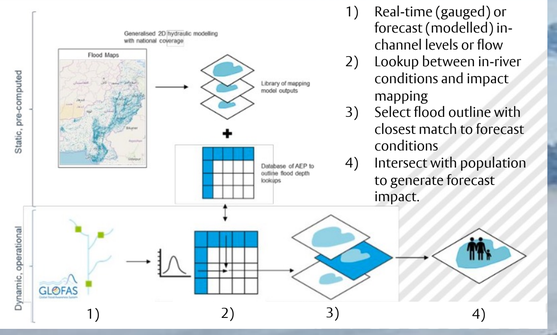
An evaluation of ensemble forecast flood inundation mapping spatial skill

Helen Hooker[1] | Sarah L Dance[1] | David Mason[1] | John Bevington[2] | Kay Shelton[2]
1. University of Reading 2. JBA Consulting

1. Introduction

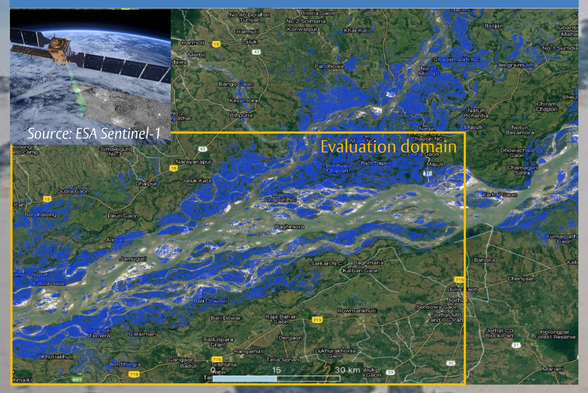
- Ensemble forecast flood maps provide valuable information to forecasters and flood risk managers and have the potential to indicate the uncertainty within a forecast.
- Satellite SAR-derived flood maps provide spatial observations and are used here to assess the ensemble spatial spread-skill.

2. Flood Foresight System ensemble simulation library approach

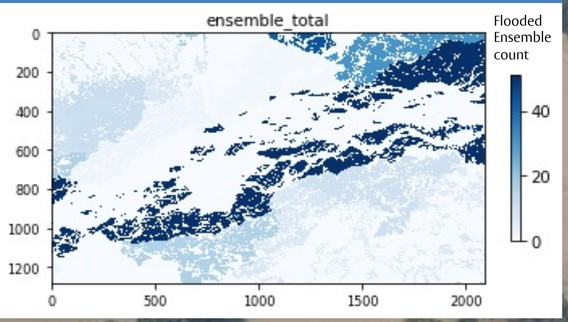


1) Real-time (gauged) or forecast (modelled) in-channel levels or flow
2) Lookup between in-river conditions and impact mapping
3) Select flood outline with closest match to forecast conditions
4) Intersect with population to generate forecast impact.

3. SAR-derived flood map, Assam region Brahmaputra, 12 August 2017



4. Total flooded cells, 51 ensemble forecast, 1-day lead time



5. Spatial Spread-Skill Summary (SSS) map derivation

- Based on methods from Dey et al., 2016. Ensemble and observed flood fields are binarized into 1 (flooded) and 0 (not flooded) to create two fields d^S_{1ij} and d^S_{2ij} . Note that these could also be flood depth maps.
- D^S_{ij} is first calculated at grid level (n = 1, S = 0)

$$D^S_{ij} = \frac{\left(d^S_{1ij} - d^S_{2ij}\right)^2}{\left(d^S_{1ij}\right)^2 + \left(d^S_{2ij}\right)^2}$$

$D^S_{ij} = -1$ if $d^S_{1ij} = 0$ and $d^S_{2ij} = 0$ (both dry)
Otherwise D^S_{ij} varies between 0 (fields match) and 1

n = 3, S = 1

1	1	1
0	0	0
1	1	1

- The fields are considered to be in agreement at scale S if

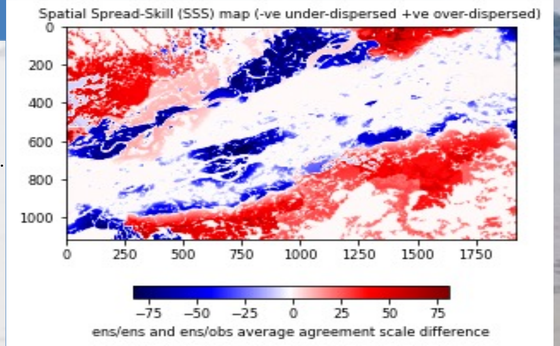
$$D^S_{ij} \le D^S_{crit,ij} \qquad D^S_{crit,ij} = \alpha + (1-\alpha)\frac{S}{S_{lim}}$$

