ENGO 500 - Geomatics Engineering Project

Professor: Michael J. Collins

Position Error Report

Project 7: GNSS relative accuracy improvements for agriculture

Advisor: Greg Roesler PEng., Novatel / Hexagon

Group Members

Name	UCID
Jan Erik Naess	30068695
Evan Prosser	30038396
Connor Johnson	30016802
Jonah Prevost	30068306

Table of Contents

Introduction

For our error detection software to function properly, analysis of the collected and provided datasets needs to be completed to set the parameters for what is considered an error in broad acre precision agriculture. Using the static receiver data provided by our advisor Greg Roesler as a baseline the position drift, position jump and pass variation over a 15 minute window were computed along with the pass variation over 15 minutes from a set of receivers run by the EUSPA across Europe. This report will outline the computation of all of these parameters as well as the visualization of the parameters and how they were used to influence our error detection software. The static data used in this report was read into MATLAB as a set of CSV files from our simulation and error detection software. All plots were generated in MATLAB. Only the EUSPA data set is included in the appendix of this report, all static data files are stored with our main software deliverable due to size.

Data Logs

The section below describes the three logs present in our static data set. Each log computes position using a different method and uses a different header structure as Binary and ASCII files which requires them to be read into our programs differently.

RTK

This log contains the low latency high accuracy position computed through real time kinematics (RTK). RTK uses enhancement and corrections from the carrier phase of the GNSS signal to reduce error in the contents of the information signal itself. This log is the most consistently accurate of the three logs measured by our static receiver array.

PPP

This log contains the precise point positioning (PPP) position computed using a network of global reference stations that broadcast satellite and receiver clock and orbit corrections to increase the accuracy and precision of the solution. PPP requires a period of time to converge to high accuracy as the corrections take time to be broadcast and received.

PSR

This log contains the pseudorange calculated position where the satellite range and travel time of signal are used to compute the coordinates. At Least 4 satellites have to be connected to the receiver for enough information to cover the required parameters and the more satellites visible and connected the better the solution accuracy.

Methodology

Static Data: Position Drift

Evaluating the position drift of the static receivers was done by first computing an estimate of the true location in UTM Zone 11. A mean of the most accurate log, the RTK log, provided the estimate for the true location. The difference between the log coordinates (N,E,height) and the true coordinates was the associated drift along that axis. This meant three sets of drift were computed, one for the RTK log, one for the PPP log, and one for the PSR log. The mean drift, standard deviation, variance, and range were calculated for each log and plots of position drift over time were generated.

Static Data: Position Jump

Running our static data logs through our error detection software flags position jumps as positions recorded greater than three standard deviations (3σ) or 10cm from the expected position, whichever value was larger. The 10cm ceiling was chosen to prevent high precision results from being flagged once the PPP and PSR logs converge while still flagging errors that would be relevant to low precision broad acre applications.The updated CSV was then brought into MATLAB to be sorted so that flagged data was displayed differently than acceptable results not identified as across track jumps in our plots.

Importance of Tractor Speed

Tractor speed plays an important role in detecting position jumps. Speed needs to be known so that magnitude of position jumps can be compared across each time epoch. To this extent an average tractor speed during operation is required in our simulation suite to help identify position jumps. Based on research done by the USDA and the Extension Foundation, the desirable range of speed for field operation is 6.4-9.7 kph[1]. Using the center of this range as the speed for our simulation, a tractor speed of 8kph is optimal for field operation.

Static Data: Pass Variation

Pass variation of the static data was simulated by using the drift of each of the three logs over 15-minute intervals to match the EUSPA data. The mean drift along each coordinate axis over the 15-minute interval is the pass-pass error / across track accuracy during that period. A timescale of the pass error across each interval was then plotted and the log range, standard deviation, variance and mean were calculated.

EUSPA Data: Pass Variation

EUSPA provides pass-pass variation data for a set of 26 different receivers across Europe over 15 minute intervals, exactly what we need for our error detection software. Appendix A has data sets computed across three different days in both the easting and northing directions. The daily and overall mean pass variations were computed first before being plotted to show the pass variation changes over the three days. In addition, range, variance and

[1] R. Grisso, Z.R. Helsel, V. Grubinger
https://farm-energy.extension.org/selecting-engine-and-travel-speeds-for-optimal-fuel-efficiency/

standard deviation of daily values were also computed to further describe the European data.

