Global Flash Flood Forecasting from the ECMWF Ensemble

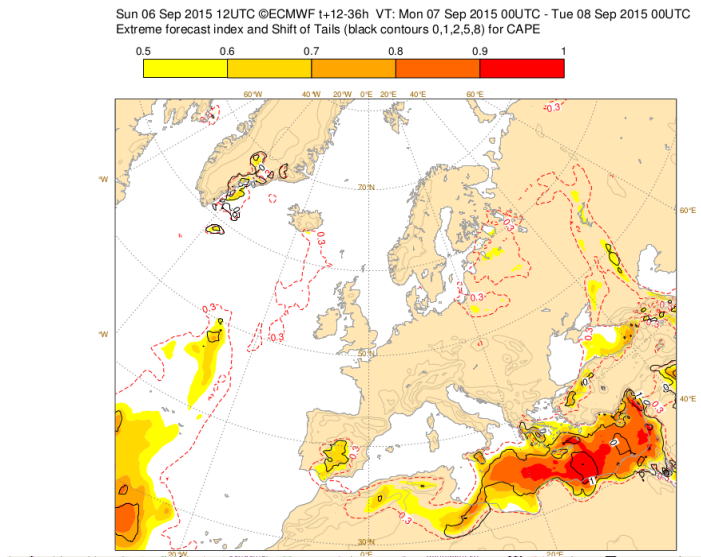
Calum Baugh

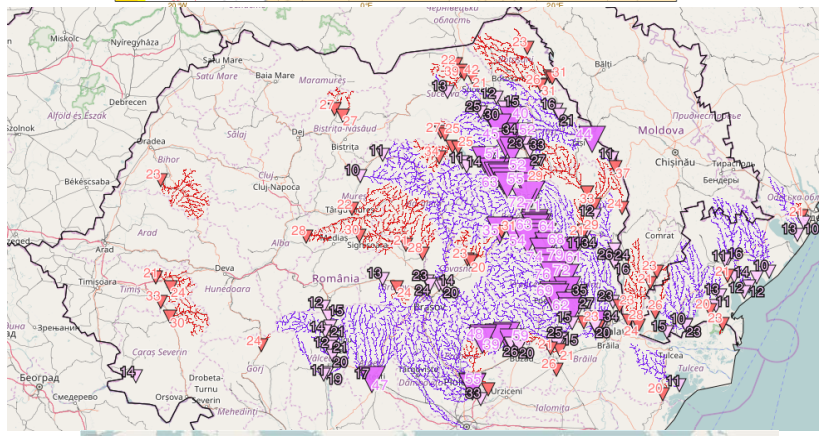
calum.baugh@ecmwf.int

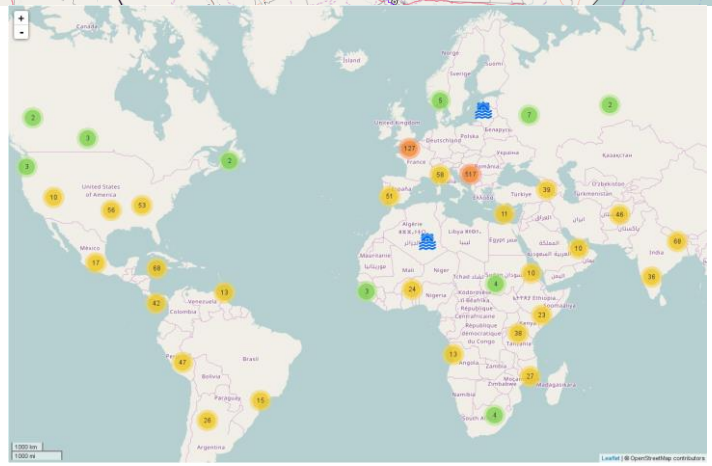
ECMWF

Building a Global FF System

1. **Current flash flood forecasting globally**
2. **Flash flood definitions**
3. **Flash flood forecasting from ECMWF ENS**
4. **Enhancing forecasts with exposure information**

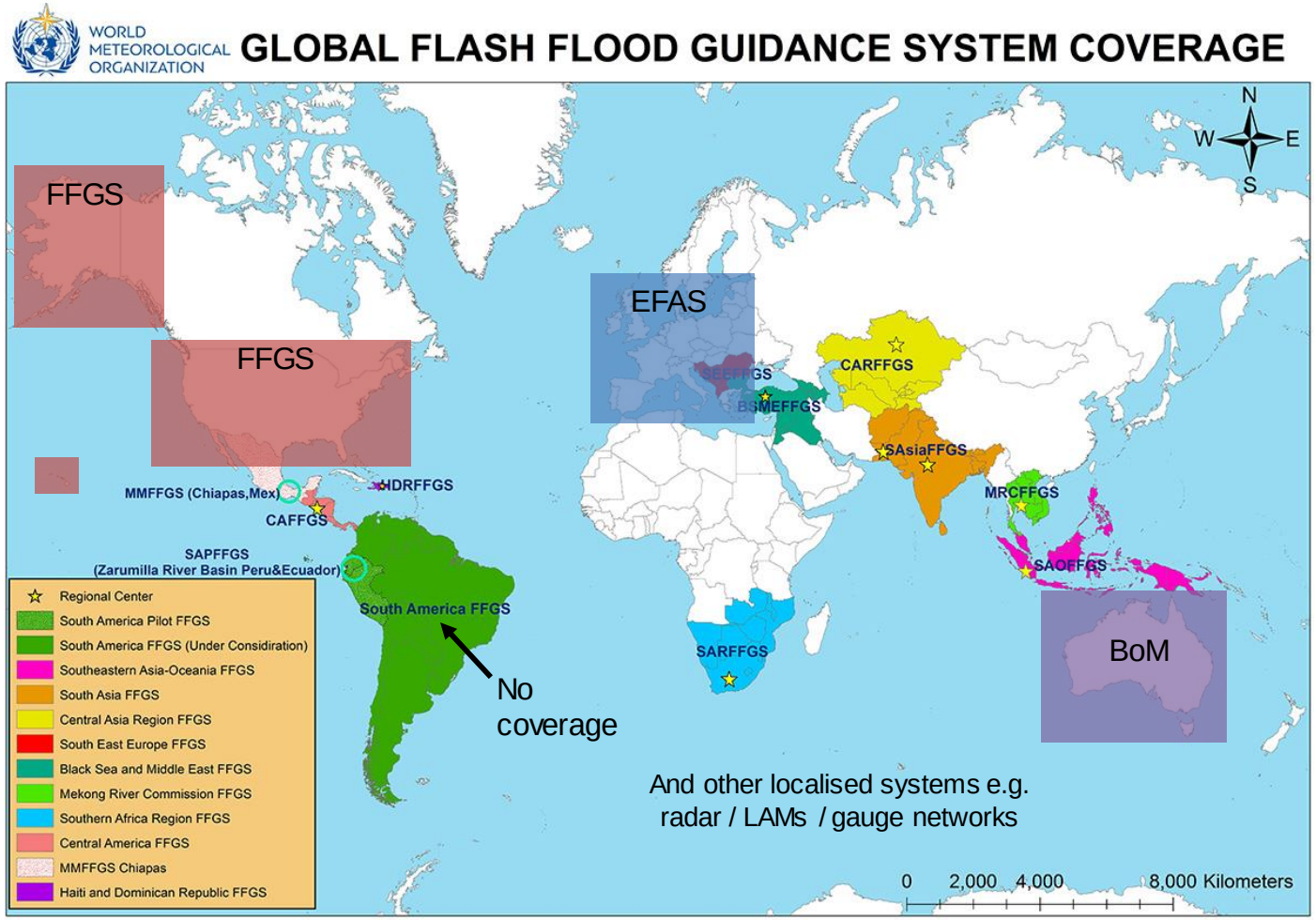






Current Flash Flood Systems Globally

- Single global system not present
- Instead a piecemeal approach regionally / locally – important?
  - Opportunity for users to tailor their own systems
  - Or contributes to high risk associated with flash floods?



Adapted from: http://www.wmo.int/pages/prog/hwrp/flood/ffgs/images/FFGS-global-coverage14_12_2016-full.jpg

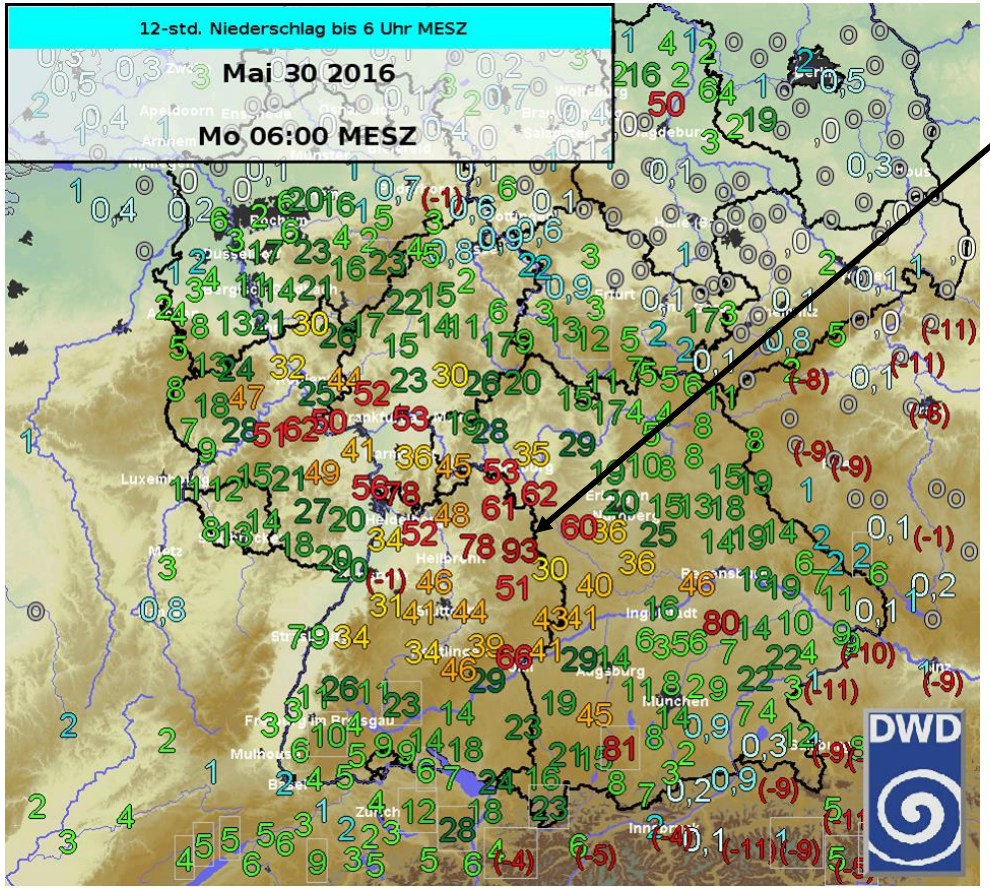
Flash Flood Definitions

- What type of flash flood?

