Remote Sensing for Improved Forecast of Typhoons

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Abstract

This poster aims to understand the importance of Remote Sensing technology in Typhoon's related investigations and predictions, which includes: (i) predicting the rainfall during landfall of a typhoon by combining GPS zenith total delay and Doppler radar data through data assimilation algorithms. (ii) understanding the interactions between typhoons' and TDs with satellite imagery and image processing techniques. (iii) studying the atmospheric gravity waves for asymmetric typhoons by numerical modelling using remote sensing observational data. (iv) understanding the oceanic surface wind impacts on typhoon's simulation and prediction using various satellites.

Introduction

Western Pacific Ocean are always more prone to typhoon's related disasters like; floods, landslides caused by torrential rains and strong winds. For example: 2965 mm of rainfall just in four days triggered massive mudslides and floods causing 673 deaths in case of Typhoon Morakot (2009) (Wu 2013). So, Improved forecast of typhoon's track, intensity, wind fields etc., is crucial for taking precautions needed to save human lives, agriculture and industries.

Four major questions investigated in this poster are as follows: (1) How much can space-borne sensor-observed water vapor improve the QPF; (2) What would be the respective tracks and intensities of the typhoons during the typhoons' and tropical depressions (TDs) interactions; (3) How would atmospheric gravity waves (GWs) evolve during the occurrence of asymmetric tropical cyclones (TCs); and (4) How large improvements can be achieved when oceanic surface wind measurements are assimilated into numerical weather prediction (NWP) models?

Methods and Materials

Case 1: Two data assimilation experiments specially designed to highlight the impact of GPS PWV on model QPF: (i) The control run: assimilating radar observations only, including radial wind and radar reflectivity. (ii) The GPS PWV run: assimilating radar observation and GPS PWV.
Case 2: Two cases: (i) TCs interaction without TD (or TDs). (ii) Two TCs interaction with TDs. Tools: The short IR channel, The image reconstruction technique (IRT), Time series cloud images of typhoons.

Case 3: Tools: SSMI (Special Sensor Microwave Imager) and GMS-5 (Geostationary Meteorological Satellite-5, i.e. Himawari 5) satellite images, operational ECMWF (European Centre for Medium-Range Weather Forecasts) analysis.
Case 4: Tools: NASA QuickSCAT (Quick Scatterometer) oceanic wind data, Global Navigation Satellite System-Reflectometry (GNSS-R) data, GPS RO data measured from FORMOSAT-3/COSMIC.

Figure 1a. The best track of Typhoon Dujuan (2015).

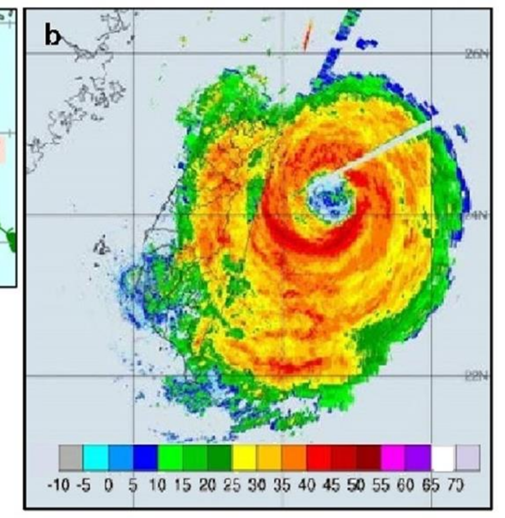

Figure 1b. The composited column maximum radar reflectivity at 0700 UTC on 28 September 2015.

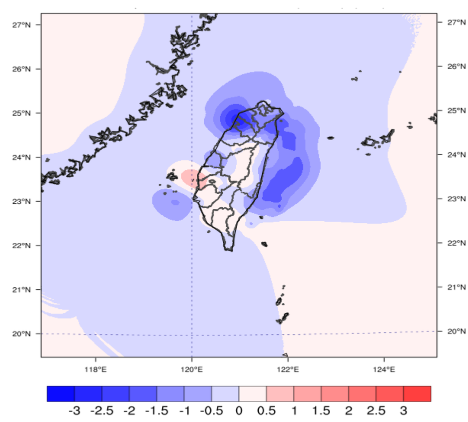

Figure 2. The difference for the initial water vapor mixing ratio (shading, g/Kg) at model level 10 between the control run and GPS PWV run. The initial time is at 1200 UTC on 28 September 2015.

