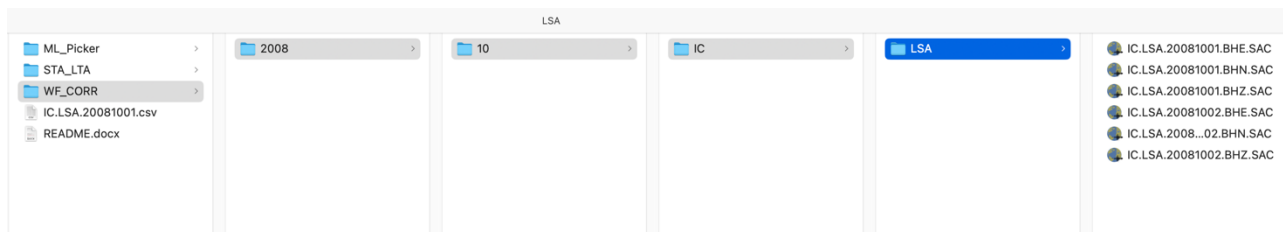


# STA-LTA & Machine-Learning Phase Picker

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Welcome using my code. The code has two parts: the STA-LTA-based phase detection and the ML-Picker-based phase detection.

To run the code, you should have all the preprocessed daily waveforms stored in the following directory structure:



Each trace is stored in the path:

**WF\_CORR/YEAR/MONTH/NET/STA/NET.STA.YYYYMMDD.CHANNEL.SAC**

For example, the one-day continuous BHZ channel trace of station LSA in network IC in 2008/10/01 is stored in:

**WF\_CORR/2008/10/IC/LSA/IC.LSA.20081001.BHZ.SAC**

For another example, the one-day continuous HHE channel trace of station EVN in network IO in 2015/05/12 is stored in:

**WF\_CORR/2015/5/IC/LSA/IO.EVN.20081001.HHE.SAC**

**IMPORTANT:** Each daily continuous waveform file should be **merged** (with fill\_value = 0), **detrended**, **pre-filtered** (e.g., 0.05-40 Hz), and **station response removed** (or divided by station sensitivity) already. Each trace should have its **network code and station code stored in the SAC file header**.

If you have any problem building a data structure like this, please contact me ([xhsong@stanford.edu](mailto:xhsong@stanford.edu)), and I'll offer help based on your available database structure.

## Install Environment

To run the code, you will need:

```
openmpi
Python=3.12
Numpy=1.26
Scipy
Pandas
Obspy
Seisbench
mpi4py
```

To solve the environment, try using the following command:

```
conda create -n phasepick python=3.12 mpi4py mpich
conda activate phasepick
```

```
pip3 install numpy==1.26
pip3 install pandas
pip3 install obspy
pip3 install seisbench
```

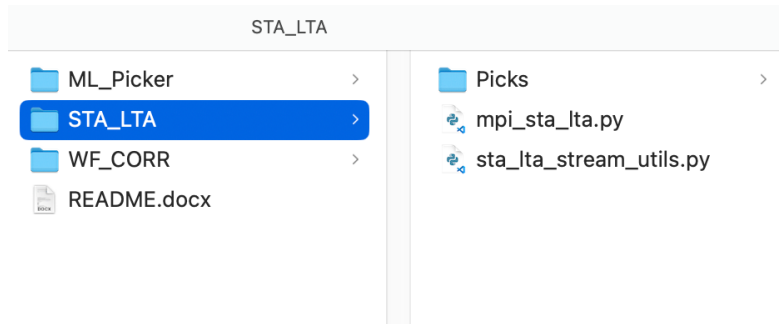
## The STA-LTA Picker code

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This code uses a rough-to-fine STA-LTA algorithm to pick the P and S phases.

