ESCAP/WMO Typhoon Committee
2nd TRCG Forum

Practical Simulation of Tropical Cyclone Impacts for Forecasting, Emergency Planning and Disaster Risk Reduction

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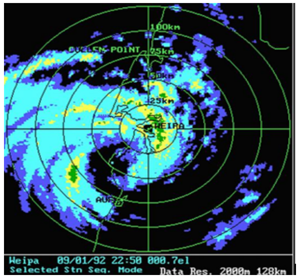
AUSTRALIA



Simulation of TC Impacts

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There are three basic activities and contexts:

Hindcasting [Research]
- Understanding
- Calibration
- Verification

Forecasting [Warning]
- Operational
- Preparedness
- Emergency response

Simulating [Planning]
- Estimation of risk
- Mitigation
- Adaptation

These are all inter-related and naturally support and influence each other. But what is the ultimate goal?

Is it the coming of the day of the perfect forecast …

Or, is it the day of achieving perfect mitigation… ?

Simulation of TC Impacts

The (practical) ultimate goal:

Plan Early and Wisely

- To avoid the impacts
- Provide design resilience

Warn Early and Well

- To prepare and protect
- Address the residual risk

Research Effectively

- In support of the above
- Focus on tools and outcomes
- Pure vs applied

Wise planning cannot wait for perfect understanding and perfect forecasts.

Simulation of TC Impacts

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The key to wise planning outcomes:

Risk based

- Recognise the variability
- Identify the vulnerability
- Aim to mitigate the risk

Quantitative

- Statistically based
- Measurable metrics
- Tangible and intangible

Robust

- Backed by evidence
- Transparent
- Repeatable

Access to practical risk modelling tools is needed to enable this to happen.

Typical Tools and Applications

Traditional Focus

	Role	Research	Warning	Planning
	Activity	Hindcasting	Forecasting	Simulating
Track (location)	Prog NWP			
	CLIPER			
	Best Tracks			
Intensity (wind)	Prog NWP			
	Dvorak/MI			
	CLIPER			
Structure (wind & precip)	Prog NWP			
	Diag NWP			
	Best Tracks			
	Parametric			

Legend:

good	
effective	
under utilised	
needs work	~
not effective	

Typical Tools and Applications

	Role	Research	Warning	Planning
	Activity	Hindcasting	Forecasting	Simulating
Track (location)	Prog NWP			
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Intensity (wind)	Prog NWP			
	Dvorak/MI	~	~	~
	CLIPER			
Structure (wind & precip)	Prog NWP		~	
	Diag NWP			~
	Best Tracks		~	~
	Parametric	~	~	~

Legend:

good	
effective	
under utilised	
needs work	~
not effective	

Storm structure determines impacts !!

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Everything should be made as simple as possible, but not simpler.

Albert Einstein (attrib.)

There is more than one way to skin a cat.

Anonymous

Why Use Simple Models?

Simple need not mean
- unsophisticated or crude
- inaccurate
- unsuitable

Simple should mean
- practical
- effective
- insightful

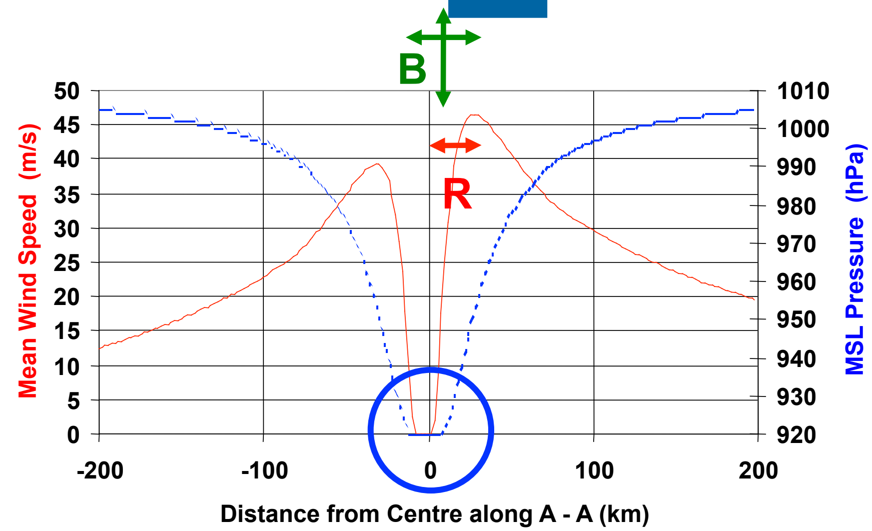
Examples:

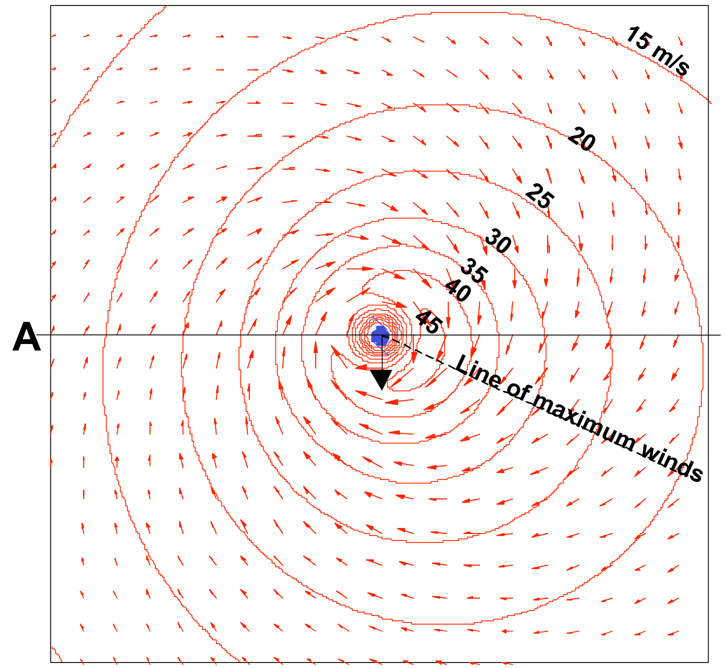
Dvorak is the universal basis for intensity estimation.

Storm surge has been one of the earliest and principal applications of parametric TC wind and pressure structure models in forecasting (Jelesnianski/SLOSH).

The Harper-Holland Wind and Pressure Model

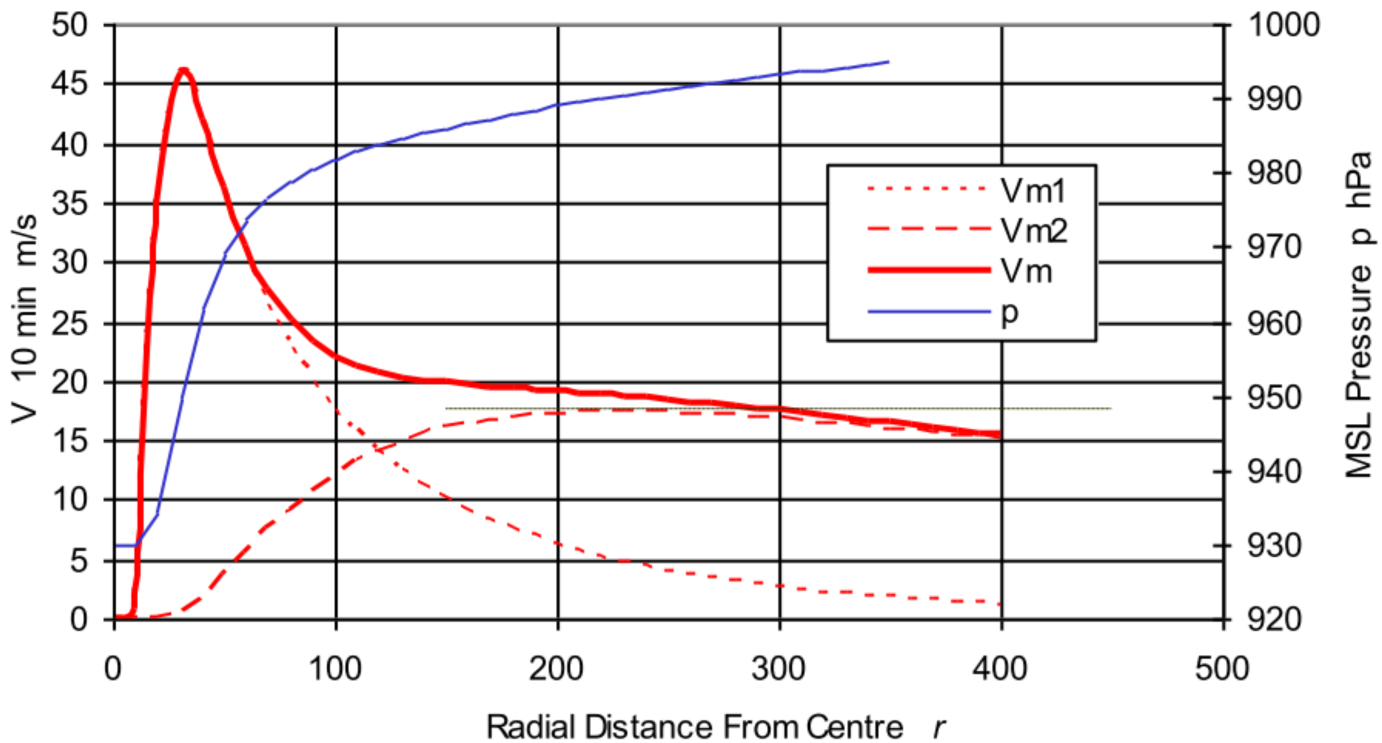
Parameter	Symbol	Value	Units
Latitude	ϕ	-20	°
Central Pressure	p_0	920	hPa
Ambient Pressure	p_n	1010	hPa
Radius to Max Wind	R	30	km
Forward Speed	V_{fm}	4	m s^{-1}
Bearing	θ_{fm}	180	°
Peakedness	B	1.5	-
Asymmetry Factor	δ_{fm}	1.0	-
Line of Max Wind	θ_{max}	65	°
Air Density	ρ_a	1.15	kg m^{-3}
B/L Coefficient	K_m	0.67	-





Harper and Holland (1999)

The Double Holland
Wind and Pressure Model



$$p = p_c + \sum_{i=1}^{2} \Delta p_i \, e^{-(R_i / r)^{B_i}}$$

$$\sum_{i=1}^{2} \Delta p_i = p_n - p_c$$

$$V_m = K_m \left[\left\{ \sum_{i=1}^{2} V_{c_i}^{\,2} + \frac{r^2 f^2}{4} \right\}^{1/2} - \frac{r f}{2} \right]$$

