A Comparison of COSMIC Temperature and Moisture Profiles Against Dropsondes, AIRS, Terra, and Aqua near Atlantic Tropical Cyclones of 2006

Patrick J. Fitzpatrick, Yee Lau, Sachin K. Bhate, and Christopher M. Hill · GeoResources Institute, Mississippi State University, Stennis Space Center, MS

Introduction

The Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) presents a promising complement to dropsondes for measuring thermodynamic properties – particularly water vapor – in the atmosphere (Anthes et al. 2000). Six microsatellites in COSMIC measure the vertical profile of refractivity (*N*) from an occulted radio signal transmitted by Global Positioning System (GPS) satellites. Refractivity is related to temperature (*T*), pressure (*p*), and vapor pressure (*e*) by the expression (after correcting for ionospheric effects):

$$N = 77.6\frac{p}{T} + 3.73\times10^{5}\frac{e}{T}$$

The technique is advantageous in hurricanes because its unaffected by clouds and rain. In addition, no calibration is needed, and the vertical resolution is 100-500 m. Through inverse methods, this technique could potentially produce valuable temperature and moisture profile information in data-void regions. Unfortunately, the horizontal resolution is very coarse, producing 2-4 "clumped" measurements every 200 km. Another problem is that the refractivity equation is an unclosed system, requiring some independent information from one variable to derive another.

As shown by Ware et al. (1996) – and assuming common values of *N*, *T*, and *p*, with negligible errors in N and p – the error ranges of *Δe* and *ΔT* can be obtained by:

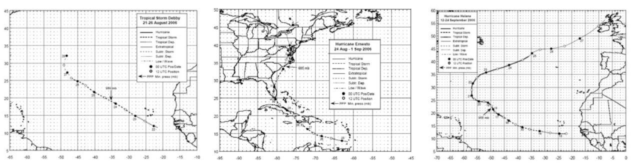
$$\Delta e \approx \frac{(2TN - 77.6p)}{3.73\times10^{5}}\Delta T \approx 0.23\Delta T$$

Thus, the measure of a vertical moisture profile by COSMIC can be, in theory, more accurate than similar measurements by dropsondes provided that a sufficiently reliable and independent measure of a vertical temperature profile is available. However, it also shows that errors in *T* will compound accuracy problems in *e*.

COSMIC became operational in 2006. In this study, we compare vertical profiles of temperature and (derived) water vapor from COSMIC against profiles from AIRS, other Aqua sounders, Terra sounders, and from dropsondes in the vicinity of three Atlantic tropical cyclones in 2006. We assess the ability of these satellites to measure moisture in the vicinity of hurricanes, and examine their usefulness in Saharan Air Layer (SAL) events.

Methodology

Vertical profiles of temperature and water vapor are examined in the vicinity of Tropical Storm Debby, Hurricane Ernesto, and Hurricane Helene, each from 2006.



Best track position maps prepared by the National Hurricane Center.

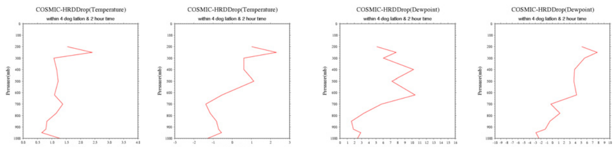
Data are collected during days when dropsonde data was available. Dewpoint temperature is calculated based on temperature and water vapor measurements. Average absolute errors and biases are calculated between COSMIC data and AIRS, Terra / Aqua, and dropsonde data within the following ranges of data point positions and times between data sources:

data source	dropsondes	AIRS	Terra / Aqua
COSMIC	4.0°, 2 hours	0.5°, 1 hour	0.5°, 30 minutes

The 10.7- through 12-μm channels on *GOES-12 and* 10.8- through 12-μm channels on *METEOSAT-8* can detect SAL events. Data from COSMIC, AIRS, and Terra / Aqua are also examined against satellite imagery depicting SAL events near Tropical Storm Debby and Hurricane Helene.

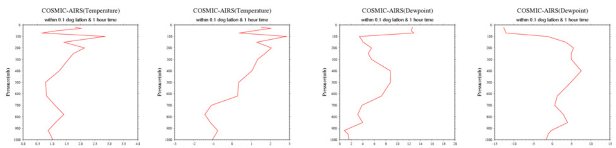
Results

Compared against the nearest dropsonde measurements, COSMIC measurements of T and T_d in the lower troposphere are agreeable, with average absolute errors as low as approximately 0.7 K and 1.8 K, respectively. Note that the error of T may have contributed to the error of T_d. The error of T increases to a maximum of only 2.5 K in the upper troposphere. However, the error for T_d is large above the boundary layer, with values of 10.5 K in the middle troposphere. The bias of COSMIC data versus dropsonde data is cooler and drier in lower troposphere, and warmer and more moist in the upper troposphere.



Absolute error and bias of temperature and dewpoint temperature between COSMIC and dropsonde data.

