QCoast$_{2100}$ Phase 3

Identifying Storm Tide Hazard

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Knowledge and Information Sharing
Forum 09/11/2017 – Townsville

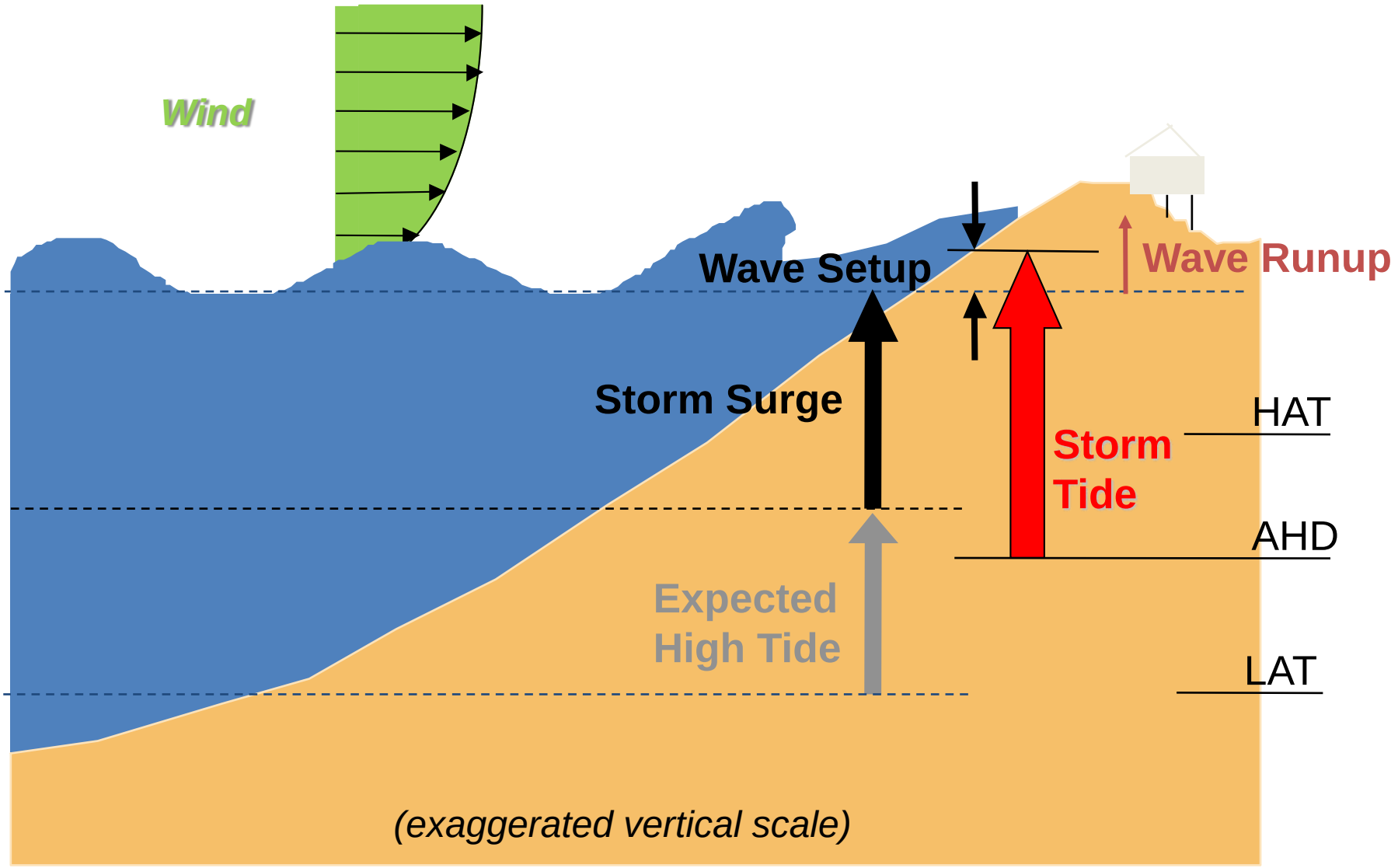
Outline

- Storm Tide “101”
- Some historical perspectives
- Key aspects of storm tide hazard methodologies
- Challenge your risk perception
- Climate change aspects
- Conclusions

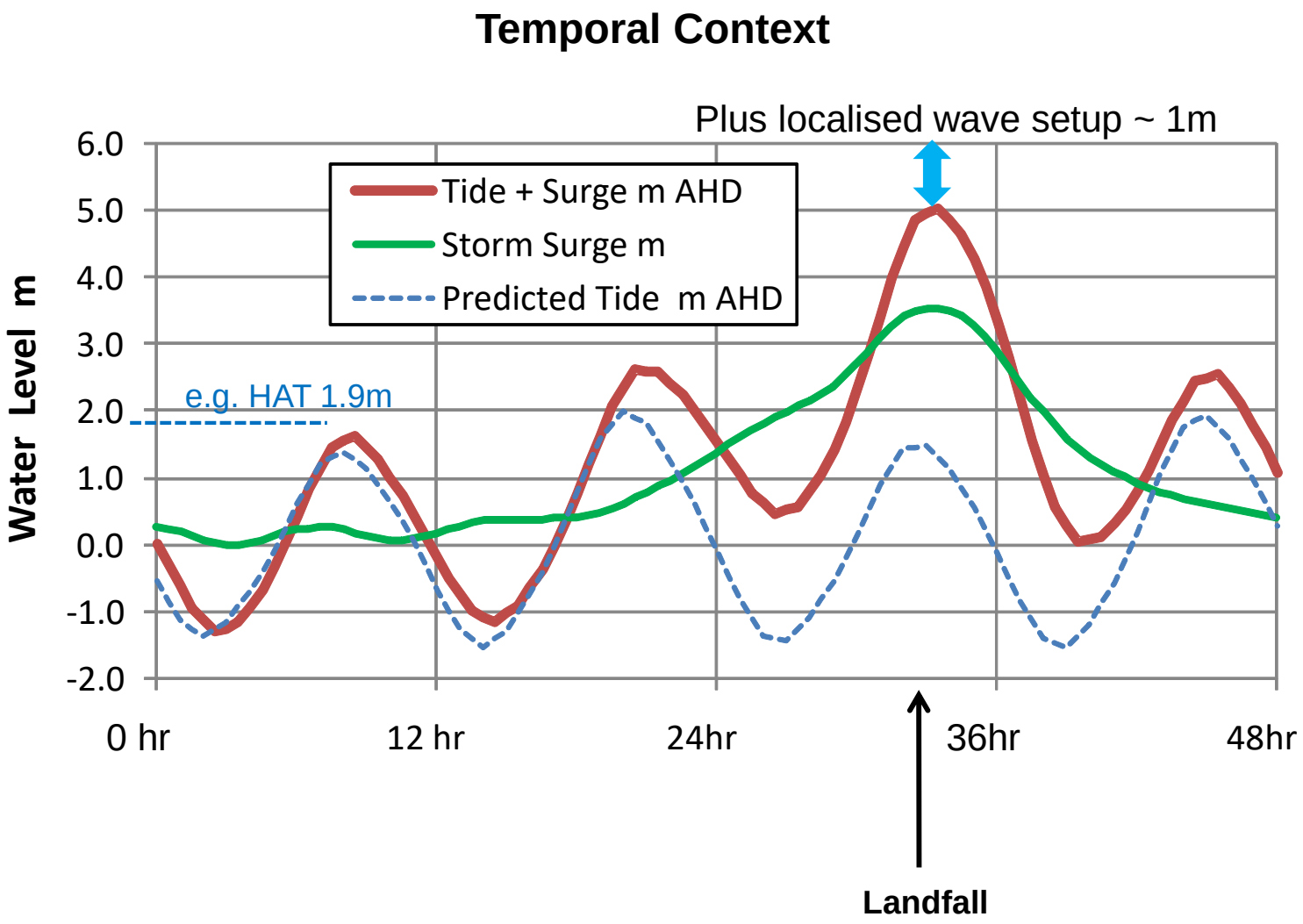
What Affects Ocean Water Levels?

- Very Long Period Geologic (100s to 10,000s years)
- Anthropogenic climate change (decades++)
- Long Period Ocean/Atmosphere Interactions (few years to decades)
- Annually (every year; seasonal)
- Daily (tides, winds)
- Intermittent extreme sea level events
  - Monsoon surges (northern Australia)
  - Non-tropical storm events (East Coast Lows etc)
  - Remote and/or close approach Tropical Cyclones

Components of a Storm Tide



Components of a Storm Tide



What Influences the Severity of Storm Tide Hazard?

- The storm climatology:
  - Intense low pressure / high wind speeds
  - Large size
  - Fast moving
  - Frequency of occurrence
- The environment:
  - Relatively wide and shallow continental shelf
  - Absence of large-scale reefs
  - Shallow water embayments providing coastal trapping
  - Track, angle of attack
- The exposure:
  - Low lying land
  - Low tidal range

Historical Storm Tide Events

Major Qld Storm Tide Events over the Past 100 Years

Date	Place	Event	Reference Central Pressure	Storm Surge	Inundation Above HAT
			hPa	m	m
21-Jan-1918	Mackay		933	3.8	2
10-Mar-1918	Mission Beach		926	>7?	3.5?
04-Feb-1920	Cairns		988	>1.5	0.7?
30-Mar-1923	Albert R Heads	*Douglas Mawson*	974	>3	2.3?
11-Mar-1934	Cape Tribulation		968	>9?	>6?
23-Feb-1948	Bentinck Is		996	>3.7	3.2?
02-Mar-1949	Gladstone		988	>1.2	0.2
03-Feb-1964	Edward River	*Dora*	974	5?	?
29-Jan-1967	Moreton Bay	*Dinah*	945	2?	1.5?
19-Feb-1971	Inkerman Station	*Fiona*	960	>4?	?
24-Dec-1971	Townsville	*Althea*	952	2.9	0.4
19-Dec-1976	Albert River	*Ted*	950	4.6?	3.6?
04-Apr-1989	Molongle Creek	*Aivu*	935 ?	3.2?	1.7?
06-Jan-1996	Gilbert River	*Barry*	950	4.5?	3.4?
10/03/2005	Night Island	*Ingrid*	960	1.15	1.19
20-Mar-2006	Clump Point	*Larry*	960	2.3	0.7
13/01/2009	Townsville	*Ex Charlotte*	987	0.7	0.4
3/02/2011	Cardwell	*Yasi*	929	5.3	2.2
28/01/2013	Brisbane	*Ex Oswald*	995	0.9	0.2
28/03/2017	Laguna Quays	*Debbie*	950	2.7	1.0

