Quantification et extraction d'ondes de surface par méthode temps-fréquence

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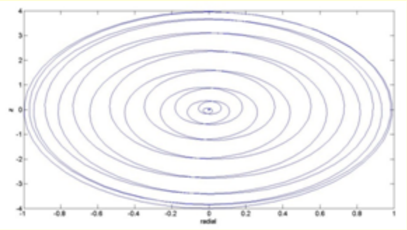

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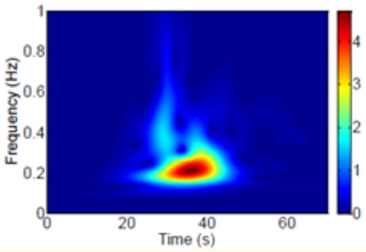

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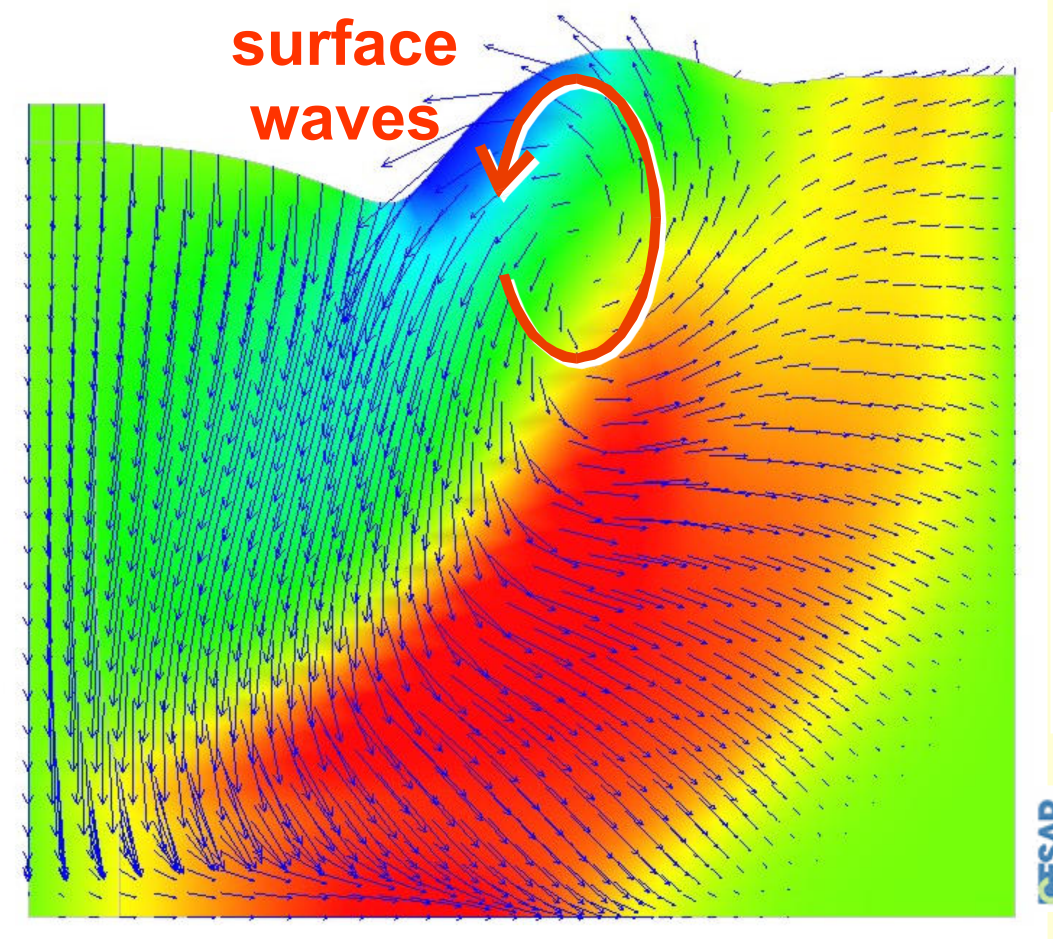
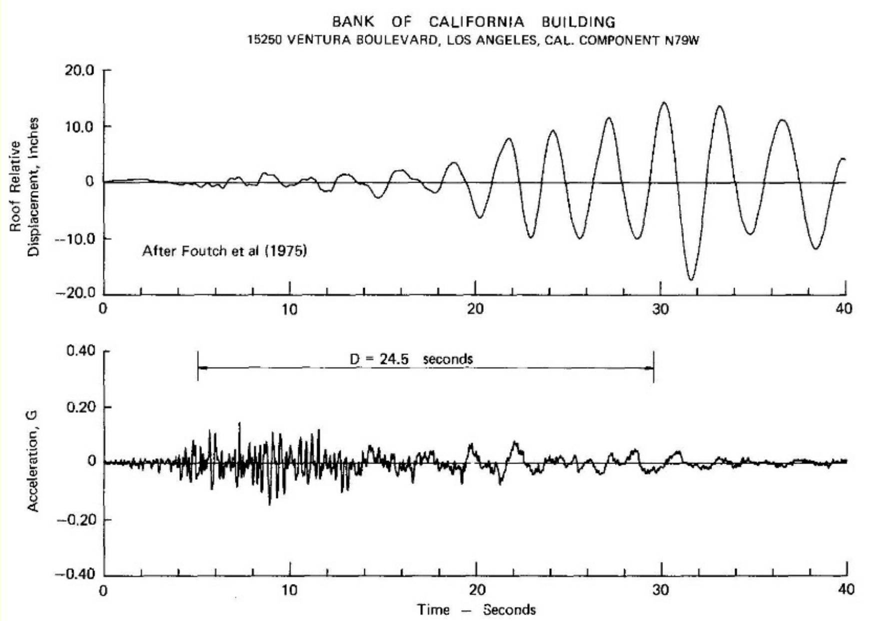
Importance of surface waves

