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Supporting Information for

A simple diagnostic for eyewall replacement based on Pressure-Wind relationship

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Introduction

The supplementary document includes details of the Holland (2010) windprofile and the parameters used in this study, statistics about using various thresholds of the diagnostic, one case study (Typhoon Muifa 2011) showing different types of secondary eyewalls (CEs), latitudinal distributions of CEs captured by the proposed diagnostic and those don't, as well as composite analysis using varying b_s values.

Text S1

The computation of the complete Holland (2010) wind profile require values of several parameters, not only the b_s parameter indicating the peakedness of wind, but also the x component, which is adjusted to ground observations of wind.

$$V = V_m \left\{ \left(\frac{r}{R_m} \right)^{-b_s} e^{\left[1 - \left(\frac{r}{R_m} \right)^{-b_s} \right]} \right\}^x$$

$$b_s = -4.4 \times 10^{-5} \Delta p_c{}^2 + 0.01 \Delta p_s + 0.03 \frac{\partial p_c}{\partial t} - 0.014\varphi + 0.15 v_t{}^{0.6\left(1 - \frac{\Delta p_c}{215}\right)} + 1.0$$

$$x = \begin{cases} 0.5\,, & r \le R_m \\ 0.5 + (r - R_m) \dfrac{x_n - 0.5}{r_n - R_m}, & r > R_m \end{cases}$$

Holland (2010) describes one hurricane in detail with V_m = 56 m/s , sea surface temperature $SST = 28\ °C$, latitude $\varphi = 20°$, central pressure deficit $\Delta p_c = 55\ hPa$, intensity change $\partial p_{cs}/\partial t = 3\ hPa\ s^{-1}$,translational speed $v_t = 5\ m\ s^{-1}$, Peripheral wind observations of 17 m/s at r = 300 km. These result in values of $b_s = 1.8$, $x_n = 0.8$, and $r_n/R_m = 15$. This hurricane is adopted in Holland (2010) as 'a base for an overall discussion on structure and sensitivity to basic parameters'. These parameters are what used in this study.

Table S1. Probability of Detection (POD) and False Alarm Ratio (FAR) with various thresholds of lifetime minimum $\frac{\partial M}{\partial r}_{min}$

Threshold (m s^{-1})	0	1	2	3	4
POD	0.45	0.59	0.69	0.80	0.87
FAR	0.59	0.61	0.65	0.69	0.74

Values show the Probability of Detection (POD, defined as the ratio of CE storms with $\frac{\partial M}{\partial r}_{min}$ < threshold in CE group) and False Alarm Ratio (FAR, defined as the ratio of non-CE storms with $\frac{\partial M}{\partial r}_{min}$ < threshold in all storms, both CE and non-CE, with $\frac{\partial M}{\partial r}_{min}$ < threshold) with various thresholds of lifetime minimum $\frac{\partial M}{\partial r}_{min}$. As in Fig. 2b-c, the number of CE/non-CE events are computed in terms of storms, not snapshots. Together with Fig. 2b-c, we decide to use a practical threshold of 2 m s^{-1} for the rest of the paper.

It's worth noted that both POD and FAR values are biased due to the sporadic nature of observations. Whether or when a storm is captured by passive microwave sensors (on low-earth orbital satellites) is very random, and the number of microwave observational snapshots vary from storm to storm. The time interval between two successive snapshots of one storm is 16.4 h on overage, and a CE event with a short duration (e.g., 6 h, as in Hurricane Andrew 1992 or Typhoon Lekima 2001) may not be captured. On overage, a storm is observed 16.8 times during its lifetime in CE group and 9.8 for non-CE group. In other words, a storm categorized in CE group is partly due to more frequent observations, and storms with eyewall replacement may be mislabeled as non-CE due to limited observations. For non-CE storms with $\frac{\partial M}{\partial r}_{min}$ < 2 m s^{-1}, 46.4% are associated with no more than 5 observations during its lifetime, which is significantly lower than the average of 16.8 observations for storms in CE group. Therefore, we argue, a considerable portion of storms in non-CE group with $\frac{\partial M}{\partial r}_{min}$ < 2 m s^{-1} may have actually experienced ERC but not captured by the satellite, resulting POD biased towards lower values and FAR biased towards higher values. Given the great difference in the sample size (1317 storms in non-CE group, 216 storms in CE group), with more satellite observations, one would expect much *better* performance of the diagnostic than what's shown in Table S1.

Table S2. Comparison of characteristics of different thresholds

Threshold (m s^{-1})	**2**	**0**	**4**
N_{CE}	268	172	333
N_{CE}/N_{total}	70.2%	45.0%	87.2%
N_{CE}(t=[0,2d])	207	139	238
N_{CE}(t=[0,2d])/N_{CE}	77.2%	80.8%	71.5%
N_{CE}(t=[0,4d])	239	153	304
N_{CE}(t=[0,4d])/N_{CE}	89.2%	89.0%	91.3%
ΔV_m (knots) in 24 h	30.0	30.5	29.0

Values show the number of CEs (N_{CE}) with lifetime minimum $\frac{\partial M}{\partial r}_{min} < threshold$, the ratio of N_{CE} to total CEs (N_{total} = 382), the number and ratio of CEs occur within 2 days/4 days of the diagnostic reaches below the threshold, and intensification of the composite mean V_m.

