Examination of the Tropical Cyclone Environment through a Comparison of COSMIC with other Satellite Data

Christopher M. Hill, Patrick J. Fitzpatrick, and Yee Lau · Northern Gulf Institute, Mississippi State University, Stennis Space Center, Mississippi, USA

Introduction

The Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) presents a promising alternative to dropsondes for accurately measuring water vapor in the atmosphere (Anthes et al. 2000). Six low-earth-orbiting microsatellites measure the refractivity (N) of the atmosphere from a radio signal transmitted by Global Positioning System (GPS) satellites.

Refractivity is related to temperature (T), pressure (p), and vapor pressure (e) by the expression:

$$N = 77.6\frac{p}{T} + 3.73\times10^{5}\frac{e}{T^{2}}$$

As shown by Ware et al. (1996), accuracy of the radio occultation measurement of water vapor pressure can be expressed by:

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

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), provided by NASA, can specifically detect dust aerosols within a vertical cross-section of the atmosphere through a measurement of LIDAR backscatter.

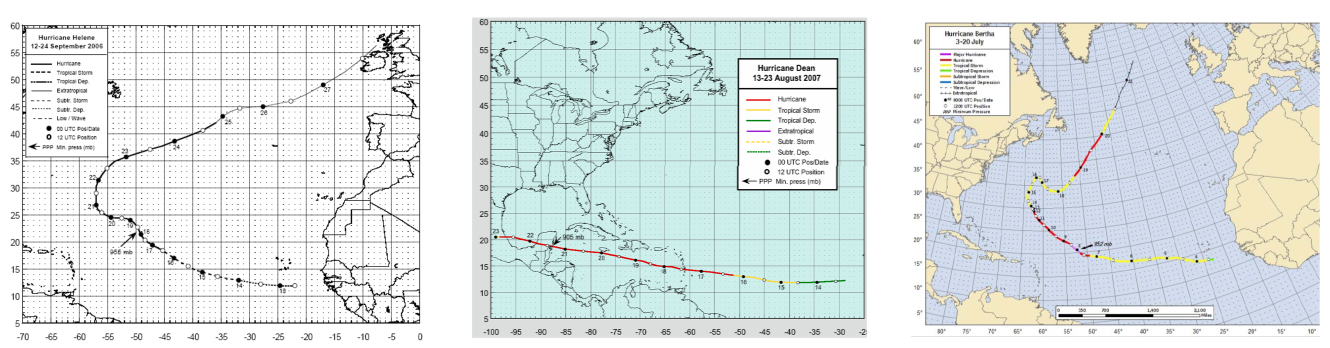
We assess the ability of these COSMIC, CALIPSO, and geostationary satellites (GOES-8, METEOSAT-8) to detect Saharan Air Layer (SAL) events in the vicinity of Atlantic tropical cyclones by:

1) Comparing COSMIC refractivity against collocated cross-sections of CALIPSO aerosol data

2) Building a climatology of SAL activity over eastern Atlantic Ocean from geostationary satellite-based data

Methodology

COSMIC and CALIPSO profiles are examined in the vicinity of Hurricane Helene of 2006, Hurricane Dean of 2007, and Hurricane Bertha of 2008.



Best track position maps prepared by the National Hurricane Center.

A difference of the 10.8-µm (10.7-µm) and 12.0-µm wavelength brightness temperatures (DBT) from METEOSAT-8 (GOES-8) provides guidance in determining the strength and coverage of the SAL (Dunion and Velden 2004).

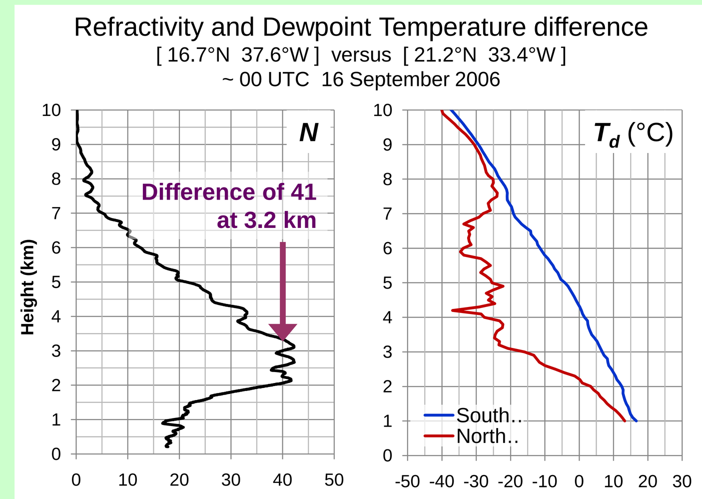
To account for the presence of clouds, as well as to emphasize the warm nature of the SAL, the DBT is multiplied by 10.7-µm temperature and each factor is "partly" normalized, resulting in an adjusted DBT (ADBT):

