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Multi-scale Isotropic/anisotropic tomography of Taiwan using seismic ambient noises

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ABSTRACT

We investigate the crustal azimuthal anisotropy of Taiwan using seismic ambient noises. Continuous data from island-wide broad-band are used. Taking advantage of the temporary arrays deployed by the TAiwan Integrated GEodynamics Research project (TAIGER), we have collected an unprecedented data amount for the noise tomography in Taiwan. We construct 2D phase velocity maps for Rayleigh waves for the period range from 4 to 20 seconds using a wavelet-based multi-scale inversion technique, in which both the isotropic and anisotropic components are taken into account. The reliability of the pattern of the resulting anisotropy is supported by the synthetic test and experiments of various azimuthal weighting schemes. In the shorter periods (5, 8, 12 s) of our anisotropy model, the fast axes of anisotropy are highly correlated to the major geological structure, i.e., from N-S in southern Taiwan to NNE-SSW in northern Taiwan. In the longer periods (16, 20 s), they are gradually shifted to a pattern dominated by W-E direction in the eastern, indicating there is a clear depth-dependence of seismic anisotropy in the crust of Taiwan.

DATA and Results of Group Velocity

The vertical component continuous records from broadband stations of BATS (14 stations), CWBBB (25 stations), and TAIGER (46 stations) in 2007 are used.

