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Leveraging Earth Observation and Data Assimilation for Improved Flood Inundation Forecasts

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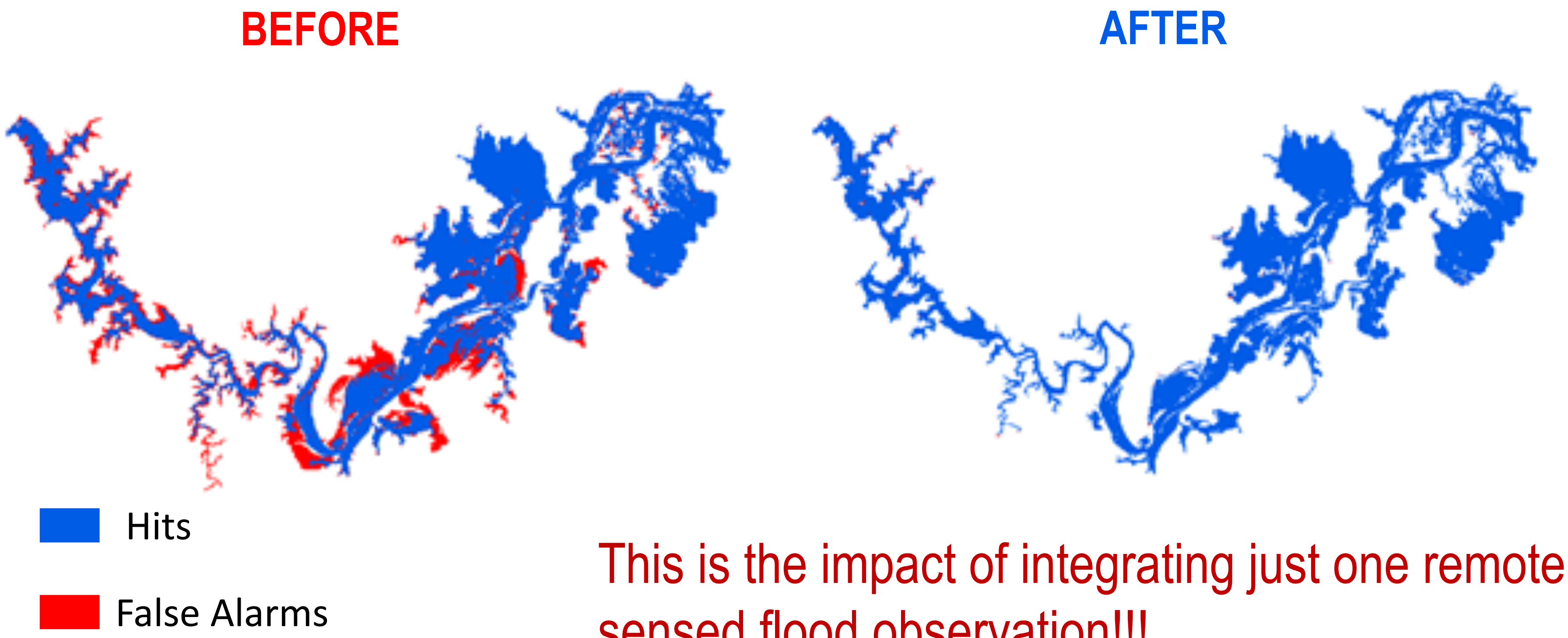
IIT BOMBAY

IITB-Monash Research Academy

An Indian-Australian research partnership

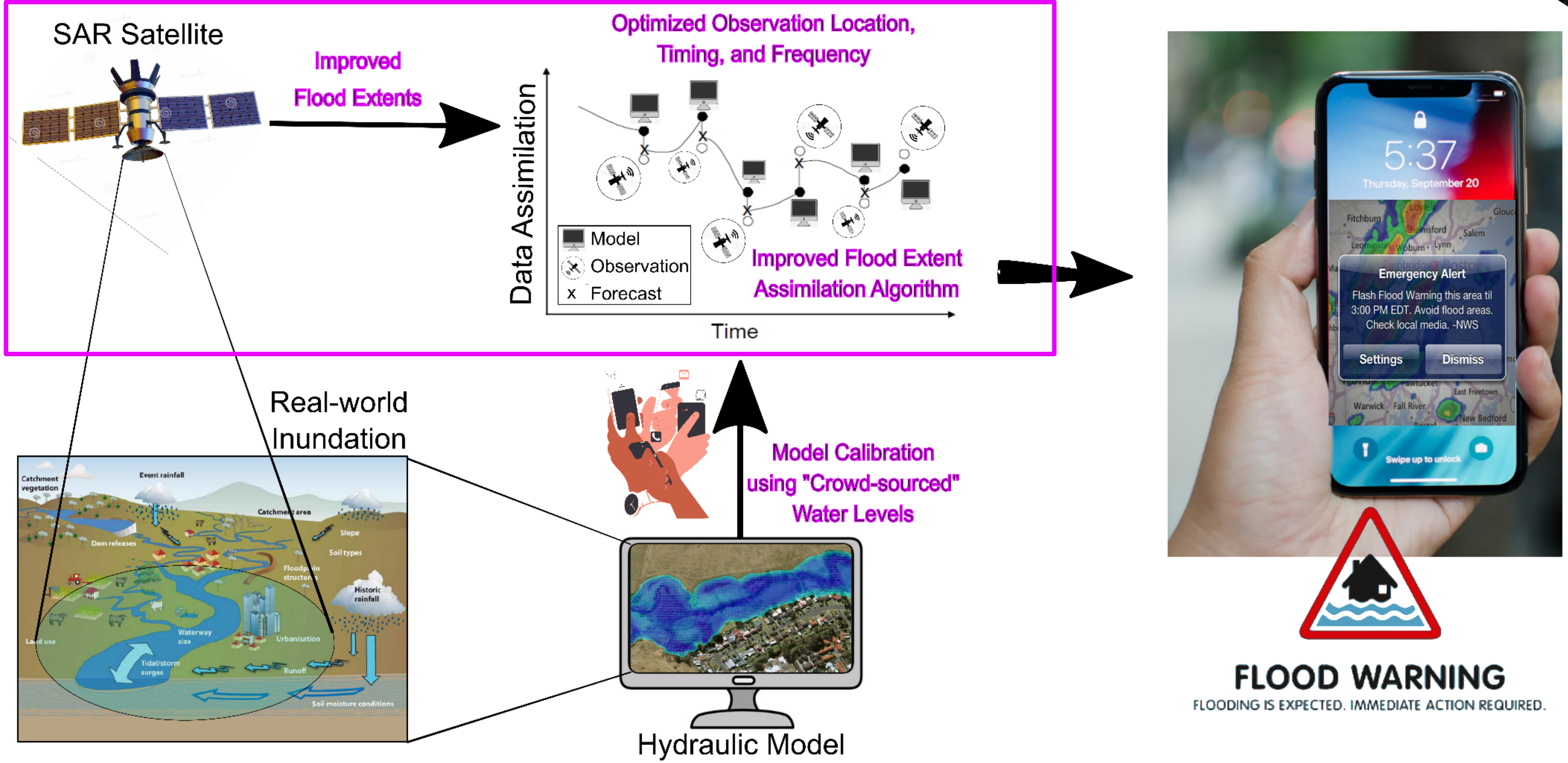
What if most satellite-based flood observations could significantly improve flood forecasts?



