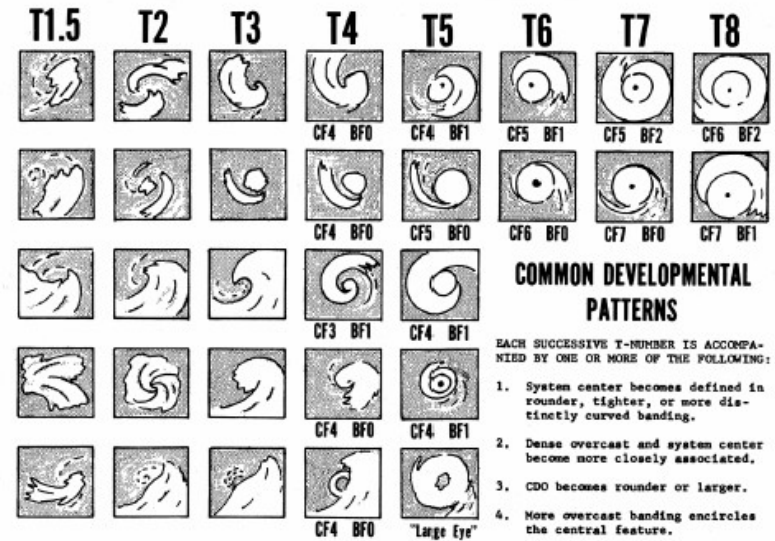# Geometry of Weather

Dr. Francis Motta, Dr. Justin Curry,
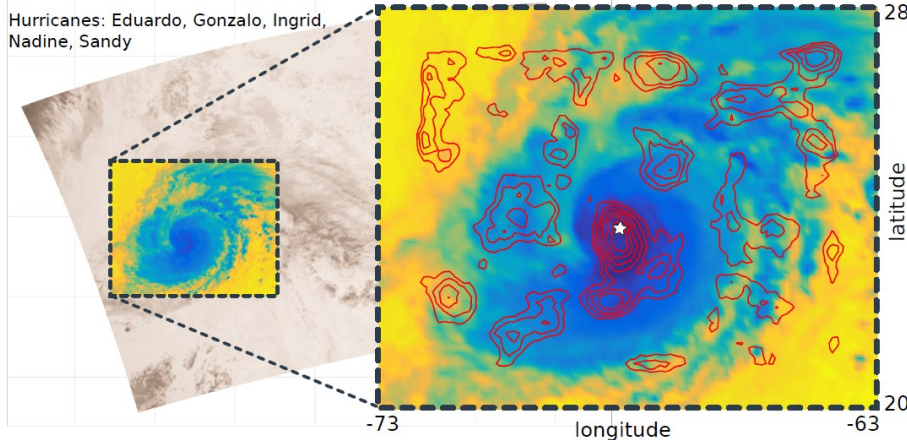Hans Riess, Joy Patel

Abstract:

In this project, we investigate tropical storms using geometric and topological features. Here, we implement and evaluate eye detection, the first step in the Dvorak Technique – a method for approximating storm intensity using satellite images.
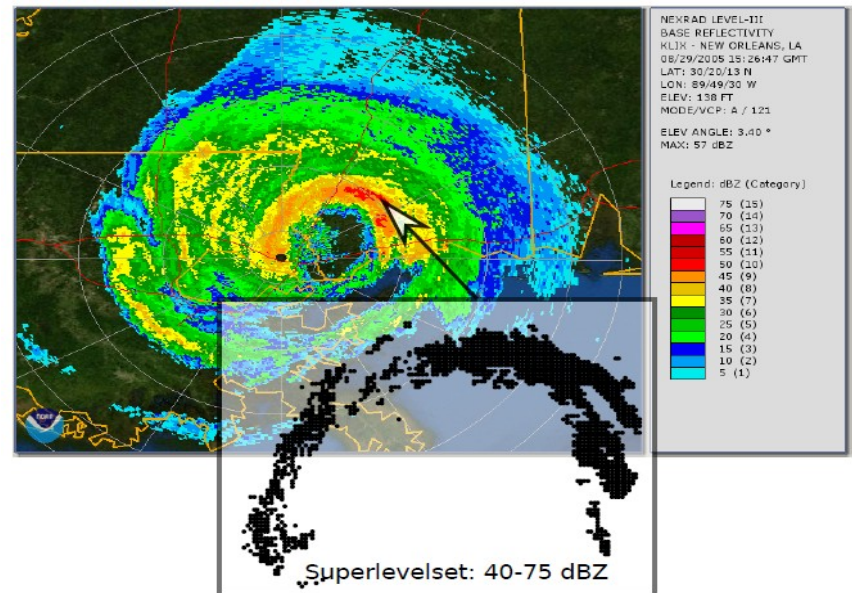
T1.5 T2 T3 T4 T5 T6 T7 T8

