

ObsPy: A Python Toolbox for Seismology

Current State, Applications, and Ecosystem
Around it



ObsPy

A Python Framework for Seismology

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and the ObsPy Development Team

June 23rd 2016

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Schedule

Now: Talk

Later & Afternoon: Practical

Schedule

Now: Talk

Motivation and Python in Science

ObsPy

Applications

Community

Later & Afternoon: Practical

Why Does This Matter?

Science requires Tools!



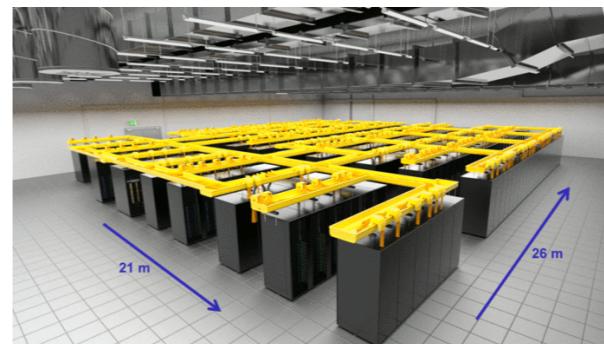
Important in Seismology

Eases Your Life!



Why Python?

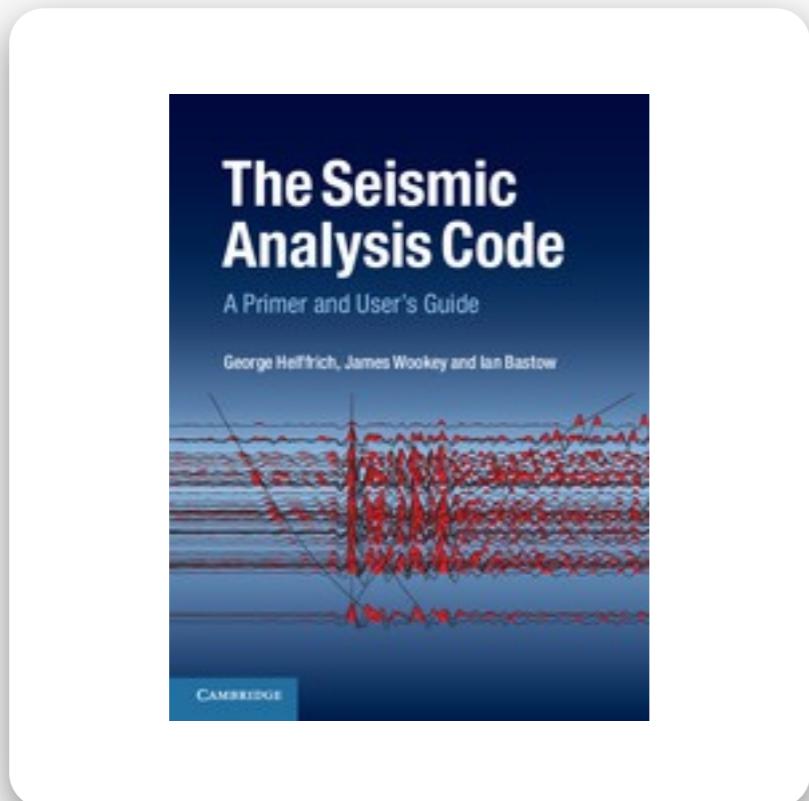
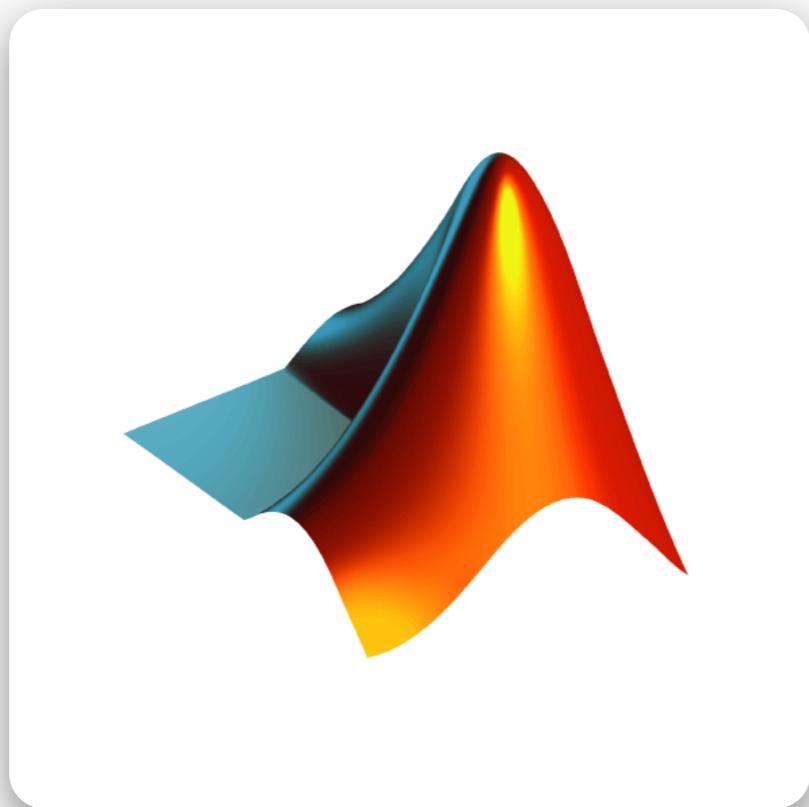
- Widely used in all areas, picking up lots of momentum in many sciences
- Backed by a number of leading technology companies
- Simple, concise, and easy-to-read syntax
- **Free and Open Source**, large scientific community
 - ⇒ potentially high impact / user base
- **General purpose programming language**
- Cross-platform: from RaspberryPi to large supercomputers



Why Python?

- No need to compile; interactive shell available
- Easy to interact with existing C and Fortran code
- Huge web development ecosystem
- Large “big data” community using Python
- **Vast scientific ecosystem;** taking advantage of developments in other sciences

Alternatives

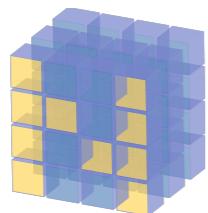
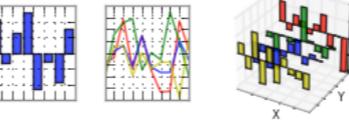


Scientific Python



Sympy

pandas
 $y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$



NumPy



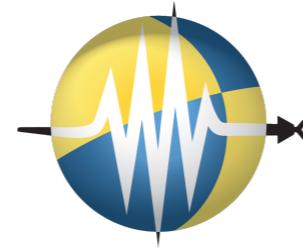
SciPy



matplotlib

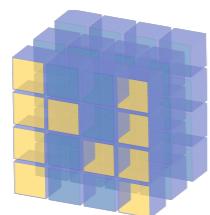


Scientific Python



ObsPy

A Python Framework for Seismology



NumPy



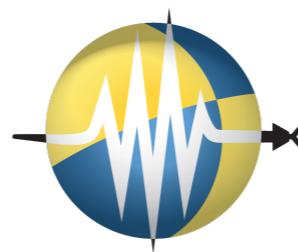
SciPy



matplotlib



ObsPy



ObsPy
A Python Framework for Seismology

What is ObsPy?

- **Python library to work with seismological data**
 - Waveform data
 - Station metadata
 - Event metadata
- **Facilitates development**
 - from short code snippets
 - to complex processing workflows
- **Develop once, use everywhere**

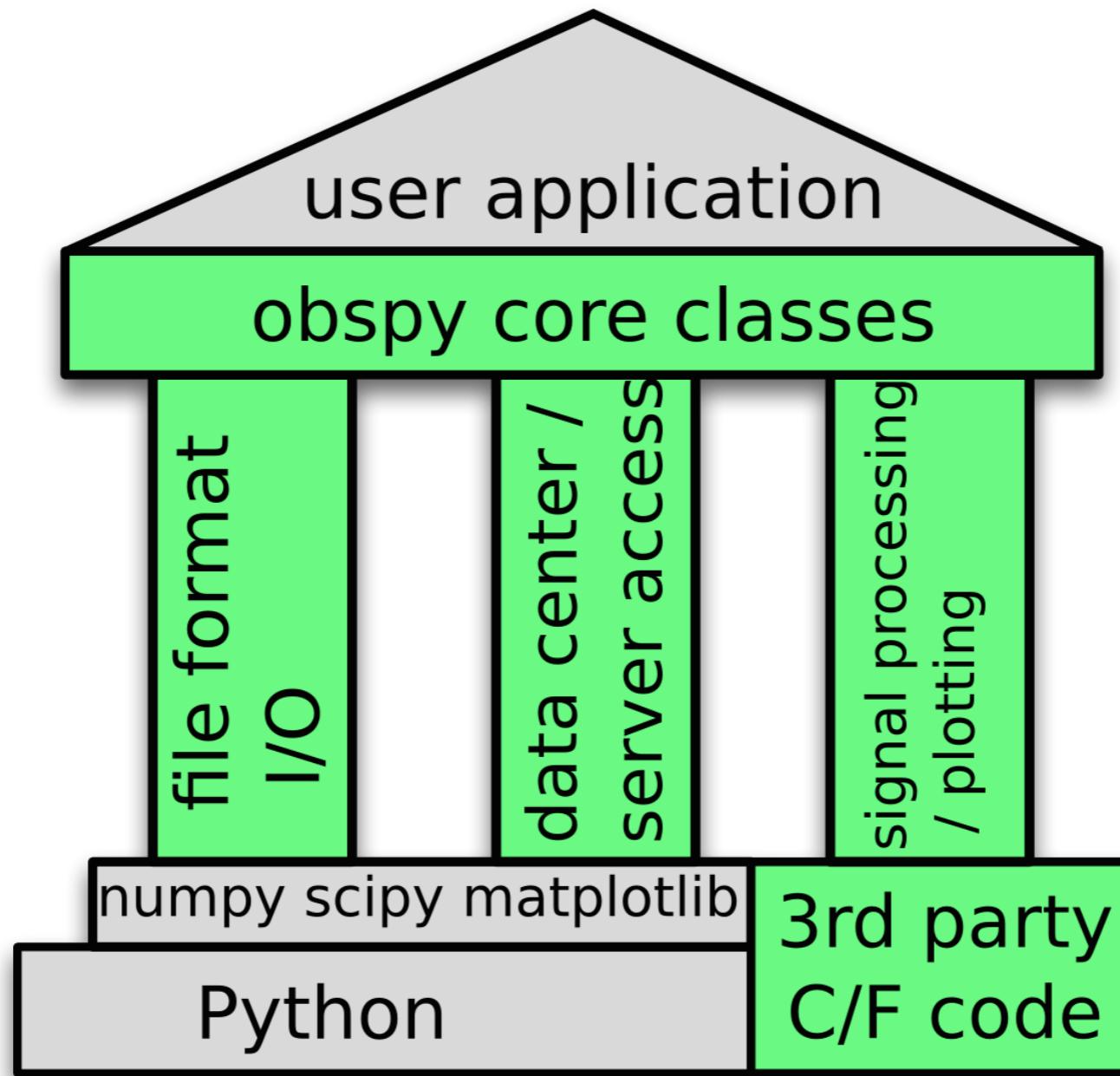
A bridge for seismologists into the scientific Python ecosystem

Seismological Processing

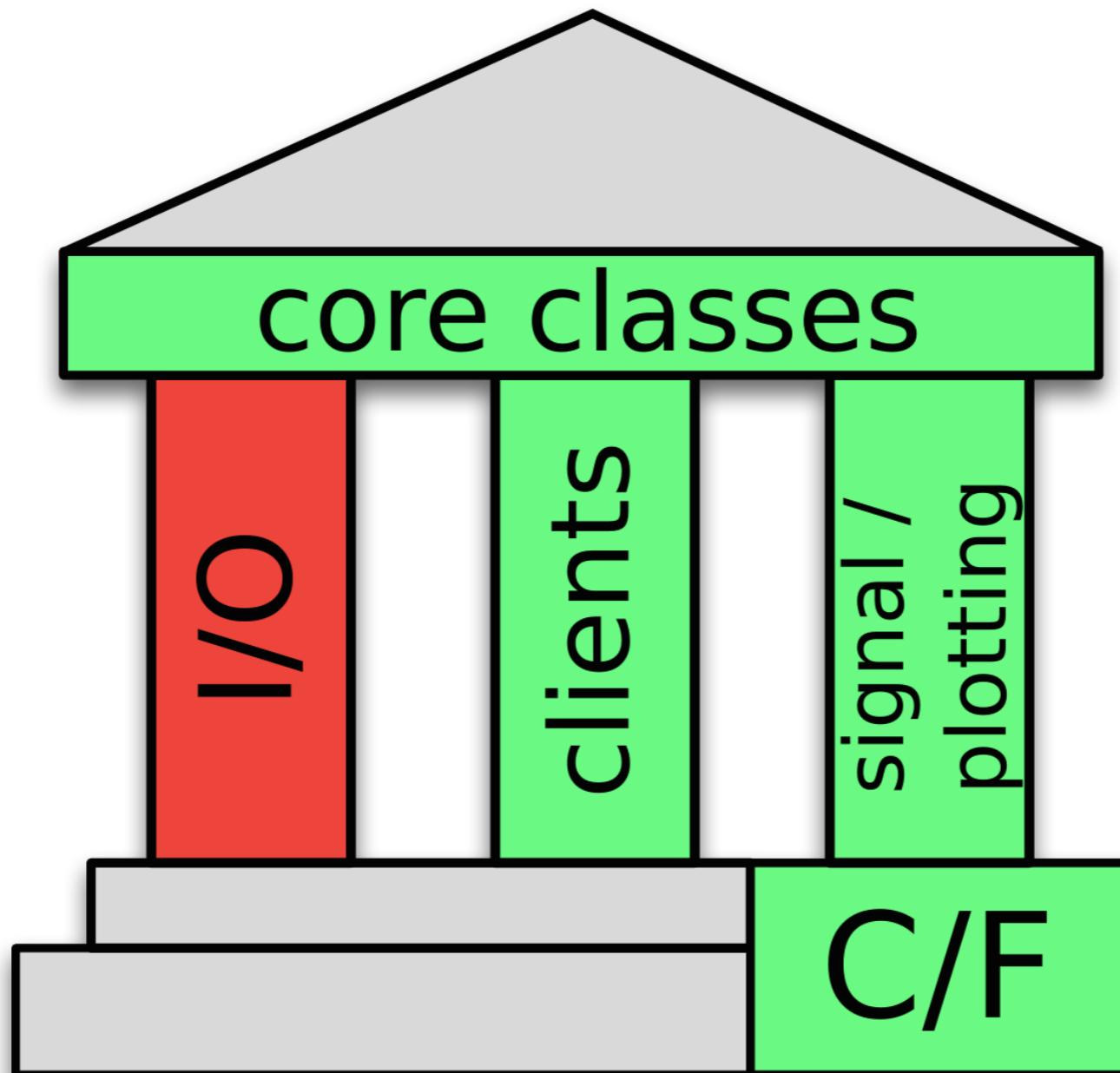
What I need is..

