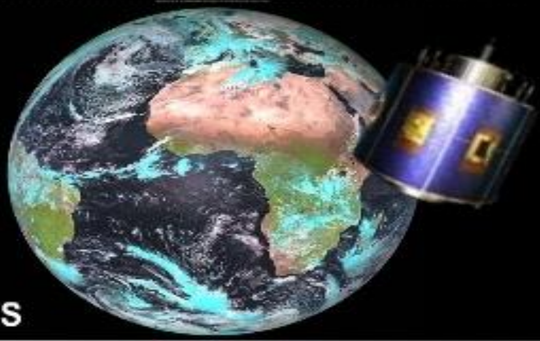
LABORATÓRIO DE ANÁLISE E PROCESSAMENTO DE IMAGENS DE SATÉLITES

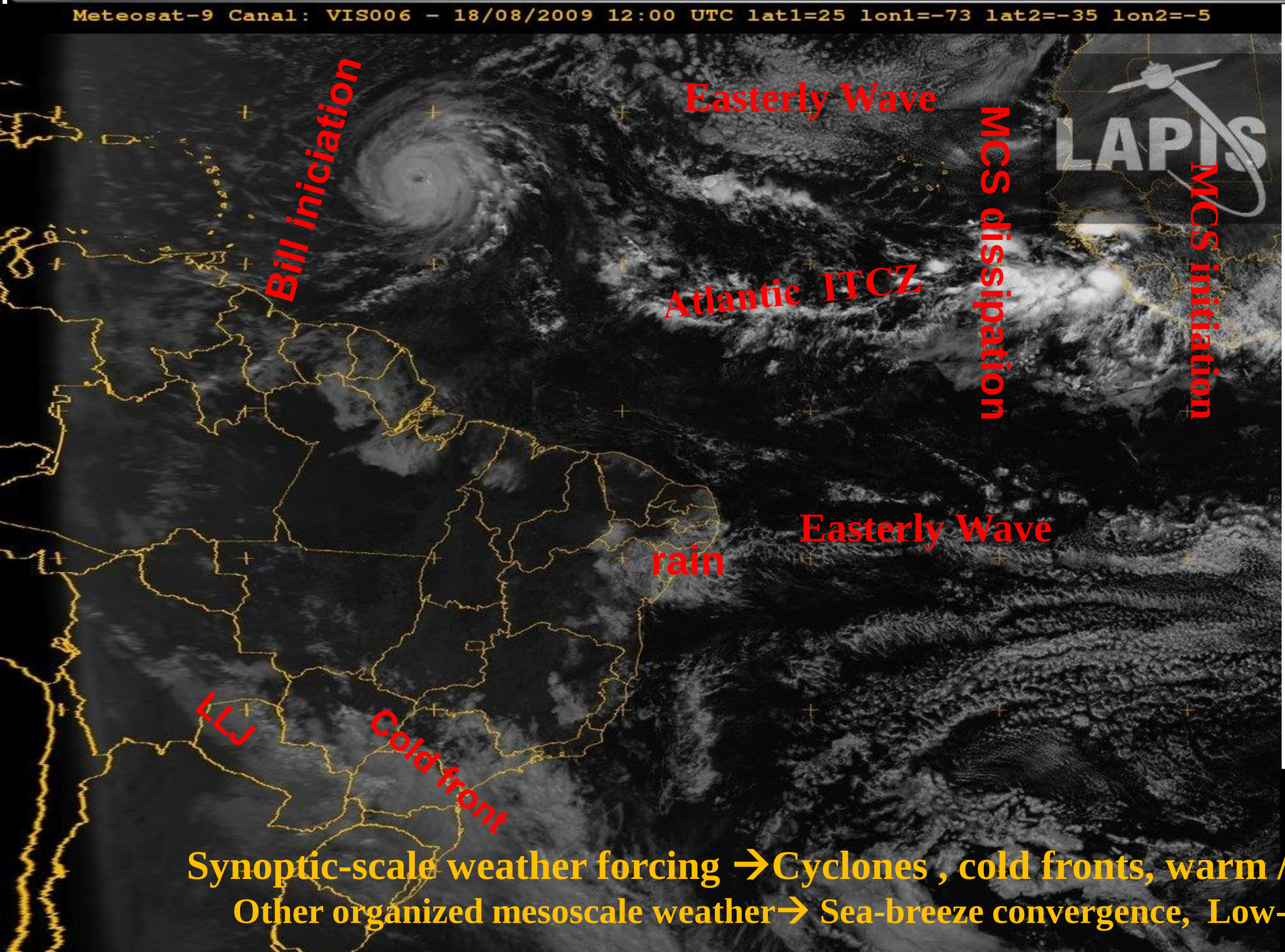
CWG Workshop,

17-19 April 2018, Ljubljana, Slovenia

Humberto A. Barbosa



The African Easterly Waves and their influence on hurricane activity in the tropical North Atlantic: An assessment of hurricane Bill (2009) using SEVIRI data



Synoptic-scale weather forcing → Cyclones , cold fronts, warm / cold air advection etc

Other organized mesoscale weather → Sea-breeze convergence, Low-level jet streaks, MCSs

MOTIVATION

Conceptual Models - the online collection Conceptual Models for Southern Hemisphere is a joint project between four southern hemispheric Centres of Excellence: Argentina, Australia, Brazil and South Africa. The project is co-funded by WMO and EUMETSAT. The purpose of the project is to improve warnings and awareness of weather risks through the use of conceptual models.

https://sites.google.com/site/cmsforsh/

OVERALL SCIENTIFIC APPROACH

Use of conceptual models in the design of a comprehensive assessment for a case study

The African Easterly Waves and their influence on hurricane activity in the tropical North Atlantic

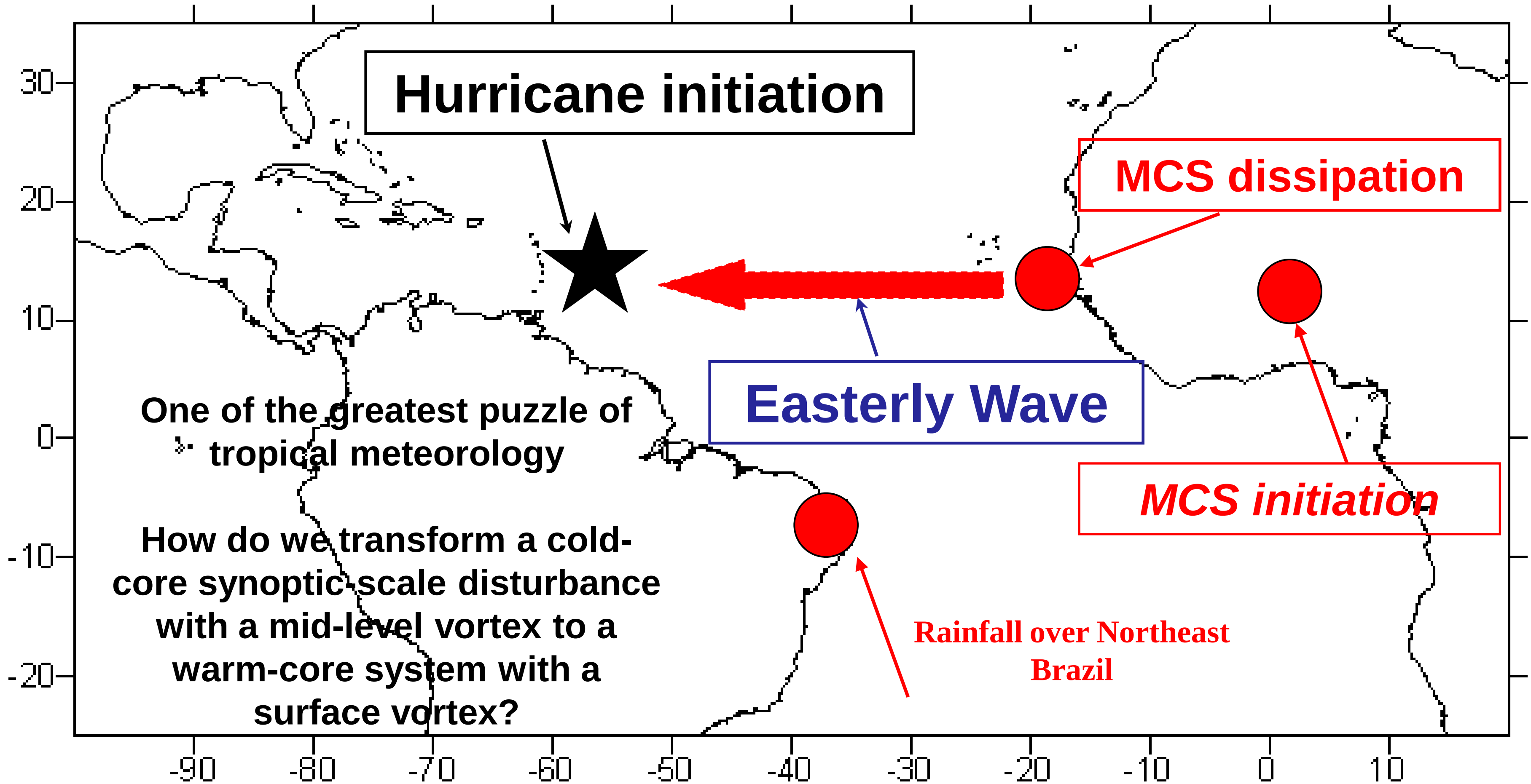
 # 1Develop a conceptual model (prepare a design)
 # 2 Identify stressors

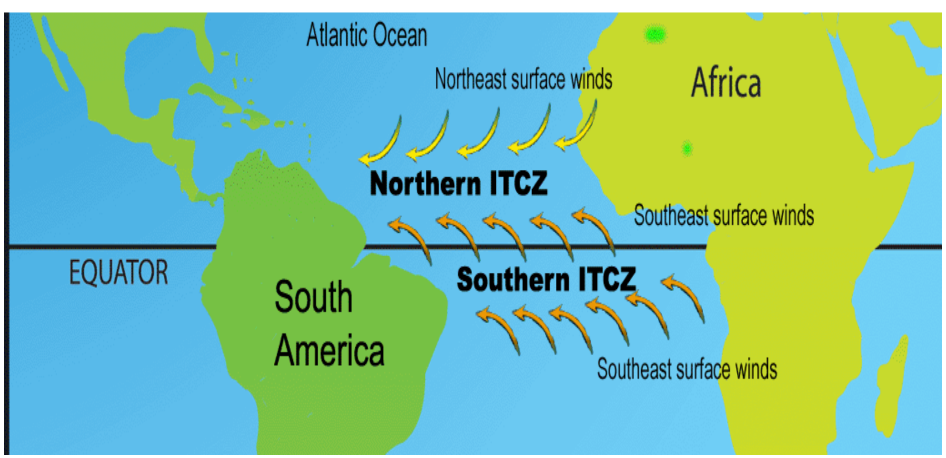
Mesoscale Convective Systems (MCSs) tracking with METEOSAT (MSG-2) images

