

## New directions in earthquake seismology

# Introduction to Back-projection

### Exercise 1

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## Install conda:

<https://docs.conda.io/projects/conda/en/latest/commands/install.html>

## Set up python environment

<https://docs.conda.io/projects/conda/en/latest/user-guide/getting-started.html>

## Next, use pip to install some necessary libraries

Open terminal window:

`pip install pydsm`

`Pip install obspy`

`Pip install geopy`



## Exercise 1:

- ARF test with different arrays
- Data request and processing
- Beamforming with an ideal point source and array
- Beamforming a real earthquake using recorded array data

## Example\_1

### Array response function (ARF)

The ratio of the amplitude of the output of the array to that of the same number of elements concentrated at one location (Sherrif & Geldart, 1995)

#### Files

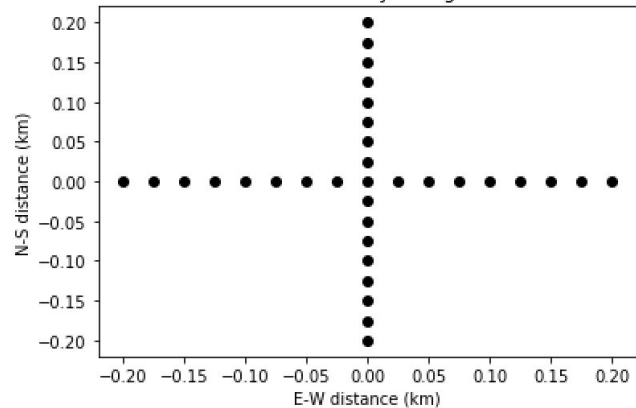
**array\_linear\_cross.txt** and **array\_ok.txt** are two txt files containing the array locations

**Array1.txt** is the synthetic array used to perform beamforming in an ideal case

**Exercise1\_ARF\_2021.ipynb**: ARF exercise

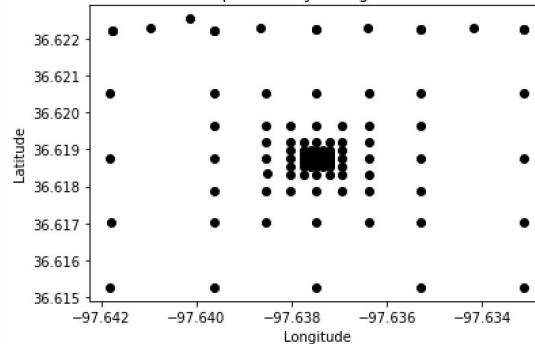
**Exercise1\_Beamforming\_2021.ipynb** : Beamforming exercise

