Improved Estimates of Key Seismic Properties of the Crust

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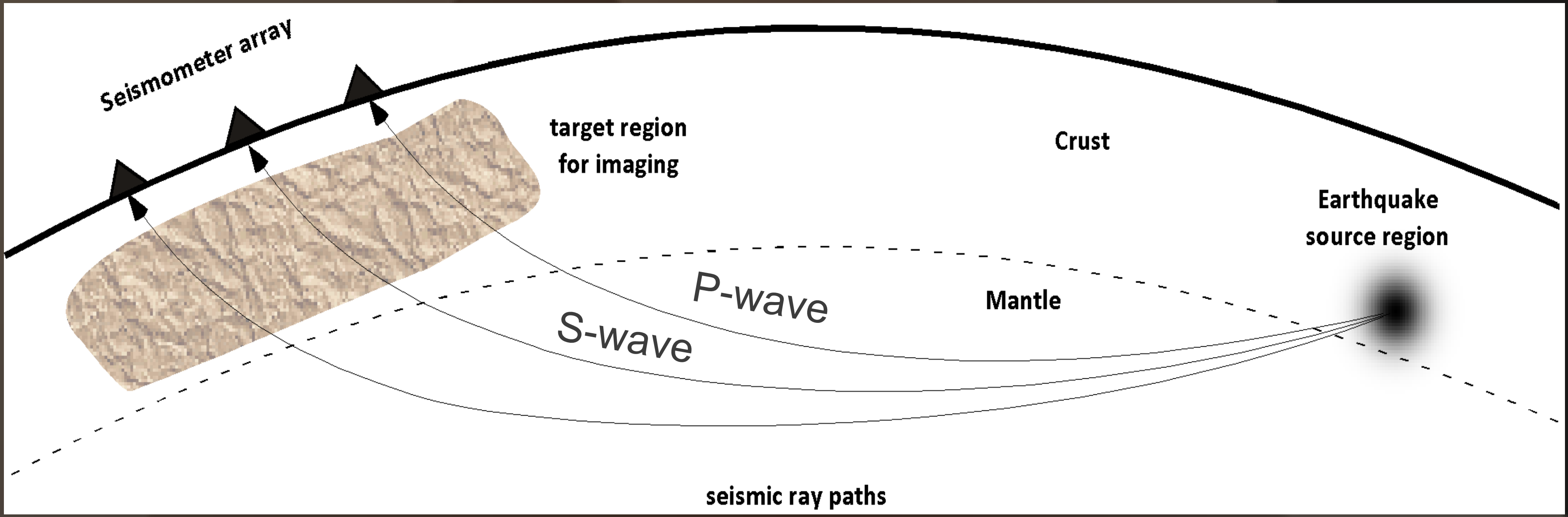
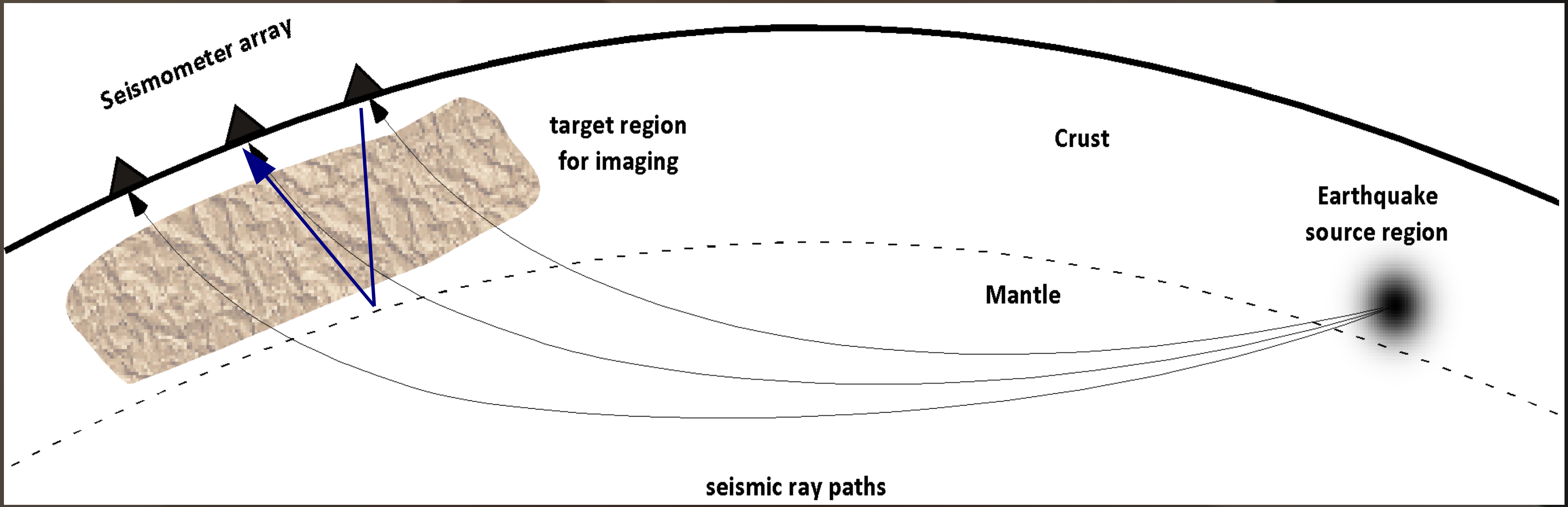
Seismic Properties

- Geologic material properties which can be extracted from seismograms.
- Seismograms are records of displacement from EQ energy.
- We are concerned with ...
    - P-wave velocity = Vp (around 6 km/s)
    - S-wave velocity = Vs (around 3.5 km/s)



Seismic Properties & Scale

- Seismic velocities are dependent on the material the seismic waves travel though.
- Thus are diagnostic property of geology.
- Project looks at the reflections within the crust.
- All properties are then bulk averages, bulk crustal composition.



