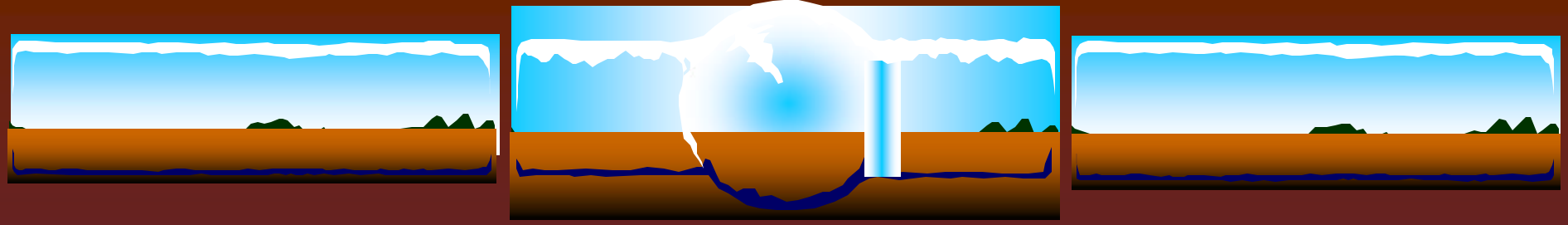

DOE's EGS Program Review

Real-time fracture monitoring in EGS with seismic waves

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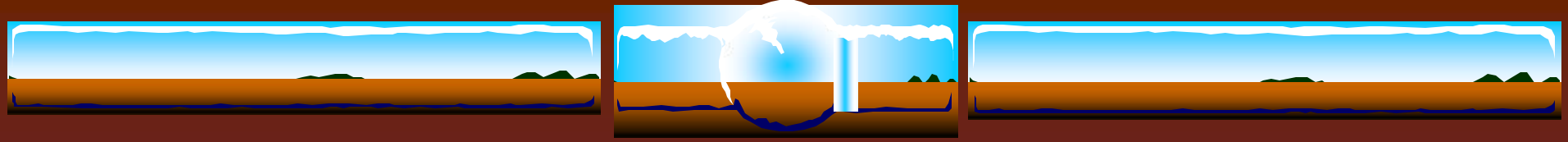
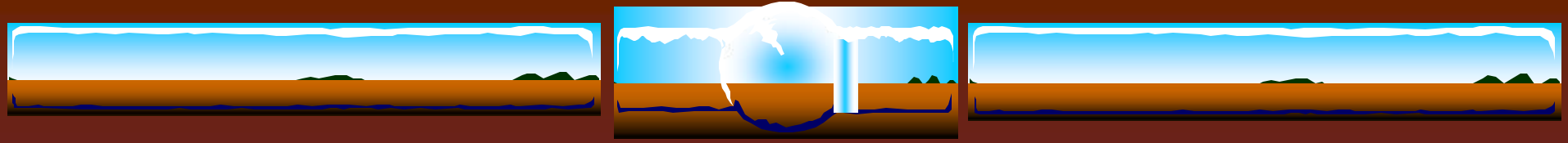


Project Objective

- Develop software to monitor in real time the spatial and temporal distributions of crack systems, intensity of fracturing, and migration of fluids.

- No changes in objectives so far.



EGS Problem

- Why is project important to EGS program?

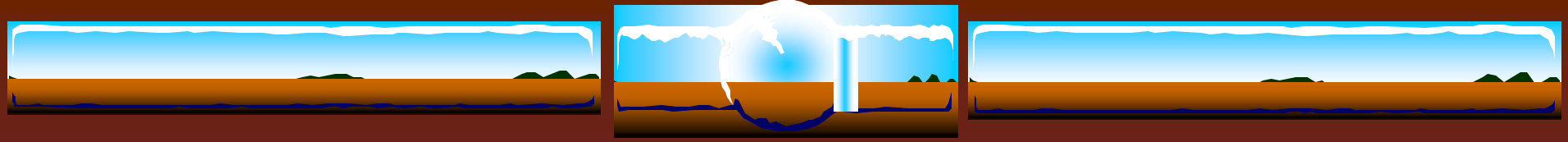
  Will provide fracture and fluid migration information upon which engineering decisions may be made in real time.

- What technical issue does the project address?

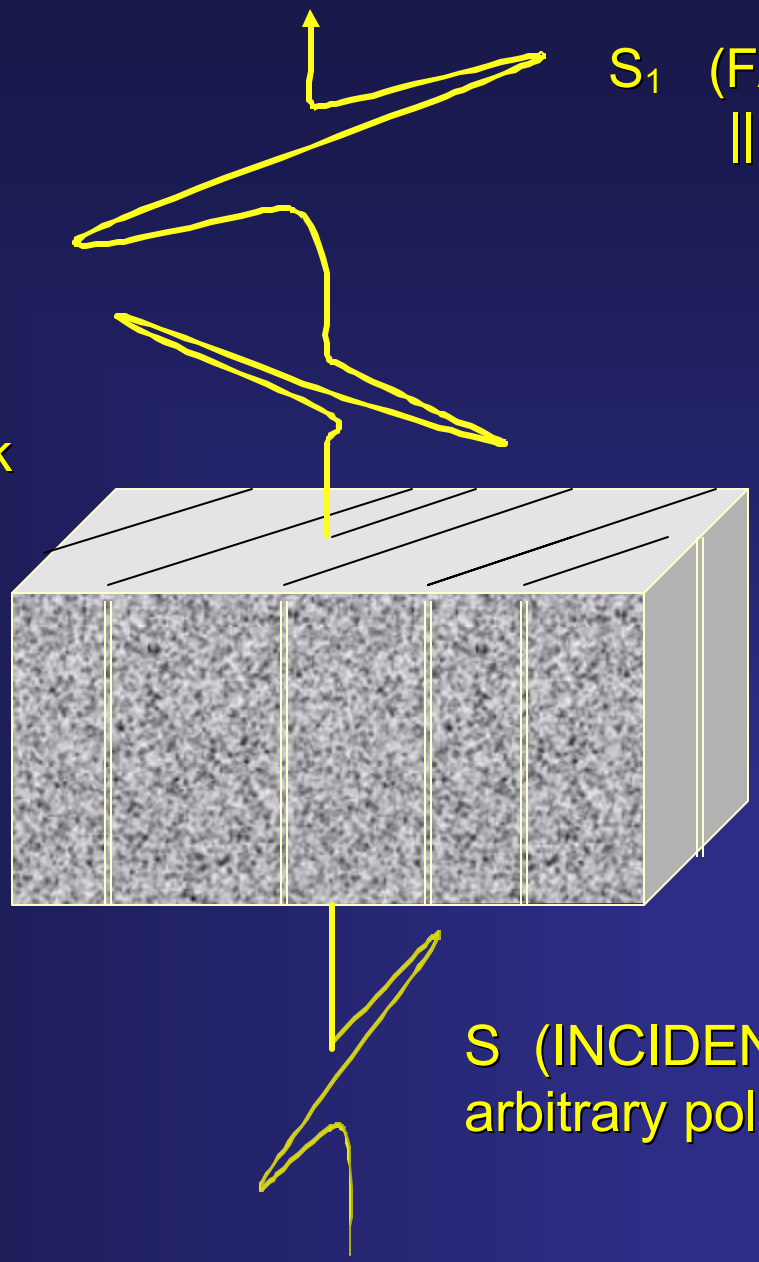
  Crack imaging, detection of fluid motions in the reservoir