Linear Cross Array configuration

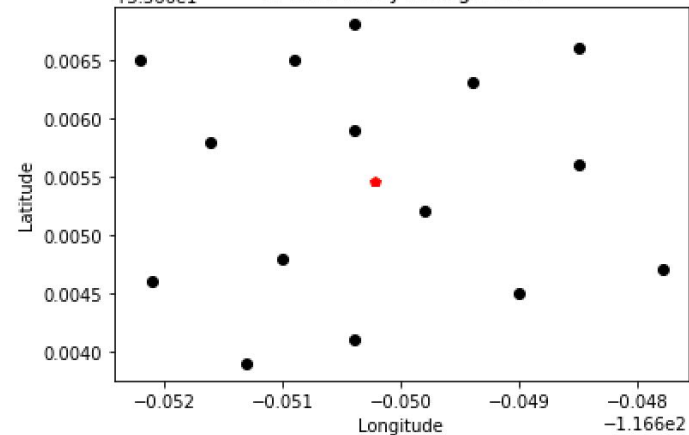


## ARF for different array configuration

Square Array configuration

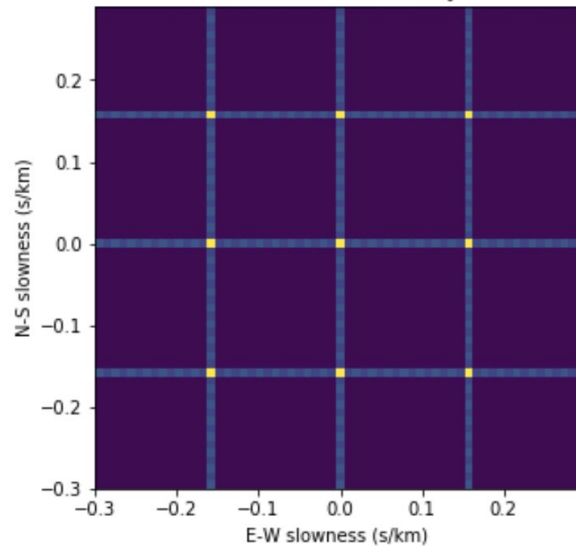


Circular Array configuration

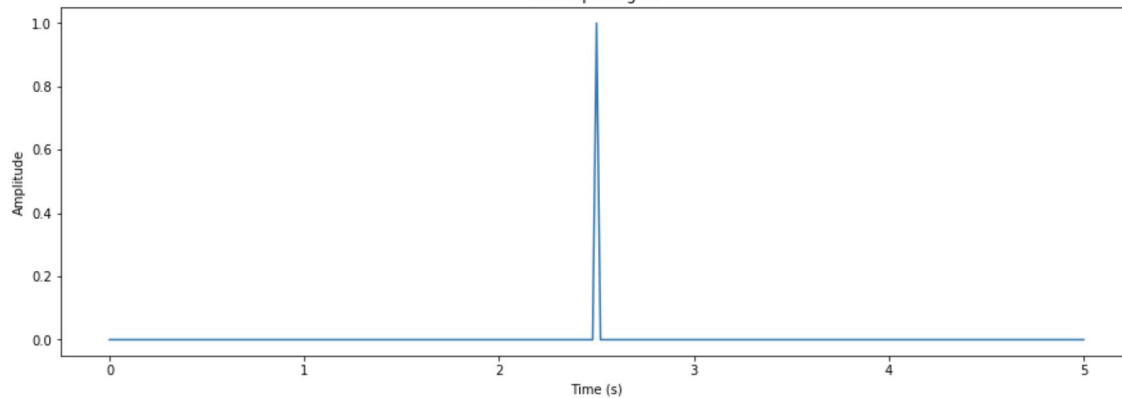


ARF for various frequency/wavenumber

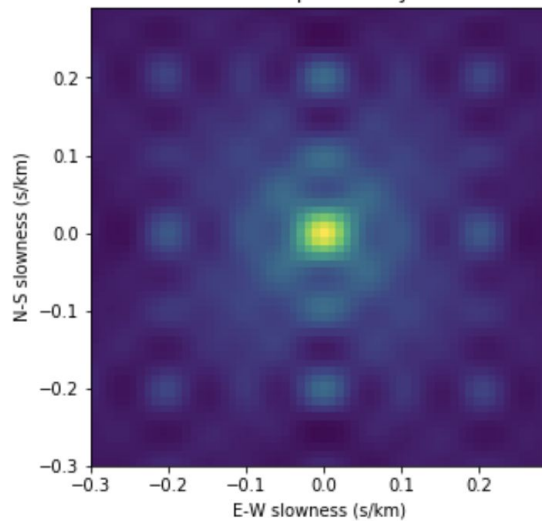
