SOPHIA UNIVERSITY 上智大学

Development of model for temporal and spatial distribution prediction of the dengue fever by deep learning

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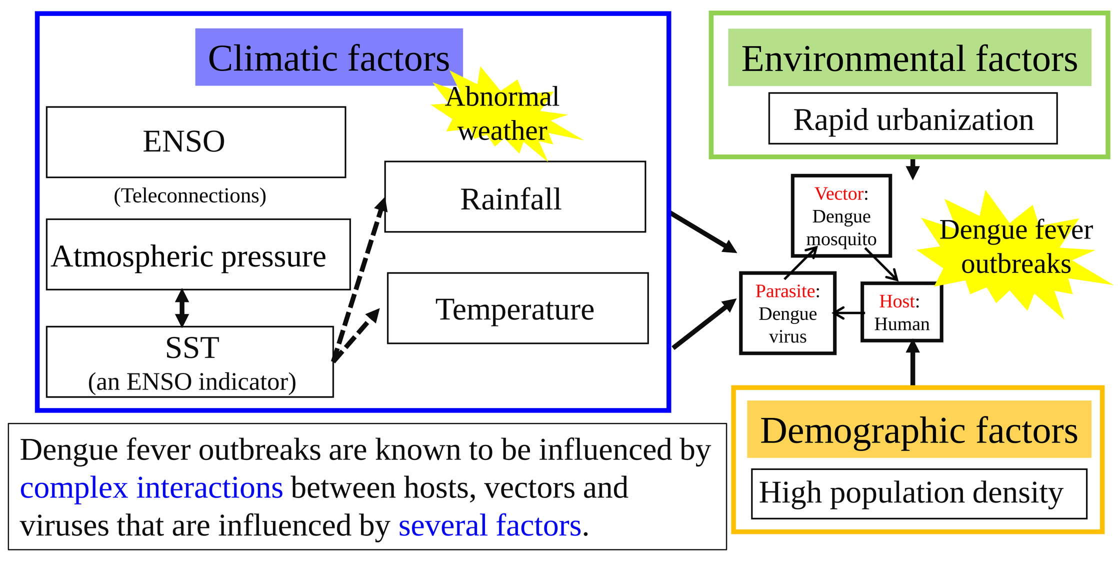
The disease-promoting factors



Dengue fever outbreaks are known to be influenced by complex interactions between hosts, vectors and viruses that are influenced by several factors.

Especially, climate variabilities are considered as the major factors affecting space-time distribution and increasing burden of dengue outbreaks in recent years.

Climatic factors

1) The ENSO is a large-scale ocean-atmosphere phenomenon which can be generally identified by sea surface temperature (SST) anomaly, and its impact can be seen directly on rainfall and temperature.

2) Rainfall and temperature as the climatic factors may directly or indirectly affect vector survival, lifespan, development and reproductive rates which could influence dengue spatiotemporal abundance and distribution.

3) Rainfall provides an increased number of breeding habitats for Aedes mosquitoes. Standing water from rainfall occupies natural depressions (wetlands, streams, etc.) and human-made containers to create a high surface area of mosquito habitat and oviposition.

4) Temperature increases impact virus development and vector survival, leading to increases in the proportion of infectious vectors, mosquito range and bite rates. As the time required for a virus to become infectious decreases, the virus spreads more efficiently

Dengue fever in Taiwan

There have been dengue fever cases concentrated mainly in southwestern Taiwan, such as Tainan City, Kaohsiung City, and Pingtung County. In 2015, Taiwan experienced the most severe dengue outbreaks with over 43,000 dengue cases.

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There is not an effective vaccine against dengue. Thus, measures against dengue fever epidemic are urgently needed.

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Forecasting disease outbreaks can be useful for public health leaders to take decisive action for preparing the response.

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The study aimed to apply a deep learning to predicting distribution of dengue fever in Taiwan using the remote sensing (RS) datasets.

