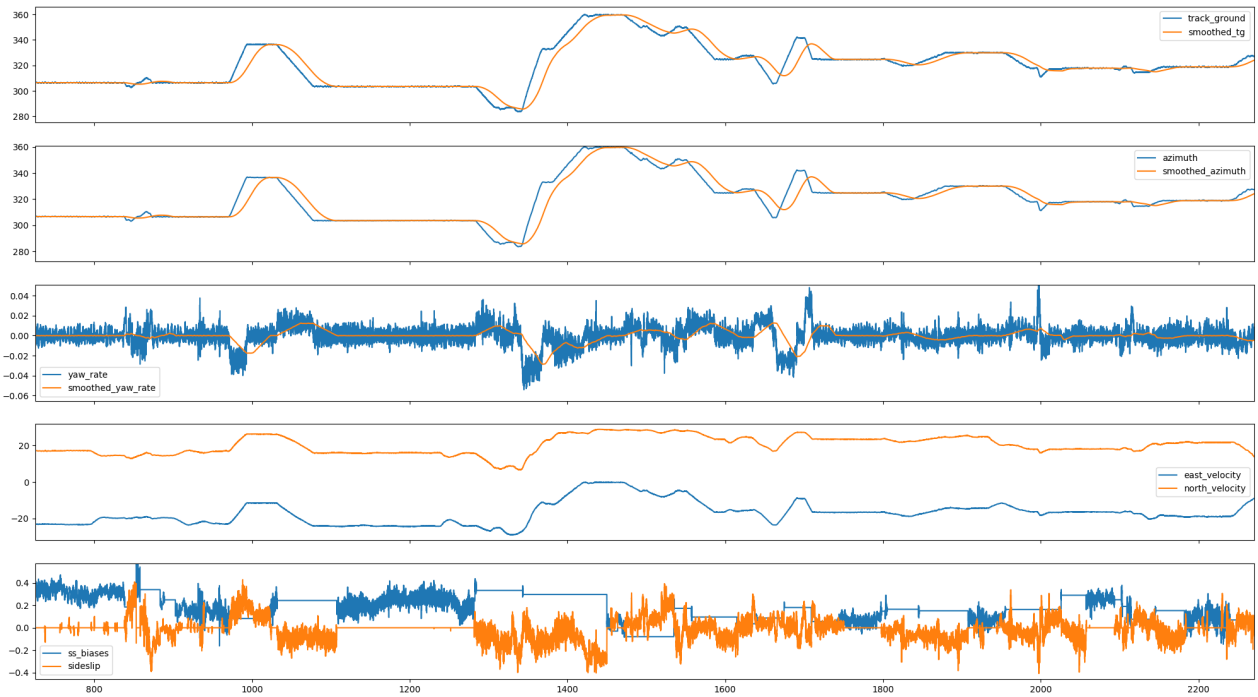
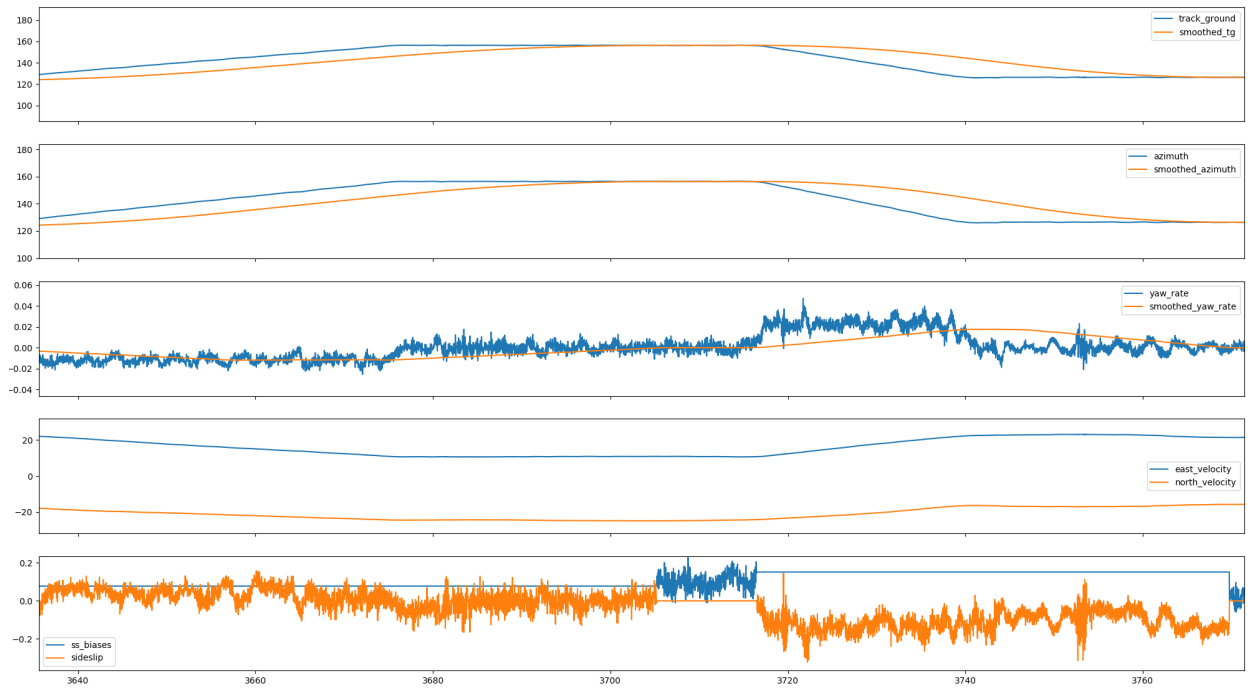
Results

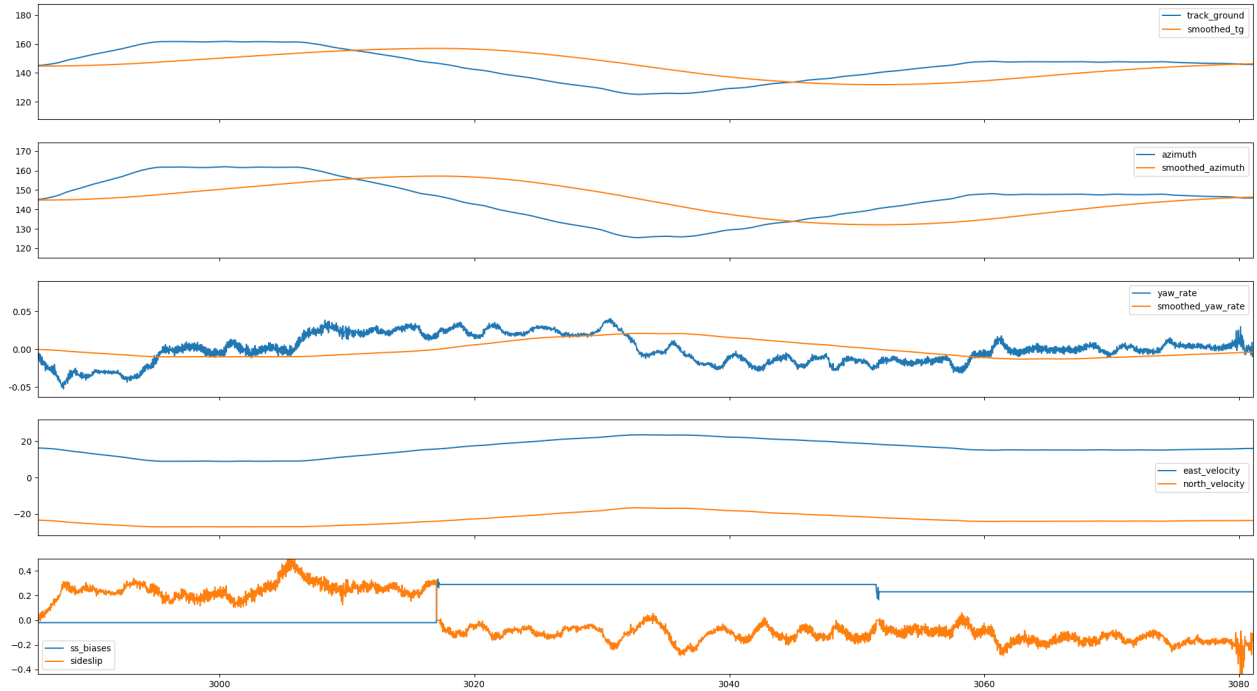
Example from one bag

- Overall observation
    - `smoothed yaw rate threshold=0.0002 rad/s, smooth_win_size=30 sec`



- Cornering segment with straightly motion in the middle



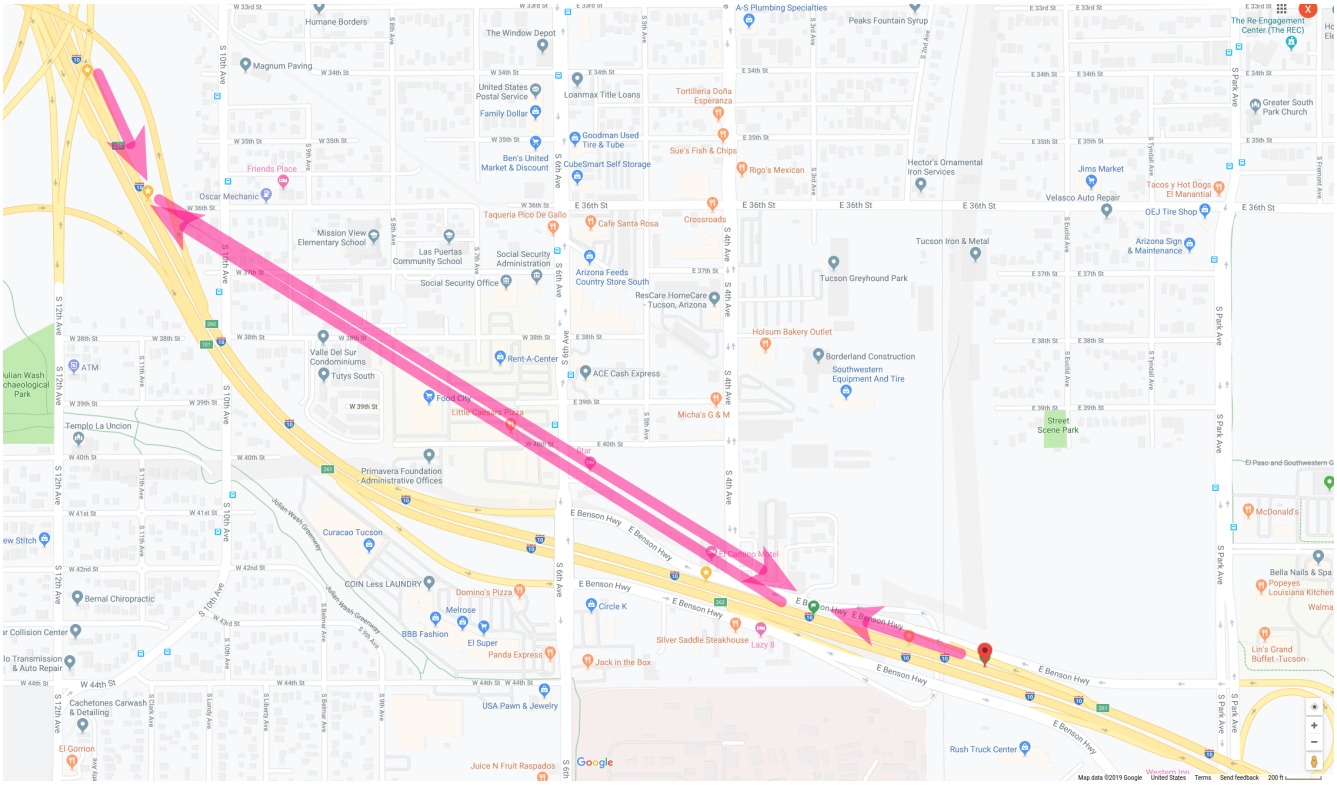


Issues

- Continuous cornering towards opposite directions (no straightly moving during the middle).