This is the impact of integrating just one remotely sensed flood observation!!!

How will it work?

Make improvements at every step of the process



IMPROVING RADAR-BASED FLOOD MAPPING

Dasgupta, A., Grimaldi, S., Ramsankaran, R., Pauwels, V. R. N., & Walker, J. P. (2018). Towards operational SAR-based flood mapping using neuro-fuzzy texture-based approaches. *Remote Sensing of Environment*, *215*(15 September 2018), 313–329. http://doi.org/10.1016/j.rse.2018.06.019.

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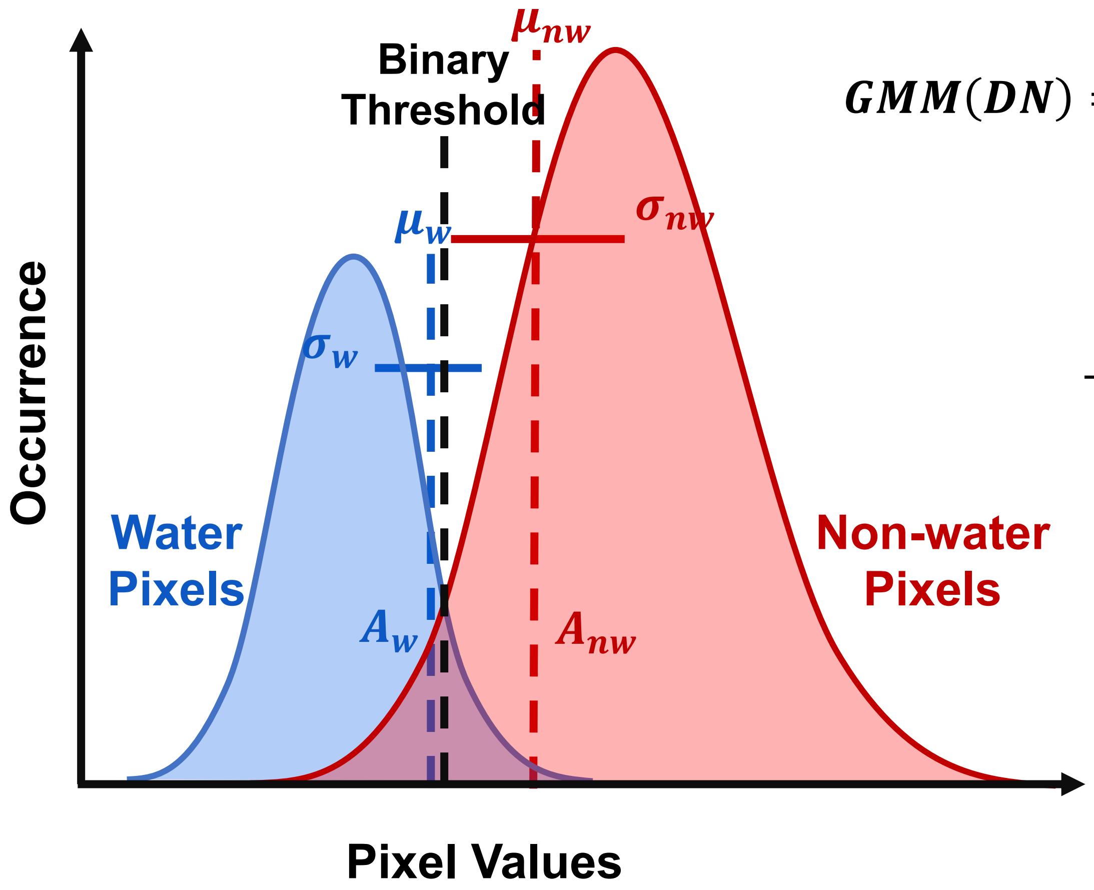
Current Challenges

Histogram dependence and deterministic outcomes

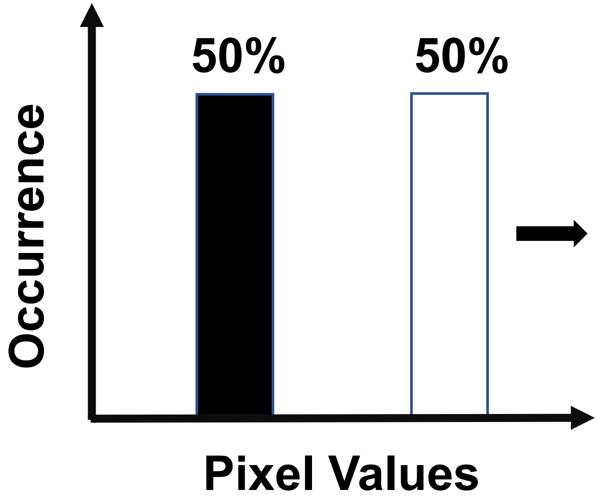
Typical Flooded Image Histogram



$$GMM(DN) = \underbrace{A_w\, exp\left[-\frac{1}{2}\frac{(DN-\mu_w)^2}{\sigma^2{}_w}\right]}_{\text{Gaussian curve for water pixels}} \underbrace{+A_{nw}exp\left[-\frac{1}{2}\frac{(DN-\mu_{nw})^2}{\sigma^2{}_{nw}}\right]}_{\text{Gaussian curve for non-water pixels}}$$

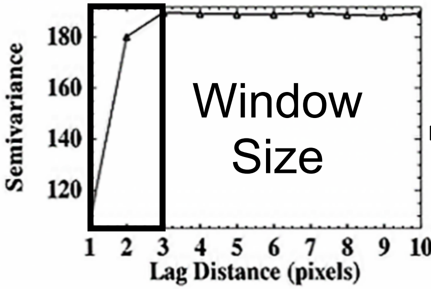
Proposed solutions

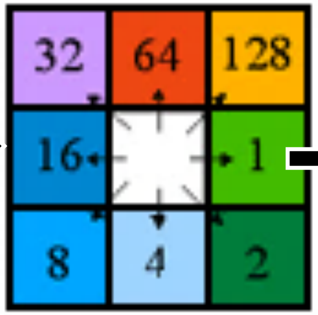
Image texture optimization and neuro-fuzzy flood mapping

