Satellite Imagery Interpretation

- Satellite Types

1. Polar Orbiter (POES)

2. Geosynchronous Orbiters
   - Geostationary Operational Env. Satellite (GOES)
   - GMS
   - EUMETSAT

Satellite Imagery Interpretation

- Image Types

	Garp
1. Visible: radiation reflected by objects	4km/0.65
2. Infrared: radiated energy of objects	4km/10.7
3. Water Vapor: radiated energy of objects	4km/6.8

Satellite Imagery Interpretation

- Visible Imagery:
  - looks very much like black and white photos
  - based on <u>reflected</u> light (reflection increases, detected light increases)
    - Sample albedos:
      - Large T-storm: 92%
      - Thick Cs: 74%
      - Thin St: 42%
      - Water surface: 9%
      - Fresh snow: 88%
      - Thick Sc: 68%
      - Thin Cs: 32%
      - White Sands, NM: 60%

Satellite Imagery Interpretation

- GOES VISIBLE Specs:
  - Resolution: 0.5 km (each pixel represents .5 x .5 km area)
  - Bands: 0.65 μm

Satellite Imagery Interpretation

- Infrared Imagery (IR)
  - Radiometer detects radiated energy of an object, emitted from a surface.
  - All objects with a temp. greater than absolute zero radiated electromagnetic radiation
  - Wavelength of max radiation emission varies w/temp

Satellite Imagery Interpretation

- GOES Radiometer Approach
  1. Fix wavelength (λ)
  2. Measure energy level at that λ
  3. Convert energy levels to temps

- GOES Specs:
  - Resolution: 4 km
  - Band: 3.9, 6.8, 10.7, 13.3

Satellite Imagery Interpretation

- Vis Imagery often has good visual contrast

- For IR images, some low clouds may have temps very similar to underlying surface so we need some means of determining subtle temp. differences.

Satellite Imagery Interpretation

- <u>Enhancement</u> :
  - Human eye can perceive 15-20 gray shades where computers can generate 256 gray shades which can be used to define more temperatures
  - IR Imagery usually enhanced.

Satellite Imagery Interpretation

- Unenhanced: many temps/colors unused

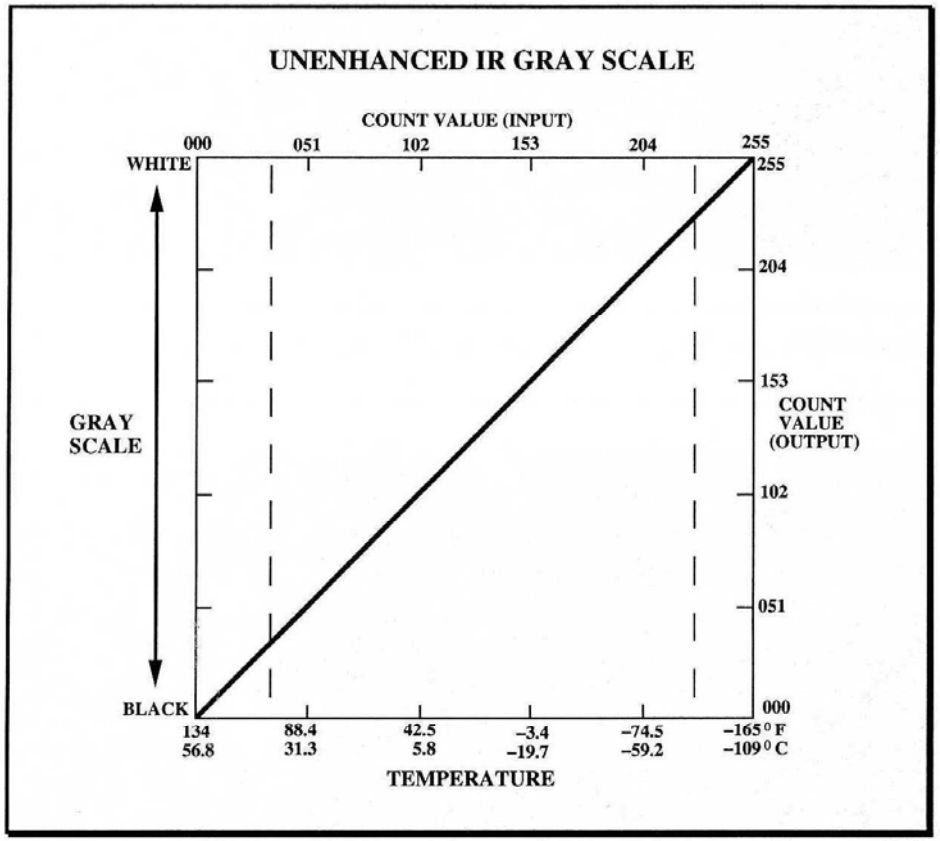


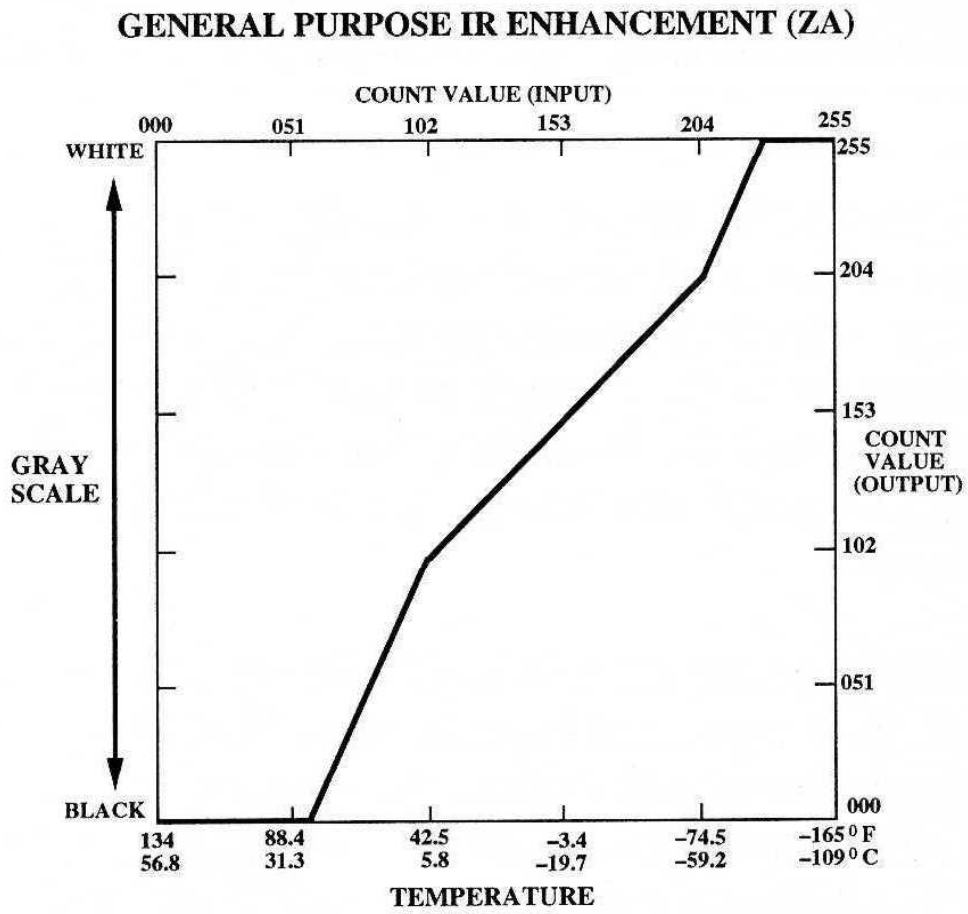
Figure 3.8. Linear gray scale for IR imagery

