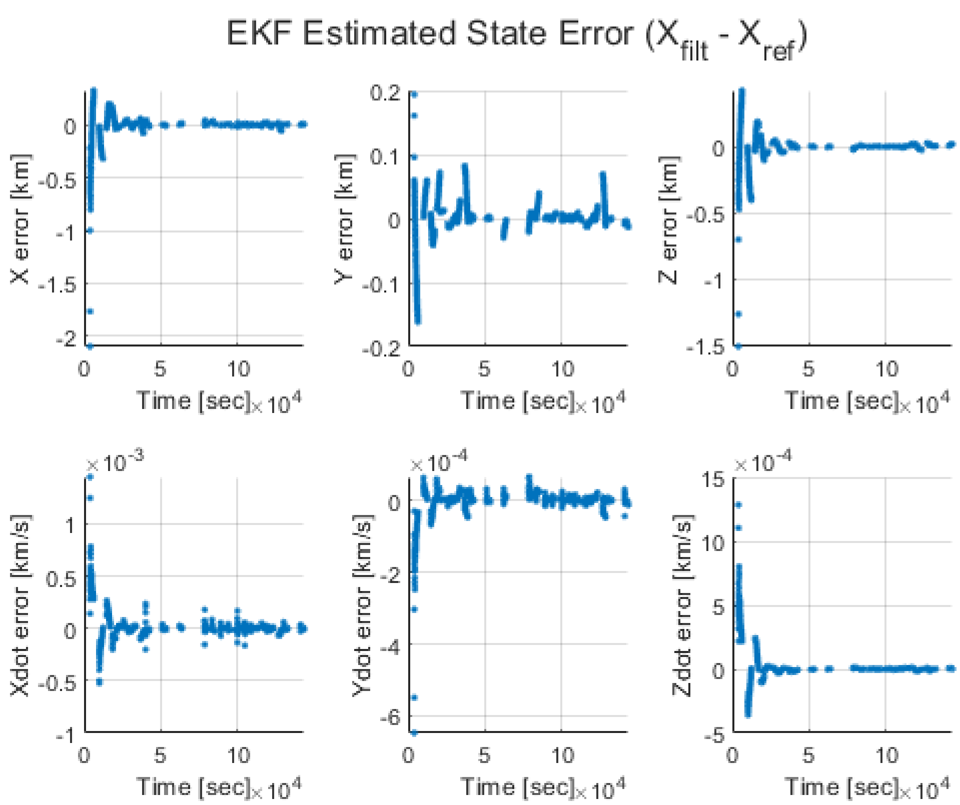

EKF Post-Fit Residuals
Range Residuals [km]
Time [sec]
Range-Rate Residuals [km/s]
μ = -1.3409e-06
σ = 9.7223e-04
μ = -6.5213e-09
σ = 8.0679e-07

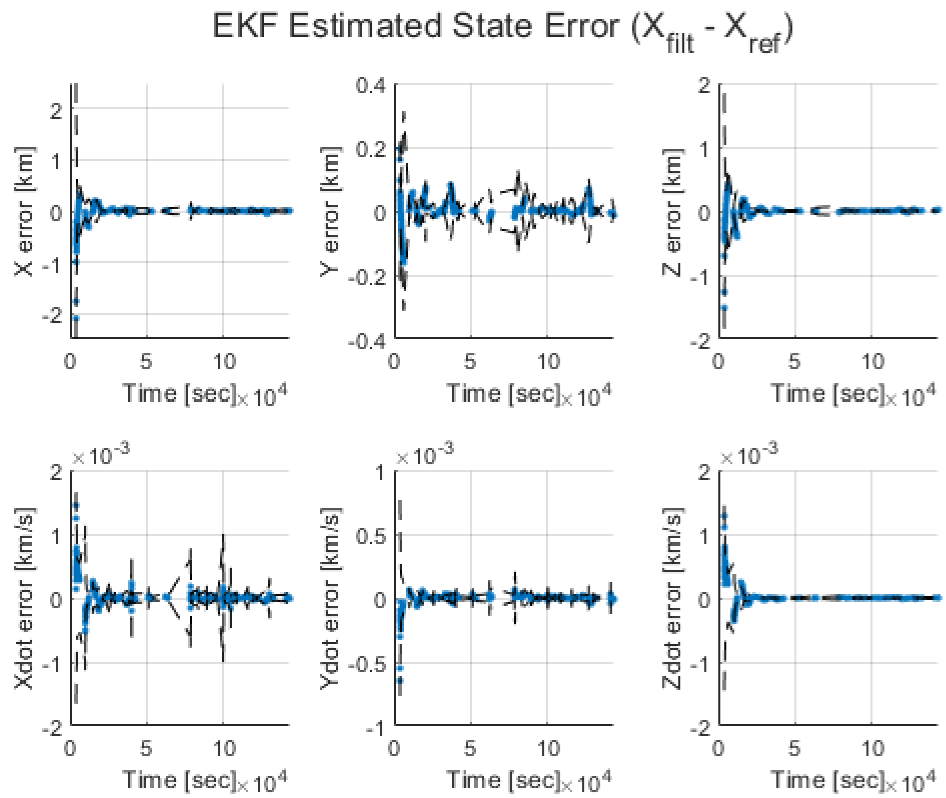

EKF R Covariance Trace
trace(P)
Time [sec]


EKF V Covariance Trace
trace(P)
Time [sec]
$\times 10^4$
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
0
5
10
15


Final EKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σ_X = 1.176e-02 km, σ_Y = 5.118e-03 km, σ_Z = 6.216e-03 m
Z [km]
X [km]
Y [km]
-128.18
-128.2
-128.22
-1131.28
-1131.26
-1131.24
-1131.22
-9946.65
-9946.7
1σ
2σ
3σ
v_1
v_2
v_3

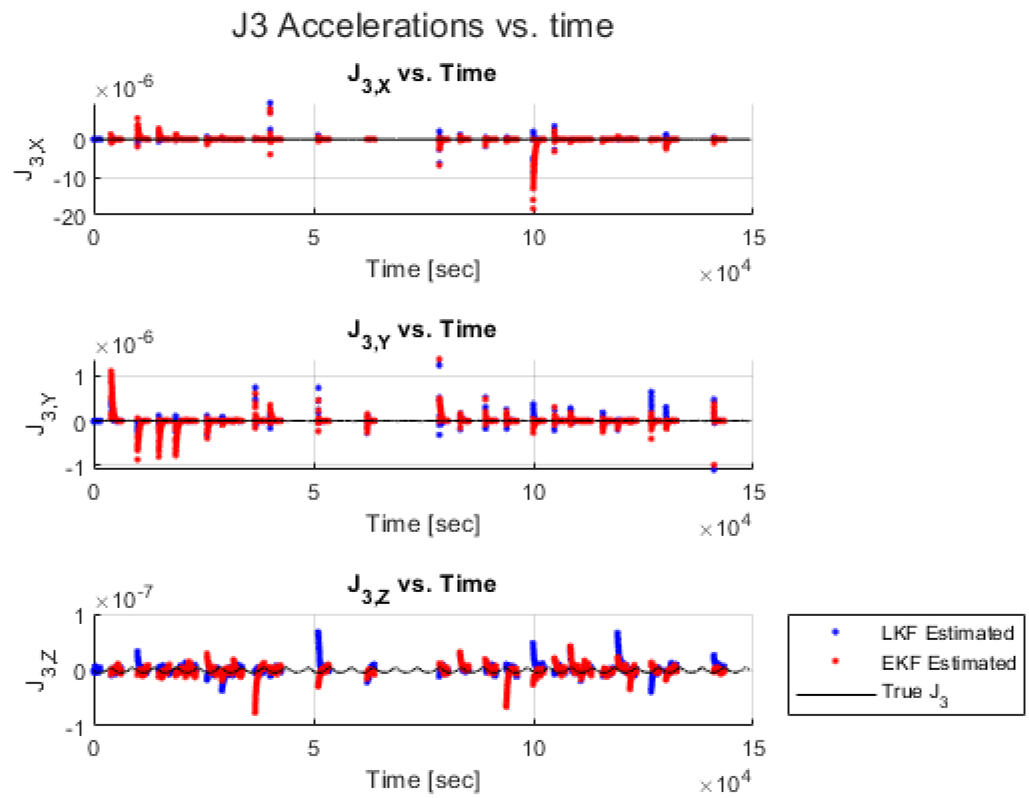

Final EKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]^T km/s
σXdot = 6.285e-06 km/s, σYdot = 1.063e-05 km/s, σZdot = 3.178e-06 km/s
1σ
2σ
3σ
v1
v2
v3
Zdot [km/s]
Xdot [km/s]
Ydot [km/s]
-4.05218
-4.0522
-4.05222
4.80498
4.805
4.80502
4.80504
4.80506
-0.49906
-0.49908
-0.4991
-0.49912

