bushfire&natural HAZARDSCRC

IMPROVING FLOOD FORECAST SKILL USING REMOTE SENSING DATA

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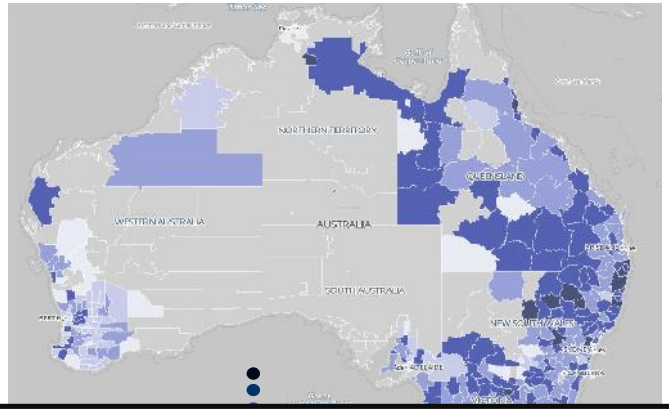
SES NSW STATE EMERGENCY SERVICE

THE COST OF FLOODS

1) Average annual cost for the last 40 years: **$377M/year**

2) More fatalities from floods than any other hazard in Australia:
   - 1859 deaths from 1900 to 2015, **178 deaths have occurred since 2000** *(Haynes et al 2016)*
   - **35** confirmed deaths, **2010-2011** floods in **QLD** ($2.38 billion damage).
   - **5+** deaths, June **2016** floods in **QLD, NSW, TAS**.
   - **5+** deaths, March-April **2017** floods in **QLD, NSW**



A **timely, accurate flood forecast**
is essential to reduce flood related mortality and damages.

HOW DO WE FORECAST FLOODS?

CASCADE OF TWO NUMERICAL MODELS:

1. HYDROLOGIC MODEL:
Input: rain
Output: discharge hydrograph

2. HYDRAULIC MODEL:
Input: discharge hydrograph
Output: water depth and velocity at each point of the flooded area

Various sources of **uncertainties** (e.g. initial conditions, model structure and parameters) **hamper accurate flood forecast**.

There is a need for truth data to check, correct, and improve models predictive skill.

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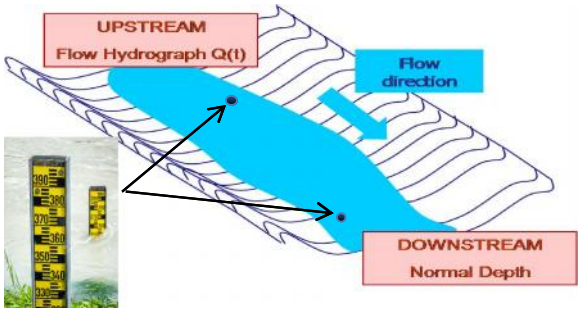
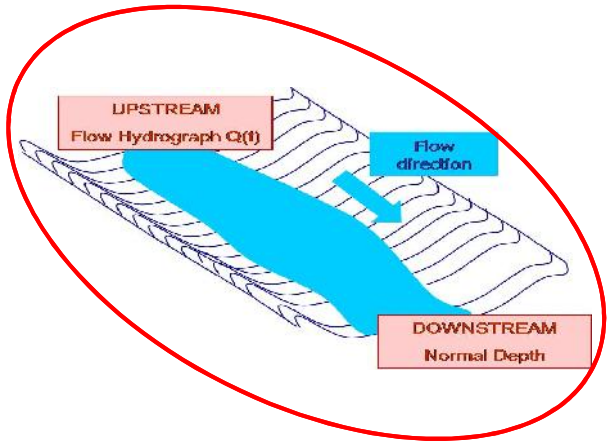
Available data for models improvement:





- **Field data:**
  - information at the **local** scale;
  - **only** gauged catchments.

- **Remote Sensing data:**
  - ✓ information at the **full** catchment scale;
  - ✓ **gauged and ungauged** catchments.

Spatially distributed **Remote Sensing data** offer **new opportunities** for flood events investigation and forecast.

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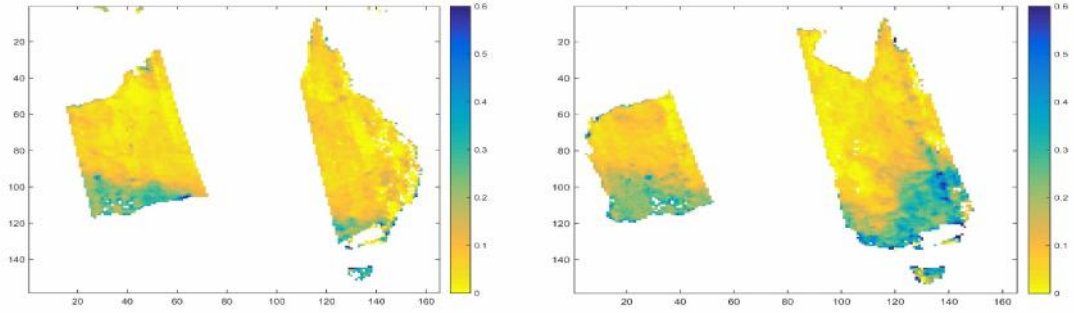
HYDROLOGIC MODEL

Remote Sensing SOIL MOISTURE

The initial wetness of the catchment affects the discharge output.



SMOS satellite coverage or

HYDRAULIC MODEL

Remote Sensing FLOOD EXTENT

Real time observations of flood extent allow the verification of the inundation forecast.

n (NSW), January 29th 2013

This innovative idea is being tested on two **Australian catchments**.