- I/O of local data
- fetch data/metadata from data centers
- convenient handling of the parsed data/metadata
- basic signal processing / data analysis / math
- visualization capabilities

Functionality



File Formats & I/O



File Formats & I/O

Situation without ObsPy



WTF!?

What am I supposed to do with it???

GSE2GSE	convseis	manual (postscript)	Onicescu & Rizescu	GSE1.0 <-> GSE2.0 DOS/Windows
GSE2MSEED	codeco_3.3c	Documentation	Urs Kradolfer	GSE1.0/2.x UNIX HP/SUN, Linux
GSE2MSEED	gse2mseed		IRIS, Chad Trabant	GSE 2.x/IMS 1.0, INT or CM6 Solaris, Linux, Mac OSX and Windows
GSE2SAC	codeco_3.3c gsesac	Documentation README	Urs Kradolfer/Hugues Dufumier	GSE1.0/2.x, SAC(A/B)
GSE2SEED	gse2seed (version2.31)	README	ORFEUS, Sleeman	Handling metadata
GSE2SUDS	convseis	manual (postscript)	Onicescu & Ritzescu	GSE1.0 -> PC-SUDS (.DMX)
MARS2MSEED	mars2mseed	Documentation	Chad Trabant	
MSEED2AH	ms2ah	QUG UCB README	IRIS/PASSCAL	-
MSEED2ASCII	mse2ascii	Documentation	Chad Trabant	
MSEED2CSS	codeco_3.3c	Documentation	Urs Kradolfer	CSS2.8/3.0
MSEED2GSE	codeco_3.3c	Documentation	Urs Kradolfer	GSE1.0/2.x
MSEED2SAC	mse2sac	Documentation	Chad Trabant	
MSEED2SAC	codeco_3.3c ms2sac	Documentation QUG UCB README	Urs Kradolfer Quanterra Users Group	-

File Formats & I/O

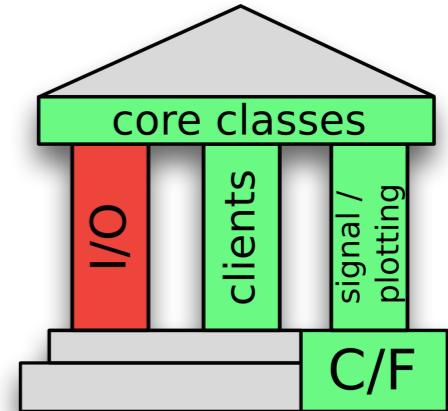
Situation with ObsPy

```
>>> import obspy  
>>> st = obspy.read("/path/to/file")
```

- Automatic File Format Detection
- Always ends up the same object
- Works with zipped files, URLs, ...

File Formats & I/O

read/write support for lots of formats:



- waveforms (**MiniSEED, GSE2, SAC, ...**)
 - *many different ways to store binary/encoded timeseries*
- station metadata (**(X)SEED, StationXML, RESP**)
 - *complex, esp. instrument response*
- event metadata (**QuakeML, NDK, PDE**)
 - *complex associations, owed to how data is assembled in realtime systems*

File Formats in ObsPy

Waveform Import/Export Plug-ins

obspy.io.ah	obspy.io.ah - AH (Ad Hoc) read support for ObsPy
obspy.io.ascii	
obspy.io.css	obspy.io.css - CSS read support for ObsPy
obspy.io.datamark	obspy.io.datamark - DataMark read support for ObsPy
obspy.io.gse2	obspy.io.gse2 - GSE2/GSE1 read and write support for ObsPy
obspy.io.kinemetrics	obspy.io.kinemetrics - Evt format support for ObsPy
obspy.io.mseed	obspy.io.mseed - MiniSEED read and write support
obspy.io.nied.knet	Reading of the K-NET and KiK-net ASCII format as defined on
obspy.io.pdas	obspy.io.pdas - PDAS file read support for ObsPy
obspy.io.sac	obspy.io.sac - SAC read and write support for ObsPy
obspy.io.seisan	obspy.io.seisan - SEISAN read support for ObsPy
obspy.io.seg2	obspy.io.seg2 - SEG-2 read support for ObsPy
obspy.io.segy	obspy.io.segy - SEG Y and SU read and write support for ObsPy
obspy.io.sh	obspy.io.sh - Q and ASC (Seismic Handler) read and write support for ObsPy
obspy.io.wav	obspy.io.wav - WAV(audio) read and write support for ObsPy
obspy.io.y	obspy.io.y - Nanometrics Y file read support for ObsPy

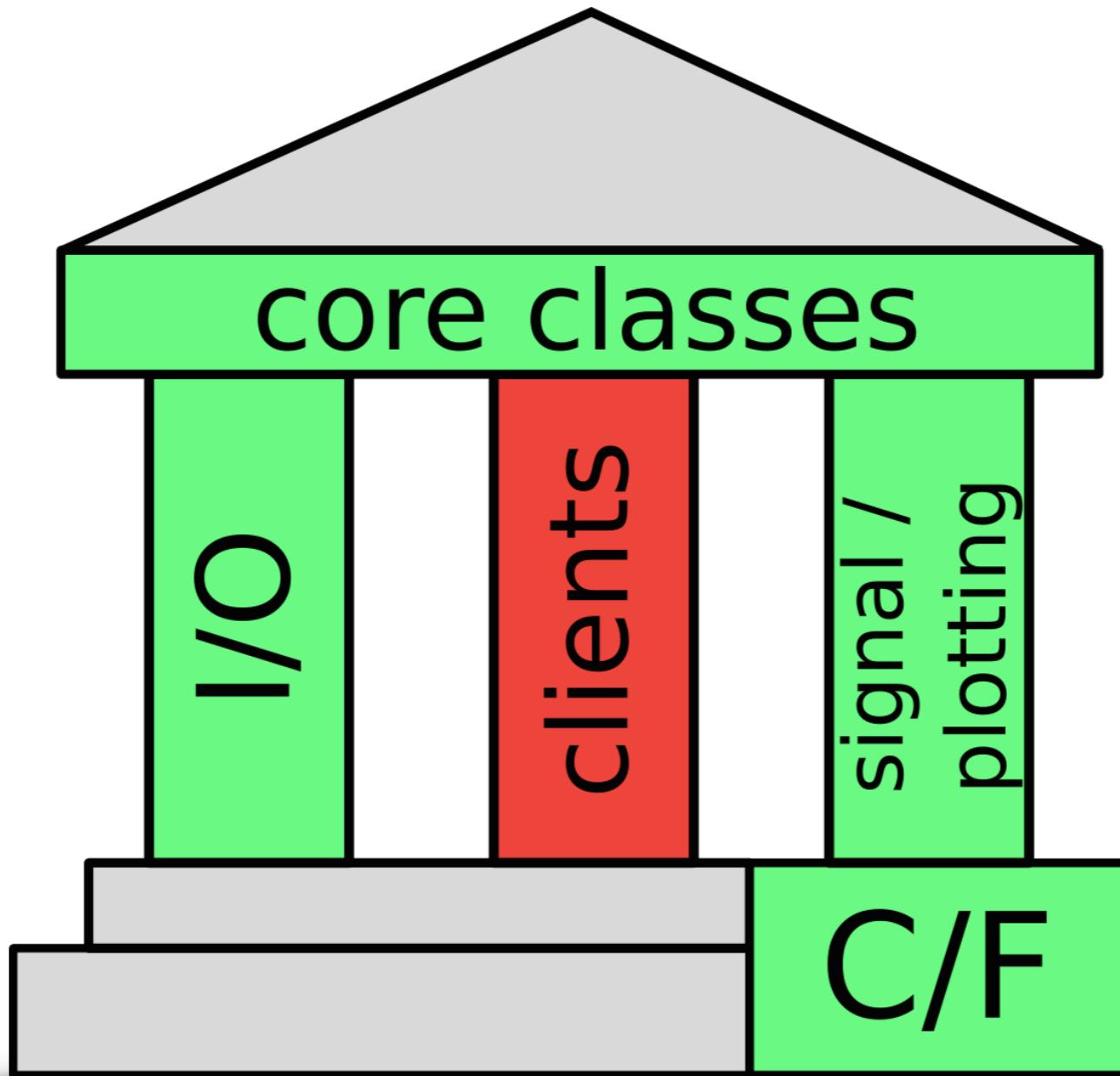
Event Data Import/Export Plug-ins

obspy.io.cmtsolution	obspy.io.cmtsolution - CMTSOLUTION file format support for ObsPy
obspy.io.cnv	obspy.io.cnv - CNV file format support for ObsPy
obspy.io.json	JSON write support
obspy.io.kml	obspy.io.kml - Keyhole Markup Language (KML) write support
obspy.io.ndk	obspy.io.ndk - NDK file support for ObsPy
obspy.io.nied.fnetmt	F-net moment tensor file format support for ObsPy.
obspy.io.nlloc	obspy.io.nlloc - NonLinLoc file format support for ObsPy
obspy.io.pde	obspy.io.pde - NEIC PDE Bulletin read support for ObsPy
obspy.io.shapefile	obspy.io.shapefile - ESRI shapefile write support
obspy.io.quakeml	
obspy.io.zmap	obspy.io.zmap - ZMAP read/write support.

Inventory Data Import/Export Plug-ins

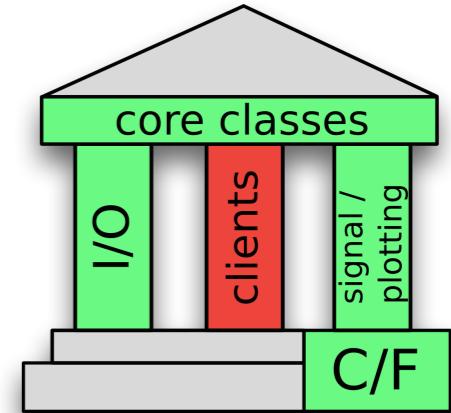
obspy.io.css	obspy.io.css - CSS read support for ObsPy
obspy.io.kml	obspy.io.kml - Keyhole Markup Language (KML) write support
obspy.io.sac.sacpz	Module for SAC poles and zero (SACPZ) file I/O.
obspy.io.seiscomp	obspy.io.seiscomp - SeisComP3 Inventory Files
obspy.io.shapefile	obspy.io.shapefile - ESRI shapefile write support
obspy.io.stationtxt	obspy.io.stationtxt - Read support for the FDSNWS station text files
obspy.io.stationxml	

Data Acquisition



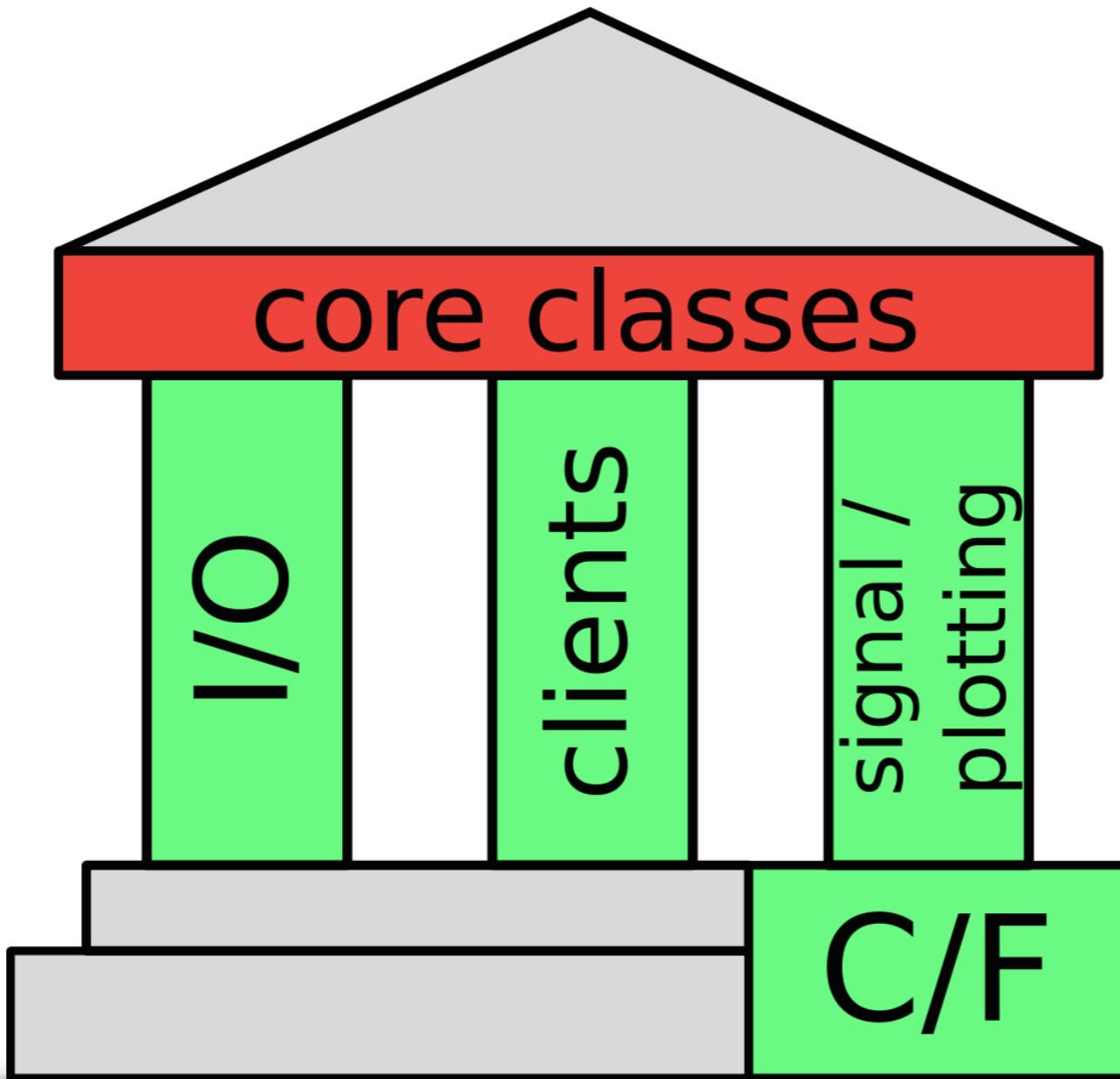
Data Center Clients

- **FDSN web service client**
 - *IRIS, Orfeus, USGS, RESIF, NCEDC, INGV, ...*
- **ArcLink client**
- **SeedLink**
- **Earthworm**
- ...



