CLAIMS

1. An apparatus to determine structural information about a geological subsurface, the apparatus comprising:

an interface configured to receive particle acceleration data;

one or more processors;

one or more storage media storing instructions, which, when executed by the one or more processors, cause the apparatus to perform:

transforming the particle acceleration data from the time domain to the frequency domain;

in the frequency domain, determining a deterministic Weiner filter having a damping factor based on the particle acceleration data, the damping factor iteratively adjusted to provide stability to the deterministic Weiner filter in the presence of noise in the particle acceleration data;

applying one of the deterministic Weiner filter to the particle acceleration data to generate particle velocity data and square of the deterministic Wiener filter to the particle acceleration data to generate particle displacement data in the frequency domain; and

generating an image of the geological subsurface using at least in part the particle velocity data or particle displacement data, the image revealing structural information about the geological subsurface.

2. The apparatus of claim 1, wherein the instructions, when executed, further cause the apparatus to perform: determining the damping factor based on the received particle acceleration data.

3. The apparatus of claim 2, wherein instructions for determining the damping factor comprise instructions for:

determining, based on the particle velocity or particle displacement data, calculated acceleration data;

determining whether a threshold is satisfied by comparing the calculated acceleration data with the particle acceleration data; and

in response to determining that the threshold is not satisfied, adjusting a damping factor.

4. The apparatus of claim 3, wherein instructions for comparing the calculated acceleration data with the particle acceleration data comprise instructions for:

determining a first energy value from the calculated acceleration data;

determining a second energy value from the particle acceleration data;

determining a difference between the first energy value and the second energy value;

wherein the threshold is satisfied if the difference is less than a threshold difference.

5. The apparatus of claim 1, wherein applying the deterministic Wiener filter with a first damping factor to the particle acceleration data to generate the particle velocity data; and

applying the square of the deterministic Wiener filter with a second damping factor to the particle acceleration data to generate the particle displacement data,

the first damping factor is different than the second damping factor.

6. The apparatus of claim 1, wherein the deterministic Weiner filter is $F_v(\omega) = -i\omega/(\omega^2 + \varepsilon)$ and the square of the deterministic Weiner filter is $F_u(\omega) = [-i\omega/(\omega^2 + \varepsilon)]^2$, where i represents an imaginary number, ω represents an angular frequency, and ε represents a damping factor.

7. The apparatus of claim 1, wherein the instructions, when executed, further cause the apparatus to perform: determining a damping factor for each distinct set of acceleration data that is received through the interface.

8. One or more non-transitory storage media storing instructions to determine structural information about a geological subsurface which, when executed by one or more computing devices, cause:

transforming particle acceleration data from the time domain to the frequency domain;

in the frequency domain, determining a deterministic Weiner filter having a damping factor based on the particle acceleration data, the damping factor iteratively adjusted to provide stability to the deterministic Weiner filter in the presence of noise in the particle acceleration data;

applying one of the deterministic Weiner filter to the particle acceleration data to generate one of particle velocity data and square of the deterministic Wiener filter to the particle acceleration data to generate particle displacement data in the frequency domain; and

generating an image of the geological subsurface using at least in part the particle velocity data or particle displacement data, the image revealing structural information about the geological subsurface.

9. The one or more non-transitory storage media of claim 8,

wherein the instructions, when executed, further cause: determining the damping factor based on the received particle acceleration data.

10. The one or more non-transitory storage media of claim 9,

wherein instructions for determining the damping factor comprise instructions for:

determining, based on the particle velocity or particle displacement data, calculated acceleration data;

determining whether a threshold is satisfied by comparing the calculated acceleration data with the particle acceleration data; and

in response to determining that the threshold is not satisfied, adjusting a damping factor.

11. The one or more non-transitory storage media of claim 10, wherein instructions for comparing the calculated acceleration data with the particle acceleration data comprise instructions for:

determining a first energy value from the calculated acceleration data;

determining a second energy value from the particle acceleration data;

determining a difference between the first energy value and the second energy value;

wherein the threshold is satisfied if the difference is less than a threshold difference.

