

Key Points:

- Efficient-UNet and cGAN models improve PDIR-Now's precipitation estimates, outperforming the original data in accuracy and bias correction
- Daily data training yields better results than aggregated sub-daily data, capturing daily precipitation patterns more effectively
- Incorporating elevation improves model performance, but accuracy varies by region, highlighting the need for further refinement

Supporting Information:

Supporting Information may be found in the online version of this article.

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Bias Correction of Satellite Precipitation Estimation Using Deep Neural Networks and Topographic Information Over the Western U.S.

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Abstract Satellite-based precipitation products (SPPs) have gained popularity among researchers due to their utility in hydrologic studies. Several gridded satellite-based precipitation products with global coverage, such as the Integrated Multi-satellite Retrievals for GPM (IMERG) and the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) family of products, are available worldwide. However, the accuracy of these products may vary due to retrieval algorithms or geographic location. Numerous correction techniques have been implemented, and machine learning techniques, especially Deep Neural Networks, have proven to be the most effective in improving precipitation estimation. This study aims to investigate the performance of the PERSIANN-Dynamic Infrared Rain Rate near real-time product (PDIR-Now) in the Western U.S. and assess the effectiveness of three deep learning models including U-Net, Efficient-UNet, and a conditional Generative Adversarial Network (cGAN) in correcting biases present in the product. The developed models are expected to be more accurate than traditional methods, as they include digital elevation information and can resolve complex geographic enhancements in precipitation processes. This incorporation will mitigate the bias associated with SPPs, enabling further potential applications in water resource management. The findings revealed that the corrected results, utilizing the Efficient-UNet and cGAN models, surpassed the original PDIR-Now product and U-Net model across various statistical and categorical metrics at different temporal scales. This bias-correction scheme will enhance the assessment and understanding of precipitation patterns and can be used to improve the quality of precipitation estimates in other regions.

Plain Language Summary The study focuses on improving satellite-based rainfall estimates, which are crucial for hydrologic research and water resource management. Current satellite-based precipitation products, such as the Integrated Multi-satellite Retrievals for GPM (IMERG) and the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), are widely used but often have accuracy issues depending on the retrieval methods and geographic areas. To address these issues, we proposed three models using advanced machine learning: U-Net, Efficient-UNet, and a conditional Generative Adversarial Network (cGAN). We tested these methods on the PERSIANN-Dynamic Infrared Rain Rate (PDIR-Now) data for the Western U.S. By including digital elevation information, our models can better account for the complex effects of mountainous terrain on rainfall. Our results showed that the Efficient-UNet and cGAN models significantly improved the accuracy of precipitation estimates compared to both the original PDIR-Now data and the U-Net model. These enhanced estimates will help in better understanding and managing water resources and can be applied to refine rainfall data accuracy in other regions as well.

1. Introduction

Precipitation is one of the fundamental components of the global hydrologic cycle. Understanding precipitation patterns is essential for predicting droughts and floods, managing water resources effectively, and ensuring sustainable water availability for various purposes. Satellite-based precipitation products (SPPs) that cover a large area over a long period have been developed and have received growing attention from researchers (Liu et al., 2017; Sun et al., 2018). Several gridded satellite-based precipitation products with high resolution and global (or quasi-global) coverage are now available worldwide. Examples include the Integrated Multi-satellite Retrievals for the Global Precipitation Measurement (GPM IMERG) satellite precipitation (Huffman et al., 2020), Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) (Huffman

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Flood Forecasting Using Machine Learning Methods Fi-John Chang,Kuolin Hsu,Li-Chiu Chang,2019-02-28

