



< Back to results | 1 of 1

Download Print E-mail Save to PDF Add to List More... >

Theoretical and Applied Climatology • Volume 150, Issue 3-4, Pages 987 - 1013 • November 2022

Document type

Article

Source type

Journal

ISSN

0177798X

DOI

10.1007/s00704-022-04205-2

View more >

Effectiveness of causality-based predictor selection for statistical downscaling: a case study of rainfall in an Ecuadorian Andes basin

Vázquez-Patiño, Angel^{a, b} ; Samaniego, Esteban^{c, d}; Campozano, Lenin^e; Avilés, Alex^{f, g}

Save all to author list

^a Faculty of Architecture and Urbanism, University of Cuenca, Cuenca, Ecuador

^b Department of Civil Engineering, University of Cuenca, Cuenca, Ecuador

^c Department of Water Resources and Environmental Sciences, University of Cuenca, Cuenca, Ecuador

^d Faculty of Engineering, University of Cuenca, Cuenca, Ecuador

View additional affiliations >

Full text options > Export >

Abstract

Indexed keywords

SciVal Topics

Metrics

Funding details

Abstract

Downscaling aims to take large-scale information and map it to smaller scales to reproduce local climate signals. An essential step in implementing a parsimonious downscaling model is the selection of a subset of relevant predictors that increase the simulation accuracy. According to relevant literature, predictive models that use predictors chosen through causality methods, not widely used in downscaling, are more interpretable and robust. Characteristics that do not necessarily pursue the selection methods are commonly used in machine learning (ML), where the primary objective is to maximize accuracy. This study then explores whether the improvement in interpretability and robustness of models that use causally selected predictors is not achieved at the

Cited by 0 documents

Inform me when this document is cited in Scopus:

Set citation alert >

Related documents

Assessment of Quarterly, Semiannual and Annual Models to Forecast Monthly Rainfall Anomalies: The Case of a Tropical Andean Basin

Vázquez-Patiño, A. , Peña, M. , Avilés, A. (2022) *Atmosphere*

Causal discovery in the geosciences—Using synthetic data to learn how to interpret results

Ebert-Uphoff, I. , Deng, Y. (2017) *Computers and Geosciences*

Rainfall and Cloud Dynamics in the Andes: A Southern Ecuador Case Study

Campozano, L. , Célleri, R. , Trachte, K. (2016) *Advances in Meteorology*

View all related documents based on references

Find more related documents in Scopus based on:

Authors > Keywords >

expense of poor downscaling performance in terms of simulation accuracy. To this end, one set of three methods based on causality and one set of four standard predictor selection methods used in ML are compared, centered on the downscaling performance of rainfall in an Ecuadorian Andes basin. One causality-based selection method is based on Granger causality (GC), and two are based on a constraint-based algorithm for structure learning, namely the Peter and Clark algorithm (PCalg) and the based on PCalg and the momentary conditional independence (PCMCI). Regarding the methods used in ML, one is based on the variance of the predictors (variance threshold), two are based on univariate statistical tests (F test and mutual information), and one is based on the recursive elimination of predictors (RFE) according to their contribution to the prediction model. The number of methods in each set results from those that are considered standard in many ML libraries or have been used for regression or climatology (causality-based). The selected predictors are used to train statistical downscaling models based on the random forest and support vector machine learning algorithms to assess their performance and rank the selection methods. Among the most remarkable findings, the methods based on causality show a robust selection. For instance, the causality-based methods selected 53 different predictors in one of the considered stations, while the ML-based methods selected 73 for downscaling models with similar performance. Furthermore, when the predictors used in the best performing downscaling models are analyzed, it is shown that the different selection methods based on causality tend to choose a subset of predictors that do not differ greatly, contrary to the methods based on machine learning. This evidences a more concise selection of the causality-based methods. Finally, the evaluation metrics of the downscaling models showed that the best selection method is RFE, but the following best were consistently those based on causality (mainly PCMCI). The study evidences no significant performance detriment when using the causally selected predictors. © 2022, The Author(s), under exclusive licence to Springer-Verlag GmbH Austria, part of Springer Nature.

