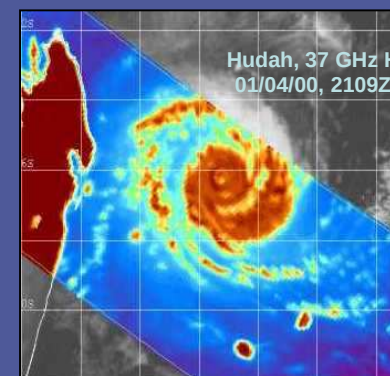
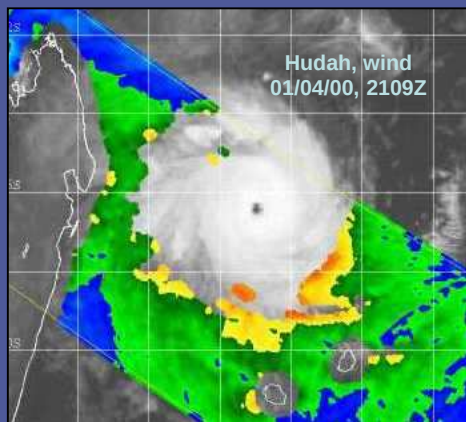
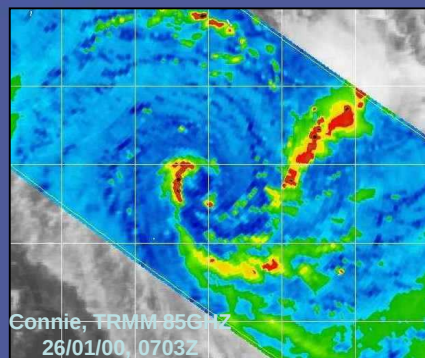




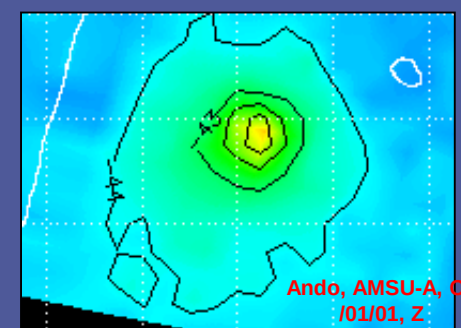
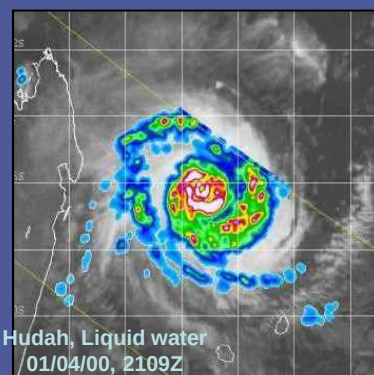
Satellite technology

Applications to tropical cyclones

7th training course about tropical cyclones

WMO / Météo-France

September 2015



Anne-Claire FONTAN
Thierry DUPONT
Sébastien LANGLADE
METEO-FRANCE



METEO FRANCE
Toujours un temps d'avance

Outline

- 1. *Synopsis on microwaves***
- 2. *SSMI, SSMI(S), GMI, AMSR2, Windsat ,AMSU-B sensors***
- 3. *TC Intensity estimate: objective guidances***
- 4. *Scatterometers***
- 5. *Cloud drift winds***

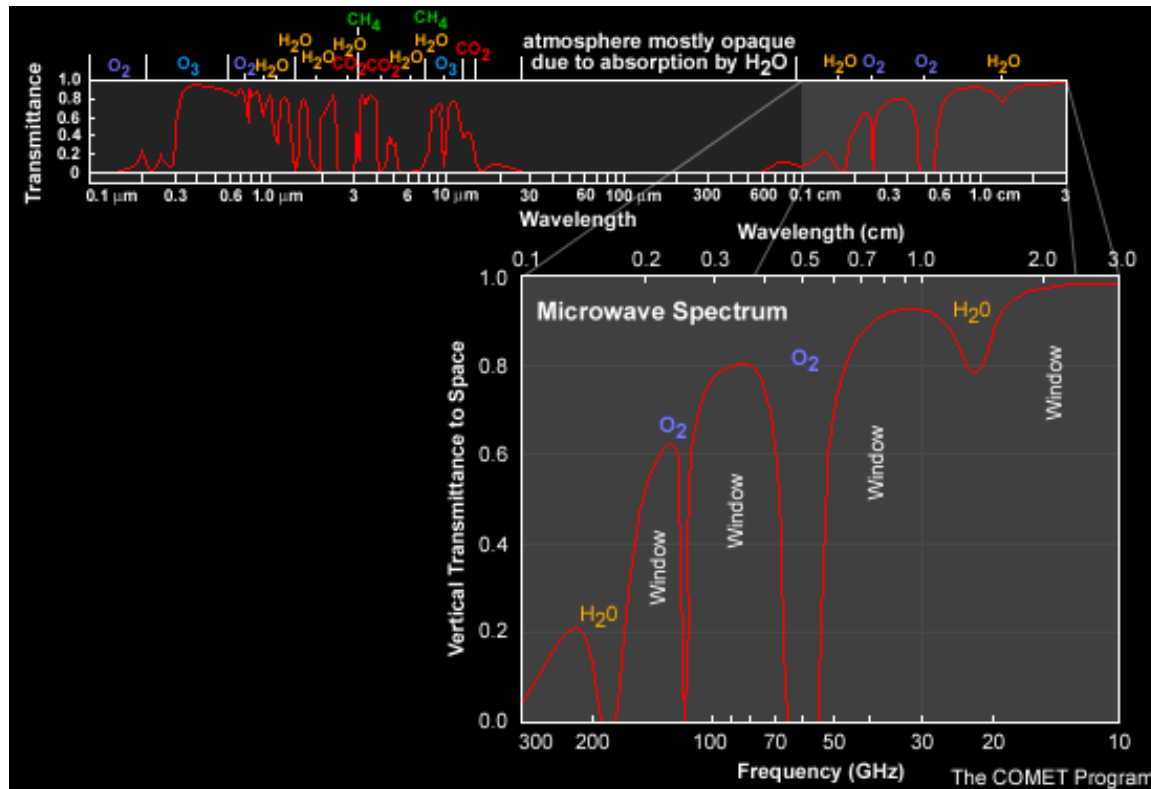


Outline

1. **Synopsis on microwaves**
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Microwave Spectrum



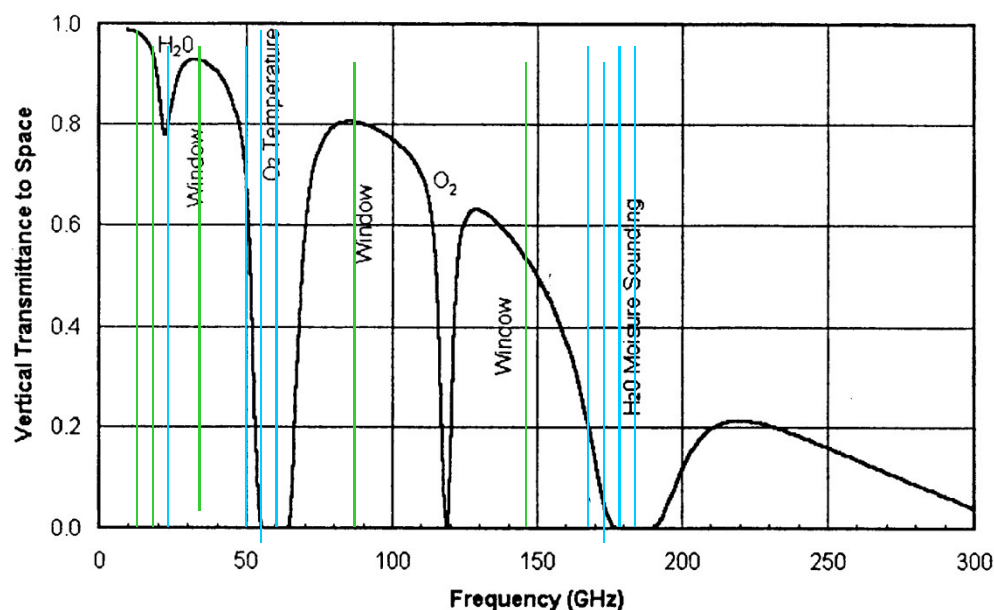
- Petite part du rayonnement émise aux fréquences micro-ondes (10 - 300 GHz) millimétriques et sous-millimétriques.
- Radiomètres micro-ondes embarqués sur les satellites à défilement.
- Mesurent généralement plusieurs fréquences dans le domaine.

- *Small proportion of thermal radiation at microwave frequencies (10 - 300 GHz)*
- *Microwave radiometers on polar-orbiting satellites.*
- *Usually measure several frequencies within the range.*



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Toujours un temps d'avance

Microwave channel selection



■ Canaux "imageurs"

- utilisent les canaux de la fenêtre de transmission
- sont destinés à observer la surface, les nuages et la pluie, etc.
- mesurent souvent la polarisation.

■ Imaging channels

- Generally use window channels
- Aim to observe surface, clouds, rain, etc
- Often measure polarization

■ Canaux "sondeurs"

- canaux situés en bordure des bandes principales d'absorption
- détectent le rayonnement de l'air ou de la vapeur d'eau
- sont destinés à produire des profils verticaux de température, d'humidité etc...
- ne mesurent pas la polarisation

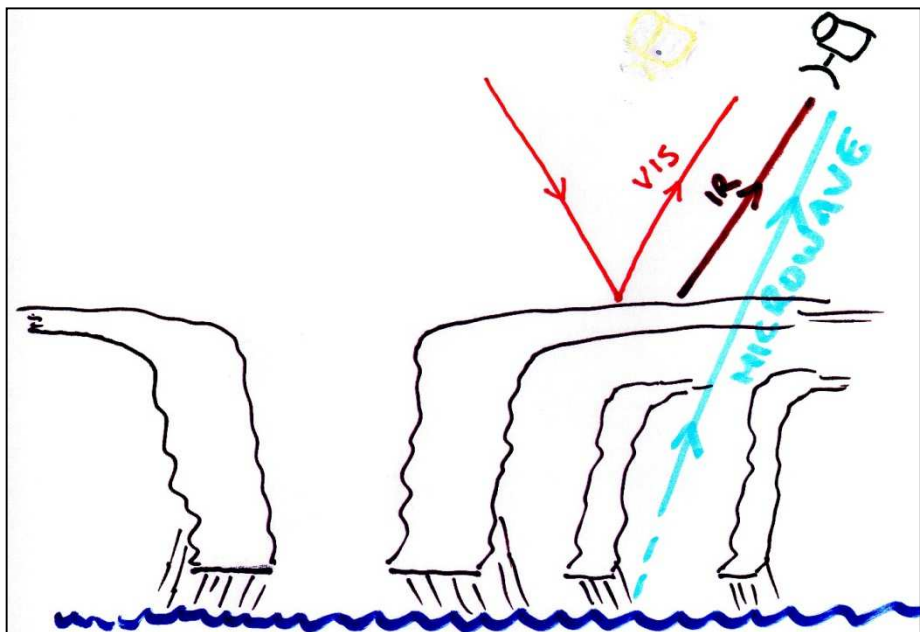
■ Sounding channels

- Closely spaced channels on edge of major absorption band.
- Detect radiation from air or water vapour.
- Aim to produce vertical profiles of temperature, moisture, etc
- Usually don't measure polarization.



