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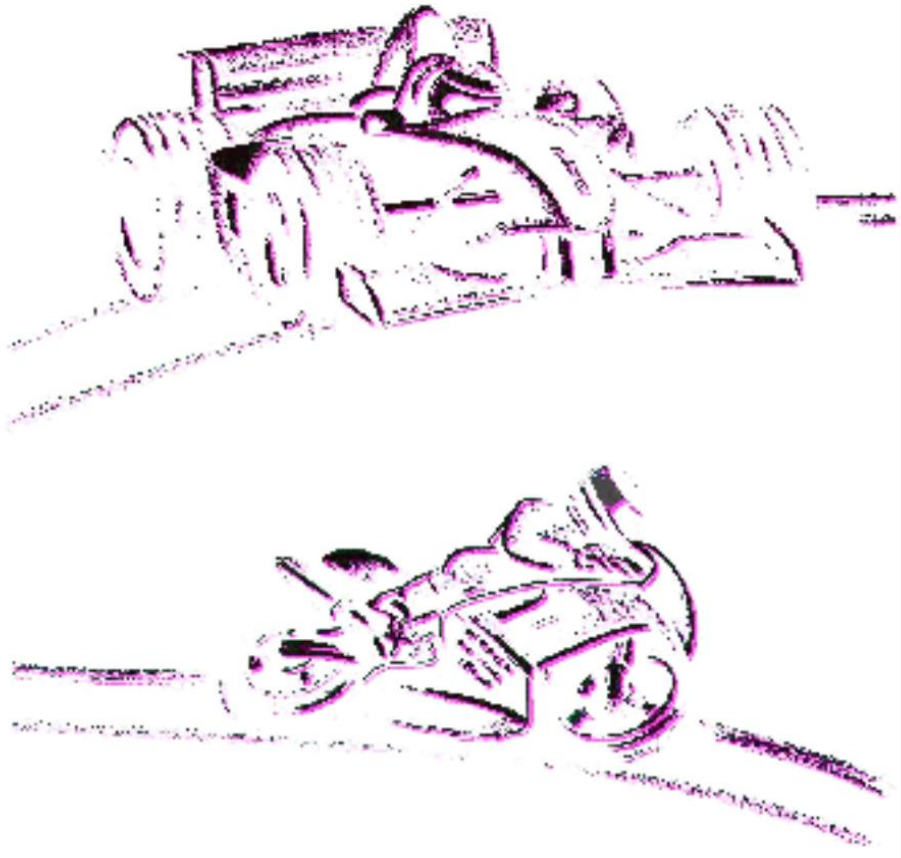
- English -



GPS/GNSS

Postprocessing

1 Revision History

Revision	Description	Release Date	Author
0	Initial Release	2021-07-29	FS

2 Content

3 Notes and symbols used in this Manual

Further Information
In the paragraphs highlighted with this symbol, you will find tips and practical advice to work with the 2D-Software.

Documentation reference
Documentation reference to another manual or handout

Important information
It is very important to follow the instructions given

4 GPS/GNSS-postprocessing

After the GPS channels have been recorded, the 2D Analyzer offers further processing of the GPS channels in post-processing.

Documentation reference
For more information about all GPS/GNSS Modules please see the manual **GPS/GNSS General description** on our website:
http://2d-datarecording.com/downloads/manuals/

This is a very big advantage of the 2D because the user can take influence on the following parameters of 2D-GPS/GNSS-postprocessing:

- Time delay correction
- Filter adjustment
- Post-processing channels

Depending on the setting of WinARace (AutoCalc-Configurator), the GPS post-processing calculation files named *2D_GPSAuto.CCF* are executed directly after the measurement data download automatically.

Documentation reference
Please see the manual **CalcTool** at download area of the 2D website for more information about Calculation files, AutoCalc-Configurator and 2D_GPSAuto.CCF

www.2D-Datarecording.com/manuals/

In order to visualize the effects of 2D GPS/GNSS post-processing, driving tests were carried out with different driving maneuvers of cars, from which all images in this chapter are taken.

Documentation reference
For more information about all new GPS/GNSS modules please see descriptions **New 2D GPS/GNSS CAN Modules 2021** and **Revision of GNSS modules**
http://2d-datarecording.com/downloads/manuals/

4.1 Important information

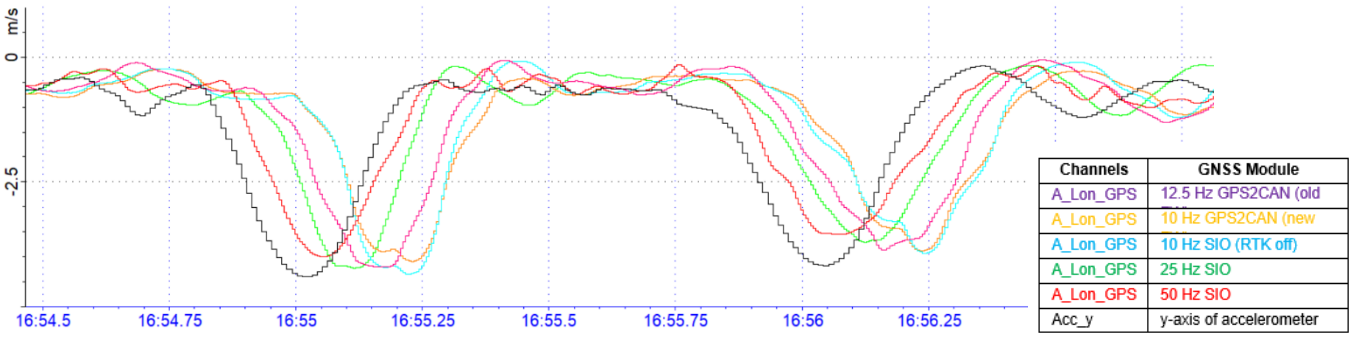
To ensure the correct function of GPS/GNSS-postprocessing toolchain it will only be executed if all the following GPS/GNSS channels are recorded:

