The Dvorak Technique
(short version)

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WHERE AMERICA’S CLIMATE AND WEATHER SERVICES BEGIN
What is the Dvorak Technique?

It is a statistical method for estimating the intensity of tropical cyclones (TCs) from *subjective* interpretation of satellite imagery.

It uses regular Infrared (IR) and Visible (VIS) imagery.

It employs a “measurement” of the TC convective cloud pattern and a set of rules.

It is used at TC warning centers around the world.

What the Dvorak Technique isn’t!

A *direct measurement* of wind, pressure, or any other meteorological variable associated with a TC!

A replacement for *in situ* measurements of a TC

Based rigorously on the physical principles of the atmosphere
There is a (imperfect) correlation between the intensity of a TC and its satellite observed cloud pattern during both development and decay.
TC Cloud Patterns – Developing


Dvorak Technique Cloud Patterns

EYE TYPES

- Central Cold Cover (VIS and IR)
- Embedded Center (IR)
- Central Dense Overcast (VIS)
- Eye (VIS and IR)
- Shear (VIS and IR)
- Curved Band (VIS and IR)

DEVELOPMENTAL PATTERN TYPES

<table>
<thead>
<tr>
<th>DEVELOPMENTAL PATTERN TYPES</th>
<th>PRE-STORM</th>
<th>TROPICAL STORM</th>
<th>HURRICANE PATTERN TYPES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5 ± 0.5</td>
<td>T1.5 - T2.5</td>
<td>T0.5 - T1.5</td>
</tr>
<tr>
<td><strong>CURVED BAND PRIMARY PATTERN TYPE</strong></td>
<td></td>
<td>T2.5 - T3.5</td>
<td>T2.5 - T3.5</td>
</tr>
<tr>
<td><strong>CURVED BAND EIR ONLY</strong></td>
<td></td>
<td>T3.5 - T4.5</td>
<td>T3.5 - T4.5</td>
</tr>
<tr>
<td><strong>CDO PATTERN TYPE VIS ONLY</strong></td>
<td></td>
<td>T4.5 - T5.5</td>
<td>T4.5 - T5.5</td>
</tr>
<tr>
<td><strong>SHEAR PATTERN TYPE</strong></td>
<td></td>
<td>T5.5 - T6.5</td>
<td>T5.5 - T6.5</td>
</tr>
</tbody>
</table>

FOUR PRIMARY PATTERNS AND TYPICAL T-NOS.'S

- CURVED BAND
- SHEAR
- EYE
- CDO

PRE-STORM TD TS HURRICANE

T-NOS. 25 30 45 65 90 115 140 170
MAX. SPC. WIND (KNOTS)
The Dvorak Technique quantifies TC intensity on a 1-8 scale (at 0.5 intervals) called T-Numbers, which are used in a variety of ways.

The final output of the technique is the Current Intensity (CI) number.

The CI number is driven by the Final-T (FT) Number.

In turn, the FT is driven by the Data-T (DT) number, the Model Expected-T (MET) number, and the Pattern-T (PT or PAT) number.

The DT is often created from other sub-numbers.
# Dvorak Technique Output

<table>
<thead>
<tr>
<th>CI Number</th>
<th>1-minute MSW</th>
<th>NHC/CPHC/JTWC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kt) (mph) (km/h) (m/s)</td>
<td>MSLP (ATL/EPAC)</td>
</tr>
<tr>
<td>1.0</td>
<td>25 29 46 13</td>
<td>1009 mb</td>
</tr>
<tr>
<td>1.5</td>
<td>25 29 46 13</td>
<td>1005 mb</td>
</tr>
<tr>
<td>2.0</td>
<td>30 35 56 15</td>
<td>1000 mb</td>
</tr>
<tr>
<td>2.5</td>
<td>35 40 65 18</td>
<td>994 mb</td>
</tr>
<tr>
<td>3.0</td>
<td>45 52 83 23</td>
<td>987 mb</td>
</tr>
<tr>
<td>3.5</td>
<td>55 63 102 28</td>
<td>979 mb</td>
</tr>
<tr>
<td>4.0</td>
<td>65 75 120 33</td>
<td>970 mb</td>
</tr>
<tr>
<td>4.5</td>
<td>77 89 143 40</td>
<td>960 mb</td>
</tr>
<tr>
<td>5.0</td>
<td>90 104 167 46</td>
<td>948 mb</td>
</tr>
<tr>
<td>5.5</td>
<td>102 117 189 52</td>
<td>935 mb</td>
</tr>
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<td>6.0</td>
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<td>921 mb</td>
</tr>
<tr>
<td>6.5</td>
<td>127 146 235 65</td>
<td>906 mb</td>
</tr>
<tr>
<td>7.0</td>
<td>140 161 259 72</td>
<td>890 mb</td>
</tr>
<tr>
<td>7.5</td>
<td>155 178 287 80</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>170 196 315 87</td>
<td></td>
</tr>
</tbody>
</table>

Note: Other warning centers and basins use different pressures and wind averaging periods.
Dvorak Technique Procedure

Dvorak (1984) 10 Steps:

1. Locate center
2. Select cloud pattern and assign Data-T Number (DT)
3. Central Cold Cover (CCC; if applicable)
4. Analyze 24-h trend
5. Assign Model Expected T-Number (MET)
6. Assign Pattern T-Number (PT/PAT)
7. Use DT, MET, and PT to get Final T-Number (FT)
8. Apply FT constraints
9. Determine Current Intensity (CI)
10. Forecast 24-h Intensity (FI)
# Dvorak Technique Worksheet

## Tropical Cyclone Analysis Worksheet

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
<th>LOCATION</th>
<th>Curved Band or Shear</th>
<th>Eye</th>
<th>Ew - Ew = CF</th>
<th>CDG</th>
<th>Emb. Centr.</th>
<th>Data T-Number Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RULES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DATE/TIME</td>
<td>LAT</td>
<td>LONG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### T-Number Estimate from Measurements for Data T-Number (DT) Computation

