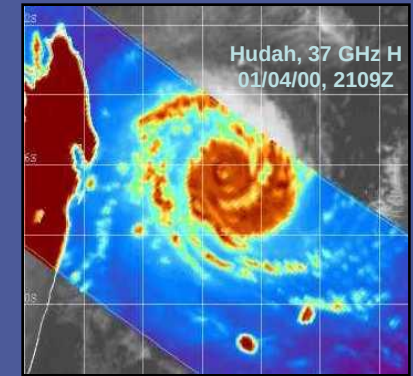
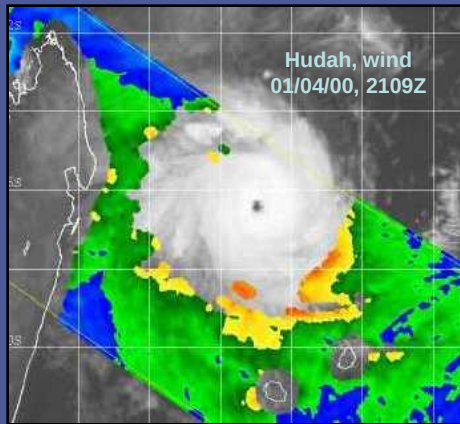
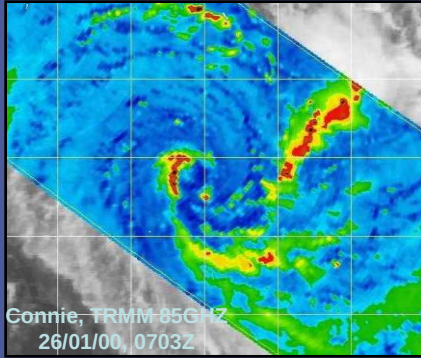




Satellite technology

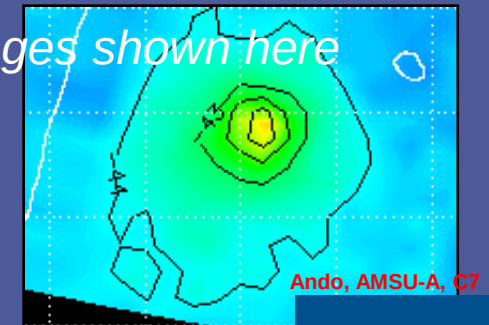
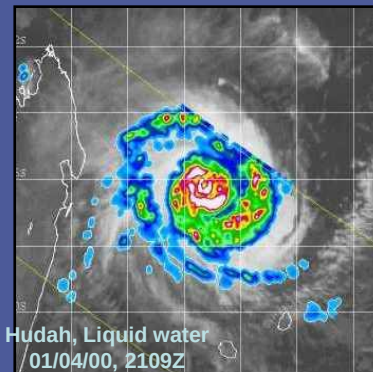
Applications to tropical cyclones

8th training course about tropical cyclones

WMO / Météo-France

September 2017

Acknowledgements to COMET, NRL for many of the images shown here



Anne-Claire FONTAN
Thierry DUPONT
Sébastien LANGLADE
MÉTÉO-FRANCE

Outline

- 1. *Synopsis on microwaves***
- 2. *Interpreting microwave data***
- 3. *Applications in TC analysis***
- 4. *TC Intensity estimate: objective guidances***
- 5. *Scatterometers***
- 6. *Cloud drift winds***

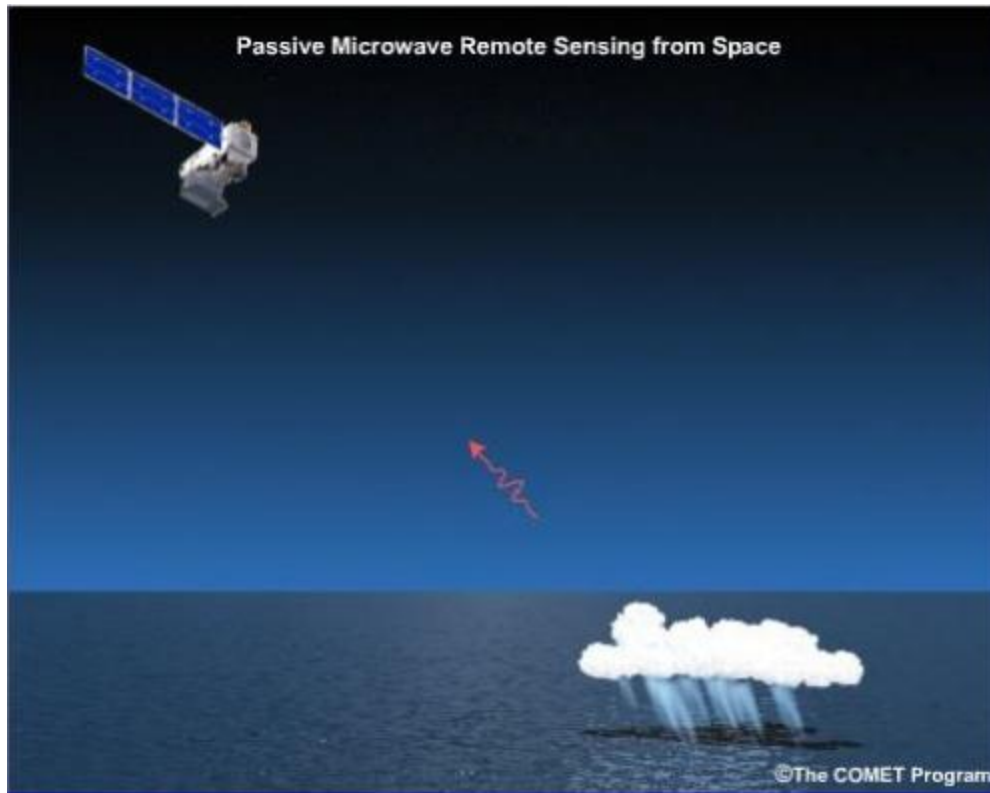


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Microwave properties



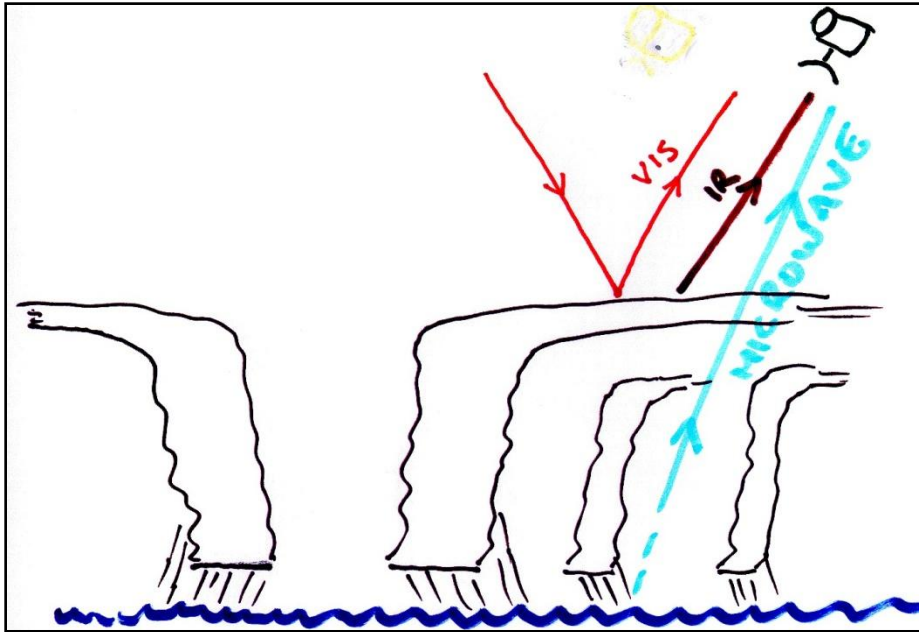
- Les imageurs micro-ondes passifs mesurent le rayonnement émis dans la gamme micro-onde 5-200 GHz.
- L'émissivité est directement convertie en température de brillance (T_b)
- Cette T_b permet de quantifier les processus radiatifs majeurs suivants:
la diffusion (neige roulée),
l'émission (RR faibles),
émission/absorption (eau nuageuse liquide et gouttes d'eau)

- *Microwave imagers passive sensors measure emitted microwave energy from 5 - 200 GHz*
- *Emissivity ("return energy") is directly related to brightness temperature (T_b)*
- *T_b is used to quantify key radiative processes:
scattering (graupeln), emission (light precip.), emission/absorption (cl. liquid water and rain droplets)*



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Microwave properties



■ Advantages

- See through cirrus
- Sensing whatever the atmospheric conditions

■ Drawbacks

- Longer wavelength than VIS/IR so less energy and less horizontal resolution.
- Only available on polar-orbiting satellites so less frequent coverage
- Interpretation is more complex

■ Avantages

- voient à travers les cirrus
- détection dans presque toutes les conditions atmosphériques

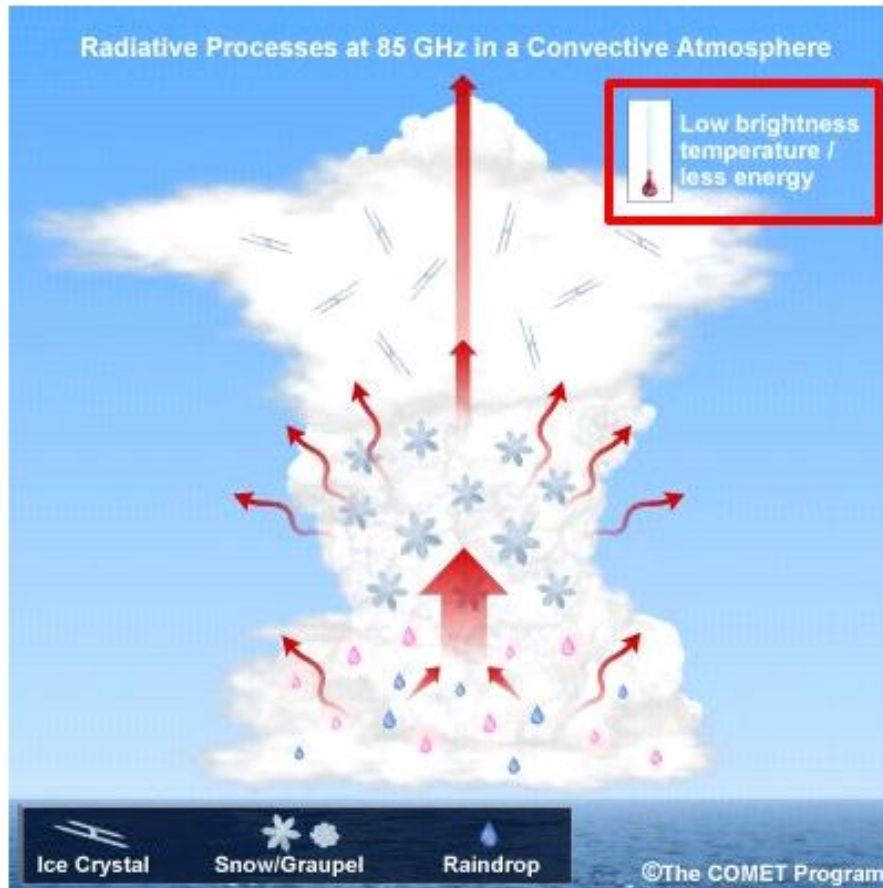
■ Inconvénients

- Une longueur d'onde plus longue que le VIS ou IR (moins d'énergie et une résolution horizontale moindre)
- Disponibles seulement sur les défilants donc une couverture moindre.
- Interprétation plus complexe.



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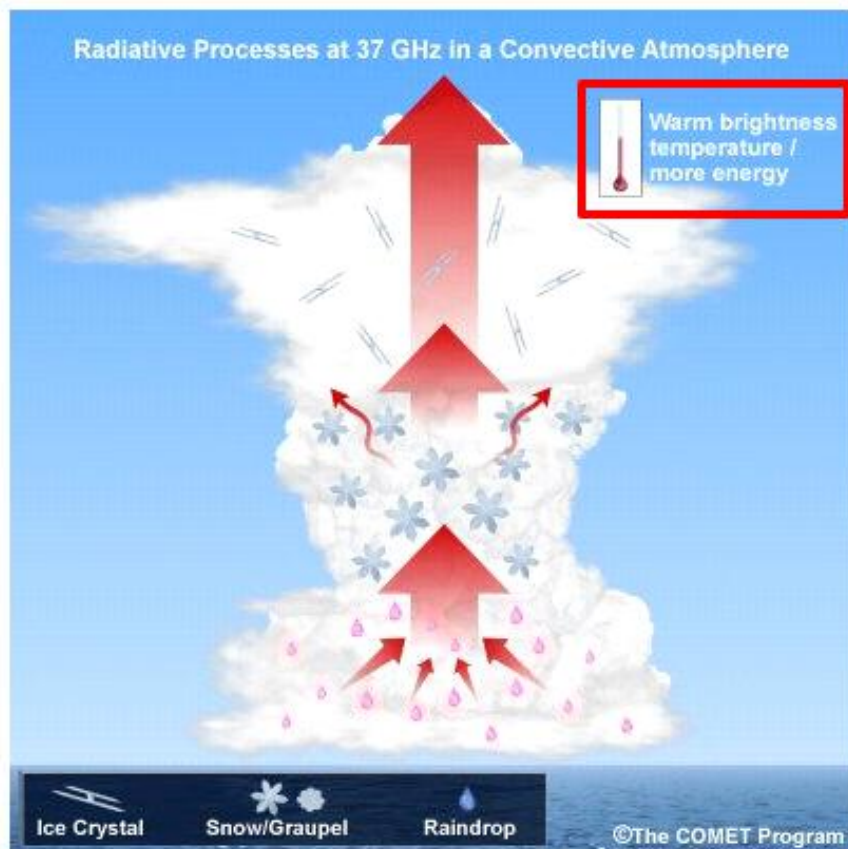
Radiative Processes at 85 GHz



- **85 Ghz. Energie radiative :**
 - absorbée, réémise ou diffusée par les gouttes d'eau
 - Diffusée ensuite par les particules de glace
 - Peu d'effet des cirrus
- **Peu d'énergie parvient au sommet**
- **DONC : températures de brillance très basses captées au dessus de la convection profonde à 85 GHz**

- **85 Ghz. Radiation :**
 - *Absorbed, re-emitted or scattered by raindrops*
 - *Scattered by precipitating ice particles*
 - *Cirrus have little effect*
- ***Radiation seriously depleted when reaching the top***
- ***SO : very low brightness temperatures are sensed above deep convection at 85 GHz***

Radiative processes at 37 Ghz



- **A 37 GHz : énergie**
 - absorbée par l'eau de pluie
 - Ré-émise par l'eau de pluie vers le le niveau supérieur
 - Peu diffusée par les particules de glace précipitantes
 - Pas d'effet des cirrus
- **Energie abondante parvient au satellite**
- **DONC : hautes températures de brillance captées au sommet**
- **At 37 GHz : radiation**
 - *Absorbed by rain water*
 - *Emitted from the rain water upwells further*
 - *Minor scattered by precipitation ice particles*
 - *Cirrus have no effect*
- **Abundant energy reaches the satellite**
- **SO : high brithness temperatures**

http://www.meted.ucar.edu/npoess/tc_analysis/index.htm

Outline

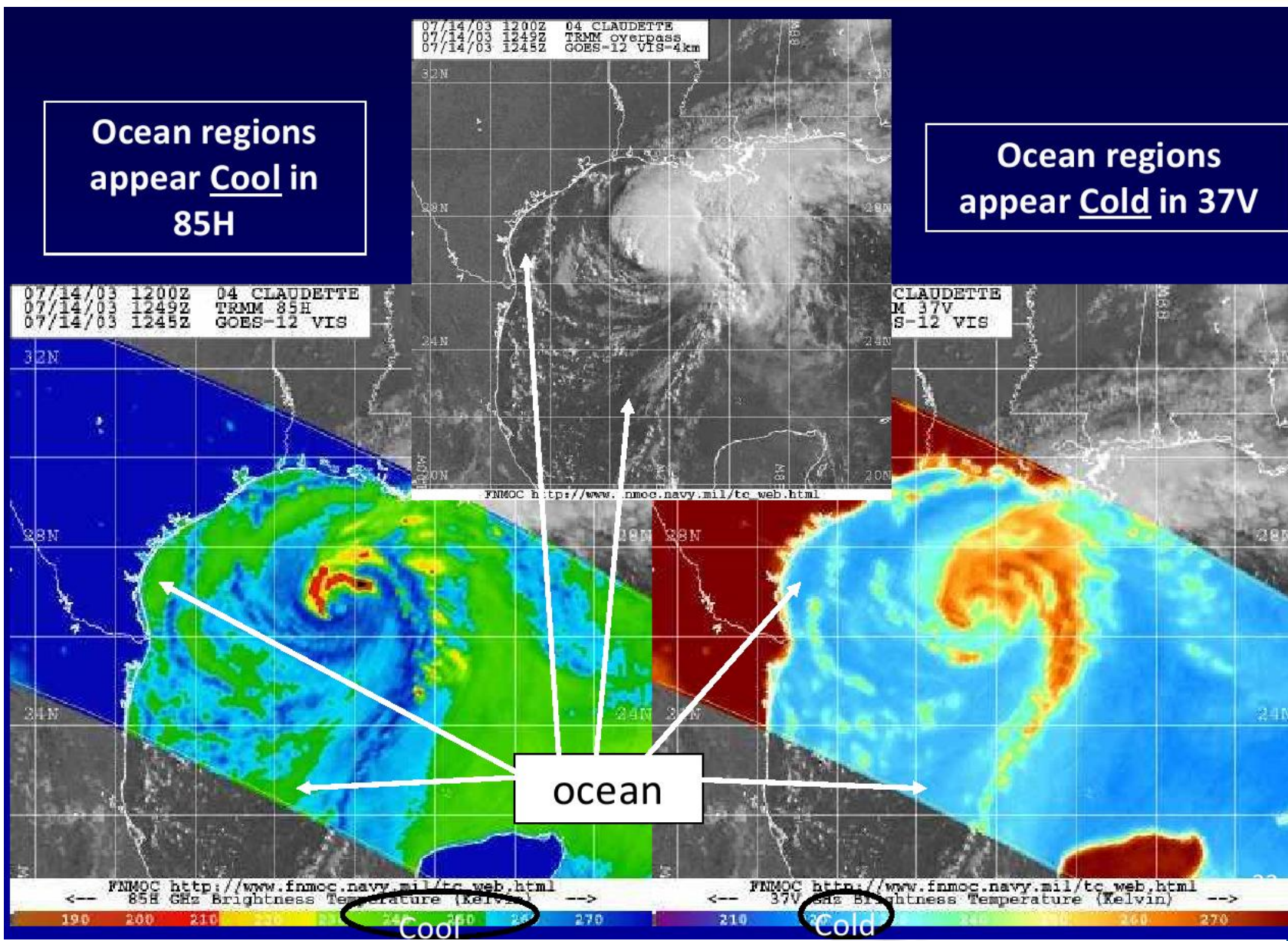
1. *Synopsis on microwaves*
2. ***Interpreting microwave data***
3. *Applications in TC analysis*
4. *TC Intensity estimate: objective guidances*
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Imagery examples at 37 and 85 Ghz

