# Verification of flood wave arrival time predictions using remote sensing-derived water levels

Stefania Grimaldi*, Ashley Wright, Jeffrey Walker, and Valentijn Pauwels.

*Stefania.Grimaldi@monash.edu

# Rationale, study aims, and hypothesis

- 2-Dimensional hydraulic models are essential tools for floodplain inundation modelling.
- Remote sensing-derived flood extent and level (at the wet/dry interface) have been increasingly used for the calibration and validation of hydraulic flood forecasting models.
- Due to their uncertainty and discrete temporal coverage, remote sensing-derived data have been so far seen as a complement to field data.

**This study presents a novel remote sensing (RS)-based methodology for the calibration of 2-Dimensional hydraulic flood forecasting models.**

The methodology was designed to meet the following criteria:

**1)** **only RS** data are employed for model calibration;

2) discrimination between underprediction and overprediction of flood wave **arrival time**;

3) limited **computational time**;

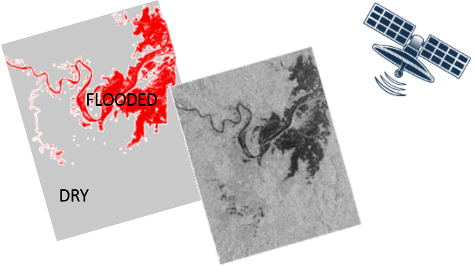
4) the selected parameter configuration has to be **robust** for different events.

Hypothesis for the application of the methodology:

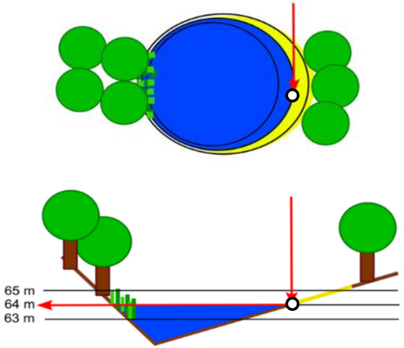
- roughness is the main parameter affecting flood dynamics.

**REMOTE SENSING-DERIVED**

**(a) FLOOD EXTENT**




**(b) WET/DRY BOUNDARY POINTS**



# RS-based calibration: workflow

1 **Initial set of model realizations with uniform river roughness** (n) values.

*E.g.: $n=0.015-0.035\ m^{1/3}\ s^{-1}$ ($\Delta n=0.0025\ m^{1/3}\ s^{-1}$)*

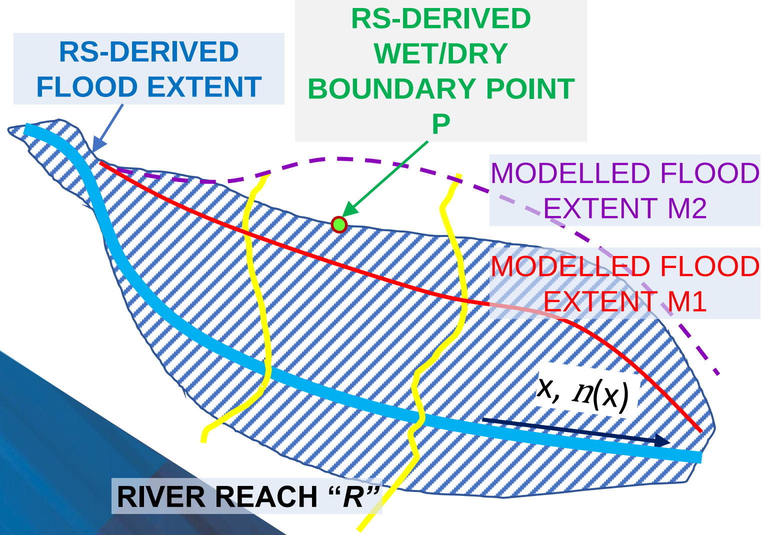
2 **Computation of the performance metrics.**

2a) RS-DERIVED WET/DRY BOUNDARY POINTS: **Space-Time-Score (new).**

2b) RS-DERIVED FLOOD EXTENT: binary performance metrics (literature).

3 **Computation of novel set of river roughness values.**

Steps 2 and 3 are repeated until there is no significant change in the computed river roughness values.




