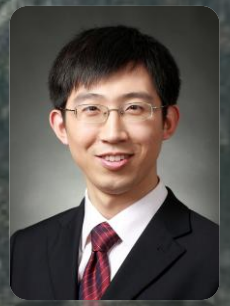
EGU25, Vienna, Austria & Online | 27 April–2 May 2025



V_{S30} Map for Chinese Mainland Constrained by Local V_{S30} Measurements and Incorporating Topographic Slope as Secondary Data via a Cokriging (SCK) Model

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Institute of Geophysics, China Earthquake Administration

2025.4.28

In China, 30 years of engineering construction have generated abundant borehole-based *Vs* measurements — but how can we make full use of these data?

- Large-scale construction projects over the past 30 years have generated hundreds of thousands of borehole data.
- Buildings, bridges, microzonation, etc.

Collected > 3,000 reports, including data > 20,000 boreholes.

Ongoing data collection and model updating.

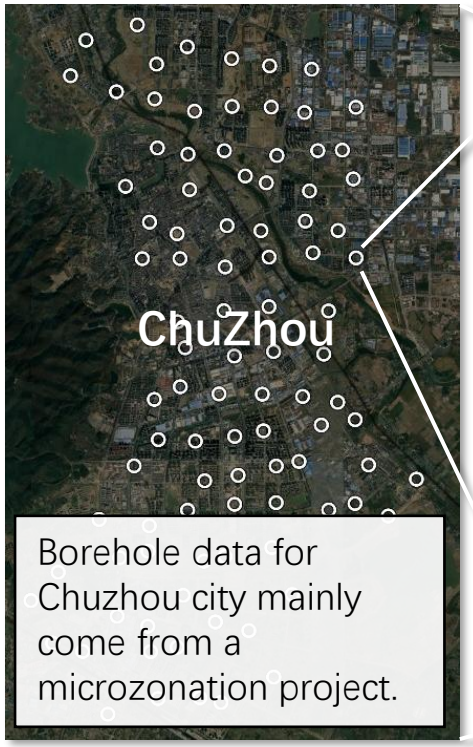
1998 **2007** **2018** **2022** **2025**

The related engineering and microzonation projects span > 20 years.

Developed database, model, and *Vs*30 maps for Chinese mainland

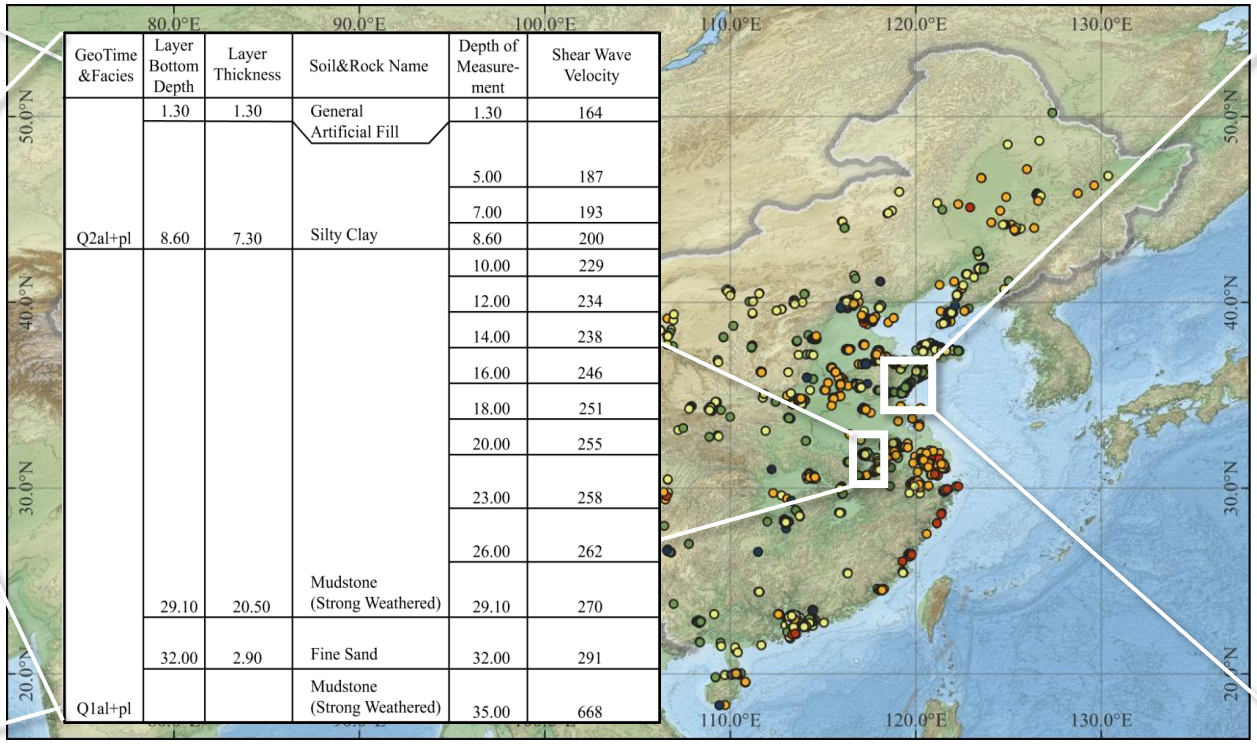
We digitized over 10,000 site profile from engineering and microzonation projects.

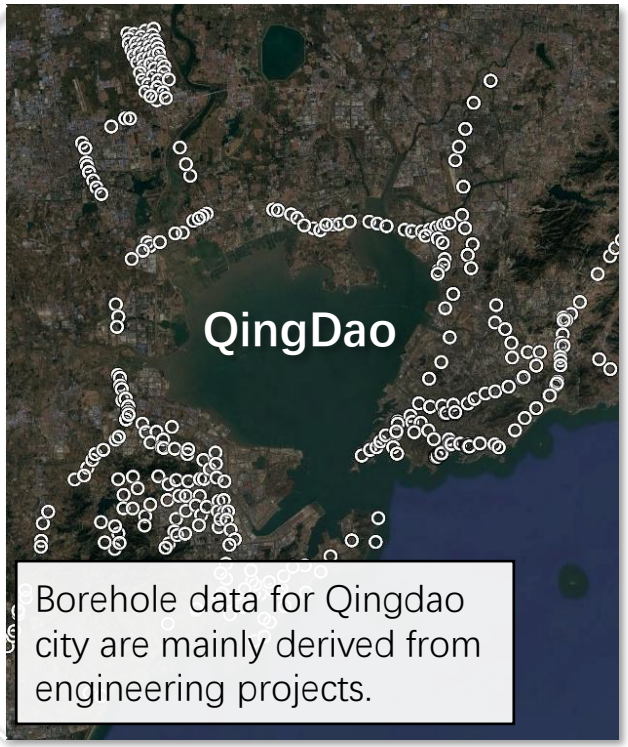
- We digitized 14,214 borehole profiles from engineering and microzonation projects.
- These profiles cover all provinces of Chinese mainland and over 200 major cities.
- Beyond *Vs* profiles, these profiles also include geotechnical soil/rock types, geological age, and depositional environment information.
- 53% of the profiles extend beyond 30 meters, and 7% reach depths greater than 100 meters.



Borehole data for Chuzhou city mainly come from a microzonation project.