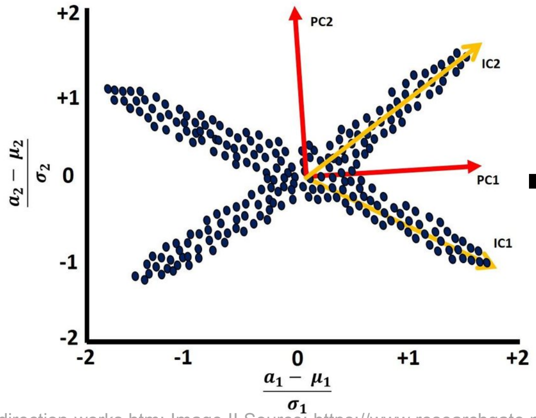


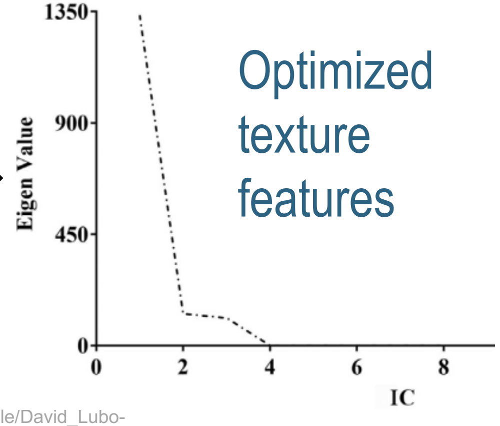
Source: Lecture notes, Advanced Satellite Image Processing, B. Krishna Mohan, IITB.

Texture optimization process







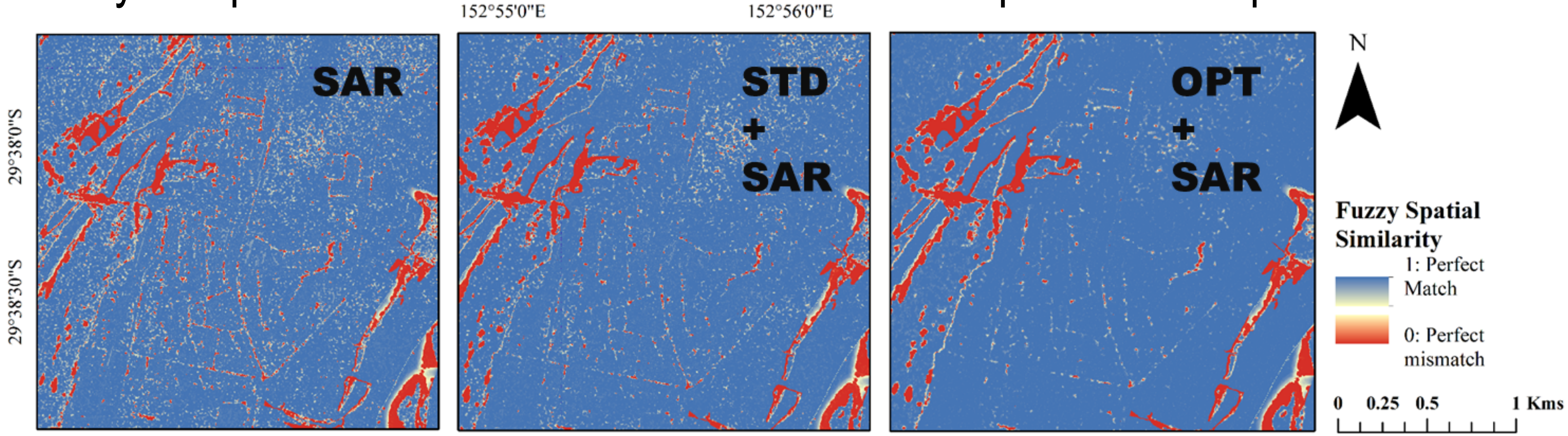


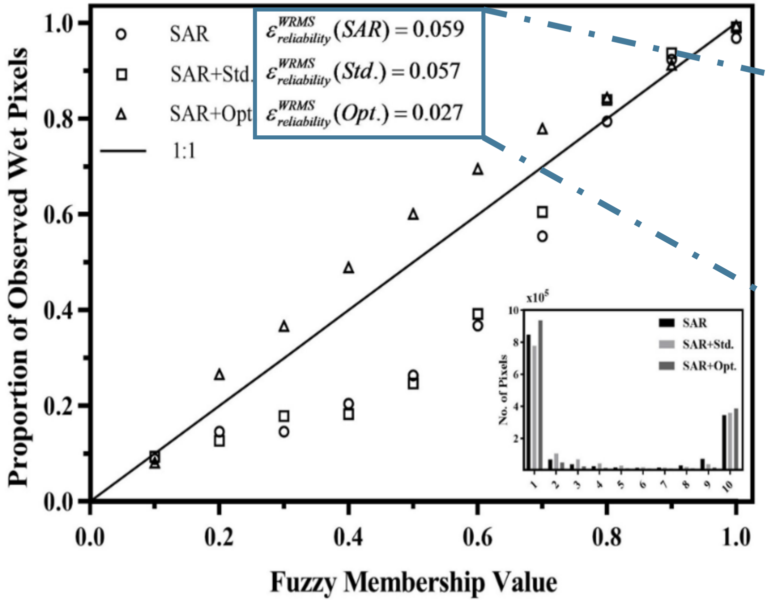
Optimized texture features

Image I Source: https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-flow-direction-works.htm; Image II Source: https://www.researchgate.net/profile/David_Lubo-Robles/publication/326199223/figure/fig2/AS:644901943398403@1530768013996/Differences-between-Principal-Component-Analysis-PCA-and-Independent-Component-Analysis.png

Key Results

Fuzzy comparison between SAR-based and aerial photo based probabilistic flood maps





Errors

$$\varepsilon^{WRMS}_{reliability}(SAR) = 0.059$$

$$\varepsilon^{WRMS}_{reliability}(Std.) = 0.057$$

$$\varepsilon^{WRMS}_{reliability}(Opt.) = 0.027$$

-54%

A New Method to Combine Satellite-based Flood Maps with Models

Dasgupta, A., Hostache, R., Ramsankaran, R., Pauwels, V.R.N., Schumann, G.J.P., Grimaldi, S., and Walker, J.P. (2020) A mutual information-based likelihood function for SAR-derived flood extent assimilation using particle filters. Water Resources Research (In Review).