Study site

The study area is the entire island of Taiwan, which consists of 368 townships.

The climate of Taiwan is subtropical in the north and tropical in the south.

High temperature and humidity, heavy rainfall and tropical cyclones in summer characterize the climate of Taiwan.

Source: https://earth.google.com/web/@23.59823745,121.02086885,1839.81063107a,681695.45746645d,35y,0h,0t,0r

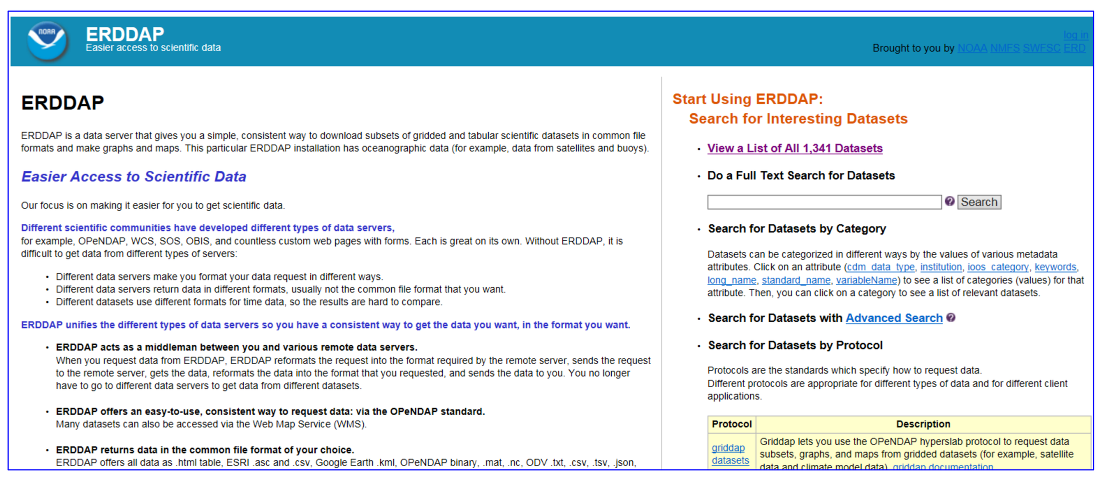
Dengue fever case data

・The daily dengue fever case data includes age, gender, township of residence, the longitude and latitude of a patient location, and the time of disease onset for each case.

Source: https://data.gov.tw/dataset/21025

Sea surface temperature data

・The daily satellite data on sea surface temperature (SST) was collected from the ERDDAP website of the National Oceanic and Atmospheric Administration (NOAA), USA.



