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| **Keywords:** | Infectious disease prediction, deep neural network, artificial neural network, long short-term memory, deep learning, social media big data |
| **Abstract:** | Infectious disease trends are variable and means prediction is not easy. This article predicts infectious diseases outbreak by optimizing the parameters of deep learning algorithms, considering big data including social media data. The performance of the deep neural network (DNN) and long-short term memory (LSTM) learning models were compared with the autoregressive integrated moving average (ARIMA) when predicting three infectious diseases one week into the future. The results show that the DNN and LSTM models perform better than ARIMA. When predicting chickenpox, the top-10 DNN and LSTM models improved average performance by 24% and 19%, respectively. The DNN model performed stably and the LSTM model was more accurate when infectious disease was spreading.  We believe that these findings can help eliminate reporting delays in existing surveillance systems and minimize costs to society. |

**Introduction:**

Infectious disease occurs when a person is infected by a pathogen from another person or an animal. It not only harms individuals, but also causes harm on a macro scale and, therefore, is regarded as a social problem [[1](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B1-ijerph-15-01596)].

Infectious disease surveillance is a comprehensive process in which information on infectious disease outbreaks and vectors are continuously and systematically collected, analyzed, and interpreted. Moreover, the results are distributed quickly to people who need them to prevent and control infectious disease.

In the conventional reporting system, some medical organizations’ infectious disease reports are incomplete and delays can occur in the reporting system. For instance, in the traditional influenza surveillance system, around two weeks elapses between when a report is made and when it is disseminated [[2](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B2-ijerph-15-01596)].

In medical organizations using the conventional infectious disease reporting system, a large number of missing and delayed reports can occur, which hinders a prompt response to infectious disease. As such, it is necessary to create a data-based infectious disease prediction model to handle situations in real time. Furthermore, if this model can understand the extent of infectious disease trends, the costs to society from infectious disease can be minimized. In medical organizations using the conventional infectious disease reporting system, a large number of missing and delayed reports can occur, which hinders a prompt response to infectious disease. As such, it is necessary to create a data-based infectious disease prediction model to handle situations in real time. Furthermore, if this model can understand the extent of infectious disease trends, the costs to society from infectious disease can be minimized.

An increasing number of researchers recognize these facts and are performing data-based infectious disease surveillance studies to supplement existing systems and design new models [[3](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B3-ijerph-15-01596),[4](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B4-ijerph-15-01596),[5](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B5-ijerph-15-01596),[6](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B6-ijerph-15-01596),[7](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B7-ijerph-15-01596),[8](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B8-ijerph-15-01596),[9](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B9-ijerph-15-01596)]. Among these, studies are currently being performed on detecting infectious disease using big data such as Internet search queries [[10](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B10-ijerph-15-01596),[11](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B11-ijerph-15-01596),[12](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B12-ijerph-15-01596),[13](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B13-ijerph-15-01596),[14](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B14-ijerph-15-01596),[15](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B15-ijerph-15-01596)]. The Internet search data can be gathered and processed at a speed that is close to real time. According to Towers et al., Internet search data can create surveillance data faster than conventional surveillance systems [[16](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B16-ijerph-15-01596)]. For example, when Huang et al. predicted hand, foot, and mouth disease using the generalized additive model (GAM), the model that included search query data obtained the best results. As such, it has been reported that new big data surveillance tools have the advantage of being easy to access and can identify infectious disease trends before official organizations [[17](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B17-ijerph-15-01596)]. In addition to Internet search data, social media big data is also being considered. Tenkanen et al. report that social media big data is relatively easy to collect and can be used freely, which means accessibility is satisfactory and the data is created continuously in real time with rich content [[18](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B18-ijerph-15-01596)]. As such, studies have used Twitter data to predict the occurrences of mental illness [[19](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B19-ijerph-15-01596)] and infectious disease [[20](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B20-ijerph-15-01596),[21](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B21-ijerph-15-01596),[22](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B22-ijerph-15-01596),[23](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B23-ijerph-15-01596)] in addition to predictions in a variety of other scientific fields [[24](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B24-ijerph-15-01596),[25](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B25-ijerph-15-01596),[26](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B26-ijerph-15-01596),[27](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B27-ijerph-15-01596)]. In particular, a study by Shin et al. reported that infectious diseases and Twitter data are highly correlated. There is the possibility of using digital surveillance systems to monitor infectious disease in the future [[20](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B20-ijerph-15-01596)]. When these points are considered, using search query data and social media big data should have a positive effect on infectious disease predictions.

