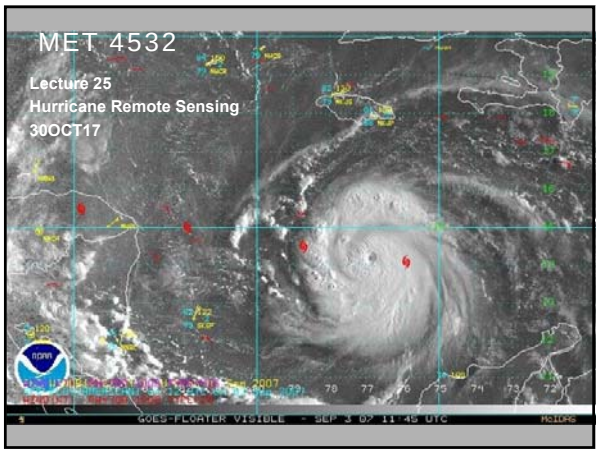
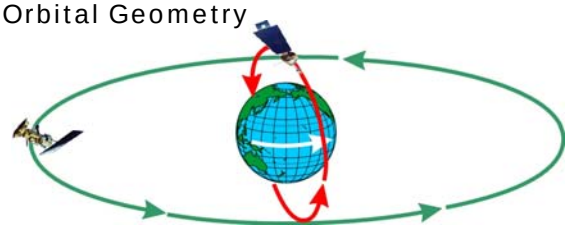


HISTORY

- TIROS-1
  - TV & IR Observation Satellite
  - Launched 01APR60
  - Polar orbit ~850 km
  - 2 looks at each place on Earth daily
  - Evolved into ESSA then NOAA satellites
- SMS
  - Synchronous Meteorological Satellite
  - Launched 1974
  - Equatorial orbit ~34,000 km
  - Stays over the same place on the equator continuously
  - Evolved into GOES statellites

Orbital Geometry

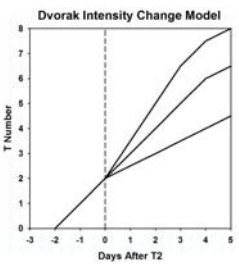


- Polar—DMSP, POES & NPOES
  - Relatively low (~850 km)
  - Earth rotates under satellite
  - Satellite passes overhead once during the day once at night
  - Or sunrise and sunset
- Geosynchronous—GOES
  - High (34,000km)
  - Earth Rotates with satellite
  - Satellite remains above a fixed point on the surface

Overview of Dvorak Technique

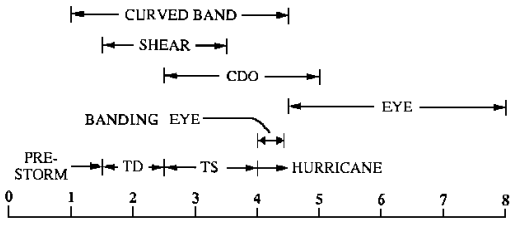
- **Estimates intensity in terms of T (Tropical) numbers that range from T0 to T8 in steps of 0.5**
- **Uses VISUAL imagery, not IR**
- **Combines**
  - **Model Estimated T-number (MET) based upon climatological rates of intensification**
  - **Data T-number (DT) based upon recognition and analysis of "Scene Types"**
- **Four main scene types, plus one**
  - **Curved Band Pattern**
  - **Shear Pattern**
  - **Central Dense Overcast (CDO) Pattern**
  - **Eye Pattern**
  - **Also, Banding Eye Pattern**
- **Choose the best estimate as the Current Intensity (CI)**
- **Relationship between T number and maximum surface wind**

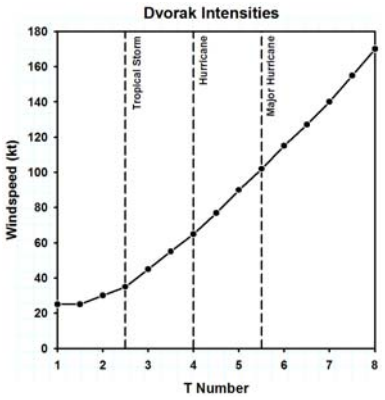
Model Estimated T-Number (MET)



- Starts at T2 (Middle Tropical Depression)
- Typical increase is one T number a day
  - Slow development increases ½ T-number a day
  - Fast development iincreases 1½ T-number a day
- NW moving TCs peak one day later than North moving
- Hold MET constant for one day after peak
- Then decrease at same slow, typical, or rapid rate

