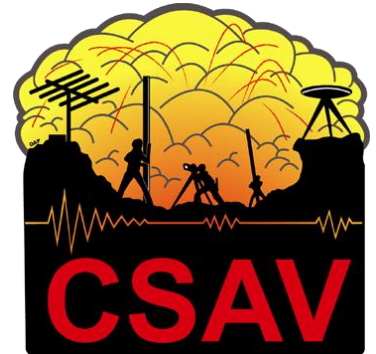
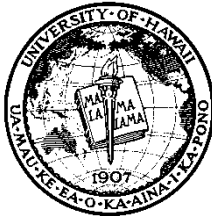
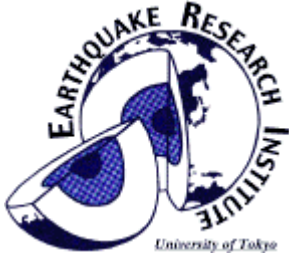


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and Ernestynne Walsh

July 2013

Institute of Geophysics, Victoria Univ. of Wellington, New Zealand
University of Hawaii, Hilo

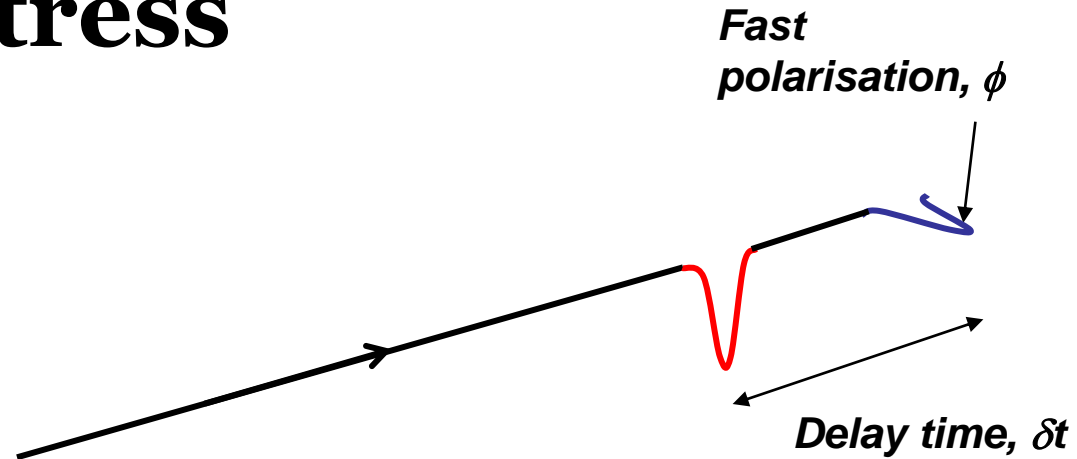
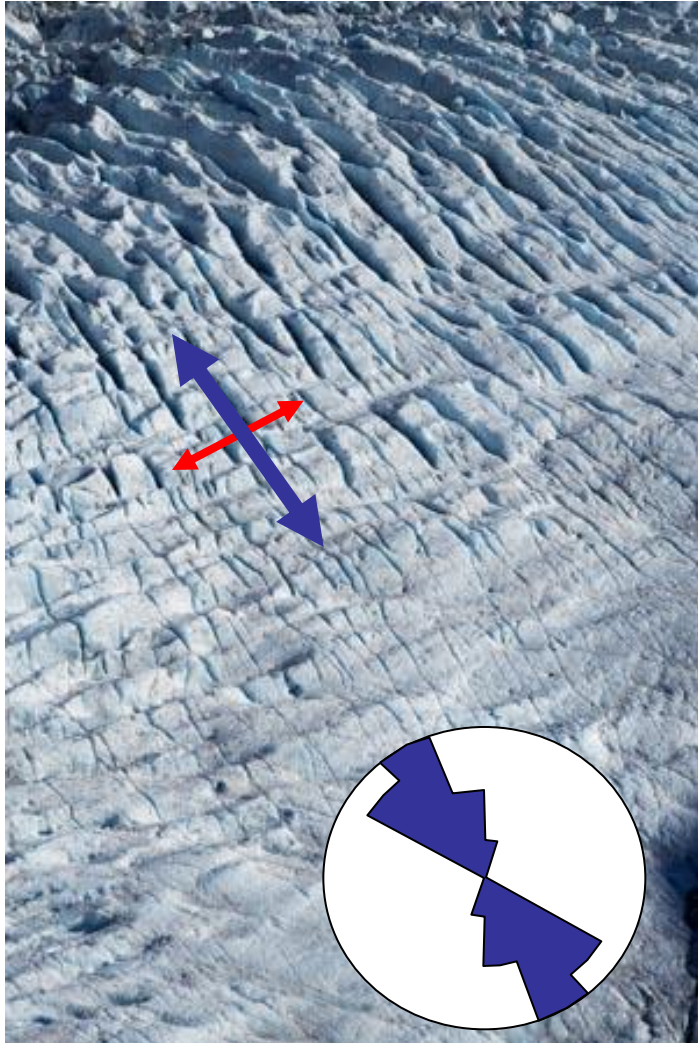
The MFAST Shear-wave splitting program methodology