Ocean regions
appear Cool in
85H

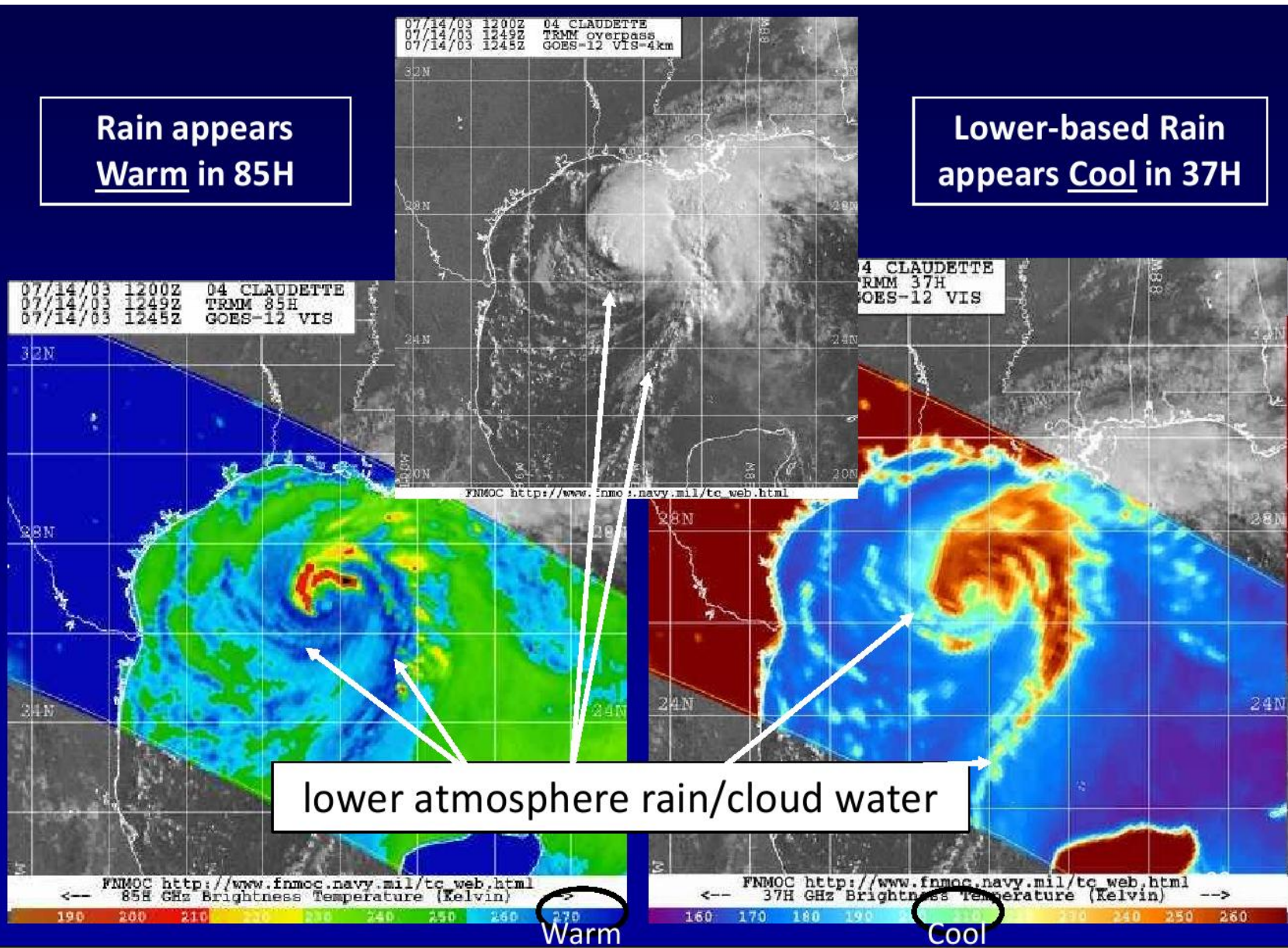
Ocean regions
appear Cold in 37V



Imagery examples at 37 and 85 Ghz

Rain appears
Warm in 85H

Lower-based Rain
appears Cool in 37H

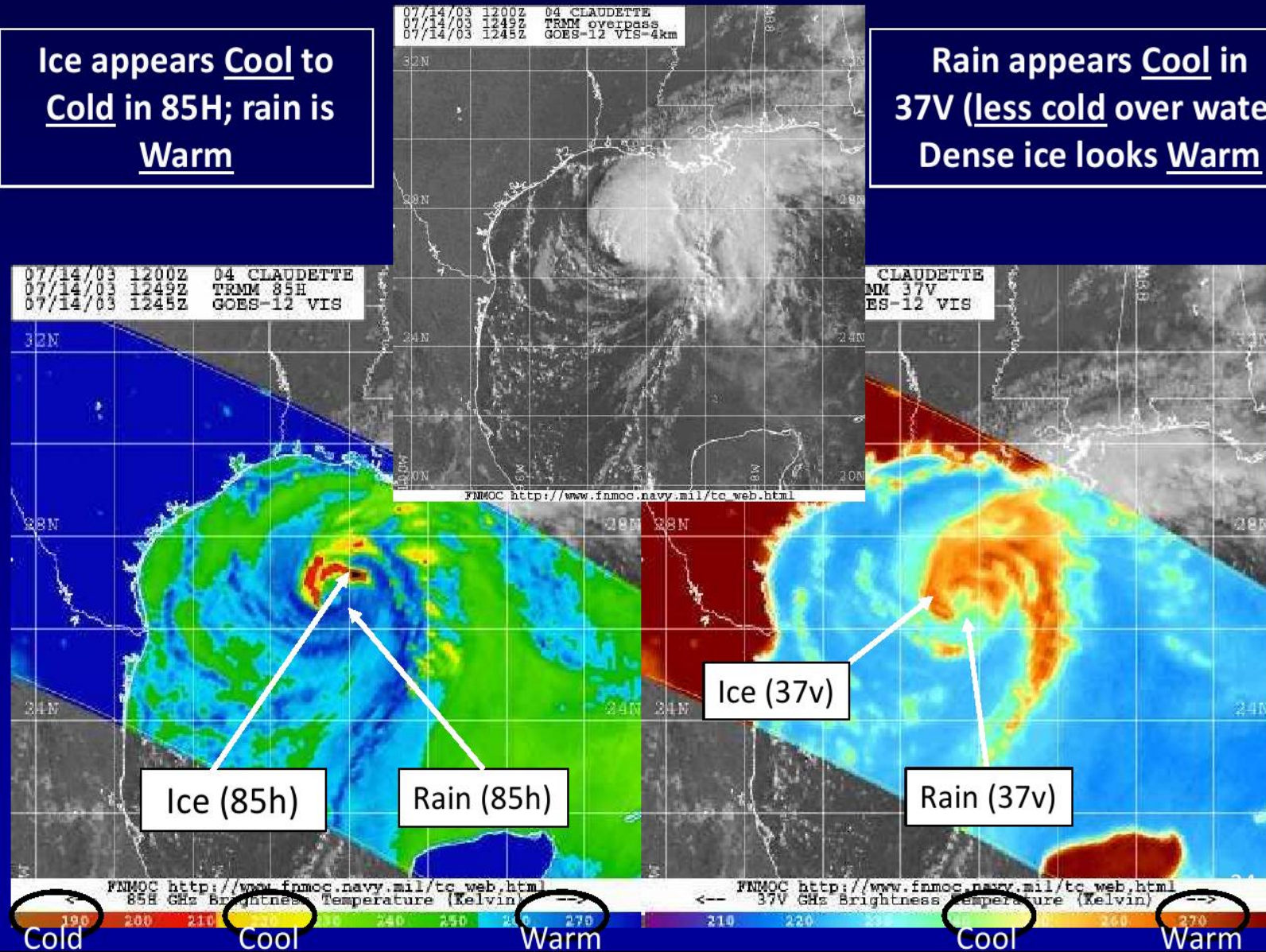


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Imagery examples at 37 and 85 Ghz

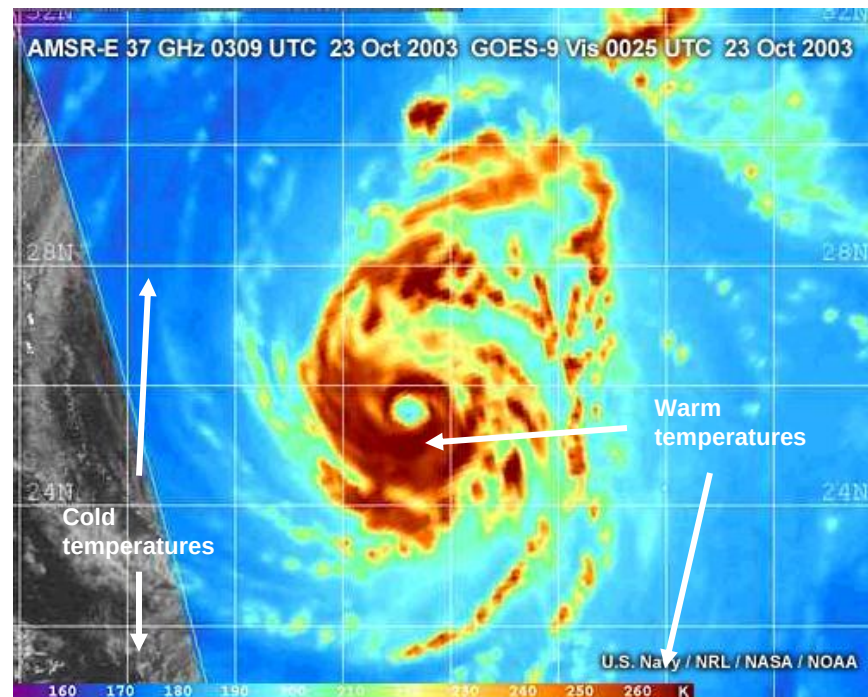
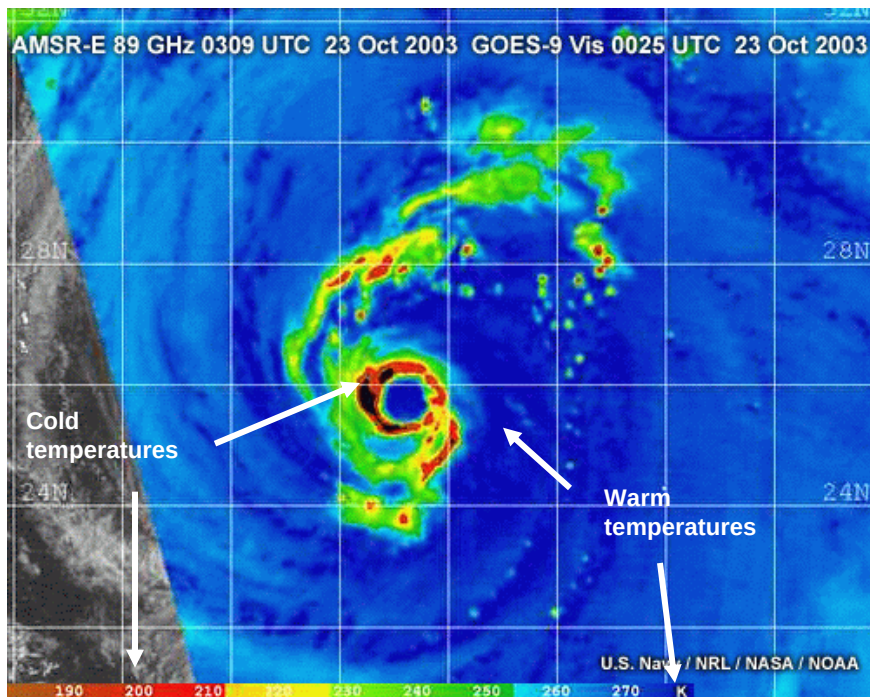
Ice appears Cool to
Cold in 85H; rain is
Warm

Rain appears Cool in
37V (less cold over water)
Dense ice looks Warm



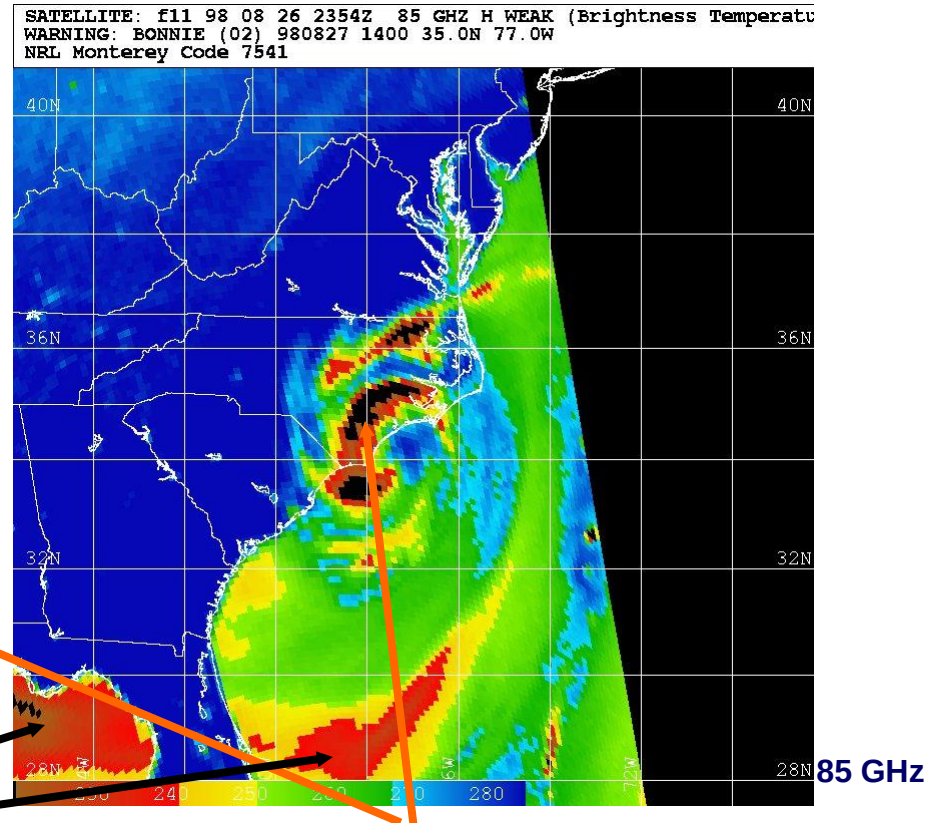
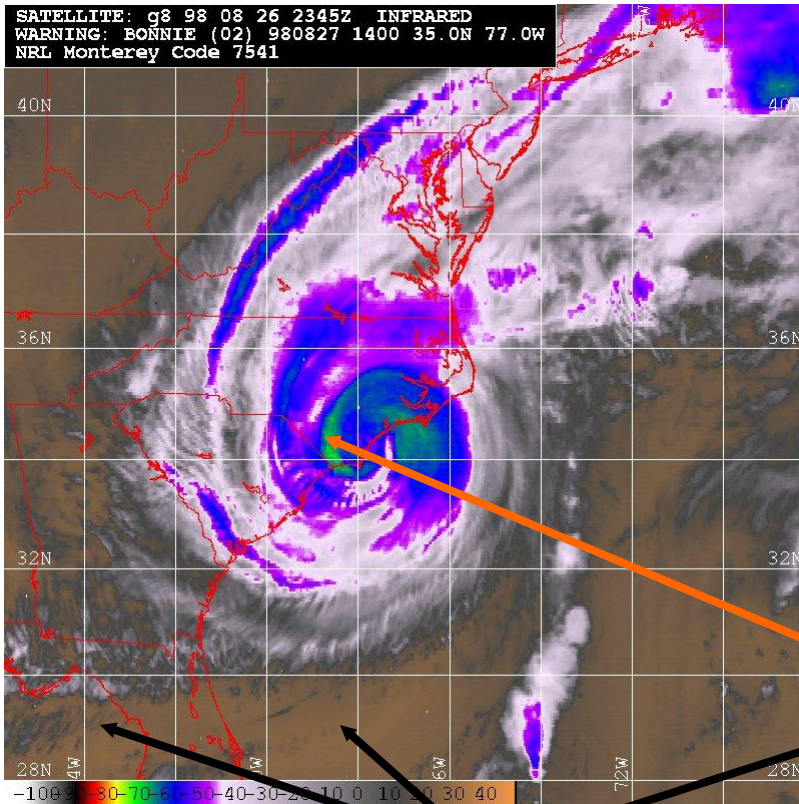
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Imagery examples at 37 and 85 Ghz



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Interpretation issues 85-91 Ghz



Air sec au dessus de la mer apparaît également froid en 85 Ghz, du fait de la faible émissivité.