In addition to these studies, there are also studies that have used techniques from the field of deep learning to predict infectious disease [[22](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B22-ijerph-15-01596),[23](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B23-ijerph-15-01596),[28](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B28-ijerph-15-01596),[29](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B29-ijerph-15-01596)]. Deep learning is an analysis method and, like big data, it is being actively used in a variety of fields [[30](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B30-ijerph-15-01596)]. Deep learning yields satisfactory results when it is used to perform tasks that are difficult for conventional analysis methods [[31](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B31-ijerph-15-01596),[32](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B32-ijerph-15-01596),[33](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B33-ijerph-15-01596)]. In a study by Xu et al., a model that used deep learning yielded better prediction performance than the generalized linear model (GLM), the least absolute shrinkage and selection operator (LASSO) model, and the autoregressive integrated moving average (ARIMA) model [[28](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B28-ijerph-15-01596)]. As such, methods of predicting infectious disease that use deep learning are helpful for designing effective models.

There are also examples of infectious disease prediction based on environmental factors such as weather [[34](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B34-ijerph-15-01596),[35](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B35-ijerph-15-01596),[36](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B36-ijerph-15-01596),[37](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B37-ijerph-15-01596)]. Previous studies have confirmed that weather data comprises a factor that has a great influence on the occurrence of infectious diseases [[38](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B38-ijerph-15-01596),[39](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B39-ijerph-15-01596),[40](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B40-ijerph-15-01596)]. Liang et al. showed that rainfall and humidity are risk factors for a hemorrhagic fever with a renal syndrome [[41](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B41-ijerph-15-01596)]. In addition, a study by Huang et al. reported that trends in dengue fever show a strong correlation with temperature and humidity [[42](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6121625/#B42-ijerph-15-01596)]. Previous studies indicate that infectious disease can be predicted more effectively if weather variables, Internet big data, and deep learning are used.

**Conclusion:**

Infectious disease is a social problem in that it can cause not only personal damage but also widespread harm. For this reason, research is being conducted to minimize social losses by predicting the spread of infectious diseases. The aim of this study was to design an infectious disease prediction model that is more suitable than existing models by using various input variables and deep learning techniques. Therefore, in this study, the optimal parameters were set using a variable selection method based on OLS. The relationship between actual instances of disease occurrence and the Internet search query data tends to have a time lag, which means a lag was added to each infectious disease’s dataset to find the future trend. Next, an analysis of ARIMA, DNN, and LSTM was performed with optimal parameters.

The results of OLS analysis using optimal parameters showed that the regression models for each infectious disease had significant results. Of the four input variables, the Naver search frequency had a significant relationship with all three infectious diseases. The performance of the OLS and ARIMA analysis was used to evaluate the deep learning models. Looking at the results for DNN and LSTM, both the deep learning models made much better predictions than the OLS and ARIMA models for all infectious diseases. Moreover, the DNN models had the best performance on average, but the LSTM models made more accurate predictions when infectious diseases were spreading. However, in the case of malaria, there were few occurrences of the disease compared to other infectious diseases, which means the predictions were not comparatively accurate.

This study was also able to reveal special characteristics of the DNN and LSTM models. The DNN model produced smaller values than the LSTM model on average when predicting infectious diseases. Suitable predictions can be made using the DNN model when predicting the minimum value for disease occurrence and using the LSTM model when predicting the maximum value.

## Supplementary Materials:

The following are available online at <http://www.mdpi.com/1660-4601/15/8/1596/s1>, Table S1: The root mean squared error (RMSE) and prediction graphs of top 10 deep neural network (DNN) and long-short term memory (LSTM) models for chickenpox. The seasonal autoregressive integrated moving average (ARIMA) model is denoted as ARIMA(p, d, q)(P, D, Q)S. where p is the order of the autoregressive part, d is the order of the differencing, q is the order of the moving-average process, and S is the length of the seasonal cycle. (P, D, Q) is the seasonal part of the model. The numbers in parentheses indicate each deep learning model’s optimizer, activation, and number of epochs, respectively. (optimizer) 1: Adadelta, 2: Adagrad, 3: Adam, 4: Adamax, 5: Nadam, 6: RMSProp, and 7: SGD, (activation function) 1: ELU, 2: ReLU, 3: SELU, and 4: SoftPlus, (number of epochs) 1: 400, 2: 600, 3: 800, and 4: 1000, Table S2: The RMSE and prediction graphs of the top 10 DNN and LSTM models for scarlet fever, Table S3: The RMSE and prediction graphs of top 10 DNN and LSTM models for malaria.