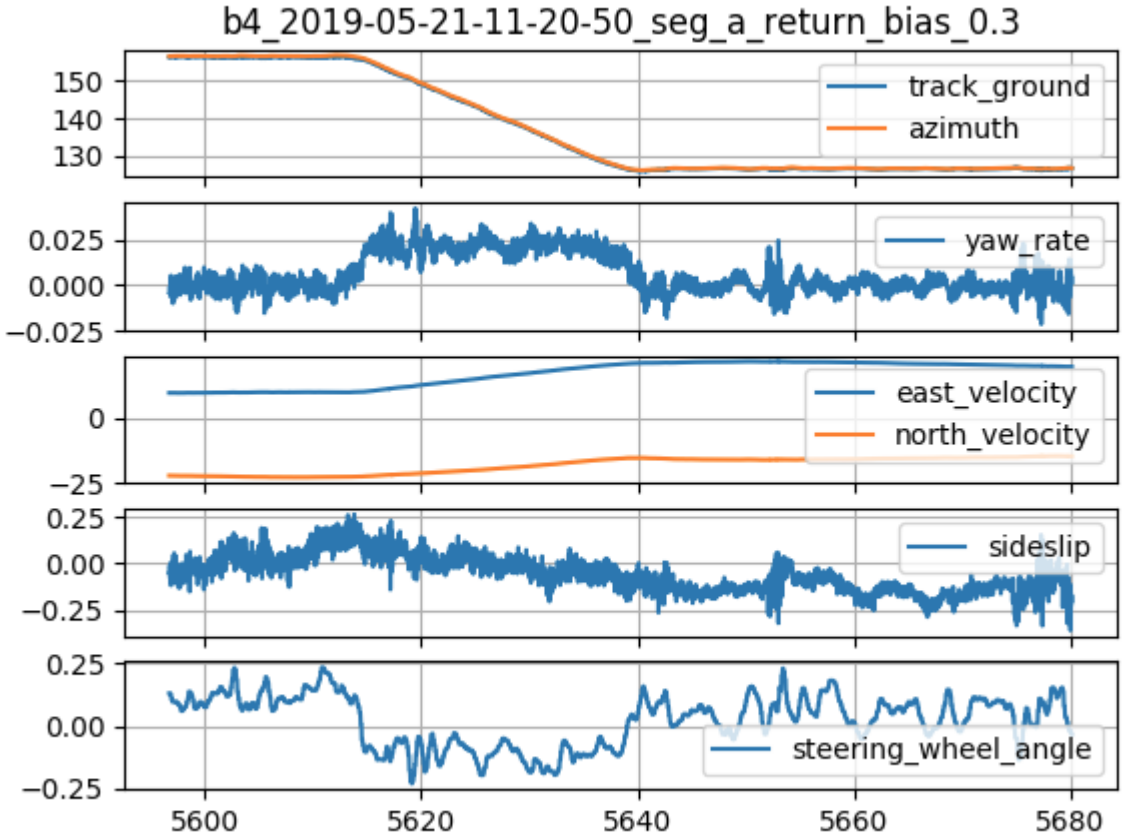
RY Side slip estimation

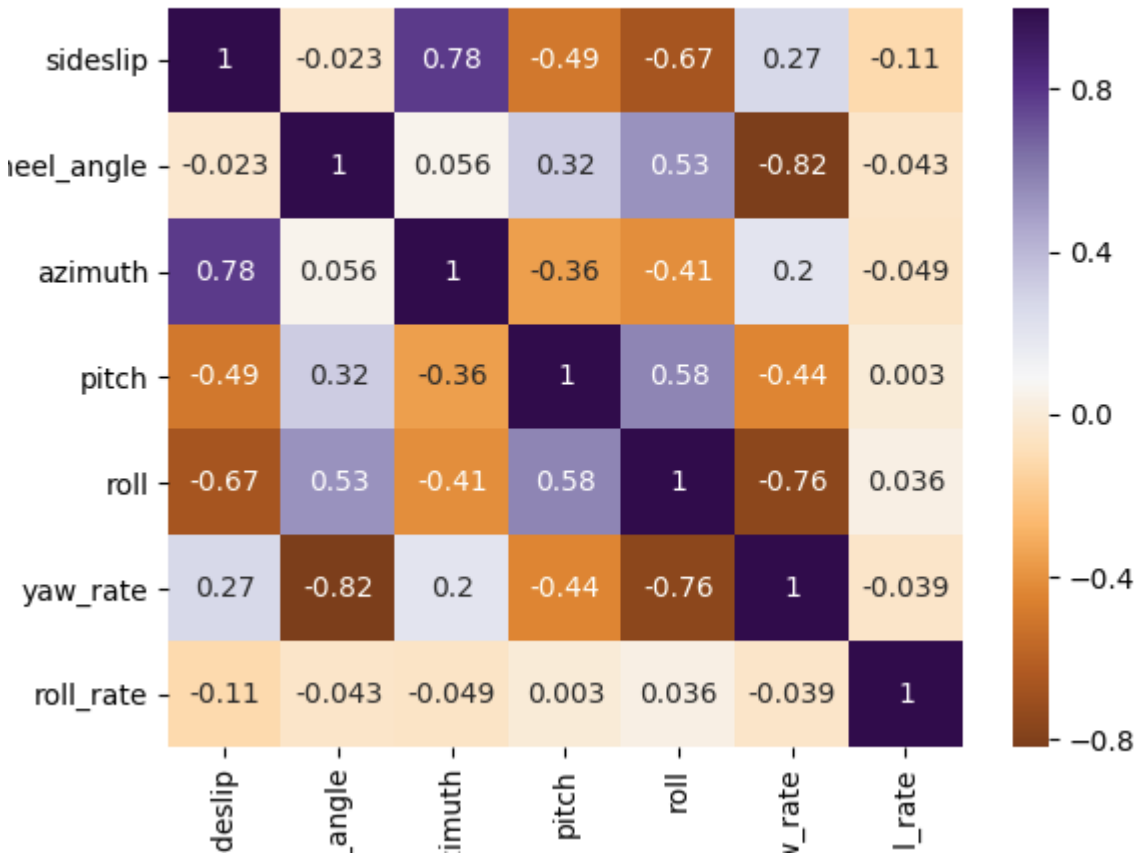
Road Segment NO. 2

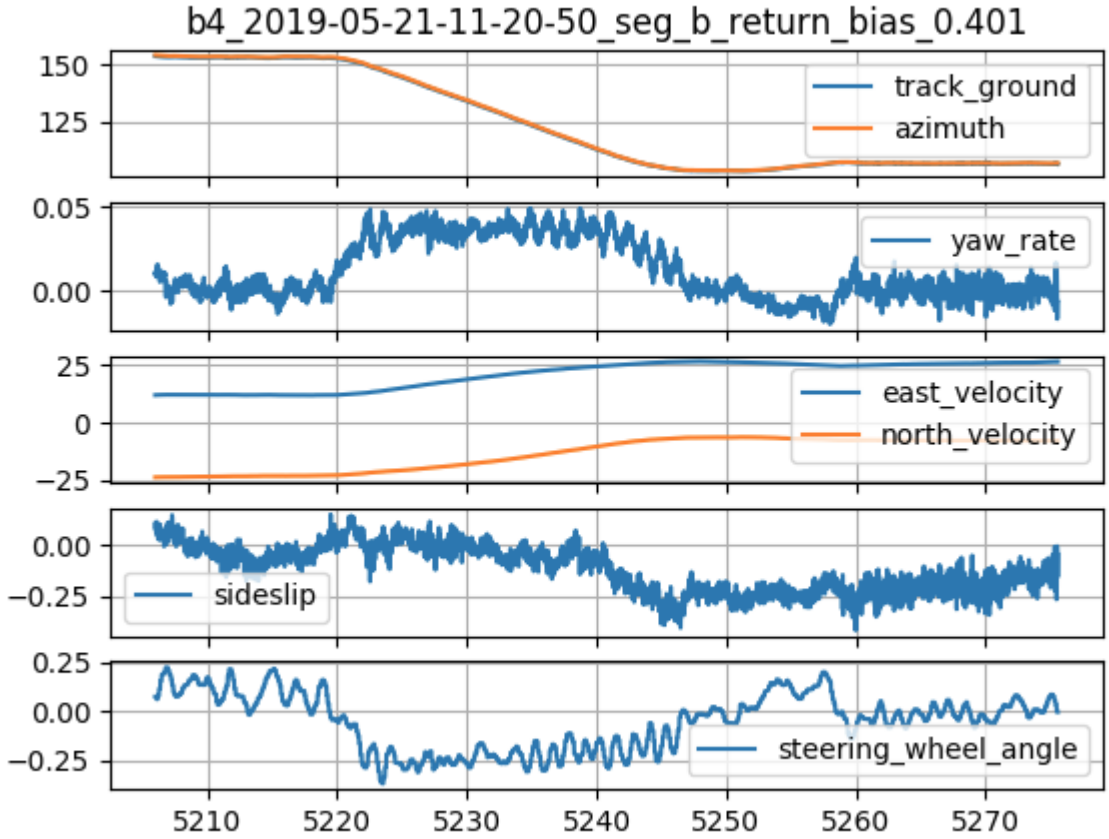


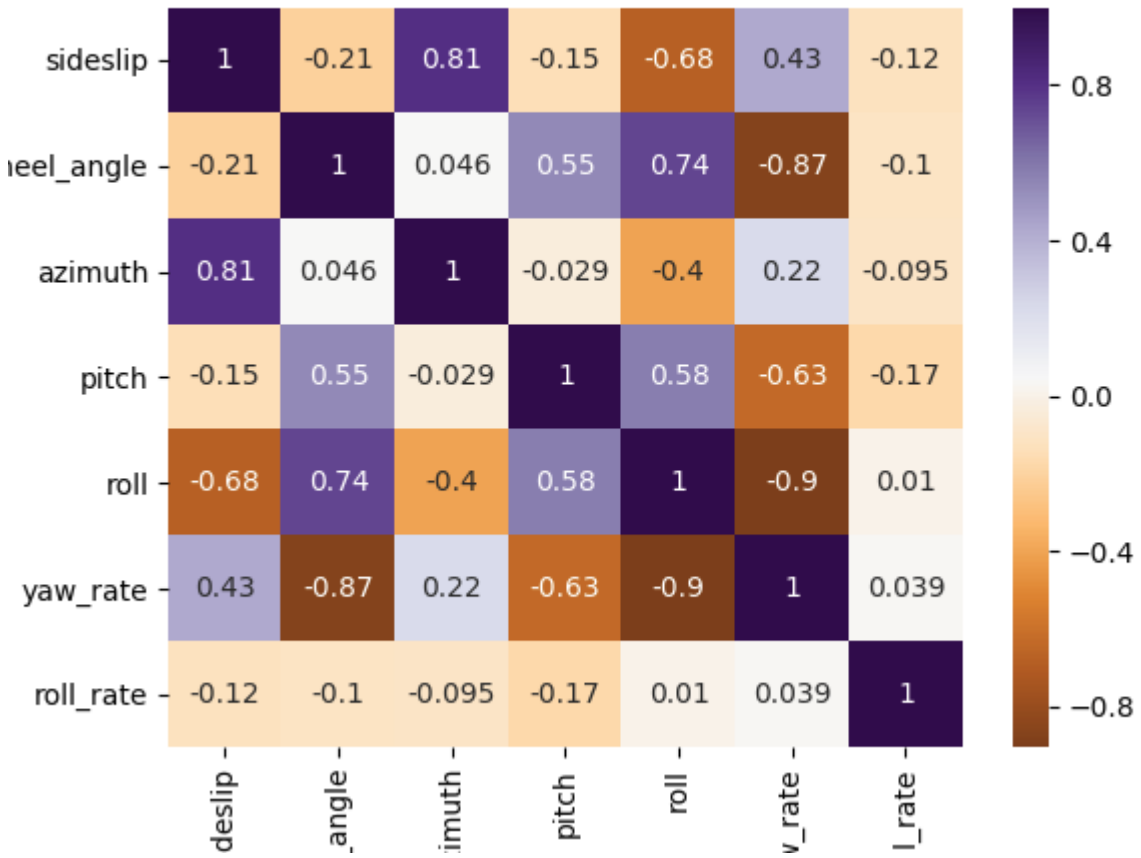
Observation in flight

The oscillation of steering wheel angle may be related to estimated side slip results . But this does not show from the covariance matrix.