CF4 BF0   CF4 BF1   CF5 BF1   CF5 BF2   CF6 BF2

CF4 BF0   CF5 BF0   CF6 BF0   CF7 BF0   CF7 BF1

COMMON DEVELOPMENTAL PATTERNS

CF3 BF1   CF4 BF1

EACH SUCCESSIVE T-NUMBER IS ACCOMPANIED BY ONE OR MORE OF THE FOLLOWING:

CF4 BF0   CF4 BF1

1. System center becomes defined in rounder, tighter, or more distinctly curved banding.

2. Dense overcast and system center become more closely associated.

3. CDO becomes rounder or larger.

CF4 BF0   "Large Eye"

4. More overcast banding encircles the central feature.

Dvorak (1973)

Dataset 1: Infrared Satellite Images of Storms

Infrared satellite images (Suomi National Polar-orbitingPartnership (S-NPP) satellite)

Hurricanes: Eduardo, Gonzalo, Ingrid, Nadine, Sandy

temperature (K)

290 270 250 230 210 190

latitude

longitude

-73   -63

Dataset 2: NEXRAD radar data:
Geometry of the eyewall
Hurricane Katrina

NEXRAD LEVEL-III
BASE REFLECTIVITY
KLIX - NEW ORLEANS, LA
08/29/2005 15:26:47 GMT
LAT: 30/20/13 N
LON: 89/49/30 W
ELEV: 138 FT
MODE/VCP: A / 121

ELEV ANGLE: 3.40 °
MAX: 57 dBZ

Legend: dBZ (Category)

75 (15)
70 (14)
65 (13)
60 (12)
55 (11)
50 (10)
45 (9)
40 (8)
35 (7)
30 (6)
25 (5)
20 (4)
15 (3)
10 (2)
5 (1)

Superlevelset: 40-75 dBZ

Eye Detection Technique

- Rectilinearize the image via cubic spline interpolation.

- For each pixel in image, $I(x, y)$, generate a log spiral vector field, $F(x, y)$, centered at the pixel. The log spiral vector field is dependent on 2 parameters: a radius and angle.

- Compute scores via the sum of the magnitudes of the cross products between the log spiral vector field and image gradient vector field:

$$S = \sum_{\text{all pixels}} \|\nabla I \times F\|$$

- Take the maximum S to be initial guess. Refine the score via dot product with circular vector field in neighborhood about maximum S.
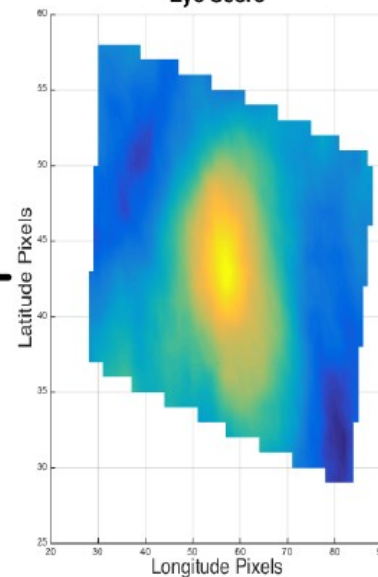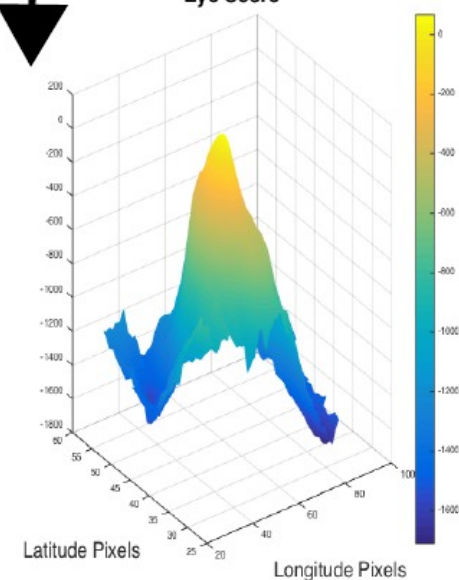

