Cyclone Hazards: waves and storm tide

- GALE FORCE WINDS
- TORRENTIAL RAIN (FLOODING)
- SURGE ON COAST AT CROSSING
- HIGH WAVES
Waves and Swell

MetEd Comet Program
Wind and Wave forecasting
https://www.meted.ucar.edu/training_course.php?id=8
Formation of Wind Waves

Factors: Wind Speed, Fetch (~30°), and Duration
At Sea: Evading the dangerous quadrant

Modified from http://www.cruising.sailingcourse.com/weather.htm
Enhanced Ocean Wave situations

1. Ongoing strong monsoon

[Map showing ocean wave conditions with a wind speed of 30+ kn]
Enhanced Ocean Wave situations

2. Large wind field; Yasi (Qld); Lua (WA) 50 kn to 110, NT –
Dynamic Trapped Fetch -15-20kn

3. Trapped fetch in fast moving TC esp for Cooks, Tonga, NZ, Niue;

COMET animation
Why makes TCs different wrt wave forecasting?

Models don’t adequately resolve the wind field – resolution limitations; not usually intense; can’t resolve small scale wind variations.

Models can’t forecast TC intensity well enough.

Complex interaction of waves depending on track direction and speed, intensity changes, size changes.

Can end up with a ‘confused’ sea – waves from different directions so very difficult for navigation.

Trapped fetch worst case scenario for wave growth.

Models: EC (metconnect), GFS Wave Watch III, BoM ACCESS.
Storm Surge and Storm Tide
Storm Tide terms?

- Storm surge
- Storm tide
- Wave Setup
- Wave runup
- HAT
- LAT/CD
- AHD (MSL)
- Astronomical Tide
Storm Surge height depends upon:

The **Wind Stress** on the surface, piling up the water. This is related to the intensity of the TC, the forward speed of the TC and the extent of the strong winds.

The **angle at which the TC crosses the coast**. The more head on the angle, the higher the surge (however, particular angles can lead to local zones of enhanced surge in narrow inlets and bays).

**The shape of the sea floor**. The surge builds up more strongly if the sea bed at the coast is shallow.

**Coastline shape** Bays, headlands and offshore islands can funnel and amplify the storm surge.
Storm Tide depends upon:

the timing of the crossing compared to the astronomical tide plus any other residual effects (SST/ENSO/coastally trapped waves) and freshwater flooding near river-mouths.
Vance 1999: Exmouth storm tide event

The predicted tide

![Graph showing predicted tide levels from 21 March 12:00 to 23 March 00:00, with peaks and predicted high tide at 2.6m at 2pm on 22 March.](image)
Vance 1999: Exmouth storm tide
The storm surge only

Peak storm surge
3.5 m at 10:20 am
Vance 1999: Exmouth storm tide

The Total Tide

Peak tide if surge at time of high tide

**Highest Astronomical Tide**

- Peak storm tide: 4.9 m at 10:20 am
- Peak storm surge: 3.5 m at 10:20 am
A relatively small cyclone (*Martin*) with a band of storm force winds moving at 11 knots towards a small Coral Atoll (Manihiki) in the Northern Cook Islands. The Island of Manikiki being a Coral Atoll was a vulnerable target for large waves.
TC Martin’s a band of storm force winds moving at 11 kn towards Manihiki a small Coral Atoll in the Northern Cook Islands

2 NOV 1997
Tropical Cyclone Martin was quite destructive on Manihiki Atoll. When the center was closest to the island, the AWS reported a lowest pressure of 994 mb, sustained winds of 39 kts (10-min avg), and a highest gust of 56 kts. However this was the last official report from the station before it was demolished by the storm surge. There were 10 known fatalities on Manihiki with 10 more persons reported missing (and presumed drowned). Almost every building on the island was destroyed by the storm surge--even a concrete water tank broke under the onslaught of the waves.
The side of the island which was hit has a fairly continuous solid carbonate barrier 4-5m above MSL. The waves would have pumped some considerable amount of water over this barrier which then ran downhill through the village towards the lagoon.

