remote sensing

Editorial

Remote Sensing Applications to Climate Change

Xander Wang [1,2]

[1] Canadian Centre for Climate Change and Adaptation, University of Prince Edward Island, St. Peter's Bay, PE C0A 2A0, Canada; xxwang@upei.ca
[2] School of Climate Change and Adaptation, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada

1. Introduction

Climate change research remains a challenging task, as it requires vast quantities of long-term data to investigate the past, present, and future scenarios of Earth's climate system and other biophysical systems at global to local scales. Both traditional ground-based observation methods and remote-sensing technologies are available options for gathering data for climate change research. Observations from weather stations have been widely used to study climate change over long periods of time. However, due to the scarcity of point-based weather observations, our understanding of the Earth's changing climate is very limited. This impedes the advancement of our knowledge of the Earth's climate system and our ability to develop well-suited climate models to simulate future climate change, which further results in considerable uncertainties associated with future climate projections. Thus, the determination of a method for quantifying and minimizing these uncertainties is quickly becoming one of the most challenging issues yet to be addressed by climate change impact assessment and adaptation studies. Remote sensing offers a new method for observing the Earth's climate system with continuous and high-resolution spatial coverage through satellite-based, aircraft-based, or drone-based sensor technologies. This can significantly improve our understanding of climate change and its potential impacts at global, regional, and local scales. The data collected with remote-sensing technologies can also be used to validate our climate models, improve our knowledge of the physical and dynamic processes of the climate system, and help us project future climate change and its impacts with minimized uncertainties.

This Special Issue intends to capture the latest research advances regarding remote-sensing technologies and their applications in climate change research. Sixteen original research articles authored by one hundred and five researchers were published in this Special Issue, presenting recent advances in remote-sensing technologies (two articles) and the application of remote-sensing technologies to climate change modelling (five articles), monitoring (six articles), and impact assessment (three articles). While the articles span multidisciplinary perspectives and methodologies, they are clustered into four themes.

check for updates

Citation: Wang, X. Remote Sensing Applications to Climate Change. *Remote Sens.* **2023**, *15*, 747. https://doi.org/10.3390/rs15030747

Received: 16 January 2023
Accepted: 27 January 2023
Published: 28 January 2023

2. The Advances in Remote-Sensing Technologies

The continuous development of remote-sensing technologies, including advanced satellites and new procedures for large scale data processing, is essential for increasing the accuracy and reliability of climate change research based on remote-sensing data. Meftah et al. [1] present the technological development of Ultraviolet and Infrared Sensors at high Quantum efficiency onboard a small Satellite (UVSQSAT). They also present the findings of the first in-orbit observations of the mapping of solar radiation reflected by the Earth and of the outgoing longwave radiation at the top of the atmosphere throughout February 2021. Their study shows the feasibility of using a miniaturized satellite to measure the Earth's energy imbalance (EEI) over a short period.

While satellite technologies are improving, the performance of remote-sensing data analysis techniques remains of great concern. Basheer et al. [2] evaluate the land-use land-cover (LULC) classification performance of two commonly used platforms (i.e., ArcGIS Pro and Google Earth Engine) with different satellite datasets (i.e., Landsat, Sentinel, and Planet) through a case study concerning the city of Charlottetown, Canada, over the period of 2017 to 2021. The study provides the scientific basis for the selection of remote-sensing classifiers and satellite imagery with which to develop accurate LULC maps.