From
An Introduction to Satellite Image Interpretation
By Eric D. Conway

Satellite Imagery Interpretation

- ZA curve: allows enhancements of high and low clouds
  - Segments
    1. Black
    2. Small difference in low clouds and SST exaggerated
    3. No enhancements
    4. Small difference in Ci exaggerated
    5. White

Satellite Imagery Interpretation



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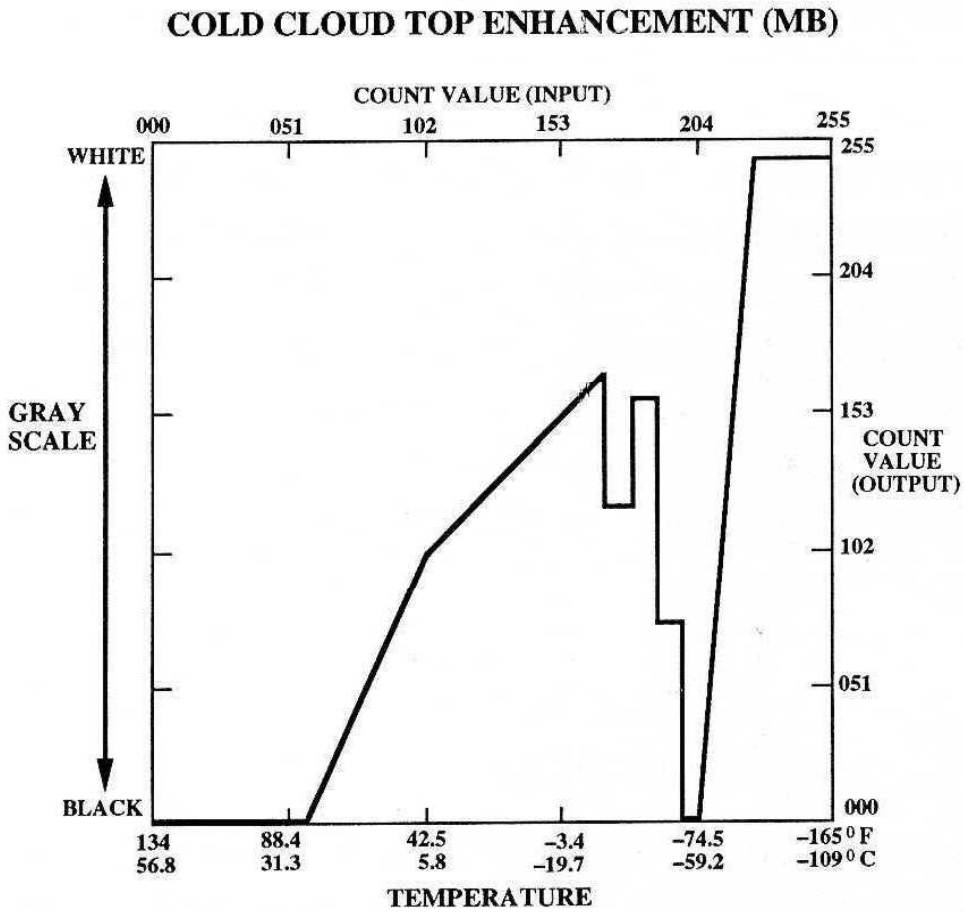
An Introduction to Satellite Image Interpretation
By Eric D. Conway

Satellite Imagery Interpretation

- MB curve
  - Allows for enhancement of convection;
  - Generally ZA curve until Cirrus level
  - Mesoscale convective complex (MCC) definition based on MB curve