ECMWF ERA Interim, wind data

#3 Establish hypotheses
#4 Scale of problem
#5 Establish indicators

MPE product from MSG

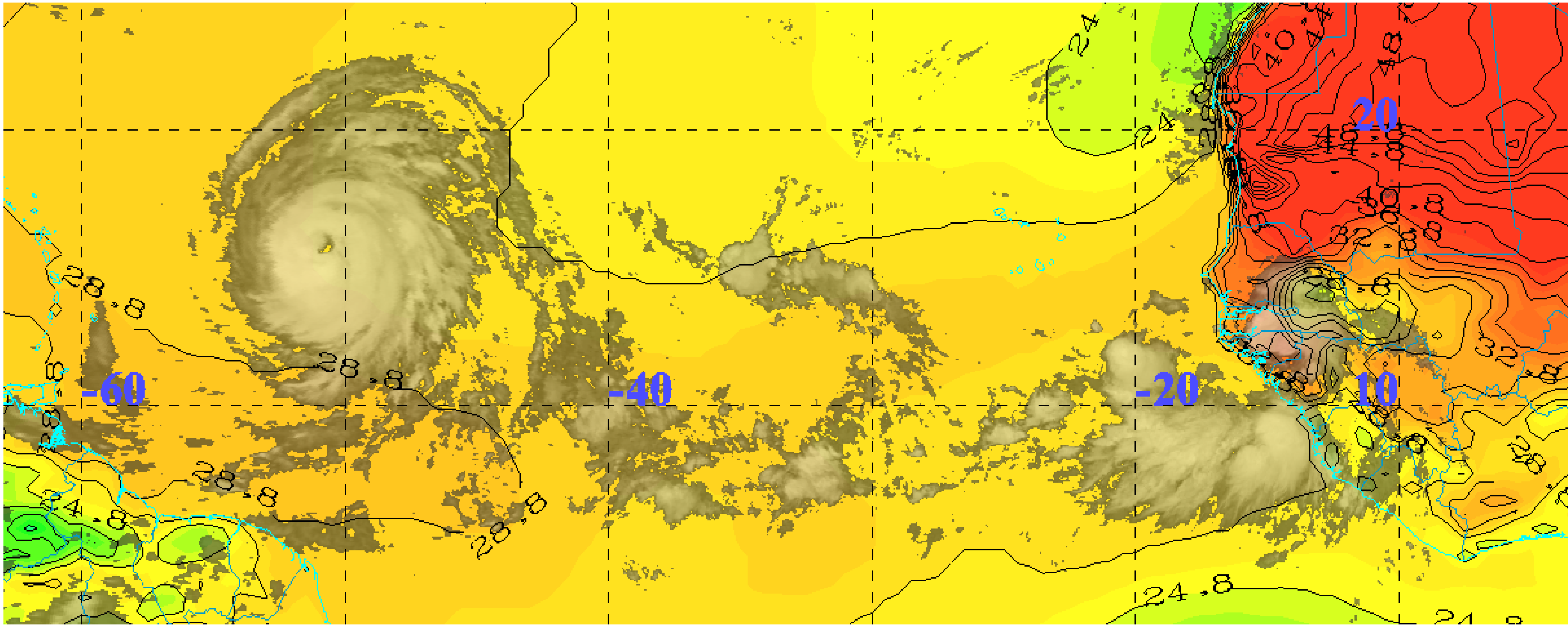

Hurricane initiation
MCS dissipation
Easterly Wave
MCS initiation
One of the greatest puzzle of tropical meteorology
How do we transform a cold-core synoptic-scale disturbance with a mid-level vortex to a warm-core system with a surface vortex?
Rainfall over Northeast Brazil
30
20
10
0
-10
-20
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10


Atlantic Ocean
Northeast surface winds
Africa
Northern ITCZ
Southeast surface winds
EQUATOR
South America
Southern ITCZ
Southeast surface winds


Warmer SSTs
Reduced Wind Shear
Lower Surface Pressure
(red area)
Higher Pressure in
Upper Atmosphere
Favorable African Easterly Jet
Weaker Easterly
Trade Winds
(dark blue arrow)
Upper-level
Easterlies Expand
Westward
(Green arrows)

Necessary environmental conditions for tropical cyclone formation

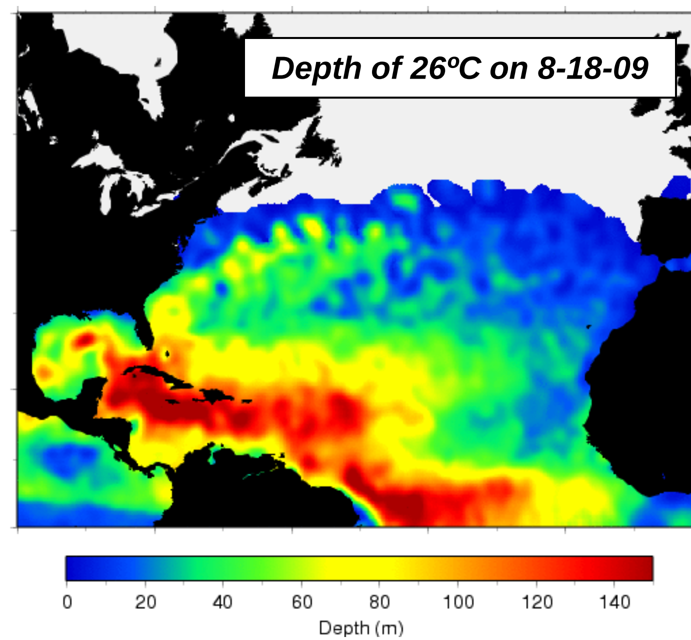
1. SST > 27 ^{o}C
2. Warm ocean mixed layer is thick enough to supply energy (this is why they weaken quickly upon landfall)
3. Unstable atmosphere with a moist lower/middle troposphere (central and western ocean basins)
4. Low vertical windshear (Otherwise upward transfer of latent heat disrupted)
5. Coriolis force (do not form between 5N-5S where Coriolis force is too weak)
6. Pre-existing low-level rotating circulations (tropical waves and other disturbances)



Deep Warm Currents and Eddies:

- A shallow oceanic mixed layer can easily be eroded by TC induced upwelling of cold water, resulting in cold SSTs and and the potential weakening of the TC

- A deep oceanic mixed layer will experience less upwelling of cold water, resulting in higher SSTs, and a better chance for intensification



Deep warm water matters, not just SST

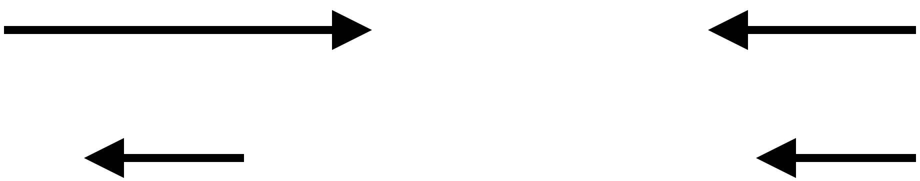
TC Genesis

Favorable Wind Shear Pattern:

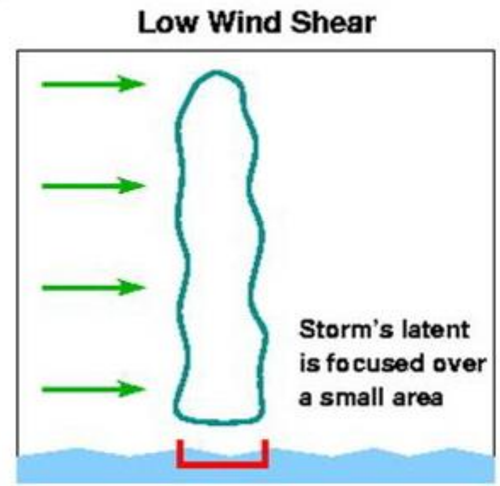
• **Wind shear is often defined as the vector difference between winds at two altitudes (850 and 200 mb)**

