Impact-based flood forecasting in India: evaluation of FHIM-India for fluvial flood impacts in Kerala

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1. Introduction

Flooding remains one of the most devastating natural hazards worldwide, affecting more than 3.2 billion people between 1990 and 2022. Hazardous hydrometeorological events can now be forecast with increasing accuracy and longer lead times. However, forecasting the hazard alone does not tell us what it will do to lives and livelihoods. Impact-Based Forecasting for Floods (IBFF) addresses this gap by focusing on the likely consequences of flood hazards, enabling clearer and more actionable warnings. Evaluation of IBFF frameworks remains a challenging task largely due to lack of robust impact data.

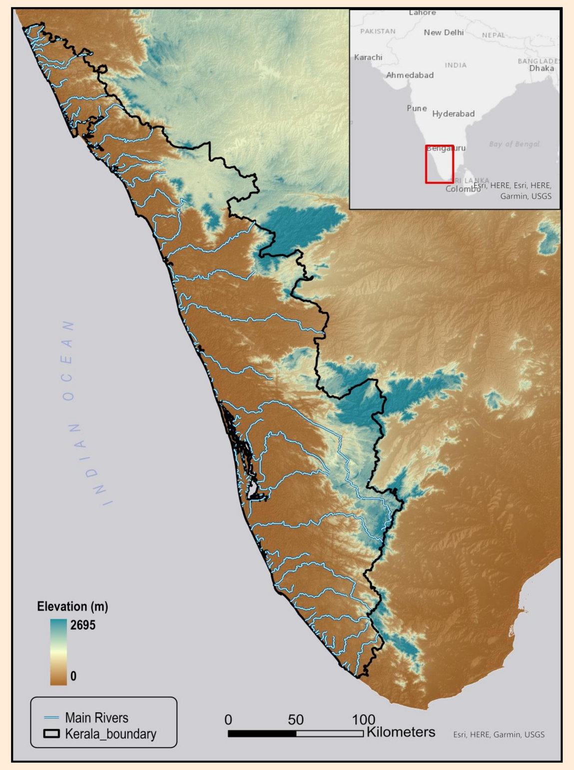

Figure 1 Kerala, India

This study aims to evaluate Flood Hazard Impact Model for India (FHIM-India) (fig. 2), an IBFF designed for the state of Kerala, India (Fig. 1). FHIM-India generates impact estimates for risk categories such as population and property. Impact estimates are automatically retrieved from FHIM's precalculated dataset when provided with daily rainfall forecast.