12. The one or more non-transitory storage media of claim 8,

wherein applying the deterministic Wiener filter to the particle acceleration data further comprises

applying the deterministic Wiener filter with a first damping factor to the particle acceleration data to generate the particle velocity; and

applying the square of the deterministic Wiener filter with a second damping factor to the particle acceleration data to generate the particle displacement data comprises processing the particle acceleration data using the filter and a second damping factor;

wherein the first damping factor is different than the second damping factor.

13. The one or more non-transitory storage media of claim 8, wherein the deterministic Weiner filter is $F_v(\omega) = -i\omega/(\omega^2 + \varepsilon)$ and the square of the deterministic Weiner filter is $F_u(\omega) = [-i\omega/(\omega^2 + \varepsilon)]^2$, where i represents an imaginary number, ω represents an angular frequency, and ε represents a damping factor.

14. The one or more non-transitory storage media of claim 8, wherein the instructions, when executed, further cause:

characterizing subterranean geological features based on the particle velocity data or the particle displacement data.

15. A method to determine structural information about a geological subsurface, the method comprising:

transforming particle acceleration data from the time domain to the frequency domain;

in the frequency domain, determining a deterministic Weiner filter having a damping factor based on the particle acceleration data, the damping factor iteratively adjusted to provide stability to the deterministic Weiner filter in the presence of noise in the particle acceleration data;

applying one of the deterministic Weiner filter to the particle acceleration data to generate particle velocity data and square of the deterministic Wiener filter to the particle acceleration data to generate particle displacement data in the frequency domain; and

generating an image of the geological subsurface using at least in part the particle velocity data or particle displacement data, the image revealing structural information about the geological subsurface.

16. The method of claim 15, further comprising determining the damping factor based on the received particle acceleration data.

17. The method of claim 16, wherein determining the damping factor comprises:

determining, based on the particle velocity or particle displacement data, calculated acceleration data;

determining whether a threshold is satisfied by comparing the calculated acceleration data with the particle acceleration data; and

in response to determining that the threshold is not satisfied, adjusting a damping factor.

18. The method of claim 17, wherein comparing the calculated acceleration data with the particle acceleration data comprises:

determining a first energy value from the calculated acceleration data;

determining a second energy value from the particle acceleration data;

determining a difference between the first energy value and the second energy value;

wherein the threshold is satisfied if the difference is less than a threshold difference.

19. The method of claim 15, further comprising:

applying the deterministic Wiener filter with a first damping factor to the particle acceleration data to generate the particle velocity data; and

applying the square of the deterministic Wiener filter with a second damping factor to the particle acceleration data to generate the particle displacement data,

the first damping factor is different than the second damping factor.

20. The method of claim 15, wherein the deterministic Weiner filter is $F_v(\omega) = -i\omega/(\omega^2 + \varepsilon)$ and the square of the deterministic Weiner filter is $F_u(\omega) = [-i\omega/(\omega^2 + \varepsilon)]^2$, where i represents an imaginary number, ω represents an angular frequency, and ε represents a damping factor.

21. A method to determine structural information about a geological subsurface, the method comprising:

determining a deterministic Weiner filter including one or more damping factors based on particle acceleration data;

applying the deterministic Weiner filter to the particle acceleration data in the frequency domain to determine one or more of particle velocity data or particle displacement data;

in response to determining that stability of the particle velocity data or the particle displacement data does not satisfy a threshold, adjusting one or more of the one or more damping factors of the filter; and

generating an image of the geological subsurface using at least in part the particle velocity data or particle displacement data the image revealing structural information about the geological subsurface, wherein the method is performed by one or more computing devices.

22. The method of claim 21, further comprising repeating said steps of applying and adjusting until the stability of the particle velocity data or the particle displacement data satisfies the threshold.

23. The method of claim 21, wherein determining that the particle displacement data does not satisfy a threshold comprises:

after applying the deterministic Weiner filter including one or more damping factors to the particle acceleration data to determine one or more of particle velocity data or particle displacement data:

calculating second particle acceleration data from the particle velocity data or particle displacement data;

determining that a difference between a first energy value of the particle acceleration data and a second energy value of the second particle acceleration data does not satisfy a threshold.

24. The method of claim 23 wherein the difference between the first energy value and the second energy value does not satisfy a threshold when greater than a threshold value.

25. The method of claim 21, wherein the deterministic Weiner filter at least approximates a Wiener filter.

26. The method of claim 21 further comprising measuring the particle acceleration data using one or more seismic sensors.