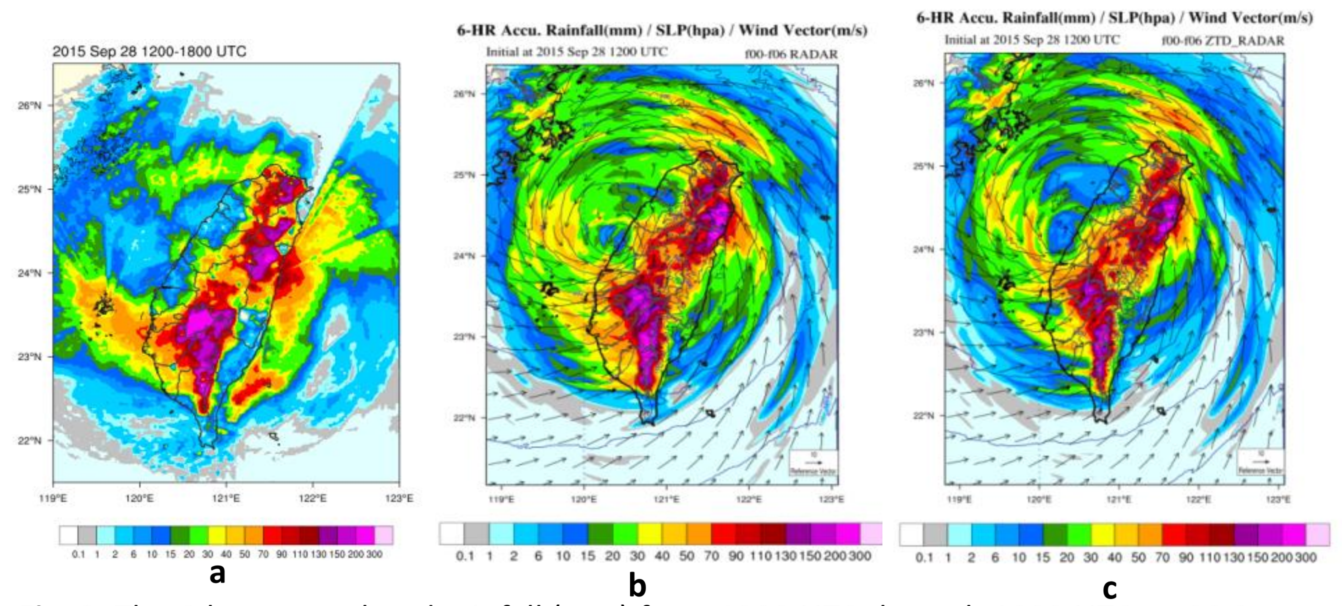

Fig. 3. The 6-hr accumulated rainfall (mm) from 1200 UTC through 1800 UTC on 28 September 2015: **a** observation; and model 0-6 hour QPF for **b** the control run, and **c** the GPS PWV run.

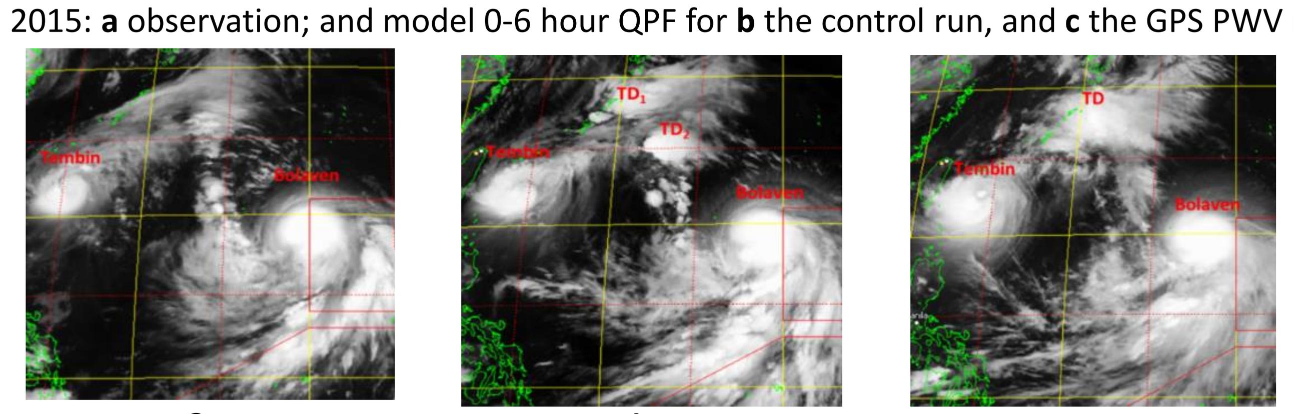

Fig. 4. Three representative time cloud images of Typhoons Tembin and Bolaven and TDs (2012): **a** at t_1 = 12h32, August 21, **b** at t_3 = 21h32, August 21, and **c** at t_5 = 05h32, August 22.