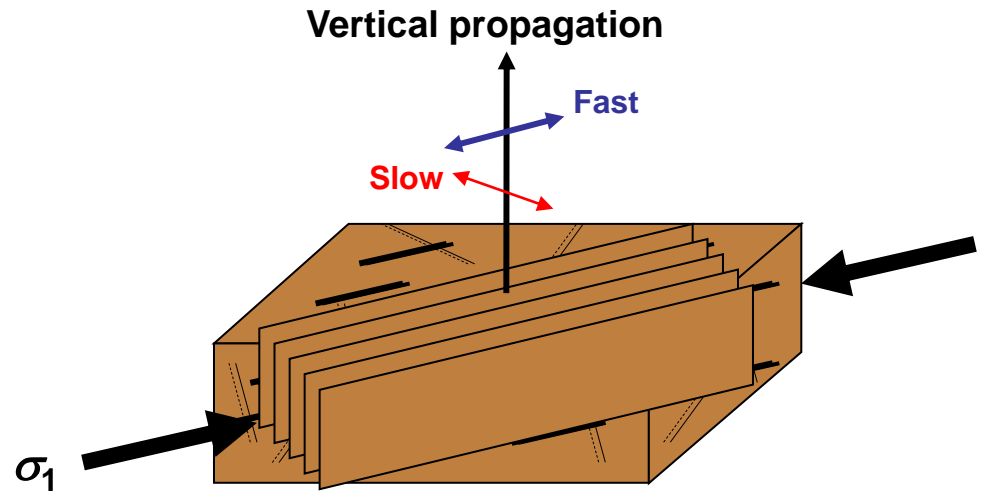
Outline

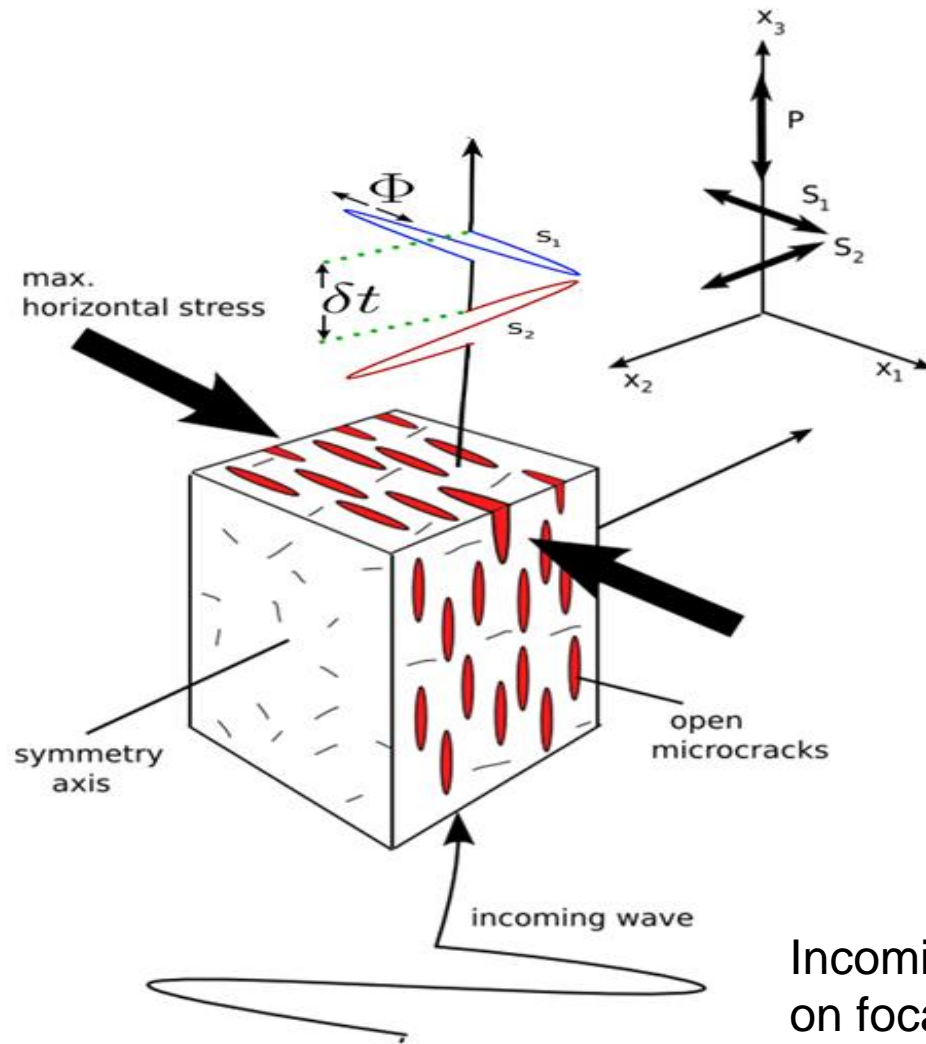
- The main principles of the technique
- Examples: Ruapehu, New Zealand
- <http://mfast-package.geo.vuw.ac.nz/>

Shear wave splitting to determine stress



δt is proportional to % anisotropy (crack density)
And length of travel path





Incoming polarization depends on focal mechanism and path before

MFAST method (Savage et al., 2010)

- Based on Teanby et al. method
- Which is based on Silver & Chan (1991) Eigenvalue method (SC91)
- Examines multiple windows using SC91
- Uses cluster analysis to determine best measurement
- MFAST: uses multiple filters. Sets windows based on S pick and frequency
- Grades output automatically

System Requirements

- Bash scripts (linux and Mac)
- Fortran compilers for Teanby codes
- GMT for plotting
- Postscript utilities for plotting
- SAC; taup (for incidence angles)
- Program mfast_precheck checks that needed codes are installed where it knows to look.

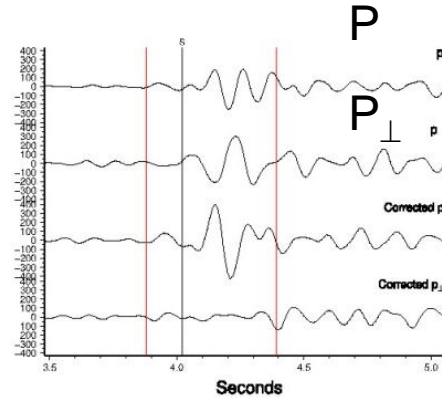
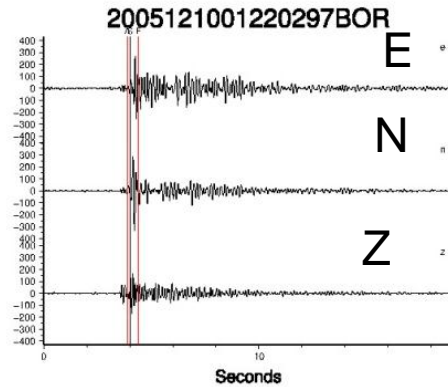
Basic underlying method: Silver and Chan (1991)

- Known as “eigenvalue” method
- Grid search over values of ϕ , dt that range from 0-180 and 0.0 to some value (for local eqs on volcanoes, usually 0.2 or 0.4, for deep earthquakes, 1.0 or 2.0 s)
- Tries to “reverse” or “correct” the splitting process for each pair of ϕ , dt
- Calculates eigenvalue of covariance matrix of “corrected” waveform
- Smallest minimum eigenvalue gives most linear particle motion
- Make diagnostic plots to determine how well it has worked (next slide)
- Calculates incoming polarization direction from corrected waveform.
- Version 2.0 and above of mfast correct errors in calculating error bars.

Basic Silver and Chan method—sample plots

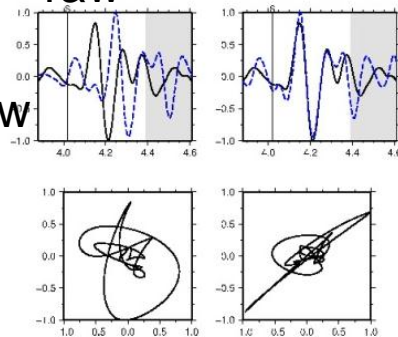
Good measurement

Original seismogram



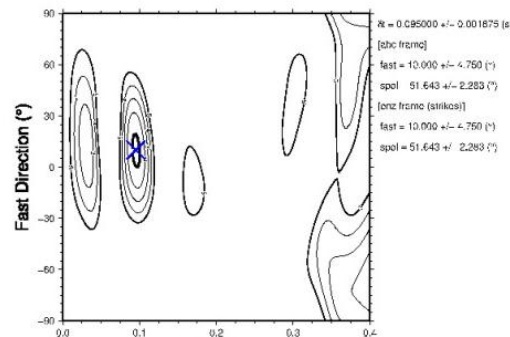
Original and corrected incoming polarization and perp

raw corrected



Solid=fast
dashed=slow

Particle motion plots



Contours all “corrected” eigenvalues. Value of 1 = 95% confidence. Smallest = best

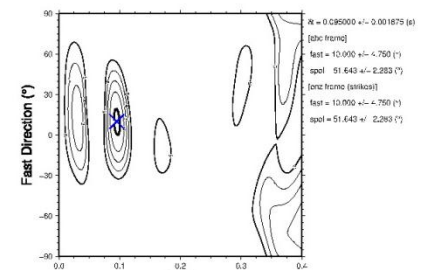
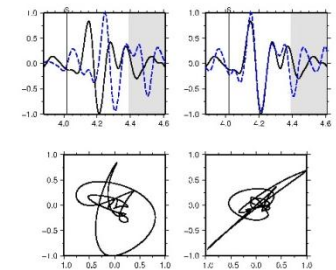
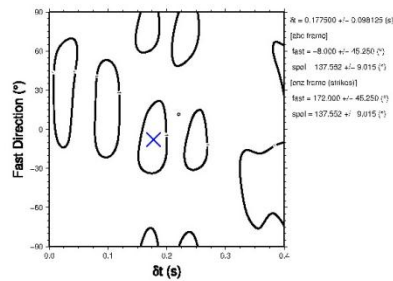
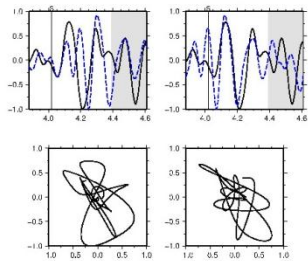
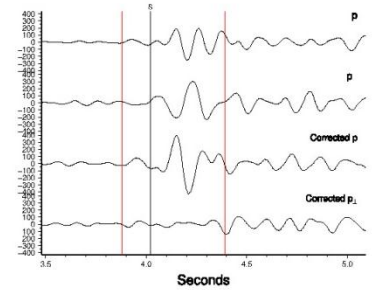
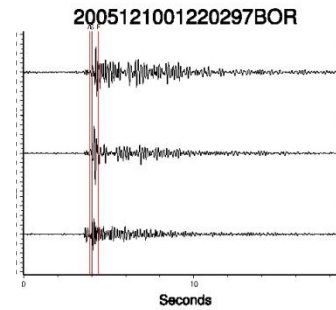
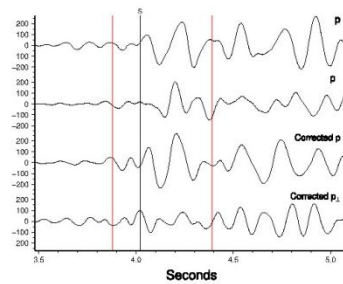
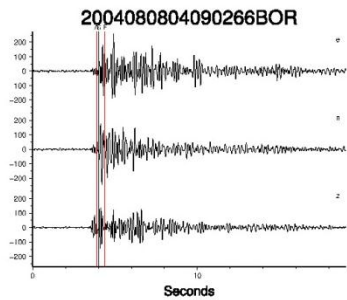
Basic Silver and Chan method—sample plots

