Optimising oceanic rainfall estimates for increased lead time of stream level forecasting:
A case study of GPM IMERG estimates application in the UK

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EGU General Assembly #EGU24 14 -19 April 2024

Introduction

Precipitation forecasting plays a crucial role in the planning and management of UDS for riverine flood events.

Among the main rainfall data sources (rain gauge stations, rainfall radar stations and weather satellites), satellites are often the most appropriate, however challenging, for exploring new ways to increase lead times in flood forecasting models.

This is particularly relevant for the UK, where severe rainfall events often travel from the Atlantic Ocean undetected by land-based instruments. For these regions, an alternative source of rainfall data for real time flood forecasting, is offered by the GPM (IMERG)* precipitation estimates.

*Global Precipitation Measurement Integrated Multi-satellitE Retrievals

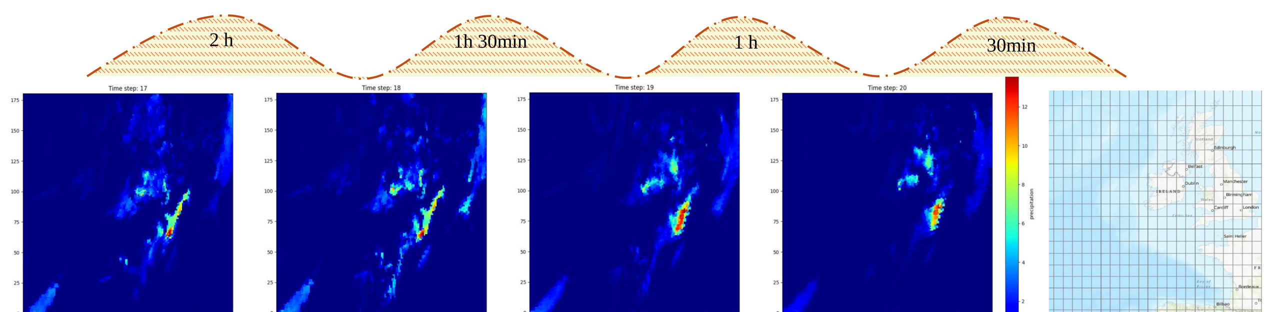


Fig. 1. Weather system movement towards London: Images plotted using rainfall information produce at 30 min interval. Source: GPM - IMERG 06, final run.

However, the adversities lies in monitoring the vast oceanic region near the UK and integrating this extensive amount of data into hydrological or data-driven models. This incurs in significant computational and time constraints. Therefore, identifying key monitoring regions for obtaining these estimates is essential to address these challenges and to effectively use this use for water level forecasting in urban drainage systems (UDS).

