Long-Range Flood Outlook for Strategic Preparedness

NHRA Project T4 – A3

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Bureau of Meteorology

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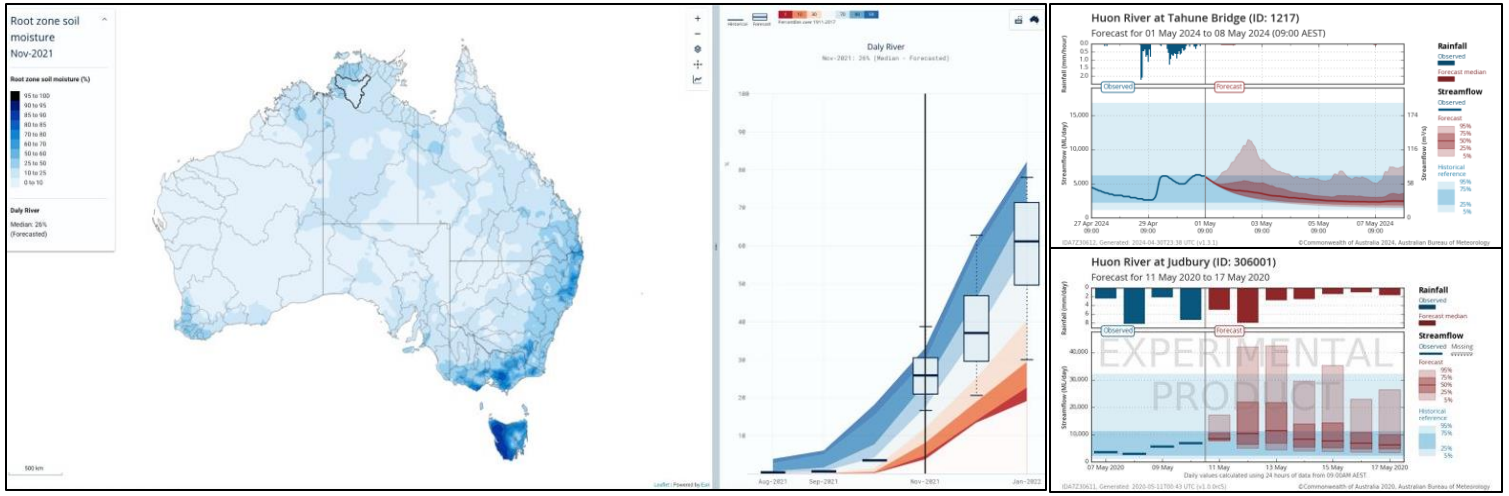
This research project is funded and supported by Natural Hazards Research Australia.

Service Gap / Similar International Products

➢ Short-term Flood Forecast Products (< 7 days)

➢ Long-term Water Forecast Products



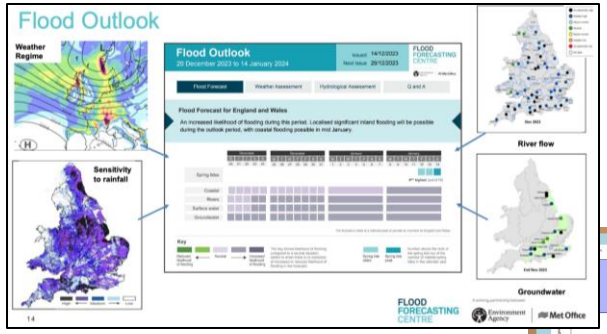
➢ Gap in Forecasting Capability

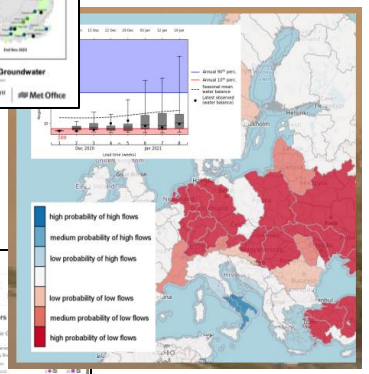
- No multi-week forecast
- Not all forecasting services are truly seamless

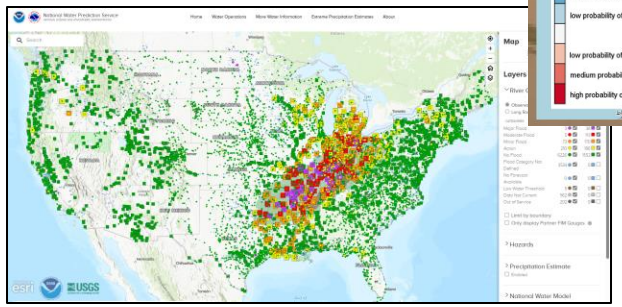
A need for a multi-week to seasonal flood risk outlook to improve flood preparedness

➢ Examples from overseas

- NOAA's Long-Range Flood Outlook
- ECMWF-Early Warning System
- UK Met-Office Flood Outlook







Long-Range Flood Risk Outlook

Building on Bureau's modeling capacity

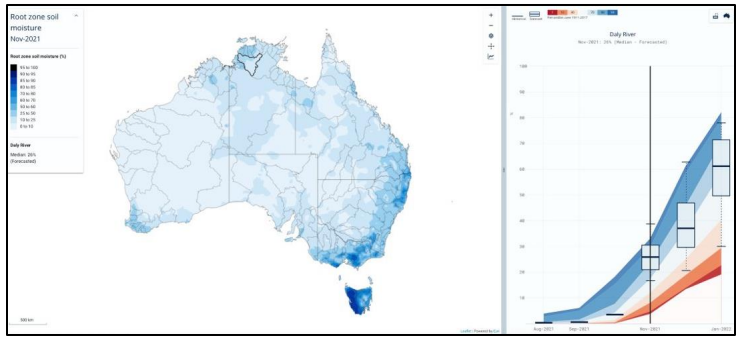
- Hydrological forecasts
  - Monthly to 3 months
  - Weekly/fortnightly to 6 weeks

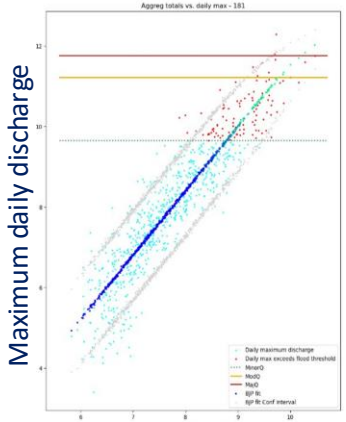
Developing a Statistical model

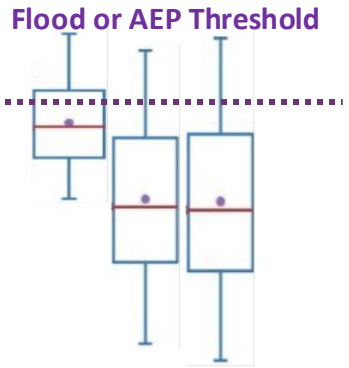
- Relationship between:
  - hydrological conditions (e.g. monthly)
  - Maximum daily discharge