Example Practical Applications

Hindcasting/Research

- Parametric *Hurricane Ivan* Gulf of Mexico wind (and wave) modelling

Warning/Forecasting

- Probabilistic storm tide modelling system used in Northern Australia

Planning/Simulation

- Gulf of Carpentaria storm tide inundation study
- Townsville coastal hazard adaptation strategy

Hindcast Application:
Oil and Gas Facilities Design Criteria

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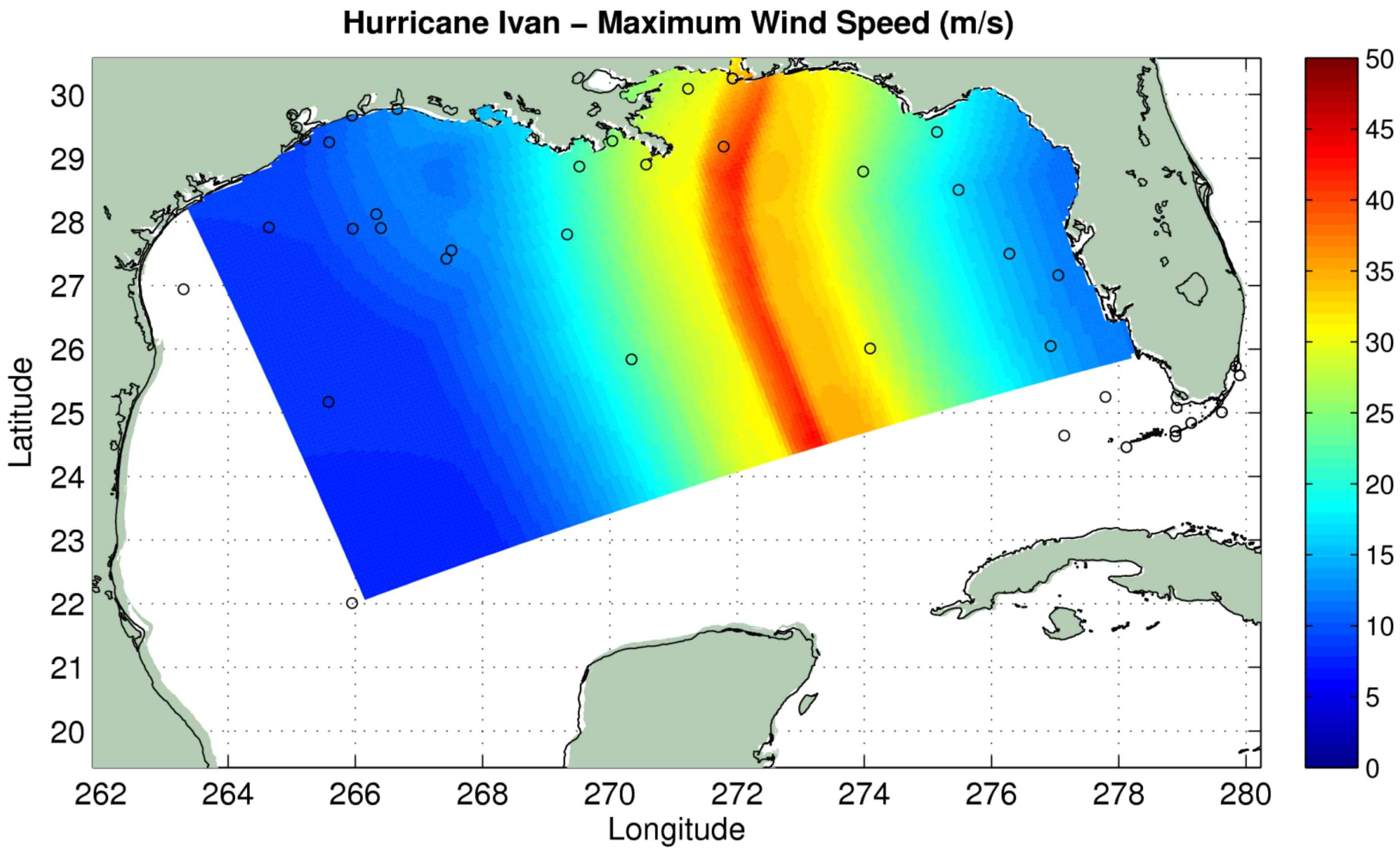
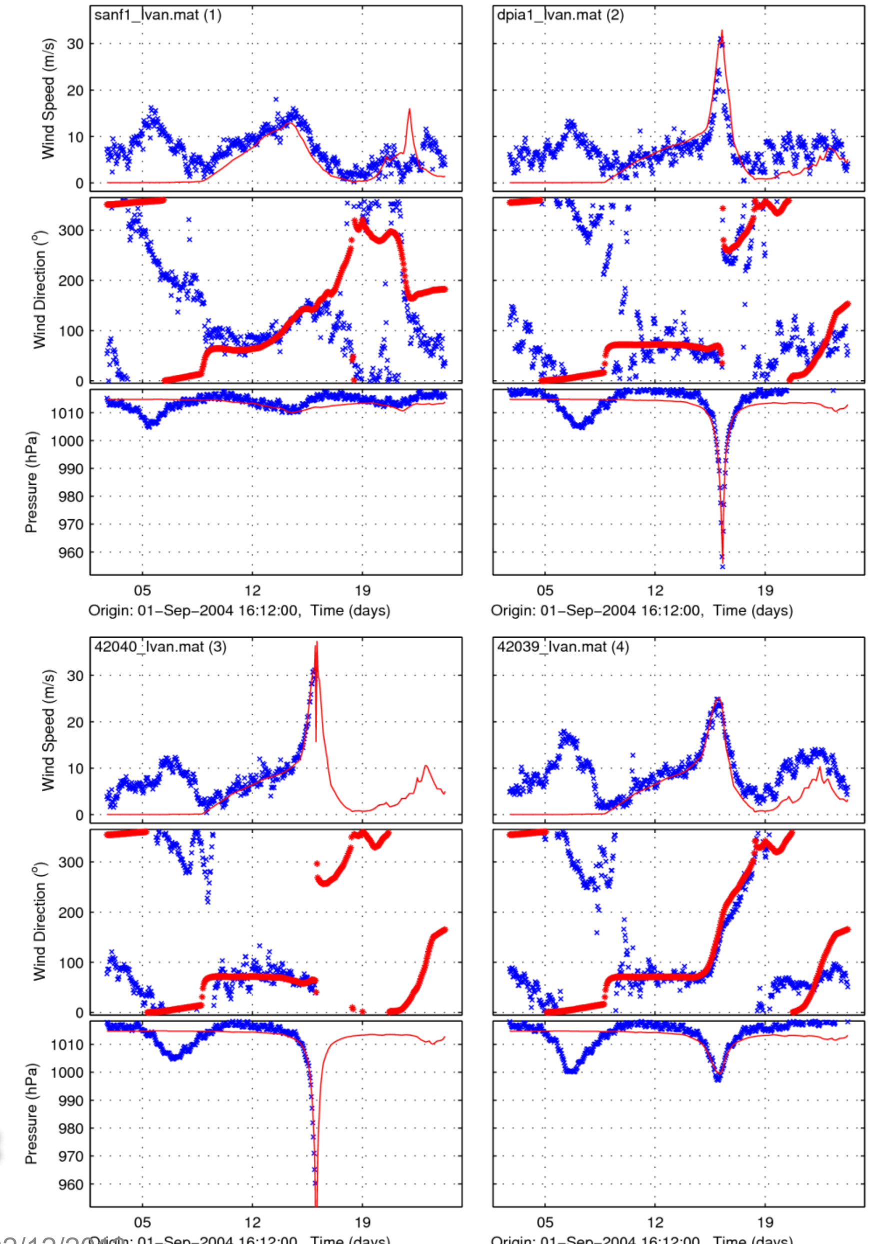


Lou Mason

Marine Modelling Unit

Wind Data Comparison



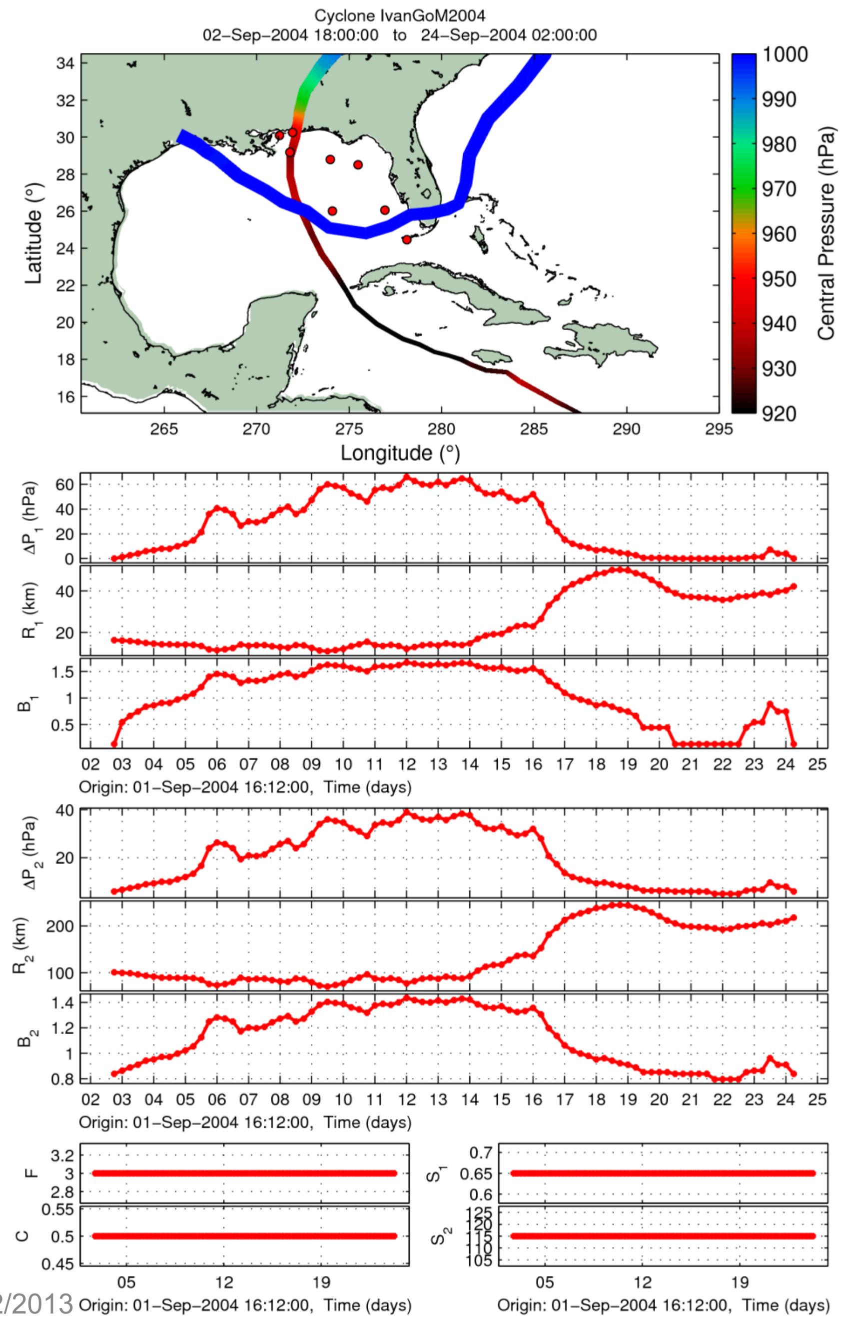
Data

Model

Lou Mason

Wind Model Parameters

Derived **entirely** by calibrating to surface data using NHC Best Track fixes and central pressure estimates.



