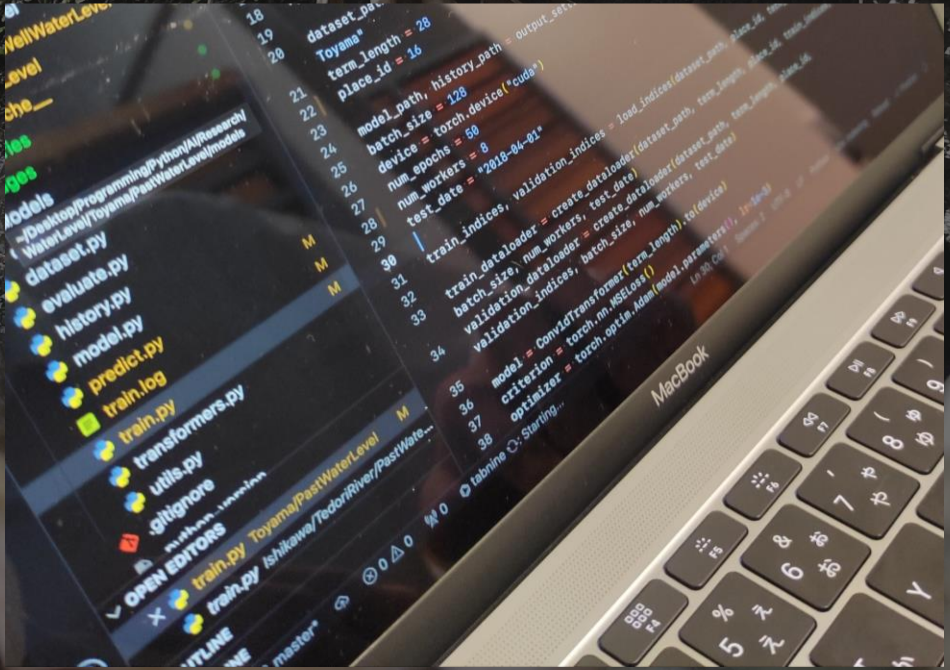
Development of the High Accuracy Groundwater Level Prediction Model Using Machine Learning



Kaijo Senior High School

Aoyama Kuya・Katsuyama Shouki

1-1. Background

Groundwater is an "invisible" water resource


Daily observations

- We‘ve been researching Otomeyama park, Shinjuku City for 13 years
- We have strongly felt the need to preserve the water environment around us
  (In Tokyo, 68 springs have disappeared in the past 10 years)
- Fluctuations in groundwater levels cause spring depletion, well depletion, land subsidence, and landslides
- We want to "visualize" groundwater and conserve it

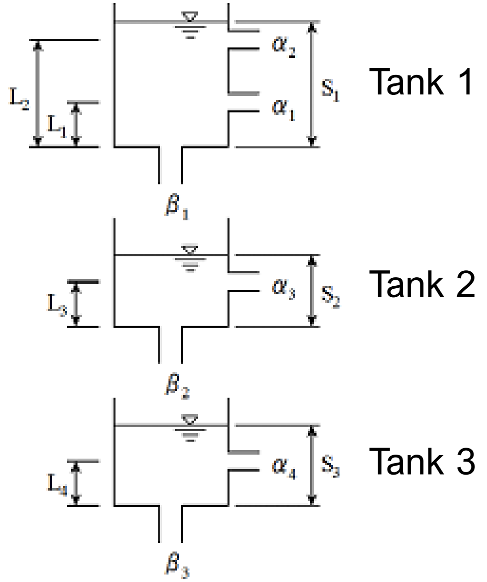
1-1. Background

Groundwater level prediction makes future groundwater "visible"

Tank Model

・Low versatility across regions
・Need more than 10 data
・Need one observation well per 2square kilometers

Place a heavy burden on local governments



In-line 3-stage tank model Method
(Japan Meteorological Agency)

1-2. Approach

1. Use only meteorological data and groundwater level data

2. Make the model applicable to different regions

Making Groundwater Level Prediction Easier

2-1. Model

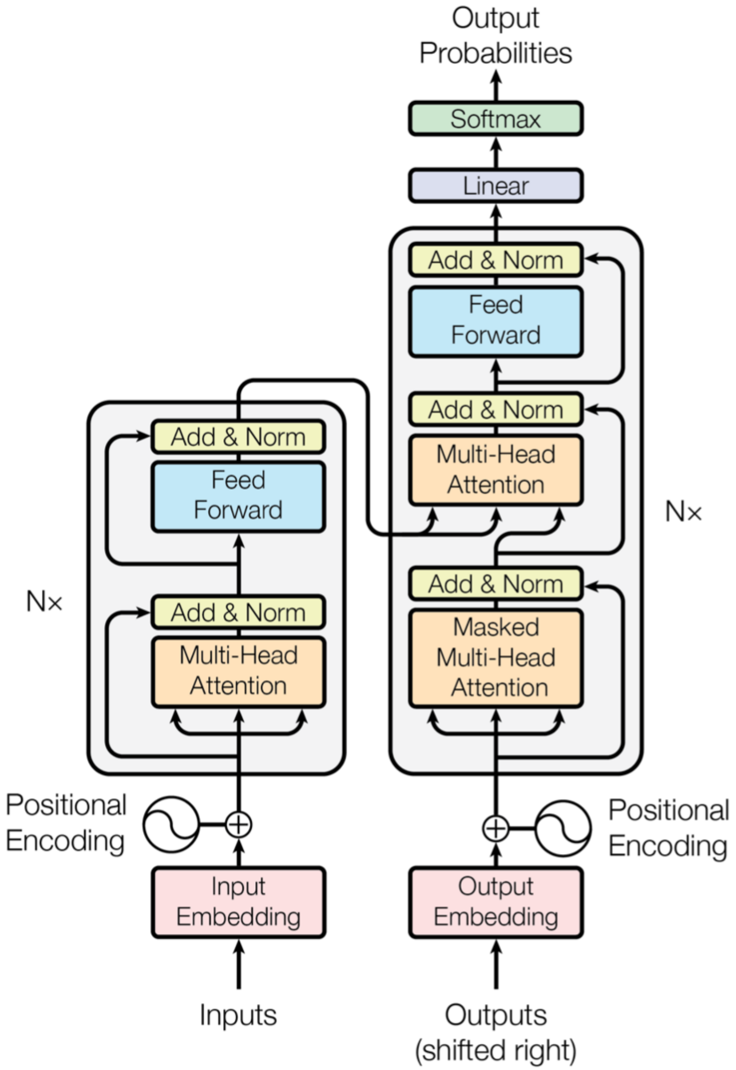
Transformer

A high-performance machine learning model for time series data

Proposed to use in
machine translation
or natural language processing

$$\mathrm{Attention}(Q, K, V) = \mathrm{softmax}(\frac{QK^T}{\sqrt{d_k}})V$$

Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Lukasz Kaiser, Illia Polosukhin
"Attention is All You Need" 2017