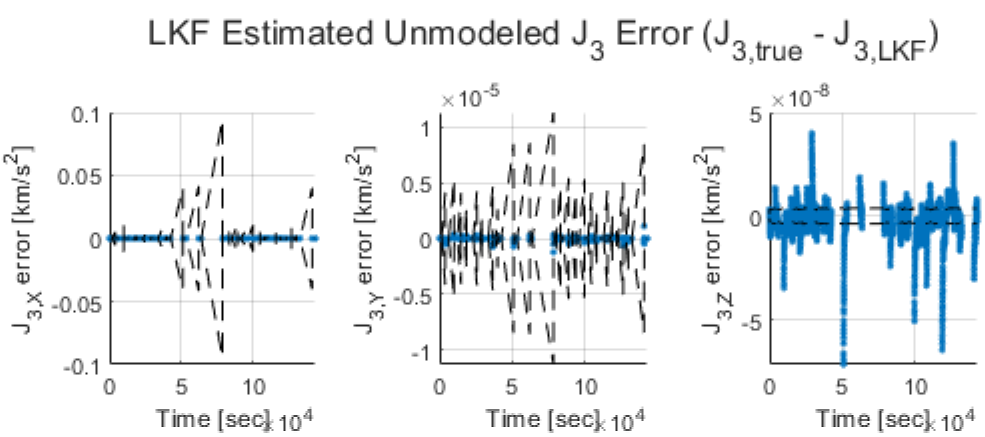

EKF Estimated State Error (Xfilt - Xref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3
×10^-4

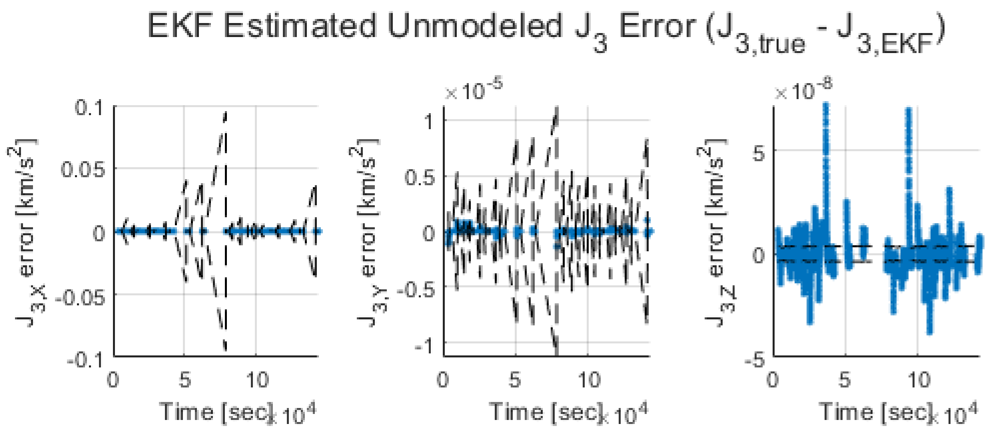


Problem 2b: Plot J3 accels and estimated filter estimates vs. time

```
Plotting true J3 accels vs. filter estimates
```

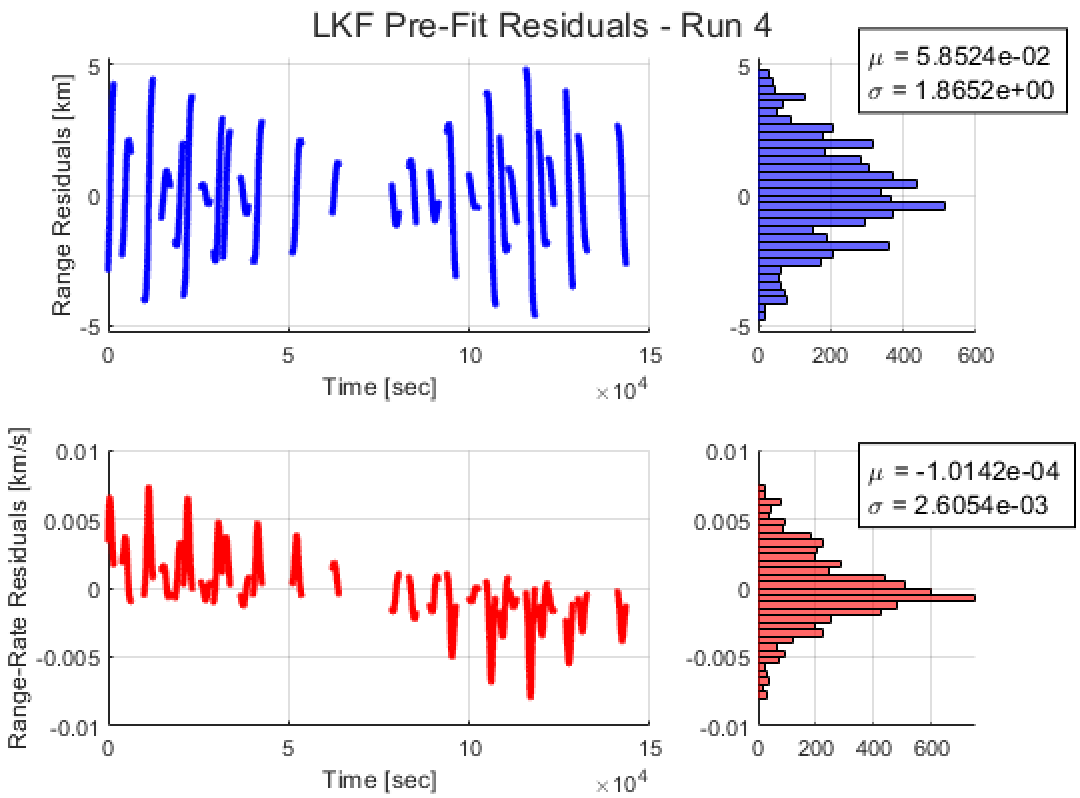

J3 Accelerations vs. time
J3,X vs. Time
J3,Y vs. Time
J3,Z vs. Time
Time [sec]
LKF Estimated
EKF Estimated
True J3

