Detection and prediction of groundwater level variation using wavelet analysis

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1. Introduction

Due to the uneven distribution of rainfall time and space and the climate change, the hydrological uncertainty has been increasing. Therefore, how to manage limited water resources effectively and sustainably is a crucial issue.

The southern part of Taiwan depends strongly on the groundwater, causing serious land subsidence there. To prevent the ground subsidence and promote wise use of the groundwater, it is necessary to understand the relationship between rainfall, human pumping, groundwater flow rate and groundwater level, and then to develop some numerical model to predict the groundwater level change. However, reliable data on water use is limited since self-excavated private wells have extracted groundwater for irrigation and residential water use in the study areas.

This study aims to clarify the relationship between rainfall and groundwater level using the wavelet analysis. Based on the analyzed relationship between wavelet time-frequency energy and wavelet decomposition, it is discussed how the groundwater level change may be caused by rainfall.

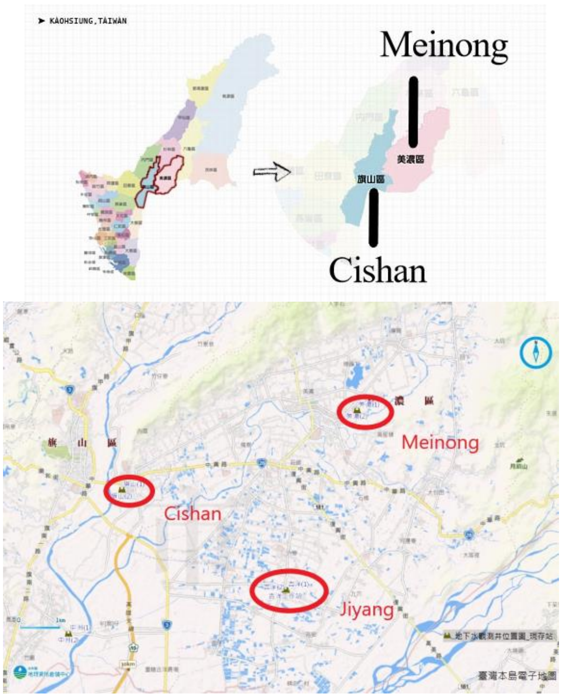


Fig. 1 Study areas in the southern Taiwan.

2. Methods

2.1. Study area and data

The study areas include the four districts in Kaohsiung city; Meinong, Cishan, Dashu and Daliao, as shown in Fig. 1. Now we have collected 14.5-year data at Meinong, Jiyang and Cishan stations.

2.2. Wavelet analysis

Wavelet analysis has been used to analyze rapidly changing transient signals. It allows us to observe the frequency and time axis at the same time with a good time resolution when the frequency is high, and a good frequency resolution when the frequency is low.

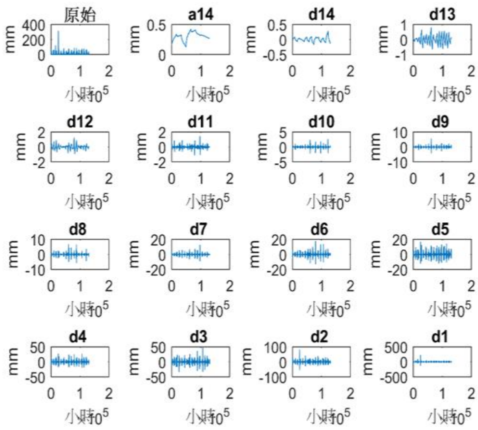
3. Results

3.1. Wavelet transform, wavelet decomposition and wavelet coherence

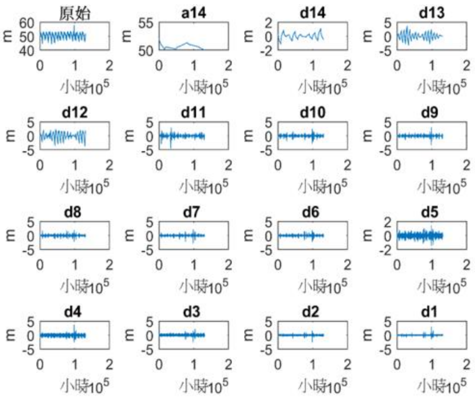
Fig. 2 shows the wavelet decompositions of the rainfall data and the groundwater level data at Meinong. It demonstrates that groundwater level and rainfall show some correlation, and gives more useful information than the wavelet transform of rainfall at Meinong.

Fig.3 shows the wavelet transform of the rainfall data and the groundwater level data at Meinong. It shows wavelet time-frequency energy conversion.

Fig.4 shows the wavelet coherence between groundwater level and rainfall at Meinong. It explains that which time and frequency having some correlation.



(a) Rainfall data



(b) Groundwater level

Fig. 2 Wavelet decomposition (Meinong).

3.2. Wavelet disassembly and recombination

presents the groundwater wavelet time-frequency energy conversion and the energy-significant part and the groundwater rainfall wavelet time-frequency first-off conversion analysis and the high correlation part of the wavelet disassembly band.

It is known that d11, d12, d13, d14 and a14 bands have high correlation whose period is larger than two to the power of ten hours around 42 days.