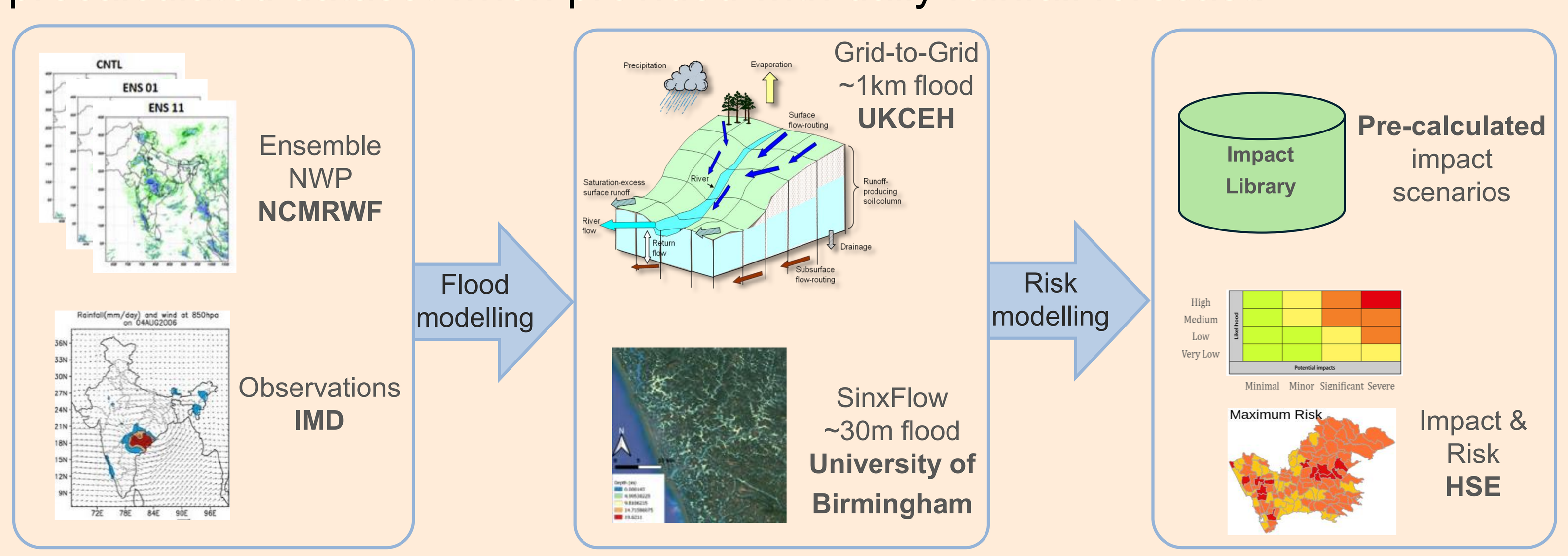

Figure 2 Schematic of FHIM-India framework

2. Method

Datasets used and hindcast impact estimates generated

- Observed daily rainfall & impact data (1991–2022)
- FHIM impact estimates and fixed rainfall thresholds used as a benchmark (fixed in Fig. 3)

Verification

Binary verification approach adopted to classify days as either "impact day" or "non-impact day" which are then compared with presence of impact, Fig 4.

- Impact level 0 to 4, represent impact severities None, Minimal, Minor, Significant, and Severe.

Metric	What it shows
POD	Probability of Detection - detecting observe impacts
FAR	False Alarm Rate - unsuccessful warnings
CSI	Critical Success Index - overall detection skill
Bias	Over- or under-forecasting
HSS	Skill relative to random chance (1 perfect, 0 same as chance)
TSS	To separate impact from non-impact (1 perfect; 0 no skill)

