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Introduction

STAR-BME (Space-Time Analysis Rendering with Bayesian Maximum Entropy) is a specialized software tool for geostatistical analysis of spatial and space-time data. In its current format, it is built as a plugin for [QGIS](#), which is a fast-growing and increasingly popular, open-sourced Geographical Information System software.

Spatiotemporal modeling with STAR-BME performs many common geostatistical tasks and extends its functionality with unique features based upon the modern geostatistics framework proposed by Christakos (Christakos 1991, Christakos 2000). This framework is known as Knowledge Synthesis, and its techniques are based on the Bayesian maximum entropy (BME) methodology. Knowledge Synthesis extends the conventional geostatistical methods by means of an epistemic approach which:

- can synthesize core knowledge bases, empirical evidence, and multi-sourced system uncertainty.
- generates a meaningful picture of real-world systems using space-time dependent probability functions and associated maps.

In the present version, the main features of STAR-BME include:

- Integration of multi-sourced space-time data in different data formats
- Incorporation of space-time data of multi-sourced uncertainties
- Analysis of space-time dependence (empirical and mathematical spatiotemporal models)
- Prediction and mapping in space and time
- Model cross-validation for prediction
- Data export in multiple formats

If you think you have found a bug in STAR-BME, or if you would like to suggest an improvement or enhancement, please submit a new issue through (hlyu@ntu.edu.tw)

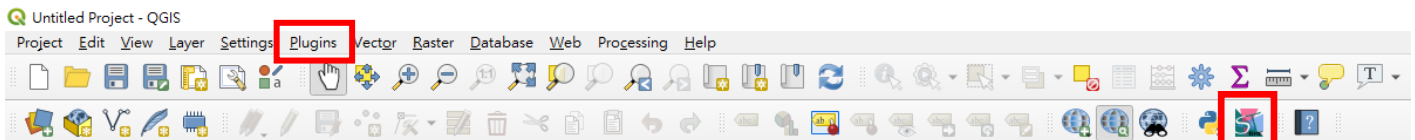
Installation

1. System Requirement
 - a. QGIS3.0 or higher (Recommend QGIS3.10.5)
2. Dependencies
 - a. Pandas 0.20.1 or higher
 - b. NumPy1.7.0 or higher
 - c. SciPy 0.19.0 or higher
 - d. Nlopt 2.6.1 or higher (Optional)
3. Quick start configuration