Dry air over sea also appears cold on 85 GHz image due to low emissivity

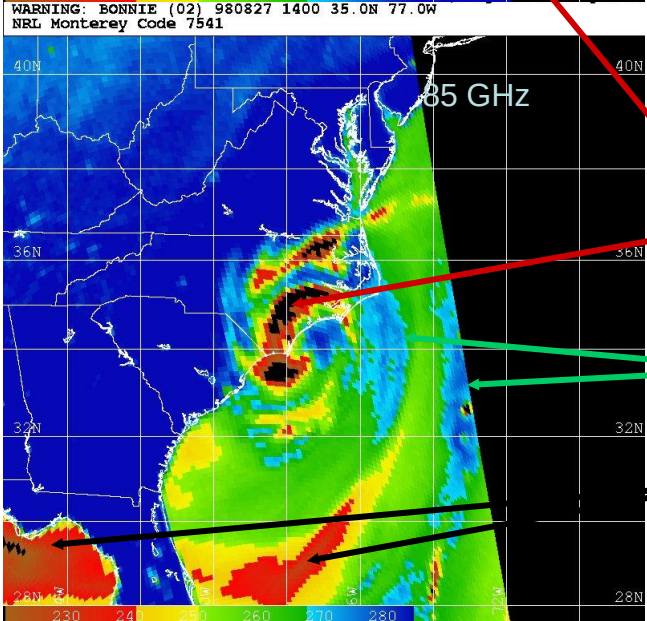
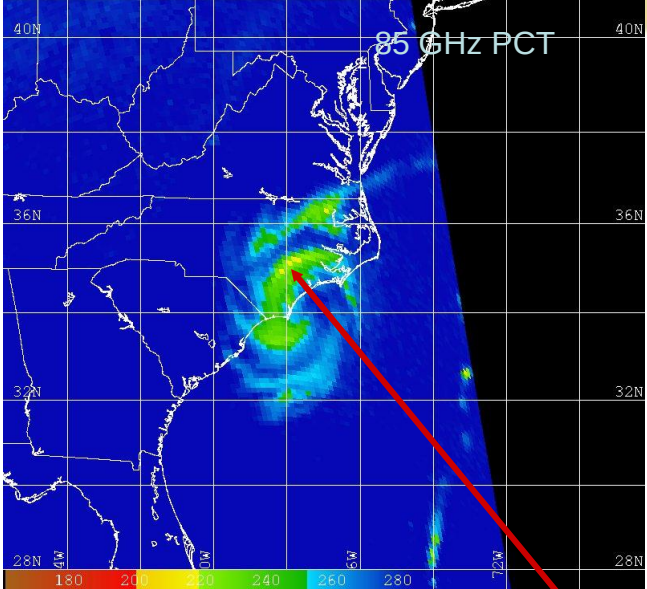
La convection du mur de l'œil apparaît froide en 85 Ghz, avec la diffusion de la glace.

Eyewall convection appears cold on 85 GHz image due to ice scattering.

Images: NRL

Interpretation issues 85-91 Ghz

SATELLITE: f11 98 08 26 2354Z PCT (Corrected Brightness Temperature)
WARNING: BONNIE (02) 980827 1400 35.0N 77.0W
NRL Monterey Code 7541



- Radiations émises de la mer polarisées, mais radiations diffusées par les grosses particules de glace non.
- Combinaison des polarisations verticale et horizontale : on s'affranchit des ambiguïtés.
- Appelé la PCT (Polarisation Corrected Temperature ou température corrigée de la polarisation)
- *Radiation from sea is polarised, while radiation scattered from large ice is not.*
- *By combining the H & V polarisations, we can get rid of the ambiguity.*
- *Called the PCT (polarisation corrected temperature).*

Eyewall convection appears cold on both images

Weak rainbands are washed out on PCT image

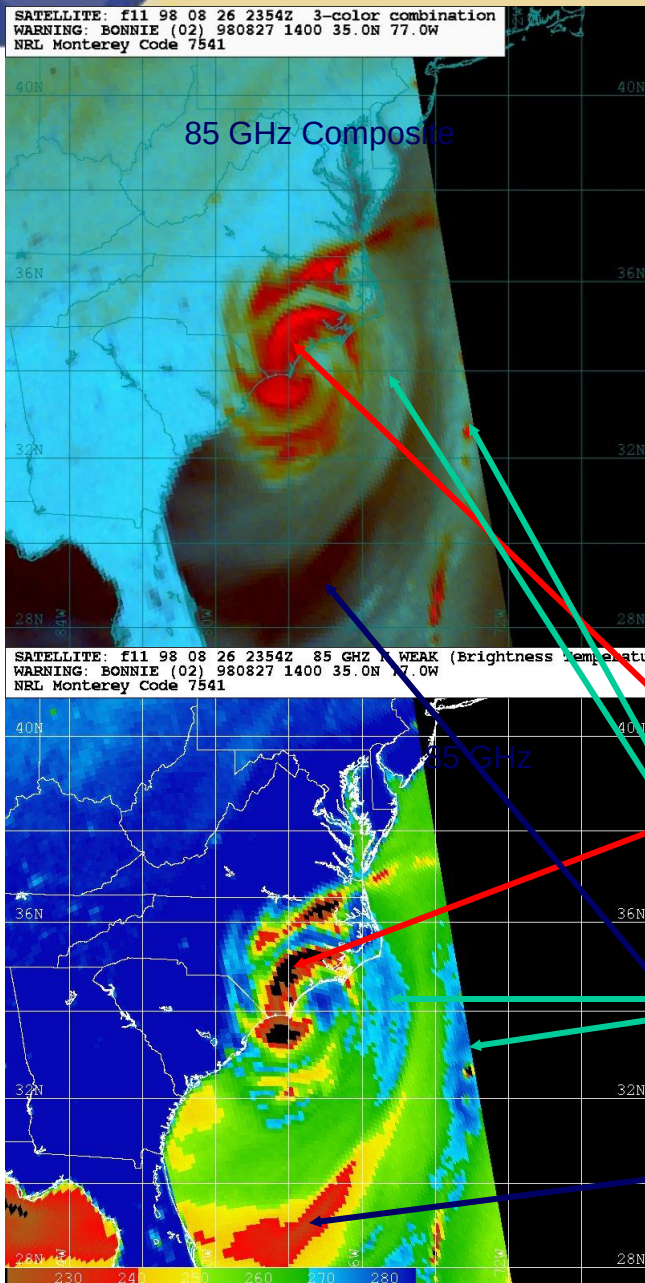
Dry air over sea not visible on PCT image

Images: NRL



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Interpretation issues 85-91 Ghz



- Image composite montre le PCT en rouge et les 85 GHz en bleu-vert.
- Composite image has PCT in red, 85GHz in blue-green, and captures both features.

Eyewall convection apparent on both images

Weak rainbands are green-blue on composite image.

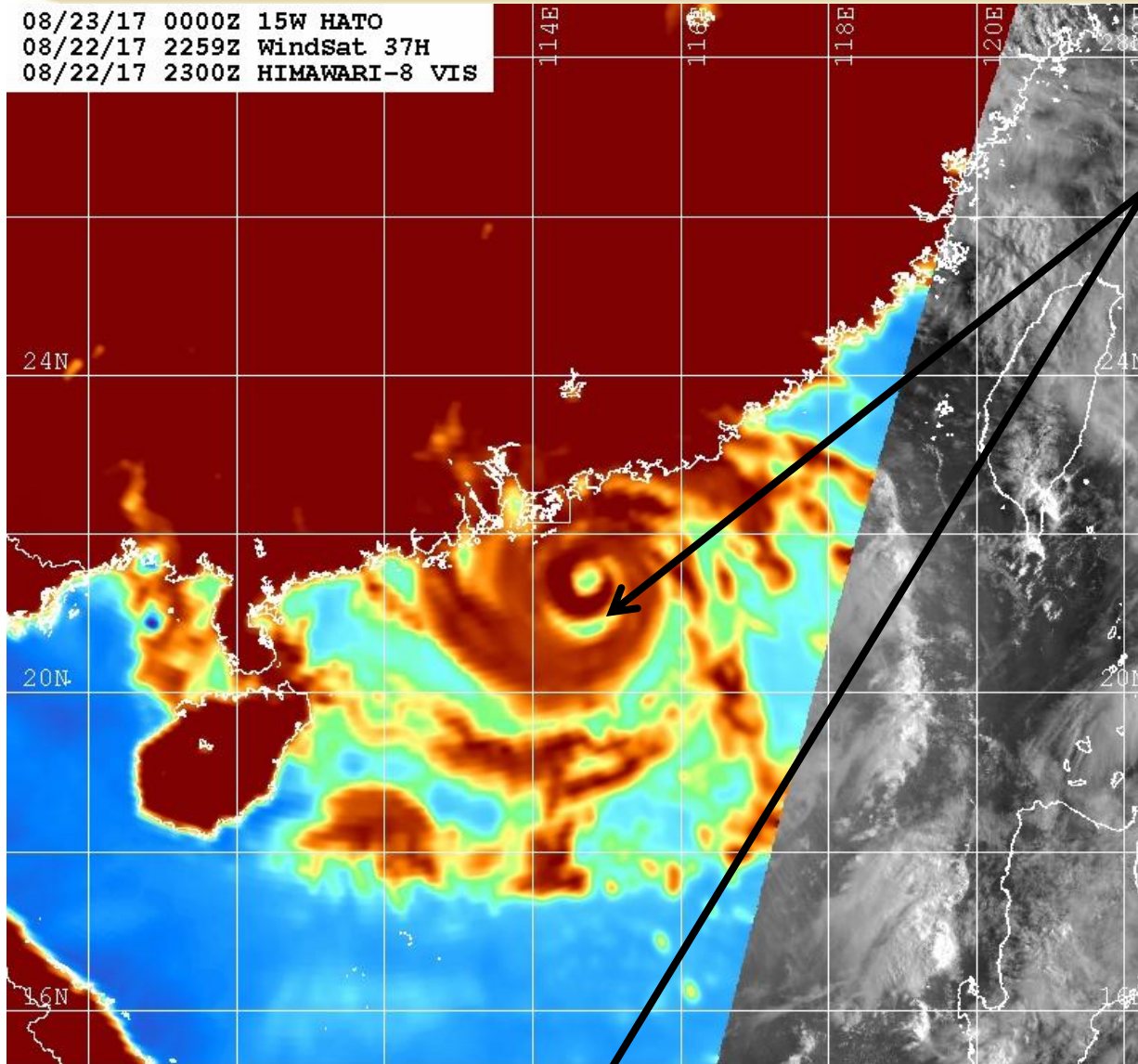
Dry air over sea near-black on composite image.



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Interpretation issues 36-37 Ghz

08/23/17 0000Z 15W HATO
08/22/17 2259Z WindSat 37H
08/22/17 2300Z HIMAWARI-8 VIS



Naval Research Lab www.nrlmry.navy.mil/sat_products.html
--- 37H Brightness Temp (Kelvin) --->

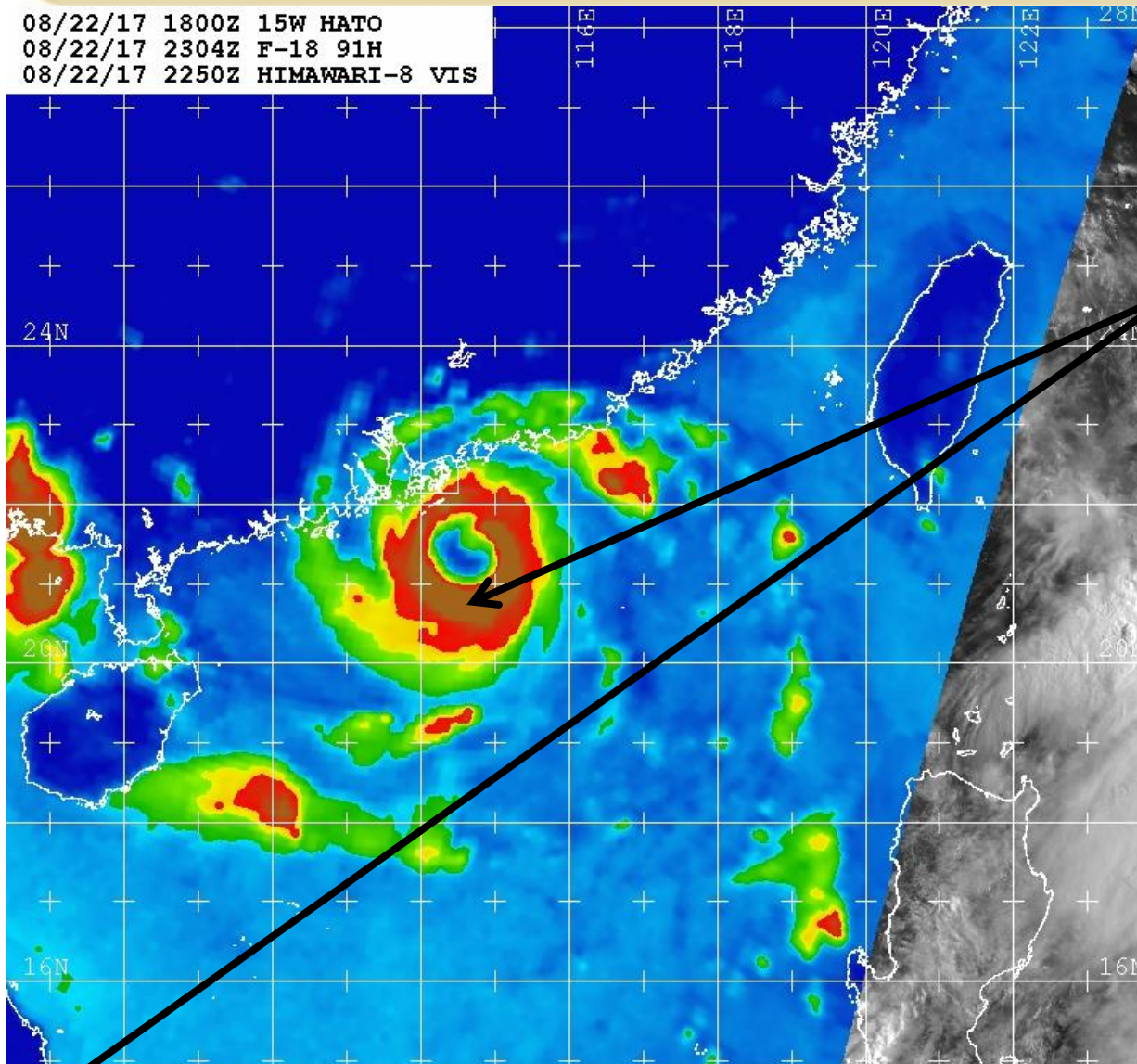
- 37 H suggère une zone de pluies faibles (Tb fraîches) en périphérie sud du mur de l'œil.
- 37H suggest an area of light rain (cool Tb) located just to the south of the southern eyewall.