Satellite Imagery Interpretation



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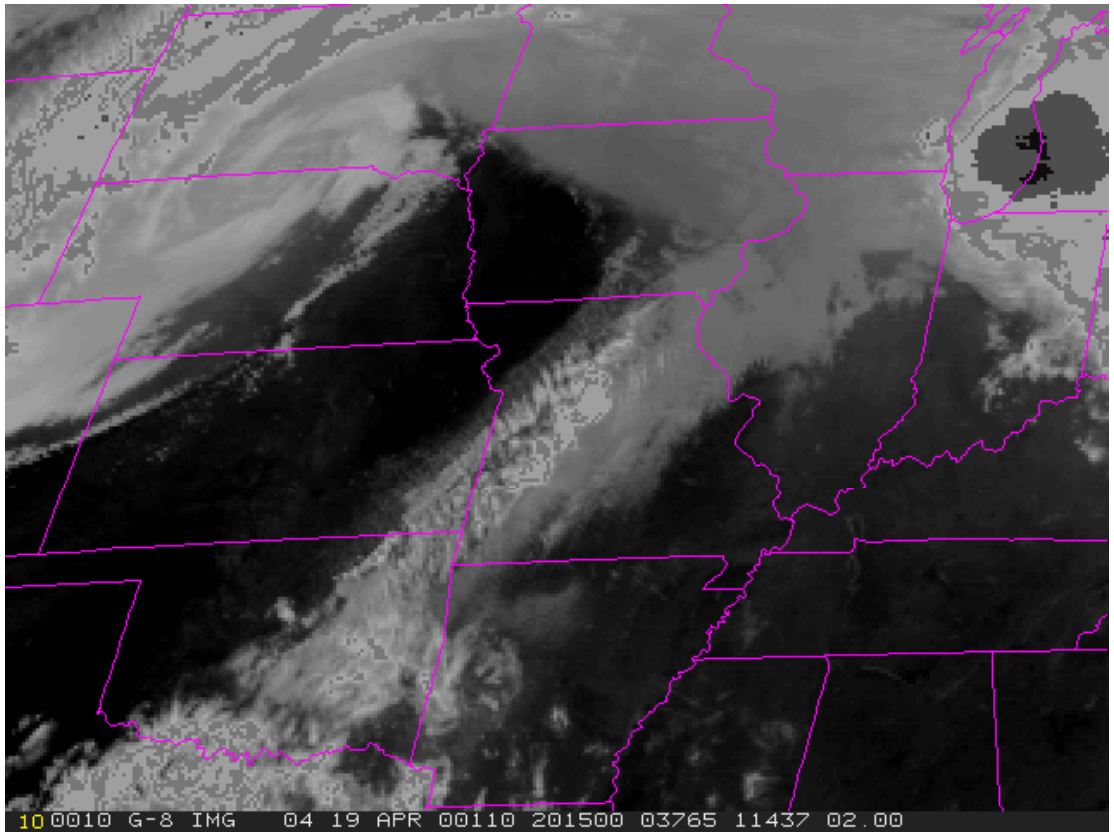
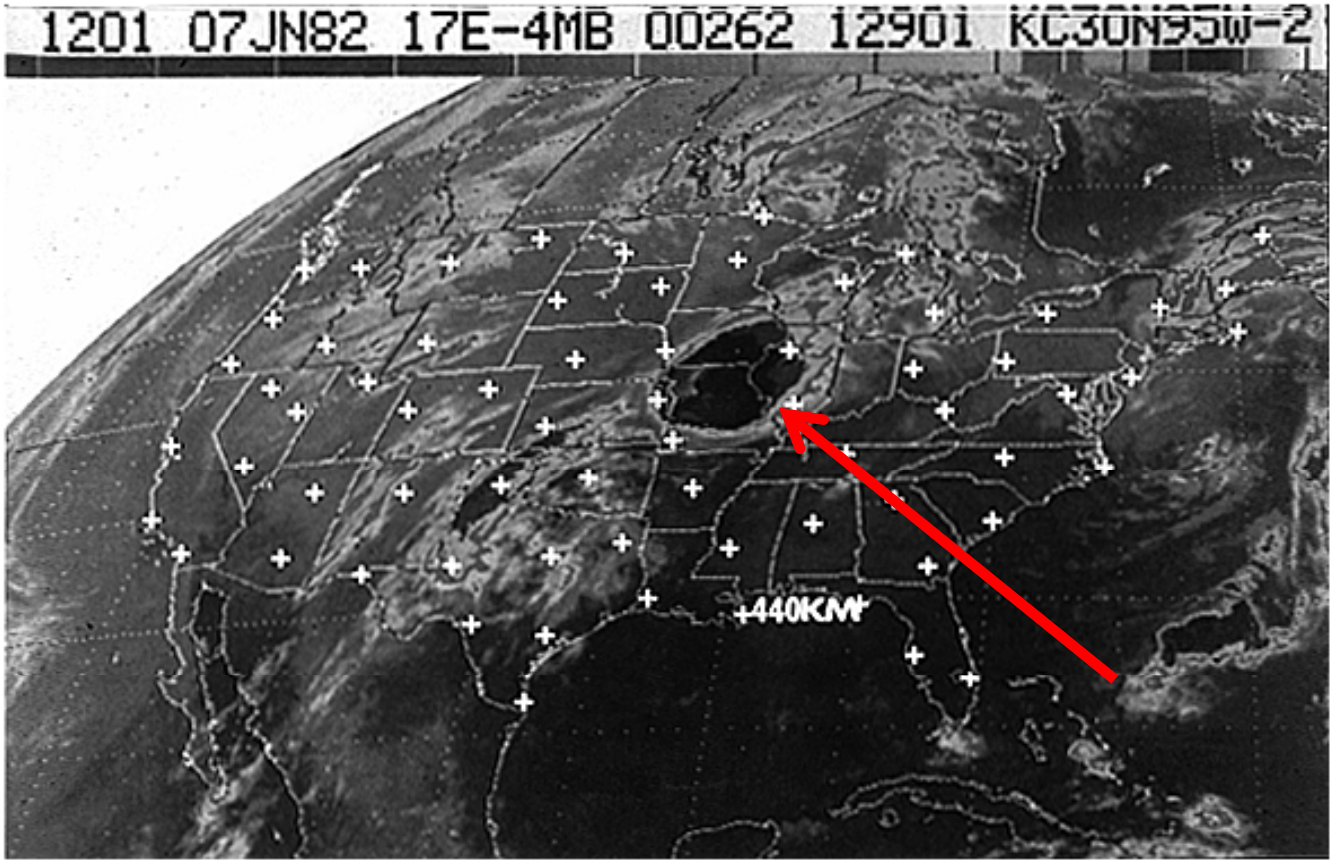
Satellite Imagery Interpretation

- MB curve



Satellite Imagery Interpretation

- MB curve – basis of MCC definition



Satellite Imagery Interpretation

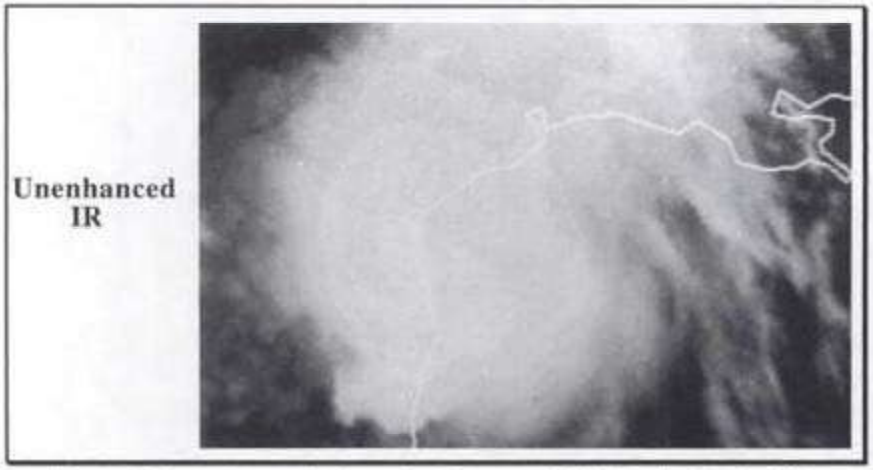


Figure 3.12. IR image of a Texas thunderstorm (GOES IR, October 8, 1994)