GeoTime &Facies	Layer Bottom Depth	Layer Thickness	Soil&Rock Name	Depth of Measure-ment	Shear Wave Velocity
	1.30	1.30	General Artificial Fill	1.30	164
				5.00	187
				7.00	193
Q2al+pl	8.60	7.30	Silty Clay	8.60	200
				10.00	229
				12.00	234
				14.00	238
				16.00	246
				18.00	251
				20.00	255
				23.00	258
				26.00	262
	29.10	20.50	Mudstone (Strong Weathered)	29.10	270
	32.00	2.90	Fine Sand	32.00	291
Q1al+pl			Mudstone (Strong Weathered)	35.00	668



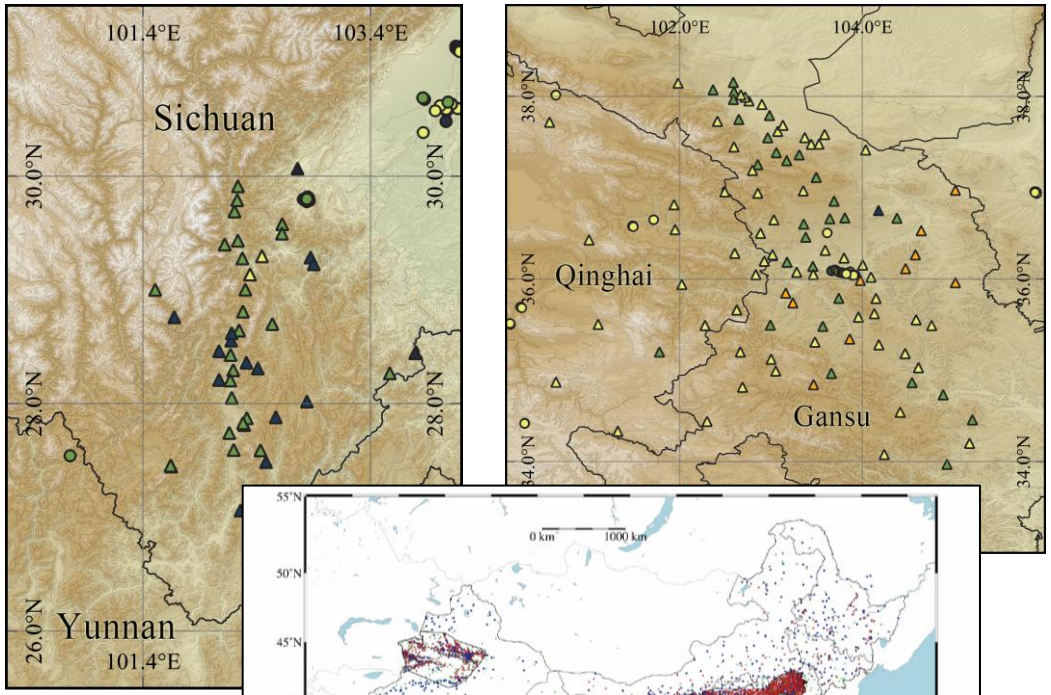


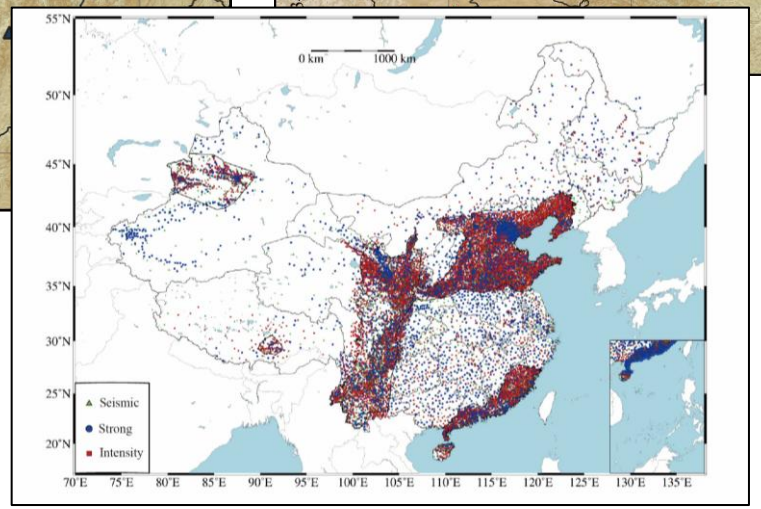
Borehole data for Qingdao city are mainly derived from engineering projects.

Zhou, J. et al., 2021. https://doi.org/10.1785/0120200178

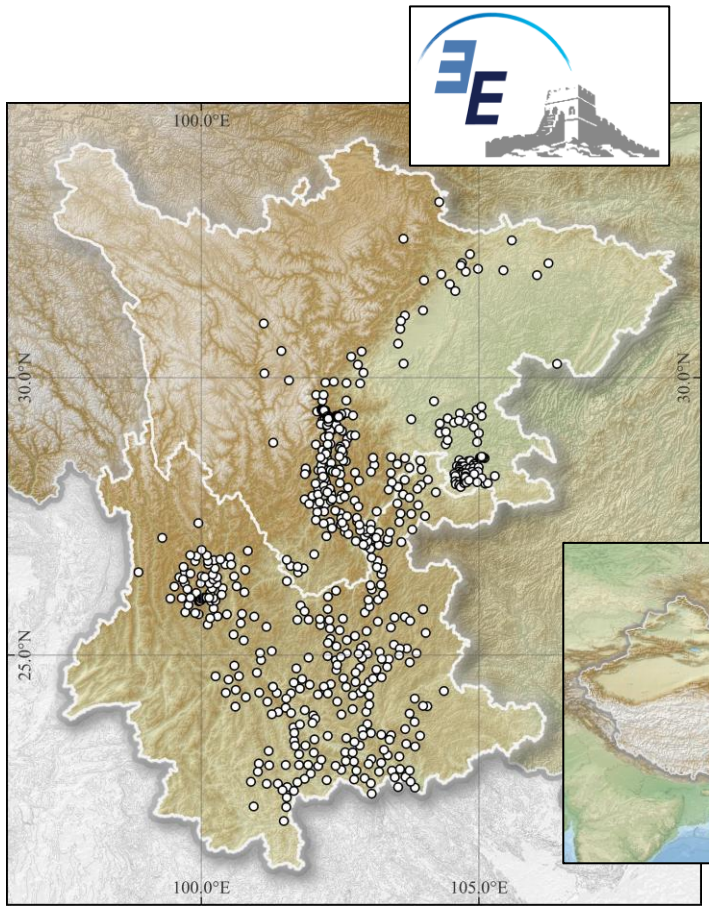
We also collected site *Vs* profiles from seismic stations.

- We have collected borehole-measured site profiles from 1,500 strong-motion stations within China's Earthquake Early Warning System.