- How will project help to achieve overall program goals?

  Increased knowledge of the subsurface fracture systems and the motions of fluids decreases exploratory risks, helps managing the resource, and reduces production costs.



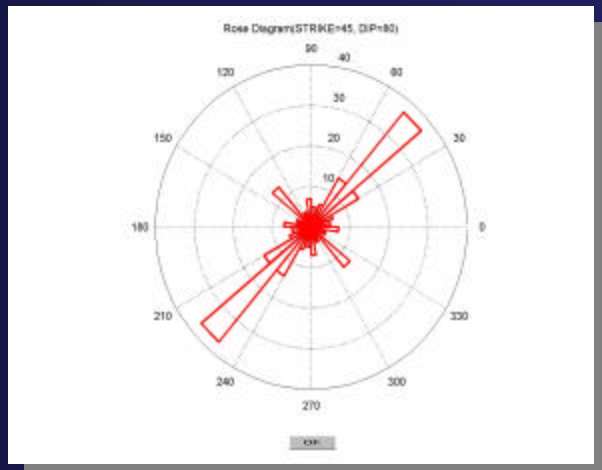
Background/Approach



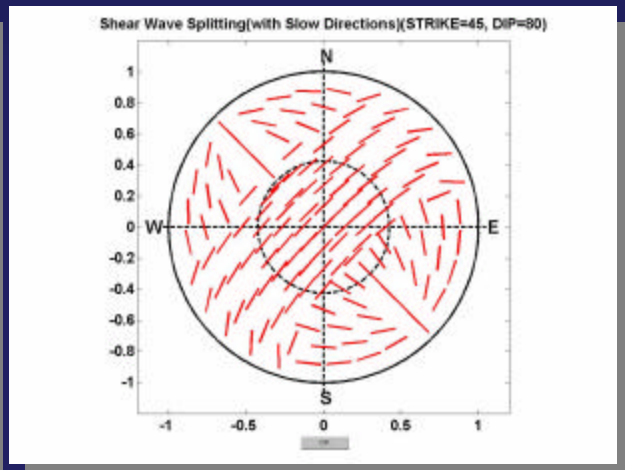
SHEAR-WAVE SPLITTING

Simulated Data