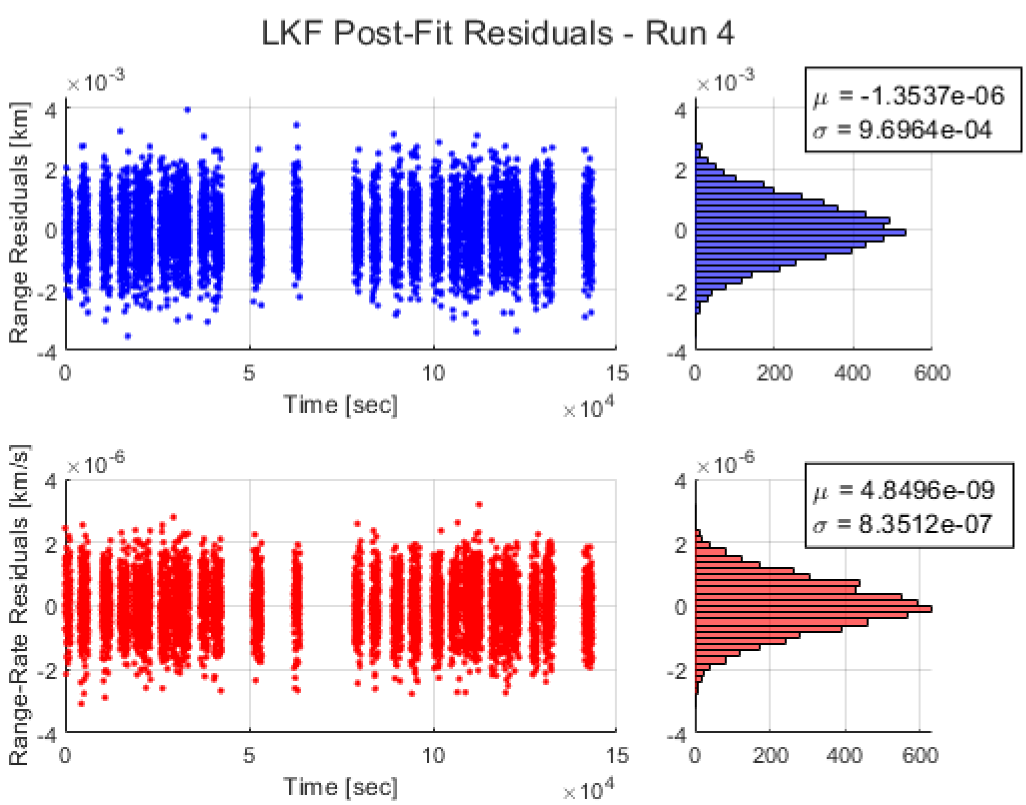

LKF Estimated Unmodeled J3 Error (J3,true - J3,LKF)
J3,X error [km/s2]
J3,Y error [km/s2]
J3,Z error [km/s2]
Time [sec]