After Harper (1999)

The Past …

Mackay Jan 1918 – 30 killed

Image courtesy Bureau of Meteorology (J. Callaghan)

The Past …

Cairns - 1920

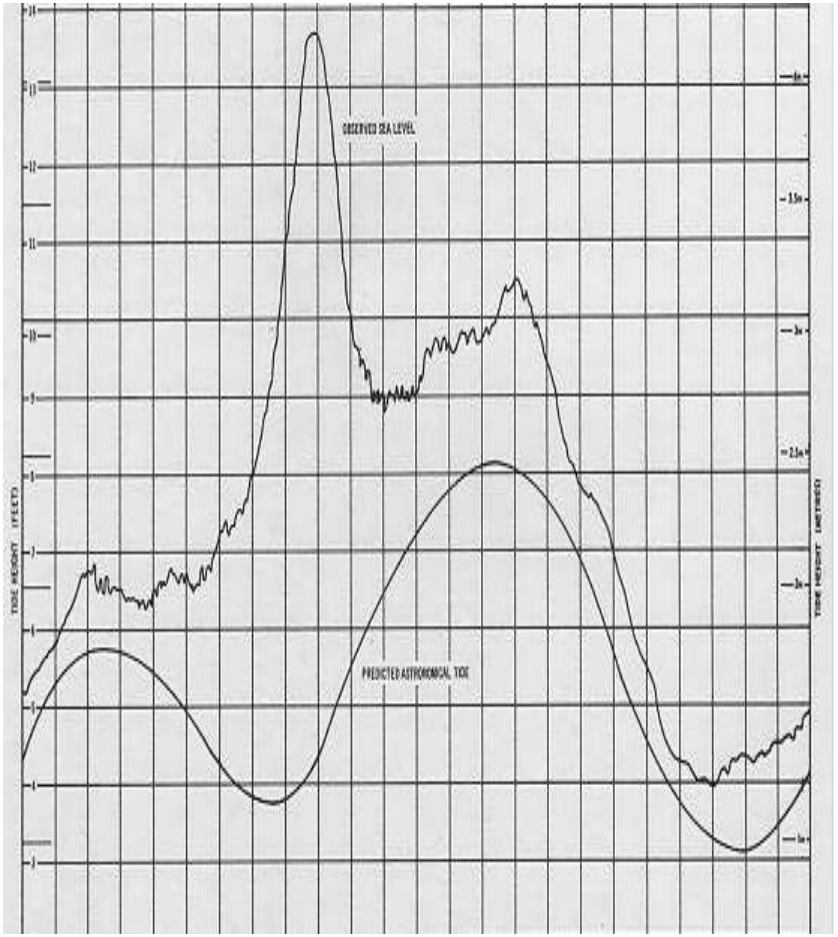
Image courtesy Bureau of Meteorology (J. Callaghan)

The Past …

Ada - Jan 1970 – Whitsunday Islands

Bureau of Meteorology Image

The Past …



***Althea* - Dec 1971 – Townsville**

Bureau of Meteorology Image

The Past …

[2.5m AHD Clump Point]

Fl

Bingil Bay

Clump Point Jetty

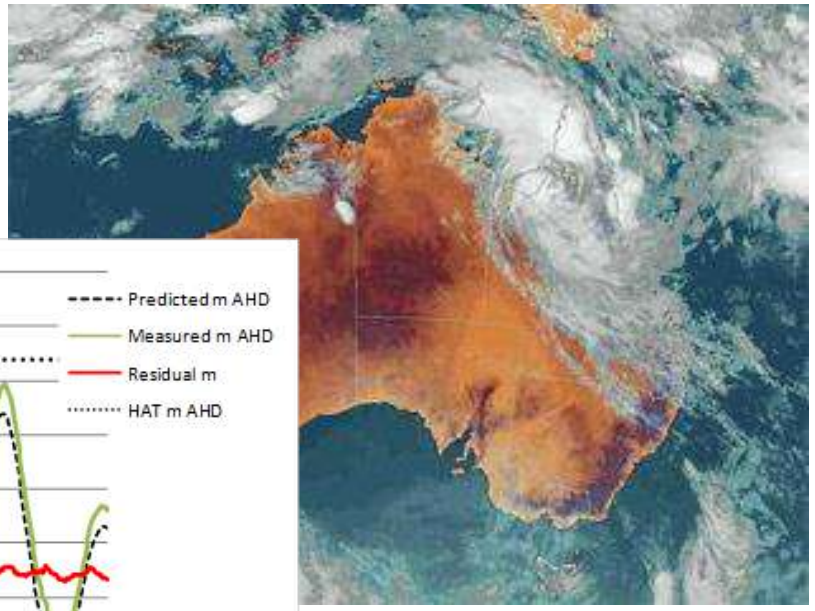
ch

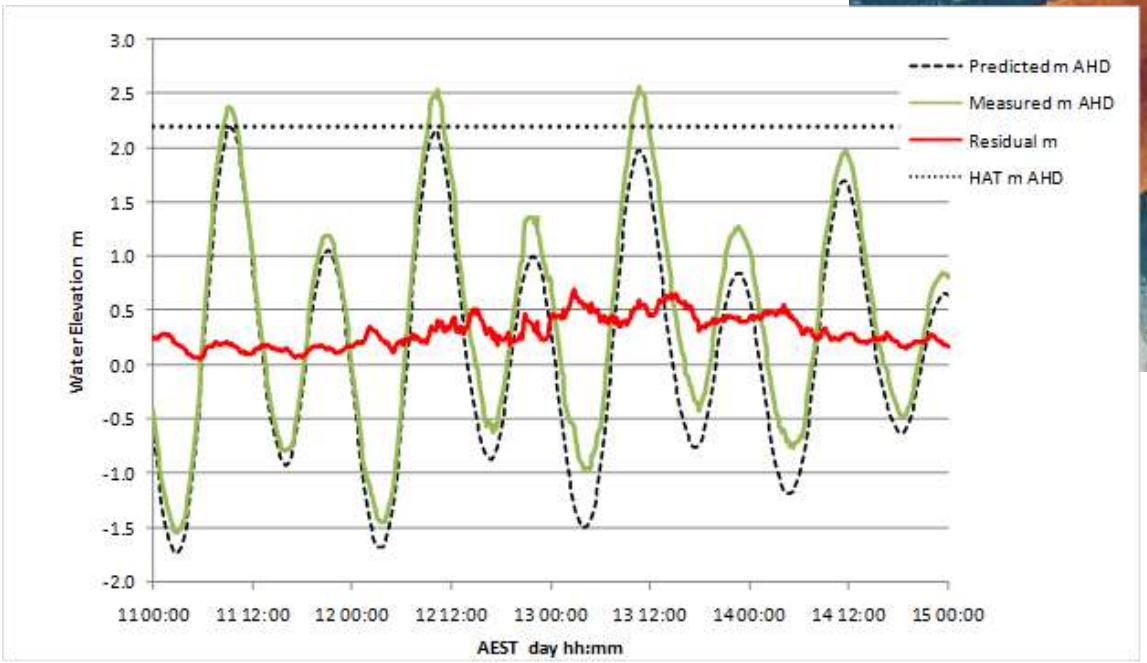
Larry - Mar 2006 - Innisfail

Willis Re - Systems Engineering Australia Images

The Past …

A very weak, remote ex-TC but with a large-scale wind field.





A persistent low-level surge coincided with a period of “King Tides”.

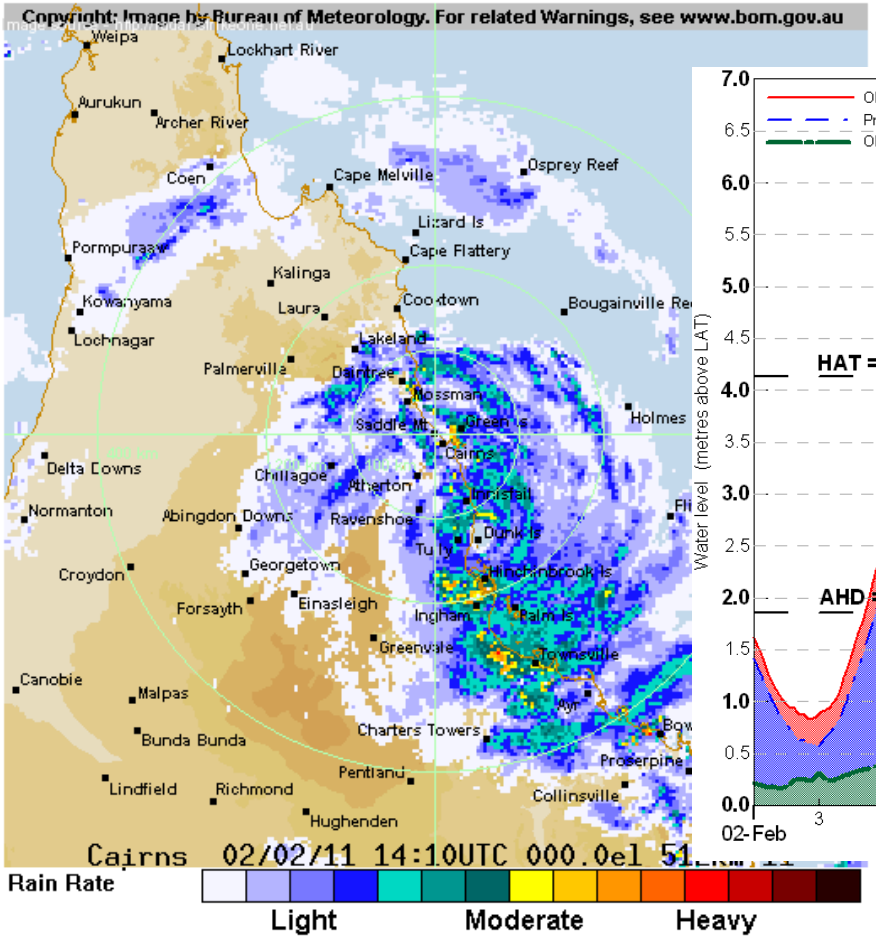
***Ex-TC Charlotte* - Jan 2009 – Townsville**

