Using COSMIC to infer moist and dry environments around tropical cyclones

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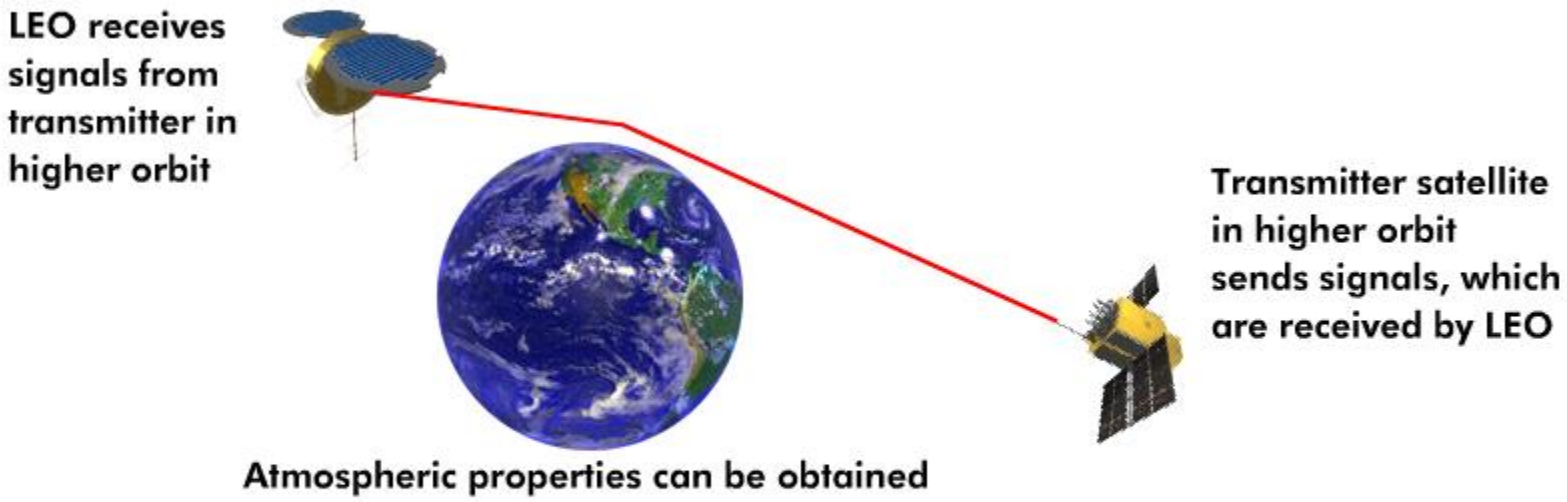
- Description of radio occultation method and its derived refractivity mathematics
- Probability product of moist and dry air around tropical cyclones
- Climatology and dewpoint profiles
- Examples – Hurricane Fred and Hurricane Helena

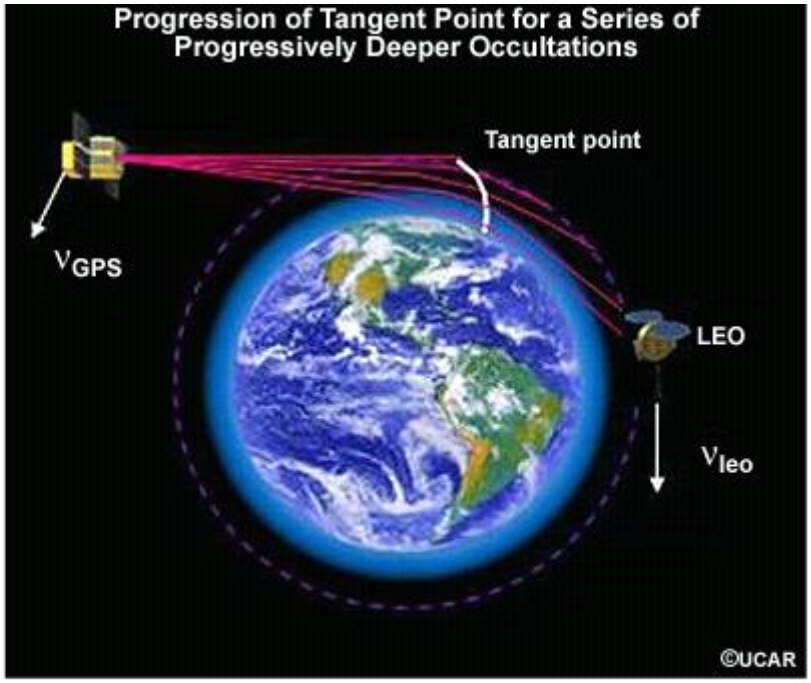
Radio occultation (limb sounding) method

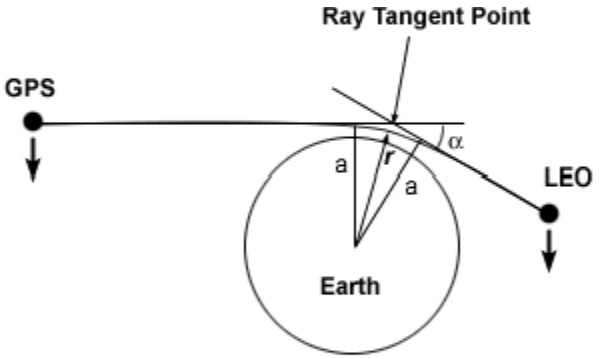


COSMIC (The Constellation Observing System for Meteorology, Ionosphere, and Climate): Launched with 6 LEOs on April 14, 2006; joint Taiwan-U.S. project

CHAMP (CHAllenging Minisatellite Payload) : Prototype for COSMIC, 1 LEO, launched on July 15, 2000; Germany project

Following figures courtesy of COSMIC webcast module





- GPS receiver in LEO "sees" the GPS set or rise behind the Earth's limb
- Delay of the signal between the GPS and the LEO is observed
- The change of the delay allows for reconstruction of the bending angle
- The vertical refractivity profile at the ray tangent point is reconstructed

Method can be coupled to refractivity equation

$$N(\mathrm{p},\mathrm{T},\mathrm{T_d}) = 77.6\frac{p}{T} + 3.73\times10^5\frac{e(\mathrm{T_d})}{T^2} + \textit{correction for ionospheric effects}$$