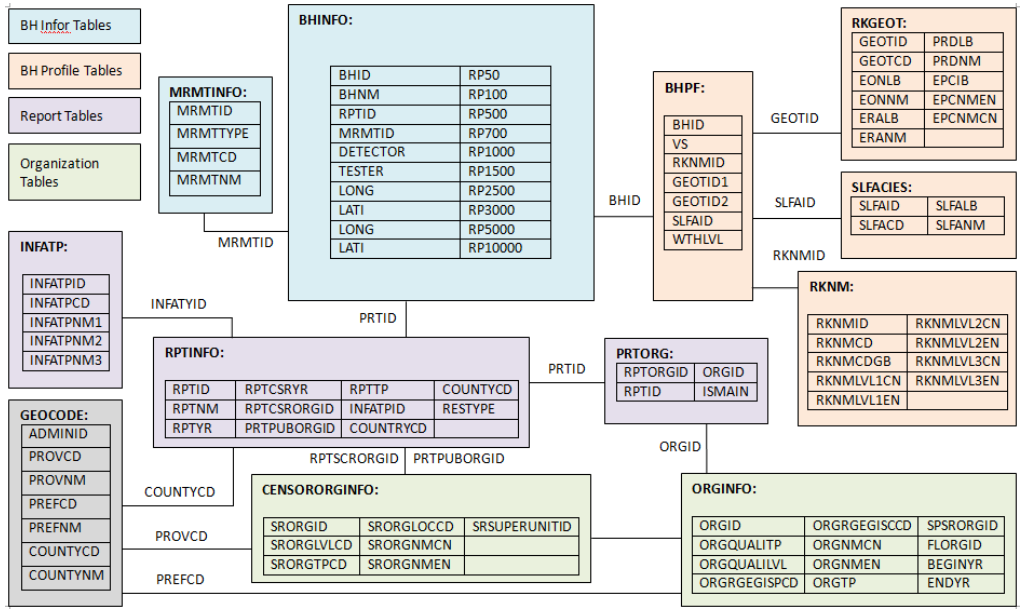


- We are conducting borehole measurements at 602 seismic stations in the mountainous regions of Sichuan and Yunnan, as part of the Seismic Experimental Site Project (2022–2027).

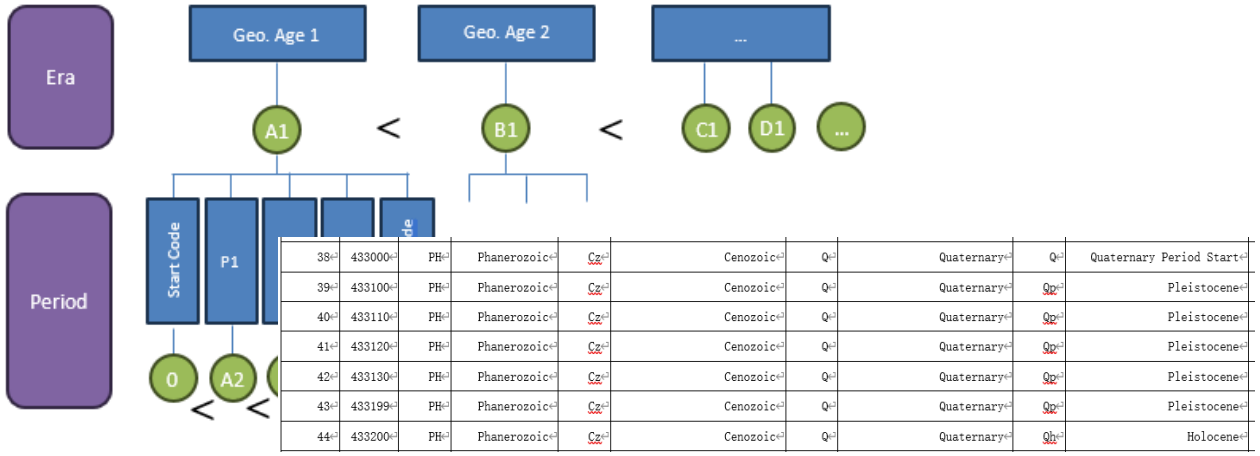


We developed a site profile database and a data platform

- Structured SQL database format instead of flat file storage

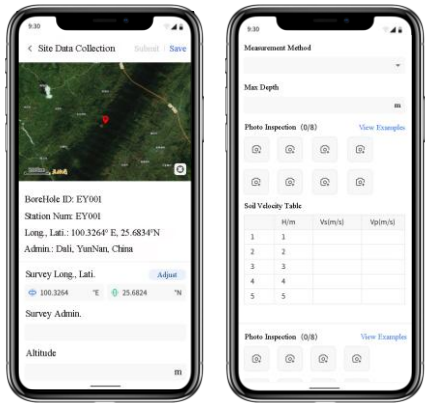


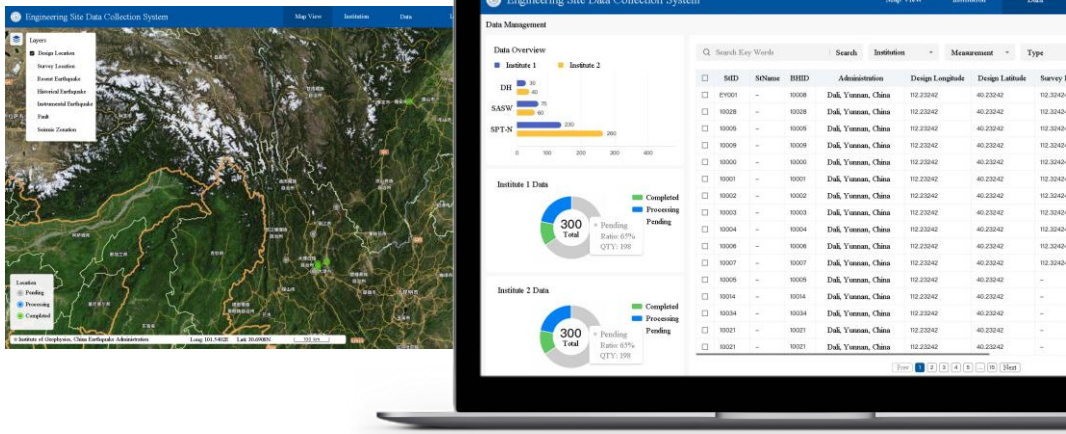
- Geological age, depositional environment, and other textual information were encoded to enable numerical analysis and comparison.



38	433000	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Q	Quaternary Period Start
39	433100	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Qp	Pleistocene
40	433110	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Qp	Pleistocene
41	433120	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Qp	Pleistocene
42	433130	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Qp	Pleistocene
43	433199	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Qp	Pleistocene
44	433200	PH	Phanerozoic	Cz	Cenozoic	Q	Quaternary	Qh	Holocene