Nowadays the degree and scale of flood hazards has been massively increasing as a result of the changing climate and large scale floods jeopardize lives and properties causing great economic losses in the inundation prone areas of the world Early flood warning systems are promising countermeasures against flood hazards and losses A collaborative assessment according to multiple disciplines comprising hydrology remote sensing and meteorology of the magnitude and impacts of flood hazards on inundation areas significantly contributes to model the integrity and precision of flood forecasting Methodologically oriented countermeasures against flood hazards may involve the forecasting of reservoir inflows river flows tropical cyclone tracks and flooding at different lead times and or scales Analyses of impacts risks uncertainty resilience and scenarios coupled with policy oriented suggestions will give information for flood hazard mitigation Emerging advances in computing technologies coupled with big data mining have boosted data driven applications among which Machine Learning technology with its flexibility and scalability in pattern extraction has modernized not only scientific thinking but also predictive applications This book explores recent Machine Learning advances on flood forecast and management in a timely manner and presents interdisciplinary approaches to modelling the complexity of flood hazards related issues with contributions to integrative solutions from a local regional or global perspective

Satellite Precipitation Measurement Vincenzo

Levizzani,Christopher Kidd,Dalia B. Kirschbaum,Christian D. Kummerow,Kenji Nakamura,F. Joseph Turk,2020-04-14 This book offers a complete overview of the measurement of precipitation from space which has made considerable advancements during the last two decades This is mainly due to the Tropical Rainfall Measuring Mission TRMM the Global Precipitation Measurement GPM mission CloudSat and a carefully maintained constellation of satellites hosting passive microwave sensors The book revisits a previous book Measuring Precipitation from Space edited by V Levizzani P Bauer and F J Turk published with Springer in 2007 The current content has been completely renewed to incorporate the advancements of science and technology in the field since then This book provides unique contributions from field experts and from the International Precipitation Working Group IPWG The book will be of interest to meteorologists hydrologists climatologists water management authorities students at various levels and many other parties interested in making use of satellite precipitation data sets

Hydrological Hazard: Analysis and Prevention Tommaso Caloiero,2018-11-26 This book is a printed edition of the Special Issue Hydrological Hazard Analysis and Prevention that was published in Geosciences *Proceedings*. 27. Workshop Computational Intelligence, Dortmund, 23. - 24. November 2017 Hoffmann, Frank,Huellermeier, E.,Mikut, Ralf ,2017-11-09

Advancing Earth Surface Representation via Enhanced Use of Earth Observations in Monitoring and Forecasting Applications Gianpaolo Balsamo,Fatima Karbou,Vanessa M. Escobar,Benjamin Ruston,Susanne

Mecklenburg,Matthias Drusch,Isabel F. Trigo,2019-08-23 The representation of the Earth s surface in global monitoring and

forecasting applications is moving towards capturing more of the relevant processes while maintaining elevated computational efficiency and therefore a moderate complexity. These schemes are developed and continuously improved thanks to well instrumented field sites that can observe coupled processes occurring at the surface atmosphere interface e.g. forest grassland cropland areas and diverse climate zones. Approaching global kilometer scale resolutions in situ observations alone cannot fulfil the modelling needs and the use of satellite observation becomes essential to guide modelling innovation and to calibrate and validate new parameterization schemes that can support data assimilation applications. In this book we review some of the recent contributions highlighting how satellite data are used to inform Earth surface model development: vegetation state and seasonality, soil moisture conditions, surface temperature and turbulent fluxes, land use change detection, agricultural indicators and irrigation when moving towards global km scale resolutions.

Earth Observation for Water Resource Management in Africa Benjamin Koetz, Zoltán Vekerdy, Massimo Menenti, Diego Fernández-Prieto, 2018-10-02

This book is a printed edition of the Special Issue Earth Observation for Water Resource Management in Africa that was published in Remote Sensing.

Geographic Information Systems in Water Resources Engineering Lynn E. Johnson, 2016-04-19 State of the art GIS spatial data management and analysis tools are revolutionizing the field of water resource engineering. Familiarity with these technologies is now a prerequisite for success in engineers and planners efforts to create a reliable infrastructure. GIS in Water Resource Engineering presents a review of the concepts and application.

