

High-Resolution Source Parameters Using Calibration from Ambient Seismic Noise

Abstract

Several new methods have been developed to retrieve local Green's functions based on the cross-correlation of ambient seismic noise (station-to-station) and conventional (source-to-station) inversions. The latter methods provide the most broadband results but require accurate source parameters for phasedelay recovery which depends on the starting model. Considerable progress is being made in providing such information from 3D modeling, Tape et al.(2008), using Adjoint Tomography. But to match waveforms for the recent Chino Hills event still requires shifting synthetics to align on data. This means that it is difficult to use 3D simulations to refine source locations in near-real time. We can avoid the 3D problems by applying the CAP method and storing shifts from past events, Tan (2006), and/or using ASN, Shapiro et al. (2005), to predict lags for surface waves. Here, we directly compare results from CAP predictions with ASN results using stations near the Chino Hills event. We use the same South California seismic model as used in the Library of Earthquakes to generate Green's functions for noise(single force) for comparison with ASN correlations and allow CAP delays. We apply these delays or corrections to determine precise Centroid locations.

48. Pnl V	Pnl R	Vertical.	Radial	Tang.	169 Pnl V	Pnl R	Vertical.	Radial	Tang.	207 Pnl V	Р
TA2A 9.1	 0.000				LRL					CLC	
65 72.	95	0.30 94	0.30 97	98 0.00	0.70 93 178	0.70 v 94 ∧	96	95	95	0.00 97 234	0.0 94
ADO	-			$-\sqrt{\beta}$	CCC	-MA					
24. 0.60 50 78.	0.60 81	1.00 ¥ 98	1.00 94	0.10 98	0.70 85 173	0.70 86	3.10 V 95	3.10 VV 95	1.00 97	0.60 96 219	0.6 97
VTV 30.	\longrightarrow	-			GSC 30.	-M	$-\sqrt{b}$			SLA	
0.10 82 58.	0.10 88	1.50 ♥ 98	1.50 96	0.50 98	1.00 93 124	1.00 ^v 91	3.30 ¥ 98	3.30 92	1.50 95	0.20 94 290	0.2 92
	$\sim \gamma$	$\sim \sim \sim \sim$	$-\sqrt{-1}$	-	RRX	-Mr	$-\sqrt{-1}$			FUR	
0.60 0 57.	0.60 75	1.00 83	1.00 93	0.20 89	0.80 84 163	0.80 93	2.20 [♥] 98	2.20 94	1.10 94 ∧	0.90 92 255	0.9 96
SBPX	\sim		$-\gamma$		HEC	-m			$-\gamma$	SHO	
0.10 93 43.	0.10 92	0.80 98	0.80 98	-0.20 99	0.80 82 115	0.80 92	3.30 V 98	3.30 98	1.70 99	0.50 96 235	0. <u>:</u> 94
CLT	$-\mathcal{M}$		$\neg \land \land$		JVA 66.	A	-			TUQ 45.	
-0.20 94 63.	-0.20 92	0.00 95	0.00 V 96	-1.30 76	0.90 73 161	0.90 84	2.40 V 98	2.40 97	1.20 99	0.20 84 201	0.2 82
SVD	\sim				MCT	A				DSC	
0.10 86 35.	0.10 88	0.50 98	0.50 98	8.70 55	1.20 54 127	1.20 ^V 80	3.40 V 97	3.40 96	1.80 86	0.30 60 264	0.3 65
RVR	\checkmark		-		BLA	- A				MTP	
-0.40 99 40.	-0.40 96	-0.20 97	-0.20 98	0.30 96	1.00 56 163	1.00 75	2.50 [♥] 98	2.50 98	1.60 95	1.20 69 214	1.2 12
RSS	$ \rightarrow $		$-\sqrt{-}$		BEL	Apr				GMR	
-0.20 95	-0.20 84	0.50 72	0.50 V 95 A	2.70 70	65 109	0.90 ^V 64	3.00 V 98	3.00 98	2.30 V 96	0.10 0.10 242	0. 85
BBS					DEV	A				IRM	
92. 0.20 68	0.20 [°] 93	0.60 98	0.60 [♥] 97	-0.20 89	90. 1.20 63	1.20 66	1.60 [♥] 99	1.60 98	1.60 99	83. -0.40 84	—0 75

Fig. 2. Comparison of synthetic(red) and data(black) for the Chino Hills event, name of station is at the left of each seismogram, number above station name is epicenter distance in kilometer and below is azimuth. The number on the lower left of the seismograms are the time shifts (upper) and cross-correlation coefficients in percent(lower). Positive time shifts indicate slow paths. Pnl waves are filtered with bandpass(0.02~0.2Hz) and surface waves are filtered with (0.02~0.1Hz), a Standard South California Model(SoCal) is used.