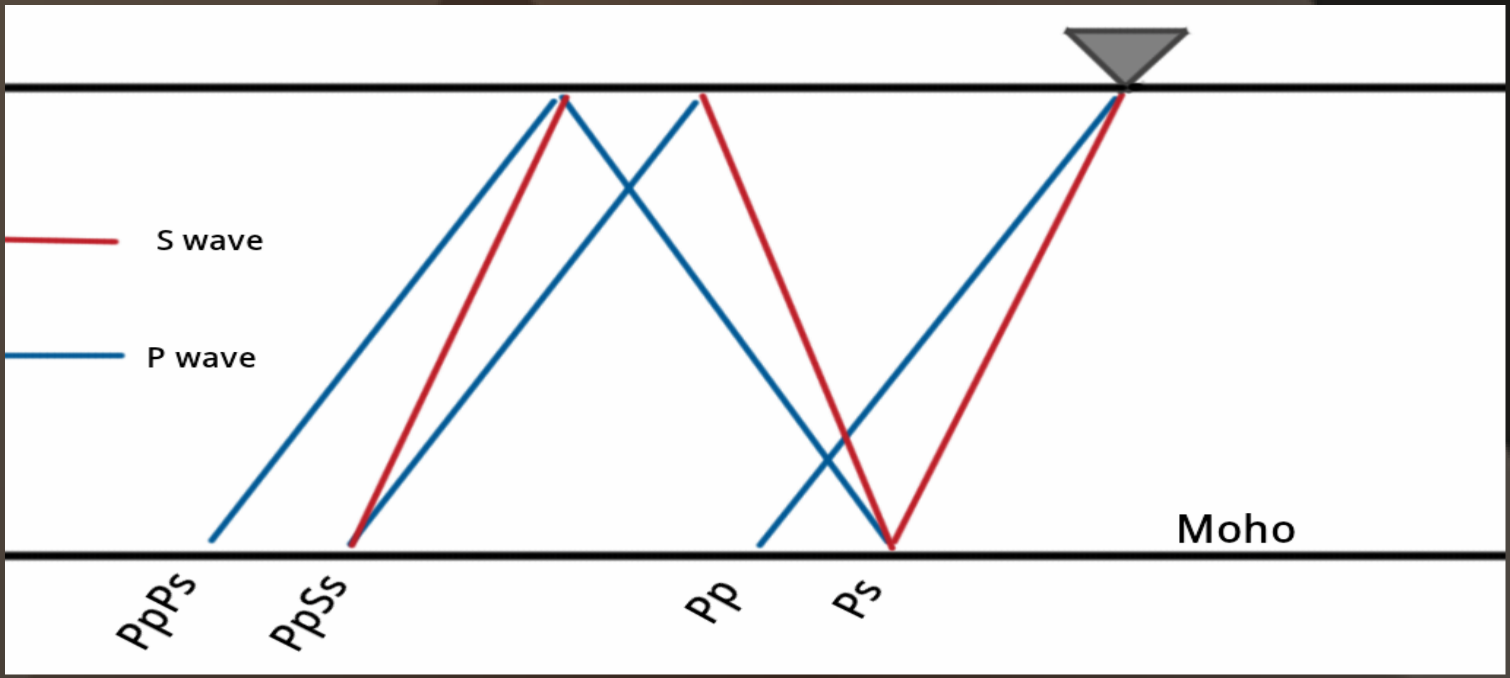
Why Improv[ed] Estimates?

- Currently a clear method for extracting the seismic velocity ratio Vp/Vs.
- This is extracted as a single value, useful in determing Poisson's Ratio.
- Michael Bostock (2008) developed a means to determine Vp and Vs individually.
- This project seeks to implement this idea and scale it out.
- Allow for more accurate estimates of bulk crustal composition.
- Useful to researchers and industry who require such data.