⇒ different types of servers, but usage of clients very similar

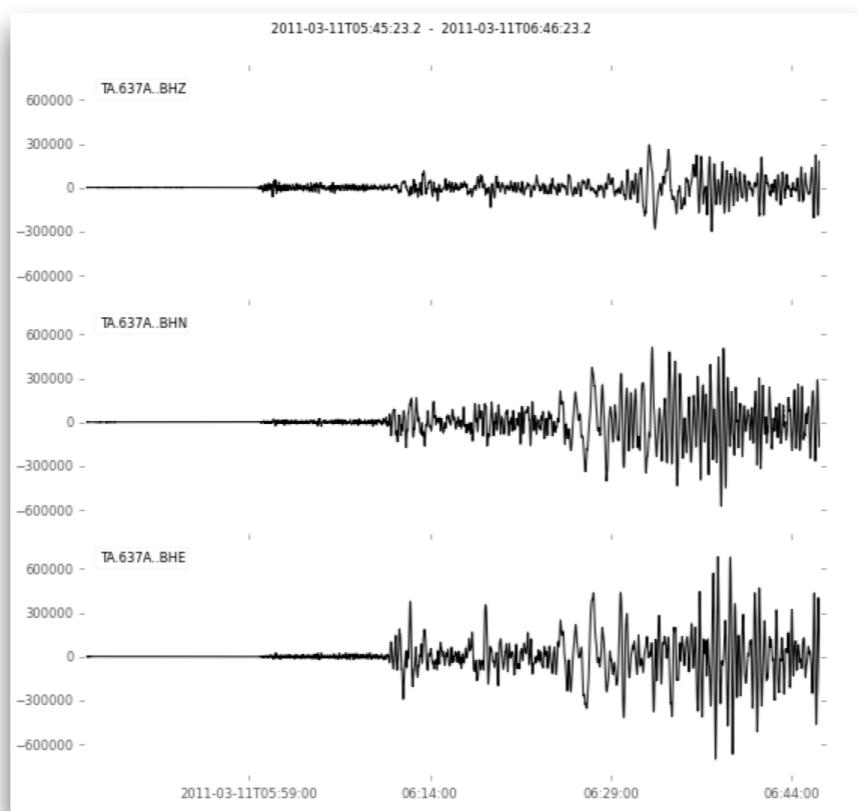
ObsPy's Core Classes



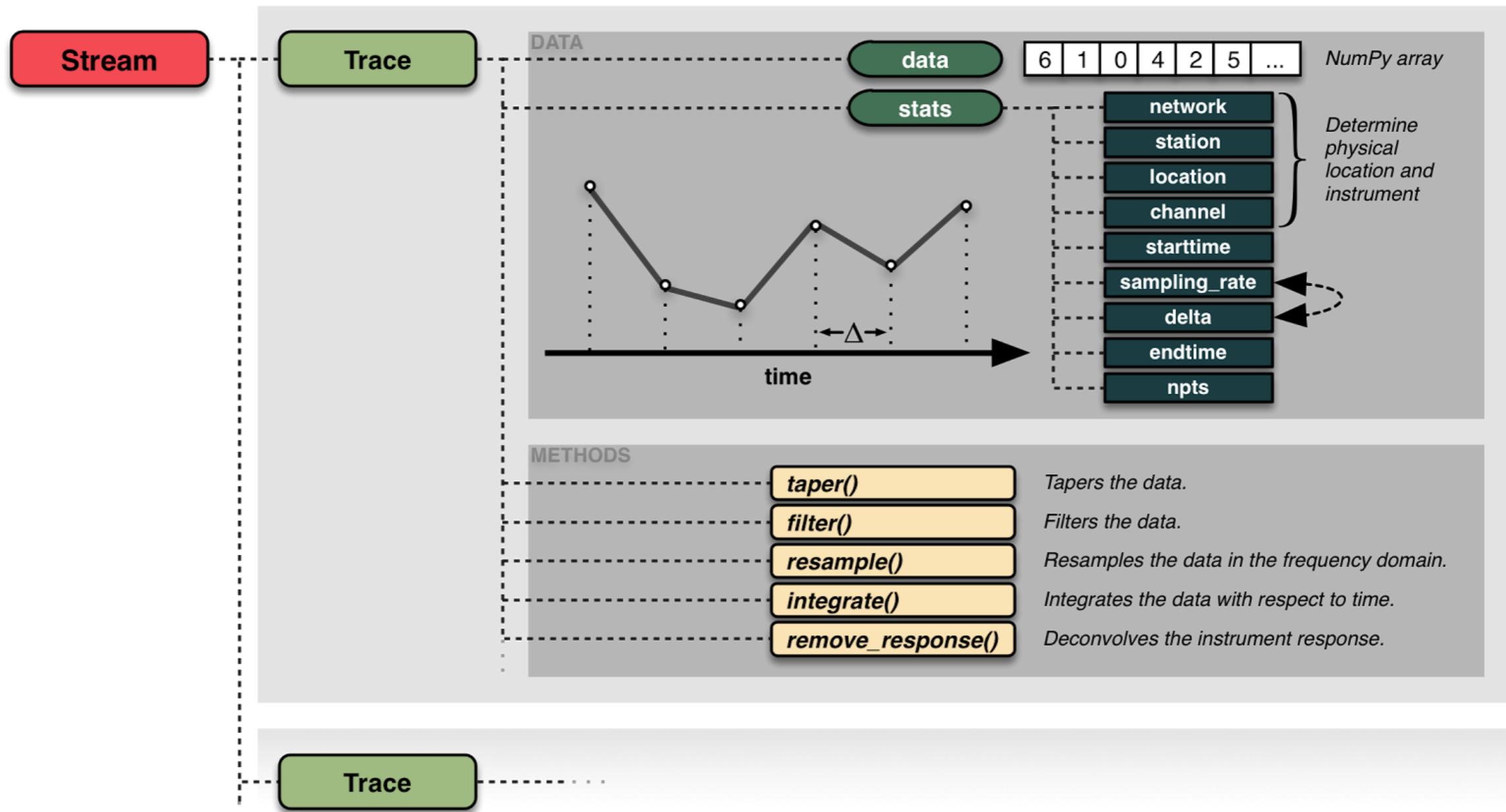
Stream/Trace for Waveforms

```
>>> import obspy  
>>> st = obspy.read("/path/to/file")
```

```
>>> st.plot()
```



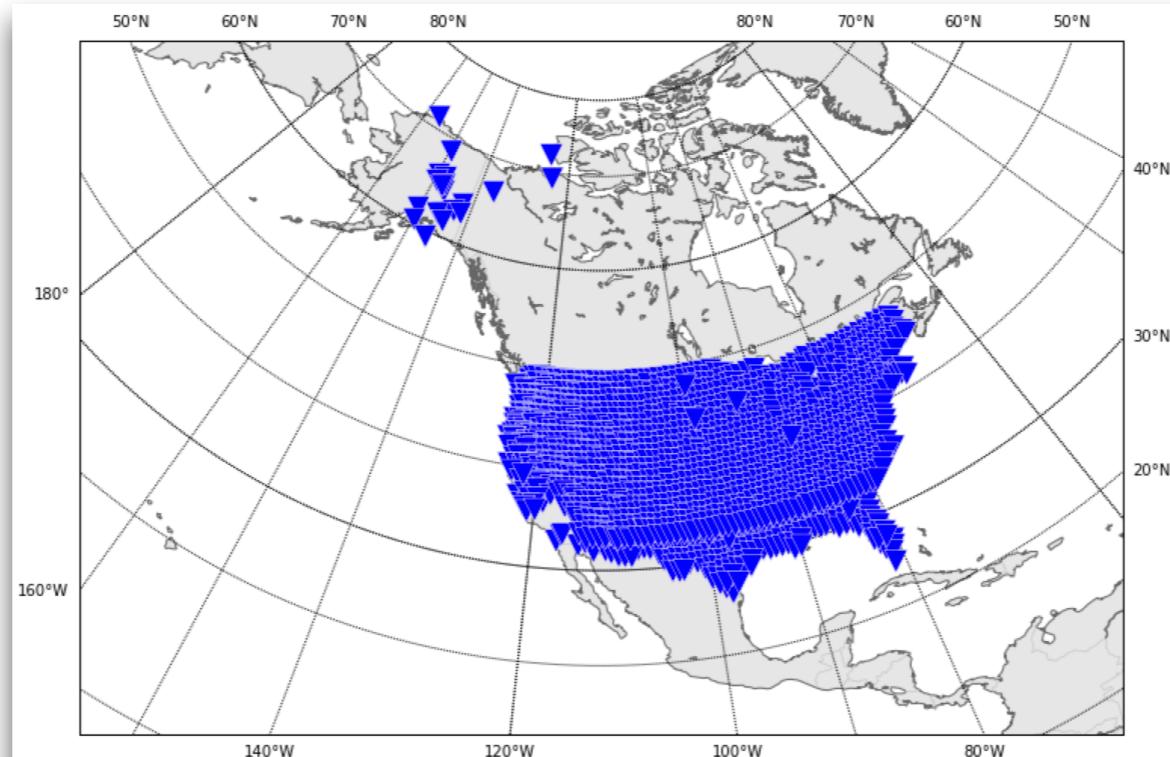
Stream/Trace for Waveforms



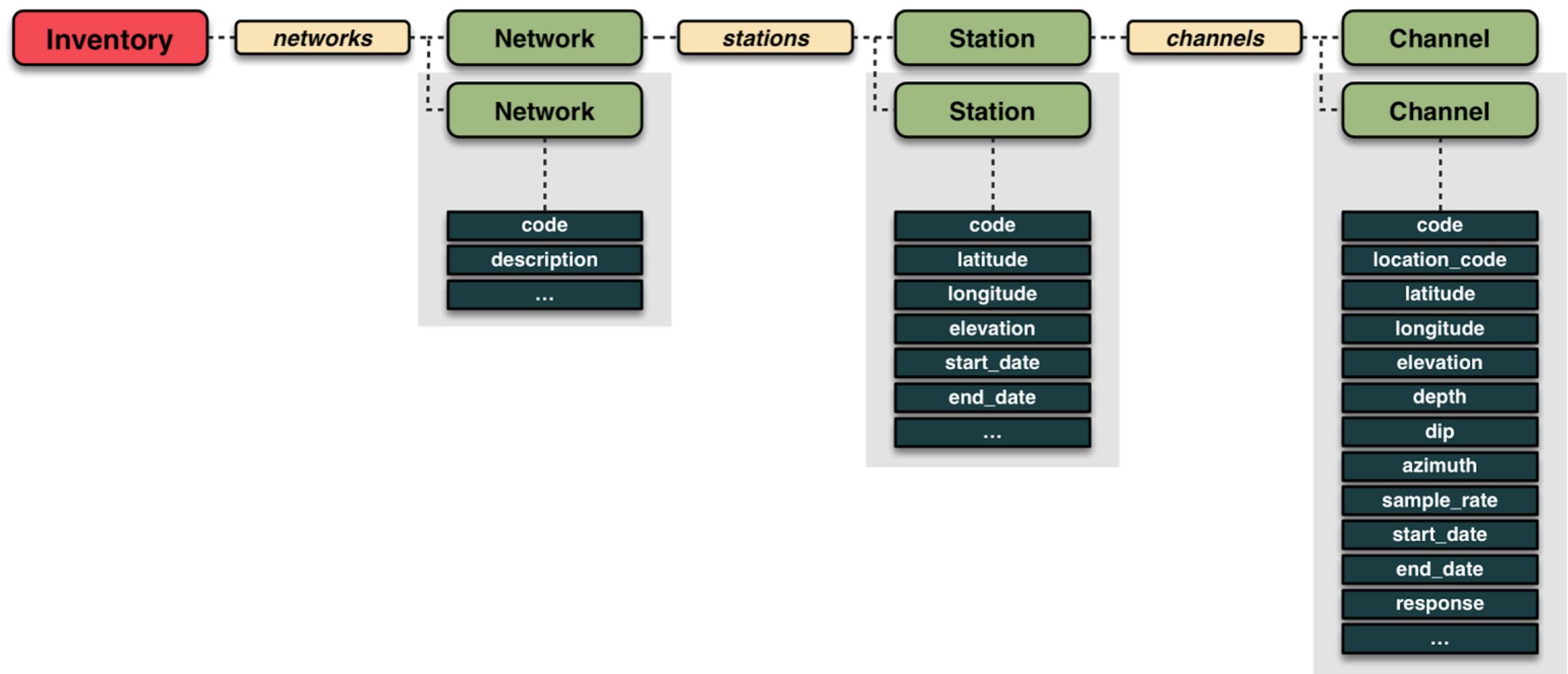
Inventory for Station Metainformation

```
>>> import obspy  
>>> inv = obspy.read_inventory("/path/to/file")
```

```
>>> inv.plot()
```



