# A Real-time System for Evaluating the Ventilation of Tropical Cyclones

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## 1. Background

Ventilation is the flux of low-entropy (or low-$\theta_e$) air from the environment into a tropical cyclone (Simpson and Riehl 1958).

Ventilation inhibits both tropical cyclogenesis and intensification (Riemer et al. 2010; Tang and Emanuel 2010, 2012a, 2012b).

The ventilation index ($\Lambda$) is a theoretically-derived measure of the ventilation of a tropical cyclone or disturbance:

$$\Lambda = \frac{u_{\text{shear}}\chi_{\text{m}}}{u_{\text{PI}}}$$

$u_{\text{shear}}$ is the 850 – 200 hPa bulk environmental vertical wind shear

$\chi_{\text{m}}$ is the nondimensional midlevel entropy deficit (600 hPa)

$u_{\text{PI}}$ is the potential intensity

**Goal:** Implement a real-time system for evaluating the ventilation index of tropical disturbances and cyclones for genesis and intensity forecasts

## 2. Ventilation Index Maps

Maps of the ventilation index can be used to assess the categorical favorability for genesis and intensification.

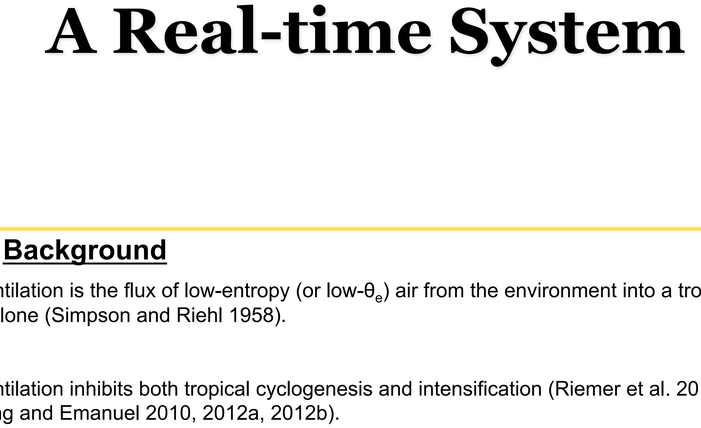



**Figure 1**
The logarithm of the ventilation index from the ECMWF analysis on 1200 UTC 20 October 2012 (shading) and the estimated position of disturbance al982012 (circle) that became Hurricane Sandy thereafter.

## 3. Genesis Applications

Time averaged ventilation index following a tropical disturbance strongly influences the probability of genesis.

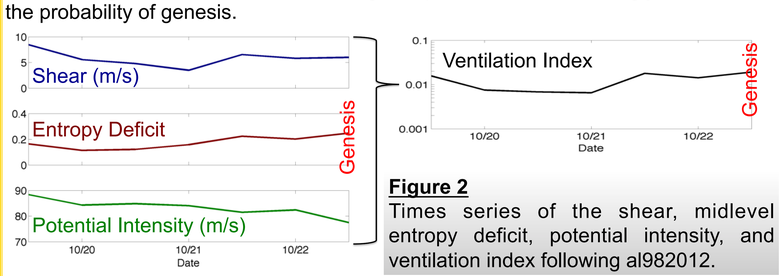



**Figure 2**
Times series of the shear, midlevel entropy deficit, potential intensity, and ventilation index following al982012.

A logistic regression model is used to assign the probability of genesis over a given forecast window given the mean ventilation index following a disturbance.

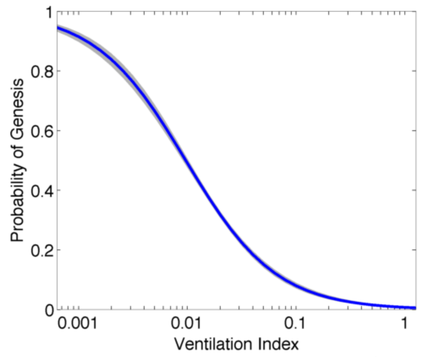
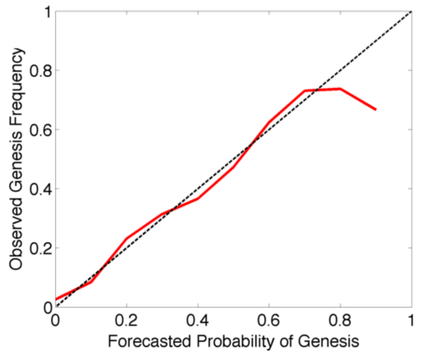



**Figure 3**
The probability of genesis within 48 hours given the mean ventilation index over a 72-hour window encompassing the prior 24 hours and the 48-hour forecast window. The gray shading denotes the 95% confidence interval.