**References:**

1. Jae C.M. Infectious disease, safety, state: History of infectious disease prevention and MERS situation. Crit. Stud. Mod. Korean Hist. 2015;34:517–542. [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Crit.+Stud.+Mod.+Korean+Hist.&title=Infectious+disease,+safety,+state:+History+of+infectious+disease+prevention+and+MERS+situation&author=C.M.+Jae&volume=34&publication_year=2015&pages=517-542&issn=1226-4199&)]
2. Cheng C.K., Lau E.H., Ip D.K., Yeung A.S., Ho L.M., Cowling B.J. A profile of the online dissemination of national influenza surveillance data. BMC Public Health. 2009;9:339. doi: 10.1186/1471-2458-9-339. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2754460/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/19754978)] [[CrossRef](https://dx.doi.org/10.1186%2F1471-2458-9-339)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=BMC+Public+Health&title=A+profile+of+the+online+dissemination+of+national+influenza+surveillance+data&author=C.K.+Cheng&author=E.H.+Lau&author=D.K.+Ip&author=A.S.+Yeung&author=L.M.+Ho&volume=9&publication_year=2009&pages=339&pmid=19754978&doi=10.1186/1471-2458-9-339&)]
3. Balcan D., Colizza V., Gonçalves B., Hu H., Ramasco J.J., Vespignani A. Multiscale mobility networks and the spatial spreading of infectious diseases. Proc. Natl. Acad. Sci. USA. 2009;106:21484. doi: 10.1073/pnas.0906910106. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2793313/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/20018697)] [[CrossRef](https://dx.doi.org/10.1073%2Fpnas.0906910106)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Proc.+Natl.+Acad.+Sci.+USA&title=Multiscale+mobility+networks+and+the+spatial+spreading+of+infectious+diseases&author=D.+Balcan&author=V.+Colizza&author=B.+Gon%C3%A7alves&author=H.+Hu&author=J.J.+Ramasco&volume=106&publication_year=2009&pages=21484&pmid=20018697&doi=10.1073/pnas.0906910106&)]
4. Colizza V., Barrat A., Barthelemy M., Valleron A., Vespignani A. Modeling the Worldwide Spread of Pandemic Influenza: Baseline Case and Containment Interventions. PLOS Med. 2007;4:e13. doi: 10.1371/journal.pmed.0040013. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1779816/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/17253899)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pmed.0040013)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLOS+Med.&title=Modeling+the+Worldwide+Spread+of+Pandemic+Influenza:+Baseline+Case+and+Containment+Interventions&author=V.+Colizza&author=A.+Barrat&author=M.+Barthelemy&author=A.+Valleron&author=A.+Vespignani&volume=4&publication_year=2007&pages=e13&pmid=17253899&doi=10.1371/journal.pmed.0040013&)]
5. Balcan D., Hu H., Goncalves B., Bajardi P., Poletto C., Ramasco J.J., Paolotti D., Perra N., Tizzoni M., van den Broeck W., et al. Seasonal transmission potential and activity peaks of the new influenza A(H1N1): A Monte Carlo likelihood analysis based on human mobility. BMC Med. 2009;1:45. doi: 10.1186/1741-7015-7-45. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2755471/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/19744314)] [[CrossRef](https://dx.doi.org/10.1186%2F1741-7015-7-45)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=BMC+Med.&title=Seasonal+transmission+potential+and+activity+peaks+of+the+new+influenza+A(H1N1):+A+Monte+Carlo+likelihood+analysis+based+on+human+mobility&author=D.+Balcan&author=H.+Hu&author=B.+Goncalves&author=P.+Bajardi&author=C.+Poletto&volume=1&publication_year=2009&pages=45&pmid=19744314&doi=10.1186/1741-7015-7-45&)]
6. Eubank S., Guclu H., Anil Kumar V.S., Marathe M.V., Srinivasan A., Toroczkai Z., Wang N. Modelling disease outbreaks in realistic urban social networks. Nature. 2004;429:180. doi: 10.1038/nature02541. [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/15141212)] [[CrossRef](https://dx.doi.org/10.1038%2Fnature02541)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Nature&title=Modelling+disease+outbreaks+in+realistic+urban+social+networks&author=S.+Eubank&author=H.+Guclu&author=V.S.+Anil+Kumar&author=M.V.+Marathe&author=A.+Srinivasan&volume=429&publication_year=2004&pages=180&pmid=15141212&doi=10.1038/nature02541&)]
7. Ferguson N.M., Cummings D.A.T., Fraser C., Cajka J.C., Cooley P.C., Burke D.S. Strategies for mitigating an influenza pandemic. Nature. 2006;442:448. doi: 10.1038/nature04795. [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/16642006)] [[CrossRef](https://dx.doi.org/10.1038%2Fnature04795)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Nature&title=Strategies+for+mitigating+an+influenza+pandemic&author=N.M.+Ferguson&author=D.A.T.+Cummings&author=C.+Fraser&author=J.C.+Cajka&author=P.C.+Cooley&volume=442&publication_year=2006&pages=448&pmid=16642006&doi=10.1038/nature04795&)]