1. Locate Cloud System Center at focal point of cloud curvature
2. Use Spiral Arc Length DT 1.5, DT 2.5, DT 3.5, DT 4.5
3. Use Size Rules
4. Adjust Model Fcast if nec.
### TROPICAL CYCLONE ANALYSIS WORKSHEET

From Vernon F. Dvorak
May 1982

**T-Number Estimates from Measurements for Data-T (DT) Computation**

<table>
<thead>
<tr>
<th>STEP</th>
<th>1.0</th>
<th>2A, B</th>
<th>2C</th>
<th>2D</th>
<th>2E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Location</td>
<td>Curved Band or Shear</td>
<td>Eye Pattern</td>
<td>Eye # + Eye Adj + Central Feature (CF)</td>
<td>Embedded Center</td>
</tr>
<tr>
<td>Rules</td>
<td>Locate cloud system center (CSC) at focal point of cloud curvature</td>
<td>Use spiral arc length (tenths) or shear distance (degrees latitude)</td>
<td>(VIS) Use embedded distance (deg. Latitude)</td>
<td>(EIR) Use surrounding temperature (shade on BD curve)</td>
<td>(VIS) Size of Central Dense Overcast (deg. latitude)</td>
</tr>
<tr>
<td>Data T-Number Computation</td>
<td>CF</td>
<td>BF</td>
<td>DT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From the VIS and EIR tables and rules</td>
<td>Use rules</td>
<td>From Step 4 trend</td>
<td>From use rules</td>
<td>Adjust model forecast if necessary</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date/Time (UTC)</th>
<th>Lat. (°N)</th>
<th>Lon. (°W)</th>
<th>2A</th>
<th>2B</th>
<th>2C</th>
<th>2D</th>
<th>2E</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT1.5</td>
<td>DT2.5</td>
<td>DT3.0</td>
<td>DT3.5</td>
<td>DT4.0</td>
<td>DT4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye number</td>
<td>Eye adjustment</td>
<td>CF</td>
<td>BF</td>
<td>DT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**T-Number Estimates from Model and DT Constraints**

<table>
<thead>
<tr>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7, 8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCC</td>
<td>Trend</td>
<td>MET</td>
<td>PAT</td>
<td>FT</td>
<td>CI</td>
<td>24-hour forecast</td>
</tr>
</tbody>
</table>

**Rules:**
- Locate cloud system center (CSC) at focal point of cloud curvature
- Use spiral arc length (tenths) or shear distance (degrees latitude)
- (VIS) Use embedded distance (deg. Latitude)
- (EIR) Use surrounding temperature (shade on BD curve)
- (VIS) Size of Central Dense Overcast (deg. latitude)
- (EIR) Embedded temperature (shade on BD curve)
- Data T-Number Computation
  - CF + Banding Feature (BF) = DT
- From 24-hr old FT and Step 4 trend
- From pictographs on the flowcharts
- Use rules
- Adjust model forecast if necessary

**List Rule Used:**
- Central Cold Cover
- Developing
- Steady
- Steady/Same
- Model Expected T-Number
- Final T-Number
- Current Intensity Number
- Forecast Intensity Number
- Analyst Initials
**Dvorak Technique Terms**

**CSC - Cloud System Center** - The center of the disturbance or cyclone. It is usually defined by an eye, a low level circulation center, or by other cloud features.

**CDO - Central Dense Overcast** - A dense solid-looking mass of clouds covering the CSC, often lying within the curve of the cyclone’s curved cloud band.

**CCC - Central Cold Cover** - A large cold or dense overcast covering the CSC that lacks structure and obscures the cyclone center.
Dvorak Technique Terms

**CI Number** - Current Intensity number - The final output of the Dvorak technique and the estimated intensity of the cyclone.

**DT Number** - Data-T number - The estimated intensity of the cyclone based on the convective cloud pattern.

**PT or PAT Number** - Pattern-T number - The intensity estimate from comparing the cyclone cloud pattern to predetermined patterns.
**Dvorak Technique Terms**

**MET Number** - Model Expected-T number - The intensity estimate from the 24-h old FT number and a determined intensity trend.

**FT Number** - Final-T number - The intensity estimate for a given time selected from the DT, PT, or MET numbers. It is used with a set of rules to determine the CI number for this time and the MET number 24 h later.

**FI Number** - Forecast Intensity number - 24 h intensity forecast based on the CI and observed signals in the cyclone cloud pattern and the environment.
**Eye Number** - Part 1 of the intensity estimate for an eye pattern based on surrounding cloud top temperatures (IR) or embedded distance in a CDO (VIS).

**Eye Adjustment** - Part 2 of the intensity estimate for an eye pattern based on eye temperature (IR) or eye size and clarity (VIS).
Dvorak Technique Terms

**CF Number** - Central Feature number - The part of the intensity estimate based on the central features of a cyclone. This number is produced by the eye, CDO, and embedded center patterns.

**BF Number** - Banding Feature number - The part of the intensity estimate based on the banding surrounding central features of a cyclone. This number can be used with the eye, CDO, and embedded center patterns.
Step 1 - Locate the Cloud System Center (CSC)

1. Locate the overall pattern center.
2. Look for small scale features.
3. Compare center location with forecast.
4. Compare center with previous pattern center.
5. Make final location adjustments.

