MASS data reprocessing

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Оглавление

1 Overview

This document describes the utilities suited for *a posteriori* interpretation of data obtained with Multi-Aperture Scintillation Sensor device. This device (MASS) has already been intensively used in several site characterization campaigns which resulted in a significant amount of data accumulated up to date.

The need of means for repeated processing of the MASS data was realized by the MASS community soon after beginning of campaigns. This was meant as a tool to obtain more justified output results (atmospheric integral parameters and turbulence distribution) than initially computed by the Turbina program since some parameters (detector characteristics, background level) were revealed to be incorrect. During some time this tool was a Playback capability of the Turbina program itself but, as time passed, more simple and handy utility was demanded.

As a result, the main data-interpretation module of Turbina, ATMOS, was converted in a standalone MASS data processor and adapted to the modern format of the data files, namely the so called "mass-file" (with parameters, observations log and processing results) and "stm-file" (with the statistics of one second data on flux in MASS apertures).

And finally, it has become clear that some simple tools for modification and filtering of these input files are needed if some tool for bulk data re-interpretation is needed.

The result of a work in fulfilling these demands is presented in the current document. It describes the last version of the MASS-data processor ATMOS and a set of scripts for filtering the input and output data for this program and plotting the characteristic graphs.

First, we briefly consider the general concept of MASS-data reprocessing; then the mass-data processor program ATMOS is described and the scripts suited for modification the input and output data are considered. The practice of reprocessing ("cook-book") and input and output data examination scripts are described in sections 6 and 8.

2 The basics of MASS data reprocessing

The MASS device main output is a stream of the statistical moments of the fluxes, measured in 4 device apertures (channels) with a millisecond exposures (micro-exposures) during the so called "Base-time". Each base-time results in one record of the output (stored in a text file `YYMMDD.stm`) which consists of flux means, dispersions, covariances of fluxes between different channels. Records have the time stamp in Universal Time. To the best of our knowledge, the count statistics information presented in stm-file is full enough for interpretation of stellar scintillation. The formulas used in Turbina program for these statistical calculations using the raw micro-exposure counts do not involve any device parameters, so moments data is a real starting point for any data reprocessing.

Apart from the statistical moments, the device and program parameters which were active during data acquisition, the mode of measurement and some target star parameters are involved. This information is stored in a `mass-file` in a form of the so called P-, M- and O-lines, respectively. Unlike statistics data, these data are subject to clarification and corrections which may be applied if more precise information on the observation circumstances was obtained after observations.

As examples, one may input more precise parameters of a detector, reject some wrong measurement of the sky background, correct the wrongly selected name (and hence the coordinates) of the target star. These corrections are introduced in the mass-file and then the latter, together

with an associated stm-file, is fed to the data interpretation program. The output of this program is again the new mass-file, which should contain more justified atmospheric parameters.

3 MASS-data processor ATMOS

The main component of the mass-data reprocessing package is a Standalone ATMOS program. It "eats" the mass- and stm-files and processes their data in exactly the same way as Turbina does during the observations[1]. Relevant parameters are read from the P-lines of a mass-file; the target star coordinates are read from O-line. Coordinates, together with site coordinate parameters and UT references, give the instant value of the airmass used in atmospheric output data scaling and altitude grid stretching for the C_n^2 profile restoration. The signal to start the data interpretation is an appearance of the next O- (object) or M- (mode) line. The scope of moments data taken from the stm-file is restricted by the `UTbeg, UTend` parameters in following I-lines; the average index values themselves are ignored[2].

The output results are sent to the standard output of the ATMOS program as a set of ASCII lines and should be redirected to the file (new mass-file) or a pipe if needed. The format is the same as of Turbina mass-files. Exceptions are the upper case of the mode names in M-lines and the different approach in output of the comment-type #-lines. The warnings from the data processing modules are output in the >-lines in the same way as in Turbina.

The current version of ATMOS is able to check the weight files and recompute them in case the geometry or spectral mismatch is found. The warnings, debug information (may be activated by the `ATMOSDEBUG` definition in `atmos.cpp` if needed) and the weights calculation progress indicators are sent to the standard errors output and thus appear on the terminal while the data are redirected elsewhere. The data needed for weights checking and calculations, the same as Turbina uses, are searched for in subdirectories of a catalogue `/opt/turbina/data` or in other places if specified explicitly in parameters of ATMOS start. Meanwhile, with the parameter `-n`, ATMOS "trusts" the operator and skips the weight file checks using them "as is" opening no spectra or response files.