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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 (Can be better to look at combinations of several channels - i.e. "products")

- **Need to consider all data.**

- **Avantages**

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

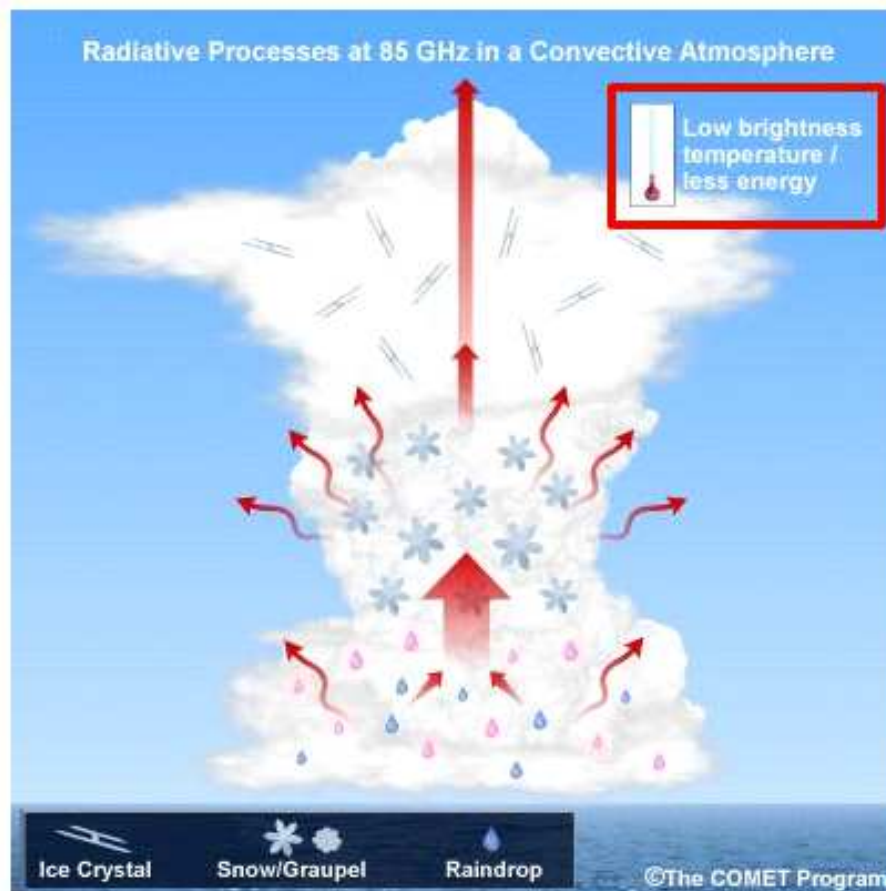
- **Inconvénients**

- 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 parfois complexe



METEO FRANCE
Toujours un temps d'avance

Radiative Processes at 85 GHz



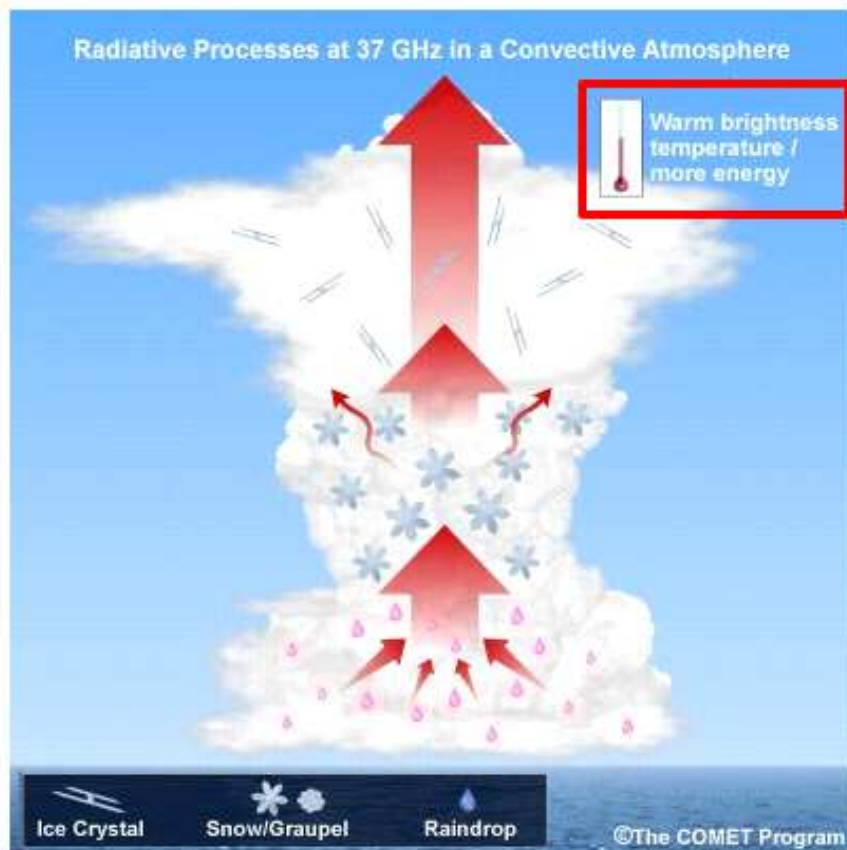
- **85 Ghz. Energie radiative :**
 - absorbée, réémise ou diffusée par les gouttes d'eau
 - Diffusée ensuite par les particules de glace
 - Peu d'effet des cirrus
- Peu d'énergie parvient au sommet
- **DONC :** températures de brillance très basses captées au dessus de la convection profonde à 85 GHz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

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



METEO FRANCE
Toujours un temps d'avance

Radiative processes at 37 Ghz



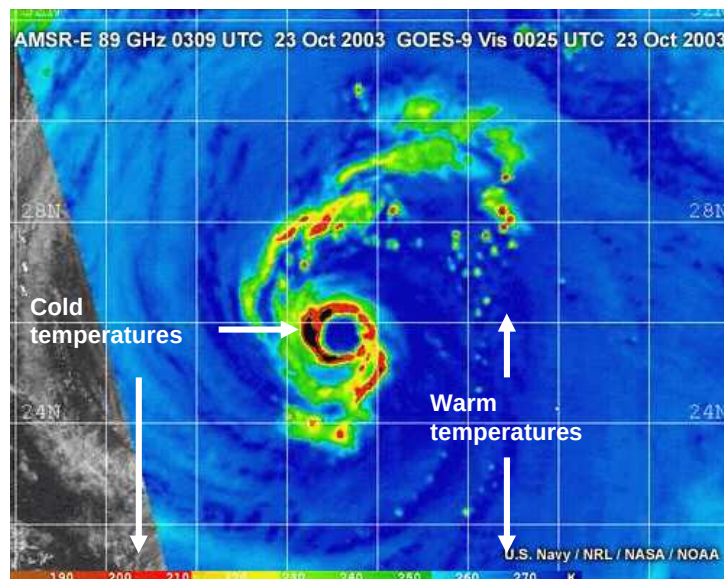
- **A 37 GHz : énergie**
 - absorbée par l'eau de pluie
 - Ré-émise par l'eau de pluie vers le le niveau supérieur
 - Peu diffusée par les particules de glace précipitantes
 - Pas d'effet des cirrus
- **Energie abondante parvient au satellite**
- **DONC : hautes températures de brillance captées au sommet**
- **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

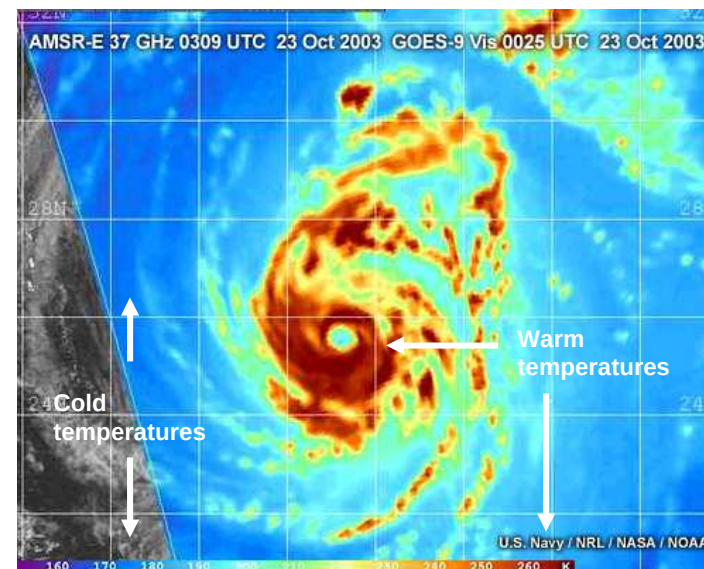


METEO FRANCE
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Imagery examples at 37 and 85 Ghz



- AMSRE 89 Ghz
 - Palette de couleur inversée
- 37 Ghz
 - Palette de couleur standard
- Ce sont les mêmes précipitations sur les 2 images mais le mécanisme de détection est différent
 - 89 montre les particules de glace en altitude
 - 37 montre les précipitations liquides sous l'iso-0°
- Images à (ou proche) de 85 GHz sont devenues des standards pour l'interprétation
 - meilleure résolution spatiale
 - montrent bien la convection profonde froide.
- Mais les 37 Ghz ont aussi de nombreux avantages que nous verrons plus tard.



- AMSRE 89 GHz
 - reversed color table
- 37 GHz
 - standard color table
- *It is precipitation in both instances, but the primary mechanism for sensing the precipitation is different.*
 - 89 GHz shows it as ice precipitation high in the storm system
 - 37 GHz shows the precipitation once it becomes more liquid below the freezing level.
- *Images based on frequencies at or near 85 GHz have become the standard for interpretation*
 - higher spatial resolution
 - show deep, cold convection well.
- *However, images from the 37 GHz channel have a number of advantages which we will discuss.*

