## Chapter Eleven

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## 11. Ready Reckoner

### 11.1 Introduction

This chapter provides a ready reference for various parameters and information related to tropical cyclones.

### 11.2 Unit conversion

Multiply the line unit by the indicated number to get the column unit; for example, on the first line inches multiplied by 12 gives 1 ft in the second column. Only conversions to higher values are shown. Take care to convert to the degree of accuracy of the original observation only; for example a ship estimate of 20 kt based on sea state should convert to $10 \mathrm{~ms}^{-1}$, a literal transformation to $10.256 \mathrm{~ms}^{-1}$ is incorrect.

SI length units are identified by an asterisk

| Length |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | mm* | in | ft | m* | km* | mi | nm | ${ }^{\circ} \mathrm{lat}$ |
| mm* | 1 | 25.4 | 304.8 | 1000 | $10^{6}$ | $1.61 \times 10^{6}$ | $1.85 \times 10^{6}$ | $1.11137 \times 10^{8}$ |
| in |  | 1 | 12 | 39.37 | 39370 | 63360 | 72913 | $4.38 \times 10^{6}$ |
| ft |  |  | 1 | 3.28 | 3281 | 5280 | 6080 | 364320 |
| m* |  |  |  | 1 | 1000 | 1609 | 1853 | $1.11137 \times 10^{5}$ |
| km* |  |  |  |  | 1 | 1.609 | 1.853 | 111.137 |
| mi |  |  |  |  |  | 1 | 1.15 | 69 |
| nm |  |  |  |  |  |  | 1 | 60 |
| Time |  |  |  |  |  |  |  |  |
|  |  | sec |  | min |  | hour |  | day |


| $\sec$ | 1 | 60 | $3.6 \times 10^{3}$ | $8.64 \times 10^{4}$ |
| :---: | :---: | :---: | :---: | :---: |
| $\mathbf{m i n}$ |  | 1 | 60 | $1.44 \times 10^{3}$ |
| hour |  |  | 1 | 24 |


| Speed |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | $\mathrm{km} \mathrm{h}^{-1}$ | mph | kt | $\mathrm{ms}^{-1}$ |
| km $\mathbf{h}^{-1}$ | 1 | 1.61 | 1.85 | 3.6 |
| mph |  | 1 | 1.15 | 2.24 |
| kt |  |  | 1 | 1.95 |

## Conversion from ${ }^{\circ} \mathrm{C}$ to ${ }^{\circ} \mathrm{F}$ <br> $$
{ }^{\circ} \mathrm{F}=\left(1.8 \times{ }^{\circ} \mathrm{C}\right)+32
$$ <br> Conversion from ${ }^{\circ} \mathrm{K}$ to ${ }^{\circ} \mathrm{C}$ <br> $$
{ }^{\circ} \mathrm{C}={ }^{\circ} \mathrm{K}-273.15
$$

### 11.3 Beaufort scale

Several versions of the Beaufort wind scale exist. They mostly vary by small degrees. The following is adapted from Pielke (1991) and Dunn and Miller (1964) following work by Black and Adams (personal communication), and using information provided by R. Simpson (personal communication).

| Beaufort Force Estimated 10-min <br> averaged wind <br> (kt) at 19m*. Description |
| :--- |
| 0 Calm Sea glassy. Appearance of being covered by oil. <br> 1 $1-3$ Slight ripple. <br> 2 $4-6$ Slight ripple. Isolated brief whitecaps. Unable to <br> determine direction. <br> 3 $7-10$ Gentle Breeze: Surface like wrinkled paper. Small. well <br> defined whitecaps of uniform size but few in number. <br> White crests disappear quickly. First able to tell <br> direction but with difficulty. |
| 4 $11-16$ |