- **ValidSat**
- **V_Sat**
- **Course**

Documentation reference
For more information about all GPS/GNSS Modules and recording GPS/GNSS channels please see the manual **GPS/GNSS General description** on our website:
http://2d-datarecording.com/downloads/manuals/

4.2 Time delay correction

One of the greatest advantages of 2D post-processing is that the time delay, which inevitably occurs due to the reception of the GNSS data, can be corrected by the user as desired.



To visualize the time delay and show the differences at modules with various GNSS rates a test was executed where an accelerometer (black channel) was used to compare the actual deceleration of the car by accelerometer with the derivation of the speed signals (longitudinal acceleration) during intermitted braking tests.

The displayed colored longitudinal acceleration channels are <u>not</u> derived from raw V_Sat channels because without processing the raw channels it is not meaningful to compare channels from modules with different GNSS rates!

Hence, the post-processing was first used to upsampling the raw GNSS speed signals to a higher, common frequency without interpolating (e.g., 200 Hz).

Afterwards a moving average filter was applied to all speed signals. The parameters of the filters differ according to the respective GNSS rate of the modules, so that the high-sampled signals are filtered in such a way that the raw speed signals of the different GNSS modules would always correspond to the same filter time.

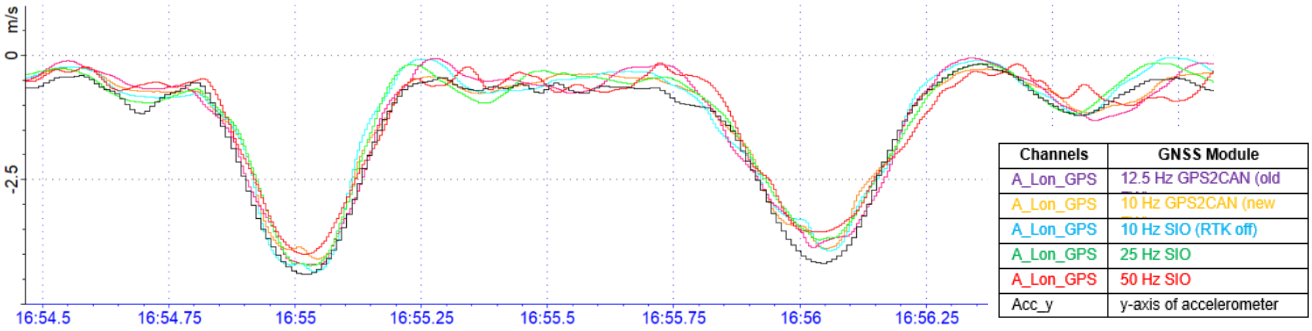
At the end, an IIR (infinite impulse response) -filter is used to finally remove the noise of the speed signals.

Only after this processing is it possible to derive the longitudinal acceleration correctly, which now clearly shows the different time delays, and compare the GNSS modules to the black acceleration signal.

The time delay of the different modules is indirectly proportional to the GNSS rate of the modules, because the higher the GNSS rate of the module, the lower the time delay.

Furthermore, the remarkably similar time delay of the two 10 Hz modules (light blue and orange) becomes clear.

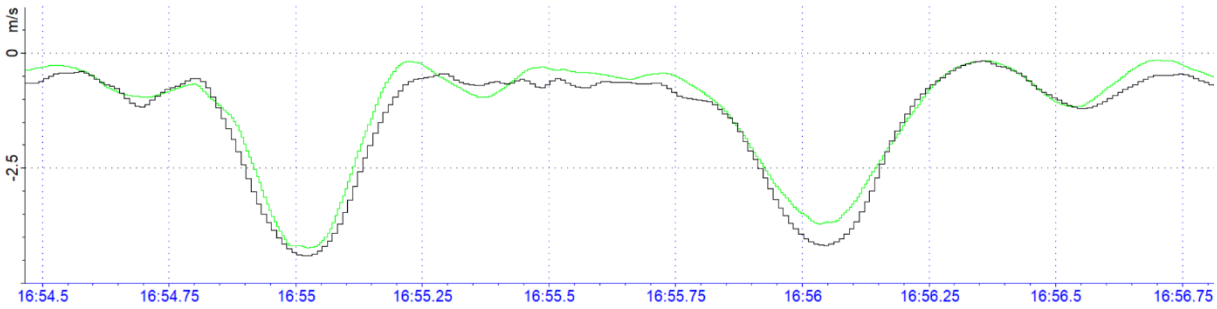
By using the 2D post-processing, the different time delays between the actual deceleration (given by the accelerometer) and the deceleration visible on the signal of the GNSS module can be determined and corrected:



GNSS Module	Time delay correction [sec]
12.5 Hz GPS2CAN (old FW)	-0.140
10 Hz GPS2CAN (new FW)	-0.210
10 Hz SIO (RTK off)	-0.210
25 Hz SIO	-0.075
50 Hz SIO	-0.065

The 2D post-processing allows the user to freely select a time correction value with a resolution of 1/1000 sec (internal post-processing is done with 1000 Hz), which corrects exactly this time delay for all channels received from the GNSS modules!