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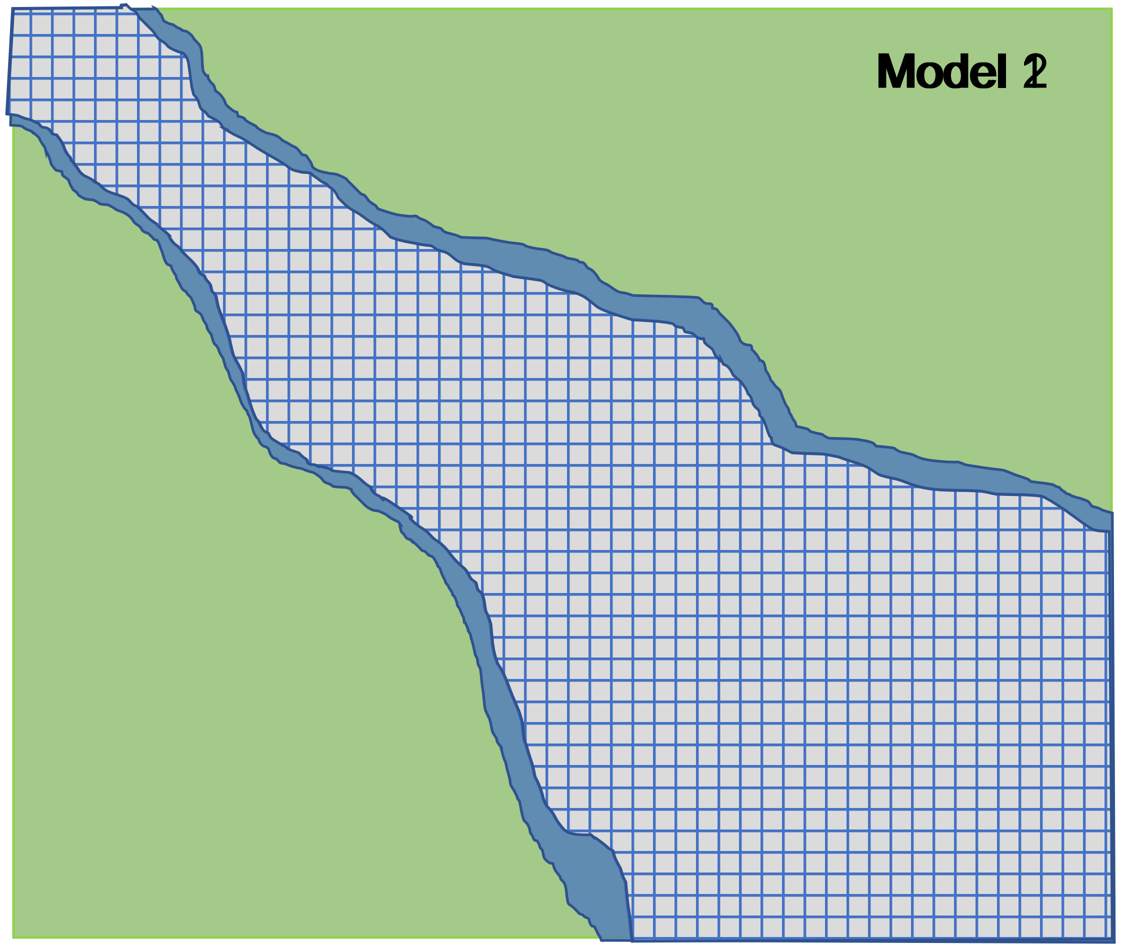
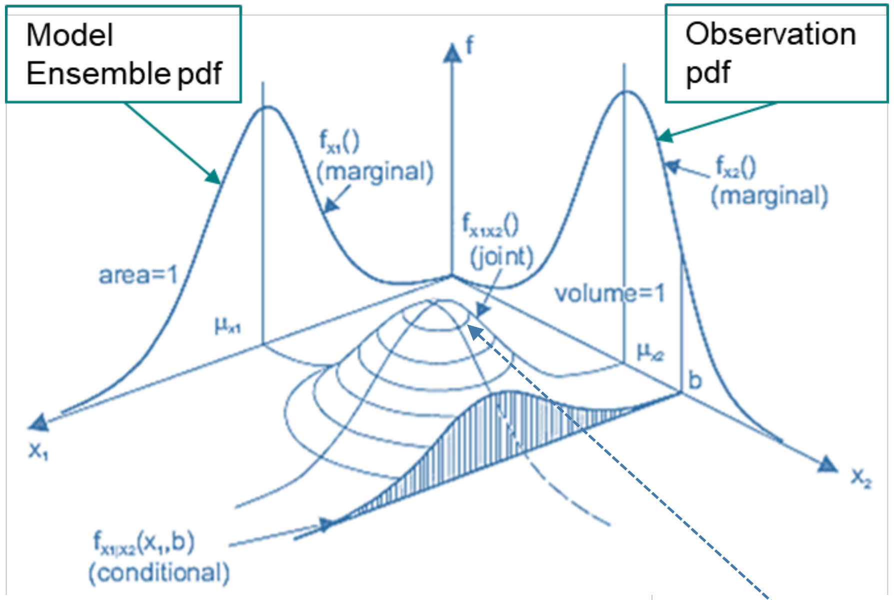
Current Challenges

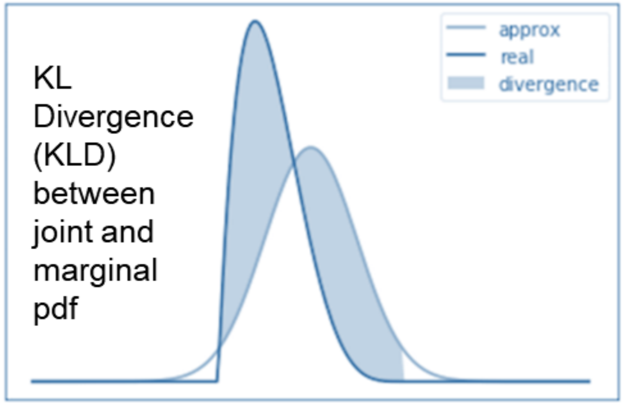
Likelihood sensitivity towards slightly varying extents