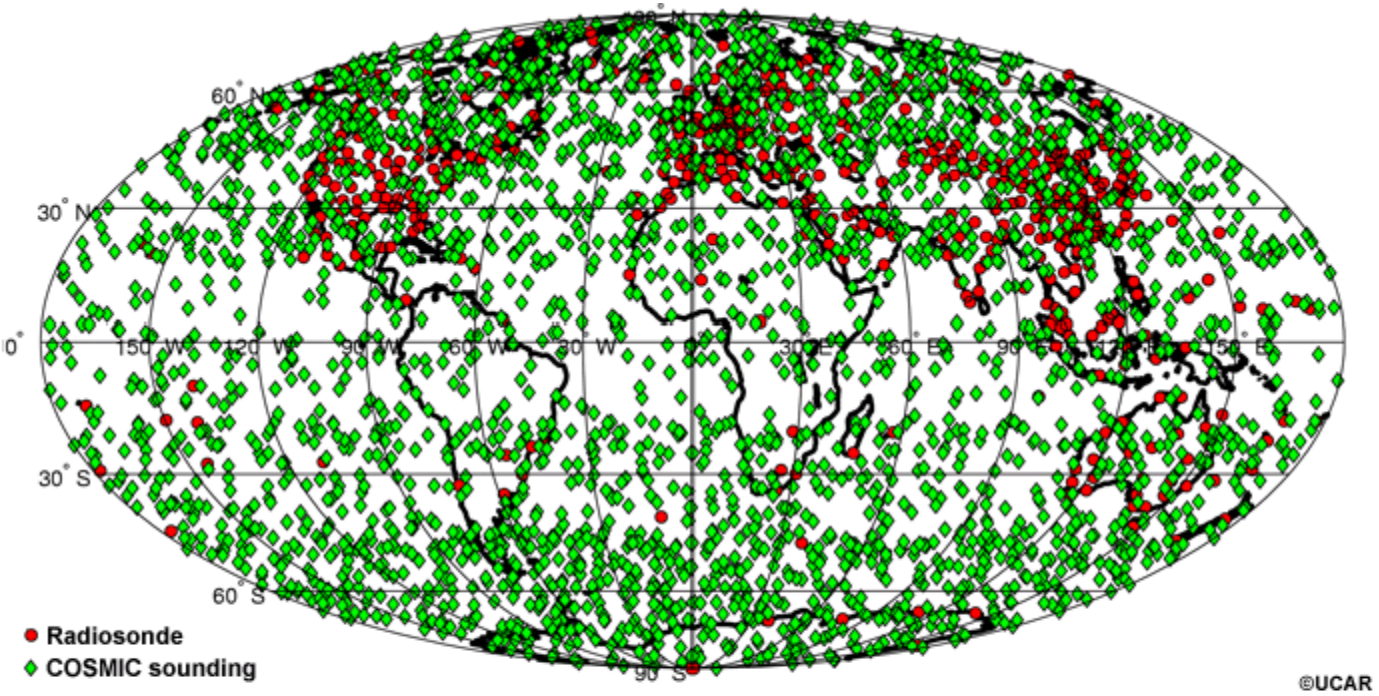
$$\left[\text{dry term}\right] \quad \left[\text{wet term}\right]$$

Advantages:

- *High vertical resolution (0.1 km)*
- *No calibration needed*
- *Not affected by clouds or rain*
- *Global coverage*

Disadvantages:

- *Horizontal resolution coarse (200 km)*
- *Refractivity equation an unclosed system where moisture abundant (lower troposphere).*



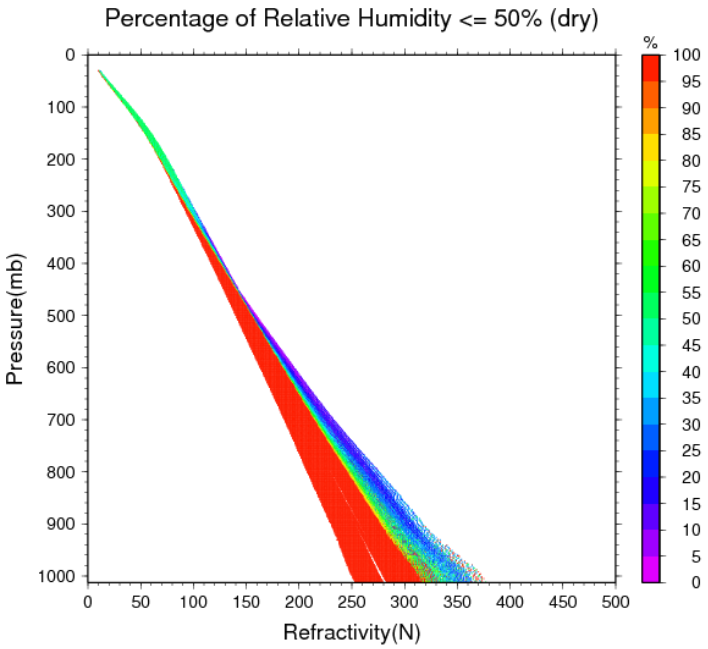
- Comprehensive daily coverage of RO soundings across globe once constellation complete

- Radiosondes heavily focused on Northern Hemisphere land masses

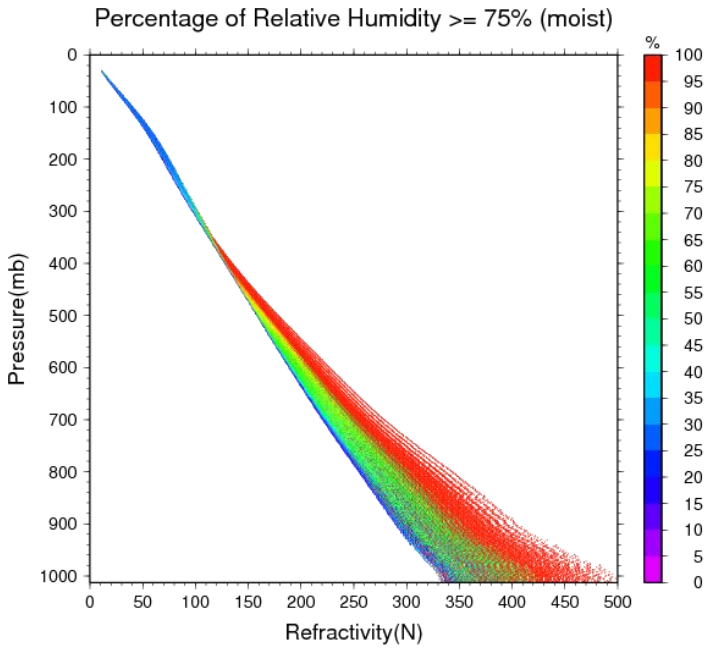
- Radio occultations will provide much more uniform measurement sampling of Earth's atmosphere