WHAT WE HAVE ACHIEVED: **STUDY BASINS**

Condamine-Balonne
(75370 sq. km)

Clarence
(20730 sq. km)

St. George, 2012 Feb 7th, http://www.abc.net.au

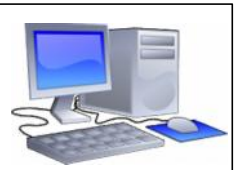
Grafton, 2013 Jan 30th, Mr. Williamson

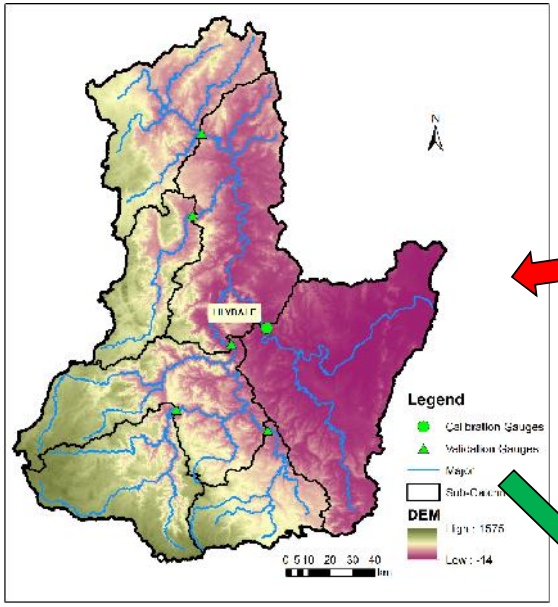
WHAT WE HAVE ACHIEVED: **HYDROLOGIC MODEL**

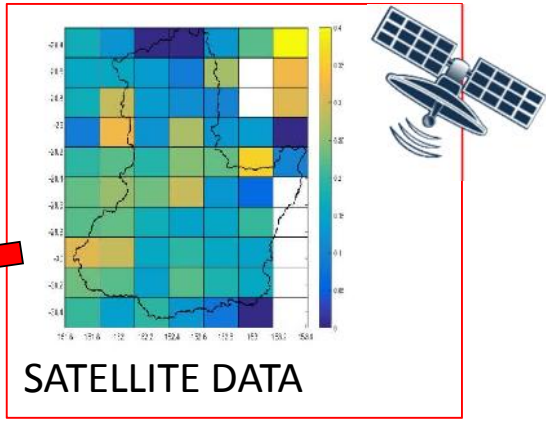
$$\frac{dV_t}{dt} = I_t - O_t$$

$$V_t = k \cdot [\mu \cdot I_t + (1-\mu) \cdot O_t]$$

NUMERICAL CODE



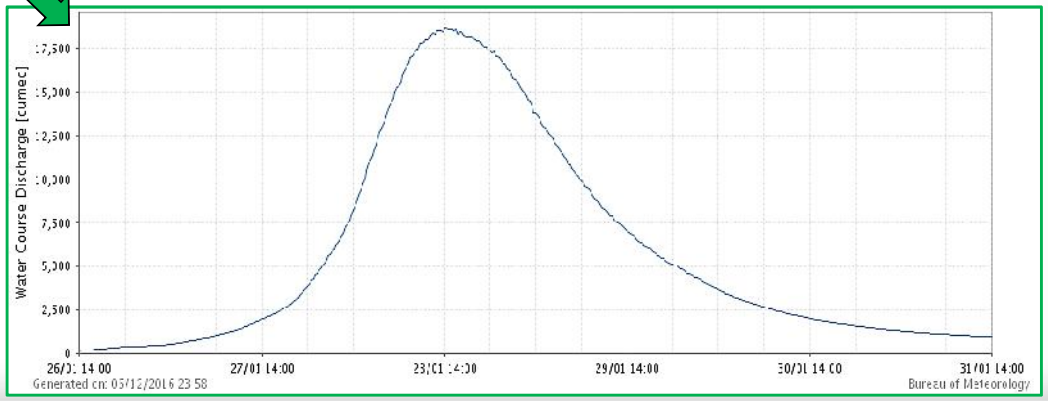




SATELLITE DATA

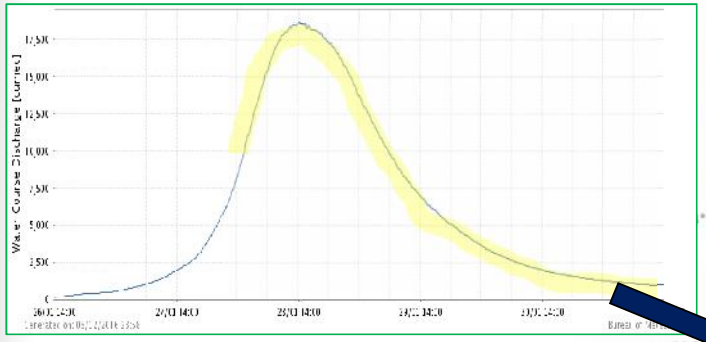
Remotely sensed soil moisture can improve discharge prediction.