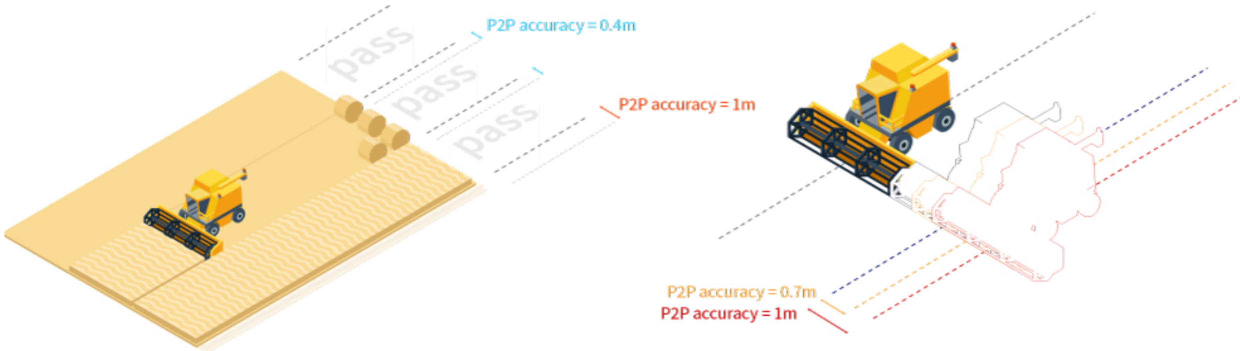

Figure 1: Pass to Pass Visualization[2]

The figure above portrays what Pass-Pass accuracy is and what is meant when the term pass variation or across track accuracy is used, both of which are synonyms for pass-pass accuracy.

[2] https://egnos-user-support.essp-sas.eu/new_egnos_ops/pass_to_pass

Results

Static Data: Position Drift

Table 1: True Coordinates of Static Receiver

Receiver Easting Estimate	5670528.265m
Receiver Northing Estimate	707668.838m

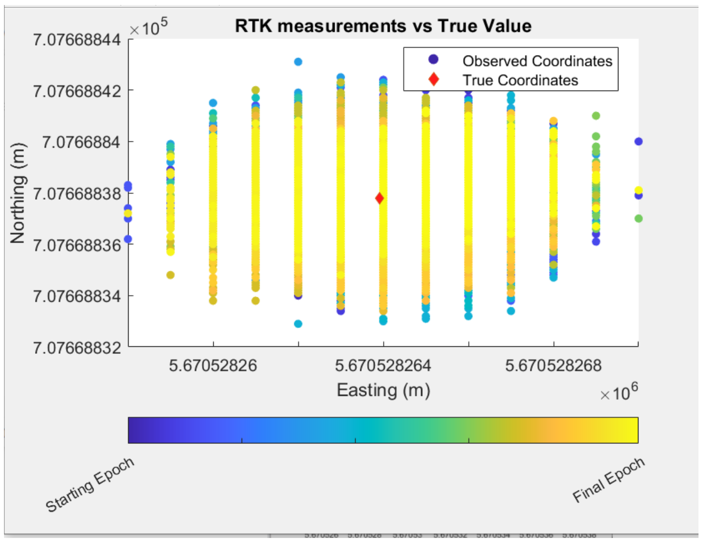

Figure 2: Position Drift of RTK Log Data

The figure above portrays the position drift of the RTK log data relative to the true receiver coordinates. Early epochs are represented by dark blue shades with the epoch color scaling to yellow as time goes on. The true position is shown with a red diamond. Note the early, darkest points are likely initial calibration and the light colored outliers are satellite connection slips.