Good measurement

Original and corrected incoming polarization and perp

Bad measurement

Original seismogram



Particle motion plots

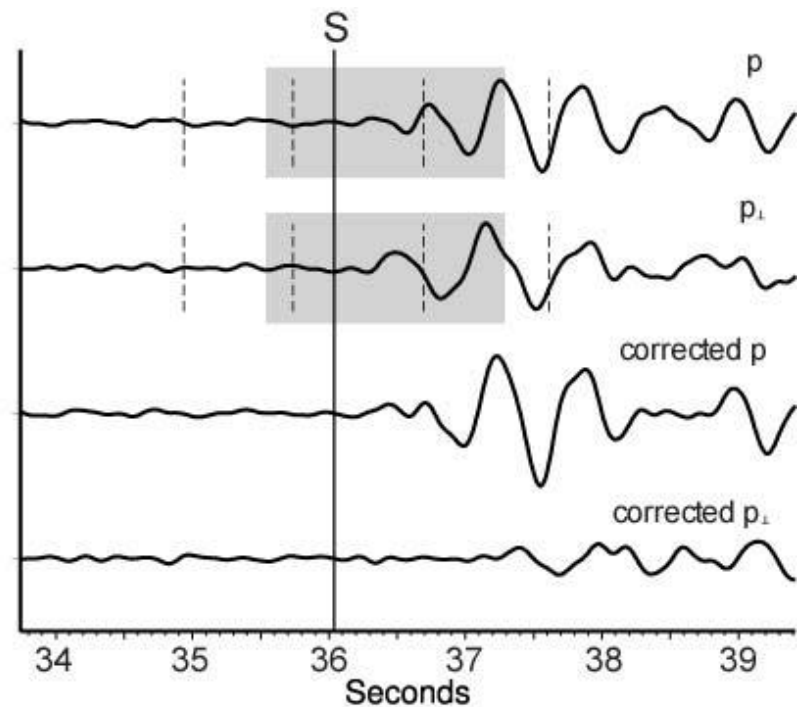
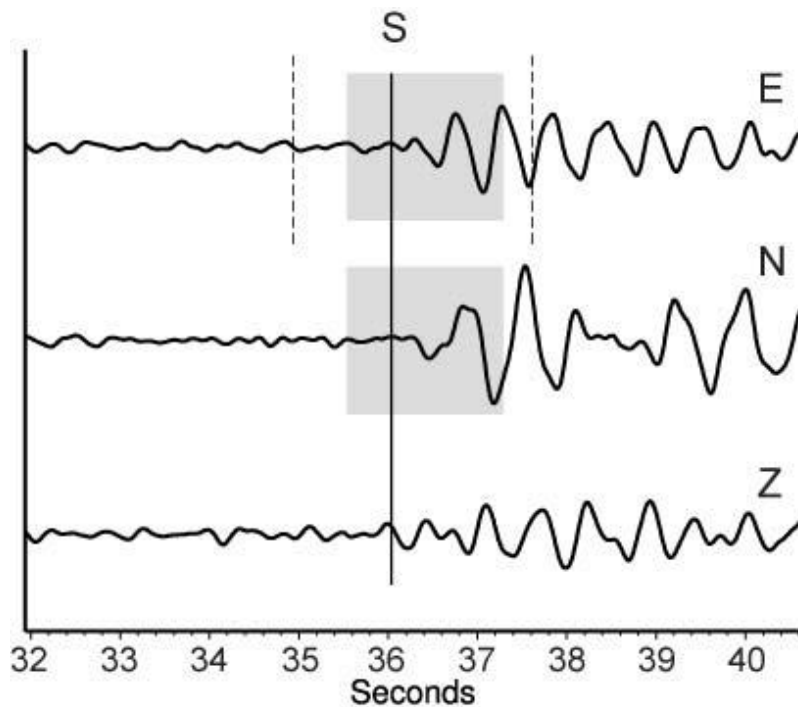
Contours all “corrected” eigenvalues

Automate Method

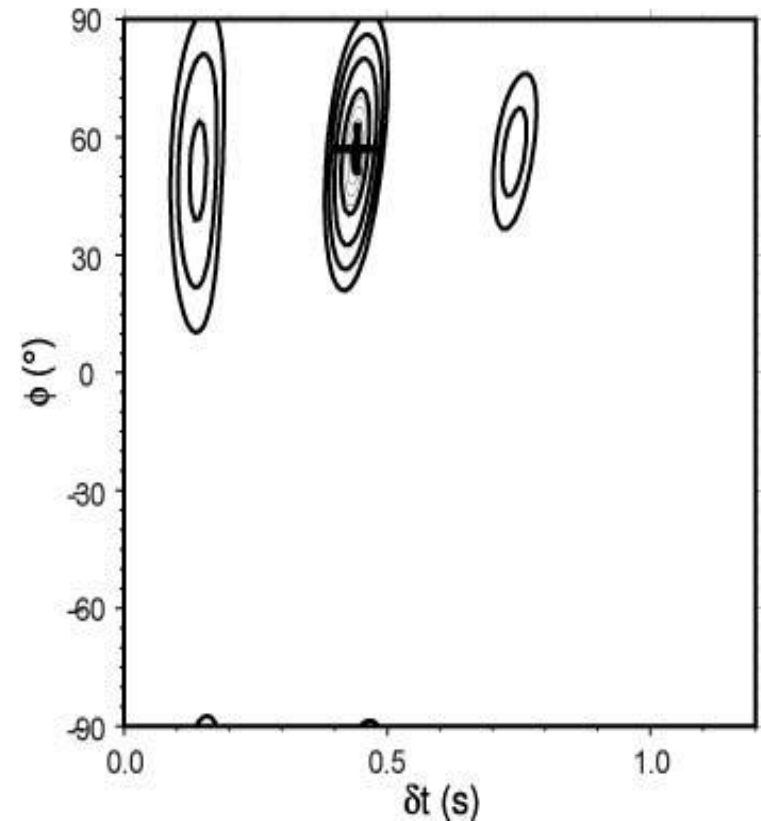
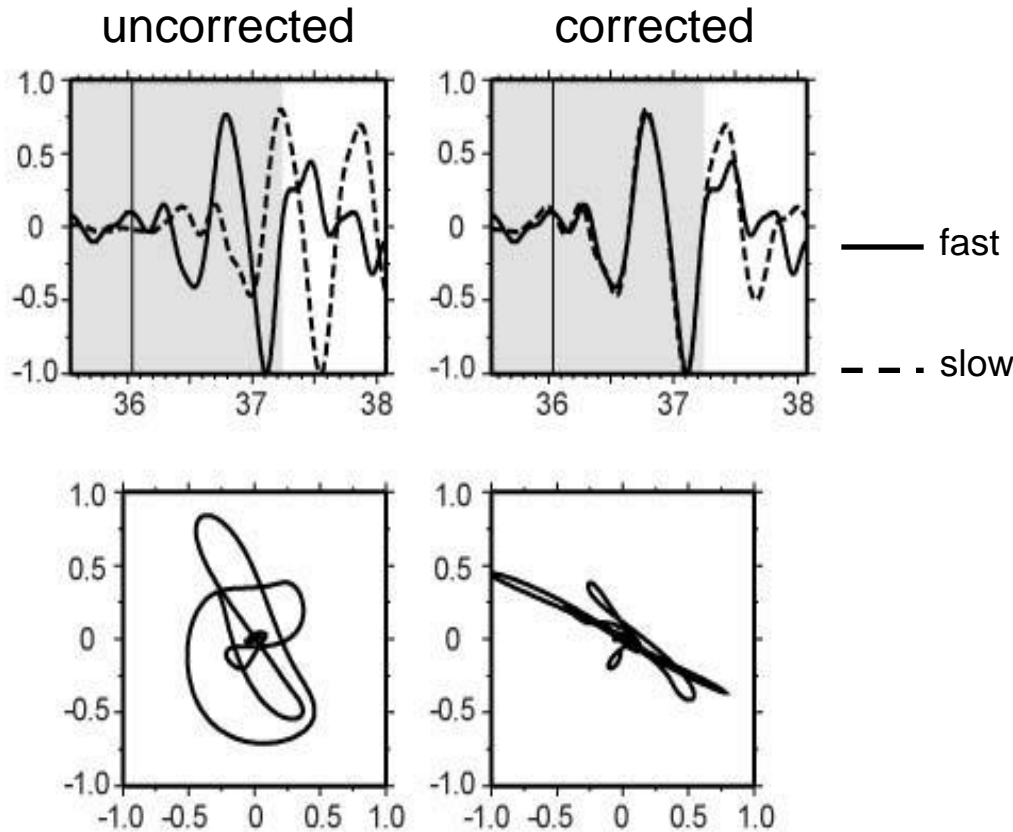
- Pick S waves (by hand-trying to automate)
- Choose 3 filters that maximise the SNR-bandwidth product
- Use filters to choose window limits for Teanby et al. cluster method, which is based on Silver & Chan (1991)
- Quality control--automate