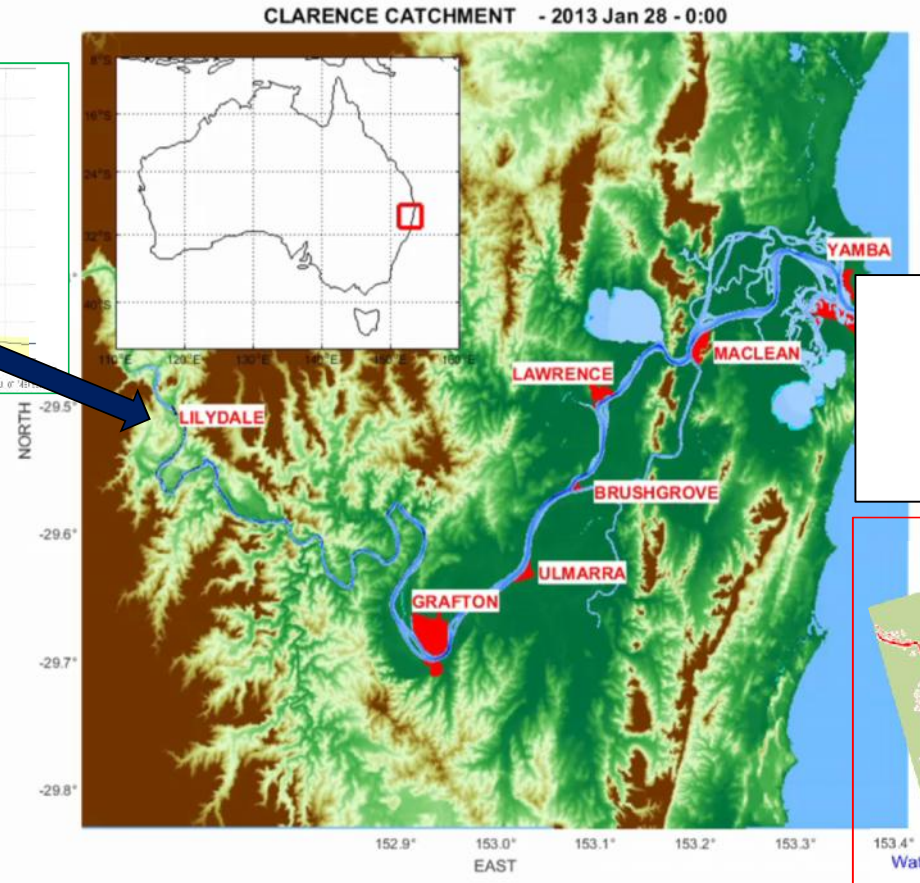
GAUGED DATA



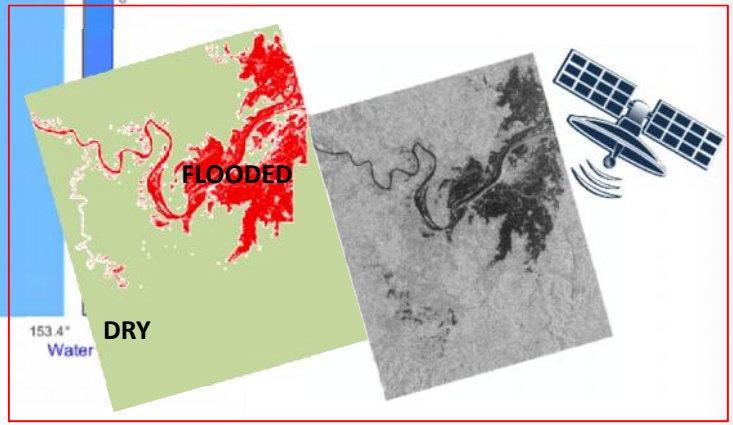
WHAT WE HAVE ACHIEVED: **HYDRAULIC MODEL**

HYDROLOGIC MODEL OUTPUT





Real time **Remote Sensing** observations of **flood extent** allow the **verification** of the inundation forecast.



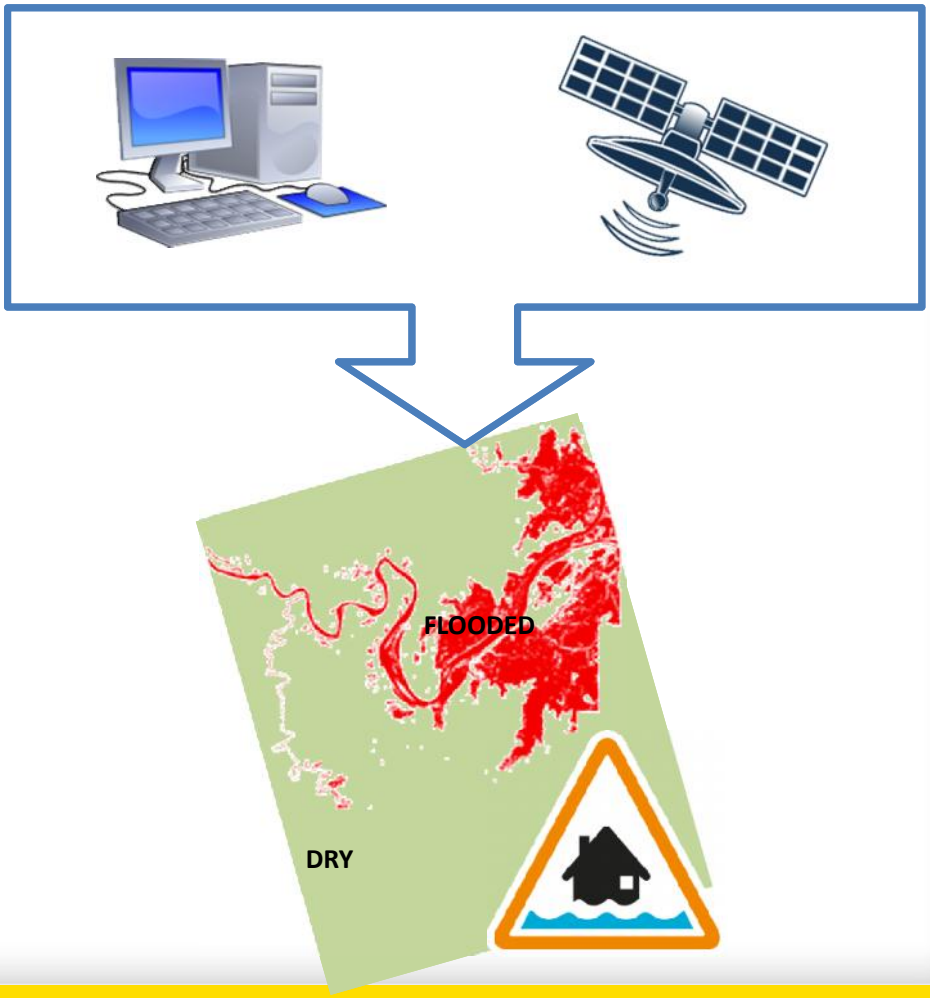
$$\begin{cases} \dfrac{\partial u}{\partial t} + u\dfrac{\partial u}{\partial x} = -g\dfrac{\partial \zeta}{\partial x} \\ \dfrac{\partial \zeta}{\partial t} = -\dfrac{\partial\left((H+\zeta)u\right)}{\partial x} \end{cases}$$