Flash Flood Type 1

‘Riverine’

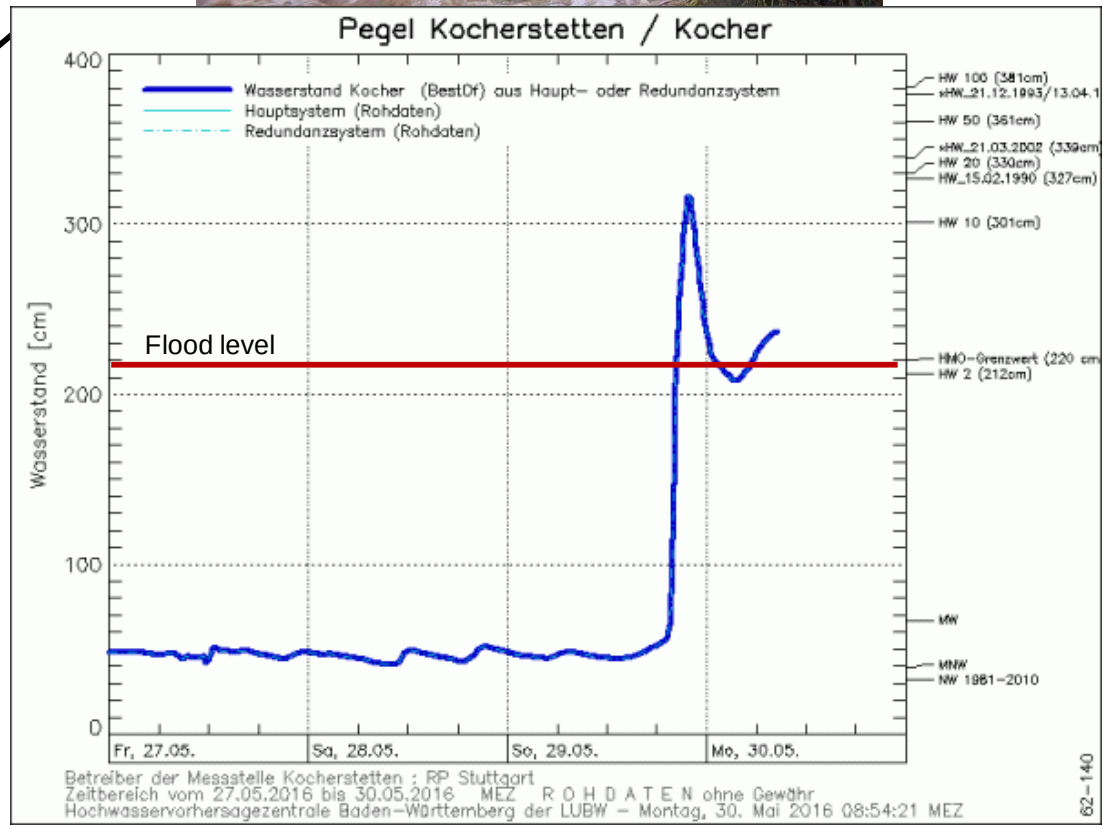
- Heavy rain, confined valleys, rapid river rise
- Germany, June 2016



https://pbs.twimg.com/media/CjpfaxiWsAEcNgK.jpg

FloodList

http://floodlist.com/europe/germany-floods-baden-wurttemberg-may-2016



Flash Flood Type 2

Urban / Surface Water

- Heavy rain (thunderstorms), impervious surfaces, poor drainage
- Luanda, Angola March 2017
- 11 deaths, 13 house collapses, falling power cables
- 80 mm of rain in 24 hours

http://www.portaldeangola.com/2017/03/sobe-para-11-numero-de-vitimas-mortais-causadas-pela-chuva-em-luanda/

Flood summary

Last updated: March 24, 2017

Event	Luanda Province, Angola, March 2017
Date	March 21, 2017
Type	Urban flood, River flood
Cause	Extreme rainfall

Locations

A - Sambizanga
B - Cacuaco
C - Cazenga
D - Belas
E - Kilamba-Kiaxi

http://floodlist.com/africa/angola-floods-luanda-province-march-2017

FloodList

Magnitude

Rainfall level	79.3 mm in 24 hours Luanda - March 21 to March 22, 2017

Damages

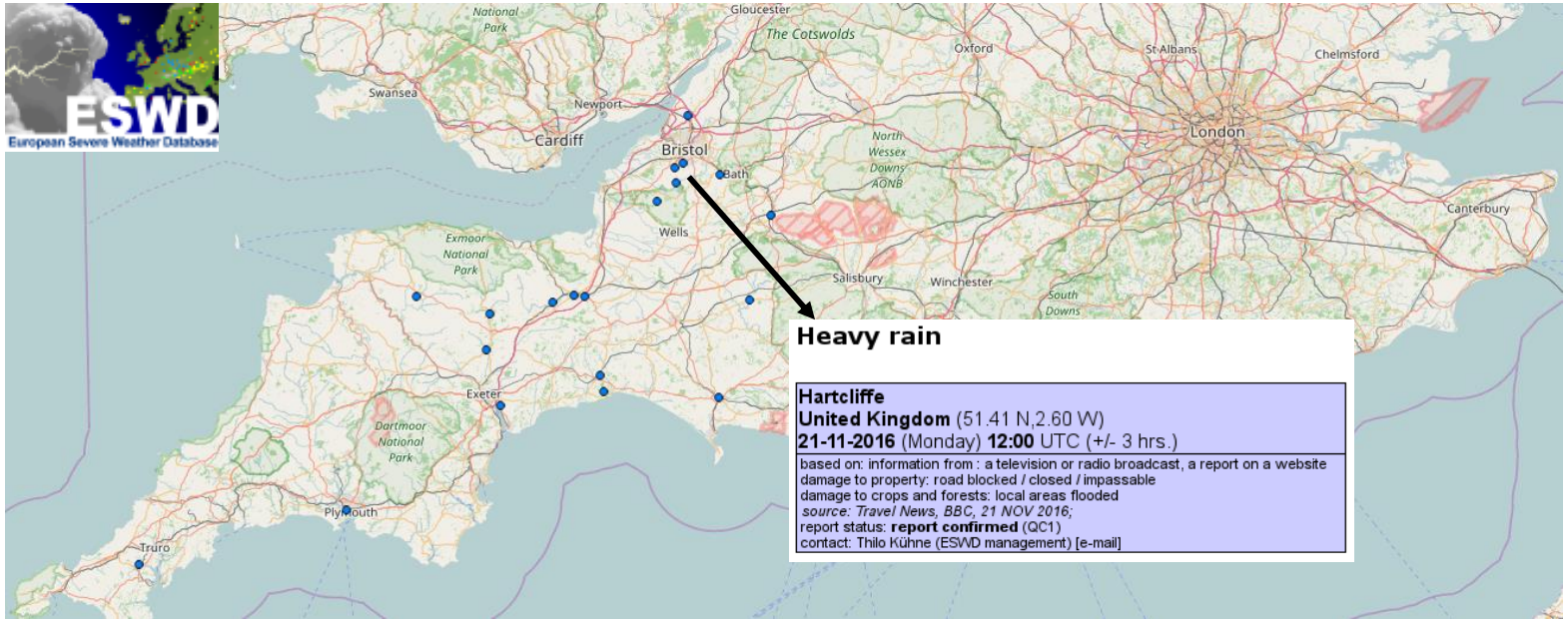
Fatalities	11 people Luanda Province - March 21 to March 23, 2017

Flash Flood Type 3

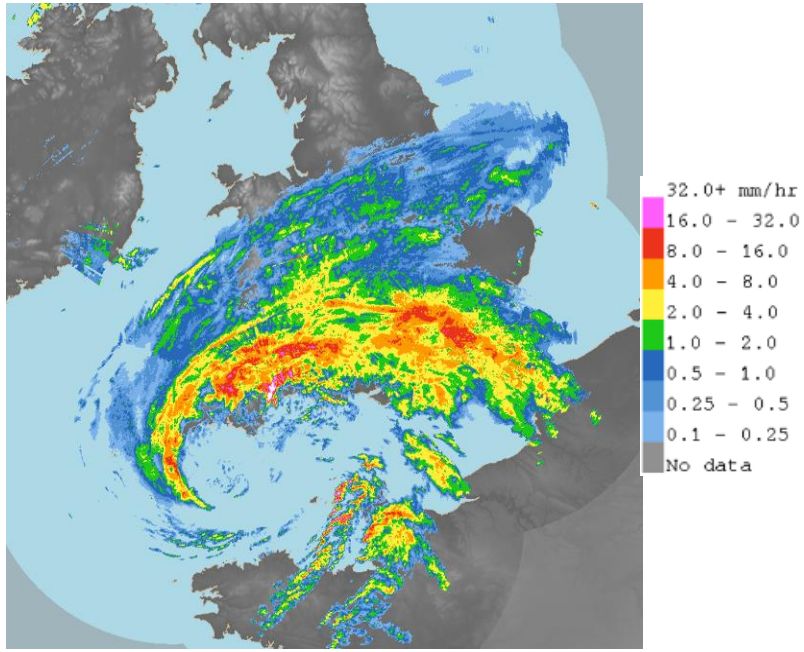
‘Nuisance’ floods

- Very localised pondings after moderately heavy rain
- Storm Angus, UK November 2016
- 40-50 mm of rain in 24 hours (and again 36 hours later)

https://www.theguardian.com/uk-news/2016/nov/21/storm-angus-prompts-200-flood-alerts-across-england-and-wales



