Leveraging Earth Observation and Data Assimilation for Improved Flood Inundation Forecasts

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

BEFORE

AFTER

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

- Hits
- False Alarms

Hits

False Alarms
How will it work?

Make improvements at every step of the process.
Typical Flooded Image Histogram

$GMM(DN) = A_w \exp \left[ -\frac{1}{2} \frac{(DN - \mu_w)^2}{\sigma_w^2} \right]$

Gaussian curve for water pixels

$+ A_{nw} \exp \left[ -\frac{1}{2} \frac{(DN - \mu_{nw})^2}{\sigma_{nw}^2} \right]$

Gaussian curve for non-water pixels
Proposed solutions

Image texture optimization and neuro-fuzzy flood mapping

Texture optimization process

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

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

Errors

\[ \varepsilon_{\text{WRMS}}^{\text{reliability}} (\text{SAR}) = 0.059 \]

\[ \varepsilon_{\text{WRMS}}^{\text{reliability}} (\text{Opt.}) = 0.027 \]
A New Method to Combine Satellite-based Flood Maps with Models

Current Challenges
Likelihood sensitivity towards slightly varying extents
Proposed Solution

Mutual Information (MI)

Model Ensemble pdf

Observation pdf

f_{m0}(\text{marginal})

f_{m0}(\text{joint})

f_{x0}(\text{conditional})

area=1

volume=1

KL Divergence (KLD) between joint and marginal pdf

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

Prior pdf for initial sampling

Unknown non-Gaussian “true” state pdf to be estimated

Updated particle weights after assimilation

Sequential Importance Sampling (SIS)

Expectation

Particle degeneracy

Zoom in using rescaling factor to enhance sensitivity

Particle Filter Algorithm

\[ H(X|Y), I(X;Y), H(Y|X) \]

\[ \text{MI}=\text{KLD} \]
Key Results

\[ CSI = \frac{\text{Hits}}{\text{Hits} + \text{Misses} + \text{False Alarms}} \]

Test event: 2011 Flood Event

Clarence Catchment, NSW
Finding the Best Flood Observations to Correct Flood Forecasts

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!!!
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
Feedback/Questions:
antara.dasgupta1@monash.edu