3. Climate Change Modelling

The application of remote sensing to climate change modelling constitutes a crucial domain in climate research. This Special Issue includes five articles presenting regional-level climate change-modelling studies using different applications of remote-sensing data. Yan et al. [3] explore potential changes in future extreme precipitation events in China based on Coupled Model Intercomparison Project Phase 6 (CMIP6) (under SSP2-4.5 scenario), using a machine learning approach to integrate and fit multiple models. The study estimates the distribution and trends in the precipitation amount (PRCPTOT), very heavy precipitation days (R20mm), extreme precipitation intensity (SDII95), extreme precipitation amount (R95pTOT), maximum consecutive 5-day precipitation (Rx5day), and precipitation intensity (SDII) for the early 21st century (2023–2050), mid-21st century (2051–2075), and late 21st century (2076–2100). Gnitou et al. [4] adopt a two-way approach to CORDEX-CORE RegCM4-7 seasonal precipitation simulations' Added Value (AV) analysis over Africa with the aim of quantifying the potential improvements introduced by a downscaling approach at high- and low-resolution using satellite-based observational products. Zhou et al. [5] use Regional Climatic Model (RegCM) simulations to downscale the boundary conditions of Geophysical Fluid Dynamics Laboratory Earth System Model Version 2M (GFDL-ESM2M) over the Prairie Provinces, and extract the daily mean, maximum, and minimum temperatures from the historical and future climate simulations. The study investigates temperature variations in two future periods (i.e., 2036 to 2065 and 2065 to 2095) compared to the baseline period (i.e., 1985 to 2004). Lu et al. [6] explore the long-term spatial and seasonal variations of three dominant variables with respect to the water cycle (i.e., precipitation, evapotranspiration, and runoff) in China using the Regional Climate Model system (RegCM) developed by the International Centre for Theoretical Physics. The research compares the simulation results with remote-sensing data and gridded observations to validate the model's performance. Ahmad et al. [7] present a two-dimensional (2D) hydrodynamic model combined with remote sensing (RS) and a geographic information system (GIS)-based approach to generate additional flood characteristic maps (e.g., flood velocity, duration, arrival time, and recession time) for the transboundary river Deg Nullah in Pakistan. The study simulates the extreme flood event that occurred in the study area in 2014 to evaluate the performance of the approach.

4. Monitoring Climate Change

Remote-sensing technologies are now being extensively applied to climate change monitoring at the global, regional, and local scales at an unprecedented rate, especially where ground observation data are scarce. Accordingly, six articles published in this Special Issue demonstrate the remote-sensing-based, long-term monitoring of climate parameters (e.g., precipitation, temperature, etc.) and glaciers. Lu et al. [8] explore possible causes for the interdecadal shift in the interannual variability in summertime precipitation (IVSP) over South China (SC) following the mid-2000s. The study uses climate datasets such as the Precipitation Reconstruction dataset (from NOAA), monthly atmospheric circulation (from NCEP/NCAR), a daily outgoing longwave radiation (OLR) dataset (from NOAA), and the NOAA OI SST V2 High-Resolution Dataset to analyze summertime precipitation variability over South China. Ran et al. [9] present a deep-learning algorithm for fog detection at dawn and dusk under terrain restrictions and an enhanced channel domain attention mechanism (DDF-Net) using advanced Himawari-8 imager data (H8/AHI). Satellite- and ground-based observational climate data concerning northern China, including the Inner Mongolia Plateau and the Loess Plateau, during the winter months (November to December) of 2015 to 2017 were used in this study. Fan et al. [10] employ downscaled climate data using machine learning algorithms and develop a Batch Gradient Descent Linear Regression model to calculate the contributions of temperature and precipitation to runoff in data-scarce high mountains. A case study of six mountainous basins originating from the Tianshan Mountains in Northwest China are used to demonstrate the application of this novel approach. Li et al. [11] demonstrate the use of ERA5-Land, a reanalysis dataset with high spatial and temporal resolution, to quantify the trends and variations in Frost-Free Periods (FFP) and Frost Days (FD) across China from 1950 to 2020. Zhou et al. [12] investigate glacier velocity changes and glacier flow patterns in the Himalayas over the period from 1999 to 2018 using 220 scenes of Landsat-7 panchromatic images taken between 1999 and 2000 and Sentinel-2 panchromatic images taken between 2017 and 2018. Wang et al. [13] analyze the spatial and temporal variations in the glaciers in the Ebi Lake basin during the period from 1964 to 2019 based on the first and second Chinese Glacier Inventories (CGI) and remote-sensing data. The study also investigates the response of glaciers to the warming climate by analyzing digital elevation modeling and meteorology.

