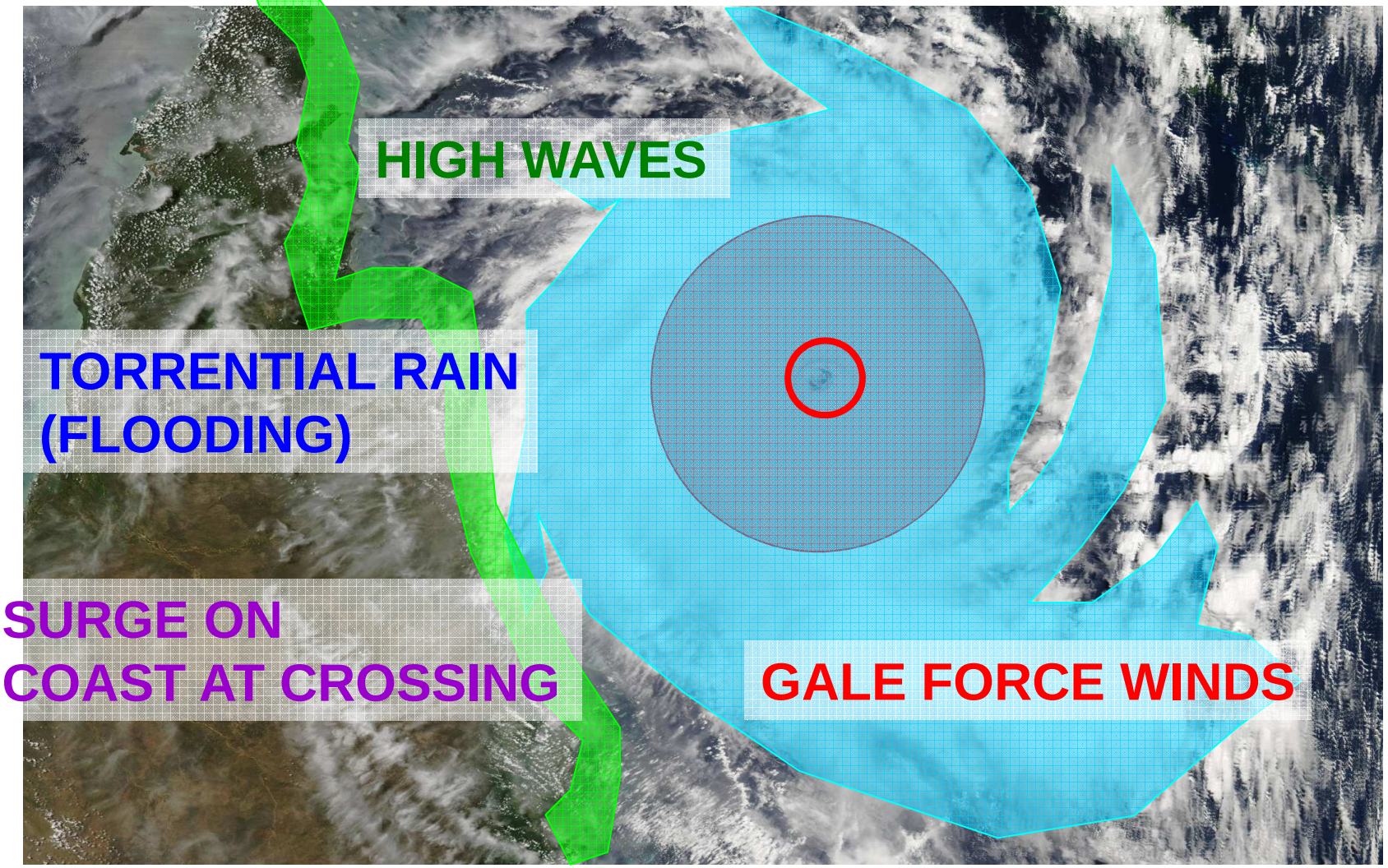
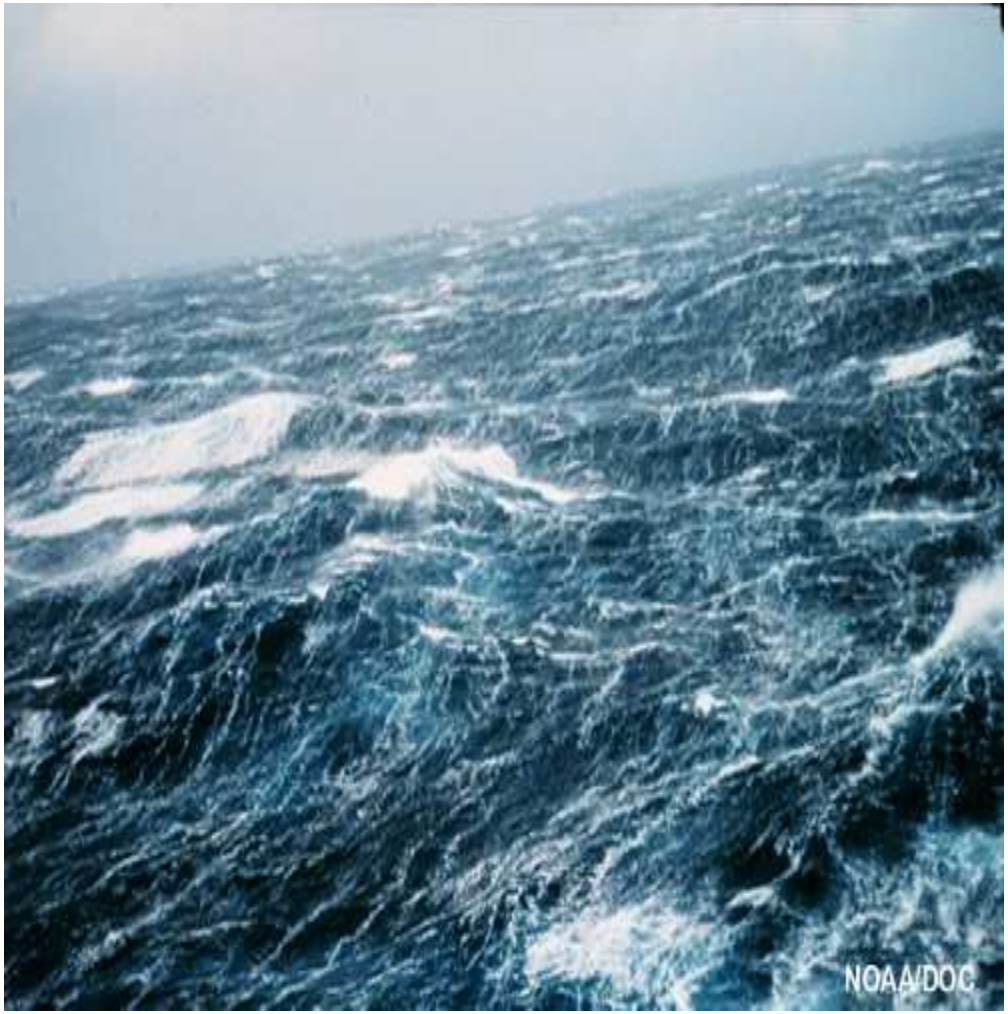
Cyclone Hazards: waves and storm tide

Australian Government
Bureau of Meteorology



Australian Government
Bureau of Meteorology

Waves and Swell



MetEd Comet Program

Wind and Wave forecasting

https://www.meted.ucar.edu/training_course.php?id=8

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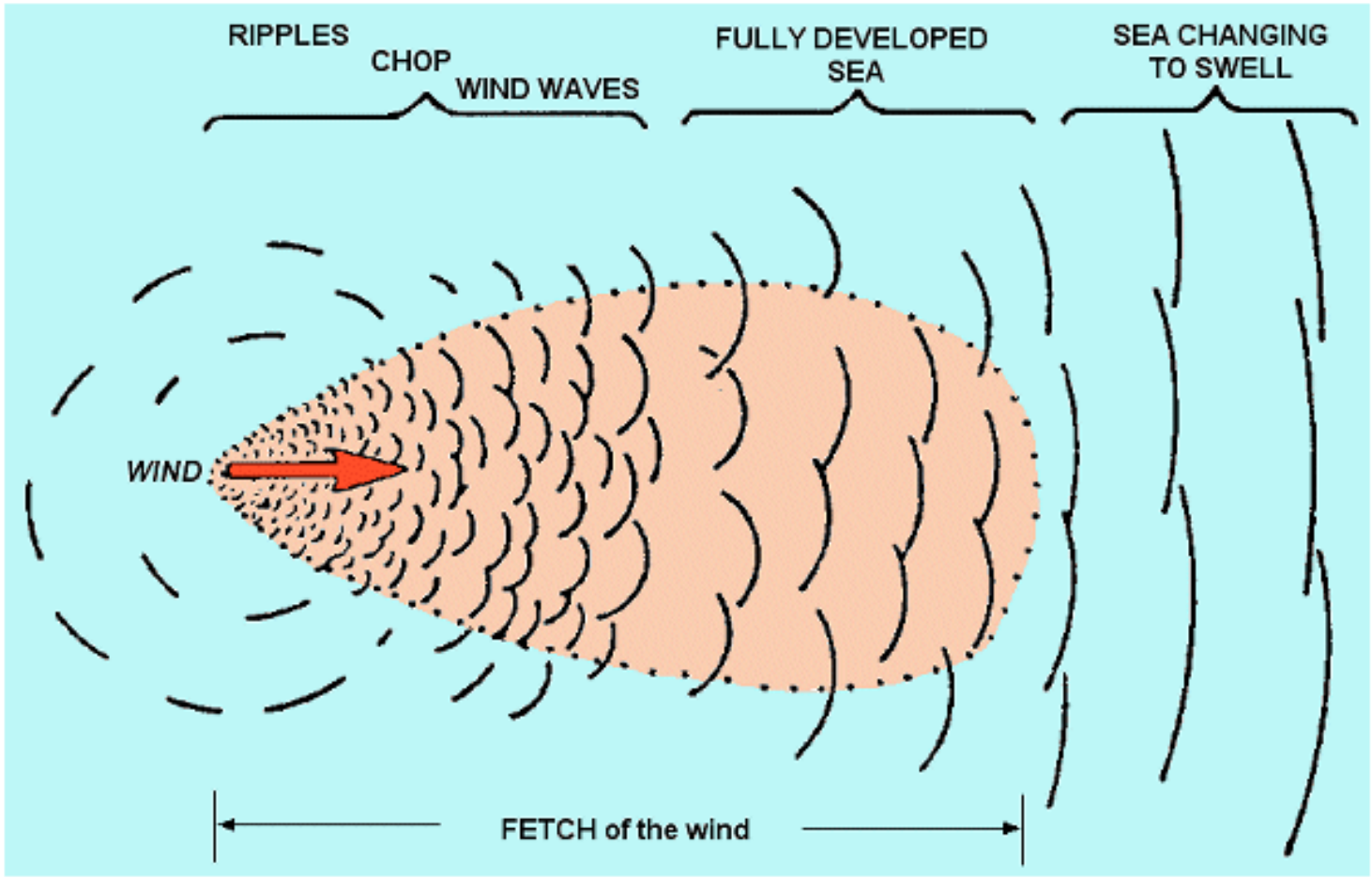
Formation of Wind Waves

Factors: Wind Speed, Fetch (~30deg), and Duration



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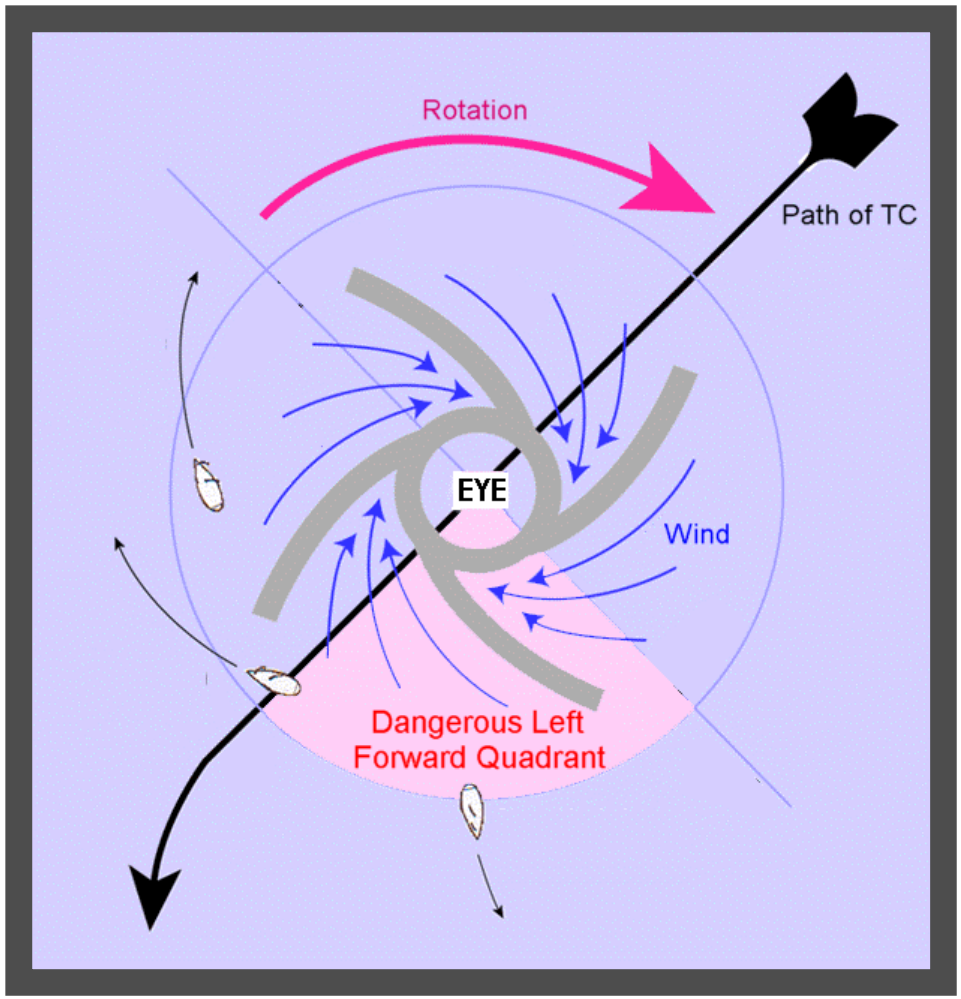
At Sea:
Evading the dangerous quadrant