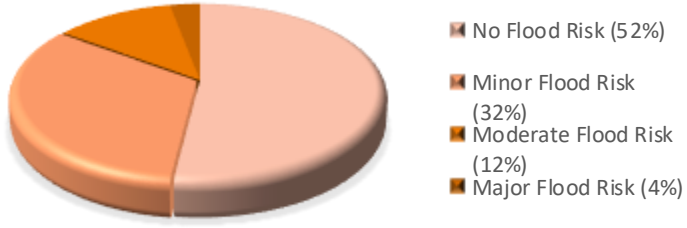
Identifying the likelihood of exceeding flood threshold

- Flood thresholds from flood forecasting operations
- AEP thresholds from FFA





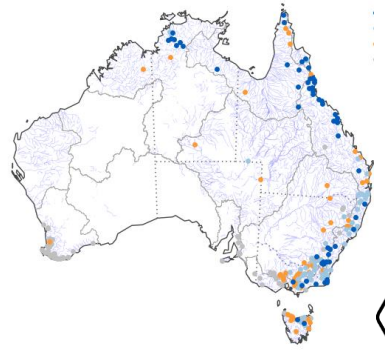




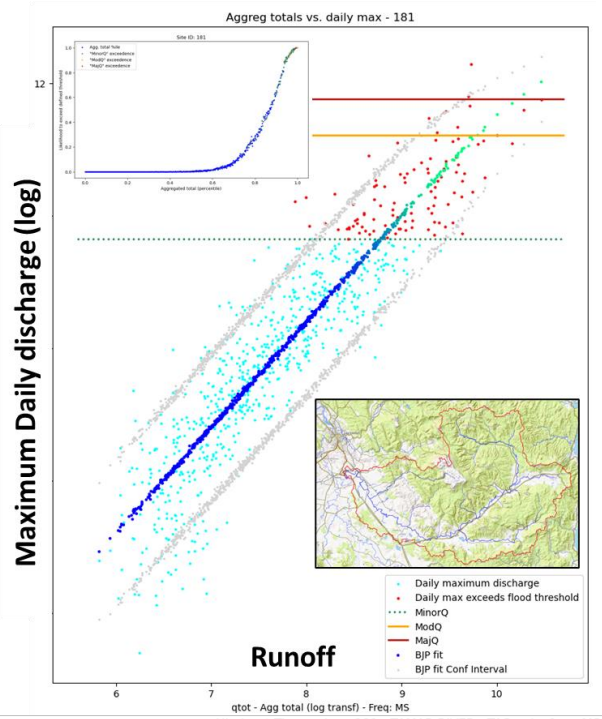
Key hydrological variables

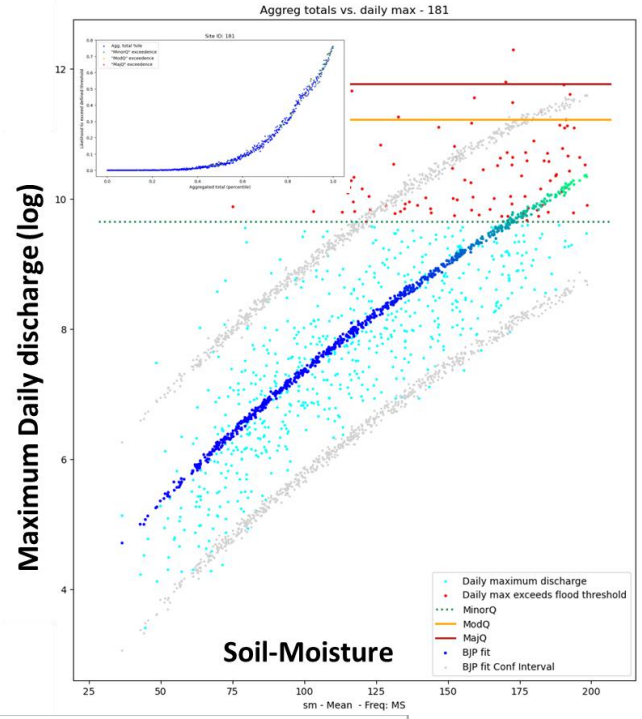
- Runoff
- Root-zone soil-moisture
- Actual evapotranspiration

From point-based flood risk results to flood risk inundation maps

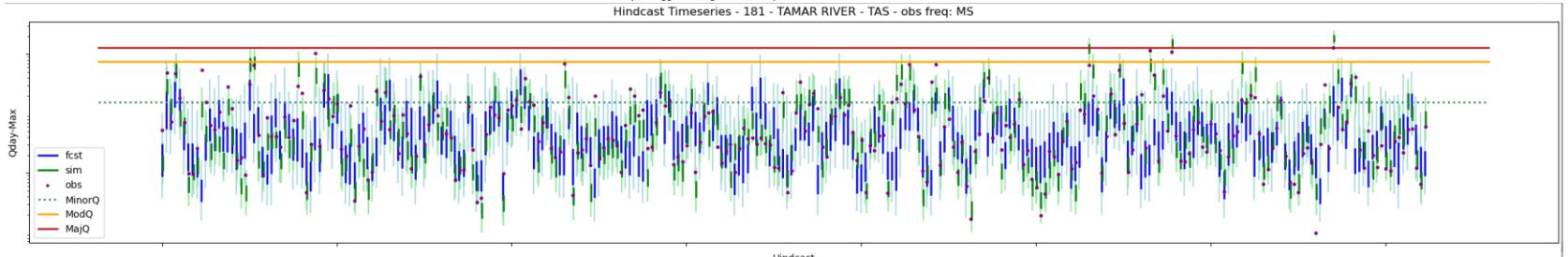


BJP model fit – South Esk River at Perth, Tas.

