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Conference Paper · October 2018

DOI: 10.1117/12.2324674

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Wenying He, "Comparisons of radiative transfer models for GMI assimilation in WRF
," Proc. SPIE 10782, Remote Sensing and Modeling of the Atmosphere, Oceans, and Interactions VII, 107820N (23 October 2018); doi: 10.1117/12.2324674

Event: SPIE Asia-Pacific Remote Sensing, 2018, Honolulu, Hawaii, United States

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ABSTRACT

Currently both RTTOV and CRTM have been used in the WRF data assimilation (DA) system for radiance assimilation under all-sky weathers. To well know the influence of both fast radiative transfer models on radiance, GPM/GMI is assimilated in WRFDA system for one storm case occurred on July 19-21, 2016, in Beijing, China，then compare the simulated brightness temperatures to their observed equivalents in this work.

The comparisons show that at GMI low frequencies(10-23 GHz) the simulated Tbs from RTTOV seems better than those from CRTM due to using emissivity atlas in RTTOV since the low frequency channels are more sensitive to the land surface. For rainy pixels over land, both simulations for GMI mid-high frequency channels are significantly affected by the cloud and precipitation. For GMI 5-9 channel, the simulated Tbs from RTTOV is more consistent with the observations than those from CRTM which is dramatically lower than both the observations and the simulated Tb from RTTOV when observed Tb is lower than 260 K. For GMI channel 10-13, both simulations are quite close but far away from the observations. In a word, for GMI 1-7 channels, simulated Tbs from RTTOV are much close to the observations, while for GMI high frequency, such as higher than 89GHz, both RTTOV and CRTM still need more improved in rainy condition.

Keywords: radiance assimilation; GMI; radiative transfer models; all-sky condition

1. Introduction

RTTOV and CRTM have been widely used in radiance assimilation in numerical weather prediction (NWP) models, such as Weather research and forecasting (WRF) model and ECMWF system. More detail about the status of the two main radiative transfer models for satellite data assimilation are described in Vidot's work[1]. Space-borne microwave observations have been widely assimilated in NWP owing to providing rich atmospheric temperature and water vapor information, and produce significant improvement on weather forecast[2]. When all observations, no matter in clear-sky, cloudy or precipitating conditions, are assimilated using the same radiative transfer model, this is often referred to as "all-sky" approach[3]. Currently the assimilation of satellite radiance is operated in all-sky conditions in the microwave and in clear-sky and overcast cloudy conditions in the infrared. However, it has been difficult to use cloud- and precipitation-affected microwave observations over land and microwave sounding channels because atmospheric scattering is most important[4]. Geer et al. [5] used the ECMWF data assimilation(DA) system to assess the performance of

Remote Sensing and Modeling of the Atmosphere, Oceans, and Interactions VII, edited by Guosheng Liu
Ziad S. Haddad, Proc. of SPIE Vol. 10782, 107820N · © 2018 SPIE
CCC code: 0277-786X/18/$18 · doi: 10.1117/12.2324674

RTTOV_SCATT, updated RTTOV model designed for assimilating microwave radiances in all-sky conditions[6], then found that using Mie spheres to model frozen hydrometeors seem to be the largest source of error in the ECMWF all-sky assimilation of microwave observations while using the discrete dipole approximation[7] to compute scattering properties, shows more accurate results for ice rosettes or simplified snowflakes. To know more about the influence of radiative transfor models on microwave radiance, we compare RTTOV and CRTM for GMI assimilation in WRFDA system in this paper. Because of using different scattering process for cloudy or rainy conditions in both fast radiative transfer models, the simulated radiance must be different in the same hydrometers profiles providing from the first-guessing (FG) or background field. Hence the comparison of simulated brightness temperatures and their observed equivalents will reflect the capability of radiative transfer model on microwave assimilation in cloudy or rainy conditions.

2. Model and method

RTTOV version 11.3 used in this work is of updated land surface emissivity deriving from TELSEM[8] and RTTOV_SCAT module for scattering calculation. Four hydrometers are considered in RTTOV_SCAT, including cloud water (Qc), rain water (Qr), ice (Qi) and snow (Qs). For icy scattering especially no-sphere shaped particles, the Discrete Dipole Approximation (DDA) treatment shows positive effect than Mie-scattering in reference [5]. Hence DDA is used for snow and the Delta-Eddington approximation method in Mie theory is used for other icy particles scattering in RTTOV 11.3.

CRTM Version 2.2.3 is used in this work. The land surface emissivity is calculated from emissivity model[9], and the Advanced Matrix Operator Method in Mie theory is used for scattering treatment[10] . Six hydrometer are considered in CRTM, including Qc, Qr,Qi,Qs, graupl (Qg) and hail (Qh) .

For satellite radiance, GPM Microwave Imager (GMI) on Global precipitation measurement (GPM) mission launched in Feb., 2014 is investigated to assimilated in WRFDA system using both RTTOV and CRTM. GMI is 13-channel microwave imager, 9-channel at lower frequencies (10- 89GHz) similar to AMSR-E and TMI, newly 4-channel at higher frequency (166 and 183 GHz). GMI product L1B for microwave brightness temperature and L2A for retrieved cloud water are used in this work.