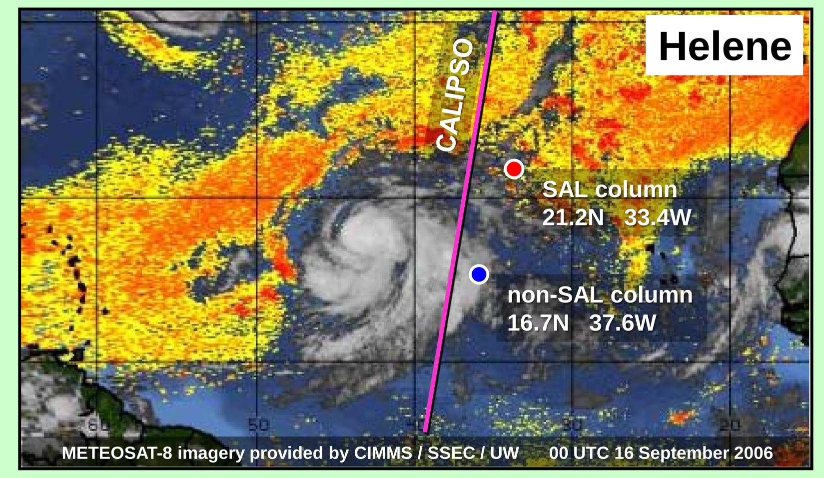
$$ADBT = \left(\frac{BT_{10.7} - BT_{\min}}{BT_{\max} - BT_{\min}}\right)\left(\frac{DBT - DBT_{\min}}{DBT_{\max} - DBT_{\min}}\right)$$

Parameters are set as BT_{max} = 300, BT_{min} = 195, DBT_{max} = 7, and DBT_{min} = -12.

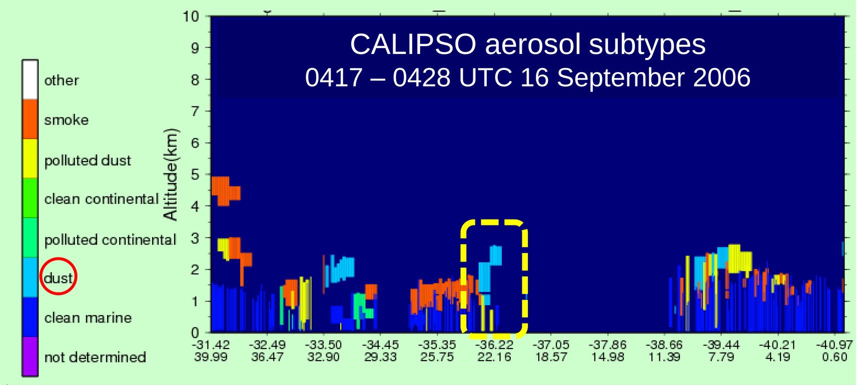
Climatologies of the ADBT are built from data of the International Satellite Cloud Climatology Project (ISCCP) for June, July, August, and September of 1996 through 2002 over the study area of 10°N, 50°W, 30°N, and 20°W. The study area is divided into 2 2 area bins, and averages computed for each area bin by month.