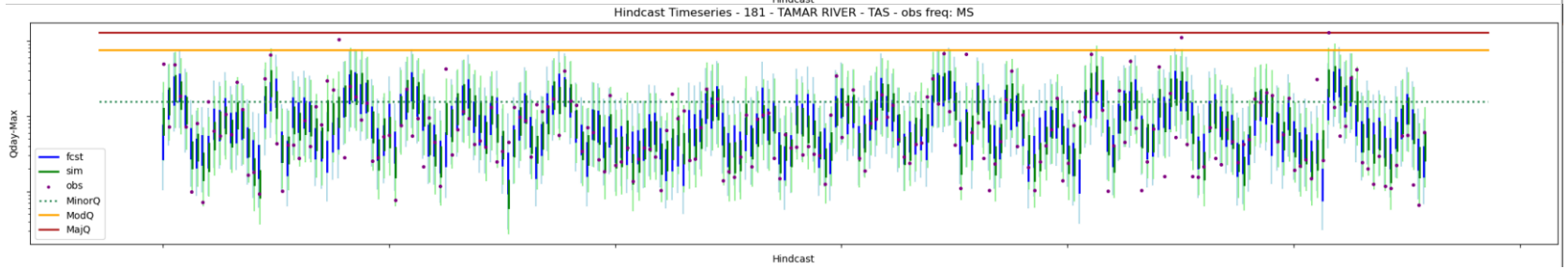


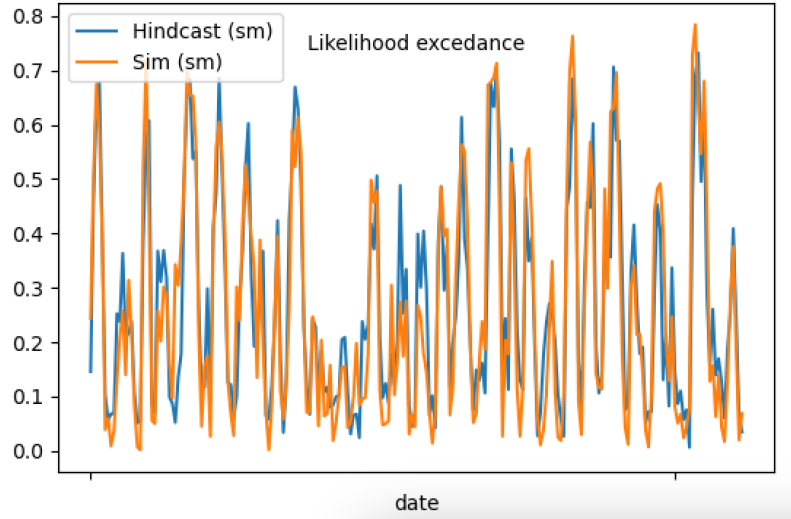


Runoff (qtot)

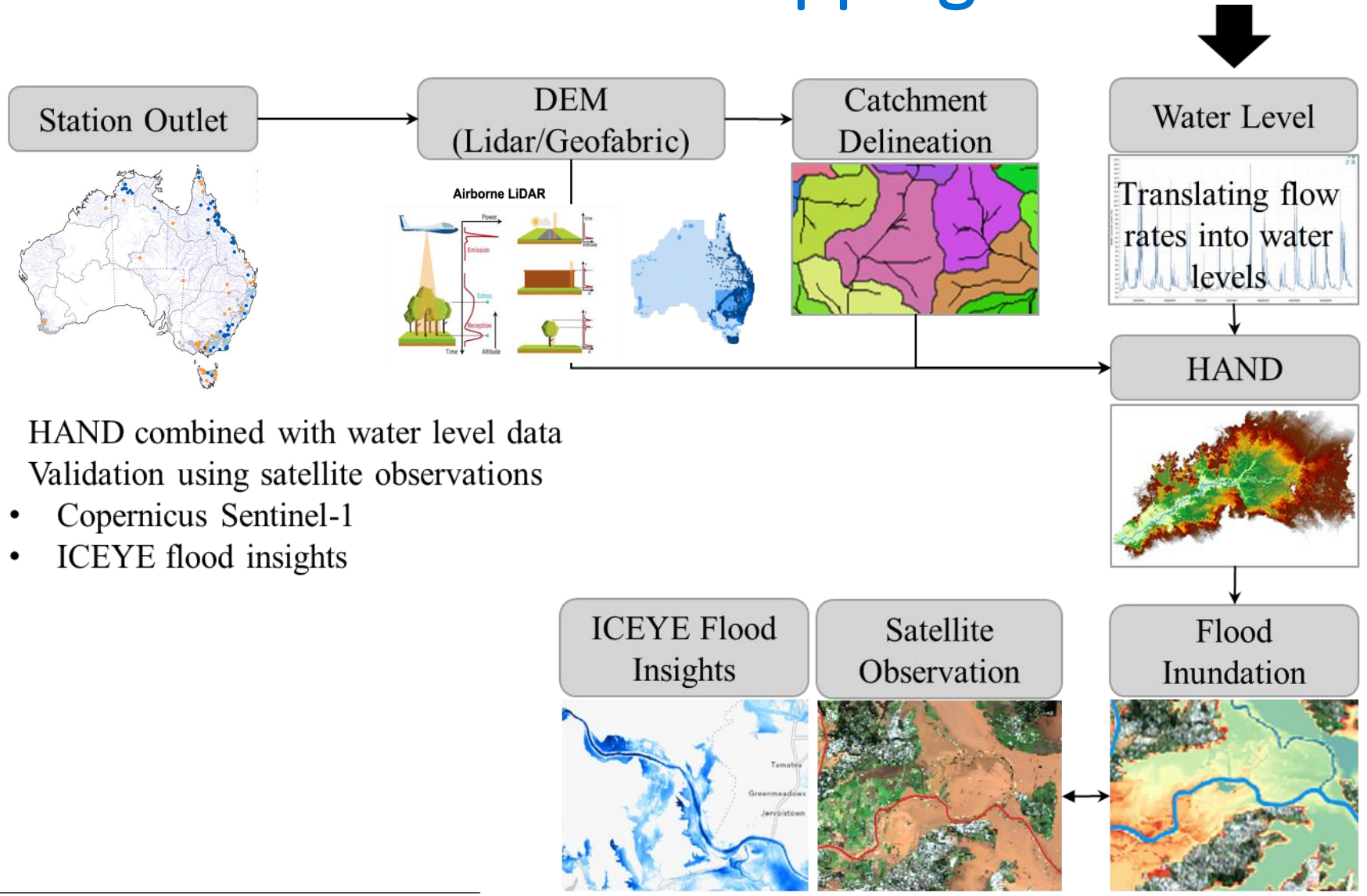


Soil-moisture





Flood Inundation and Mapping



- HAND combined with water level data
- Validation using satellite observations
  - Copernicus Sentinel-1
  - ICEYE flood insights

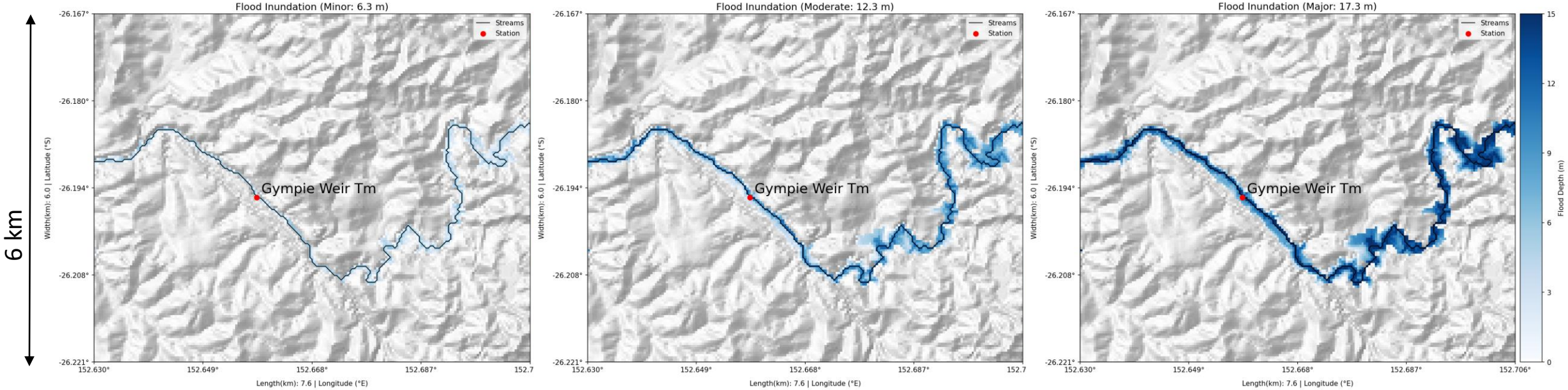
DEM: Digital Elevation Model
HAND: Height Above Nearest Drainage