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Interpretation issues 36-37 Ghz

08/22/17 1800Z 15W HATO
08/22/17 2304Z F-18 91H
08/22/17 2250Z HIMAWARI-8 VIS



Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- 91H Brightness Temp (Kelvin) -->

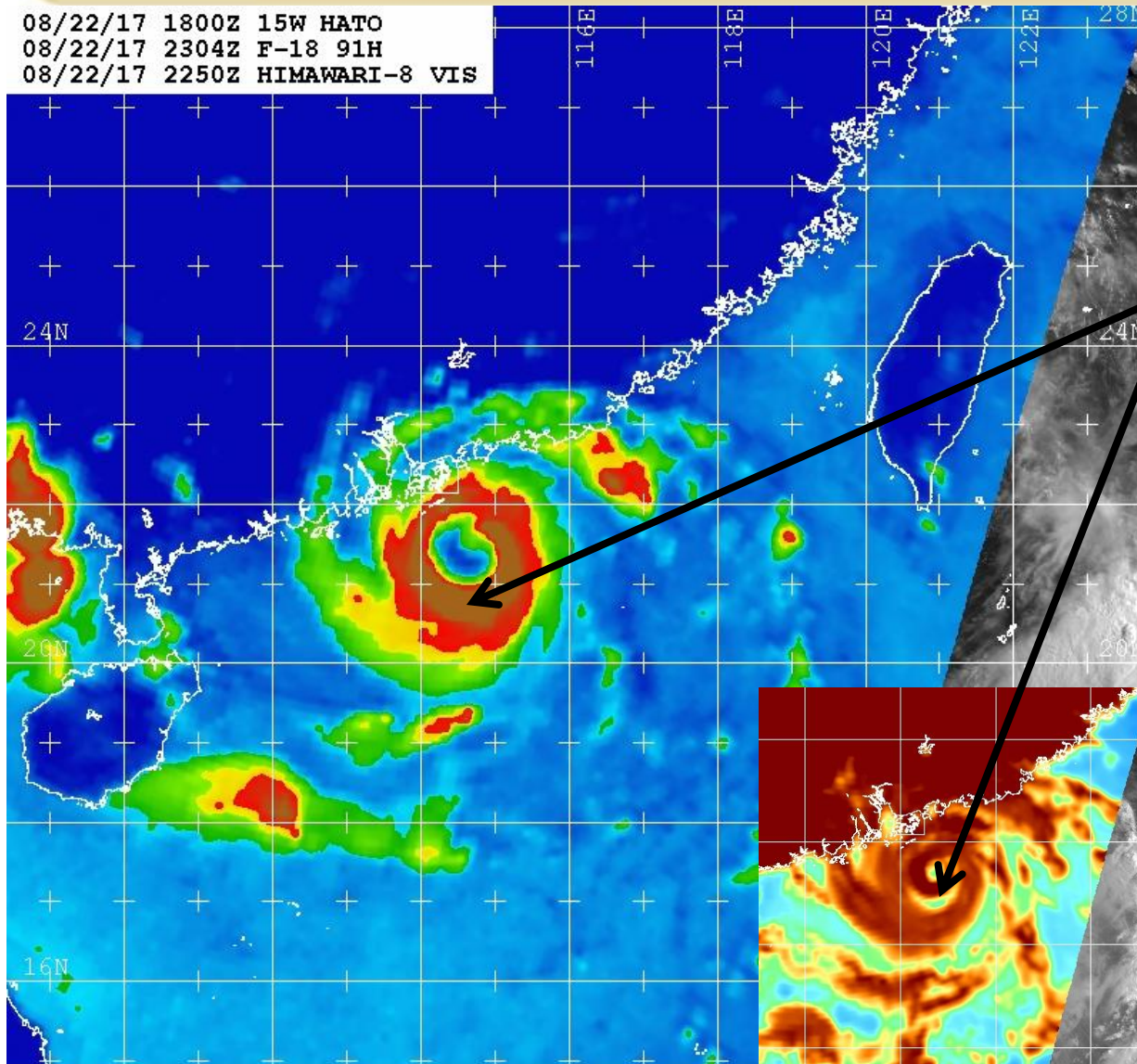
- 85 H montre que cette zone est en fait le siège d'une convection profonde très intense avec une production intense de noyaux de glace en moyenne / haute troposphère.
- 85H show actually very strong convection located in this part of the eyewall associated with large amount of graupel in the mid and upper layers



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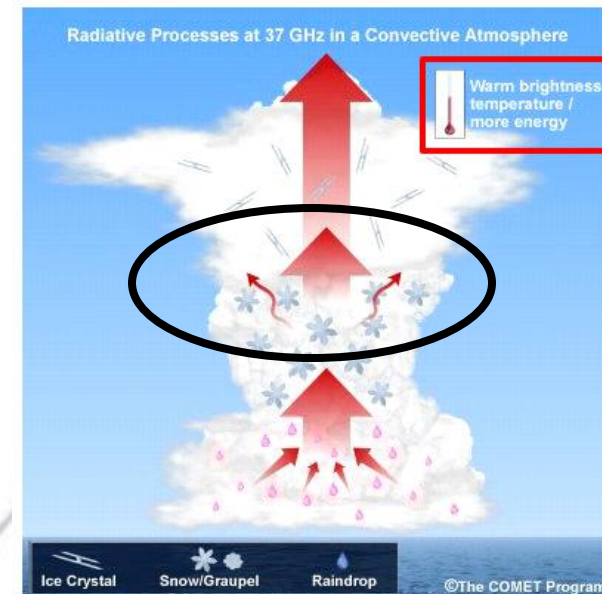
Interpretation issues 36-37 Ghz

08/22/17 1800Z 15W HATO
08/22/17 2304Z F-18 91H
08/22/17 2250Z HIMAWARI-8 VIS



Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- 91H Brightness Temp (Kelvin) -->

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Interpretation issues 36-37 Ghz

08/23/17 0000Z 15W HATO
08/22/17 2259Z Windsat 37V
08/22/17 2300Z HIMAWARI-8 VIS

37 V

08/23/17 0000Z 15W HATO
08/22/17 2259Z Windsat 37H
08/22/17 2300Z HIMAWARI-8 VIS

37 H

Very strong
convection
~ 200-210 °K

Ocean ~
220-230 °K

Ocean ~
170 °K

Naval Research Lab www.nrlmry.navy.mil/sat_products.html
--- 37V Brightness Temp (Kelvin) ---

Naval Research Lab www.nrlmry.navy.mil/sat_products.html
--- 37H Brightness Temp (Kelvin) ---

210 220 230 240 250 260 270

160 170 180 190 200 210 220 230 240 250 260

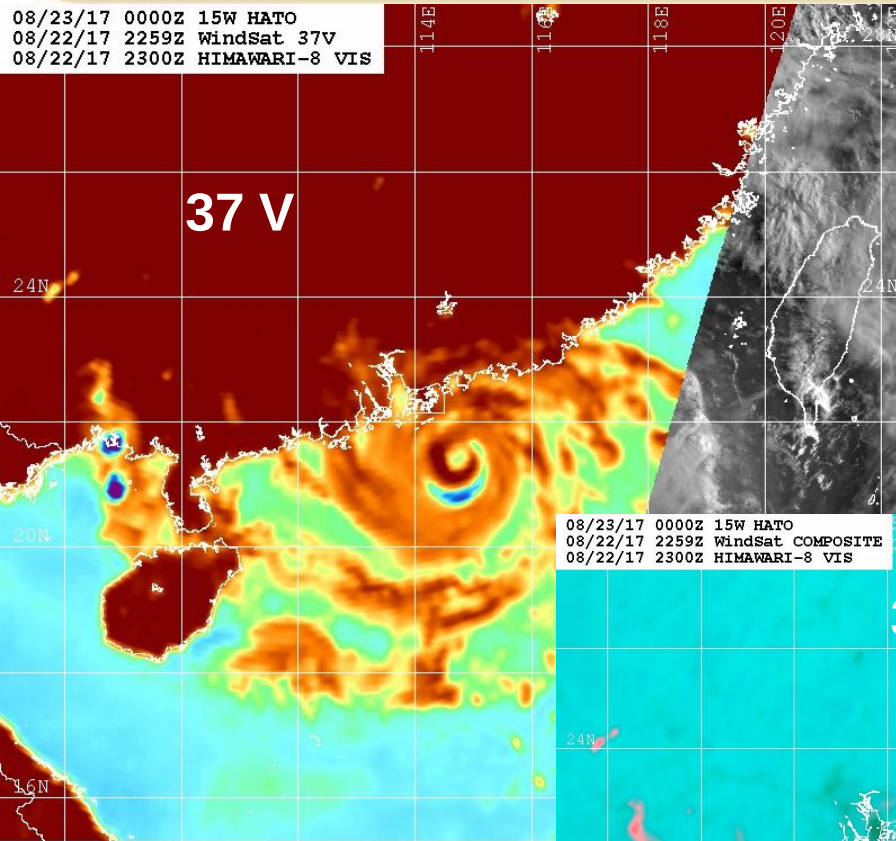
200°K → 280°K 150°K → 270°K



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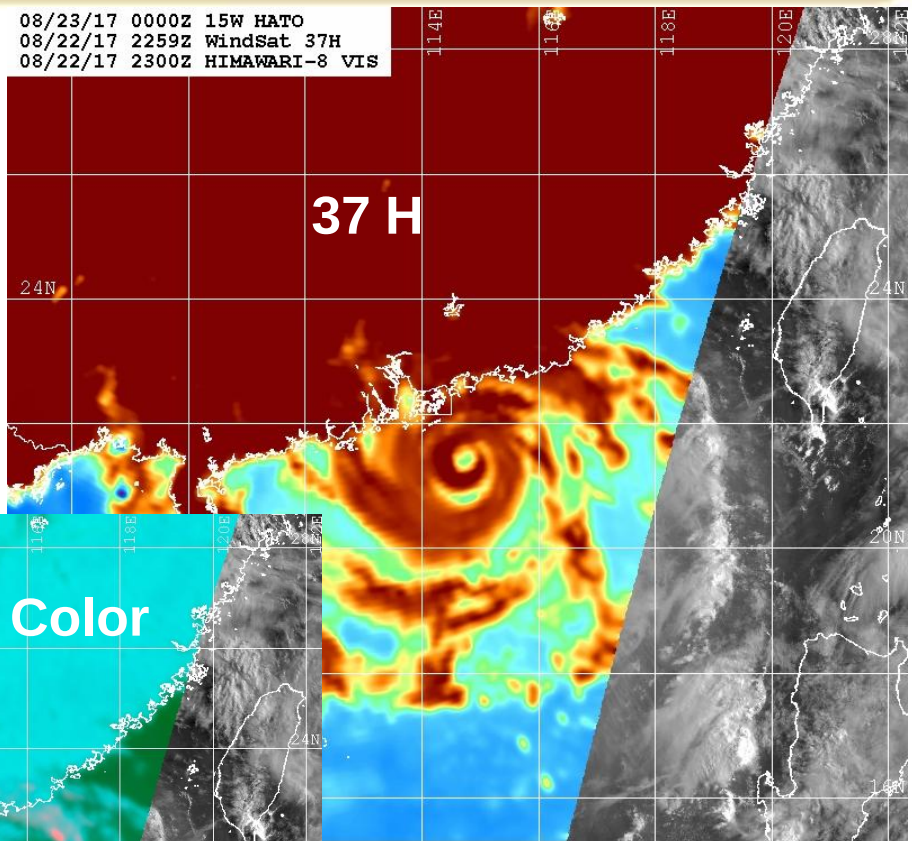
Interpretation issues 36-37 Ghz

08/23/17 0000Z 15W HATO
08/22/17 2259Z WindSat 37V
08/22/17 2300Z HIMAWARI-8 VIS



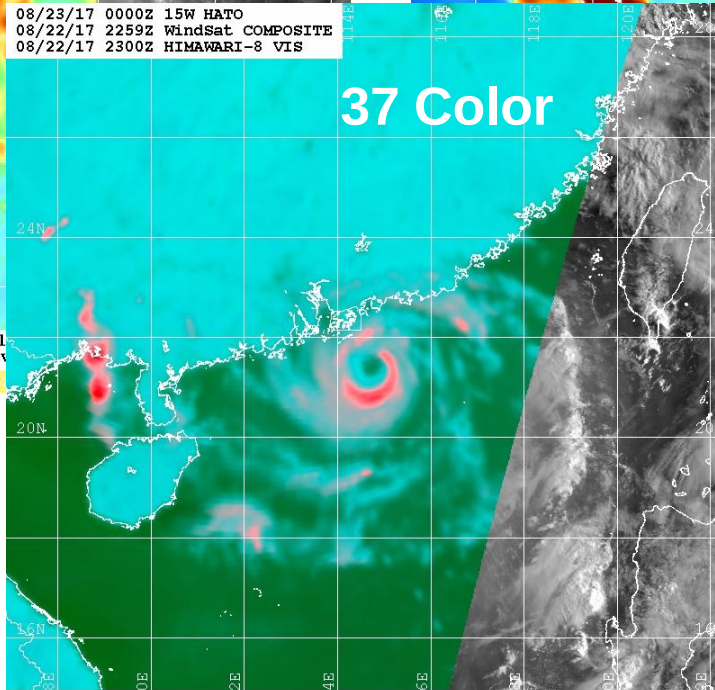
Naval Research Lab www.nrlmry.navy.mil
--- 37V Brightness Temp (Kelvin)

08/23/17 0000Z 15W HATO
08/22/17 2259Z WindSat 37H
08/22/17 2300Z HIMAWARI-8 VIS



Lab www.nrlmry.navy.mil/sat_products.html
7H Brightness Temp (Kelvin) -->

08/23/17 0000Z 15W HATO
08/22/17 2259Z WindSat COMPOSITE
08/22/17 2300Z HIMAWARI-8 VIS



Naval Research Lab www.nrlmry.navy.mil/sat_products.html
Red=37PCT Green=37V Blue=37H



