Implications of dedicated seismometer measurements on Newtonian-noise cancellation for Advanced LIGO

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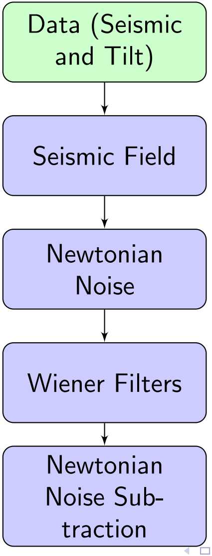
Newtonian Noise

Newtonian noise or "gravity-gradient noise" arises from fluctuating seismic fields and atmospheric disturbances such as pressure and temperature fluctuations leading to a direct gravitational force on the test masses.

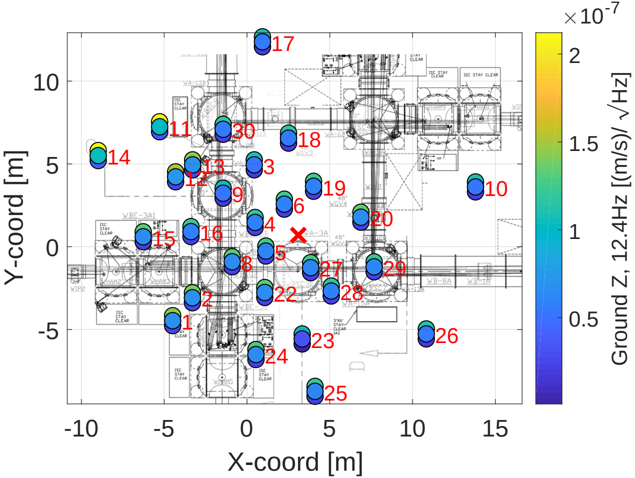
- LIGO Hanford → Caltech/Hanford/GSSI.
- Virgo WEB → Poland/GSSI.
- Homestake (3D array) → Caltech/Minnesota.
- Seismic NN modeling → Nikhef/GSSI.
- Atmospheric NN modeling → APC/GSSI.

I am only worried about the seismic field portion in the following.

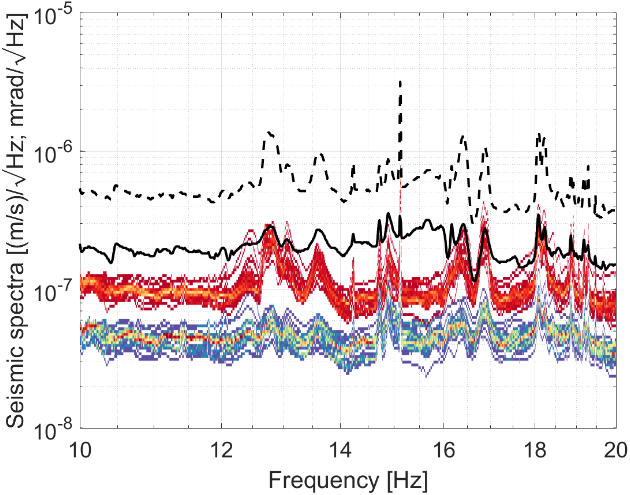
Flowchart


Data (Seismic and Tilt)
Seismic Field
Newtonian Noise
Wiener Filters
Newtonian Noise Sub- traction