Indexed keywords 

SciVal Topics  

Metrics 

Funding details 

References (118)

[View in search results format >](#)

All

[Export](#)  [Print](#)  [E-mail](#)  [Save to PDF](#) [Create bibliography](#)

- 1 Almazroui, M., Ashfaq, M., Islam, M.N., Rashid, I.U., Kamil, S., Abid, M.A., O'Brien, E., (...), Sylla, M.B.
Assessment of CMIP6 Performance and Projected Temperature and Precipitation Changes Over South America
([Open Access](#))

(2021) *Earth Systems and Environment*, 5 (2), pp. 155-183. Cited 44 times.
<https://link.springer.com/journal/41748>
doi: 10.1007/s41748-021-00233-6

[View at Publisher](#)

-
- 2 Araya-Osses, D., Casanueva, A., Román-Figueroa, C., Uribe, J.M., Paneque, M.
Climate change projections of temperature and precipitation in Chile based on statistical downscaling ([Open Access](#))
- (2020) *Climate Dynamics*, 54 (9-10), pp. 4309-4330. Cited 46 times.
<http://link.springer.de/link/service/journals/00382/index.htm>
doi: 10.1007/s00382-020-05231-4
- [View at Publisher](#)
-
- 3 Arias, P.A., Ortega, G., Villegas, L.D., Martínez, J.A.
Colombian climatology in CMIP5/CMIP6 models: Persistent biases and improvements ([Open Access](#))
- (2021) *Revista Facultad de Ingeniería*, (100), pp. 75-96. Cited 12 times.
<https://revistas.udea.edu.co/index.php/ingenieria>
doi: 10.17533/udea.redin.20210525
- [View at Publisher](#)
-
- 4 Athey, S.
Beyond prediction: Using big data for policy problems
- (2017) *Science*, 355 (6324), pp. 483-485. Cited 231 times.
<http://science.sciencemag.org/content/sci/355/6324/483.full.pdf>
doi: 10.1126/science.aal4321
- [View at Publisher](#)
-
- 5 Attanasio, A., Pasini, A., Triacca, U.
Granger causality analyses for climatic attribution
(2013) *Atmospheric Clim Sci*, 3, pp. 515-522. Cited 42 times.
-
- 6 Avilés, A., Palacios, K., Pacheco, J., Jiménez, S., Zhiña, D., Delgado, O.
Sensitivity exploration of water balance in scenarios of future changes: a case study in an Andean regulated river basin
- (2020) *Theoretical and Applied Climatology*, 141 (3-4), pp. 921-934. Cited 3 times.
<https://rd.springer.com/journal/volumesAndIssues/704>
doi: 10.1007/s00704-020-03219-y
- [View at Publisher](#)
-
- 7 Bellman, R.
(1957) *Dynamic programming*. Cited 10192 times.
Princeton University Press, Princeton, NJ
-
- 8 Bendix, J., Lauer, W.
Rainy seasons in Ecuador and their climate-dynamic interpretation
- (1992) *Erdkunde*, 46 (2), pp. 118-134. Cited 79 times.
-

- 9 Biau, G., Scornet, E.
A random forest guided tour ([Open Access](#))

(2016) *Test*, 25 (2), pp. 197-227. Cited 907 times.
<http://www.springerlink.com/content/1133-0686>
doi: 10.1007/s11749-016-0481-7

View at Publisher
-
- 10 Breiman, L.
Random forests ([Open Access](#))

(2001) *Machine Learning*, 45 (1), pp. 5-32. Cited 63869 times.
doi: 10.1023/A:1010933404324

View at Publisher
-
- 11 Breiman, L.
Arcing classifiers

(1998) *Annals of Statistics*, 26 (3), pp. 801-849. Cited 1005 times.

View at Publisher
-
- 12 Buytaert, W., Celleri, R., Willems, P., Bièvre, B.D., Wyseure, G.
Spatial and temporal rainfall variability in mountainous areas:
A case study from the south Ecuadorian Andes ([Open Access](#))

(2006) *Journal of Hydrology*, 329 (3-4), pp. 413-421. Cited 294 times.
doi: 10.1016/j.jhydrol.2006.02.031

View at Publisher
-
- 13 Buytaert, W., Vuille, M., Dewulf, A., Urrutia, R., Karmalkar, A., Céleri, R.
Uncertainties in climate change projections and regional
downscaling in the tropical Andes: Implications for water
resources management ([Open Access](#))