Thus, the synopsis is following:

```
./atmos [-d tdir] [-w wfdir] [-r rfile] [-s spdir] [-n] <mass> [<stm>]
  Options:
        -d tdir - directory with /weight/*.wf, /data/mass.crv, /spectra/*.sp
        -w weight-files directory (overrides -d) or file (if no O-lines in mass)
        -r response-file (overrides -d)
        -s spectra-files directory (overrides -d)
        -n - force no weights checking/recalculations (hence ignore -r and -s)
  mass - mass-file, may also be '-' for standard input.
  stm  - stm-file (content may, properly sorted, be mixed into mass-file.
```

Example of a start of reprocessing with the specified data sources:

[1] It should be stressed, however, that Turbina makes calculations on binary statistic moments data. Stm ASCII-files contain the statistics with the 10^{-3}–10^{-4} relative precision of the number representation. Thus, standalone ATMOS has the slightly (still insignificantly) different input due to truncation errors.

[2] The use of I-lines does not mean thus that we exploit somehow the original processing results. The content of stm-file may be, properly sorted, intermixed with mass-file records with the same output result; in such a mode (devoted to future generation of on-line MASS data processor) I-lines are completely ignored.

```
./atmos -w wf/ -rdata/mass.crv -sspectra/ 050821.mass 050821.stm >050821.r.mass
```

Finally, we should note that current ATMOS computes the airmasses itself and ignores the *secz* values given in the Normal mode lines. The computed airmass is also printed to the right of the mode name for control (e.g "M 2005-08-21 16:21:12 Normal 1.234"). Also, the star coordinates derived from the input O-lines are given in output, so one may check that there is no problem with O-lines format matching.

Described ATMOS processor is a part of Turbina distribution starting from version 2.05. For compiling ATMOS, one must use `make atmos` command in the Turbina program sources directory (root permissions may be needed). More information on the ATMOS organization details is given in its source file `atmos.cpp` in the section mainpage (Doxygen format, convertible to "ATMOS Reference Manual").

4 Filters for input data

A set of AWK scripts is provided to modify the content of a mass-file. They correspond to the most frequently encountered cases when the original values of some parameters were incorrect:

- Background values measured with a star in aperture (`BKGR.AWK`)
- Detector characteristics not matching the actually used PMT; Wrong magnification values (e.g. taken from other instruments) (`PARAM.AWK`)
- Time stamps shifted by one hour (e.g. after daylight-saving time changes, `DTIME.AWK`)

These filters search for the respective lines in the input and replace the values using the parameters a filter start. Some defaults are given in the scripts themselves but more justified values are strongly preferred. Original or discarded lines are not removed but commented out using a '#'-sign. Each script also reports its application adding the first line in the output which is called a "super-header". Finally, scripts append a comment line with a number of applied corrections to the end of the output (except for `DTIME.AWK` which modifies all the records of input).

Being put in a chain, these filters are able to produce a single modified file where all the demanded corrections are introduced, which has to be fed to ATMOS.

Note: AWK program must use the decimal sign point which is replaced with a comma in some locales (check it by the command: `$ awk 'BEGIN{print 2/3}'`). Proper localization is normally achieved by assigning the system variable: `export LC_NUMERIC=C` (in `sh` or `bash` shells) or `setenv LC_NUMERIC=C` (in `csh`).

4.1 BKGR.AWK filter

This script serves for cutting the implausibly high values of the background and replacing them with some "default" values if no "good" value is available since beginning of the night. If some intermediate background appeared to be too high, its simply removed (commented out).

The critical value of the background (`MAX_BG_D` threshold) is estimated by the user in the largest (D) aperture. If the default should be printed, the `FIXED_BG_D` parameter is used for D-aperture, while *ratio* of fluxes in apertures is used for computing the A, B, and C default backgrounds. So, changing the default sky backgrounds involves the change of only one number

for a given device. In case ratios are incorrect (e.g. zero defaults are left), the message is printed on error and results output.