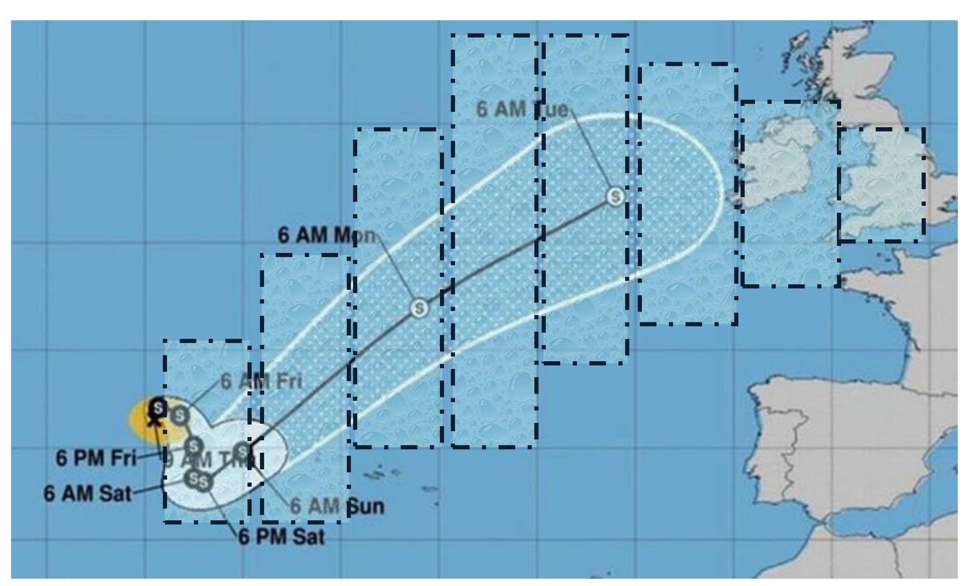


Fig. 2. Representation of the minimal monitoring region required to identify the path, speed and intensity of one weather event generated in the Atlantic ocean

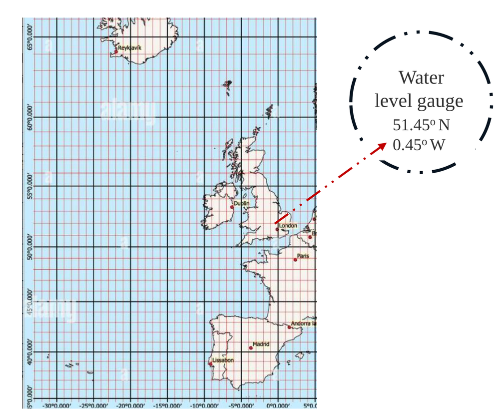
Methodology

This study introduced an optimized data-driven method streamlining the collection and use of GPM IMERG rainfall estimates for water level forecasting in UDS. We conducted a cross-correlation analysis between water level records in a river and each IMERG data pixel within the selected oceanic area using MATLAB R2023a. The method effectiveness was demonstrated by comparing the performances of selected IMERG pixels and rainfall gauges data on forecasting the river's water level. This methodology aims to identify the most probably path of rainfall from the Atlantic to optimize use of satellite data for flood forecasting models.

Case study - Data

Data summary

- Period of data: June 2000 to September 2021
- Time-steps: 374,016
- IMERG data grid: 181 x 181 grid = 37.761 pixels
- Key area: 101 x 181 = 18,281 pixels
- Data processed: 18,282 x 374,016 = 6,837,760,512



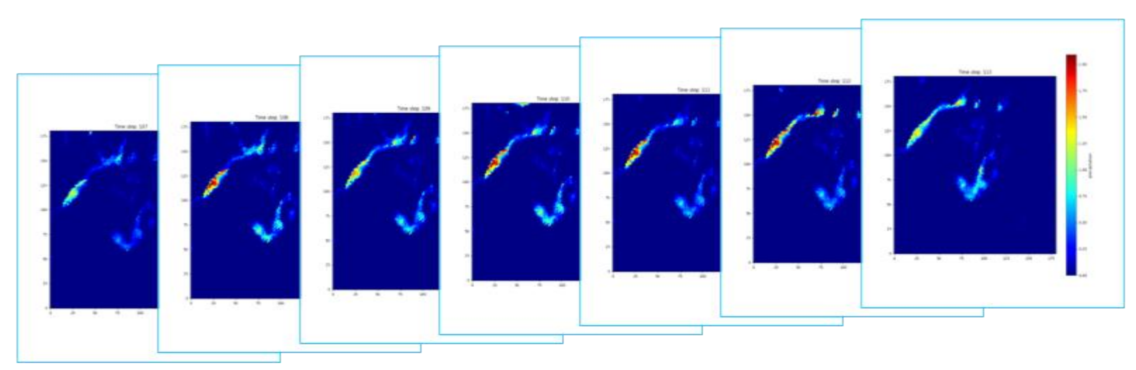


Fig. 3. Representation of the point of hydrological data collection and rainfall information collected from GPM-IMERG 06.

