Introduction to Dvorak's method

Main principles and concepts

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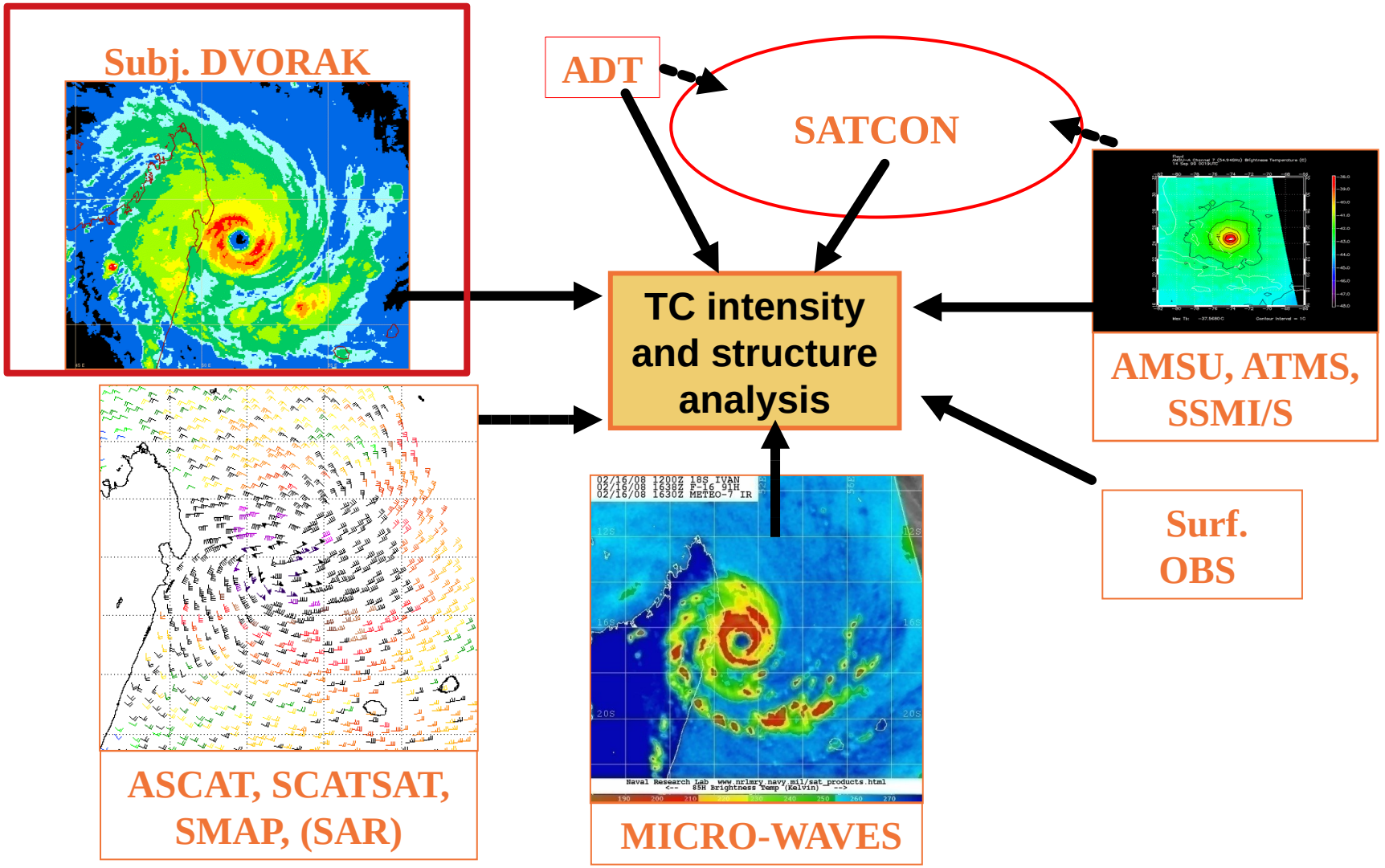
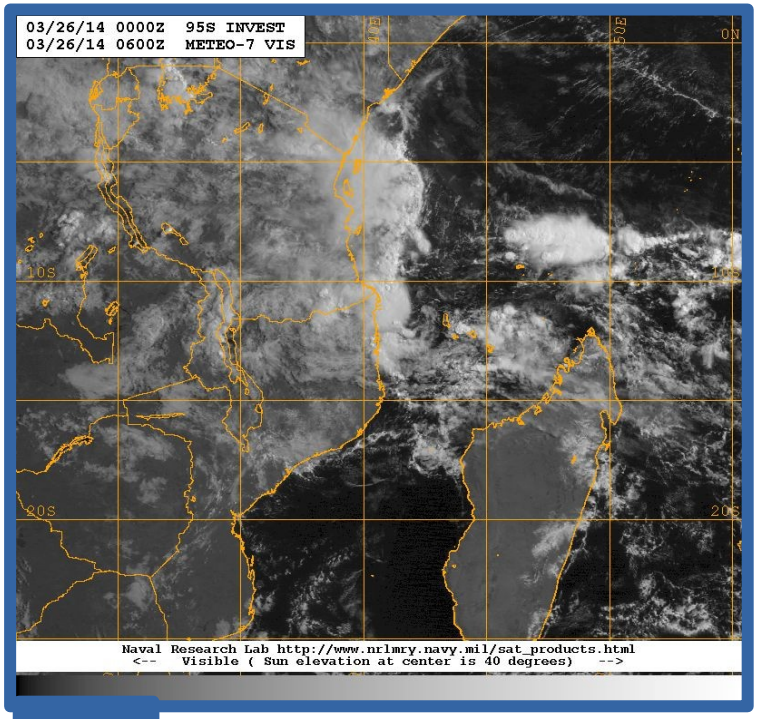
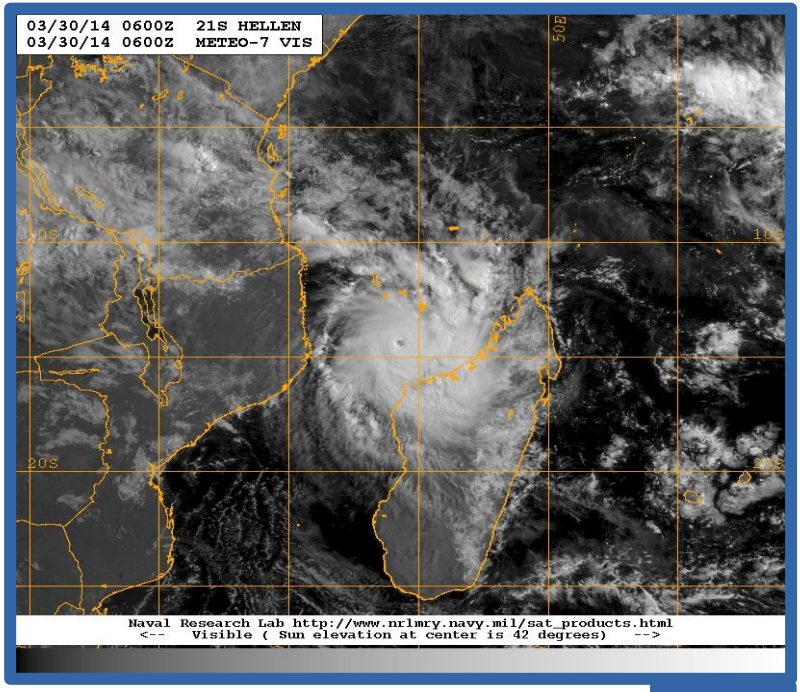
(with some materials from J. Beven - NOAA)
RA I WMO training course on tropical cyclones 2021

The Dvorak method, an essential input for estimating TC intensity





A



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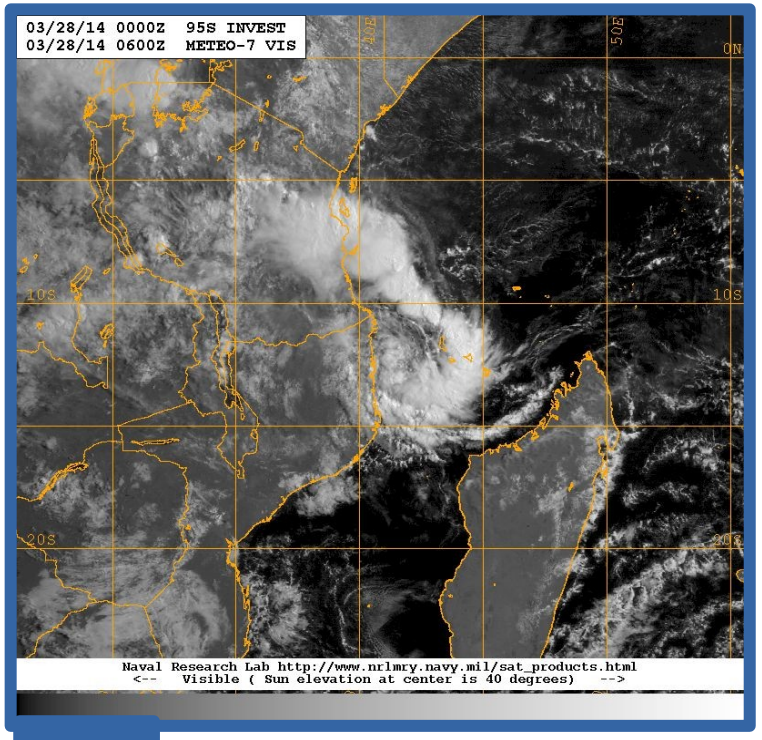
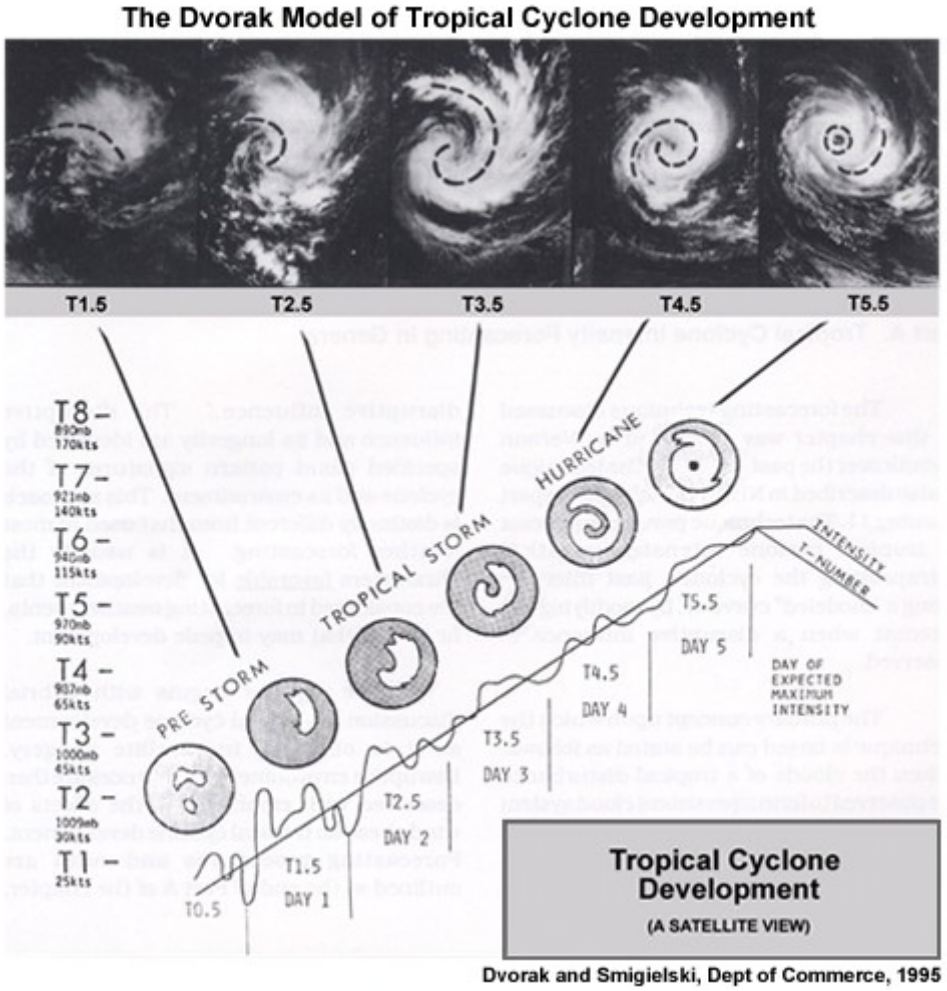


C

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)

Introduction to Dvorak's method

Main principles and concepts

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

Introduction to Dvorak's method

Main principles and concepts

METEO FRANCE

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)**

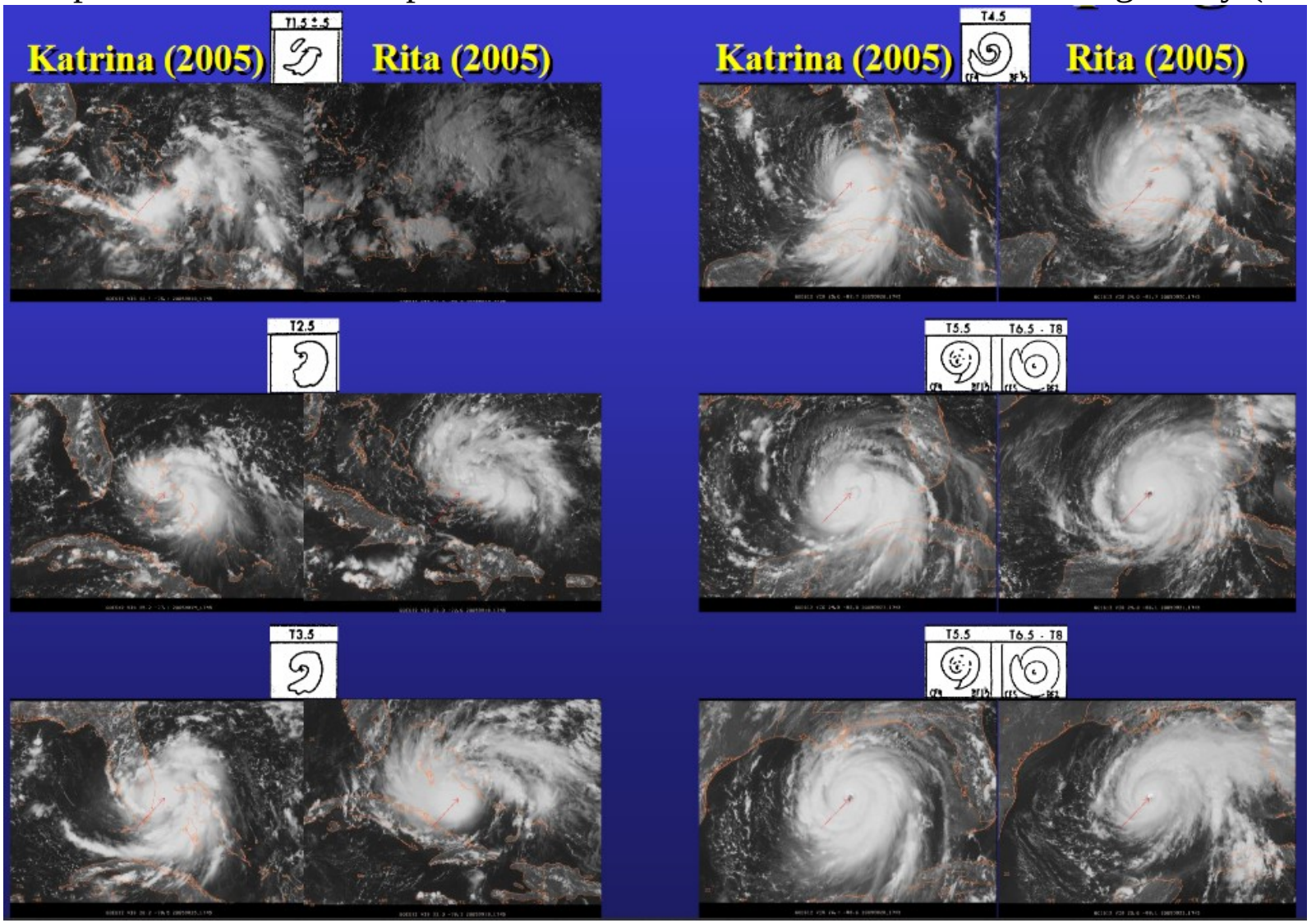
✔**Based on a conceptual model of development of a tropical system, with rules, constraints, measures to be carried out.**

✔**Still widely used today by all RSMC/TCWC around the world, if in-situ measurements are missing.**

METEO FRANCE

Method of Dvorak

Comparison of the development of hurricanes Katrina and Rita - 1 image / day (VIS)



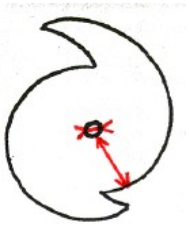
→ A finite number of cloud configurations are found over a fairly common development cycle among all systems.

Method of Dvorak

The 4 main SDT cloud patterns according to Dvorak:

✗ **The curved band**

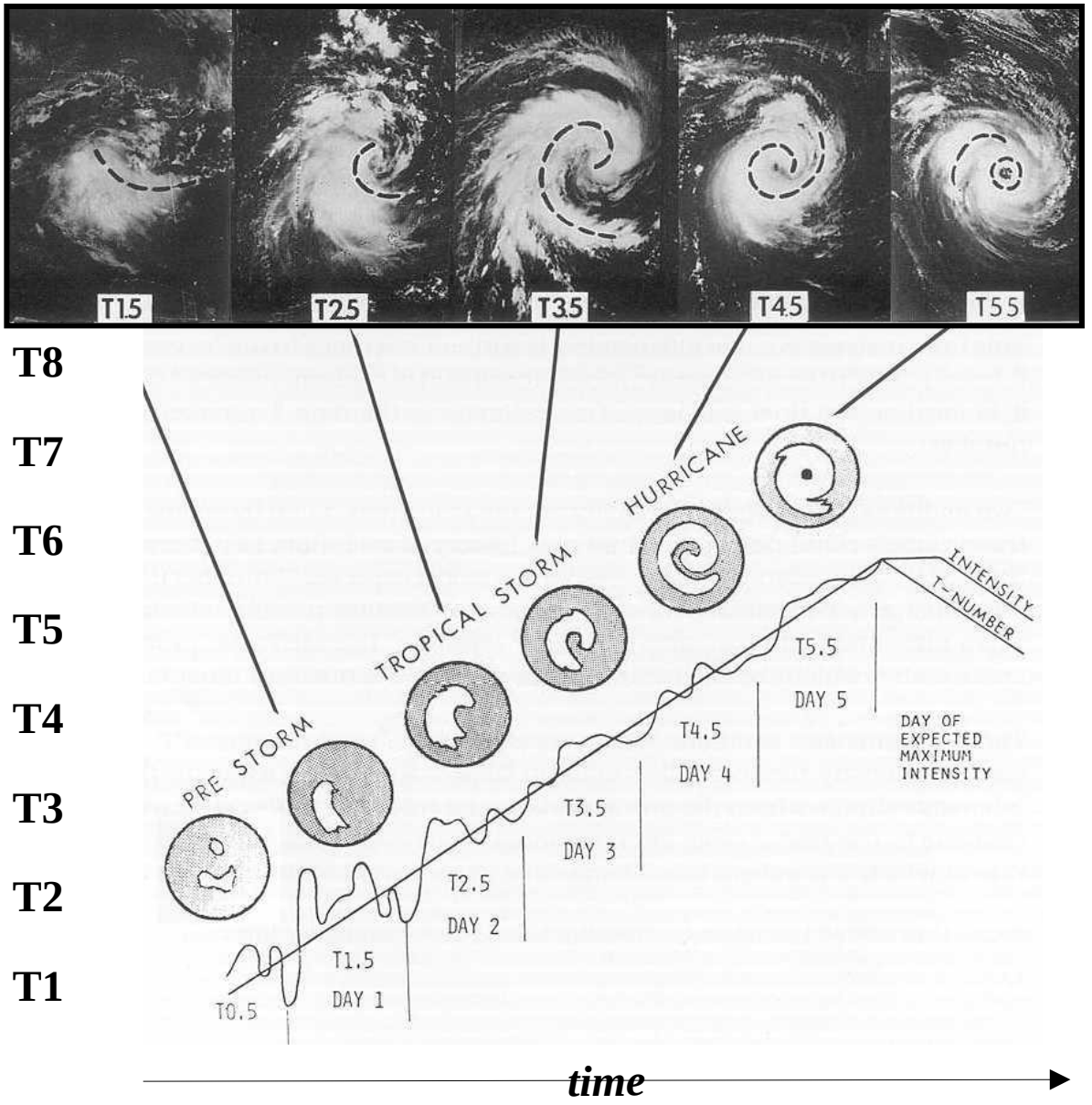
✗ The **embedded center** (IR) or **CDO** (Visible) for **Central Dense Overvast** ie central area with high cloudiness.



✗ **Eye**

✗ **Sheared**

Method of Dvorak

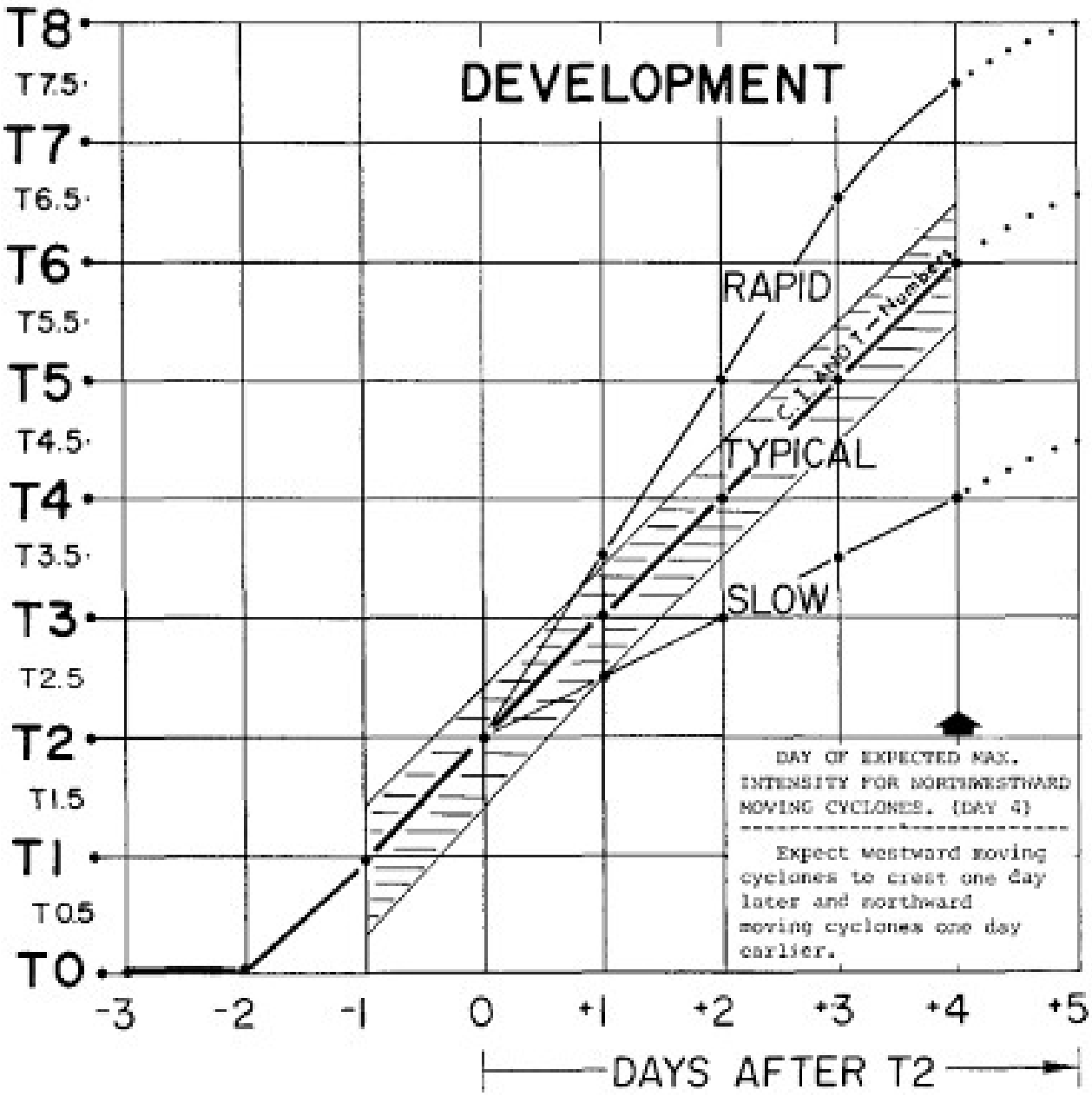


"Climatological" tropical cyclone development model:

→ **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

Method of Dvorak

Nombre T	Vmax 1' (kt)	Vmax 10' (kt)
1.0	25	22
1.5	25	22
2.0	30	26
2.5	35	31
3.0	45	40
3.5	55	48
4.0	65	57
4.5	77	68
5.0	90	79
5.5	102	90
6.0	115	101
6.5	127	112
7.0	140	123
7.5	155	136
8.0	170	150

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.