$0 < \alpha \le 1, \alpha = 0$ means there is no bias at grid level.
S_{lim} is a predetermined, fixed maximum scale

- Where the criteria are not met, an increasingly larger neighbourhood size is compared until S is determined for each grid cell.
- Each unique pair of ensemble flood map agreement scales are averaged to produce an ensemble/ensemble agreement scale map.
- A second average agreement scale map is calculated for the ensemble/observation comparison.
- The Spatial Spread-Skill (SSS) map is the difference between these two agreement scale maps and tells us at specific locations whether the ensemble is over or under-dispersed.

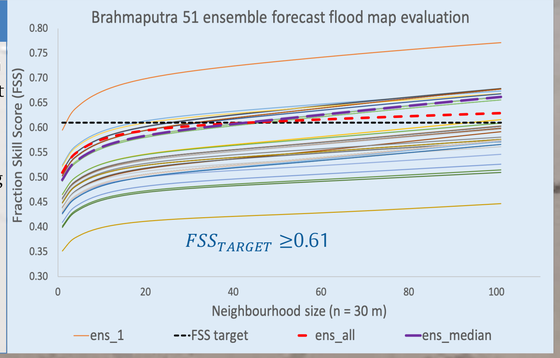
6. SSS Results

- The forecast performance is summarised here in terms of the spatial spread-skill of the full ensemble.
- White areas indicate regions that are well-spread, red implies over-dispersion and blues indicate under-dispersion.
- A dark blue region just to the north of the Brahmaputra indicates a 'miss' region, most likely associated with a tributary running from the north.
- The SSS map provides a useful tool for model evaluation under different scenarios and forecast lead times.



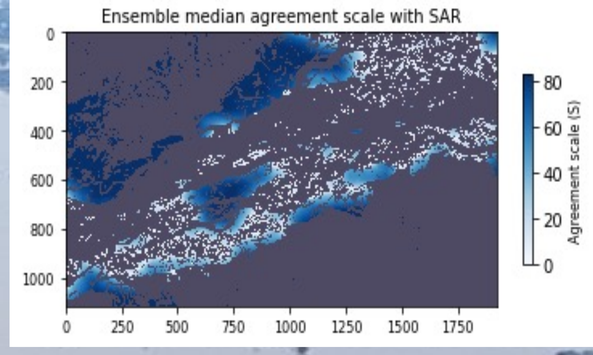
7. Skillful scale evaluation

- The Fraction Skill Score (FSS, Roberts and Lean, 2008) is a domain averaged score that can determine the scale at which the forecast is becomes useful/skillful.
- The FSS is calculated for every ensemble member, the ensemble median and the total combined ensemble (ens_all) for increasing neighbourhood sizes.
- ens_all is more skillful than ens_median up to FSS_{TARGET} (n = 41, S = 20, 600 m), where the reverse becomes true.
- One ensemble member (ens_1, orange) outperforms the others showing excellent skill at n = 3, S = 1 (30 m).



8. Ensemble median agreement scale map

- The ensemble median (spatial) agreement scale map adds location specific detail indicating correctly predicted dry or wet areas (grey/brown).
- Areas that are 'close' in white and lighter blue indicate regions that are skillful at a scale larger than grid level.



9. Conclusions and future work

- The SSS map provides a useful tool for investigating how the full ensemble spatial spread-skill varies with location.
- The FSS indicates a useful scale for flood map presentation to end users and for comparison with observations for model development and data assimilation.
- Considering only the ensemble median may neglect important spatial information held within the individual members.
- Further work will apply these methods to ensemble forecasts at various lead times for monsoonal flooding in the Indus basin, summer 2020.

10. References

- Dey, S. R. A., Plant, R. S., Roberts, N. M., & Migliorini, S. (2016). Assessing spatial precipitation uncertainties in a convective-scale ensemble. *Quarterly Journal of the Royal Meteorological Society*. https://doi.org/10.1002/qj.2893
- FloodList 2017. http://floodlist.com/asia/india-assam-floods-august-2017
- Hooker et al. Spatial scale evaluation of forecast flood inundation maps. In preparation.
- Roberts, N. M., & Lean, H. W. (2008). Scale-selective verification of rainfall accumulations from high-resolution forecasts of convective events. *Monthly Weather Review*. https://doi.org/10.1175/2007MWR2123.

Floodlist, 2017

h.hooker@pgr.reading.ac.uk