MET 4994 Remote Sensing: Radar and Satellite Meteorology
MET 5994 Remote Sensing in Meteorology

Lecture 20: Satellite Imagery Interpretation:

Distinguishing Different Image Types and Identifying Weather Systems

Distinguishing Different Image Types

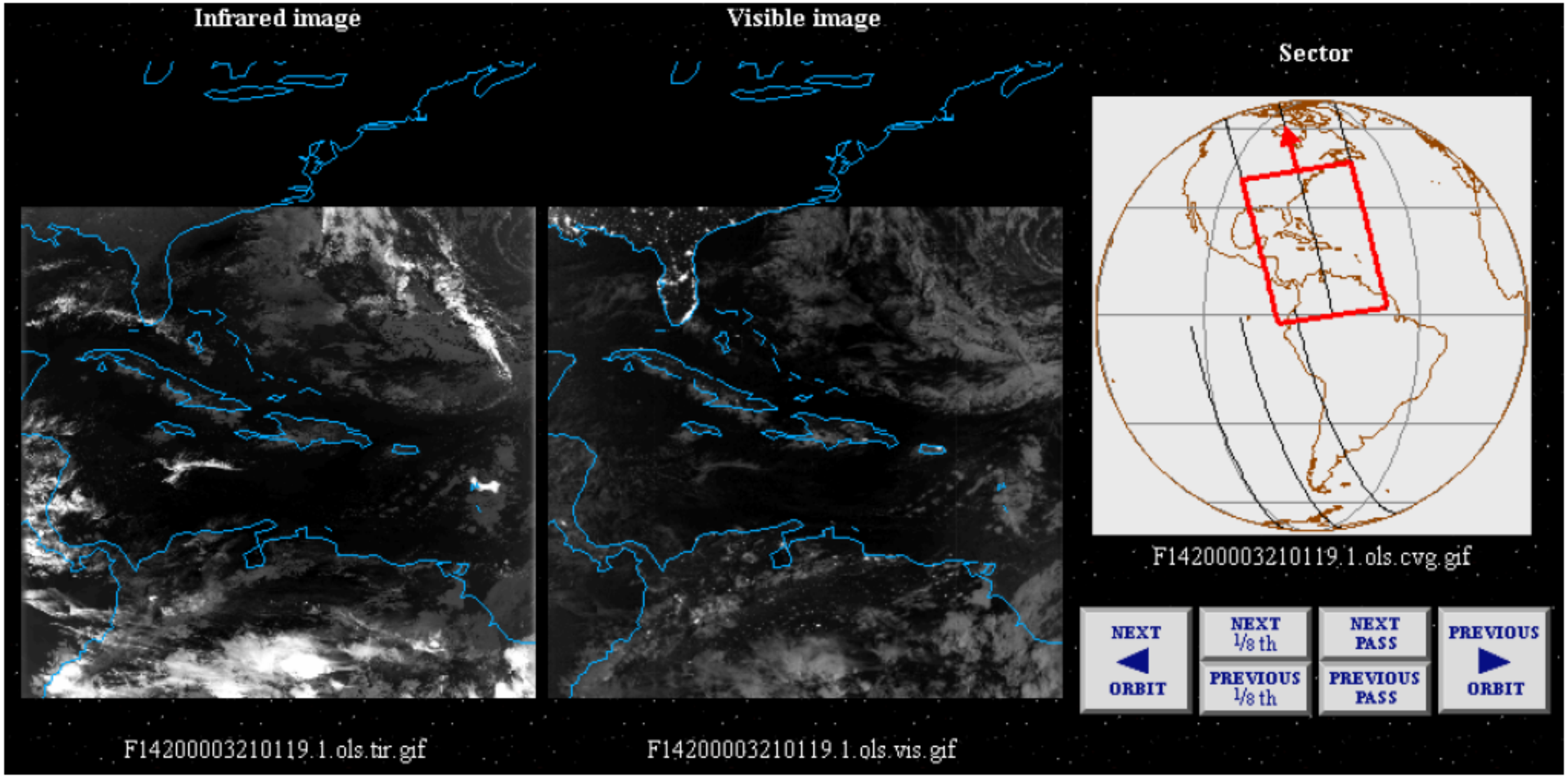
Polar vs. Geostationary

- Read the header
  - Know the appropriate acronyms for satellites and sensors.
- Areal Coverage
  - Polar: limited coverage, look for swath edges
  - Geostationary: full disk or continental.
  - Polar can be confused with GOES rapid scan.
- Surface Detail: surface terrain features are more easily seen on Polar images.

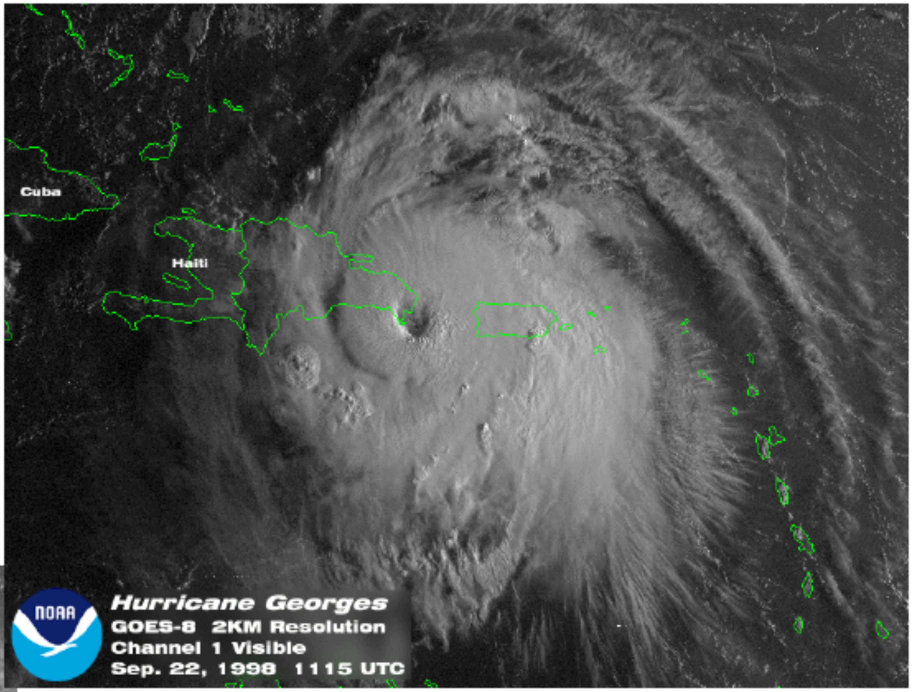
Read the Header

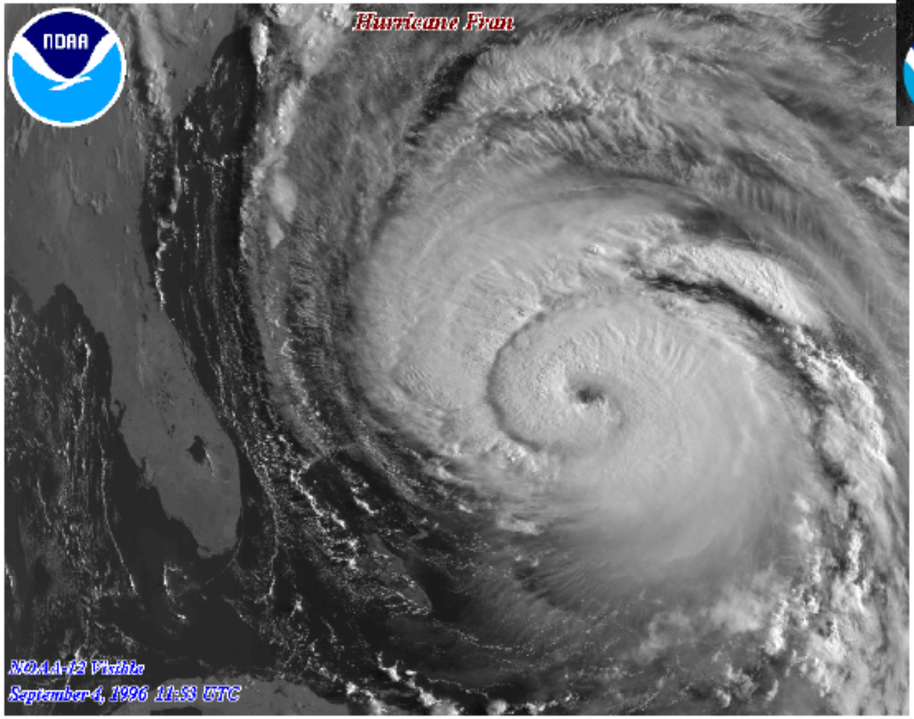
- Geostationary satellites known by acronym and satellite number.
  - Examples: GOES 8, METEOSAT 7
- LEO satellites known by acronym and satellite number,
- *Or by acronym of the sensor.*
- NOAA POES: NOAA # or AVHRR sensor
- DMSP: F# or sensors OLS, SSM/I, SSMIS.
- Aqua satellite or MODIS sensor
- TRMM or sensors VIRS, TMI

Read the Header

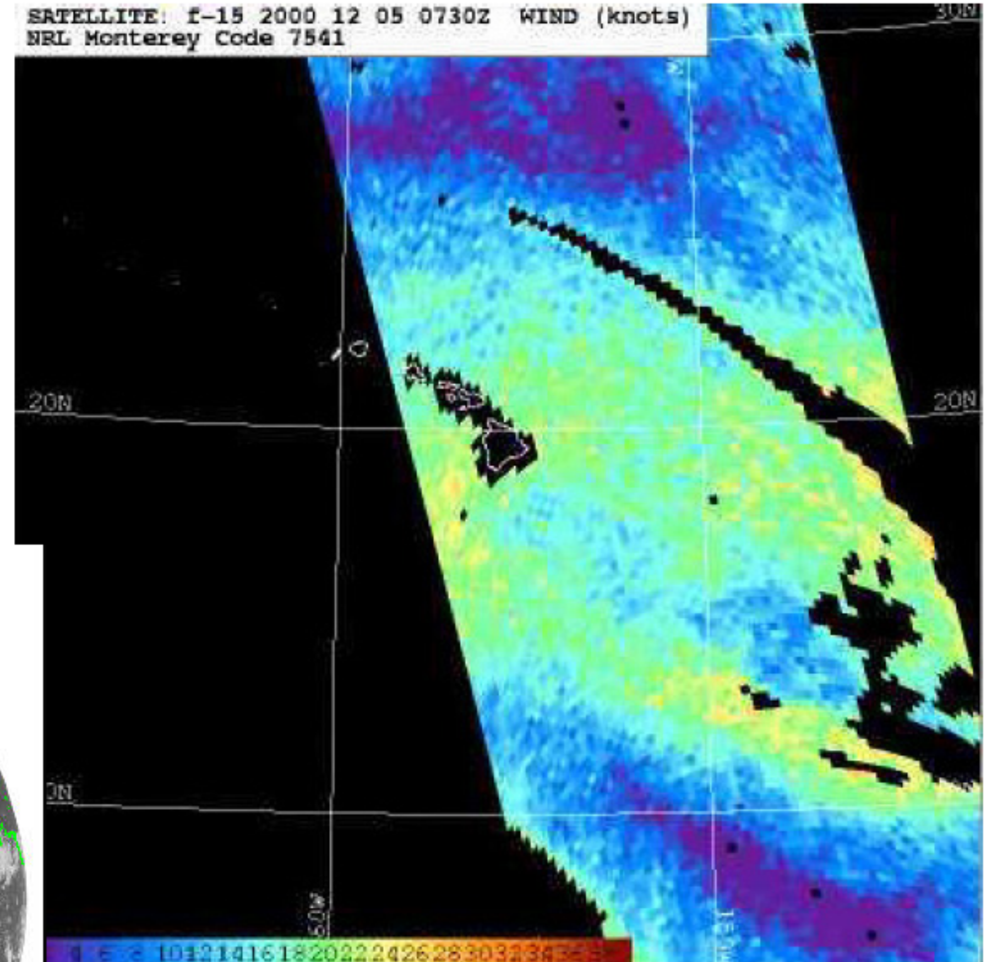


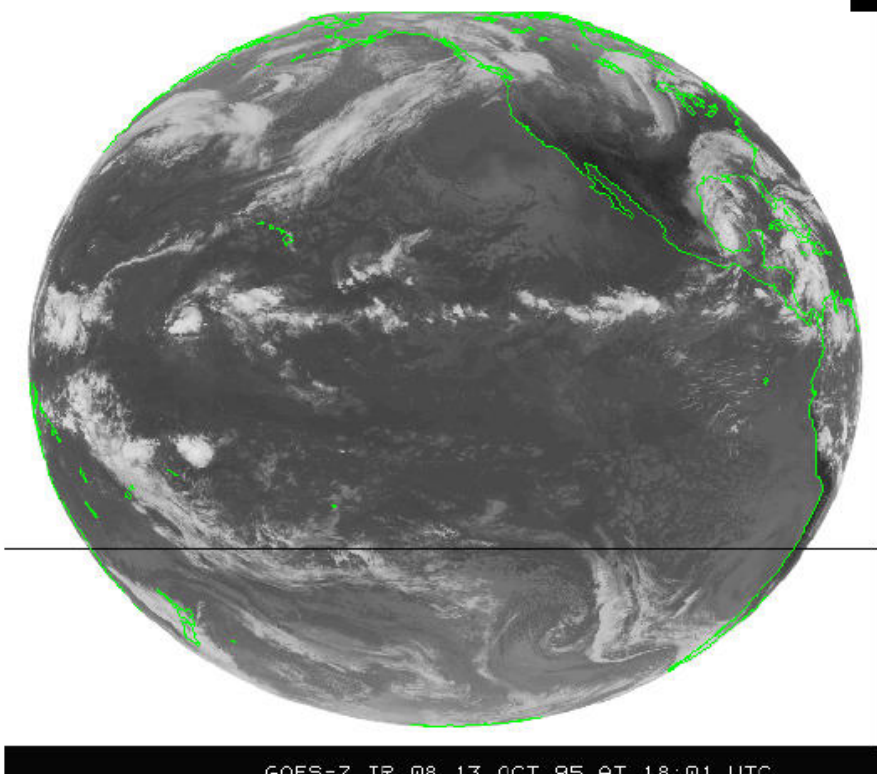
Read the Header



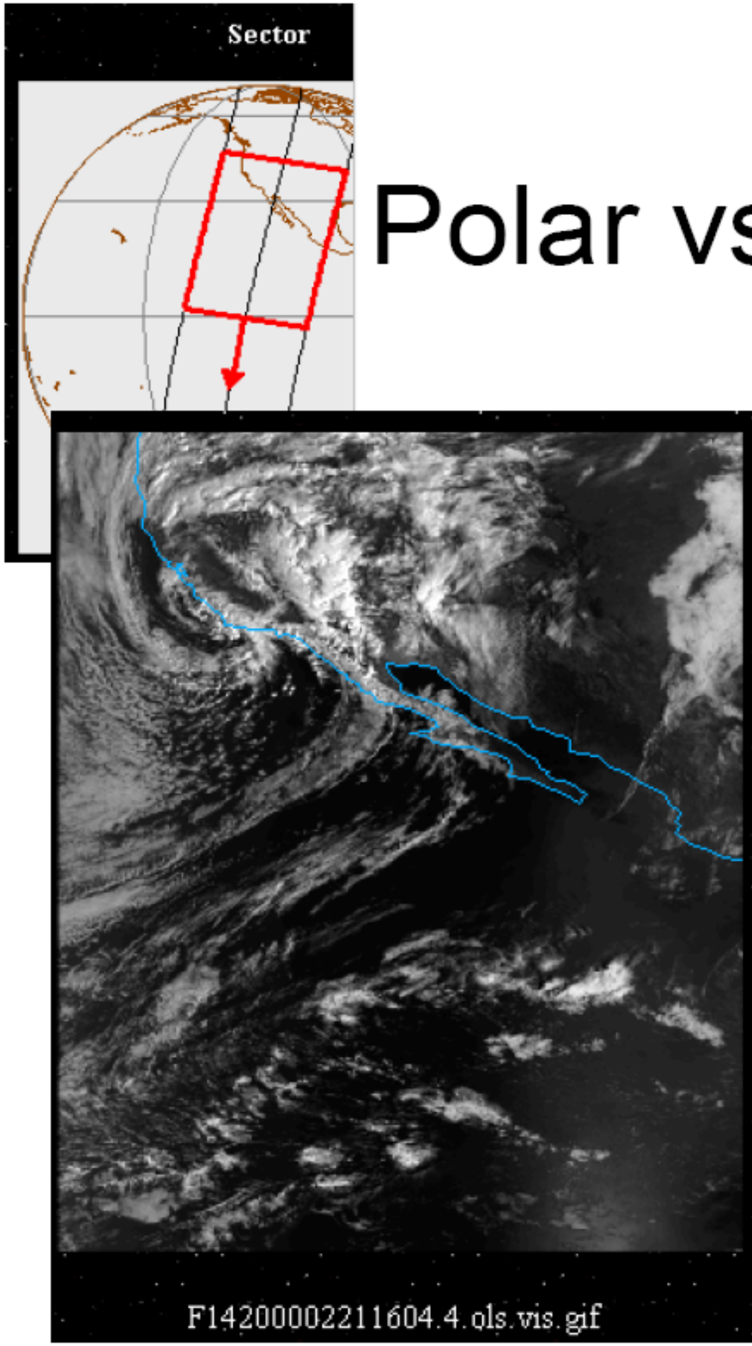


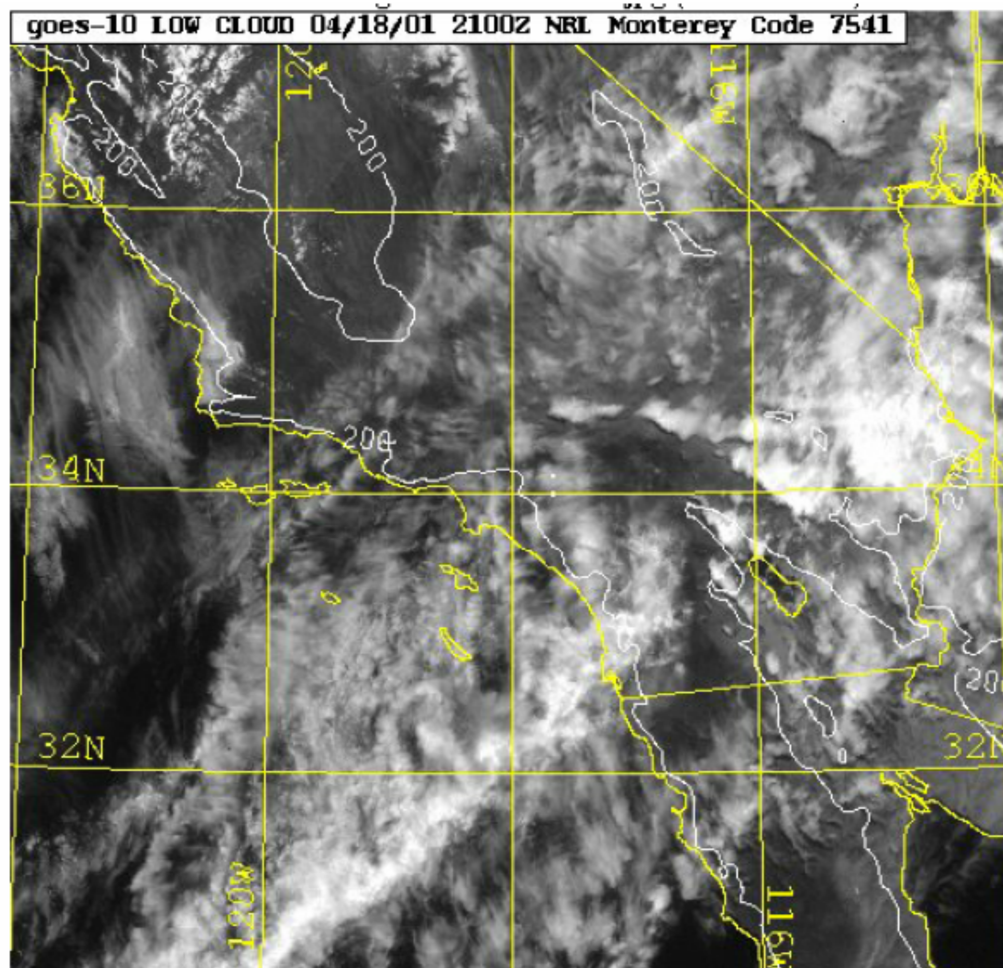
Areal Coverage





Polar vs. GOES Rapid Scan





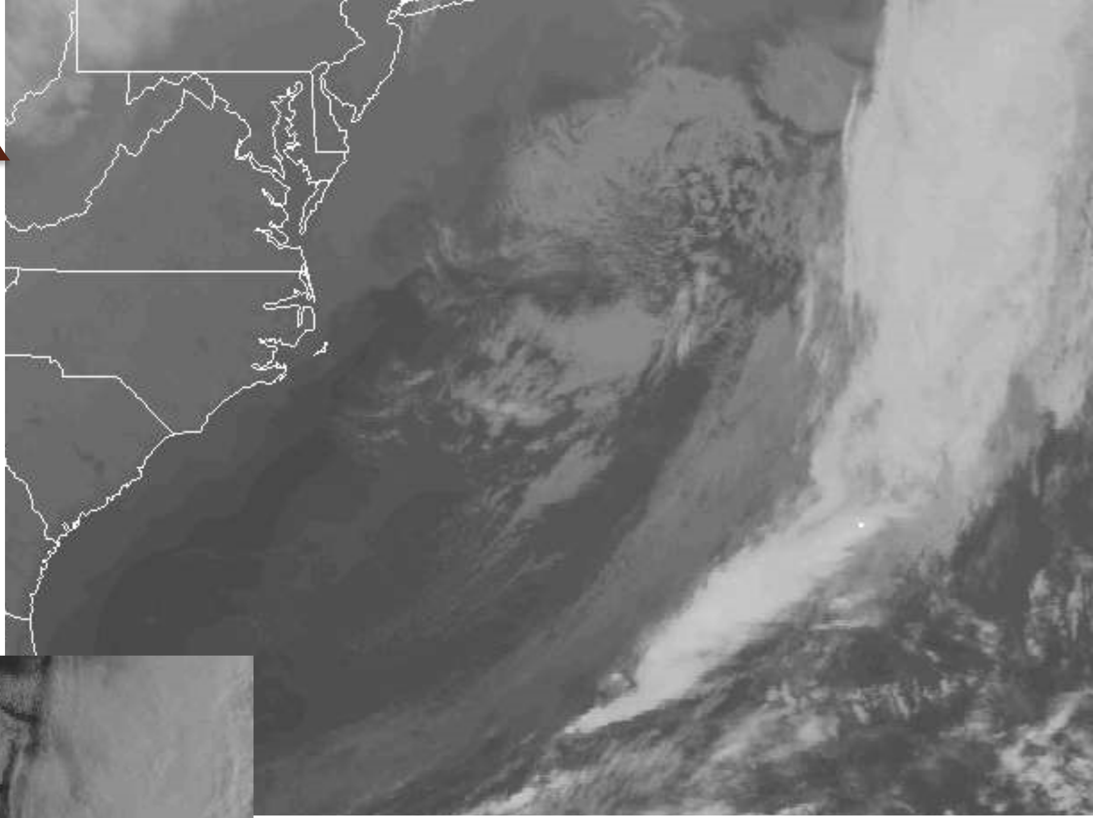
Distinguishing Different Image Types

Visible vs. IR

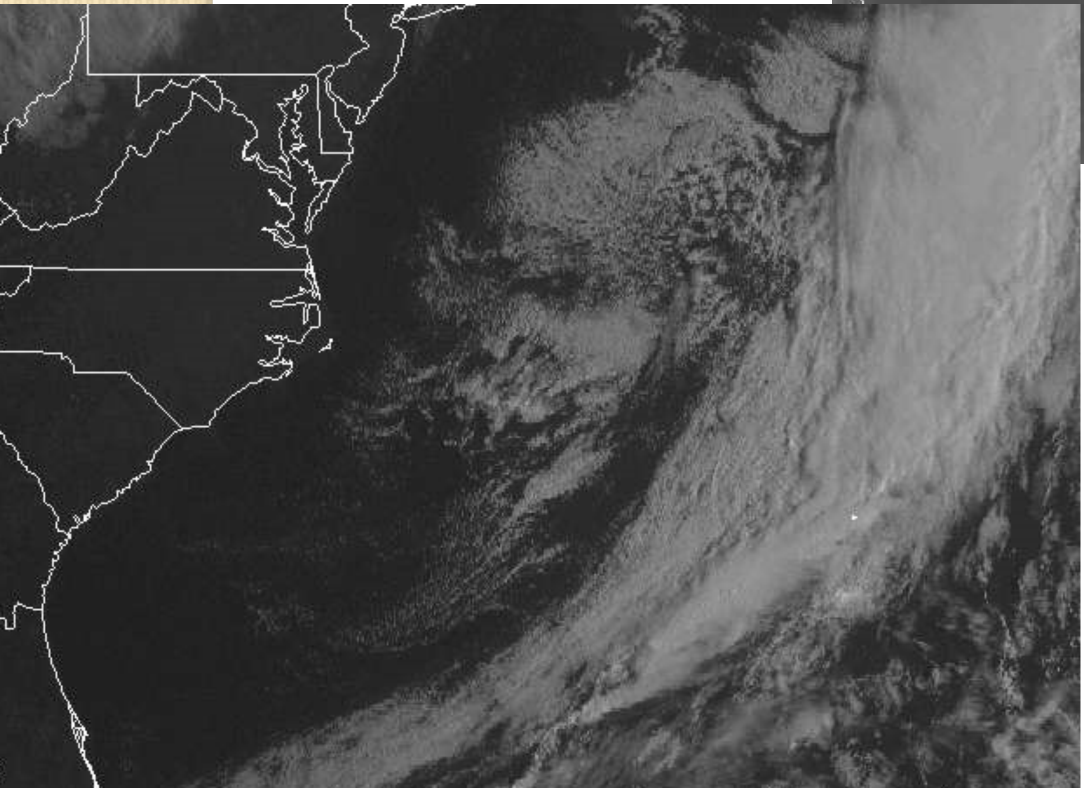
- Visible:
  - More clouds
  - More texture
  - Gray shades (usually)
- IR
  - Nighttime coverage*
  - Often color or BW enhanced

