VarPy: A python library for volcanic and rock physics data analysis

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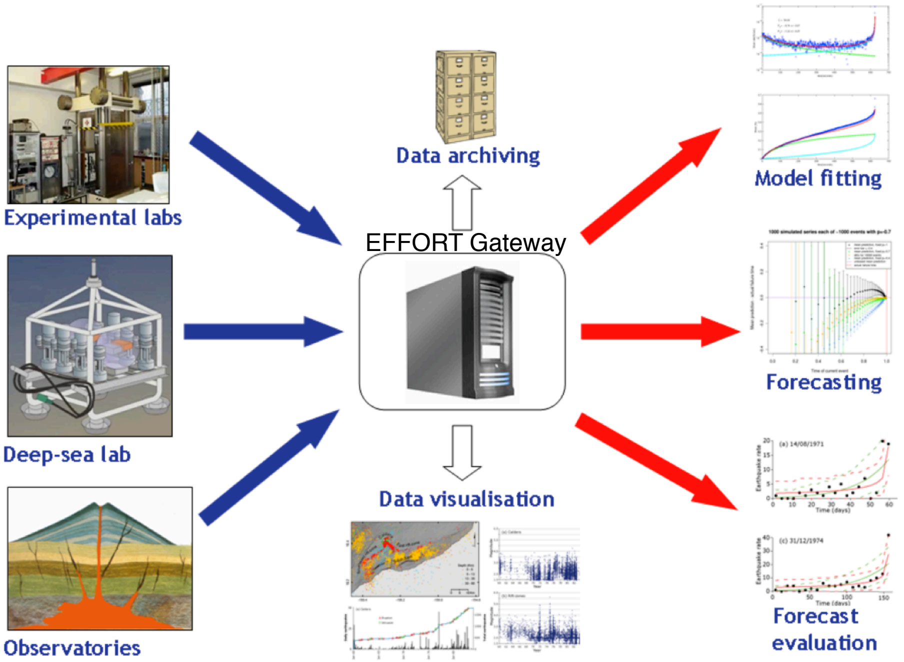
Introduction- EFFORT

Multi-disciplinary project: Geoscientists, Rock-Physicists, and Computer Scientists

- **EFFORT aims**:
  - To predict brittle failure of rock samples
  - To scale these predictions with geo-system complexity
  - To provide facility for moving an storing big data.
  - To provide facility for developing and testing codes

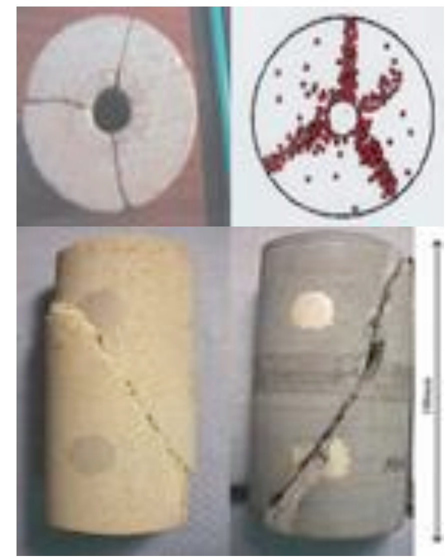


Rock Physics Laboratory experiments

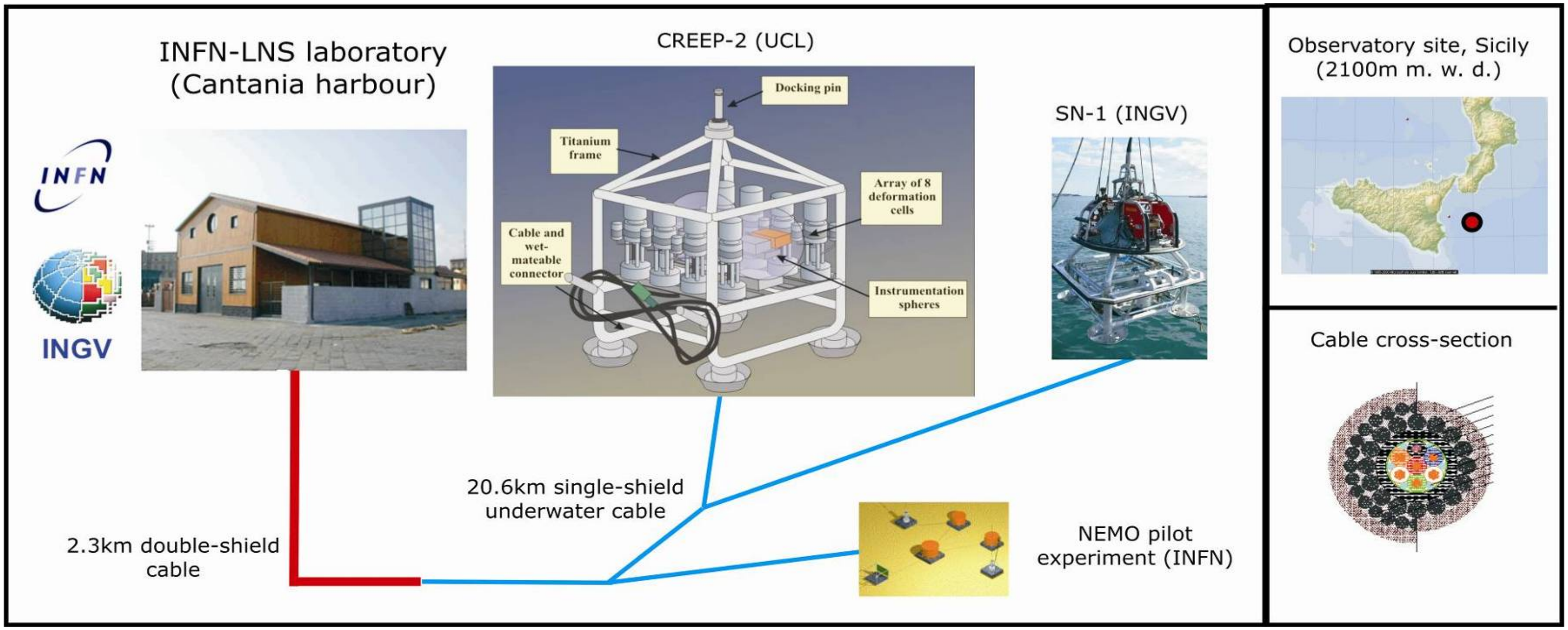
Pressure Vessel

UCL- RP Laboratory

Rock Samples



Complex laboratory experiment:



Initial target: 30 months
Deploy under the sea- Mediterranean
8 rock samples- different features
Different interval of times and data sizes

EFFORT Science Gateway

- **Science gateway for rock physicists and volcanologists, which supports:**
  - sharing data from laboratories and observatories in real-time
  - sharing models and methods for analyzing data
  - supporting recurrent operational tasks

Volcanology and Rock Physics Communities

- Increase of digital instrumentation in volcanology and rock physics
  - Huge amount of seismicity data that need for computational analyses and models.
- Those communities they have recently started to share:
  - Data & Models
- Each researcher develops each own codes
- Not library designed specifically for volcanic earthquake and rock physics data

Proposal: VarPy

- New open-source python toolbox
- Aim: facilitate rapid application development for those communities
  - Focus in seismicity deformation data
  - Full repertoire of commonly required actions
    - Analysis and modeling in real time and retrospective
    - Capabilities for data exploration, data analysis, quality check
  - Users can define their own workflows to develop
    - models, analyses and visualizations

EFFORT and VarPy

- VarPy will help run the user's models in the gateway automatically.
- Two variants of the VarPy with many of the functions identical: Gateway & Developers versions

Expected Benefits

- Easy method to analyze **seismicity data**
- Standardize different tasks/procedures
- Using the same functions by different researches → easier to compare results and performance of models
- Cost of maintaining the library is shared among the community

VarPy design

- Library style from **ObsPy:**
  - Open-source Python toolbox for **seismological data processing.**
  - Well documented, many user, grows progressively, users support
- VarPy does not attempt to replace the functions provided by other python libraries (NumPy, SciPy) → complementary of them
- VarPy & Ipython notebooks

VarPy datatypes

- **Seismicity deformation: strain and stress data**
- Time-series data of two classes
  - *Event catalogue data* (ECD)
    - Series of events (acoustic emissions, earthquakes, volcanic eruptions)
    - Occur at discrete times
    - Specific attributes (location, depth, magnitude, duration)

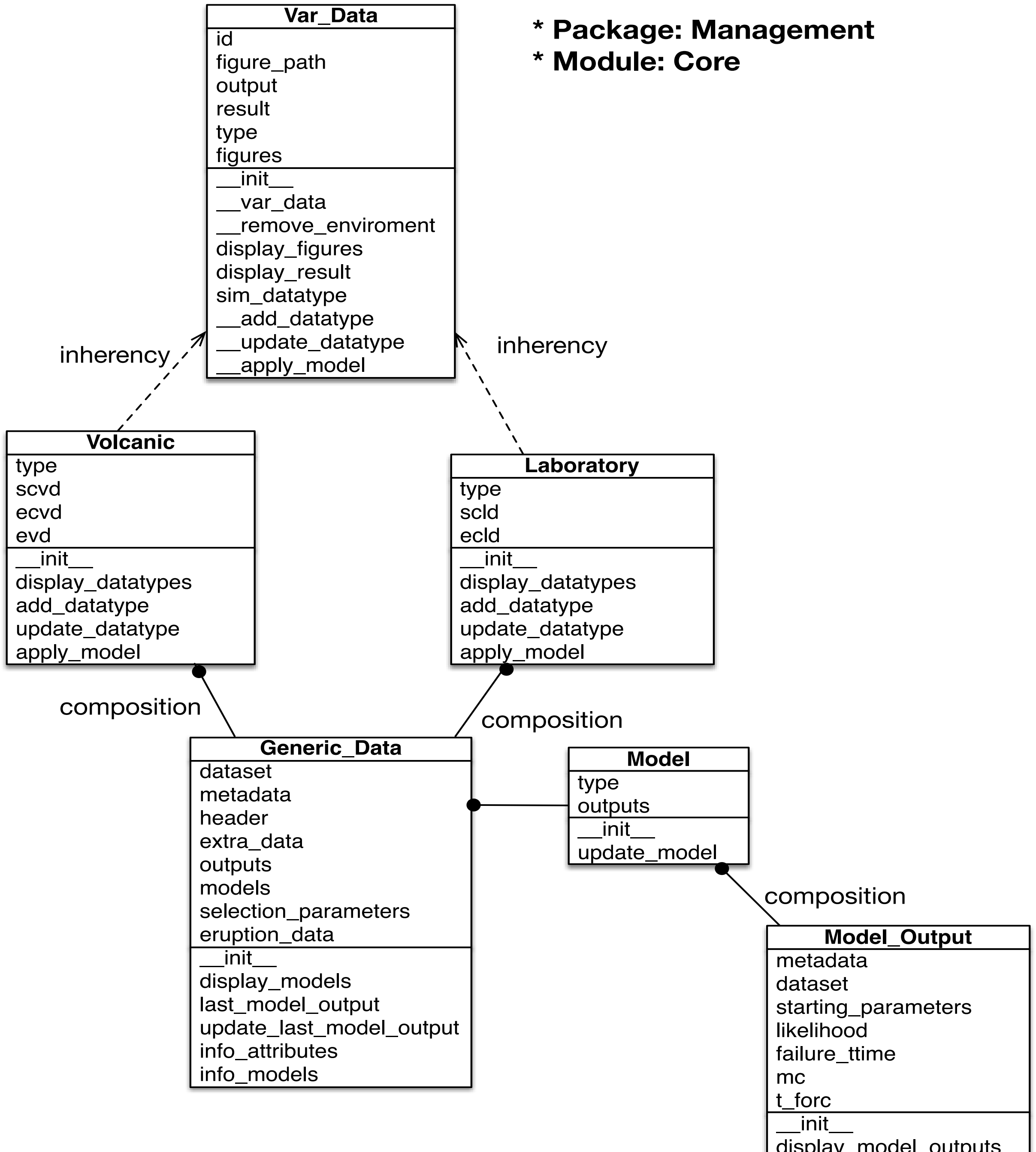
  - *Sampled continuous data* (SCD)
    - Series of times at which a continuous variable has been measured, and the value of that variable
    - Sample times are defined by the instruments' operator
    - May (or may not) be evenly spaced (daily, every second).