Flood Inundation and Mapping

	Site_id	Name	State	Y	X	Minor_FLD_	Moderate_F	Major_FLD_
1	210001	Singleton (Hunter River)	NSW	-32.54999999...	151.16669999...	10.000000000...	11.500000000...	13.000000000...
2	212202	Wallacia Weir (Nepean River)	NSW	-33.86110000...	150.63030000...	5.000000000...	9.000000000...	11.000000000...
3	210002	Muswellbrook (Hunter River)	NSW	-32.25750000...	150.88749999...	7.200000000...	8.000000000...	10.000000000...
4	210055	Denman (Hunter River)	NSW	-32.38190000...	150.71080000...	6.500000000...	7.900000000...	9.000000000...
5	210064	Greta (Hunter River)	NSW	-32.66669999...	151.40000000...	NULL	NULL	NULL
6	138007A	Fishermans Pocket Tm	QLD	-26.17109999...	152.59940000...	7.000000000...	13.000000000...	18.000000000...
7	138020A	Gympie Weir Tm	QLD	-26.19440000...	152.65690000...	6.300000000...	12.300000000...	17.300000000...
8	181	South Esk River at Perth	TAS	-41.59720000...	147.20439999...	4.300000000...	7.200000000...	8.900000000...
9	150	South Esk River at Llewellyn	TAS	-41.81720000...	147.56639999...	4.000000000...	5.000000000...	8.500000000...
10	60	Liena (Mersey River)	TAS	-41.56029999...	146.22360000...	2.400000000...	NULL	NULL
11	447	MERSEY RIVER AT SHALE ROAD	TAS	-41.27000000...	146.41999999...	NULL	NULL	NULL
12	403242A	Ovens River at Wangaratta	VIC	-36.35070000...	146.32089999...	11.900000000...	12.400000000...	12.699999999...
13	403230A	Ovens River at Rocky Point	VIC	-36.53529999...	146.66720000...	3.200000000...	4.400000000...	5.200000000...
14	403205	Ovens River at Bright	VIC	-36.72749999...	146.95140000...	3.000000000...	3.600000000...	4.300000000...
15	403233	Buckland River at Harris Lane	VIC	-36.72279999...	146.88030000...	2.800000000...	3.500000000...	4.200000000...

FIM using different Flood Classification Levels:

- Minor
- Moderate
- Major



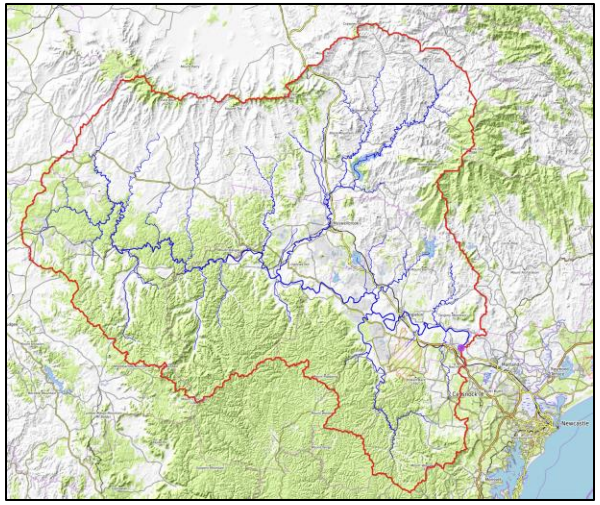
Gympie Weir Tm, Queensland, Australia

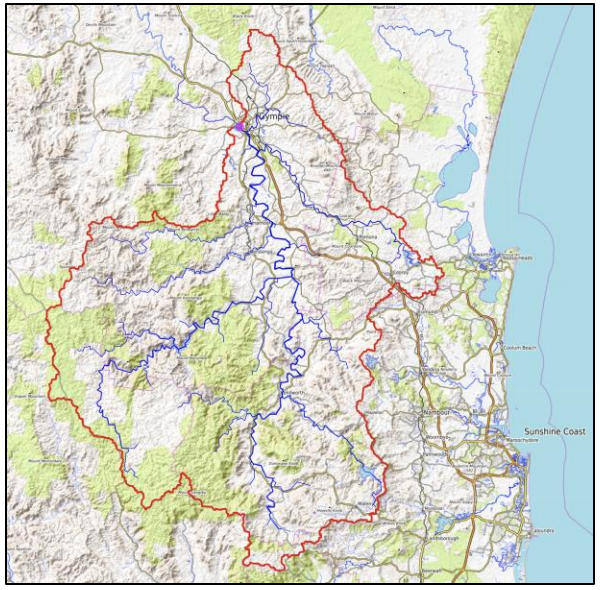
Priority Case Study Areas

➢ **Six locations chosen in areas of relatively high flood impact**

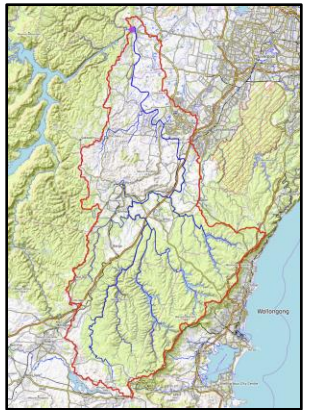
- Co-design workshop with end users:
  - FSWISTG
  - TasSES
  - QRA
- Spread of case studies in different states and geography/climate zones.
- Sufficient availability of historical, Hindcast, RS data.
- Availability of Bureau flood-thresholds (minor, moderate, major)
- Proper modelling skill