Looking for lowest possible center in terms of altitude (Surface center if possible).
Step 1 – Locate the Cloud System Center (CSC)

In this image the CSC is the focal point of curved cloud lines.
### Typical Cloud Pattern Evolution

<table>
<thead>
<tr>
<th>Day</th>
<th>T1.5</th>
<th>T2.5</th>
<th>T3.5</th>
<th>T4.5</th>
<th>T5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Day 1" /></td>
<td><img src="image2" alt="Day 2" /></td>
<td><img src="image3" alt="Day 3" /></td>
<td><img src="image4" alt="Day 4" /></td>
<td><img src="image5" alt="Day 5" /></td>
<td></td>
</tr>
</tbody>
</table>

**Basic Curved Band Pattern Type**

| ![Day 1](image6) | ![Day 2](image7) | ![Day 3](image8) | ![Day 4](image9) | ![Day 5](image10) |

**Central Dense Overcast (CDO) Pattern Type**

| ![Day 1](image11) | ![Day 2](image12) | ![Day 3](image13) | ![Day 4](image14) | ![Day 5](image15) |

+ marks the expected center position

"Shear" Pattern Type
Expected CSC Positions for Curved Band Patterns (Wedge Method)

The expected center position is halfway between the end of the curved band (A) and the end of the associated dry slot or cloud minimum wedge (B).
CSC Curved Band Examples

Dry slot

Dry slot
Good first guess position is the upshear side of the strongest convection
CSC Eye Pattern Examples

Rita (2005) – clear eye

Gordon (2006) – ragged eye
CDO/Embedded Center Pattern CSC Examples

Look for overshooting tops

IR CSC position often uncertain
CSC Location Error - Didn’t Follow the Low Clouds

Marco (1996): A sheared and tilted system!
Potential Error - Shear Surprise

The previous day

Overnight

Surprise!

Hurricane Harvey (1981)
Animated Imagery

The technique center finding principles were designed for single images and not animation.

Animation can show the circulation associated with a tropical cyclone or disturbance and make center fixing easier.

Motions of high-level clouds can complicate center fixing, especially when using IR imagery or if the system is tilted.

Use of animation does not guarantee a correct center location!
Other types of imagery (including microwave) and enhancements may be used in finding the CSC. These may be especially useful at night.

The CSC of a weak system is not always a closed circulation center.

In a system with multiple centers, use a mean center position between the centers.

It’s hard to analyze the intensity if you don’t know where the cyclone is!
T. S. Lisa (1998) Multispectral Image
Cyclones with Multiple Centers

WESTPAC disturbance (2021) – Multiple swirls present – need to use a mean center (courtesy CIMSS)

Jeanne (2004) - New center forms northeast of the old exposed center (images are 3 h apart)
Step 1A - A T1 classification can be given when...

- A convective cluster has persisted for 12 h or more.

- The cluster has a CSC defined within a 2.5° latitude wide or less area which has persisted for 6 h.

- Associated convection is dark gray (DG) or colder on the Dvorak BD enhancement curve over an area >1.5° diameter less than 2° from the center.
An existing CSC that does not meet the criteria of Step 1A can be tracked as a system “too weak to classify” - a location without an intensity estimate.

Pre-Debby (2012) low – too weak to classify using the Dvorak Technique
Step 2 – Analyze the cyclone cloud pattern

The cloud pattern analysis produces the Data-T (DT) number intensity estimate.

Tool: Log 10° spiral for measuring curved bands

Tool: BD enhancement for infrared imagery

Cloud patterns can change considerably on time scales of a few hours.

Recognizing the correct cloud pattern is vital to a proper intensity analysis.
## BD Enhancement Curve

<table>
<thead>
<tr>
<th>Segment Number</th>
<th>Color Range</th>
<th>Cloud Top Temperature Range (°C)</th>
<th>Name/Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0-255</td>
<td>&gt;9.0</td>
<td>Warm Medium Gray (WMG)</td>
</tr>
<tr>
<td>3</td>
<td>109-202</td>
<td>9.0 to -30</td>
<td>Off White (OW)</td>
</tr>
<tr>
<td>4</td>
<td>60-60</td>
<td>-31 to -41</td>
<td>Dark Gray (DG)</td>
</tr>
<tr>
<td>5</td>
<td>110-110</td>
<td>-42 to -53</td>
<td>Medium Gray (MG)</td>
</tr>
<tr>
<td>6</td>
<td>160-160</td>
<td>-54 to -63</td>
<td>Light Gray (LG)</td>
</tr>
<tr>
<td>7</td>
<td>0-0</td>
<td>-64 to -69</td>
<td>Black (B)</td>
</tr>
<tr>
<td>8</td>
<td>255-255</td>
<td>-70 to -75</td>
<td>White (W)</td>
</tr>
<tr>
<td>9</td>
<td>135-135</td>
<td>-76 to -80</td>
<td>Cold Medium Gray (CMG)</td>
</tr>
<tr>
<td>10</td>
<td>85-85</td>
<td>&lt;-80</td>
<td>Cold Dark Gray (CDG)</td>
</tr>
</tbody>
</table>

The BD enhancement curve was developed in an era of 256 shades of gray technology.
On this image, light gray (LG) is the coldest BD color shade that completely surrounds the eye.
Step 2A – Measuring Curved Bands

Fit the spiral parallel to the inner edge of the band (VIS) or to the coldest tops in the band (IR)

Measure only the primary band of the cyclone - other bands don’t count

Endpoints of bands can be rather subjective

Important: The center of the log 10° spiral is usually **not** the center of the cyclone!

Note: Nature does not always produce bands with 10 degrees crossing angles 😊
Step 2A - Curved Band Patterns

These patterns are for both visible and infrared imagery. Use banding eyes in Step 2C for unusual band widths and lengths in visible imagery.

<table>
<thead>
<tr>
<th>Flow chart images</th>
<th>Spiral arc distance (tenths along log $10^\circ$ spiral)</th>
<th>Data-T Number (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; .20 Spiral DT 1.5 ± .5</td>
<td>0.20 - 0.35</td>
<td>1.0 to 2.0</td>
</tr>
<tr>
<td>.40 to .55 DT2.5</td>
<td>0.40 - 0.55</td>
<td>2.5</td>
</tr>
<tr>
<td>.60 to .75 DT3</td>
<td>0.60 - 0.75</td>
<td>3.0</td>
</tr>
<tr>
<td>.80 to 1.00 DT3.5</td>
<td>0.80 - 1.00</td>
<td>3.5</td>
</tr>
<tr>
<td>1.05 to 1.30 DT4</td>
<td>1.05 - 1.30</td>
<td>4.0</td>
</tr>
<tr>
<td>1.35 to 1.70 DT4.5</td>
<td>1.35 - 1.70</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Step 2A - Curved Band Example
Step 2A - Measuring Curved Bands

0.8 Banding - DT=3.5
Measure the distance (in degrees of latitude) from the low-level center to the edge of the dense overcast (VIS) or to the edge of the DG shade (IR).