5. Climate Change Impact Assessment

The assessment of climate change's impacts on biophysical systems is a highly complex area of research wherein remote-sensing technologies are widely used to evaluate the changes in these systems over time. In this Special Issue, three articles present case studies demonstrating integrated impact assessments with the aid of remote-sensing data. Wang et al. [14] investigate the changes in vegetation across the Three-Rivers Headwaters Region (TRHR) (the Yangtze, the Yellow, and the Lancang (Mekong) rivers) by mapping the normalized difference vegetation index (NDVI) over the growing season from 1982 to 2015. Moreover, the study examines how the vegetation cover has changed with the changing temperature and precipitation at different altitudes of the TRHR region throughout the past few decades. Guild et al. [15] estimate forest loss within Kutai National Park (KNP) in Indonesia precipitated by illegal logging and wildfires over various time periods since 1997 using an extensive catalogue and the processing power of the Google Earth Engine. Comparing time-series estimates of precipitation, the ENSO index, burned area, and forest loss, the paper demonstrates that the risk of fire within KNP mainly depends on drought severity, and that the rates of non-fire- (gradual) and fire-related (extreme) forest loss threaten the remaining forests of this National Park. Chen et al. [16] investigate the relative importance of plant nutrient traits and soil nutrient availability with respect to mediating the climatic sensitivity of desert scrub biomes in the Tibetan Plateau. This study analyzes the vegetation sensitivity index (VSI) of desert scrub for the period from 2000 to 2015 and field measurements of the nutrients in the soil and plant leaves from research conducted in 2016 for seven types of desert scrub communities in the Qaidam Basin (NE Tibetan Plateau). Multiple linear and structural equation models were used to reveal how leaf and soil nutrient regimes affect desert scrubs' sensitivity to climate variability.

This collection of articles addresses some of the knowledge gaps in the field of 'remote sensing applied to climate change.' I hope this will encourage further investigation in this area and thus improve the performance of remote-sensing technologies and data analysis techniques as well as widen applications in research related to climate change modelling, monitoring, and impact assessment.

Funding: This research was funded by the Natural Science and Engineering Research Council of Canada, the New Frontiers in Research Fund, and the Government of Prince Edward Island.