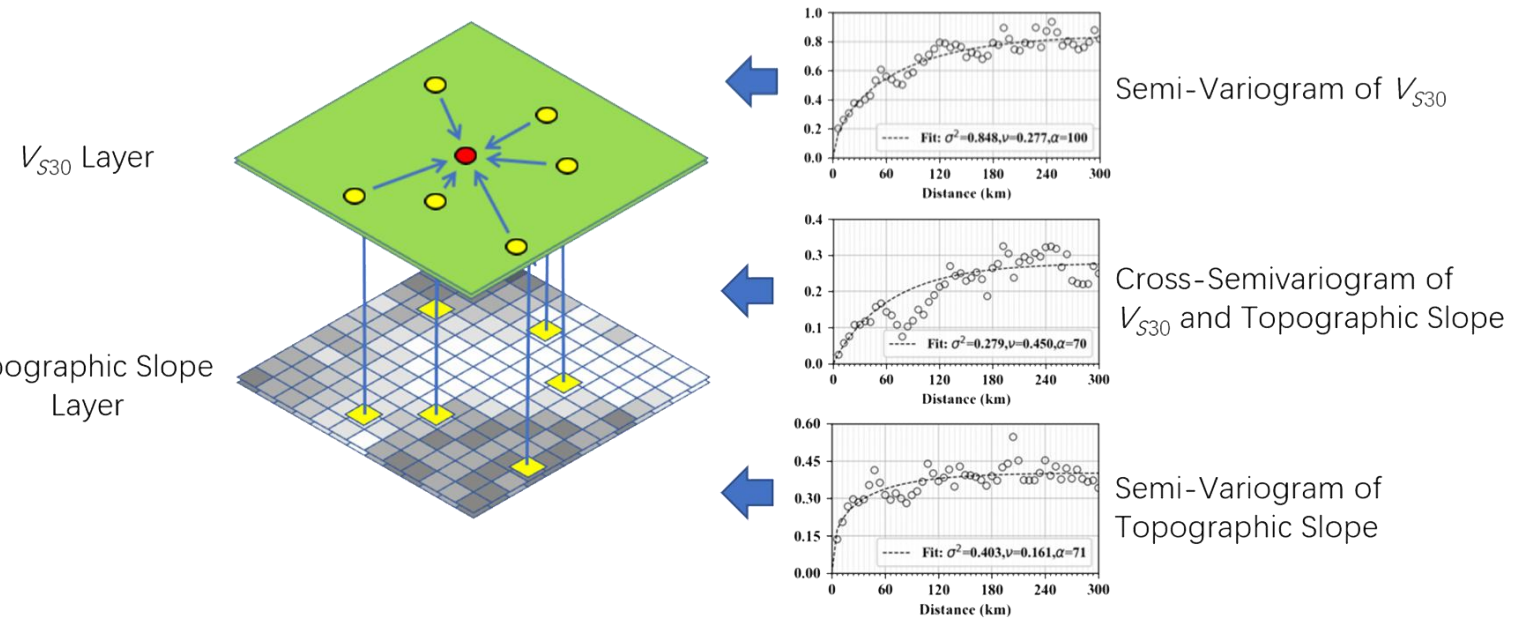
- The data platform enables real-time integration of borehole data from field surveys into the database, with dynamic display on a map interface.





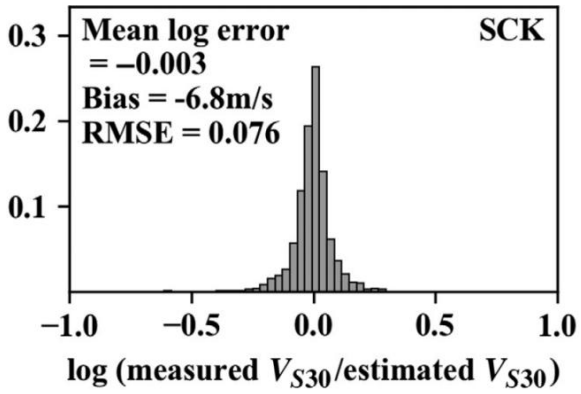
We developed a cokriging-based $Vs30$ proxy model (SCK model)

- We proposed a $Vs30$ proxy model based on the cokriging method (SCK model).
- The model estimates $Vs30$ using nearby measurement data as constraints and topographic slope as a secondary variable.



SCK

RMSE = 0.076

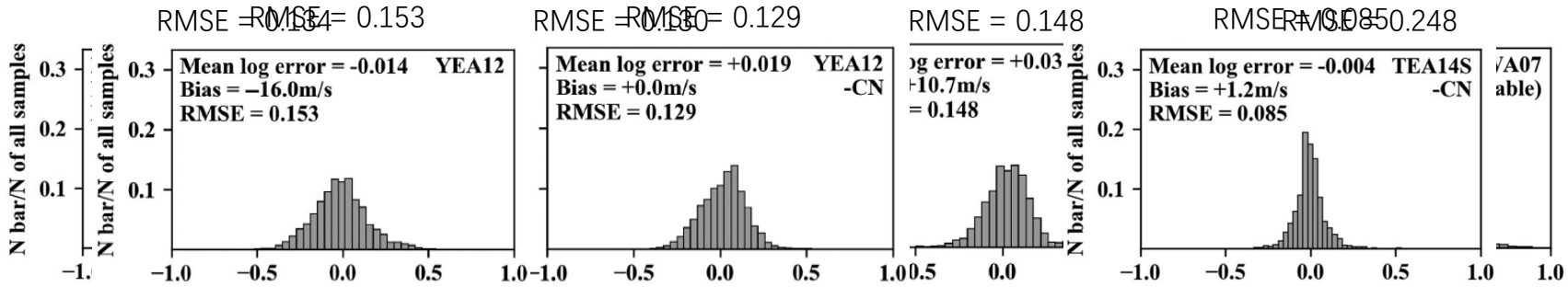


USGS topographic slope ShakeMap

Yong et al. (2012)

(Wald&Allen 2007)

Thompson et al. 2014



Zhou, J. et al., 2022. https://doi.org/10.1785/0120210227

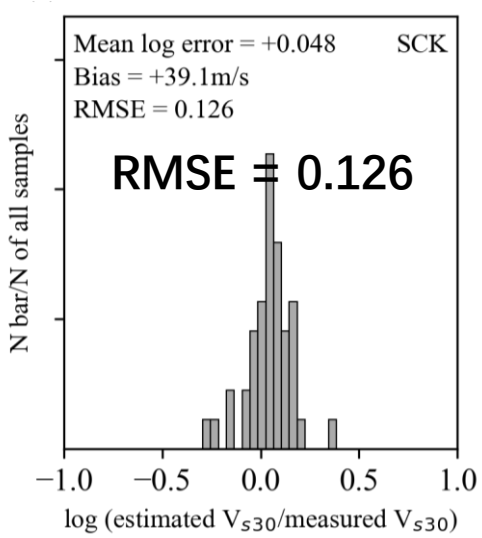
We validated the SCK model using borehole data from other regions.