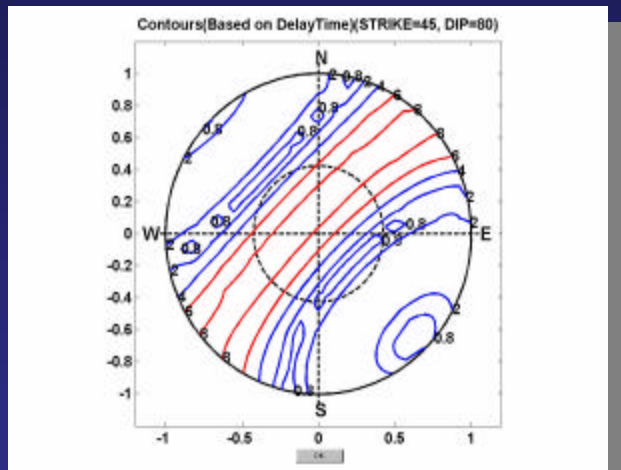
Rose diagram



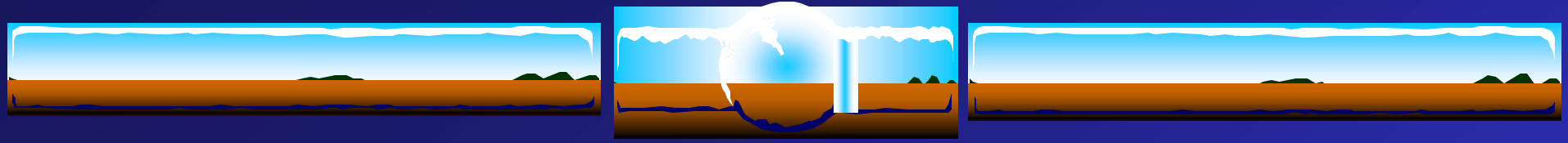
Polarization



Time delay



Fracture model
Strike: N45°E
Dip: 80°SE
Crack density: 0.02



Inversion for Crack Geometry and Crack Intensity

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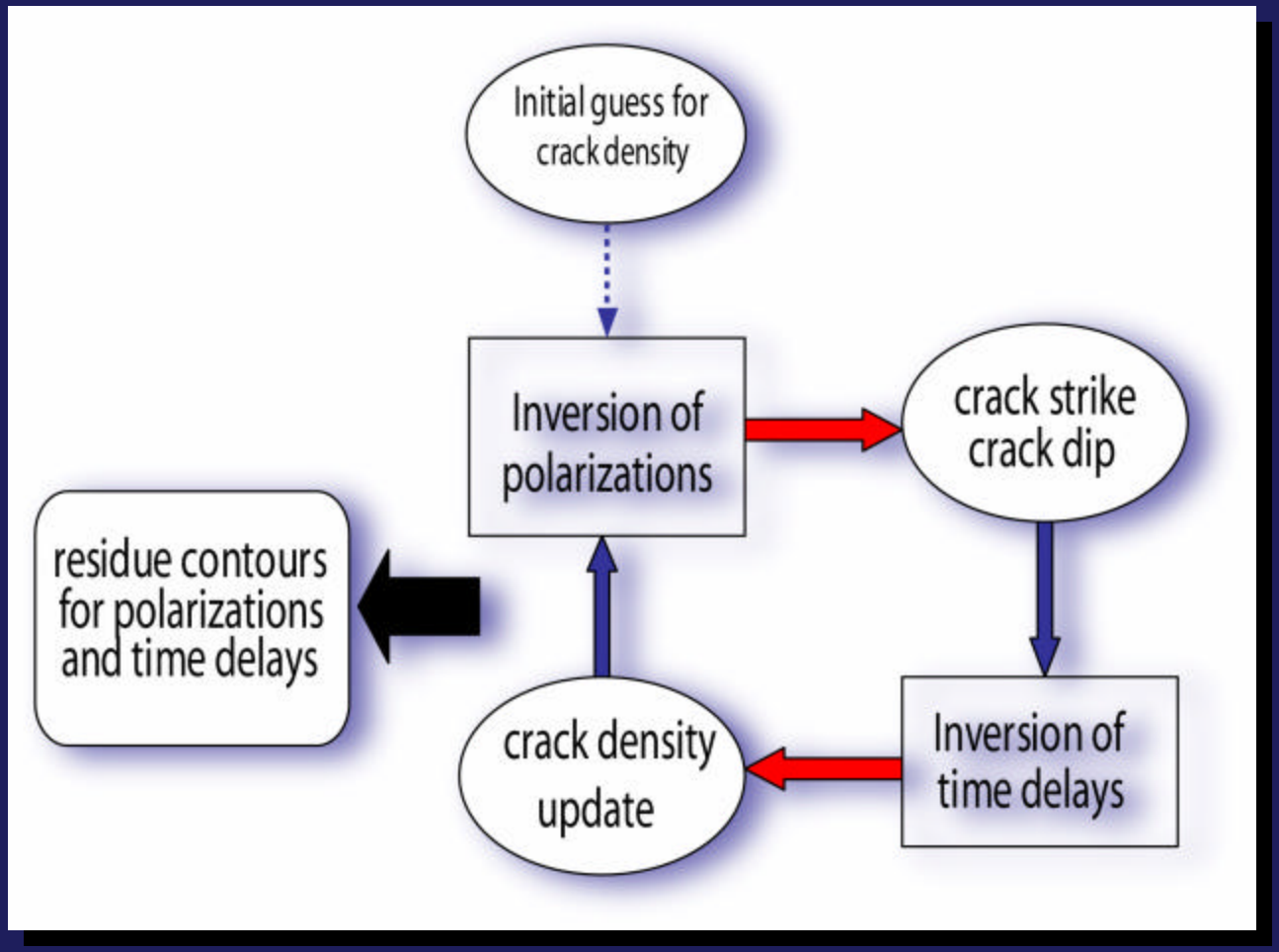
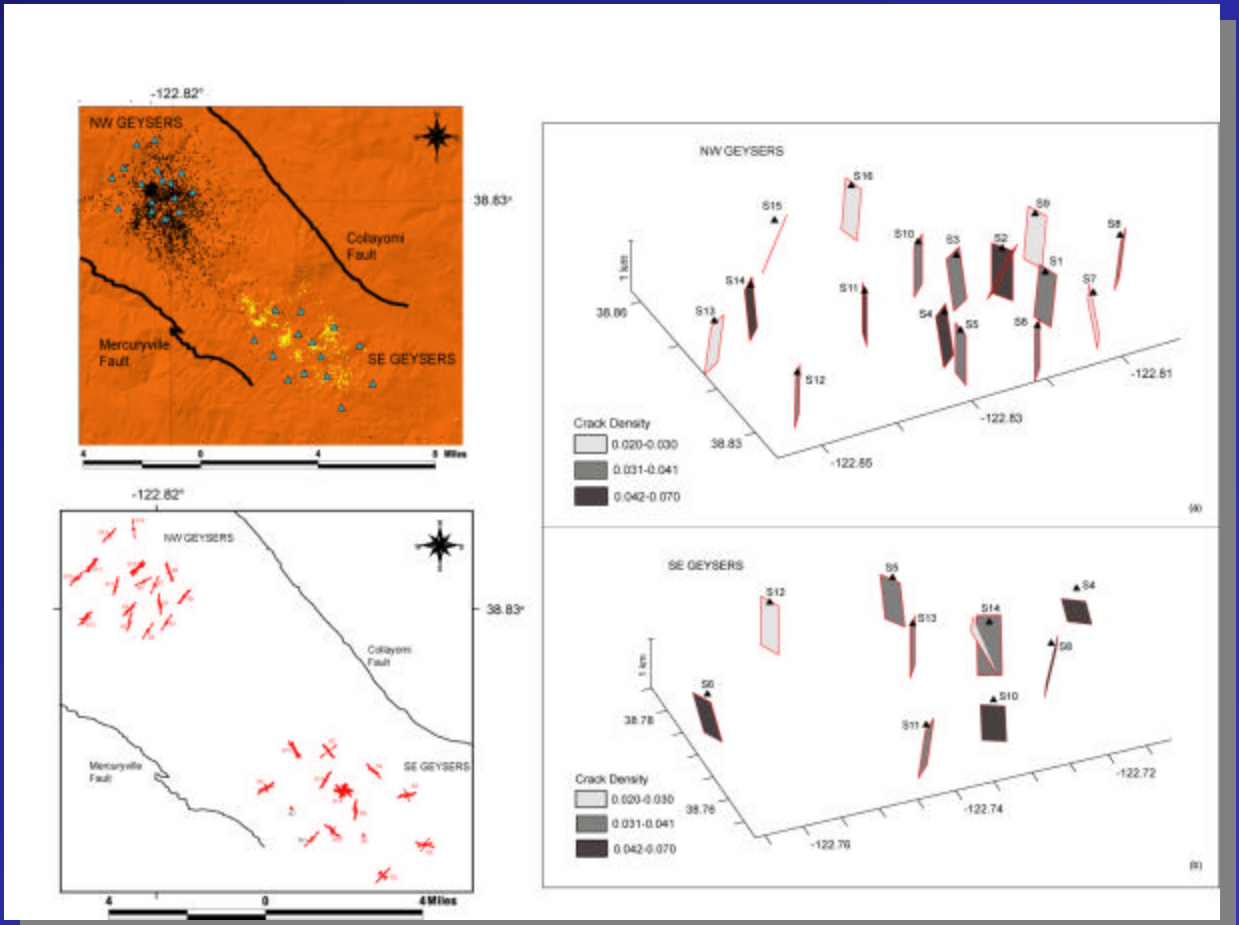
Inversion Scheme