The Space-Time-Score (STS) quantifies:

- **how far** is the observed point P from the modelled flood extent (how far outside in M1/inside in M2) ;
- **how long it takes** for model M1 to reach P/for how long P was wet in model M2 → **VERIFICATION OF THE FLOOD WAVE ARRIVAL TIME**

STS<0 overestimation & early arrival time ($STS_o$, $n_o$)
STS>0 underestimation & late arrival time ($STS_u$, $n_u$)

The STS allows comparing the performances of different model realizations for each river reach "*R*".

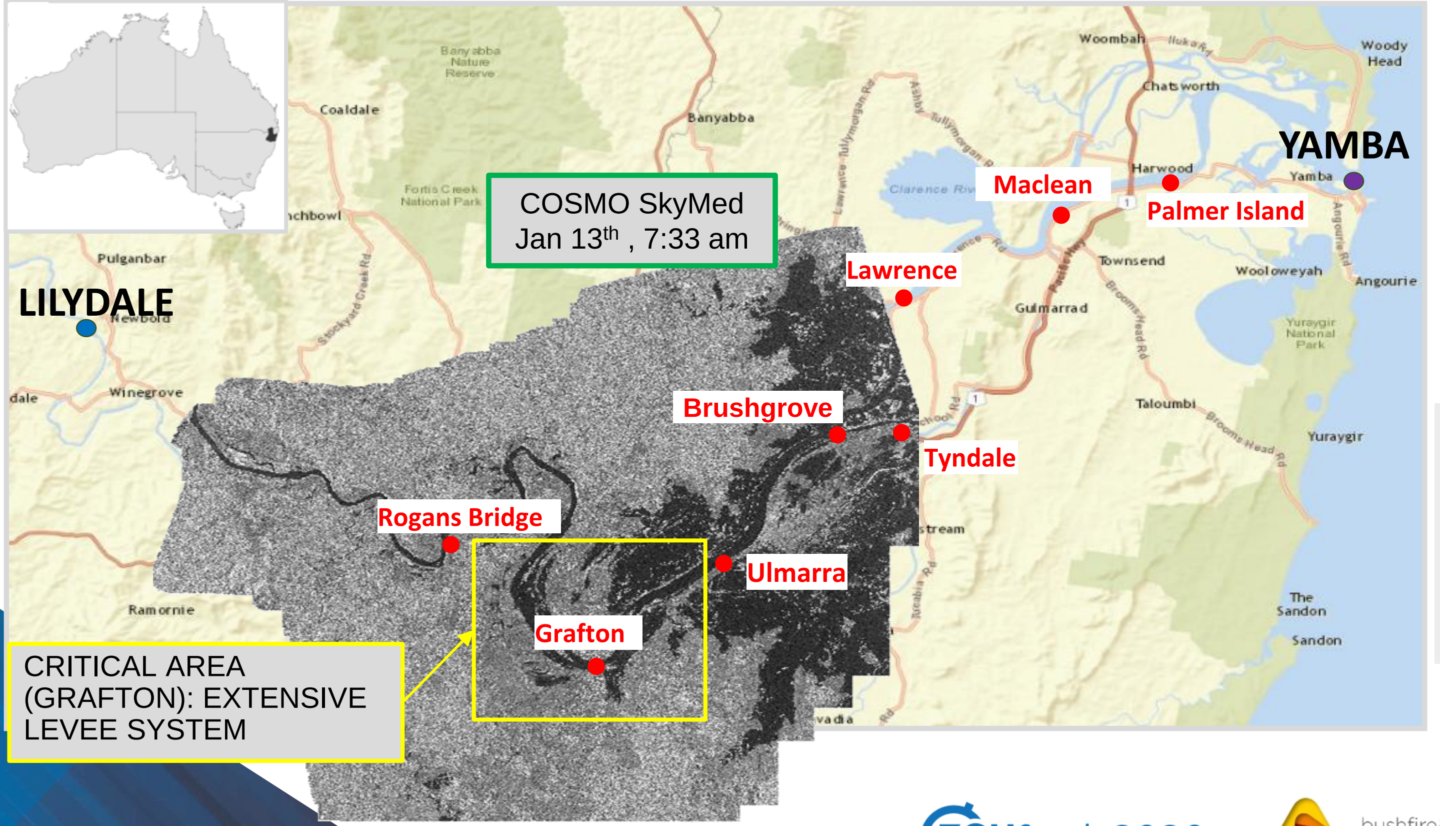
The novel roughness values aims to minimise the discrepancies between model and observations:

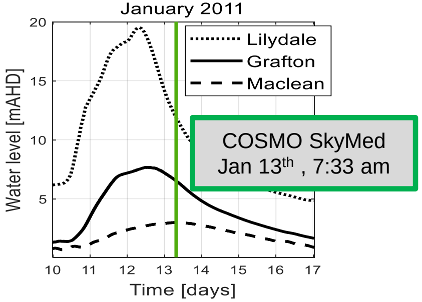
$$n_{new,"R"} = \frac{STS_u * n_o - STS_o * n_u}{STS_u - STS_o}$$

EGU General Assembly 2020 | bushfire&natural HAZARDS CRC | MONASH University

# Test case 1: Clarence River (Australia), January 2011

Remote Sensing observation: 1 high resolution image, good spatial coverage (63% of the modelled river length); which includes the critical area (Grafton); acquisition time: immediately after the flood peak.



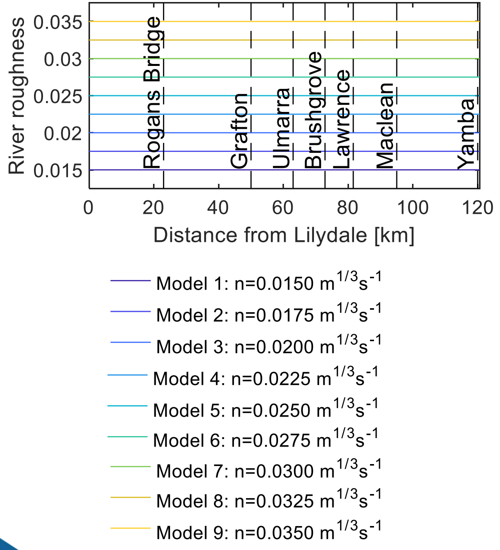

**Verification of the calibrated model:**

gauged time series of water level are used as independent validation dataset.

EGU General Assembly 2020 | bushfire&natural HAZARDS CRC | MONASH University

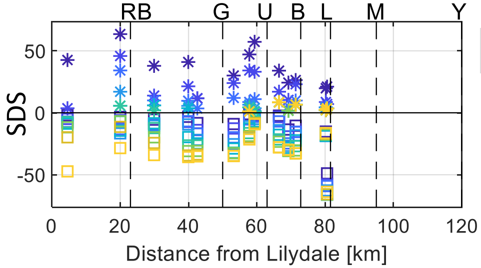
# RESULTS: 2011 flood – schematic of the application of the calibration algorithm