NUMERICAL CODE

WHAT ARE THE PROJECT OUTPUTS/PRODUCTS?

- An **integrated forecasting system** that consists of:
  - a coupled hydrologic-hydraulic model;
  - a satellite data integration module.

- Capability to deliver **flood inundation warnings.**



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NSW STATE EMERGENCY SERVICE

Geoscience Australia's need for surface water data

GA produces a Water Observations from Space (WOfS) product to help understand the frequency of surface water inundation across Australia.

The WOfS product provides a 30 year history of surface water observations that is used for water monitoring and the understanding of flooding.

However WOfS is based on optical satellite imagery which cannot see the ground through clouds.

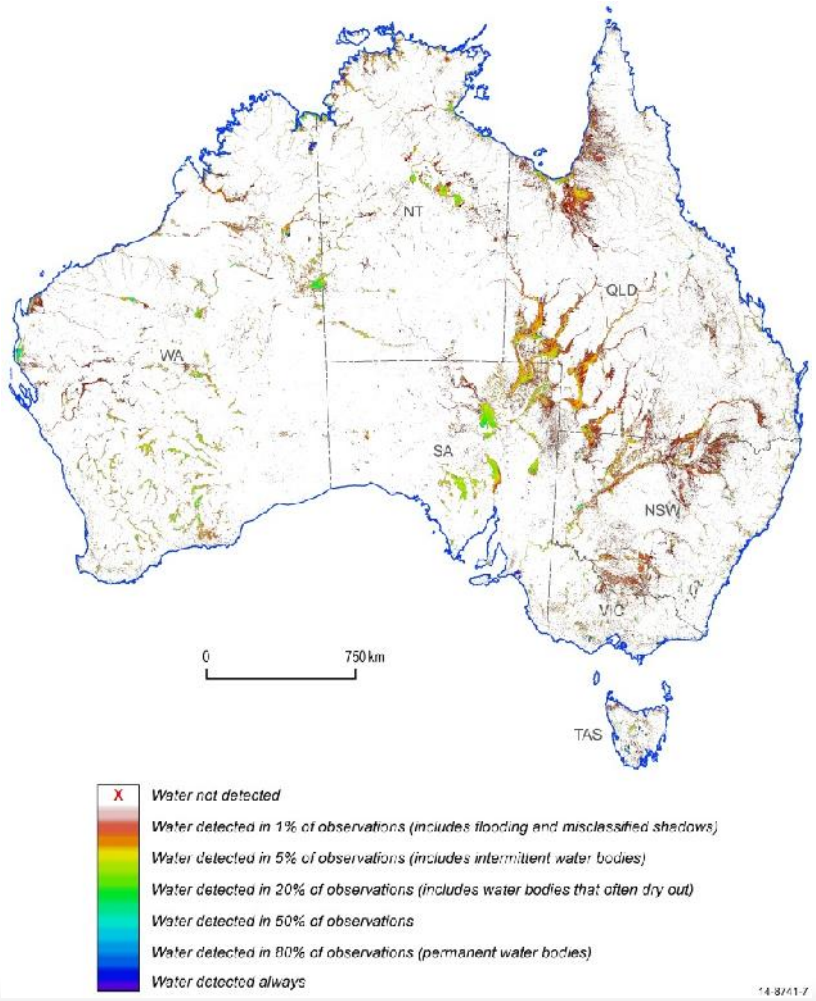
To create a better understanding of surface water and flooding, data are needed from satellites that can "see" through the clouds, especially as flooding and cloudy conditions go hand in hand.

Radar observations and subsequent modelling are expected to meet this need.

Water Observations from Space

The frequency of surface water observed by Landsat 5, 7 and 8 since 1987.

[WOfS Online Viewer]



GA's expected use of the BNH-CRC flood data

Over the last few years GA has provided flood extent maps to emergency services such as the NSW SES, derived from satellite imagery. However the data are often sporadic and badly affected by clouds.

GA sees the BNH-CRC work as a way to fill the gap between infrequent direct observations and more frequent products that can provide the flood extents when they are most needed.

Work demonstrated so far by the project has been extremely promising.