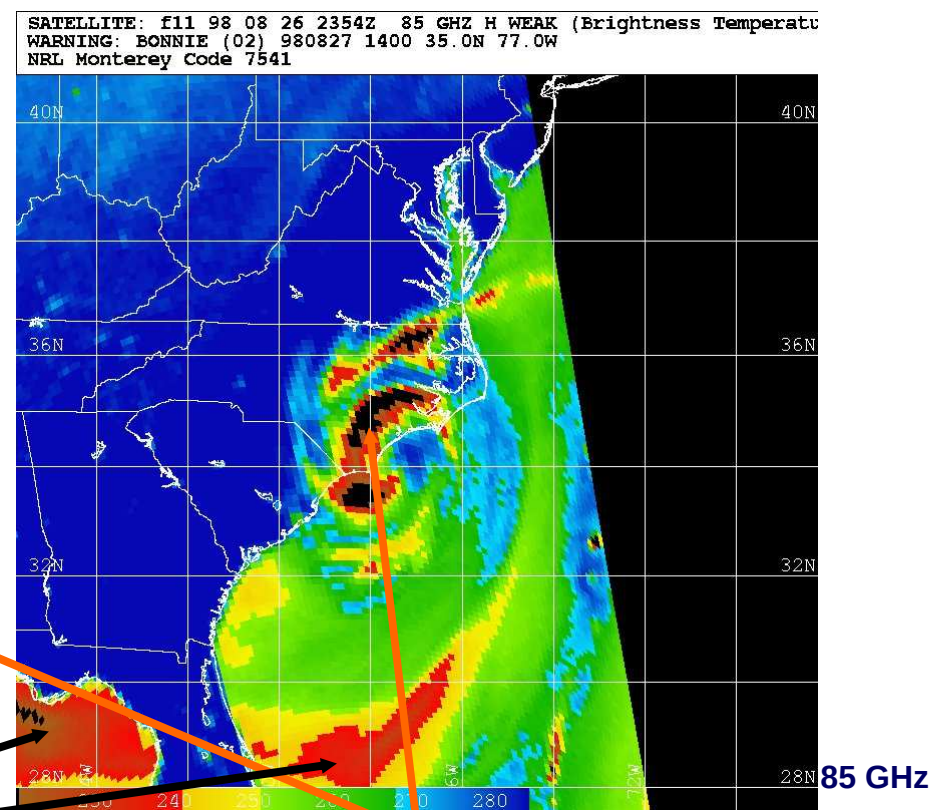
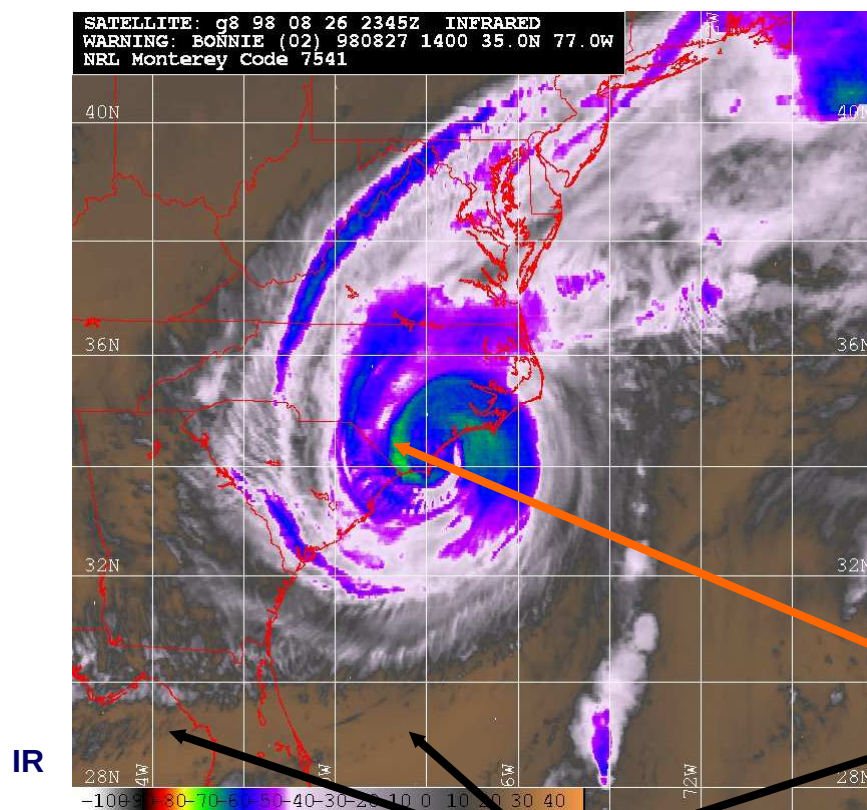
Outline

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SSMI(S) / GMI / AMSR-2 – 85 à 91 GHz

Interpretation issues



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.

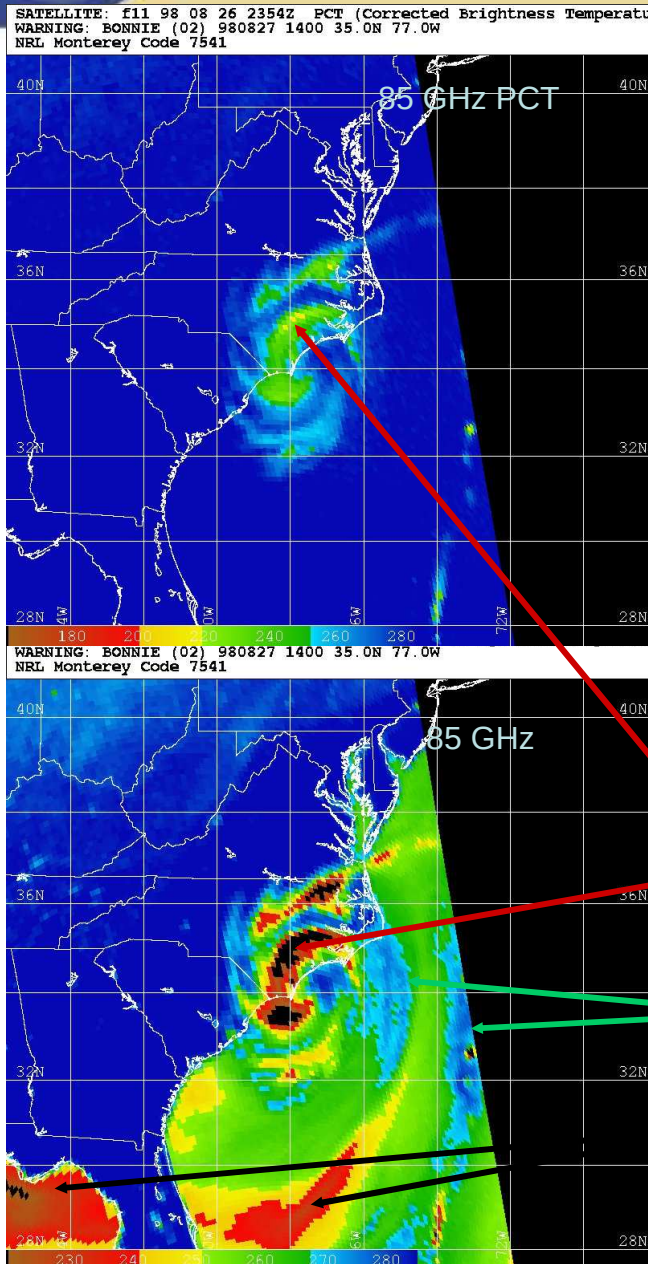
Images: NRL



METEO FRANCE
Toujours un temps d'avance

SSMI(S) / GMI / AMSR-2 - Derived products

85 à 91 GHz PCT



- 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).*

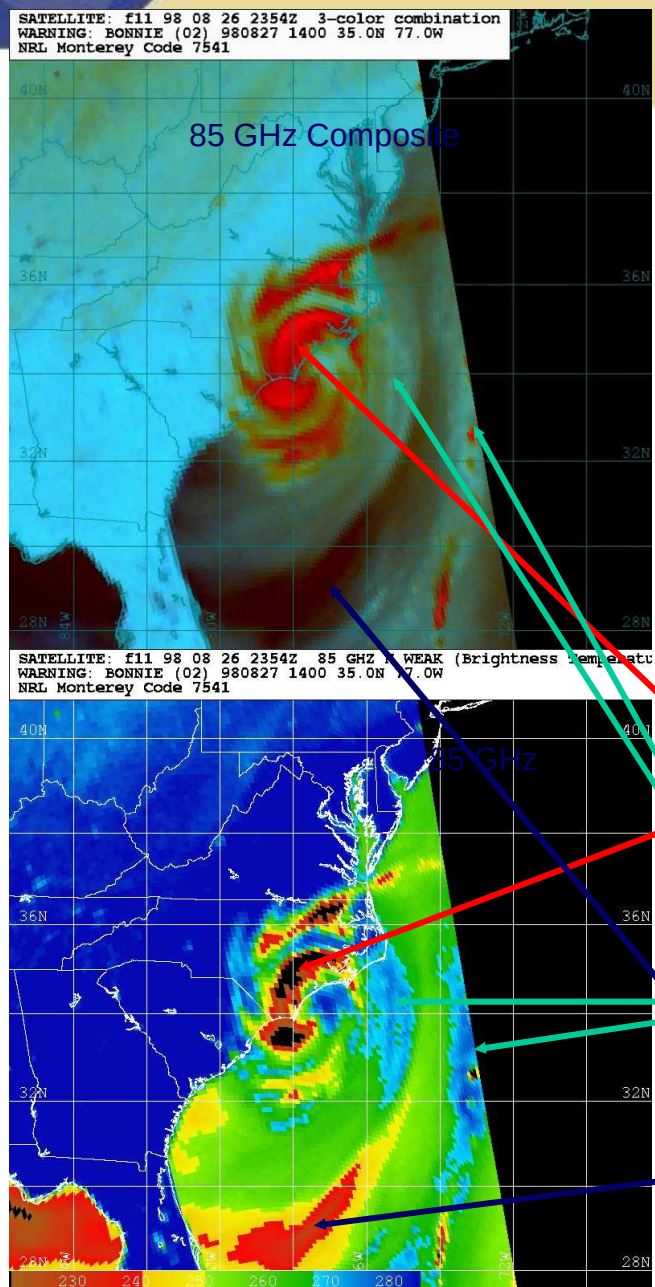
Eyewall convection appears cold on both images

Weak rainbands are washed out on PCT image

Dry air over sea not visible on PCT image

Images: NRL

SSMI(S) / GMI / AMSR-2 - Derived Products 85 à 91 GHz Color Composite



- Image PCT distingue l'air sec de la convection profonde.
- Mais il perd des détails des bandes nuageuses de basses couches.
- Image composite montre le PCT en rouge et les 85 GHz en bleu-vert.
- *PCT image distinguished between dry air and deep convection.*
- *But it lost details of low level cloud bands.*
- *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.