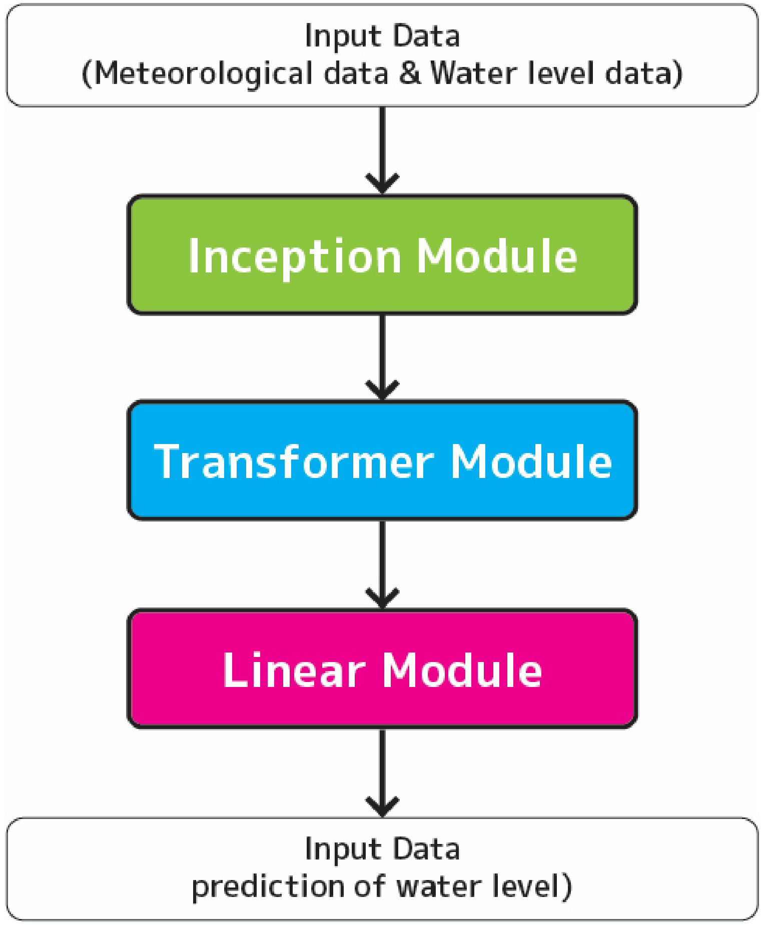


The Transformer-model architecture

2-2. Architecture

The model consists of three modules

1. Inception Module
2. Transformer Module
3. Linear Module

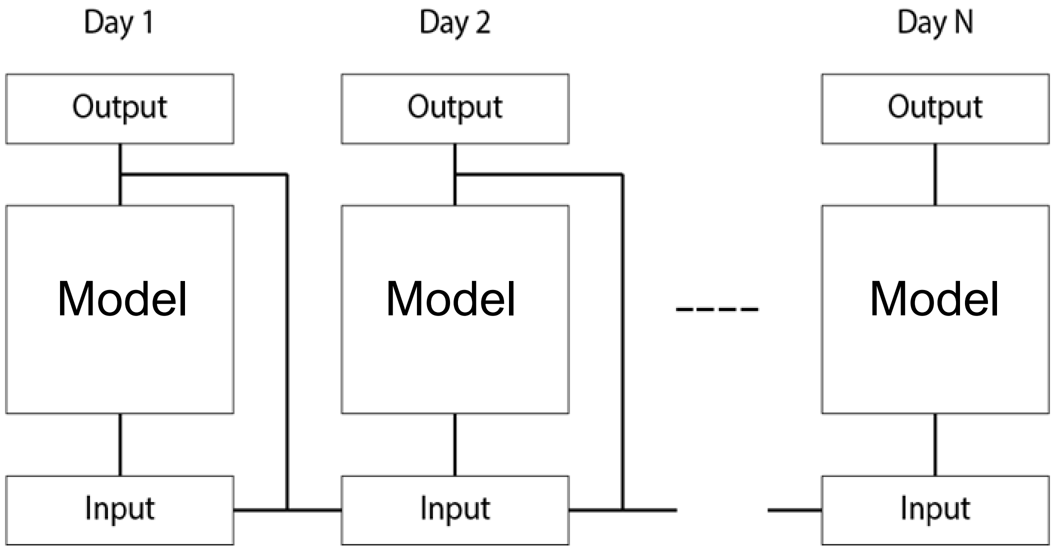


2-2. Architecture

Prediction Method

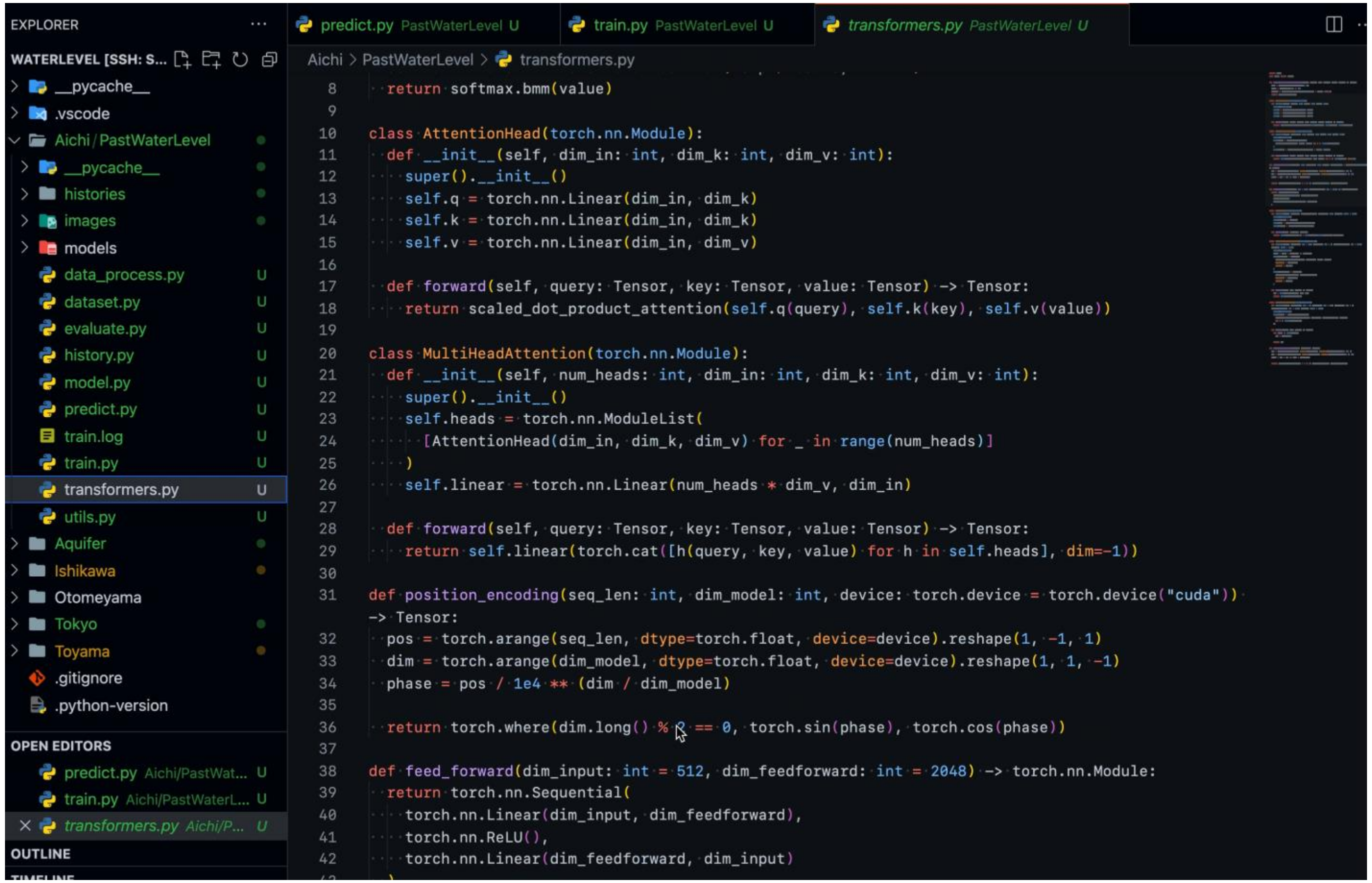
Passing the previous segment's output
to the next segment's input