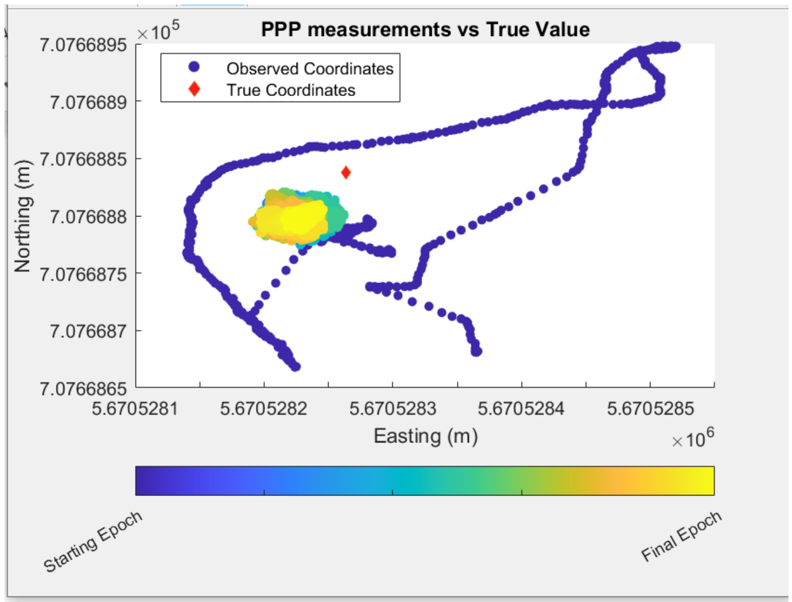

Figure 3: Position Drift of PPP Log Data

The figure above portrays the position drift of the PPP log data relative to the true receiver coordinates. Early epochs are represented by dark blue shades with the epoch color scaling to yellow as time goes on. Longer calibration times for this data log account for the initial discrepancy while broadcast parameter bias is responsible for the small differences between the late epoch and true positions.

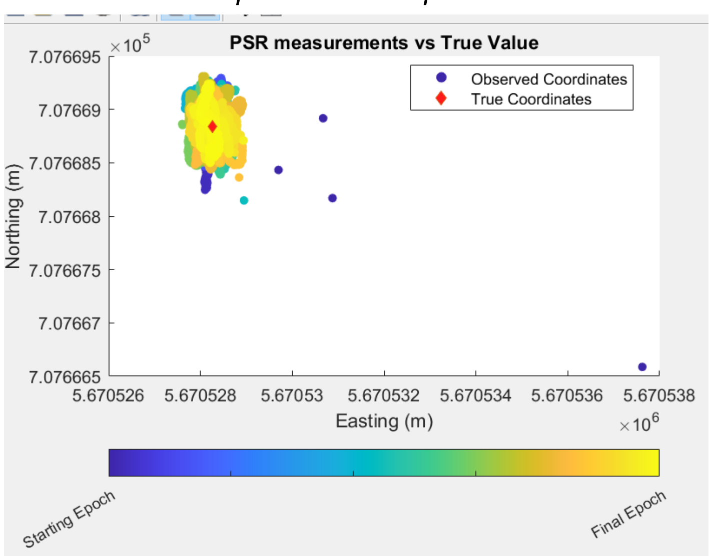

Figure 4: Position Drift of PSR Log Data

The figure above portrays the position drift of the PSR log data relative to the true receiver coordinates. Early epochs are represented by dark blue shades with the epoch color scaling to yellow as time goes on. Outliers/ position jumps are shown by the points away from the main cloud.

Table 2: Drift Standard Deviations for Static Data

	RTK	PSR	PPP
Easting	+/- 0.0012m	+/- 0.1726m	+/- 0.0154m
Northing	+/-0.0015m	+/- 0.1540m	+/- 0.0091m

