BayesWavEx

Returns you can trust.

Efficient point cloud extraction from full waveform LiDAR data
with extended attributes and uncertainty computation

QUICK DOCUMENTATION AS OF 11 / 14 / 2018

BayesWavEx 1.1 beta with LASlib 171030*

The use of this software subject to licensing:

- New users: visit bayesmap.com/licensing for information and to request a demo license.
- Existing users: please check your EULA for conditions and restrictions.

* *Based on LASlib with LASzip (c) 2007-2018 martin.isenburg@rapidlasso.com*
Latest version: http://www.lastools.org/download/LAStools.zip

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What is BayesWavEx and what is it for?

This software package extracts 3D points from raw, full waveform LiDAR files. A rigorous approach helps get more points and more accurate results even at high altitude and in difficult cases with low vegetation. High throughput is achieved through the use of efficient algorithms and an optimized implementation. WavEx is fully optimized to run on multi-core architectures using multi and hyper-threading.

SDF features (new in version 1.1):

- Direct decoding of Riegl SDF files (compatible with 560, 680, 780 and 1560 scanner series)
- Single pass decoding, processing, georeferencing and LAS/LAZ/ASCII file generation
- Automatic MTA (multiple times around) resolution
- Advanced waveform modeling and optimal pre-calibrated sensor parameters
- Automatic amplitude-based range, amplitude and width corrections
- Channel fusion and pulse ordering

Main features:

- Ground extraction robust to overlaps due to low vegetation and noise
- Underground false alarm suppression using pulse shape (impulse response calibration option)
- Fast, accurate, rigorous waveform decomposition proprietary algorithm
- Ultra-fast extraction options for quick preview
- Physically meaningful target attribute extraction (intensity, thickness, widening)
- Uncertainty attribute export options as LAS extended attributes (LAS/LAZ 1.4 compatible)
- Basic outlier filtering (high/low point elimination)
- Intensity correction options (incidence angle, range, atmospheric attenuation)

Please refer to the end of this document for common error messages (appendix A1), and current software requirements and limitations (appendix A2).

Should anything unexpected happen, please re-run with option -ostat to write all text outputs, send bug reports along with the text files, including the latest log files, to *support@bayesmap.com*. Log files are in the output directory (or current directory if not specified); in case of crash they are still in the executable directory, with the archived ones.

Please note that this is not a manual, but a documentation listing all commands, options, inputs and inputs systematically. . There will be a manual and tutorials, please check back on bayesmap.com!

1. INTRODUCTION - THE BASICS

BayesWavEx is a command-line tool that requires a terminal (e.g. cmd or ConEmu on Windows, Terminal on Mac OS) or an external interface to be run. Currently it has no interface, so *double-clicking on the icon will not do anything*, as the software requires the user to select the input dataset and enter some optional parameters. Complex tasks can be achieved automatically with a simple command line. Good results can be achieved with default (missing) options in most cases so the command can be really very short. Commands can also be used in sequences in batch files, and invoked through high-level software interfaces.

OPTIONS AND ARGUMENTS

-n l name <arg>	option: short form n, long form name; argument <arg> (if any); options are case-sensitive
Conventions	[] means optional, l means mutually exclusive, ... means multiple
Argument syntax	-n<arg>, -n <arg>, -n=<arg>, -name <arg>, -name=<arg> equivalent
Spaces	Separate multiple arguments, or must be in "" if part of argument (file names etc.)
Missing boolean arg.	Equivalent to 1 (-n same as -n1)
Units	Metre, second and decimal degree, unless specified
Persistent option file	Text file stripalign.opt in exec. dir.; command-line options override persistent options.
Persistent option syntax	name=<arg> (only form accepted), one per line, "" not necessary, see example below.

GENERAL OPTIONS

Directory

-I l idir <dir>	Set input directory (unless explicit path is given) [default: current]
-O l odir <dir>	Set output directory [default: current]

Processing

-mem <MB>	Memory made available to the program in MB [default: 1024]
-N l nthreads <n>	Max number of simultaneous threads [default: depends on processor]

Behavior

-q l quiet <0l1>	Quiet mode, no text output, no progress bar [default: 0]
-progress <0l1>	Display progress bar [default: 1]