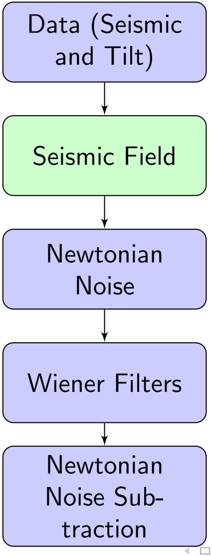
LHO Corner Station Array



LHO Corner Station Array



Flowchart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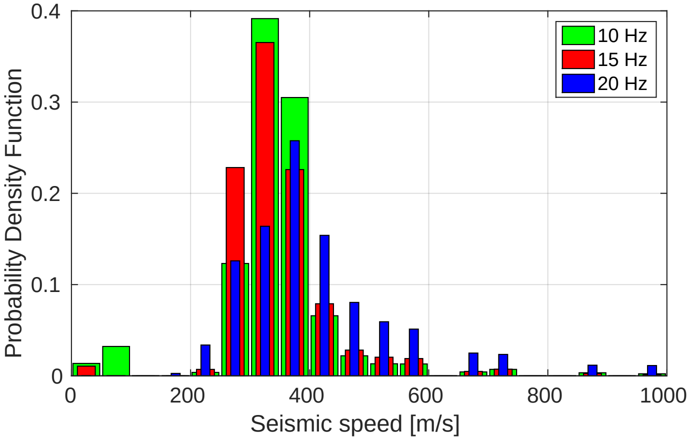
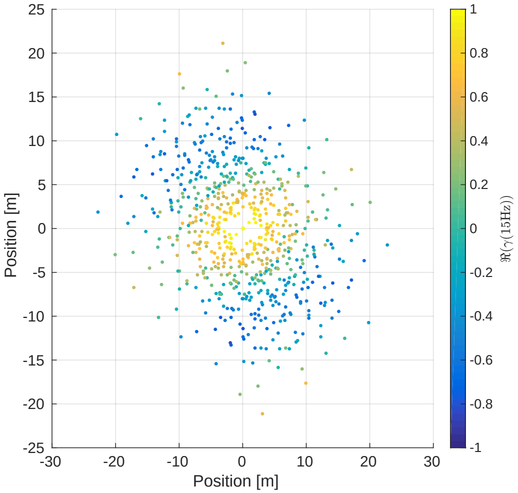
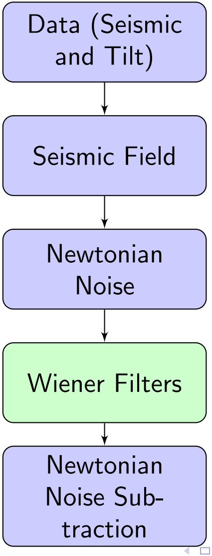
Seismic Velocity Histogram



Coherence of the array (all possible pairs)



Flowchart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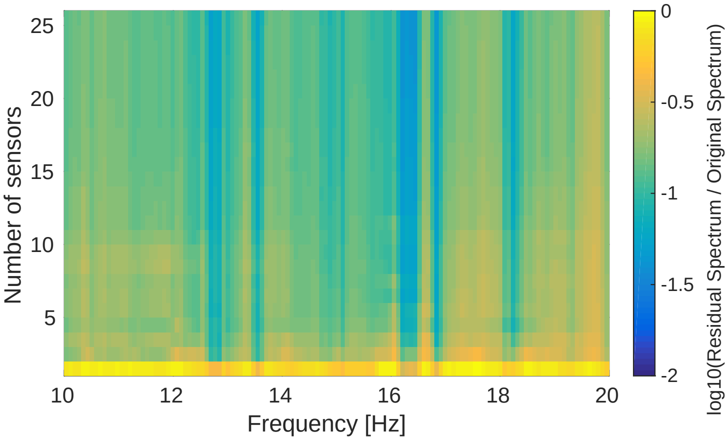
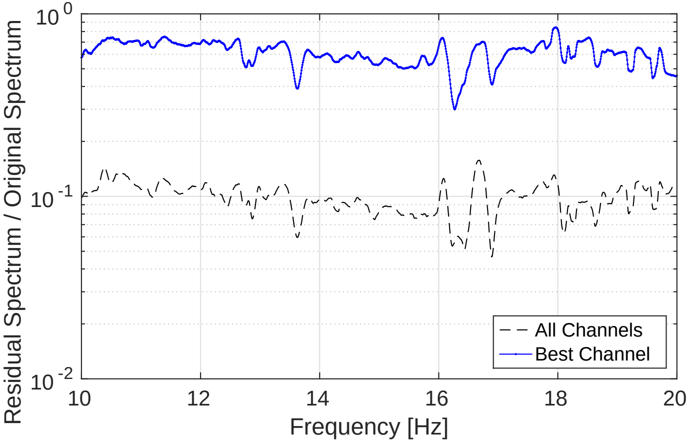
Tiltmeters?!?

