Introduction to Dvorak's method

Main principles and concepts

Sebastien Langlade
Tarik Kriat
(with some materials from J. Beven - NOAA)
RA I WMO training course on tropical cyclones 2021
The Dvorak method, an essential input for estimating TC intensity

TC intensity and structure analysis

AMSU, ATMS, SSMI/S

Surf. OBS

MICRO-WAVES

ASCAT, SCATSAT, SMAP, (SAR)

Subject DVORAK

ADT

SATCON
Classify the images in order of increasing intensity
→ There is a correlation between the satellite cloud configuration of a system and its intensity.

This is the initial idea of the DVORAK technique (developed from 1969 to 1984)
I) Main principles of the method
   1) Scope of application
   2) Different cloud patterns

II) Stages of analysis
   1) Find the center
   2) Data T-Number (DT)
   3) MET and PT
   4) FT and CI
I) Main principles
Method of Dvorak

✔ Method for estimating the maximum winds of a tropical system from satellite imagery.

✔ Applies to VIS or IR satellite images only.

✗ Not applicable to subtropical systems (Hebert-Poteat method) or to systems undergoing extratropicalization (Post-Tropical)

✔ Based on a conceptual model of development of a tropical system, with rules, constraints, measures to be carried out.

✔ Still widely used today by all RSMC/TCWC around the world, if in-situ measurements are missing.
A finite number of cloud configurations are found over a fairly common development cycle among all systems.
Method of Dvorak

The 4 main SDT cloud patterns according to Dvorak:

✗ The curved band

✗ The embedded center (IR) or CDO (Visible) for Central Dense Overvast ie central area with high cloudiness.

✗ Eye

✗ Sheared
"Climatological" tropical cyclone development model:

→ Max intensity on average 5 days after the first signs of curvature in deep convection.

To quantify this model, creation of a scale from 1 to 8 (0.5 step), such that a gain of 1 unit in 24 hours represents a climatological development.
Method of Dvorak

Alternatives to "climatological" development:

→ Rapid Dev: +1.5T/D

→ Slow development: +0.5T/D

Similar model and alternatives for weakening phases
TC aircraft data primarily in the Northwest Pacific (1945-1987) and to a lesser degree, in the North Atlantic, were used as in-situ observations to quantify the intensity associated with each T number.
Method of Dvorak

1. Find the center

2. Assessment / measurement

Measurement of the convective pattern:
- Curved band
- Shear
- Eye
- CDO
- Embedded center

→ Data T. number (DT)

24h comparison:
→ Model Expected T. number (MET)

Pattern matching:
→ Pattern adjusted model T. number (PT)

3. Choose the best estimate between DT / MET or DT/PT

4. Apply constraints

5. → Final T. number - FT and Current Intensity – CI
I) Stages of analysis
Method of Dvorak

1. Find the center

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Method of Dvorak

- **Step 1:** Find the center

- Identifying the cloud pattern can help
- Focus on the curvature of low-level clouds
- In case of invisible center covered under the mass, **look for possible signs of shear (strong asymmetry in cirrus outflow)** to look for the center on the "**windward**" edge of the convection.
Method of Dvorak

- **Step 1:** Find the center

Here's to you!
Method of Dvorak

- **Step 1**: Find the center
Method of Dvorak

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Method of Dvorak

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Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

➢ **Identify the configuration, make the measurements.**

- ❌ **The curved band**, beginning of life / maturity. The more it is curved, the more intense the system is.

- ❌ **The embedded center** (IR) or **CDO** (Visible). The colder and more extensive the clouds, the more intense the system... DT is generally not clear-cut in this case.

- ❌ **The eye**, that we no longer present... We prefer to look at it in IR, because the rules of estimation are then strict and explicit and leaves little room for interpretation.

- ❌ **Sheared**, common at the end of life but not only: it is found as soon as an environmental VWS constraint becomes too strong. The further the circulation center is from the main convection, the weaker the system is considered to be.
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

➢ Identify the configuration
➢ Carry out the recommended measures

Curved band

/

the center of the spiral is not necessarily on the center of the system.

Gael, 2009

5 sectors of the log10 spiral covered → 0.5° on log10 → DT=2.5
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

- **Identify the configuration**
- **Carry out the recommended measures**

Curved band

/\ the center of the spiral is not necessarily on the center of the system.