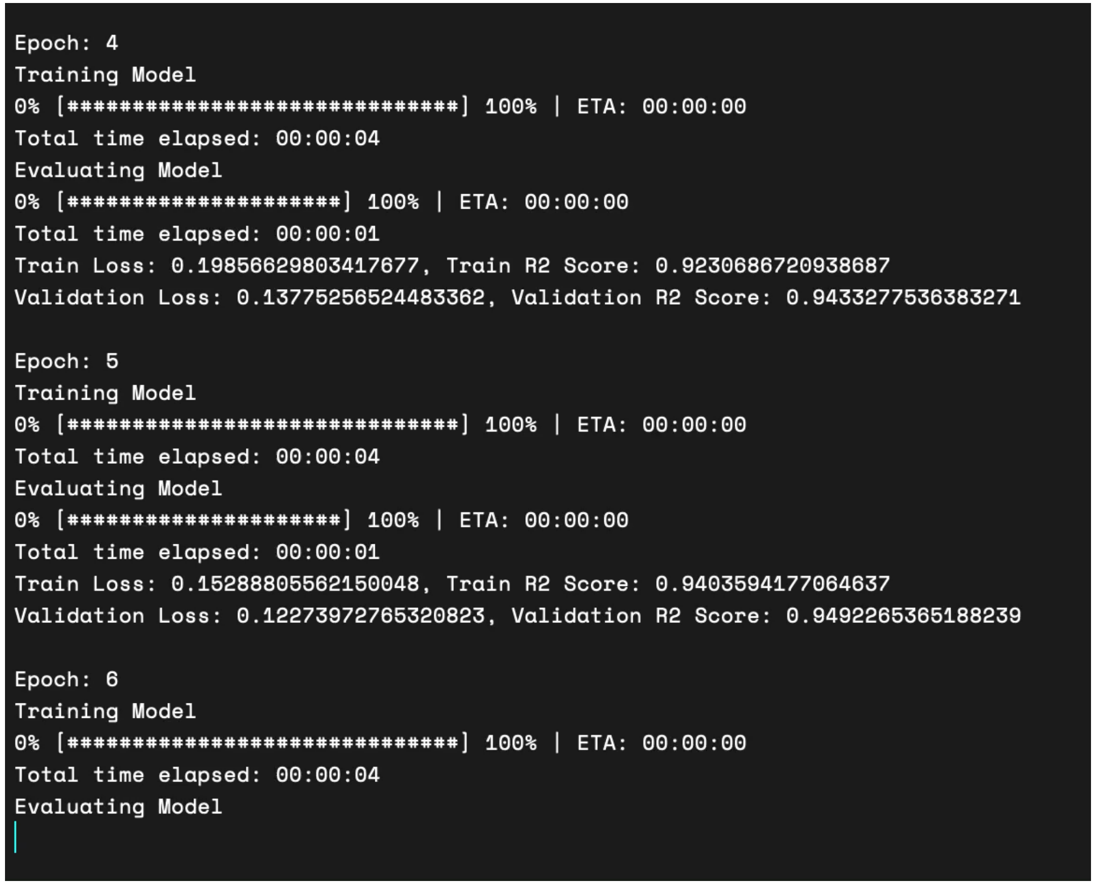
This model can predict
without the
latest ground water level data
by predicting recurrently

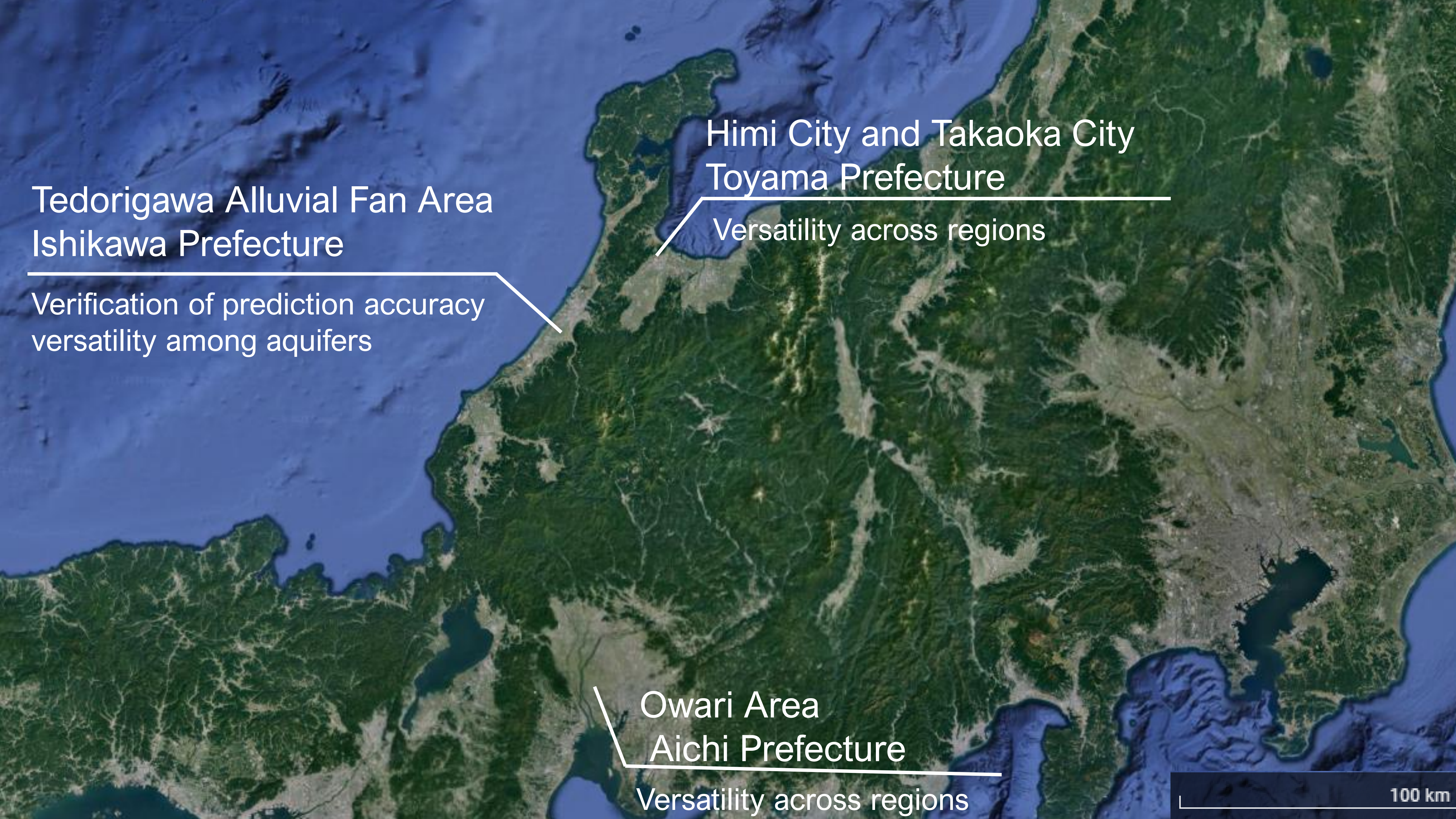


2-3. Implementation

This model was implemented with Python, a programming language.






Himi City and Takaoka City
Toyama Prefecture
Versatility across regions
Tedorigawa Alluvial Fan Area
Ishikawa Prefecture
Verification of prediction accuracy
versatility among aquifers
Owari Area
Aichi Prefecture
Versatility across regions
100 km

3-1. Data Used

Tank Model

- Groundwater level data
- Coefficient of transmissibility
- Coefficient of storage

- Amount of rainfall
- Amount of evapotranspiration
- Groundwater increment
- Penetration rate

- Industrial water
- Agricultural water
- Water for daily use
- Water for snow melt
- Water for fighting fires
- Water for environment

