Assessments of Cloud Liquid Water Contribution to GPSRO Refractivity Assimilation in the GSI Data Assimilation System

Zaizhong Ma[1,2], Fuzhong Weng[2] and Xiaolei Zou[3]

[1]Univ. of Maryland/ESSIC, MD, [2]NOAA/NESDIS, College Park, MD and [3]Florida State Univ.

1. Introduction

Clouds are widespread and very common phenomena, and cover about 60% of the sky. Yet, in the current operational Gridpoint Statistical Interpolation (GSI) data assimilation system, Global Positioning System (GPS) Radio Occultation (RO) refractivity operator didn't include the impact of Cloud Liquid Water (CLW) while simulating GPS refractivity observations. Therefore, it is important to add the cloud liquid water contributions for simulating GPS refractivity in cloudy conditions, special in the Hurricane Genesis stage. After double checking GPS quality control in the GSI system, the contribution from liquid water content (W) has been added into the GPS local refractivity operator:

$$N = 77.6\frac{P}{T} + 3.73\times10^5\frac{P_w}{T^2} + 1.45W \qquad (1)$$

where P is pressure in hPa, T is temperature in K, Pw is water vapor pressure in hPa, and W is the liquid water content in grams per cubic meter.

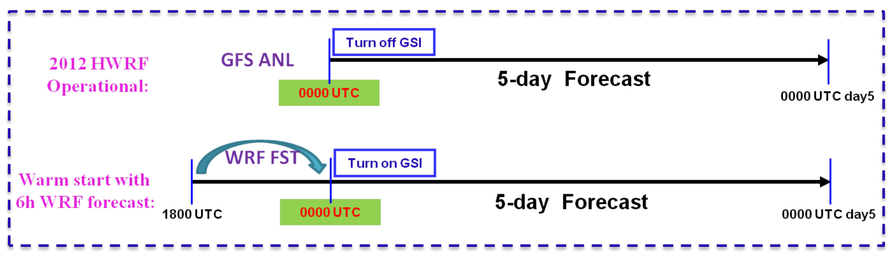
This paper will describe the ongoing efforts on assimilating Constellation Observing System for Meteorology Ionosphere & Climate (COSMIC) GPS RO observations using the Hurricane Weather Research and Forecast system (HWRF) and Gridpoint Statistical Interpolation (GSI) system in a near operational environment. The impact with/without liquid water content term on HWRF tropical cyclone genesis and forecasts will be investigated in case studies.

2. Model Description

Investigation of the impact of Cloud Liquid Water in the GPSRO refractivity operator is based on the 2012 NCEP operational version of Hurricane Weather Research and Forecast system (HWRF) in this study. The efforts are mainly focused on:

1) The model top of HWRF was raised from 50 hPa (operational) to 0.5 hPa and the vertical levels were increased from 43L to 61L;
2) Turn on the GSI option. The current NCEP operational HWRF only use GFS analysis field for initialization without performing the further GSI assimilation;
3) Replace GFS analysis with WRF-NMM 6h forecast fields as first guess in HWRF system to avoid the double uses of satellite data.

Comparison of the HWRF Configurations' Design



3. GPS Refractivity Operator with CLW Contribution

If the GPSRO Refractivity operator Eq.(1) can be written as

$$N_{new} = 77.6\frac{P}{T} + 3.73\times10^5\frac{P_w}{T^2} + 1.45W\,(g/m^3)$$
$$= f(ps, T, q, cwmr)$$

Then, the tangent linear of Eq. (1) will be

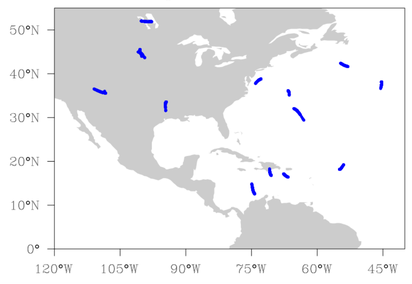
$$\frac{\partial N_{new}}{\partial(ps,T,q,cwmr)} = k_1\frac{\partial f}{\partial ps} + k_2\frac{\partial f}{\partial T} + k_3\frac{\partial f}{\partial q} + k_4\frac{\partial f}{\partial cwmr}$$

After adding the contribution from liquid water content into the GPSRO Refractivity operator, the GSI system passed the tangent linear and adjoint check successfully.

