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IMPROVED PREDICTIONS OF AUSTRALIAN EXTREME SEA LEVELS THROUGH A COUPLED WAVE-SURGE MODEL

AFAC 2016, Brisbane

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The University of Western Australia, WA

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Australian Government
Department of Industry,
Innovation and Science

Business
Cooperative Research
Centres Programme



THE UNIVERSITY OF
WESTERN
AUSTRALIA

PROJECT TEAM

Researchers

- Chari Pattiaratchi (UWA)
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- Ivan Haigh (University of Southampton, UK)
- Mathew Eliot (UWA, DamaraWA).
- Yasha Hetzel
- Ivica Janeković

Endusers

- R. Schwartz (Queensland)
- James Guy (SA)
- Kaylene Jones & David Hanslow (NSW)
- Steve Gray (WA)
- Bureau of Meteorology



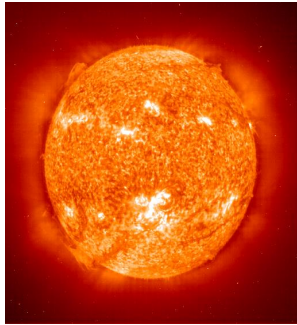
PROBLEM STATEMENT

- Potential impacts and hazards of extreme water level events along our coasts are significantly increasing.
- The occurrence of extreme water levels along low-lying, highly populated and/or developed coastlines can lead to loss of life and of damage to coastal infrastructure
- To better prepare, coastal engineers, emergency managers and planners require accurate estimates of extreme water levels.



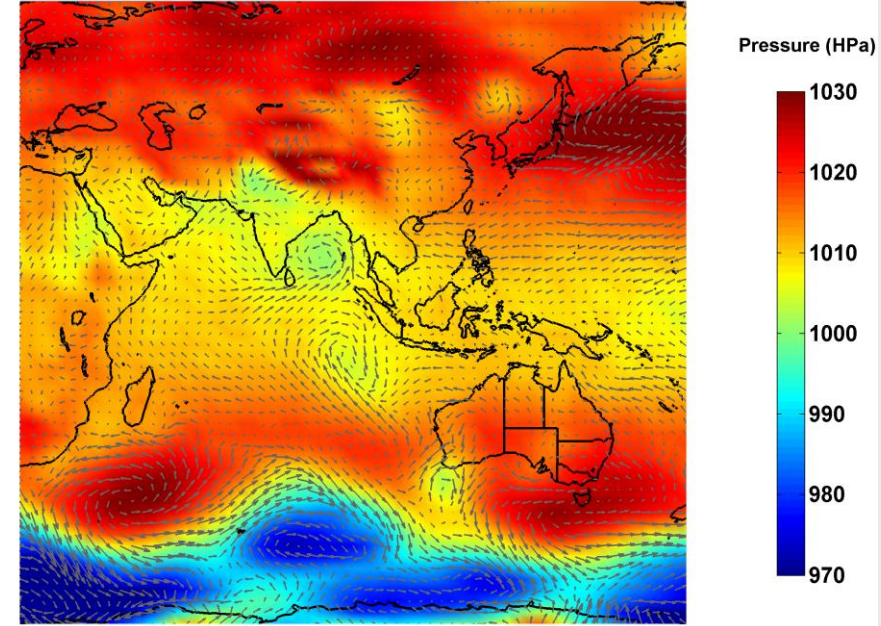
FORCING: A RANGE OF SPATIAL SCALES

Astronomical

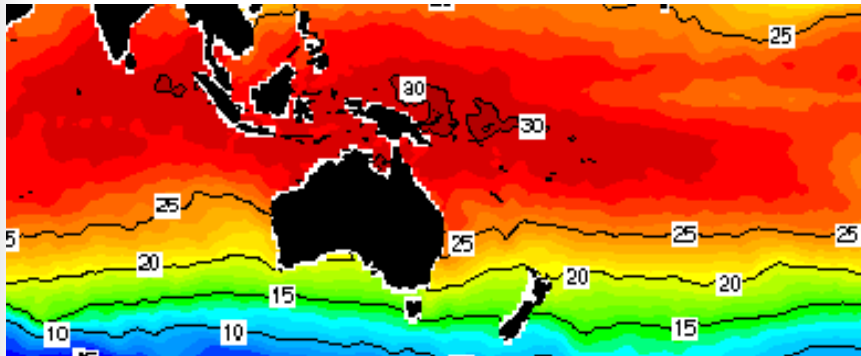


Meteorological

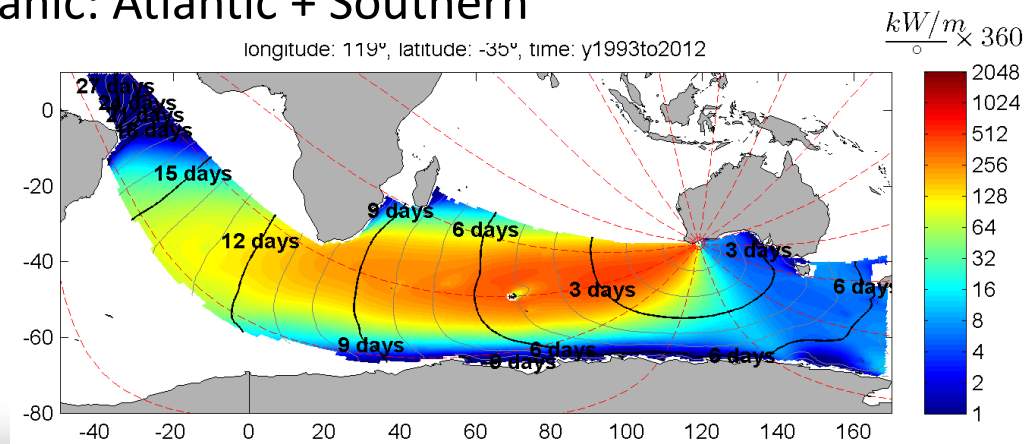
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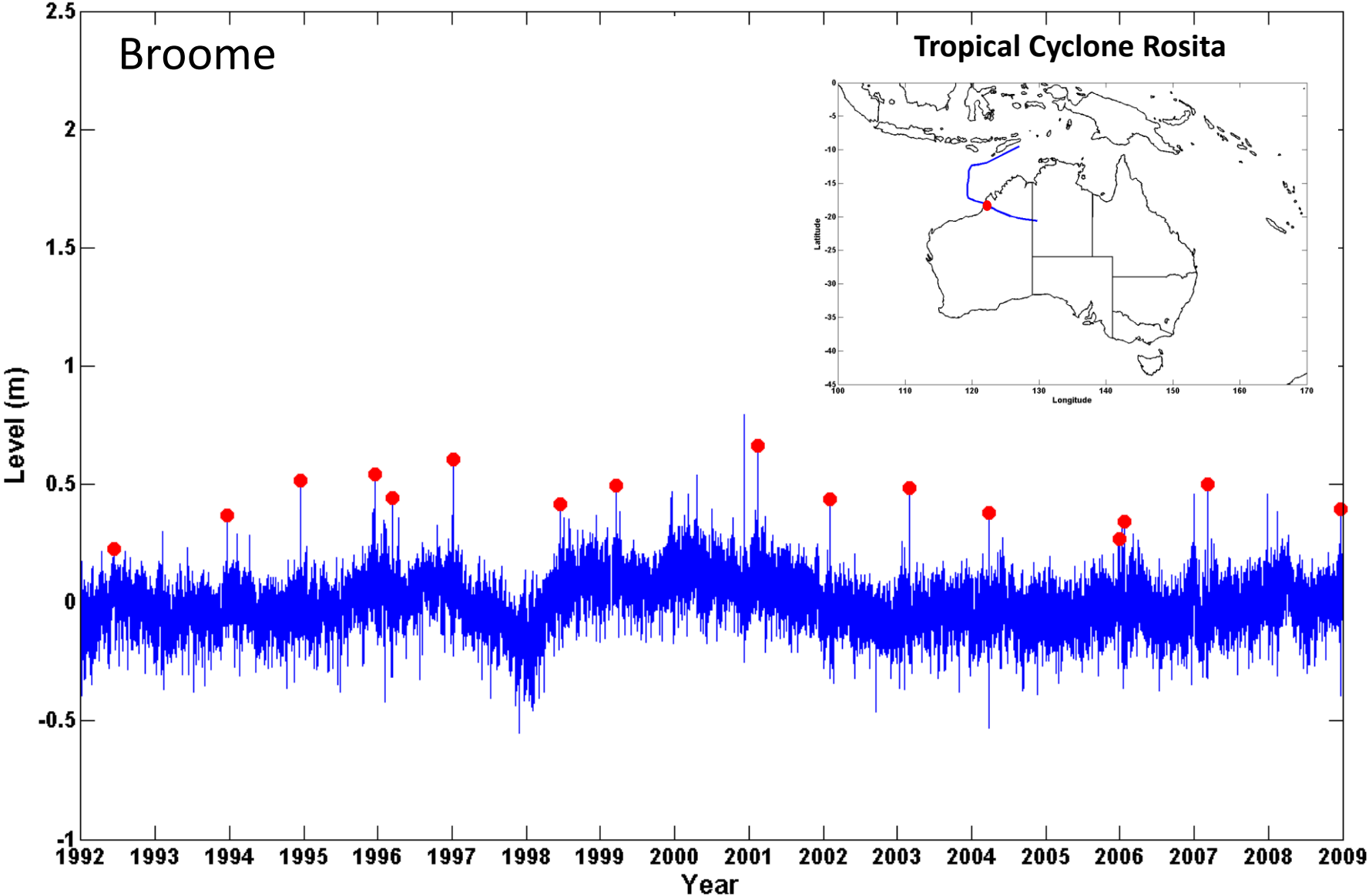
Oceanic: Indian + Pacific



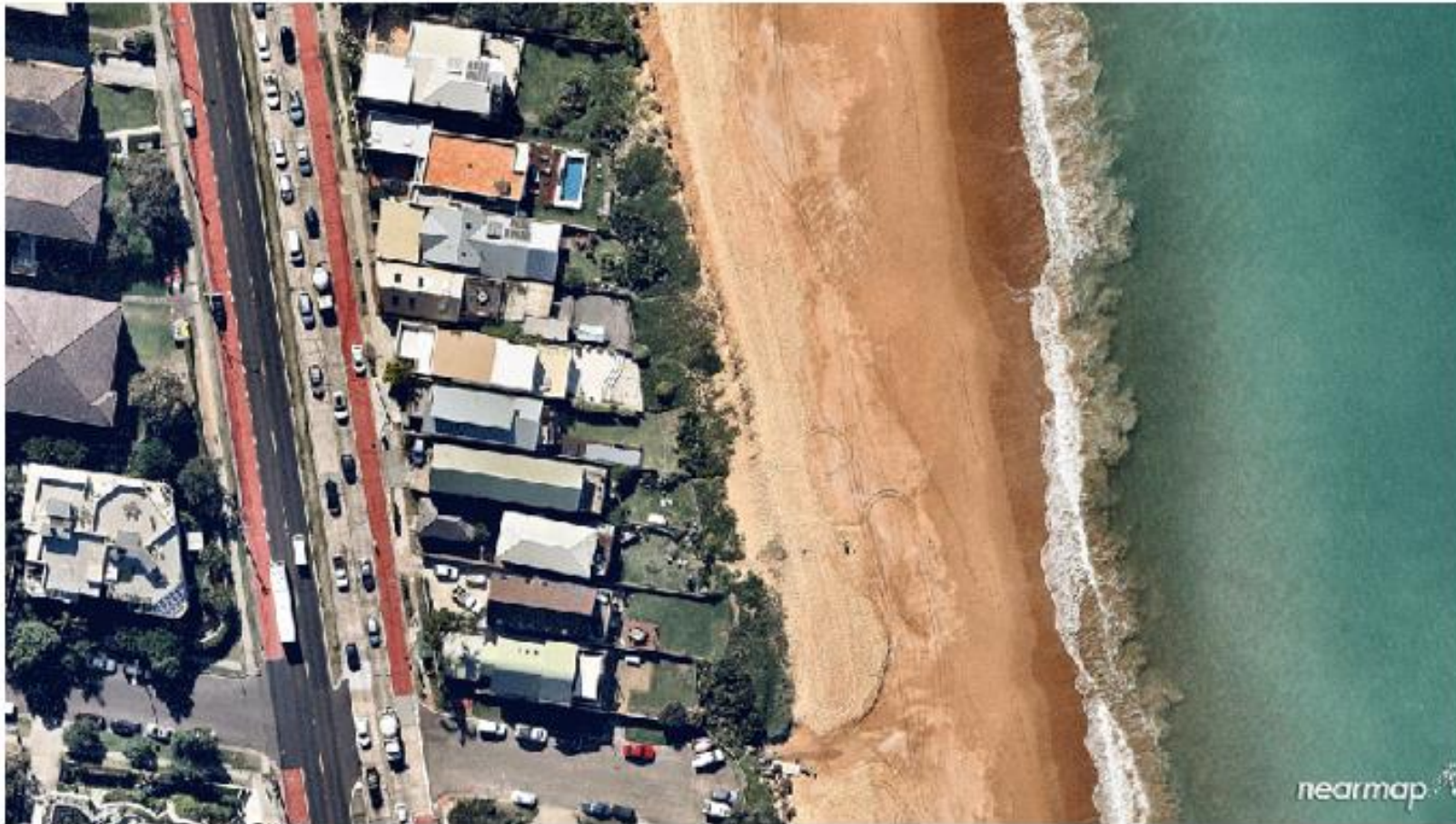
Oceanic: Atlantic + Southern



EXTREME EVENTS: STORM SURGE



MITIGATION-RECOVERY-RESPONSE: GETTING THE BALANCE RIGHT



Before and after: a low pressure cell leaves Sydney's Collaroy beach devastated. (Nearmap)

MITIGATION-RECOVERY-RESPONSE: GETTING THE BALANCE RIGHT



Before and after: a low pressure cell leaves Sydney's Collaroy beach devastated. (Nearmap)

MITIGATION-RECOVERY-RESPONSE: GETTING THE BALANCE RIGHT



Climate Council
@climatecouncil

Follow

Australians Recovering From 15th 'Once In A Lifetime' Disaster bit.ly/1PCownN

@SBSComedy #SydneyStorms 😂😂😂



RETWEETS 46
LIKES 20



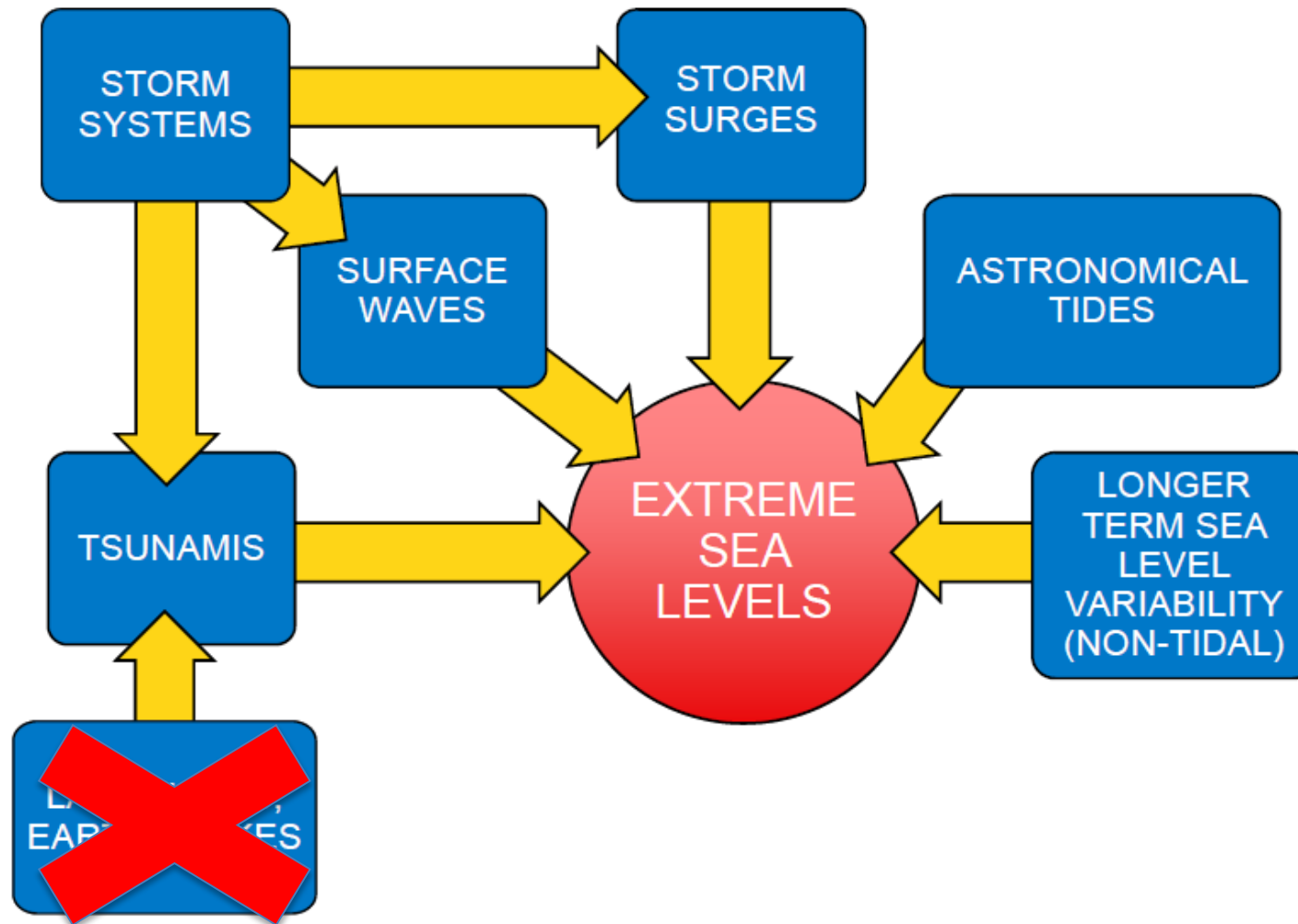
9:24 PM - 6 Jun 2016

Reply 46 Like 20 More



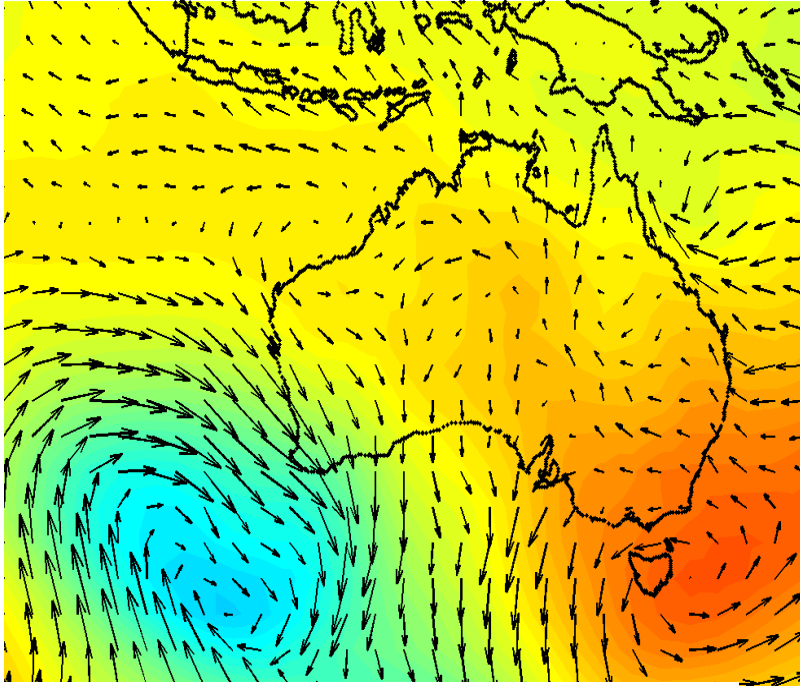
© Damian Shaw/Daily Mail Australia

EXTREME SEA LEVELS



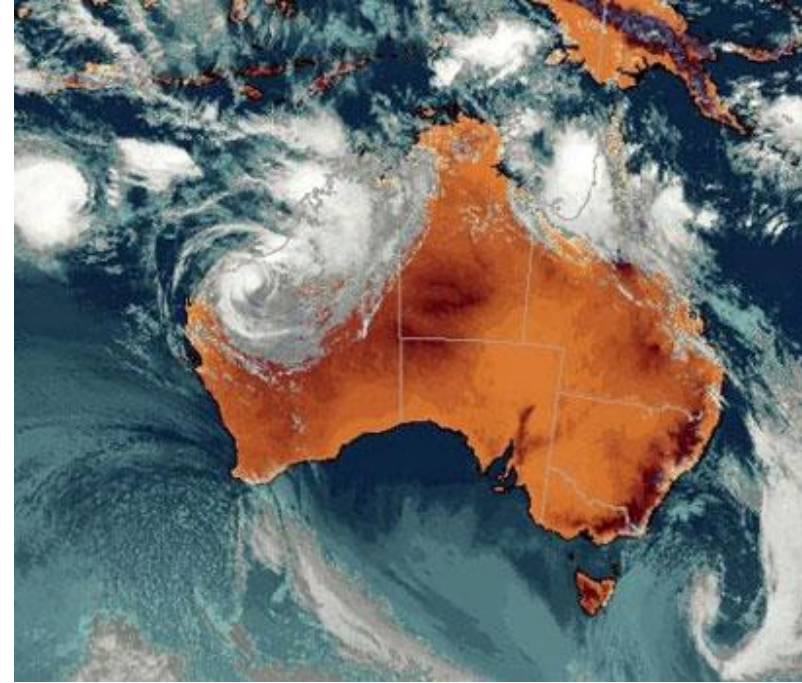
EXTREME EVENTS – STORM SURGE

Extra-tropical



1,000 ± 500 km
Surge - 2-5 days
Several hundred km
Sprawling geometry
Apr-Aug

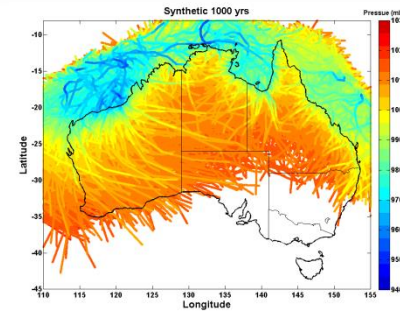
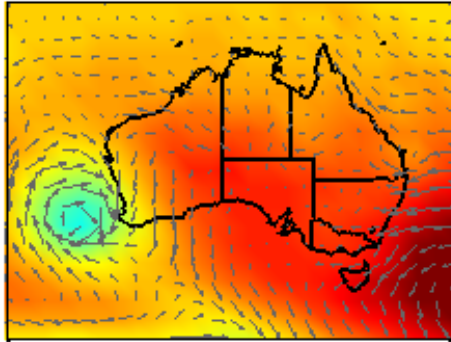
Tropical (cyclones)



