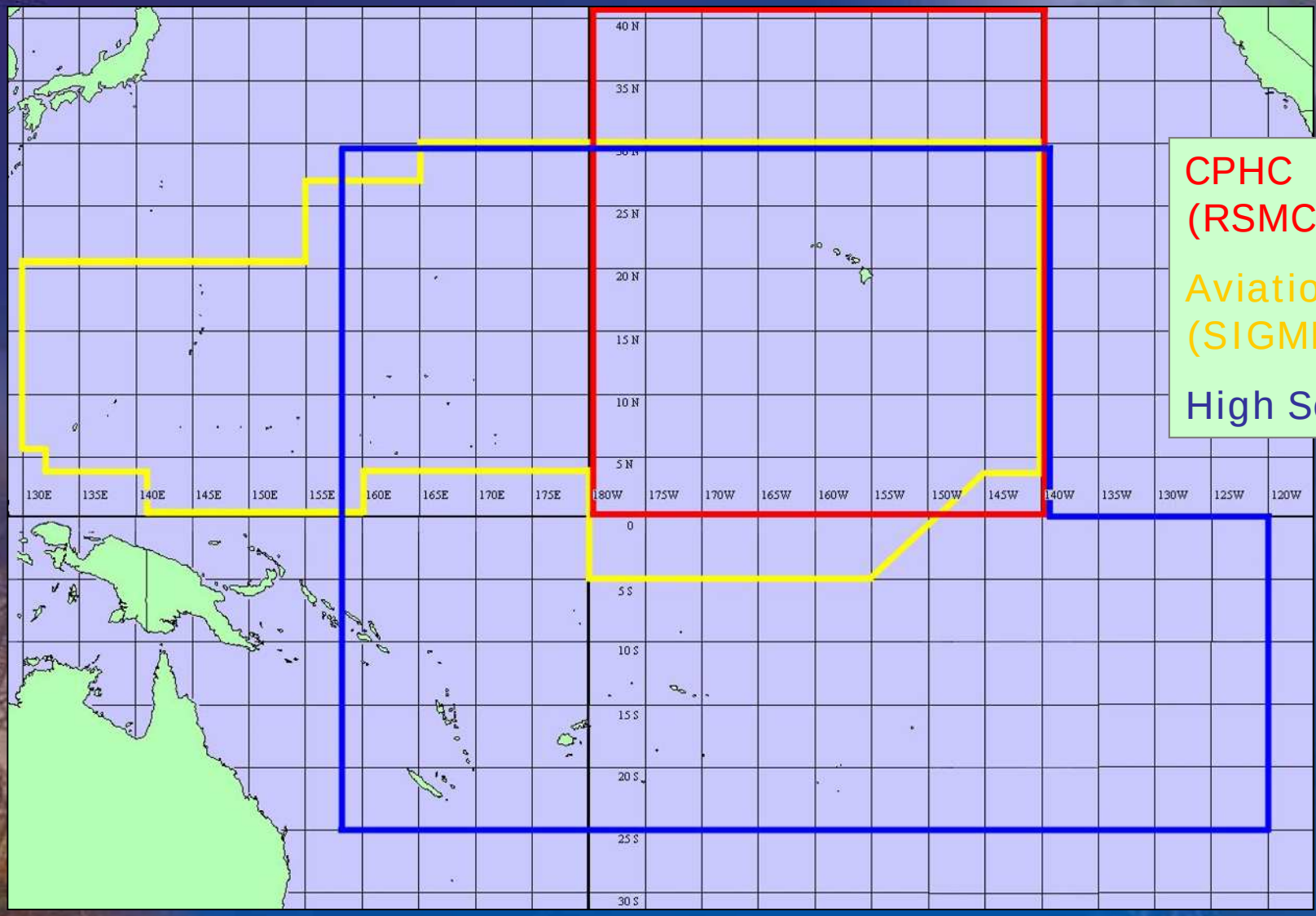
National Weather Service
Central Pacific Hurricane Center
Honolulu, Hawaii

Derek Wroe

Area of Responsibility



CPHC (RSMC)

Aviation (SIGMET)

High Seas

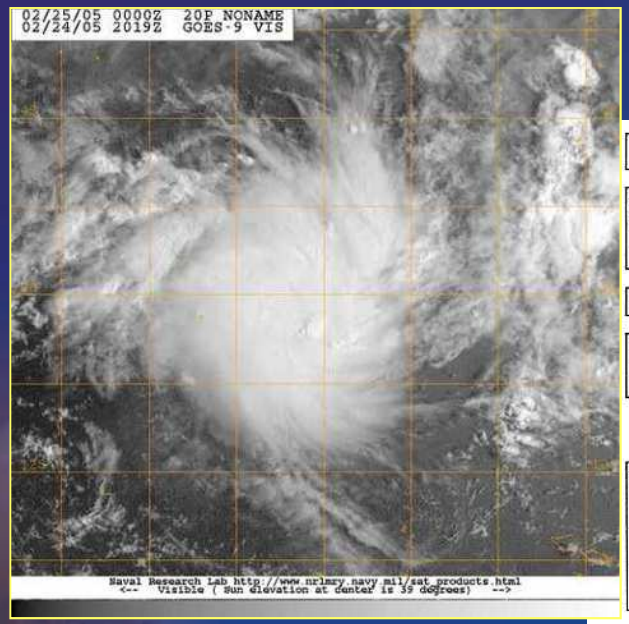
Central Pacific Tropical Cyclone Climatology

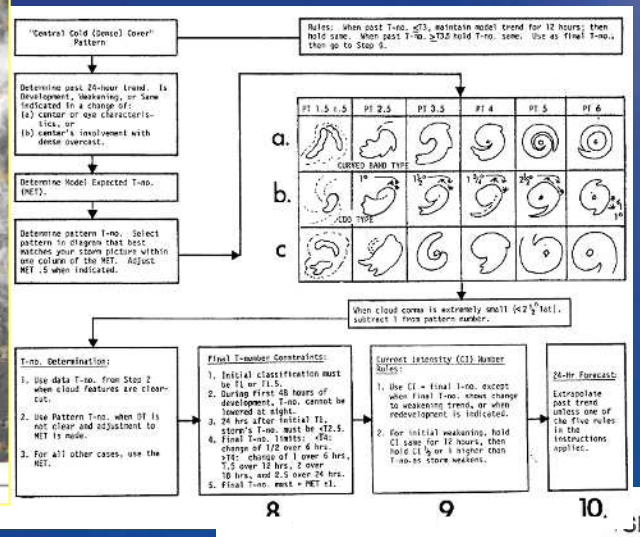
- Season: June 1 to November 30
- Central Pacific Average per Year
  - 4 - 5 Tropical Cyclones
  - 1 - 2 Hurricanes
  - 1 - 2 Tropical Storms
  - 1 - 2 Tropical Depressions

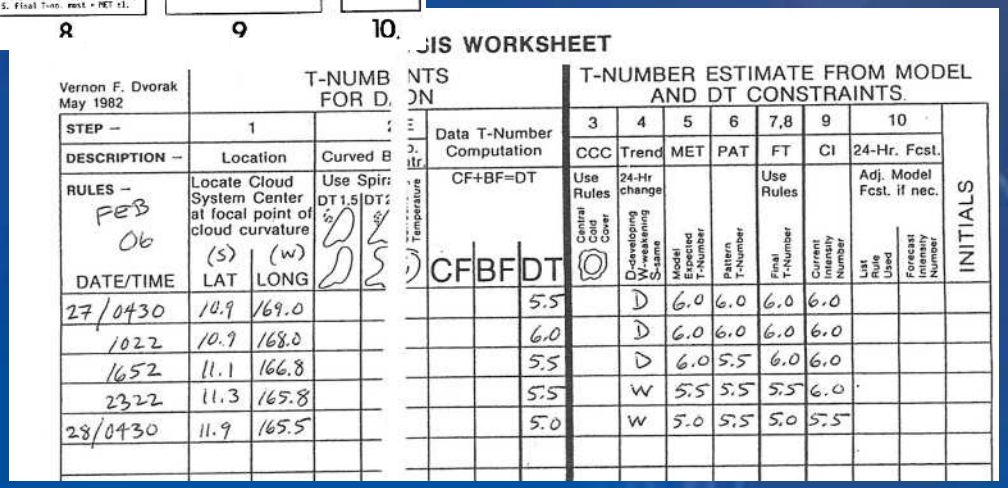
CPHC Staff

- 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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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)

CI	MSW (kt)
1.0	25
1.5	25
2.0	30
2.5	35
3.0	45
3.5	55
4.0	65
4.5	77
5.0	90
5.5	102
6.0	115
6.5	127
7.0	140
7.5	155
8.0	170

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!

CI	MSW (kt)
1.0	25
1.5	25
2.0	30
2.5	35
3.0	45
3.5	55
4.0	65
4.5	77
5.0	90
5.5	102
6.0	115
6.5	127
7.0	140
7.5	155
8.0	170

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:

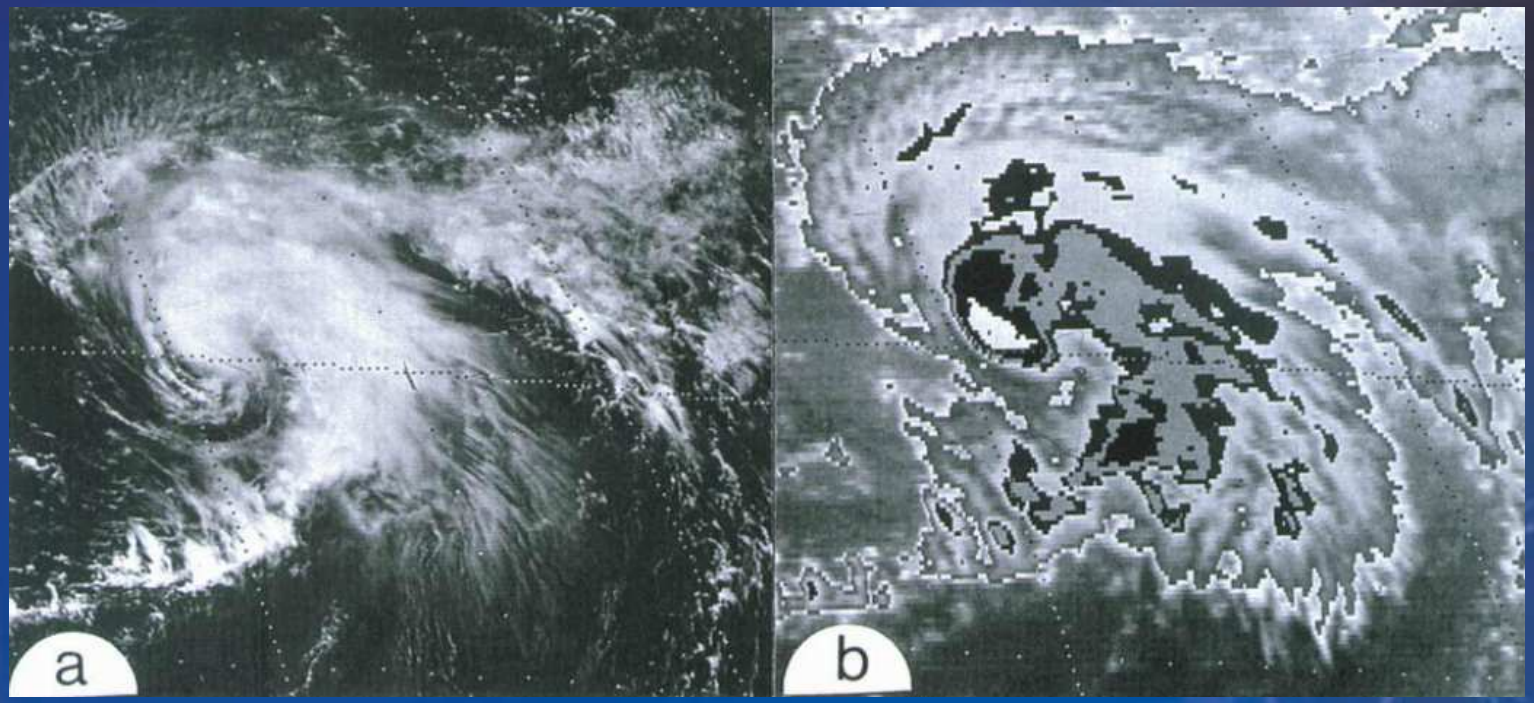
  1. System has persisted for 12 hours or more
  2. System center defined in area 2.5º latitude or less which has persisted for 6 hours
  3. System possesses an area of dense, cold overcast less than 2º from the center

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)

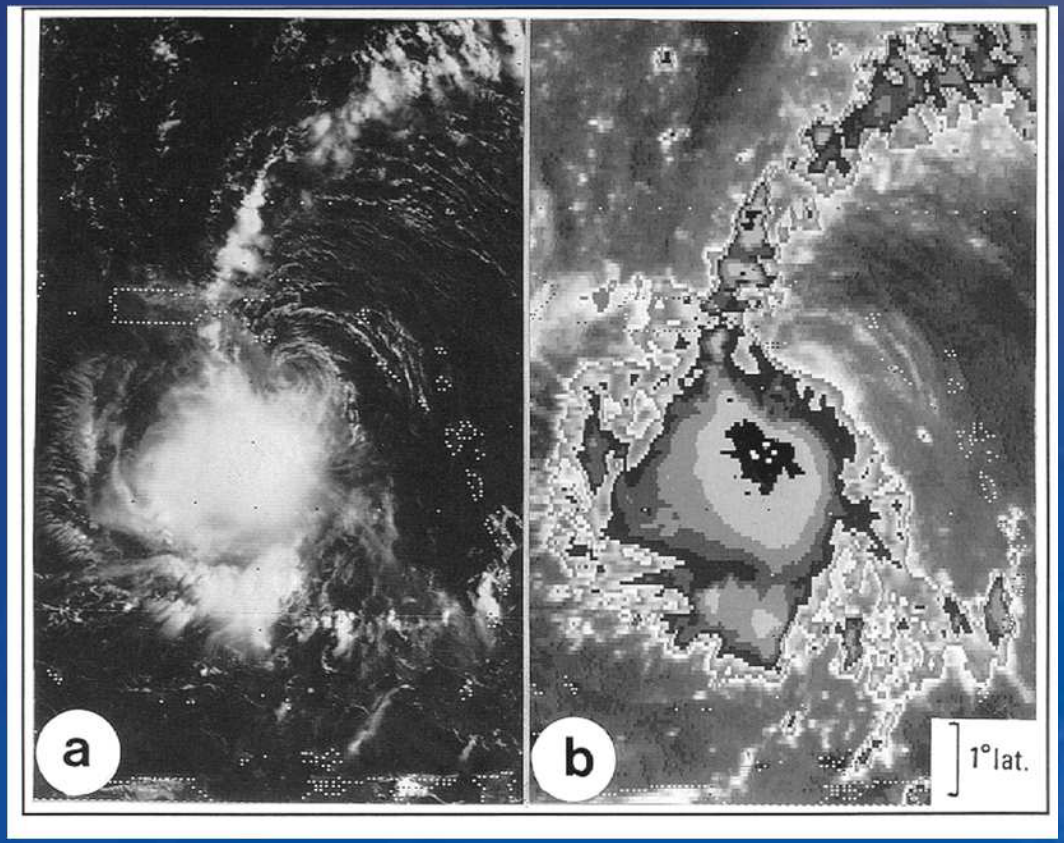
Dvorak Technique
Cloud Patterns

- Curved Band (VIS and IR)