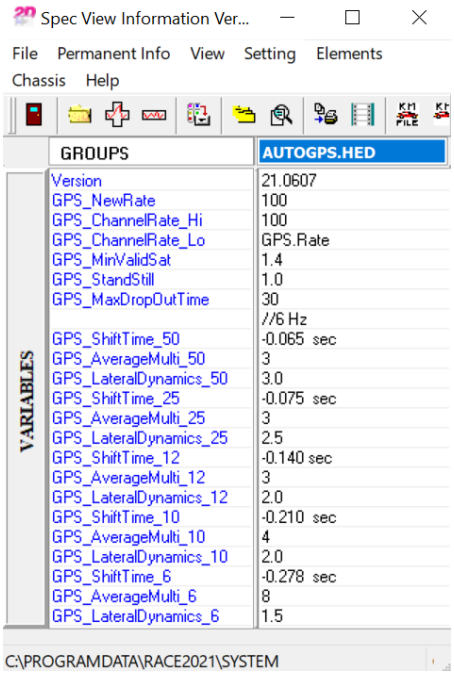
If only the 25 Hz is compared to the accelerometer signal the incredibly good dynamic performance of this module becomes obvious:



All parameters of the 2D_GPSAuto calculations are stored in the *AutoGPS.HED* file which is located in the race application directory. When executing the 2D-GPS/GNSS-postprocessing calculation files 2D_GPSAuto.CCF the CalcTool accesses the currently stored values from *AutoGPS.HED* for Time delay corrections, and LateralDynamics-Filterparameters.

Adjust Time delay corrections:

1. Open WinARace and press [CTRL] + [ALT] + [D] to open race application directory
2. Open folder *System* and subsequently folder *Cal*
3. Open AutoGPS.HED by double-clicking



Further Information
It is recommended to doublicate the existing, original AutoGPS.HED file and use another name it, e.g. AutoGPS_org.HED

4. Adjust the respective *GPS_ShiftTime_...* value of the GPS/GNSS module used
5. Save via *File* → *Save all changes*
6. Open desired measurement and recalculate the *2D_GPSAuto.CCF* via *AutoCalc*

Further Information
2D_GPSAuto.CCF files must be recalculated twice after changing the AutoGPS.HED parameters.

4.3 Filter adjustment

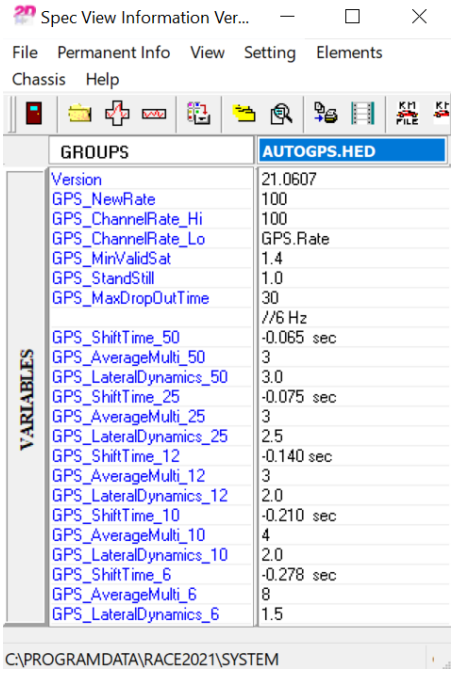
By adjusting the filter parameters of the 2D_AutoGPS calculation files, the user can freely adapt the filtering to his respective application, as the multi-level IIR filtering can be set by the user and thus adapted to the dynamics of the vehicle used.

Different applications such as vehicle development or ski tests require different filter parameters. The default setting is basically aligned to car dynamics.

All parameters of the 2D_GPSAuto calculations are stored in the *AutoGPS.HED* file which is located in the race application directory. When executing the 2D-GPS/GNSS-postprocessing calculation files 2D_GPSAuto.CCF the CalcTool accesses the currently stored values from *AutoGPS.HED* for Time delay corrections, and LateralDynamics-Filterparameters.