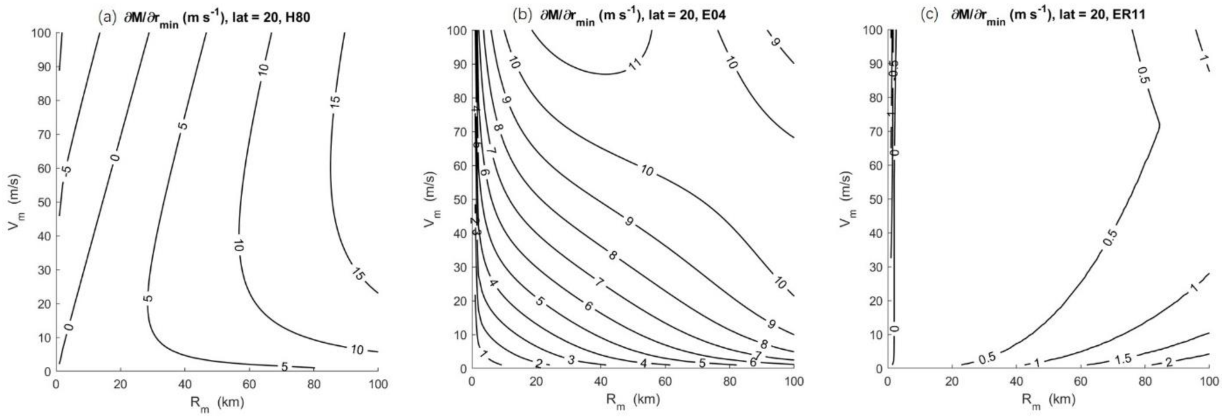

Figure S1. Contours of $\frac{\partial M}{\partial r}_{min}$ for varying V_m and R_m for (a) H10, (b) E04 and (c) ER11 at latitude = 20°.

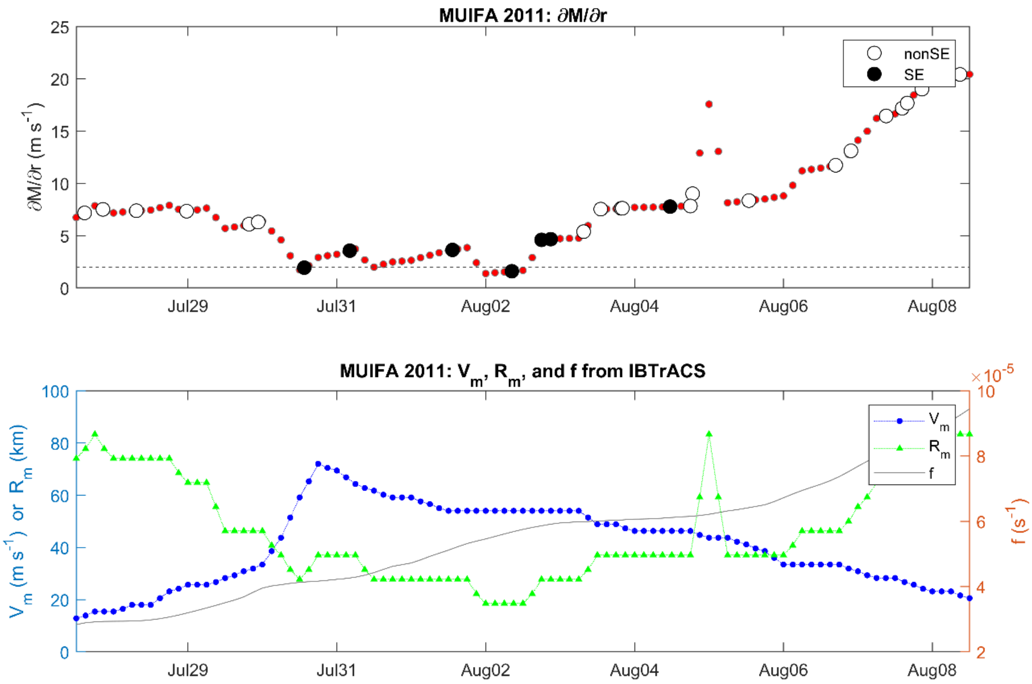

Figure S2. Time serial of $\frac{\partial M}{\partial r}_{\boldsymbol{min}}$ for Super Typhoon Muifa (2011), and $\boldsymbol{V_m}$, $\boldsymbol{R_m}$, and $\boldsymbol{f}$ from IBTrACS. Black/white circles mark time of observed CEs /non-CEs.