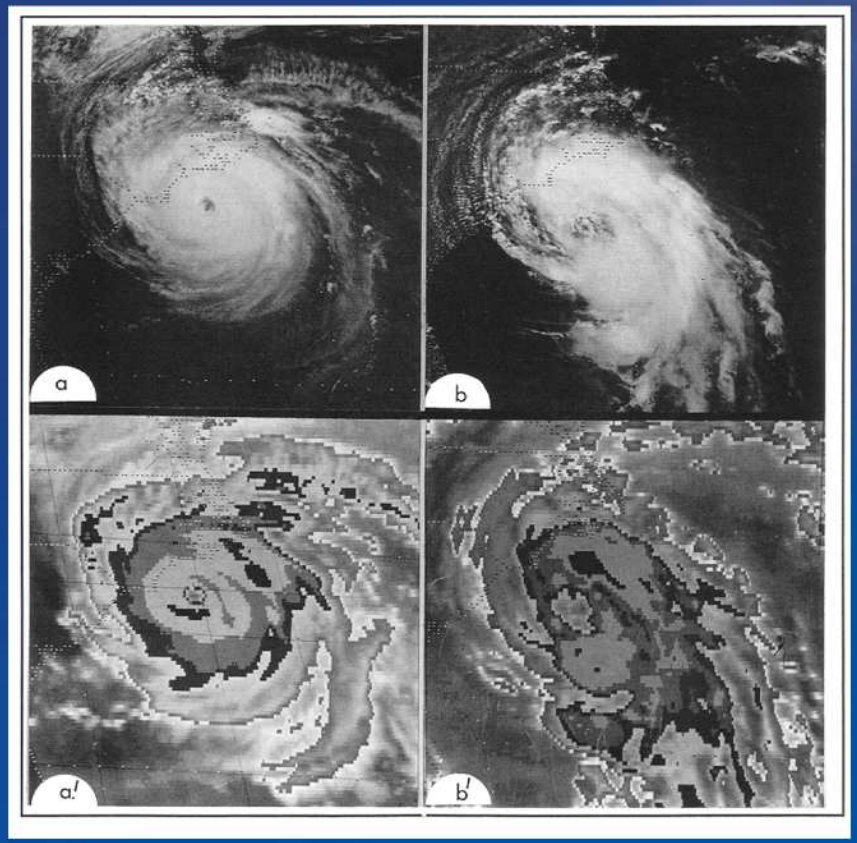
Dvorak Technique
Cloud Patterns

- Shear (VIS and IR)



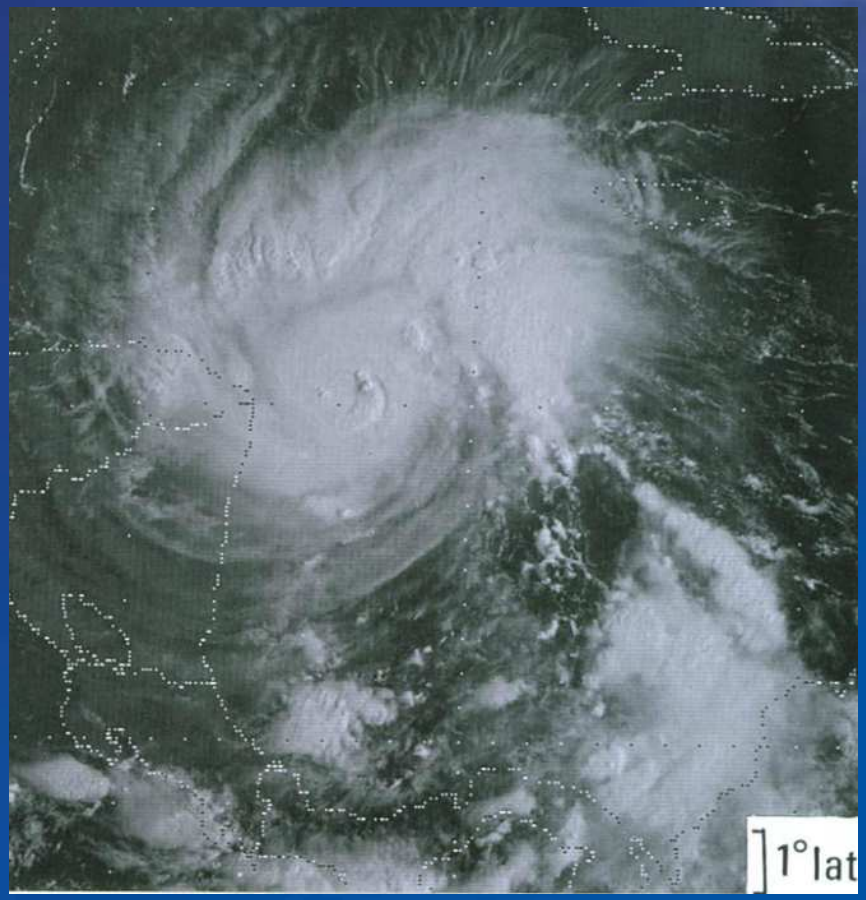
Dvorak Technique
Cloud Patterns

- Eye (VIS and IR)



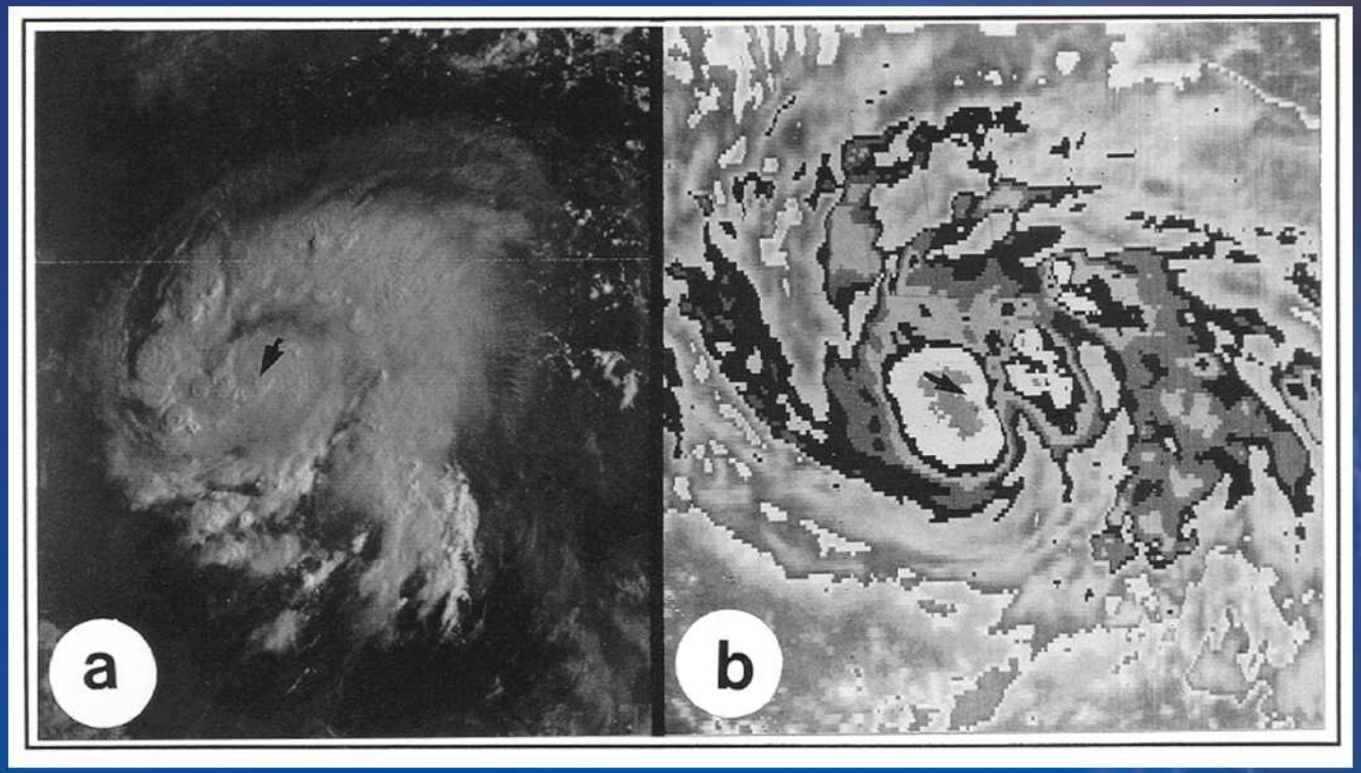
Dvorak Technique
Cloud Patterns

- Central Dense Overcast (VIS)



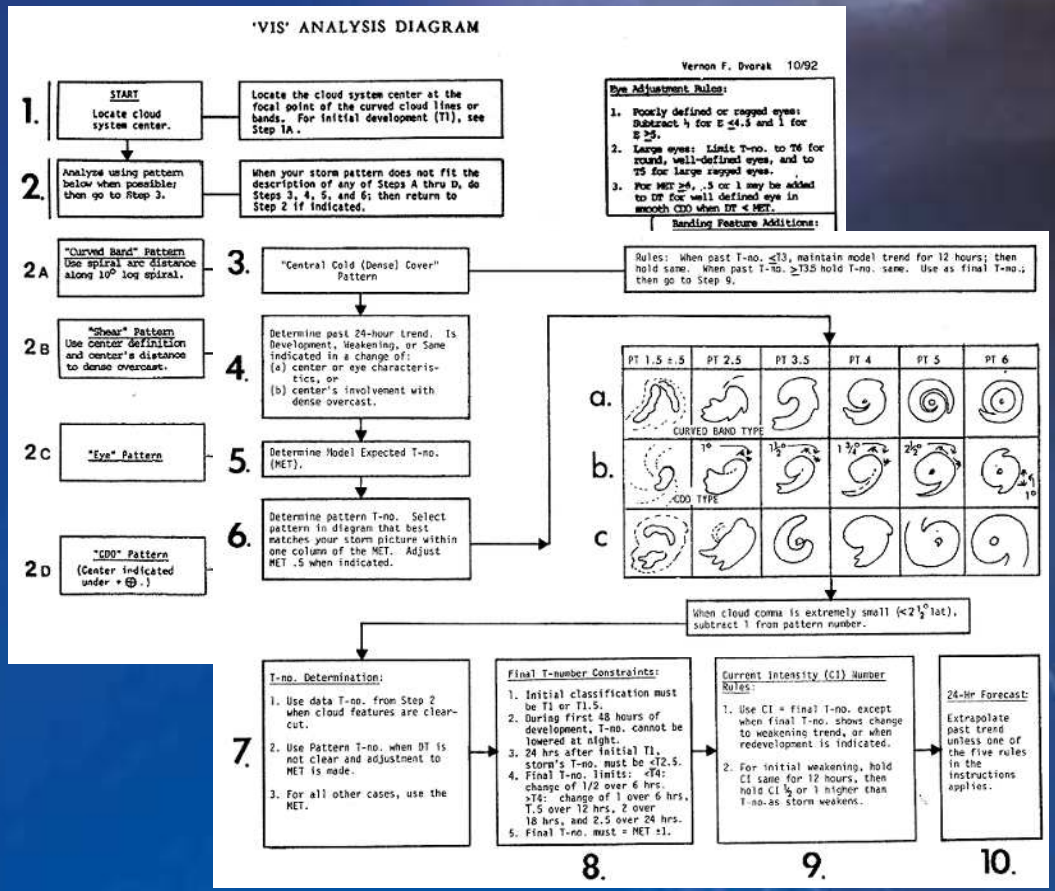
Dvorak Technique
Cloud Patterns

- Embedded Center (IR)