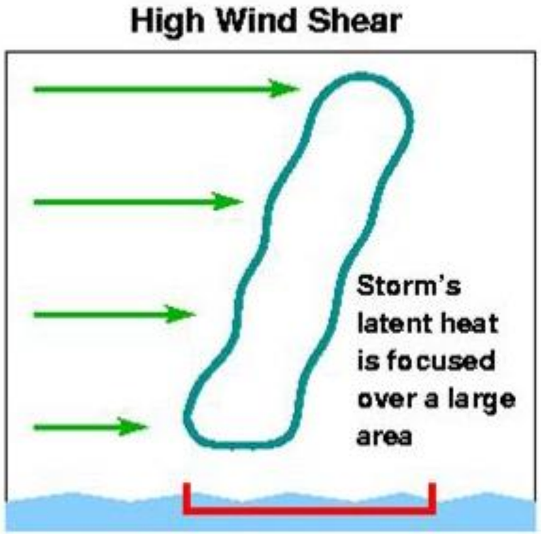
Bad – convection torn apart

Good – latent heat can concentrate in one area



High Westerly shear ***Low Easterly shear***



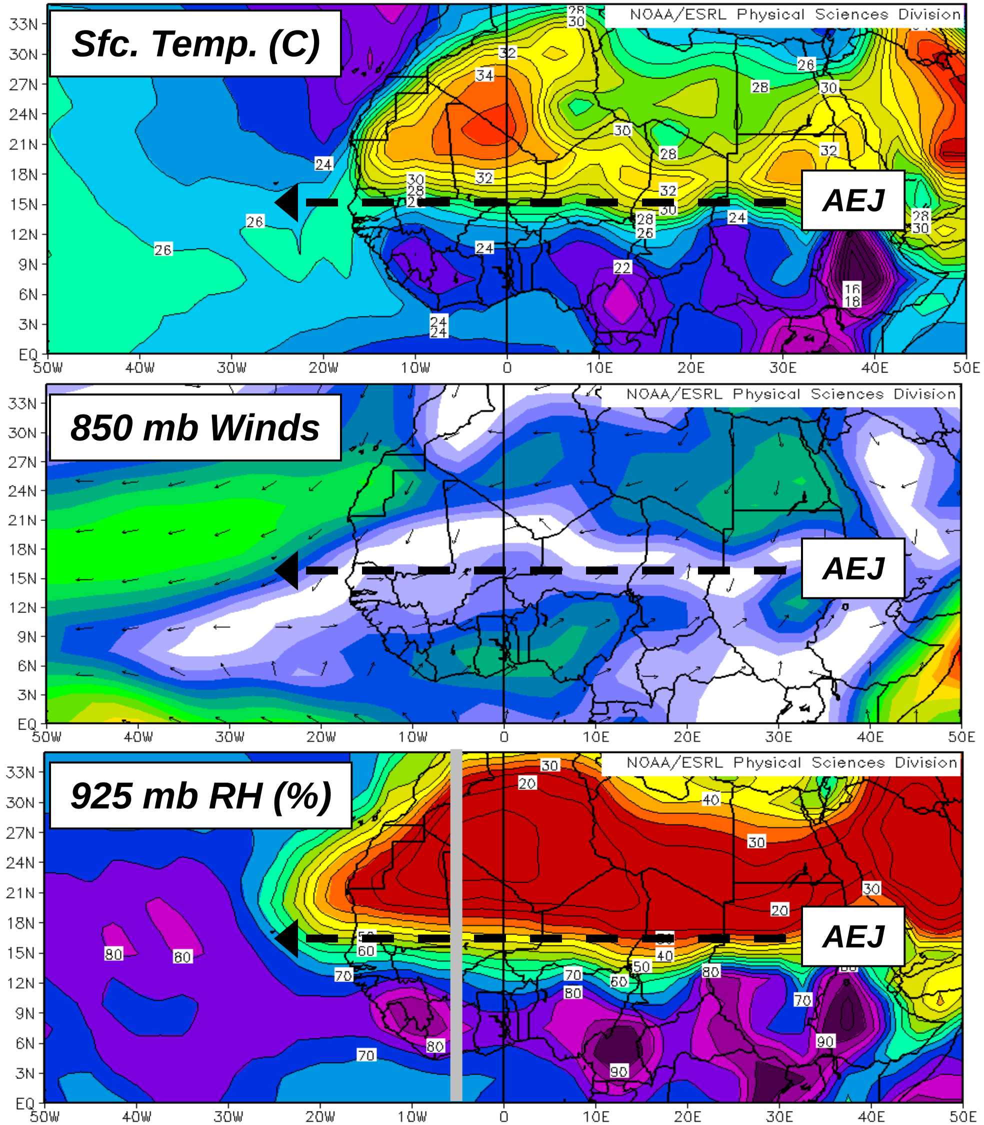


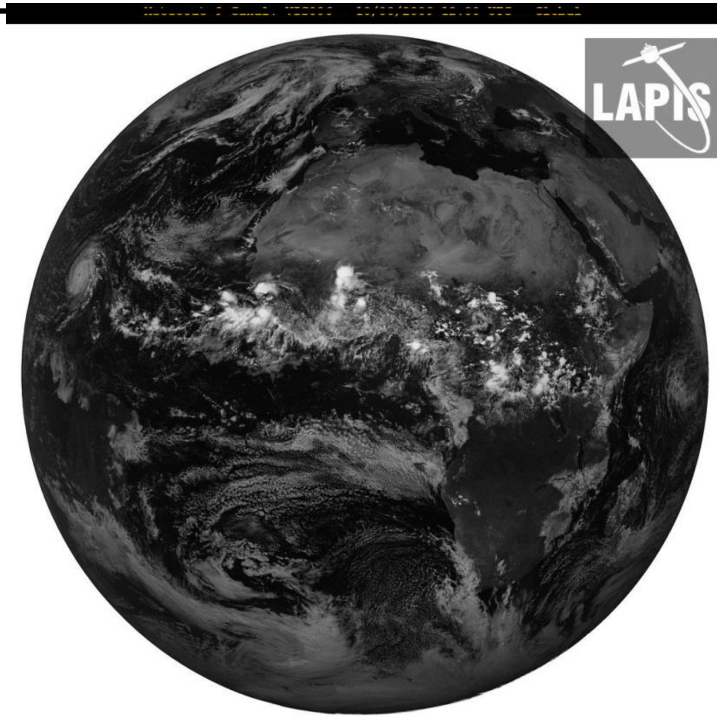
African Easterly Jet (AEJ)

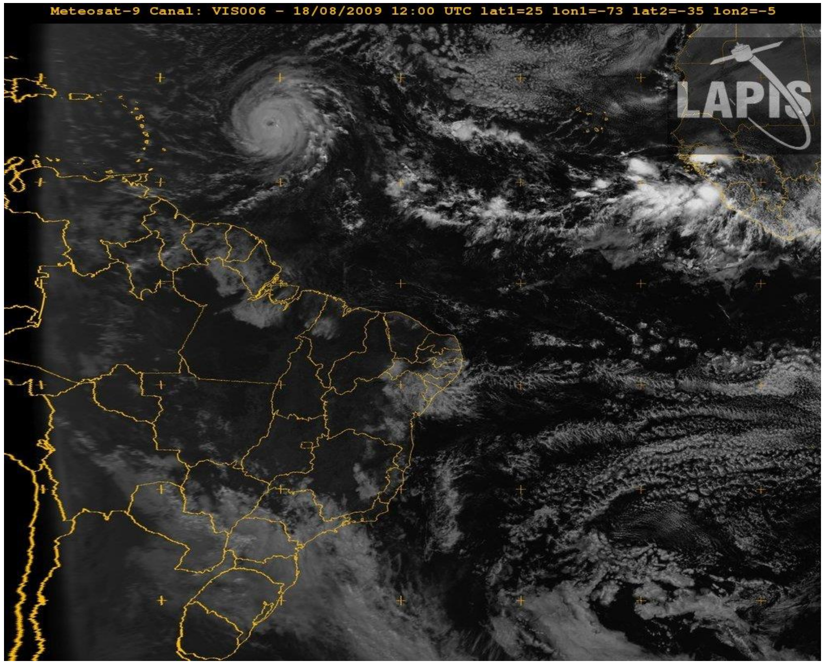
Origin: **Develop over sub-Saharan Africa from instabilities along the African Easterly Jet**

Basics:

- **Wavelengths of ~3000 km**
- **Move westward at 6-8 m/s**
- **60-80 easterly waves cross the Atlantic each year between June and October**
- **7-9 develop into tropical cyclones**