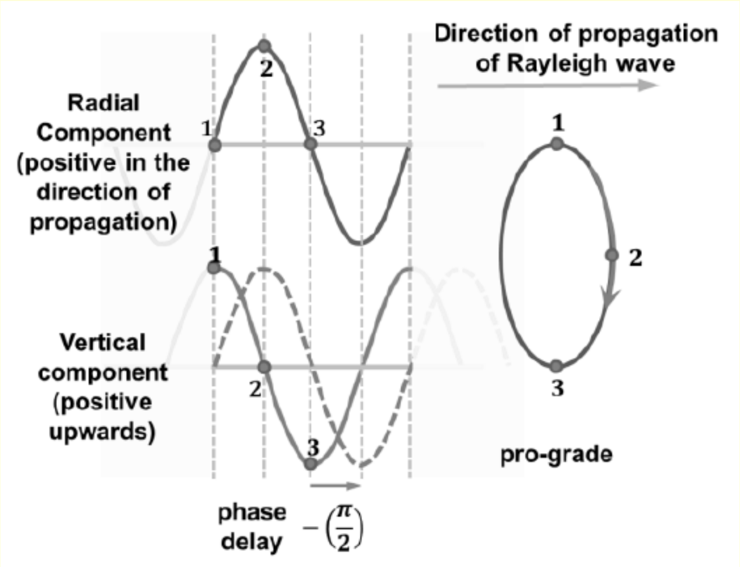
- In vibration engineering: In earthquake eng.:

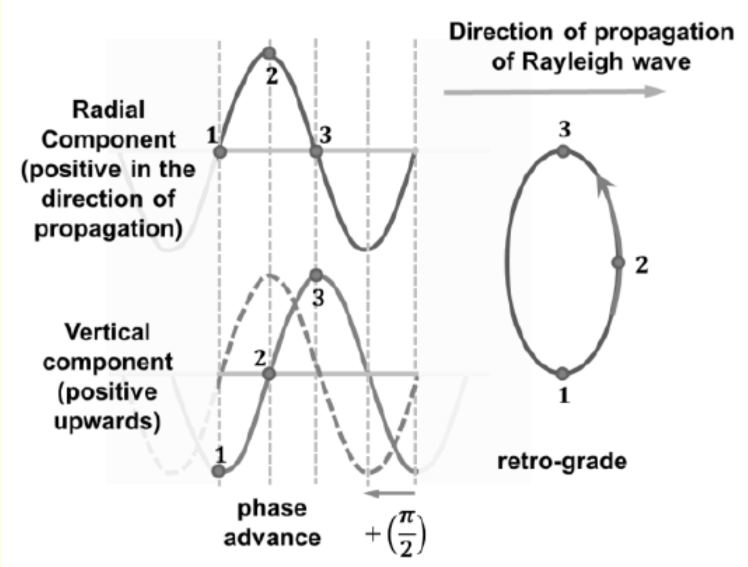




Surface waves polarization

- Polarization of Rayleigh waves: *pro-grade or retro-grade*
- Influence of time shift for vertical component
- 3 cases: linear, circular, elliptical polarization





Time-freq. polarization analysis

- 3 steps procedure
  - Time-freq. Analysis > Stockwell transform:

$$S(t,f)=\int_{-\infty}^{+\infty}h(\tau)\frac{|f|}{\sqrt{2\pi}}\exp\left[-\frac{(t-\tau)^2 f^2}{2}\right]\exp[-2\pi i f t]d\tau$$