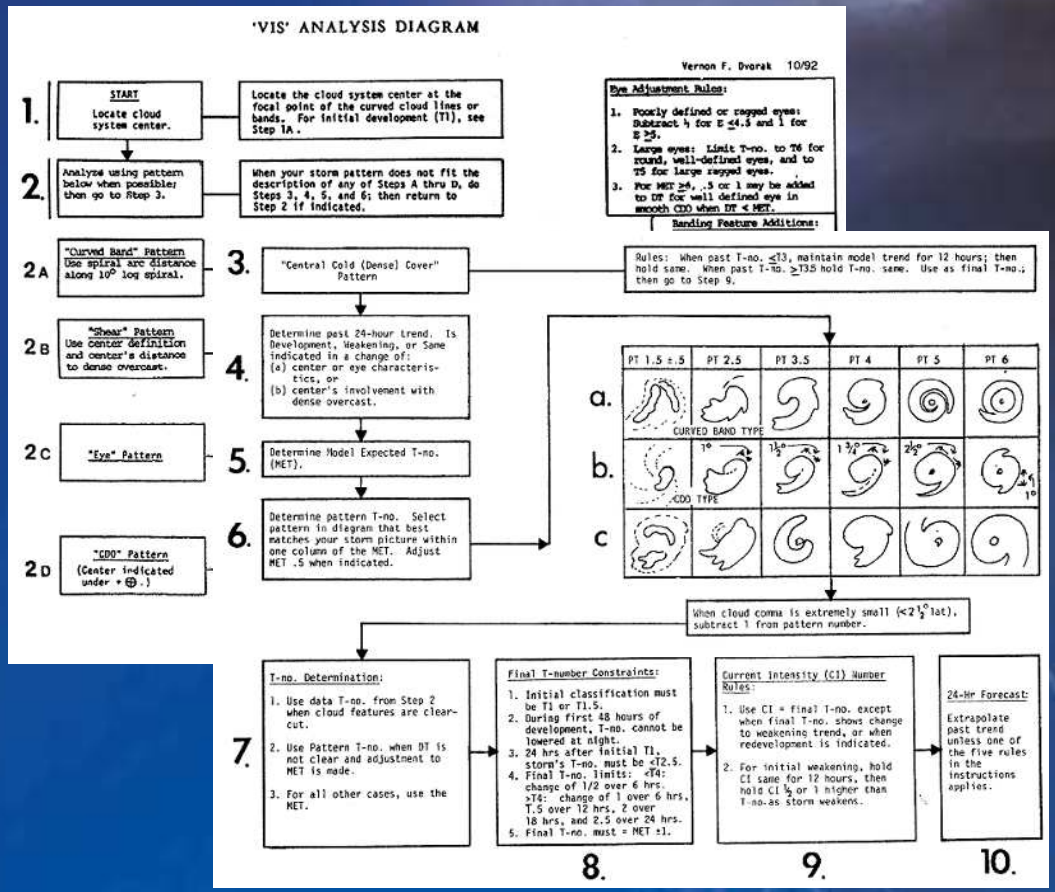
Dvorak Technique Flowchart

- 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



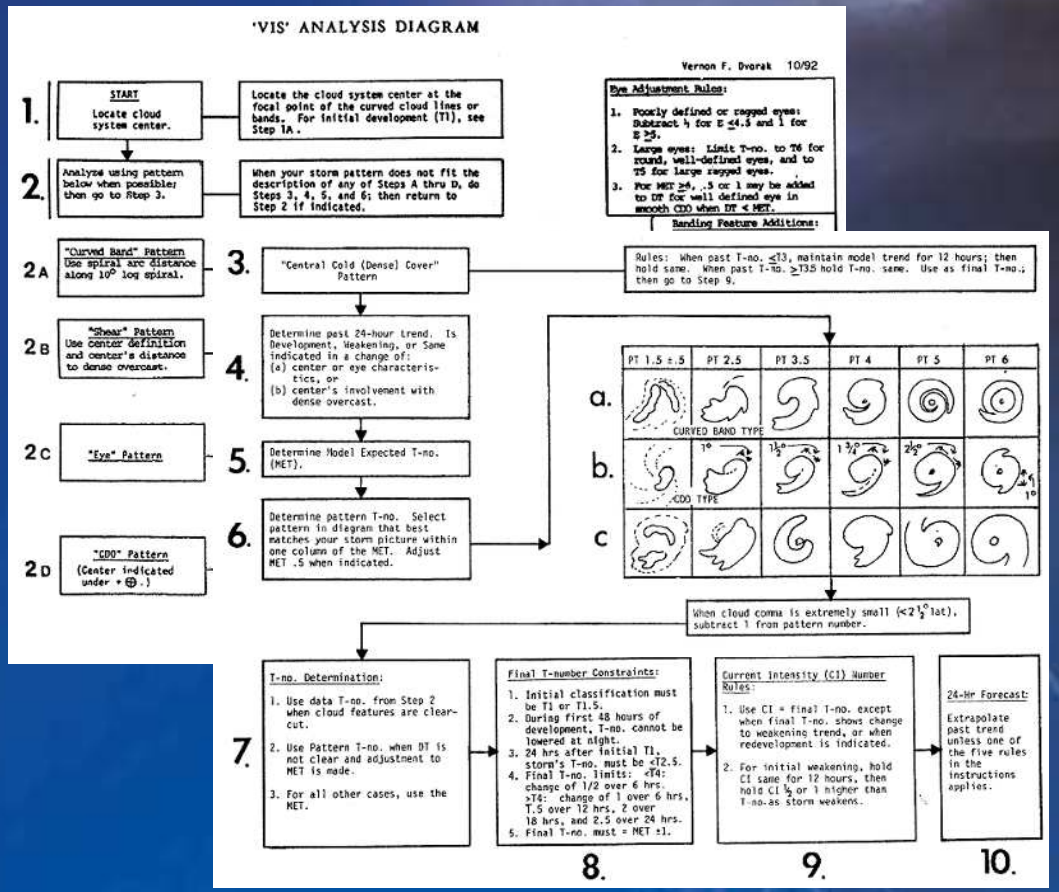
Dvorak Technique Flowchart

- Step 1: Locate the cloud system center



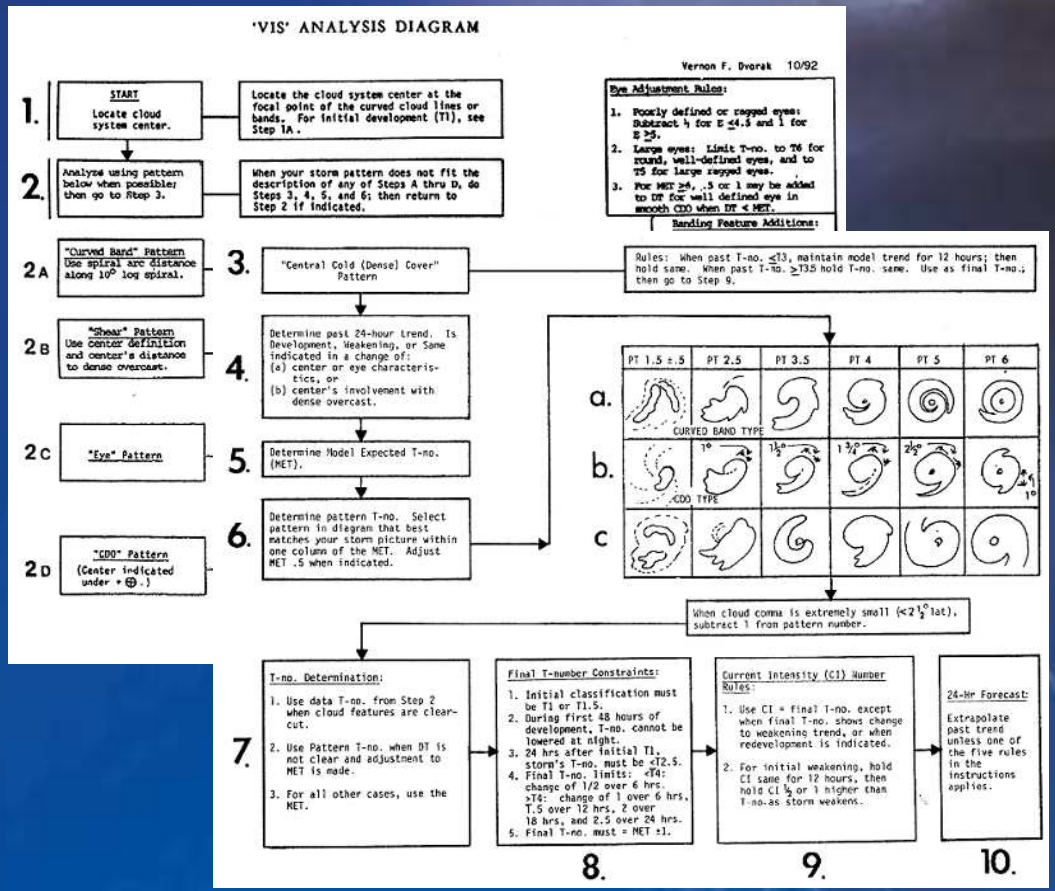
Dvorak Technique Flowchart

- Step 2: Determine DT by analyzing the intensity using satellite based measurements



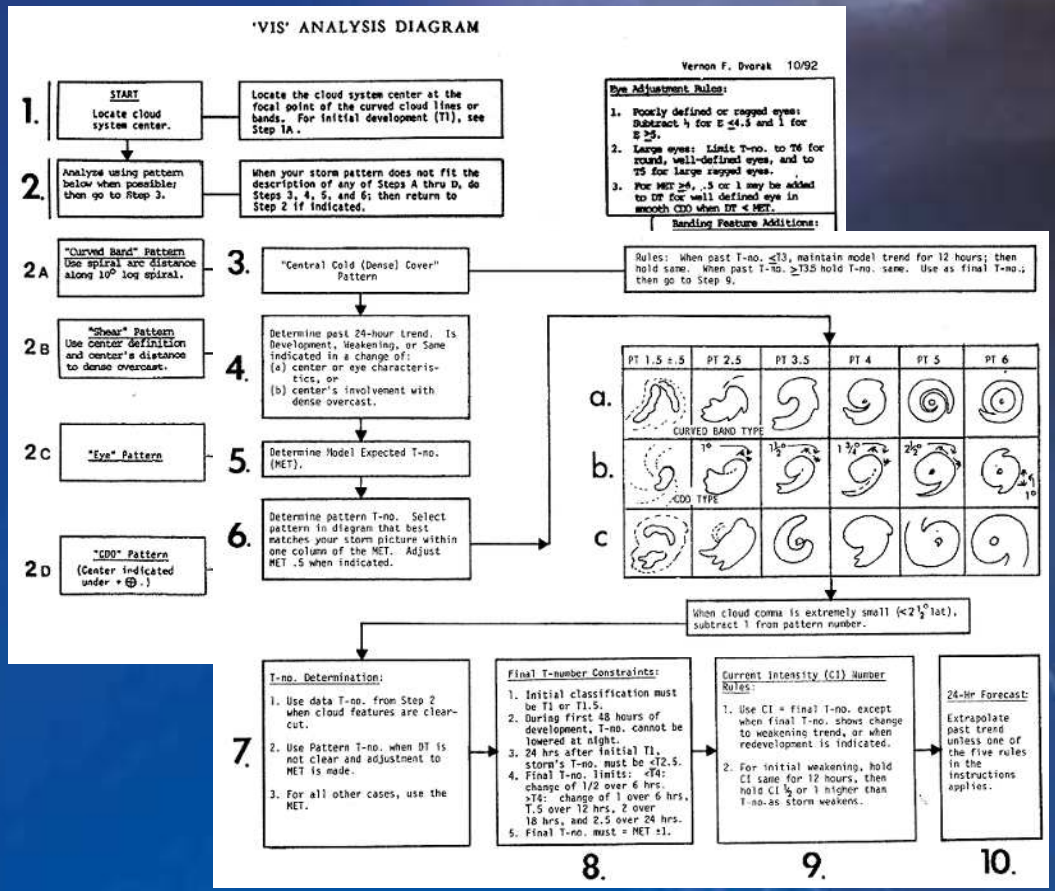
Dvorak Technique Flowchart

- Step 4: Determine intensity change in the past 24 hours in order to:
- Step 5: Determine MET