LiDAR input/output

-i l input <files>	Input file names (only SDF waveform supported in 1.1 beta)
-o l out <str>	Output naming convention and extension [default: laz, same base name as input]
	Use prefix*suffix.ext to specify custom name and format, eg. -o*_ex.las
-oparse <str>	Use the column format parse string for ASCII output, as defined in las2las [link]
-oext <0l1>	Write extended LAS point attributes (amplitude, width etc.) [default: 1]
-ounc <0l1>	If -oext activated, write uncertainty attributes (for amplitude, width, range etc.) [default: 1]
-o12 <0l1>	Set the LAS/LAZ version to 1.2 [default: 0, version 1.4]
-olax	Write LASindex file, appended or separate file (see next option) [default: 0]
-lax_append	Append LASindex data to LAS/LAZ output [default: 0, separate file]
-nil	Disable LiDAR data output [default: 0]

Logs and text output

-log <0l1>	Leave a copy of the latest log files in the output directory [default: 1]
-log_flush <0l1>	Empty log file buffer after each write to help debugging [default: 0]
-clear_log	Clear log history from exe directory
-olstat <0l1>	Write statistics text file, one row per scanline [default: 0]
-otraj <0l1>	Export projected, subsampled trajectory text file [default: 1]
-osdfstat <0l1>	Export misc. histograms and stats with base name set by -name [default: 0]
-name <str>	Set name for debug info and SDF histograms and stats [default: out]

Information

-h l help	Display brief documentation and usage examples
-v l version	Display the version and license information

PROCESSING COMMANDS AND PARAMETERS

Speed-up	[default: iterative refinement, optimal speed]
-f l fastest <0l1>	Fastest processing, no iterative refinement [default: 0]
-s l fastsep <0l1>	Fast processing (no iterative refinement) if separated peaks (no overlap) [default: 0]
-a l auto <0l1>	Fast options (-f or -s) only: enable iterative refinement if deviation exceeded or overlap detected [default: 0]
-slow <0l1>	Slower iterative refinement when enabled (more iterations, better convergence) [default: 0]
Extraction, basic	
-d l det <float>	Detection threshold in noise std.dev. units [default: 4.5]
-det_lm <float>	... same for last of many returns only [default: 0, disabled]
-out_flt <0l1>	Outlier wave filtering [default: 1]
-em_flt <0l1>	Emitted pulse cross-talk filtering [default: 0]
Extraction, expert	
-min_width <float>	Keep only returns with minimum width, in impulse response FWHM units [default: 0.8]
-max_width <float>	Keep only returns with maximum width, in impulse response FWHM units [default: 10.0]
-out_min_a <float>	Minimum angle with neighbor points for outlier wave rejection [default: 2.0]
-out_max_h <float>	Maximum height difference for outlier wave rejection / point detection [default: 50.0]
-out_max_r <float>	Maximum range for outlier point detection [default: 4.0]
-bge <0l1>	Automatic background level estimation [default: 1]
-decay_a	Decay amplitude coefficient [default: auto]
-decay_t	Decay time constant [default: auto]
Time interval selection	
- t_min <float>	Minimum timestamp [default: disabled]
- t_max <float>	Maximum timestamp [default: disabled]
- t_adj <0l1>	min/max timestamps in adjusted GPS time [default: 0, week seconds]
Timing & range correction	
-ibrc <0l1>	Amplitude based range/timing correction from SDF data [default: 1]
-utc <0l1>	SDF timestamps are in UTC [default: 0, GPS]
-gps_date <str>	Override date from SDF data, format YYYY-MM-DD [default: 0, SDF file name]
-t_corr <float>	Time offset to add to SDF timestamps [default: 0.0]
-t_err <float>	Set the minimum system timing error (unit: ns) [default: 0.02]
-n_ppm <float>	Set the air refractive index (unit: PPM) [default: 0, get from SDF file]
-odd_dt <float>	Shift odd samples by x sampling units (useful for some digitizers) [default: 0.0]
-ibrc_fit <0l1>	Use model fit for SDF correction tables (reduce noise) [default: 1]
Amplitude, intensity & width correction	
-ibic <0l1>	Amplitude based amplitude correction from SDF data [default: 1]
-icf <0l1>	Intensity shading correction assuming flat terrain [default: 1]
-icr <float>	Intensity range-based correction using reference range r0 [default: 1000 m]
-ica <float>	Intensity atmospheric attenuation correction, a in dB/km [default: disabled]
-awc <float>	Amplitude dependent width correction coefficient for LO power channel [default: auto]
-awc1 <float>	Amplitude dependent width correction coefficient for HI power channel [default: auto]
PO data	
-po <file>	Set PO data file name [default: none, georef disabled]
-po_adj <0l1>	PO timestamps in adjusted GPS time [default: format-dependent]
-po_day <0l1>	PO timestamps in day seconds [default: 0, week seconds]
-po_rad <0l1>	PO attitude data in radians [default: 0, deg]
-po_parse <str>	Column format string for ASCII PO data t x y z w p k # for time longitude latitude ell.height roll pitch heading skip, respectively
-plot_po <str>	Export subsampled and projected PO file as ASCII, format t lon lat h x y z w p k (use georeferencing options to specify the projection)
-po_sub <n>	Set the decimation factor for the exported ASCII PO file