|  |  | breaking crests increase slightly and are a little larger. First able to tell direction with confidence. Wrinkle texture of surface is very evident. |
| :---: | :---: | :---: |
| 5 | 17-21 | Fresh Breeze: Size and number of whitecaps and foam patches increase significantly. Whitecaps on most wave crest. Very short streaks may appear in foam patches. |
| 6 | 22-27 | Strong Breeze: Well defined short streaks in foam patches. Small whitecaps on most wave crests. Occasional medium-size foam patch or breaker. Isolated green patches of short duration. Foam patches, short streaks, and whitecaps (white water) cover 5-7\% of sea surface. |
| 7 | 28-33 | Moderate Gale: Medium-size breaking crest. Dense foam patches and accompanying short streaks are numerous. Average length of streaks equal to diameter of average foam patch. Small green patches occasionally visible. |
| 8 | 34-40 | Fresh Gale - Tropical Cyclone: Streaks more numerous and occasionally longer. Some streaks may appear unassociated with breaking waves or foam patches. Area covered by whitecaps stabilises at 7$10 \%$. Occasional large foam patch. Small green patches continually visible with occasional moderatesize green patch. |
| 9 | 41-47 | Strong Gale: Streaks readily apparent between foam patches. Streak length varies from patch size to occasional regions of long, nearly continual streaking. Streaks, patches, and breaking waves cover 15-20\% of sea. $50 \%$ of foam patches are green. |
| 10 | 48-55 | Storm Force: Wind streaks become the most obvious surface feature and are continuously or nearly so. Well-defined, thinly breaking waves form on long crestlines, often preceded by short breaking wavelets giving a step-like appearance. Occasional large foam patches are quickly fragmented and elongated into streaks. Sea covered 2-25\% by white water. |
| 11 | 56-63 | Streaks are well-defined, parallel, thin, close together, and continuous with very short capillary wavelets cutting across and perpendicular to streaks, giving sea surface a 'shattered glass' effect in certain areas. Some large breaking crests may take on 'rolling' or |


|  |  | 'tumbling' appearance. Sea covered $30-40 \%$ by white water. |
| :---: | :---: | :---: |
| 12 | 64-69 | Hurricane Force: Sea may occasionally be obscured by spray and take on a murky appearance. Large, curved, breaking crests have undulating effect on steaks, giving churning appearance. Streaks appear to thicken and become milky or pale green. |
| 13 | 70-75 | Surface features generally become murky. Streaks and foam patches begin to sole their sharp definition and appear to smudge, thicken, or merge together. Frequent, extremely large, almost semicircular crests outlined by thinly breaking waves with occasional groups of large foam patches after entire crest breaks. |
| 14 | 76-80 | Quantity of spray increases. Streaks thicken and appear to have more depth. Previous crisp, shattered glass appearance now appears blurred. Most features appear to be a submerged rather than a surface phenomenon, owing to obscuration. Very short capillary wavelets which cut across streaks give surface a stressful appearance as though undergoing compression. Sea surface $50 \%$ white. |
| 15 | 81-85 | Sea appears flatter and entire surface takes on a whitish/greyish cast. Streaks organise somewhat into broader, diffuse bands. All features lose some definition and appear submerged. Surface 50-55\% white. |
| 16 | 86-90 | Many thin streaks are partially obscured and those which can be seen may appear as bands spaced farther apart. Occasional cloud below aircraft blots out or obscures surface. Sea appears almost flat. Whitish cast covers $60-65 \%$ of surface. |
| 17 | 91-95 | Breaking waves and foam patches appear as diffuse, white, puffy areas. Streaks become fuzzy bands. Surface 70-80\% white. |
| 18 | 96-100 | Cloud, spray, and foam patches merge into large, white, indefinable areas historically referred to as 'white sheets'. Surface features have only rough boundary definition. |
| 19 | 101-105 | Isolated large, white puffs. Only strongest features of previously seen thick streaks remain to be observed |


|  |  | and result gives impression of only a very few widely <br> scattered and non-parallel streaks or wide bands. <br> Whitish and greenish cast covers 100\% of surface. |
| :--- | :--- | :--- |
| 20 | $106-110$ | Foam patches, bands, and whitecaps merge into large <br> indefinable areas or white sheets. Variations in <br> brightness are less distinct but still result in churning <br> appearance. |
| 21 | $>110$ | Sea $100 \%$ white and green. Only slight variation in <br> whiteness is apparent. |

* The standard height for ship observations is 19 m , rather than the 10 m used for land.


### 11.4 Useful tropical cyclone parameters

### 11.4.1 Tropical cyclone severity scales

The Saffir Simpson Hurricane Scale (Simpson and Riehl, 1981) was developed to provide a sliding scale of damage potential for hurricanes, including that arising from storm surge. A similar scale, though adapted for local conditions is used in Australia. Global adoption of such scales is strongly recommended.

| Hurricane or Severe Tropical Cyclone | Maximum Sustained Winds |  |
| :---: | :---: | :---: |
|  | Saffir-Simpson | Australian Scale |
|  | Level (1-min mean, kt) | ( 10 min mean, $\mathrm{km} \mathrm{h}^{-1}$ ) |
| 1 | 64-83 | 63-90 |
| 2 | 84-96 | 91-125 |
| 3 | 97-113 | 126-165 |
| 4 | 114-135 | 166-225 |
| 5 | >135 | >225 |

Some of the tables from the main text are also listed on the following pages for convenience.