Diagnostic tool dry and moist air in hurricanes

Probability of dry air

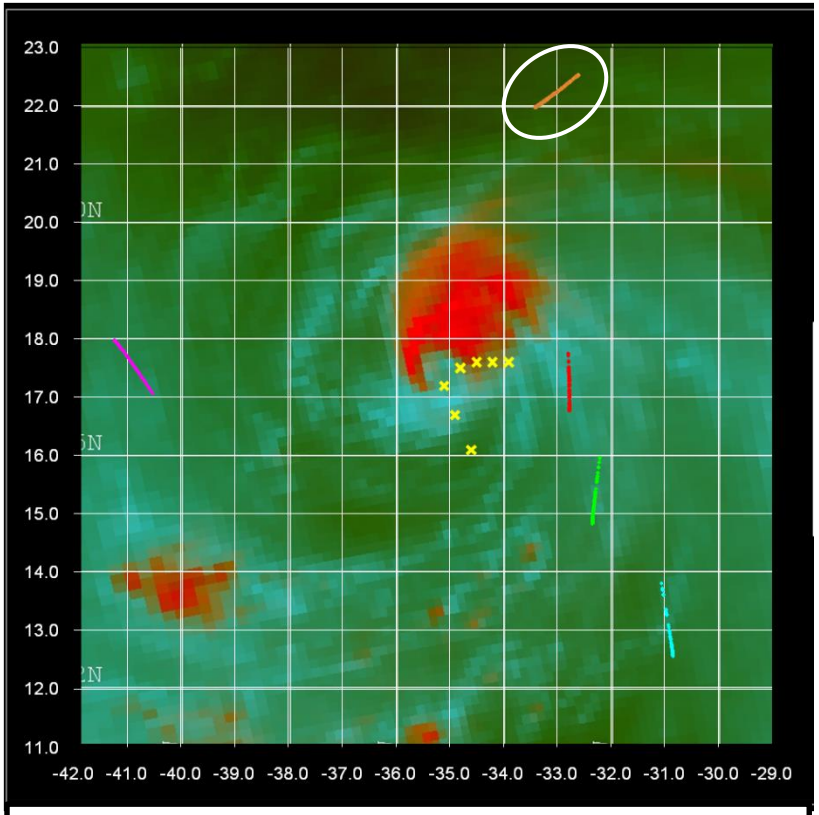


Probability of moist air

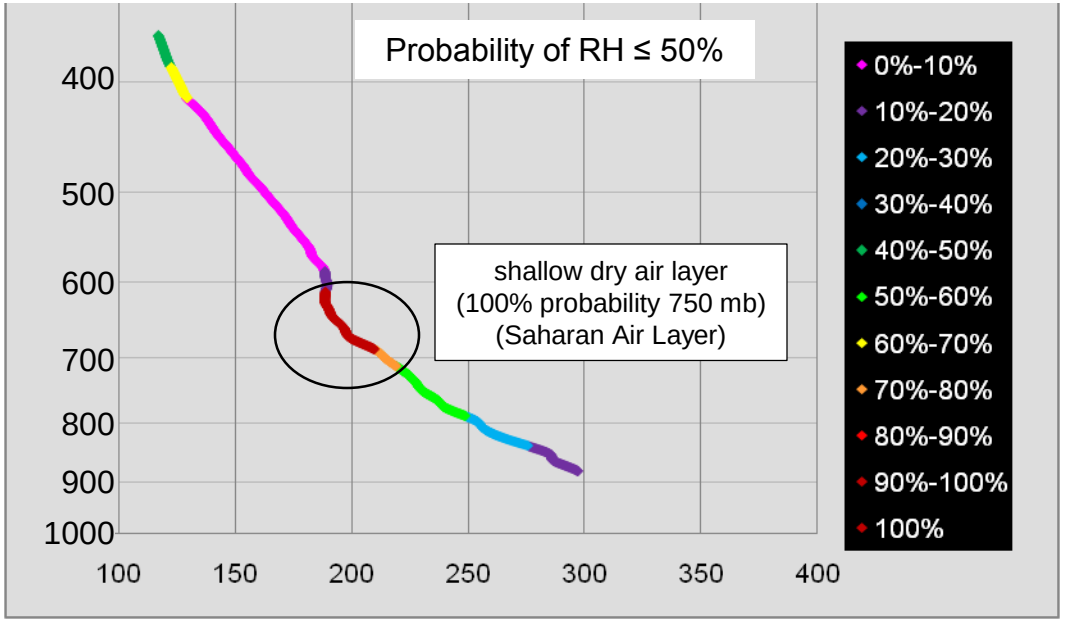


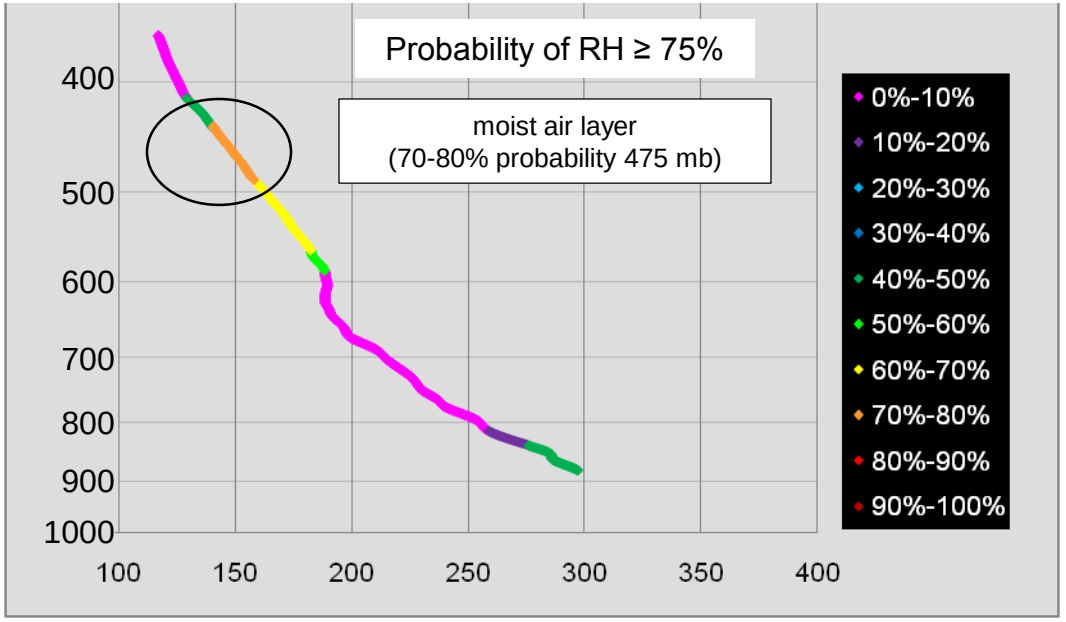
Understanding of optimum use of refractivity in hurricane models

