# Development of a Secondary Eyewall Formation Index for Improvement of Tropical Cyclone Intensity Forecasting

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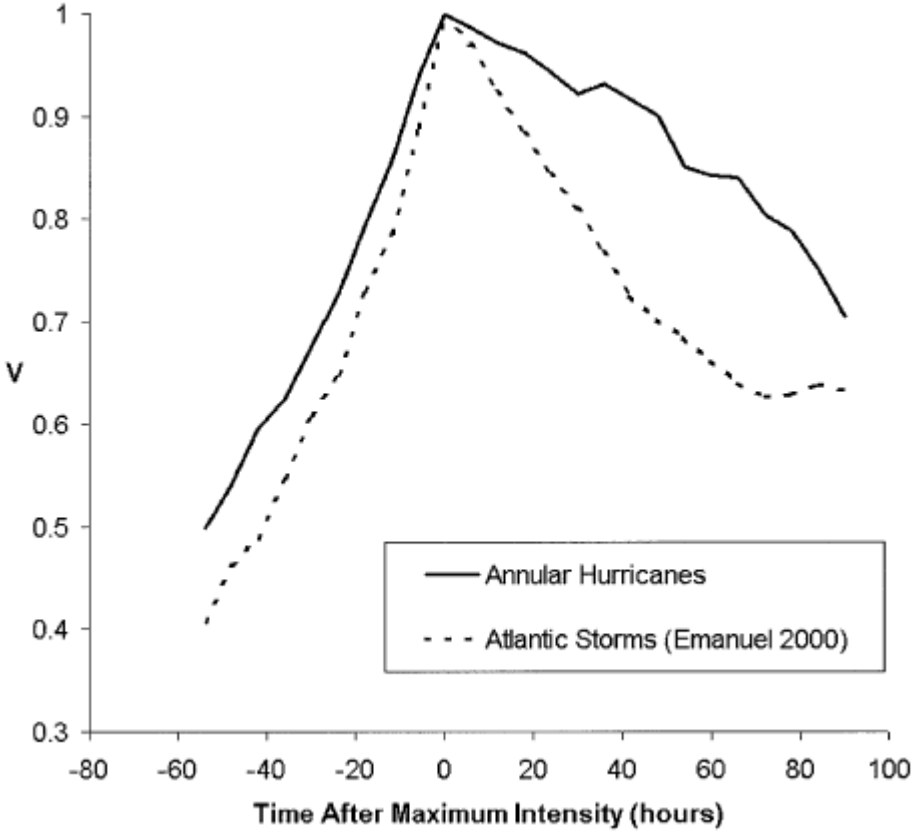
Climatology of tropical cyclone intensity change (Emanuel 2000):

~ +12 m/s per day for ~5 days, then ~ –8 m/s per day until end of life

But there are two identifiable classes of storms that behave differently and introduce systematic errors into intensity forecasts:

1. Storms undergoing eyewall replacement cycles.
2. Storms that become “annular” (Knaff et al. 2003).

# Intensity forecast errors




Annular Hurricanes are systematically under-forecast

OFCL 24-hour forecast bias increases from –0.8 kt to –6.0 kt

OFCL 36-hour forecast bias increases from –1.7 kt to –10.8 kt

Mean absolute error increases by 23% at 36 h.

# Intensity forecast errors

Secondary eyewall formation (SEF) signals the onset of an eyewall replacement cycle (ERC). Contrary to annular hurricanes, storms undergoing an ERC are systematically *over*-forecast.