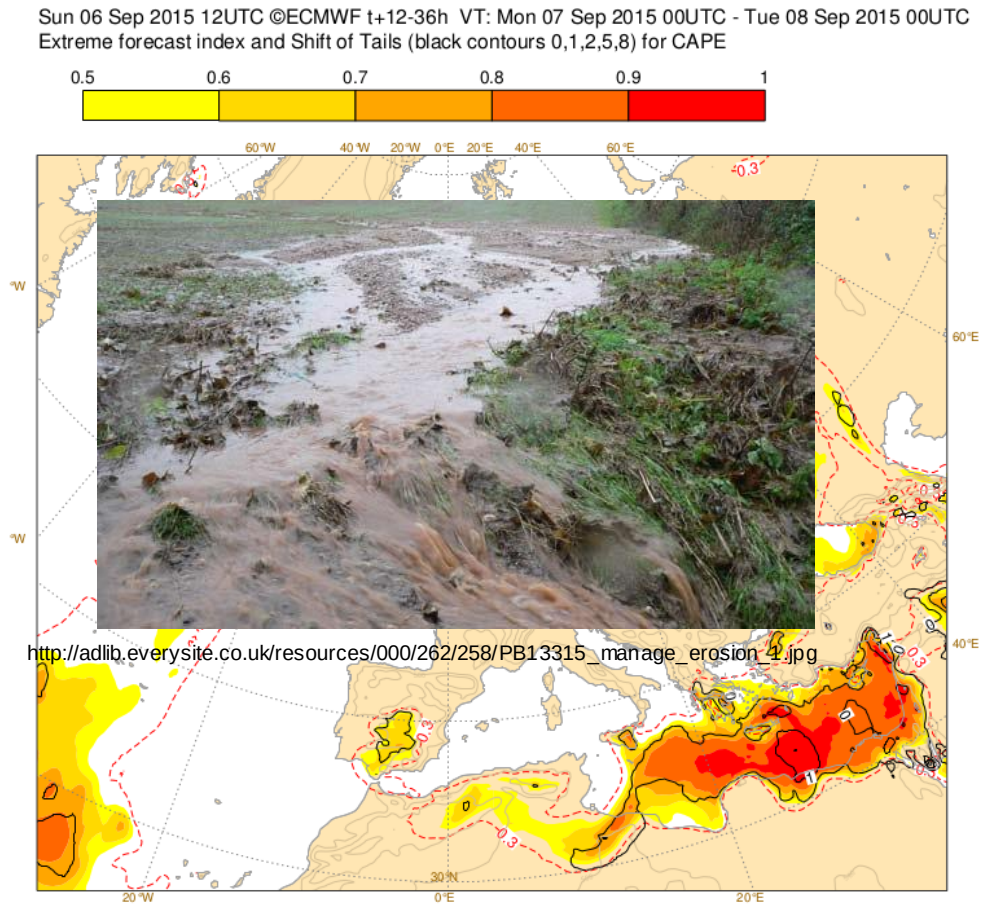
https://www.eswd.eu/



Radar rain rate at 0030 GMT 20th November 2016
http://www.metoffice.gov.uk/climate/uk/interesting/november2016_rain

Forecasting Flash Floods

- What type of flash flood?
  - Want to represent as many as possible
- What variable should we forecast?
  - River discharge
    - High computational demand
    - Excludes non-riverine flash floods
  - Atmospheric – Precipitation/CAPE
    - Excludes influence of land surface
  - Surface runoff
    - Catches main driver of flash floods

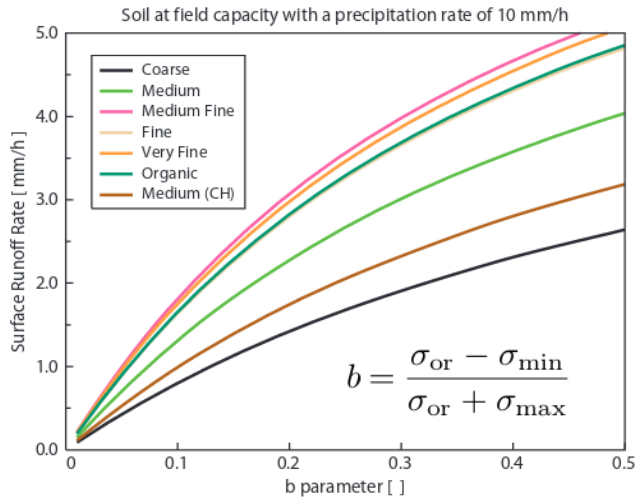


Global Forecasts of Surface Runoff

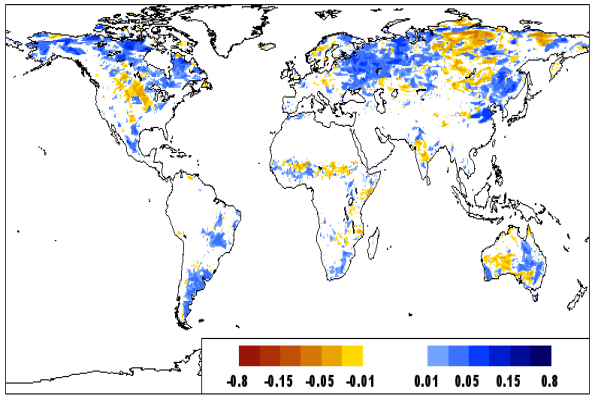
- ECMWF land surface scheme – HTESSEL
  - 18 km resolution
  - Twice daily, hourly (first 90 hours), 3 hourly thereafter
- Variable infiltration Arno scheme
  - Parameterises effect of subgrid orography on runoff rate
- Hortonian runoff formulation (over top 50 cm)
  - Runoff = (Snowmelt+Throughfall) – Max Infiltration

Limitations:

- LSM designed for EVT budget – subsurface hydrology has limited representation
  - Significant for instantaneous surface runoff generation?
- Assimilation of ASCAT soil moisture to top 7cm soil layer
  - Over corrects for limited sub-surface representation?



$$I_{max} = (W_{sat} - W) + \max\left[0, W_{sat}\left[\left(1 - \frac{W}{W_{sat}}\right)^{\frac{1}{b+1}} - \left(\frac{T+M}{(b+1)W_{sat}}\right)\right]^{b+1}\right]$$

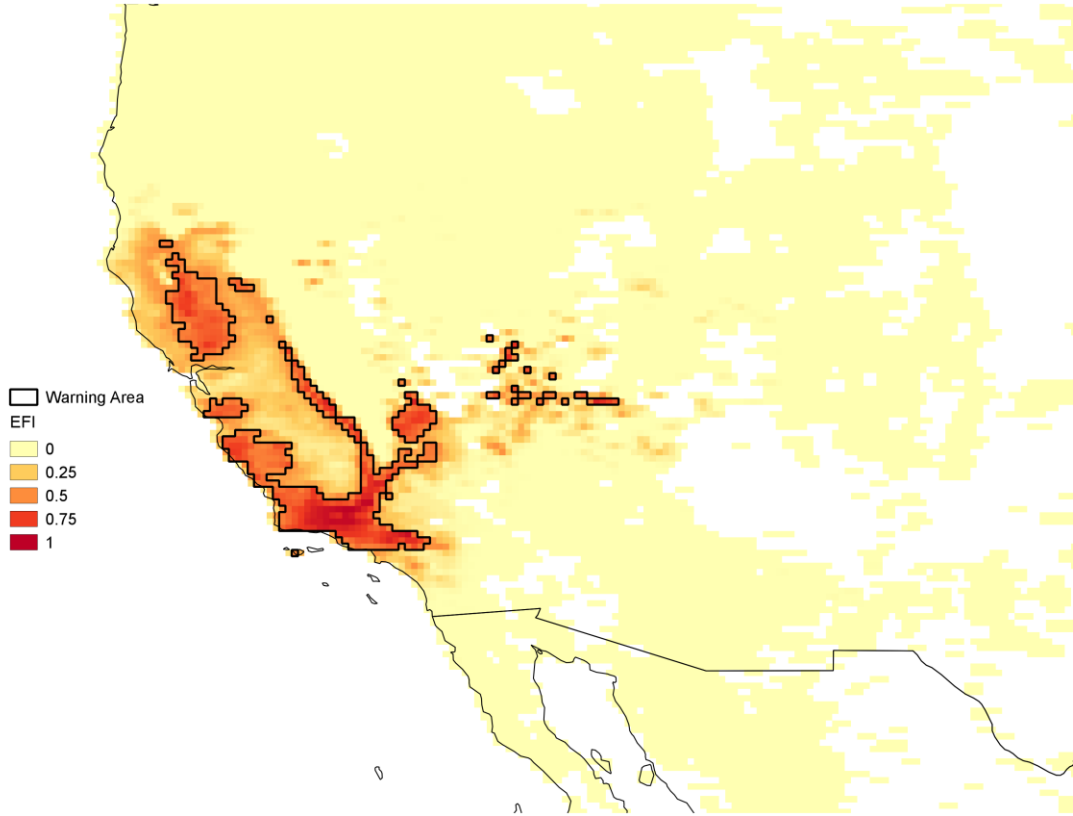


Soil water removed/added by ASCAT assimilation

Converting Forecasts to Warnings

Extreme Forecast Index (EFI):

- Integration of difference between model forecast and model climatology (20 years reforecasts)
  - EFI>~0.5 = severe event
- Convert to warning areas based on:
  - Minimum EFI threshold
  - Minimum size of warning area
  - Filtering EFI grid

