Central Pacific
Tropical Cyclone Climatology

- Season: June 1 to November 30
- Central Pacific Average per Year
  - 4 - 5 Tropical Cyclones
  - 1 - 2 Hurricanes
  - 1 - 2 Tropical Storms
  - 1 - 2 Tropical Depressions
CPHC Staff

• 20 Meteorologists
  – 5 Hurricane Specialists

• 4 Management Meteorologists
  – Proficient in tropical cyclone forecasting

• Operate 24 hours a day, 7 days a week
  – 4 meteorologists on duty

• Backup for National Hurricane Center in the eastern Pacific east of 140W
Dvorak Technique:
An Introduction

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Hurricane Specialist
Central Pacific Hurricane Center

Acknowledgements:
Jack Bevin, National Hurricane Center
Peter Donaldson, Central Pacific Hurricane Center
Robert Ballard, Central Pacific Hurricane Center
What the Dvorak Technique Is

- An empirical method for estimating the intensity of a tropical cyclone from visible and infrared satellite imagery
- Based on a “measurement” of the cyclone’s convective cloud pattern and a set of rules
What the Dvorak Technique Is Not

- A direct measurement of wind, pressure, or any other meteorological variable associated with a tropical cyclone!

- A replacement for *in situ* measurements of a tropical cyclone
Dvorak Technique Premise

- Tropical cyclones have characteristic evolutions of cloud patterns that correspond to stages of development and certain intensities
- The technique was not designed to be used with high resolution or short interval data
- If you are trying to analyze features only apparent on high resolution or short interval data you are probably on the wrong track
Dvorak Technique
Essential Output

- Estimated location of the tropical cyclone center
- Estimated tropical cyclone intensity (CI)
  - Maximum sustained wind speed (MSW)

<table>
<thead>
<tr>
<th>CI</th>
<th>MSW (kt)</th>
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<tbody>
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Dvorak Technique
History & Accuracy

• Developed in 1970s and 1980s

• Verification:
  – 85% of MSW estimates within ~10 kt of reconnaissance
  – 50% of MSW estimates within 5 kt of reconnaissance (Brown and Franklin, 2004)

• Still an essential tool today!

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Definitions

• Data T (DT): Intensity estimate based only on measurements of satellite imagery

• Model T (MET): Intensity estimate based only on 24 hour comparisons

• Pattern T (PAT): Intensity estimate based on general cloud pattern

• Final T (FT): Intensity estimate based on DT, MET, or PAT

• Current Intensity (CI): Intensity estimate based on FT
Initial Dvorak Fix

- Earliest signs of development are typically observed 1 to 1.5 days before disturbance reaches tropical storm intensity
- Initial Dvorak fix conducted when a cluster of convective clouds showing curvature has three properties:
  1. System has persisted for 12 hours or more
  2. System center defined in area 2.5° latitude or less which has persisted for 6 hours
  3. System possesses an area of dense, cold overcast less than 2° from the center
Dvorak Technique
Cloud Patterns

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

- Curved Band (VIS and IR)
Dvorak Technique
Cloud Patterns

- Shear (VIS and IR)
Dvorak Technique
Cloud Patterns

• Eye (VIS and IR)
Dvorak Technique
Cloud Patterns

• Central Dense Overcast (VIS)
Dvorak Technique
Cloud Patterns

- Embedded Center (IR)
The Dvorak Technique possesses a clear set of rules.

Most rules needed for a complete analysis are stated on the flowcharts.

There are two flowcharts, one each for visible and infrared imagery.
Dvorak Technique Flowchart

- Step 1: Locate the cloud system center
Dvorak Technique Flowchart

- Step 2: Determine DT by analyzing the intensity using satellite based measurements.
• Step 4: Determine intensity change in the past 24 hours in order to:
• Step 5: Determine MET
• Step 6: Determine PAT
- Step 7: Determine FT from either the DT, MET, or PAT
- Step 8: Consider constraints to FT and make any needed adjustments
Dvorak Technique Flowchart

- Step 9: Determine CI based on FT
• Step 1: Locate the cloud system center.
Step 1 - Locate the Cloud System Center

- Locate the Overall Pattern Center
- Examine for Small Scale Features
- Compare Center with Previous Pattern Center
- Compare Center Location with Forecast
- Make Final Center Adjustments
- Looking for Lowest Possible Center
- Tip: imagery animation is crucial
Step 1 - Locate the Cloud System Center