8. Epstein J.M., Goedecke D.M., Yu F., Morris R.J., Wagener D.K., Bobashev G.V. Controlling Pandemic Flu: The Value of International Air Travel Restrictions. PLoS ONE. 2007;2:e401. doi: 10.1371/journal.pone.0000401. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1855004/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/17476323)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0000401)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Controlling+Pandemic+Flu:+The+Value+of+International+Air+Travel+Restrictions&author=J.M.+Epstein&author=D.M.+Goedecke&author=F.+Yu&author=R.J.+Morris&author=D.K.+Wagener&volume=2&publication_year=2007&pages=e401&pmid=17476323&doi=10.1371/journal.pone.0000401&)]
9. Ciofi degli Atti M.L., Merler S., Rizzo C., Ajelli M., Massari M., Manfredi P., Furlanello C., Scalia Tomba G., Iannelli M. Mitigation Measures for Pandemic Influenza in Italy: An Individual Based Model Considering Different Scenarios. PLoS ONE. 2008;3:e1790. doi: 10.1371/journal.pone.0001790. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2258437/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/18335060)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0001790)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Mitigation+Measures+for+Pandemic+Influenza+in+Italy:+An+Individual+Based+Model+Considering+Different+Scenarios&author=M.L.+Ciofi+degli+Atti&author=S.+Merler&author=C.+Rizzo&author=M.+Ajelli&author=M.+Massari&volume=3&publication_year=2008&pages=e1790&pmid=18335060&doi=10.1371/journal.pone.0001790&)]
10. Zhang Y., Milinovich G., Xu Z., Bambrick H., Mengersen K., Tong S., Hu W. Monitoring Pertussis Infections Using Internet Search Queries. Sci. Rep. 2017;7:10437. doi: 10.1038/s41598-017-11195-z. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5585203/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/28874880)] [[CrossRef](https://dx.doi.org/10.1038%2Fs41598-017-11195-z)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Monitoring+Pertussis+Infections+Using+Internet+Search+Queries&author=Y.+Zhang&author=G.+Milinovich&author=Z.+Xu&author=H.+Bambrick&author=K.+Mengersen&volume=7&publication_year=2017&pages=10437&pmid=28874880&doi=10.1038/s41598-017-11195-z&)]
11. Rohart F., Milinovich G.J., Avril S.M.R., Lê Cao K., Tong S., Hu W. Disease surveillance based on Internet-based linear models: An Australian case study of previously unmodeled infection diseases. Sci. Rep. 2016;6:38522. doi: 10.1038/srep38522. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5172376/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27994231)] [[CrossRef](https://dx.doi.org/10.1038%2Fsrep38522)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Disease+surveillance+based+on+Internet-based+linear+models:+An+Australian+case+study+of+previously+unmodeled+infection+diseases&author=F.+Rohart&author=G.J.+Milinovich&author=S.M.R.+Avril&author=K.+L%C3%AA+Cao&author=S.+Tong&volume=6&publication_year=2016&pages=38522&pmid=27994231&doi=10.1038/srep38522&)]
12. Lampos V., Miller A.C., Crossan S., Stefansen C. Advances in nowcasting influenza-like illness rates using search query logs. Sci. Rep. 2015;5:12760. doi: 10.1038/srep12760. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4522652/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/26234783)] [[CrossRef](https://dx.doi.org/10.1038%2Fsrep12760)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Advances+in+nowcasting+influenza-like+illness+rates+using+search+query+logs&author=V.+Lampos&author=A.C.+Miller&author=S.+Crossan&author=C.+Stefansen&volume=5&publication_year=2015&pages=12760&pmid=26234783&doi=10.1038/srep12760&)]
13. Cho S., Sohn C.H., Jo M.W., Shin S.Y., Lee J.H., Ryoo S.M., Kim W.Y., Seo D.W. Correlation between national influenza surveillance data and google trends in South Korea. PLoS ONE. 2013;8:e81422. doi: 10.1371/journal.pone.0081422. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3855287/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/24339927)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0081422)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Correlation+between+national+influenza+surveillance+data+and+google+trends+in+South+Korea&author=S.+Cho&author=C.H.+Sohn&author=M.W.+Jo&author=S.Y.+Shin&author=J.H.+Lee&volume=8&publication_year=2013&pages=e81422&pmid=24339927&doi=10.1371/journal.pone.0081422&)]
14. Teng Y., Bi D., Xie G., Jin Y., Huang Y., Lin B., An X., Feng D., Tong Y. Dynamic Forecasting of Zika Epidemics Using Google Trends. PLoS ONE. 2017;12:e0165085. doi: 10.1371/journal.pone.0165085. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5217860/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/28060809)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0165085)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Dynamic+Forecasting+of+Zika+Epidemics+Using+Google+Trends&author=Y.+Teng&author=D.+Bi&author=G.+Xie&author=Y.+Jin&author=Y.+Huang&volume=12&publication_year=2017&pages=e0165085&pmid=28060809&doi=10.1371/journal.pone.0165085&)]