Modified from http://www.cruising.sailingcourse.com/weather.htm

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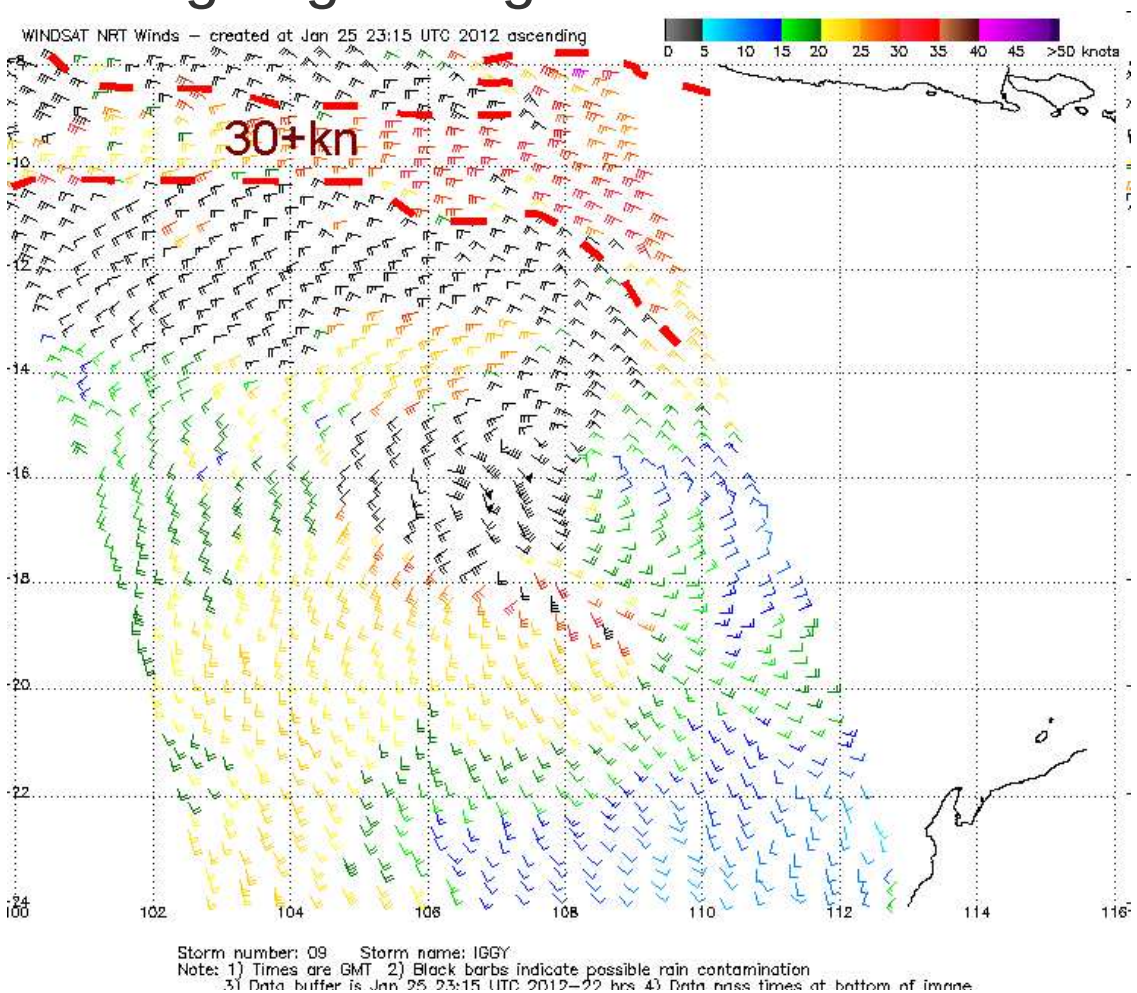
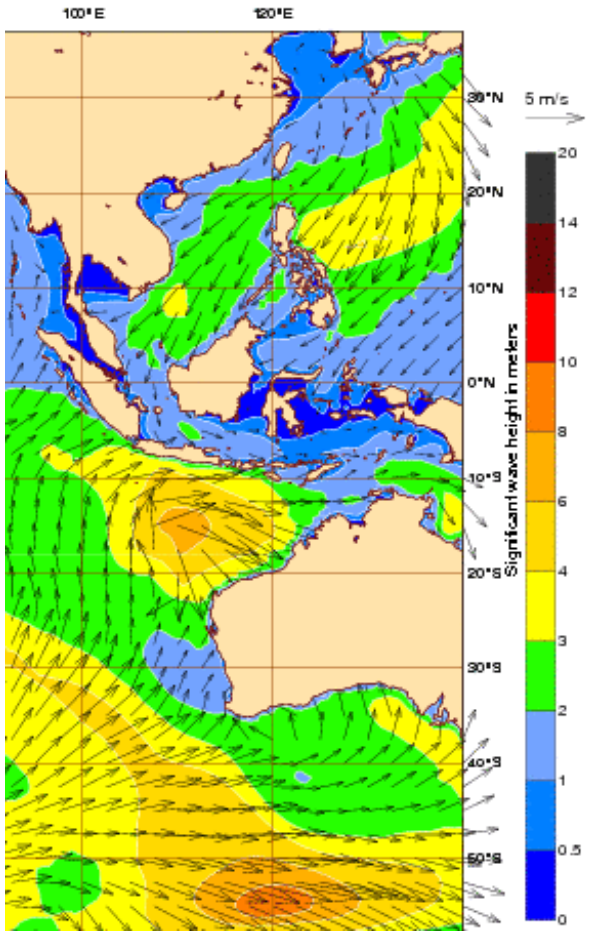
Enhanced Ocean Wave situations

1. Ongoing strong monsoon





Enhanced Ocean Wave situations

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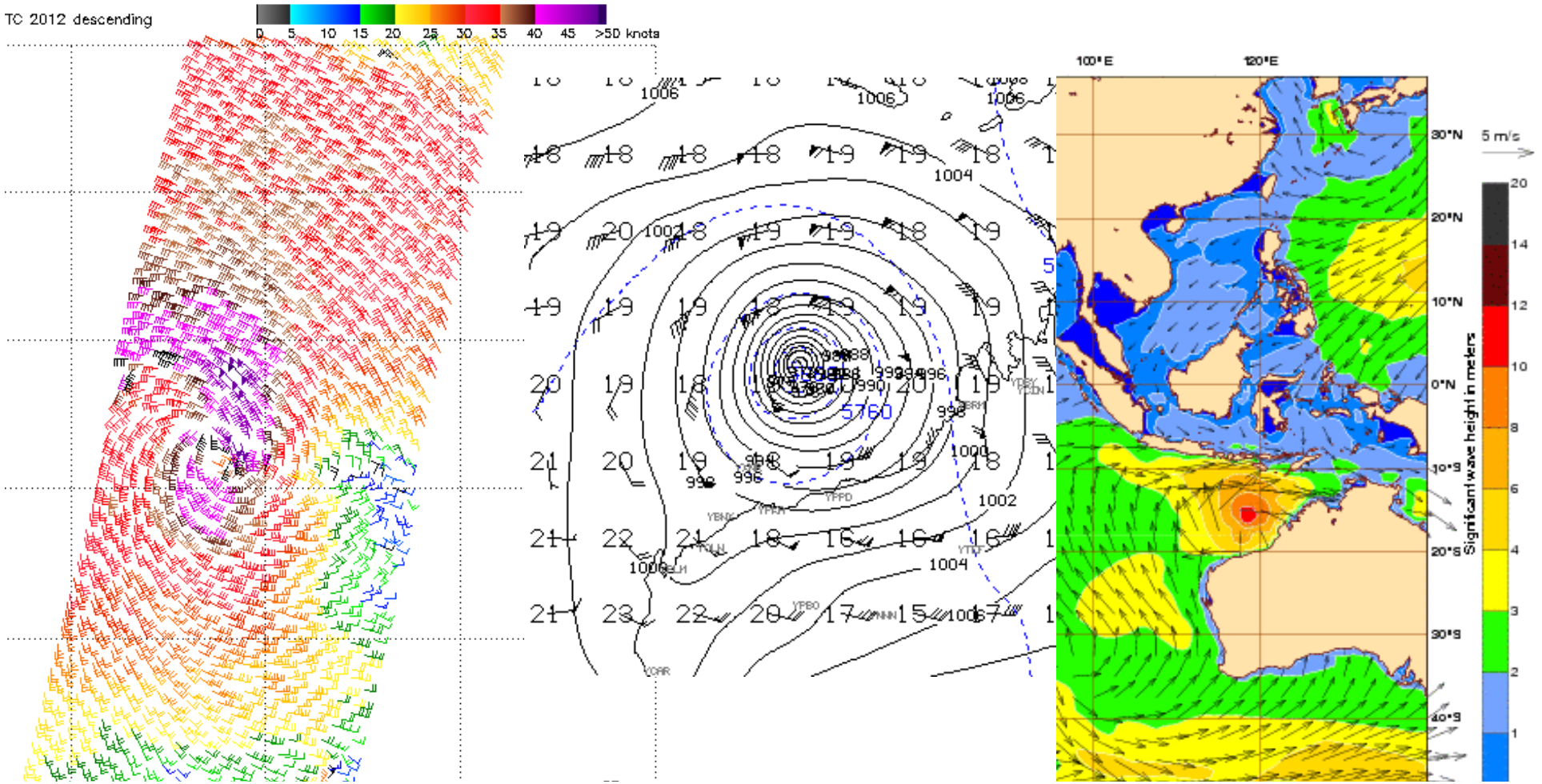
2. Large wind field; Yasi (Qld); Lua (WA) 50 kn to 110, NT –



Dynamic Trapped Fetch -15-20kn

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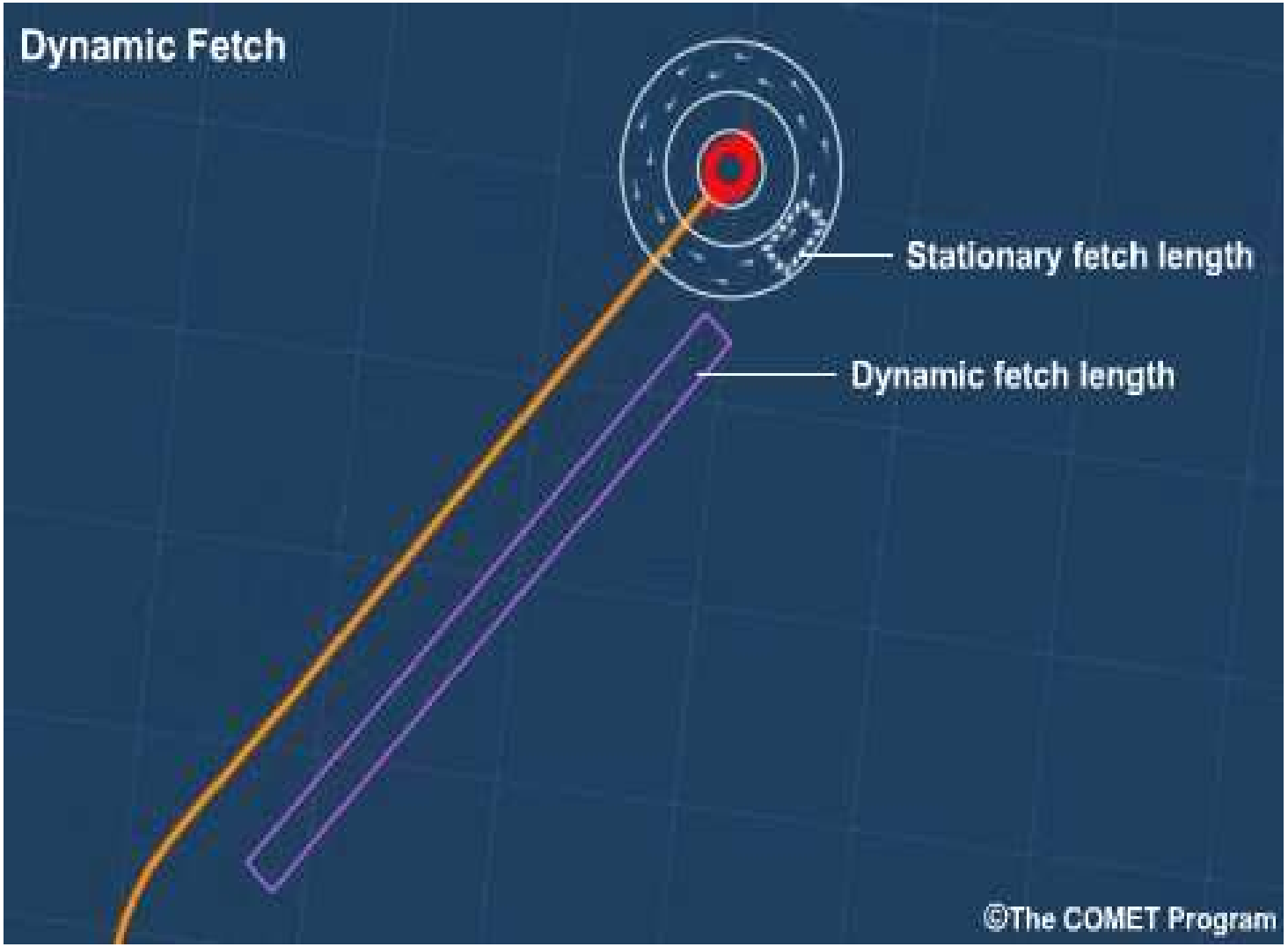
3. Trapped fetch in fast moving TC esp for Cooks, Tonga, NZ, Niue;

COMET animation



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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

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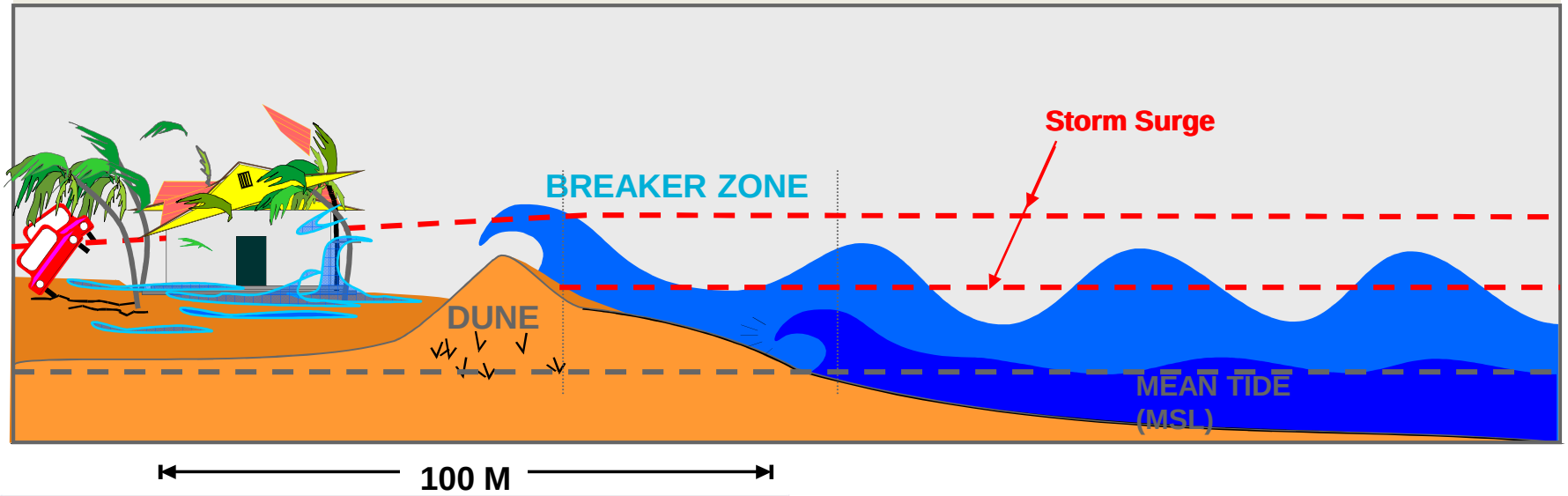
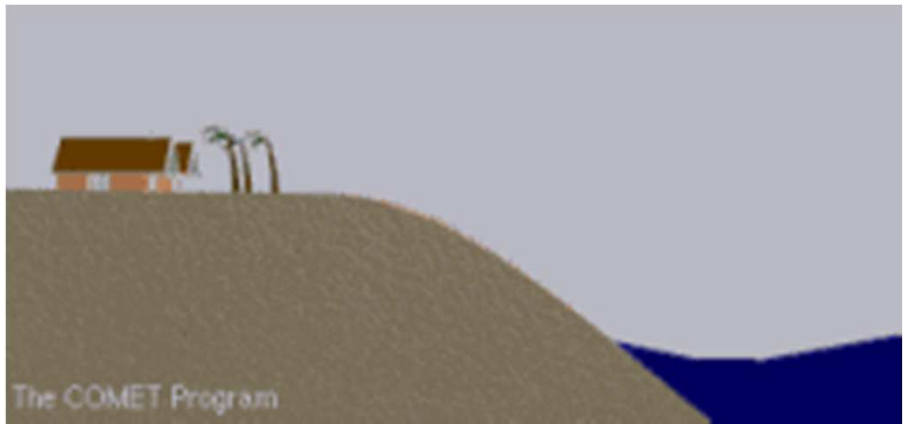
Storm Surge and Storm Tide





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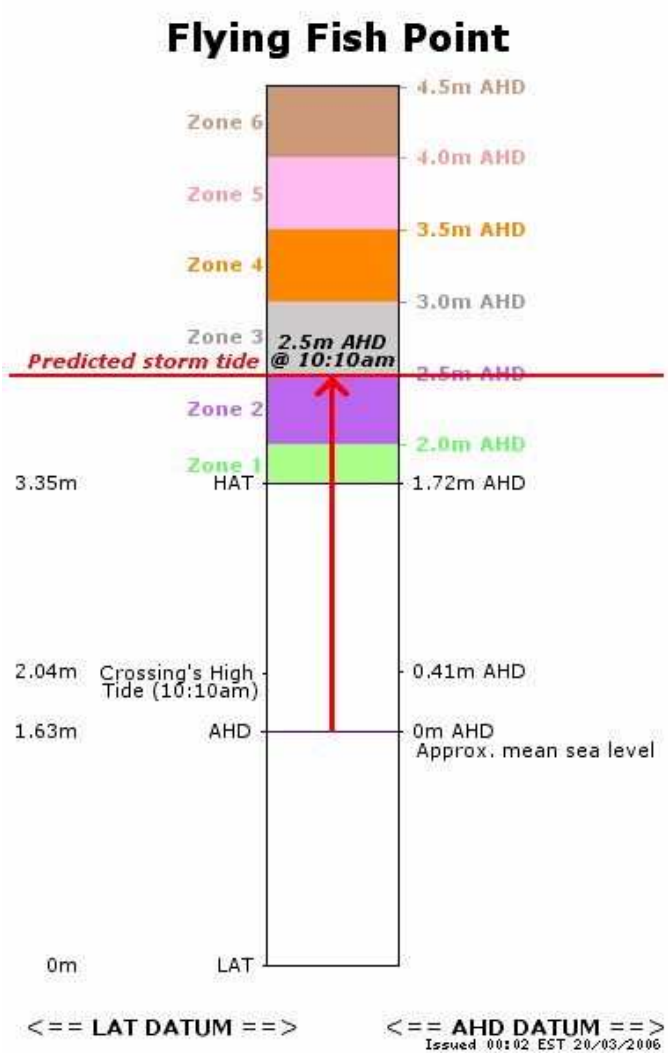
Storm Tide terms?