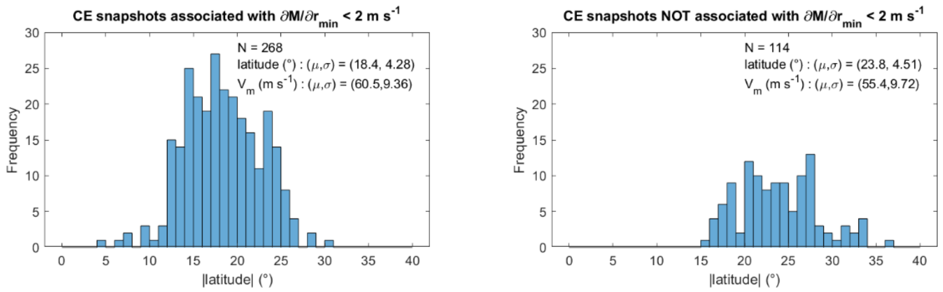

Figure S3. Latitudinal distribution of CEs associated with lifetime minimum $\frac{\partial M}{\partial r}_{\boldsymbol{min}} < \boldsymbol{2\ m\ s^{-1}}$, and those don't.

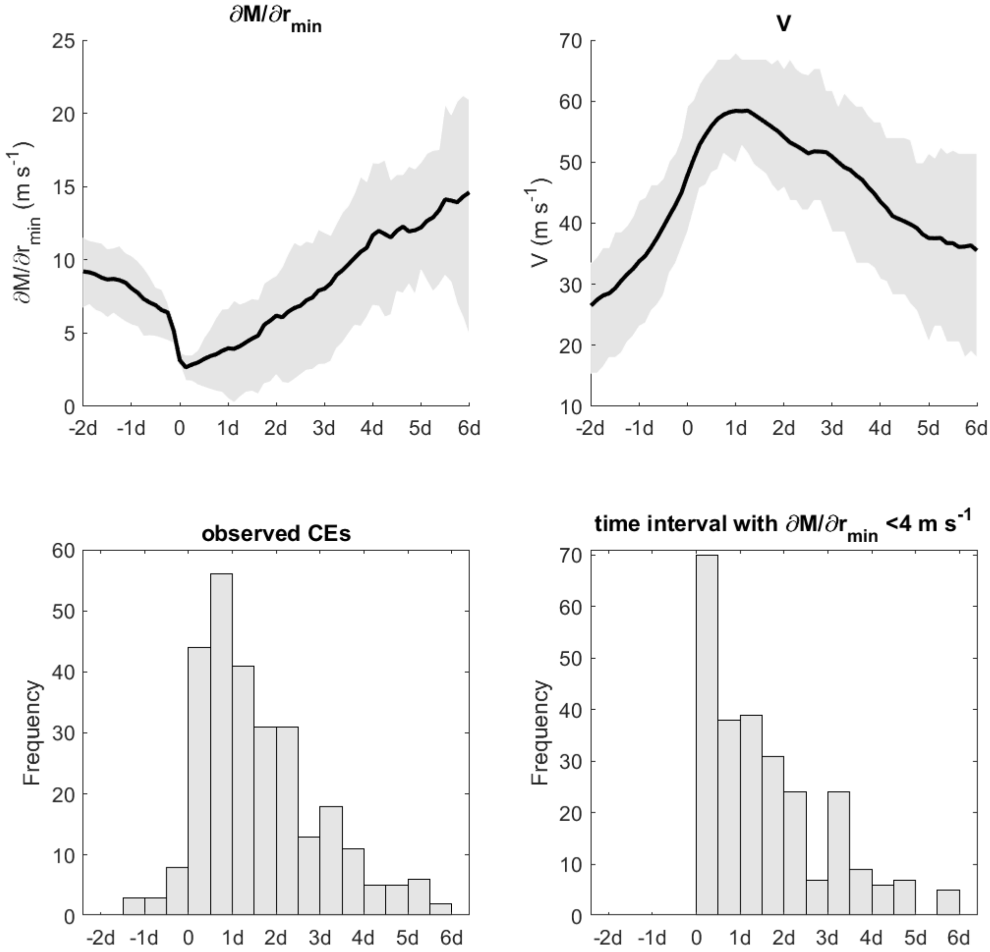

Figure S4. Same as Fig. 3 except $\mathbf{b_s}$ from Eqn. (5) is used. There are 284 storms in CE group (account for 74.4% of total observed CEs) with lifetime minimum $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ <4 m s^{-1}, and they are used in the following analysis: (a) evolution of the proposed diagnostic $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ aligned at the time when $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ <4 m s^{-1}, shading indicates the 25th and 75th percentile of the spread; (b) same as (a) but for the evolution of $\mathbf{V_m}$; (c) incidence of CE snapshots regarding to the time when $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ < 4 m s^{-1}; (d) distribution of the time window associated with $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ < 4 m s^{-1}. The number of CEs in the composites is 284 for lifetime minimum $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ < 4 m s^{-1} (account for 74.4% of total observed CEs), among which 75.7% occur within 2 days after $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ < 4 m s^{-1}, 91.6% within 4 days. As the diagnostic approaches $\frac{\partial \mathbf{M}}{\partial \mathbf{r}}_{\mathbf{min}}$ < 4 m s^{-1}, the intensification rate of the composite mean $\mathbf{V_m}$ is 30.0 knots in 24 h.