Probing the Structure of the Crust and Mantle Lithosphere beneath the Southern New England Appalachians via the SEISConn Deployment

Maureen D. Long*[1] and John C. Aragon[1,2]

Abstract

The eastern margin of North America has been affected by a range of fundamental tectonic processes in the geologic past. Major events include the Paleozoic Appalachian orogeny, which culminated in the formation of the supercontinent Pangea, and the breakup of Pangea during the Mesozoic. The southern New England Appalachians exhibit a particularly rich set of geologic and tectonic structures that reflect multiple episodes of subduction and terrane accretion, as well as subsequent continental breakup. It remains poorly known, however, to what extent structures at depth in the crust and lithospheric mantle reflect these processes, and how they relate to the geological architecture at the surface. The Seismic Experiment for Imaging Structure beneath Connecticut (SEISConn) was a deployment of 15 broadband seismometers in a dense linear array across northern Connecticut. The array traversed a number of major tectonic boundaries, sampling across the Laurentian margin in its western portion to the Avalonian terrane at its eastern end. It also crossed the Hartford rift basin in the central portion of the state. The SEISConn stations operated between 2015 and 2019; data from the experiment are archived at the Incorporated Research Institutions for Seismology Data Management Center and will be publicly available beginning in 2021. A suite of imaging techniques is being applied to SEISConn data, with the goal of providing a detailed view of the crust and mantle lithosphere (including discontinuities, seismic velocities, and seismic anisotropy) beneath the southern New England Appalachians. Results from these analyses will inform a host of fundamental scientific questions about the structural evolution of orogens, the processes involved in continental rifting, and the nature of crustal and mantle lithospheric deformation during subduction, terrane accretion, and continental breakup.

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Introduction

Eastern North America is a passive continental margin that has been shaped by multiple episodes of supercontinent assembly and breakup. The most recent of these cycles encompassed the Appalachian orogeny, which culminated in the formation of the Pangaea supercontinent, as well as subsequent rifting that broke apart Pangaea and formed the present-day Atlantic Ocean basin. Appalachian orogenesis involved several distinct phases over a period of several hundred million years (e.g., Hatcher, 2010). The first phase, the Taconic orogeny, involved the accretion of arc terranes onto the margin of Laurentia (e.g., Karabinos *et al.*, 1998), whereas later phases (the Acadian-Neoacadian and Alleghanian orogenies) involved superterrane accretion and continental collision (e.g., Bartholomew and Whitaker, 2010; Hatcher, 2010; Ver Straeten, 2010). Supercontinental breakup was accomplished via a complex set of rifting processes and was accompanied by voluminous magmatism that was associated with the Central Atlantic Magmatic Province (e.g., Schlische *et al.*, 2003). These Mesozoic rifting processes are expressed in a number of abandoned rift basins

1. Department of Geology and Geophysics, Yale University, New Haven, Connecticut, U.S.A.; 2. Now at Earthquake Science Center, U.S. Geological Survey, Menlo Park, California, U.S.A.

*Corresponding author: maureen.long@yale.edu

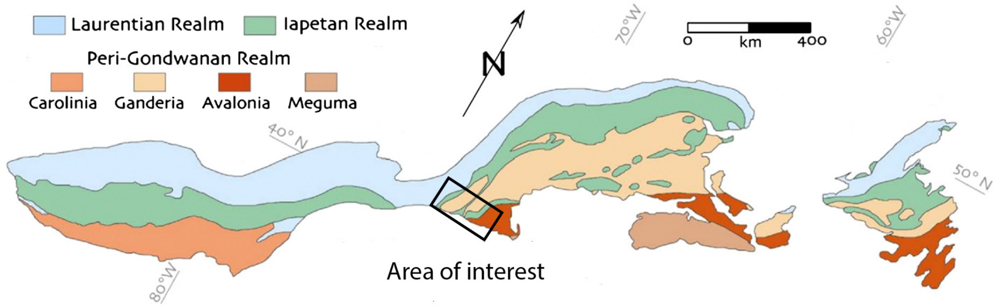

Figure 1. Generalized lithotectonic map of the Appalachian orogen, modified from Murphy *et al.* (2010), after Hibbard *et al.* (2006). Box outlines the region targeted by the Seismic Experiment for Imaging Structure beneath Connecticut (SEISConn) array, which affords the opportunity to probe the deep structure associated with a number of distinct terrains (as well as the Hartford rift basin, not shown) with a relatively compact seismic array. The color version of this figure is available only in the electronic edition.

along eastern North America; the Hartford basin is among the most prominent of these (e.g., Withjack and Schlische, 2005; Withjack *et al.*, 2012).

The southern New England Appalachians present a prime opportunity to investigate, within a compact region, the nature of complex structures that have resulted from a complicated history of subduction and terrane accretion (Fig. 1). The bedrock geology of Connecticut expresses the juxtaposition of a variety of terranes, of both continental and volcanic arc affinity and from across the Laurentian and peri-Gondwanan realms. Specifically, proto-North American units are found in the northwestern portion of Connecticut, including Grenville basement rocks up to ~1.1 Ga old (Fig. 2). A protracted series of subduction-collision events during Appalachian orogenesis resulted in the accretion of various terranes onto proto-North America (e.g., Karabinos *et al.*, 1998; Aleinikoff *et al.*, 2007), including the Avalonian terrane in the southeastern corner of Connecticut (e.g., Wintsch *et al.*, 1992). Later rifting during the Mesozoic modified (and was likely influenced by) these pre-existing structures and formed the Hartford rift basin in the central portion of the state (Fig. 2; e.g., Schlische, 1993).