### 11.4.2 Gust factors

Gust factors defined by the ratio of peak 2-s wind to the mean wind at 10 m elevation for various exposures and averaging times and in wind speeds of at least hurricane force.

Parentheses give an indication of the range in gust factors. From Atkinson (1974), Spillane and Dexter (1976) and Padya (1975).

|  | OCEAN | FLAT GRASSLAND | WOODS/CITY |
| :---: | :---: | :---: | :---: |
| 1-min Mean | 1.25 (1.17-1.29) | 1.35 (1.29-1.45) | 1.65 (1.61-1.77) |
| 10-min Mean | 1.41 (1.37-1.51) | 1.56 (1.51-1.70) | 2.14 (1.89-2.14) |
| 10-min Mean over Ocean | 1.41 | 1.31 | 1.11 |

### 11.4.3 Dvorak intensity relationship

Empirical relationship between the current intensity number (CI), the Maximum sustained 1min Wind Speed (MWS, kt), and the central pressure (hPa) in tropical cyclones. The central pressure values for the western North Pacific are from Shewchuk and Weir (1980).

|  |  | Central Pressure |  |
| :---: | :---: | :---: | :---: |
| Cl | MWS (kt) | (Atlantic) | (NW Pacific) |
| 0.0 | <25 |  |  |
| 0.5 | 25 |  |  |
| 1 | 25 |  |  |
| 1.5 | 25 |  |  |
| 2 | 30 | 1009 | 1000 |
| 2.5 | 35 | 1005 | 997 |
| 3 | 45 | 1000 | 991 |
| 3.5 | 55 | 994 | 984 |
| 4 | 65 | 987 | 976 |
| 4.5 | 77 | 979 | 966 |
| 5 | 90 | 970 | 954 |
| 5.5 | 102 | 960 | 941 |
| 6 | 115 | 948 | 927 |


|  |  |  |  |  |  |  | 127 | 935 | 914 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 7 | 140 | 921 | 898 |  |  |  |  |  |  |
| 7.5 | 155 | 906 | 879 |  |  |  |  |  |  |
| 8 | 170 | 890 | 858 |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |

### 11.5 Useful constants

### 9.6.1 Universal constants

| Avogadro's Number, | $\mathrm{N}_{\mathrm{A}}$ | $6.02247 \times 1 \mathrm{O}^{26} \mathrm{kmol}^{-1}$ |
| :--- | :--- | :--- |
| Base of Natural Logarithms, | e | 2.71828 |
| Boltzmann's Constant, | k | $1.381 \times 10^{-23} \mathrm{~J} \mathrm{~K}^{-1} \mathrm{molecule}^{-1}$ |
| Gravitational Constant |  | $6.673 \times 10^{-11} \mathrm{Nm}^{2} \mathrm{~kg}^{-1}$ |
| Pi | $\pi$ | 3.1415927 |
| Planck's Constant, | h | $6.6262 \times 10^{-34} \mathrm{~J} \mathrm{~s}^{-1}$ |
| Speed of Light, | C | $2.998 \times 10^{8} \mathrm{~ms}^{-1}$ |
| Speed of Sound in Air at $0^{\circ} \mathrm{C}$ |  | $340 \mathrm{~ms}^{-1}$ |
| Stefan-Boltzmann Constant, | $\sigma$ | $5.6696 \times 10^{-8} \mathrm{~W} \mathrm{~m}^{-2} \mathrm{~K}^{-4}$ |
| Universal Gas Constant, | R | $8.3143 \times 10^{3} \mathrm{~J} \mathrm{~K}^{-1} \mathrm{kmol}^{-1}$ |

### 9.6.2 The Earth

| Angular Velocity, | $\Omega$ | $7.292 \times 10^{-5} \mathrm{~s}^{-1}$ |
| :--- | :--- | :--- |
| Gravitational Acceleration <br> at the surface, | g | $9.81 \mathrm{~ms}^{-2}$ |
| Radius: |  |  |
| Mean, |  | 6370 km |
| Equatorial | $\mathrm{R}_{\mathrm{E}}$ | 6379 km |
| Polar |  | 6357 km |
| Volume |  | $1.083 \times 10^{21} \mathrm{~m}^{3}$ |
| Surface Area |  | $5.1 \times 10^{12} \mathrm{~m}^{2}$ |

Mass
Mean Density
Mean Distance to Moon
Mean Distance to Sun
Orbital Speed around Sun
Azimuthal Speed at Equator
Solar Irradiance