Shear Wave Splitting Results in The Geysers



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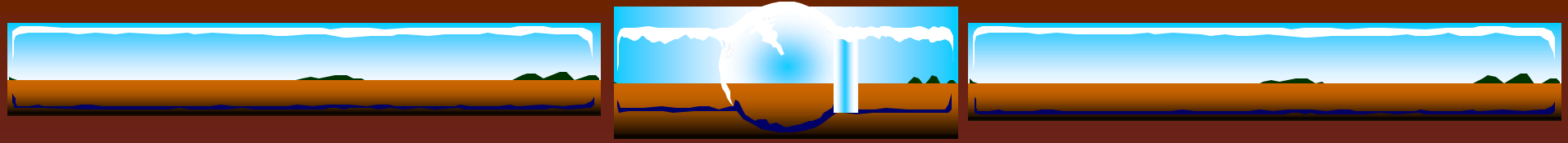


Results/Accomplishments

Accomplished:

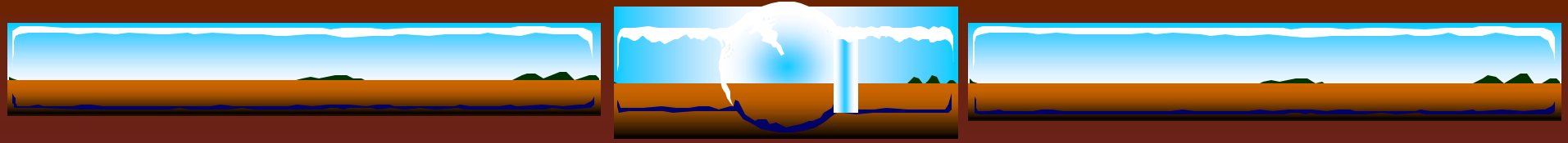
- Real-time micro-earthquake detection and location
- Delayed-time seismic velocity model inversion

In progress:

- Real-time detection of shear-wave splitting

Future implementation:

- Delayed-time inversion of shear-wave splitting
- Real-time display of 3D field geometry