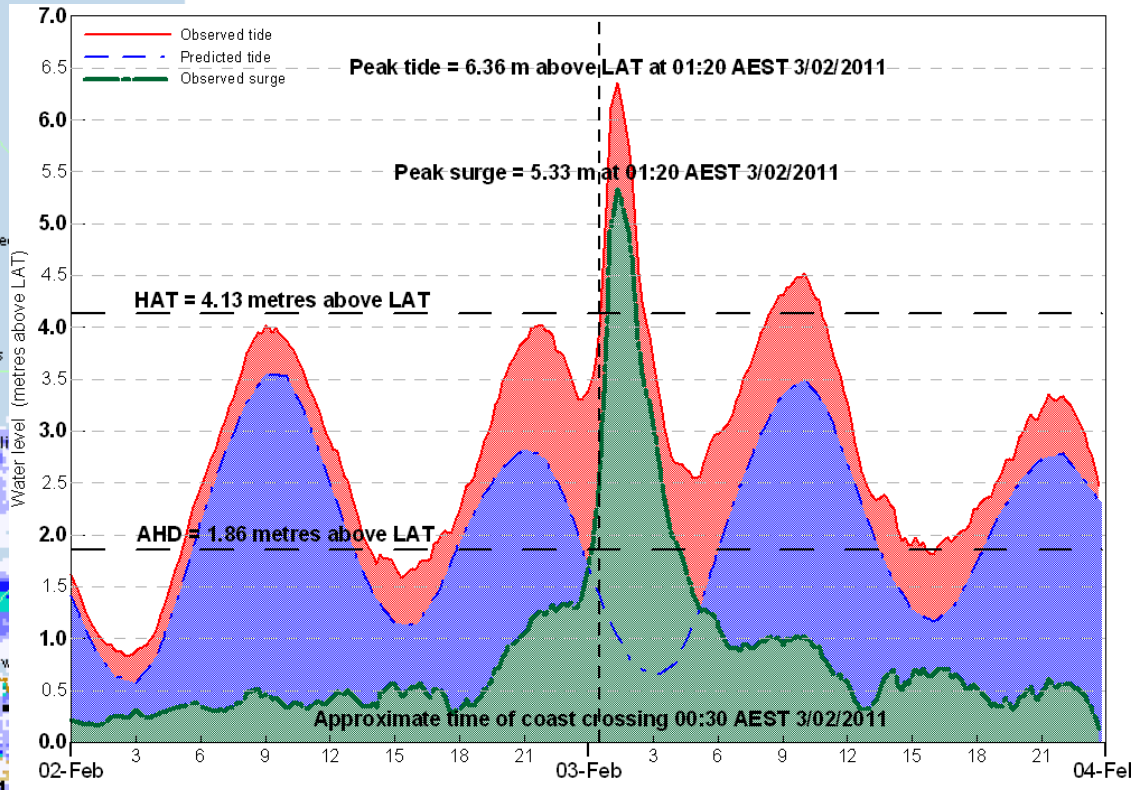
The Past …

***Ex-TC Charlotte* - Jan 2009 – Townsville**

Ex-TC Charlotte peak storm tide levels were +0.04m higher than TC Althea in 1971 but wind and wave impacts were much lower.

The Past …





***Yasi* - Feb 2011 – Kurrimine to Tully Heads**

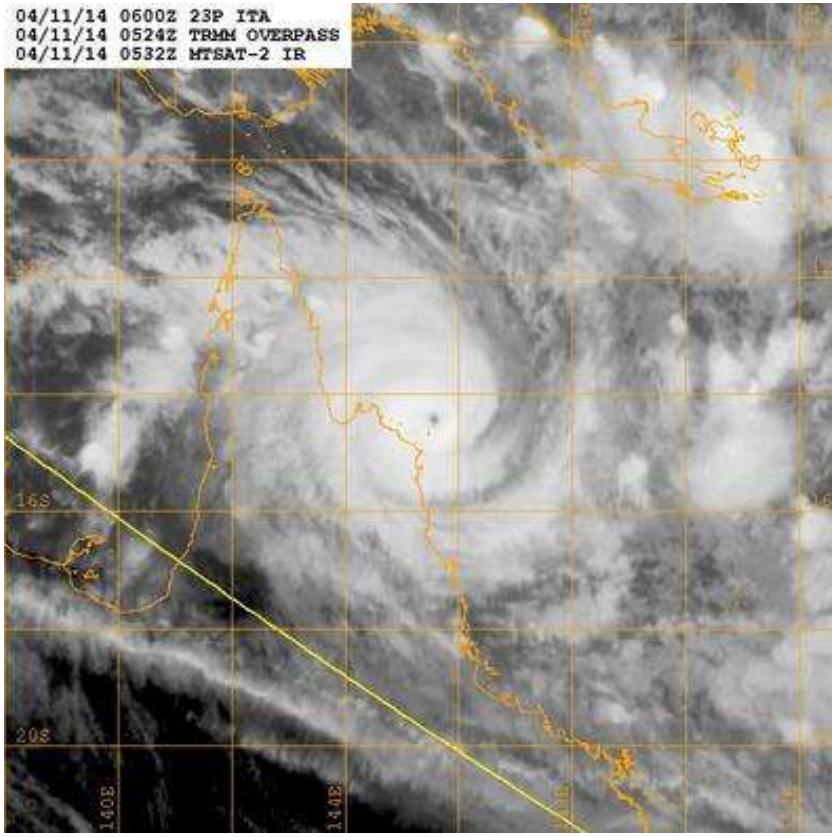
The Past …

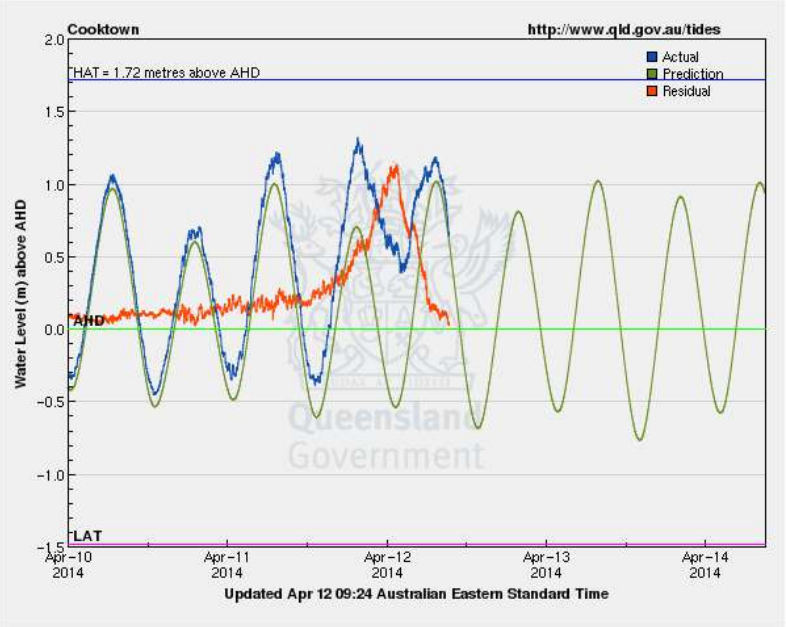
[4m AHD at Tully Heads; 5?m inland]