### 9.6.3 The Atmosphere

Density of dry air at $0^{\circ} \mathrm{C}$ and 1000 hPa
Gas Constant:
Universal
For Dry Air,
Mass of Atmosphere
Molecular Weight of Dry Air
Specific Heat of Dry Air:
at Constant Pressure,
at Constant Volume,
Standard Sea Level:
Pressure,
Temperature,
Density,
Speed of Sound,

### 9.6.4 Water

Density of Water
Density of Ice
Gas Constant for Vapour,
Molecular Weight of Water Vapor
Specific Heat:
Water Vapour:
Constant Pressure
$5.988 \times 10^{24} \mathrm{~kg}$
$5.529 \times 10^{3} \mathrm{~kg} \mathrm{~m}^{-3}$
$3.8 \times 10^{5} \mathrm{~km}$
$1.49 \times 10^{8} \mathrm{~km}$
$2.977 \times 10^{4} \mathrm{~ms}^{-1}$
$465 \mathrm{~ms}^{-1}$
$1.38 \times 10^{3} \mathrm{~W} \mathrm{~m}^{-2}$
$1.29 \mathrm{~kg} \mathrm{~m}^{-3}$
$8.31436 \times 10^{3} \mathrm{~J} \mathrm{~K}^{-1} \mathrm{kmol}^{-1}$
$\mathrm{R}_{\mathrm{d}} \quad 287 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$
$5.3 \times 10^{18} \mathrm{~kg}$
$28.966 \mathrm{~kg} \mathrm{kmole}^{-1}$
$c_{p} \quad 1004 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$
$c_{v} \quad 717 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$
$\mathrm{p}_{\mathrm{s}} \quad 1013.28 \mathrm{hPa}$
$\mathrm{T}_{\mathrm{s}} \quad 288.16 \mathrm{~K}$
$\rho_{\mathrm{s}} \quad 2.225 \mathrm{~kg} \mathrm{~m}^{-3}$
$\begin{array}{ll}c_{5} & 331.3 \mathrm{~ms}^{-1}\end{array}$
$\left(0^{\circ} \mathrm{C}\right) \quad 1.0 \times 10^{3} \mathrm{~kg} \mathrm{~m}^{-3}$
$\left(0^{\circ} \mathrm{C}\right) \quad 0.917 \times 10^{3} \mathrm{~kg} \mathrm{~m}^{-3}$
$R_{v}$
$461.5 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$
$18.016 \mathrm{~kg} \mathrm{kmol}^{-1}$
$1810 \mathrm{JK}^{-1} \mathrm{~kg}^{-1}$

| Constant Volume | $1350 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$ |
| :--- | :--- |
| Liquid Water at $0^{\circ} \mathrm{C}$ | $4218 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$ |
| Ice at $0^{\circ} \mathrm{C}$ | $2106 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~kg}^{-1}$ |
| Latent Heat: | $2.5 \times 10^{6} \mathrm{~J} \mathrm{~kg}^{-1}$ |
| Vaporisation at $0^{\circ} \mathrm{C}$ | $2.25 \times 10^{6} \mathrm{~J} \mathrm{~kg}^{-1}$ |
| Vaporisation at $100^{\circ} \mathrm{C}$ | $3.34 \times 10^{5} \mathrm{~J} \mathrm{~kg}^{-1}$ |
| Fusion at $0^{\circ} \mathrm{C}$ | $2.83 \times 10^{6} \mathrm{~J} \mathrm{~kg}^{-1}$ |
| Sublimation at $0^{\circ}$ |  |

### 11.6 Derived parameters

### 11.6.1 Definition of terms

b empirical constant
$\mathrm{Cg}_{\mathrm{g}} \quad$ gravity wave phase speed
$c_{p} \quad$ specific heat of dry air at constant pressure
$c_{1}, c_{2} \quad$ empirical constants
e base of natural logarithm
$f \quad$ Coriolis parameter
h, H atmospheric scale height
I inertial frequency
k unit vector perpendicular to the earth surface
L latent heat of condensation
$\mathrm{L}_{r} \quad$ Rossby radius of deformation
In natural logarithm
$\mathrm{M}_{\mathrm{a}} \quad$ absolute angular momentum
$\mathrm{N} \quad$ Brunt Vaisala frequency, total number in population sample
$p \quad$ air pressure
$\mathrm{p}_{\mathrm{c}} \quad$ central (minimum) pressure of a tropical cyclone
$\mathrm{p}_{\mathrm{n}} \quad$ representative environmental pressure for a tropical cyclone
q specific humidity
$\mathrm{R} \quad$ universal gas constant