- Volcanic observatories and rock physics laboratories can produce data of both classes in a single experiment.

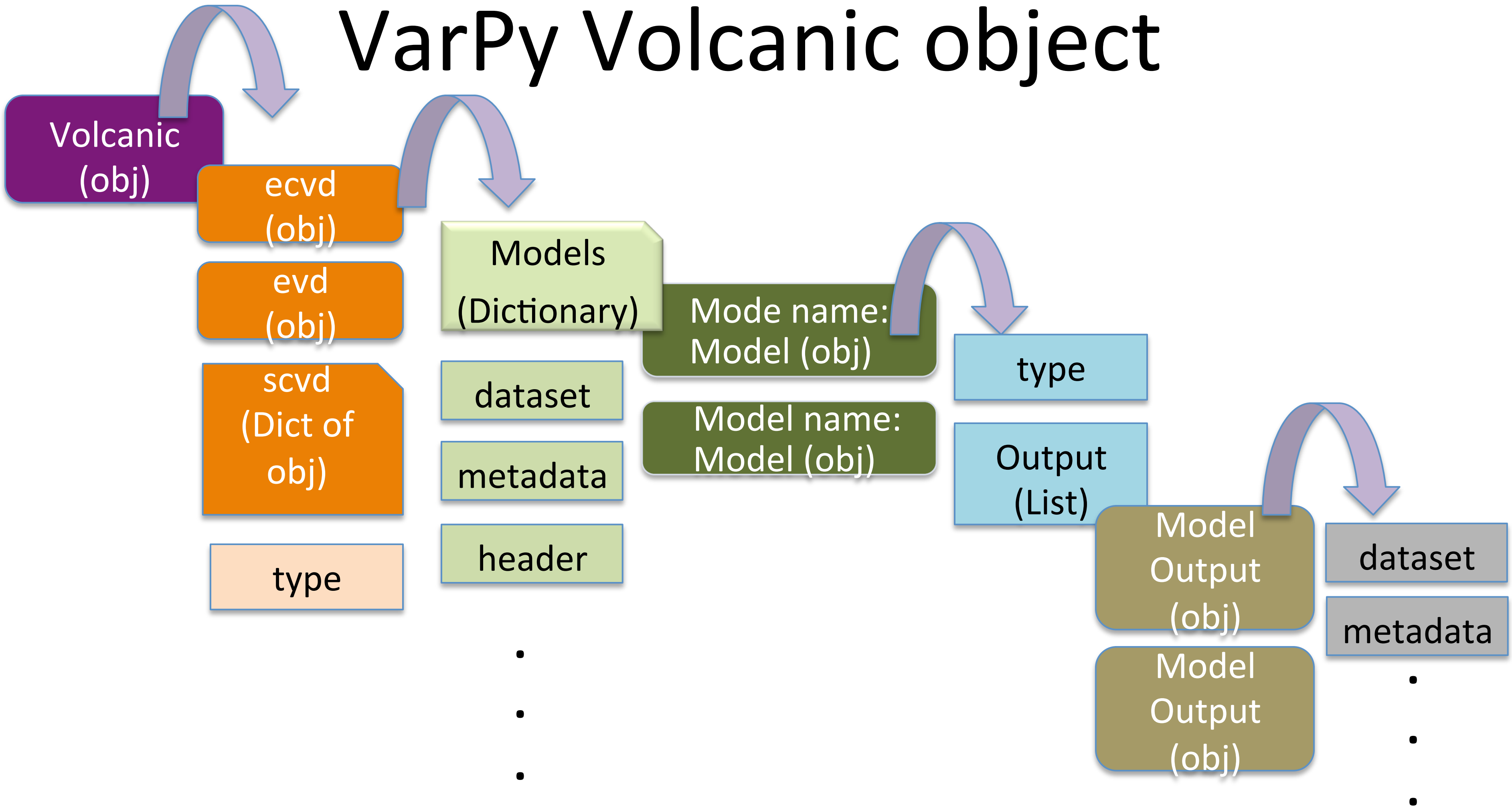
VarPy datatypes

- Representation by using 4 different datatypes
  - *Event catalogue laboratory data* (ECLD)
  - *Event catalogue volcanic earthquake data* (ECVD)
  - *Sampled continuous laboratory data* (SCLD)
  - *Sampled continuous volcanic earthquake data* (SCVD)
- Volcanic data also have:
  - Eruption volcanic data (EVD):
    - Time-series data of volcanic eruptions, intrusions, or other events
    - with descriptions (type, size, duration,)

