1. Tropical Cyclones: Fundamentals and basic processes

- Definitions and naming
- Life cycle
- Structure
- Processes
- Broadscale influences

Should you use these resources please acknowledge the Bureau of Meteorology.

Image courtesy of BoM/JMA
What is a TROPICAL CYCLONE?

A low pressure system that forms over warm waters having organised deep convection and gales near the centre extending more than half way around the system centre and persisting for at least six hours.

Modis Image of Pam courtesy of NASA

+ Australia: extending more than half way around the system centre and persisting for at least six hours.
Same thing … different names

Tropical cyclone is a generic term for Tropical Revolving Storm, Hurricane, Typhoon, Severe Tropical Cyclone (sustained winds >= 64 knots).

(Non-severe) tropical cyclone, tropical storm (winds >= 34 knots, < 64 knots)
Cyclone Names: by region
Australia; SPAC (FMS); PNG; BMKG; JMA (NWPAC)

**Australian Region Names (Pronunciation in brackets)**

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**South Pacific Ocean**

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**Jakarta TCWC Area of Responsibility**

**List A**
- Anggrek
- Bakung
- Cempaka
- Dahlia
- Flambayan
- Kenanga
- Lili
- Mawar
- Seroja
- Teratai

**List B**
- Anggur
- Belimbing
- Duku
- Jambu
- Lengkeng
- Mangga
- Nangka
- Pisang
- Rambuta
- Sawo

**Port Moresby’s Area of Responsibility**

**List A**
- Alu
- Buri
- Dodo
- Emau
- Nat
- Olo
- Pita
- Rae
- Sheila
- Tam
- Umi
- Vaianu

**List B (Standby)**
- Nou
- Obaha
- Paia
- Ranu
- Sabi
- Tau
- Ume
- Vali
- Wau
- Maila
- Auram

http://severe.worldweather.org/tc/au/tcname.html
http://severe.worldweather.org/tc/sp/tcname.html
The life cycle of a cyclone: genesis, maturing, weakening, decay
Every cyclone is unique!

brief Vs long, weak Vs strong, small Vs big, impacts
The life cycle of a cyclone

Examples CIMSS

March 2015 [http://tropic.ssec.wisc.edu/archive/data/stettner/11MAR15/11MAR15.html](http://tropic.ssec.wisc.edu/archive/data/stettner/11MAR15/11MAR15.html)

What do you notice?

Hires Himawari shows variations over shorter time scales

ST Noul (May15) [http://cimss.ssec.wisc.edu/goes/blog/wp-content/uploads/2015/05/150509-10_himawari8_visible_band3_STY_Noul_anim.gif](http://cimss.ssec.wisc.edu/goes/blog/wp-content/uploads/2015/05/150509-10_himawari8_visible_band3_STY_Noul_anim.gif)

Anatomy of a tropical cyclone
inner and outer circulations
Technical parameters

Intensity: max wind, central pressure
Size: Gale radius, ROCI (POCI)

Radius of maximum winds (RMW)

Radius of Outer Closed Isobar (ROCI)

R34 asymmetry

R34

R48

R64

Image courtesy of BoM/JMA
## Australian Intensity Scale

<table>
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<th>Cat. No.</th>
<th>Max wind (kn)</th>
<th>Wind Impact</th>
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<tr>
<td>1</td>
<td>34-47</td>
<td>“Damaging” winds</td>
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<tr>
<td>2</td>
<td>48-63</td>
<td>“Destructive” winds</td>
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<td>3</td>
<td>64-85</td>
<td>SEVERE</td>
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<tr>
<td>4</td>
<td>86-106</td>
<td>“Very destructive”</td>
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<td>5</td>
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Importance of Size

Size: warning area, duration, waves, surge, spin down rate

R34: 'midget' <60nm; ave 80-100nm; large >120nm
Eye diameter: ~5-20nm
RMW: 5-30nm;
Simplified: Cyclones as heat engines
Cyclones as heat engines

IN, UP and OUT

Tropopause
TC Meteorology Key Terms

Convergence & Vorticity (IN), Convection (UP), Outflow (OUT)

IN, UP and OUT
The 3 Dimensional Wind Structure
Which one has the highest winds?

- Tangential wind
- Vertical wind
- Radial wind
Idealised picture: intensification of winds at low levels

Basic principle: conservation of absolute angular momentum:

\[ M = rv + \frac{1}{2}fr^2 \]

\[ v = \frac{M}{r} - \frac{1}{2}fr \]

If \( r \) decreases, \( v \) increases!

Spin up requires radial convergence

Modified from R. Smith, Aspects of TC dynamics: Part 1 the Boundary Layer
More realistic picture –
effect of friction

\[ \frac{du}{dt} = f v + \frac{v^2}{r} - \frac{1}{\rho} \frac{\partial P}{\partial r} + F_r \]

Acceleration of the radial wind

Acceleration due to radial Pressure gradient

\( f v \) = Coriolis force on rotating wind

\( \frac{v^2}{r} \) = centrifugal acceleration

\( F_r \) = small scale mixing

FD = Frictionally driven inflow

The Planetary Boundary Layer is a momentum sink, Absolute Angular Momentum is not conserved

Modified from R. Smith, Aspects of TC dynamics: Part 1 the Boundary Layer
Circulations at different levels
(streamlines and isotachs)

Low levels (Gradient-850 hPa)
Boundary Layer
- large scale inflow
- convergence not uniform
- max winds near core

Mid levels (700-400 hPa)
- the ‘steering’ level

Upper levels (100-300 hPa)
- cyclonic core for strong TC
- peripheral outflow as anticyclonic (peripheral ridge)
upward spiralling air in the core spreads out with height (it diverges) & slows.

Cyclonic movement decelerates, so 0 tangential velocity ~ 200km from the centre of the TC.

Anticyclonic upper air movement builds a peripheral ridge (Ri)

Away from the core winds are the prevailing (environmental) upper winds.

Vorticity = rotation of air around a vertical axis.
The inner & outer regions of a TC

**Inner region (0-100 km) – Convection dominates**

- Large absolute vorticity, small radius of rotation
- Coriolis effect small – cyclostrophic balance
- Inertially very stable (will resist changes in radial displacement of winds by the environment)
- Very symmetric (does not interact much with surroundings)
- Winds adjust to changes in the mass field (heating/cooling, convergence/divergence will lead to changes in the wind).

**Outer region (100-600 km) environmental infl.**

- Smaller absolute vorticity, larger radius
- Coriolis effect significant – gradient balance.
- Not so symmetric – influenced by environmental flow (eg monsoon, STR)
- Mass adjusts to the wind field
Summary

- Defined TCs and naming convention

- Simplified view of TC engine: IN-UP-OUT

- Key terms convergence, convection, vorticity, outflow

- The strongest winds are tangential winds, and are located in the eyewall and within the boundary layer

- Complex dynamics and processes within TCs