FOUR PRIMARY PATTERNS AND TYPICAL T - NO.'s

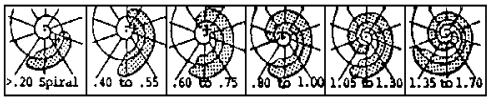




Curved Band

- Cloud band bent into an arc by TC circulation
- T1.0-T4.5
- Depression to CAT 1 hurricane
- T number Increase as band arcs more around the center
- Analyzed using a spiral overlay

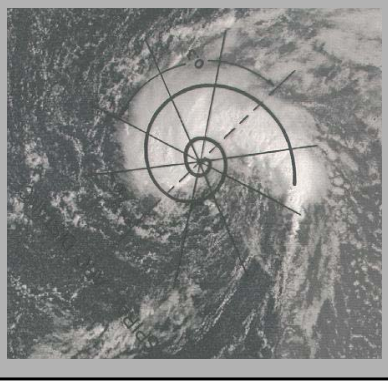
Curved Band Pattern Values



1.0 to 2.0 2.5 3.0 3.5 4.0 4.5

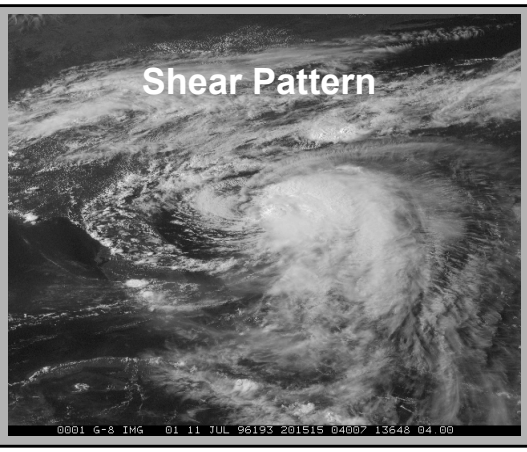
DT Number

Example: TS Ivan 1115Z on 23SEP98, Arc = 0.7, equivalent to DT=3

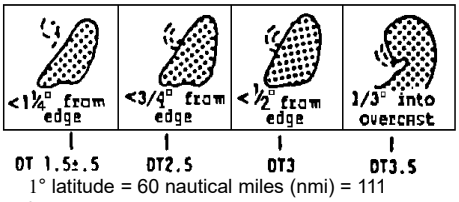


Shear Pattern

- Visible center exposed near or partly under the cloud mass
- T1.5 to T3.5
- Depression to strong tropical storm
- T number increases as center gets closer to the cloud mass and then partly under it



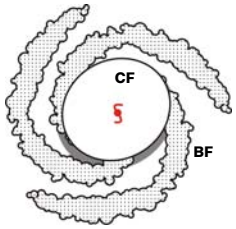
Shear Pattern DT Numbers



1° latitude = 60 nautical miles (nmi) = 111 km

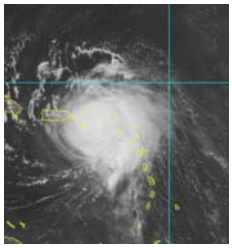
CDO Pattern

- **Central Dense Overcast**
- **More or less circular mass of high cloud over the center**
- **No visible eye**
- **T2.5-T5.0**
- **Tropical storm to CAT 1**
- **T number combines**
  - **CF: Central feature parameter that increases with CDO size**
  - **BF: Banding feature that increases as bands become wider and arc farther around the center**
  - **DT = CF + BF**

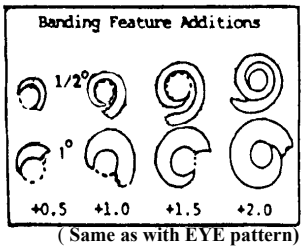


Example: Hurricane Georges 1545 UTC 21 September 1998

- To get CF, measure Diameter of CDO in degrees latitude
- For a well defined CDO
  - 3/4 ° → CF=2
  - 1 1/4 ° → CF=3
  - 1 3/4 ° → CF=4
  - >2 1/4 ° → CF=5
- For an irregular CDO
  - 1° to 1 1/2 ° → CF=2
  - >1 1/2 °→ CF=3



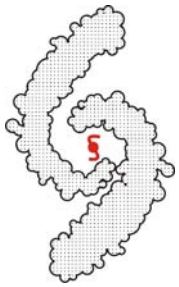
CDO and Eye Banding Feature (BF)



(Same as with EYE pattern)