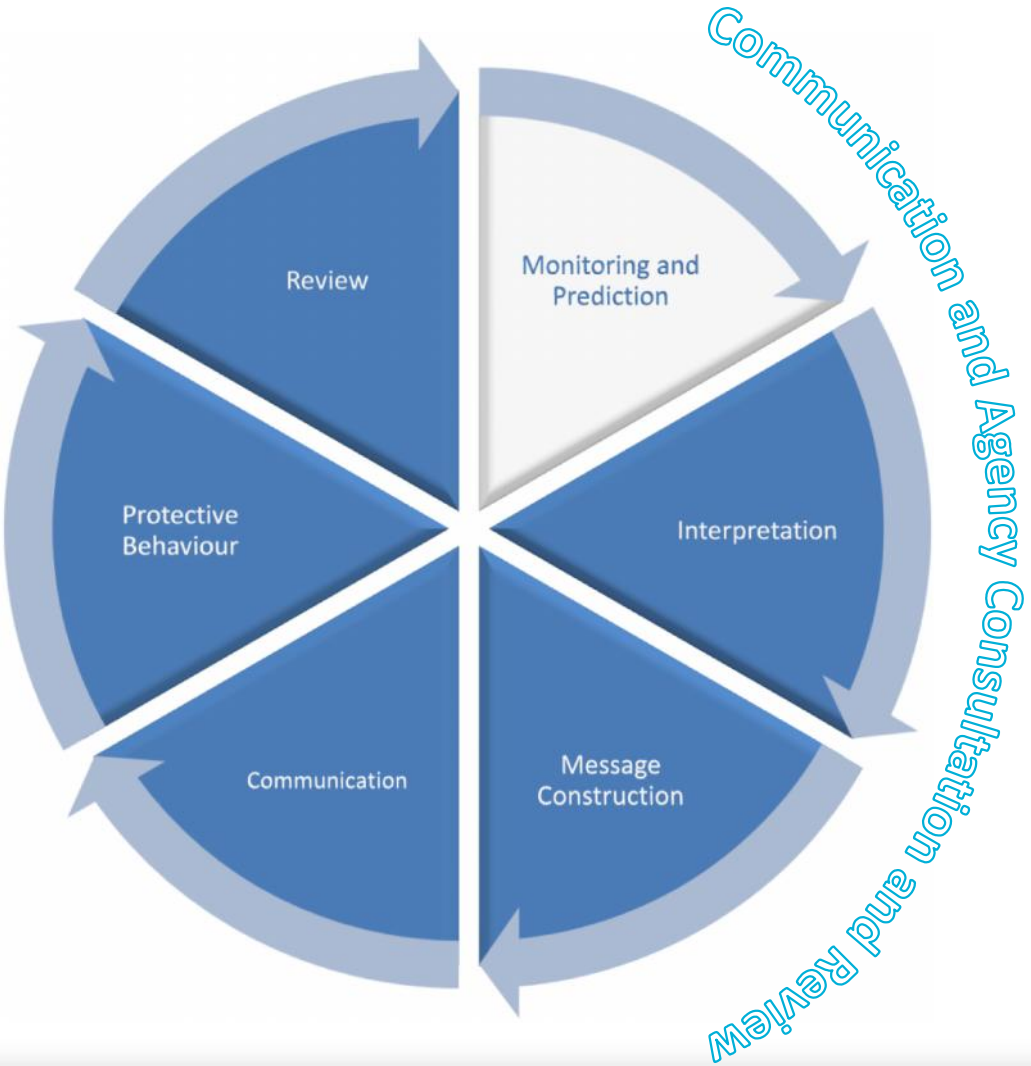
GA is hoping that this will provide code to detect surface water using the Sentinel-1 satellites, that can subsequently be implemented in Digital Earth Australia.

The Total Flood Warning System

Combines all levels of government including emergency services.

The Bureau's main involvement is in Monitoring and Prediction.

In each region the Flood Warning Consultative Committee (FWCC) meets twice a year.

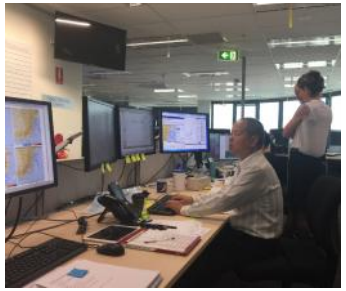


Flood warning service partnerships

Observations

Dam Operators

Forecasting



Bureau

Decision Making

Emergency Services

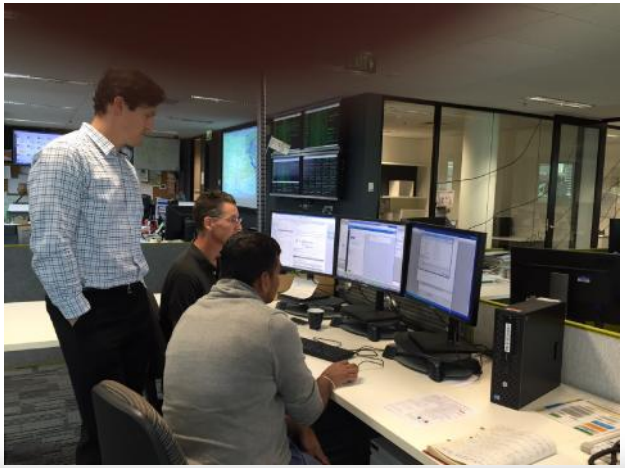
Response

Community

- The flood warning service is a partnership across all levels of government and the community.
- Strong working relationships are essential.
- Uncertainty needs to be understood by all.