Hurricane Fred 2009

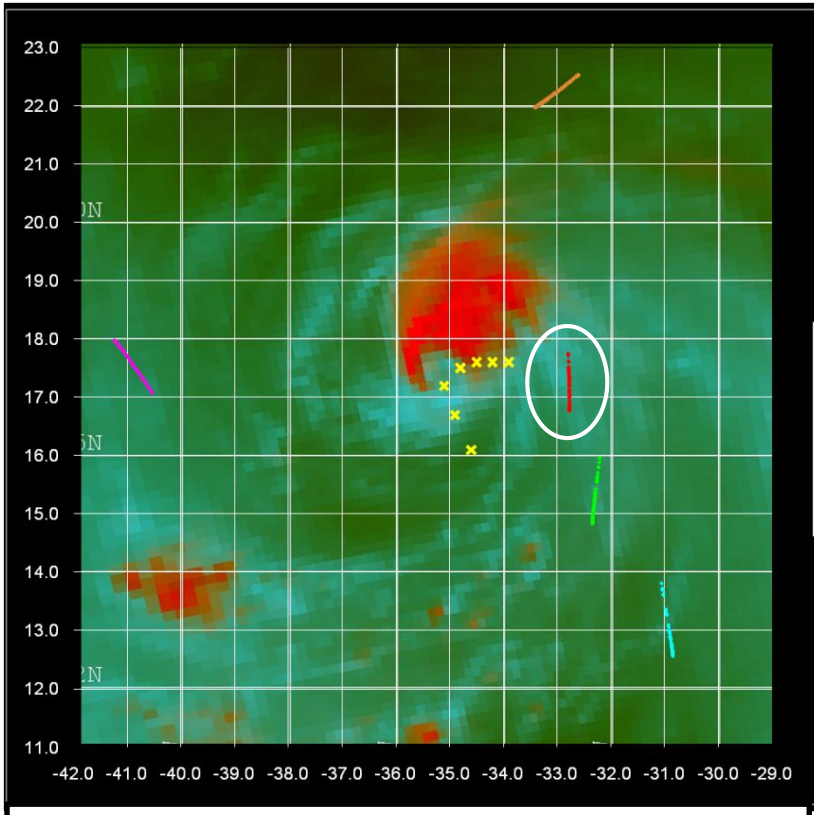


23:41 UTC 10 September 2009
AMSU-B image from METOP-A satellite
(image provided by NRL-Monterey)





Hurricane Fred 2009



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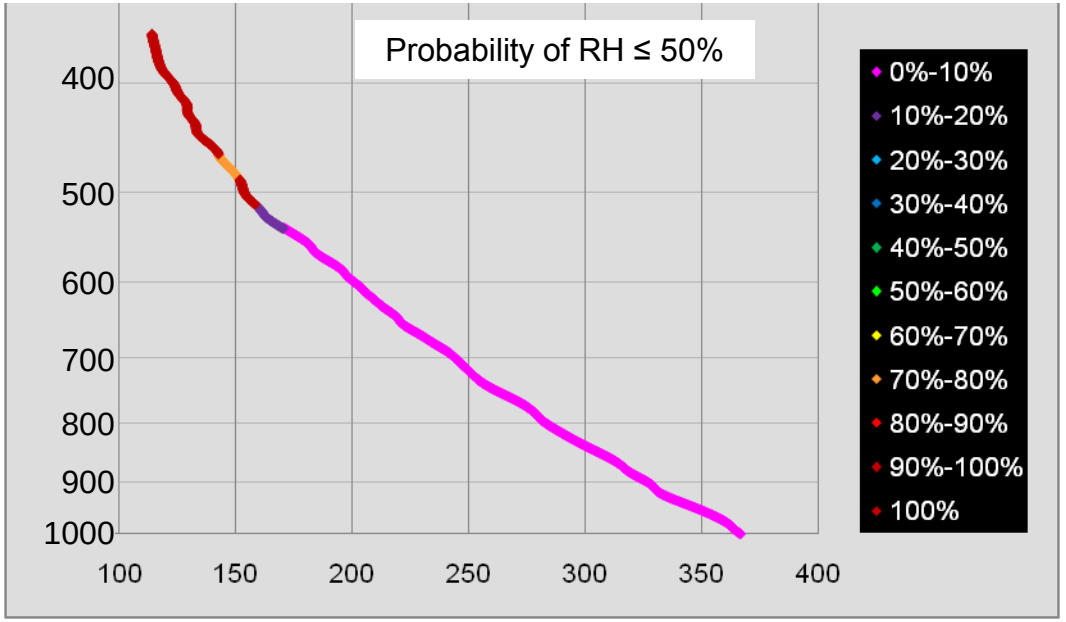
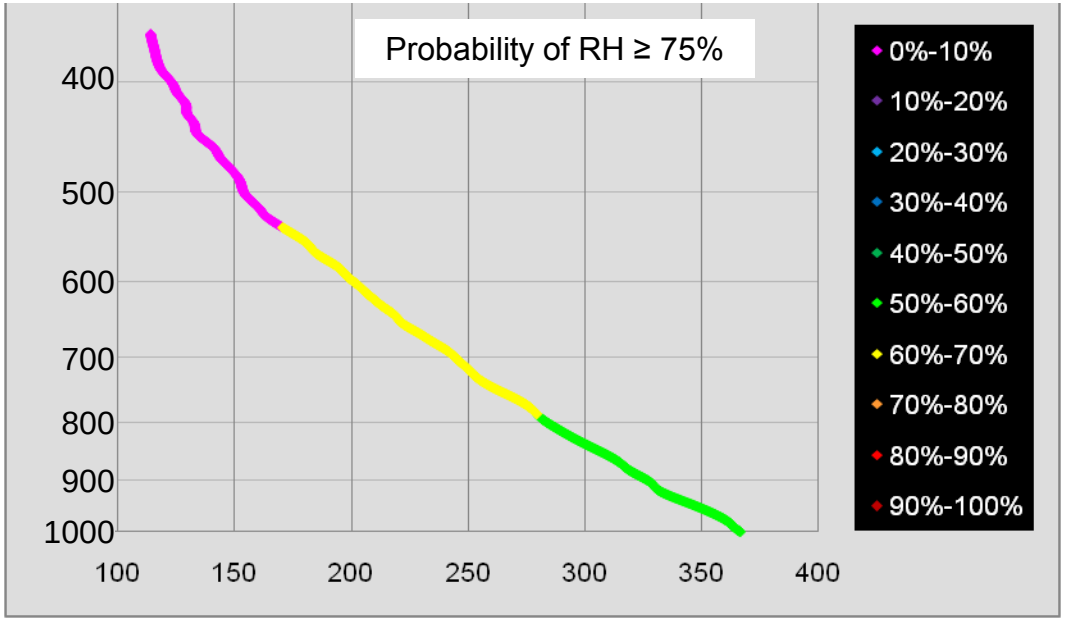
AMSU-B image from METOP-A satellite
(image provided by NRL-Monterey)