To run the STA-LTA picker, enter the STA\_LTA folder:

**cd STA\_LTA**



Run code with:

**mpirun -np NUMBER\_OF\_TASK python3 mpi\_sta\_lta.py NET STARTTIME ENDTIME**

For example (and for debugging), if you want to run this code on network IC, and you want to detect phases between 2008-10-01T00:00:00 to 2008-11-01T00:00:00, and you can run the code on 8 cores (8 parallel tasks):

**mpirun -np 8 python3 mpi\_sta\_lta.py IC 2008-10-01 2008-11-01**

The picks will be stored in folder **STA\_LTA /Picks**

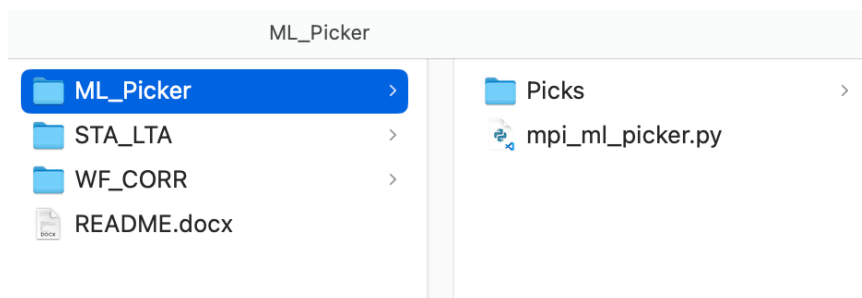
## The Machine-Learning Picker code

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This code uses PhaseNet(Original, Diting, Neic, Instance), SkyNet, and EQTransformer to pick the P and S phases.

To run the ML Picker, enter the ML\_Picker folder:

**cd ML\_Picker**



Run code with:

**mpirun -np NUMBER\_OF\_TASK python3 mpi\_ml\_picker.py NET STARTTIME ENDTIME**

For example (and for debugging), if you want to run this code on station network IC, you want to detect phases between 2008-10-01T00:00:00 and 2008-11-01T00:00:00, and you want to run the code on 8 cores (8 parallel tasks), you can run:

