MSNoise Documentation

Release 1.6

Thomas Lecocq and MSNoise Devs

Sep 03, 2019

CONTENTS

Originally, MSNoise was a "Python Package for Monitoring Seismic Velocity Changes using Ambient Seismic Noise". With the release of MSNoise 1.4, and because of the Plugin Support, we could call MSNoise: "Measuring with Seismic Noise". The current release version of MSNoise is **MSNoise 1.6**.

The standard MSNoise workflow is designed to go from seismic data archives to dv/v curves. The monitoring is achieved by computing the cross-correlation of continuous seismic records for each pair of a network and by studying the changes in the cross-correlation function relative to a reference.

The goal of the "suite" is to provide researchers with an efficient processing tool, while keeping the need for coding to a minimum and avoiding being a black box. Moreover, as long as the in- and outputs of each step are respected, they can easily be replaced with one's own codes ! (See *Workflow* (page 13)).

Plugins can be added and extend the standard workflow from any steps, e.g. using MSNoise as a cross-correlation toolbox until the *stack* step, and then branching to the workflow provided by one's plugin.

If you use MSNoise for your research and prepare publications, please consider citing MSNoise: **Lecocq, T., C. Caudron, et F. Brenguier (2014)**, MSNoise, a Python Package for Monitoring Seismic Velocity Changes Using Ambient Seismic Noise, *Seismological Research Letters*, 85(3), 715-726, doi:10.1785/0220130073.

This documentation is also available in PDF format on the MSNoise Website (PDF).

CHAPTER

ONE

INSTALLATION

1.1 Installation

MSNoise is a python package that uses a database (sqlite or MySQL) for storing station and files metadata together with jobs. When installed, it provides a top level command `msnoise` in the console.

This version will be the last to be tested on Python 2.7. The EOL (end of life) of 2.7 is 2020, which means it is high time for users to migrate. For users having a complete set of tools in Python 2.7 and not keen to move to 3.x soon, the incredible easiness of creating a Python 3.x environment in conda, for example, will allow them to run MSNoise in the future.

Note that MSNoise is always tested against the latest release versions of the main packages, so older installations that are not maintained/updated regularly (years) could encounter issues. Please make sure you have the latest version of Numpy and Scipy (and MKL), as performance gets better and better (especially since Anaconda Inc. released its fast MKL implementations for all users, in the conda-forge channel).

To run MSNoise, you need:

- A recent version of Python (3.x recommended). We suggest using Anaconda with a few extra modules. MSNoise is tested "continuously" by automatic build systems (TravisCI and Appeveyor) for **Python 2.7** and **Python 3.7**, on **Windows, Linux and MacOSX** 64 bits systems! Support for **Python 2 .7** will be dropped as soon as the TravisCI test don't pass and the corrections would take too much dev time.
  - Those modules are already distributed with Anaconda:
    * setuptools
    * numpy
    * scipy
    * pandas
    * matplotlib
    * statsmodels
    * sqlalchemy
    * click
    * flask
    * pymysql

    * wtforms

  - Not shipped with Anaconda:

    * obspy
    * flask-admin
    * markdown
    * folium
    * flask-wtf

- MySQL: if you want to use MySQL, you need to install and configure a MySQL Server beforehand. This is not needed for sqlite. Read *About Databases and Performances* (page 106) for more information. We recommend using MySQL.

1.1.1 Full Installation

1. Download and install Anaconda for your machine, make sure Anaconda's Python is the default python for your user
2. Execute the following command to install the missing packages:

```
conda install -c conda-forge flask-admin flask-wtf markdown folium pymysql␣
↪logbook
conda install -c conda-forge obspy
```

3. Install a MySQL server and MySQL Workbench:

   Download and install MySQL Community Server (MySQLs) and MySQL Workbench (MySQLw) ; On Windows one can also use the MySQL installer (MySQLi).

   On Linux, the MySQL server can also be installed using the following command:

```
sudo apt-get install mysql-server
```

4. Create a privileged user and a database:
   - Start MySQL Workbench and connect to the local database
   - Click on "Privileges" and create a new user, with all privileges (Select all). Ideally, create user "msnoise" with password "msnoise".
5. Install the latest release version of MSNoise:

```
pip install msnoise
```

   Power user could install the development version too, but it is not recommended.

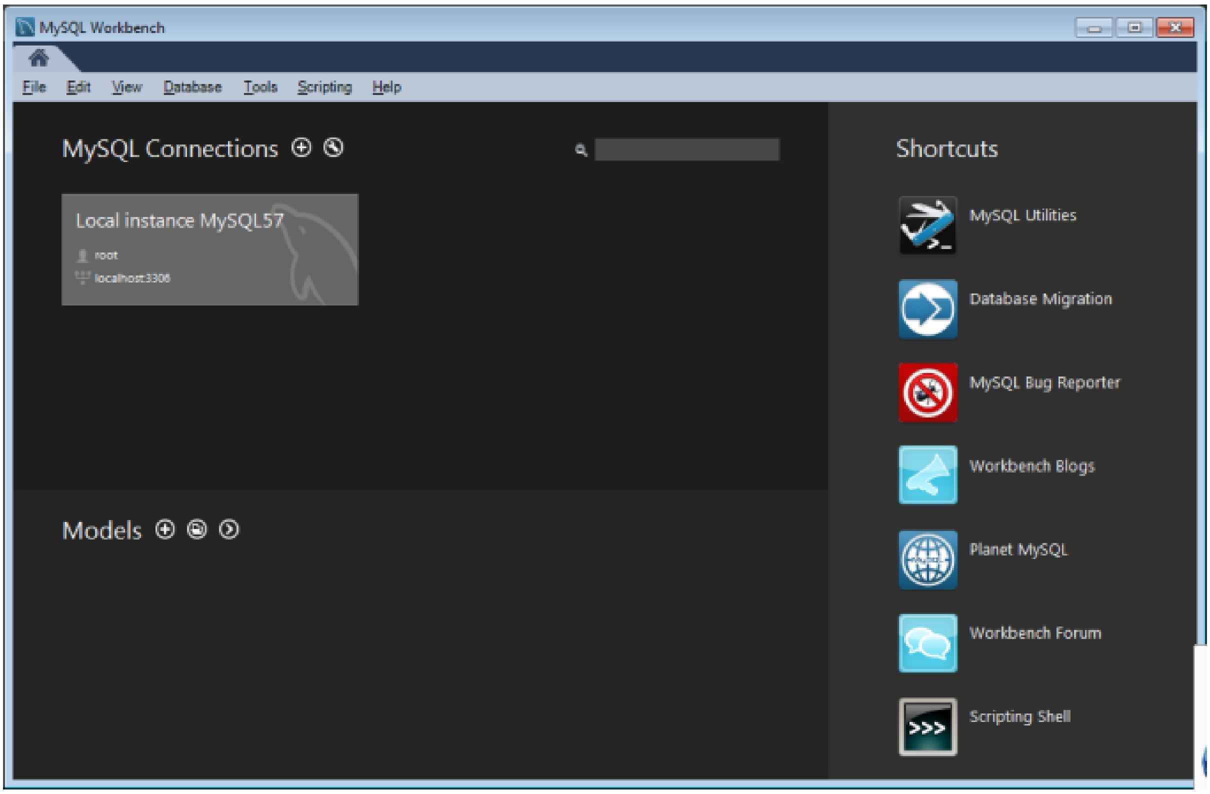
6. Check which required packages you are still missing by executing the `msnoise bugreport` command. (See *Testing the Dependencies* (page 60))
7. To be sure all is running OK, one could start the `msnoise test` command. This will start the standard MSNoise test suite, which should end with a "Ran xx tests in yy seconds : OK".
8. Proceed to the *Workflow* (page 13) description to start MSNoise!

Done !

1.1.2 MySQL Server and Workbench

Using the MySQL Server and Workbench is fairly easy and lots of tutorials are available online as text or videos.

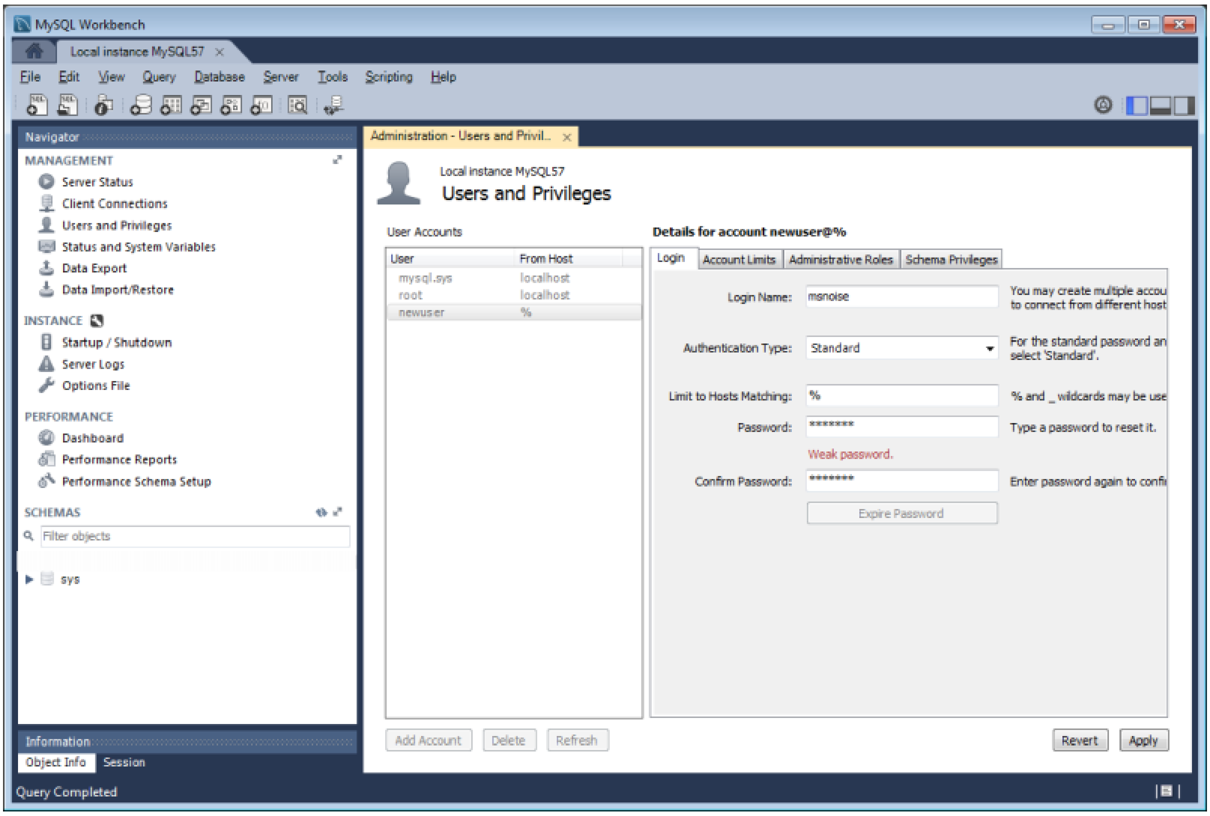
Once both are installed, start Workbench and you should see the local MySQL server automatically identified:



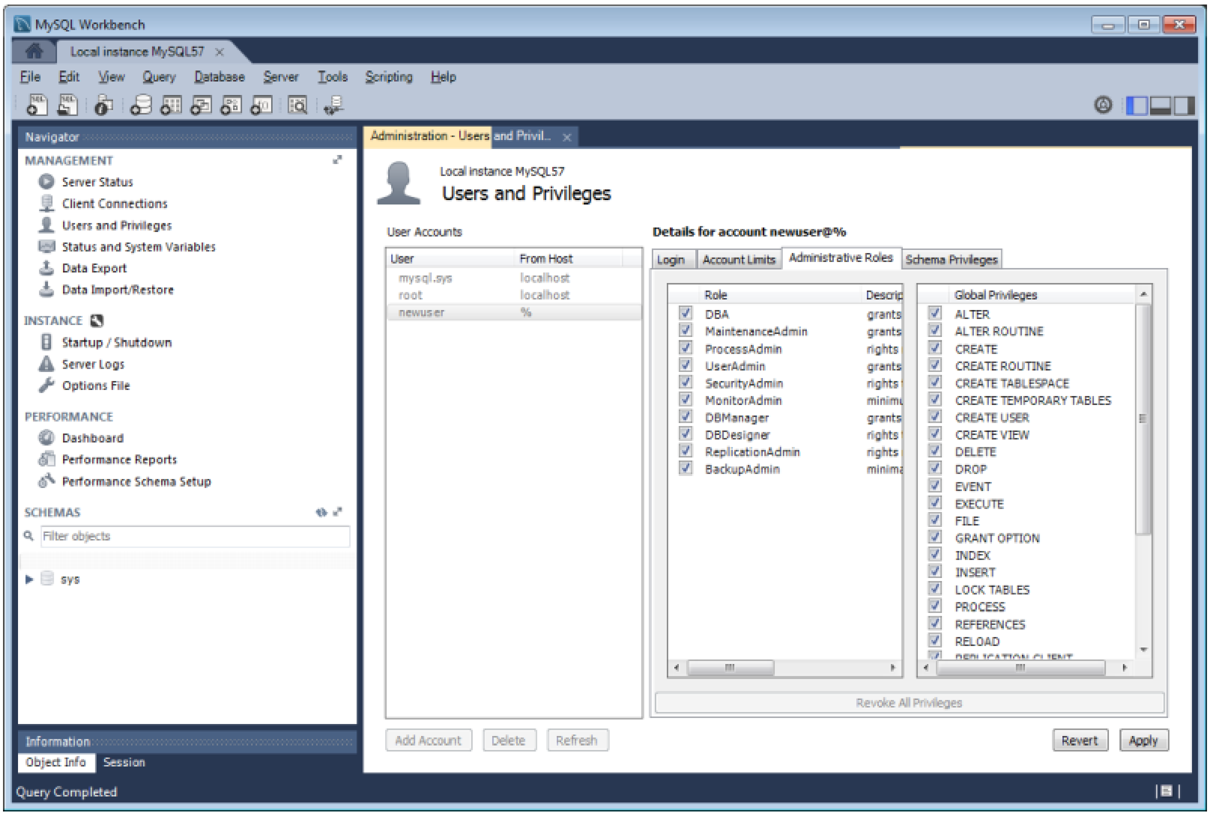
And by clicking on "Local Instance …" another tab should open, connected to the local database.

Create a msnoise user

Select "Users and Privileges" in the left sidebar, then "Add Account". Define the username and the password (msnoise:msnoise could do, although "weak"):



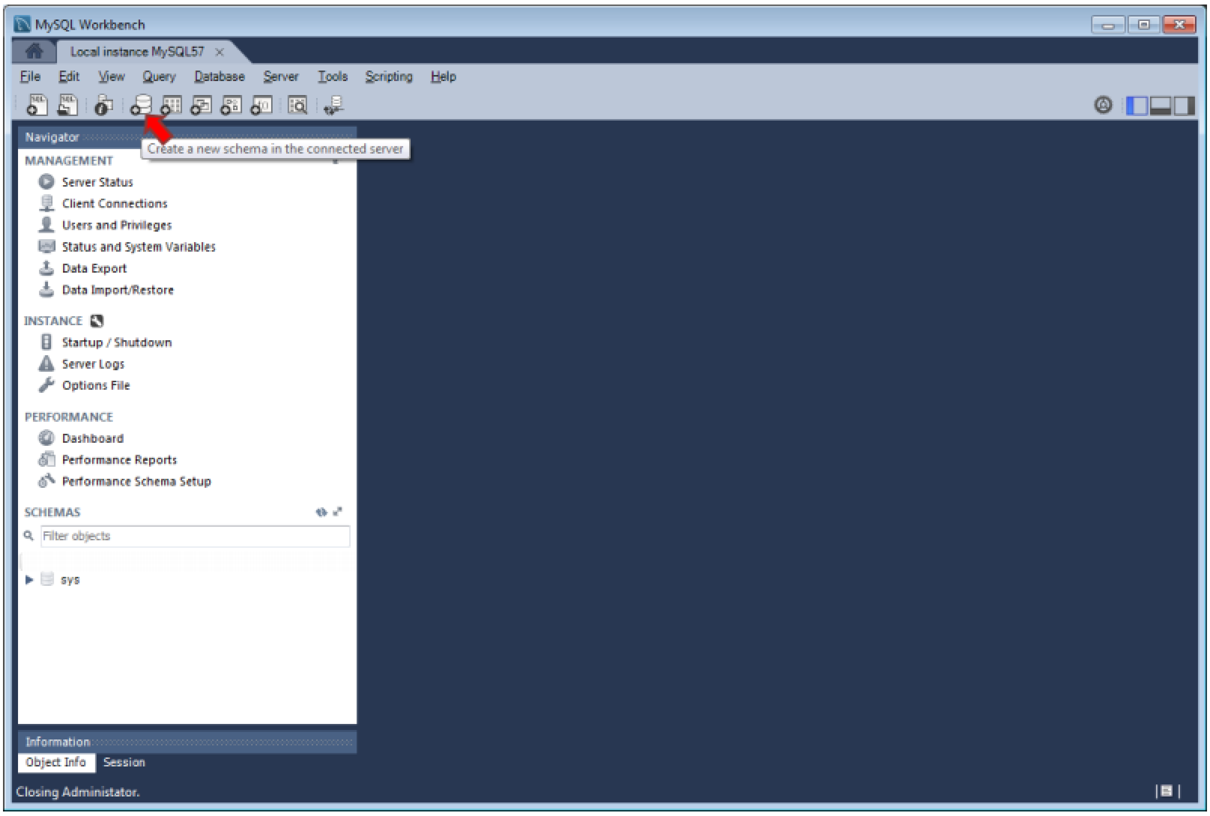
Then, under "Administrative Roles", grant this user the *DBA* mode (user can perform all tasks on the database server) and click "Apply".



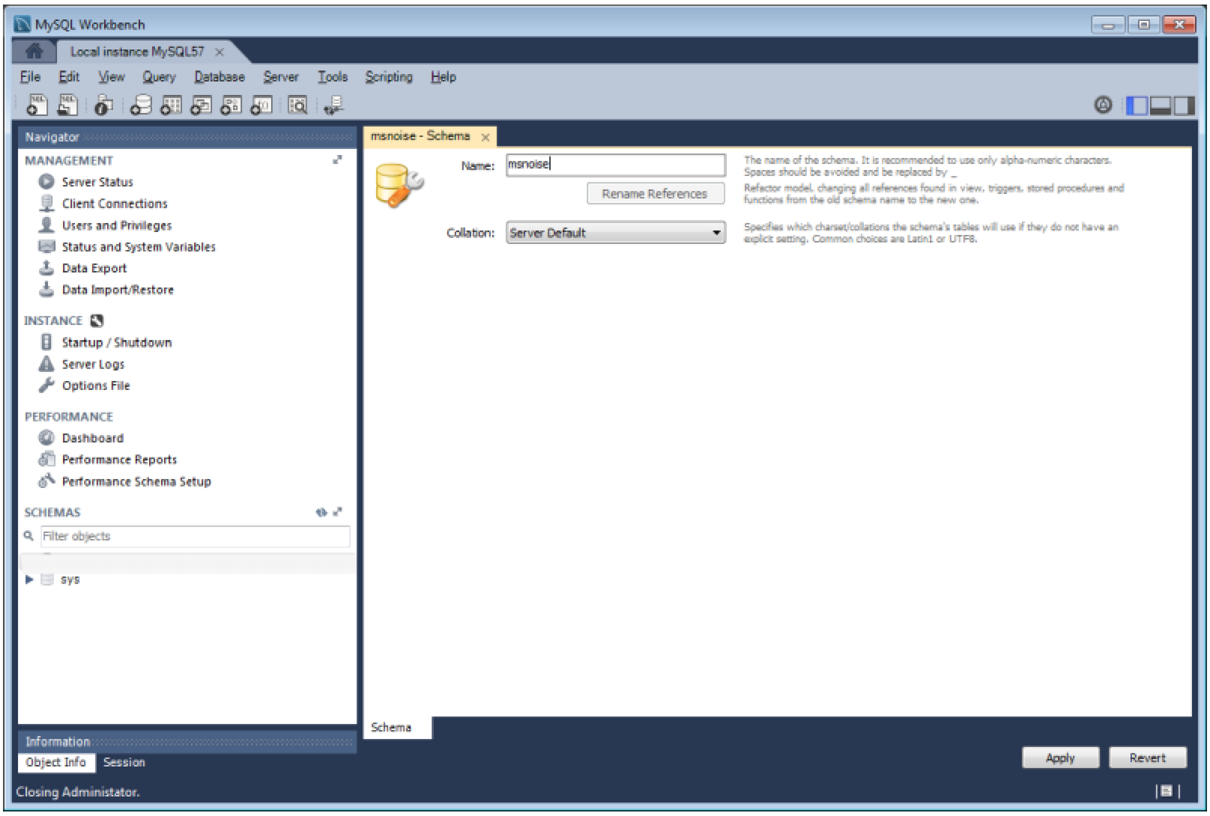
Create an empty database

Ideally, each "project" needs a database. For example, if one has two different volcanoes and wants to run MSNoise using the these distinct datasets, one needs to create two empty databases. For users who have access to only 1 database, the `msnoise db init allows to provide a prefix`, which works like the Wordpress prefixes: for example if a prefix is "vA", the `config table that will be created is `vA_config` in the database.

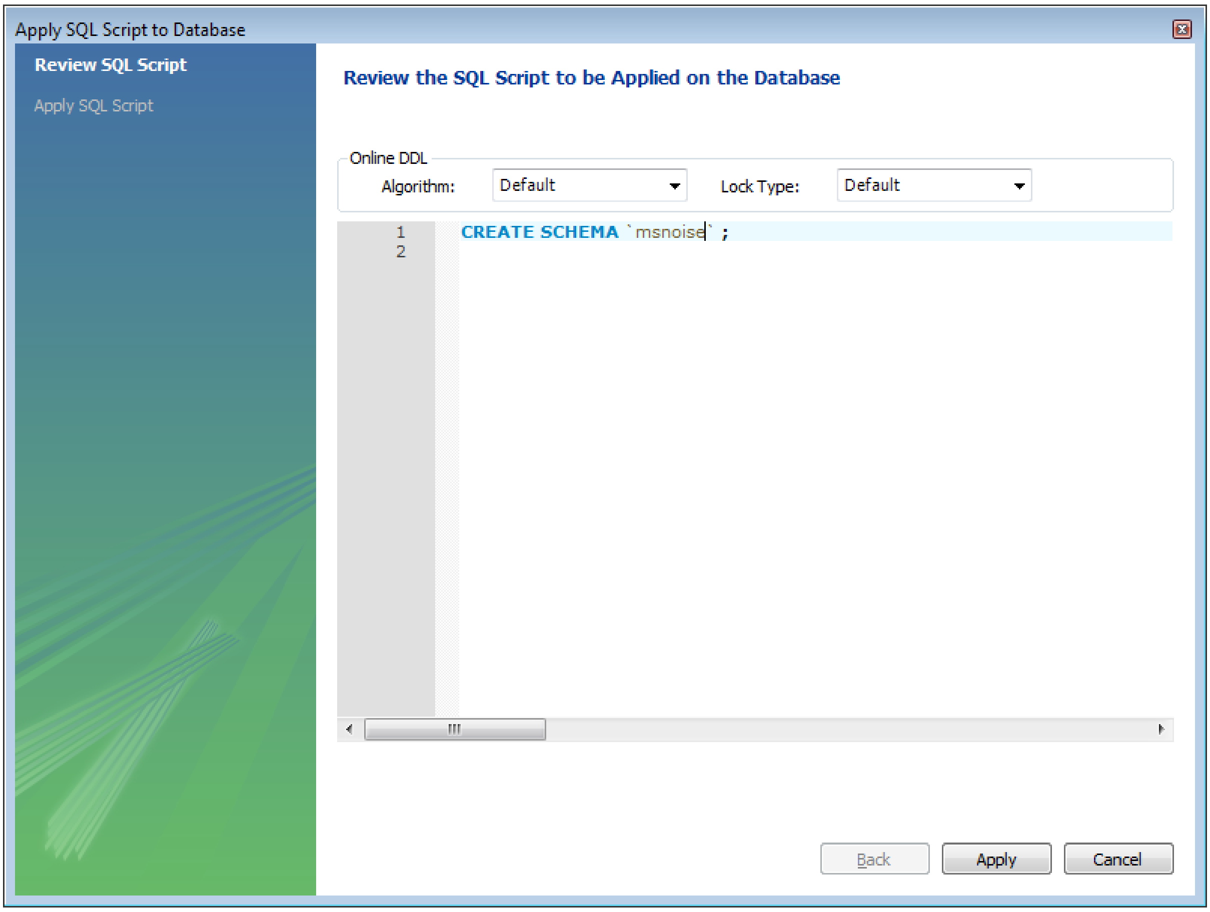
Click on the "Create new schema" button in the taskbar:

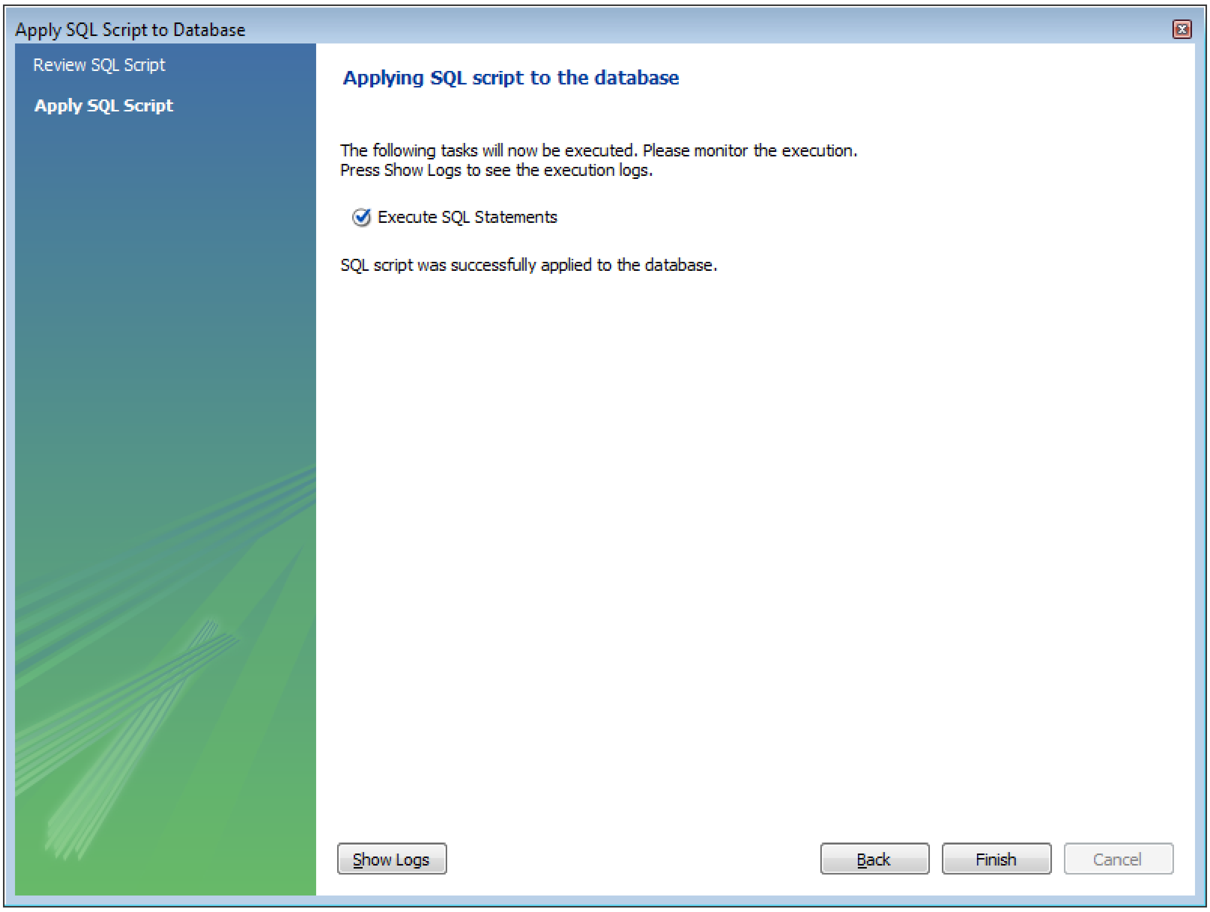


and provide a name for the database (for example msnoise; or msnoise_project1, or project1, or anything else) ; and click "Apply":

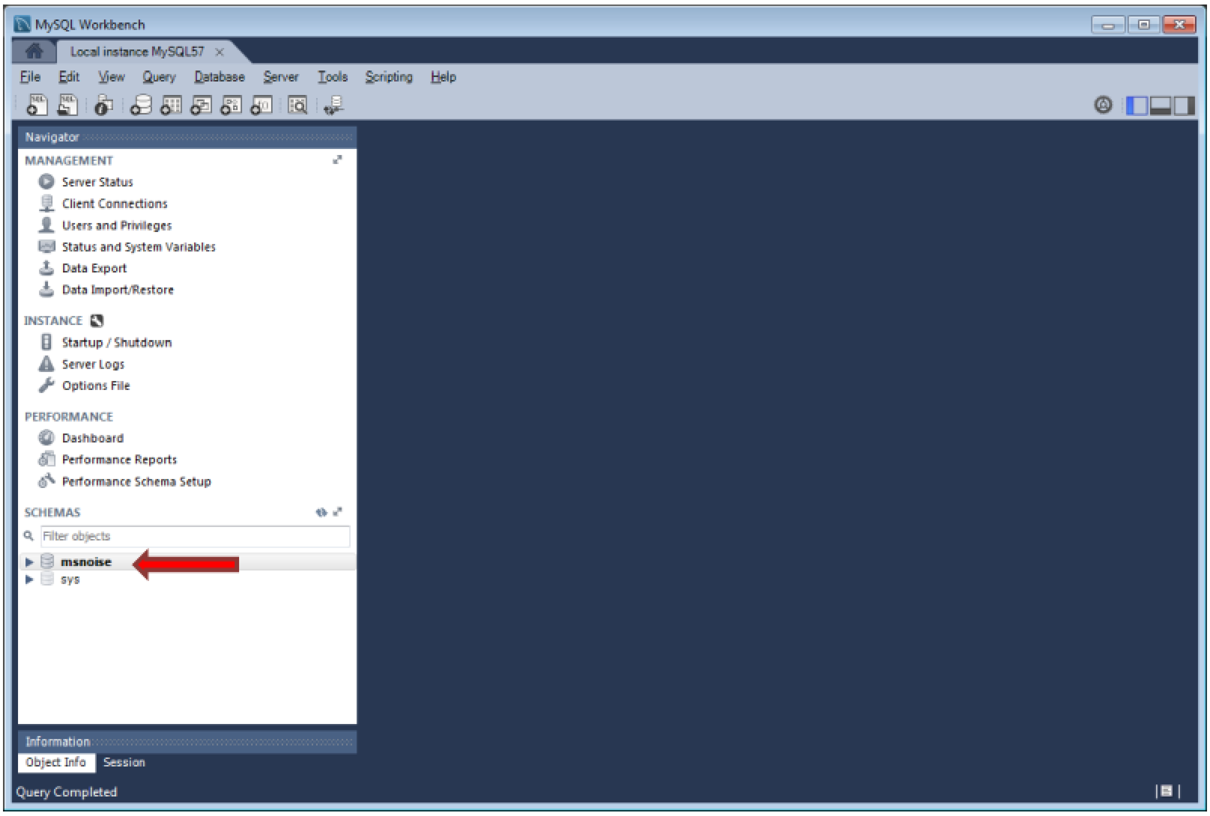


and click "Apply" again and it should state all is OK:





When done, the database we can be seen in the left sidebar:



And you're ready to start your first project: *Workflow* (page 13).