Yasi - Feb 2011 – Kurrimine to Tully Heads

JCU Cyclone Testing Station and GHD Pty Ltd Images

The “not so long ago” …

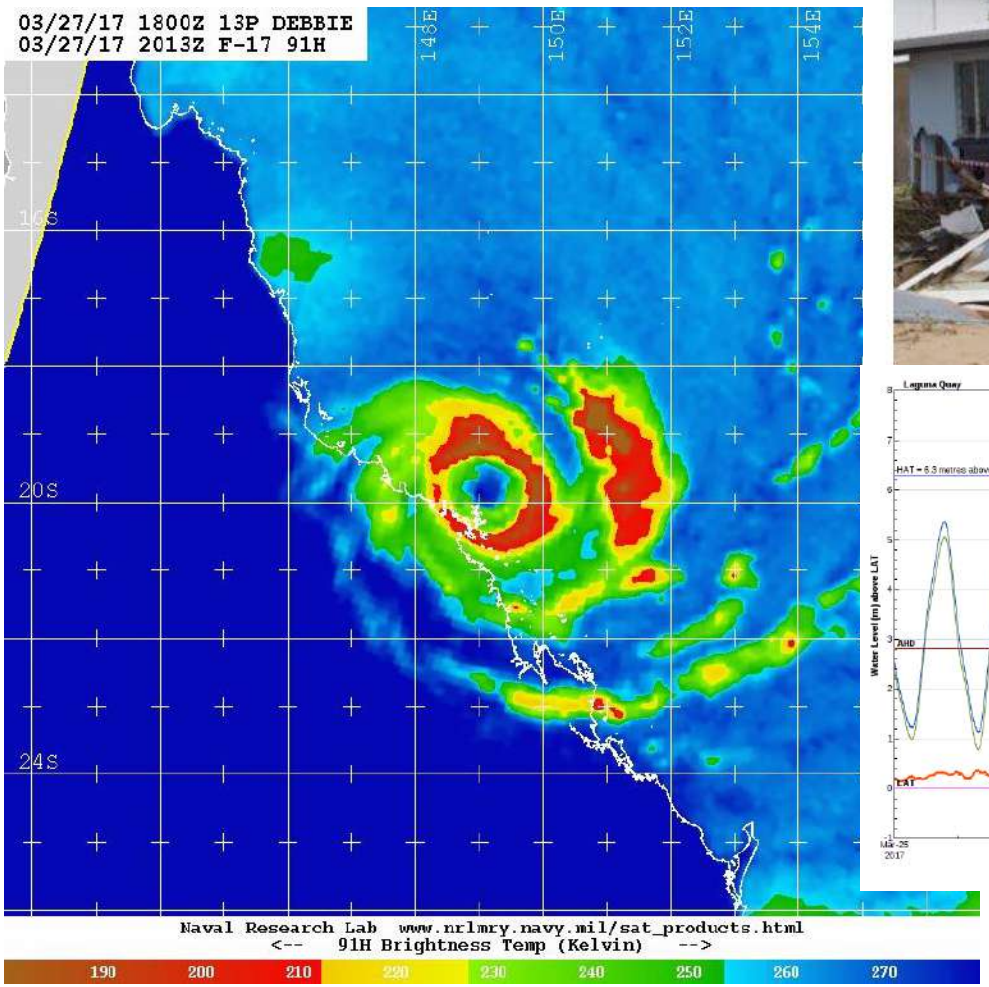


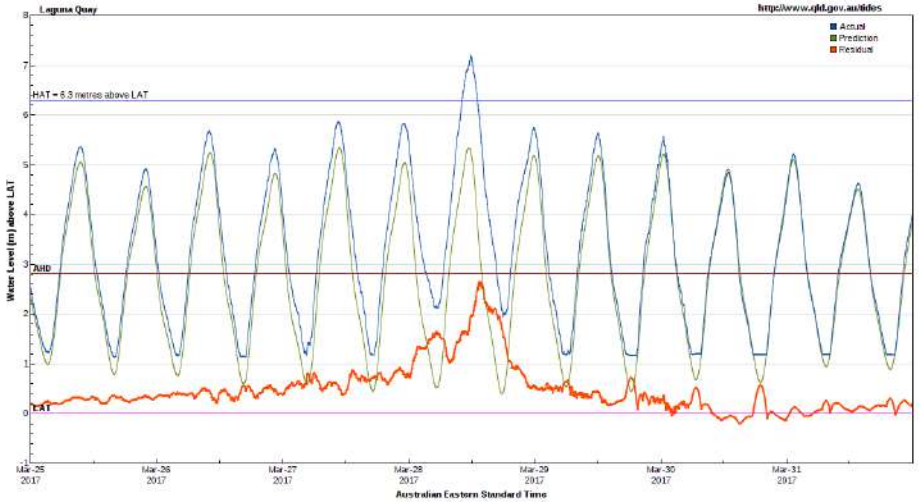


Ita – 11 Apr 2014 – Cape Flattery to Cooktown

US NRL, DSITI images

The “just recently” ..



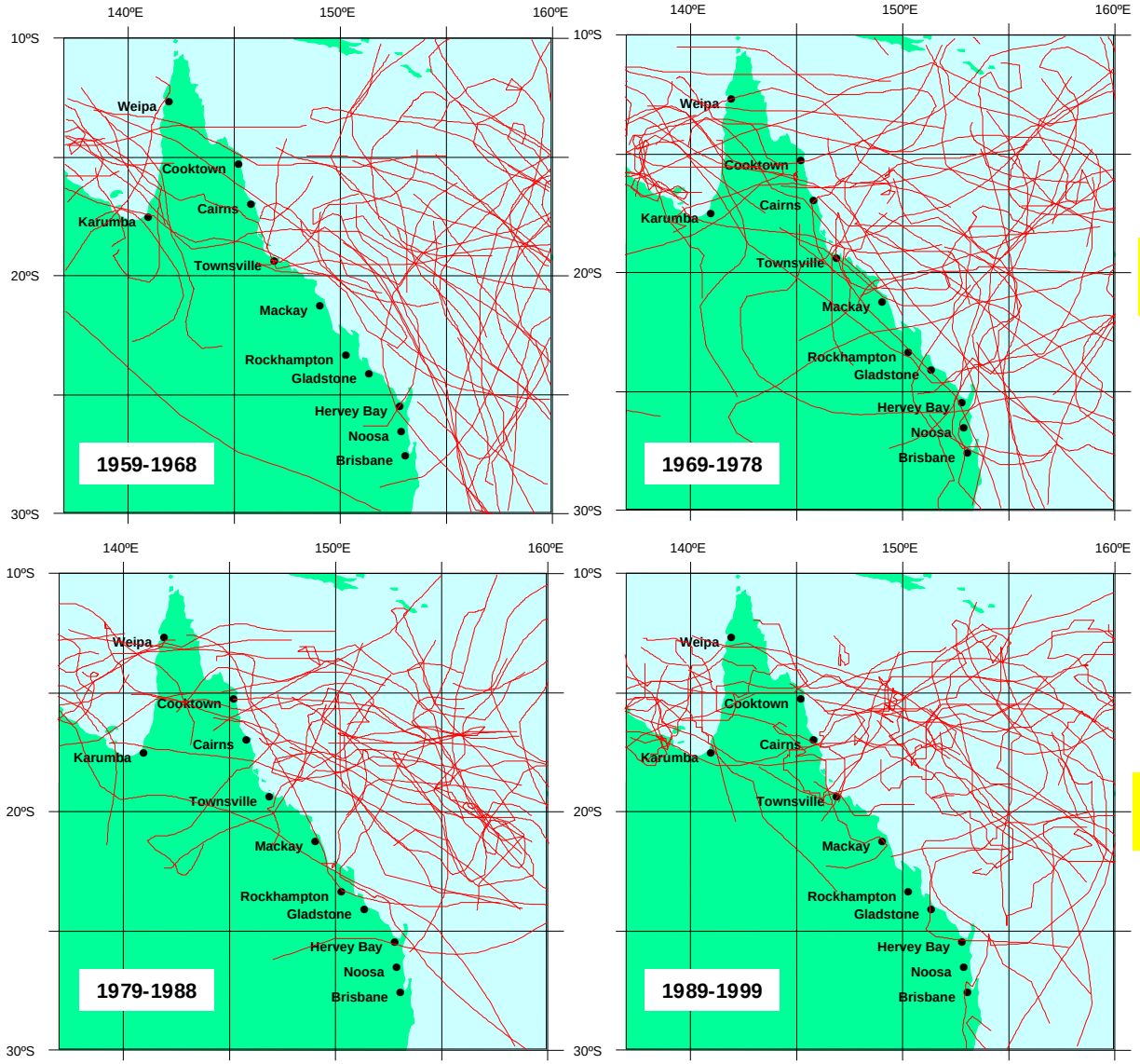


Debbie – 28 Mar 2017 – Whitsundays

US NRL, DSITI, JCU Cyclone Testing Station images

Tropical Cyclone Climatology

Decadal variability



La Niña

El Niño

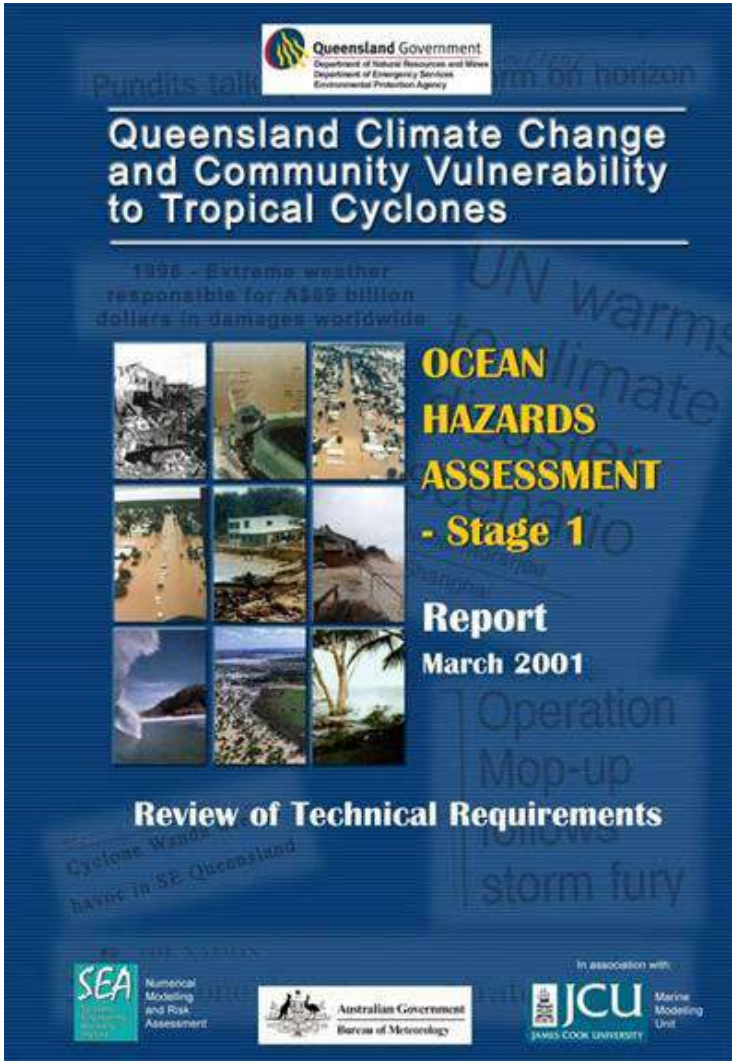
Coastal Hazard Methodologies

- Quite specialised expertise is required
- Requires a statistical approach:
  - TC climatology analyses
  - Development of coastal hydrodynamic models for tide, storm surge and waves
  - Application of stochastic simulation methods
- Requires calibration and validation
  - Knowledge is continuously advancing
  - More and better data is being collated
- Valuable references:
  - “Queensland Climate Change Study 2001-2004”
  - Various investigation reviews are available

Queensland Climate Change and Community Vulnerability to Tropical Cyclones

STAGE 1:
Technical blueprint
Climatology
Greenhouse Effects
Modelling Approaches
- **Wind**
- **Surge**
- **Waves**

