**Referee 1**

Specific comments

1. Lines 108: the content of section 2.1.1 has to be moved into section 2.2.1 of WRF-ARW regional model.

Answer: Thanks for your suggestion. We have followed it in the revised manuscript in lines 195-200.

1. Lines 110：Is 0.5° × 0.5° the finest GFS horizontal resolution available?

Answer: Thanks for your question. The NCEP GFS Analysis and Forecast System was upgraded on January 14, 2015 (1200 UTC), providing 0.25° × 0.25° gridded output which is the finest GFS horizontal resolution available. As the finer GFS product, 0.5° × 0.5° gridded output is still available. We have made some experiments comparing the winter and summer forecast over Tibetan Plateau while the 0.25° product was not available in the whole January 2015. So we choose the 0.5 degree gridded output at first.

1. Page.7, line 116: change the title of section 2.1.2 in “Data used for the evaluation/verification”（2.1.2）

Answer: We have followed your suggestion in the revised manuscript in line 121.

1. Page.8, line 137: change the title of section 2.1.3 in “Data used for the assimilation”（new 2.1.1）

Answer: We have followed your suggestion in the revised manuscript in line 104.

1. Page.10, line 171: change the title of section 2.2.1 in “The GSI 3D-VAR system and the Community Radiative Transfer Model”; please give in this paragraph some theory concepts on GSI 3D-Var system

Answer: We have followed your suggestion in the revised manuscript in lines 203-221.

Instead of the spectral definition of backgrounds errors in the SSI, GSI is constructed in physical space which the background errors can be represented by a non-homogeneous and anistropic gridpoint and used for both global and regional forecasts. GSI utilizes recursive filters and is designed to be a flexible system that is efficient on available parallel computing platforms (Wu et al., 2002; Purser et al., 2003a,b). The GSI 3D-Var system provides an optimal analysis through two outer iterative minimization of a prescribed function as follows:

(1)

Where is the analysis state can be calculated by minimizing the penalty function , is the first guess that comes from GFS product in this article representing background model state, are the observations including conventional observation, satellite radiance data, radar data, etc. is the transformation operator from the analysis variable to the form of the error. By means of the two sources of priori data: the first guess and the observations , the solution for the penalty function which indicates the posteriori maximum likelihood estimate of the true atmospheric state can be found. While B and are the error estimates of (covariance matrix of the background error ) and (covariance matrix of the observation error) respectively which are used to weight the analysis fit to individual observations (Wu et al., 2002).

Wu, W., R. Purser, and D. Parrish: Three-Dimensional Variational Analysis with Spatially Inhomogeneous Covariances. *Mon. Wea. Rev*., 130, 2905–2916, 2002

Purser, R. J., Wu, W. S., Parrish, D. F., and Roberts, N. M: Numerical aspects of the application of recursive filters to variational statistical analysis. Part I: Spatially homogeneous and isotropic Gaussian covariances. *Monthly Weather Review*, 131(8), 1524-1535, 2003a

Purser, R. J., Wu, W. S., Parrish, D. F., and Roberts, N. M: Numerical aspects of the application of recursive filters to variational statistical analysis. Part II: Spatially inhomogeneous and anisotropic general covariances. *Monthly Weather Review*, 131(8), 1536-1548, 2003b

1. Line 185: In my opinion this paragraph would follow the one on assimilation data becoming 2.1.3

Answer: We have followed your suggestion in the revised manuscript in lines 155-178.

1. Line 210 section 3.1: please indicate in this section which is the best value for each score

Answer: We have followed your suggestion in the revised manuscript in lines 239-262.

1. Lines 242-245: the sentences here are not so clear

Answer: Following your suggestion, we have added the text in lines 269-273:

The CTRL experiment was carried out first with an initial time of 00:00 UTC and made 54 h forecasts. The data assimilation was applied on the D01 region of the output from CTRL at 06:00 UTC. The initial condition of the DA experiments was derived from the CTRL 6 h forecasts and then DA experiments made a 48 h forecast for each day.