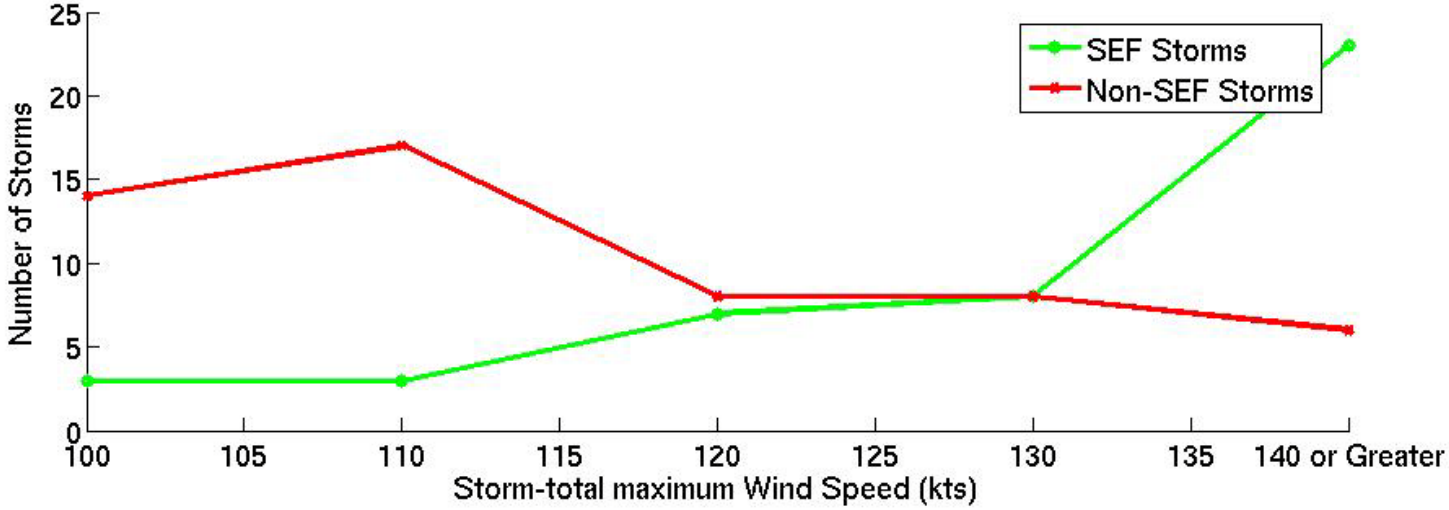
OFCL Forecast bias (kt). $V_{max}$ > 100 kt

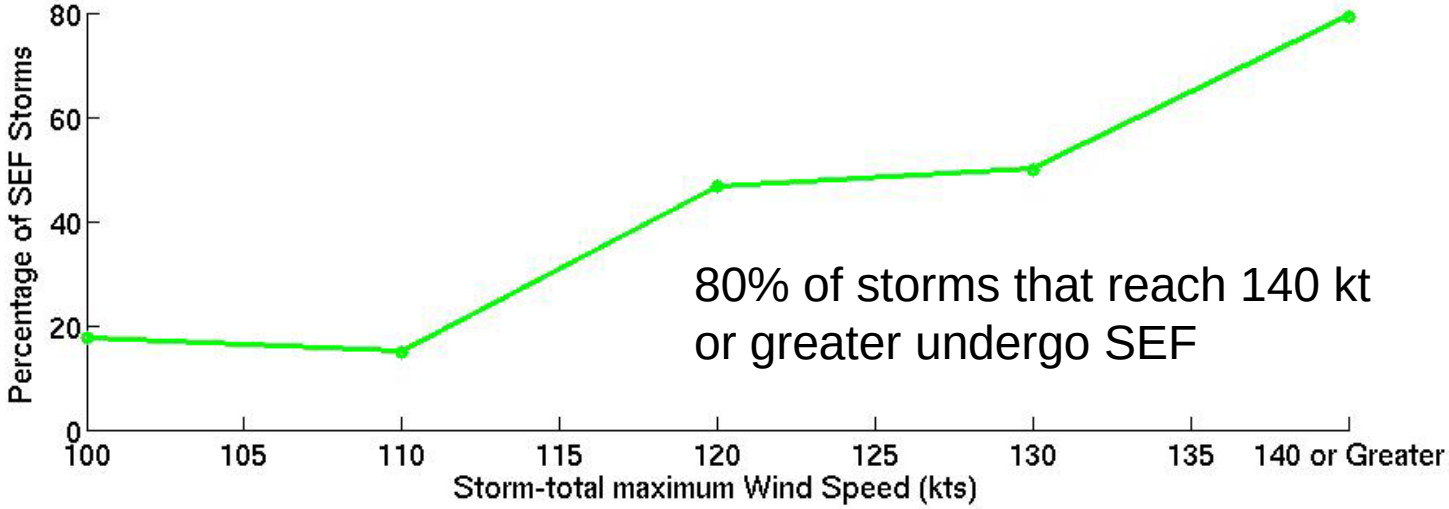
| | 12 h | 24 h | 36 h | 48 h |
|---|---|---|---|---|
| SEF cases | +1.5 | +2.4 | +3.1 | +3.7 |
| Non-SEF cases | –0.4 | –1.4 | –2.9 | –4.6 |

Mean absolute error increases by 16 – 20% out to 48 h.