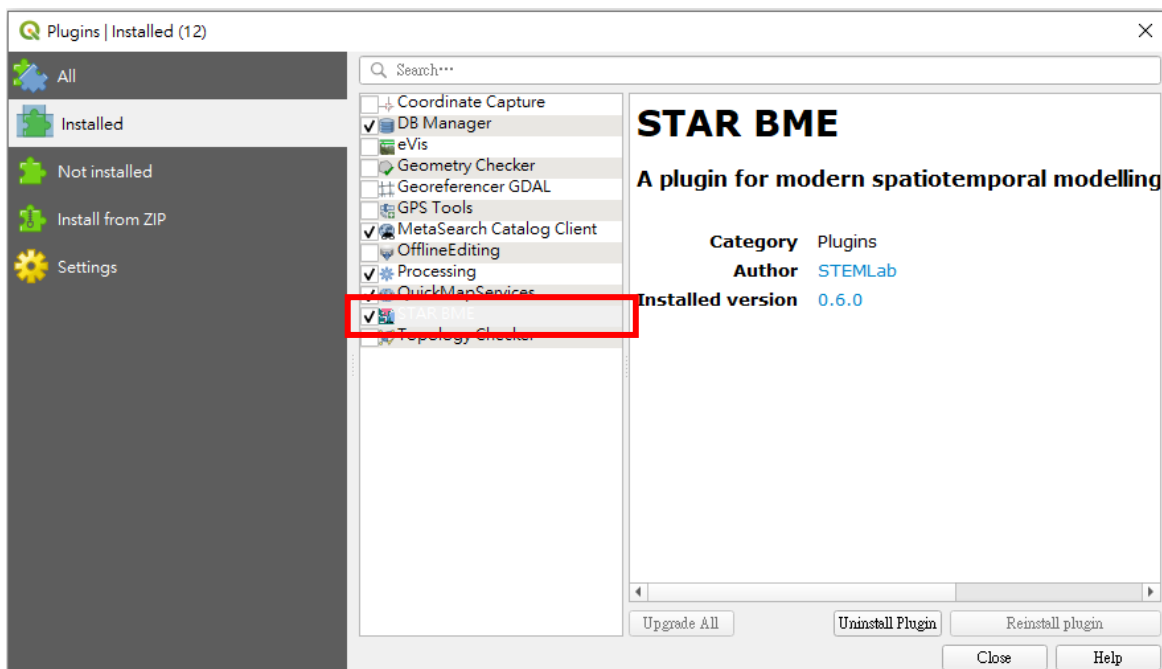
4. Set-up configuration

➤ Windows

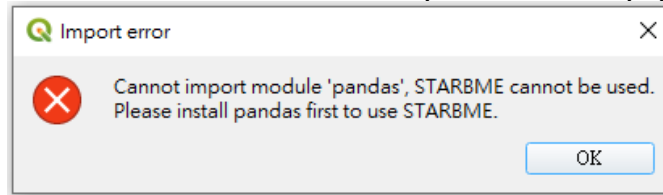
- I. Copy the downloaded file to
“C:\Users\“Username”\AppData\Roaming\QGIS\QGIS3\profiles\default\python\plugins.”
- II. Restart QGIS, and STARBME will be available in the QGIS toolbar.



If the STARBME icon does not exist in the toolbar, select “Plugin” → “Manage and Install Plugins”. Search “star bme” and click the checkbox of the STARBME plugin.



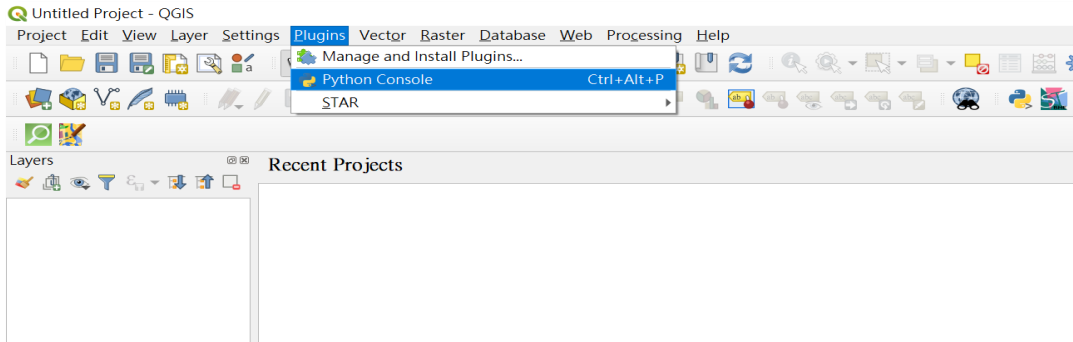
III. Click the STARBME icon, and an “import error” will pop up.



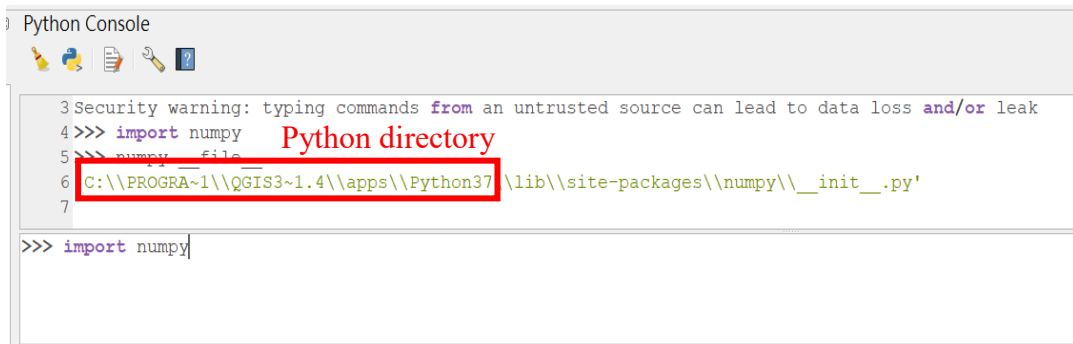
The required package should be installed first. Follow the steps below.