The edge of the convection can be rather subjective.

Shear patterns tend to be rather unstable, as the convection often shows strong pulses or bursts. Therefore the DT is often considered not to be clear cut.

Shear pattern convection can dissipate between pulses/bursts to the point where a DT cannot be determined. The Pattern-T or Model Expected-T can be used to classify such systems.
### Step 2B

**Shear Patterns**

<table>
<thead>
<tr>
<th>Flow chart images</th>
<th>Distance from edge of convection or DG (tenths of deg latitude)</th>
<th>Data-T Number (DT)</th>
<th>Satellite Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Diagram 1]</td>
<td>1.25 – 0.75</td>
<td>1.0 to 2.0</td>
<td>![Image 1]</td>
</tr>
<tr>
<td>![Diagram 2]</td>
<td>0.74 – 0.50</td>
<td>2.5</td>
<td>![Image 2]</td>
</tr>
<tr>
<td>![Diagram 3]</td>
<td>0.49 from Cnvtn to 0.32 into Cnvtn</td>
<td>3.0</td>
<td>![Image 3]</td>
</tr>
<tr>
<td>![Diagram 4]</td>
<td>&gt;0.33 into Cnvtn</td>
<td>3.5</td>
<td>![Image 4]</td>
</tr>
</tbody>
</table>

**Note:** This is the 1984 version of the shear pattern measurements.
Step 2B - Measuring Shear Patterns

Shear Distance < 0.5°
DT=3.0
Notes on Steps 2A and 2B

When available, VIS curved band and shear patterns are preferable to their IR counterparts.

Curved bands and shear patterns directly produce DT numbers.

The measurements are the same for both VIS and IR imagery.

A possible intensity adjustment in the IR curved band pattern: Add 0.5 to the DT if the curved band is White (W) or colder.

Sandy (2012) with a White (W) or colder band – add 0.5 to the band DT!
Step 2C – Measuring Eye Patterns
Some Assembly Required!

Find the eye number (E-number).

Perform an Eye Adjustment.

Create the Central Feature (CF) number from the E-number and Eye Adjustment.

Add applicable banding features (BF) to the CF number to get the DT number.

There are significant differences between what is measured in the VIS and IR eye patterns as shown on the flow chart.
Step 2C - Visible Eye Patterns

1. Measure the distance (‘embedded distance’) from the center of the eye to the edge of the Central Dense Overcast (E-number).

2. Make eye adjustment based on size and clarity of eye (E-Number + Eye Adjustment = CF Number).

3. Add BF for applicable outer banding (CF + BF = DT).

Eye Adjustment Rules:
1. Poorly defined or ragged eyes: Subtract ½ for E ≤ 4.5 and 1 for E ≥ 5.
2. Large eyes: Limit T-no. to T6 for round, well-defined eyes, and to T5 for large ragged eyes.
3. For MET ≥ 6, .5 or 1 may be added to DT for well defined eye in smooth COO when DT < MET.

Banding Feature Additions:
1. 1/2
2. 1/4
3. 1/4
4. 1/4
5. 1/4
6. 1/4

If the eye pattern has 24 hr old T-no. ≥ T2?

Yes: Step 2A or 4

No: Step 2C

Embedded Distance

Average Band Width

Banding Eyes

Eye Adjustment?
E-no. + Eye Adj = CF

Banding Feature (BF)
CF + BF = DT
**Step 2C - Eye Patterns**

Visible Technique

<table>
<thead>
<tr>
<th>Eye in CDO - Embedded Distance (deg)</th>
<th>&gt;1</th>
<th>~1</th>
<th>~0.75</th>
<th>~0.5</th>
<th>~0.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banding Eye - Avg. Width of Band Around Eye (deg)</td>
<td></td>
<td></td>
<td>1.25</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>Eye Number (E#)</td>
<td>7.0</td>
<td>6.0</td>
<td>5.0</td>
<td>4.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Note: You can interpolate between the eye numbers when appropriate!

Is the 24-h old FT > 2.0? If not, go to step 2A or step 4.
Step 2C - Visible Eye Adjustment

VIS Eye Adjustment Rules:

1) Poorly defined or ragged eyes: subtract 0.5 for $E \leq 4.5$ and 1 for $E \geq 5$.

2) Large eyes (30 nm/56 km or greater): Limit $T$-no to $T6$ for round well-defined eyes and to $T5$ for large ragged eyes.

3) For $MET \geq 6$, 0.5 or 1 may be added to $DT$ for well-defined eye in smooth CDO when $DT < MET$. 
Step 2C - Visible Outer Banding

Banding Feature (BF) Numbers: Match the banding outside of the central convection to that shown in the pictograph.

Note: You can add multiple bands when applicable up to a total of 2.5 BF numbers.

Kirk (2012) – outer band on W side for +0.5 BF

Ike (2008) – multiple bands for +2.0-2.5 BF
Step 2C - Measuring a Visible Eye

The eye is $\frac{3}{4}$ degrees into the CDO (Eye number 5.0), with no Eye adjustment (0.0). This produces a CF5 + 2.0 for banding features $\rightarrow$ DT=7.0
Average band width 1.0° – Eye number = 4.5
Eye adjustment = -0.5 for CF4.0

Can also used a curved band with 1.2-1.3 banding for a DT=4.0+

E-number is determined by the average width of the band surrounding the eye.
The pattern uses the eye adjustment rules.
It is only used with visible imagery.
Step 2C - Infrared Eye Patterns

1. Find the coldest color on the BD enhancement that completely surrounds the eye with a thickness greater than the specified width (closed ring surrounding the eye).

2. Make eye adjustment based on the color on the warmest BD enhancement color in the eye (E-Number + Eye Adjustment = CF Number).