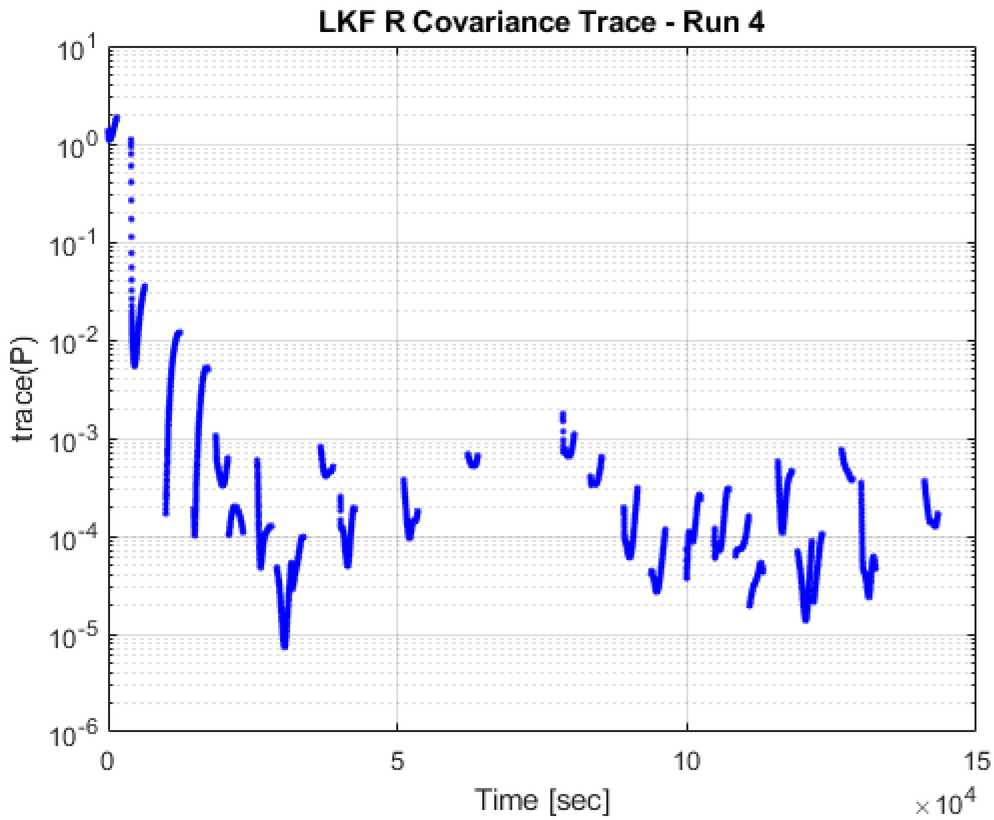


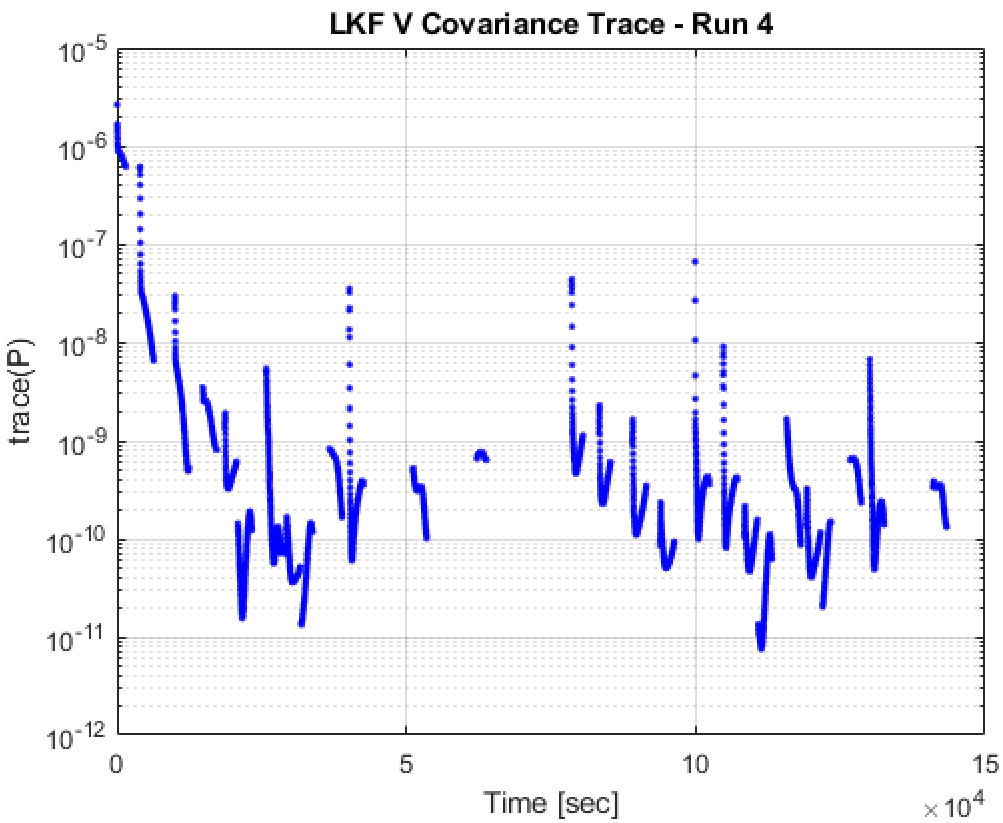
Problem 2b: Different value of tau

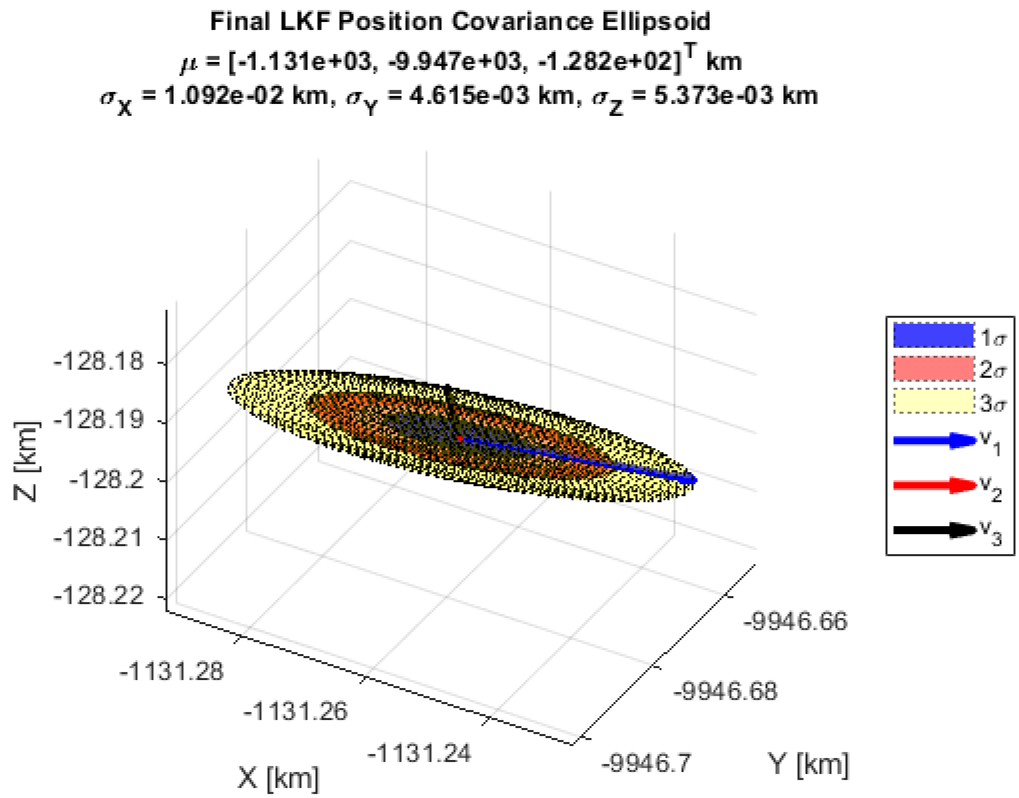
```
Running filters with tau_x = 3.173e+02, tau_y = 3.173e+02, tau_z = 1.587e+01
    Running LKF:
Prefit RMS: 9534.1497, Postfit RMS: 0.9887. Iterating LKF. Runs so far: 1
Prefit RMS: 5324.0627, Postfit RMS: 0.9317. Iterating LKF. Runs so far: 2
Prefit RMS: 3521.5149, Postfit RMS: 0.9247. Iterating LKF. Runs so far: 3
Prefit RMS: 2330.8700, Postfit RMS: 0.9041. Iterating LKF. Runs so far: 4
Final prefit RMS: 2267.0795. Converged after 4 runs
Final postfit RMS: 0.9048. Converged after 4 runs

    Running EKF:
Prefit RMS: 0.9017
Postfit RMS: 0.9017
```

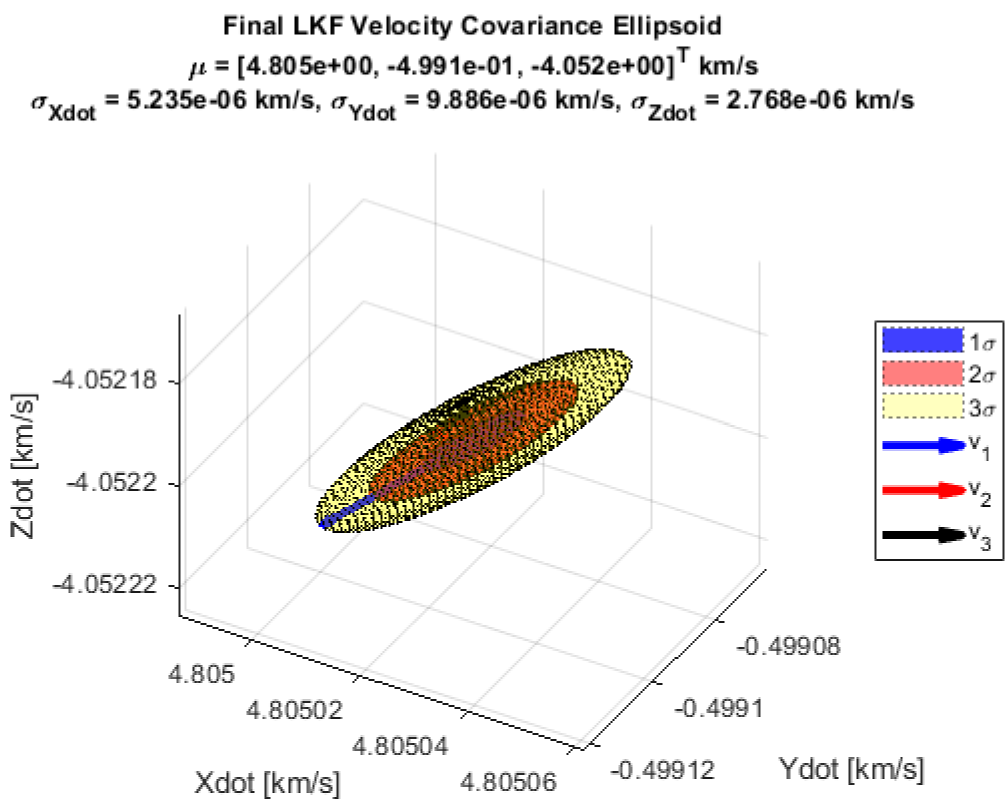

LKF Pre-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
$\times 10^4$
μ = 5.8524e-02
σ = 1.8652e+00
Range-Rate Residuals [km/s]
μ = -1.0142e-04
σ = 2.6054e-03

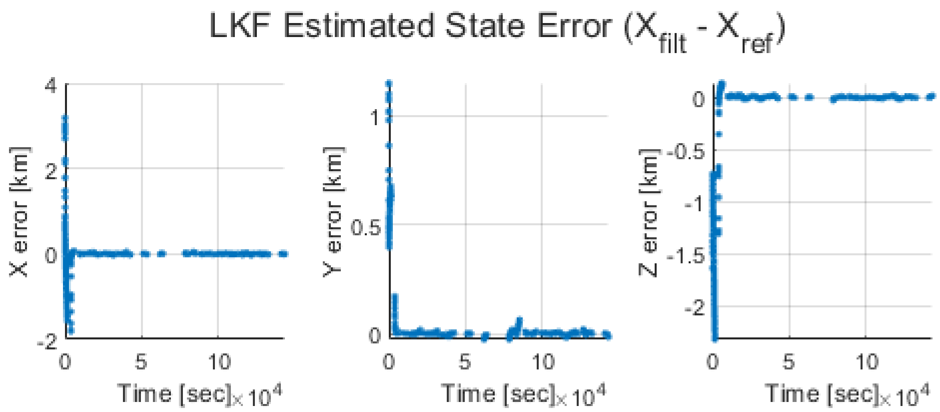

LKF Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
$\times 10^{-3}$
$\times 10^4$
μ = -1.3537e-06
σ = 9.6964e-04
Range-Rate Residuals [km/s]
$\times 10^{-6}$
μ = 4.8496e-09
σ = 8.3512e-07