Storm surge
Storm tide
Wave Setup
Wave runup
HAT
LAT/CD
AHD (MSL)
Astronomical Tide



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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.

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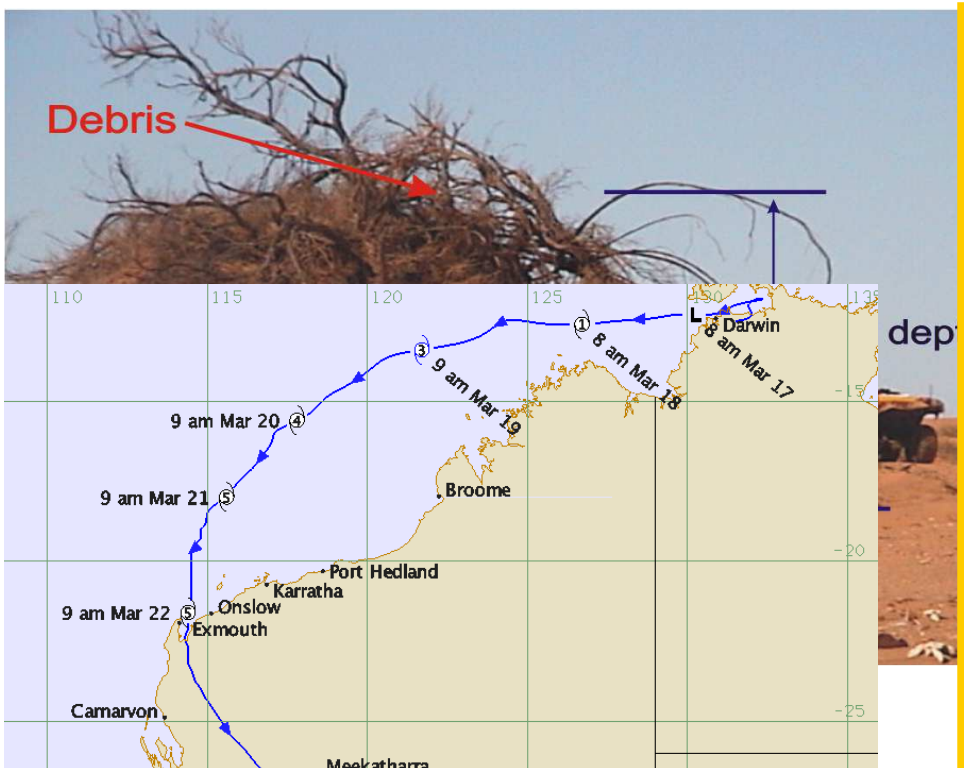
Storm Tide depends upon :

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



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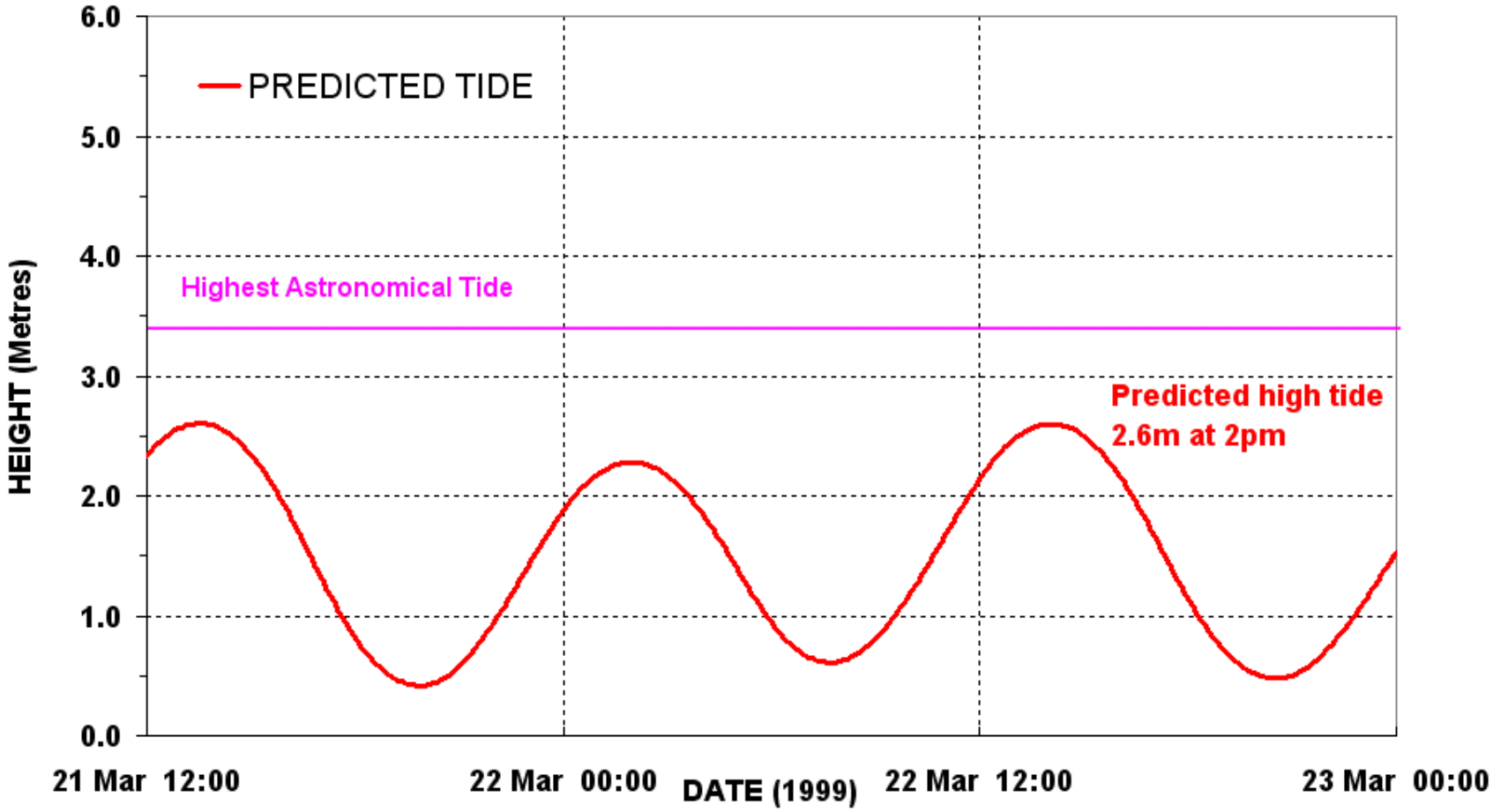
Vance 1999: Exmouth storm tide event

The predicted tide



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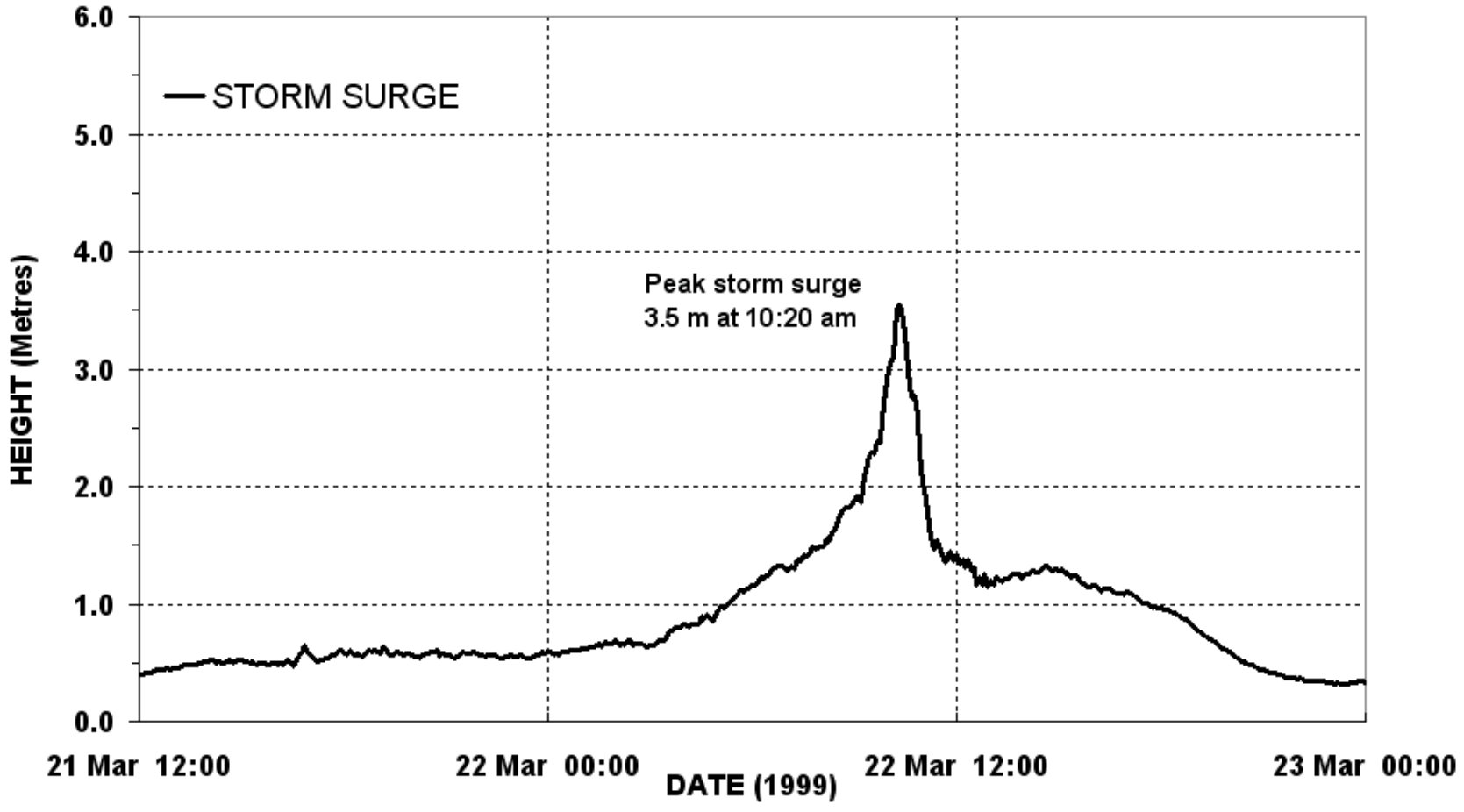
Vance 1999: Exmouth storm tide
The storm surge only



Vance 1999: Exmouth storm tide

The Total Tide

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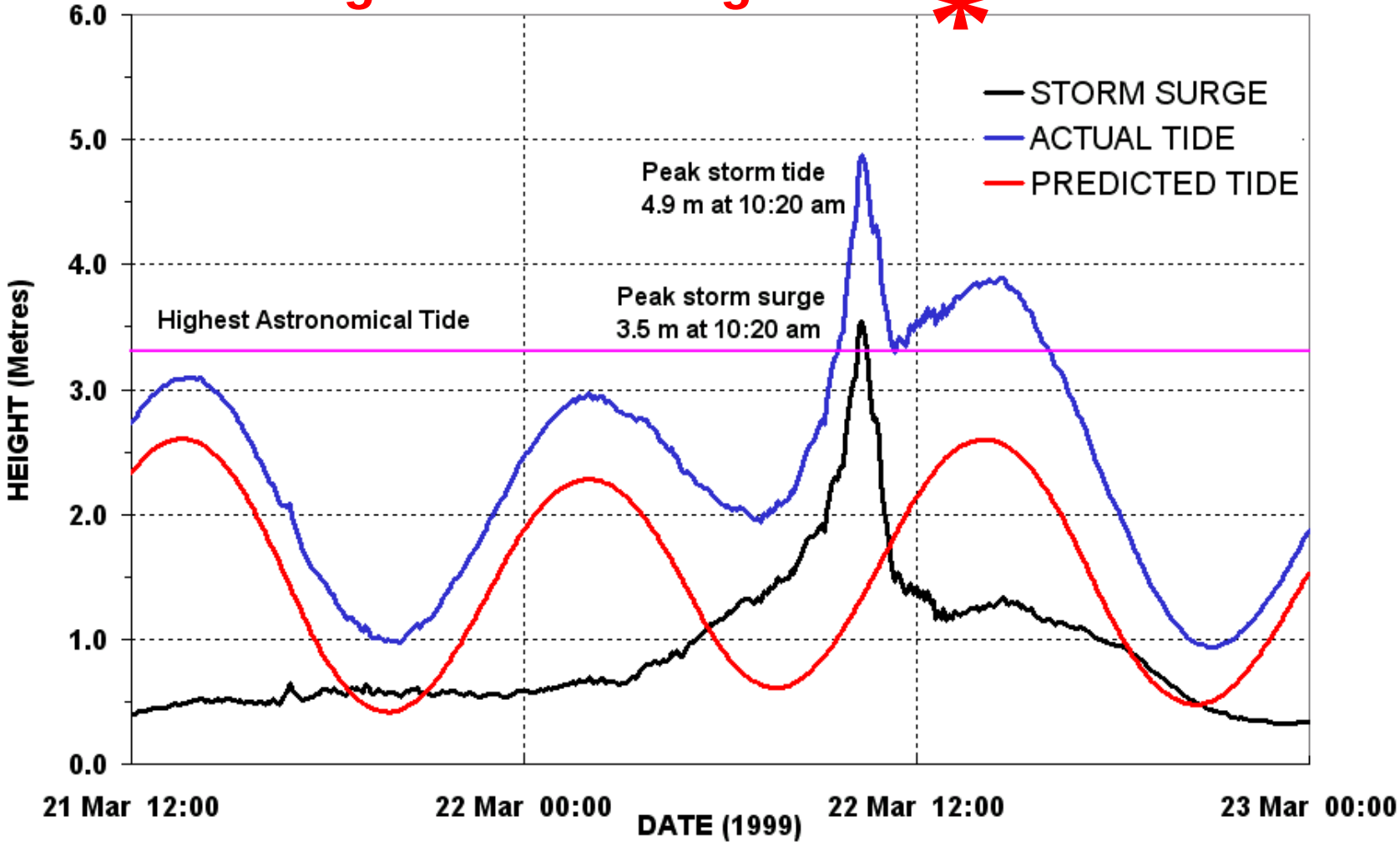
Peak tide if surge at time of high tide *



TC Martin: Northern Cook Is 1997

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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: Northern Cook Is 1997