Pressure Deficit

Inner Radius

Inner Peakedness

Outer Pressure

Outer Radius

Outer Peakedness

Scaling Ratios

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Peak Significant Wave Height Comparisons

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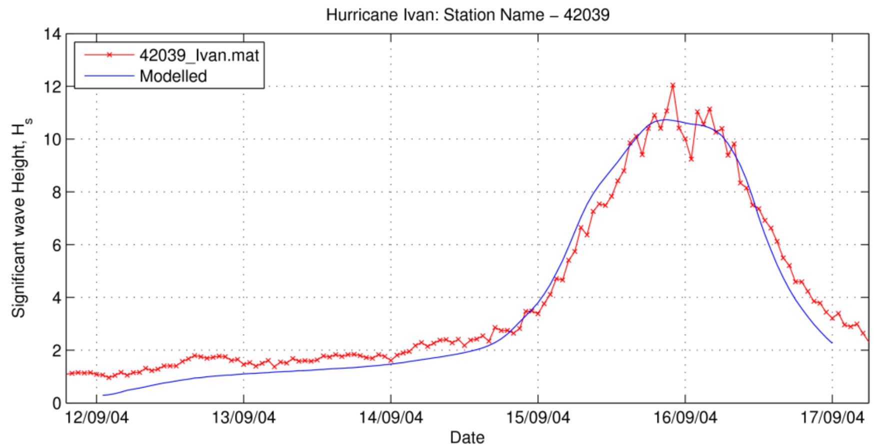
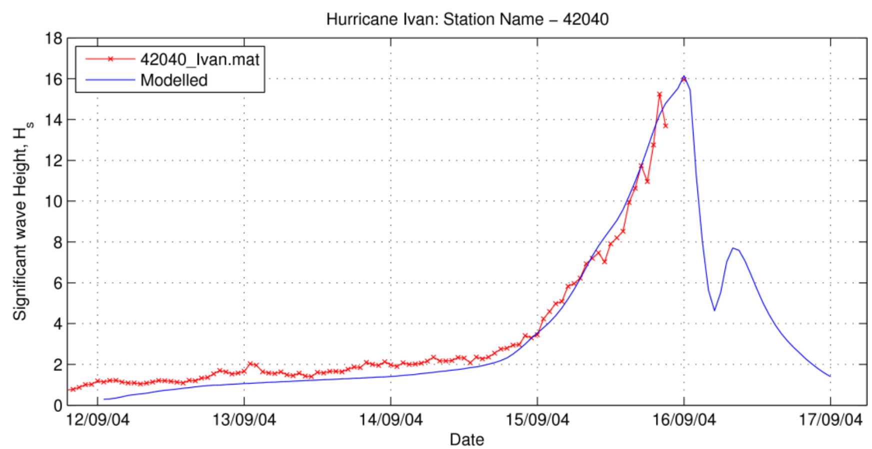
Surface winds driving a spectral wave model. (no complex drag coefficients, or wave-current coupling etc)





Data

Model

This was a blind test – wave data was withheld.

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Peak Significant Wave Height Swath

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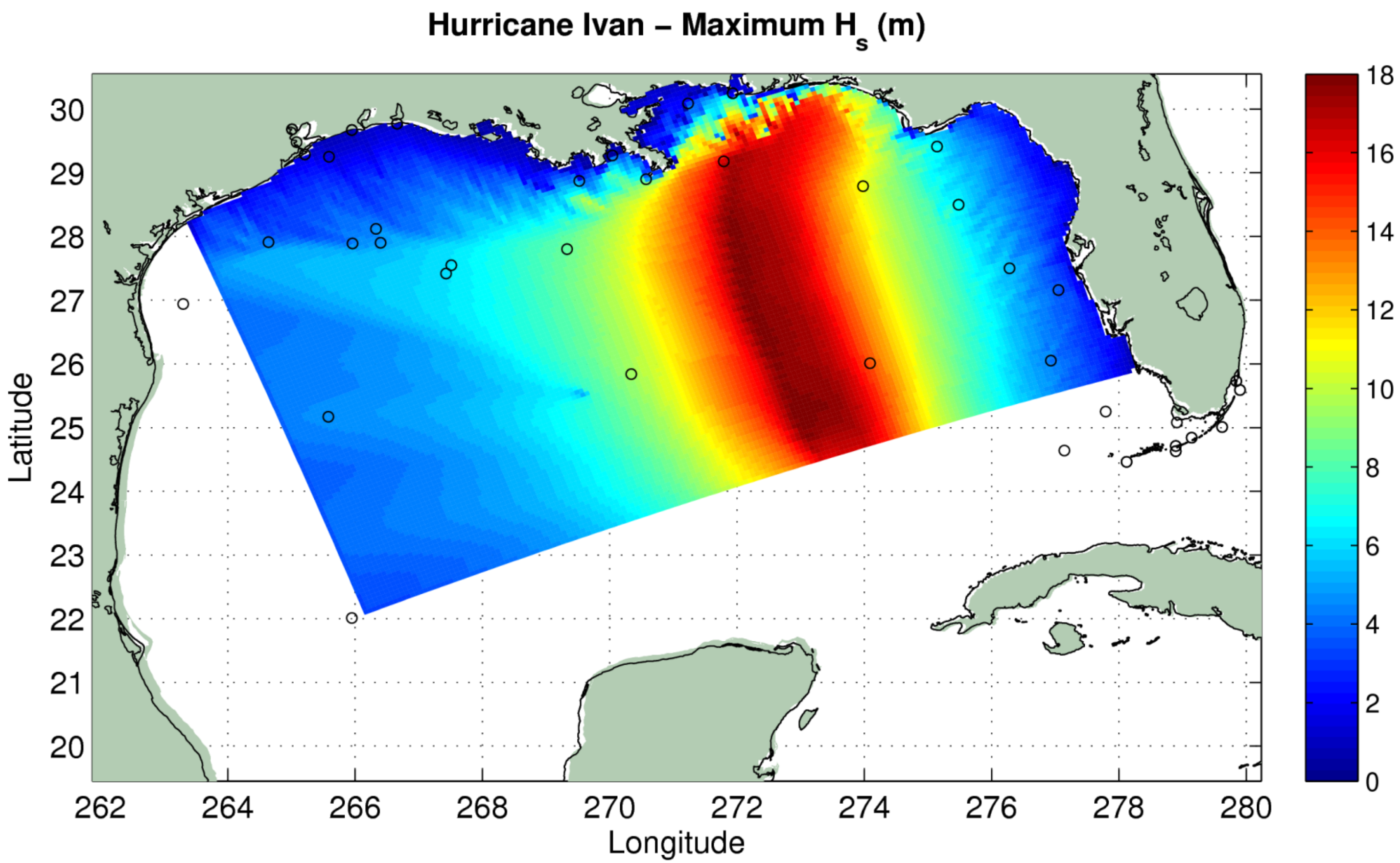

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Warning Application:
Operational Probabilistic Storm Tide Forecasting

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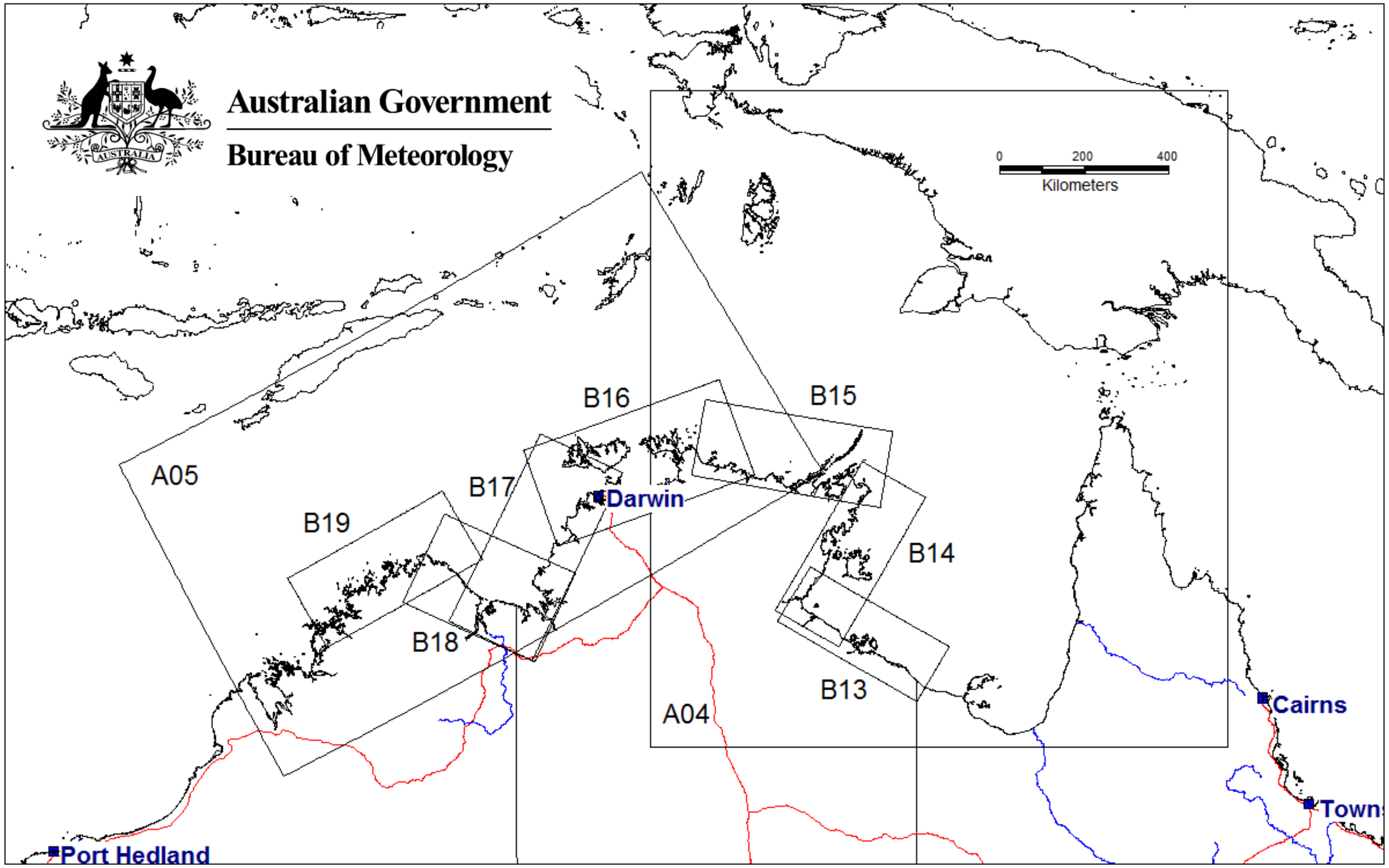

SEA 2005: Darwin TCWC Northern Region Storm Tide Prediction System - System Development Technical Report. Prep by Systems Engineering Australia Pty Ltd for the Bureau of Meteorology, Darwin. SEA Report J0308-PR001C. Dec.