When moving your project to a larger server, HPC or else, just add the connection to this server in Workbench and you're good to go with the very same interface/tool !

1.1.3 MySQL/MariaDB configuration

You can also set up a database server using MariaDB, there are plenty tutorials of how to set it up as well. The new default character set for MySQL or MariaDB is not simple utf8, so make sure that the configuration file (/etc/mysql/my.cnf under Linux) contains the following lines. There are issues with the latest MySQL versions which prevent a "traditional group by" statement.

```
[mysqld]
character-set-server=utf8
collation-server=utf8_unicode_ci
sql_mode="TRADITIONAL,NO_AUTO_CREATE_USER"
```

For Mac, this seemed to work for users (see Issue72):

```
[mysqld]
 sql_mode=STRICT_TRANS_TABLES,NO_ZERO_IN_DATE,NO_ZERO_DATE,ERROR_FOR_DIVISION_BY_ZERO,
↪NO_AUTO_CREATE_USER,NO_ENGINE_SUBSTITUTION
```

1.1.4 Database Structure - Tables

MSNoise will create the tables automatically upon running the installer script (see *Workflow* (page 13)).

1.1.5 Building this documentation

To build this documentation, some modules are required:

```
pip install sphinx
pip install sphinx_bootstrap_theme
```

Then, this should simply work:

```
make html
```

it will create a .build folder containing the documentation.

You can also build the doc to Latex and then use your favorite Latex-to-PDF tool.

1.1.6 Using the development version

This is not recommended, but users willing to test the latest development (hopefully stable) version of MSNoise can:

```
pip uninstall msnoise
pip install http://msnoise.org/master.zip
```

Please note this version most probably uses the very latest version of every package: Release versions of *numpy*, *scipy*, etc obtained from conda-forge and "master" version of *obspy*. The development version (master) of obspy can be installed from github:

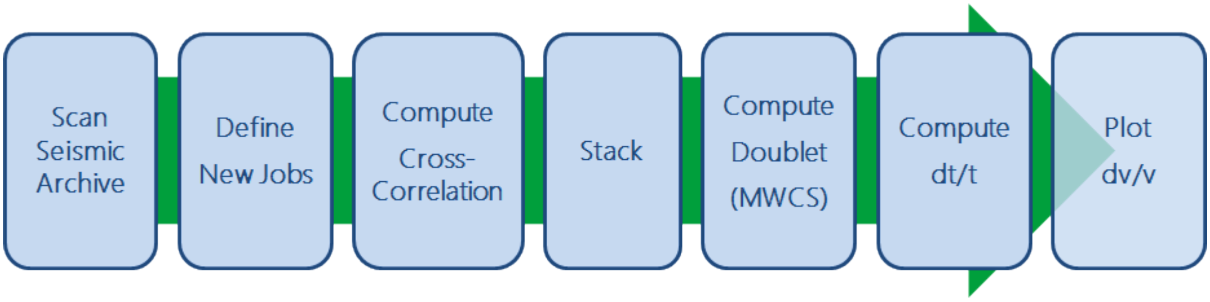
```
pip uninstall obspy
pip install https://github.com/obspy/obspy/archive/master.zip
```

If you are using the master version, please use the issue tracker of github to communicate about bugs and not the mailing list, preferably used for Releases.

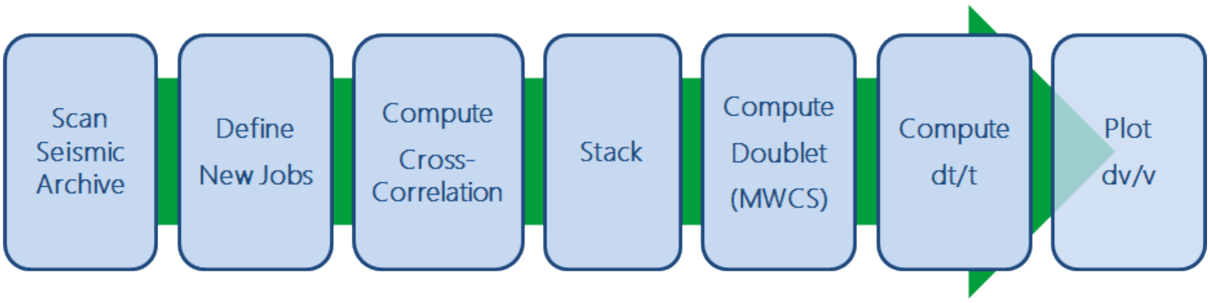
CHAPTER

TWO

WORKFLOW



2.1 Workflow



This section only presents the "init" and configuration of MSNoise (read "the first startup of MSNoise"), not the installation of the required software, which is described in *Installation* (page 3).

2.1.1 Initialize Project

This console script is responsible for asking questions about the database connection, to create the db.ini file and to create the tables in the database.

Questions are:

- What database technology do you want to use?
  - sqlite: this will create a file in the current folder and use it as DB
  - mysql: this will connect to a local or remote mysql server, additional information is then required:
    - hostname: of the mysql server, defaults to 127.0.0.1

* database: must already exist on *hostname*
* username: as registered in the privileged users of the mysql server
* password: his password
* prefix: useful when users have only access to a single database. Similar to the way wordpress handles prefixes. The tables will be named `%prefix%_config` (etc) instead of `config`, for example.

The SQLite choice will create a xxx.sqlite file in the current (project) folder, while, for MySQL, one has to create an empty database first on the mysql server, see *how to do this* (page 7) .

To run this script:

```
msnoise db init --help

Usage:  [OPTIONS]

  This command initializes the current folder to be a MSNoise Project by
  creating a database and a db.ini file.

Options:
  --tech TEXT  Database technology: 1=SQLite 2=MySQL
  --help       Show this message and exit.
```

> **Warning:** The credentials will be saved in a flat text file in the current directory. It's not very safe, but until now we haven't thought of another solution.

2.1.2 MSNoise Admin (Web Interface)

MSNoise Admin is a web interface that helps the user define the configuration for all the processing steps. It allows configuring the stations and filters to be used in the different steps of the workflow and provides a view on the database tables.

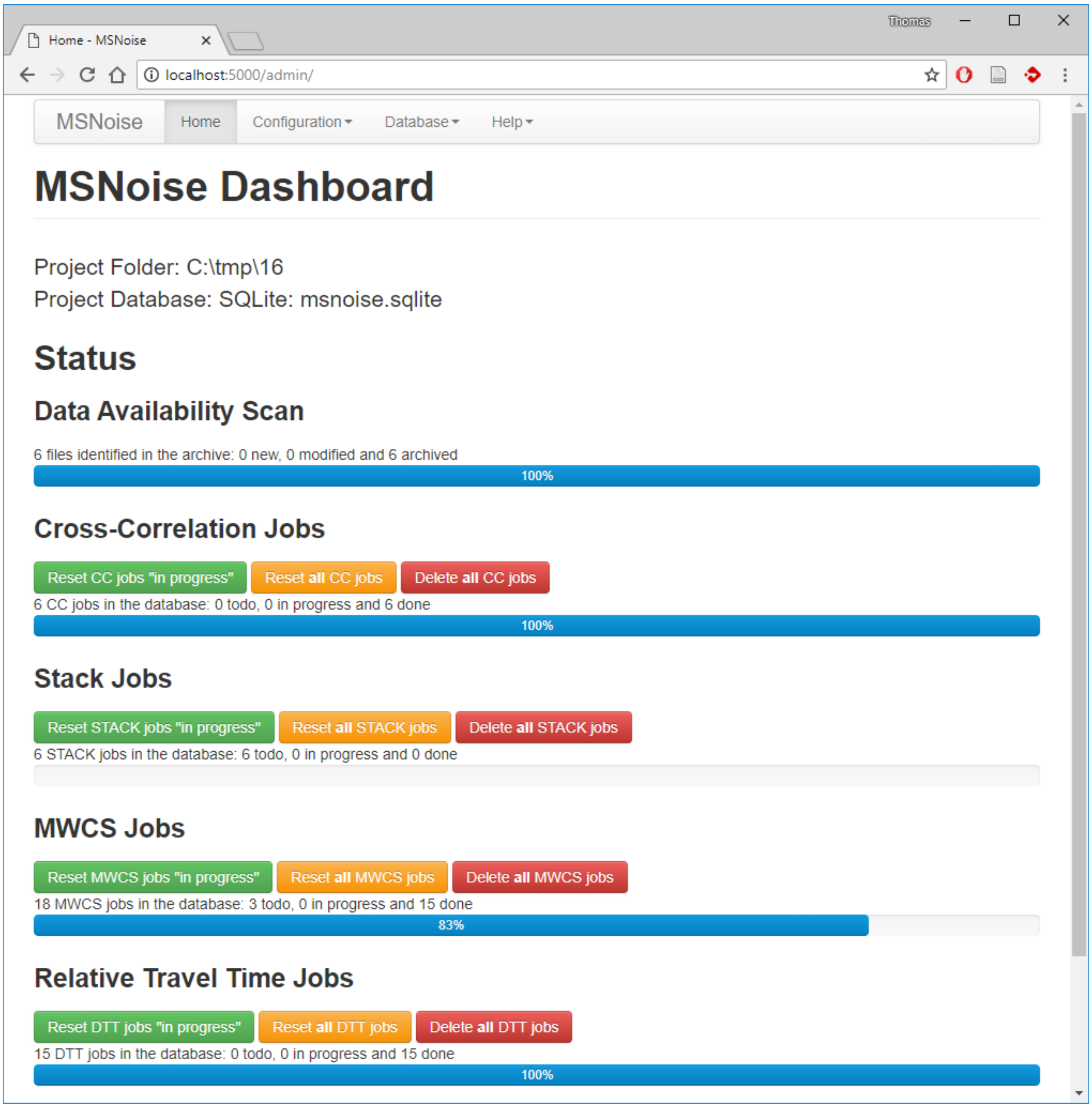
To start the admin:

```
$ msnoise admin
```

Which, by default, starts a web server listening on all interfaces on port 5000. This can be overridden by passing parameters to the command, e.g. for port 5099:

```
$ msnoise admin -p 5099
```

The next step consists of opening a web browser and open the ip address of the machine, by default on the current machine, it'll be http://localhost:5000/ or http://127.0.0.1:5000/.



The top level menu shows four items:

Home

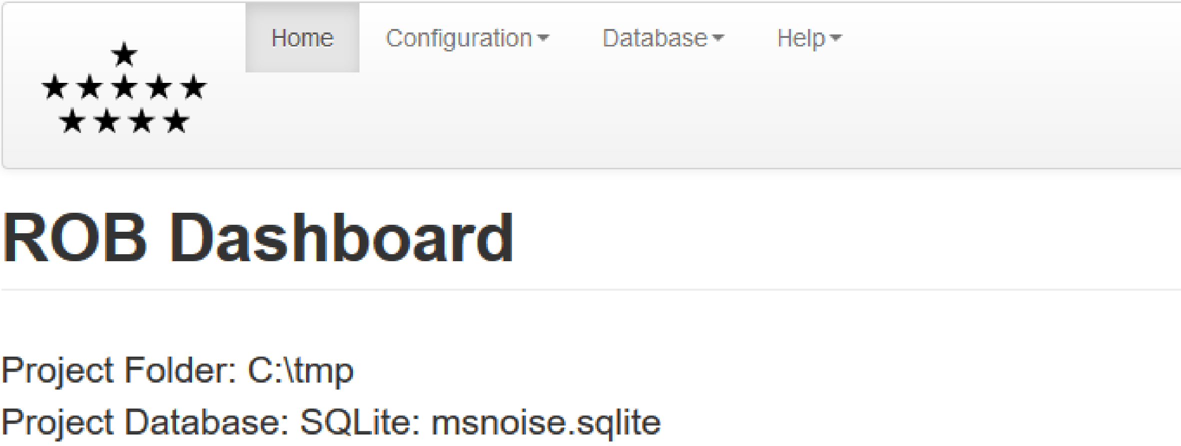
The index page shows

- The project location and its database
- Stats of the Data Availability, the CC, STACK, MWCS and DTT jobs.
- Quick action buttons for resetting or deleting jobs.

The name and the logo of the page can be overridden by setting an environment variable with a name and the HTML tag of the logo image:

```
set msnoise_brand="ROB|<img src='http://www.seismologie.be/img/oma/ROB-logo.svg' width=200 height=200>"
```

and then starting msnoise admin:



Configuration

Station

Stations appear as a table and are editable.

Stations are defined as:

`class msnoise.msnoise_admin.Station(*args)`
Station Object

Parameters

- `ref` (*int*) – The Station ID in the database
- `net` (*str*) – The network code of the Station
- `sta` (*str*) – The station code
- `X` (*float*) – The X coordinate of the station
- `Y` (*float*) – The Y coordinate of the station
- `altitude` (*float*) – The altitude of the station
- `coordinates` (*str*) – The coordinates system. "DEG" is WGS84 latitude/ longitude in degrees. "UTM" is expressed in meters.
- `instrument` (*str*) – The instrument code, useful with PAZ correction
- `used` (*bool*) – Whether this station must be used in the computations.

Attributes

X

Y

altitude

coordinates

instrument

net

ref

sta

used

Filter

Filters appear as a table and are editable. The filter parameters are validated before submission, so no errors should happen. Note: by default, the *used* parameter is set to *False*, **don't forget to change it!**

Filters are defined as:

class msnoise.msnoise_admin.Filter(***kwargs*)

Filter base class.

Parameters

- ref (*int*) – The id of the Filter in the database
- low (*float*) – The lower frequency bound of the Whiten function (in Hz)
- high (*float*) – The upper frequency bound of the Whiten function (in Hz)
- mwcs_low (*float*) – The lower frequency bound of the linear regression done in MWCS (in Hz)
- mwcs_high (*float*) – The upper frequency bound of the linear regression done in MWCS (in Hz)
- rms_threshold (*float*) – Not used anymore
- mwcs_wlen (*float*) – Window length (in seconds) to perform MWCS
- mwcs_step (*float*) – Step (in seconds) of the windowing procedure in MWCS
- used (*bool*) – Is the filter activated for the processing

Attributes

high

low

mwcs_high

mwcs_low

mwcs_step

mwcs_wlen

ref

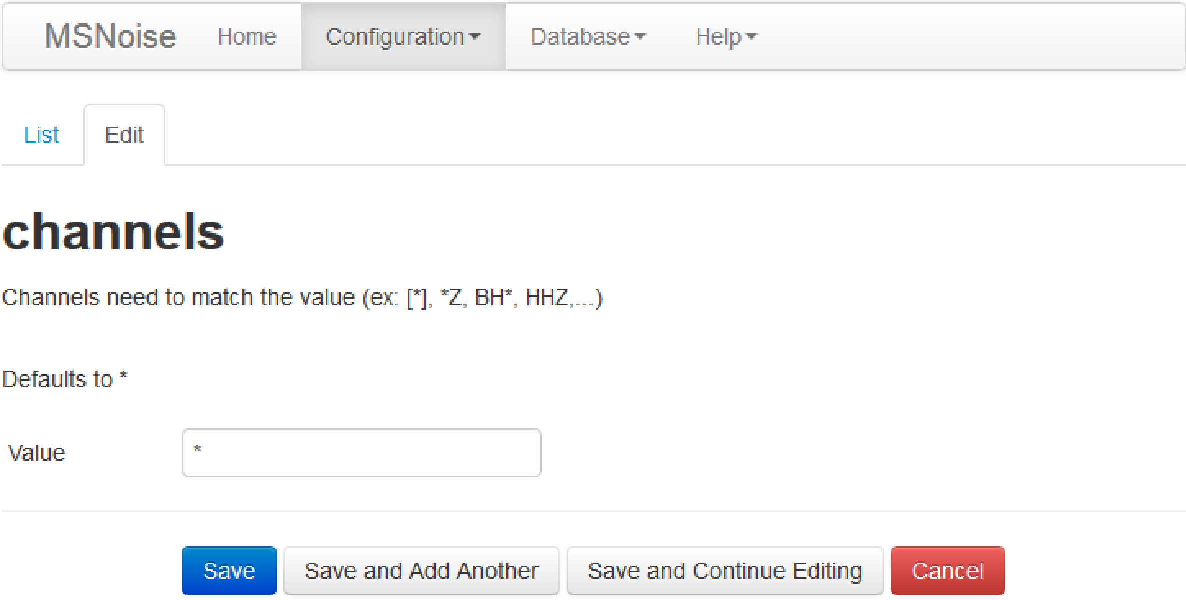
rms_threshold

used

Config

All configuration bits appear as a table and are editable. When editing one configuration item, the Edit tab shows extra information about the parameter, where it is used and its default value. Most of the configuration bits are case-sensitive!

Example view:



The table below lists the different fields:

Parameter Name	Description	Default Value
data_folder	Data Folder	
output_folder	CC Output Folder in case keep_all=Y, to store the individual windows. The daily CCF will always be stored in the STACKS/001_DAYS folder.	CROSS_CORRELATIONS
data_structure	Either a predefined acronym [SDS]/BUD/IDDS, or /-separated path (e.g. NET/STA/YEAR/NET.STA.YEAR.DAY.MSEED).	SDS
archive_format	Force format of archive files to read? Leave empty for slightly slower auto-detection by Obspy, or specify any format supported by obspy.core.stream.read.	
network	Network to analyse [*]	•

Continued on next page

Table 1 – continued from previous page

Parameter Name	Description	Default Value
channels	Channels need to match the value (ex: [*], *Z, BH*, HHZ,. . .)	•
startdate	Start Date to process: [1970-01-01]='since beginning of the archive'	1970-01-01
enddate	End Date to process: [2100-01-01]='No end'	2021-01-01
analysis_duration	Duration of the Analysis (total in seconds : 3600, [86400])	86400
cc_sampling_rate	Sampling Rate for the Cross-Correlation [20.0]	20.0
resampling_method	Resampling method Decimate/[Lanczos]	Lanczos
preprocess_lowpass	Preprocessing Low-pass value in Hz [8.0]	8.0
preprocess_highpass	Preprocessing High-pass value in Hz [0.01]	0.01
preprocess_max_gap	Preprocessing maximum gap length that will be filled by interpolation [10.0] seconds	10.0
preprocess_taper_length	Duration of the taper applied at the beginning and end of trace during the preprocessing, to allow highpassfiltering	20.0
remove_response	Remove instrument response Y/[N]	N
response_format	Remove instrument file format [dataless]/inventory/paz/resp	dataless
response_path	Instrument correction file(s) location (path relative to db.ini), defaults to './inventory', i.e. a subfolder in the current project folder. All files in that folder will be parsed.	inventory
response_prefilt	Remove instrument correction **pre-filter** (0.005, 0.006, 30.0, 35.0)	(0.005, 0.006, 30.0, 35.0)
maxlag	Maximum lag (in seconds) [120.0]	120.
corr_duration	Data windows to correlate (in seconds) [1800.]	1800.
overlap	Amount of overlap between data windows [0:1[[0.]	0.0

Continued on next page

Table 1 – continued from previous page

Parameter Name	Description	Default Value
windsorizing	Windsorizing at N time RMS , 0 disables windsorizing, -1 enables 1-bit normalization [3]	3
whitening	Whiten Traces before cross-correlation: [A]ll (except for autocorr), [N]one, or only if [C]omponents are different: [A]/N/C	A
whitening_type	Type of spectral whitening function to use: [B]rutal (amplitude to 1.0), divide spectrum by its [PSD]: [B]/PSD. WARNING: only works for compute_cc, not compute_cc_rot, where it will always be [B]	B
stack_method	Stack Method: Linear Mean or Phase Weighted Stack: [linear]/pws	linear
pws_timegate	If stack_method='pws', width of the smoothing in seconds : 10.0	10.0
pws_power	If stack_method='pws', Power of the Weighting: 2.0	2.0
crondays	Number of days to monitor with scan_archive, typically used in cron (should be a float representing a number of days, or a string designating weeks, days, and/or hours using the format 'Xw Xd Xh') [1]	1
components_to_compute	List (comma separated) of components to compute between two different stations [ZZ]	ZZ
cc_type	Cross-Correlation type [CC]	CC
components_to_compute_single_station	List (comma separated) of components within a single station. ZZ would be the autocorrelation of Z component, while ZE or ZN are the cross-components. Defaults to [], no single-station computations are done.	
cc_type_single_station_AC	Auto-Correlation type [CC]	CC

Continued on next page

Table 1 – continued from previous page

Parameter Name	Description	Default Value
cc_type_single_station_SC	Cross-Correlation type for Cross-Components [CC]	CC
autocorr	DEPRECATED, add the components to compute on single stations in the *components_to_compute_single_station* config parameter.	N
keep_all	Keep all cross-corr (length: corr_duration) [Y]/N	N
keep_days	Keep all daily cross-corr [Y]/N	Y
ref_begin	Beginning or REF stacks. Can be absolute (2012-01-01) or relative (-100) days	1970-01-01
ref_end	End or REF stacks. Same as ref_begin	2021-01-01
mov_stack	Number of days to stack for the Moving-window stacks ([5]= [day-4:day]), can be a comma-separated list 1,2,5,10	5
export_format	Export stacks in which format(s) ? SAC/MSEED/[BOTH]	MSEED
sac_format	Format for SAC stacks ? [doublets]/clarke	doublets
dtt_lag	How is the lag window defined [dynamic]/static	static
dtt_v	If dtt_lag=dynamic: what velocity to use to avoid ballistic waves [1.0]km/s	1.0
dtt_minlag	If dtt_lag=static: min lag time	5.0
dtt_width	Width of the time lag window [30]s	30.0
dtt_sides	Which sides to use [both]/left/right	both
dtt_mincoh	Minimum coherence on dt measurement, MWCS points with values lower than that will **not** be used in the WLS	0.65
dtt_maxerr	Maximum error on dt measurement, MWCS points with values larger than that will **not** be used in the WLS	0.1

Continued on next page

Table 1 – continued from previous page

Parameter Name	Description	Default Value
dtt_maxdt	Maximum dt values, MWCS points with values larger than that will **not** be used in the WLS	0.1
plugins	Comma separated list of plugin names. Plugins names should be importable Python modules.	
hpc	Is MSNoise going to run on an HPC? Y/[N]	N
stretching_max	Maximum stretching coefficient, e.g. 0.5 = 50%, 0.01 = 1%	0.01
stretching_nsteps	Number of stretching steps between 1-stretching_max and 1+stretching_max	1000

Database

Data Availability

Gives a view of the *data_availability* table. Allows to bulk edit/select rows. Its main goal is to check that the *scan_archive* procedure has successfully managed to list all files from one's archive.

Jobs

Gives a view of the *jobs* table. Allows to bulk edit/select rows. Its main goal is to check the *new_jobs* or any other workflow step (or Plugins) successfully inserted/updated jobs.

Help

About

Shows some links and information about the package. Mostly the information present on the github readme file.

Bug Report

Web view of the *msnoise bugreport -m*, allows viewing if all required python modules are properly installed and available for MSNoise.

2.1.3 Populate Station Table

This script is responsible for rapidly scanning the data archive, identifying the Networks/Stations and inserting them in the *stations* table in the database.

The `data_folder` (as defined in the config) is scanned following the `data_structure`. Possible values for the data_structure are defined in *data_structures.py*:

```
data_structure['SDS'] = "YEAR/NET/STA/CHAN.TYPE/NET.STA.LOC.CHAN.TYPE.YEAR.DAY"
data_structure['BUD'] = "NET/STA/STA.NET.LOC.CHAN.YEAR.DAY"
data_structure['IDDS'] = "YEAR/NET/STA/CHAN.TYPE/DAY/NET.STA.LOC.CHAN.TYPE.YEAR.DAY.
↪HOUR"
data_structure['PDF'] = "YEAR/STA/CHAN.TYPE/NET.STA.LOC.CHAN.TYPE.YEAR.DAY"
```

If your data structure corresponds to one of these 4 structures, you need to select the corresponding acronym (SDS, BUD, IDDS or PDF) for the data_structure field.

More info on the recommended SDS ("SeisComP Data Structure") can be found here: https://www.seiscomp3.org/wiki/doc/applications/slarchive/SDS For other simple structures, one has to edit the *data_structure* configuration (see below).

By default, station coordinates are initialized at 0.

To run this script:

```
$ msnoise populate
```

Custom data structure & station table population

If one's data structure does not belong to the pre-defined ones, it can be defined directly in the `data_structure` configuration field using forward slashes, e.g.:

`data_structure` = "NET/STA/YEAR/NET.STA.YEAR.DAY.MSEED"

MSNoise expects to find a file named `custom.py` in the current folder. This python file will contain a function called `populate` wich will accept one argument and return a station dictionary with keys of the format `NET_STA` , and fields for the stations table in the database: Net,Sta,X,Y,Altitude, Coordinates(UTM/DEG),Instrument.

```
import os, glob
def populate(data_folder):
    datalist = sorted(glob.glob(os.path.join(data_folder, "*", "*")))
    stationdict = {}
    for di in datalist:
        tmp = os.path.split(di)
        sta = tmp[1]
        net = os.path.split(tmp[0])[1]
        stationdict[net+"_"+sta]=[net,sta,0.0,0.0,0.0,'UTM','N/A']
    return stationdict
```

Expert (lazy) mode:

If the *DataAvailability* has already been filled in by another process, for example using the *"scan from path"* (page 24) procedure, the network/station names can be "populated" from the *DataAvailability* table automatically. To do this, simply run:

```
msnoise populate --fromDA
```

and MSNoise will insert the unique NET.STA in the *Stations* table.

2.1.4 Scan Archive

One advantage of MSNoise is its ability to be used as an automated monitoring tool. In order to run every night on the data acquired during the previous day, MSNoise needs to check the data archive for new or modified files.

Those files could have been acquired during the last day, but be data of a previously offline station and contain useful information for, say, a month ago. The time to search for is defined in the config from the 'crondays' value. For convenience, this parameter can be temporarily redefined on the command line using the *–crondays* option of the *scan_archive* sub-command. In both cases, it can be a float designating a number of days in the past, or a string designating a number of weeks, days, and/or hours in the format 'Xw Xd Xh' (each group being optional, as well as the separating blanks).