Better contraints = Better results

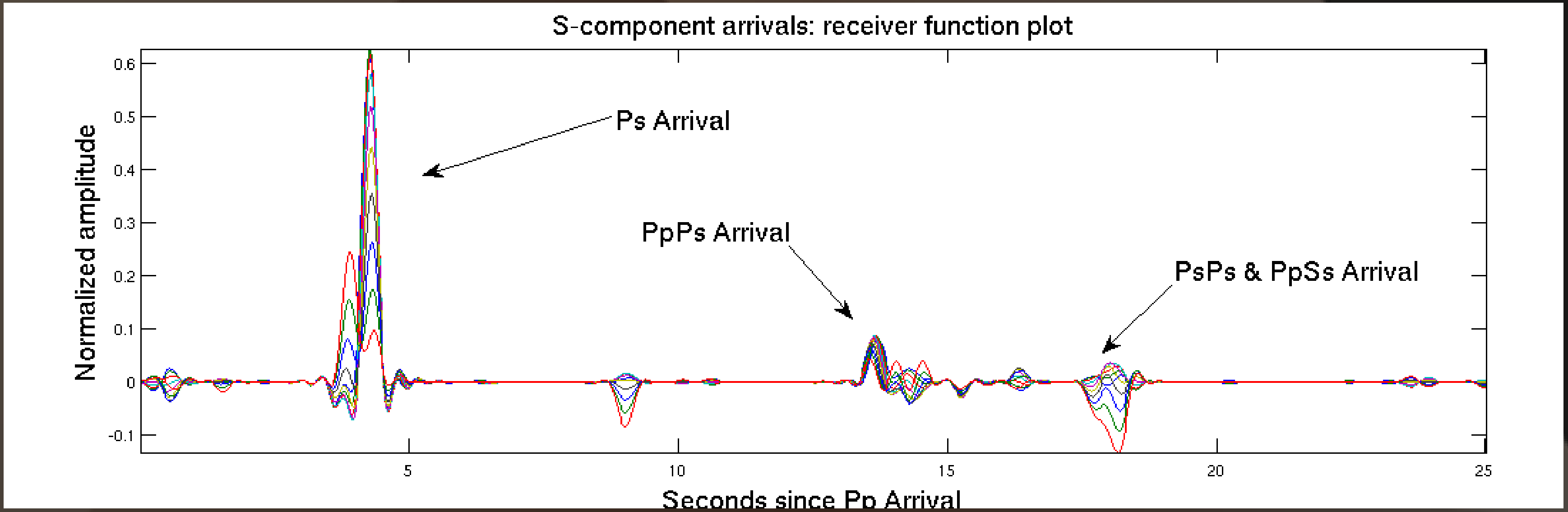
How: Reflected Phases

- Kanamori (2000) put together machinery in use today.
- Focused on reflected S-wave phases.



How: Reflected Phases

- Rotate seismograms into S-component and P-component space.
- Three events of interest contained in S-component seismogram.
- P-component seismogram used as approximation to source function

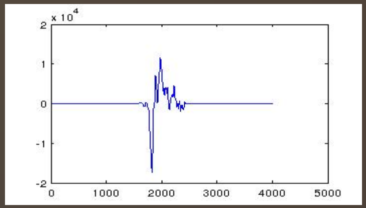


How: Convolution

- Seismogram can be conceived as a convolution between source signature and a receiver function.

Convolution

source



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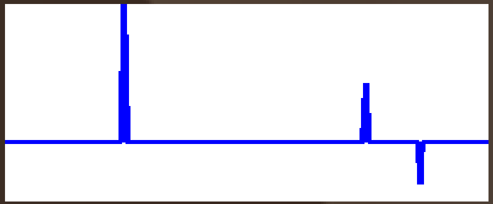
receiver function



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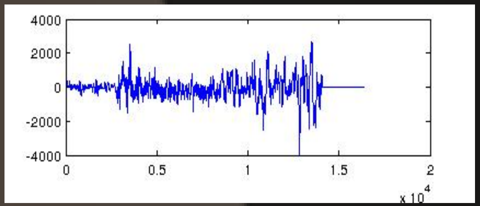
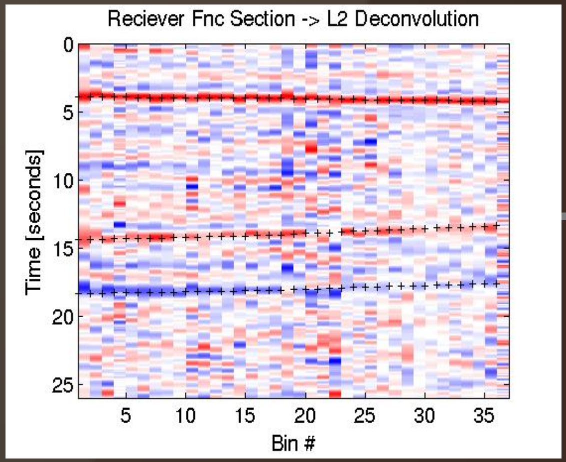
seismogram

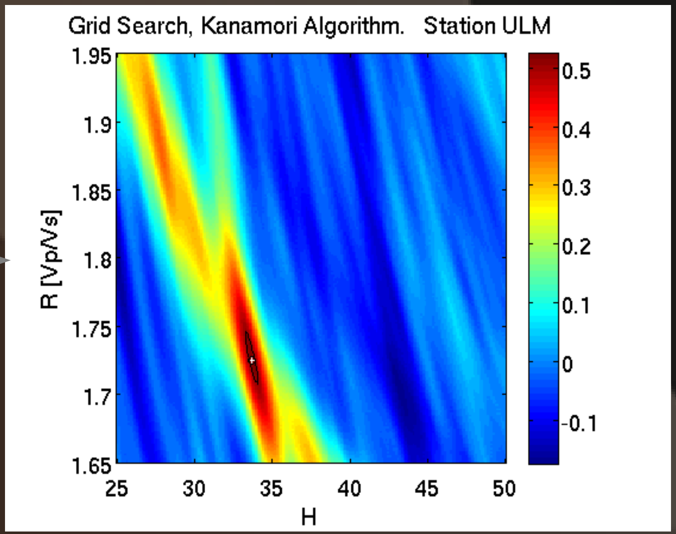


- Unfortunately the earth is not a 1D layered model, and the discontinuities are not perfect reflectors or spikes.
- Noise & correlated error. Deconvolution = difficult.

How: Receiver Functions

- Perform deconvolution on all S-wave seismograms from particular angle -> produce 1 reciever function.
- Do this for different angles, stack reciever function side by side.
- These receiver functions become the data used to test models using different Vp/Vs and H values in a grid search.
- Grid search is the process of solving the equations in the model for a range of Vp/Vs values.
- The values that best predict the data = best estimates for the values of the material properties.