<u>Adjust Time delay corrections:</u>

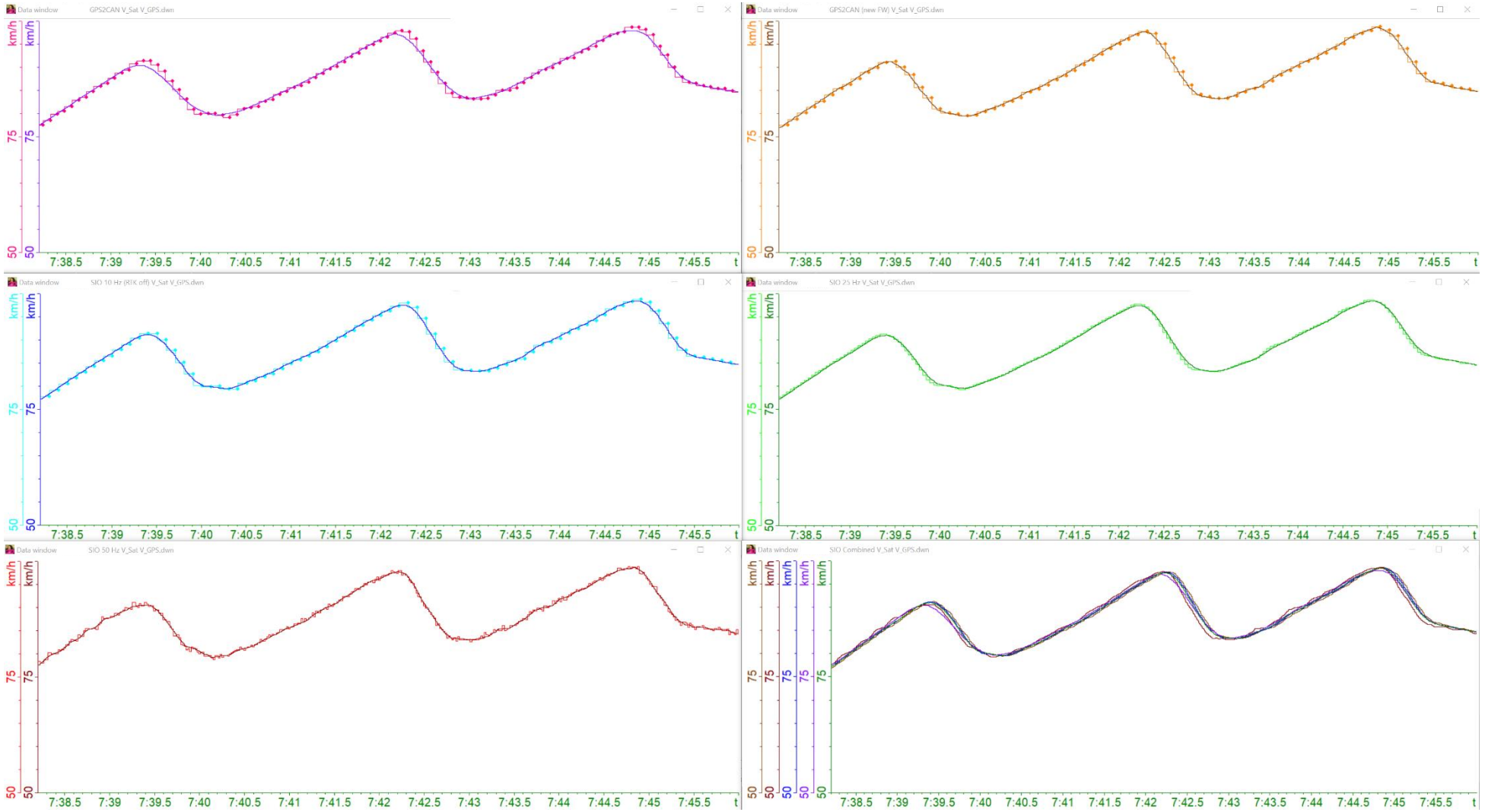
1. Open WinARace and press [CTRL] + [ALT] + [D] to open race application directory
2. Open folder *System* and subsequently folder *Cal*
3. Open AutoGPS.HED by double-clicking



Further Information
It is recommended to doublicate the existing, original AutoGPS.HED file and use another name it, e.g. AutoGPS_org.HED

4. Adjust the respective *GPS_LateralDynamics_...* value of the GPS/GNSS module used
5. Save via *File* → *Save all changes*
6. Open desired measurement and recalculate the *2D_GPSAuto.CCF* via *AutoCalc*

Further Information
2D_GPSAuto.CCF files must be recalculated twice after changing the AutoGPS.HED parameters.