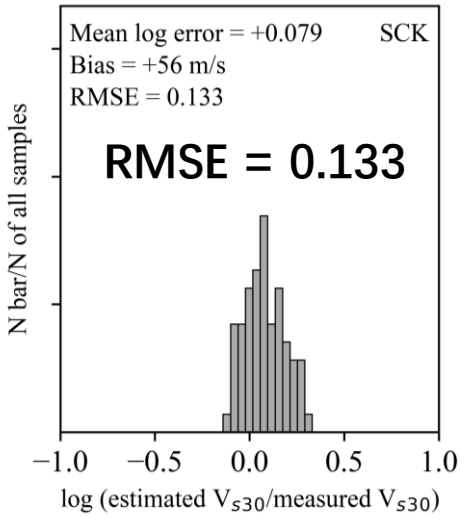
Sichuan, China

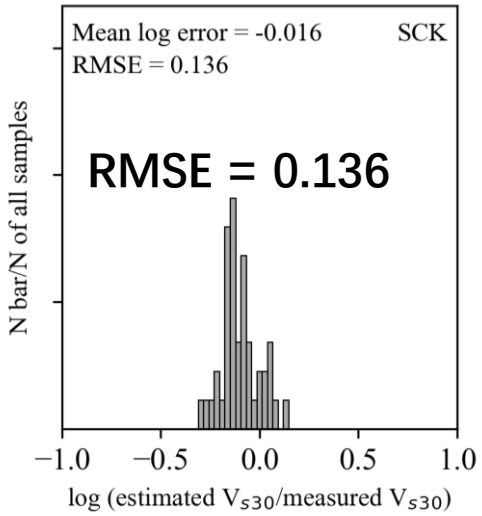
Gansu, China

Türkiye

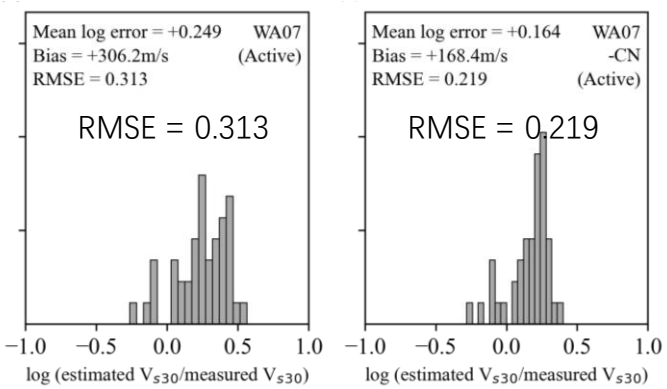
SCK Model

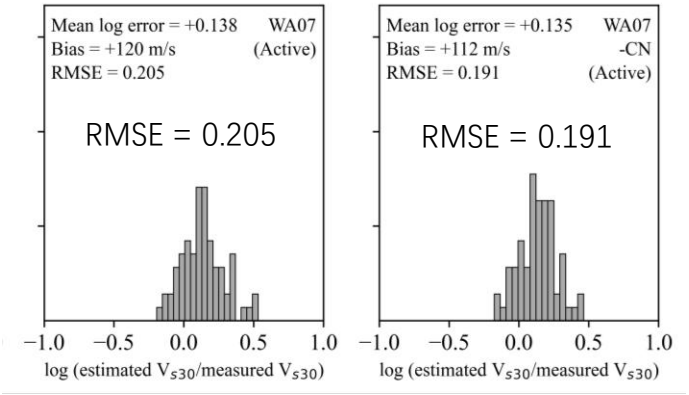


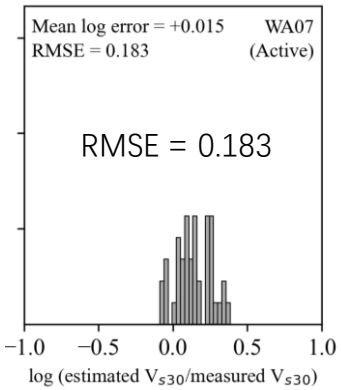




USGS Topographic slope Model



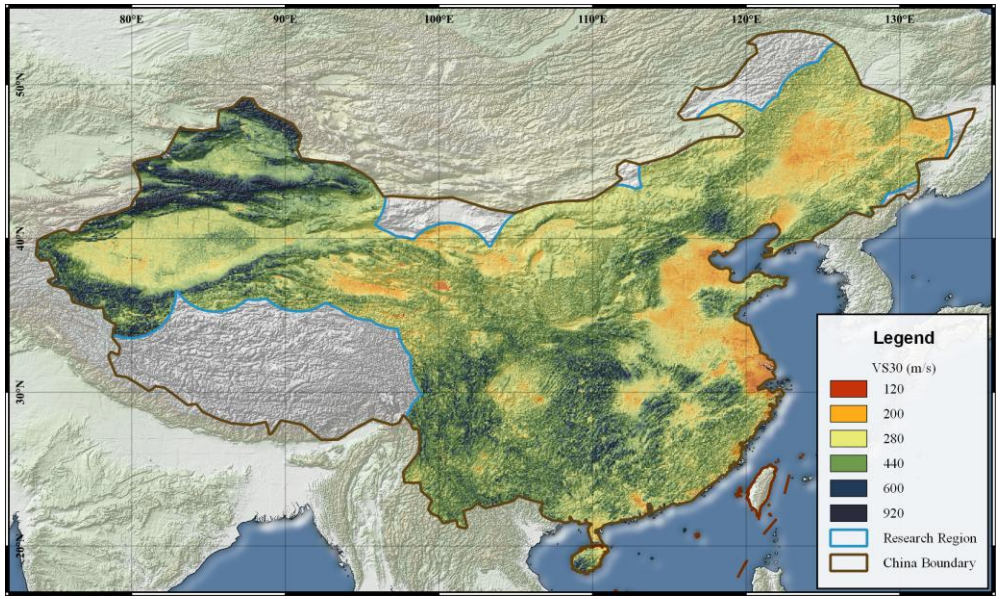




Using the SCK model, we developed *Vs*30 Maps for Chinese mainland and other regions

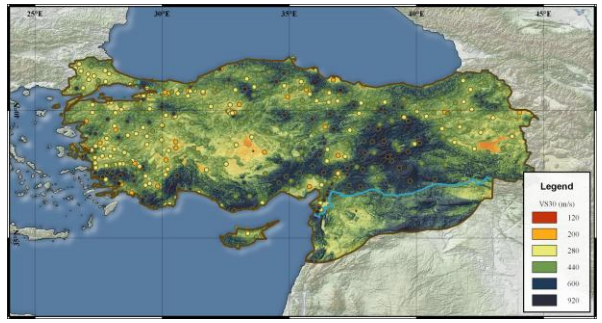
- 7,797 *Vs*30 measurements
- Covers most regions of Chinese mainland

*Vs*30 Map for Chinese mainland (2022)