- Land use data

This Research

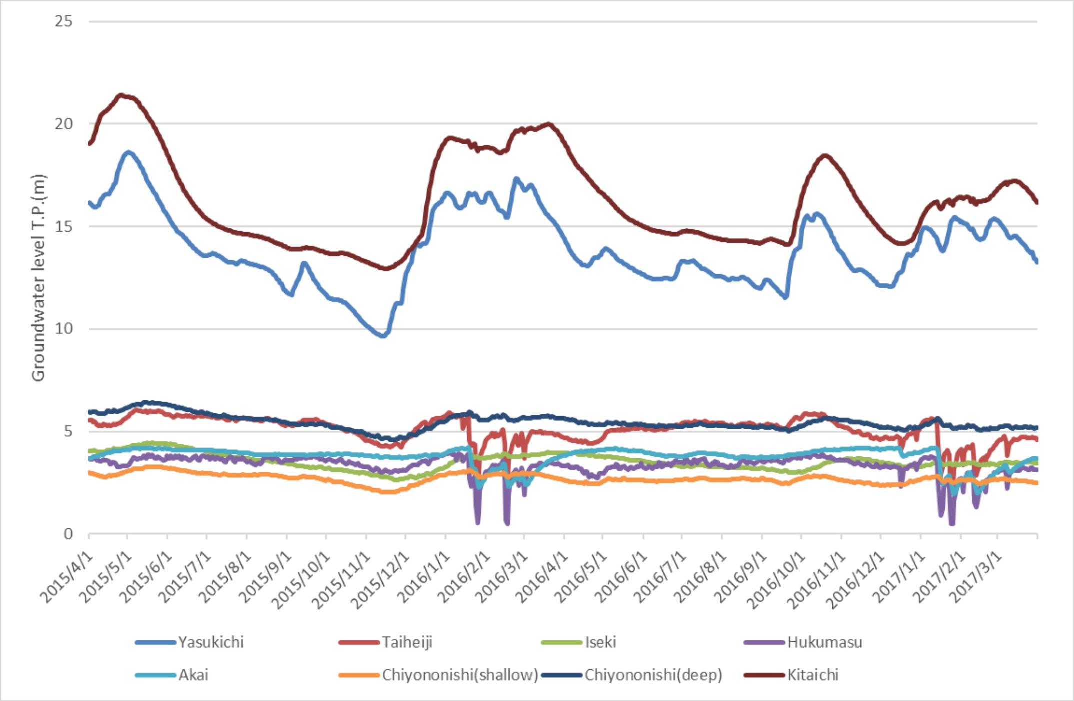
Provided directly by the local government

Using open data from the Japan Meteorological Agency

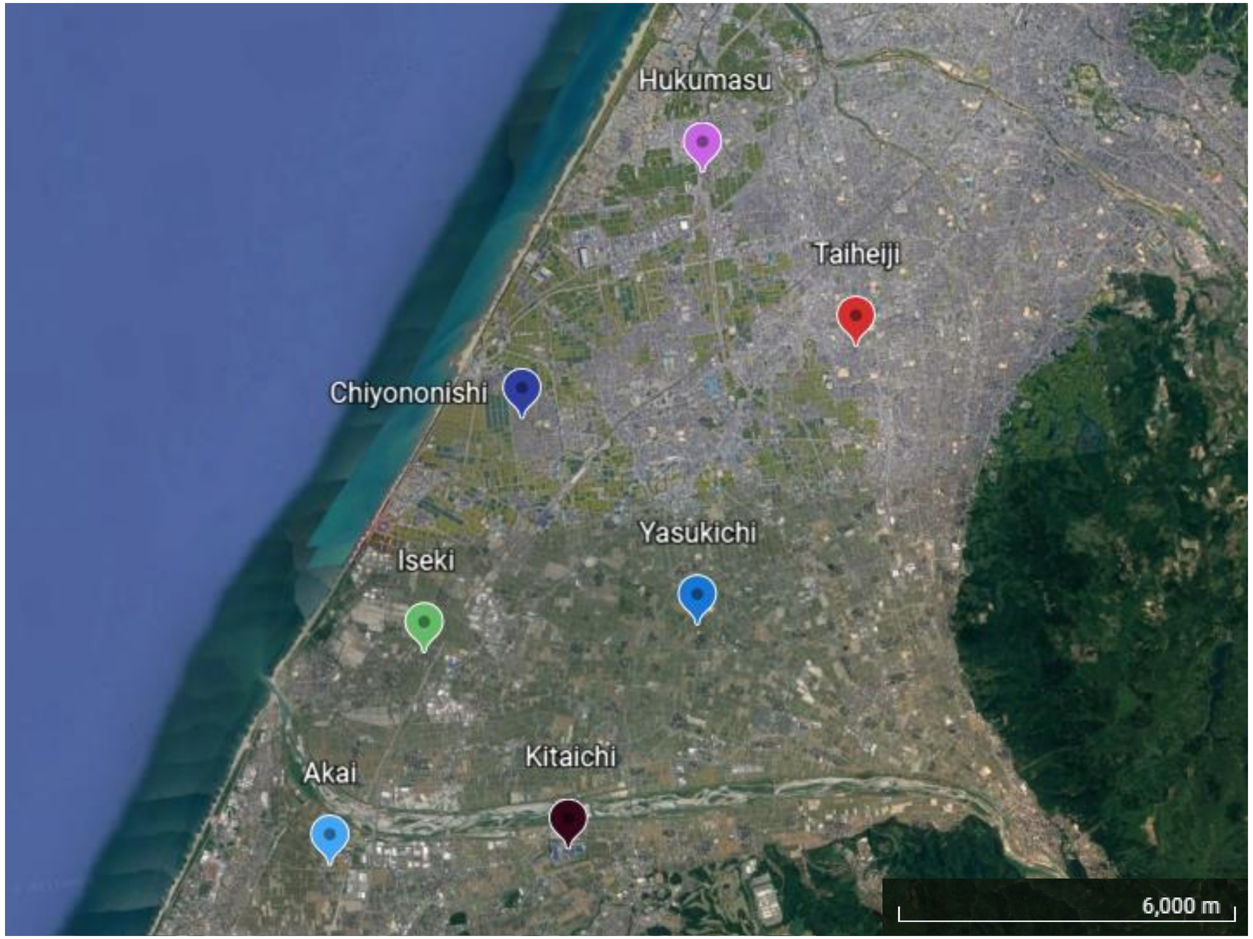
3-2. Dataset Tedorigawa Alluvial Fan Area

Training data
1974/04/01~2015/03/31(about 40 years)