| $\mathrm{R}_{\mathrm{d}}$ | gas constant for dry air |
| :---: | :---: |
| R。 | Rossby number |
| r | radius |
| $\mathrm{r}_{\mathrm{m}}$ | radius of maximum winds |
| T | temperature |
| t | time |
| u | wind component, either zonal or radial |
| V | velocity |
| v | wind component, either meridional or azimuthal |
| $\mathrm{V}_{\mathrm{g}}$ | geostrophic wind |
| $v_{m}$ | maximum wind speed |
| x | empirical parameter |
| z | height above the earth surface |
| $\partial$ | gradient operator |
| $\partial$ | partial derivative |
| ! | factorial |
| $\zeta$ | relative vorticity |
| $\theta$ | potential temperature |
| $\theta_{\text {e }}$ | equivalent potential temperature |
| $\lambda$ | latitude, azimuthal angle |
| $\rho$ | air density |
| $\Sigma$ | summation convention |
| $\sigma$ | standard deviation |
| $\Omega$ | earth angular velocity |

## Angular Momentum:

$$
M_{a}=r v+\frac{f_{o} r^{2}}{2}
$$

where $f_{0}$ is evaluated at the cyclone centre (Holland, 1983)
Brunt Vaisala Frequency (Static Stability):

$$
N^{2}=g \frac{\partial \ln \theta}{\partial z}
$$

## Coriolis Parameter:

$$
\begin{aligned}
f & =2 \Omega \sin (\lambda) \\
& =14.584 \sin (\lambda) s^{-1}
\end{aligned}
$$

Divergence:

$$
\begin{aligned}
\text { General: } D & =\nabla . \mathbf{v} \\
\text { Cartesian: } D & =\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} \\
\text { Cylindrical: } D & =\frac{1}{r}\left(\frac{\partial r u}{\partial r}+\frac{\partial v}{\partial \lambda}\right)
\end{aligned}
$$

## Equation of State:

$$
\rho=p R T
$$

Equivalent Potential Temperature:

$$
\begin{aligned}
& \theta_{E} \approx T_{E}\left(\frac{1000}{p}\right)^{R_{d} / c_{p}} \\
& T_{E}=T e^{L_{q} / c_{p} T}
\end{aligned}
$$

Inertial Frequency (Inertial Stability):

$$
I^{2}=\left(f_{0}+\zeta\right)\left(f_{0}+\frac{2 v}{r}\right)
$$

Mean:

$$
\bar{x}=\frac{\sum x}{N}
$$

Poisson Distribution: The discrete probability distribution

$$
p(x)=\frac{\lambda^{x} e^{-\lambda}}{x!}
$$

which has the properties of mean $=\lambda$ and standard deviation, $\sigma=\lambda^{1 / 2}$

## Potential Temperature:

$$
\theta=T\left(\frac{p_{o}}{p}\right)^{R} / c_{p}
$$

Rossby Number:

$$
R_{o}=\frac{v}{f r}
$$

## Rossby Radius of Deformation:

$$
\begin{aligned}
L_{R} & =\frac{c_{g}}{\zeta+f} \\
& =\frac{\sqrt{g h}}{\zeta+f} \\
& =\frac{N H}{I}
\end{aligned}
$$

## Standard Deviation:

$$
\sigma=\sqrt{\left(\overline{x^{2}}-\bar{x}^{2}\right)}
$$

Thermal Wind:

$$
\begin{aligned}
& \text { Geostrophic: } \quad f \frac{\partial v_{g}}{\partial \ln p}=-R \nabla T \\
& \text { Cylindrical: }\left(\frac{2 v}{r}+f\right) \frac{\partial v}{\partial \ln p}=-R \frac{\partial T}{\partial r}
\end{aligned}
$$

## Vorticity:

$$
\begin{aligned}
\text { General: } \zeta & =k . \nabla \times \boldsymbol{V} \\
\text { Cartesian: } \zeta & =\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y} \\
\text { Cylindrical: } \zeta & =\frac{1}{r}\left(\frac{\partial r v}{\partial r}-\frac{\partial u}{\partial \lambda}\right)
\end{aligned}
$$

## Wind Balance:

$$
\begin{aligned}
\text { Gradient: } v & =\frac{-f r}{2} \pm \sqrt{\left(\frac{r \partial p}{\rho \partial r}+\frac{f^{2} r^{2}}{4}\right)} \\
\text { Cyclostrophic: } v & = \pm \sqrt{\frac{1 \partial p}{\rho r \partial r}}
\end{aligned}
$$

For cyclones, the positive (negative) root is used in the northern (southern) hemisphere

