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

The Bureau of Meteorology

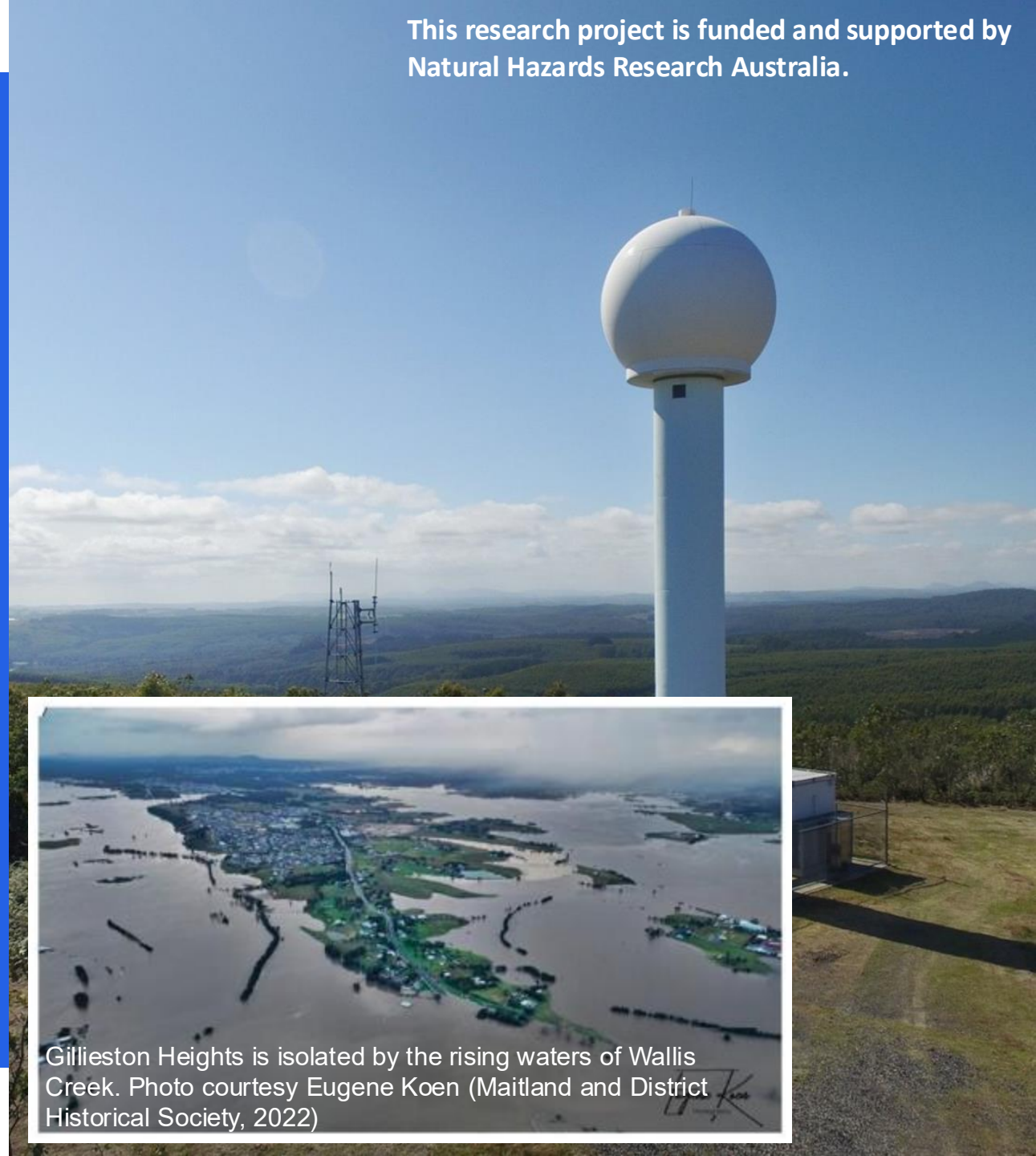
Natural Hazards Research Australia

T4-A7 Developing an integrated predictive capability for extreme rainfall and inundation

(June 2025 Update)

Dr. Carlos Velasco-Forero,

Paul Fox-Hughes, Jayaram Pudashine, Dragana Zovko-Rajak, Wendy Sharples, Jiawei Hou, Foad Brakhasi, Carla Mooney, David Wilke, Karen Hudson, Victoria Heinrich, Navid Ghajarnia, Christopher Pickett-Heaps, …



Gillieston Heights is isolated by the rising waters of Wallis Creek. Photo courtesy Eugene Koen (Maitland and District Historical Society, 2022)

Flash Flooding Preparedness, Response, Forecast, Warning and Communication

Part of a collection of research projects funded by Natural Hazards Research Australia (NHRA) and the Bureau of Meteorology (the Bureau) focused on flooding preparedness, response, forecast, warnings and communication.

- T2-A2 Flash flooding case studies to improve predictions and the communication of uncertainty
- T3-A4 Long-Range Flood Outlook for Strategic Preparedness

- **T4-A7 Developing an integrated predictive capability for extreme rainfall and inundation**

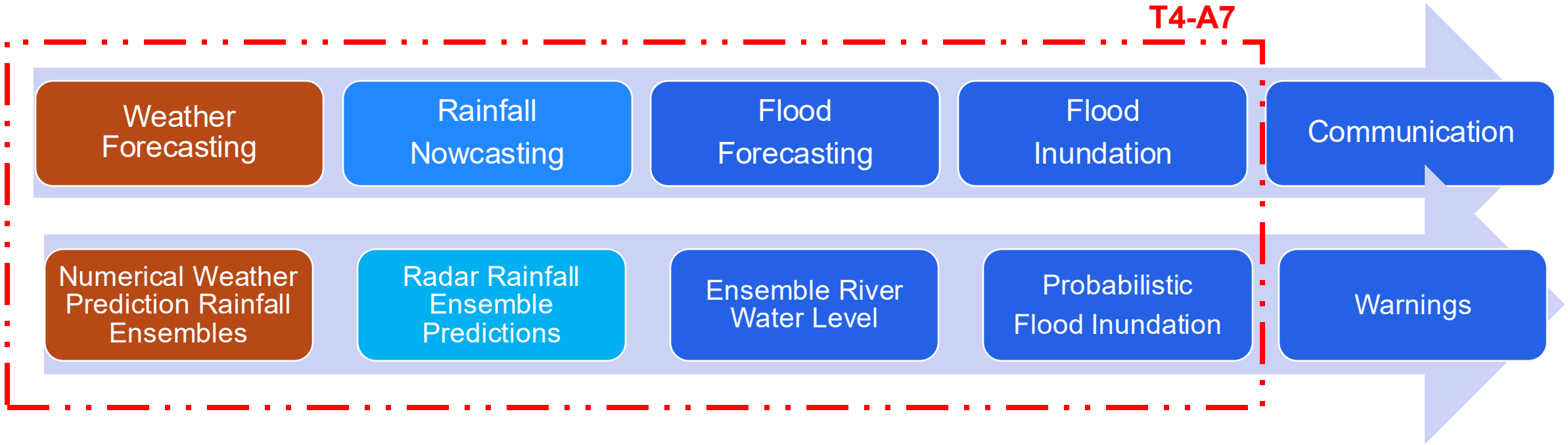
  - **review mechanisms** which may lead to **heavy rainfall** and subsequent **flash flooding**
  - assist understanding of the reasons for potential **uncertainty** in those forecasts and warnings and enhance the efficiency of communication
  - examine **the physical science context** of a **series of events**, including the mesoscale meteorology, model short-term rainfall and potential to predict land surface inundation
    - Wallis Creek – July 2022 , Hobart - May 2018, Adelaide – Nov 2023