(2010) *Hydrology and Earth System Sciences*, 14 (7), pp. 1247-1258. Cited 148
times.
doi: 10.5194/hess-14-1247-2010

View at Publisher
-
- 14 Campozano, L., Céleri, R., Trachte, K., Bendix, J., Samaniego, E.
Rainfall and Cloud Dynamics in the Andes: A Southern
Ecuador Case Study ([Open Access](#))

(2016) *Advances in Meteorology*, 2016, art. no. 3192765. Cited 50 times.
<http://www.hindawi.com/journals/amet/>
doi: 10.1155/2016/3192765

View at Publisher
-

-
- 15 Campozano, L., Robaina, L., Samaniego, E.
The Pacific decadal oscillation modulates the relation of ENSO with the rainfall variability in coast of Ecuador
- (2020) *International Journal of Climatology*, 40 (13), pp. 5801-5812. Cited 11 times.
[http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)1097-0088](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1097-0088)
doi: 10.1002/joc.6525
- [View at Publisher](#)
-
- 16 Campozano, L., Tenelanda, D., Sanchez, E., Samaniego, E., Feyen, J.
Comparison of Statistical Downscaling Methods for Monthly Total Precipitation: Case Study for the Paute River Basin in Southern Ecuador ([Open Access](#))
- (2016) *Advances in Meteorology*, 2016, art. no. 6526341. Cited 40 times.
<http://www.hindawi.com/journals/amet/>
doi: 10.1155/2016/6526341
- [View at Publisher](#)
-
- 17 Campozano, L., Trachte, K., Célleri, R., Samaniego, E., Bendix, J., Albuja, C., Mejia, J.F.
Climatology and Teleconnections of Mesoscale Convective Systems in an Andean Basin in Southern Ecuador: The Case of the Paute Basin ([Open Access](#))
- (2018) *Advances in Meteorology*, 2018, art. no. 4259191. Cited 22 times.
<http://www.hindawi.com/journals/amet/>
doi: 10.1155/2018/4259191
- [View at Publisher](#)
-
- 18 Celleri, R., Willems, P., Buytaert, W., Feyen, J.
Space-time rainfall variability in the Paute basin, Ecuadorian Andes ([Open Access](#))
- (2007) *Hydrological Processes*, 21 (24), pp. 3316-3327. Cited 113 times.
doi: 10.1002/hyp.6575
- [View at Publisher](#)
-
- 19 (2021) *Annual report 2020 (in Spanish)*. Cited 124 times.
National center for energy control, Quito Ecuador
-
- 20 Chen, J., Brissette, F.P., Leconte, R.
Coupling statistical and dynamical methods for spatial downscaling of precipitation
- (2012) *Climatic Change*, 114 (3-4), pp. 509-526. Cited 45 times.
doi: 10.1007/s10584-012-0452-2
- [View at Publisher](#)
-

-
- 21 Chicco, D.
Ten quick tips for machine learning in computational biology
([Open Access](#))
- (2017) *BioData Mining*, 10 (1), art. no. 35. Cited 419 times.
<http://www.biodatamining.org/>
doi: 10.1186/s13040-017-0155-3
- [View at Publisher](#)
-
- 22 Chimborazo, O., Vuille, M.
Present-day climate and projected future temperature and precipitation changes in Ecuador
- (2021) *Theoretical and Applied Climatology*, 143 (3-4), pp. 1581-1597. Cited 5 times.
<https://rd.springer.com/journal/volumesAndIssues/704>
doi: 10.1007/s00704-020-03483-y
- [View at Publisher](#)
-
- 23 Chu, T., Danks, D., Glymour, C.
(2005) *Data driven methods for nonlinear granger causality: climate teleconnection mechanisms*, p. 15213. Cited 11 times.
Carnegie Mellon University, Pittsburgh, PA
-
- 24 Colombo, D., Maathuis, M.H.
Order-independent constraint-based causal structure learning
- (2014) *Journal of Machine Learning Research*, 15, art. no. 32, pp. 3741-3782. Cited 181 times.
<http://jmlr.csail.mit.edu/papers/volume15/colombo14a/colombo14a.pdf>
- [View at Publisher](#)
-
- 25 Contreras, P., Orellana-Alvear, J., Muñoz, P., Bendix, J., Céleri, R.
Influence of random forest hyperparameterization on short-term runoff forecasting in an andean mountain catchment
([Open Access](#))
- (2021) *Atmosphere*, 12 (2), art. no. 238. Cited 12 times.
www.mdpi.com/journal/atmosphere
doi: 10.3390/atmos12020238
- [View at Publisher](#)
-
- 26 Donner, R.V., Lindner, M., Tupikina, L., Molkenthin, N.
Characterizing flows by complex network methods
(2019) *A Mathematical Modeling Approach from Nonlinear Dynamics to Complex Systems*, pp. 197-226. Cited 13 times.
Macau EEN, (ed), Springer International Publishing, Cham
-