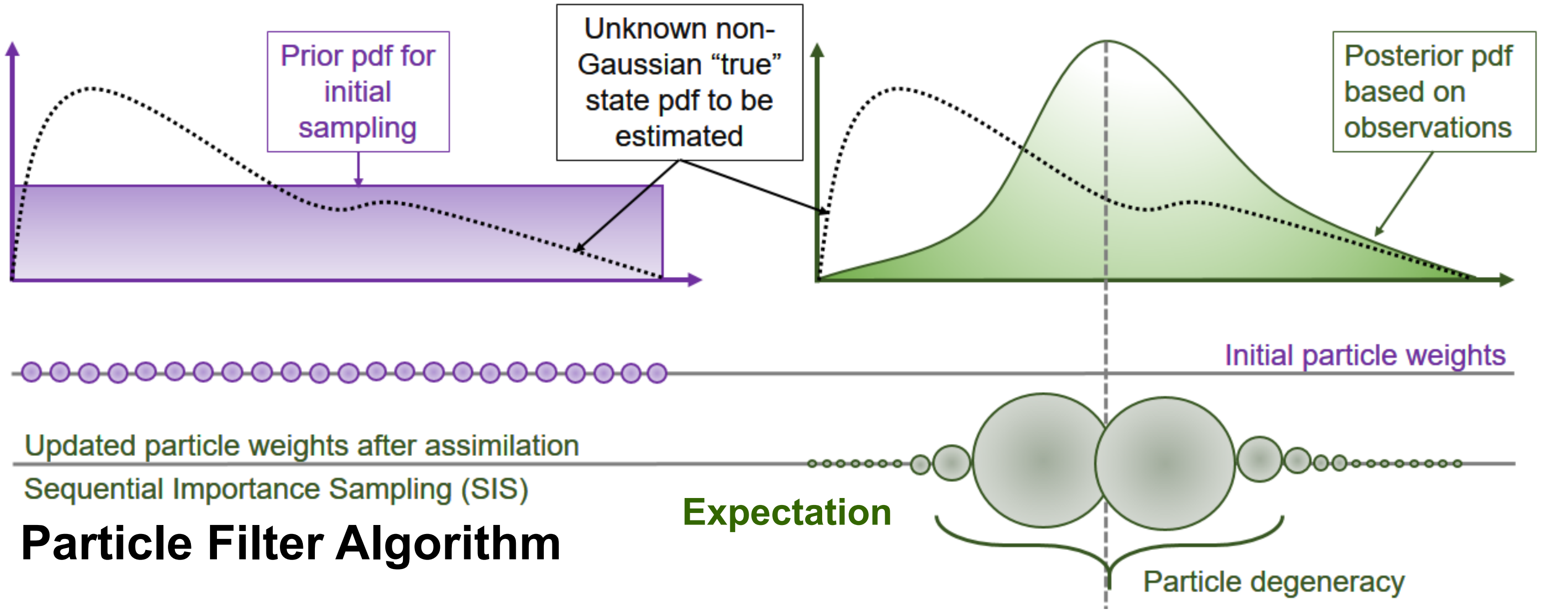
Proposed Solution

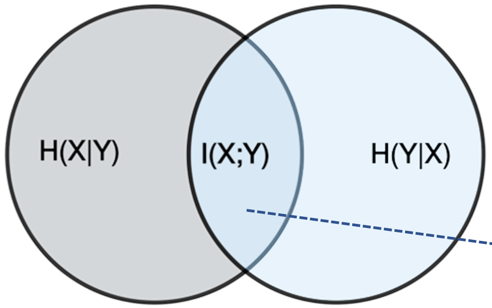
Mutual Information (MI)