Source: https://coastwatch.pfeg.noaa.gov/erddap

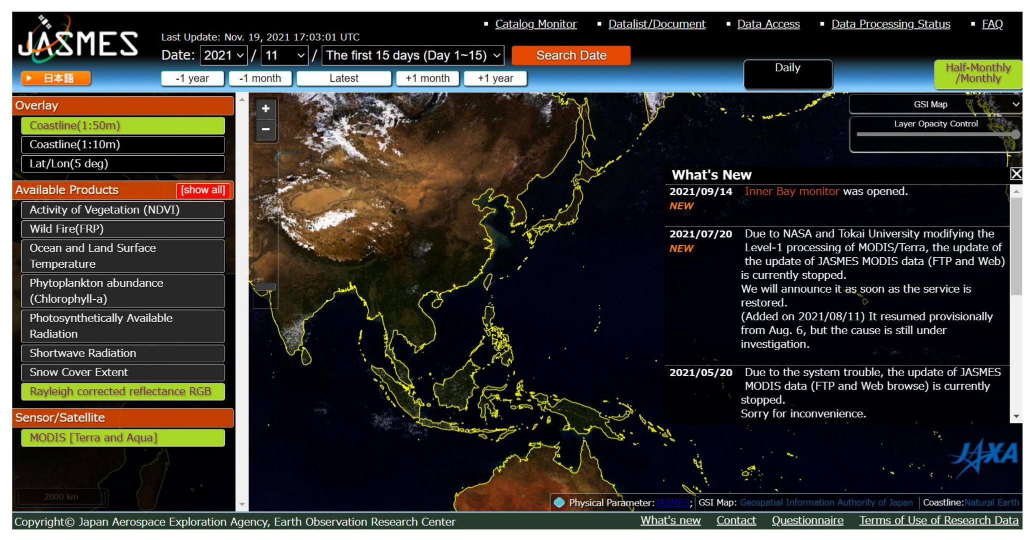
Rainfall data

・The daily rainfall data was collected from the Global Satellite Mapping of Precipitation (GSMaP) website.

Source: https://sharaku.eorc.jaxa.jp/GSMaP/index.htm

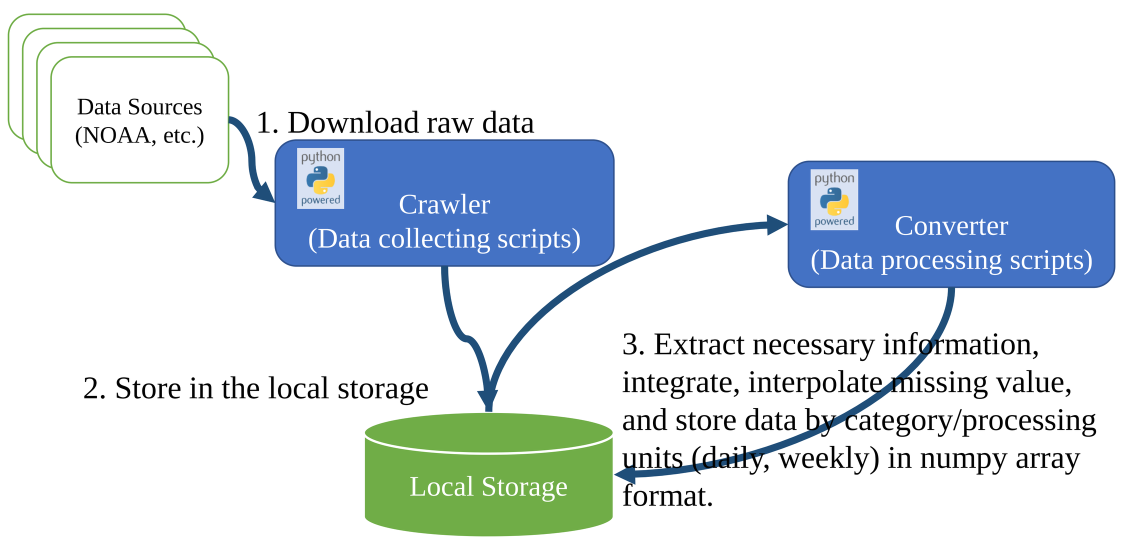
Shortwave radiation data

・The daily shortwave radiation data was collected from the JAXA Satellite Monitoring for Environmental Study (JASMES).



Source: https://www.eorc.jaxa.jp/JASMES/index.html

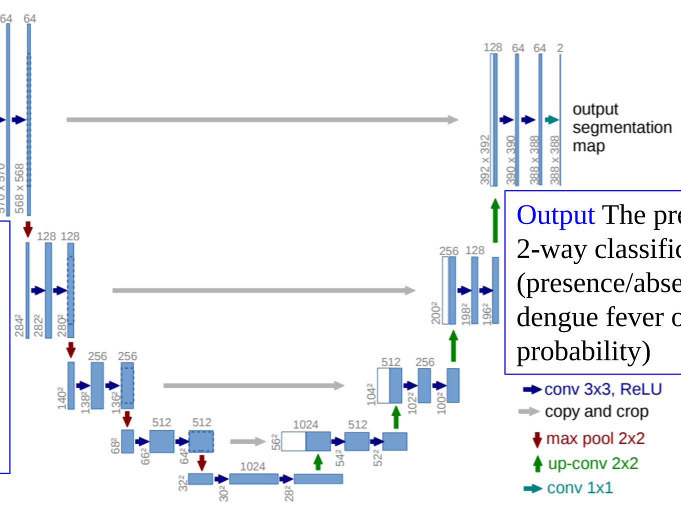
Data processing



U-Net-based encoder-decoder model

The architecture consists of a contracting path to capture context and a symmetric expanding path that enables precise localization.