b4_2019-05-21-11-20-50_seg_a_return_bias_0.3
track_ground
azimuth
150
140
130
yaw_rate
0.025
0.000
−0.025
east_velocity
north_velocity
0
−25
sideslip
0.25
0.00
−0.25
steering_wheel_angle
0.25
0.00
−0.25
5600
5620
5640
5660
5680


sideslip
heel_angle
azimuth
pitch
roll
yaw_rate
roll_rate
1 -0.023 0.78 -0.49 -0.67 0.27 -0.11
-0.023 1 0.056 0.32 0.53 -0.82 -0.043
0.78 0.056 1 -0.36 -0.41 0.2 -0.049
-0.49 0.32 -0.36 1 0.58 -0.44 0.003
-0.67 0.53 -0.41 0.58 1 -0.76 0.036
0.27 -0.82 0.2 -0.44 -0.76 1 -0.039
-0.11 -0.043 -0.049 0.003 0.036 -0.039 1
deslip
angle
imuth
pitch
roll
v_rate
l_rate
0.8
0.4
0.0
−0.4
−0.8

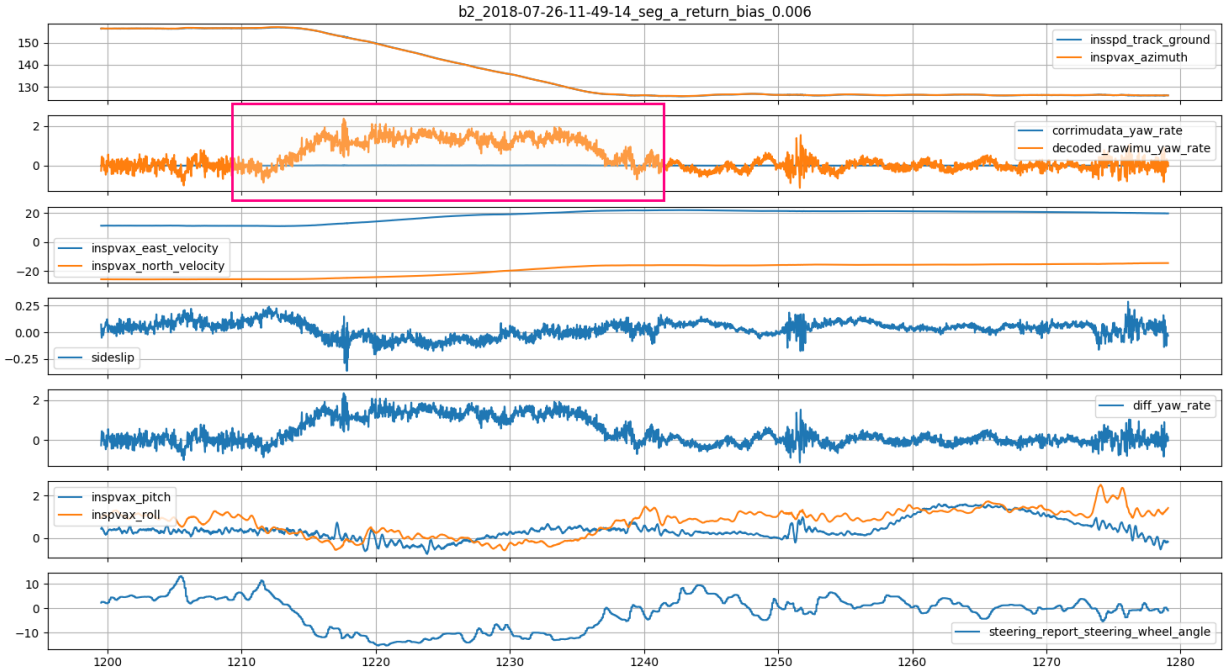

b4_2019-05-21-11-20-50_seg_b_return_bias_0.401
150
125
track_ground
azimuth
0.05
0.00
yaw_rate
25
0
−25
east_velocity
north_velocity
0.00
−0.25
sideslip
0.25
0.00
−0.25
steering_wheel_angle
5210
5220
5230
5240
5250
5260
5270

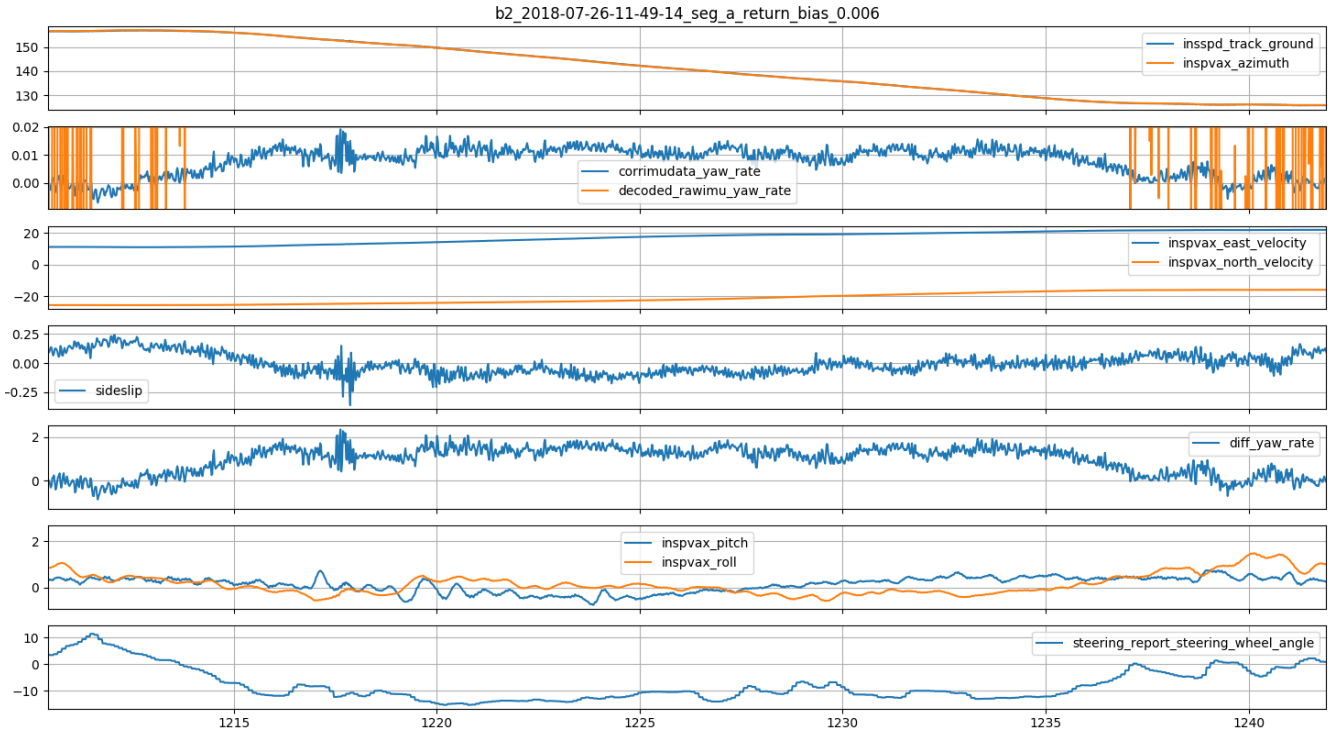


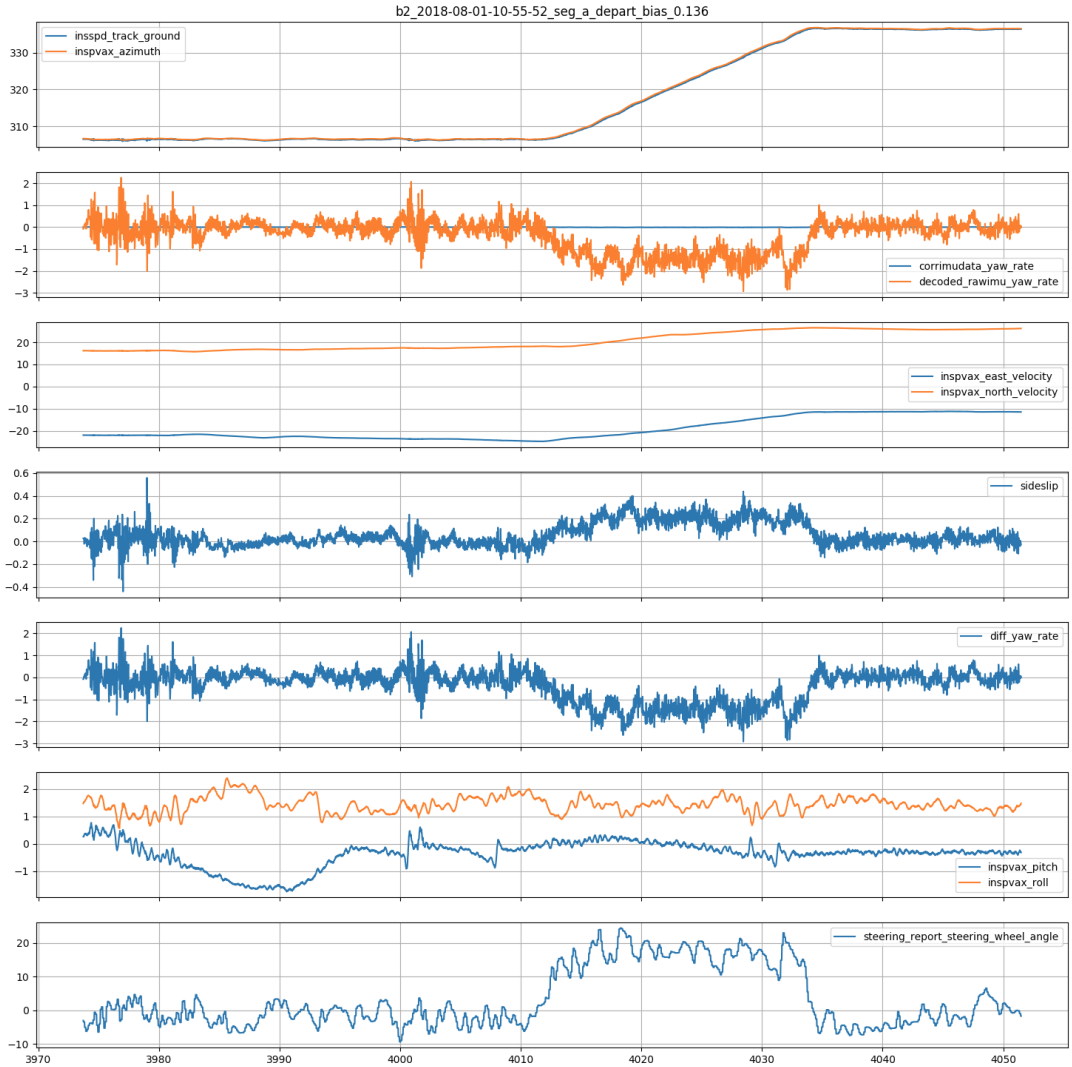
Side slip angle observations (Use degree for angles.)

From curves.