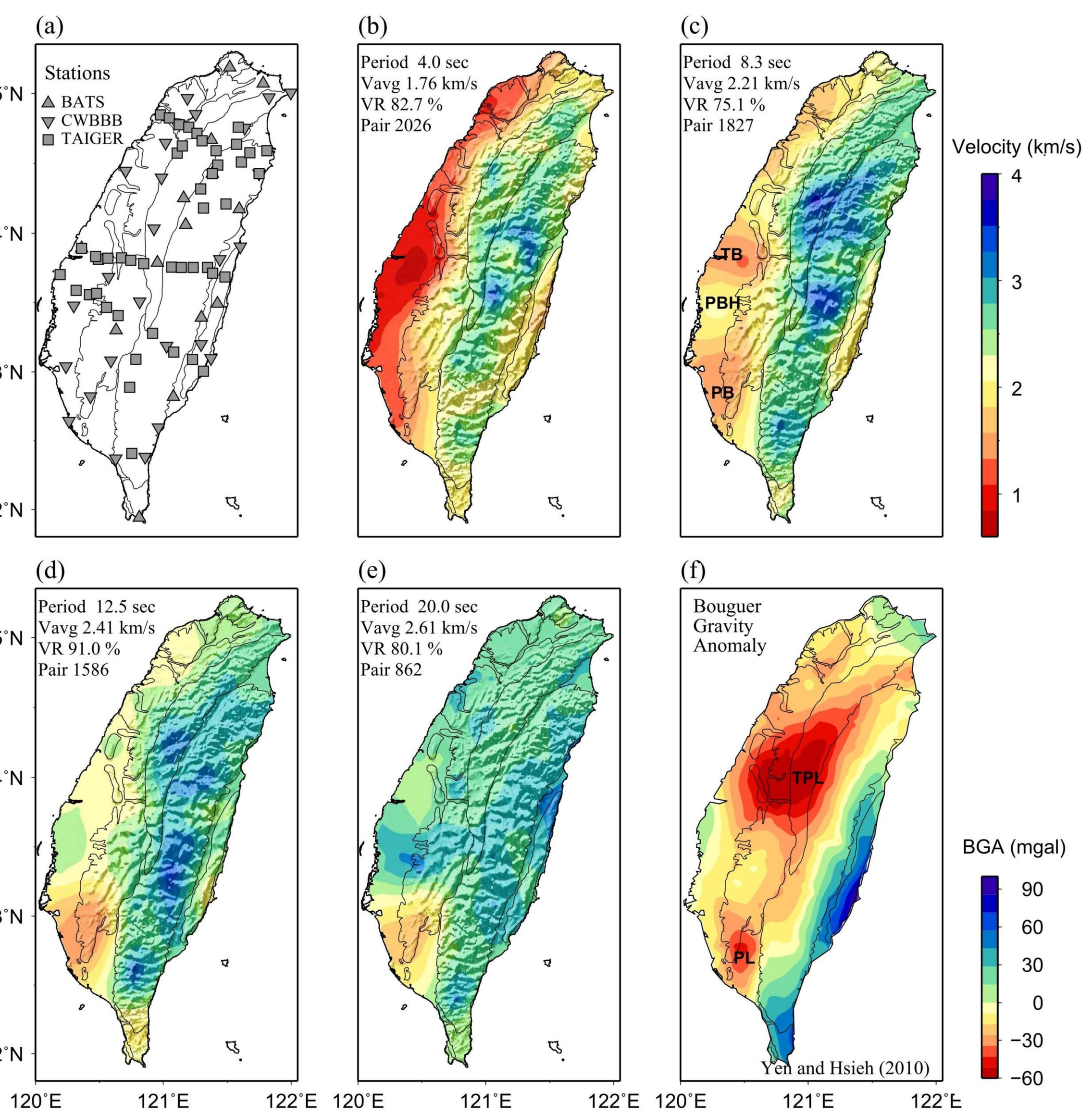


Figure 1. (a) Stations used in this study. Dark lines in the map are boundaries of major tectonic units. (b-e) Maps of Rayleigh wave group velocity derived by ANT.(f) Bouguer Gravity anomaly of Taiwan, where two major negative gravity anomalies Taichung-Puli low (TPL) and Pingtung low (PL) are labeled on the map. Our results provide vital constraint on resolving the long-lasting controversy about most prominent Bouguer gravity anomaly in central Taiwan (TPL), implying that it is likely caused by a deeper mountain root. (Huang et al, 2012).

Feasibility of Eikonal Tomography

We examine the feasibility of Eikonal tomography (Lin et al, 2009) with the available station of our study. Results for period 5 s and 12 s are shown below along with their corresponding standard deviations (STD). The results suggest that the Eikonal tomography might not be an adequate approach with our current data.

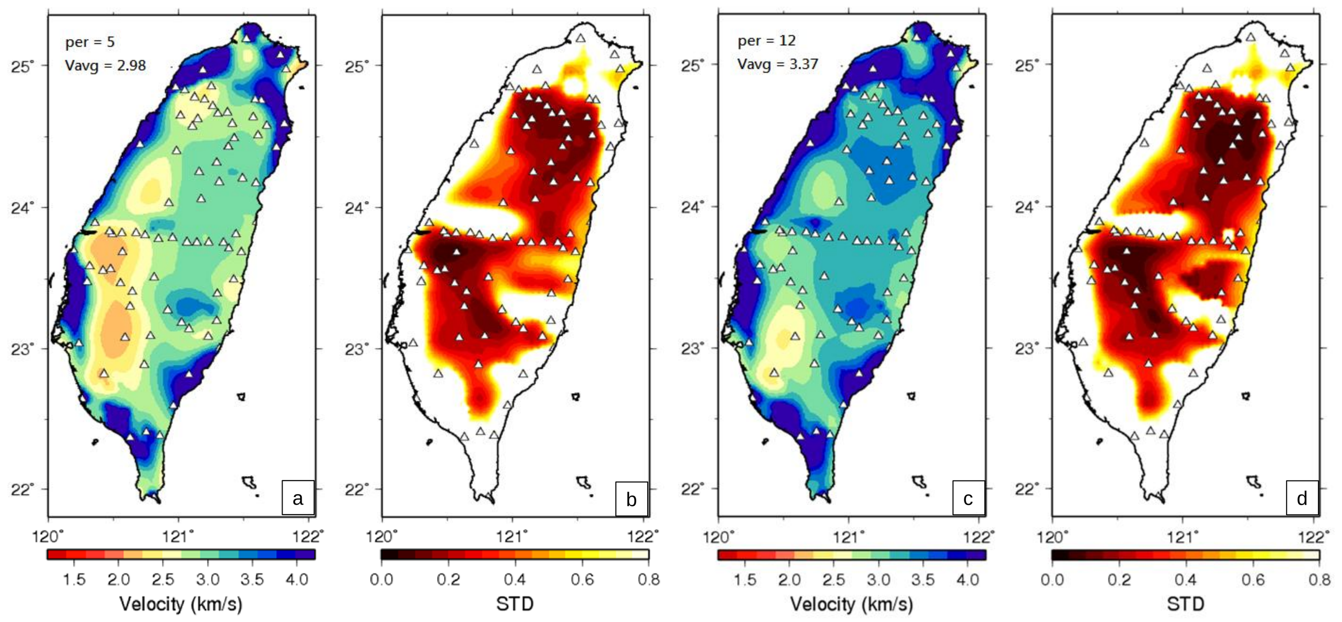


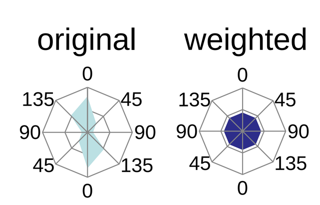
Figure 2. Results of Eikonal tomography. (a) average phase velocity and (b) standard deviation at 5 seconds. (c), (d) same as (a) and (b), but for period 12 seconds.