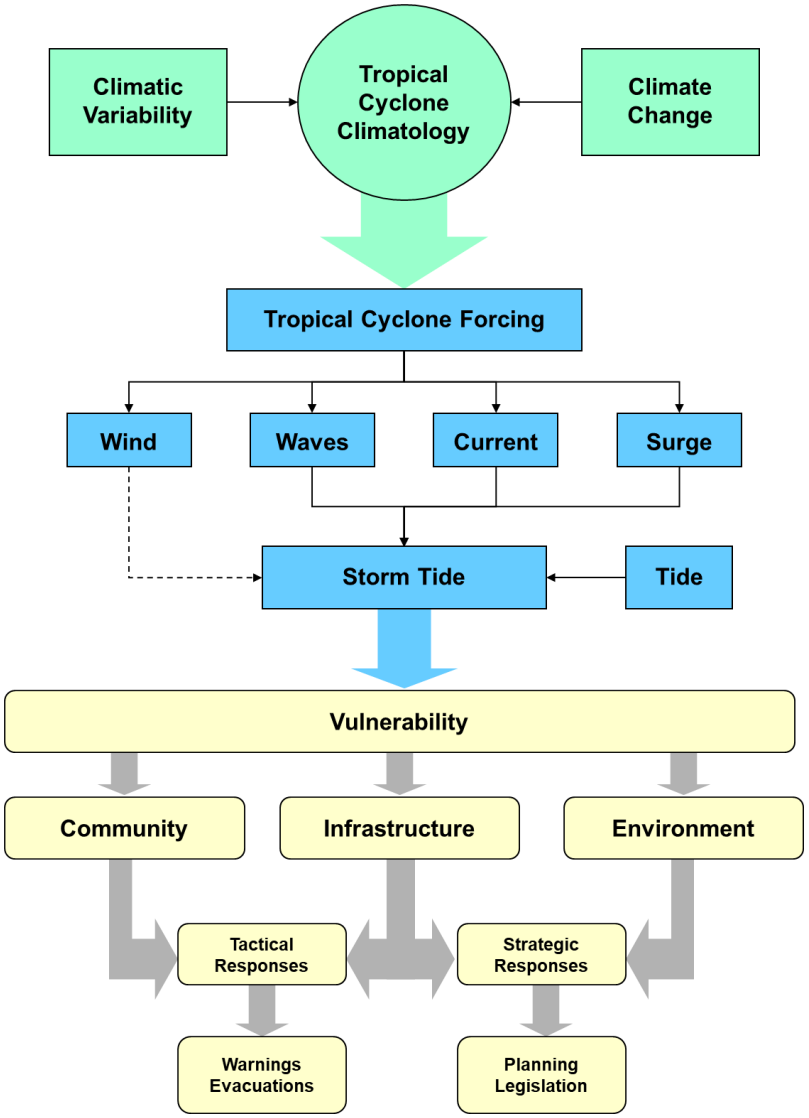
Calibration and Verification
Statistical methodologies
Information needs
Recommendations
STAGE 2: Tide + Surge + Wave Setup (selected)
STAGE 3: Tide + Surge (East Coast of Qld)
STAGE 4: Housing Vulnerability to Wind
SYNTHESIS REPORT RECOMMENDATIONS



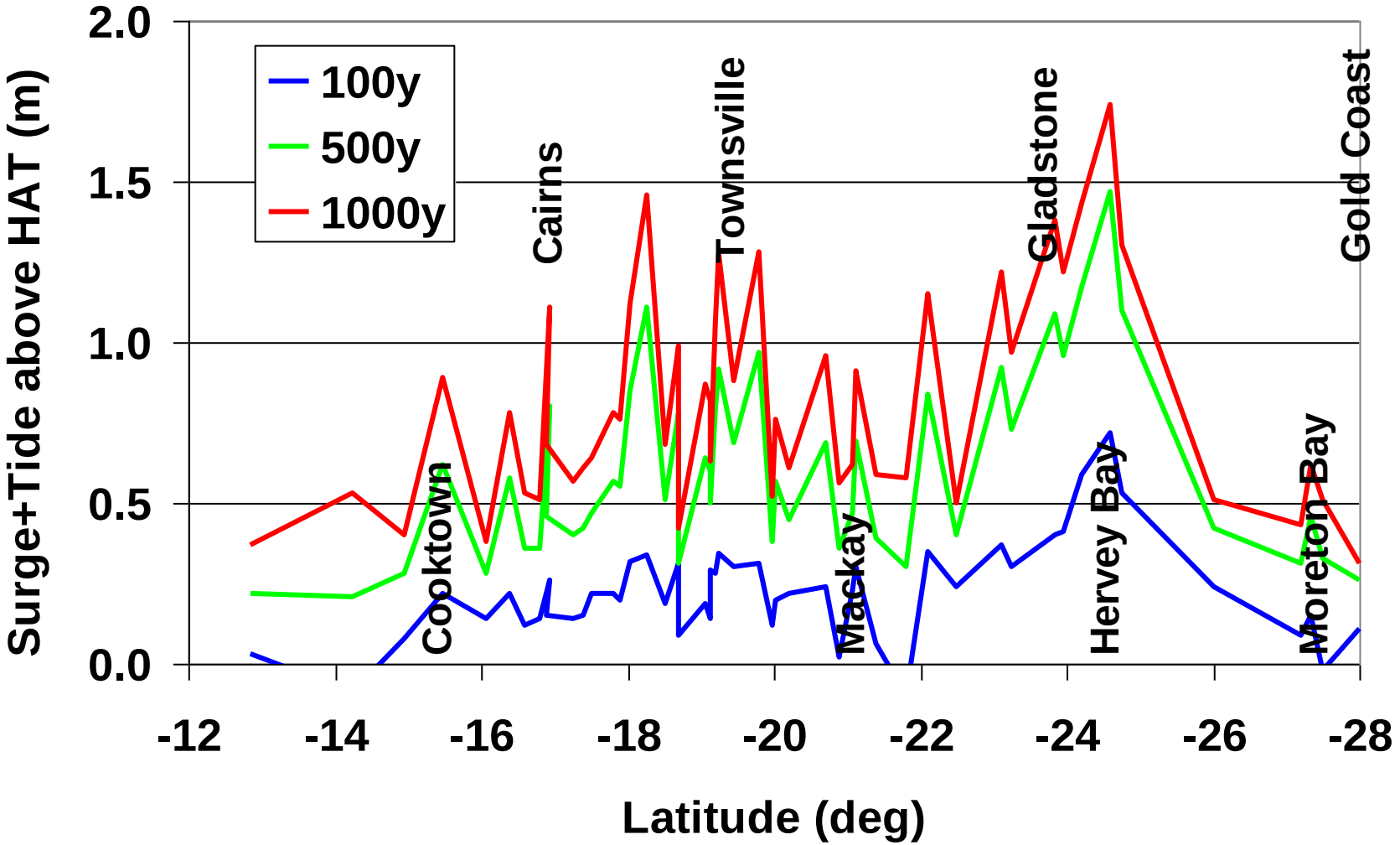
Harper (2001)

https://www.longpaddock.qld.gov.au/about/publications/vulnerabilitytocyclones/index.html

The Need for a Comprehensive Methodology



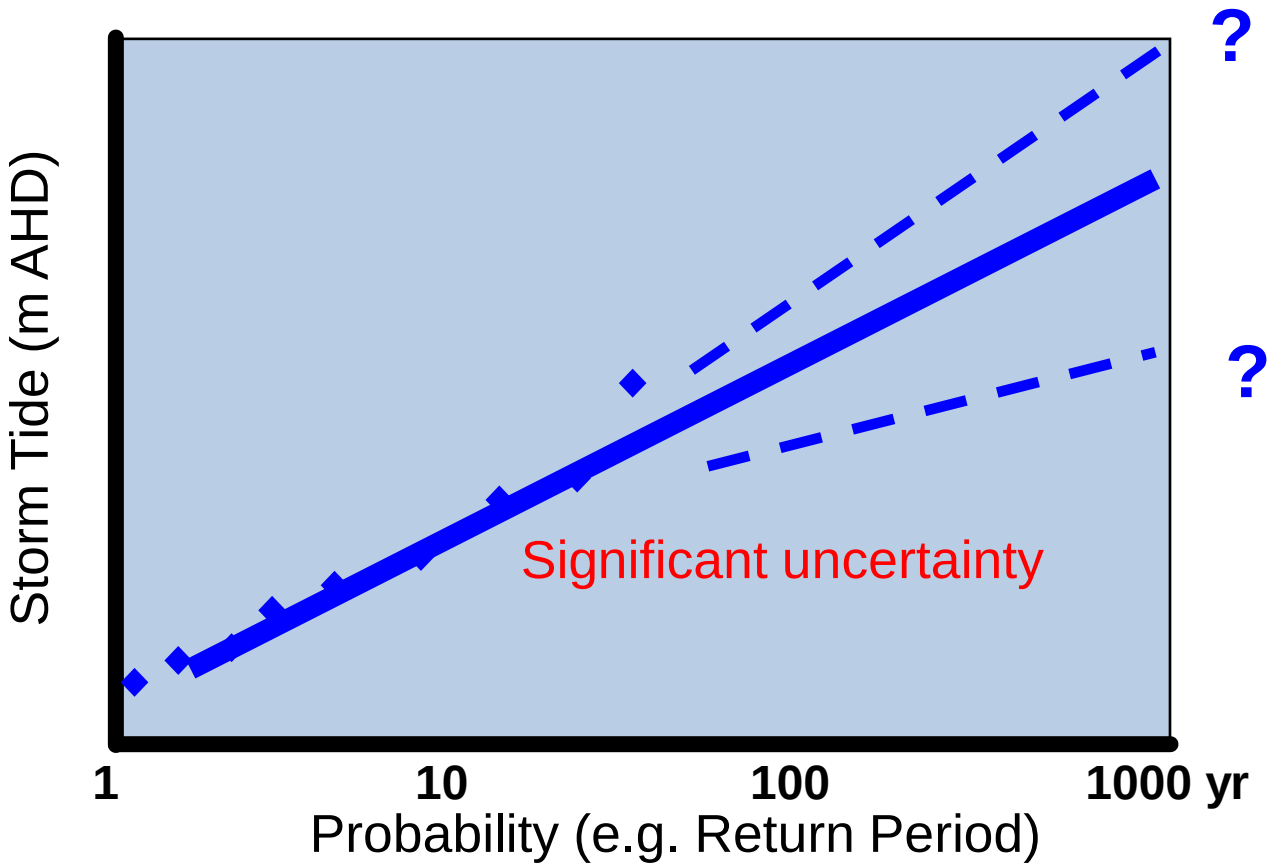
State-wide Storm Tide Hazard



From Queensland Climate Change Studies (SEA)