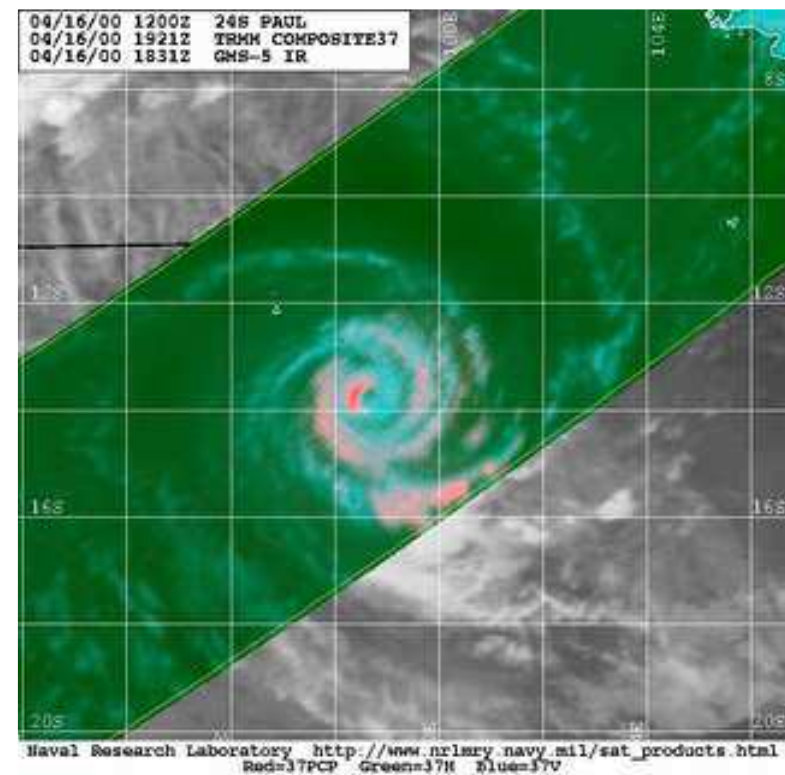
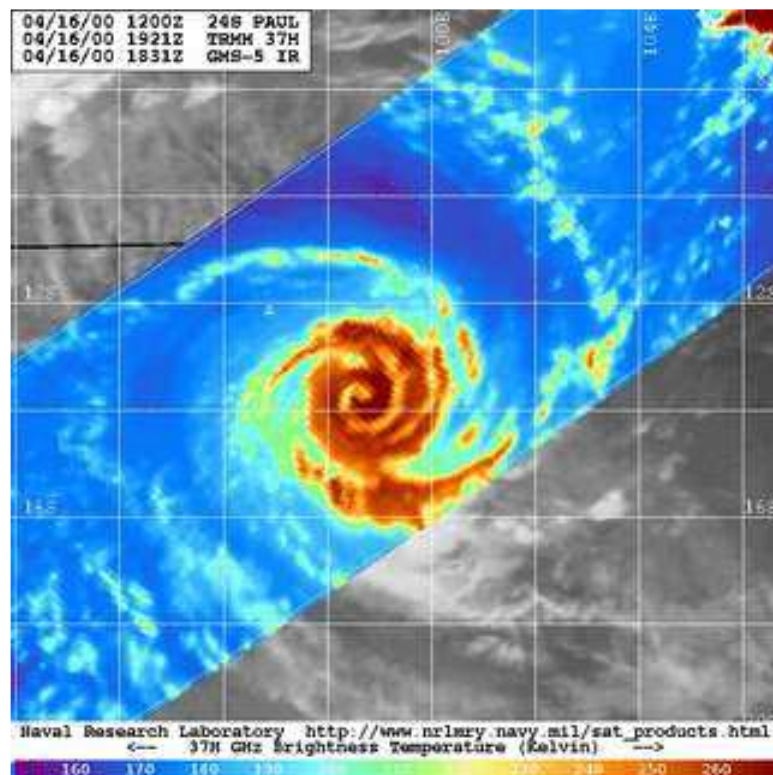
Dry air over sea near-black on composite image.



METEO FRANCE
Toujours un temps d'avance

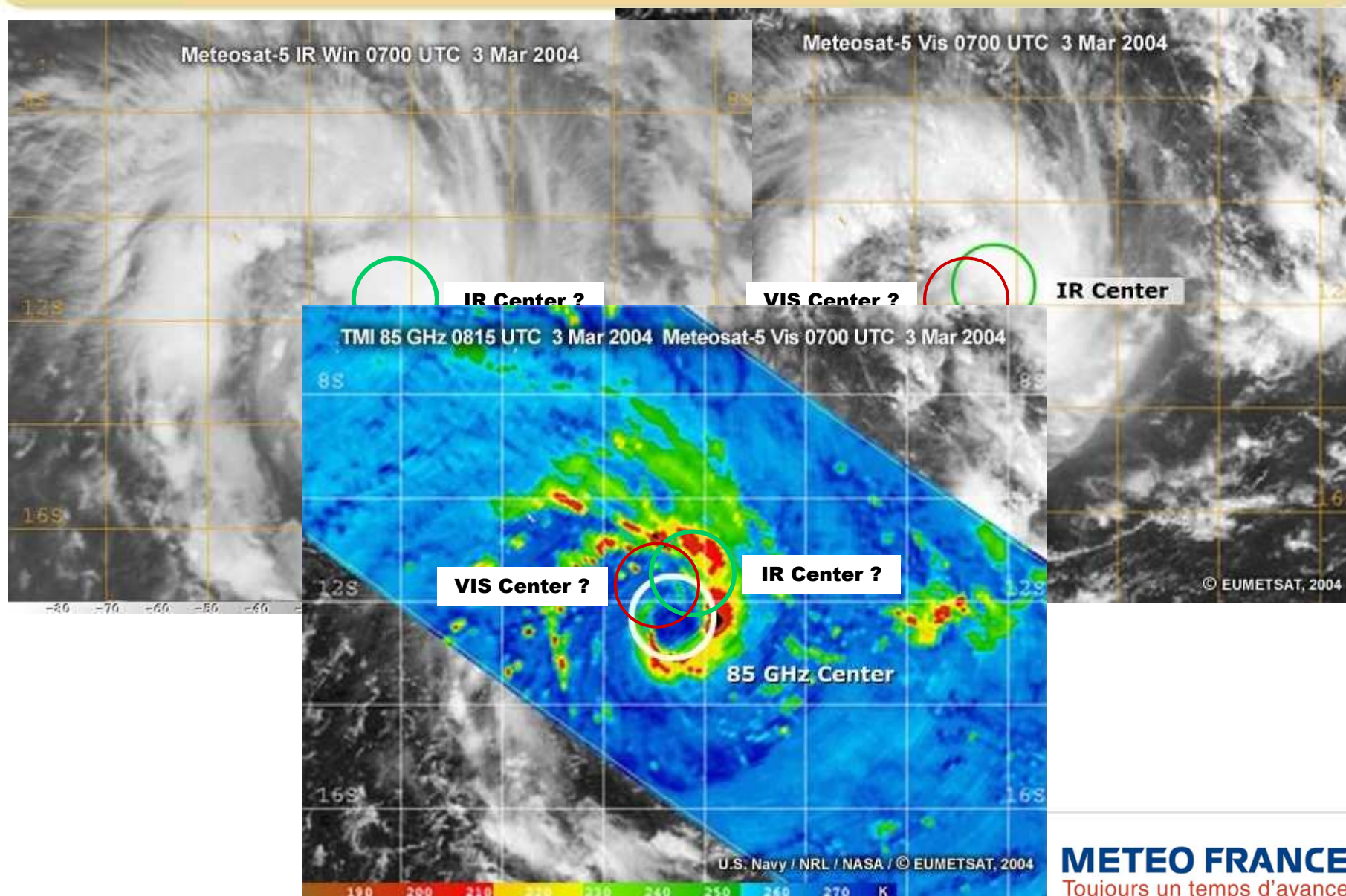
SSMI(S) / GMI / AMSR-2 / Windsat - *Derived Products - 37 color*

- Même conception que pour le " 85 Color " : " 37 color " associe la PCT au rouge, la 37GHz-V au vert, et la 37 GHz-H au bleu.
 - On a donc la surface de la mer en vert, les nuages stratiformes en cyan et la convection profonde en rose
- Same as "85 color"; "37 color associates PCT to red, 37 GHz-V to green, and 37GHz-H to blue.
 - Sea surface in green, stratiform clouds in cyan and deep convection in pink.



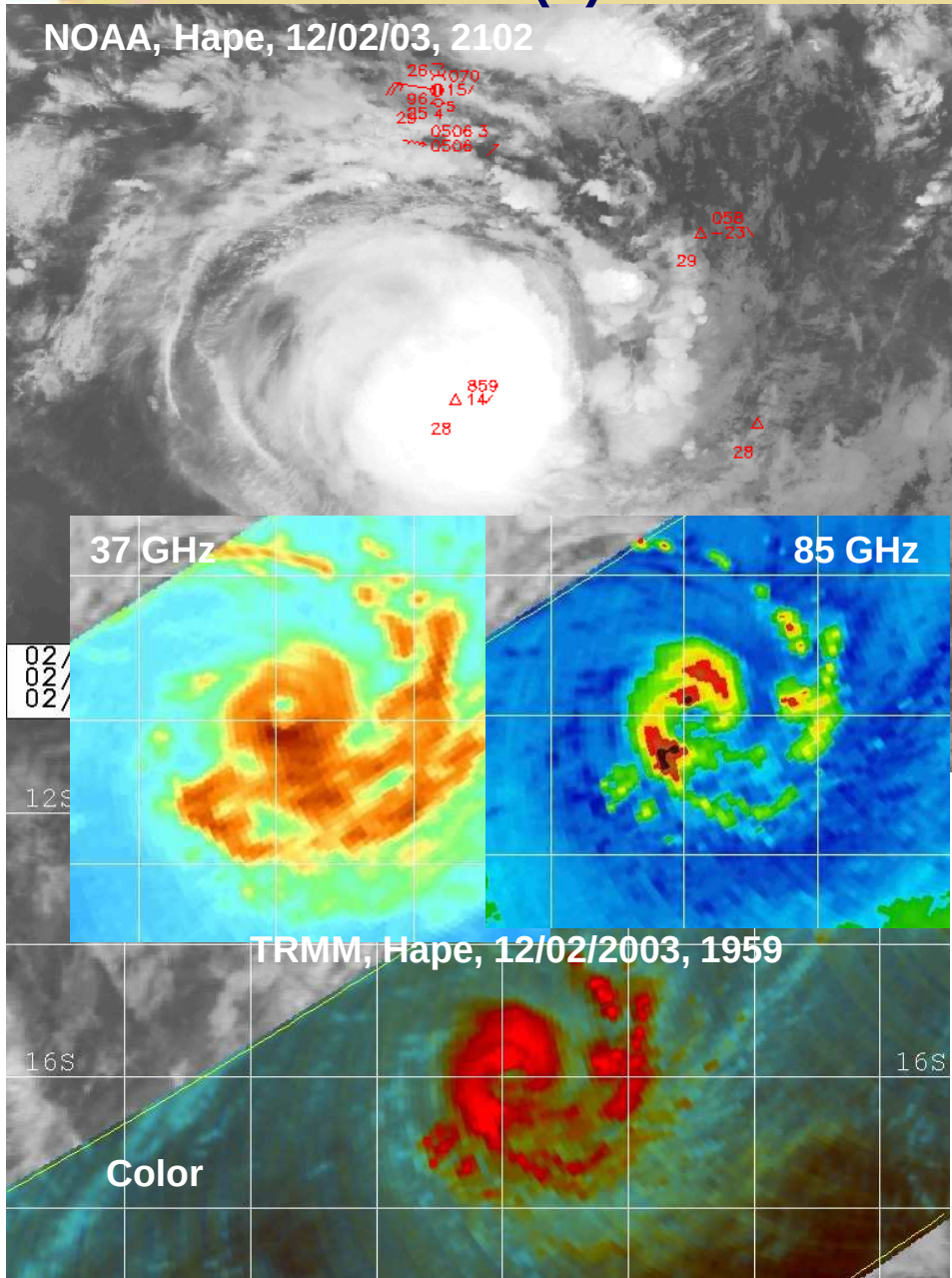
Images: NRL

SSMI(S) / GMI / AMSR-2 – 85 à 91 GHz vs IR and VIS (1)