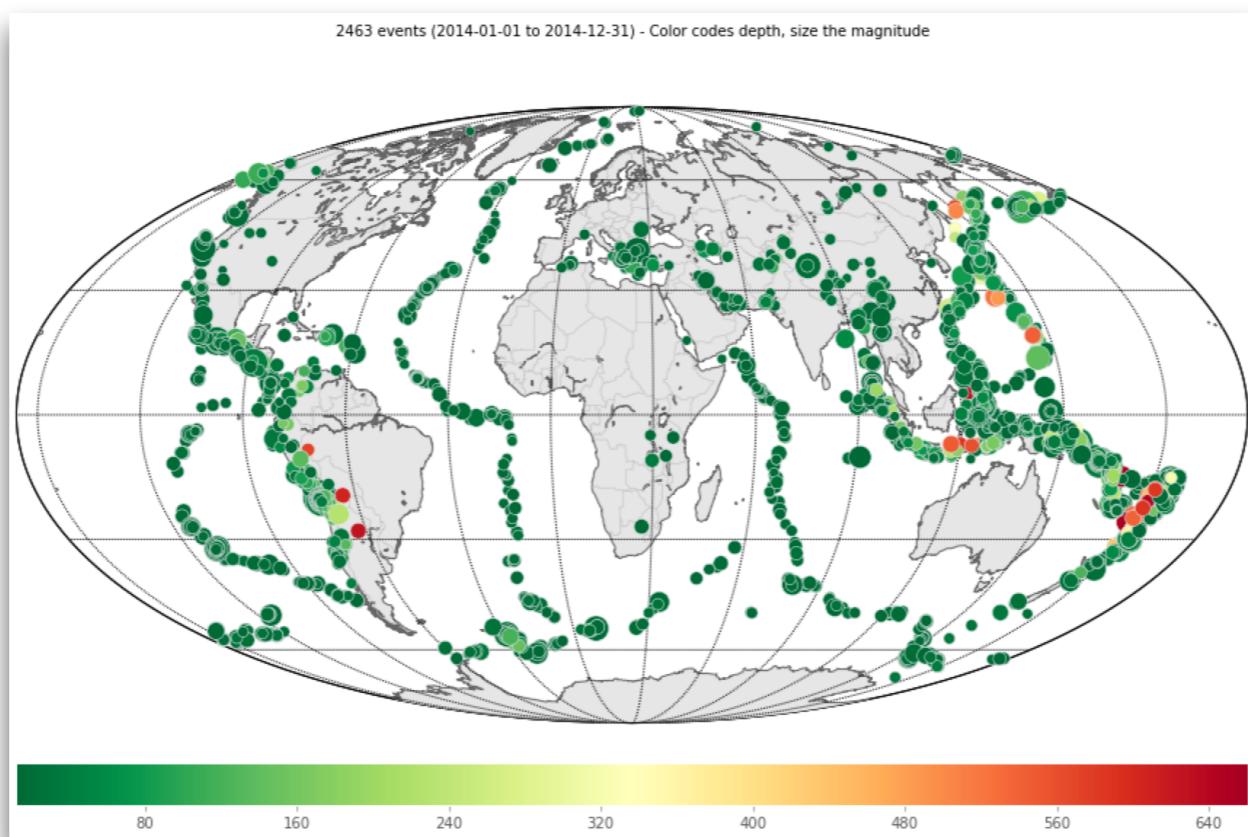
Inventory for Station Metainformation



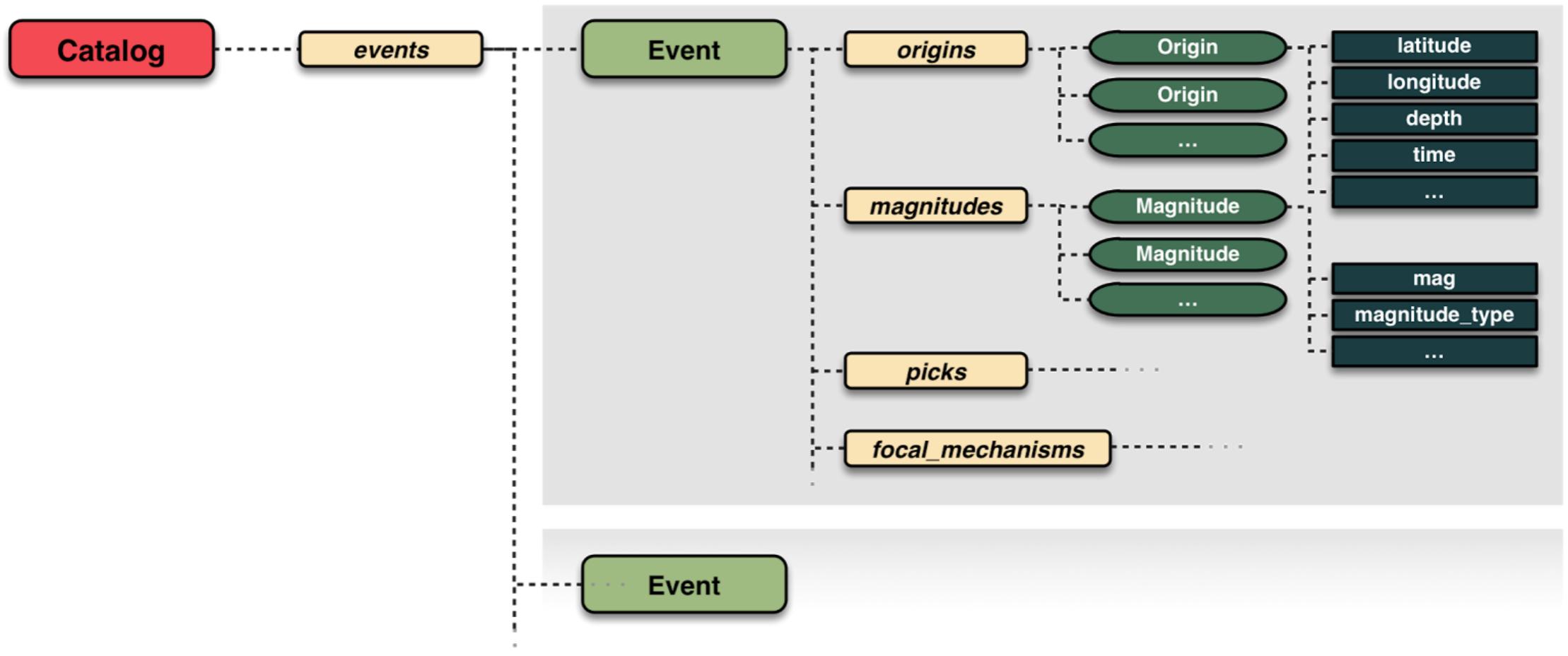
Catalog for Events

```
>>> import obspy  
>>> cat = obspy.readEvents("/path/to/file")
```

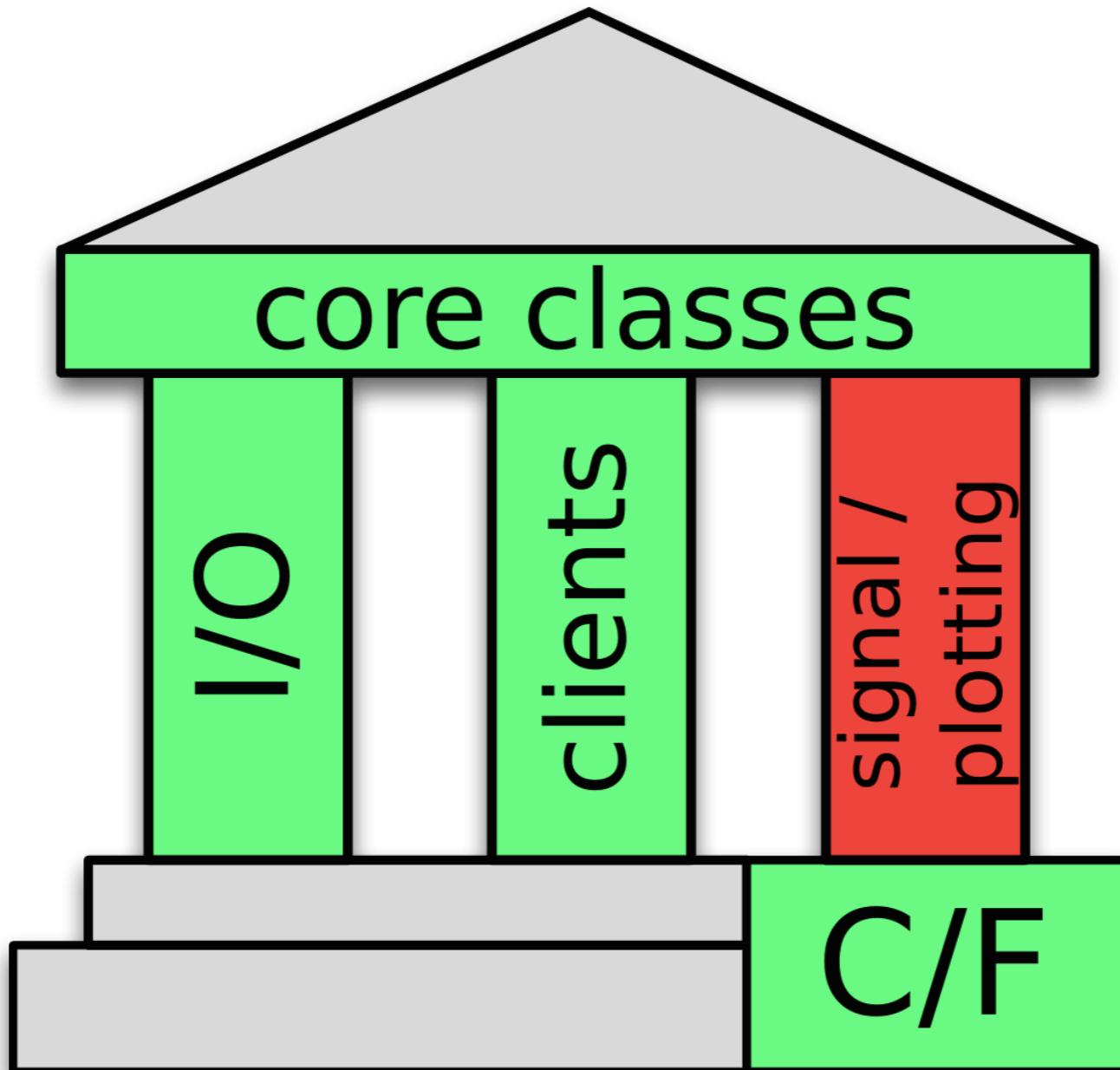
```
>>> cat.plot()
```



Catalog for Events



Signal Processing and Plotting



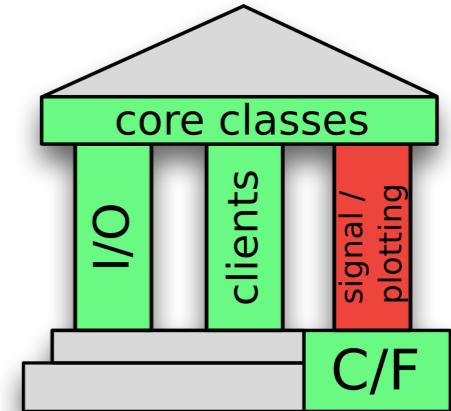
Signal Processing and Plotting

Basic signal processing:

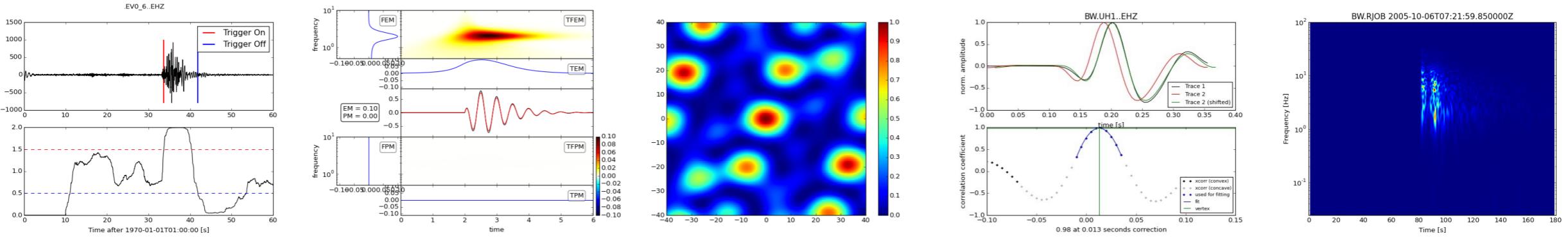
- trim, merge, rotate, ...
- filter, resample, instrument correction
- array analysis, cross correlations
- different types of triggers
- probabilistic power spectral densities
- ...

Basic plotting:

- waveform preview plots
- stations/events location plots
- channel instrument response plots (bode plots)