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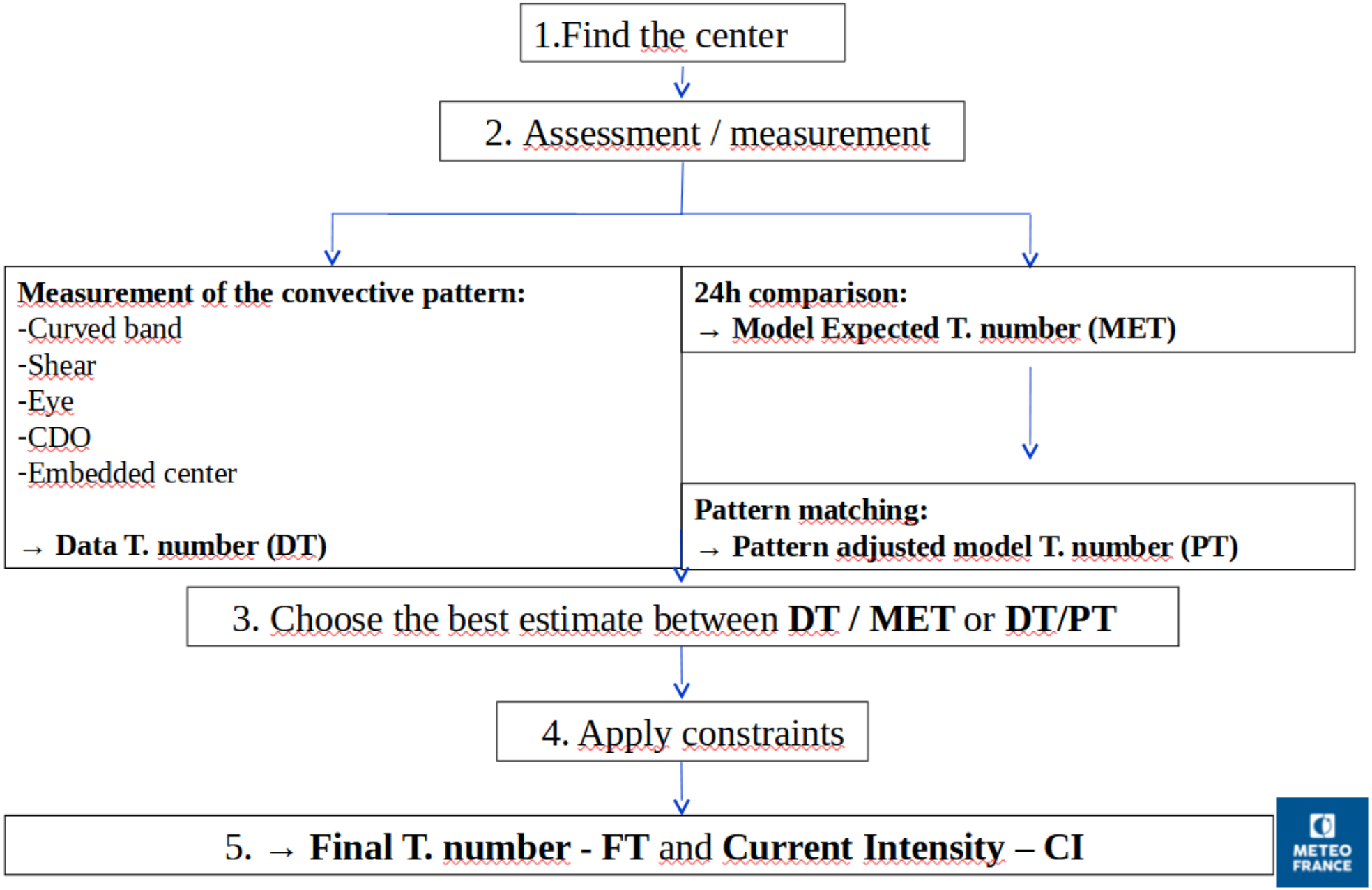
Method of Dvorak

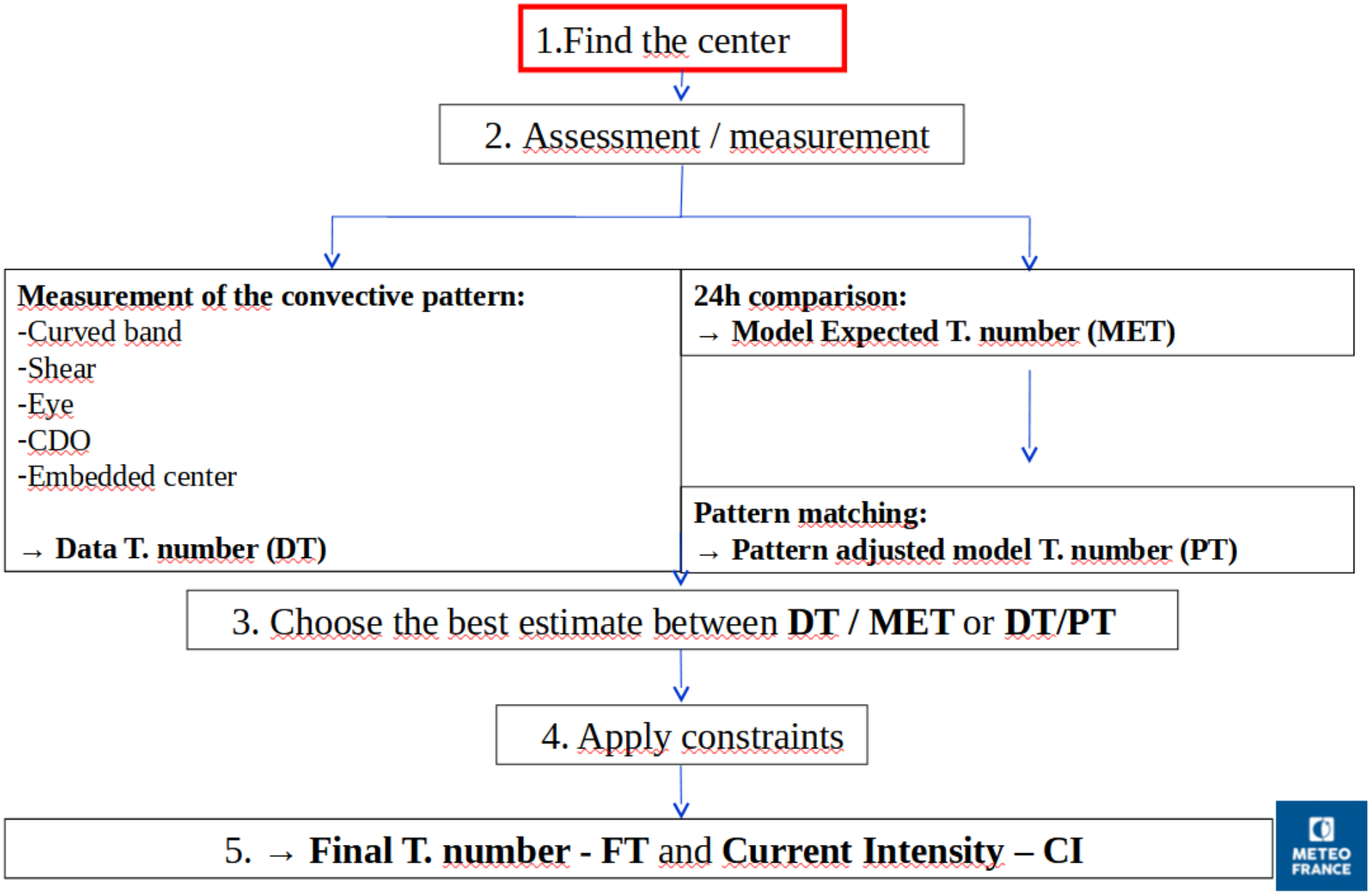


Introduction to Dvorak's method

Main principles and concepts

I) Stages of analysis

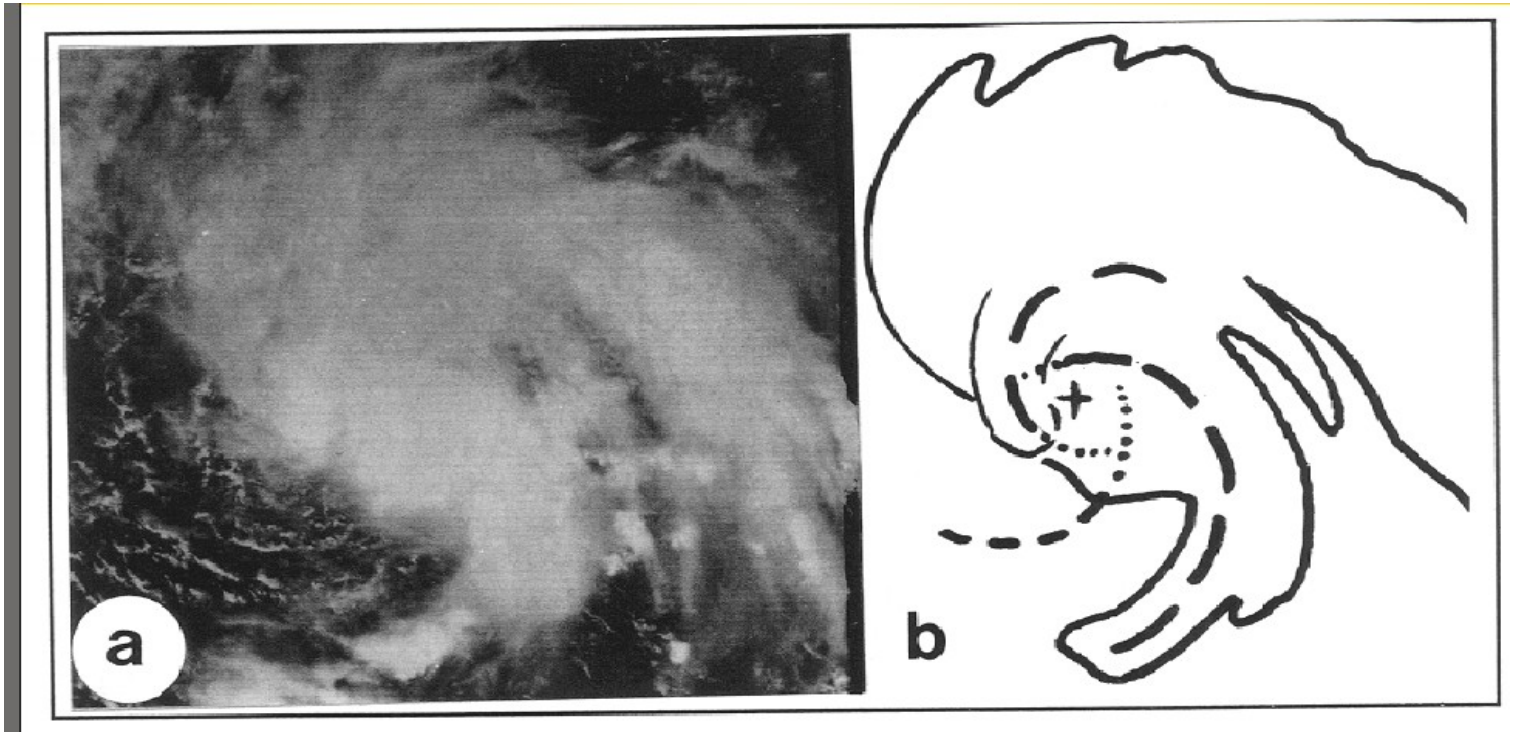
Method of Dvorak



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 :**

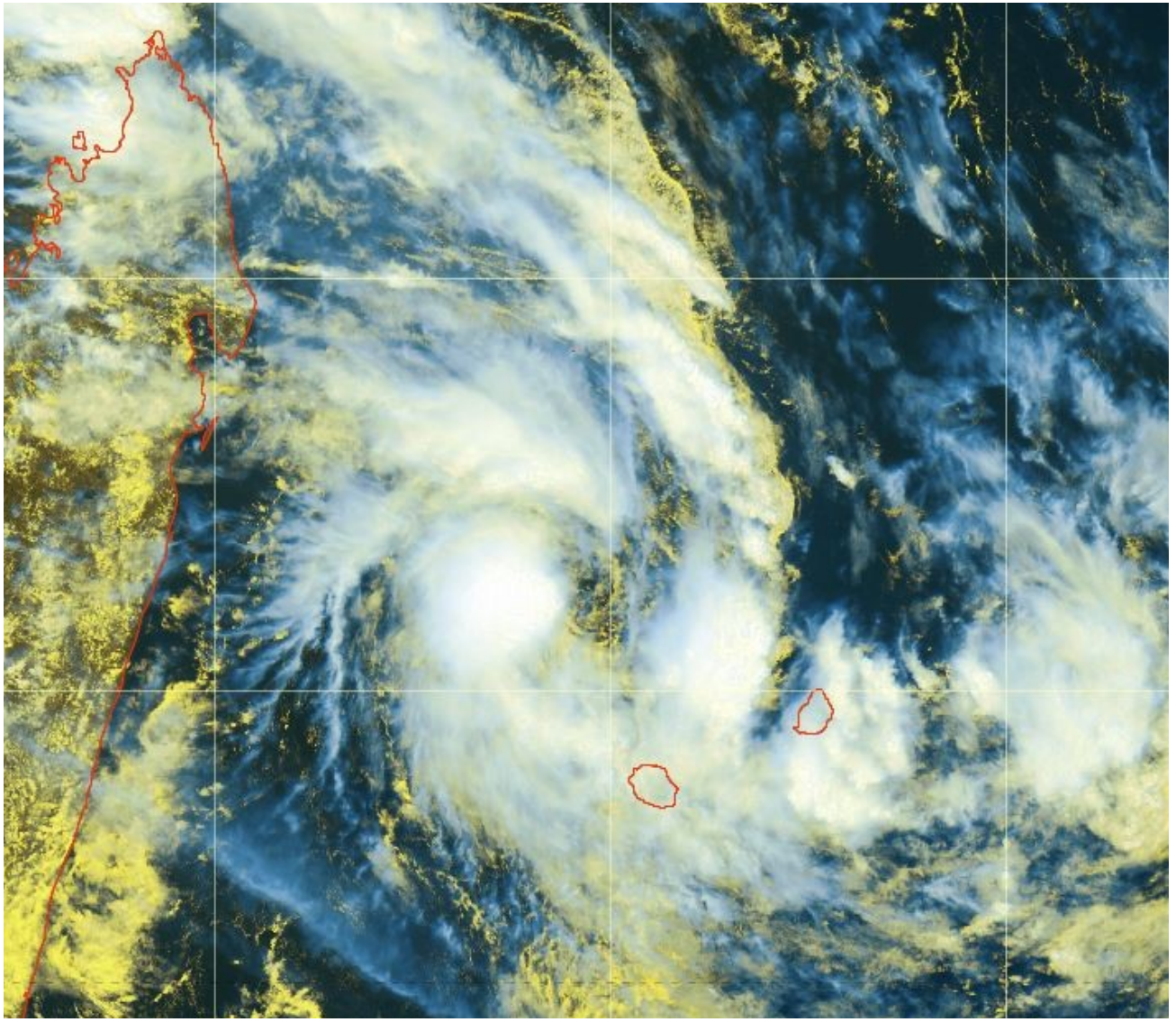
  Find the center

Here's to you!

Method of Dvorak

- **Step 1 :**

  Find the center



Method of Dvorak

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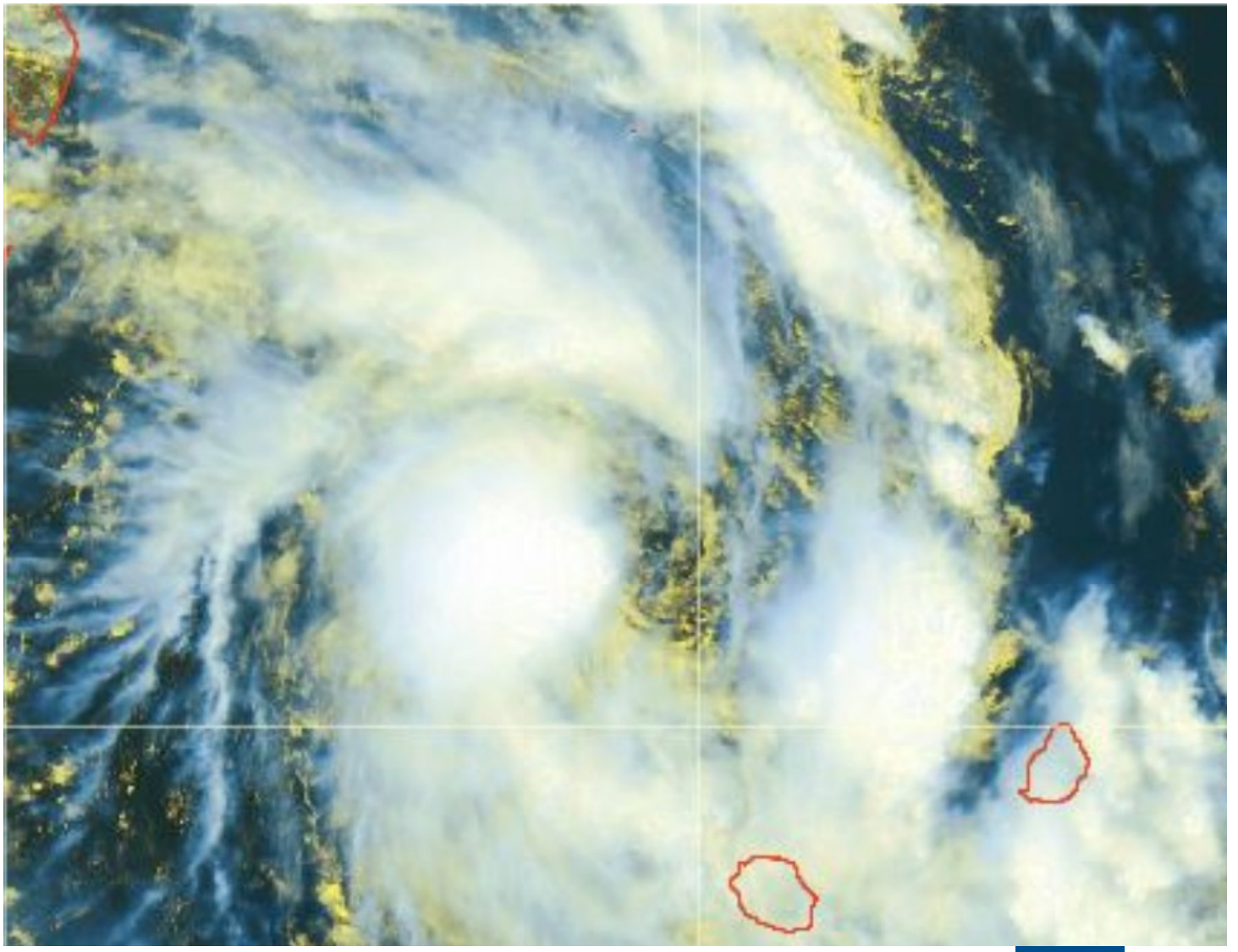

Method of Dvorak

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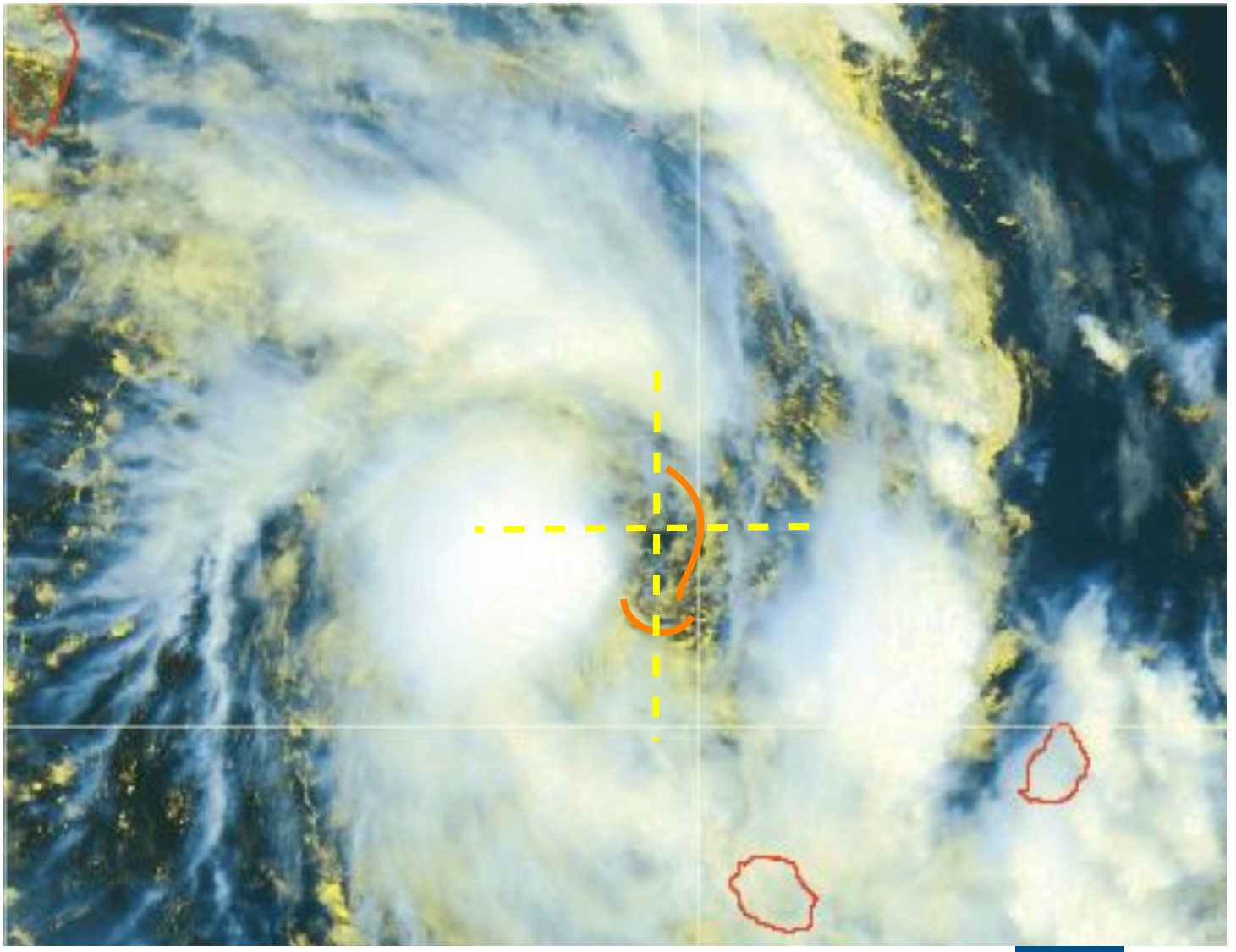
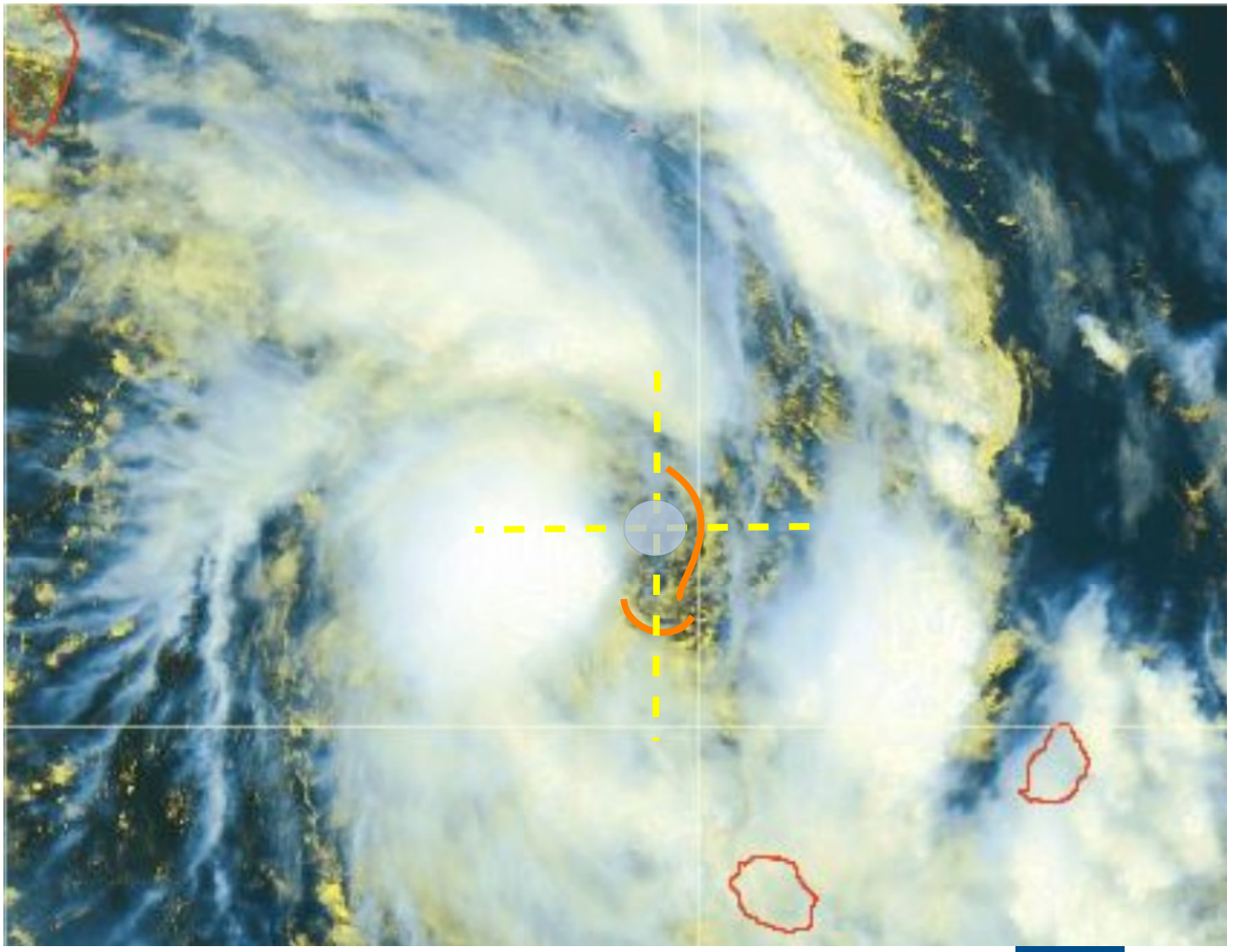