Today and forward

- Kanamori's method was employed recently in the 2010 paper “Precambrian crustal evolution: Seismic constraints from the Canadian Shield”.
- Bostock in work from 2008 & 2010 show that it is possible to solve for Vp and Vs individually.
- Does not require assumptions on Vp.
- 2 Problems:

  1) Heavier reliance on TPps and Tpss.
  2) Requires Tps data

Travel time equations

$$t_{Ps}(p_i) = H\left[\sqrt{R^2 - p_i^2 V_p^2} - \sqrt{1 - p_i^2 V_P^2}\right] \quad (1)$$

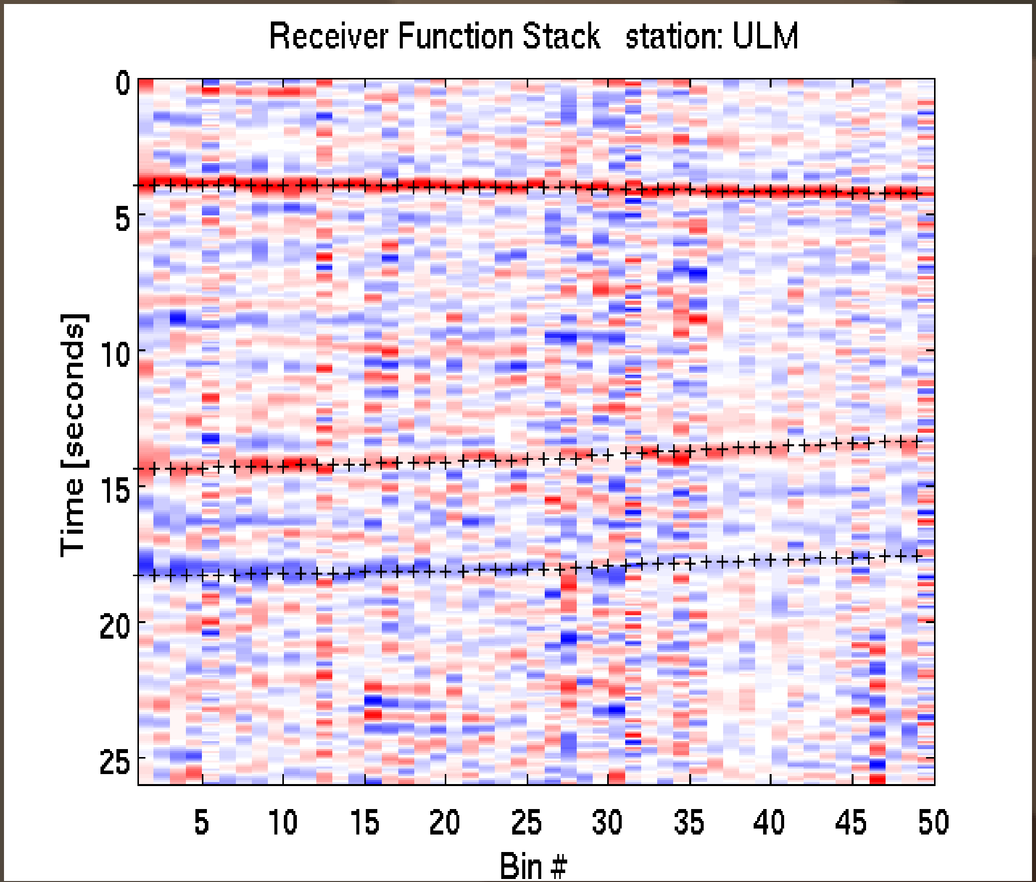
$$t_{Pps}(p_i) = H\left[\sqrt{R^2 - p_i^2 V_p^2} + \sqrt{1 - p_i^2 V_P^2}\right] \quad (2)$$

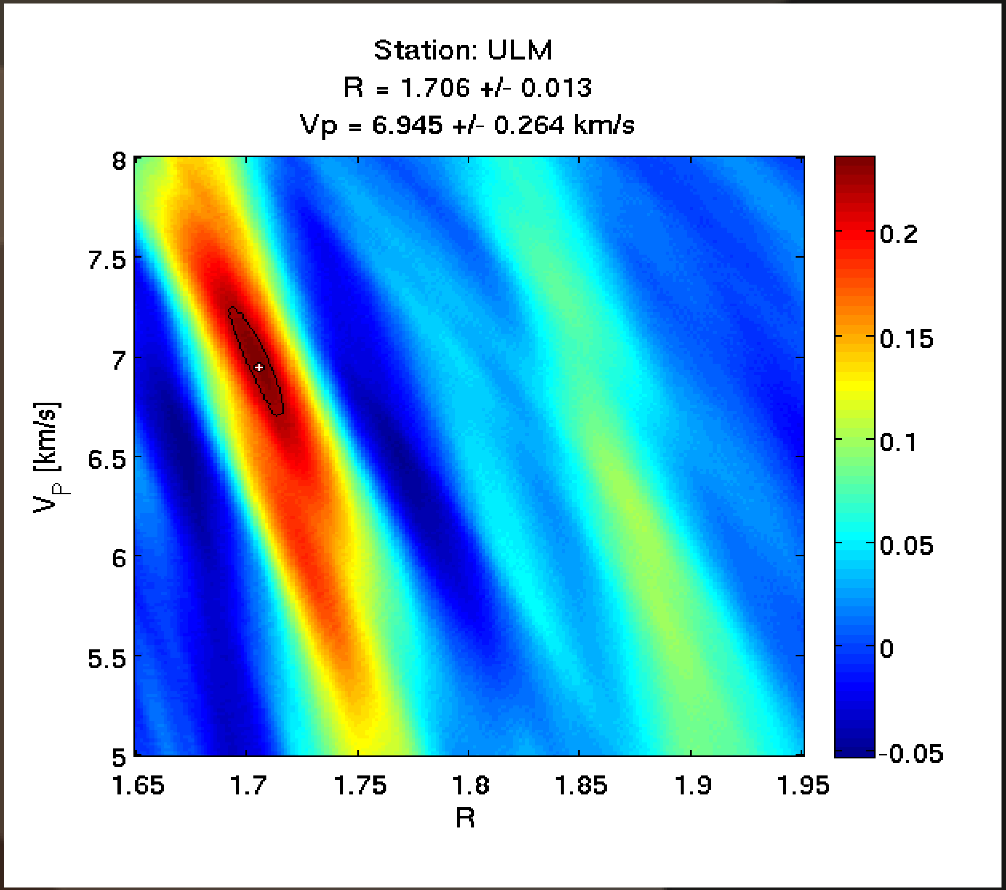
$$t_{Pss}(p_i) = 2H\sqrt{R^2 - p_i^2 V_p^2} \quad (3)$$