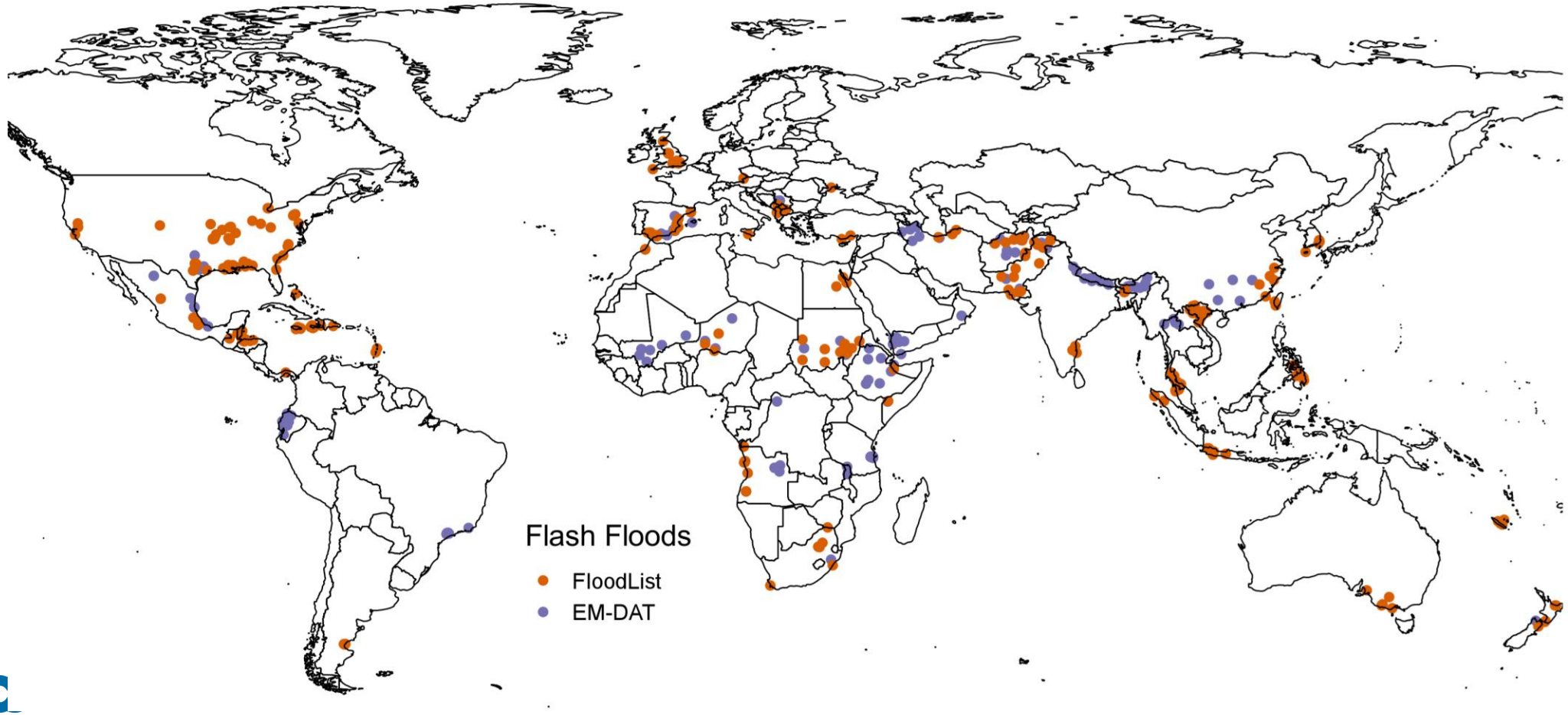


$$\pi J_0 \sqrt{p(1-p)}$$

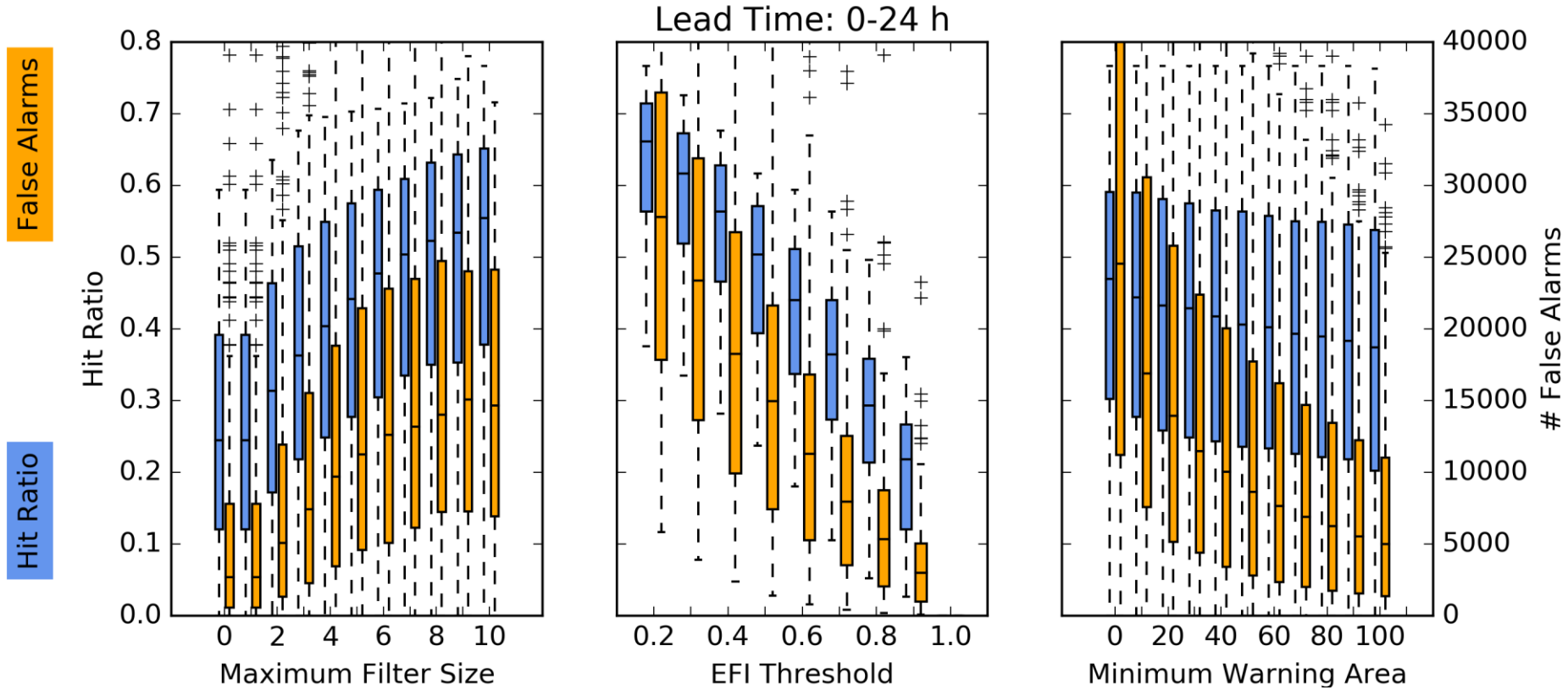
-1 ≤ EFI ≤ 1

Verification Experiment: March 2016 – March 2017

- Calculate surface runoff EFI daily at 00 UTC, 6 hourly out to 120 h lead time
- Create warning areas using 1089 parameter combinations
- Compare against ‘flash flood’ observations from EM-DAT (161) & FloodList.com (238)

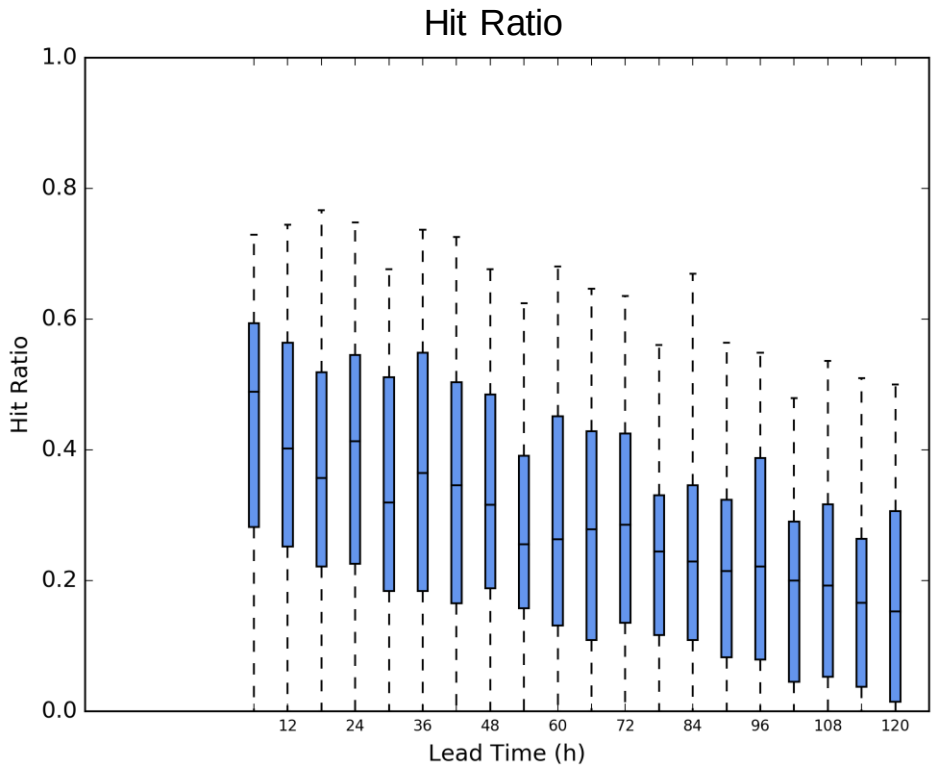


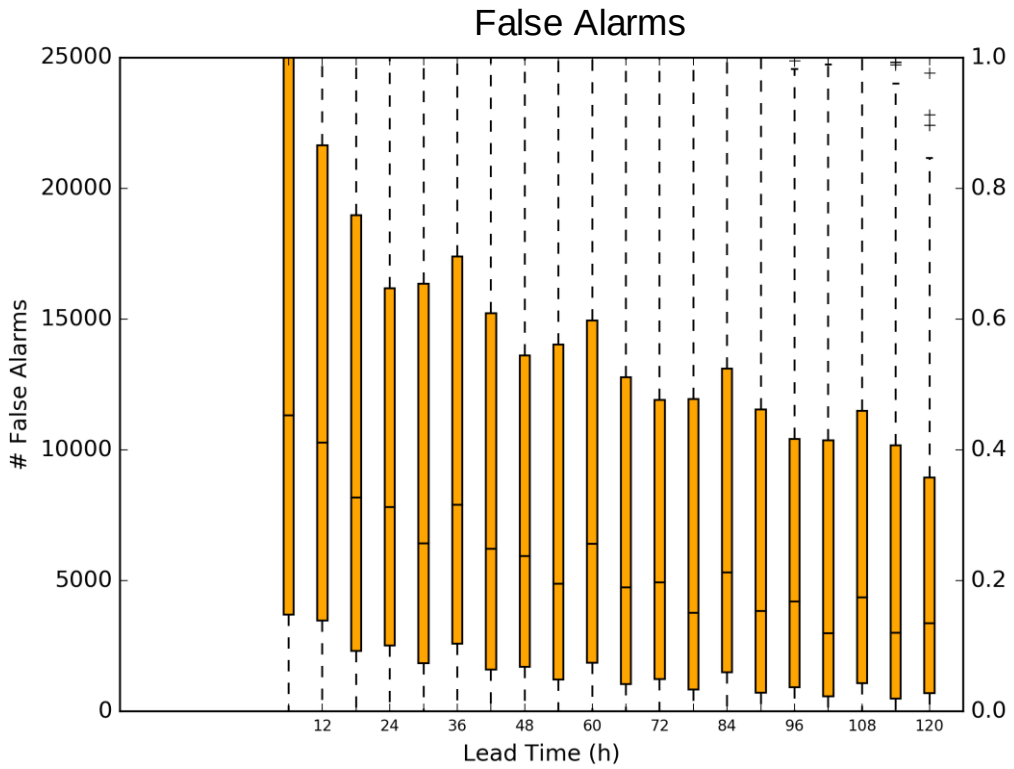
Verification Results: Parameter Sensitivity



- EFI threshold most sensitive parameter
- Minimum warning area good at reducing false alarms
- Large number of false alarms
  - Could be omissions in observations