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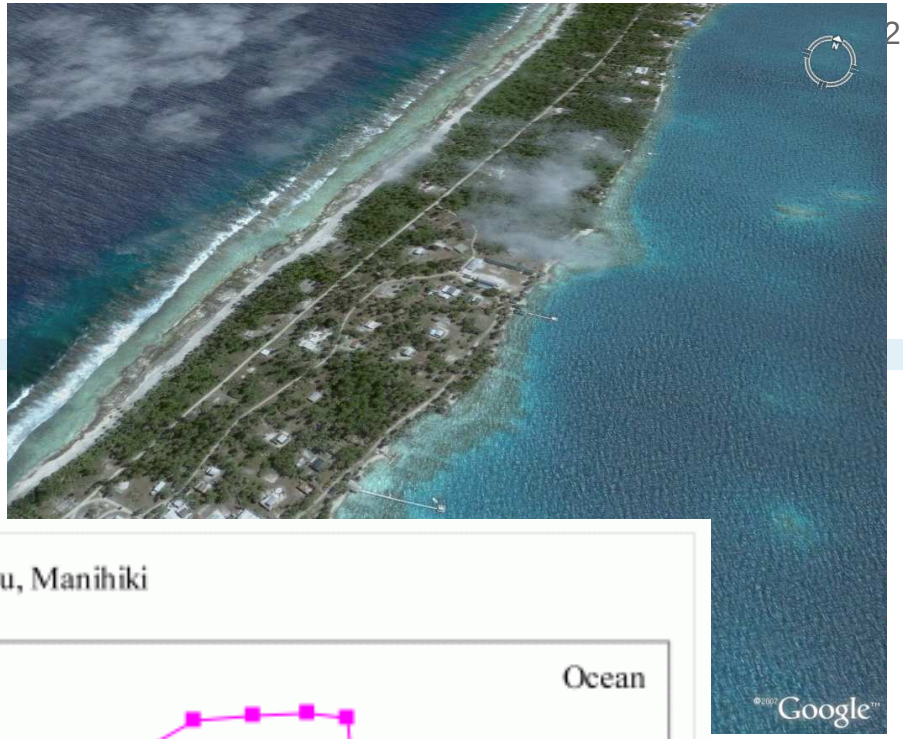
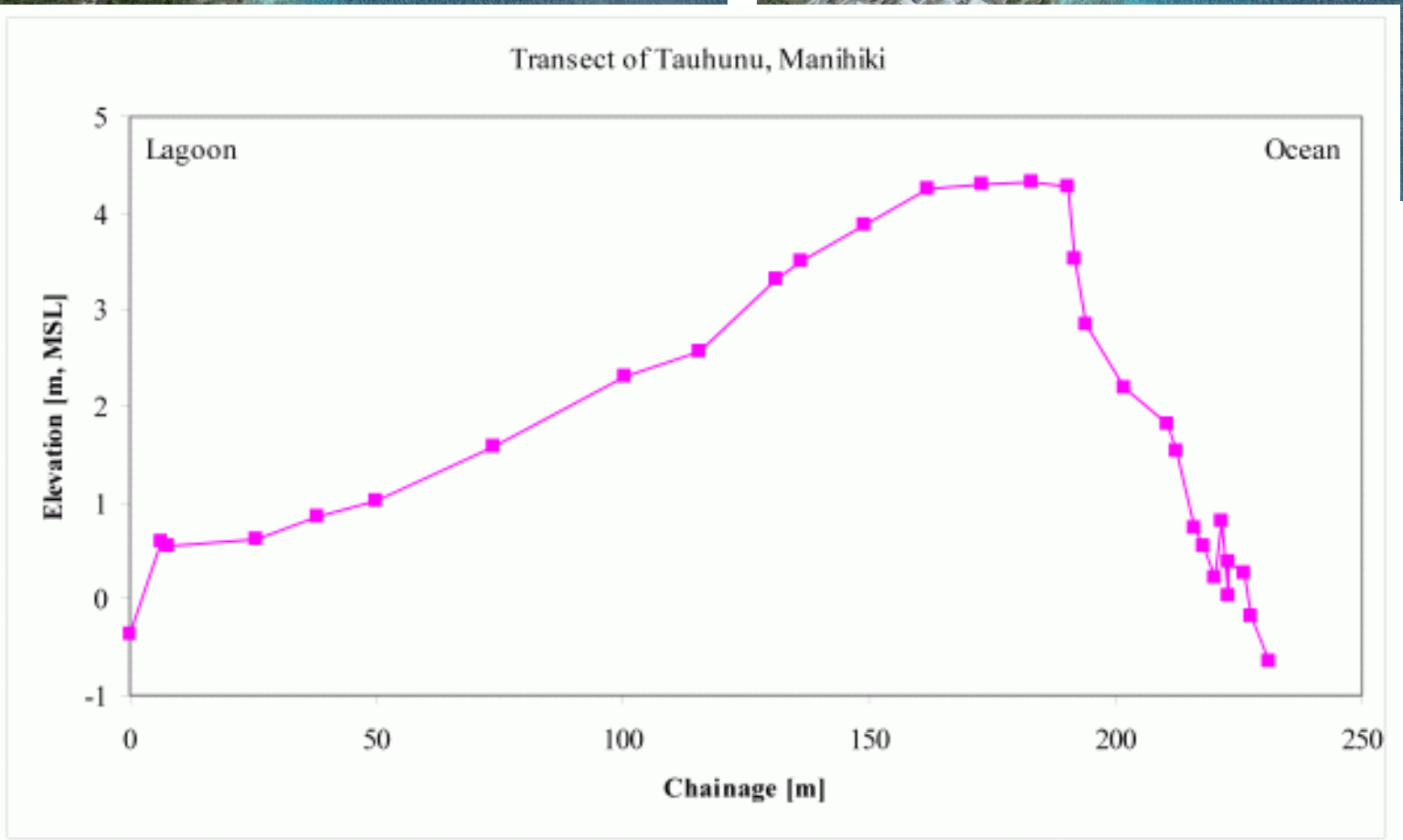
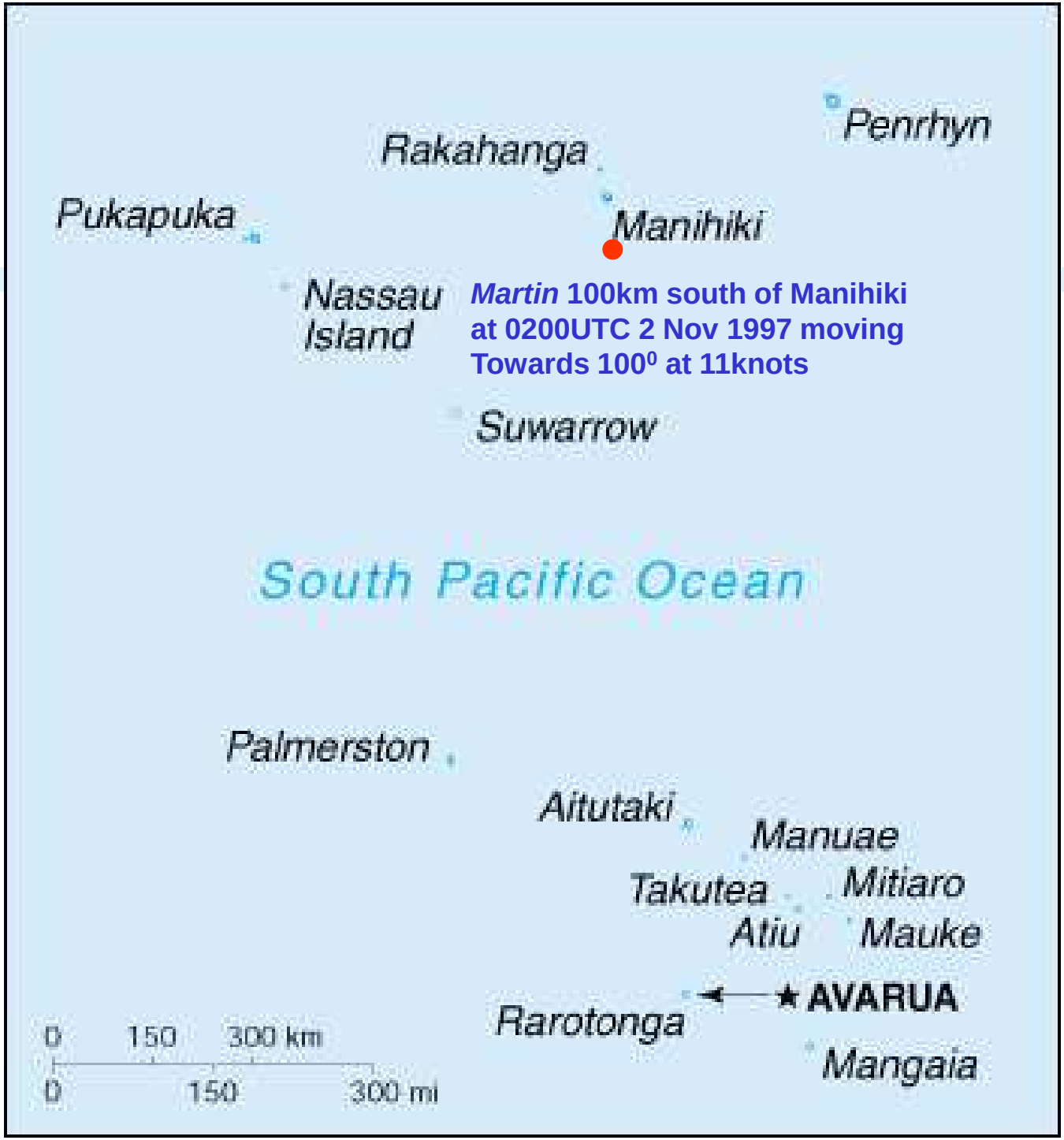
TC *Martin's*
a band of storm force winds moving at 11 kn towards Manihiki a small Coral Atoll in the Northern Cook Islands

2 NOV 1997


©2007 Google™


Transect of Tauhunu, Manihiki
Lagoon
Ocean
Elevation [m, MSL]
5
4
3
2
1
0
-1
0
50
100
150
200
250
Chainage [m]



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.

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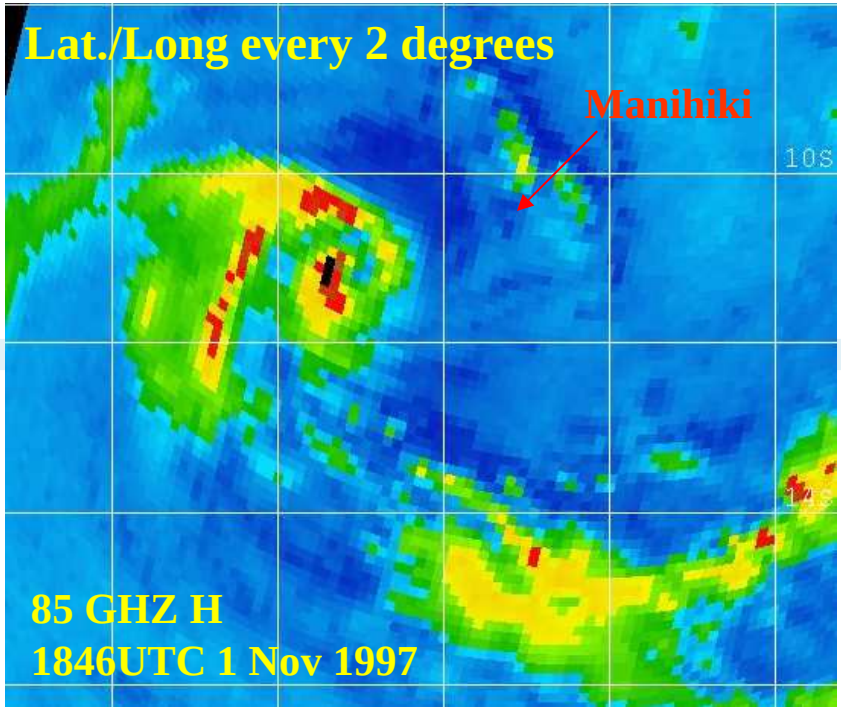
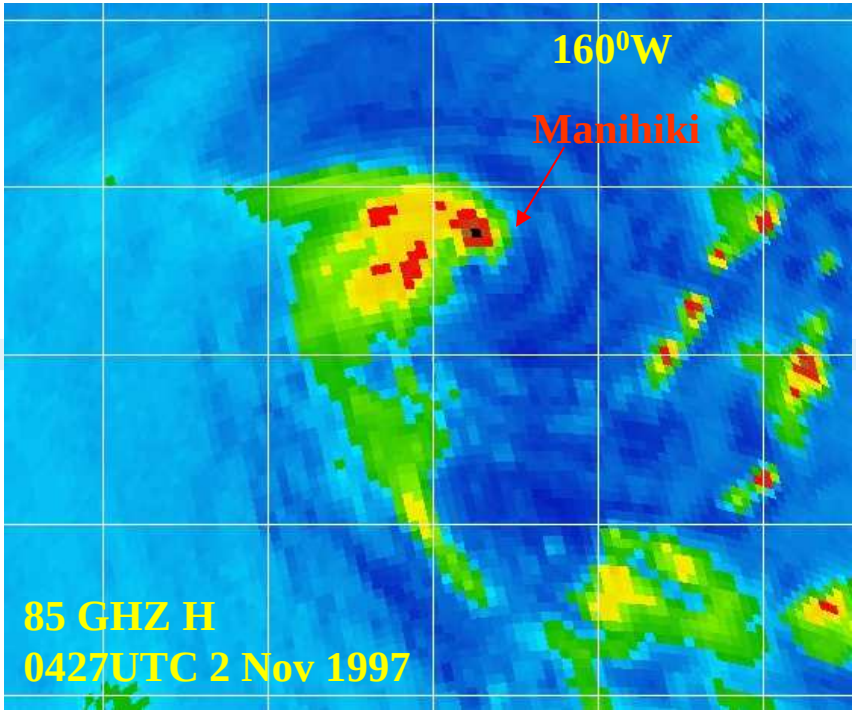
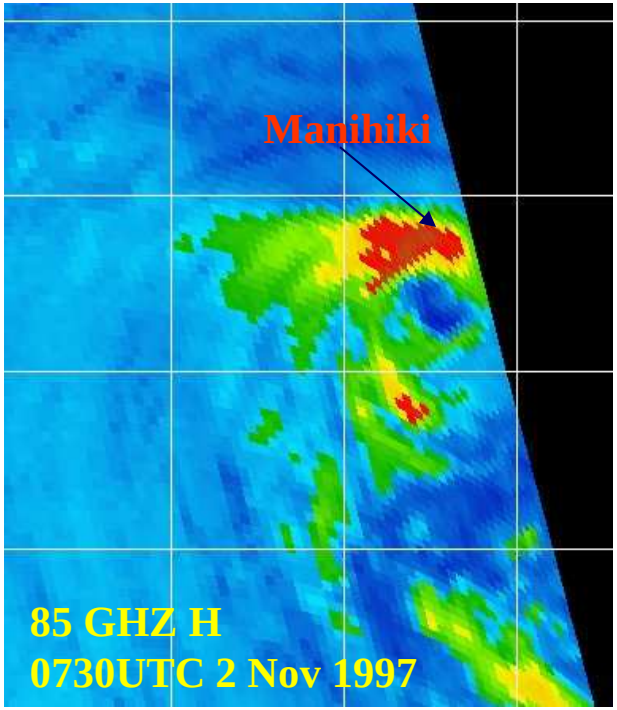
The side of the island which was hit has a fairly continuous solid carbonate barrier 4-5m above MSL.
The waves would have pumped some considerable amount of water over this barrier which then ran downhill through the village towards the lagoon.