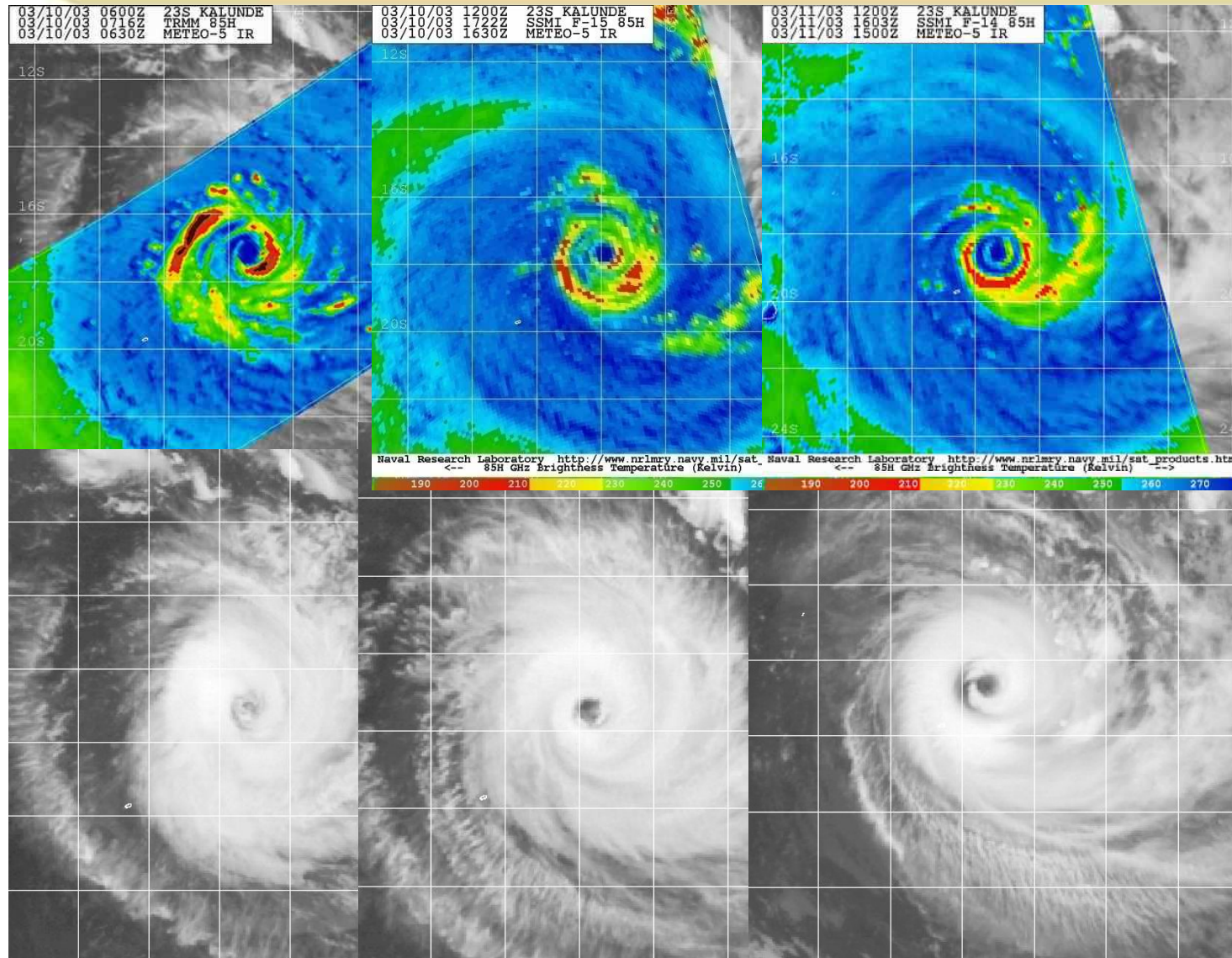
SSMI(S) / GMI / AMSR-2 – 85 à 91 GHz vs IR (2)

NOAA, Hape, 12/02/03, 2102



- **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

SSMI(S) / GMI / AMSR-2 – 85 à 91 GHz vs IR (3)



- **85 GHz**
 - Enroulement des bandes de pluie
 - Cycle de l'œil
- **IR**
 - Presque aucun détail de visible

- **85 GHz**
 - Rainband starts to wrap up.
 - Concentric eyewall cycle
- **IR**
 - Almost no detail visible.

10/03/03, 0716

10/03/03, 1122

11/03/03, 1603



METEO FRANCE
Toujours un temps d'avance

Images: NRL

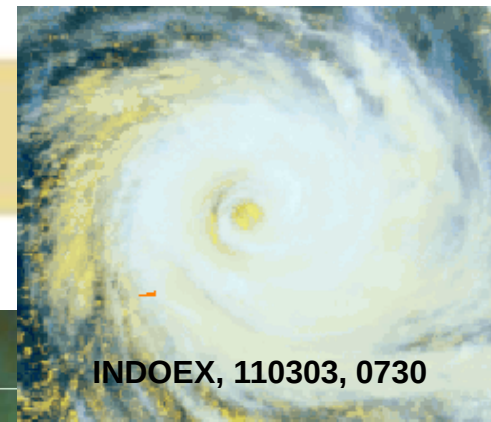
SSMI (S) / GMI / AMSR-2 -
Derived Products
85 à 91 GHz Color Composite