The scan_archive script inspects the modified time attribute ('mtime') of files in the archives to locate new or modified files. Once located, they are inserted (if new) or updated (if modified) in the data availability table.

To run the code on two Process, execute the following in console:

```
$ msnoise -t 2 scan_archive
```

Compulsory Special case: first run

This script is the same as for the routine, but one has to pass the –init option. The `scan_archive` will scan all files in the data folders, regardless of their modification time.

```
$ msnoise -t 2 scan_archive --init
```

This will scan the data_archive folder the configured stations and will insert all files found in the data_availability table in the database. As usual, calling the script with a –help argument will show its usage.

Expert (lazy) mode:

Sometimes, you only want to scan a few files and run MSNoise on them. To do this simply run:

```
$ msnoise scan_archive --path /path/to/where/files/are --init
```

and MSNoise will read anything ObsPy can (provided the files have a proper header (network code, station code and channel code). Then, once done, simply run the *"populate from DataAvailability"* (page 23) procedure.

This command can also scan folders recursively:

```
$ msnoise scan_archive --path /path/to/archive --recursively --init
```

2.1.5 New Jobs

This script searches the database for files flagged "N"ew or "M"odified. For each date in the configured range, it checks if other stations are available and defines the new jobs to be processed. Those are inserted in the *jobs* table of the database.

To run it from the console:

```
$ msnoise new_jobs
```

Upon first run, if you expect the number of jobs to be large (many days, many stations), pass the `--init` parameter to optimize the insert. Only use this flag once, otherwise problems will arise from duplicate entries in the jobs table.

```
$ msnoise new_jobs --init
```

Performance / running on HPC

By setting the `hpc` configuration parameter to `Y`, you will disable the automatic creation of jobs during the workflow, to avoid numerous interactions with the database (select & update or insert). The jobs have then to be inserted manually:

```
$ msnoise new_jobs --hpc CC:STACK
```

should be run after the `msnoise compute_cc` step in order to create the `STACK` jobs.

2.1.6 Compute Cross-Correlations

This code is responsible for the computation of the cross-correlation functions.

This script will group *jobs* marked "T"odo in the database by day and process them using the following scheme. As soon as one day is selected, the corresponding jobs are marked "I"n Progress in the database. This allows running several instances of this script in parallel.

As of MSNoise 1.6, the `compute` step has been completely rewritten:

- The `compute_cc` step has been completely rewritten to make use of 2D arrays holding the data, processing them "in place" for the different steps (FFT, whitening, etc). This results in much more efficient computation. The process slides on time windows and computes the correlations using indexes in a 2D array, therefore avoiding an exponential number of identical operations on data windows.
- This new code is the default `compute_cc`, and it doesn't allow computing rotated components. For users needing `R` or `T` components, there are two options: either use the old code, now named `compute_cc_rot`, or compute the full (6 components actually are enough) tensor using the new code, and rotate the components afterwards. From initial tests, this latter solution is a lot faster than the first, thanks to the new processing in 2D.
- It is now possible to do the Cross-Correlation (classic "CC"), the Auto- Correlation ("AC") or the Cross-Components within the same station ("SC"). To achieve this, we removed the *ZZ*, *ZT*, etc parameters from the configuration and replaced it with `components_to_compute` which takes a list: e.g. *ZZ,ZE,ZN,EZ,EE,EN,NZ,NE,NN* for the full non-rotated tensor between stations. Adding components to the new

`components_to_compute_single_station` will allow computing the cross-components (SC) or auto-correlation (AC) of each station.

- The cross-correlation is done on sliding windows on the available data. For each window, if one trace contains a gap, it is eliminated from the computation. This corrects previous errors linked with gaps synchronised in time that lead to perfect sinc autocorrelation functions. The windows should have a duration of at least "2 times the 'maxlag'+1" to be computable.

Configuration Parameters

The following parameters (modifiable via `` `msnoise admin` ``) are used for this step:

- `components_to_compute`: List (comma separated) of components to compute between two different stations [ZZ] (default=ZZ)
- `components_to_compute_single_station`: List (comma separated) of components within a single station. ZZ would be the autocorrelation of Z component, while ZE or ZN are the cross-components. Defaults to [], no single-station computations are done. (default=) | *new in 1.6*
- `cc_sampling_rate`: Sampling Rate for the CrossCorrelation [20.0] (default=20.0)
- `analysis_duration`: Duration of the Analysis (total in seconds : 3600, [86400]) (default=86400)
- `overlap`: Amount of overlap between data windows [0:1[[0.] (default=0.0)
- `maxlag`: Maximum lag (in seconds) [120.0] (default=120.)
- `corr_duration`: Data windows to correlate (in seconds) [1800.] (default=1800.)
- `windsorizing`: Windsorizing at N time RMS , 0 disables windsorizing, -1 enables 1-bit normalization [3] (default=3)
- `resampling_method`: Resampling method Decimate/[Lanczos] (default=Lanczos)
- `remove_response`: Remove instrument response Y/[N] (default=N)
- `response_format`: Remove instrument file format [dataless]/inventory/paz/resp (default=dataless)
- `response_path`: Instrument correction file(s) location (path relative to db.ini), defaults to './inventory', i.e. a subfolder in the current project folder. | All files in that folder will be parsed. (default=inventory)
- `response_prefilt`: Remove instrument correction **pre-filter** (0.005, 0.006, 30.0, 35.0) (default=(0.005, 0.006, 30.0, 35.0))
- `preprocess_lowpass`: Preprocessing Low-pass value in Hz [8.0] (default=8.0)
- `preprocess_highpass`: Preprocessing High-pass value in Hz [0.01] (default=0.01)
- `preprocess_max_gap`: Preprocessing maximum gap length that will be filled by interpolation [10.0] seconds (default=10.0) | *new in 1.6*
- `preprocess_taper_length`: Duration of the taper applied at the beginning and end of trace during the preprocessing, to allow highpassfiltering (default=20.0) | *new in 1.6*
- `keep_all`: Keep all cross-corr (length: corr_duration) [Y]/N (default=N)

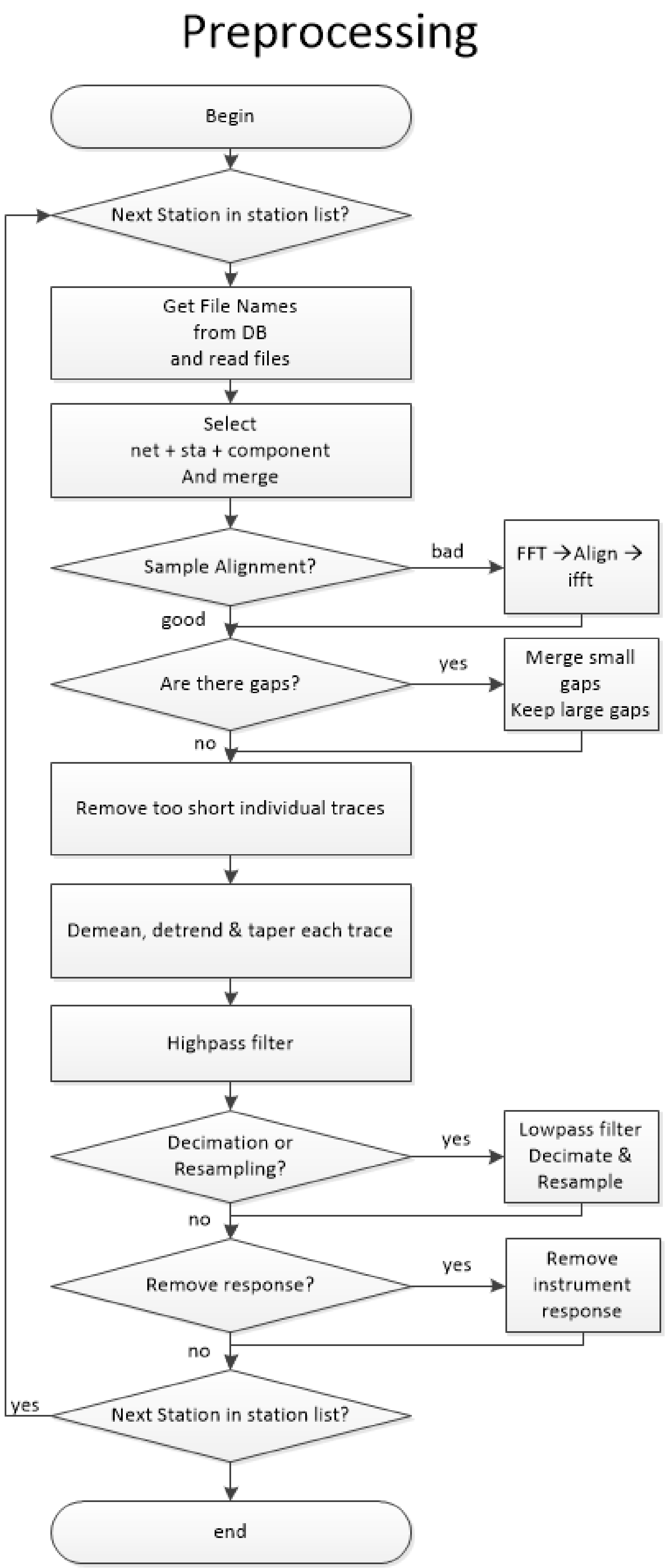
- `keep_days`: Keep all daily cross-corr [Y]/N (default=Y)
- `stack_method`: Stack Method: Linear Mean or Phase Weighted Stack: [linear]/pws (default=linear)
- `pws_timegate`: If stack_method='pws', width of the smoothing in seconds : 10.0 (default=10.0)
- `pws_power`: If stack_method='pws', Power of the Weighting: 2.0 (default=2.0)
- `whitening`: Whiten Traces before cross-correlation: [A]ll (except for autocorr), [N]one, or only if [C]omponents are different: [A]/N/C (default=A) | *new in 1.5*
- `whitening_type`: Type of spectral whitening function to use: [B]rutal (amplitude to 1.0), divide spectrum by its [PSD]: [B]/PSD. WARNING: only works for compute_cc, not compute_cc_rot, where it will always be [B] (default=B) | *new in 1.6*
- `hpc`: Is MSNoise going to run on an HPC? Y/[N] (default=N) | *new in 1.6*

Waveform Pre-processing

Pairs are first split and a station list is created. The database is then queried to get file paths. For each station, all files potentially containing data for the day are opened. The traces are then merged and split, to obtain the most continuous chunks possible. The different chunks are then demeaned, tapered and merged again to a 1-day long trace. If a chunk is not aligned on the sampling grid (that is, start at a integer times the sample spacing in s) , the chunk is phase-shifted in the frequency domain. This requires tapering and fft/ifft. If the gap between two chunks is small, compared to `preprocess_max_gap`, the gap is filled with interpolated values. Larger gaps will not be filled with interpolated values.

Each 1-day long trace is then high-passed (at `preprocess_highpass` Hz), then if needed, low-passed (at `preprocess_lowpass` Hz) and decimated/downsampled. Decimation/Downsampling are configurable (`resampling_method`) and users are advised testing Decimate. One advantage of Downsampling over Decimation is that it is able to downsample the data by any factor, not only integer factors. Downsampling is achieved with the ObsPy Lanczos resampler which we tested against the old scikits.samplerate.

If configured, each 1-day long trace is corrected for its instrument response. Currently, only dataless seed and inventory XML are supported.


Preprocessing
Begin
Next Station in station list?
Get File Names
from DB
and read files
Select
net + sta + component
And merge
Sample Alignment?
bad
FFT → Align →
ifft
good
Are there gaps?
yes
Merge small
gaps
Keep large gaps
no
Remove too short individual traces
Demean, detrend & taper each trace
Highpass filter
Decimation or
Resampling?
yes
Lowpass filter
Decimate &
Resample
no
Remove response?
yes
Remove
instrument
response
no
yes
Next Station in station list?
end

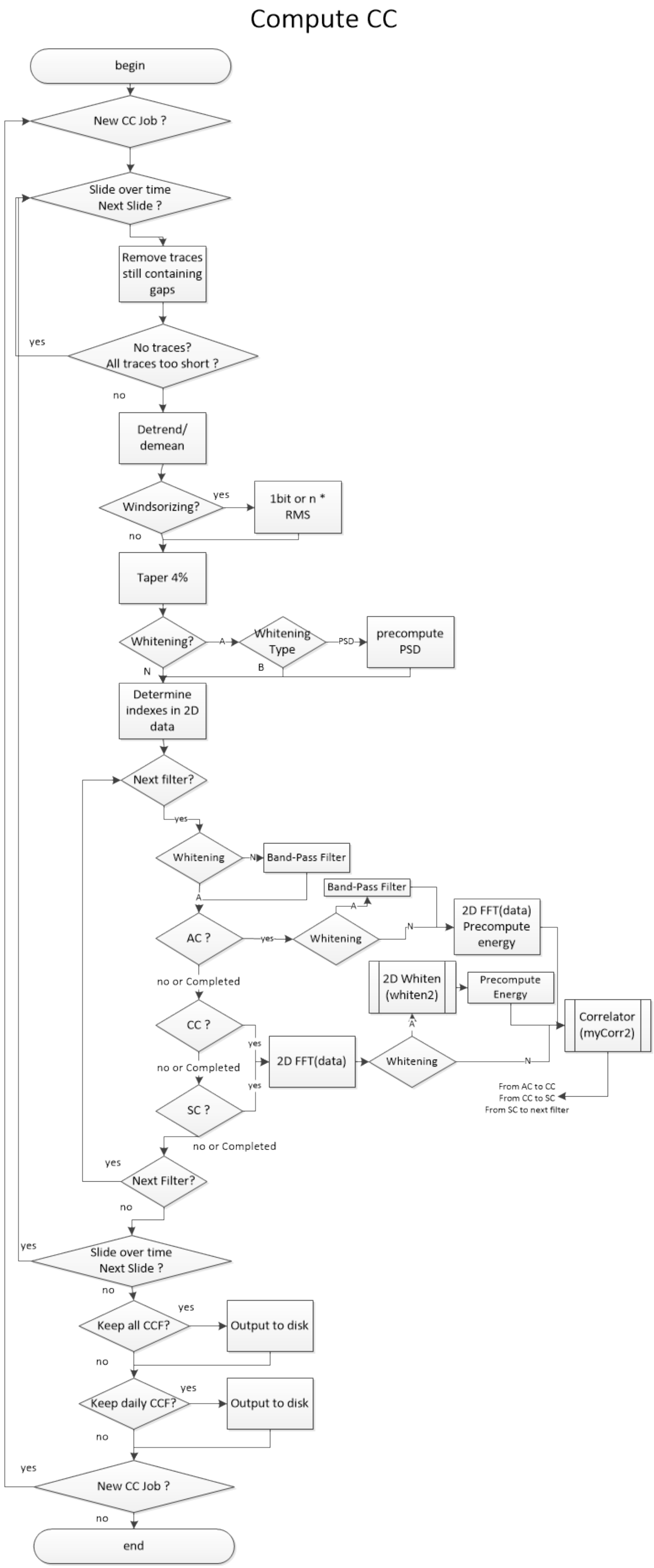
As from MSNoise 1.5, the preprocessing routine is separated from the compute_cc and can be used by plugins with their own parameters. The routine returns a Stream object containing all the traces for all the stations/components.

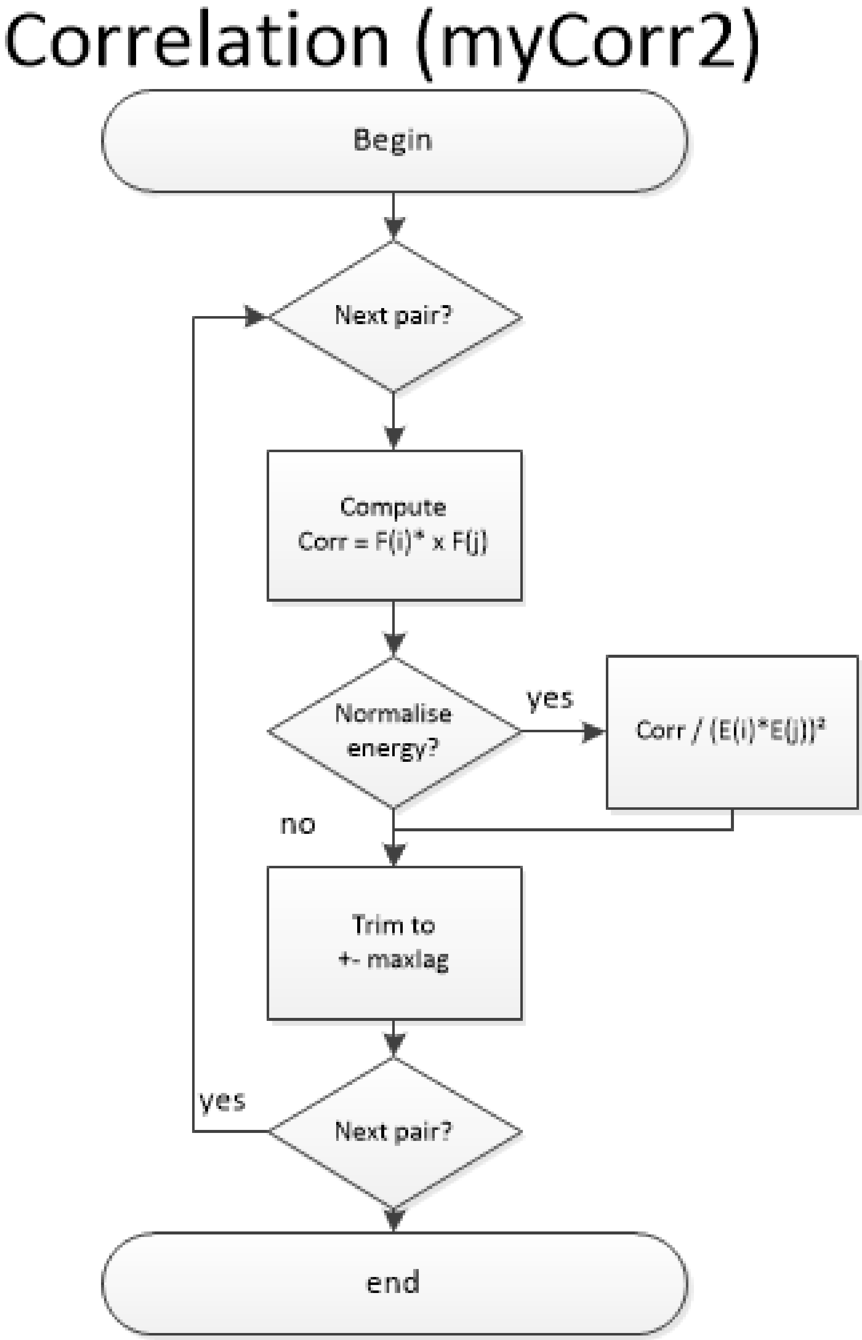
Computing the Cross-Correlations

Processing using `msnoise compute_cc`

Todo: We still need to describe the workflow in plain text, but the following graph should help you understand how the code is structured

---


Compute CC
begin
New CC Job ?
Slide over time
Next Slide ?
Remove traces still containing gaps
yes
No traces?
All traces too short ?
no
Detrend/ demean
yes
Windsorizing?
1bit or n * RMS
no
Taper 4%
Whitening?
A
Whitening Type
PSD
precompute PSD
N
B
Determine indexes in 2D data
Next filter?
yes
Whitening
N
Band-Pass Filter
A
Band-Pass Filter
A
AC ?
yes
Whitening
N
2D FFT(data) Precompute energy
no or Completed
2D Whiten (whiten2)
Precompute Energy
A
Correlator (myCorr2)
CC ?
yes
no or Completed
2D FFT(data)
Whitening
N
yes
From AC to CC
From CC to SC
From SC to next filter
SC ?
no or Completed
yes
Next Filter?
no
yes
Slide over time
Next Slide ?
no
yes
Keep all CCF?
Output to disk
no
yes
Keep daily CCF?
Output to disk
no
yes
New CC Job ?
no
end



Processing using `msnoise compute_cc_rot`

Once all traces are preprocessed, station pairs are processed sequentially. If a component different from *ZZ* is to be computed, the traces are first rotated. This supposes the user has provided the station coordinates in the *station* table. The rotation is computed for Radial and Transverse components.

Then, for each `corr_duration` window in the signal, and for each filter configured in the database, the traces are clipped to `windsorizing` times the RMS (or 1-bit converted) and then whitened in the frequency domain (see whiten) between the frequency bounds. The whitening procedure can be skipped by setting the `whitening` configuration to *None*. The two other `whitening` modes are "[A]ll except for auto-correlation" or "Only if [C]omponents are different". This allows skipping the whitening when, for example, computing ZZ components for very close by stations (much closer than the wavelength sampled), leading to spatial autocorrelation issues.

When both traces are ready, the cross-correlation function is computed (see mycorr). The function returned contains data for time lags corresponding to `maxlag` in the acausal (negative lags) and causal (positive lags) parts.

Saving Results (stacking the daily correlations)

If configured (setting `keep_all` to 'Y'), each `corr_duration` CCF is saved to the hard disk in the `output_folder`. By default, the `keep_days` setting is set to True and so "N = 1 day / corr_duration" CCF are stacked to produce a daily cross-correlation function, which is saved to the hard disk in the `STACKS/001_DAYS` folder.

Note: Currently, the keep-all data (every CCF) are not used by next steps.

If `stack_method` is 'linear', then a simple mean CCF of all windows is saved as the daily CCF. On the other hand, if `stack_method` is 'pws', then all the Phase Weighted Stack (PWS) is computed and saved as the daily CCF. The PWS is done in two steps: first the mean coherence between the instataneous phases of all windows is calculated, and eventually serves a weighting factor on the mean. The smoothness of this weighting array is defined using the `pws_timegate` parameter in the configuration. The weighting array is the power of the mean coherence array. If `pws_power` is equal to 0, a linear stack is done (then it's faster to do set `stack_method` = 'linear'). Usual value is 2.

Warning: PWS is largely untested, not cross-validated. It looks good, but that doesn't mean a lot, does it? Use with Caution! And if you cross-validate it, please let us know!!

Schimmel, M. and Paulssen H., "Noise reduction and detection of weak, coherent signals through phase-weighted stacks". Geophysical Journal International 130, 2 (1997): 497-505.

Once done, each job is marked "D"one in the database.

Usage

To run this script:

```
$ msnoise compute_cc
```

This step also supports parallel processing/threading:

```
$ msnoise -t 4 compute_cc
```

will start 4 instances of the code (after 1 second delay to avoid database conflicts). This works both with SQLite and MySQL but be aware problems could occur with SQLite.

New in version 1.4: The Instrument Response removal & The Phase Weighted Stack & Parallel Processing

New in version 1.5: The Obspy Lanczos resampling method, gives similar results as the scikits.samplerate package, thus removing the requirement for it. This method is defined by default.

New in version 1.5: The preprocessing routine is separated from the compute_cc and can be called by external plugins.

New in version 1.6: The compute_cc has been completely rewritten to be much faster, taking advantage from 2D FFT computation and in-place array modifications. The standard compute_cc does process CC, AC and SC in the same code. Only if users need to compute R and/or T components, they will have to use the slower previous code, now called `compute_cc_rot`.

2.1.7 Stack

MSNoise is capable of using a reference function defined by absolute or relative dates span. For example, an absolute range could be “from 1 January 2010 to 31 December 2011” and a relative range could be “the last 200 days”. In the latter case, the REF will need to be exported at every run, meaning the following steps (MWCS and DTT) will be executed on the whole configured period. If the REF is defined between absolute dates, excluding “today”, the MWCS and DTT will only be calculated for new data (e.g. “yesterday” and “today”). The corresponding configuration bits are `ref_begin` and `ref_end`. In the future, we plan on allowing multiple references to be defined.

Only data for new/modified dates need to be exported. If any CC-job has been marked “Done” within the last day and triggered the creation of STACK jobs, the stacks will be calculated and a new MWCS job will be inserted in the database. For dates in the period of interest, the moving-window stack will only be exported if new/modified CCF is available. The export directory are “REF/” and “DAY%03i/” where %03i will be replaced by the number of days stacked together (DAYS_005 for a 5-days stack, e.g.).

Please note that within MSNoise, stacks are always *inclusive* of the time/day mentioned. For example, a 5-days stack on January 10, will contain cross-correlation functions computed for January 6, 7, 8, 9 AND 10! The graphical representation centered on a “January 10” tick might then display changes in the CCF that occurred *on* the 10th !

Moving-window stacks are configured using the `mov_stack` parameter in `msnoise admin`.

If `stack_method` is ‘linear’, then a simple mean CFF of all daily is saved as the mov or ref CCF. On the other hand, if `stack_method` is ‘pws’, then all the Phase Weighted Stack (PWS) is computed and saved as the mov or ref CCF. The PWS is done in two steps: first the mean coherence between the instantaneous phases of all windows is calculated, and eventually serves a weighting factor on the mean. The smoothness of this weighting array is defined using the `pws_timegate` parameter in the configuration. The weighting array is the power of the mean coherence array. If `pws_power` is equal to 0, a linear stack is done (then it’s faster to do set `stack_method` = ‘linear’). Usual value is 2.

Warning: PWS is largely untested, not cross-validated. It looks good, but that doesn’t mean a lot, does it? Use with Caution! And if you cross-validate it, please let us know!!

Schimmel, M. and Paulssen H., “Noise reduction and detection of weak, coherent signals through phase-weighted stacks”. Geophysical Journal International 130, 2 (1997): 497-505.

Configuration Parameters

- `ref_begin`: Beginning or REF stacks. Can be absolute (2012-01-01) or relative (-100) days (default=1970-01-01)
- `ref_end`: End or REF stacks. Same as ref_begin (default=2021-01-01)
- `mov_stack`: Number of days to stack for the Moving-window stacks ([5]= [day-4:day]), can be a comma-separated list 1,2,5,10 (default=5)
- `stack_method`: Stack Method: Linear Mean or Phase Weighted Stack: [linear]/pws (default=linear) | *new in 1.4*
- `pws_timegate`: If stack_method='pws', width of the smoothing in seconds : 10.0 (default=10.0) | *new in 1.4*
- `pws_power`: If stack_method='pws', Power of the Weighting: 2.0 (default=2.0) | *new in 1.4*
- `hpc`: Is MSNoise going to run on an HPC? Y/[N] (default=N) | *new in 1.6*

Once done, each job is marked "D"one in the database and, unless `hpc` is `Y`, MWCS jobs are inserted/updated in the database.

Usage:

```
msnoise stack --help

Usage:  [OPTIONS]

  Stacks the [REF] or [MOV] windows. Computes the STACK jobs.

Options:
  -r, --ref    Compute the REF Stack
  -m, --mov    Compute the MOV Stacks
  -s, --step   Compute the STEP Stacks
  --help       Show this message and exit.
```

For most users, the REF stack will need to be computed only once for specific dates and then, on routine basis, only compute the MOV stacks:

```
$ msnoise stack -r
$ msnoise reset STACK
$ msnoise stack -m
```

as for all other steps, this procedure can be run in parallel:

```
$ msnoise -t 4 stack -r
$ msnoise reset STACK
$ msnoise -t 4 stack -m
```

New in version 1.4: The Phase Weighted Stack.

New in version 1.6: The `hpc` parameter that can prevent the automatic creation of MWCS jobs. The REF and MOV stacks have been separated and need to be run independently.

2.1.8 Compute MWCS

> **Warning:** if using only `mov_stack` = 1, no MWCS jobs is inserted in the database and consequently, no MWCS calculation will be done! FIX!

Following Clarke et al (2011), we apply the mwcs to study the relative dephasing between Moving-Window stacks ("Current") and a Reference using Moving-Window Cross-Spectral analysis. The *jobs* "T"o do have been inserted in the datavase during the stack procedure.

Filter Configuration Parameters

- `mwcs_low`: The lower frequency bound of the linear regression done in MWCS (in Hz)
- `mwcs_high`: The upper frequency bound of the linear regression done in MWCS (in Hz)
- `mwcs_wlen`: Window length (in seconds) to perform MWCS
- `mwcs_step`: Step (in seconds) of the windowing procedure in MWCS
- `hpc`: Is MSNoise going to run on an HPC? Y/[N] (default=N) | *new in 1.6*

In short, both time series are sliced in several overlapping windows and preprocessed. The similarity of the two time-series is assessed using the cross-coherence between energy densities in the frequency domain. The time delay between the two cross correlations is found in the unwrapped phase of the cross spectrum and is linearly proportional to frequency. This "Delay" for each window between two signals is the slope of a weighted linear regression (WLS) of the samples within the frequency band of interest.

For each filter, the frequency band can be configured using `mwcs_low` and `mwcs_high`, and the window and overlap lengths using `mwcs_wlen` and `mwcs_step`.