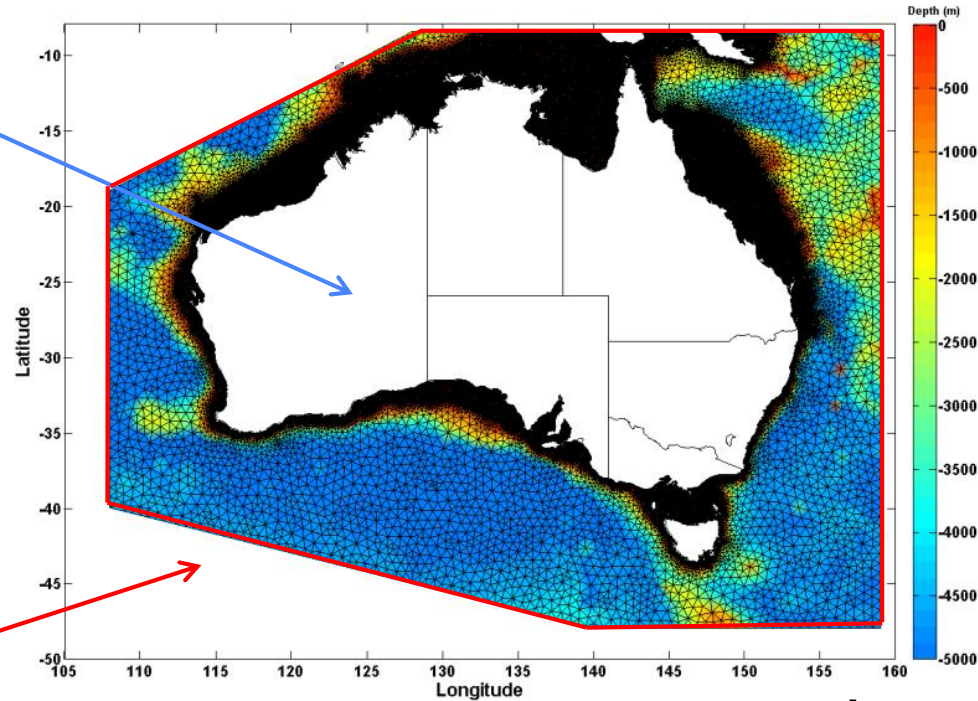
500 ± 200 km
Surge - up to half a day
Usually < 200 km
Compact and nearly symmetrical
Nov-Apr

SEA LEVEL HINDCASTS

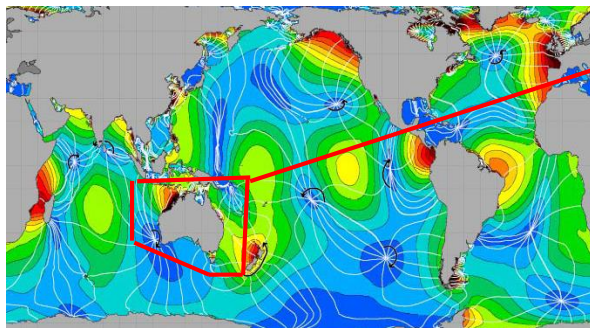
JRA55/ NCEP: 1949-2016



Tropical Cyclones



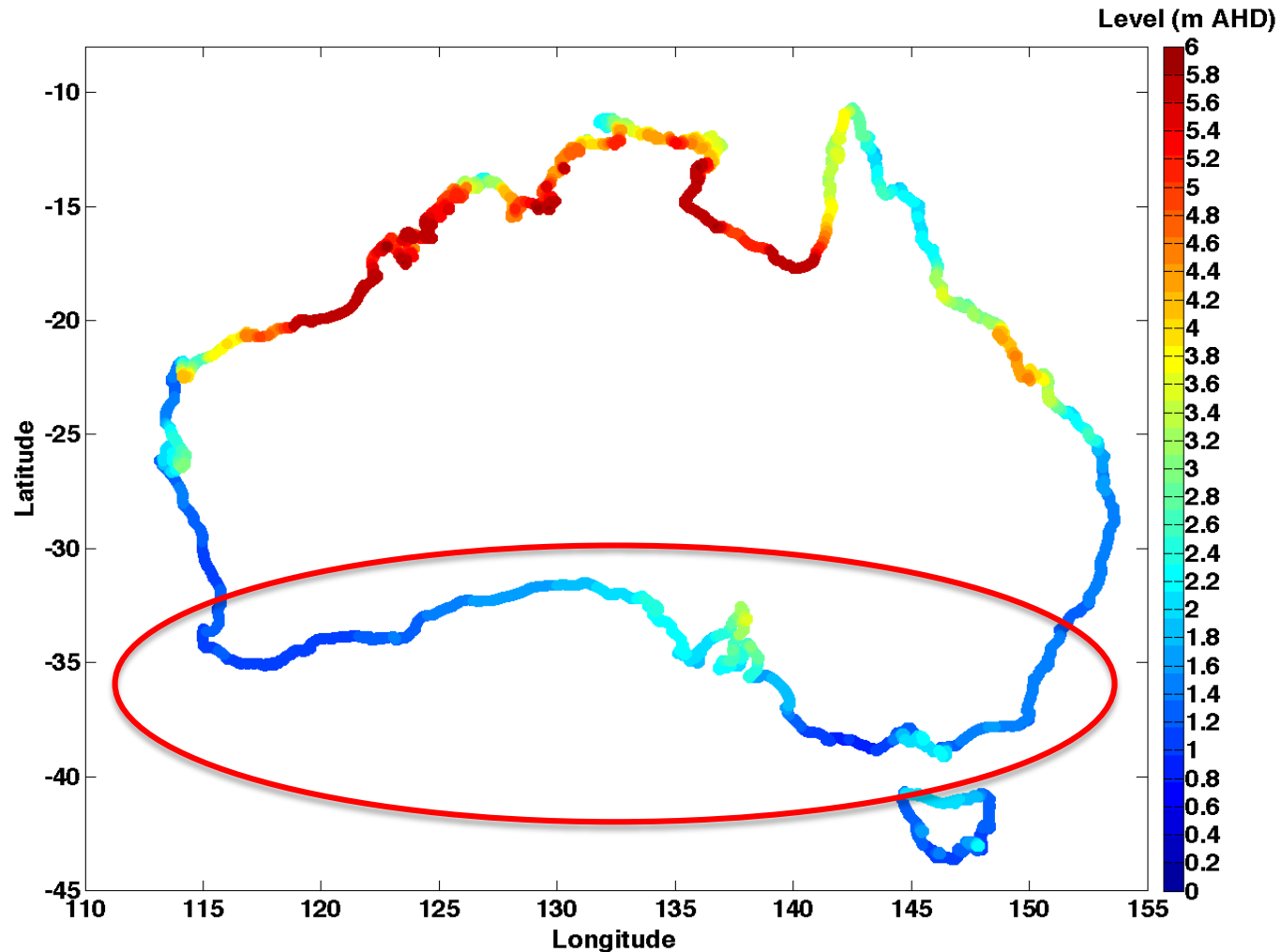
Global tidal model



~75,000 simulations
equivalent to 10,000 years

Total Sea level
(~60 year time series)

1:1000 ARI: TOTAL WATER LEVEL (TROPICAL + EXTRATROPICAL)

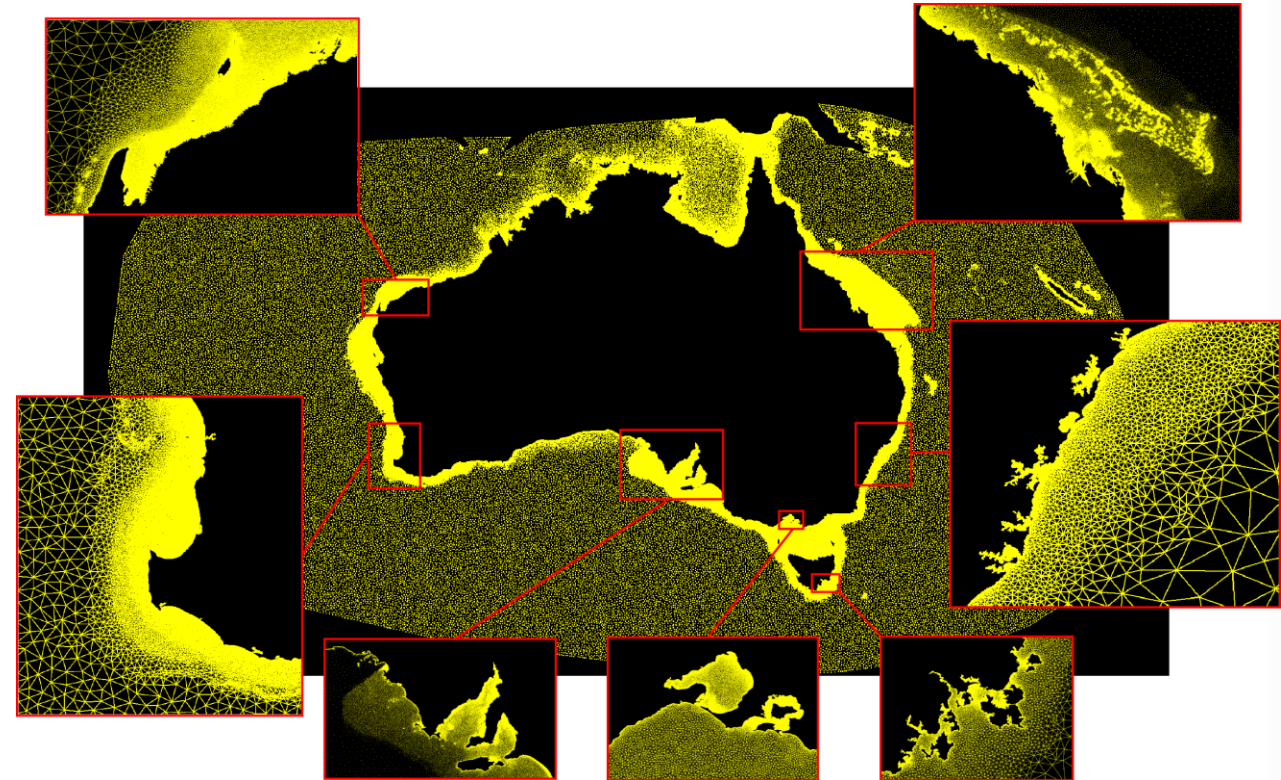


- A range of processes influence extreme water levels
- The southern margin of Australia was found to underestimate extreme sea levels in some cases due to:
 1. Coastal trapped waves
 2. Transitioning tropical cyclones
 3. Meteorological tsunamis
 4. Wave setup effects
- The present model better includes these processes

COUPLED WAVE-SURGE MODEL

- The **SCHISM hydrodynamic model** was 2-way coupled with the advanced **Wind Wave III (WWMIII model)**
- 3D Finite element **unstructured** hydrodynamic model (~100 m resolution at coast)
- Inundation (wet/dry)
- Supercomputer enables simulations for entire Australian coast

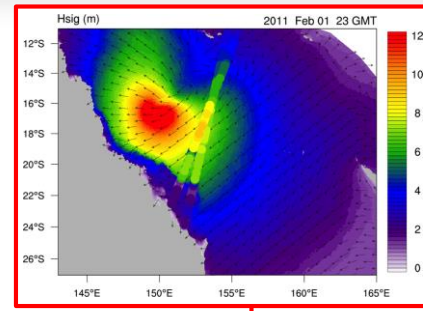
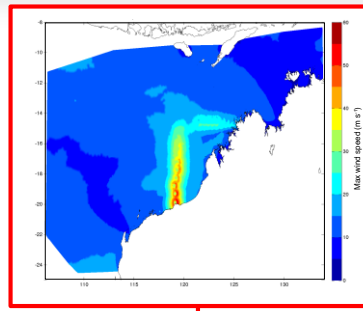
SCHISM storm surge model grid



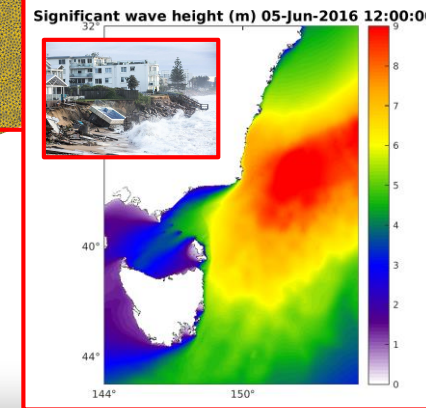
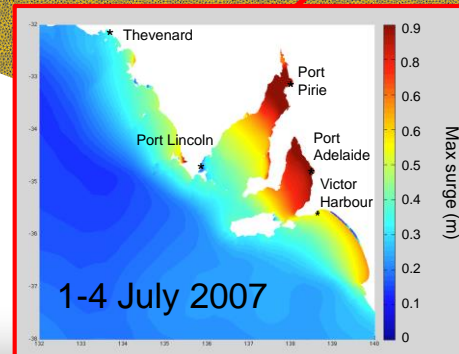
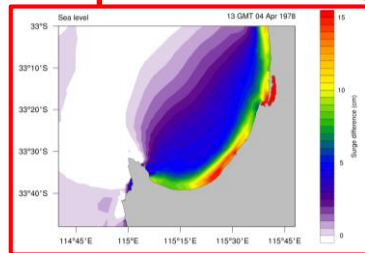
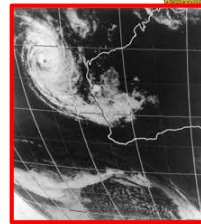
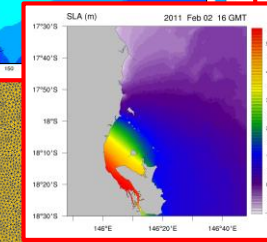
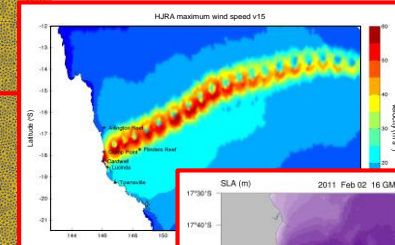
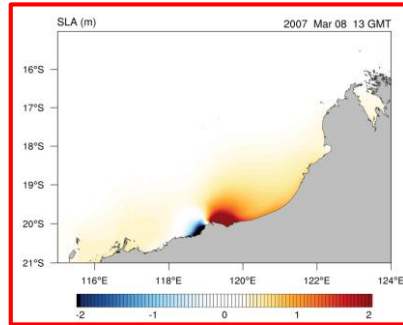
100 m resolution near the coast!

TROPICAL CYCLONE GEORGE

APRIL 2007



TROPICAL CYCLONE YASI FEBRUARY 2011



EAST COAST LOW JUNE 2016

CYCLONE ALBY APRIL 1978

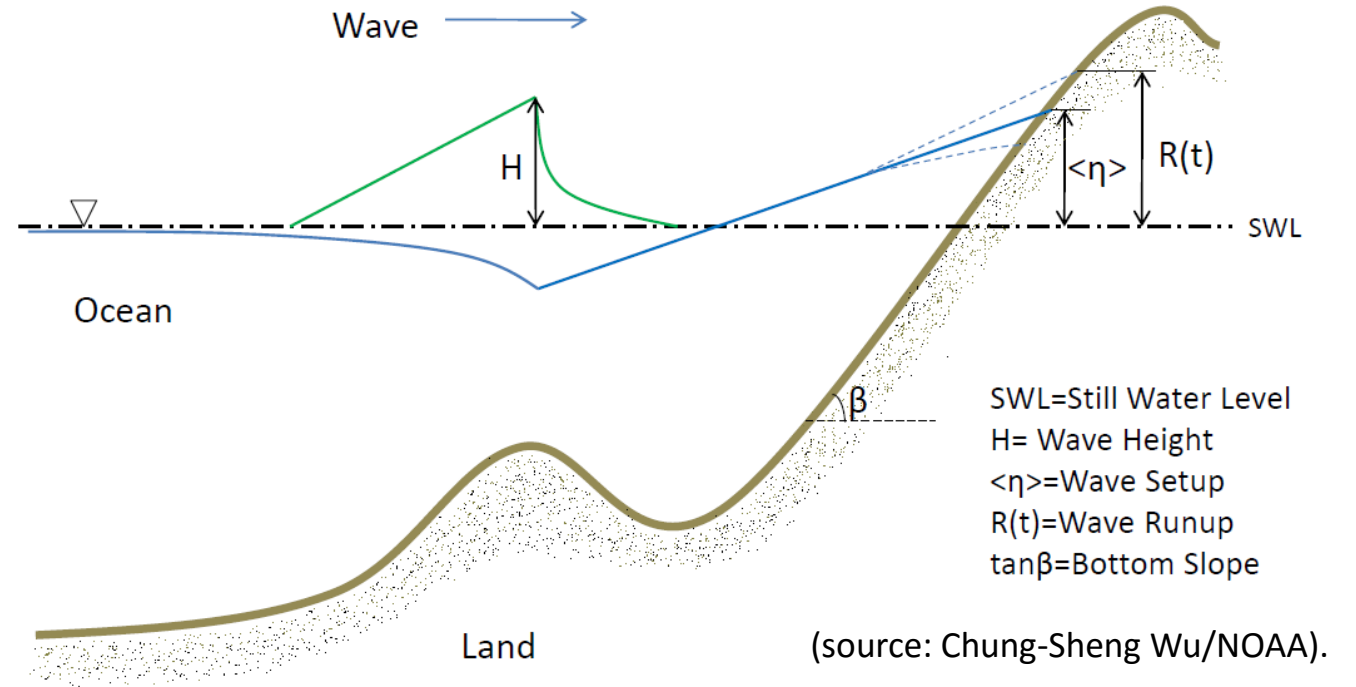
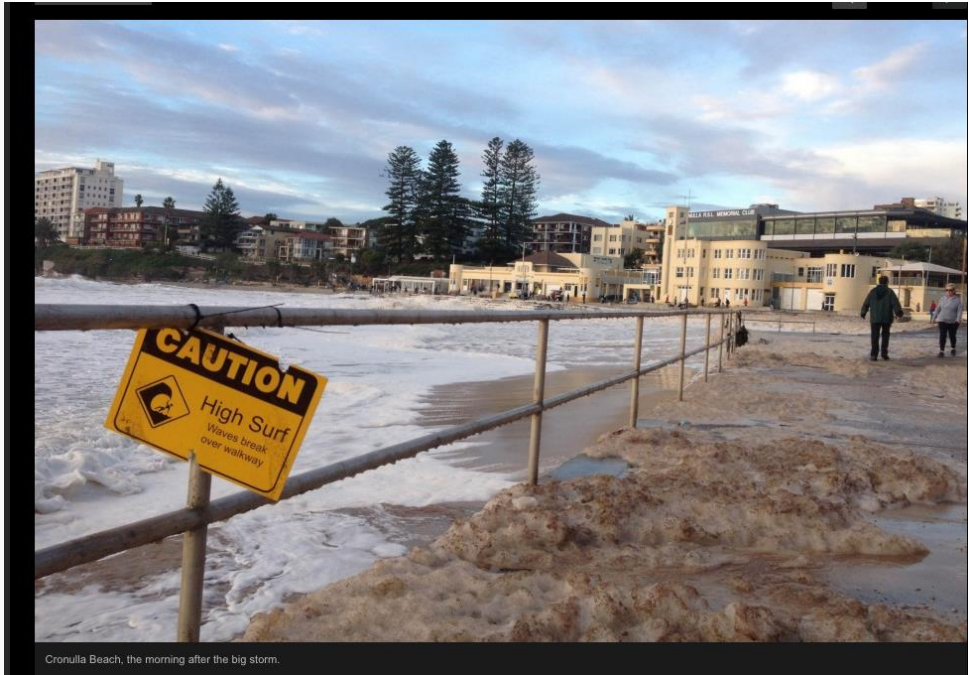
IMPROVED EXTREME SEA LEVEL PREDICTIONS ARISING FROM:

1. Tropical to extratropical storm transition
2. Surface wave effects
3. Continental Shelf Waves
4. Meteorological tsunamis

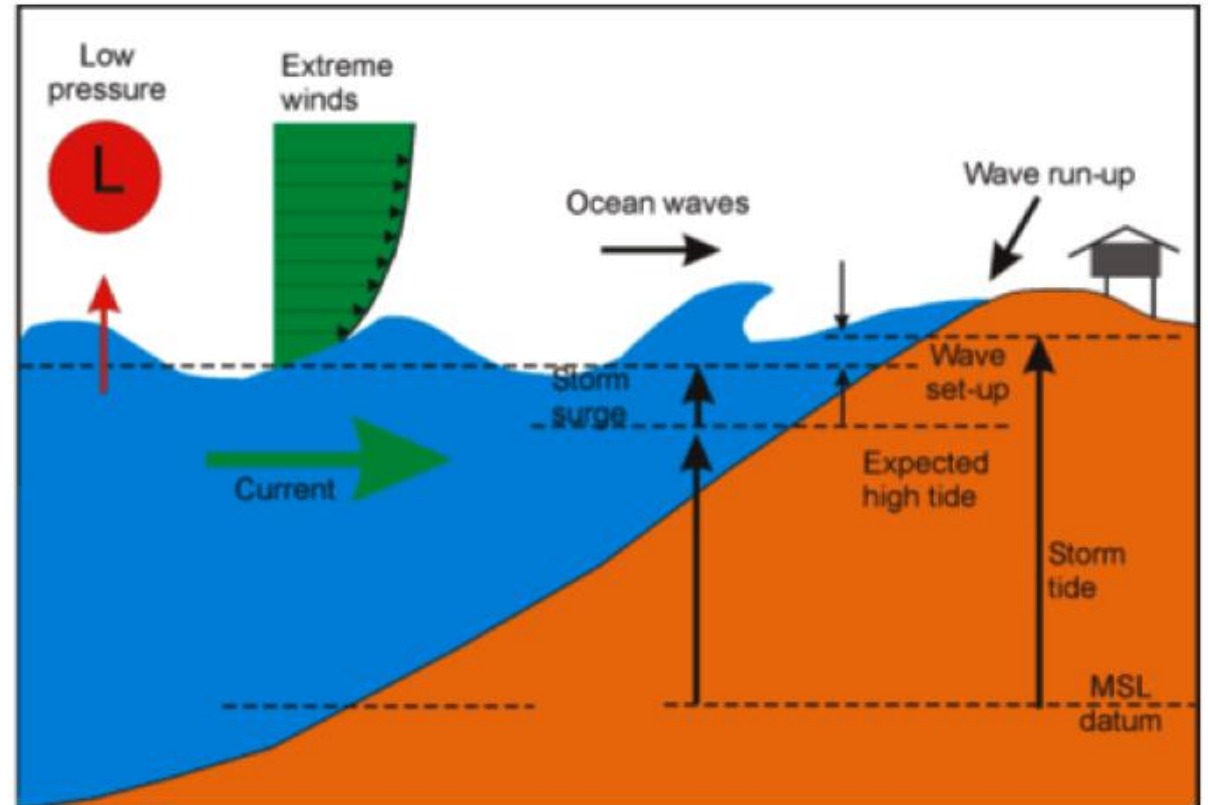
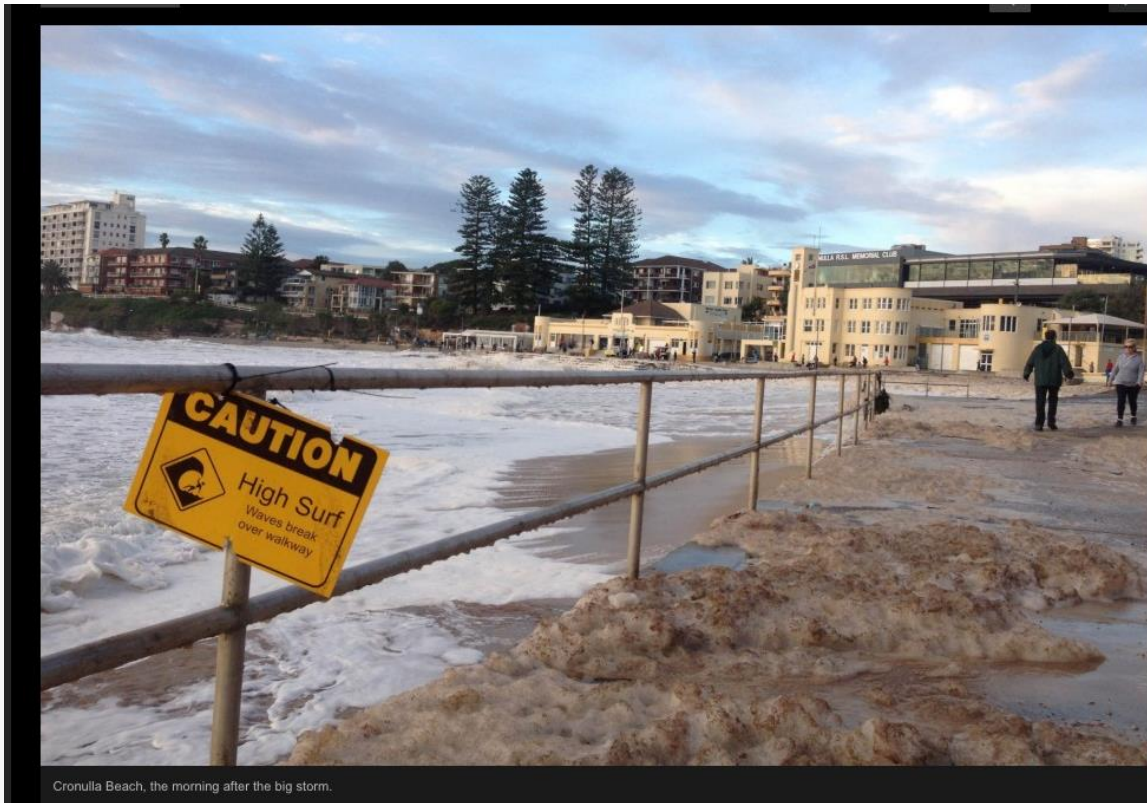


Damian Shaw Daily Telegraph

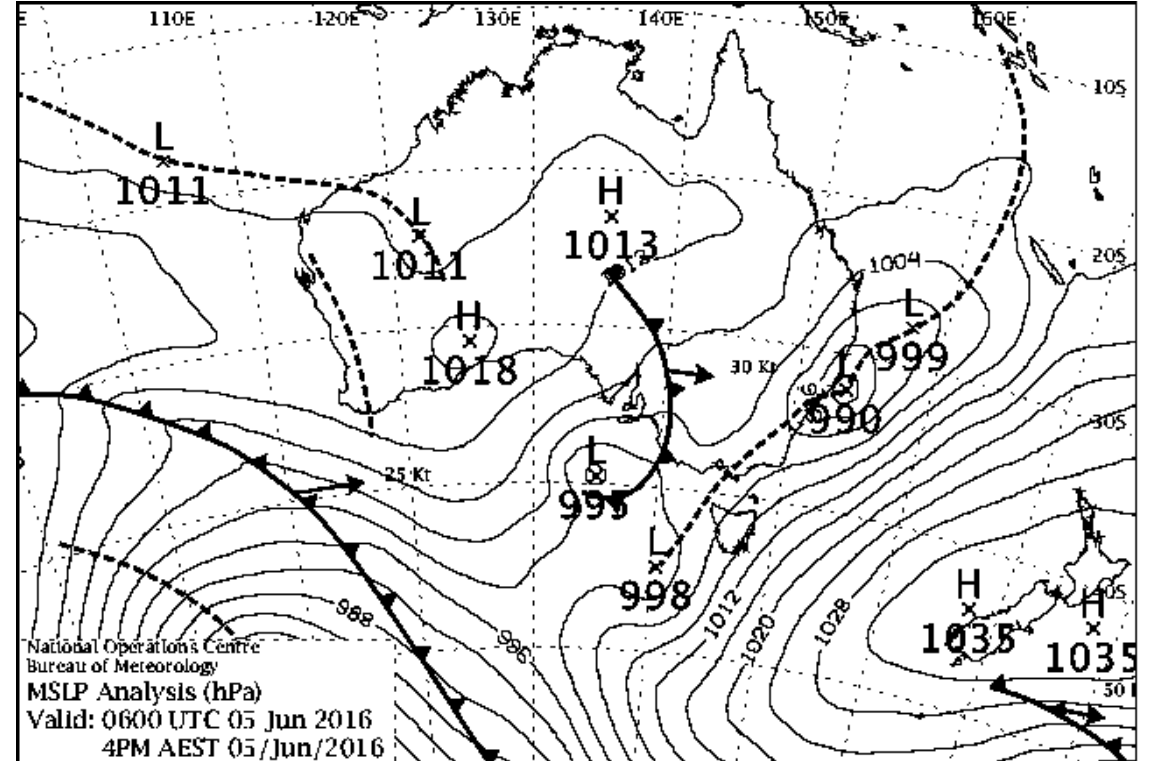
HOW WAVES CAUSE COASTAL EROSION AND FLOODING



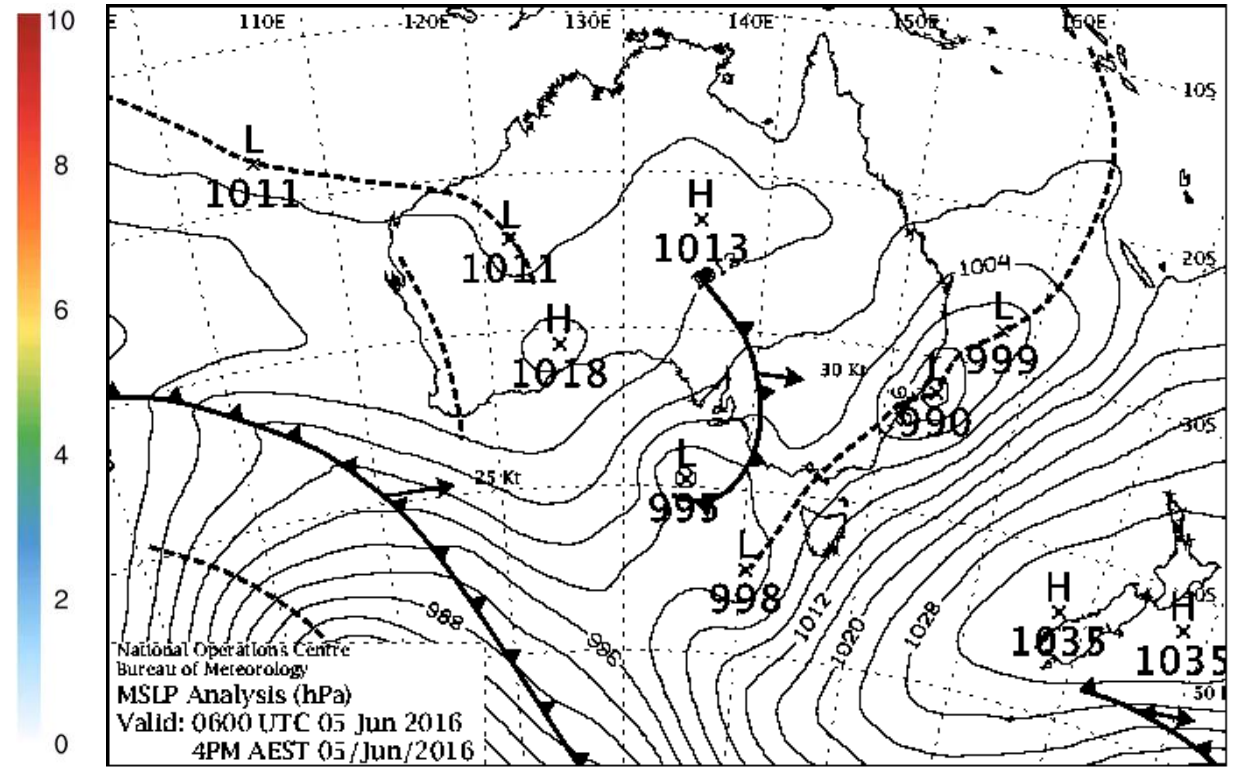
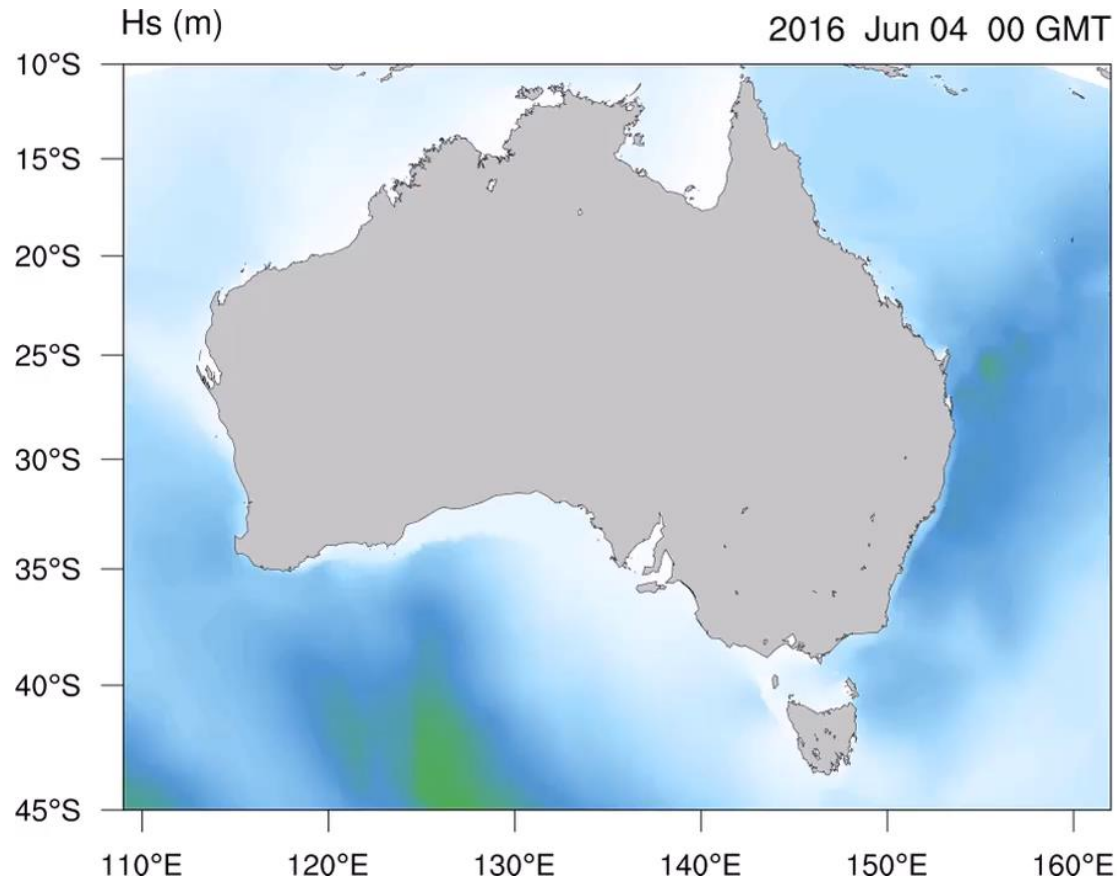
HOW WAVES CAUSE COASTAL EROSION AND FLOODING



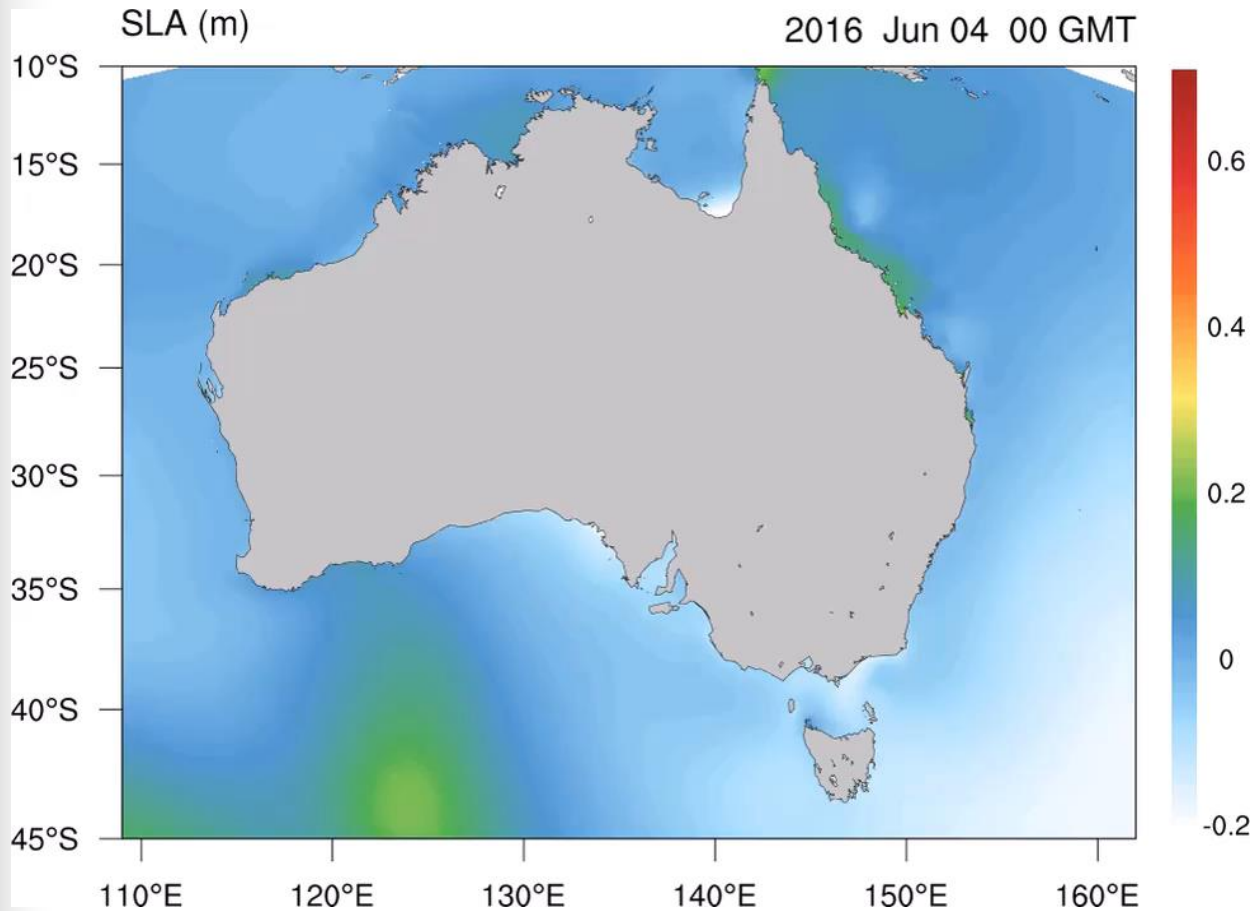
4-7 JUNE 2016 EAST COAST LOW – NSW TO TASMANIA