Wind Profiles: (Holland, et al, 2010)
Knowledge of radial wind profiles has become quite complex. This is best understood by consulting the reference at:http://nldr.library.ucar.edu/repository/assets/osgc/OSGC-000-000-001-080.pdf

## Wind/Pressure Relationships:

Recent research into wind-pressure relationships have shown involvement of storm motion, size \& latitude. The following equations are taken from (Knaff and Zehr, 2007):

$$
\begin{align*}
\mathrm{MSLP}= & 23.286-0.483 V_{\mathrm{srm}}-\left(\frac{V_{\mathrm{srm}}}{24.254}\right)^{2}-12.587 S \\
& -0.483 \phi+P_{\mathrm{env}} \tag{7}
\end{align*}
$$

where $\mathrm{V}_{\text {srm }}$ is the maximum wind speed adjusted for storm speed, S (i.e., $=\mathrm{V}_{500} / \mathrm{V}_{500 \mathrm{c}}$ ) is the normalized size parameter (see below), and $\varphi$ is latitude (in degrees). $V_{500}$ is the mean tangential wind at 500 km from the cyclone centre and $\mathrm{V}_{500 \mathrm{c}}$ is defined below.

$$
\begin{equation*}
V_{500 \mathrm{c}}=V_{\max }\left(\frac{R_{\max }}{500}\right)^{x} \tag{4}
\end{equation*}
$$

where $x$, the shape factor, and $R_{\max }$, the radius of maximum winds in kilometers, are functions of latitude $(\phi)$ in degrees and intensity $\left(V_{\max }\right)$ in knots:

$$
\begin{align*}
x & =0.1147+0.0055 V_{\max }-0.001(\phi-25) \quad \text { and }  \tag{5}\\
R_{\max } & =66.785-0.09102 V_{\max }+1.0619(\phi-25) \tag{6}
\end{align*}
$$

### 11.7 Tropical cyclone records

Recording records is a difficult task, because of the extreme nature of the event and the tendency for observing equipment to break. The following records are backed up by good analysis methods and are considered to be reasonably reliable.

### 11.7.1 Global records

These records have been taken from http://wmo.asu.edu/\#cyclone and from tropical cyclone records. Visit the page for the sources for these records and also any recent updates.

| Tropical Cyclone Characteristic | Value | Date (D/M/Y) | $\begin{aligned} & \text { Length } \\ & \text { of } \\ & \text { Record } \end{aligned}$ | Tropical Cyclone | Latitude/ <br> Longitude |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Most Intense - by Central Pressure (World and Eastern Hemisphere) | 870mb (25.69") | 12/10/1979 | 1951present | Typhoon Tip in the Northwest Pacific Ocean | $\begin{aligned} & 16^{\circ} 44^{\prime} \mathrm{N}, \\ & 137^{\circ} 46^{\prime} \mathrm{E} \end{aligned}$ |
| Most Intense - by Central Pressure (western hemisphere) | 882mb (26.05") | 19/10/2005 | 1951present | Hurricane Wilma in Caribbean Sea | $\begin{aligned} & 17^{\circ} 18^{\prime} \mathrm{N}, \\ & {82^{\circ} 48^{\prime} \mathrm{W}}^{2} \end{aligned}$ |