Validation data
2015/04/01~2017/03/31



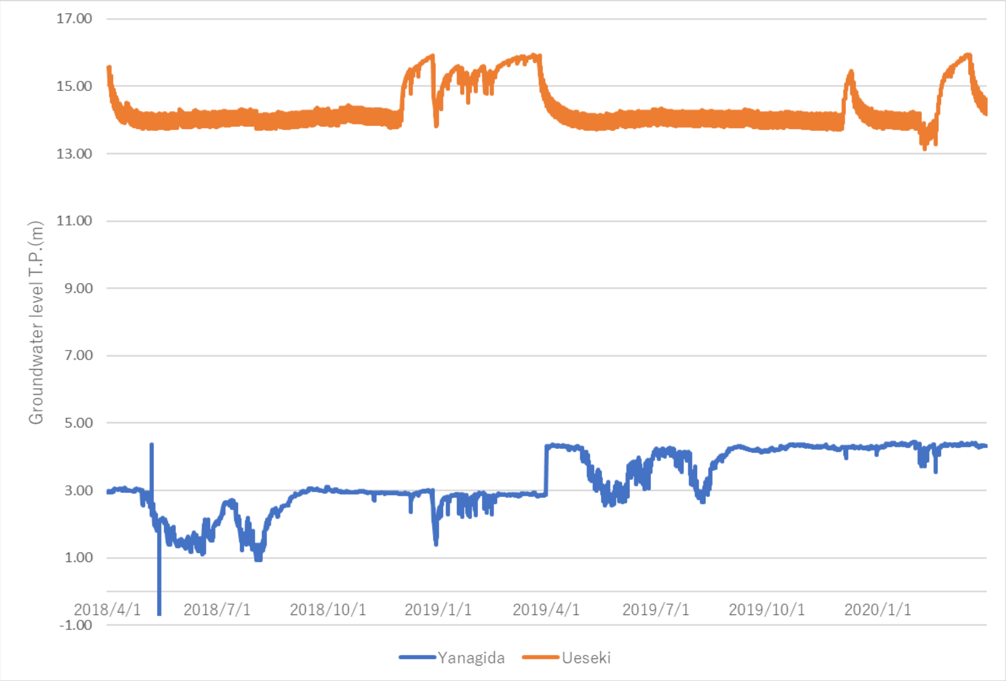
Groundwater level fluctuation graph



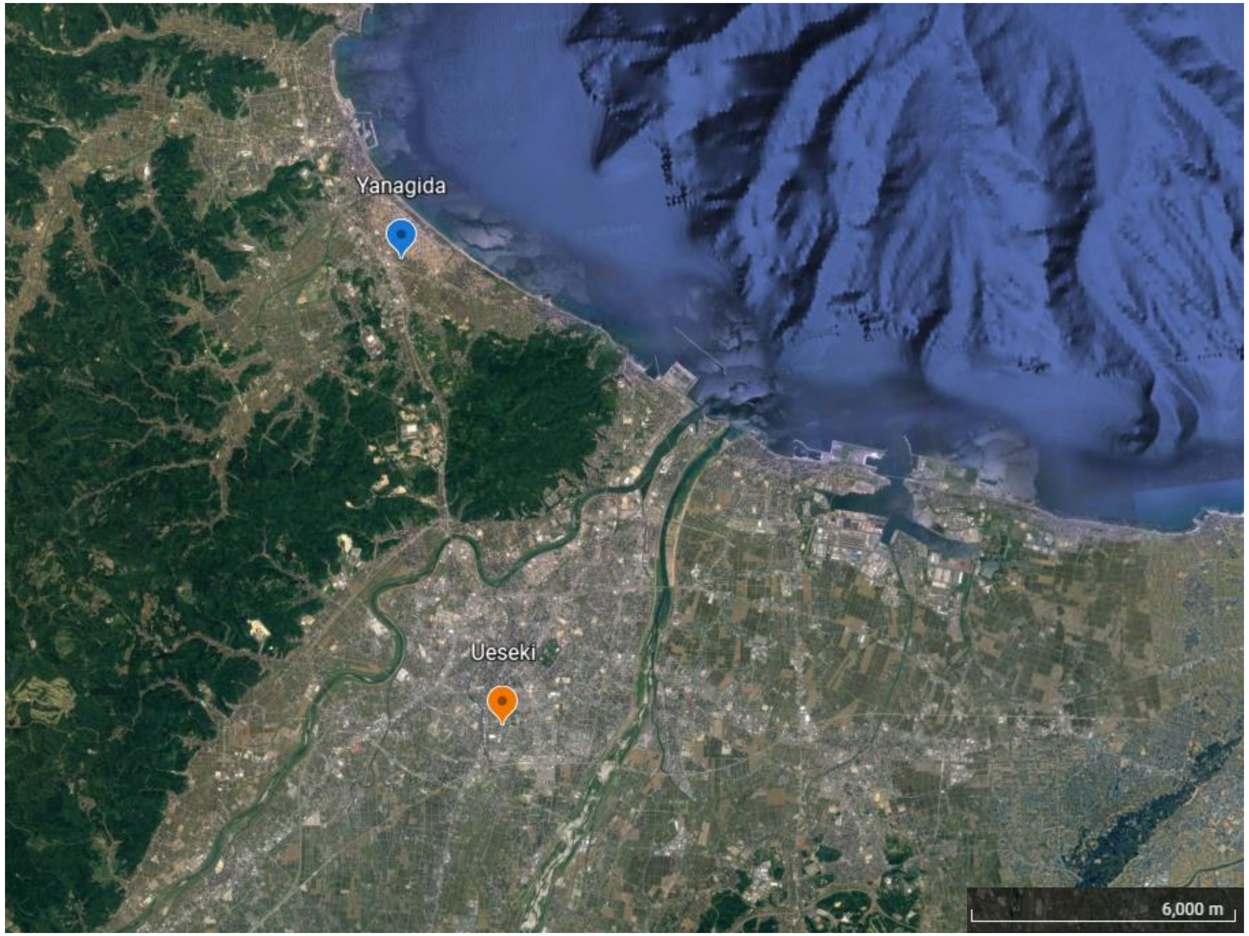
3-2. Dataset Himi city and Takaoka city

Training data
2007/04/01～2018/03/31(about 10 years)