The flux ratios are approximately computed using any mass-file using `fl_rat` utility (see below). The values of ratios must be saved into the parameters `RAT_F_AD, RAT_F_BD, RAT_F_CD`. As mentioned above, these parameters, as well the critical and "default" D-background values, may either be replaced in the script `BKGR.AWK` itself or (better) given as separate parameters of its start:

`./bkgr.awk FIXED_BG_D=0.5 MAX_BG_D=3 RAT_F_AD=0.07 ... orig.mass >new.mass`.

4.2 PARAM.AWK corrector

This script searches and checks the device parameters – the detector non-linearity values nA, nB, nC, nD (in ns, normally around 10–15), the detector non-Poisson values PA, PB, PC, PD (normally in a range 1.00 to 1.10), the channel scattered light fractions SA, SB, SC, SD, and the optics magnification k (of the order of 15-20, must be precisely measured for each instrument!). It helps to correct one of the major drawbacks of the current mass-file content – the absence of the detector characteristics[3]. If the magnification value or channel non-linearity or non-poissonity are encountered in the input, the values are replaced with the values of the supplied parameters `k, PA,PB,PC,PD, nA,nB,nC,nD`. If parameters are absent in the mass-file, they are printed in the end of preamble-block (heading P-lines), this is the usual case for P and n-parameters. If neither the mass file nor the script parameters contain any of these quantities, the warning message is printed on the standard error output and the default values of $P = 1$ and $n = 0$ are introduced in the output[4]. The scattering light account by the parameters `SA .. SD` is introduced in the latest version of ATMOS and is optional in data processing while allows to significantly improve the quality of interpretation of scintillations[5].

One may use the following alternative way to extract the detector characteristics P and n from the configuration file to the mass-file preamble and use them as actual values:

```
./cfg2mass.awk DATE="2005-08-21 12:00:00" device.cfg |grep -e Line -e Pois >np.mass
cat np.mass 050821.mass | param.awk k=16 | ./atmos -d ../turb/ - 050821.stm >new.mass
```

But usually its more reliable to measure the correct P and n values and provide them as parameters to `param.awk` (see section 8).

4.3 DTIME.AWK UT corrector

In case the Turbina UT time was wrong during data acquisition, it may be corrected using DTIME filter accepting the dt parameter of time shift in seconds. For example:

```
./dtime.awk dt=-3600 040330.mass >040330c.mass
./dtime.awk dt=-3600 040330.stm >040330c.stm
```

[3]The mass-file presently contains only the links between the counters (as Counter 1,2,3,4,5 or Bicounter 1A, 2B etc) and channels A, B, C, D, but the actual values of the counter non-linearity and non-Poissonity are uniquely located in the file `device.cfg` used by Turbina during observations.

[4]In case the input mass-file does not contains the non-linearity or non-Poissonity of some channel, the default value 0 or 1, respectively, are also used in ATMOS. Omitted magnification will cause weights checking/calculation failure.

[5]A number of MASS devices used to have the significant scattering on the pupil mask in some channels; adjustment of an appropriate scattering in channels allows to get rid of significant systematics in index residuals.

Such corrections are needed when Turbina continues to use the same time-zone value (given in `turbina.cfg`) after the change of the daylight saving in spring or autumn time. The UT date and time are correctly recomputed by DTIME for any time shift; the rest of information is retained unchanged.

Another functionality of DTIME (introduced later) is the conversion of the old-format mass- and stm-data files (having only time stamps without date and where UT went over 24h after Greenwich midnight) into the new format. For this the date parameter is needed to be specified. E.g.:

```
./dtime.awk date=020330 in/020330.stm >out/020330.stm
./dtime.awk date=020330 in/020330.mass >out/020330.mass
```

The date parameter in format YYMMDD (YY = year - 2000) means the "evening" date of observations and is normally taken by user from the name of the input file. The date is incremented by DTIME after UT-midnight and UT hours 24, 25... are converted into 0,1... Thus the output becomes fully compatible with the new format data. This functionality of format conversion is supported by `remass.sh` (see below).

5 Filtering output data

In some circumstances, even the good set of input parameters produces the bad output data. Most usually it is a casual loss of the target star when the flux becomes variated by the diaphragm edge or by clouds causing the spurious and strong "scintillation". These data spoil the general seeing and turbulence statistics and should be eliminated from the output analysis. A number of simple criteria – flux level and error, seeing error, profile restoration quality – allow to isolate the bad data by commenting them out. This capability is implemented in a simple script `filter.awk`, which works already on the output data from ATMOS.