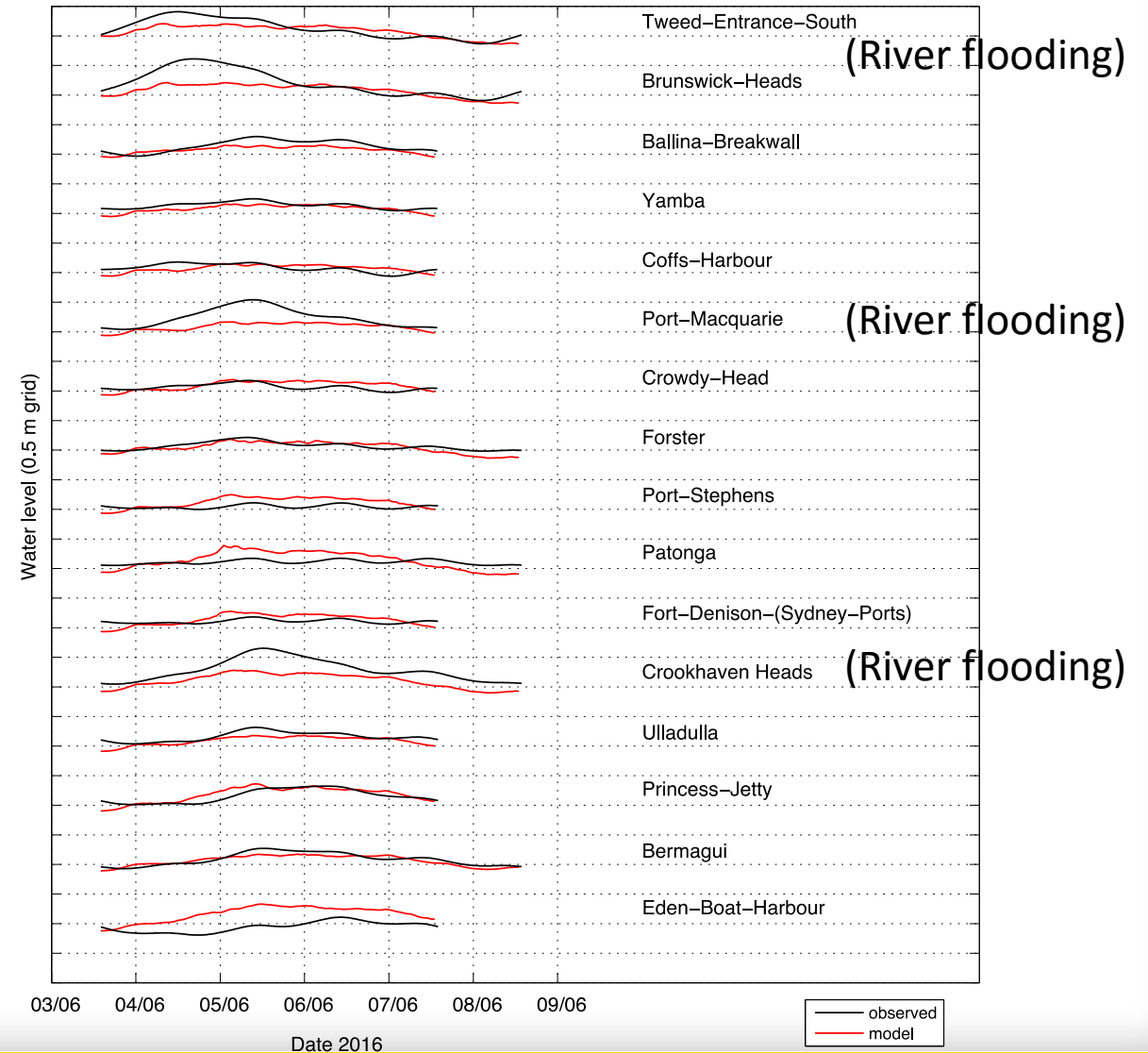
4-7 JUNE 2016 EAST COAST LOW – NSW TO TASMANIA



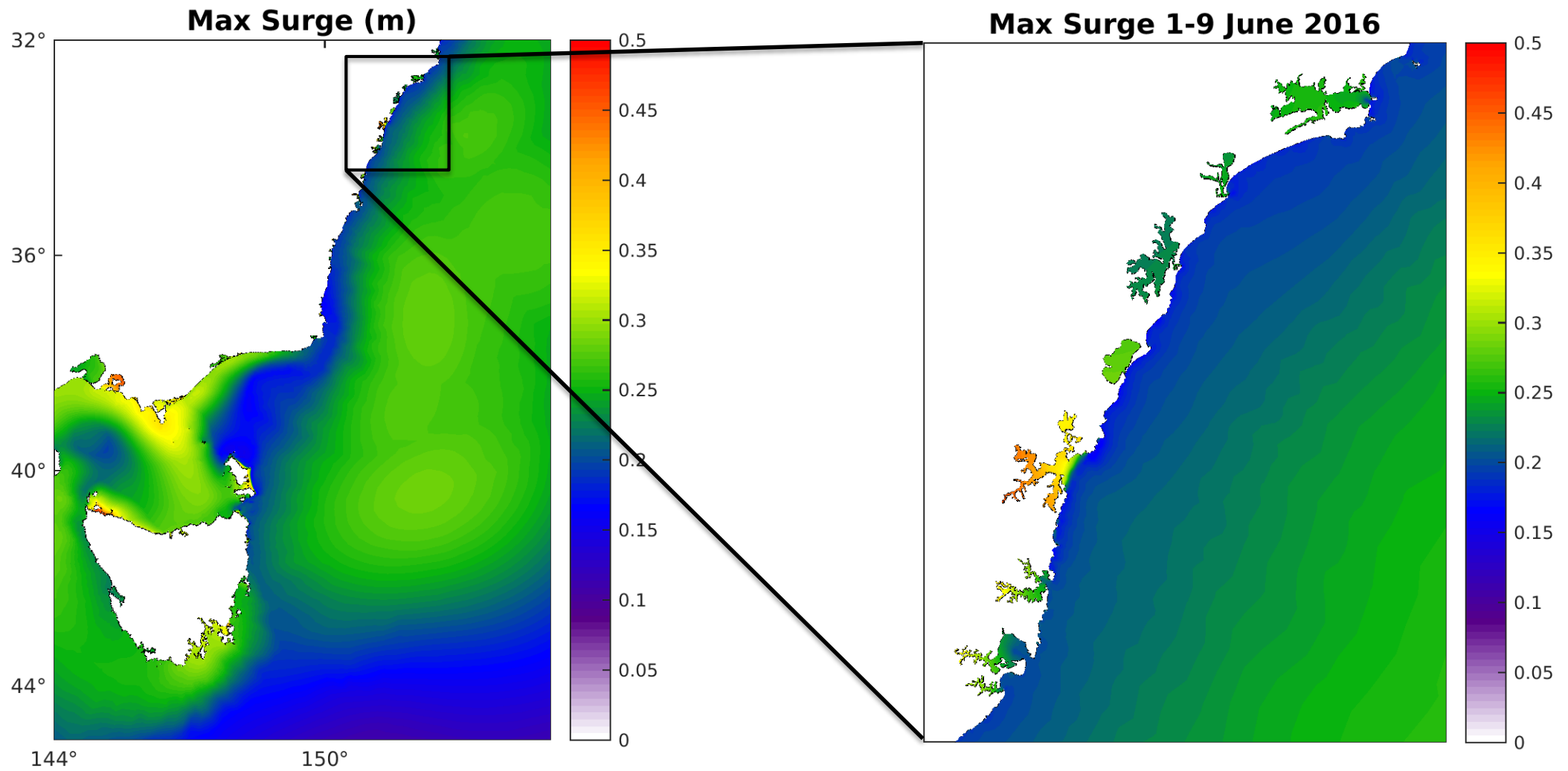
STORM SURGE COMPONENT OF WATER LEVEL



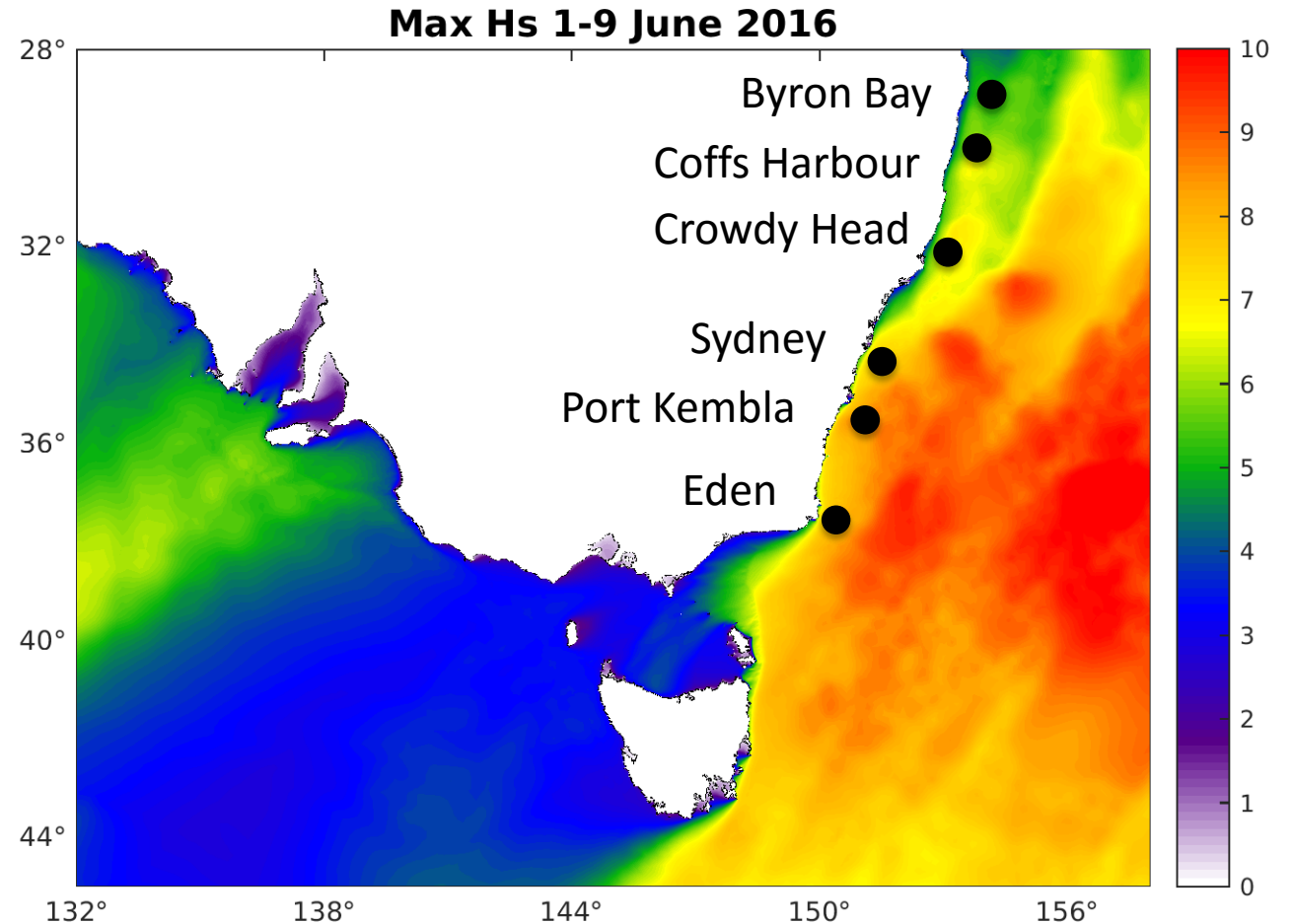
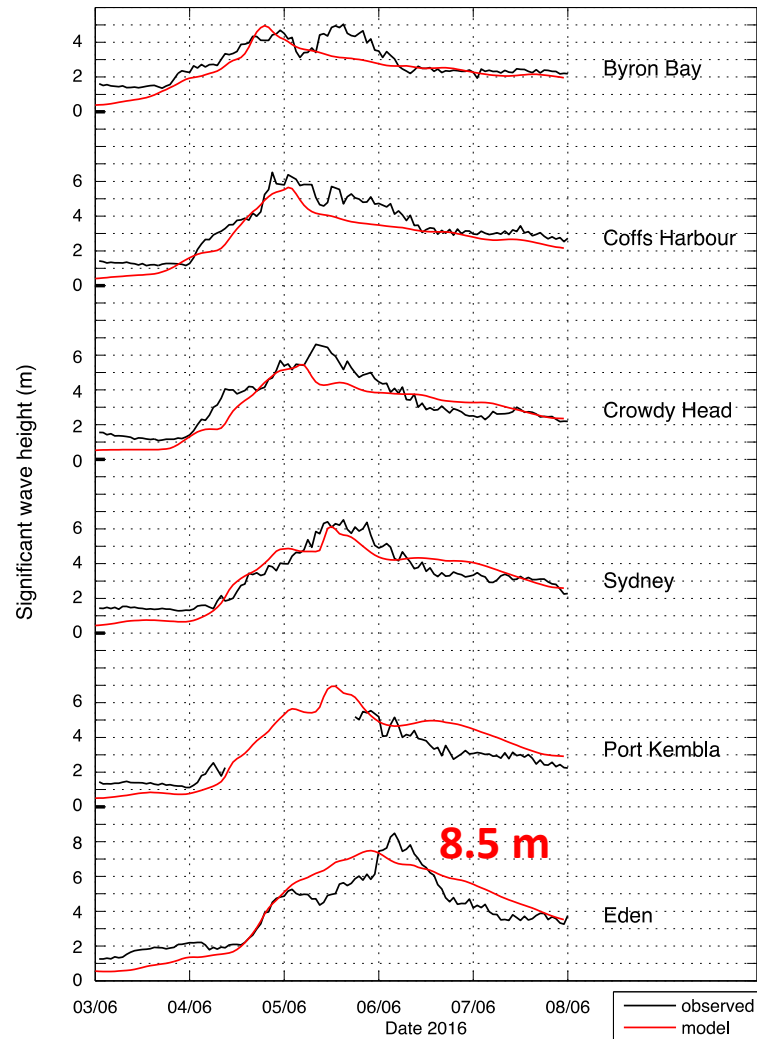
Insert surge animation here



STORM SURGE COMPONENT OF WATER LEVEL



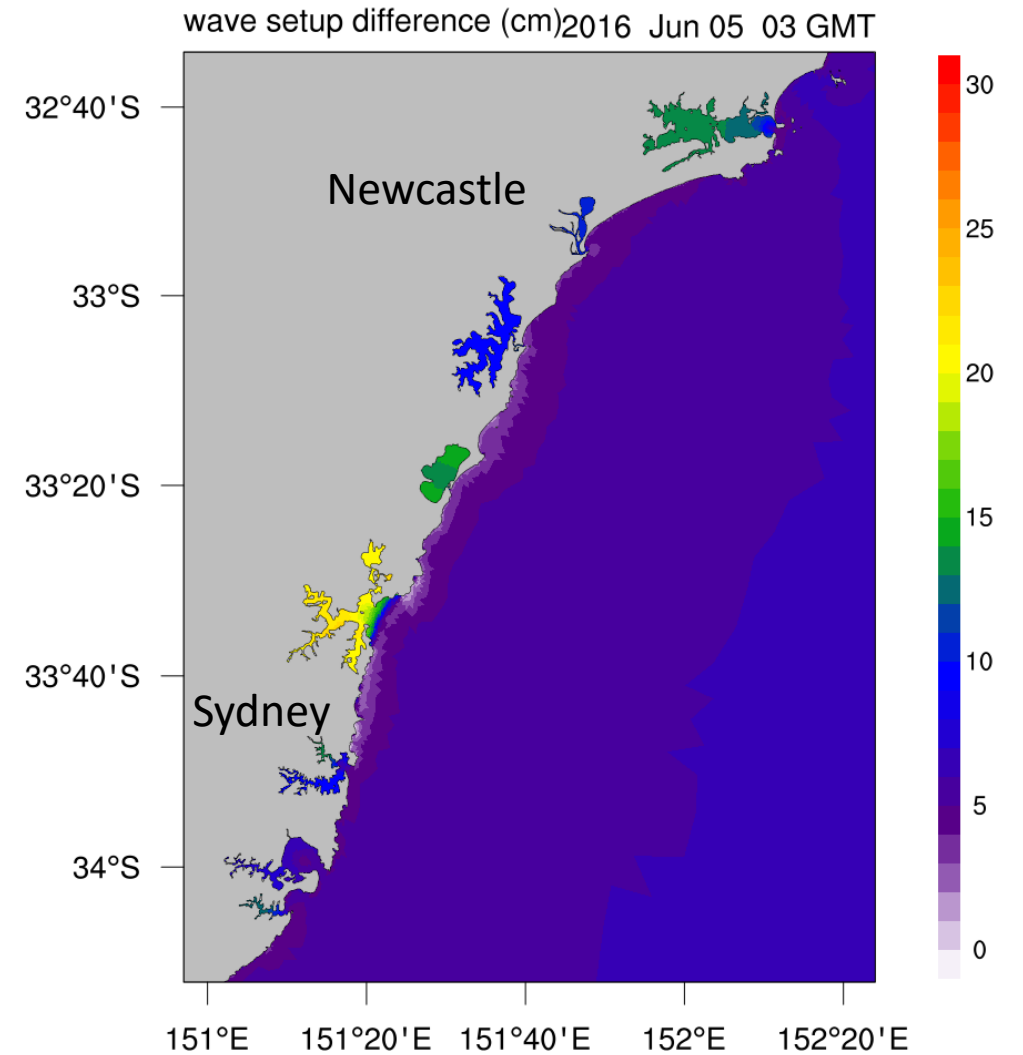
NSW RECORDED AND MODELED WAVE HEIGHTS



4-7 JUNE 2016 EAST COAST LOW – WAVE EFFECTS



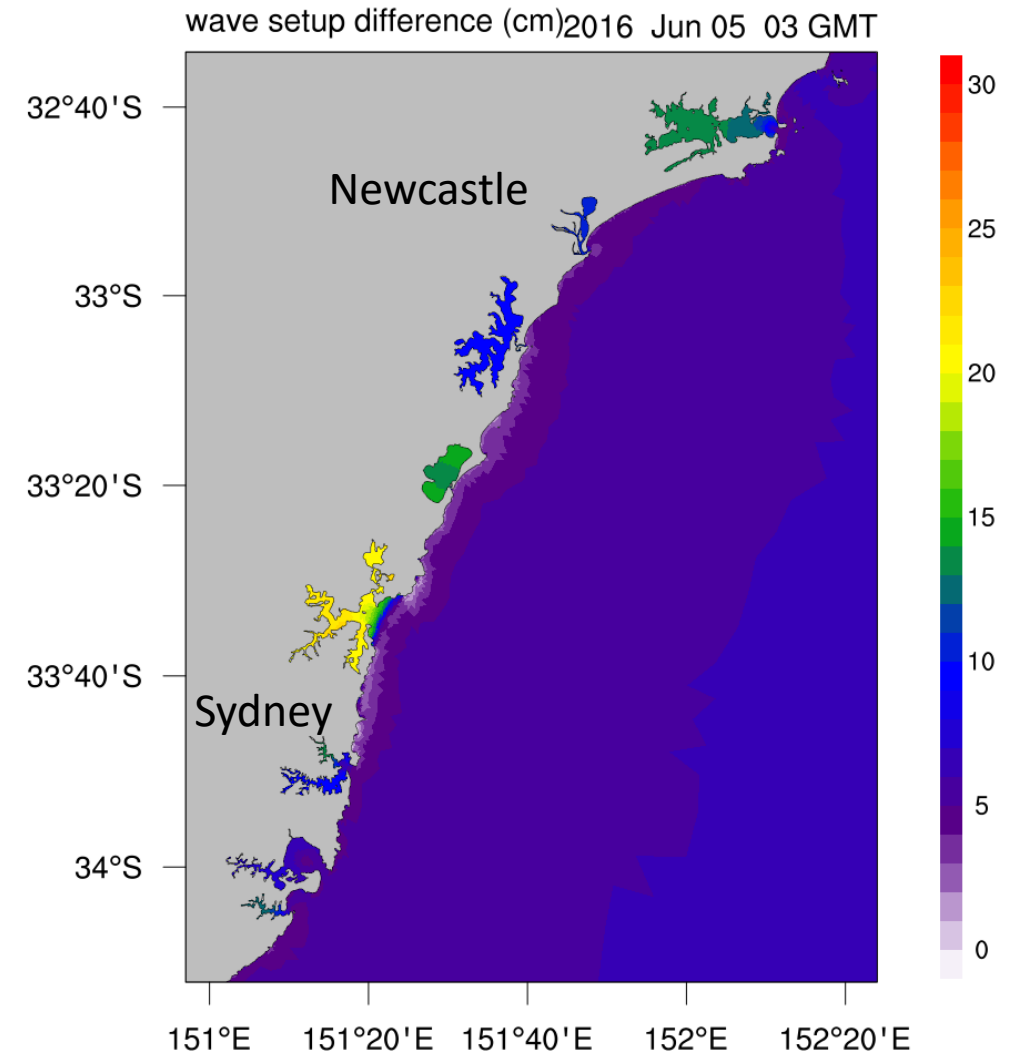
Hayden Blair dwarfed by a Wollongong beachbreak (Pic Steen Barnes)