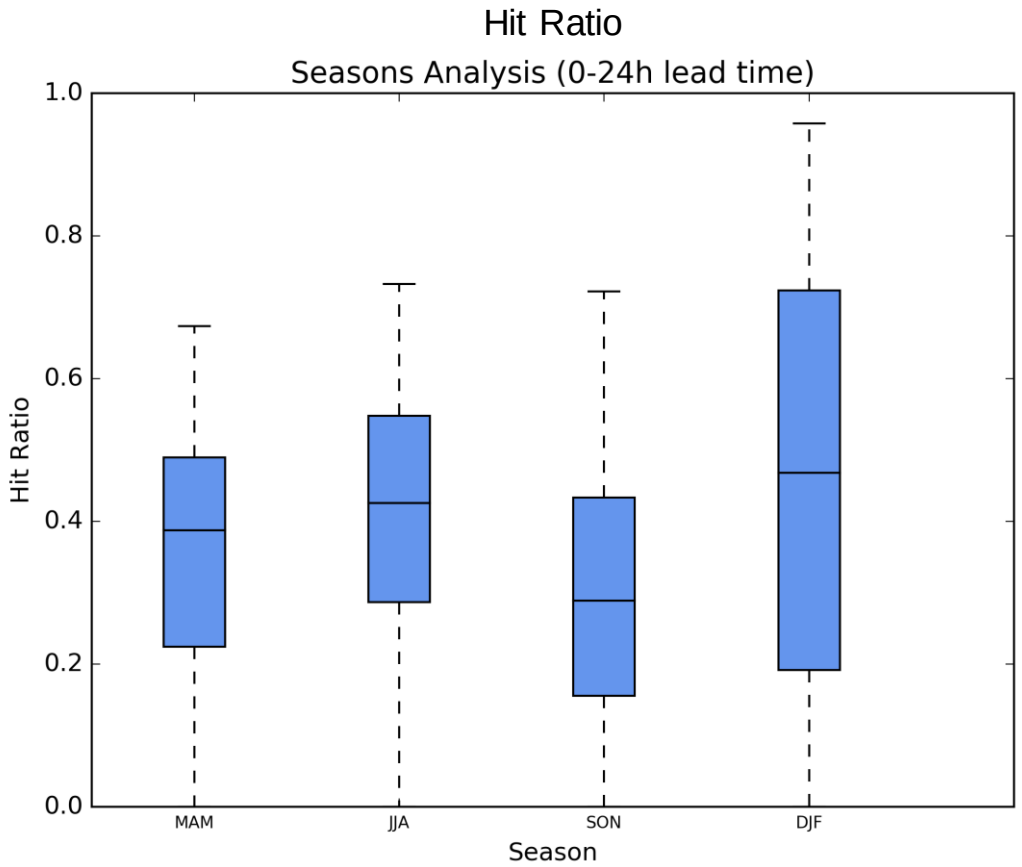
Verification Results: by Lead Time

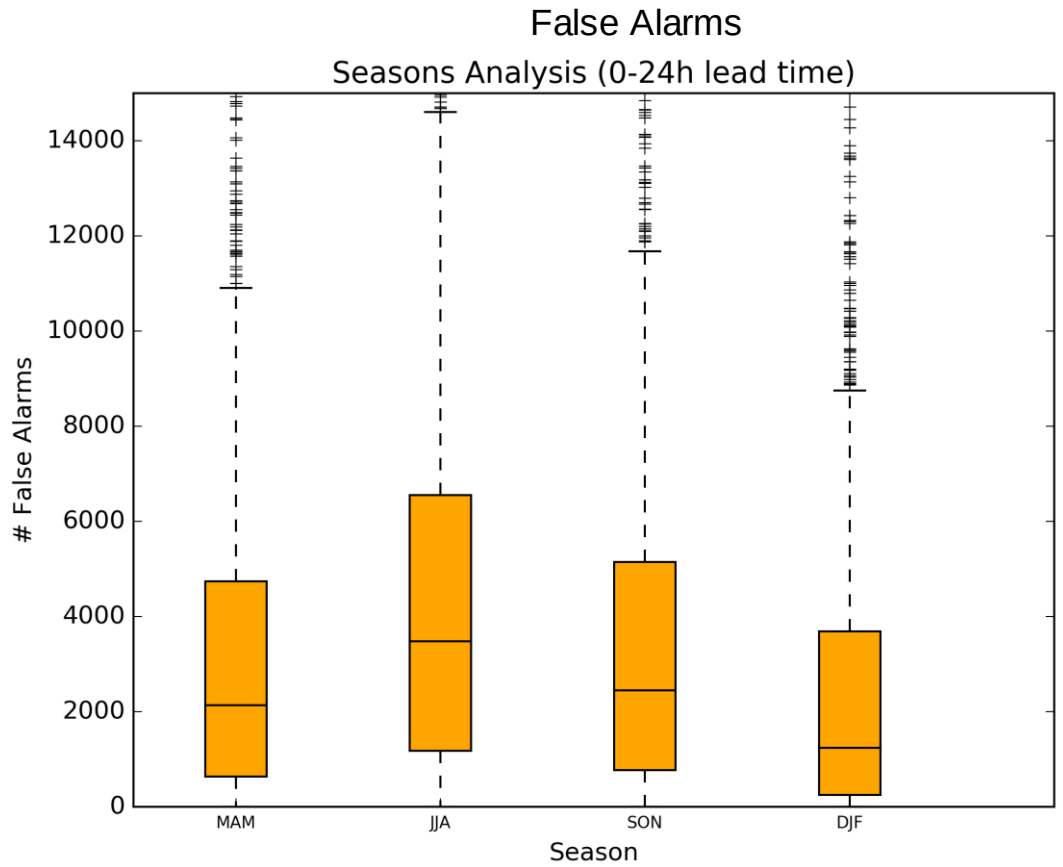




- Less activity with increasing lead time
  - Increased ENS spread at longer lead times – less certainty
  - Impact of soil moisture assimilation?
    - Water inserted at start but then removed by EVT over forecast run
  - Differences in initial conditions between forecast and reforecast

Verification Results: by Season

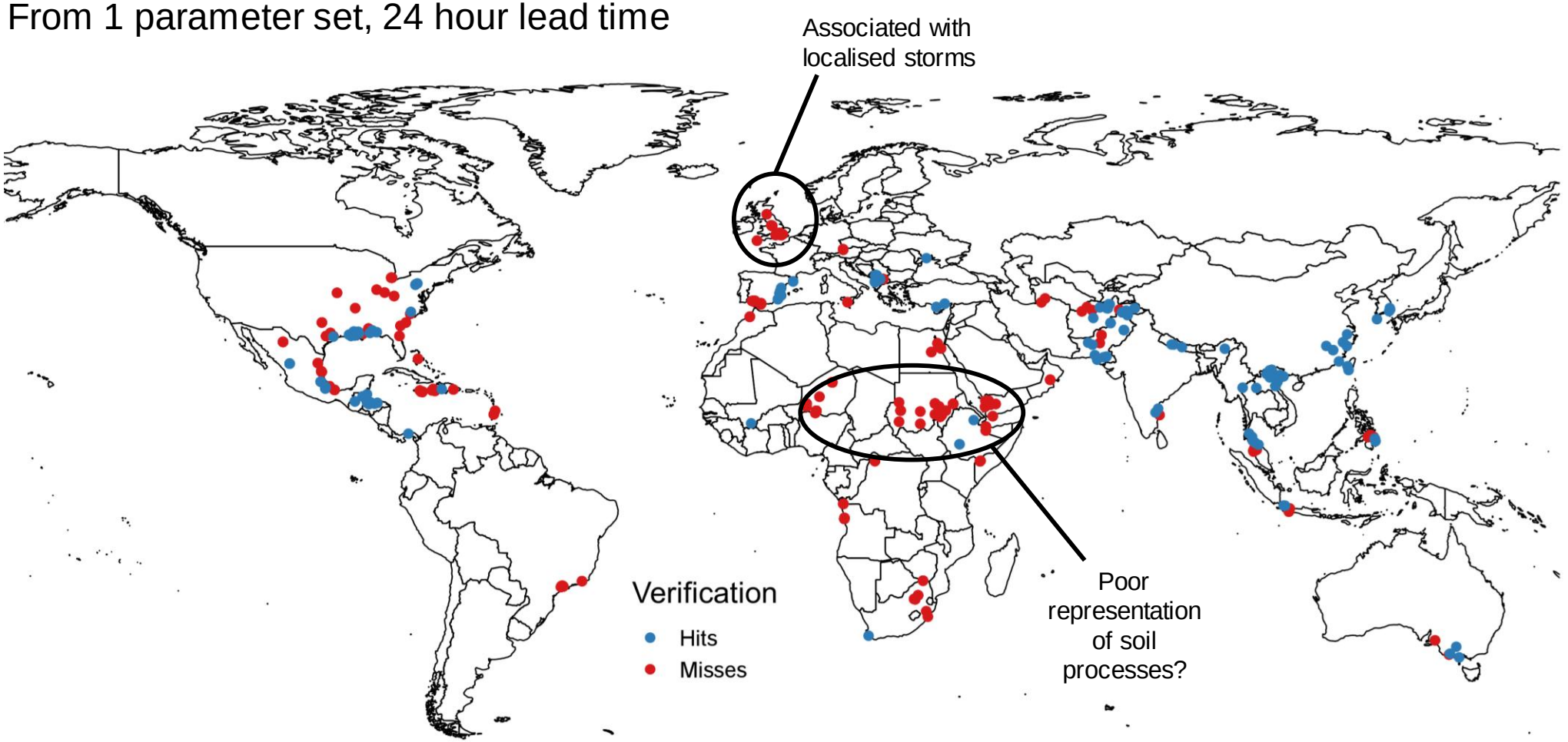




- Lowest hit ratio in Autumn, winter has ~stronger results
  - Associated with weather patterns? Large scale systems in winter with more predictability?
- Most false alerts in summer, same trend with #hits