Figure 3.13. IR image of a Texas thunderstorm (GOES IR, October 8, 1994)

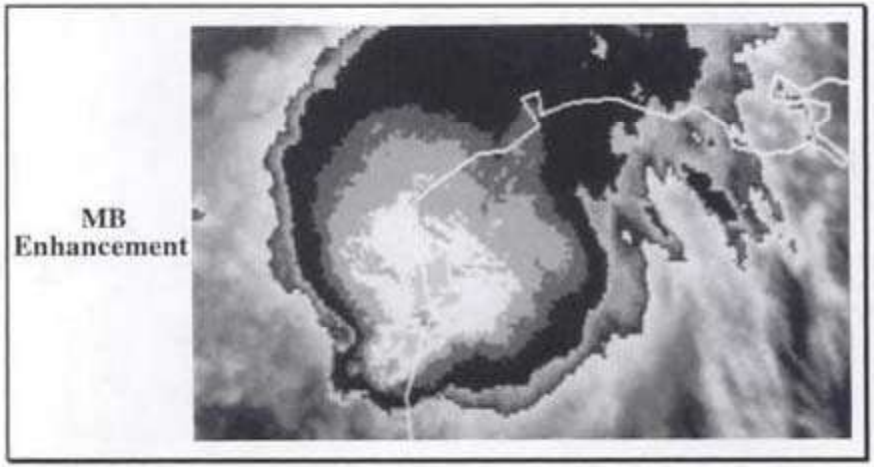


Figure 3.14. IR image of a Texas thunderstorm (GOES IR, October 8, 1994)

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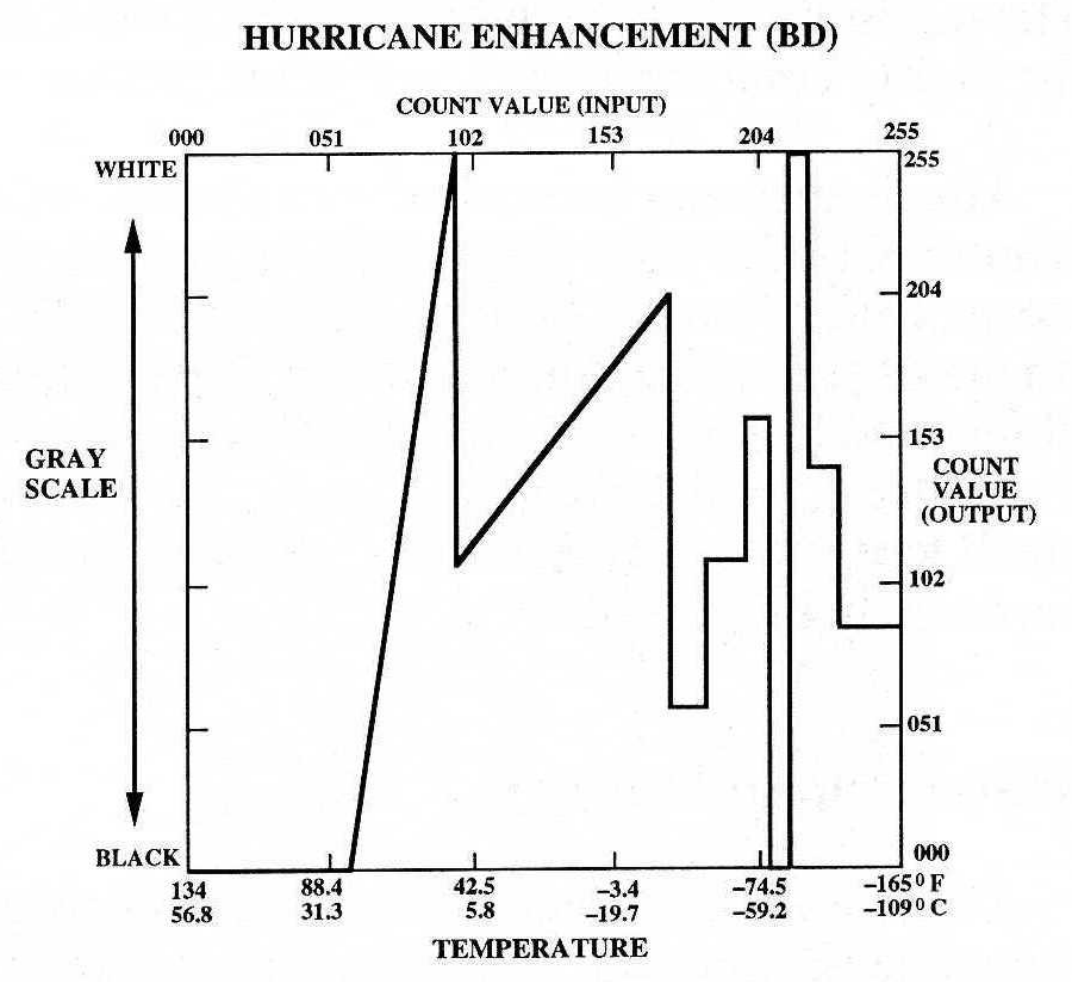
Satellite Imagery Interpretation

- BD curve
  - Allows for enhancement of hurricanes;
  - More detail in cloud top temps between eye and eyewall

Satellite Imagery Interpretation



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Satellite Imagery Interpretation