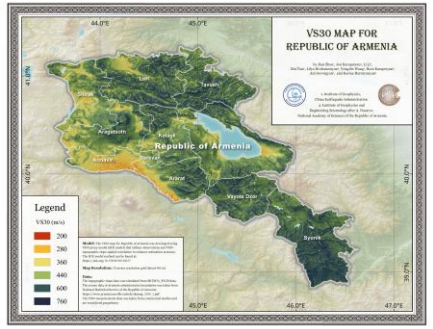


Zhou, J. et al., 2022. https://doi.org/10.1785/0120210227

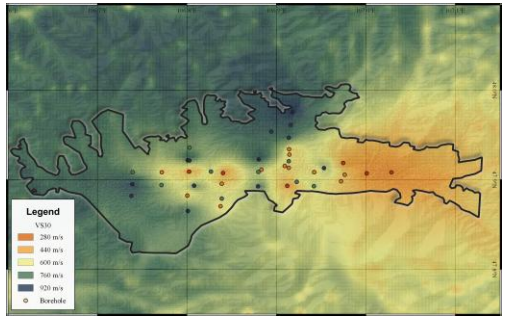
Türkiye



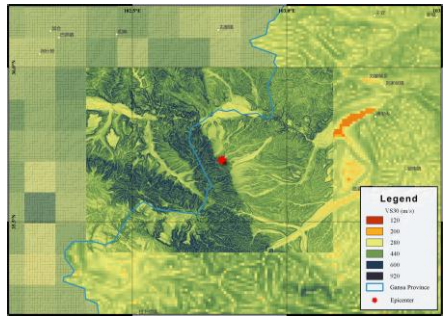
Armenia



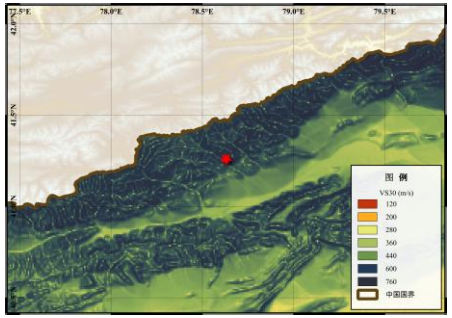
Ulaanbaatar, Mongolia



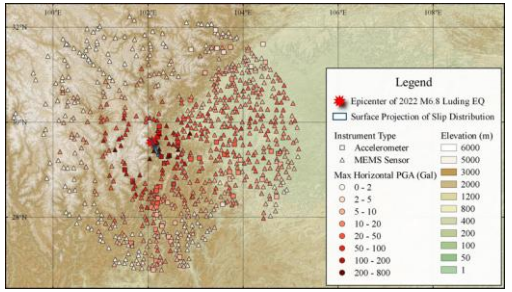
Jishishan, China



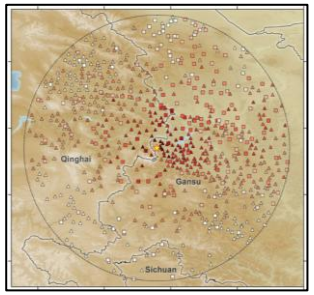
Wushi, China



Sichuan Strong-motion Stations



Gansu Strong-motion Stations

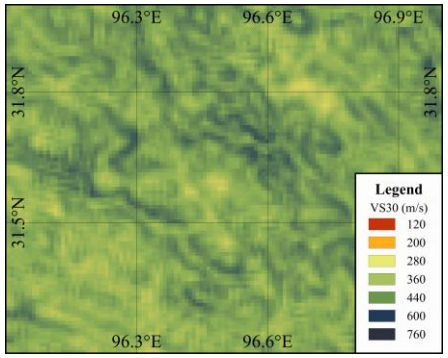


In 2024, we refined the SCK model.

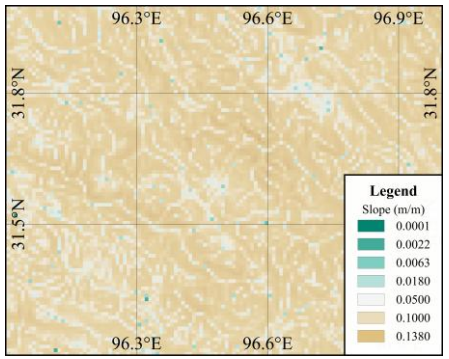
- Emphasized the influence of surrounding terrain on *Vs*30;
- Ensured azimuth coverage when selecting neighboring *Vs*30 measurements;
- Expanded the model's calculation range.

Where no measurements are available, the model output becomes entirely controlled by topographic slope.

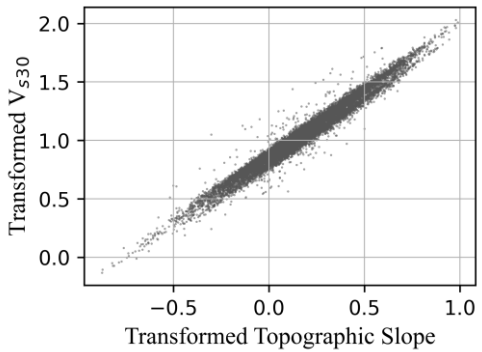
*Vs*30



Topographic Slope



*Vs*30 -Topographic Slope

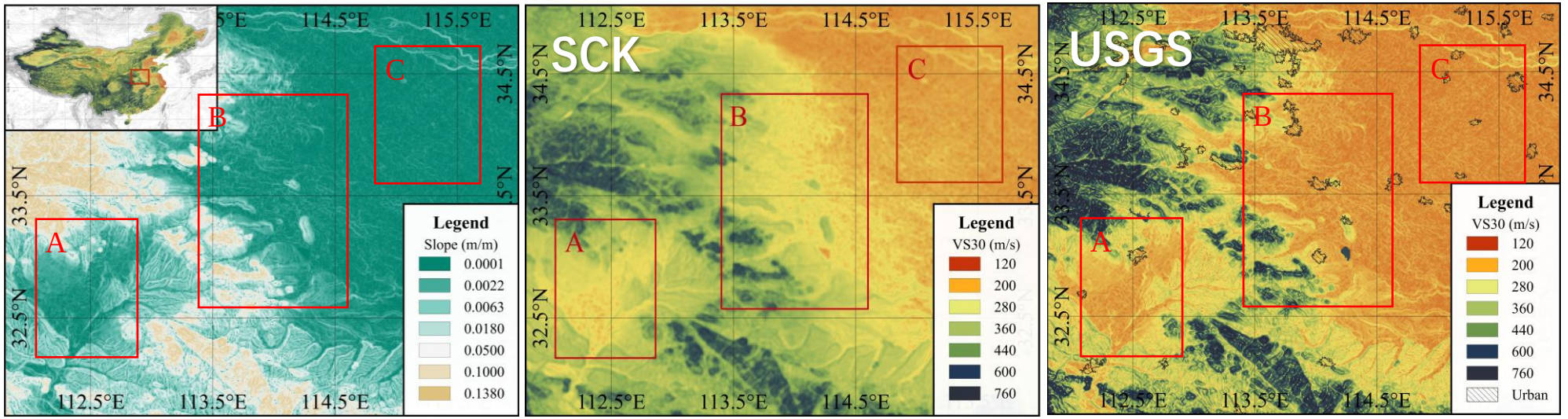


Consider surrounding slope values rather than the value at a single point.

Similar topographic slope values

The *Vs*30 in the plain is lower than that in the mountain front and basin.