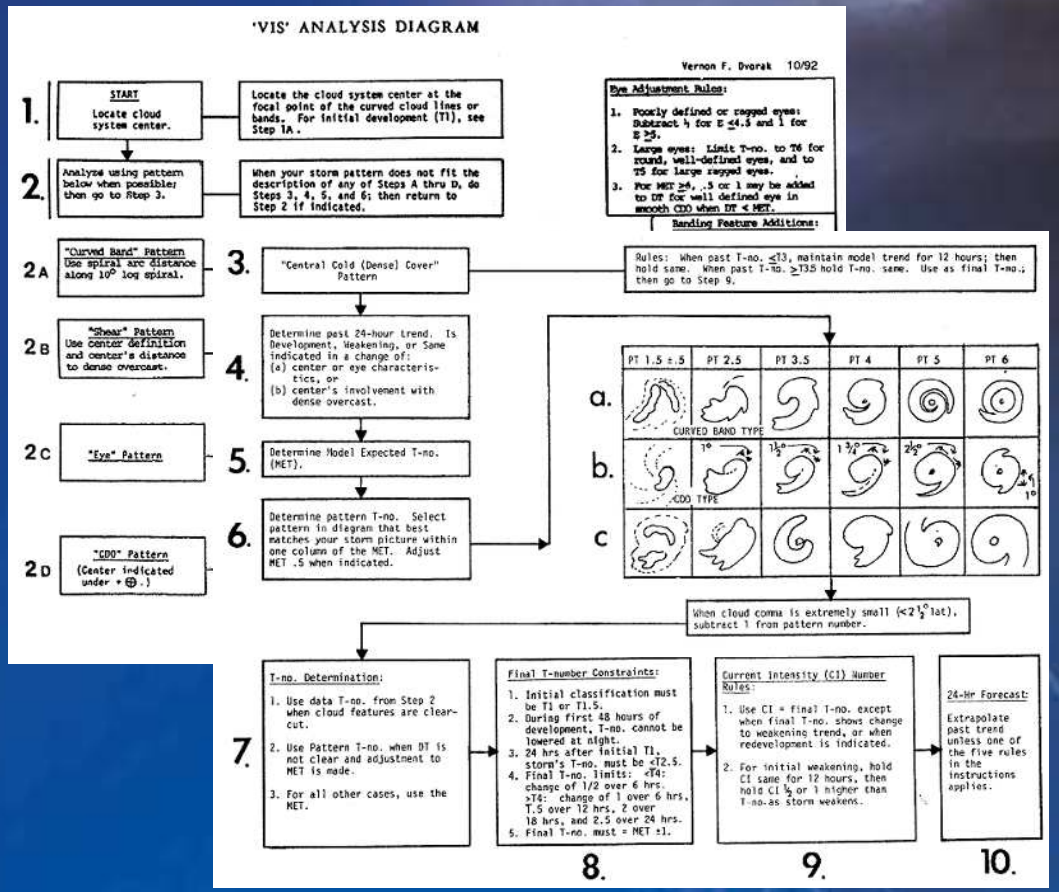
Dvorak Technique Flowchart

- Step 6: Determine PAT



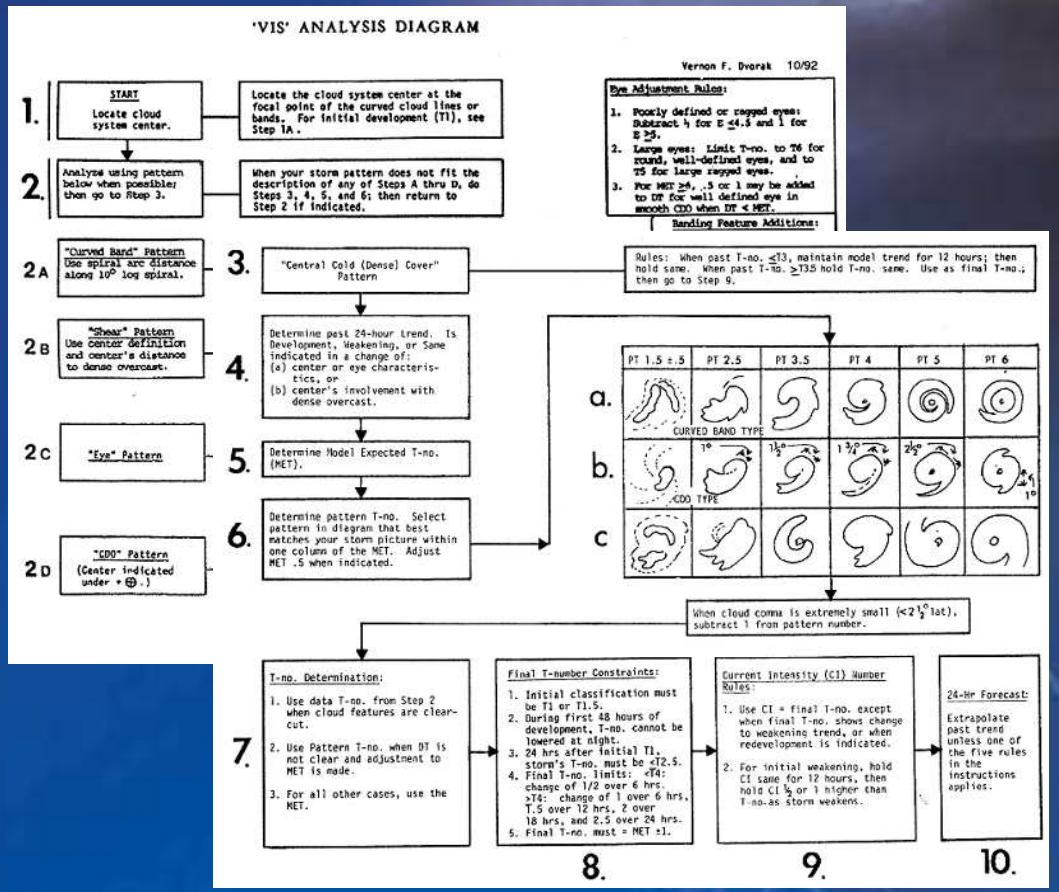
Dvorak Technique Flowchart

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



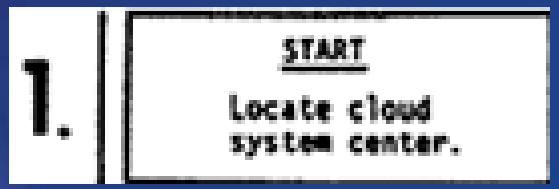
Dvorak Technique Flowchart

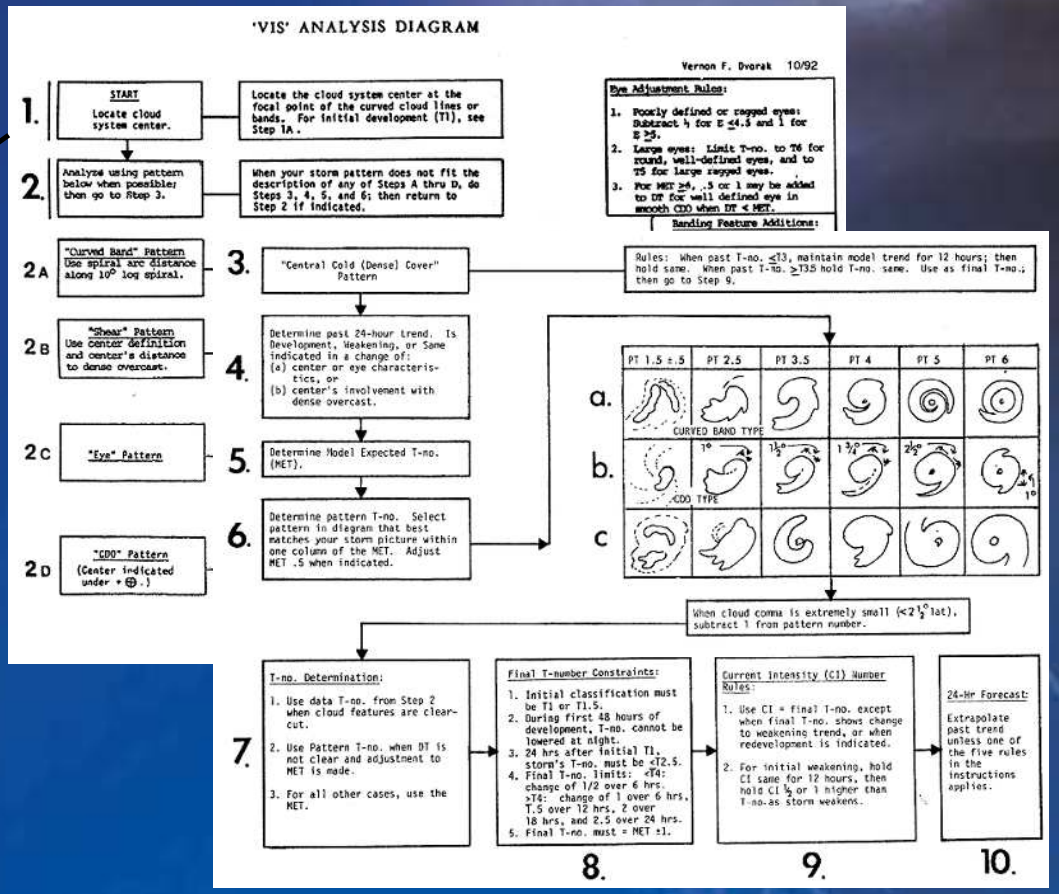
- Step 9: Determine CI based on FT



Dvorak Technique Flowchart

- 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

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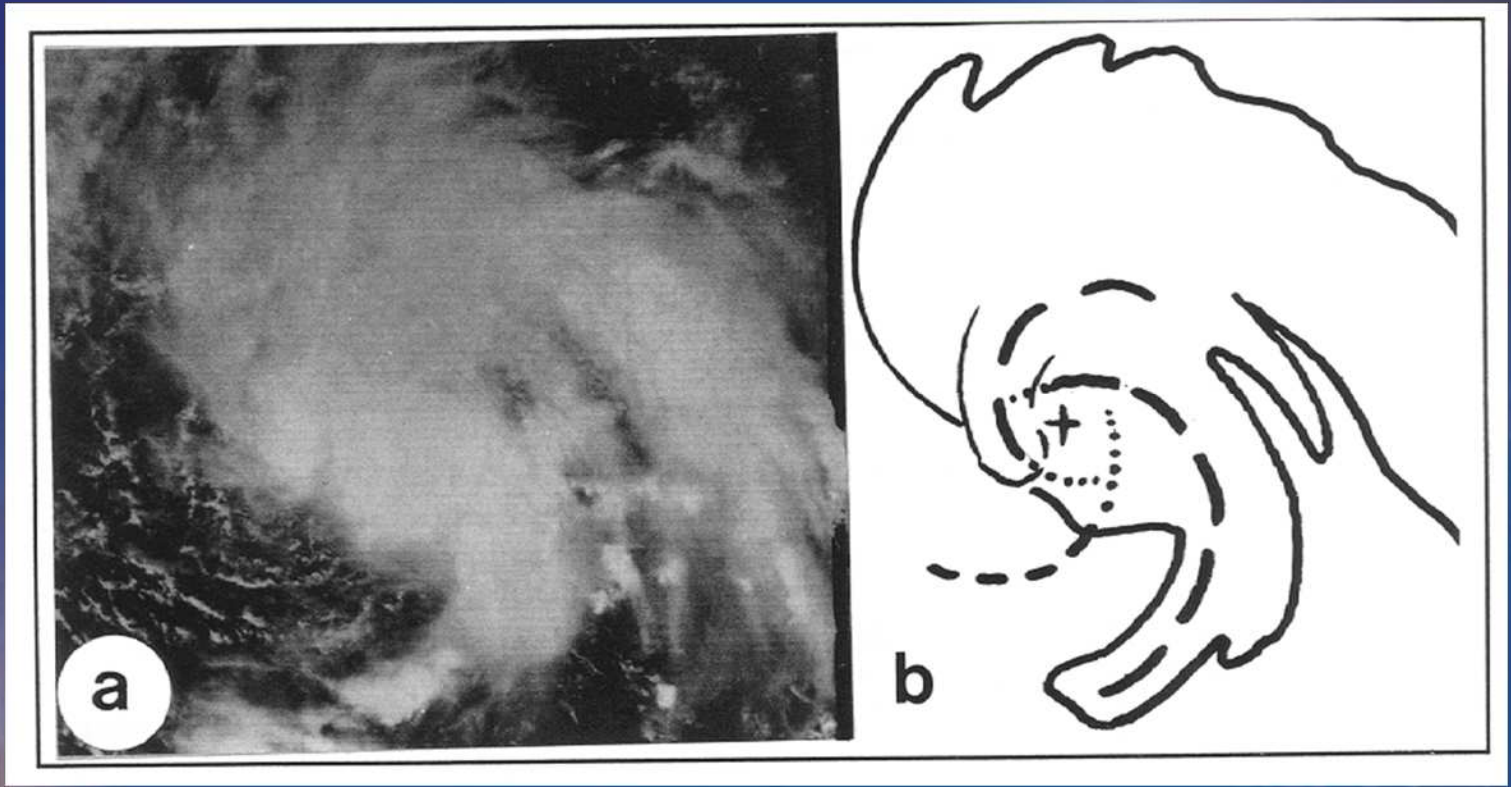
- Locate the Overall Pattern Center



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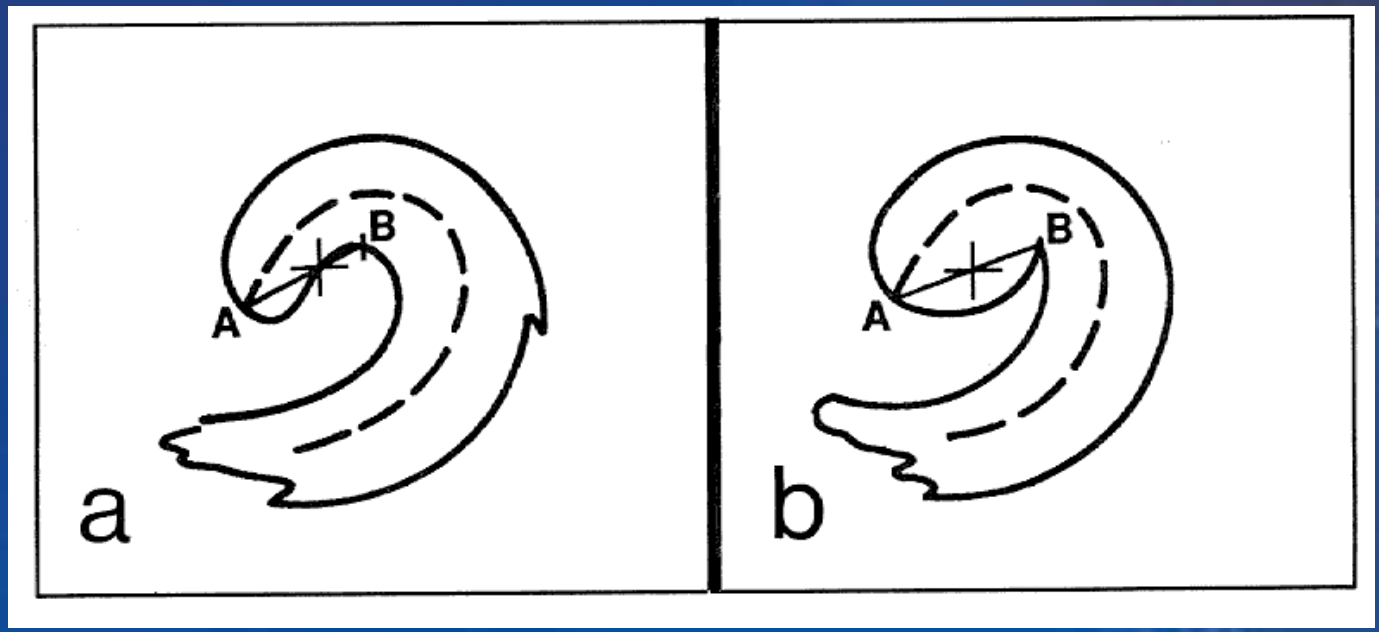
Step 1 - Locate the Cloud System Center

