Air Mass Partitioning of Historical Weather Station Data to Incorporate Meteorological Principles into Water Resources Engineering

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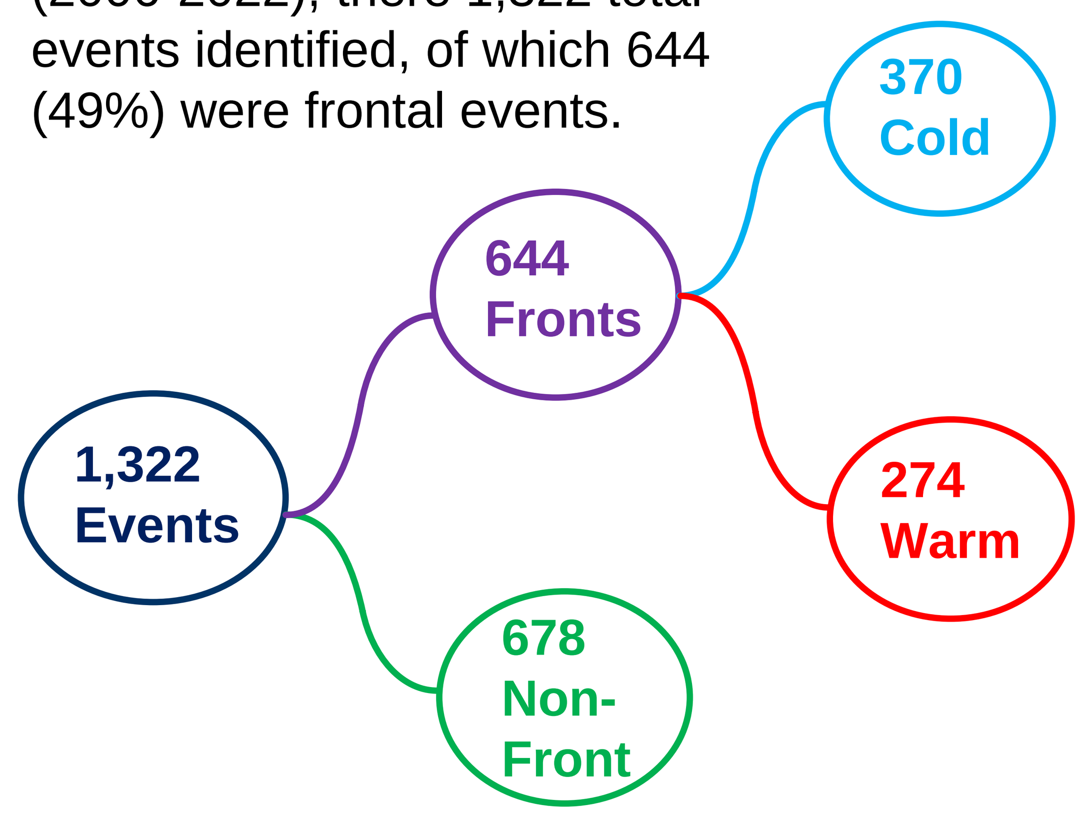
MOTIVATION

Green stormwater infrastructure (GSI) systems are designed based on design storm criteria, which have been criticized for their static assumptions that can misrepresent the true propagation of rain events.[5] In some climates, weather front storm types comprise a large portion of regional precipitation, aligning with the types of smaller, frequent events GSI are intended to manage[1]. The present study asks: **How can historical data be evaluated under weather front regimes to achieve distinguishable storm patterns for GSI design?** To address this question:

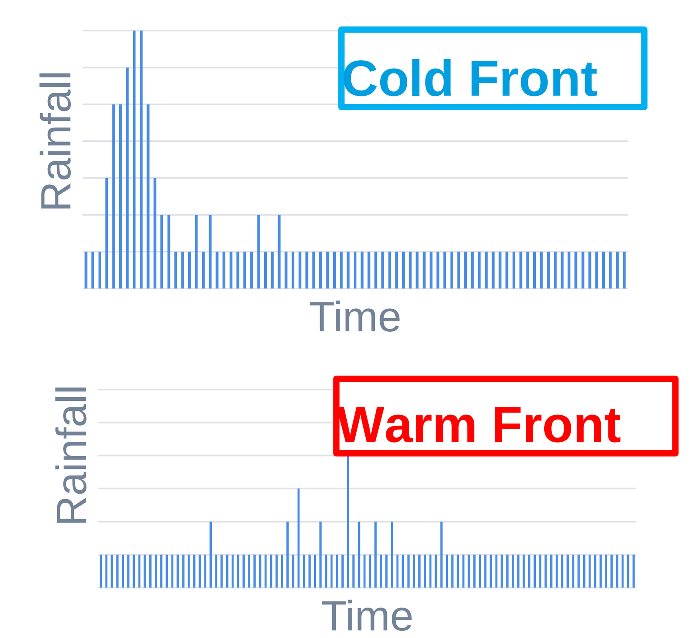
- Methods in meteorology are applied to enhance historical rainfall dataset development to consider storm type
- Hydrologic parameters are statistically compared to highlight key differences between storm types