1) Find the Python directory QGIS working on.

✓ Select “Plugins” → “Python Console”



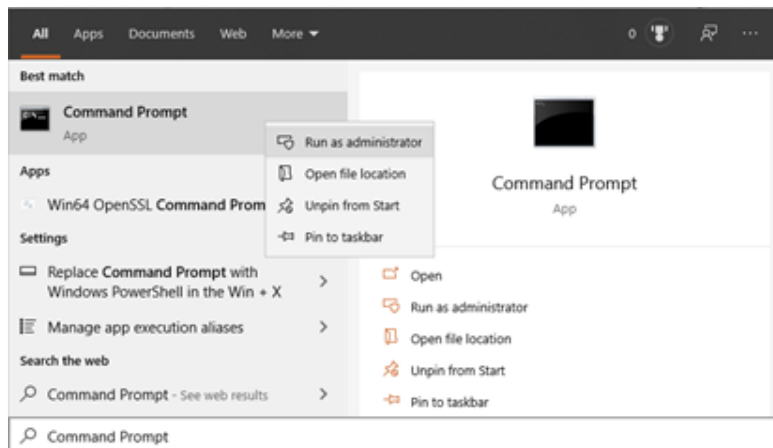
✓ Enter “import numpy” in the console, and then enter “numpy.__file__”.



✓ Go to “C:\Program Files\QGIS 3.4\apps\Python37”
“QGIS 3.4” will be different if the different version of QGIS is installed;
for example, it can be “QGIS 3.2” or “QGIS 3.10”.

2) Install required packages.

✓ Run the “Command Prompt” as administrator.



- ✓ Enter “cd C:\Program Files\QGIS 3.4\apps\Python37”

```
Administrator: Command Prompt
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>cd C:\Program Files\QGIS 3.4\apps\Python37

C:\Program Files\QGIS 3.4\apps\Python37>
```

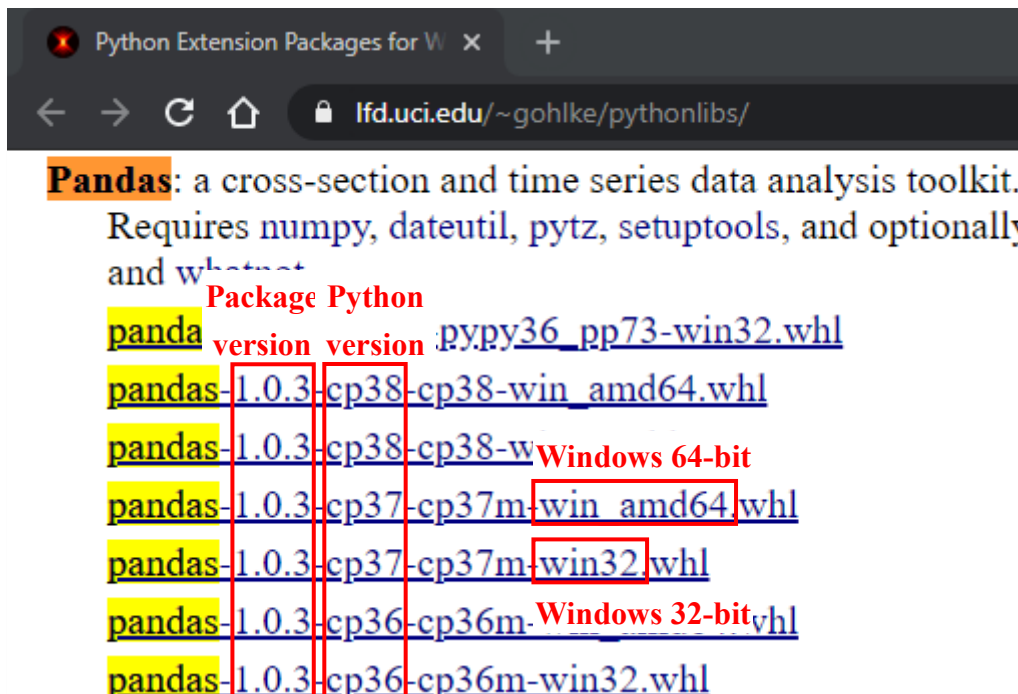
- ✓ Enter “python”. Then, enter “import numpy”, “import scipy”, “import nlopt” and “import pandas” respectively to find the missing packages.

```
Administrator: Command Prompt - python
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>cd C:\Program Files\QGIS 3.4\apps\Python37

C:\Program Files\QGIS 3.4\apps\Python37>python
Python 3.7.0 (v3.7.0:1bf9cc5093, Jun 27 2018, 04:59:51) [MSC v.1914 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import numpy
>>> import scipy
>>> import nlopt
>>> import pandas
Traceback (most recent call last):
  File "<stdin>", line 1, in <module> "pandas" needs to be installed.
ModuleNotFoundError: No module named 'pandas'
```