## 1 INITIAL SET OF MODEL REALIZATIONS




## 2 COMPUTATION OF THE PERFORMANCE METRICS using REMOTE SENSING data

### 2a RS-derived WET/DRY BOUNDARY POINTS

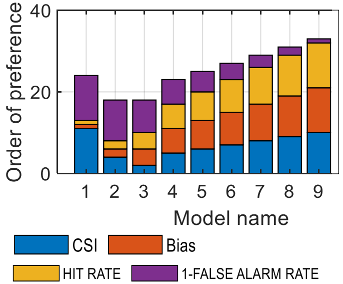



***UNDERESTIMATION***

***The closer to 0, the better***

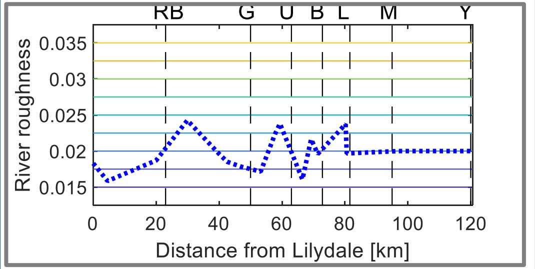
***OVERESTIMATION***

### 2b RS-derived FLOOD EXTENT

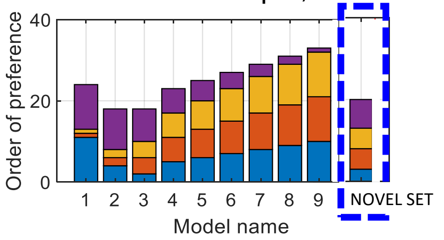



***The shorter the bar, the better***

## 3 COMPUTATION OF THE NOVEL SET OF RIVER ROUGHNESS VALUES



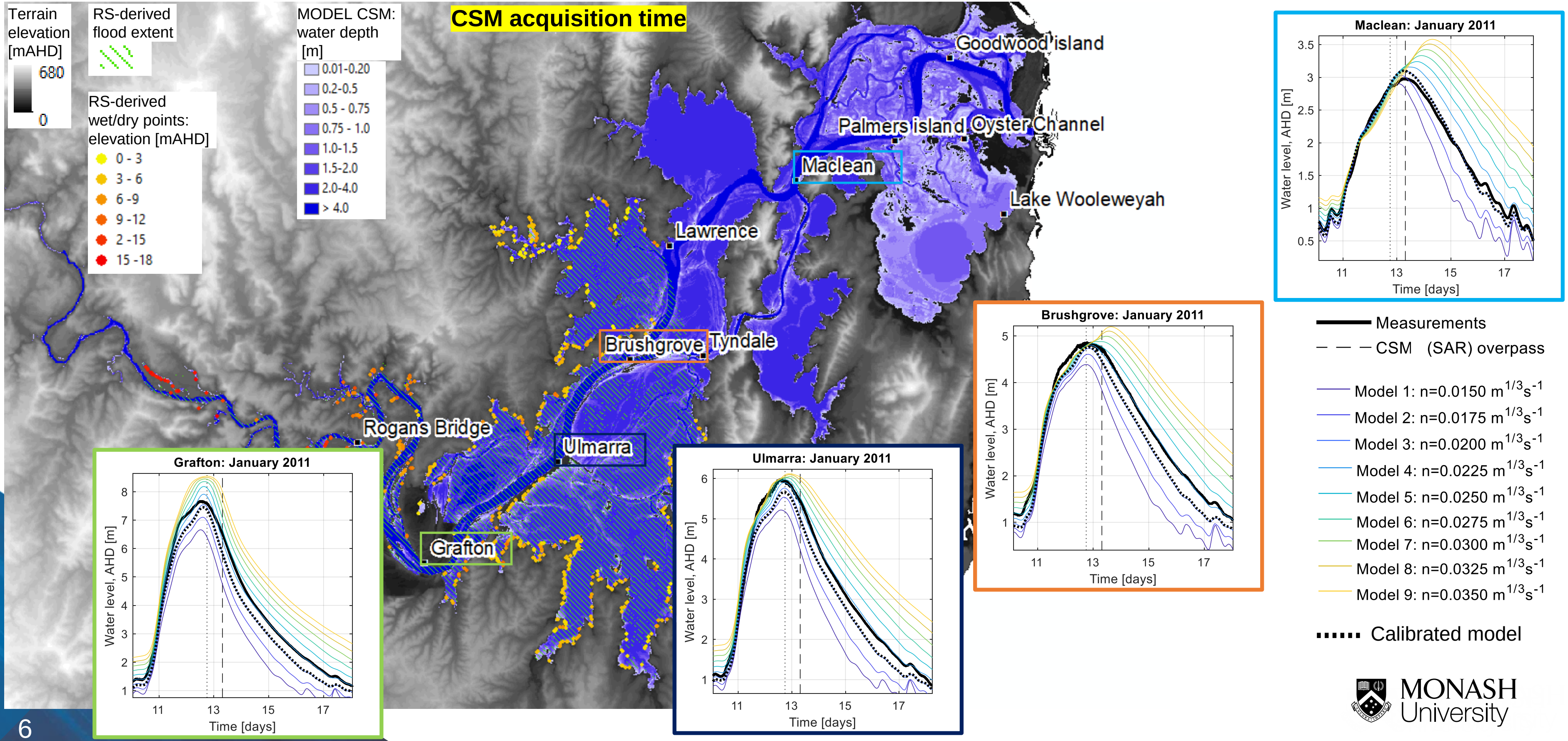

STEP 2 is used to evaluate the performances of the novel set of roughness values. Example, STEP 2b:




EGU General Assembly 2020 | bushfire&natural HAZARDS CRC | MONASH University

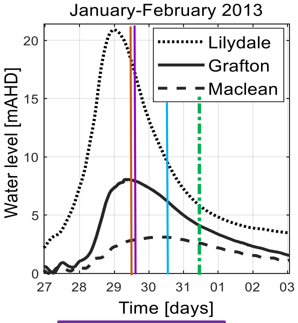
# RESULTS: 2011 flood – one "large" image including the critical area

**Calibrated model:** - comparison between modelled and RS-derived flood extent and wet/dry boundary points;
- comparison between modelled and gauged water level (independent validation dataset).