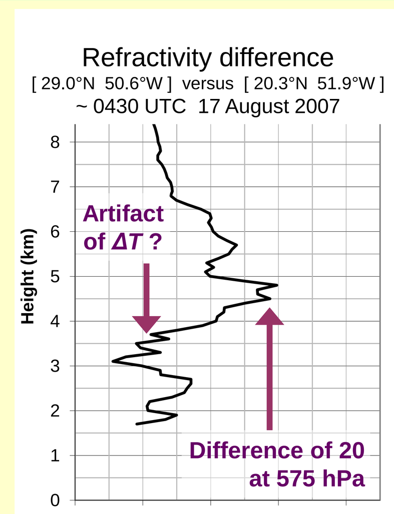
Results

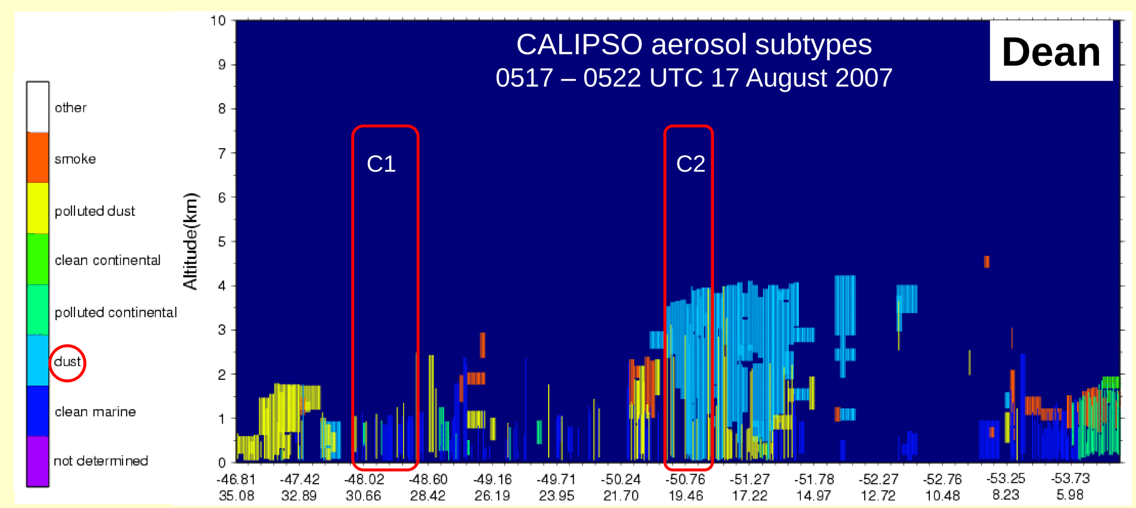




COSMIC profiles of refractivity and retrieved T_d near Helene distinguishes SAL and non-SAL air columns. The METEOSAT-8 SAL product and CALIPSO assist in the identification of the SAL and non-SAL regions.