3. Add BF for applicable banding when IR banding rules apply (CF + BF = DT).

---

**Gray Shade Code (BD Curve)**

- **WNG** (Warm Medium Gray), > +9°C
- **OW** (Off White), +9 to -30°C
- **DG** (Dark Gray), -31 to -41°C
- **MG** (Medium Gray), -42 to -53°C
- **LG** (Light Gray), -54 to -63°C
- **B** (Black), -64 to -69°C
- **W** (White), -70 to -75°C
- **CNG** (Cold Medium Gray), -76 to -80°C
- **CDG** (Cold Dark Gray), ≤ -81°C

---

**Eye Temperature**

<table>
<thead>
<tr>
<th>EYE TEMPERATURE</th>
<th>WNG</th>
<th>OW</th>
<th>DG</th>
<th>MG</th>
<th>LG</th>
<th>B</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>WNG</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>-0.5</td>
</tr>
<tr>
<td>OW</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
</tr>
<tr>
<td>DG</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>-0.5</td>
<td>0</td>
<td>-0.5</td>
</tr>
<tr>
<td>MG</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
</tr>
<tr>
<td>LG</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
</tr>
<tr>
<td>W</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>-1.0</td>
<td>-1.0</td>
</tr>
</tbody>
</table>

---

**Addition Adjustments**

- **a.** Add 1/2 no.
- **b.** Add 1/2 no.
- **c.** Add 1 no.
# Step 2C - Eye Patterns

**Infrared Technique**

Is the 24-h old FT > 2.0? If not, go to step 2A or step 4.

<table>
<thead>
<tr>
<th>Surrounding BD Color</th>
<th>CMG</th>
<th>W</th>
<th>B</th>
<th>LG</th>
<th>MG</th>
<th>DG</th>
<th>OW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrowest width (deg)</td>
<td>≥0.5</td>
<td>≥0.5</td>
<td>≥0.5</td>
<td>≥0.4</td>
<td>≥0.4</td>
<td>≥0.3</td>
<td>≥0.3</td>
</tr>
<tr>
<td>Eye Number (E#)</td>
<td>6.5</td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
<td>4.5</td>
<td>4.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

**Eye Temperature**

<table>
<thead>
<tr>
<th>Sur. BD Color</th>
<th>W</th>
<th>OW</th>
</tr>
</thead>
<tbody>
<tr>
<td>OW</td>
<td>0</td>
<td>-0.5</td>
</tr>
<tr>
<td>DG</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MG</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LG</td>
<td>+0.5</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>+1.0</td>
<td>+0.5</td>
</tr>
<tr>
<td>W</td>
<td>+1.0</td>
<td>+0.5</td>
</tr>
<tr>
<td>CMG</td>
<td>+1.0</td>
<td>+0.5</td>
</tr>
</tbody>
</table>

**Eye Adjustment:**
Step 2C - Measuring an Infrared Eye

Light Gray (LG) is the coldest color surrounding the eye that meets the width criteria. The eye temperature is Warm Medium Gray (WMG). The Eye number is 5.0, while the Eye adjustment is +0.5 - CF=5.5
Step 2C - Size Doesn’t Matter for an Infrared Eye

The coldest color completely surrounding the eye is Black (B) even though that color is more than 60 n mi from the eye in some areas. The eye temperature is Off White (OW). The Eye number is 5.5 and the Eye adjustment is 0.5 – CF=6.0

Note: This is not in total agreement with page 36 of the manual!
Step 2C - BD Color Used For Eye Adjustment Can Differ From Color Used For Eye Number

Black (B) completely surrounds the eye. However, the B ring is less than 0.5 degrees thick. So, it cannot be used for the eye number. The eye number uses Light Gray (LG) for a 5.0, while the eye adjustment is determined by a Warm Medium Gray (WMG) embedded in B (+1.0) - CF=6.0
Step 2C - Infrared banding

\textit{Differs significantly} from visible banding

\textbf{Used only} when the CF/DT without banding is less than MET

\textbf{Used only} for cloud patterns of CF=4 or more

Band must be MG or colder while dry slot must be DG or warmer

Daniel (2012) – A potentially eligible IR outer band
Notes on Step 2C

VIS embedded distances are measured from the center of the eye for small eyes and the edge of the eye for **large** eyes (30 nm/56 km or more in diameter on VIS).

IR Eye Pattern is the most objective of all Dvorak measurements, but it cannot produce a DT=8.0 without adding banding.

Beware large satellite zenith/viewing angles and not being able to see to the bottom of the eye!

Beware sucker holes!
The satellite zenith/viewing angle of a TC can impact the Dvorak analysis. TCs close to the satellite have low zenith/viewing angles and thus are less of a problem. TCs far from the satellite (e.g. near the edge of a full disk scan) are a problem for IR analysis, as IR cloud top temperatures appear too cold. High zenith/viewing angles can also make it difficult to see to the bottom of the eye. Use the satellite closest to the TC for a Dvorak analysis if at all possible, and use IR DT numbers made at high zenith/viewing angles with caution.

METEOSAT-11 is at 0W, GOES-East at 75W, and GOES-West at 137.5W.
Problem: Can’t See the Bottom of the Eye

For small eyes (generally less than 10 n mi wide), the satellite may not be able to measure the warmest temperature at the bottom of the eye. This can result in an underestimate of the intensity in both subjective and objective Dvorak techniques.

High zenith/viewing angles also make it difficult to see to the bottom of the eye even when they are larger than 10 n mi wide.

Wilma 2005 - Eye diameter 4 n mi
GOES Eye temperature ~ 0C
NOAA/Aqua Eye temperature ~ +20C
How strong are these?

Supertyphoon Haiyan (T8.0)
Western North Pacific,
1630Z 7 November 2013

Hurricane Patricia (180 kt)
Eastern North Pacific,
0645Z 23 October 2015
Steps 2D and 2E - Central Dense Overcast (CDO) and Embedded Center Patterns

Patterns are complimentary - CDO uses VIS imagery and Embedded Center uses IR.

Both patterns directly produce CF numbers.

CDO pattern measures the size of the CDO.

Embedded Center pattern measures how far the CSC is embedded into specified colors on the BD curve.