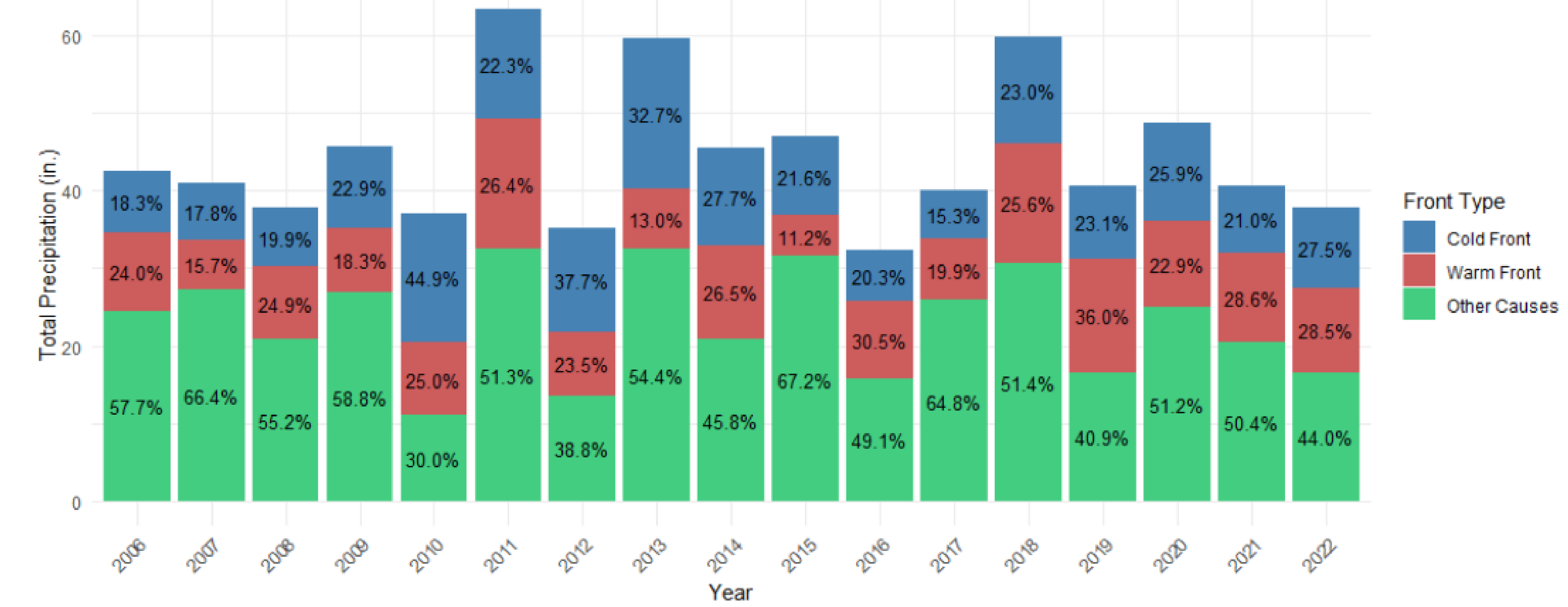
RESULTS

For the 17-year study period (2006-2022), there 1,322 total events identified, of which 644 (49%) were frontal events.