$$t_{Pss}(p_i) = \frac{\sqrt{R^2 - p_i^2 V_p^2} + \sqrt{1 - p_i^2 V_P^2}}{\sqrt{R^2 - p_i^2 V_p^2} - \sqrt{1 - p_i^2 V_P^2}}\, t_{Ps}(p_i) \quad (4)$$

$$t_{Pss}(p_i) = \frac{2\sqrt{R^2 - p_i^2 V_p^2}}{\sqrt{R^2 - p_i^2 V_p^2} - \sqrt{1 - p_i^2 V_P^2}}\, t_{Ps}(p_i) \quad (5)$$

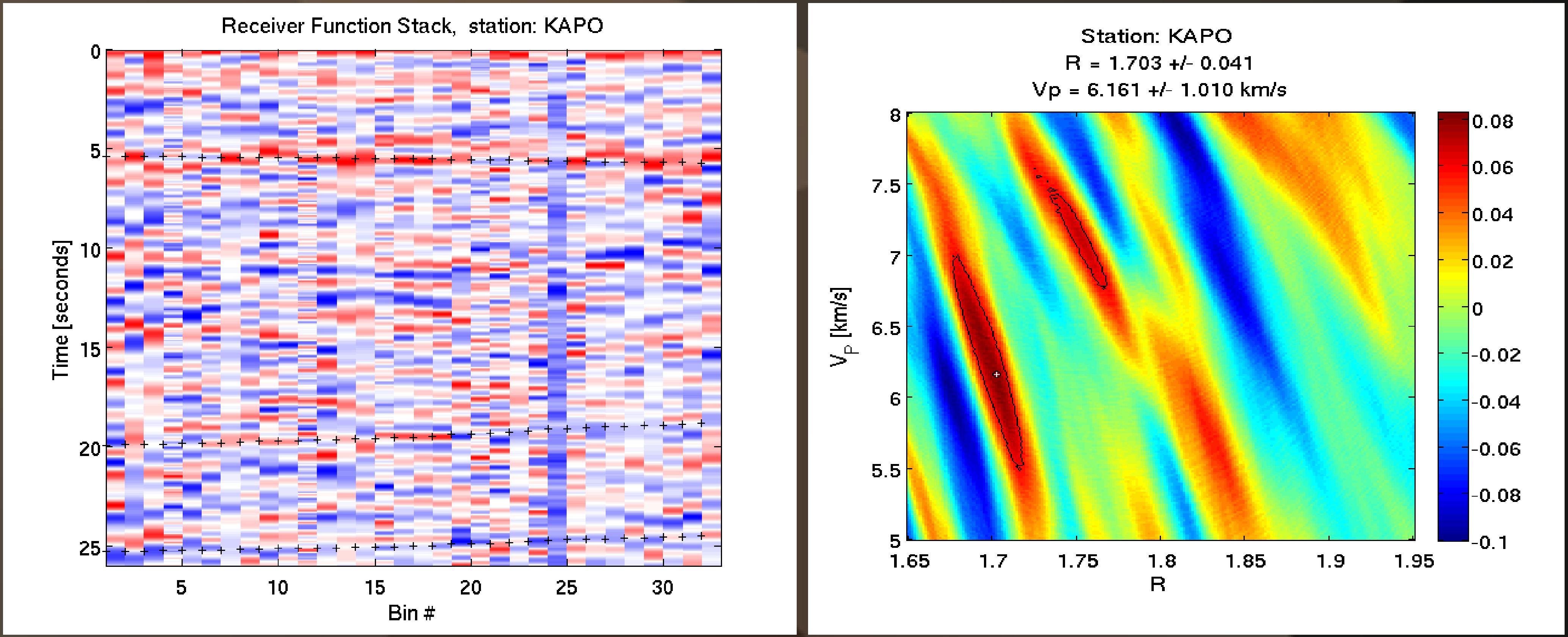
Results: The Good





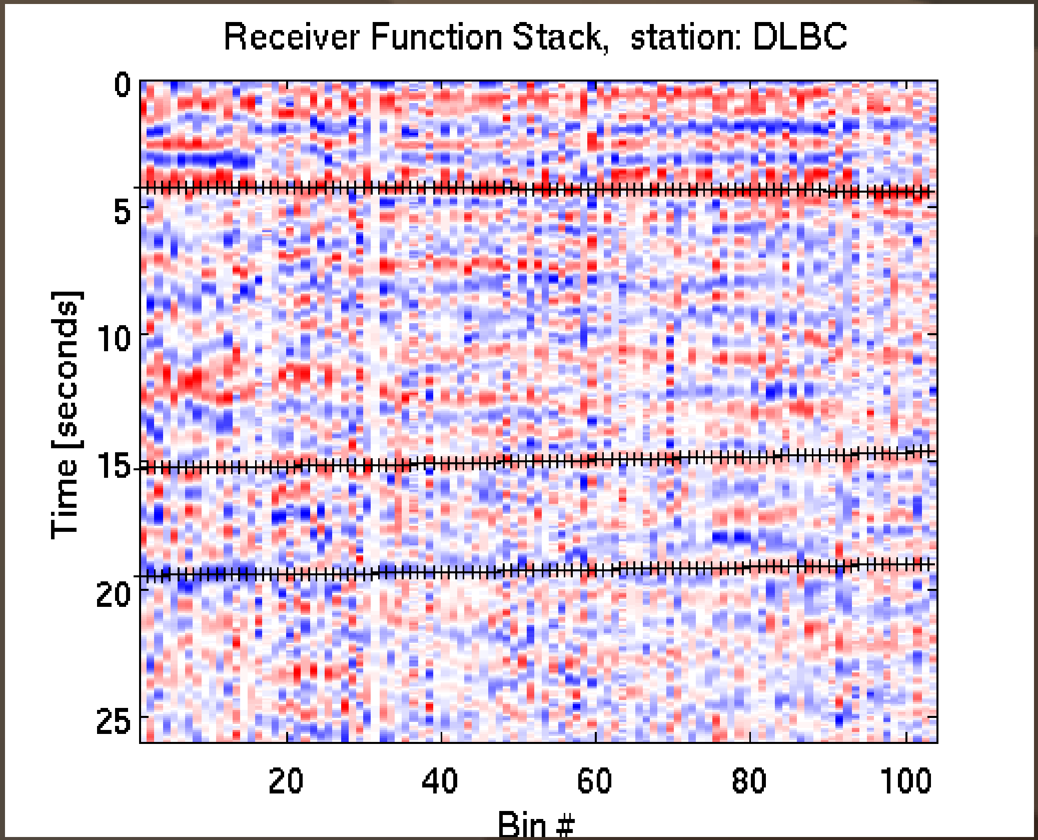
Receiver Function Stack -------------------> Grid Search for Vp & Vs