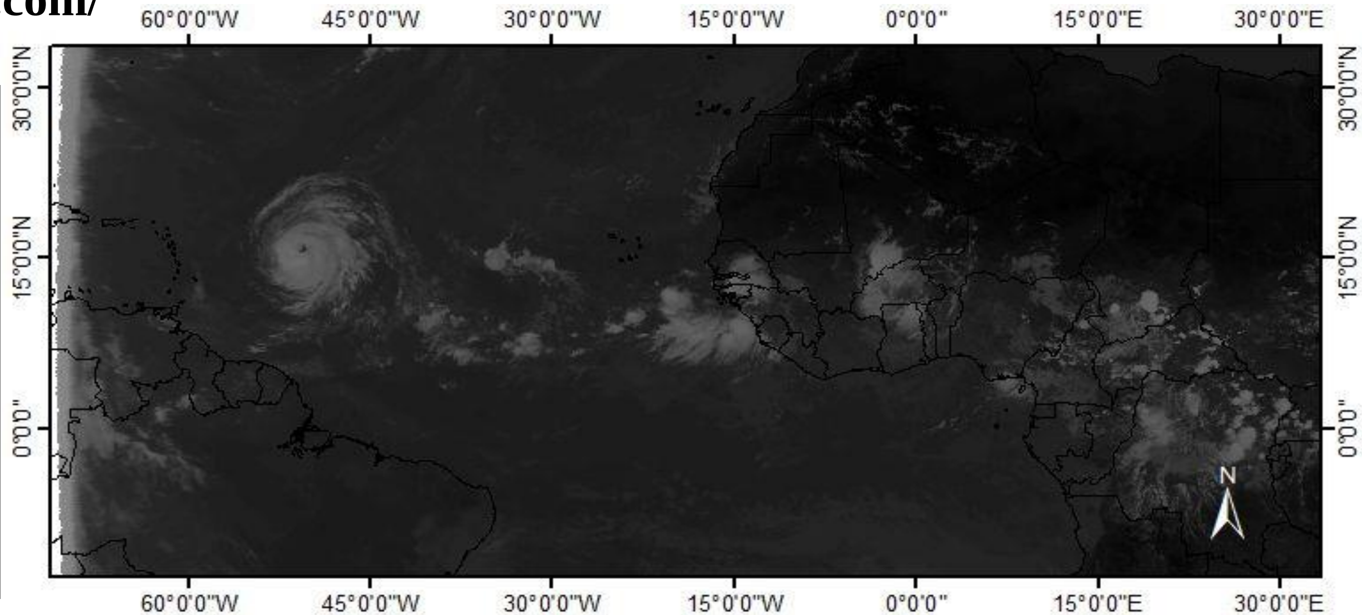




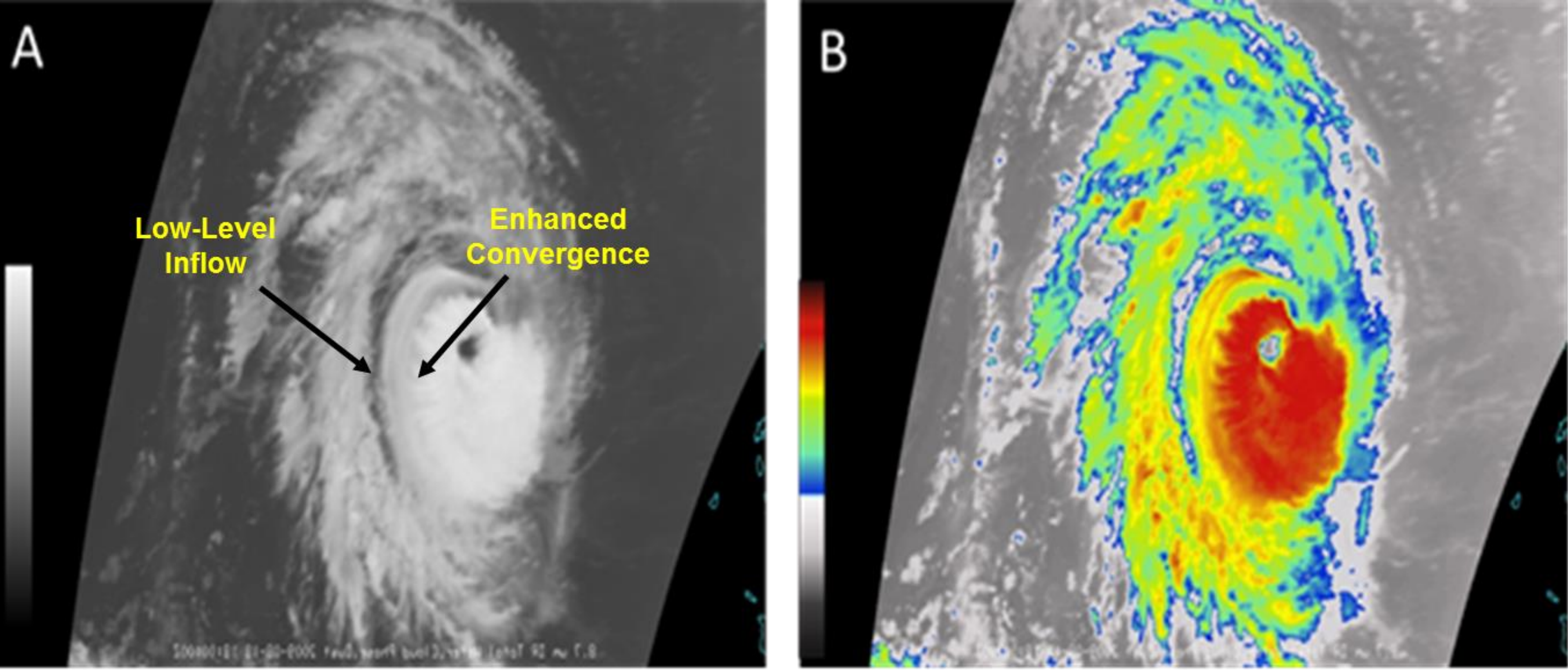
http://www.lapismet.com/

MSG IR10.8
Aug 18th, 2009
1200 UTC

From EUMETCast station at LAPIS

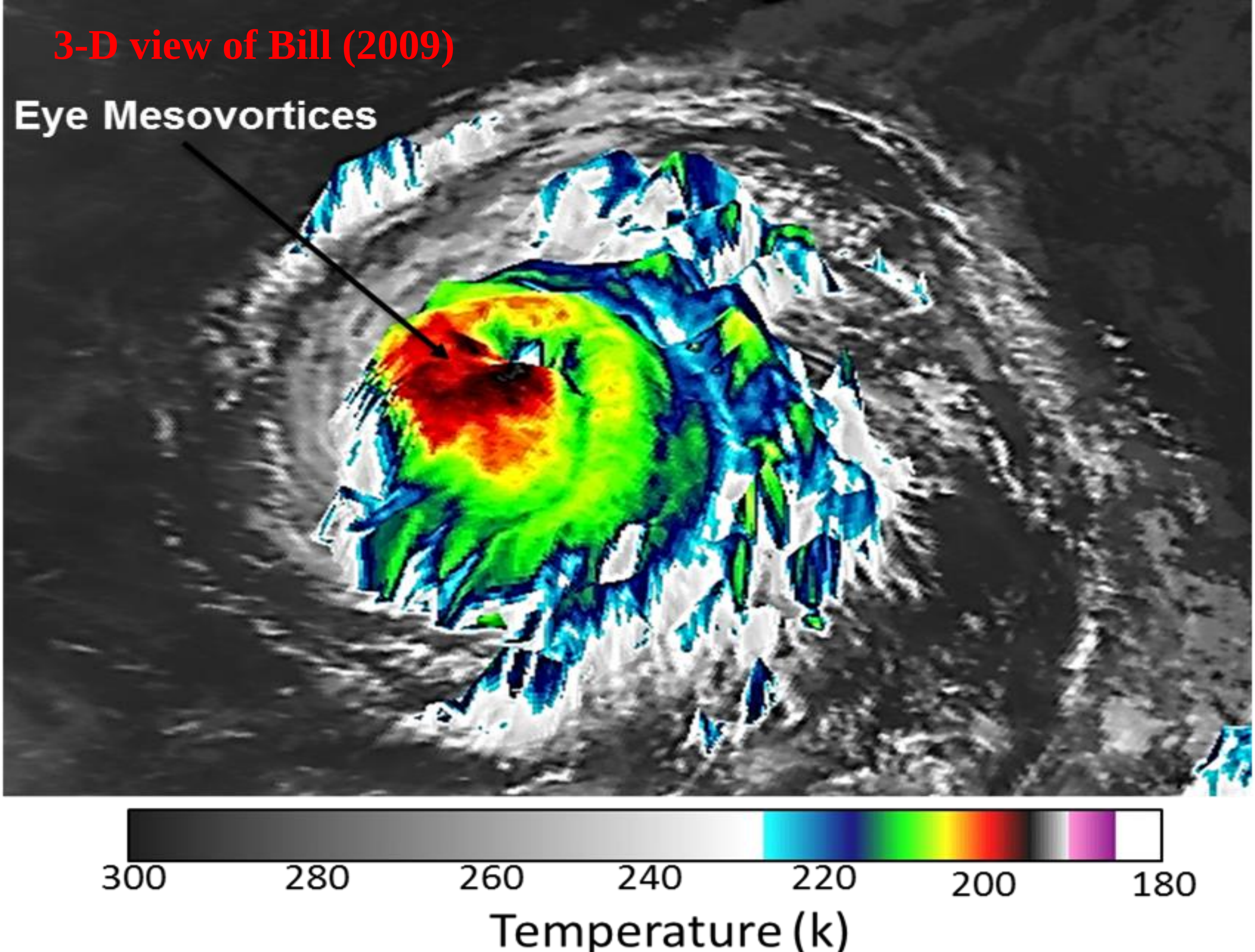


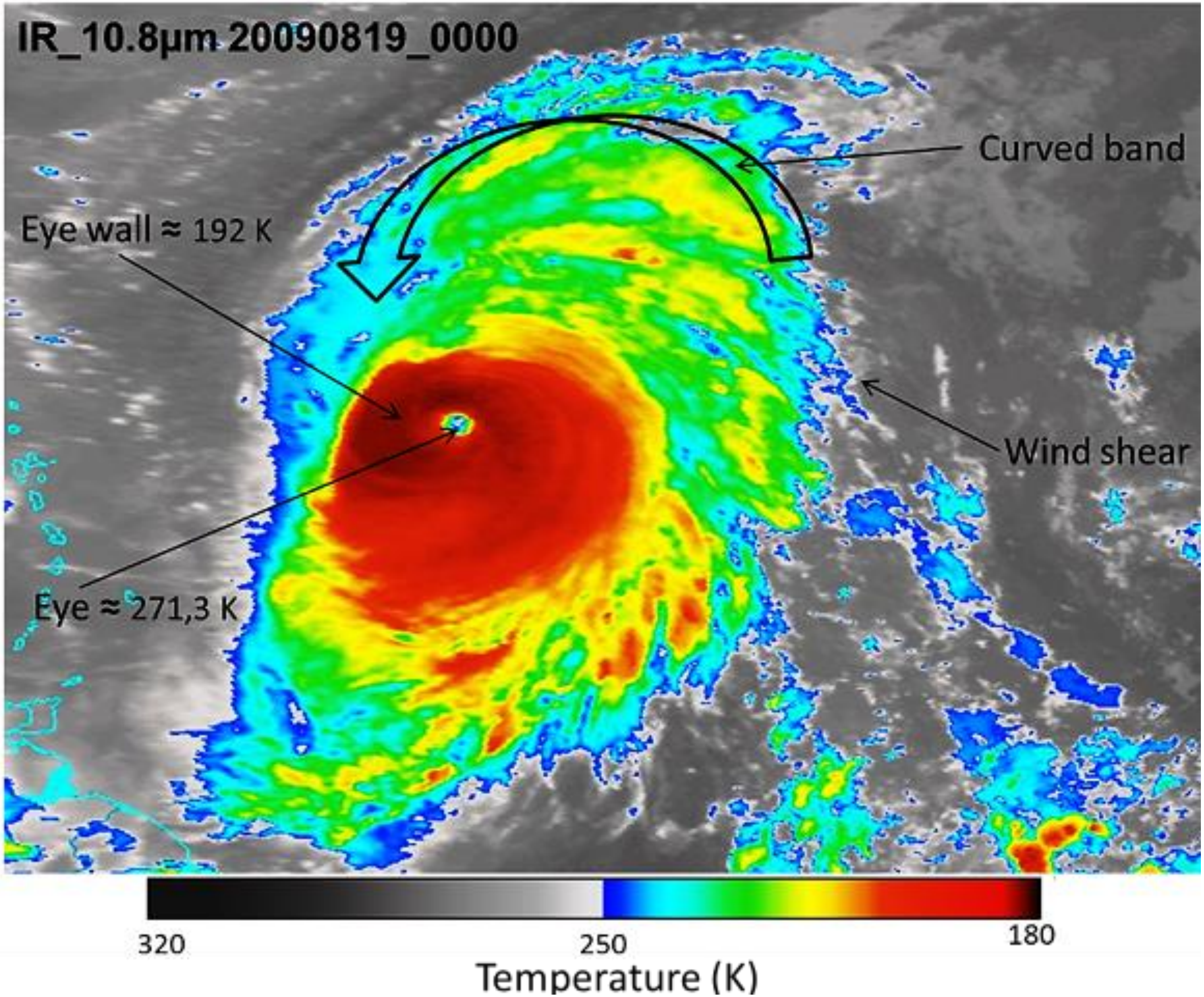
Data through the system of low cost for receiving environmental data – the EUMETCast system



19 August 2009 / 06UTC. Meteosat-9 IR images of the Hurricane Bill. A) IR imagery and B) Enhanced IR imagery.

Eye mesovortices (distinct cyclonic and anti-cyclonic features in the low-level clouds) generate buoyant convection in the eyewall by ejecting the warm, moist air from the low-level eye and producing enhanced convergence at the eyewall cloud base. These features can usually be seen clearly in the visible, infrared and water vapour images.