The output of this process is a table of delays measured at each window in the functions. The following is an example for lag times between -115 and -90. In this case, the window length was 10 seconds with an overlap of 5 seconds.

```
      LAG_TIME          DELAY           ERROR         MEAN COHERENCE
-1.1500000000e+02 -1.4781146383e-01 5.3727119135e-02 2.7585243911e-01
-1.1000000000e+02 -6.8207526992e-02 2.0546644311e-02 3.1620999352e-01
-1.0500000000e+02 -1.0337029577e-01 8.6645155402e-03 4.2439269880e-01
-1.0000000000e+02 -2.8668775696e-02 6.2522215988e-03 5.7159849528e-01
-9.5000000000e+01  4.1803941008e-02 1.5102285789e-02 4.1238557789e-01
-9.0000000000e+01  4.8139400233e-02 3.2700657018e-02 3.0586187792e-01
```

This process is job-based, so it is possible to run several instances in parallel.

Once done, each job is marked "D"one in the database and, unless `hpc` is `Y`, DTT jobs are inserted/updated in the database.

To run this step:

```
$ msnoise compute_mwcs
```

This step also supports parallel processing/threading:

```
$ msnoise -t 4 compute_mwcs
```

will start 4 instances of the code (after 1 second delay to avoid database conflicts). This works both with SQLite and MySQL but be aware problems could occur with SQLite.

New in version 1.4: Parallel Processing

2.1.9 Compute dt/t

This code is responsible for the calculation of dt/t using the result of the MWCS calculations.

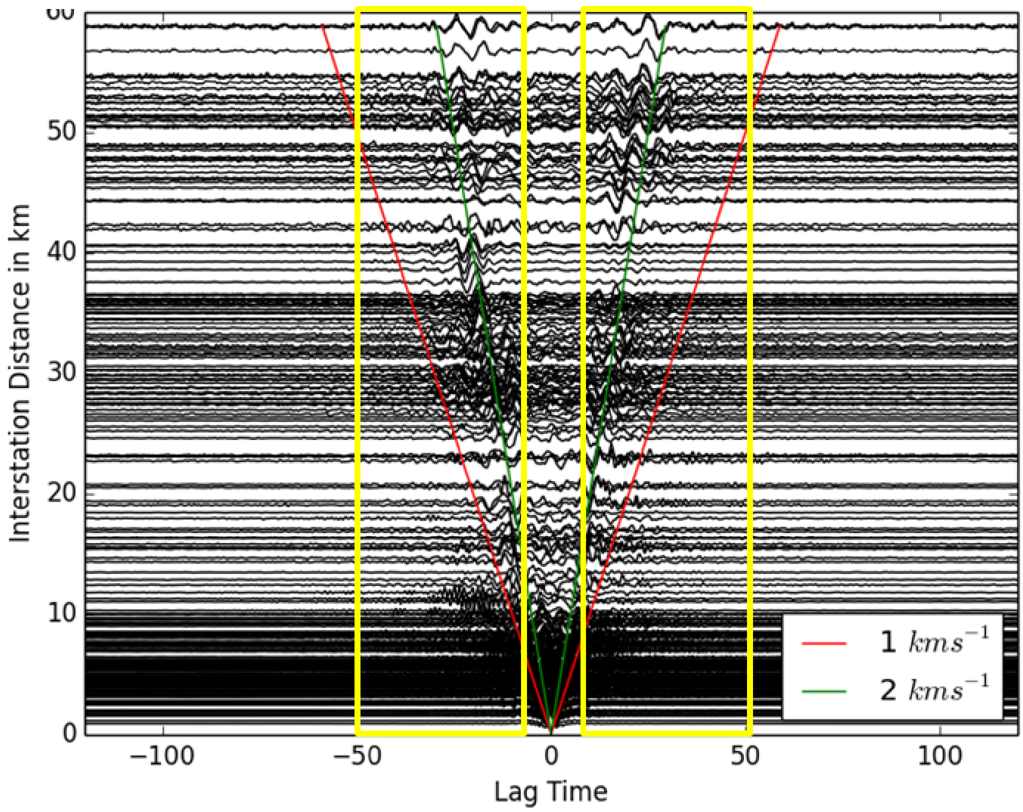
Configuration Parameters

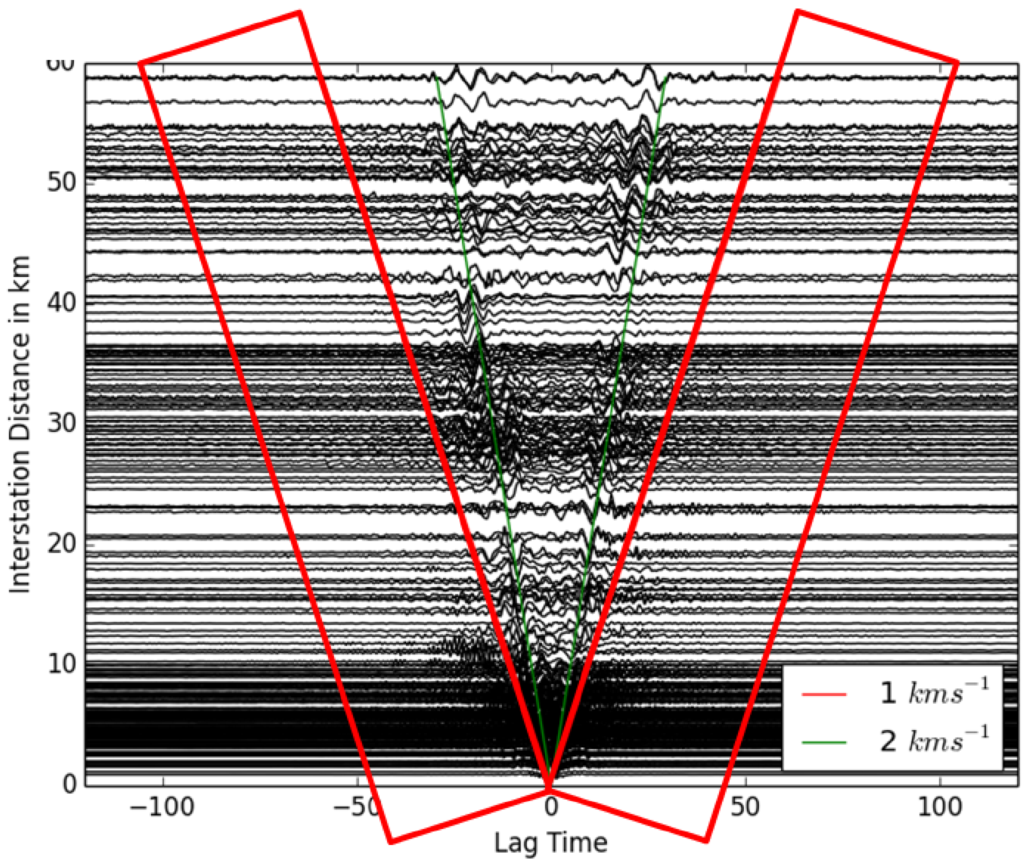
- `dtt_lag`: How is the lag window defined [dynamic]/static (default=static)
- `dtt_v`: If dtt_lag=dynamic: what velocity to use to avoid ballistic waves [1.0]km/s (default=1.0)
- `dtt_minlag`: If dtt_lag=static: min lag time (default=5.0)
- `dtt_width`: Width of the time lag window [30]s (default=30.0)
- `dtt_sides`: Which sides to use [both]/left/right (default=both)
- `dtt_mincoh`: Minimum coherence on dt measurement, MWCS points with values lower than that will **not** be used in the WLS (default=0.65)
- `dtt_maxerr`: Maximum error on dt measurement, MWCS points with values larger than that will **not** be used in the WLS (default=0.1)
- `dtt_maxdt`: Maximum dt values, MWCS points with values larger than that will **not** be used in the WLS (default=0.1)

The dt/t is determined as the slope of the delays vs time lags. The slope is calculated a weighted linear regression (WLS) through selected points.

1. The selection of points is first based on the time lag criteria. The minimum time lag can either be defined absolutely or dynamically. When `dtt_lag` is set to "dynamic" in the database, the inter-station distance is used to determine the minimum time lag. This lag is calculated from the distance and a velocity configured (`dtt_v`). The velocity is determined by the user so that the minlag doesn't include the ballistic waves. For example, if ballistic waves are visible with a velocity of 2 km/s, one could configure dtt_v=1.0. This way, if stations are located 15 km apart, the minimum lag time will be set to 15 s. The `dtt_width` determines the width of the lag window used. A value of 30.0 means the process will use time lags between 15 and 45 s in the example above, on both sides if configured (`dtt_sides`), or only causal or acausal parts of the CCF. The following figure shows the static time lags of `dtt_width` = 40s starting at `dtt_minlag` = 10s and the dynamic time lags for a `dtt_v` = 1.0 km/s for the Piton de La Fournaise network (including stations *not* on the volcano),

Note: It seems obvious that these parameters are frequency-dependent, but they are currently common for all filters !

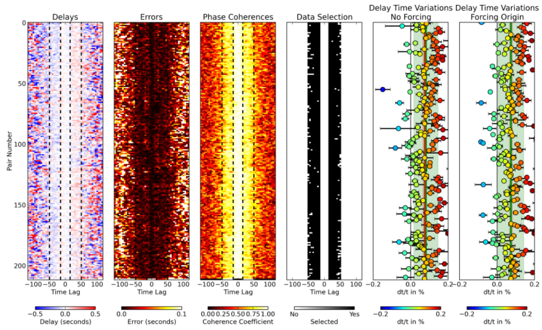




Warning: In order to use the dynamic time lags, one has to provide the station coordinates

!

2. Using example values above, we chose to use only 15-45 s coda part of the signal, neglecting direct waves in the 0-15 seconds range. We then select data which match three other thresholds: `dtt_mincoh`, `dtt_maxerr` and `dtt_maxdt`.



Each of the 4 left subplot of this figure shows a colormapper matrix of which each row corresponds to the data of 1 station pair and each column corresponds to different time lags. The cells are then colored using, from left to right: Delays, Errors, Phase Coherence and Data Selection.

Once data (cells) have been selected, they are analyzed two times: first using a WLS that is forced to pass the origin (0,0) and second when a constant is added to allow for the WLS to be offset from the origin. For each value, the error is computed and stored. M0 and EM0 are the slope and its error for the first WLS, and M, EM together with A and EA are the slope, its error, the constant and its error for the second WLS. The output of this calculation is a table, with one row for each station pair.

```
Date,          A,        EA,        EM,       EM0,          M,         M0,       Pairs
2013-01-06,-0.1683728,0.0526606,0.00208377,0.00096521, 0.00682021, 0.00037757,BE_GES_
↪BE_HOU
2013-01-06,-0.0080464,0.0577936,0.00291327,0.00097298,-0.00226910,-0.00264354,BE_GES_
↪BE_MEM
2013-01-06, 0.1007472,0.0144648,0.00179566,0.00454172,-0.00145738, 0.00741478,BE_GES_
↪BE_RCHB
2013-01-06,-0.0556811,0.0098926,0.00057839,0.00108102,-0.00328965,-0.00136075,BE_GES_
↪BE_SKQ
2013-01-06, 0.0150866,0.0202243,0.00096543,0.00089832, 0.00083714, 0.00104507,BE_GES_
↪BE_STI
2013-01-06, 0.0268309,0.0328997,0.00153137,0.00150261, 0.00302331, 0.00302451,BE_GES_
↪BE_UCC
2013-01-06,-0.0121293,0.0043351,0.00039019,0.00041347, 0.00025836,-0.00042709,BE_HOU_
↪BE_MEM
2013-01-06, 0.1076247,0.0188662,0.00076824,0.00216383,-0.00030791, 0.00112692,BE_HOU_
↪BE_RCHB
2013-01-06,-0.0468485,0.0194492,0.00069968,0.00078207,-0.00066133, 0.00027102,BE_HOU_
↪BE_SKQ
2013-01-06, 0.0203057,0.0161316,0.00131522,0.00131182, 0.00051626,-3.10306611,BE_HOU_
↪BE_STI
...
2013-01-06,-0.0022588,0.0037141,0.00010340,9.1996e-05, 0.00073635, 0.00076238,ALL
```

To run this script:

```
msnoise compute_dtt
```

Grouping Station Pairs

Although not clearly visible on the figure above, the very last row of the matrix doesn't contain information about one station pair, but contains a weighted mean of all delays (from all pairs) for each time lag. For each time lag, delays from each pair is taken into account if it satisfies the same criteria as for the individual data selection. Once the last row (the ALL line) has been calculated, it goes through the normal process of the double WLS and is saved to the output file, as visible above. In the future, MSNoise will be able to treat as many groups as the user want, allowing, e.g. a "crater" and a "slopes" groups.

Forcing vs No Forcing through Origin

The reason for allowing the WLS to cross the axis elsewhere than on (0,0) is, for example, to study the potential clock drifts or noise source position variations. By default, the `msnoise plot dvv` plot shows the results of the `` `Not Forced `` WLS.

Mean of All Pairs vs Mean Pair

> **Warning:** the `ALL` pair is still calculated and output in the DTT files, but its output is no longer displayed on the graphs. *new in 1.6.*

The dt/t calculated using the mean pair (ALL, in red on subplots 4 and 5) and by calculating the weighted mean of the dt/t of all pairs (in green) don't show a significant difference. The standard deviation around the latter is more spread than on the former, but this has to be investigated.

CHAPTER

THREE

PLOTTING

3.1 Plotting

MSNoise comes with some default plotting tools.

All plotting commands accept the `--outfile` argument. If provided, the figure will be saved to the disk. Names can be explicit, or tell the code to generate the filename automatically (using the *?* question mark), for example:

```
# automatic naming, save to PNG
msnoise plot dvv -o ?.png

# automatic naming, save to PDF
msnoise plot dvv -o ?.pdf

# explicit naming, save to JPG
msnoise plot dvv -o mydvv.jpg
```


3.1.1 Customizing Plots

All plots commands can be overridden using a *-c* argument *in front of the plot command* !!

Examples:

- `msnoise -c plot distance`
- `msnoise -c plot ccftime YA.UV02 YA.UV06 -m 5`
- etc.

To make this work, one has to copy the plot script from the msnoise install directory to the project directory (where your db.ini file is located, then edit it to one's desires. The first thing to edit in the code is the import of the *MSNoise API* (page 66):

`from ..api import *`

to

`from msnoise.api import *`

and it should work.

New in version 1.4.

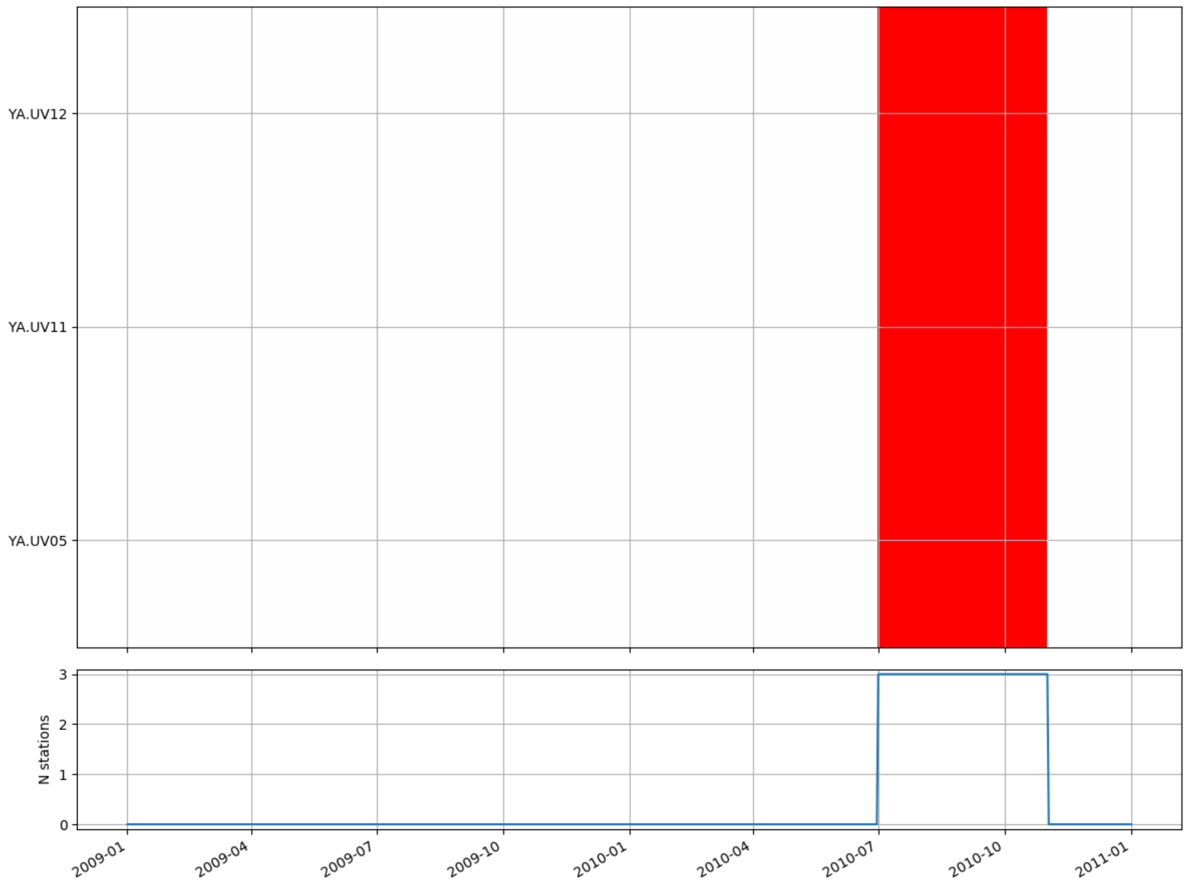
3.1.2 Data Availability Plot

Plots the data availability, as contained in the database. Every day which has a least some data will be coloured in red. Days with no data remain blank.

```
msnoise plot data_availability --help

Usage:  [OPTIONS]

  Plots the Data Availability vs time

Options:
  -s, --show BOOLEAN  Show interactively?
  -o, --outfile TEXT  Output filename (?=auto)
  --help              Show this message and exit.
```

Example:

`msnoise plot data_availability :`



3.1.3 Station Map

3.1.4 Interferogram Plot

This plot shows the cross-correlation functions (CCF) vs time in a very similar manner as on the *ccftime* plot above, but shows an image instead of wiggles. The parameters allow to plot the daily or the mov-stacked CCF. Filters and components are selectable too. Passing `--refilter` allows to bandpass filter CCFs before plotting (new in 1.5).

```
msnoise plot interferogram --help

Usage:  [OPTIONS] STA1 STA2 [EXTRA_ARGS]...

  Plots the interferogram between sta1 and sta2 (parses the CCFs)

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  -r, --refilter TEXT      Refilter CCFs before plotting (e.g. 4:8 for
                           filtering CCFs between 4.0 and 8.0 Hz. This will
```

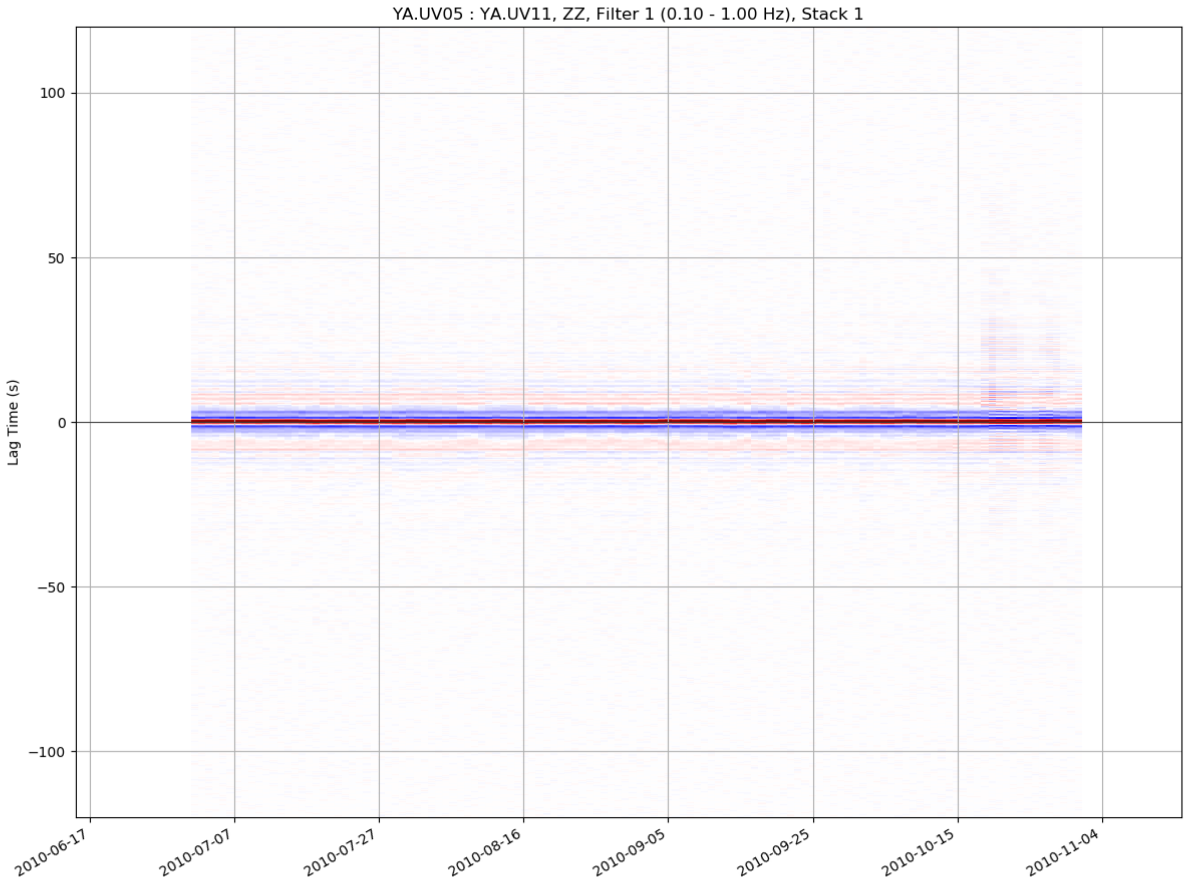
(continues on next page)

(continued from previous page)

```
                        update the plot title.
  --help                Show this message and exit.
```

Example:

`msnoise plot interferogram YA.UV06 YA.UV11 -m5` will plot the ZZ component (default), filter 1 (default) and mov_stack 5:



3.1.5 CCF vs Time

This plot shows the cross-correlation functions (CCF) vs time. The parameters allow to plot the daily or the mov-stacked CCF. Filters and components are selectable too. The `--ampli` argument allows to increase the vertical scale of the CCFs. The `--seismic` shows the up-going wiggles with a black-filled background (very heavy !). Passing `--refilter` allows to bandpass filter CCFs before plotting (new in 1.5).

```
msnoise plot ccftime --help

Usage:  [OPTIONS] STA1 STA2 [EXTRA_ARGS]...

  Plots the ccf vs time between sta1 and sta2

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
```

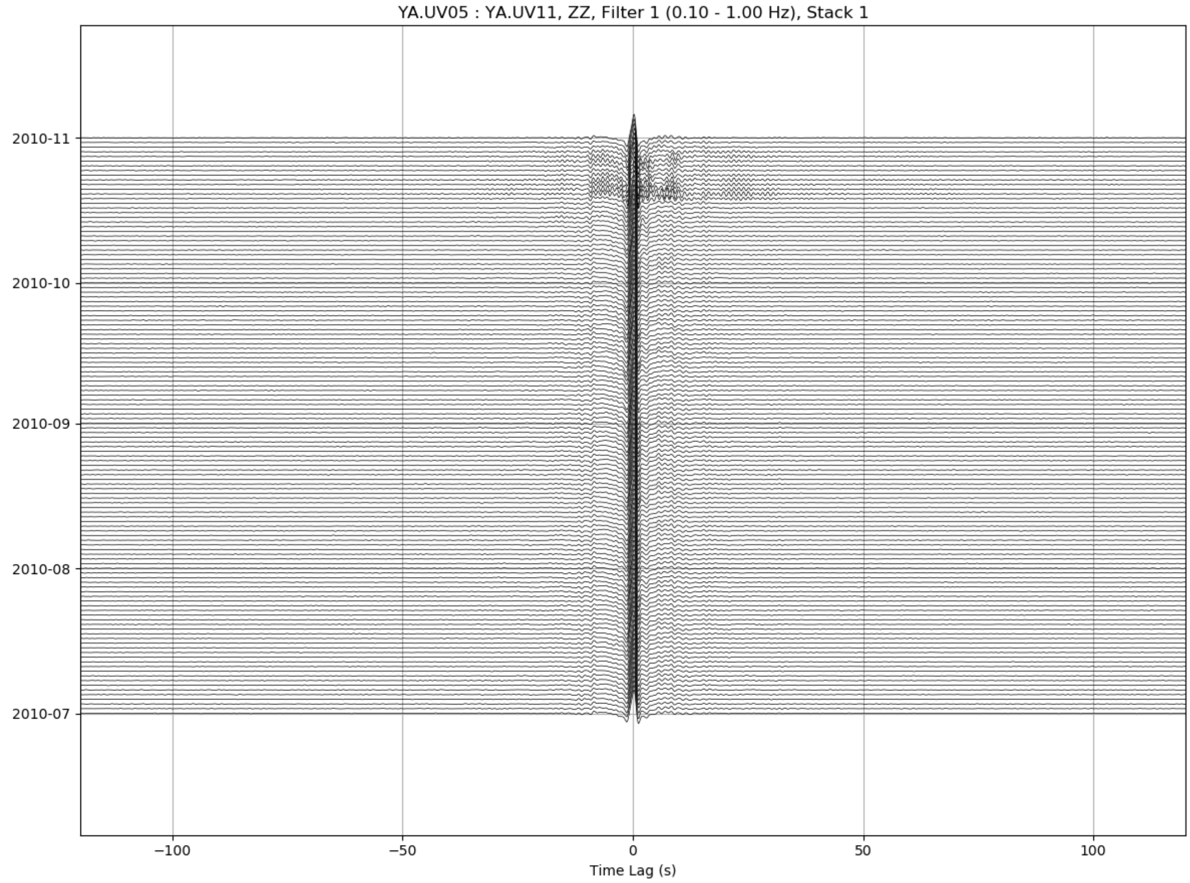
(continues on next page)

(continued from previous page)

```
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -a, --ampli FLOAT        Amplification
  -S, --seismic            Seismic style
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  -e, --envelope           Plot envelope instead of time series
  -r, --refilter TEXT      Refilter CCFs before plotting (e.g. 4:8 for
                           filtering CCFs between 4.0 and 8.0 Hz. This will
                           update the plot title.
  --normalize TEXT
  --help                   Show this message and exit.
```

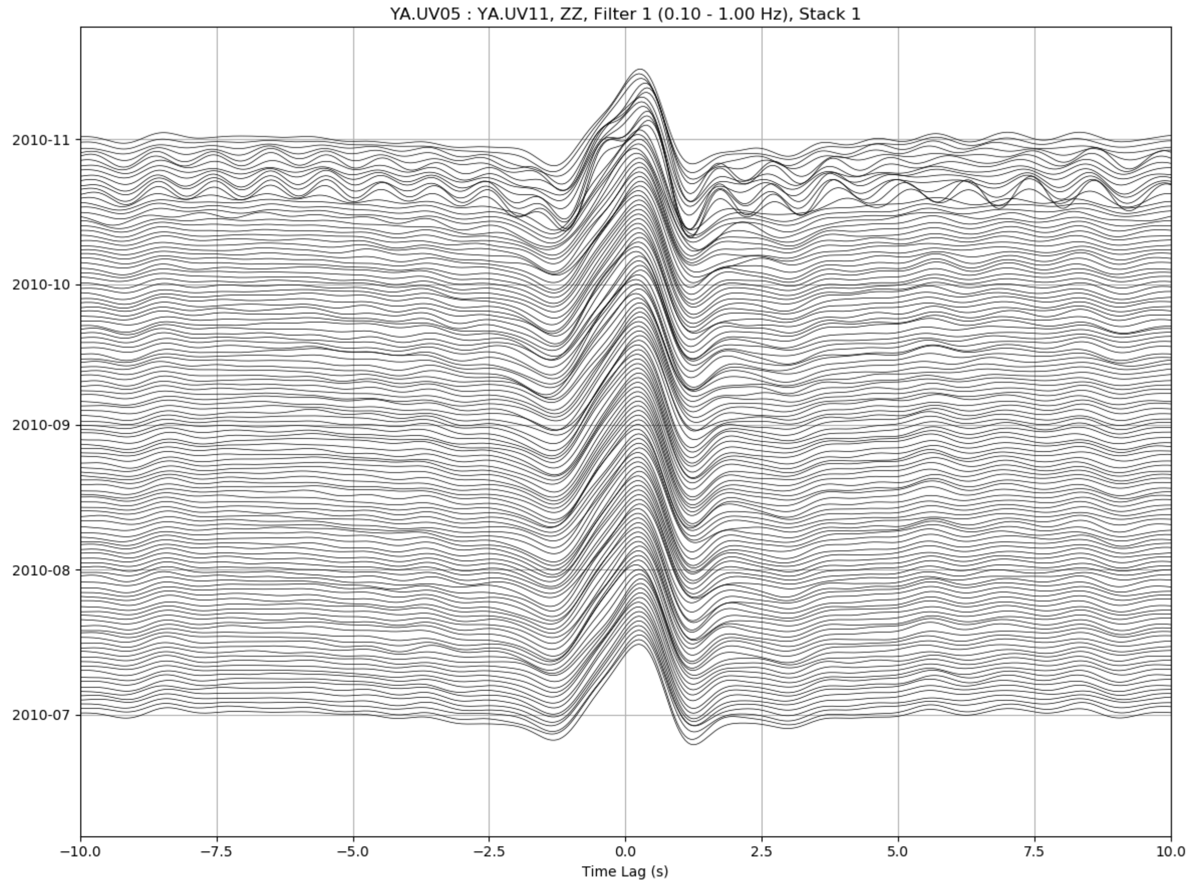
Example:

`msnoise plot ccftime YA.UV06 YA.UV11` will plot all defaults:



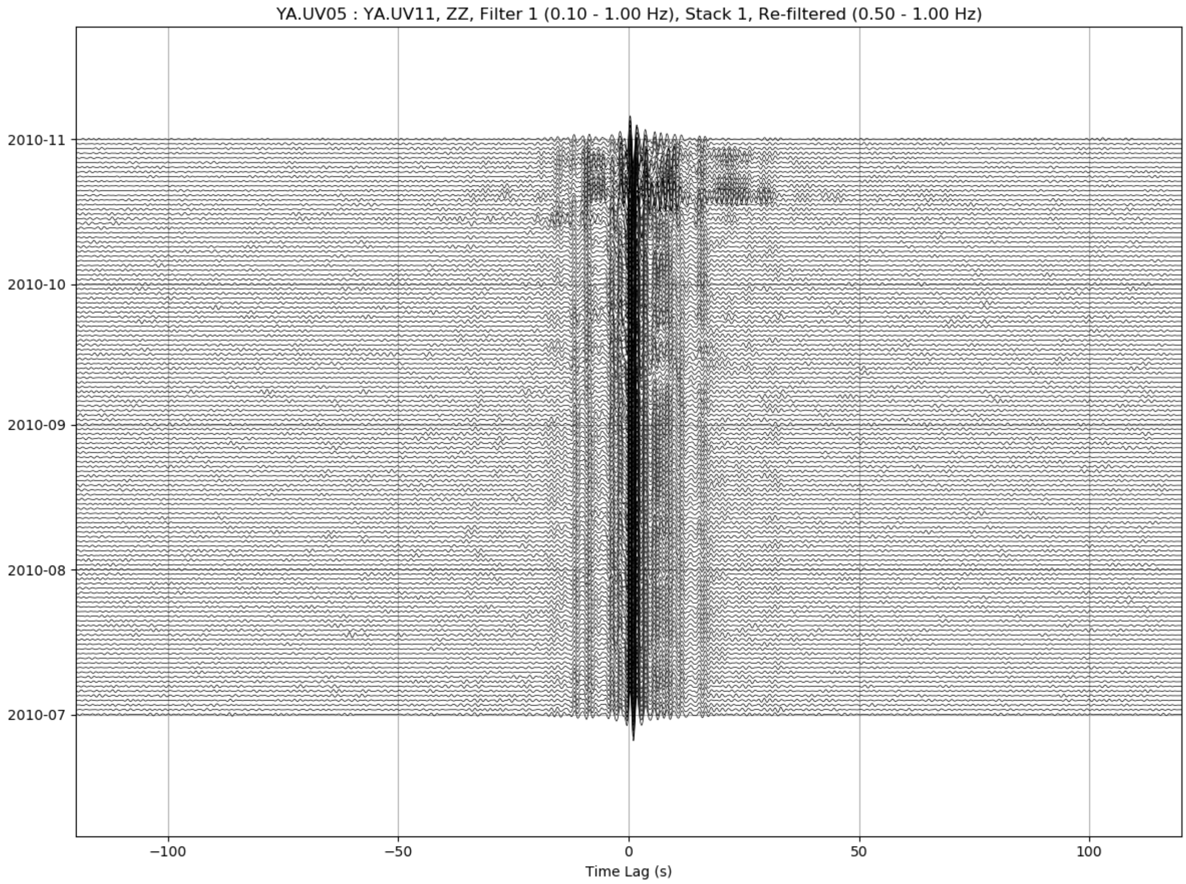
For zooming in the CCFs:

`msnoise plot ccftime YA.UV05 YA.UV11 --xlim=-10,10 --ampli=15`:



It is sometimes useful to refilter the CCFs on the fly:

`msnoise plot ccftime YA.UV05 YA.UV11 -r 0.5:1.0`:



3.1.6 CCF's spectrum vs Time

This plot shows the cross-correlation functions' spectrum vs time. The parameters allow to plot the daily or the mov-stacked CCF. Filters and components are selectable too. The `--ampli` argument allows to increase the vertical scale of the CCFs. Passing `--refilter` allows to band-pass filter CCFs before computing the FFT and plotting. Passing `--startdate` and `--enddate` parameters allows to specify which period of data should be plotted. By default the plot uses dates determined in database.

```
msnoise plot spectime --help

Usage:  [OPTIONS] STA1 STA2 [EXTRA_ARGS]...

  Plots the ccf's spectrum vs time between sta1 and sta2

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -a, --ampli FLOAT        Amplification
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  -r, --refilter TEXT      Refilter CCFs before plotting (e.g. 4:8 for
                           filtering CCFs between 4.0 and 8.0 Hz. This will
```

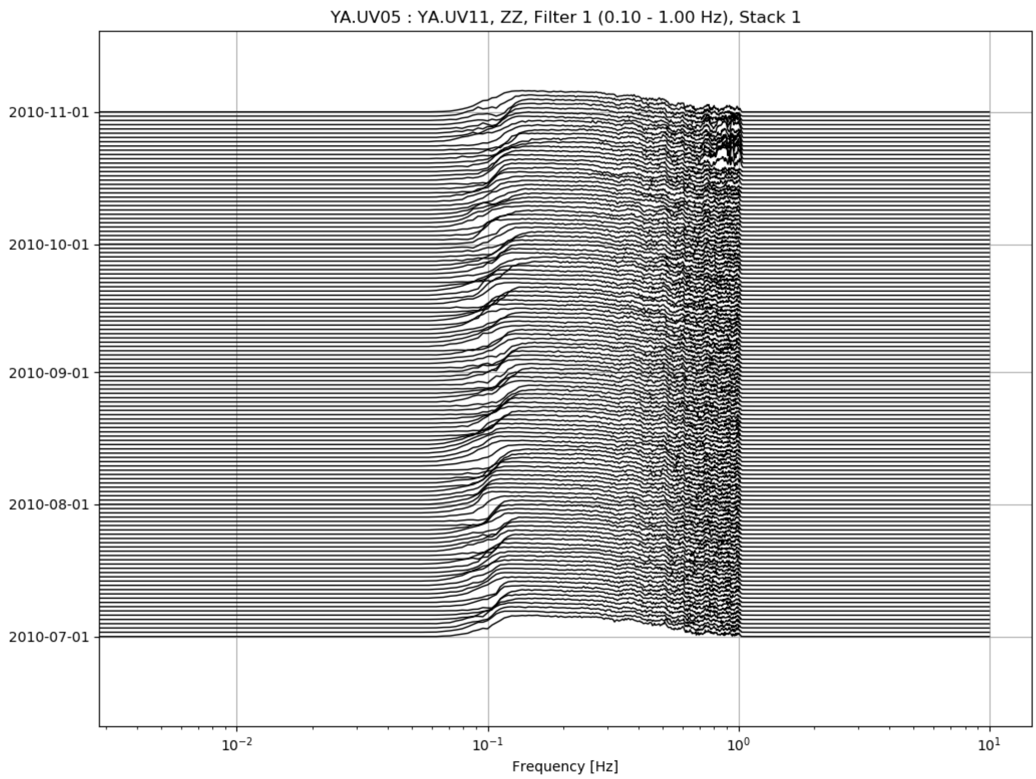
(continues on next page)

(continued from previous page)

```
                          update the plot title.
  --help                  Show this message and exit.
```

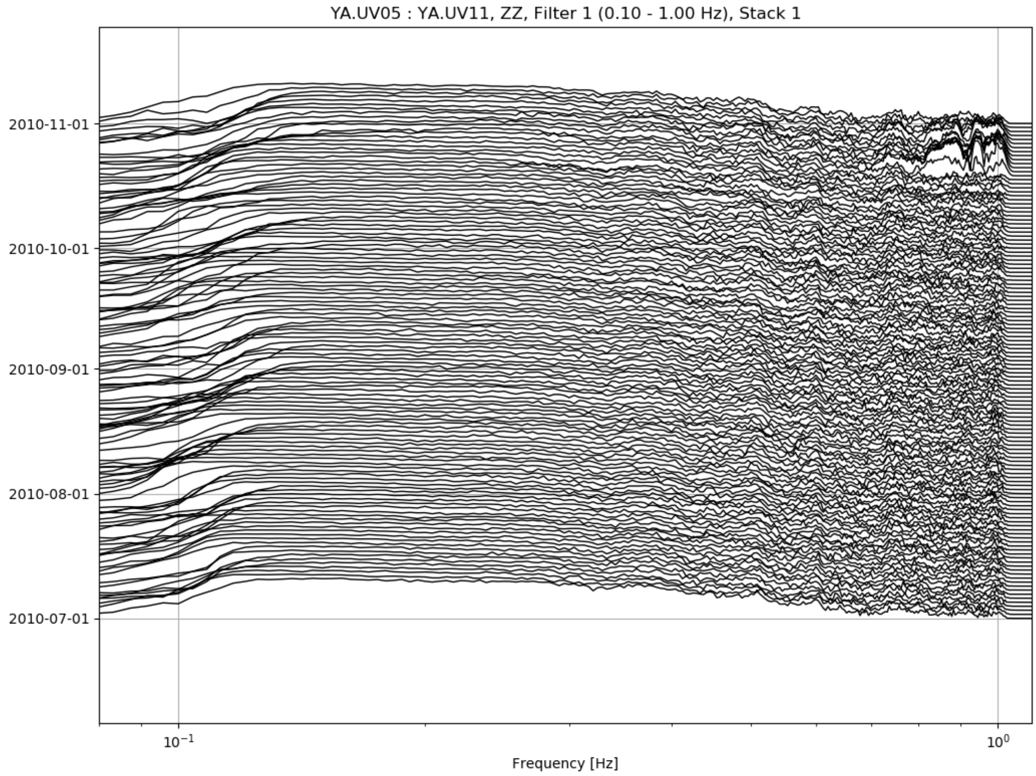
Example:

`msnoise plot spectime YA.UV05 YA.UV11` will plot all defaults:



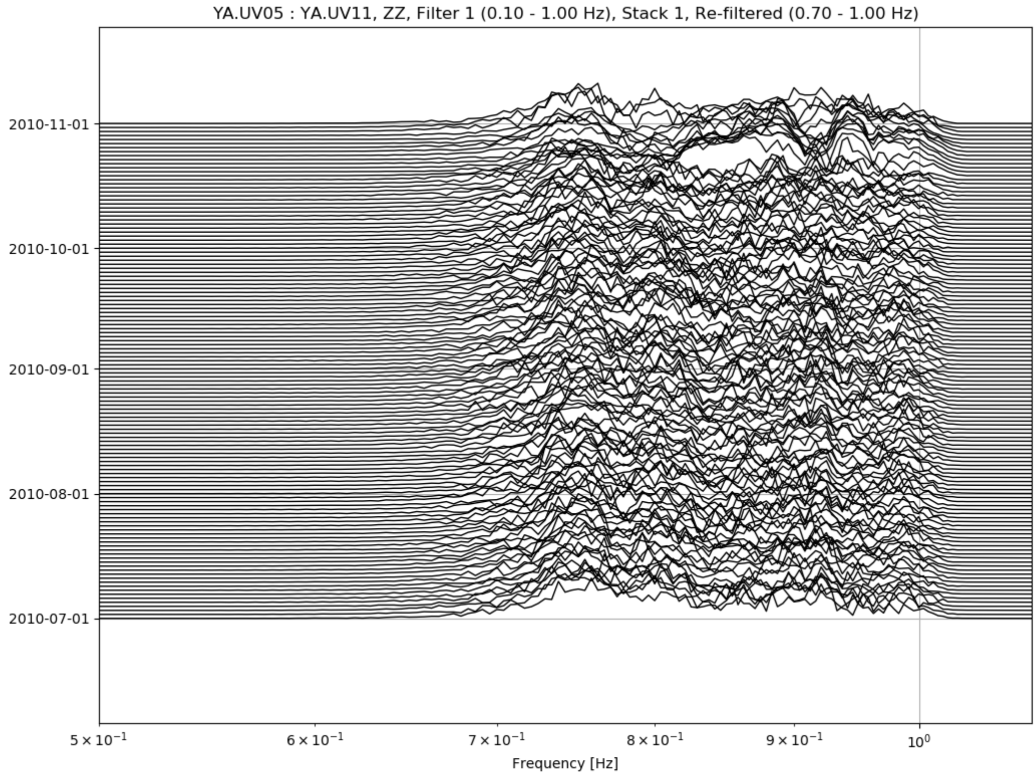
Zooming in the X-axis and playing with the amplitude:

`msnoise plot spectime YA.UV05 YA.UV11 --xlim=0.08,1.1 --ampli=10`:



And refiltering to enhance high frequency content:

`msnoise plot spectime YA.UV05 YA.UV11 --xlim=0.5,1.1 --ampli=10 -r0.7:1.0`:



3.1.7 MWCS Plot

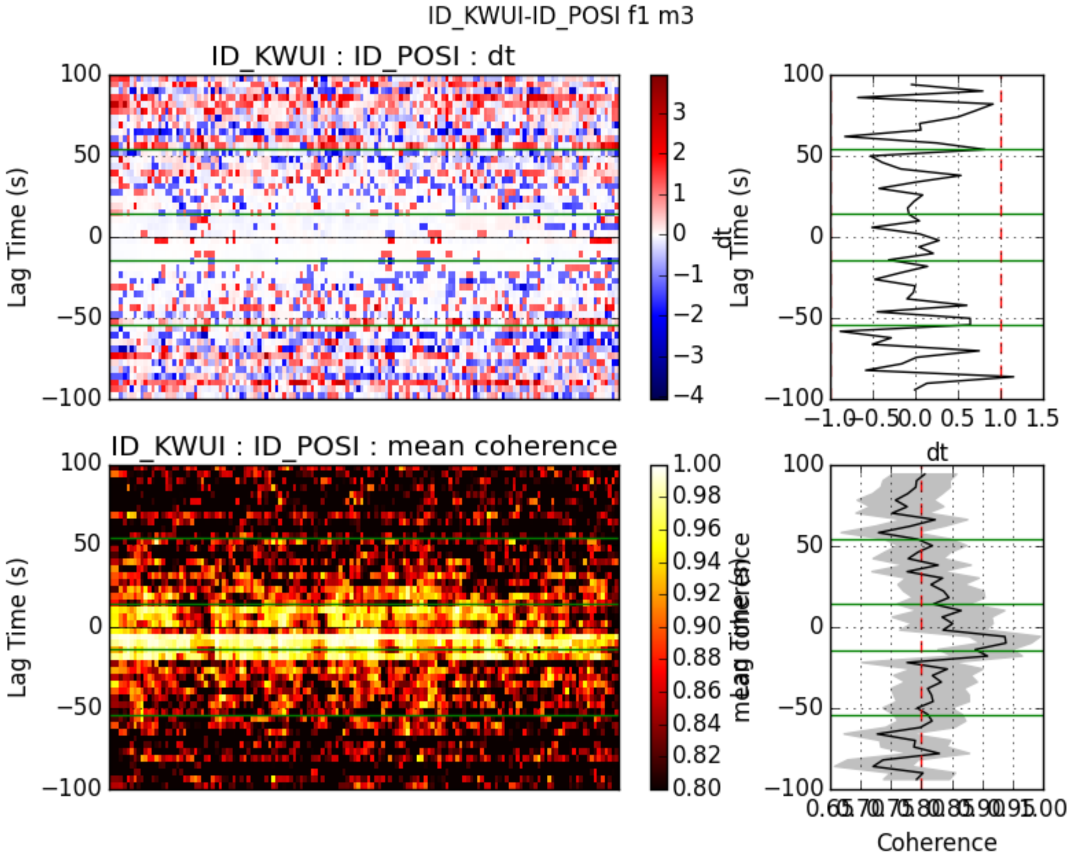
This plot shows the result of the MWCS calculations in two superposed images. One is the dt calculated vs time lag and the other one is the coherence. The image is constructed by horizontally stacking the MWCS of different days. The two right panels show the mean and standard deviation per time lag of the whole image. The selected time lags for the dt/t calculation are presented with green horizontal lines, and the minimum coherence or the maximum dt are in red.

The `filterid`, `comp` and `mov_stack` allow filtering the data used.

```
msnoise plot mwcs --help

Usage:  [OPTIONS] STA1 STA2

  Plots the mwcs results between sta1 and sta2 (parses the CCFs)

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

Example:

`msnoise plot mwcs ID.KWUI ID.POSI -m 3` will plot all defaults with the mov_stack = 3:



3.1.8 Distance Plot

Plots the REF stacks vs interstation distance. This could help deciding which parameters to use in the dt/t calculation step. Passing `--refilter` allows to bandpass filter CCFs before plotting (new in 1.5). It is also possible to only draw CCFs for pairs including one station by passing `--virtual-pair` followed by the desired `NET.STA` (new in 1.5).

```
msnoise plot distance --help

Usage:  [OPTIONS] [EXTRA_ARGS]...

  Plots the REFs of all pairs vs distance

Options:
  -f, --filterid INTEGER  Filter ID
  -c, --comp TEXT         Components (ZZ, ZR,...)
  -a, --ampli FLOAT       Amplification
  -s, --show BOOLEAN      Show interactively?
  -o, --outfile TEXT      Output filename (?=auto)
  -r, --refilter TEXT     Refilter CCFs before plotting (e.g. 4:8 for
                          filtering CCFs between 4.0 and 8.0 Hz. This will
                          update the plot title.
  --virtual-source TEXT   Use only pairs including this station. Format must
```

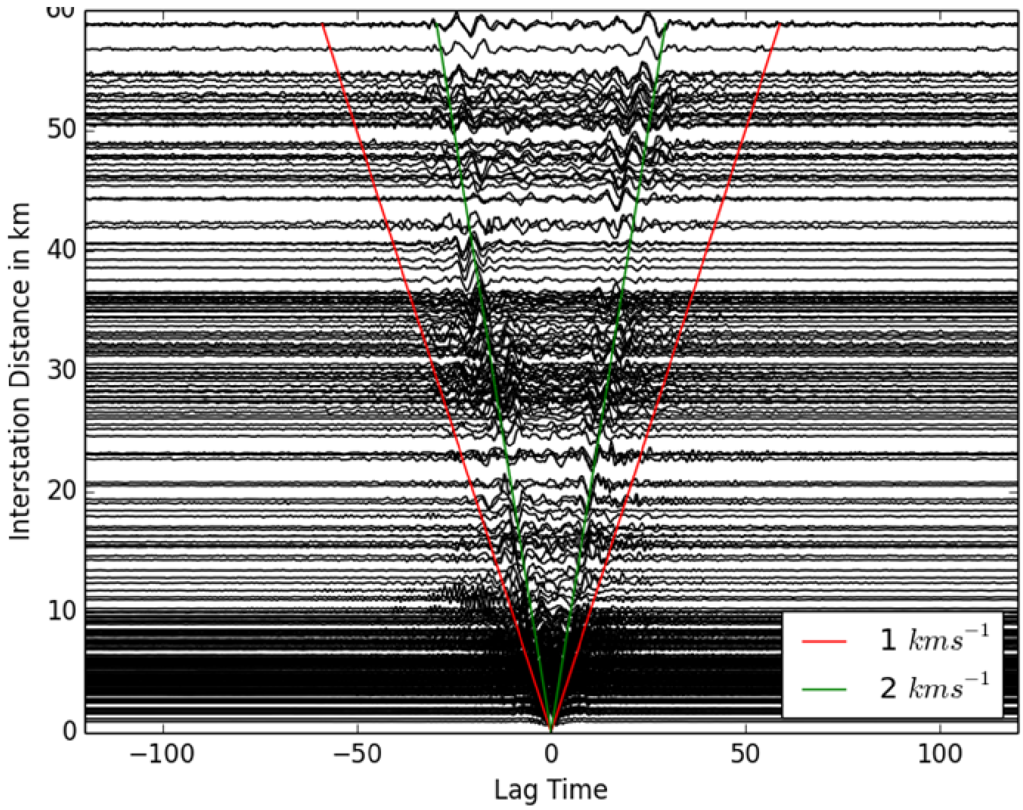
(continues on next page)

(continued from previous page)

```
                        be NET.STA
  --help                Show this message and exit.
```

Example:

`msnoise plot distance` will plot all defaults:



3.1.9 dv/v Plot

This plot shows the final output of MSNoise.

```
msnoise plot dvv --help

Usage:  [OPTIONS]

  Plots the dv/v (parses the dt/t results)

  Individual pairs can be plotted extra using the -p flag one or more times.

  Example: msnoise plot dvv -p ID_KWUI_ID_POSI

  Example: msnoise plot dvv -p ID_KWUI_ID_POSI -p ID_KWUI_ID_TRWI

  Remember to order stations alphabetically !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
```

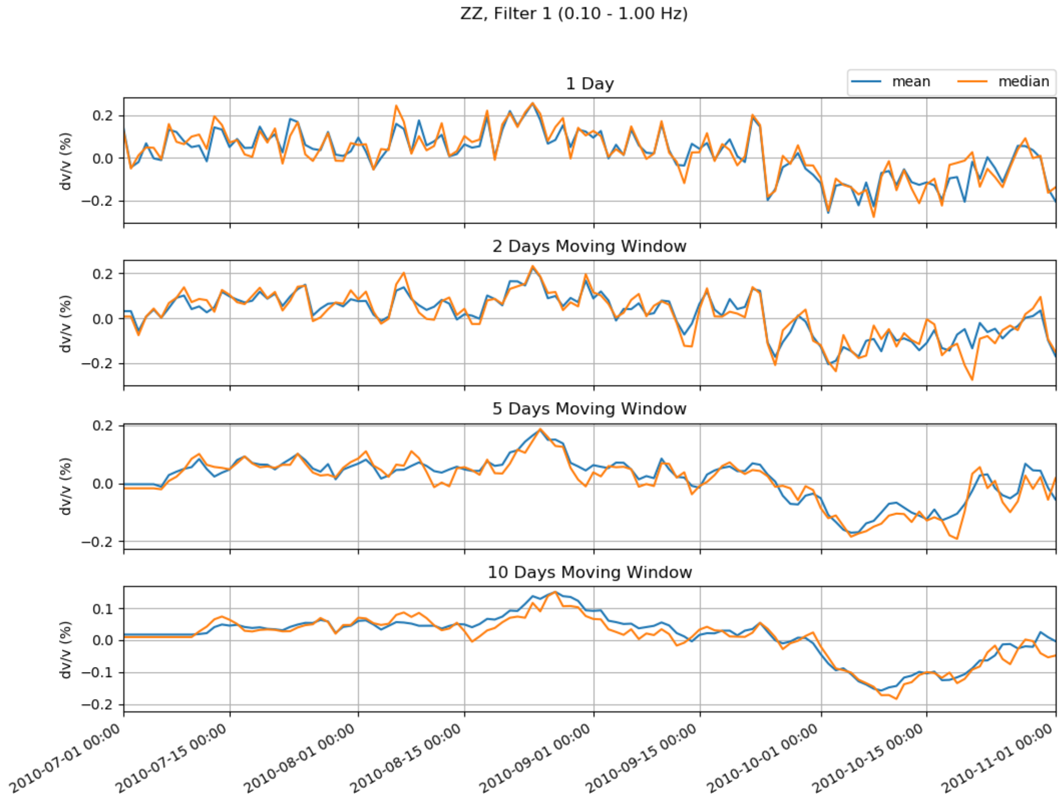
(continues on next page)

(continued from previous page)

```
  -m, --mov_stack INTEGER  Plot specific mov stacks
  -p, --pair TEXT          Plot a specific pair
  -A, --all                Show the ALL line?
  -M, --dttname TEXT       Plot M or M0?
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

Example:

`msnoise plot dvv` will plot all defaults:



3.1.10 dt/t Plot

This plots dt (delay time) against t (time lag). It shows the results from the MWCS step, plus the calculated regression lines M0 and M. The errors in the regression lines are also plotted as fainter lines. The time lags used to calculate the regression are shown in blue.

```
msnoise plot dtt --help

Usage:  [OPTIONS] STA1 STA2 DAY

  Plots a graph of dt against t

  STA1 and STA2 must be provided with this format: NET.STA !
```

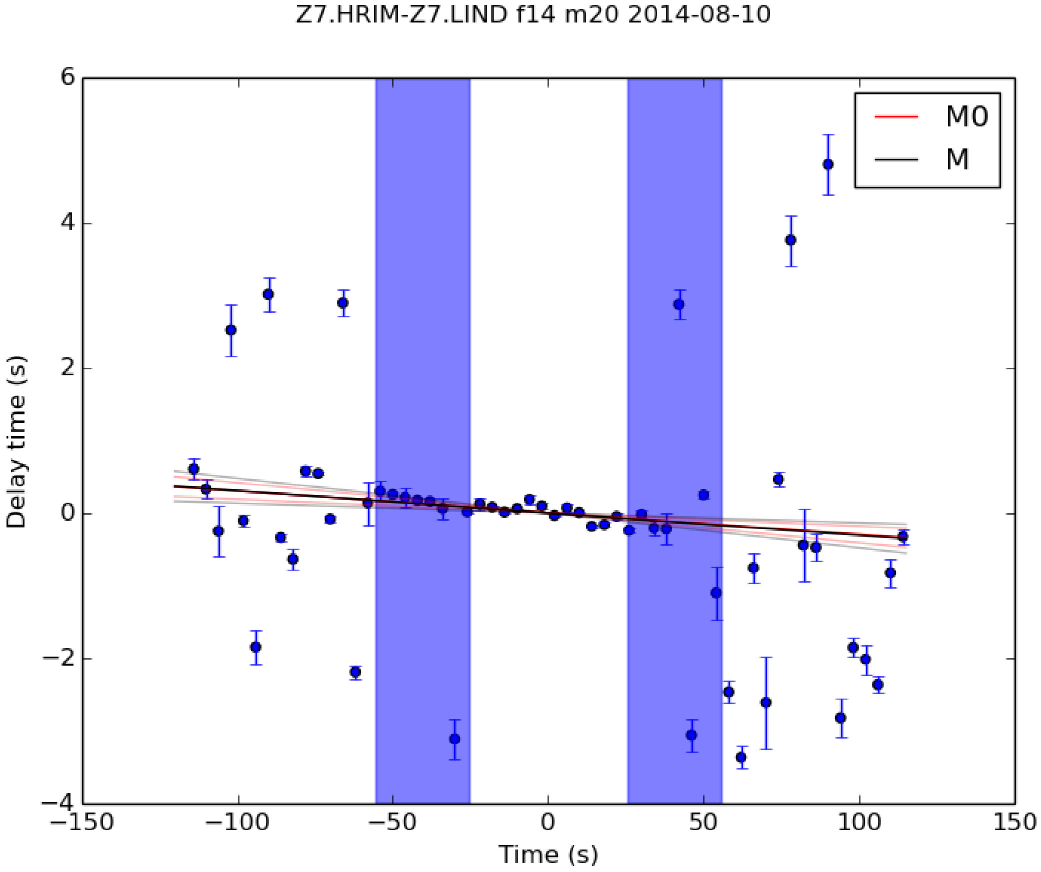
(continues on next page)

(continued from previous page)

```
  DAY must be provided in the ISO format: YYYY-MM-DD

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

Example

`msnoise plot dtt Z7.HRIM Z7.LIND 2014-08-10 -f 14 -m 20` will plot:



New in version 1.4: (Thanks to C.G. Donaldson)

CHAPTER

FOUR

INTERACTING WITH MSNOISE

4.1 How To's

4.1.1 Run the simplest MSNoise run ever

This recipe is a kind of "let's check this data rapidly":