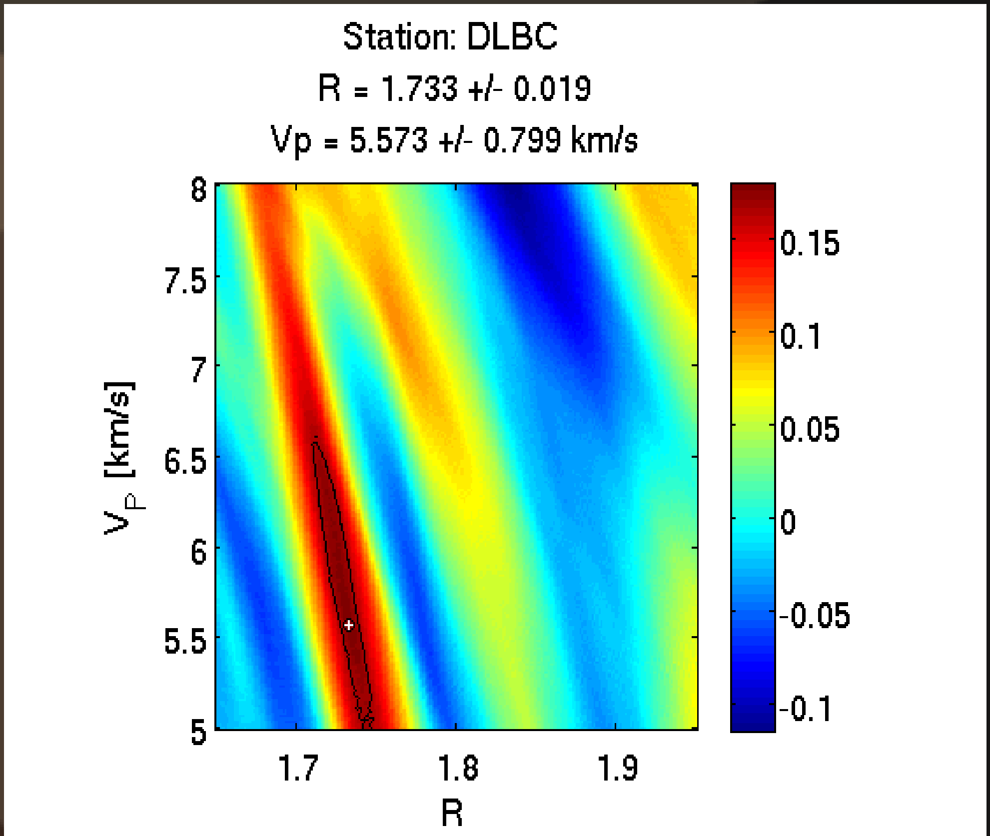
Results: The Bad



Receiver Function Stack ------------------> Grid Search for Vp & Vs

Results: The Ugly



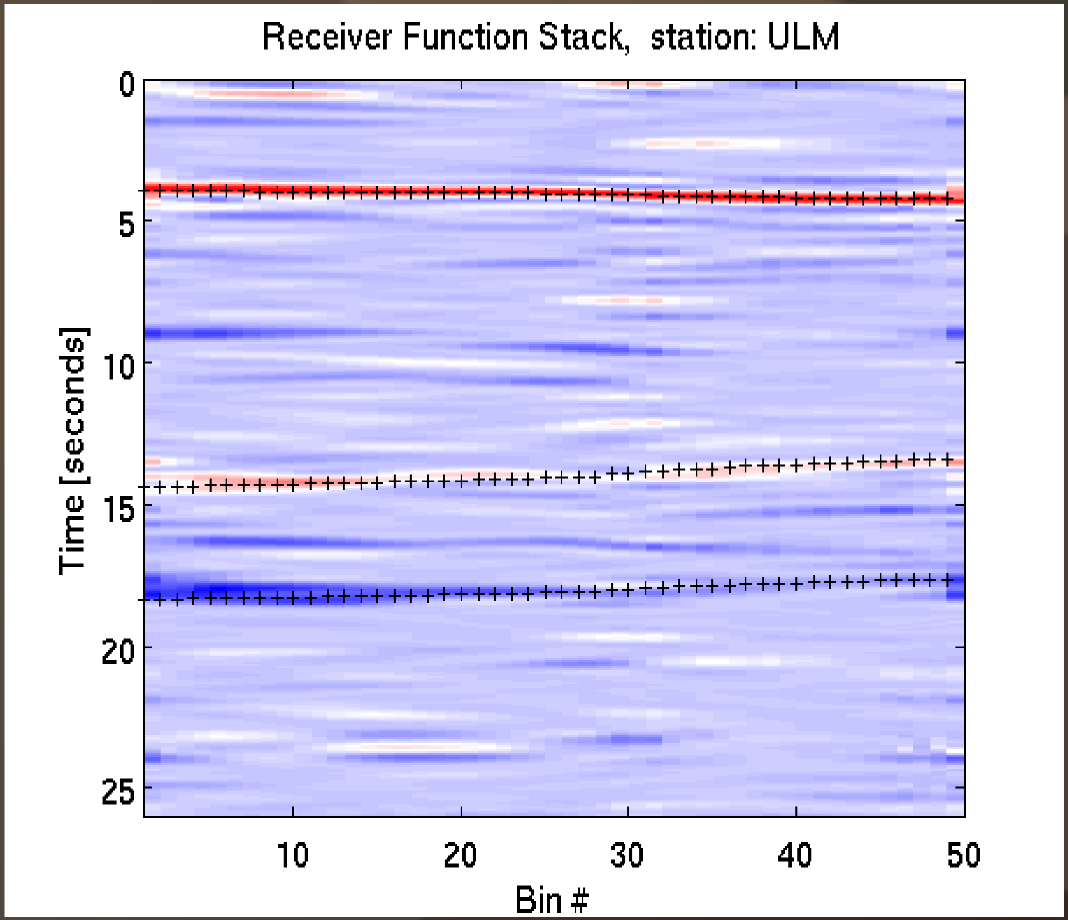


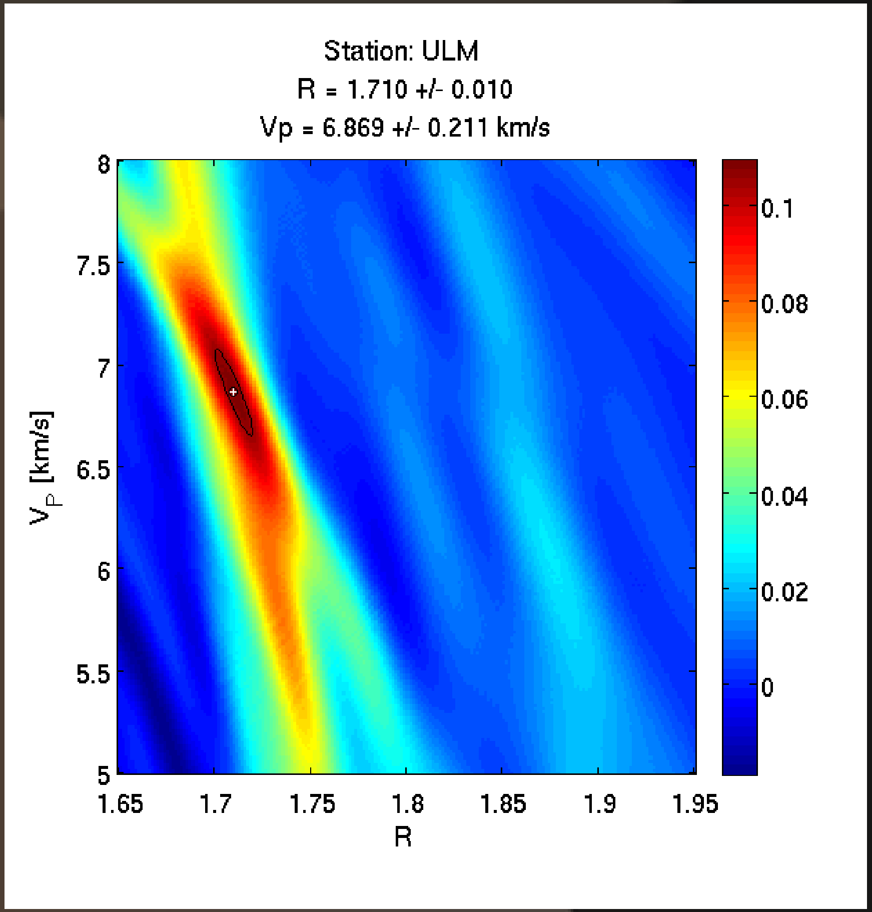
Receiver Function Stack -------------------> Grid Search for Vp & Vs

Discussion & Future Direction

- Around 30% of data fits into the good category.
- 30% into bad and 40% into the ugly.
- High hopes for the ugly.
- SLIM group at UBC:
    - Sparsity promotion (Curvelets)
    - Randomized sampling
    - Compressive Sensing.