**Figure 4**
The reliability (forecasted probability of genesis versus observed genesis frequency) of the model in fig. 3 when used to hindcast the probability of genesis within 48 hours for the 2005-2009 National Hurricane Center and Joint Typhoon Warning Center "invests."




## 4. Intensity Applications

The **normalized intensity** is the maximum sustained surface wind speed divided by the potential intensity, and the **normalized intensification** is the change in normalized intensity over a defined time interval.

The normalization is critical for extracting a ventilation signal in the observed data.

Well-defined regions in the joint ventilation index and normalized intensity parameter space where tropical cyclones intensify and weaken in the mean.

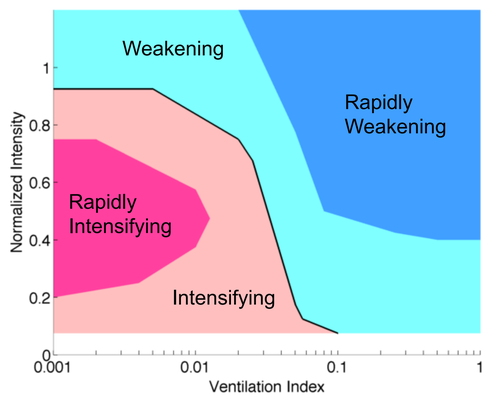



**Figure 5**
Phase diagram of the mean normalized intensification as a function of the ventilation index and the normalized intensity of a tropical cyclone. Rapid intensification (weakening) regions are where >30% of tropical cyclones are observed to have a normalized intensification of at least ±0.2 over 24 hours.

Based on the locational of a tropical cyclone in the parameter space, a probability distribution of the intensification may be generated.

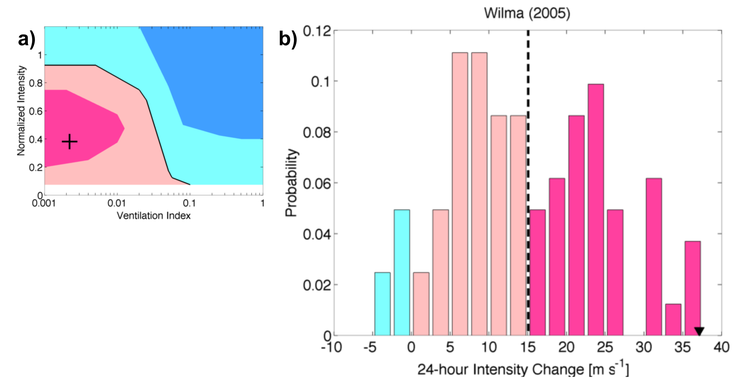



**Figure 6**
(a) The location of Hurricane Wilma (2005) in joint ventilation index and normalized intensity parameter space at 0000 UTC 18 October 2005. (b) Probability distribution of the 24-hour intensity change based on historical tropical cyclones with similar normalized intensities and ventilation indices in the best-track database. The dashed line is the mean of the distribution, and the triangle is the observed 24-hour intensification of Wilma.

Ensemble data may be used to assess forecast uncertainty in the parameter space.

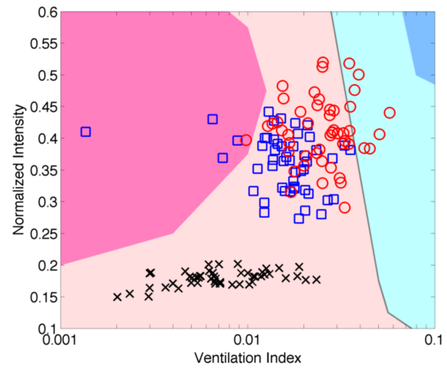



**Figure 7**
Locations of Hurricane Sandy (2012) in joint ventilation index and normalized intensity parameter space from the ECMWF ensemble, initialized at 0000 UTC 23 October 2012. Black crosses are at the analysis time, blue squares are 24-hour forecasts, and red circles are 48-hour forecasts.

## 5. Conclusions

The ventilation index is a nonlinear combination of the vertical wind shear, nondimensional midlevel entropy deficit, and the potential intensity.

Guidance products that feature the ventilation index may be used as tools to forecast both tropical cyclogenesis and tropical cyclone intensity change.

Future work will focus on incorporating the ventilation index into multivariate genesis and intensity products.

## 6. References

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