15. Dugas A.F., Jalalpour M., Gel Y., Levin S., Torcaso F., Igusa T., Rothman R.E. Influenza forecasting with Google Flu Trends. PLoS ONE. 2013;8:e56176. doi: 10.1371/journal.pone.0056176. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3572967/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/23457520)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0056176)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Influenza+forecasting+with+Google+Flu+Trends&author=A.F.+Dugas&author=M.+Jalalpour&author=Y.+Gel&author=S.+Levin&author=F.+Torcaso&volume=8&publication_year=2013&pages=e56176&pmid=23457520&doi=10.1371/journal.pone.0056176&)]
16. Towers S., Afzal S., Bernal G., Bliss N., Brown S., Espinoza B., Jackson J., Judson-Garcia J., Khan M., Lin M., et al. Mass Media and the Contagion of Fear: The Case of Ebola in America. PLoS ONE. 2015;10:e0129179. doi: 10.1371/journal.pone.0129179. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4465830/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/26067433)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0129179)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Mass+Media+and+the+Contagion+of+Fear:+The+Case+of+Ebola+in+America&author=S.+Towers&author=S.+Afzal&author=G.+Bernal&author=N.+Bliss&author=S.+Brown&volume=10&publication_year=2015&pages=e0129179&pmid=26067433&doi=10.1371/journal.pone.0129179&)]
17. Huang D.C., Wang J.F. Monitoring hand, foot and mouth disease by combining search engine query data and meteorological factors. Sci. Total Environ. 2018;612:1293–1299. doi: 10.1016/j.scitotenv.2017.09.017. [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/28898935)] [[CrossRef](https://dx.doi.org/10.1016%2Fj.scitotenv.2017.09.017)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Total+Environ.&title=Monitoring+hand,+foot+and+mouth+disease+by+combining+search+engine+query+data+and+meteorological+factors&author=D.C.+Huang&author=J.F.+Wang&volume=612&publication_year=2018&pages=1293-1299&pmid=28898935&doi=10.1016/j.scitotenv.2017.09.017&)]
18. Tenkanen H., di Minin E., Heikinheimo V., Hausmann A., Herbst M., Kajala L., Toivonen T. Instagram, Flickr, or Twitter: Assessing the usability of social media data for visitor monitoring in protected areas. Sci. Rep. 2017;7:17615. doi: 10.1038/s41598-017-18007-4. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5730565/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/29242619)] [[CrossRef](https://dx.doi.org/10.1038%2Fs41598-017-18007-4)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Instagram,+Flickr,+or+Twitter:+Assessing+the+usability+of+social+media+data+for+visitor+monitoring+in+protected+areas&author=H.+Tenkanen&author=E.+di+Minin&author=V.+Heikinheimo&author=A.+Hausmann&author=M.+Herbst&volume=7&publication_year=2017&pages=17615&pmid=29242619&doi=10.1038/s41598-017-18007-4&)]
19. Reece A.G., Reagan A.J., Lix K.L.M., Dodds P.S., Danforth C.M., Langer E.J. Forecasting the onset and course of mental illness with Twitter data. Sci. Rep. 2017;7:13006. doi: 10.1038/s41598-017-12961-9. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5636873/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/29021528)] [[CrossRef](https://dx.doi.org/10.1038%2Fs41598-017-12961-9)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Forecasting+the+onset+and+course+of+mental+illness+with+Twitter+data&author=A.G.+Reece&author=A.J.+Reagan&author=K.L.M.+Lix&author=P.S.+Dodds&author=C.M.+Danforth&volume=7&publication_year=2017&pages=13006&pmid=29021528&doi=10.1038/s41598-017-12961-9&)]
20. Shin S., Seo D., An J., Kwak H., Kim S., Gwack J., Jo M. High correlation of Middle East respiratory syndrome spread with Google search and Twitter trends in Korea. Sci. Rep. 2016;6:32920. doi: 10.1038/srep32920. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5011762/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27595921)] [[CrossRef](https://dx.doi.org/10.1038%2Fsrep32920)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=High+correlation+of+Middle+East+respiratory+syndrome+spread+with+Google+search+and+Twitter+trends+in+Korea&author=S.+Shin&author=D.+Seo&author=J.+An&author=H.+Kwak&author=S.+Kim&volume=6&publication_year=2016&pages=32920&pmid=27595921&doi=10.1038/srep32920&)]
21. Thapen N., Simmie D., Hankin C., Gillard J. DEFENDER: Detecting and Forecasting Epidemics Using Novel Data-Analytics for Enhanced Response. PLoS ONE. 2016;11:e0155417. doi: 10.1371/journal.pone.0155417. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4871418/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27192059)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0155417)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=DEFENDER:+Detecting+and+Forecasting+Epidemics+Using+Novel+Data-Analytics+for+Enhanced+Response&author=N.+Thapen&author=D.+Simmie&author=C.+Hankin&author=J.+Gillard&volume=11&publication_year=2016&pages=e0155417&pmid=27192059&doi=10.1371/journal.pone.0155417&)]