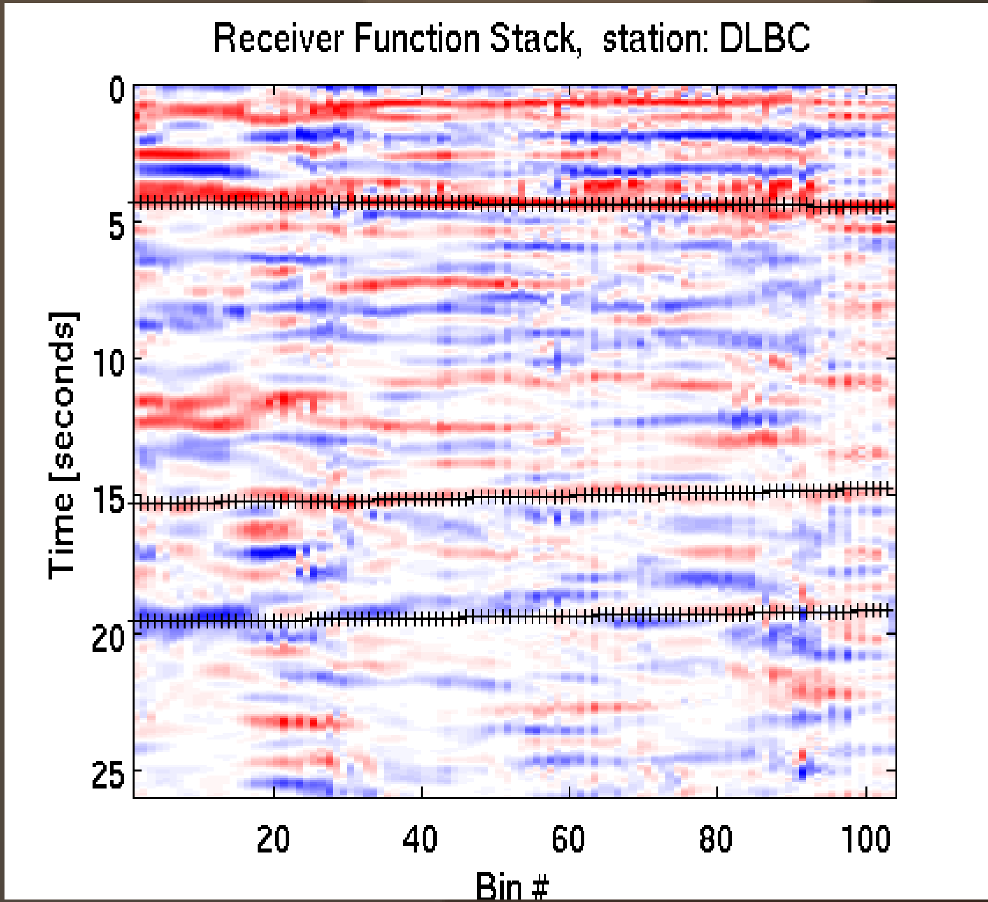
Discussion & Future Direction

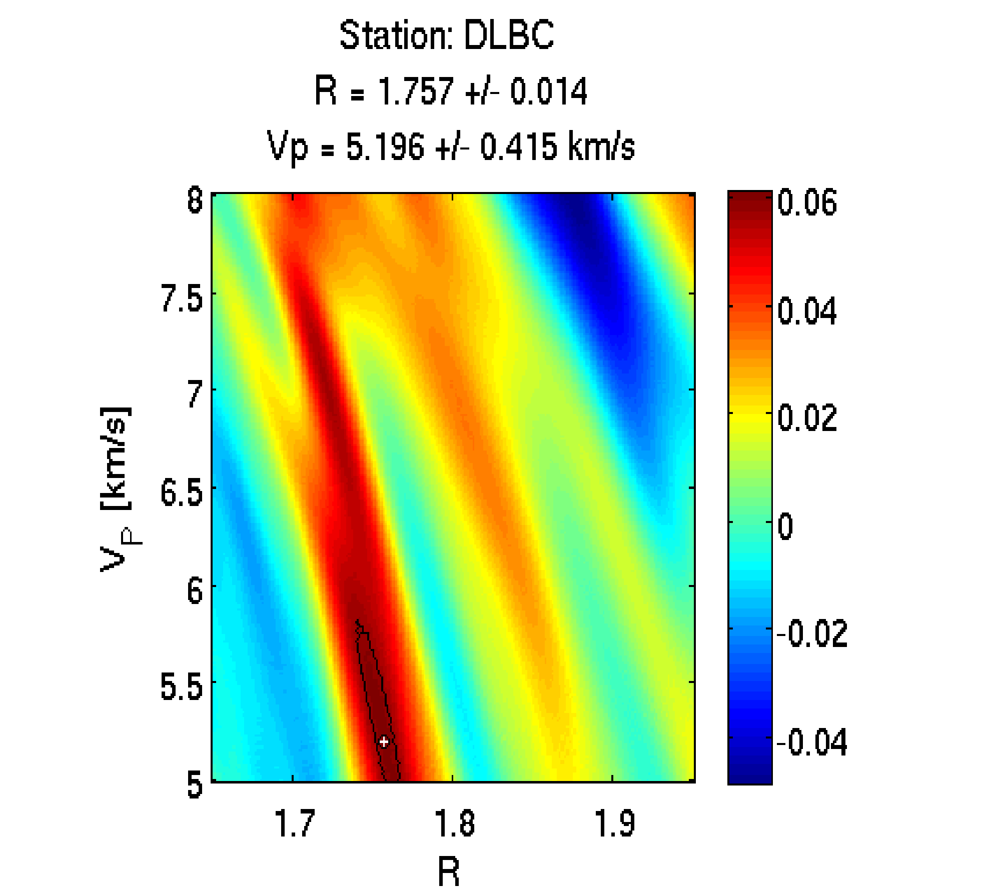




Shift Invariant Curvelet Soft-Thresholding

Discussion & Future Direction





Shift Invariant Curvelet Soft-Thresholding

Thank you!

References:

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