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, say1/10 - 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

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Wave damage at Manihiki

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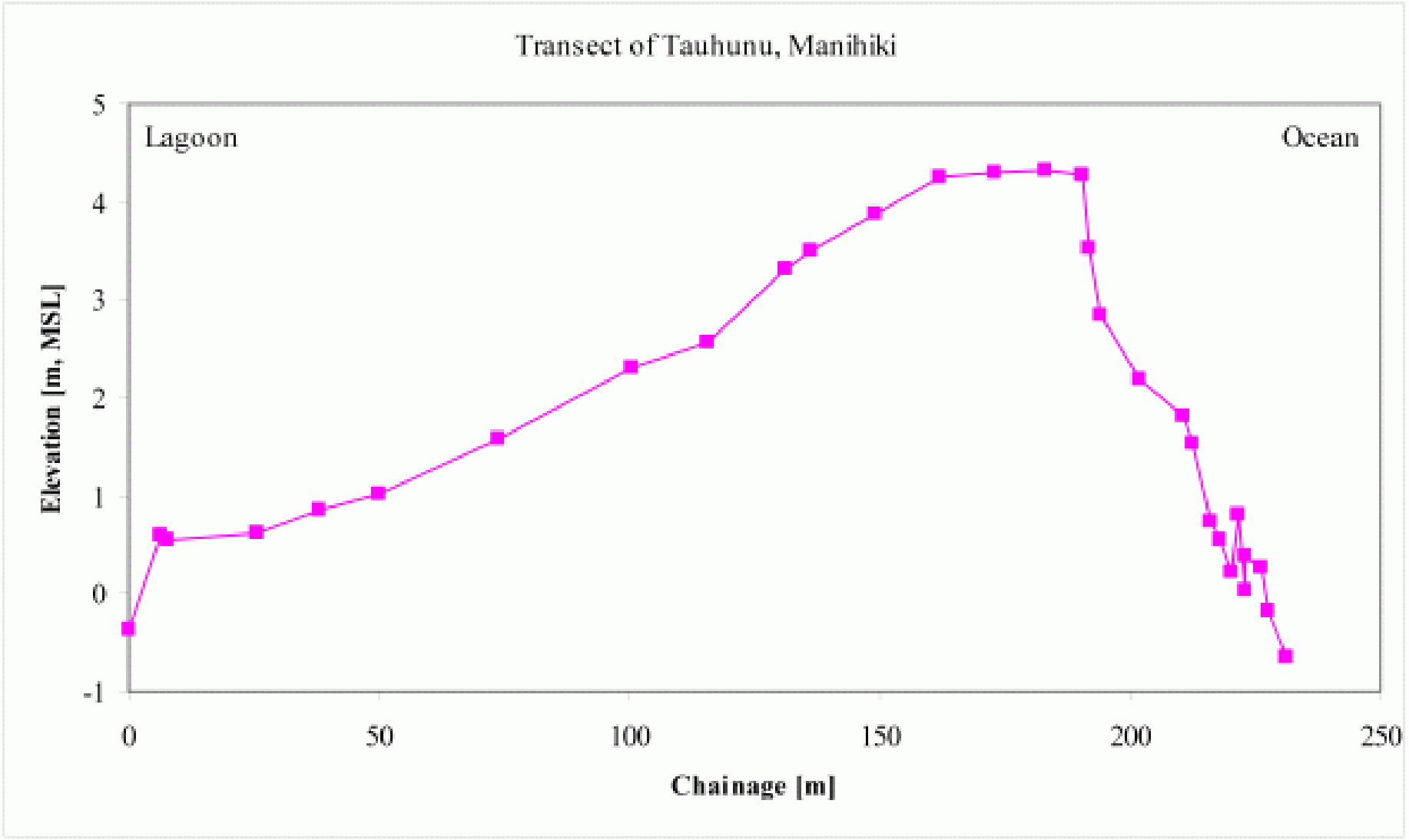
Transect across Tauhuna, which is on the western side of Manihiki (ie, the Martin's first impact side). The topography is related to MSL.



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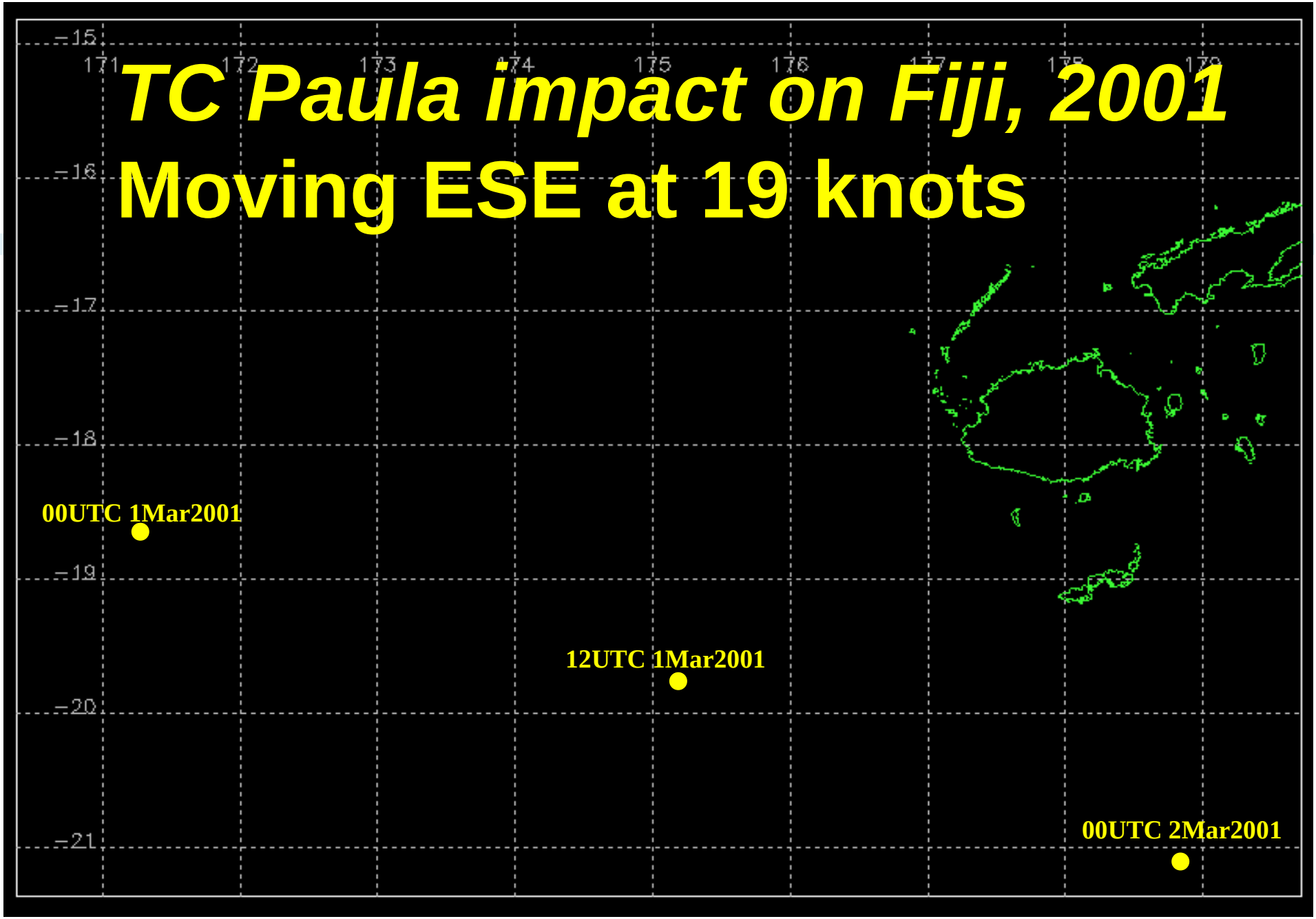
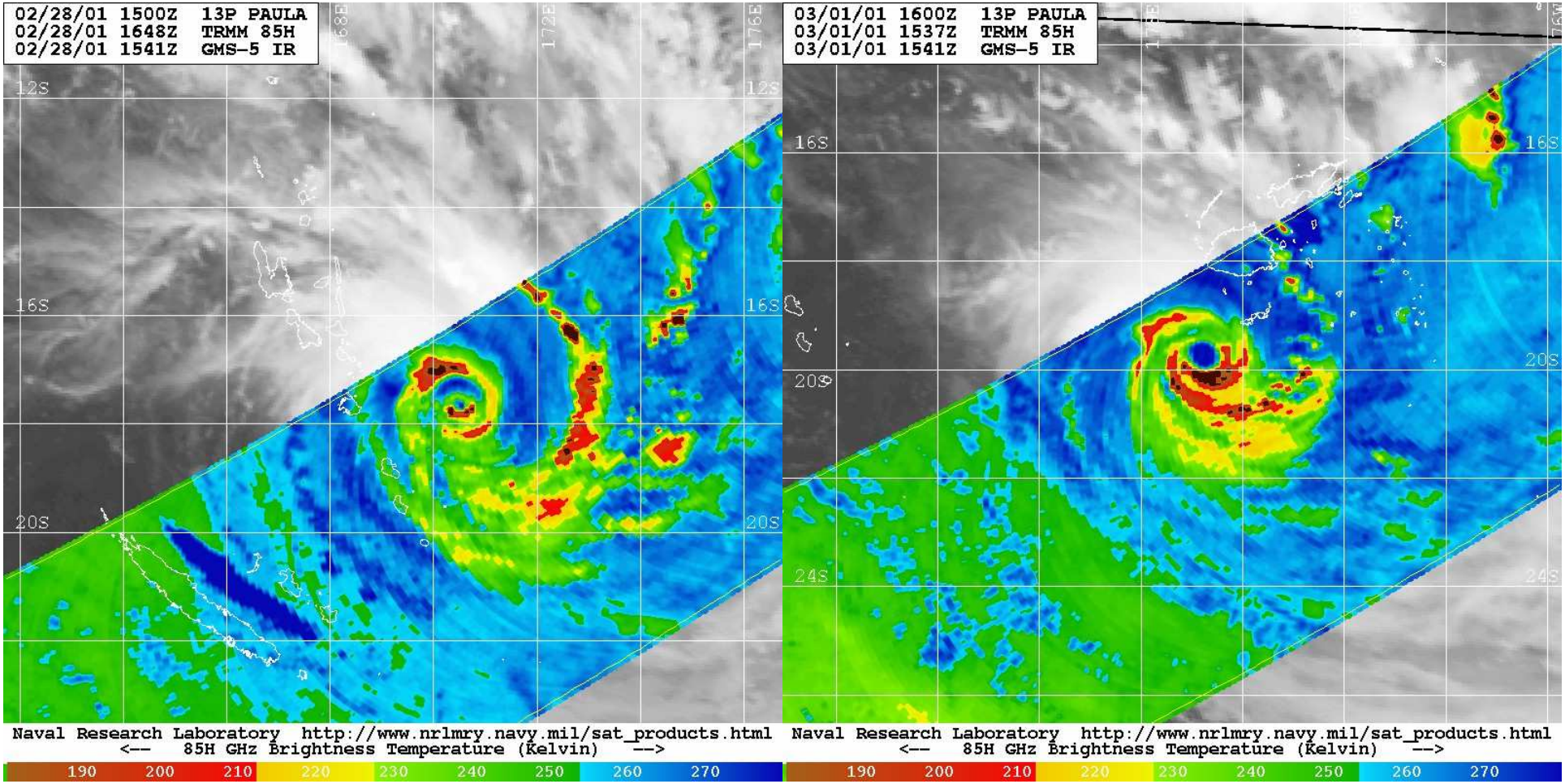
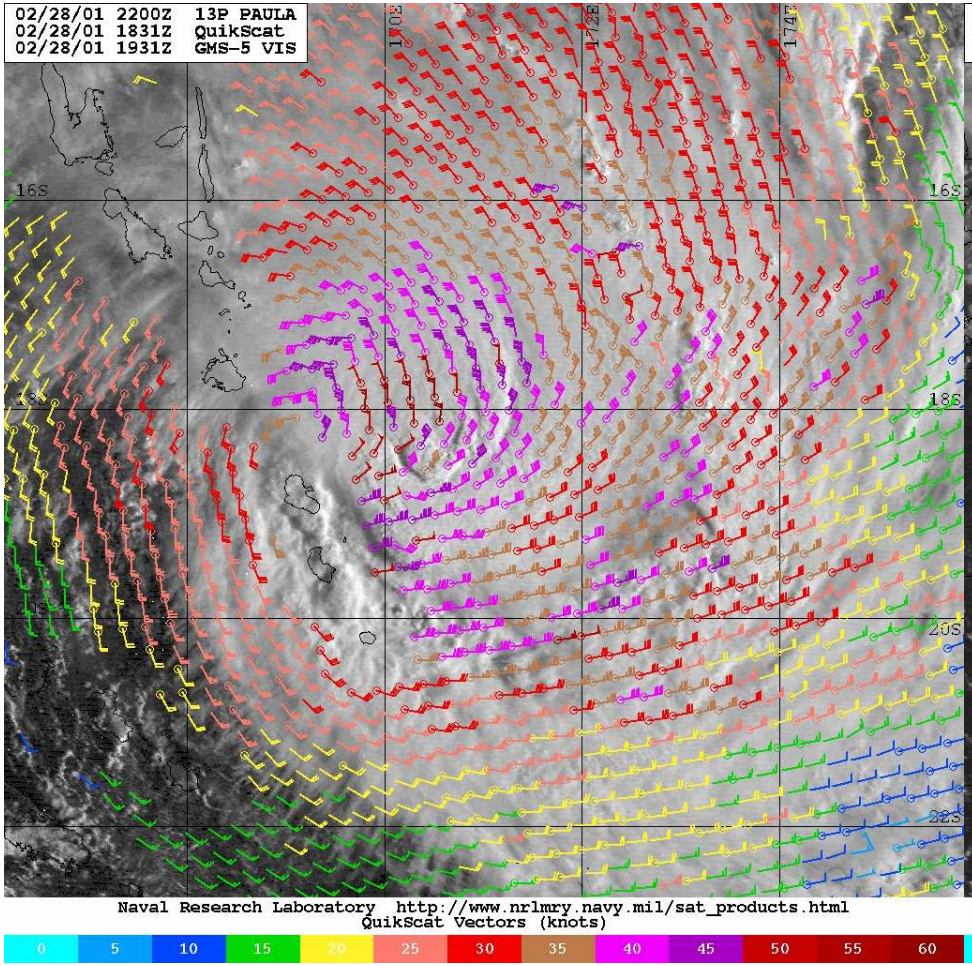
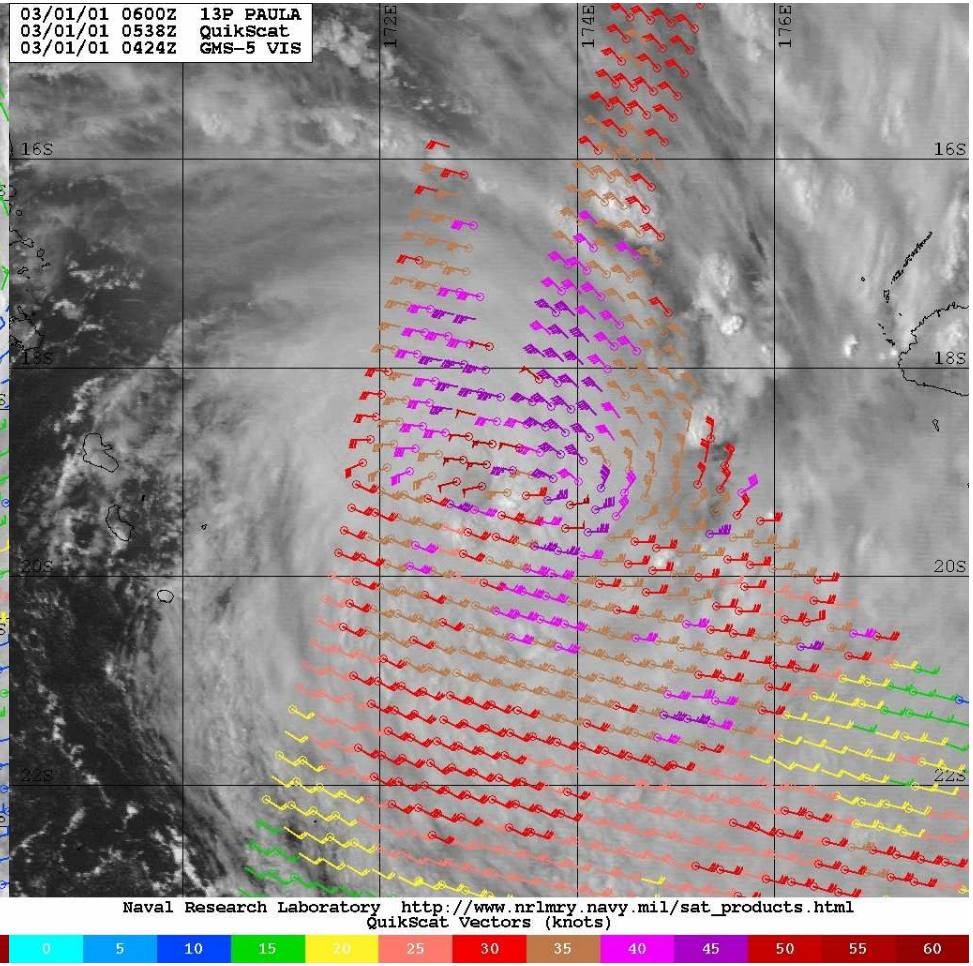
3.2.4 Fast moving tropical cyclone caused severe wave damage in Fiji.