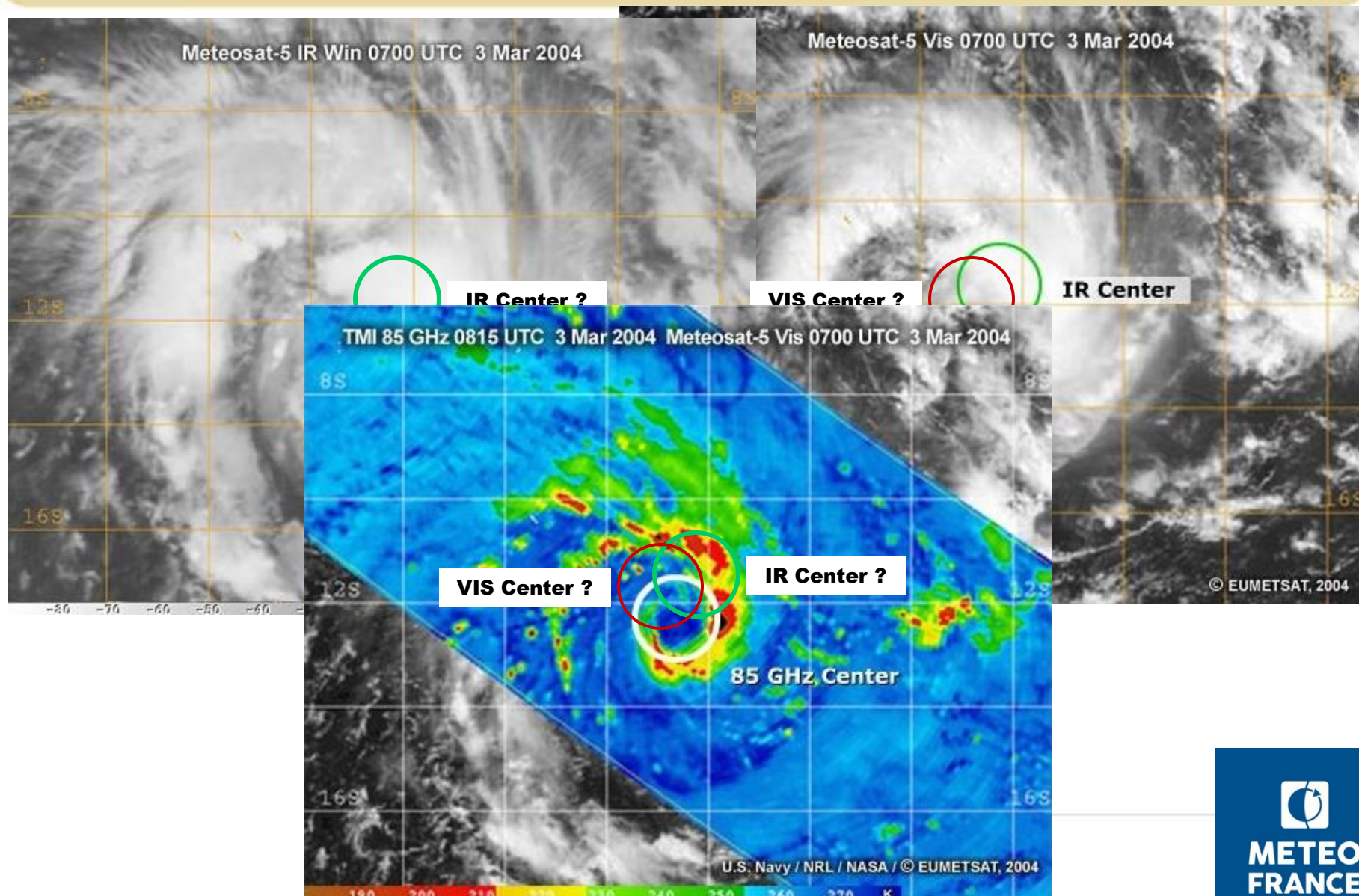
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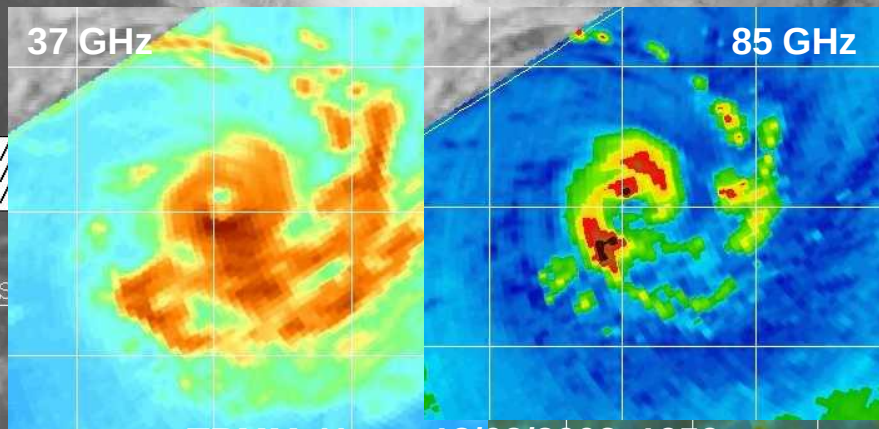
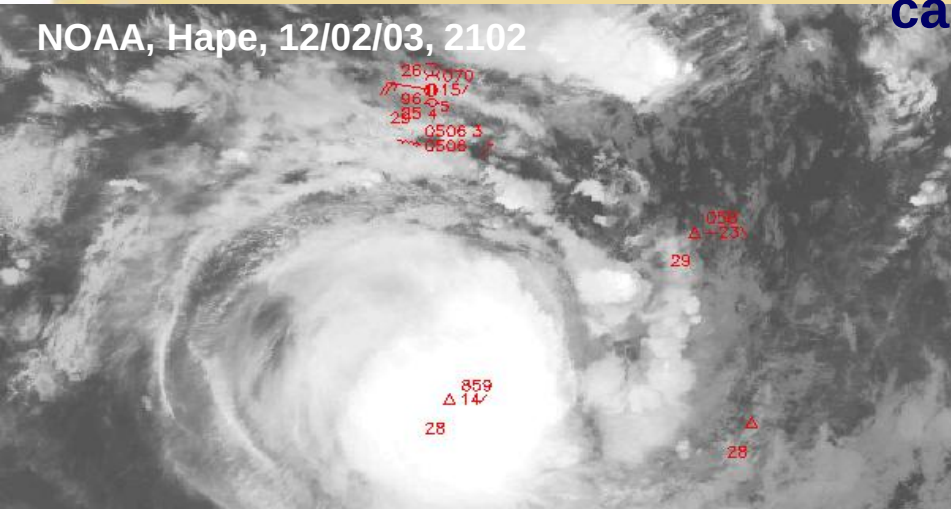


Locate the center

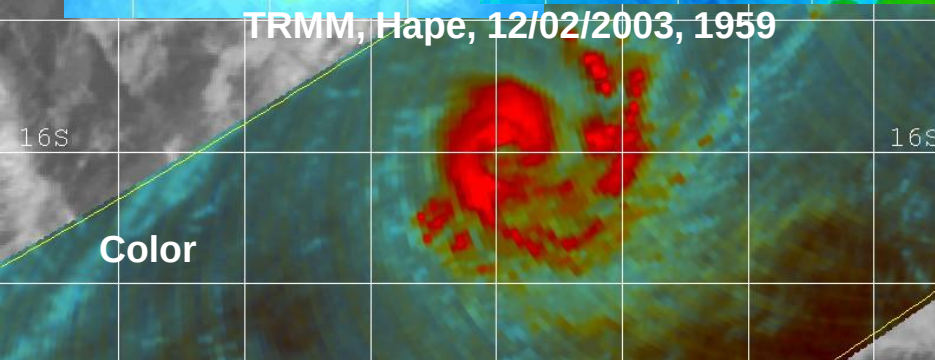


Locate the center and see internal structure under cirrus canopy

NOAA, Hape, 12/02/03, 2102



TRMM, Hape, 12/02/2003, 1959



- **Détails de la convection et de l'œil clairement visibles en micro-onde, mais cachés derrière le voile de cirrus sur l'image IR**
- **Typiquement, l'œil apparaît (Ray Zehr)**
 - IR : 70-75 kt (type CDO)
 - 85 GHz : ~ 50 kt
 - 37 GHz : ~35 kt
- *Details of convection and eye are clearly visible in 85 GHz, but hidden beneath cirrus shield in IR image.*
- *Eye typically appears at (Ray Zehr):*
 - IR : 70-75 kt (CDO-type)
 - 37 GHz : ~ 35 kt
 - 85 GHz : ~ 50 kt

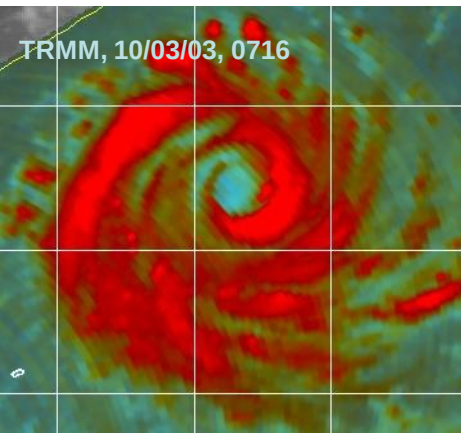


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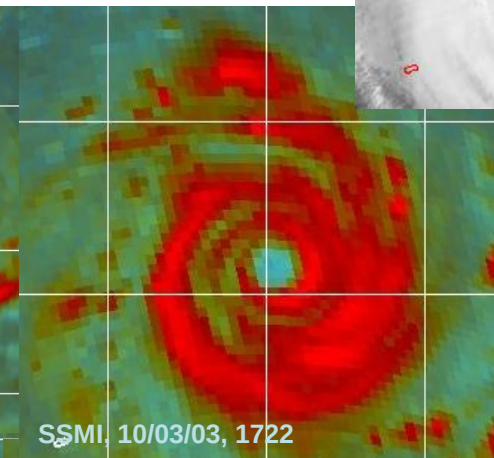
Noaa 16, 10/03/03, 2113

Reveal eyewall replacement cycle

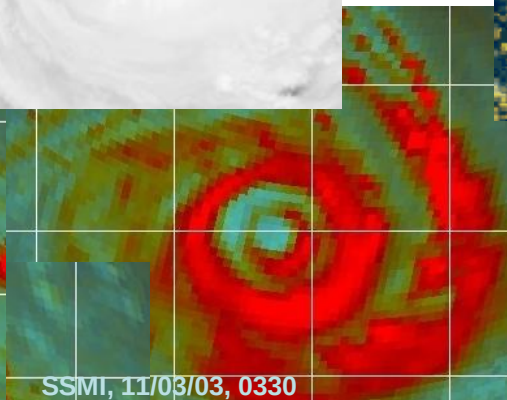
TRMM, 10/03/03, 0716



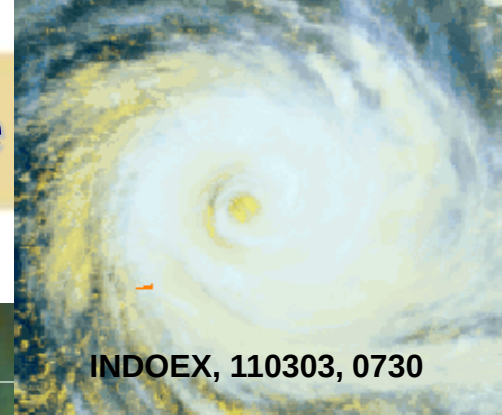
SSM/I, 10/03/03, 1722



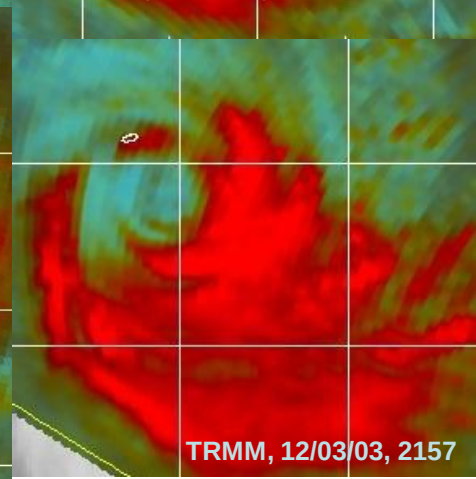
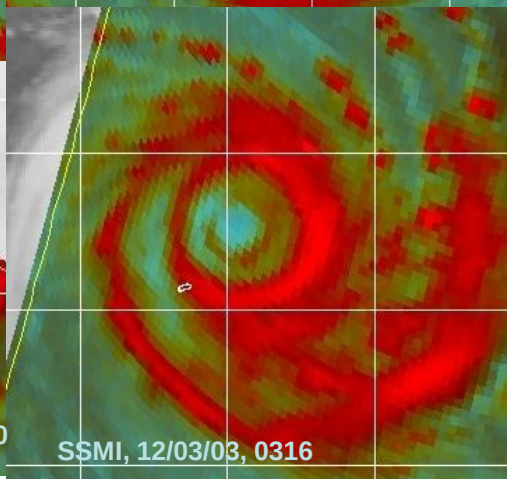
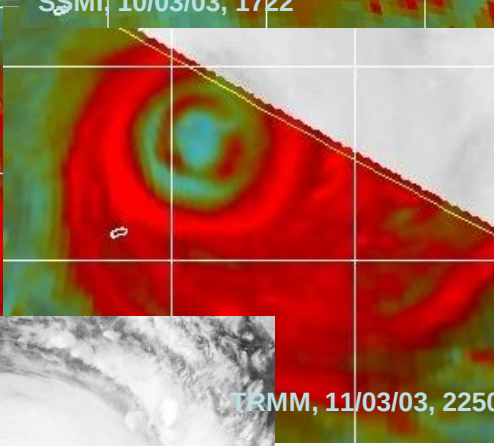
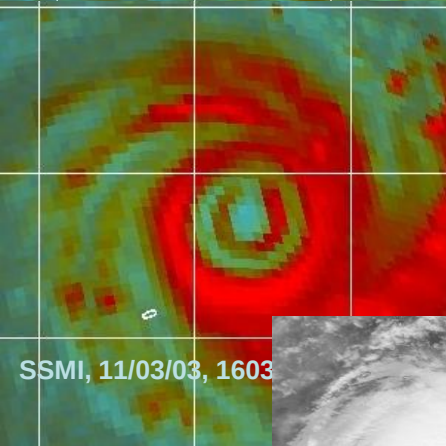
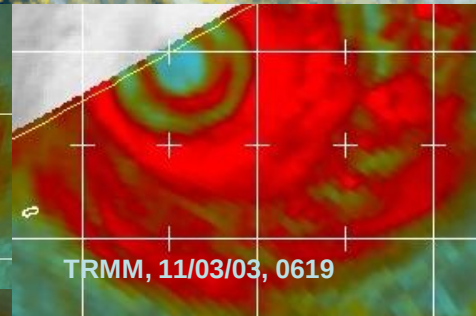
SSM/I, 11/03/03, 0330



INDOEX, 110303, 0730

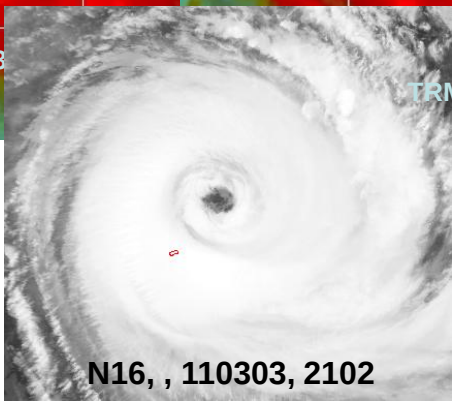


TRMM, 11/03/03, 0619



SSM/I, 11/03/03, 1603

TRMM, 11/03/03, 2250

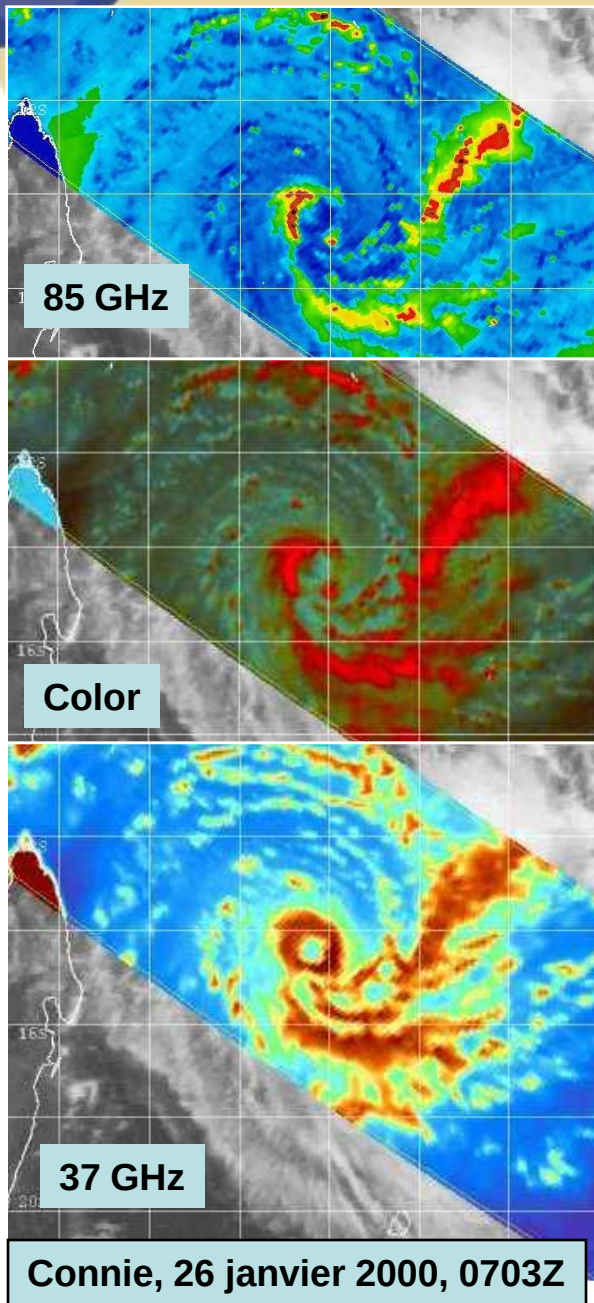


N16, , 110303, 2102

- Bonne visualisation des changements de structure
- *Better vision of structure changes*

Images: NRL

Early precursor for rapid intensification



- En 85-91 GHz, la convection ne montre pas encore de structure en œil, pourtant déjà apparente dans le canal 31-37 GHz.
- Le canal 31-37 GHz apporte clairement ici des détails sur la structure des bandes de pluie des niveaux inférieurs
- *No eye pattern in 85 Ghz, yet already clearly visible in 37 GHz.*
- *37 GHz clearly shows details about lower level rain bands.*

