Examination of the tropical cyclone environment through comparison of COSMIC with other satellite data

Christopher M. Hill, Patrick J. Fitzpatrick, and Yee Lau
Geosystems Research Institute / Northern Gulf Institute
Mississippi State University

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Motivation to use COSMIC

• Tropospheric sounding data are provided:
  • in the absence of reconnaissance flights or other satellite data
  • in cloudy or rain-filled regions, where other satellite data are contaminated

• Regions or layers of contrasting moisture content can be identified within:
  • the span and depth of a Saharan Air Layer (SAL)
  • the core of a tropical cyclone
Motivation to use COSMIC

The radio occultation method gives refractivity ($N$) from GPS signal delay

$$N = 77.6 \frac{p}{T} + 3.73 \times 10^5 \frac{e}{T^2} + \text{ correction for ionospheric effects } \{ \text{ correction for ionospheric effects } \}$$

[dry term] \quad [\text{wet term}]

Given $N(p)$, it is possible to solve for $T$ and/or $e$ (and therefore $T_d$)

According to Ware et al. (1996), the error of $e$ in terms of the error of $T$ is:

$$\Delta e \approx \frac{(2TN - 77.6p)}{3.73 \times 10^5} \Delta T \approx 0.23 \Delta T$$

With $N$ and $p$ known, a value of $T$ known within $\pm 3$ K can typically provide a value of $e$ within $\pm 1$ hPa
Methodology

- Within the environment of the tropics, where temperature differences are small, the analysis of refractivity ($N$) alone can provide useful information regarding the distribution of moisture within one of the profiles.

- COSMIC data are collected in the vicinity of recent tropical cyclones—Helene 2006, Dean 2007, Bertha 2008.

- Based on water vapor imagery and METEOSAT SAL (12.0 $\mu$m minus 10.8 $\mu$m) imagery, likely “dry” and “moist” profiles are qualitatively identified and differenced.

- To detect SALs, COSMIC refractivity data are compared against CALIPSO aerosol subtype data.
Differences of COSMIC refractivity between SAL and non-SAL columns
(approx. 00 UTC 16 Sept 2006)

- SAL column point
- non-SAL column point

COSMIC retrieved dewpoint ($^\circ$C)

COSMIC refractivity

Non-SAL minus SAL refractivity

Difference of 41 at 3.2 km
COSMIC and CALIPSO data near Dean 2007
17 Aug 2007

COSMIC refractivity difference \([C1 - C2]\)
Retrieved \(T_d\) difference \([C1 - C2]\)
\(\sim 04:30\) UTC 17 Aug 2007

Difference of 20 at 4.8 km

Influence of \(\Delta T\) ?

COSMIC point #1: 29.0°N 50.6°W
COSMIC point #2: 20.3°N 51.9°W

GOES-12 imagery provided by NCDC 03 UTC 17 August 2007
Methodology

- COSMIC data are found within the circulation area of recent tropical cyclones
  - STY Sepat 2007, Bertha and Ike 2008

- 4th-order polynomial curve fitted against COSMIC profile

- Difference between profile and fitted curve should show refractivity (moisture) anomalies

- COSMIC data are compared against water vapor and microwave imagery to determine cyclone structure

\[
\begin{array}{c|c|c}
\text{Series1} & \text{Poly. (Series1)} & \text{COSMIC profile} \\
\hline
\text{4th-order polynomial} & & \\
\end{array}
\]

\[
\text{Refractivity}
\]

\[
\begin{array}{c|c|c}
\text{Height (km)} & 100 & 150 & 200 & 250 & 300 & 350 \\
\hline
\text{Refractivity} & & & & & & \\
\end{array}
\]

\[
R^2 = 0.9997
\]
COSMIC and CALIPSO data near Bertha 2008
08 July 2008

Difference of COSMIC refractivity profile and 4th-order fitted curve
14:19 UTC 08 July 2008

CALIPSO aerosol subtypes
~ 04:32 UTC 08 July 2008

Estimated radius of max. wind
Intersection heights

Est. radius of max. wind
4.9 km
10.0 km

Bertha center
CALIPSO pass
COSMIC and CALIPSO data near Bertha 2008
08 July 2008

Difference of COSMIC refractivity profile and 4th-order fitted curve
14:19 UTC 08 July 2008

AMSU-B 13:48 UTC 08 July 2008
GOES-12 VIS 13:45 UTC 08 July 2008

est. radius of max. wind
intersection heights

Bertha center
CALIPSO pass
COSMIC analysis of Hurricane Ike 2008

NOAA-18
AMSU-B 06:23 UTC 06 Sept 2008

NRL

05:25 UTC
21.0
21.5
22.0
22.5
23.0
23.5
24.0
-67.0 -66.5 -66.0 -65.5 -65.0 -64.5 -64.0
Height (km)
est. radius of max. wind

06 UTC 06 Sept

Refractivity Difference
profile minus 4th-order fitted curve

dry air
Rainbands?

GOES-12
WV 06:45 UTC 06 Sept 2008

05:25 UTC
Eyewall replacement cycle with Supertyphoon Sepat  08/16/2007

microwave imagery archived at the Naval Research Laboratory
COSMIC analysis of Supertyphoon Sepat 2007

COSMIC profile relative to estimations of the storm center and the radii of concentric eyes

AMSU-B 08:44 UTC 16 Aug 2007

Refractivity Difference profile minus 4th-order fitted curve

SW Outer Eyewall ??
Outer Eye ??
Inner Eyewall ??
Outer Eye ??

06:05 UTC
Some conclusions on use of COSMIC near tropical cyclones

- Difference of COSMIC refractivity can show dry air signature of SAL

- Combined use of COSMIC and CALIPSO can definitively show SAL

- COSMIC can detect inner core features of a cyclone hidden under the cirrus canopy (precise matching with other data is crucial!)

- COSMIC may help to determine the stage of eyewall replacement cycle

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