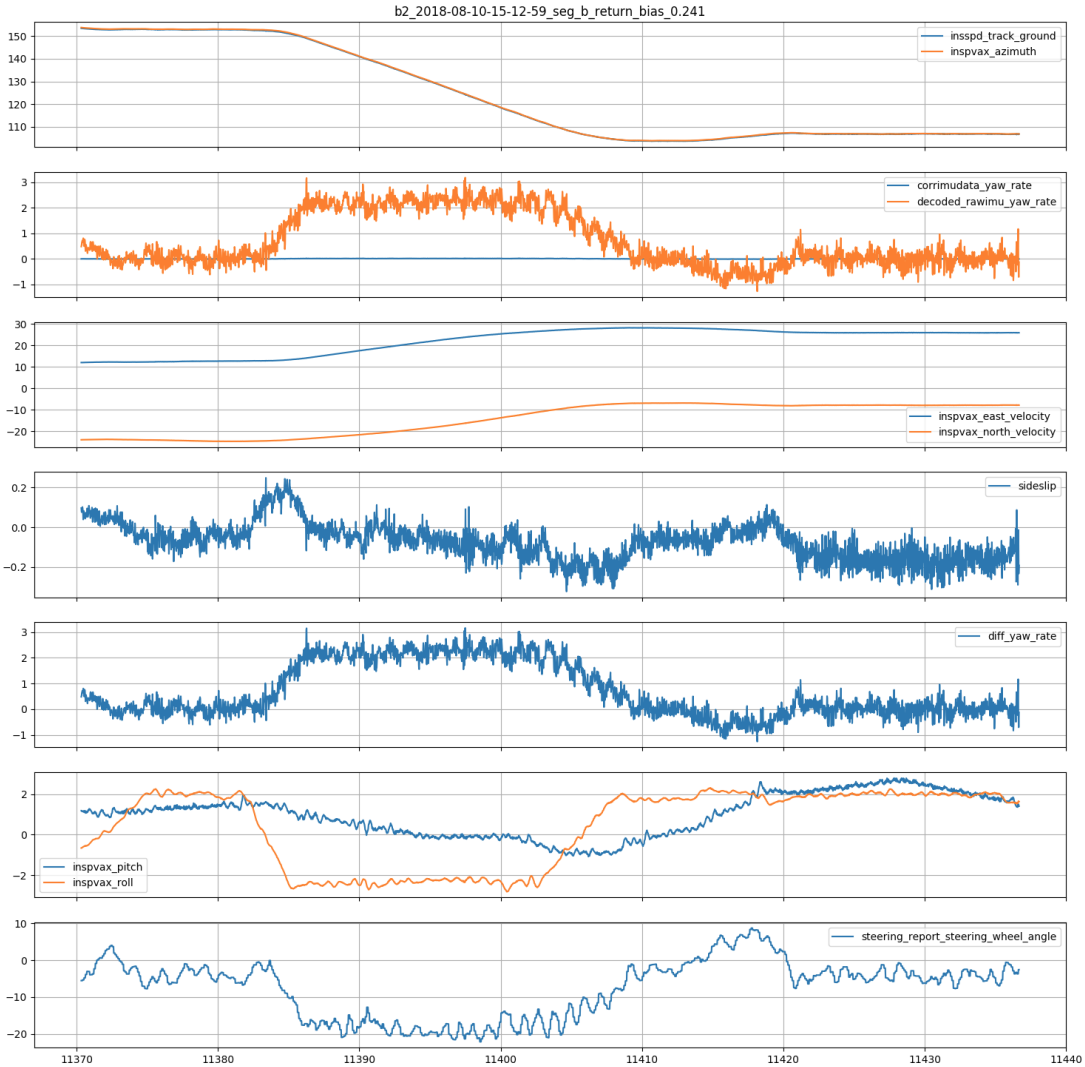
- The corrected yaw rate is abnormally low when cornering.
    - 2018-07-26-11-49-14


b2_2018-07-26-11-49-14_seg_a_return_bias_0.006
insspd_track_ground
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle


b2_2018-07-26-11-49-14_seg_a_return_bias_0.006
insspd_track_ground
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle



- The trend of side slip angle and steering wheel angle may be worth noticing as a estimation of side slip performance.


b2_2018-08-10-15-12-59_seg_b_return_bias_0.241
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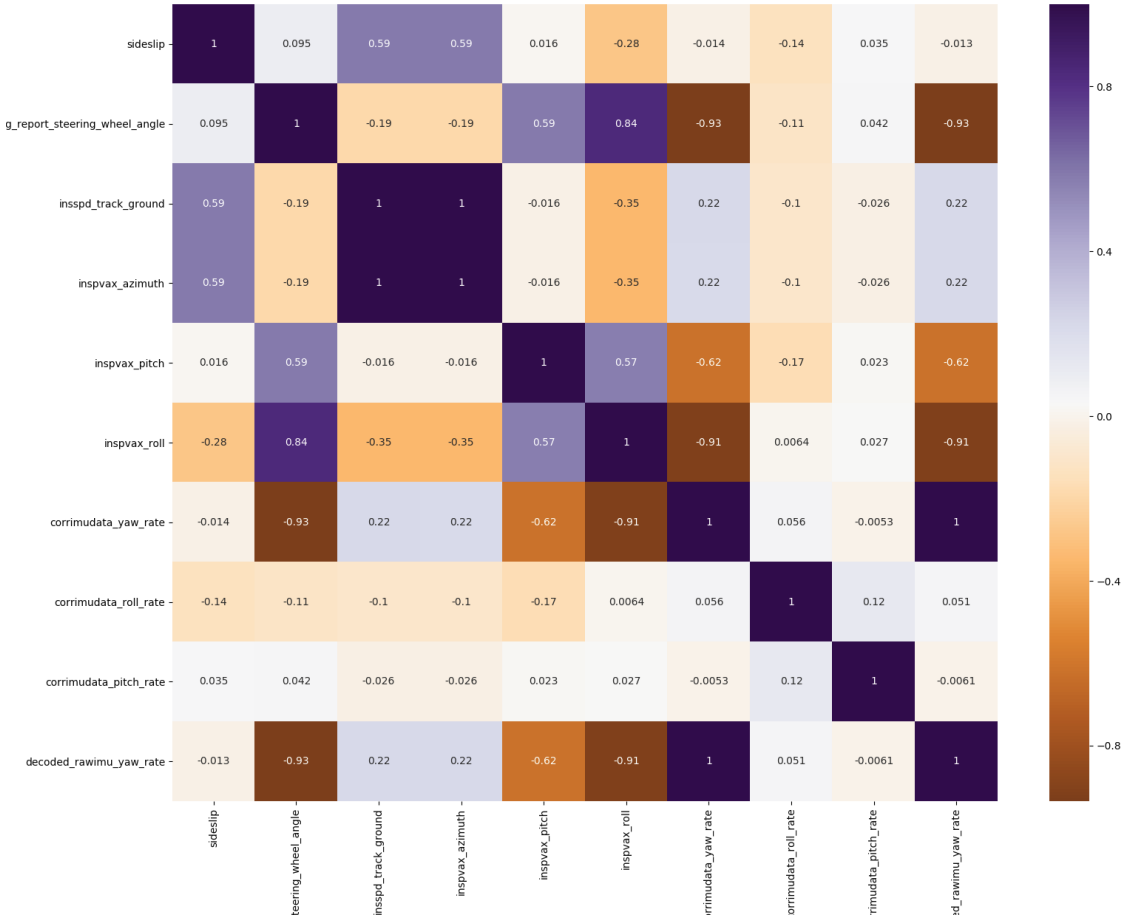
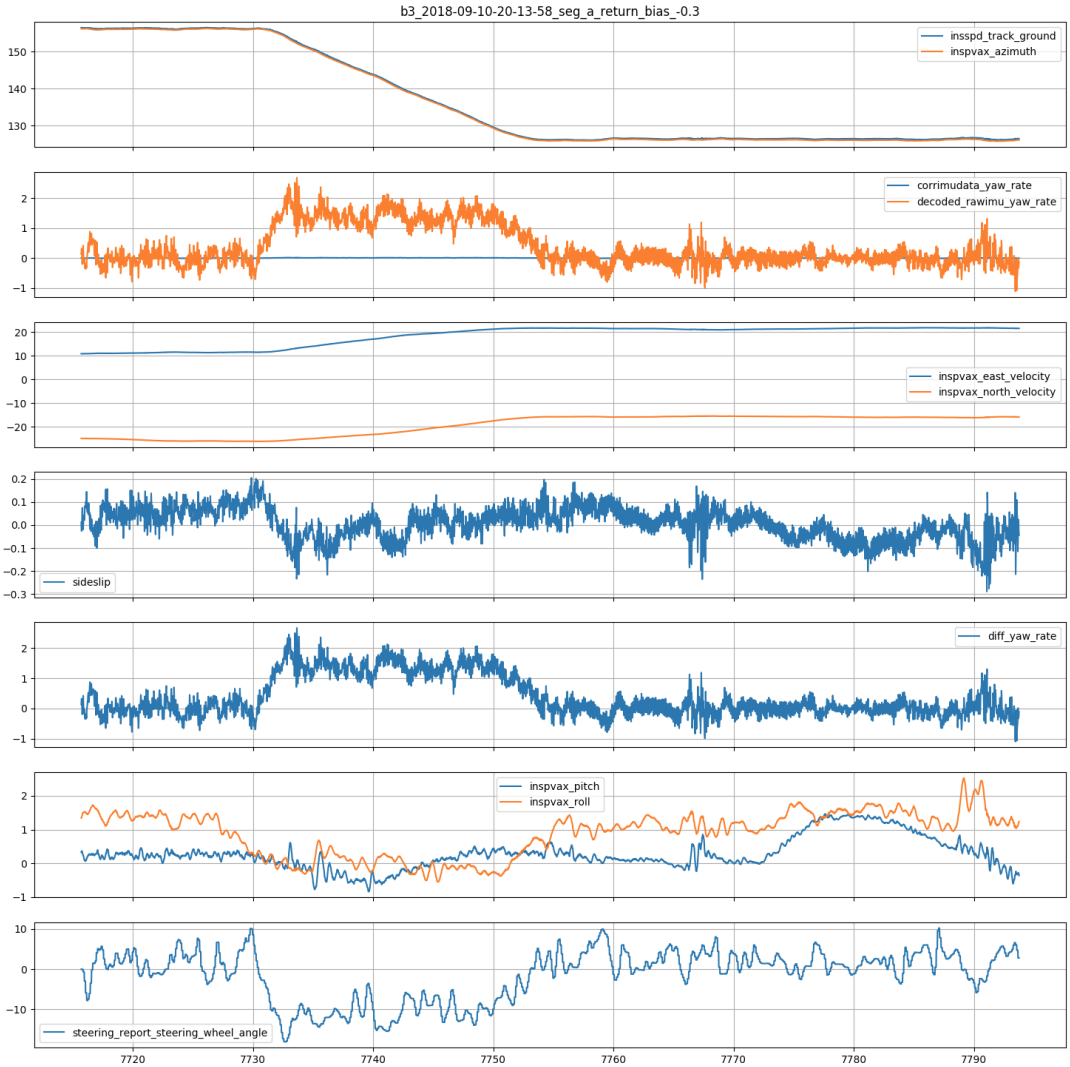
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
11370
11380
11390
11400
11410
11420
11430
11440


sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 0.095 0.59 0.59 0.016 -0.28 -0.014 -0.14 0.035 -0.013
0.095 1 -0.19 -0.19 0.59 0.84 -0.93 -0.11 0.042 -0.93
0.59 -0.19 1 1 -0.016 -0.35 0.22 -0.1 -0.026 0.22
0.59 -0.19 1 1 -0.016 -0.35 0.22 -0.1 -0.026 0.22
0.016 0.59 -0.016 -0.016 1 0.57 -0.62 -0.17 0.023 -0.62
-0.28 0.84 -0.35 -0.35 0.57 1 -0.91 0.0064 0.027 -0.91
-0.014 -0.93 0.22 0.22 -0.62 -0.91 1 0.056 -0.0053 1
-0.14 -0.11 -0.1 -0.1 -0.17 0.0064 0.056 1 0.12 0.051
0.035 0.042 -0.026 -0.026 0.023 0.027 -0.0053 0.12 1 -0.0061
-0.013 -0.93 0.22 0.22 -0.62 -0.91 1 0.051 -0.0061 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8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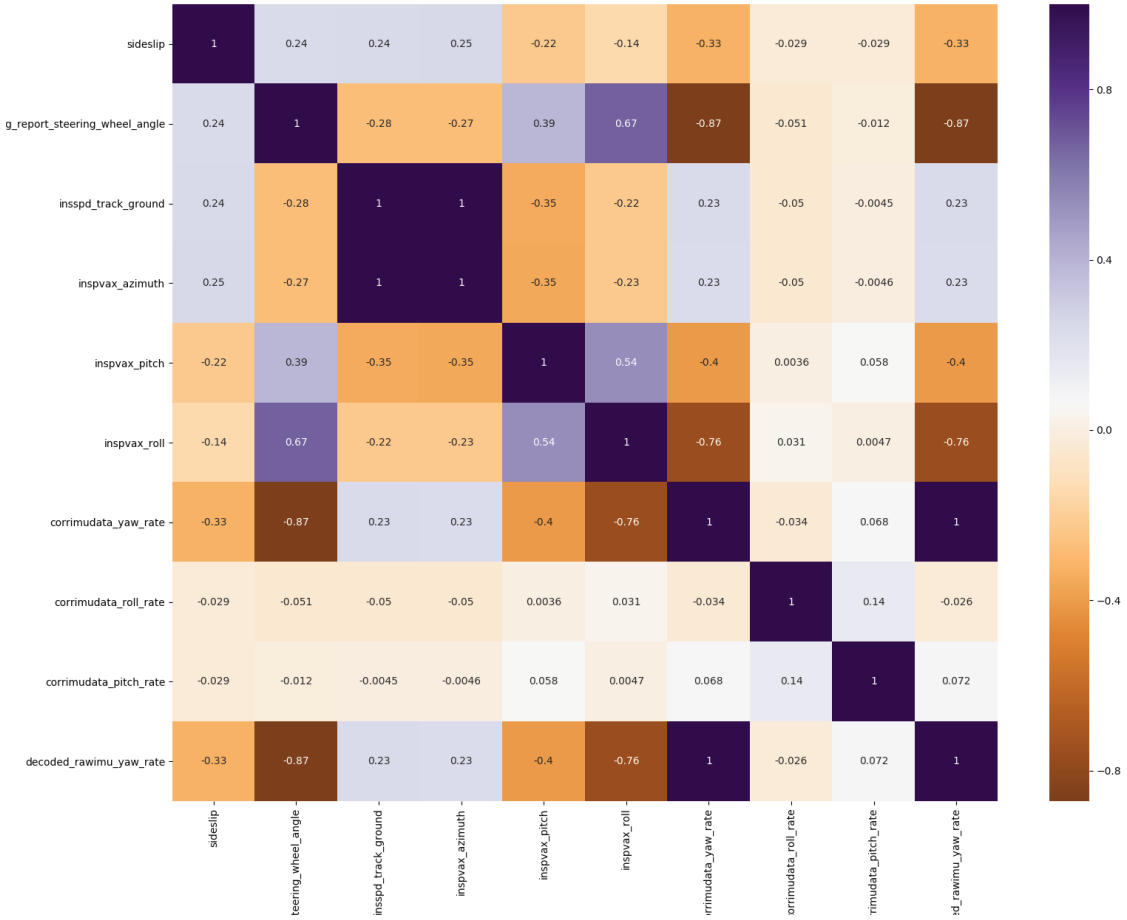
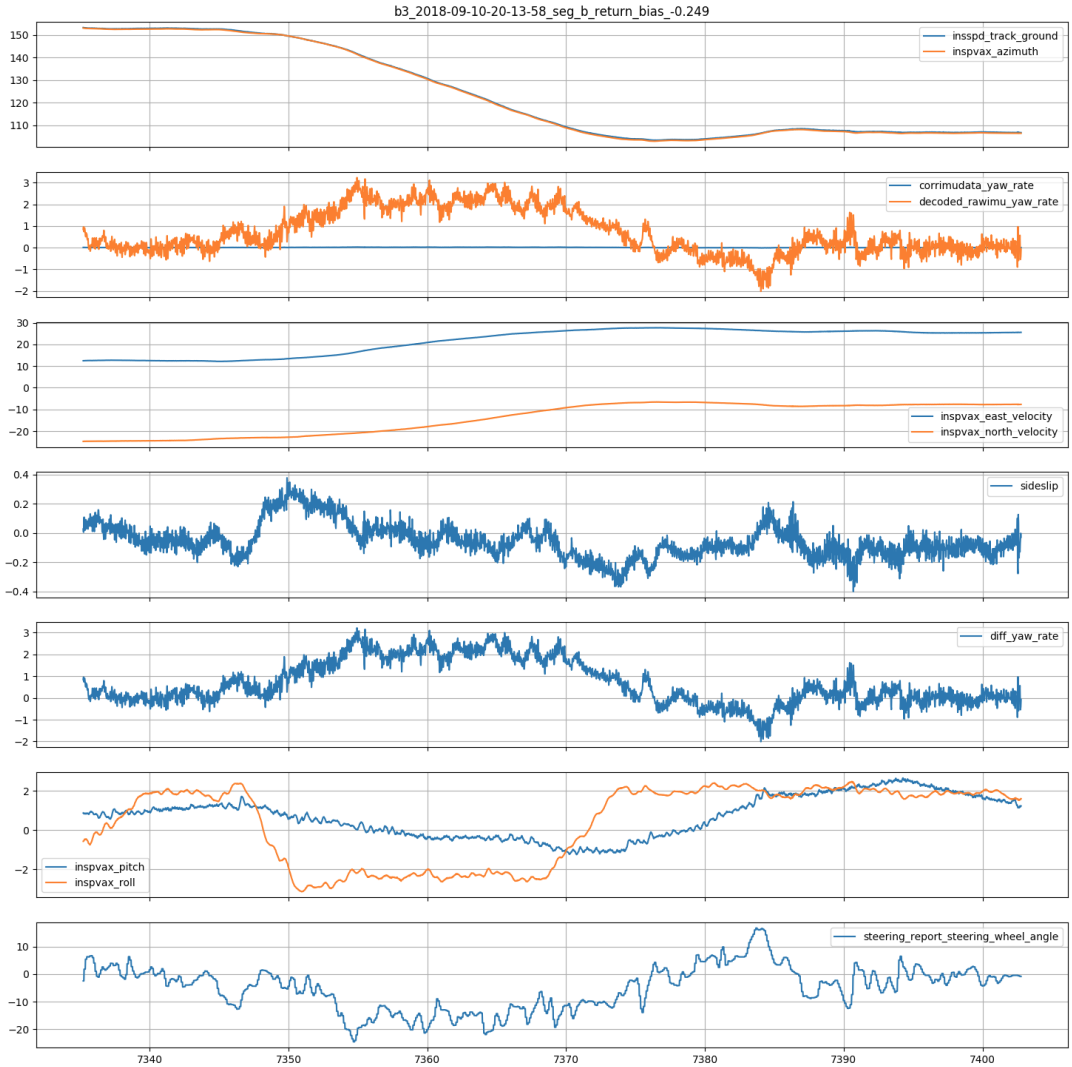
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
7720
7730
7740
7750
7760
7770
7780
7790


sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 0.24 0.24 0.25 -0.22 -0.14 -0.33 -0.029 -0.029 -0.33
0.24 1 -0.28 -0.27 0.39 0.67 -0.87 -0.051 -0.012 -0.87
0.24 -0.28 1 1 -0.35 -0.22 0.23 -0.05 -0.0045 0.23
0.25 -0.27 1 1 -0.35 -0.23 0.23 -0.05 -0.0046 0.23
-0.22 0.39 -0.35 -0.35 1 0.54 -0.4 0.0036 0.058 -0.4
-0.14 0.67 -0.22 -0.23 0.54 1 -0.76 0.031 0.0047 -0.76
-0.33 -0.87 0.23 0.23 -0.4 -0.76 1 -0.034 0.068 1
-0.029 -0.051 -0.05 -0.05 0.0036 0.031 -0.034 1 0.14 -0.026
-0.029 -0.012 -0.0045 -0.0046 0.058 0.0047 0.068 0.14 1 0.072
-0.33 -0.87 0.23 0.23 -0.4 -0.76 1 -0.026 0.072 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8


b3_2018-09-10-20-13-58_seg_b_return_bias_-0.249
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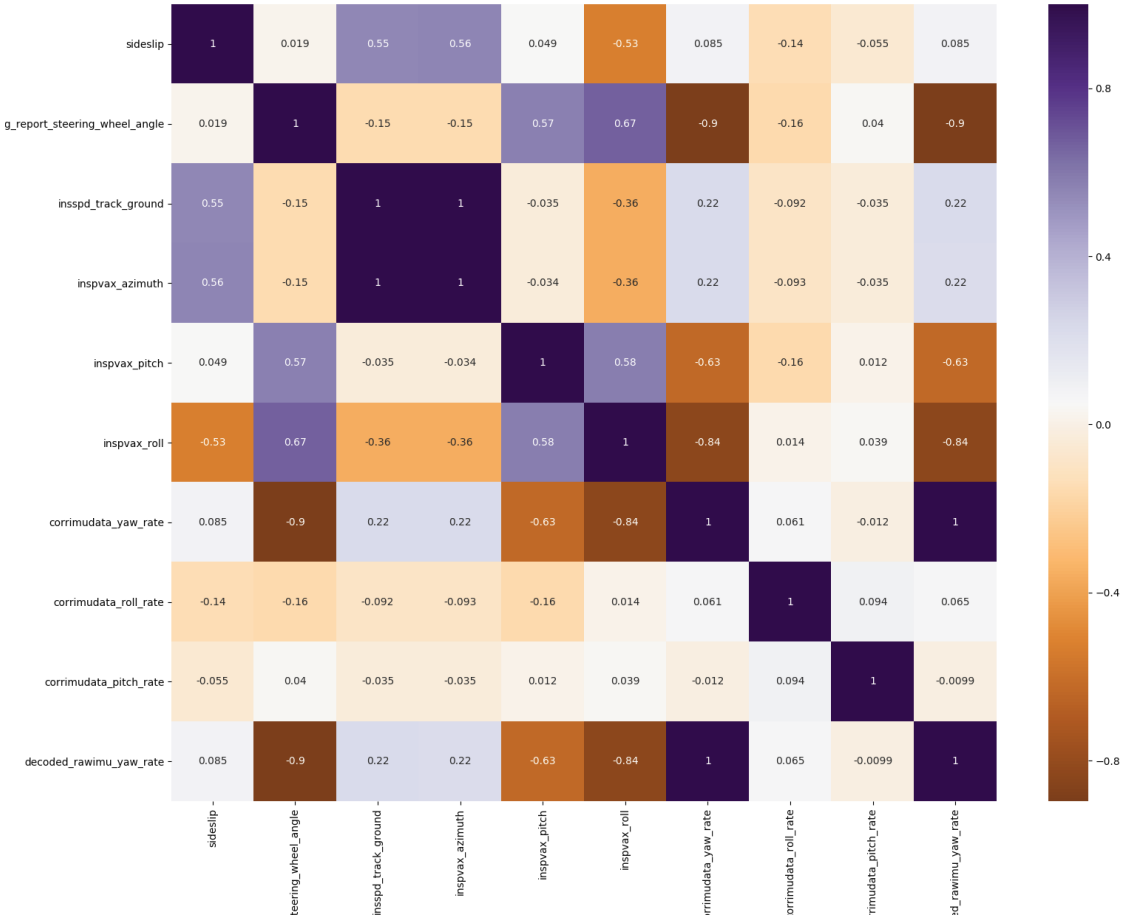
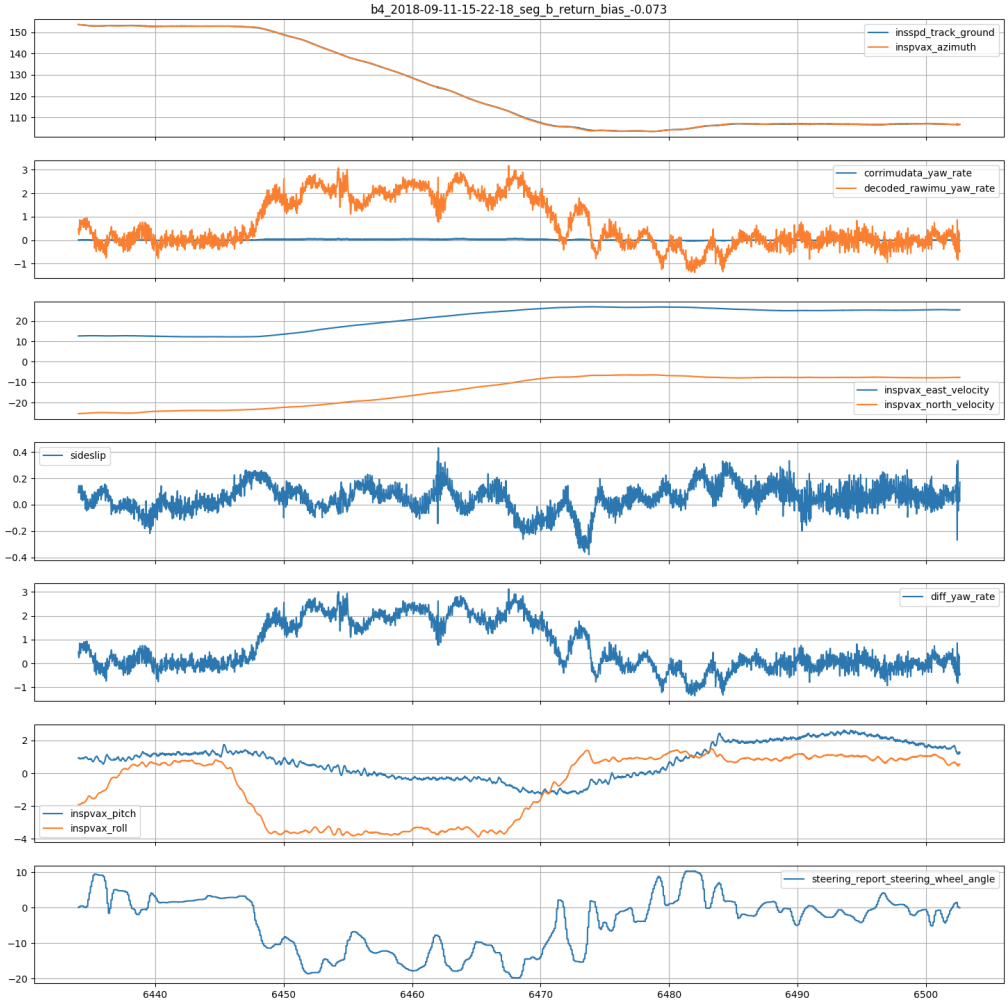
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
7340
7350
7360
7370
7380
7390
7400


sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 0.019 0.55 0.56 0.049 -0.53 0.085 -0.14 -0.055 0.085
0.019 1 -0.15 -0.15 0.57 0.67 -0.9 -0.16 0.04 -0.9
0.55 -0.15 1 1 -0.035 -0.36 0.22 -0.092 -0.035 0.22
0.56 -0.15 1 1 -0.034 -0.36 0.22 -0.093 -0.035 0.22
0.049 0.57 -0.035 -0.034 1 0.58 -0.63 -0.16 0.012 -0.63
-0.53 0.67 -0.36 -0.36 0.58 1 -0.84 0.014 0.039 -0.84
0.085 -0.9 0.22 0.22 -0.63 -0.84 1 0.061 -0.012 1
-0.14 -0.16 -0.092 -0.093 -0.16 0.014 0.061 1 0.094 0.065
-0.055 0.04 -0.035 -0.035 0.012 0.039 -0.012 0.094 1 -0.0099
0.085 -0.9 0.22 0.22 -0.63 -0.84 1 0.065 -0.0099 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8