Storm Tide Hazard Estimation

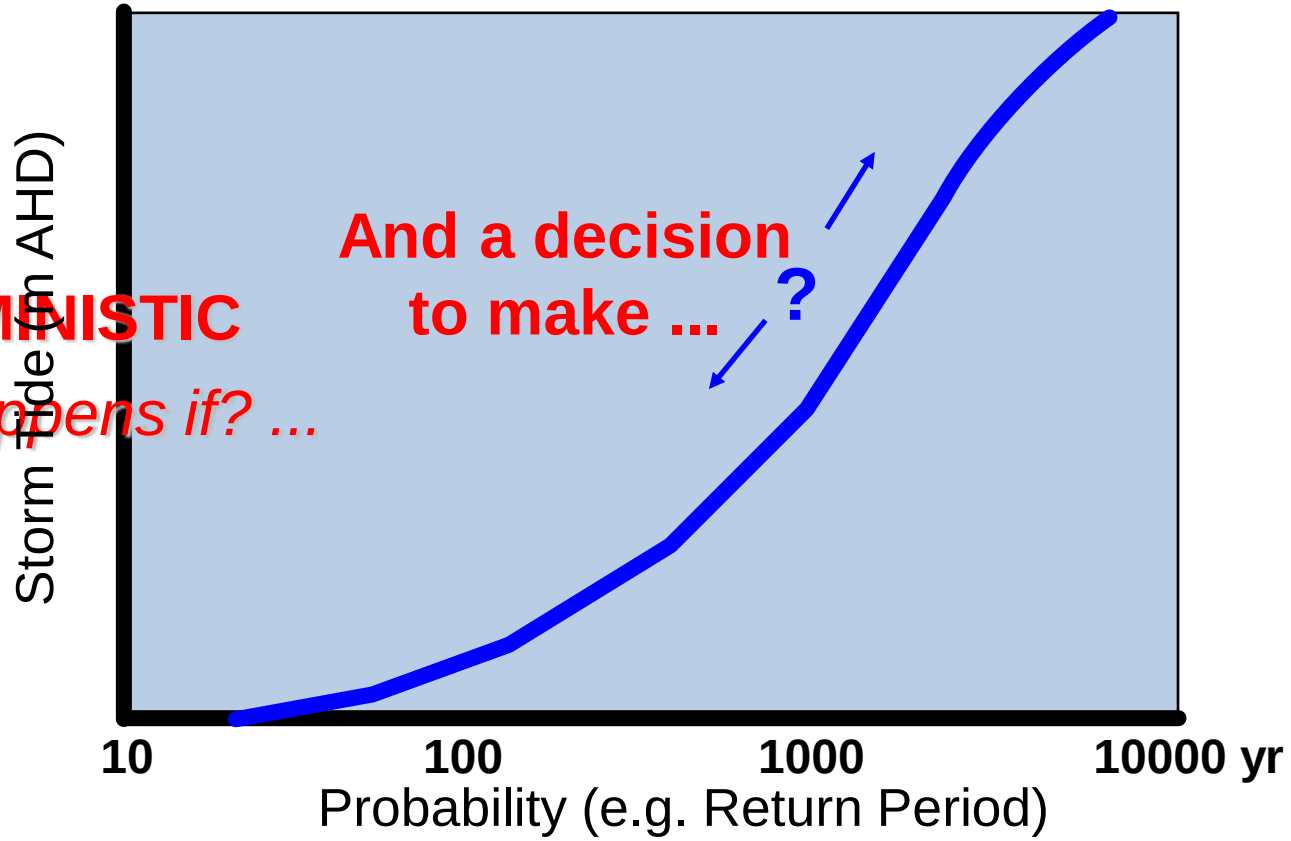
Rare Events = Not enough TC data for robust statistical analysis



Numerical simulation approaches are required

Storm Tide Hazard Estimation

There are <u>two</u> elements to this problem ...



DETERMINISTIC

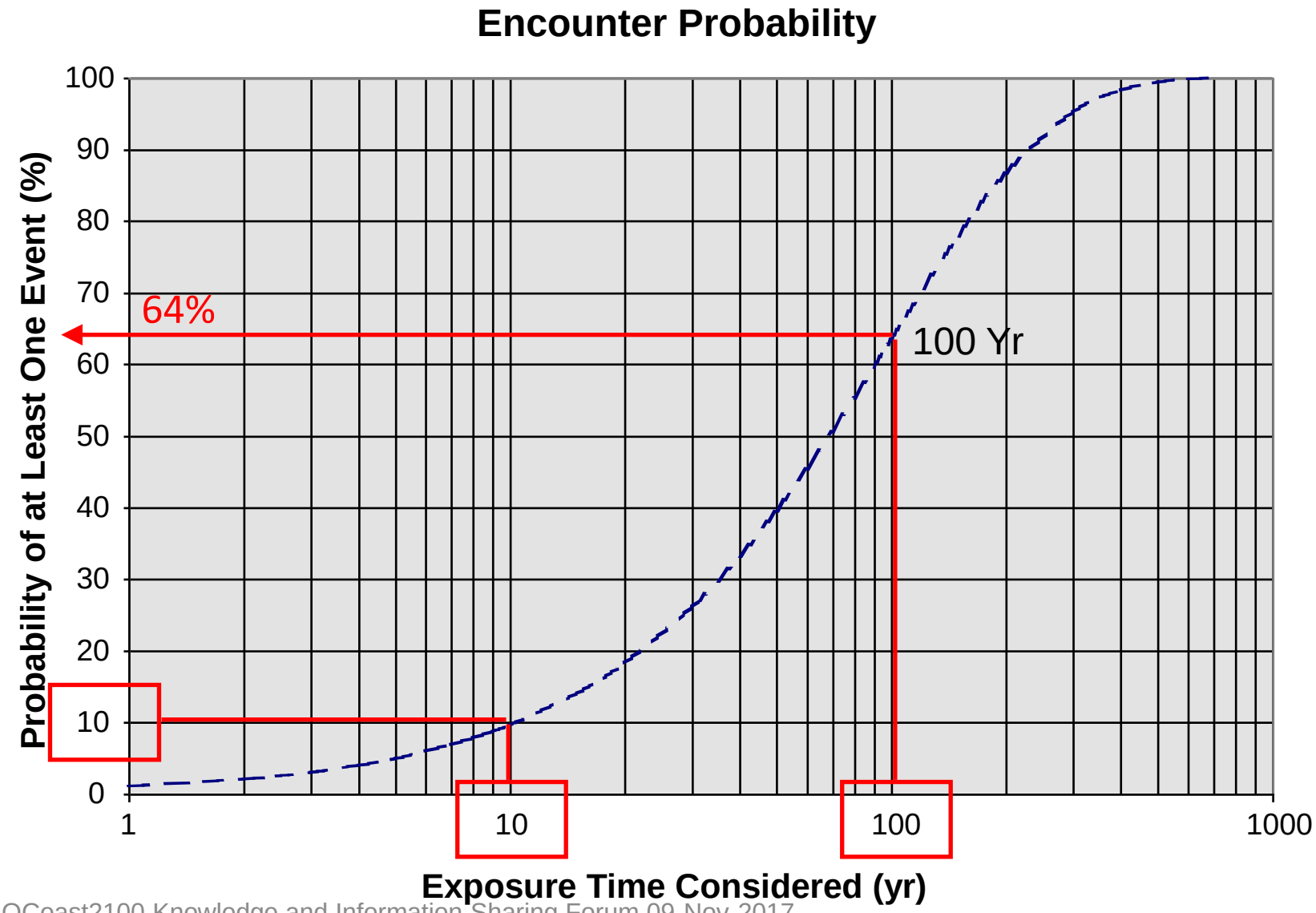
what happens if? ...

And a decision to make ... ?

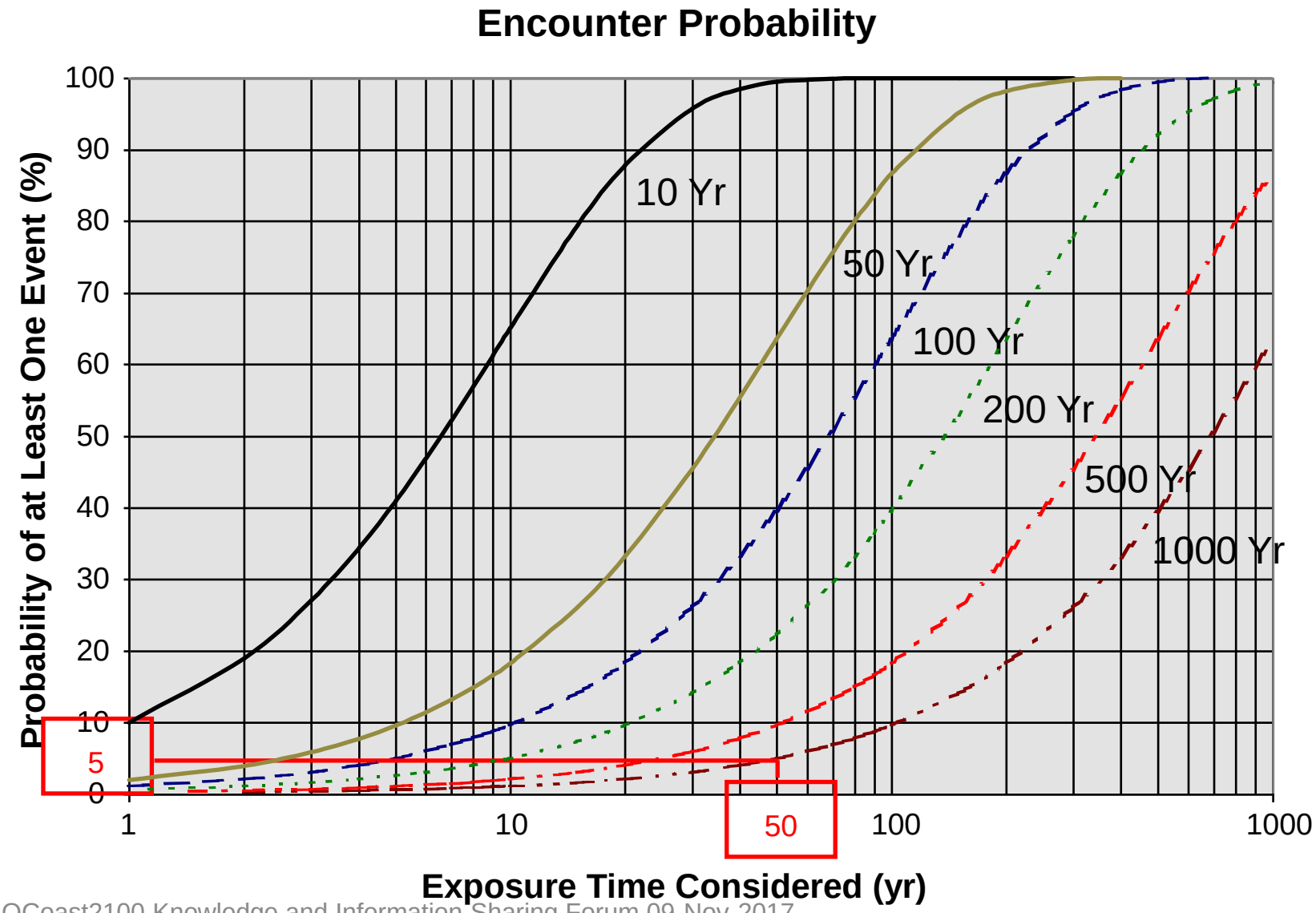
PROBABILISTIC

How likely is it to happen? ...