1. Pag.15 lines 275-277: the values in brackets are referred to L24h, is it right? If yes, please specify it in the text

Answer: Thanks for your question. The values in brackets are referred to L24h. Following your suggestion, we have added the text in lines 309-312:

The overall bias statistic in D02 is 0.97 mm (0.86 mm), 0.52 mm (0.70 mm), 1.08 mm (0.97 mm), and 0.98 mm (0.76 mm) CTRL, CONV, ATMS and CRIS respectively. The values in brackets are referred to L24h.

1. Pag.17 lines 313-316: please indicate on figure 8 (for example using circles or arrows) the overestimated and underestimated events

Answer: Thanks for your mention, we have added the grey shadings to indicate the underestimated events in figure 8.

1. Pag. 18 lines 325-326: please add a reference figure

Answer: We have followed your suggestion in the revised manuscript in lines 362-367.

It is usual to define the amount of 25.0 to 49.9 mm and 50 mm daily precipitation as heavy rain and rainstorm, respectively. However, due to the history data sets of the TP indicating that the days of precipitation exceeding 50 mm are few (only accounting for 0.3% of rain days) (Wei et al., 2003) and referring to previous studies (Wang et al., 2011; Zhao et al., 2015), the heavy rainfall threshold was defined as above 20 mm for the 24 h precipitation in this study.

Wei, Z.，R. H. Huang，W. J. Dong: Interannual and interdecadal variations of air temperature and precipitation over the Tibetan Plateau. Chinese Journal of Atmospheric Sciences, 27(2), 157-170, 2003.

Wang, C. H., S. W. Zhou, X. P. Tang, and P. Wu: Temporal and spatial distribution of heavy precipitation over Tibetan Plateau in recent 48 years. Scientia Geographica Sinica, 31(4), 470-477, 2011.

Zhao, X. Y., Y. R. Wang, Q. Zhang, and L. Luo: Climatic characteristics of heavy precipitation events during summer half year over the Eastern Tibetan Plateau in recent 50 years. Arid Land Geography, 4, 004, 2015.

1. It would be useful to consider bootstrap confidence intervals when discussing the results

Answer: Thanks for these very thoughtful suggestions. To consider bootstrap confidence intervals may be a useful way to present our results. Actually, we calculate these statistics based on a threshold with the different coefficients, please check Figure 7 and the description in lines 327-341 in section 4.1. If we want to consider bootstrap confidence intervals with the different threshold, the calculation should be very complicated. But we accept your suggestion with the different way discussion.

Technical corrections

1. Line 36: a space has to be added between “hours” and “and”

Answer: Thanks for pointing out this issue to us. We have corrected it in the revised manuscript in lines 30-31.

For the first 24-hour and last 24-hour accumulated daily precipitation……

1. Line 52: “influences” rather than “influence”; “causes” rather than “cause”

Answer: Thanks for pointing out this error to us. We have corrected it in the revised manuscript in line 47.

The dramatic modification caused by the rugged terrain influences the local atmospheric circulation and causes strong local convection to arise……

15．Line 127: “several” rather than “Several”

Answer: Thanks for pointing out this issue to us. We have corrected it in the revised manuscript in line 141.

Of the several merged satellite precipitation products……

1. Lines 138-141-142-143: please specify the acronyms: GDAS, pibal, SSM/I and TCW

Answer: Following your suggestion, we have added the text in lines 105-112.

The conventional data which is from the Global Data Assimilation System (GDAS)-prepared BUFR files (gdas1.tCCz.prepbufr.nr) is composed of a global set of surface and upper air reports operationally collected by the National Centers for Environmental Prediction (NCEP). It includes radiosondes, surface ship and buoy observations, surface observations over land, pilot balloon (pibal) winds and aircraft reports from the Global Telecommunications System (GTS), profiler and US radar derived winds, Special Sensor Microwave Imager (SSM/I) oceanic winds and atmospheric total column water (TCW) retrievals, and satellite wind data from the National Environmental Satellite Data and Information Service (NESDIS).