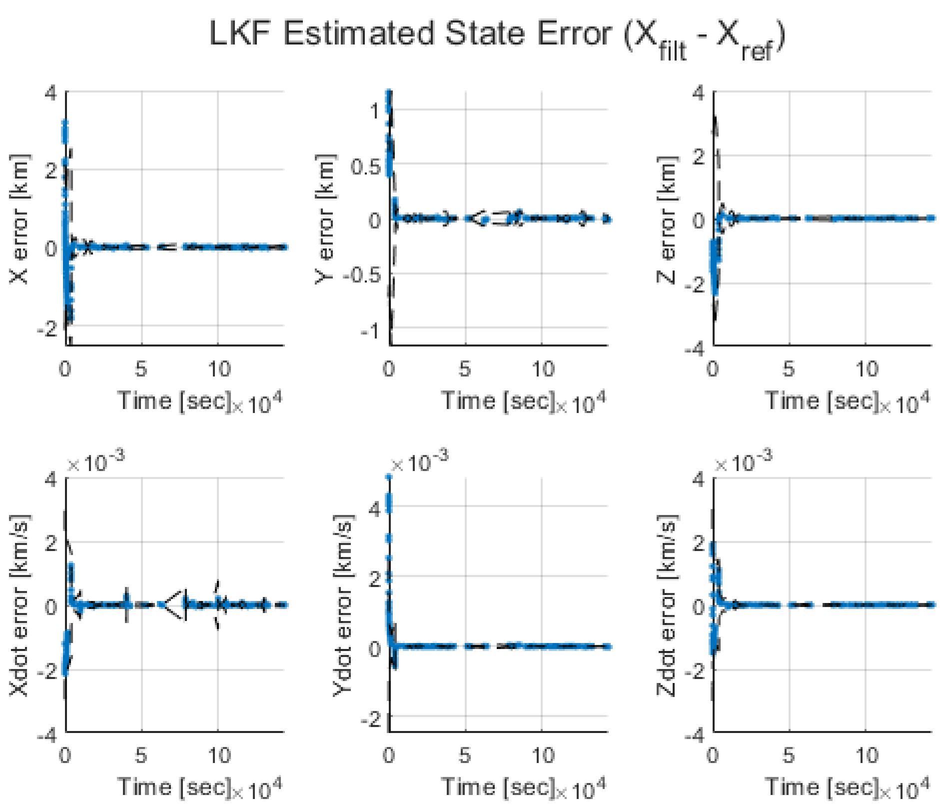

LKF R Covariance Trace - Run 4
trace(P)
Time [sec]
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
5
10
15
$\times 10^4$

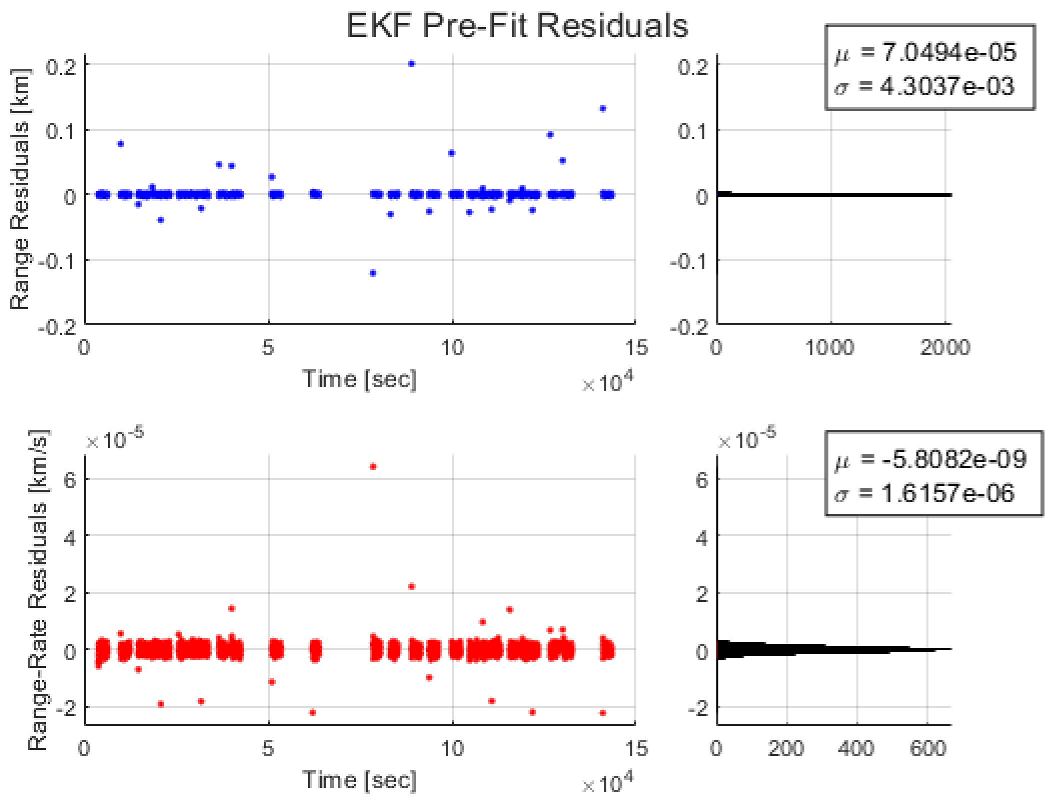

LKF V Covariance Trace - Run 4
trace(P)
Time [sec]
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
0
5
10
15
$\times 10^4$

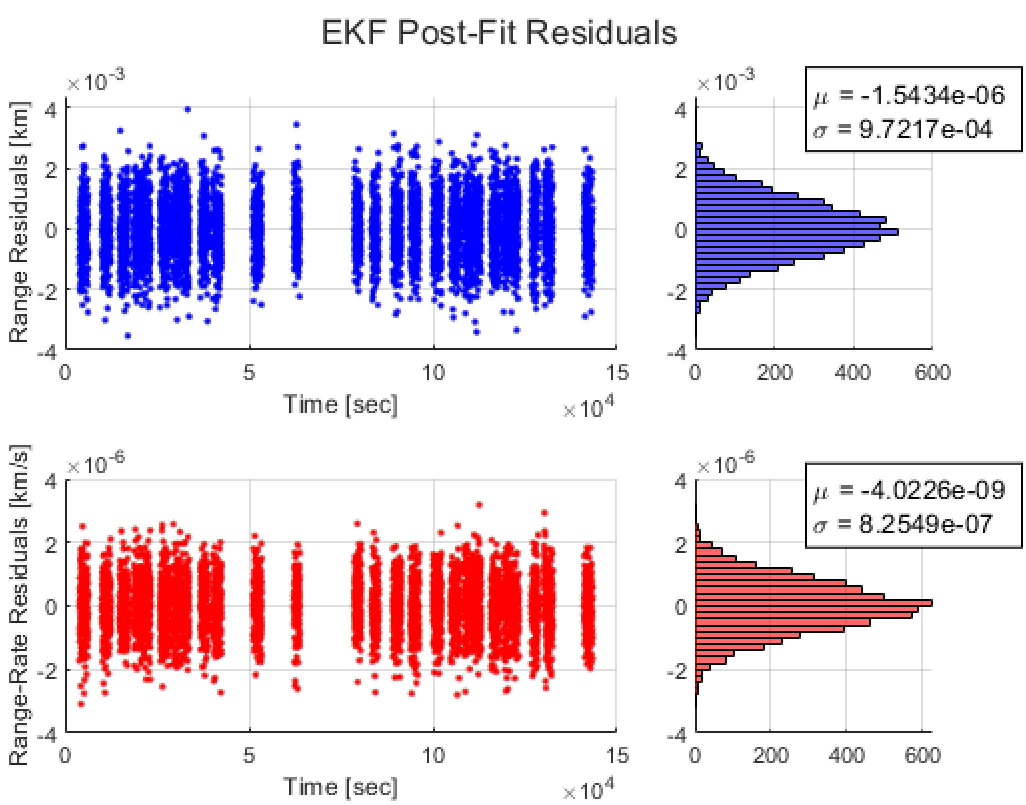

Final LKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σX = 1.092e-02 km, σY = 4.615e-03 km, σZ = 5.373e-03 km
Z [km]
-128.18
-128.19
-128.2
-128.21
-128.22
X [km]
-1131.28
-1131.26
-1131.24
Y [km]
-9946.66
-9946.68
-9946.7
1σ
2σ
3σ
v1
v2
v3