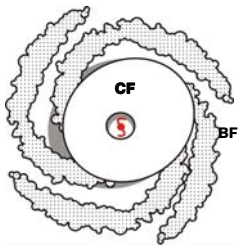
Banding Eye Pattern

- Bands encircle center to form an eye.
- Not obscured by CDO
- Only T4-T4.5

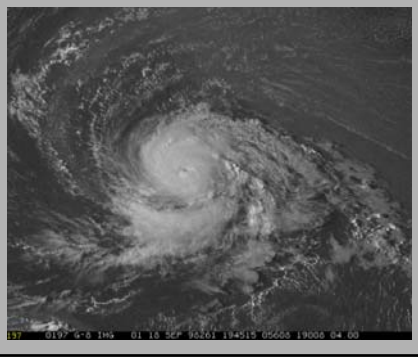


Eye Pattern

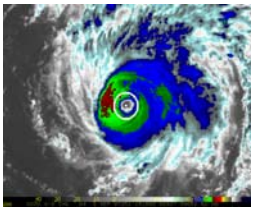
- An eye appears within the CDO
- DT combines CF and BF as before
- Presence of an eye increases CF by ~ 1
- T4.5-T8
- CAT 1 to CAT 5
- CF increases as CDO gets bigger and the eye moves to its center
- Also for smooth CDOs and circular small eyes
- BF works the same as for CDO



Hurricane Georges 1945 UTC 18 September 1998



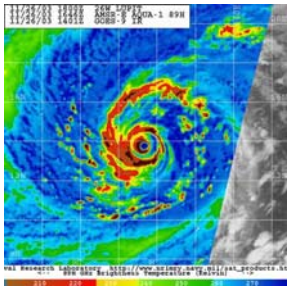
Digital (IR) Dvorak: Example, Hurricane Erika 1515 UTC 8 September 1997

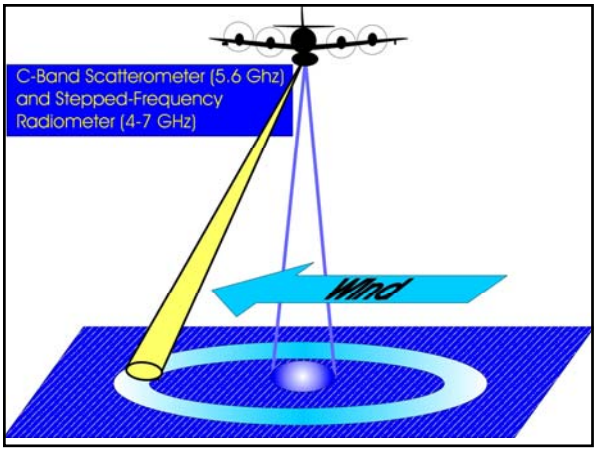


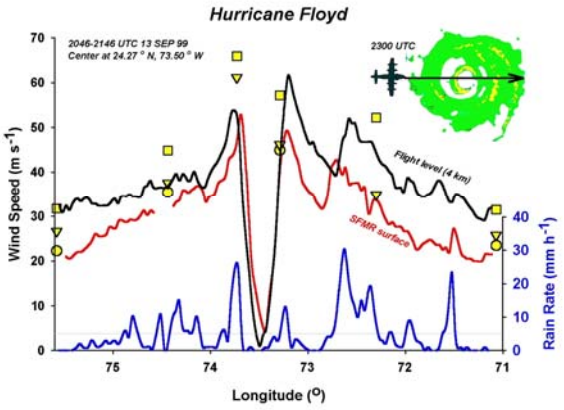
- Compares warmest temperature inside the eye with the surrounding cloud top temperatures
- Formula gives Eye no.
- Works at night
- Can be made automatic

Microwave Imagers

- **Mostly carried on polar orbiters**
- **Frequencies 85-89 GHz, wavelength 3.4-3.5 mm**
- **Passive radiometers that see through ice in the CDO**
- **Signal is cold rain above the warm sea**
- **Can extract rain rate**
- **Gives radar-like image of the storm**
- **Examples SSMI, AVHRR**







Summary

- The Dvorak technique uses patterns and measurements from satellite imagery to estimate the strength of a tropical cyclone.
- Uses T-numbers that typically increase by one each day after reaching T2
- Combines "modeled" (MET) with "data" DT
- Four basic types plus one
  - Curved band pattern, TD to CAT 1 (T1-T4.5)
  - Shear pattern, TD to TS (T1.5 to T3.5)
  - CDO pattern, TS to CAT 2 (T2.5 to T5)
  - Banding eye, CAT 1 (T4 to T 4.5)
  - Eye pattern, CAT1 to CAT 5 (T4.5 to T 8)
- Digital and objective Dvorak get E numbers from temperature differences between eye and CDO
- Microwave imagers like SSMI & AVHRR see cold rain against warm sea. Radar-like images
- Airborne Scatterometer and radiaometer suite senses surface wind speed and direction from flight level even through rain

For Next Time
S&W 157-178