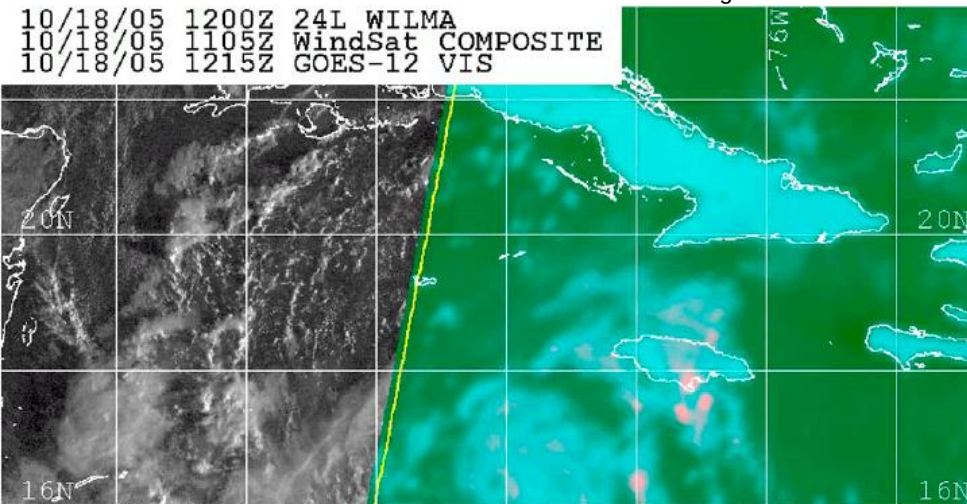
Images: NRL



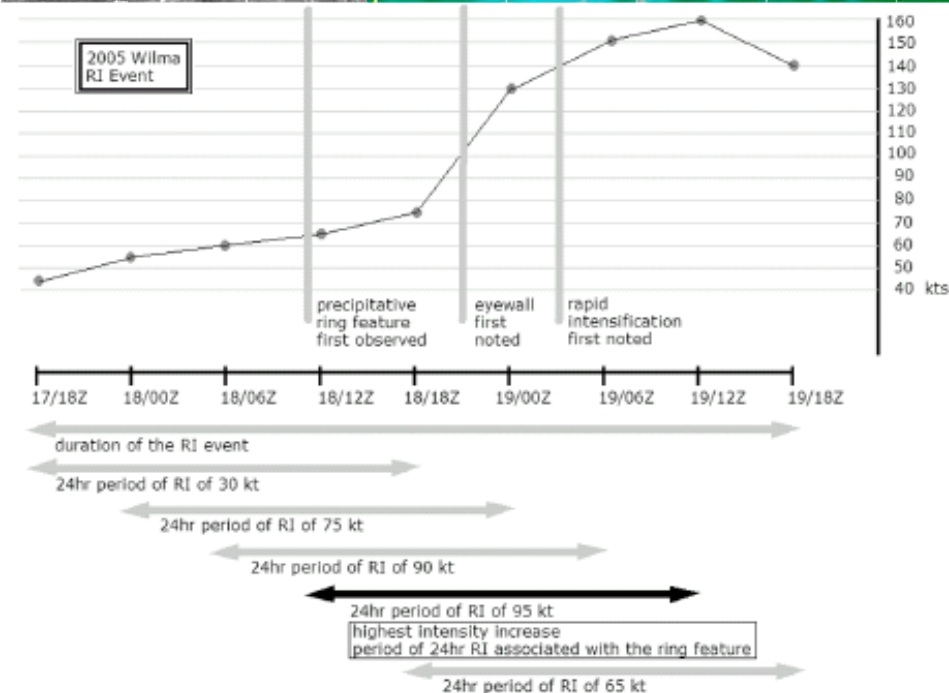
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Early precursor for rapid intensification

Images: NRL



- Kieper et Jiang, 2012
- Une structure d'anneau de la couleur cyan sur le canal 37 Ghz "color" permet d'anticiper les intensifications rapides pouvant se produire dans les 24h
- Cette méthode combinée à l'utilisation de SHIPS (Atlantique Nord) a donné un POD à 75% et FAR à 9% (période 2003-2007) sur la détection des intensifications rapides



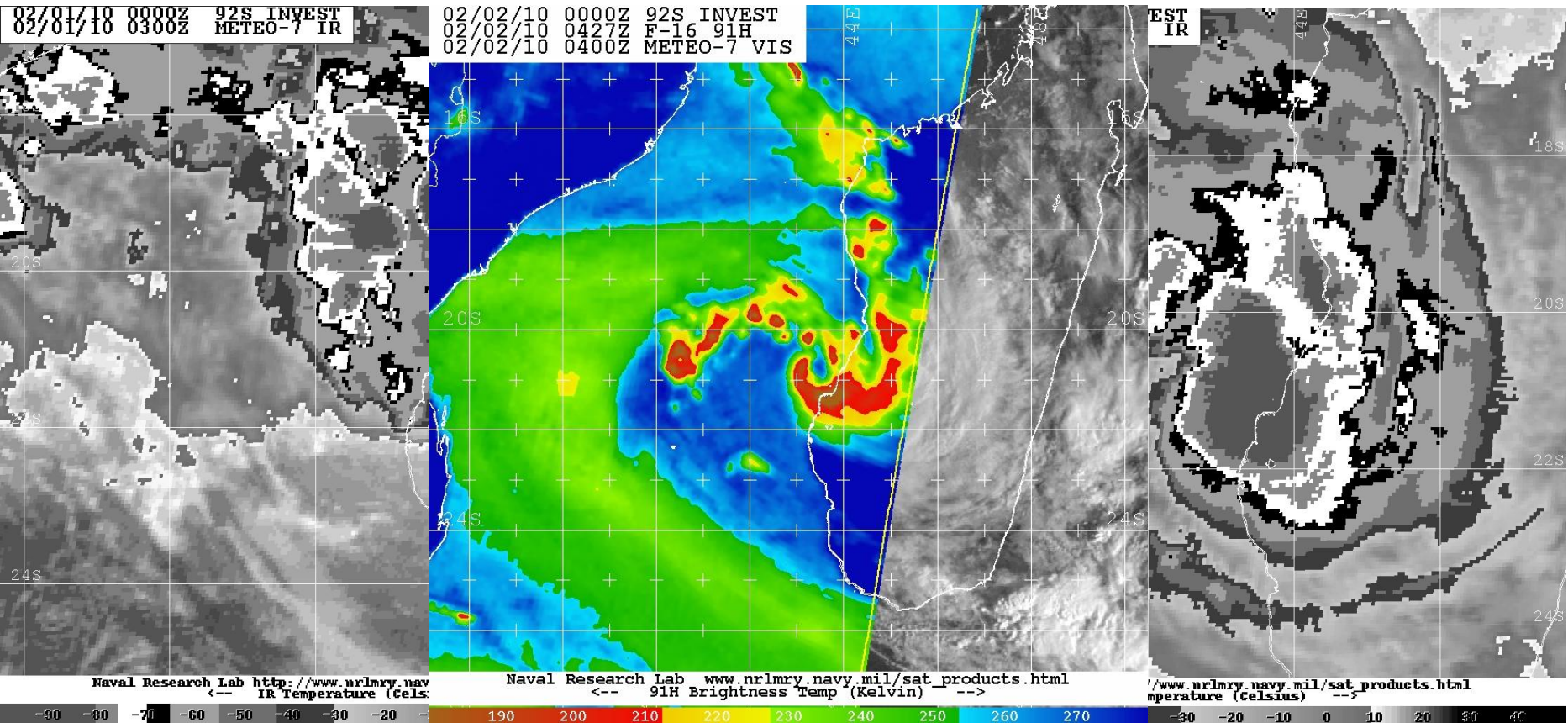
- Kieper and Jiang, 2012
- 37 GHz cyan ring pattern anticipates rapid intensification within the next 24 hours
- This methodology combined with the SHIPS guidance (North Atlantic) gives a POD at 75% and a FAR at 9% (2003-2007) for RI detection.



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Subjectively precise the intensity assessment

Images: NRL

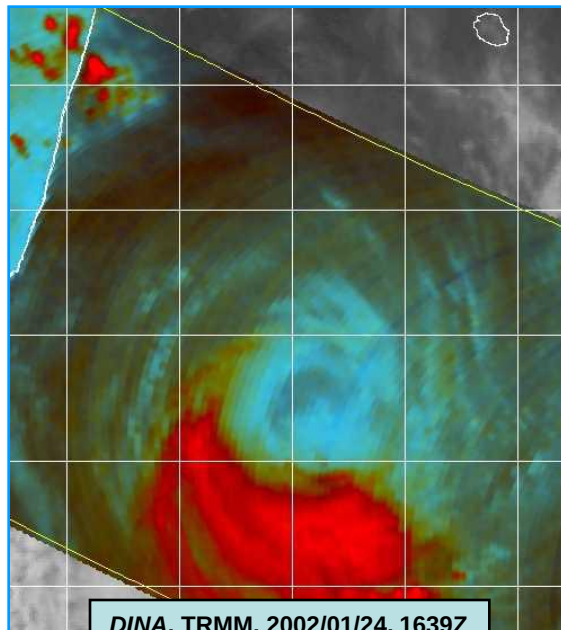
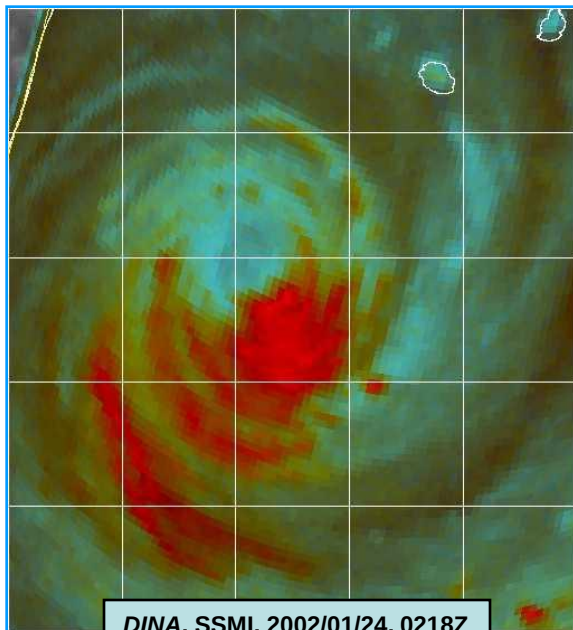
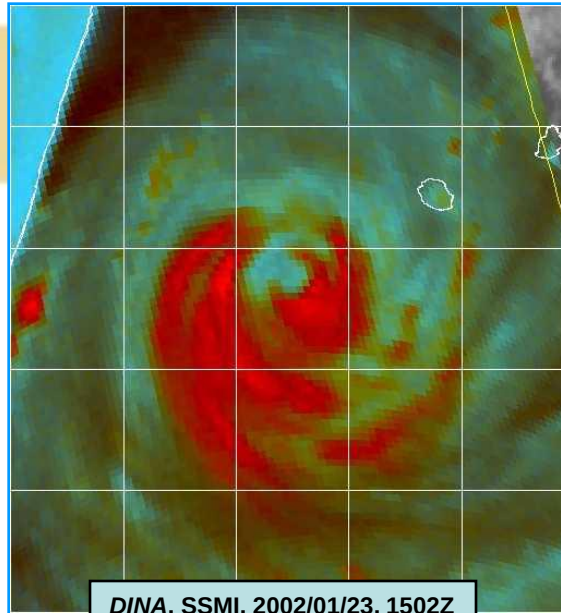
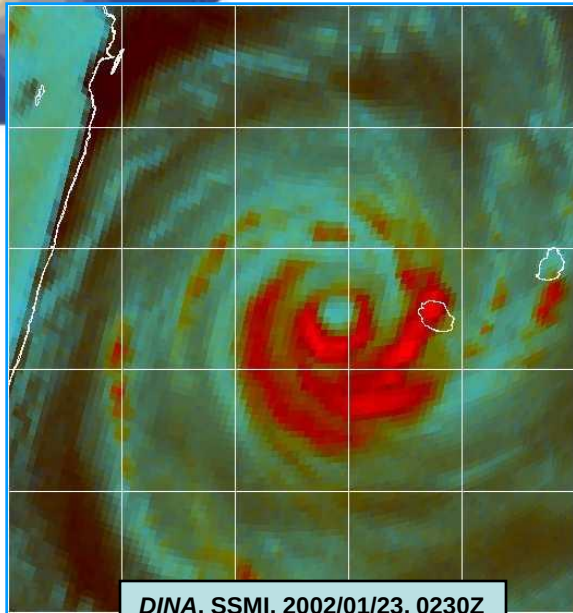


FAMI (02/2009):

- doubt about naming at 06Z based only on classical imagery (EIR)
- SSMI/S of 0427Z
- FAMI named at 06Z with 40 kt in ops. (increased at 45 kt in BT then 50 kt at landfall around 08Z)

Help locate the center in shear pattern

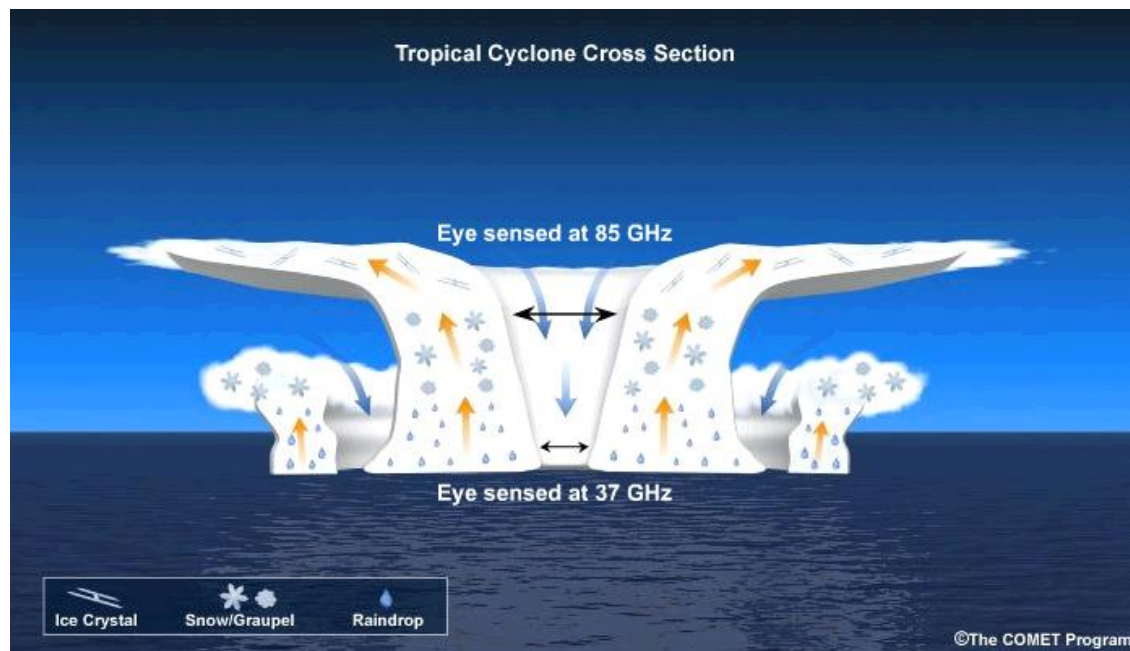
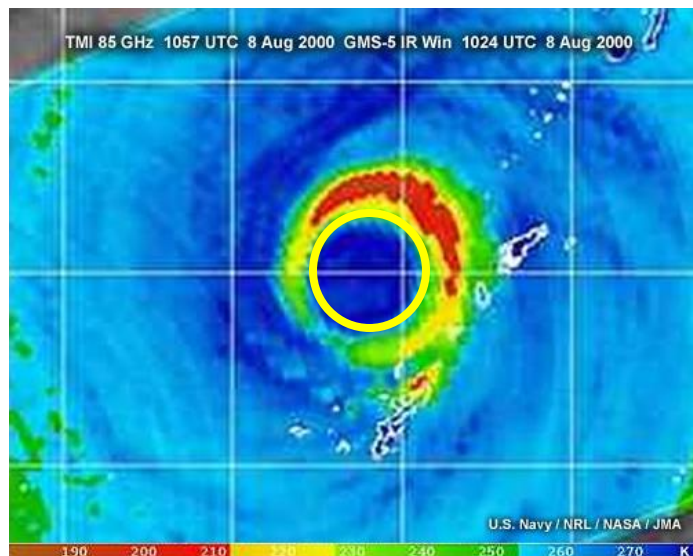
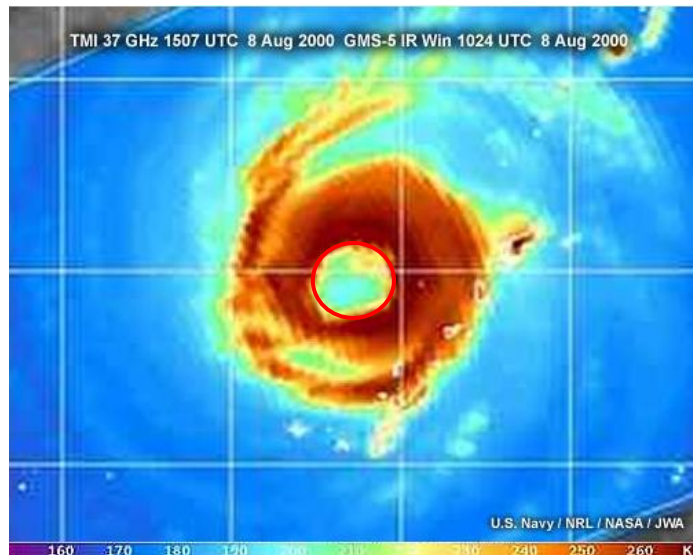
- Meilleure localisation des centres de basses couches des systèmes lors du stade initial de cisaillement
- Bonne visualisation des changements de structure