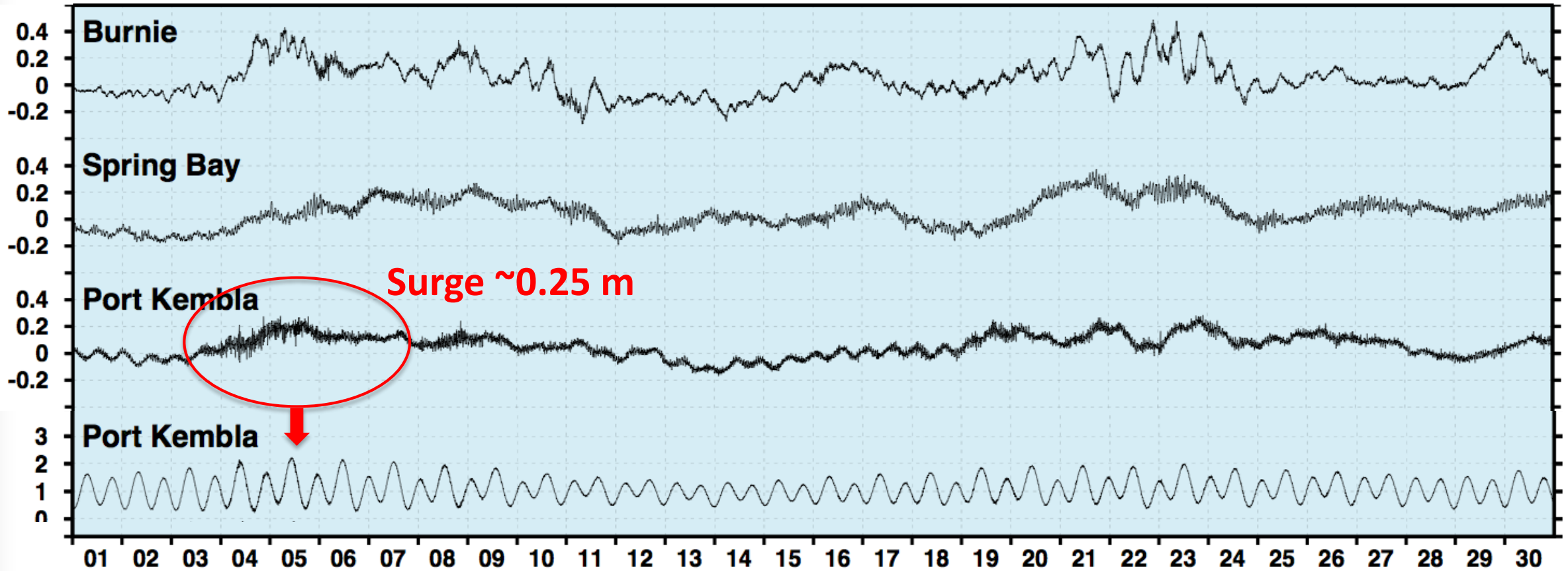
WAVE EFFECTS: WAVE SETUP + RUN UP + EROSION



king tide at Coogee, Surf life saving club in doubt Photo: Peter Rae



SPRING/NEAP TIDES VS SURGE: TIMING IS CRITICAL!

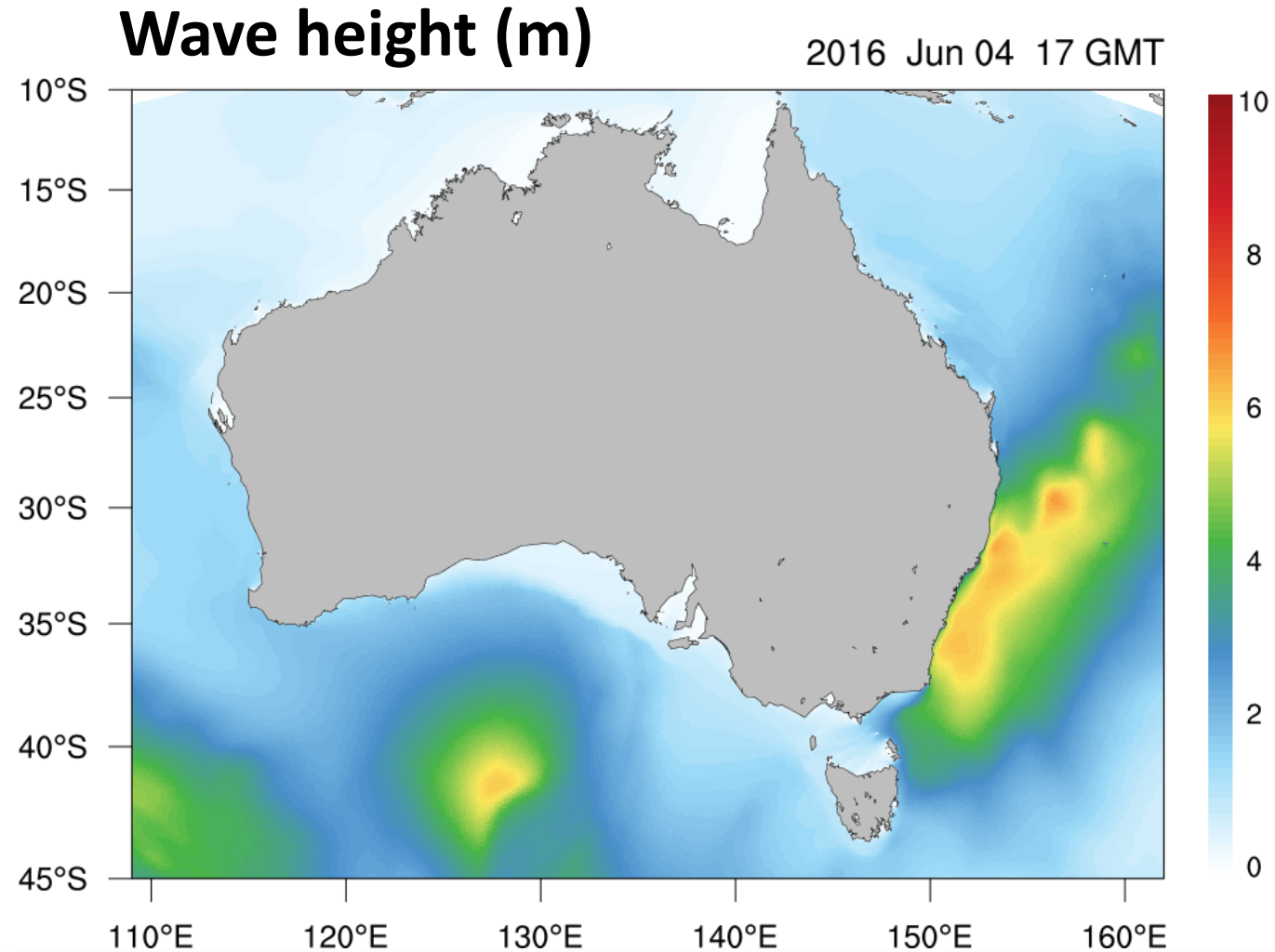


Spring tides: ~2m

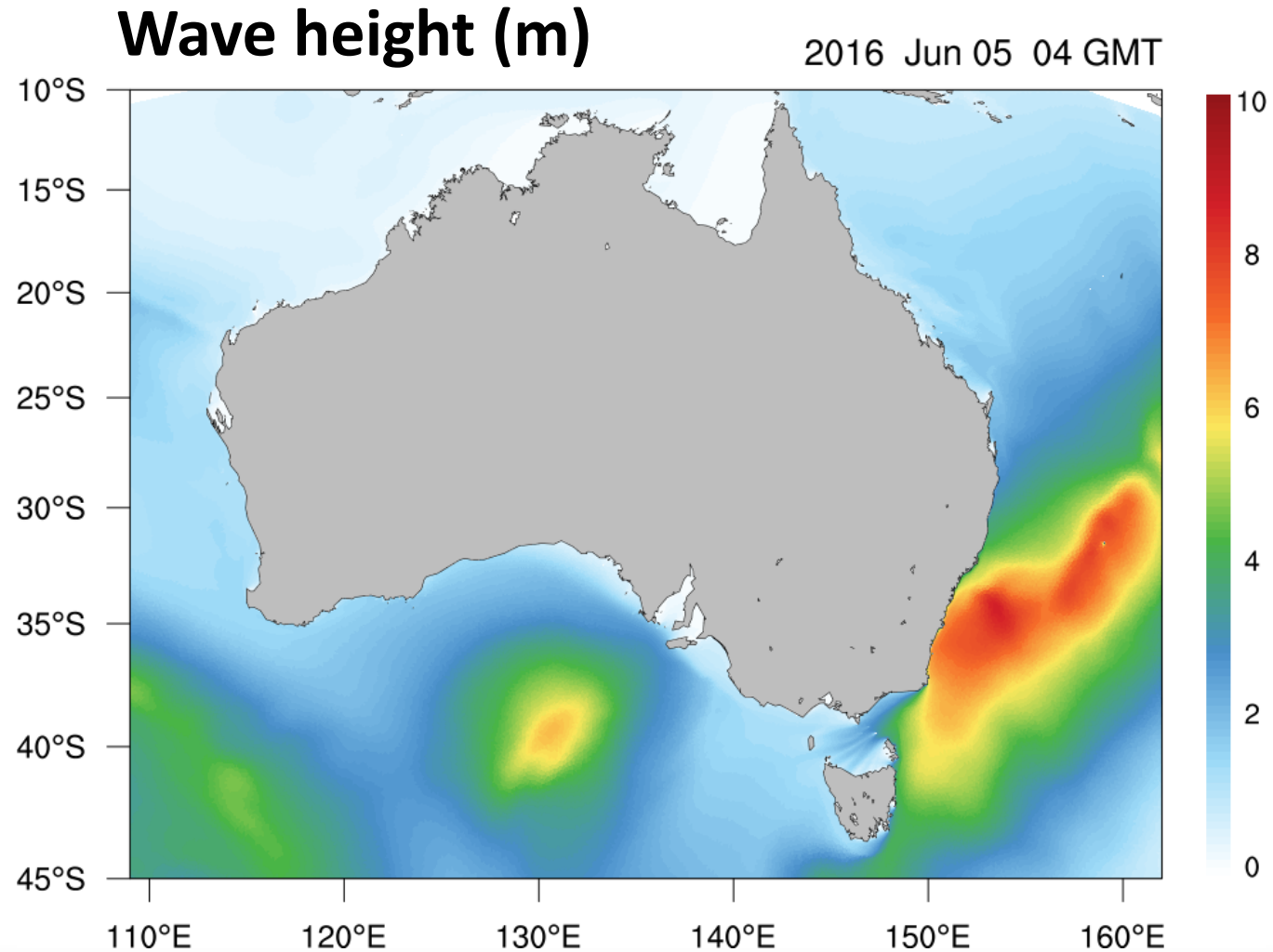
Neap tides: ~1m

(data: NTC/Bom)

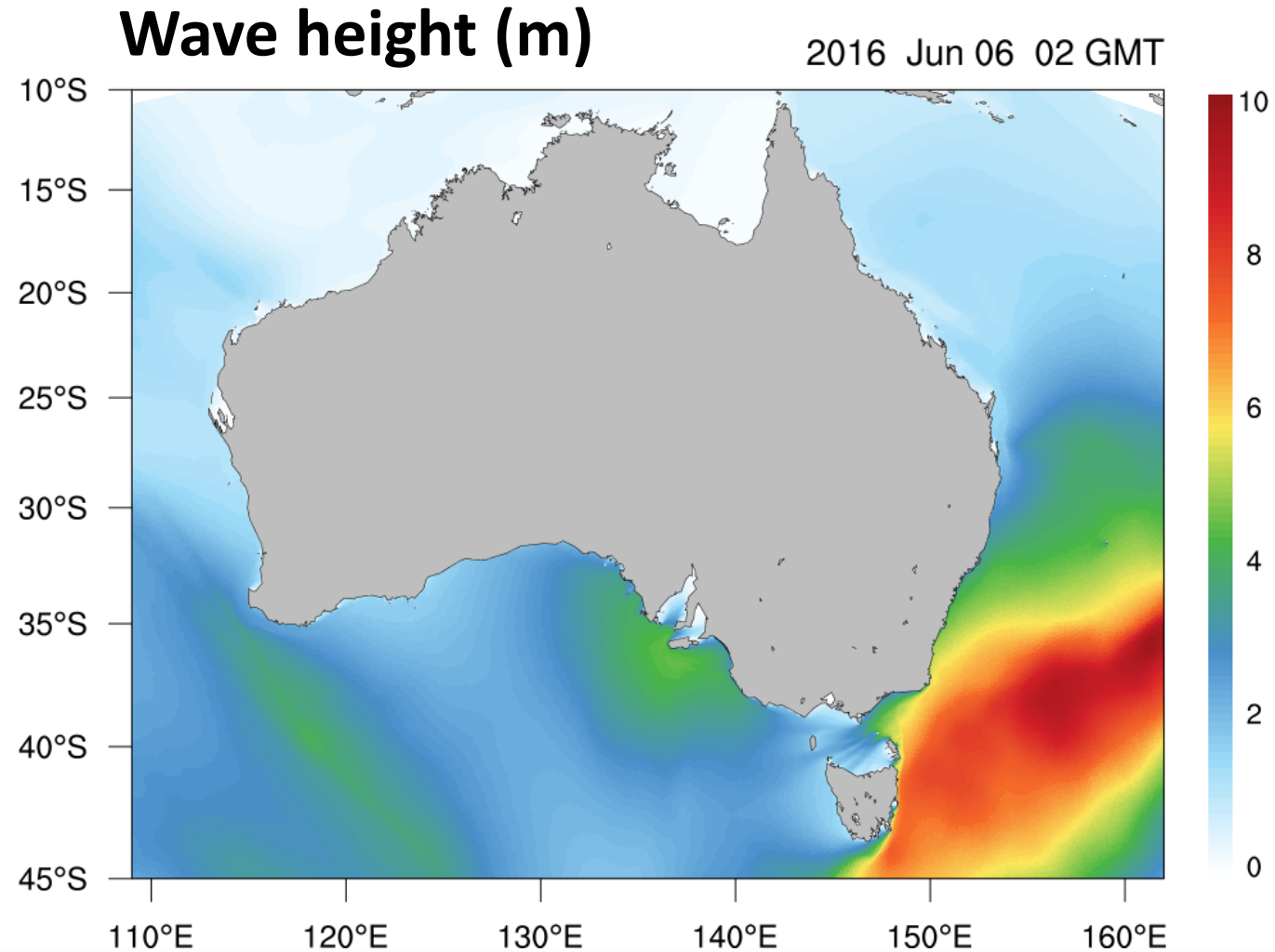
8 JUNE 2016 SOUTHERN OCEAN WINTER STORM – SOUTH AUSTRALIA



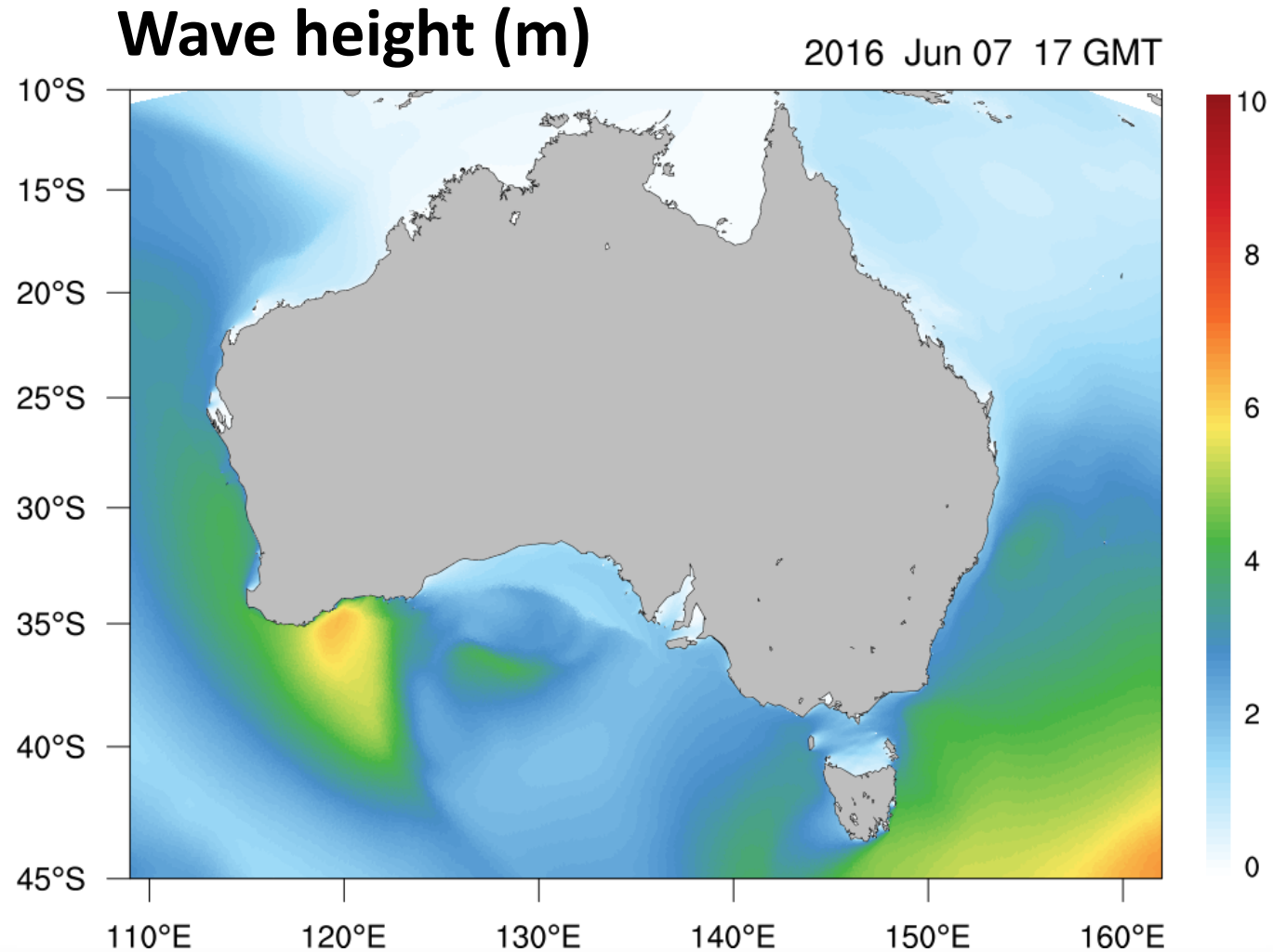
8 JUNE 2016 SOUTHERN OCEAN WINTER STORM – SOUTH AUSTRALIA