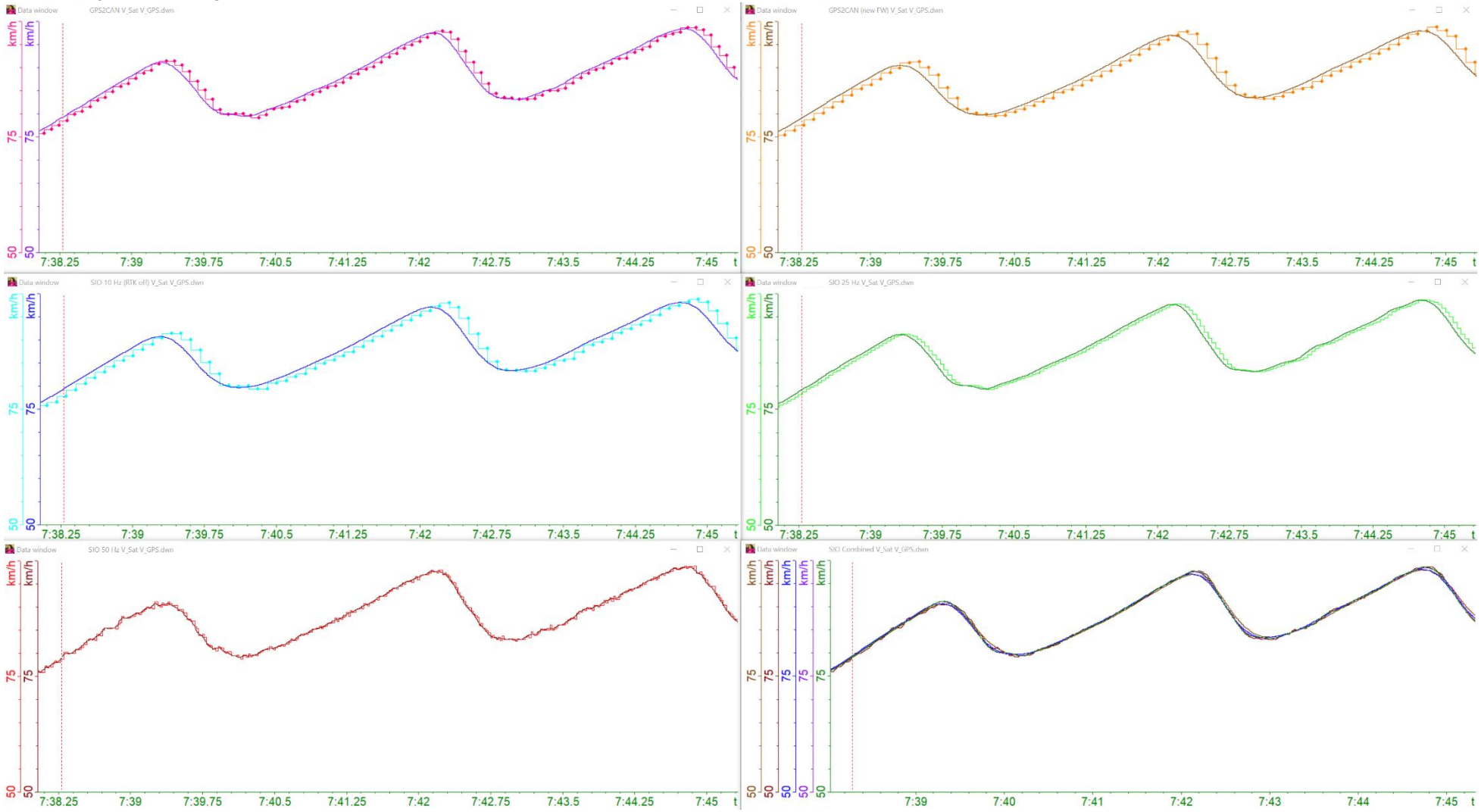


In addition to compensating for the time delay of GNSS channels, further options are available in 2D post-processing, for example for filtering the GNSS channels. The raw speed channel *V_Sat* is filtered by a freely adjustable moving average filter and results in the channel V_GPS (darker colour in each case). By default the filtering frequency is aligned to the GNSS frequency of the module used! Due to the freely adjustable parameters, the post-processing can be adapted to any application and the user can determine whether and how much filtering should be applied to the raw values.

For better comparison, shifting was disabled here by using ShiftTime 0 sec for all modules!

Channels	Channels	GNSS Module
V_Sat	V_GPS	12.5 Hz GPS2CAN (old FW)
V_Sat	V_GPS	10 Hz GPS2CAN (new FW)
V_Sat	V_GPS	10 Hz SIO (RTK off)
V_Sat	V_GPS	25 Hz SIO
V_Sat	V_GPS	50 Hz SIO

LateralDynamic Filtering and Time correction:



After filtering the raw values in the previous step, the time delay correction mentioned above is now applied. In post-processing, all GNSS channels are shifted to 1/1000 sec with the respective values entered and thus aligned with each other and the actual car movements.

Channels	Channels	GNSS Module
V_Sat	V_GPS	12.5 Hz GPS2CAN (old FW)
V_Sat	V_GPS	10 Hz GPS2CAN (new FW)
V_Sat	V_GPS	10 Hz SIO (RTK off)
V_Sat	V_GPS	25 Hz SIO
V_Sat	V_GPS	50 Hz SIO

4.4 Processing non-2D GPS/GNSS channels in post-processing

Beside the time delay correction and filtering of the GNSS channels, additional channels are created from the recorded GPS/GNSS channels.

The processing and alignment of channels from non-2D GPS/GNSS modules is also done in post-processing.

To also benefit from 2D GPS/GNSS post-processing, the non-2D GPS/GNSS channels can be prepared so that they can also be used in post-processing.

Various calculation files can be created for this purpose.

In order to be able to use the *Dellorto*-GPS-channels in the MOTO3 motorbike racing class, a separate form of the 2D_GPSAuto.CCF files is available in the *AutoCalc-Configurator*.

Further Information
If other non-2D GPS/GNSS channels are to be used, please contact 2D via **contact form**

4.5 GPS/GNSS post-processing channels

Original-CH	Calculation/Input-CH	Interpol	Shift	Filter	Frequency	Other	Output-CH	Unit	Res
ValidSat (16 bit)			x		@GPS_ChannelRate_Hi		ValidSat	-	16 bit
	ValidSat > @GPS_MinValidSat				@GPS_ChannelRate_Lo		GPSValid	-	16 bit
Lon_deHi (16 bit) + Lon_deLo (16 bit)						Conversion 16 --> 32 Bit	Longitude	deg	32 bit
Lat_deHi (16 bit) + Lat_deLo (16 bit)						Conversion 16 --> 32 Bit	Latitude	deg	32 bit
Lon_dez (32 bit)						Range -180 --> +180 + DoublePrec float	Longitude	deg	32 bit
Lat_dez (32 bit)						Range -180 --> +180 + DoublePrec float	Latitude	deg	32 bit
	Longitude (32 bit)	x	x		@GPS_ChannelRate_Lo		Longitude	deg	32 bit
	Latitude (32 bit)	x	x		@GPS_ChannelRate_Lo		Latitude	deg	32 bit
AltituHi (16 bit) + AltituLo (16 bit)						Conversion 16 --> 32 Bit	Altitude	m	32 bit
Altitude (32 bit)	Altitude (32 bit)	x	x		@GPS_ChannelRate_Lo		Altitude	m	32 bit
V_Sat (16 bit)		x	x		@GPS_ChannelRate_Hi	Range 0 --> 655.35	V_GPS	km/h	16 bit
Course (16 bit)		x	x	x	@GPS_ChannelRate_Hi	Range 0 --> 360	Course	deg	16 bit
	Derivate(#Course)			x	@GPS_ChannelRate_Hi		GPS_Yaw	deg/s	16 bit
	((#V_GPS/3.6)/#GPS_Yaw)/DEG2RAD			x	@GPS_ChannelRate_Hi		Radius	m	16 bit
	1/#Radius			x	@GPS_ChannelRate_Hi		Curvature	m	16 bit
	Derivate(#V_GPS)			x	@GPS_ChannelRate_Hi	Range -32.767 --> +32.767	A_Lon_GPS	m/s²	16 bit
	(#V_GPS/3.6)*(#GPS_Yaw*DEG2RAD)			x	@GPS_ChannelRate_Hi	Range -32.767 --> +32.767	A_Lat_GPS	m/s²	16 bit
	(Arctan(#A_Lat_GPS/-9.81 m/s²)*RAD2DEG				@GPS_ChannelRate_Hi		Banking	deg	16 bit
	#HHMM --> #HH & #MM #HH * 3600 + #MM * 60 + # SSHH				@GPS_ChannelRate_Hi		SOD	sec	16 bit