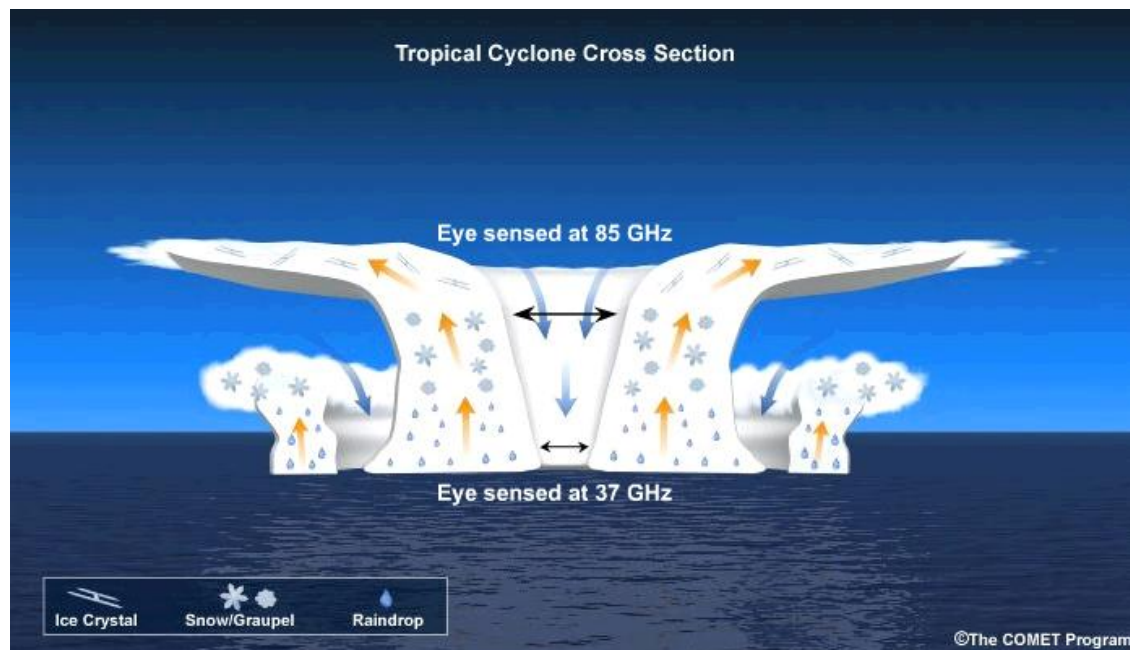
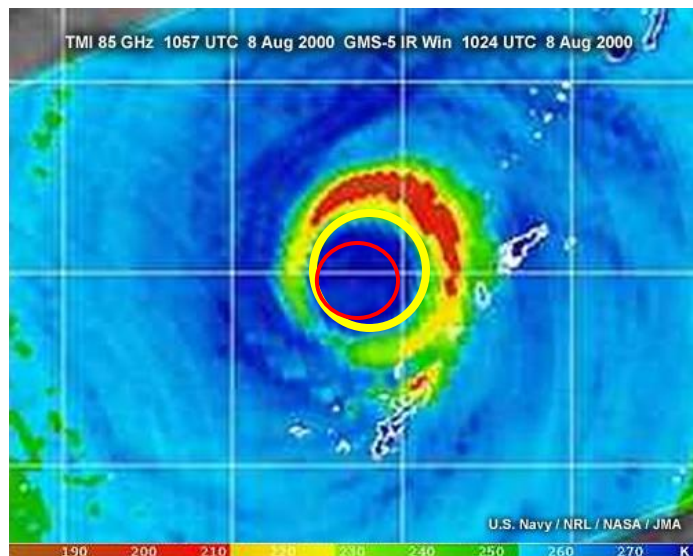
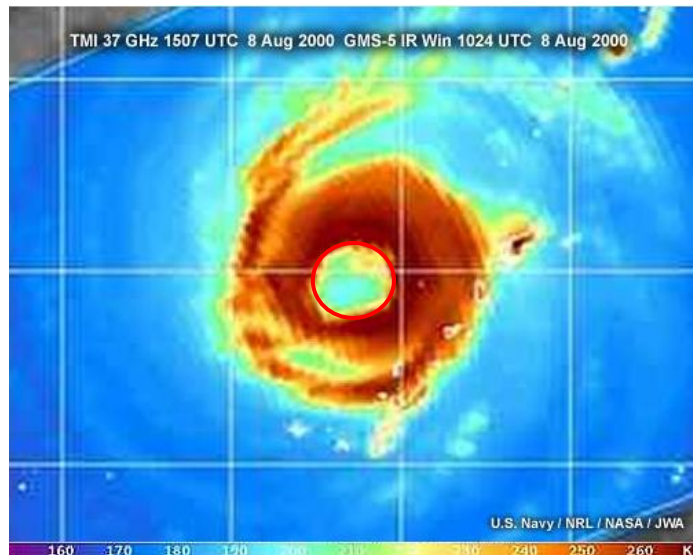
- *Better location of LLCC for systems during initial shearing stage*
- *Better vision of structure changes*

Source : NRL Monterey

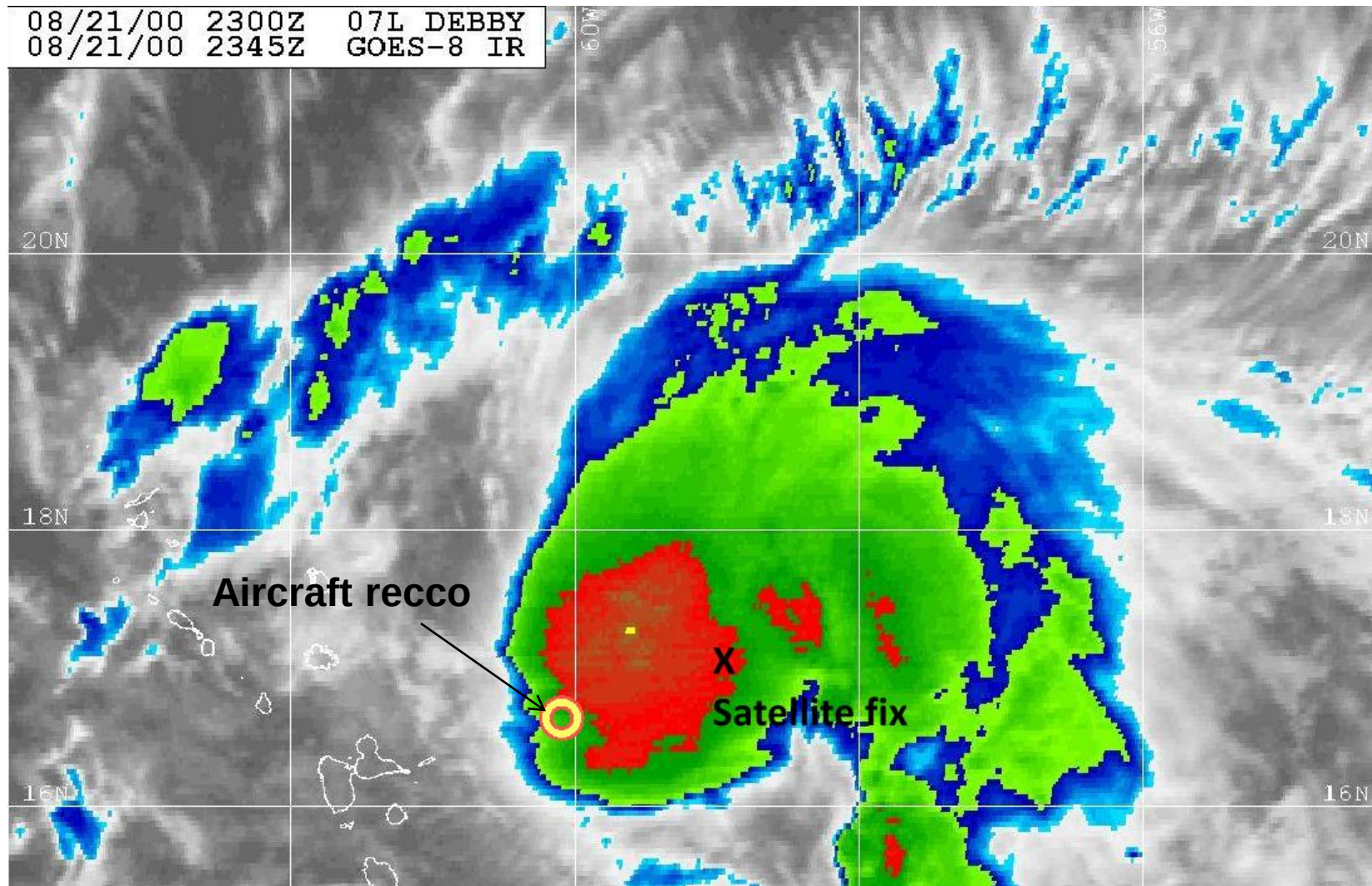
3D view of the inner core structure



3D view of the inner core structure



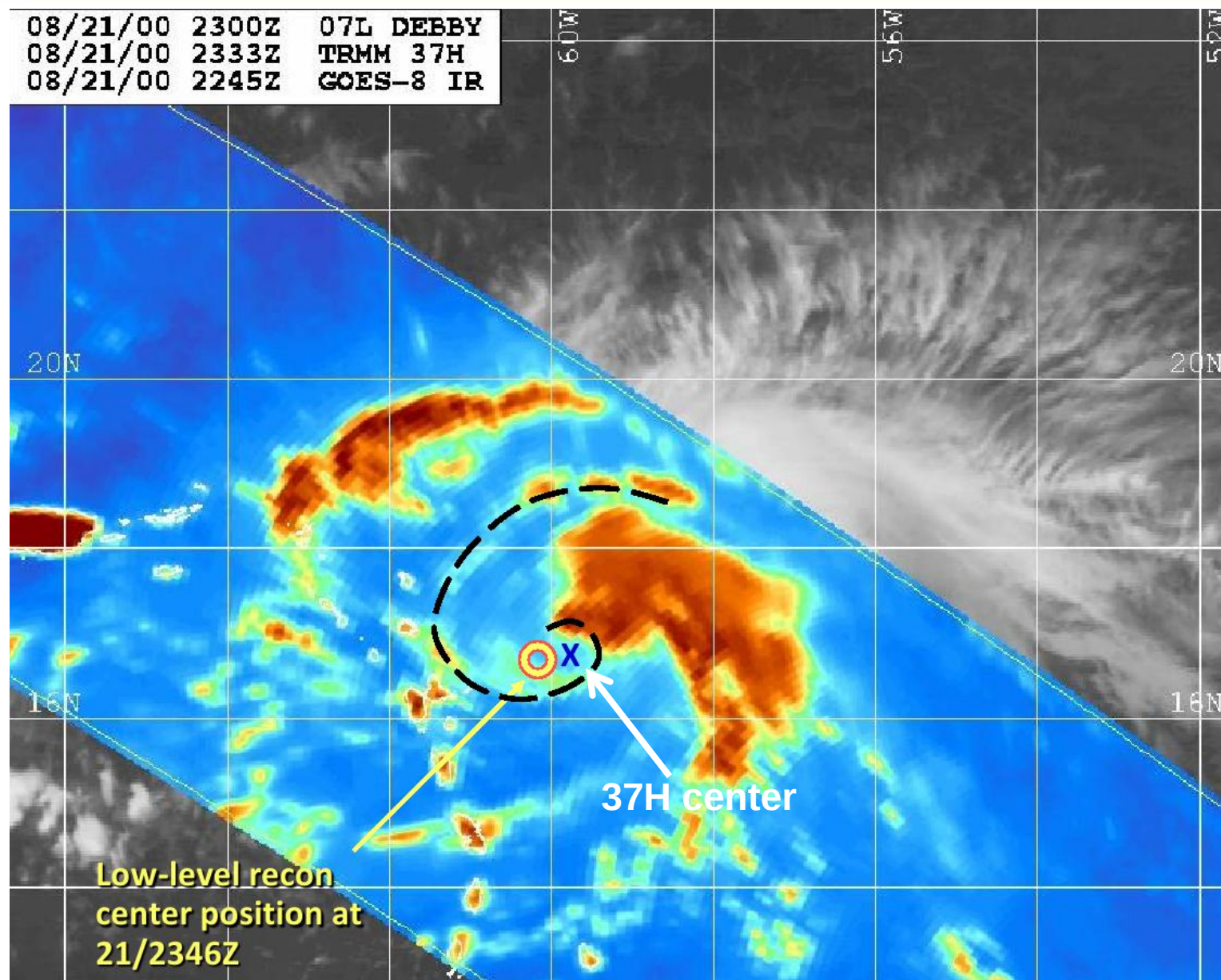
3D view of the inner core structure



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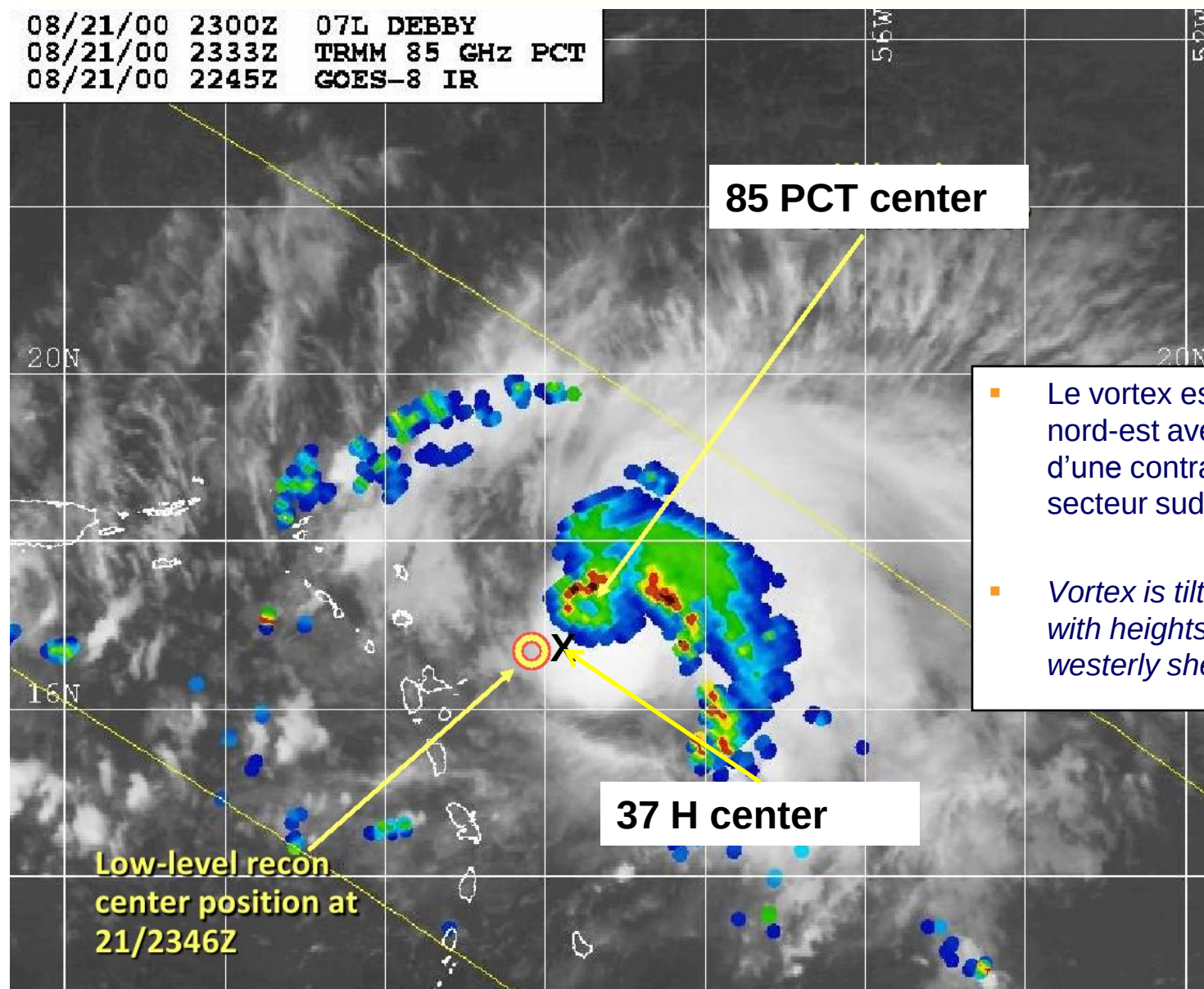
3D view of the inner core structure

08/21/00 2300Z 07L DEBBY
08/21/00 2333Z TRMM 37H
08/21/00 2245Z GOES-8 IR



3D view of the inner core structure

08/21/00 2300Z 07L DEBBY
08/21/00 2333Z TRMM 85 GHz PCT
08/21/00 2245Z GOES-8 IR



- Le vortex est incliné vers le nord-est avec l'altitude en raison d'une contrainte cisailée de secteur sud-ouest.
- Vortex is tilted north-eastwards with heights due to south-westerly shear*

http://www.nrlmry.navy.mil/tc_pages/tc_home.html

NOTE: this page is short lived (10 m). Please **DO NOT** bookmark it or save it to Favorites; instead, bookmark <http://www.nrlmry.navy.mil/TC.html> thank you.