Validation data
2018/04/01～2020/03/31



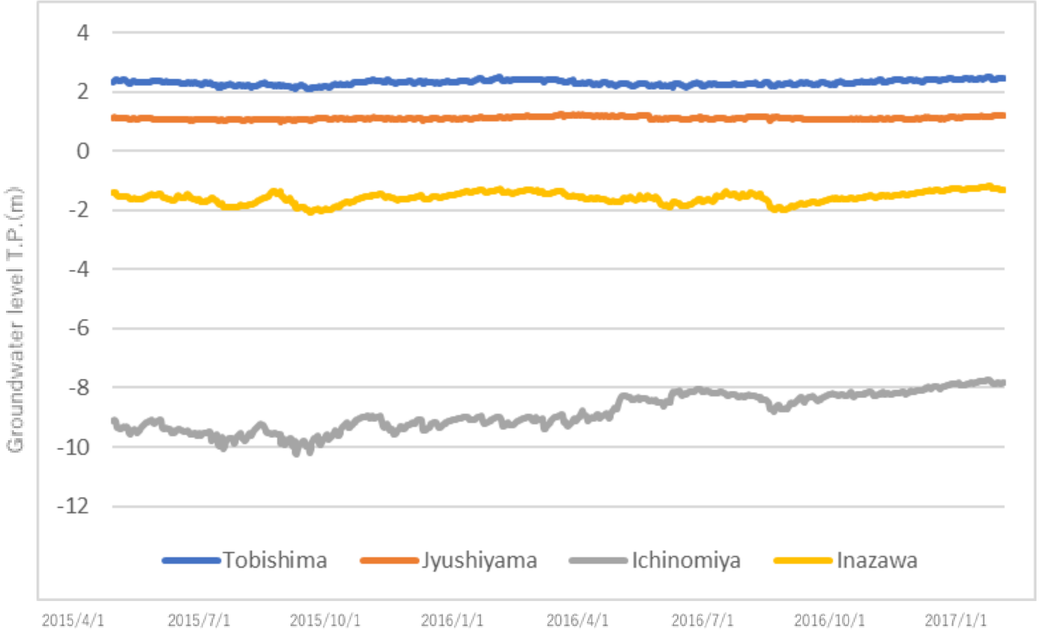
Groundwater level fluctuation graph



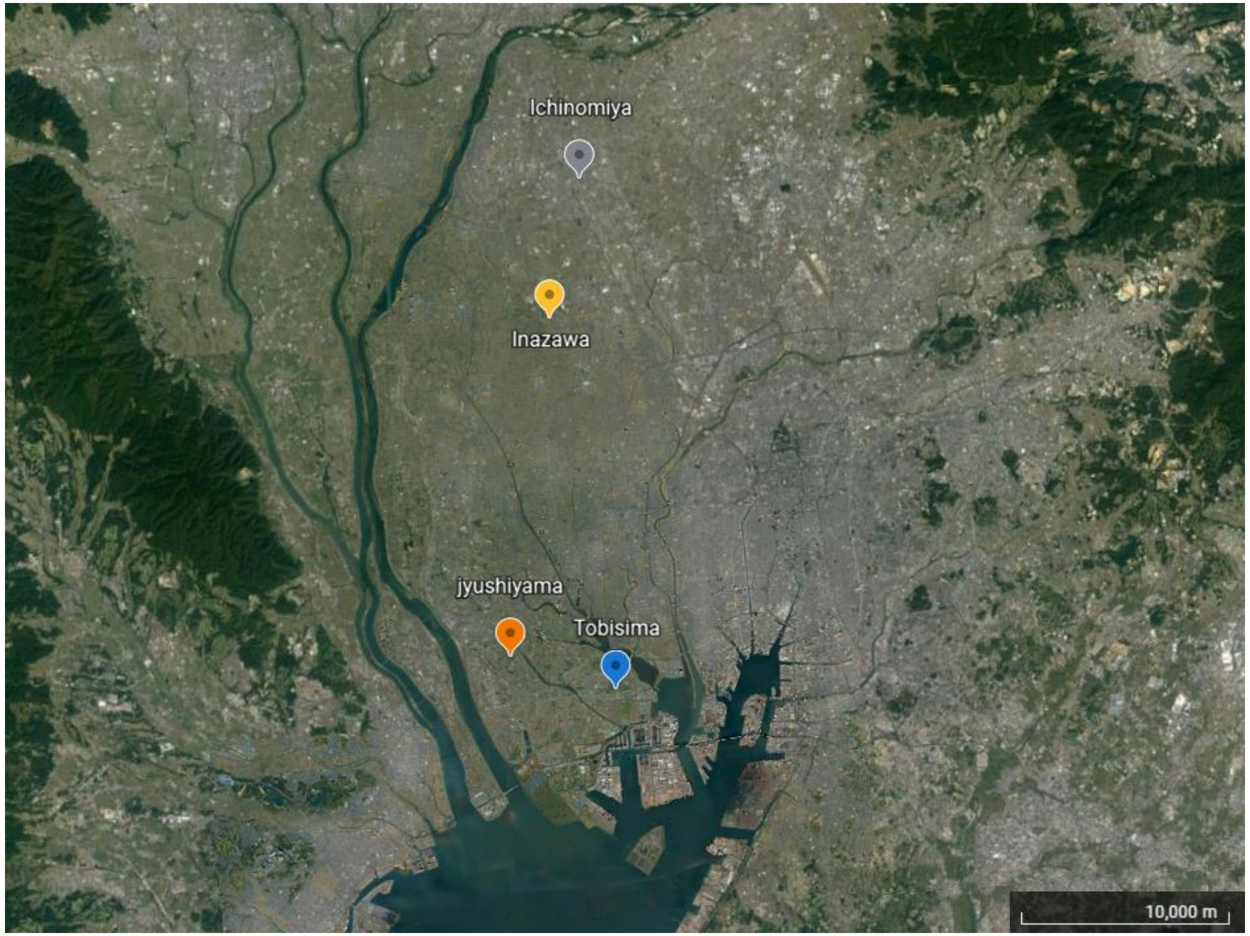
3-2. Dataset Owari Area, Aichi Prefecture

Training data
1974/04/01~2015/03/31(about 40 years)

Validation data
2015/04/01~2017/03/31

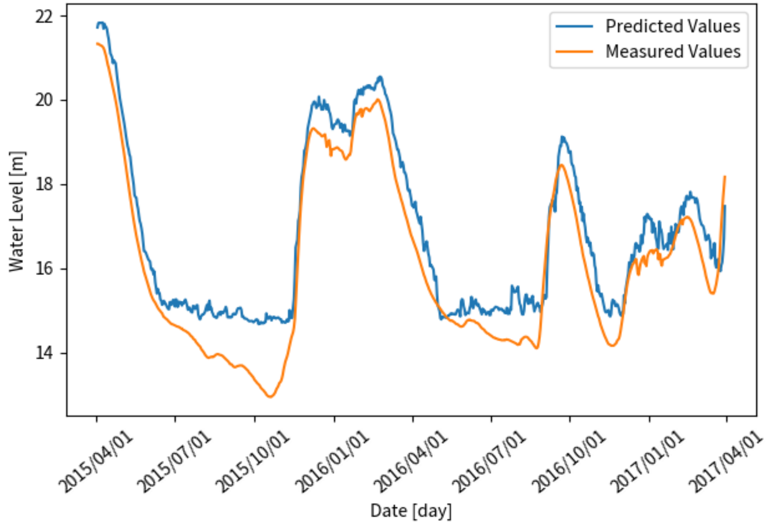


Groundwater level fluctuation graph

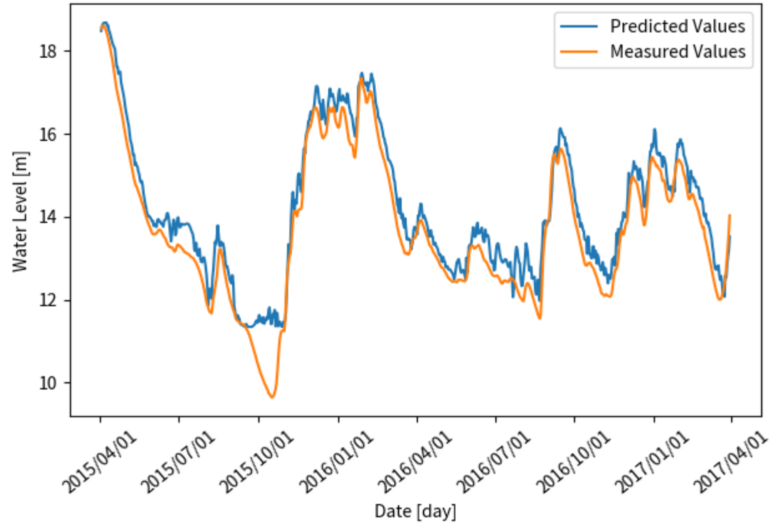


4-1. Results 1 Tedorigawa Alluvial Fan Area

Kitaichi,2nd aquifer



Yasukichi,2nd aquifer



Model	Yasukichi	Kitaichi
Chono et al.(2017)	0.0063	0.0032
This research	0.0035	0.0019

MSE score for each location

$$MSE(y,\hat{y}) = \frac{1}{N}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

y: measured values, $\hat{y}$: output values N: the number of data

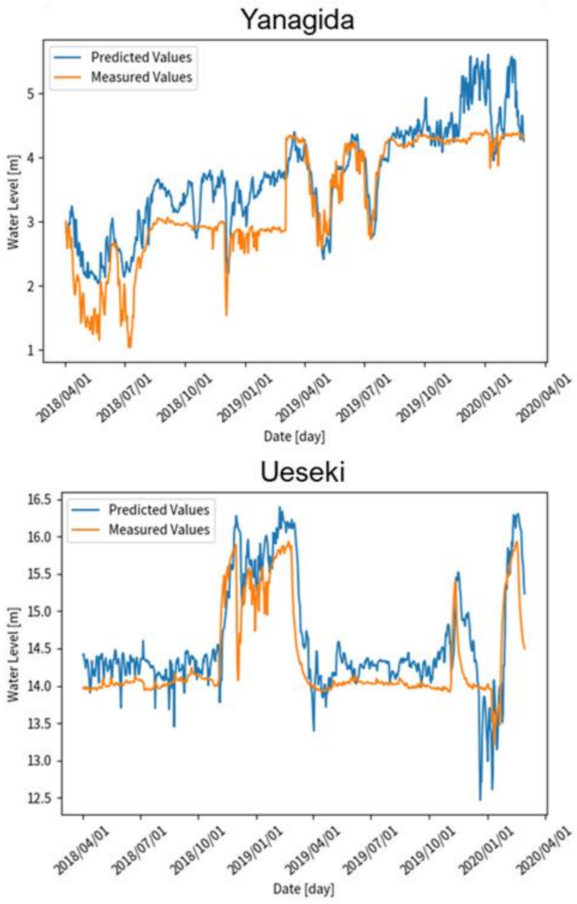
The lower the MSE score, the higher the accuracy