Static Data: Position Jump

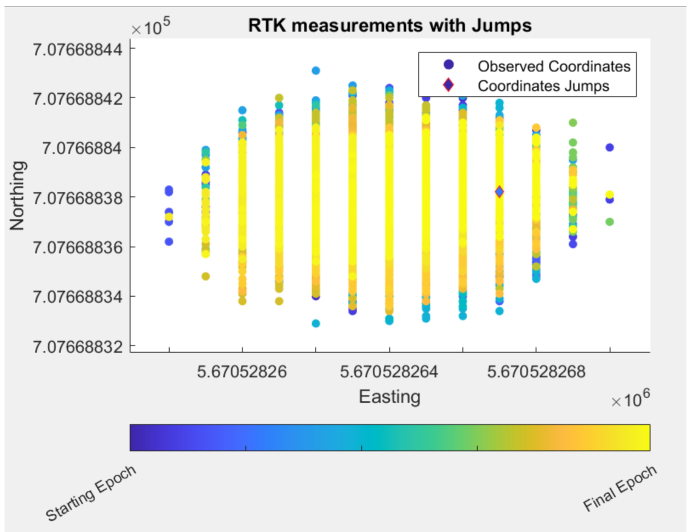

Figure 5: Across Track Jumps for RTK Data Log

The above figure displays all detected positioning jumps in a diamond shape outlined in red. The jumps are detected if the position falls outside of 3 standard deviations of the static estimate. For the RTK dataset, only one such jump was detected. This shape shares the same color scheme indicating when the jump occurred. As it is colored sea blue, we can place this jump as somewhere close to the start, around a fifth through the dataset. Even though the position is within the acceptable range for the dataset, it is still considered a jump due to the fact that it exceeded the parameters of the standard deviations.

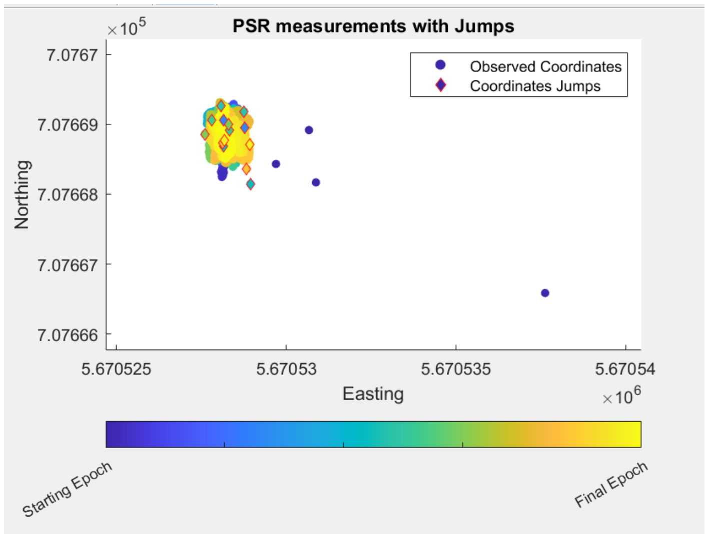

Figure 6: Across Track Jumps for PSR Data Log

The above figure displays all detected positioning jumps in a diamond shape outlined in red. The jumps are detected if the position falls outside of 3 standard deviations of the static estimate. For the PSR dataset, 14 jumps were detected. These shapes share the same color scheme indicating when the jump occurred.These jumps can be seen to have occurred both in the middle and end of the dataset. The dark blue points are not considered outliers or jumps due to the fact that they are calibration points, and fall within the standard deviations at their epochs.

Static Data: Pass Variation

Table 3: Pass to Pass Accuracy for RTK Static Data-Set over 15-minute Intervals

	Easting	**Northing**
Mean Pass-Pass Error:	1.6340e-05m	6.6021e-06m
Error Range:	0.0042m	0.0029m
Pass-Pass Variance:	6.8304e-07m^2	3.9627e-07m^2
Pass-Pass Sample Standard Deviation:	8.2646e-04m	6.2950e-04m

Table 4: Pass to Pass Accuracy for PPP Static Data-Set over 15-minute Intervals

	Easting	**Northing**
Mean Pass-Pass Error:	-0.0387m	-0.0403m
Error Range:	0.0703m	0.0178m

Pass-Pass Variance:	8.2879e-05m^2	1.4723e-05m^2
Pass-Pass Sample Standard Deviation:	0.0091m	0.0038m

Table 5: Pass to Pass Accuracy for PSR Static Data-Set over 15-minute Intervals

	Easting	**Northing**
Mean Pass-Pass Error:	0.0126m	-0.0050m
Error Range:	0.4889m	0.5072m
Pass-Pass Variance:	0.0094m^2	0.0077m^2
Pass-Pass Sample Standard Deviation:	0.0970m	0.0877m