3-D view of Bill (2009)
Eye Mesovortices
300
280
260
240
220
200
180
Temperature (k)



19 August 2009 / 00:00 UTC. Meteosat-9 Enhanced IR 10.8 image for Hurricane Bill

Mesoscale Convective Vortices (MCVs)

Origin: Develop within persistent mesoscale convection from heating aloft (convection) and cooling below (cold downdrafts)

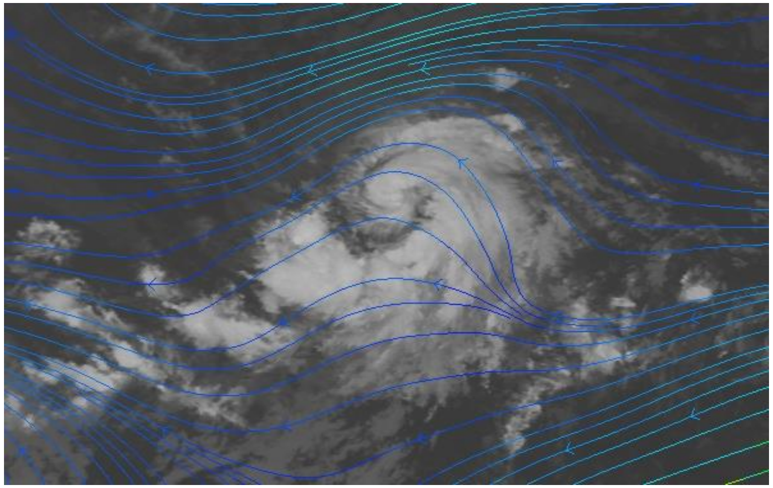
Basics:

- Confined to mid-levels with little or no signature at the surface
- Often present in easterly waves
- Dynamically stable (last several days)
- Multiple convective cycles
- Can emerge from the continental U.S. and developed into tropical cyclones (e.g. Hurricane Danny 1997)

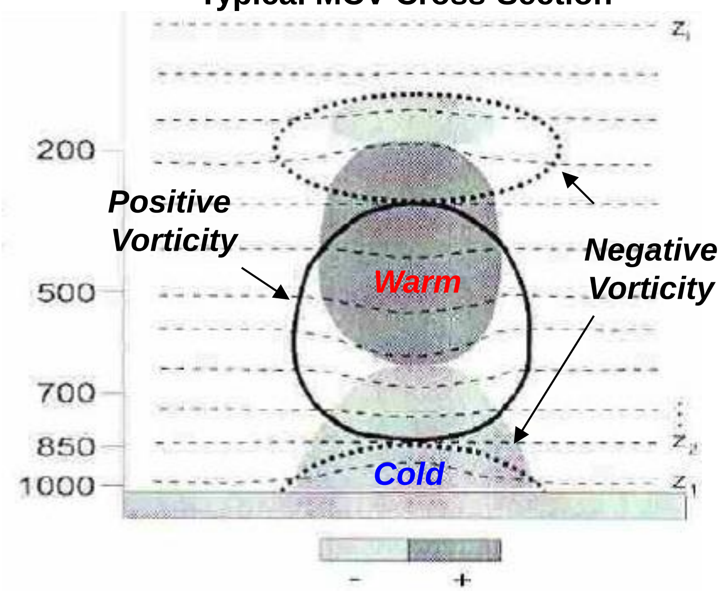
Why do we care about MCVs?

- Often emerge over warm waters with convection
- Systems "pre-conditioned" for successful genesis

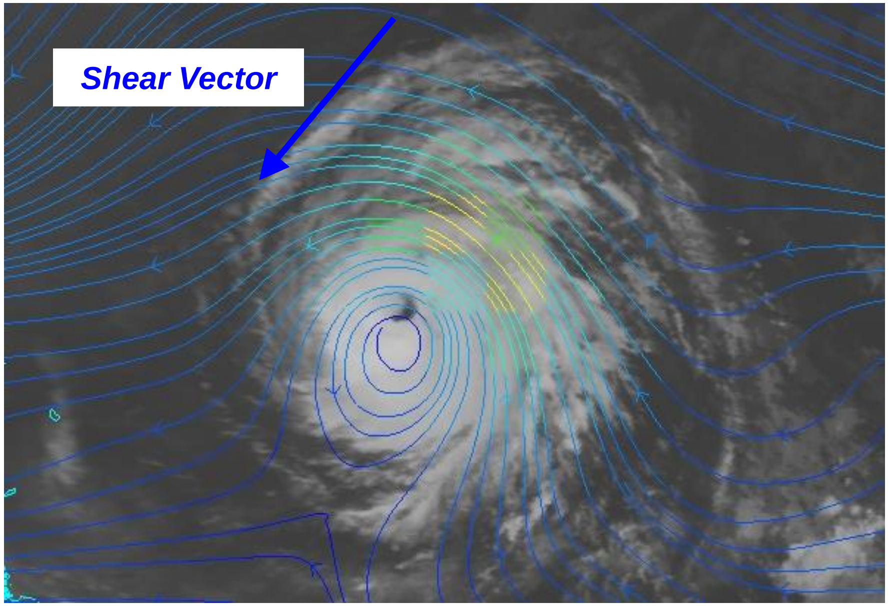
SEVIRI IR 10.8 image



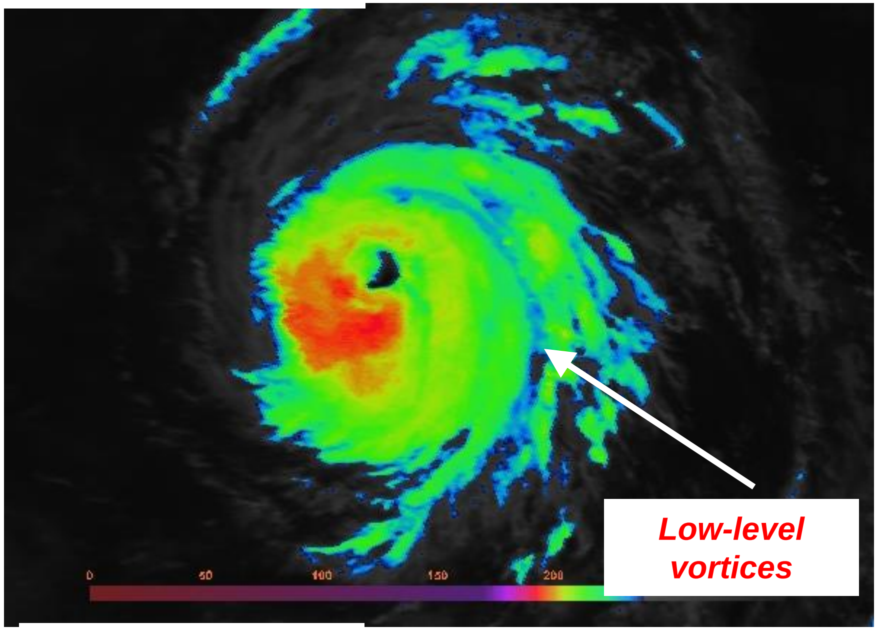
Typical MCV Cross-Section



SEVIRI Image



IR 10.8 + wind 250



IR 10.8 enhanced

Observational Evidence:

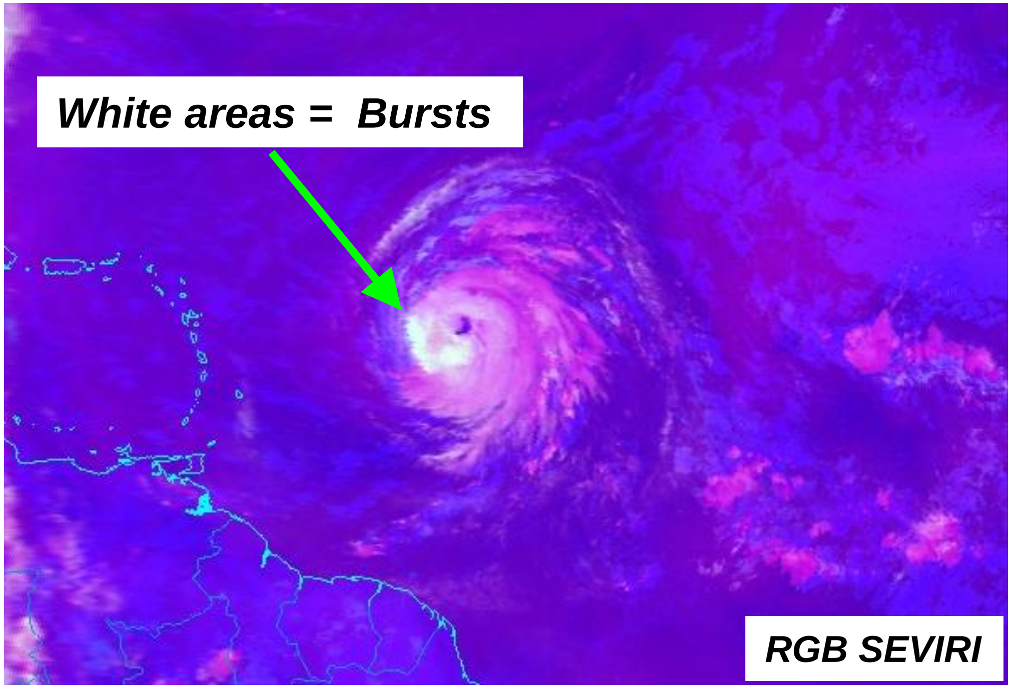
<u>TC Aug 18th, 2009</u>

Vertically sheared from the northeast

- **Exposed low-level circulation**
- **Convection confined to the southwest**

Episodic convective bursts (hot towers) developed multiple low-level vortices that rotated around to the northeast

Source: Lapis



Source: Lapis

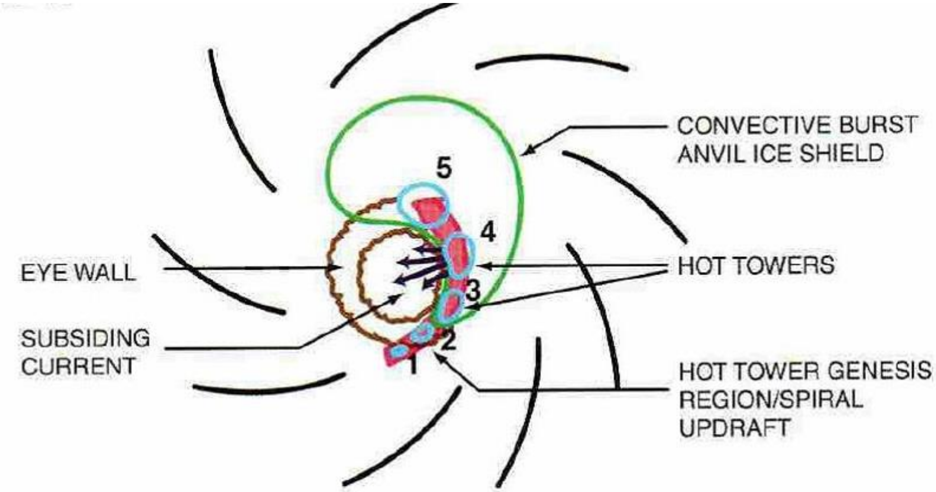
Convective Bursts:

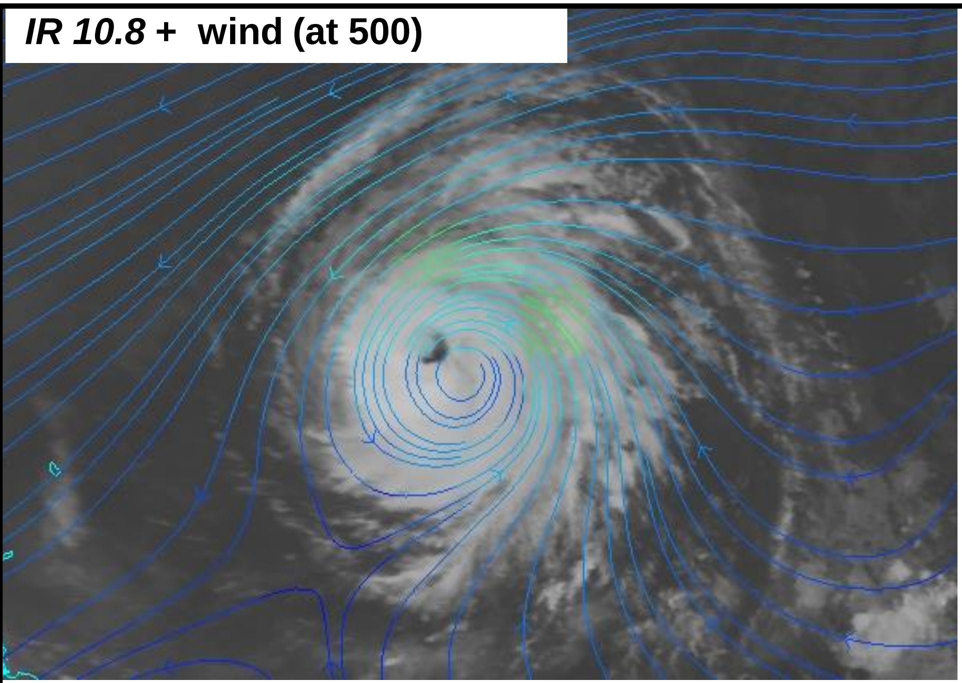
• *Overshooting and diverging convection at upper levels drives asymmetric mesoscale descent (adiabatic warming) in the eye, which lowers the pressure, increasing the pressure gradient and tangential winds*

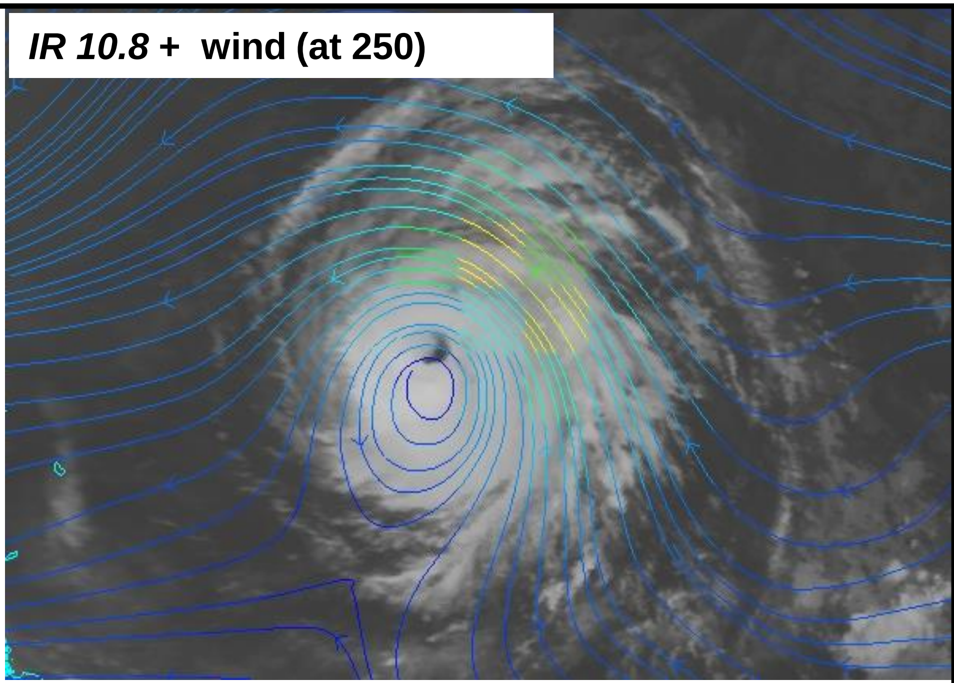
•*A recent survey of convective bursts:*

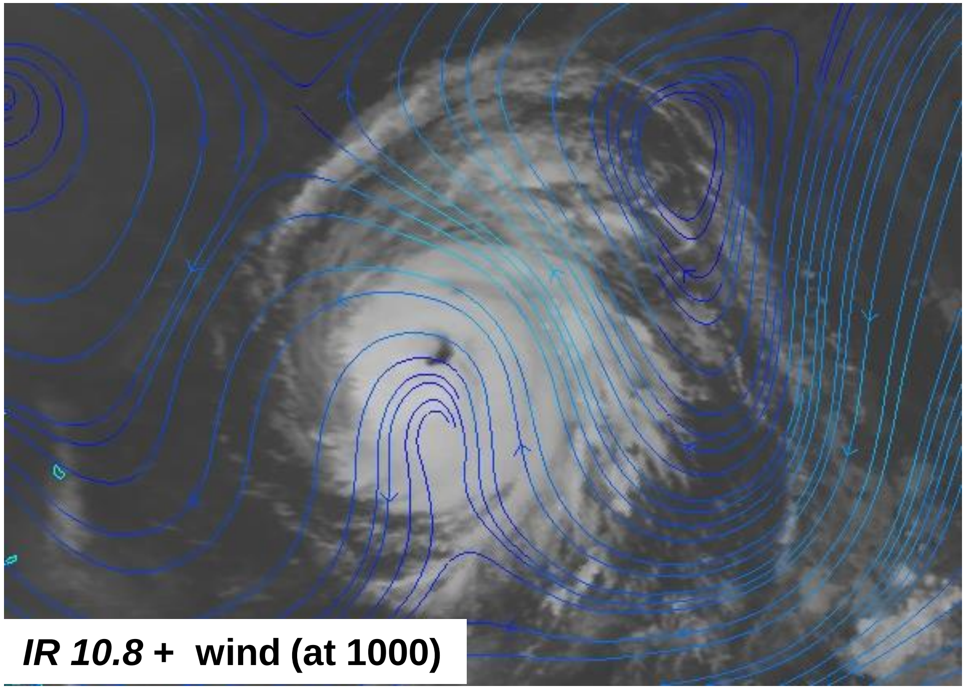
- *80% of TCs have at least one "burst"*
- *70% of TCs intensify after a "burst"*

Conceptual Model of Convective Burst









Intensity change can be a slow and steady process or it can occur rapidly over the course of several hours

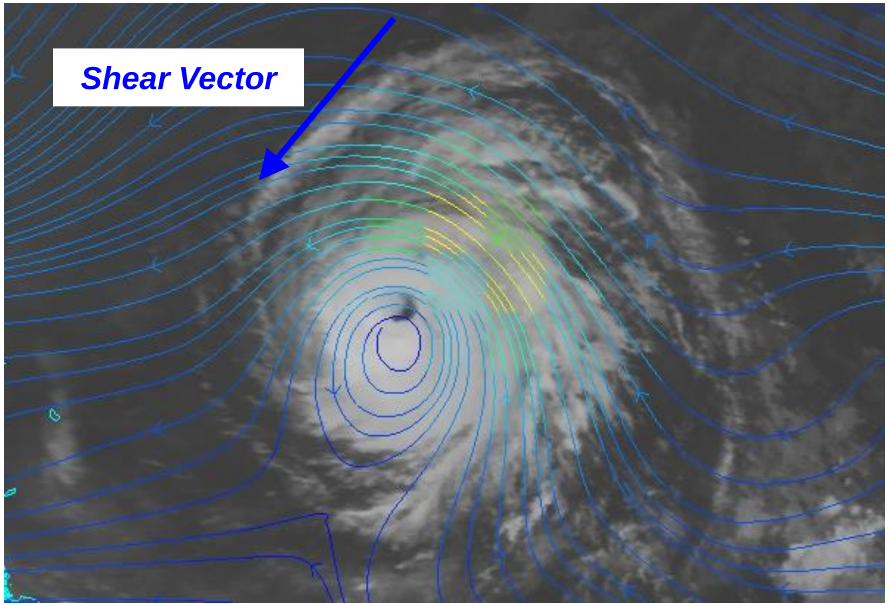
Forcing exists on multiple scales

- **Seasonal (SST, relative humidity)**
- **Synoptic (wind shear)**
- **Mesoscale (convective features, MCV, eyewall cycles)**
- **Microscales (air-sea interface, water phase changes)**

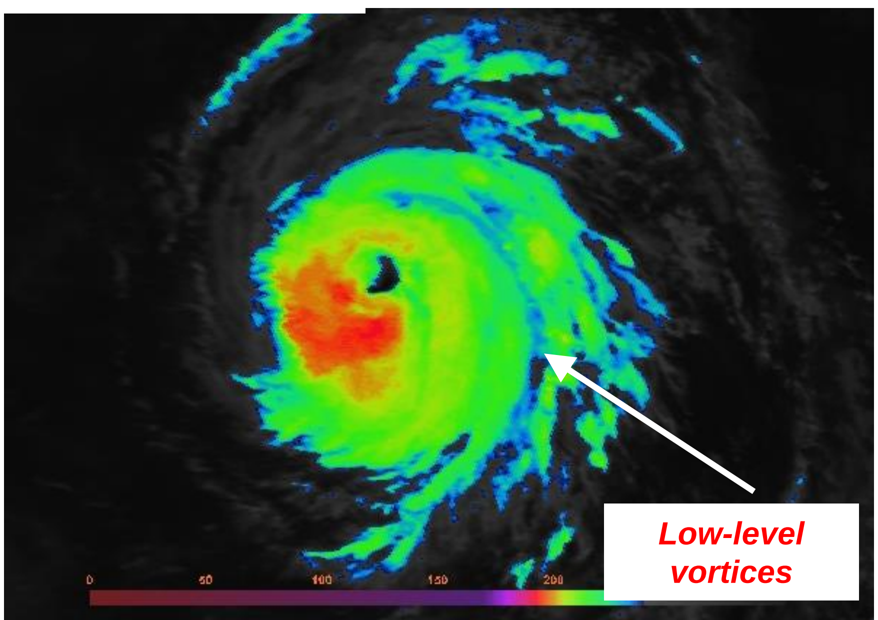
Complex interactions exist between the scales

Very difficult forecast problem!!!