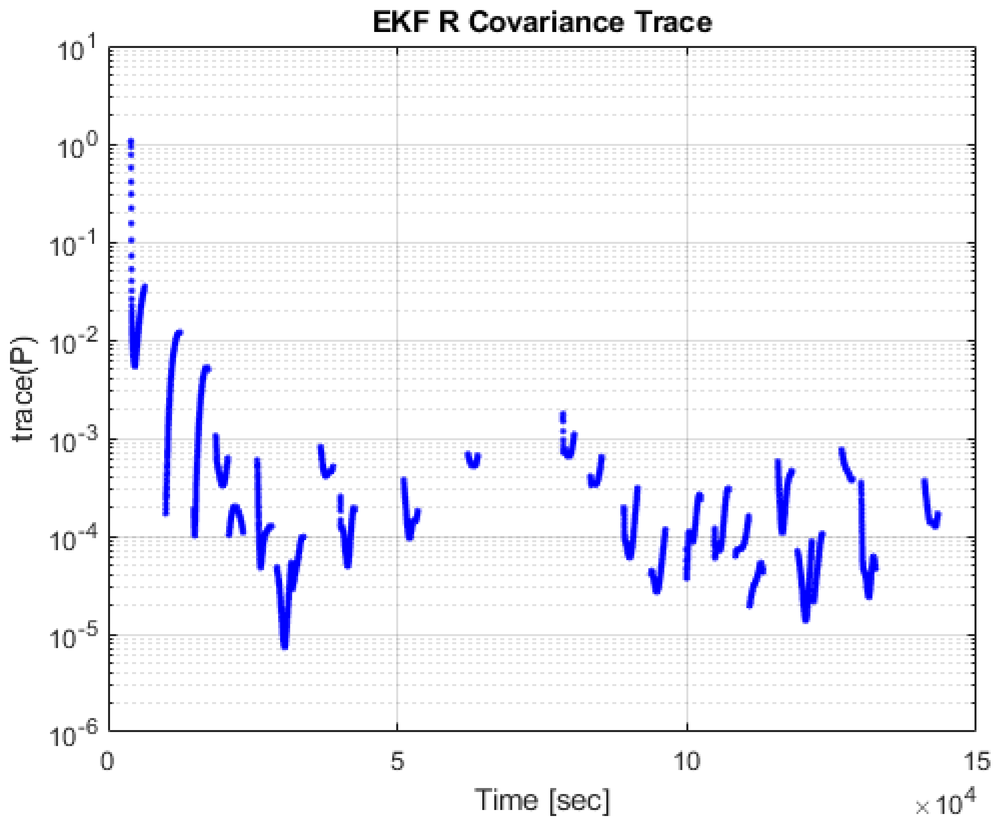

Final LKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]^T km/s
σXdot = 5.235e-06 km/s, σYdot = 9.886e-06 km/s, σZdot = 2.768e-06 km/s
Zdot [km/s]
-4.05218
-4.0522
-4.05222
Xdot [km/s]
4.805
4.80502
4.80504
4.80506
Ydot [km/s]
-0.49908
-0.4991
-0.49912
1σ
2σ
3σ
v1
v2
v3