Input 384 × 512 × 3 channel images integrated by the following datasets: (1) sea surface temperature, (2) rainfall, and (3) shortwave radiation.



Output The predictions of 2-way classification (presence/absence of dengue fever occurrence probability)

[1] Ronneberger, O., Fischer, P., Brox, T.: U-net: Convolutional networks for biomedical image segmentation. In: Medical Image Computing and Computer-Assisted Intervention–MICCAI 2015, pp. 234–241. Springer (2015)

Experiment

・Five different experiments: 1) sea surface temperature, rainfall and shortwave radiation, 2) sea surface temperature, 3) rainfall, 4) shortwave radiation, and 5) rainfall and shortwave radiation were conducted, combining three different kinds of data.

・The datasets from 2002/4/16 to 2020/9/30, 2002/4/16 to 2017/12/31 was used as the training data, 2018/1/1 to 2018/12/31 as the validation data, and 2019/1/1 to 2020/9/22 as the testing data.

・The model was evaluated using Overall Accuracy, Mean Accuracy, Mean Intersection over Union (Mean IoU), Frequency Weighted Accuracy/Frequency Weighted Intersection over Union (FWA/FWIoU), and Dice index coefficient (DI).

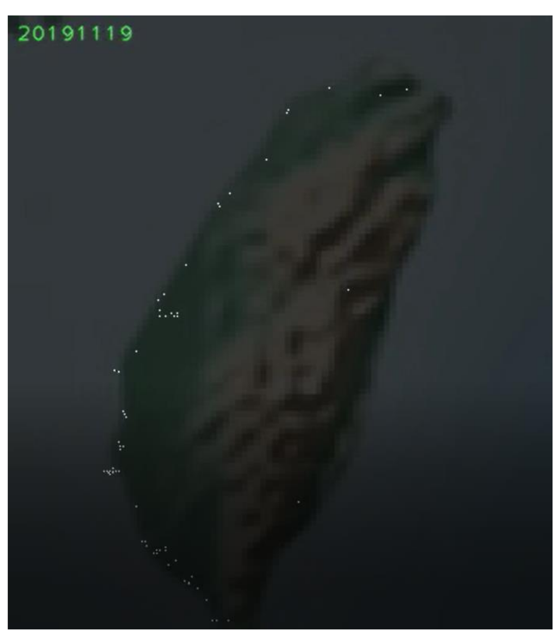
Results

Testing dataset	Overall Accuracy	Mean Accuracy	Mean Intersection over Union	Frequency Weighted Accuracy	Dice index coefficient
SST+R+SWR	0.999845	0.509462	0.504506	0.9977	0.018169
SST	0.999557	0.502009	0.500152	0.999481	0.001494
R	0.999875	0.501437	0.50082	0.999799	0.003524
SWR	0.999903	0.503644	0.502796	0.999828	0.011312
R+SWR	0.999872	0.507283	0.504232	0.999797	0.017036

・Overall, the accuracies of all the models were low, but the accuracies tended to increase as the number of variables increased.

Results

Ground truth



Prediction with test data, combining three kinds of data

Discussion

・The prediction accuracy of the proposed model was low in our study and showed only a few overlapping areas between the ground truth and prediction results due to small objects in satellite images and the imbalanced data on the dengue fever.

・Yet, it implies the possibility that the utilization of RS data and deep learning may assist in predicting the distribution of dengue fever outbreaks with further improvements in a deep learning model to effectively learn small object features.