200				200				200	1		
300				300		$\sim \sim $	6.10 0.805	300 -			
	EHN=REY		4:00 0:939								5.00 0.012
290			-	290 - ₈₁₁ -	GO ACT		5.40 0.798 — 3.20 0.833 —	290 -	SRN-GLA		2.40 0.814
	CHN-GLA EHN=E&B		► 1.50 0.557 = 6:70 0:788	OLI-	.DF		_ 5.20 0.827			\checkmark	
280			_	280 —				280 -	- SRN-LDF		5.20 0.810 -
				8EI=			3:88 8:733		SRN–SPG2 SRN–MTP		3.50 0.891 4.70 0.831
270	CHN–CWC		6.10 0.835	270				270			
270				270 -				270 -	SRN–SHO		4.80 0.784
	CHN-SPG2		-6.60 0.583	OLI- OLI-	GHO GPG2		5.00 0.752 3.10 0.900				6.40 0.745
260			5.20 0.428	260 - oli-	RM		4.20 0.910	260 —			6.40 0.745
	CHN-MTP		4.00 0.898						SRN_VES		4.00 0.935
250			_	250 —				250 -	_ SRN-CAR SRN-MPM		6.00 0.627 4.40 0.787
	EHN=EAR	Add Vacent	1 :88 8:433	OLI-			3.90 0.835		SRN-IRAQ		3.80 0.999
240	CHN–VES		3.40 0.861	0Ll=			<u>5:70</u> 0.940	240			
240					MPM		4.20 0.841 3.70 0.944	240 -	SRN–JRC2		4.50 0.654
	CHN-IRM		4.60 0.930		CAR AS	A A A	6.10 0.868 2.60 0.837		SRN–SLA		3.90 0.793
230			5.80 0.802 2.30 0.764				4.40 0.577 1.10 0.914	230 -	-		-
			5.00 0.869	OLI-	RC2		4.30 0.695 4.80 0.759		SRN–WES SRN–GMR		1.300.9593.000.917
220	CHN–JRC2	\sim	4.30 0.699	220 -			1.30 0.945	220 –	SRN–CLC		4.00 0.824
				OLI-	ERR	A	1.40 0.941		SRN–BC3		1.80 0.624
210	CHN-SLA CHN-SWS		4.40 0.723 1.50 0.856 3.99 0.34 3	210 – OLI-			4.20 0.838	- 210 –	SRN=DSC - SBN_SEAS		3.80 0.937 9.88 8.823
210	CHN-GMR		-9.30 0.654	E				Ű,	SRN-BAK		3.90 0.824
	CHN–TFT CHN–CLC		3.70 0.871 4.50 0.531	(e)				()	SRN–DVT		1.30 0.941
200	CHN-BRAK	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	3.80 0.693		SA A		3.10 0.815	0 200 -	SRN–ERR		0.80 0.901 -
	CHN–SBC CHN–DSC		-0.40 0.497 3.70 0.895		GAL		0.50 0.761	iistä	SRN-10/BS	A A A A	3.90 0.885
190	_		-				4.60 0.823 3.58 8.857	□ ₁₉₀ –	SRN–SBC		4.70 0.472
									SRN–GSC		3.60 0.917 3.60 0.943
180	CHN–SCZ2		3.40 0.748	180 -			\$.890 0:882 —	180 -			
	EHN=\$ABs		4.930 0.933				2:80 0:838 2:50 0:794 9:60 0:950		SRN-SAL		0.40 0.902
170	CHN-CCC		-0.20 0.846 3.30 0.823		RL		3.30 0.889	170	SRN=SEZ2		4:40 0:888 3:78 0:898 4:40 0:898
170	CHN-OLP CHN-NSS2		-0.10 0.964 -2.90 0.270 2.00 0.913	170 -	~ V			170 -	SRN=GEET		0.90 2:40 0:894
	EHN=ARV		2:90 0:387 1.60 0.755	OLI-	SDR	\sim	0.30 0.961		SRN–BAR		0.10 0.953
160	CHN-TEH CHN-WGR		2.90 0.905 3.40 0.537	160 — _{OLI}			9:60 0:938	160 —	- SBN-QLPD		9.28 8.95 4
	EHN=BER EHN=MET		<u>2.9</u> d0 0:888 3:58 8:939	8EI= OLI-			2:48 8:942 0.30 0.965				4.90 0.783
150				150 — _{oll-}	;DG		1.00 0.916	150 —	-		_
	CHN–EML CHN–SDG		-0.50 0.971 0.10 0.855	ŎĒİ= OLI-	AGE		0:400:0240.800.922		SRN–SDR	$\sim \wedge \wedge \sim$	0.00 0.963
140	CHN-BOR		1.10 0.980		BVA2 PFO MGR		0.00 0.987 0.60 0.881 4.20 0.769	140 –	SRN-BOR		0.30 0.994
i rU							1.30 0.951		SRN-LDR SRN-BRX		3.00 0.968 2.00 0.887 0.10 0.948
	CHN-DPP		-0.30 0.987	OLI- OLI-	RRX SECOND		2.50 0.778 0.30 0.910	400	SBN=BAAD SRN-SBC		0.30 0.30 0.991
130		85% of the station	0.90 0.668 -0.30 0.947 8:88 8:85	130 - 8E	SZN SZN	95% of the station	8:20 9:879 0.30 0.942	130 -		⁷ 95% of the station	0.10 0.000
	CHN-MGE	pairs have CCs	2:00 0:829 1.60 0.915	OLI- BELE	DEV	pairs have CCs	1.00 0.916 9:99 8:979		SRN-JVA SRN-JVA SRN-REU	pairs have CCs	2.00 0.931 2:4日 日:868
120	CHN-PFO CHN-BLA CHN-OSI	larger than 0.7 and	0.40 0.945 1.20 0.889 0.90 0.820			arger than U./ and	0:00 0:937	120 -		larger than 0.7 and	0:60 0:950 1:20 0:839
	CHN-RRX CHN-FRD	75% have CCs	2.10 0.893 0.70 0.969	OLI-		ou% nave LLS	0.30 0.820		SRN-FRD SRN-FRD	85% have CCs	–0.30 0.970 T ବ୍ୟୁର୍ବିତ କ୍ୟୁଥିନ୍ତୁ
110		larger than 0.8.	0.60 0.925 0.50 0.923 —	110 - oli-	GOR	iaiyei tilali U.ö.	0.90 0.970	110 -	SRN-BZN	Targer than 0.8.	-0.20 0.985
	CHN-JVA		2.70 0.980 0.60 0.948		.GU		1.90 0.824 0.00 0.989 2:00 9:989	-	SBN=XLPC		-0.70 0.959 1.80 0.972
100	EHN=EBW2		₽.90° 0.849				1.10 0.950	100	SBN-CRY SRN=RAW		-0.50 0.980 0.70 0.980
IUU		50 100	150		0 50	100	150	100 -		50 100	150
	U	50 100			0 30				U	50 100	
		Time(s)				Time(s)				Time(s)	