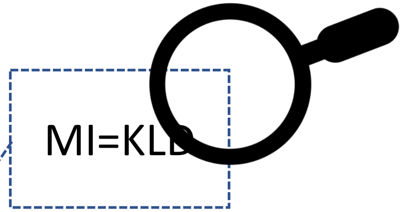




MI=0 iff the joint pdf is equal to the product of marginals

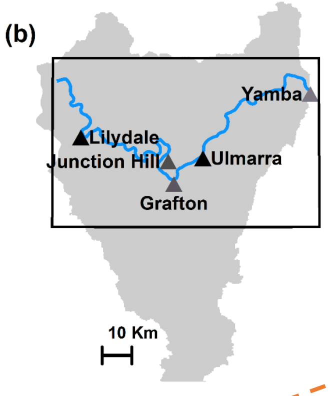


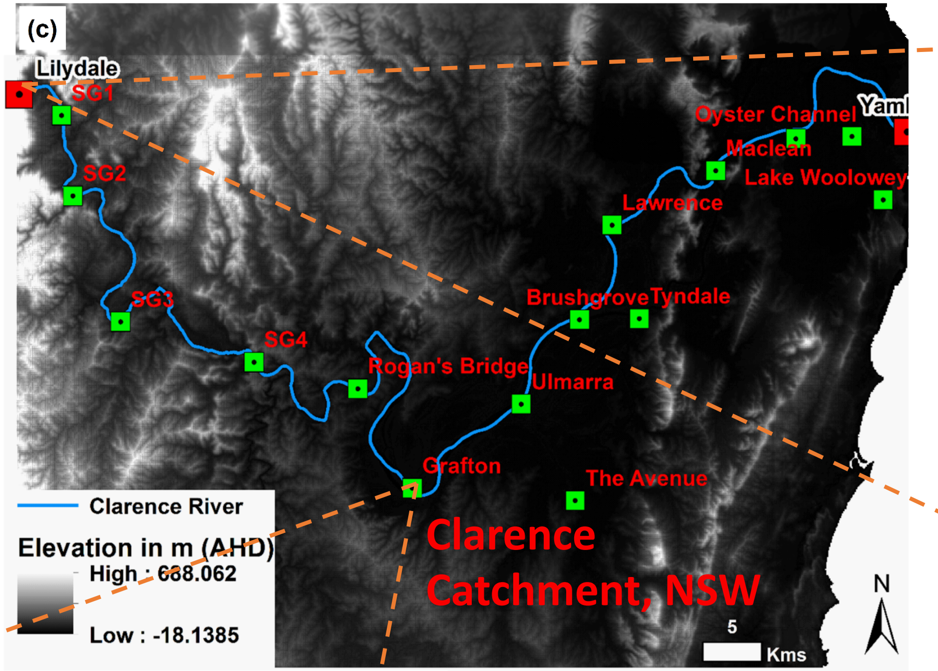


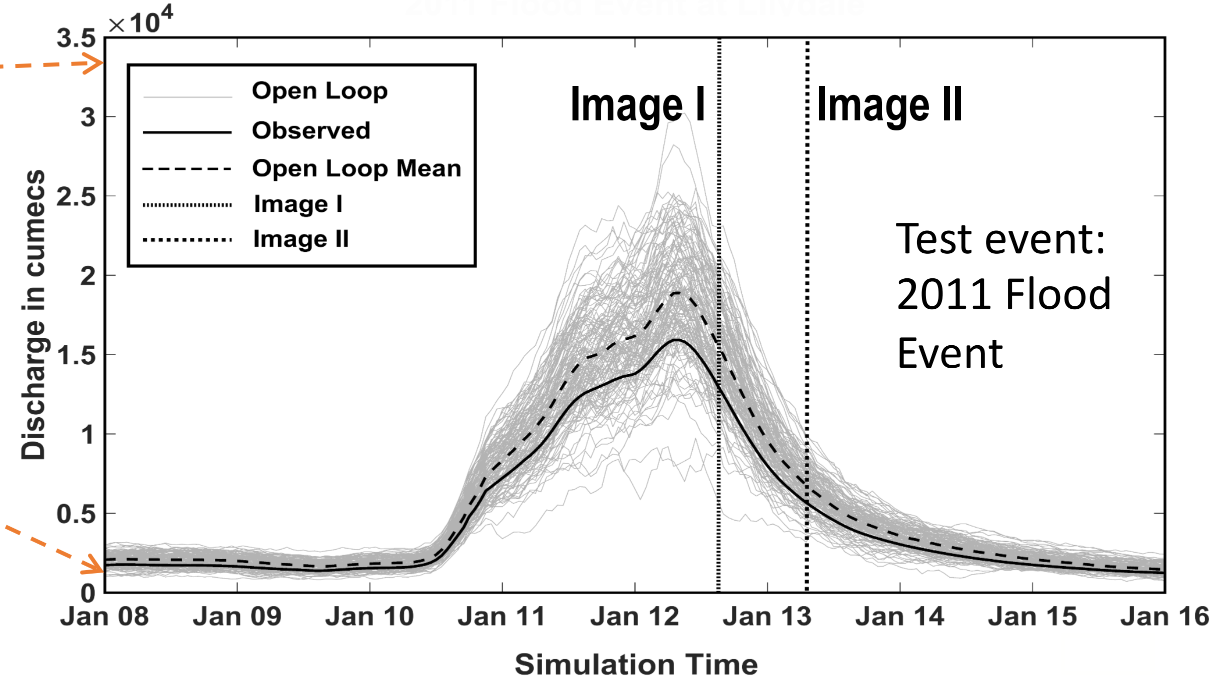


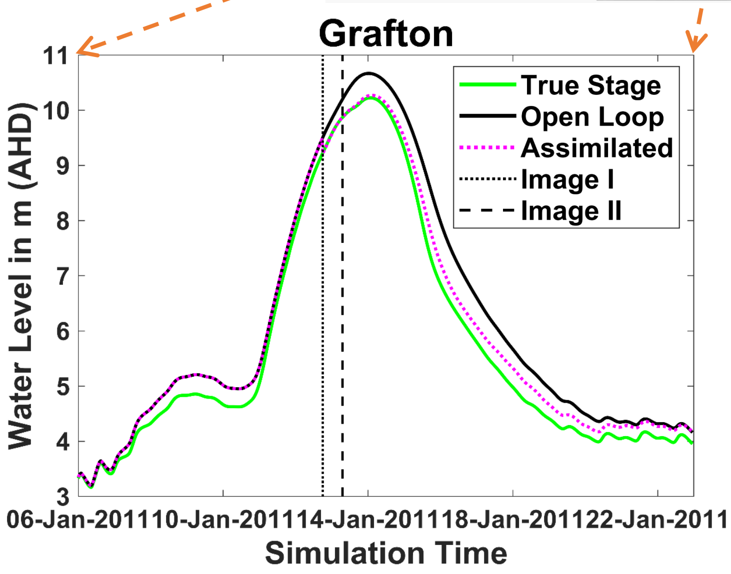
Zoom in using rescaling factor to enhance sensitivity

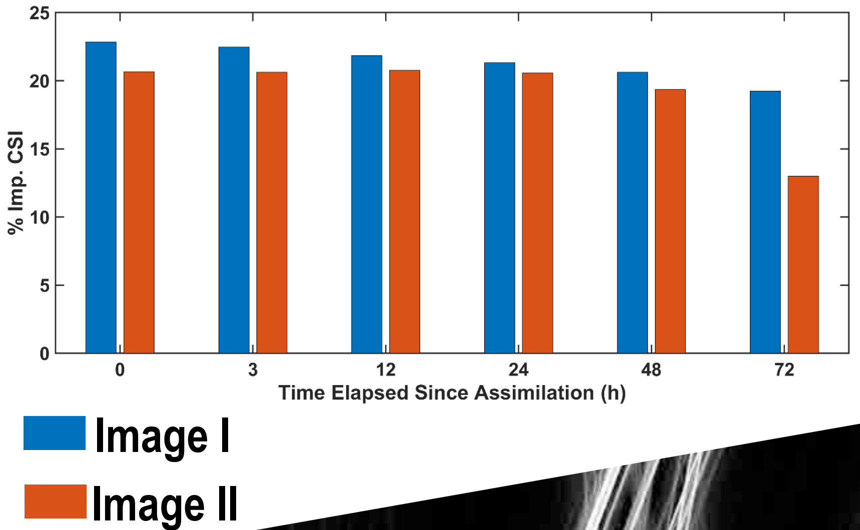
Key Results











$$CSI = \frac{Hits}{Hits + Misses + False\ Alarms}$$

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Finding the Best Flood Observations to Correct Flood Forecasts

Dasgupta, A., Hostache, R., Ramsankaran, R., Pauwels, V.R.N., Schumann, G.J.P., Grimaldi, S., and Walker, J.P. On the impacts of observation footprint, timing, and frequency on flood extent assimilation performance. Water Resources Research (Accept after minor revisions).