Teanby Cluster Technique

- Good Measurement
- Checks 75 windows between dashed lines

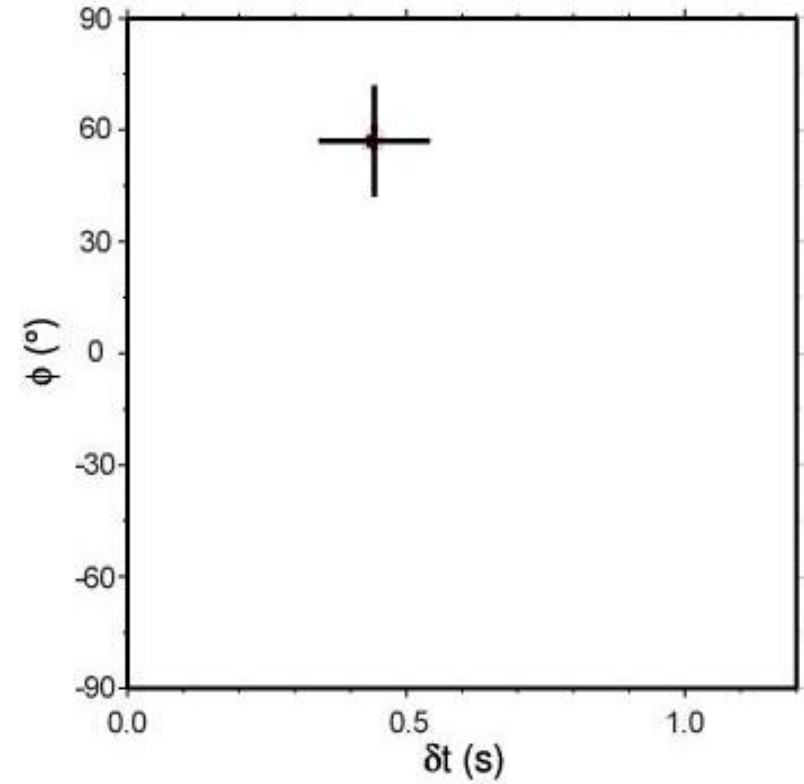
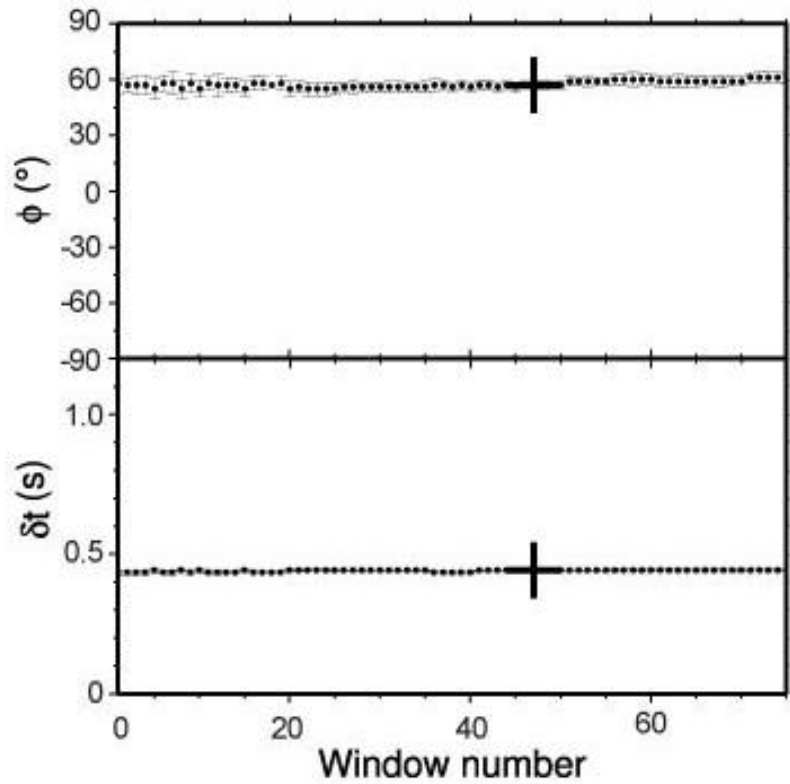


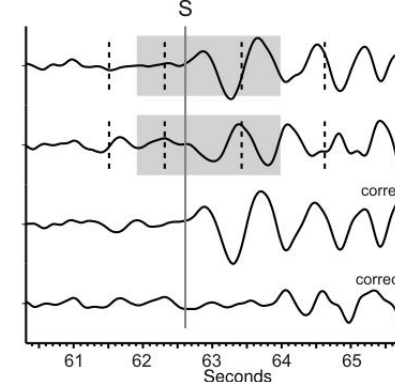
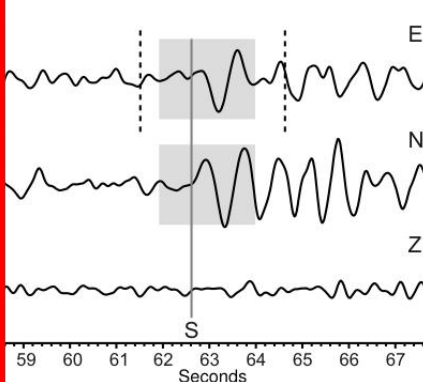
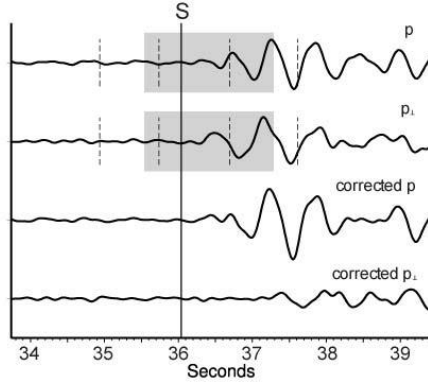
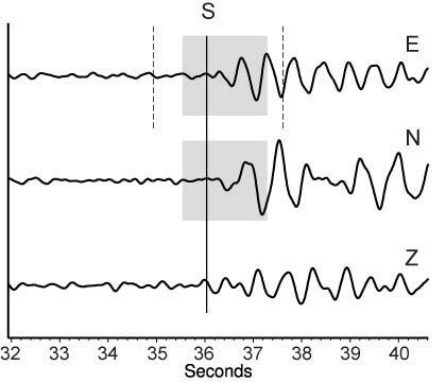
Uses Silver & Chan (1991) to Find most linear particle motion