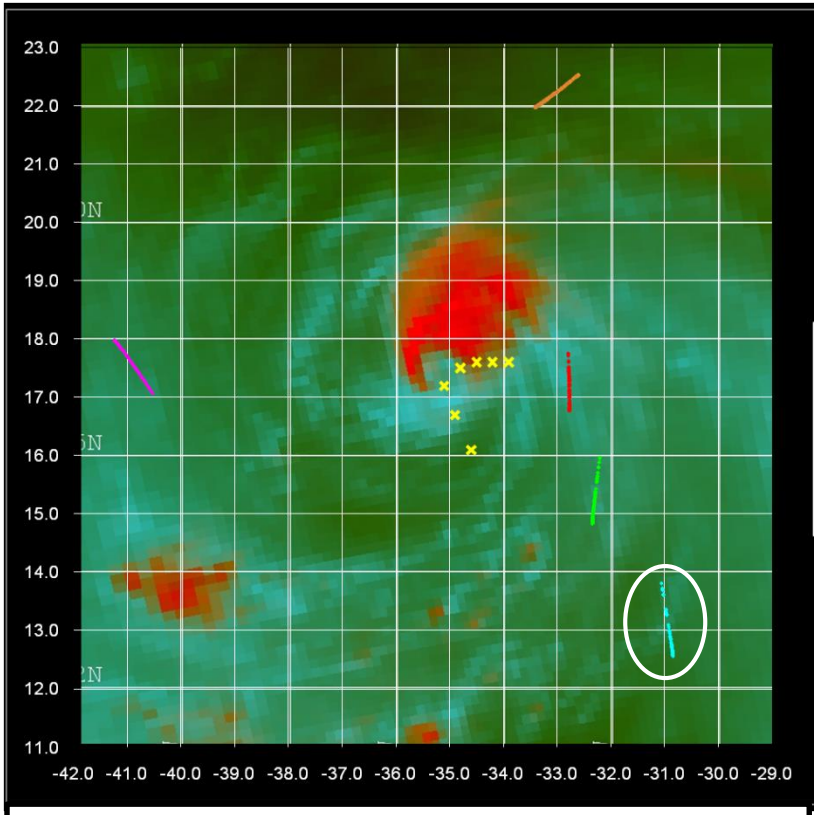
COSMIC refractivity for 02:56 UTC 11 Sept 2009





COSMIC refractivity for 04:24 UTC 11 Sept 2009

Hurricane Fred 2009



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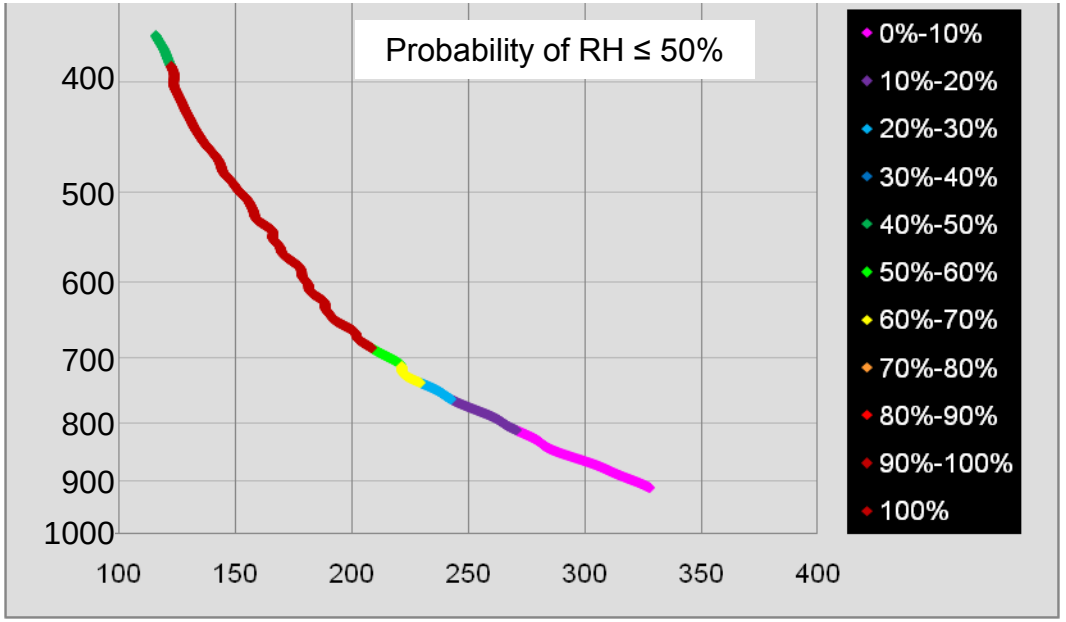
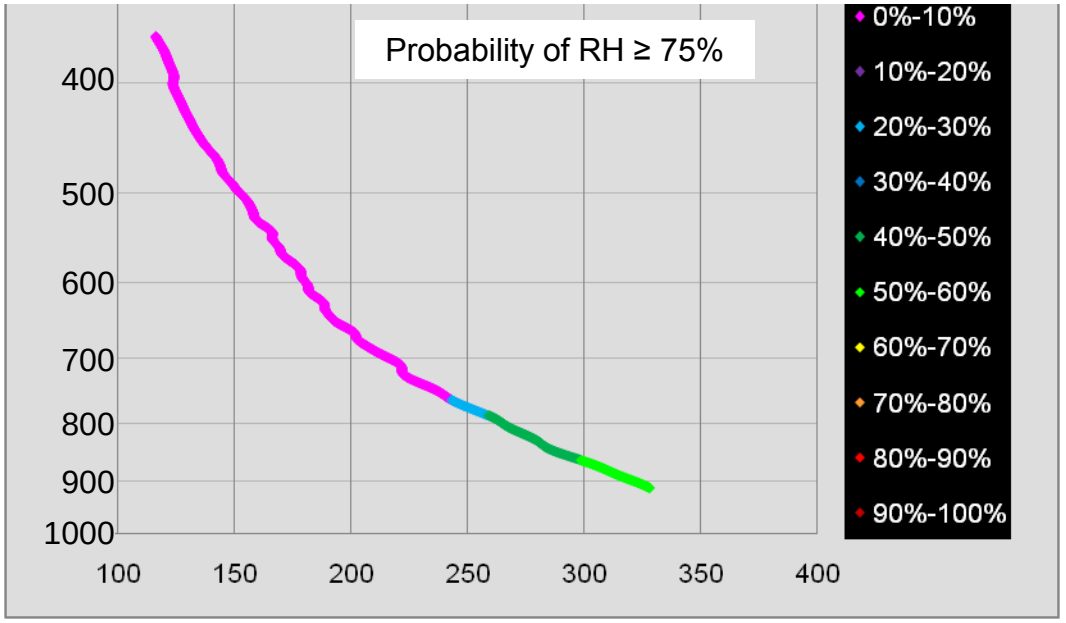
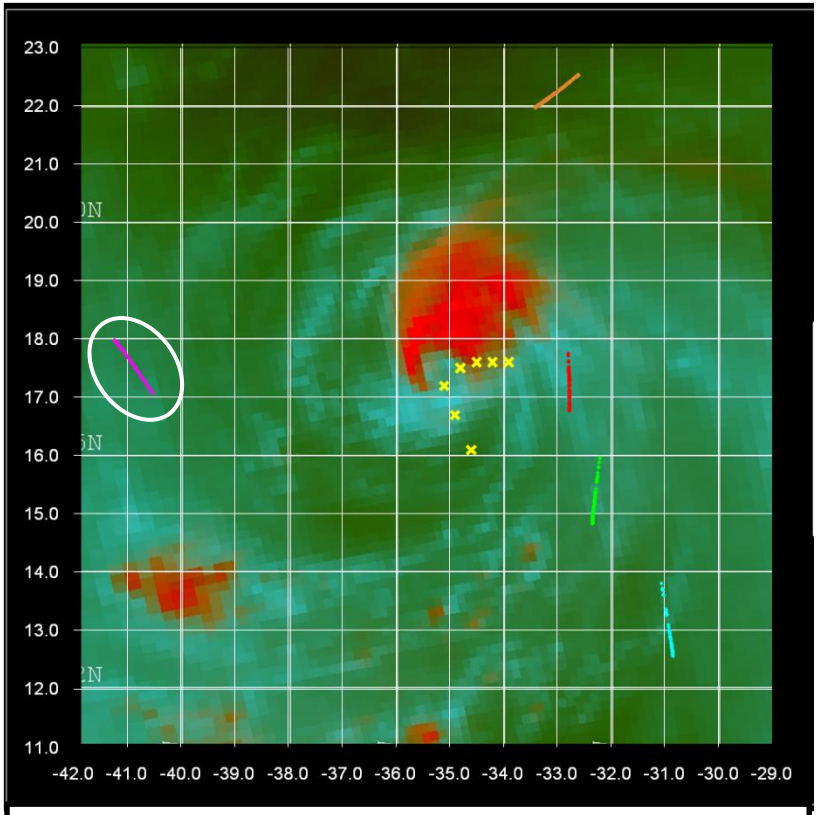
AMSU-B image from METOP-A satellite
(image provided by NRL-Monterey)