Our Approach

Developing an integrated predictive capability for extreme rainfall and inundation (project **NHRA T4-A7**)

Flash flooding:

rapid onset speed (within minutes to hours),
short-term duration (hours to a day),
very localised (urban areas to small catchments),
produced by high-intense, short-duration rainfall



Our Approach – Summary

Developing an integrated predictive capability for extreme rainfall and inundation (project **NHRA T4-A7**)

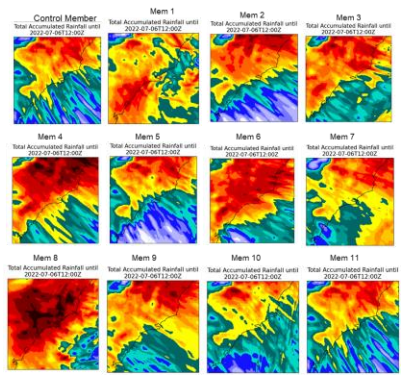
Numerical Weather Prediction Rainfall Ensembles

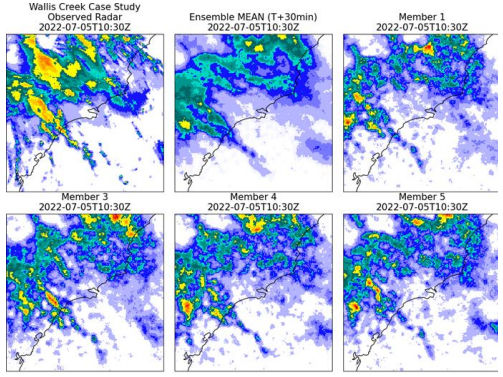
Radar Rainfall Ensemble Predictions

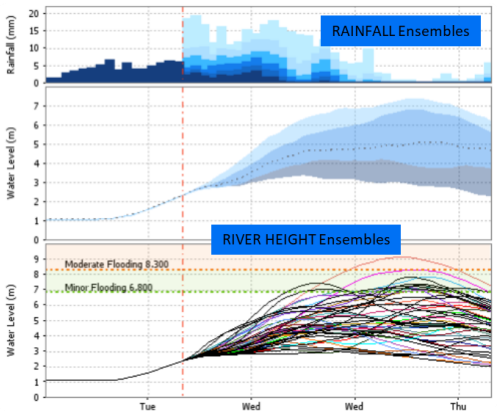
Ensemble River Water Level

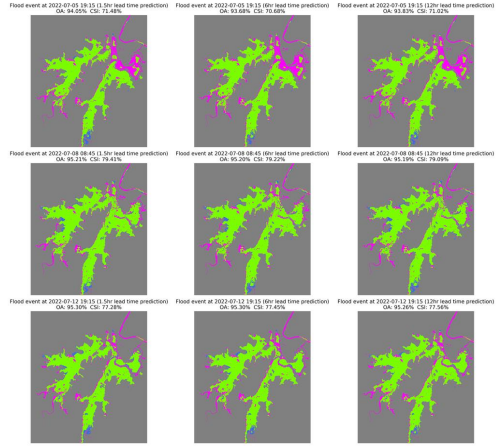
Probabilistic Flood Inundation

Warnings









High Resolution
Uncertainty

Preparedness

High Resolution
Rapid updates

Response

Rapid updates
Uncertainty

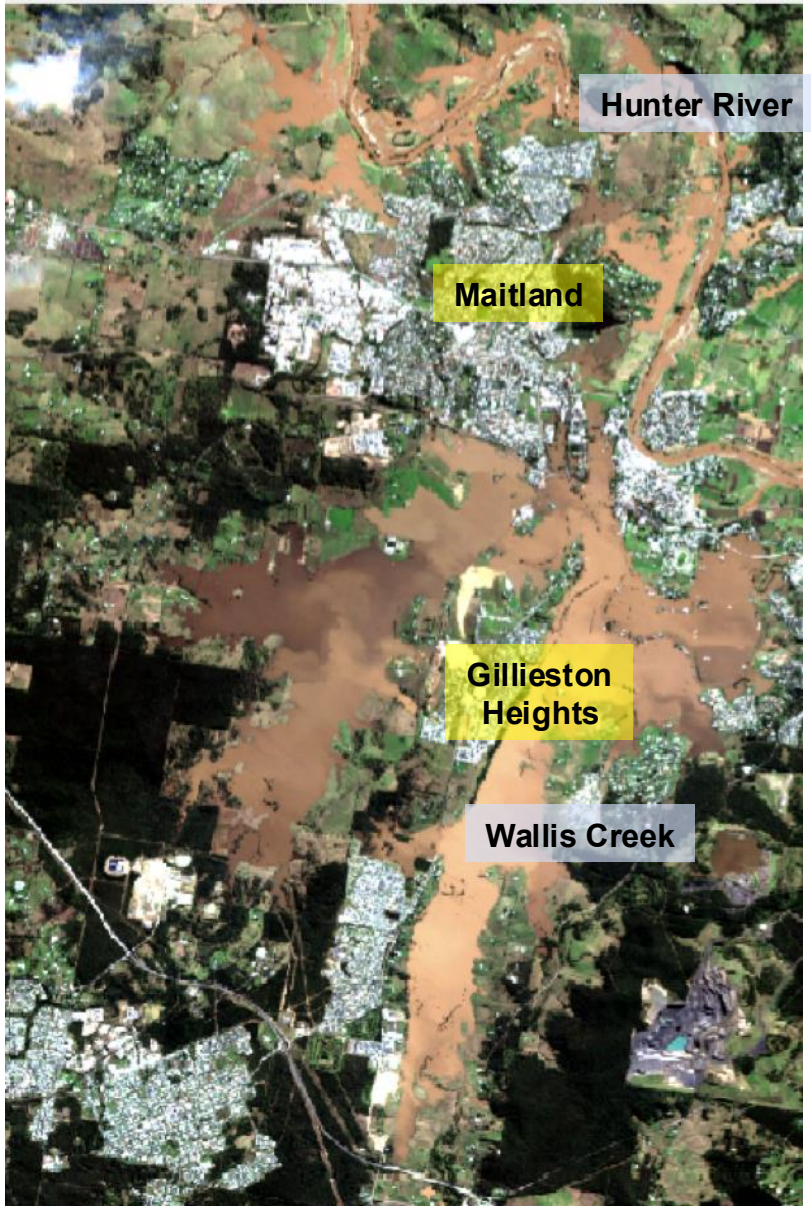
Response

Rapid updates
Local effects

Response

Case Study : Wallis Creek Flood – July 2022

- The event was marked by various factors that contributed to **significant uncertainty**.