The assessment of quality is a topic of discussion, so, as with the parameters of some input-data filters, the choice of critical values should be done quite thoroughly. The defaults given in the script itself serve only for a reference.

The use of an output data filter is simple:

```
./filter.awk MIN_D=60 MAX_CHI2=100 old.mass >new.mass
```

This is the tail of the reprocessing pipeline described as a whole in the next section.

6 Mass-data visualization scripts

A number of plotting scripts is provided for graph representation of intermediate (scintillation indices, fluxes) and final MASS results. They are also written in AWK language but have no name extension. These are namely following:

integrals : 4-graphs plotting the integral turbulence characteristics: isoplanatic angle, free seeing, time constant and effective altitude

chi2 : plot χ^2 in X- and L-method C_n^2 profiles

cn2 `[scale=`*scale*`] [type=X/L]`: boxplot of X- or L-method profiles

flux : plot FluxD and BkgrD*100

fl_rat : plot A/B, B/C and C/D aperture flux ratios and print their statistics on terminal

seeing : plot fSee from C_n^2 for >2 and >0.5km (free and boundary layer)

aux : 4-graph summary plot of fluxes, residuals and χ^2

indices `[idx=`*range*`]`: plot selected set of scintillation indices (normal by default)

results `[scale=`*scale*`] [type=X/L]`: 2-graph summary plot of C_n^2 and seeing

residuals `[idx=`*range*`] [type=X/L]`: plot residuals for selected indices (normal by default) in X- or L-method profiles

The plotting scripts use the XMGRACE program which must be installed in the system. Formatting the graphs requires the presence of the parameter files which, with the same base names as scripts themselves, are provided as well in `.grace` directory. The scripts must be started from their directory only; the directory with visualized data must have writing permissions for creating the temporary files (named as *input-file*`.tmp1,2...`).

The scripts are normally started first on input data and then on data after reprocessing if some feature (high background causing fake scintillation increase, imperfect restoration quality by χ^2 criterion etc) is expected to disappear after correction.

Scripts provide the automatic range setting and folding of the UT-axis around 0^h or 24^h to put the morning data close to evening data. For this, evening points are attributed to negative UT-references (for western hemisphere) or morning points moved to values $> 24^h$ (eastern longitudes). This allows to avoid the gaps in graphs. The appearance of graphs may be modified using the XMGRACE menu.

Apart from visualization, a small script `log.awk` is provided printing the observed objects and UT-range, Nprof, and seeing statistics for a mass-file on the standard output. It may be used with >>-redirection of output for logging the nights summary.

7 Installation

Mass-data reprocessing distribution is part of the latest releases of the Turbina program. Two components are of interest there – the set of scripts for reprocessing and the reprocessing program ATMOS. Here we show step by step how to install the reprocessing software.

Please take into account that compared to previous Turbina distributions, the location of its parent directory has changed to comply with the Unix Filesystem Hierarchy Standard. Now the parent directory is `/opt/turbina/` which contains the very slightly changed set of following subdirectrories:

bin/ : binary executables of Turbina, ATMOS and some utilities;

doc/ : some documentations, mainly for data reprocessing;

etc/ : configuration files;

data/ : catalogue with enclosed directories (mainly Turbina-related), of which the following are of interest: `data/mass.crv` – response curve of the MASS device; `spectra/` – star spectra energy distributions for weight function calculation. `weight/` catalogue is used by Turbina only.

share/rescripts/ : MASS data reprocessing scripts.

The installation may be done in two ways:
1) Quickly – for the SuSE Linux distribution:

1. Take the last version of Turbina RPMs (precompiled packages) from `http://dragon.sai.msu.ru/mass/turbina`: `turbina-2.052-1.i586.rpm`, `turbina-utils-2.052-1.i586.rpm` and `turbina-data-2.052-1.i586.rpm`;
2. Be root
3. install the packages by the command `rpm -i` *`package`*`.rpm`.