Interpol: GPS/GNSS signal dropouts up to a certain length (@GPS_MaxDropoutTime) are filled by interpolation in postprocessing.

Shift: Correcting time delay (chapter 0)

Filter: Filtering signals (chapter 4.3)

Frequency: Setting the frequency of the output channel

Important information
All parameters with @ can be adjusted in AutoGPS.HED!

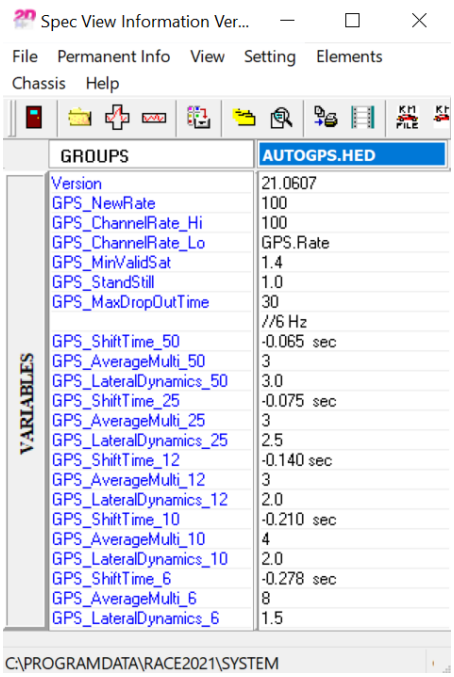
4.5.1 Adjust parameters of AutoGPS.HED

1. Open WinARace and press [CTRL] + [ALT] + [D] to open race application directory
2. Open folder *System* and subsequently folder *Cal*
3. Open AutoGPS.HED by double-clicking

Further Information
It is recommended to doublicate the existing, original AutoGPS.HED file and use another name it, e.g. AutoGPS_org.HED

4. Adjust the respective parameters
5. Save via *File* → *Save all changes*
6. Open desired measurement and recalculate the *2D_GPSAuto.CCF* via *AutoCalc*

Further Information
2D_GPSAuto.CCF files must be recalculated twice after changing the AutoGPS.HED parameters.

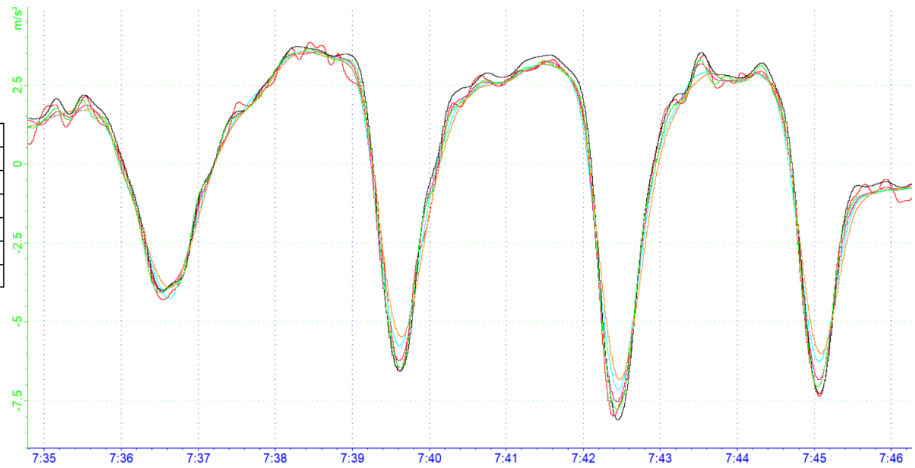


4.5.2 Longitudinal acceleration

Like seen before, the post-processing creates various channels from recorded GPS/GNSS channels. For example, by using the GNSS speed, **longitudinal acceleration** is created which is compared with a signal of an accelerometer (**black**) as reference signal in the following figure. The accelerometer was sampled with 1000 Hz.

By eliminating the time delay and filtering the coloured longitudinal acceleration channels are compared to the black acceleration signal which shows the actual acceleration of the car at braking and accelerating tests.