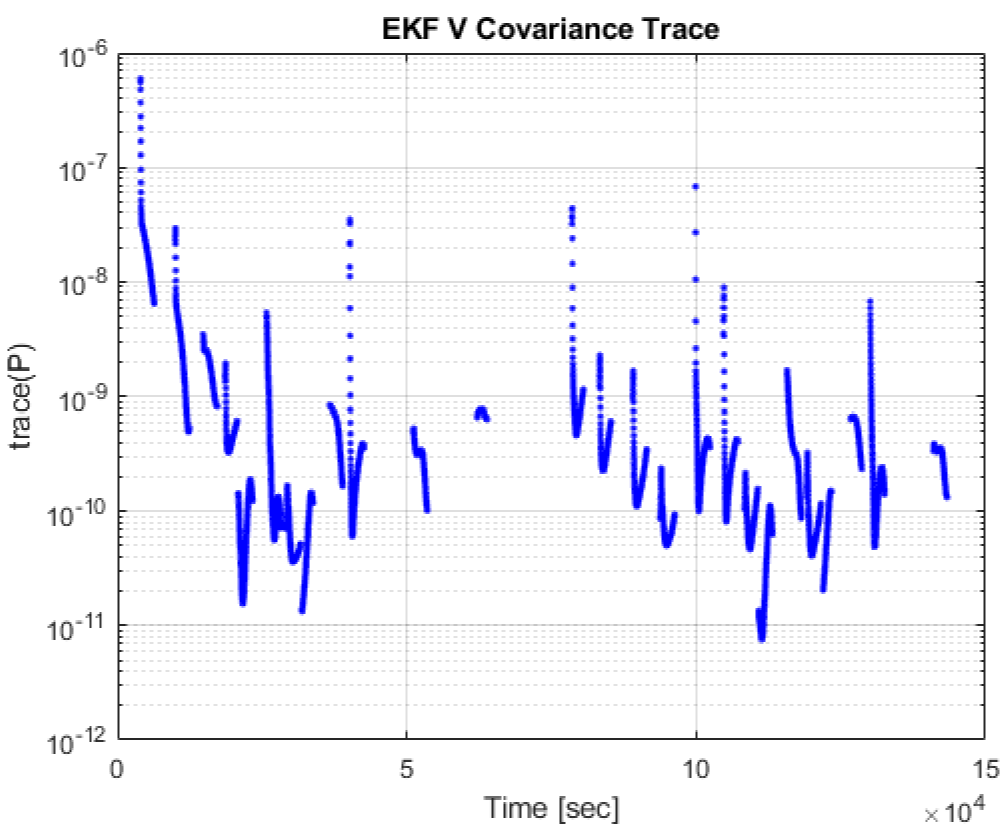

LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
×10^-3
Time [sec]
×10^4

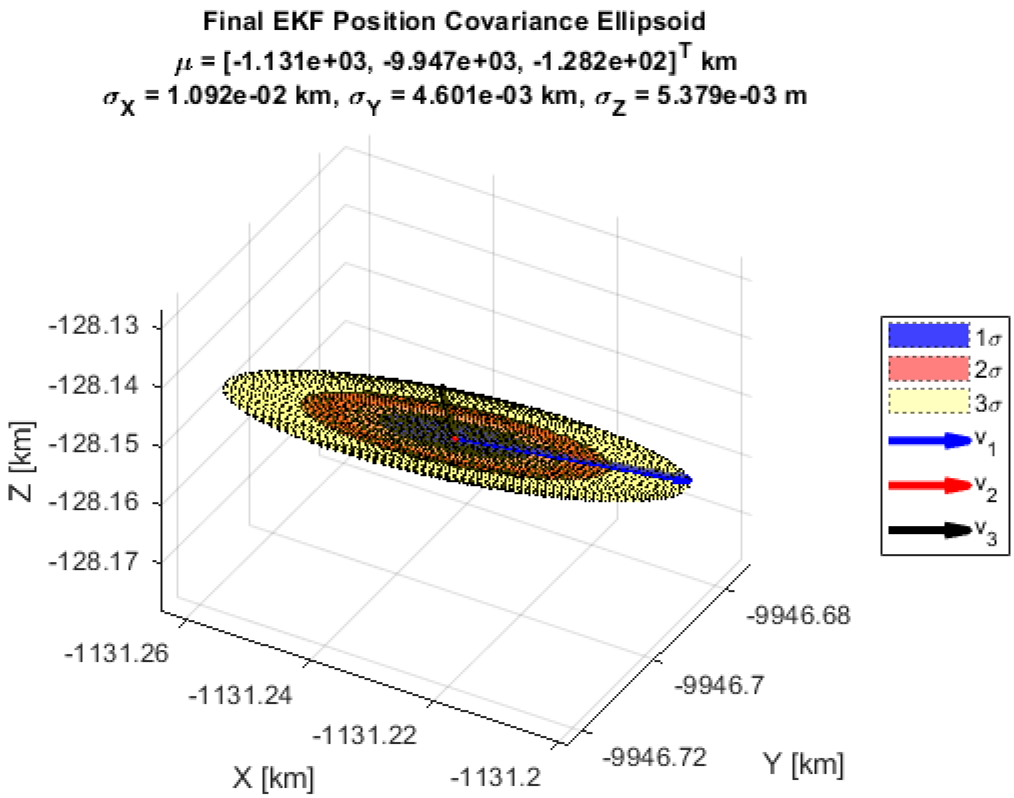

LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
×10^-3
Time [sec]
×10^4

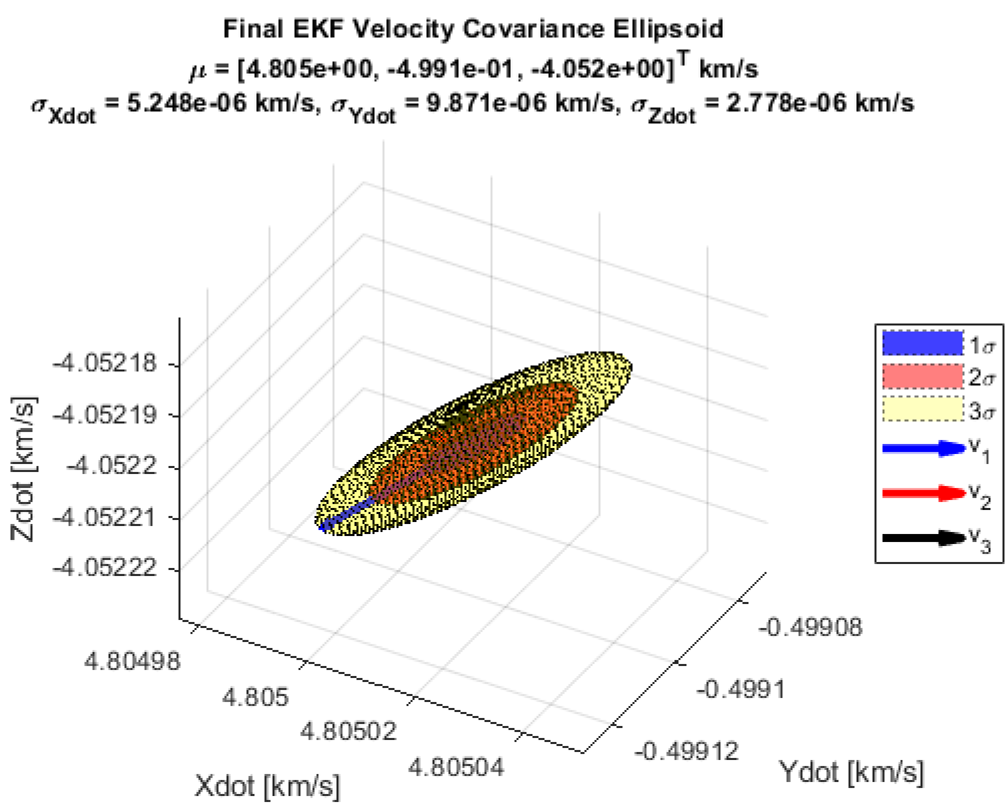

EKF Pre-Fit Residuals
Range Residuals [km]
Time [sec]
×10^4
μ = 7.0494e-05
σ = 4.3037e-03
Range-Rate Residuals [km/s]
×10^-5
μ = -5.8082e-09
σ = 1.6157e-06

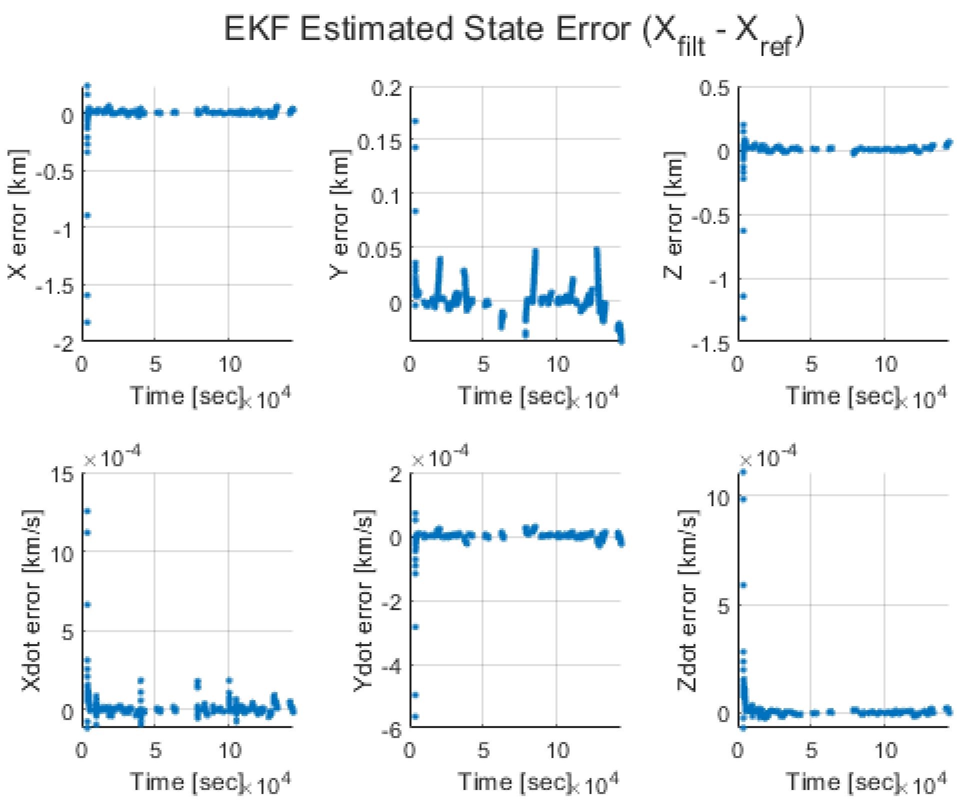

EKF Post-Fit Residuals
Range Residuals [km]
×10^-3
Time [sec]
×10^4
μ = -1.5434e-06
σ = 9.7217e-04
Range-Rate Residuals [km/s]
×10^-6
μ = -4.0226e-09
σ = 8.2549e-07