*DMSP exception

IR



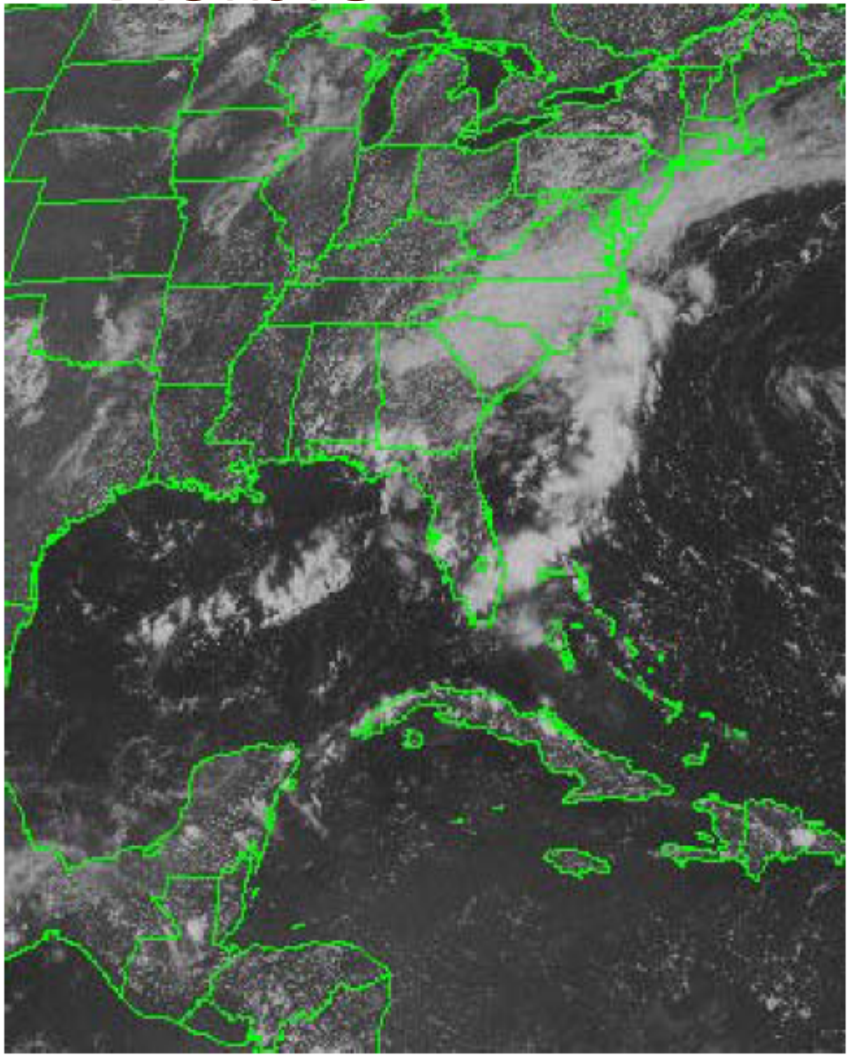
Visible



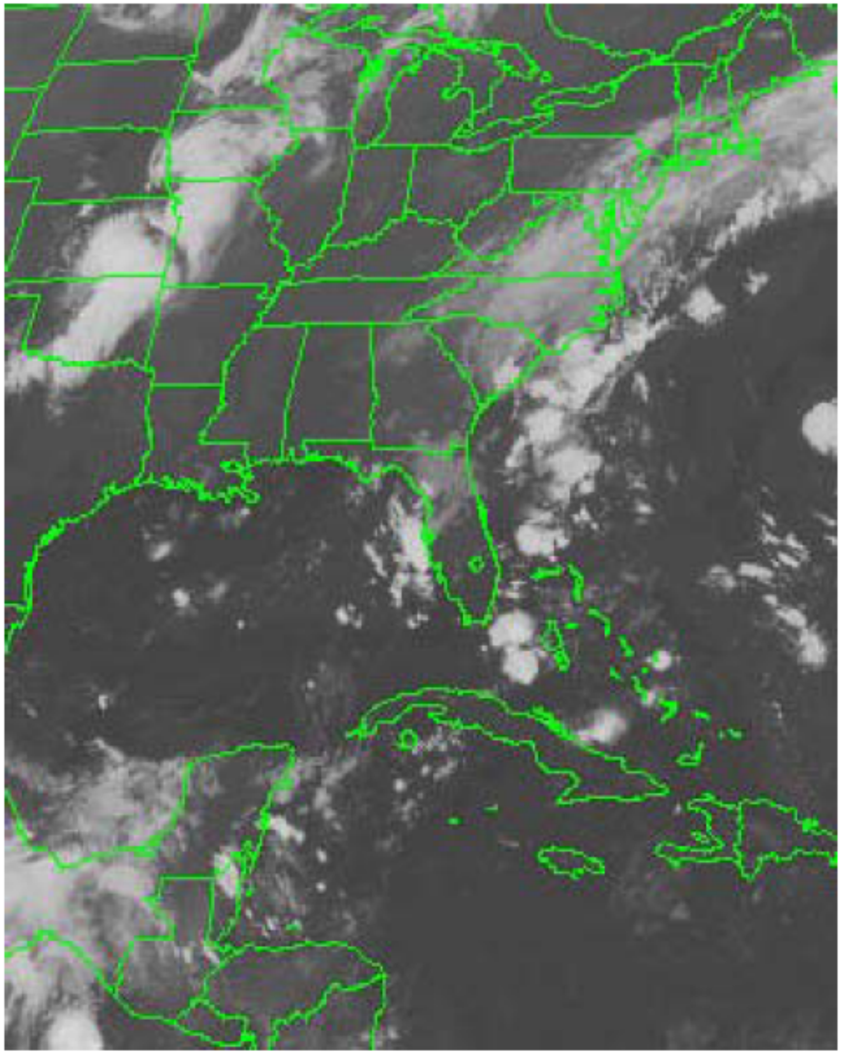
US East Coast, 12:15 UTC (7:15 local time), Apr. 6, 2011

More Clouds

Visible

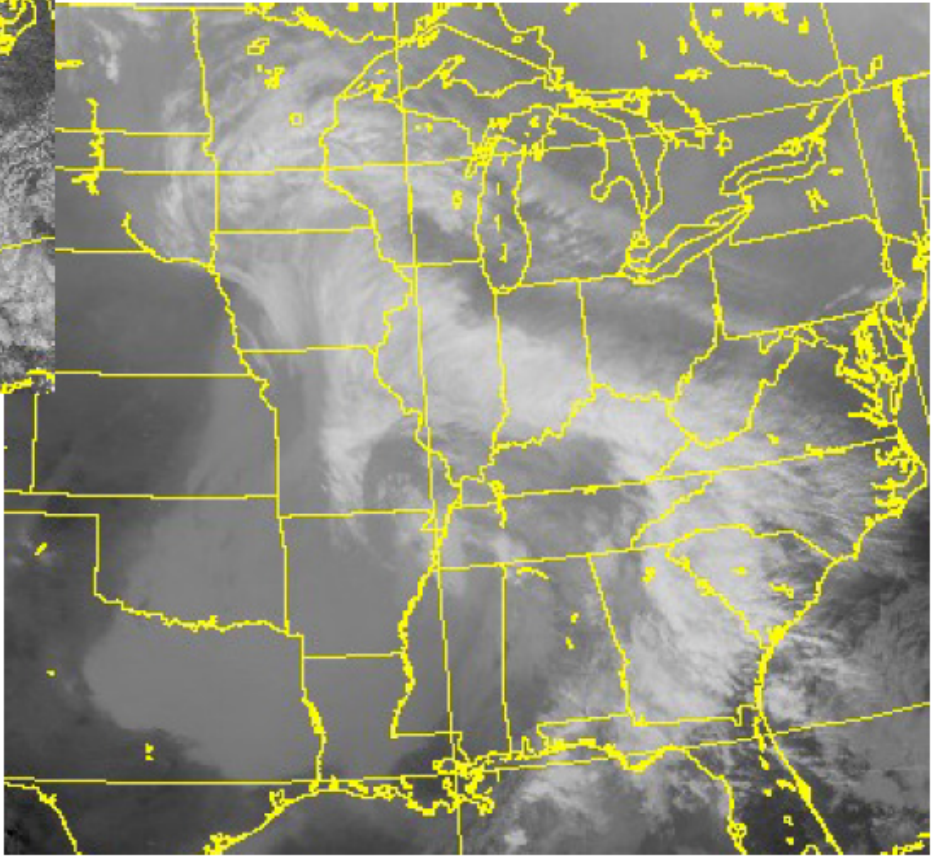


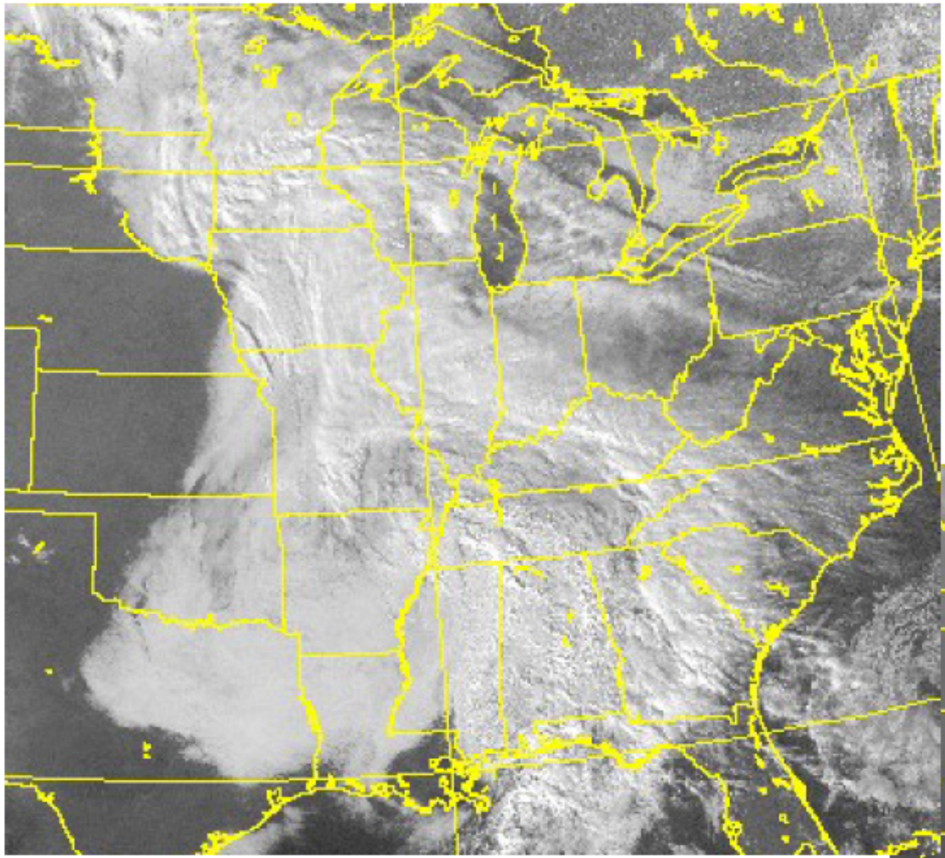
IR



More Texture

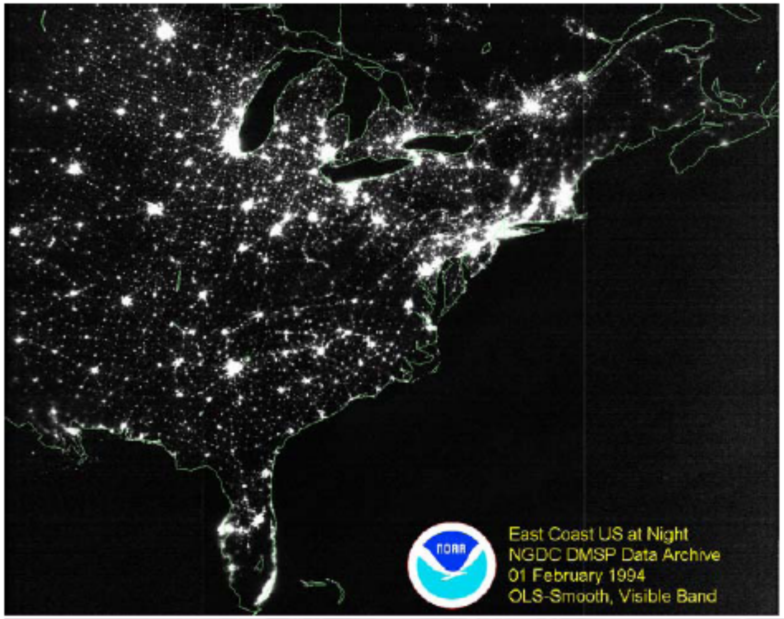
IR

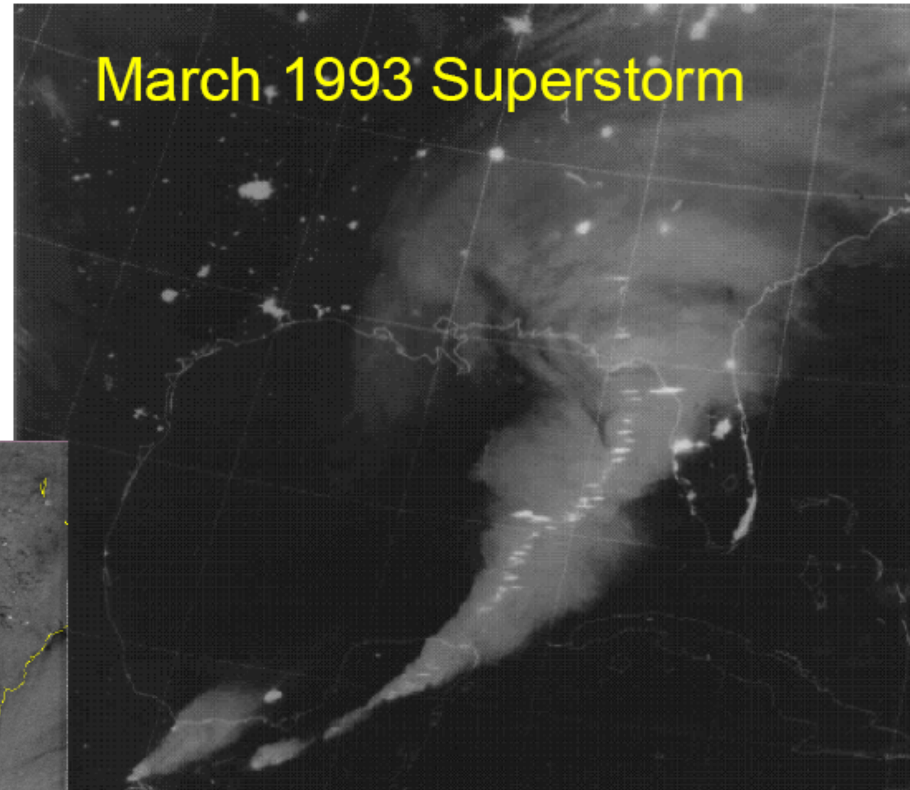


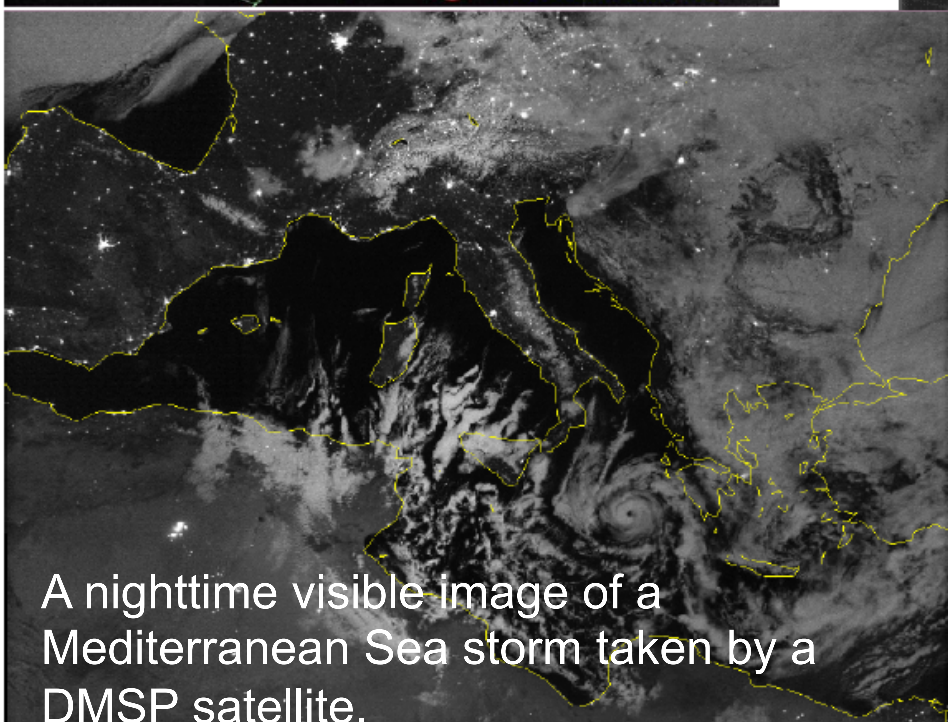


Visible

The DMSP Exception

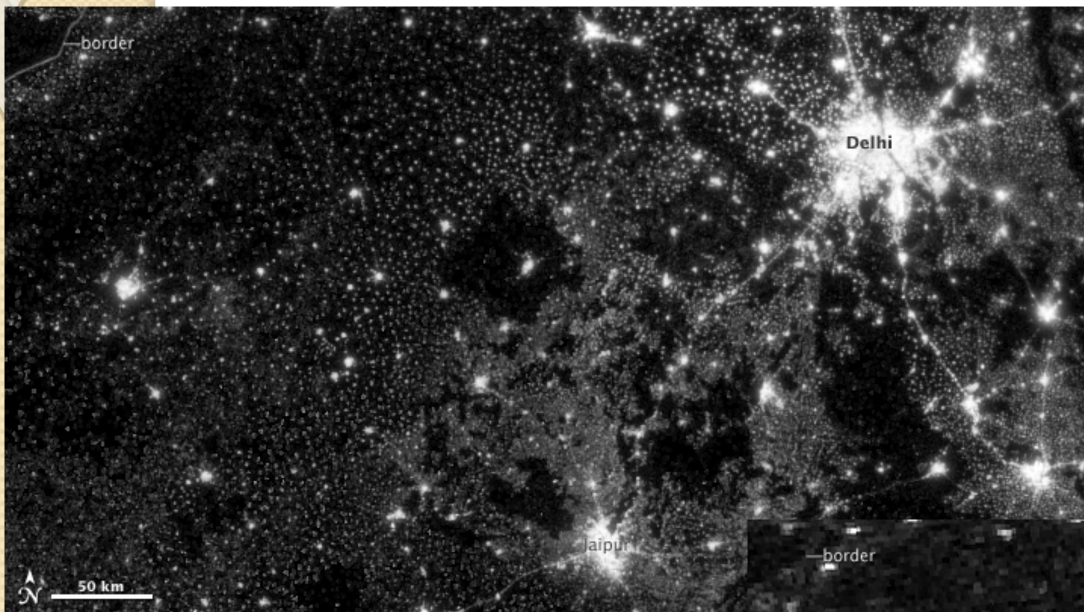




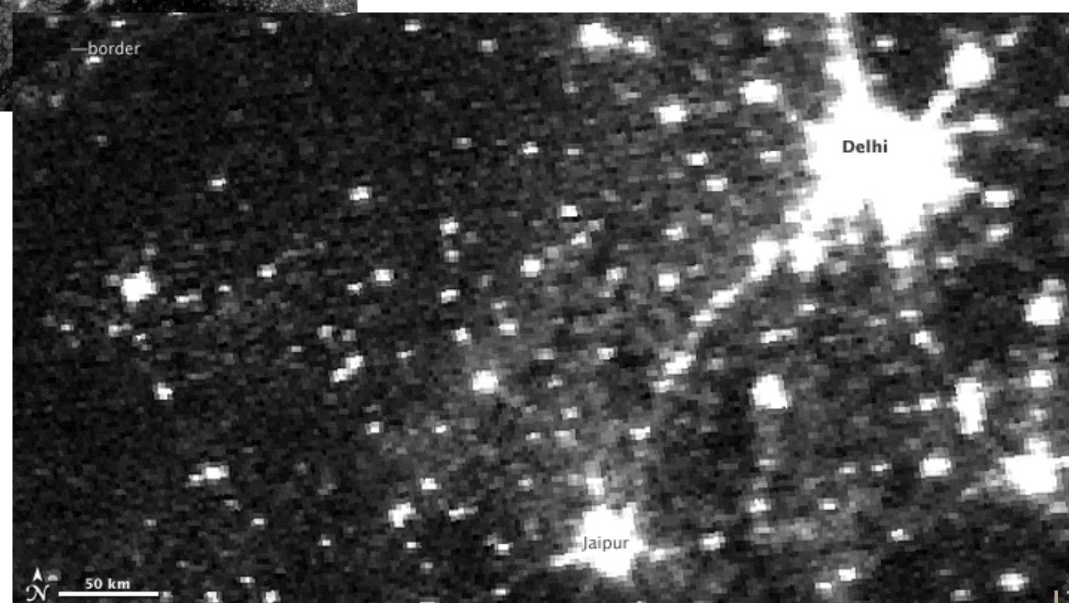

A nighttime visible image of a Mediterranean Sea storm taken by a DMSP satellite.

The DMSP OLS has a *photomultiplier tube* that acts like night vision goggles.