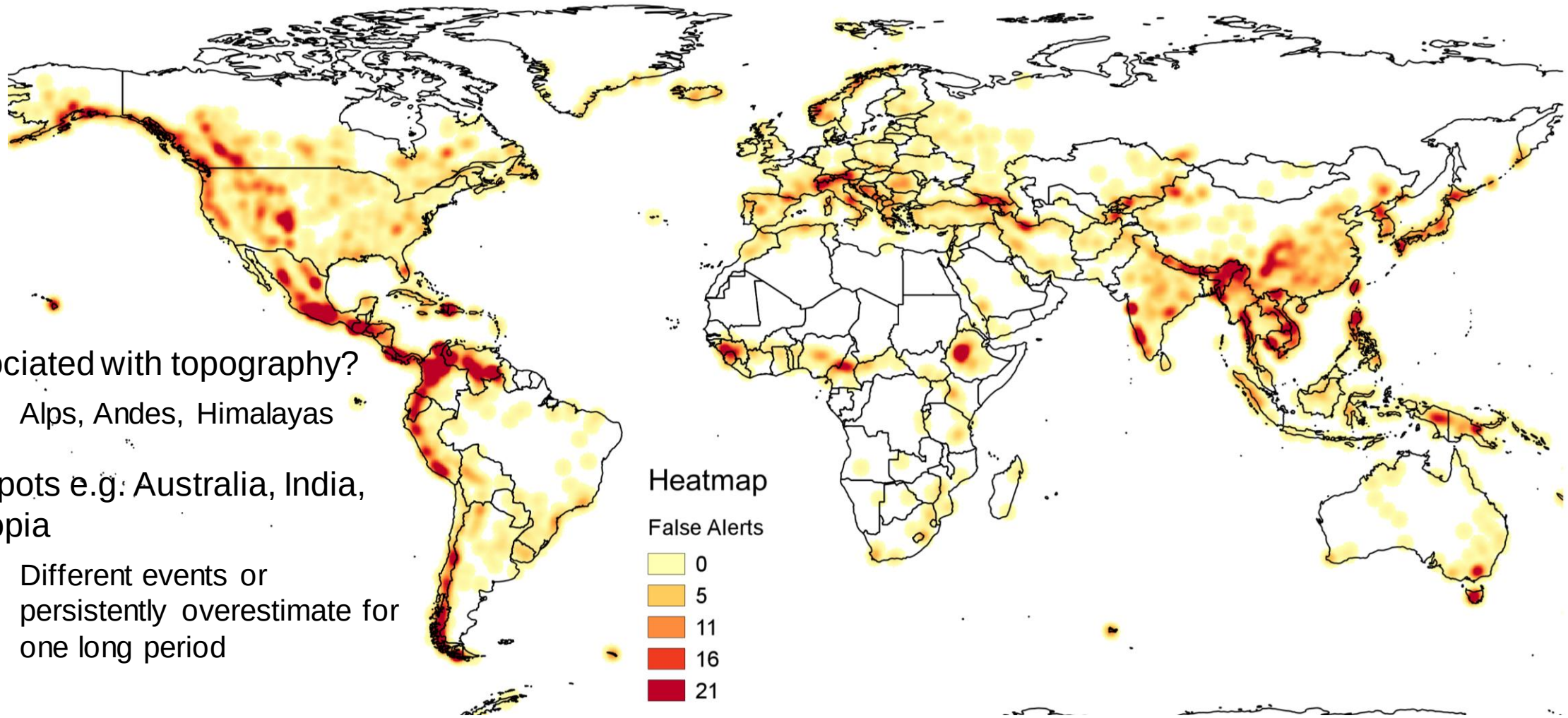
Verification Results: Hits and Misses

- From 1 parameter set, 24 hour lead time



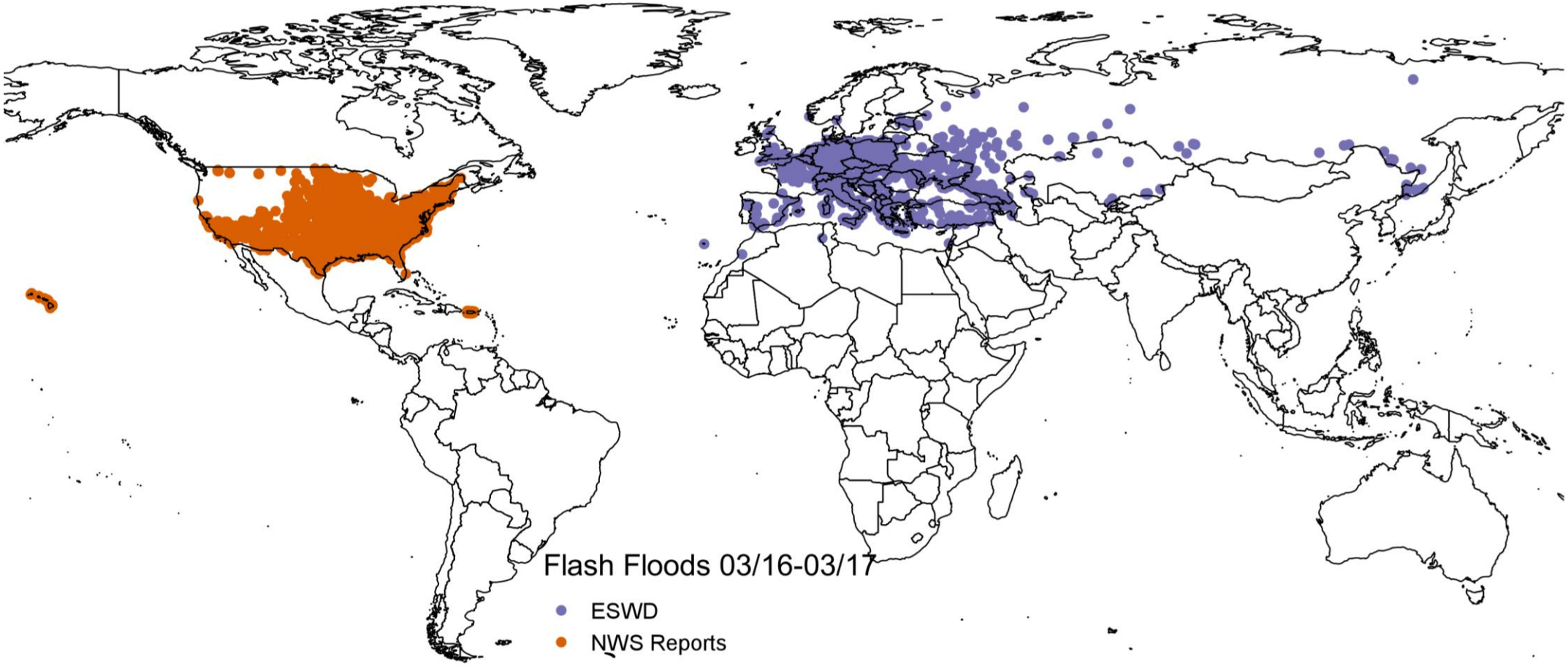
Verification Results: False Alerts Heatmap

- Associated with topography?
  - Alps, Andes, Himalayas
- Hotspots e.g. Australia, India, Ethiopia
  - Different events or persistently overestimate for one long period



Verification Results: Missed Observations?

Could explain some false alerts, need more detailed observations globally

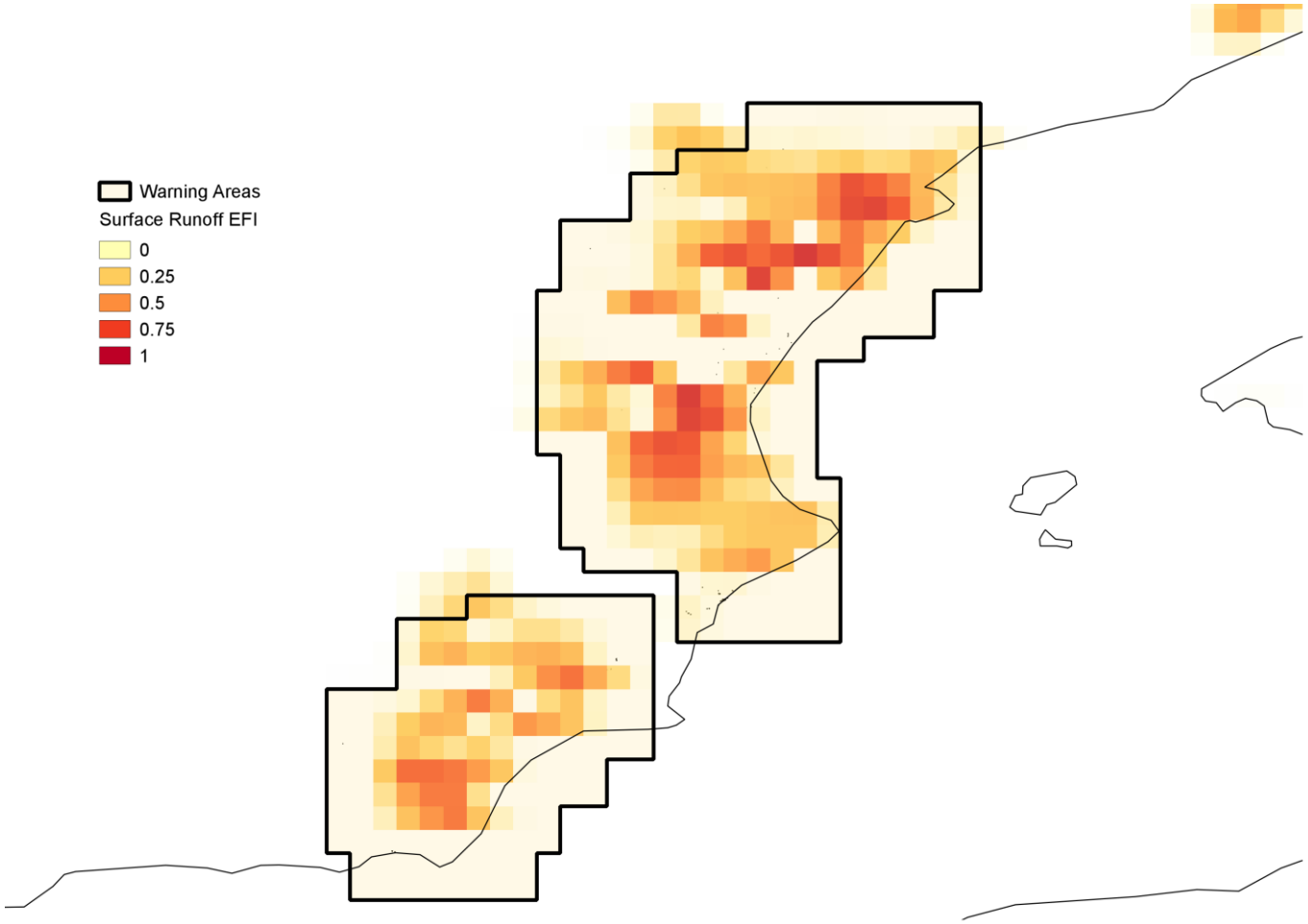


Conclusions: Flash Flood Forecasting from ECMWF ENS

- HTESSEL surface runoff EFI can predict flash floods globally but…
  - Limited hit ratio ~0.5
  - Large number of false alerts
  - Lead time restricted to ~1-2 days
- Issues may stem from:
  - Representation of soil processes – false alerts in mountainous areas, misses in sub-Saharan Africa
  - Assimilation of soil moisture and initialisation differences between forecasts and re-forecasts
    - May be simpler to focus on atmospheric variables
  - Scale of processes – too localised for coarse global NWP
- Future work:
  - Re-run analysis with atmospheric variables – Precipitation
  - Investigate if hits, misses, false alerts relate to scale of associated weather pattern
  - Combine warnings with exposure/vulnerability data …