Table 1, Analytical metrics

3. Result

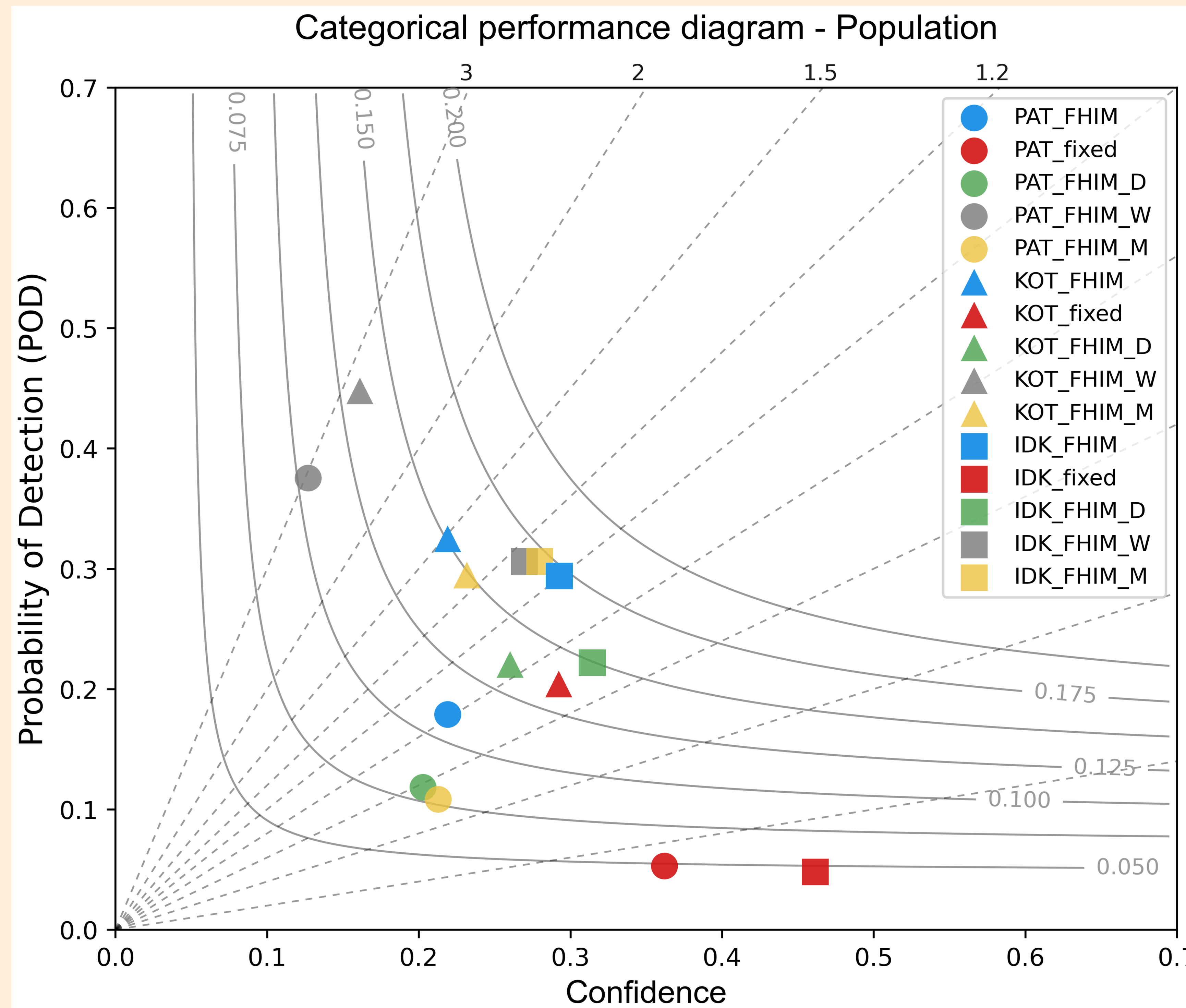

Figure 3 The three districts Pathanamthitta (PAT), Idukki (IDK), and Kottayam (KOT) with impact level ≥ 2. Confidence (1 – FAR). Dashed lines bias, contours mark levels of CSI. FHIM with soil conditions set to dry, medium, and wet (FHIM_D/M/W)