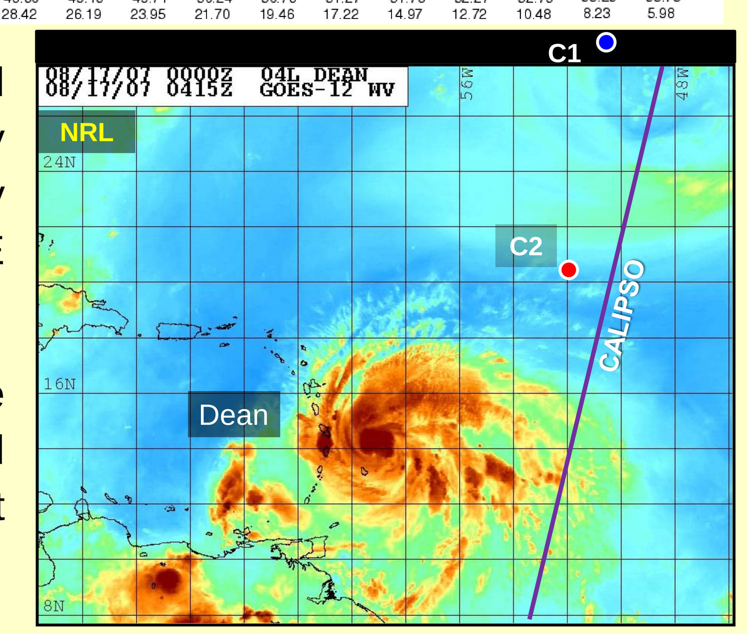


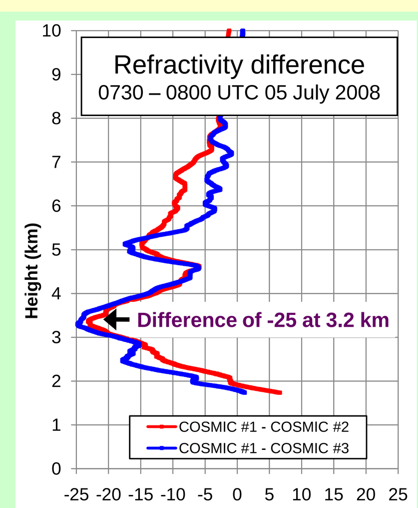


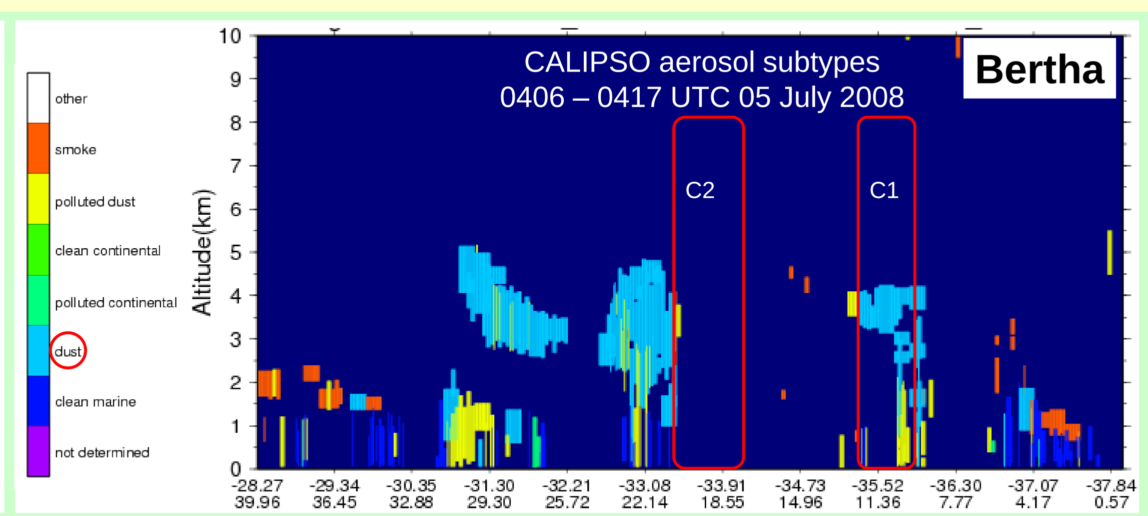


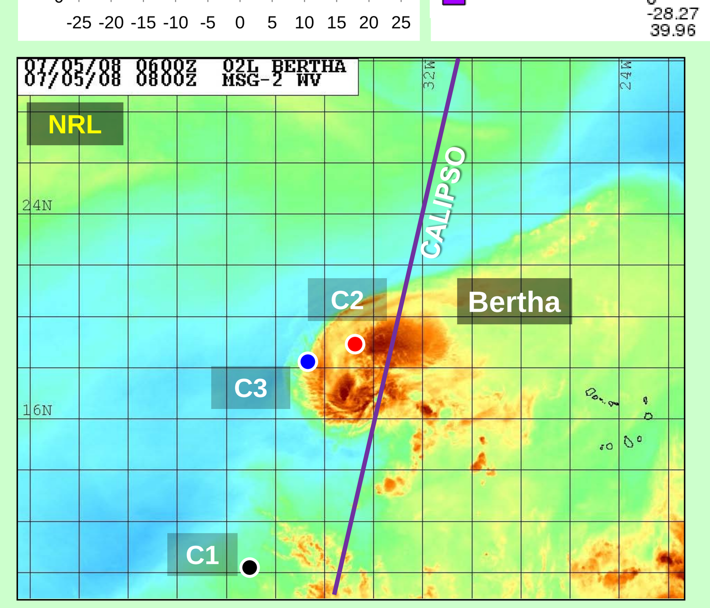
Combined analysis of the COSMIC and CALIPSO data identifies a SAL, identified by lower relative mid-tropospheric refractivity and a 4-km layer of dust aerosols, to the NE of strengthening Hurricane Dean

A GOES-12 water vapor (6.7-µm) image indicates dry air at the SAL column point and moist air around an upper-level cyclone at the non-SAL column point.