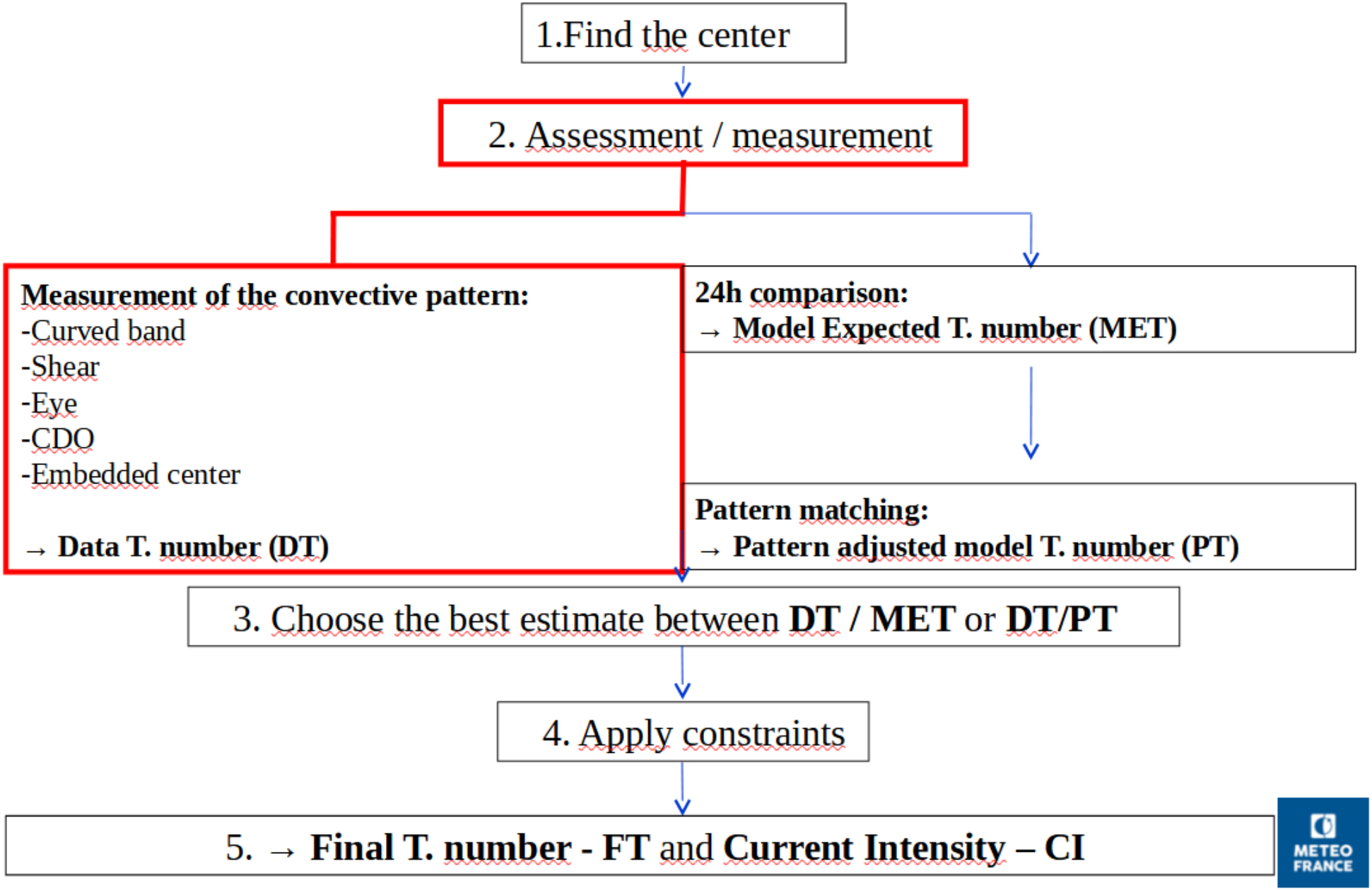
Method of Dvorak

- **Step 1 :**

  Find the center



Method of Dvorak



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

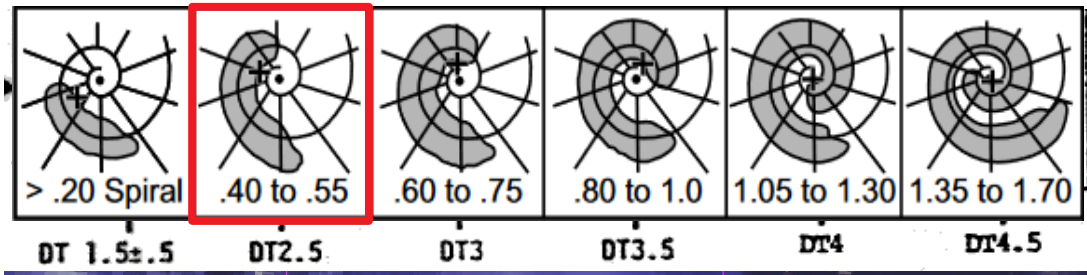
- **Step 2 :**

  Determine DT

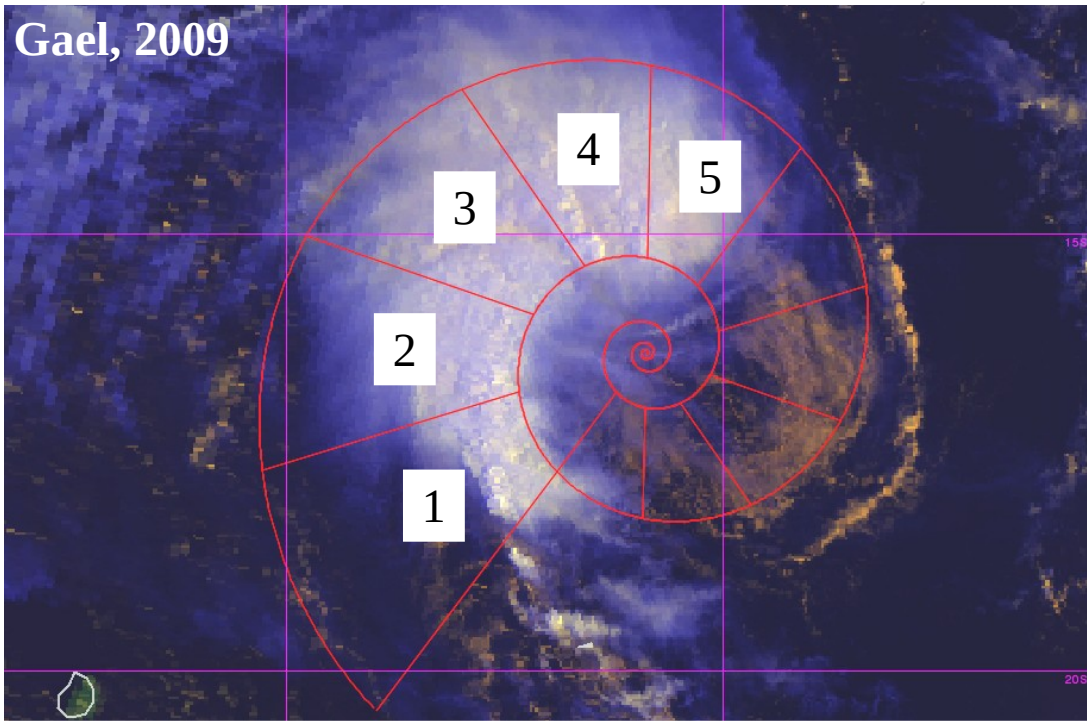
➢ **Identify the configuration**

➢ **Carry out the recommended measures**

Curved band



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



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

Method of Dvorak

- **Step 1 :**

  Find the center

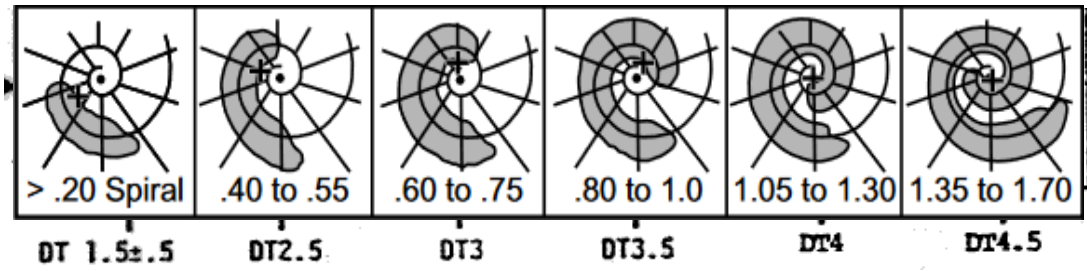
- **Step 2 :**

  Determine DT

➢ **Identify the configuration**

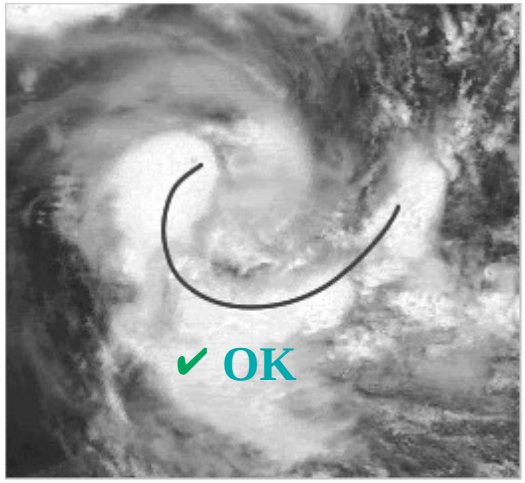
➢ **Carry out the recommended measures**

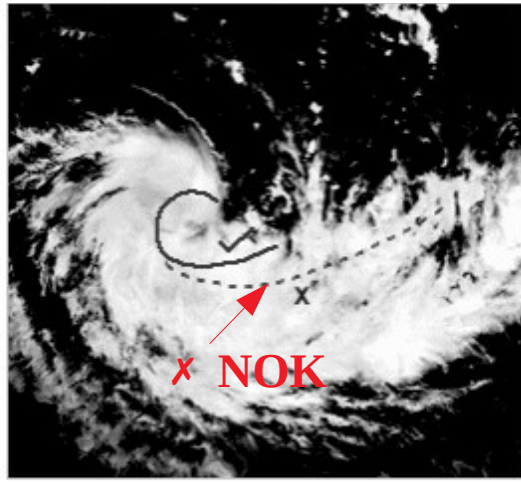
Curved band



/!\ 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 <u>can be</u> incorporated





Method of Dvorak

- **Step 1 :**

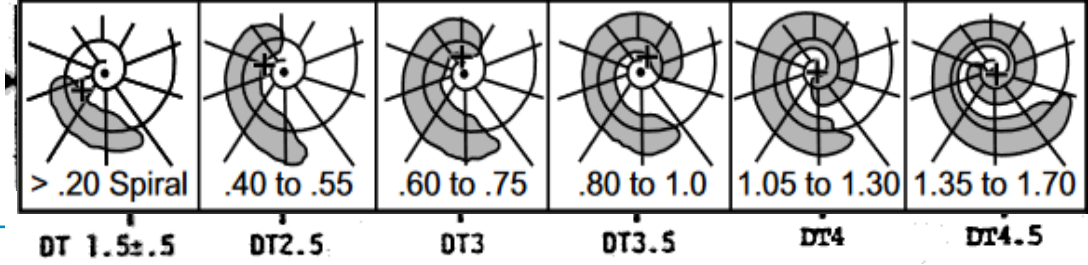
  Find the center

- **Step 2 :**

  Determine DT

Here's to you!

Method of Dvorak

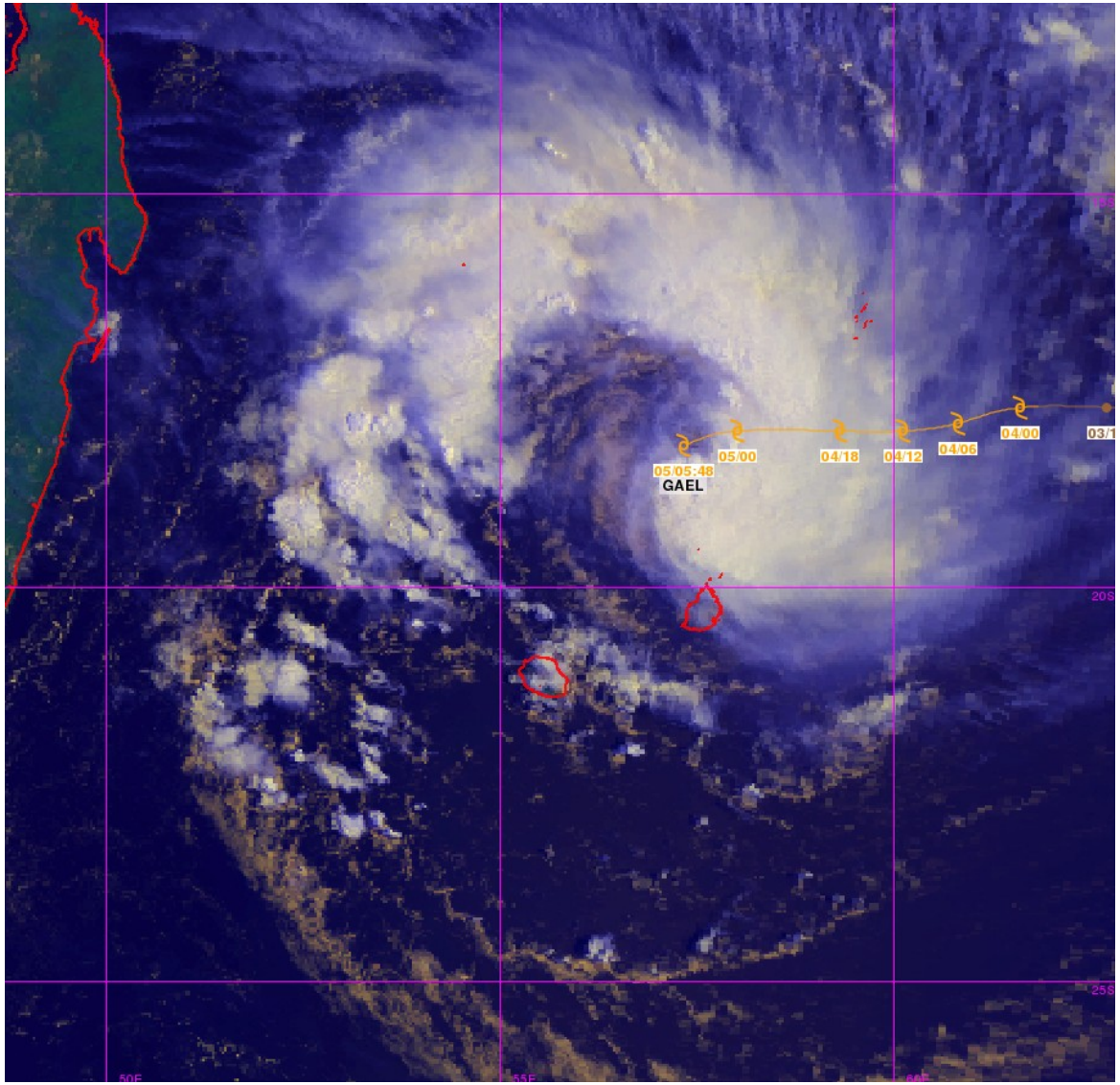


- **Step 1 :**

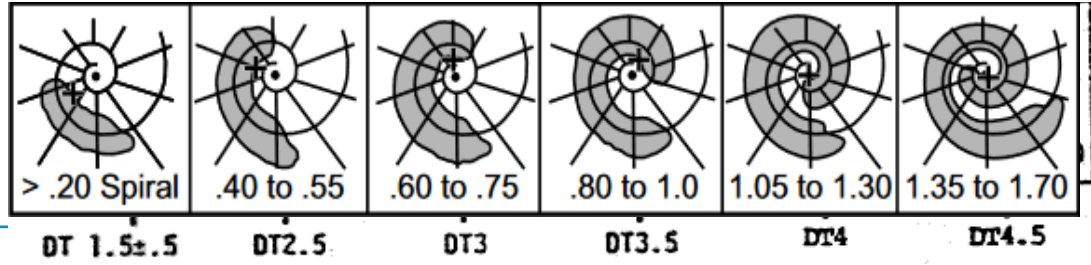
  Find the center

- **Step 2 :**

  Determine DT



Method of Dvorak

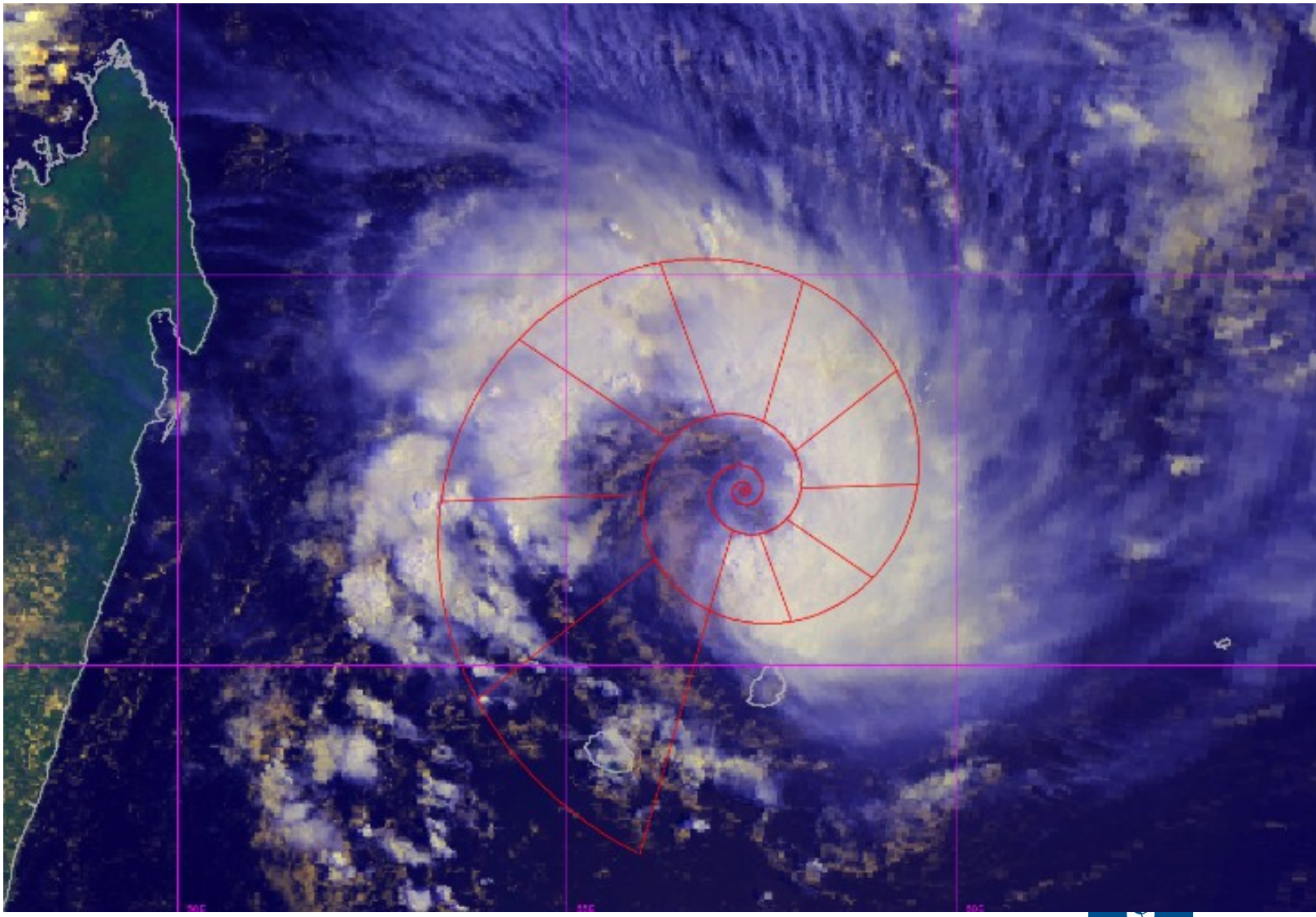


- **Step 1 :**

  Find the center

- **Step 2 :**

  Determine DT



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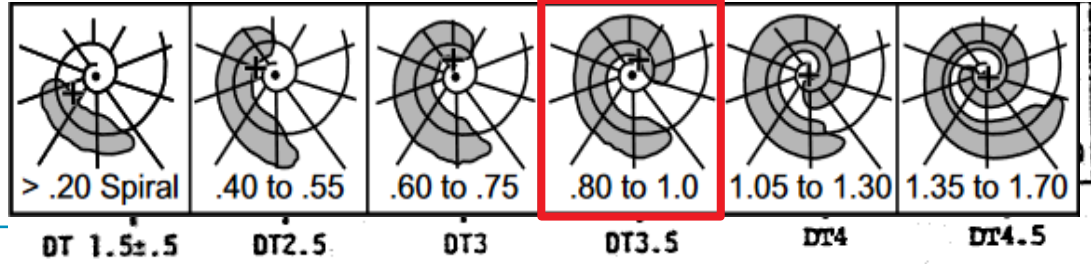
Method of Dvorak