- 27 Dutta, R., Maity, R.
Identification of potential causal variables for statistical downscaling models: effectiveness of graphical modeling approach

(2020) *Theoretical and Applied Climatology*, 142 (3-4), pp. 1255-1269. Cited 4 times.
<https://rd.springer.com/journal/volumesAndIssues/704>
doi: 10.1007/s00704-020-03372-4

View at Publisher
-
- 28 Dutta, R., Maity, R.
Temporal Networks-Based Approach for Nonstationary Hydroclimatic Modeling and its Demonstration With Streamflow Prediction

(2020) *Water Resources Research*, 56 (8), art. no. e2020WR027086. Cited 11 times.
[http://agupubs.onlinelibrary.wiley.com/hub/journal/10.1002/\(ISSN\)1944-7973/](http://agupubs.onlinelibrary.wiley.com/hub/journal/10.1002/(ISSN)1944-7973/)
doi: 10.1029/2020WR027086

View at Publisher
-
- 29 Dutta, R., Maity, R.
Time-varying network-based approach for capturing hydrological extremes under climate change with application on drought (Open Access)

(2021) *Journal of Hydrology*, Part B 603, art. no. 126958. Cited 6 times.
www.elsevier.com/inca/publications/store/5/0/3/3/4/3
doi: 10.1016/j.jhydrol.2021.126958

View at Publisher
-
- 30 Ebert-Uphoff, I., Deng, Y.
Causal discovery in the geosciences—Using synthetic data to learn how to interpret results (Open Access)

(2017) *Computers and Geosciences*, 99, pp. 50-60. Cited 12 times.
www.elsevier.com/inca/publications/store/3/9/8/
doi: 10.1016/j.cageo.2016.10.008

View at Publisher
-
- 31 Ebert-Uphoff, I., Deng, Y.
A new type of climate network based on probabilistic graphical models: Results of boreal winter versus summer

(2012) *Geophysical Research Letters*, 39 (18), art. no. L19701. Cited 41 times.
[http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)1944-8007/issues?year=2012](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1944-8007/issues?year=2012)
doi: 10.1029/2012GL053269

View at Publisher
-

- 32 Eyring, V., Bony, S., Meehl, G.A., Senior, C.A., Stevens, B., Stouffer, R.J., Taylor, K.E.
Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization
([Open Access](#))
- (2016) *Geoscientific Model Development*, 9 (5), pp. 1937-1958. Cited 3172 times.
http://www.geosci-model-dev.net/volumes_and_issues.html
doi: 10.5194/gmd-9-1937-2016

[View at Publisher](#)

- 33 Ferri, F.J., Pudil, P., Hatef, M., Kittler, J.
Comparative study of techniques for large-scale feature selection
- (1994) *Machine Intelligence and Pattern Recognition*, 16 (C), pp. 403-413. Cited 229 times.
doi: 10.1016/B978-0-444-81892-8.50040-7

[View at Publisher](#)

- 34 Fiedler, S., Crueger, T., D'Agostino, R., Peters, K., Becker, T., Leutwyler, D., Paccini, L., (...), Stevens, B.
Simulated tropical precipitation assessed across three major phases of the coupled model intercomparison project (CMIP)
([Open Access](#))
- (2020) *Monthly Weather Review*, 148 (9), pp. 3653-3680. Cited 48 times.
<https://journals.ametsoc.org/mwr/article/148/9/3653/353426/Simulated-Tropical-Precipitation-Assessed-across>
doi: 10.1175/MWR-D-19-0404.1

[View at Publisher](#)