SEAtide Storm Tide Prediction System

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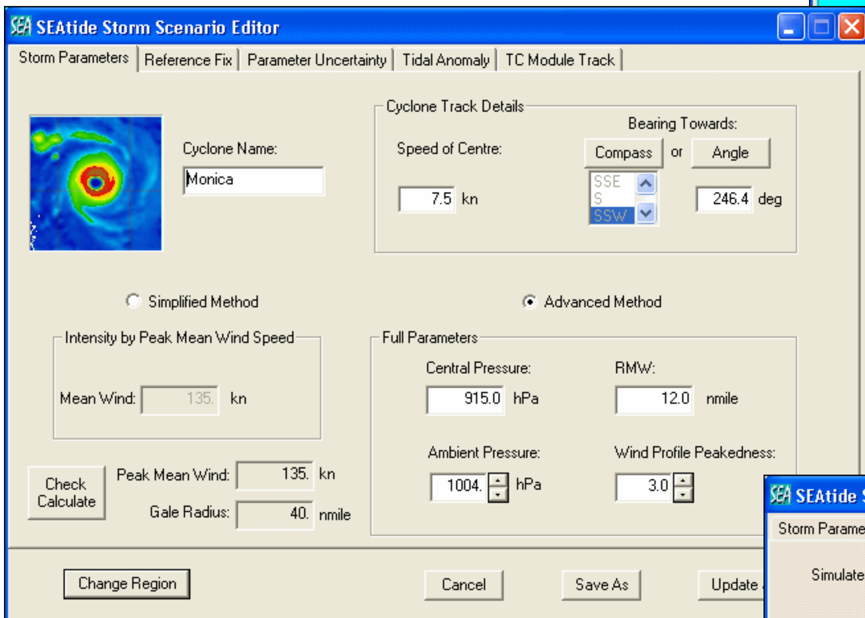

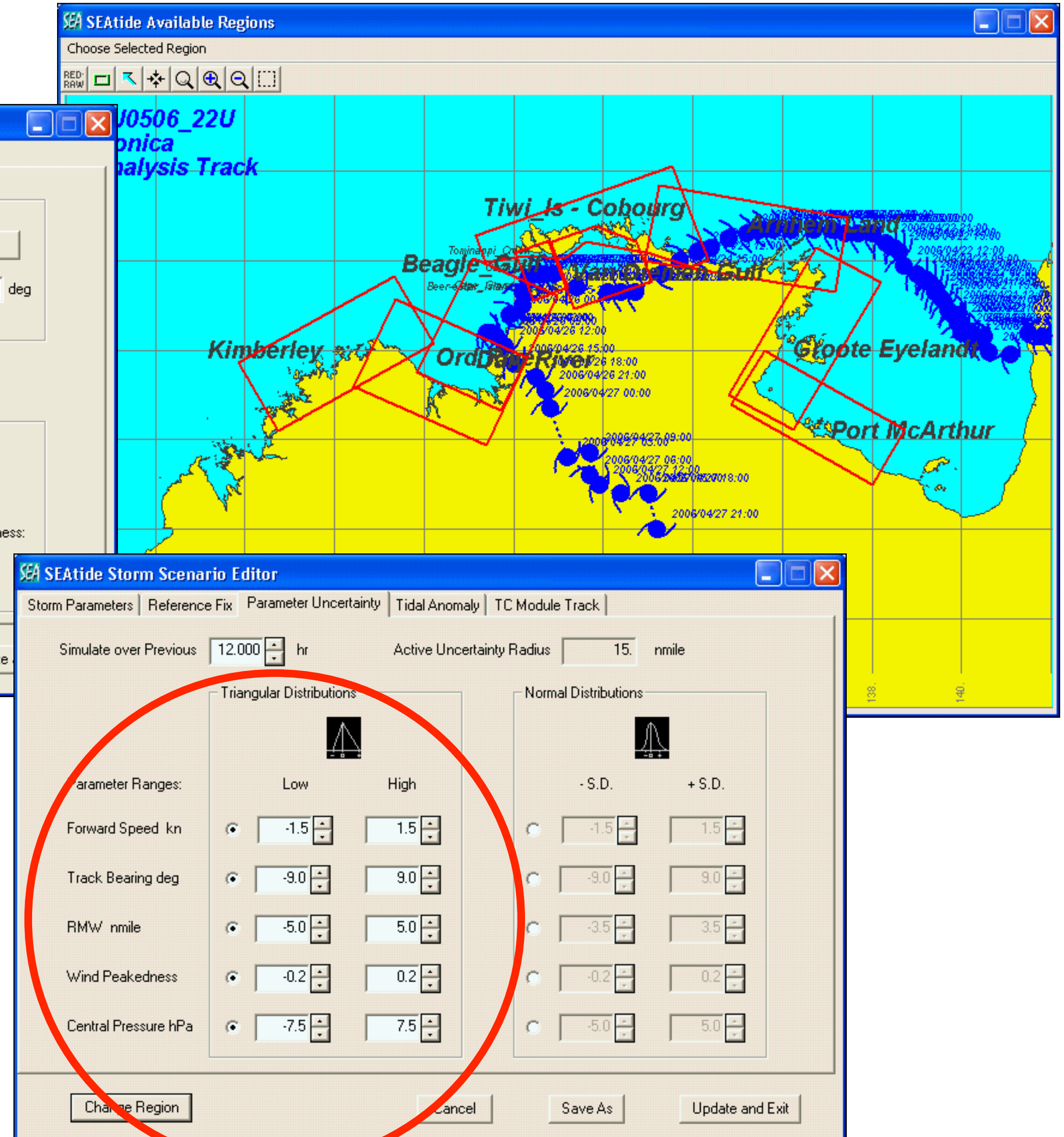

Forecaster provides best forecast position and intensity but also the probability distribution.

Australian Government
Bureau of Meteorology

SEAtide Storm Tide Prediction System

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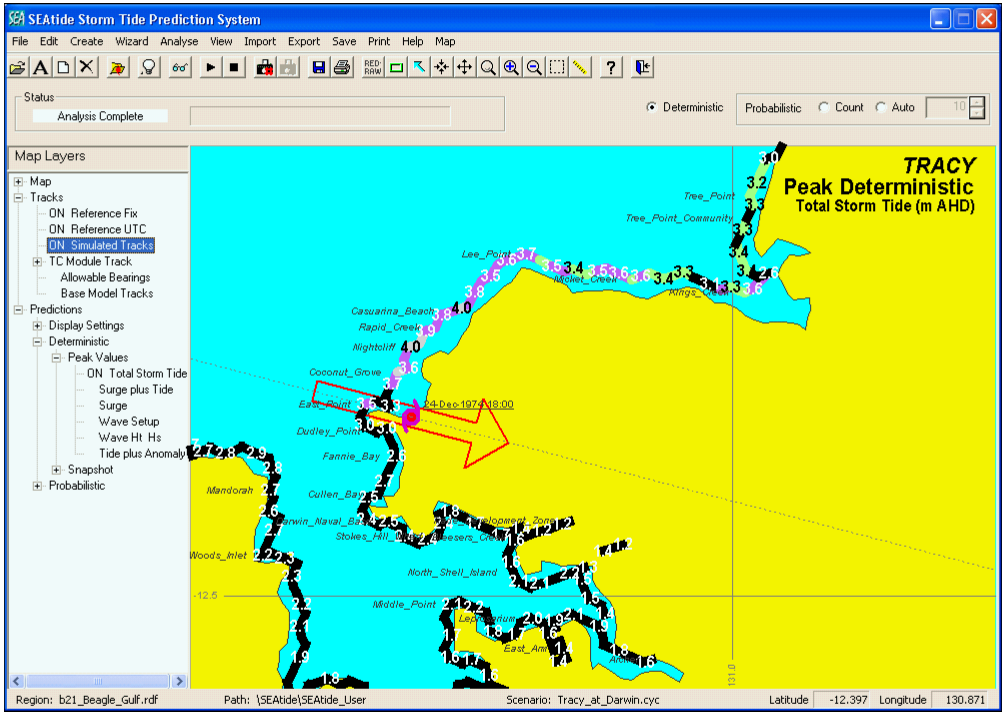

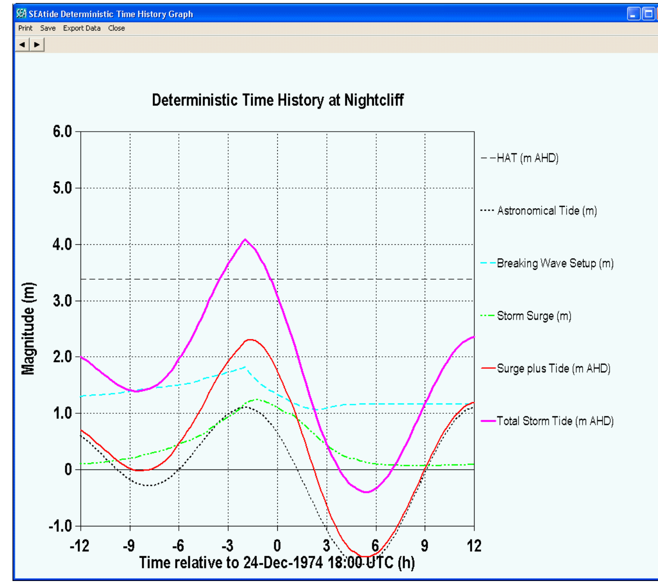

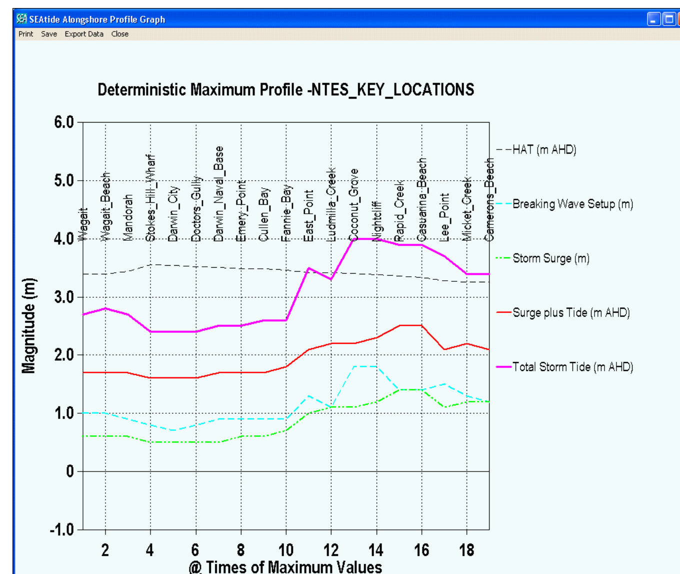

Deterministic parametric wind fields are combined with barotropic tide and surge modelling that is also then parameterised.