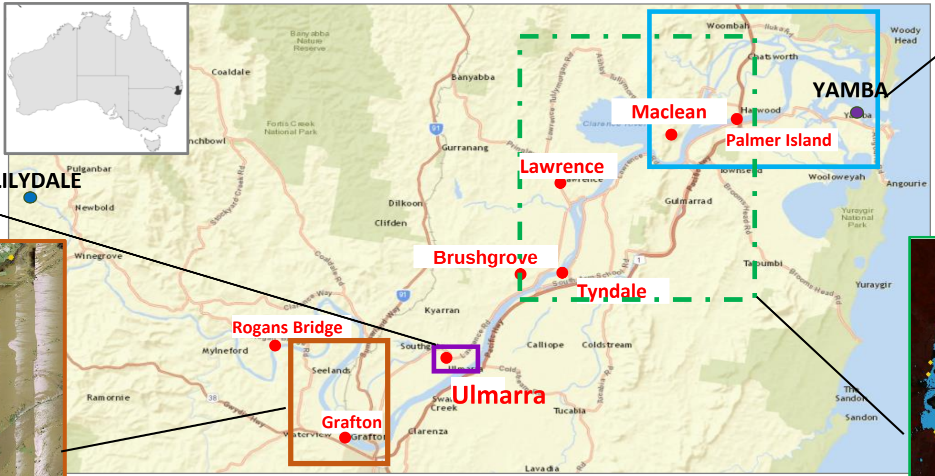

MONASH University

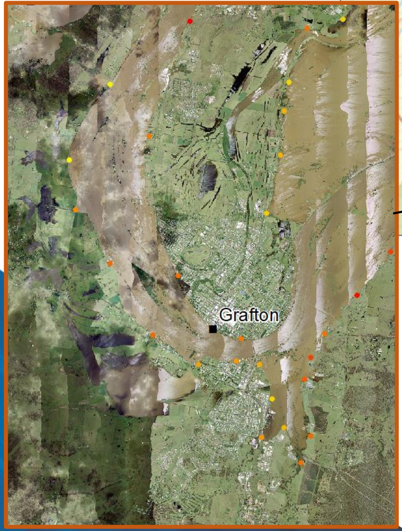
# Test case 2: Clarence River, January-February 2013

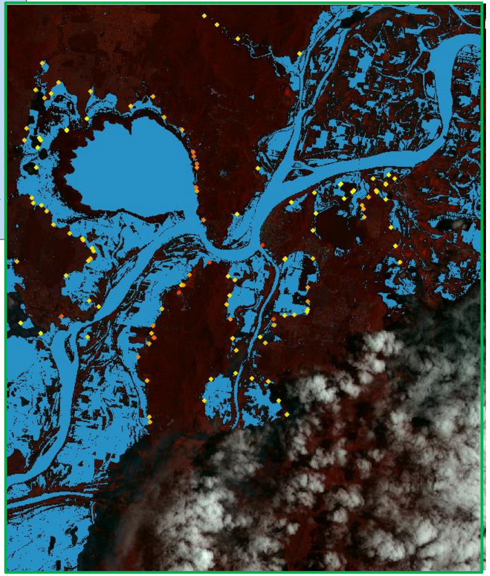



Remote Sensing observations: 4 high resolution images, with limited spatial coverage (up to 18% of the river length), all acquired after the flood peak.
Only one image included the critical area (Grafton).