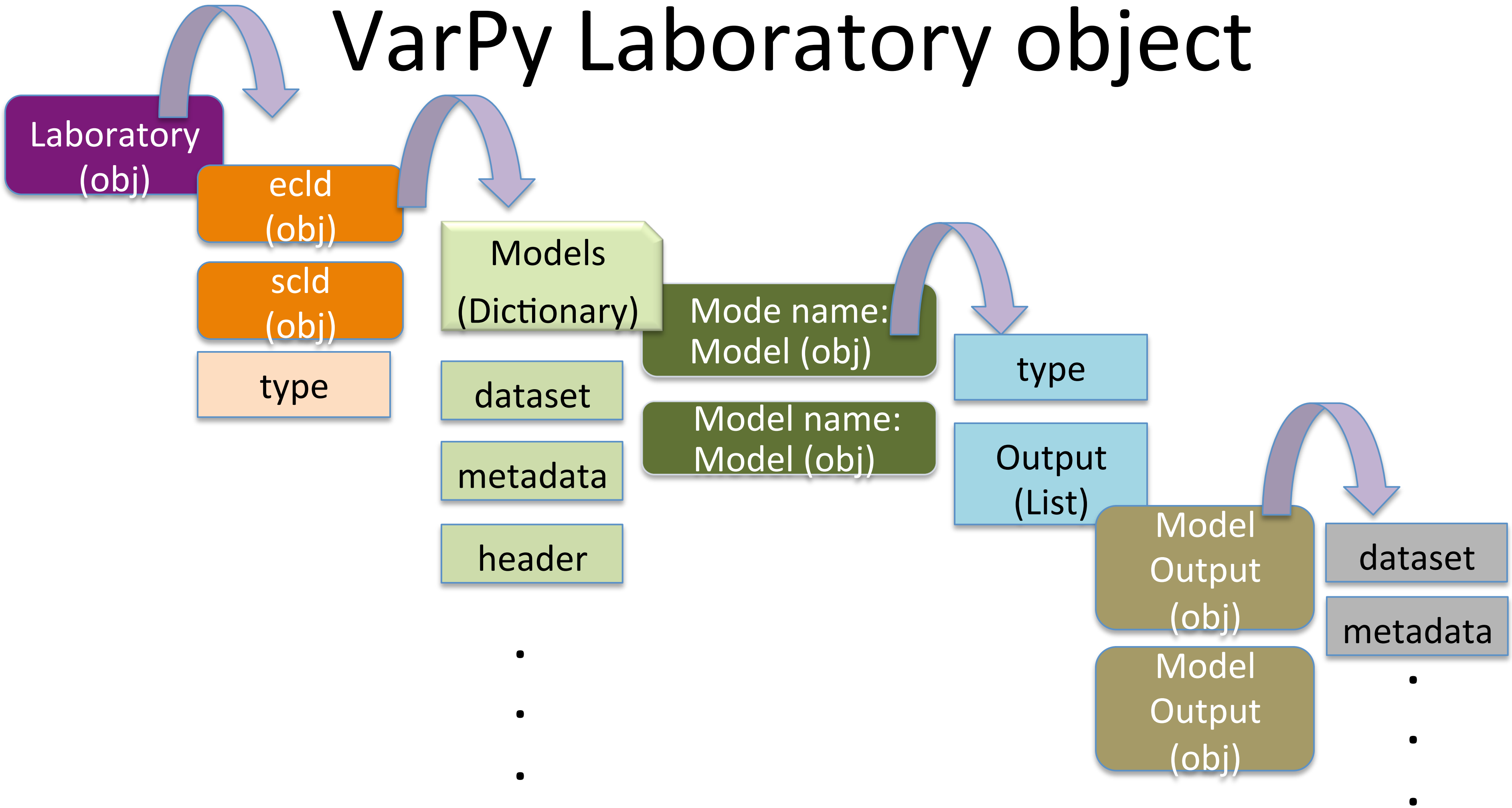
* **Package: Management**
* **Module: Core**



VarPy Volcanic object



VarPy Laboratory object



Example of VarPy objects

- Volcanic object with *ecvd* datatype:

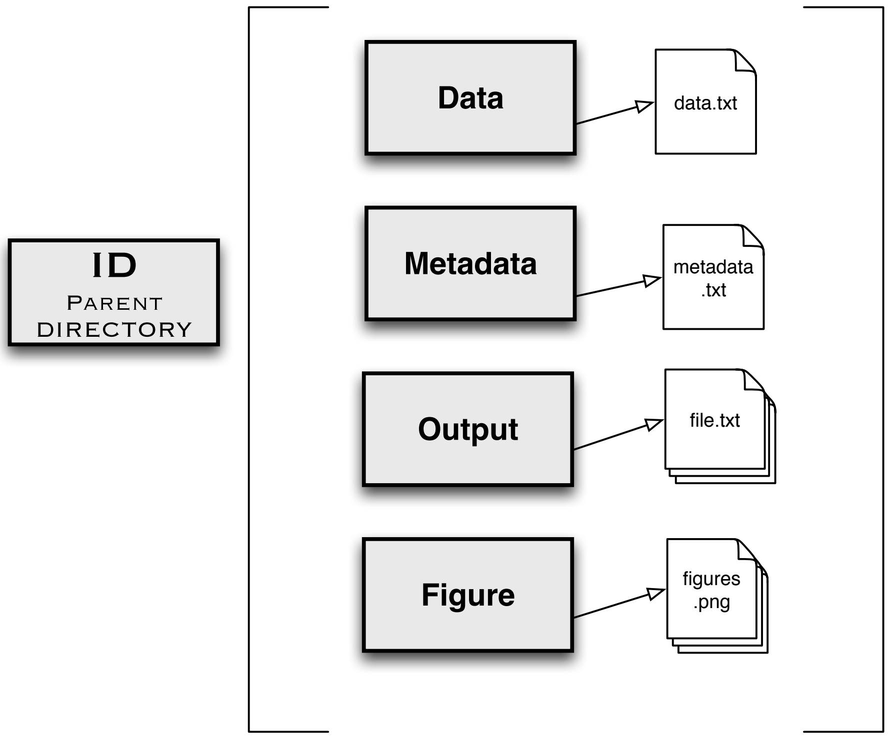
```
from varpy.management import core
ID = 'Tjornes_ex1'
ecvd_data_file = ’Iceland_IMO_C1_95-onwards.txt'
ecvd_metadata_file = ‘Iceland_IMO_C1_meta.txt’
d1 = core.Volcanic(ID)
d1.add_datatype('ecvd’,ecvd_data_file,ecvd_metadata_file)
```