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SEAtide Storm Tide Prediction System

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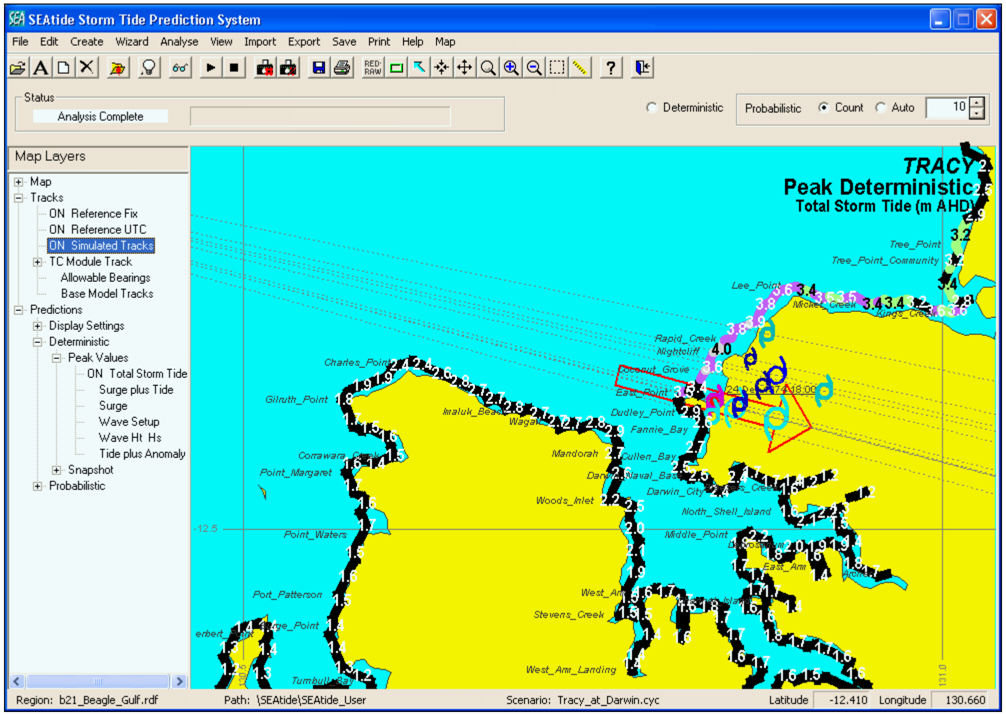
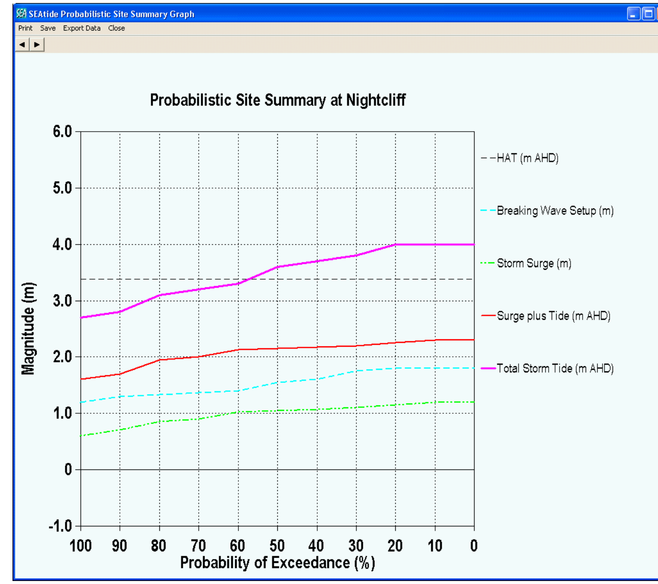
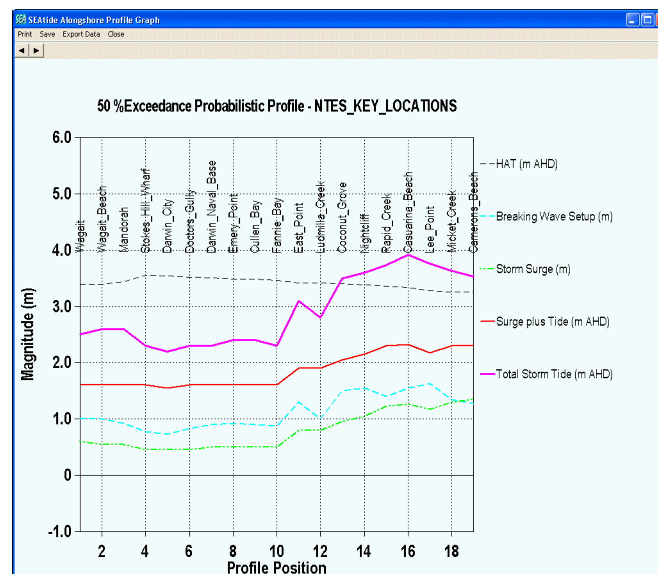






Probabilistic mode generates hundreds of possible TC storm tide events per minute on any desktop PC

Australian Government
Bureau of Meteorology

Planning Application:
Gulf of Carpentaria Storm Tide Study

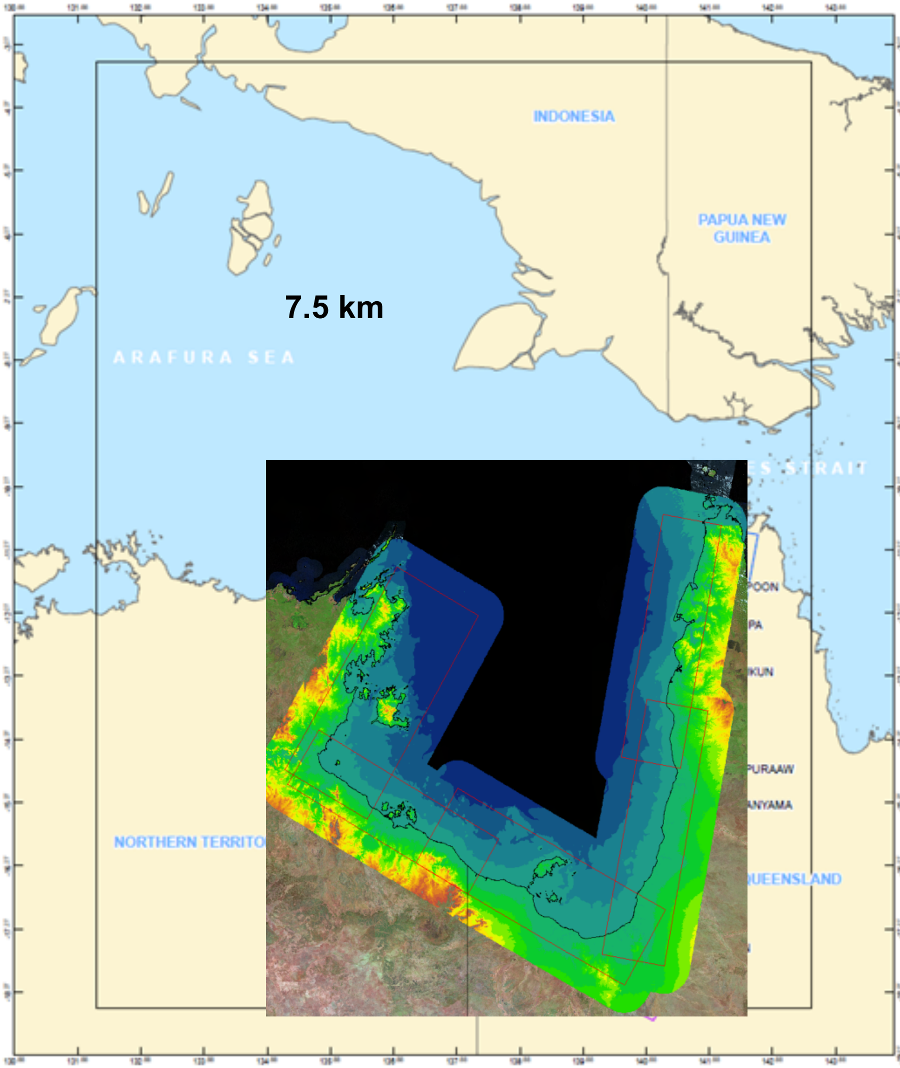
Study Area

- Over 2,500 km of coastline
- Shallow tropical sea < 70 m
- Highly storm surge prone
- Tradewinds, monsoon and TC impacts
- Complex tides
- Sparsely populated
- Sparse data