AZIMUTHMUL WEIGHTING SCHEME

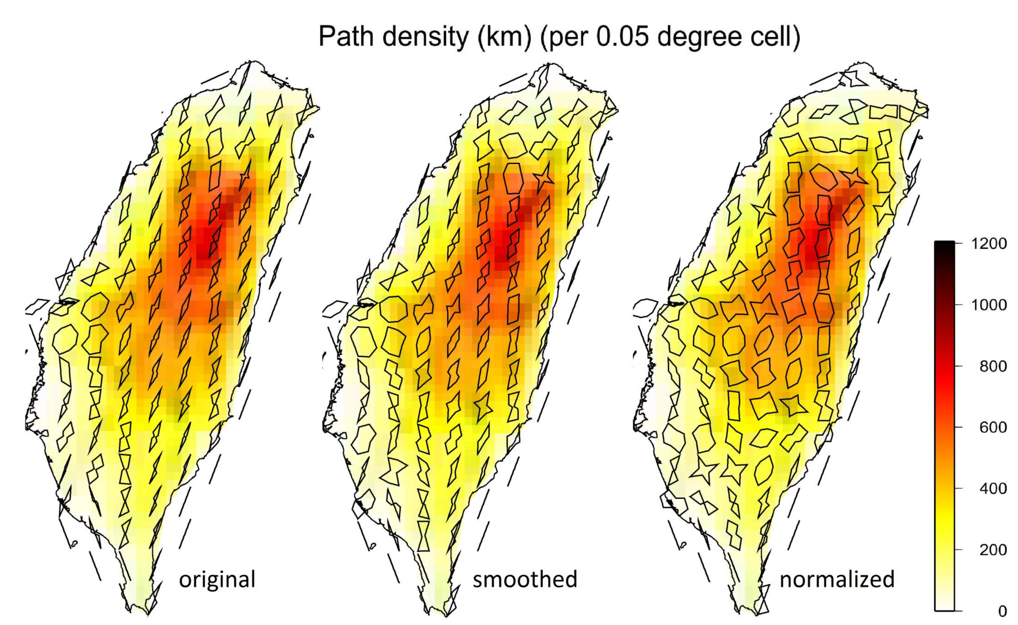
Since the path orientation in Taiwan, especially for paths of longer periods, are dominated by NNE-SSW trend, we explore various weighting scheme to avoid resulting anisotropy being biased by irregular azimuthal path distribution.

weighting for path i

$$\overline{W}_i = \frac{\sum_j^N W_{ij}}{\mathrm{N}} \qquad W_{ij} = \frac{\overline{L}_{bin}\ \text{(average length of each bin)}}{L_{bin}\text{(total length within the bin)}}$$



→ **Figure 3.** Path density and azimuthal coverage in 2 weighting schemes. (a) normalized weighting W. (b) smoothed by square W.



TOPOGRAPHY CORRECTION

By comparing synthetic Green's function with and without topography calculated by SEM, we build up the empirical topography corrections to phase velocities at different periods. (Chen at al, 2012)

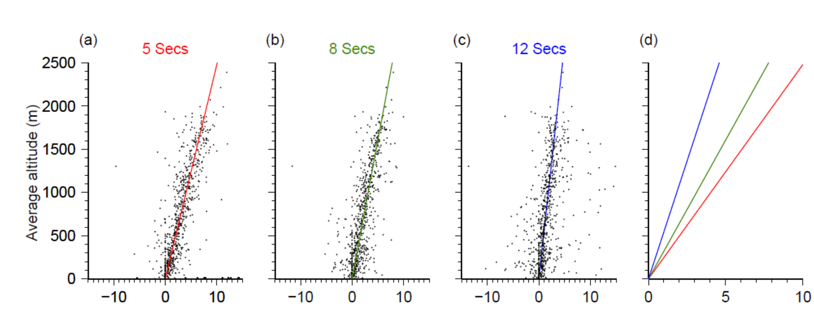


Figure 4. The comparison between phase velocities with and without topography at different period bands. The colored lines are the results of linear regression.