Hunter River at Greta, Hunter Valley, NSW

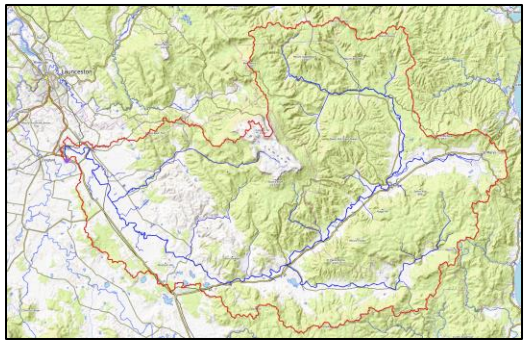




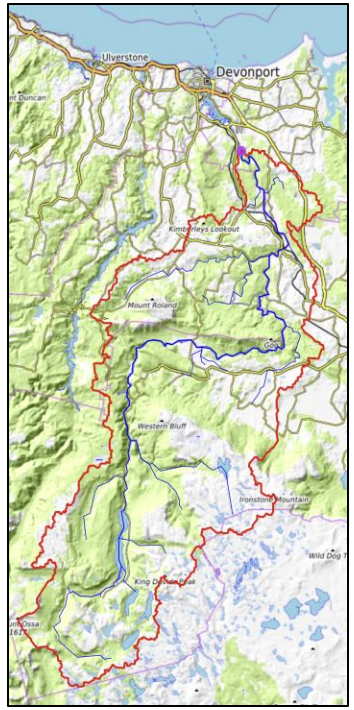
Marry River at Gympie, QLD



Nepean River, Wallacia Weir, NSW

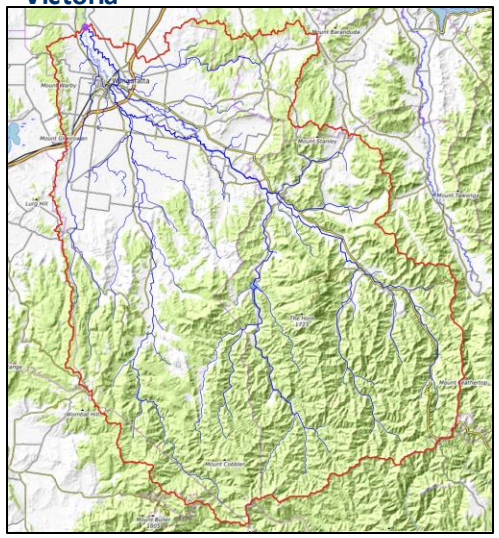


South Esk River at Perth, Tasmania



Mersey River at Shale Road, Tasmania

Ovens River at Wangaratta Victoria



Thank you…

Hydrological Applications Team;

Bureau of Meteorology

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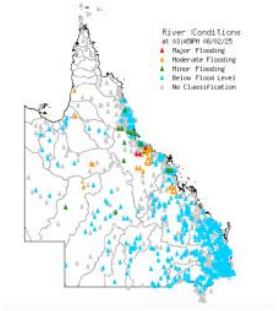
This research project is funded and supported by Natural Hazards Research Australia.

Natural Hazards Research Australia

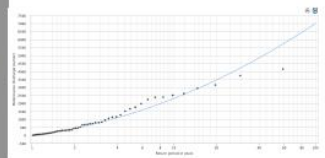
The Bureau of Meteorology

Project Components/Methodology

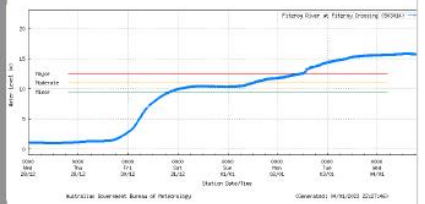
Select flood forecast river gauges



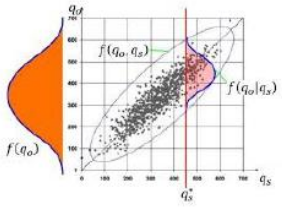
Perform AEP analysis for each gauge, creating AEP thresholds



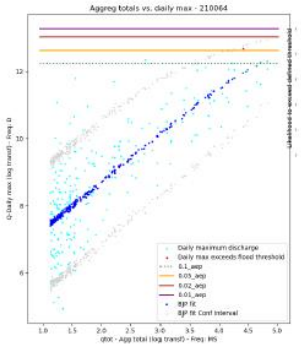
Use Bureau rating curves to get the discharge at the flood forecast thresholds, creating FFT thresholds



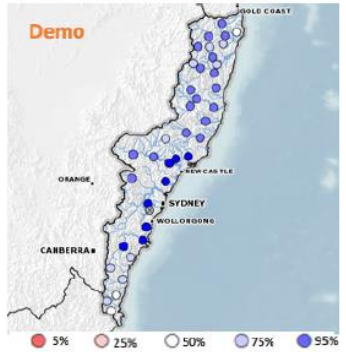
Apply BJP to provide flood likelihoods of 25%, 50%, and 75% at each gauge



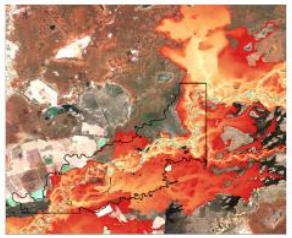
Use each BJP model to relate the likelihood of exceeding a given flood threshold and the accumulated total runoff for the forecast period



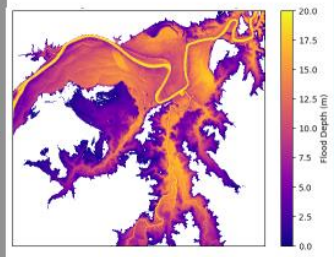
Create a gauge based probability of exceedance long range forecast



Apply inundation mapping to those selected river regions for forecast hazard extent

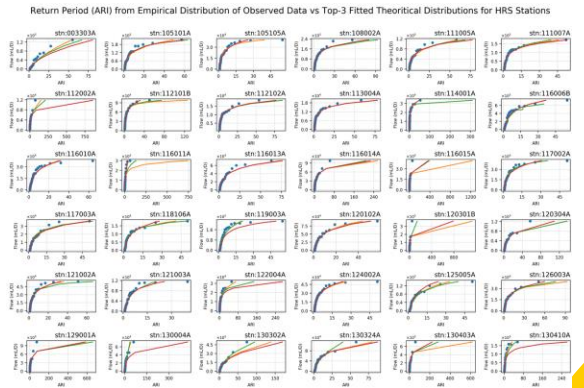


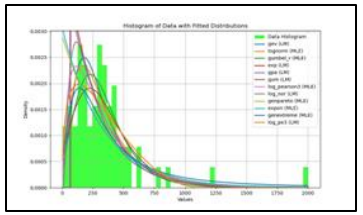
Create an inundation extent for each gauge for each flood threshold



Create an inundation map based long range forecast

Flood Frequency Analysis (FFA)





Implementation

- Priority case studies
- AEP quantiles estimated

FFA Code

- Fit distributions
- Propper GOF index
- Estimate AEP quantiles

Flood Thresholds

- Risk quantification (BJP)
- Flood Inundation

AEP (%)	ARI	Estimated Flow (cms)
0.1	1000	5514.24
0.2	500	4725.55
0.5	200	3782.92
1	**100**	**3138.5**
2	**50**	**2547.78**
4	25	2006.28
5	**20**	**1841.74**
10	**10**	**1359.07**
20	5	916.62
50	2	387.8