- These included **initial model variation in the forecast rainfall**, **limited observations within the catchment area**, **complex interactions between riverine and flash flooding**, and concerns regarding the structural integrity of levee systems and emergency management capacity to respond, particularly considering the **short period available for recovery** from the February-March events.
- Numerous flood watches, severe weather, riverine flooding and evacuation were issued for the area starting from the 30 June.
- The evacuation for Maitland itself proved not to be necessary, but the area of **Gillieston Heights**, immediately to the south, **was completely cut off for more than a week,** and other areas up to 12 days.



Copernicus, 8th July 2022

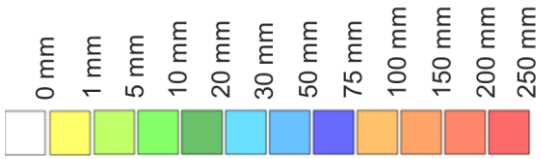
David Wilke, Carla Mooney, Karen Hudson, Victoria Heinrich

Preparedness

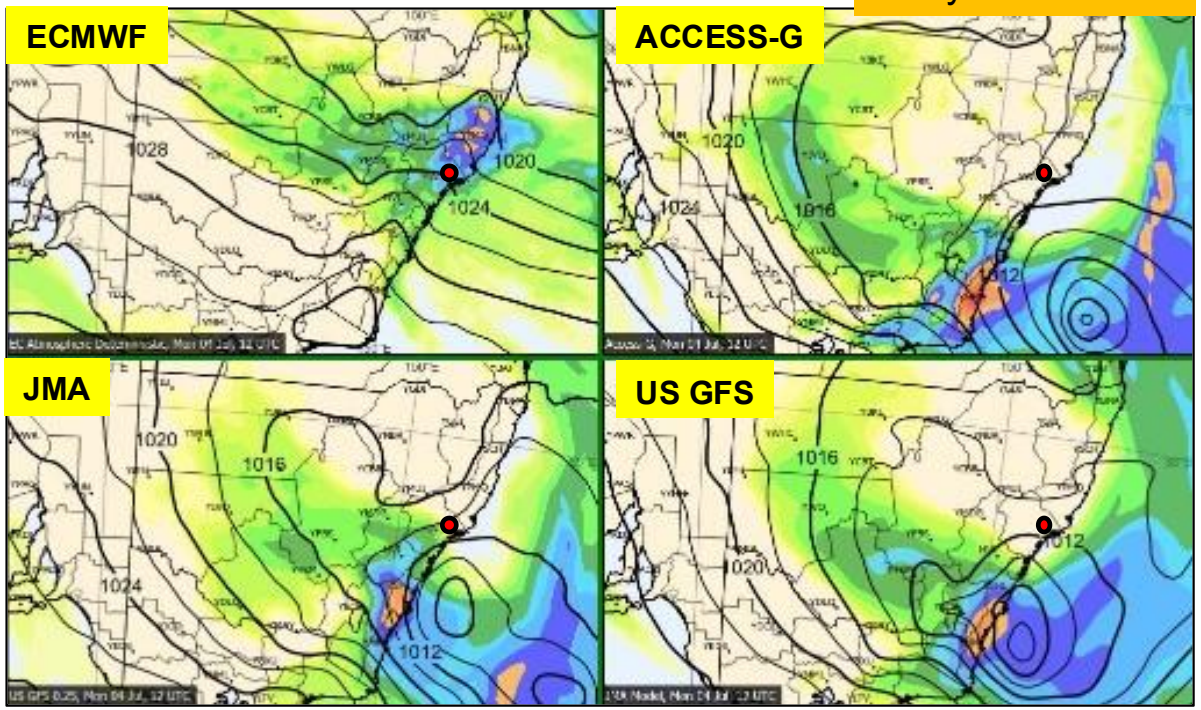
Case Study : Wallis Creek Flood – July 2022

Weather Forecasts – Uncertainty

- There was significant variation among the **deterministic** global models in the days leading up to the Wallis Creek event. Not enough resolution for flash flooding