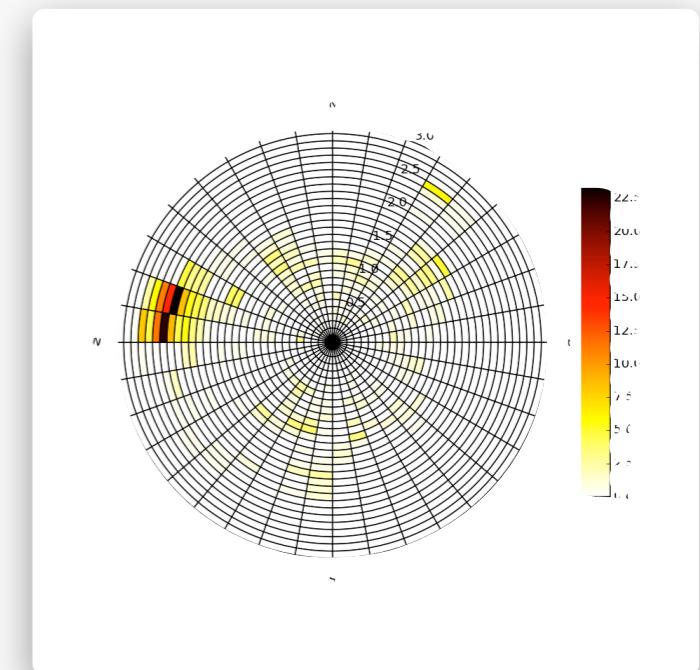
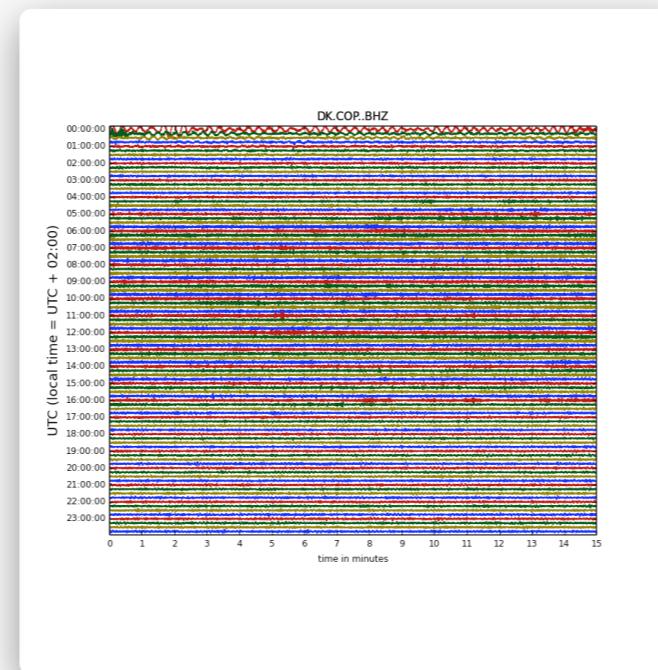
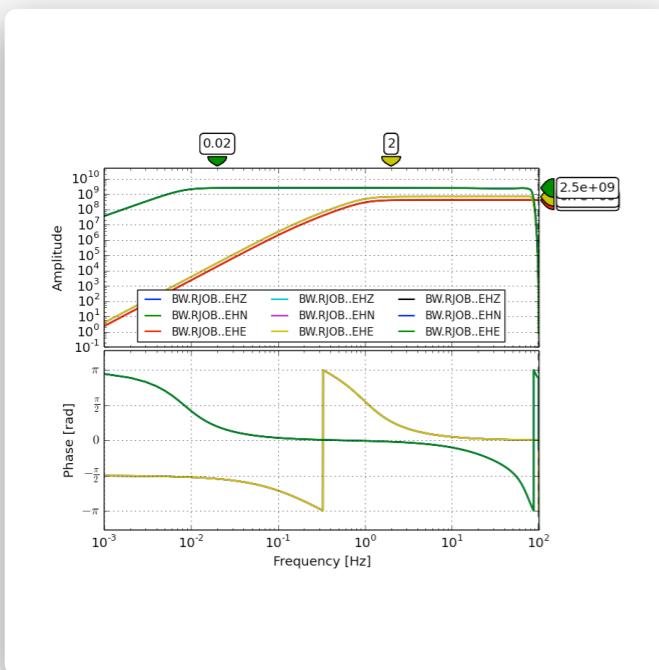
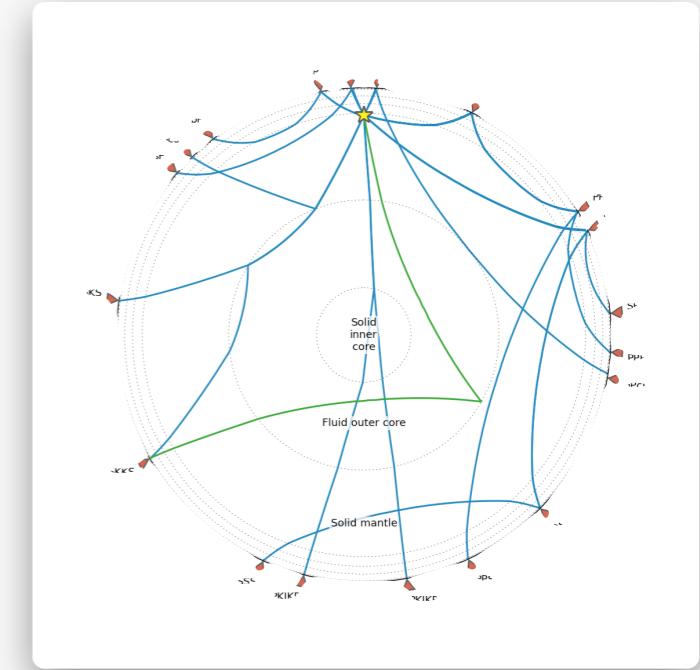
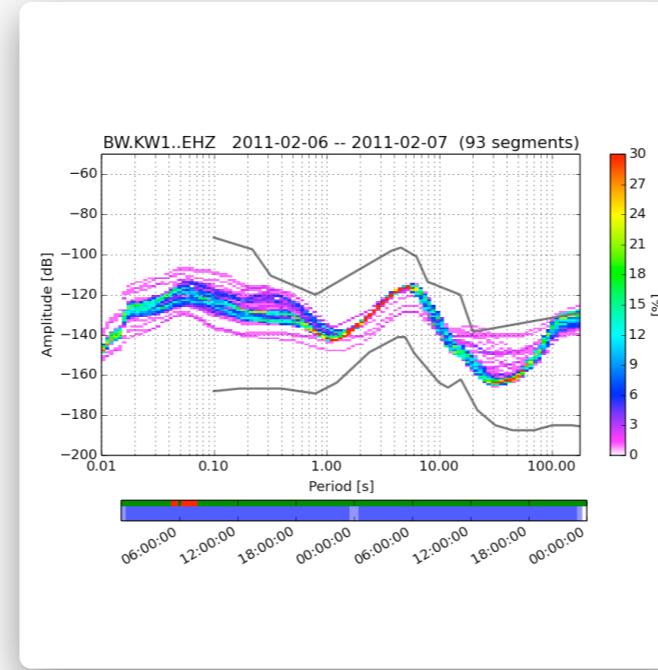
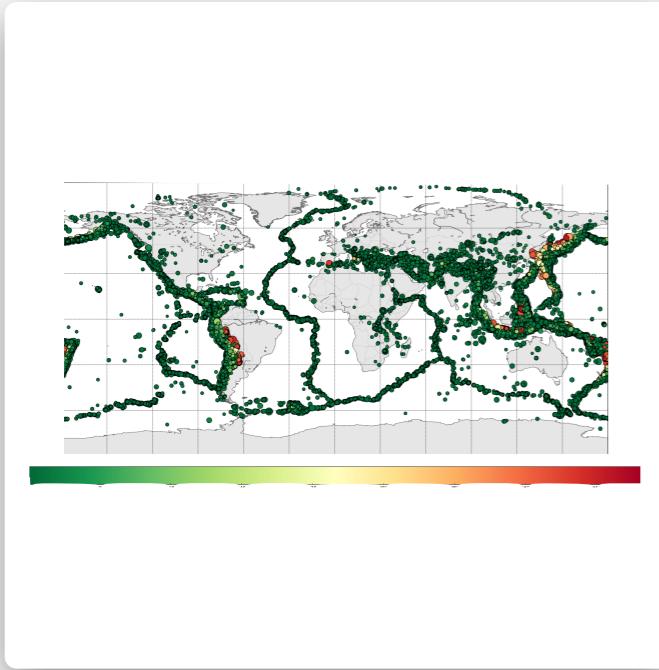


Signal Processing Showcase

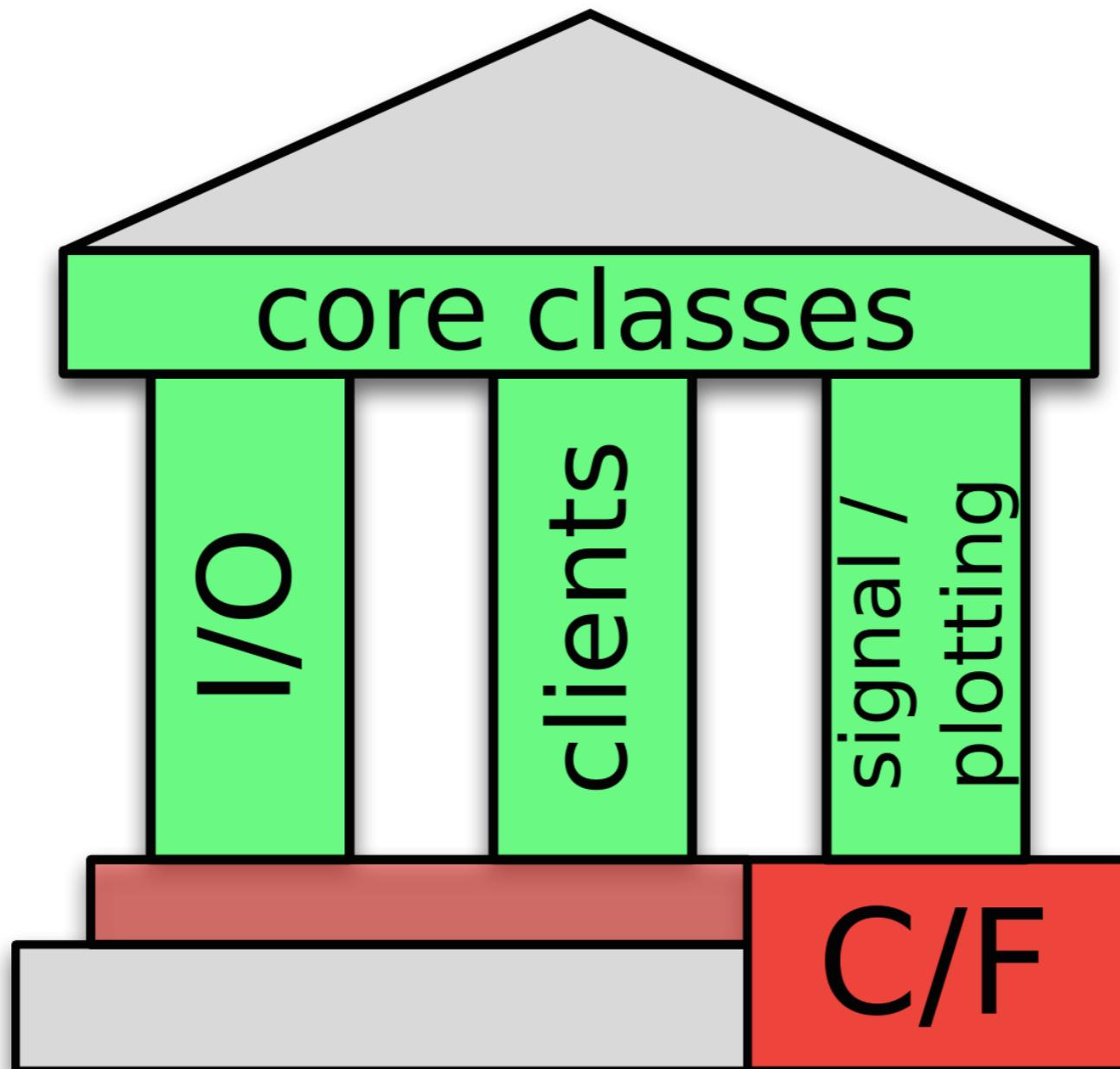


- **instrument correction / simulation**
 - using poles and zeros & overall sensitivity
 - calculated using evalresp
- **local magnitude estimation**
- **spectral estimation (psd/spectrogram/PPSDs/konno-ohmachi-smoothing)**
- **cross correlations**
 - pick correction
 - similarity analysis
- **triggering**
 - classic/delayed/recursive STA/LTA
 - z-Detector, Baer picker, AR picker
 - network coincidence triggers
- **filters**
- **relative instrument calibration**
- **array analysis**
 - beamforming
 - FK analysis
 - array transfer function
 - array derived rotation
- **time-frequency misfit calculations**
- **rotations ZRT, LQT**
- **complex trace analysis / frequency attributes / half octave bands /**

Showcase



Wrap C and Fortran codes



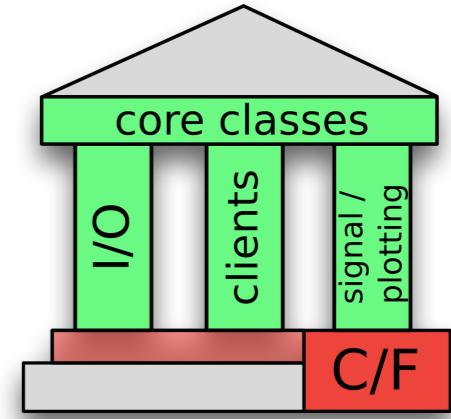
Wrap C and Fortran codes

3rd party code:

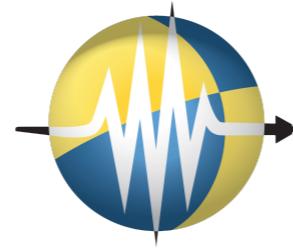
- don't reinvent the wheel
- reuse well established and maintained code

we use:

- NumPy: *fast array operations (BLAS and Lapack)*
- SciPy: *signal processing routines (UMFPACK, ...)*
- libmseed: *MiniSEED I/O (IRIS)*
- evalresp: *instrument correction (ISTI/IRIS)*
- GSE_UTI: *GSE2 I/O (Strange et al.)*

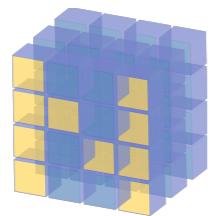


ObsPy Stack



ObsPy

A Python Framework for Seismology



NumPy



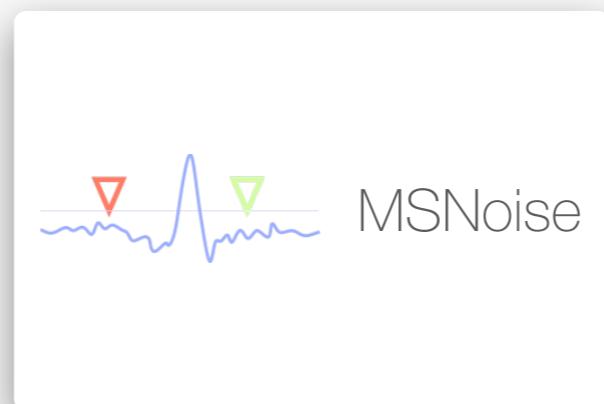
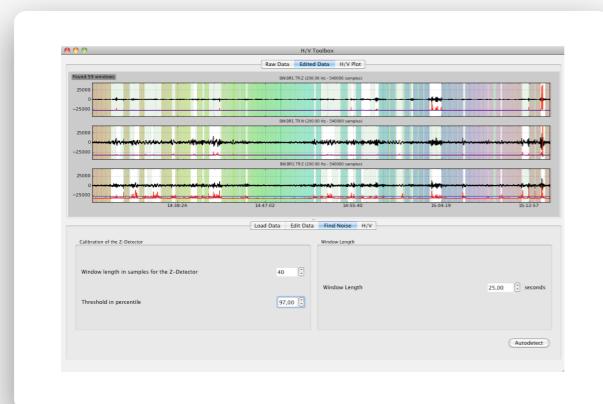
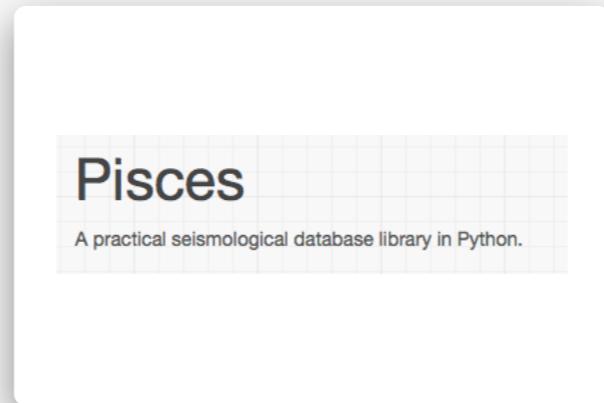
SciPy