Acknowledgments: I would like to thank all the authors for their contributions and all the reviewers for their valuable comments and feedback.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Meftah, M.; Boutéraon, T.; Dufour, C.; Hauchecorne, A.; Keckhut, P.; Finance, A.; Bekki, S.; Abbaki, S.; Bertran, E.; Damé, L.; et al. The UVSQ-SAT/INSPIRESat-5 CubeSat Mission: First In-Orbit Measurements of the Earth's Outgoing Radiation. *Remote Sens.* **2021**, *13*, 1449. [CrossRef]
2. Basheer, S.; Wang, X.; Farooque, A.A.; Nawaz, R.A.; Liu, K.; Adekanmbi, T.; Liu, S. Comparison of Land Use Land Cover Classifiers Using Different Satellite Imagery and Machine Learning Techniques. *Remote Sens.* **2022**, *14*, 4978. [CrossRef]
3. Yan, Y.; Wang, H.; Li, G.; Xia, J.; Ge, F.; Zeng, Q.; Ren, X.; Tan, L. Projection of Future Extreme Precipitation in China Based on the CMIP6 from a Machine Learning Perspective. *Remote Sens.* **2022**, *14*, 4033. [CrossRef]
4. Gnitou, G.T.; Tan, G.; Hongming, Y.; Nooni, I.K.; Lim Kam Sian, K.T.C. Resolution-Sensitive Added Value Analysis of CORDEX-CORE RegCM4-7 Past Seasonal Precipitation Simulations over Africa Using Satellite-Based Observational Products. *Remote Sens.* **2022**, *14*, 2102. [CrossRef]
5. Zhou, X.; Huang, G.; Li, Y.; Lin, Q.; Yan, D.; He, X. Dynamical Downscaling of Temperature Variations over the Canadian Prairie Provinces under Climate Change. *Remote Sens.* **2021**, *13*, 4350. [CrossRef]
6. Lu, C.; Huang, G.; Wang, G.; Zhang, J.; Wang, X.; Song, T. Long-Term Projection of Water Cycle Changes over China Using RegCM. *Remote Sens.* **2021**, *13*, 3832. [CrossRef]
7. Ahmad, I.; Wang, X.; Waseem, M.; Zaman, M.; Aziz, F.; Khan, R.Z.N.; Ashraf, M. Flood Management, Characterization and Vulnerability Analysis Using an Integrated RS-GIS and 2D Hydrodynamic Modelling Approach: The Case of Deg Nullah, Pakistan. *Remote Sens.* **2022**, *14*, 2138. [CrossRef]
8. Lu, W.; Zhu, Y.; Zhong, Z.; Hu, Y.; Ha, Y. Weakened Impacts of the East Asia-Pacific Teleconnection on the Interannual Variability of Summertime Precipitation over South China since the Mid-2000s. *Remote Sens.* **2022**, *14*, 5098. [CrossRef]
9. Ran, Y.; Ma, H.; Liu, Z.; Wu, X.; Li, Y.; Feng, H. Satellite Fog Detection at Dawn and Dusk Based on the Deep Learning Algorithm under Terrain-Restriction. *Remote Sens.* **2022**, *14*, 4328. [CrossRef]
10. Fan, M.; Xu, J.; Chen, Y.; Fan, M.; Yu, W.; Li, W. Temperature Contributes More than Precipitation to Runoff in the High Mountains of Northwest China. *Remote Sens.* **2022**, *14*, 4015. [CrossRef]
11. Li, H.; Liu, G.; Han, C.; Yang, Y.; Chen, R. Quantifying the Trends and Variations in the Frost-Free Period and the Number of Frost Days across China under Climate Change Using ERA5-Land Reanalysis Dataset. *Remote Sens.* **2022**, *14*, 2400. [CrossRef]
12. Zhou, Y.; Chen, J.; Cheng, X. Glacier Velocity Changes in the Himalayas in Relation to Ice Mass Balance. *Remote Sens.* **2021**, *13*, 3825. [CrossRef]
13. Wang, L.; Bai, C.; Ming, J. Current Status and Variation since 1964 of the Glaciers around the Ebi Lake Basin in the Warming Climate. *Remote Sens.* **2021**, *13*, 497. [CrossRef]
14. Wang, K.; Zhou, Y.; Han, J.; Chen, C.; Li, T. Long-Term Tibetan Alpine Vegetation Responses to Elevation-Dependent Changes in Temperature and Precipitation in an Altered Regional Climate: A Case Study for the Three-Rivers Headwaters Region, China. *Remote Sens.* **2023**, *15*, 496. [CrossRef]
15. Guild, R.; Wang, X.; Russon, A.E. Tracking Deforestation, Drought, and Fire Occurrence in Kutai National Park, Indonesia. *Remote Sens.* **2022**, *14*, 5630. [CrossRef]
16. Chen, B.; Chen, H.; Li, M.; Fiedler, S.; Mărgărint, M.C.; Nowak, A.; Wesche, K.; Tietjen, B.; Wu, J. Climate Sensitivity of the Arid Scrublands on the Tibetan Plateau Mediated by Plant Nutrient Traits and Soil Nutrient Availability. *Remote Sens.* **2022**, *14*, 4601. [CrossRef]