MI3 Detecting the impact of natural disasters by nighttime light intensity change

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Abstract: This study explores the efficacy of utilizing three distinct nighttime light (NTL) products to assess the impact of natural disasters. Initially, a pixel-based long-term statistical analysis was conducted by utilizing NPP-VIIRS monthly cloud-free product. Subsequently, case studies were conducted using 10-days composite generated from NASA's Black Marble daily product, focusing on two flood events in Hunan Province, China—a region prone to the natural disasters. Despite the moderate performance observed in long-term supervised learning, the outcomes of the case studies strongly support the notion that NTL changes can serve as a valuable indicator for measuring post-flood social changes.

Keywords: NPP-VIIRS product, Black Marble daily product, anomaly detection, China, flood

1. Background

In recent decades, together with population growth, economic development and rapid urbanization, China, one of the most disaster-prone countries, is facing higher disaster risks in the future due to climate change [1]. Beyond the immediate concern of detecting physical damages post-disaster, there exists a critical knowledge gap regarding the sociodemographic changes such as migration decision-making and resilience development in the aftermath of disasters [2]. Therefore, this study attempts to utilize the nighttime light (NTL) products to assess the impact of natural disasters on social changes in Hunan Province, China.

2. Methodology

2.1 Long-term Statistical Analysis

An anomaly detection technique was employed to three distinct NPP-VIIRS monthly NTL time series dataset (Table 1). The identified anomalous pixels, characterized by a sudden drop in brightness, were then cross verified with actual disaster events recorded at the county level source from both EM-DAT (The International Disaster Database) and Chinese medias. Here two hypotheses regarding the duration of disaster impact were formulated: Hypothesis 1 posited a transient effect confined to the month of the disaster, while Hypothesis 2 suggested a lasting impact extending into the subsequent month.

2.2 Short-term Case Studies

Case studies were conducted using 10-days composite generated from NASA's Black Marble daily product, focusing on two flood events: One flood event occurred between June 22 and July 2, 2017, across the majority of Hunan Province; One combination of two heavy precipitation events in a short period of time that occurred on May 24-25, 2014, and May 30 to June 2, 2014. The analysis involved calculating and comparing the spatial distribution of nighttime light (NTL) decreases and the county-level area ratios of NTL decrease across two distinct groups of cities/counties. The first group encompassed reported affected locations, while the counterpart consisted of those that remained unreported in terms of flood impact.

Table 1. Optimal Results of The Two Hypotheses in Three Different NTL Time Series Dataset, where Data 1 represents the original NTL monthly time series dataset, Data 2 represents the normalized NTL monthly time series dataset and Data 3 represents the residual component of NTL monthly time series dataset

Data type	Threshold	Values				Metrics (%)			
		TP	TN	FP	FN	Accuracy	Precision	Recall	F1 score
Data 1									
H1	5.3	95	912	852	35	53.17	10.03	73.08	17.64
H2	5.3	95	2667	854	165	73.05	10.01	36.54	15.72
Data 2									
H1	850	499	1155	695	39	69.26	41.79	92.75	57.62
H2	870	477	2915	682	533	73.63	41.16	47.23	43.98
Data 3									
H1	5.2	36659	285377	258274	9556	54.59	12.43	79.32	21.49
H2	5.2	39212	788976	293943	53218	70.46	11.77	42.42	18.43

3. Results

3.1 Long-term Statistical Analysis

Although the performance of long-term analysis (Table 1) is moderate, reaching the optimized results of Hypothesis 1 applied to the normalized NTL dataset, boasting 69.26% accuracy, 41.79% precision, 92.75% recall, and a 57.62% F1 score at a threshold of 850, the findings suggest a transient impact following a disaster, with effects diminishing beyond the immediate aftermath.

3.2 Short-term Case Studies

The spatial analysis of case studies revealed two key insights, one is the influence of floods in urban areas appears to be mitigated, attributed to the elevated level of economic development and robust disaster management practices. Another is a significant correlation between areas with reported damages and a decrease in NTL intensity (Figure 1). Box plot analysis of calculated ratios depicting NTL decrease areas of cities/counties with reported damages exhibit a markedly higher mean compared to their unreported counterparts. Specially, the mean ratios are 12.04 and 3.08 for the reported locations, in contrast to 12.25 and 5.49 for the unreported ones. A t-test further demonstrate statistically significant disparities of affected areas post-disaster between two groups.

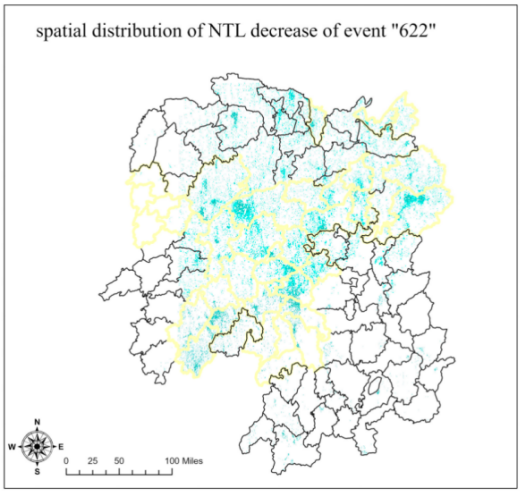

Figure 1. Spatial Distribution Map of NTL Decreases of Event "622". The yellow-lining polygons represent the reported affected cities/counties

4. Future Task

To establish the broader generalizability of this methodology, further research across a spectrum of disaster categories is warranted. The observed limitations in long-term supervised learning signal a direction for exploring alternative anomaly detection techniques and refining disaster damages information sources to ensure more precise assessments of disaster impacts. Further, the good performance of case study opens new avenues for studying environmental impacts upon human activities such as temporary migration during and post disasters.

Reference

[1] World Bank. Learning from experience: Insights from China's progress in disaster risk management[J]. 2020.

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