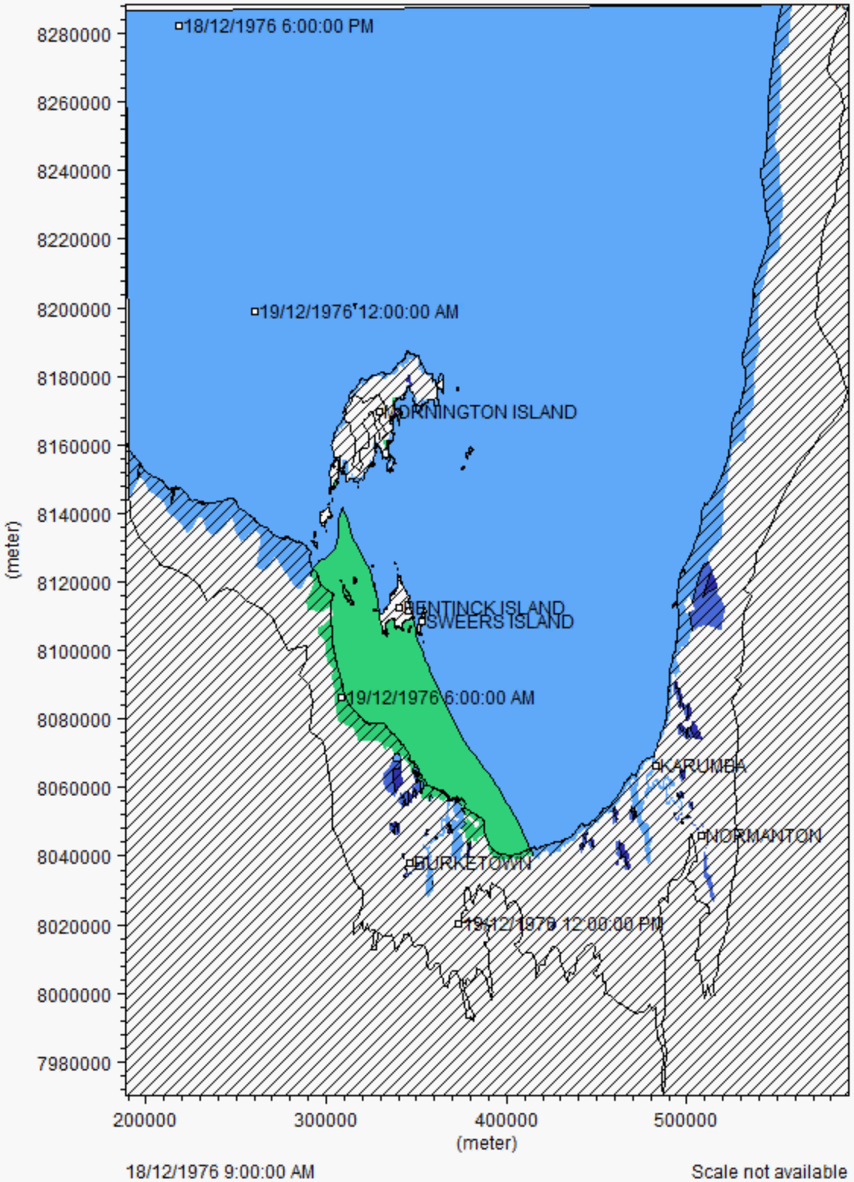
Modelling

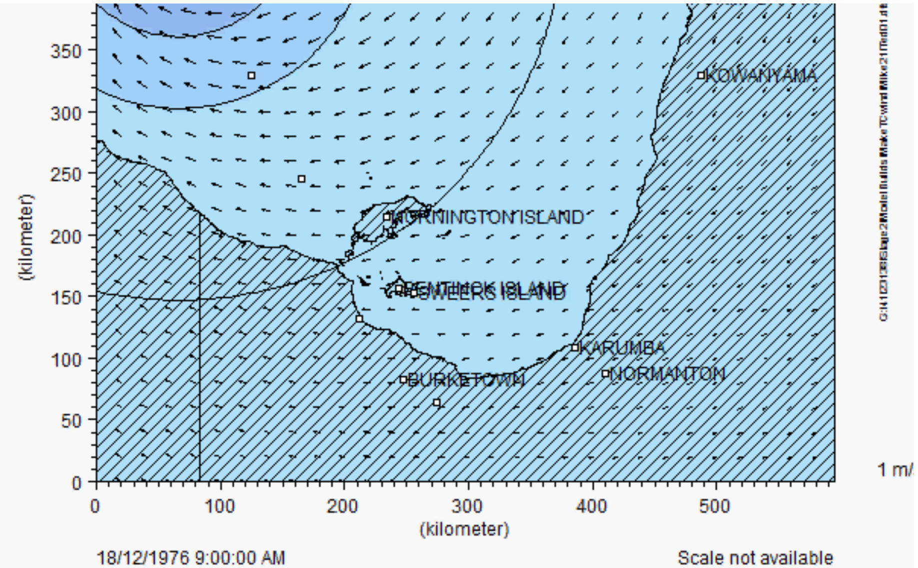
- 1,300 years of non-cyclonic water level impacts (SOI, NCEP, LAPS)
- 50,000 years TC impacts synthetic tracks, parametric winds
- Present, 2050 and 2100 climates

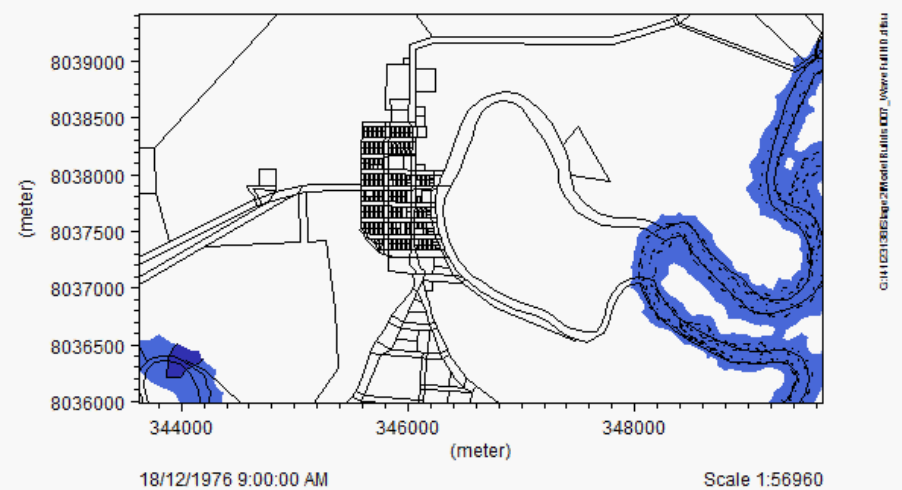
Hydrodynamic Model Domains



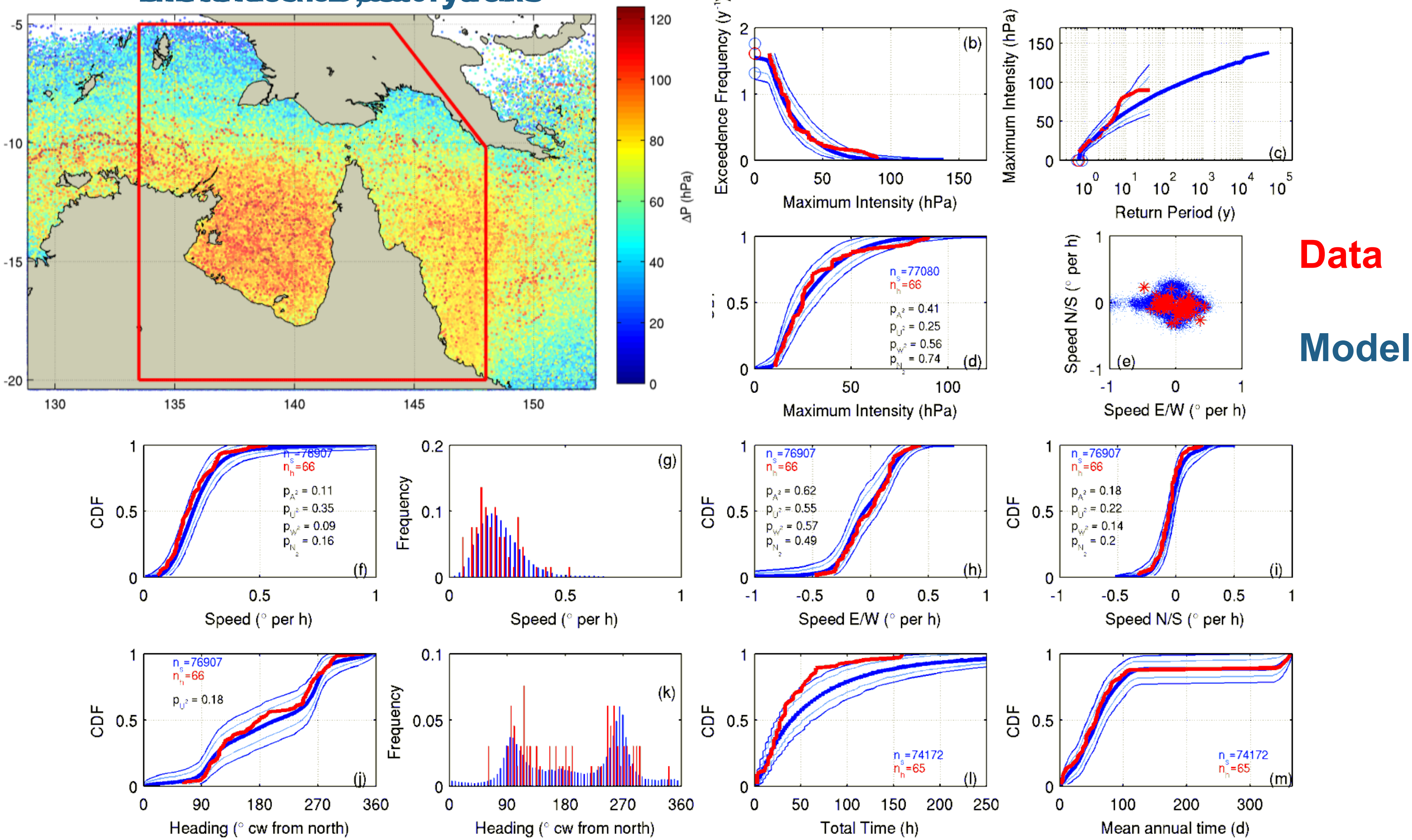
Integrated Wind and Storm Surge Model of TC Ted