Geometry

-mount <file>	BODY/IMU rotation angle file, format {Rx Ry Rz} [default: none, 0 0 0]
-calib_corr <file>	Calibration correction file [default: none, all 0] Format: LeverArms {X Y Z} Boresight {roll pitch yaw} Internal {e0...e5 [e6 e7]}

Georeferencing

-wkt <file>	Use WKT file to define a TM/LCC projection, optional unit [default: none, UTM projection]
-utm <n>	Set the UTM zone manually [default: auto]
-geo	Use geodetic coordinates [default: 0]
-ecef	Use ECEF coordinates [default: 0]
-geoid <str>	Use geoid (file w/o extension from Geoid directory in exe directory) [default: none]
-metre	Set unit=metre, override WKT [default: 0, from WKT or m]
-feet	Set unit=survey foot, override WKT [default: 0, from WKT or m]
-int_feet	Set unit=international foot, override WKT [default: 0, from WKT or m]
-dumv <float>	Use fake velocity to help visualize the file in BODY coordinates (no georef) [default: 0.0]

EXAMPLE USAGE

```
> wavex -i data.sdf -po file.pof -fastest
```

extracts a point cloud in LAZ 1.4 format (same name as input) from input file data.sdf, using fastest algorithm (no refinement, but uncertainties are computed and exported along all other extra attributes); georeferencing done using PO data in POF format and default UTM projection (default unit m) with ellipsoidal heights; global stat file and subsampled projected PO data are exported.

```
> wavex -i data.sdf -po file.pof -lstat -o12
```

same with LAZ 1.2 output and refined, accurate extraction; scanline stats are exported.

```
> wavex -i data.sdf -po file.pof -lstat -olas -olax
```

same with LAS 1.4 output and LAS index file (as a separate .lax file, use option -lax_append for single file).

```
> wavex -i data.sdf -po file.pof -lstat -I indir -O outdir -ounc 0 -o*_abc
```

input and output directories are specified; uncertainty attribute computation and export disabled; file base names have _abc appended.

```
> wavex -i indir/*.sdf -O outdir -po podir/file.pof -fastest -oext 0
```

same as first example using all files from indir, using explicit output directory, and using fastest possible extraction setting (all extended attributes are disabled).

```
> wavex -i indir/*.sdf -O outdir -po sbet.out -wkt proj.txt -geoid g2012bu0
```

same as first example using all files from indir, using explicit output directory, SBET PO file, accurate extraction, and custom projection (TM or LCC) and unit defined in WKT file with manually specified geoid name (WKT geoid is not parsed); the wkt info is written into the LAS file.

```
> wavex -i indir/*.sdf -O outdir -po sbet.out -wkt proj.txt -calib_corr cal.txt
```

same without geoid, and with calibration corrections (lever arms, boresight angles and internal distortions).

```
> wavex -i indir/*.sdf -O outdir -po sbet.out -utm 55 -feet -calib_corr cal.txt -mount mnt.txt
```

same with UTM projection and manual zone, survey feet; BODY/IMU mount angles specified in file mnt.txt.

```
> wavex -i indir/*.sdf -O outdir -po sbet.out -calib_corr cal.txt -utc -t_corr 0.72 -t_min 82300 -t_max 82400
```

same with default projection and time options: SDF file in UTC, time offset 0.72 s (added to SDF timestamps); extraction only for the specified time interval (use -t_adj to use adjusted GPS time for this option)

```
> wavex -i data.sdf -po file.txt -A -po_parse xyztwpk -fastest
```

same as first example, with ASCII PO file (custom column format and adjusted GPS timestamps).

```
> wavex -i data.sdf -po file.txt -A -po_parse xyztwpk -fastest -geo
```

same without projection: geodetic coordinates are exported, and the projection can be done with another software.

```
> wavex -i data.sdf
```

same as first example without georeferencing (data exported in body frame coordinates); use option -dumv to specify a fake aircraft velocity that allows the point cloud to look georeferenced for visual inspection.

```
> wavex -i data.sdf -det 6 -lm_det 10
```