# SEF climatology

SEF-yes storms: N = 44
SEF-no storms: N = 53

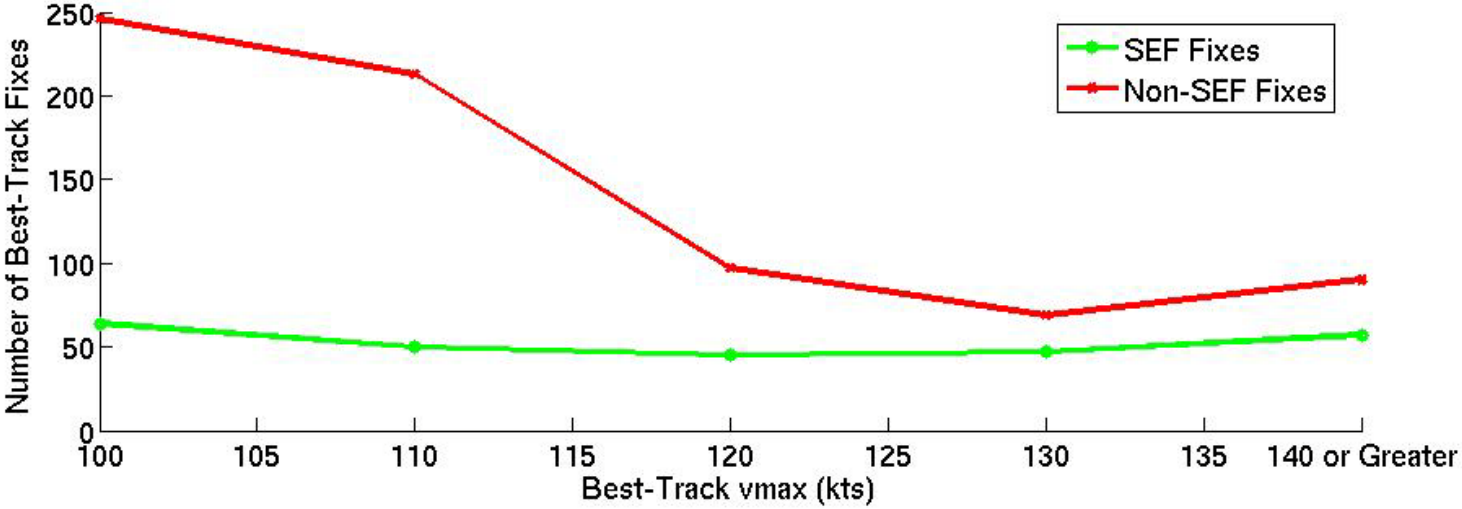


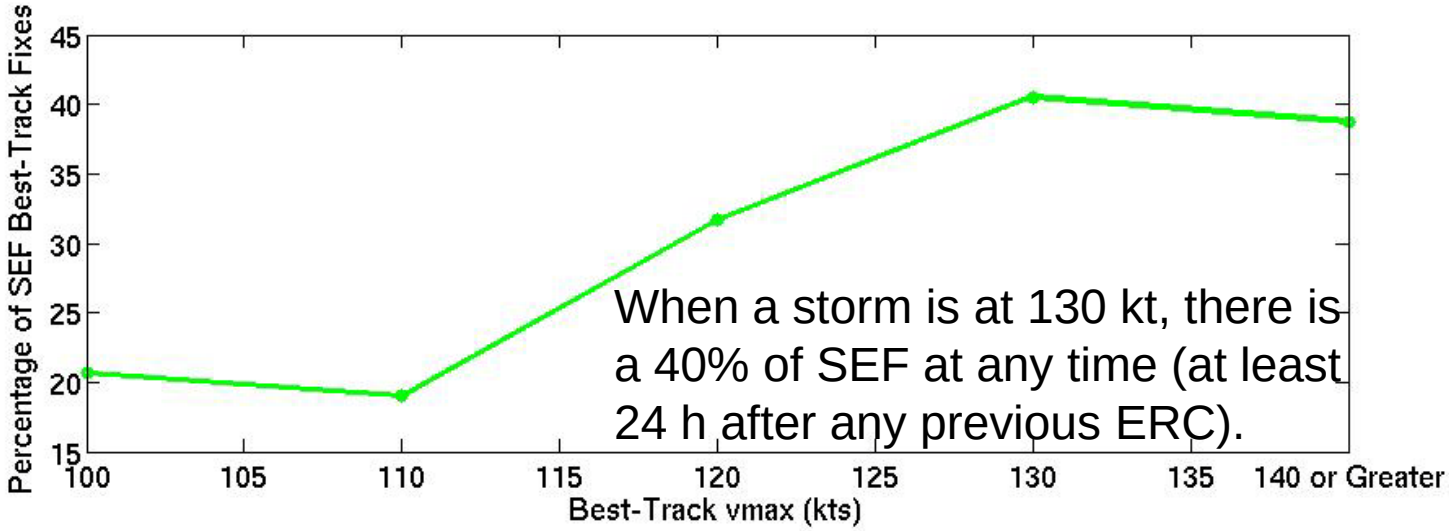




80% of storms that reach 140 kt or greater undergo SEF

# SEF climatology

SEF-yes best track fixes: N = 263
SEF-no best track fixes: N = 715




When a storm is at 130 kt, there is a 40% of SEF at any time (at least 24 h after any previous ERC).

# Formation of an objective index to diagnose SEF

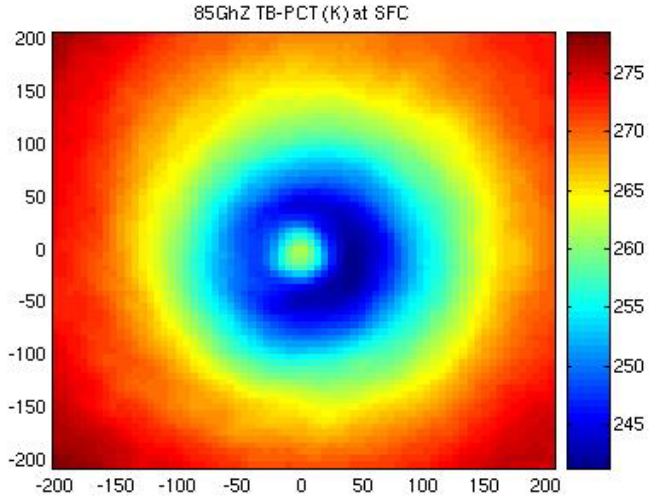