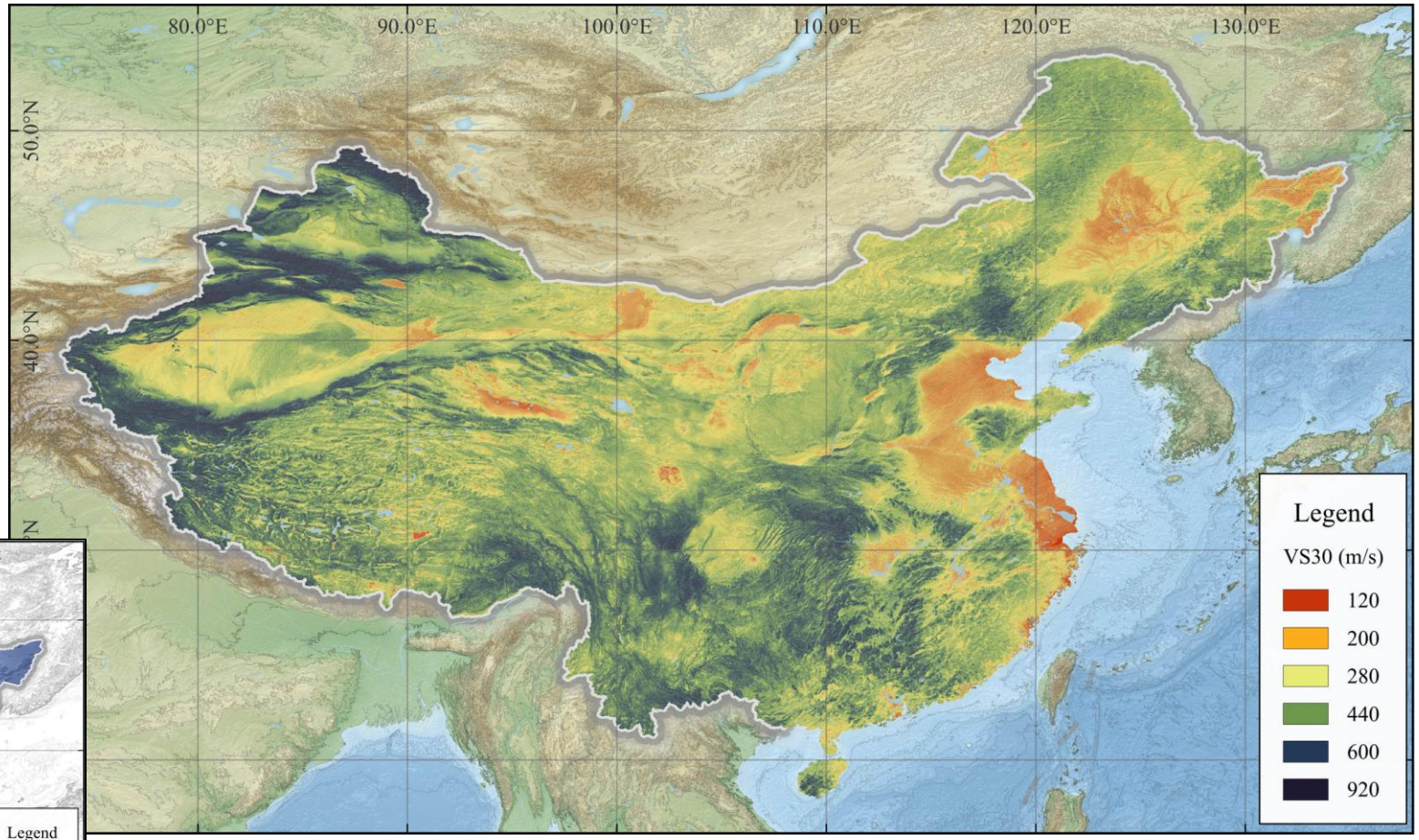
The *Vs*30 in the plain is similar to that of the mountain front and basin.

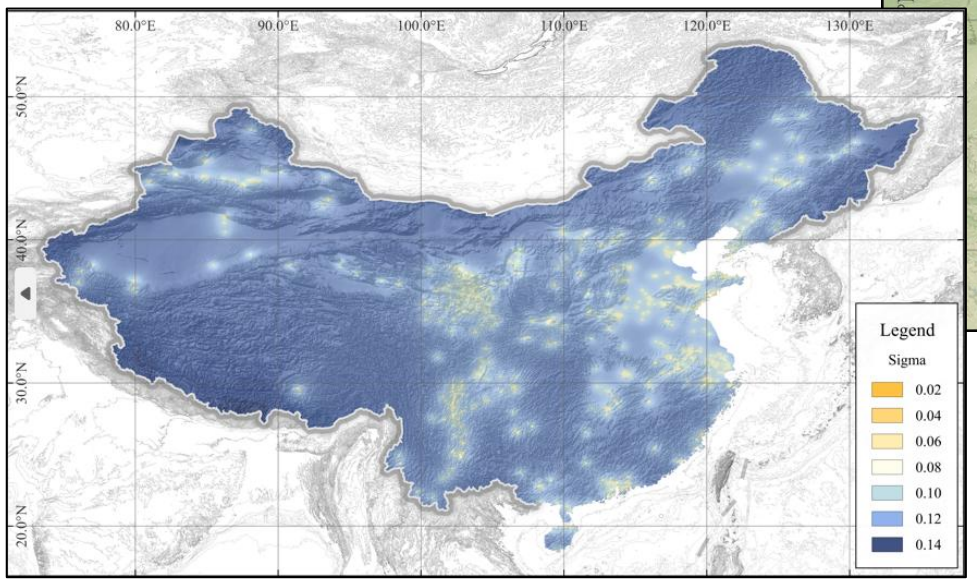


Zhou, J. et al., 2024. https://doi.org/10.1785/0120240104

*Vs*30 map for Chinese mainland - 2024 version

- Based on the refined SCK model
- 7,797 *Vs*30 measurements, plus 142 from strong-motion stations
- 30 arcsec resolution (~900 m)
- Covering all regions of Chinese mainland





The map data can be downloaded at: https://seismisite.net/index_en.html

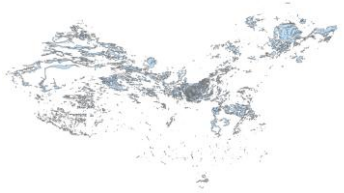
Zhou, J. et al., 2024. https://doi.org/10.1785/0120240104

Incorporating geological age and depositional environment as new parameters to build a hybrid model

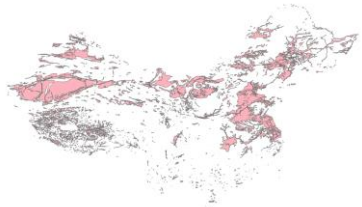
- 1: 1,500,000-scale geology map
- 19 classes based on surface geological age and depositional environment.
- Considered sample bias from preferential sampling within each class.