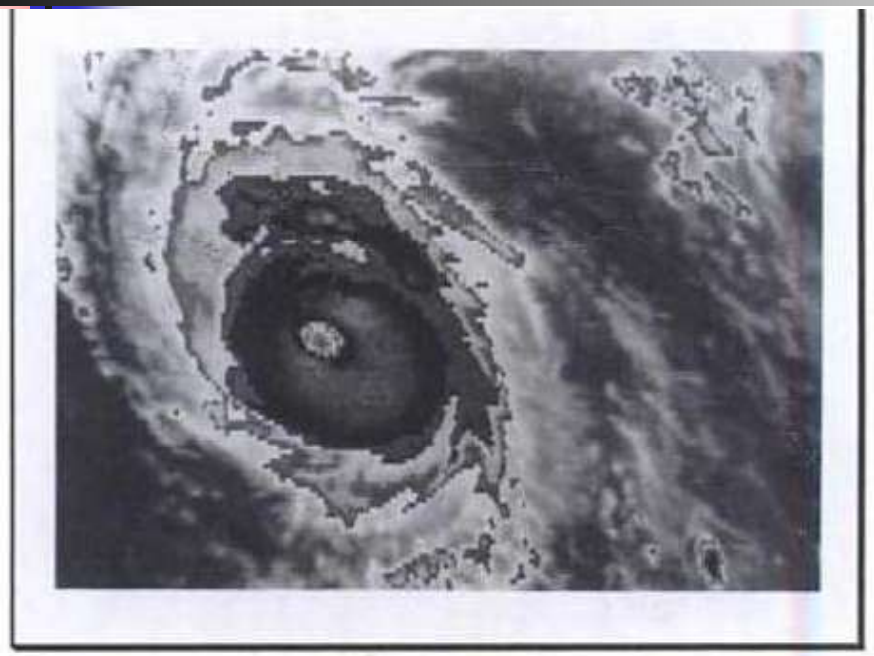

Figure 3.15. MB enhanced IR image of Hurricane Andrew (GOES IR, August 25, 1992)

From
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By Eric D. Conway

Figure 3.16. BD enhanced IR image of Hurricane Andrew (GOES IR, August 25, 1992)

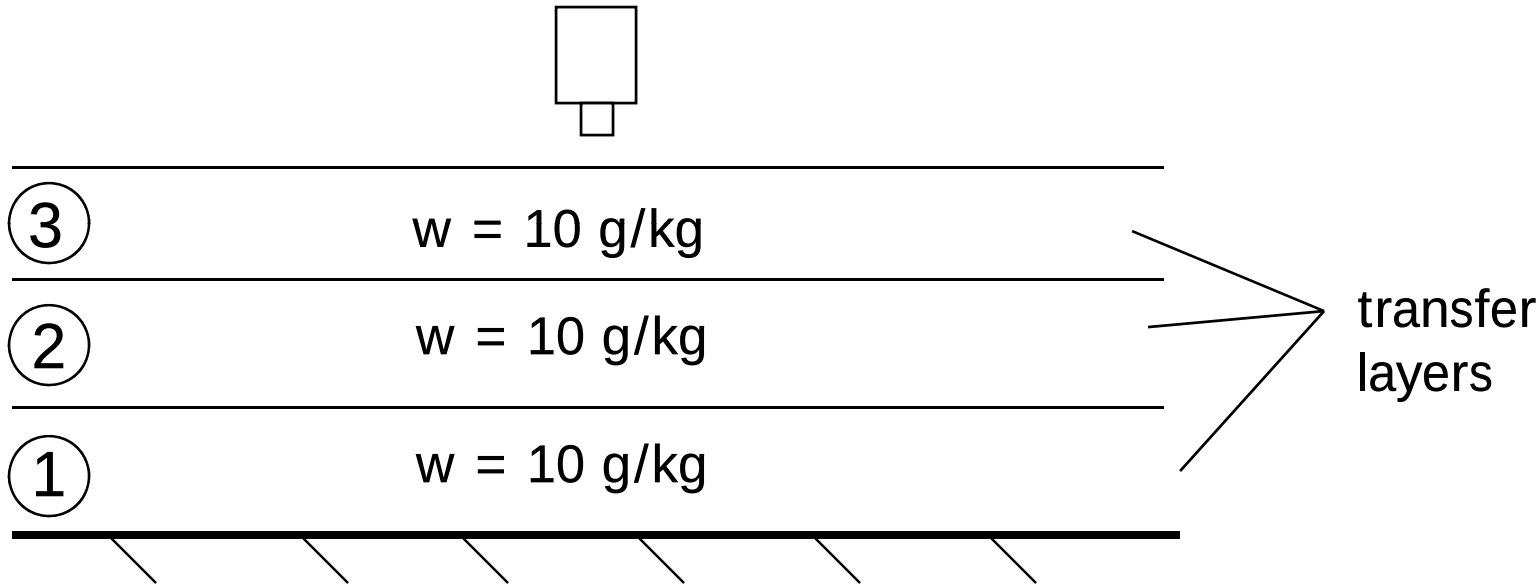
Satellite Imagery Interpretation

- Water Vapor is a good absorber of 6.8 μm E.

more vapor
↓
greater absorption
↓
lower E (reaching satellite)
↓
lower T (Stefan-Boltzmann)
↓
brighter white

Corresponds to ~400-mb flow pattern

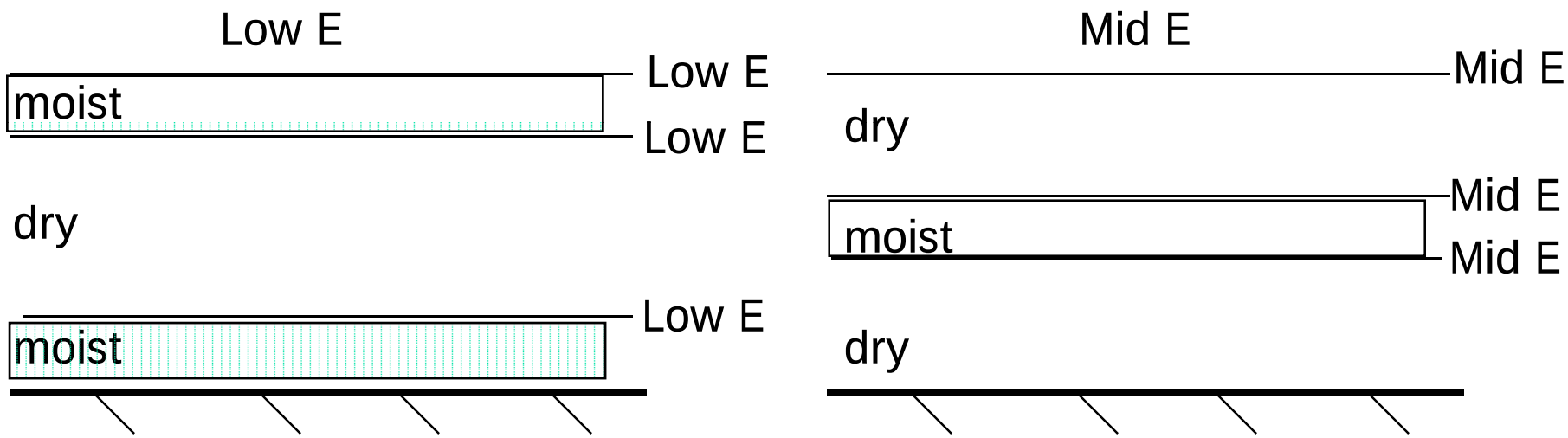
Satellite Imagery Interpretation



- Layer 3 allows more E through. Why?