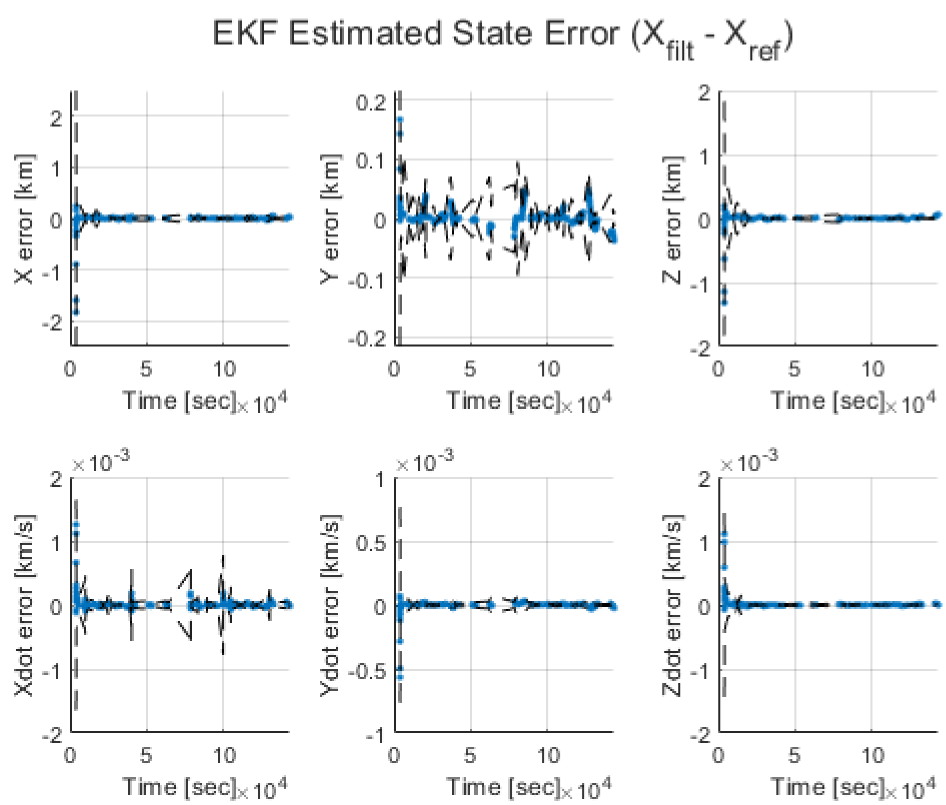

EKF R Covariance Trace
trace(P)
Time [sec]
$\times 10^4$

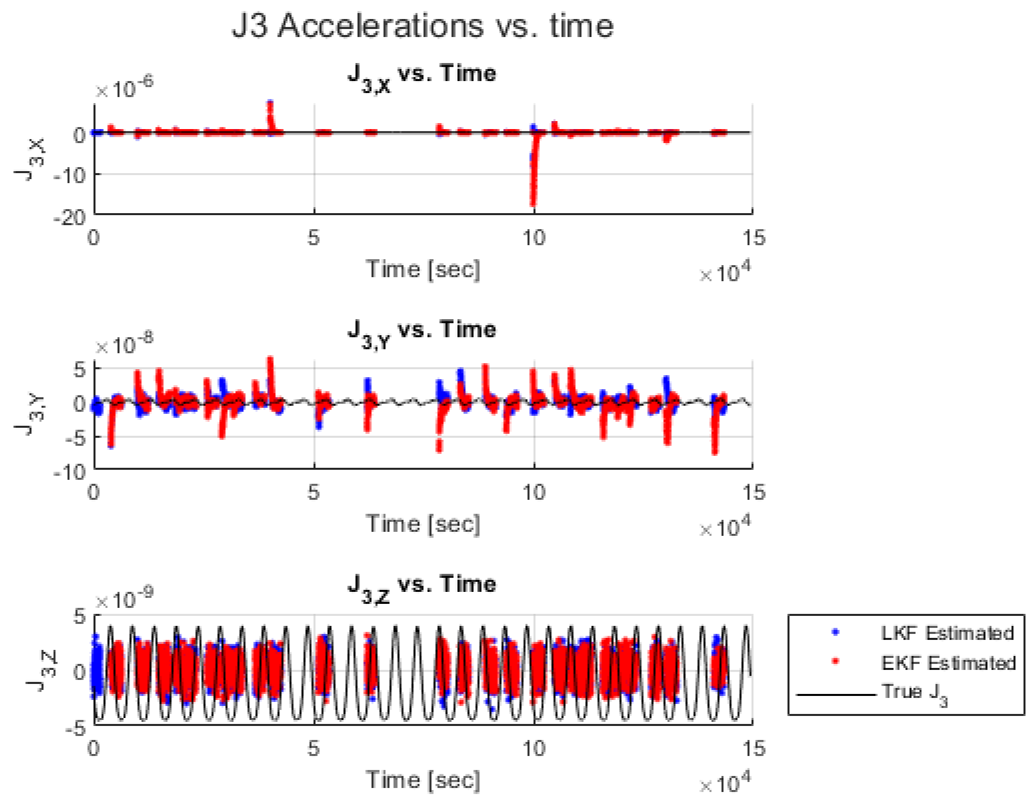

EKF V Covariance Trace
trace(P)
Time [sec]
$\times 10^4$

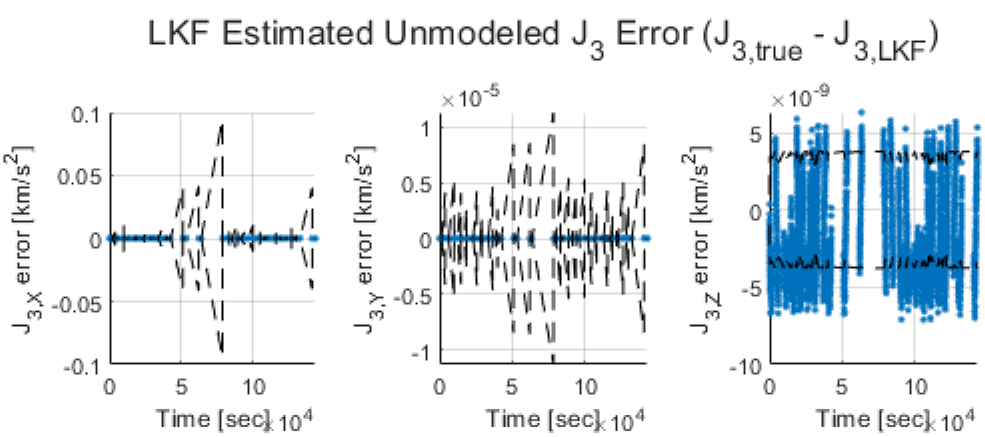

Final EKF Position Covariance Ellipsoid
μ = [-1.131e+03, -9.947e+03, -1.282e+02]^T km
σX = 1.092e-02 km, σY = 4.601e-03 km, σZ = 5.379e-03 m
Z [km]
-128.13
-128.14
-128.15
-128.16
-128.17
X [km]
-1131.26
-1131.24
-1131.22
-1131.2
Y [km]
-9946.68
-9946.7
-9946.72
1σ
2σ
3σ
v1
v2
v3

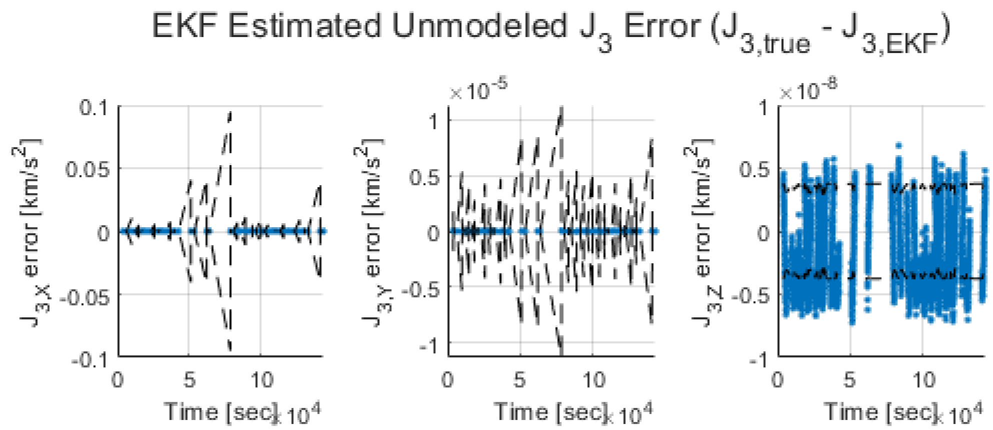

Final EKF Velocity Covariance Ellipsoid
μ = [4.805e+00, -4.991e-01, -4.052e+00]^T km/s
σXdot = 5.248e-06 km/s, σYdot = 9.871e-06 km/s, σZdot = 2.778e-06 km/s
Zdot [km/s]
-4.05218
-4.05219
-4.0522
-4.05221
-4.05222
Xdot [km/s]
4.80498
4.805
4.80502
4.80504
Ydot [km/s]
-0.49908
-0.4991
-0.49912
1σ
2σ
3σ
v1
v2
v3


EKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
$\times 10^4$
$\times 10^{-4}$


EKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
$\times 10^4$
$\times 10^{-3}$


J3 Accelerations vs. time
J3,X vs. Time
J3,Y vs. Time
J3,Z vs. Time
Time [sec]
LKF Estimated
EKF Estimated
True J3


LKF Estimated Unmodeled J3 Error (J3,true - J3,LKF)
J3,X error [km/s2]
J3,Y error [km/s2]
J3,Z error [km/s2]
Time [sec]



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