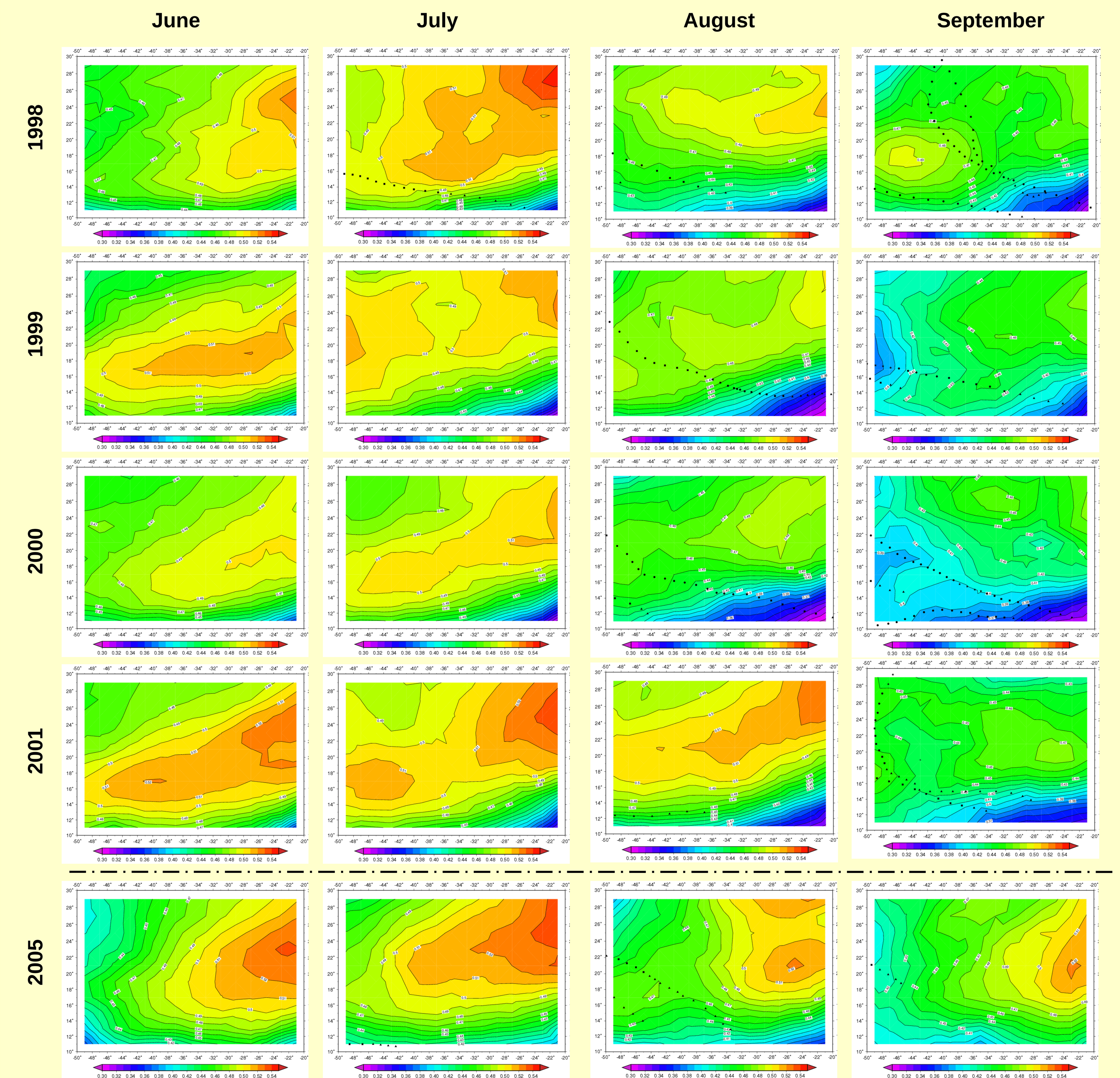


In comparing three COSMIC profiles and a CALIPSO profile, the southernmost (C1) profile is found to be in a SAL region.

CALIPSO shows 4-km deep layers of dust east of C1 and north of C2. Both C2 and C3 have been enveloped by the high moisture region associated with Tropical Storm Bertha.

Acknowledgements: Ken Knapp of NOAA / NCDC for contributing ISCCP data. Research is funded by NOAA.

Monthly averages of ADBT derived from ISCCP data, combined with cyclone tracks



A preliminary analysis of the ISCCP data reveals:

- Higher values of ADBT cover a greater latitudinal and longitudinal span in June and July
- ADBT data suggest greater SAL intensity and area in 1998 and 2001
- ISCCP data are derived from METEOSAT-8 (with nadir at the Prime Meridian) in 2005, and from GOES-8 (with nadir at 75°W) in 1996 – 2002, which may affect the climatology
- Tropical cyclone tracks occur away from SAL maximums

Conclusions

- Though sporadic in space and time, COSMIC data can provide moisture profile information where reconnaissance flight data and other satellite data are not available – useful for observing the environment of remote tropical cyclones
- COSMIC and CALIPSO data can help to resolve the areal coverage of SAL
- A quantified index using geostationary satellite data, which factors absolute temperature, shows promise for detecting SAL over the tropical Atlantic Ocean
- Based on the relationships found between SAL and the storm tracks, we hypothesize that strong SAL events suppress genesis, and that mature cyclones outflow deflects SAL influence

Future Work

- Study effects of SAL on cyclone genesis and cyclone intensity
- Compare SAL index with COSMIC, CALIPSO data, and upper-air analyses
- Expand SAL climatology from METEOSAT-based ISCCP satellite data

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.

Dunion, J. P., and C. S. Velden, 2004: The impact of the Saharan Air Layer on Atlantic tropical cyclone activity. *Bull. Amer. Meteor. Soc.*, **85**, no. 3, 353-365.

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.