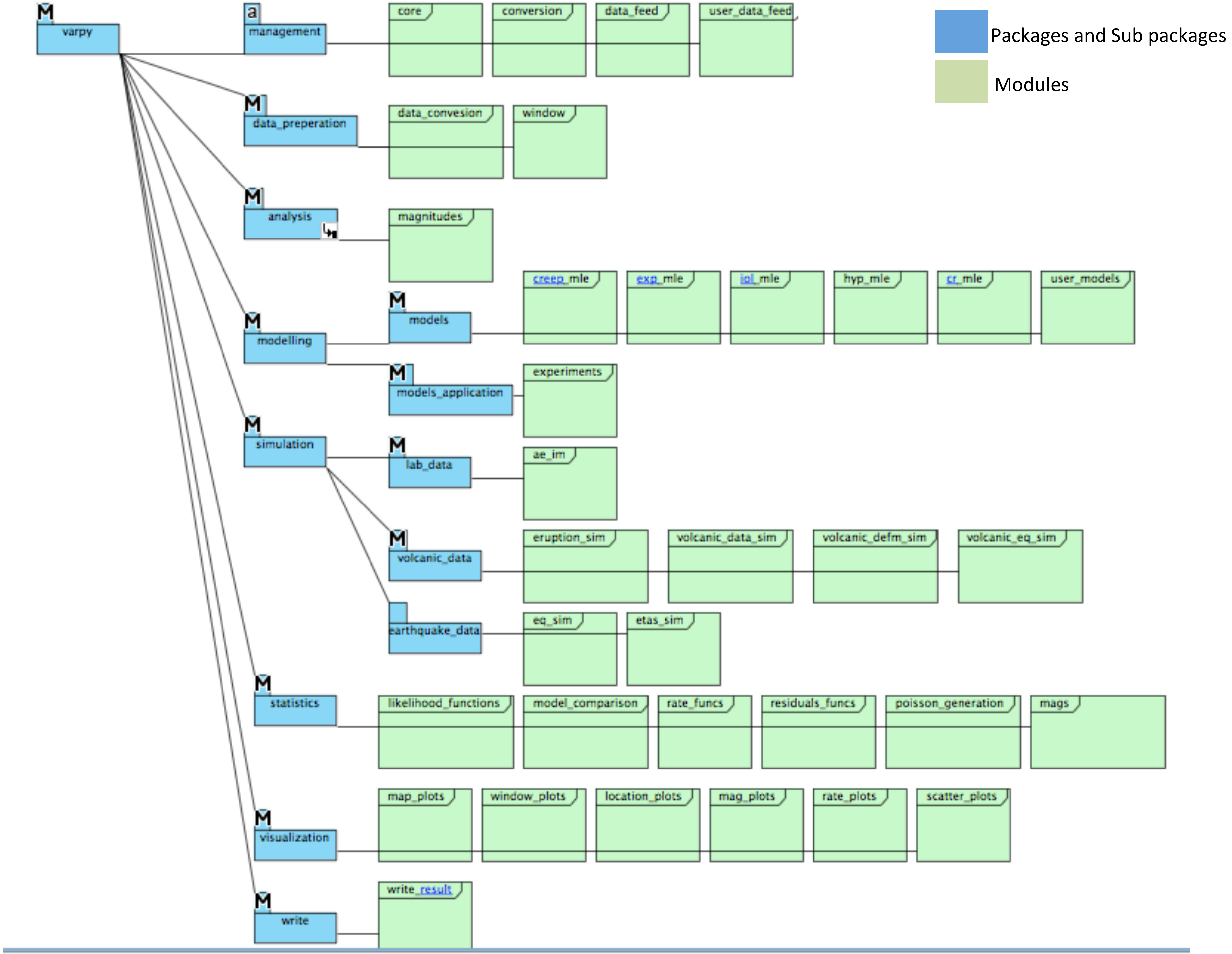
- Laboratory object with *scld* datatype:

```
from varpy.management import core
ID = ’UCL_Lab’
scld_data_file = ’UCL-exp1.txt’
scld_metadata_file = ‘UCL-exp1-meta.txt’
d2 = core.Laboratory(ID)
d2.add_datatype(‘scld’,scld_data_file,scld_metadata_file)
```

VarPy environment

- `d1 = core.Volcanic(ID) or`
- `d1 = core.Laboratory(ID)`
- Creates a tree-directory in the current directory