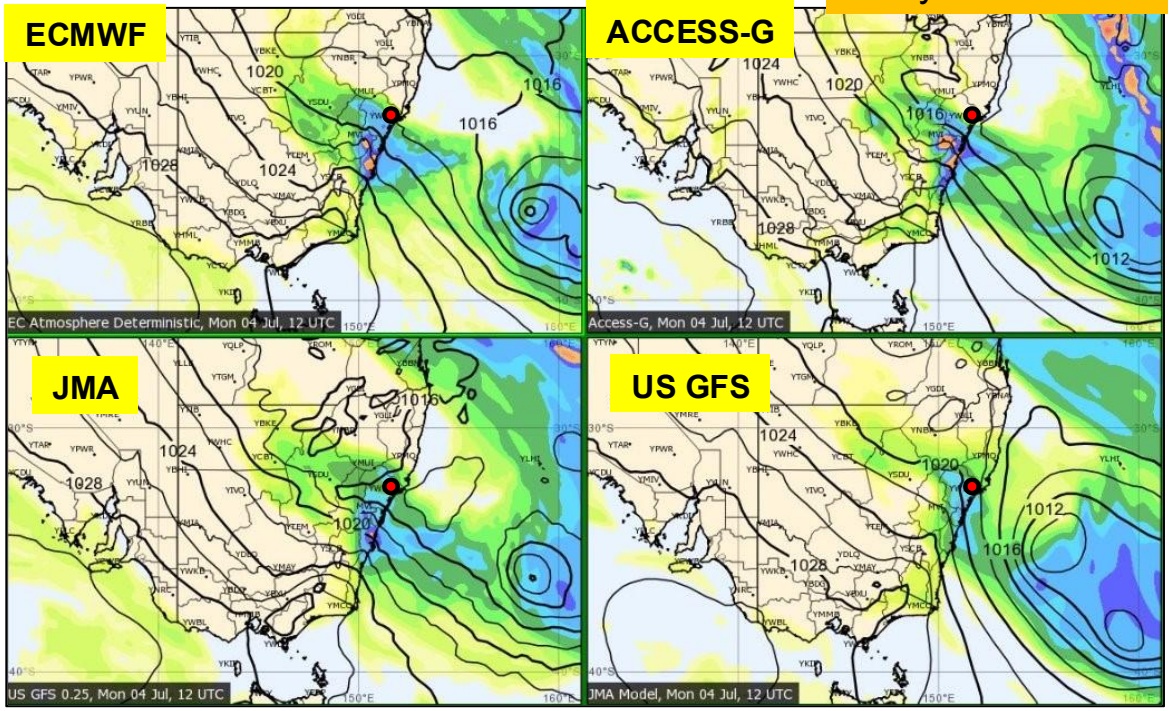


6 days in advance



24hr rainfall forecast to 10:00pm AEST July 4 2022 (run on June 28 2022). The location of Maitland is indicated by the red marker

1 days in advance



24hr rainfall forecast to 10:00pm AEST July 4 2022 (run on July 3 2022). The location of Maitland is indicated by the red marker

Paul Fox-Hughes, Dragana Rajak, Gabrielle Woodhouse

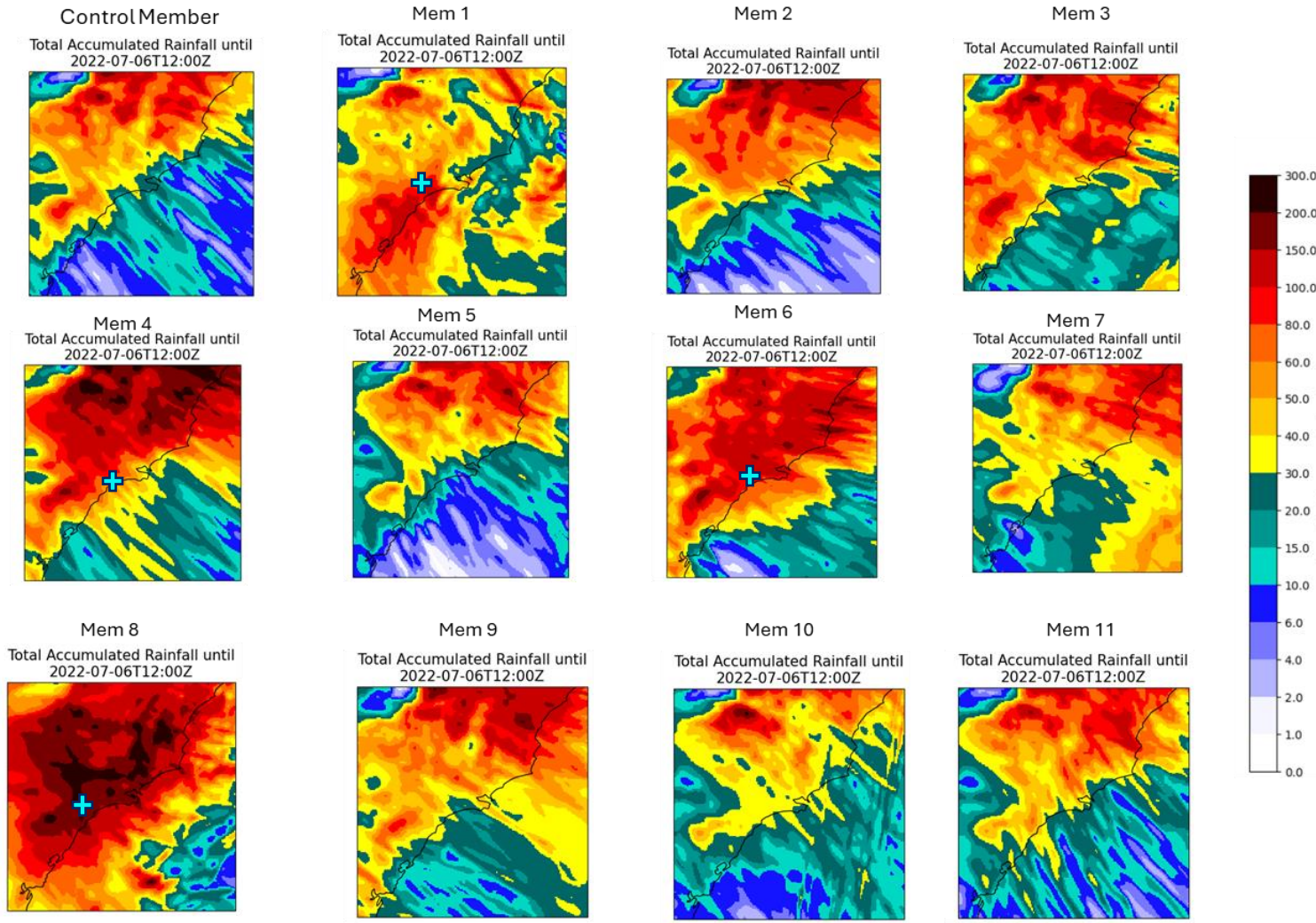
Preparedness

Case Study : Wallis Creek Flood – July 2022

Weather Forecasts – Uncertainty

Exploring the use of **high-resolution Ensemble models,** Bureau's **ACCESS-CE** models

- Provide uncertainty based on perturbations of initial conditions (physically based)
- Multiple scenarios allow
  - assessment of uncertainty
  - use in hydrological modelling
- Higher resolution than global models (1.5 kms, 10 minutes)
- Shorter latencies from run time than global models (+ 2 to 4 hours)
- Few updates per day (once every 6 hours)
- Widely used by flood and weather forecasters



12hr rainfall forecast to 22:00PM AEST July 6 2022 (run on July 5 2022 10AM AEST).