COSMIC refractivity for 06:15 UTC 11 Sept 2009

Hurricane Fred 2009



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AMSU-B image from METOP-A satellite
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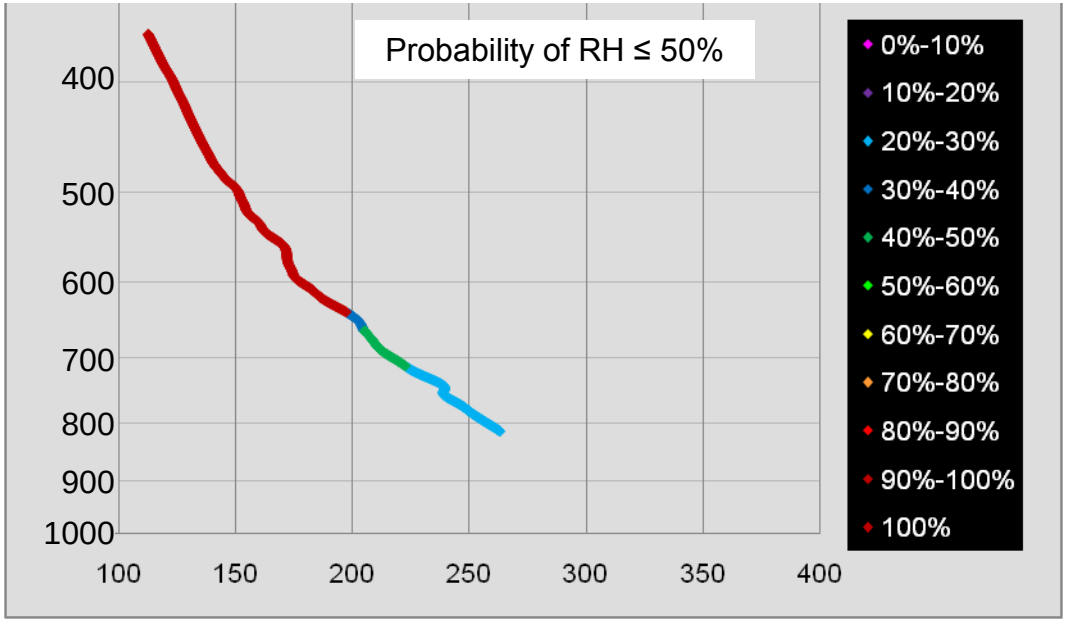
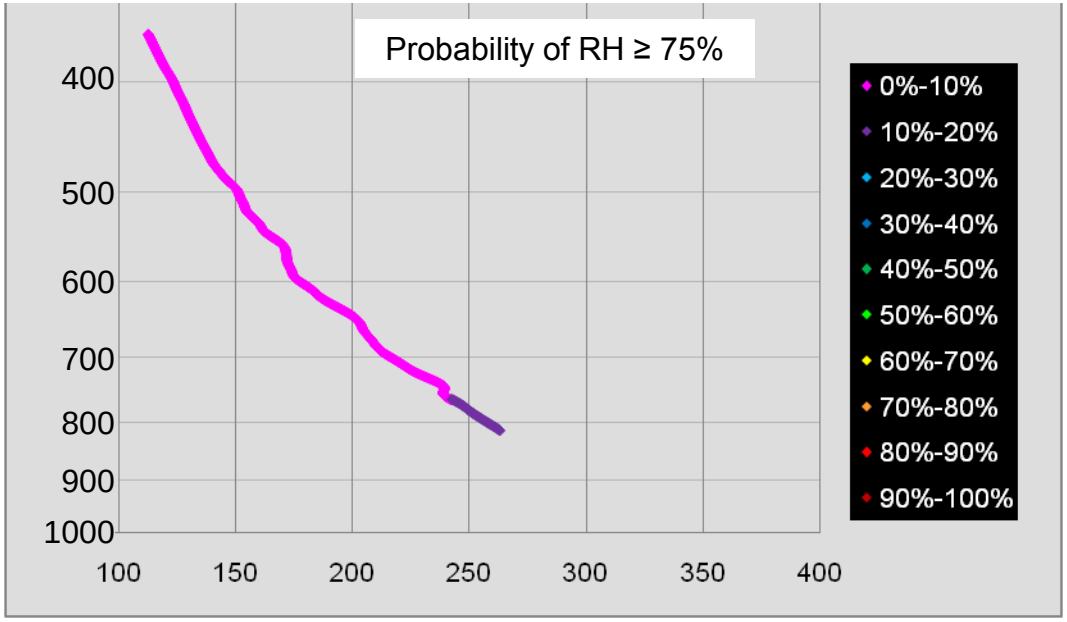
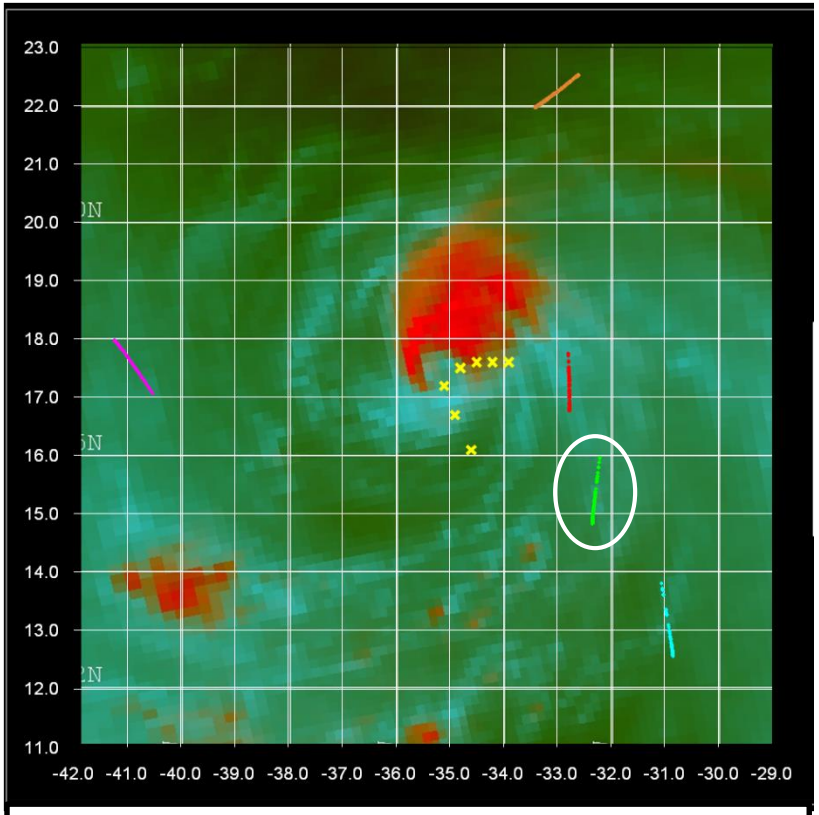