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Step 1 - Locate the Cloud System Center

- Examine for Small Scale Features
  - Indications of an eye
  - Low level cloud line curvature
  - Cloud line mergence
  - Cloud minimum areas
  - Middle of upper level cloud features such as band curvature and cumulonimbus tops
Step 1 - Locate the Cloud System Center: Curved Band

- Draw line from dry slot tip (B) to end of curved band (A)
- Overall center at line mid point
- Confidence is inversely proportional to line length
Step 1 - Locate the Cloud System Center: Curved Band
Step 1 - Locate the Cloud System Center: Shear Pattern

- Examine for Small Scale Features

- Shear patterns can pose a significant center finding challenge, especially at night
Step 1 - Locate the Cloud System Center: Eye Pattern

- Examine for Small Scale Features
- Eye patterns typically pose less center finding challenge
Step 1 - Locate the Cloud System Center: Embedded Center & CDO Patterns

- Examine for Small Scale Features

- Embedded center and CDO patterns often pose a center finding challenge
Step 1 - Locate the Cloud System Center

- Locate the Overall Pattern Center
- Examine for Small Scale Features
- Compare Center with Previous Pattern Center
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- Looking for Lowest Possible Center
- Tip: imagery animation is crucial
Step 1 - Locate the Cloud System Center

- **Compare Center with Previous Pattern Center**
  - Track center features from prior images
  - Best done with animation
Step 1 - Locate the Cloud System Center

- Locate the Overall Pattern Center
- Examine for Small Scale Features
- Compare Center with Previous Pattern Center
- Compare Center Location with Forecast
- Make Final Center Adjustments
- Looking for Lowest Possible Center
- Tip: imagery animation is crucial
Step 1 - Locate the Cloud System Center

- Compare Center Location with Forecast
  - w is evening psn
  - Vertical wind shear about to develop
  - x is extrap 6 hr psn
  - y is extrap 12 hr psn
  - Analyst chose center at arrow, following cloud curvature
Step 1 - Locate the Cloud System Center

- Compare Center Location with Forecast
  - In 18 hrs, system center moved from point w to point z
  - Sunrise surprise!
Step 1 - Locate the Cloud System Center

- Locate the Overall Pattern Center
- Examine for Small Scale Features
- Compare Center with Previous Pattern Center
- Compare Center Location with Forecast
- Make Final Center Adjustments
- Looking for Lowest Possible Center
- Tip: imagery animation is crucial
• Step 2: Determine DT by analyzing the intensity using satellite based measurements
Step 2 – Measure to Find DT

• Select cloud pattern type
• Measure cloud features that relate to intensity to obtain DT
• If cloud patterns show no resemblance to patterns, proceed to rarely used Step 3: Central Cold Cover
• Note: DT does not necessarily give the final intensity estimate!
Step 2 – Measure to Find DT: Curved Band

- Most common pattern
- Curved band axis parallel to inner edge of band
- Measure amount of curvature
- Can average images
Step 2 – Measure to Find DT: Shear Pattern

- For less than typhoon intensity
- Factors:
  - Definition of center
  - Distance between center and dense overcast
- Easier with VIS
Step 2 – Measure to Find DT: Eye Pattern

- Most complex
- Must make several measurements and adjustments
- Add banding feature for VIS or eye adjustment for IR

### Eye Temperature

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<tr>
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<th>WMG</th>
<th>OW</th>
<th>DG</th>
<th>MG</th>
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Surr. Ring Temp

2c "Eye" Pattern

Narrowest Width Surrounding Gray Shade

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Step 2 – Measure to Find DT: Central Dense Overcast

- VIS only
- Measure size and definition of CDO
- Add banding feature
Step 2 – Measure to Find DT: Embedded Center

- IR only
- For strong TS or typhoon
- Determine coldest overcast that center is embedded within a required distance
- Can add banding feature
- Highly sensitive to center position!
Dvorak Technique Flowchart

Steps 4 – 6: Model Comparisons

• Step 4: Determine intensity change in the past 24 hours in order to:
  • Step 5: Determine MET
  • Step 6: Determine PAT
  • Many errors made here!
Step 4 – Determine Intensity Trend