Preparedness

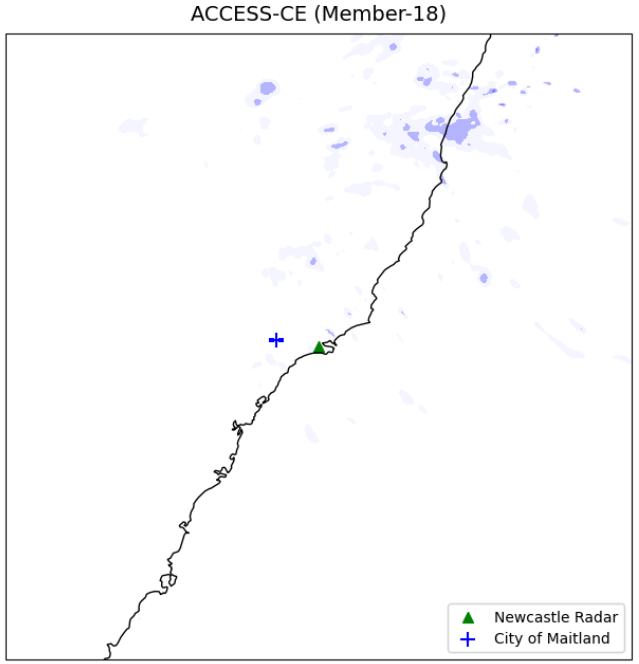
Case Study : Wallis Creek Flood – July 2022

Weather Forecasts – Uncertainty

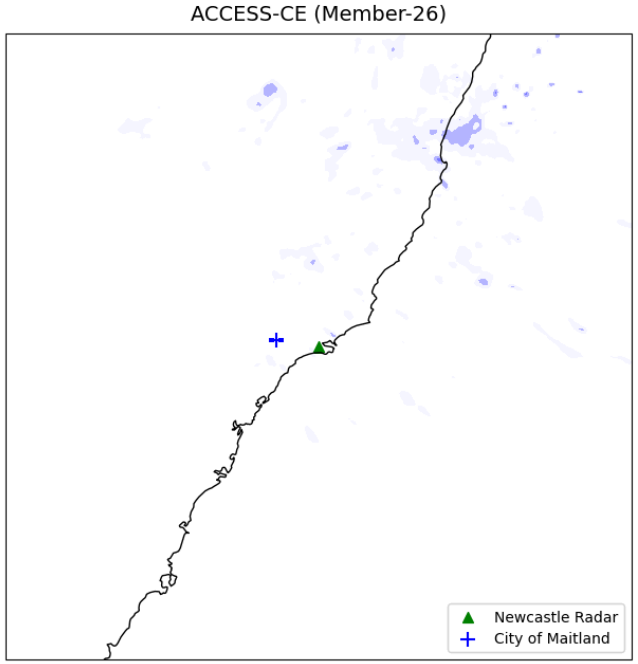
Exploring the use of **high-resolution Ensemble models,** Bureau's **ACCESS-CE** models

10-min rainfall fields accumulated from 2022-07-05T18Z to 2022-07-0712Z

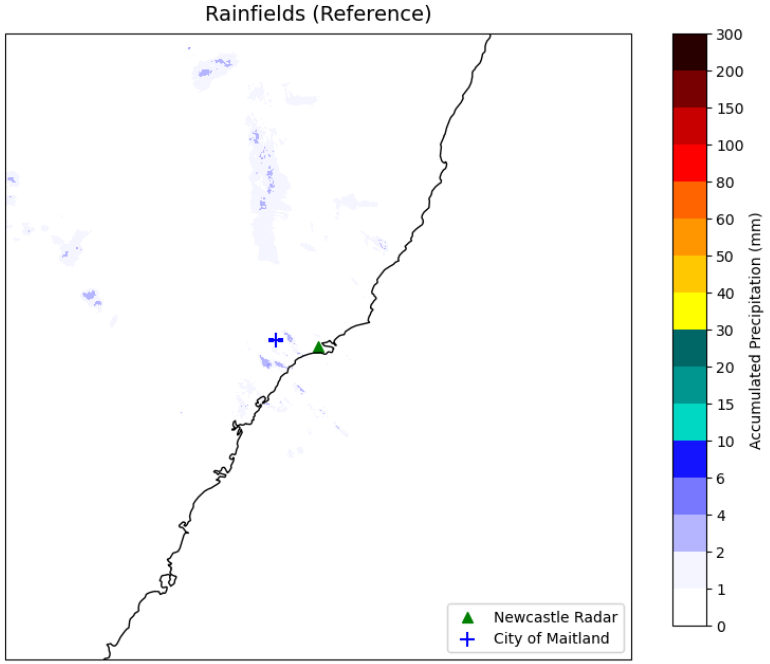
ACCESS-CE Member 18



ACCESS-CE Member 26



RADAR RAINFALL



Paul Fox-Hughes, Dragana Zovko-Rajak, Jayaram Pudashine

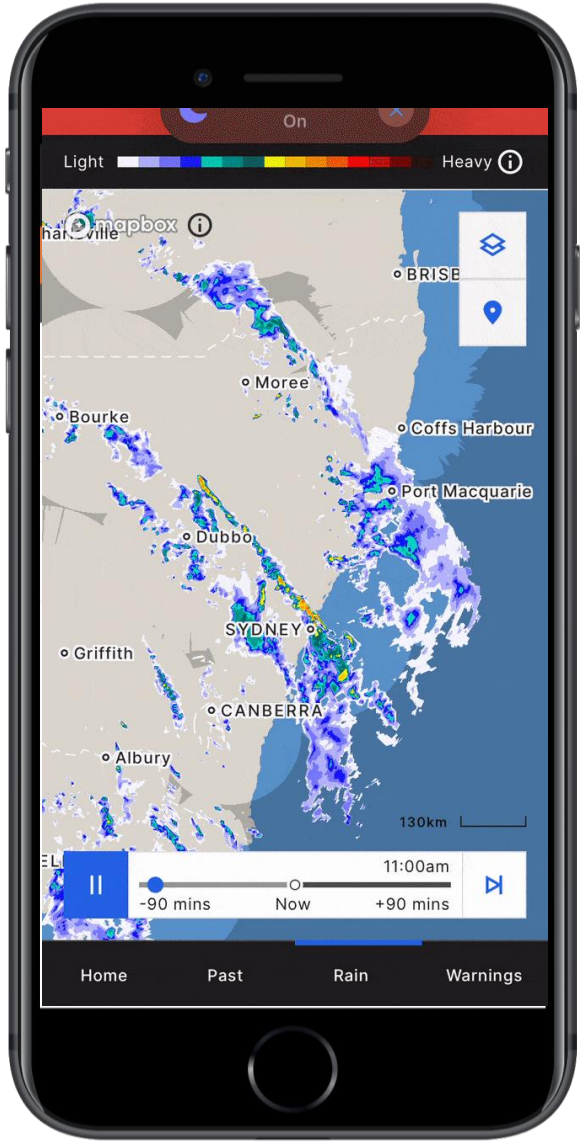
Real-time Rainfall Nowcasting

Response

Radar Rainfall nowcasts 5-min

Exploring the use of **radar rainfall nowcasting**

- Bureau's STEPS system
- Provide **ensemble** of rainfall predictions for the next few hours **based on latest radar observations**
- Multiple scenarios allow
  - assessment of uncertainty
  - use in hydrological modelling
- **Small latencies** from run time (+ 5 to 10 minutes)
- **Numerous updates per hour** (one update every 5 minutes)
- "Informed" stochastic perturbations
- One of the members available for everyone in **Bureau's Weather Apps**