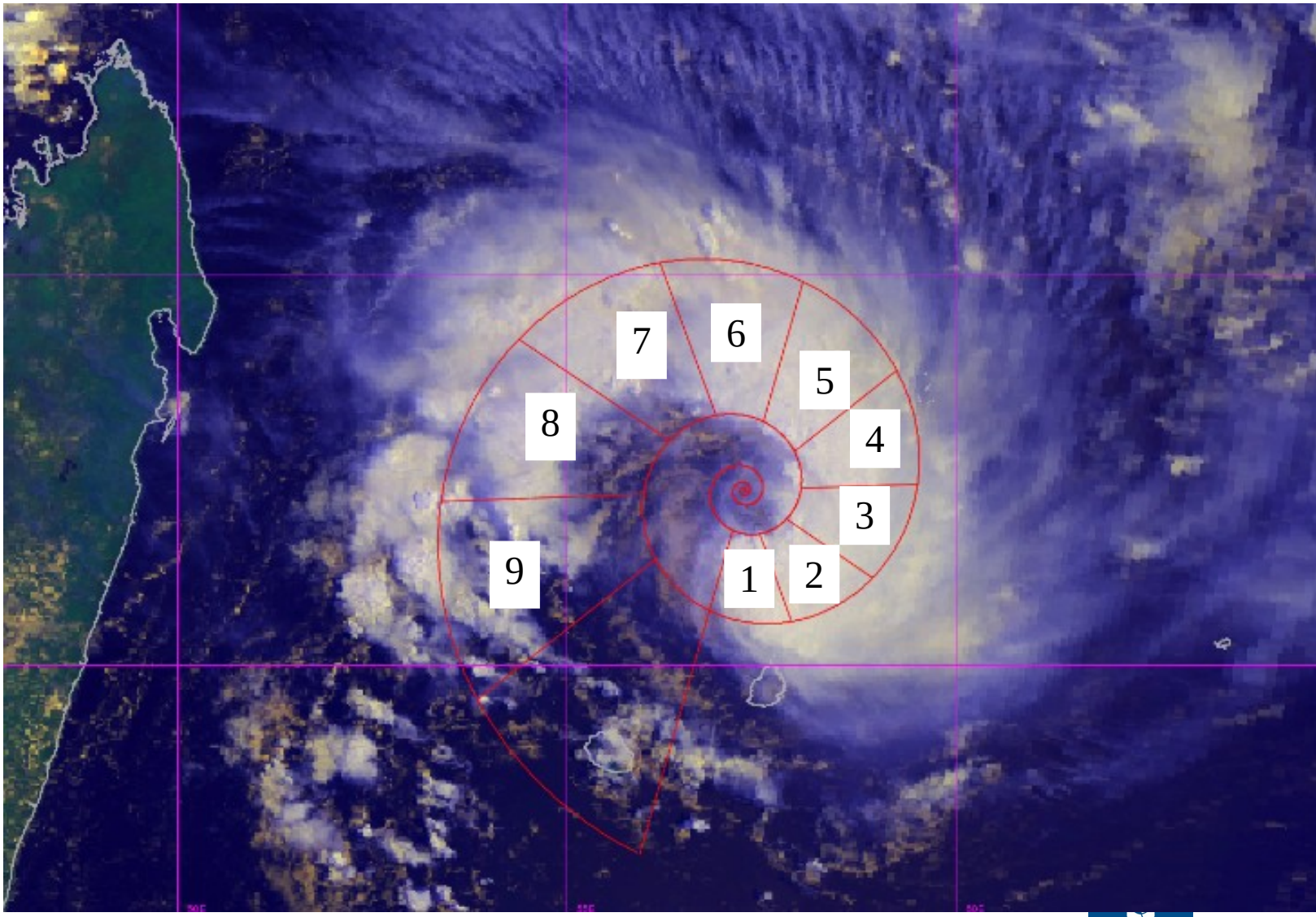


- **Step 1 :**

  Find the center

- **Step 2 :**

  Determine DT



METEO FRANCE

Method of Dvorak

- **Step 1 :**

  Find the center

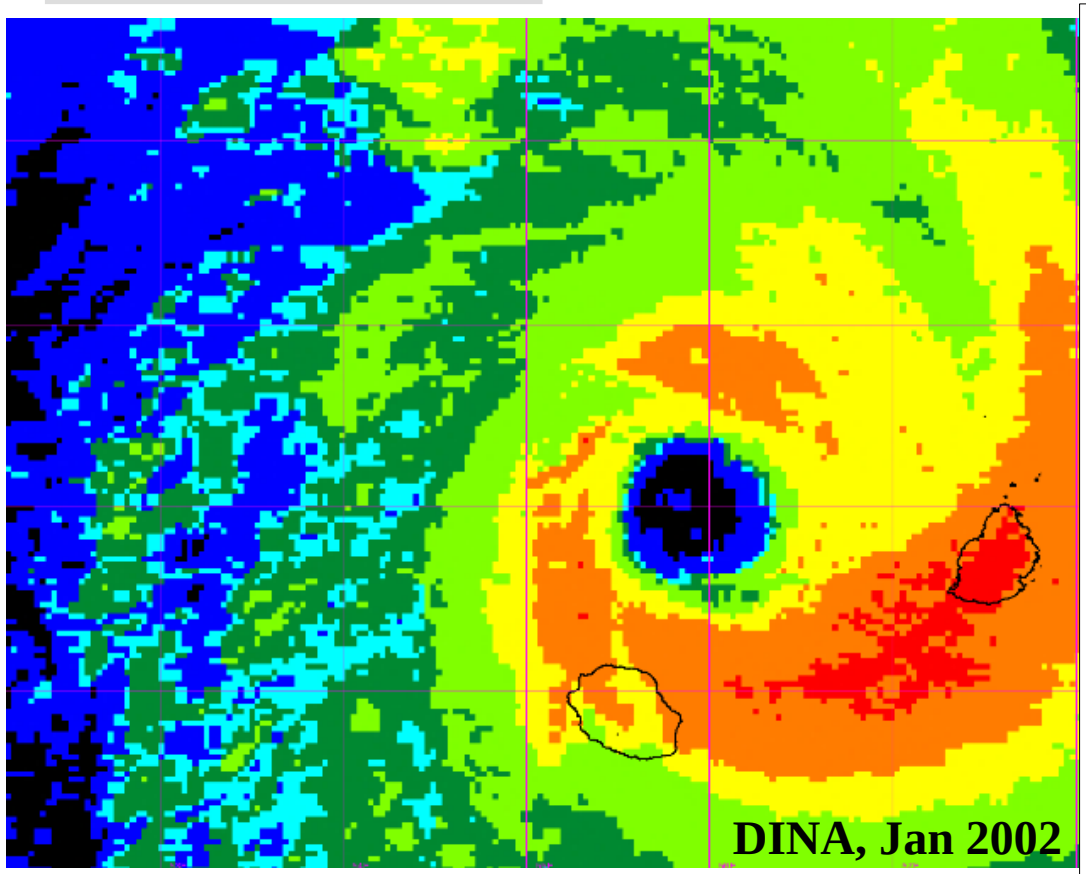
- **Step 2 :**

  Determine DT

➢ **dentify 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 brigthness temp. around the eye, is cold, wide and associated with warm brigtness temp. in the eye, the more the DT is high.

METEO FRANCE

Method of Dvorak

- **Step 1 :**

  Find the center

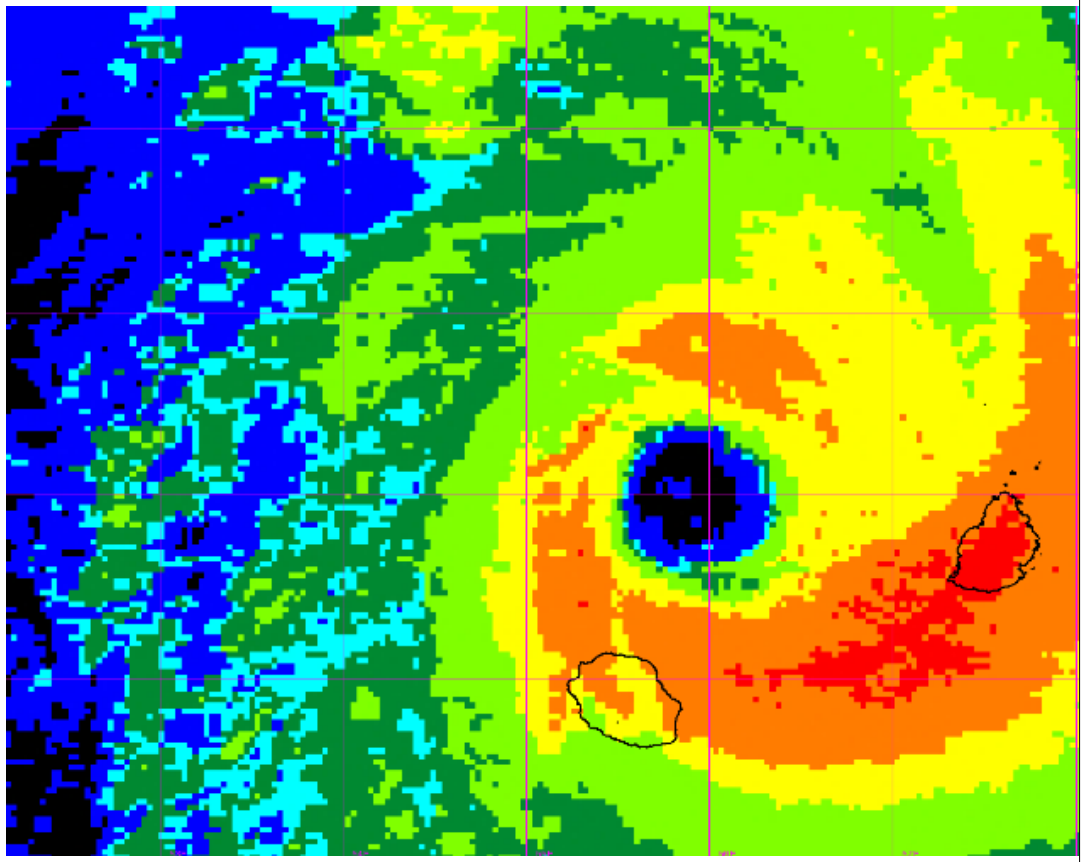
- **Step 2 :**

  Determine DT

➢ **dentify the configuration**

➢ **Carry out the recommended measures**

Eye in EIR



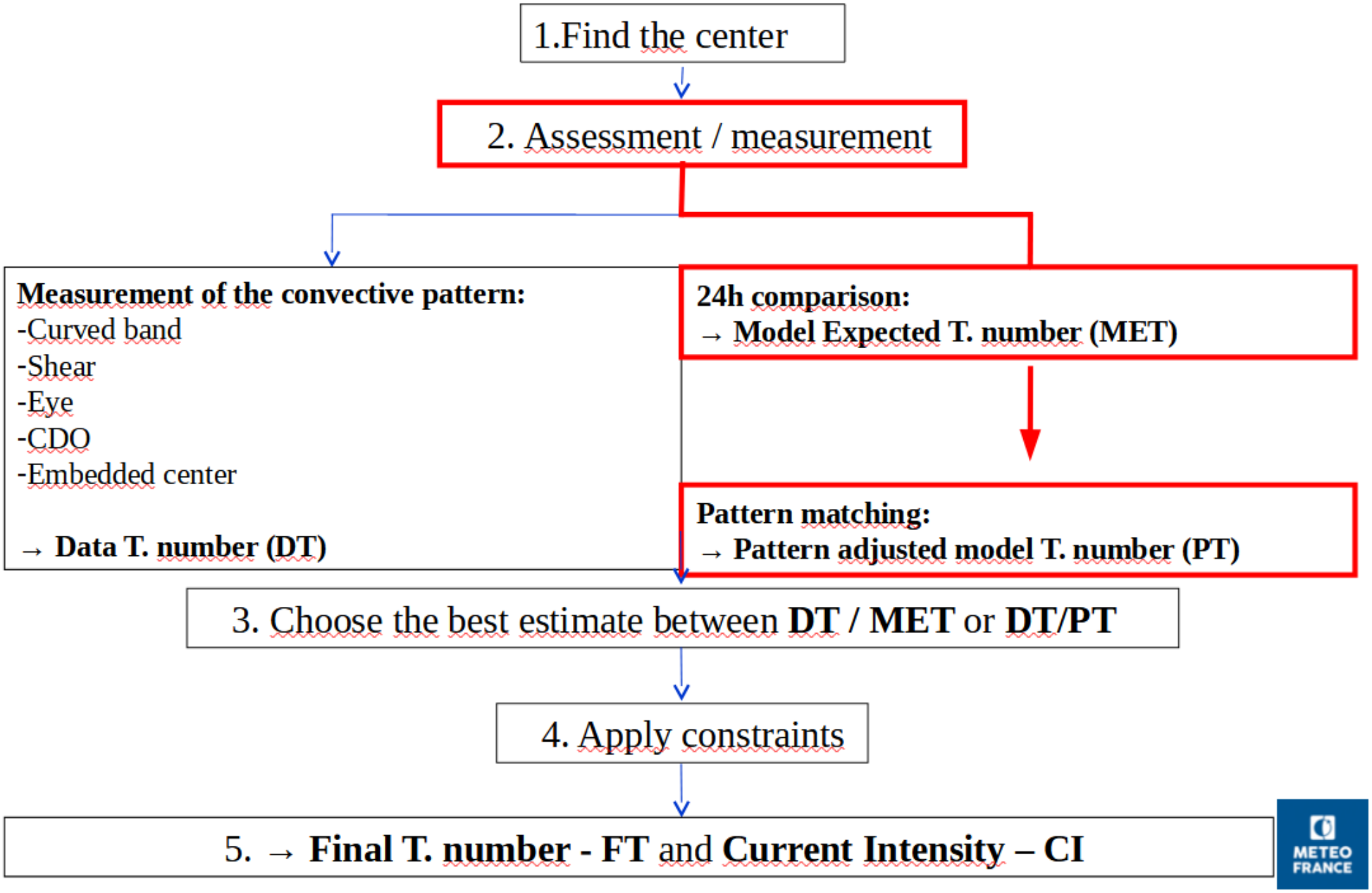
DT =

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



Method of Dvorak

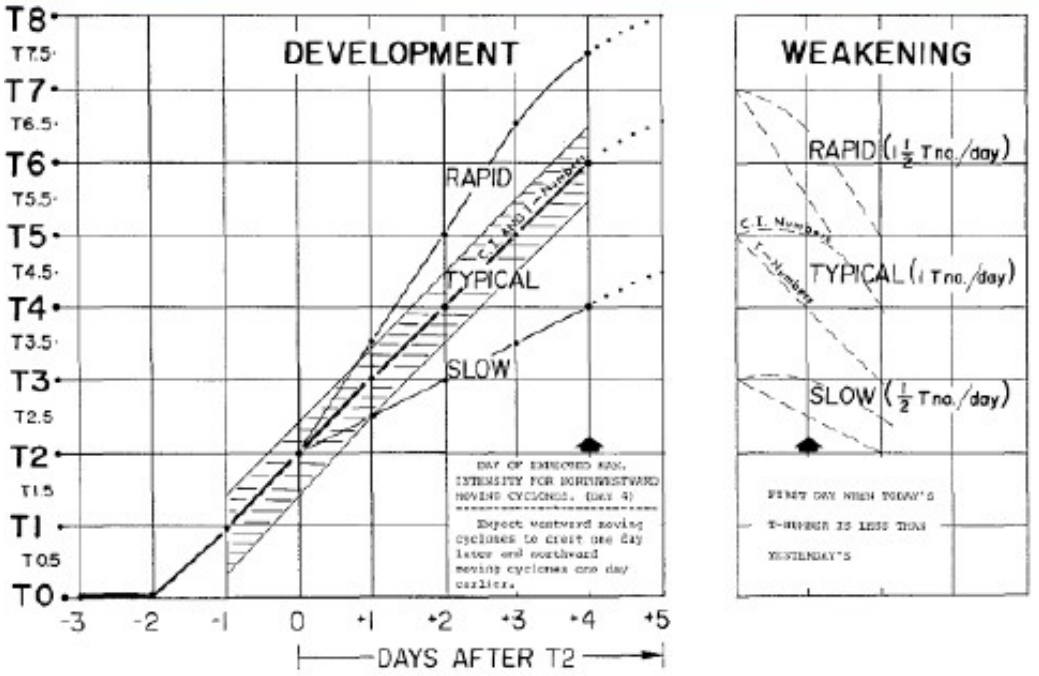
- **Step 1 :**

  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 **Climo (default)** **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**

METEO FRANCE

Method of Dvorak

- **Step 1 :**

  Find the center
- **Step 2 :**

  Determine DT
- **Step 3 :**

  Determine MET

Criteria for the 24-hour trend:

Stationnary (S):

- **No significant change**
- **Existence of contradictory signs**

METEO FRANCE

Method of Dvorak : MET

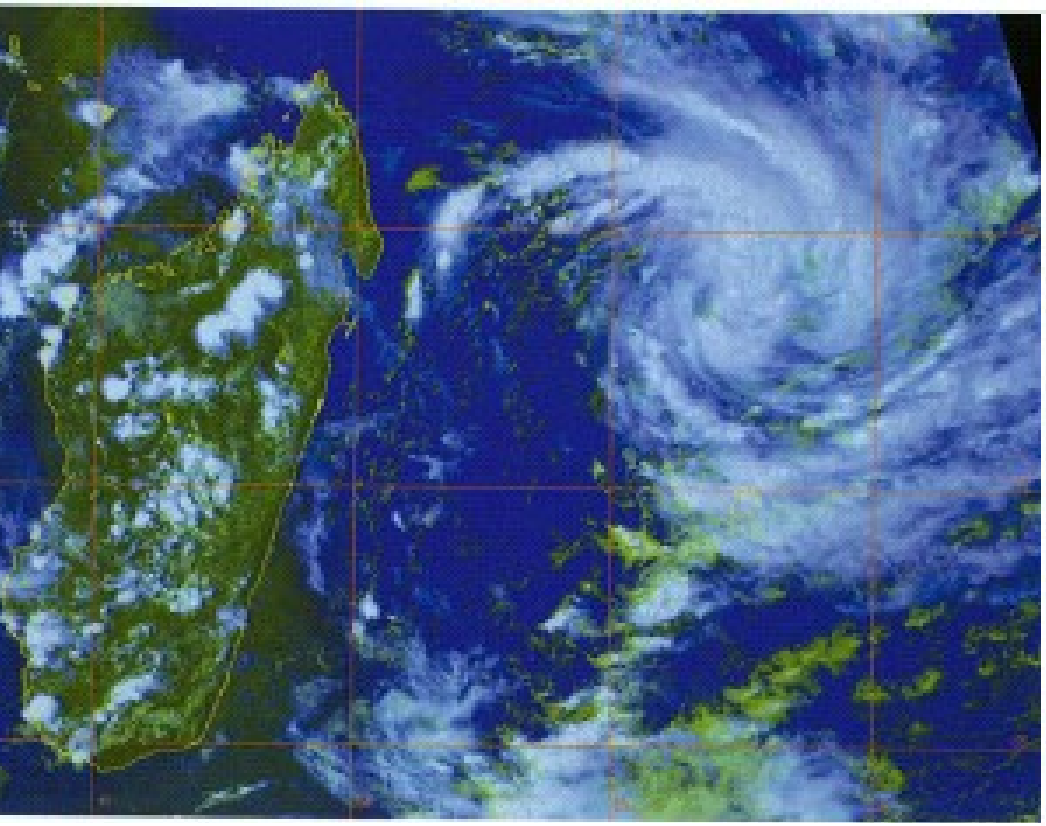
D, S or W ?

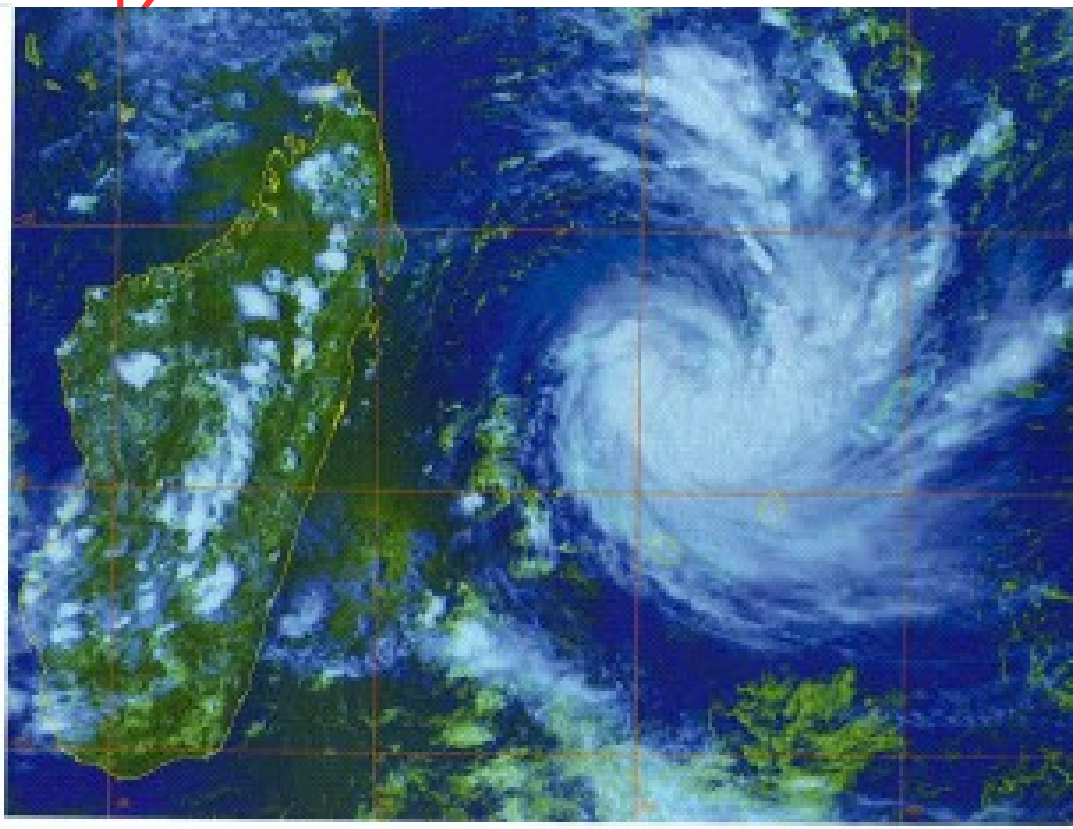
GRETELLE (janv. 1997)

FT=2.5

24h

MET= ?