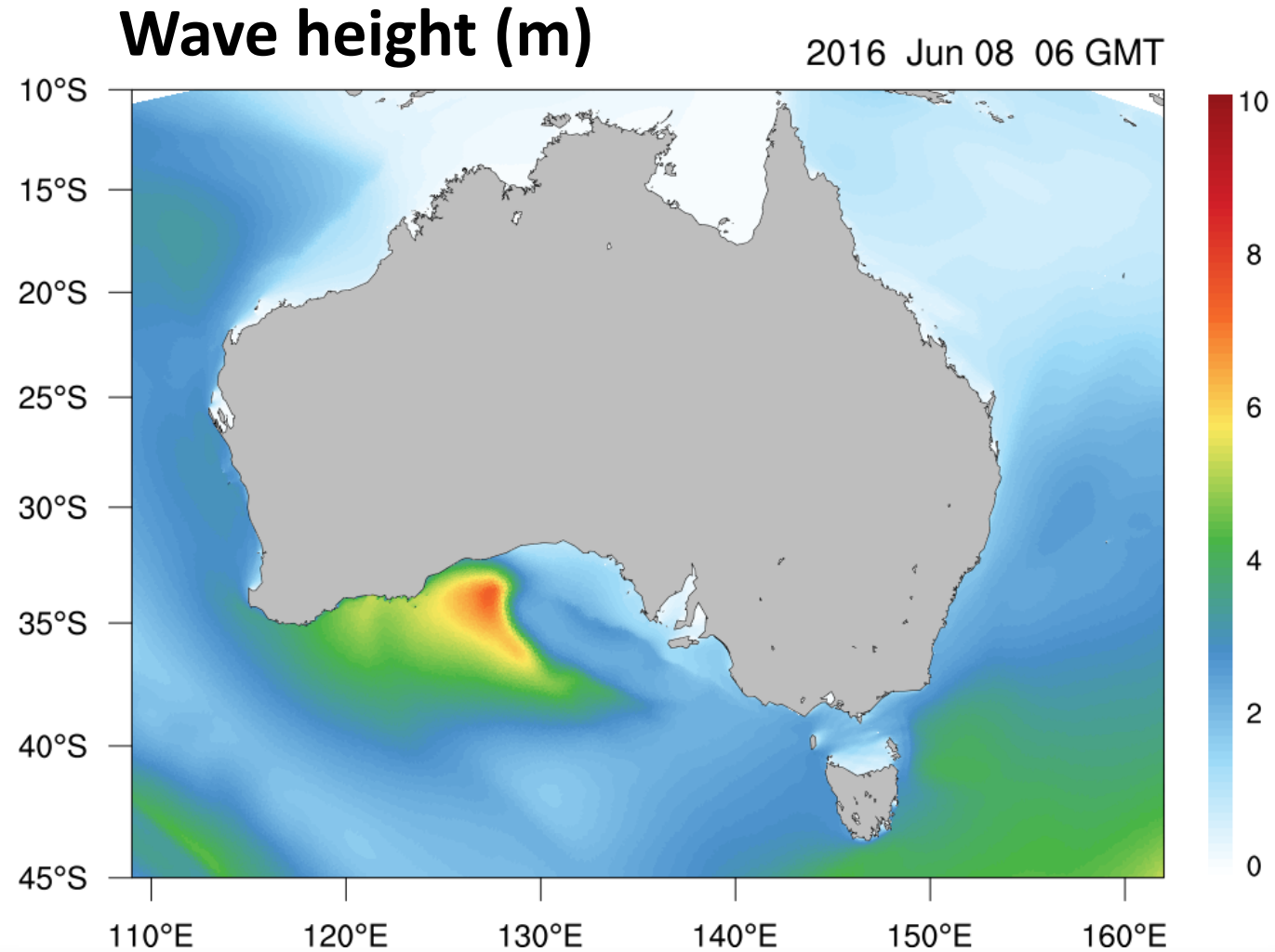
8 JUNE 2016 SOUTHERN OCEAN WINTER STORM – SOUTH AUSTRALIA



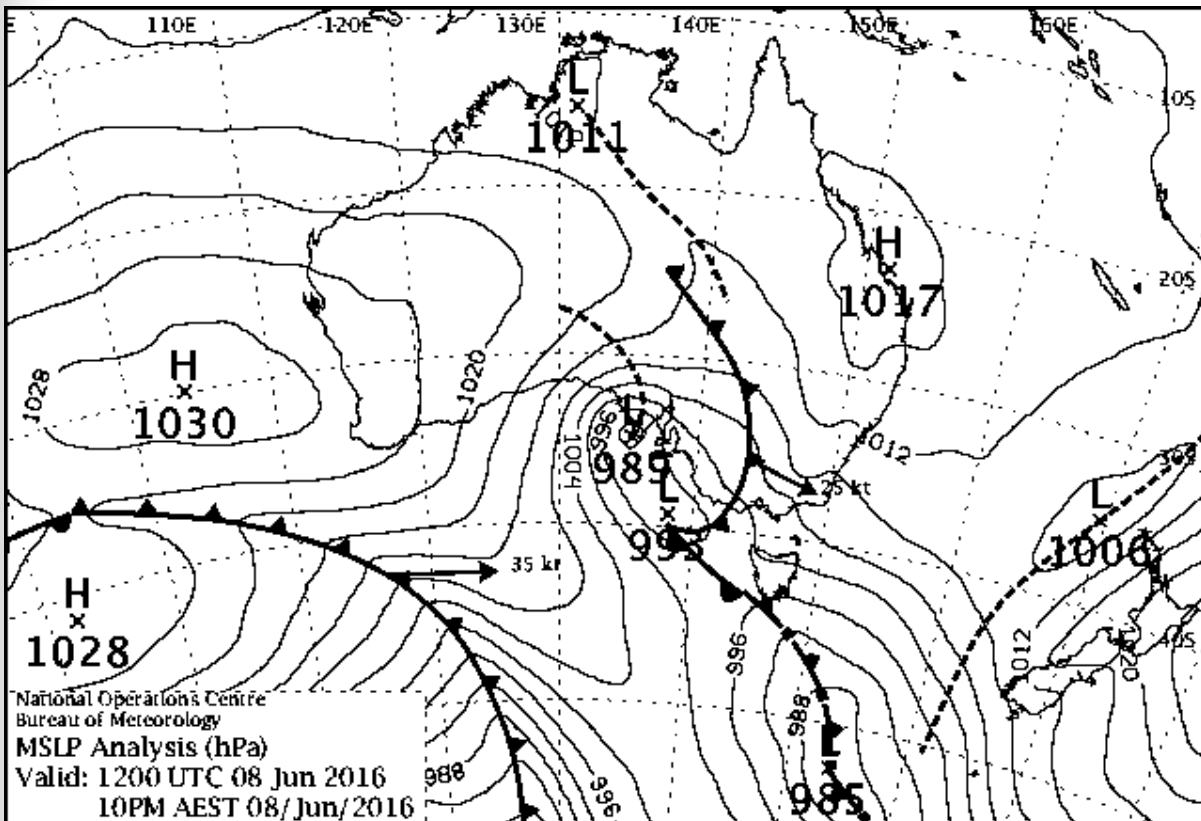
8 JUNE 2016 SOUTHERN OCEAN WINTER STORM – SOUTH AUSTRALIA



8 JUNE 2016 SOUTHERN OCEAN WINTER STORM – SOUTH AUSTRALIA

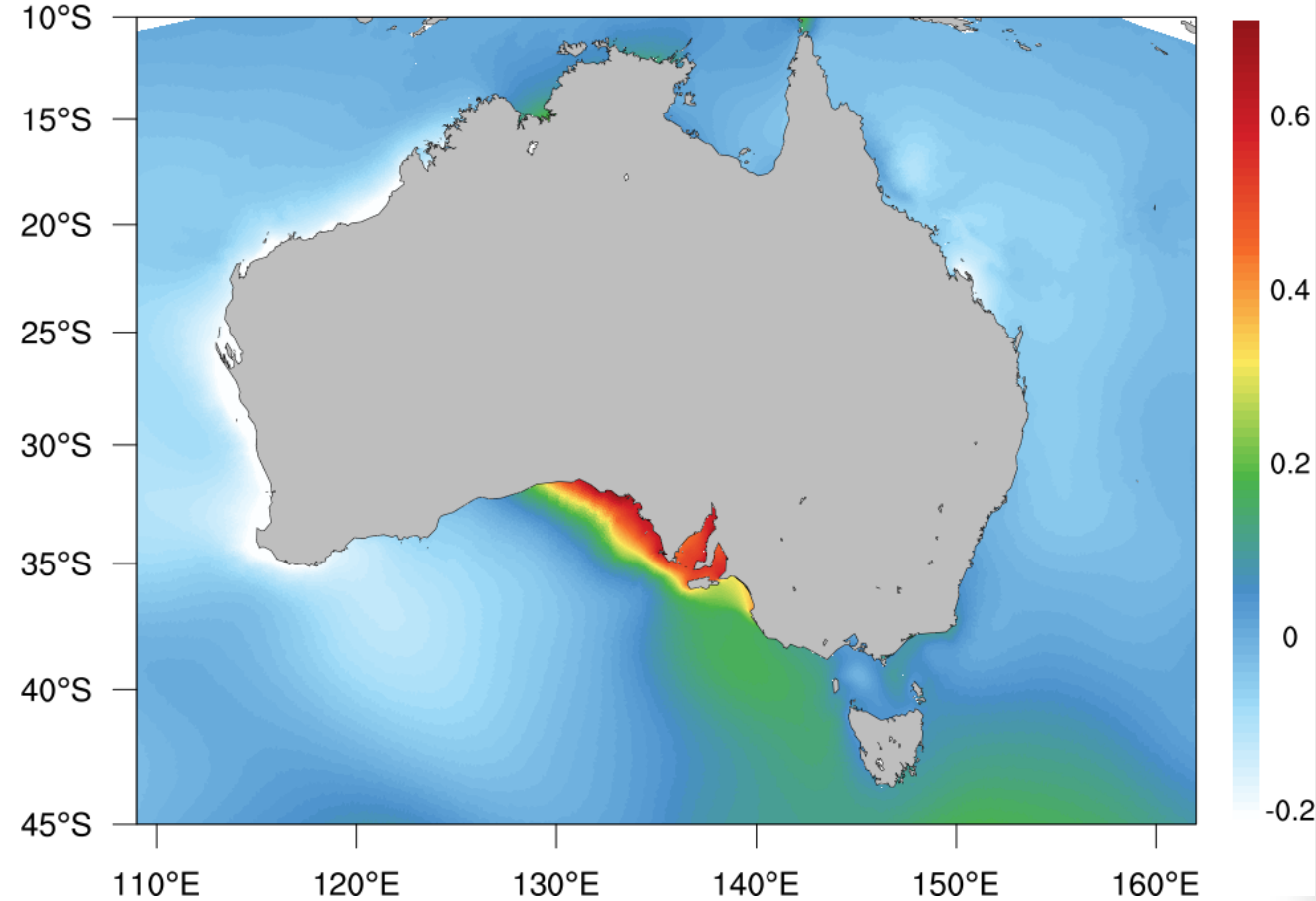


8 JUNE 2016 SOUTHERN OCEAN WINTER STORM – SOUTH AUSTRALIA



Surge (m)

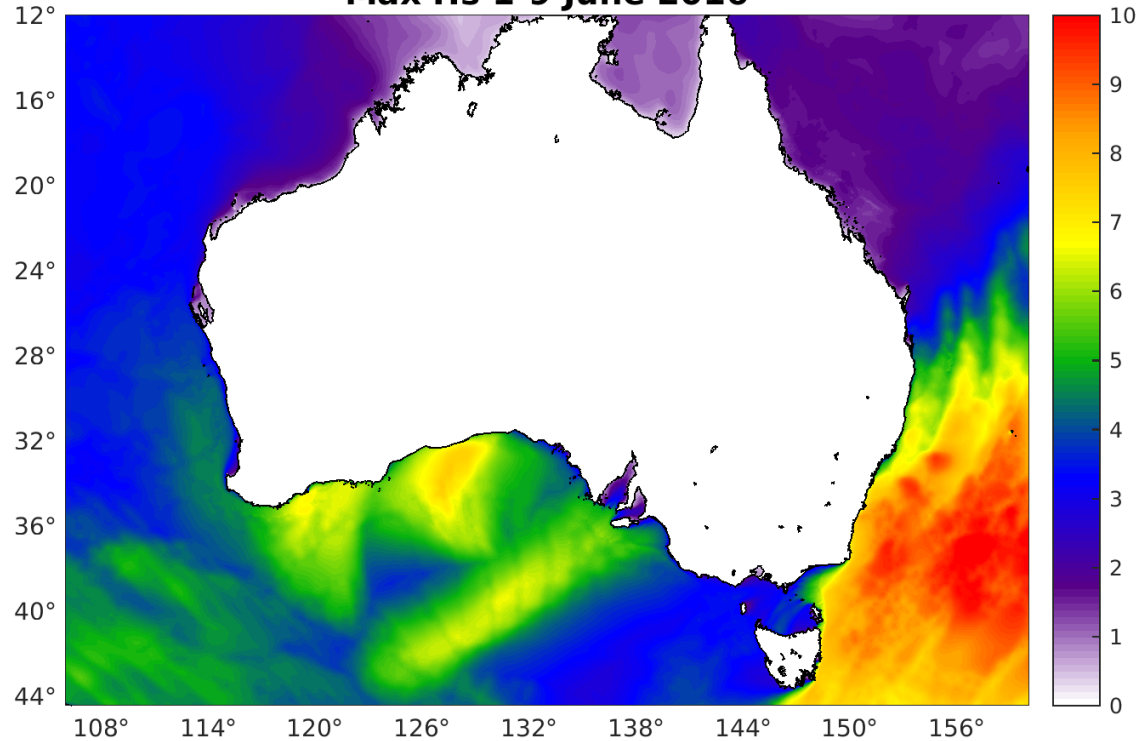
2016 Jun 08 14 GMT



8 JUNE 2016

SOUTH AUSTRALIA

Max Hs 1-9 June 2016



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Adelaide beachfront housing 'facing erosion risks' like those at Collaroy, Sydney

891 ABC Adelaide

Updated 8 Jun 2016, 12:20pm



PHOTO: Storm damage has left little access to West Beach in Adelaide. (Supplied: City of Charles Sturt)

8 JUNE 2016 SOUTH AUSTRALIA



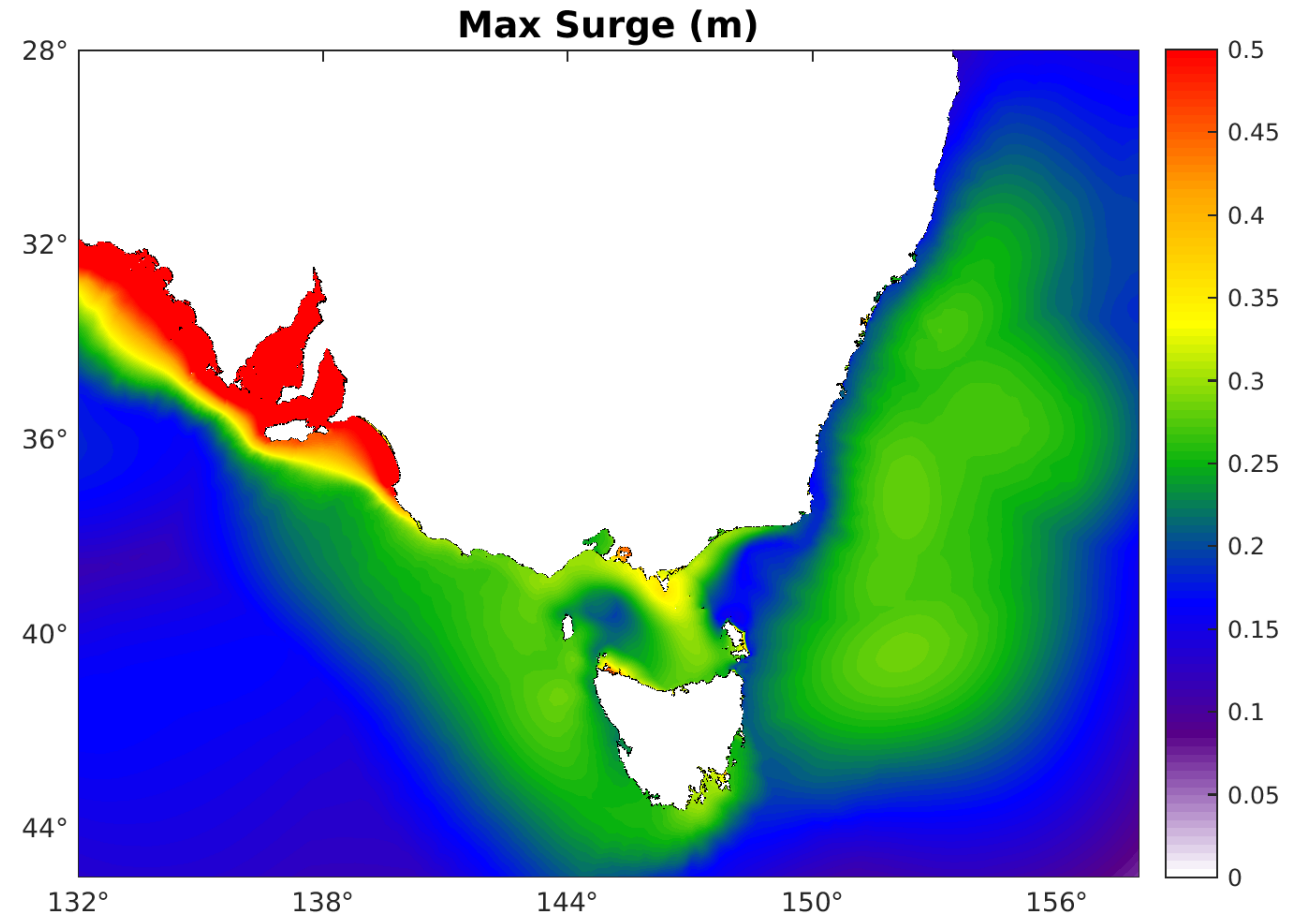
Adelaide weather: Residents prepare for flooding, storm front

Updated 21 Jun 2016, 2:42pm

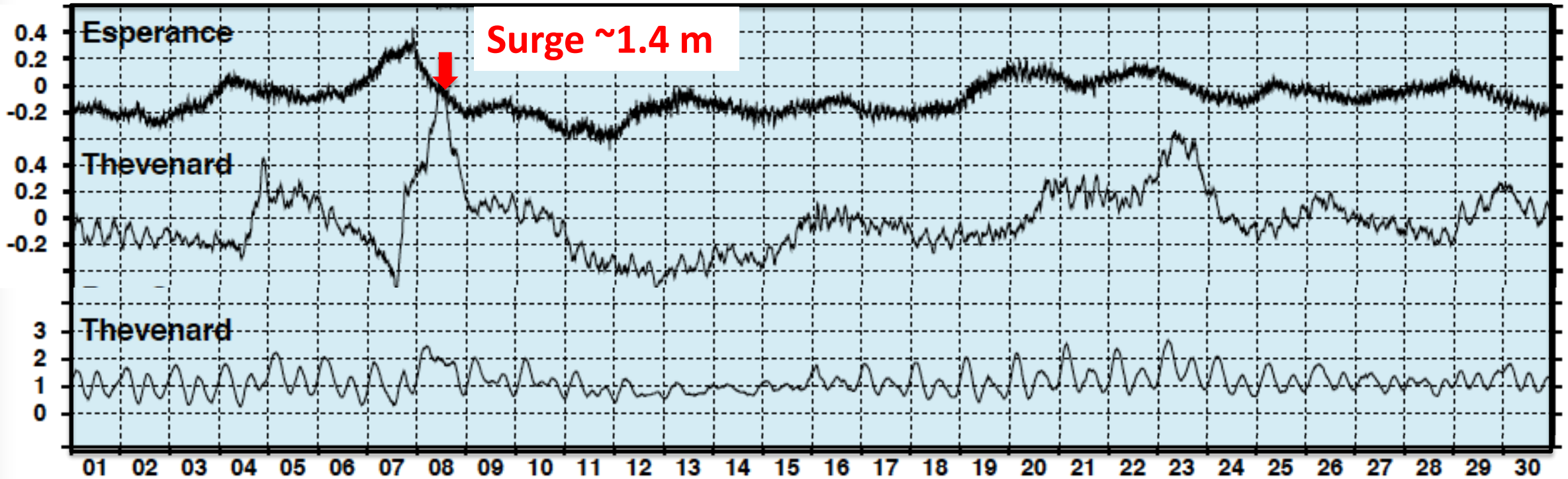
About 3,000 sandbags are being made ready for Port Adelaide and Birkenhead residents ahead of wild weather and high tides.

The State Emergency Service (SES) said it had been advised by the Bureau of Meteorology that a "vigorous front" was expected to pass across South Australia from the west and reach Adelaide on Thursday afternoon.

The front will coincide with forecast high tides at Port Adelaide on Thursday evening.



SPRING/NEAP TIDES VS SURGE



Spring tides – range ~2m

Neap tides – range ~0.5m

(data: NTC/Bom)

TROPICAL CYCLONE YASI FEB 2011

Dunk Island, QLD



BEFORE



Source: News Ltd.