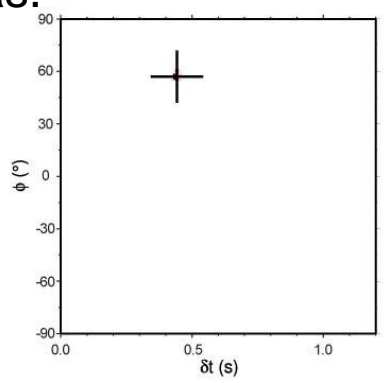
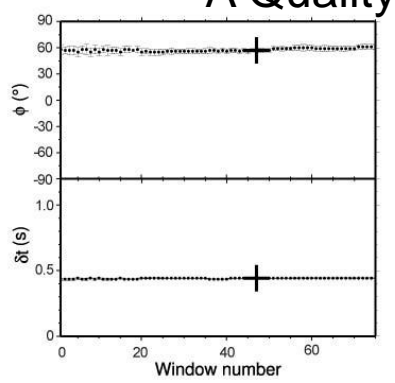
Note also large numbers of contours—bullseye—use as a measure of quality

Checks 75 windows
Cluster analysis finds best window

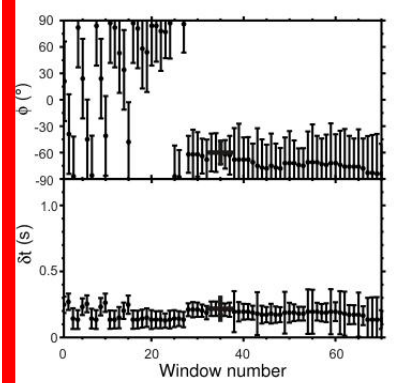




A Quality Meas.

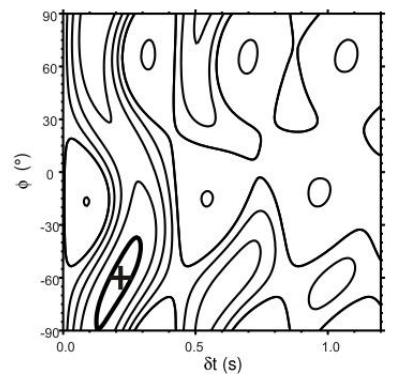
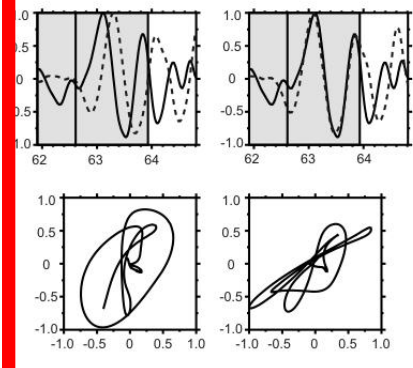
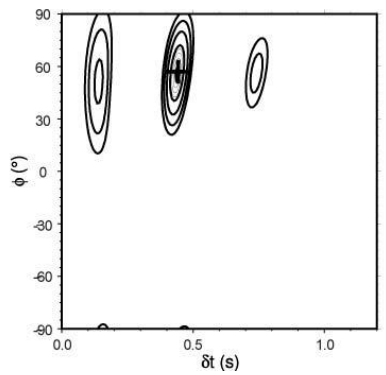
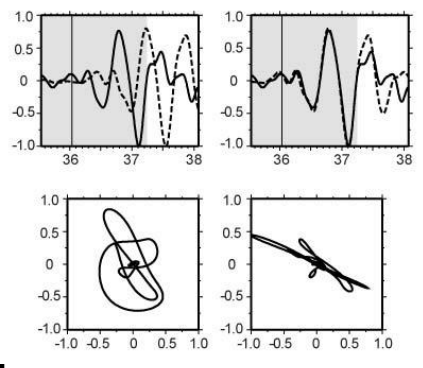
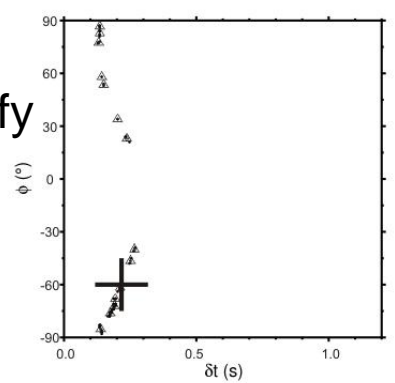


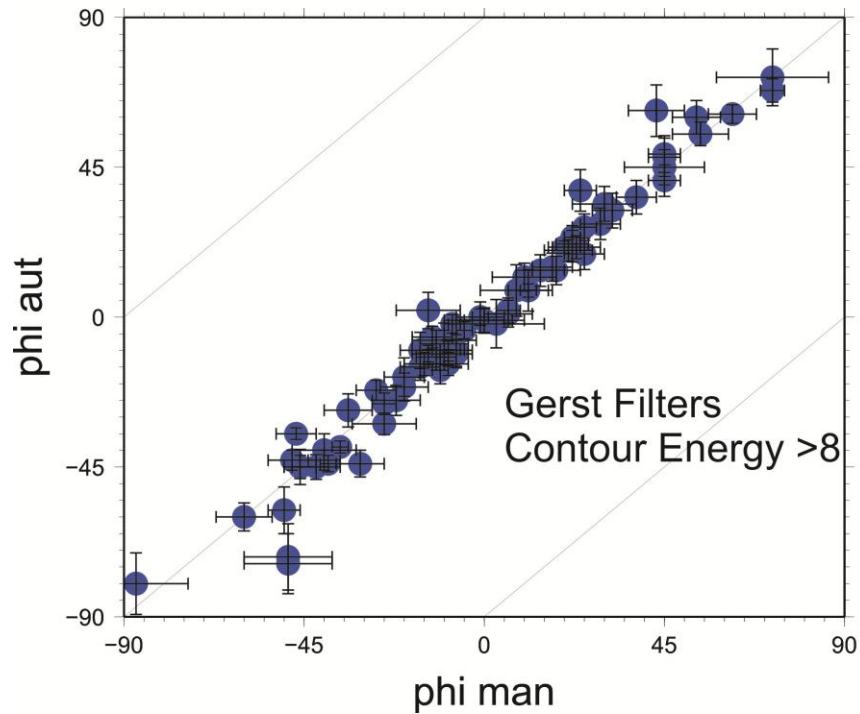
"C" Quality Meas.



Quantify fit.