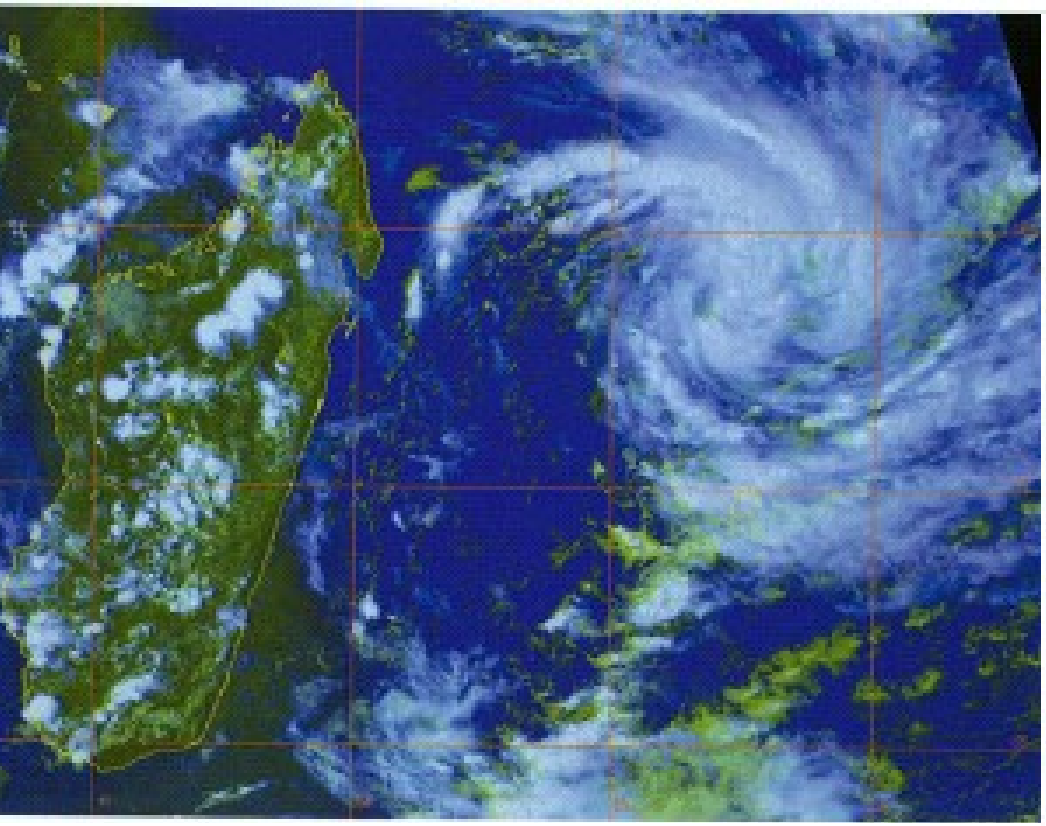
Method of Dvorak : MET

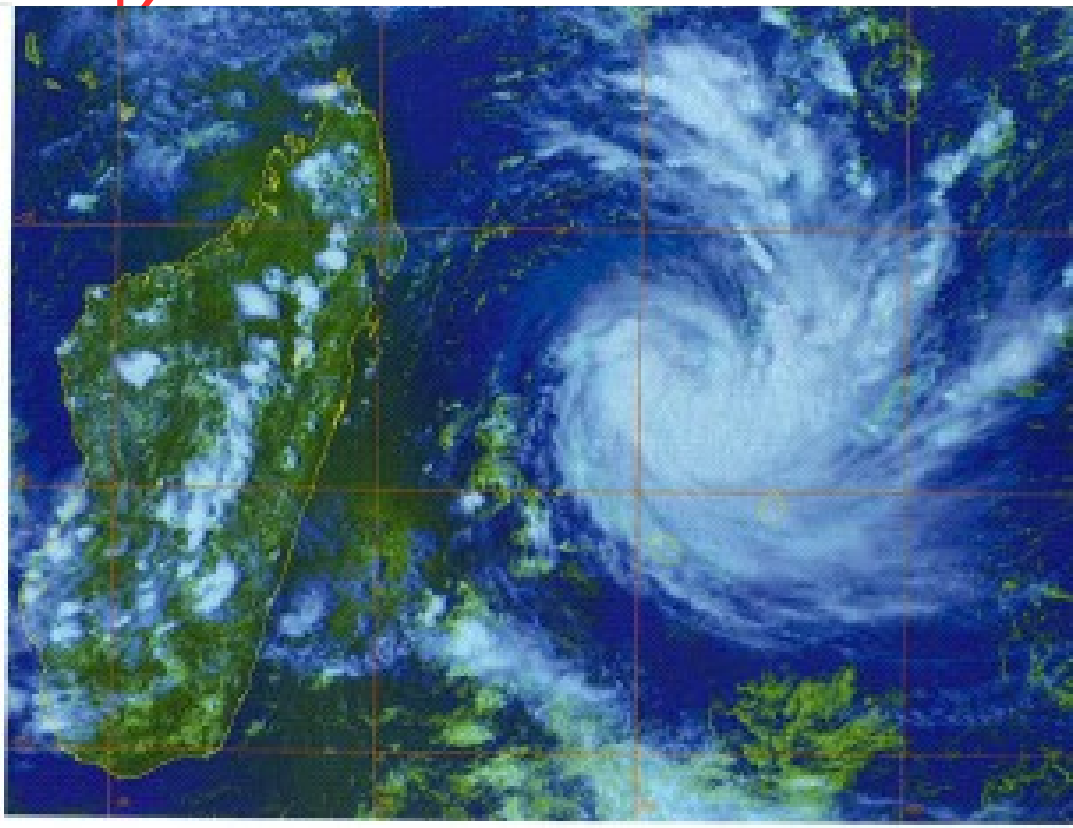
GRETELLE (janv. 1997)

FT=2.5

24h

D,
MET= 3.5





Method of Dvorak : MET

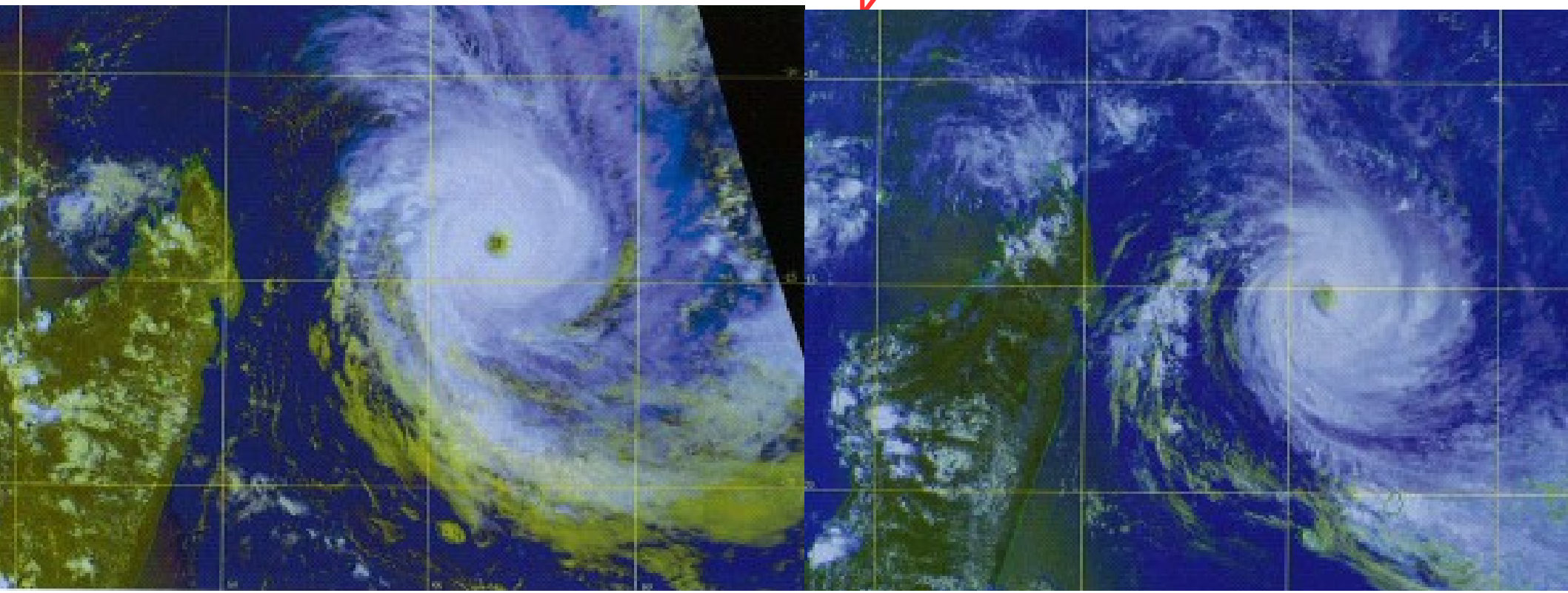
D, S or W ?

DANIELLA (dec. 1996)

FT=6.5

24h

MET= ?



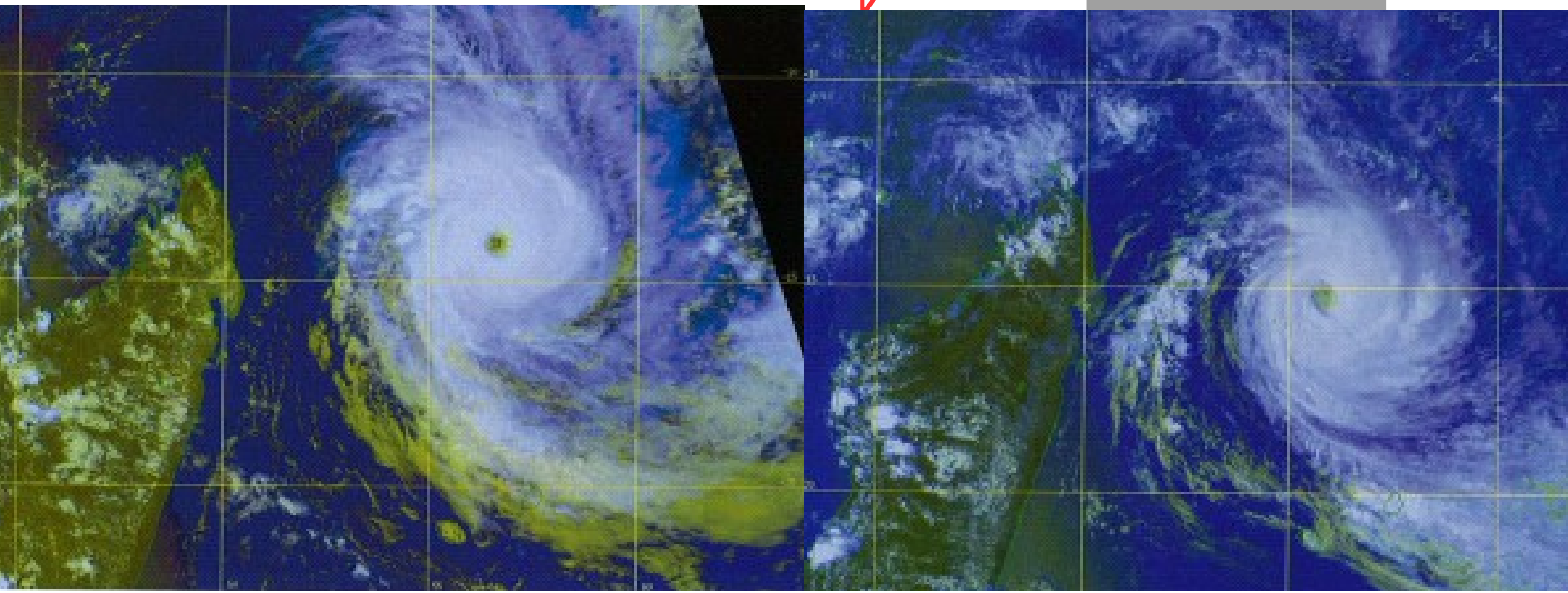
Method of Dvorak : MET

DANIELLA (dec. 1996)

FT=6.5

24h

W,
MET= 5.5



Method of Dvorak : MET

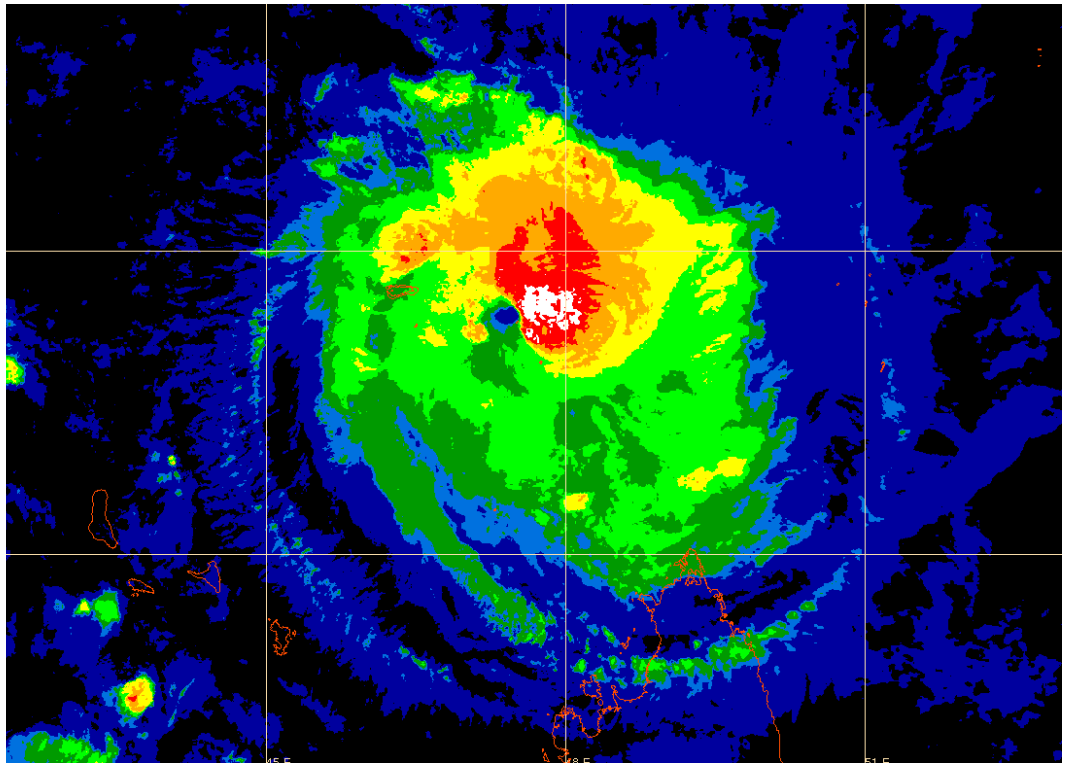
D, S or W ?

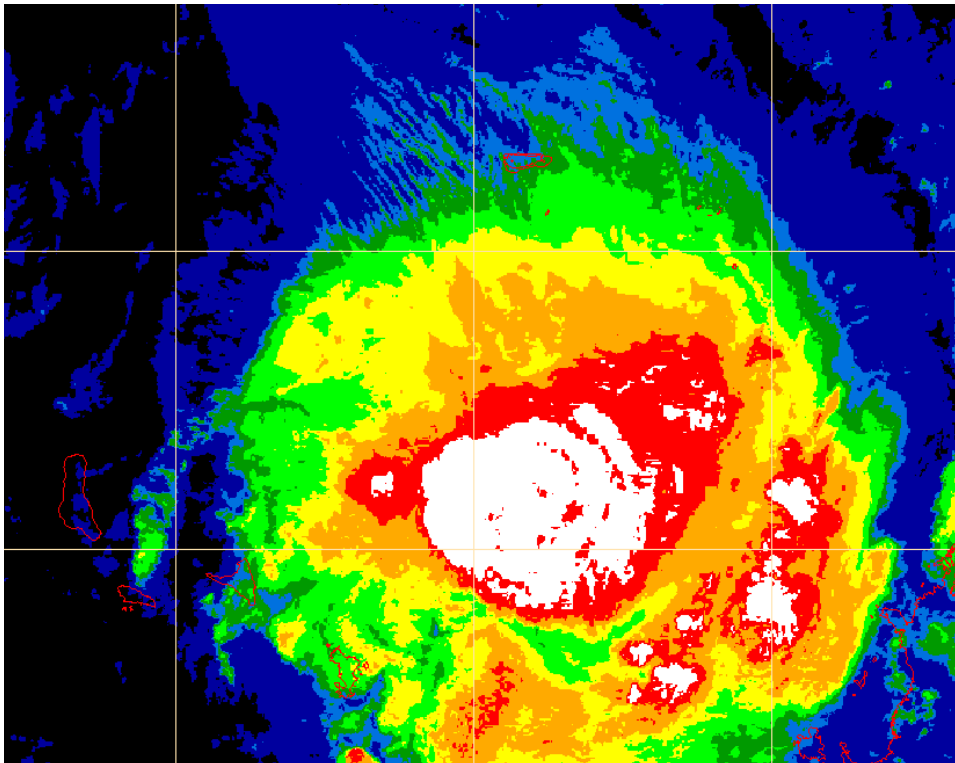
BELNA (dec. 2019)

FT=4.5

24h

MET= ?





Method of Dvorak : MET

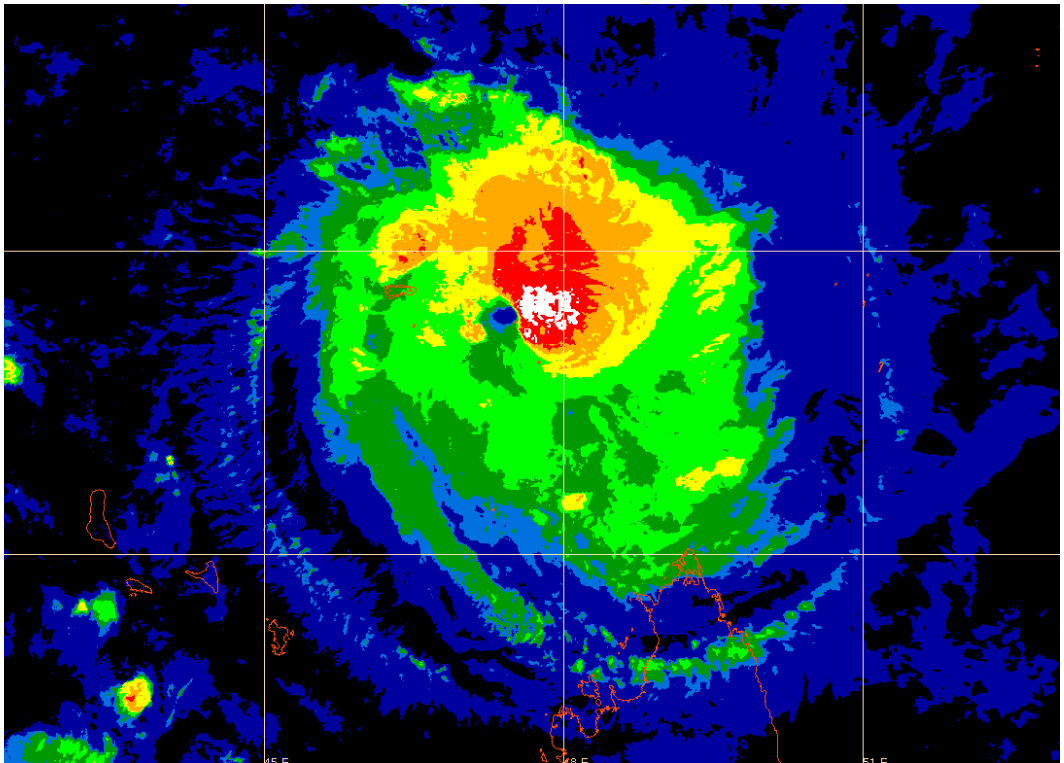
BELNA

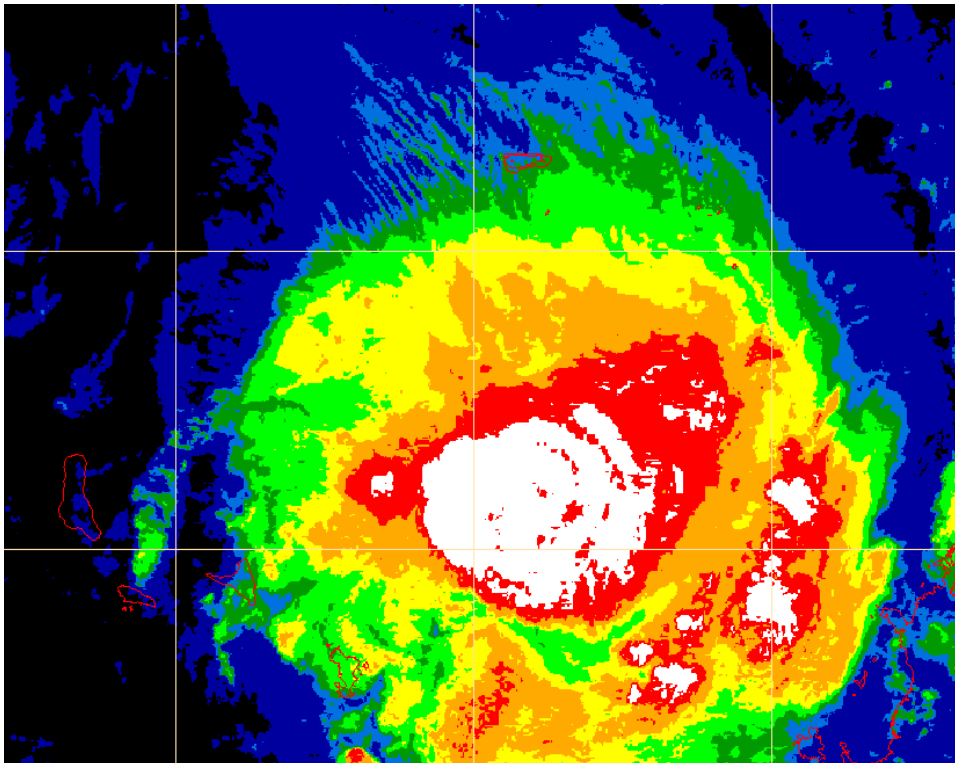
(dec. 2019)

FT=4.5

24h

S,
MET= 4.5

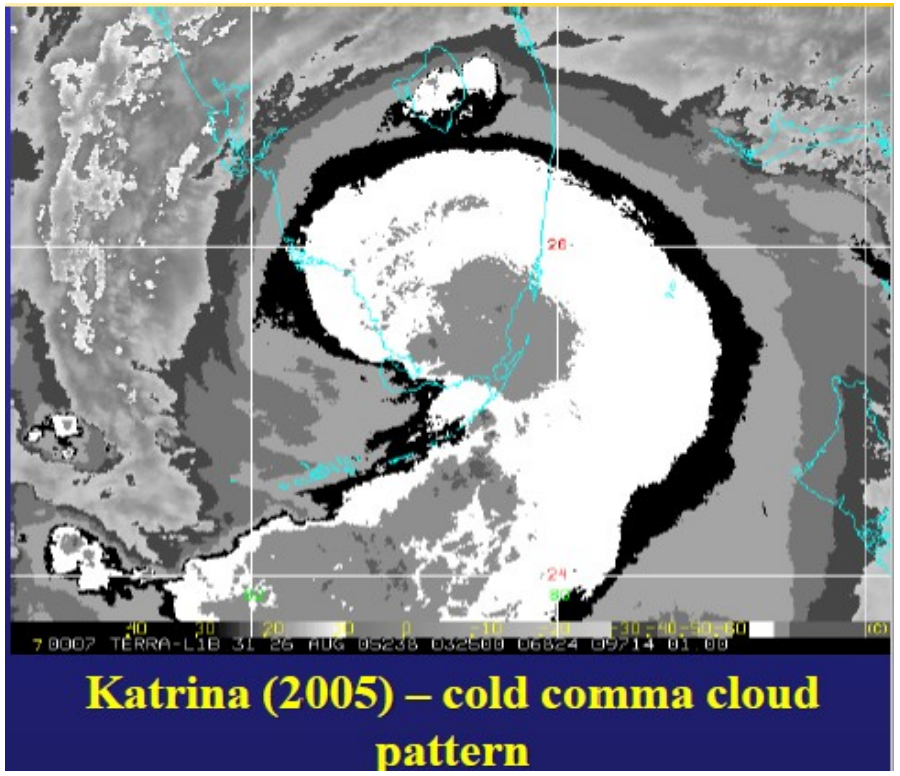




Method of Dvorak : MET

DVORAK signs of rapid intensification:

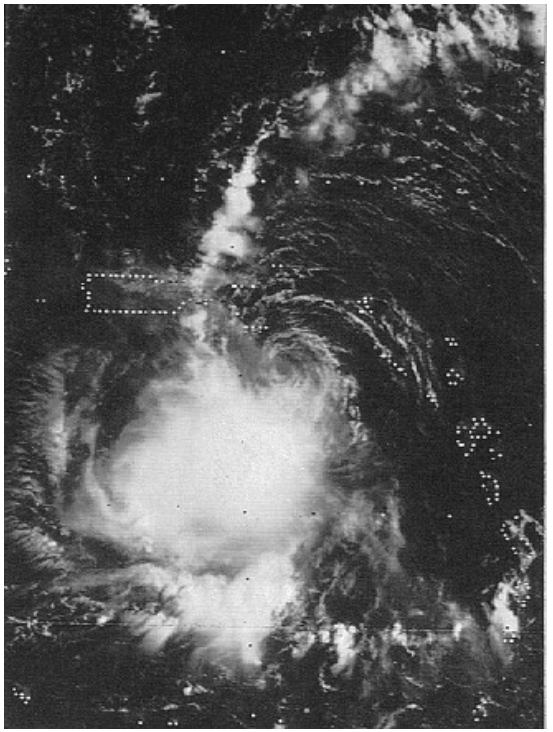
- Cold comma cloud
- Formation of multiple outflow channels
- « Pinhole » eye formation



Katrina (2005) – cold comma cloud pattern

DVORAK signs of rapid weakening :

- Warming of the convective tops over more than 12 hours
- Shear pattern rapidly established or elongation of the pattern



Method of Dvorak

- **Step 1 :**

  Find the center

- **Step 2 :**

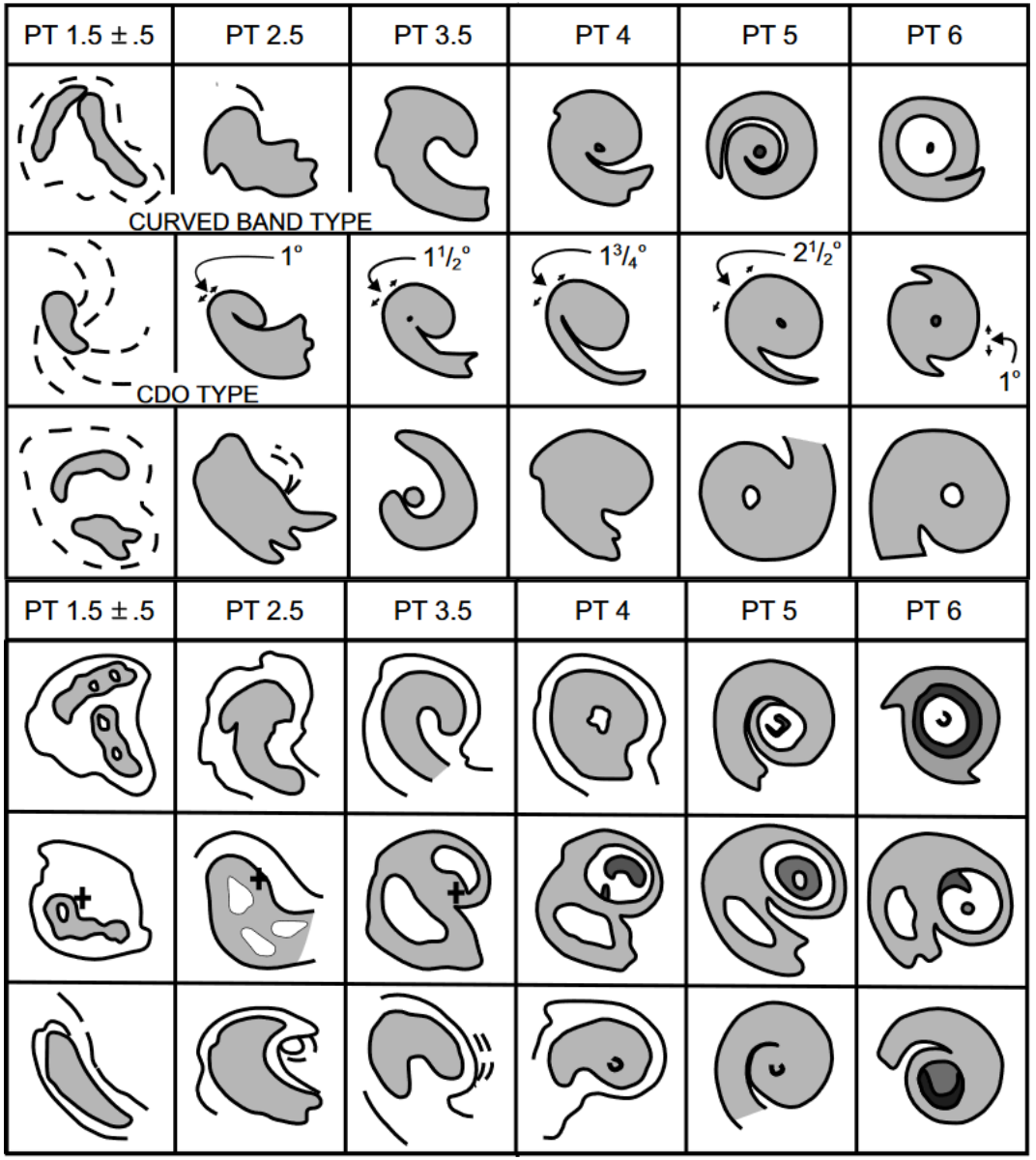
  Determine DT

- **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

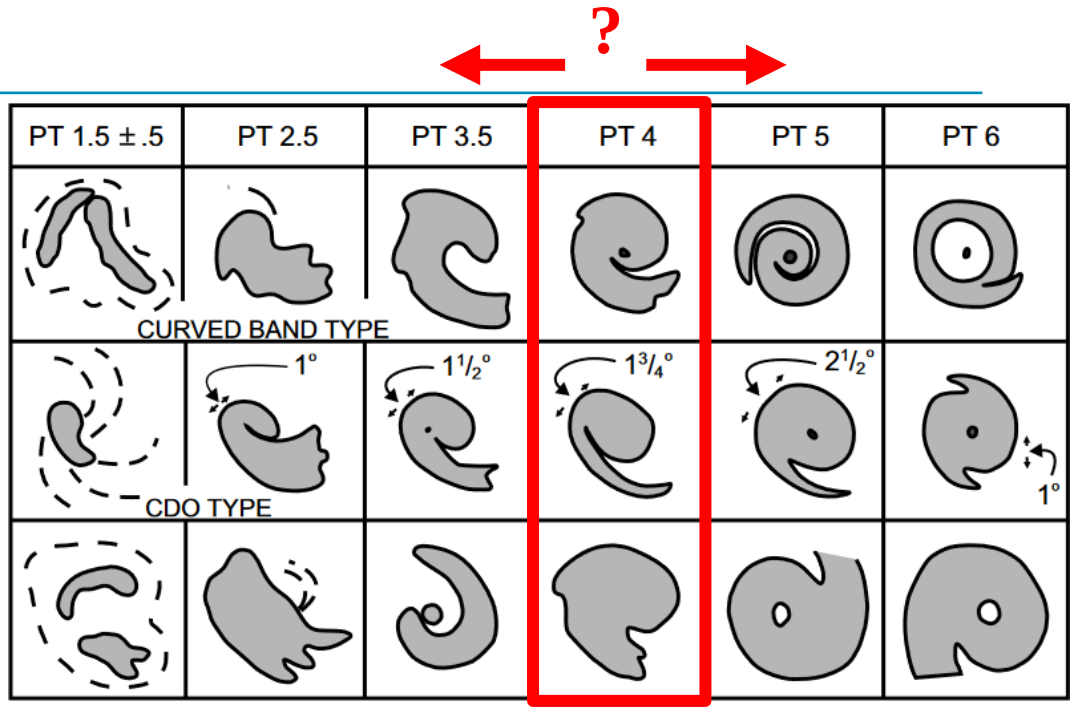
- **Step 1 :**

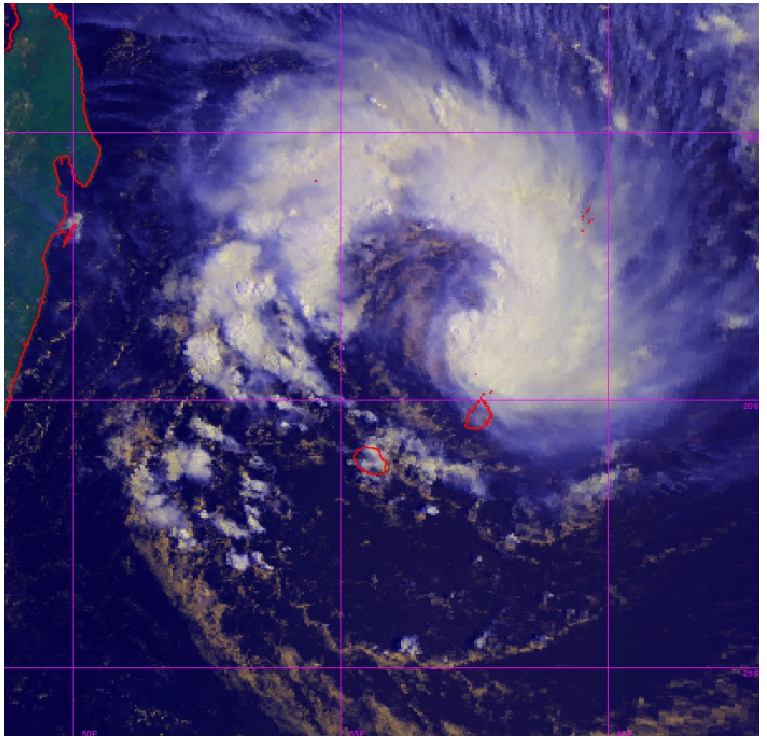
  Find the center
- **Step 2 :**

  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

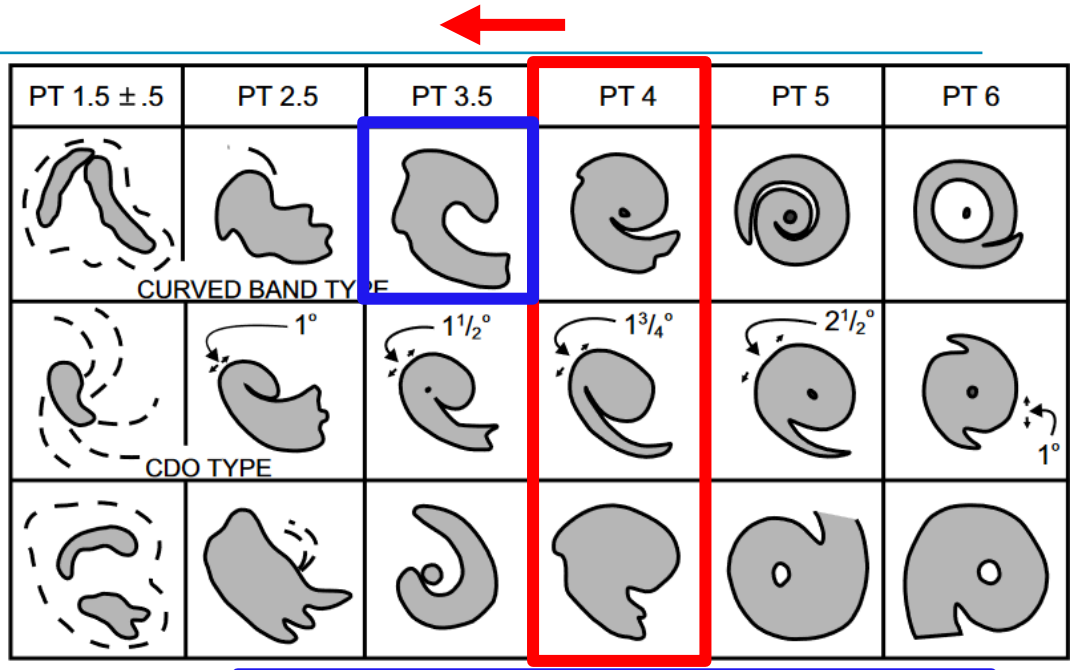
- **Step 1 :**

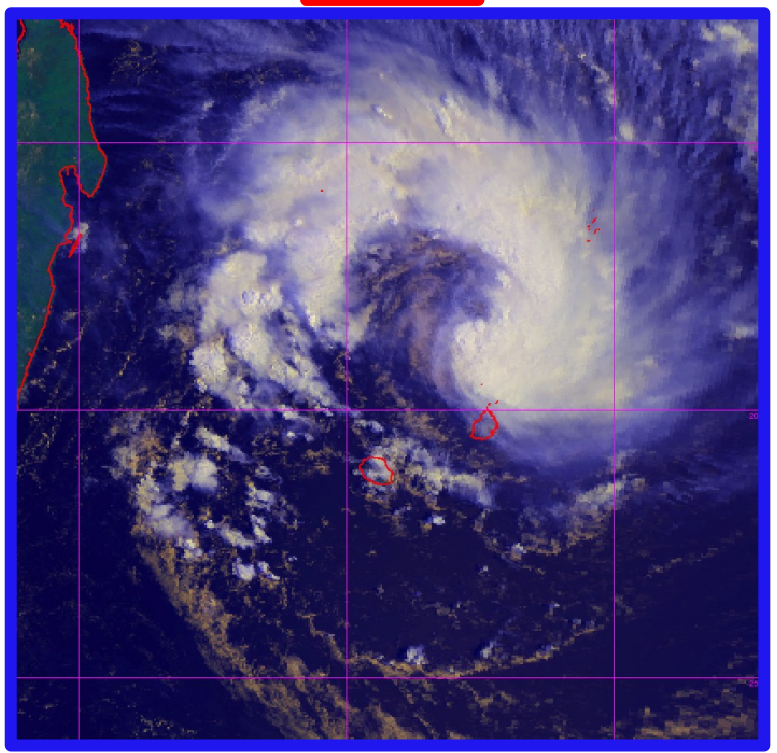
  Find the center
- **Step 2 :**

  Determine DT
- **Step 3 :**

  Determine MET
- **Step 4 :**

  Adjust MET with PT





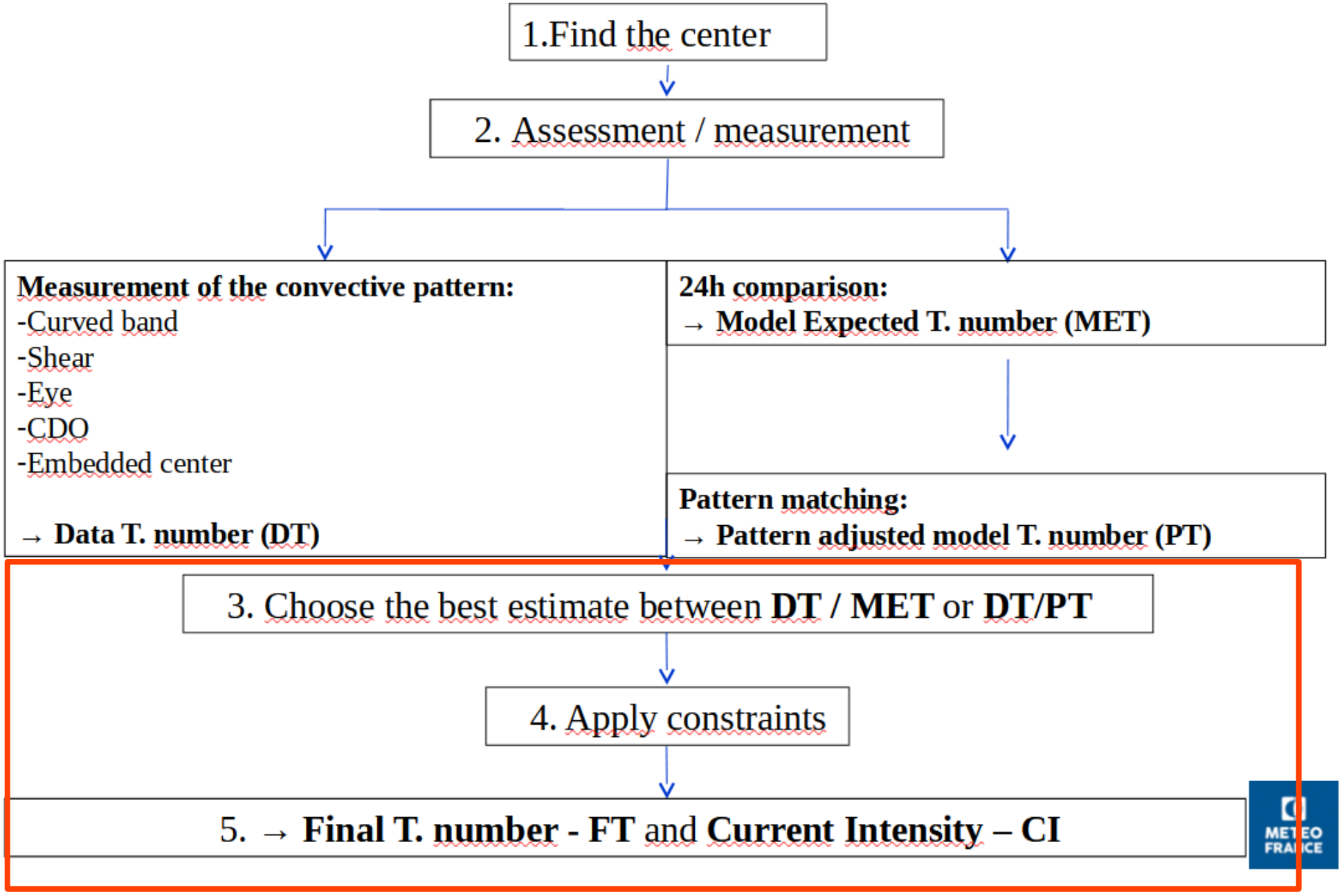
We determine the closest pattern to adjust the MET by ± 0.5 if necessary

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

→ PT=3.5

METEO FRANCE

Method of Dvorak



Method of Dvorak

- **Step 1 :**

  Find the center
- **Step 2 :**

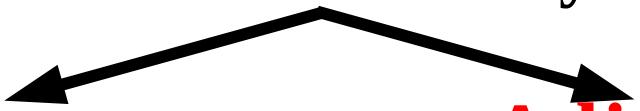
  Determine DT
- **Step 3 :**

  Determine MET
- **Step 4 :**

  Adjust MET with PT
- **Final step :**

  Determine FT and CI

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

METEO FRANCE

Method of Dvorak

- **Step 1 :**

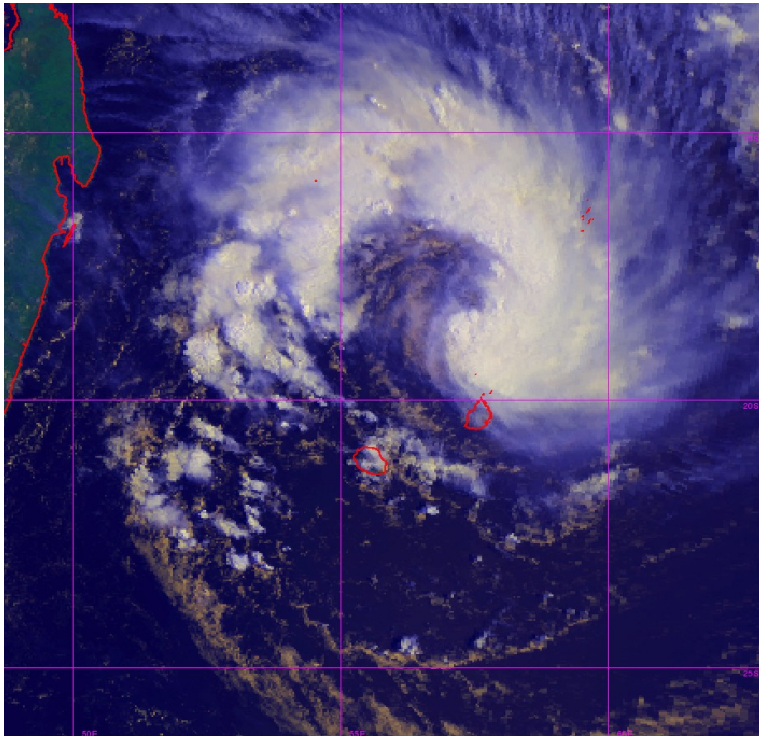
  Find the center
- **Step 2 :**

  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 :**

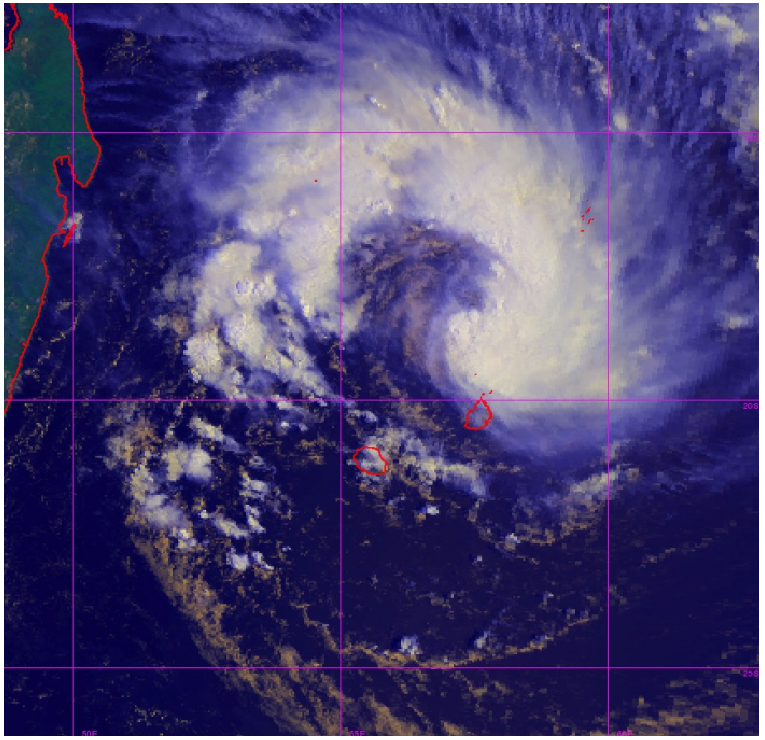
  Find the center
- **Step 2 :**

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

CI — Equal to FT In intensification And lag by 6/9/12h in weakening

METEO FRANCE

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

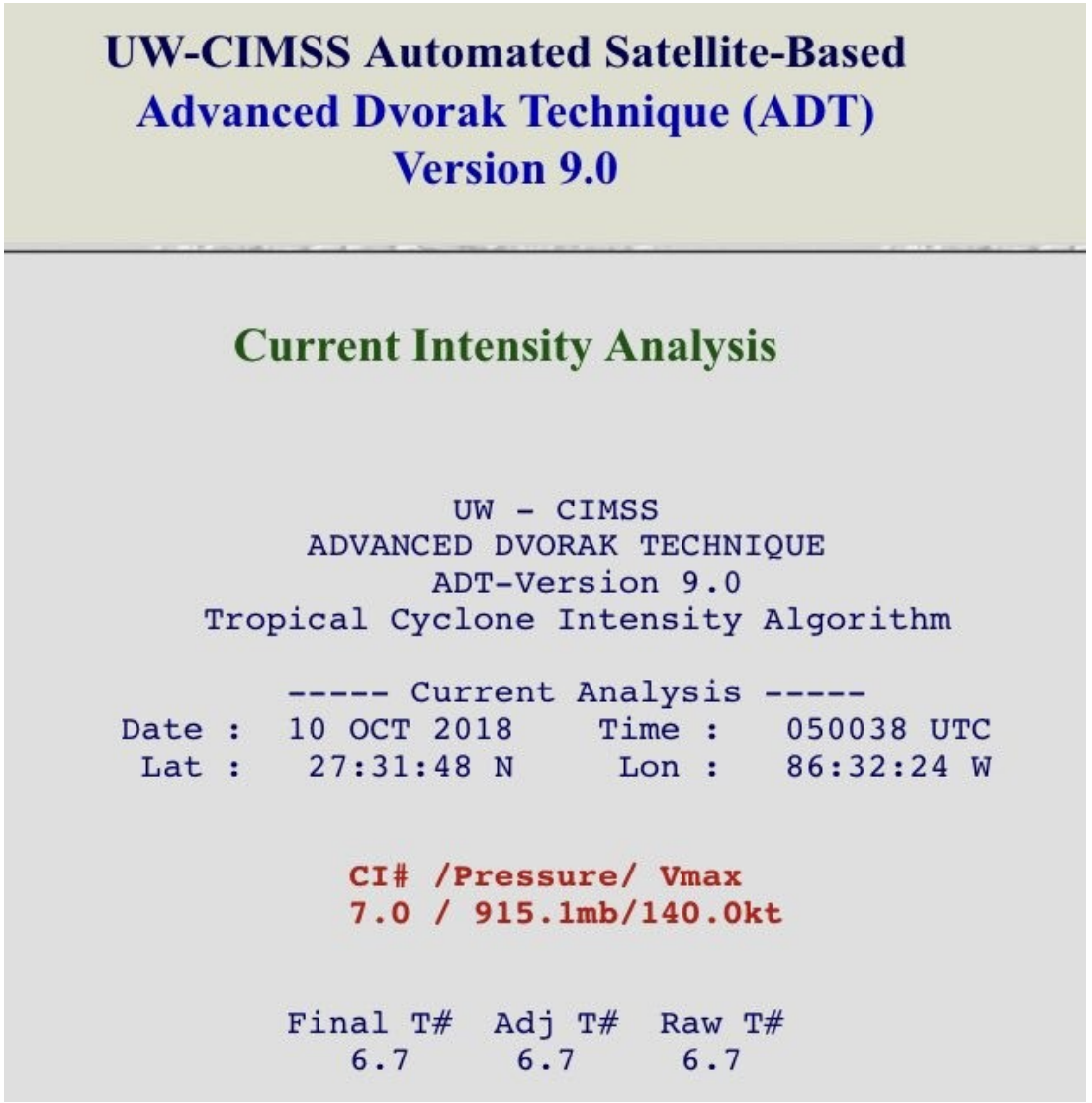
- **The JTWC with the Analyst (PGTW) position:**
  https://www.metoc.navy.mil/jtwc/jtwc.html
  - available on the site once the JTWC follows the system ("satellite fix" item)
  - available in alphanumeric messages
  - broadcast **every 3 hours**

```
TXNT23 KNES 201810
TCSNTL

A.  13L (NONAME)

B.  20/1730Z

C.  16.3N

D.  52.8W

E.  THREE/GOES-E

F.  T2.5/2.5

G.  IR/EIR/VIS

H.  REMARKS...>2/10 BANDING WAS MEASURED AROUND THE LLCC RESULTING IN A
DT OF 1.5. THE MET IS 2.0 AND THE PT IS 2.5. THE FT IS BASED ON THE PT
DUE TO CLOUD FEATURES NOT BEING CLEAR-CUT.

I.  ADDL POSITIONS

    NIL


...MLEVINE
```

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_ADT_CIMSS_TimOLANDER_ChrisVELDEN.pdf

METEO FRANCE

Method of Dvorak

- **Step 1 :**

  Find the center

- **Step 2 :**

  Determine DT

Here's to you!