  - Instantaneous reciprocal ellipticity…

$$\varphi(\tau,f)=\frac{b(\tau,f)}{a(\tau,f)}$$

semi-minor axis

semi-major axis

$$a(\tau,f)=\frac{1}{\sqrt{2}}\sqrt{A+\sqrt{B^2+C^2}}$$

$$b(\tau,f)=\frac{1}{\sqrt{2}}\sqrt{A-\sqrt{B^2+C^2}}$$

$$A(\tau,f)=X_R^2+X_I^2+Y_R^2+Y_I^2+Z_R^2+Z_I^2$$

$$B(\tau,f)=X_R^2-X_I^2+Y_R^2-Y_I^2+Z_R^2-Z_I^2$$

$$A(\tau,f)=-2\left(X_R X_I+Y_R Y_I+Z_R Z_I\right)$$

+ filtering:
ellipticity threshold

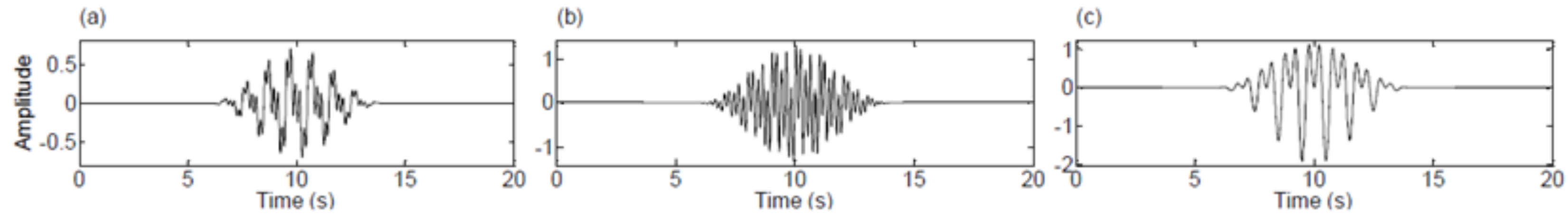
Rayleigh

$$\varphi(\tau,f)>0.5$$

  - Inverse Stockwell transform: time domain

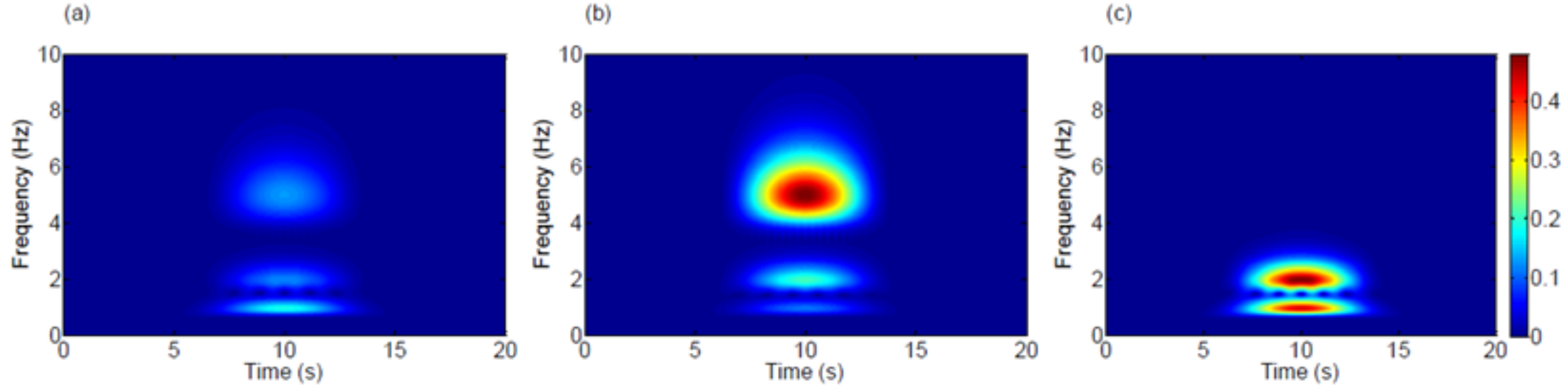
Synthetics: t-f analysis

- Synthetics (combination of sinusoids)



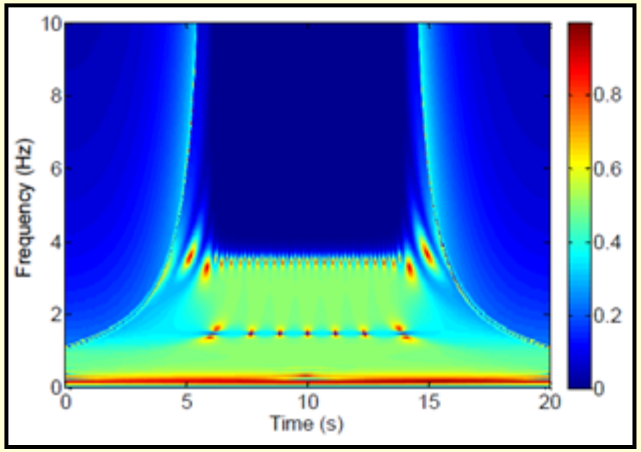
Three-component synthetic signal. (a) North component, (b) East component, (c) Vertical component.

