

Track Introduction and Commands

Lecture 03

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Kinematic GPS

- The style of GPS data collection and processing suggests that one or more GPS stations is moving (e.g., car, aircraft)
- To obtain good results for positioning as a function of time it helps if the ambiguities can be fixed to integer values. Although with the “back smooth” option in track this is not so critical.
- Program `track` is the MIT implementation of this style of processing. The real time version is `trackRT` and `trackRTB`
- Unlike many programs of this type, track pre-reads all data before processing. (This approach has its pros and cons)

General aspects

- The success of kinematic processing depends on separation of sites
- If there are one or more static base stations and the moving receivers are positioned relative to these.
- For separations < 10 km, usually easy
- 10>100 km more difficult but often successful
- >100 km very mixed results depending on quality of data collected.

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3

Issues with length

- As site separation increases, the differential ionospheric delays increases, atmospheric delay differences also increase
- For short baselines (<2-3 km), ionospheric delay can be treated as ~zero and L1 and L2 ambiguities resolved separately. Positioning can use L1 and L2 separately (less random noise).
- For longer baselines this is no longer true and track uses the MW-WL to resolve L1-L2 cycles
- IONEX files can now be included to help with the ionospheric delay on long baselines.

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4

Track features

- Track uses the Melbourne-Wubena Wide Lane to resolve L1-L2 and then a combination of techniques to determine L1 and L2 cycles separately.
- “Bias flags” are added at times of cycle slips and the ambiguity resolution tries to resolve these to integer values.
- Track uses floating point estimate with LC, MW-WL and ionospheric delay constraints to determine the integer biases and the reliability with which they are determined.
- Kalman filter smoothing can be used. (Non-resolved ambiguity parameters are constant, and atmospheric delays are consistent with process noise). When atmospheric delays are estimated, the smoothing option should always be used.

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5

Ambiguity resolution

- Algorithm is “relative-rank” approach. Chi-squared increment of making L1 and L2 ambiguities integer values for the best choice and next best are compared. If best has much smaller chi-squared impact, then ambiguity is fixed to integer values.
- Test is on inverse-ratio of chi-squared increments (i.e., Large relative rank (RR) is good).
- Chi-squared computed from:
 - Match of LC combination to estimated value (LC)
 - Match to MW-WL average value (WL)
 - Closeness of ionospheric delay to zero (less weight on longer baselines) (LG)
- Relative weights of LC, WL and LG can be set.
- Estimates are iterated until no more ambiguities can be resolved.

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6

Basic GPS phase and range equations

- Basic equations show the relationship between pseudorange and phase measurements

$$\phi_{1i}^k = \gamma_i^k / \lambda_1 - I_i^k / \lambda_1 + N_{1i}^k + v_{1i}^k$$

$$\phi_{2i}^k = \gamma_i^k / \lambda_2 - I_i^k / \lambda_2 \left(\frac{f_1}{f_2} \right)^2 + N_{2i}^k + v_{2i}^k$$

$$R_{1i}^k = \gamma_i^k + I_i^k + w_{1i}^k$$

$$R_{2i}^k = \gamma_i^k + I_i^k \left(\frac{f_1}{f_2} \right)^2 + w_{2i}^k$$

γ is range,

I is ionospheric delay

λ is wavelength

v and w are noise

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7

L1-L2 and Melbourne-Wubbena Wide Lane

- The difference between L1 and L2 phase with the L2 phase scaled to the L1 wavelength is often called simply the widelane and used to detect cycle slips. However it is effected fluctuations in the ionospheric delay which in delay is inversely proportional to frequency squared.
- The lower frequency L2 has a larger contribution than the higher frequency L1
- The MW-WL removes both the effects on the ionospheric delay and changes in range by using the range measurements to estimate the difference in phase between L1 and L2

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8

MW-WL Characteristics

- In one-way form as shown the MW-WL does not need to be an integer or constant
- Slope in one-way is common, but notice that both satellites show the same slope.
- If same satellite-pair difference from another station (especially when same brand receiver and antenna) are subtracted from these results then would be an integer (even at this one station, difference is close to integer)
- The MW-WL tells you the difference between the L1 and L2 cycles. To get the individual cycles at L1 and L2 we need another technique.
- There is a formula that gives L1+L2 cycles but it has 10 times the noise of the range data ($\Sigma f/\Delta f$) and generally is not used.