**mpirun -np 8 python3 mpi\_ml\_picker.py IC 2008-10-01 2008-11-01**

The picks will be stored in folder **ML\_Picker/Picks**

**Example Picks**

The P and S phases picked using PhaseNet (Trained on Diting)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	station	time	start_time	end_time	probability	phase	amp_z	amp_n	amp_e	nos_z	nos_n	nos_e	rms_z	rms_n	rms_e	snr_z	snr_n	snr_e	source
2	ICLSA	40:46.9	40:45.9	40:47.2	0.11313009	P	1.86E-08	1.52E-08	1.02E-08	5.16E-09	6.03E-09	5.72E-09	6.39E-09	6.81E-09	5.13E-09	1.03929196	1.03320807	1.19288393	diting
3	ICLSA	40:48.5	40:48.4	40:49.3	0.07484374	P	1.35E-08	1.52E-08	1.13E-08	6.87E-09	5.25E-09	5.97E-09	5.65E-09	6.37E-09	6.34E-09	1.50516923	0.98006111	1.32159235	diting
4	ICLSA	02:44.9	02:44.9	02:45.1	0.07005007	P	1.09E-07	2.21E-08	3.35E-08	5.48E-09	6.35E-09	6.57E-09	3.69E-08	1.48E-08	1.77E-08	4.82376732	1.65449749	3.28491611	diting
5	ICLSA	50:36.3	50:36.2	50:36.5	0.08029245	P	2.09E-07	3.06E-07	1.10E-07	8.62E-09	9.43E-09	8.43E-09	8.95E-08	1.24E-07	5.91E-08	6.43982694	9.28120939	4.09590811	diting
6	ICLSA	06:27.3	06:27.1	06:27.5	0.2666163	P	4.55E-08	6.15E-08	2.06E-08	7.92E-09	5.61E-09	5.93E-09	2.40E-08	3.24E-08	9.21E-09	2.24236967	3.36362971	1.28637963	diting
7	ICLSA	31:13.2	31:13.0	31:13.4	0.28657573	P	1.88E-08	1.89E-08	1.52E-08	5.55E-09	1.14E-08	7.17E-09	8.02E-09	8.54E-09	8.09E-09	2.40374328	0.88703645	1.07871373	diting
8	ICLSA	43:30.3	43:30.3	43:30.6	0.10456495	P	2.13E-08	2.75E-08	1.74E-08	6.69E-09	8.32E-09	6.23E-09	1.21E-08	1.11E-08	6.63E-09	1.80690046	1.69758011	1.06029428	diting
9	ICLSA	13:07.7	13:07.6	13:08.0	0.08757151	P	2.11E-08	1.78E-08	1.91E-08	7.55E-09	8.30E-09	7.58E-09	7.88E-09	7.48E-09	7.41E-09	1.46547911	1.25567135	0.90112887	diting
10	ICLSA	55:12.3	55:12.2	55:12.8	0.09945133	P	1.61E-08	1.73E-08	9.83E-09	9.56E-09	8.19E-09	6.33E-09	8.14E-09	6.43E-09	4.87E-09	1.23388687	0.72388518	0.96173777	diting
11	ICLSA	55:13.5	55:13.1	55:13.9	0.15293522	P	1.96E-08	1.37E-08	9.83E-09	7.59E-09	8.58E-09	6.67E-09	8.08E-09	6.45E-09	5.73E-09	1.53251263	0.64360363	0.94818584	diting
12	ICLSA	42:39.6	42:38.5	42:40.3	0.14321838	P	1.31E-08	1.42E-08	1.60E-08	7.03E-09	7.41E-09	6.52E-09	4.40E-09	7.13E-09	7.15E-09	1.07221461	2.34917247	1.50875832	diting
13	ICLSA	44:53.3	44:53.1	44:53.6	0.93340683	P	3.62E-07	1.77E-07	3.17E-07	9.96E-09	6.39E-09	7.60E-09	1.44E-07	1.05E-07	1.29E-07	61.9332961	17.9607331	41.2075068	diting
14	ICLSA	51:24.4	51:24.4	51:24.7	0.07505318	P	1.65E-08	1.62E-08	1.38E-08	6.72E-09	1.03E-08	5.90E-09	6.30E-09	9.31E-09	4.34E-09	1.27377848	1.44101718	1.35854195	diting
15	ICLSA	54:46.1	54:46.0	54:46.4	0.15238172	P	1.75E-08	1.61E-08	1.34E-08	9.35E-09	5.84E-09	7.24E-09	6.16E-09	6.48E-09	6.01E-09	1.05452033	1.16269634	0.77806843	diting
16	ICLSA	00:57.7	00:57.5	00:58.0	0.11656752	P	2.04E-08	2.02E-08	1.56E-08	1.08E-08	8.14E-09	6.31E-09	7.69E-09	7.38E-09	6.83E-09	1.41552905	0.87287531	0.97917266	diting
17	ICLSA	34:27.3	34:26.9	34:27.7	0.82186854	P	1.23E-08	1.57E-08	1.34E-08	4.81E-09	5.01E-09	6.32E-09	6.87E-09	7.06E-09	8.41E-09	2.63188712	2.734085818	2.97315606	diting