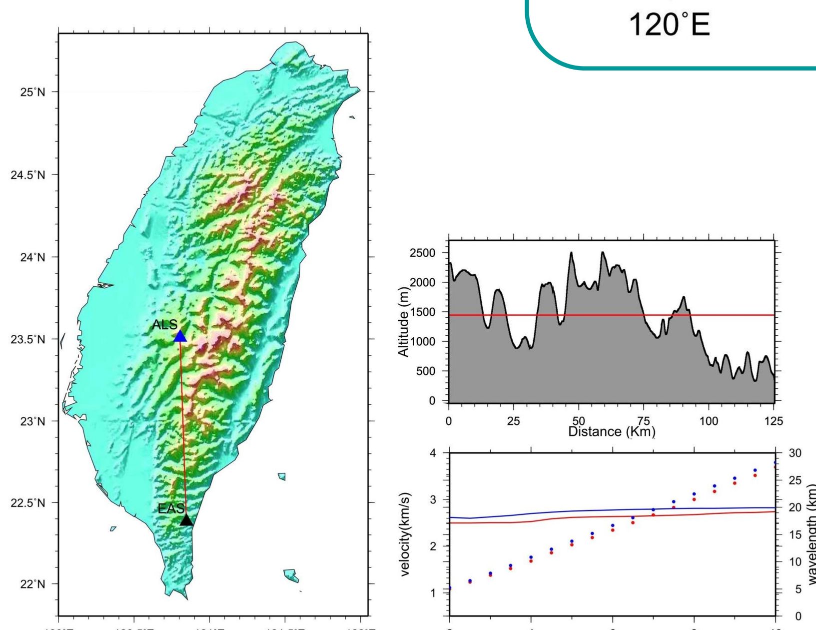


Figure 5. Example of topographic effects in phase velocity measurements.

Synthetic Tests

To ensure our results are not biased by the uneven path azimuthal coverage. We implement the following resolution tests (Fig 6), where the input pattern of western Taiwan in panel (c) is taken from the shear wave splitting results by Chang et al. (2009). All the input amplitude of anisotropy are 0.3 km/s, and no azimuthal weightings are used in this test.

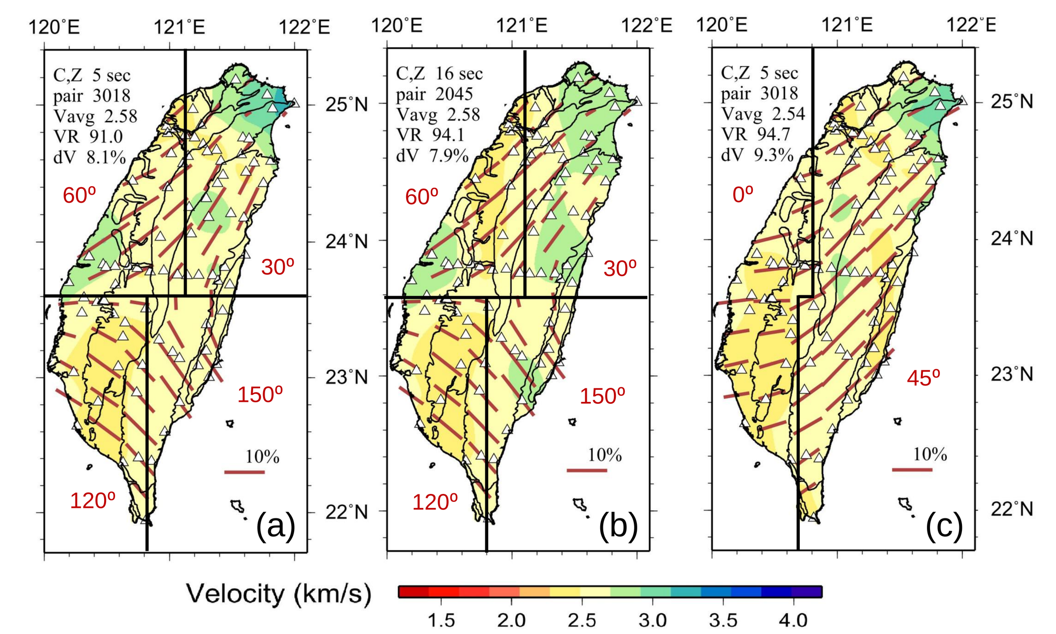


Figure 6. Results of resolution tests. Input models are shown in numbers in each panel, and results are shown in red bars. (a) for period 5 s, (b) input model is the same as (a), but for 12s, and (c) for 5 s but with different input model.