- Time-frequency analysis

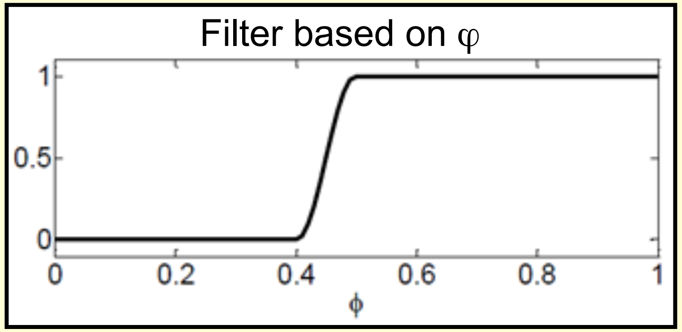


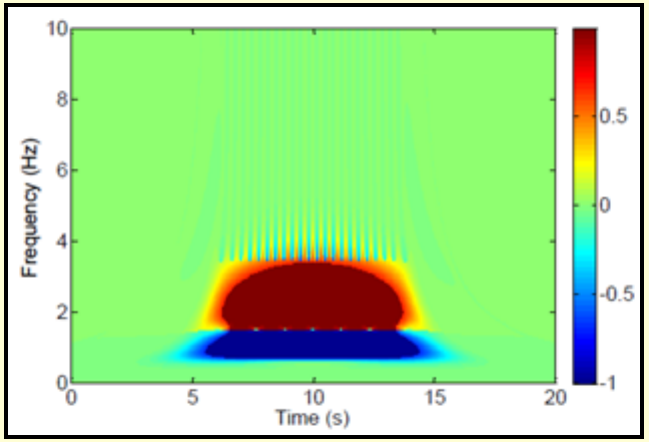
Amplitude of Stockwell transforms of the NEV components of the synthetic signal. (a) North component, (b) East component, (c) Vertical component.