Fig.5 shows the recombination of wavelet transform of groundwater at Meinong. It only has magnitude over around the period of 32 days because that only d11, d12, d13, d14 and a14 bands

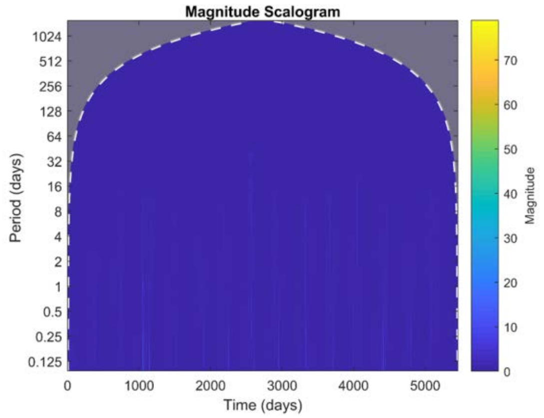
Fig.6 explains the recombination wavelet coherence between groundwater level and rainfall at Meinong. The under the period of 32 days coherence is 1 because no period in these periods.

Fig.7 shows the recombination lag between groundwater level and rainfall at Meinong. The lag is 38 hours.

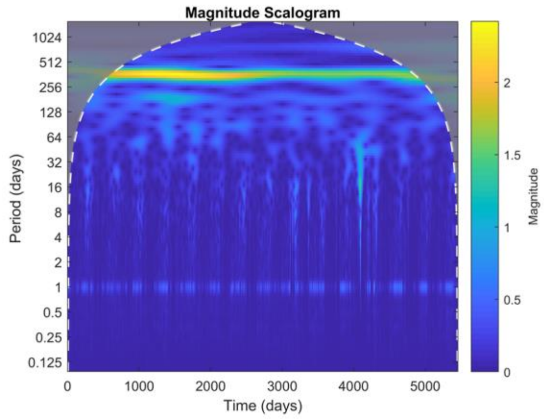
4. Conclusion

This study found out the approximate relationship between rainfall and groundwater at the location. Meinong combines the disassembled d11, d12, d13, d14 and a14 bands with a delay of 38 hours, which is about 1.6 days. Applying the same method to Jiyang and Cishan stations, it is found that Jiyang combines the disassembled d10, d11, d12, d13, d14 and a14 bands with a delay of 358 hours (about 15 days), Cishan combines the disassembled d10, d11, d12, d13, d14 and a14 bands combined with a delay of 436 hours (about 18 days).

Although this method seems to capture the high correlation part and lag easily, the relation between groundwater level and



(a) Rainfall data



(b) Groundwater level

Fig. 3 Wavelet transform (Meinong).

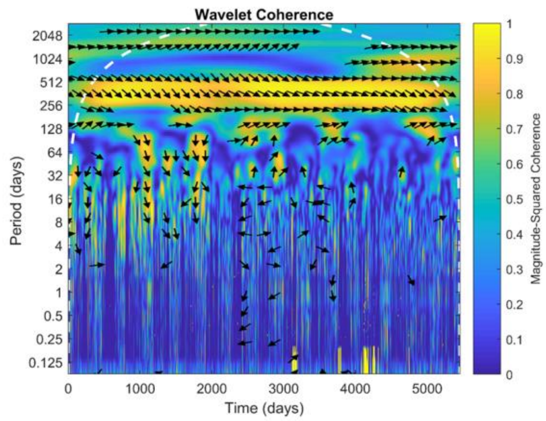


Fig. 4 Wavelet coherence between groundwater level and rainfall (Meinong).

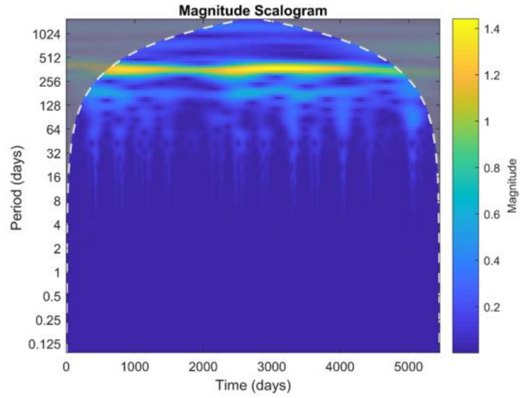


Fig. 5 Recombination of wavelet transform of groundwater (Meinong)

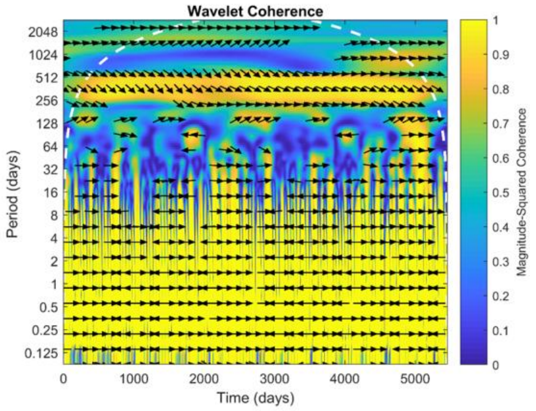


Fig. 6 Recombination wavelet coherence between groundwater level and rainfall (Meinong)

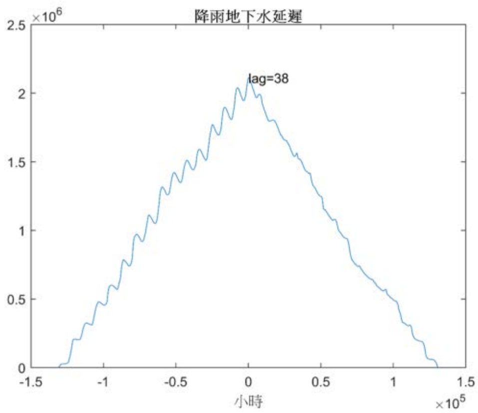


Fig.7 Recombination lag between groundwater level and rainfall

rainfall is complicated. The way to use high correlation is a little strange because the period I choose is larger than one month, since the change in groundwater level is not detected if heavy rainfalls continue for only two or three days. The way I find the time delay also may need improvement because it should not just using cross correlation to find lag between each other.

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