SEVIRI Image



IR 10.8 + wind 250



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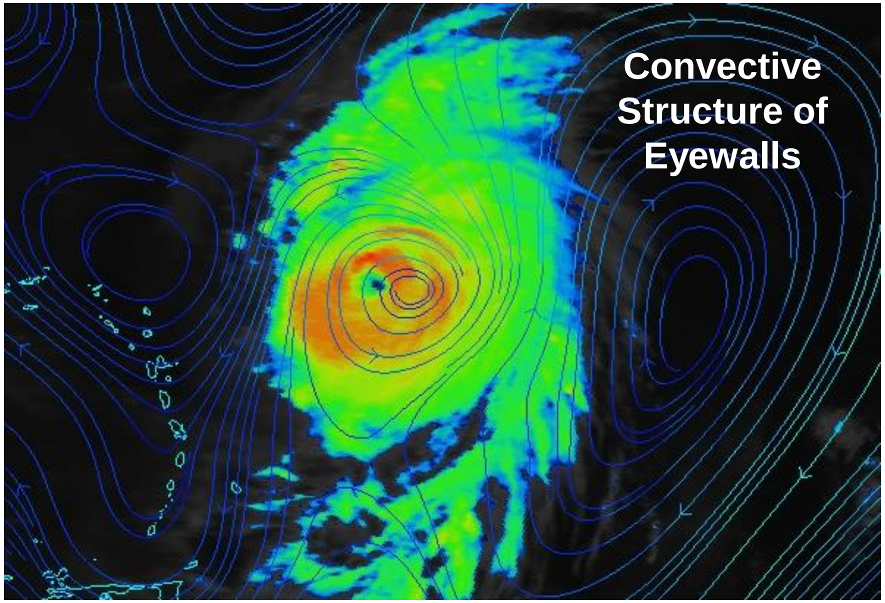
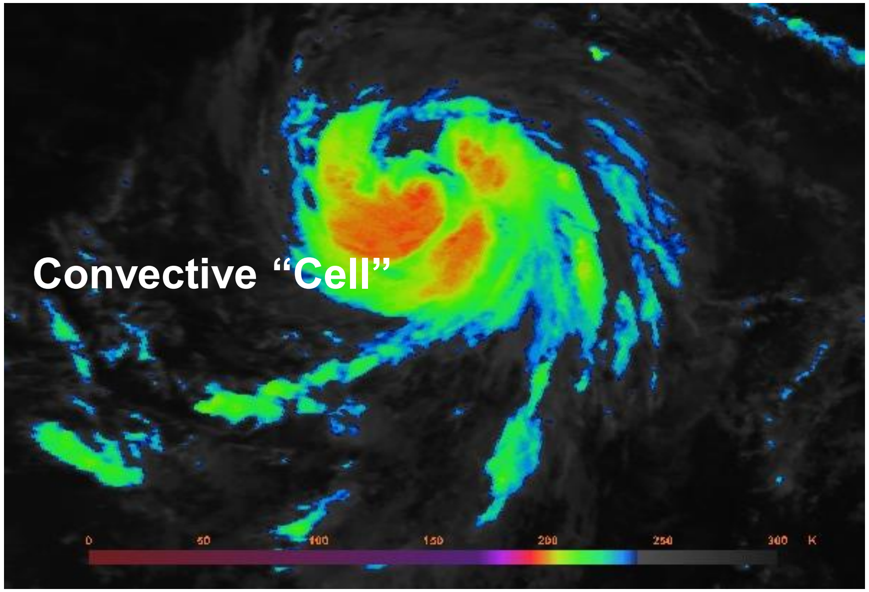
Tropical Cyclone Eyewalls



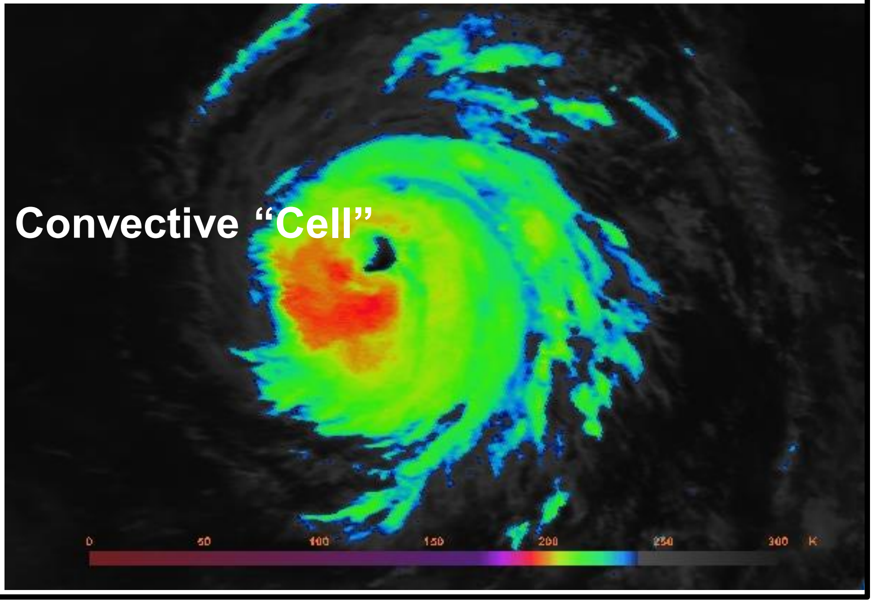
- Convection is rarely organized into a uniform ring of ascent

- Individual cells often develop, mature, and decay within 1 *hour*

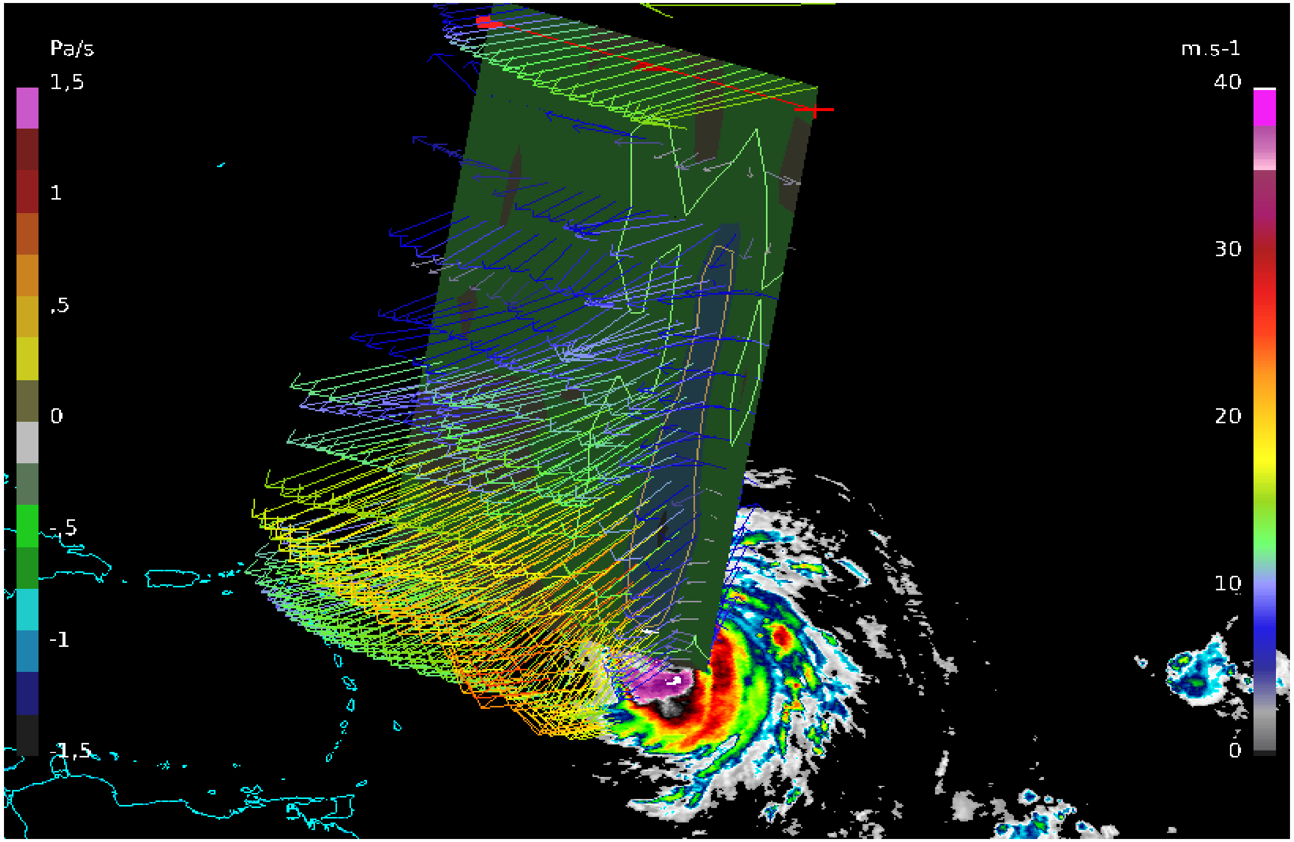


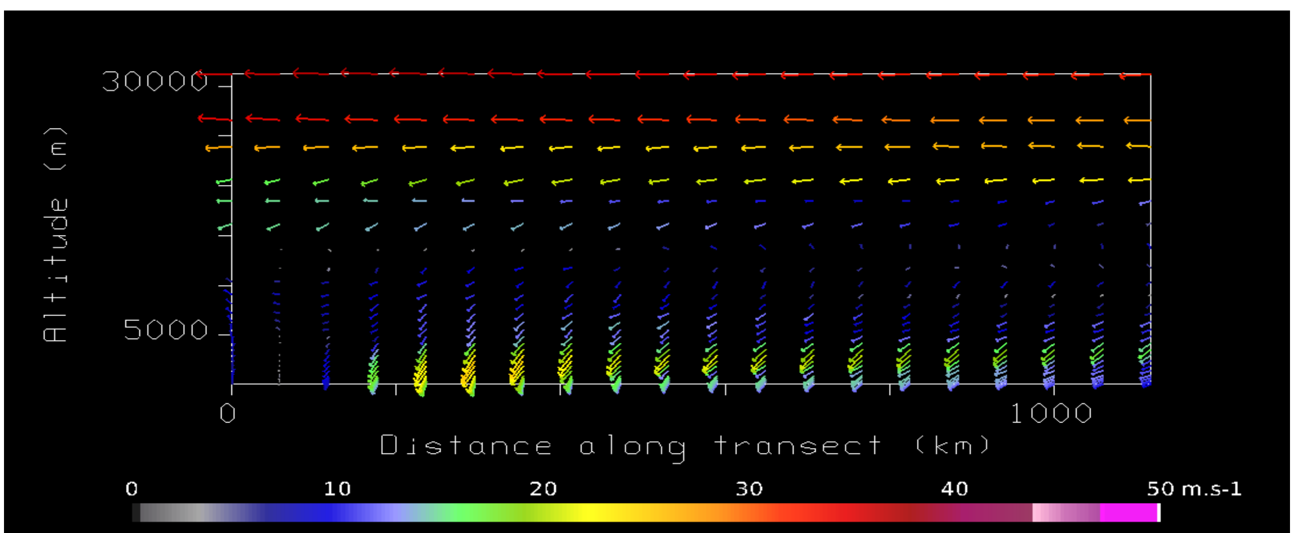
- Cells are the "detectable result" of strong updrafts