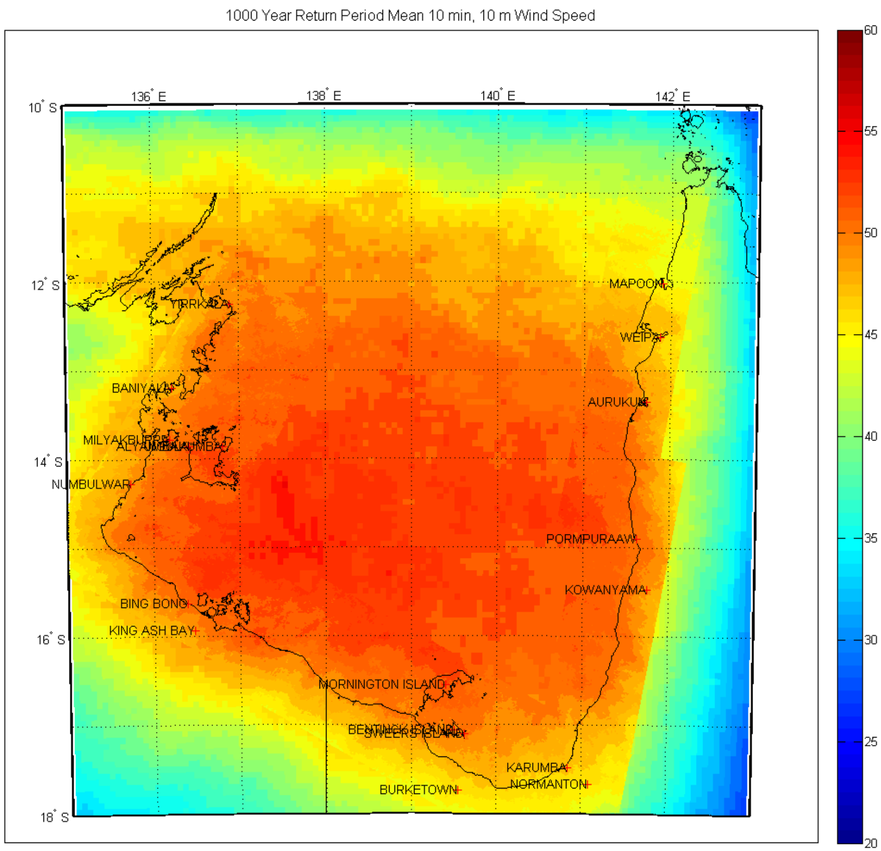


Statistical TC Track Model

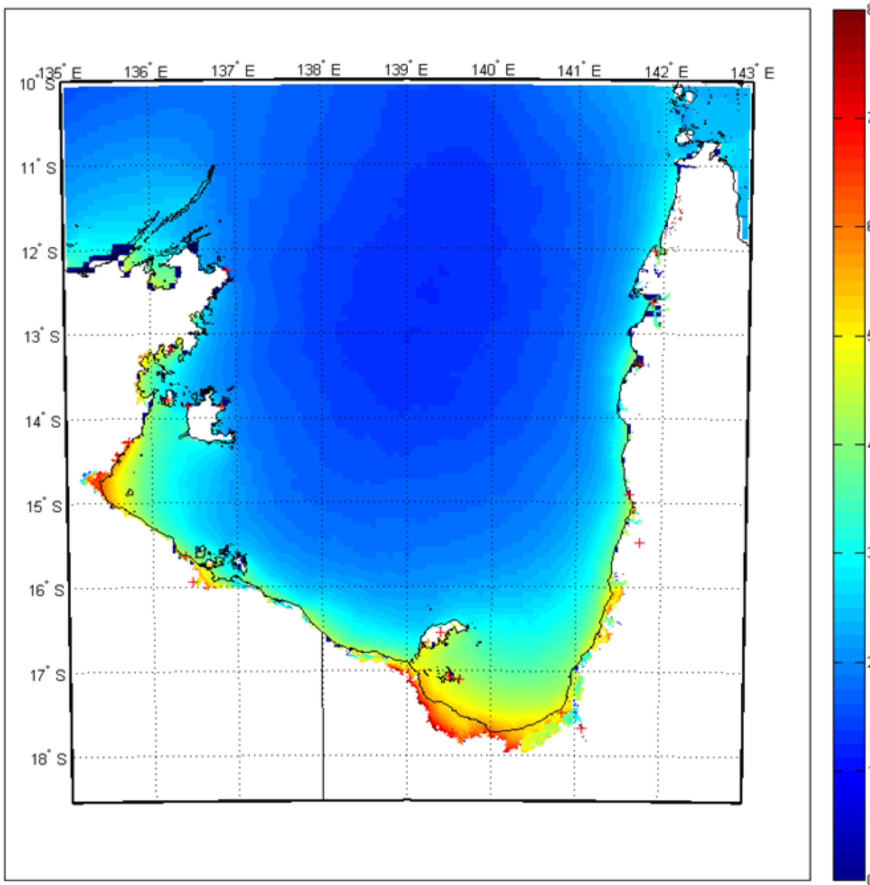


Simulated Winds and Storm Tide

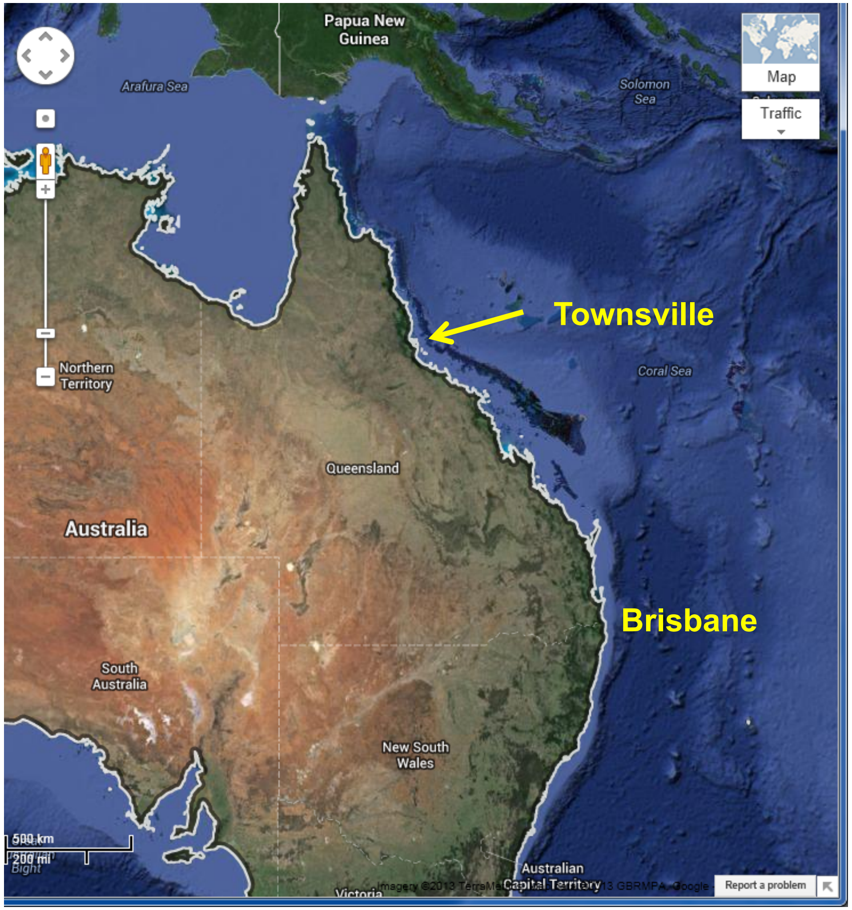
TC Wind Speed 1000 yr Return Period (m/s)



Combined Non-Cyclonic and TC Storm Tide Levels 1000 yr Return Period (m)



Planning Application:
Coastal Hazard Adaptation Strategy Study



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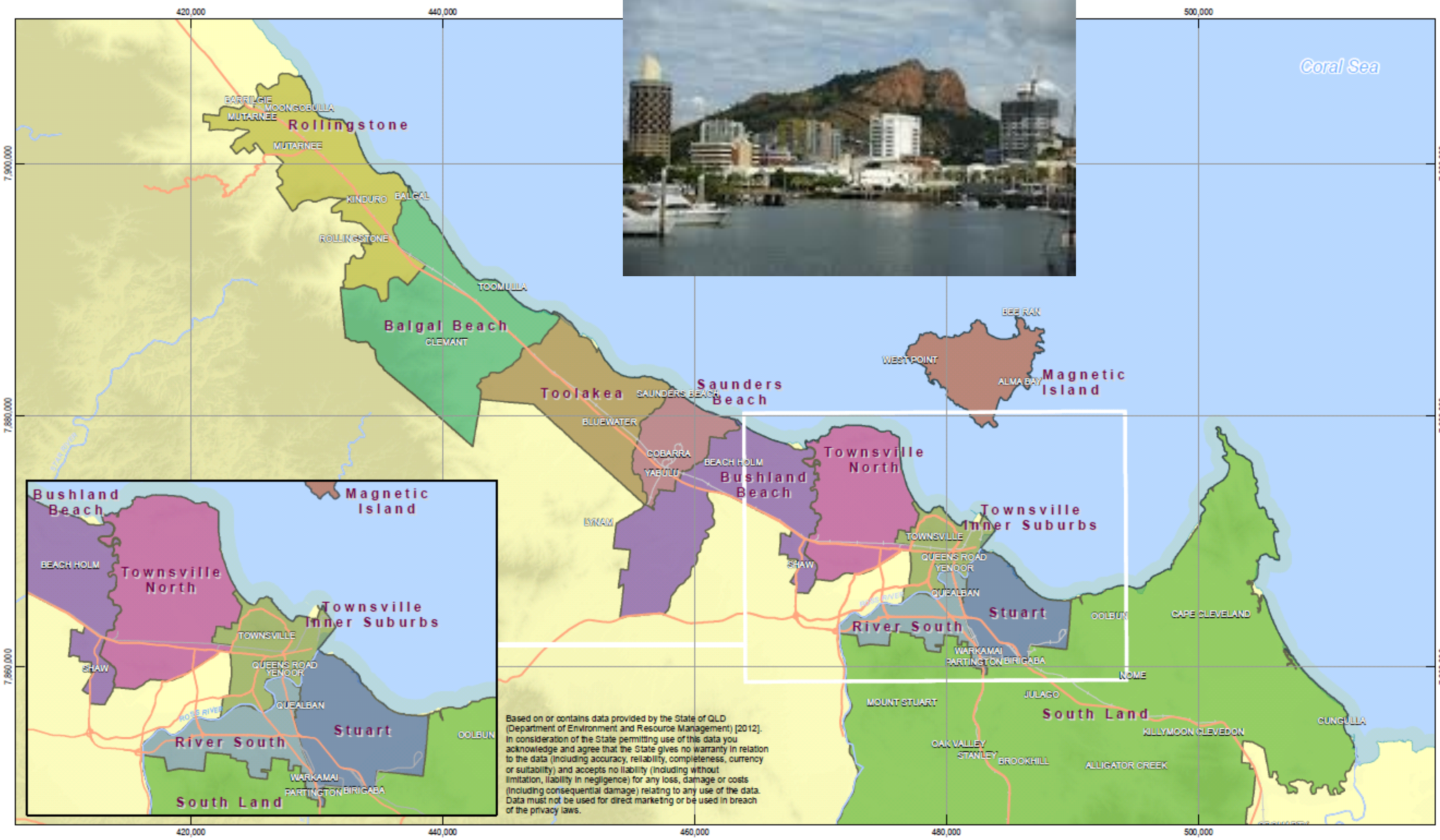