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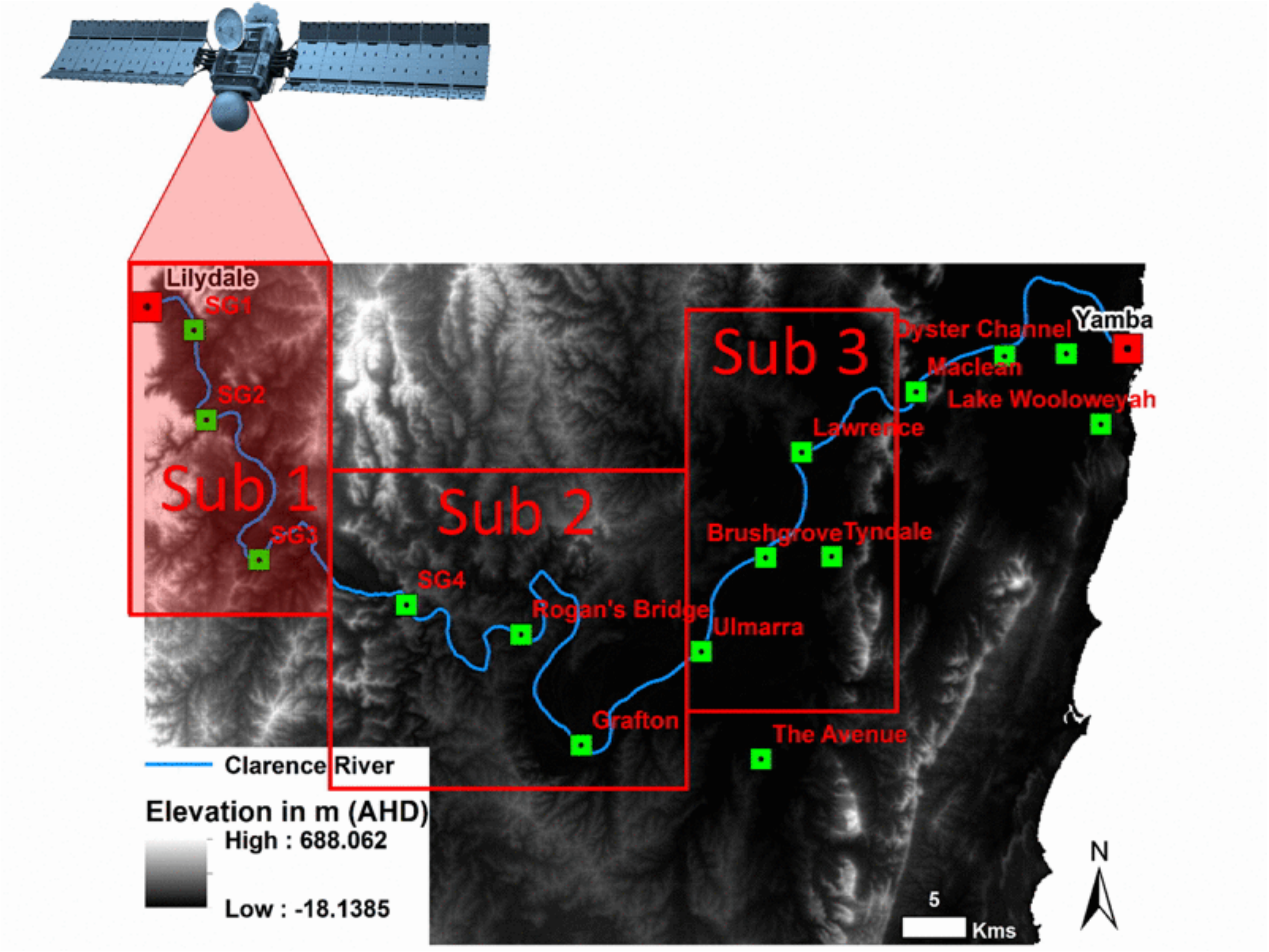
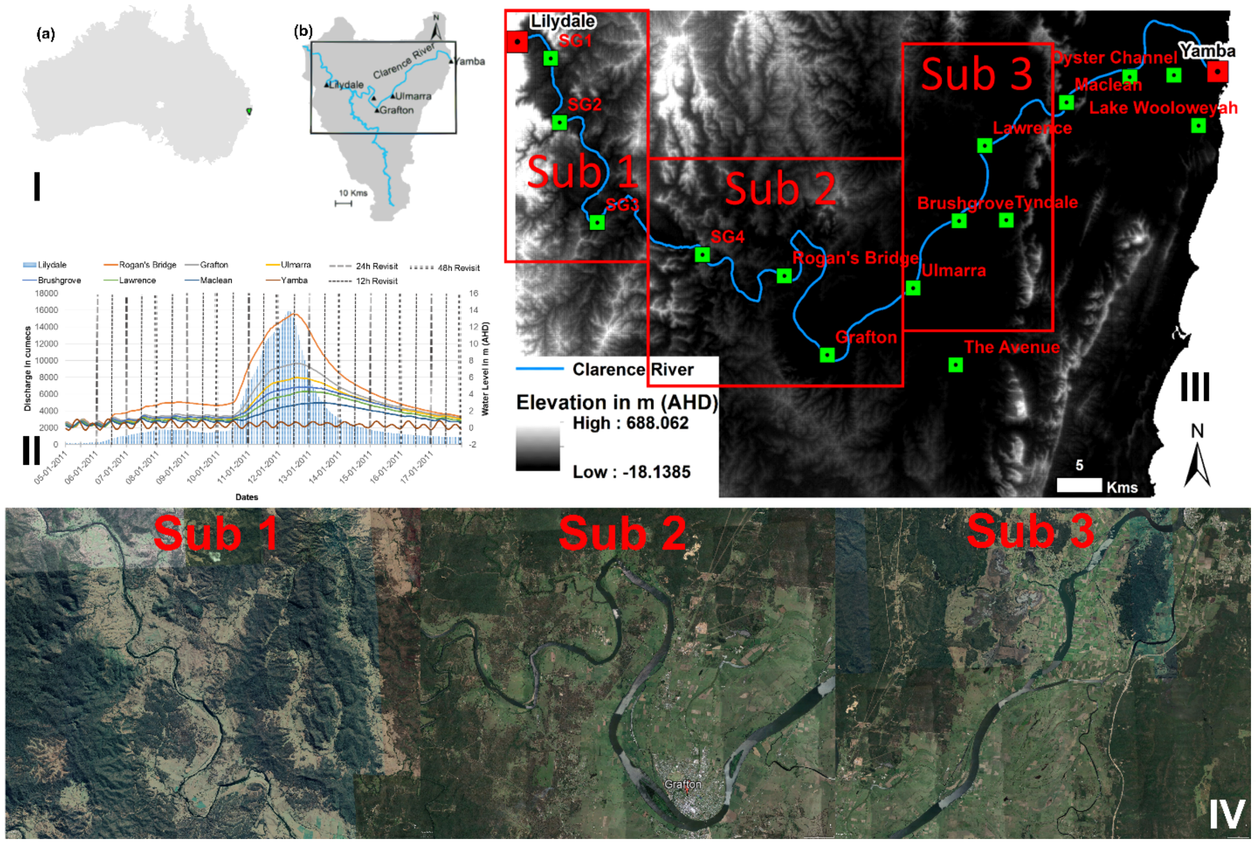
Current Challenges