China Geology Map

Qp_All



Qh_All

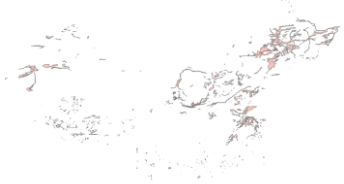


Pz+PrePz

Qh_alpl

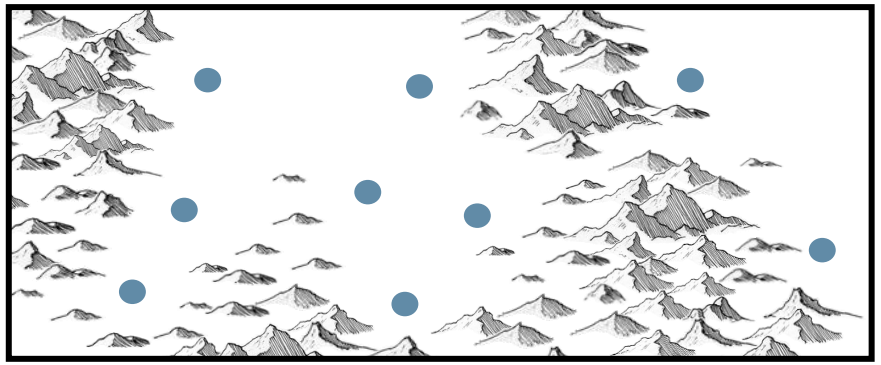
Mz

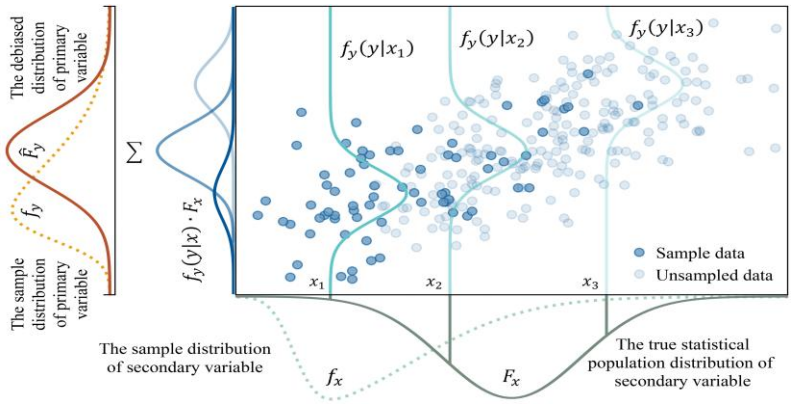
Qh_al



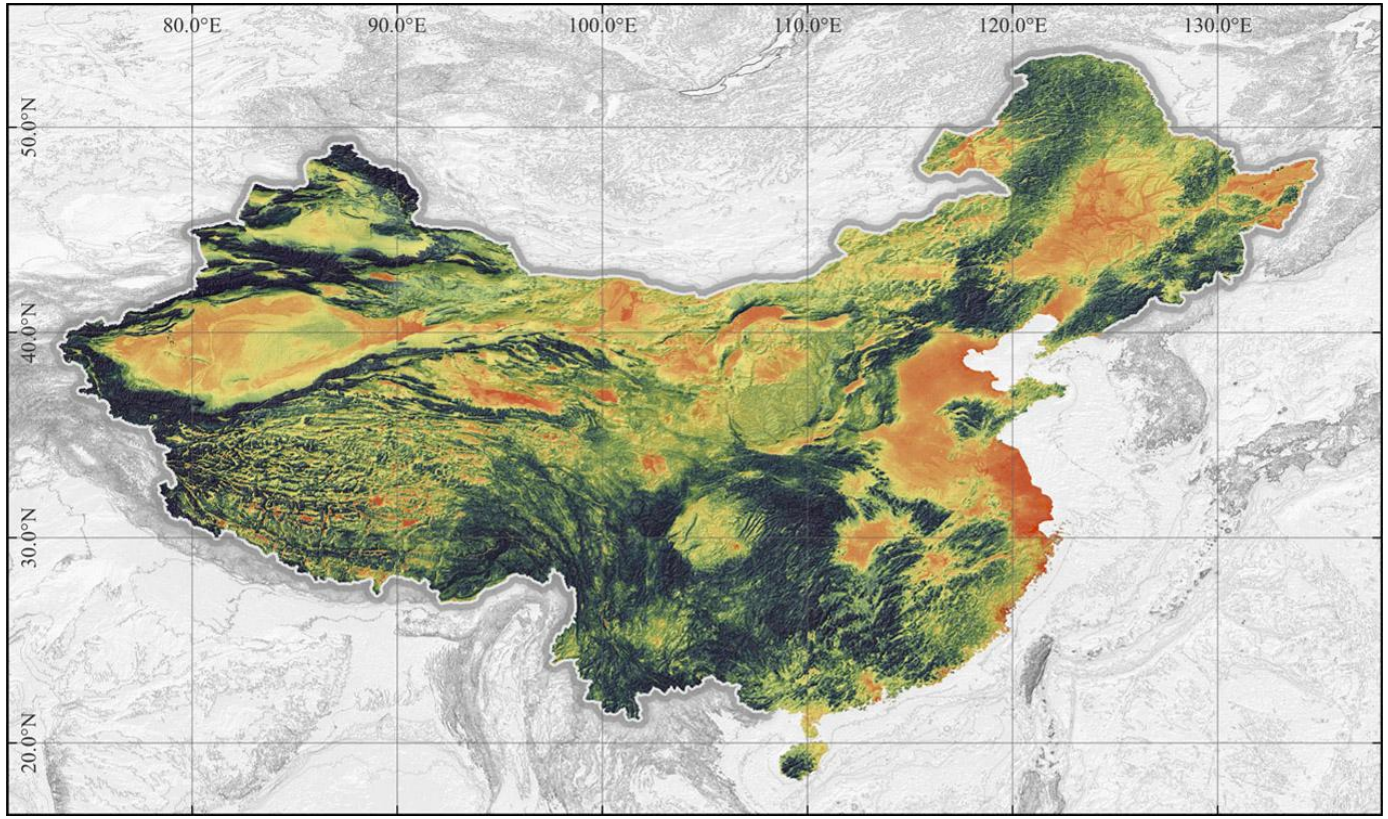
Consider preferential sampling bias when estimating the mean and std of *Vs30*

- Preferential sampling occurs when certain values are more likely to be sampled than others.
- Flat terrains are often over-sampled, while mountainous regions are under-sampled.
- This bias cannot be detected solely from the spatial distribution of samples.
- We proposed a method to mitigate preferential sampling bias using a secondary parameter.





Preliminary (unpublished)



zhou et al., 2024. https://doi.org/10.1785/0220230376

Summary

- We digitized over 14,214 $Vs30$ measurements across Chinese mainland.
- We developed a cokriging-based $Vs30$ proxy model (SCK model) in 2022 and refined it in 2024.
- We produced a $Vs30$ map for Chinese mainland using the SCK model and 7,797 $Vs30$ measurements.
- We updated the map in 2024 using the refined SCK model and 7,939 $Vs30$ measurements.
- We are incorporating geological age and depositional environment as new parameters to build a hybrid $Vs30$ model and develop the next version of the $Vs30$ map for Chinese mainland.
- We addressed preferential sampling bias and proposed a secondary-parameter-based debiasing method.

Related Journal Articles

- **Site Profile Database Introduction:**

  Zhou, J., X. Li, Z. Dai, and K. Chen (2021). Parametrical Model for Estimating *Vs*30 from Shallow Borehole Profiles Using a Database for China, Bull. Seismol. Soc. Am. 111, 1199–1220, https://doi.org/10.1785/0120200178

- **Cokriging *Vs*30 Proxy (SCK) Model and 2022 version of *Vs*30 Map for Chinese Mainland:**

  Zhou J., X. Li, X. Tian, and G. Xu (2022). New Framework of Combining Observations with Topographic Slope to Estimate *Vs*30 and Its Application on Building a *Vs*30 Map for Mainland China, Bull. Seismol. Soc. Am. 112, 2049–2069, https://doi.org/10.1785/0120210227

- **Refined SCK Model and 2024 version of *Vs*30 Map for Chinese Mainland:**

  Zhou, J., L. Li, X. Li, N. Xi, and X. Tian (2024). A 30 Arcsec Resolution *Vs*30 Map for Mainland China Using Refined Topographic Slope-Based Cokriging (SCK) Model, Bull. Seismol. Soc. Am. 115, 332–348, https://doi.org/10.1785/0120240104

- **Preferential Sampling Debias Method Using Secondary Parameters:**

  Zhou, J., L. Li, and X. Li (2024). Investigating Sampling Bias in Seismological Research Through Secondary Variable: Insights from *Vs*30 Datasets of Mainland China, Japan, Türkiye, and Taiwan, Seismol. Res. Lett. XX,1–14, https://doi.org/10.1785/0220230376

Thanks

https://www.Seismisite.net

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