COSMIC refractivity for 08:14 UTC 11 Sept 2009

Hurricane Fred 2009



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AMSU-B image from METOP-A satellite
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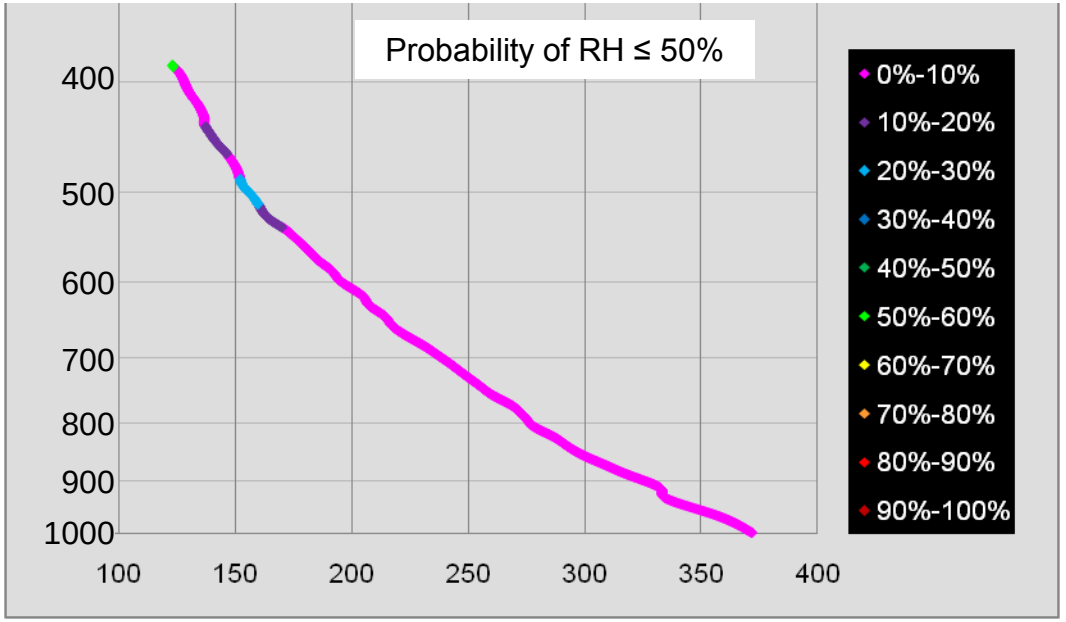
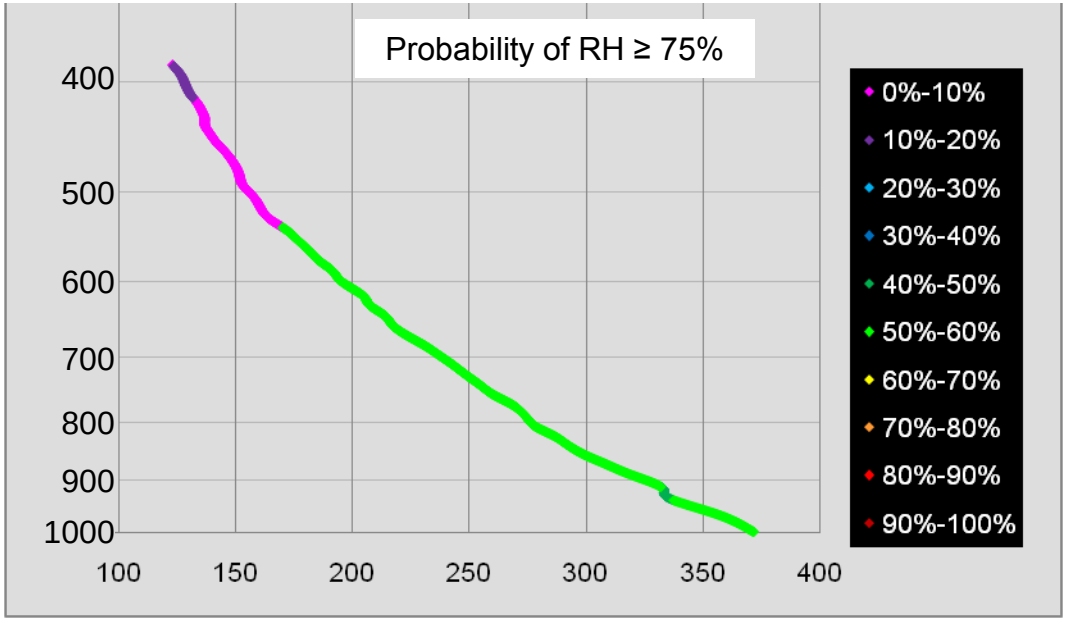
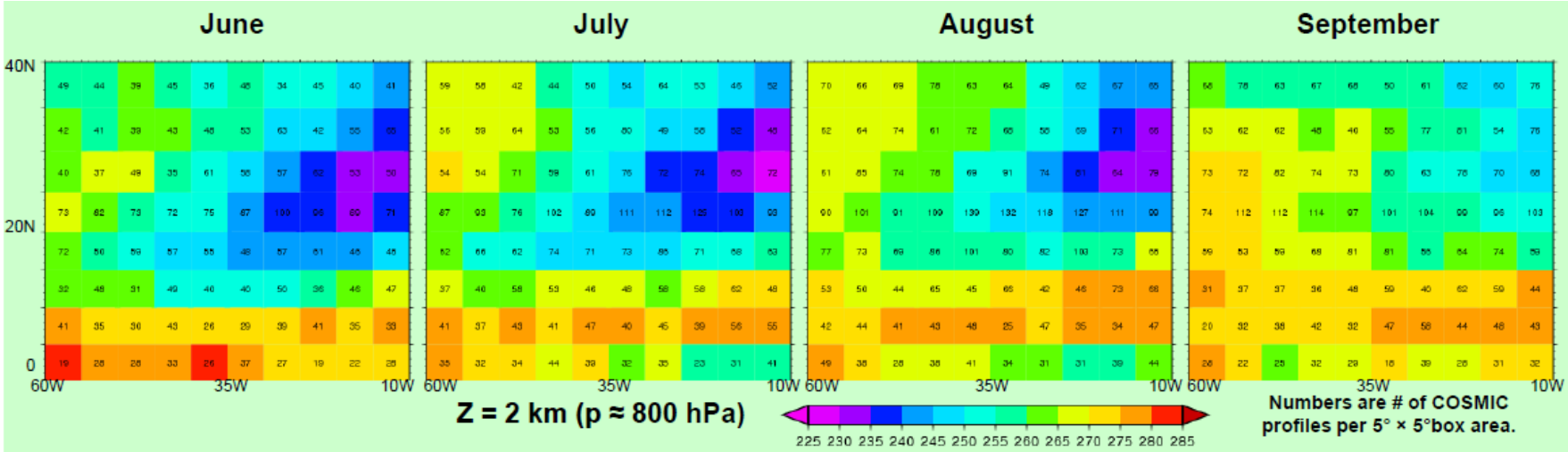