| Most Intense - by Maximum Sustained Surface Wind | 95m/s (185 kt, 215 mph) | 12/9/1961 | 1945present | Typhoon Nancy in the Northwest Pacific Ocean | $\begin{aligned} & 15^{\circ} 30^{\prime} \mathrm{N} \\ & 137^{\circ} 30^{\prime} \mathrm{E} \end{aligned}$ |
| Maximum Surface Wind Gust for Tropical Cyclone | $\begin{aligned} & 113.2 \mathrm{~m} / \mathrm{s}(253 \mathrm{mph} ; \\ & 220 \mathrm{kt} \end{aligned}$ | $\begin{aligned} & \text { 1055 UTC, } \\ & \text { 10/4/1996 } \end{aligned}$ | 1949present | Barrow Island, Australia | $\begin{aligned} & 20^{\circ} 49^{\prime} \mathrm{S} \\ & 115^{\circ} 23^{\prime} \mathrm{E} \end{aligned}$ |
| Northern <br> Hemispheric <br> Maximum Surface <br> Wind Gust for <br> Tropical Cyclone | $\begin{aligned} & 94.4 \mathrm{~m} / \mathrm{s} \text { (211.3 mph; } \\ & 183.5 \mathrm{kt} \end{aligned}$ | $\text { ; } 2235 \text { UTC, }$ | 1949present | Pinar del Rio, Cuba | $\begin{aligned} & 22^{\circ} 34^{\prime} \mathrm{N}, \\ & 83^{\circ} 40^{\prime} \mathrm{W} \end{aligned}$ |
| Fastest Intensification | 100mb (976 to 876 mb ) in just under 24 hours | $\begin{aligned} & 22- \\ & 23 / 9 / 1983 \end{aligned}$ | 1951present | Typhoon Forrest in Northwest Pacific Ocean | $\begin{aligned} & 18^{\circ} 0^{\prime} \mathrm{N}, \\ & 136^{\circ} \mathrm{O}^{\prime} \mathrm{E} \end{aligned}$ |
| Highest Storm Surge | 13m (42 feet) | 5/3/1899 |  | Tropical Cyclone Mahina; Bathurst Bay, Queensland, Australia | $\begin{aligned} & 14^{\circ} 15^{\prime S}, \\ & 144^{\circ} 23^{\prime} \mathrm{E} \end{aligned}$ |
| First Identified South Atlantic Hurricane |  | 28/3/2004 | 1966present | Tropical Cyclone Catarina; state of Santa Catarina, Brazil | approximate <br> ly $27^{\circ} \mathrm{S}, 48^{\circ} \mathrm{W}$ |
| Largest Tropical Cyclone (winds from center) | Gale winds [17m/s, $34 \mathrm{kt}, 39 \mathrm{mph}]$ extending 1100km ( 675 mi ) from center | 12/10/1979 | 1945present | Typhoon Tip in Northwest Pacific Ocean | $\begin{aligned} & 16^{\circ} 44^{\prime} \mathrm{N}, \\ & 137^{\circ} 46^{\prime} \mathrm{E} \end{aligned}$ |
| Smallest Tropical Cyclone (winds from center) | Gale winds [17m/s, 34 kt , 39 mph ] extending 50km (30 mi) from center | 24/12/1974 | 1956present | Tropical Cyclone Tracy near Darwin, Australia | $\begin{aligned} & 12^{\circ} 12^{\prime} \mathrm{S} \\ & 130^{\circ} 00^{\prime} \mathrm{E} \end{aligned}$ |
| Longest Lasting Tropical Cyclone | 31 days | $\begin{aligned} & \text { 10/8/1994- } \\ & 10 / 9 / 1994 \end{aligned}$ | 1945present | Hurricane / Typhoon John in Northeast \& Northwest Pacific |  |