Results and Discussion

Case 1: The GPS PWV run produces less rainfall over the Southwestern Taiwan. Rainfall near typhoon center over the Western Taiwan in the GPS PWV run is less than that in the control run. Results in the GPS PWV run are more consistent with the observation as shown in Fig. 3a. So, assimilation of GPS PWV has potential to improve short-range rainfall forecast during a typhoon landfall period.

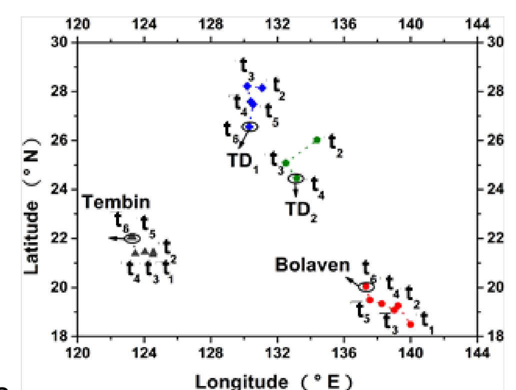

Fig. 5. Tracks of Typhoons Tembin and Bolaven and two TDs (2012) in the period of August 21–22

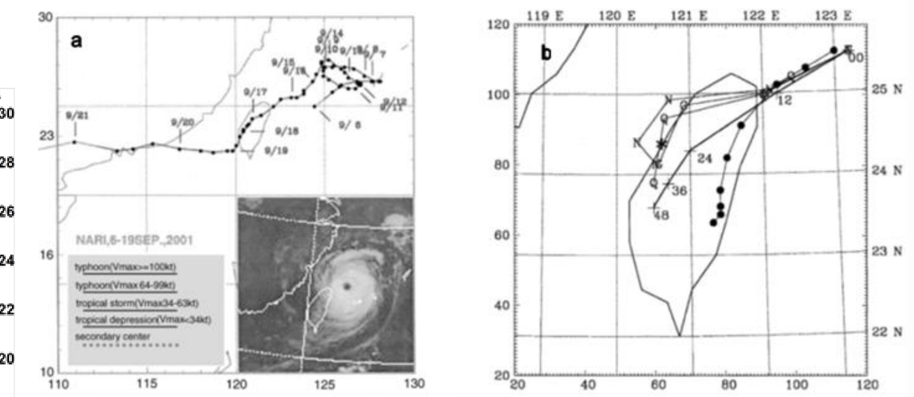

Fig. 8. a The best tracks from CWB for Typhoon Nari (Sep. 2001) and the satellite images at 0032 UTC 16 Sep 2001, and **b** the simulated tracks for Nari every 12 h marked by N (no GPS data), G (with GPS data) and Q (with both GPS and QuickSCAT wind data), and the best track from CWB (plus signs) and from JTWC (solid circles) at an interval of 6 h.

Case 2: Despite the large distances (>1,600 km) between the TCs, the combined depression-cyclone interactions formed. TD1 and TD2 merged and then formed a new TD. This newly formed TD provided upward convections to make typhoon(s) to start rotating and generate strengthened power, with the effect of the TC to TC interaction. Hence, two long distance typhoons can also indirectly interact in the presence of TD (or TDs) in between them.
Case 3: Remote sensing imagery and observations have proved to be important for future studies on TC such as TC asymmetry and induced-stratospheric GWs. FORMOSAT-3/COSMIC radio occultation data are useful to derive GW activity and characteristics of vertical wavelengths over the ocean and validate modeling of TC environment.
Case 4: The impact of QuickSCAT winds in the Pacific Typhoon Nari (2001), which exhibits severe undulation over the metropolitan Taipei and southwest coast of Taiwan was clearly seen. As the GPS RO data are assimilated into a regional model, the offshore track off the northwestern coast of Taiwan in the sensitivity experiment without the RO data is moved inland to be more consistent with the best track.

The QuickSCAT wind data are assimilated together, the track ends up closer the observed position. Simulated inverted wind speed by GNSS-R can be assimilated into typhoon/hurricane models to improve the model forecast. RO data (by FORMOSAT-3/COSMIC launched in April 2006) have been proven valuable for a variety of climate and weather analyses and in improving typhoon track prediction.