Source: Lapis



- Convection is often organized into multiple distinct "cells" that rotate cyclonically around the eyewall

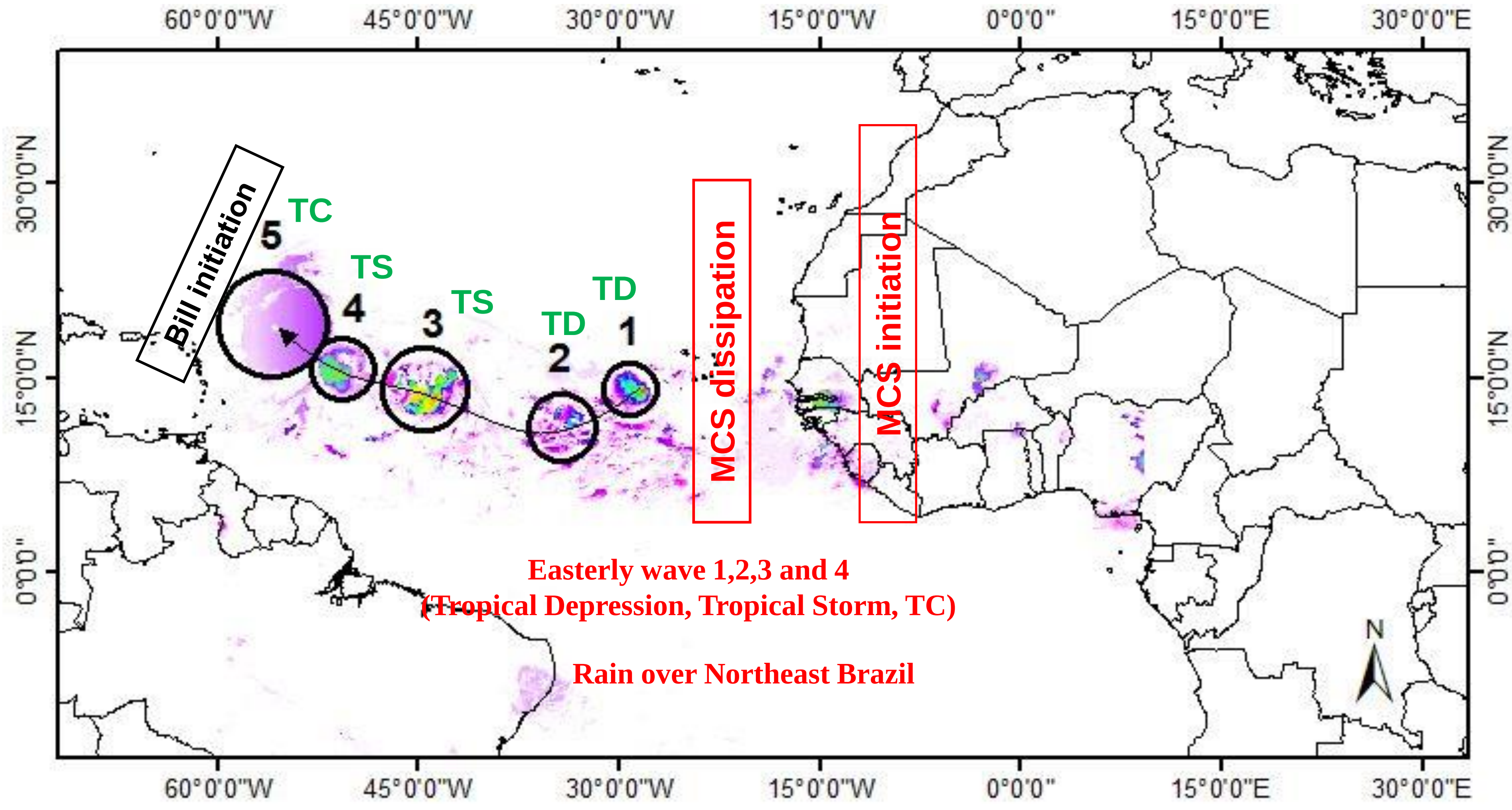




Vertical cross-section

- **Tropical cyclones are "warm core"**
- **Air near the center of circulation (in the eye) is much warmer than air in the large-scale environment**
- **Maximum temperature anomalies located in the upper-level eye**
- **Anomalies result from eye subsidence and eyewall latent heat release**
- **The warm core is responsible for the extremely low surface pressures in the eye and large pressure gradients across the eyewall**
- **Warm core is in thermal wind balance with the primary circulation**

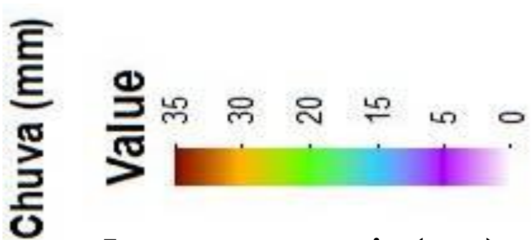
Tropical Cyclone (TC) Bill (Rain Band)



Source: Lapis

Tool: McIDAS-V

1-> Aug 14th 2009 at 1200 UTC
2->Aug 15th 2009 at 1200 UTC
3->Aug 16th 2009 at 1200 UTC
4->Aug 17th 2009 at 1200 UTC
5->Aug 18th 2009 at 1200 UTC



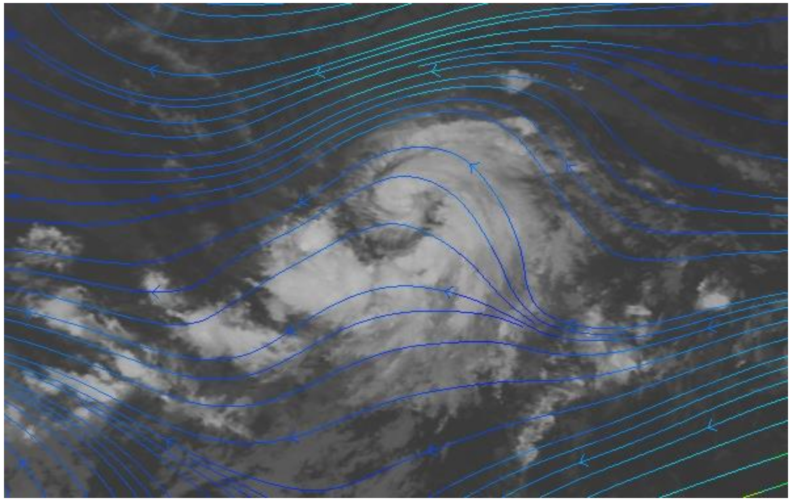
Instantaneous rain (mm)

SUMMARY:

Genesis of TC: **The transformation of a "disorganized" cold-core convective system into a self-sustaining synoptic-scale warm-core vortex with a cyclonic circulation at the surface**

Necessary (but not sufficient) Conditions:

- **Pre-existing convection**
- **Significant planetary vorticity**
- **Favorable wind shear pattern**
- **Moist mid-troposphere**
- **Warm ocean with deep mixed layer**
- **Conditionally unstable atmosphere**



SEVIRI IR 10.8 image + ECMWF wind data
Source: Lapis

How do we transform a cold-core synoptic-scale disturbance with a mid-level vortex to a warm-core system with a surface vortex?

- **Easterly Waves**

- **Mesoscale Convective Vortices**

References

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Braun, S. A., and W.-K. Tao, 2000: Sensitivity of high-resolution simulations of Hurricane Bob (1991) to planetary boundary layer parameterizations. Mon. Wea. Rev., 128, 3941-3961.

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www.lapismet.com

LAPIS

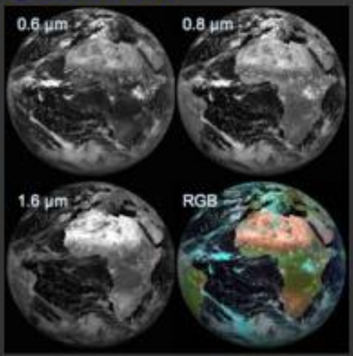
LABORATÓRIO DE ANÁLISE E PROCESSAMENTO DE IMAGENS DE SATÉLITES

•Thank you for attention!

•Questions?

Links

EUMETSAT



Lapis

Qui, 24 de Setembro de 2009 11:08

O **L**aboratório de **A**nálise e **P**rocessamento de **I**magens de **S**atélites (LAPIS) da Universidade Federal de Alagoas (UFAL) realiza atividades de pesquisa, assistência tecnológica e treinamento de recursos humanos para a recepção, processamento, interpretação e integração de imagens dos satélites da série METEOSAT. Para atender a essa demanda, em 2007 a UFAL instalou e operacionalizou a terceira estação de recepção de imagens do satélite METEOSAT Segunda Geração (MSG) do Brasil. Como atividades de pesquisa e transferência de conhecimento, a equipe do LAPIS elabora aplicativos para tratamento de imagens, disponibiliza produtos meteorológicos e ambientais derivados do MSG para setores operacionais e oferece treinamento na área. Desenvolvidas inteiramente com ferramentas open-source e freeware.

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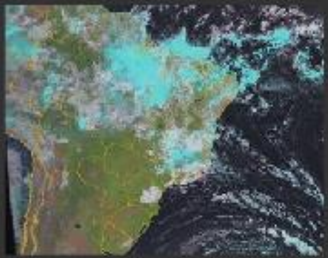

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