- ✓ Go to <https://www.lfd.uci.edu/~gohlke/pythonlibs/>.
- ✓ Download the suitable .whl file. (“pandas” as an example)



- ✓ Find the location of the downloaded file. The file might be in “C:\Users\“Username”\Downloads” or the other user-specified location for download.

- ✓ Enter “quit()” in the command line.

```
Administrator: Command Prompt
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>cd C:\Program Files\QGIS 3.4\apps\Python37

C:\Program Files\QGIS 3.4\apps\Python37>python
Python 3.7.0 (v3.7.0:1bf9cc5093, Jun 27 2018, 04:59:51) [MSC v.1914 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import numpy
>>> import scipy
>>> import nlopt
>>> import pandas
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ModuleNotFoundError: No module named 'pandas'
>>> quit()

C:\Program Files\QGIS 3.4\apps\Python37>
```

- ✓ Enter “python -m pip install C:\Users\“Username”\Downloads\pandas-1.0.3-cp37-cp37m-win_amd64.whl”

```
Administrator: Command Prompt - python -m pip install C:\Users\SYLee\Downloads\pandas-1.0.3-cp37-cp37m-win_amd64.whl
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>cd C:\Program Files\QGIS 3.4\apps\Python37

C:\Program Files\QGIS 3.4\apps\Python37>python
Python 3.7.0 (v3.7.0:1bf9cc5093, Jun 27 2018, 04:59:51) [MSC v.1914 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import numpy
>>> import scipy
>>> import nlopt
>>> import pandas
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ModuleNotFoundError: No module named 'pandas'
>>> quit()

C:\Program Files\QGIS 3.4\apps\Python37>python -m pip install C:\Users\SYLee\Downloads\pandas-1.0.3-cp37-cp37m-win_amd64.whl
```