Some people said the water was preceded by a particular loud noise perhaps indicating that it was a surge wave generating different noises from the large wind waves.

The Manihiki scenario is different from the Heron Island one in that there is no reef rim off the coast which the waves have to pass. There is an irregularly shaped carbonate rock rampart stretching 50 or so metres out, submerged 2-3m, after which the depth increases rather rapidly, say 1/10 - 1/20 and the bed is fairly flat.
Microwave images show northern eye wall intensify as it approached Manihiki. Estimated band of 50kn winds through the red area.
Wave damage at Manihiki
Wave damage at Manihiki
Transect across Tauhuna, which is on the western side of Manihiki (i.e., the Martin's first impact side). The topography is related to MSL.
3.2.4 Fast moving tropical cyclone caused severe wave damage in Fiji.
TC Paula impact on Fiji, 2001
Moving ESE at 19 knots
Paula was a SH example of fetch enhancement in 2001 when large waves damaged parts of Fiji. In Western Division high waves destroyed or damaged a number of houses in nine villages along the Coral Coast (the South Coast of Viti Levu). The owners of these houses were forced to evacuate. Root crops, fruit trees and some sugar cane fields were damaged, by sea-borne debris. The most distant islands in Eastern Division, the Southern Lau Group also suffered damage to buildings and crops.
Summary

- Hazards vary with each system
- Intensity relates to wind, surge and wave
- Oceanic risk: enhanced fetch => large waves
- Storm tide has potential to be the biggest impact; most difficult forecast to get ‘right’ because of many factors including timing with astronomical tide
Typhoon Meena  2005-Feb-06  17:13 UTC  QSCAT rev 29353
Rescue in the Pacific
21 rescued 7 yachts and 3 people lost
Large swells damaged Majuro
one metre seawater inundation

The sea flooded 120 dwellings, damaged infrastructures and closed the airport for 48 hours.
Toolakea ideal site in Mangrove creeks behind beach 5.81m wave debris LAT 5.20m surge debris LAT 4.27m/3.66m surge.

Pallarenda debris level 5.5m LAT

Saunders Beach waves over top of dunes onto road

Kennedy St Debris level 7.4m LAT

Tobruk Pool debris level 6.17m LAT

Harbour Tide Gauge 4.14m LAT 2.9m surge

Black R. surge 2.74m/3.05m debris 2m higher
Toolakea 3.66m surge measured in Mangrove Creeks draining into Bluewater Creek.
Waves demolished the Strand seawall during Althea
Wave action destroyed the bitumen road at Pallarenda. Houses in the background were flooded by sea water to a depth of 60cm
Low Isle: $H_{\text{sig}}$ reached 3.5m and $H_{\text{peak}}$ reached 6.3m

Cairns: $H_{\text{sig}}$ reached 2.49m at 1100UTC 11 Feb 1999 and $H_{\text{peak}}$ reached 4.65m at 1200UTC 11 Feb 1999. The peak energy period was around 6 sec during the large waves.

Dunk Island: $H_{\text{sig}}$ reached 3.06m at 0930UTC 11 Feb 1999 and $H_{\text{peak}}$ reached 5.69m at 0800UTC 11 Feb 1999. The peak energy period was around 7 sec during the large waves.

At 1300UTC 11 Feb 1999 Mossman River tide gauge recorded a storm surge of 1.38m.
Track of *Rona*
11 Feb 1999
Low Isle AWS
060/71 knots
10 min mean at 1228 UTC

105 km open water
Daintree R mouth to Sudbury Reef
2.9 to 3.4m surge with waves

2.5 to 3m AHD debris lines Jon Nott
HAT 1.78m AHD

Waves from SE
Gale Fetch 105 km

1.4m surge
0.8m below HAT
Low Isle
$H_{\text{sig}}$ reached 3.5m
$H_{\text{peak}}$ reached 6.3m