BOM

Download on the App Store

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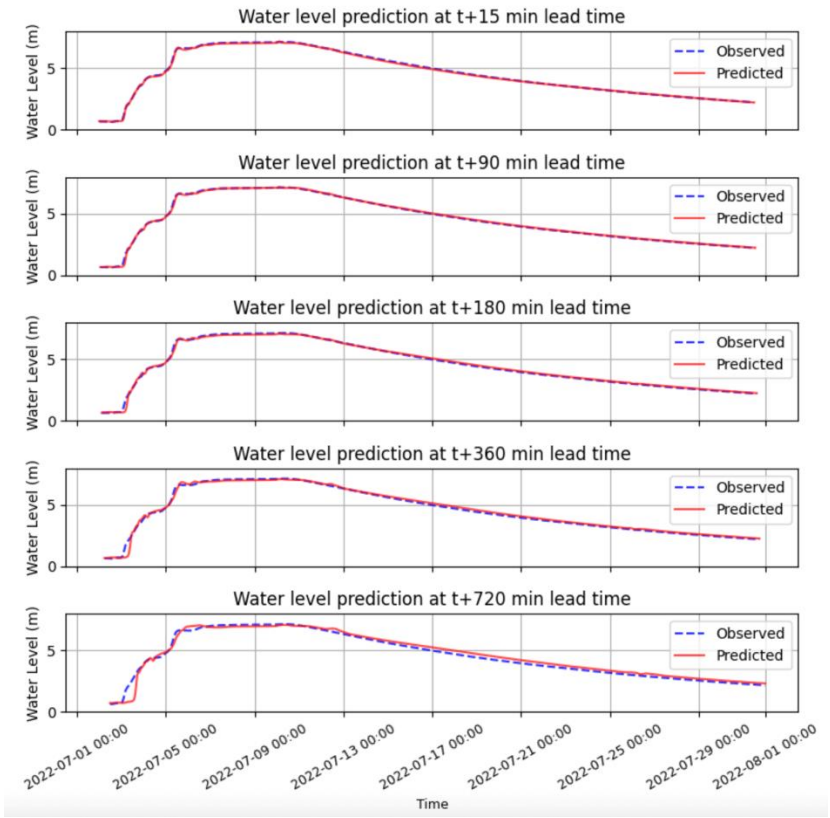
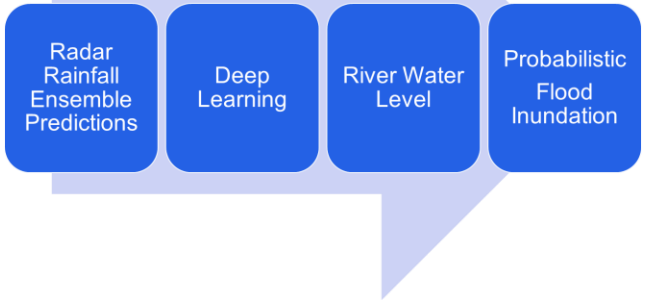
Jayaram Pudashine and Carlos Velasco

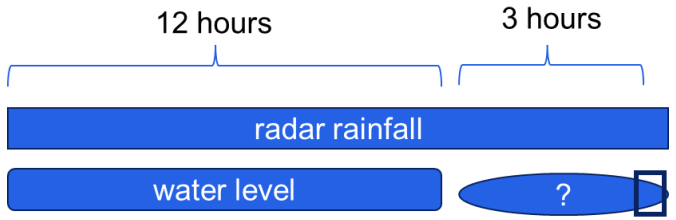
Case Study : Wallis Creek Flood – July 2022 Inundation Maps

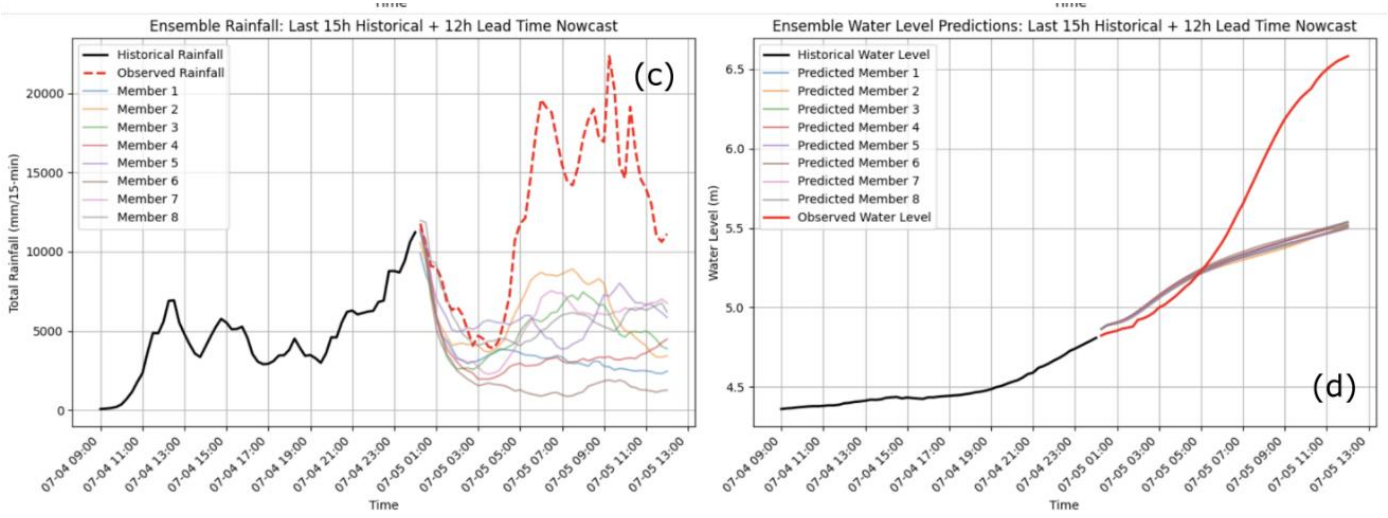
Response

Testing the use of Long Short Term Memory (LSTM) (and potentially Convolutional LSTM (ConvLSTM)) to **rapid** generation of water level forecasts