Eye cycle

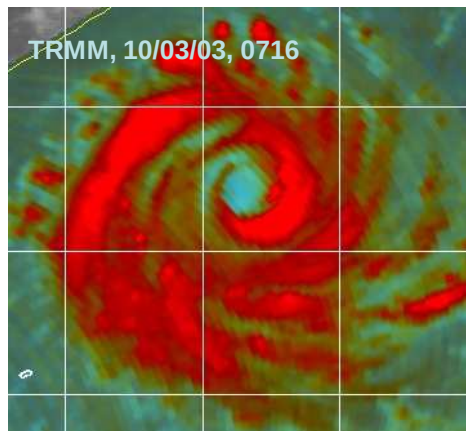
Noaa 16, 10/03/03, 2113



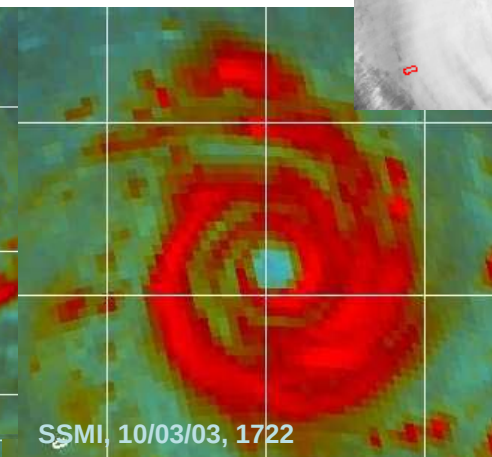
INDOEX, 110303, 0730



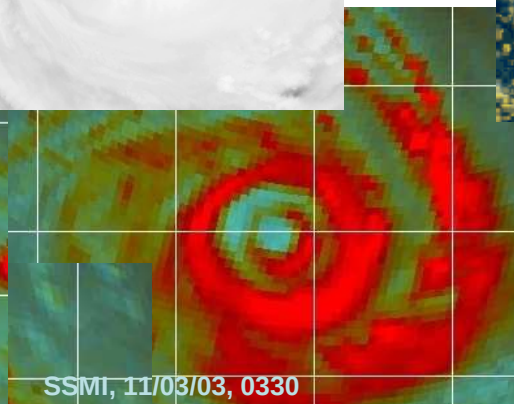
TRMM, 10/03/03, 0716



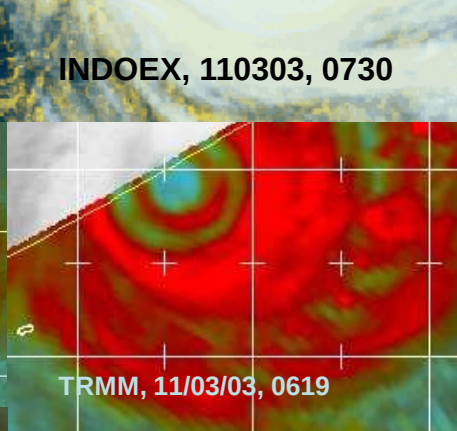
SSMI, 10/03/03, 1722



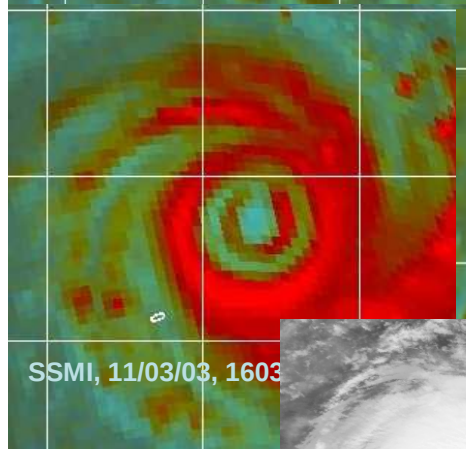
SSMI, 11/03/03, 0330



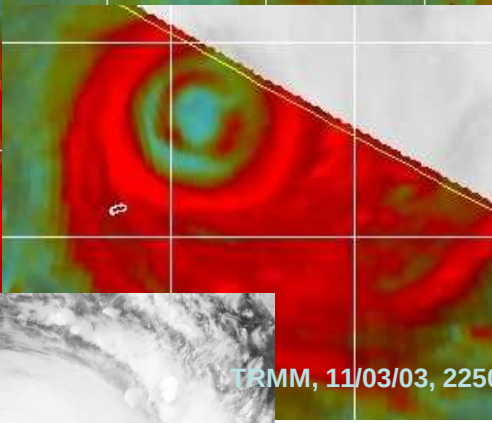
TRMM, 11/03/03, 0619



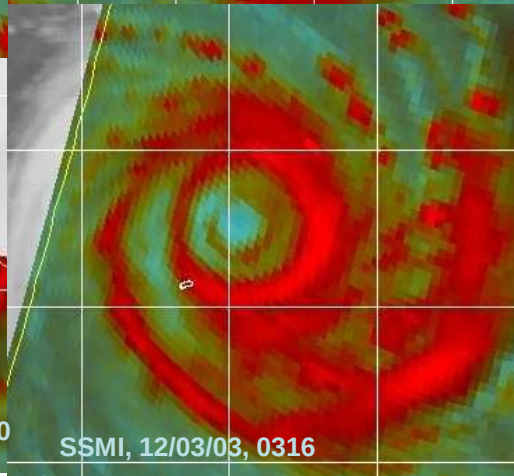
SSMI, 11/03/03, 1603



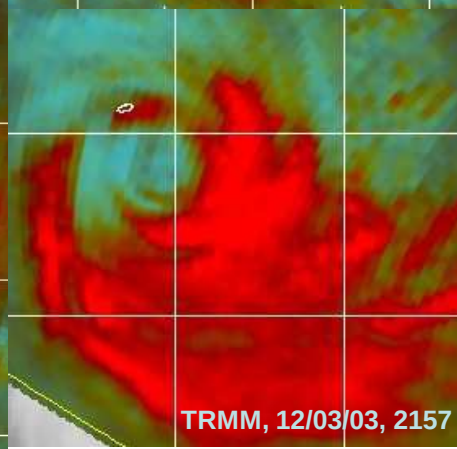
TRMM, 11/03/03, 2250



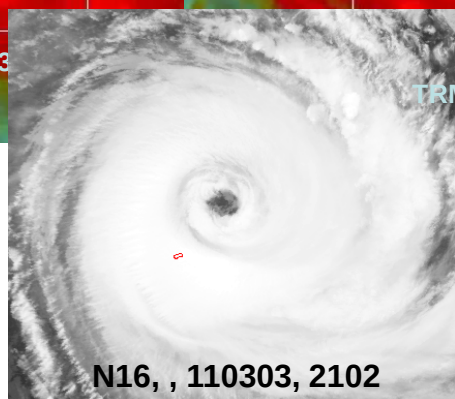
SSMI, 12/03/03, 0316



TRMM, 12/03/03, 2157



Images: NRL



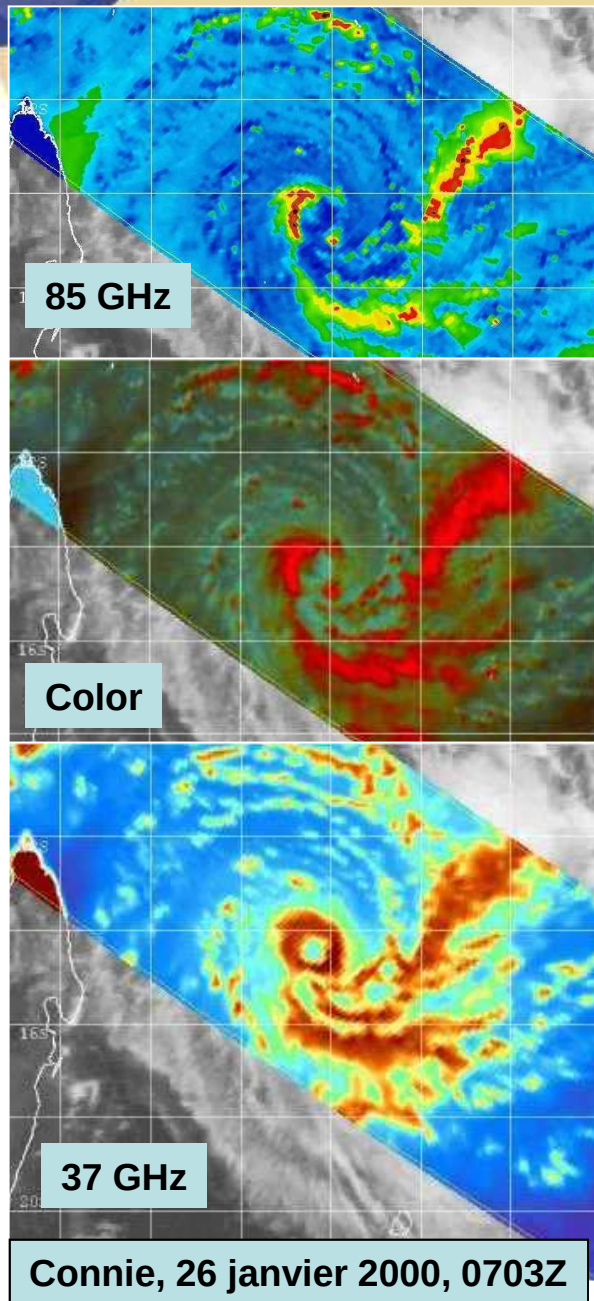
N16, , 110303, 2102

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



METEO FRANCE
Toujours un temps d'avance

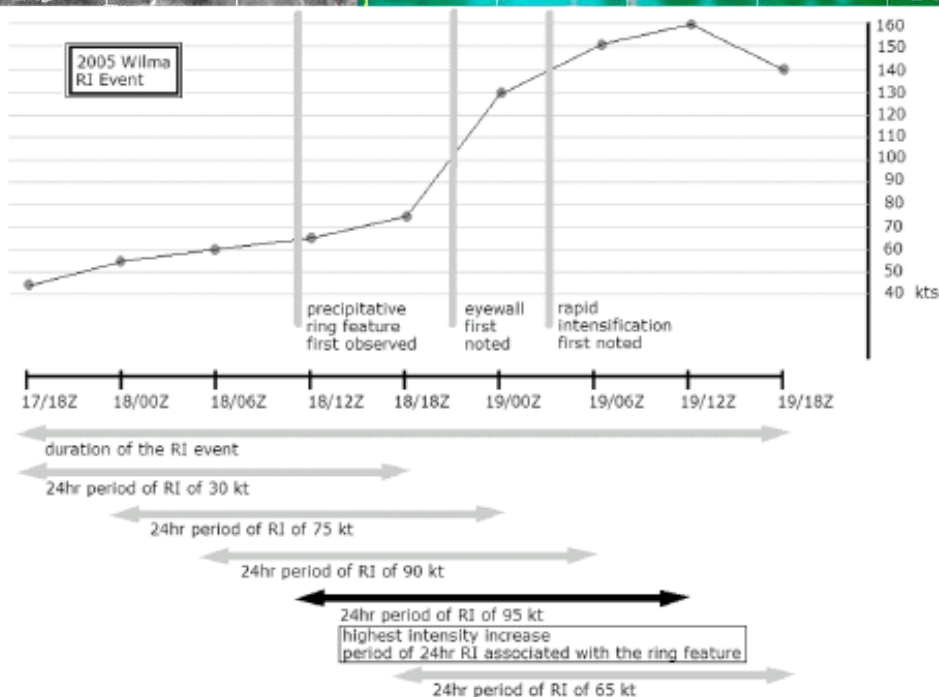
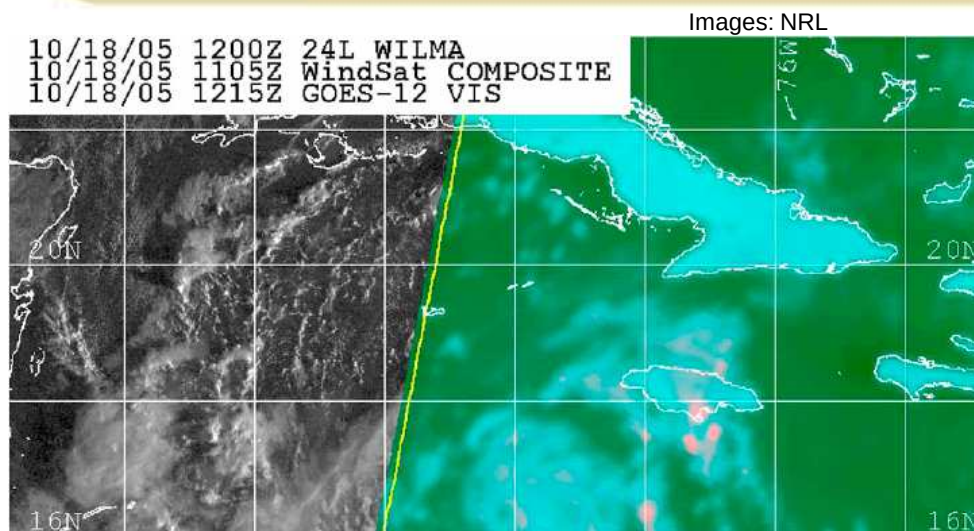
SSMI(S) / GMI / AMSR-2 / Windsat - 31 à 37 GHz vs 85 à 91 GHz



- 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

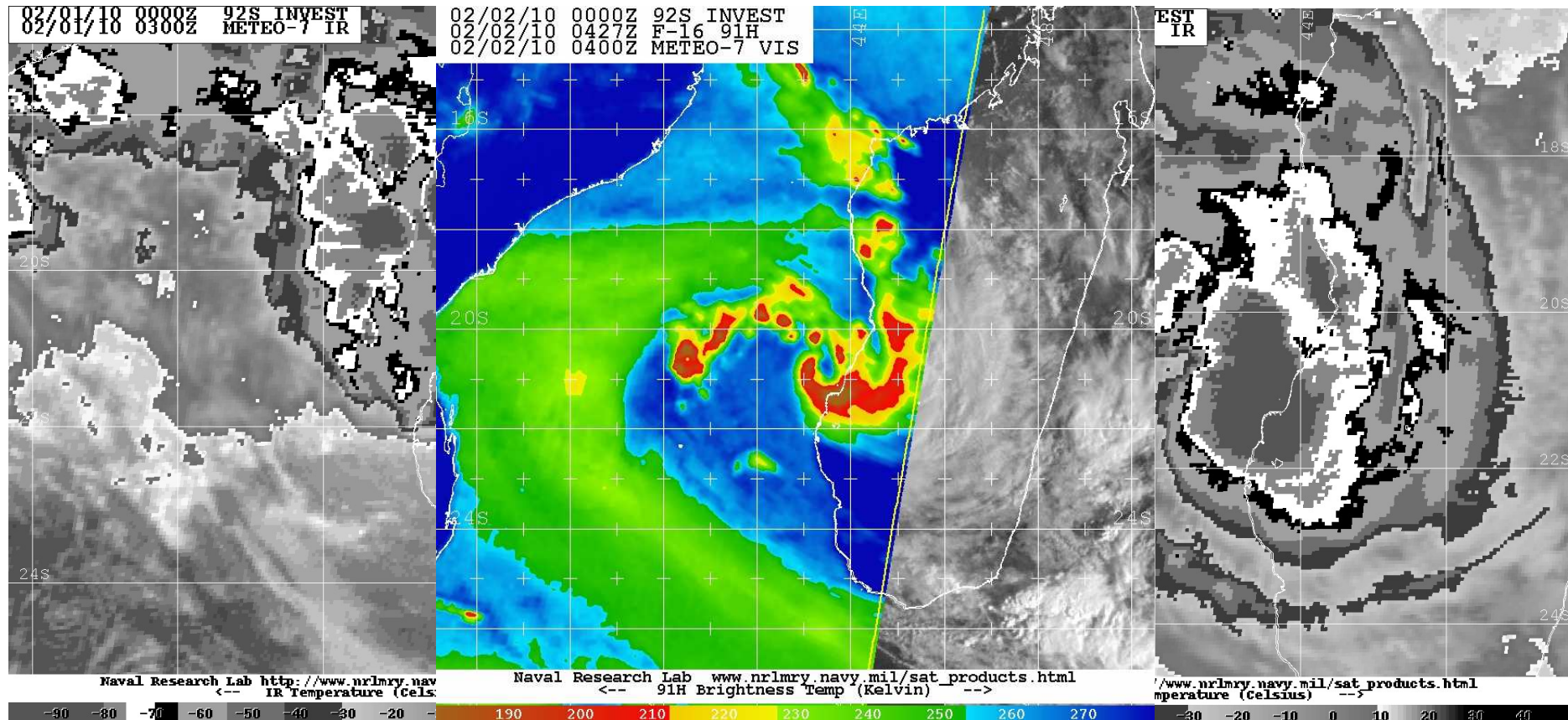
SSMI(S) / GMI / AMSR-2 / Windsat - 31 à 37 GHz vs 85 à 91 GHz



- 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.