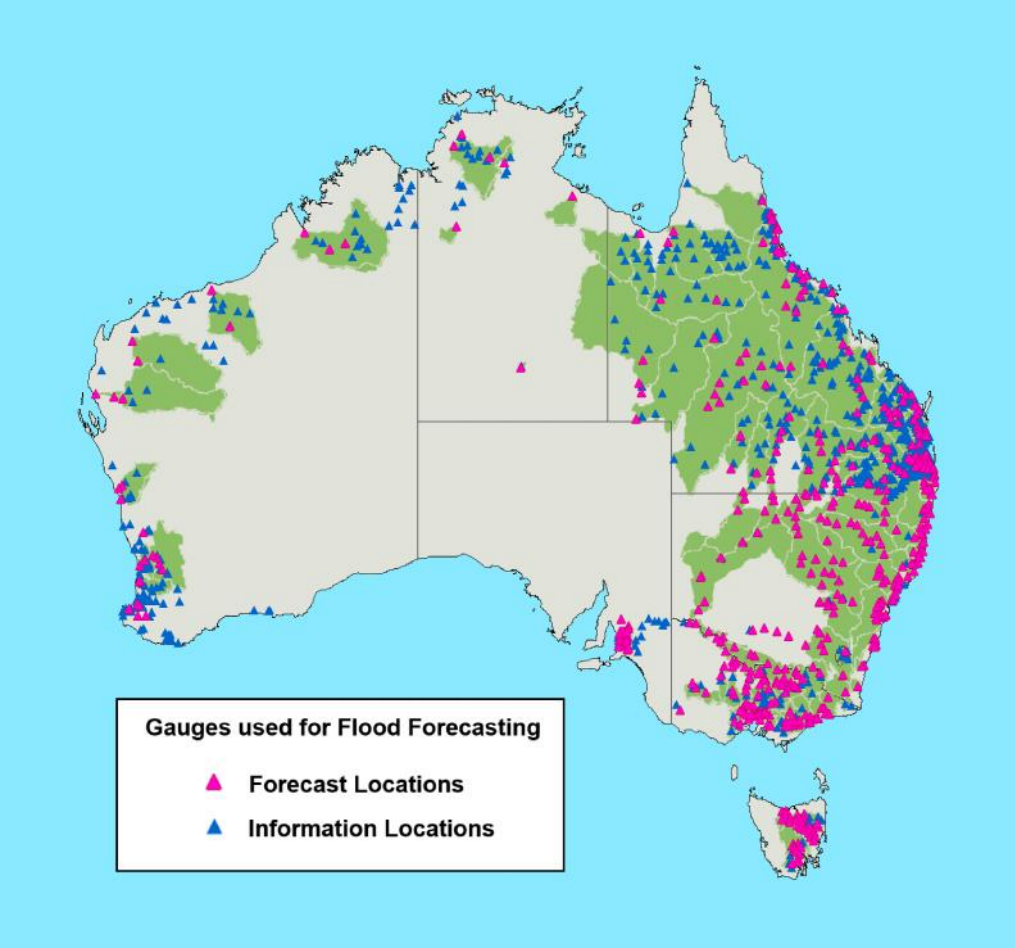
Flood Warning Services – What does the Bureau do?

- Measure rainfall data (and some river heights).
- Collect and publish real-time rainfall and river height data.
- Carry out routine monitoring of flood potential.
- Develop flood forecasting models and systems.
- Run flood models and provide predictions.
- Prepare and issue flood watches, flood warnings and river height predictions.
- Deliver briefings to Government, emergency management services and media.
- Maintain historical flood intelligence.
- Answer public queries.
- Maintain the Bureau's network of rain and river level gauges.



Where is our service?

- Models across most populated areas with additional methods and services in other areas.
- Around 500 Forecast Locations around the country.
- Over 800 Information Locations.
- Service Level Specifications for each State and Territory provide the details.

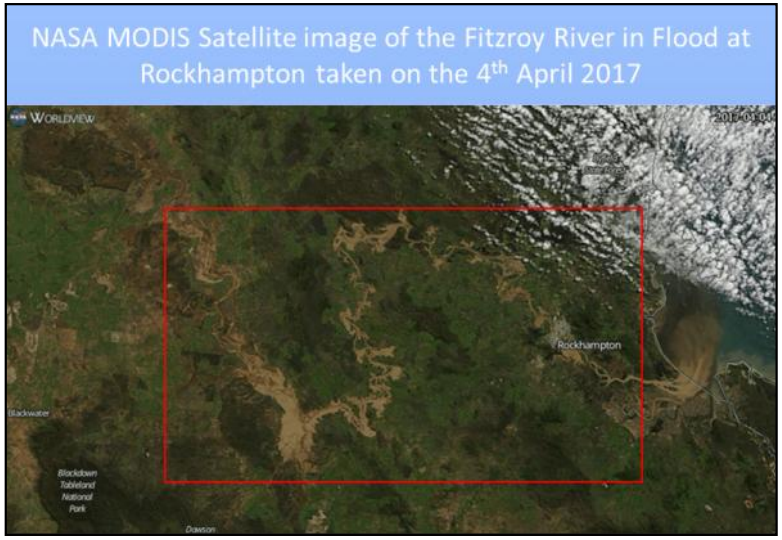


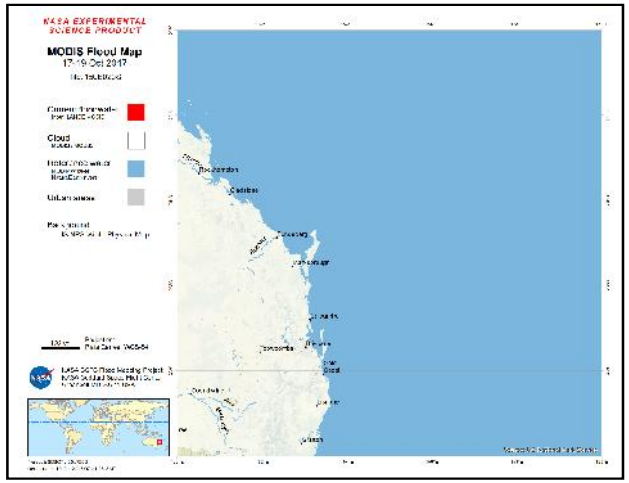
Current use of satellite data

- Opportunistic use of available flood extent data during flooding:
  - MODIS imagery used in tweets to help communicate flood extent (e.g. TC Debbie).
  - MODIS data used to track flood progression in WA in areas with little ground data.
  - MODIS data used in western Victoria during significant widespread flooding.