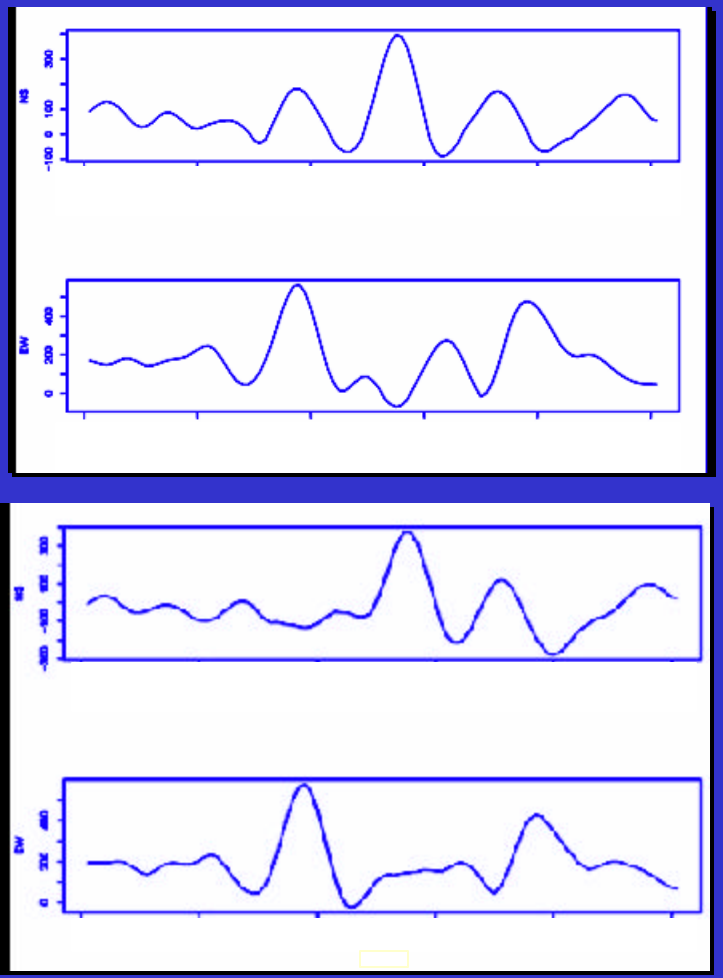


Automatic SWS Measurements

- Cross-correlation techniques
- Wavelet Transforms
- Cepstrum analysis

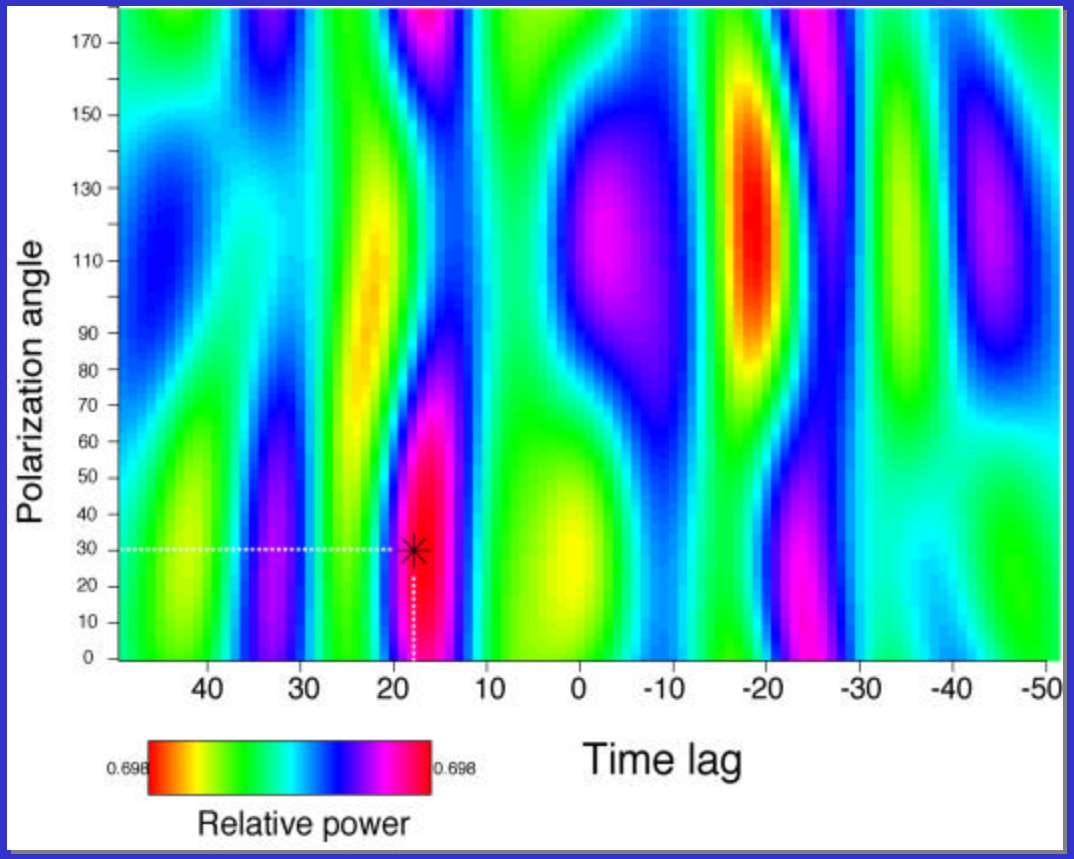
Cross-Correlation

Data (Analyzed by hand)