Probabilistic Decision Making

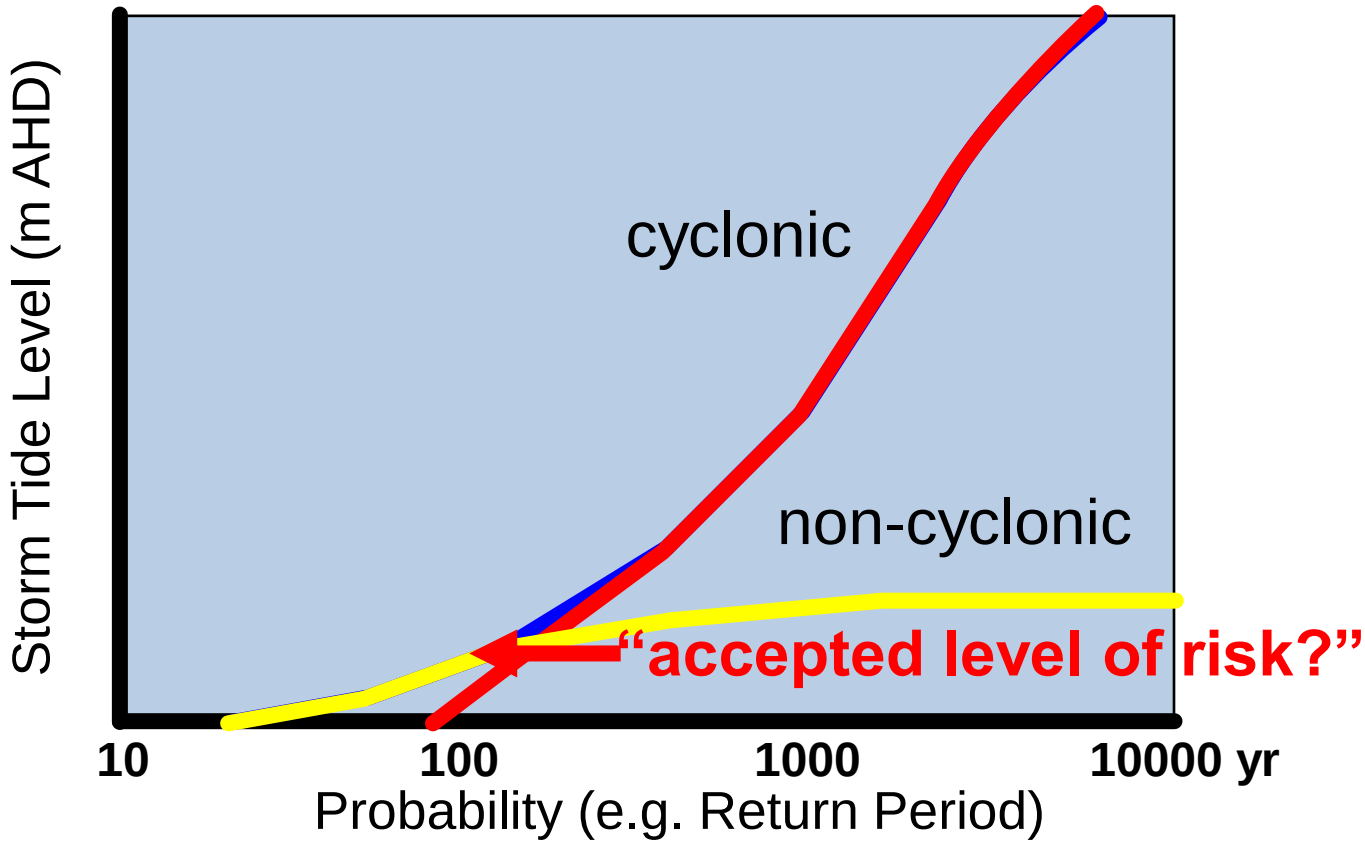


Probabilistic Decision Making



Storm Tide Hazard Estimation

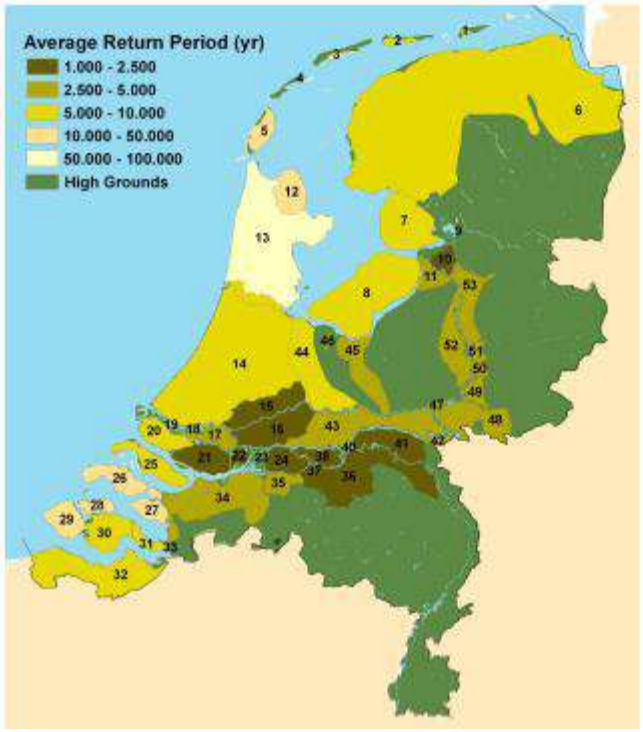
100 yr Return Period : More benign than you might think?



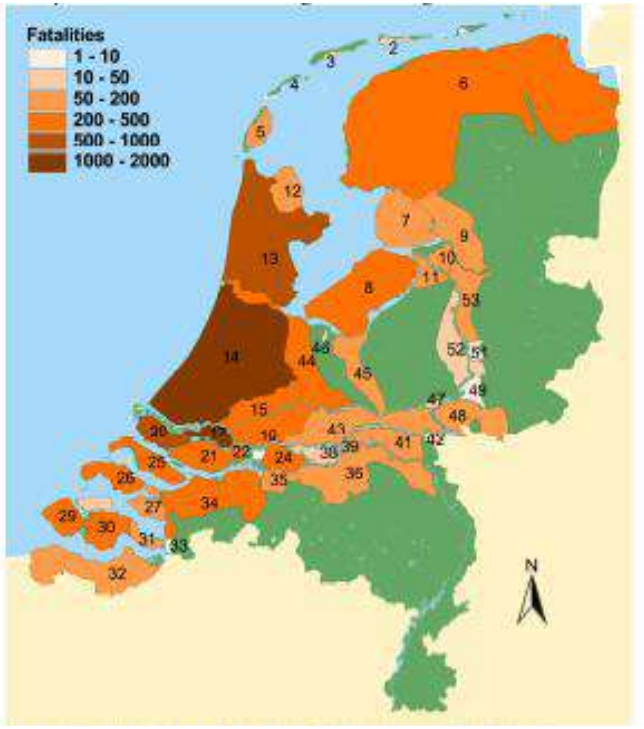
Note: The minimum prescribed building risk for wind loads is a 500 yr ARI event