ARF Linear Cross Array



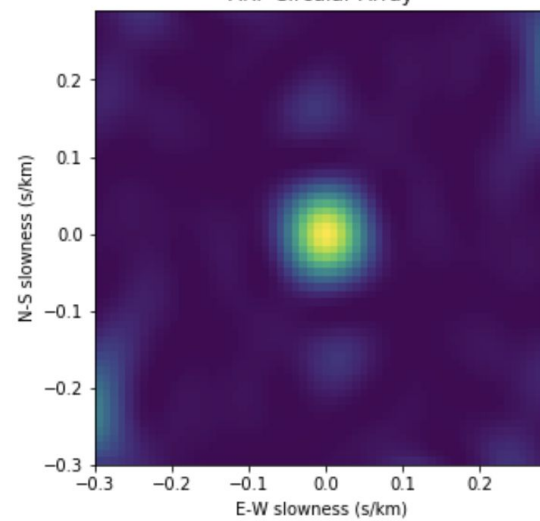
ARF Input Signal



ARF Square Array



ARF Circular Array



## Example\_2

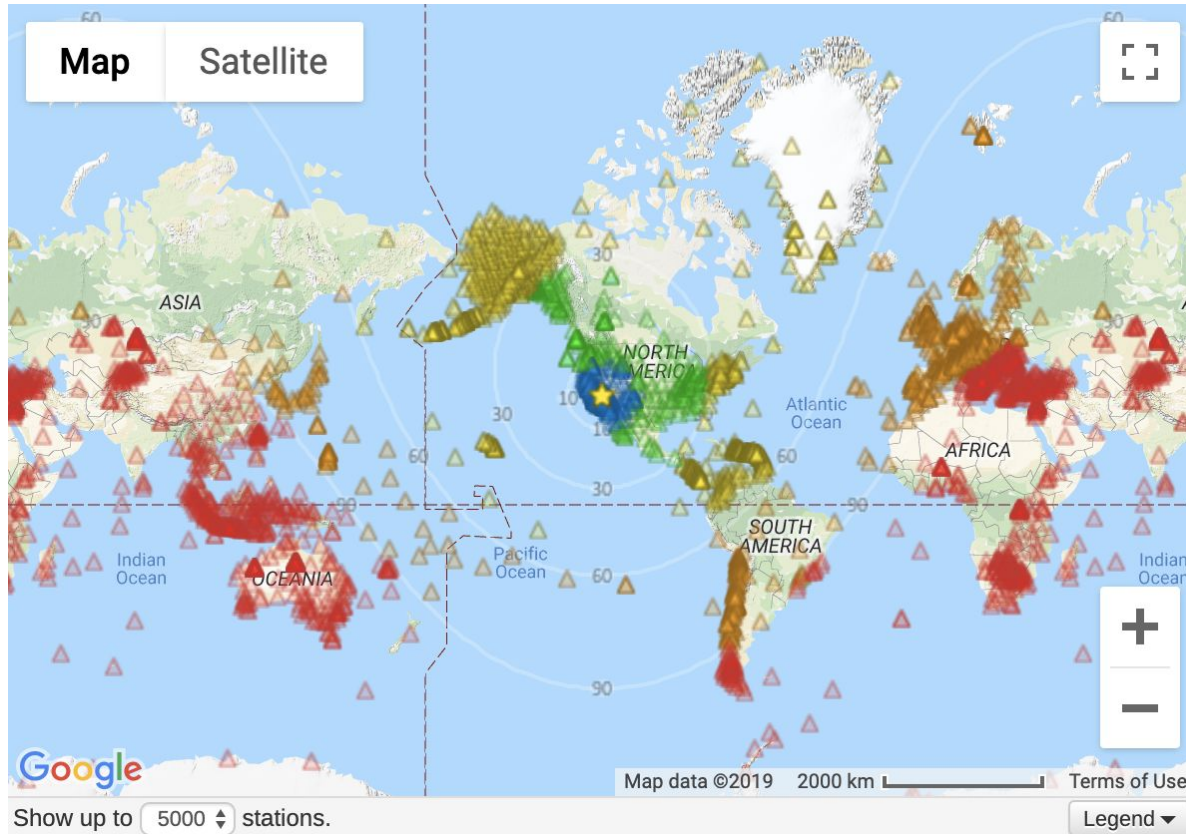
### Data process and beamforming

#### Beamforming with an ideal case

#### Beamforming of a real earthquake in Southern CA:

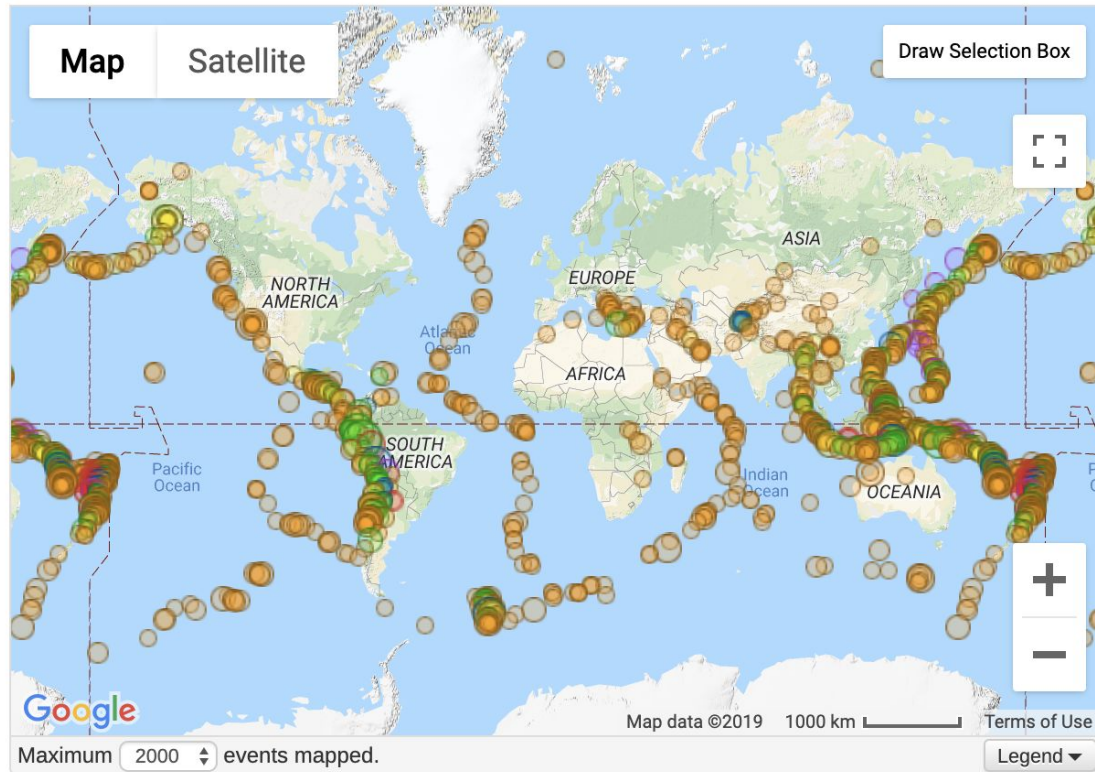
- Download data
- Remove instrument response
- Beamforming for each array
- Find earthquake location

## Global arrays & stations recorded the 2019 Ridgecrest earthquake





Request data from web: [http://ds.iris.edu/wilber3/find\\_event](http://ds.iris.edu/wilber3/find_event)



Past 12 months, M5.0+ ?