```
msnoise db init --tech 1

msnoise config set startdate=2019-01-01
msnoise config set enddate=2019-02-01
msnoise config set overlap=0.5
msnoise config set mov_stack=1,5,10

msnoise scan_archive --path /path/to/archive --recursively
msnoise populate --fromDA
msnoise new_jobs --init

msnoise admin # add 1 filter in the Filter table
# or
msnoise db execute "insert into filters (ref, low, mwcs_low, high, mwcs_high, rms_
↪threshold, mwcs_wlen, mwcs_step, used) values (1, 0.1, 0.1, 1.0, 1.0, 0.0, 12.0, 4.
↪0, 1)"

msnoise compute_cc
msnoise stack -r
msnoise reset STACK
msnoise stack -m
msnoise compute_mwcs
msnoise compute_dtt
msnoise plot dvv
```

4.1.2 Run MSNoise using lots of cores on a HPC

Avoid Database I/O by using the `hpc` flag

With MSNoise 1.6, most of the API calls have been cleaned from calling the database, for example the `def stack()` called a SELECT on the database for each call, which is useless as configuration parameters are not supposed to change during the execution of the code. This modification allows running MSNoise on an HPC infrastructure with a remote central MySQL database.

The new configuration parameter `hpc` is used for flagging if MSNoise is running High Performance. If True, the jobs processed at each step are marked Done when finished, but the next jobtype according to the workflow is not created. This removes a lot of select/update/insert actions on the database and makes the whole much faster (one INSERT instead of tons of SELECT/UPDATE/INSERT).

Commands and actions with `hpc` = N :

- `msnoise new_jobs`: creates the CC jobs
- `msnoise compute_cc`: processes the CC jobs and creates the STACK jobs
- `msnoise stack -m`: processes the STACK jobs and creates the MWCS jobs
- etc. . .

Commands and actions with `hpc` = Y :

- `msnoise new_jobs`: creates the CC jobs
- `msnoise compute_cc`: processes the CC jobs
- `msnoise new_jobs --hpc CC:STACK`: creates the STACK jobs based on the CC jobs marked "D"one
- `msnoise stack -m`: processes the STACK jobs
- `msnoise new_jobs --hpc STACK:MWCS`: creates the MWCS jobs based on the STACK jobs marked "D"one
- etc. . .

Set up the HPC

To avoid having to rewrite MSNoise for using techniques relying on MPI or other parallel computing tools, I decided to go "simple", and this actually works. The only limitation of the following is that you need to have a strong MySQL server machine that accepts hundreds or thousands of connections. In my case, the MySQL server is running on a computing blade, and its my.cnf is configured to allow 1000 users/connections, and to listen on all its IPs.

The easiest set up (maybe not your sysadmin's preferred, please check), is to

- install miniconda on your home directory and make miniconda's python executable your default python (I add the paths to .profile).
- Then install the requirements and finally MSNoise.
- As usual, create a project folder and `msnoise db init` there, choose MySQL and provide the hostname of the machine running the MySQL server.

At that point, your project is ready. I usually request an interactive node on the HPC for doing the `msnoise populate` and `` `msnoise scan_archive ``. Our jobs scheduler is PBS, so this command

```
qsub -I -l walltime=02:00:00 -l select=1:ncpus=16:mem=1g
```

requests an Interactive node with 16 cpus, 1GB ram, for 2 hours. Once connected, check that the python version is correct (or source .profile again). Because we requested 16 cores, we can `msnoise -t 16 scan_archive --init`.

Depending on the server configuration, you can maybe run the `msnoise admin` on the login node, and access it via its hostname:5000 in your browser. If not, the easiest way to set up the config is running `msnoise config set <parameter>=<value>` from the console. To add filters, do it either:

- in the Admin
- using MySQL workbench connected to your MySQL server
- using such commands `msnoise db execute "insert into filters (ref, low, mwcs_low, high, mwcs_high, rms_threshold, mwcs_wlen, mwcs_step, used) values (1, 0.1, 0.1, 1.0, 1.0, 0.0, 12.0, 4.0, 1)"`
- using `msnoise db dump`, edit the filter table in CSV format, then `msnoise db import filters --force`

Once done, the project is set up and should run. Again, test if all goes OK in an interactive node.

To run on N cores in parallel, we have the advantage that, e.g. for CC jobs, the day-jobs are independent. We can thus request an "Array" of single cores, which is usually quite easy to get on HPCs (most users run heavily parallel codes and request large number of "connected" cores, while we can run "shared").

The job file in my PBS case looks like this for computing the CC:

```
#!/bin/bash
#PBS -N MSNoise_PDF_CC
#PBS -l walltime=01:00:00
#PBS -l select=1:ncpus=1:mem=1g
#PBS -l place=shared
#PBS -J 1-400
cd /scratch-a/thomas/2019_PDF
source /space/hpc-home/thomas/.profile
msnoise compute_cc2
```

This requests 400 cores with 1GB of RAM. The content of my .profile file contains:

```
# added by Miniconda3 installer
export PATH="/home/thomas/miniconda3/bin:$PATH"
export MPLBACKEND="Agg"
```

The last line is important as nodes are usually "head-less" and matplotlib and packages relating to it would fail if they expect a gui-capable system.

For submitting this job, run `qsub qc.job`. The process usually routes stdout and stderr to files in the current directory, make sure to check them if jobs seem to have failed. If all goes well, calling `msnoise info -j` repeatedly from the login or interactive node's console should show the evolution of Todo, In Progress and Done jobs.

Note: HPC experts are welcome to suggest, comment, etc... It's a quick'n'dirty solution, but it works for me!

4.1.3 Reprocess data

When starting to use MSNoise, one will most probably need to re-run different parts of the Workflow more than one time. By default, MSNoise is designed to only process "what's new", which is antagonistic to what is wanted. Hereafter, we present cases that will cover most of the re-run techniques:

When adding a new filter

If new filter are added to the filters list in the Configurator, one has to reprocess all CC jobs, but not for filters already existing. The recipe is:

- Add a new filter, be sure to mark 'used'=1
- Set all other filters 'used' value to 0
- Redefine the flag of the CC jobs, from 'D'one to 'T'odo with the following:
- Run `msnoise reset CC --all`
- Run `msnoise compute_cc`
- Run next commands if needed (stack, mwcs, dtt)
- Set back the other filters 'used' value to 1

The compute_cc will only compute the CC's for the new filter(s) and output the results in the STACKS/ folder, in a sub-folder named by a formatted integer from the filter ID. For example: STACKS/01 for 'filter id'=1, STACKS/02 for 'filter id'=2, etc.

When changing the REF

When changing the REF (`ref_begin` and `ref_end`), the REF stack has to be re-computed:

```
msnoise reset STACK --all
msnoise stack -r
```

The REF will then be re-output, and you probably should reset the MWCS jobs to recompute daily correlations against this new ref:

```
msnoise reset MWCS --all
msnoise compute_mwcs
```

When changing the MWCS parameters

If the MWCS parameters are changed in the database, all MWCS jobs need to be reprocessed:

```
msnoise reset MWCS --all
msnoise compute_mwcs
```

shoud do the trick.

When changing the dt/t parameters

```
msnoise reset DTT --all
msnoise compute_dtt
```

Recompute only the specific days

You want to recompute CC jobs after a certain date only, for whatever reason:

```
msnoise reset CC --rule="day>='2019-01-01'"
```

SQL experts can also use the `msnoise db execute` command (with caution!):

```
msnoise db execute "update jobs set flag='T' where jobtype='CC' and day>='2019-01-01'"
```

If you want to only reprocess one day:

```
msnoise reset CC --rule="day='2019-01-15'"
```

4.1.4 Define one's own data structure of the waveform archive

The data_structure.py file contains the known data archive formats. If another data format needs to be defined, it will be done in the `custom.py` file in the current project folder:

See also:

Check the "Populate Station Table" step in the *Populate Station Table* (page 23).

4.1.5 How to have MSNoise work with 2+ data structures at the same time

In this case, the easiest solution is to scan the archive(s) with the "Lazy Mode":

```
msnoise scan_archive --path /path/to/archive1/ --recursively
msnoise scan_archive --path /path/to/archive2/ --recursively
```

etc.

Remember to either manually fill in the station table, or

```
msnoise populate --fromDA
```

4.1.6 How to duplicate/dump the MSNoise configuration

To export all tables of the current database, run

```
msnoise db dump
```

This will create as many CSV files as there are tables in the database.

Then, on a new location, init a new msnoise project and import the tables one by one:

```
msnoise db init
msnoise db import config --force
msnoise db import stations --force
msnoise db import filters --force
msnoise db import data_availability --force
msnoise db import jobs --force
```

4.1.7 Testing the Dependencies

Once installed, you should be able to import the python packages in a python console. MSNoise comes with a little script called *bugreport.py* that can be useful to check if you have all the required packages (+ some extras).

The usage is such:

```
$ msnoise bugreport -h

usage: msnoise bugreport [-h] [-s] [-m] [-e] [-a]

Helps determining what didn\'t work

optional arguments:
  -h, --help     show this help message and exit
  -s, --sys      Outputs System info
  -m, --modules  Outputs Python Modules Presence/Version
  -e, --env      Outputs System Environment Variables
  -a, --all      Outputs all of the above
```

On my Windows machine, the execution of

```
$ msnoise bugreport -s -m
```

results in:

```
************* Computer Report *************

----------------+SYSTEM+-------------------
Windows
PC1577-as
10
10.0.17134
AMD64
Intel64 Family 6 Model 158 Stepping 9, GenuineIntel

----------------+PYTHON+-------------------
Python:3.7.3 | packaged by conda-forge | (default, Jul  1 2019, 22:01:29) [MSC v.1900␣
↪64 bit (AMD64)]

This script is at d:\pythonforsource\msnoise_stack\msnoise\msnoise\bugreport.py

---------------+MODULES+-------------------

Required:
[X] setuptools: 41.2.0
[X] numpy: 1.15.4
```

(continues on next page)

(continued from previous page)

```
[X] scipy: 1.3.0
[X] pandas: 0.25.0
[X] matplotlib: 3.1.1
[X] sqlalchemy: 1.3.8
[X] obspy: 1.1.0
[X] click: 7.0
[X] pymysql: 0.9.3
[X] flask: 1.1.1
[X] flask_admin: 1.5.3
[X] markdown: 3.1.1
[X] wtforms: 2.2.1
[X] folium: 0.10.0
[X] jinja2: 2.10.1

Only necessary if you plan to build the doc locally:
[X] sphinx: 2.2.0
[X] sphinx_bootstrap_theme: 0.7.1

Graphical Backends: (at least one is required)
[ ] wx: not found
[ ] pyqt: not found
[ ] PyQt4: not found
[X] PyQt5: present (no version)
[ ] PySide: not found

Not required, just checking:
[X] json: 2.0.9
[X] psutil: 5.6.3
[ ] reportlab: not found
[ ] configobj: not found
[X] pkg_resources: present (no version)
[ ] paramiko: not found
[X] ctypes: 1.1.0
[X] pyparsing: 2.4.2
[X] distutils: 3.7.3
[X] IPython: 7.7.0
[ ] vtk: not found
[ ] enable: not found
[ ] traitsui: not found
[ ] traits: not found
[ ] scikits.samplerate: not found
```

The [X] marks the presence of the module. In the case above, PyQt4 is missing, but that's not a problem because *PyQt5* is present. The "not-required" packages are checked for information, those packages can be useful for reporting / hacking / rendering the data.

4.2 Interaction Examples & Gallery

The following examples are meant to show you how to interact with MSNoise using its API, thus avoiding having to dive into the folder structure.

Users should try examples while checking the *MSNoise API* (page 66). (application programming interface) for understanding the calls to different functions.

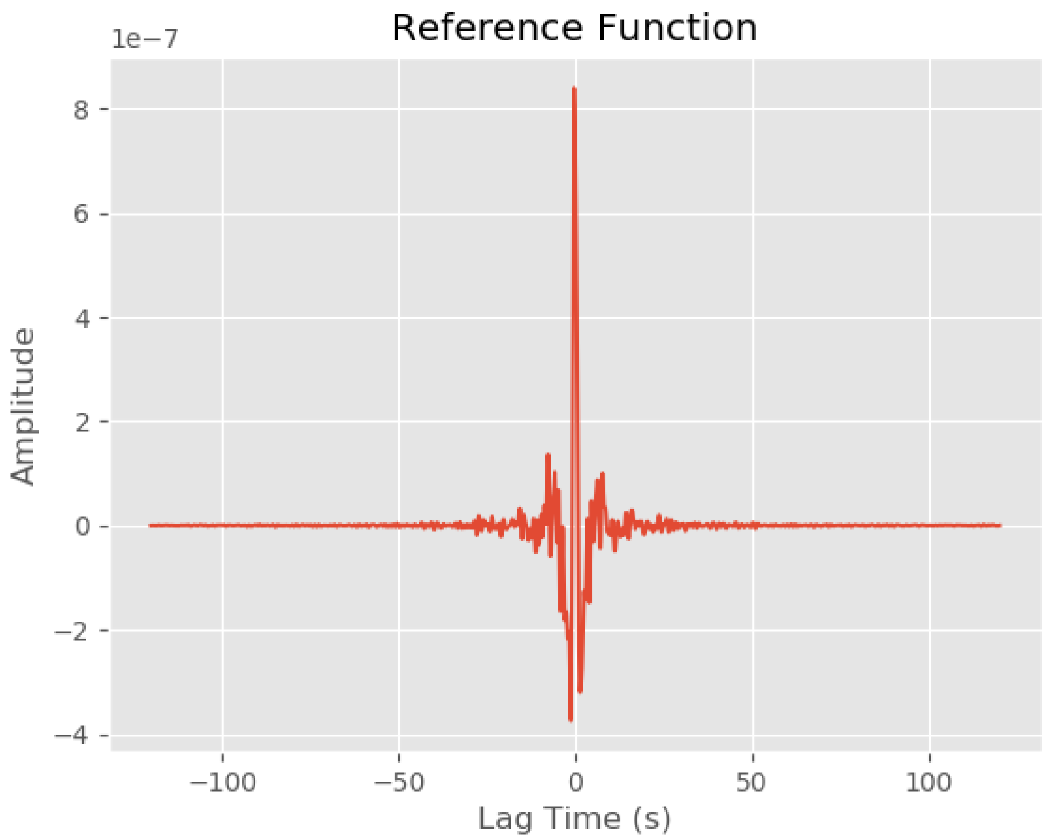
In a nutshell, all examples start with the following Python code:

```
from msnoise.api import db
db = connect()
```

This, if run in an MSNoise project folder (= a folder where you have already run `msnoise db init`), will provide a `Session` object, connected to the database.

Note: Click *here* (page 63) to download the full example code

4.2.1 Plot a Reference CCF




```
# The following two lines are only needed for building this documentation
# Delete them and run the code in your project folder.

import os
if "SPHINX_DOC_BUILD" in os.environ:
    os.chdir(r"C:\tmp\msnoise_doc_project")

import matplotlib
matplotlib.use("agg")

import matplotlib.pyplot as plt
import numpy as np
```

(continues on next page)

(continued from previous page)

```
import pandas as pd
from pandas.plotting import register_matplotlib_converters
register_matplotlib_converters()


plt.style.use("ggplot")

from msnoise.api import connect, get_results, build_movstack_datelist, get_params,␣
↪get_t_axis

# connect to the database
db = connect()

# Obtain a list of dates between ``start_date`` and ``enddate``
start, end, datelist = build_movstack_datelist(db)

# Get the list of parameters from the DB:
params = get_params(db)

# Get the time axis for plotting the CCF:
taxis = get_t_axis(db)

# Get the results for two station, filter id=1, ZZ component, mov_stack=1 and stack␣
↪the results:
n, ccf = get_results(db, "YA_UV05", "YA_UV12", 1, "ZZ", datelist, 1, format="stack",␣
↪params=params)

plt.figure()
plt.plot(taxis, ccf)
plt.title("Reference Function")
plt.xlabel("Lag Time (s)")
plt.ylabel("Amplitude")


#EOF
```

Total running time of the script: (0 minutes 0.926 seconds)

Note: Click *here* (page 66) to download the full example code

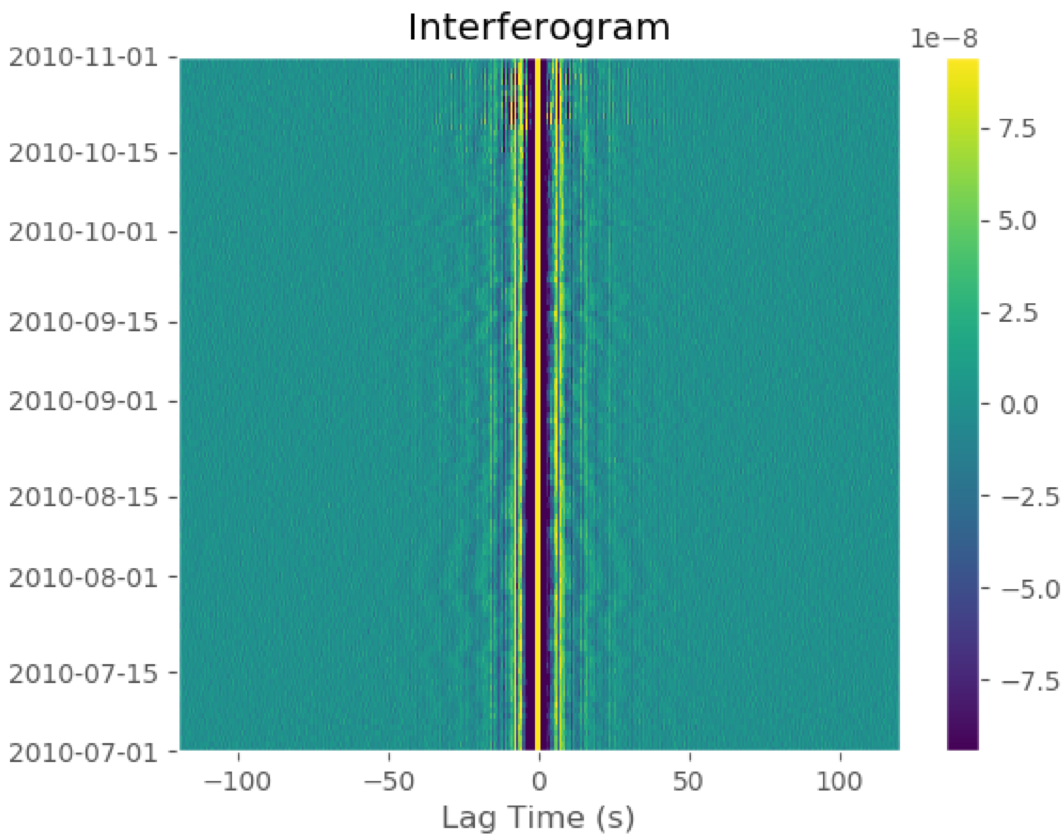
4.2.2 Plot an interferogram

```
import os
if "SPHINX_DOC_BUILD" in os.environ:
    os.chdir(r"C:\tmp\msnoise_doc_project")

import matplotlib
matplotlib.use("agg")

import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
```

(continues on next page)

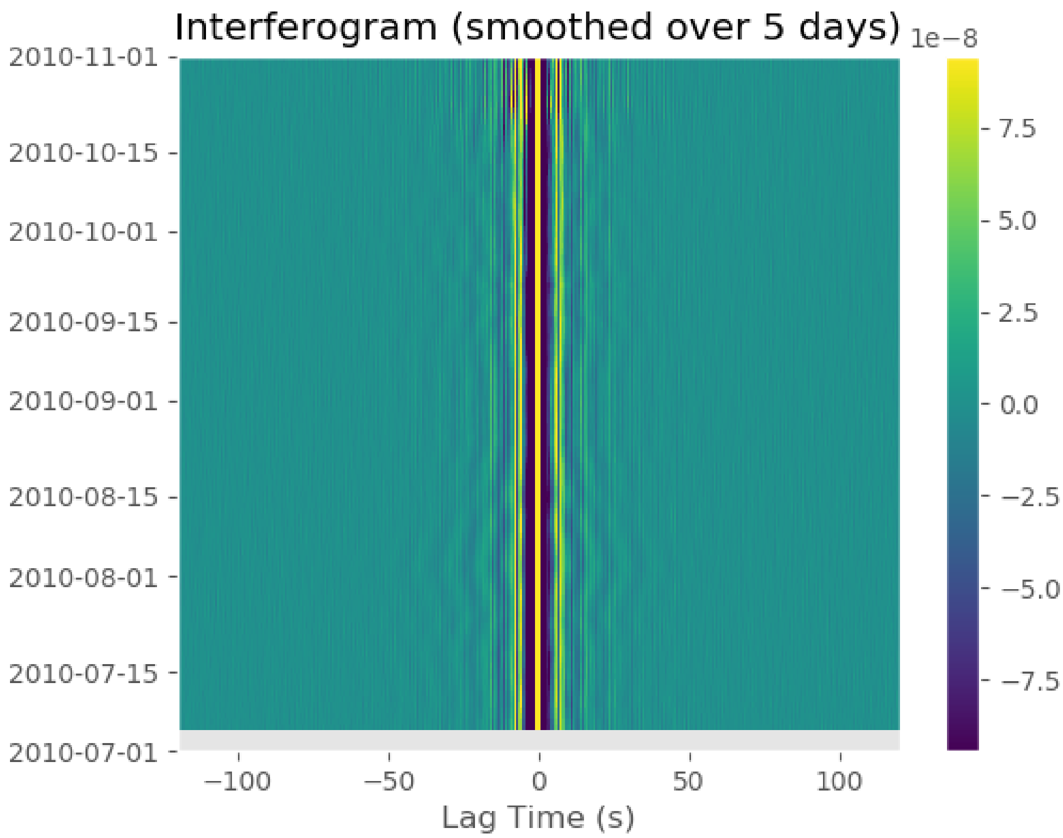
(continued from previous page)

```
from pandas.plotting import register_matplotlib_converters
register_matplotlib_converters()

plt.style.use("ggplot")

from msnoise.api import connect, get_results, build_movstack_datelist, get_params,
↪get_t_axis

# connect to the database
db = connect()

# Obtain a list of dates between ``start_date`` and ``enddate``
start, end, datelist = build_movstack_datelist(db)

# Get the list of parameters from the DB:
params = get_params(db)

# Get the time axis for plotting the CCF:
taxis = get_t_axis(db)

# Get the results for two station, filter id=1, ZZ component, mov_stack=1 and the
↪results as a 2D array:
n, ccfs = get_results(db, "YA_UV05", "YA_UV12", 1, "ZZ", datelist, 1, format="matrix",
↪ params=params)

# Convert to a pandas DataFrame object for convenience, and drop empty rows:
df = pd.DataFrame(ccfs, index=pd.DatetimeIndex(datelist), columns=taxis)
df = df.dropna()

# Define the 99% percentile of the data, for visualisation purposes:
clim = df.mean(axis="index").quantile(0.99)

fig, ax = plt.subplots()
plt.pcolormesh(df.columns, df.index.to_pydatetime(), df.values,
               vmin=-clim, vmax=clim, rasterized=True)
plt.colorbar()
plt.title("Interferogram")
plt.xlabel("Lag Time (s)")
plt.ylim(df.index[0],df.index[-1])
plt.xlim(df.columns[0], df.columns[-1])
plt.subplots_adjust(left=0.15)
```



Running a simple moving window average can be done with pandas's functions:

```
smooth = df.rolling(5).mean()

fig, ax = plt.subplots()
plt.pcolormesh(smooth.columns, smooth.index.to_pydatetime(), smooth.values,
               vmin=-clim, vmax=clim, rasterized=True)
plt.colorbar()
plt.title("Interferogram (smoothed over 5 days)")
plt.xlabel("Lag Time (s)")
plt.ylim(smooth.index[0],smooth.index[-1])
plt.xlim(smooth.columns[0], smooth.columns[-1])
plt.subplots_adjust(left=0.15)


plt.show()
#EOF
```



Out:

```
D:\PythonForSource\MSNoise_Stack\MSNoise\examples\plot_interferogram.py:75:
↪UserWarning: Matplotlib is currently using agg, which is a non-GUI backend, so
↪cannot show the figure.
  plt.show()
```

Total running time of the script: (0 minutes 1.870 seconds)

4.3 MSNoise API

`msnoise.api.get_logger`(*name*, *loglevel=None*, *with_pid=False*)
Returns the current configured logger or configure a new one.

`msnoise.api.get_engine`(*inifile=None*)
Returns the a SQLAlchemy Engine

Parameters `inifile` (*str*) – The path to the db.ini file to use. Defaults to os.cwd() + db.ini

Return type `sqlalchemy.engine.Engine`

Returns An `Engine` Object

`msnoise.api.connect`(*inifile=None*)
Establishes a connection to the database and returns a Session object.

Parameters `inifile` (*string*) – The path to the db.ini file to use. Defaults to os.cwd() + db.ini

Return type `sqlalchemy.orm.session.Session`

Returns A `Session` object, needed for many of the other API methods.

`msnoise.api.create_database_inifile`(*tech*, *hostname*, *database*, *username*, *password*, *prefix=''*)

Creates the db.ini file based on supplied parameters.

Parameters

- `tech` (*int*) – The database technology used: 1=sqlite 2=mysql
- `hostname` (*string*) – The hostname of the server (if tech=2) or the name of the sqlite file if tech=1)
- `database` (*string*) – The database name
- `username` (*string*) – The user name
- `prefix` (*string*) – The prefix to use for all tables
- `password` (*string*) – The password of *user*

Returns None

`msnoise.api.read_db_inifile`(*inifile=None*)

Reads the parameters from the db.ini file.

Parameters `inifile` (*string*) – The path to the db.ini file to use. Defaults to os.cwd() + db.ini

Return type tuple

Returns tech, hostname, database, username, password

`msnoise.api.get_config`(*session*, *name=None*, *isbool=False*, *plugin=None*)

Get the value of one or all config bits from the database.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by `connect()` (page 66)
- `name` (*str*) – The name of the config bit to get. If omitted, a dictionnary with all config items will be returned
- `isbool` (*bool*) – if True, returns True/False for config *name*. Defaults to False
- `plugin` (*str*) – if provided, gives the name of the Plugin config to use. E.g. if "Amazing" is provided, MSNoise will try to load the "AmazingConfig" entry point. See *Extending MSNoise with Plugins* (page 82) for details.

Return type str, bool or dict

Returns the value for *name* or a dict of all config values

`msnoise.api.update_config`(*session*, *name*, *value*, *plugin=None*)

Update one config bit in the database.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `name` (*str*) – The name of the config bit to set.
- `value` (*str*) – The value of parameter *name*. Can also be NULL if you don't want to use this particular parameter.
- `plugin` (*str*) – if provided, gives the name of the Plugin config to use. E.g. if "Amazing" is provided, MSNoise will try to load the "AmazingConfig" entry point. See *Extending MSNoise with Plugins* (page 82) for details.

`msnoise.api.get_params(`*session*`)`

Get config parameters from the database.

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)

Returns a Param class containing the parameters

`msnoise.api.get_filters(`*session*, *all=False*`)`

Get Filters from the database.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `all` (*bool*) – Returns all filters from the database if True, or only filters where *used* = 1 if False (default)

Return type list of `Filter`

Returns a list of Filter

`msnoise.api.update_filter(`*session*, *ref*, *low*, *mwcs_low*, *high*, *mwcs_high*, *rms_threshold*, *mwcs_wlen*, *mwcs_step*, *used*`)`

Updates or Insert a new Filter in the database.

See also:

`msnoise.msnoise_table_def.declare_tables.Filter`

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `ref` (*int*) – The id of the Filter in the database
- `low` (*float*) – The lower frequency bound of the Whiten function (in Hz)
- `high` (*float*) – The upper frequency bound of the Whiten function (in Hz)
- `rms_threshold` (*float*) – Not used anymore
- `mwcs_wlen` (*float*) – Window length (in seconds) to perform MWCS

- `mwcs_step` (*float*) – Step (in seconds) of the windowing procedure in MWCS
- `used` (*bool*) – Is the filter activated for the processing

`msnoise.api.get_networks`(*session*, *all=False*)
Get Networks from the database.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `all` (*bool*) – Returns all networks from the database if True, or only networks at least one station has *used* = 1 if False (default)

Return type list of str

Returns a list of network codes

`msnoise.api.get_stations`(*session*, *all=False*, *net=None*)
Get Stations from the database.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `all` (*bool*) – Returns all stations from the database if True, or only stations where *used* = 1 if False (default)
- `net` (*str*) – if set, limits the stations returned to this network

Return type list of `msnoise.msnoise_table_def.declare_tables.Station`

Returns list of `Station`

`msnoise.api.get_station`(*session*, *net*, *sta*)
Get one Station from the database.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `net` (*str*) – the network code
- `sta` (*str*) – the station code

Return type `msnoise.msnoise_table_def.declare_tables.Station`

Returns a `Station` Object

`msnoise.api.update_station`(*session*, *net*, *sta*, *X*, *Y*, *altitude*, *coordinates='UTM'*, *instrument='N/A'*, *used=1*)
Updates or Insert a new Station in the database.

See also:

`msnoise.msnoise_table_def.declare_tables.Station`

Parameters

- **session** (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- **net** (*str*) – The network code of the Station
- **sta** (*str*) – The station code
- **X** (*float*) – The X coordinate of the station
- **Y** (*float*) – The Y coordinate of the station
- **altitude** (*float*) – The altitude of the station
- **coordinates** (*str*) – The coordinates system. "DEG" is WGS84 latitude/ longitude in degrees. "UTM" is expressed in meters.
- **instrument** (*str*) – The instrument code, useful with PAZ correction
- **used** (*bool*) – Whether this station must be used in the computations.

`msnoise.api.get_station_pairs`(*session*, *used=None*, *net=None*)

Returns an iterator over all possible station pairs. If auto-correlation is configured in the database, returns N*N pairs, otherwise returns N*(N-1)/2 pairs.

Parameters

- **session** (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- **used** (*bool*, *int*) – Select only stations marked used if False (default) or all stations present in the database if True
- **net** (*str*) – Network code to filter for the pairs.

Return type iterable

Returns An iterable of `Station` object pairs

`msnoise.api.get_interstation_distance`(*station1*, *station2*, *coordinates='DEG'*)

Returns the distance in km between *station1* and *station2*.

> **Warning:** Currently the stations coordinates system have to be the same!

Parameters

- **station1** (Station) – A Station object
- **station2** (Station) – A Station object
- **coordinates** (*str*) – The coordinates system. "DEG" is WGS84 latitude/ longitude in degrees. "UTM" is expressed in meters.

Return type float

Returns The interstation distance in km

`msnoise.api.update_data_availability`(*session*, *net*, *sta*, *comp*, *path*, *file*, *starttime*, *endtime*, *data_duration*, *gaps_duration*, *samplerate*)

Updates a DataAvailability object in the database

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by `connect()` (page 66)
- `net` (*str*) – The network code of the Station
- `sta` (*str*) – The station code
- `comp` (*str*) – The component (channel)
- `path` (*str*) – The full path to the folder containing the file
- `file` (*str*) – The name of the file
- `starttime` (*datetime.datetime*) – Start time of the file
- `endtime` (*datetime.datetime*) – End time of the file
- `data_duration` (*float*) – Cumulative duration of available data in the file
- `gaps_duration` (*float*) – Cumulative duration of gaps in the file
- `samplerate` (*float*) – Sample rate of the data in the file (in Hz)

`msnoise.api.get_new_files(`*session*`)`

Returns the files marked "N"ew or "M"odified in the database

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by `connect()` (page 66)

Return type list

Returns list of `DataAvailability`

`msnoise.api.get_data_availability(`*session*, *net=None*, *sta=None*, *comp=None*, *starttime=None*, *endtime=None*`)`

Returns the `DataAvailability` objects for specific *net*, *sta*, *starttime* or *endtime*

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by `connect()` (page 66)
- `net` (*str*) – Network code
- `sta` (*str*) – Station code
- `starttime` (*datetime.datetime*, *datetime.date*) – Start time of the search
- `endtime` (*datetime.datetime*, *datetime.date*) – End time of the search

Return type list

Returns list of `DataAvailability`

`msnoise.api.mark_data_availability(`*session*, *net*, *sta*, *flag*`)`

Updates the flag of all `DataAvailability` objects matching *net.sta* in the database

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)
- `net` (*`str`*) – Network code
- `sta` (*`str`*) – Station code
- `flag` (*`str`*) – Status of the DataAvailability object: New, Modified or Archive. Values accepted are {'N', 'M', 'A'}

`msnoise.api.count_data_availability_flags`(*session*)

Count the number of `DataAvailability`, grouped by *flag*

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)

Return type list

Returns list of [count, flag] pairs

`msnoise.api.update_job`(*session, day, pair, jobtype, flag, commit=True, returnjob=True, ref=None*)

Updates or Inserts a new `Job` in the database.

Parameters

- `day` (*`str`*) – The day in YYYY-MM-DD format
- `pair` (*`str`*) – the name of the pair (EXAMPLE?)
- `jobtype` (*`str`*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `flag` (*`str`*) – Status of the Job: "T"odo, "I"n Progress, "D"one.
- `commit` (*`bool`*) – Whether to directly commit (True, default) or not (False)
- `returnjob` (*`bool`*) – Return the modified/inserted Job (True, default) or not (False)

Return type `Job` or None

Returns If returnjob is True, returns the modified/inserted Job.

`msnoise.api.massive_insert_job`(*jobs*)

Routine to use a low level function to insert much faster a list of `Job`. This method uses the Engine directly, no need to pass a Session object.

Parameters `jobs` (*`list`*) – a list of `Job` to insert.

`msnoise.api.massive_update_job`(*session, jobs, flag='D'*)

Routine to use a low level function to update much faster a list of `Job`. This method uses the Job.ref which is unique.

Parameters

- `jobs` (*`list`*) – a list of `Job` to update.
- `flag` (*`str`*) – The destination flag.

`msnoise.api.is_next_job`(*session, flag='T', jobtype='CC'*)

Are there any `Job` in the database, with flag='flag' and jobtype='type'

Parameters

- `session` (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- `jobtype` (*str*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `flag` (*str*) – Status of the Job: "T"odo, "I"n Progress, "D"one.

Return type bool

Returns True if at least one `Job` matches, False otherwise.

`msnoise.api.get_next_job(`*session*, *flag='T'*, *jobtype='CC'*`)`

Get the next `Job` in the database, with flag='flag' and jobtype='jobtype'. Jobs of the same *type* are grouped per day. This function also sets the flag of all selected Jobs to "I"n progress.

Parameters

- `session` (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- `jobtype` (*str*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `flag` (*str*) – Status of the Job: "T"odo, "I"n Progress, "D"one.

Return type list

Returns list of `Job`

`msnoise.api.is_dtt_next_job(`*session*, *flag='T'*, *jobtype='DTT'*, *ref=False*`)`

Are there any DTT `Job` in the database, with flag='flag' and jobtype='jobtype'. If *ref* is provided, checks if a DTT "REF" job is present.

Parameters

- `session` (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- `jobtype` (*str*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `flag` (*str*) – Status of the Job: "T"odo, "I"n Progress, "D"one.
- `ref` (*bool*) – Whether to check for a REF job (True) or not (False, default)

Return type bool

Returns True if at least one Job matches, False otherwise.

`msnoise.api.get_dtt_next_job(`*session*, *flag='T'*, *jobtype='DTT'*`)`

Get the next DTT `Job` in the database, with flag='flag' and jobtype='jobtype'. Jobs are then grouped per station pair. This function also sets the flag of all selected Jobs to "I"n progress.

Parameters

- `session` (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- `jobtype` (*str*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `flag` (*str*) – Status of the Job: "T"odo, "I"n Progress, "D"one.

Return type tuple

Returns (pairs, days, refs): List of station pair names - Days of the next DTT jobs - Job IDs (for later being able to update their flag).

`msnoise.api.reset_jobs(`*session*, *jobtype*, *alljobs=False*, *rule=None*`)`

Sets the flag of all *jobtype* Jobs to "T"odo.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)
- `jobtype` (*`str`*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `alljobs` (*`bool`*) – If True, resets all jobs. If False (default), only resets jobs "I"n progress.

`msnoise.api.reset_dtt_jobs(`*session*, *pair*`)`

Sets the flag of all DTT Jobs of one *pair* to "T"odo.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)
- `pair` (*`str`*) – The pair to update

`msnoise.api.get_job_types(`*session*, *jobtype='CC'*`)`

Count the number of Jobs of a specific *type*, grouped by *flag*.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)
- `jobtype` (*`str`*) – CrossCorrelation (CC) or dt/t (DTT) Job?

Return type list

Returns list of [count, flag] pairs

`msnoise.api.get_jobs_by_lastmod(`*session*, *jobtype='CC'*, *lastmod=datetime.datetime(2019, 9, 3, 16, 18, 56, 303960)*`)`

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)
- `jobtype` (*`str`*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `lastmod` (*`datetime.datetime`*) – Jobs' modification time

Return type list

Returns list of Job objects.

`msnoise.api.export_allcorr(`*session*, *ccfid*, *data*`)`

`msnoise.api.export_allcorr2(`*session*, *ccfid*, *data*`)`

`msnoise.api.add_corr(`*session*, *station1*, *station2*, *filterid*, *date*, *time*, *duration*, *components*, *CF*, *sampling_rate*, *day=False*, *ncorr=0*, *params=None*`)`

Adds a CCF to the data archive on disk.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *connect()* (page 66)
- `station1` (*str*) – The name of station 1 (formatted NET.STA)
- `station2` (*str*) – The name of station 2 (formatted NET.STA)
- `filterid` (*int*) – The ID (ref) of the filter
- `date` (*datetime.date or str*) – The date of the CCF
- `time` (*datetime.time or str*) – The time of the CCF
- `duration` (*float*) – The total duration of the exported CCF
- `components` (*str*) – The name of the components used (ZZ, ZR, ...)
- `sampling_rate` (*float*) – The sampling rate of the exported CCF
- `day` (*bool*) – Whether this function is called to export a daily stack (True) or each CCF (when keep_all parameter is set to True in the configuration). Defaults to True.
- `ncorr` (*int*) – Number of CCF that have been stacked for this CCF.
- `params` (*dict*) – A dictionnary of MSNoise config parameters as returned by *get_params()* (page 68).

`msnoise.api.export_sac`(*db, filename, pair, components, filterid, corr, ncorr=0, sac_format=None, maxlag=None, cc_sampling_rate=None, params=None*)

`msnoise.api.export_mseed`(*db, filename, pair, components, filterid, corr, ncorr=0, maxlag=None, cc_sampling_rate=None, params=None*)

`msnoise.api.stack`(*data, stack_method='linear', pws_timegate=10.0, pws_power=2, goal_sampling_rate=20.0*)

Parameters

- `data` (`numpy.ndarray`) – the data to stack, each row being one CCF
- `stack_method` (*str*) – either `linear`: average of all CCF or `pws` to compute the phase weigthed stack. If `pws` is selected, the function expects the `pws_timegate` and `pws_power`.
- `pws_timegate` (*float*) – PWS time gate in seconds. Width of the smoothing window to convolve with the PWS spectrum.
- `pws_power` (*float*) – Power of the PWS weights to be applied to the CCF stack.
- `goal_sampling_rate` (*float*) – Sampling rate of the CCF array submitted

Return type `numpy.array`

Returns the stacked CCF.

`msnoise.api.get_results`(*session, station1, station2, filterid, components, dates, mov_stack=1, format='stack', params=None*)

Parameters

- **session** (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- **station1** (*str*) – The name of station 1 (formatted NET_STA)
- **station2** (*str*) – The name of station 2 (formatted NET_STA)
- **filterid** (*int*) – The ID (ref) of the filter
- **components** (*str*) – The name of the components used (ZZ, ZR, ...)
- **dates** (*list*) – List of TODO datetime.datetime
- **mov_stack** (*int*) – Moving window stack.
- **format** (*str*) – Either `stack`: the data will be stacked according to the parameters passed with `params` or `matrix`: to get a 2D array of CCF.
- **params** (*dict*) – A dictionnary of MSNoise config parameters as returned by *get_params()* (page 68).

Return type numpy.ndarray

Returns Either a 1D CCF (if format is `stack` or a 2D array (if format= `matrix`).

`msnoise.api.get_results_all(`*session*, *station1*, *station2*, *filterid*, *components*, *dates*`)`

Parameters

- **session** (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)
- **station1** (*str*) – The name of station 1 (formatted NET_STA)
- **station2** (*str*) – The name of station 2 (formatted NET_STA)
- **filterid** (*int*) – The ID (ref) of the filter
- **components** (*str*) – The name of the components used (ZZ, ZR, ...)
- **dates** (*list*) – List of TODO datetime.datetime

Return type pandas.DataFrame

Returns All CCF results in a pandas.DataFrame, where the index is the time of the CCF and the columns are the times in the coda.

`msnoise.api.get_maxlag_samples(`*session*`)`

Returns the length of the CC functions. Gets the maxlag and sampling rate from the database.

Parameters **session** (sqlalchemy.orm.session.Session) – A Session object, as obtained by *connect()* (page 66)

Return type int

Returns the length of the CCF in samples

`msnoise.api.get_t_axis(`*session*`)`

Returns the time axis (in seconds) of the CC functions. Gets the maxlag from the database and uses *get_maxlag_samples* function.

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)

Return type `numpy.array`

Returns the time axis in seconds

`msnoise.api.get_components_to_compute`(*session*, *plugin=None*)
Returns the components configured in the database.

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)

Return type list of str

Returns a list of components to compute

`msnoise.api.get_components_to_compute_single_station`(*session*, *plugin=None*)
Returns the components configured in the database.

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)

Return type list of str

Returns a list of components to compute

`msnoise.api.build_ref_datelist`(*session*)
Creates a date array for the REF. The returned tuple contains a start and an end date, and a list of individual dates between the two.

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)

Return type tuple

Returns (start, end, datelist)

`msnoise.api.build_movstack_datelist`(*session*)
Creates a date array for the analyse period. The returned tuple contains a start and an end date, and a list of individual dates between the two.

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)

Return type tuple

Returns (start, end, datelist)

`msnoise.api.updated_days_for_dates`(*session*, *date1*, *date2*, *pair*, *jobtype='CC'*, *interval=datetime.timedelta(days=1)*, *returndays=False*)
Determines if any Job of jobtype='jobtype' and for pair='pair', concerning a date between *date1* and *date2* has been modified in the last interval='interval'.

Parameters

- `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by *`connect()`* (page 66)
- `date1` (*`datetime.datetime`*) – Beginning of the period of interest
- `date2` (*`datetime.datetime`*) – End of the period of interest

- `pair` (*str*) – Pair of interest
- `jobtype` (*str*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `interval` (*datetime.timedelta*) – Interval of time before now to search for updated days
- `returndays` (*bool*) – Whether to return a list of days (True) or not (False, default)

Return type list or bool

Returns List of days if returndays is True, only "True" if not. (not clear!)

`msnoise.api.azimuth(`*coordinates, x0, y0, x1, y1*`)`
Returns the azimuth between two coordinate sets.

Parameters

- `coordinates` (*str*) – {'DEG', 'UTM', 'MIX'}
- `x0` (*float*) – X coordinate of station 1
- `y0` (*float*) – Y coordinate of station 1
- `x1` (*float*) – X coordinate of station 2
- `y1` (*float*) – Y coordinate of station 2

Return type float

Returns The azimuth in degrees

`msnoise.api.nextpow2(`*x*`)`
Returns the next power of 2 of *x*.

Parameters `x` (*int*) – any value

Return type int

Returns the next power of 2 of *x*

`msnoise.api.check_and_phase_shift(`*trace, taper_length=20.0*`)`

`msnoise.api.getGaps(`*stream, min_gap=None, max_gap=None*`)`

`msnoise.api.make_same_length(`*st*`)`
This function takes a stream of equal sampling rate and makes sure that all channels have the same length and the same gaps.

`msnoise.api.clean_scipy_cache()`
This functions wraps all destroy scipy cache at once. It is a workaround to the memory leak induced by the "caching" functions in scipy fft.

`msnoise.api.preload_instrument_responses(`*session*`)`
This function preloads all instrument responses from `response_format` and stores the seed ids, start and end dates, and paz for every channel in a DataFrame.

> **Warning:** This function only works for `response_format` being "inventory" or "dataless".

Parameters `session` (`sqlalchemy.orm.session.Session`) – A `Session` object, as obtained by `connect()` (page 66)

Return type pandas.DataFrame

Returns A table containing all channels with the time of operation and poles and zeros.

4.4 Core Functions

`msnoise.move2obspy.myCorr(`*data*, *maxlag*, *plot=False*, *nfft=None*`)`

This function takes ndimensional *data* array, computes the cross-correlation in the frequency domain and returns the cross-correlation function between [-*maxlag*:*maxlag*].

Parameters

- `data` (`numpy.ndarray`) – This array contains the fft of each timeseries to be cross-correlated.
- `maxlag` (*int*) – This number defines the number of samples (N=2*maxlag + 1) of the CCF that will be returned.

Return type `numpy.ndarray`

Returns The cross-correlation function between [-maxlag:maxlag]

`msnoise.move2obspy.myCorr2(`*data*, *maxlag*, *energy*, *index*, *plot=False*, *nfft=None*, *normalized=False*`)`

This function takes ndimensional *data* array, computes the cross-correlation in the frequency domain and returns the cross-correlation function between [-*maxlag*:*maxlag*].

Parameters

- `data` (`numpy.ndarray`) – This array contains the fft of each timeseries to be cross-correlated.
- `maxlag` (*int*) – This number defines the number of samples (N=2*maxlag + 1) of the CCF that will be returned.

Return type `numpy.ndarray`

Returns The cross-correlation function between [-maxlag:maxlag]

`msnoise.move2obspy.pcc_xcorr(`*data*, *maxlag*, *energy*, *index*, *plot=False*, *nfft=None*, *normalized=False*`)`

Parameters

- `data` –
- `maxlag` –
- `energy` –
- `index` –
- `plot` –
- `nfft` –
- `normalized` –

Returns

`msnoise.move2obspy.whiten(`*data*, *Nfft*, *delta*, *freqmin*, *freqmax*, *plot=False*`)`

This function takes 1-dimensional *data* timeseries array, goes to frequency domain using fft, whitens the amplitude of the spectrum in frequency domain between *freqmin* and *freqmax* and returns the whitened fft.

Parameters

- `data` (`numpy.ndarray`) – Contains the 1D time series to whiten
- `Nfft` (*int*) – The number of points to compute the FFT
- `delta` (*float*) – The sampling frequency of the *data*
- `freqmin` (*float*) – The lower frequency bound
- `freqmax` (*float*) – The upper frequency bound
- `plot` (*bool*) – Whether to show a raw plot of the action (default: False)

Return type `numpy.ndarray`

Returns The FFT of the input trace, whitened between the frequency bounds

`msnoise.move2obspy.whiten2(`*fft*, *Nfft*, *low*, *high*, *porte1*, *porte2*, *psds*, *whiten_type*`)`

This function takes 1-dimensional *data* timeseries array, goes to frequency domain using fft, whitens the amplitude of the spectrum in frequency domain between *freqmin* and *freqmax* and returns the whitened fft.

Parameters

- `data` (`numpy.ndarray`) – Contains the 1D time series to whiten
- `Nfft` (*int*) – The number of points to compute the FFT
- `delta` (*float*) – The sampling frequency of the *data*
- `freqmin` (*float*) – The lower frequency bound
- `freqmax` (*float*) – The upper frequency bound
- `plot` (*bool*) – Whether to show a raw plot of the action (default: False)

Return type `numpy.ndarray`

Returns The FFT of the input trace, whitened between the frequency bounds

`msnoise.move2obspy.smooth(`*x*, *window='boxcar'*, *half_win=3*`)`

some window smoothing

`msnoise.move2obspy.getCoherence(`*dcs*, *ds1*, *ds2*`)`

`msnoise.move2obspy.mwcs(`*current*, *reference*, *freqmin*, *freqmax*, *df*, *tmin*, *window_length*, *step*, *smoothing_half_win=5*`)`

The *current* time series is compared to the *reference*. Both time series are sliced in several overlapping windows. Each slice is mean-adjusted and cosine-tapered (85% taper) before being Fourier- transformed to the frequency domain. $F_{cur}(\nu)$ and $F_{ref}(\nu)$ are the first halves of the Hermitian symmetric Fourier-transformed segments. The cross-spectrum $X(\nu)$ is defined as $X(\nu) = F_{ref}(\nu)F_{cur}^{*}(\nu)$

in which * denotes the complex conjugation. $X(\nu)$ is then smoothed by convolution with a Hanning window. The similarity of the two time-series is assessed using the cross-coherency between energy densities in the frequency domain:

$$C(\nu) = \frac{|\overline{X(\nu))}|}{\sqrt{|\overline{F_{ref}(\nu)|^2}|\overline{F_{cur}(\nu)|^2}}}$$

in which the over-line here represents the smoothing of the energy spectra for F_{ref} and F_{cur} and of the spectrum of X. The mean coherence for the segment is defined as the mean of $C(\nu)$ in the frequency range of interest. The time-delay between the two cross correlations is found in the unwrapped phase, $\phi(u)$, of the cross spectrum and is linearly proportional to frequency:

$$\phi_j = m.u_j, m = 2\pi\delta t$$

The time shift for each window between two signals is the slope m of a weighted linear regression of the samples within the frequency band of interest. The weights are those introduced by [Clarke2011], which incorporate both the cross-spectral amplitude and cross-coherence, unlike [Poupinet1984]. The errors are estimated using the weights (thus the coherence) and the squared misfit to the modelled slope:

$$e_m = \sqrt{\sum_j(\frac{w_j\nu_j}{\sum_i w_i\nu_i^2})^2\sigma_\phi^2}$$

where w are weights, ν are cross-coherences and σ_ϕ^2 is the squared misfit of the data to the modelled slope and is calculated as $\sigma_\phi^2 = \frac{\sum_j(\phi_j - m\nu_j)^2}{N-1}$

The output of this process is a table containing, for each moving window: the central time lag, the measured delay, its error and the mean coherence of the segment.

Warning: The time series will not be filtered before computing the cross-spectrum! They should be band-pass filtered around the *freqmin-freqmax* band of interest beforehand.

Parameters

- `current` (numpy.ndarray) – The "Current" timeseries
- `reference` (numpy.ndarray) – The "Reference" timeseries
- `freqmin` (*float*) – The lower frequency bound to compute the dephasing (in Hz)
- `freqmax` (*float*) – The higher frequency bound to compute the dephasing (in Hz)
- `df` (*float*) – The sampling rate of the input timeseries (in Hz)
- `tmin` (*float*) – The leftmost time lag (used to compute the "time lags array")
- `window_length` (*float*) – The moving window length (in seconds)
- `step` (*float*) – The step to jump for the moving window (in seconds)
- `smoothing_half_win` (*int*) – If different from 0, defines the half length of the smoothing hanning window.

Return type numpy.ndarray

Returns [time_axis,delta_t,delta_err,delta_mcoh]. time_axis contains the central times of the windows. The three other columns contain dt, error and mean coherence for each window.

4.5 Extending MSNoise with Plugins

New in version 1.4.

Starting with releasenotes/msnoise-1.4, MSNoise supports Plugins, this means the default workflow "from archive to dv/v" can be branched at any step!

4.5.1 What is a Plugin and how to declare it in MSNoise

A plugin is a python package, properly structured, that can be imported from msnoise, i.e. it has to be "installed" like any other python package.

After installing a plugin, its **package name** must be declared in the `plugins` parameter in the configuration. This must be done **PER PROJECT**. This configuration field supports a list of plugins, separated by a simple comma (!no space), e.g. `msnoise_amazing,msnoise_plugin101`.

Once configured in a project, the plugin should appear when calling the `msnoise plugin` command:

```
$ msnoise plugin

  Usage: msnoise-script.py plugin [OPTIONS] COMMAND [ARGS]...

  Runs a command in a named plugin

Options:
  --help  Show this message and exit.

Commands:
  amazing  Example Amazing Plugin for MSNoise
```

4.5.2 Plugin minimal structure

A plugin is a python package, so its minimal structure is:

```
msnoise-amazingplugin
 __init__.py
 setup.py
 msnoise_amazingplugin
     __init__.py
     plugin_definition.py
```

The `setup.py` declares where the plugin actually hooks into MSNoise:

```
from setuptools import setup, find_packages

setup(
    name='msnoise_amazing',
    version='0.1a',
    packages=find_packages(),
    include_package_data=True,
    install_requires=['msnoise',
                      'obspy'],
    entry_points = {
        'msnoise.plugins.commands': [
            'amazing = msnoise_amazing.plugin_definition:amazing',
            ],
        },
    author = "Thomas Lecocq & MSNoise dev team",
    author_email = "Thomas.Lecocq@seismology.be",
    description = "An example plugin",
    license = "EUPL-1.1",
    url = "http://www.msnoise.org",
    keywords="amazing seismology"
)
```

The most important line of this file is the one declaring the `amazing` entry point in `msnoise.plugins.commands` and linking it to the plugin's `plugin_definition.py` file.

The content of `plugin_definition.py` must then provide at least one `click.Command`, or more commonly, one `click.Group` and many `click.Command`.

```
import click

@click.group()
def amazing():
    """Example Amazing Plugin for MSNoise"""
    pass

@click.command()
def sayhi():
    """A Very Polite Command"""
    print("Hi")

amazing.add_command(sayhi)
```

This way, once properly installed and activated (declared in the `plugins` config), the plugin will be callable from msnoise:

```
$ msnoise plugin amazing
```

(continues on next page)

(continued from previous page)

```
  Usage: msnoise-script.py plugin amazing [OPTIONS] COMMAND [ARGS]...

  Example Amazing Plugin for MSNoise

Options:
  --help  Show this message and exit.

Commands:
  sayhi  A Very Polite Command
```

and its command too:

```
$ msnoise plugin amazing sayhi

Hi
```

Amazing, isn't it ?

4.5.3 Declaring Job Types - Hooking

Plugin-based job types are defined by providing a `register_job_types` method in `plugin_definition.py`. A new job type is defined with two parameters:

- `name`: the actual job name (acronym style) used all over (example: CC2, TEST)
- `after`: when is this job added to the database.

Current supported "after" are:

- `new_files`: will be created when running the `new_jobs` command and will create a job with those parameters (nf is a new file identified in the scan_archive procedure). In this specific case, the `pair` field of the job will only be NET.STA, not a "pair". A job will only be inserted if the station is "Used" in the configuration.

```
all_jobs.append({"day": current_date, "pair": "%s.%s"%(nf.net,nf.sta),
                 "jobtype": jobtype, "flag": "T",
                 "lastmod": datetime.datetime.utcnow()})
```

- `scan_archive`: will be created when running the `new_jobs` command, in parallel to `CC` jobs. This is, for example, useful when one wants to compute relative amplitude ratios between station pairs. In this case, the `pair` field of the job is set to the pair name.
- `refstack`: will be created when running the `stack` command and when a new REF stack needed to be calculated. This is, for example, useful when one wants to work on the REF stacks using a Ambient Seismic Noise Tomography code.

Plugin's Job Types are first declared in `setup.py` (in Entry Points):

```
'msnoise.plugins.jobtypes': [
'register = msnoise_amazing.plugin_definition:register_job_types',
],
```

```
def register_job_types():
    jobtypes = []
```

(continues on next page)

(continued from previous page)

```
    jobtypes.append( {"name":"AMAZ1", "after":"new_files"} )
    return jobtypes
```

Then, adding a `compute` command to the `plugin_definition.py`:

```
@click.command()
def compute():
    """Compute an Amazing Value"""
    from .compute import main()
    main()

amazing.add_command(compute)
```

and creating a `compute.py` file in the plugin folder:

```
import os
from obspy.core import UTCDateTime, read

from msnoise.api import connect, is_next_job, get_next_job, \
    get_data_availability, get_config, update_job

def main():
    db = connect()
    while is_next_job(db, jobtype='AMAZ1'):
        jobs = get_next_job(db, jobtype='AMAZ1')
        for job in jobs:
            net, sta = job.pair.split('.')
            gd = UTCDateTime(job.day).datetime
            print("Processing %s.%s for day %s"%(net,sta, job.day))
            files = get_data_availability(
                    db, net=net, sta=sta, starttime=gd, endtime=gd,
                    comp="Z")
            for file in files:
                fn = os.path.join(file.path, file.file)
                st = read(fn, starttime=UTCDateTime(job.day), endtime=UTCDateTime(job.
↪day)+86400)
                print(st)
```

Aaaand:

```
$ msnoise plugin amazing compute

Processing YA.UV05 for day 2010-09-01
1 Trace(s) in Stream:
YA.UV05.00.HHZ | 2010-09-01T00:00:00.000000Z - 2010-09-01T23:59:59.990000Z | 100.0 Hz,␣
↪8640000 samples
Processing YA.UV06 for day 2010-09-01
1 Trace(s) in Stream:
YA.UV06.00.HHZ | 2010-09-01T00:00:00.000000Z - 2010-09-01T23:59:59.990000Z | 100.0 Hz,␣
↪8640000 samples
Processing YA.UV10 for day 2010-09-01
1 Trace(s) in Stream:
YA.UV10.00.HHZ | 2010-09-01T00:00:00.000000Z - 2010-09-01T23:59:59.990000Z | 100.0 Hz,␣
↪8640000 samples
```

Provided you have reset the DataAvailability rows with a "M" or "N" flag so that when you ran `new_jobs` it actually inserted the `AMAZ1` jobs !

Because job-based stuff always requires a lot of trial-and-error, remember that the `msnoise reset` command is your best friend. In this example, we would need to `msnoise reset AMAZ1` to reset "I"n Progress jobs, or `msnoise reset AMAZ1 --all` to reset all `AMAZ1` jobs to "T"o Do.

Note:

- Currently, not all MSNoise workflow steps use the `is_next_job` - `get_next_job` logic, but it'll be the case for MSNoise 1.5
- Only three hooks are currently present, of course, more will be added in in the future.

4.5.4 Plugin's own config table

Plugins can create a new table in the database, e.g. in an `install` command. First, a `amazing_table_def.py` table definition file must be created:

```
# Table definitions for Amazing
from sqlalchemy import Column, String
from sqlalchemy.ext.declarative import declarative_base

Base = declarative_base()


class AmazingConfig(Base):
    """
    Config Object

    :type name: str
    :param name: The name of the config bit to set.