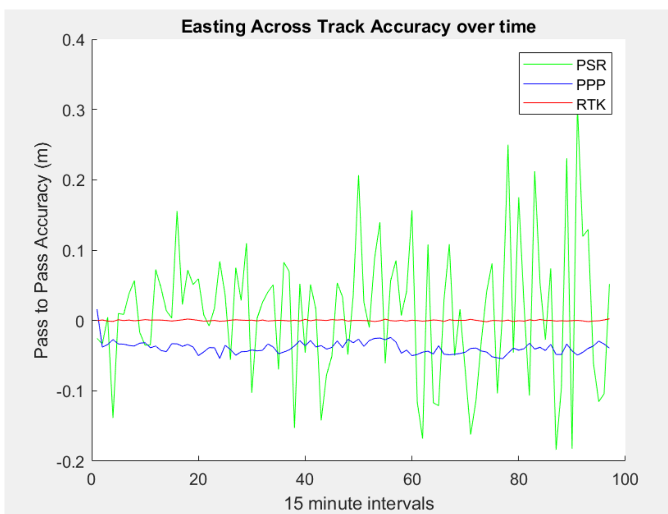

Figure 8: Across Track Accuracy (m) for Static Receiver Data (Easting)

The figure above tracks the across track accuracy or pass-pass variation in meters of the static data over 15-minute intervals. Each log is represented by a different color with the PSR log having the largest error in the easting direction consistent with the magnitude of the EUSPA data featured later. The RTK log had the least amount of variation and was the closest to a pass variation of zero. The PPP log had low error but included a bias of approximately -3cm.

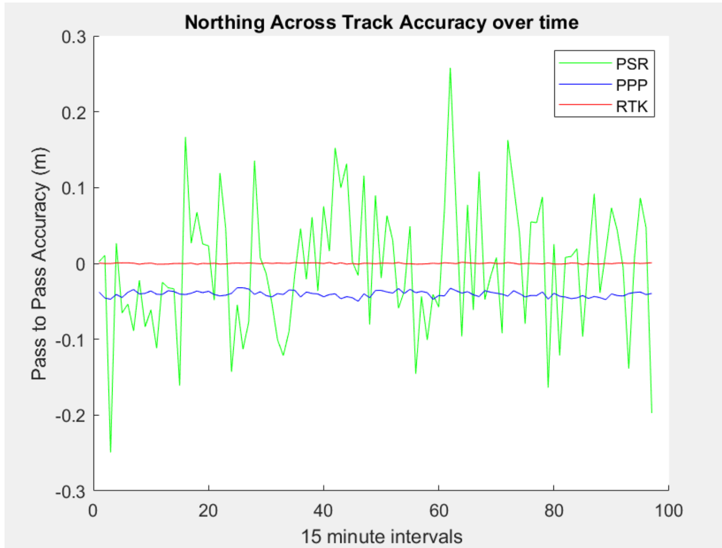

Figure 9: Across Track Accuracy (m) for Static Receiver Data (Northing)

The figure above tracks the across track accuracy or pass-pass variation in meters of the static data over 15-minute intervals. Each log is represented by a different color with the PSR log having the largest error in the northing direction consistent with the magnitude of the EUSPA data featured later. The RTK log had the least amount of variation and was the closest to a pass variation of zero. The PPP log had low error but included a bias of approximately -3cm.

EUSPA Data: Pass Variation

Table 6: Pass to Pass Accuracy for EUSPA Data-Set over 15-minute Intervals

	Easting	**Northing**
Pass-Pass Error:	0.1784m	0.1363m
Error Range:	0.0265m	0.0182m
Pass-Pass Variance:	+/- 1.23e-4m^2	+/- 5.85e-5m^2
Pass-Pass Sample Standard Deviation:	+/- 0.0111m	+/- 0.0076m

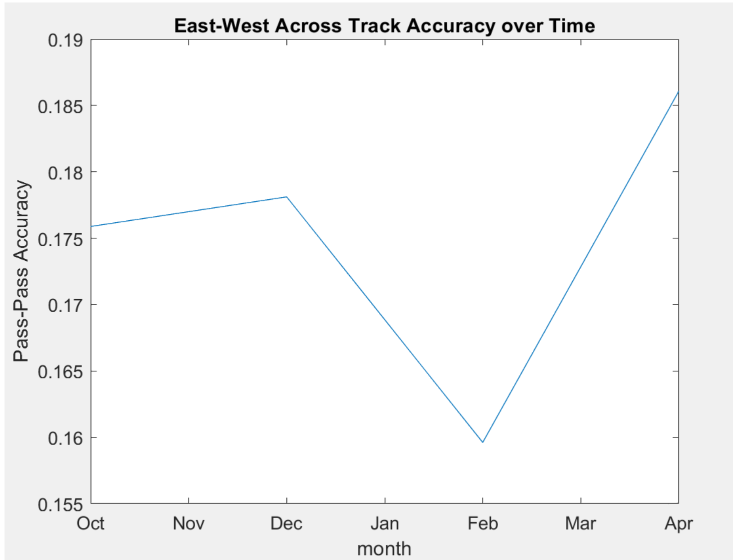

Figure 10: Across Track Accuracy (m) for EUSPA DATA (East-West Direction)