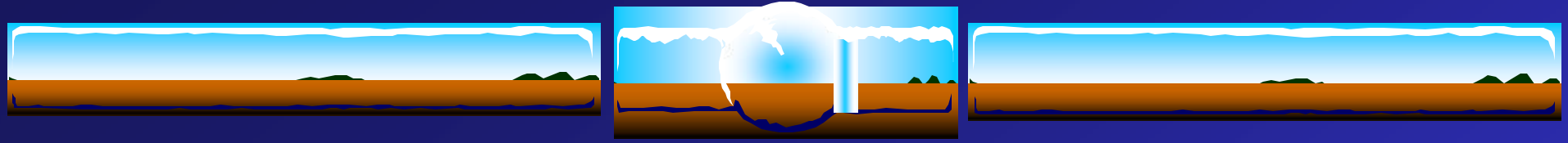


Azimuth 31 deg Delta t 18ms

Automatic rotation vs correlation

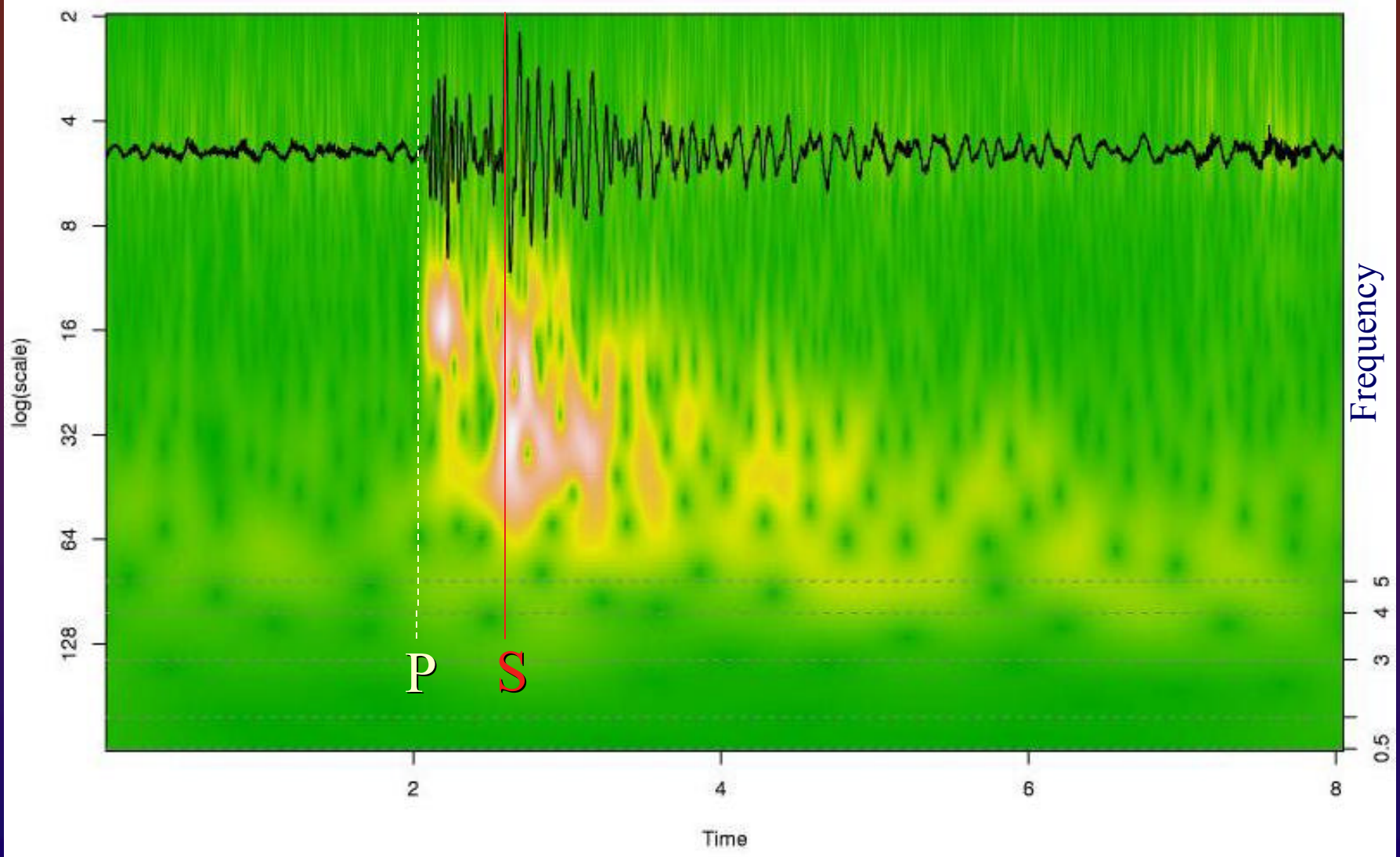


The maximum in the correlation map gives the polarization angle and delay time

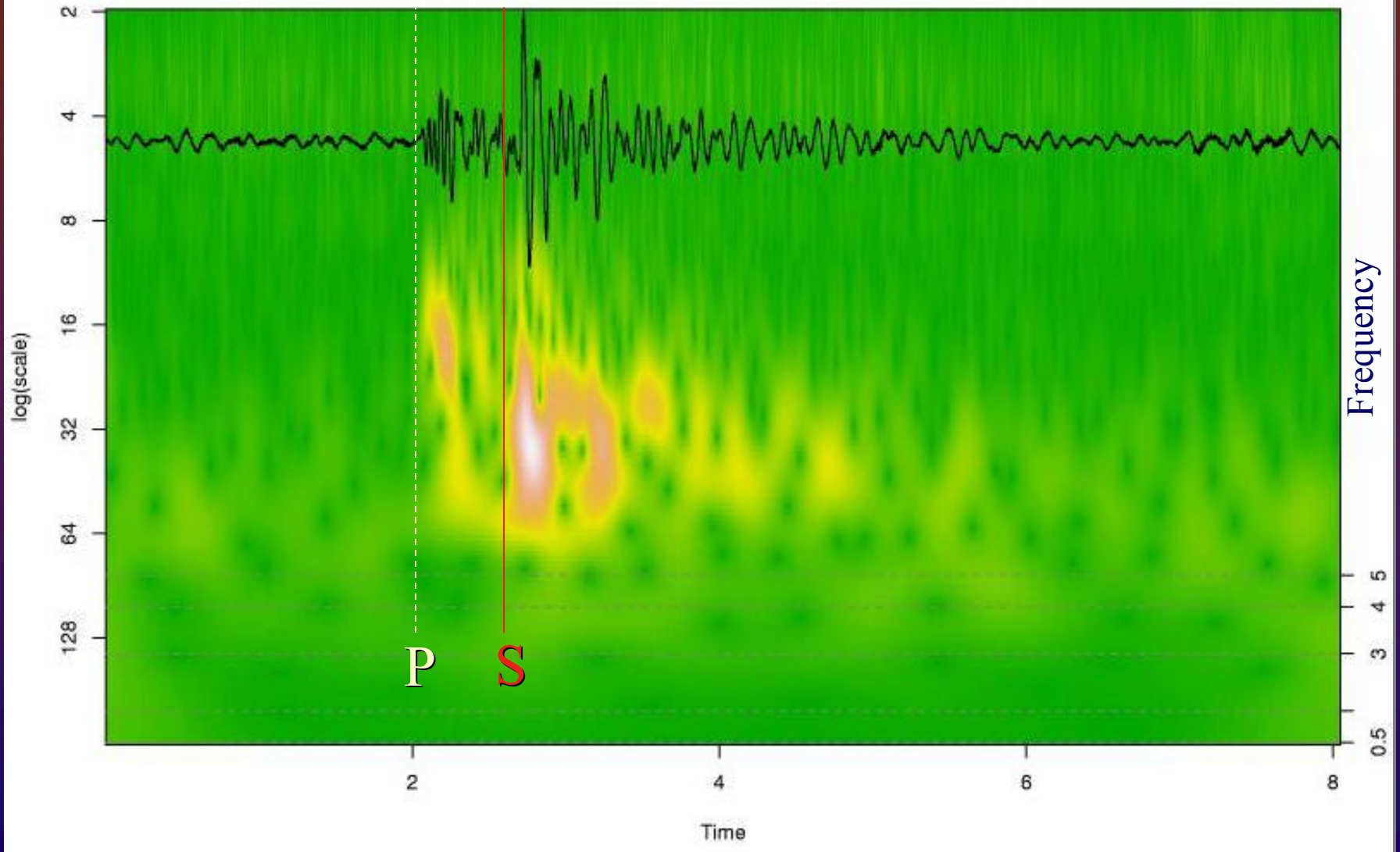


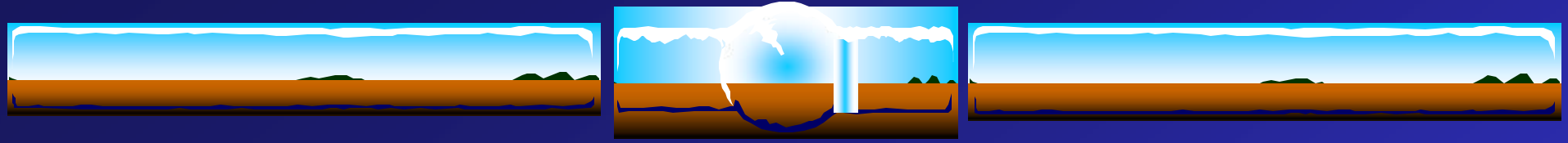