Only partial coverage for large catchments using high-res satellites



Potential Solution

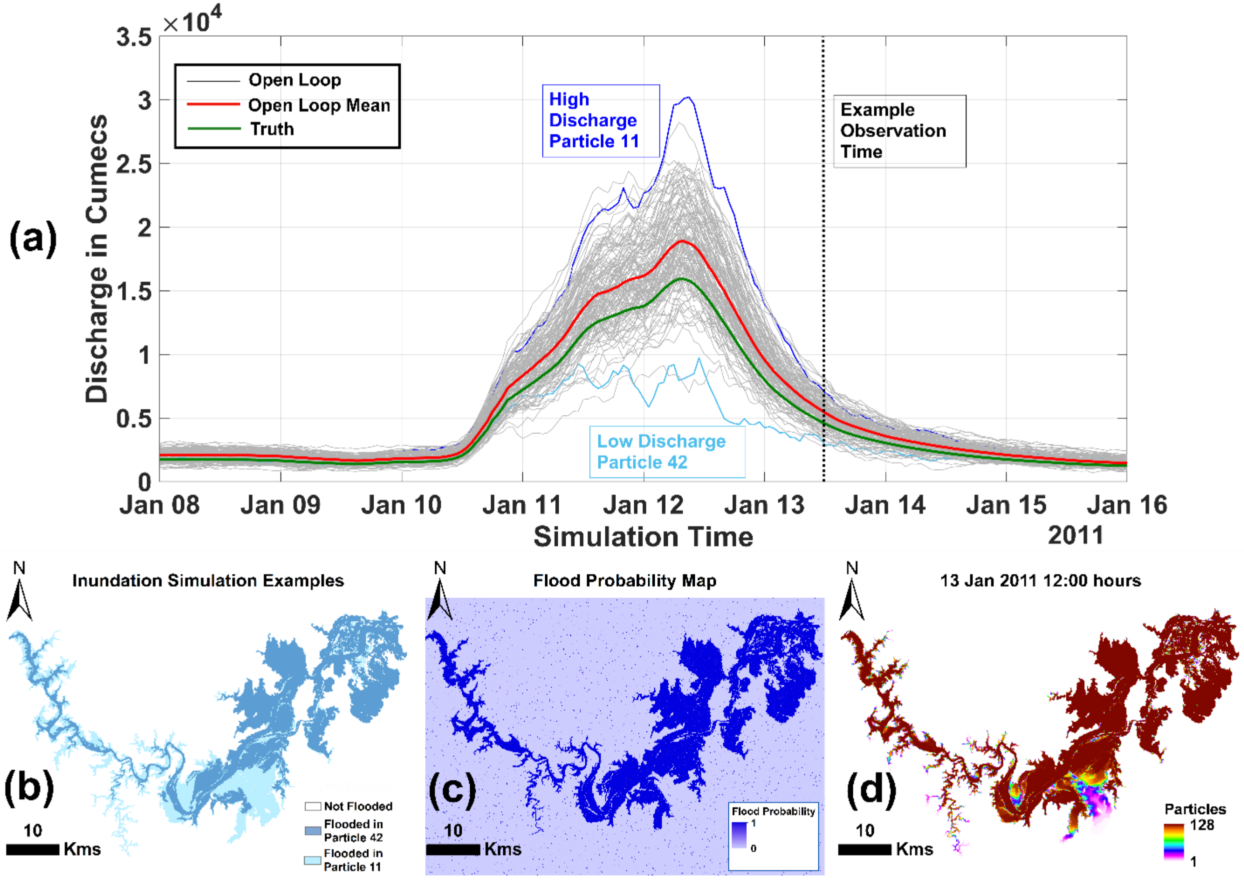
Targeted observations based on river reach characteristics



Narrow steep valley, no backwater

Flat gentle valley, little backwater

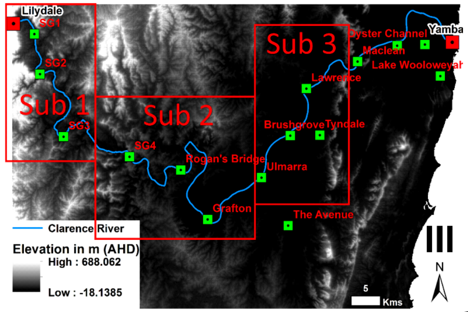
Flat gentle valley, dominant backwater

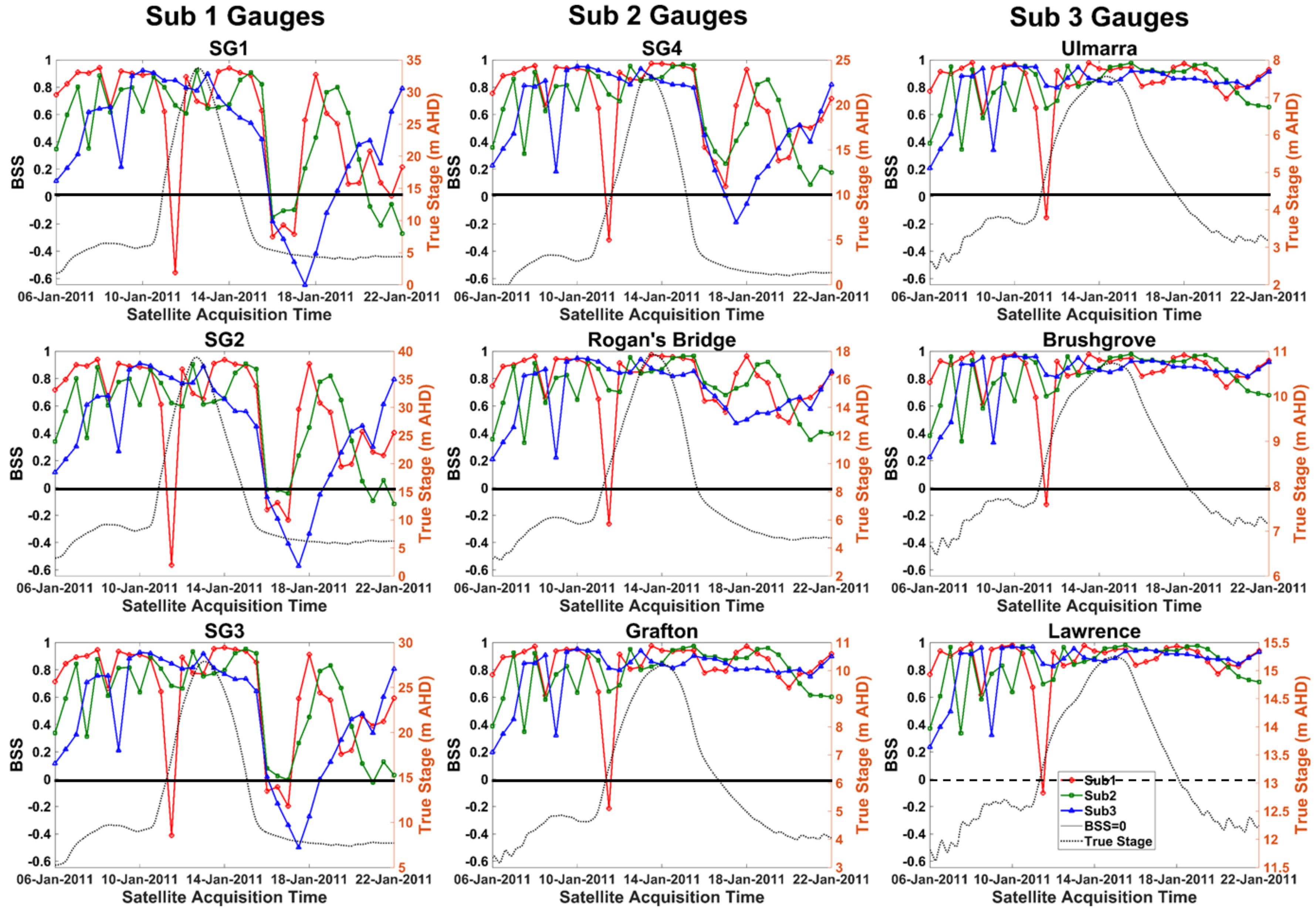


Key Results

Brier Skill Scores showing the improvement in the forecast with the assimilation as compared to the forecast without the assimilation

BSS=1 means 100% improvement!!!





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The Way Forward

Outlook

Develop observation localization strategy in space and time

Test for different catchment characteristics and real cases

Scale for global implementation and integration with GloFAS

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Feedback/Questions:

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