New NASA VIIRS "Day-Night Band" on Suomi NPP satellite launched in 2012

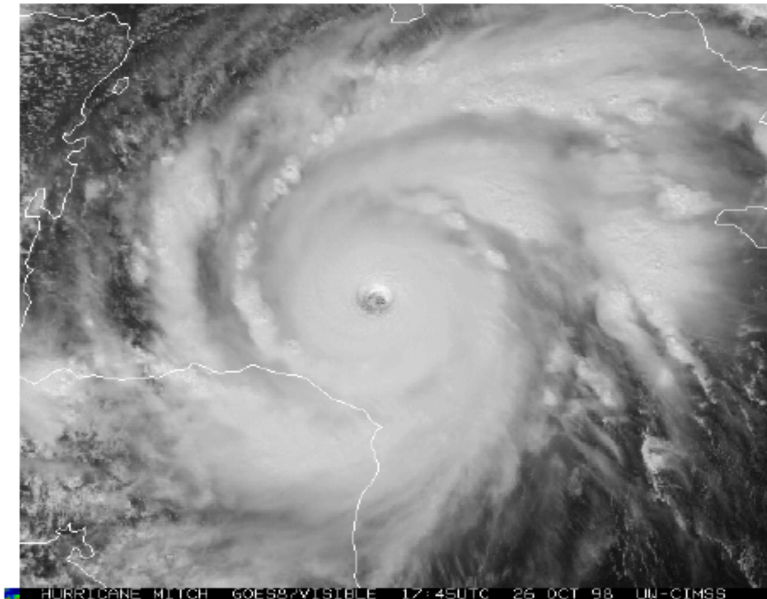


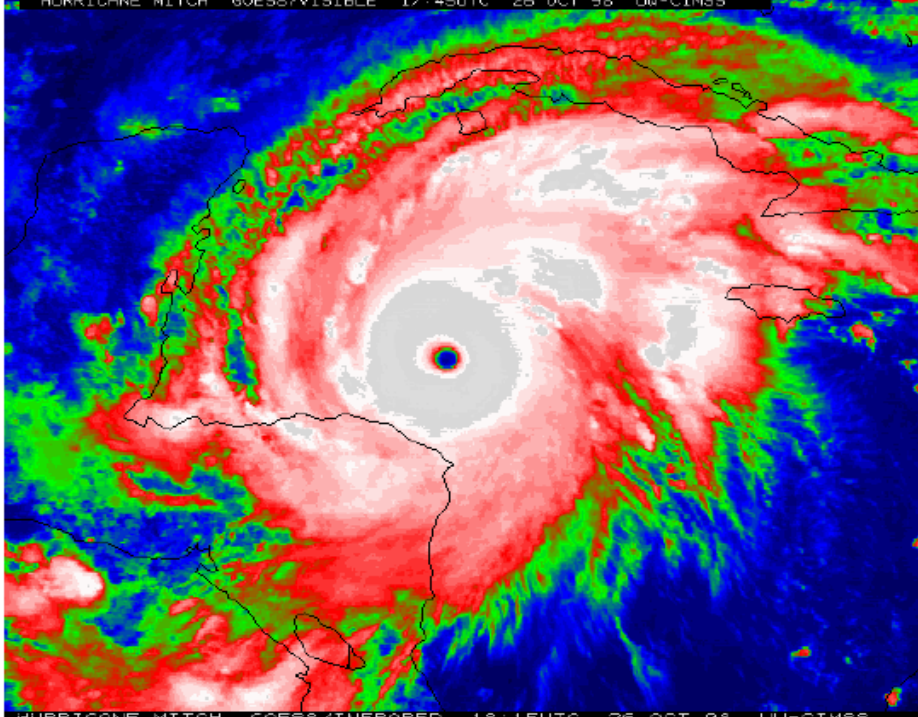
NASA VIIRS DNB: city, village, and highway lights near Delhi, India at Nov. 12, 2012 (742 m^2 resolution)

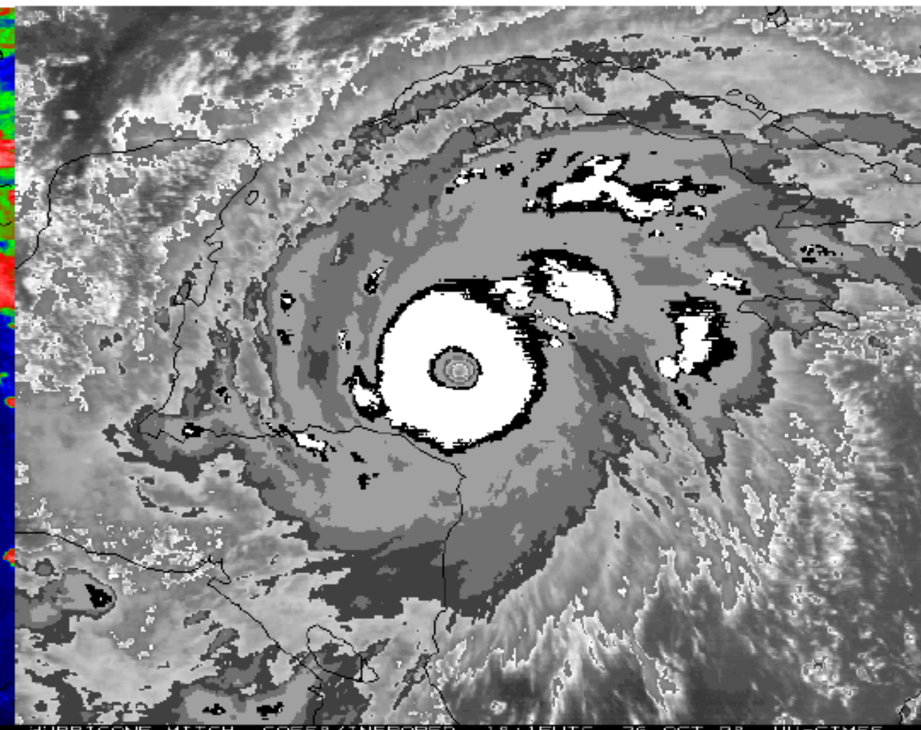


Same Area one night earlier by DMSP OLS (5 km^2 resolution)

Enhancement

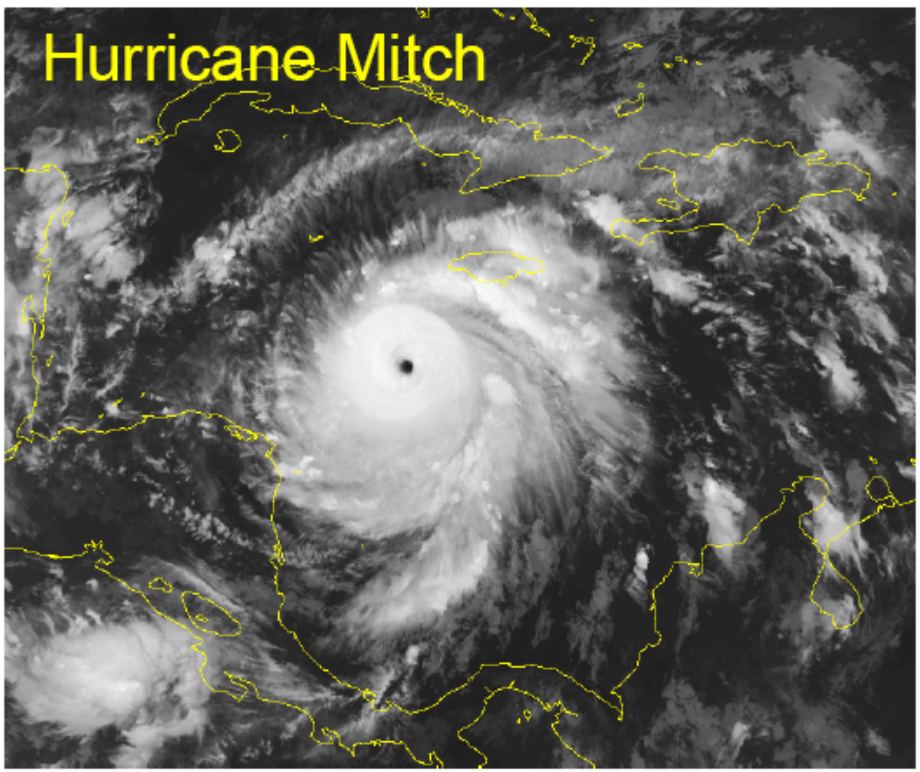




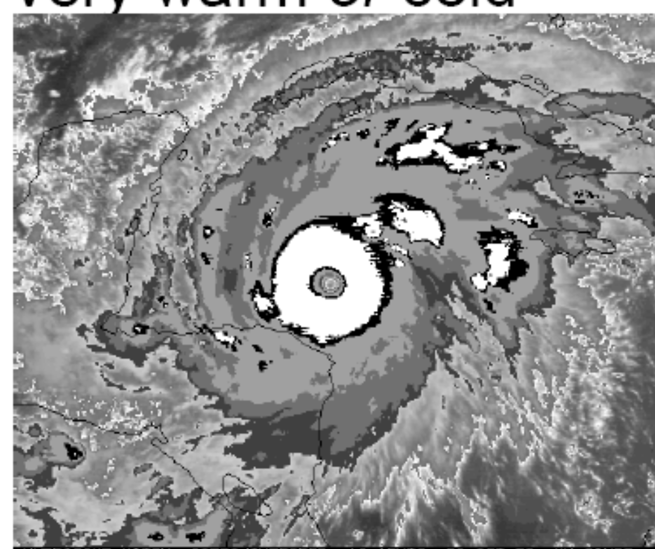


Gray Shades vs. BW Enhance

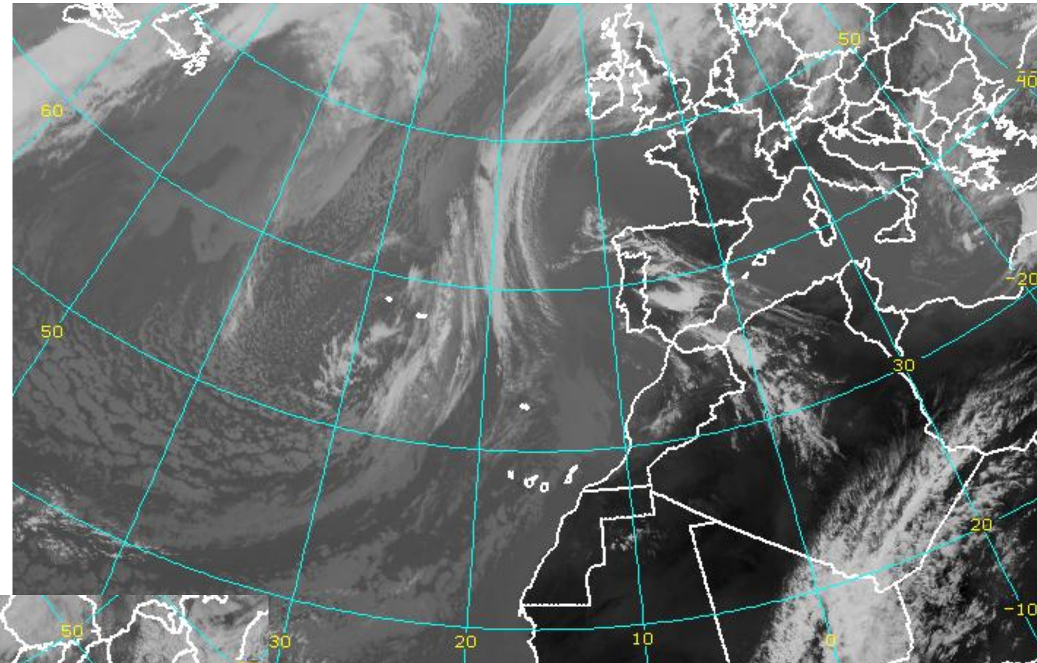
- Continuous tones from black (warm) to white (cold)



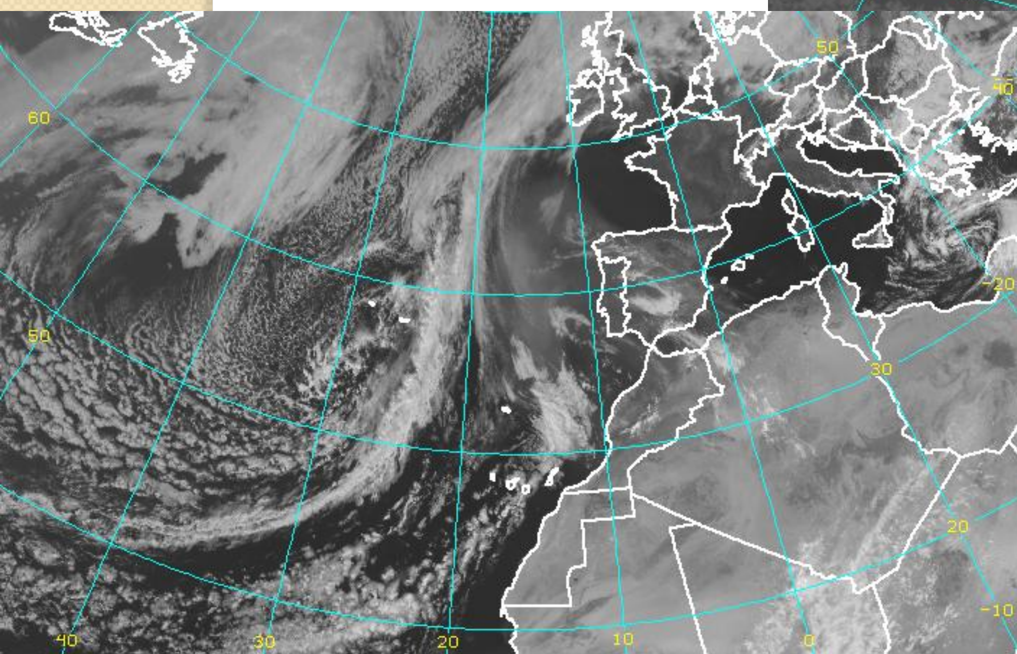
- Discrete tones (levels) corresponding to specific temperature ranges
- Requires a lookup table for interpretation
  - Black may correspond to very warm *or* cold



Example 1 (12:00UTC Apr. 6, 2011, METEOSAT-9)



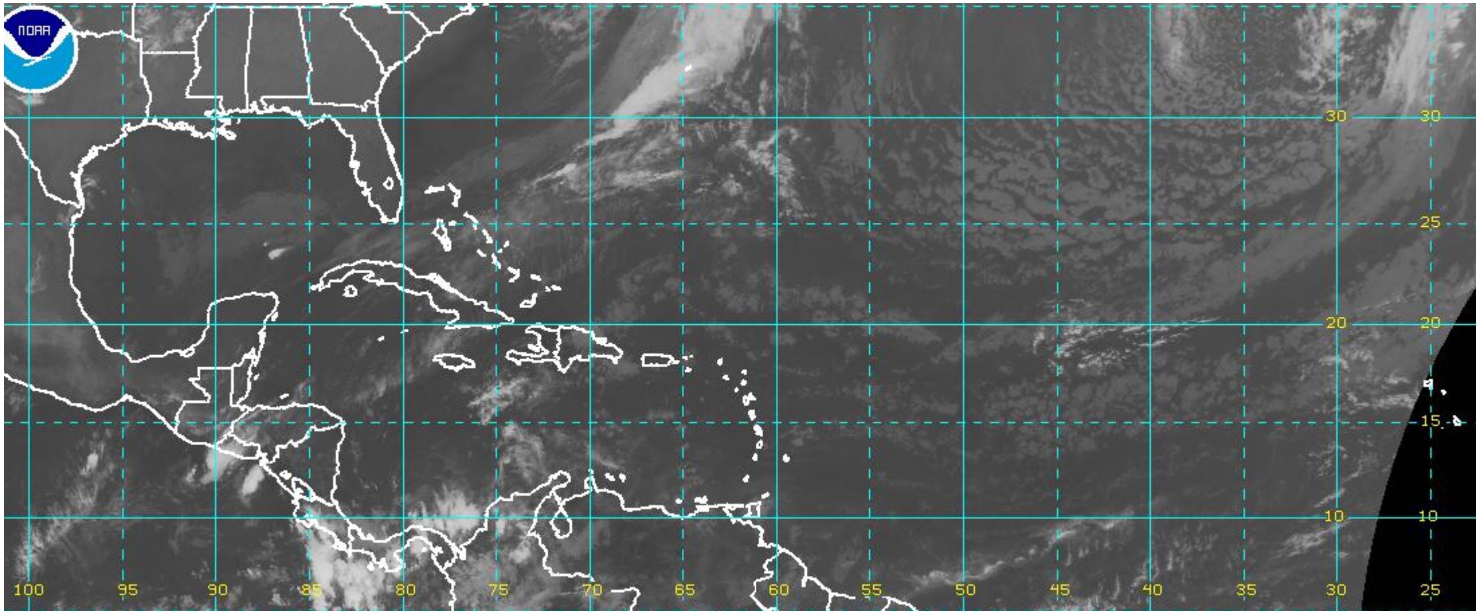
Visible



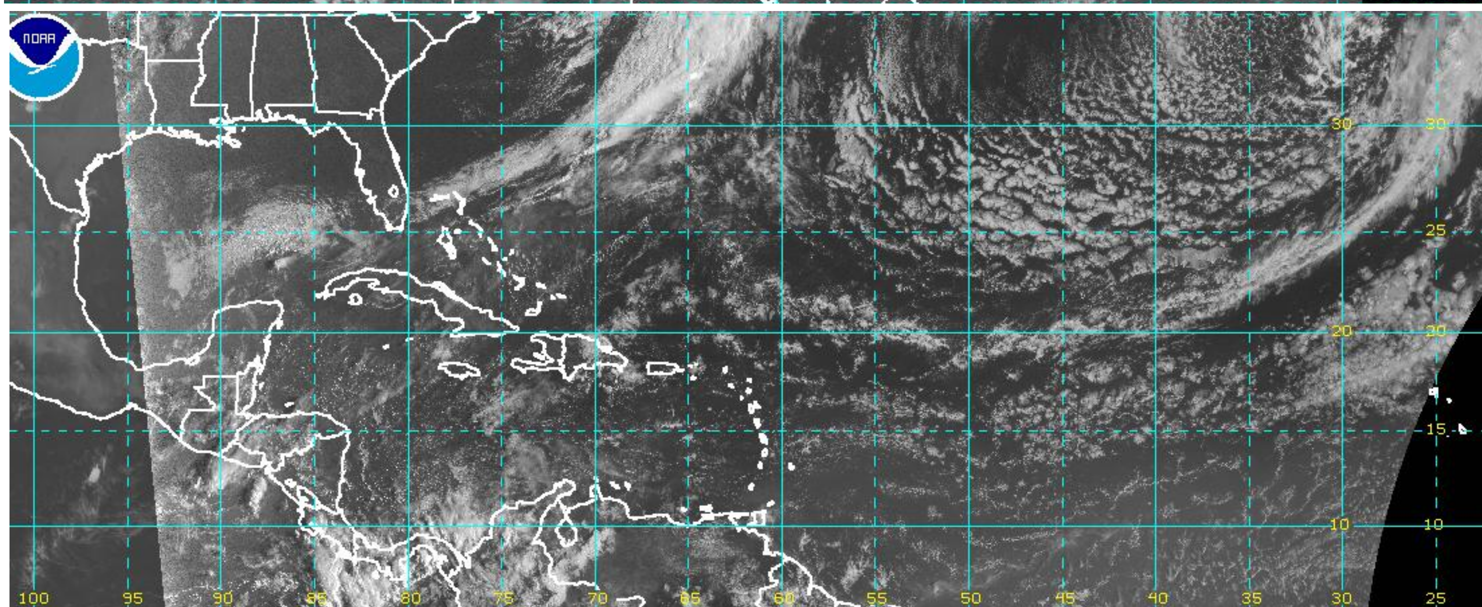
IR

Example 2 (12:45UTC Apr. 6, 2011, GOES East)

IR

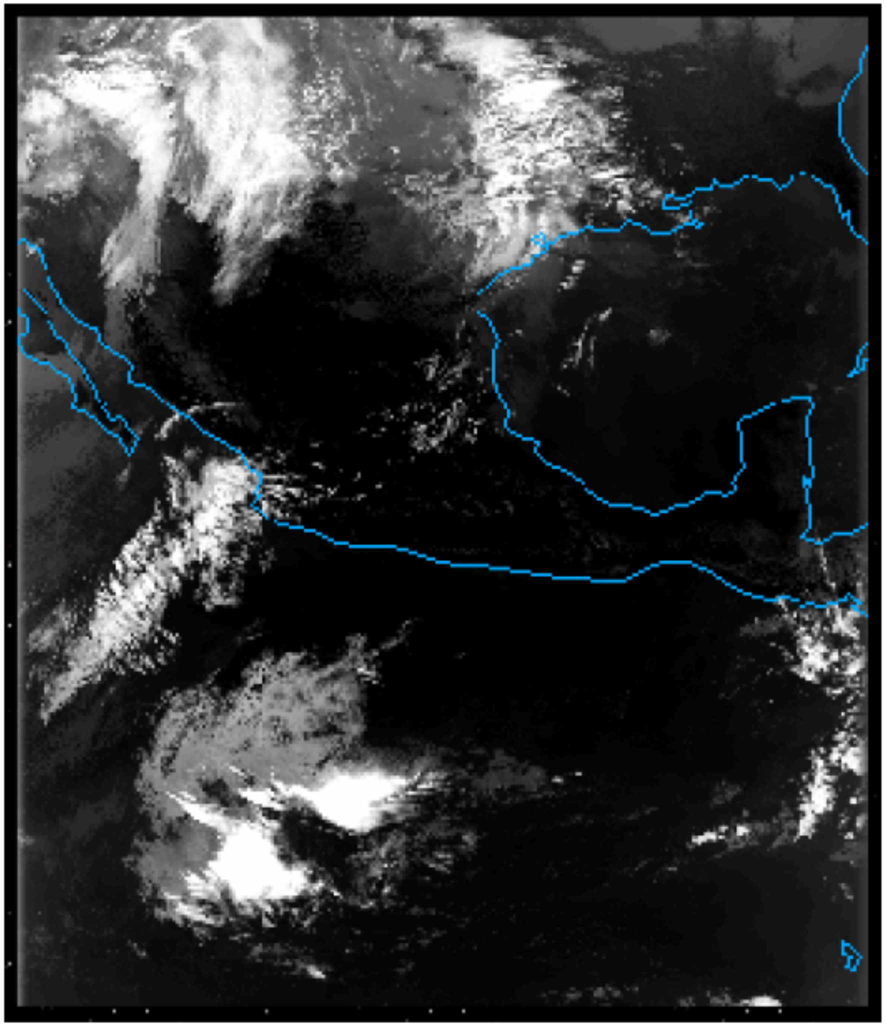


Visible

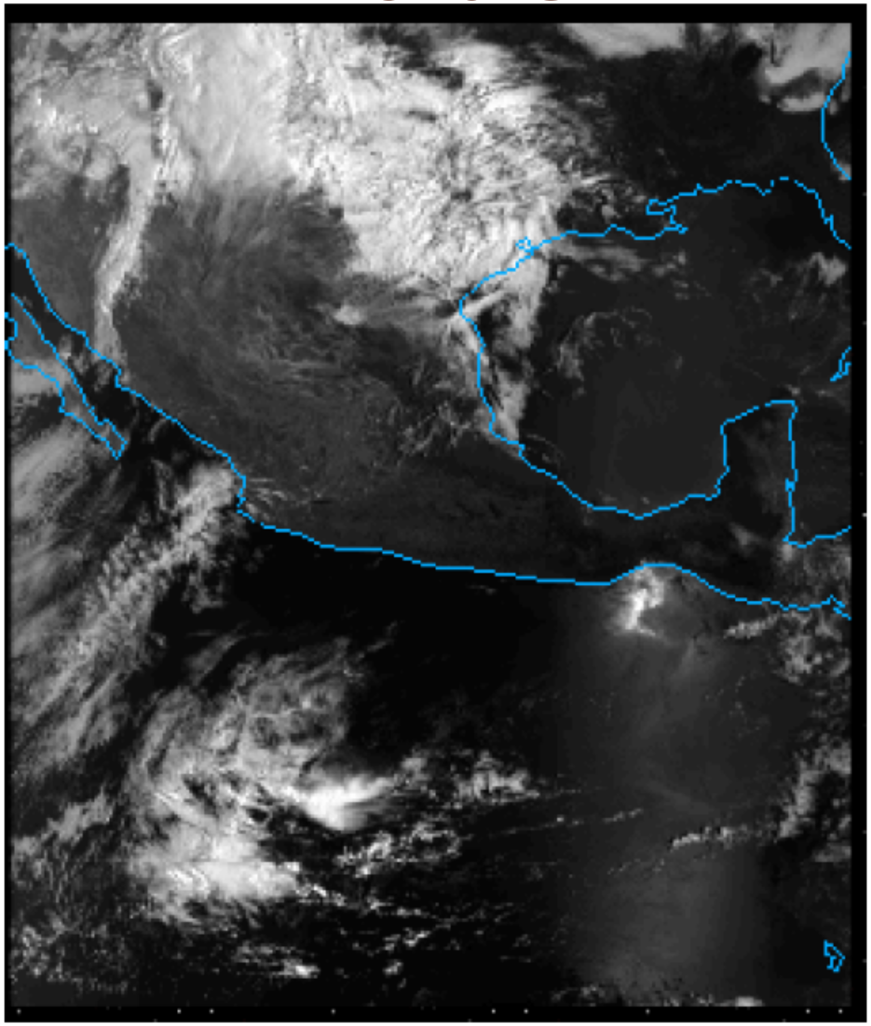


Guess?

IR

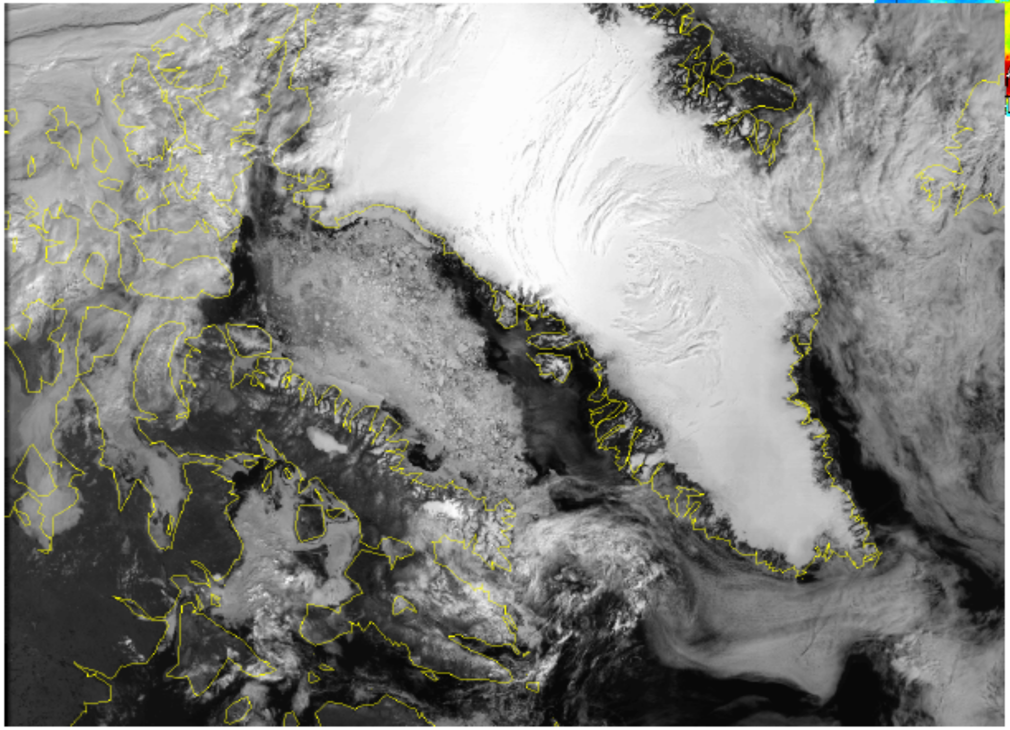


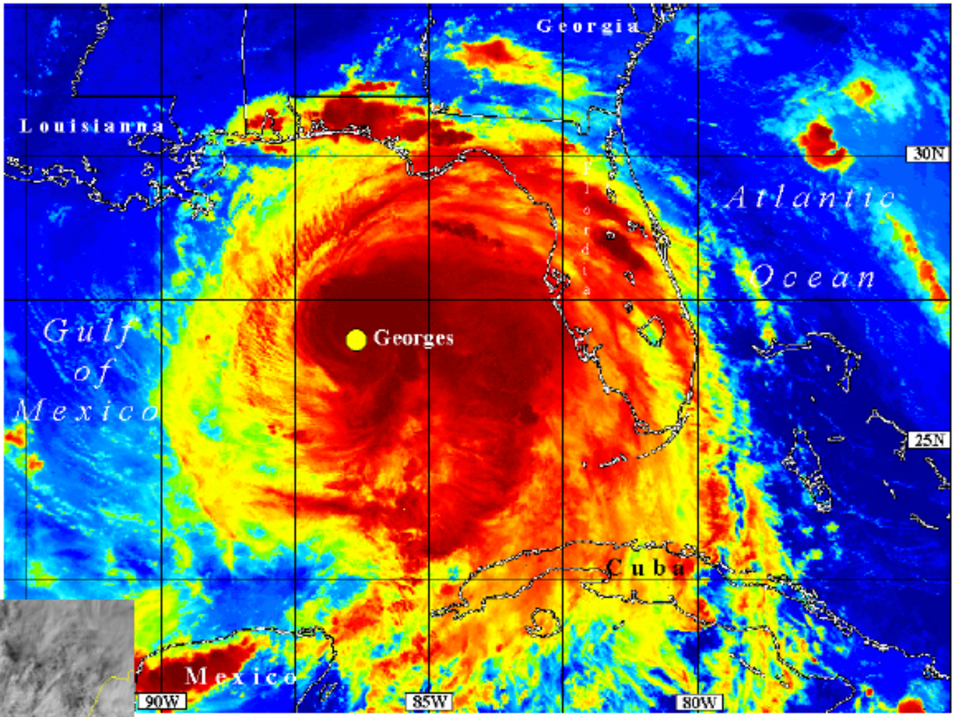
Visible



Guess?