**Dataset Mode:** Inputs filter within the dataset. Use [Custom Query](#) to make an open query.

Date: 2018-11-27 - 2019-11-27

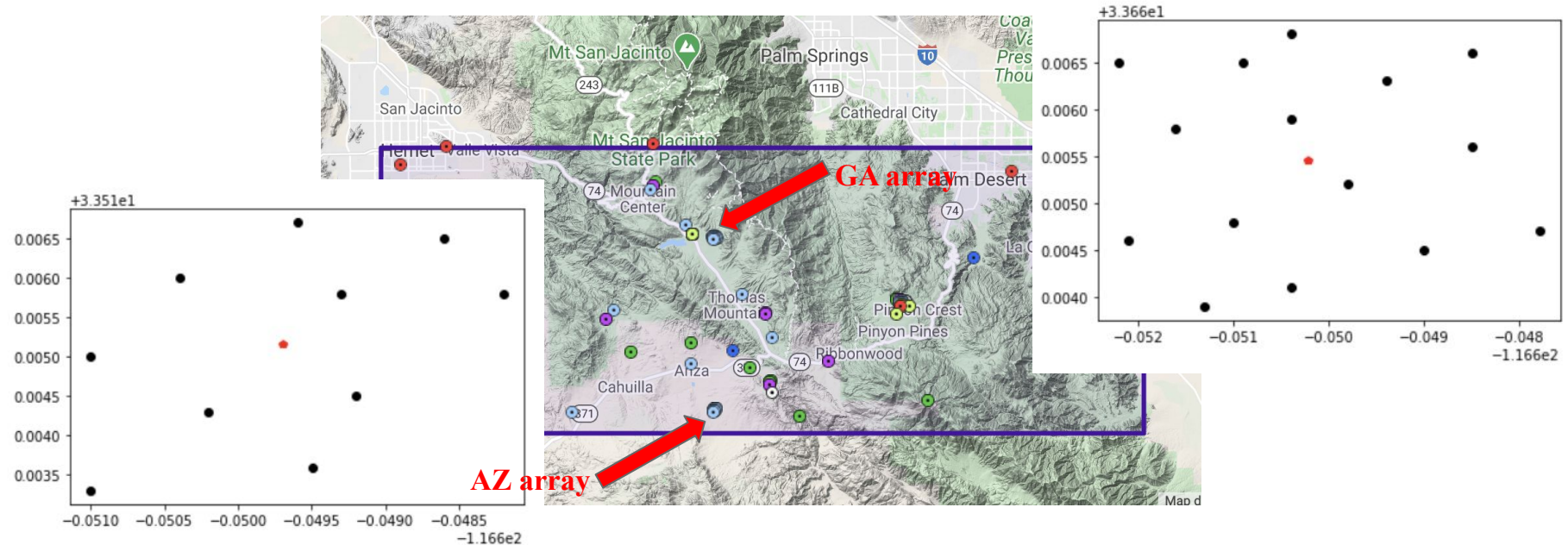
Magnitude: 5 - 10

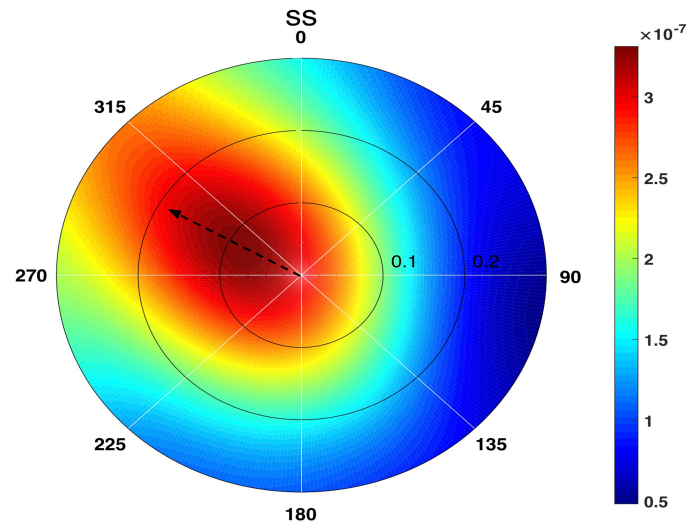
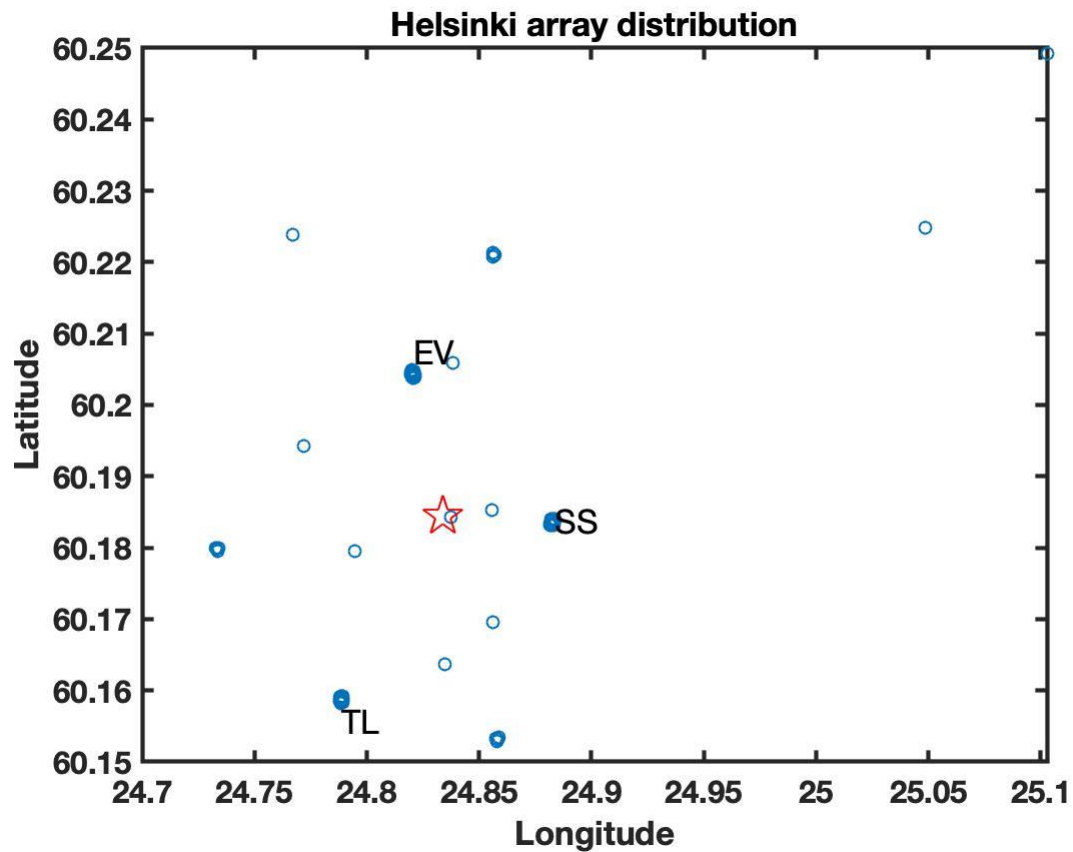
Depth: 0.0 - 6371