1. Line 201: (Table 1) instead of (Table 2)

Answer: Thanks for pointing out this mistake for us, we have changed it in the revised manuscript in line 172.

1. Line 280: “(Table 2)” instead of “(Table 1)”

Answer: Thanks for pointing out this mistake for us, we have changed it in the revised manuscript in line 236.

1. Line 313: “It can be seen in the time series of Figure 8a that”

Answer: Thanks for pointing out this issue for us, we have added it in the revised manuscript in line 350.

It can be seen in the time series of Figure 8a that there are four observed heavy rainfall events….

1. Line 317: “The L24H forecasts (fig.8b) showed a….”

Answer: Thanks for pointing out this issue for us, we have added it in the revised manuscript in line 355.

The L24H forecasts (fig. 8b) showed a similar pattern.

1. Line 322: “the CONV (blue line) experiment”

Answer: Thanks for pointing out this issue for us, we have added it in the revised manuscript in line 360.

the CONV (blue line) experiment captured the accumulated amount of precipitation….

1. Line 324:“the ATMS (red line) performed the worst….the 24h precipitation maxima”

Answer: Thanks for pointing out errors for us, we have added and corrected them in the revised manuscript in line 361 and line 367.

the ATMS (red line) performed the worst…..the 24 h precipitation maxima surpassing 20 mm are spread in the main precipitation region

1. Line 349: a space has to be added between“experiments” and“data”

Answer: Thanks for pointing out this issue for us, we have added a space it in the revised manuscript in line 393.

1. Line 354:“but the results are not the same….”

Answer: Thanks for pointing out this issue for us, we have changed the words in the revised manuscript in line 398.

but the results are not the same when different data sets are injected.

1. Line 377:“(bottom left in Fig. 11m)”

Answer: Thanks for pointing out this issue for us, we have added the words in the revised manuscript in line 437.

1. Line 408: delete the double comma

Answer: Thanks for pointing out this issue for us, we have deleted it in the revised manuscript in line 469.

1. Line 409: a space has to be added between “25” and “July”

Answer: Thanks for pointing out this issue for us, we have added a space it in the revised manuscript in line 470.

1. Line 445: “we choose” rather than “we chose”

Answer: Thanks for pointing out errors for us, we have added and corrected them in the revised manuscript in line 507.

1. Table 1: New Table 1 will be the one about ATMS and CrIS channels and the caption could be modified as follows: “The channels for ATMS and CrIS data that have been selected for the data assimilation procedure”

Answer: Following your suggestion, we have revised the text in the caption of new Table 1 in lines 648-649.

Table 1.The channels for ATMS and CrIS data that have been selected for the data assimilationprocedure

1. Table 2: New Table 2 will be the one about contingency table; please add also more details in the caption

Answer: We have followed your suggestion to add more details in the caption of new Table 2 in lines 651-652.

Table 2. Rain contingency table used in the verification studies. As a threshold, 6 mm day-1 is chose to separate rain from no-rain events

1. Figure 1: please add more details into the caption of figure 1a (resolution of the domains for example)

Answer: Following your suggestion, we have added more details into the caption of figure 1 in lines 661-665.

Figure 1. (a) Simulation domains and topography. Resolutions are at 12 km and 4 km for the outer (coarse grid, D01) and inner (nested grid, D02) boxes, respectively. The shading indicates the terrain elevation (unit: m). (b)–(d) Distribution of (b) conventional data observations, (c) scan coverage of ATMS data after data assimilation, and (d) scan coverage of CrIS data after data assimilation at 06:00 UTC on 1 July 2015.