/\ As long as the band is curved, small breaks in the convection can be incorporated.
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

Here's to you!
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

![Image of a weather map with a satellite view of a storm system, including a legend for DT categories.]
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT
Method of Dvorak

- **Step 1:** Find the center
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Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

- Identify the configuration
- Carry out the recommended measures

Eye in EIR

- Use of a **specific color code** with IR imagery (reversed palette)

- General principle: the more the ring formed by the coldest brightness temp. around the eye, is cold, wide and associated with warm brightness temp. in the eye, the more the DT is high.
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

- **Identify the configuration**
- **Carry out the recommended measures**

**Eye in EIR**

\[ DT = \text{Eye number} + \text{Eye adjustment} \]

**Eye number**: coldest wide ring surrounding the eye (required minimum width defined by Dvorak for each color)

**Eye adjustment**: temperature contrast between the coldest closed ring (regardless of its width) and the warmest temperature in the eye
Method of Dvorak

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5. → Final T. number - FT and Current Intensity – CI
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT
- **Step 3**: Determine MET

We determine how the configuration of the system has evolved in 24 hours (comparison of the two satellite images at 24 hour intervals to avoid the diurnal cycle).

Based on this trend (Dev., Weak., Stat.):

\[ MET = FT_{-24h} \pm [0, 0.5, 1, 1.5] \]

- Slow (default)
- Rapid

Slow

Climo

Rapid
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT
- **Step 3**: Determine MET

### Criteria for the 24-hour trend:

**Intensification (D) / Weakening (W):**

- Increase / decrease in convection near the center (wider / smaller CDO with / or cooler / warmer cloud tops)
- Increase / decrease of the curvature of the curved bands (both the main band and the bands around a CDO)
- An eye forms / disappears or becomes warmer / colder and more distinct / less well defined
- Exposed center moving towards / away from the convection
- Increase / decrease of the curvature of the low layer clouds near the center
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT
- **Step 3**: Determine MET

**Criteria for the 24-hour trend:**

**Stationary (S):**

- No significant change

- Existence of contradictory signs
Method of Dvorak: MET

D, S or W?

GRETELLE

(janv. 1997)

FT=2.5

24h

MET=?
Method of Dvorak: MET

GRETELLE
(janv. 1997)

FT=2.5

24h

D,
MET=3.5
Method of Dvorak: MET

D, S or W?

FT=6.5

24h

DANIELLA

(dec. 1996)

MET=?
Method of Dvorak: MET

DANIELLA (dec. 1996)

FT=6.5

24h

W, MET= 5.5
Method of Dvorak: MET

D, S or W?

FT = 4.5

BELNA (dec. 2019)

MET = ?

24h
Method of Dvorak: MET

BELNA (dec. 2019)

FT=4.5

24h

S, MET= 4.5
Method of Dvorak: MET

**DVORAK signs of rapid intensification:**
- Cold comma cloud
- Formation of multiple outflow channels
- « Pinhole » eye formation

**DVORAK signs of rapid weakening:**
- Warming of the convective tops over more than 12 hours
- Shear pattern rapidly established or elongation of the pattern

**Katrina (2005) – cold comma cloud pattern**
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT
- **Step 3:** Determine MET
- **Step 4:** Adjust MET with PT

We determine the closest pattern to adjust the MET by ± 0.5 if necessary.
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT
- **Step 3**: Determine MET
- **Step 4**: Adjust MET with PT

We determine the closest pattern to adjust the MET by ± 0.5 if necessary.

MET = 4.0 (FT_{24h} = 3.0, 24h tendency = intensification)
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT
- **Step 3:** Determine MET
- **Step 4:** Adjust MET with PT

We determine the closest pattern to adjust the MET by ± 0.5 if necessary.

MET = 4.0 (FT_{-24h} = 3.0, 24h tendency = intensification)

→ PT = 3.5
Method of Dvorak

1. Find the center

2. Assessment / measurement

- Measurement of the convective pattern:
  - Curved band
  - Shear
  - Eye
  - CDO
  - Embedded center

  → Data T. number (DT)

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3. Choose the best estimate between DT / MET or DT/PT

4. Apply constraints

5. → Final T. number - FT and Current Intensity – CI
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT
- **Step 3**: Determine MET
- **Step 4**: Adjust MET with PT
- **Final step**: Determine FT and CI

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We have two intensity estimates

- DT
- Adjust MET

We take the one that seems the most reliable (if eye → DT, by default MET adjusted or MET if DT uncertain)

We check the constraints on the "allowed" limits of FT variations over the last 6h, 12h, 18h and 24h.