-WV is measured by <u>mass</u>. As you ascend, <u>volume</u> (of 1 kg) <u>increases</u>, density decreases and more E penetrates.

Satellite Imagery Interpretation



- Due to the reduced density, E leaves 2nd moist layer about the same way as it entered.

Synoptic Scale Cloud Bands

Deformation Zones:

- Tend to hide in flow field
- Not always easy to see (w/o other aids, like clouds)

Synoptic Scale Cloud Bands

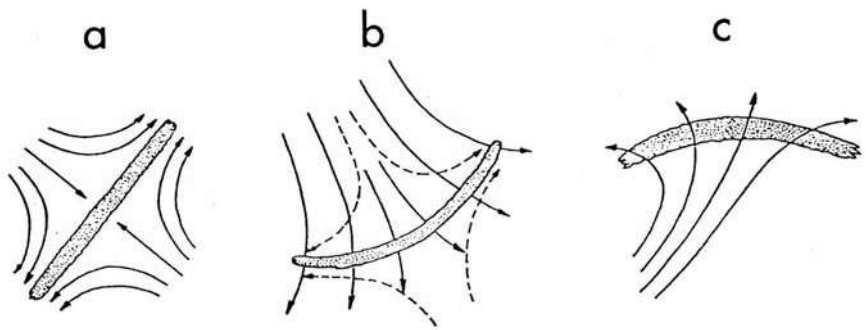


Fig 5

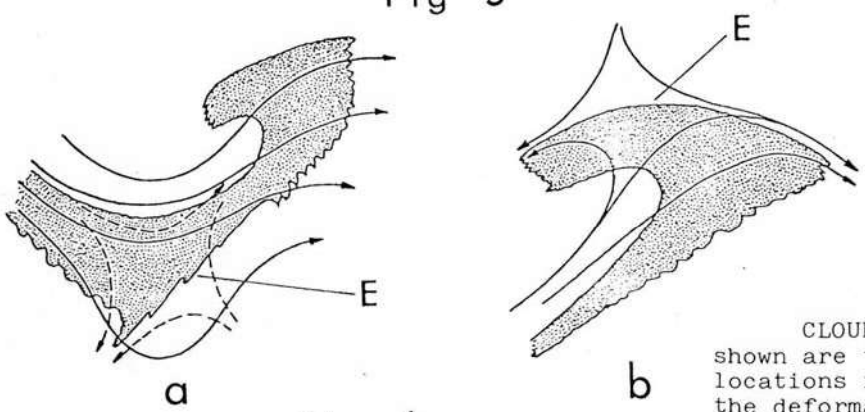


Fig 6

From
Synoptic Scale Cloud Systems
by Roger Weldon

CLOUD BOUNDARIES along Deformation Zones. The cloud patterns shown are those of synoptic scale midlatitude storms. Two common locations for deformation zone borders are shown. In Figure 6a, the deformation zone boundary is at "E". It is common for this boundary to be moving. In that case, the southern trough is not likely a "closed" circulation. The hyperbolic motions are in the relative flow, and would be defined in the vorticity field. The boundary at "E" in Figure 6b is more common, and is also frequently associated with a col or hyperbolic zone in the upper level winds.

Synoptic Scale Cloud Bands

Baroclinic Leaf

- Early stage of surface cyclogenesis
- Associated w/frontogenetic stage of storm development
- 75% of leaf cloud systems evolve to comma systems