- 35 Forbes, K.F.
Evidence of causality between the atmospheric concentration level of carbon dioxide and temperature
(2014) *AGU Fall Meet Abstracts GC43B-0709*
<https://ui.adsabs.harvard.edu/abs/2014AGUFMGC43B0709F>

- 36 Gaitan, C.F., Dixon, K.W., McPherson, R., Balaji, V.
Statistically downscaled North American precipitation using support vector regression and the big brother approach
(2014) *Proceedings of the 11th International Conference on Hydroinformatics*
CUNY Academic Works, New York City, USA

- 37 García, V.J., Márquez, C.O., Rodríguez, M.V., Orozco, J.J., Aguilar, C.D., Ríos, A.C.
Páramo ecosystems in ecuador's southern region: Conservation state and restoration ([Open Access](#))
- (2020) *Agronomy*, 10 (12), art. no. 1922. Cited 3 times.
<https://www.mdpi.com/2073-4395/10/12/1922/pdf>
doi: 10.3390/agronomy10121922

[View at Publisher](#)

-
- 38 Graf, R.
Analysis of Granger causality between daily and monthly temperatures of water and air, as illustrated with the example of Noteć River
(2018) *Acta Sci Pol Form Circumiectus*, 18, pp. 101-117. Cited 2 times.
-
- 39 Granger, C.W.J.
Investigating causal relations by econometric models and cross-spectral methods
(1969) *Econometrica*, 37, pp. 424-438. Cited 12674 times.
-
- 40 Gulizia, C., Camilloni, I.
Comparative analysis of the ability of a set of CMIP3 and CMIP5 global climate models to represent precipitation in South America

(2015) *International Journal of Climatology*, 35 (4), pp. 583-595. Cited 100 times.
[http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)1097-0088](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1097-0088)
doi: 10.1002/joc.4005

View at Publisher
-
- 41 Gupta, H.V., Kling, H., Yilmaz, K.K., Martinez, G.F.
Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling (Open Access)

(2009) *Journal of Hydrology*, 377 (1-2), pp. 80-91. Cited 2324 times.
doi: 10.1016/j.jhydrol.2009.08.003

View at Publisher
-
- 42 Guyon, I., Weston, J., Barnhill, S., Vapnik, V.
Gene selection for cancer classification using support vector machines (Open Access)

(2002) *Machine Learning*, 46 (1-3), pp. 389-422. Cited 6745 times.
doi: 10.1023/A:1012487302797

View at Publisher
-
- 43 Hannachi, A.
(2004) *A Primer for EOF Analysis of Climate Data*, pp. 1-33. Cited 65 times.
Reading RG6 6BB, U.K
<http://www.o3d.org/eas-6490/lectures/EOFs/eofprimer.pdf>
-
- 44 Hmamouche, Y., Casali, A., Lakhel, L.
A causality based feature selection approach for multivariate time series forecasting
(2017) *The Ninth International Conference on Advances in Databases Knowledge and Data Applications*, pp. 97-102. Cited 7 times.
IARIA, Barcelona, Spain
-

- 45 Hofman, J.M., Sharma, A., Watts, D.J.
Prediction and explanation in social systems

(2017) *Science*, 355 (6324), pp. 486-488. Cited 215 times.
<http://science.sciencemag.org/content/sci/355/6324/486.full.pdf>
doi: 10.1126/science.aal3856

View at Publisher
-
- 46 Hsieh, W.W.
Machine learning methods in the environmental sciences:
Neural networks and Kernels

(2009) *Machine Learning Methods in the Environmental Sciences: Neural Networks and Kernels*, pp. 1-349. Cited 226 times.
<http://dx.doi.org/10.1017/CBO9780511627217>
ISBN: 978-051162721-7; 978-052179192-2
doi: 10.1017/CBO9780511627217

View at Publisher
-
- 47 Jones, C.
Recent changes in the South America low-level jet ([Open Access](#))

(2019) *npj Climate and Atmospheric Science*, 2 (1), art. no. 20. Cited 31 times.
<https://www.nature.com/npjclimatsci/>
doi: 10.1038/s41612-019-0077-5

View at Publisher
-
- 48 Kaiser, H.F.
The varimax criterion for analytic rotation in factor analysis

(1958) *Psychometrika*, 23 (3), pp. 187-200. Cited 4341 times.
doi: 10.1007/BF02289233