18	ICLSA	49:42.2	49:42.1	49:42.4	0.11692053	P	1.80E-08	1.09E-08	1.68E-08	5.48E-09	5.89E-09	9.34E-09	6.73E-09	8.42E-09	5.72E-09	1.95416963	1.08084013	1.42618124	diting
19	ICLSA	38:24.7	38:24.7	38:24.9	0.30084997	P	1.97E-08	2.07E-08	1.52E-08	8.62E-09	7.84E-09	4.91E-09	1.03E-08	1.02E-08	6.47E-09	1.23924129	1.53533229	1.20521469	diting
20	ICLSA	46:22.6	46:22.5	46:22.8	0.07674422	P	1.58E-08	1.31E-08	1.40E-08	7.46E-09	7.51E-09	6.53E-09	4.06E-09	7.60E-09	7.18E-09	1.67320897	1.02287994	0.96430862	diting
21	ICLSA	08:37.5	08:37.4	08:37.9	0.14663076	P	1.36E-08	1.30E-08	1.77E-08	7.23E-09	9.12E-09	7.40E-09	6.82E-09	7.29E-09	6.85E-09	1.17868896	1.04025344	1.32174944	diting
22	ICLSA	45:19.6	45:19.2	45:20.0	0.3268405	P	5.89E-07	1.18E-07	2.33E-07	2.27E-08	6.10E-09	1.29E-08	2.46E-07	5.59E-08	1.76E-07	12.3967894	4.29977382	9.94030573	diting
23	ICLSA	54:20.3	54:20.2	54:20.7	0.0776744	P	2.00E-08	2.11E-08	1.21E-08	9.64E-09	9.70E-09	8.08E-09	1.01E-08	9.11E-09	6.98E-09	1.46398727	1.23175344	0.87900006	diting
24	ICLSA	23:25.0	23:24.9	23:25.2	0.07250772	P	1.24E-08	1.48E-08	9.31E-09	6.39E-09	5.78E-09	6.15E-09	7.15E-09	7.28E-09	5.42E-09	1.47633496	0.95700806	1.11338061	diting
25	ICLSA	06:29.6	06:29.3	06:29.9	0.10092269	P	1.56E-08	1.86E-08	1.20E-08	7.59E-09	6.53E-09	6.60E-09	1.35E-08	7.98E-09	5.65E-09	2.57808381	1.13407333	1.17770217	diting
26	ICLSA	08:02.1	08:02.0	08:02.4	0.10988776	P	1.75E-08	1.81E-08	8.25E-09	7.54E-09	8.24E-09	9.79E-09	1.28E-08	9.38E-09	5.32E-09	1.56779352	1.04865049	0.78396269	diting
27	ICLSA	09:11.9	09:11.8	09:12.1	0.08742411	P	1.83E-08	1.22E-08	1.14E-08	6.28E-09	4.88E-09	4.39E-09	6.70E-09	6.68E-09	4.41E-09	2.20206944	0.9649596	1.02118007	diting
28	ICLSA	10:58.3	10:58.1	10:58.6	0.28645915	P	2.24E-08	1.03E-08	1.17E-08	6.21E-09	4.44E-09	5.60E-09	6.91E-09	8.96E-09	6.52E-09	2.49960356	1.1182625	1.28022727	diting
29	ICLSA	13:24.7	13:24.6	13:25.0	0.12324413	P	2.64E-08	2.93E-08	1.13E-08	5.98E-09	7.07E-09	7.01E-09	9.11E-09	1.26E-08	5.40E-09	1.72427956	1.4944882	1.16291326	diting
30	ICLSA	19:22.2	19:22.2	19:22.5	0.07214651	P	1.01E-08	1.80E-08	9.77E-09	6.71E-09	5.85E-09	3.82E-09	5.67E-09	7.93E-09	3.46E-09	2.08435907	2.79123091	0.8450667	diting
31	ICLSA	27:46.1	27:46.0	27:46.3	0.12446497	P	7.22E-09	9.42E-09	2.40E-08	4.50E-09	5.94E-09	3.50E-09	7.58E-09	4.28E-09	5.12E-09	2.3350357	0.81952189	1.45955062	diting
32	ICLSA	29:36.4	29:36.3	29:36.7	0.08309811	P	3.37E-08	2.17E-08	1.03E-08	9.34E-09	6.25E-09	5.38E-09	1.19E-08	9.03E-09	5.67E-09	1.48244298	1.6594012	0.99820758	diting
33	ICLSA	30:13.2	30:13.2	30:13.5	0.07097519	P	8.10E-09	1.35E-08	1.01E-08	6.70E-09	5.09E-09	4.35E-09	5.33E-09	9.78E-09	6.18E-09	1.56553293	0.96185221	1.31759266	diting
34	ICLSA	31:27.2	31:27.2	31:27.5	0.07067313	P	8.79E-09	2.04E-08	1.42E-08	5.59E-09	5.57E-09	6.19E-09	4.72E-09	7.96E-09	7.47E-09	1.68656109	1.57298479	1.0620813	diting
35	ICLSA	31:51.7	31:51.6	31:52.0	0.09627336	P	2.12E-08	1.78E-08	1.20E-08	1.21E-08	4.22E-09	5.44E-09	9.29E-09	9.32E-09	5.86E-09	1.34144075	1.07544525	0.8122934	diting