TC Paula impact on Fiji, 2001
Moving ESE at 19 knots
-15
-16
-17
-18
-19
-20
-21
171
172
173
174
175
176
177
178
179
00UTC 1Mar2001
12UTC 1Mar2001
00UTC 2Mar2001


02/28/01 1500Z 13P PAULA
02/28/01 1648Z TRMM 85H
02/28/01 1541Z GMS-5 IR
168E
172E
176E
12S
16S
20S
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- 85H GHz Brightness Temperature (Kelvin) -->
190 200 210 220 230 240 250 260 270
03/01/01 1600Z 13P PAULA
03/01/01 1537Z TRMM 85H
03/01/01 1541Z GMS-5 IR
176W
16S
20S
24S
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- 85H GHz Brightness Temperature (Kelvin) -->
190 200 210 220 230 240 250 260 270


02/28/01 2200Z 13P PAULA
02/28/01 1831Z QuikScat
02/28/01 1931Z GMS-5 VIS
170E
172E
174E
16S
18S
20S
22S
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
QuikScat Vectors (knots)
0 5 10 15 20 25 30 35 40 45 50 55 60


03/01/01 0600Z 13P PAULA
03/01/01 0538Z QuikScat
03/01/01 0424Z GMS-5 VIS
172E
174E
176E
16S
18S
20S
22S
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
QuikScat Vectors (knots)
0 5 10 15 20 25 30 35 40 45 50 55 60

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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.

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TC Meena 2005 Rarotonga

Meena's storm surge Avarua Harbour Rarotonga 6 Feb 2005

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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

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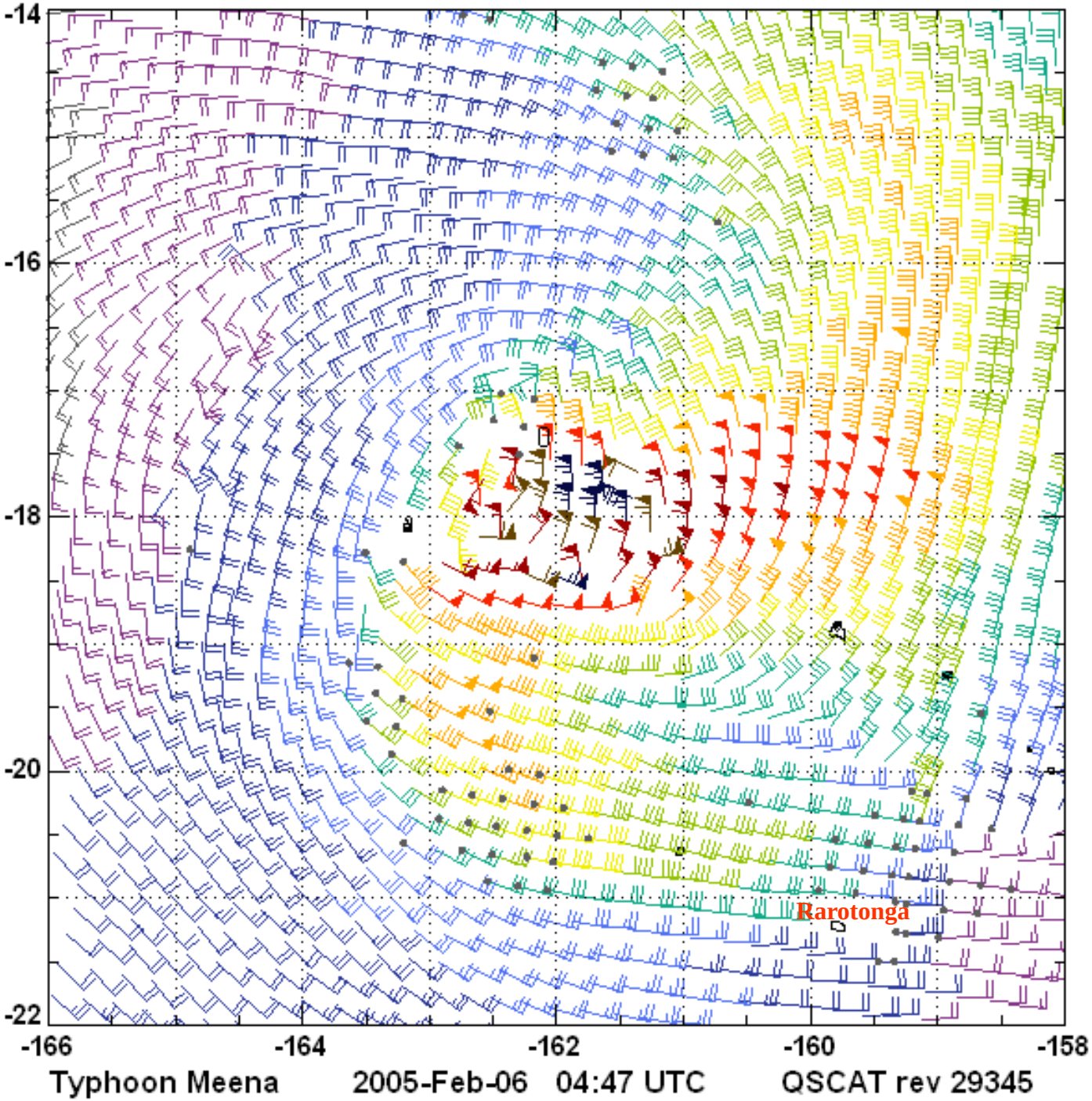

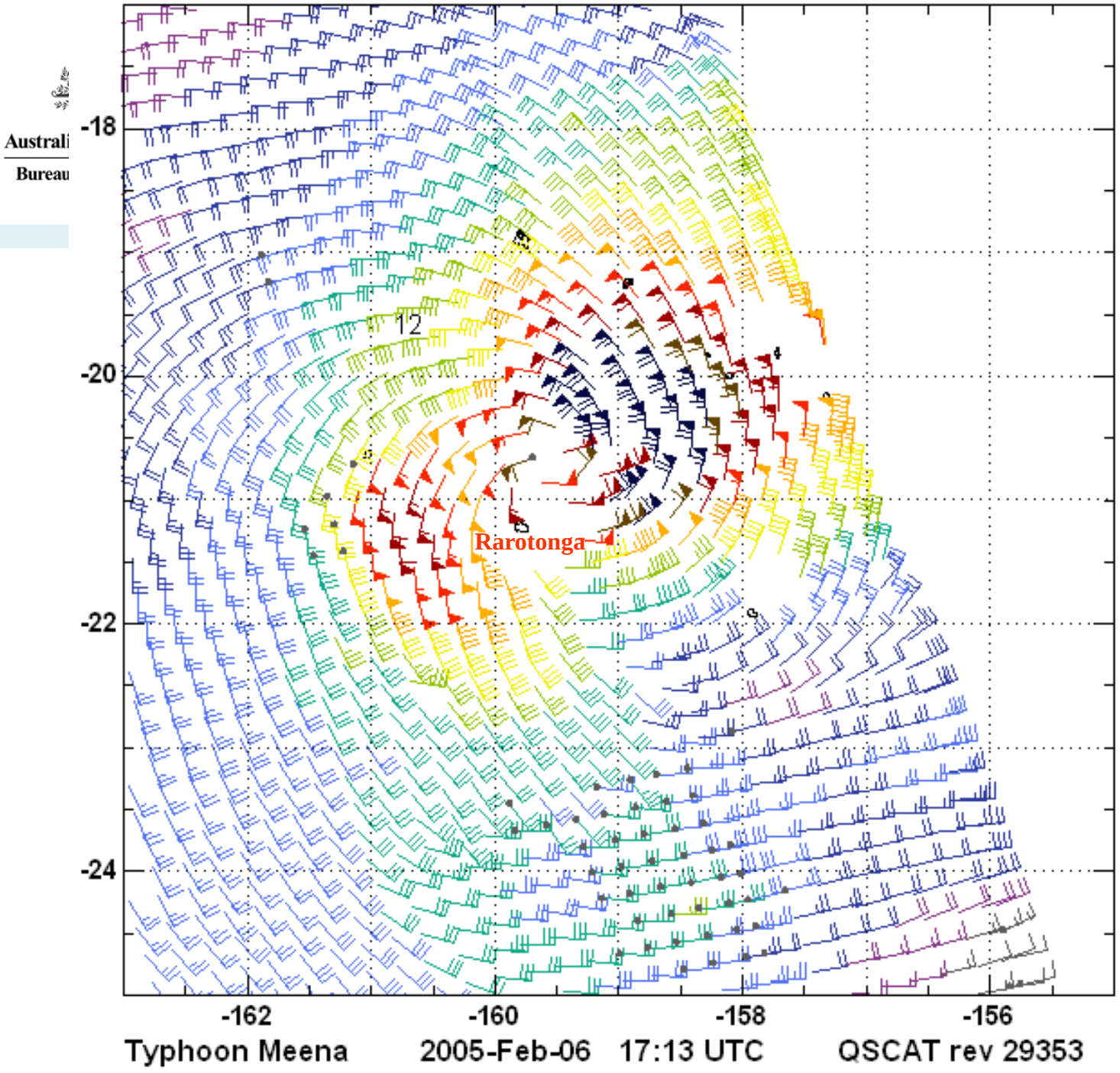
Australi
Bureau
-18
-20
-22
-24
12
Rarotonga
-162
-160
-158
-156
Typhoon Meena
2005-Feb-06
17:13 UTC
QSCAT rev 29353

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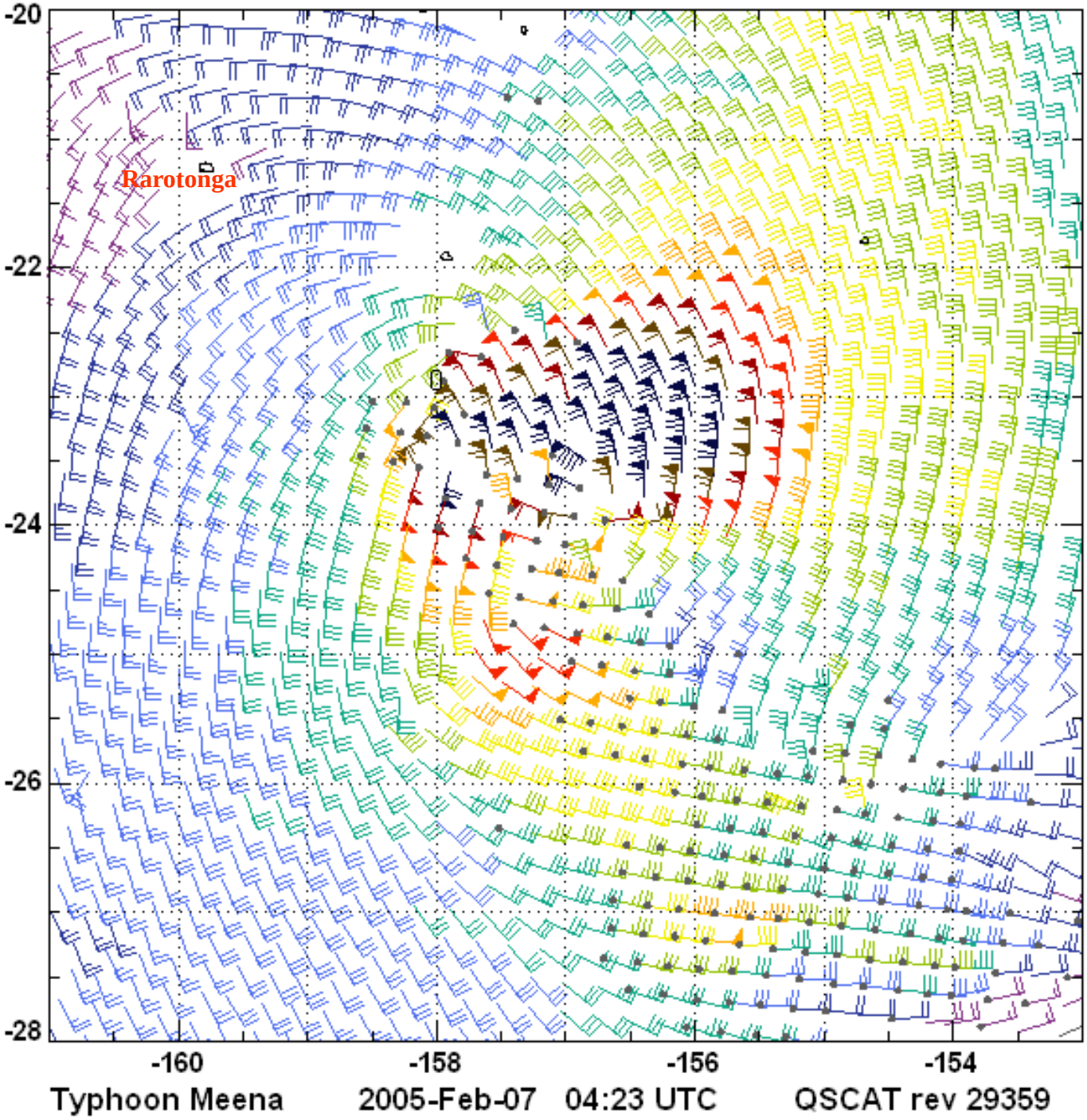

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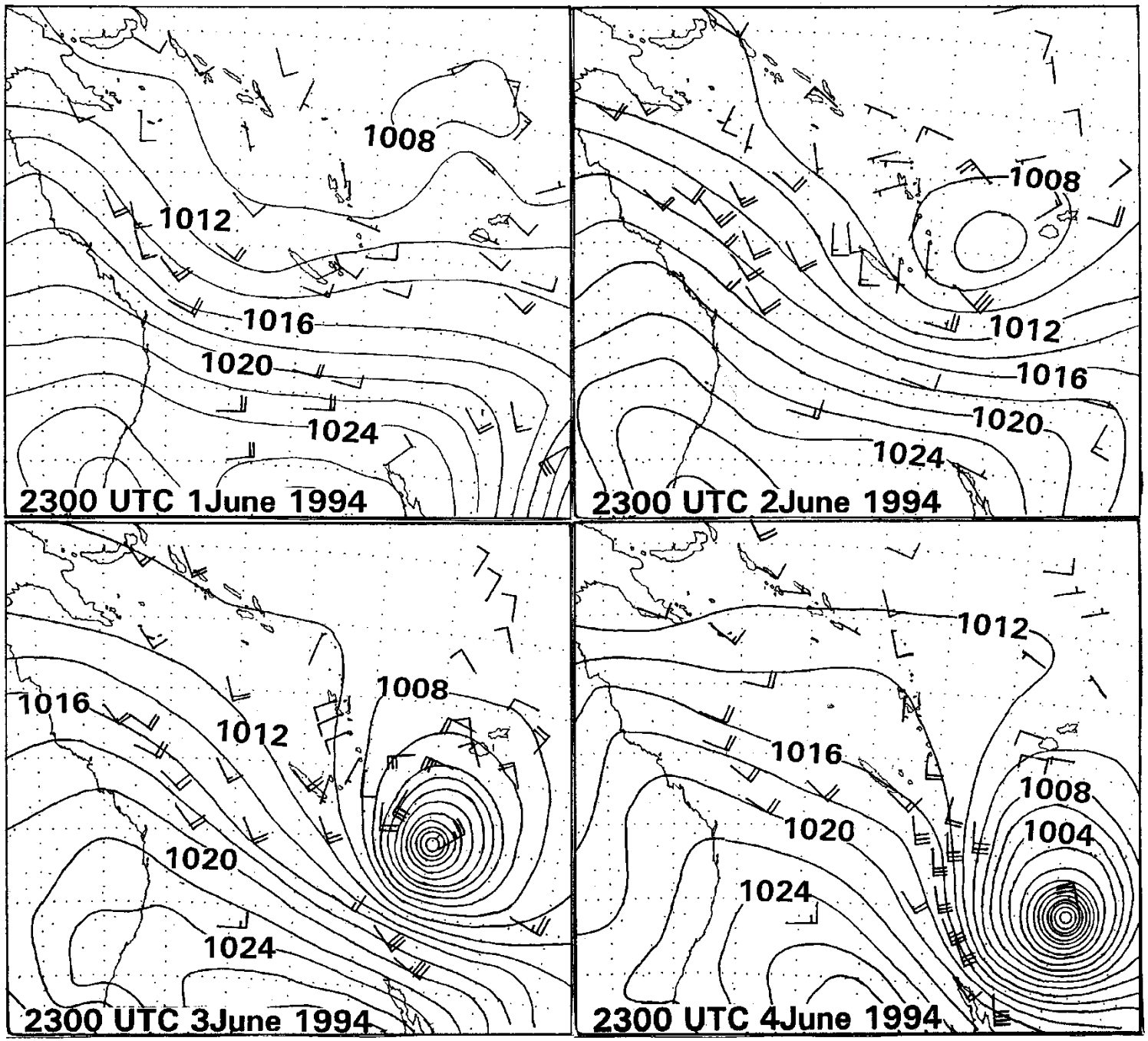
Rescue in the Pacific