- Access to rapid scanning flood extent data with international support during flood disasters – activated during the 2011 Queensland floods.

- Use of soil moisture data to calibrate the Australian Water Resource Assessment Landscape model.



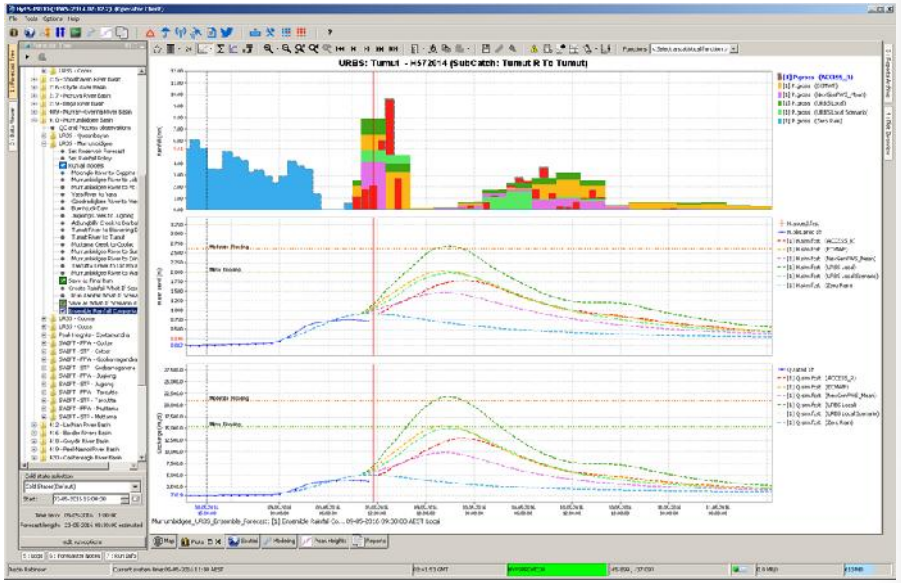


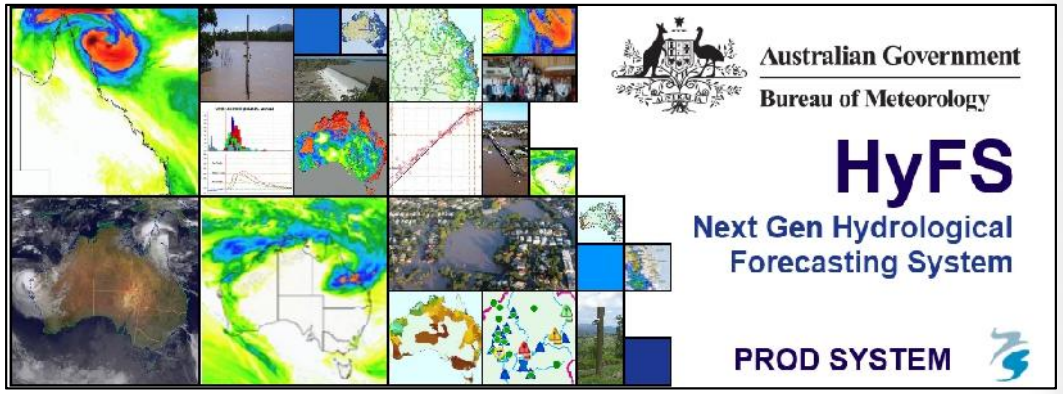
https://floodmap.modaps.eosdis.nasa.gov/Australia.php

HyFS – one national system

- HyFS is our Hydrological Forecasting System.
  - Flood forecasting and warning services.
  - Short-term streamflow forecasting services.

- Combines rainfall forecasts with observations (rain and river) and catchment conditions.
  - Used as inputs to hydrologic models.
  - Forecaster experience to interpret outputs.
  - Includes other tools such as hydrographs from previous floods and correlations.
  - All this information is used to provide the official forecast.



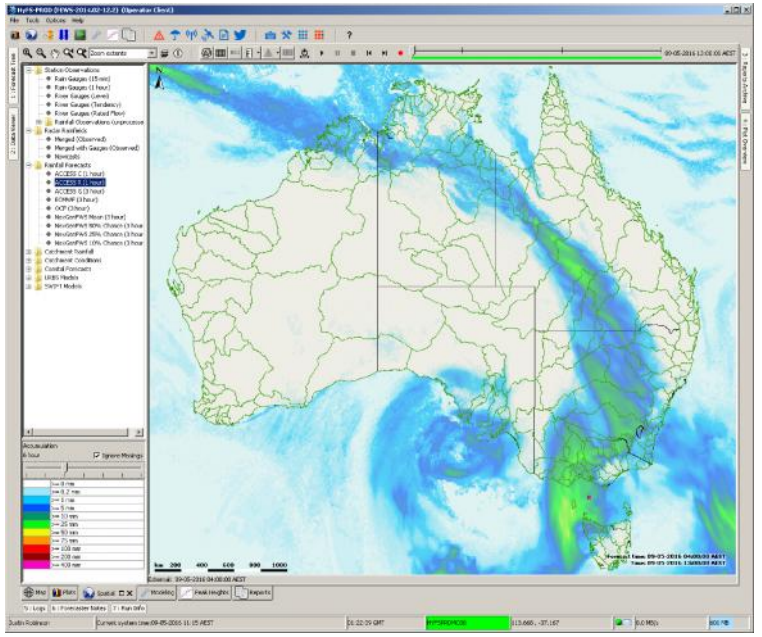


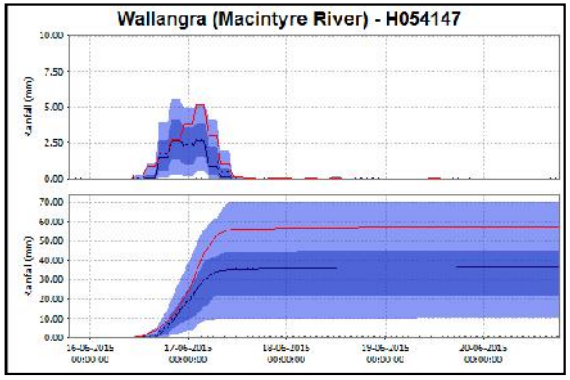
✓ Can evolve to use new approaches.