View at Publisher
-
- 49 Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., (...), Joseph, D.
The NCEP/NCAR 40-year reanalysis project

(1996) *Bulletin of the American Meteorological Society*, 77 (3), pp. 437-471. Cited 24306 times.
<http://ams.allenpress.com>
doi: 10.1175/1520-0477(1996)077<0437:TNYRP>2.0.CO;2

View at Publisher
-
- 50 Kennaway, R.
When causation does not imply correlation: robust violations of the faithfulness axiom

(2020) *The Interdisciplinary Handbook of Perceptual Control Theory: Living Control Systems IV*, pp. 49-72. Cited 2 times.
<https://www.sciencedirect.com/book/9780128189481>
ISBN: 978-012818948-1; 978-012818949-8
doi: 10.1016/B978-0-12-818948-1.00004-6

View at Publisher

- 51 Kistler, R., Kalnay, E., Collins, W., Saha, S., White, G., Woollen, J., Chelliah, M., (...), Fiorino, M.
The NCEP-NCAR 50-year reanalysis: Monthly means CD-ROM and documentation ([Open Access](#))
- (2001) *Bulletin of the American Meteorological Society*, 82 (2), pp. 247-267. Cited 3642 times.
<http://ams.allenpress.com>
doi: 10.1175/1520-0477(2001)082<0247:TNNYRM>2.3.CO;2
- [View at Publisher](#)
-
- 52 Kong, D., Miao, C., Duan, Q., Lei, X., Li, H.
Vegetation-Climate Interactions on the Loess Plateau: A Nonlinear Granger Causality Analysis
- (2018) *Journal of Geophysical Research: Atmospheres*, 123 (19), pp. 11,068-11,079. Cited 16 times.
[http://agupubs.onlinelibrary.wiley.com/doi/jgr/journal/10.1002/\(ISSN\)2169-8996/](http://agupubs.onlinelibrary.wiley.com/doi/jgr/journal/10.1002/(ISSN)2169-8996/)
doi: 10.1029/2018JD029036
- [View at Publisher](#)
-
- 53 Kretschmer, M., Coumou, D., Donges, J.F., Runge, J.
Using causal effect networks to analyze different arctic drivers of midlatitude winter circulation ([Open Access](#))
- (2016) *Journal of Climate*, 29 (11), pp. 4069-4081. Cited 149 times.
<http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-15-0654.1>
doi: 10.1175/JCLI-D-15-0654.1
- [View at Publisher](#)
-
- 54 Kubat, M.
An Introduction to Machine Learning ([Open Access](#))
- (2017) *An Introduction to Machine Learning*, pp. 1-348. Cited 201 times.
<https://www.springer.com/in/book/9783319639123>
ISBN: 978-331963913-0; 978-331963912-3
doi: 10.1007/978-3-319-63913-0
- [View at Publisher](#)
-
- 55 Lenters, J.D., Cook, K.H.
On the origin of the Bolivian high and related circulation features of the South American climate ([Open Access](#))
- (1997) *Journal of the Atmospheric Sciences*, 54 (5), pp. 656-677. Cited 302 times.
<http://journals.ametsoc.org/loi/atsc>
doi: 10.1175/1520-0469(1997)054<0656:otootb>2.0.co;2
- [View at Publisher](#)
-
- 56 Liu, H., Motoda, H.
(2008) *Computational methods of feature selection*. Cited 363 times.
(eds), 1, Chapman and Hall/CRC, Boca Raton
-