RS-derived wet/dry points: elevation [m AHD]
- 0 - 3
- 3 - 6
- 6 -9
- 9 -12
- 2 -15
- 15 -18



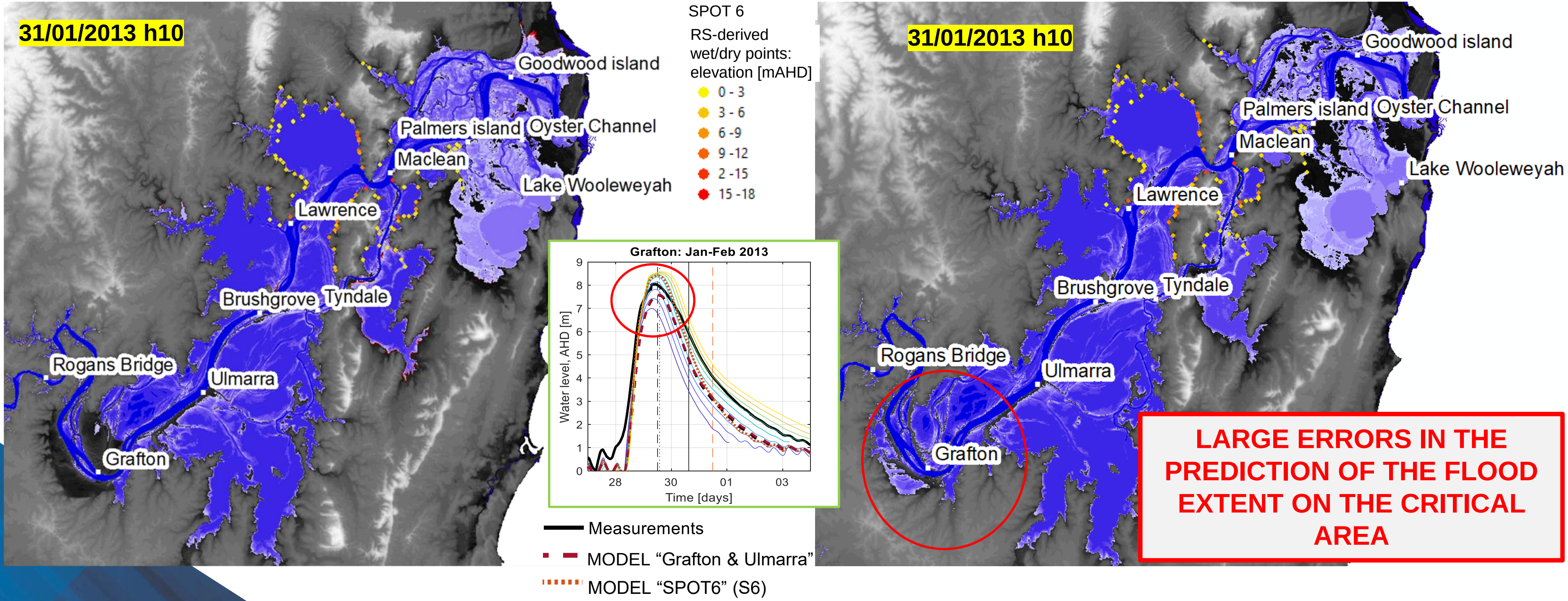
THE LEVEE SYSTEM WAS NEARLY OVERTOPPED

# RESULTS: 2013 flood – analysis of the importance of the acquisition footprint

Calibration using two small images (7.5% of river length) including **the critical area** (Grafton, levees): MODEL “Grafton & Ulmarra”

↔

Calibration using a larger image (18%) acquired **downstream of the critical area**: MODEL “SPOT6” [figures: wet/dry points from SPOT6, 31/01/2013 h10]



# Summary and future work

- This study proposed a calibration methodology that makes exclusive use of RS-derived observations and consequently enables model calibration in ungauged catchments.
- RS observations are used in a two-fold manner: **1) flood extent; 2) wet/dry boundary points.**
- A novel performance metric (named Space Time Score) was introduce to discriminate between underprediction and overprediction of flood dynamics (in space and time).
- Differently from a Monte-Carlo approach, this methodology requires a limited number of simulations. Nevertheless there is a potential caveat: the iterations stop when all the available information has been used (but the model could still have poor accuracy).
- The analysis of a number of scenarios demonstrated the **importance of the footprint of RS acquisitions.**
- The accuracy of RS-derived observation and terrain data clearly affects the effectiveness of the calibration exercise.
- Future research include:
  - the analysis of the impact of remote sensing uncertainty on the effectiveness of the calibration methodology.
  - the testing of a large number of case studies to investigate the impacts of different catchment morphologies, flood dynamics, image resolution and accuracy on the results of the calibration methodology.



EGU General Assembly 2020 | bushfire&natural HAZARDS CRC | MONASH University