21 rescued
7 yachts and 3 people lost



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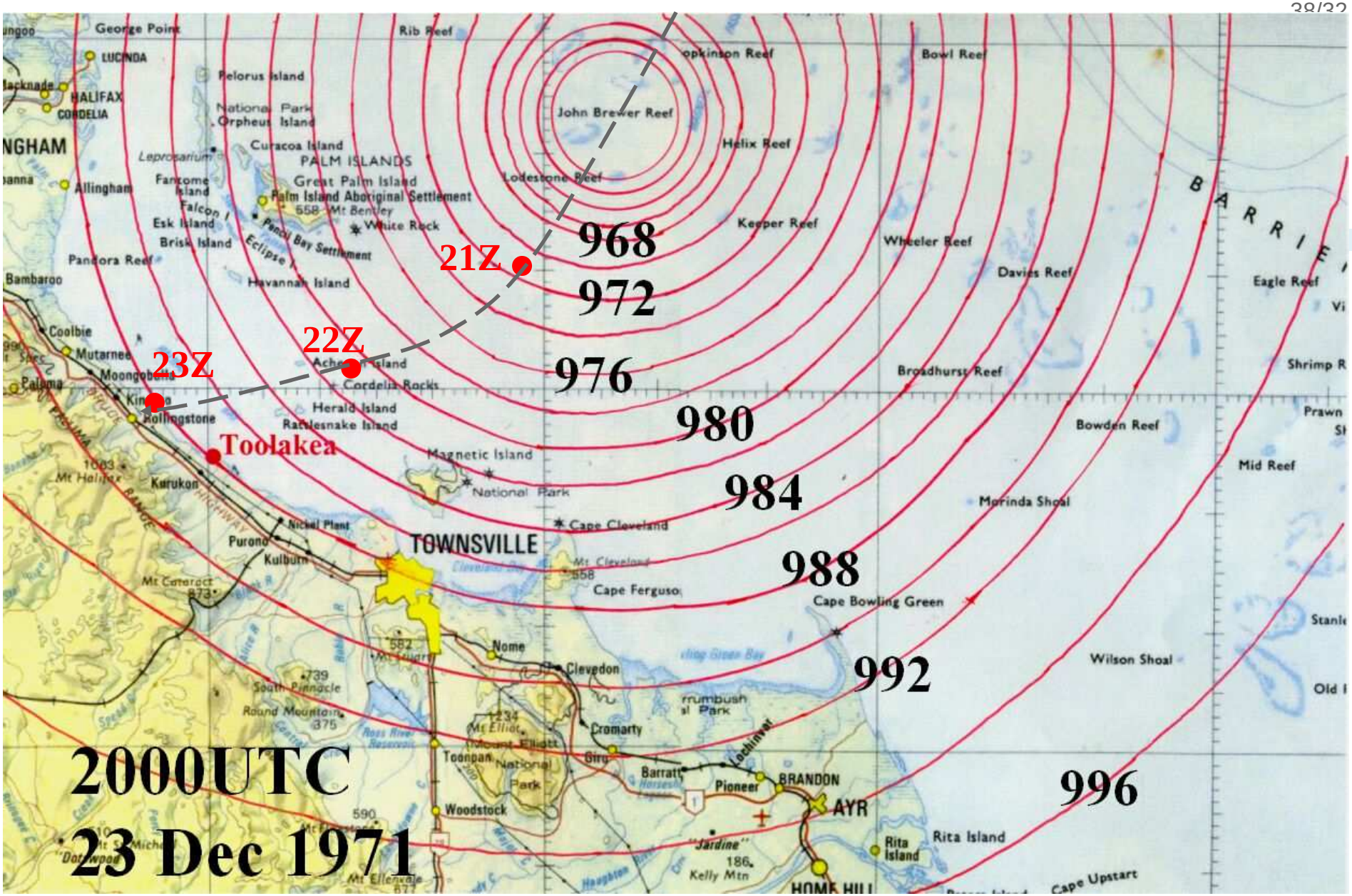
Large swells damaged Majuro
one metre seawater inundation

The sea flooded 120 dwellings, damaged infrastructures and closed the airport for 48 hours.


968
972
976
980
984
988
992
996
21Z
22Z
23Z
Toolakea
2000UTC
23 Dec 1971
TOWNSVILLE
George Point
LUCINDA
HALIFAX
CORDELIA
Pelorus Island
Orpheus Island
Curacoa Island
PALM ISLANDS
Great Palm Island
Palm Island Aboriginal Settlement
Fantome Island
Falcon I.
Esk Island
Brisk Island
Pandora Reef
Bambaroo
Allingham
White Rock
Pearl Bay Settlement
Eclipse I.
Havannah Island
Coolbie
Mutarnee
Moongobarra
Paluma
Kirknie
Rollingstone
Herald Island
Rattlesnake Island
Cordelia Rocks
Magnetic Island
National Park
Kurukon
Nickel Plant
Purono
Kulburn
Mt Cleveland
Cape Cleveland
Cape Ferguson
Nome
Clevedon
Cromarty
Giru
Barratt
Pioneer
BRANDON
AYR
Rita Island
Toonpan
Woodstock
Mt Elliott
Mt Cuthbert
Mt Cataract
South Pinnacle
Round Mountain
Kelly Mtn
HOME HILL
Cape Upstart
John Brewer Reef
Lodestone Reef
Helix Reef
Keeper Reef
Wheeler Reef
Davies Reef
Bowl Reef
Eagle Reef
Broadhurst Reef
Bowden Reef
Morinda Shoal
Cape Bowling Green
Wilson Shoal
Mid Reef
Shrimp R
Prawn
Rib Reef
BARRIER


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
CORAL
SEA
Rattlesnake Island
Herald Island
HALIFAX
BAY
MAGNETIC ISLAND
Horseshoe Bay
Arcadia
Nelly Bay
West Point
CLEVELAND
BAY
Toolakea
Julloonda
Bluewater
Yabulu
Black River
Deeragun
Pallarenda
The Town Common
Garbutt
TOWNSVILLE
Oonoonba
Shelly Beach

Australian Go
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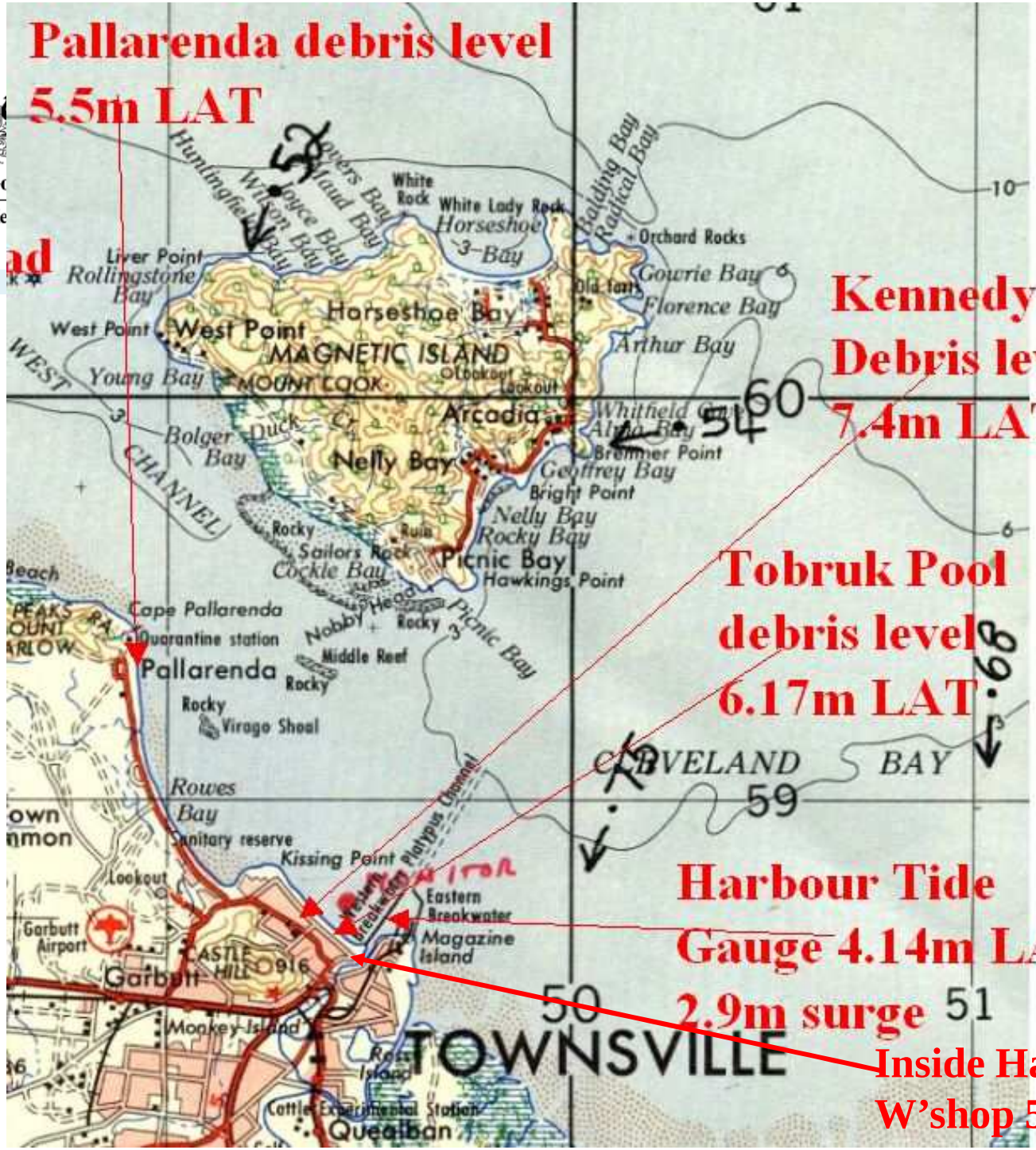


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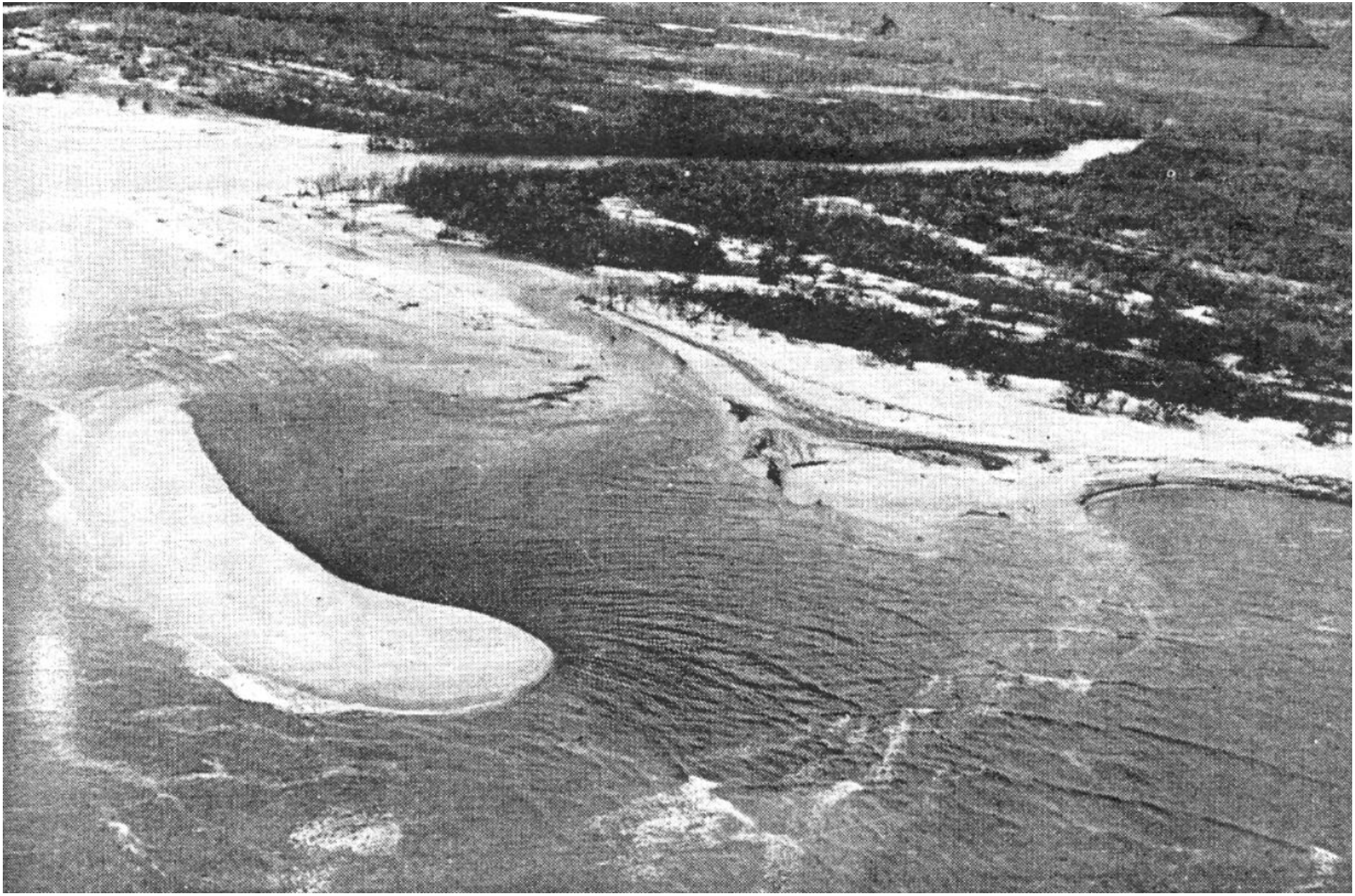
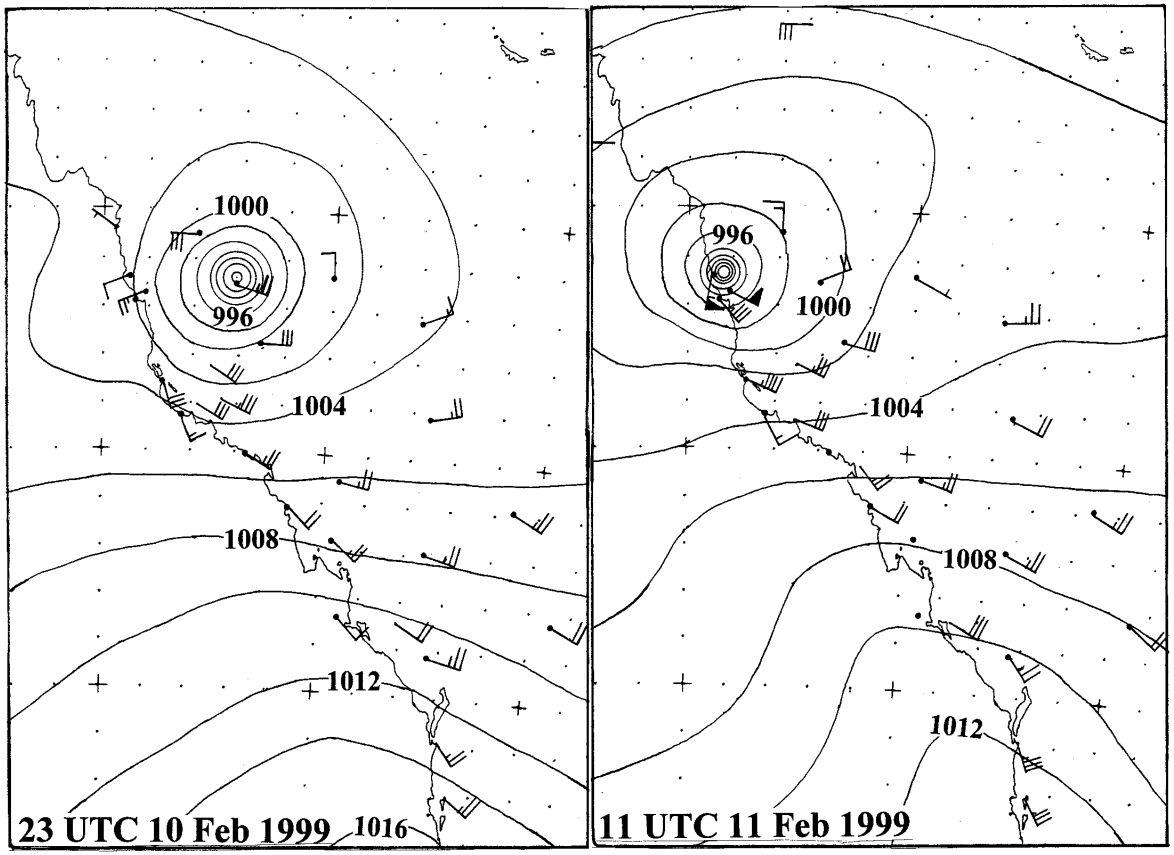


Toolakea 3.66m surge measured in Mangrove Creeks draining into Bluewater Creek.