Synthetics: filtering

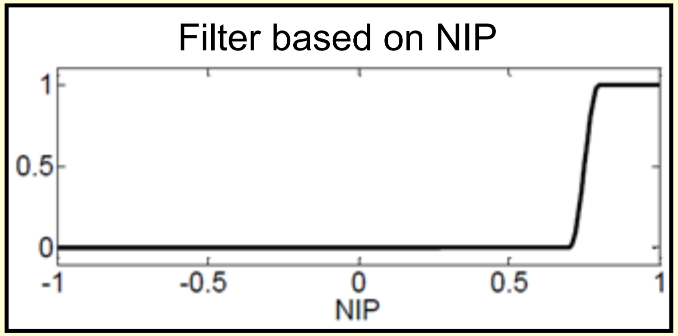


Instantaneous reciprocal ellipticity and related filter

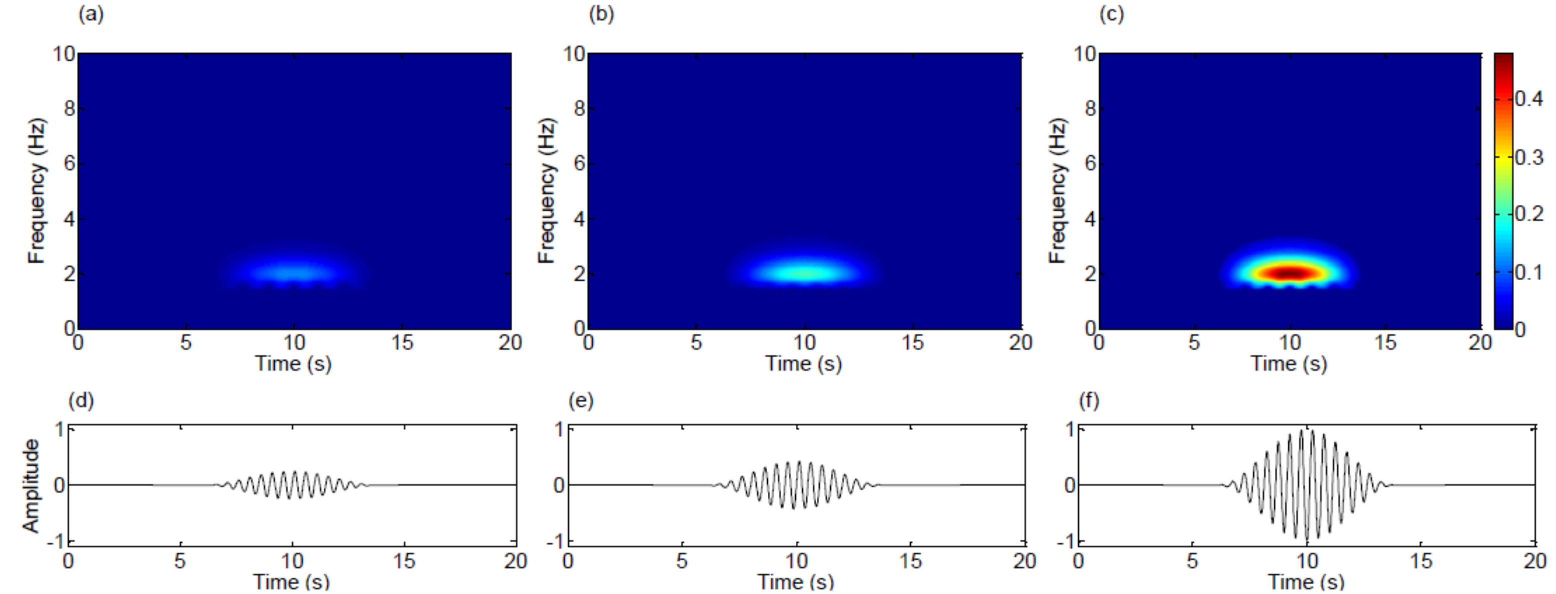




Alternative: *normalized inner product* and related filter

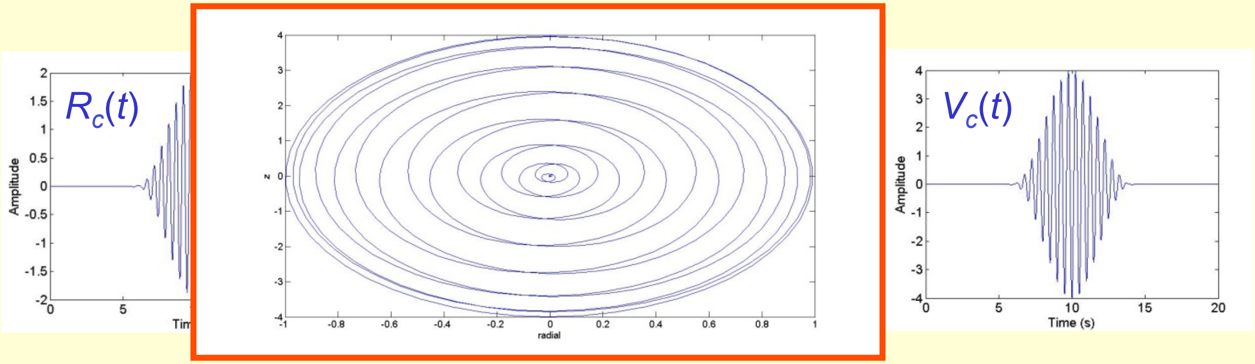


Synthetics: filtered signals

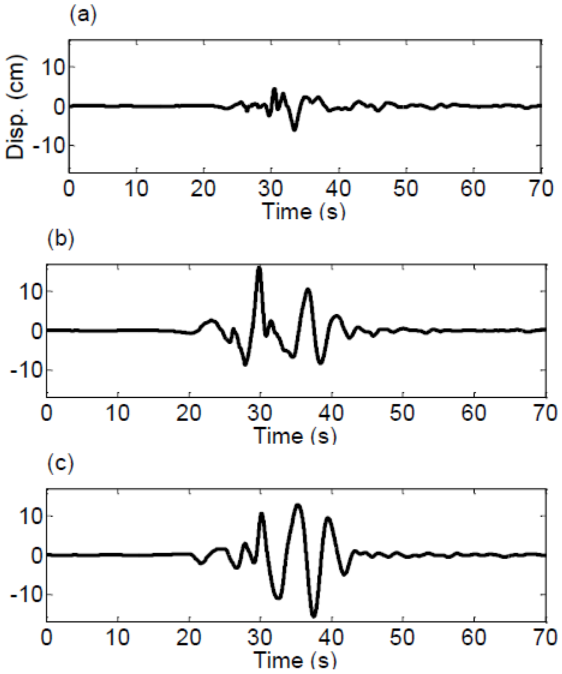


Extracted retro-grade Rayleigh wave. (a) Amplitude of filtered $S_N(\tau,f)$ component, (b) Amplitude of filtered $S_E(\tau,f)$ component, (c) Amplitude of filtered $S_V(\tau,f)$ component, (d) North component, (e) East component, (f) Vertical component.