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9

Melbourne-Wubena Wide Lane (MW-WL)

$$mw - wl = \phi_1 - \phi_2 - \frac{(f_1 - f_2)}{(f_1 + f_2)} \left[R_1 f_1 / c + R_2 f_2 / c \right]$$

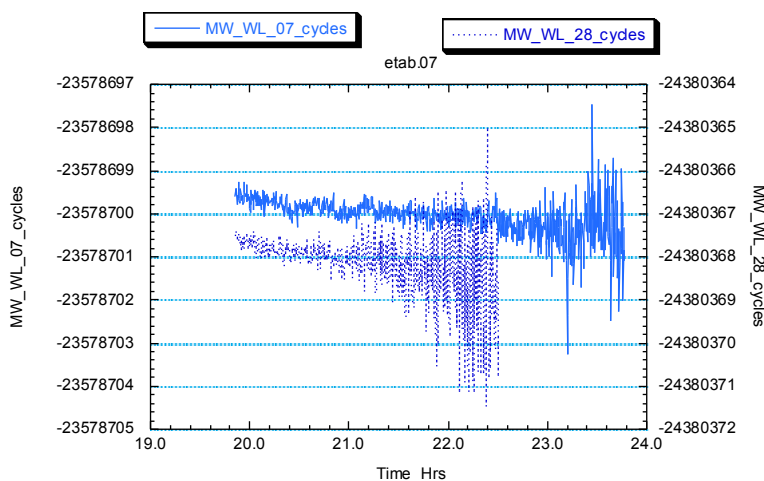
- Equation for the MW-WL. The term Rf/c are the range in cycles (notice the sum due to change of sign ionospheric delay)
- The $\Delta f/\Sigma f$ term for GPS is ~ 0.124 which means range noise is reduced by a about a factor of ten.
- The ML-WL should be integer (within noise) when data from different sites and satellites (double differences) are used.
- However, receiver/satellite dependent biases need to be accounted for (and kept up to date).

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10

Example MW-WL PRN 07 and PRN 28)



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11

EX-WL Extra-Wide-lane

- The other measure of the difference in cycles between L1 and L2 used by track is the EX-WL (Extra Wide-lane).

$$EX - WL = \phi_1 - \phi_2 \frac{\lambda_2}{\lambda_1} ; \frac{\lambda_2}{\lambda_1} = 1.28$$

- This measure is independent of geometry but is affected by the ionospheric delays. On short separations this measure is often more robust than the MW-WL.
- When we look at track bias fixing note that a 1 L1 and L2 slip (1/1 slip) changes the EX-WL by only 0.28 cycles.

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12

Basic Inputs for track.

- Track runs using a command file
- The base inputs needed are:
 - Obs_file specifies names of rinex data files. Sites can be K kinematic or F fixed
 - Nav_file orbit file either broadcast ephemeris file or sp3 file
 - Mode air/short/long -- Mode command is not strictly needed but it sets defaults for variety of situations
 - Normally back_type smooth would also be specified.
- Normally start with just these commands and see how the run looks and based on this output start tuning track.

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13

Basic use

- Recommended to start with above commands and see how the solution looks
- Usage: track -f track.cmd >&! track.out
- Basic quality checks:
- `egrep '^APRMS|TYPE'` on summary file or track out (RMS by PRN in mm)

```

TYPE Site DT ALL 02 05 08 10 15 21 26 29
PRMS usn3 LC 7.0 9.4 3.6 10.5 7.9 7.5 7.2 3.9 3.5
TYPE Site DT ALL 02 05 08 15 21 26 29
PRMS mitb LC 7.2 8.3 3.7 11.0 6.5 8.4 3.6 4.5
TYPE Site DT ALL 02 05 08 15 21 26 29
PRMS rovr LC 7.4 7.8 4.3 12.5 6.8 8.5 4.4 4.5

```

- `grep Kinematic track.out | head -<number of sites>`

```

TRACK Version 1.27 GPS Kinematic trajectory program
Kinematic site usn3 appears static Coordinate RMS XYZ 1.84 2.81 2.23 m, Apriori
coordinates good: Diff XYZ -0.25 0.74 -0.17 m
Kinematic site mitb appears static Coordinate RMS XYZ 0.95 1.46 1.11 m, Apriori
coordinates good: Diff XYZ 0.93 -1.77 1.70 m
Kinematic site rovr appears dynamic Coordinate RMS XYZ 17.84 18.26
17.40 m.