2) From the source file package – hopefully will work in your system also:

1. Take the last version of Turbina sources from `http://dragon.sai.msu.ru/mass/turbina` which is `turbina-2.052.tgz` archive.
2. unpack it in the current (say, home) directory:

   ```
   $ tar xfz turbina-2.052.tgz
   ```

3. Enter Turbina directory, configure the software and compile the ATMOS and other utility programs:

   ```
   $ cd turbina-2.052
   $ ./configure
   $ make utils
   ```

   The configuration utility will probably detect the absence of the RS485 driver include files which is allowed if you do not plan to compile Turbina itself.
4. Be root
5. Do

   ```
   # make install-utils
   # make install-hierarchy
   # make install-permissions
   ```

Now you will have the binaries, data and scripts directories in `/opt/turbina/` same way as described in RPM installation section above.

Note, that Turbina software may also be installed in the user domain (say, in `/home/massuser/turbina`). Configuration and compilation are made similarly in this case. But the path to the ATMOS program and to its data files and directory must be modified in the first section of the `/home/massuser/rescripts/remass.sh` script.

If still absent, install XMGRACE program (from your Linux distribution disk or `http://plasma-gate.weizmann.ac.il/Grace/`).

6. Being already the ordinary user, copy the MASS reprocessing scripts to your home directory (we suggest the user name is `massuser`):

```
$ cd
$ cp -r /opt/turbina/share/rescripts .
$ cd rescripts/
$ ls -a
```

A catalogue `rescripts` contains four subdirectories: `in/`, `out/`, `weight/` and (usually invisible) `.grace/`. The reprocessing filter and visualization scripts are stored in `rescripts/` itself, while input data catalogue `in/` for original `mass-` and `stm`-files, output data catalogue `out/` and the catalogue of weight functions `weight/` are empty (only `readme` files are there). The catalogue `.grace` contains the parameter files for the visualization graphs.

8 Typical organization of reprocessing

Data reprocessing requires a substantial amount of disk space and a moderate to high speed of PC for treatment of the season data. Typical night data is about 10Mb, so, to avoid storage of intermediate files, we prefer to make a single pipeline to obtain final data directly from initial. For example:

```
./bkgr.awk old.mass | ./param.awk k=16 | ./atmos - old.stm | ./filter.awk >new.mass
```

Here we omitted majority of parameters for simplicity. Such a pipeline is implemented in the main script `remass.sh` for data pipeline reprocessing. This script has three sections:

- AWK-scripts and ATMOS call specifications (paths to programs and data)
- call parameters for scripts – the main attention locus of the reprocessing operator
- pipeline itself taking original files from input catalogue `in/` and putting the reprocessed files in `out/`. To be left unchanged.

How to do.

1. The instrument and site information must be collected. This concerns primarily the detector characteristics and the system magnification (which may variate from one device to another even for the same brand of instruments).

PMT non-Poisson and non-linearity parameters must be measured *in situ* using the Turbina mode "Detector statistics", preferentially in the night time with the open enclosure to have the natural thermo-conditions. The system magnification must be thoroughly measured on the entrance aperture and, having the segmentator physical dimensions from the `device.cfg` file, the unique value k of magnification must be derived.

The obtained P, n and k parameters must be written in PA,nA,...nD and k parameters in the $PARAM\_DATA$ line of the parameters section of the reprocessing script `/home/massuser/rescripts/remass.sh`. During the reprocessing this file must not be modified, but its convenient to have it open in an editor all the time, since it is the major operator instrument for manipulation of reprocessing parameters. Make sure once again that those parameters refer exactly to that instrument which data are to be reprocessed! Note, that last version of ATMOS is able to take into account the scattering light fraction in channels by assigning here the optional parameters $SA..SD$.

Site coordinates and UT precision are not that important since they affect only the airmass-correction, so several degrees and minutes of time precision is enough. In case the site coordinates may require systematic significant modifications in mass-files, an additional utility will be provided on request.

In case you have a number of old-format data (with a time-stamp without date and time going beyond 24^h), `remass.sh` will reprocess them as well if you will set the `OLDUNTIL` variable in the middle section of the script to the date (year month day) after which your data are all in the new format.

If all of your data are in the new format, set OLDUNTIL to the old enough date. Reprocessing of the old data like new (i.e. your old-format file name was based on the date *after* `OLDUNTIL`) would be incorrect. Meanwhile, the interpretation of the new data as old causes no consequences except for copying of the stm-files in the `out/` directory during reprocessing.