Synoptic Scale Cloud Bands

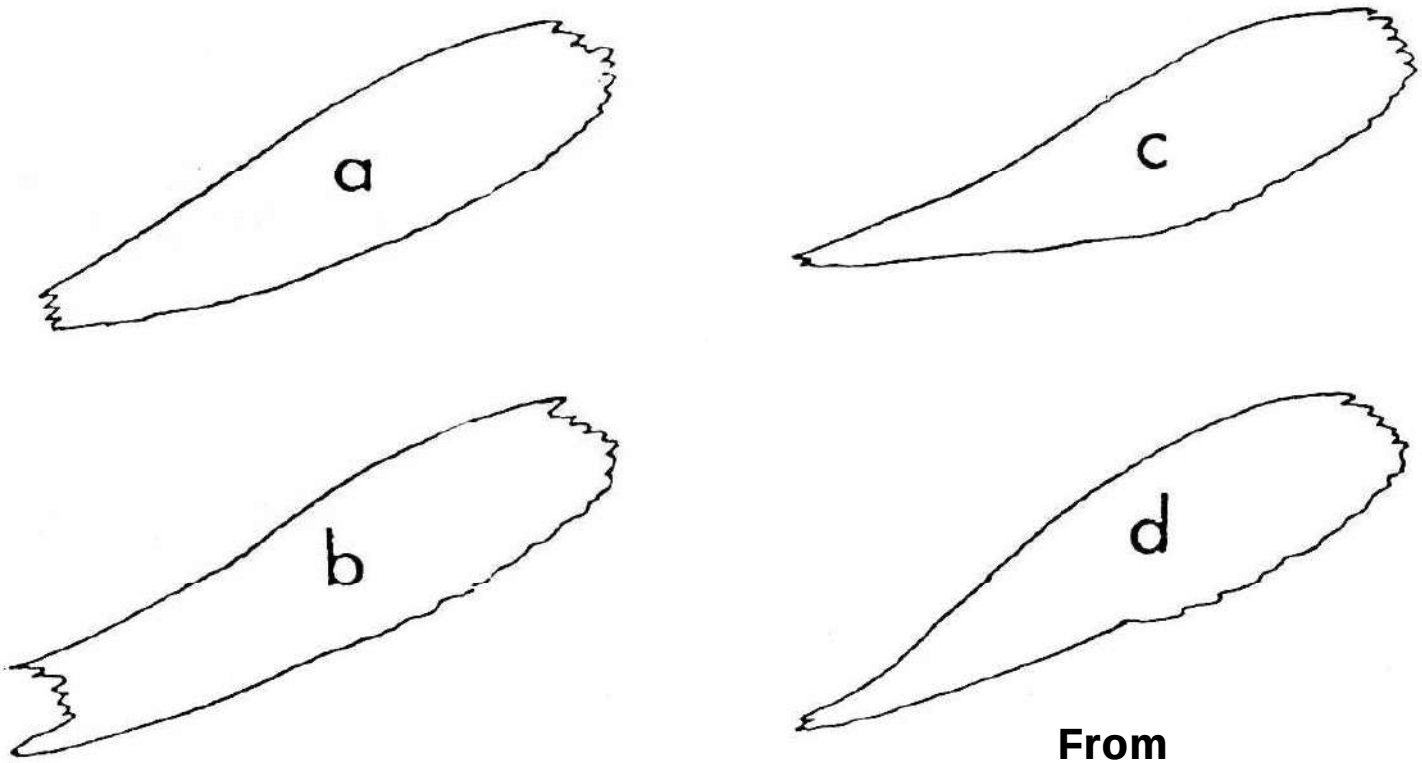
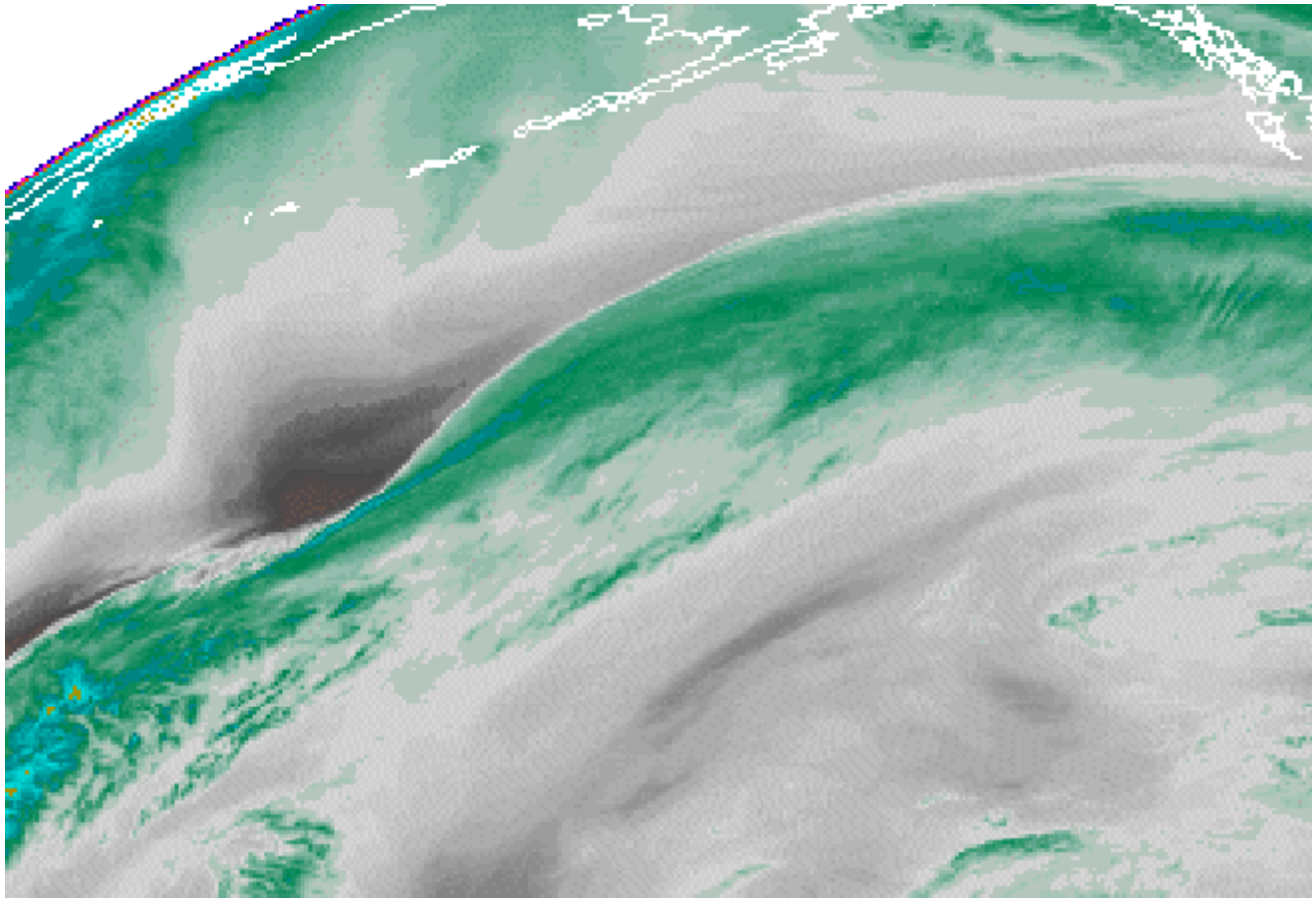


FIGURE 20

From
Synoptic Scale Cloud Systems
by Roger Weldon

Synoptic Scale Cloud Bands

Baroclinic Leaf



Synoptic Scale Cloud Bands

Comma Pattern:

- S shape in cloud pattern, assoc. with cyclogenesis.
- Max tangent velocity near to center
- 500 mb vort. max often found at inflection pt. of S shape
- Note:
  - Comma clouds **w/o** jet stream cirrus typical w/large UA low ---- left of jet.
  - Comma cloud **w/** jet stream cirrus typical w/new comma formation just left of jet stream.