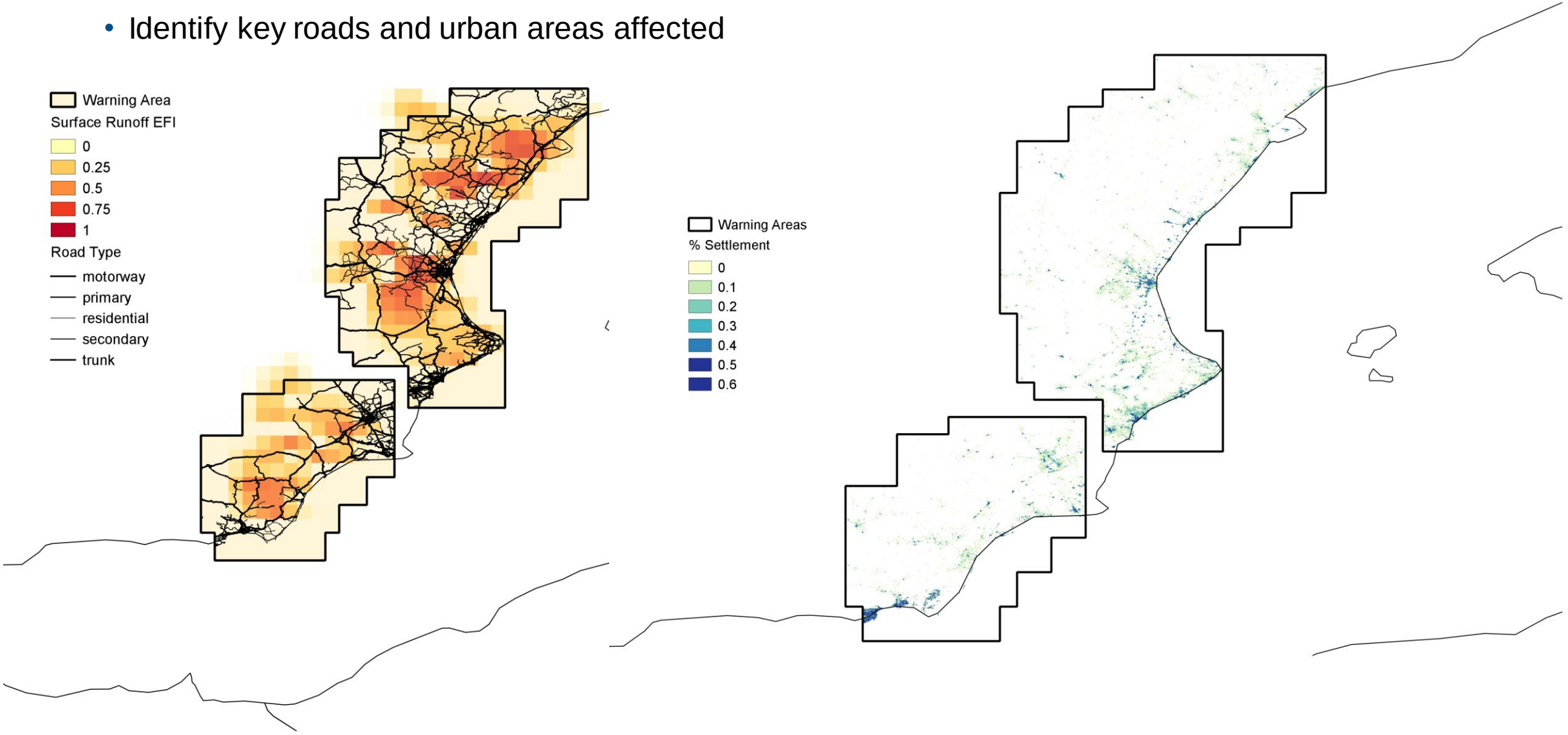
Enhancing with Exposure Information: Valencia December 2016

- Focus attention within warning area using exposure information



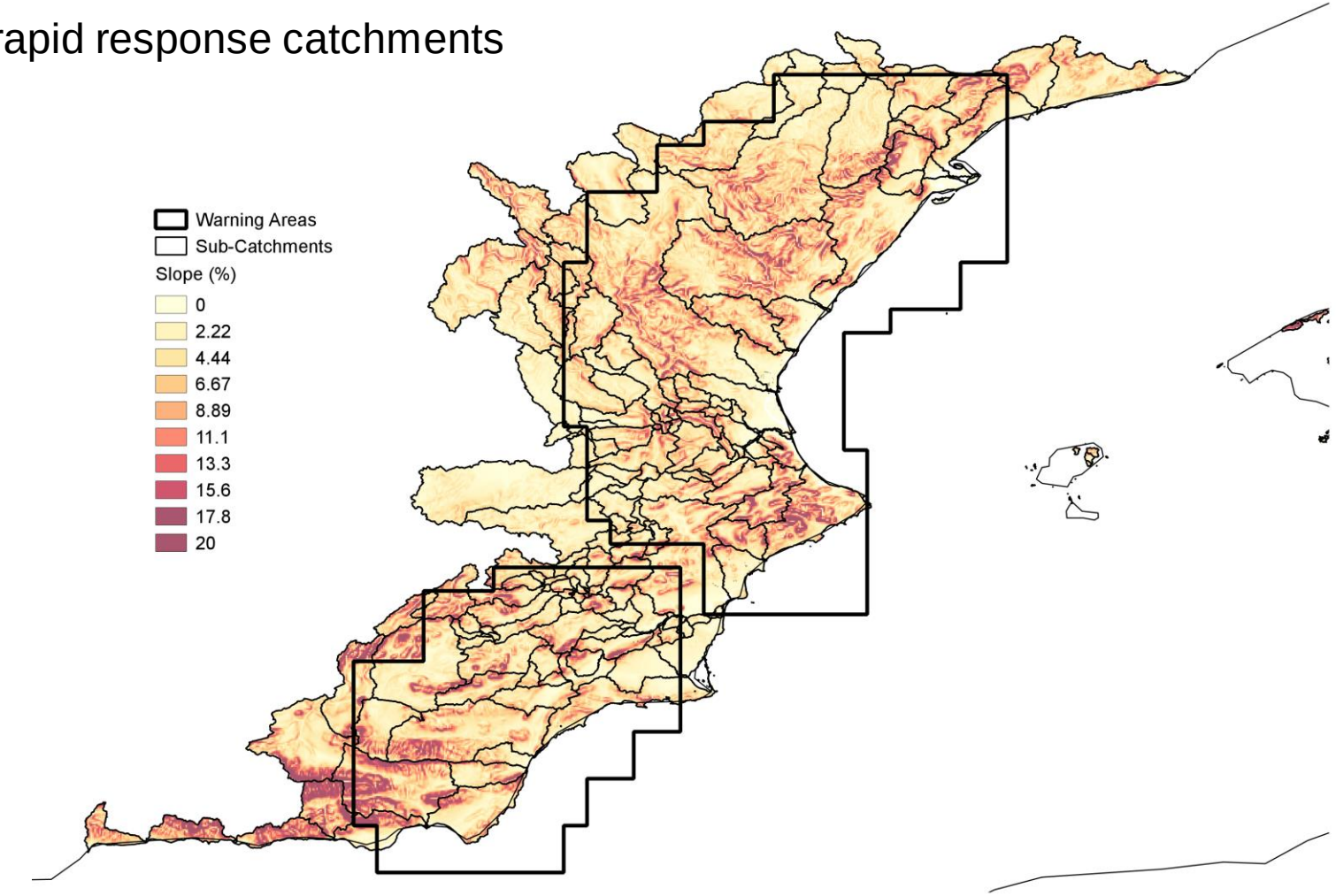
Enhancing with Exposure Information: Valencia December 2016