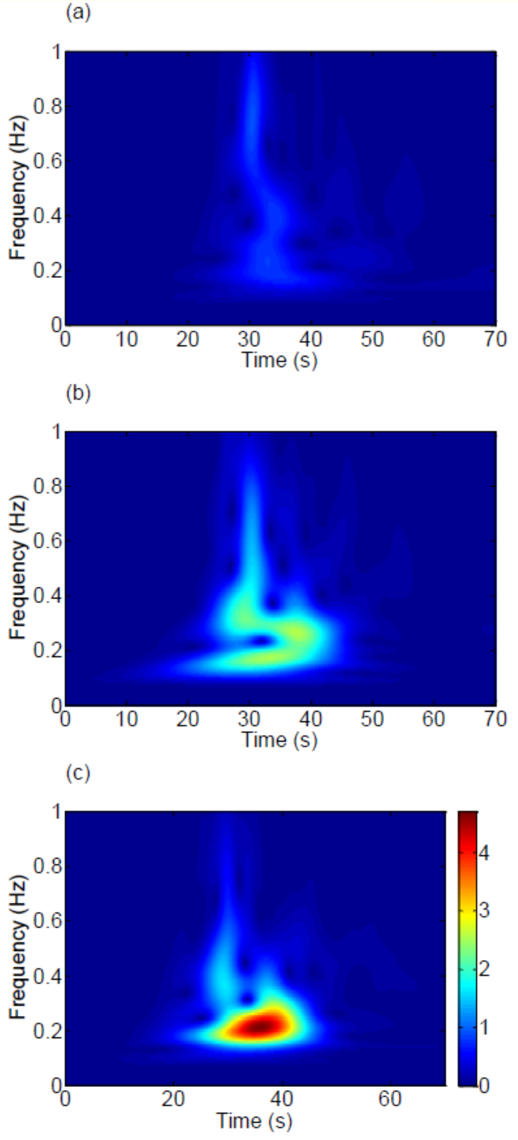
Compute azimuth + new frame (R,T,V)



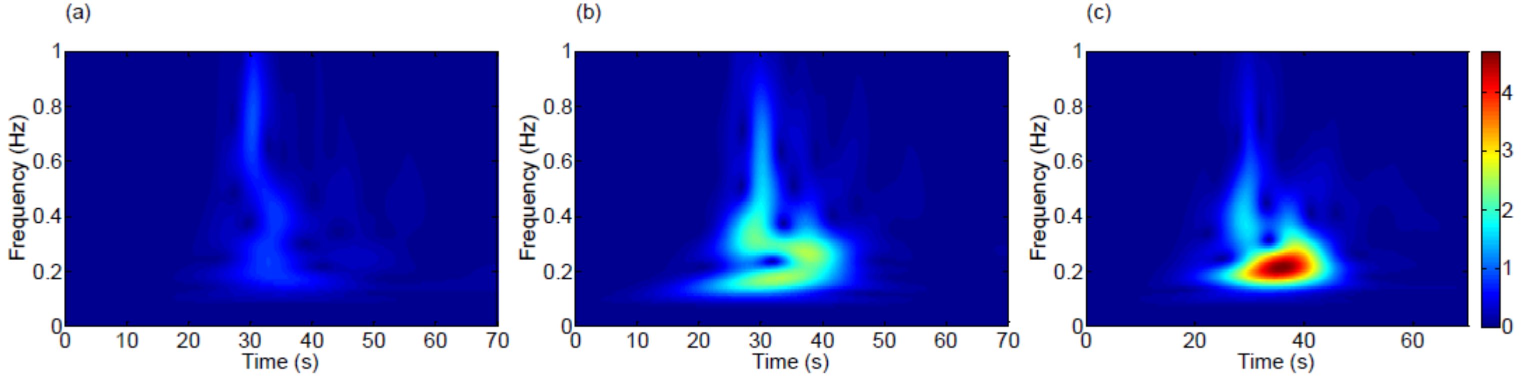
Actual motions: Chi-chi qke



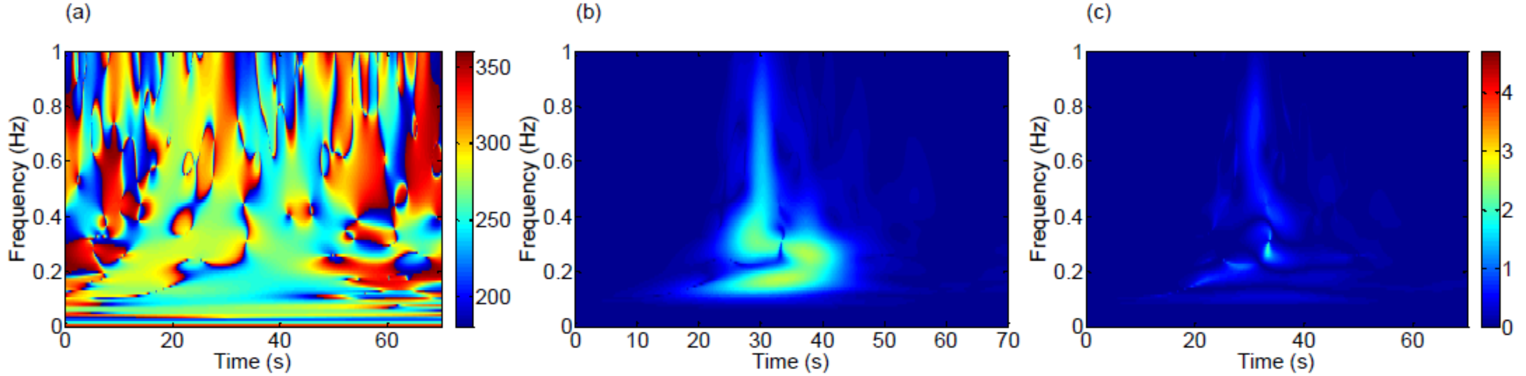
NEV components of the displacement history recorded during the aftershock at station TCU116 (a) North component, (b) East component, (c) Vertical component.