Assimilation of Remote Sensing Data into Earth System Models Jean-Christophe Calvet, Patricia De Rosnay, Stephen G. Penny, 2019-11-20 In the Earth sciences a transition is currently occurring in multiple fields towards an integrated Earth system approach with applications including numerical weather prediction, hydrological forecasting, climate impact studies, ocean dynamics estimation and monitoring and carbon cycle monitoring. These approaches rely on coupled modeling techniques using Earth system models that account for an increased level of complexity of the processes and interactions between atmosphere, ocean, sea ice and terrestrial surfaces. A crucial component of Earth system approaches is the development of coupled data assimilation of satellite observations to ensure consistent initialization at the interface between the different subsystems. Going towards strongly coupled data assimilation involving all Earth system components is a subject of active research. A lot of progress is being made in the ocean atmosphere domain but also over land. As atmospheric models now tend to address subkilometric scales assimilating high spatial resolution satellite data in the land surface models used in atmospheric models is critical. This evolution is also challenging for hydrological modeling. This book gathers papers reporting research on various aspects of coupled data assimilation in Earth system models. It includes contributions presenting recent progress in ocean atmosphere, land atmosphere and soil vegetation data assimilation.

Remote Sensing of Precipitation Silas Michaelides, 2019-07-23 Precipitation is a well recognized pillar in global water and energy balances. An accurate and timely understanding of its characteristics at the global, regional and local scales is

indispensable for a clearer understanding of the mechanisms underlying the Earth's atmosphere-ocean complex system. Precipitation is one of the elements that is documented to be greatly affected by climate change. In its various forms, precipitation comprises a primary source of freshwater which is vital for the sustainability of almost all human activities. Its socio-economic significance is fundamental in managing this natural resource effectively in applications ranging from irrigation to industrial and household usage. Remote sensing of precipitation is pursued through a broad spectrum of continuously enriched and upgraded instrumentation embracing sensors which can be ground-based (e.g. weather radars), satellite-borne (e.g. passive or active space-borne sensors), underwater (e.g. hydrophones), aerial or ship-borne.

Extreme Hydrology and Climate Variability Assefa Melesse, Wossenu Abtew, Gabriel Senay, 2019-07-03. Extreme Hydrology and Climate Variability: Monitoring, Modelling, Adaptation and Mitigation is a compilation of contributions by experts from around the world who discuss extreme hydrology topics from monitoring to modeling and management. With extreme climatic and hydrologic events becoming so frequent, this book is a critical source adding knowledge to the science of extreme hydrology. Topics covered include hydrometeorology, monitoring, climate variability and trends, hydrological variability and trends, landscape dynamics, droughts, flood processes and extreme events, management, adaptation and mitigation. Each of the book's chapters provides background and theoretical foundations followed by approaches used and results of the applied studies. This book will be highly used by water resource managers and extreme event researchers who are interested in understanding the processes and teleconnectivity of large-scale climate dynamics and extreme events, predictability, simulation and intervention measures. Presents datasets used and methods followed to support the findings included, allowing readers to follow these steps in their own research. Provides variable methodological approaches, thus giving the reader multiple hydrological modeling information to use in their work. Includes a variety of case studies, thus making the context of the book relatable to everyday working situations for those studying extreme hydrology. Discusses extreme event management including adaptation and mitigation.

Remote Sensing of Hydrometeorological Hazards George P. Petropoulos, Tanvir Islam, 2017-11-02. Extreme weather and climate change aggravate the frequency and magnitude of disasters. Facing atypical and more severe events, existing early warning and response systems become inadequate both in scale and scope. Earth Observation (EO) provides today's information at global, regional and even basin scales related to agrometeorological hazards. This book focuses on drought, flood, frost, landslides and storms, cyclones and covers different applications of EO data used from prediction to mapping damages as well as recovery for each category. It explains the added value of EO technology in comparison with conventional techniques applied today through many case studies.