Function to fit different distributions using MLE or LM methods

Code Output:

```
All distributions were fitted using Maximum Likelihood Estimation (MLE) method.
#########
Sorted distributions based on P-Value:
   Distribution  K-S Statistic       P-Value
0     genpareto       0.081918  8.389277e-01
1      pearson3       0.099903  6.008564e-01
2     nakagami       0.121496  3.430813e-01
3         gamma       0.122828  3.302549e-01
4         expon       0.167971  7.109277e-02
5     gumbel_r        0.182524  3.912433e-02
6         norm        0.204733  1.426824e-02
7     rayleigh        0.238966  2.387128e-03
8            t        0.254616  9.579782e-04
9    genextreme       0.549051  2.220446e-16
10      lognorm       0.611398  0.000000e+00
#########
Distribution Parameters:
genpareto: (0.4006050418037051, 7.915999054829319, 479.30813995067456)
pearson3: (2.2834510906616372, 713.0782442603729, 805.1017478589187)
nakagami: (0.26389595922725979, 7.915999999999999, 887.5520786166418)
gamma: (0.7543310332895965, 7.915999999999995, 772.8245872749493)
expon: (7.916, 739.3018596491227)
gumbel_r: (387.74285880221345, 523.7700562175391)
norm: (747.2178596491227, 869.7435006906919)
rayleigh: (-543.1863724177397, 1100.3628364320487)
t: (1.1456785496436288, 277.0587640548747, 291.6548295551252)
genextreme: (-4.57106698493946, 9.266466914286177, 6.175476236877123)
lognorm: (5.292342994355911, 7.915999999997035, 3.1535778599757194)
```

Case study areas:

1. Hunter Valley, NSW
2. Marry River, QLD
3. Nepean River, NSW
4. Mersey River, Tasmania
5. South Esk River, Tasmania
6. Ovens River, Victoria

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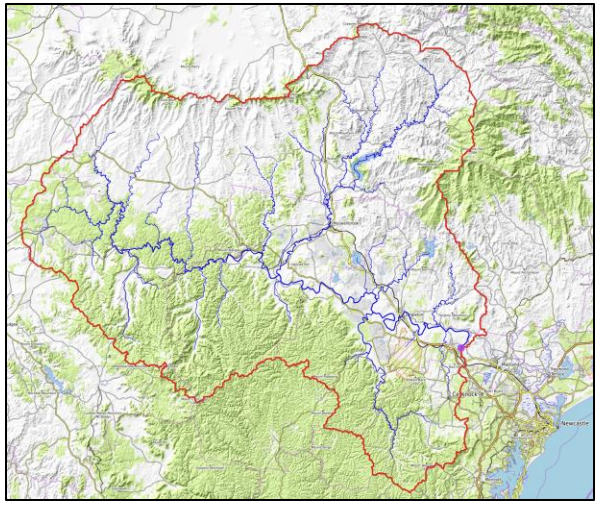

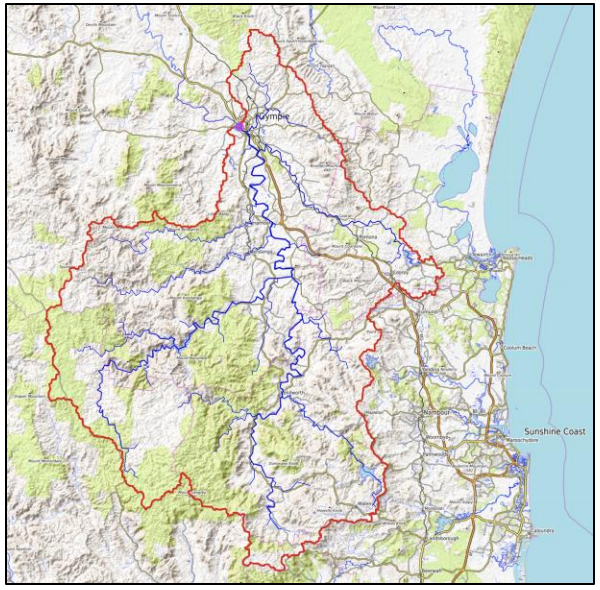

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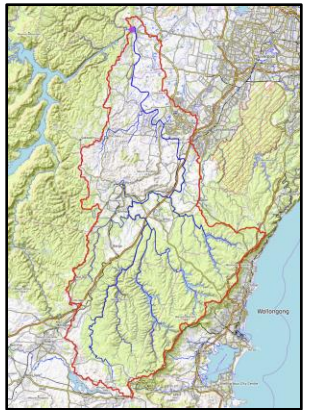

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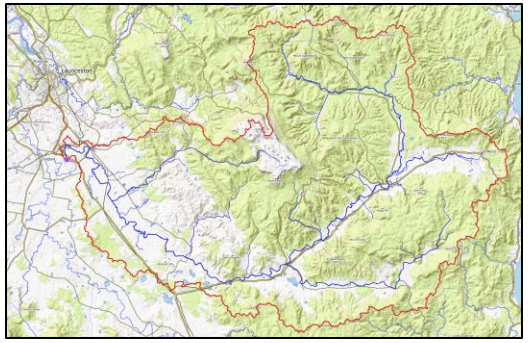
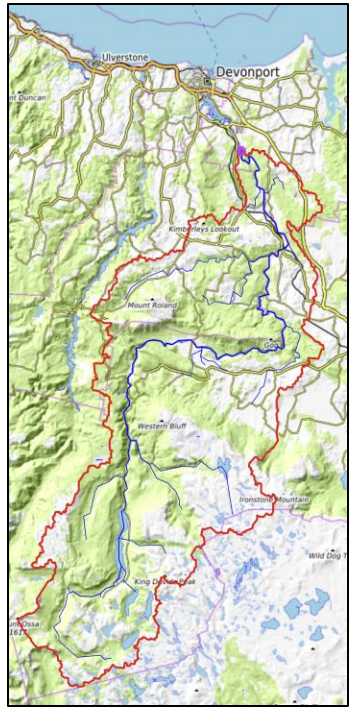
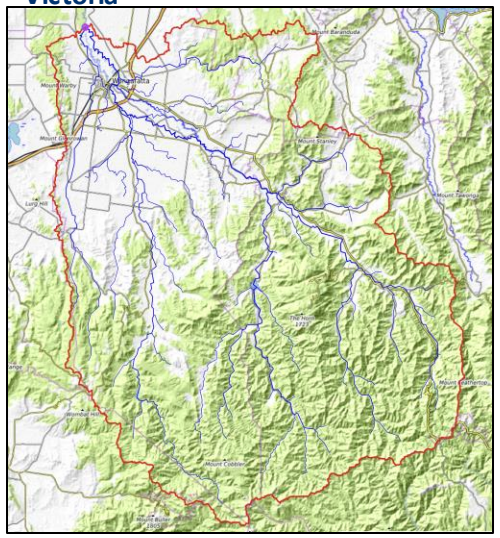


South Esk River at Perth, Tasmania



Mersey River at Shale Road, Tasmania

Ovens River at Wangaratta Victoria



Service Gap / Similar International Products

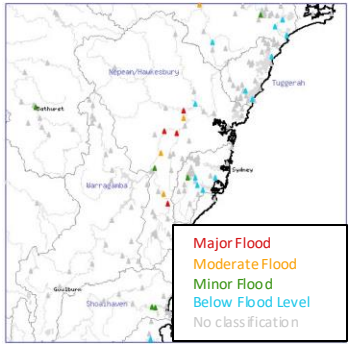
➢ Short-term Flood Forecast Products (< 7 days)