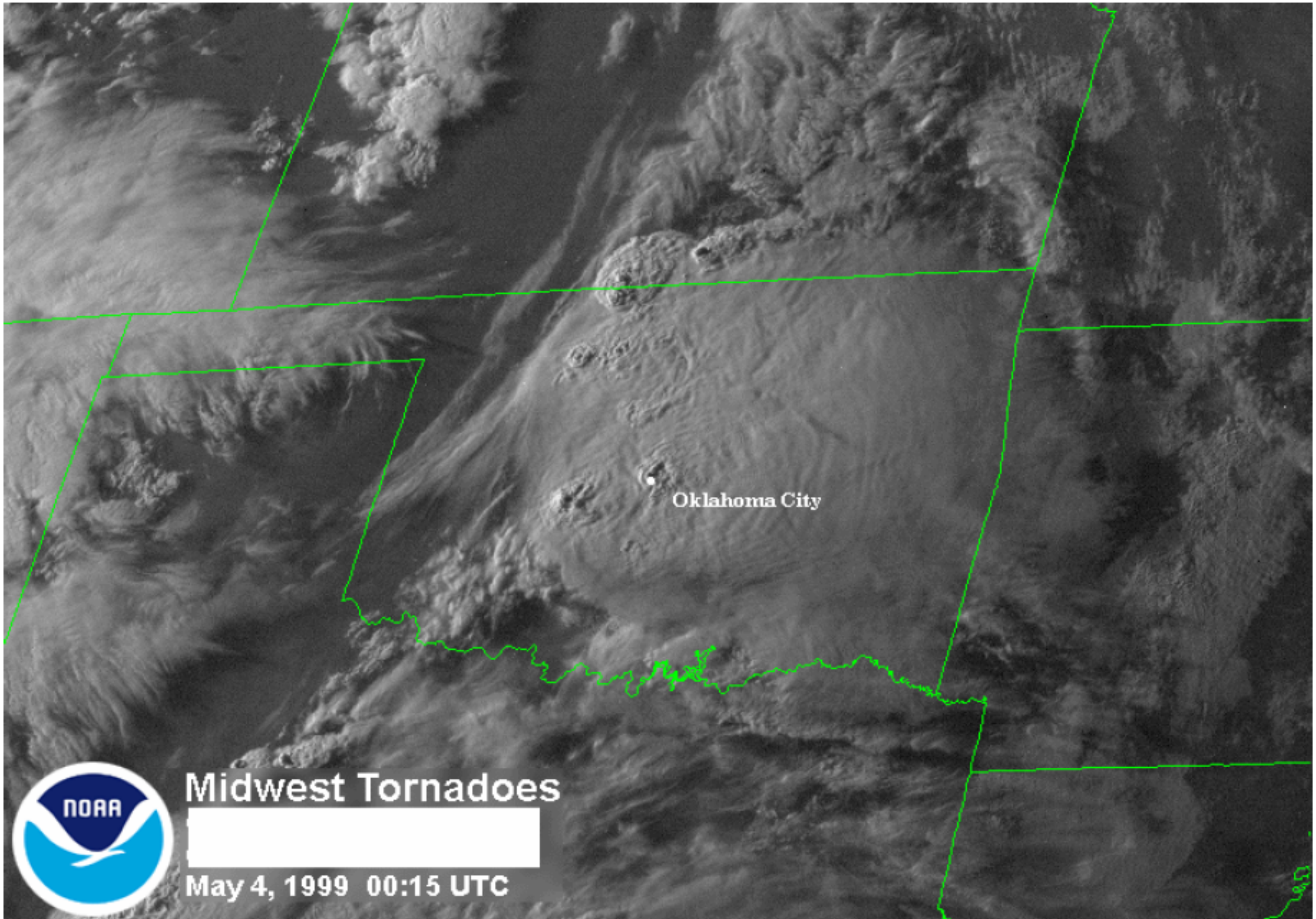
Visible



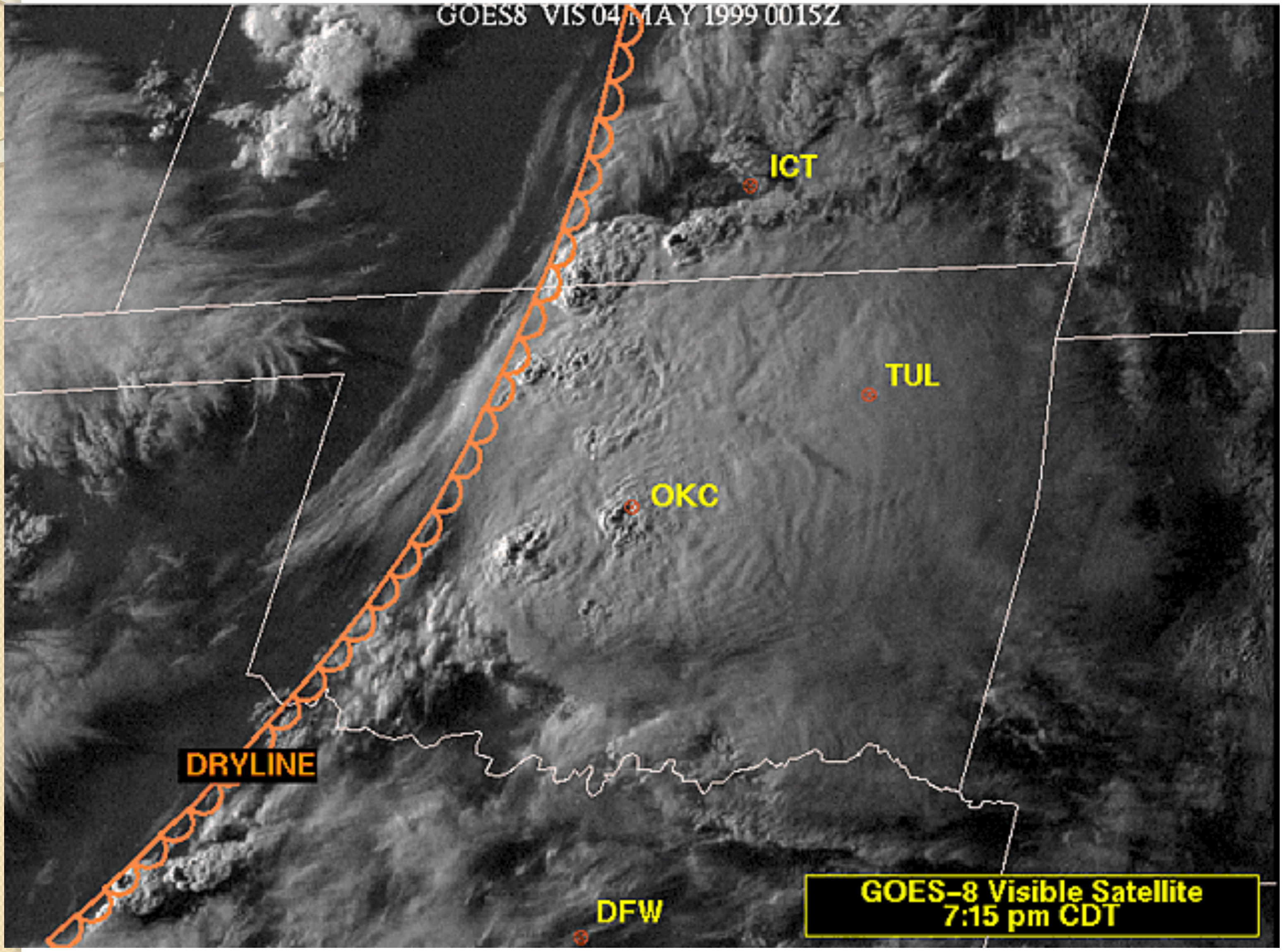


IR

Guess?

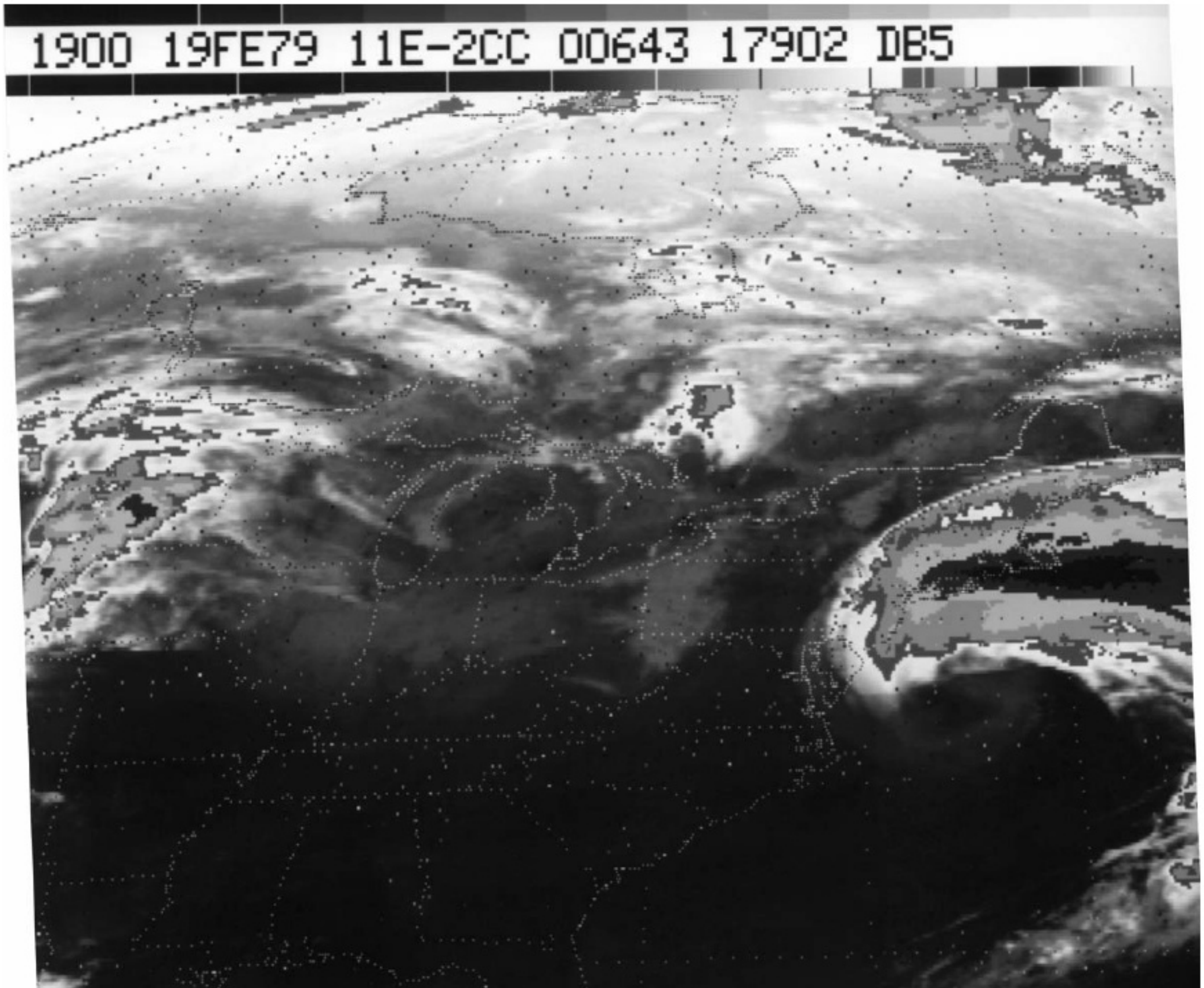


Answer!


GOES8 VIS 04 MAY 1999 0015Z
ICT
TUL
OKC
DRYLINE
DFW
GOES-8 Visible Satellite
7:15 pm CDT

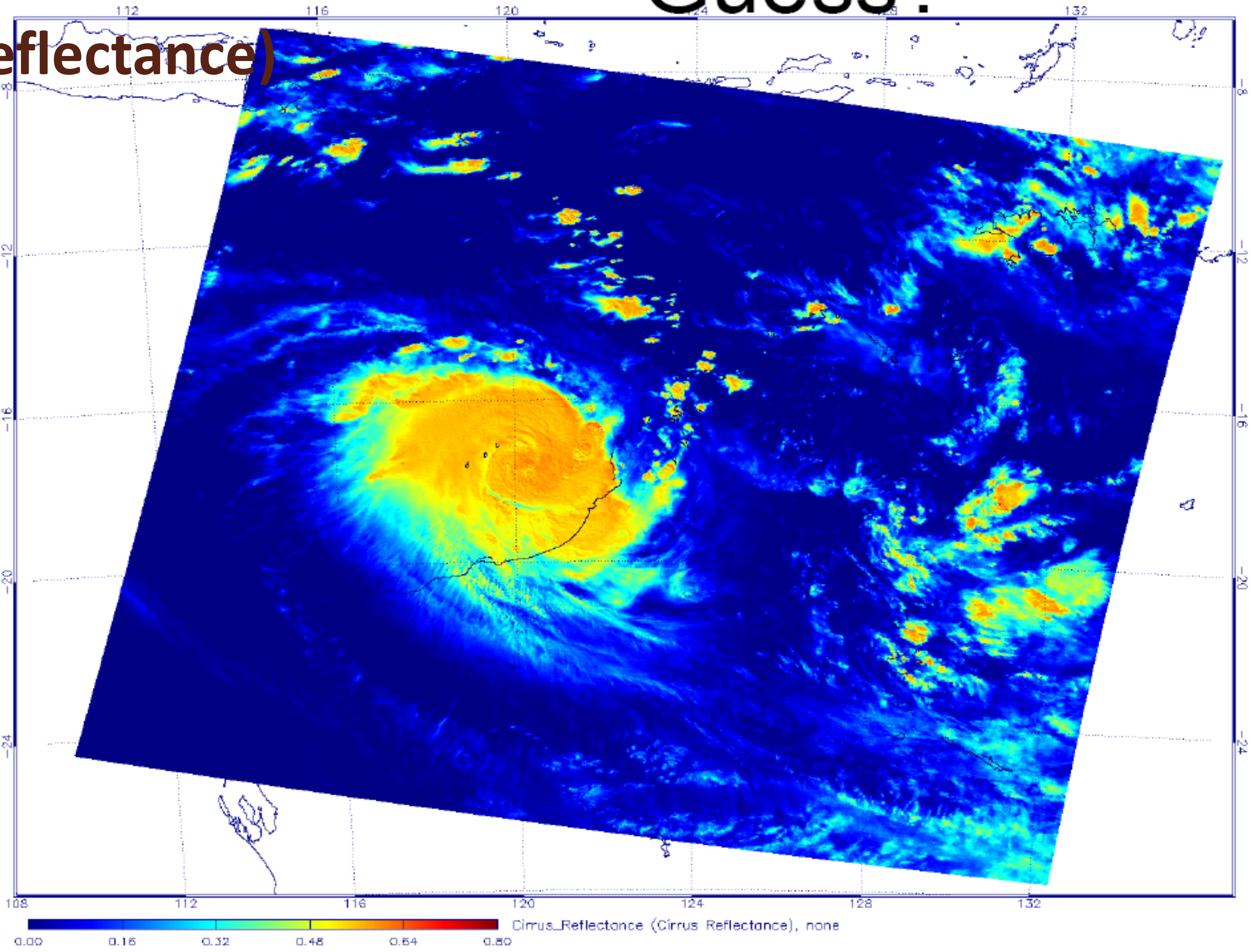
Guess?

IR



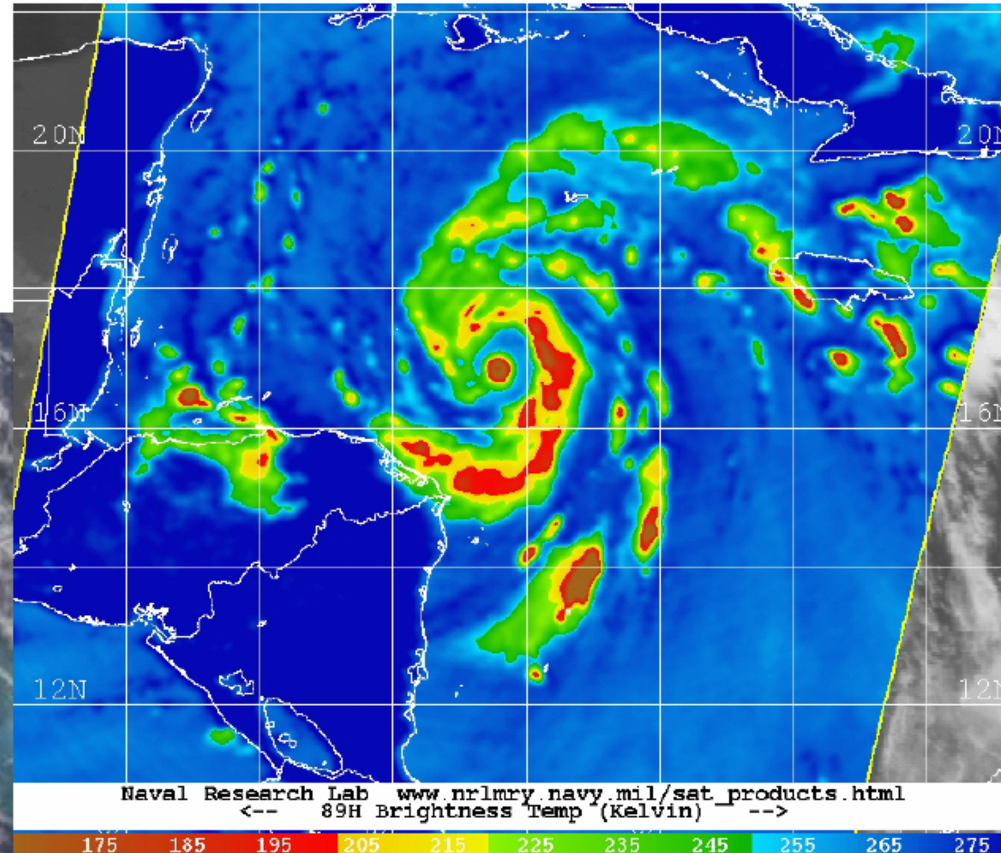
Visible (reflectance)

Guess?



Guess?

IR



Microwave-

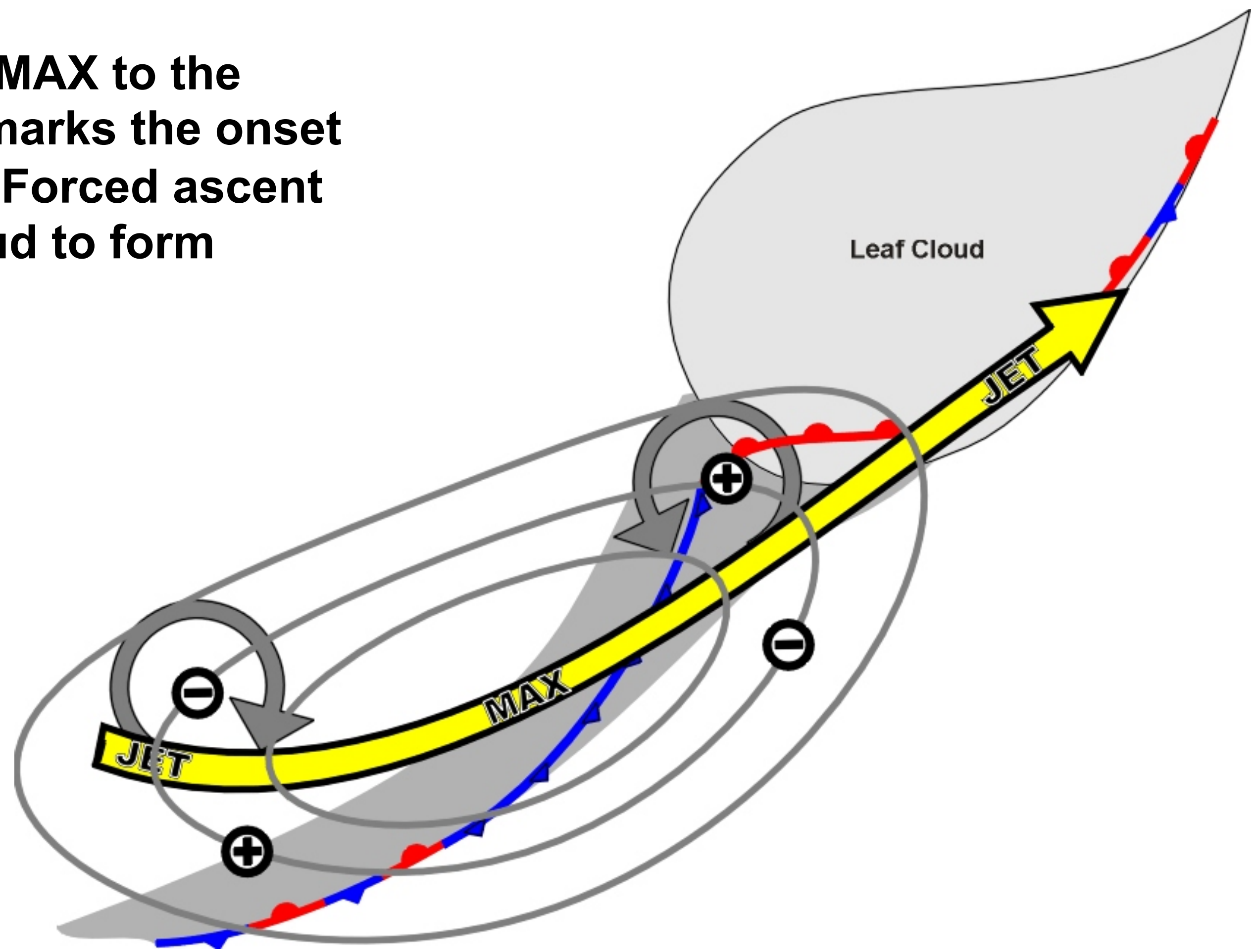
89 GHz Brightness Temperature

Identifying Weather Systems

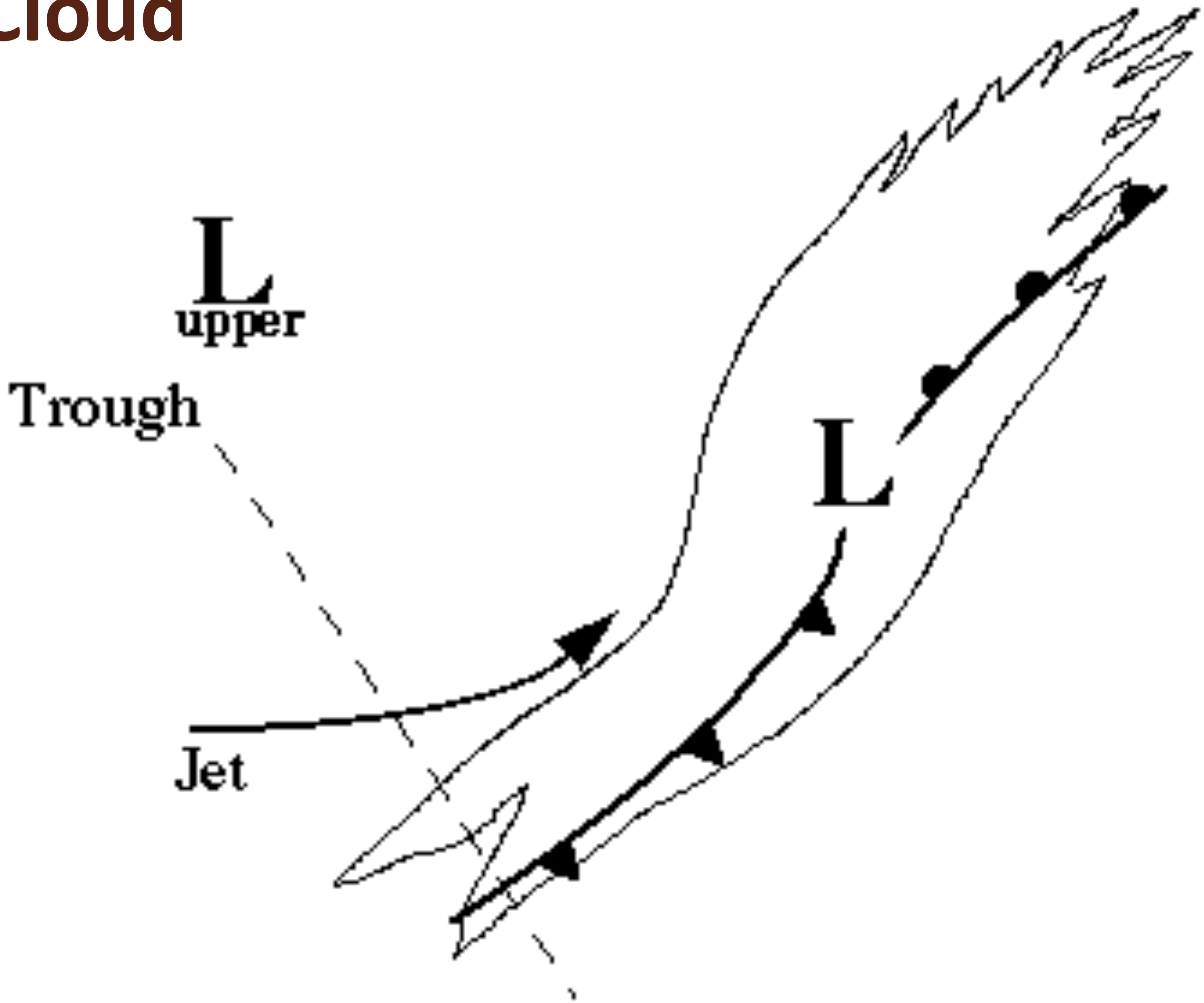
- Mid-latitude Cyclones: four stages
  - Perturbation stage: leaf cloud
  - Open wave stage: open comma cloud
  - Mature/occlussion stage: comma cloud
  - Shearing stage
- Hurricanes – Dvorak technique
- Short waves (lows)
- Surface highs and ridges