matplotlib



ObsPy Stack



Mission Statement

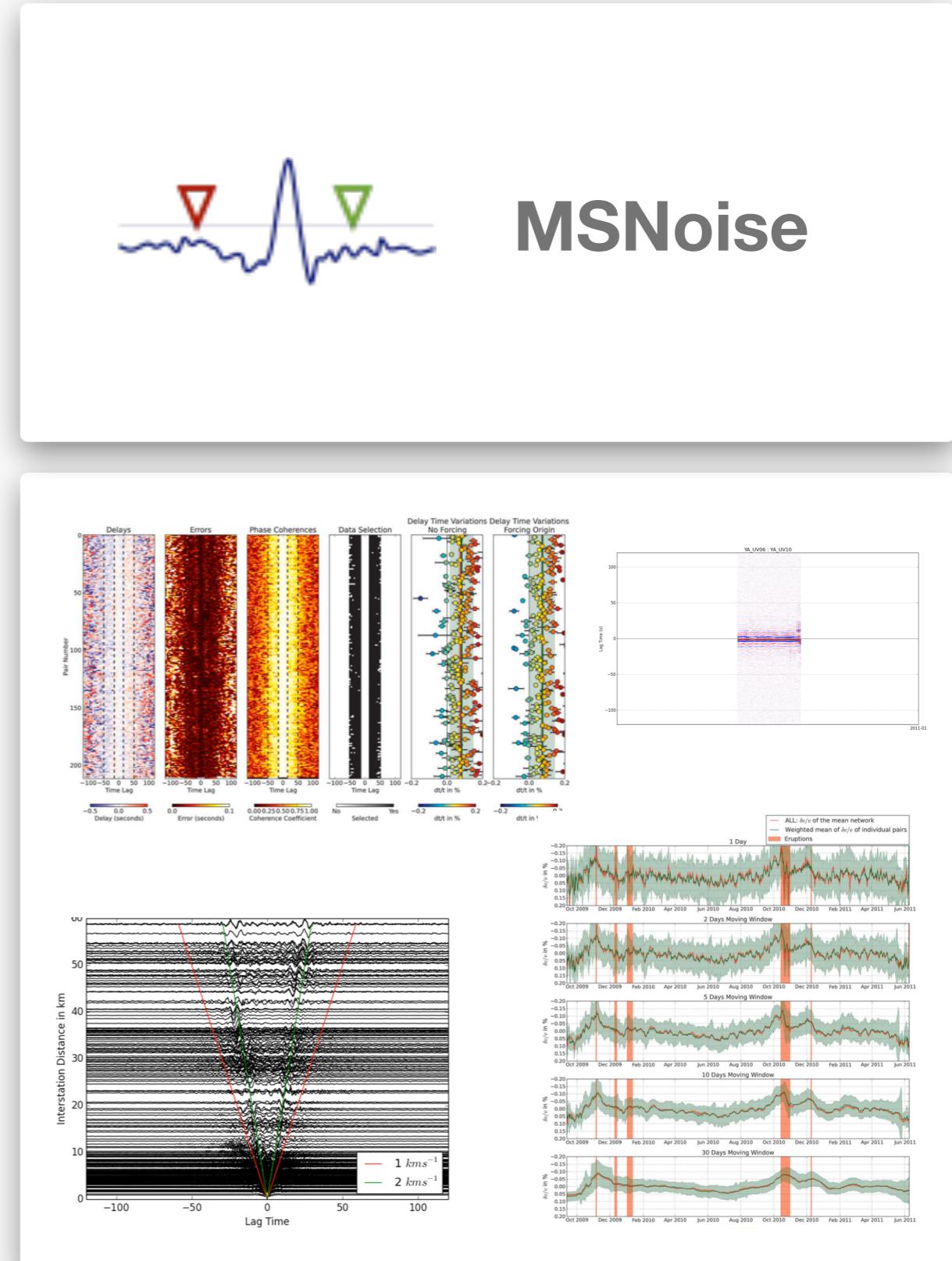
“The goal of the ObsPy project is to facilitate rapid application development for seismology.”

MSNoise

- A Python Package for Monitoring Seismic Velocity Changes using Ambient Seismic Noise
- Runs continuously on a couple sides world-wide

www.msnoise.org

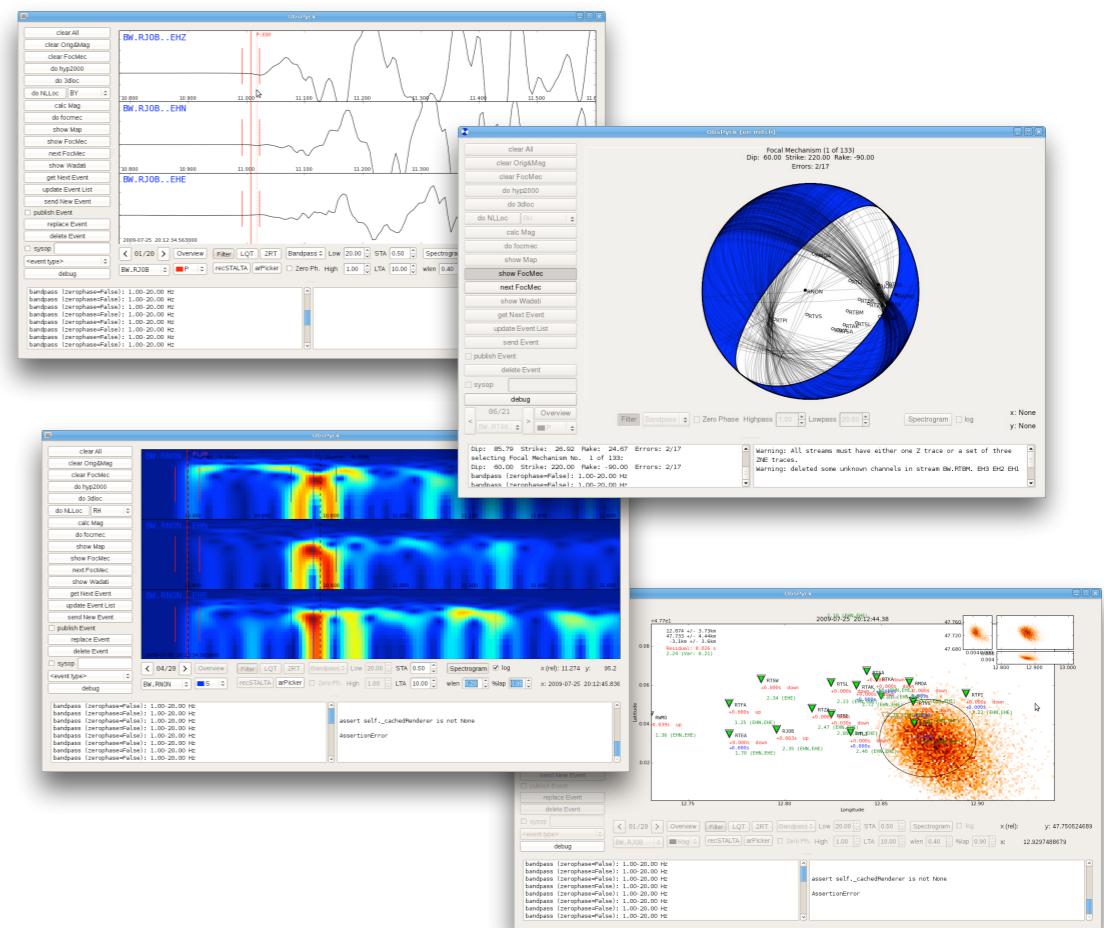
Lecocq, T., Caudron, C., & Brenguier, F. (2014).
MSNoise, a Python Package for Monitoring Seismic Velocity Changes Using Ambient Seismic Noise.
Seismological Research Letters, 85(3), 715–726.



ObsPyck

- Graphical user interface to cover the analysis tasks in seismological observatories
- Picking / Locating / Focal Mechanism Estimations / ...

ObsPyck



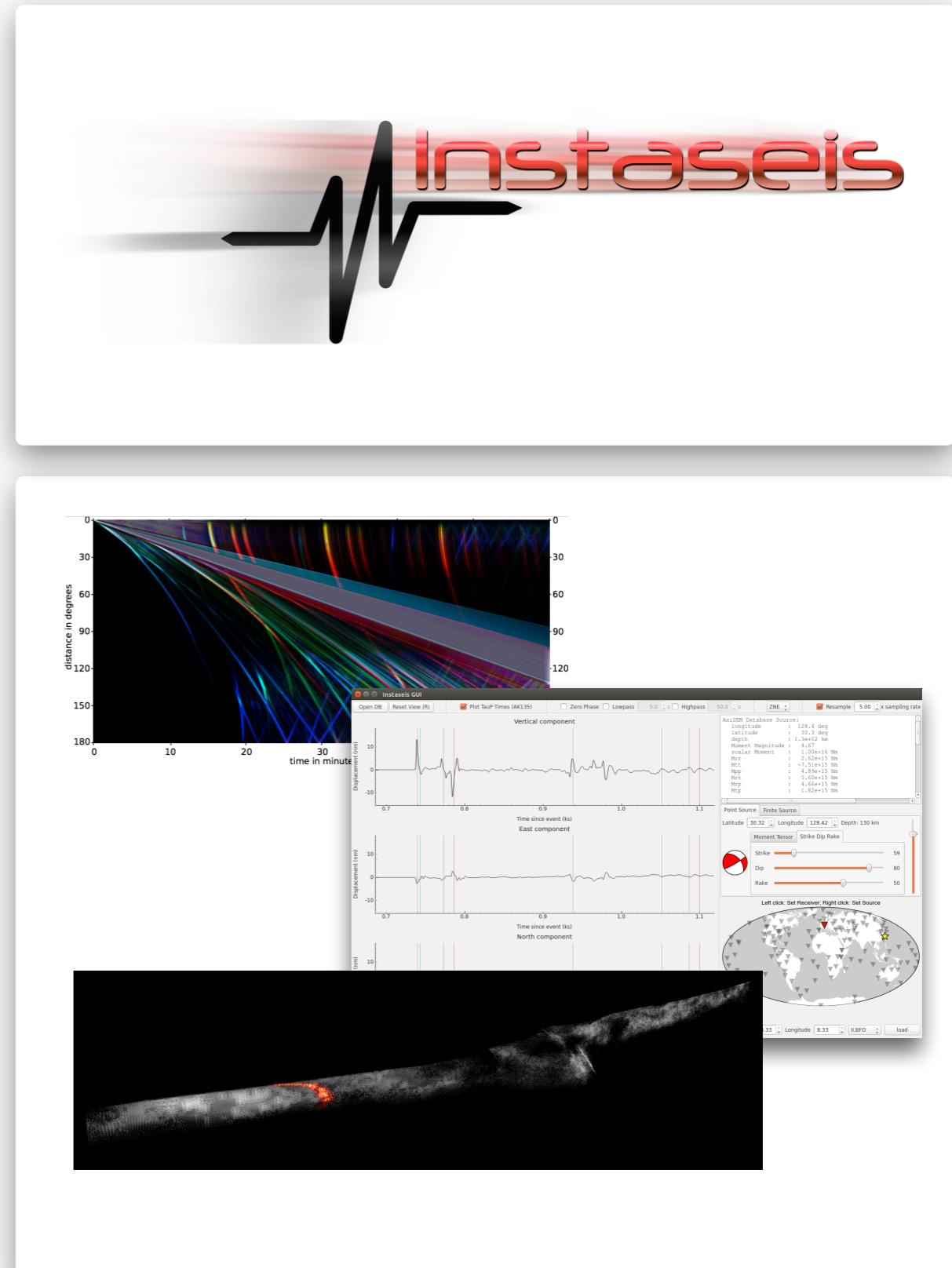
<https://github.com/megies/obspyck/wiki>

Instaseis

- Rapid generation of high-frequency seismograms in a 1D background model

www.instaseis.net

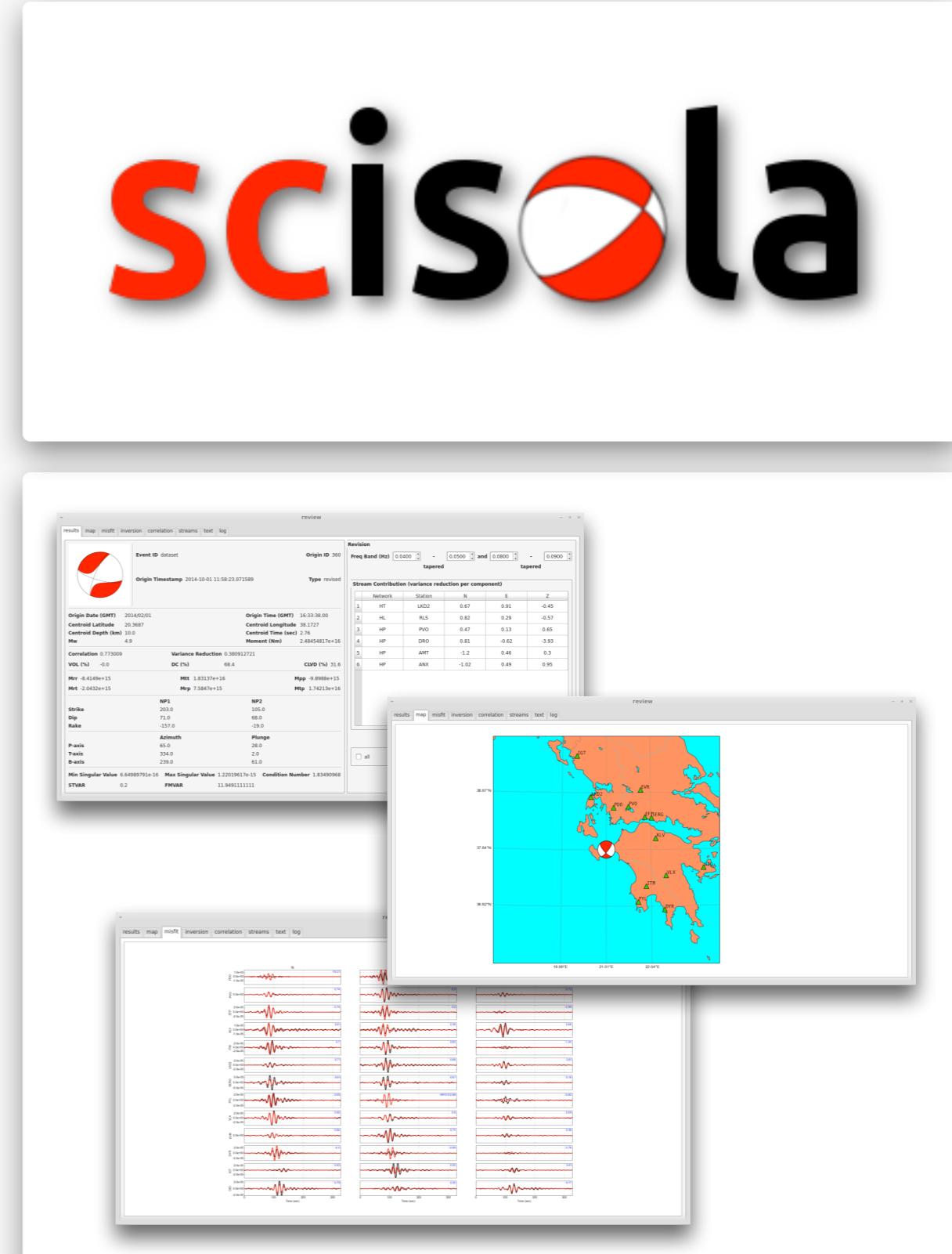
van Driel, M., Krischer, L., Stähler, S. C., Hosseini, K., and Nissen-Meyer, T. (2015). Instaseis: instant global seismograms based on a broadband waveform database. Solid Earth. 6, 701-717



Scisola

- Software for automatic moment tensor calculation of events which are provided in real time by SeisComP3