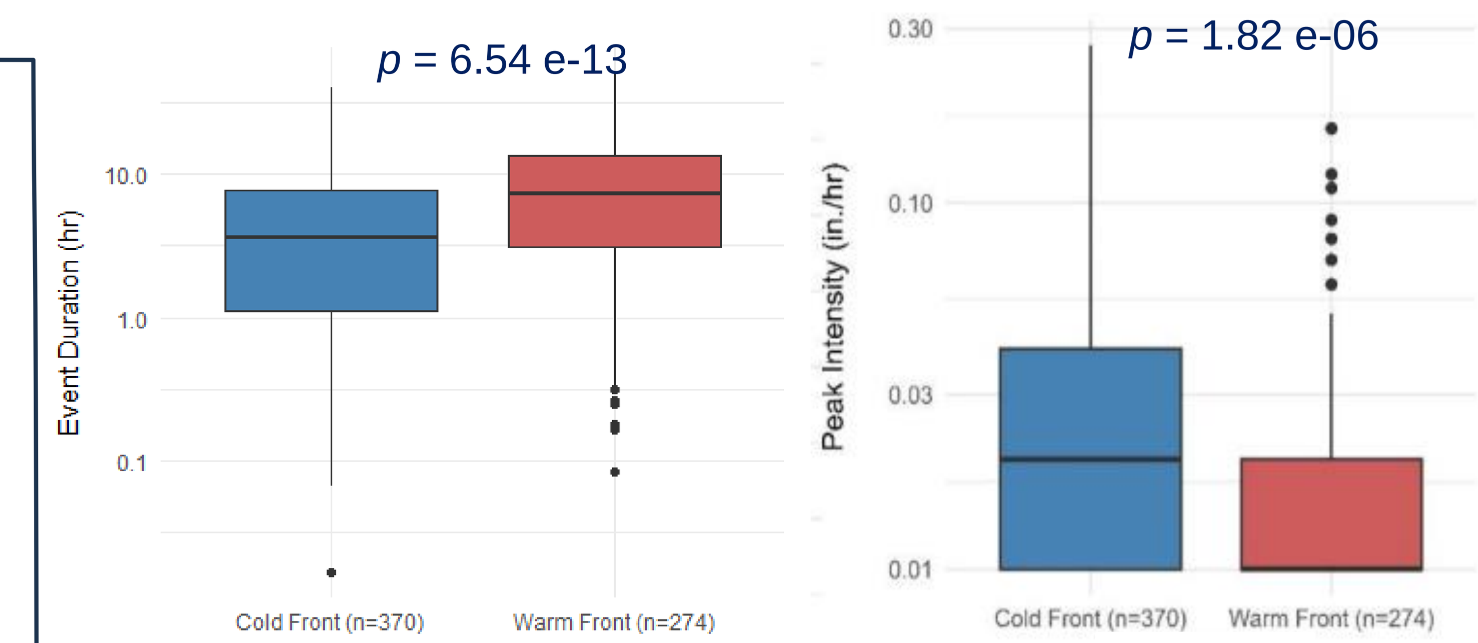


Simplified depictions of cold front and warm front hyetographs demonstrate the differences in event propagation in time.





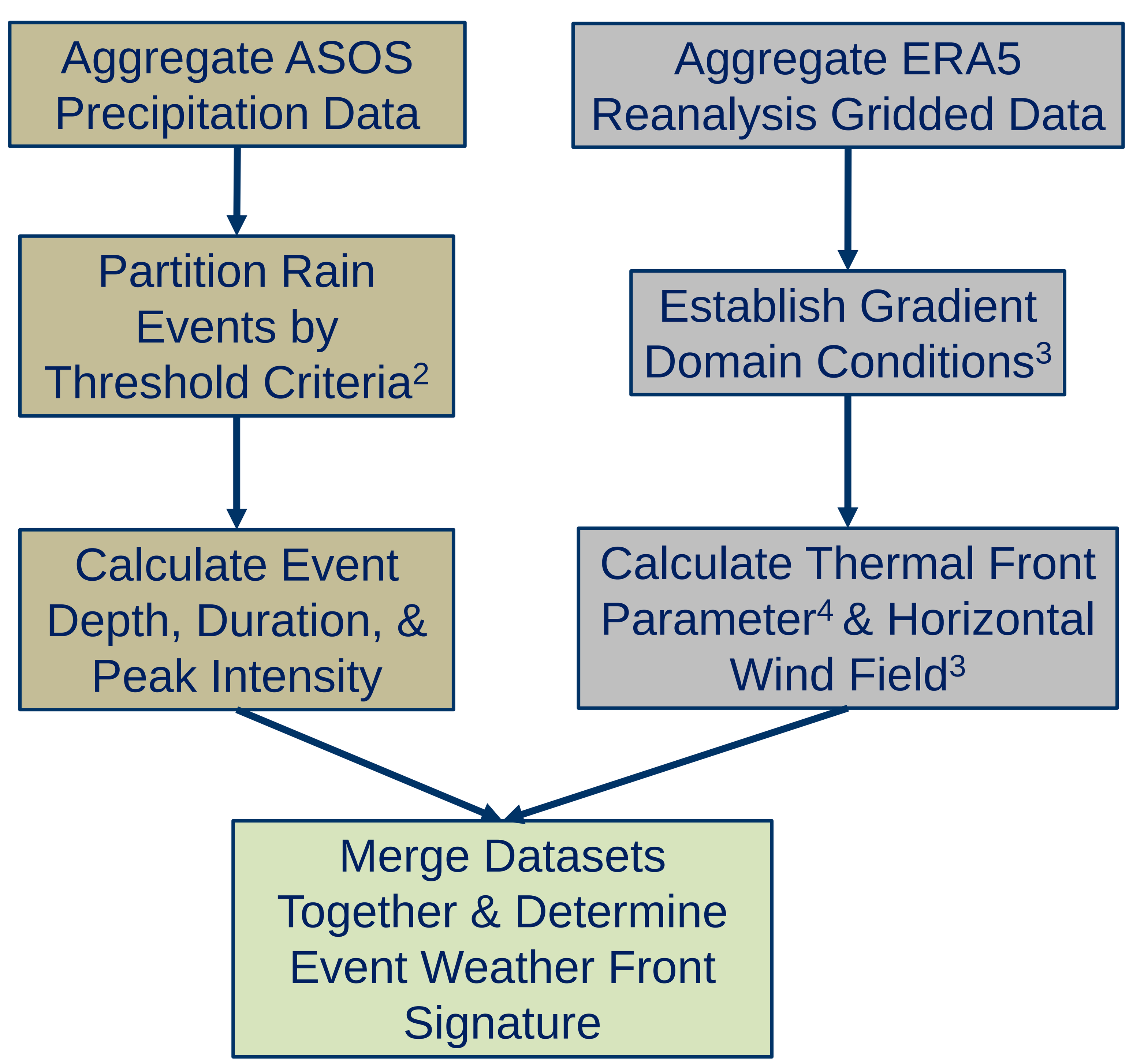
When partitioned by air mass signature, weather fronts comprise around 50% of the total annual rainfall for any given year for the Philadelphia case study.