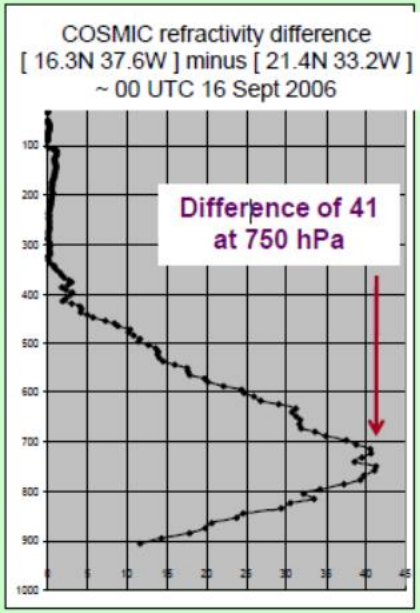


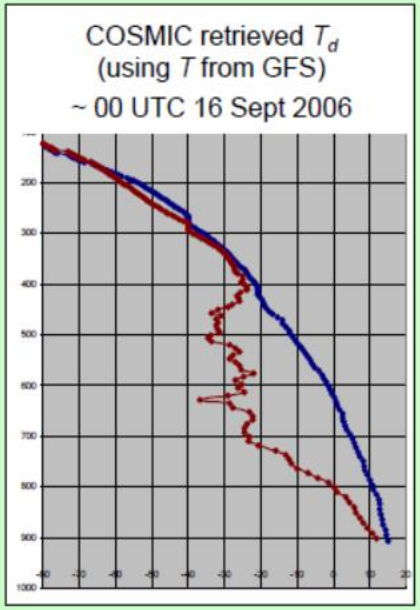
Refractivity near African coast (TC genesis region)

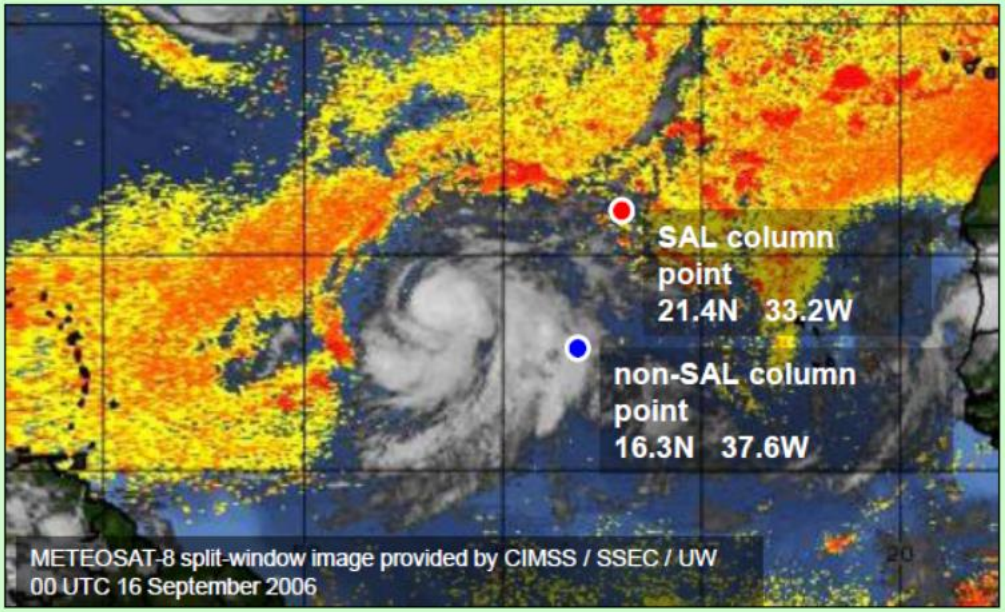


Based on average *N*, there exists a significant contrast of moisture at z = 2 km along 10°N in June and along 15°N in July. This contrast becomes more diffuse through August and September, with increased moisture and cloudiness throughout the study area. *N* at this level may serve as a better indicator for probable convection.

Compute $T_d(p)$ assuming T(p) relatively well-known Example, Hurricane Helene (2006)







LEFT and CENTER: Profiles of differenced refractivity, and profiles of GFS-based T_d, from apparent SAL and non-SAL air columns near Helene. RIGHT: A difference of 12.0-μm and 10.8-μm wavelength brightness temperatures from METEOSAT-8 assists in the identification of the SAL and non-SAL regions.

Summary

- COSMIC (GPS occultation-derived refractivity) offers potential to identify moist and dry regimes around tropical cyclones
- Presented a high and low RH probability diagnostic tool useful in data-sparse regions since impervious to rainfall and deep convection (east Atlantic)
- Simple to implement, could be incorporated into ATCF easily
- Helpful in identifying good case studies for refractivity assimilation in HWRF
- Climatology maps also have applications
- Dewpoint profiles may be derived and used subjectively where T(p) model data is reasonably confident
- Limited by satellite passes coinciding with tropical cyclone “hits”, but with more LEOs scheduled for launch, this problem will become less troublesome