Make sure you use a correct system spectral response function which is normally stored in the `data/mass.crv` file of the Turbina directory. This file is needed for data reprocessing as well in case the magnification value will be modified or wrong response function was used on-line. Its full name with the path is given in `RESPFILE` parameter of the first section of `remass.sh`. Close to `RESPFILE`, the weights and spectra directory names `WEIGHTDIR` and `SPECDIR` reside. The latter must contain the usual set of spectral energy distributions `a05.sed, f05.sed...` etc.

2. Estimate the D-background threshold value. For this you can use `fluxD` script on the full-Moon data to see where is the plausible upper limit on real backgrounds. Increase it by 20–30% and save in `MAX_D_BG` parameter in `BKGR_DATA` setting of `remass.sh` text. Don't forget that a significant background may be also encountered if observations were made short after or before dawn. The signature of unacceptably high dusk background are the characteristic bending "tails" downward in the scintillation index graphs (use `index`) and upward in the flux graphs.

3. Check that the flux ratios used for calculation of the default backgrounds in A, B, C apertures are correct in parameters `RAT_F_AD, RAT_F_BD, RAT_F_CD`. Use `fl_rat` on any night data for this.

4. Select the data for reprocessing which were obtained with the instrument in question and copy them into input data catalogue. For example:

```
$ cd /home/massuser/maidanak
$ cp 05*.mass 05*.stm /home/massuser/rescripts/in
```

5. Try reprocessing of the single file. For example:

```
$ cd /home/massuser/rescripts/
$ ./remass.sh in/050821.mass
```

Look at the scripts warnings appearing on the terminal (they are sent to the standard errors output). Each reprocessing is also reported as "process ... in ..." on the terminal. E.g.:

```
process in/050821.mass with in/050821.stm in out/050821.r.mass
2005-08-21T15:27:53 BKGR DEFAULTS USED
2005-08-21T15:29:19 PARAM PA defaulted to 1!
```

Apart from warnings and messages about calculation of weight functions, reprocessing goes silently (you may trace it by a command like `tail -f out/050821.r.mass`).

Each warning has a time stamp by which one may find which of the input files caused the problem. For tracing these warnings, the bulk data reprocessing may be performed as follows:

```
$ cd /home/massuser/remass/
$ ./remass.sh in/*.mass 2>remass.log
```

In such a way all warnings will be collected in the file `remass.log`.

6. Treatment of the files where the UT has to be corrected is a bit special.

First, determine precisely which data files are affected by the same UT error. If, for example, time has to be "shifted" forward by one hour (the observations have to obtain UT references "later" than original), the *positive dt* parameter should be specified in `DTIME_DATA` line of `remass.sh`: `DTIME_DATA= "dt=3600"`.

This is the case when the operating system shifted the system time back by one hour in autumn (daylight saving), but no timezone change was introduced in `turbina.cfg`. This is an inconvenient drawback of Turbina timing system.

In case such a correction *dt* was introduced in `remass.sh`, the reprocessing starts with correction of UT references in the respective stm-file, producing its correct version named as `YYMMDD.r.stm` in the `out/` catalogue (the message "process in/YYMMDD.stm in out/YYMMDD.r.stm" will first appear). Then reprocessing of the mass-file is started using already the reprocessed statistics file. All these motions are made automatically with no user interference.

Do not forget to turn *dt* back to 0 when the wrong-timing data are already processed.

7. As explained above, the output data are also filtered using the quality criteria by background-to-flux in D, D-flux limitations and maximal error (variation), profile restoration quality χ^2, and the error of seeing estimate. The respective thresholds given in `FILTER_OUT_DATA` parameter in the second section of `remass.sh` were suggested by A.Tokovinin in trial reprocessing of Cerro Tololo MASS-DIMM data but, of cause, may be reconsidered. See the `## FILTER out NN observations` statistics in the last lines of reprocessed files on how much data are rejected in the output. This filtering, if too strict criteria applied, causes large gaps in output data graphs when seen with visualization scripts.

8. Visualize output data. For example:

```
$ ./integrals out/050821.r.mass &
$ ./aux  out/050821.r.mass &
```

   The graph appearance may be changed by the menu tags. The modified appearance may be saved in the respective parameters file (`integr.par` or `aux.par`) in the directory `.grace/` if desired.