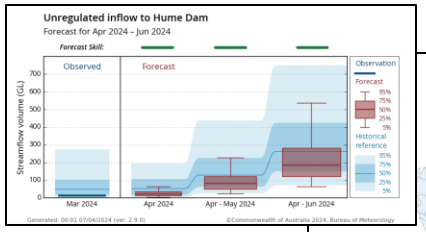
- Flood Watch & Warnings (Point-based)
- 7-Day Streamflow forecasts (Point-based)

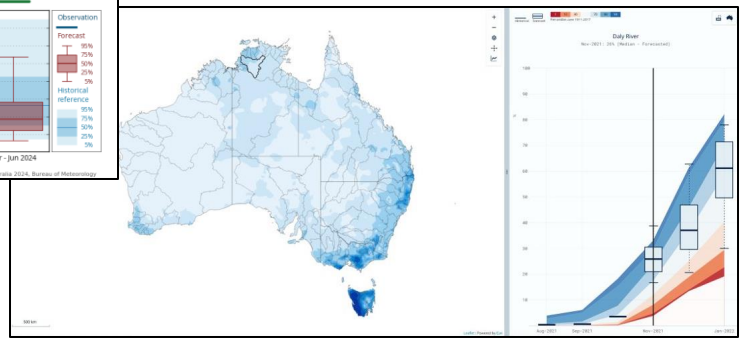
➢ Long-term Water Forecast Products

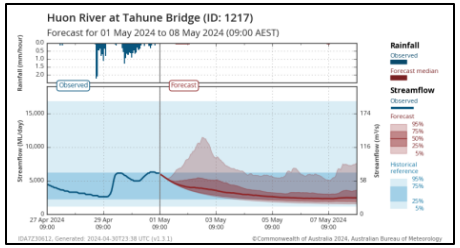
- Seasonal Streamflow Forecasts (Point-based)
- Surface water balance (SM, R, ET)

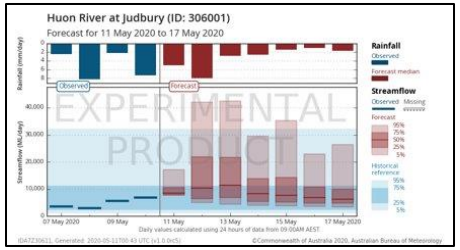
Current flood warnings









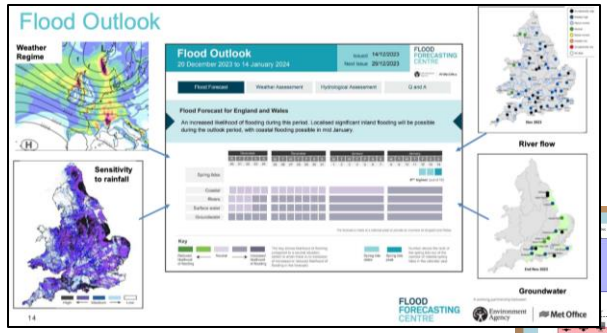


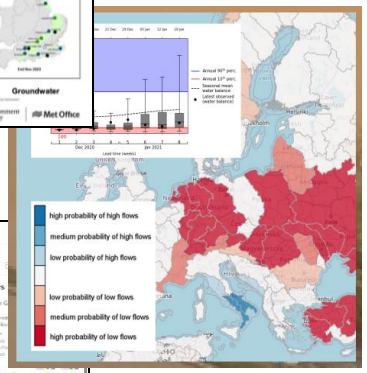
➢ Gap in Forecasting Capability

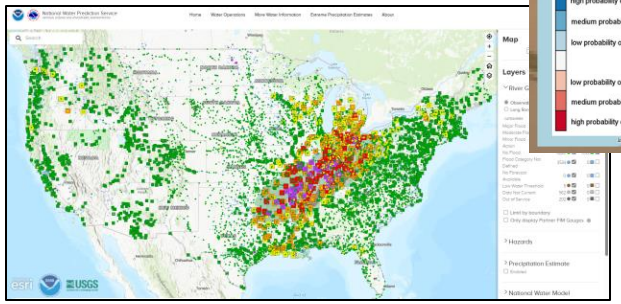
- No multi-week forecast products for hydrology (with focus on extremes)
- Not all forecasting services are truly seamless
- **A need for a multi-week to seasonal flood risk outlook to improve flood preparedness**

➢ Examples from overseas

- US National Weather Service Long-Range Flood Outlook products (NOAA)
- ECMWF-Probabilistic Early Warning System for Flood Risk and Hazards
- UK Met-Office & the UK Environment Agency Flood Outlook

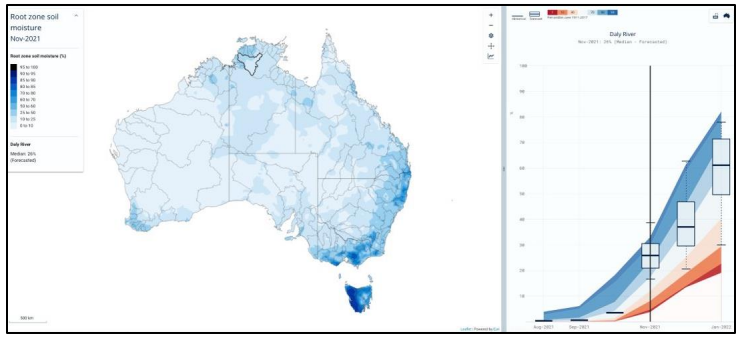






Long-Range Flood Outlook for Australia

- **A long-range (multi-week to seasonal) flood risk outlook to improve preparedness for SES & local government by identifying areas at higher risk of flooding due to a forecast change in hydrological conditions**
- **Complement existing forecast services: Long-range (seasonal) climate, AFDRS (fire risk) & hydrological forecasts**
- **Flood risk based on relationship between (forecast) hydrological conditions and likely range in maximum daily discharge within the forecast period – An increase in forecast runoff → Increase in maximum daily discharge**

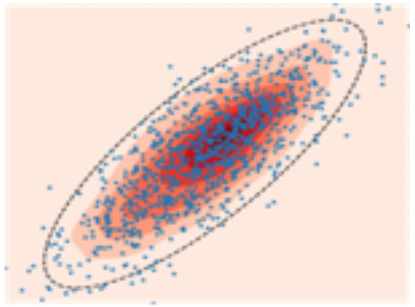


Hydrological forecasts

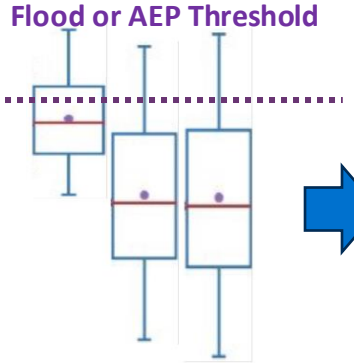
- Monthly to 3 months
- Weekly/fortnightly to 6 weeks