4. Experiment Setup

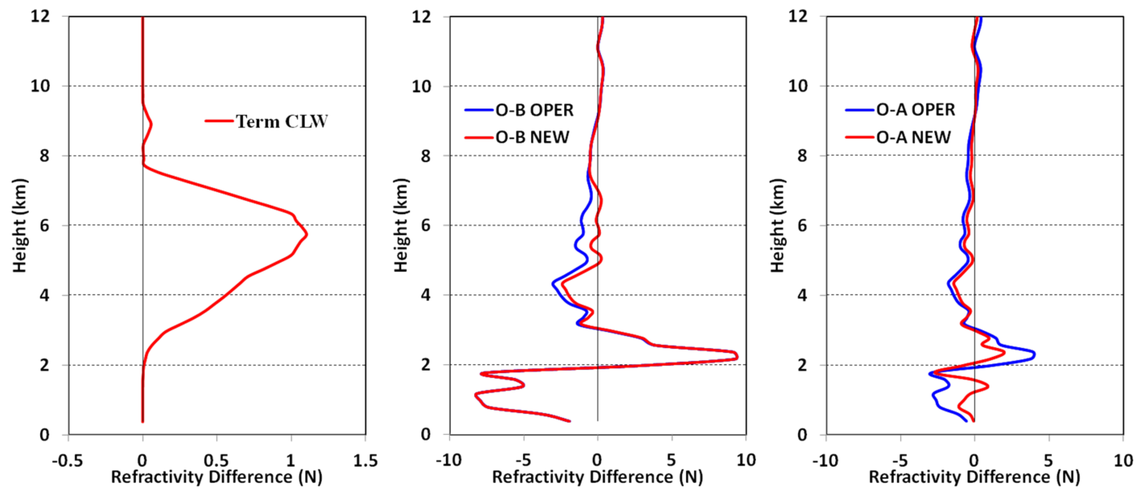
Hurricane Sandy is picked up in this study, and a series of comparison experiments are performed to evaluate the performance of the CLW for GPSRO refractivity assimilation.

- OPER: assimilate Conv.+ GPSRO without CLW
- NEW : assimilate Conv. + GPSRO with CLW



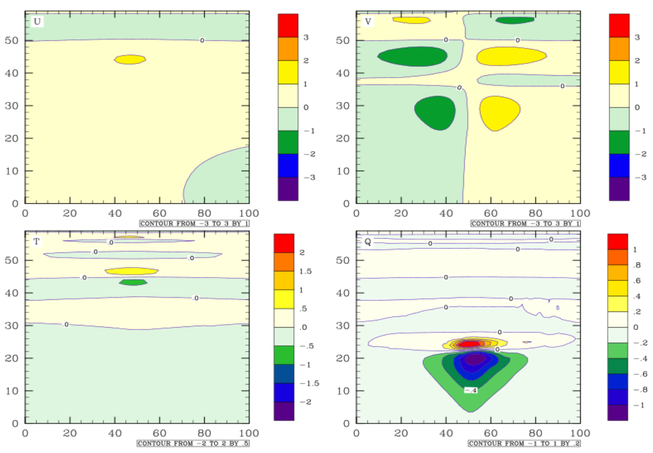
5.1 Single GPSRO Profile Test

Single GPSRO Profile test was performed to evaluate the impact of Cloud Liquid Water in the new operator. The GPSRO profile picked up is located at (29° N, 65° W), which is close to the Hurricane center.