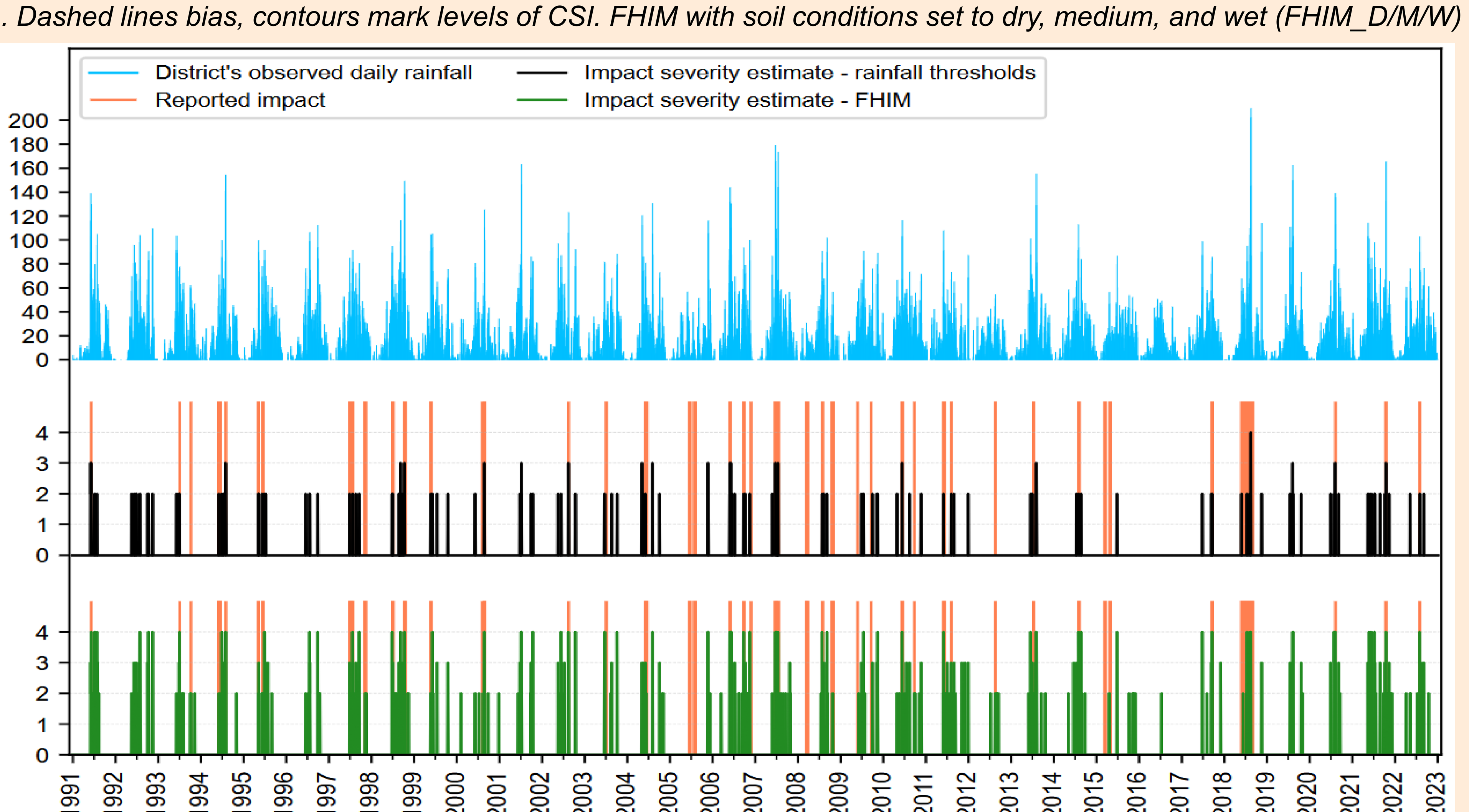

Figure 4 Timeseries of classified impact and non-impact days for Kottayam district.

- In all three districts, FHIM-India has higher CSI score and bias closer to one than other estimates Fig. 3
- Model outputs summarised in Fig. 4 - Daily rainfall (top row), impact estimates from fixed rainfall thresholds (middle row), FHIM-India (bottom row) and observed impact days (orange).
- FHIM-India improves CSI by up to threefold compared with the benchmark, indicating better detection of impact days.
- FHIM shows consistently higher HSS across districts and antecedent condition assumptions.
- TSS and HSS scores of FHIM with constant antecedent conditions are comparable to that of FHIM.