Weather systems reaching the UK typically travel at average speeds of 10 to 30 km/h, with exceptional storms reaching speeds of up to 70 km/h. Also, the processing time to produce near-real-time satellite estimates is at least 4 hours (IMERG early run). This information was taken into account when selecting the region in the Atlantic for data collection to be used in forecasting the water level of a stream near Heathrow in London. The area of interest in the oceanic region extends from 2°W to 20°W and from 42°N to 60°N, while the stream level gauge is located at 51.45°N, 0.45°W. The data spans from June 2001 to September 2021, with readings taken at 30-minute intervals.

Results

Cross-correlation results:

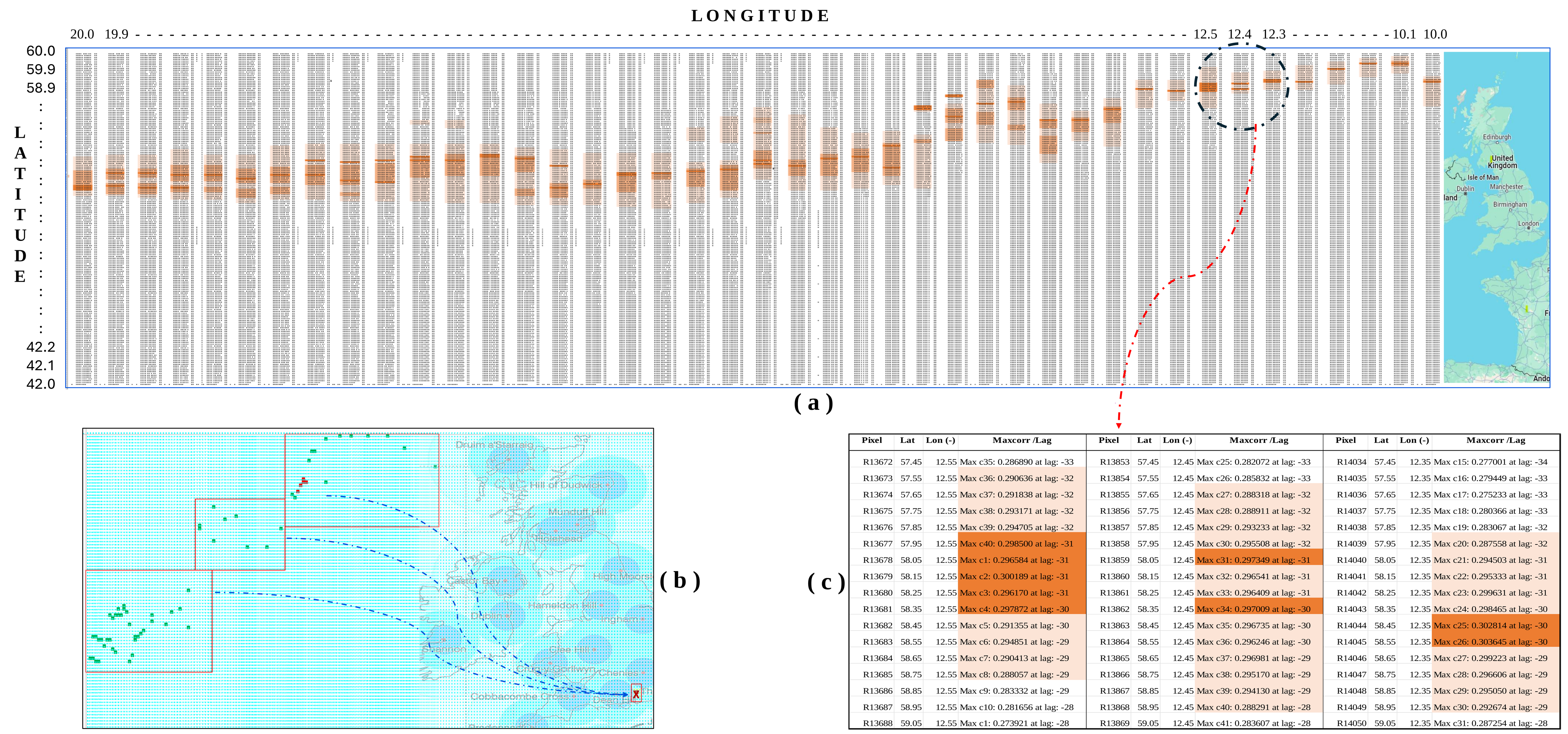


Fig. 3. (a) Correlation results between water level data and each IMERG pixel within the selected. (b) Display of the zones and path of pixels with the highest cross-correlation results with level readings at the X gauge. (c) Zoomed extracted section from figure (a) contained the pixels with highest cross-correlation results.