The figure above tracks pass-pass accuracy along the east-west axis for north-south vector passes over a 6 month period. Data is sampled weekly by the EUSPA and was collected from their website 4 times throughout the year starting in mid october and running to early April.

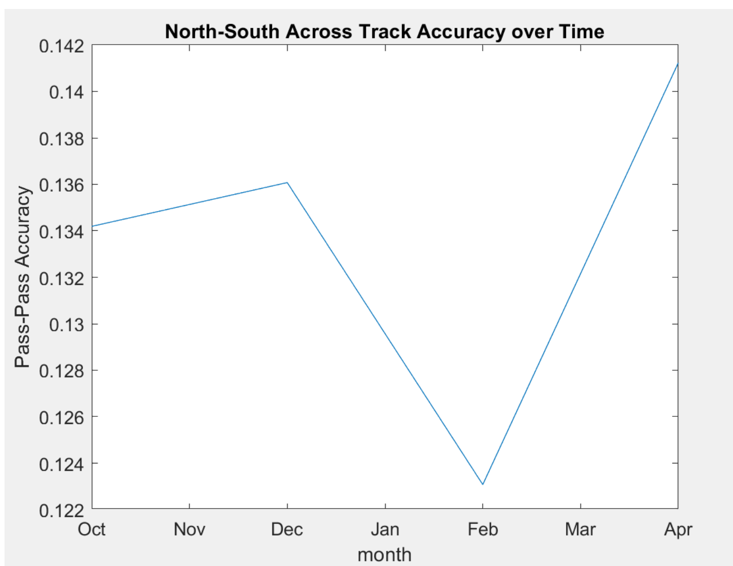

Figure 11: Across Track Accuracy (m) for EUSPA DATA (North-South Direction)

The figure above tracks pass-pass accuracy along the north-south axis for east-west vector passes over a 6 month period. Data is sampled weekly by the EUSPA and was collected from their website 4 times throughout the year starting in mid october and running to early April.

Conclusions

The positioning plots and their results fall within our expectations. The RTK dataset is the most precise, having access to satellite positioning, while the PSR dataset has the greatest error and contains the most jumps, as it is composed solely of predicted pseudoranges. While the PPP positioning seemed to be off from the true position, it acted as predicted, spending time calibrating before settling on a position that was only a small, consistent 30 cm offset from the true mean that can be easily accounted for in future passes. Our static RTK dataset had a much lower error, variation, and range compared to the EUSPA dataset, by 4 decimal places for the error. While the across track accuracy for the PSR was much worse than the EUSPA, the static dataset was extremely precise and consistent in comparison. The PPP dataset was also similarly acceptable, and differed from the RTK measurements by a consistent offset. This is most likely due to having a larger data pool to work with than the EUSPA data, in addition to having precise measurements.

Overall the displayed datasets demonstrate a more than acceptable level of precision for our purposes in precision agriculture, compared to the EUSPA data. Areas of improvement exist for improving pseudorange measurements, though Precise Point Positioning shows great promise in practical and cheap applications for precision agriculture and our pursuit of acceptable pass to pass accuracy.