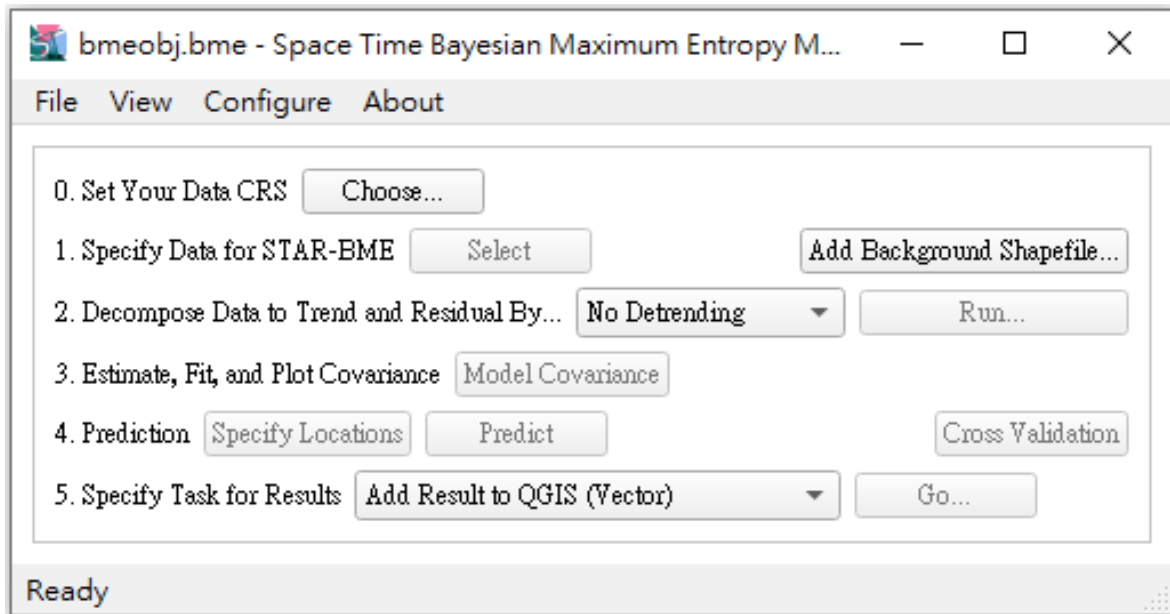
- ✓ Successfully installed.

```
Administrator: Command Prompt - python
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ModuleNotFoundError: No module named 'pandas'
>>> quit()

C:\Program Files\QGIS 3.4\apps\Python37>python -m pip install C:\Users\SYLee\Downloads\pandas-1.0.3-cp37-cp37m-win_amd64.whl
Processing c:\users\sylee\downloads\pandas-1.0.3-cp37-cp37m-win_amd64.whl
Requirement already satisfied: numpy>=1.13.3 in c:\program files\qgis 3.4\apps\python37\lib\site-packages (from pandas==1.0.3) (1.17.3)
Requirement already satisfied: pytz>=2017.2 in c:\program files\qgis 3.4\apps\python37\lib\site-packages (from pandas==1.0.3) (2019.3)
Requirement already satisfied: python-dateutil>=2.6.1 in c:\program files\qgis 3.4\apps\python37\lib\site-packages (from pandas==1.0.3) (2.8.1)
Requirement already satisfied: six>=1.5 in c:\program files\qgis 3.4\apps\python37\lib\site-packages (from python-dateutil>=2.6.1->pandas==1.0.3) (1.12.0)
Installing collected packages: pandas
Successfully installed pandas-1.0.3
```

```
Administrator: Command Prompt - python
C:\Program Files\QGIS 3.4\apps\Python37>python
Python 3.7.0 (v3.7.0:1bf9cc5093, Jun 27 2018, 04:59:51) [MSC v.1914 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import pandas
>>>
```

IV. STARBME is successfully installed in QGIS.



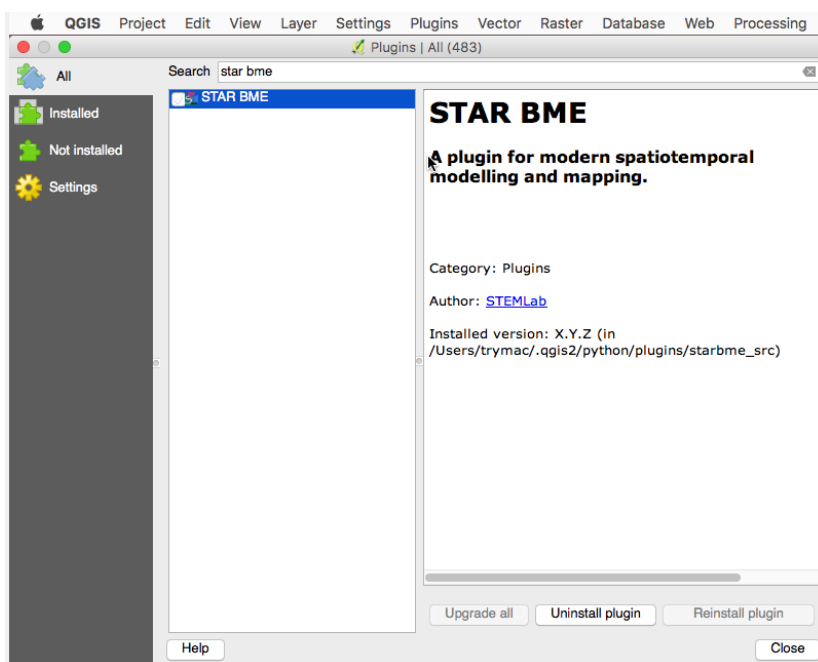
Mac-OS and Linux haven't been modified yet.