Best Practice Lessons from The Netherlands

Chosen Hazard Criteria



Potential Fatalities

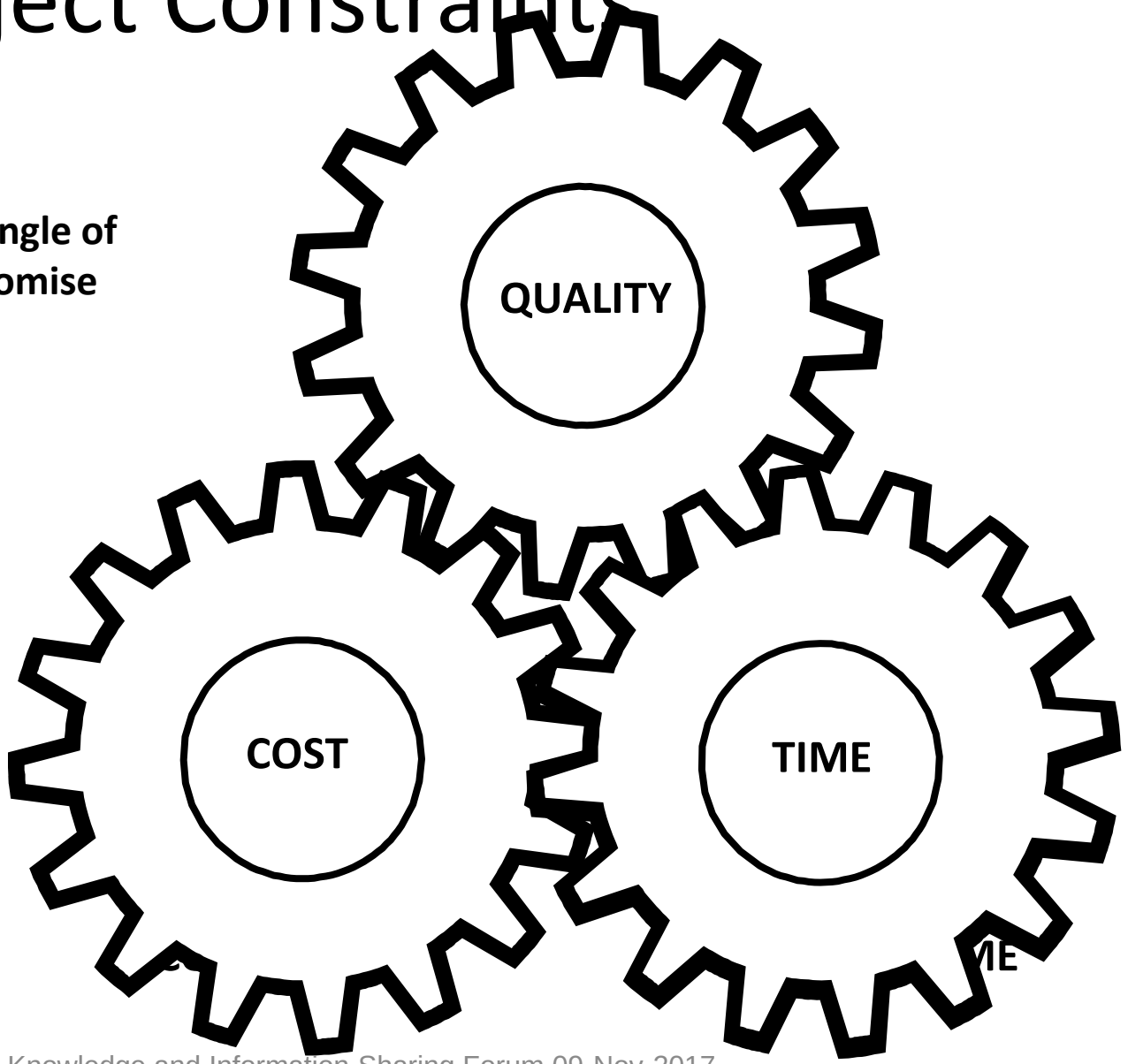


The Return Period of the Hazard is chosen depending on the potential for <u>Loss of Life</u>

(after Jonkman et al. 2010)

Project Constraints

The Triangle of Compromise



Climate Change – Sea Level Rise

- Global sea levels are impacted by, in order of decreasing contribution:
  - An accelerating thermal expansion throughout the 21st century
  - The melting of glaciers
  - Retreat of the Greenland ice shelf
  - Antarctic ice losses

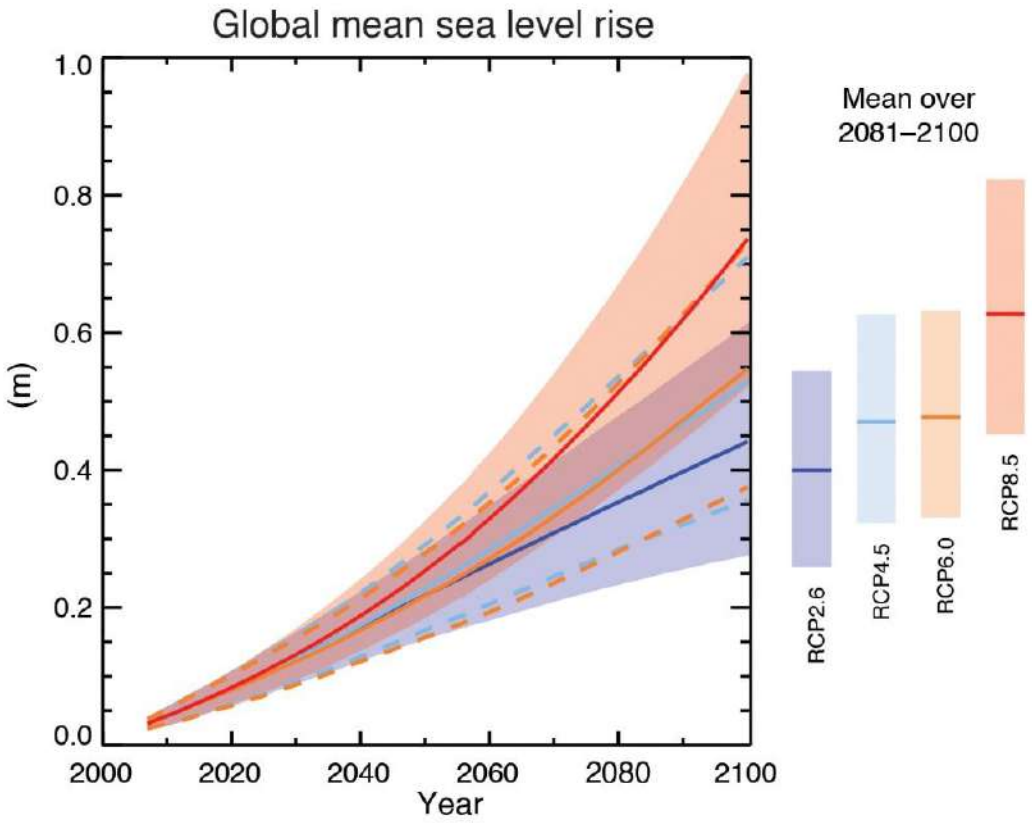
IPCC (2013) “Assessment Report 5” (aka AR5)

Climate Change – Sea Level Rise

- Global sea levels measured by satellite altimetry 1993 to 2012 was 3.2 ± 0.4 mm p.a.
- Versus estimated total of 2.8 ± 0.7 mm p.a.
- AR5 projections of global average sea level rise by 2100 are in the range 0.28 to 0.98 m (relative to the average sea level in 1995 and representing nominally 5% to 95% confidence levels).

IPCC (2013) “Assessment Report 5” (aka AR5)

Climate Change – Sea Level Rise



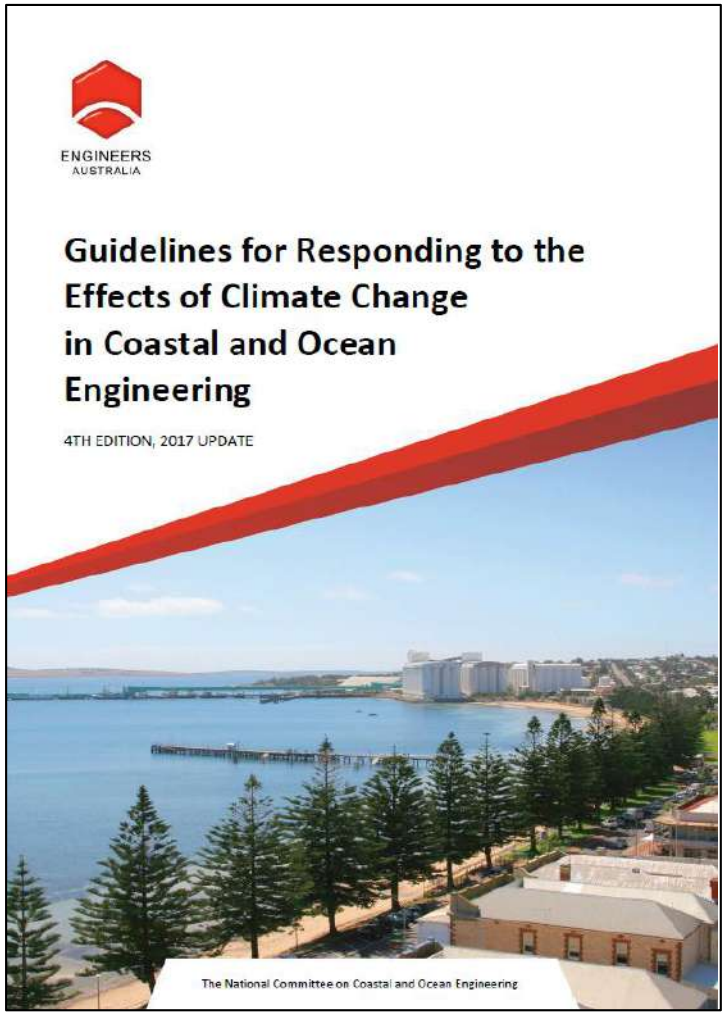
IPCC (2013) “Assessment Report 5” (aka AR5)

Climate Change – Tropical Cyclones

- Potentially up to 10% increase in peak intensity (winds) by 2100
- Potentially reduction in frequency of occurrence (> 30%)
- Minor changes in track expected
- Minor changes in size/speed
- Increased rainfall rates
- Waves, currents, storm surge hazards likewise

IPCC (2013) “Assessment Report 5” (aka AR5)

Climate Change – Guidance



- Latest science summary of relevance to coastal and ocean engineering across Australia
- Framework for investigation and modelling
- Encounter probability

https://www.engineersaustralia.org.au/Communities-And-Groups/National-Committees-And-Panels/Coastal-And-Ocean-Engineering

Summary and Conclusions

- Queensland has a history of significant threats from tropical cyclone storm tide impacts
- Storm tide hazard estimation requires specialised expertise
  - Require adherence to established guidelines
  - “High (spatial) resolution” does not guarantee “high accuracy”
  - Seek evidence of deterministic and probabilistic skill (e.g. winds)
  - Specify sensitivity analysis of assumptions
  - Seek independent peer review of outcomes
- Investigate the full range of hazard magnitudes
  - Don’t blindly prescribe a specific (nominal) risk level (e.g. 100 y ARI etc)
  - Must allow the hazard risk profile to influence the adaptation options and decisions

Summary and Conclusions

- Decision Making
  - Consider the impacts from the full range of hazards
  - Include encounter probability thinking
- Accuracy vs Precision
  - LiDaR (stated) precision does not dictate accuracy of hazards
  - Look beyond “bathtub” mapping – statistical surfaces are not flat
- Climate change is another sensitivity analysis
  - Consider the uncertainty in the IPCC predictions
  - Seek methodologies that can realistically include these effects
- Study scope and budget
  - Develop realistic time and cost expectations
  - Aim for a comprehensive scope
  - Remember that you get what you pay for …