⇒ This model showed a high accuracy

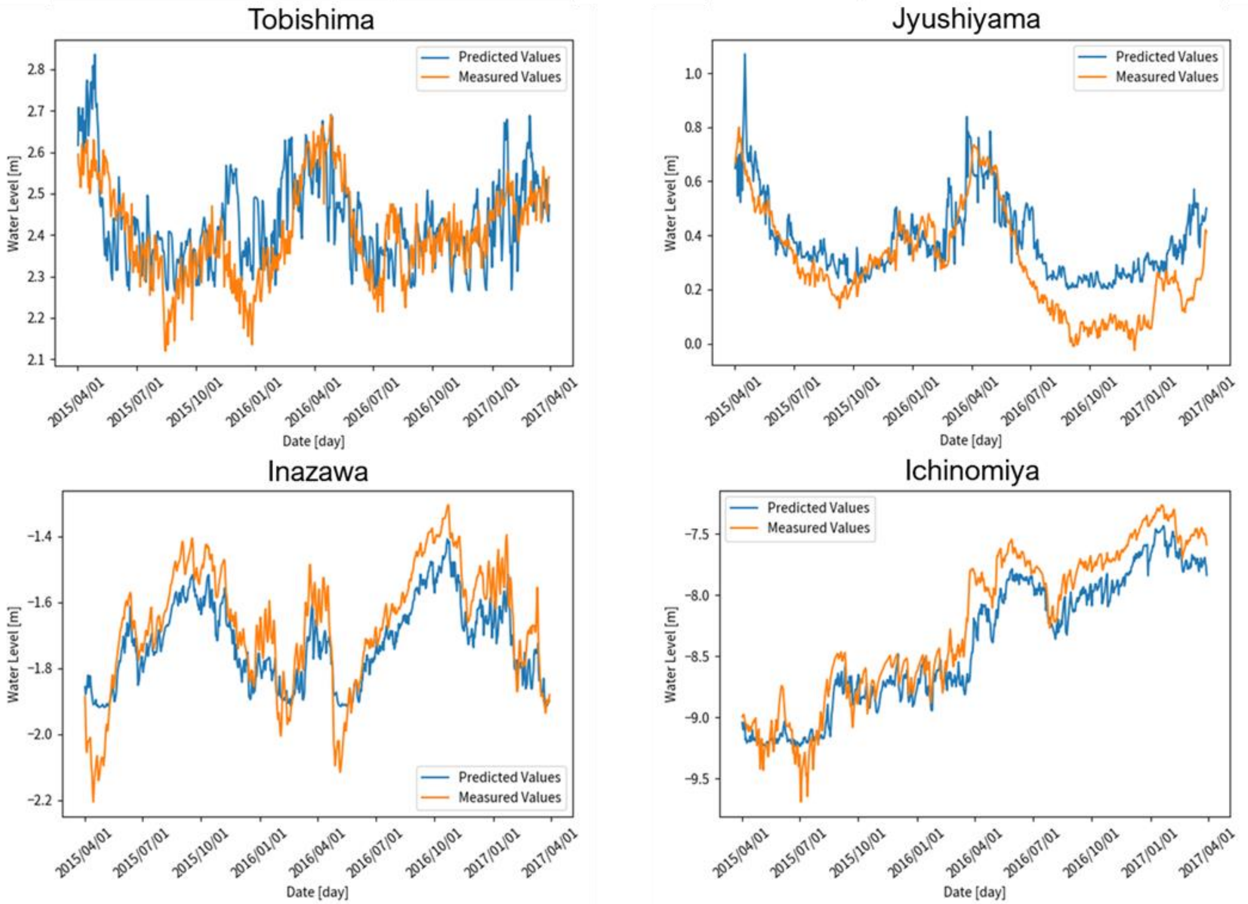
4-1. Results 1 Toyama and Aichi prefecture

Predict to a certain extent of accuracy

Himi city・Takaoka city
Toyama Prefecture



Owari Area
Aichi prefecture



4-1. Results 1

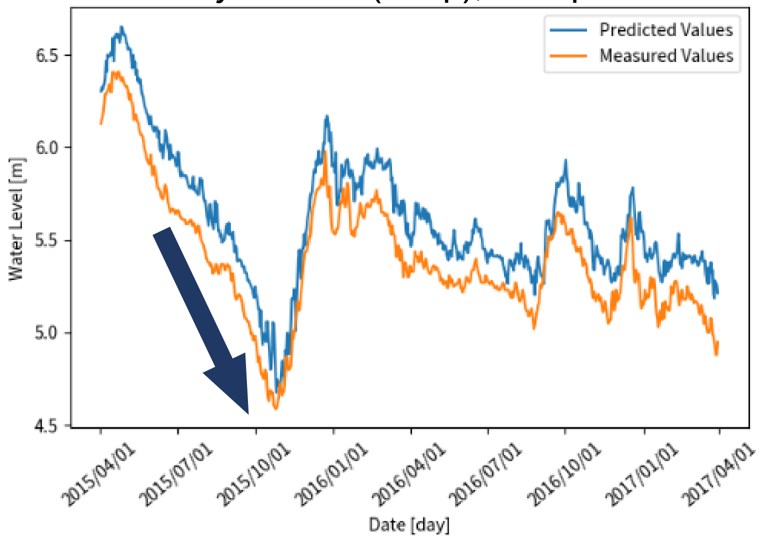
Types of versatility

- Between **Wells**
- Between **Aquifers**
- Between **Regions**

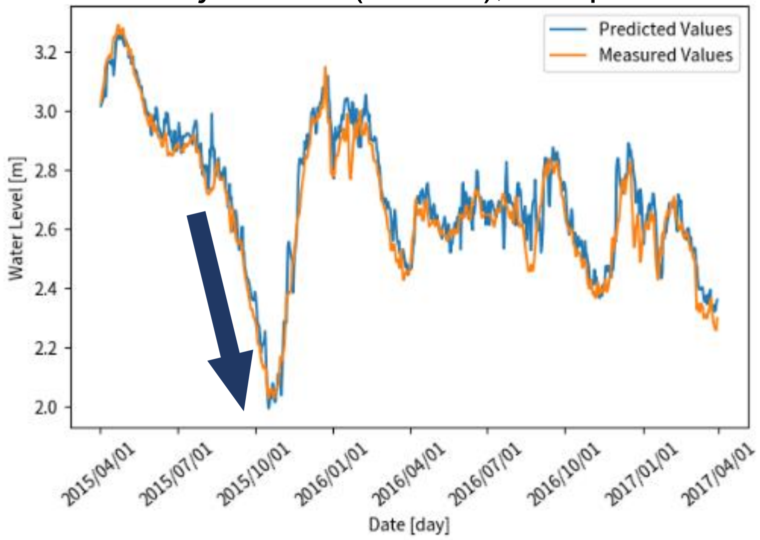
High versatility was confirmed
by using the same model

