Investigation of climate sensitive natural hazards using machine learning approach

Student：Yu-Lun Mai[1)]
Supervisor：Kate Hui-Hsuan Chen[2)]、Wan-Ru Huang[2)]、Hsiang-Han Chen[2)]
Acknowledgement：Chun-Hsiang Chan[2)]、Wei Peng[2)]、Yao-Chieh Chen[2)]
[1)] *National Taichung University of Education*
[2)] *National Taiwan Normal University*

Key Questions

- Is there a regional difference in the climate sensitivity of surface deformation?
- Can we develop a climate sensitivity model of surface deformation?

Surface Deformation and natural hazard

The Global Navigation Satellite System (GNSS) can detect subtle surface deformations, helping us better understand earthquakes and natural hazards.

- (**Fig. 1A**) shows the time series at station HUAL in Hualien, where the sudden subsidence on February 6, 2018 corresponds to the Mw 6.4 earthquake, and its decay resembles the temporal pattern of seismicity.
- (**Fig. 1B**) shows gradual deformation that closely follows groundwater level variations rather than seismicity, indicating hydrological control on the seasonal signal.

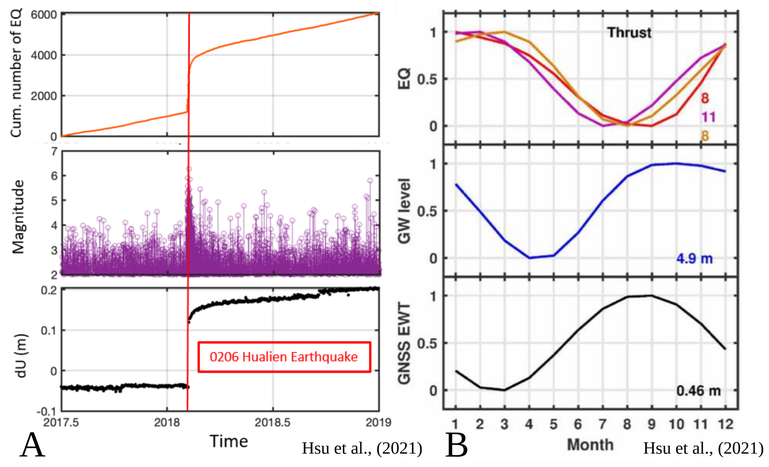
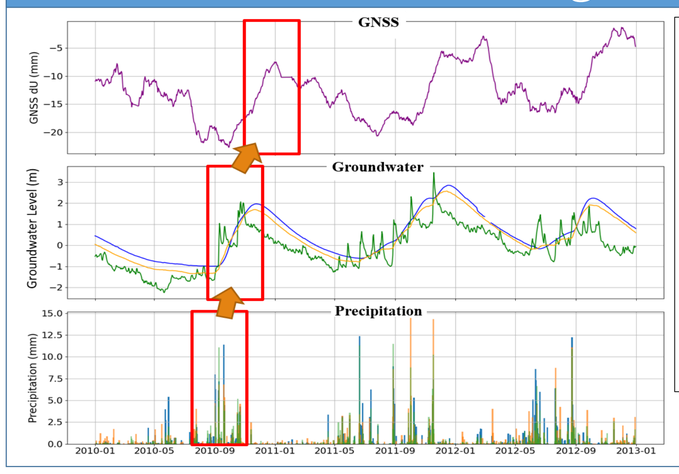


Fig. 1 The relationship between surface deformation and natural hazard

Factors affecting surface deformation



- **(Fig. 2)**This figure shows time series of GNSS vertical displacement, groundwater level, and precipitation in the Taipei area. All three display annual periodicity with a time lag, where rainfall increases groundwater level, which in turn uplifts the ground surface.
  This demonstrates that GNSS is highly sensitive to environmental and hydrological changes.

Fig. 2 Correlation between surface deformation and environmental characteristics

Research Process

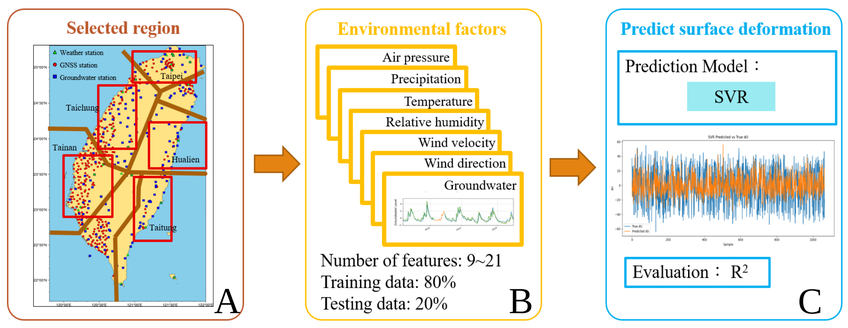


Fig. 3 Research framework diagram

- **(Fig. 3A)** Study areas follow Taiwan's seismic zoning.
- **(Fig. 3B)** For each GNSS station, 9–21 nearby environmental features are selected.
- **(Fig. 3C)** SVR is applied with 80% training and 20% testing data, and performance is evaluated by R^2.