AFTER

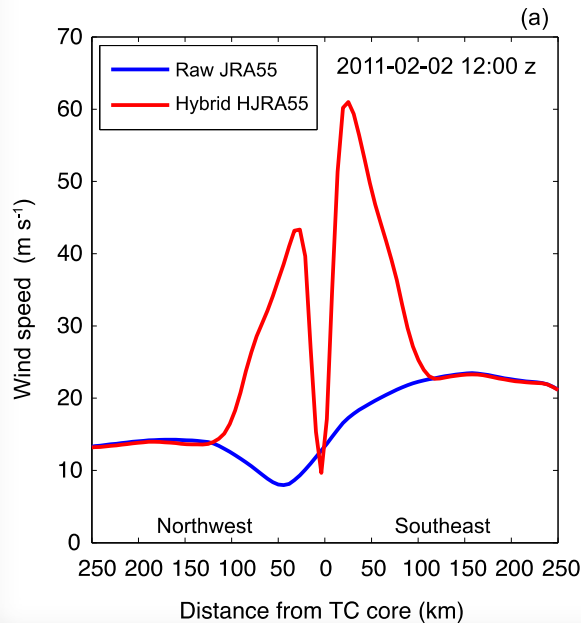
- One of the most intense and largest tropical cyclones to cross the coast in Australia
- Major damage (~\$800 M) caused by inundation and erosion from extreme waves (>5m) and storm surge (up to 5.3 m!)

TROPICAL CYCLONE YASI

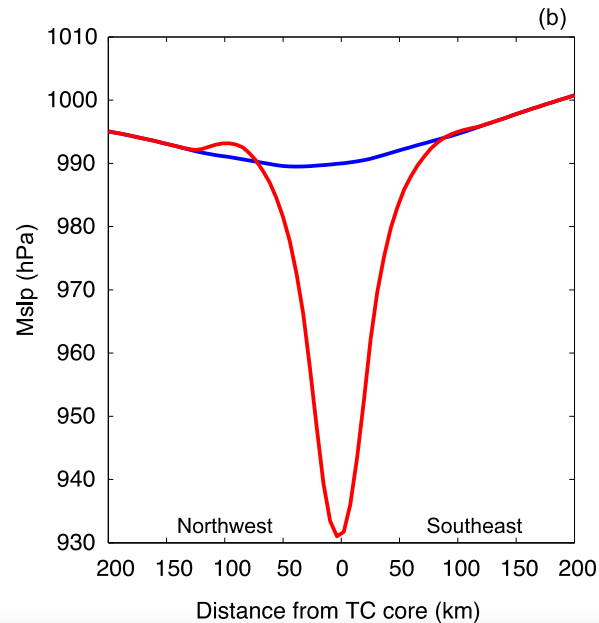
- Weather models typically underestimate the intensity of tropical cyclones

Cross sections of TC Yasi:

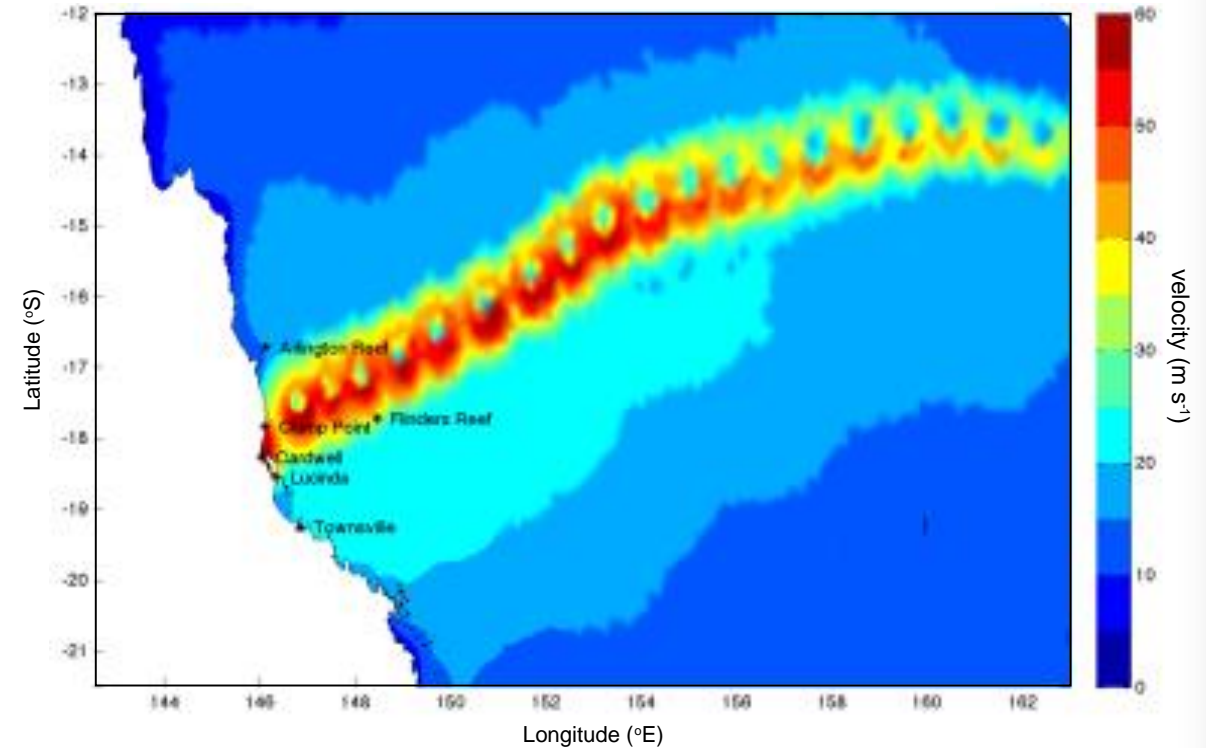
Wind



Pressure



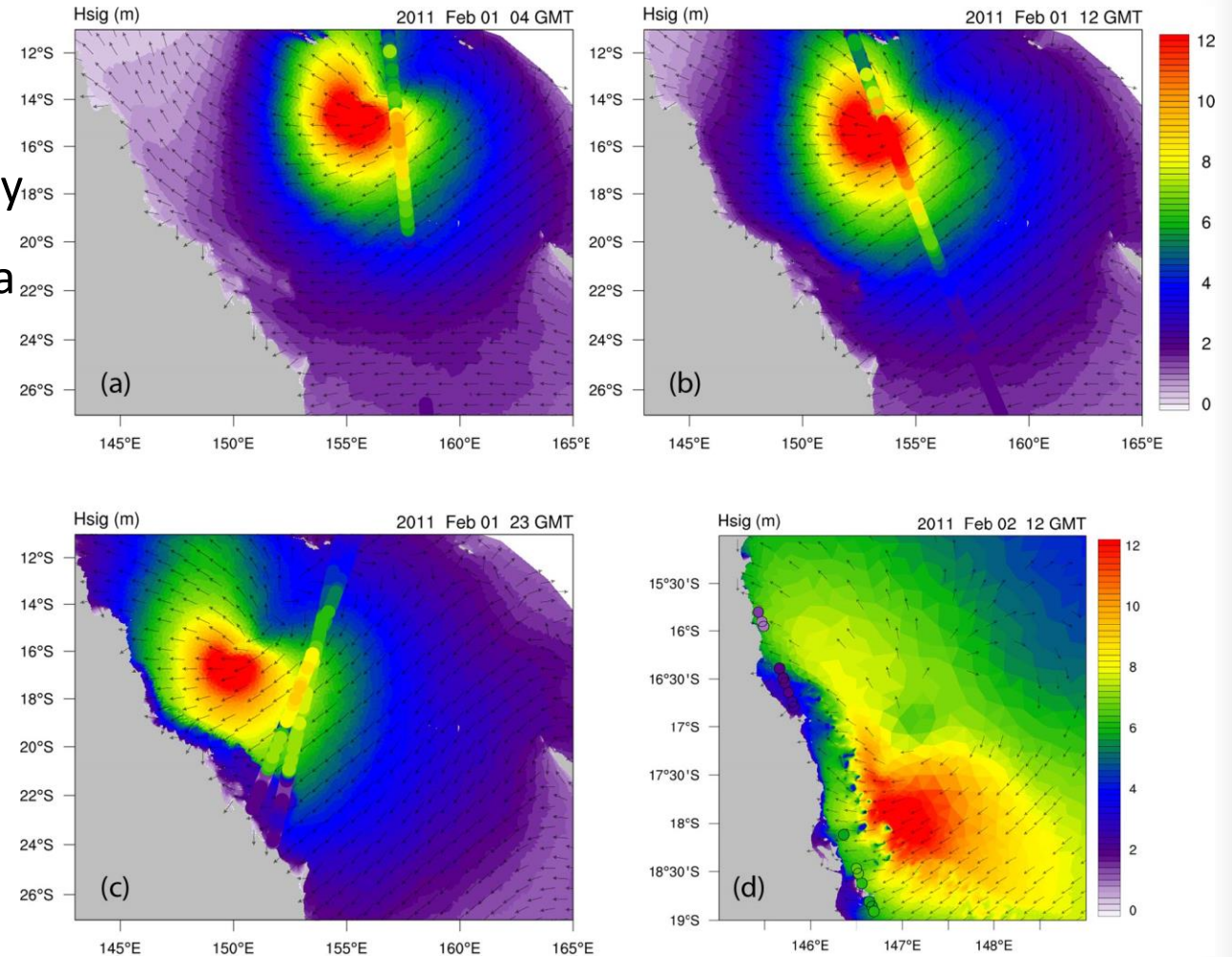
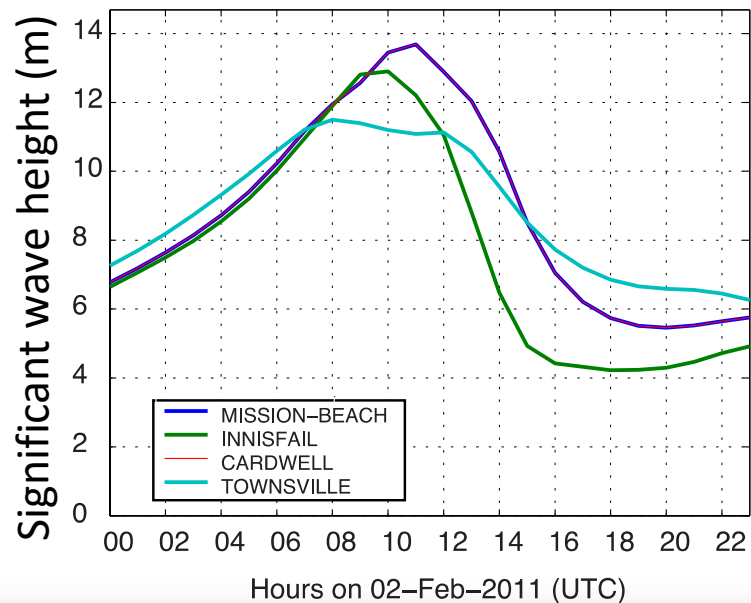
Simulated maximum wind speed



- Parametric wind models are used to simulate the vortex of tropical cyclones (e.g. Holland 2010)
- To force our surge-wave model we **merged** a **parametric wind model** with **JRA55** model data

TROPICAL CYCLONE YASI – EXTREME WAVES

- Yasi waves > 12 m offshore and 6 m nearshore
- Great Barrier Reef dissipated much of the wave energy
- Waves made a significant contribution to extreme sea levels and improved model accuracy



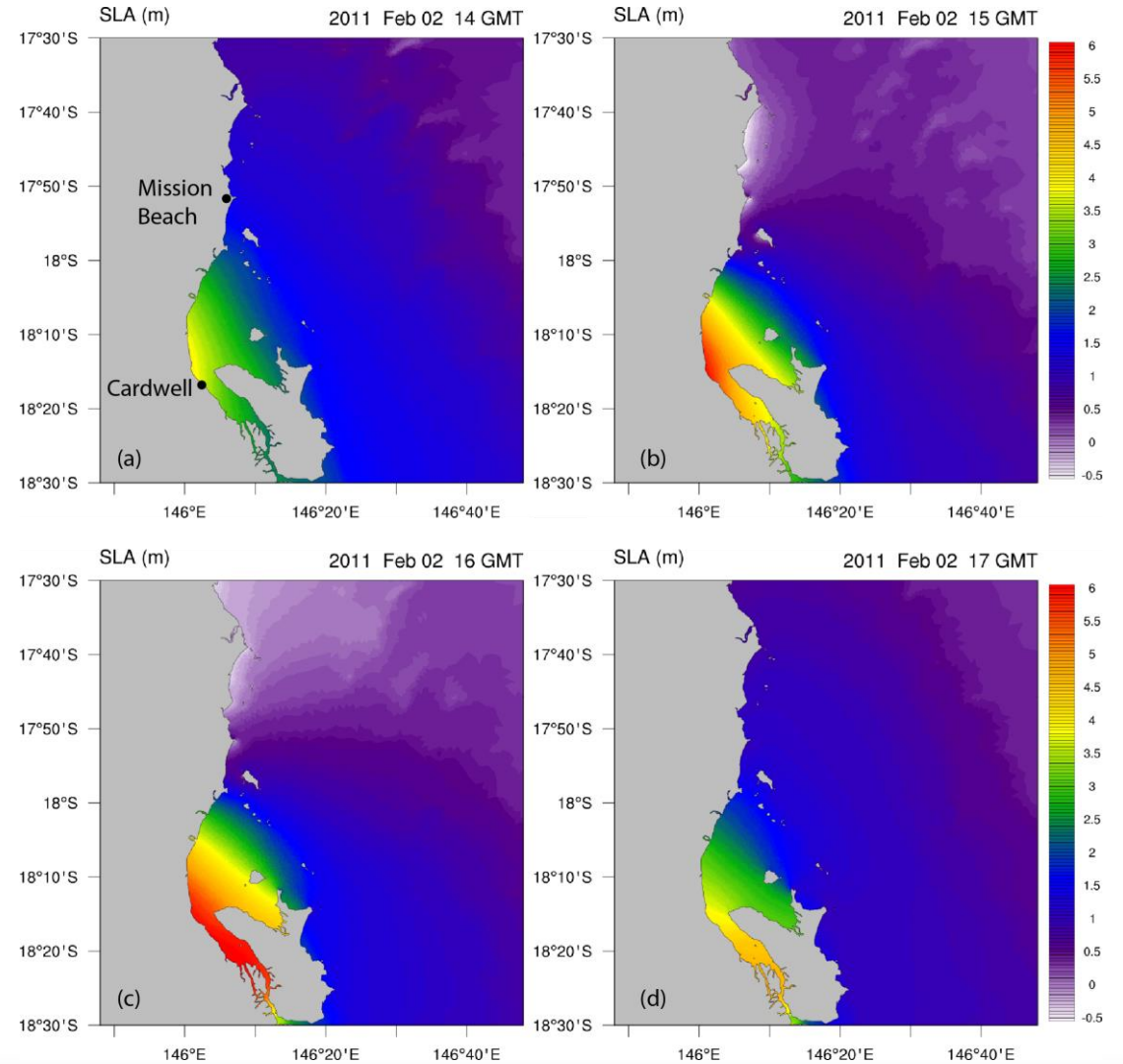
Simulated waves matched well with satellite observations

TROPICAL CYCLONE YASI – STORM SURGE

- Storm surge in Cardwell reached >5 m!



(source: DSITIA)

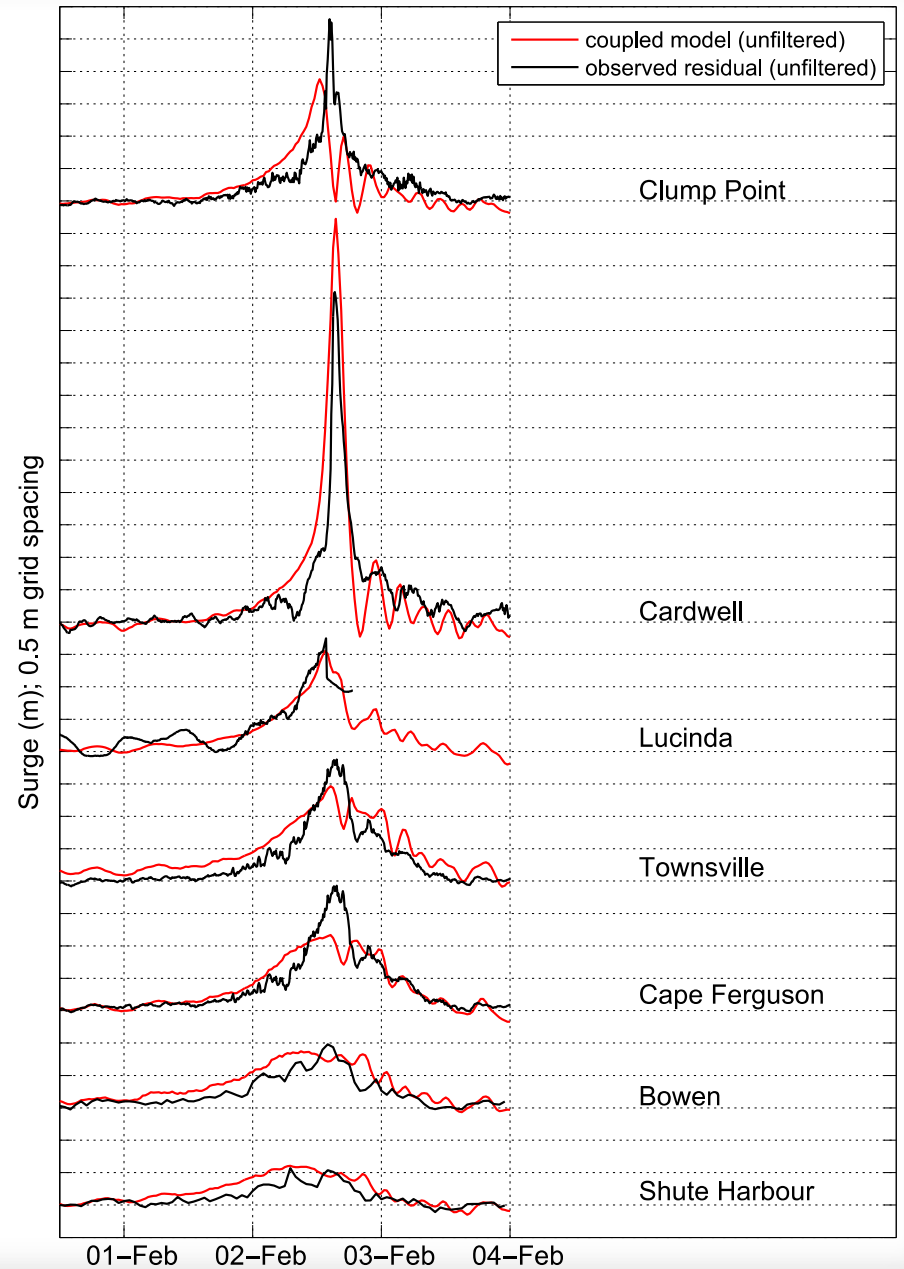


TROPICAL CYCLONE YASI – STORM SURGE

- Storm surge in Cardwell reached >5 m!