IMERG rainfall data performance evaluation

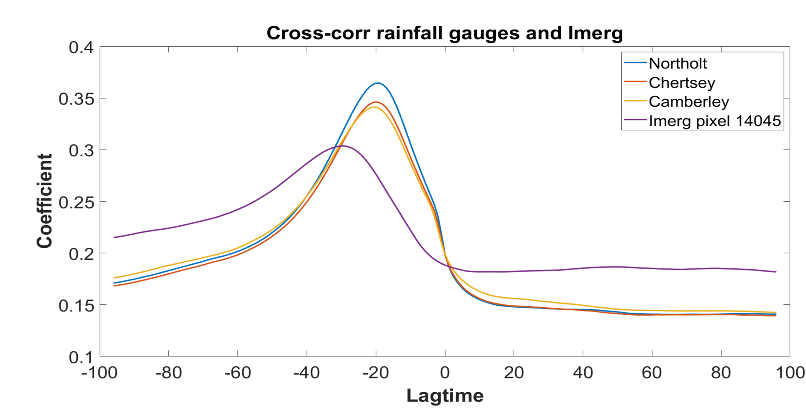


Fig. 4. Comparison between water level correlation with rainfall data from the three local gauges and with IMERG optimum rainfall pixel.

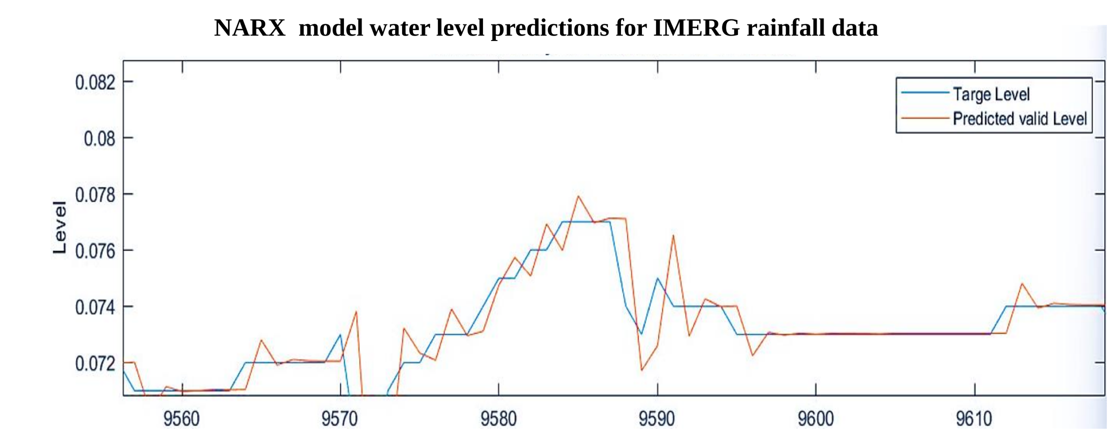


Fig. 5. IMERG rainfall pixel performance for two days-ahead stream level prediction in a NARX model.

Conclusions and future work

- ✓ This investigation enhances our comprehension of long-distance rainfall pathways towards the UK, which allow the optimization of satellite data collection for data driven forecasting models.
- ✓ It advances a step towards NRT prediction of flood events by enabling the use of satellite data from Oceanic regions in hydrological models.
- ✓ It contributes in reducing the volume of information and processing times in data driven models which will lead to higher speed and lower computational costs.

The next steps of the research looks into the optimization and fine-tune of models to use GPM-IMERG Early Run estimates for near real-time (NRT) predictions