All banding rules from Eye patterns apply to CDO and Embedded Center patterns.

<table>
<thead>
<tr>
<th>From Vernon F. Dvorak May 1983</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STEP</strong></td>
</tr>
<tr>
<td><strong>1.0</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td><strong>Rules</strong></td>
</tr>
<tr>
<td><strong>Data/Time (UTC)</strong></td>
</tr>
</tbody>
</table>
### Steps 2D and 2E - CDO and Embedded Center Patterns

#### Step 2D - Is the CDO ≥ 0.75 deg wide? If not, go to step 2A or step 4.

<table>
<thead>
<tr>
<th>CDO edge is:</th>
<th>Well-defined</th>
<th>Irregular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (deg)</td>
<td>≥2.25</td>
<td>1.75</td>
</tr>
<tr>
<td>Central Feature Number (CF)</td>
<td>5.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

#### Step 2E - Is the 12 hour old FT ≥ 3.5? If not, go to step 2A or step 4.

<table>
<thead>
<tr>
<th>Surrounding BD Color</th>
<th>W or colder</th>
<th>B</th>
<th>LG</th>
<th>MG</th>
<th>DG</th>
<th>OW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedded distance (deg)</td>
<td>≥0.6</td>
<td>≥0.6</td>
<td>≥0.5</td>
<td>≥0.5</td>
<td>≥0.4</td>
<td>≥0.4</td>
</tr>
<tr>
<td>Central Feature Number (CF)</td>
<td>5.0</td>
<td>5.0</td>
<td>4.5</td>
<td>4.0</td>
<td>4.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Step 2D - Measuring a CDO

The CDO is about 2 deg wide – $\text{CF}=4.5 + 1.0$ for banding around the CDO $\rightarrow DT=5.5$
Step 2E - Measuring an Embedded Center

CSC embedded in W - DT=5.0

Maria (2017)
Microwave Data Helped Interpret This Pattern

0430 UTC 27 August 2004 GOES-10 IR TS Georgette

0000 UTC Classification
6/10 Banding DT=3.0 or 45 kt

0600 UTC Classification
“Really an embedded center but constrained to not use it”
3.5/3.5 = 55 kt
Notes on Steps 2D and 2E

Edge of CDO is often subjective.

You can interpolate between the CDO CF numbers when appropriate.

For an elliptical CDO, the CDO size is the average of the sizes of the long and short axes of the ellipse.

Embedded Center pattern can only be used when the 12-h old FT is 3.5 or greater as otherwise it can produce unrealistically high intensity estimates.

Embedded Center pattern is an uncertain Dvorak measurement - where the classifier puts the CSC makes a significant difference in the intensity estimate.

When available and appropriate, use of VIS CDO is preferable to use of IR embedded center.
To summarize the cloud pattern types...

<table>
<thead>
<tr>
<th>PATTERN</th>
<th>IMAGE</th>
<th>INTENSITY GIVEN BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURVED BAND</td>
<td>VIS, EIR</td>
<td>SPIRAL DISTANCE OF BAND SURROUNDING CENTER</td>
</tr>
<tr>
<td>SHEAR</td>
<td>VIS, EIR</td>
<td>DISTANCE OF CENTER FROM EDGE OF DEEP CB CLOUDS AND CENTER DEFINITION</td>
</tr>
<tr>
<td>CDO (Central Dense Overcast)</td>
<td>VIS</td>
<td>SIZE OF CDO AND BANDING</td>
</tr>
<tr>
<td>CDO (Embedded Center)</td>
<td>EIR</td>
<td>SURROUNDING TEMP.</td>
</tr>
<tr>
<td>EYE</td>
<td>VIS</td>
<td>DISTANCE OF EYE FROM CDO EDGE AND BANDING</td>
</tr>
<tr>
<td>EYE</td>
<td>EIR</td>
<td>SURROUNDING TEMP. AND EYE TEMP.</td>
</tr>
</tbody>
</table>
Step 3 - Central Cold Cover Pattern

Central Cold (Dense) Cover Pattern

Rules: When past T-no. $\leq T_3$, maintain model trend for 12 hours; then hold same. When past T-no $\geq T_{3.5}$ hold T-no same. Use as final T-no; then go to Step 9

Danielle (2010) – a likely CCC pattern

It is also known as “bursting” pattern.

It can resemble shear or CDO/embedded center patterns.
Steps 4 and 5 - Determine 24-h Trend and Model Expected T-Number (MET)

The Dvorak Technique employs a conceptual model of TC growth and decay rates over 24-h periods to help filter the diurnal convective variations observed in TC cloud patterns.

For trend purposes, always use 24-h comparisons even though intensity estimate are made more frequently (e.g. every 6 h).

24-h trends are reported as Developing, Weakening, or Steady.

### T-Number Estimates from Model and DT Constraints

<table>
<thead>
<tr>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7, 8</th>
<th>9</th>
<th>10</th>
<th>24-hour forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCC</td>
<td>Trend</td>
<td>MET</td>
<td>PAT</td>
<td>FT</td>
<td>CI</td>
<td>Adjust model forecast if necessary</td>
<td></td>
</tr>
<tr>
<td>Use rules</td>
<td>24-h change</td>
<td>From 24-h old FT and Step 4 trend</td>
<td>From pictographs on the flowcharts</td>
<td>Use rules</td>
<td>Use rules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Cold Cover</td>
<td>Developing</td>
<td>Developing, W - Steady, S</td>
<td>Model Expected T-Number</td>
<td>Pattern T-Number</td>
<td>Final T-Number</td>
<td>Current Intensity Number</td>
<td>List Rule Used</td>
</tr>
</tbody>
</table>
Dvorak Model Development Curves

In the Dvorak conceptual model, ‘normal’ strengthening or weakening is 1 T-number/day. Rapid changes are 1.5 T-numbers per day, while slow changes are 0.5 T-numbers/day.