22. Allen C., Tsou M., Aslam A., Nagel A., Gawron J. Applying GIS and Machine Learning Methods to Twitter Data for Multiscale Surveillance of Influenza. PLoS ONE. 2016;11:e0157734. doi: 10.1371/journal.pone.0157734. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4959719/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27455108)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0157734)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Applying+GIS+and+Machine+Learning+Methods+to+Twitter+Data+for+Multiscale+Surveillance+of+Influenza&author=C.+Allen&author=M.+Tsou&author=A.+Aslam&author=A.+Nagel&author=J.+Gawron&volume=11&publication_year=2016&pages=e0157734&pmid=27455108&doi=10.1371/journal.pone.0157734&)]
23. Volkova S., Ayton E., Porterfield K., Corley C.D. Forecasting influenza-like illness dynamics for military populations using neural networks and social media. PLoS ONE. 2017;12:e0188941. doi: 10.1371/journal.pone.0188941. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5731746/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/29244814)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0188941)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Forecasting+influenza-like+illness+dynamics+for+military+populations+using+neural+networks+and+social+media&author=S.+Volkova&author=E.+Ayton&author=K.+Porterfield&author=C.D.+Corley&volume=12&publication_year=2017&pages=e0188941&pmid=29244814&doi=10.1371/journal.pone.0188941&)]
24. Simon T., Goldberg A., Aharonson-Daniel L., Leykin D., Adini B. Twitter in the Cross Fire—The Use of Social Media in the Westgate Mall Terror Attack in Kenya. PLoS ONE. 2014;9:e104136. doi: 10.1371/journal.pone.0104136. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4143241/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/25153889)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0104136)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Twitter+in+the+Cross+Fire%E2%80%94The+Use+of+Social+Media+in+the+Westgate+Mall+Terror+Attack+in+Kenya&author=T.+Simon&author=A.+Goldberg&author=L.+Aharonson-Daniel&author=D.+Leykin&author=B.+Adini&volume=9&publication_year=2014&pages=e104136&pmid=25153889&doi=10.1371/journal.pone.0104136&)]
25. Tafti A., Zotti R., Jank W. Real-Time Diffusion of Information on Twitter and the Financial Markets. PLoS ONE. 2016;11:e0159226. doi: 10.1371/journal.pone.0159226. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4978482/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27504639)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0159226)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Real-Time+Diffusion+of+Information+on+Twitter+and+the+Financial+Markets&author=A.+Tafti&author=R.+Zotti&author=W.+Jank&volume=11&publication_year=2016&pages=e0159226&pmid=27504639&doi=10.1371/journal.pone.0159226&)]
26. Xia F., Su X., Wang W., Zhang C., Ning Z., Lee I. Bibliographic Analysis of Nature Based on Twitter and Facebook Altmetrics Data. PLoS ONE. 2016;11:e0165997. doi: 10.1371/journal.pone.0165997. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5132397/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27906981)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0165997)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Bibliographic+Analysis+of+Nature+Based+on+Twitter+and+Facebook+Altmetrics+Data&author=F.+Xia&author=X.+Su&author=W.+Wang&author=C.+Zhang&author=Z.+Ning&volume=11&publication_year=2016&pages=e0165997&pmid=27906981&doi=10.1371/journal.pone.0165997&)]
27. Patel R., Belousov M., Jani M., Dasgupta N., Winakor C., Nenadic G., Dixon W.G. Frequent discussion of insomnia and weight gain with glucocorticoid therapy: An analysis of Twitter posts. Npj Digit. Med. 2018;1:7. doi: 10.1038/s41746-017-0007-z. [[CrossRef](https://dx.doi.org/10.1038%2Fs41746-017-0007-z)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Npj+Digit.+Med.&title=Frequent+discussion+of+insomnia+and+weight+gain+with+glucocorticoid+therapy:+An+analysis+of+Twitter+posts&author=R.+Patel&author=M.+Belousov&author=M.+Jani&author=N.+Dasgupta&author=C.+Winakor&volume=1&publication_year=2018&pages=7&doi=10.1038/s41746-017-0007-z&)]
28. Xu Q., Gel Y.R., Ramirez Ramirez L.L., Nezafati K., Zhang Q., Tsui K.L. Forecasting influenza in Hong Kong with Google search Queries and statistical model fusion. PLoS ONE. 2017;12:e0176690. doi: 10.1371/journal.pone.0176690. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5413039/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/28464015)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0176690)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Forecasting+influenza+in+Hong+Kong+with+Google+search+Queries+and+statistical+model+fusion&author=Q.+Xu&author=Y.R.+Gel&author=L.L.+Ramirez+Ramirez&author=K.+Nezafati&author=Q.+Zhang&volume=12&publication_year=2017&pages=e0176690&pmid=28464015&doi=10.1371/journal.pone.0176690&)]