- Compare cloud pattern now to 24 hours prior
- Determine if system has developed (D), weakened (W), or remained steady state (S)
- Development (D):
  - Increased dense overcast around center
  - Increased center definition

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<tr>
<th>DEVELOPMENTAL PATTERN TYPES</th>
<th>PRE STORM</th>
<th>TROPICAL STORM (Minimal)</th>
<th>TROPICAL STORM (Strong)</th>
<th>HURRICANE PATTERN TYPES (Minimal)</th>
<th>HURRICANE PATTERN TYPES (Strong)</th>
<th>HURRICANE PATTERN TYPES (Super)</th>
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Step 4 – Determine Intensity Trend

24 hours ago

24 hour change: Developed (D)

Based on: increased amount of curved band axis has formed around the TC center

now
Step 5 – Determine MET

- Add or subtract trend obtained in Step 4 from the 24 hour old FT
- For normal Development or Weakening:
  - MET = 24 hr old FT ± 1.0
- For rapid Development (D+) or Weakening (W+):
  - MET = 24 hr old FT ± 1.5
- For slow Development (D-) or Weakening (W-):
  - MET = 24 hr old FT ± 0.5
- For a Steady State (S) trend:
  - MET = the 24 hr old FT
Step 6 – Determine PAT

- PAT is an adjustment to MET
- PAT = MET or MET ± 0.5
- If PAT ≠ MET ± 0.5, adjust MET by 0.5, if possible
- Many errors made here!

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<thead>
<tr>
<th>PT 1.5±.5</th>
<th>PT 2.5</th>
<th>PT 3.5</th>
<th>PT 4</th>
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Dvorak Technique Flowchart
Step 7 – 9: FT & CI

- Step 7: Determine FT from either the DT, MET, or PAT
- Step 8: Consider constraints to FT and make any needed adjustments
- Step 9: Determine CI based on FT
Step 7 - Determine FT

• Use DT when cloud features are clear cut
• Use PAT when DT is not clear cut and MET was adjusted
• Otherwise, use MET
• Rule underscores need for good MET & PAT!

T-no. Determination:

1. Use data T-no. from Step 2 when cloud features are clear-cut.

2. Use Pattern T-no. when DT is not clear and adjustment to MET is made.

3. For all other cases, use the MET.
Step 8 - FT Constraints

- These include the constraints that are, at times, broken in special cases
- If constraints are broken, explain why to colleagues
- If necessary, go back and conduct a reanalysis...You may not be breaking constraints after all!
  - Dvorak encourages reanalysis as a routine

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<th>Final T-number Constraints:</th>
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<td>1. Initial classification must be T1 or T1.5.</td>
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<td>2. During first 48 hours of development, T-no. cannot be lowered at night.</td>
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<td>3. 24 hrs after initial T1, storm's T-no. must be &lt; T2.5.</td>
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<tr>
<td>&gt; T4: change of 1 over 6 hrs, T.5 over 12 hrs, 2 over 18 hrs, and 2.5 over 24 hrs.</td>
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<tr>
<td>5. Final T-no. must = MET ± 1.</td>
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Step 9 – Determine CI

- For developing cloud patterns:
  - CI = FT

- For weakening cloud patterns:
  - For initial weakening in first 12 hours, hold CI same
  - Beyond 12 hours, CI remains 0.5 to 1.0 higher than FT

- For redevelopment:
  - CI remains same until FT rises to CI

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Reanalysis

- 24 hrs after initial fix, FT must be $\leq 2.5$. If not, you might want to consider a reanalysis

- Doing a reanalysis can help get better results down the road (what you do now can affect the 3rd, 4th, 5th, etc fix) – You may not be breaking constraints on the 4th fix after all!

- Some systems legitimately break constraints

- Reanalysis should be a routine consideration
Dvorak Technique
Error Reduction

• Follow the rules!
• A good MET & PAT are important
• Reanalysis is usually a better option than breaking constraints
• Communicate reasoning for reanalysis or breaking constraints
Summary

- The Dvorak Technique is a time-tested method employing geostationary imagery
- Output: center position and intensity
- Intensity estimates proven to be reliable
- Follow the rules on the flowchart
- Do not fear a reanalysis
- Even if your agency does provide intensity estimates, the center finding guidance is essential
Questions?

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