The state of Connecticut thus encompasses widely varied bedrock geology, reflecting a range of subduction, terrane accretion, and rifting processes, within a compact area. For this reason, it can be efficiently sampled with a relatively modest seismic array. The goal of the Seismic Experiment for Imaging Structure beneath Connecticut (SEISConn) project is to carry out imaging of the crust and mantle that will inform a set of scientific questions; these questions are related to the formation and preservation of structures in the deep crust and mantle lithosphere. First, we are interested in how episodes of subduction and terrane accretion during Appalachian orogenesis affected crustal and mantle lithospheric structure, as well as whether (and how) present-day deep structure corresponds to surface geology. Second, we are interested in how structure was modified by (failed) rifting during the Mesozoic and how the structure beneath the Hartford rift basin compares with structure across the (ultimately successful) rifted margin of eastern North America (e.g., Lynner and Porritt, 2017). Third, we wish to understand how the crust and lithospheric mantle were deformed during subduction, terrane accretion, and rifting, and to what extent the signature of this past deformation has been preserved over geologic time.

Motivated by these scientific questions, the SEISConn field experiment was carried out across northern Connecticut between 2015 and 2019. The experiment was conceptualized and run by principal investigator (PI) Maureen Long (Yale University), while John Aragon (Yale University) served as project manager and field technician and designed the station layout, to be described later. The deployment itself was funded mainly by Yale, with some support for field participants that was provided by the U.S. National Science Foundation (NSF), via the Field Experiences for Science Teachers program, to be described later. The analysis of SEISConn data is being supported by the EarthScope and Geophysics programs of NSF. We deployed a linear array of 15 broadband seismometers across northern Connecticut and Rhode Island (Fig. 2), with data collection beginning in August 2015 and ending in August 2019. The instruments recorded data continuously and relied on natural (passive) earthquake sources, recording both teleseismic and regional events, as well as ambient noise that was useful for imaging. The dense station spacing of the experiment (roughly 10 km) allows for unaliased imaging of crustal structure on length scales that are relevant for the complex geology of the area (Fig. 1). The SEISConn array traversed a number of geologic terranes, from Laurentian rocks at its western end to the Avalonian terrane at its eastern end, and it crossed through the Hartford rift basin in its central portion.

Instrument Deployment and Details

A map of seismic stations that operated as part of the SEISConn experiment is shown in Figure 2. The SEISConn array extended from Lakeville, Connecticut in the west to Chepachet, Rhode Island in the east. The easternmost station location in Rhode Island was chosen to achieve coverage across the Lake Char-Honey Hill fault in eastern Connecticut (Fig. 2), which marks the boundary between Avalonia (to the east) and other peri-Gondwanan terranes (to the west). The station naming convention involved sequential labeling from CS01 at

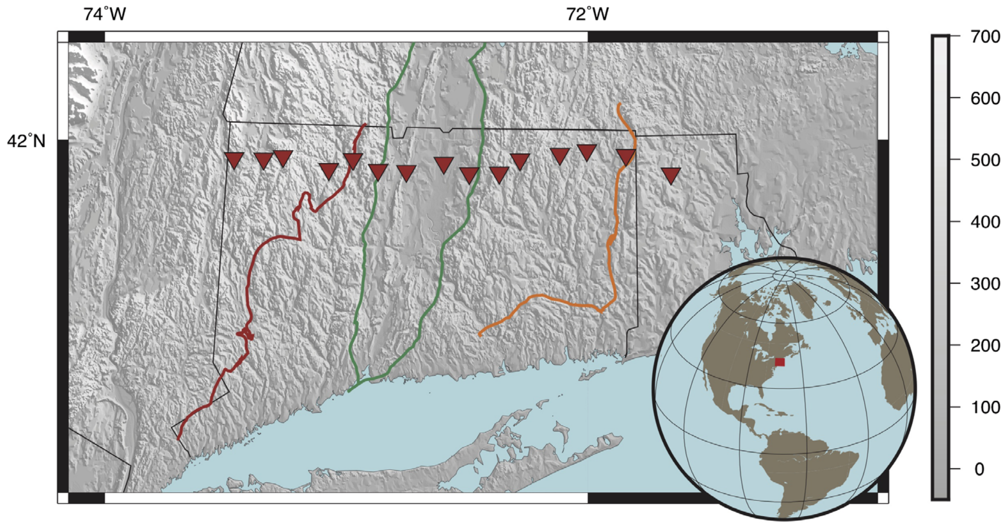

Figure 2. Map of SEISConn station locations (red triangles). Background grayscale shows topography (m), as shown by scale bar at right. Thin black lines indicate state boundaries. Major tectonic boundaries are indicated with thick lines. These include the boundaries of the Hartford rift basin (green) in the central portion of the state, as well as the Lake Char-Honey Hill fault (orange) in the eastern part of the state; this marks the western boundary of the Avalonian terrane, and Cameron's Line (red) in the western part of the state, which marks the eastern edge of Proto-North America (including Proterozoic Grenville Basement units and allochthonous units that were displaced during the Taconic orogeny). Tectonic boundaries are from the Generalized Bedrock Geologic Map of Connecticut (Connecticut Geological Survey, 2013). (Inset) The geographic region of our study area. The color version of this figure is available only in the electronic edition.

the western end to CS15 at the eastern end. The array aperture was 150 km, and 15 stations were installed, for a nominal station spacing of just over 10 km. We deployed Trillium 120PA broadband seismometers, paired with Taurus digitizer–datalogger, manufactured by Nanometrics, Inc., and owned by Yale University. Data were recorded at 40 Hz sample rate on channels BHE, BHN, and BHZ, and were stored locally on compact flash cards.

We began deploying instruments in August 2015, and we installed six stations (CS02, CS03, CS04, CS05, CS13, and CS14) in the summer and fall of 2015. An additional six stations (CS06, CS07, CS08, CS10, CS12, and CS15) were installed in summer 2016, and the remaining three instruments (CS01, CS09, and CS11) were deployed (or, in the case of CS01, repaired) in summer 2017. We demobilized three stations (CS04, CS05, and CS12) in fall 2018 due to equipment failures (and a desire to relocate working equipment to stations that had experienced persistent equipment problems). The bulk of the array was demobilized in summer 2019. In total, we collected between 18 and 47 months of continuous data at each station. Service visits were carried out at approximately 4–8-month intervals, depending on weather conditions; during service runs, we would assess station health, swap data cards, and fix any problems. The proximity of the station locations to our home university proved to be a major advantage during servicing, as it allowed us to (re)visit stations that were experiencing problems with a minimum of time and logistical planning.