1. Figure 2: clarify into the caption the difference between “observations kept and used”

Answer: Thanks for your suggestion, we have revised the caption in lines 666-670 as follows:

Figure 2. Blue bars indicate the total amount of radiance read in the DA system. Red bars present the number of kept radiance after first step of quality control. The used percentage after final quality control is shown as black curves. The right y-axis indicates the ratio of used amount to read amount. Top panel is for ATMS (a) and bottom is for CrIS data (b).

1. Figure 3: in the caption there are no info about the part of the figure at the top; please also mention into the caption the initial time of each experiment

Answer: Thanks for your suggestion, we have revised the caption in lines 671-676 as follows:

Top panel shows the schematic of data assimilation configuration with 3D-Var. Bottom panel presents the experiments design. CTRL: control experiment without data assimilation that the initial time is 00:00 UTC from 1 to 31 July; CONV: data assimilation with conventional data only; ATMS: data assimilation with conventional and ATMS data; CRIS: data assimilation with conventional and CrIS data. CONV, ATMS and CRIS experiments all start at 06:00 UTC from 1 to 31 July.

1. Figure 4: put the unit also close to the color bar; “black contours are altitude”

Answer: Thanks for your mention, we have put the unit above the color bar now and revised the manuscript in lines 677-678.

Figure 4. Daily precipitation averaged (unit: mm) for the month of July 2015. (a), (b) are F24H forecast and (c), (d) are L24H forecast. Black contours are altitude (unit: m).

1. Figure 5: put the unit also close to the color bar

Answer: We have put the unit above the color bar now.

1. Figure 7: please list into the caption the validation statistics presented in the figure

Answer: The validations statistics is listed into the caption in lines 686-689.

Figure 7. Monthly and domain average validation statistics for F24H forecast (a–f) and L24H forecast (g–l). (a) and (g) are Bias Score; (b) and (h) are Fraction skill Score; (c) and (i) are Equitable Threat Score; (d) and (j) are Probability of False Detection; (e) and (k) are Probability of Detection; (f) and (l) are False Alarm ratio.

1. Figure 8: please add more details into the caption

Answer: We have added more details in to the caption in lines 690-693: Time series of daily precipitation distribution for F24H forecast (a) and L24H forecast (b). The black, grey, blue, red and green lines indicate observation, CTRL, CONV, ATMS and CRIS, respectively. The unit is mm. The grey shadings indicate the underestimated events.

1. Figure 11: put the unit also close to the color bar

Answer: We have put the unit above the color bar now.

1. Can be figures 4-5-6-10-11 a little bit bigger?

Answer: Those figures are bigger now.

Referee 2

Major points

1. Section 2.1.2 Observation data: Even if there is the reference to a previous study on the (Guo et al., 2014), it is interesting to have some more details about it, especially about its performance on the TP, considering that the rain gauges are sparse over the TP.

Answer: Thanks for these thoughtful suggestions. Due to the gauge distribution is very sparse in TP area, satellite-based estimates have become very important sources for precipitation information. We have further explain the performance of the CMORPH dataset for TP in the revised that paragraph in lines 129-151:

Considering the topographically complex terrain characterizing the TP, satellite precipitation data with very high spatial resolution is especially needed. CMORPH product makes use of the precipitation estimates technique that have been derived from low orbiter satellite microwave observations and geostationary satellite IR data with spatial propagation features. Several studies (Gao et al., 2013; Guo et al., 2014; Tong et al., 2014; Zhang et al., 2015) have compared the CMORPH data with satellite precipitation data sets in the TP area with the conclusion that CMORPH data is one of the most suitable product to use in studying precipitation over the TP. During the period from May to October 2004-2009, Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis real-time research 3B42 version 6 (TMPA) and CMORPH show better performance in higher correlation and lower RMSE than the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Network (PERSIANN) and its real time version (TMPART) over the TP(Gao et al., 2013). Of the several merged satellite precipitation products (i.e.TMPA, PERSIANN, and the Global Satellite Mapping of Precipitation (GSMaP)), the CMORPH product with the highest resolution (8 km) can capture the afternoon-to-evening precipitation pattern (Guo et al.,2014). Tong (2014) has also compared the performance of four widely-used high resolution satellite precipitation estimates against gauge observations (the CMA data) over the TP during January 2006-December 2012. It’s worth noticing that TMPA and CMORPH data had better performance in depicting precipitation timing and amount than the TMPART and PERSIANN at both the plateau and basin scale. Zhang (2015) has also made a conclusion that the high resolution CMORPH data can depict finer regional details, such as a less coherent phase pattern over the TP and better capture the features of the diurnal cycle of summer precipitation compared with TRMM 3B42.