Location: N, S, E, W

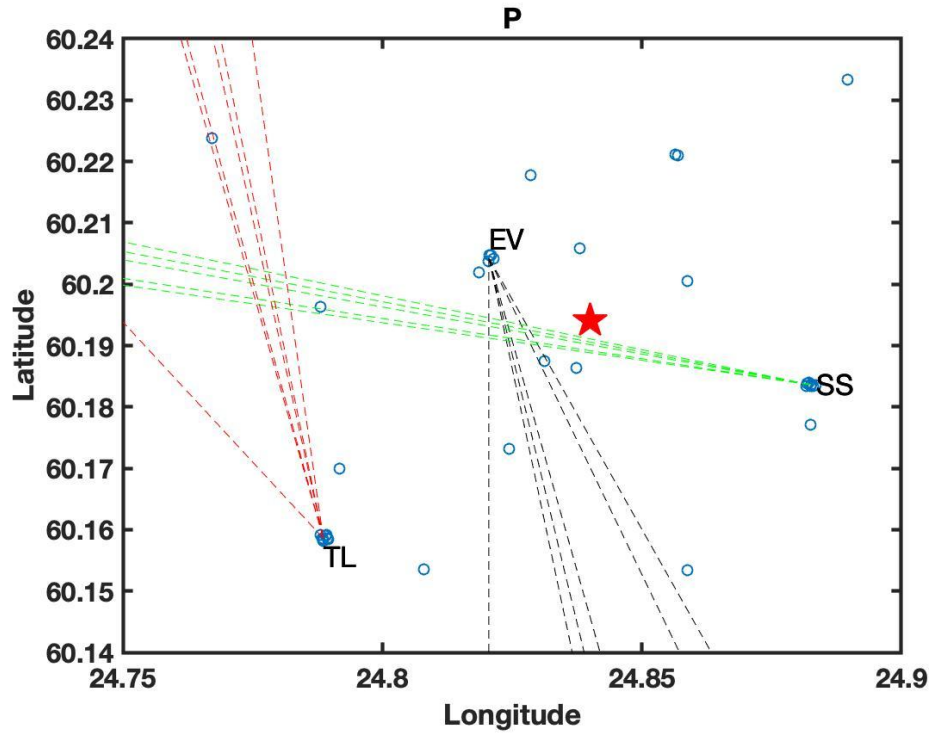
<https://ds.iris.edu/mda/>

[https://ds.iris.edu/gmap/#network=\\*&starttime=2011-06-06T00:00:00&endtime=2011-06-06T23:59:59&maxlat=33.75&maxlon=-116.2&minlat=33.5&minlon=-117&drawingmode=box&planet=earth](https://ds.iris.edu/gmap/#network=*&starttime=2011-06-06T00:00:00&endtime=2011-06-06T23:59:59&maxlat=33.75&maxlon=-116.2&minlat=33.5&minlon=-117&drawingmode=box&planet=earth)