Mid-latitude cyclone: Perturbation stage & Leaf Cloud

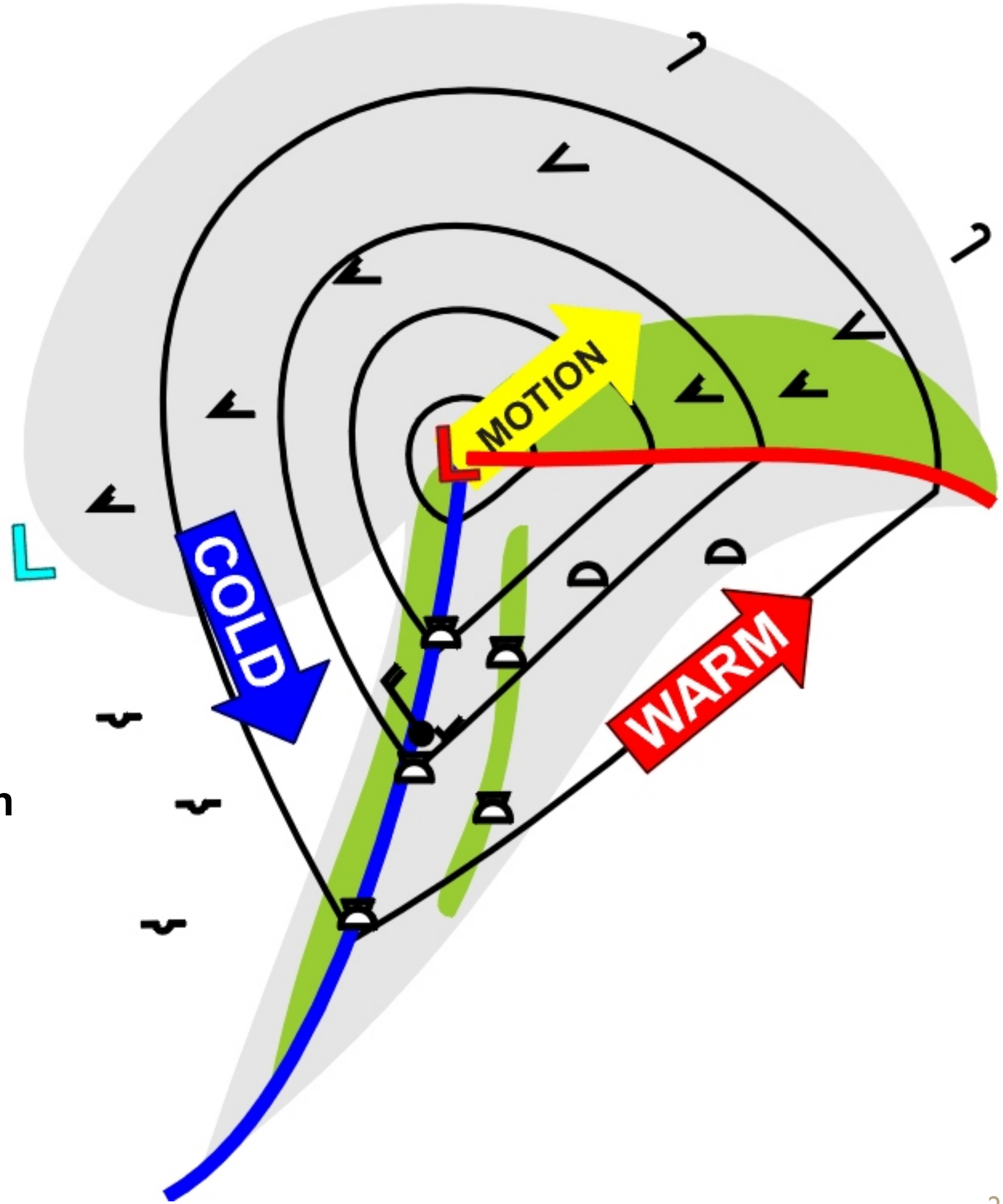
Approach of Jet MAX to the baroclinic zone marks the onset of cyclogenesis. Forced ascent causes Leaf Cloud to form



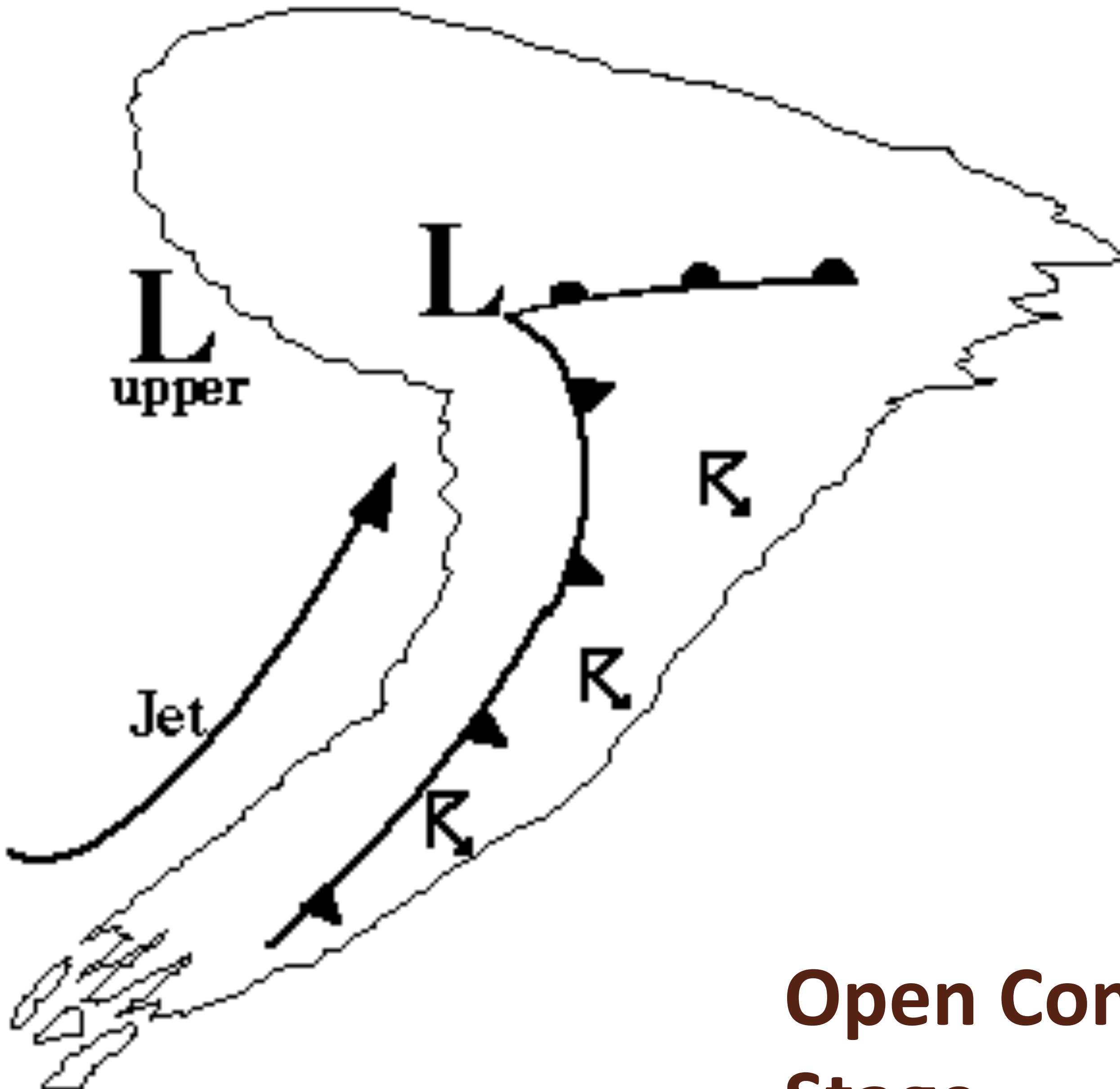
Leaf Cloud



Mid-latitude cyclone: Open Wave & Comma Cloud

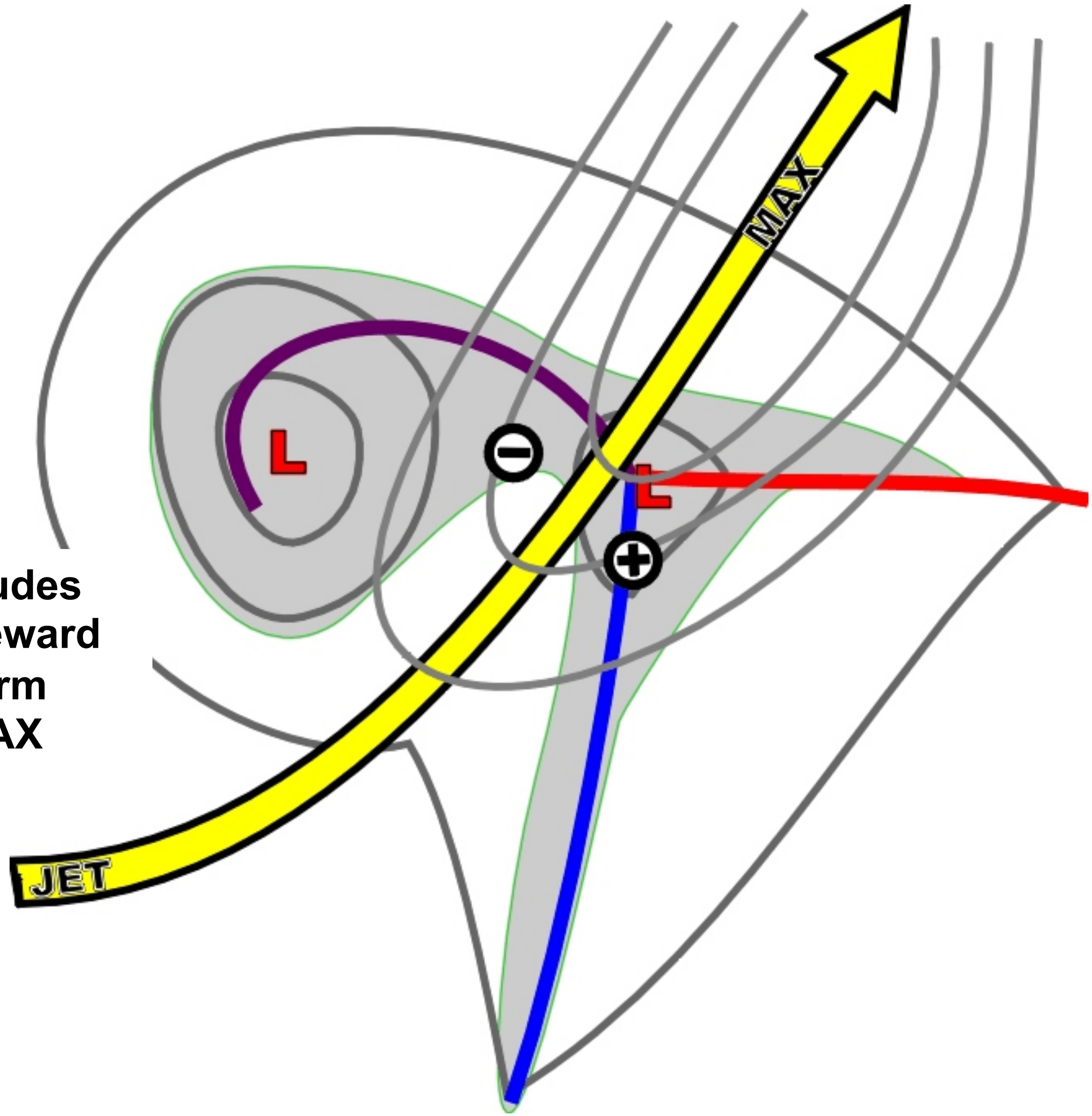


Leaf cloud becomes a comma cloud as the open wave intensifies through baroclinic instability

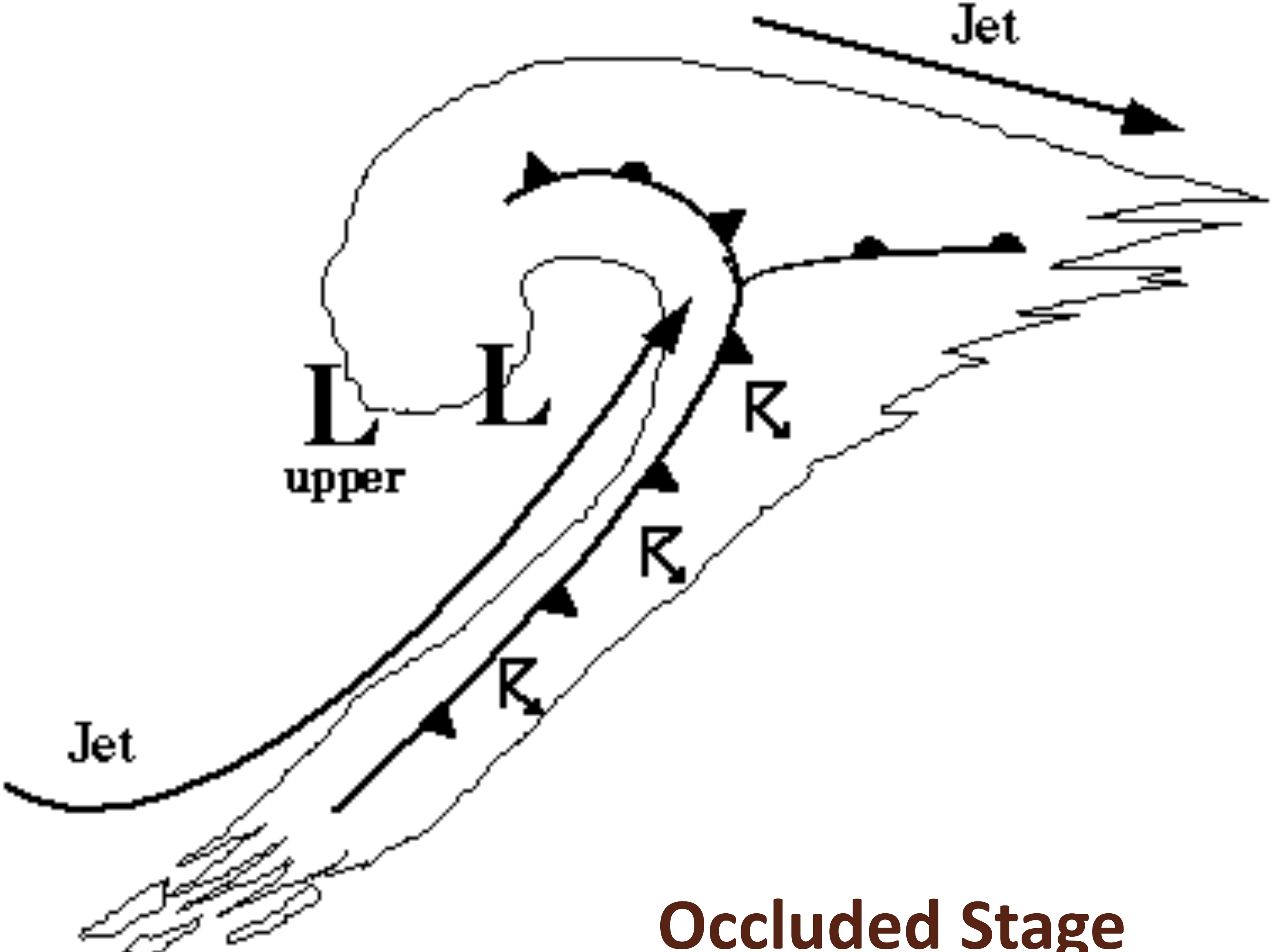


Open Comma Stage

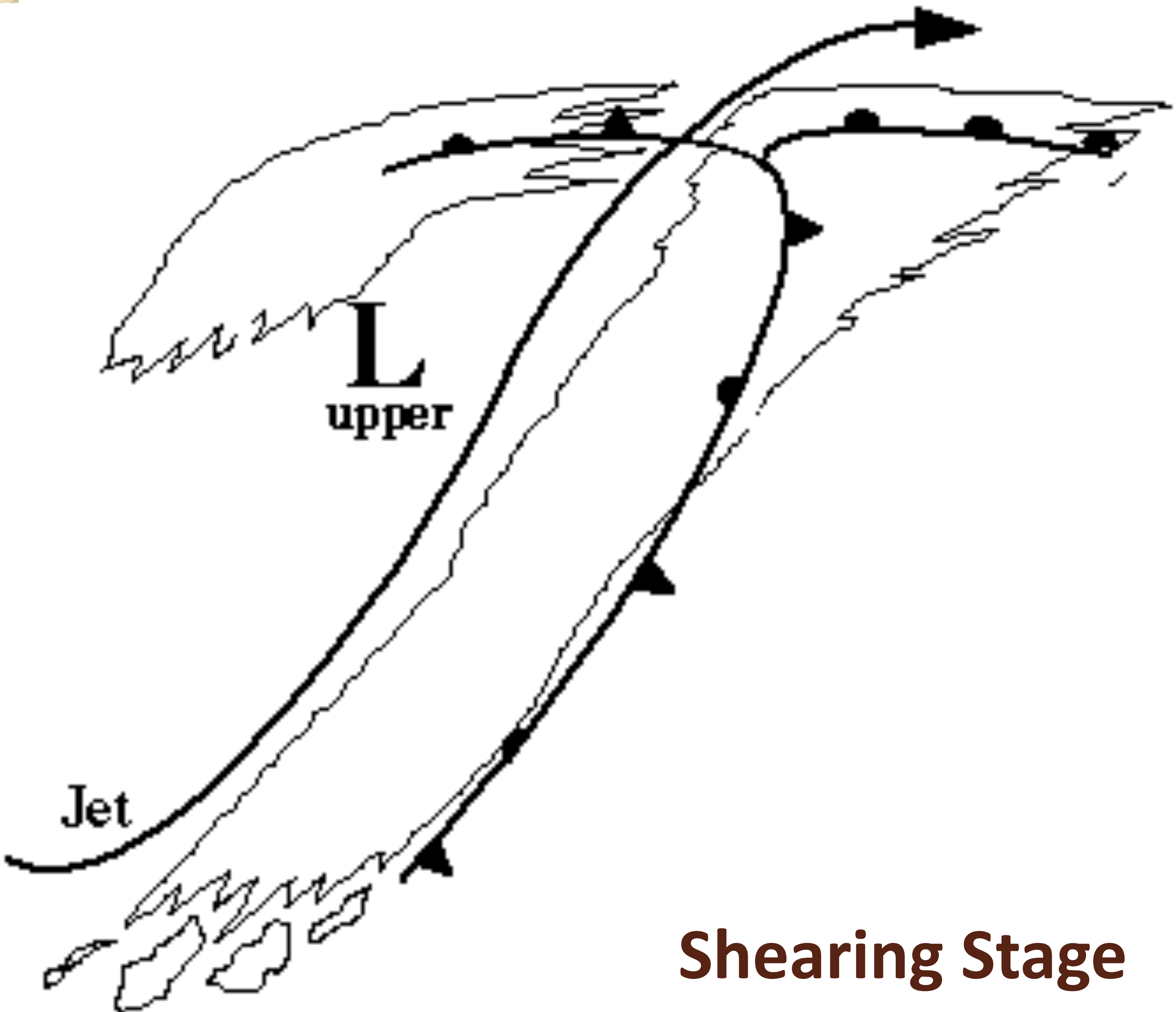
Occlusion



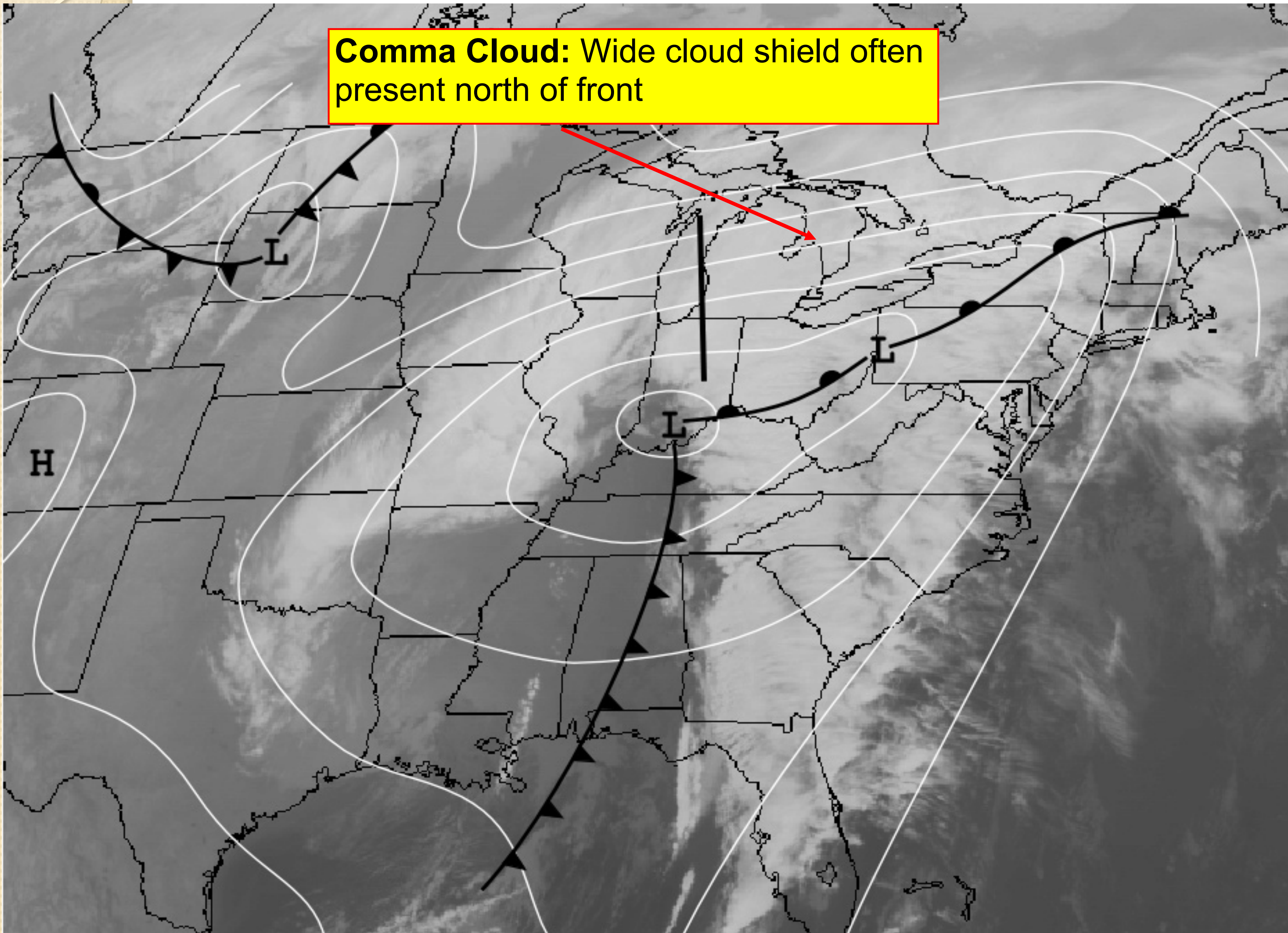
Frontal cyclone occludes as the jet moves poleward of the apex of the warm sector and the Jet MAX moves past it