Note: Eyewall replacement cycles are not part of the Dvorak conceptual model.
**Step 4 - Determine 24-h Trend**

<table>
<thead>
<tr>
<th>Developing</th>
<th>Weakening</th>
<th>Steady</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased convection near CSC (larger or colder CDO)</td>
<td>Decreased convection near CSC (smaller or warmer CDO)</td>
<td>No noticeable 24-h change</td>
</tr>
<tr>
<td>Increased curved banding (primary band or bands around the CDO)</td>
<td>Decreased curved banding</td>
<td>Both developing and weakening signs present (mixed signals)</td>
</tr>
<tr>
<td>Eye forms, or becomes warmer, or more distinct</td>
<td>Eye disappears, or becomes cooler, or less distinct</td>
<td>CCC in a cyclone of T3.5 or greater or CCC for 12 h or more in a weaker cyclone</td>
</tr>
<tr>
<td>Exposed center closer to overcast</td>
<td>Exposed center further from overcast or covered center becomes exposed</td>
<td></td>
</tr>
<tr>
<td>Increased curvature of low clouds near CSC</td>
<td>Decreased curvature of low clouds near CSC</td>
<td></td>
</tr>
</tbody>
</table>
Step 5 - Model Expected T-Number

The MET is a first guess estimate of the intensity based on the 24-hold Final T-Number and the current determined 24-h trend.

For a Steady trend, the MET = the 24-h old FT.

The MET for the first classification of a system is 1.0.
Step 5 - Model Expected T-Number
Rapid or Slow Changes

Two consecutive previous Dvorak measurements of rapid or slow development/weakening are needed to establish rapid or slow 24-h changes.

- Look at the previous two FT values and compare them to the respective FT values from 24 h prior.
- If the difference between both of these values is more (less) than 1.0, then you have rapid (slow) development/weakening (add the +/- to the D or W).
- This does not count the measurement your currently making.

Or, one previous Dvorak measurement of rapid development/weakening and signs of strong intensification or weakening (Step 10, rules C and A).
Step 5 - Model Expected T-Number
Rapid or Slow Changes

Example: For the upcoming fix for 00Z/14 Oct 2014, note there are two consecutive 24-h changes in the column labeled “FT 24h Change”. If the 24-h trend for the 00Z /14 Oct fix is weakening, the prior trends justify a W+, since there are two consecutive 24-h changes for FT that are more than 1.0.

<table>
<thead>
<tr>
<th>Name</th>
<th>Satellite Image Info</th>
<th>Cloud System Center Location</th>
<th>Classification Type</th>
<th>Tropical Pattern</th>
<th>FT</th>
<th>CI</th>
<th>FT -24h</th>
<th>FT 24h Change</th>
<th>FT 12h Change</th>
<th>Fix</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL072014</td>
<td>13 Oct 17:45</td>
<td>33.7</td>
<td>-51.0</td>
<td>Weak</td>
<td>---</td>
<td>1.5</td>
<td>2.5</td>
<td>4.5</td>
<td>-3.0</td>
<td>-2.0</td>
</tr>
<tr>
<td>AL072014</td>
<td>13 Oct 11:45</td>
<td>34.2</td>
<td>-53.6</td>
<td>Trop</td>
<td>shr</td>
<td>2.5</td>
<td>3.0</td>
<td>4.0</td>
<td>-1.5</td>
<td>-2.0</td>
</tr>
<tr>
<td>AL072014</td>
<td>13 Oct 5:45</td>
<td>34.4</td>
<td>-57.0</td>
<td>Trop</td>
<td>shr</td>
<td>3.5</td>
<td>4.5</td>
<td>3.5</td>
<td>0.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>AL072014</td>
<td>12 Oct 23:45</td>
<td>35.7</td>
<td>-59.0</td>
<td>Trop</td>
<td>embctr</td>
<td>4.5</td>
<td>4.5</td>
<td>3.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>AL072014</td>
<td>12 Oct 17:45</td>
<td>34.3</td>
<td>-62.2</td>
<td>Trop</td>
<td>embctr</td>
<td>4.5</td>
<td>4.5</td>
<td>3.0</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>AL072014</td>
<td>12 Oct 11:45</td>
<td>33.1</td>
<td>-63.8</td>
<td>Trop</td>
<td>embctr</td>
<td>4.0</td>
<td>4.0</td>
<td>3.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>AL072014</td>
<td>12 Oct 5:45</td>
<td>31.6</td>
<td>-64.7</td>
<td>Trop</td>
<td>shr</td>
<td>3.5</td>
<td>3.5</td>
<td>3.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Notes on steps 4 and 5

The trend for step 4 is determined by examining satellite images 24 h apart.

The trend for the initial classification is always a normal D.

You need at least 24 h of Dvorak classifications to change the development trend. The first 18 h after the initial T1 are always a normal D.

Changes in the development rate for step 5 from D to D- or D+ (or W to W- or W+) need to use the technique rules. Just because you think you are on a different development rate does not allow you to change it arbitrarily!
Step 6 - Pattern T-Number (PT or PAT)

Choose the Pattern T-number by comparing the cyclone cloud pattern to the diagrams on the flow charts.

PATs above T6 require extrapolation!

If the PT is 1 or more T-numbers from the MET, check your work!
Step 6 - Pattern T-Number (PT or PAT)

Megi (2010) – PT ??

Sandy (2012) – PT 2.0a

Isaac (2012) – PT 3.0b

Ivan (2004) – PT ??

<table>
<thead>
<tr>
<th>PT 1.5±0.5</th>
<th>PT 2.5</th>
<th>PT 3.5</th>
<th>PT 4</th>
<th>PT 5</th>
<th>PT 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. When cloud comma is extremely small (<2.5° lat), subtract 1 from pattern number.

b. When hatched part of these patterns is white or colder, add .5 to pattern number.
Step 7 - Final T-Number (FT)

Choose the FT from the DT, PT and MET:

- Use DT from Step 2 when cloud features are *clear-cut*.
- Use PT from Step 6 when DT is not clear and when PT is different from MET.
- For all other cases, use the MET from Step 5.

Beware constraints! (Step 8)
What comprises a clear-cut DT?