Appendices

Appendix A: EUSPA Pass Variation Data

Location Code	East-West (m)	North- South (m)	Date
JME	0.252	0.179	17-Oct
TRO	0.217	0.169	17-Oct
KIR	0.184	0.144	17-Oct
RKK	0.278	0.202	17-Oct
EGI	0.162	0.136	17-Oct
TRD	0.137	0.095	17-Oct
GVL	0.144	0.11	17-Oct
LAP	0.142	0.115	17-Oct
GLG	0.185	0.145	17-Oct
ALB	0.123	0.087	17-Oct
CRK	0.129	0.102	17-Oct
SWA	0.21	0.155	17-Oct
PAR	0.295	0.228	17-Oct
BRN	0.189	0.138	17-Oct
WRS	0.18	0.148	17-Oct
ZUR	0.17	0.133	17-Oct
SDC	0.14	0.106	17-Oct
TLS	0.167	0.115	17-Oct
LSB	0.162	0.124	17-Oct
MLG	0.137	0.105	17-Oct

ROM	0.189	0.134	17-Oct
SOF	0.203	0.155	17-Oct
PDM	0.128	0.093	17-Oct
CTN	0.137	0.103	17-Oct
ATH	0.169	0.135	17-Oct
GOL	0.144	0.133	17-Oct
JME	0.275	0.208	5-Dec
TRO	0.199	0.154	5-Dec
KIR	0.16	0.116	5-Dec
RKK	0.259	0.174	5-Dec
EGI	0.138	0.114	5-Dec
TRD	0.124	0.093	5-Dec
GVL	0.143	0.113	5-Dec
LAP	0.137	0.113	5-Dec
GLG	0.18	0.145	5-Dec
ALB	0.128	0.093	5-Dec
CRK	0.132	0.105	5-Dec
SWA	0.212	0.151	5-Dec
PAR	0.258	0.223	5-Dec
BRN	0.203	0.146	5-Dec
WRS	0.185	0.147	5-Dec
ZUR	0.173	0.131	5-Dec
SDC	0.151	0.117	5-Dec
TLS	0.167	0.121	5-Dec
LSB	0.196	0.145	5-Dec

MLG	0.174	0.128	5-Dec
ROM	0.196	0.142	5-Dec
SOF	0.21	0.169	5-Dec
PDM	0.153	0.105	5-Dec
CTN	0.155	0.115	5-Dec
ATH	0.17	0.134	5-Dec
GOL	0.153	0.136	5-Dec
JME	0.203	0.151	2-Feb
TRO	0.202	0.157	2-Feb
KIR	0.188	0.135	2-Feb
RKK	0.273	0.16	2-Feb
EGI	0.141	0.118	2-Feb
TRD	0.121	0.093	2-Feb
GVL	0.14	0.116	2-Feb
LAP	0.138	0.107	2-Feb
GLG	0.185	0.143	2-Feb
ALB	0.126	0.093	2-Feb
CRK	0.136	0.096	2-Feb
SWA	0.198	0.163	2-Feb
PAR			2-Feb
BRN	0.203	0.146	2-Feb
WRS	0.174	0.133	2-Feb
ZUR	0.177	0.142	2-Feb
SDC	0.133	0.1	2-Feb
TLS	0.158	0.121	2-Feb

LSB	0.158	0.13	2-Feb
MLG	0.124	0.098	2-Feb
ROM	0.193	0.146	2-Feb
SOF	0.212	0.179	2-Feb
PDM	0.116	0.093	2-Feb
CTN	0.134	0.105	2-Feb
ATH	0.164	0.134	2-Feb
GOL	0.153	0.141	2-Feb

JME	0.337	0.254	28-Mar
TRO	0.246	0.188	28-Mar
KIR	0.239	0.18	28-Mar
RKK	0.346	0.213	28-Mar
EGI	0.187	0.144	28-Mar
TRD	0.156	0.109	28-Mar
GVL	0.168	0.134	28-Mar
LAP	0.175	0.141	28-Mar
GLG	0.193	0.158	28-Mar
ALB	0.142	0.107	28-Mar
CRK	0.141	0.106	28-Mar
SWA	0.208	0.164	28-Mar
PAR			28-Mar
BRN	0.217	0.154	28-Mar
WRS	0.199	0.142	28-Mar
ZUR	0.188	0.137	28-Mar

SDC	0.145	0.144	28-Mar
TLS	0.179	0.123	28-Mar
LSB	0.178	0.133	28-Mar
MLG	0.164	0.113	28-Mar
ROM	0.187	0.148	28-Mar
SOF	0.201	0.176	28-Mar
PDM	0.138	0.097	28-Mar
CTN	0.158	0.117	28-Mar
ATH	0.181	0.143	28-Mar
GOL	0.165	0.147	28-Mar