<http://students.ceid.upatras.gr/~triantafyl/scisola/>

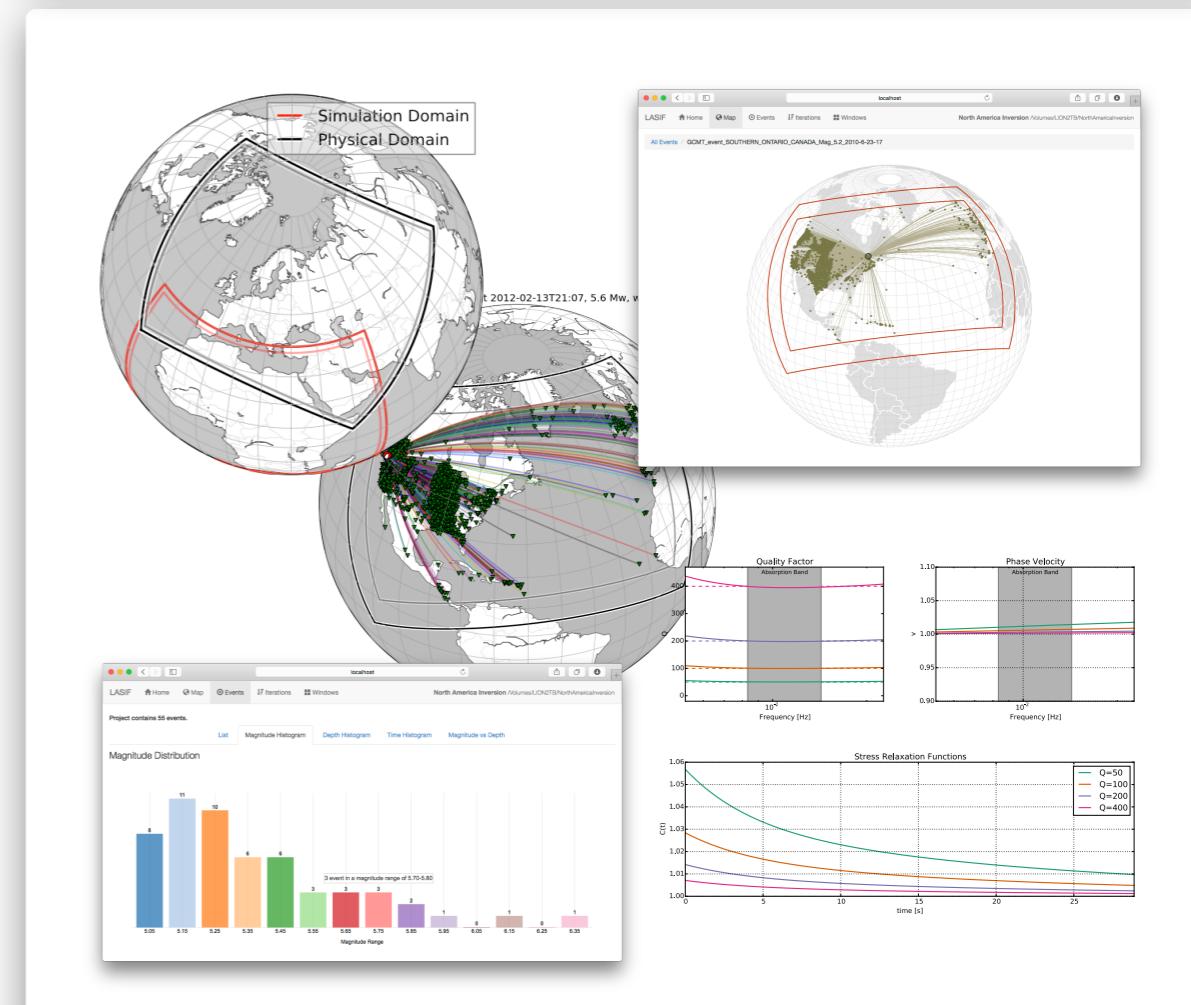


LASIF

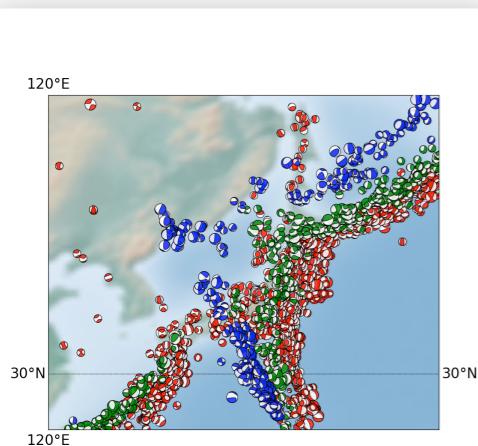
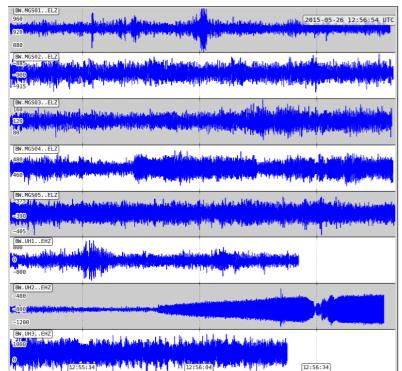
- Framework to deal with data handling, organization, and provenance in the context of iterative inversions
- Enhances reproducibility
- Enables collaboration
- Aims to significantly reduce the time to research

www.lasif.net

Lion Krischer, Andreas Fichtner, Saule Zukauskaite, and Heiner Igel (2015), Large-Scale Seismic Inversion Framework, Seismological Research Letters, doi:10.1785/0220140248.



Lots of other stuff

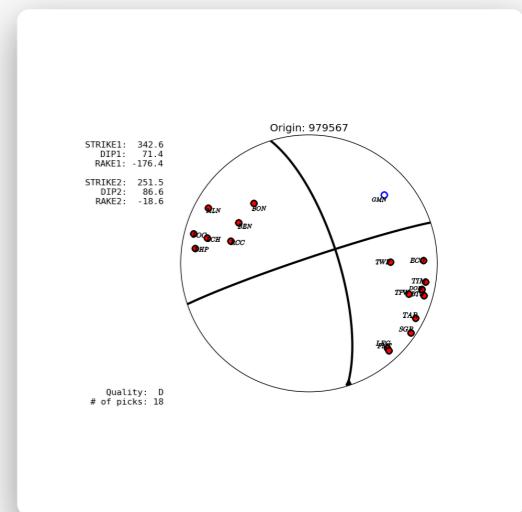
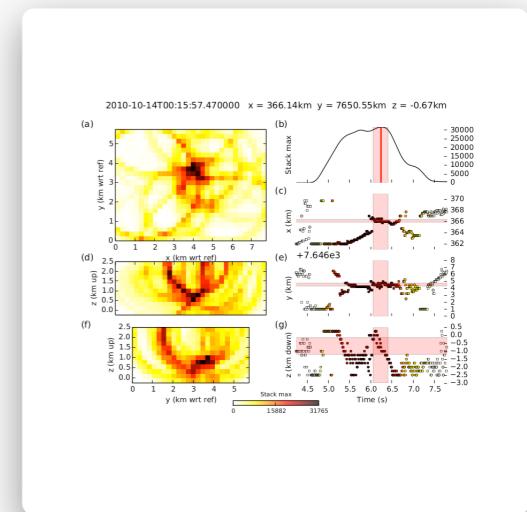


Pisces

A practical seismological database library in Python.

Use Cases / Applications Using ObsPy

- [ObsPyck](#)
 - [SeismicHandler](#)
 - [SeisHub](#)
 - [SeishubExplorer](#)
 - [HtoVToolbox](#)
 - [wavePicker](#)
 - [Antelope Python moment tensor code](#)
 - [Using ObsPy with py2exe](#)
 - [Whisper](#)
 - [Wavesdownloader \(on GitHub\)](#)
 - [ADMIRE project](#)
 - [pSysmon](#)
 - [ObsPyDMT](#)
 - [seedlink plotter](#)
 - [pyTDMT - Python Time Domain Moment Tensor \(on GitHub\)](#)
 - [MSNoise - Monitoring Seismic Velocity Changes using Ambient Seismic Noise \(on GitHub\)](#)
 - [Pisces: A practical seismological database library in Python \(on GitHub\)](#)
 - [HASHpy: Python wrapped fork of HASH first motion focal mechanism code](#)
 - [waveloc \(on GitHub\)](#)
 - [scisola \(on GitHub\)](#)
 - [instaseis - Instant Global High Frequency Seismograms](#)
 - [LASIF - Large-Scale Seismic Inversion Framework](#)
 - [pyflex - Enhanced port of FLEXWIN](#)
 - [hypoDDpy - Run hypoDD in a data driven manner.](#)
 - [wfs_input_generator - Generate input files for many waveform solvers directly from data.](#)
 - [rf - Calculate receiver functions.](#)
 - [Qopen - Separation of intrinsic and scattering Q by envelope inversion.](#)
 - [EQcorrscan - Match-filter earthquake detection](#)



Final Words

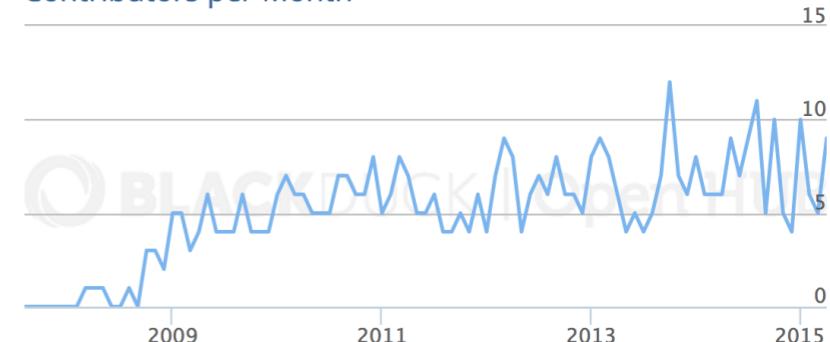
Usage and Community

Development

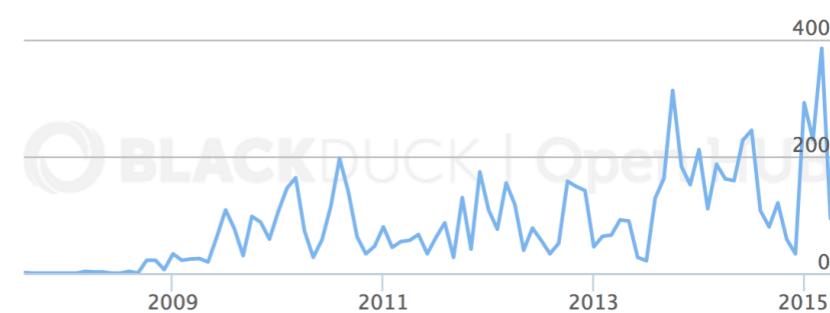
- Around 53 people contributed code
- ~ 9600 commits
- > 1500 tests
- Tested multiple times per day on around 15 different platforms
- > 1400 GitHub Issues



Contributors per Month



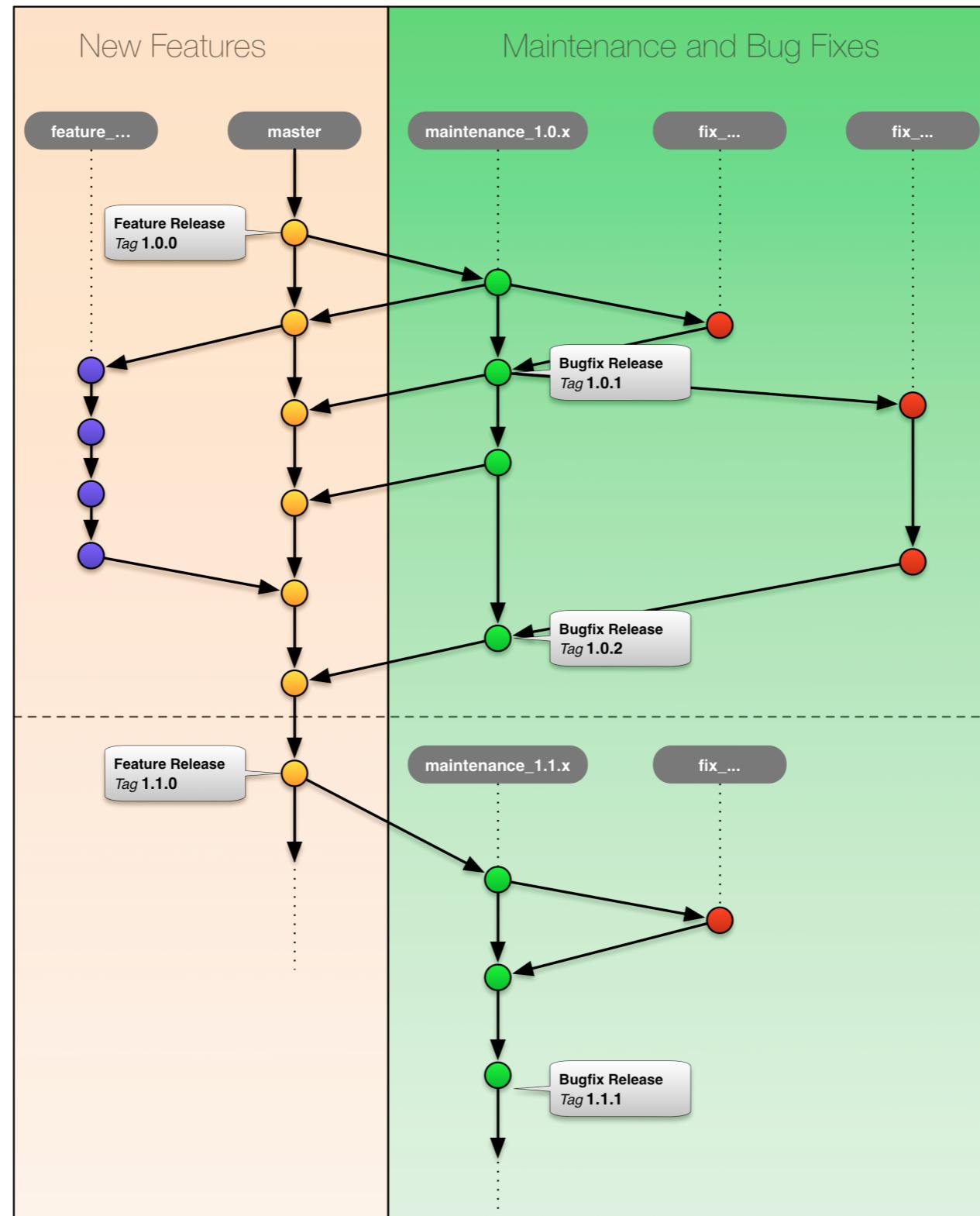
Commits per Month



Test Reports Overview of the latest 20 test reports						
Report	Errors / Errors / Errors	Obspy	Nodes	Python Version	System	Finished
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_7_wheel	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_13_1	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-debian_7_whacky	2.7.8	Linux (32bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_14_04_trusty	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_14_10_xpico	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-debian_8_jessie	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-fedora_20	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-fedora_21	2.7.8	Linux (64bit)	an hour ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-opensuse_13_2	2.7.8	Linux (64bit)	2 hours ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_12_04_precise	2.7.8	Linux (64bit)	2 hours ago
✗42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	38	sphinx	2.7.8	Linux (32bit)	2 hours ago
✗42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	38	sphinx	2.7.8	Linux (64bit)	2 hours ago
✗42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	38	sphinx	2.7.8	Linux (32bit)	10 hours ago
✗42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1196	27	locahost	3.4.3	Linux (64bit)	21 hours ago
✗42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	38	sphinx	2.7.8	Linux (32bit)	a day ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-debian_7_whacky	2.7.8	Linux (64bit)	a day ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_14_04_trusty	2.7.8	Linux (64bit)	a day ago
✓42541 - 0.10.3rc1.dev0+258.g42029d4f.obspy master	1216	32	docker-ubuntu_14_10_xpico	2.7.8	Linux (64bit)	a day ago