Station sites were identified by first conducting an initial survey of nominal locations on Google Earth. When possible, we contacted local nonprofit entities via email to identify willing station hosts. Many of the nominal station locations were located in residential neighborhoods; for those sites, we carried out a successful campaign of distributing fliers that asked for volunteers who would be willing to host a station. Two of our stations were located on land owned by Yale University; one was in the Yale-Myers Forest in Eastford, Connecticut, and the other was at the Yale Camp at Great Mountain Forest in Norfolk, Connecticut. We sited four of our stations on property owned by farms or nonprofits, such as retreat centers and camps. Most (nine) of our stations were hosted by private landowners and located in the backyards of homes in rural or suburban residential neighborhoods.

Our seismic station design (Fig. 3) included a large (roughly 35 gal) high-density polyethylene barrel that was buried in the ground to serve as a vault. We seated each vault in concrete to achieve coupling with the ground, and we poured additional concrete into the barrel to serve as a pad for the seismometer. Two 36 W solar panels were installed using a mount built of fence posts and polyvinyl chloride (PVC) pipes (Fig. 3); the Global Positioning System (GPS) clock antenna was mounted next to the solar panels. A covered wooden housing for electronics was built for each station, using a sawhorse as a starting point and adding a plywood floor and sides. Cables from the sensor, the GPS antenna, and the solar panels were run through PVC pipes to the electronics housing, which held the Taurus datalogger, the solar converter, and one or more 12 V deep cycle marine batteries. We used a mix of batteries with different specifications and manufacturers on the experiment, with most rated near 80 Ah. We used up to three batteries (in parallel) for a few stations that received limited sunlight during the day. A removable plywood side panel was mounted with wood screws onto the electronics housing; the panel was removed (using a cordless drill) for each service

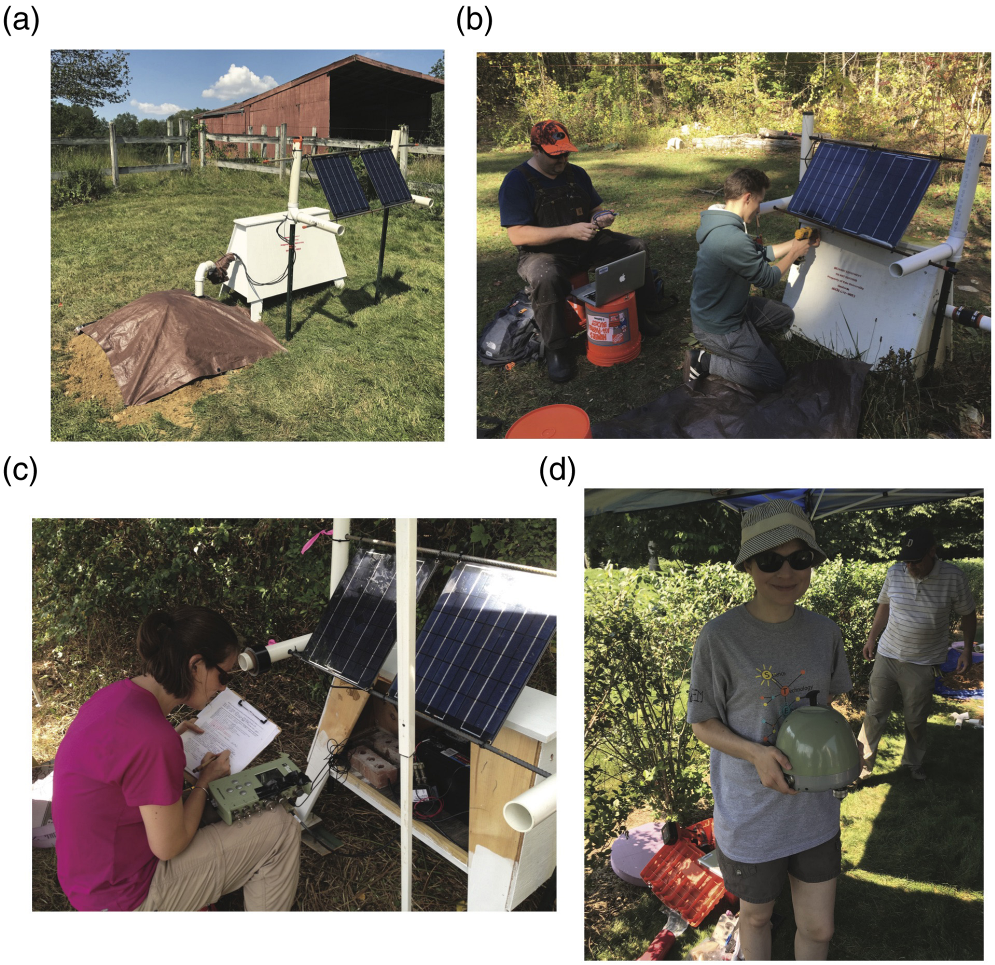

Figure 3. Field photos from the SEISConn seismic deployment. (a) Photo of a completed station (CS11 in Willington, Connecticut, installed in August 2017), showing the wooden electronics enclosure, the solar panel mount, and the buried vault (covered with dirt and tarp for thermal insulation). (b) Visit to station CS03 (Norfolk, Connecticut) for servicing in October 2017; photo shows removal of the front panel of the electronics enclosure. (c) Configuration of electronics system during installation of station CS14 (Thompson, Connecticut) in September 2015. (d) Preparing to install the sensor at station CS09 (Ellington, Connecticut) in August 2017. The color version of this figure is available only in the electronic edition.

visit and remounted before departing the station. We found that this station design provided excellent security and reliability, with minimal risk of water damage or vandalism. Because the electronics were located off the ground in the wooden housing and not partially buried in a plastic box as in some of our previous deployments (e.g., Long *et al.*, 2020), we had no problems with flooding or water damage to the equipment; furthermore, we had no episodes of vandalism.