Fig. 3.

We compute Cross-Correlation Functions (CCFs) of Ambient Seismic Noise(ASN) between further away stations(big yellow circles) and close by stations(SRN, CHN, OLI shown as small yellow circles in the map). The CCFs(black line) are shifted to obtain maximum Cross-correlation Coefficients(CC) with single force Green's function between the two station from the same 1D Southern California Model as used in CAP. The resulting time delays and CC are shown on the right side of the seismograms. Most of the station pairs have CCs larger than 0.8. Both the CCFs and the Green's functions have been filtered between 10s and 50s. Note that most lags are similar between the pseudo-sources.

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Station and event locations. Stations at local distance, blackcrosses represent the TriNet stations which are available for Chino-Hills event; yellow circles are stations used in ASN, in which three small yellow circles are source stations; red square symbols are those stations used in CAP inversion.

Time(s)

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Time shifts of 10-50s surface waves with respect to Green's functions from the 1D South California Model. Stations are colored in cross-correlation coefficients between surface waves and Green's functions. Color of paths shows the time shifts obtained from CAP inversioin and ASN cross-correlation functions, using CHN, OLI and SRN as source stations. Note the similarity in delays for the three pseudo-sources (stations CHN, SRN, OLI), except for some interesting paths displayed as black lines in Fig. 1. Moreover, note the similarity between delays derived from the above CAP routine which are usually within one second. This means we can use the time shift s from ASN to calibrate the paths, then relocate the earthquake!





Chino Hills event as displayed on the left.

Conclusion and Future Work

We have demonstrated the usefulness of ASN in calibrating surface wave paths. This method can give an independent estimation of earthquake centroid from the long period surface waves. It is especially useful in regions without well-determined 2D or 3D velocity models, but with a few seismic stations close to the source area (such as PASSCAL stations in South America and Tibet). These stations need not to be working during the earthquake, but only used to calibrate the paths. The well-located earthquakes near these stations can serve as reference to locate other nearby events.

Earthquake centroid located with time corrections from ASN. Beach balls marked with SCEC and EH are the epicenters from SCEC data center and Egill Hauksson, respectively. Centroid1 is the relocated centroid using long period (10-50s) Rayleigh and Love waves. Time shift corrections from ambient seismic noise are then used to locate Centroid2. The blue ellipses are the 95% confidence regions. It is obvious that the confidence region gets much smaller after correction. The gray dots are aftershocks until Dec 2008. The epicenters show that the Chino-Hills earthquake is in the middle of the Whittier fault and the Chino Fault. Noise-corrected centroid is closer to the Whittier fault. And the azimuth of centroid2 to EH epicenter is also very close to the strike of the Whittier fault. This is consistent with the preferred fault plane from a finite fault inversion (Shao, et al., in review, 2009).