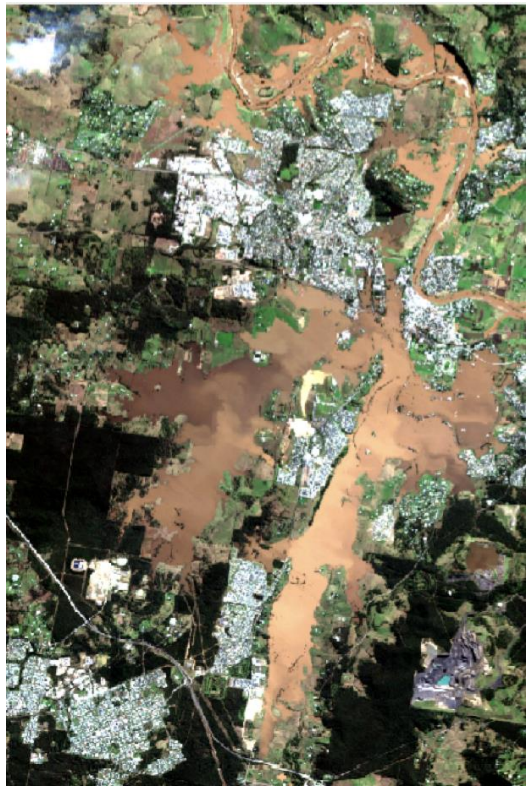


*Wendy Sharples, **Jiawei Hou**, Navid Ghajarnia, and Christopher Pickett-Heaps*

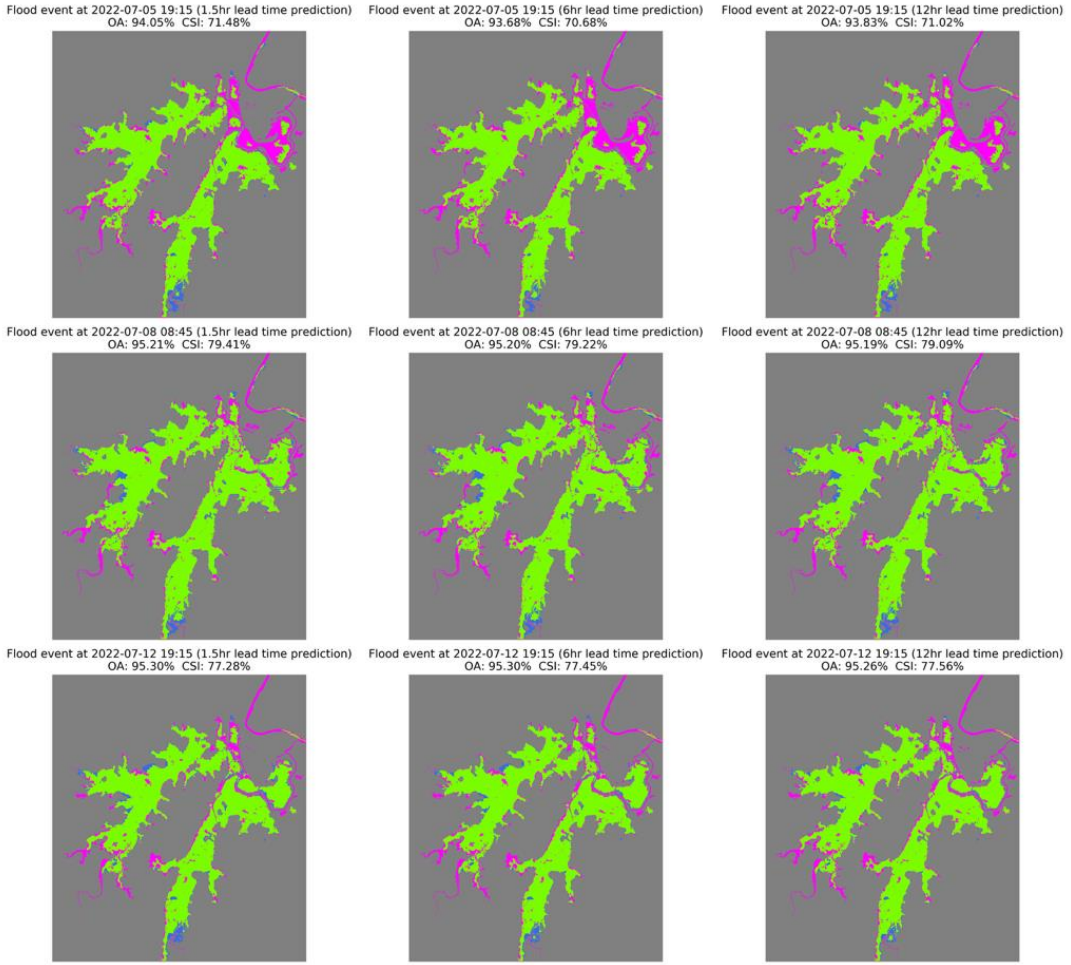
Case Study : Wallis Creek Flood – July 2022 Inundation Maps

Response

Testing the **rapid** generation of inundation maps from water level time series from rainfall forecasts



Copernicus, 8th July 2022



Comparison of LSTM model-predicted flood inundation maps with the Copernicus GFM Sentinel-1 flood map (left) for the July 2022 flood event

at lead times of 1.5 hours(left), 6 hours (center), and 12 hours (right)

(green: wet agreement; grey: dry agreement; pink: overestimation; blue: underestimation).

Wendy Sharples, ***Jiawei Hou,*** Foad Brakhasi

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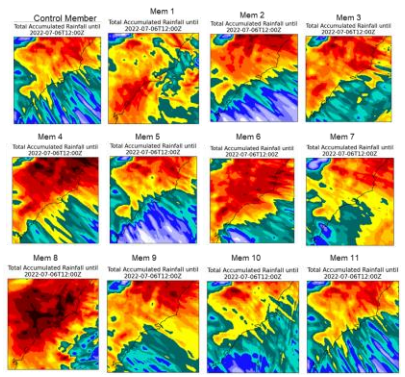