tests.obspy.org

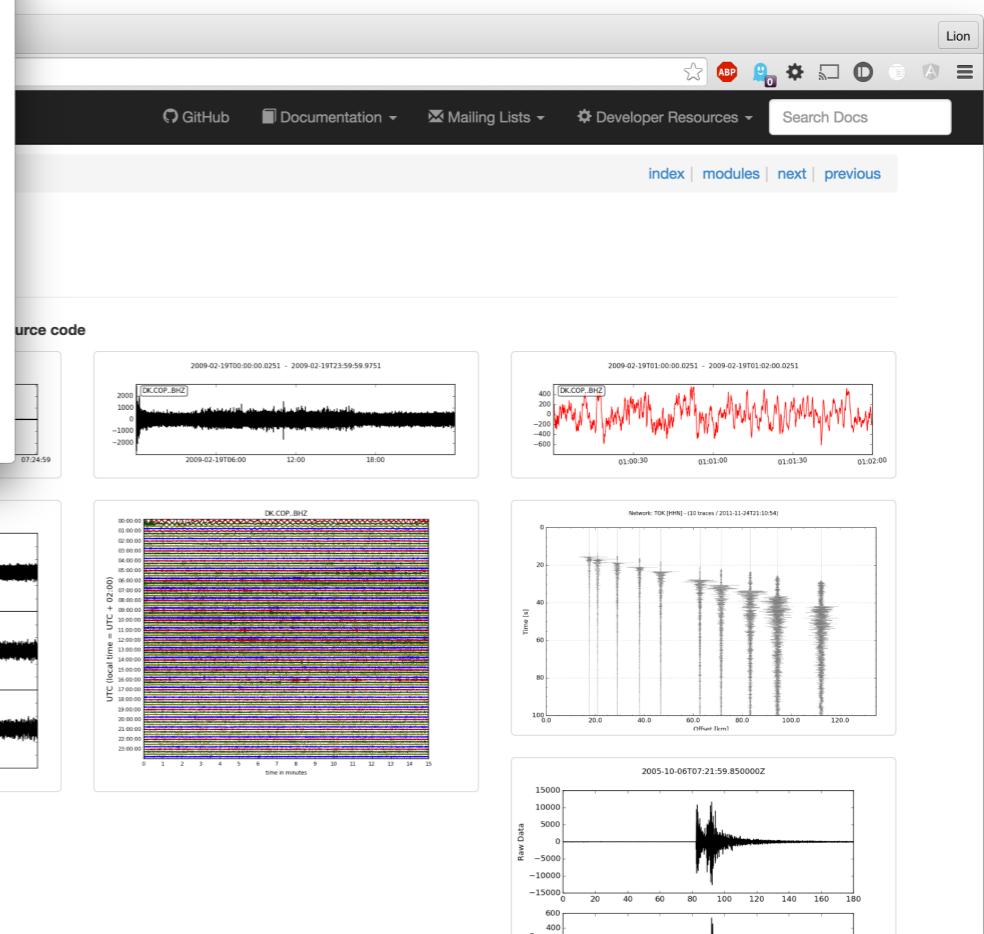
Development



Documentation

The screenshot shows the ObsPy Documentation website at docs.obspy.org. The main page features a large "Welcome to the ObsPy Documentation! (1.0.1)" heading and a subheading "A Python Toolbox for seismology/seismological observatories.". Below this is a brief introduction about ObsPy's purpose and a statement about its goal. The page includes sections for "Documentation", "Indices and Tables", and "Source code". The "Documentation" section contains links to "Tutorial", "Library Reference", "Announcements / User Mailing Lists", "Gallery", "FAQs", and "Help!". The "Indices and Tables" section has links to "Global Module Index" and "Complete Table of Contents". The "Source code" section displays several seismic waveform plots, including a 3-panel plot for DK.COP.BHZ, a spectrogram for DK.COP.BHZ, and a plot for Network.TOK.DHHB.

docs.obspy.org



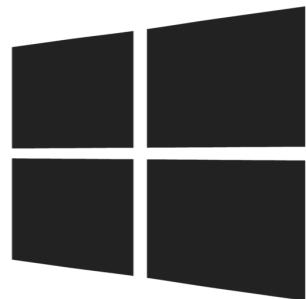
Installation



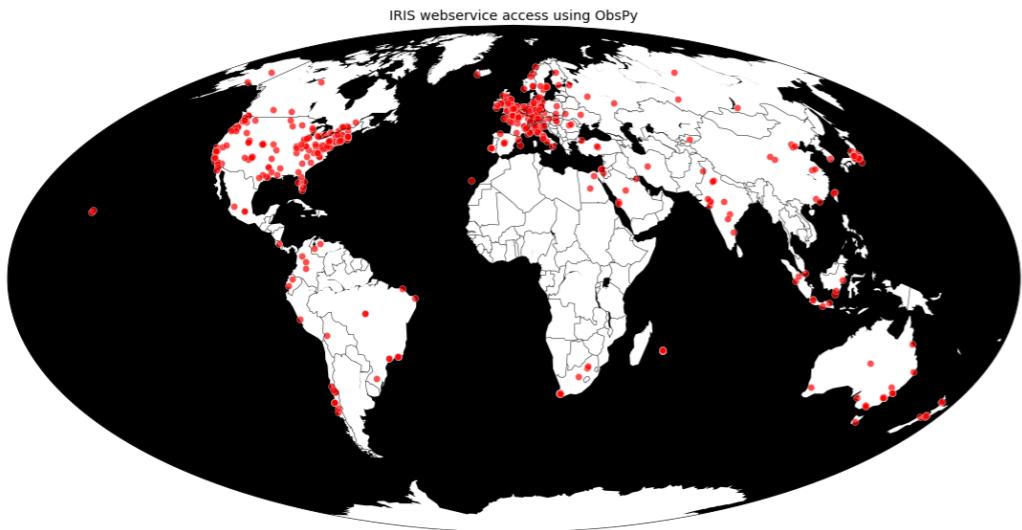
Anaconda

```
$ conda install -c obspy obspy
```

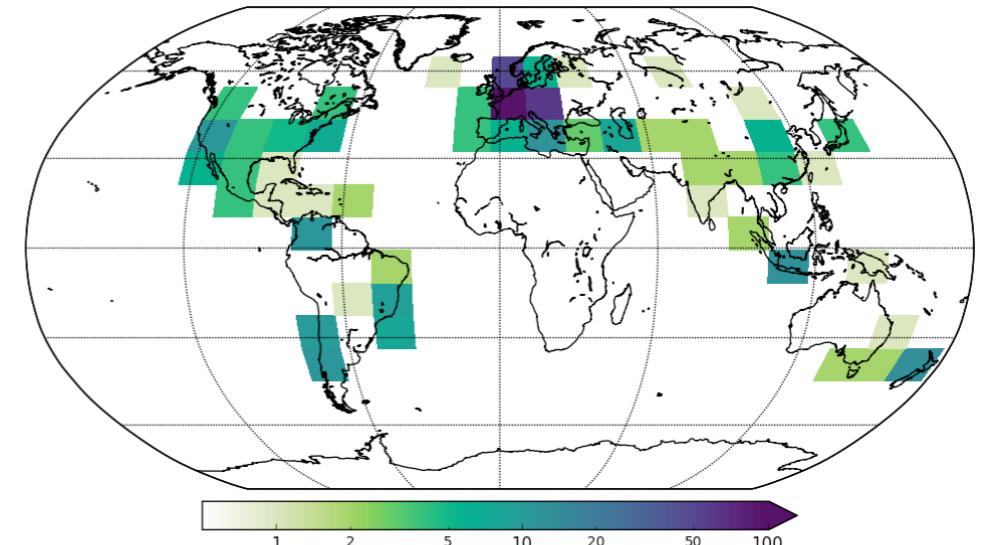
Installers/Packages for many platforms as well



Do People Use It?



Each point represents one city where at least one person used ObsPy to download data from IRIS.



ObsPy 1.0.1-1 Debian/Ubuntu package downloads (422 unique IPs in 28 days)
This represents only a small subset of all Obspy downloads.

Mailing List

419 members total

GitHub

Unwatch ▾ 89 Unstar 218 Fork 161

We have no hard metrics.

Conda Installations

LGPLv3

7997 total downloads

Publications citing ObsPy

- Currently ~ 178
- Many don't cite us :-(
- Applications include event (re)locations, ambient seismic noise analysis, seismic tomography, rotational seismology studies, time-dependent seismology, big data processing, attenuation kernels, ...



Grigoli, F., Cesca, S., Amoroso, O., Emolo, A., Zollo, A., & Dahm, T. (2013). Automated seismic event location by waveform coherence analysis. *Geophysical Journal International*, 196(3), 1742–1753.



Hadzioannou, C., Gaebler, P., Schreiber, U., Wassermann, J., & Igel, H. (2012). Examining ambient noise using colocated measurements of rotational and translational motion. *Journal of Seismology*, 16(4), 787–796.



Fichtner, A., & van Driel, M. (2014). Models and Fréchet kernels for frequency-(in)dependent Q. *Geophysical Journal International*, 198(3), 1878–1889.

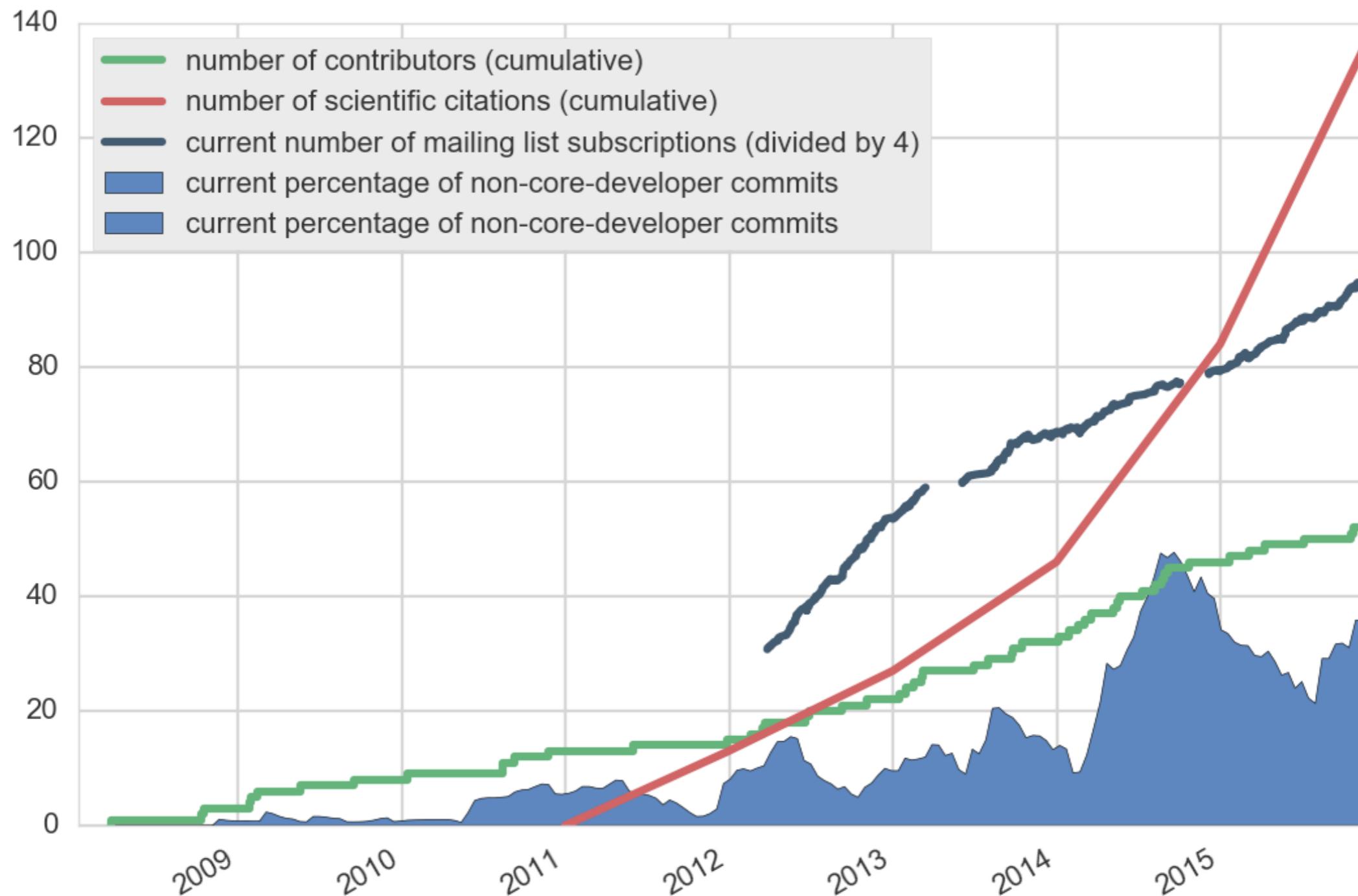


Richter, T., Sens-Schönenfelder, C., Kind, R., & Asch, G. (2014). *Journal of Geophysical Research : Solid Earth* Comprehensive observation and modeling of earthquake and temperature-related seismic velocity changes in northern Chile with passive image interferometry, 4747–4765.



MacCarthy, J. K., & Rowe, C. a. (2014). Pisces: A Practical Seismological Database Library in Python. *Seismological Research Letters*, 85(4), 905–911.

Timeline



Who Pays?

No formal funding ever!

Get Involved!

There is always stuff to do.

We need new people to sustain this.

True community project!

Thank you

<http://www.obspy.org>

[obspy-users] mailing list: users@obspy.org



@obspy



obspy