

General guidance, intensification metrics for tropical cyclones

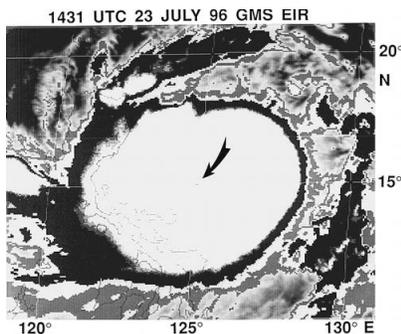
Use with caution

Assembled by Pat Fitzpatrick

	Intensification	Rapid Intensification (>30 kts in 24 hours) possible
850-200 mb wind shear	$VWS \leq 10 \text{ ms}^{-1}$	$VWS \leq 5 \text{ ms}^{-1}$
Water temperature	$SST \geq 27^{\circ}\text{C}$	$SST \geq 28.5^{\circ}\text{C}$
Ocean Heat Content	$OHC \geq 37 \text{ KJ cm}^{-2}$	$OHC \geq 55 \text{ KJ cm}^{-2}$
Percent area from eyewall to 200 km covered by deep convection	Coverage $\geq 60 \%$	Coverage $\geq 75 \%$
Potential= $MPI-V_{\max}$ (don't use for Cat 4 or 5)	$POT \geq 35 \text{ ms}^{-1}$	$POT \geq 40 \text{ ms}^{-1}$
850- to 700-mb relative humidity 200-800 km	$RH \geq 70 \%$	$RH \geq 75 \%$
Precipitable water, upshear quadrant out to 500 km	$PW \geq 45 \text{ mm (1.8 inches)}$	$PW \geq 55 \text{ mm (2.2 inches)}$
	Spiral banding occurs	Eye formation, or obvious eyewall contraction
		Lightning in eyewall, or other indications of unusual vertical motion in eyewall

General guidance, steady-state tropical cyclones

- A balance of some positive thresholds and mildly negative thresholds.
- POT is low and other environmental conditions remain favorable.
- A Central Cold Cover (CCC) occurs. This is the occurrence of a sudden spreading of cold clouds over the central features of a tropical cyclone. An example is shown below.



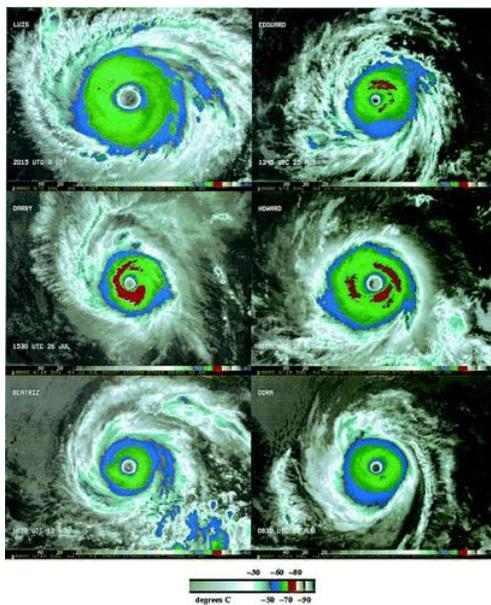
Hurricane Gloria with a large CCC. From Landers (1999)

When a CCC persists, it signals an interruption in the development of the storm. According to Dvorak, the CCC pattern is defined when a more or less round, cold overcast mass of high cloud which covers the tropical cyclone center. The CCC is a very cold layer of cirrus that spreads over, and obscures, the core and primary rainbands of the tropical cyclone. It usually begins with an explosive growth of deep convection near the core of the TC with a subsequent spreading of a very large, smooth, and very cold

cirrus canopy over the tropical cyclone. It is a relatively rare phenomenon observed in a small fraction of tropical cyclones.

Vern Dvorak discovered the CCC relationship, but offered no explanation. Tropical meteorologist Derrick Herndon hypothesizes it indicates the presence of at least moderate shear. The morphology is one of apparent convective symmetry with quite cold clouds tops. The convective symmetry may occur because the shear is beneath the cirrus level, so a large coverage of cirrus is still able to spread upstream against the upper level flow.

- The hurricane becomes “annular.” Annual hurricanes are a large and nearly symmetrical eye, little or no discernable banding, and an eyewall entirely surrounded by intense thunderstorm activity. These are typically major hurricanes at 80% MPI, maintain their peak intensities longer, and weaken more slowly than average hurricanes. (Typically, hurricanes in the Atlantic experience their peak intensity for very short periods, and then fill rather rapidly). They are also known as truck tire or doughnut hurricanes. They are rare (4% of all hurricanes) and develop more often in the Pacific than the Atlantic.



Examples of annular hurricanes. From Knaff and Kossin (2003).

General guidance, weakening tropical cyclones

- The majority of guidelines become mildly negative.
- A second eyewall begins to form. This is also referred to as a concentric eyewall cycle, or an eyewall replacement cycle.
- Brief landfall, such as over a small island.
- All other factors being relatively favorable, a tropical cyclone moves over colder water such that $POT < 0$. In some cases, the surface water meets the criterion but OHC does not (no warm water depth).

Caveat -, even if the convection appears to be dissipating rapidly, often there is a lag in the wind field weakening. Also, if a recurving tropical cyclone is moving fast (>25 knots), the storm translation speed can offset much of the weakening. East Coast storms experience such situations.

General guidance, rapid weakening of tropical cyclones

- Several guidelines become strongly negative. The most important criteria include $SST \leq 25^{\circ}\text{C}$, and $VWS \geq 20 \text{ ms}^{-1}$
- Landfall over a large island or peninsula, or over a continent (where it will either dissipate or become extratropical).

Reference for some of the rapid intensifier metrics

Kaplan, J., M. DeMaria, and J. A. Knaff, 2010: A revised tropical cyclone rapid intensification index for the Atlantic and Eastern North Pacific Ocean. *Weather and Forecasting*, **25**, 220-241.