- b4


b4_2018-09-11-15-22-18_seg_b_return_bias_-0.073
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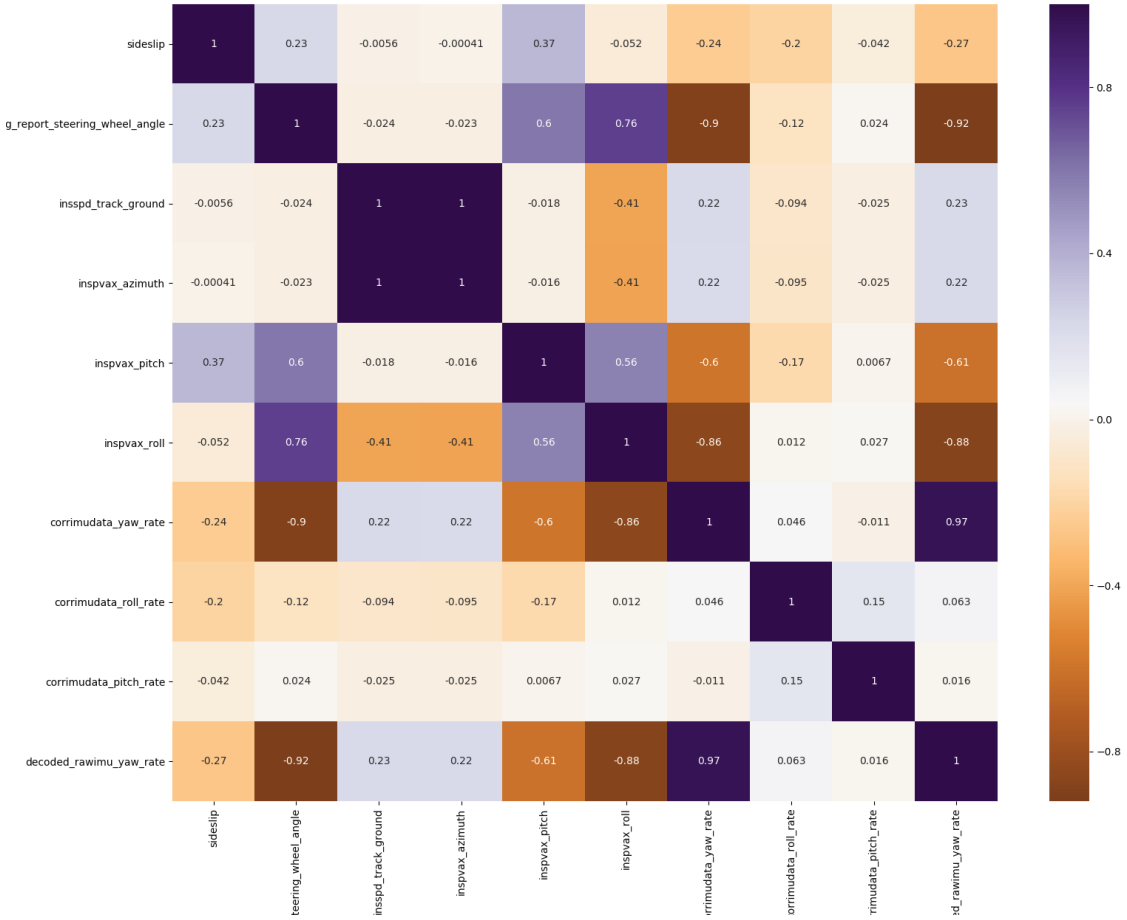
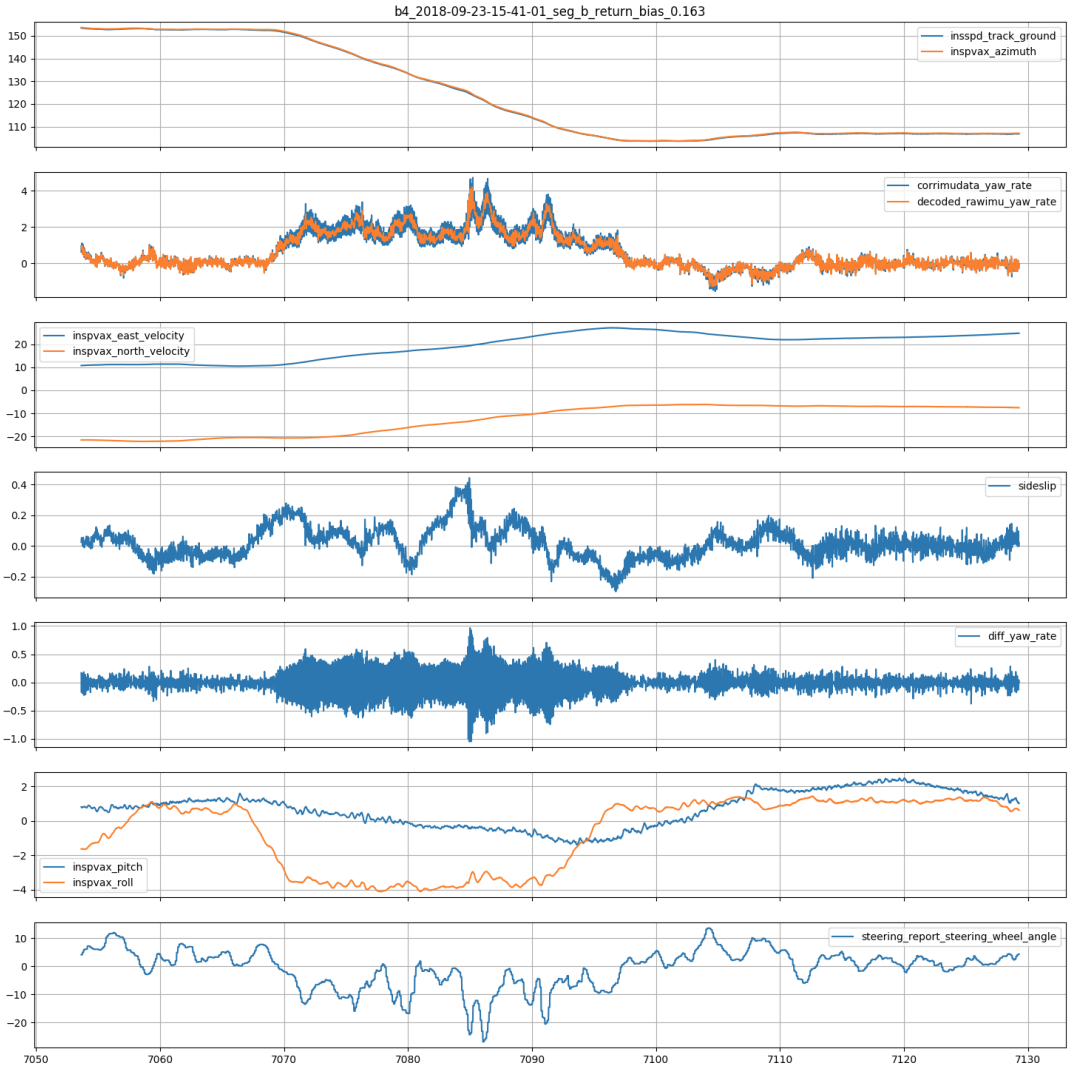
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
6440
6450
6460
6470
6480
6490
6500


sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 0.23 -0.0056 -0.00041 0.37 -0.052 -0.24 -0.2 -0.042 -0.27
0.23 1 -0.024 -0.023 0.6 0.76 -0.9 -0.12 0.024 -0.92
-0.0056 -0.024 1 1 -0.018 -0.41 0.22 -0.094 -0.025 0.23
-0.00041 -0.023 1 1 -0.016 -0.41 0.22 -0.095 -0.025 0.22
0.37 0.6 -0.018 -0.016 1 0.56 -0.6 -0.17 0.0067 -0.61
-0.052 0.76 -0.41 -0.41 0.56 1 -0.86 0.012 0.027 -0.88
-0.24 -0.9 0.22 0.22 -0.6 -0.86 1 0.046 -0.011 0.97
-0.2 -0.12 -0.094 -0.095 -0.17 0.012 0.046 1 0.15 0.063
-0.042 0.024 -0.025 -0.025 0.0067 0.027 -0.011 0.15 1 0.016
-0.27 -0.92 0.23 0.22 -0.61 -0.88 0.97 0.063 0.016 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8