➤ Mac-OS

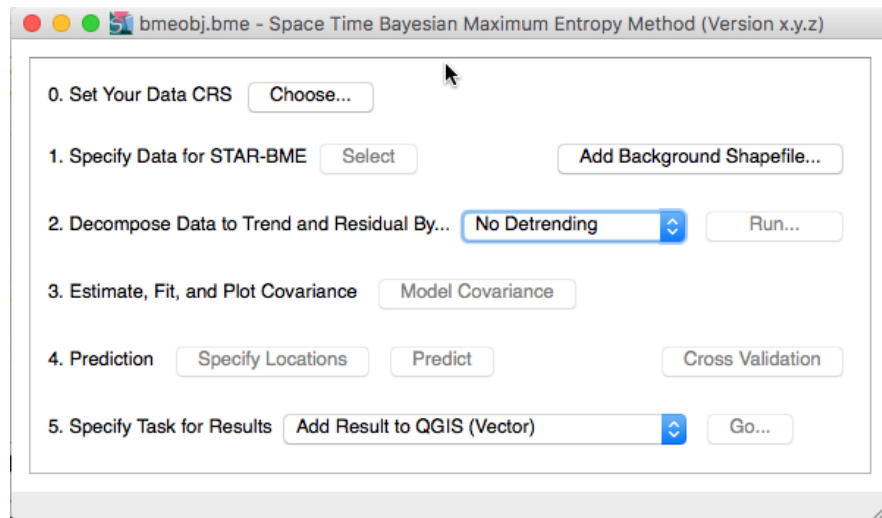
- I. Copy downloaded file to /Users/"Username"/.qgis2/python /plugins.
- II. Restart QGIS, STARBME will be available in QGIS tool bar.



If STARBME plugin does not exist in tool bar, select Plugin-Manager and Install Plugins. Search "star bme" and checked the box of STARBME plugin.



III. STARBME successfully install in QGIS.



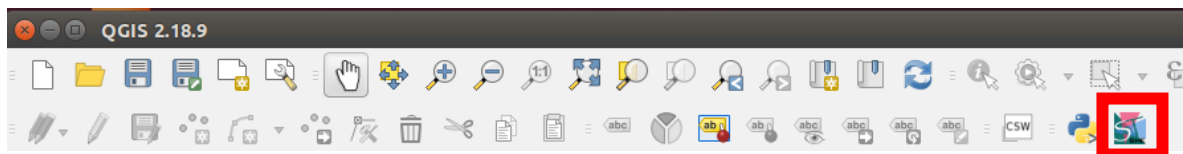
➤ Linux

I. Copy downloaded file to /usr/share/qgis/python/plugins.

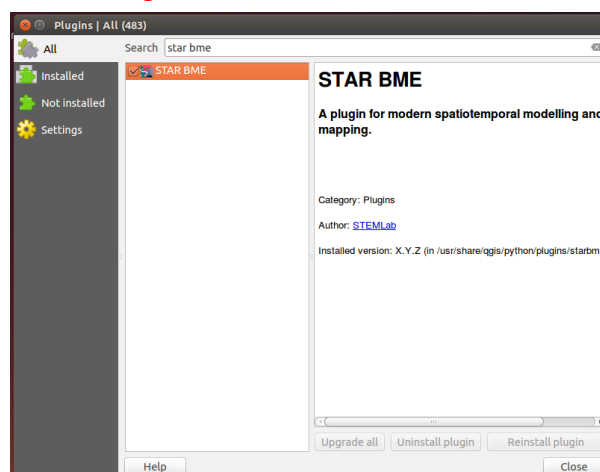
Example:

```
sudo cp -r /home/Username/Desktop/starbme_src  
/usr/share/qgis/python/plugins
```

