Study on Distribution of Tropical Tropospheric Water Vapor using Global Positioning System (GPS) Radio Occultation (RO) data

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ABSTRACT: Water vapor is the most important greenhouse gas in the Earth's atmosphere, inducing about two third of the natural greenhouse effect. As such, understanding the mechanisms that regulate it is of central importance for understanding past and future climate change. In the lower and middle troposphere, particularly in the tropical regions, changes in water vapor abundances provide one of the most sensitive indicators of modeled climate change. The lack of adequate data limits our ability to analyze or simulate important aspects of the global climate system. In this study, the reliability and limitations of water vapor retrieval from GPS RO measurements combined with analyses from ECMWF/NCEP is investigated for tropical conditions. Intensive Väisälä radiosondes were specially launched for validation of COSMIC RO data from Gadanki (13.48oN, 79.18oE), a tropical site in India. In comparison with independent techniques like radiosonde (Väisälä) over 12 stations, it is found that COSMIC GPS RO wet profiles are more accurate up to 6-7 km (assuming radiosonde is standard technique). Being validated at several stations, we also extended the study for monitoring the global distribution of water vapor. Global distribution of relative humidity observed in two contrasting seasons at 5 km show low and high humidity concentrations over Indian region during Jan. 2007 and Jul. 2007, respectively

1 Introduction

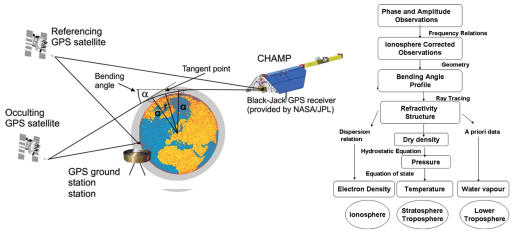
For characterizing any atmospheric constituent, its vertical resolution should be measured at least
3 times per scale height. Given water vapor 1.5 km average scale height in troposphere, it should me measured at least once every 500m vertically.

Measurement techniques for Atmospheric water vapor:
Ground based: Radio sonde and LIDAR- good vertical resolution but poor spatial resolution.

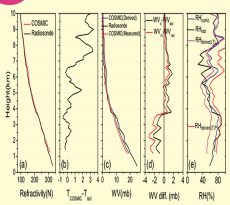
Space born: IR sounders and Microwave sounders - poor vertical resolution and also most of the IR measurements are cloud contaminated, where as microwave provide good data but over marine environment

Unique properties of GPS RO measured water vapor
- **High accuracy and vertical resolution: With <1 K temperature, < 5-10% humidity, 500m-1 km height Resolution in individual profiles)**
- **Long term stability**
- **All weather capability: Can provide data in all weather conditions**
- **Global and even coverage: Equal over both ocean and land**

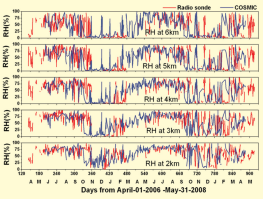
2 GPS Radio Occultation Technique and Algorithm



3 Results 3.1 Typical and day-to-day comparison

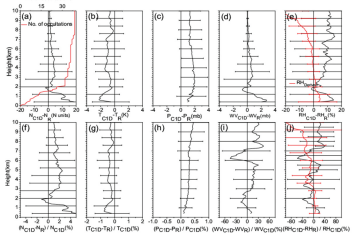


Comparison of (a) refractivity, (c) water vapor, and (e) relative humidity between COSMIC GPS RO and Radiosonde on 24 July 2006. Difference in (b) temperature, and (d) water vapor between the two.



Day to day comparison of relative humidity between COSMIC and Radio sonde from April 2006 to 2008 May over Gadanki at different height regions.

3.2 Statistical mean and fractional difference over Gadanki



- Statistical mean difference between COSMIC and Radio sonde

(a) refractivity, (b) temperature (c) pressure, (d) water vapor pressure, and (e) relative humidity.

Number of occultation's reaching at various heights down below is also given in (a) with axis on the top.