**What comprises clear cut:**
- An unambiguous cloud pattern measurement. For example, an infrared eye measurement is often considered clear cut.
- Measurements using multiple cloud pattern types that give the same DT

**What does not:**
- Ambiguous or hard to measure/interpret cloud pattern measurements. For example, shear pattern measurements are often not clear cut.
- Measurements using multiple cloud pattern types that give different DTs
Step 8 - FT Constraints

1. Initial classification must be T1 or T1.5.

2. During first 24 h of development, FT cannot be lowered at night.

3. 24 h after initial T1, FT must be ≤ 2.5.

4. Modified FT limits (next slide)

5. FT must = MET ± 1

Note: The CI never constrains the FT!
**Step 8 - FT Number Change Limits**

For **early development**: 0.5 T-numbers over 6 h

<table>
<thead>
<tr>
<th>Original FT Constraints for storms with ( T \geq 4.0 ) (Dvorak):</th>
<th>Modified FT Constraints now used for developing storms above T1.5 (24 h or more after the initial T1) (Pike NHC study):</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 T-numbers over 6 h</td>
<td></td>
</tr>
<tr>
<td>1.5 T-numbers over 12 h</td>
<td></td>
</tr>
<tr>
<td>2.0 T-numbers over 18 h (Now 2.5)</td>
<td></td>
</tr>
<tr>
<td>2.5 T-numbers over 24 h (Now 3.0)</td>
<td></td>
</tr>
</tbody>
</table>

These are the **maximum** changes in FT number allowed over the given time periods.
Step 9 - Current Intensity Number (CI)

During the initial development and some stages of re-development, CI = FT

For weakening or re-developing systems, hold the CI to the highest FT during the preceding 12 h, but never more than 1.0 above the current FT

CI is never < FT!
## Step 9 - CI Examples

(6 h intervals)

<table>
<thead>
<tr>
<th>FT/CI</th>
<th>FT/CI</th>
<th>FT/CI</th>
<th>FT/CI</th>
</tr>
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- **Steady rapid development**
- **Accelerating weakening**
- **Interrupted weakening**
- **Weakening, then re-development**
Step 9 - What’s wrong here?
(6 h intervals)

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Step 9 - What’s wrong here? (6 h intervals)

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Development constraints all broken  CI > 1.0 above FT  CI needs to be held to highest FT during the past 12 h
<table>
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<th>Why are there constraints on the FT and CI?</th>
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<td><strong>Weak systems sometimes lose all convection during the diurnal minimum.</strong></td>
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<tr>
<td><strong>Cloud patterns for weak systems sometimes look unrealistically strong.</strong></td>
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<td><strong>Strong systems sometimes don’t intensify as quickly as the cloud pattern suggests.</strong></td>
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<tr>
<td><strong>In weakening systems, the decay of winds and pressures usually somewhat lags behind that of the cloud pattern.</strong></td>
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<tr>
<td><strong>Issue of constraints can be quite controversial!</strong></td>
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Some tropical cyclones clearly violate the Dvorak development constraints. Wilma deepened from 970 mb to 882 mb in ~12 h.
Air recon best track intensity lagged behind Dvorak estimates during intensification.
Cyclones Stronger Than They Appeared

At peak intensity, Dorian was stronger than its Dvorak satellite signature, as was Andrew in 1992.
Cyclones Stronger Than They Appeared

Reconnaissance data showed Debby and Sandy were stronger than their Dvorak intensity estimates. Dvorak estimates are less reliable for monsoonish cyclones (Debby) and partly baroclinic cyclones (Sandy).
Reconnaissance data showed Jeanne and Ernesto were not as strong as their satellite appearance. The cloud patterns weakened after these images.
Dvorak Error Distribution

**Distribution of Dvorak Classification Errors (1998-2012)**

- Fifty percent of the Dvorak intensity estimates are within 6 kt of the best track intensity, 75% are within 12 kt and 90% are within 18 kt.

**Distribution of Dvorak Position Errors (1998-2012)**

- Fifty percent of the Dvorak position estimates are within 11 nm of the best track position, 75% are within 20 nm and 90% are within 33 nm.

Images courtesy of Brown and Franklin
Step 10 - Forecast Intensity (FI)

This is a 24-h forecast of the intensity based on the current CI and satellite-observed signals in the cyclone cloud pattern and the environment.

The set of rules has not been consistent through the revisions of the technique.
A Few More Tips

Previous daylight satellite imagery may help locate CSCs during night shifts.

If time permits, try multiple methods of classifying one system to see if the Data-T numbers agree (e.g., curved band and CDO or VIS and IR eyes) - if they don’t, use the Data-T number closest to the MET.

Some imagers (DMSP/OLS, NPP/VIIRS) are sensitive enough to provide moonlight visible imagery, thus allowing use of VIS cloud patterns and center location at night.

Humberto (2019) NPP VIIRS Lunar Reflectance Moonlight Visible Imagery
Related Techniques

- Hebert-Poteat Subtropical Cyclones Technique
- Automated/Objective Dvorak Technique
- ARCHER Objective TC center location
- Microwave sounding-based TC intensity estimates
- Satellite Consensus (SATCON) Technique
- Experimental Techniques - Microwave Data and Other Approaches
Acknowledgements

• Vernon Dvorak – creator of the technique and of much of the material in these presentations
• Max Mayfield (former NHC director) – the previous teacher of the technique whose class material was the foundation for these presentations
• Ray Zehr (formerly of the Cooperative Institute For Research in the Atmosphere at Colorado State University) – several examples are from his Dvorak training module
• Andrew Burton (Australia Bureau of Meteorology) – whose comments helped improve the presentations
• Todd Kimberlain (formerly of NHC) – collaborator in updating these presentations
• James Franklin and Dan Brown (NHC) – Dvorak Technique error slide
• The Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin – many satellite images and related technique material
• The Cooperative Institute for Research in the Atmosphere at Colorado State University – satellite imagery and animations
• The Naval Research Laboratory, Monterey, CA – satellite images
• NASA – satellite images
• Liz Ritchie (UNSW), Margie Kieper (FIU) for related technique material