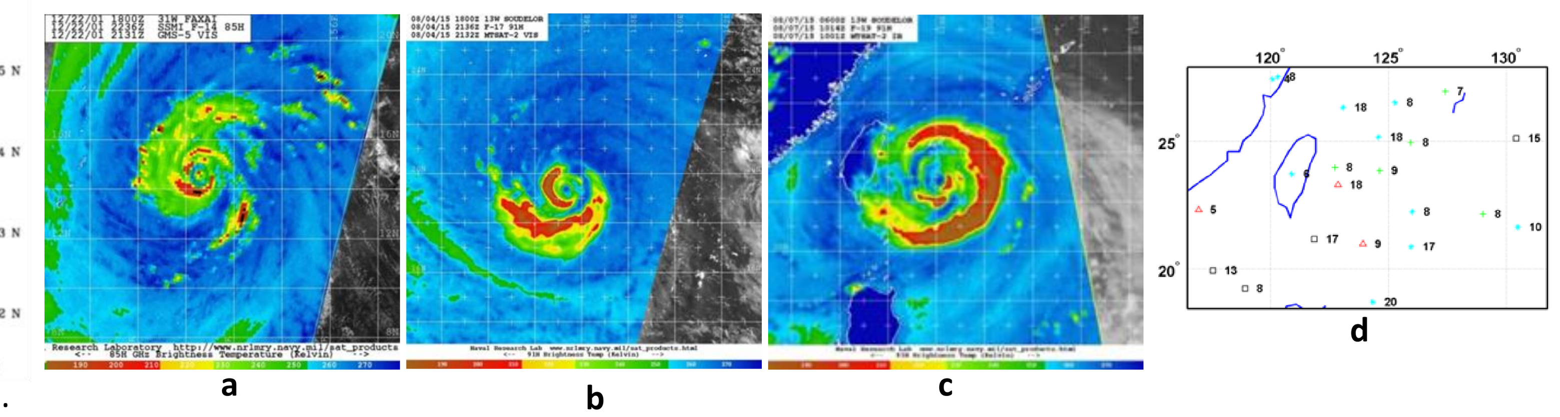

Fig. 6. Satellite images for a category-5 typhoon: **a** TC Faxai on 22 December 2001 at 1800 UTC near its peak intensity, **b** TC Soudelor near Saipan (4 August 2015), **c** TC Soudelor near Taiwan (7 August 2015), and **d** Distribution of FormoSat-3/COSMIC GPS RO data during TC Soudelor on 6, 7, 8 and 9 August 2015 marked with x, +, triangle, square symbols, respectively. Numbers indicate hours (UTC) for corresponding dates (symbols)

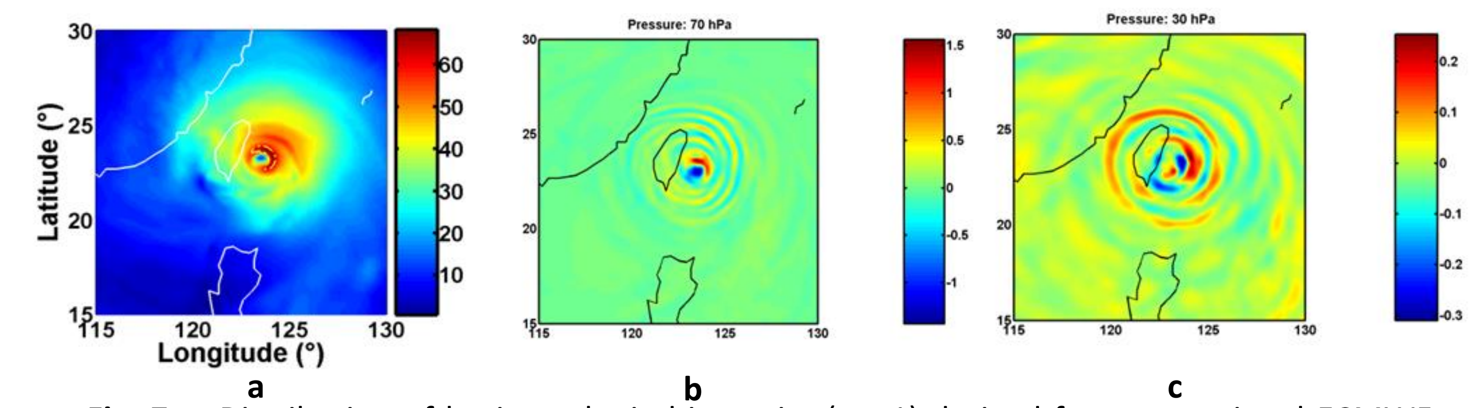

Fig. 7. a Distribution of horizontal wind intensity (ms-1) derived from operational ECMWF analyses with 0.125°x0.125° horizontal resolution on 7 August at 1200 UTC and 4-km heights. The yellow dash-dot line indicates wind values > 60 ms-1. Corresponding vertical velocity in the pressure coordinate (Pa s-1), **b** in the upper troposphere at 70 hPa, and **c** in the lower stratosphere at 50 hPa.

Conclusions

In all above mentioned cases remote sensing tools were utilized to investigate and it was found that remote sensing is very fruitful along with a future hope of more improvement with the launches of new advance satellites like FORMOSAT-7/COSMIC-2 etc. So, Remote Sensing is an effective tool in the field of typhoon modeling and forecasts for disaster prevention and reduction.

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