Results – Phase Velocity and Azimuthal Anisotropy

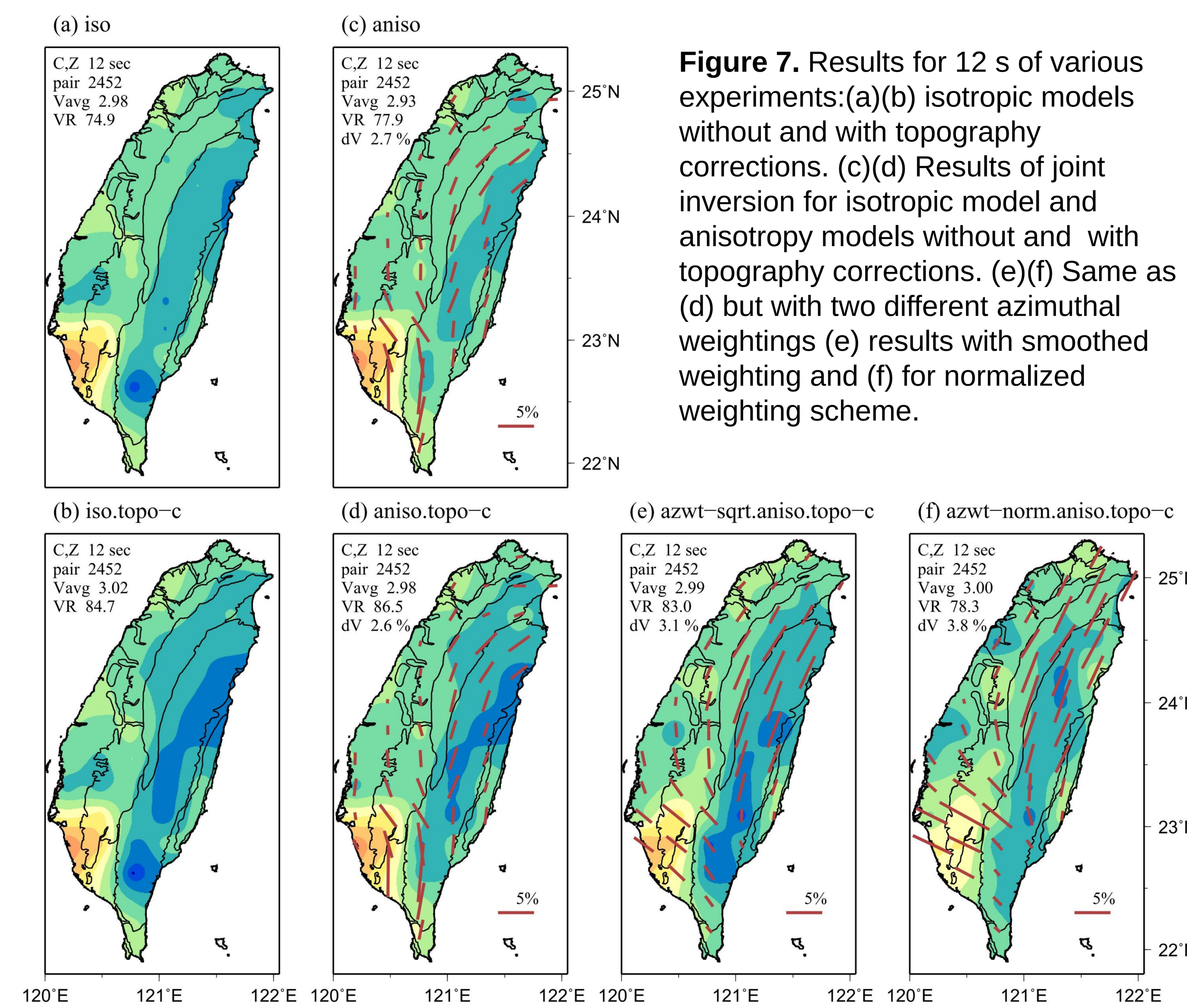
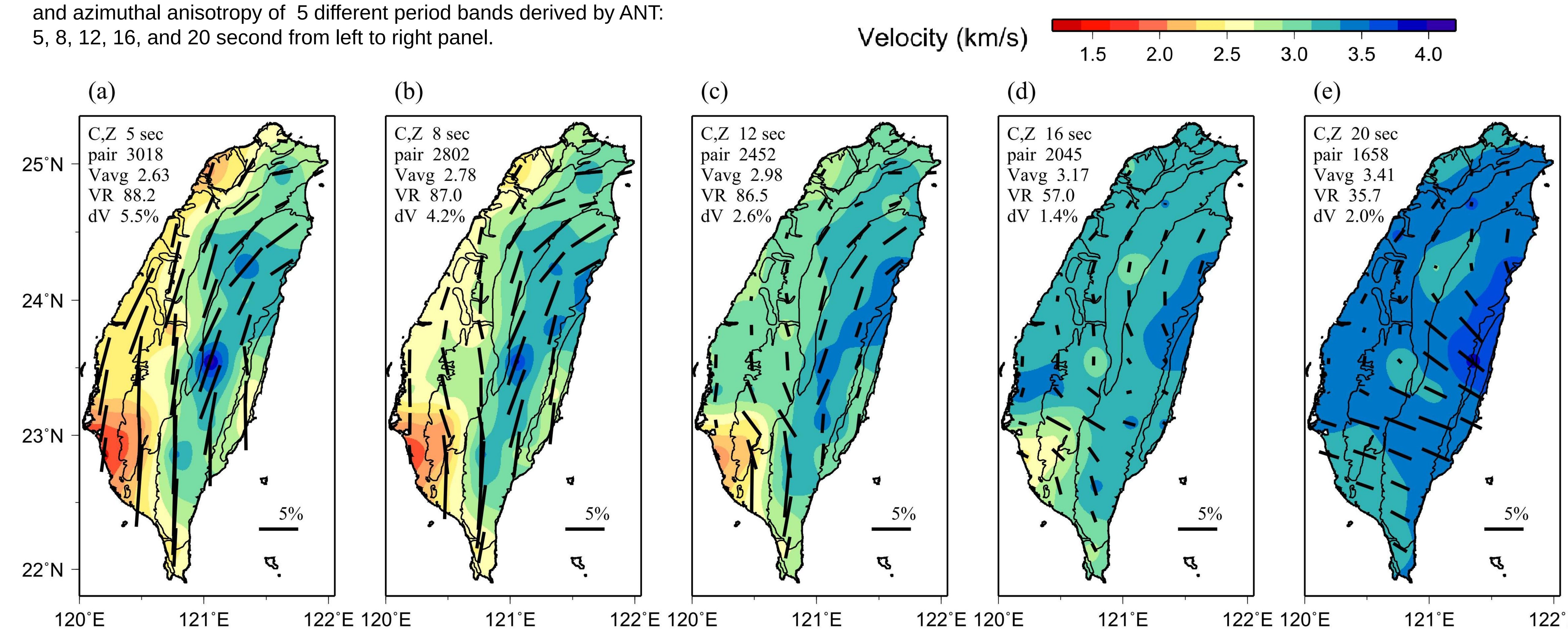