Occluded Stage

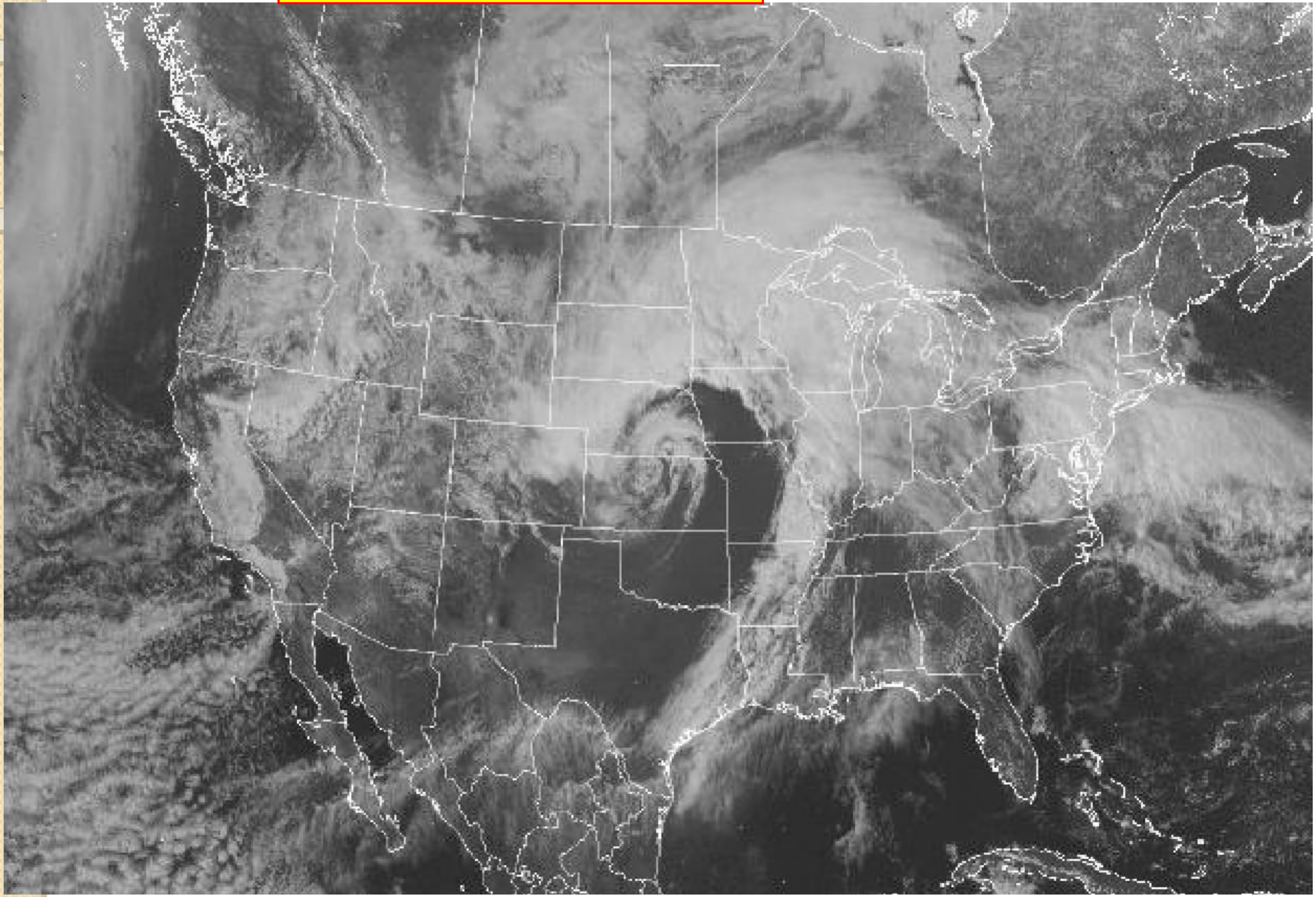


Shearing Stage

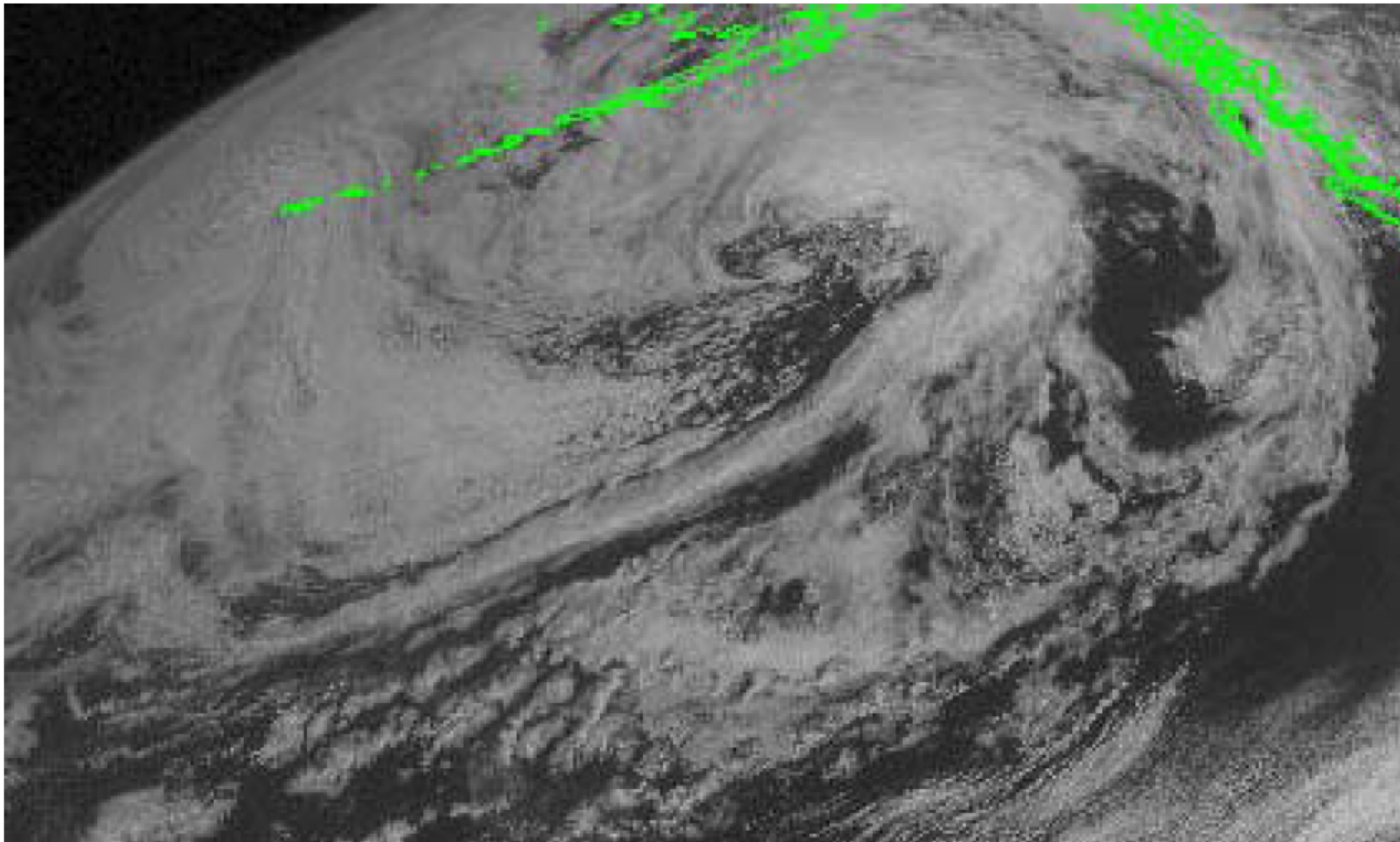


Comma Cloud: Wide cloud shield often present north of front
L
L
L
H

Occluded Stage



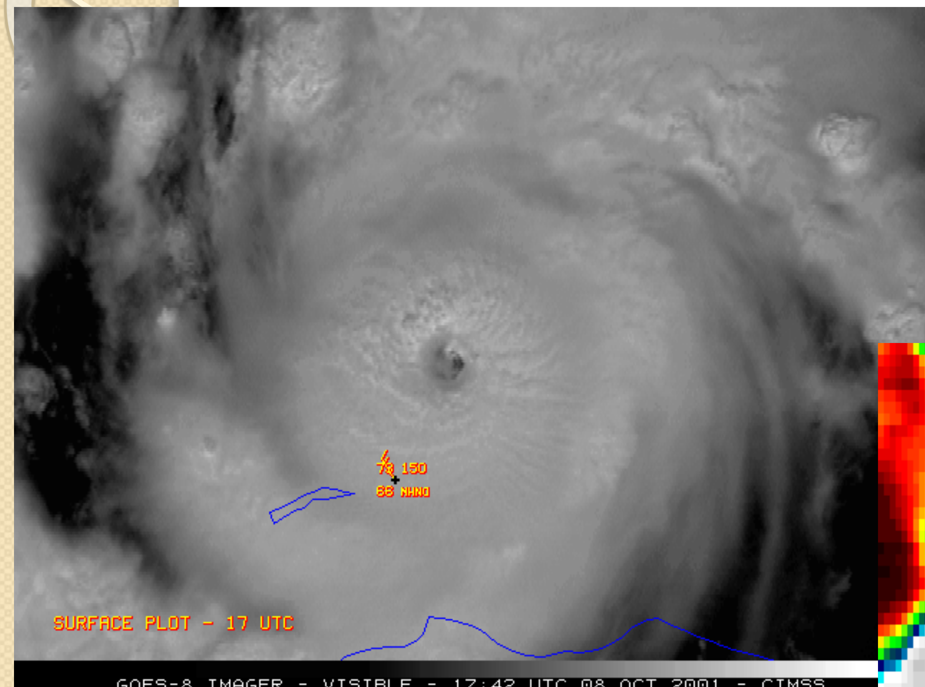
A Mature Cyclone

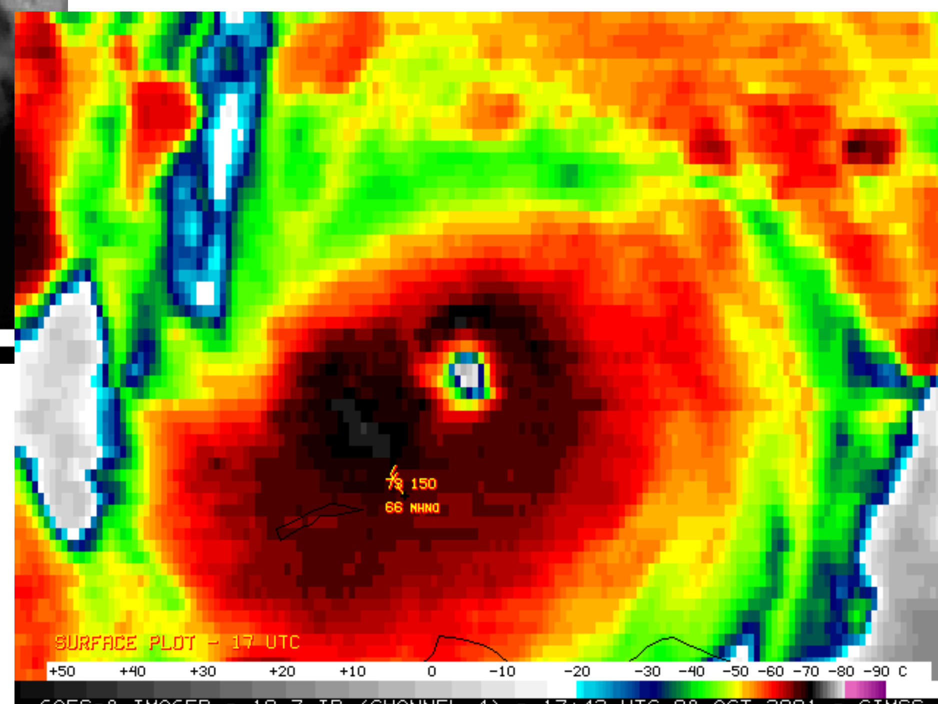


Hurricanes

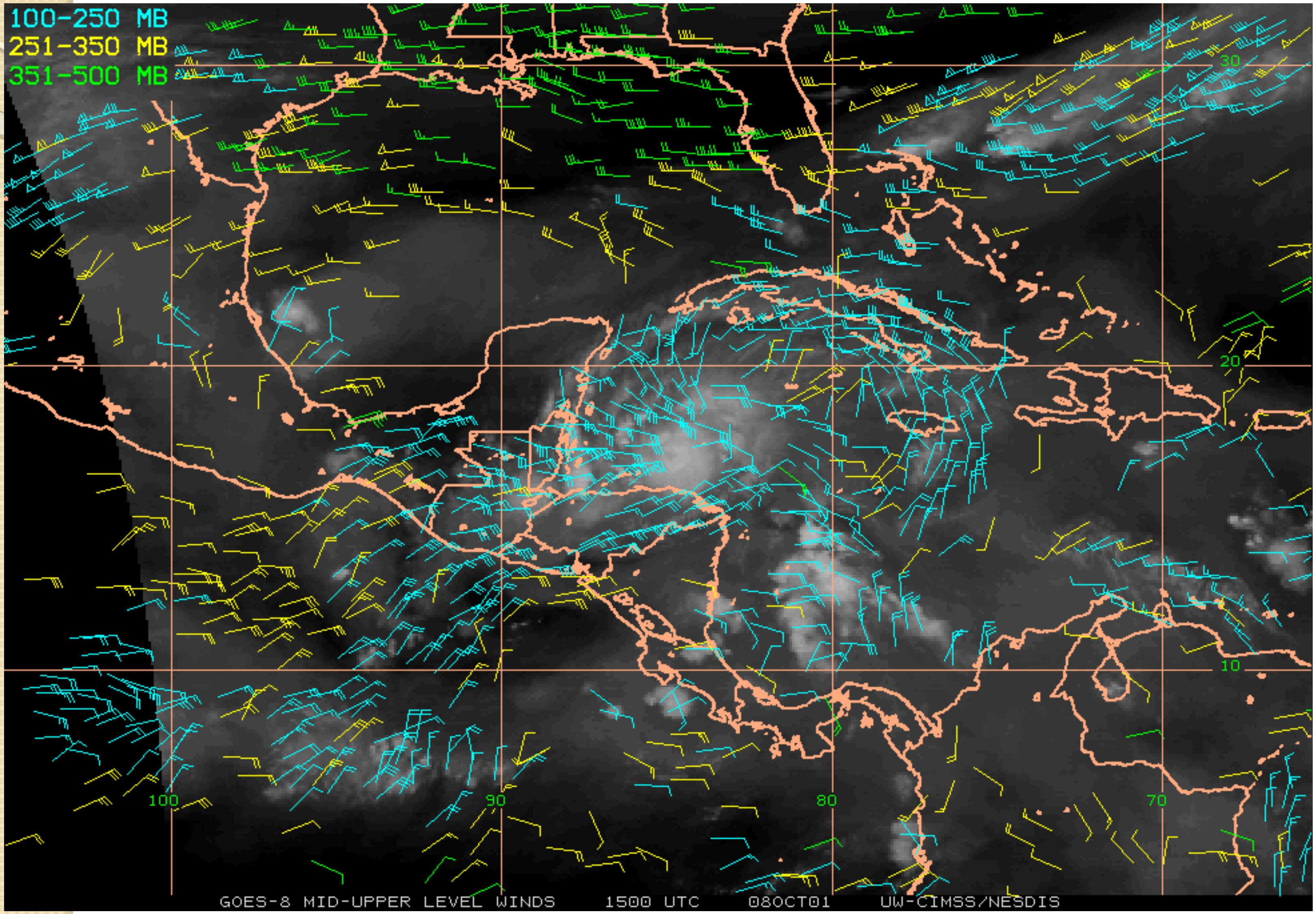
- Both hurricanes and typhoons are tropical cyclones (TCs)
- Tropical cyclones include tropical depressions, tropical storms, and hurricanes (or typhoons).
- Maximum surface wind must be greater than 64 knots to be qualified as a hurricane.
- In satellite imagery, hurricanes feature a circular cloud pattern and in stronger storms, a nearly clear eye at the center.

The Eye of Hurricane Iris (08 October 2001)