Data Quality and Availability

All data and associated metadata from the SEISConn experiment are held in the archive of the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC) and can be accessed with a range of data access tools. The dataset (network code XP; see Data and Resources) was archived at the DMC beginning in 2016. The data are embargoed for a period that extends until 2 yr after the end of the experiment (consistent with NSF data sharing policies) and will be released to the public in August 2021. Researchers who are interested in using SEISConn data before the end of the embargo period are encouraged to contact the PI, who will grant access to data for any analyses that are not already in progress. We note that there were other broadband seismic instruments deployed in southern New England either before or during our experiment, and data from these stations are also being incorporated into several of the analyses we describe later. Other relevant networks include the USArray Transportable Array (network code TA; see Data and Resources), the central and eastern U.S. Network (network code N4; see Data and Resources), the Lamont Doherty Cooperative Seismographic Network (network code LD), and the New England Seismic Network (network code NE; see Data and Resources).

The quality of the data from the SEISConn experiment was generally high, although there were a few notable problems. In particular, we had persistent issues with power and equipment failures at several SEISConn stations. Figure 4 shows a matrix of data availability and downtime, highlighting data gaps of greater than 10,000 s (roughly 3 hr). On average, the experiment had an 83% data return, with data return at a few individual stations (CS02, CS04, and CS10) that was as low as 40%–50%. Each of these stations had persistent problems with datalogger failures (CS02 and CS10) or challenges with the power supply (CS04), due to insufficient sun exposure. The datalogger at station CS10 was replaced in summer 2018 to ensure that at least one complete and continuous year of data would be collected at this site. Station CS13 experienced a

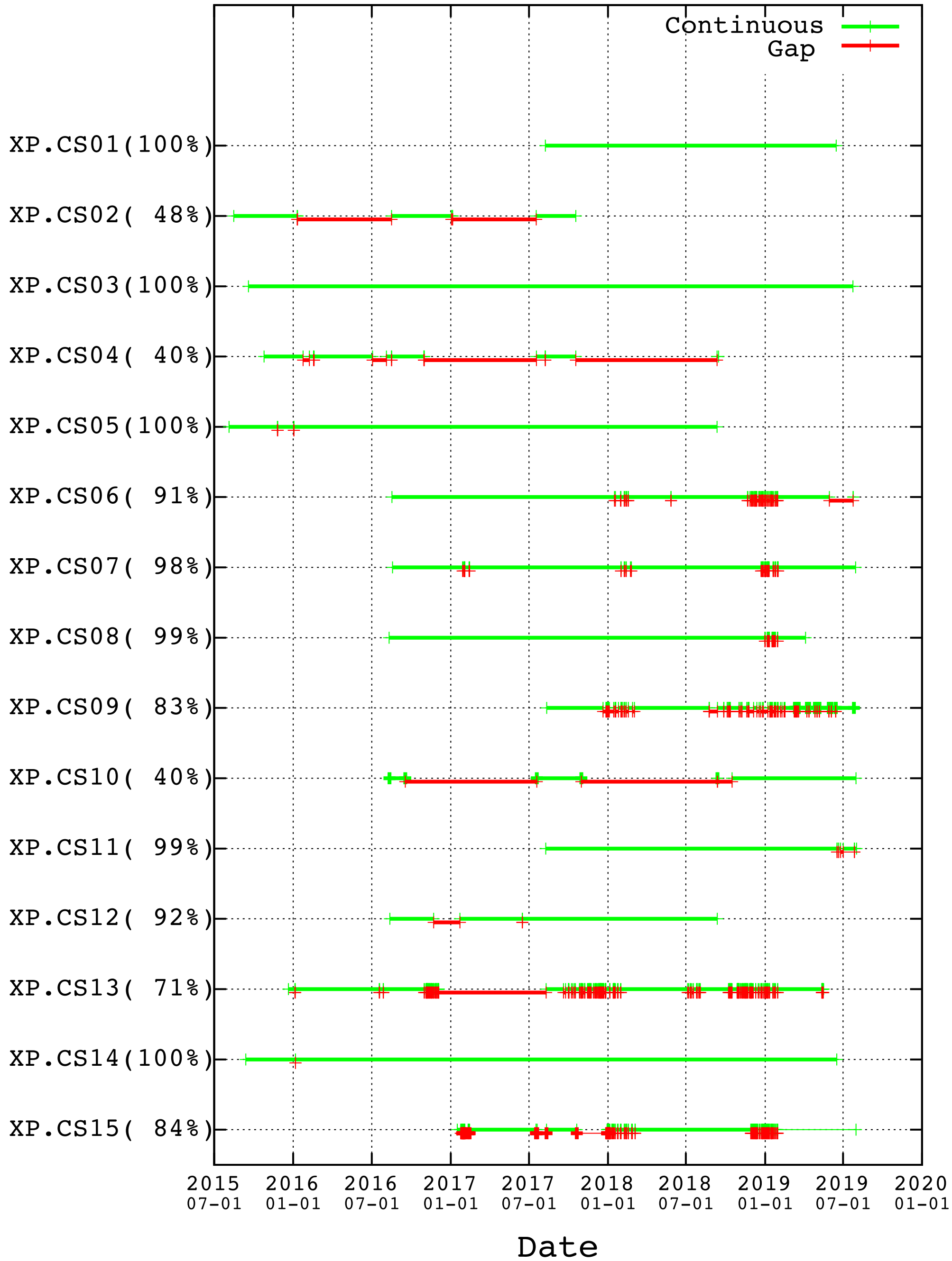

Figure 4. Matrix of data availability for the SEISConn seismic deployment. Individual stations are shown on the *y* axis, while the *x* axis indicates time. Periods of continuous data availability are shown with green lines, while gaps of greater than 10,000 s are shown with red lines. Numbers to the right of the station names on the *y* axis indicate the percentage of data returned for each station. The color version of this figure is available only in the electronic edition.

power failure in late 2016 from a short circuit in a solar panel cable that was replaced in summer 2017. A few stations experienced generally good data return but had intermittent gaps of 10,000 s or more throughout portions of the deployment time (CS06, CS09, and CS15). Of the 15 stations, nearly half (seven) had data returns of 95% or more.