Figure 7. Results for 12 s of various experiments:(a)(b) isotropic models without and with topography corrections. (c)(d) Results of joint inversion for isotropic model and anisotropy models without and with topography corrections. (e)(f) Same as (d) but with two different azimuthal weightings (e) results with smoothed weighting and (f) for normalized weighting scheme.

↘ **Figure 8.** Fundamental mode Rayleigh wave phase velocity maps and azimuthal anisotropy of 5 different period bands derived by ANT: 5, 8, 12, 16, and 20 second from left to right panel.



SUMMARY

1. Robust empirical Green's functions (EGF) derived from island-wide dense seismic networks are used to construct models of Rayleigh wave phase velocity and azimuthal anisotropy using a wavelet-based multi-scale inversion.
2. Eikonal tomography in Taiwan is highly limited by uneven distribution of stations and short inter-station distance in W-E direction.
3. Given the irregular path azimuthal distribution, resolution tests show that it is still possible to recover the azimuthal anisotropy without enforcing any azimuthal weighting.
4. The pattern of our resulting anisotropy model gradually varies with increasing periods, from convergence-perpendicular striking NNE-SSW trend at shorter periods to near convergence-parallel E-W at longer periods, suggesting that there is a strong depth dependence of seismic anisotropy in the crust of Taiwan.

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