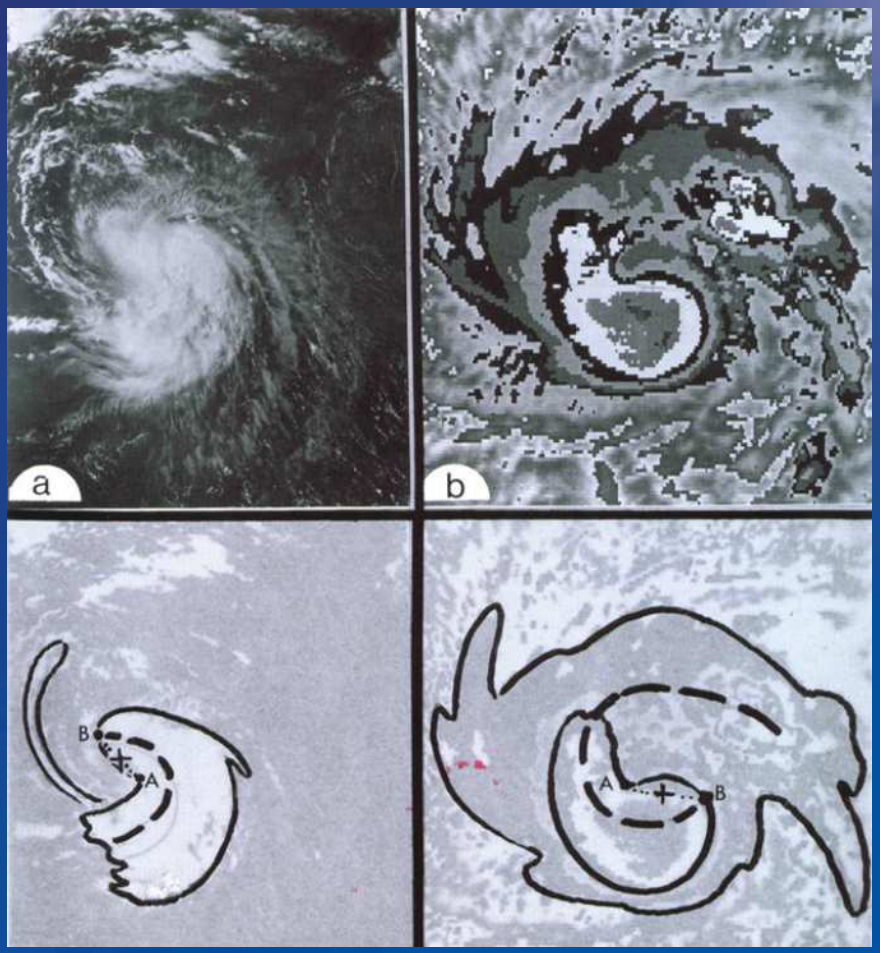
- Examine for Small Scale Features
  - Indications of an eye
  - Low level cloud line curvature
  - Cloud line mergence
  - Cloud minimum areas
  - Middle of upper level cloud features such as band curvature and cumulonimbus tops

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

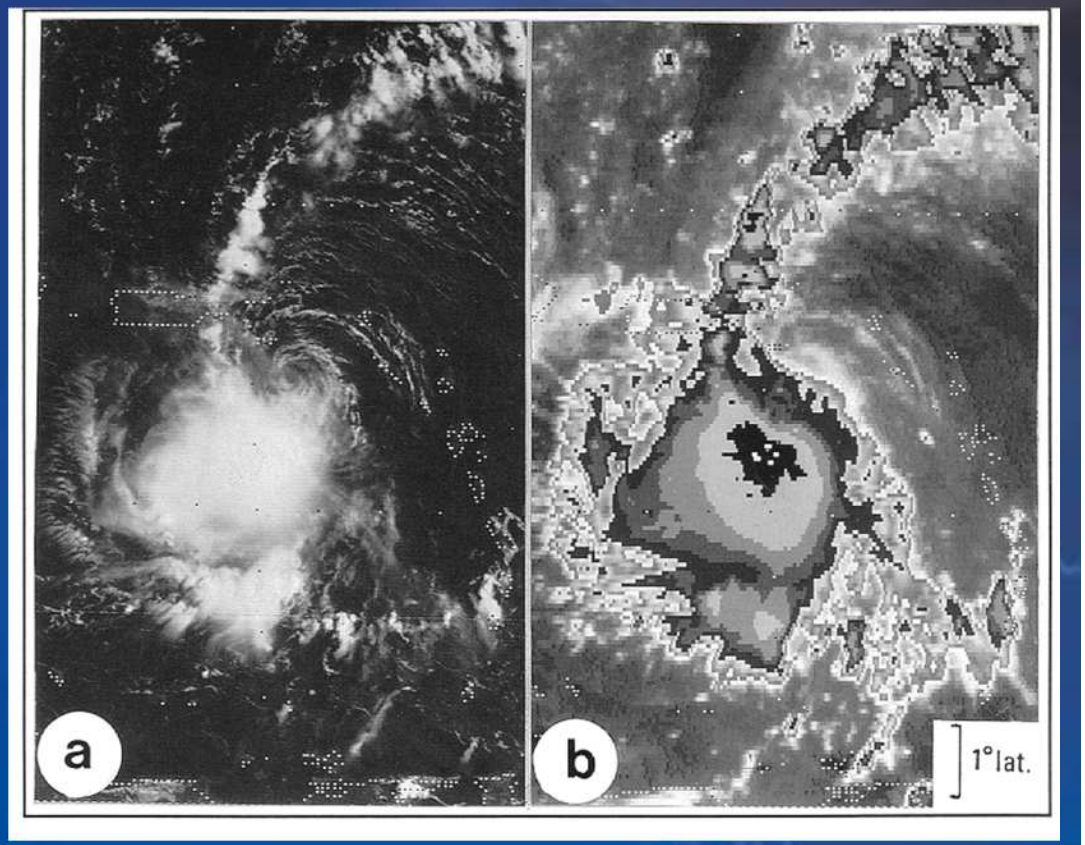


Step 1 - Locate the Cloud System Center: Curved Band



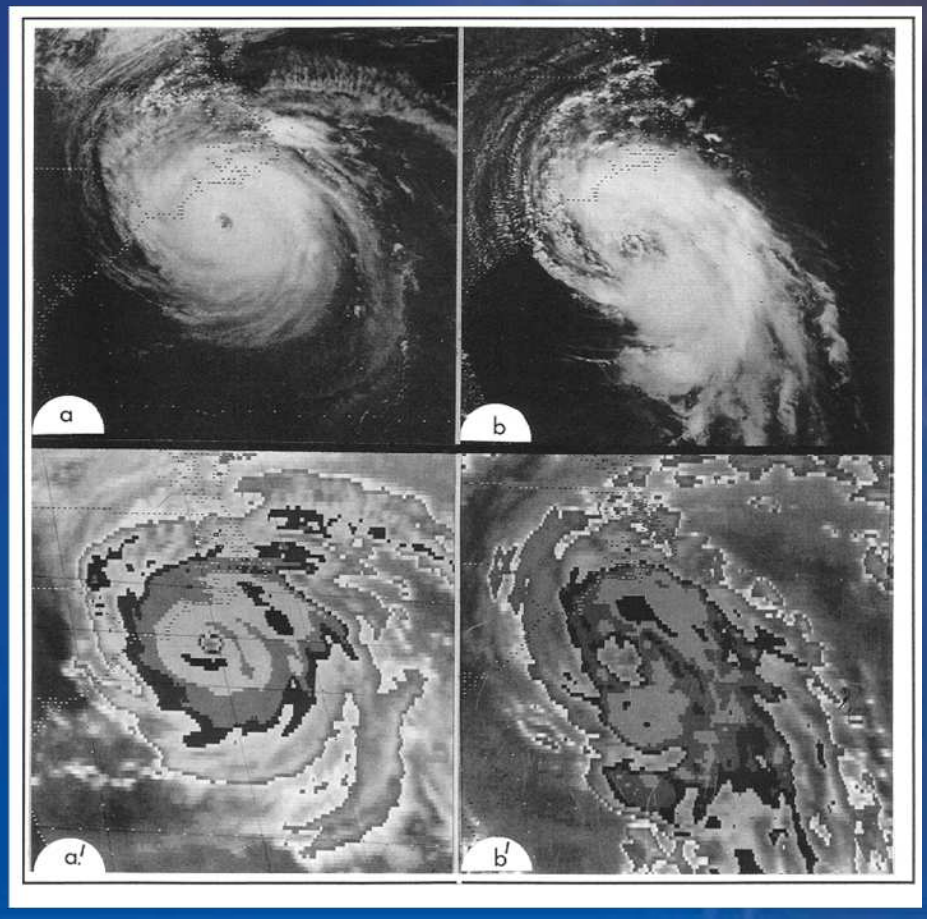
Step 1 - Locate the Cloud System Center: Shear Pattern

- Examine for Small Scale Features
- Shear patterns can pose a significant center finding challenge, especially at night



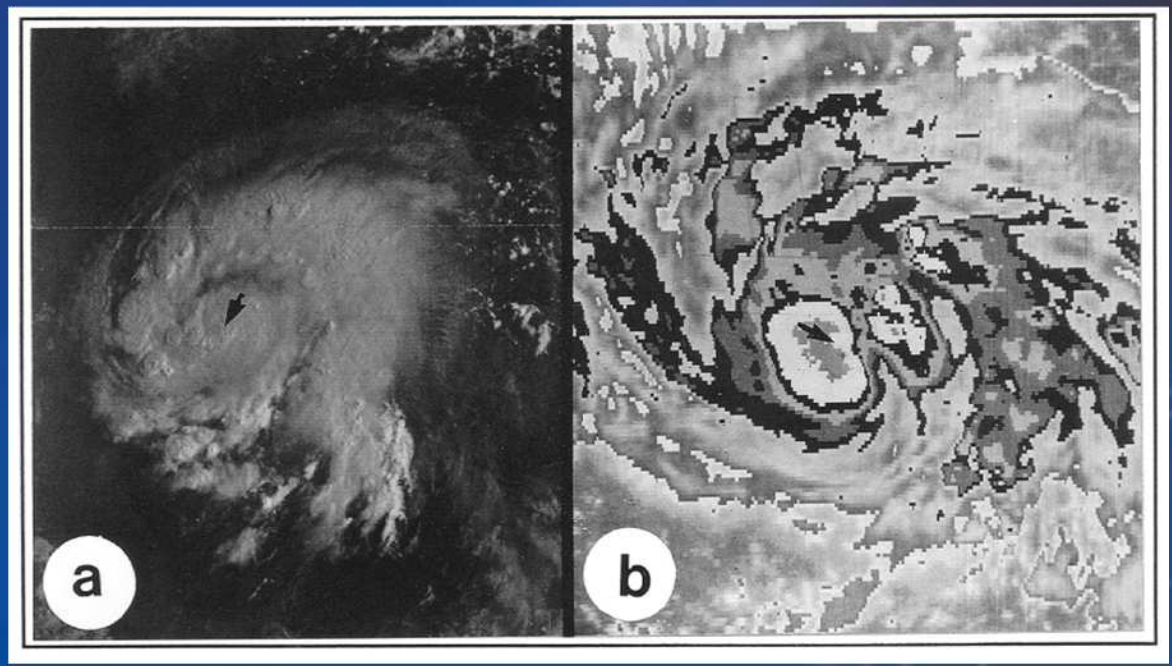
Step 1 - Locate the Cloud System Center: Eye Pattern

- 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
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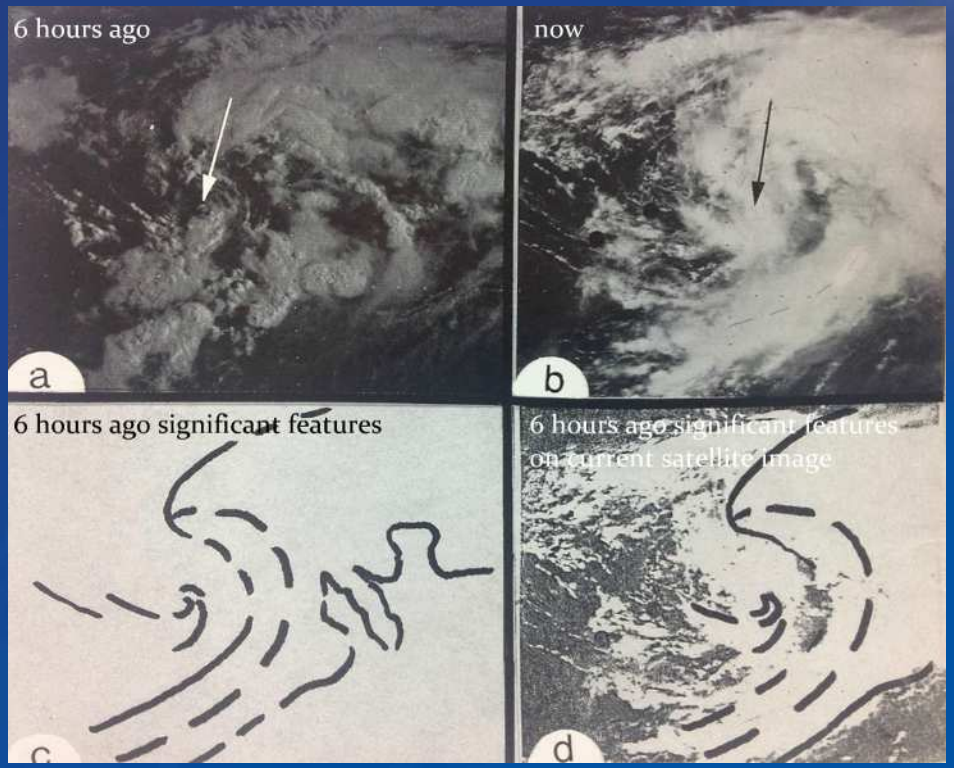
- Make Final Center Adjustments
- Looking for Lowest Possible Center
- Tip: imagery animation is crucial

Step 1 - Locate the Cloud System Center

- Compare Center with Previous Pattern Center
  - Track center features from prior images
  - Best done with animation