1:400,000 At Paper Size A4
0 2.5 5 10
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Watercourse
Road
Rail

TCC CHAS Districts: Balgal Beach, Bushland Beach, Magnetic Island, River South, Rollingstone, Saunders Beach, South Land, Stuart, Toolakea, Townsville Inner Suburbs, Townsville North

Townsville City Council
Coastal Hazard Adaptation Strategy

Job Number 41-24069
Revision A
Date 10 Oct 2012

Coastal Hazard Districts in Townsville City Council

Figure 1

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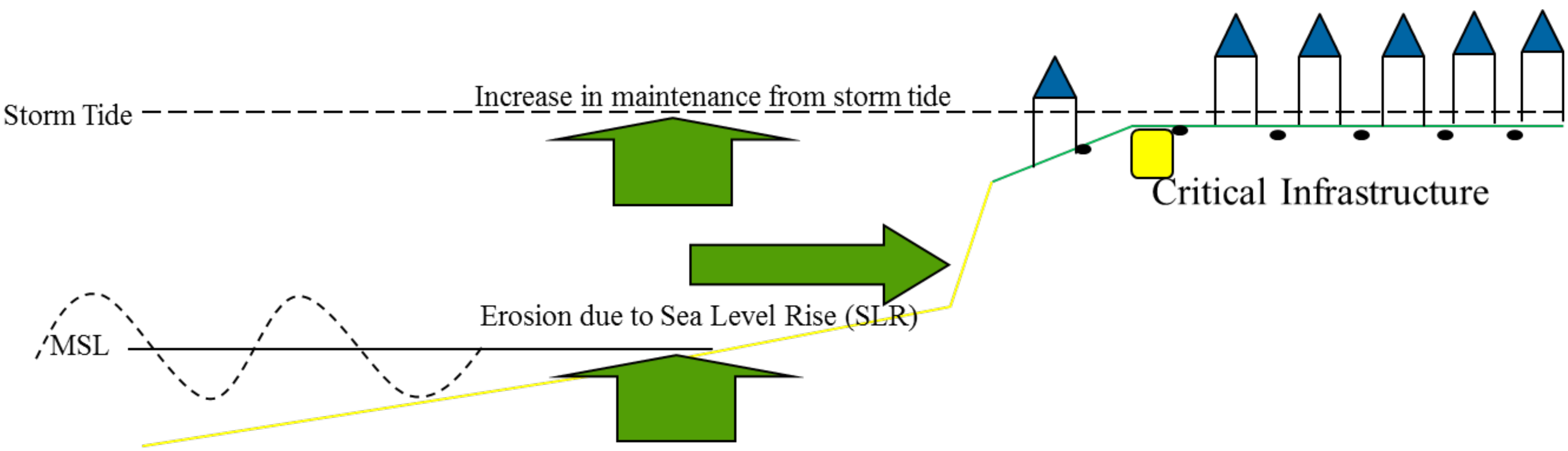
Level 9, 145 Ann Street Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

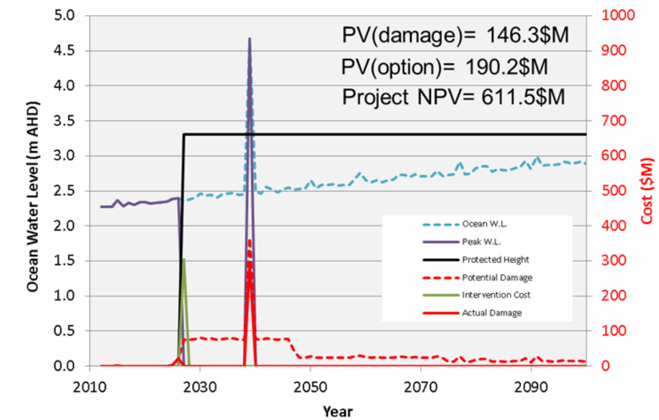
Data source: TCC/GHD, TCC CHAS Districts/2012. TCC, Rail/2011. GA, Watercourse © Copyright Commonwealth of Australia (Geoscience Australia)/2007. DERM, Place Names/2010, Elevation/2008. Created by:lhamilton

Four Classic Strategies
Adapting to Coastal Hazards

- **Defend**
- **Accommodate**
- **Retreat (Planned Retreat)**
- **Maintain Status Quo (Forced Retreat)**

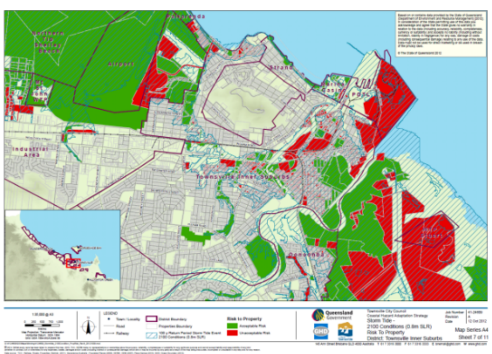


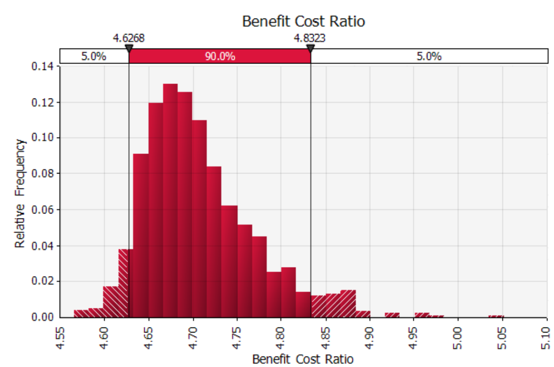
Adaptation Strategy Development

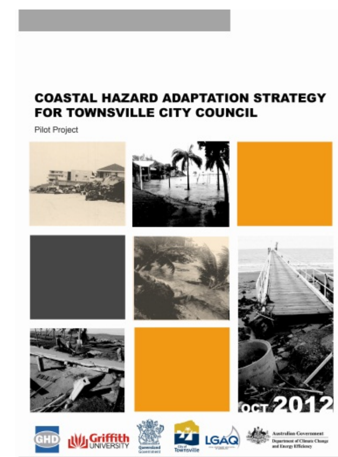


- Detailed vulnerability and risk mapping with LiDAR DEMs
- Property and infrastructure layers
- Over 150 options for 11 districts
- Existing and future sea level rise
- Existing and future storm tide events
- Mitigation strategies
- Monte-Carlo Cost-Benefit

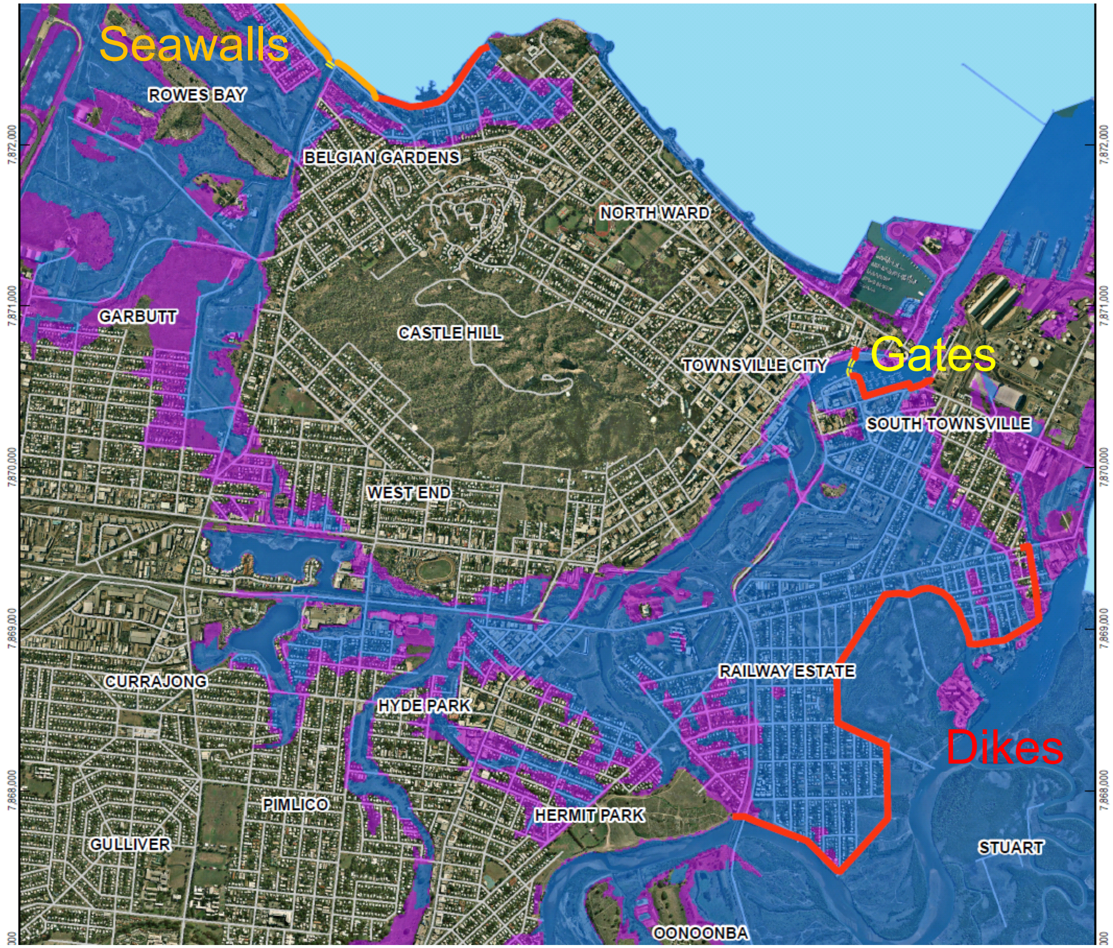
Define Hazard → Determine Risk → Evaluate Adaptation Options → Prepare CHAS → Consider Planning Implementation







Future Inundation Hazards and Potentially Viable Defences



Year 2100: Blue= HAT   Purple= 1% AEP storm tide (100 yr return Period)

In Conclusion

Practical Simulation of Tropical Cyclone Impacts

It's not all about high-resolution deterministic NWP modelling.

The important goal is to deliver probabilistic (risk based) advice to:

- Designers
- Planners
- Emergency Managers

It requires stochastically-driven models sampling a climatology:

- Models must be efficient and practical, matched to the availability and accuracy of the other various data that is required.
- Calibration and verification is an essential part of the process to provide objective confidence in any model's results.

Thank You

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