- Single horizontal sensor beneath test mass: Seismic sensors are sensitive to Rayleigh waves... and Love (shear) waves (non-NN contributing).
- Multiple vertical sensors: Requires an array some distance from test-mass with relatively weak correction with test-mass acceleration
- Single tiltmeter beneath test mass: Not sensitive to Love waves so... no problem (theoretically).

Optimal Tiltmeter Subtraction



Actual Tiltmeter Subtraction



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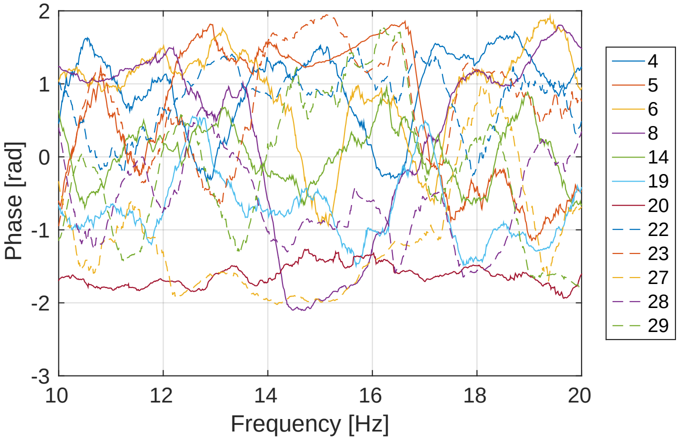
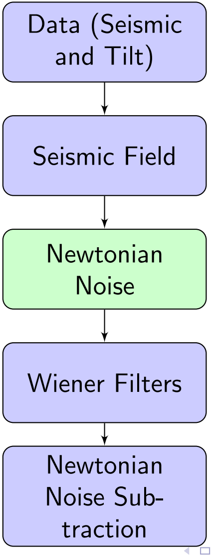
Wiener Filter Bode Plots



Flowchart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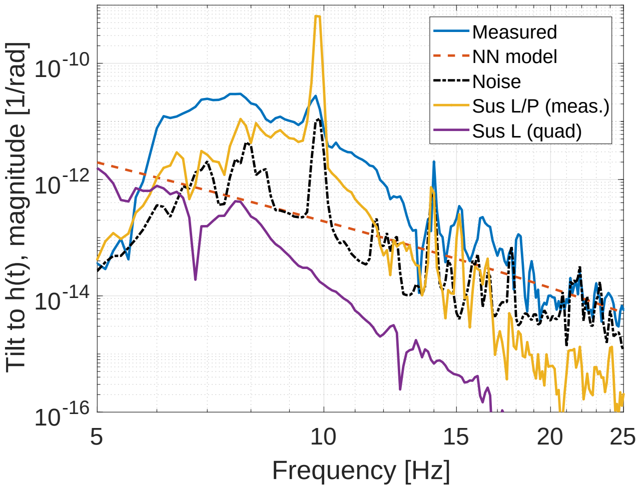
Tiltmeter-DARM Transfer Function



Other to-dos and conclusions

Highlights:

- We used dedicated measurements at the LIGO Hanford site to predict NN cancellation levels.
- We showed how we were able to achieve significant subtraction in line with expectations based on correlation measurements.
- We showed that significant subtraction is achievable with only a few seismometers.

Future extensions:

- Calculation of optimized arrays in inhomogeneous seismic fields without constraints on seismometer locations.
- Calculate the best sensor locations from correlation measurements (to reach ultimate cancellation limits for a given number of sensors)
- Devise the strategy to optimally pick sensors in a large underground array.