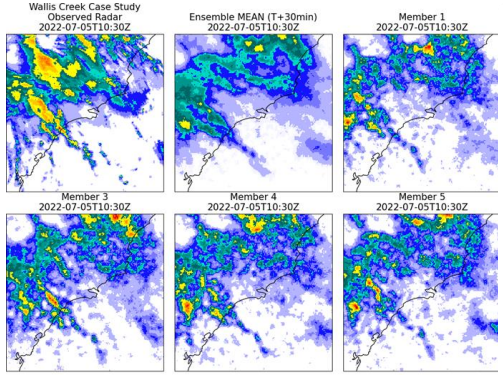

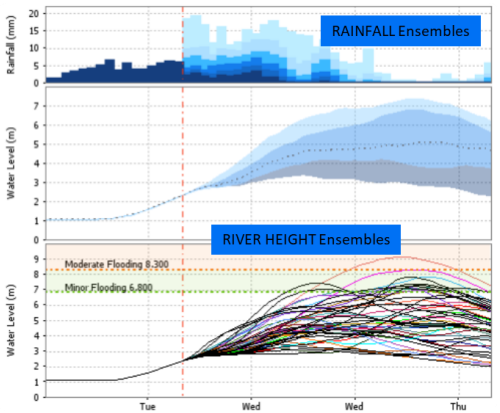

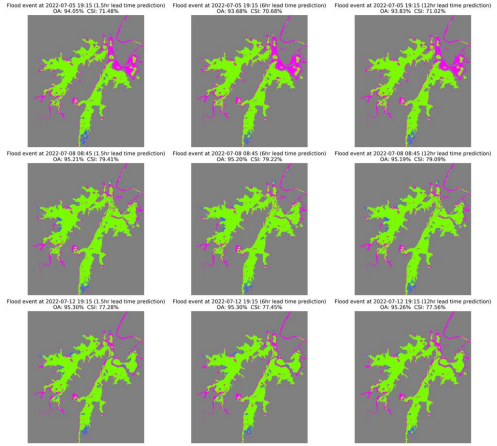

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Uncertainty

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Rapid updates
Local effects

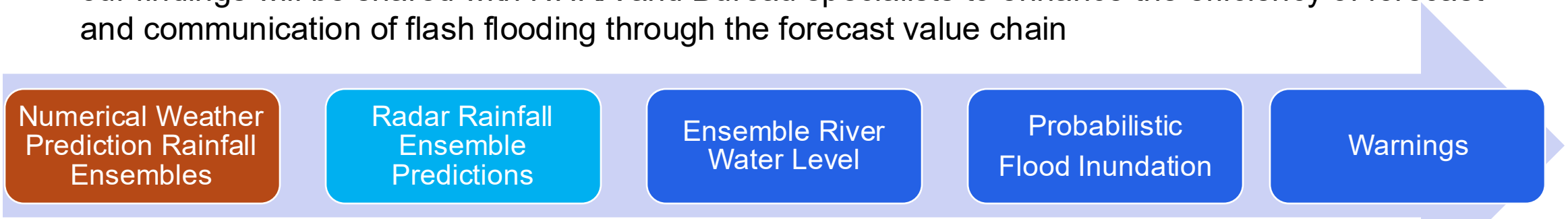
Response

Next Steps – Project NHRA T4-A7

- Assess additional events
  - The Wallis Creek (NSW) – July 2022 - heavy rainfall and inundation event (reassess)
  - Hobart, Tas - May 2018 – A high impact, exceptionally rare event of short duration (in progress)
  - Adelaide, SA - November 2023 - A comparatively lower impact, more common event of short duration

- Assess additional products to facilitate the understanding of uncertainty that provide emergency management personnel with context for forecasts and warnings issued by the Bureau of Meteorology. For example, next generation of Bureau's high resolution model (ACCESS-AE)
- Implement and test ML/DL model of WL prediction connected with ensemble forecast and nowcast rainfall
- Connect inundation map generation with ML/DL WL predictions

- This is a **research** project, so unfortunately do not expect a new widget in our Bureau App, but
  - our findings will be shared with NHRA and Bureau specialists to enhance the efficiency of forecast and communication of flash flooding through the forecast value chain



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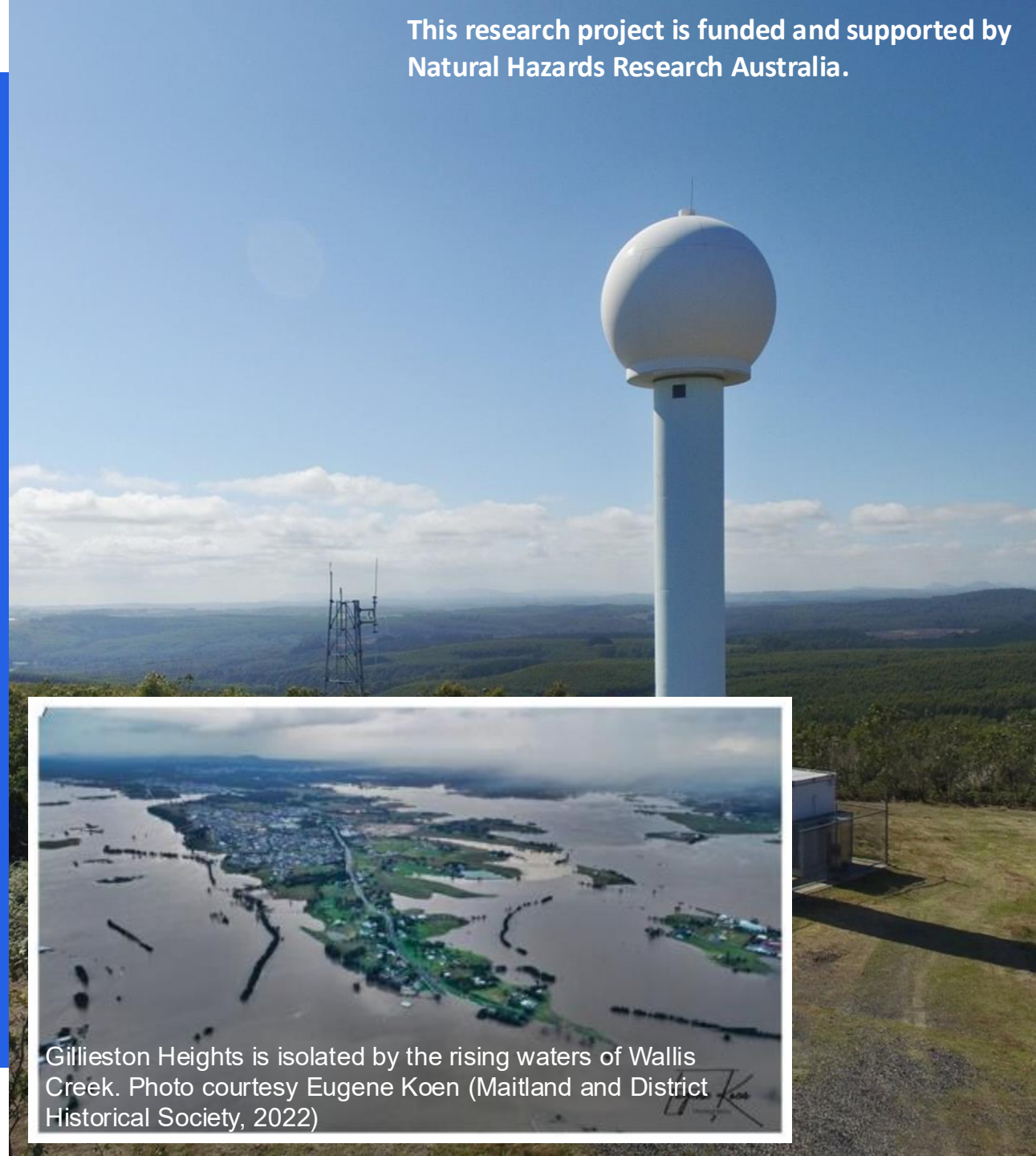

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