Precipitation distribution and forecasting in hurricane ‘Hermine’

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Abstract. Retrievals and forecasting of precipitation based on FY-3C microwave humidity and temperature sounder (MWHTS) are carried out to validate the possibility of microwave sounder in meteorological applications. Different from current research, a novel idea combining radiative transfer theory and historical statistical method is presented. Hurricane Hermine (the first hurricane to make landfall along the apalachee bay coast Since 1966) as a study case is chose to analyse the precipitation distribution and give forecasting results in 72 hours.

Keywords: Precipitation; Passive Sounding; All Weather; Forecasting

1. Introduction
Precipitation, as one of important atmospheric meteorological parameters, plays a vital role in regional and global meteorological and climate change [1]. In the current, satellite remote sensing is an important type to obtain informative signal to retrieve atmospheric parameter information. Compared with radiosonde and ground-based observations, satellite-borne microwave observations have the advantages of high temporal and spatial resolution. Normally, AMSR-E rainfall estimation, the National Snow and Ice Data Center (NSIDC) precipitation product, and active rainfall radar (Precipitation Radar, PR) precipitation product are the main sources of precipitation products, which are used by most of researchers [2]. While, MWHTS, as one of microwave atmospheric payload, also has the ability of precipitation sounding[3].

2. Instrument and Datasets
For FY-3C satellite, it has been successfully launched on September 23, 2013[4]. In this paper, MWHTS observations form a full power microwave radiometer with 4 superheterodyne receivers onboard FY-3C are used to retrieve and forecast the atmosphere precipitation.

The MWHTS onboard FY-3C satellite has 15 channels distributed in 4 frequency-bands, they are:

- 89GHz: Channel 1
- 118GHz: Channel 2-9
- 166GHz: Channel 10
- 183.31GHz: Channel 11-15
All four frequency-bands adapt hyper-heterodyne mixing receiver, converting RF signals to IF for amplification, filtering and detection, see the schematic in Figure 1. Of which, eight detection channels at 118GHz share one RF front end and five detection channels at 183GHz share another RF front end.

**Figure 1.** the schematic of MWHTS onboard FY-3C satellite.

The gain adjusting mechanism for each channel can be described as follows: the upper threshold (9V) and lower threshold (1V) are set for outputs, if the output (observing cosmic) is less than 1V, then the AGC adjusts the value to make the output greater than 1V. If the output (observing black body) is higher than 9V, the AGC makes gain adjustment to make the output lower than 9V. It means that the output is always between 1 to 9V for all channels.

In this paper, we focus on hurricane ‘Hermine’, which is happened in Aug 28 to Sept 2, 2016, making landfall around 1:30 AM EDT just east of St. Marks, Florida near the Wakulla-Jefferson County line [5]. Hermine was initially highlighted by the National Hurricane Center (NHC) well before it formed into a Tropical Cyclone in the Five-Day Tropical Weather Outlook on Thursday, August 18, 2016 (2 PM EDT). As we know from observations reanalysis and path correction, it slammed into the Big Bend early Friday morning Maximum sustained winds were near 80 mph with a central pressure of 982mb as recorded.
For Level1 dataset [6], which is calibrated from original L0 data, with channel nonlinearity and warm target correction considered. And also, time, latitude and longitude information can be provided given by satellite GPS. The scanning period is 2.667s, it means that it takes 2.667s to finish 98 field of views of about 2650km a swath. As a polar-orbiting satellite, it orbits the earth 14 times everyday, with global coverage. The observations in Level 1 named Earth_Obs_BT, which is memorized as follows:

Dataset 'Earth_Obs_BT'
Size: 98x2384x15
MaxSize: 98x2384x15
Datatype: H5T_IEEE_F32BE (single)
ChunkSize: 98x2384x1
Filters: deflate(5)
FillValue: 0.000000
Attributes:
  'units': 'K'
  'valid_range': 80.000000 340.000000
  'FillValue': 65535.000000
  'Intercept': 0.000000
  'Slope': 1.000000
  'long_name': 'Earth Observation Brightness Temperature'
  'band_name': 'Channel 1 to 15'

Using python code, observations for all channels can be sampled with time and space information, as shown in Figure 2 for one channel, which will be the input of retrieving and forecasting system.

![Figure 2. One-orbit observations at 150GHz.](image)

3. Flowchart of methods and processing
As shown in Figure 3, given L1 observations, data quality control is critical to the further work after data matchup (±0.5°) and time screen (±30 mins) roughly. The footprint of MWHTS will be flagged as invalid if brightness temperature for that pixel is less than 50K or greater than 400K. For data matching, the observations are screened if latitude is greater than 40N or smaller than 20N and the longitude is larger than 50W or smaller than 80W. As to retrieving and forecasting method, a novel method combining statistical and physical retrieval method is used to retrieve the precipitation and forecasting precipitation in 3 days.
4. Results
Statistical inversion methods rely more on data sets, and the quality of the data sets will directly affect the inversion accuracy. Preprocessing the data sets more accurately based on the observation brightness temperature error will further improve the inversion accuracy. The method in this study based on atmospheric transmission equations and statistics has a good effect on solving nonlinear problems of precipitation retrieving and forecasting, especially in hurricane situations.

Based on brightness temperatures like in Figure 4, the precipitation forecasting results are shown in Figure 5, from Aug 28 to 31, 2016, and the precipitation distribution in 12:00 Sept 2, 2016 are compared with precipitation results from gauge in Figure 6, Figure 7 shows the orbit-products of precipitation distribution from MWHTS.

![Diagram](image)

**Figure 3.** The flowchart of precipitation retrieval and forecasting.

**Figure 4.** The brightness temperature of MWHTS observing hurricane Hermine.

(a) 150GHz  
(b) 89GHz
Figure 5. Precipitation distribution and forecasting from 28, Aug, to 2, Sept., 2016.
Figure 6. Precipitation products from gauge at 12:00, Sept. 2, 2016.

Figure 7. The precipitation comparison between MWHTS and gauge at about 12:00, Sept 2, 2016.

5. Conclusion
A new precipitation retrieval and forecasting method in extreme rainfall system was developed with microwave observations from meteorological satellite. It can provide rainfall quantitative forecast up to +72h. The reference data include gauge and satellite precipitation products. Future work will focus on large-scale meteorological and hydrological applications based on the precipitation results.

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