    :type value: str
    :param value: The value of parameter `name`
    """
    __tablename__ = "amazing-config"
    name = Column(String(255), primary_key=True)
    value = Column(String(255))

    def __init__(self, name, value):
        """"""
        self.name = name
        self.value = value
```

and a `default.py` file containing the parameters names, explanation and default value:

```
from collections import OrderedDict
default = OrderedDict()

default['parameter1'] = ["Some really useful text",'1']
default['parameter2'] = ["Some really useful text",'1']
default['parameter3'] = ["Some really useful text",'1']
default['parameter4'] = ["Some really useful text",'1']
```

(continues on next page)

(continued from previous page)

```
default['question1'] = ["Is this a useful text [Y]/N",'Y']
```

Then, the `install.py` file contains the method to add this table to the database:

```
from msnoise.api import *

from .amazing_table_def import AmazingConfig
from .default import default

def main():
    engine = get_engine()
    Session = sessionmaker(bind=engine)
    session = Session()

    AmazingConfig.__table__.create(bind=engine, checkfirst=True)
    for name in default.keys():
        session.add(AmazingConfig(name=name,value=default[name][-1]))

    session.commit()
```

then add the command to the `plugin_definition.py`:

```
@click.command()
def install():
    """ Create the Config table"""
    from .install import main
    main()

amazing.add_command(install)
```

When all this is prepared, running the `msnoise plugin amazing install` command will connect to the current database, create the *amazing-config* table and add the parameters names and their default value.

An entry point to the `setup.py` file has to be defined in order to access Plugin's config tables via the msnoise api *`msnoise.api.get_config()`* (page 67) method:

```
'msnoise.plugins.table_def': [
        'AmazingConfig = msnoise_amazing.amazing_table_def:AmazingConfig',
    ],
```

Then, running a simple python command:

```
from msnoise.api import connect, get_config

db = connect()
print(get_config(db, "parameter1", plugin="Amazing"))
print(get_config(db, "parameter2", plugin="Amazing"))
print(get_config(db, "parameter3", plugin="Amazing"))
print(get_config(db, "parameter4", plugin="Amazing"))
print(get_config(db, "question1", plugin="Amazing", isbool=True))
```

should print:

```
1
1
1
1
True
```

4.5.5 Adding Web Admin Pages

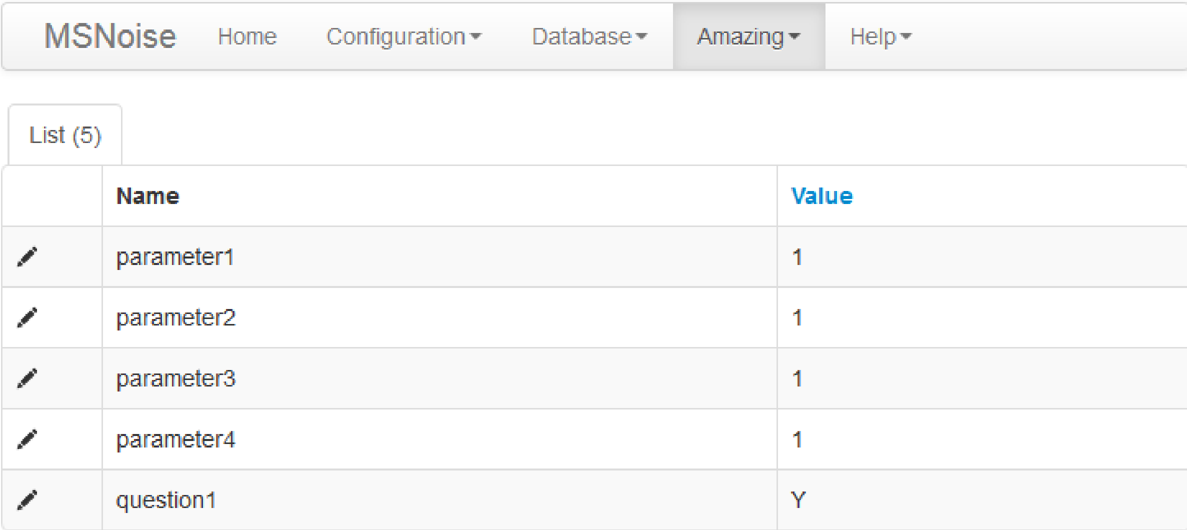
Plugins can also declare new pages to the Web Admin ! This is simply done by, againg, declaring some entry points in `setup.py`:

```
'msnoise.plugins.admin_view': [
        'AmazingConfigView = msnoise_amazing.plugin_definition:AmazingConfigView',
        ],
```

and the corresponding object in `plugin_definition.py`:

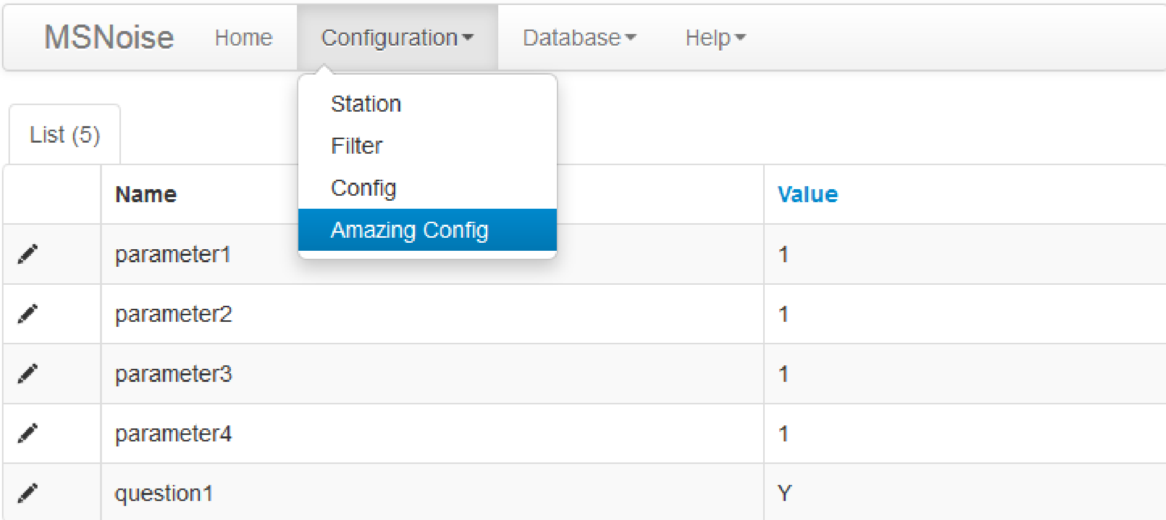
```
from flask.ext.admin.contrib.sqla import ModelView
from .amazing_table_def import AmazingConfig


class AmazingConfigView(ModelView):
    # Disable model creation
    view_title = "MSNoise Amazing Configuration"
    name = "Configuration"

    can_create = False
    can_delete = False
    page_size = 50
    # Override displayed fields
    column_list = ('name', 'value')

    def __init__(self, session, **kwargs):
        # You can pass name and other parameters if you want to
        super(AmazingConfigView, self).__init__(AmazingConfig, session,
                                                endpoint="amazingconfig",
                                                name="Config",
                                                category="Amazing", **kwargs)
```

Then (as always, after re-developing/installing the package), the magic occurs:



Or, changing the last 4 lines of the previous code to:

```
super(AmazingConfigView, self).__init__(AmazingConfig, session,
                                        endpoint="amazingconfig",
                                        name="Amazing Config",
                                        category="Configuration", **kwargs)
```



4.5.6 Uninstalling Plugins

Plugins can be de-activated by removing their package name from the `plugins` configuration parameter. Ideally, plugins should provide an `uninstall` command similar to the `install` to take care of deleting/dropping the tables in the project database.

4.5.7 Download Amazing Plugin

That's cheating, you know ? :-)

Download the Amazing Plugin

4.6 Help on the msnoise commands

This page shows all the command line interface commands

4.6.1 msnoise admin

```
msnoise admin --help

Usage:  [OPTIONS]

  Starts the Web Admin on http://localhost:5000 by default

Options:
  -p, --port INTEGER  Port to open
  --help              Show this message and exit.
```

4.6.2 msnoise bugreport

```
msnoise bugreport --help

Usage:  [OPTIONS]

  This command launches the Bug Report script.

Options:
  -s, --sys      System Info
  -m, --modules  Modules Info
  -e, --env      Environment Info
  -a, --all      All Info
  --help         Show this message and exit.
```

4.6.3 msnoise compute_cc

```
msnoise compute_cc --help

Usage:  [OPTIONS]

  Computes the CC jobs (based on the "New Jobs" identified)

Options:
  --help  Show this message and exit.
```

4.6.4 msnoise compute_cc_rot

```
msnoise compute_cc_rot --help

Usage:  [OPTIONS]

  Computes the CC jobs (based on the "New Jobs" identified)
```

(continues on next page)

(continued from previous page)

```
Options:
  --help  Show this message and exit.
```

4.6.5 msnoise compute_dtt

```
msnoise compute_dtt --help

Usage:  [OPTIONS]

  Computes the dt/t jobs based on the new MWCS data

Options:
  -i, --interval FLOAT  Number of days before now to search for modified Jobs
  --help                Show this message and exit.
```

4.6.6 msnoise compute_mwcs

```
msnoise compute_mwcs --help

Usage:  [OPTIONS]

  Computes the MWCS jobs

Options:
  --help  Show this message and exit.
```

4.6.7 msnoise compute_stretching

```
msnoise compute_stretching --help

Usage:  [OPTIONS]

  [experimental] Computes the stretching based on the new stacked data

Options:
  --help  Show this message and exit.
```

4.6.8 msnoise config

msnoise config get

```
msnoise config get --help

Usage:  [OPTIONS] [NAMES]...
```

(continues on next page)

(continued from previous page)

```
  Display the value of the given configuration variable(s).

Options:
  --help  Show this message and exit.
```

msnoise config gui

```
msnoise config gui --help

Usage:  [OPTIONS]

  Run the deprecated configuration GUI tool.  Please use the configuration
  web interface using 'msnoise admin' instead.

Options:
  --help  Show this message and exit.
```

msnoise config set

```
msnoise config set --help

Usage:  [OPTIONS] NAME_VALUE

  Set a configuration value. The argument should be of the form
  'variable=value'.

Options:
  --help  Show this message and exit.
```

msnoise config sync

```
msnoise config sync --help

Usage:  [OPTIONS]

  Synchronise station metadata from inventory/dataless.

Options:
  --help  Show this message and exit.
```

4.6.9 msnoise db

msnoise db clean_duplicates

```
msnoise db clean_duplicates --help

Usage:  [OPTIONS]

  Checks the Jobs table and deletes duplicate entries

Options:
  --help  Show this message and exit.
```

msnoise db dump

```
msnoise db dump --help

Usage:  [OPTIONS]

  Dumps the complete database in a formatted structure.

Options:
  --format TEXT
  --help         Show this message and exit.
```

msnoise db execute

```
msnoise db execute --help

Usage:  [OPTIONS] SQL_COMMAND

  EXPERT MODE: Executes 'sql_command' on the database. Use this command at
  your own risk!!

Options:
  --help  Show this message and exit.
```

msnoise db import

```
msnoise db import --help

Usage:  [OPTIONS] TABLE

  Imports msnoise tables from formatted files (csv).

Options:
  --format TEXT
  --force
  --help         Show this message and exit.
```

msnoise db init

```
msnoise db init --help

Usage:  [OPTIONS]

  This command initializes the current folder to be a MSNoise Project by
  creating a database and a db.ini file.

Options:
  --tech TEXT  Database technology: 1=SQLite 2=MySQL
  --help       Show this message and exit.
```

msnoise db upgrade

```
msnoise db upgrade --help

Usage:  [OPTIONS]

  Upgrade the database from previous to a new version.

  This procedure adds new parameters with their default value in the config
  database.

Options:
  --help  Show this message and exit.
```

4.6.10 msnoise info

```
msnoise info --help

Usage:  [OPTIONS]

  Outputs general information about the current install and config, plus
  information about jobs and their status.

Options:
  -j, --jobs  Jobs Info only
  --help      Show this message and exit.
```

4.6.11 msnoise install

```
msnoise install --help

Usage:  [OPTIONS]

  DEPRECATED: since MSNoise 1.6, please use "msnoise db init" instead

Options:
  --help  Show this message and exit.
```

4.6.12 msnoise jupyter

```
msnoise jupyter --help

Usage:  [OPTIONS]

  Launches an jupyter notebook in the current folder

Options:
  --help  Show this message and exit.
```

4.6.13 msnoise new_jobs

```
msnoise new_jobs --help

Usage:  [OPTIONS]

  Determines if new CC jobs are to be defined

Options:
  -i, --init  First run ? This disables the check for existing jobs.
  --nocc      Disable the creation of CC jobs.
  --hpc TEXT  Format PREVIOUS:NEXT. When running on HPC, create the next jobs
              in the workflow based on theprevious step mentioned here.
              Example:"msnoise new_jobs --hpc CC:STACK" will create STACK jobs
              based on CC jobs marked "D"one.
  --help      Show this message and exit.
```

4.6.14 msnoise p

Will be automatically populated with the commands declared by the plugins (*p* is an alias for *plugin*)

4.6.15 msnoise plot

msnoise plot ccftime

```
msnoise plot ccftime --help

Usage:  [OPTIONS] STA1 STA2 [EXTRA_ARGS]...

  Plots the ccf vs time between sta1 and sta2

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
```

(continues on next page)

(continued from previous page)

```
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -a, --ampli FLOAT        Amplification
  -S, --seismic            Seismic style
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  -e, --envelope           Plot envelope instead of time series
  -r, --refilter TEXT      Refilter CCFs before plotting (e.g. 4:8 for
                           filtering CCFs between 4.0 and 8.0 Hz. This will
                           update the plot title.
  --normalize TEXT
  --help                   Show this message and exit.
```

msnoise plot data_availability

```
msnoise plot data_availability --help

Usage:  [OPTIONS]

  Plots the Data Availability vs time

Options:
  -s, --show BOOLEAN  Show interactively?
  -o, --outfile TEXT  Output filename (?=auto)
  --help              Show this message and exit.
```

msnoise plot distance

```
msnoise plot distance --help

Usage:  [OPTIONS] [EXTRA_ARGS]...

  Plots the REFs of all pairs vs distance

Options:
  -f, --filterid INTEGER  Filter ID
  -c, --comp TEXT         Components (ZZ, ZR,...)
  -a, --ampli FLOAT       Amplification
  -s, --show BOOLEAN      Show interactively?
  -o, --outfile TEXT      Output filename (?=auto)
  -r, --refilter TEXT     Refilter CCFs before plotting (e.g. 4:8 for
                          filtering CCFs between 4.0 and 8.0 Hz. This will
                          update the plot title.
  --virtual-source TEXT   Use only pairs including this station. Format must
                          be NET.STA
  --help                  Show this message and exit.
```

msnoise plot dtt

```
msnoise plot dtt --help

Usage:  [OPTIONS] STA1 STA2 DAY

  Plots a graph of dt against t

  STA1 and STA2 must be provided with this format: NET.STA !

  DAY must be provided in the ISO format: YYYY-MM-DD

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

msnoise plot dvv

```
msnoise plot dvv --help

Usage:  [OPTIONS]

  Plots the dv/v (parses the dt/t results)

  Individual pairs can be plotted extra using the -p flag one or more times.

  Example: msnoise plot dvv -p ID_KWUI_ID_POSI

  Example: msnoise plot dvv -p ID_KWUI_ID_POSI -p ID_KWUI_ID_TRWI

  Remember to order stations alphabetically !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Plot specific mov stacks
  -p, --pair TEXT          Plot a specific pair
  -A, --all                Show the ALL line?
  -M, --dttname TEXT       Plot M or M0?
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

msnoise plot interferogram

```
msnoise plot interferogram --help

Usage:  [OPTIONS] STA1 STA2 [EXTRA_ARGS]...

  Plots the interferogram between sta1 and sta2 (parses the CCFs)

```

(continues on next page)

(continued from previous page)

```
  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  -r, --refilter TEXT      Refilter CCFs before plotting (e.g. 4:8 for
                           filtering CCFs between 4.0 and 8.0 Hz. This will
                           update the plot title.
  --help                   Show this message and exit.
```

msnoise plot mwcs

```
msnoise plot mwcs --help

Usage:  [OPTIONS] STA1 STA2

  Plots the mwcs results between sta1 and sta2 (parses the CCFs)

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

msnoise plot spectime

```
msnoise plot spectime --help

Usage:  [OPTIONS] STA1 STA2 [EXTRA_ARGS]...

  Plots the ccf's spectrum vs time between sta1 and sta2

  STA1 and STA2 must be provided with this format: NET.STA !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Mov Stack to read from disk
  -a, --ampli FLOAT        Amplification
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  -r, --refilter TEXT      Refilter CCFs before plotting (e.g. 4:8 for
                           filtering CCFs between 4.0 and 8.0 Hz. This will
                           update the plot title.
  --help                   Show this message and exit.
```

msnoise plot station_map

```
msnoise plot station_map --help

Usage:  [OPTIONS]

  Plots the station map (very very basic)

Options:
  -s, --show BOOLEAN  Show interactively?
  -o, --outfile TEXT  Output filename (?=auto)
  --help              Show this message and exit.
```

msnoise plot timing

```
msnoise plot timing --help

Usage:  [OPTIONS]

  Plots the timing (parses the dt/t results)

  Individual pairs can be plotted extra using the -p flag one or more times.

  Example: msnoise plot timing -p ID_KWUI_ID_POSI

  Example: msnoise plot timing -p ID_KWUI_ID_POSI -p ID_KWUI_ID_TRWI

  Remember to order stations alphabetically !

Options:
  -f, --filterid INTEGER   Filter ID
  -c, --comp TEXT          Components (ZZ, ZR,...)
  -m, --mov_stack INTEGER  Plot specific mov stacks
  -p, --pair TEXT          Plot a specific pair
  -A, --all                Show the ALL line?
  -M, --dttname TEXT       Plot M or M0?
  -s, --show BOOLEAN       Show interactively?
  -o, --outfile TEXT       Output filename (?=auto)
  --help                   Show this message and exit.
```

4.6.16 msnoise plugin

Will be automatically populated with the commands declared by the plugins (*p* is an alias for *plugin*)

4.6.17 msnoise populate

```
msnoise populate --help

Usage:  [OPTIONS]
```

(continues on next page)

(continued from previous page)

```
  Rapidly scan the archive filenames and find Network/Stations

Options:
  --fromDA  Populates the station table using network and station codes found
            in the data_availability table, overrides the default workflow
            step.
  --help    Show this message and exit.
```

4.6.18 msnoise reset

```
msnoise reset --help

Usage:  [OPTIONS] JOBTYPE

  Resets the job to "T"odo. JOBTYPE is the acronym of the job type. By
  default only resets jobs "I"n progress. --all resets all jobs, whatever
  the flag value. Standard Job Types are CC, STACK, MWCS and DTT, but
  plugins can define their own.

Options:
  -a, --all        Reset all jobs
  -r, --rule TEXT  Reset job that match this SQL rule
  --help           Show this message and exit.
```

4.6.19 msnoise scan_archive

```
msnoise scan_archive --help

Usage:  [OPTIONS]

  Scan the archive and insert into the Data Availability table.

Options:
  -i, --init          First run ?
  --path TEXT         Scan all files in specific folder, overrides the default
                      workflow step.
  -r, --recursively   When scanning a path, walk subfolders automatically ?
  --crondays TEXT     Number of past days to monitor, typically used in cron
                      jobs (overrides the 'crondays' configuration value). Must
                      be a float representing a number of days, or designate
                      weeks, days, and/or hours using the format 'Xw Xd Xh'.
  --help              Show this message and exit.
```

4.6.20 msnoise stack

```
msnoise stack --help

Usage:  [OPTIONS]
```

(continues on next page)

(continued from previous page)

```
  Stacks the [REF] or [MOV] windows. Computes the STACK jobs.

Options:
  -r, --ref   Compute the REF Stack
  -m, --mov   Compute the MOV Stacks
  -s, --step  Compute the STEP Stacks
  --help      Show this message and exit.
```

4.6.21 msnoise test

```
msnoise test --help

Usage:  [OPTIONS]

  Runs the test suite, should be executed in an empty folder!

Options:
  -p, --prefix TEXT  Prefix for tables
  --help             Show this message and exit.
```

4.6.22 msnoise upgrade-db

```
msnoise upgrade-db --help

Usage:  [OPTIONS]

  DEPRECATED: since MSNoise 1.6, please use "msnoise db upgrade" instead

Options:
  --help  Show this message and exit.
```

CHAPTER

FIVE

DEVELOPMENT & MISCELLANEOUS

5.1 Table Definitions

`class msnoise.msnoise_table_def.Filter(**kwargs)`

Filter base class.

Parameters

- `ref` (*int*) – The id of the Filter in the database
- `low` (*float*) – The lower frequency bound of the Whiten function (in Hz)
- `high` (*float*) – The upper frequency bound of the Whiten function (in Hz)
- `mwcs_low` (*float*) – The lower frequency bound of the linear regression done in MWCS (in Hz)
- `mwcs_high` (*float*) – The upper frequency bound of the linear regression done in MWCS (in Hz)
- `rms_threshold` (*float*) – Not used anymore
- `mwcs_wlen` (*float*) – Window length (in seconds) to perform MWCS
- `mwcs_step` (*float*) – Step (in seconds) of the windowing procedure in MWCS
- `used` (*bool*) – Is the filter activated for the processing

Attributes

high

low

mwcs_high

mwcs_low

mwcs_step

mwcs_wlen

ref

rms_threshold

used

`class msnoise.msnoise_table_def.Job(`*day, pair, jobtype, flag, lastmod=datetime.datetime(2019, 9, 3, 14, 18, 56, 296951)*`)`

Job Object

Parameters

- `ref` (*int*) – The Job ID in the database
- `day` (*str*) – The day in YYYY-MM-DD format
- `pair` (*str*) – the name of the pair (EXAMPLE?)
- `jobtype` (*str*) – CrossCorrelation (CC) or dt/t (DTT) Job?
- `flag` (*str*) – Status of the Job: "T"odo, "I"n Progress, "D"one.

Attributes

day

flag

jobtype

lastmod

pair

ref

`class msnoise.msnoise_table_def.Station(`**args*`)`

Station Object

Parameters

- `ref` (*int*) – The Station ID in the database
- `net` (*str*) – The network code of the Station
- `sta` (*str*) – The station code
- `X` (*float*) – The X coordinate of the station
- `Y` (*float*) – The Y coordinate of the station
- `altitude` (*float*) – The altitude of the station
- `coordinates` (*str*) – The coordinates system. "DEG" is WGS84 latitude/ longitude in degrees. "UTM" is expressed in meters.
- `instrument` (*str*) – The instrument code, useful with PAZ correction
- `used` (*bool*) – Whether this station must be used in the computations.

Attributes

X

Y

altitude

coordinates

instrument

net

ref

sta

used

`class msnoise.msnoise_table_def.Config(`*name*, *value*`)`

Config Object

Parameters

- `name` (*str*) – The name of the config bit to set.
- `value` (*str*) – The value of parameter *name*

Attributes

name

value

`class msnoise.msnoise_table_def.DataAvailability(`*net*, *sta*, *comp*, *path*, *file*, *starttime*, *endtime*, *data_duration*, *gaps_duration*, *samplerate*, *flag*`)`

DataAvailability Object

Parameters

- `ref` (*int*) – The Station ID in the database
- `net` (*str*) – The network code of the Station
- `sta` (*str*) – The station code
- `comp` (*str*) – The component (channel)
- `path` (*str*) – The full path to the folder containing the file
- `file` (*str*) – The name of the file
- `starttime` (*datetime*) – Start time of the file
- `endtime` (*datetime*) – End time of the file
- `data_duation` – Cumulative duration of available data in the file
- `gaps_duration` (*float*) – Cumulative duration of gaps in the file
- `samplerate` (*float*) – Sample rate of the data in the file (in Hz)
- `flag` (*str*) – The status of the entry: "N"ew, "M"odified or "A"rchive

Attributes

comp

data_duration

endtime

file

flag

gaps_duration

net

path

ref

samplerate

sta

starttime

5.2 About Databases and Performances

To quote the SQLite website:

> Appropriate Uses For SQLite
>
> SQLite is different from most other SQL database engines in that its primary design goal is to be simple:
>
> - Simple to administer
> - Simple to operate
> - Simple to embed in a larger program
> - Simple to maintain and customize
>
> Many people like SQLite because it is small and fast. But those qualities are just happy accidents. Users also find that SQLite is very reliable. Reliability is a consequence of simplicity. With less complication, there is less to go wrong. So, yes, SQLite is small, fast, and reliable, but first and foremost, SQLite strives to be simple.
>
> Simplicity in a database engine can be either a strength or a weakness, depending on what you are trying to do. In order to achieve simplicity, SQLite has had to sacrifice other characteristics that some people find useful, such as high concurrency, fine-grained access control, a rich set of built-in functions, stored procedures, esoteric SQL language features, XML and/or Java extensions, tera- or peta-byte scalability, and so forth. If you need some of these features and do not mind the added complexity that they bring, then SQLite is probably not the database for you. SQLite is not intended to be an enterprise database engine. It is not designed to compete with Oracle or PostgreSQL.
>
> The basic rule of thumb for when it is appropriate to use SQLite is this: Use SQLite in situations where simplicity of administration, implementation, and maintenance are more important than the countless complex features that enterprise database engines provide. As it turns out, situations where simplicity is the better choice are more common than many people realize.
>
> Another way to look at SQLite is this: SQLite is not designed to replace Oracle. It is designed to replace fopen().

To test MSNoise, one can work with a SQLite database. SQLite communication is supported by default in Python (part of the standard library). The major drawback of SQLite is that it doesn't support high concurrency. In the case of MSNoise, this means that only one Thread (or

Process) can interact with the database "at a time". For small batch tests or small runs, that is OK, but when processing larger archives (years of data of 5+ stations), then the implementation of a MySQL database will allow to process the jobs in parallel.

Note: I have been working on some sort of API server layer above a single SQLite database, working as a Queuing system. The API server is the only client of the database, and exchanges data with the code *via* json HTTP requests. Any help, idea, brainstorming on this is welcome!

5.3 References

5.4 Contributors

The following poeple have contributed to MSNoise (sorted alphabetically):

- Xavier Béguin
- Corentin Caudron
- Clare Donaldson
- Raphaël De Plaen
- Robert Green
- Damiam Kula
- Thomas Lecocq
- Aurélien Mordret
- Lukas E. Preiswerk
- Carmelo Sammarco
- Arnaud Watlet

5.5 Release Notes

The release notes are not converted to PDF, please read them online.

BIBLIOGRAPHY

[Jones2001] • Jones, Eric, Travis Oliphant, Pearu Peterson, et others. 2001. SciPy: Open source scientific tools for Python.

[Oliphant2006] • Oliphant, Travis E. 2006. Guide to NumPy. Provo, UT: Brigham Young University.

[Beyreuther2010] • Beyreuther, Moritz, Robert Barsch, Lion Krischer, Tobias Megies, Yannik Behr, et Joachim Wassermann. 2010. ObsPy: A Python Toolbox for Seismology. *Seismological Research Letters* 81 (3)

[Megies2011] • Megies, Tobias, Moritz Beyreuther, Robert Barsch, Lion Krischer, et Joachim Wassermann. 2011. ObsPy – What Can It Do for Data Centers and Observatories?, *Annals of Geophysics* 54 (1)

[DeCastroLopo2013] • De Castro Lopo, Erik. 2013. Secret Rabbit Code (aka libsamplerate).

[Hunter2007] • Hunter, J.D. 2007. Matplotlib: A 2D Graphics Environment. *Computing in Science Engineering* 9 (3)

[McKinney2012] • McKinney, Wes. 2012. Python for Data Analysis. *O'Reilly Media*.

[Clarke2011] • Clarke, D., Zaccarelli, L., Shapiro, N.M., Brenguier, F., 2011. Assessment of resolution and accuracy of the Moving Window Cross Spectral technique for monitoring crustal temporal variations using ambient seismic noise. *Geophysical Journal International* 186, 867–882. https://doi.org/10.1111/j.1365-246X.2011.05074.x

[Poupinet1984] • Poupinet, G., Ellsworth, W.L., Frechet, J., 1984. Monitoring Velocity Variations in the Crust Using Earthquake Doublets: An Application to the Calaveras Fault, California. *Journal of Geophysical Research* 89, 5719–5731.