Throw out more data

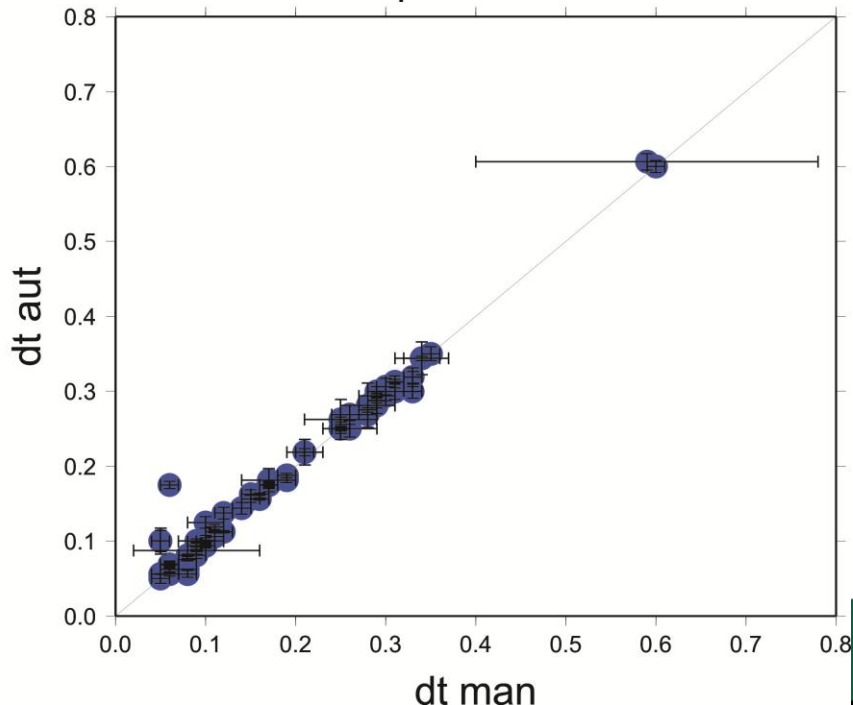




All Stations operating in 2002

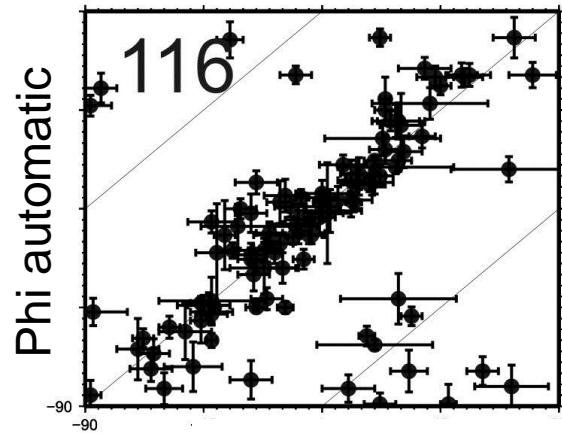
Compare best measurements

Same filters for manual and auto

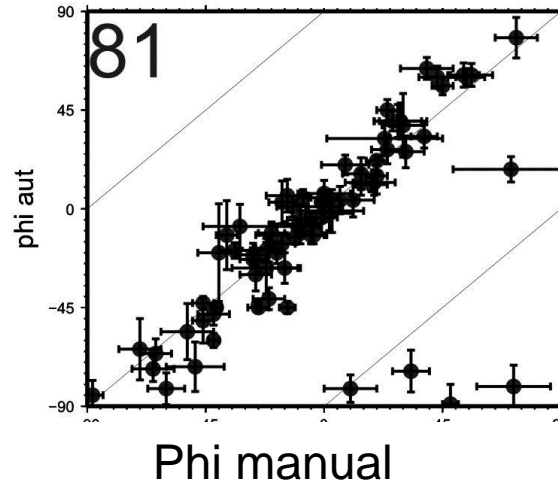


Automatic pick of best one filter

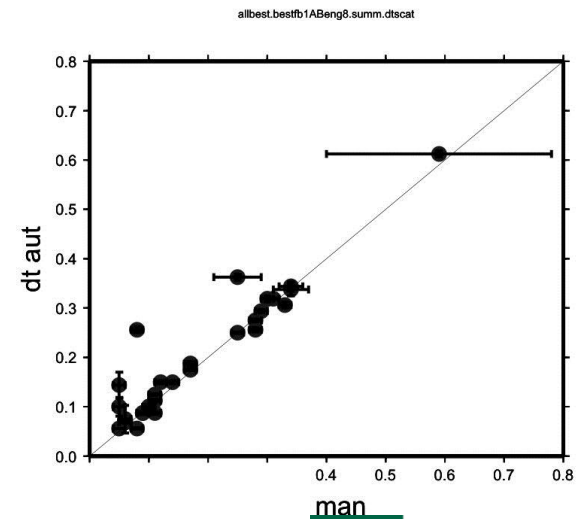
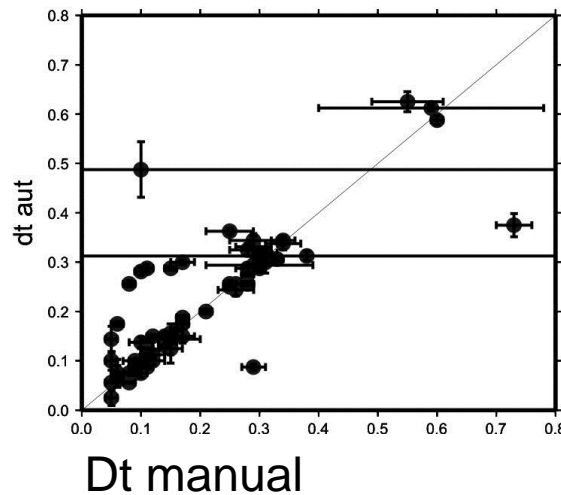
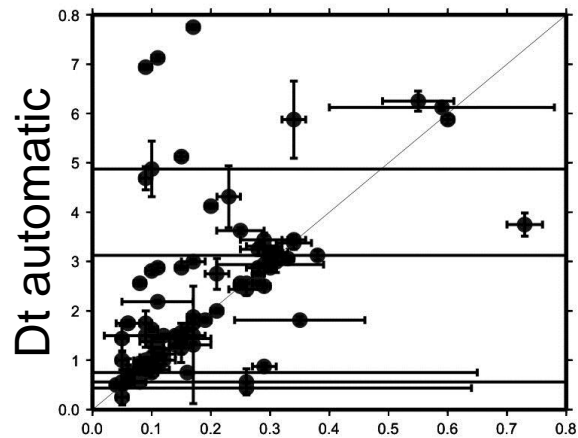
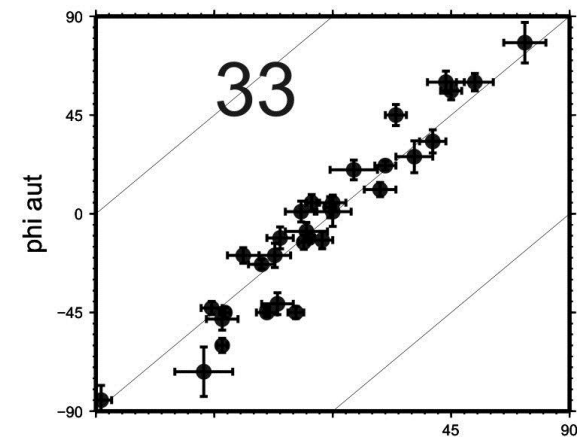
No selection