Key hydrological variables

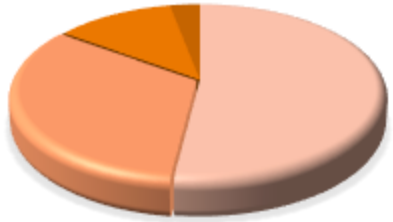
- Runoff
- Root-zone soil-moisture
- Actual evapotranspiration



Statistical Model

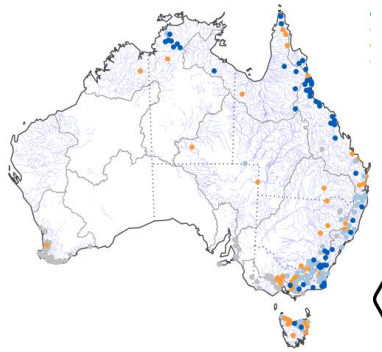


Range in maximum daily discharge in forecast period



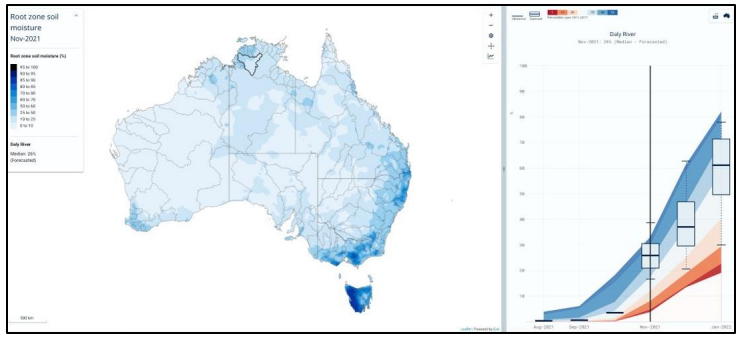
Likelihood to exceed flood threshold

Potential for catchment-based national coverage of flood risk



Long-Range Flood Outlook for Australia

- A long-range (multi-week to seasonal) flood risk outlook to improve flood preparedness
  - Identify areas at higher risk of flooding
- Flood risk based on relationship between hydrological conditions and maximum daily discharge
  - Increase in forecast runoff & soil-moisture ➡ Increase in the maximum daily discharge



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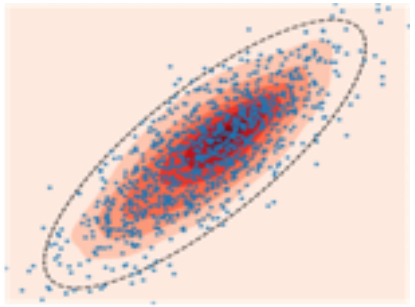

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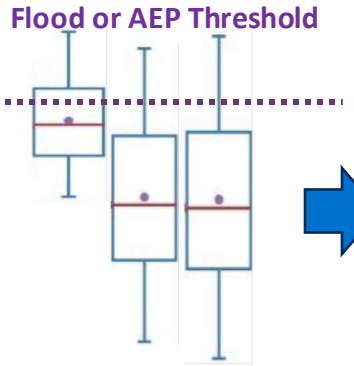

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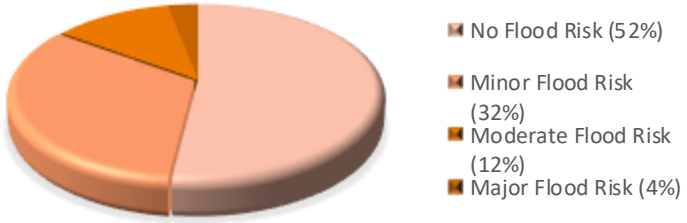

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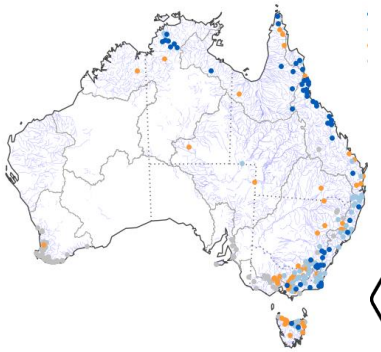
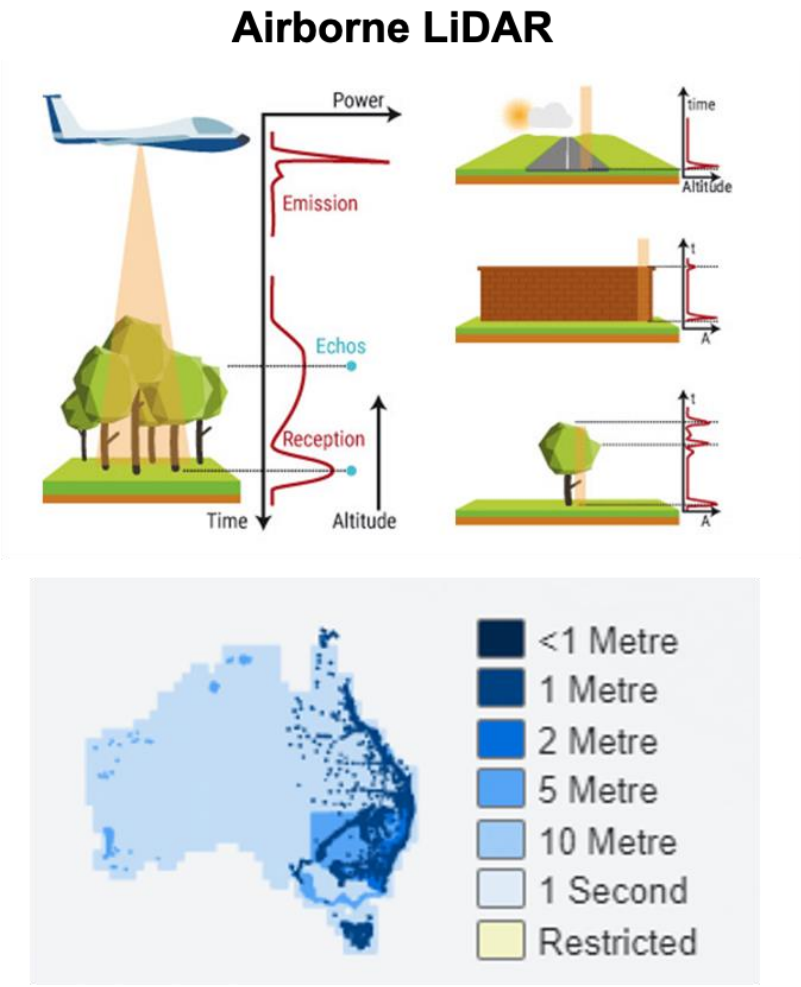


Flood Inundation and Mapping

Accurate Flood Inundation Mapping using high resolution (1~5 m) airborne LiDAR DEM



Satellite-derived flood inundation flood mapping for validation