b4_2018-09-23-15-41-01_seg_b_return_bias_0.163
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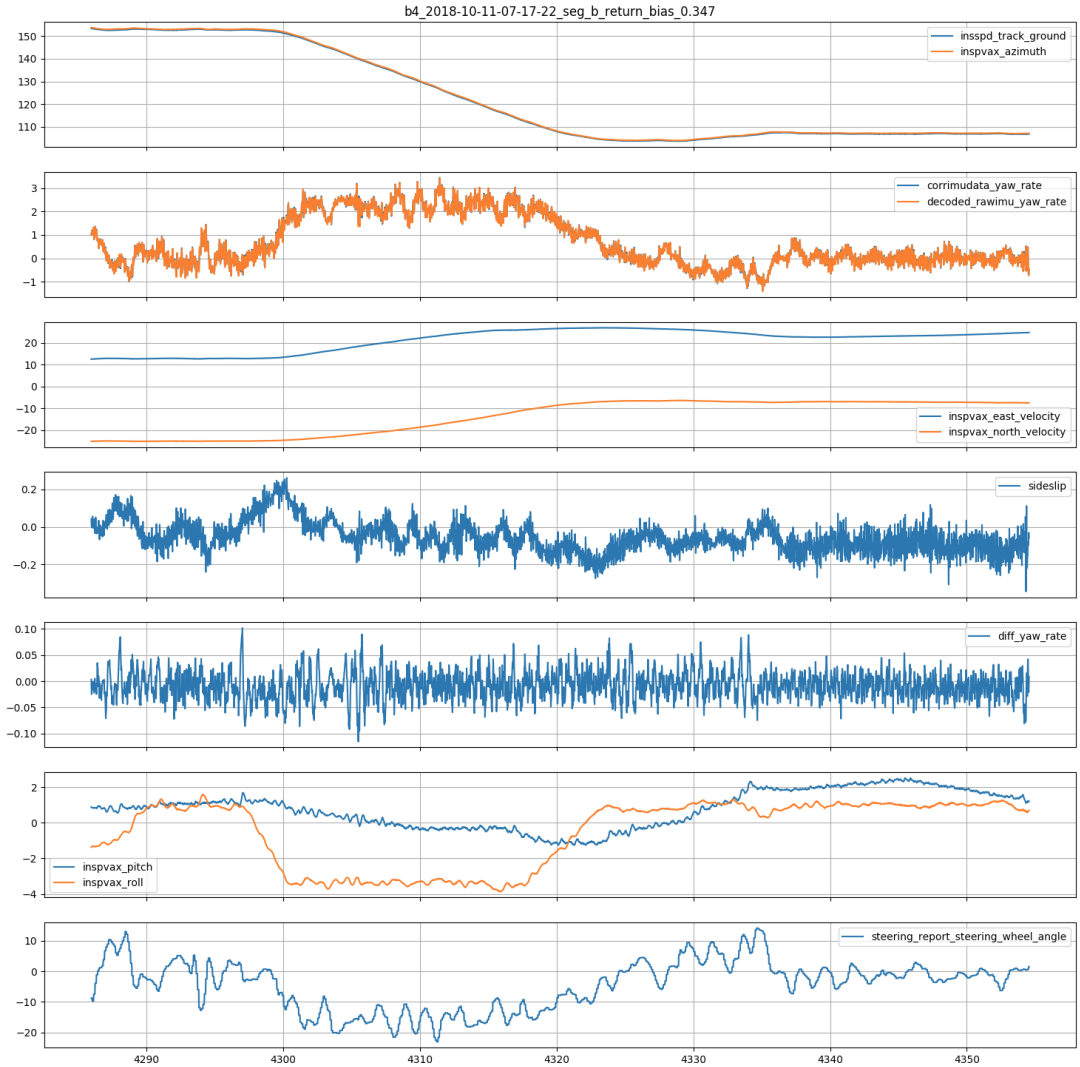
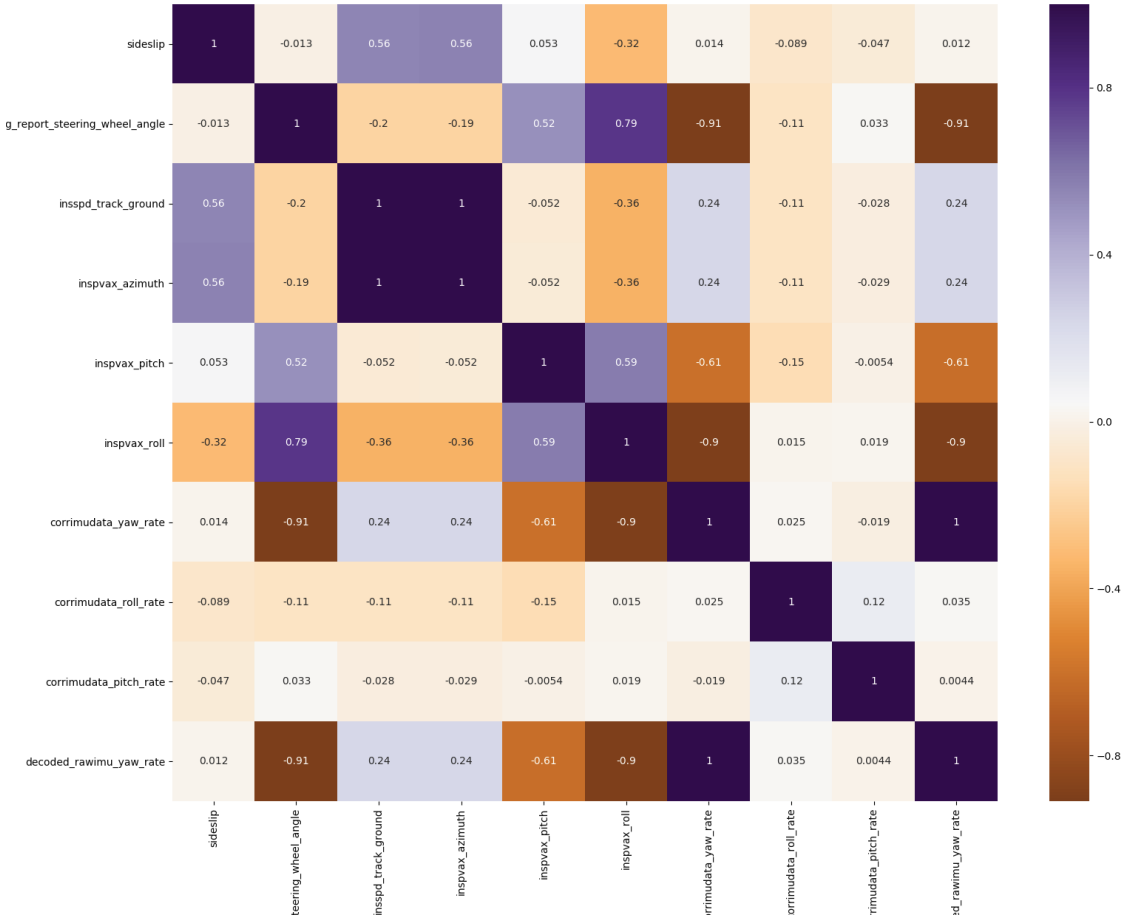
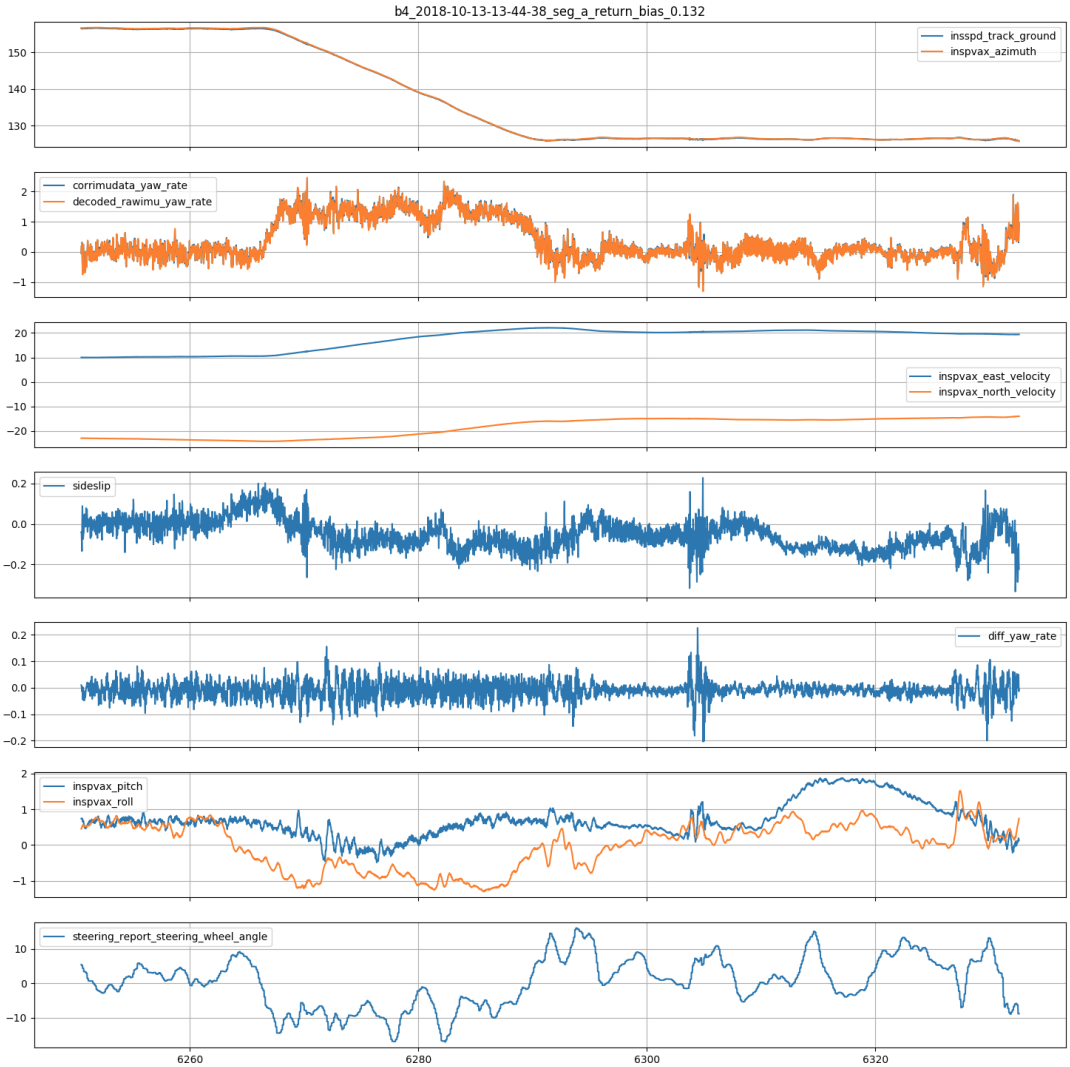
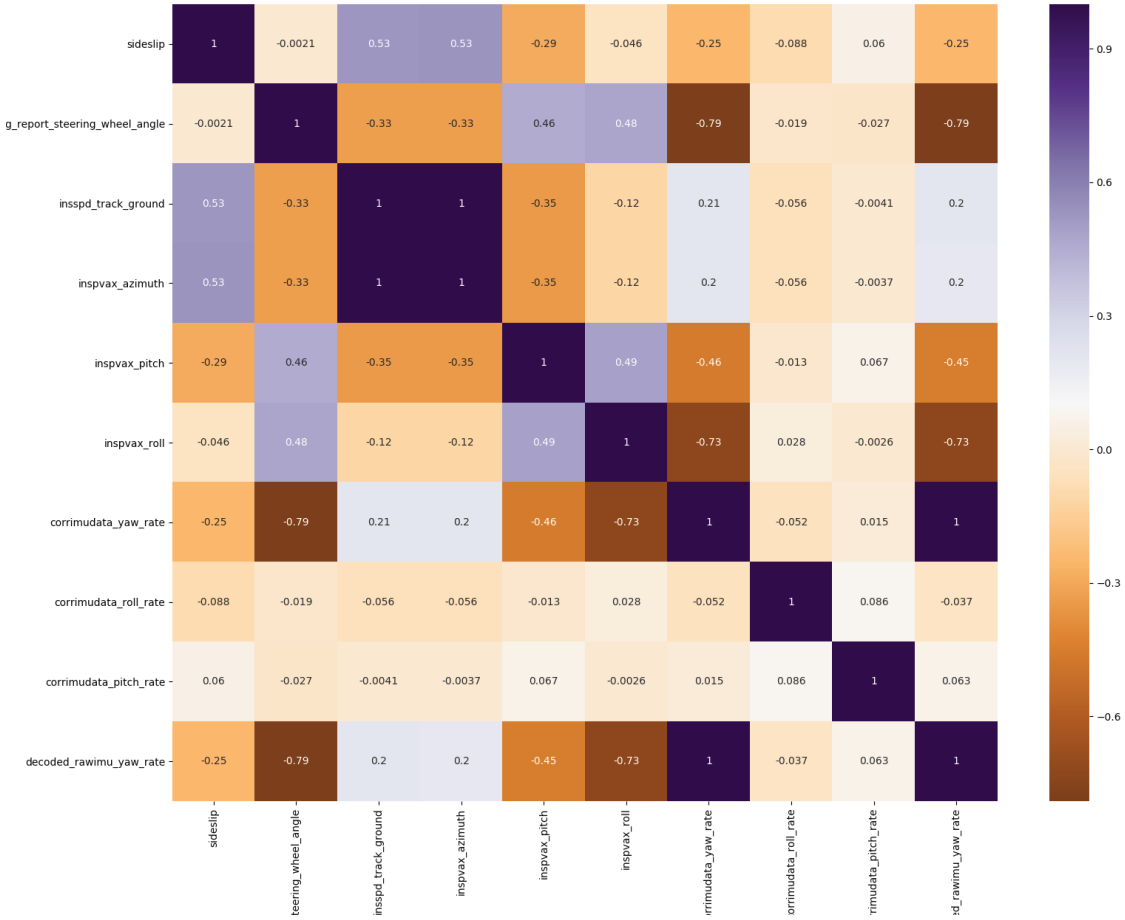
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
7050
7060
7070
7080
7090
7100
7110
7120
7130

sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 -0.11 0.22 0.22 0.023 -0.5 0.23 -0.11 -0.028 0.22
-0.11 1 -0.018 -0.019 0.53 0.65 -0.86 -0.16 0.017 -0.88
0.22 -0.018 1 1 -0.027 -0.38 0.2 -0.11 -0.026 0.21
0.22 -0.019 1 1 -0.027 -0.38 0.2 -0.11 -0.026 0.21
0.023 0.53 -0.027 -0.027 1 0.62 -0.61 -0.17 -0.0058 -0.63
-0.5 0.65 -0.38 -0.38 0.62 1 -0.84 0.015 0.016 -0.86
0.23 -0.86 0.2 0.2 -0.61 -0.84 1 0.051 0.0079 0.97
-0.11 -0.16 -0.11 -0.11 -0.17 0.015 0.051 1 0.081 0.058
-0.028 0.017 -0.026 -0.026 -0.0058 0.016 0.0079 0.081 1 0.022
0.22 -0.88 0.21 0.21 -0.63 -0.86 0.97 0.058 0.022 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8