Data (*global*):

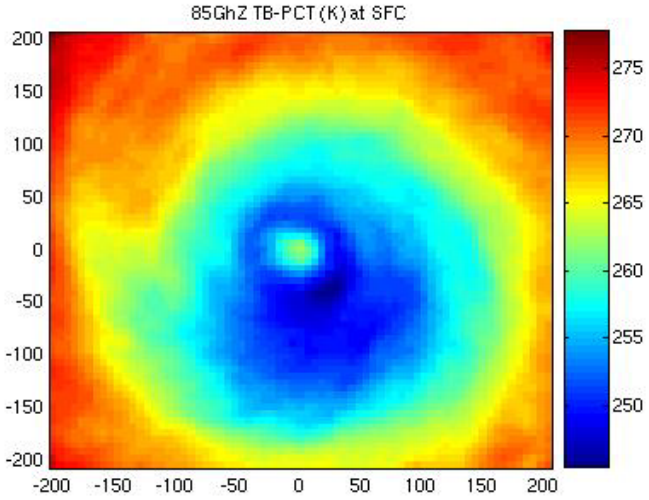
1. SSM/I and TMI data.
2. Reanalysis fields (vorticity, divergence, shear, moisture, etc).
3. SST fields.
4. Geostationary IR data (ATL only at present).

# Method

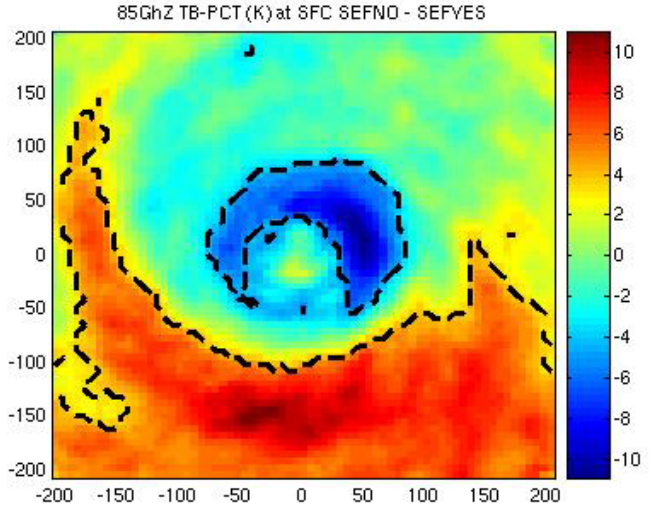
1. Composite analyses of SEF-yes versus SEF-no.
2. Feature extraction from the composite analyses.
3. Apply features to Classification algorithms.