Synoptic Scale Cloud Bands

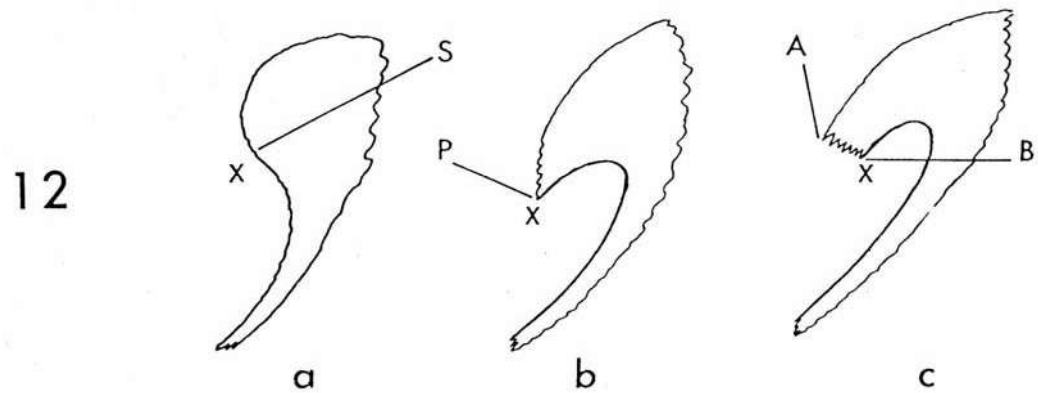


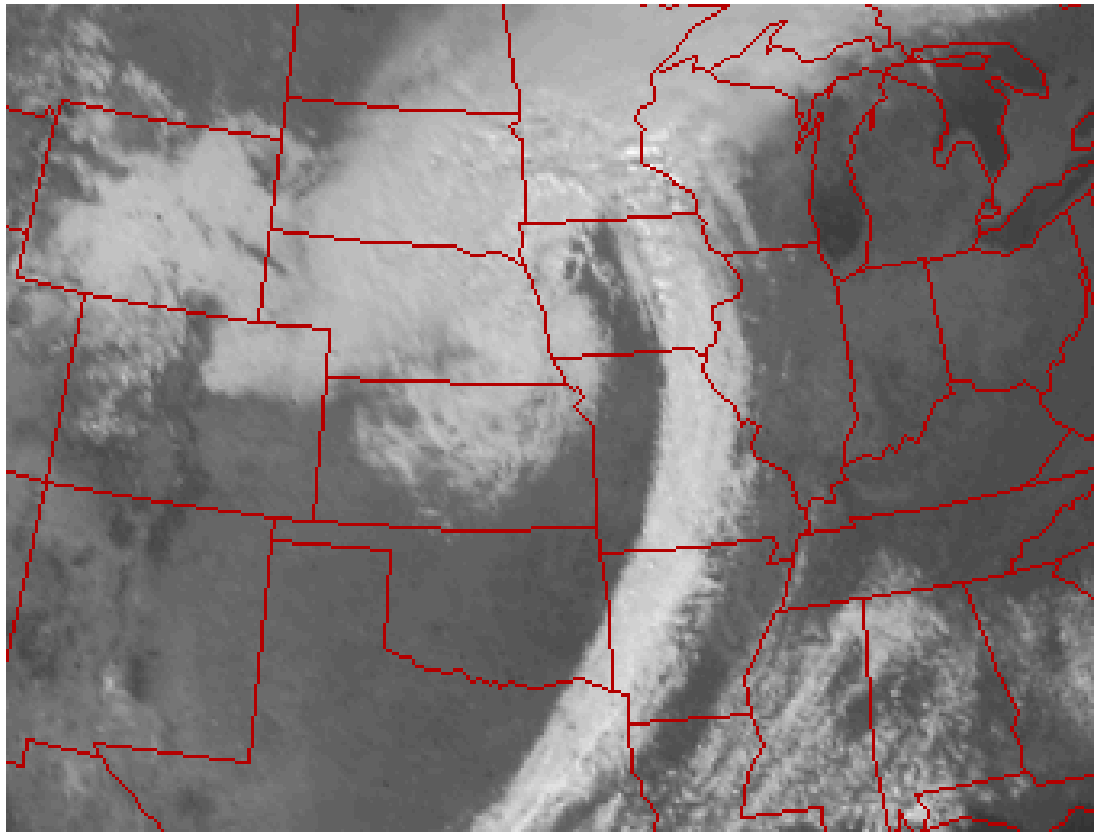
FIGURE 12

The three drawings show typical cloud comma patterns observed in satellite imagery. The pattern in Figure 12a has an "S" shaped upstream border similar to the punctuation mark comma. More common is the pattern in Figure 12b, in which the inflection point is replaced by a single apex or sharp corner on the cloud border. Even more frequently observed, is the pattern in Figure 12c, with a double point or double corner separating the well defined convex and concave portions of the border. If the cloud systems shown are in the westerlies and of middle or high cloud tops, the "X" on the drawings indicates the most likely location of the maximum cyclonic vorticity at 500mb. The relationships were determined by observations of satellite imagery and 500mb vorticity analyses.

From
Synoptic Scale Cloud Systems
by Roger Weldon

Synoptic Scale Cloud Bands

Comma Pattern:



Global Positioning System Meteorology

- GPS signals are:
  - delayed and refracted by atm gasses as they propagate from GPS satellites to Earth-based receivers.

1. Water vapor produces a significant and unique delay
   - Only common atm constituent having a permanent dipole moment
   - Dipole moment caused by asymmetric charge distribution in water molecule
   - Retards propagation of electromagnetic radiation in the atm

Global Positioning System Meteorology

2. Refractivity of WV is ~17 times greater than that of dry air.
   - The atm refractivity is very sensitive to the presence of WV.
   - WV introduces a delay in propagation of microwave radiation to earth-based GPS receivers.

↓

"wet delay"

↓

"wet delay" nearly α integrated vapor along signal path

- Liquid water & ice are largely not a factor. Why?
- Hydrogen bond between water molecules reduces the contribution of dipole moment to delay.

Global Positioning System Meteorology

- Refractivity may also be used to profile an atm pressure and temp

1. Coherent dual-band radio signals transmitted by ground station to satellite on far side of planet.
2. Signals are bent thru atm or way back to planet surface
3. Receiver (ground station) picks up signal
4. The two-way differential phase measurements are used to retrieve profiles of atm temp and pressure.

Global Positioning System Meteorology

- **Currently**
  - One may also employ geostationary satellites w/GPS transmitters w/ GPS receivers on Low Earth Orbit (LEO) satellites:
    a. LEO tracks GPS satellite as it occults Earth's atm
    b. Arrival time of GPS signal at receiver delayed:
       -refractive bending and slowing of signal

Global Positioning System Meteorology

- **Currently**

  c. Measure change in carrier phase own entire occultation event

  d. Determine atm refractive index as function of altitude

Global Positioning System Meteorology

- **Currently**

e. T and p profiles derived via downward integration using

i) linear relationship btwn refractivity and ρ_{air}
ii) gas law
iii) hydrostatic assumption

only in trop. away from moisture

Global Positioning System Meteorology

- GPS Strengths
  - Profiles of atmospheric q (and T and P) available with greater <u>spatial</u> <u>density</u>.
  - Have greater temporal density
    - ~ hourly profiles

Global Positioning System Meteorology

- GPS Weaknesses
  - Significant lateral (spacial) averaging
  - Earth-based observing provides continuous measurements at fixed location
    - GPS discrete in time
  - Space-based measurements subject to
    i. Mountain obstructions
    ii. Adjacent low-lying areas

    } much of lower trop may not be visible

Global Positioning System Meteorology

- SuomiNet: Real time GPS for atm monitoring
  - Named for Verner Suomi
    - meteo satellite pioneer