- 57 Marken, R.S., Horth, B.
When causality does not imply correlation: More spadework at the foundations of scientific psychology
(2011) *Psychological Reports*, 108 (3), pp. 943-954. Cited 8 times.
<http://www.amsclpub.com/doi/pdf/10.2466/03.PR0.108.3.943-954>
doi: 10.2466/03.PR0.108.3.943-954
View at Publisher
-
- 58 Mora, D.E., Campozano, L., Cisneros, F., Wyseure, G., Willems, P.
Climate changes of hydrometeorological and hydrological extremes in the Paute basin, Ecuadorean Andes ([Open Access](#))
(2014) *Hydrology and Earth System Sciences*, 18 (2), pp. 631-648. Cited 40 times.
doi: 10.5194/hess-18-631-2014
View at Publisher
-
- 59 Mora, D.E., Liu, T., Cisneros, F.
Statistical analysis on the performance of global and regional climate models for the Paute River Basin in the South-Ecuadorian Andes
(2012) *In: Proceedings of 10Th International Conference on Hydroinformatics*. Cited 5 times.
Hamburg, Germany
-
- 60 Mora, D.E., Willems, P.
Characterization of main external climate influences in rainfall and air temperature in the Paute River Basin - Southern Andes of Ecuador
(2011) *Maskana*, 2, pp. 31-47.
-
- 61 Mora, D.E., Willems, P.
Decadal oscillations in rainfall and air temperature in the Paute River Basin-Southern Andes of Ecuador ([Open Access](#))
(2012) *Theoretical and Applied Climatology*, 108 (1-2), pp. 267-282. Cited 35 times.
<http://link.springer.de/link/service/journals/00704/>
doi: 10.1007/s00704-011-0527-4
View at Publisher
-
- 62 Najafi, M.R., Moradkhani, H., Wherry, S.A.
Statistical downscaling of precipitation using machine learning with optimal predictor selection
(2011) *Journal of Hydrologic Engineering*, 16 (8), pp. 650-664. Cited 78 times.
doi: 10.1061/(ASCE)HE.1943-5584.0000355
View at Publisher
-
- 63 Nash, J.E., Sutcliffe, J.V.
River flow forecasting through conceptual models part I - A discussion of principles
(1970) *Journal of Hydrology*, 10 (3), pp. 282-290. Cited 16022 times.
doi: 10.1016/0022-1694(70)90255-6
View at Publisher

-
- 64 Nowack, P., Runge, J., Eyring, V., Haigh, J.D.
Causal networks for climate model evaluation and constrained projections ([Open Access](#))
- (2020) *Nature Communications*, 11 (1), art. no. 1415. Cited 25 times.
<http://www.nature.com/ncomms/index.html>
doi: 10.1038/s41467-020-15195-y
- [View at Publisher](#)
-
- 65 Ochoa, A., Campozano, L., Sánchez, E., Gualán, R., Samaniego, E.
Evaluation of downscaled estimates of monthly temperature and precipitation for a Southern Ecuador case study ([Open Access](#))
- (2016) *International Journal of Climatology*, 36 (3), pp. 1244-1255. Cited 23 times.
[http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)1097-0088](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1097-0088)
doi: 10.1002/joc.4418
- [View at Publisher](#)
-
- 66 Olsson, T., Kämäräinen, M., Santos, D., Seitola, T., Tuomenvirta, H., Haavisto, R., Lavado-Casimiro, W.
Downscaling climate projections for the Peruvian coastal Chancay-Huaral Basin to support river discharge modeling with WEAP ([Open Access](#))
- (2017) *Journal of Hydrology: Regional Studies*, 13, pp. 26-42. Cited 15 times.
doi: 10.1016/j.ejrh.2017.05.011
- [View at Publisher](#)
-
- 67 Ortega, G., Arias, P.A., Villegas, J.C., Marquet, P.A., Nobre, P.
Present-day and future climate over central and South America according to CMIP5/CMIP6 models
- (2021) *International Journal of Climatology*, 41 (15), pp. 6713-6735. Cited 31 times.
[http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)1097-0088](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1097-0088)
doi: 10.1002/joc.7221
- [View at Publisher](#)
-
- 68 Pajankar, A., Joshi, A.
Supervised learning methods: Part 2
(2022) *Hands-on Machine Learning with Python*, pp. 149-165. Cited 2 times.
1, Apress, Berkeley, CA
-
- 69 Pajankar, A., Joshi, A.
Preparing data for machine learning
(2022) *Hands-on Machine Learning with Python*, pp. 79-97. Cited 2 times.
1, Apress, Berkeley, CA
-