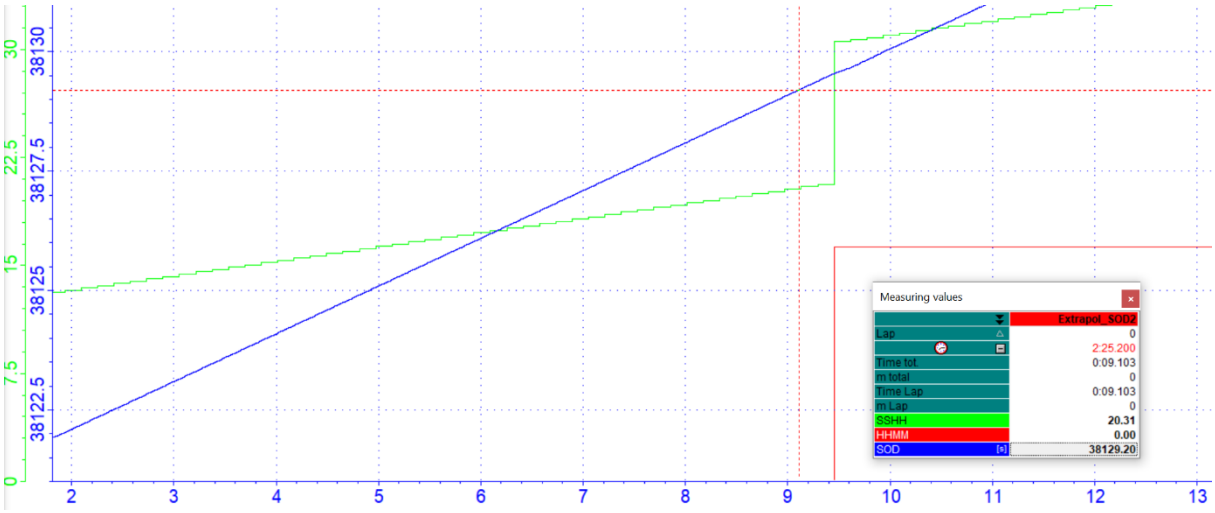
Channels	GNSS Module
A_Lon_GPS	12.5 Hz GPS2CAN (old
A_Lon_GPS	10 Hz GPS2CAN (new
A_Lon_GPS	10 Hz SIO (RTK off)
A_Lon_GPS	25 Hz SIO
A_Lon_GPS	50 Hz SIO
Acc_y	y-axis of accelerometer



4.5.3 SOD (SecondOfDay)

The time channels MMDD, HHMM and SSHH are very important for adding time information to your measurement. The channels HHMM and SSHH are combined to a channel SOD (SecondOfDay) in post-processing.

In addition to the simple generation of the SOD channel, this is also further improved in GPS post-processing, since, for example, an initially non-existent GPS/GNSS reception is compensated for in the best possible way by extrapolation by calculating the time from a valid GPS/GNSS reception retroactive to the start of measurement.



As you can be seen here, the *SOD* value is already displayed correctly before *HHMM* and *SSHH* even jump to its correct value.

Further Information
SSHH already is up counting from zero even no GPS/GNSS reception is given.

Time information is also required for *GoPro AutoSync* feature or synchronizing measurements.

Documentation reference
For more information about **GoPro AutoSync** please see respective manual on 2D website:
http://2d-datarecording.com/downloads/manuals/

At GPS/GNSS-postprocessing toolchain the following SpecSheet entries are created:

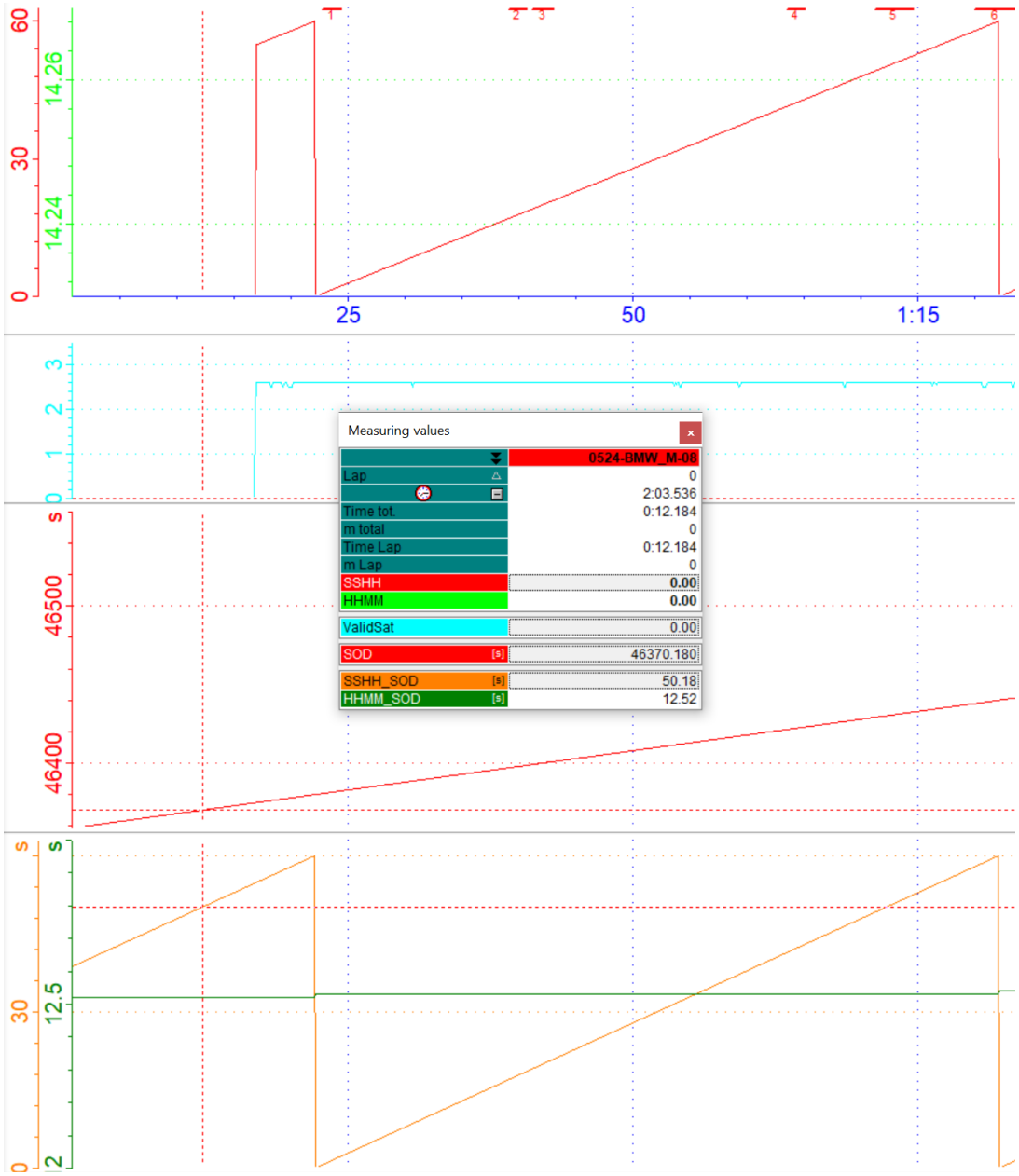
MES.Date_Mes	Date of measurement (YYYY.MMDD)
MES.SOD_Mes_FV	First SOD value of measurement
MES.SOD_Mes_LV	Last SOD value of measurement