We investigated the noise profiles of the SEISConn stations by constructing power spectral density (PSD) plots using the Modular Utility for STatistical kNowledge Gathering tool (Casey *et al.*, 2018), which was provided by the IRIS DMC. Figure 5 shows a suite of probability density functions (PDFs) of PSDs for representative stations of the SEISConn seismic experiment, and it compares them with high- and low-noise models of Peterson (1993). We show PDFs of all three components for a station with a representative noise profile (station CS10, Fig. 5a–c). These PDFs exhibit a typical shape, with a peak in the microseismic noise band and with the horizontal components being substantially noisier at long periods than the vertical component, as expected. For station CS10, the mode of the distribution lies between the high- and low-noise models at nearly all period ranges; it is close to the high-noise model at long periods on the horizontal components and close to the low-noise model at long periods on the vertical components. We compare the vertical-component PDFs for several additional stations in Figure 5d–f; of these, two (CS06 and CS14) have moderate to low noise, whereas one (CS02) is representative of a high-noise station, particularly at high frequencies. We found that most of the SEISConn stations had generally moderate noise levels, with a few exhibiting notably higher noise. Specifically, two stations (CS02 and CS08) exhibited elevated noise levels at high frequencies; both stations were located closer to roads or other cultural noise sources than would be ideal. We also found that a few stations were notably noisier than average at long periods (~10 s and greater), specifically CS01, CS05,

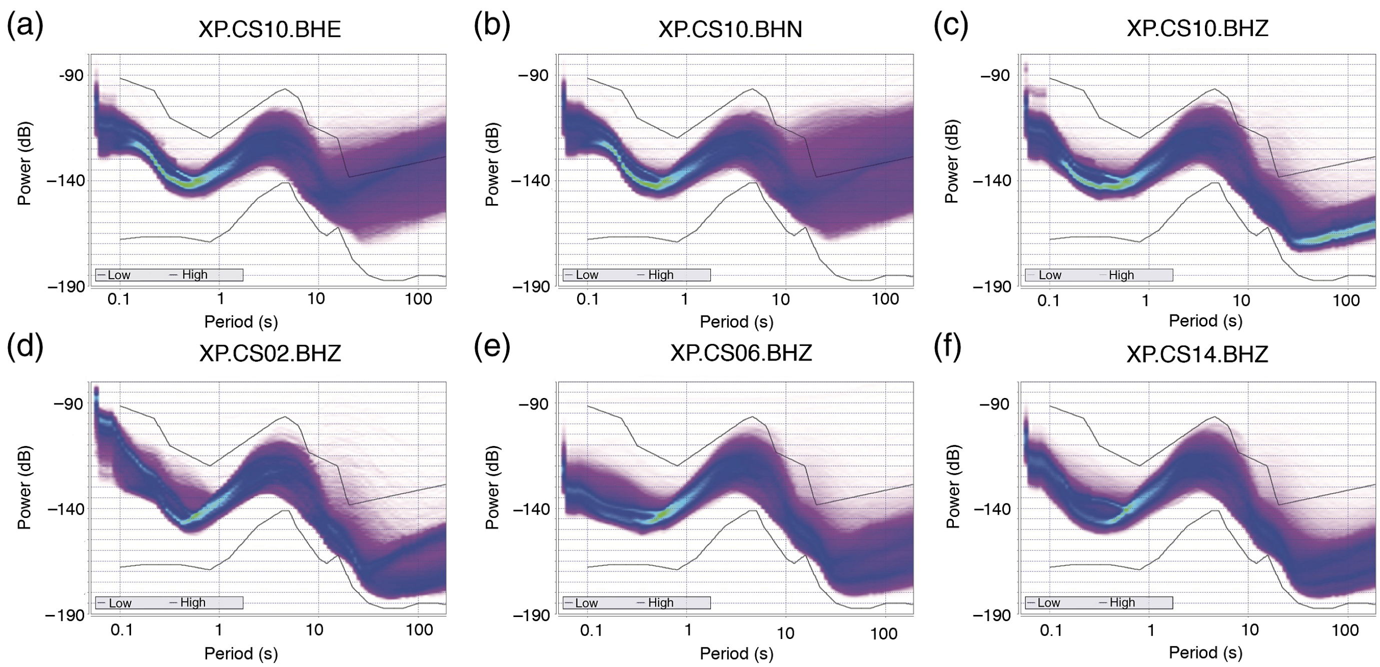

Figure 5. Examples of probability density functions of power spectral density plots (power in dB as a function of period in seconds), generated using the Incorporated Research Institutions for Seismology Modular Utility for STatistical kNowledge Gathering tool (Casey *et al.*, 2018), showing noise levels at SEISConn seismic stations. Color scale indicates the density. (a–c) Noise profiles for a representative station (CS10, located in Tolland, Connecticut) for channels (a) BHE, (b) BHN, and (c) BHZ. (d–f) Noise profiles for vertical (BHZ) components for three additional stations for comparisons, including one (CS02, located in Falls Village, Connecticut) with relatively high levels of cultural noise (visible at high frequencies, in the 1–10 Hz [0.1–1 s period] range), one (CS06, located in West Simsbury, Connecticut) with low levels of cultural noise, and one (CS14, in Thompson, Connecticut) with moderate levels of cultural noise. The high- and low-noise models of Peterson (1993) are also indicated. The color version of this figure is available only in the electronic edition.

and CS13. Station CS11 exhibited an unusual noise spike at the ~100 s period, for reasons that are not clear.

Given the generally good data quality and relatively long deployment times (18–47 months of available data) for most SEISConn stations, the coverage and completeness of the dataset is more than sufficient for the analyses that are being applied to the data, which are discussed further later. Figure 6 shows a record section of SEISConn data for the September 2017 M_w 8.2 earthquake near Chiapas, Mexico (e.g., Ye *et al.*, 2017), a large normal-fault earthquake that occurred within the subducting Cocos plate. The earthquake epicenter was located approximately 33° from the center of the SEISConn array. Figure 6 shows clear arrivals of both body-wave and surface-wave phases across the array. We recorded a large number of high-quality teleseisms during the time period of the SEISConn deployment, providing ample sources for analyses that rely on distant events. Figure 7 shows a map of 822 earthquakes of moment magnitude 5.8 and greater, at epicentral distances of 40° and greater, that occurred within the time frame of our experiment (August 2015–August 2019).