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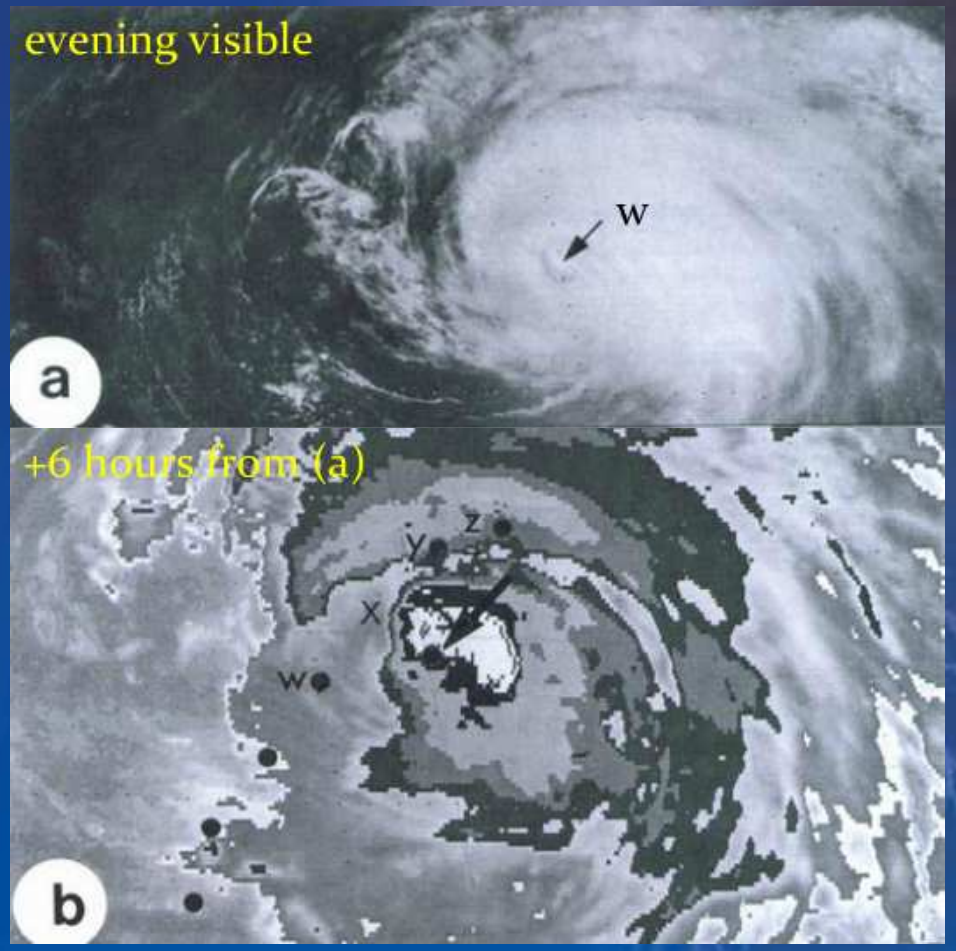
- Looking for Lowest Possible Center
- Tip: imagery animation is crucial

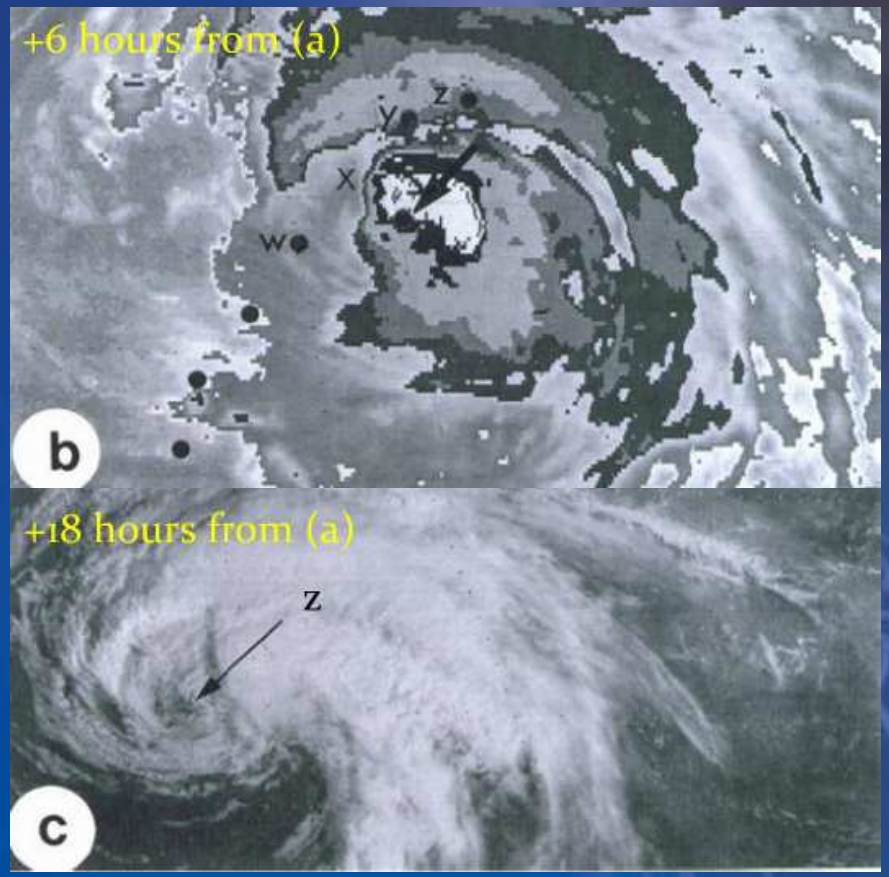
Step 1 - Locate the Cloud System Center

- 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!



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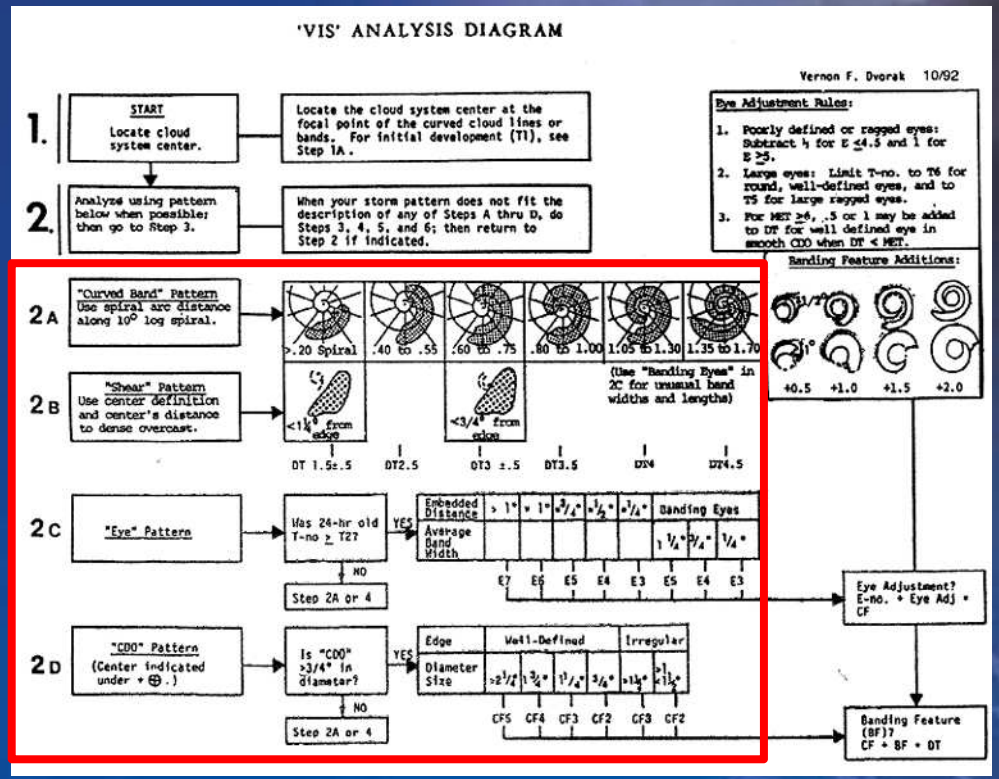
Dvorak Technique Flowchart

- Step 2: Determine DT by analyzing the intensity using satellite based measurements

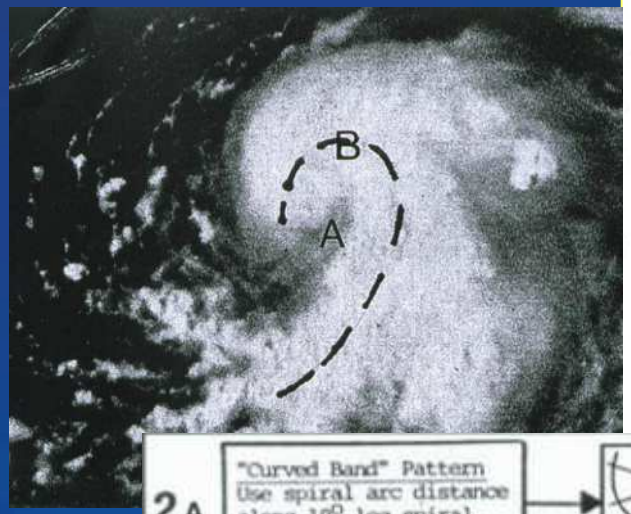


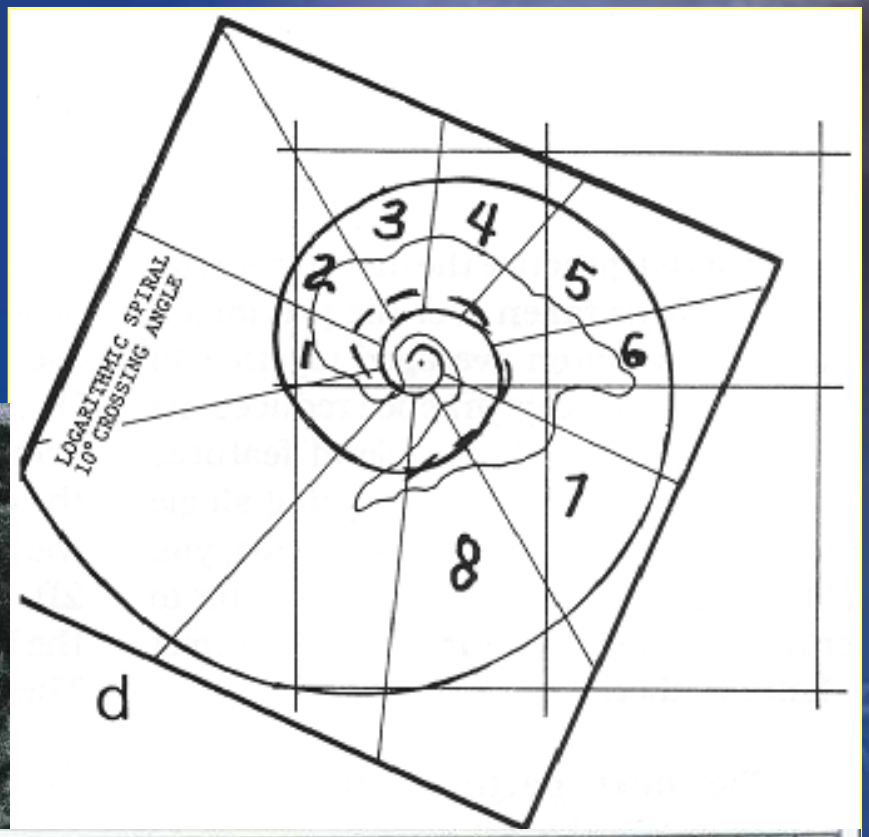
Step 2 – Measure to Find DT

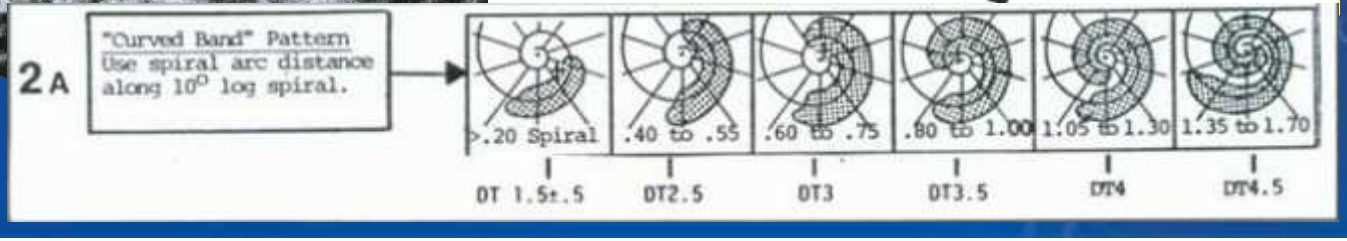
- Select cloud pattern type
- Measure cloud features that relate to intensity to obtain DT
- If cloud patterns show no resemblance to patterns, proceed to rarely used Step 3: Central Cold Cover
- Note: DT does not necessarily give the final intensity estimate!

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

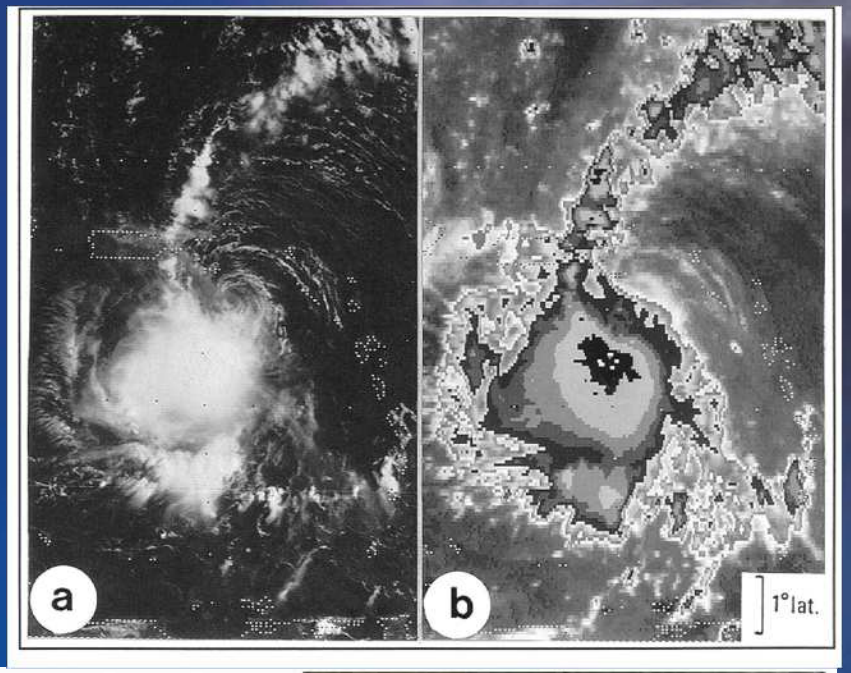


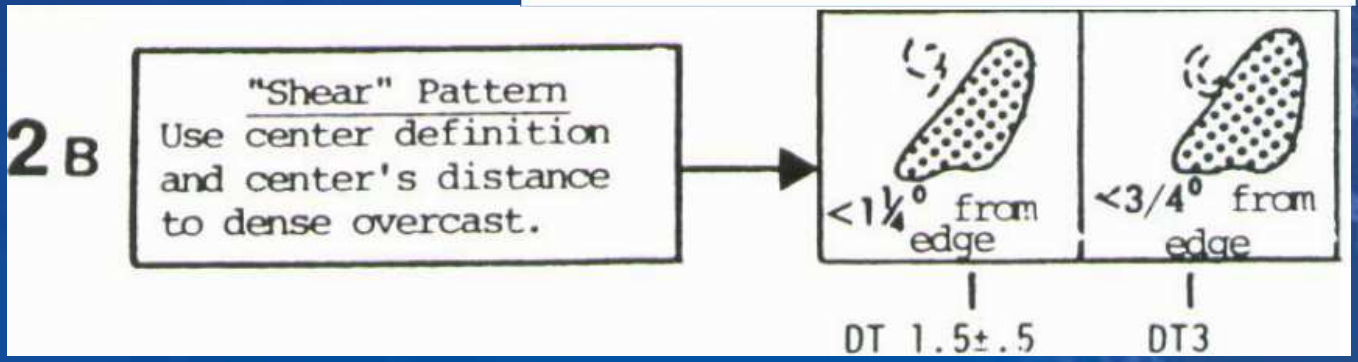




Step 2 – Measure to Find DT: Shear Pattern

- For less than typhoon intensity
- Factors:
  - Definition of center
  - Distance between center and dense overcast
- Easier with VIS