SSMI(S) / GMI / AMSR-2 / Windsat - *A decisive element for intensity estimate*

Images: NRL

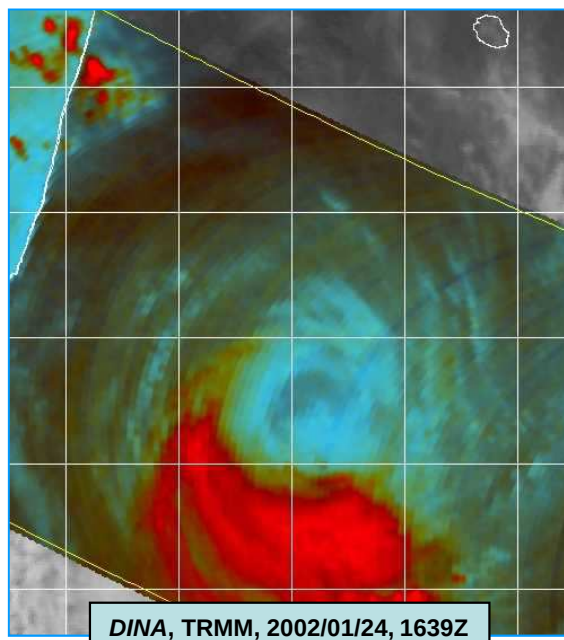
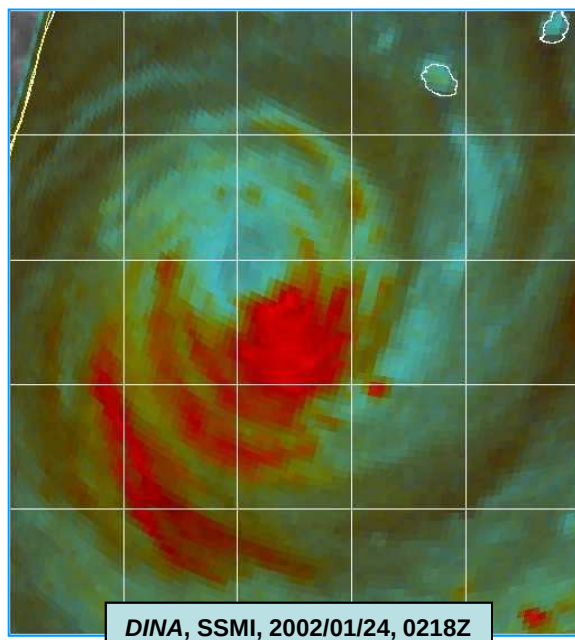
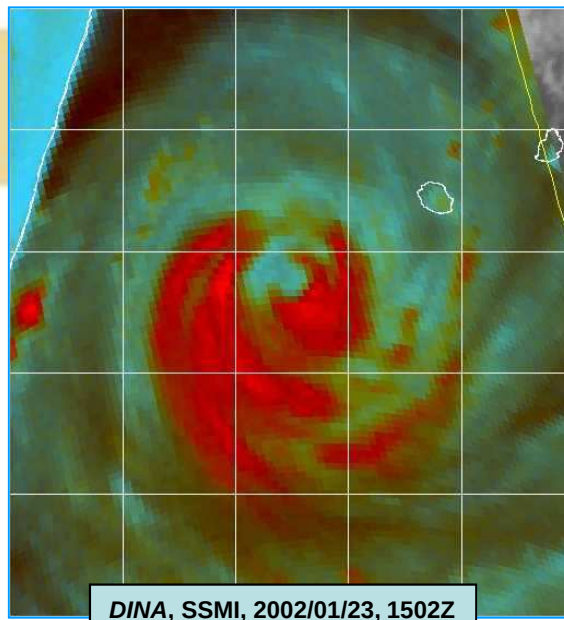
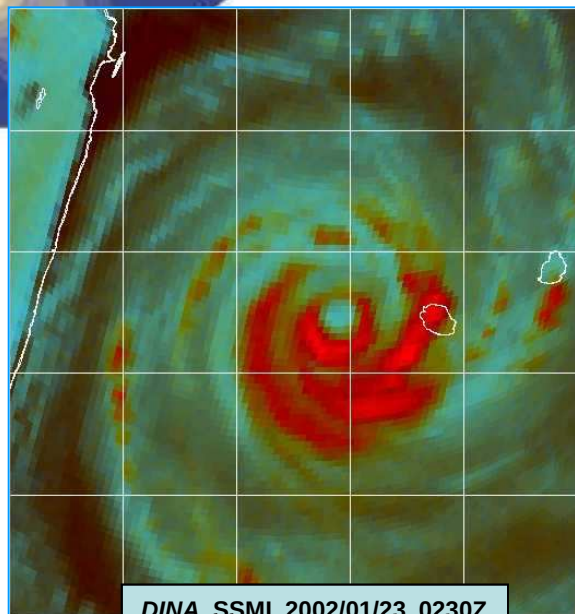


FAMI (02/2009):

- 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)

SSMI / GMI / AMSR-2 - Derived Products 85 à 91 GHz Color Composite

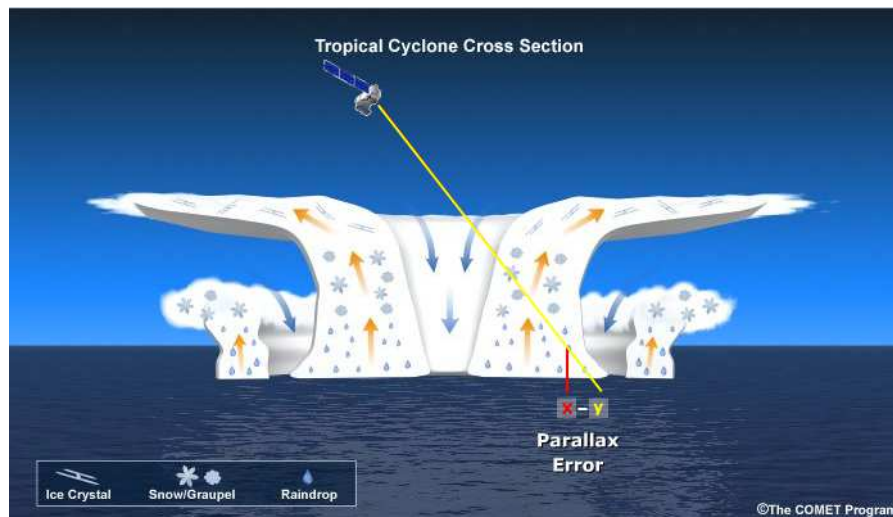
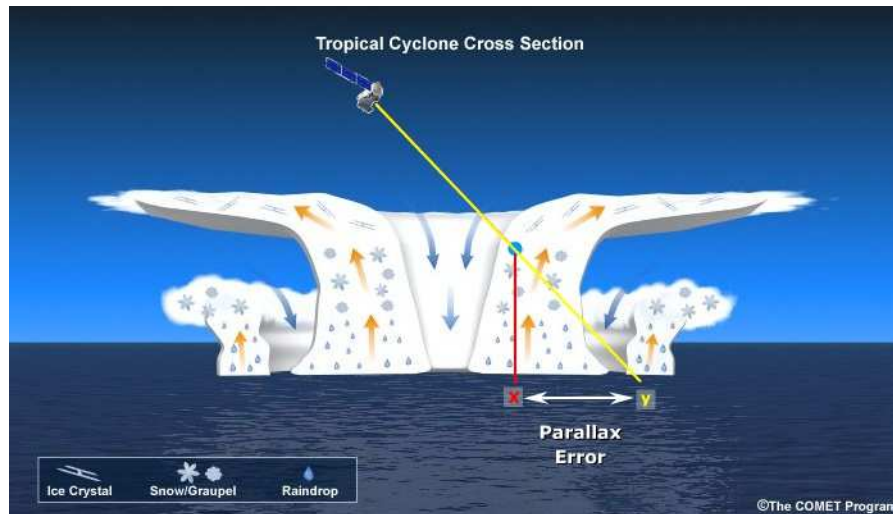
- Meilleure localisation des centres de basses couches des systèmes lors du stade initial de cisaillement
- Bonne visualisation des changements de structure



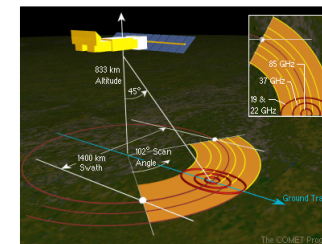
- *Better location of LLCC for systems during initial shearing stage*
- *Better vision of structure changes*

Source : NRL Monterey

Characteristics of microwave imagery at 37 and 85 GHz

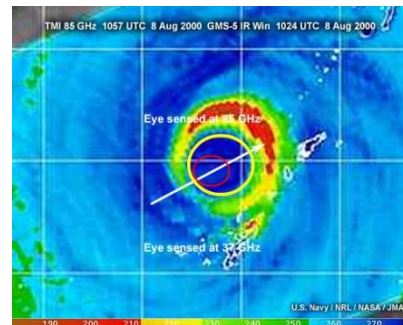


- Dû aux erreurs de parallaxe, centres des systèmes paraissent décalés de leur position réelle
- 37 GHz capte précipitations à des niveaux plus bas : erreur de parallaxe moindre

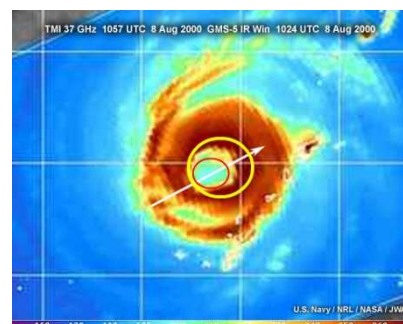


- *Storm centers appear displaced from their true positions due to the parallax errors.*
- *37 GHz imagery senses precipitation at lower levels resulting in smaller parallax errors*

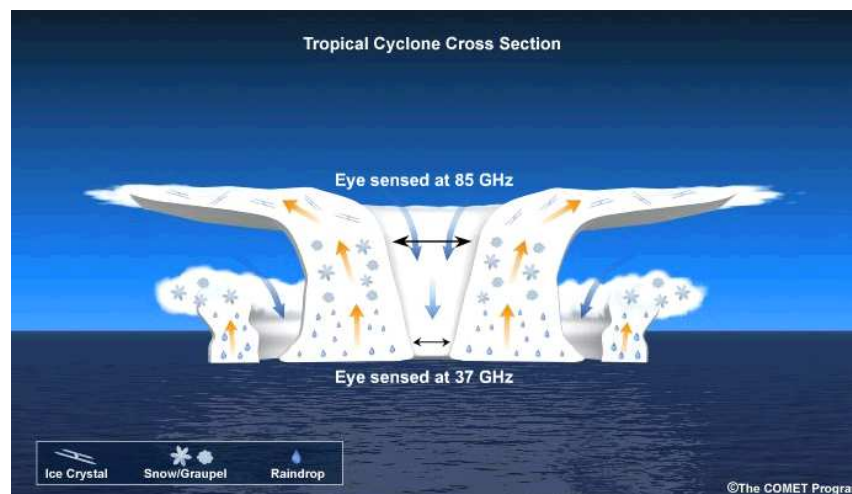
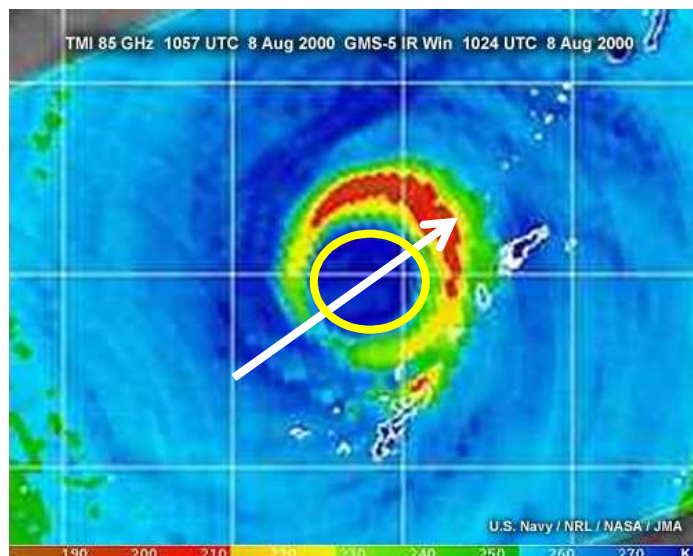
Characteristics of microwave imagery