Precipitation: Advances in Measurement, Estimation and Prediction Silas C. Michaelides, 2008-02-27. Water cycling and the future availability of fresh water resources are immense societal concerns that impact all nations on Earth as it affects virtually every environmental issue. Precipitation is also a fundamental component of the weather-climate system for it regulates the global energy and radiation

balance through coupling to clouds water vapor global winds and atmospheric transport Accurate and comprehensive information on precipitation is essential for understanding the global water energy cycle and for a wide range of research and applications with practical benefits to society However rainfall is difficult to measure because precipitation systems tend to be random in character and also evolve and dissipate very rapidly It is not uncommon to see a wide range of rain amounts over a small area and in any given area the amount of rain can vary significantly over a short time span These factors together make precipitation difficult to quantify yet measurements at such local scales are needed for many hydrometeorological applications such as flood and landslide forecasting Historical multi decadal measurements of precipitation from surface based rain gauges are available over continents but oceans remained largely unobserved prior to the beginning of the satellite era Early visible and infrared satellites provided information on cloud tops and their horizontal extent however wide band microwave frequencies proved extremely useful for probing into the precipitating liquid and ice layers of clouds

Measuring Precipitation from Space V. Levizzani,P. Bauer,F. Joseph Turk,2007-05-11 No other book can offer such a powerful tool to understand the basics of remote sensing for precipitation to make use of existing products and to have a glimpse of the near future missions and instruments This book features state of the art rainfall estimation algorithms validation strategies and precipitation modeling More than 20 years after the last book on the subject the worldwide precipitation community has produced a comprehensive overview of its activities achievements ongoing research and future plans

Flood Forecasting Thomas E. Adams,Chandana Gangodagamage,Thomas C. Pagano,2024-09-18 Flood Forecasting A Global Perspective Second Edition covers hydrologic forecasting systems on both a national and regional scale This updated edition includes a breakdown by county contribution and solutions to common issues with a wide range of approaches to address the difficulties inherent in the development implementation and operational success of national scale flood forecasting systems Special attention is given to recent advances in machine learning techniques for flood forecasting Overall the information will lead to improvements of existing systems and provide a valuable reference on the intricacies of forecast systems in different parts of the world Covers global and regional systems thus allowing readers to understand the different forecasting systems and how they developed Offers practical applications for groups trying to improve existing flood forecasting systems Includes innovative solutions for those interested in developing new systems Contains analytical and updated information on forecasting and monitoring systems

The Earth Observer ,2011

Floods in a Changing Climate Ramesh S. V. Teegavarapu,2012-11-22 Measurement analysis and modeling of extreme precipitation events linked to floods is vital in understanding changing climate impacts and variability This book provides methods for assessment of the trends in these events and their impacts It also provides a basis to develop procedures and guidelines for climate adaptive hydrologic engineering Academic researchers in the fields of hydrology climate change meteorology environmental policy and risk assessment and professionals and policy makers working in hazard mitigation water resources engineering and