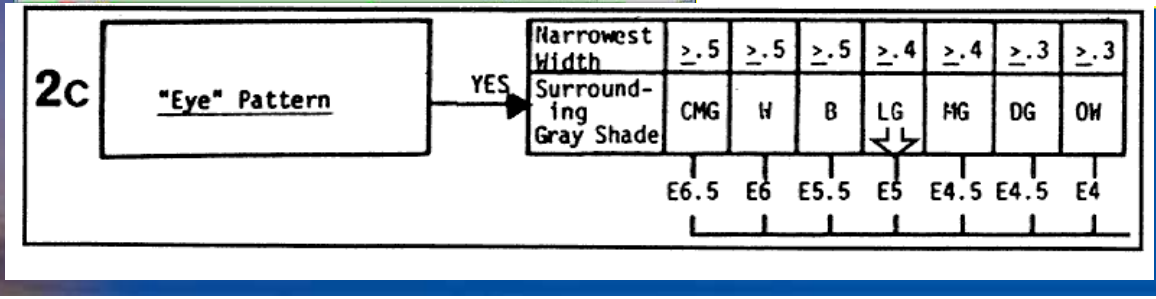
Step 2 – Measure to Find DT: Eye Pattern

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

Eye Temperature

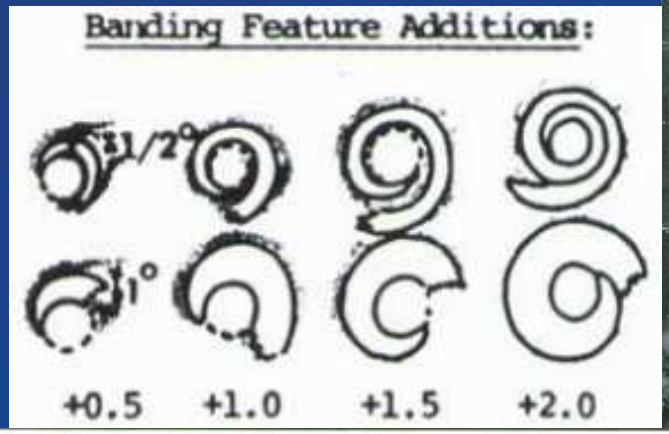
Surr. Ring Temp

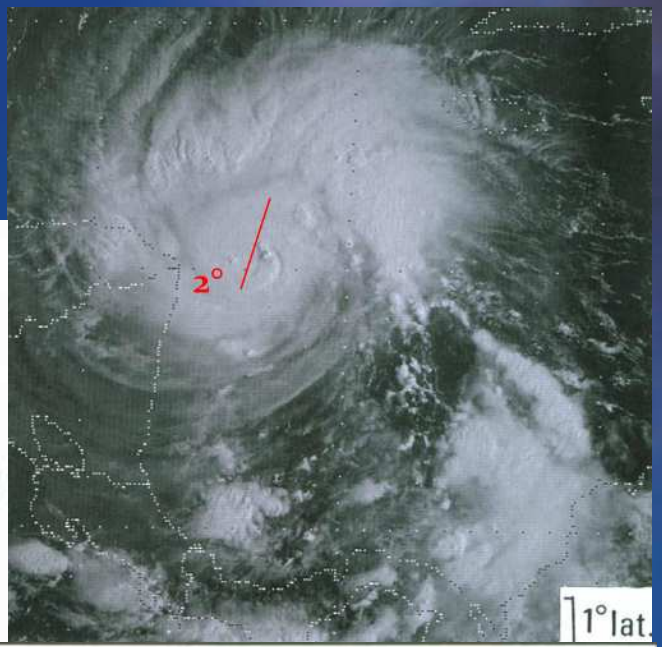
	WMG	OW	DG	MG	LG	B	W
OW	0	-0.5					
DG	0	0	-0.5				
MG	0	0	-0.5	-0.5			
LG	+0.5	0	0	-0.5	-0.5		
B	+1.0	+0.5	0	0	-0.5	-0.5	
W	+1.0	+0.5	+0.5	0	0	-1.0	-1.0
CMG	+1.0	+0.5	+0.5	0	0	-0.5	-1.0

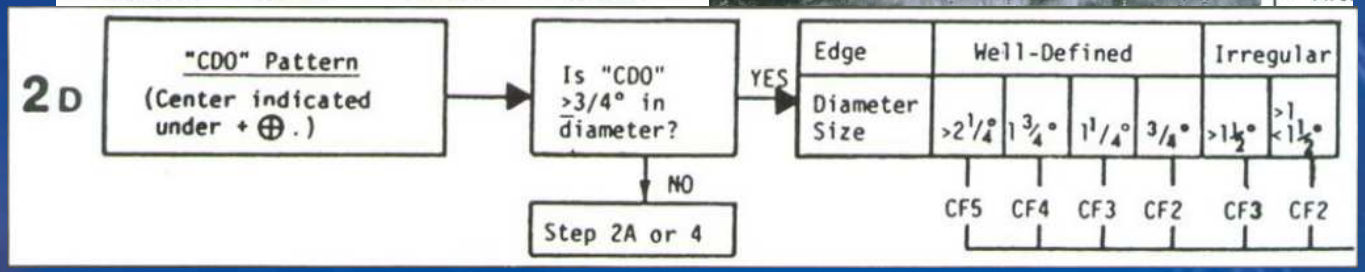


Step 2 – Measure to Find DT: Central Dense Overcast

- VIS only
- Measure size and definition of CDO
- Add banding feature

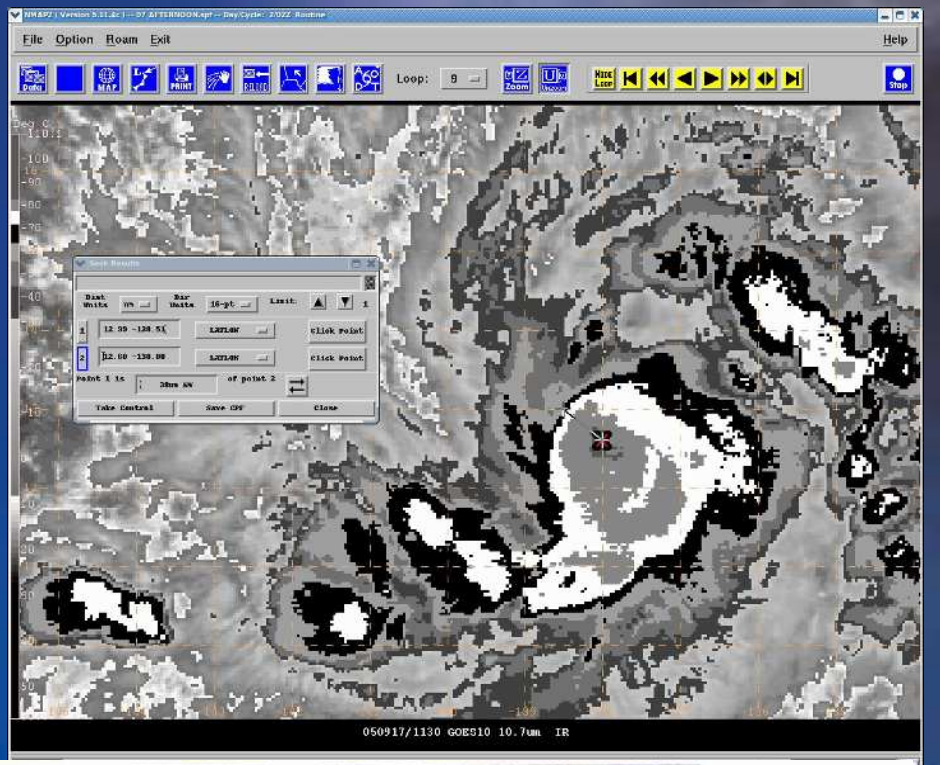


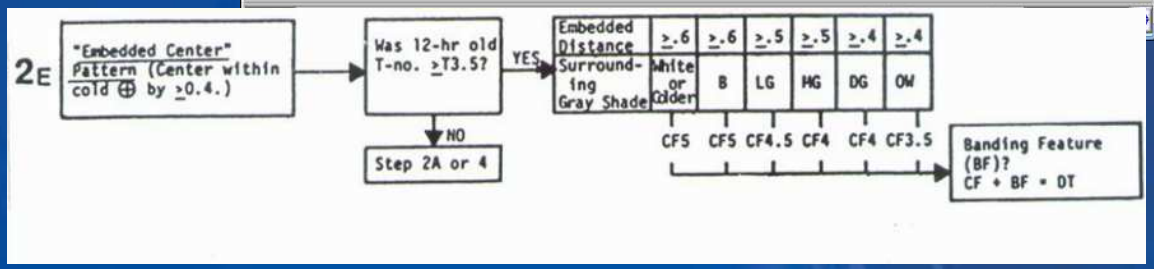




Step 2 – Measure to Find DT: Embedded Center

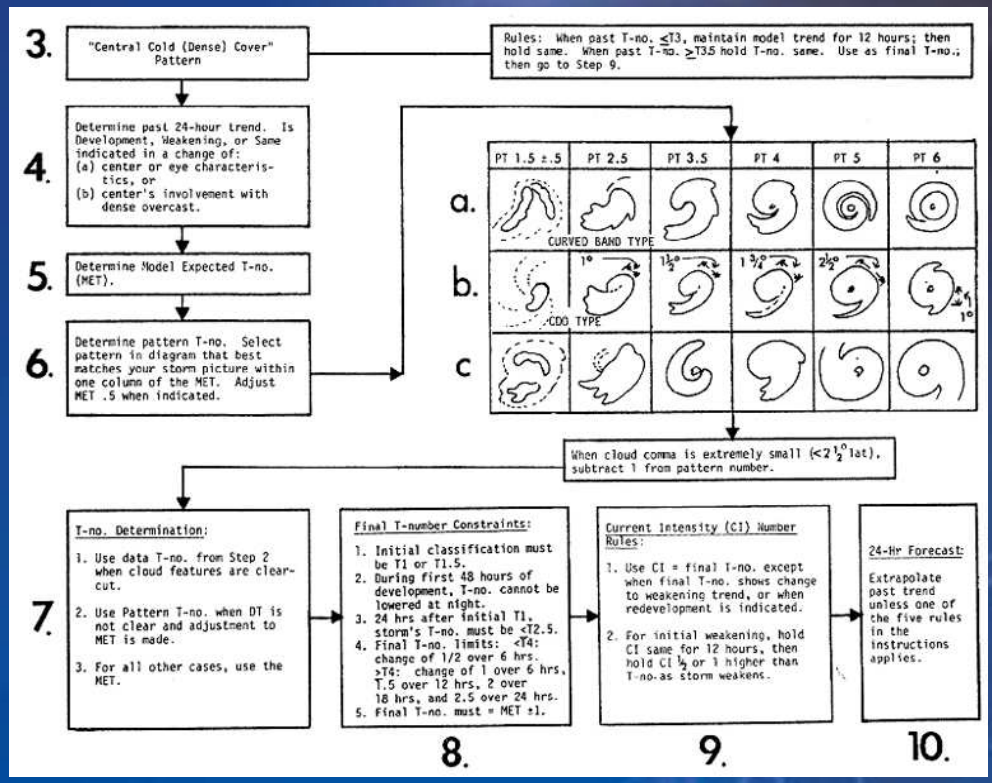
- IR only
- For strong TS or typhoon
- Determine coldest overcast that center is embedded within a required distance
- Can add banding feature
- Highly sensitive to center position!





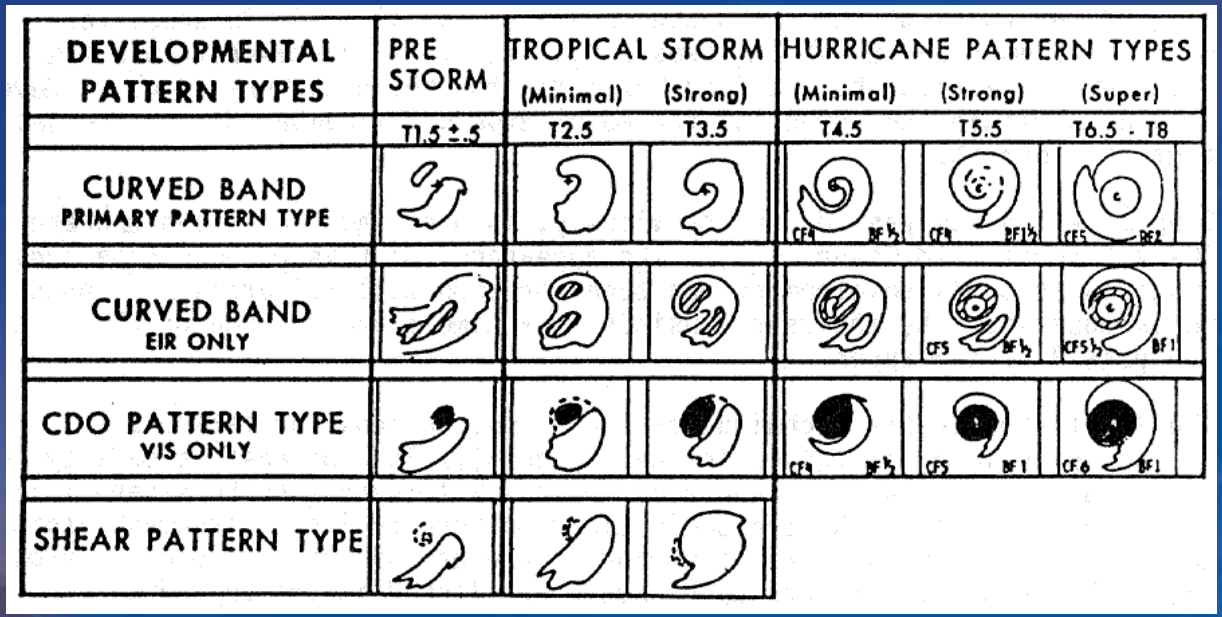
Dvorak Technique Flowchart
Steps 4 – 6: Model Comparisons

- 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!