Initial Observations, Results, and Future Directions

A number of data analysis efforts are underway using data from the SEISConn experiment. We have presented preliminary results based on *P*-to-*S* (Long *et al.*, 2018, 2019) and *S*-to-*P* (Goldhagen *et al.*, 2019) receiver function analysis, *SKS* splitting measurements (Lopes *et al.*, 2020), and full-wave ambient-noise tomography (Yang *et al.*, 2019; H. Gao *et al.*, unpublished manuscript, 2020; see Data and Resources). A suite of additional analyses are either in progress or will soon be underway, including the application of Generalized Radon Transform (GRT)-based wavefield migration imaging (e.g., Rondenay, 2009; Hopper *et al.*, 2016), body-wave time analysis (e.g., Menke *et al.*, 2016), finite-frequency *SKS* splitting tomography for imaging anisotropic structure (e.g., Mondal and Long, 2020), joint inversion of surface-wave and scattered body-wave data (e.g., Eilon *et al.*, 2018), and anisotropy-aware receiver function analysis (e.g., Long *et al.*, 2017). Finally, a key component of our project plan involves the integration of SEISConn imaging results, with constraints obtained from complementary approaches involving petrology, geochemistry, geochronology, and structural geology investigations (e.g., Long *et al.*, 2019; Severson *et al.*, 2020). Data from the SEISConn project will eventually be used to test specific hypotheses relating to southern New England tectonics that have been formulated based on geologic observations (e.g., Wintsch *et al.*, 2014; Kuiper *et al.*, 2017; Massey *et al.*, 2017).

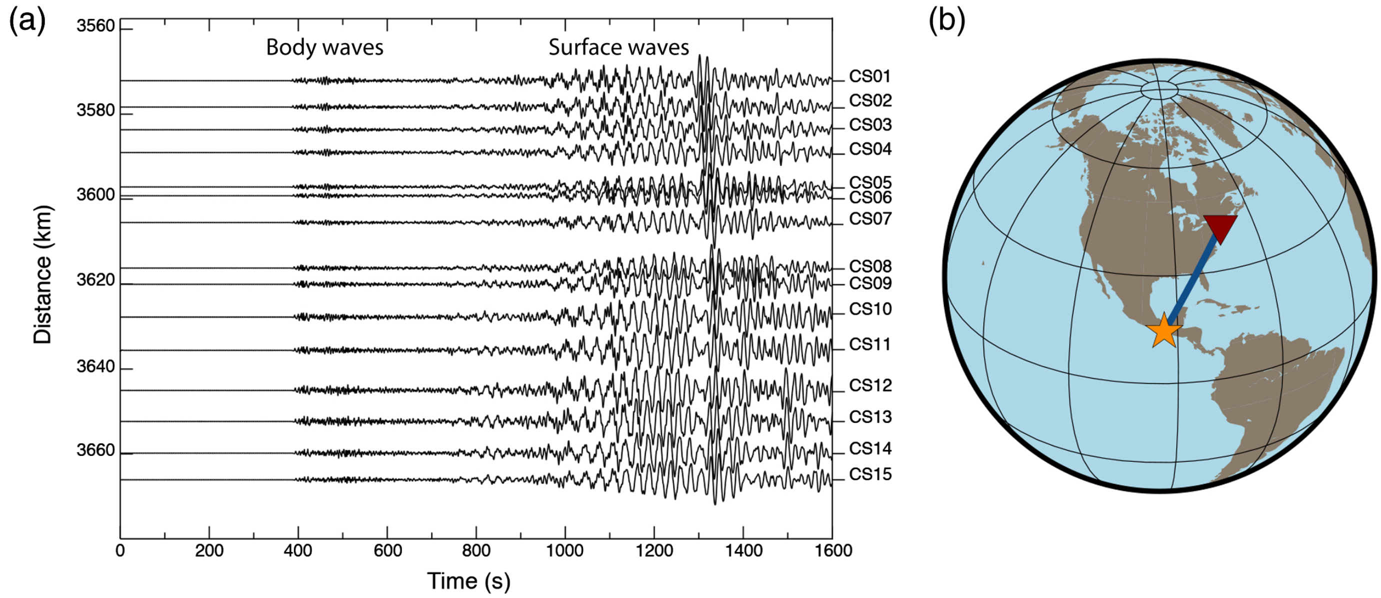

Figure 6. (a) Vertical-component record section showing recordings at SEISConn stations of the magnitude 8.2 earthquake near Chiapas, Mexico in September 2017. Records have been bandpass filtered to retain energy at periods between 1 and 100 s. Body- and surface-wave phases are visible. (b) Location of the earthquake (orange star) and great circle path (thick blue line) to the center of the SEISConn array (red triangle). The color version of this figure is available only in the electronic edition.

Our crustal imaging targets include the depth, strength, and sharpness of the Moho interface; the existence and character of intracrustal layering; crustal velocity structure; the presence, characteristics, and geometry of dipping interfaces that may represent relict slab- or suture-related structures; and the presence and strength of crustal seismic anisotropy. Initial results on crustal structure from *Ps* receiver function analysis and ambient-noise tomography are shown in Figure 8, which is modified from H. Gao *et al.* (unpublished manuscript, 2020; see Data and Resources). We find evidence for profound lateral variations in crustal structure across northern Connecticut; of particular interest is the very sharp step in the Moho that is evident in the western portion of the array (Fig. 8). Specifically, we estimate Moho depths of ~45 km at the western end of the profile, with an abrupt transition to much thinner crust (~28 km) over a distance of ~15–20 km (Long *et al.*, 2019). The Moho step appears to coincide with the edge of Laurentia; this is similar to findings elsewhere in the northeastern United States (e.g., Li *et al.*, 2018, 2020), but the tight station spacing of the SEISConn array allows us to place more precise constraints on the geometry of the transition in crustal thickness. Our shear-wave velocity model for the crust beneath Connecticut (H. Gao *et al.*, unpublished manuscript, 2020; see Data and Resources; Fig. 8) reveals evidence for a widespread low-velocity zone in the midcrust (depths between ~10 and 20 km), which may reflect radial seismic anisotropy due to deformation that is associated with rifting and extension during the Mesozoic era. Finally, we also image a prominent high-velocity zone in the lower crust directly beneath the Hartford rift basin (Fig. 8), which we interpret as a reflection of the presence of dense, mafic material that was emplaced during Mesozoic rifting and volcanic activity.