29. He F., Hu Z., Zhang W., Cai L., Cai G., Aoyagi K. Construction and evaluation of two computational models for predicting the incidence of influenza in Nagasaki Prefecture, Japan. Sci. Rep. 2017;7:7192. doi: 10.1038/s41598-017-07475-3. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5543162/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/28775299)] [[CrossRef](https://dx.doi.org/10.1038%2Fs41598-017-07475-3)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Construction+and+evaluation+of+two+computational+models+for+predicting+the+incidence+of+influenza+in+Nagasaki+Prefecture,+Japan&author=F.+He&author=Z.+Hu&author=W.+Zhang&author=L.+Cai&author=G.+Cai&volume=7&publication_year=2017&pages=7192&pmid=28775299&doi=10.1038/s41598-017-07475-3&)]
30. Najafabadi M.M., Villanustre F., Khoshgoftaar T.M., Seliya N., Wald R., Muharemagic E. Deep learning applications and challenges in big data analytics. J. Big Data. 2017;2 doi: 10.1186/s40537-014-0007-7. [[CrossRef](https://dx.doi.org/10.1186%2Fs40537-014-0007-7)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=J.+Big+Data&title=Deep+learning+applications+and+challenges+in+big+data+analytics&author=M.M.+Najafabadi&author=F.+Villanustre&author=T.M.+Khoshgoftaar&author=N.+Seliya&author=R.+Wald&volume=2&publication_year=2017&doi=10.1186/s40537-014-0007-7&)]
31. Janowczyk A., Madabhushi A. Deep learning for digital pathology image analysis: A comprehensive tutorial with selected use cases. J. Pathol. Inform. 2016;7:29. doi: 10.4103/2153-3539.186902. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4977982/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/27563488)] [[CrossRef](https://dx.doi.org/10.4103%2F2153-3539.186902)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=J.+Pathol.+Inform.&title=Deep+learning+for+digital+pathology+image+analysis:+A+comprehensive+tutorial+with+selected+use+cases&author=A.+Janowczyk&author=A.+Madabhushi&volume=7&publication_year=2016&pages=29&pmid=27563488&doi=10.4103/2153-3539.186902&)]
32. Esteva A., Kuprel B., Novoa R.A., Ko J., Swetter S.M., Blau H.M., Thrun S. Dermatologist-level classification of skin cancer with deep neural networks. Nature. 2017;542:115. doi: 10.1038/nature21056. [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/28117445)] [[CrossRef](https://dx.doi.org/10.1038%2Fnature21056)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Nature&title=Dermatologist-level+classification+of+skin+cancer+with+deep+neural+networks&author=A.+Esteva&author=B.+Kuprel&author=R.A.+Novoa&author=J.+Ko&author=S.M.+Swetter&volume=542&publication_year=2017&pages=115&pmid=28117445&doi=10.1038/nature21056&)]
33. Bychkov D., Linder N., Turkki R., Nordling S., Kovanen P.E., Verrill C., Walliander M., Lundin M., Haglund C., Lundin J. Deep learning based tissue analysis predicts outcome in colorectal cancer. Sci. Rep. 2018;8:3395. doi: 10.1038/s41598-018-21758-3. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5821847/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/29467373)] [[CrossRef](https://dx.doi.org/10.1038%2Fs41598-018-21758-3)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Deep+learning+based+tissue+analysis+predicts+outcome+in+colorectal+cancer&author=D.+Bychkov&author=N.+Linder&author=R.+Turkki&author=S.+Nordling&author=P.E.+Kovanen&volume=8&publication_year=2018&pages=3395&pmid=29467373&doi=10.1038/s41598-018-21758-3&)]
34. Song Y., Wang F., Wang B., Tao S., Zhang H., Liu S., Ramirez O., Zeng Q. Time Series Analyses of Hand, Foot and Mouth Disease Integrating Weather Variables. PLoS ONE. 2015;10:e0117296. doi: 10.1371/journal.pone.0117296. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4346267/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/25729897)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0117296)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Time+Series+Analyses+of+Hand,+Foot+and+Mouth+Disease+Integrating+Weather+Variables&author=Y.+Song&author=F.+Wang&author=B.+Wang&author=S.+Tao&author=H.+Zhang&volume=10&publication_year=2015&pages=e0117296&pmid=25729897&doi=10.1371/journal.pone.0117296&)]
35. Hii Y.L., Rocklöv J., Ng N. Short Term Effects of Weather on Hand, Foot and Mouth Disease. PLoS ONE. 2011;6:e16796. doi: 10.1371/journal.pone.0016796. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3037951/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/21347303)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0016796)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Short+Term+Effects+of+Weather+on+Hand,+Foot+and+Mouth+Disease&author=Y.L.+Hii&author=J.+Rockl%C3%B6v&author=N.+Ng&volume=6&publication_year=2011&pages=e16796&pmid=21347303&doi=10.1371/journal.pone.0016796&)]