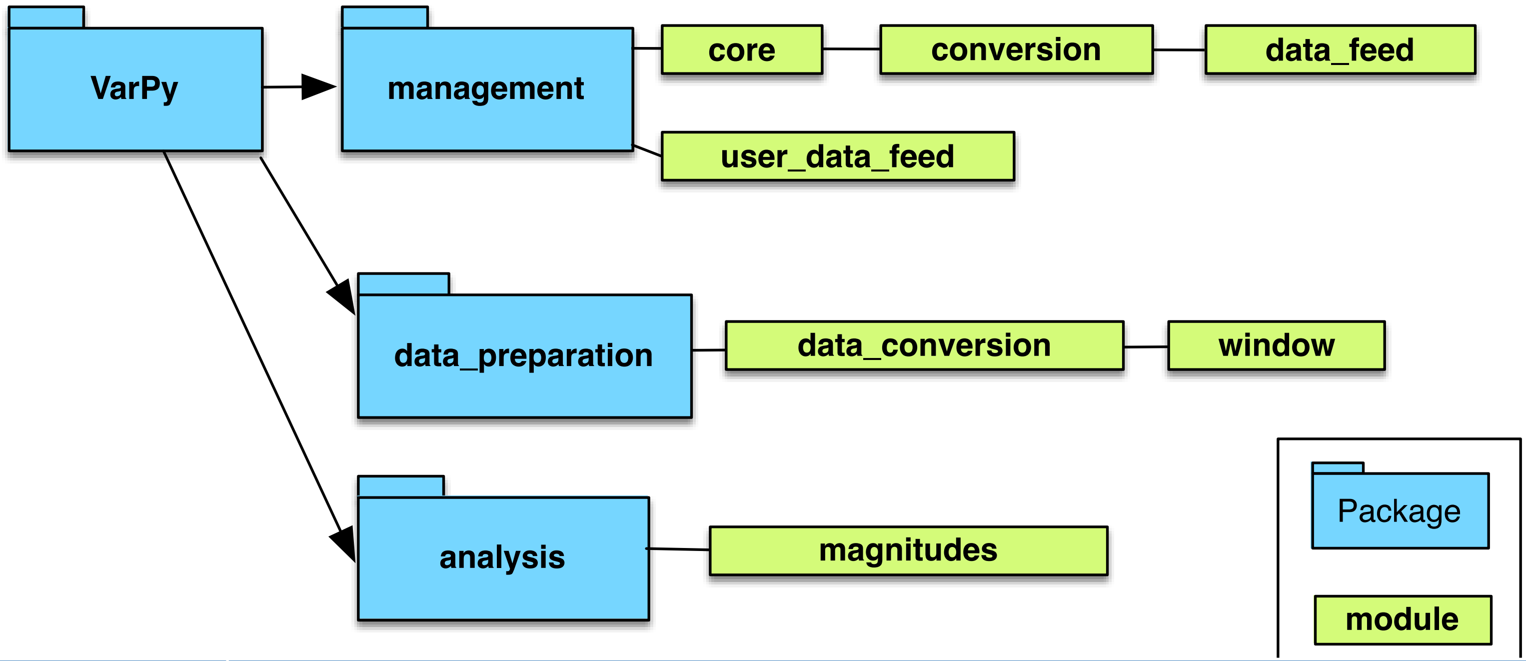




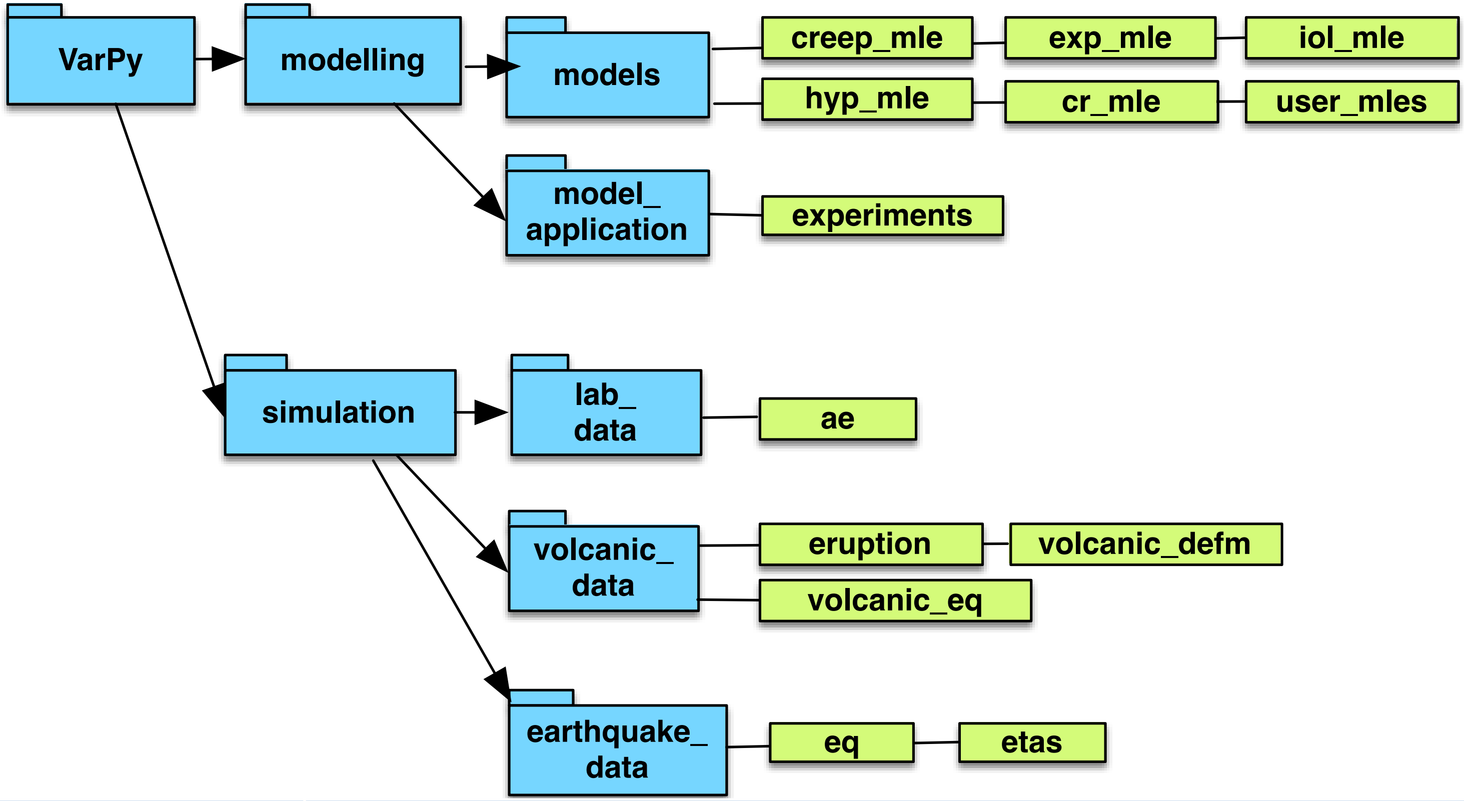
Packages and Sub packages
Modules
varpy
management
core
conversion
data_feed
user_data_feed
data_preperation
data_convesion
window
analysis
magnitudes
modelling
models
creep_mle
exp_mle
iol_mle
hyp_mle
cr_mle
user_models
models_application
experiments
simulation
lab_data
ae_im
volcanic_data
eruption_sim
volcanic_data_sim
volcanic_defm_sim
volcanic_eq_sim
earthquake_data
eq_sim
etas_sim
statistics
likelihood_functions
model_comparison
rate_funcs
residuals_funcs
poisson_generation
mags
visualization
map_plots
window_plots
location_plots
mag_plots
rate_plots
scatter_plots
write
write_result