- Identify key roads and urban areas affected



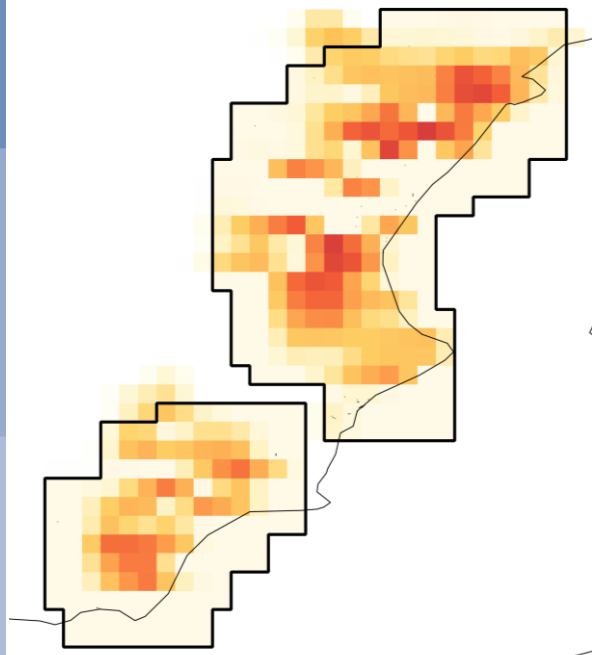
Enhancing with Geophysical Information

- Identify rapid response catchments



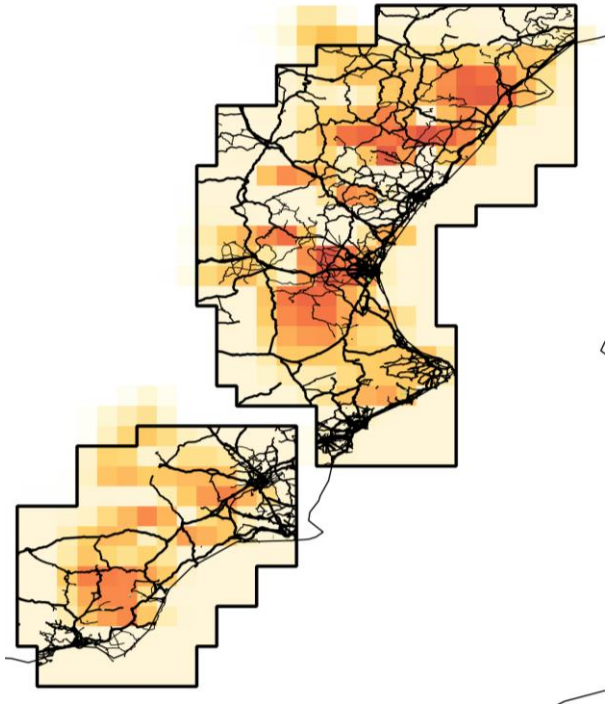
Combining Hazard & Exposure Information

Hazard



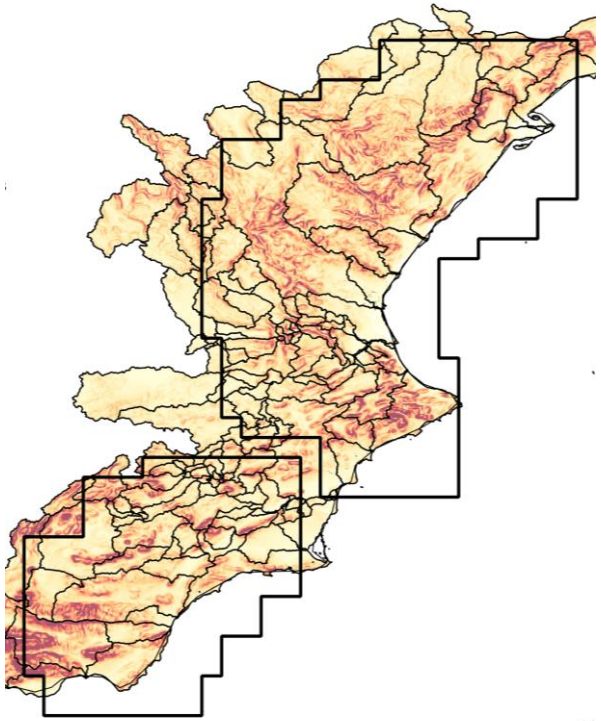
+

Socio-Economic Exposure



+

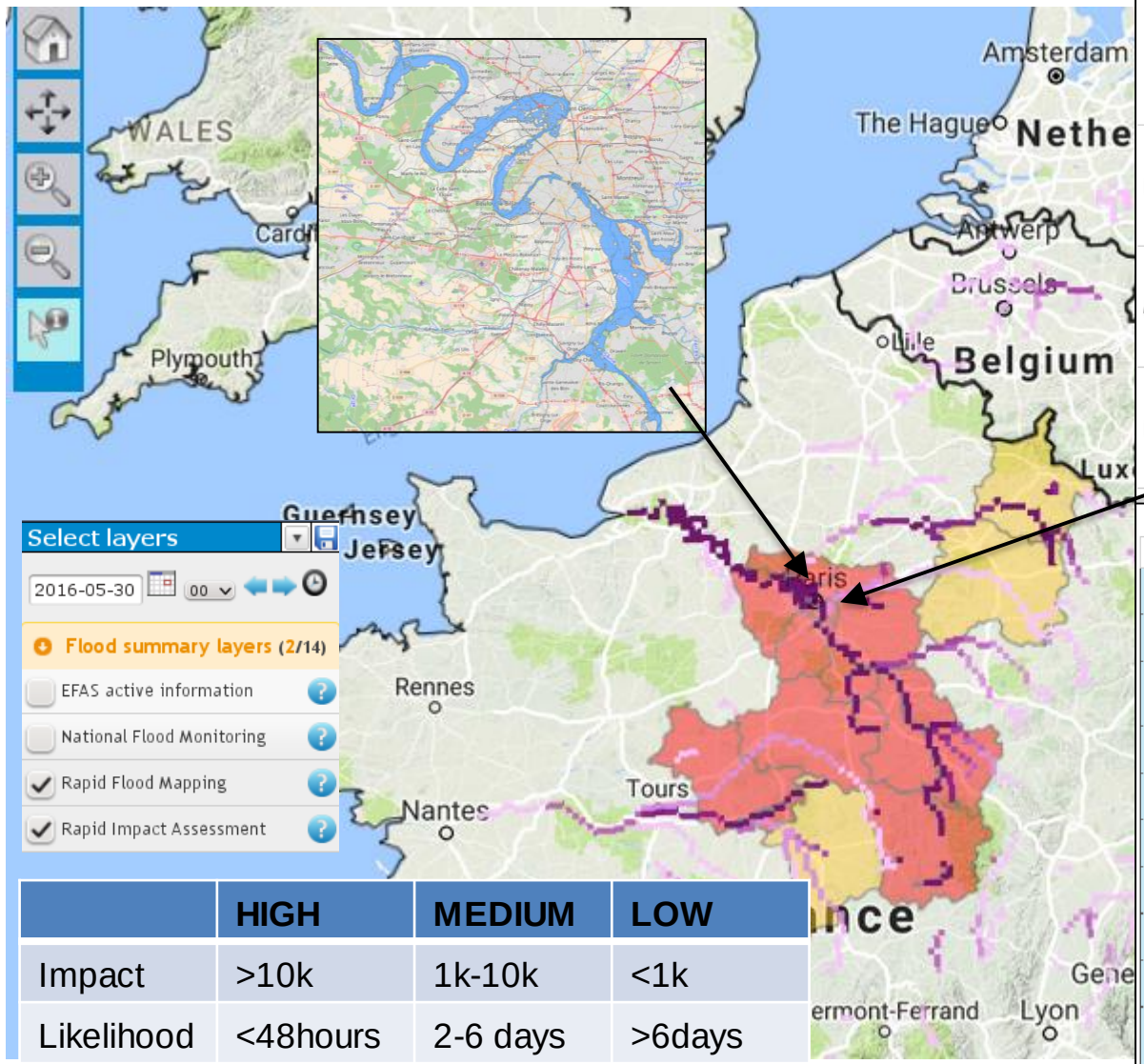
Geophysical Exposure



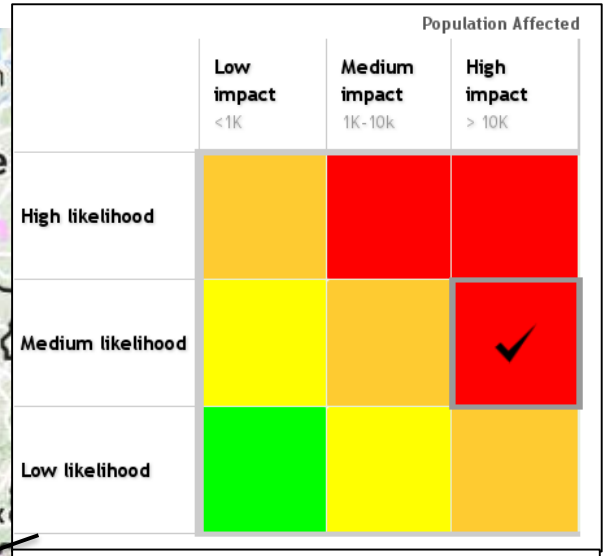
=

Flash Flood Risk

Alternative: EFAS Rapid Risk Mapping approach?



	HIGH	MEDIUM	LOW
Impact	>10k	1k-10k	<1k
Likelihood	<48hours	2-6 days	>6days



*Rapid Impact Assessment for **Val-de-Marne** region*

	PROTECTED	UNPROTECTED
Estimated peak time	4	4
Estimated mean return period [yr]	1,536	926
Estimated protection levels [yr]	179	179
Population affected [Nr. of people]	401,212	452,270
Total roads affected [km]	8	8
Artificial surfaces [ha]	7,136	7,796
Agricultural surfaces [ha]	0	0
Forest and seminatural [ha]	876	1,056
Potential monetary damage [M Euro]	1,261	1,366
Cities/proportion affected [%]	[Alfortville/51.05%] [Chennevires-sur-Marne/3.28%] [Choisy-le-Roi/101.44%] [Crteil/9.3%] [Joinville-	[Alfortville/51.05%] [Chennevires-sur-Marne/3.28%] [Choisy-le-Roi/101.44%] [Crteil/9.3%] [Joinville-

ECMWF

Final Conclusions

- No global flash flood forecasting system – leaves areas with no capability

- Different types of flash flood
  - Want forecast to be as inclusive as possible

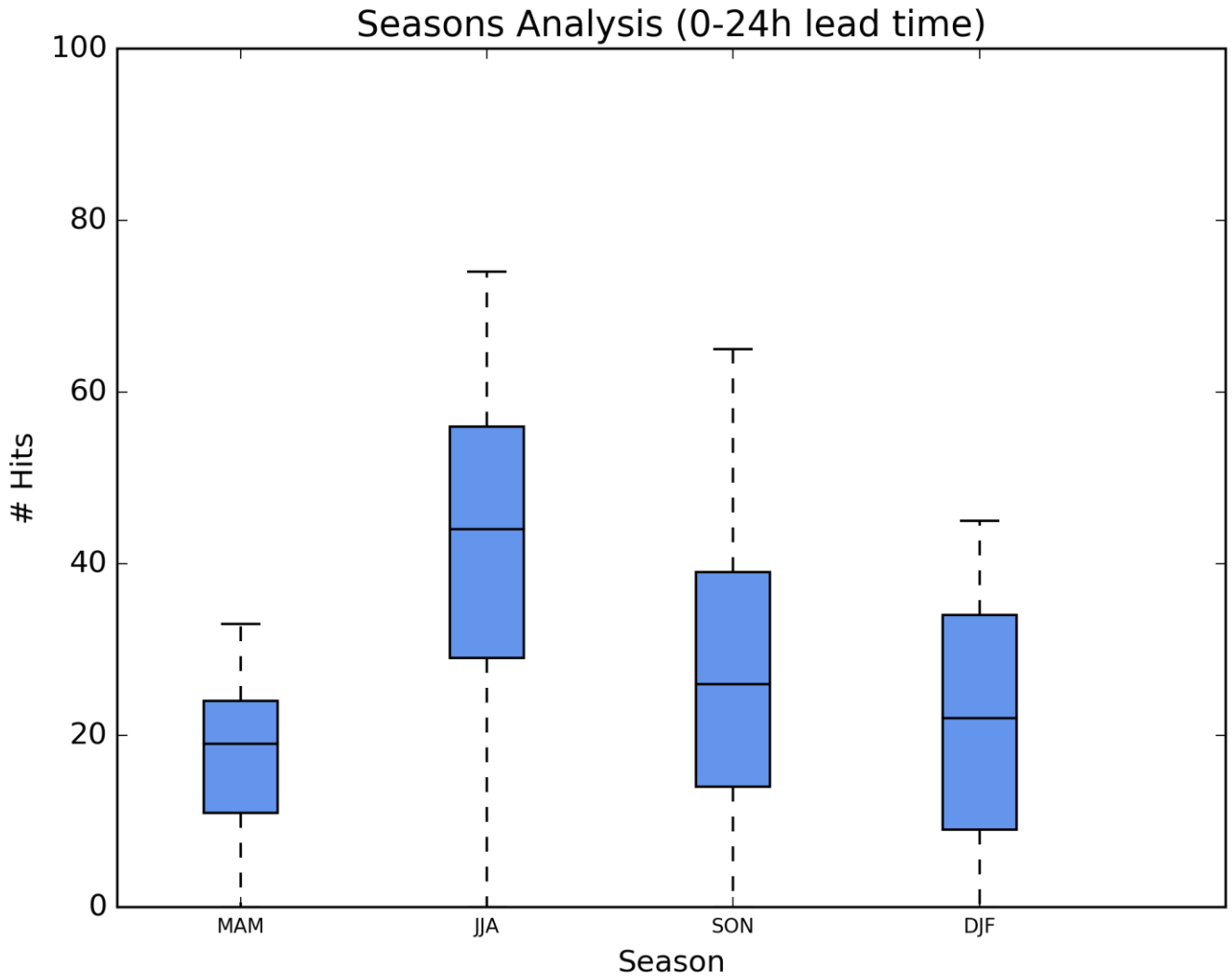
- Global land surface model forecasts give limited predictability of flash floods globally
  - Issue of scale
  - Complex impact of assimilation scheme - atmospheric variables may offer more clarity

- Forecasts are made at a regional scale, exposure information could be used for localised focus

Thank You

Questions?

calum.baugh@ecmwf.int


Seasons Analysis (0-24h lead time)
100
80
60
40
20
0
Hits
MAM
JJA
SON
DJF
Season

How spatially detailed can we make FF forecasts?

- Depends on uncertainty of the forecasting method

Points:

- Implies high situational certainty

n occur anywhere along