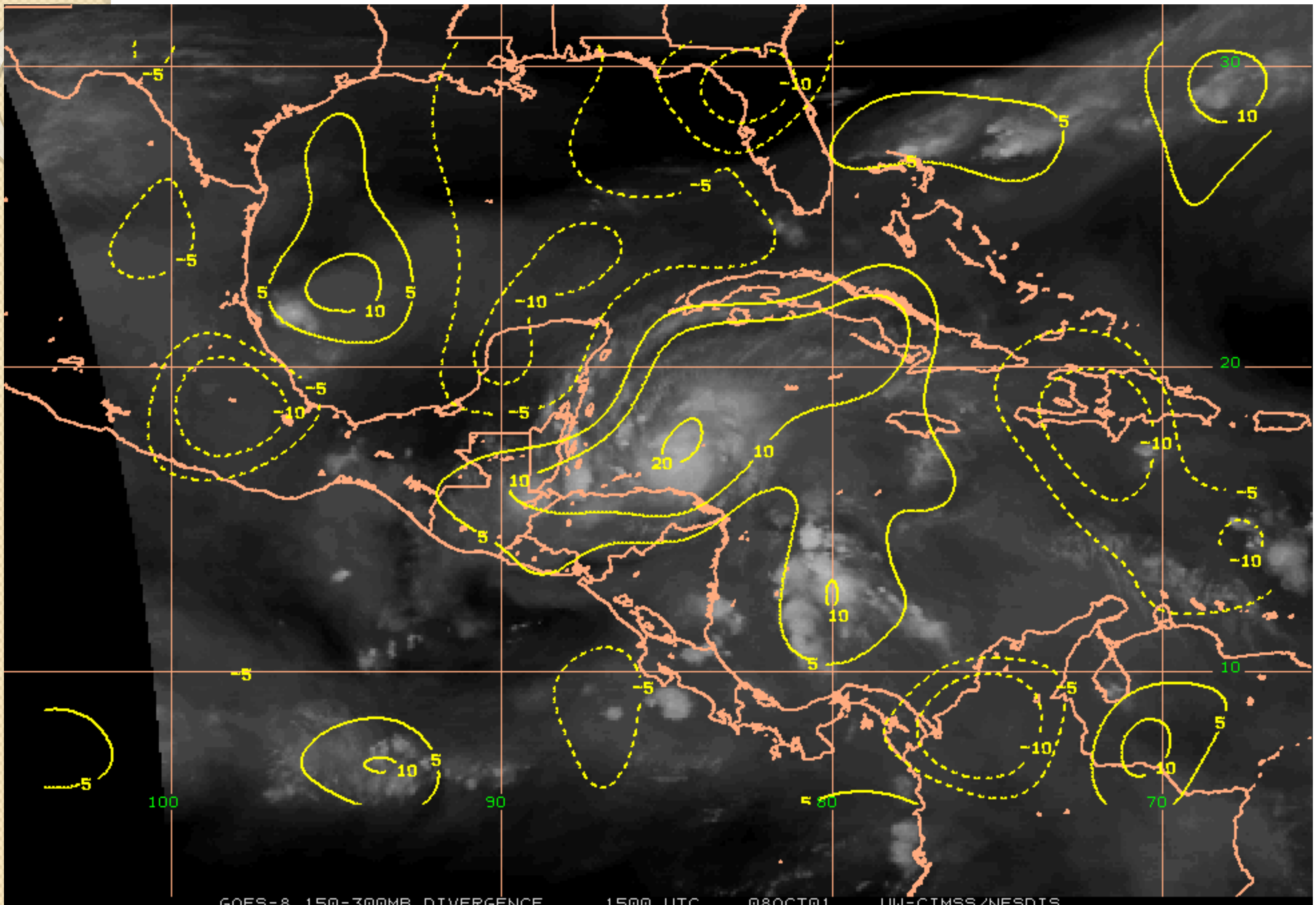




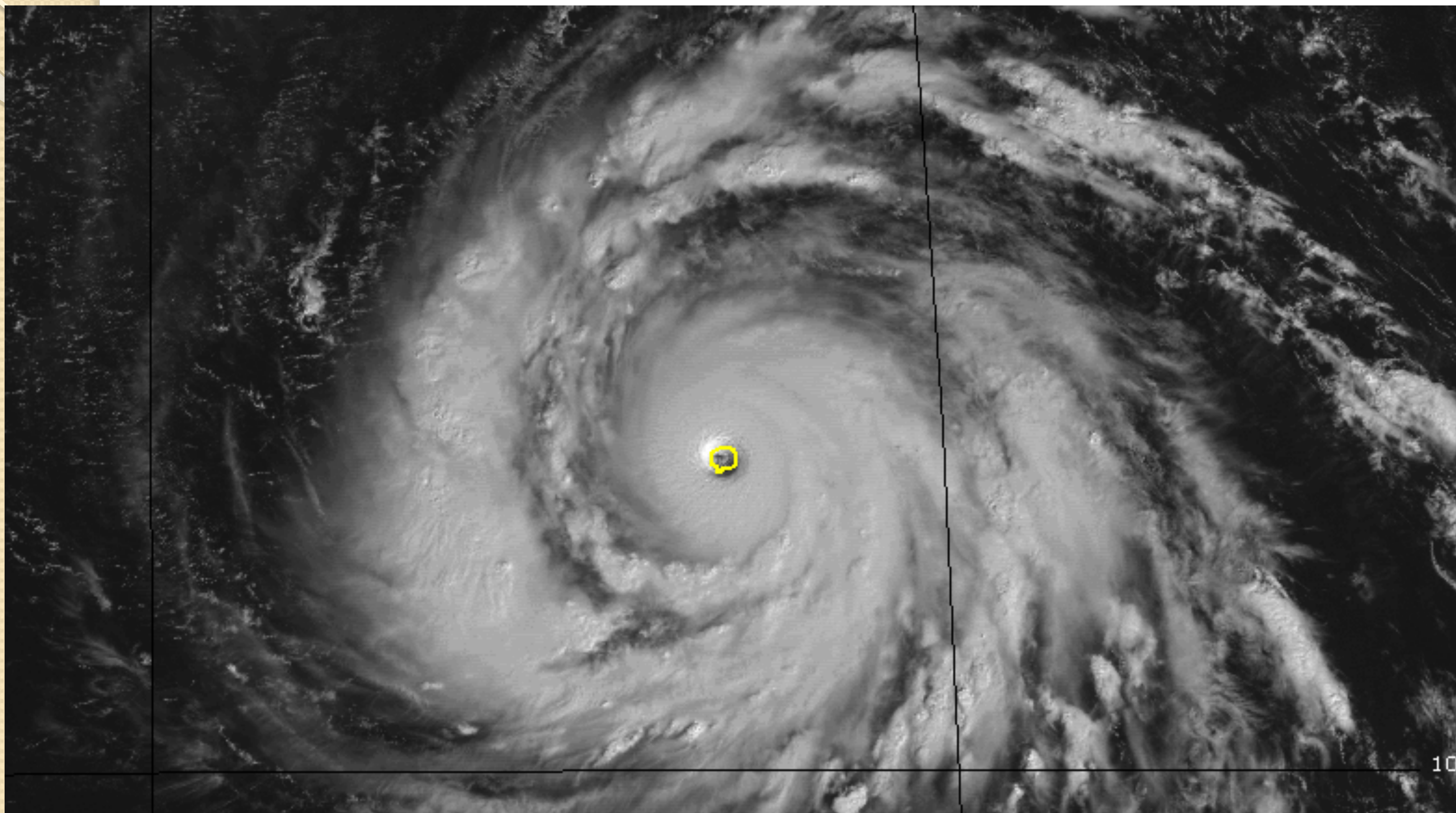
Upper-level winds



Upper-level divergence

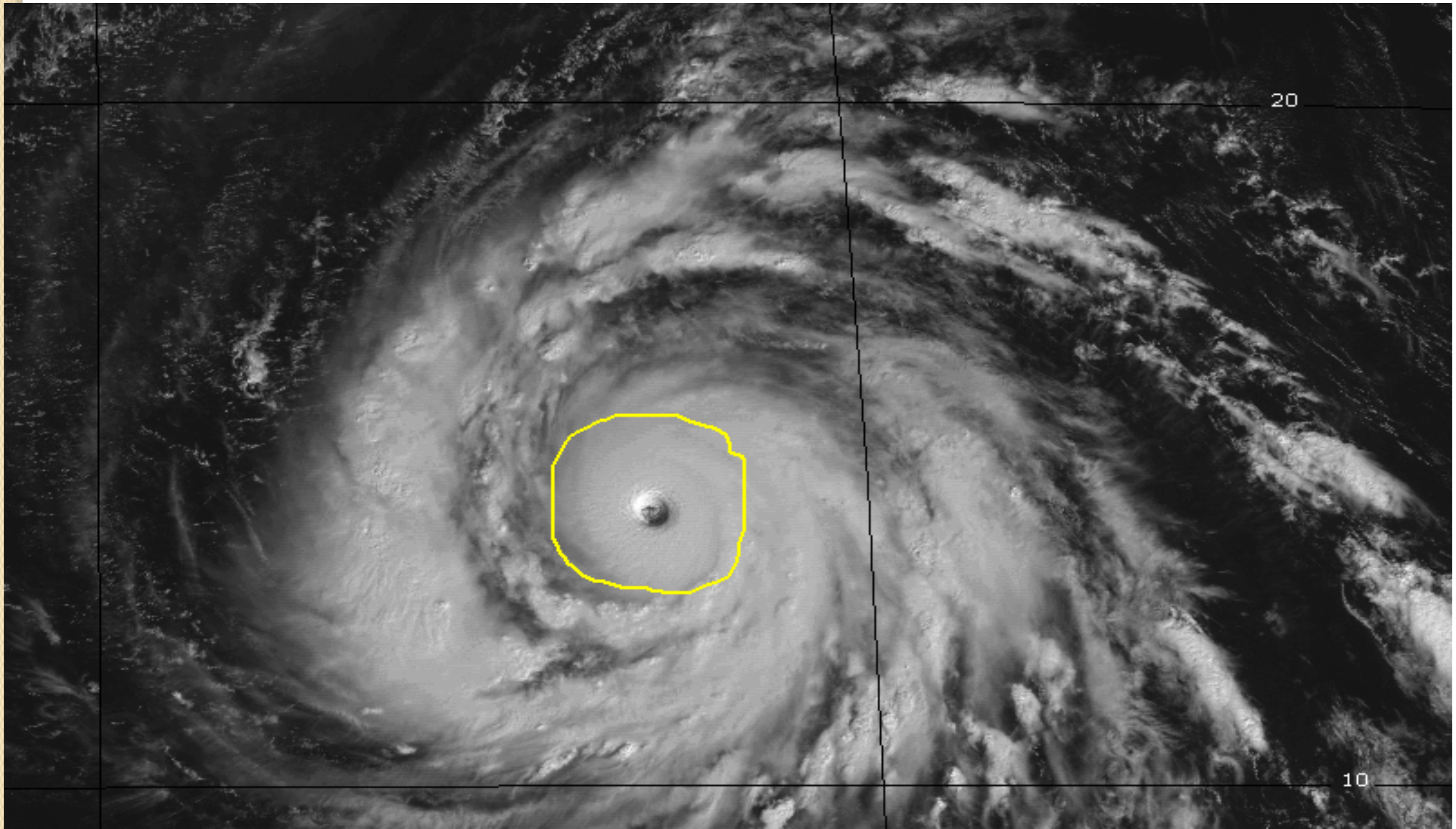


An example: Eye

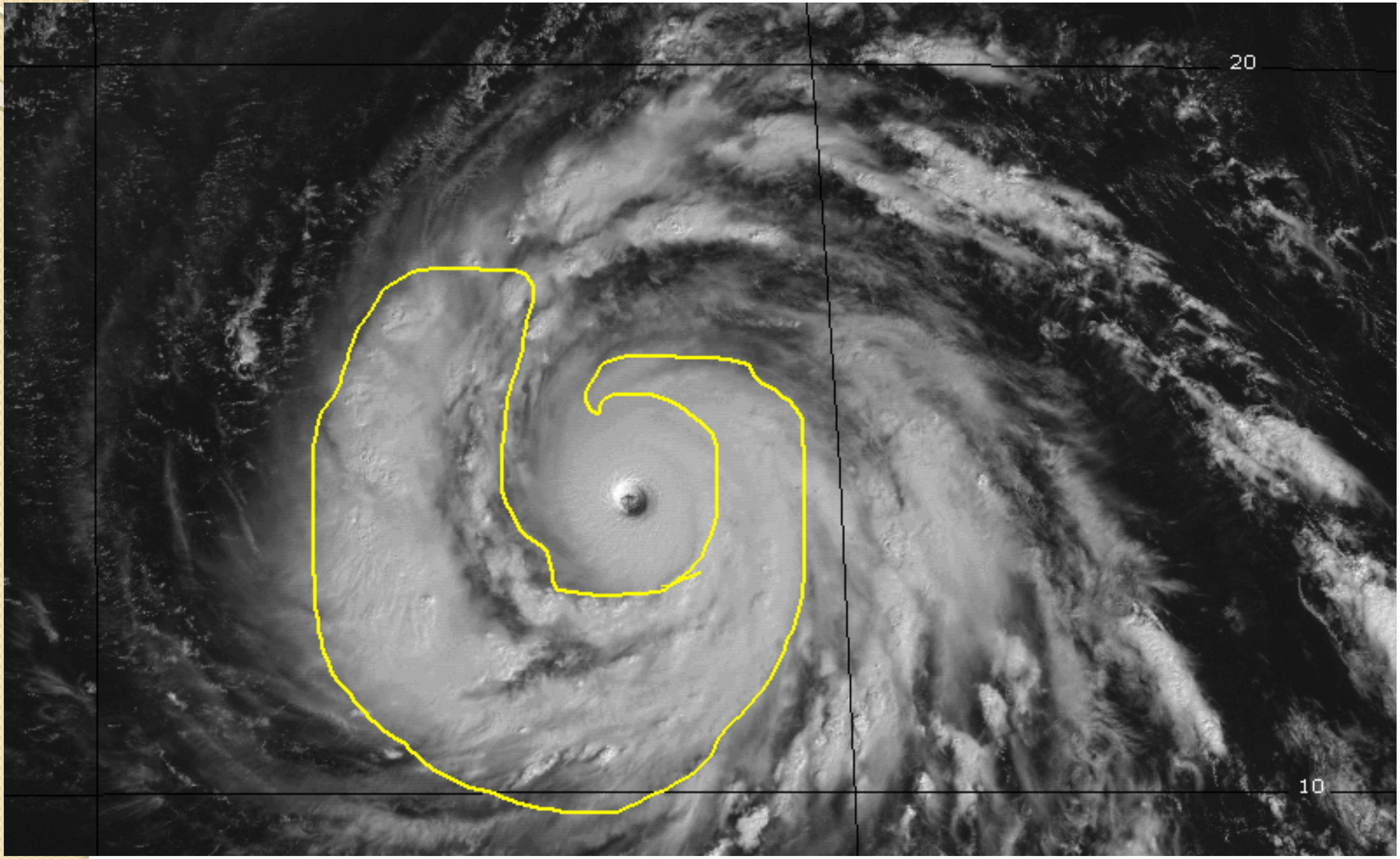


Central dense overcast (CDO):

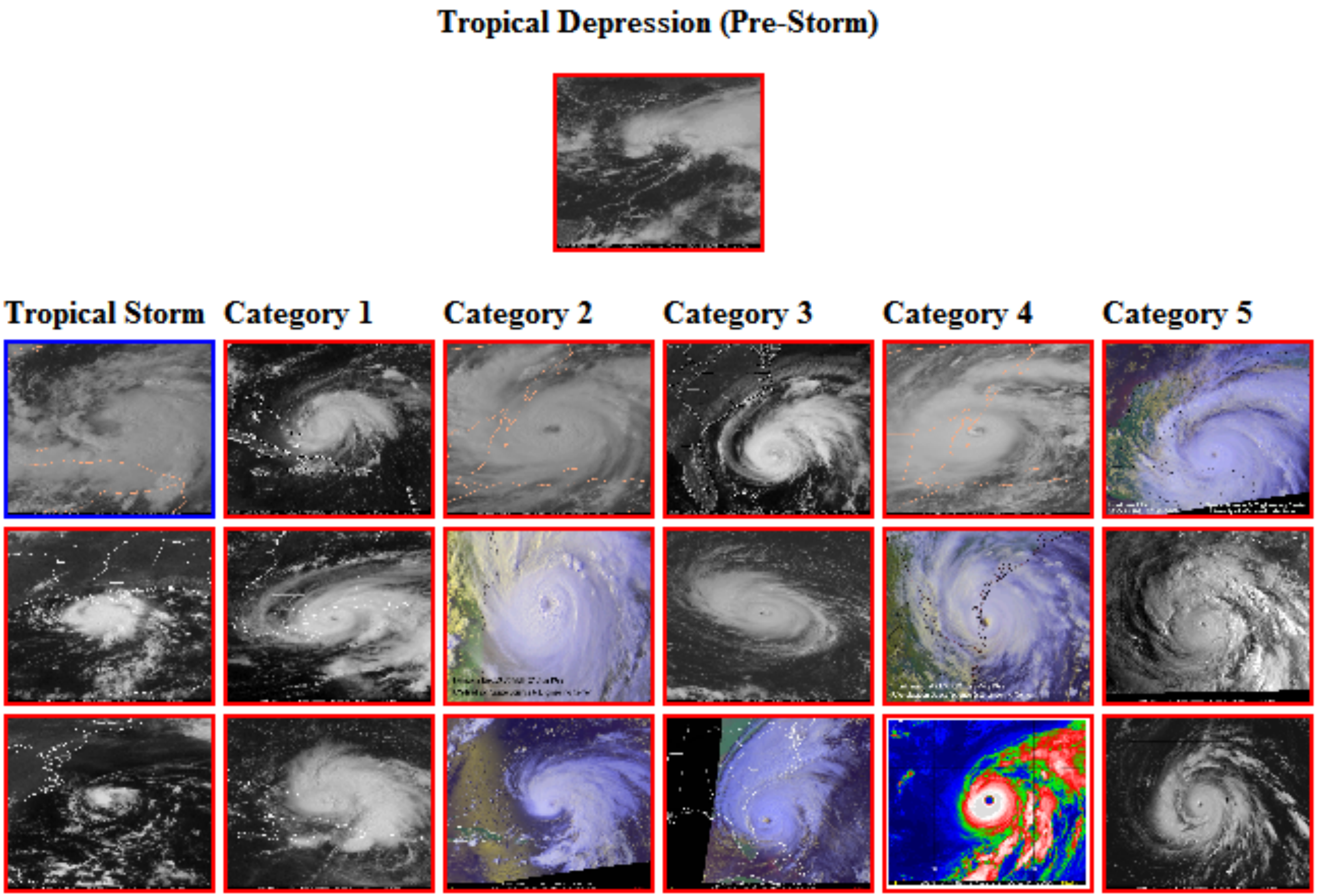
- CDO is the cirrus cloud shield of the storm that results from the thunderstorms in the eyewall of a TC and its rainbands. The CDO is typically uniform, showing the cold cloud tops of the cirrus with no eye apparent prior to the TC reaching hurricane strength. TCs that have nearly circular CDO's are indicative of favorable, low vertical shear environments. Once the storm reaches hurricane strength an eye can usually be seen in either the infrared or visible channels of the satellites.



Spiral bands



Satellite Images and TC intensity



The DVORAK Tropical Cyclone (TC) Intensity Estimation Technique – A Satellite-based Method

-- Has been used for TC monitoring for three decades and has saved tens of thousands of lives.

-- Dvorak technique is an empirical method relating TC cloud structures as seen from satellite images to storm intensity using a simple numerical index , corresponding to an estimate of the maximum sustained (surface) wind (MSW).

Vernon Dvorak (1970s)
From Veldon et al. 2006 BAMS

Basics Behind the Method

- It is the pattern formed by the clouds of a TC that is related to the TC intensity and not the amount of clouds in the pattern.
- Relying on 4 properties that relate organized cloud pattern to TC intensity:

Property 1 (dynamic): vorticity -- Strength and distribution of circular wind **(curved band pattern)**

Property 2 (dynamic): Shear -- degree of distortion **(shear pattern)**

Property 3 (thermodynamic): Convection – IR cloud top temperature **(CDO pattern)**

Property 4 (thermodynamic): Core -- In cases of TCs with eyes, the technique determines the temperatures of the eye and surrounding clouds (eyewall) using IR data and relates them to Intensity **(Eye pattern).**

Basic Steps

- Determine the TC center location.
- Determine T-numbers and Current Intensity (CI) numbers according to cloud patterns.
- Choose the best intensity estimate.
- Apply selected rules to determine the final estimate

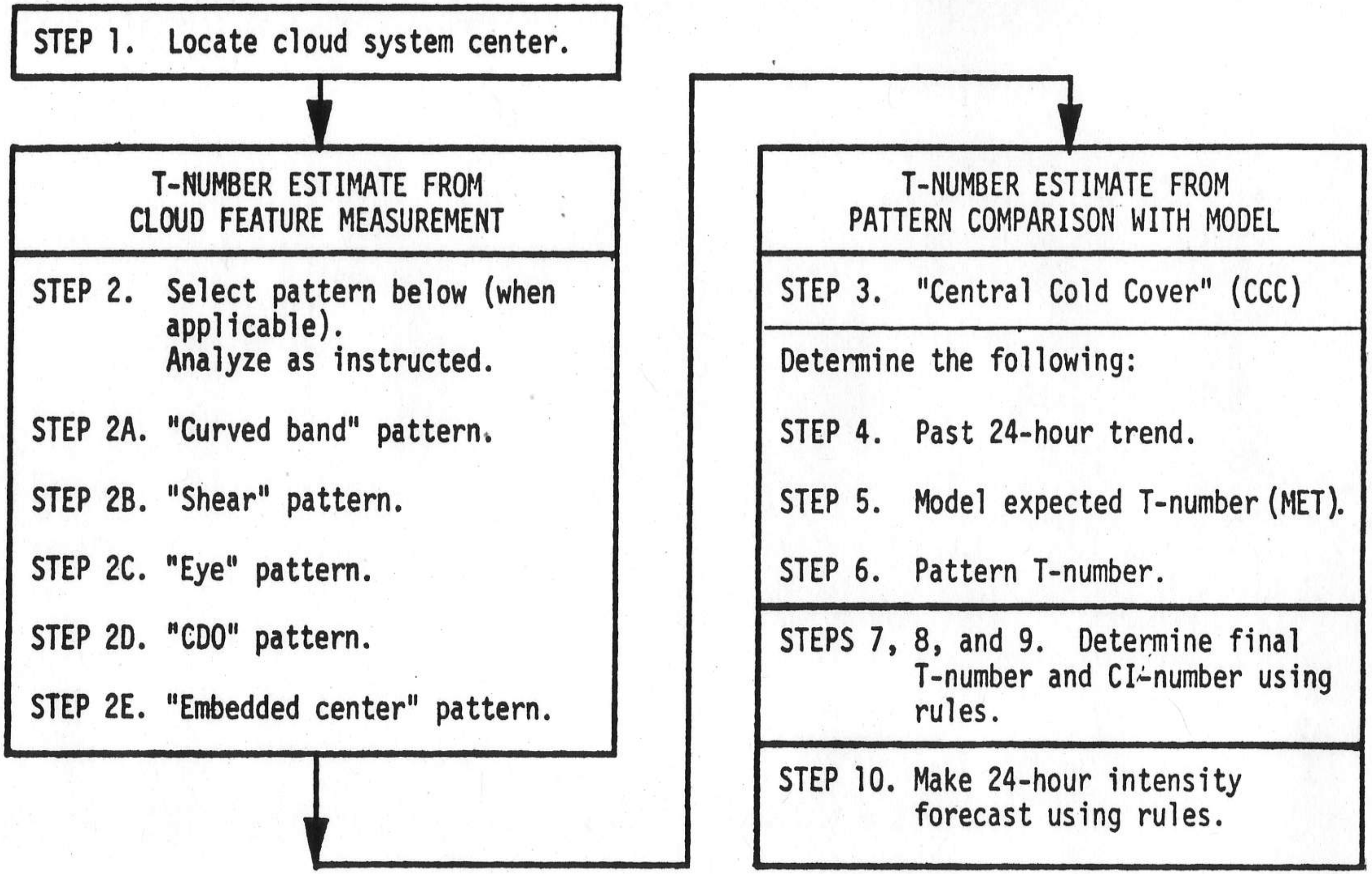


Fig. 4. Procedures for T-number determination.

Curved Band Pattern

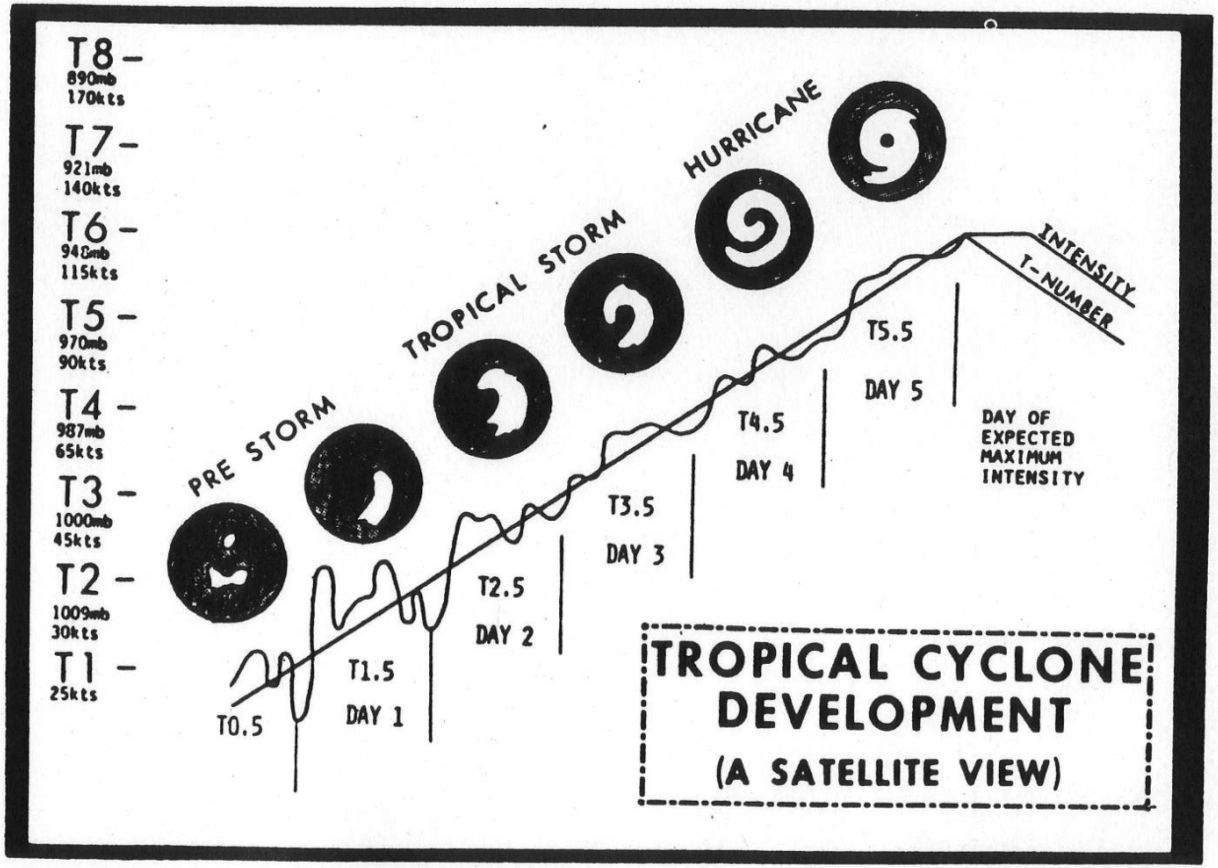


Fig. 1. Model of tropical cyclone development used in intensity analysis (curved band pattern type).

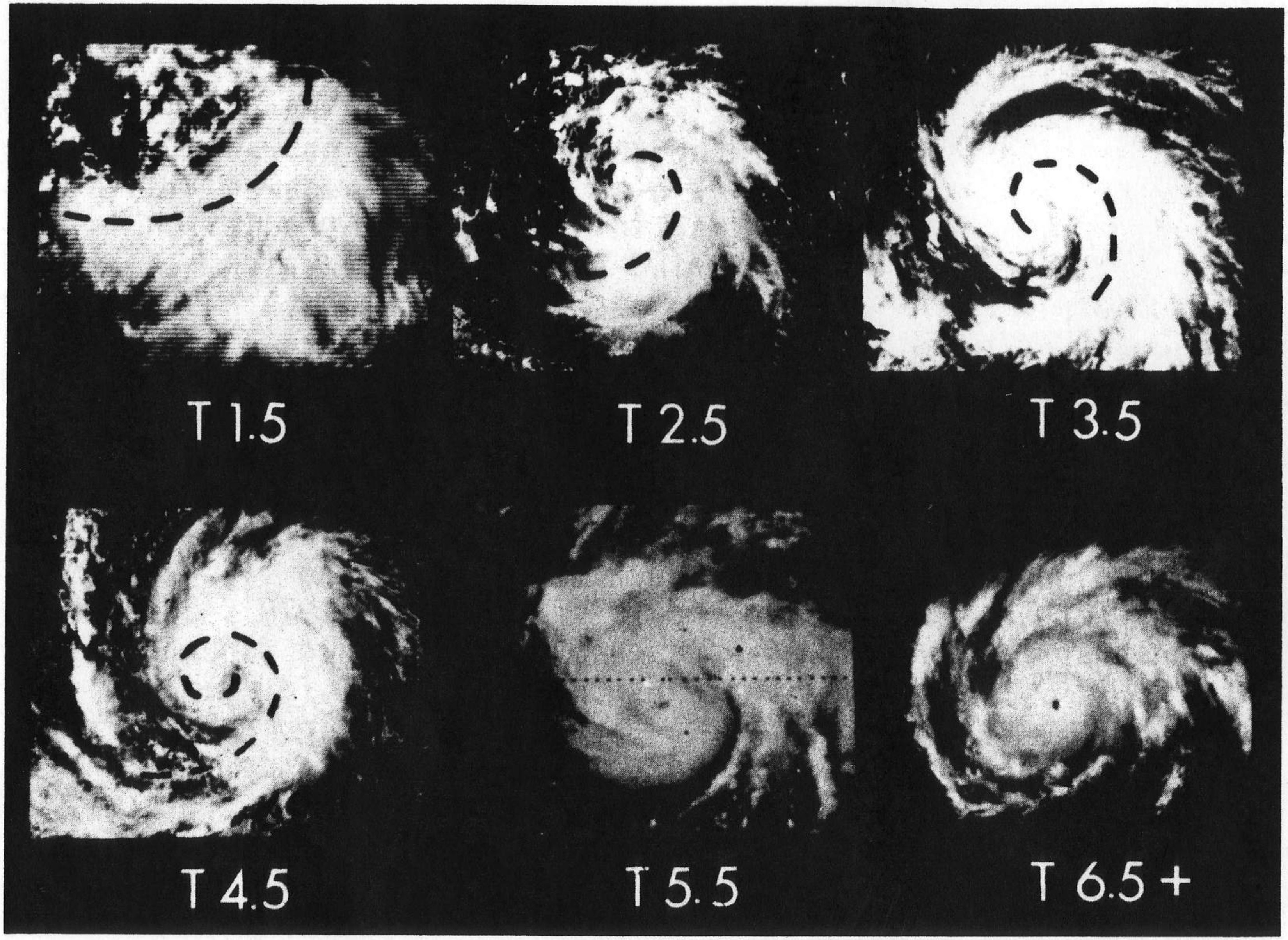


Fig. 2. Examples of tropical cyclone cloud patterns at each stage (T-number) of development. The dashed line follows the curved band axis.

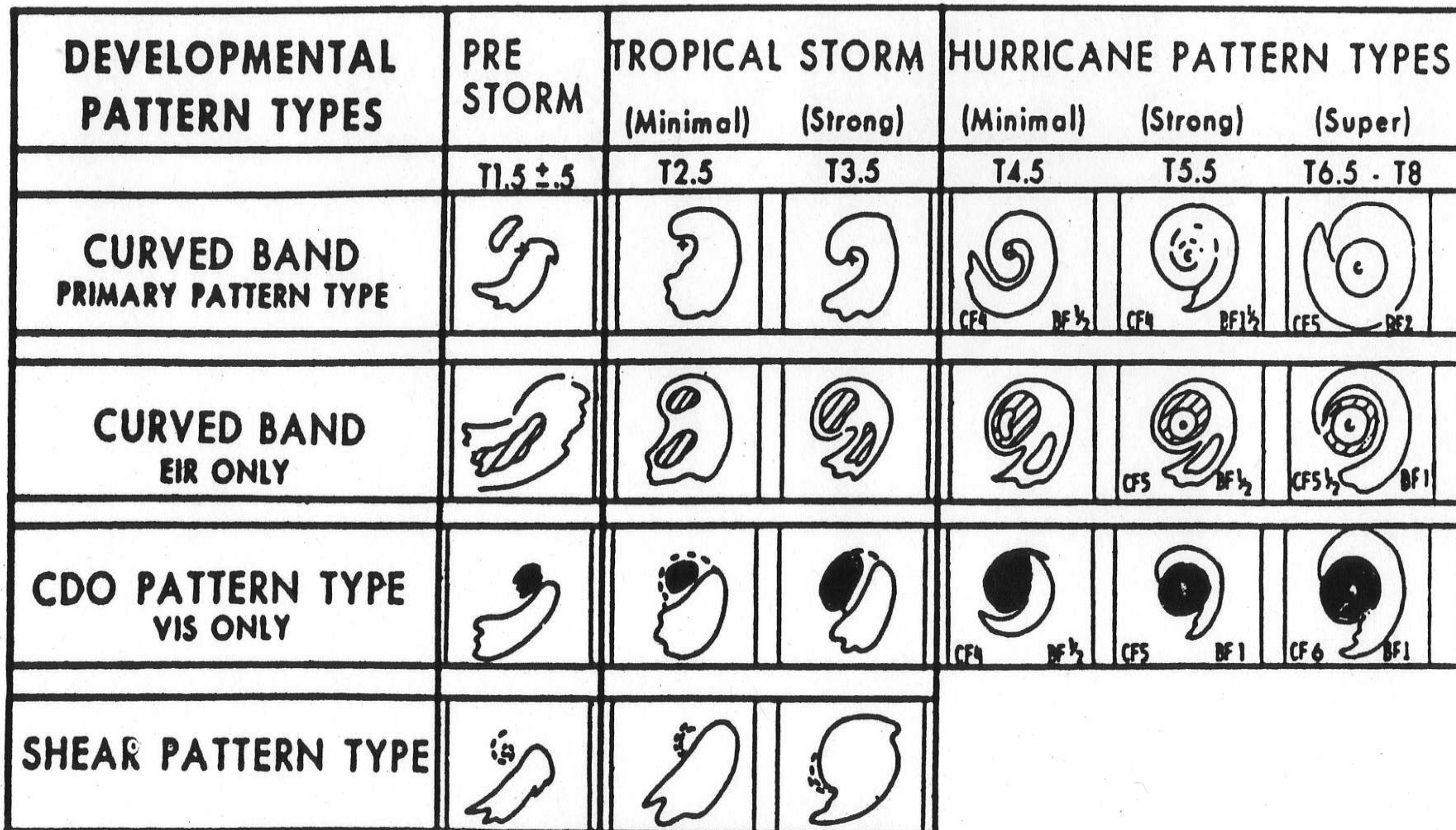
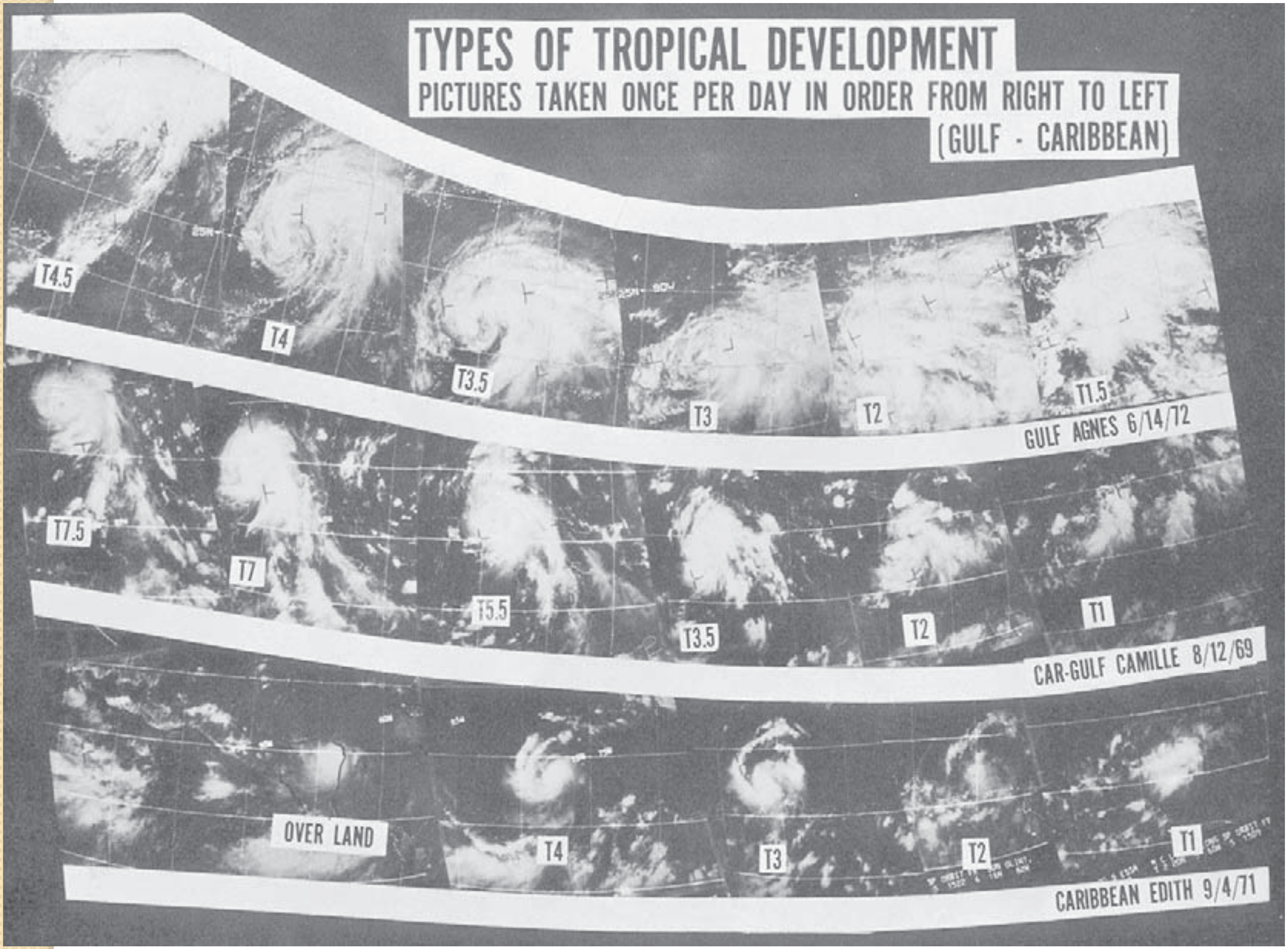


Fig. 5. Developmental cloud pattern types used in intensity analysis. Pattern changes from left to right are typical 24-hourly changes.