General Packages

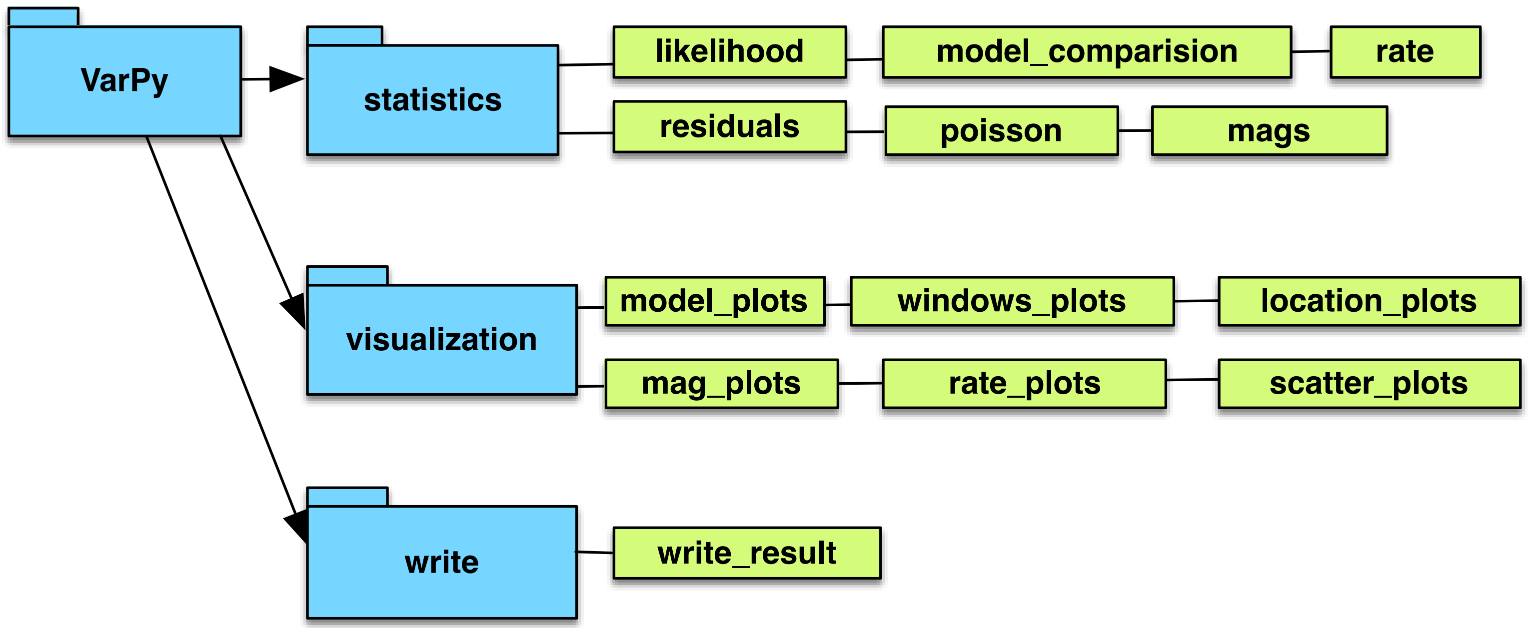
Package	Functionality
varpy.mangement	Core classes
varpy.data_preparation	Filtering routines
varpy.analysis	Analyzing filtered data routines
varpy.modeling	Modeling routines
varpy.simulation	Simulating routines of seismic data
varpy.statistics	Statistical routines for assisting with other routines
varpy.visualization	Plotting routines
varpy.write	Writing results routines



Module	Functionality: Module for
core	Handling varpy objects and methods.
conversion	Converting dates and time into different formats.
data deed & user_data_feed	Importing metadata and storing it into the varpy object
data_conversion	Converting values to another type of data (AE energy to magnitude)
window	Selecting a smaller sample based on a single (time window between two given dates) or on a combination of variables
magnitudes	Analyzing the filtered data (calculates completeness magnitude)