same with detection threshold set to 6 noise std devs, and 10 for last of many returns.

```
> wavex -i data.sdf -fastest -oext 0 -nil
```

same with fastest possible extraction and output disabled; use for detailed scanning and stat file generation.

```
> wavex -sdfscan -i data.sdf -name scan
```

scans a SDF file and writes various histogram and stat files starting with name scan; displays basic stats; useful to check the integrity of a file; use -sdfscanfast for a faster, more basic scanning without waveform data decoding

```
> wavex -h
```

displays a basic documentation (general options and processing commands above).

```
> wavex -v
```

shows the version and licensing info.

```
> wavex -clear_log
```

deletes all the archived log files from the exe directory.

PERSISTENT OPTION FILE EXAMPLE (wavex.opt.txt)

```
mem=4096
det=5
R=1000
```

allows the same options to be used often without having to specify them in each command line; if they are found in the command line they override those from the file.

INSTALL INSTRUCTIONS

- Create a folder for the software and put the DLL, executable and license file in it
- Create a Geoids folder in the same location as the executable and download only the needed geoids
- Update the PATH environment variable to include the new software location

2. INPUT FILES

SDF files

Currently only Riegl SDF files are supported (560 to 1560 including V-line scanners if exported to SDF).

PO data (optional)

PO data is required for georeferencing but not for extraction. The software can produce body frame points that can be later georeferenced by other software if necessary.
The data file must contain GPS timestamps (day seconds, week seconds or adjusted), position in geodetic coordinates (longitude latitude ellipsoidal height) and attitude (roll pitch heading). Other data are not used.
This is supported by formats such as SBET, POF, SOL and any ASCII file (using the -po_parse option to specify the column format, and other options for attitude and time unit).

Calibration corrections & mount (recommended)

Option -calib_corr is used to specify the ASCII file containing lever arms, boresight angles and internal corrections. These parameters are fully compatible with StripAlign. If a calibration flight is processed with StripAlign, then the parameters (3 lever + 3 bore + 6 internal) can be pasted directly into an ASCII file and used for optimal geometric accuracy of body frame coordinates, thus simplifying any further correction.

Format:
Lever arms: X Y Z
Boresight: roll pitch yaw
Internal:

e0: range bias
e1: range scale - 1
e2: angle distortion order 1
e3: angle distortion order 2
e4: angle distortion order 3
e5: misalignment [not used by WavEx]
e6: optional - angle bias [WavEx only]
e7: optional - LO/HI range bias [WavEx only]

3. OUTPUT FILE FORMAT

LIDAR POINT CLOUD (LAS/LAZ 1.2-1.4)

The timestamps are always exported as **adjusted GPS time** and are automatically determined from the SDF file or by manually specifying the date with option -gps_date if necessary.

Depending on options -oext and -ounc (on by default) the following **extra attributes** are exported.

Name	*Description*	*Scale*	*Offset*	*Type*	*Bytes*
WideRatio	Pulse widening ratio (%)	0.025	0.5	unsigned char	1
TargetThick	Target thickness (m)	0.008	0.0	unsigned char	1
Amp	Target amplitude	1.000	0.0	unsigned short	2
DevRatio	Residual-Noise, Chi2 stddev unit	0.100	0.0	unsigned char	1
RangeErr	Range std. dev. (m)	0.001	0.0	unsigned char	1
IntErr	Corrected intensity std. dev.	0.200	0.0	unsigned char	1
WideErr	Pulse widening std. dev. (%)	0.002	0.0	unsigned char	1
ThickErr	Target thickness std. dev. (m)	0.001	0.0	unsigned char	1
Channel	Riegl power channel (see below)			unsigned char	1

User data byte: contains information specific to the fitting algorithm for each waveform.

Bit 0	iterative refinement used
Bit 1	peak overlap detected
Bit 2	timing divergence requiring extra refinement
Bit 3	received wave overlapped by emitted pulse (cross-talk) case 1
Bit 4	received wave overlapped by emitted pulse (cross-talk) case 2
Bit 5	bad timing due to emitted pulse overlapped by received pulse (cross-talk)
Bit 6	saturation detected
Bit 7	extreme saturation detected, wave truncated

Withheld bit and LAS class: points classified as outliers (low or air points) are marked as withheld, and assigned class 20 (undefined). Other points are left unclassified or class 0.

Point source ID: contains the MTA zone number.

Channel (LAS 1.4): contains the Riegl power channel number (0 LO, 1 HI) used for intensity computation.