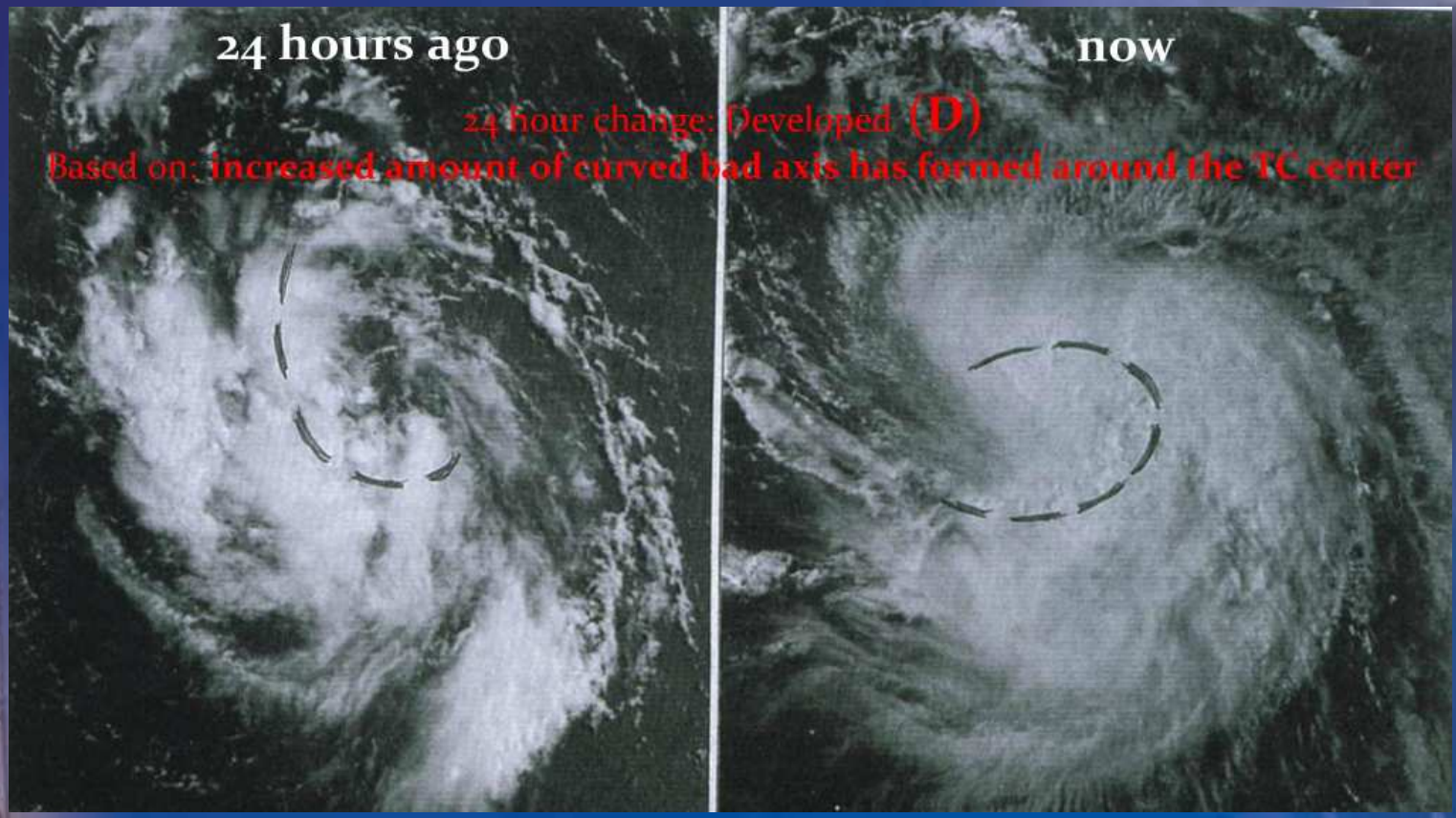


Step 4 – Determine Intensity Trend

- 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



Step 4 – Determine Intensity Trend

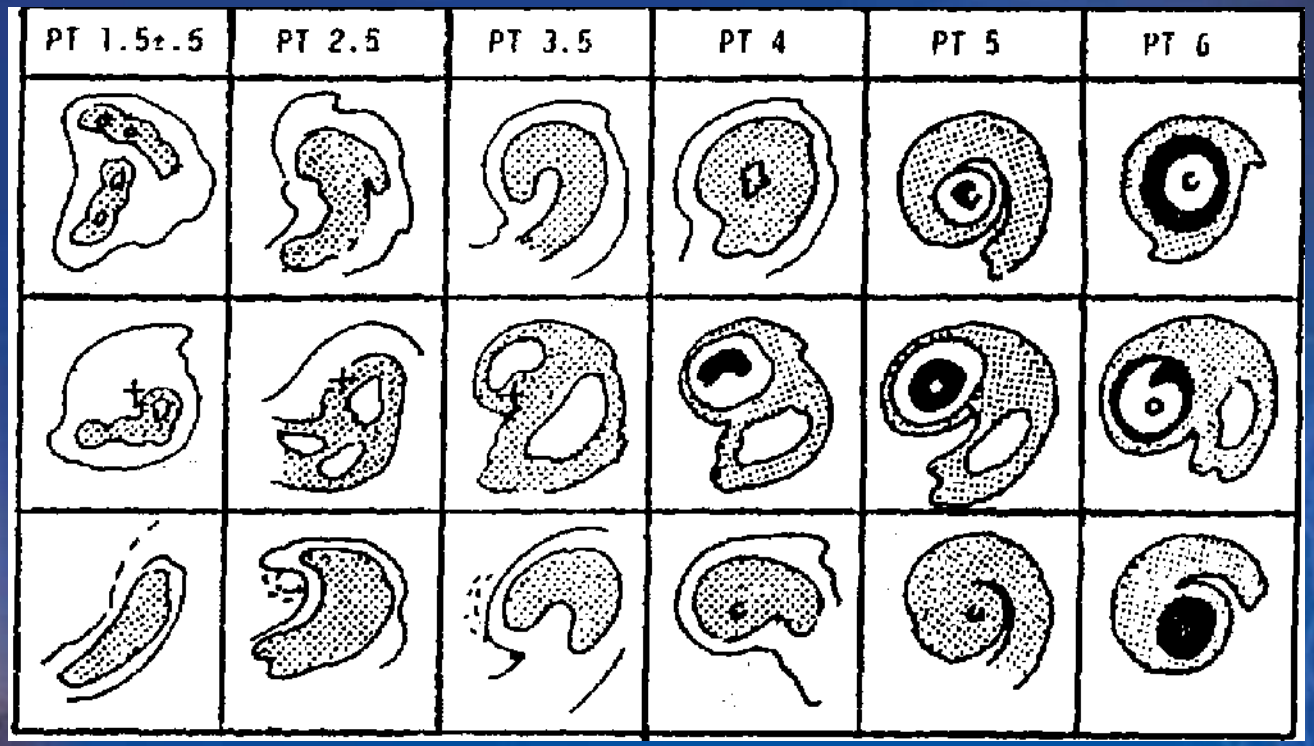


Step 5 – Determine MET

- 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

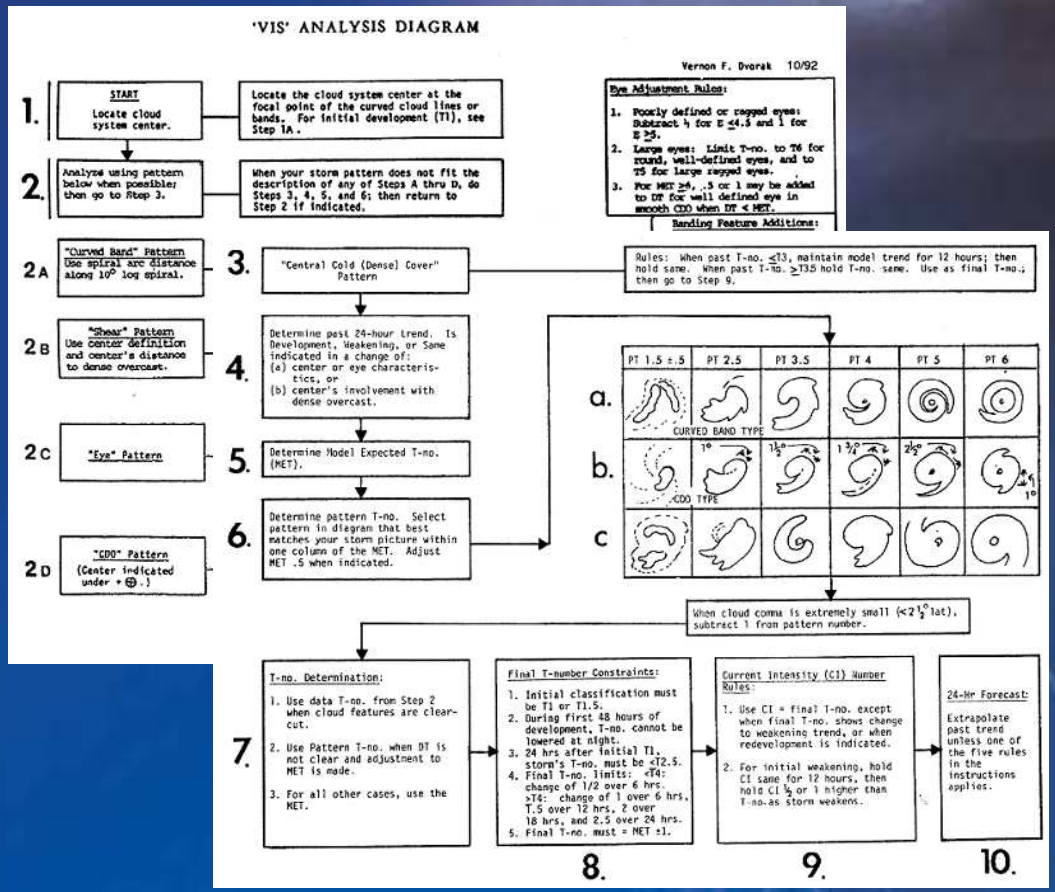
Step 6 – Determine PAT

- 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!



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

Final T-number Constraints:

1. Initial classification must be T1 or T1.5.
2. During first 48 hours of development, T-no. cannot be lowered at night.
3. 24 hrs after initial T1, storm's T-no. must be <T2.5.
4. Final T-no. limits: <T4: change of 1/2 over 6 hrs.. >T4: change of 1 over 6 hrs, T.5 over 12 hrs, 2 over 18 hrs, and 2.5 over 24 hrs.
5. Final T-no. must = MET ±1.

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

CI	MSW (kt)
1.0	25
1.5	25
2.0	30
2.5	35
3.0	45
3.5	55
4.0	65
4.5	77
5.0	90
5.5	102
6.0	115
6.5	127
7.0	140
7.5	155
8.0	170

Reanalysis

- 24 hrs after initial fix, FT must be ≤ 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

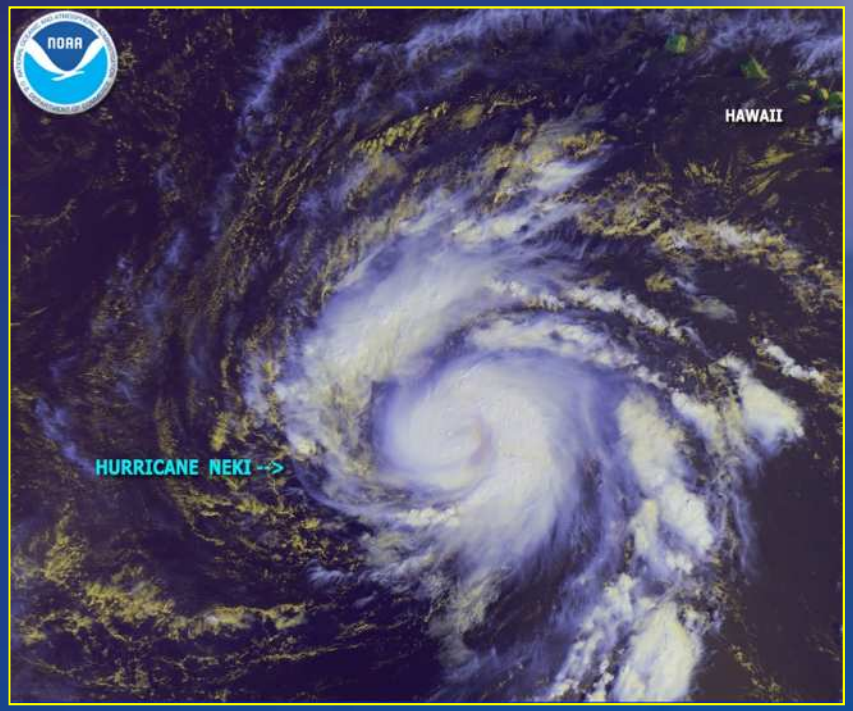
Dvorak Technique Error Reduction

- 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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