Sub-package	Functionality: Contains modules with
models	Various models which can be fitted to data.
model_application	Experiments: single analysis and multiple analysis
lab_data	Rock physics seismic data simulators
volcanic_data	Volcanic seismic data simulators
earthquake	Earthquake data simulators



Package	Functionality: Contains modules for
statistics	Assisting with the generation of synthetic data, fitting models and comparing models
visualization	Plotting filtered data, the results of analyses, simulated data and model
write	Writing the results of analyses and experiments into text files

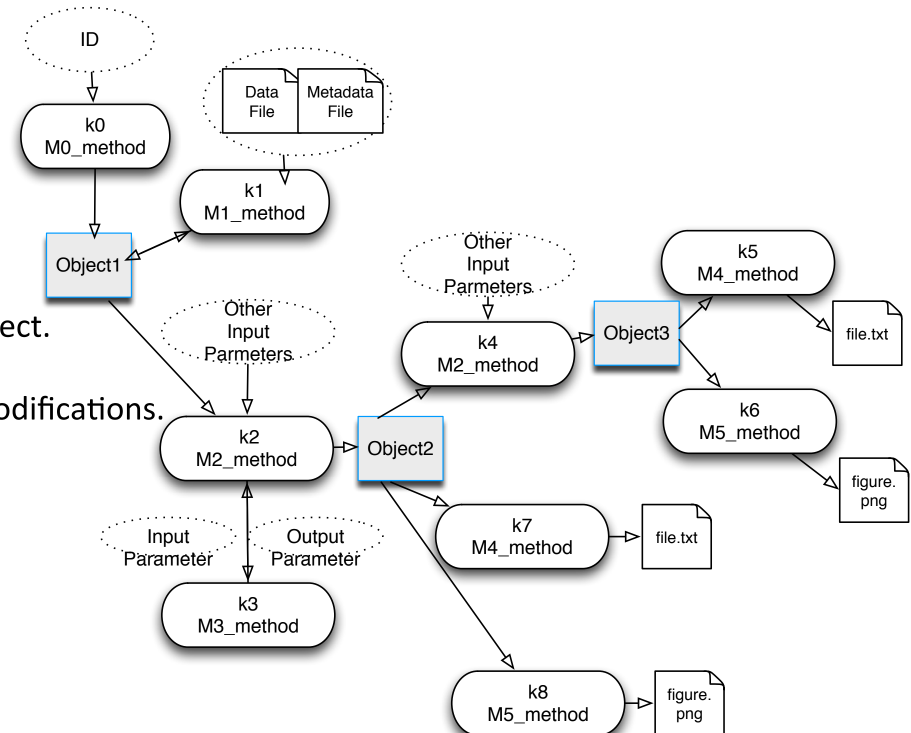
Varpy Experiments

- Experiments : Model + Filtered data + Parameters
- Experiment types:
  - Single Analysis → Apply once a model
    - Retrospective Analysis:
      - Known failure/eruption time (ft)
      - Output: How well the model explains the data
    - Single Forecast
      - ft is not known
      - Output: Prediction of the failure/eruption.

  - Multiple Analysis → Apply several time a model → Data is streamed
    - Prospective Forecast
      - ft not known
      - Output: Prediction in real time of the failure/eruption.
    - Retrospective Forecast:
      - Simulate ft not known
      - Output: Prediction of the failure/eruption

Type of methods

- M0 method
  - Aim: to create a volcanic or laboratory object
  - Input: ID
  - Output: new object with and tree-directory.
- M1 method:
  - Aim: to add an attribute to an object
  - Input: data and metadata files
  - Output: Add the attribute to the object,
    and copy the files into the tree-directory
- M2 method
  - Aim: to modify an attribute (or several attributes) of a object.
  - Input: object
  - Return: new object (copy of the input object) with the modifications.
    NO creates another tree-directory
- M3 method
  - Aim: to transform data.
  - Input: data
  - Output: data transformed
- M4 method
  - Aim: to write an attribute of an object to file.
  - Input: attribute of the object
  - Output: store a new file in the tree-directory
- M5 method
  - Aim: to plot into a figure an attribute of an object.
  - Input: attribute of the object
  - Output: store new figure the tree-directory



VarPy Iptyhon Notebooks

- Notebook-1
  - Example of data exploration and visualization based on the Tjornes fracture zone (Iceland)
- Notebook-2
  - Example of applying forecasting methods using volcanic data from Mt. Etna

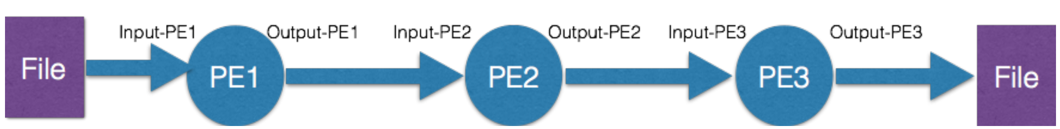
VarPy contributions

- VarPy already allows:
  - Data exploration
  - Quality check
  - Data analysis
- Researchers could contribute:
  - Developing standards for:
    - Data format
    - Methodology for processing data
  - New models, simulators of seismic data, filters …

Dispel4py

Dispel4Py is a library used to describe abstract workflows for distributed data-intensive applications

- Python language for describing tasks and connections
- PEs represent the basic computational blocks of any dispel4Py workflow: algorithm, service, data transformation
  - Shared: Storing them into the registry
  - Reusable: To be recombined in many different applications
- Graph: topology of the workflow
- Partitions, Groupings, Composite Pes
- Automatic mappings: MPI, STORM, Multiprocessing, Sequential
  - Scalability



Conclusions

- New Python open-source toolbox for volcanologists and rock physicists
- Study seismicity data
- Full repertory of common actions:
  - Analysis and Modelling
  - Real-time and retrospective-time
- Encourage collaboration between scientists

Questions

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