- 70 Palomino-Lemus, R., Córdoba-Machado, S., Gámiz-Fortis, S.R., Castro-Díez, Y., Esteban-Parra, M.J.
Summer precipitation projections over northwestern South America from CMIP5 models
(2015) *Global and Planetary Change*, 131, pp. 11-23. Cited 20 times.
<http://www.sciencedirect.com/science/journal/09218181>
doi: 10.1016/j.gloplacha.2015.05.004
View at Publisher
-
- 71 Papagiannopoulou, C., Miralles, D.G., Decubber, S., Demuzere, M., Verhoest, N.E.C., Dorigo, W.A., Waegeman, W.
A non-linear Granger-causality framework to investigate climate-vegetation dynamics (Open Access)
(2017) *Geoscientific Model Development*, 10 (5), pp. 1945-1960. Cited 67 times.
http://www.geosci-model-dev.net/volumes_and_issues.html
doi: 10.5194/gmd-10-1945-2017
View at Publisher
-
- 72 Pearl, J.
Causality: Models, reasoning, and inference, second edition
(2011) *Causality: Models, Reasoning, and Inference, Second Edition*, pp. 1-464. Cited 391 times.
<http://dx.doi.org/10.1017/CBO9780511803161>
ISBN: 978-051180316-1; 978-052189560-6
doi: 10.1017/CBO9780511803161
View at Publisher
-
- 73 Pearl, J., Mackenzie, D.
(2018) *The book of why: the new science of cause and effect*. Cited 1070 times.
1, Basic Books, New York
-
- 74 Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Blondel, M., (...), Duchesnay, É.
Scikit-learn: Machine learning in Python
(2011) *Journal of Machine Learning Research*, 12, pp. 2825-2830. Cited 39665 times.
<http://jmlr.csail.mit.edu/papers/volume12/pedregosa11a/pedregosa11a.pdf>
View at Publisher
-
- 75 Pena, M., Vazquez-Patino, A., Zhina, D., Montenegro, M., Aviles, A.
Improved Rainfall Prediction through Nonlinear Autoregressive Network with Exogenous Variables: A Case Study in Andes High Mountain Region (Open Access)
(2020) *Advances in Meteorology*, 2020, art. no. 1828319. Cited 8 times.
<http://www.hindawi.com/journals/amet/>
doi: 10.1155/2020/1828319
View at Publisher
-

76 Pineda, L.E., Willems, P.
Rainfall extremes, weather and climate drivers in complex terrain: A data-driven approach based on signal enhancement methods and EV modeling ([Open Access](#))

(2018) *Journal of Hydrology*, 563, pp. 283-302. Cited 11 times.
www.elsevier.com/inca/publications/store/5/0/3/3/4/3
doi: 10.1016/j.jhydrol.2018.05.062

[View at Publisher](#)

77 Quinlan, J.R.
Induction of Decision Trees ([Open Access](#))

(1986) *Machine Learning*, 1 (1), pp. 81-106. Cited 12844 times.
doi: 10.1023/A:1022643204877

[View at Publisher](#)


78 Raschka, S., Mirjalili, V.
(2019) *Python Machine Learning: Machine Learning and Deep Learning with Python, Scikit-Learn, and Tensorflow*, 2.
2nd edn, Packt Publishing Ltd., Birmingham, UK

79 Ribeiro, M.T., Singh, S., Guestrin, C.
"Why should i trust you?" Explaining the predictions of any classifier

(2016) *Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 13-17-August-2016, pp. 1135-1144. Cited 5294 times.
ISBN: 978-145034232-2
doi: 10.1145/2939672.2939778

[View at Publisher](#)

80 Runge, J.
(2014) *Detecting and Quantifying Causality from Time Series of Complex Systems*. Cited 13 times.
Ph.D. Thesis
<https://doi.org/10.18452/17017>

 Vázquez-Patiño, A.; Faculty of Architecture and Urbanism, University of Cuenca, Cuenca, Ecuador; email:angel.vazquezp@ucuenca.edu.ec
© Copyright 2022 Elsevier B.V., All rights reserved.

About Scopus

[What is Scopus](#)

[Content coverage](#)

[Scopus blog](#)

[Scopus API](#)

[Privacy matters](#)

Language

[日本語版を表示する](#)

[查看简体中文版本](#)

[查看繁體中文版本](#)

[Просмотр версии на русском языке](#)

Customer Service

[Help](#)

[Tutorials](#)

[Contact us](#)

ELSEVIER

[Terms and conditions](#) ↗ [Privacy policy](#) ↗

Copyright © Elsevier B.V. ↗. All rights reserved. Scopus® is a registered trademark of Elsevier B.V.

We use cookies to help provide and enhance our service and tailor content. By continuing, you agree to the use of cookies ↗.