```

- The message is repeated during the run (thus the head above) but the RMS position drops to 0.00 for non-kinematic sites. This is a pseudo range solution so RMS will be high. Make sure site behave the way you think they should.
- Check track.sum file for ambiguity status and RMS scatter of residuals.

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14

Track command line

```
% track -f <command file> -a <ambiguity file> -d <day> -w <week> -s <S01>
<S02> .. <S10>
```

where <command file> is a required file containing a list of commands to control the program (see below)

<ambiguity file> is an optional file containing a modified set of integer bias parameters and settings (see full description below).

<day> the string in this argument replaces <day> in the command file lines (e.g., bas1<day>0.03o will become bas12220.03o if the -d 222 option is given.

<week> the string here will replace any <week> strings in the command file (useful for the nav_file name which could be a week of concatenated sp3 files.

<S01>, <S02> .. <S10> are up to 10 strings that can be replaced in the command file i.e. the string <S01> in the command file will be replaced by the first string, <S02> by the second and so on. If one of the strings is called space (all lower case), the corresponding <SXX> entry will be replaced by a blank character (This provides a means to un-comment lines)

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15

Basic use: Things to check

- Check on number of ambiguities (biases) fixed
 - grep FINAL <summary file>
- A 3 in column "Fixd" means fixed, 1 means still floating point estimate
- If still non-fixed biases or atmospheric delays are estimated then smoothing solution should be made (back_type smooth)
- output in NEU, geodetic, DHU, XYZ coordinates. NEU are simple North East distances and height differences from fixed site. (Convenient for plotting and small position changes). DHU is similar but difference are from the a priori coordinates of the site.

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16

More advanced features

- Track has a large help file which explains strategies for using the program, commands available and an explanation of the output and how to interpret it.
- It is possible to read a set of ambiguities in.
 - Works by running track and extracting FINAL lines into an ambiguity file. Setting 7 for the Fixd column will force fix the ambiguity. ambiguity file is then read into track (-a option or ambin_file)

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17

Advanced features

- Commands allow control of how the biases are fixed and editing criteria for data
- Editing is tricky because on moving platform, jumps in phase could simply be movement
- Ionospheric delay and MW WL used for editing.
- Explicit edit_svs command
- Explicit add and remove bias flags

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18

Main Tunable commands

- **BF_SET** <Max gap> <Min good>
 - Sets sizes of gaps in data that will automatically add bias flag for possible cycle slip. Default is 1, but high rate data often misses measurements.
- **ION_STATS** <Jump>
 - Size of jump in ionospheric delay that will be flagged as cycle slip. Can be increased for noisy data
- **FLOAT_TYPE** <Start> <Decimation> <Type> <Float sigma Limits(2)> <WL_Fact> <Ion_fact> <MAX_Fit> <RR>
 - Main control on resolving ambiguities. Float sigma limits (for LC and WL) often need resetting based on data quality.
 - <WL_Fact> <Ion_fact> control relative weights of WL and LG chi-squared contributions.
 - RR is relative rank tolerance
- Fcode in output is diagnostic of why biases are not resolved.

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19

Other common commands

- **USR_ADDBF** <site> <prn #> <time (ymdhms)>
Allows user to add a bias file at site <site> for PRN <prn #> at time <time>. First valid measurement at or after time will be flags.
- **USR_DELBF** <site> <prn #> <time (ymdhms)>
Allows user to delete a bias file at site <site> for PRN <prn #> at time <time>. The time must match within 50% of sampling interval.

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20

Other common commands

This command is useful when sites are static and then move (e.g., MIT kinematic data and earthquake data on long baselines)

@ TIMEDEP_PROCNS

@ Site Sig XYZ (m/sqrt(t)) Start YY MM DD MN Sec End YY MM DD MN Sec

Allows time dependent process noise to be added the statistics of a site or to all sites. The noise sigmas are added (in a variance sense) to the noise processes specified in the SITE_STATS command. Note only the random walk process noise is changed.

This command is useful for long-baseline processing of surface wave arrivals (process noise increased during surface wave arrivals).

Next

- Next lecture will look at commands in more detail
- Tutorial session will look at some of these results.