|  |  |  |  | Basins |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Longest Distance <br> Traveled by <br> Tropical Cyclone | $13280 \mathrm{~km}(7165 \mathrm{st}$. <br> mi.) | $10 / 8 / 1994-$ <br> $10 / 9 / 1994$ | $1961-$ <br> present <br> (satellite <br> era) | Hurricane / Typhoon <br>  <br> Northwest Pacific <br> Basins |  |
| Smallest eye | $6.7 \mathrm{~km}(4$ mile) | $24 / 12 / 1974$ | $1956-$ <br> present | Tropical Cyclone <br> Tracy at Darwin <br> Australia | $12^{\circ} 1^{\prime} 2^{\prime} \mathrm{S}$, <br> $130^{\circ} 00^{\prime} \mathrm{E}$ |
| Largest eye | $90 \mathrm{~km}(56$ mile) | $21 / 2 / 1979$ | $1956-$ <br> present | Tropical Cycle Kerry, <br> Coral Sea | $17^{\circ} 30^{\prime} \mathrm{S}$, <br> $154^{\circ} 0^{\prime} \mathrm{W}$ |


| Largest Rainfall of Tropical Cyclones | Value | Date (D/M/Y) | Length of Record | Tropical Cyclone | Latitude/ Longitude |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 12 hr | 1.144m (45.0') | 7- <br> 8/1/1966 | $\begin{aligned} & 1966- \\ & 1990 \end{aligned}$ | Tropical Cyclone Denise in South Indian Ocean | $\begin{aligned} & 21^{\circ} 14^{\prime} \mathrm{S}, \\ & 55^{\circ} 41^{\prime} \mathrm{E} \end{aligned}$ |
| 24 hr | 1.825m (71.8') | 7- <br> 8/1/1966 | $\begin{aligned} & \text { 1966- } \\ & 1990 \end{aligned}$ | Tropical Cyclone Denise in South Indian Ocean | $\begin{aligned} & 21^{\circ} 14^{\prime} \mathrm{S}, \\ & 55^{\circ} 41^{\prime} \mathrm{E} \end{aligned}$ |
| 48 hr | 2.467m (97.1") | $\begin{aligned} & 7- \\ & 9 / 4 / 1958 \end{aligned}$ | $\begin{aligned} & 1952- \\ & 1980 \& \\ & \text { 2004- } \\ & \text { present } \end{aligned}$ | Unnamed Tropical Cyclone In South Indian Ocean | $\begin{aligned} & 21^{\circ} 00^{\prime} \mathrm{S}, \\ & 55^{\circ} 26^{\prime} \mathrm{E} \end{aligned}$ |
| 72 hr | 3.930m (154.7") | $\begin{aligned} & 24- \\ & 27 / 2 / 2007 \end{aligned}$ | 1968present | Tropical Cyclone Gamede in South Indian Ocean | $\begin{aligned} & 21^{\circ} 12 ' \mathrm{~S}, \\ & 55^{\circ} 39^{\prime} \mathrm{E} \end{aligned}$ |
| 96 hr | 4.869m (191.7") | $\begin{aligned} & 24- \\ & 27 / 2 / 2007 \end{aligned}$ | 1968present | Tropical Cyclone Gamede in South Indian Ocean | $\begin{aligned} & 21^{\circ} 12 ' \mathrm{~S}, \\ & 55^{\circ} 39^{\prime} \mathrm{E} \end{aligned}$ |
| 10-day | 5.678m (223.5") | $\begin{aligned} & 18- \\ & 27 / 1 / 1980 \end{aligned}$ | 1968- present | Tropical Cyclone Hyacinte in South Indian Ocean | $\begin{aligned} & 21^{\circ} 12 ' \mathrm{~S}, \\ & 55^{\circ} 39^{\prime} \mathrm{E} \end{aligned}$ |

### 11.7.2 Regional Records

When printing this file include your regional records here.

### 11.8 Trivia corner

Hurricane Rubble: Surge and waves from Hurricane Bebe at Funafuti Atoll $\left(8^{\circ} \mathrm{S}, 179^{\circ} \mathrm{E}\right)$ during 21 October, 1972 raised a permanent rubble rampart 3.5 m high, 37 m wide and 18 km long (Maragos et al., 1973).

Hot Air: A localised region of extremely warm stratospheric air with 240 hPa temperature anomaly of $18^{\circ}$ attained over a distance of 13 km at the end of a cloud band outside the eye of Tropical Cyclone Kerry, February 1979, Coral Sea (Holland et al., 1984); measured by 747 with meteorologist in the cockpit, caused a major scare as the jet engines lost substantial power; in a similar incident in Western Australia a jet descended to 3 km altitude before regaining engine power.

Best Ship Observations: Caught in a typhoon in the western North Pacific during 26 September 1935, officers of the Japanese Imperial Navy collected the first, and possibly still the most comprehensive set of observations of the surface structure of a tropical cyclone (Arakawa and Suda, 1953).

Best Book Title: "An Attempt To Develop The Law of Storms By Means of Facts, Arranged According To Place and Time; and Hence To Point Out A Cause For The Variable Winds With The View To Practical Use In Navigation" (Reid, 1838).

Meteorology: This word seems to have been introduced to the language by Rear Admiral FitzRoy (1862), who begged his readers to accept the "abbreviation" from the then accepted meteorologic or meteorological.

Cyclone=Coiled Snake: Piddington (1855) first coined the term cyclone based on the Greek word, кик $\lambda \circ \zeta$ or coil of a snake, which indicated the characteristic circular and centripetal air flow.

Typhoon=Big Wind: The derivative of the word typhoon seems to have arisen from very appropriate Mandarin word t'ai fung for great wind.

Hurricane=Angry God: The derivative of the word hurricane comes from Huracan, or "God of Evil" used by the Central American Tainos tribe (Anthes, 1982).

Cock-Eyed Bobs: Contrary to popular belief, tropical cyclones are not referred to as Willy Willys in Australia. This name refers to dust devils. However, old timers on the Australian west coast often used the colourful name Cock-Eyed Bob to refer to severe tropical cyclones.

Divine Wind: In the $13^{\text {th }}$ century, a Mongol fleet, possibly the largest fleet ever assembled up to that time, was destroyed by a typhoon on its way to what would have been a successful invasion of Japan. This great fortune for Japan gave rise to the term kamikaze, for Divine Wind.

Friend or Foe: Clement Wragge, the Australian forecaster who started the convention of naming tropical cyclones, occasionally named a particularly severe one after politicians with whom he was displeased.

Coincidences? The TCM-90 Field experiment was initiated following a less than good series of forecasts for Typhoon Abby; the Project Manager was Bob Abbey. The Director of the field experiment in Guam was Russ Elsberry; several months later Guam was badly damaged by Supertyphoon Russ.

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