- Parallax error
 - 85 GHz : 10-20 km
 - 37 GHz : 5 km or less



- **Parallax error**
 - **85 GHz : 10-20 km**
 - **37 GHz : 5 km or less**



SSM/I (DMSP) - SSMIS (DMSP) - GMI (GPM) – AMSU - WINDSAT (Coriolis)
AMSR2 (Shizuku GCOM-W1) (2)

Imager	SSM/I	SSMIS	GMI (core)	AMSR 2	Wind sat	MWRI	ATMS	AMSU
Satellite (Agency)	F 13, 14, 15 (Status degraded) (DMSP)	F 16, 17, 18 (planned 2014 :S19) (DMSP)	GPM Core Observatory NASA + INPE (Brz) + JAXA (Jpn)	« SHIZUKU » (GCOM-W1) (JAXA)	Coriolis (US Navy)	FY-3B (2010-2013) FY-3C (2013-2016) (CMA – China)	Suomi-NPP (NASA)	N5 (Degraded), N16 (Degraded), N18, N19 (NOAA) Metop-A, Metop-B (ESA)
Satellite altitude (km)	850	850	407	700	750	836	834	810 (NOAA) 820 (METOP)
Orbit	Sun-synchronous	Sun-synchronous	high latitudes (> 70°) not covered	Sun-synchronous	Sun-synchronous	Sun-synchronous	Sun-synchronous	Sun-synchronous
Swath width (km)	1400	1700	850	1450	1025	1400	2200	2200
Scanning	Conical	Conical	Conical	Conical	Conical	Conical	Cross	Cross
Pixel Resolution (km)	85 GHz : 15 37 GHz : 25x12.5	91 GHz : 12.5 37 GHz : 25x12.5	36.5 GHz : 6x13 89 GHz : 3x13	89 GHz : 5x5 36.5 GHz : 10 x10	37 GHz : 6.25x12.5	36.5 GHz : 18x30 89 GHz : 9x15	Nadir 89.5GHz : 32 Nadir 31.4 GHz : 75	Nadir : A 45, B 16 Edge : A 150, B 45

Source: <http://www.wmo-sat.info/oscar/instruments/>

Toujours un temps d'avance

Other MW Radiometers

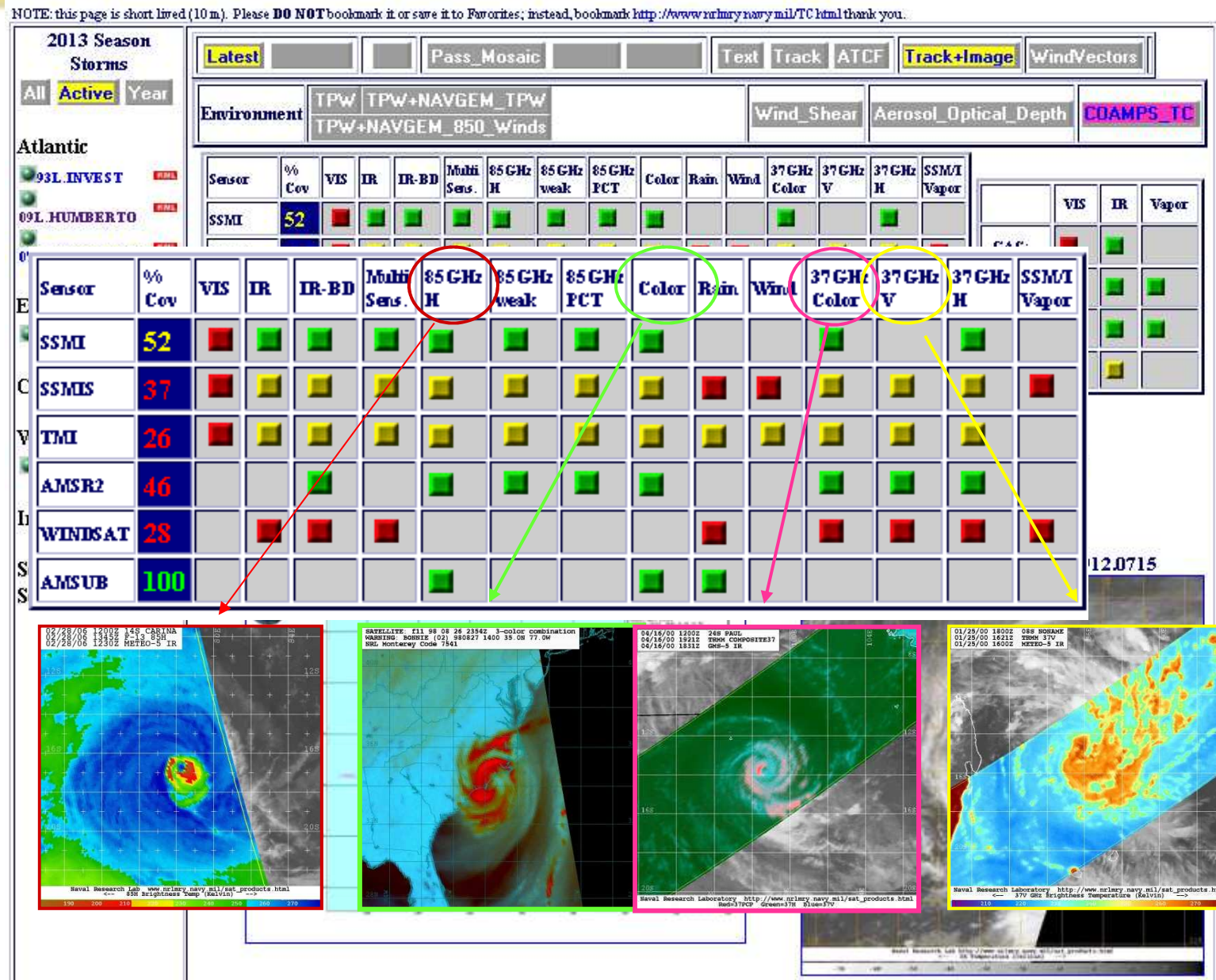
Planned or operationnal but datas unavailable

Imager	MWI	MWI	MTVZA-GY-MP	MADRAS
Satellite (Agency)	HY-2B (2013-2016) (NSOAS – China)	METOP-SG (planned 2022) (ESA)	Meteor-MP N1 (planned 2017) (Roscosmos – Russia)	Megha-Tropiques (ISRO - CNES)
Satellite altitude (km)	973	817	830	865
Orbit	Sun-synchroneous	Sun-synchroneous	Sun-synchroneous	Intertropical coverage (best coverage 15°N-15°S)
Swath width (km)	?	1700	2200	1700
Scanning	Conical	Conical	Conical	Conical
Resolution (km)	37.0 Ghz : 15x22	31.4 Ghz : 10 89 Ghz : 8	36.7 Ghz : 32 92 Ghz : 16	36.5Ghz : 40x60 89.0 Ghz : 10x15



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



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

NOTE: this page is short lived (10 m). DO NOT bookmark it or save it to Favorites. Instead, bookmark http://www.nrlmry.navy.mil/tc_pages/tc_home.html

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/T F15

20130912.0548 52 %

AMSU/ GCOMW1

20130912.0357 46 %

AMSU-B N19

20130912.0352 100 %

Age 6-12 hrs.

From 20130912.0548

SSM/I OCEANSAT-2

20130912.0050 Bytes

AMSU-B METOP-A

20130911.2252 81 %

Age > 12 hrs.

From 20130912.0548

SSMIS F16

20130911.1907 65 %

AMSU-B N19

20130911.1745 74 %

SSMIS F15

20130911.1714 49 %

AMSU-B N19

20130911.1517 29 %

SSM/I OCEANSAT-2

20130911.1154 Bytes

AMSU-B METOP-A

20130911.1143 79 %

SSMIS F15

20130911.0951 12 %

CRR10LAS

20130911.0726 78 %

SSMIS F19

20130911.0724 54 %

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

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

COMET

1km_zoom/20061029.0530

CIMARON 5 VIS

VIS. 29 OCT 2003 0530Z

Alert (View All)

2249 Z, F-13	0663
0000 Z, F-16	0054
0539 Z, TRMM	0097
1632 Z, AQUA	1421
0925 Z, WIND	0014

AMSUB

10/29 0536 Z, II-18

0637

10/29 0606 Z, II-16

1509

SCATT

10/28 2232 Z, SCAT_FHMOC

1474

10/29 0917 Z, QUIK

0951

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



Morphed Integrated Microwave Imagery



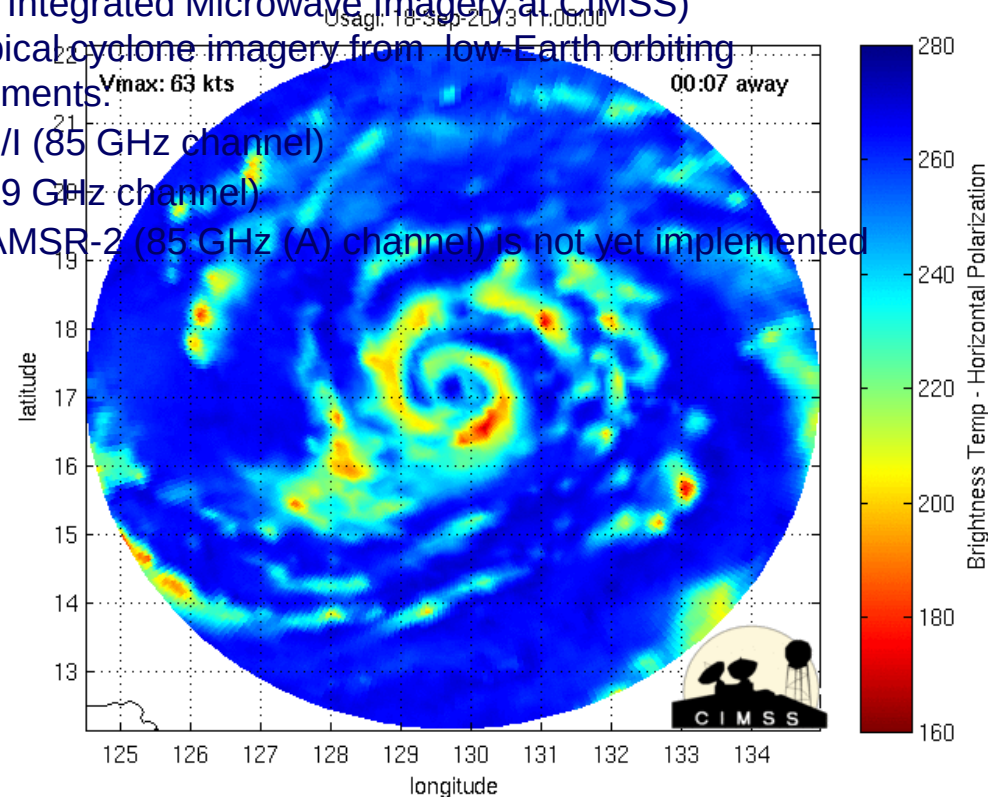
METEO FRANCE
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<http://tropic.ssec.wisc.edu/real-time/mimic-tc/tc.shtml>

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 -](#)