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



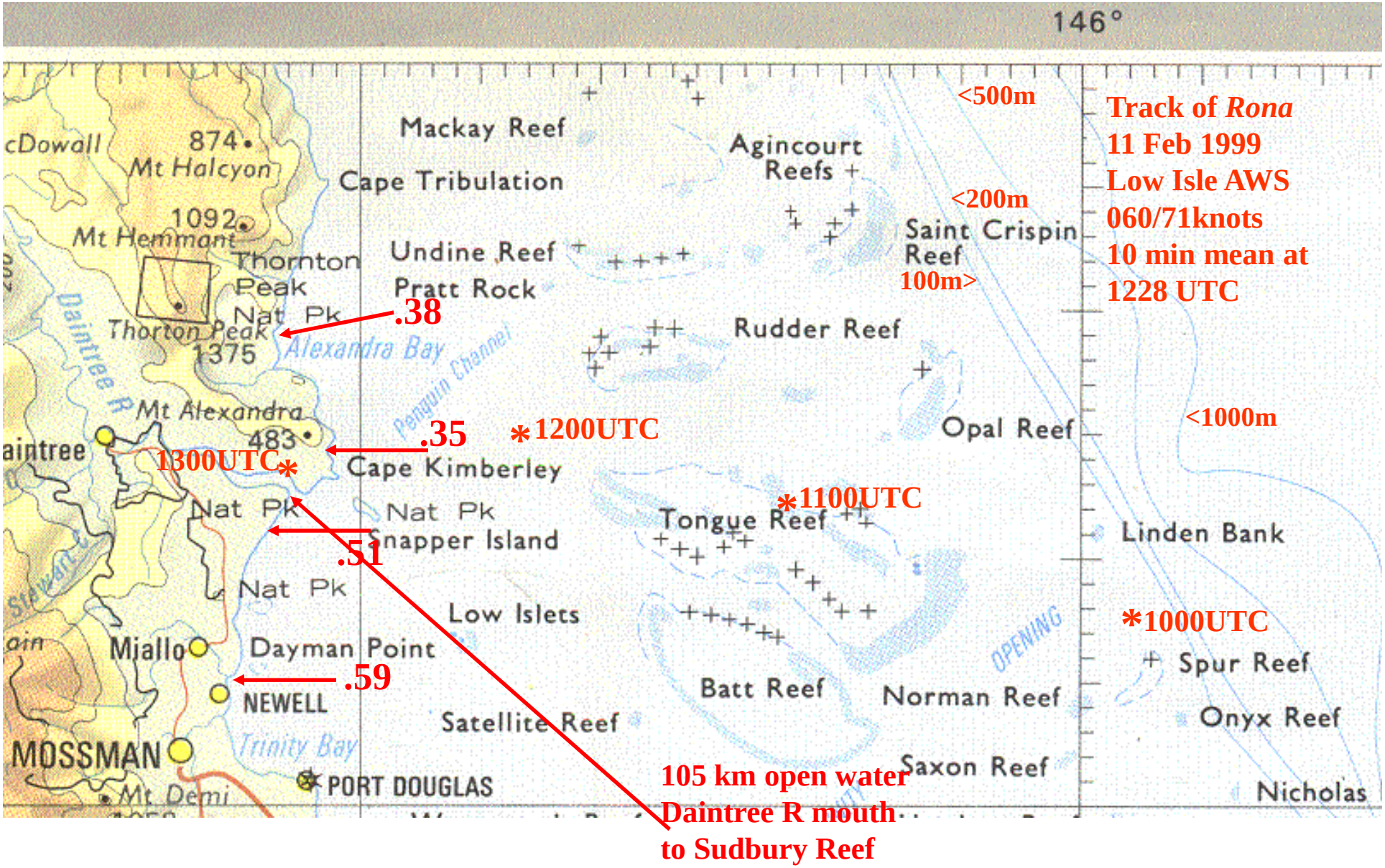
Tropical cyclone *Rona*

Low Isle: H_{sig} reached 3.5m and H_{peak} reached 6.3m

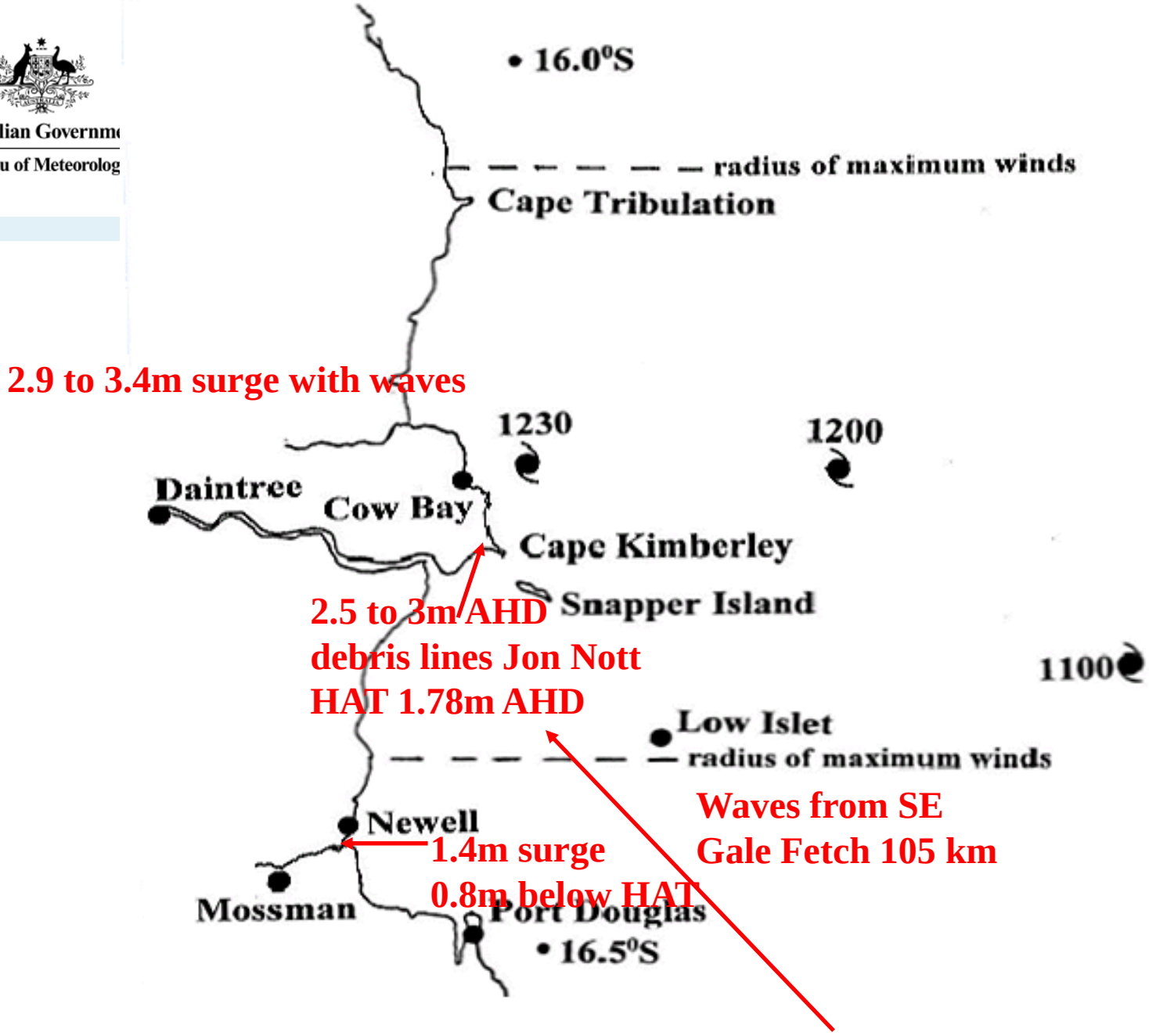
Cairns: H_{sig} reached 2.49m at 1100UTC 11 Feb 1999 and H_{peak} reached 4.65m at 1200UTC 11 Feb 1999. The peak energy period was around 6 sec during the large waves.

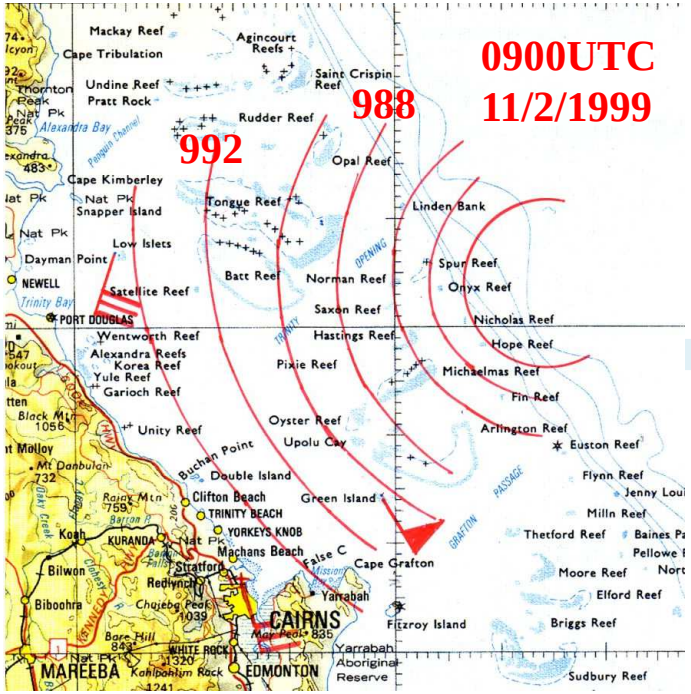
Dunk Island: H_{sig} reached 3.06m at 0930UTC 11 Feb 1999 and H_{peak} reached 5.69m at 0800UTC 11 Feb 1999. The peak energy period was around 7 sec during the large waves.

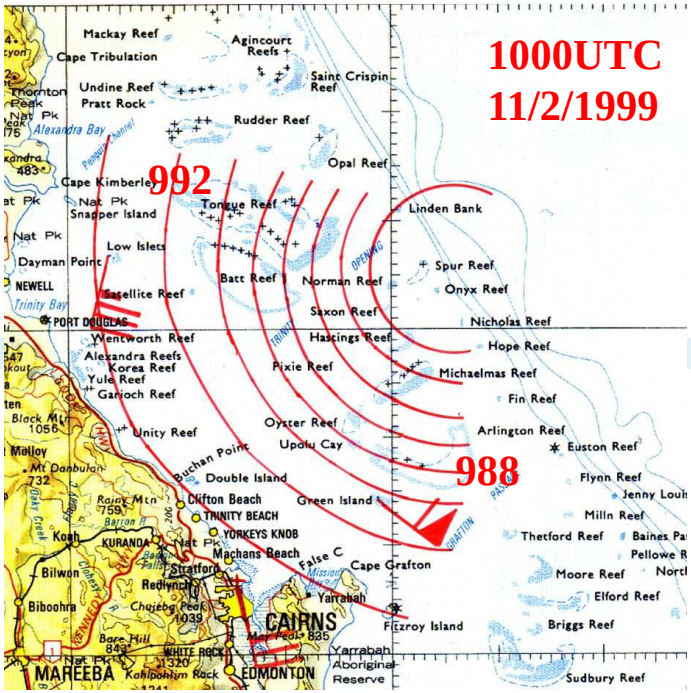
At 1300UTC 11 Feb 1999 Mossman River tide gauge recorded a storm surge of 1.38m.

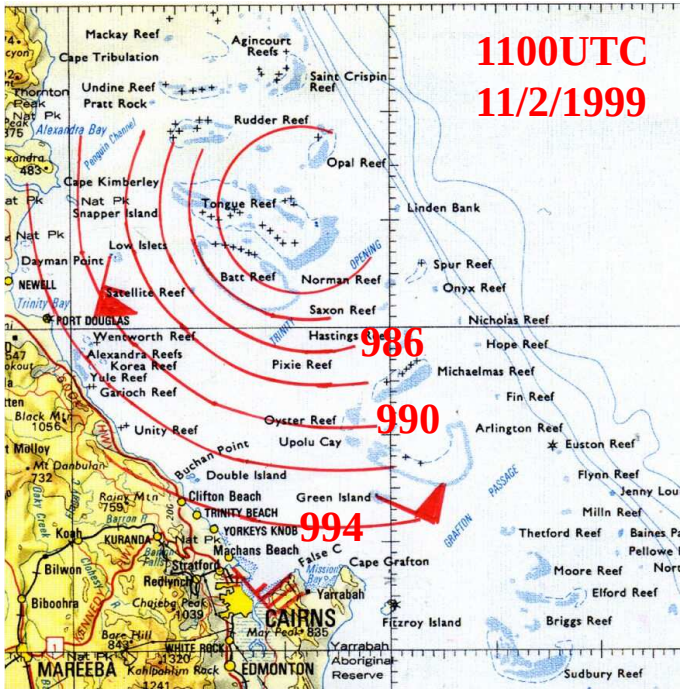

146°
Track of *Rona*
11 Feb 1999
Low Isle AWS
060/71knots
10 min mean at
1228 UTC
<500m
<200m
100m>
<1000m
Mackay Reef
Agincourt Reefs
Cape Tribulation
Saint Crispin Reef
Undine Reef
Pratt Rock
Rudder Reef
Thornton Peak
Nat Pk
Thorton Peak
1375
Mt Hemmant
1092
Mt Halcyon
874
cDowall
Daintree R
Alexandra Bay
Penguin Channel
Mt Alexandra
483
.38
.35
*1200UTC
1300UTC*
Cape Kimberley
Opal Reef
Nat Pk
Nat Pk
Snapper Island
.51
*1100UTC
Tongue Reef
Linden Bank
Nat Pk
Low Islets
Dayman Point
Mjallo
.59
NEWELL
*1000UTC
Spur Reef
Batt Reef
Norman Reef
Onyx Reef
Satellite Reef
Trinity Bay
MOSSMAN
PORT DOUGLAS
Saxon Reef
Mt Demi
Nicholas
105 km open water
Daintree R mouth
to Sudbury Reef

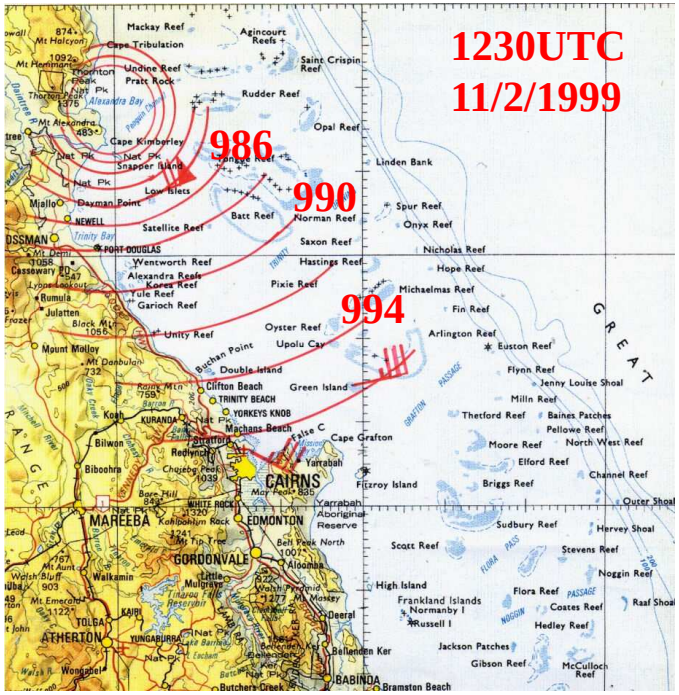
Australian Governme
Bureau of Meteorolog











Low Isle
H_{sig} reached 3.5m
H_{peak} reached 6.3m