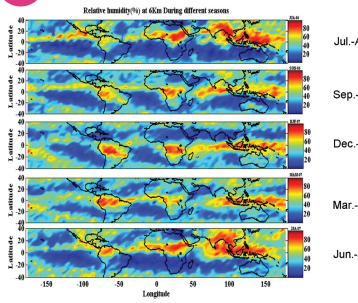
•Fractional difference of (f) refractivity, (g) temperature (h) pressure, (i) water vapor pressure, and (j) relative humidity.

3.3 Global Validation

We have extended the validation of water vapor over the globe in Tropics with CHAMP GPS RO from April 2001 to July 2007 and COSMIC GPS RO data from July 2006 to July 2007.

Station	Lat	Lon	Matches		N FD (1-5km)		VP FD (1-5 km)		RH FD (1-5km)	
			COSMIC	CHAMP	COSMIC	CHAMP	COSMIC	CHAMP	COSMIC	CHAMP
Singapore	1.4	104.0	91	39	0.02	2.07	-2.59	-3.58	0.17	0.85
Darwin	-12.4	131.0	66	49	-0.75	-1.32	-5.30	-7.34	0.15	-2.69
Seychelles	-4.7	55.5	64	46	-1.13	-0.79	-2.31	-4.05	3.04	2.30
Bagota	4.7	-74.2	57	56	0.02	0.99	-2.45	-1.51	-2.57	-2.12
Nairobi	-1.3	36.8	47	43	-1.17	-2.02	0.38	0.40	-4.18	-4.57
Ascensions	-8.0	-14.4	19	11	-0.14	-0.75	-2.58	-4.69	2.34	2.44
Truk	7.4	151.8	78	66	0.82	0.058	-3.53	-3.97	1.38	1.55
Tarawa	1.4	172.9	46	50	0.32	2.42	-4.06	-3.96	2.62	2.51
Trivendrum	8.5	76.9	17	57	-1.53	-0.14	-6.15	-5.90	-2.52	-1.84
Ouagadougou	12.4	-1.5	48	45	2.72	2.09	-1.85	-1.60	2.45	2.08

4 Global distribution of Relative humidity observed during different seasons



Jul.-Aug. 2006

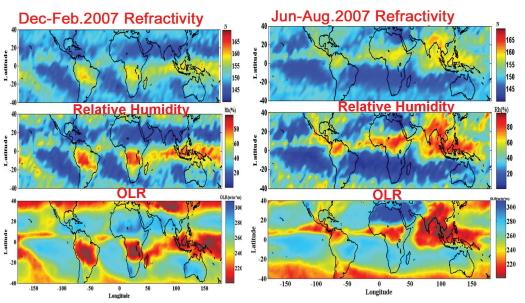
Sep.-Nov. 2006

Dec.-Feb. 2007

Mar.-May 2007

Jun.-Jul. 2007

5 Global distribution of Refractivity, Relative Humidity & their comparison with OLR



6 Summary

- **Special Radiosonde campaign from July 2006 to March 2007 is conducted at Gadanki to validate the water vapor profiles observed by COSMIC GPS RO.**
- **A very good comparison in both trend and amplitude is noticed between COSMIC and Radiosonde with temperature difference of 1-2 k , Relative humidity with 5-10% difference.**
- **RH between COSMIC and Radiosonde is also comprising well on day-to-day basis.**
- **The mean and fractional difference of RH in the tropical stations is ±10% below 6-7 km suggesting GPS RO data is most useful below 6-7 km (assuming Radiosonde is standard).**
- **The Southern Hemisphere stations like Seychelles, Darwin etc are showing negative bias in water vapor.**
- **Our simulation studies show that pressure plays a key role in estimating Refractivity.**
- **The global distribution of RH during different seasons show good correlation with OLR.**
- **Quite different features in RH during summer and winter are noticed over Indian Sub-continent as expected.**
- **Our study provides first comprehensive study on validation of water vapor of GPS RO across the globe, suggesting GPS RO as a new tool for monitoring earths water vapor, hence climate change.**

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