AB



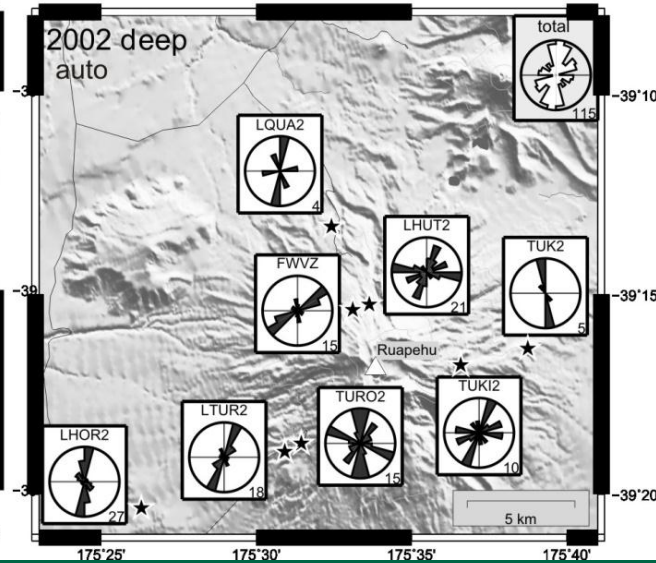
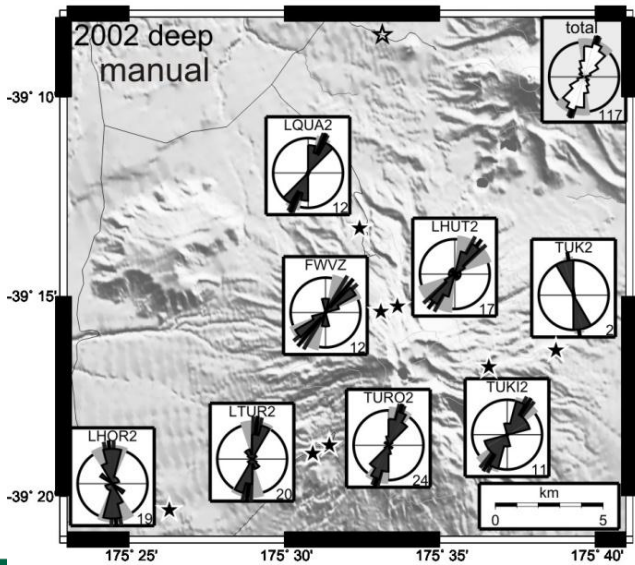
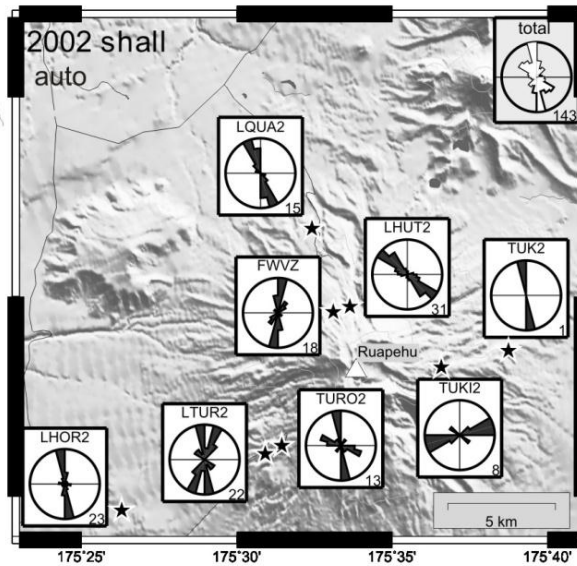
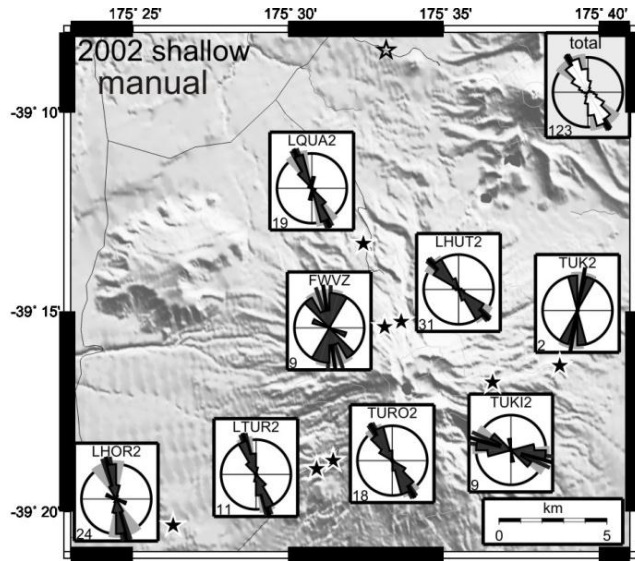
AB eng8



Manual

Auto

2002



Some auto less scattered (FWVZ)

Others more scattered or bimodal (LHUT2)

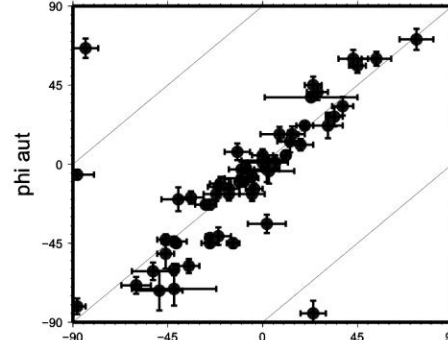
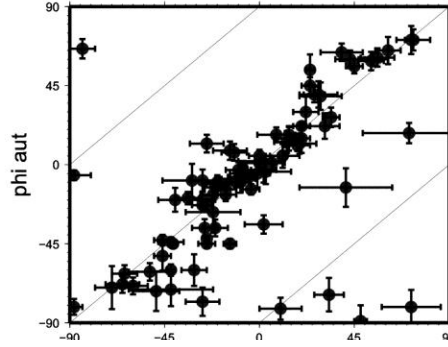
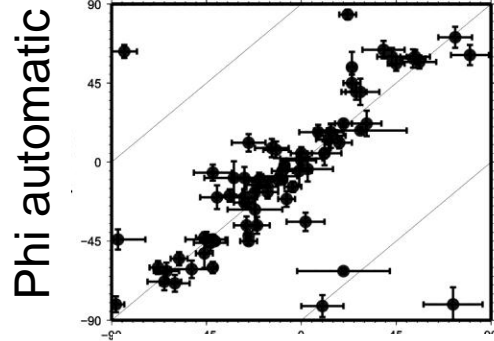
Less difference between shallow and deep

Best meas from three filters

No selection—77 pts

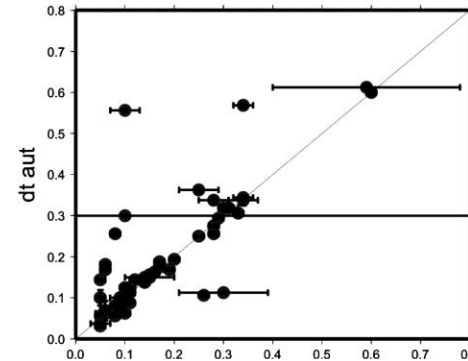
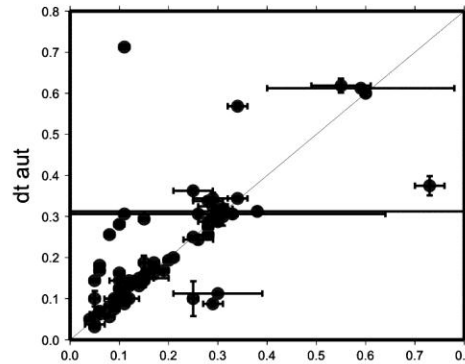
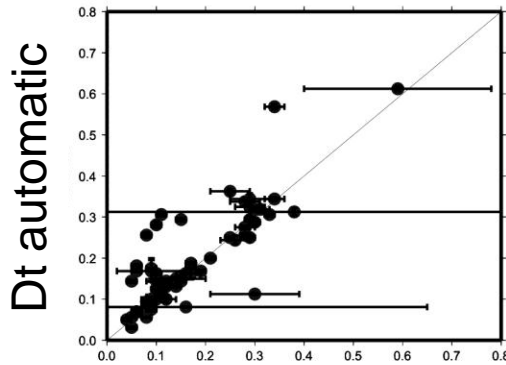
AB—86 pts