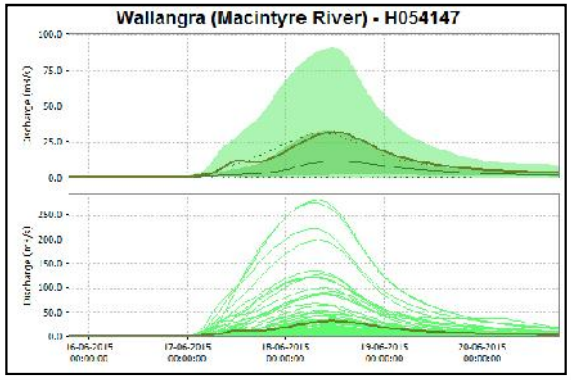
✓ Supports collaboration with agencies in Australia and overseas.

Planned modelling advances

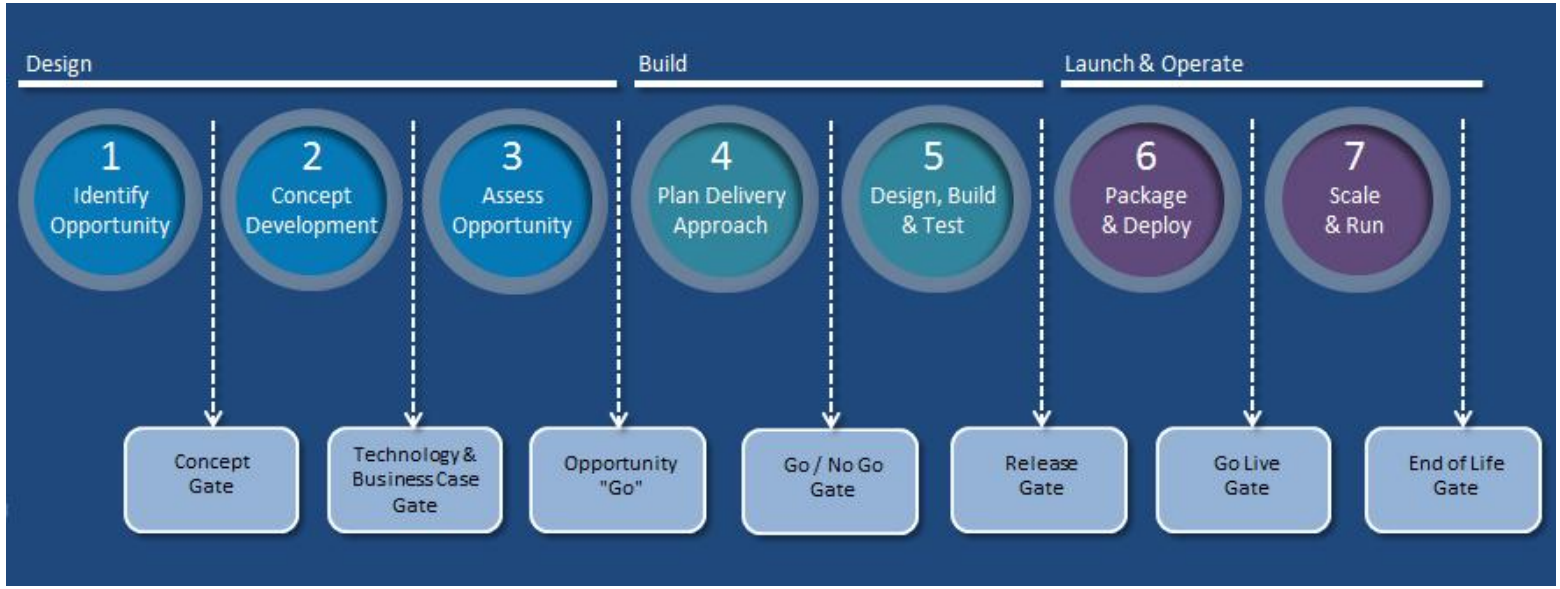
- Use of ensemble rainfall forecast as input to provide estimates of uncertainty.
- Continuous running of models instead of running only during events.
- Use of the AWRA-L continental water balance model to estimate initial losses.
- Investigating use of real-time hydraulic modelling for complex areas.







Path to operations through Bureau IT systems



- A stage gate model has been adopted to build consistency and standardisation across ICT development in the Bureau.
- The ICT Operating Model consists of seven stages, each with a stage gate that defines exit criteria required to be completed prior to moving to the next stage.
- While the flood forecasting modelling environment in FEWS is in a supported enterprise architecture, any significant additions with new data types etc. will be through this process.

Summary

- Floods are very difficult natural phenomena to model, even harder to predict.

  "Making predictions is very difficult, especially about the future."

- Models for the test site have been developed.
- A remote sensing flood detection algorithm is under way.

- The project will support GA and the BoM in a number of ways:
  - Help in the development of the Water Observations from Space product.
  - Help in the improvement of the Hydrologic Forecasting System.
  - Help to implement a hydraulic forecasting model in two pilot catchments.