Important information
MES-SpecSheet entries are only created if channels HHMM and SSHH are recorded! Nevertheless, if possible a recording should start with good GPS/GNSS receiption outsides!

Documentation reference
For more information about **SpecSheet** please see the manual ***SpecView*** on 2D website:
http://2d-datarecording.com/downloads/manuals/

By using the predefined CAL file *2D_SOD_Reverse.CAL* the GPS time channels (#HHMM and #SSHH) can be recalculated from channel #SOD (SecondOfDay) to get corrected GPS time channels #HHMM_SOD and #SSHH_SOD.

Documentation reference
For more information about *2D_SOD_Reverse.CAL* please see the manual “CalcTool” on 2D website:
http://2d-datarecording.com/downloads/manuals/

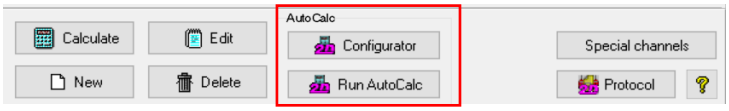


4.6 Executing GPS/GNSS-postprocessing

Depending on the setting of WinARace (AutoCalc-Configurator), the GPS post-processing calculation files named *2D_GPSAuto.CCF* are executed directly after the measurement data download automatically.

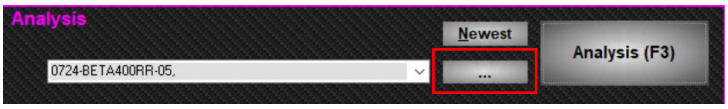
To run AutoCalc routine manually, the corresponding measurement must be opened in the 2D *Analyzer* where the *Calculation File Manager* can be opened via the *Functions* tab.

In lower area of *Calculation File Manager*, the AutoCalc routine can be configurated or executed:

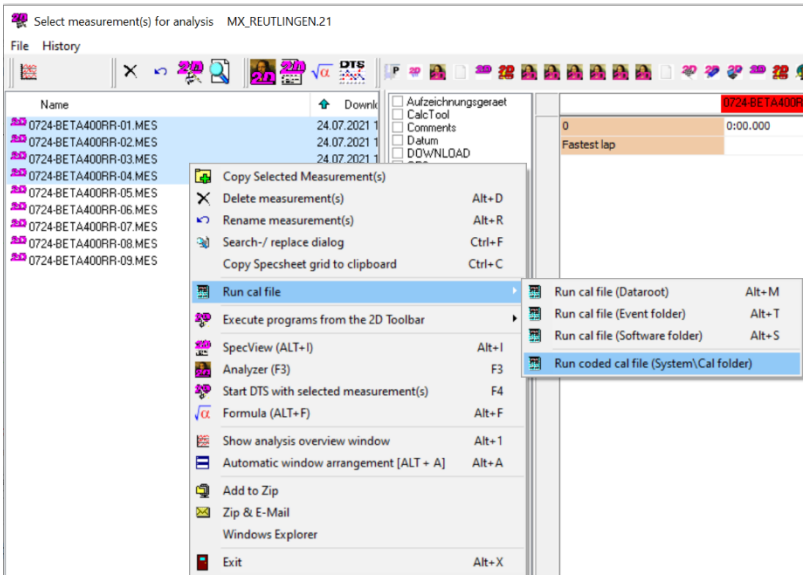


If more than one measurement should be recalculated it is better to follow the subsequent steps:

1. Open *WinARace* and events measurement overview via highlighted button



2. Select all measurements to be recalculated and open sub-menu via right-click



3. Select *2D_GPSAuto.CCF* for execution

5 FAQ

1. After downloading a new measurement, GPS/GNSS post-processing toolchain is not executed automatically.

   ➔ 2D_GPSAuto.CCF calculation file is not linked to *AutoCalc* routine (0).

2. After executing 2D_GPSAuto.CCF calculation file, there are no newly calculated GPS/GNSS **CALC** channels available, only the **originally recorded** GPS/GNSS channels.

   ➔ Not all channels required for correct GPS/GNSS post-processing were recorded (4.1).

3. After executing 2D_GPSAuto.CCF calculation file, there are no SOD channel was created.

   ➔ Not all channels required for correct SOD creation were recorded (4.5.3).

4. *Dellorto*-GPS-channels (Moto3) cannot be handled by 2D_AutoGPS.CCF calculation files

   ➔ Special 2D_GPSAuto_MOTO3.CCF must be used (4.5).