AB eng8—56 pts



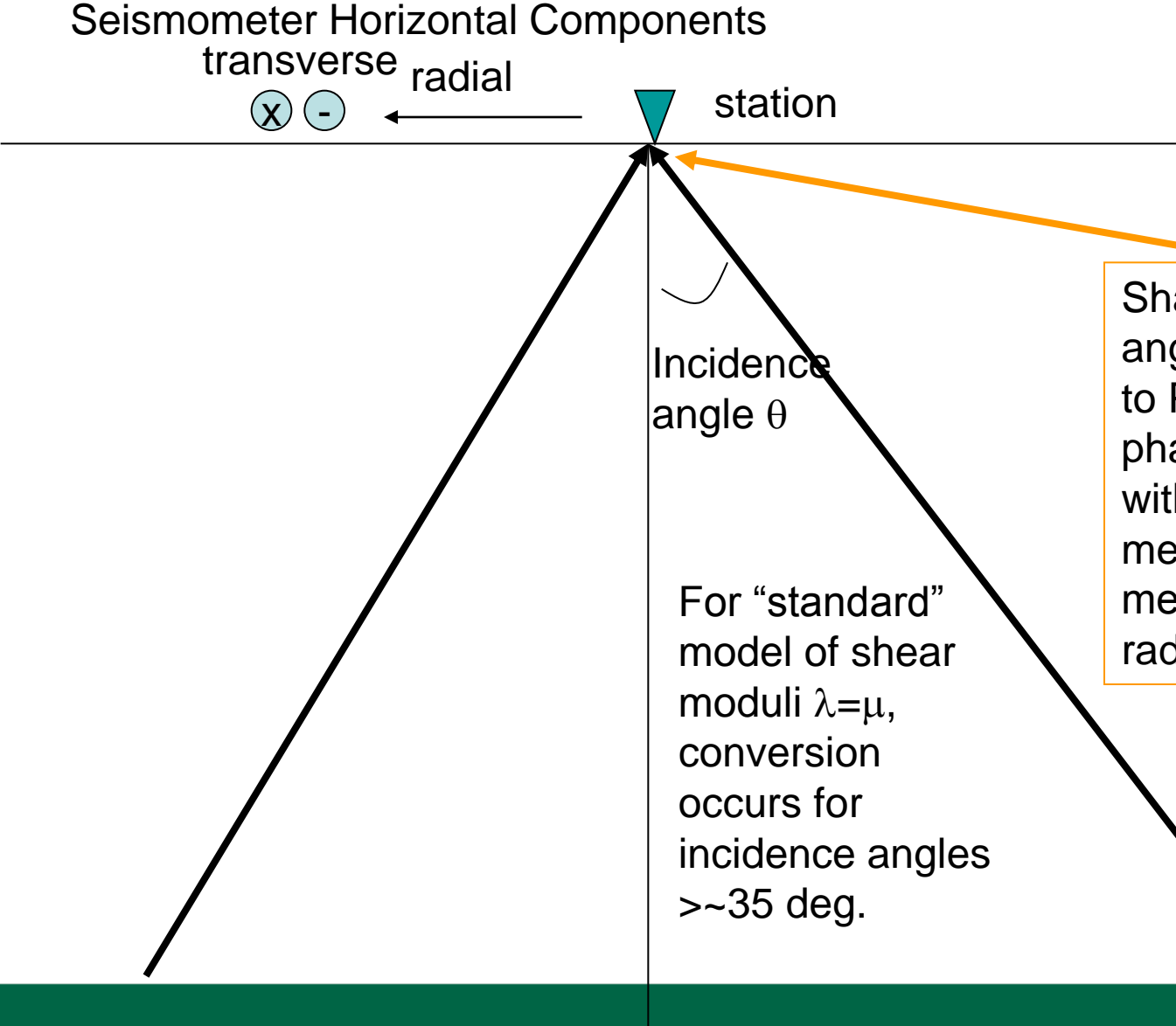
Deleting inconsistent filters cleans up data too

Phi manual



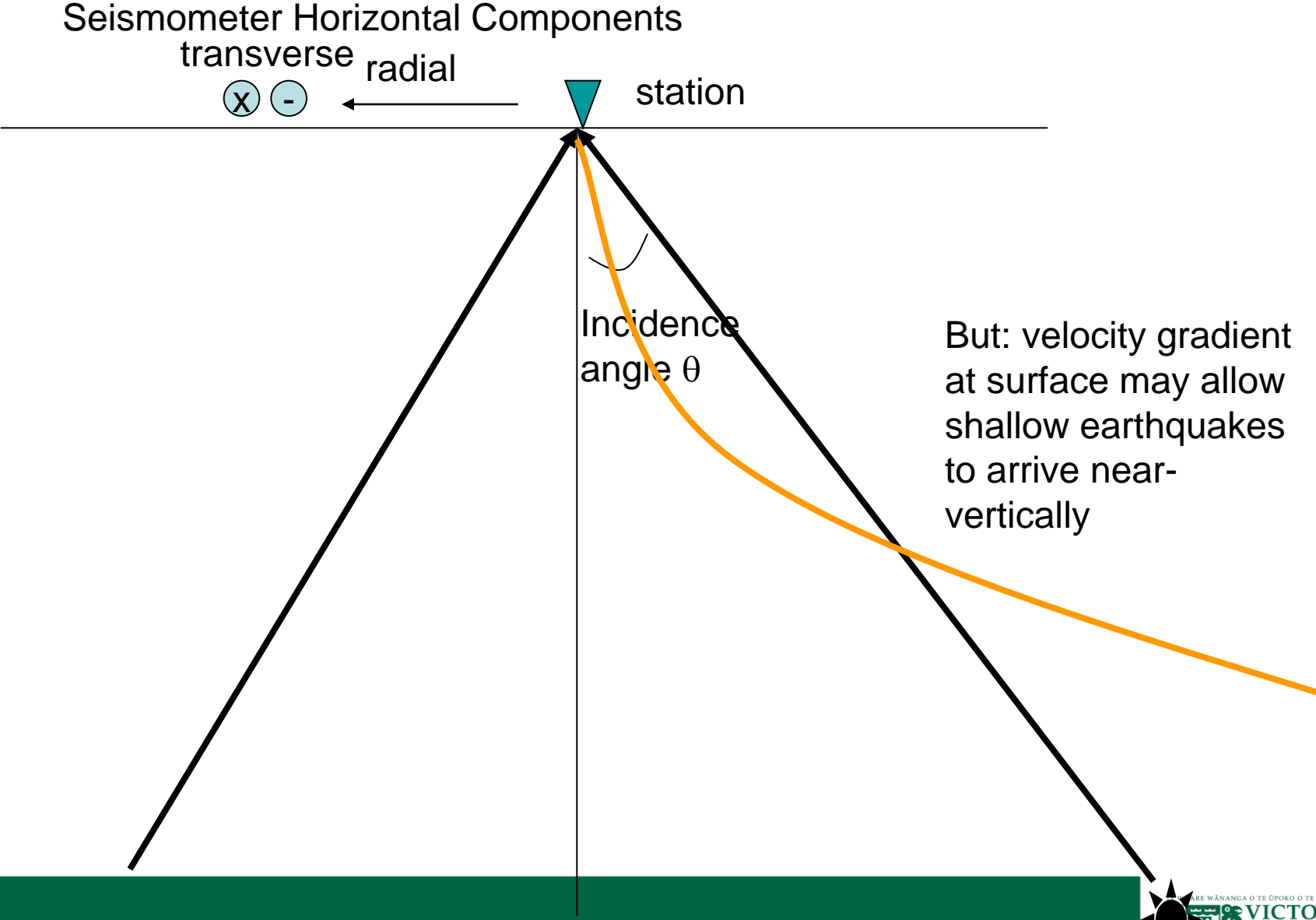
Dt manual

Concept of the “shear wave window”



Shallow incidence angles convert from S to P at surface— phase may interfere with splitting measurement: measured “ ϕ ” will be radial

Concept of the “shear wave window”



MFAST and the SWW

- Calculates angle of incidence from given velocity model
- Current grading does not take it into account
- May not be conservative enough

Output of MFAST

- *.summ file with 41 parameters
- Top line tells what each one is.
- Can use awk to select, or read into excel or Matla
- 29 intermediate files
- 10 postscript files
- Archive.sh cleans them up
- Recommend it once have program working on your data

Utilities directory

- Some programs to make maps with rose diagrams
- Calculate averages of parameters using circular statistics
- Calculate and plot moving averages
- Not supported, most likely you will want to modify plots especially

Running MFAST

- Follow instructions on web page:
- Download package and untar
- Compile fortran codes
- Set paths in `.bashrc` and `mfast_config`
- Check paths via `mfast_precheck`
- Get working on sample data
- Try on your own data

Common problems

- Paths not correctly set
- Sac files don't have S picks in right variable, or missing values (not fatal except if missing S pick)
- SAC components expected to be E and N—doesn't properly use cmpaz variable.
- Currently, SAC version 101.6 is not compatible with any version of mfast.

Trouble shooting

- Read manual
- Read papers
- Look at *auto.log output files
- Look at other output files
- Run do_station_mfm one line at a time
- Run each line separately for each earthquake.
- Copy scripts and put print statements at important points

Most recent material should be at

- <http://mfast-package.geo.vuw.ac.nz/>