Wavelet Transforms

Station 16 NS



Station 16 EW





Cepstrum Analysis

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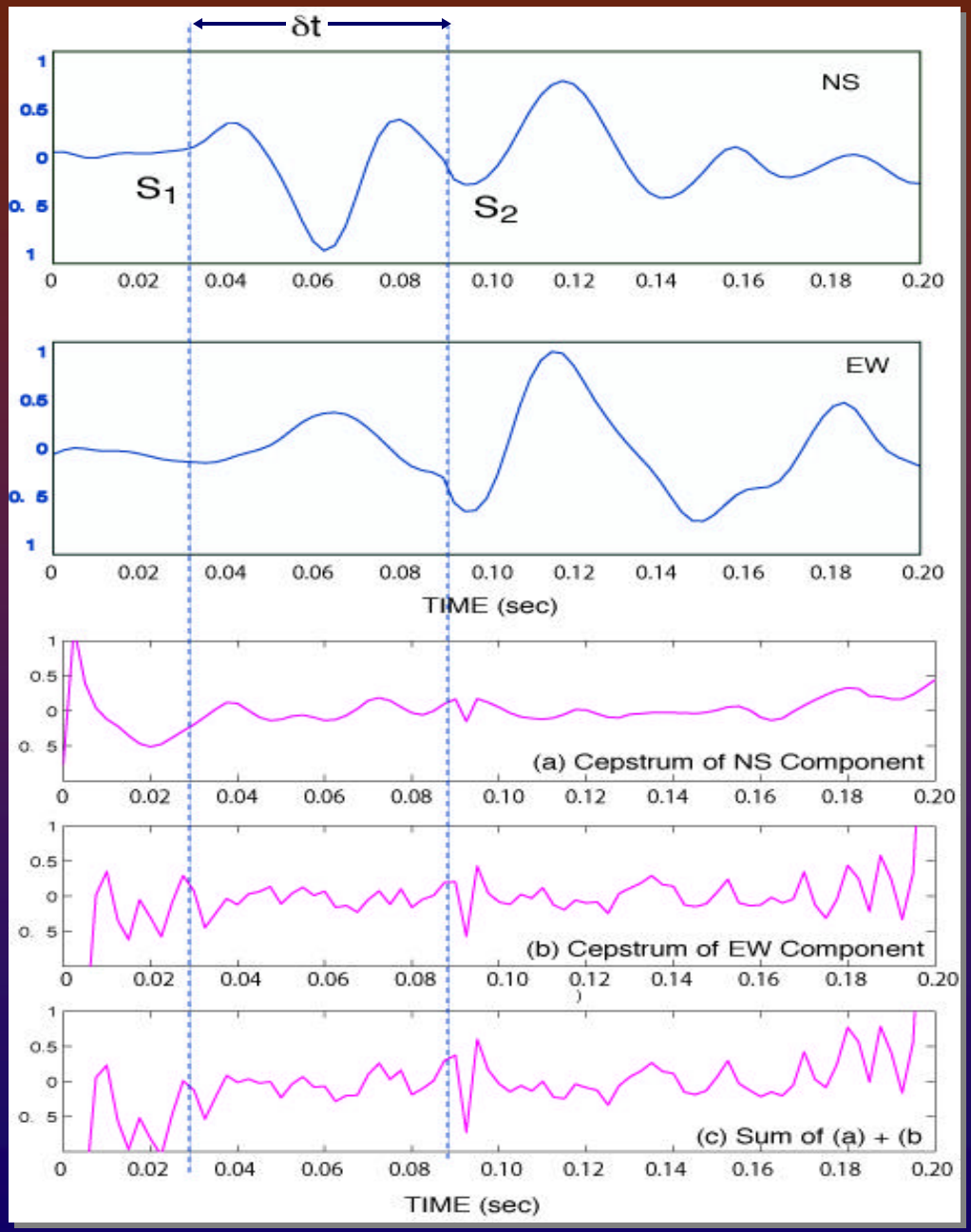
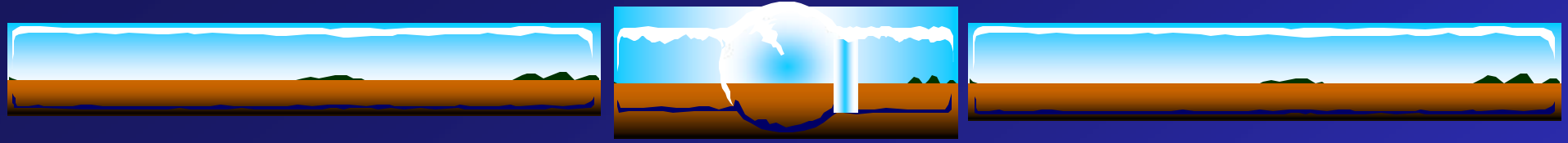
The cepstrum (Fourier transform of the Fourier transform) detects the arrival of the split shear wave