Actual motions: t-f analysis

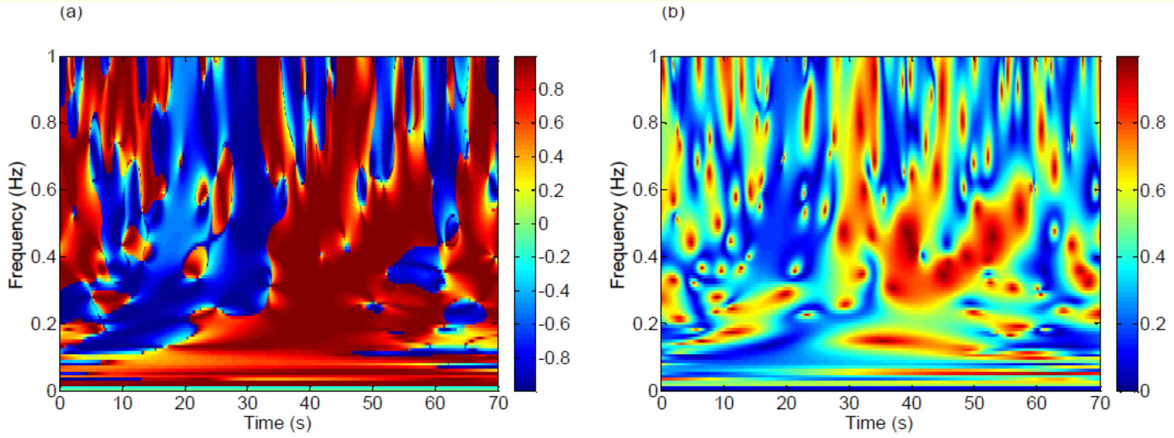


Amplitude of Stockwell Transforms of the *N-E-V* displacement components during aftershock 1803 at station TCU116. (a) North component (b) East component (c) Vertical component.

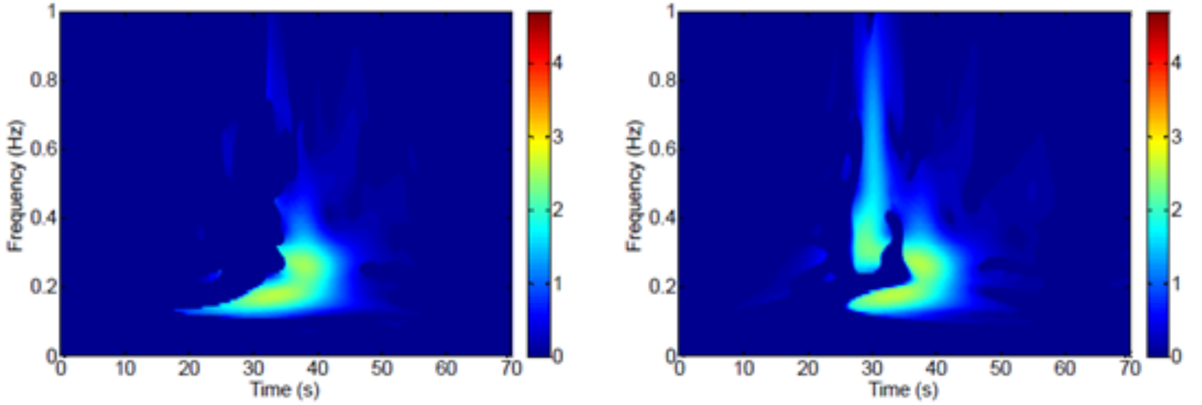


Radial and Transverse displacement components for the NIP at station TCU116. (a) Azimuth of direction of propagation, (b) Amplitude of radial components (c) Amplitude of transverse component.