All other attributes are computed according to the LAS specification (scan angle, scan direction etc.).

LIDAR POINT CLOUD (ASCII)

If the output format is set to ASCII (eg. with -otxt) then the -oparse string is used to define the column format, consult the las2las documentation for more info: rapidlasso.com/lastools/las2las
Example: -oparse txzyi will only export time and 3D coordinates followed by intensity.

TRAJECTORY FILE

The exported trajectory is stored as an ASCII file with each row as follows: time X Y Z [roll pitch heading]
The timing information is in the same format as the LiDAR file and X Y Z are in the same coordinate system.
If a PO file is used, attitude information is also exported. The PO info is subsampled.

STAT FILES

The global stat file (_stat.log) is saved as a human readable file, and contains information on runtime, SDF file and format, decoding and extraction, as well as PO data, georeferencing and output file.

The scanline extraction stats are stored as a text file (_lstat.txt), with each row corresponding to one scanline:
gps_time nw np np_xtalk np_filtered np_merged np_air np_low np_range np_atm np_ibrc np_ibic
nw_empty nw_saturated nw_refined1x nw_refined2x nw_deleted nw_truncated n_georef AGL
(where np, nw are for number of points and waveforms, respectively)
See exported global stat file for more explicit names.

4. NOTES

EXTRACTION PARAMETERS

Detection thresholds (-det and -det_lm)
The parameter specified by -det is crucial, as the false alarm rate and the missed return rate depend on it. If an efficient point cloud filtering software is available it is recommended to set the threshold to a low value (4 sigma or less), so no returns will be missed, and the high number of false alarms (mostly low points, just a few meters below ground) will be filtered after extraction. Otherwise, we recommend setting a value of 4.5 sigma (default setting) to keep a false alarm rate below 1/10000; in this case faint ground returns under vegetation might be lost. Here sigma stands for the noise standard deviation ratio (estimated automatically, as well as the correlation coefficient). A Gaussian, signal-independent noise model is assumed.
There is no simple rule giving the false alarm rate as a function of the threshold, since digitizer noise is correlated. The software takes into account this correlation for uncertainty estimation but the choice of the detection threshold is left to the user.
For noisy scanners (eg. early 780) high peaks tend to have unusually high and unpredictable ringing, so we recommend to use option -det_lm with a higher value (eg. 10) so that last of many returns are processed with this threshold, which reduces the low point rate (and helps the outlier filtering that cannot cope with a high density of low points). For other scanners or if the first extraction attempt looks good, ignore this option.

Minimum width of detected pulse (-min_width)
The pulse minimum width is specified with respect to the system impulse response FWHM (estimated automatically). Due to noise, and to the variability of the impulse response function in real world digitizers, this minimum width should not be set to 1 otherwise peaks may be lost. However, a low value such as 0.2 would allow more false alarms, as peaks much narrower than the system response are very unlikely to occur. It is recommended to keep the default value (0.8) for most systems, and lower it to 0.5 for digitizers having an amplitude-dependent impulse response, (usually wider at higher amplitudes so that the estimated function is too wide for small peaks and the minimum width threshold filters out good peaks). Leica ALS-50 digitizers tend to behave this way.

Outlier filtering parameters (-out_min_a, -out_max_h, -out_max_r)
Nearest neighbors in the scanline are considered when performing outlier waveform rejection. Only waves having a height jump over max_h compared to both neighboring points will be rejected (and counted as low if they are more than max_h below the neighbors, or high if they are more than max_h above the neighbors). The rejection happens only if the angle formed by the wave anchor point and its two neighbors is below min_a (very acute triangle). Default values should be used, unless there is no power line (in that case max_h can be lower), in that case the maximum tree height should be considered. Default parameters are set to minimize data loss, and further filtering (e.g. ground filtering, classification) can be performed by other software.
While outlier waveforms can be safely rejected, outlier points (after return extraction from waveforms) are analyzed and outliers are detected but only marked as withheld and classified accordingly. The point based algorithm may produce false detections and ultimately a high level classifier should be used if possible (if not, withheld points can be removed). The max_r parameter helps detect low points for noisy scanners, or rare returns that are above the detection threshold but underground or isolated.

Other parameters (background, decay etc.)
The default values have been calibrated for each type of instrument, so we do not recommend to change them. In some cases, instruments may exhibit unusual characteristics and require manual settings, usually through interaction with client support.