climate adaptation will find this an invaluable resource This volume is the first in a collection of four books on flood disaster management theory and practice within the context of anthropogenic climate change The others are Floods in a Changing Climate Hydrological Modeling by P P Mujumdar and D Nagesh Kumar Floods in a Changing Climate Inundation Modeling by Giuliano Di Baldassarre and Floods in a Changing Climate Risk Management by Slodoban Simonovi *Remote Sensing of Natural Hazards* Jay Gao,2023-06-16 This book presents a comprehensive coverage of remote sensing technology used to gather information on 12 types of natural hazards in the terrestrial sphere biosphere hydrosphere and atmosphere It clarifies in detail how to yield spatial and quantitative data on a natural hazard including its spatial distribution severity causes and the likelihood of occurrence The author explains multiple methods of attaining data describes the pros and cons of each method and encourages readers to choose the best method applicable to their case The author offers a practical approach to data analysis using the most appropriate methods and software 1 Covers all major natural hazards including hurricanes tornadoes wildfires and avalanches 2 Studies each natural hazard holistically ranging from spatial extent severity impact assessment causes and prediction of occurrence 3 Explains different remotely sensed data and the most appropriate method used 4 Compares different ways of sensing and clarifies the pros and cons of any selected data or their analysis 5 Provides ample examples of each aspect of a natural hazard studied augmented with graphic illustrations and quality assurance information All professionals working in the field of natural hazards senior undergraduate and graduate students will find in depth approaches and sufficient information to become knowledgeable in the methods of yielding and analyzing data provided with remote sensing technology ultimately providing a deeper understanding of natural hazards **Proceedings of the International Conference on Mathematical Sciences and Statistics 2022 (ICMSS 2022)** Nadihah

Wahi,Muhammad Aslam Mohd Safari,Roslan Hasni,Fatimah Abdul Razak,Ibragimov Gafurjan,Anwar Fitrianto,2023-02-10 This is an open access book The ICMSS2022 is an international conference jointly organised by the Department of Mathematics and Statistics Faculty of Science Universiti Putra Malaysia together with the Banasthali University Jaipur India This international conference aims to give exposure and to bring together academicians researchers and industry experts for intellectual growth The ICMSS2022 serves as a platform for the scientific community members to exchange ideas and approaches to present research findings and to discuss current issues and topics related to mathematics statistics as well as their applications Objectives to present the most recent discoveries in mathematics and statistics to serve as a platform for knowledge and information sharing between experts from industries and academia to identify and create potential collaboration among participants The organising committee of ICMSS2022 welcomes all delegates to deliberate over various aspects related to the conference themes and sub themes *Global Flood Hazard* Guy J-P. Schumann,Paul D. Bates,Heiko Apel,Giuseppe T. Aronica,2018-06-05 Global Flood Hazard Subject Category Winner PROSE Awards 2019 Earth Science Selected from more than 500 entries demonstrating exceptional scholarship and making a significant contribution to the field

of study Flooding is a costly natural disaster in terms of damage to land property and infrastructure This volume describes the latest tools and technologies for modeling mapping and predicting large scale flood risk It also presents readers with a range of remote sensing data sets successfully used for predicting and mapping floods at different scales These resources can enable policymakers public planners and developers to plan for and respond to flooding with greater accuracy and effectiveness Describes the latest large scale modeling approaches including hydrological models 2 D flood inundation models and global flood forecasting models Showcases new tools and technologies such as Aqueduct a new web based tool used for global assessment and projection of future flood risk under climate change scenarios Features case studies describing best practice uses of modeling techniques tools and technologies Global Flood Hazard is an indispensable resource for researchers consultants practitioners and policy makers dealing with flood risk flood disaster response flood management and flood mitigation

Nile and Grand Ethiopian Renaissance Dam Assefa M. Melesse, Wossenu Abtew, Semu A. Moges, 2021-08-31 This book is a contribution by the presenters of the 2020 International Conference on the Nile and Grand Ethiopian Renaissance Dam GERD The Nile basin is facing unprecedented level of water right challenges after the construction of GERD has begun Ethiopia Egypt and Sudan have struggled to narrow their differences on filling and operation of the GERD The need for science and data based discussion for a lasting solution is crucial Historical perspectives water rights agreements failed negotiations and other topics related to the Nile is covered in this book The book covers Nile water claims past and present international transboundary basin cooperation and water sharing Nile water supply and demand management Blue Nile Abbay and Grand Ethiopian Renaissance Dam land and water degradation and watershed management emerging threats of the Lakes Region in the Nile Basin and hydrologic variation and monitoring This book is beneficial for students researchers sociologists engineers policy makers lawyers water resources and environmental managers and for the people and governments of the Nile Basin

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