In addition to our crustal imaging targets, we are working to elucidate the structure (isotropic and anisotropic) of the mantle lithosphere and asthenospheric upper mantle beneath the SEISConn array. Preliminary results from *SKS* splitting analysis (Lopes *et al.*, 2020) reveal single-station average splitting parameters (fast direction and delay time) that vary only slightly across the SEISConn array; they are consistent with the generally nearly east–west fast splitting directions that are observed across much of New England (e.g., Long *et al.*, 2016; Levin *et al.*, 2018). Examination of *SKS* splitting parameters at individual stations shows that there is some variability in apparent splitting with back azimuth, as would be expected in the presence of multiple layers of anisotropy. Our preferred interpretation is that *SKS* splitting beneath SEISConn mainly reflects present-day flow in the upper mantle, driven by the motion of the North American plate over the underlying asthenosphere, as well as a modest contribution from lithospheric anisotropy that is frozen in from past deformation episodes. This view is generally consistent with the results of previous studies in the region (e.g., Li *et al.*, 2019). Future work on anisotropy-aware receiver function analysis and the application of *SKS* splitting tomography should help elucidate the details of the lithospheric contribution. Initial results on the discontinuity structure of the mantle lithosphere beneath our study area from *Sp* receiver functions (Goldhagen *et al.*, 2019) reveal evidence for generally thin lithosphere beneath southern New England, with a pronounced lateral transition in lithospheric structure that coincides with the step in the Moho at the edge of Laurentia.

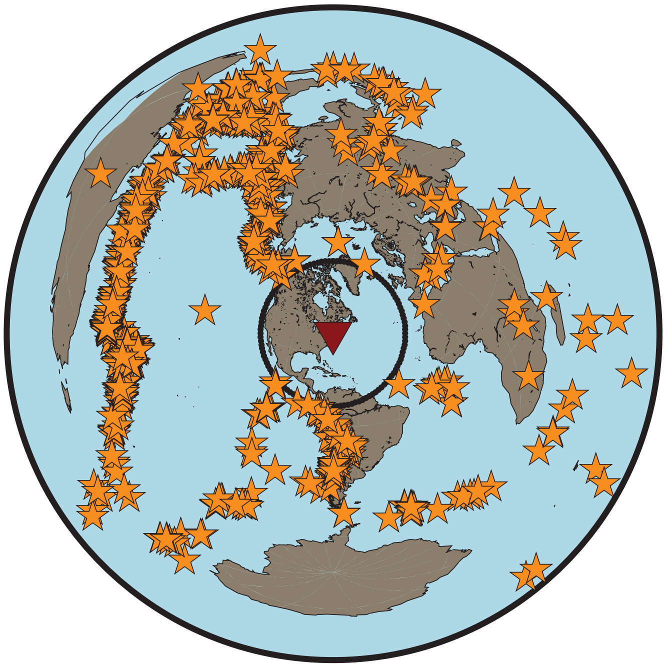

Figure 7. Map of 822 teleseismic events (orange stars) of magnitude 5.8 and greater at epicentral distances beyond 40° (black circle) during the time of the deployment (August 2015–August 2019). The center of the SEISConn array is marked with a red triangle. The color version of this figure is available only in the electronic edition.

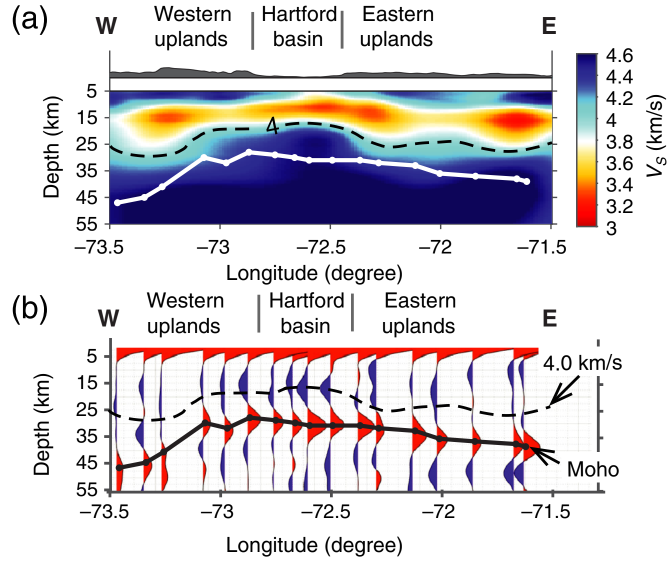

Figure 8. Initial results on crustal structure beneath northern Connecticut from the SEISConn project, after H. Gao *et al.* (unpublished manuscript, 2020; see Data and Resources). (a) Shear-wave velocity profile along the SEISConn array, derived from full-waveform ambient-noise tomography. The dot-connected solid white line shows the estimated depth to Moho beneath each SEISConn station, from Long *et al.* (2019). Depths are estimated from the single-station migrated receiver function traces in (b). The dashed line shows the $V_S = 4.0$ km/s velocity contour, highlighting the high-velocity root, which is particularly prominent beneath the Hartford basin. (b) Single-station stacked radial-component receiver function traces, migrated to depth. Red pulses correspond to a positive velocity gradient (increase in velocity with depth), and blue pulses correspond to a negative velocity gradient (decrease in velocity with depth). Solid black line indicates estimated depths to the Moho across the profile, with the sharp step in crustal thickness visible in the western portion of the array. Dashed line indicates the $V_S = 4.0$ km/s velocity contour from the model shown in (a). E, east; W, west. The color version of this figure is available only in the electronic edition.