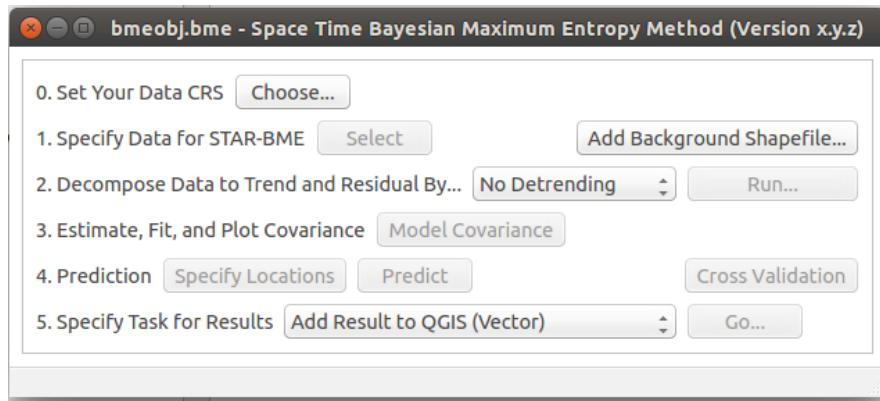
II. Restart QGIS, STARBME will available in QGIS tool bar.



If STARBME plugin does not exist in tool bar, select Plugin-Manager and Install Plugins. Search “star bme” and checked the box of STARBME plugin.



III. STARBME successfully install in QGIS.



[Maintenance, Error message and Troubleshooting]

a. Import error

I. If python module dependency error occurs, to update or install python module of QGIS.

a. Install pip

```
sudo apt-get install python-pip
```

- Install Pandas

```
sudo apt-get install python-pandas
```

- Upgrade SciPy

```
sudo pip install scipy -- upgrade
```

- Install matplotlib

```
sudo apt-get install matplotlib
```

II. If libblas and liblapack are not installed.

```
sudo apt-get install libblas-dev liblapack-dev
```

III. If Fortran is not installed.

```
sudo apt-get install gfortran
```

Maintenance, Error message and Troubleshooting

a. Error message

Due to Python module is not available in QGIS, therefore user needs to install this module to QGIS. For able to install python module, user can use pip to install.

I. Import error

a. Install pip

```
curl -O https://bootstrap.pypa.io/get-pip.py
```

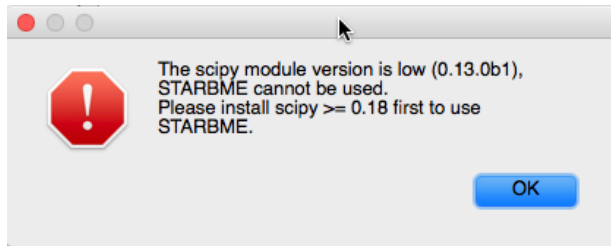
```
sudo python get-pip.py
```

- Pandas import error



Run “sudo pip install pandas” on terminal to install.

- SciPy import error or SciPy version error



Run “sudo pip install scipy --upgrade” on terminal to upgrade. If occurs “Operation not permitted” of NumPy. Use “sudo pip install --ignore-installed scipy -- upgrade” to upgrade both numpy and scipy.

Reference

Christakos, G. (1991). "On certain classes of spatiotemporal random fields with applications to space-time data processing." IEEE transactions on systems, man, and cybernetics **21**(4): 861-875.

Christakos, G. (2000). "Modern Spatiotemporal Geostatistics: Oxford Univ." Press, New York, NY.