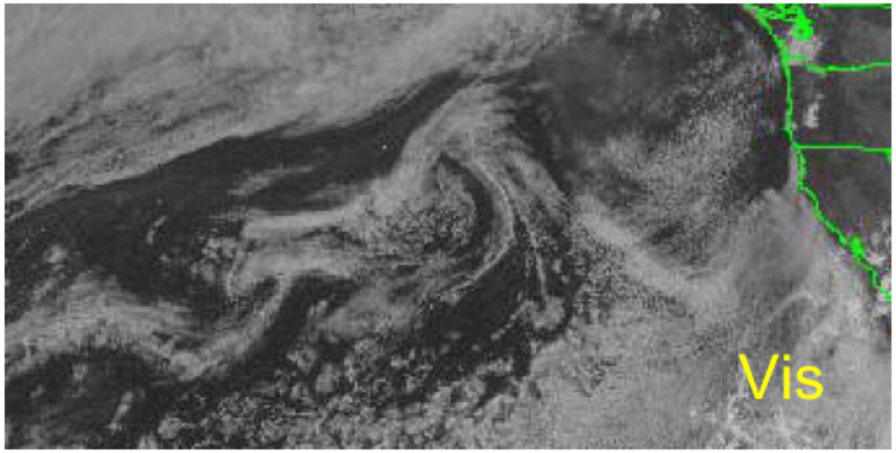


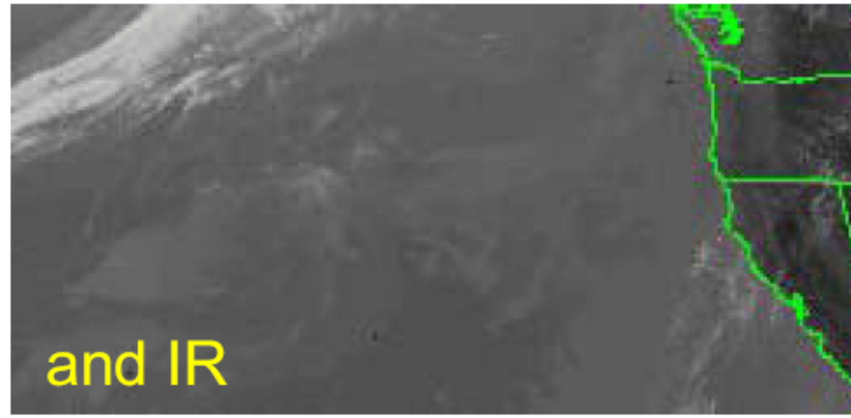
Examples of characteristic cloud patterns of developing TCs (from Dvorak 1973).

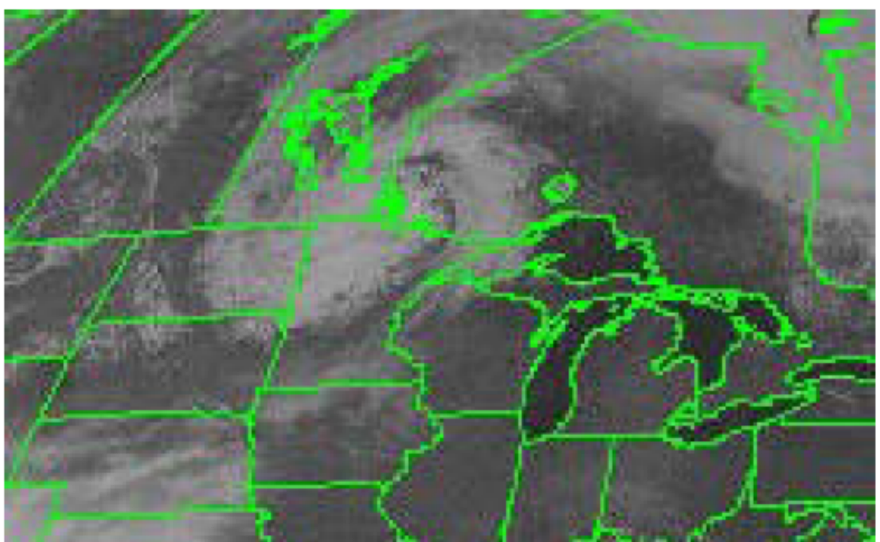
TABLE Summary of the Dvorak (1984) Atlantic and WestPac wind–pressure relationships.

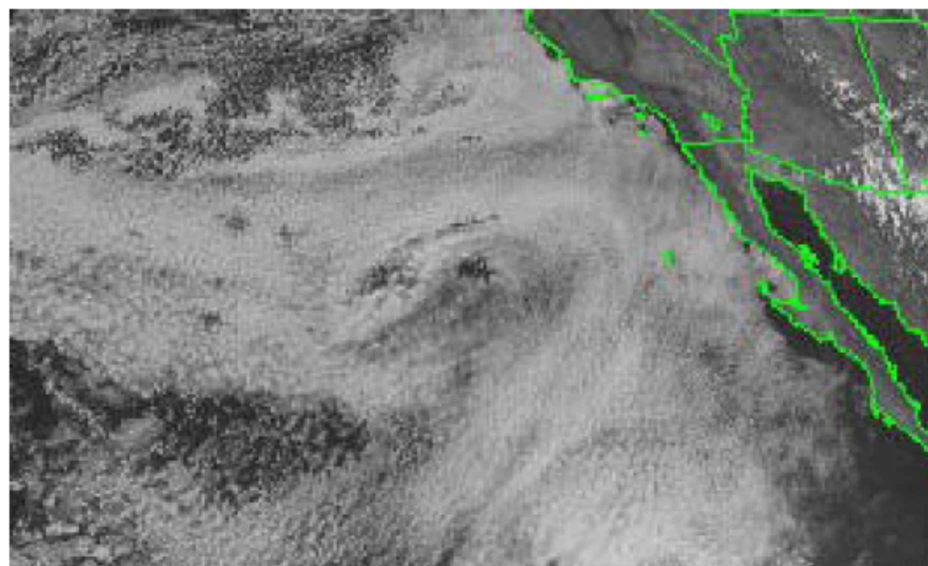
CI	MSW (kt)	Atlantic MSLP(hPa)	WestPac MSLP(hPa)
1.0	25		
1.5	25		
2.0	30	1009	1000
2.5	35	1005	997
3.0	45	1000	991
3.5	55	994	984
4.0	65	987	976
4.5	77	979	966
5.0	90	970	954
5.5	102	960	941
6.0	115	948	927
6.5	127	935	914
7.0	140	921	898
7.5	155	906	879
8.0	170	890	858

Short Waves

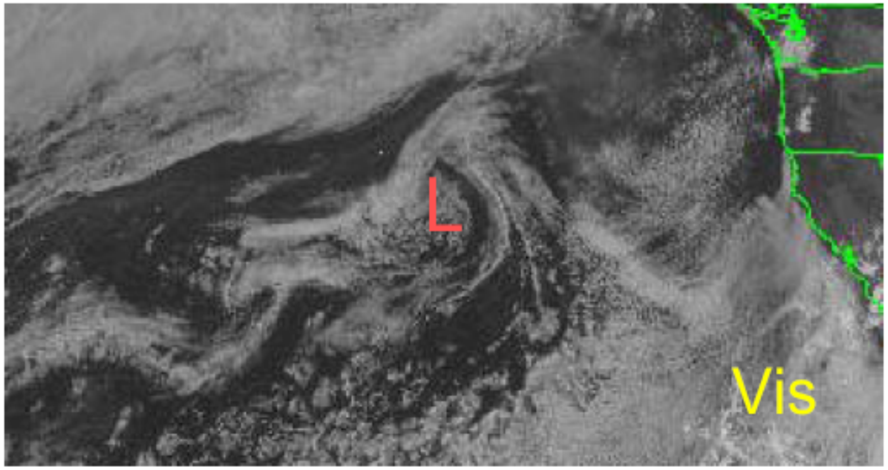


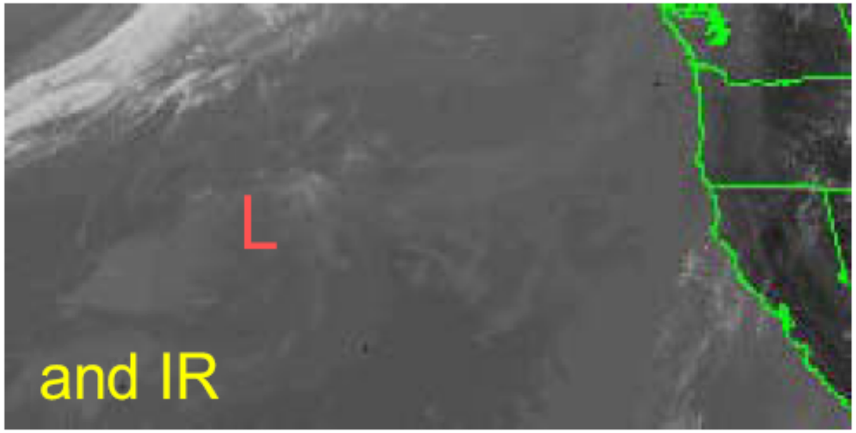


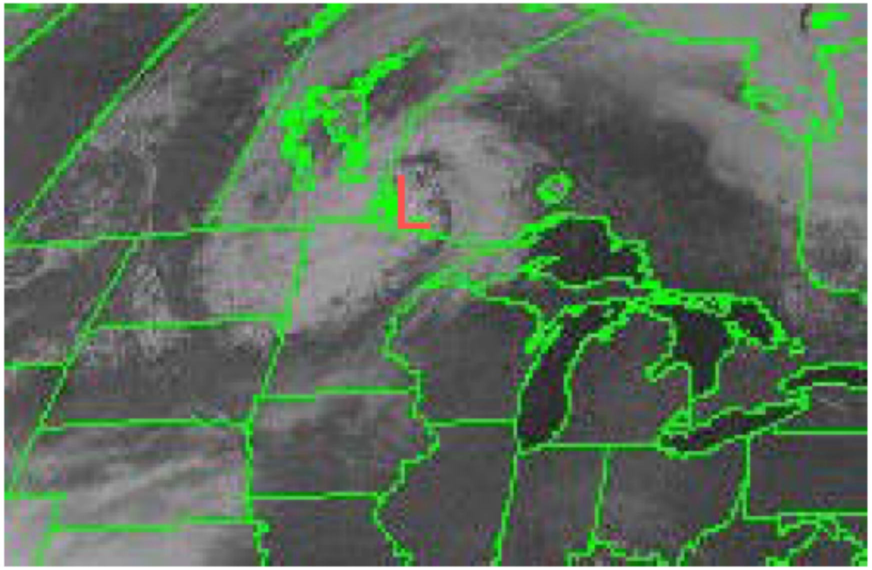


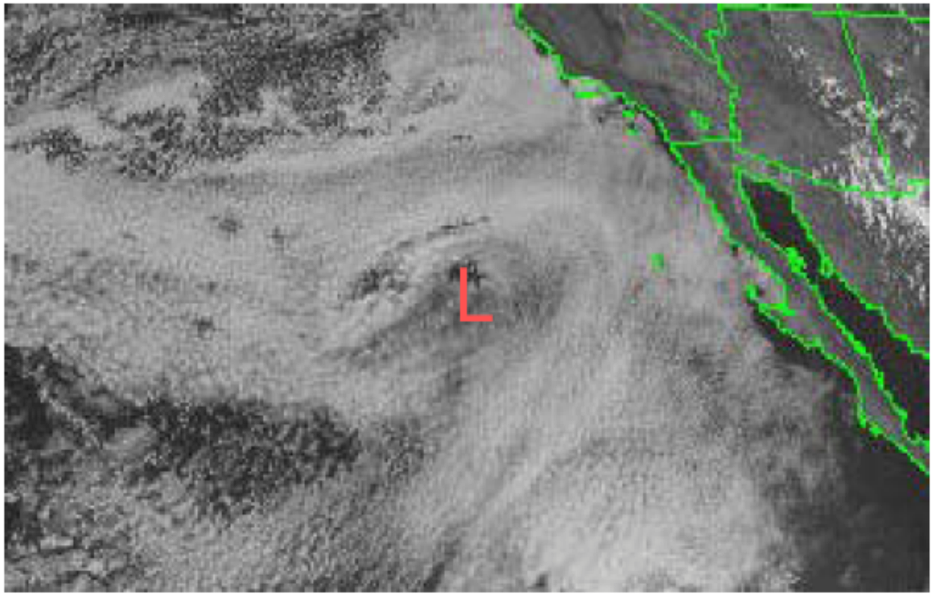


Short Waves



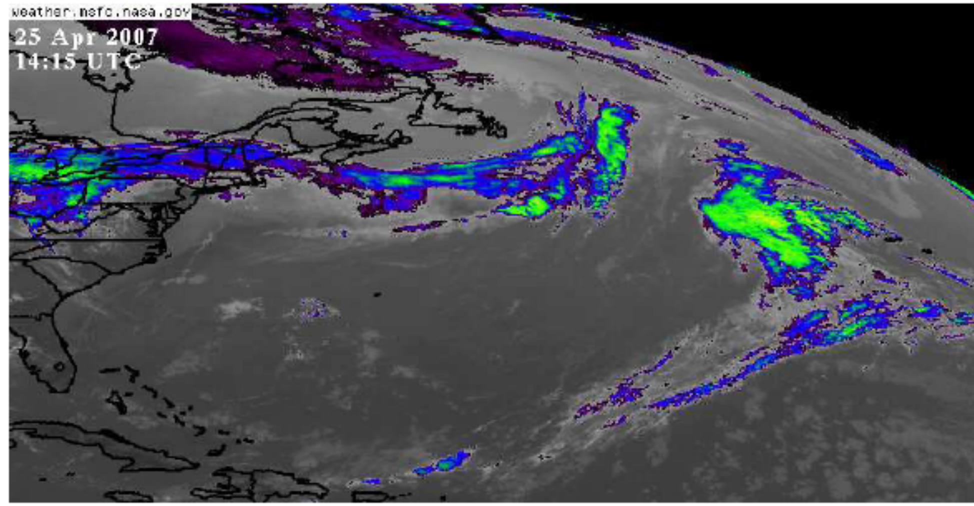


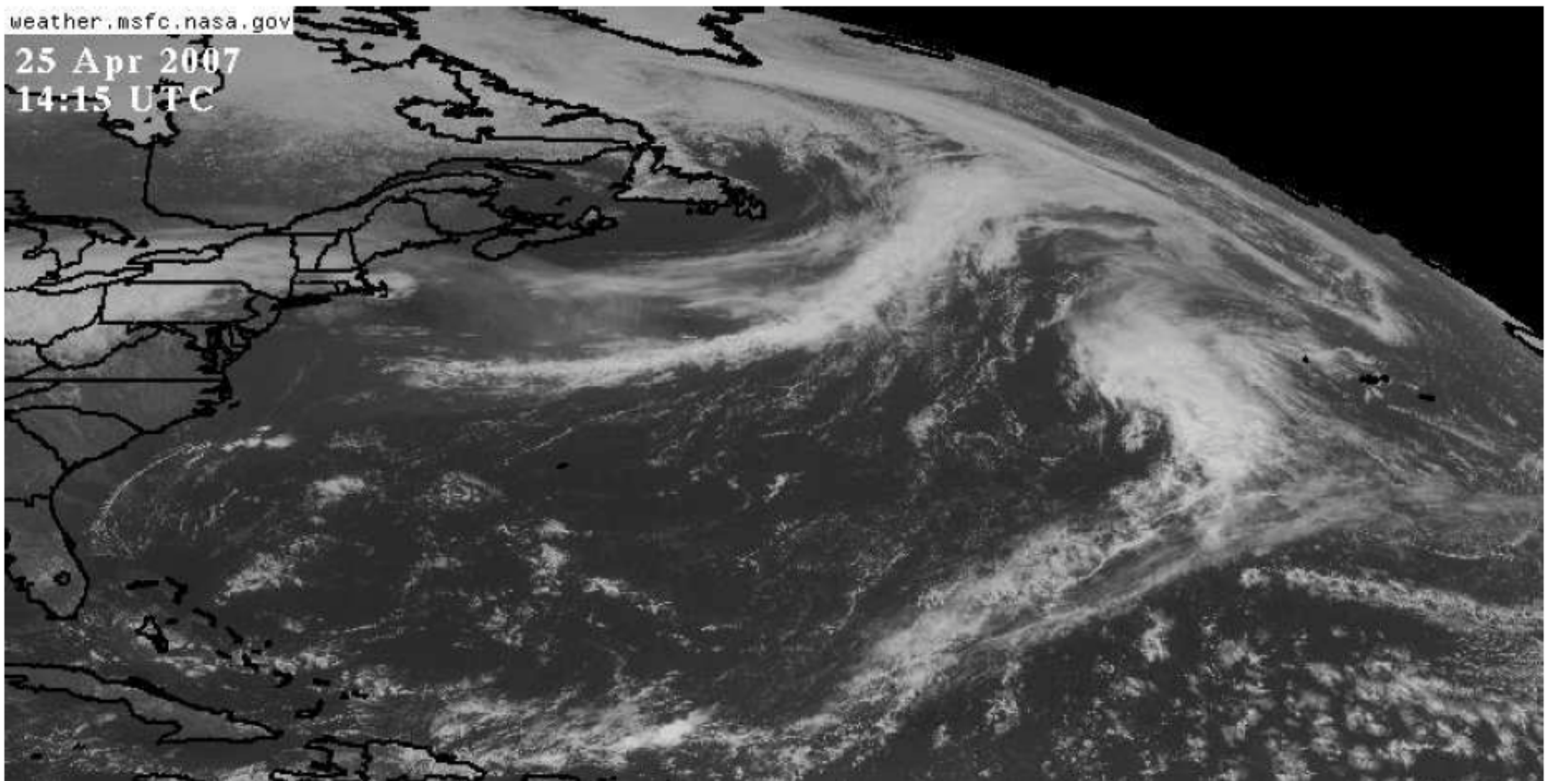




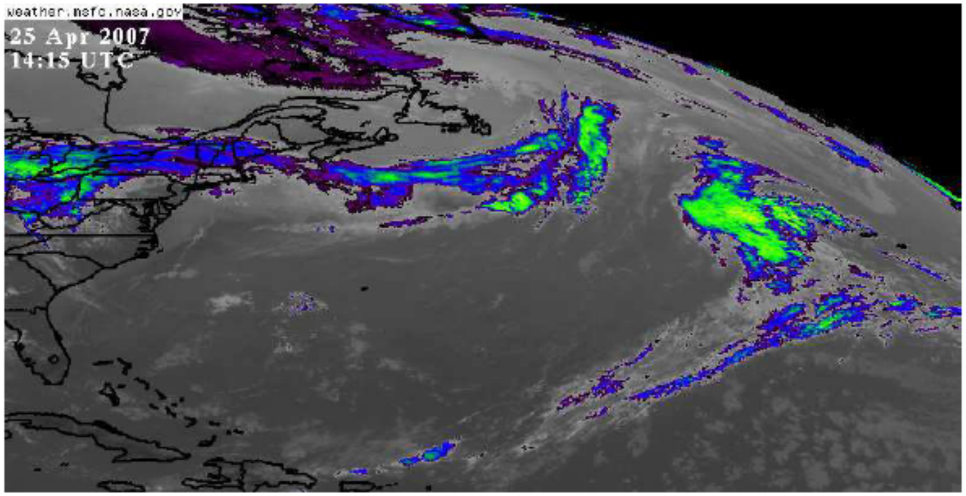
Surface Highs and Ridges

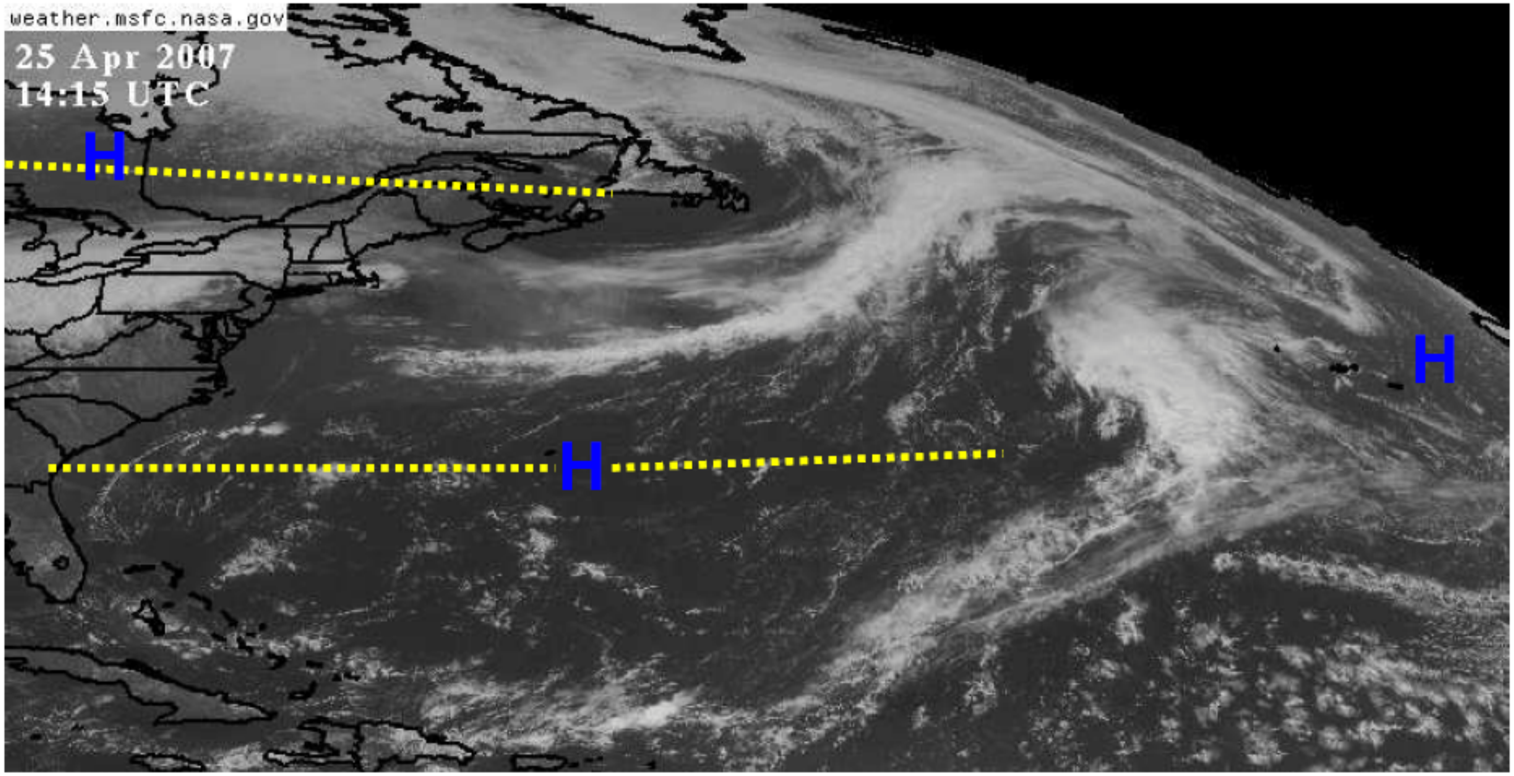
It can be difficult to identify surface highs without surface maps.





Surface Highs and Ridges





Surface Highs and Ridges