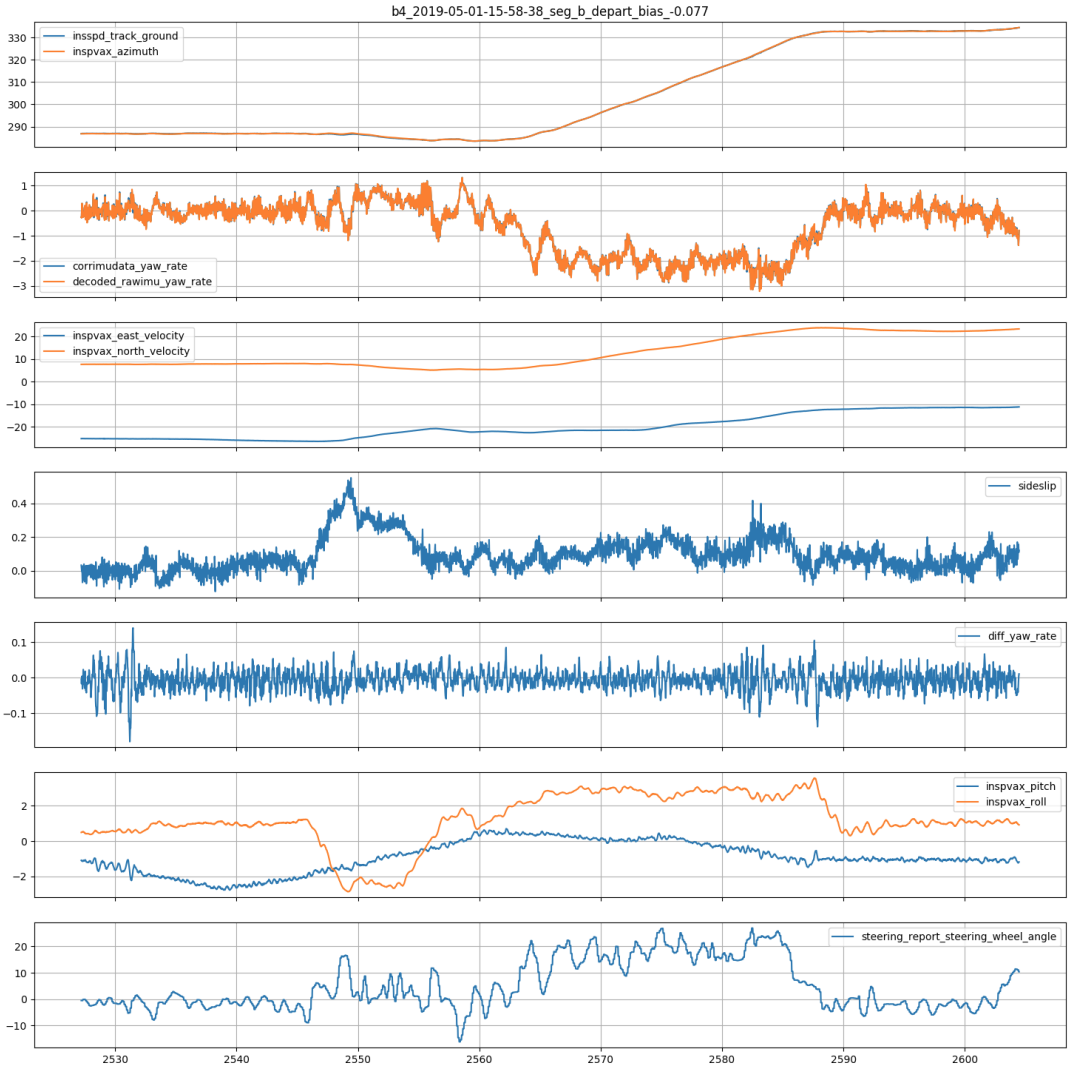

b4_2018-10-11-07-17-22_seg_b_return_bias_0.347
insspd_track_ground
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
4290
4300
4310
4320
4330
4340
4350

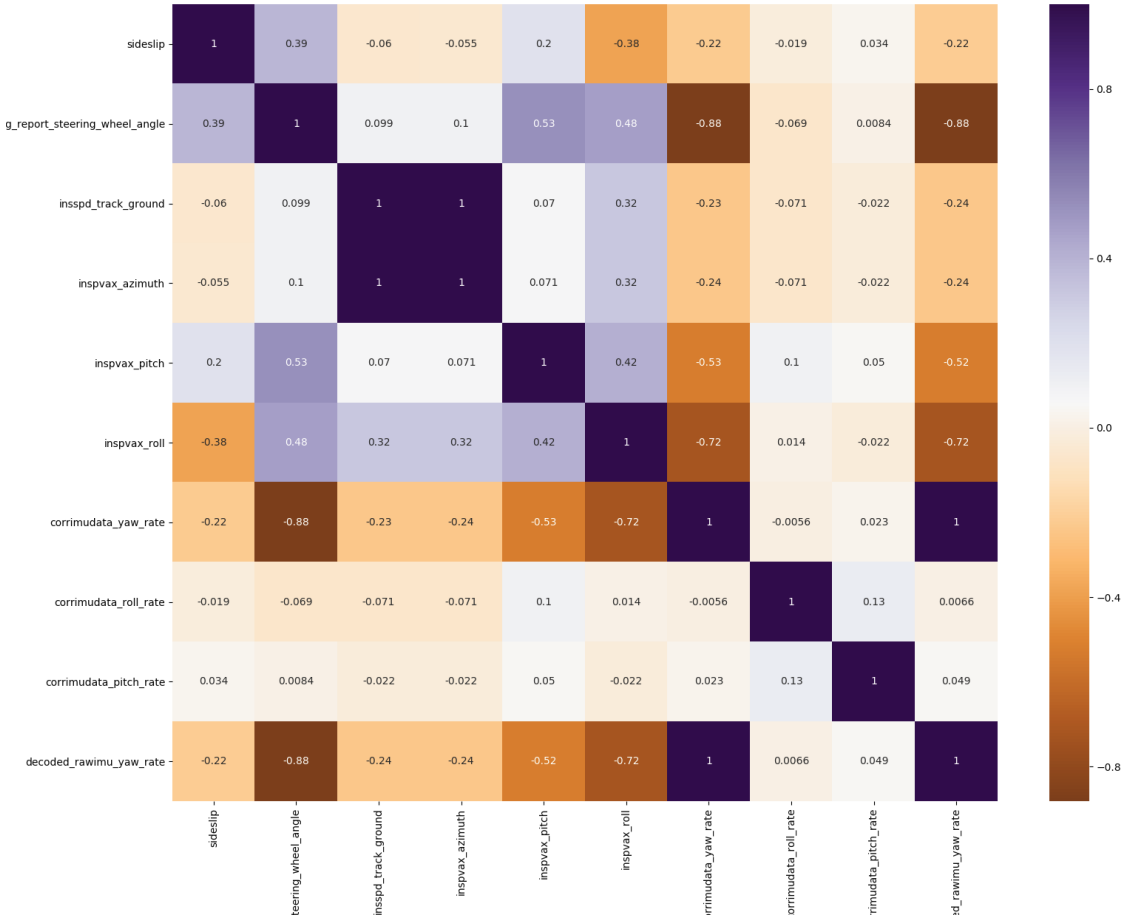

sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 -0.013 0.56 0.56 0.053 -0.32 0.014 -0.089 -0.047 0.012
-0.013 1 -0.2 -0.19 0.52 0.79 -0.91 -0.11 0.033 -0.91
0.56 -0.2 1 1 -0.052 -0.36 0.24 -0.11 -0.028 0.24
0.56 -0.19 1 1 -0.052 -0.36 0.24 -0.11 -0.029 0.24
0.053 0.52 -0.052 -0.052 1 0.59 -0.61 -0.15 -0.0054 -0.61
-0.32 0.79 -0.36 -0.36 0.59 1 -0.9 0.015 0.019 -0.9
0.014 -0.91 0.24 0.24 -0.61 -0.9 1 0.025 -0.019 1
-0.089 -0.11 -0.11 -0.11 -0.15 0.015 0.025 1 0.12 0.035
-0.047 0.033 -0.028 -0.029 -0.0054 0.019 -0.019 0.12 1 0.0044
0.012 -0.91 0.24 0.24 -0.61 -0.9 1 0.035 0.0044 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8


b4_2018-10-13-13-44-38_seg_a_return_bias_0.132
insspd_track_ground
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
6260
6280
6300
6320



- When the correlation between side slip and azimuth, track ground is low. May because there are frequent or heavy steering wheel angle changes.


b4_2019-05-01-15-58-38_seg_b_depart_bias_-0.077
insspd_track_ground
inspvax_azimuth
corrimudata_yaw_rate
decoded_rawimu_yaw_rate
inspvax_east_velocity
inspvax_north_velocity
sideslip
diff_yaw_rate
inspvax_pitch
inspvax_roll
steering_report_steering_wheel_angle
2530
2540
2550
2560
2570
2580
2590
2600


sideslip
g_report_steering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
corrimudata_yaw_rate
corrimudata_roll_rate
corrimudata_pitch_rate
decoded_rawimu_yaw_rate
1 0.39 -0.06 -0.055 0.2 -0.38 -0.22 -0.019 0.034 -0.22
0.39 1 0.099 0.1 0.53 0.48 -0.88 -0.069 0.0084 -0.88
-0.06 0.099 1 1 0.07 0.32 -0.23 -0.071 -0.022 -0.24
-0.055 0.1 1 1 0.071 0.32 -0.24 -0.071 -0.022 -0.24
0.2 0.53 0.07 0.071 1 0.42 -0.53 0.1 0.05 -0.52
-0.38 0.48 0.32 0.32 0.42 1 -0.72 0.014 -0.022 -0.72
-0.22 -0.88 -0.23 -0.24 -0.53 -0.72 1 -0.0056 0.023 1
-0.019 -0.069 -0.071 -0.071 0.1 0.014 -0.0056 1 0.13 0.0066
0.034 0.0084 -0.022 -0.022 0.05 -0.022 0.023 0.13 1 0.049
-0.22 -0.88 -0.24 -0.24 -0.52 -0.72 1 0.0066 0.049 1
sideslip
teering_wheel_angle
insspd_track_ground
inspvax_azimuth
inspvax_pitch
inspvax_roll
rrimudata_yaw_rate
orrimudata_roll_rate
rimudata_pitch_rate
d_rawimu_yaw_rate
0.8
0.4
0.0
−0.4
−0.8

From correlations.

- The `corrected yaw rate` changes exactly with `decoded raw IMU` yaw rate. Sown from the correlation between the two is within [0.97, 1.00]. Also these two variables change in proportion with steering wheel angle.
- `side slip angle` correlates with `pitch`, `roll`, and `azimuth`, but not stably correlated.
- `Track ground` is tightly correlated with `azimuth`.

To-do:

- ✅ Select cornering (lat, lon) range and corresponding straight range.
- ✅ Generate tuned results.
- ✅ Plot.
  - ✅ jjjsteering angle
- ✅ save plots
- ✅ Statistically analyze.
  - ✅ Covariance
    - fixed sideslip and steering angle.
    - fixed sideslip and yaw rate.
    - yaw rate and steering angle
- ✅ test with more vehicles.
- ✅ Test with more road segments.
  - ✅ Add road segment NO.2
  - ✅ Plot two straight segments preceding and following the corners.
- ✅ plot additional variables
  - ✅ Add plots of roll, pitch.
  - ✅ Add plots of yaw rate bias estimation (yaw rate std).
- ⭕ Analyze the reason of insignificant returning side-slip.
  - ⭕ interaction with decoded raw IMU yaw rate
  - ⭕ with roll, pitch

- see raw roll rate and pitch rate??
- Solutions?
  - Use a separate yaw (or plus attitude) estimation based on short-term gyro outputs.