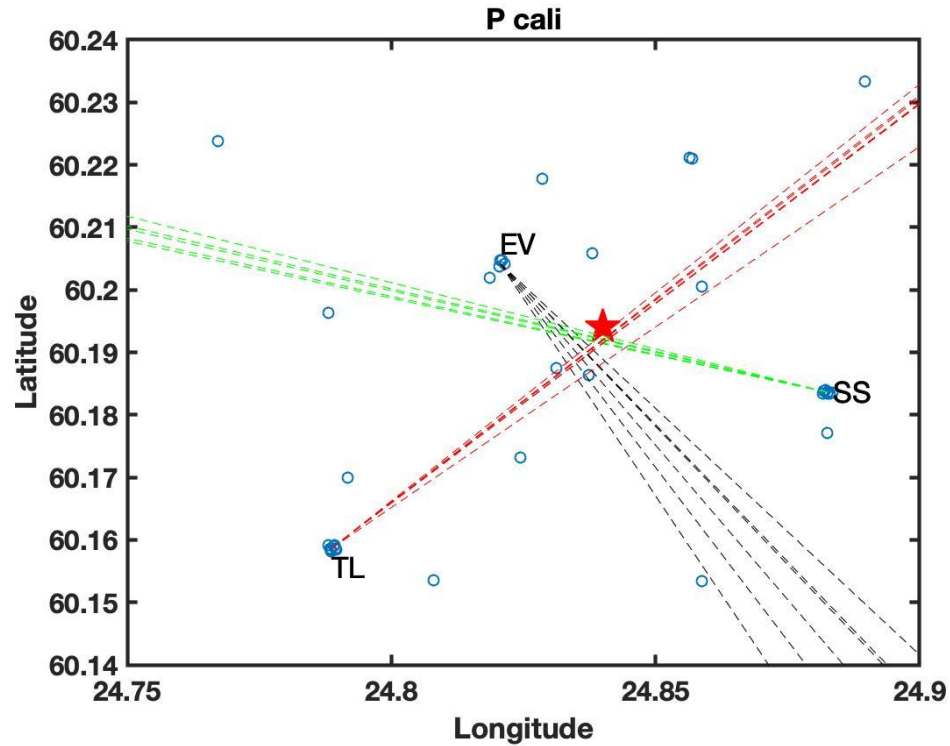


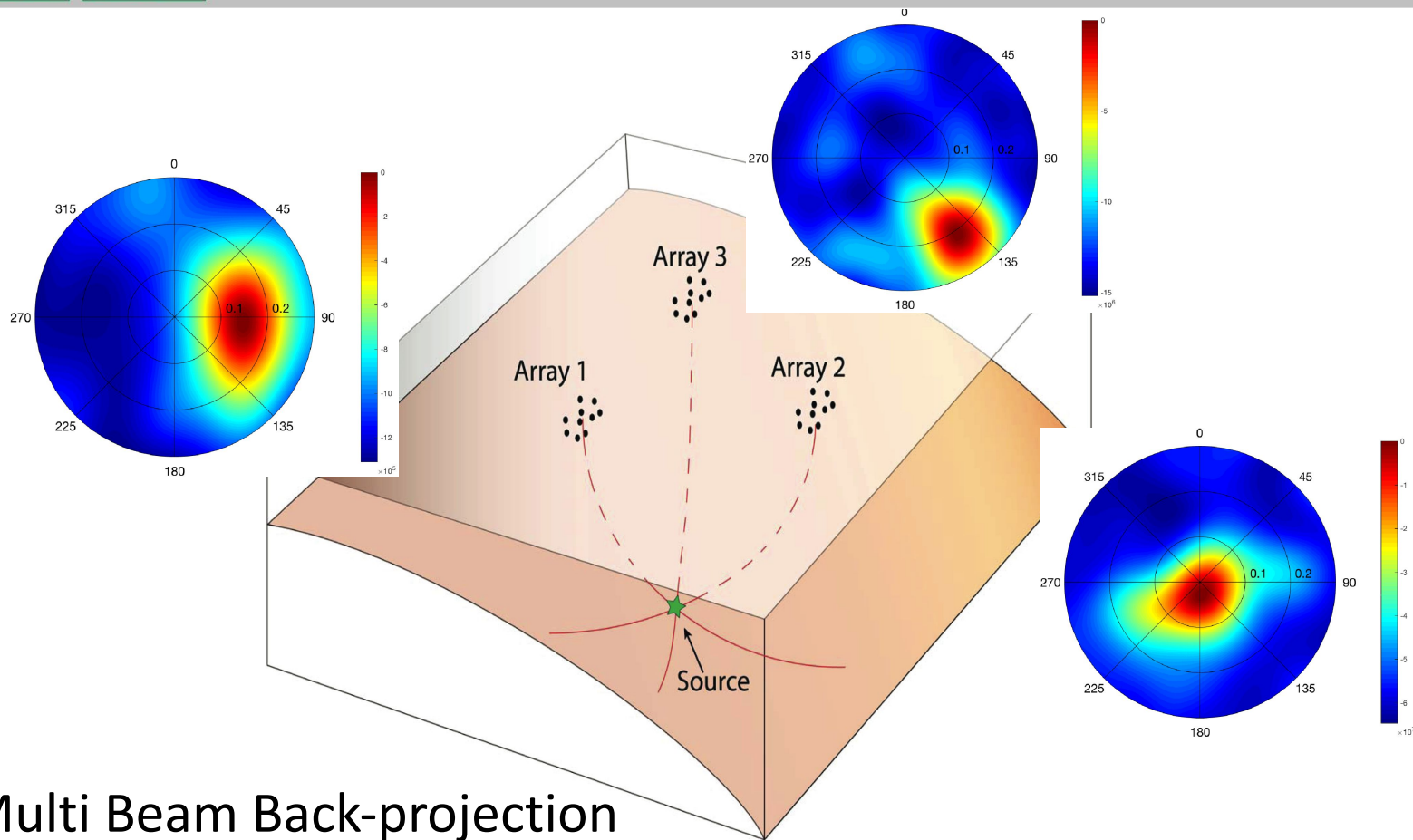
# Beam Back-projection



P phase beamforming for a Mg 1.4 events in Helsinki. Each dashed line shows the slowness vector direction in each bootstrap beamforming result. The red star represents catalog location.

## After calibration





## Multi Beam Back-projection