Method of Dvorak

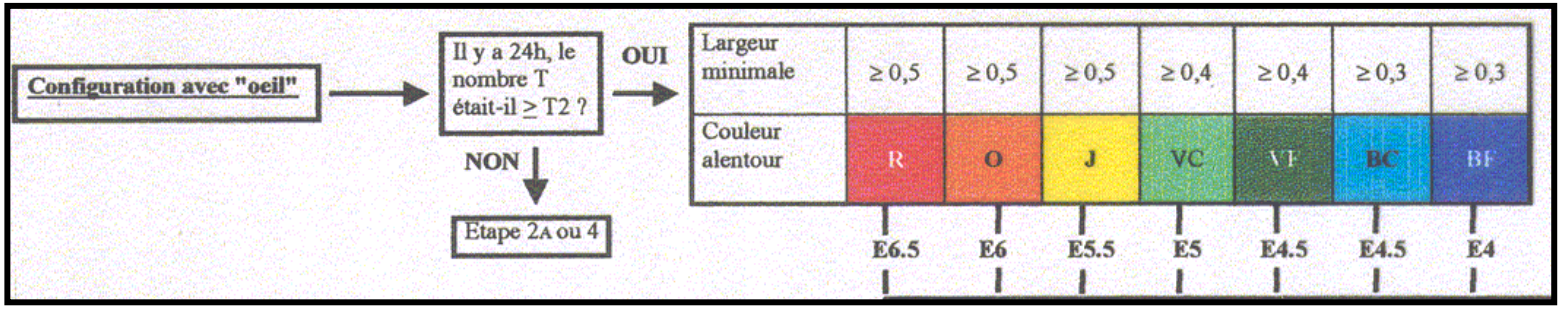
- **Step 1 :**

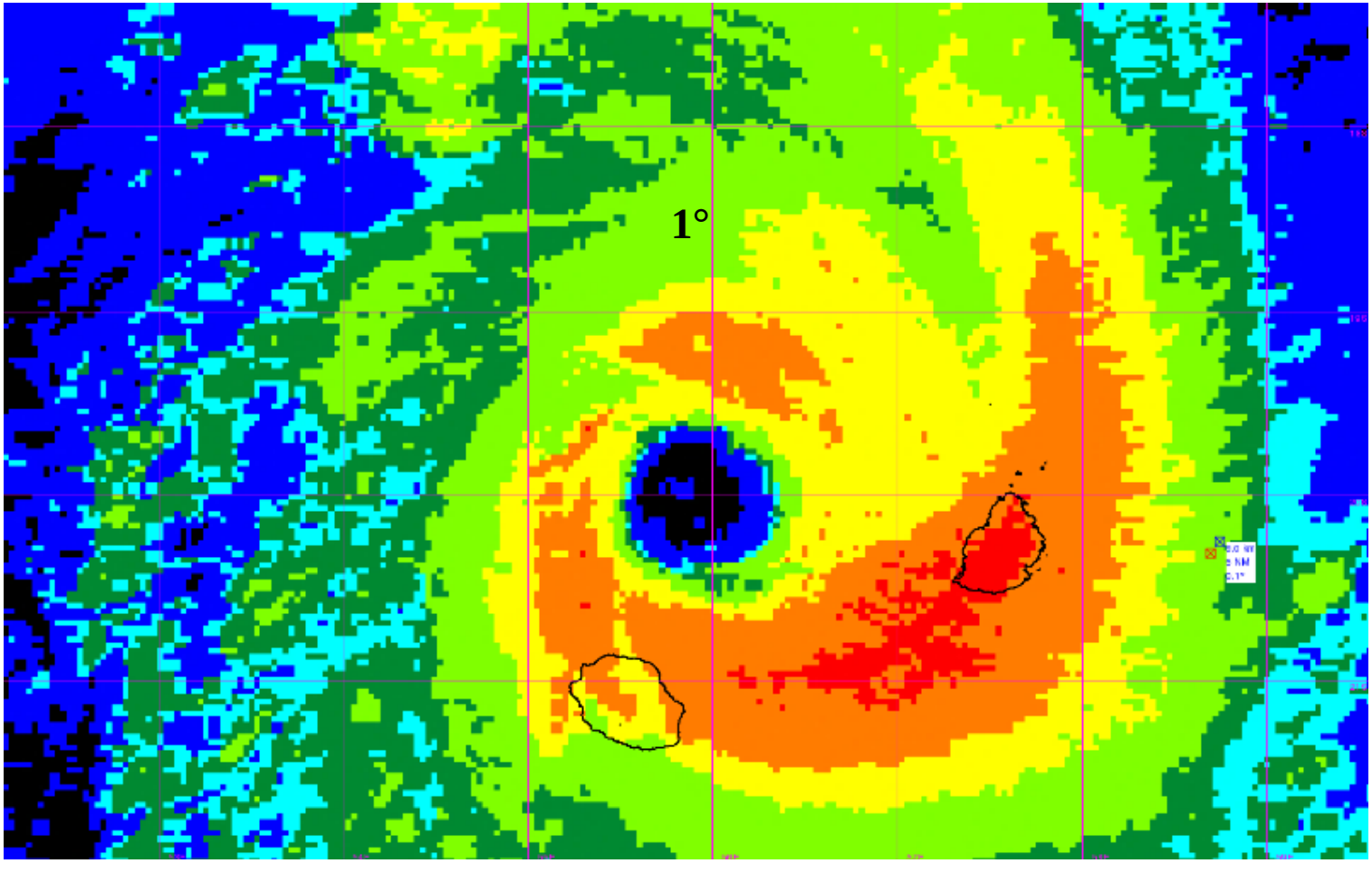
  Find the center

- **Step 2 :**

  Determine DT

Eye number





Method of Dvorak

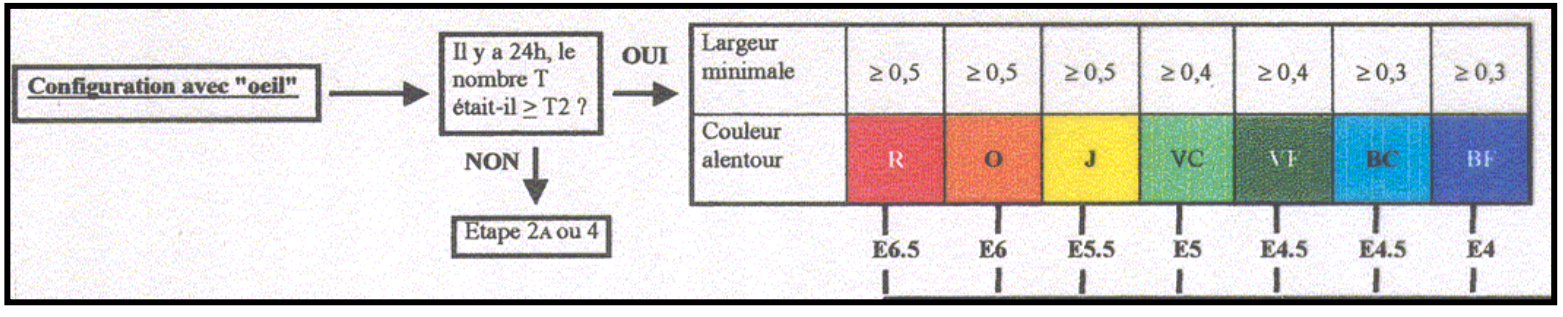
- **Step 1 :**

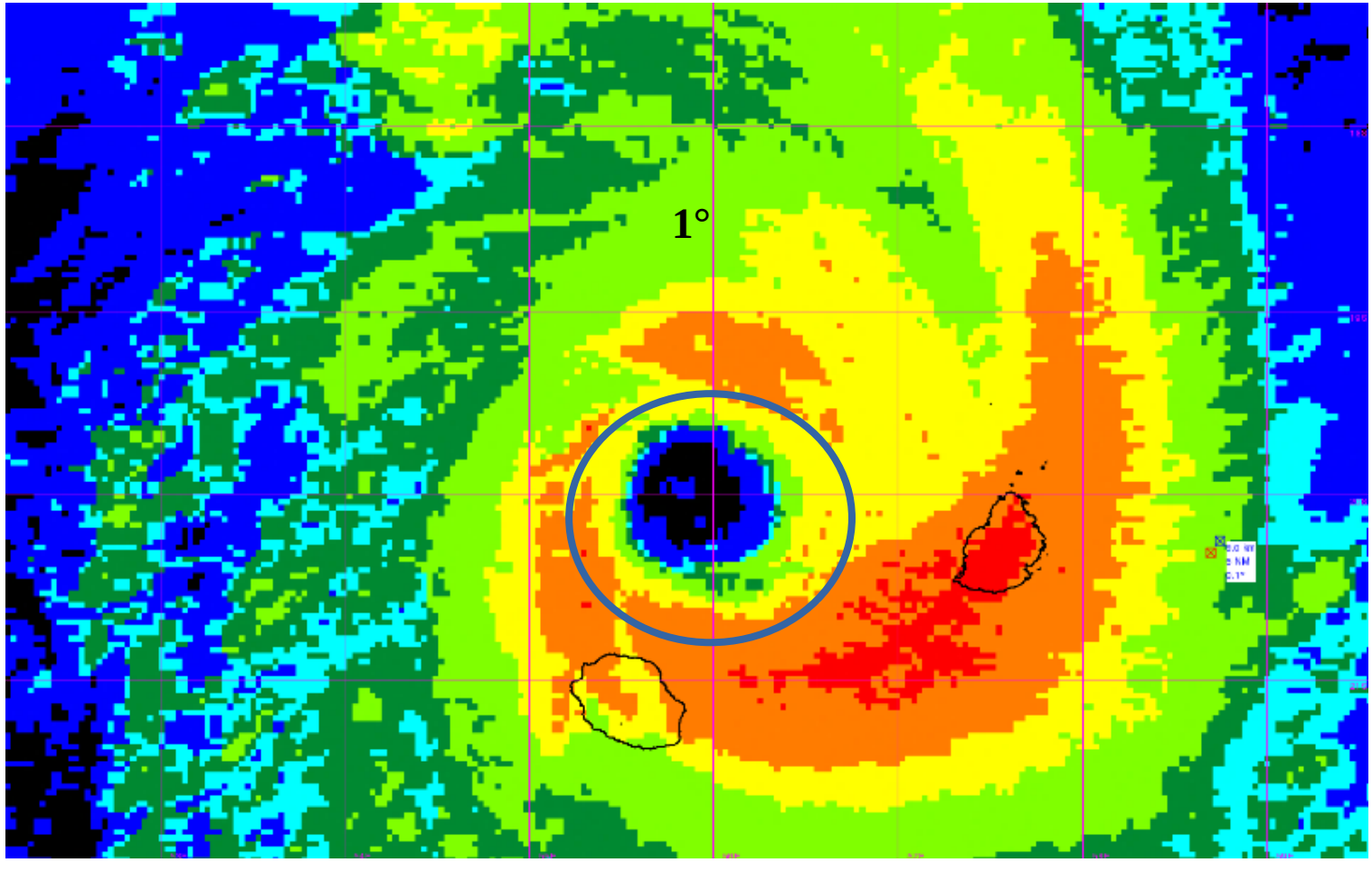
  Find the center

- **Step 2 :**

  Determine DT

Eye number





Method of Dvorak

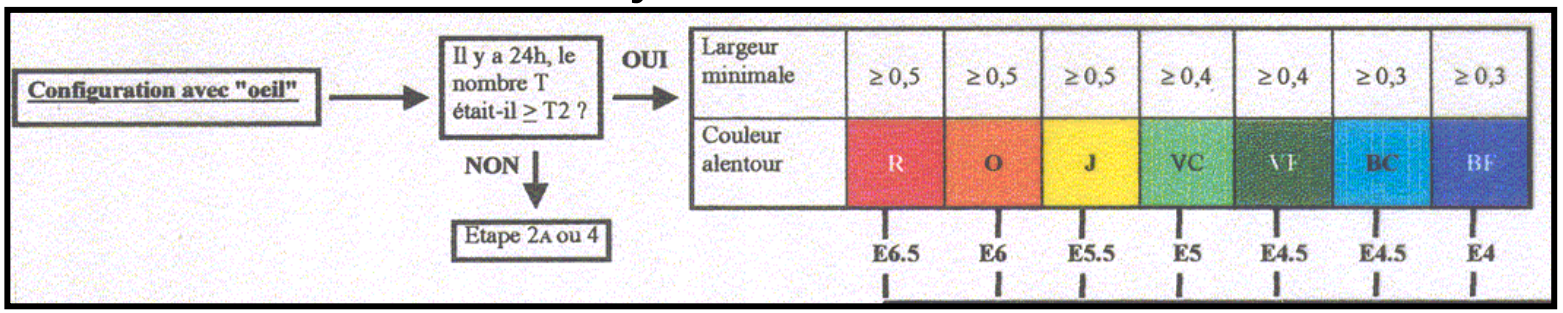
- **Step 1 :**

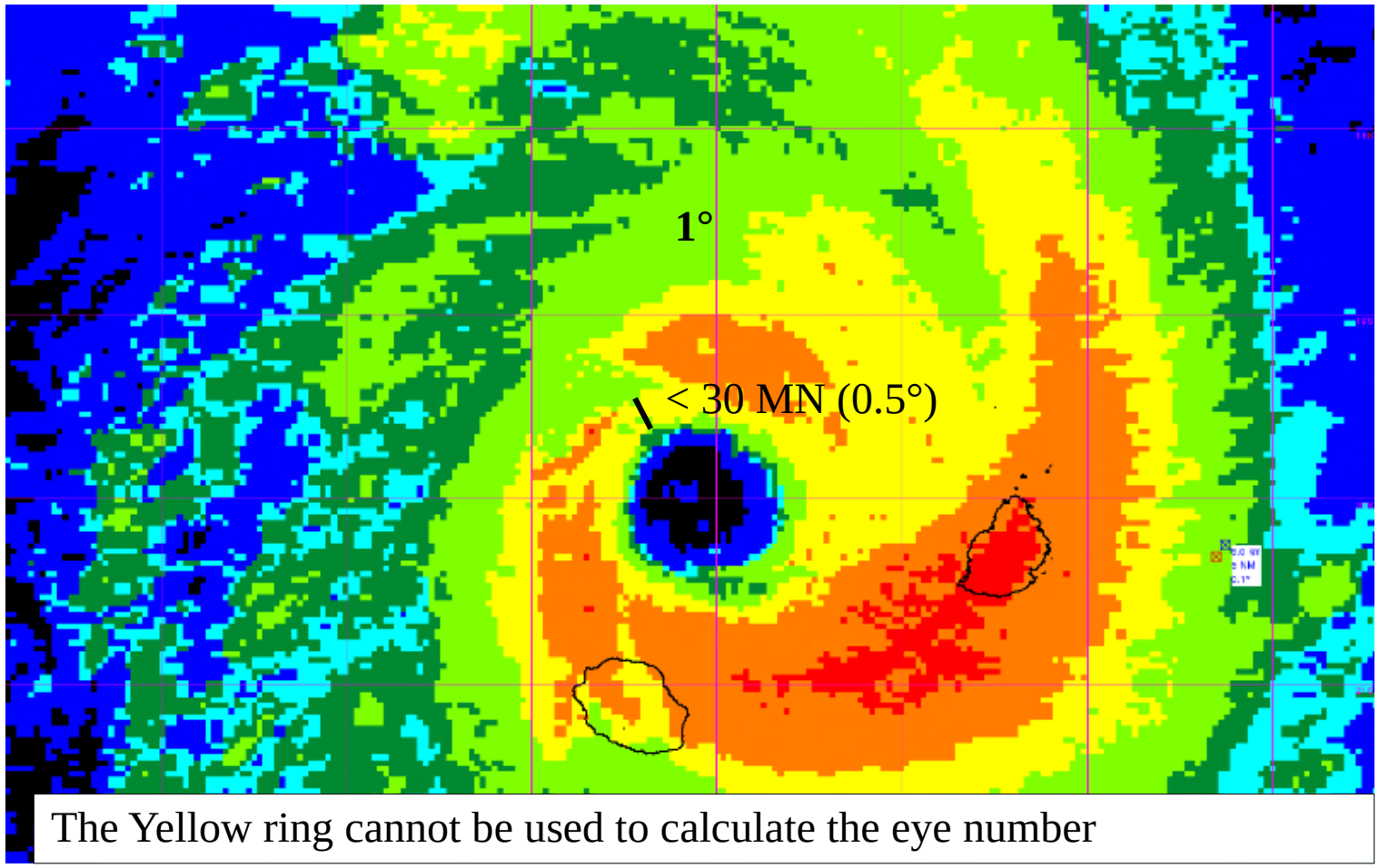
  Find the center

- **Step 2 :**

  Determine DT

Eye number





The Yellow ring cannot be used to calculate the eye number

Method of Dvorak

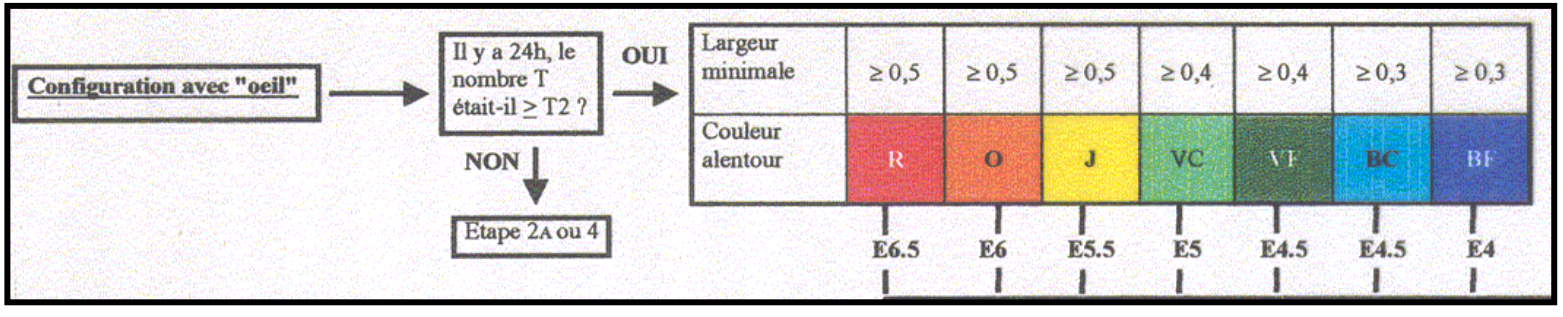
- **Step 1 :**

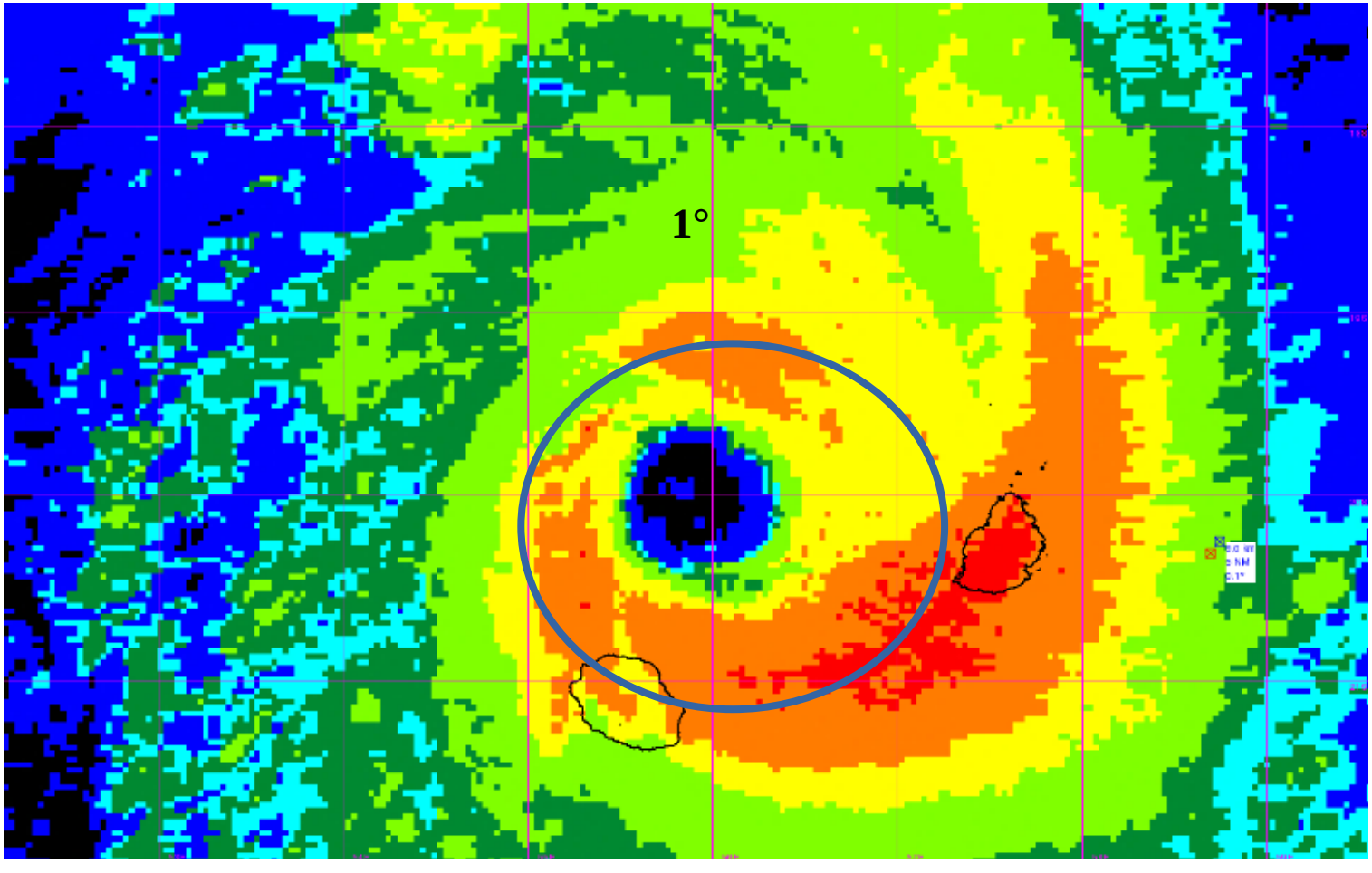
  Find the center

- **Step 2 :**

  Determine DT

Eye number





Method of Dvorak

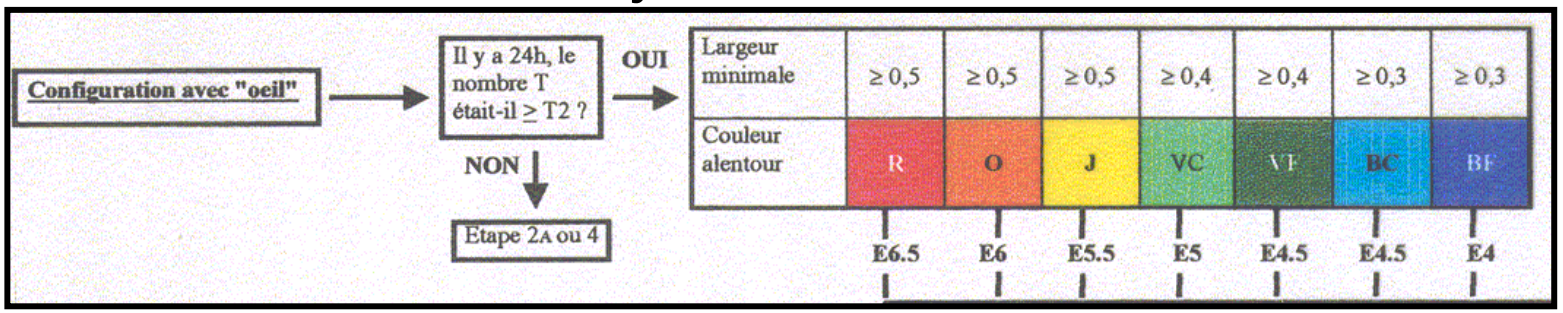
- **Step 1 :**

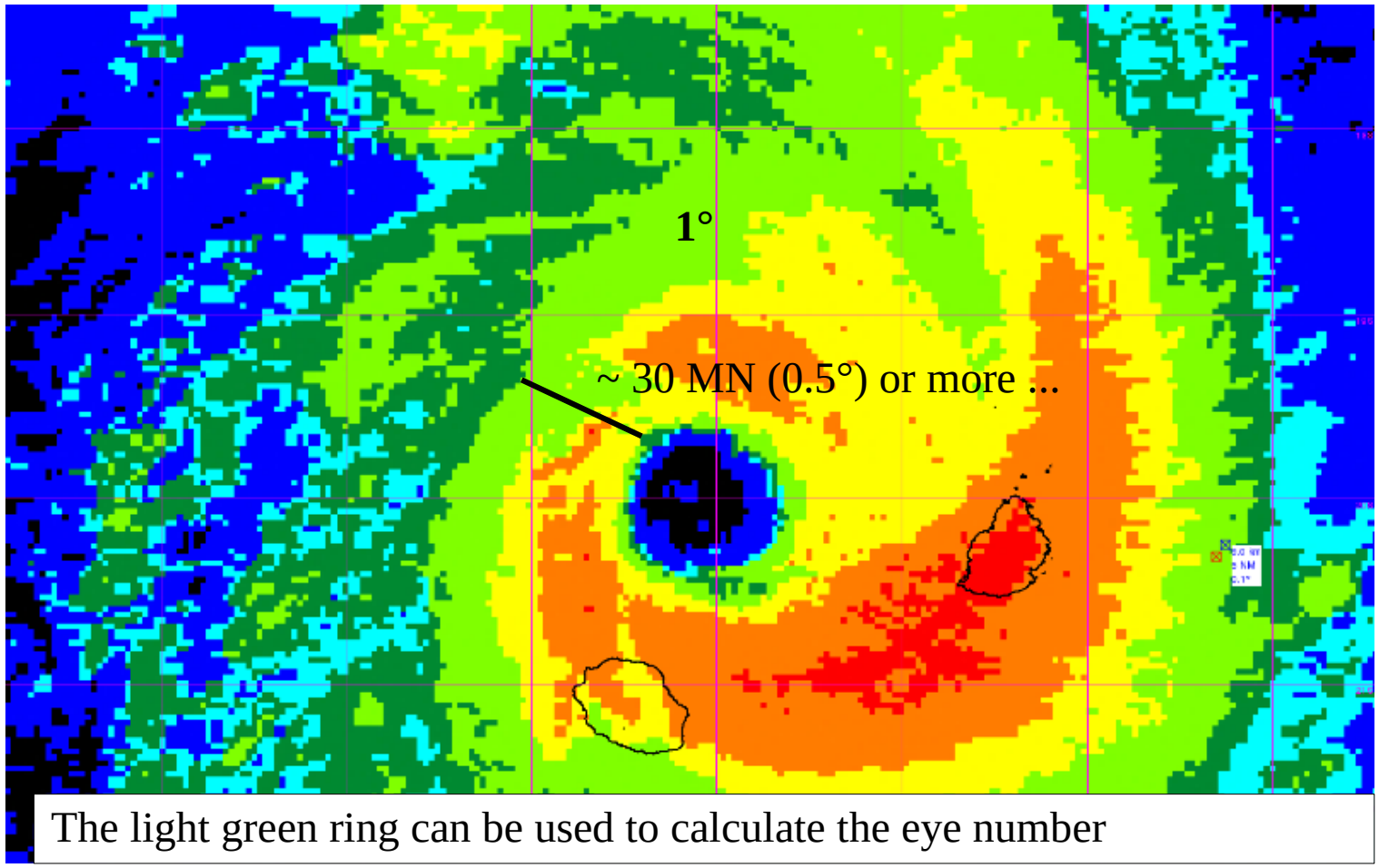
  Find the center

- **Step 2 :**

  Determine DT

Eye number





The light green ring can be used to calculate the eye number

Method of Dvorak

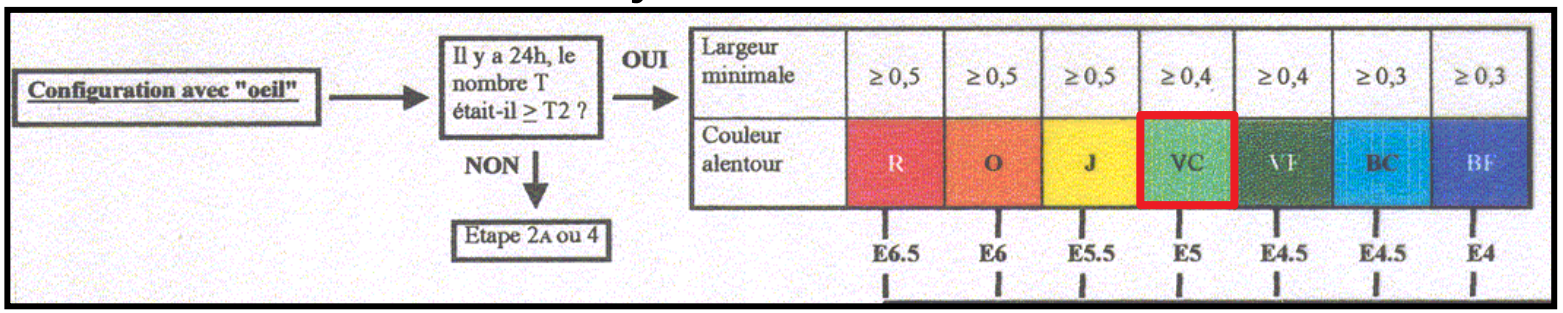