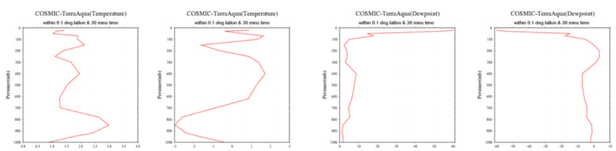
The absolute errors of T and T_d between COSMIC and AIRS range from 0.7 K and 1.8 K, respectively, in the lower troposphere to 2.8 K and 13.5 K in the upper troposphere. Errors within the middle troposphere are less than versus dropsonde data, and the biases between COSMIC and AIRS are relatively low throughout the troposphere.



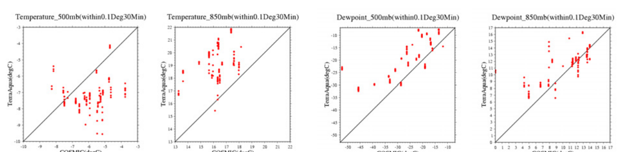
Absolute error and bias of temperature and dewpoint temperature between COSMIC and AIRS data.

The absolute errors of T between COSMIC and Terra and Aqua sounders (except AIRS) range from 0.9 K to 3.0 K within the lower troposphere, and only from 1.0 K to 2.1 K in the middle and upper troposphere. The error of T_d ranges from 1.8 K in the lower troposphere to 8.5 K at 400 hPa, with a much greater error within the stratosphere. There is a significant cool bias of COSMIC data versus Terra/Aqua sounders data in the lower troposphere, and a slight warm bias in the upper troposphere.

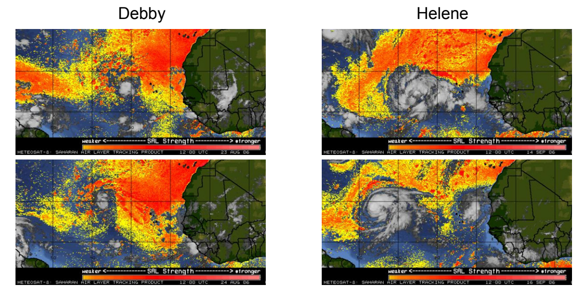
The large sample size of the Terra/Aqua data versus COSMIC data helps to show the bias trends at 500 hPa and 850 hPa, as well as the range of values from Terra/Aqua data that comprise the average absolute errors.



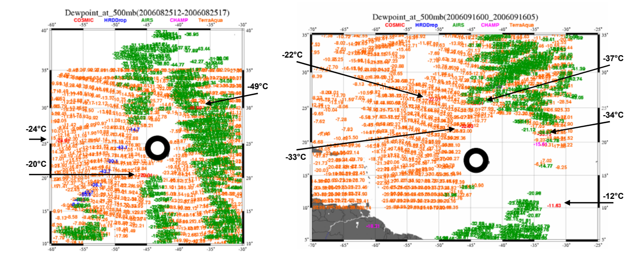
Absolute error and bias of temperature and dewpoint temperature between COSMIC and Terra/Aqua sounders.



Difference of temperature and dewpoint temperature, at 500 and 850 hPa, between COSMIC and Terra/Aqua sounders.



SAL enhancement of METEOSAT-8 imagery, provided by Univ. of Wisc. - CIMSS through the Hurricane Research Division.



T_d measured at 500 hPa by the four platforms near Debby and Helene. COSMIC is in red, and indicated by arrows. Orange is for Terra/Aqua (subsampled due to high resolution), green is for AIRS, and blue is for dropsondes.

Enhanced satellite imagery shows SALs surrounding Debby and Helene. Debby eventually dissipated within a SAL. Helene eventually intensified into a category-3 hurricane as a SAL was displaced from the cyclone center.

The few available COSMIC data points – along with AIRS, Terra/Aqua, and dropsonde data – help to show dry mid-level air surrounding Debby, especially to the northeast. The mid-level air surrounding Helene is not as dry as with Debbie, but exists near the center of Helene to the north as the cyclone was gradually intensifying.

Conclusions

- Values of dewpoint temperature differ greatly amongst the different data platforms at a given time, especially in the upper troposphere. All satellite moisture retrieval schemes should be used with caution.
- Temperature profiles from all satellite platforms appear reasonable.
- Against other data platforms, COSMIC data exhibits a cool, dry bias in the lower troposphere, and a warm, exceedingly moist bias in the mid and upper troposphere. The bias of moisture may stem, in part, from the bias of temperature. However, it also appears the retrieval scheme requires modification.
- The spatial resolution of COSMIC data is currently coarse, but should still be useful near tropical cyclones – especially before and between reconnaissance flights, and when other satellite data is absent.
- Once their biases are identified, all satellite platforms should be able to detect the extreme dry air of SAL events.

Printouts of all satellite and COSMIC cases are available at the poster for further examination.

References

Anthes, R. A., C. Rocken, and Y.-H. Kuo, 2000: Applications of COSMIC to meteorology and climate. *Terrestrial, Atmospheric, and Oceanic Sciences*, **11**, 115-156.

Ware, R., M. Exner, D. Feng, M. Gorbunov, K. Hardy, B. Herman, Y. Kuo, and others, 1996: GPS sounding of the atmosphere from low Earth orbit: preliminary results. *Bull. Amer. Meteor. Soc.*, **77**, 19-40.