Education and Outreach Activities

In addition to the scientific analyses being carried out, a number of education and outreach activities have been executed as an integral part of the SEISConn project. The most notable of these is the Field Experiences for Science Teachers (FEST) program, which is described in detail by Long (2017). This program brings together Connecticut-based high school science teachers and Yale personnel who are working on the SEISConn experiment. Teachers have participated in one-week summer field experiences that include one day of orientation and safety training at Yale and four days of field work visiting SEISConn stations for installation, servicing, and/or demobilization activities. As noted by Long (2017), the workflow of broadband seismic experiments allows for novice field personnel to make a meaningful contribution to data collection, even in the context of a relatively brief field experience. Six one-week FEST sessions have been run as of Summer 2019; to date, the program has reached 19 teacher participants from across Connecticut and from districts that include urban, suburban, and rural settings. Most FEST participants teach at public schools, with a few participants coming from private institutions. Funding for the FEST program, which included stipends for teacher participants, was provided by NSF via a Faculty Early Career Development Program (CAREER) grant to PI Maureen Long and via a subsequent grant from the EarthScope and Geophysics programs that is also supporting the analysis of SEISConn data. FEST program participants have made up the bulk of the field personnel for the SEISConn deployment, and they have thus made an integral contribution to the success of the project.

A seventh session of FEST (originally planned for summer 2020, but now deferred to 2021 because of the COVID-19 pandemic) will bring back previous field participants and will focus on crafting lesson plans and classroom activities, aimed at high school students in earth science or physics courses; these plans and activities will involve using SEISConn data to teach students about wave propagation and/or the geologic history of Connecticut. These materials will be distributed through the IRIS Education and Public Outreach InClass portal (see Data and Resources) for instructional resources, and they will be publicized via the Connecticut Science Teachers Association (CSTA; see Data and Resources) email list. Results from SEISConn have been presented to Connecticut science teachers through sessions at the annual CSTA conference in 2017 and 2018, which focused on the scientific aspects of the project and on best practices in cultivating science-teacher partnerships, respectively.

In addition to the FEST program, other SEISConn education and outreach activities have included the participation of undergraduate (and graduate) students in field work and research, as well as the dissemination of results to the public through media interviews, public talks, and displays. Approximately a dozen undergraduate students took part in SEISConn field activities, including students from Yale University, Rutgers University, the University of Wisconsin, Williams College, the University of Münster, and Highline Community College. Several of these students were participating in undergraduate research internships, including one through the IRIS summer intern program and one through the Research Experiences for Veteran Undergraduates program at Yale (see Data and Resources). Results from the project have been shared with the general public through interviews with local media and talks at venues, which have included a local Rotary Club meeting and the Yale-Myers Forest Summer Seminar Series. One of our station hosts, a farm and maple syrup producer who regularly welcomes school-age children for field trips, included material on the project and a stop at the seismic station in visitor tours of the property. A planned series of talks on the SEISConn project, geared toward the general public and to be offered at local libraries in Connecticut, has been postponed until 2021 but should offer an excellent avenue for sharing results with Connecticut residents.

Summary

The SEISConn experiment, a linear array of 15 broadband seismic stations, was deployed across northern Connecticut between 2015 and 2019. The major scientific goals of the SEISConn project include an investigation of how the present-day structure of the crust and mantle beneath Connecticut has been affected by episodes of subduction and terrane accretion during Appalachian orogenesis, with a focus on characterizing the structure near major terrane boundaries. We are also interested in how lithospheric structure was modified by extension and rifting associated with the breakup of Pangaea during the Mesozoic, as well as in the detailed structure of the crust and mantle lithosphere beneath the Hartford rift basin. Finally, we are investigating the nature of crustal and mantle deformation during subduction, terrane accretion, and rifting. Data from the SEISConn experiment are being used to construct images of the crust and mantle lithosphere that can address this set of scientific questions. Preliminary results from crustal imaging reveal a step in the Moho in the western portion of the array, coincident with the boundary of Laurentia, with thin crust beneath the Hartford rift basin. We image a region of high shear velocities in the lower crust directly beneath the basin, which we interpret as evidence for the presence of dense mafic material emplaced during volcanism that was contemporaneous with rifting. Preliminary *SKS* splitting measurements reveal fast splitting directions that are close to absolute plate motion, indicating that upper-mantle anisotropy is likely controlled mainly by the absolute motion of the North American plate, perhaps with a moderate contribution from frozen-in anisotropy in the lithosphere. Initial views of lithospheric discontinuity structure from receiver function analysis reveal complex and laterally variable structure. Education and outreach activities associated with the SEISConn project have emphasized field experiences for high school science teachers and the communication of results from the experiment to teachers and to the general public. SEISConn data are archived at the IRIS DMC and will be publicly available beginning in August 2021.

Data and Resources

Data from the Seismic Experiment for Imaging Structure beneath Connecticut (SEISConn) experiment (network code XP; doi: 10.7914/SN/XP_2015) are archived at the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC; https://ds.iris.edu/ds/nodes/dmc, last accessed May 2020). The data are under embargo until August 2021, consistent with National Science Foundation (NSF) data sharing policies. Researchers who are interested in using the data prior to this date are encouraged to contact the principal investigator (PI) for access, which will be granted for any analyses not already in progress. The IRIS Education and Public Outreach InClass portal can be found at https://www.iris.edu/hq/inclass (last accessed May 2020); the Connecticut Science Teachers Association website can be found at https://www.csta-us.org (last accessed May 2020); and the Research Experiences for Veteran Undergraduates website can be found at https://www.revuprogram.com (last accessed May 2020). Other relevant networks include the USArray Transportable Array (network code TA; doi: 10.7914/SN/TA), the central and eastern U.S. Network (network code N4; doi: 10.7914/SN/N4), and the New England Seismic Network (network code NE; doi: 10.7914/SN/NE). The unpublished manuscript by H. Gao, X. Yang, M. D. Long, and J. C. Aragon (2020), "Seismic evidence for crustal modification beneath the Hartford Rift Basin in the northeastern United States," submitted to *Geophys. Res. Lett.*, revised manuscript in review.

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