2013 Season Storms

All **Active** Year

Atlantic

03L INVEST **WML**

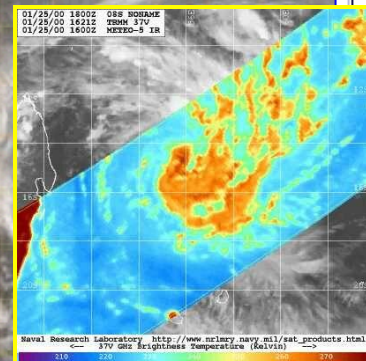
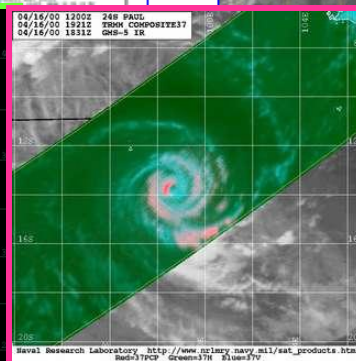
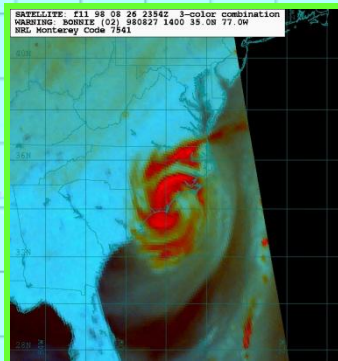
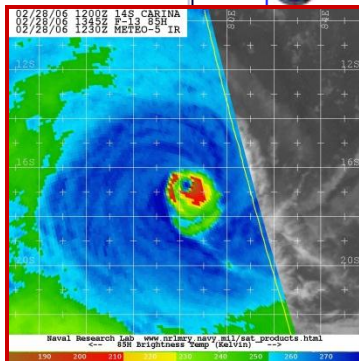
09L HUMBERTO **WML**

01

Environment TPW TPW+NAVGEM_TPW TPW+NAVGEM_850_Winds Wind_Shear Aerosol_Optical_Depth **COAMPS_TC**

Sensor	% Cov	VIS	IR	IR-BD	Multi Sens.	85 GHz H	85 GHz weak	85 GHz PCT	Color	Rain	Wind	37 GHz Color	37 GHz V	37 GHz H	SSM/I Vapor
SSM/I	52														
SSMIS	37														
TMI	26														
AMSR2	46														
WINDSAT	28														
AMSUB	100														

12.0715



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http://www.nrlmry.navy.mil/tc_pages/tc_home.html

Privacy Policy Disclaimer NRL Monterey Marine Meteorology Division (Code 7500) Tropical Cyclone Page (Ver.4.12.25) Development Team

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2006 Storms

All Active Year

Latest Previous

Pass_Mosaic Mosaic Animate

Text Track ATCF

Track&Image

Scatt

CloudSat

Environment

Total Precip. Water Vapor(TPW) TPW&NOGAPS_TPW TPW&NOGAPS_850_Winds Wind_Shear

09L HUMBERTO

07:51:47 UTC (Z)

Previous | Shift time 24 hrs/click: 130911.0724 <-> 130912.0548 |

Age <= 6 hrs. From 20130912.0548

SSM/I E15 AMSR2 GCOMW1 AMSU-B N19

20130912.0548 52 % 20130912.0387 46 % 20130912.0352 100 %

Age 6-12 hrs. From 20130912.0548

SSM/I OCEANSAT-2 AMSU-B MKT01A

20130912.0050 Bytes 20130911.2282 81 %

Age > 12 hrs. From 20130912.0548

SSM/I E16 AMSU-B N18 SSM/I E15 AMSU-B N19 SSM/I OCEANSAT-2

20130911.1907 68 % 20130911.1745 74 % 20130911.1715 61 % 20130911.1517 99 % 20130911.1254 Bytes

AMSU-B MKT01A SSM/I E14 CEROLS SSM/I E17

20130911.1143 99 % 20130911.0951 63 % 20130911.0728 20 % 20130911.0724 53 %

85GHz PCT Color Rain Wind 37GHz Color 37GHz 37GHz SSM/I

<= 6 hrs. old

VIS. 29 OCT 2006 0530Z

Heat (View All)

2249 Z, F-13 0663

0000 Z, F-16 0054

0539 Z, TRMM 0097

1632 Z, AQUA 1421

0925 Z, WIND 0014

22W.CIMARON Completed Passes

Date	Time (Z)	Sat	CPA (km)
2006/10/28	06:17:45	N-16	1203
2006/10/28	06:34:49	TRMM	448
2006/10/28	07:58:12	N-16	1450
2006/10/28	08:01:02	N-15	1667
2006/10/28	09:27:13	F-14	44
2006/10/28	09:40:34	N-15	957
2006/10/28	09:43:00	QUIK	264
2006/10/28	09:43:24	WIND	477
2006/10/28	10:15:23	F-13	294
2006/10/28	11:13:37	F-15	643
2006/10/28	11:25:14	F-16	448
2006/10/28	13:19:31	N-17	780
2006/10/28	13:44:10	TERRA	461
2006/10/28	14:12:09	ERS2	314
2006/10/28	14:47:01	TRMM	115
2006/10/28	14:59:21	N-17	1869
2006/10/28	16:32:31	AQUA	1421
2006/10/28	16:42:44	N-18	1332
2006/10/28	18:10:03	AQUA	1162
2006/10/28	18:23:17	N-18	1325
2006/10/28	18:53:14	N-16	828
2006/10/28	20:30:03	N-15	1434
2006/10/28	20:33:30	N-16	1806
2006/10/28	20:49:06	QUIK	1159
2006/10/28	22:01:25	F-14	430
2006/10/28	22:09:44	N-15	1203
2006/10/28	22:16:00	WIND	805
2006/10/28	22:28:38	QUIK	1474

Vapor

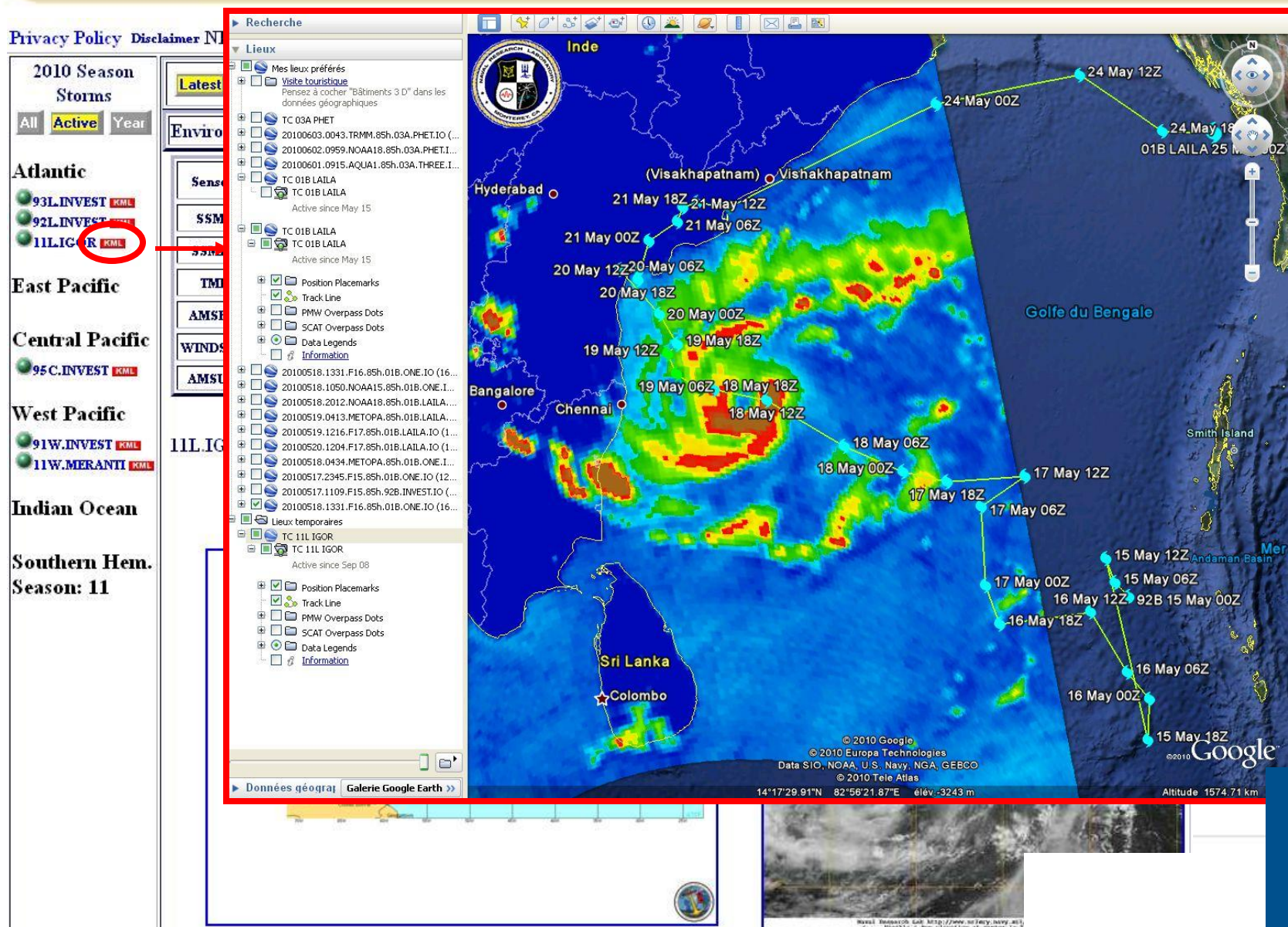
1km_zoom/20061029.0530

CIMARON 5 VIS

EOCE

AMSUB	10/29 0536 Z, H-18	0637	10/29 0606 Z, H-16	1509
SCATT	10/28 2232 Z, SCAT_FHMO	1474	10/29 0917 Z, QUIK	0951

http://www.nrImry.navy.mil/tc_pages/tc_home.html

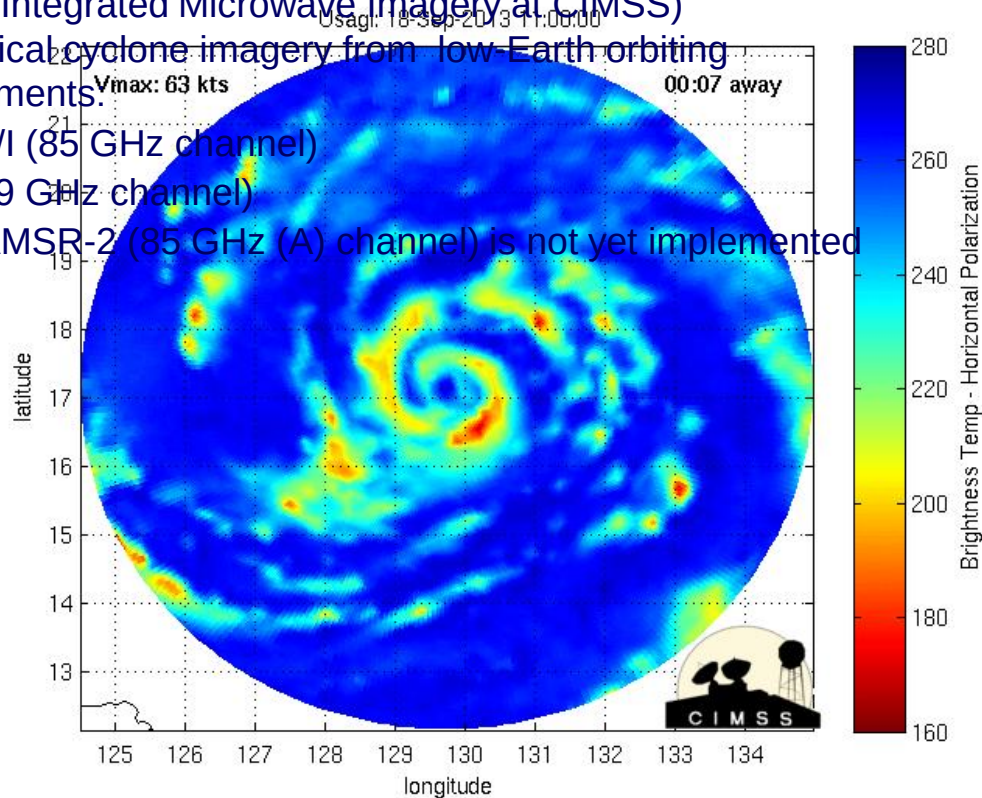


<http://tropic.ssec.wisc.edu/real-time/mimic-tc/tc.shtml>

MIMIC creates a morphed image animated sequence with 15 minute time steps (image frames).

Morphed Integrated Microwave Imagery at CIMSS
(MIMIC)
Version 1

- The MIMIC (Morphed Integrated Microwave Imagery at CIMSS) is a synthetic blend of tropical cyclone imagery from low-Earth orbiting satellite micro-wave instruments.
 - the DMSP- SSM/I (85 GHz channel)
 - the GPM-GMI (89 GHz channel)
 - the GCOM-W1 AMSR-2 (85 GHz (A) channel) is not yet implemented

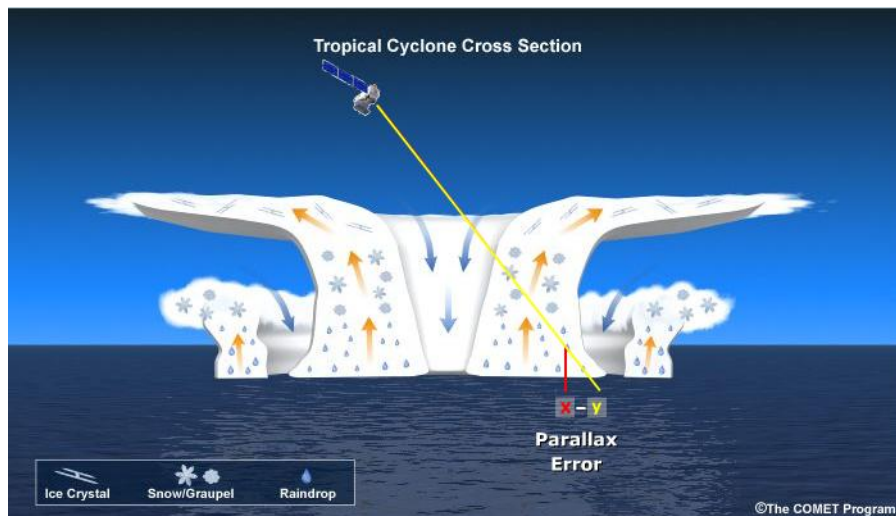
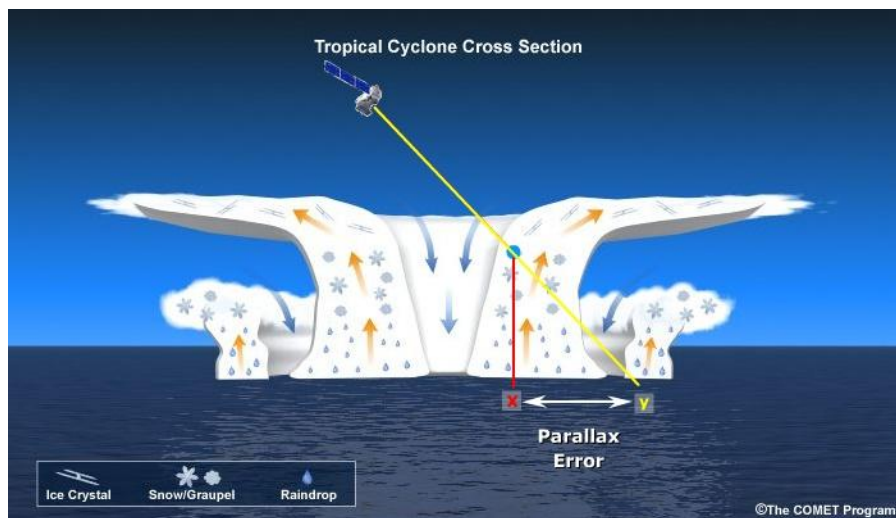


[- Return to main storm menu -](#)

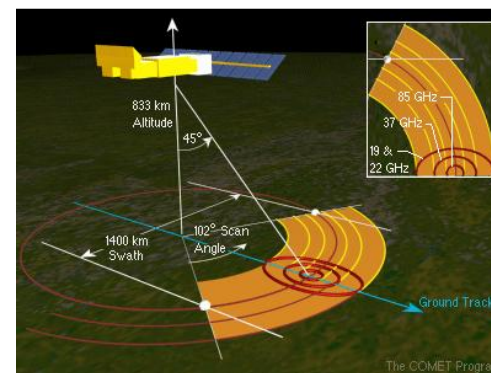


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Characteristics of microwave imagery at 37 and 85 GHz



- Dû aux erreurs de parallaxe et au type de scan (scan conique), centres des systèmes paraissent décalés de leur position réelle
- 37 GHz capte précipitations à des niveaux plus bas : erreur de parallaxe moindre



- *Storm centers appear displaced from their true positions due to the parallax errors.*
- *37 GHz imagery senses precipitation at lower levels resulting in smaller parallax errors*



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