Coso 2001 and Krafla 2004 Injection Experiments

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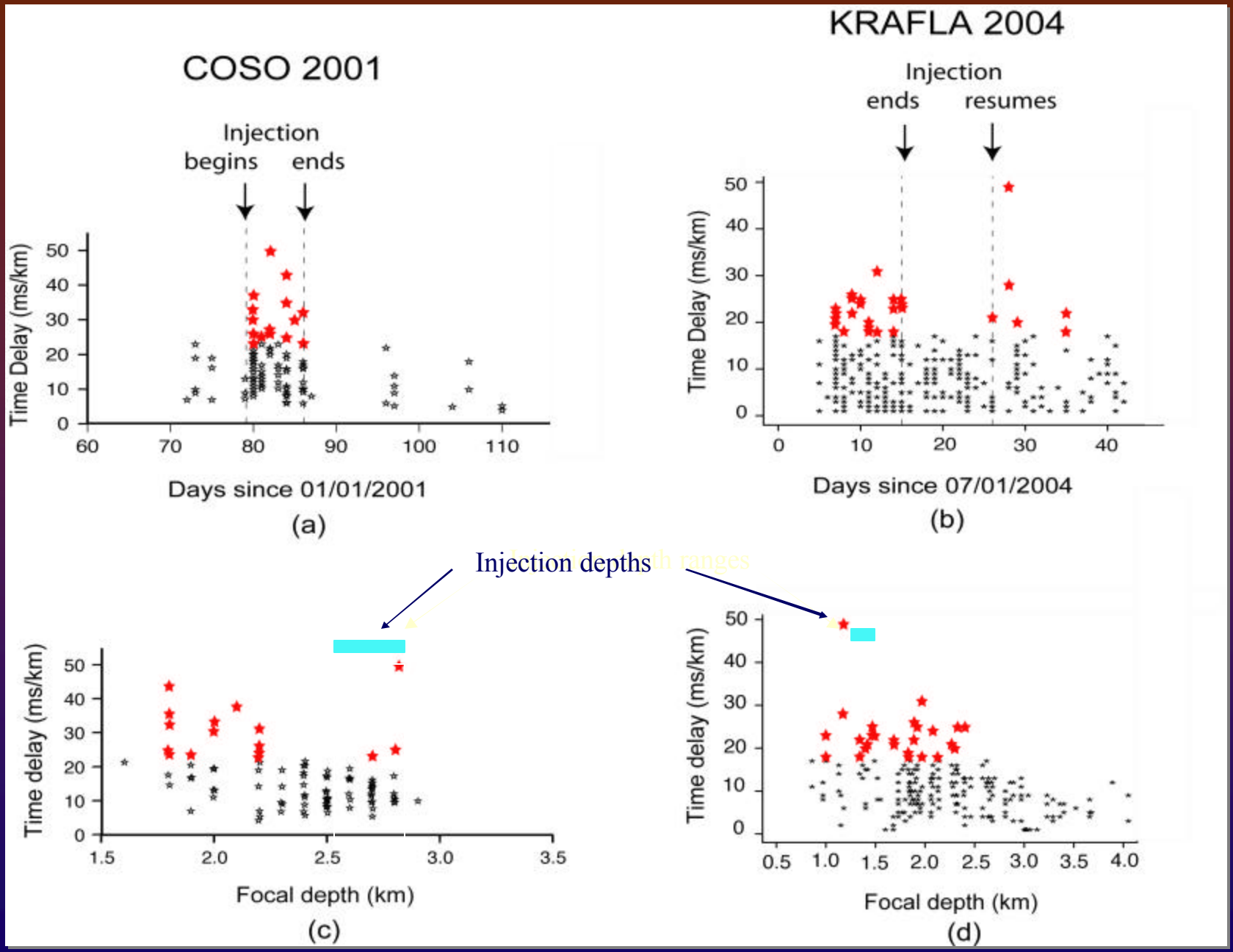
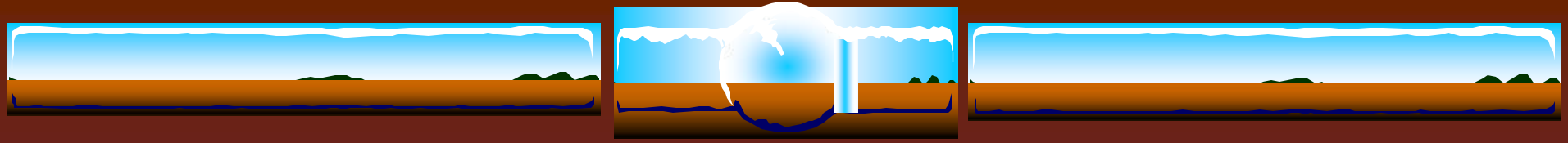


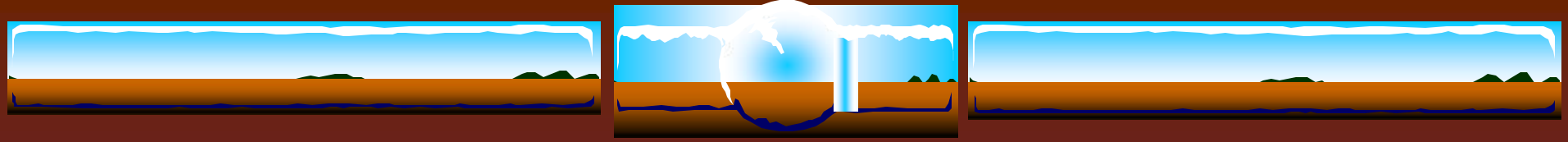
Tang et al., 2005



Next:

Coso Injection Experiment 2006

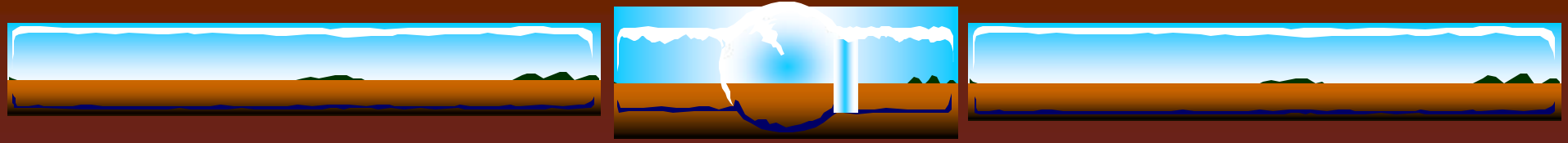
- Focus on variation in delay time as a function of injection history.
- Detail comparison with Krafla and Coso.
- Theoretical study



Conclusion

Project is on schedule. Grant will expire on December 31st, 2007.

Software will provide technology to image the EGS reservoir, detect subsurface fracture systems and fluid motions in real time.



REFERENCES

Tang, C., Rial, J.A., and J. Lees (2005): Shear wave splitting: A diagnostic tool to monitor fluid pressure in geothermal fields, *Geophys. Res. Lett.* **32**, L21317,doi:10.1029/2005GL023551,2005.

Yang, M., M. Elkibbi and J.A. Rial (2005) : An inversion scheme to model subsurface fracture systems using shear wave splitting polarization and delay time observations simultaneously, *Geophys. J. Int.* 160, 939-947.

Rial, J.A., M. Elkibbi and M. Yang (2005): Shear wave splitting as a tool for the characterization of geothermal fractured reservoirs: Lessons learned, *Geothermics*, **34**, 365-385.

Elkibbi, M. and J.A. Rial (2005): The Geysers geothermal field: results from shear-wave splitting analysis in a fractured reservoir, *Geophys. Jour. Int.*, **162**, 1024-1035.

Elkibbi, M., M. Yang and J.A. Rial (2005): Crack-induced anisotropy models in the Geysers geothermal field, *Geophys. Jour. Int.*, **162**, 1036-1048.

Vlahovic, G., M. Elkibbi and J.A. Rial (2002): Shear wave splitting and reservoir crack characterization: The Coso geothermal field, *J. Volcan.Geotherm. Res.*,**120**,123-140.