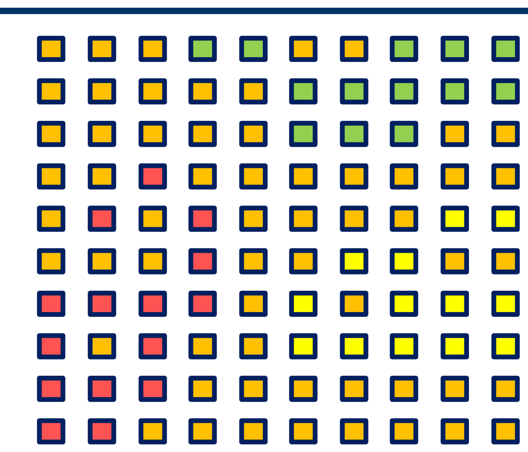


Wilcoxon Rank Sum testing between cold fronts and warm fronts revealed significant statistical differences across hydrologic parameters, such as event duration (hr) and peak intensity (in/hr).

METHODS

By merging concepts in hydrology and applied meteorology, a multidisciplinary framework was developed that identifies rain events and attributes a weather front signature to each storm (see below).





Gridded Atmospheric Thermodynamic Field (ERA5 Reanalysis)

Temporal Rainfall Data (Automated Surface Observing System)

30,000 mi² Grid Surrounding KPHL

17-Year Study Period (2006-2022)

Gridded atmospheric data (at 900-mb pressure surface) and temporal rainfall data (at 1-min resolution) served as inputs for the multidisciplinary analysis.

The spatial and temporal domain allowed for an extensive dataset to be developed.

Following standard convention in atmospheric science[4], weather front signature is determined by:

$$TFP = \nabla|\nabla\theta_W| \cdot \frac{\nabla\theta_W}{|\nabla\theta_W|} < K_1 \; where \; K_1 \leq 0 \; K \, m^{-2}$$

$$V_{front} = \frac{V \cdot \nabla|\nabla\theta_W|}{|\nabla|\nabla\theta_W||}$$

where the Thermal Front Parameter (TFP) implements the gridded wet-bulb temperature field (θ_W) to determine the presence/absence of a weather front and the horizontal wind field (V_{front}) allows for the separation between cold front and warm front to be made.

CONCLUSIONS & FUTURE WORK

Air mass partitioning of historical time series rainfall data highlights significant differences between storm types and establishes an objective framework for similar studies in different locales. Future work will turn to enhancements for GSI design storm pathology that include weather front signature as additional criteria.

REFERENCES

[1] Dagon, K. et. al. (2022. **[2]** Driscoll, E. D., et. al. (1989). *U.S. Environmental Protection Agency, OCLC*. **[3]** Hewson, T. D. (1998). *Meteorological Applications.* **[4]** Sansom, P. G., & Catto, J. L. (2022). **[5]**Watt, E., & Marsalek, J. (2013).

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