- FT

And we determine the current intensity CI which equals FT in intensification or which lags behind by 0.5 or 1 in weakening trend
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT
- **Step 3:** Determine MET
- **Step 4:** Adjust MET with PT
- **Final step:** Determine FT and CI

- DT = 3.5 (0.9° Curved band)
- Adjust MET (PT) = 3.5 (24h Tend = D, MET at 4.0 then adjusted to 3.5)
- FT_{6h} = 3.5 ; FT_{-24h/-18h/-12h} = 3.0

→ FT = ??
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT
- **Step 3:** Determine MET
- **Step 4:** Adjust MET with PT
- **Final step:** Determine FT and CI

- DT = 3.5 (0.9° Curved band)
- Adjust MET (PT) = 3.5 (24h Tend = D, MET at 4.0 then adjusted to 3.5)
- FT$_{-6h}$ = 3.5 ; FT$_{-24h/-18h/-12h}$ = 3.0
  - → FT = 3.5 (and CI = 3.5 since we are in intensification phase ie FT = CI)
- Vmax (estimated with subj. Dvo) = 50 kt (10-min winds)
The numbers of DVORAK's technique

**DT**
- Based on measurements made on an identified cloud pattern

**MET**
- Based on the comparison with the satellite image of the previous day (-24h)

**PT**
- Resulting from the comparison of the satellite image with sketches. Used to readjust the MET if necessary

**FT**
- Equal to **FT** in intensification and lag by 6/9/12h in weakening

Choose between PT/MET and DT, depending on the situation. (Subject to constraints that limit its evolution)
DVORAK estimates available on SWIO

- **RSMC bulletin (section 3.A)**:
  http://www.meteo.fr/temps/domtom/La_Reunion/webcmrs9.0/anglais/activiteope/bulletins/cmrs/liste.html
  - Released upon RSMC activation and **every 6 hours** once there is an active system (not necessarily from the initial classification)

- **NOAA with SAB (Satellite Analysis Branch)**:
  https://www.ssd.noaa.gov/PS/TROP/bulletins.html
  - broadcast **every 6 hours** at about the synoptic hours from the initial classification

- **The JTWC with the Analyst (PGTW) position**:
  - available on the site once the JTWC follows the system ("satellite fix" item)
  - available in alphanumeric messages
  - broadcast **every 3 hours**

Example of Dvorak SAB bulletin
The ADT: an automatic and objective DVORAK estimation

Available at http://tropic.ssec.wisc.edu/real-time/adt/adt.html

Based on the DVORAK method with a center fixing and structure analysis algorithm

Basically, it computes FT and CI from a DT by taking advantage of the results of statistical analysis revisited in the light of recent aerial reconnaissance data in the Northern Hemisphere to refine constraints for the FT variations.

For further information:
https://www.wmo.int/pages/prog/www/tcp/documents/2.4_ADTCIMSS_TimOLANDER_ChrisVELDEN.pdf
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

Here's to you!
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT

Eye number

![Eye number chart](chart.png)
Method of Dvorak

- **Step 1**: Find the center
- **Step 2**: Determine DT

**Eye number**
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT

Eye number

The Yellow ring cannot be used to calculate the eye number
Method of Dvorak

**Step 1:** Find the center

**Step 2:** Determine DT

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Eye number

![Eye number diagram](image-url)
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT

The light green ring can be used to calculate the eye number.
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT

Eye number = 5.0

The light green ring can be used to calculate the eye number.
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT

Eye number = 5.0

Configuration avec "œil"

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<th>Il y a 24h, le nombre T était-il ≥ T2 ?</th>
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<td>NON</td>
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Largueur minimale

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Adjustment

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1°
Method of Dvorak

- **Step 1:** Find the center
- **Step 2:** Determine DT

Eye number = 5.0

\[ \text{DT} = 5.0 + 1.0 = 6.0 \]