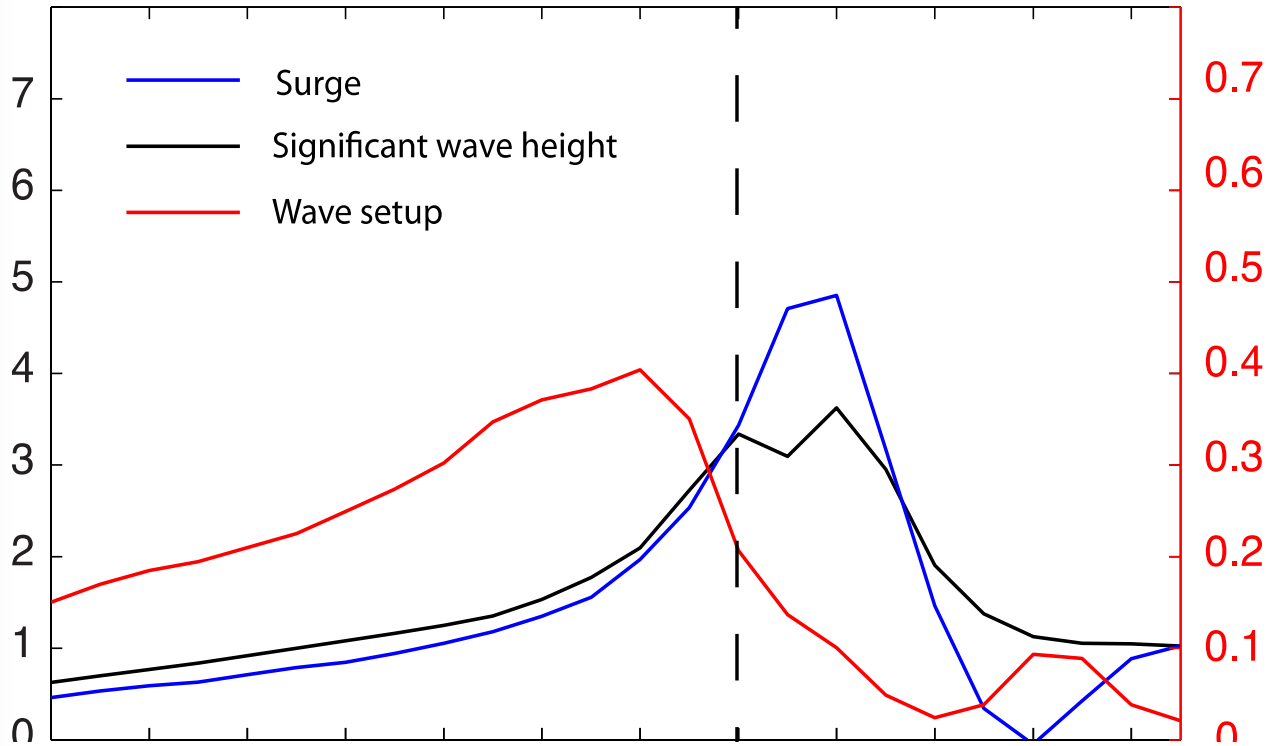


(source: DSITIA)

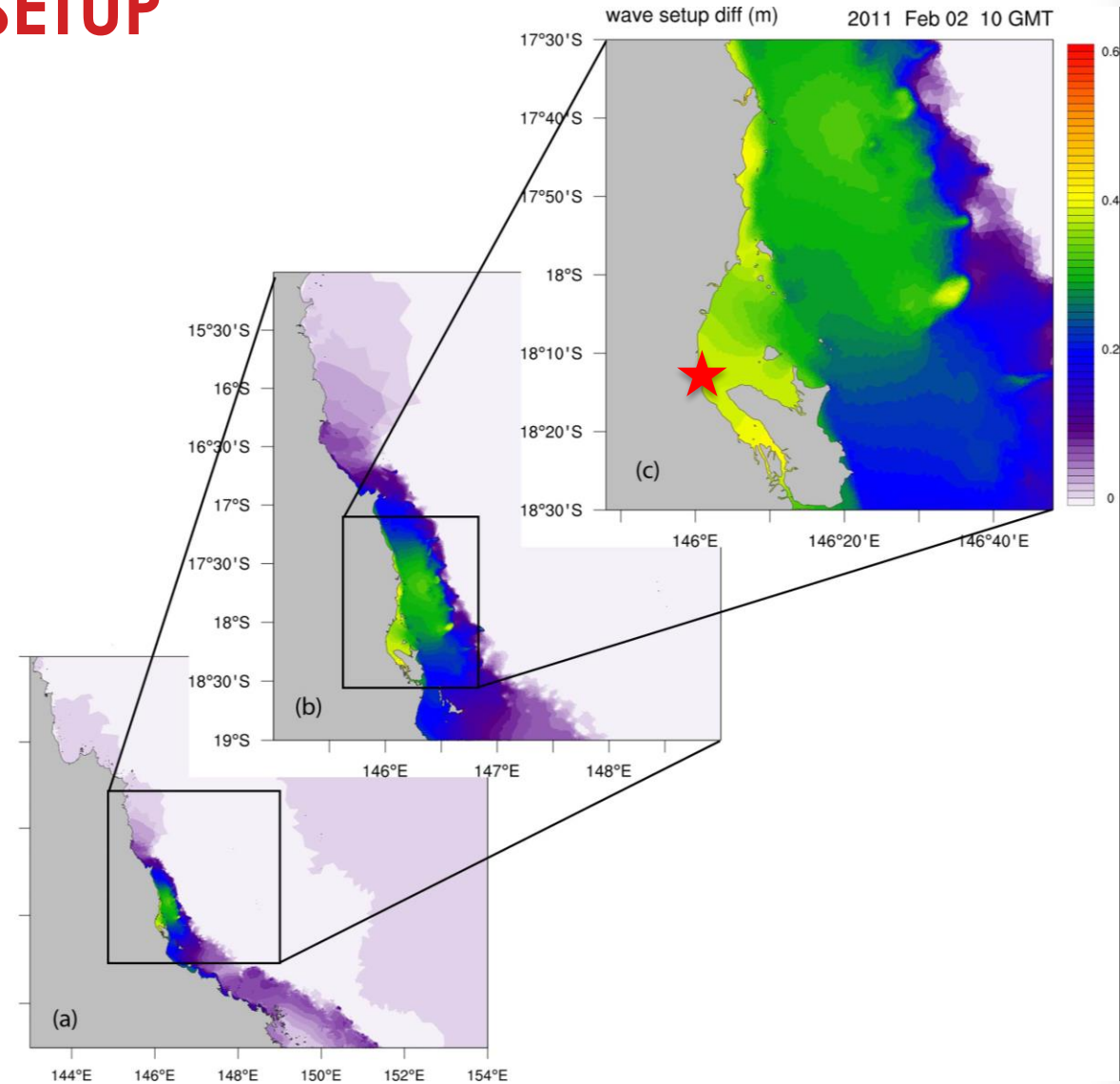


TROPICAL CYCLONE YASI – WAVE SETUP

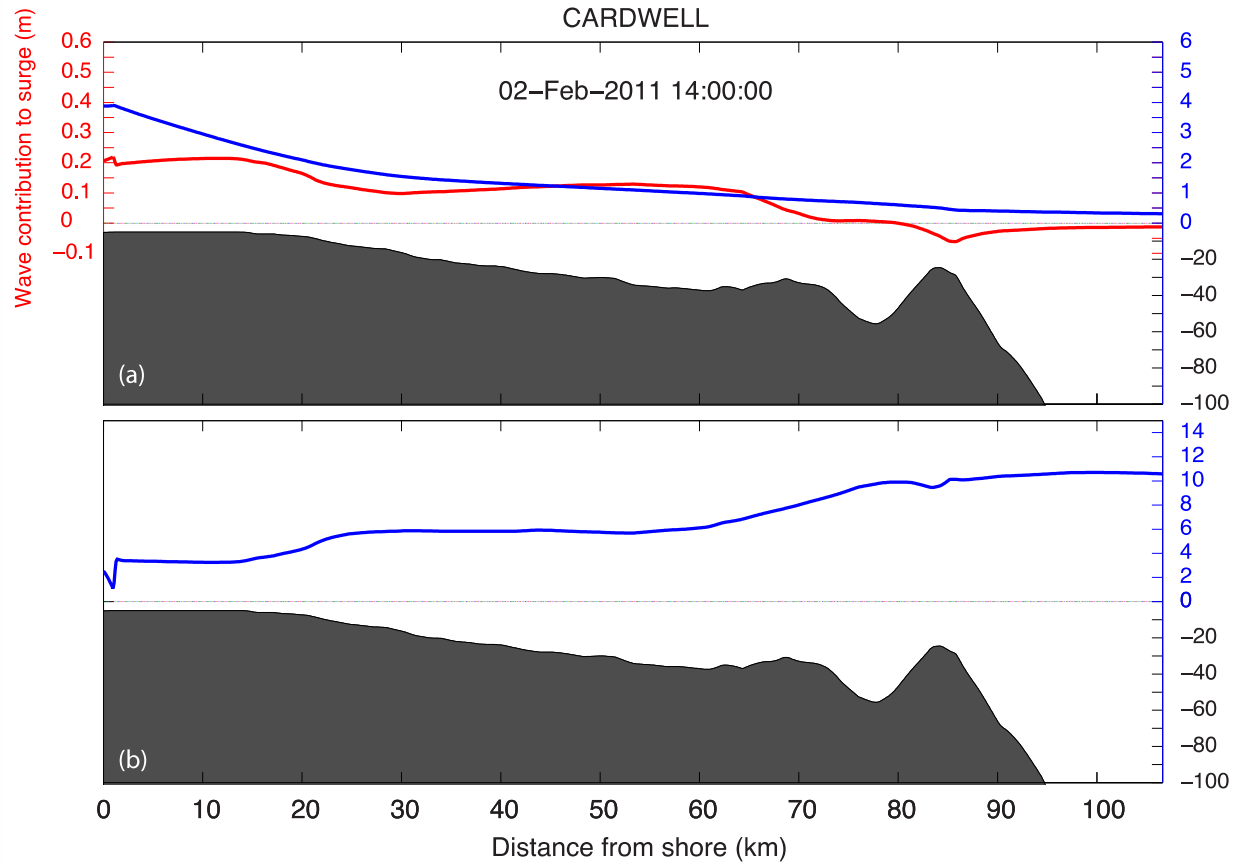
CARDWELL nearshore (5 m depth)



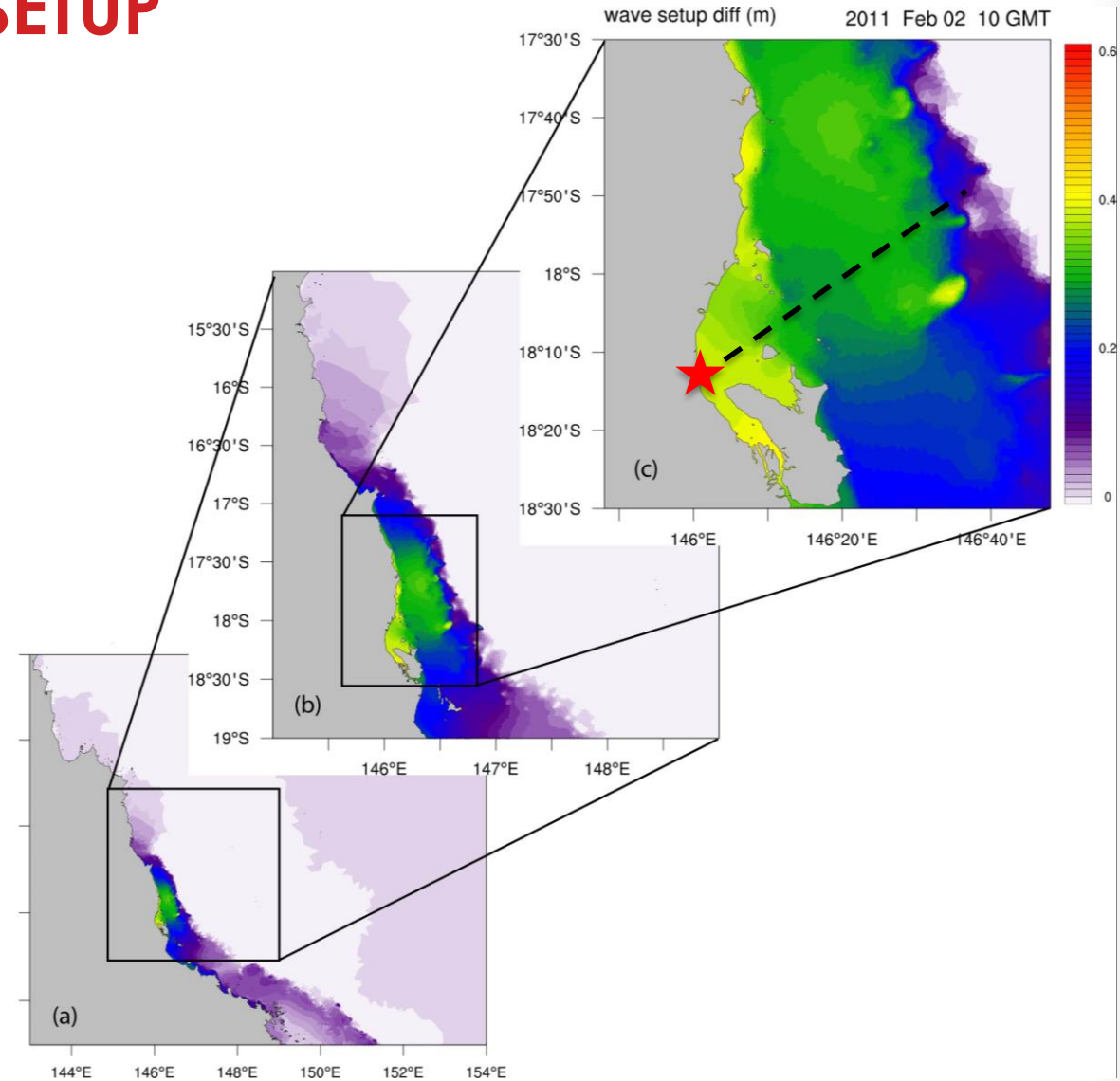
- Wave setup up to 0.4 m
- Varied depending on exposure and bathymetry



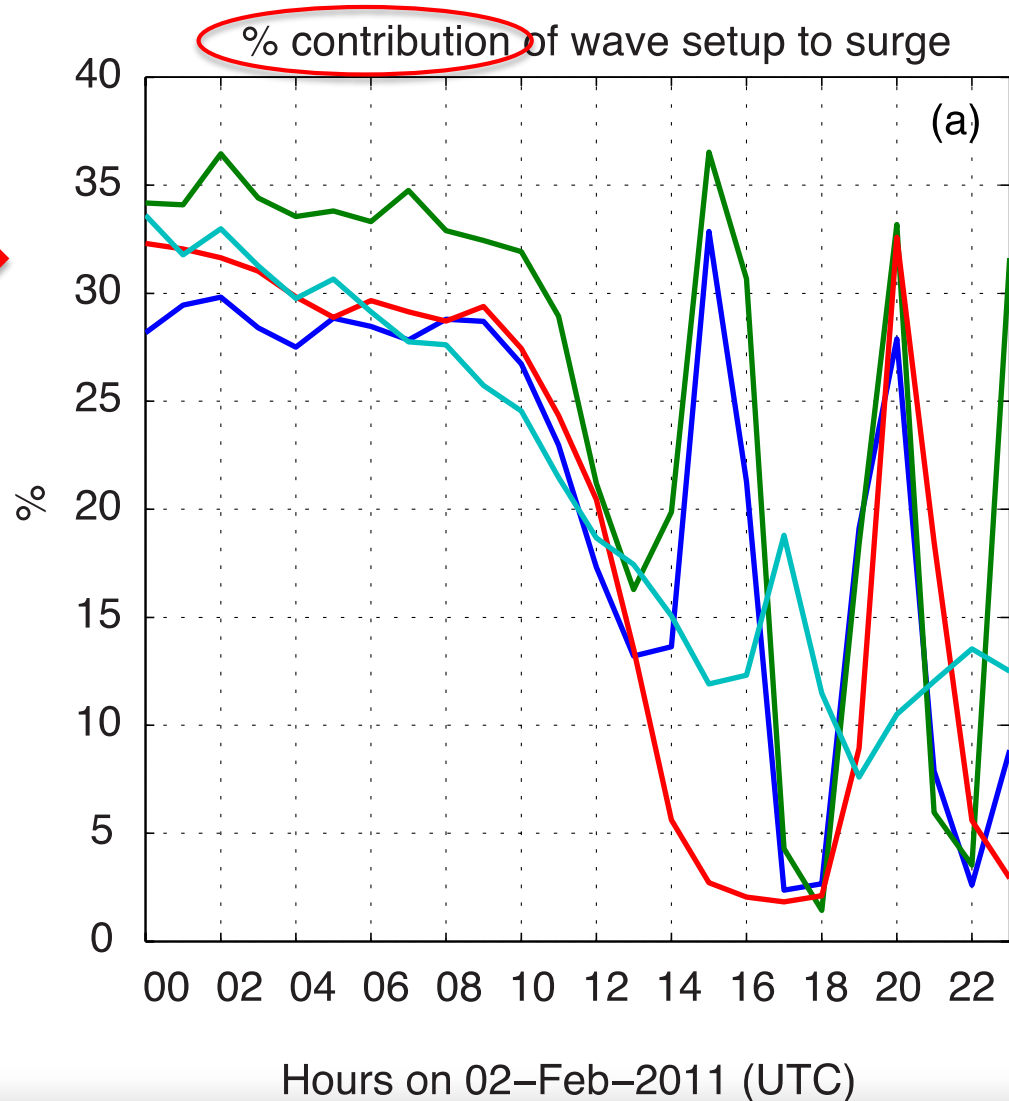
TROPICAL CYCLONE YASI – WAVE SETUP



- Cross shelf depths determined contribution of wave setup

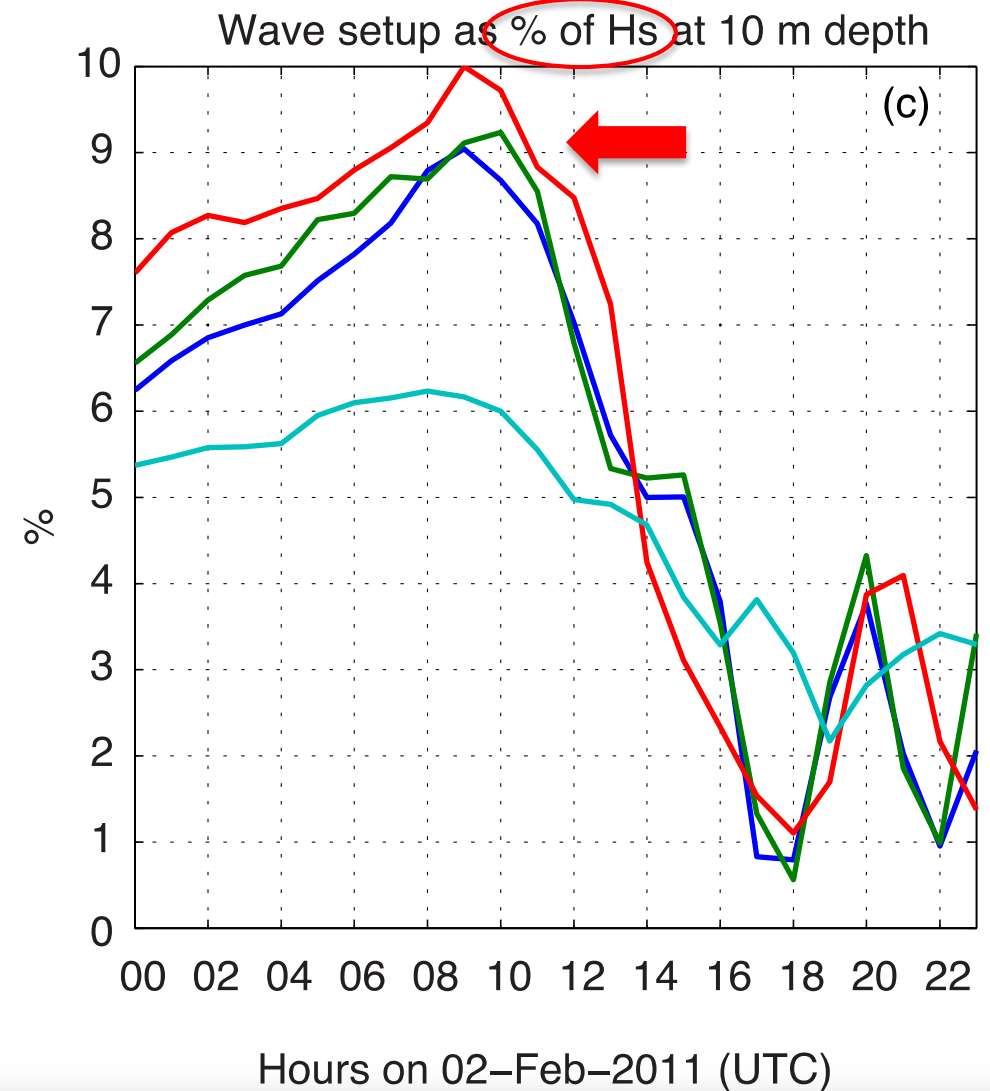


TROPICAL CYCLONE YASI – WAVE SETUP



Photograph 31: Coastal erosion and damage to buildings and infrastructure at Cardwell following TC Yasi (Source: News Limited)

TROPICAL CYCLONE YASI – WAVE SETUP



SUMMARY

- An advanced coupled surge-wave model has been set up for the entire Australian coastline and allows for estimation of wave setup over large areas
- Three test cases : Cyclone Alby (1978) in W.A. and Cyclone Yasi (2011) in Queensland, NSW June 2016 East Coast Low
- **15-35%** of simulated surge heights during an extreme event were due to wave setup
- The amplitude of **wave setup** is closely linked with **wave height and bathymetry**
- Wave setup at the coast ranged between **6-10%** of significant wave height measured at 10 m depth
- Accurate high resolution bathymetry is the major limiting factor for simulations of wave setup
- The capability to simulate waves and hydrodynamics over all Australia is made possible by a supercomputer

THANK YOU