Actual motions: filtered signals

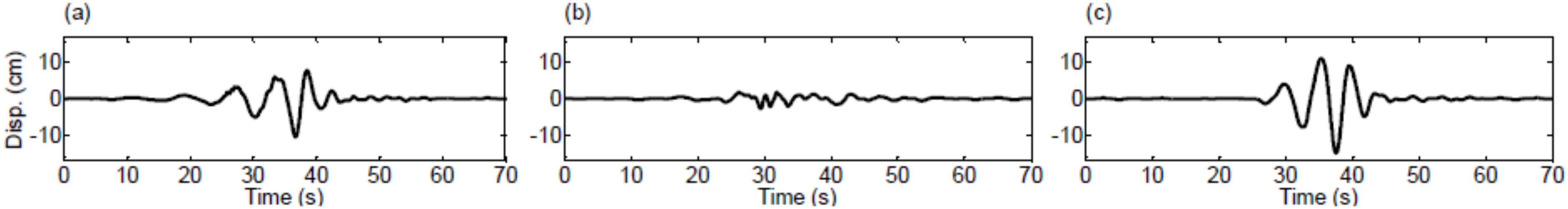


Comparison between instantaneous reciprocal ellipticity and NIP criteria. (a) Normalized inner product of radial and phase advanced vertical component, (b) Instantaneous reciprocal ellipticity computed with the three-components of the signal.

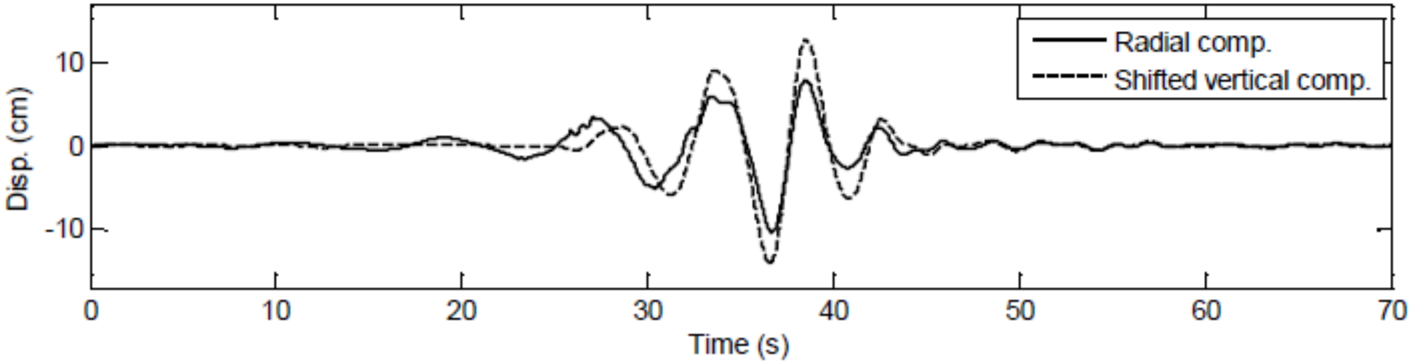


Amplitude of filtered radial displacement component $S_R(\tau, f)$ for recording at station TCU116. (a) Filtering based on the NIP of $S_R(\tau, f)$ and the shifted ($\pi/2$ phase advance) $S_V(\tau, f)$. (b) Filtering based on the instantaneous reciprocal ellipticity.

Actual motions: filtered signals



Displacement components of extracted Rayleigh retro-grade wave at station TCU116. (a) Radial component, (b) Transverse component, (c) Vertical component.

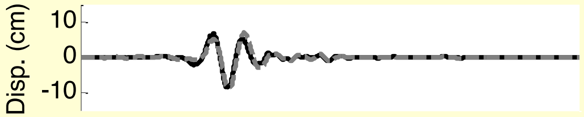


Comparison between the radial and shifted vertical displacement components for the extracted retro-grade wave from recording at station TCU116.

Actual motions: synthesis

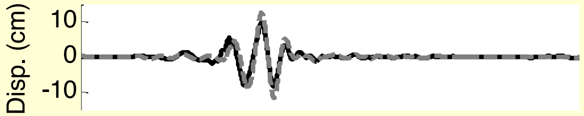
- Identification at various stations

TCU129



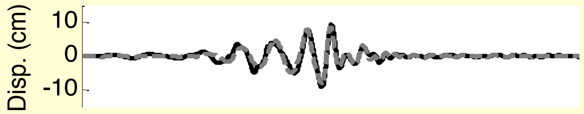
Azimuth: 293.757 degrees

TCU122



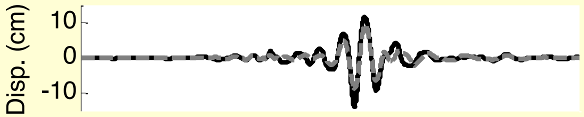
Azimuth: 265.8207 degrees

CHY025



Azimuth: 294.2067 degrees

TCU141



Azimuth: 254.5216 degrees

TCU113

Azimuth: 279.9617 degrees

Conclusions

- Instantaneous Reciprocal Ellipticity and Normalized Inner Product are efficient for:
  - Surface wave identification
  - Surface wave extraction
- Time-frequency transform needed (*S*)
- Verification on synthetic signals
- Validation on actual recordings
- Application to vibrations