36. Lopman B., Armstrong B., Atchison C., Gray J.J. Host, Weather and Virological Factors Drive Norovirus Epidemiology: Time-Series Analysis of Laboratory Surveillance Data in England and Wales. PLoS ONE. 2009;4:e6671. doi: 10.1371/journal.pone.0006671. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2726937/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/19701458)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0006671)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Host,+Weather+and+Virological+Factors+Drive+Norovirus+Epidemiology:+Time-Series+Analysis+of+Laboratory+Surveillance+Data+in+England+and+Wales&author=B.+Lopman&author=B.+Armstrong&author=C.+Atchison&author=J.J.+Gray&volume=4&publication_year=2009&pages=e6671&pmid=19701458&doi=10.1371/journal.pone.0006671&)]
37. Huang X., Williams G., Clements A.C.A., Hu W. Imported Dengue Cases, Weather Variation and Autochthonous Dengue Incidence in Cairns, Australia. PLoS ONE. 2013;8:e81887. doi: 10.1371/journal.pone.0081887. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3862568/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/24349148)] [[CrossRef](https://dx.doi.org/10.1371%2Fjournal.pone.0081887)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=PLoS+ONE&title=Imported+Dengue+Cases,+Weather+Variation+and+Autochthonous+Dengue+Incidence+in+Cairns,+Australia&author=X.+Huang&author=G.+Williams&author=A.C.A.+Clements&author=W.+Hu&volume=8&publication_year=2013&pages=e81887&pmid=24349148&doi=10.1371/journal.pone.0081887&)]
38. Liu T., Zhang Y., Lin H., Lv X., Xiao J., Zeng W., Gu Y., Rutherford S., Tong S., Ma W. A large temperature fluctuation may trigger an epidemic erythromelalgia outbreak in China. Sci. Rep. 2015;5:9525. doi: 10.1038/srep09525. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4377627/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/25820221)] [[CrossRef](https://dx.doi.org/10.1038%2Fsrep09525)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=A+large+temperature+fluctuation+may+trigger+an+epidemic+erythromelalgia+outbreak+in+China&author=T.+Liu&author=Y.+Zhang&author=H.+Lin&author=X.+Lv&author=J.+Xiao&volume=5&publication_year=2015&pages=9525&pmid=25820221&doi=10.1038/srep09525&)]
39. Blanford J.I., Blanford S., Crane R.G., Mann M.E., Paaijmans K.P., Schreiber K.V., Thomas M.B. Implications of temperature variation for malaria parasite development across Africa. Sci. Rep. 2013;3:1300. doi: 10.1038/srep01300. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3575117/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/23419595)] [[CrossRef](https://dx.doi.org/10.1038%2Fsrep01300)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Implications+of+temperature+variation+for+malaria+parasite+development+across+Africa&author=J.I.+Blanford&author=S.+Blanford&author=R.G.+Crane&author=M.E.+Mann&author=K.P.+Paaijmans&volume=3&publication_year=2013&pages=1300&pmid=23419595&doi=10.1038/srep01300&)]
40. Noden B.H., Kent M.D., Beier J.C. The impact of variations in temperature on early Plasmodium falciparum development in Anopheles stephensi. Parasitology. 1995;111:539–545. doi: 10.1017/S0031182000077003. [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/8559585)] [[CrossRef](https://dx.doi.org/10.1017%2FS0031182000077003)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Parasitology&title=The+impact+of+variations+in+temperature+on+early+Plasmodium+falciparum+development+in+Anopheles+stephensi&author=B.H.+Noden&author=M.D.+Kent&author=J.C.+Beier&volume=111&publication_year=1995&pages=539-545&pmid=8559585&doi=10.1017/S0031182000077003&)]
41. Liang W., Gu X., Li X., Zhang K., Wu K., Pang M., Dong J., Merrill H.R., Hu T., Liu K., et al. Mapping the epidemic changes and risks of hemorrhagic fever with renal syndrome in Shaanxi Province, China, 2005–2016. Sci. Rep. 2018;8:749. doi: 10.1038/s41598-017-18819-4. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5768775/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/29335595)] [[CrossRef](https://dx.doi.org/10.1038%2Fs41598-017-18819-4)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Sci.+Rep.&title=Mapping+the+epidemic+changes+and+risks+of+hemorrhagic+fever+with+renal+syndrome+in+Shaanxi+Province,+China,+2005%E2%80%932016&author=W.+Liang&author=X.+Gu&author=X.+Li&author=K.+Zhang&author=K.+Wu&volume=8&publication_year=2018&pages=749&pmid=29335595&doi=10.1038/s41598-017-18819-4&)]
42. Huang X., Clements A.C.A., Williams G., Milinovich G., Hu W. A threshold analysis of dengue transmission in terms of weather variables and imported dengue cases in Australia. Emerg. Microbes Amp Infect. 2013;2:e87. doi: 10.1038/emi.2013.85. [[PMC free article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3880872/)] [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/26038449)] [[CrossRef](https://dx.doi.org/10.1038%2Femi.2013.85)] [[Google Scholar](https://scholar.google.com/scholar_lookup?journal=Emerg.+Microbes+Amp+Infect.&title=A+threshold+analysis+of+dengue+transmission+in+terms+of+weather+variables+and+imported+dengue+cases+in+Australia&author=X.+Huang&author=A.C.A.+Clements&author=G.+Williams&author=G.+Milinovich&author=W.+Hu&volume=2&publication_year=2013&pages=e87&pmid=26038449&doi=10.1038/emi.2013.85&)]

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