Prediction results for different areas

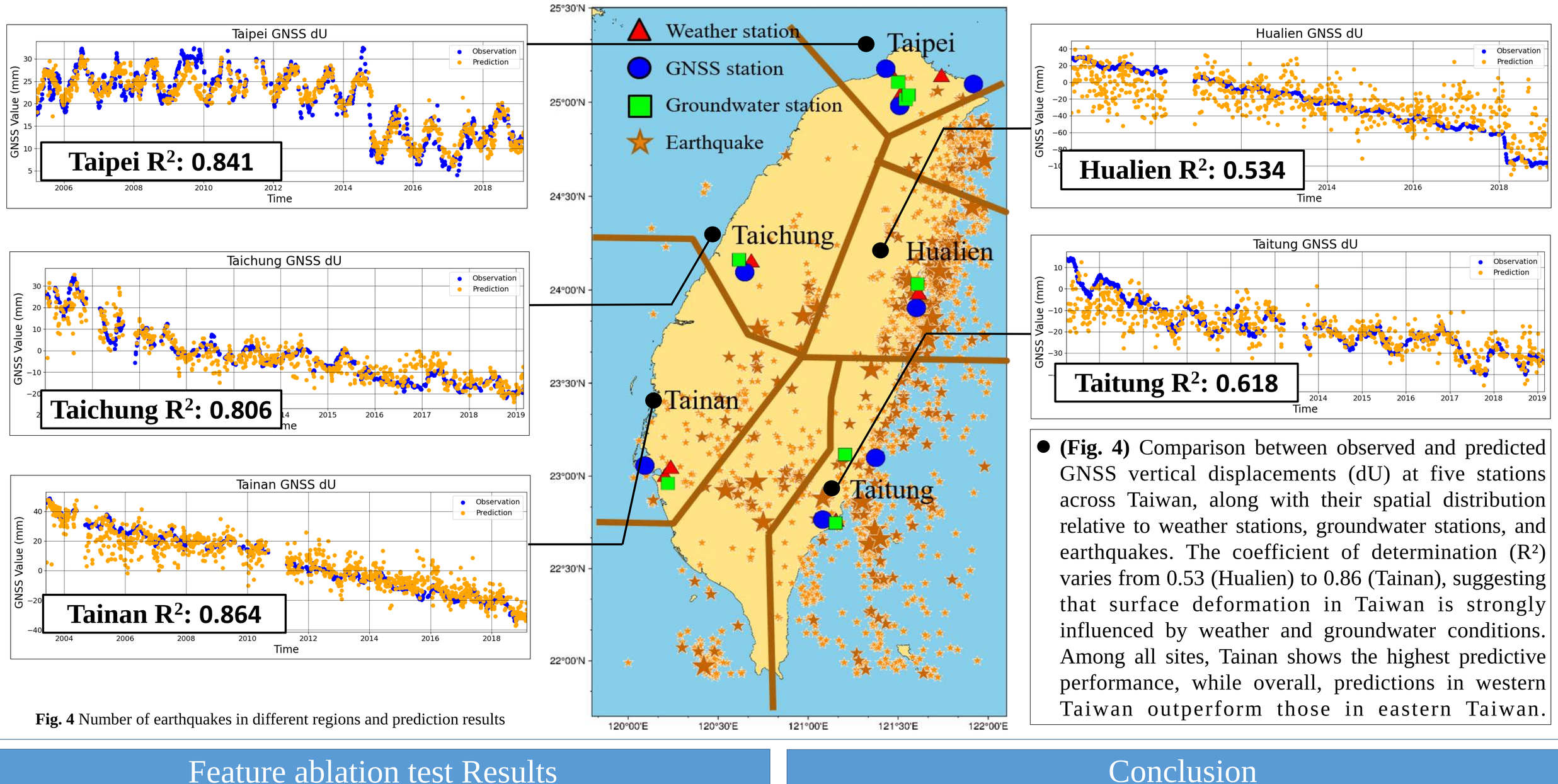


Fig. 4 Number of earthquakes in different regions and prediction results

- **(Fig. 4)** Comparison between observed and predicted GNSS vertical displacements (dU) at five stations across Taiwan, along with their spatial distribution relative to weather stations, groundwater stations, and earthquakes. The coefficient of determination (R^2) varies from 0.53 (Hualien) to 0.86 (Tainan), suggesting that surface deformation in Taiwan is strongly influenced by weather and groundwater conditions. Among all sites, Tainan shows the highest predictive performance, while overall, predictions in western Taiwan outperform those in eastern Taiwan.

Feature ablation test Results

Feature removed	R^2 after removal	ΔR^2 (R^2 after removal – Baseline R^2)	Influence Ranking
Baseline (all features)	0.864	--	--
Pressure	0.869	+0.005	5
Precipitation	0.883	+0.019	6
Temperature	0.844	-0.020	3
Relative humidity	0.834	-0.030	2
Wind speed	0.886	+0.022	7
Wind direction	0.867	+0.003	4
Ground water	0.689	-0.175	1

Tbl. 1 Feature ablation test Results

- **(Tbl. 1)** Feature removal analysis indicates that groundwater level is a key factor, exerting a notable influence on GNSS surface deformation predictions.

Number of earthquakes in each region

Area	Magnitude ≧ 4	Magnitude ≧ 5	Magnitude ≧ 6
Taipei	57	7	0
Taichung	83	12	3
Tainan	101	10	1
Hualien	716	85	7
Taitung	417	50	5

Tbl. 2 Number of earthquakes with a magnitude of 4 or above in different regions

- **(Tbl. 2)** Hualien and Taitung experience more earthquakes than other regions, which may explain the lower predictive performance when using only environmental features. This suggests that tectonic activity is an important factor in GNSS surface deformation.

Conclusion

- Surface deformation is influenced by both geological hazards and environmental factors.
- SVR can stably predict GNSS time series using environmental data
- Groundwater level is the most significant environmental factor affecting deformation.
- Prediction works better in western Taiwan than in eastern Taiwan
- Tectonic activity reduces prediction accuracy, while stable regions show stronger correlations.

Reference

1. Hsu et al.,(2020). Assessing seasonal and interannual water storage variations in Taiwan using geodetic and hydrological data
2. Hsu et al.,(2021). Synchronized and asynchronous modulation of seismicity by hydrological loading: A case study in Taiwan