# Results (simple two-variate example)

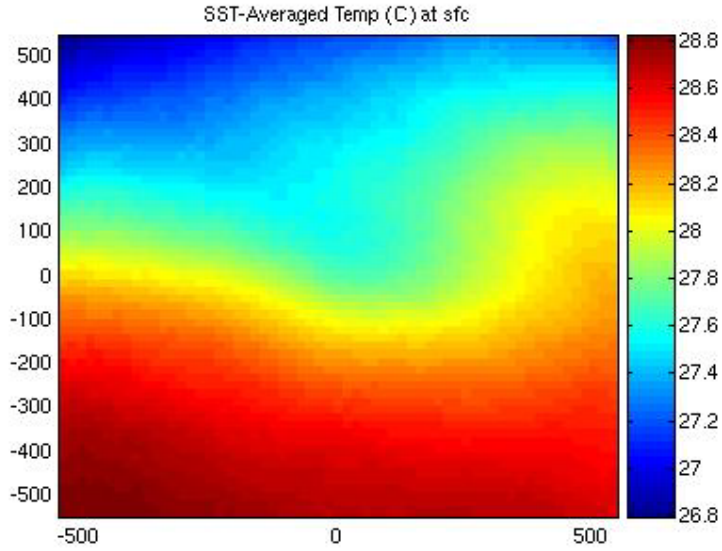


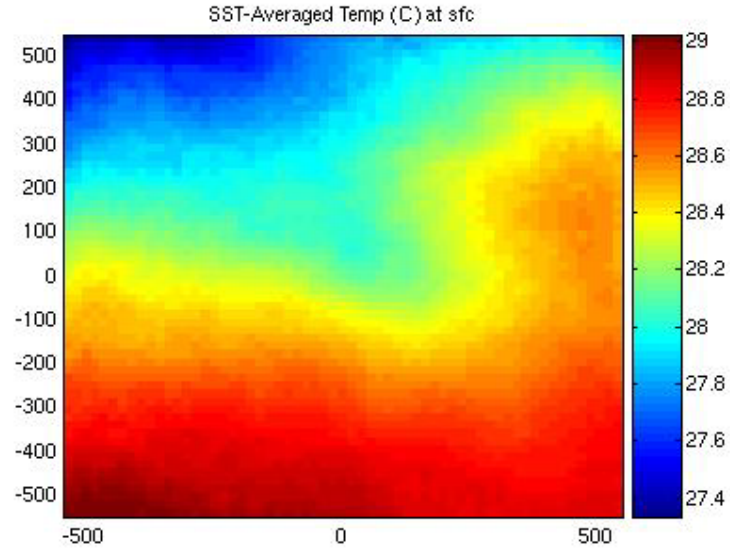



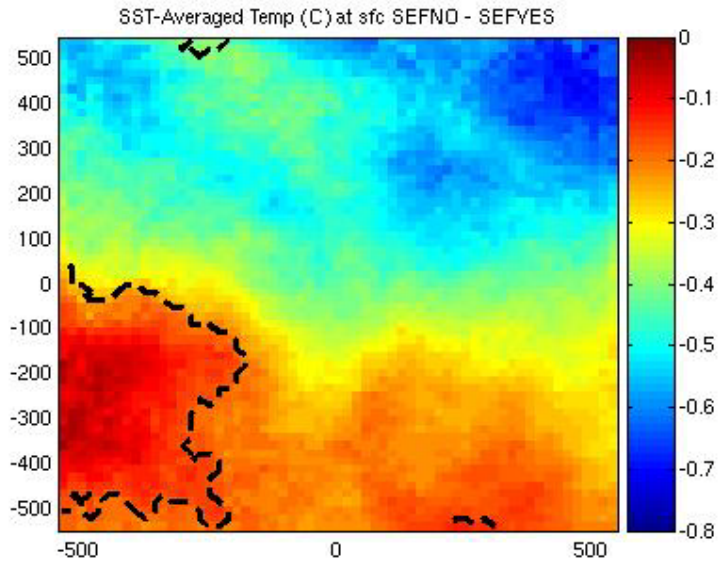

Axes are km from center




Microwave composites



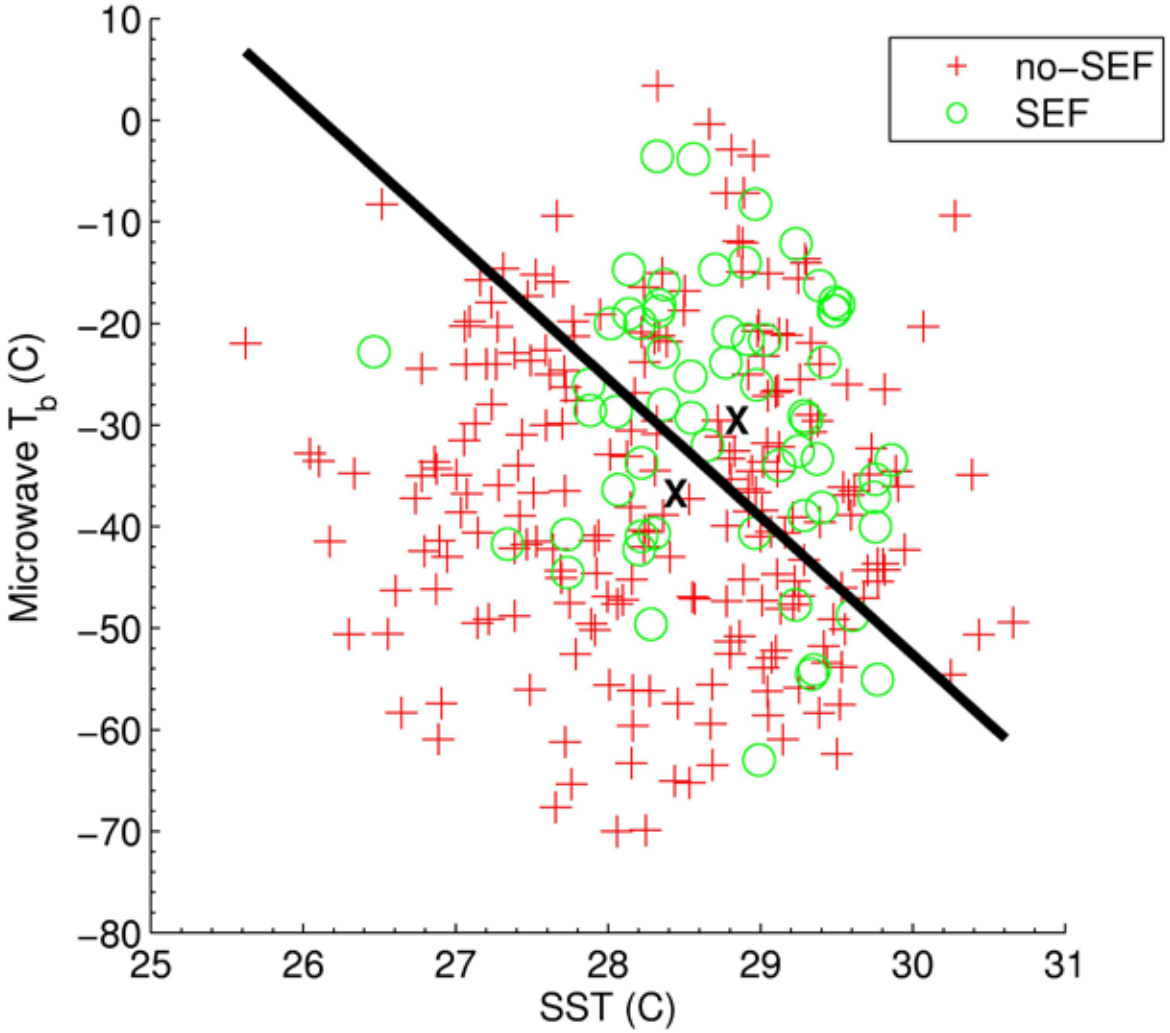




# SST composites

# Linear Discriminating (Classifier) Function

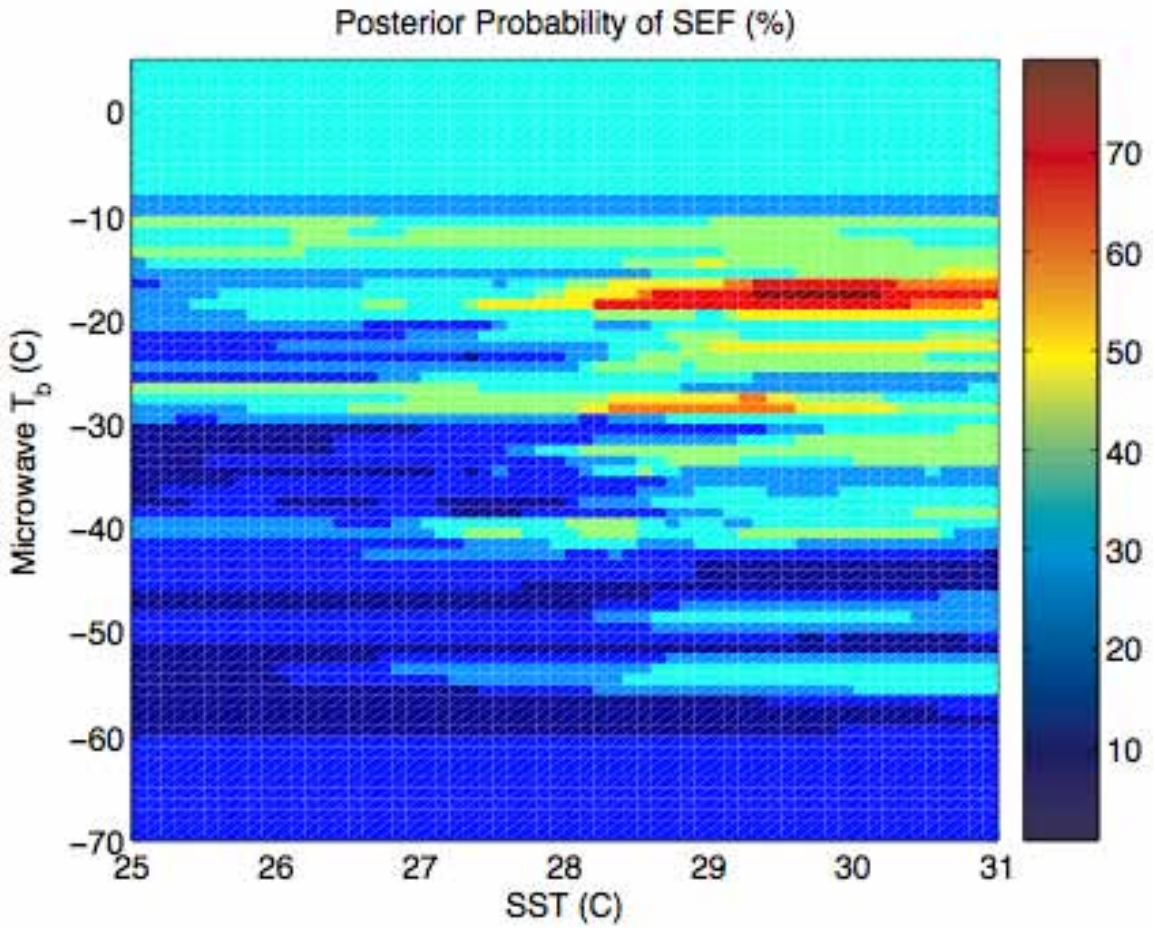
Predicts group membership — Yes or No.




**x** = sample means

# Bayes Classifier

Provides probability of SEF




Combines *a priori* (climatological) probability of group membership and probability of membership based on feature values. Probability density in feature phase-space is determined by the method of K-nearest neighbors.

# Concluding remarks

1. Algorithms should be ready for testing during 2006 TC season.
2. They will give the forecaster a probability of SEF based on real-time measurements from analyses and satellites. This in turn will alert the forecaster to the onset of an ERC and the associated intensity changes that are expected, even though all other factors may be saying otherwise.
3. We expect to formulate algorithms that include Microwave-based parameters and similar algorithms that do not rely on this data. This will allow us to run the algorithm more often, but use the MW data when it's available.
4. The algorithms will be combined with a similar index that diagnoses the formation of annular hurricanes, and is presently being constructed in a joint effort by members of the NOAA/NESDIS/RAMMB team at Colorado State University. Since annular hurricanes tend to maintain a more steady intensity while they are annular, they represent a very different population than storms that undergo ERCs and exhibit more intensity variance than average during the eyewall replacement.