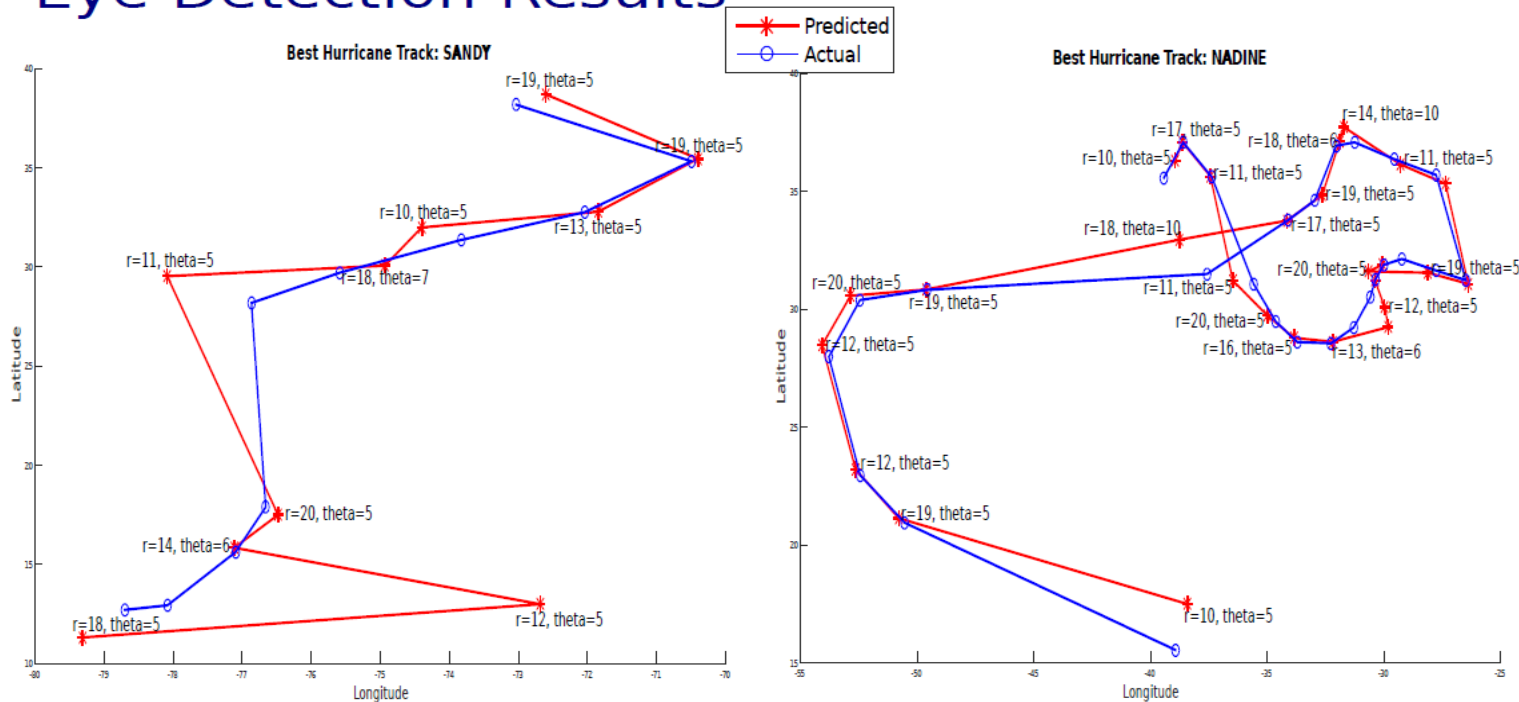Log Spiral (Red) vs Image Gradient (Blue)
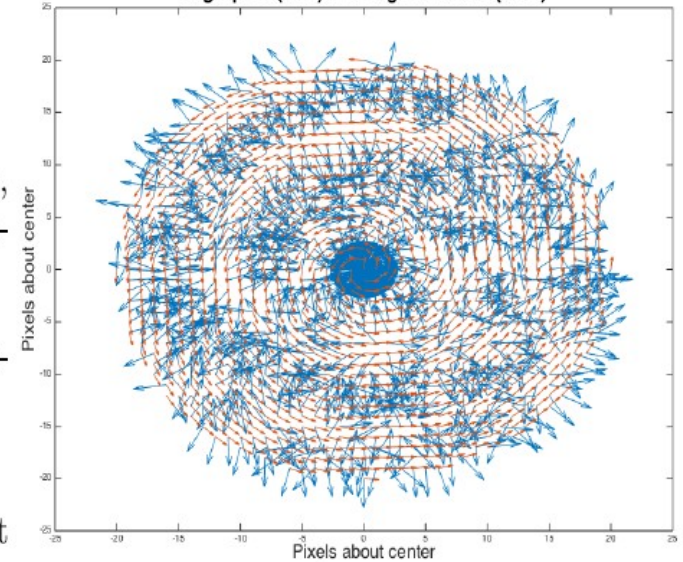
Hurricane Nadine Image
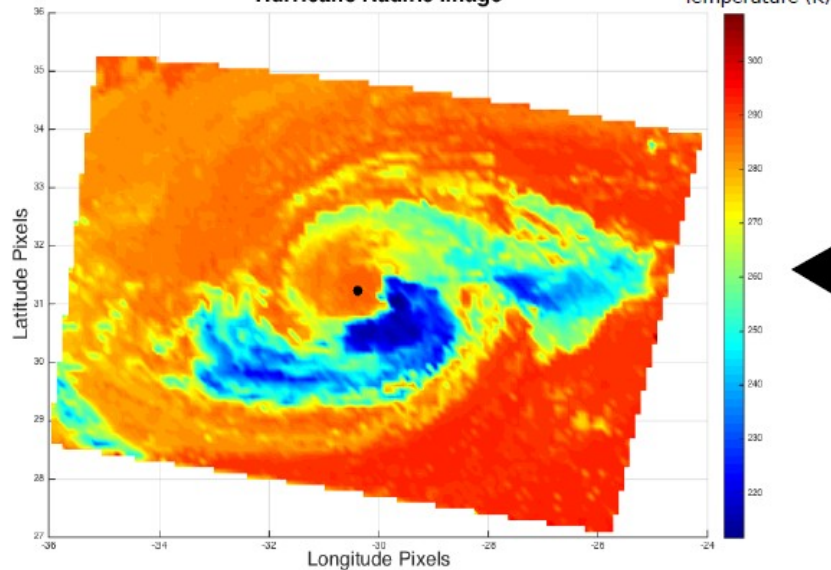
Eye Score

Eye Score

Eye Detection Results

Best Hurricane Track: SANDY

Best Hurricane Track: NADINE

Legend: Predicted, Actual

Conclusion: Overall, we are able to detect the eye center with varying accuracy. The spiral score technique produces low error for the stronger storms, but performs poorly for the weaker storms. We hope to improve this technique via topological and geometric data analysis. Finally, after improving eye detection, we will classify the intensity of the storm (a Dvorak number) using features extracted about the eye and spiral bands.

Error vs Intensity for Eye Finding (r=20, theta=5)

Legend: GONZALO, INGRID, NADINE, SANDY