4-2. Results 2 Periods of unusual variation

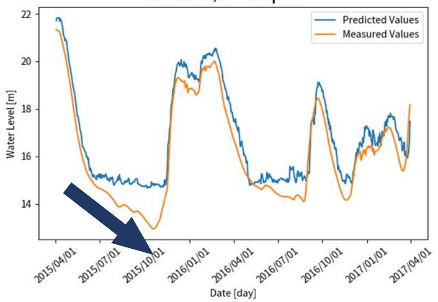
Chiyononishi(deep),3rd aquifer



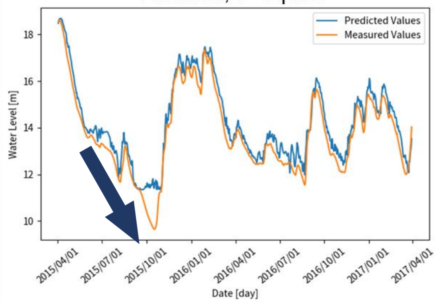
Chiyononishi(shallow),1st aquifer



Kitaichi,2nd aquifer

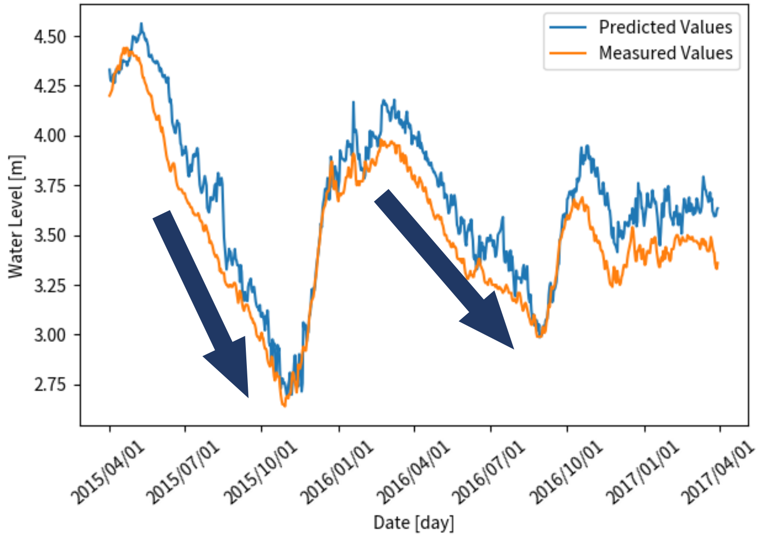


Yasukichi,2nd aquifer



landslide

Iseki,3rd aquifer

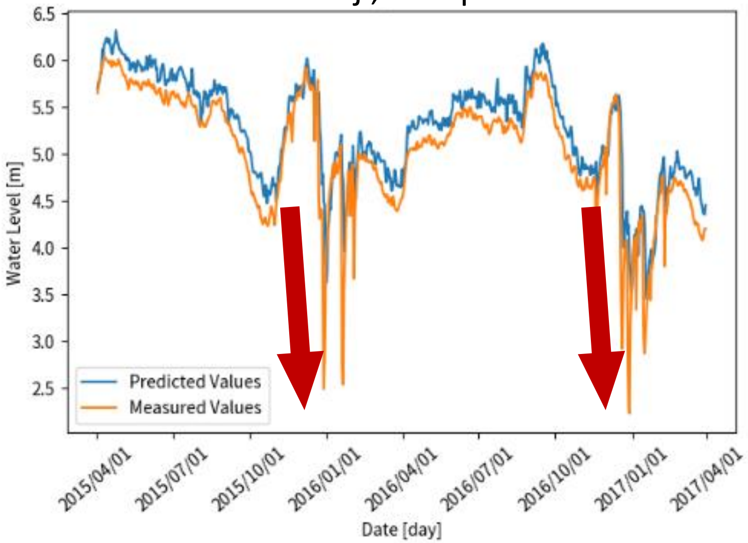


Landslide that occurred in 2015(Forestry Agency)

Prediction with high accuracy

4-2. Results 2 Periods of unusual variation

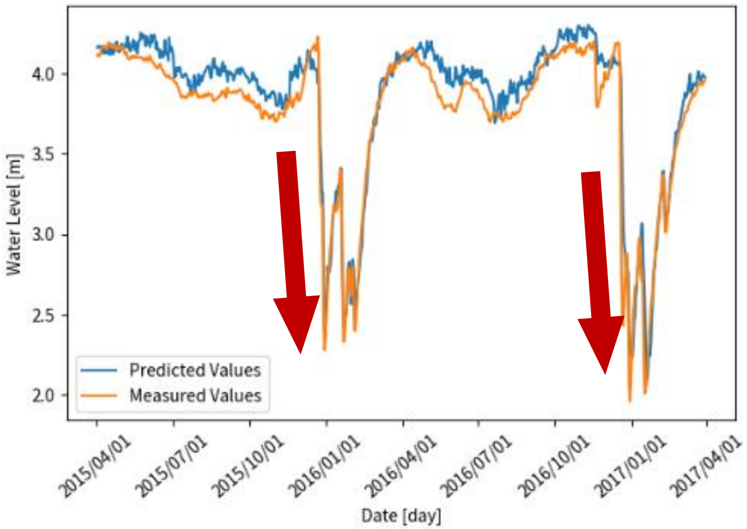
Taiheiji,3rd aquifer



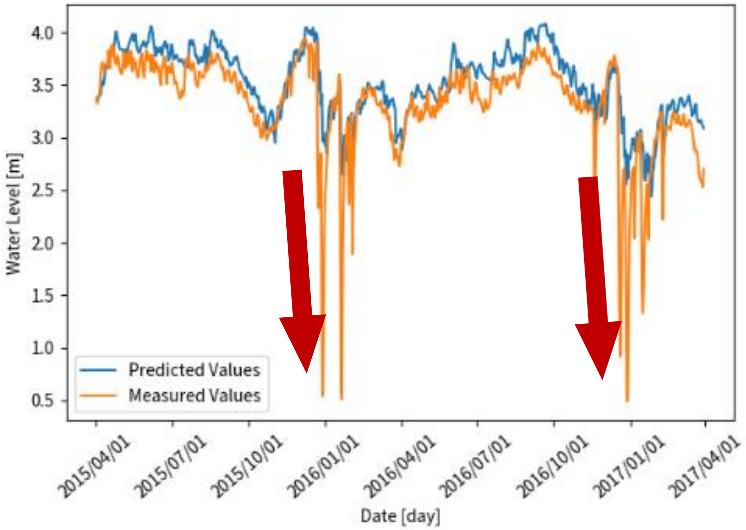
Snow removal equipment

Half the accuracy of normal

Akai(deep),3rd aquifer



Hukumasu,3rd aquifer



Snow Removal Equipment Using Groundwater
(Hukui Shinbun Online)

4-2. Results 2 Tedorigawa Alluvial Fan Area

Periods of unusual variation

- Lowering of the groundwater level due to **landslides**
- Lowering of groundwater level due to operation of snow **removal equipment**

↓

Some prediction is possible

5. Conclusion

1. Only used meteorological data and groundwater level data
2. Showed a high accuracy
3. Versatility across wells, aquifers and regions
4. Making Groundwater Level Prediction Easier

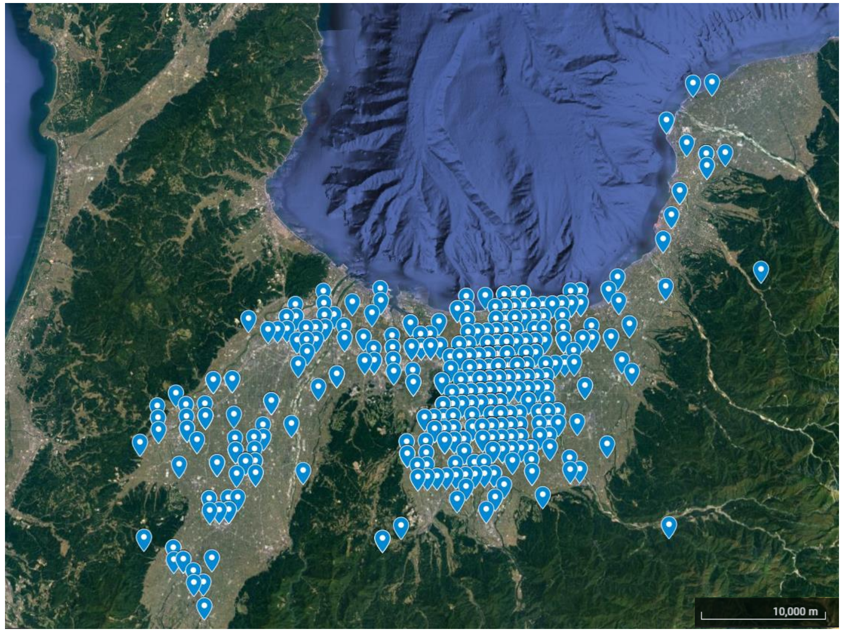
It will lead to the protection of the water environment around all people

6. Prospect

Use of groundwater data ledgers

- Over 60,000 boring data available
- Model with a larger number of points

Prediction will be possible even at points where there are no observation wells



Points with drilling data (Toyama Prefecture)

7. Acknowledgement

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- Members of Environmental Conservation Division,
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  Tokyo Metropolitan Government Civil Engineering Technical Support and Human Resource Development Center)
- Mr. Nakayama Toshio (Technical Support Section,
  Tokyo Metropolitan Government Civil Engineering Technical Support and Human Resource Development Center)

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