Gao, Y. C., & Liu, M. F. Evaluation of high-resolution satellite precipitation products using rain gauge observations over the tibetan plateau. *Hydrology & Earth System Sciences Discussions,* 2013, 9(8), 9503-9532.

Tong, K., Su, F., Yang, D., & Hao, Z. Evaluation of satellite precipitation retrievals and their potential utilities in hydrologic modeling over the tibetan plateau. *Journal of Hydrology,* 2014, *519*, 423–437.

1. Section 4.1- Lines 255-264：I can’t understand what is shown in Figure 4. If the panels a) and c) are observed values for July they should be the same, while they show different values. Explain.

Answer: Thanks for your attention, we have explained it in the revised manuscript in lines 290-295.

Due to the Figure 4 a) standing for the F24H, the first day calculated in Figure 4 a) was during the period of 06:00 UTC 1st July to 06:00 UTC 2nd July and finally ended in the period of 06:00 UTC 29th July to 06:00 UTC 30th July. Therefore the different values in Figure 4 a) and c) can be explained that the Figure 4 c) shows the L24H observed monthly mean accumulated precipitation of which the computing process are different in in two days with Figure 4 a).

1. Section 4.3- Details need to be added on the computations you did in Figure 10, including the mathematical formulation.

Answer: Thanks for your suggestion, we have revised the manuscript in lines 403-418 as follows:

Zonal component of wind velocity (u), meridional component of wind velocity (v), specific humidity (q), and covariance, which are needed for flux computations, are provided at eight standard pressure levels (1000, 925, 850, 700, 600, 500, 400, and 300 hPa). The equation of unit side length, vertically integrated between the surface level and the top of the atmosphere and averaged in time atmospheric water vapor flux (unit: kg\*m-1\*s-1) can be written as:

(11)

The zonal and merdional component of vapor flux is described by:

(12),

and (13) , respectively.

 Where ps is the surface pressure and p is the pressure at the "top" of the atmosphere, g is the gravitational constant ( 9.8 m\*s-2 ).

The water vapor flux divergence (D, unit: kg•m-2•s-1) is given by:

+ (14)

where a is the radius of the model earth taken as 6371.2 km,  is latitude in radians, and  is longitude in radians.

Minor points

4. Line 36: “hourand” should be “hour and”.

Answer: Thanks for pointing out this issue to us. We have corrected it in the revised manuscript in lines 30-31.

For the first 24-hour and last 24-hour accumulated daily precipitation……

5. Lines 42-45: reformulate the last sentence of the abstract because is not clearly understandable.

Answer: Thanks for your suggestion. We have revised the abstract in the last sentence into “ Overall, based on the experiments in July 2015, the satellite data assimilation improved to some extent the prediction of precipitation pattern over the Tibetan Plateau although the simulation of rainbelt without data assimilation shows the regional shifting.”

6. Lines 75: Put a dot after “2008)”.

Answer: Thanks for your attention. We have revised it in line 71.

7. Line 85: two dots after “2013)”.

Answer: Thanks for your attention. We have deleted one dot in line 81.

8. Line 96: change “has” with “had”.

Answer: Thanks for pointing out this mistake for us. We have revised it in line 92.