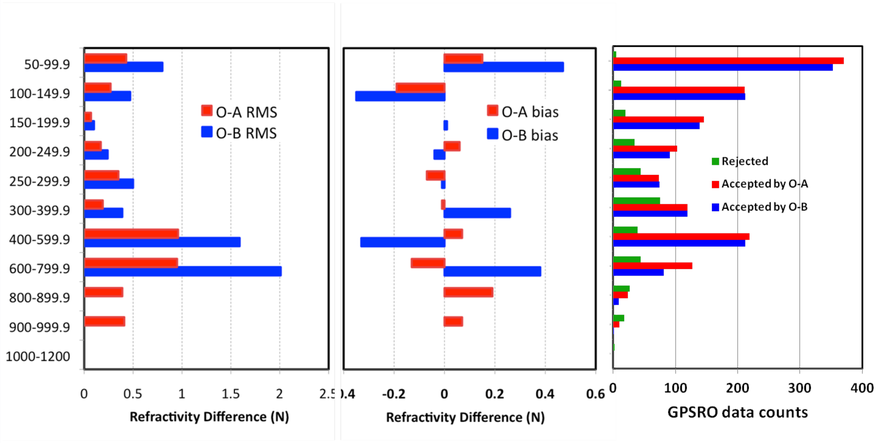
Comparison the performance with/without the Cloud Liquid Water in the GSI.
Left: CLW contribution for simulating GPS refractivity; Middle: O-B; and Right: O-A.

5.2 Single GPSRO Profile Test (Con't)

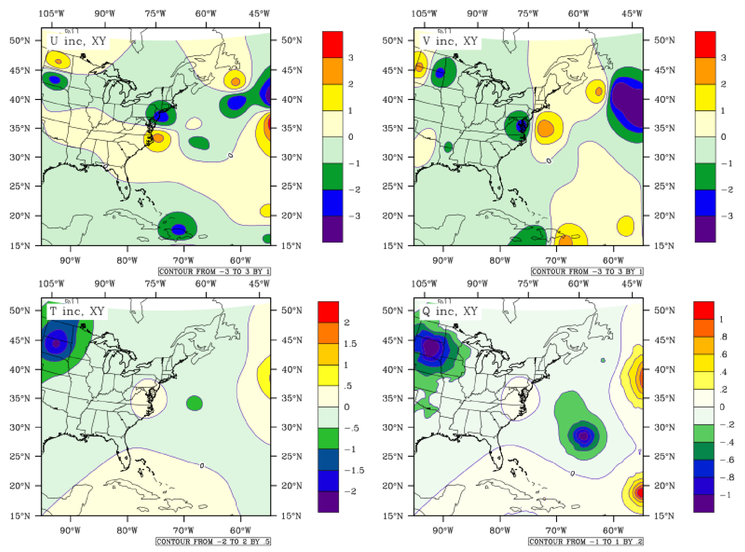


The vertical distribution of analysis increments for temperature (K) and wind (m/s) and water vapor mixing ratio (g kg^{-1}) along west–east cross section cutting through the center of GPS RO soundings.

6. One-time Data Assimilation



Comparison of the GPSRO refractivity performance before/after assimilation with the model pressure layers. Left: RMS; Middle: BIAS; and Right: GPSRO refractivity data counts.



The horizontal analysis increments for temperature (K) and wind (m/s) and water vapor mixing ratio (g kg^{-1}) at 850 hPa for Hurricane Sandy at 0000 UTC Oct 23, 2012.

7. Discussion and Future Plan

Cloud liquid water contribution has been considered when assimilating the GPSRO refractivity data in the GSI part in the HWRF system. And the preliminary impact was investigated based on the single GPSRO profile test and one-time data assimilation check. Currently most basic hard model works have been done.

In the future, more sensitivity tests for the cloud liquid water will be focused on the GPSRO refractivity assimilation at the hurricane genesis stage. And more comparison experiments will be designed with/without cloud liquid water contribution as well. And then implementing this new operator into the global option will be considered.