OUTPUT PARAMETERS

Uncertainty output (-ounc)
Even if most existing software do not know how to use predictive uncertainty, we recommend to export and inspect the range uncertainty attribute. It will be supported by future BayesMap products (such as accurate gridding). In certain cross-talk cases (emitted pulse contaminated by received wave) the timing is inaccurate and the uncertainty is set to the maximum. It does not mean that returns should be rejected, but that their range is not reliable (this is also valid for intensity and the related uncertainty attribute) and they should be given less weight when computing derived quantities.

Extended attribute output (-oext)
For simple applications and quick inspection, extended attribute export can be disabled, and computation will also be faster in most cases. In general, attributes are very useful for classification and should be exported. For instance, pulse widening or target thickness help during classification, as no other attribute is equivalent (the geometry of the target, as well as its roughness, directly determine the pulse width; the software compensates for instrumental artifacts such as amplitude-dependent widening to provide physically meaningful quantities).

A1. COMMON ERRORS MESSAGES, CAUSE, SOLUTION

Nothing happens when I click on the icon...
Cause: normal behavior, this is a command-line software
Solution: run wavex in a terminal window (cmd, conemu, etc.), please read the documentation!

Executable not starting properly, no error message
Cause: antivirus software (e.g. Avast) may be blocking, or sandboxing "unsafe" or "unknown" executables
Solution: whitelist the application, or exclude the directory from scanning - please do not submit it to any virus scanning website, and use your antivirus to scan it instead.

The application was unable to start correctly (0xc000007b)
Cause: missing or incompatible DLLs (Visual C++ Redistributable Packages for Visual Studio)
Solution: go to www.microsoft.com/en-us/download/details.aspx?id=48145 and follow the instructions

ERROR: stopping due to option argument errors (use -h for help)
Cause: some options have wrong argument types, are unknown, or arguments are missing
Solution: check previous error messages and supply correct arguments

ERROR: missing waveform file...
Cause: no valid command arguments found, or no arguments given, or no input file name given
Solution: use option -i to specify an input file, or -clear_log_history to delete stored log files

ERROR: Unsupported full waveform format...
Cause: only Riegl SDF files are currently accepted
Solution: use version 1.0 for LAS 1.3 FWF, use Riegl export utility for VQ scanners

ERROR: one instance already running!
Cause: parallel runs would not improve performance and are disabled to avoid potential issues.
Solution: run only one instance!

ERROR: missing bin file for geoid...
Cause: misspelled geoid name, or geoid .bin file not installed, must be in "Geoids" directory in exe directory
Solution: create "Geoids" directory in exe directory and download .bin files from the WavEx distribution Google drive or from the NGS website www.ngs.noaa.gov/GEOID/models.shtml (USA only)

ERROR: PO data format cannot be used, PO file...
ERROR: failed to read PO file...
Cause: PO file not recognized, not in geodetic coordinates, or does not have attitude data
Solution: provide PO data in one of the formats: SBET, POF, SOL or ASCII

ERROR: WKT string parse error
Cause: projection parameters not found or unsupported projection
Solution: use Transverse Mercator only and check the syntax (must be OGC WKT)

ERROR: SDF georeferencing error: lon/lat out of bounds for selected geoid
Cause: wrong geoid used given geodetic coordinates in PO file
Solution: check geoid name (preferably use full geoids instead of regions, eg. g2012bu0)

ERROR: SDF georeferencing error: timestamp not found in PO file
Cause: error in time correction or conversion, timestamp outside of PO time interval because wrong PO file
Solution: check file name, check date if manual options, and other time options if used

ERROR: SDF unsupported type xxx
Cause: not a SDF file, format error in SDF file header, or unsupported instrument type
Solution: contact support if the displayed type matches the supported type list

ERROR: SDF Type xxx format / SDF Type xxx header decoding
Cause: format error in SDF file (possibly correct but unsupported) / header parameter decoding issue
Solution: none, file is not readable; contact support if file is readable with other software

A2. CURRENT LIMITATIONS

- LAS 1.3 FWF input disabled in 1.1 beta (use version 1.0)
- Supported projections: UTM, TM, LCC (most US state planes)
- Fixed impulse response (amplitude independent), might not be rigorous for all scanners
- Scanline-based outlier detection method simple, fast and effective but not guaranteed to flag all outliers
- Hard surfaces only! no bathymetric LiDAR modeling

A3. PLANNED FEATURES

- LAS 1.3 FWF input with new 1.1 extraction algorithms

- Add more projections
- Input: add PulseWaves reading capability
- Plug in a model-based outlier rejection algorithm