9. Line 113: “The GFS data are. . .”

Answer: Thanks for pointing out this mistake for us. We have revised it in line 199.

10. Lines 291-294: The two sentences are unclear. Please, rewrite.

Answer: Thanks for your attention. We have revised it in lines 326-330 as follows:

The ~84-89% high percentage of hits and correct rejections events indicates that rainfall events are well predicted. Furthermore, as the false alarms were primarily located in the east of the TP in contrast to the misses in the west, this special pattern can help WRF-ARW model reduce model error in the future which means that WRF-ARW model has promising potential in TP area.

11. Line 314: put a space between events and “(“.

Answer: Thanks for your attention. We have revised it.

12. Line 316 and after: I would not call a 6 mm/day precipitation as a “heavy rains”. Check thorough the paper.

Answer: Thanks for your attention. Precipitation is mainly distributed in the south edge of the TP, and the rainfall in other area is very small (Figure 4). The threshold of 6 mm is defined by calculating the whole D02 regional average precipitation so that the value seems relatively small.

13. Line 318: “between” is “among”.

Answer: Thanks for pointing out this mistake for us. We have revised it in line 355.

14. Line 359: In the figure 10 the period is 3-5 July and not 3-6. Please change.

Answer: Thanks for your attention. We have revised the period in the manuscript in line 403.

1. Line 374: The score shown is FSS not ETS.

Answer: Thanks for pointing out this issue for us. We have revised it in line 434.

1. Line 383: Figure 10l does not exist.

Answer: Thanks for your attention. We have revised it the manuscript in line 444 as follows: the precipitation experiments all underestimated the amount of precipitation, and CRIS performed particularly badly (Fig. 10c, f, i).

1. Line 385: Change “This phenomenon” with “This result”.

Answer: We have followed your suggestion in the revised manuscript in line 446 as follows: This result indicates that DA can indeed improve the heavy rainfall forecast.

1. Line 386: Figure 10 refers to CTRL and not to DA experiments, likely you would refer Figure 11.

Answer: Thanks for pointing out this mistake for us. We have revised it in line 447:

From the above analysis of Figure 9 and 11, it is clear that before the heavy rainfall, DA can improve the simulation of precipitation spatially.

1. Figure 2: It is unclear what is shown on the right-y axis. The Figure caption must clearly state what is represented.

Answer: We have followed your suggestion in the revised caption of figure 2 as follows:

Figure 2. Blue bars indicate the total amount of radiance read in the DA system. Red bars present the number of kept radiance after first step of quality control. The used percentage after final quality control is shown as black curves. The right y-axis indicates the ratio of used amount to read amount. Top panel is for ATMS (a) and bottom is for CrIS data (b).

1. Figure 4: The Figure 4 caption must be rewritten. It is unclear. “Spatial pattern of the monthly mean precipitation in July 2015”. I believe it is the daily precipitation averaged for the month of July 2015

Answer: We have followed your suggestion in the revised caption of figure 4 as follows:

Figure 4. Daily precipitation averaged (unit: mm) for the month of July 2015. (a), (b) are F24H forecast and (c), (d) are L24H forecast. Black contours are altitude (unit: m).

1. Figure 8: title is “precipatation”.

Answer: Thanks for pointing out this mistake for us. We have corrected the title.

1. Figure 10: the period is 3-5 July not 3-6 July. In the caption, “precipitation quantity” is“precipitation”.

Answer: Thanks for pointing out this mistake for us. We have corrected the caption.

Figure 10. (a)–(f) 24 h forecasts of precipitation quantity (shadings) and water vapor flux (vectors) during 3–5 July for (a)–(c) OBS and (d)–(f) CTRL. (g)–(i) Differences in water vapor flux (vectors) and water vapor divergence (shadings) between CTRL and OBS. The unit of precipitation is mm. The units for water vapor flux and divergence is kg/(m\*s) and kg/(m2\*s), respectively.