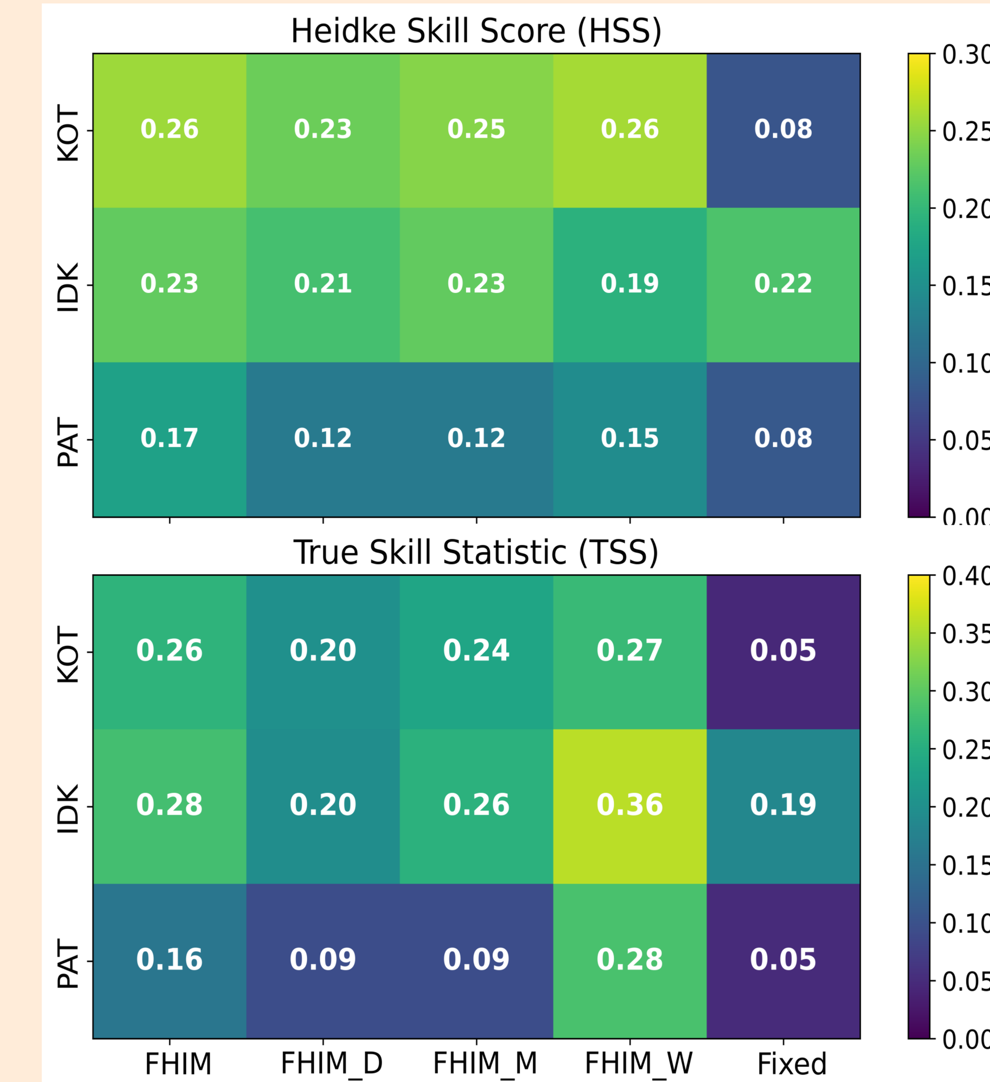

Figure 5. HSS and TSS across districts and models

4. Discussion

- FHIM's use of antecedent conditions improves the detection of impact days.
- While FHIM_D/M/W and FHIM display comparable HSS and TSS score, FHIM has better CSI scores across districts. This indicates FHIM's dynamic approach has higher adoptability.
- A strength of the study is the use of long-term historical data, which enabled evaluation over a longer period.
- There were low scores across all impact estimates due to poor quality of impact data available; for example, inconsistency in reporting, and poor geographical resolution.
- A limitation of the study is that the binary approach does not distinguish between major and minor impacts when classifying impact days.
- This study focuses on the impact-calculation component of FHIM-India; further work is needed to evaluate its ensemble forecasting and early warning components.

5. Conclusion

- FHIM-India model outperform the fixed rainfall-threshold benchmark, likely due to integration of receptor exposure data into the impact calculation. This is regardless of antecedent condition assumptions.
- Impact calculation on local level makes FHIM's approach highly adoptable.
- Using publicly available data, this approach can be implemented in other countries/localities.

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