- **Step 1 :**

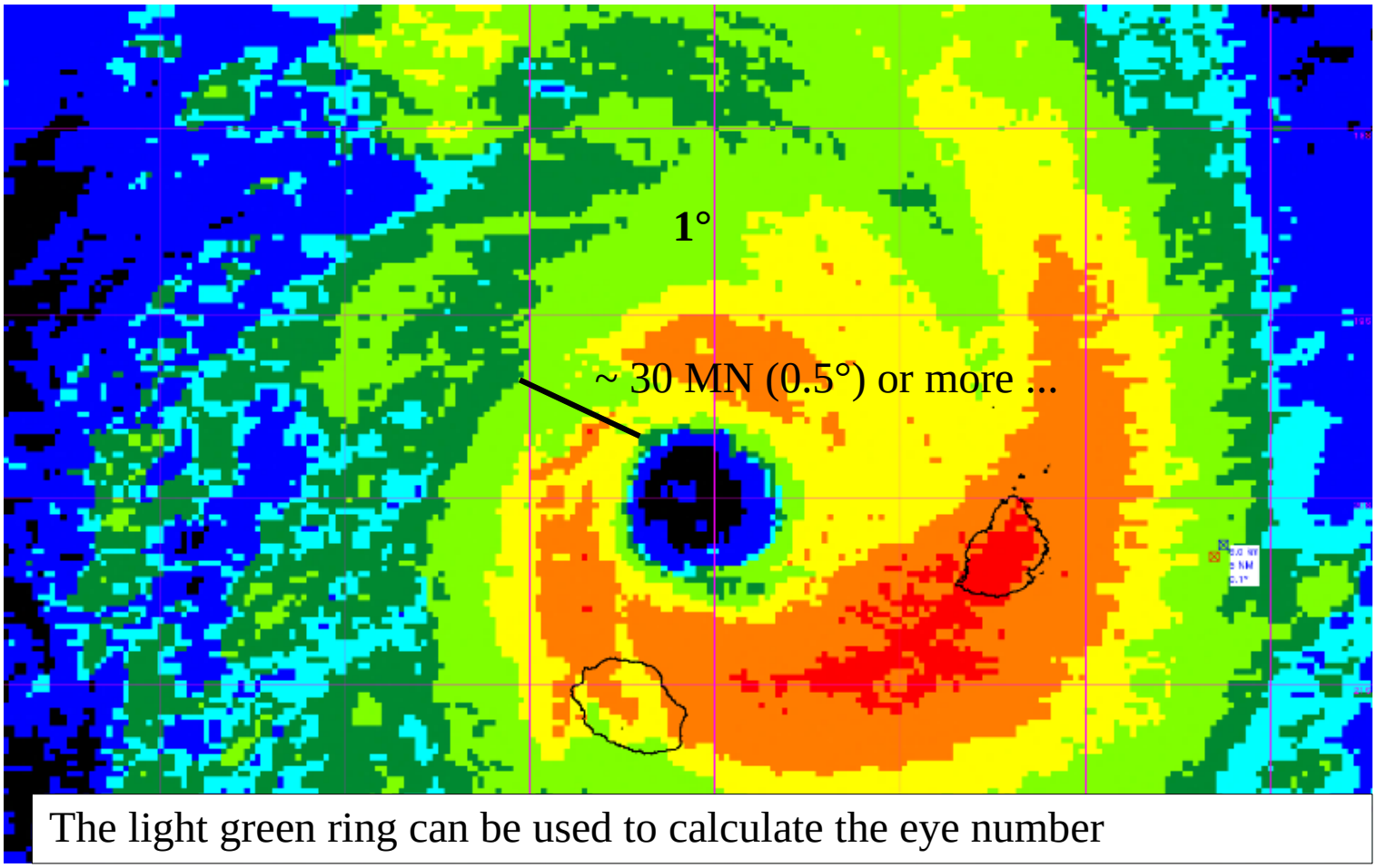
  Find the center

- **Step 2 :**

  Determine DT

Eye number = 5.0





The light green ring can be used to calculate the eye number

Method of Dvorak

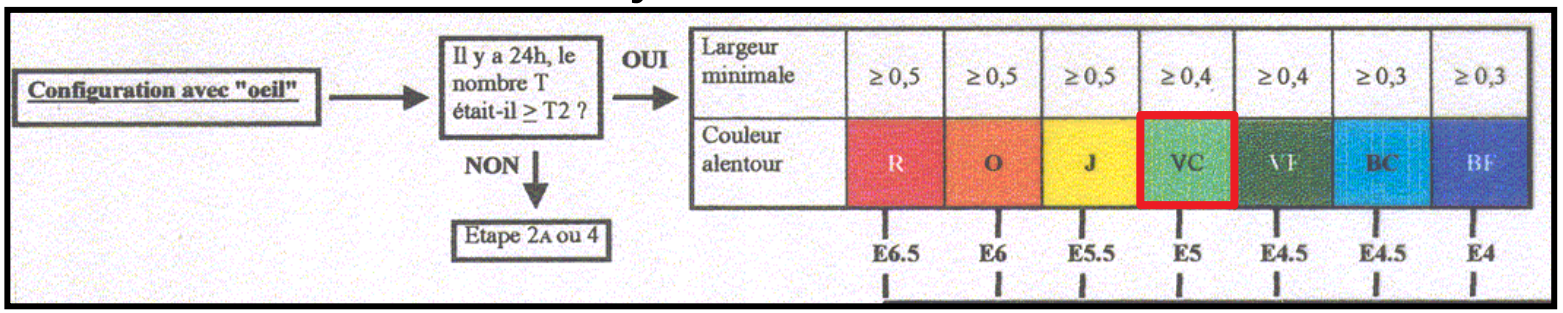
- **Step 1 :**

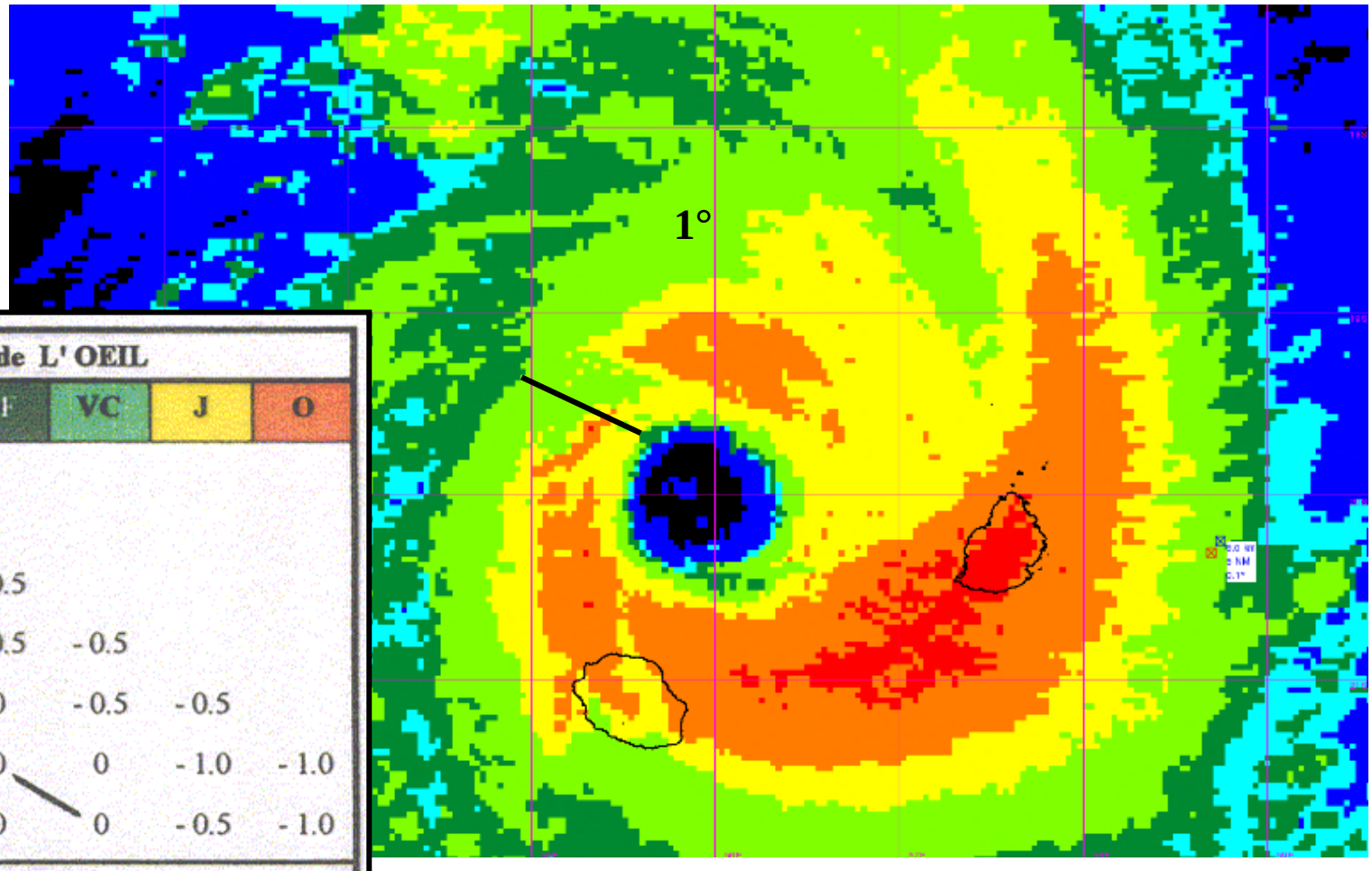
  Find the center

- **Step 2 :**

  Determine DT

Eye number = 5.0





Adjustment

TEMPERATURE de L'OEIL

Température ANNEAU environnant

	N	BF	BC	VF	VC	J	O
BF	0	-0.5					
BC	0	0	-0.5				
VF	0	0	-0.5	-0.5			
VC	+0.5	0	0	-0.5	-0.5		
J	+1.0	+0.5	0	0	-0.5	-0.5	
O	+1.0	+0.5	+0.5	0	0	-1.0	-1.0
R	+1.0	+0.5	+0.5	0	0	-0.5	-1.0

Method of Dvorak

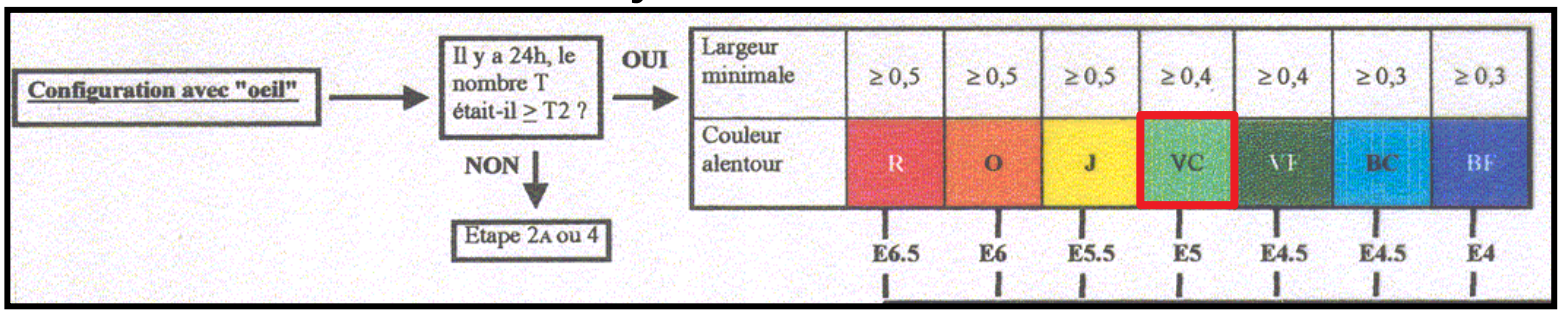
- **Step 1 :**

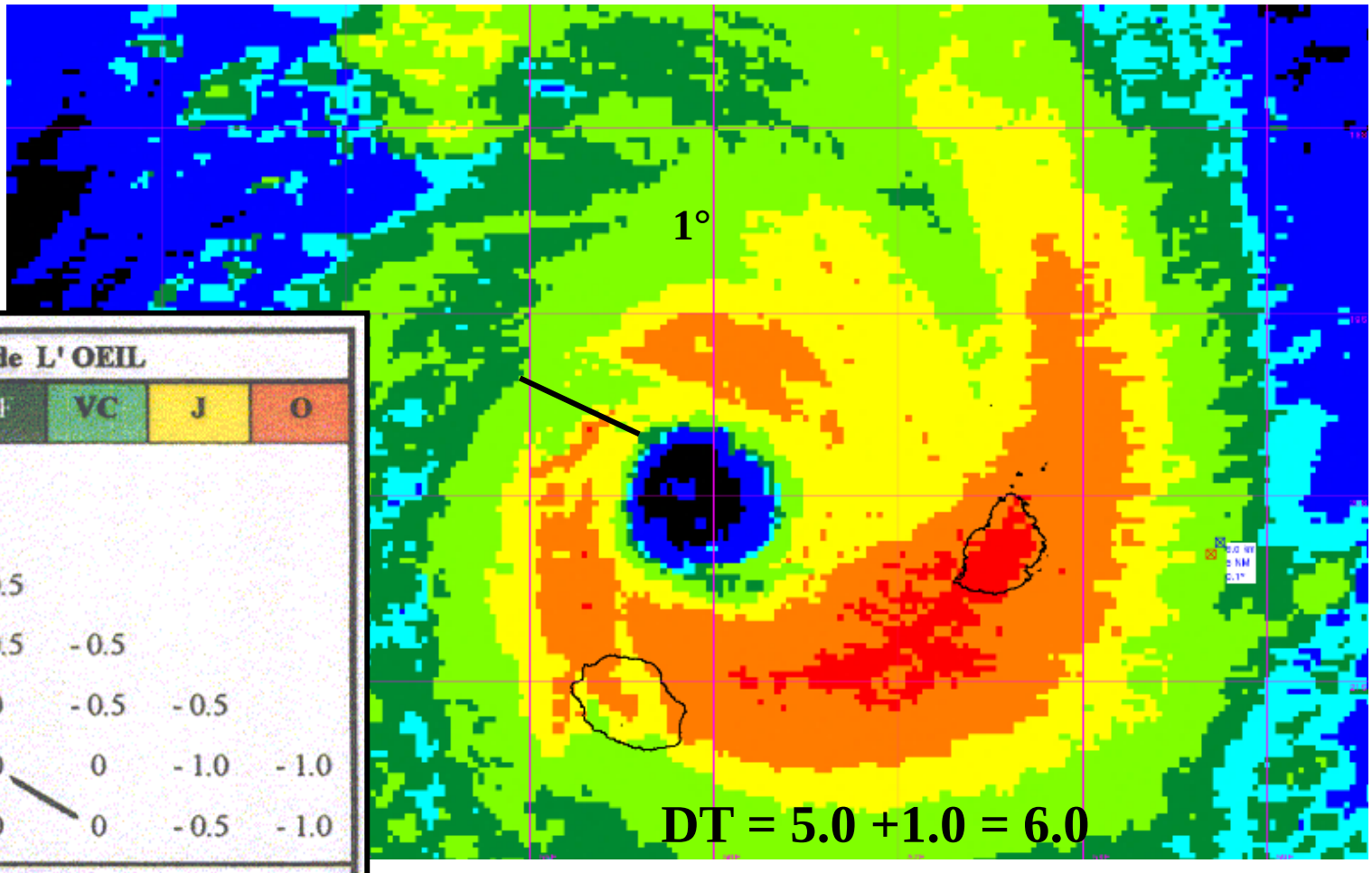
  Find the center

- **Step 2 :**

  Determine DT

Eye number = 5.0





Adjustment = 1

TEMPERATURE de L'OEIL

Température ANNEAU environnant

	N	BF	BC	VF	VC	J	O
BF	0	-0.5					
BC	0	0	-0.5				
VF	0	0	-0.5	-0.5			
VC	+0.5	0	0	-0.5	-0.5		
J	+1.0	+0.5	0	0	-0.5	-0.5	
O	+1.0	+0.5	+0.5	0	0	-1.0	-1.0
R	+1.0	+0.5	+0.5	0	0	-0.5	-1.0