To see more detailed difference between RTTOV and CRTM on radiance assimilation in all-sky conditions, one storm event occurred in Beijing, China on July 19-21, 2016 is studied in this paper. First chose the available GMI observation during the event. One GMI orbit observation is found at 20:00 (UTC) July 19, 2011 as Fig.1a shown, it is seen the rainfall area reflected from the brightness temperature (Tb) of channel 8 (ch8), 89GHz, is more consistent with the ground rainfall measurement from rain gauges, the lower Tb shows the stronger rainfall due to more scattering from precipitation hydrometers. There are more than two orbits observations cover this storm event, therefore it is a good case to study GMI all-sky assimilation. Then using RTTOV and CRTM to simulated the GMI brightness temperature(shorted for TB_RTTOV and TB_CRTM, respectively) during the storm event in WRFDA, and the first-guessing field is provided from WRF forecast model. Before assimilated GMI radiance into WRFDA, the simulated Tbs from two models are compared with the corresponding observations to see the performance of the radiative transfer models.

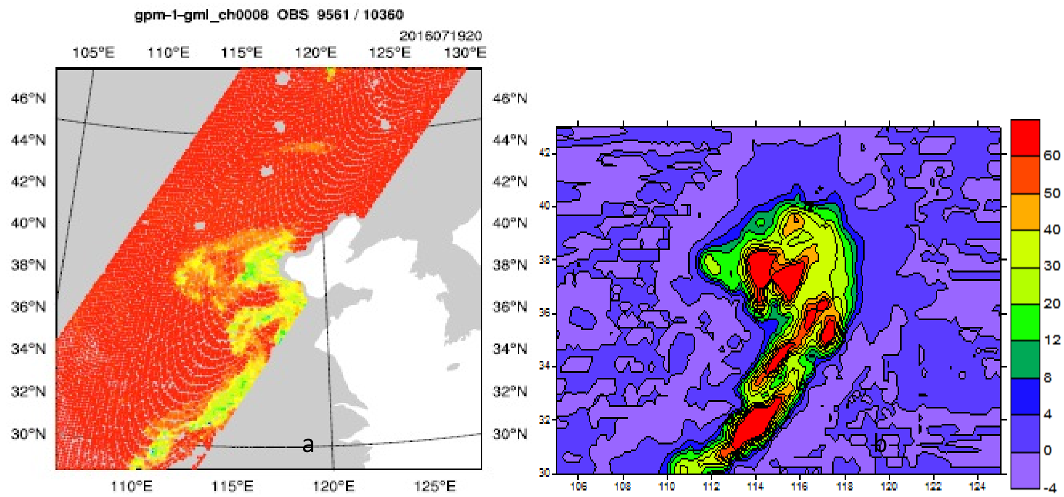

Fig.1 The distribution of Tb observation of GMI ch8 (a) and hourly rainfall from ground rain gauge (b)

3. Results

Aim to the good rainfall coverage at 20:00 July 19, 2016, firstly the simulated Tb at GMI ch8 (Tb8) from both RTTOV and CRTM are shown in Fig.2. In generally, the distribution of Tb8 calculated from models are more consistent with that of the observation shown in Fig.1a, especially the lower Tb in rainy area. But the Tb8 from CRTM is much lower than that from RTTOV and the observations in rainy area. Then more detail works are made for those obvious difference.

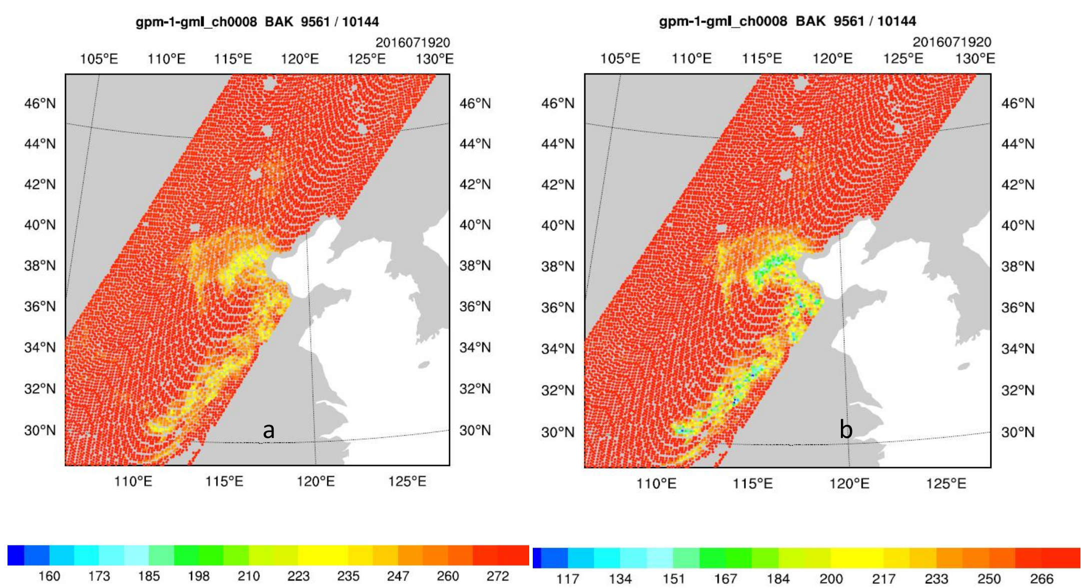

Fig.2 The distribution of simulated Tb8 from RTTOV (a) and CRTM (b) on 20:00 Jul.19,2016

Combining the simulated results with GMI L1B and L2A product, we get the matching pixels with quality flag, surface rain rate, and surface type from the GMI observation. Then the matching samples passed the quality checking and located within (30-45N，110-120E) over land are used to make the following comparisons.

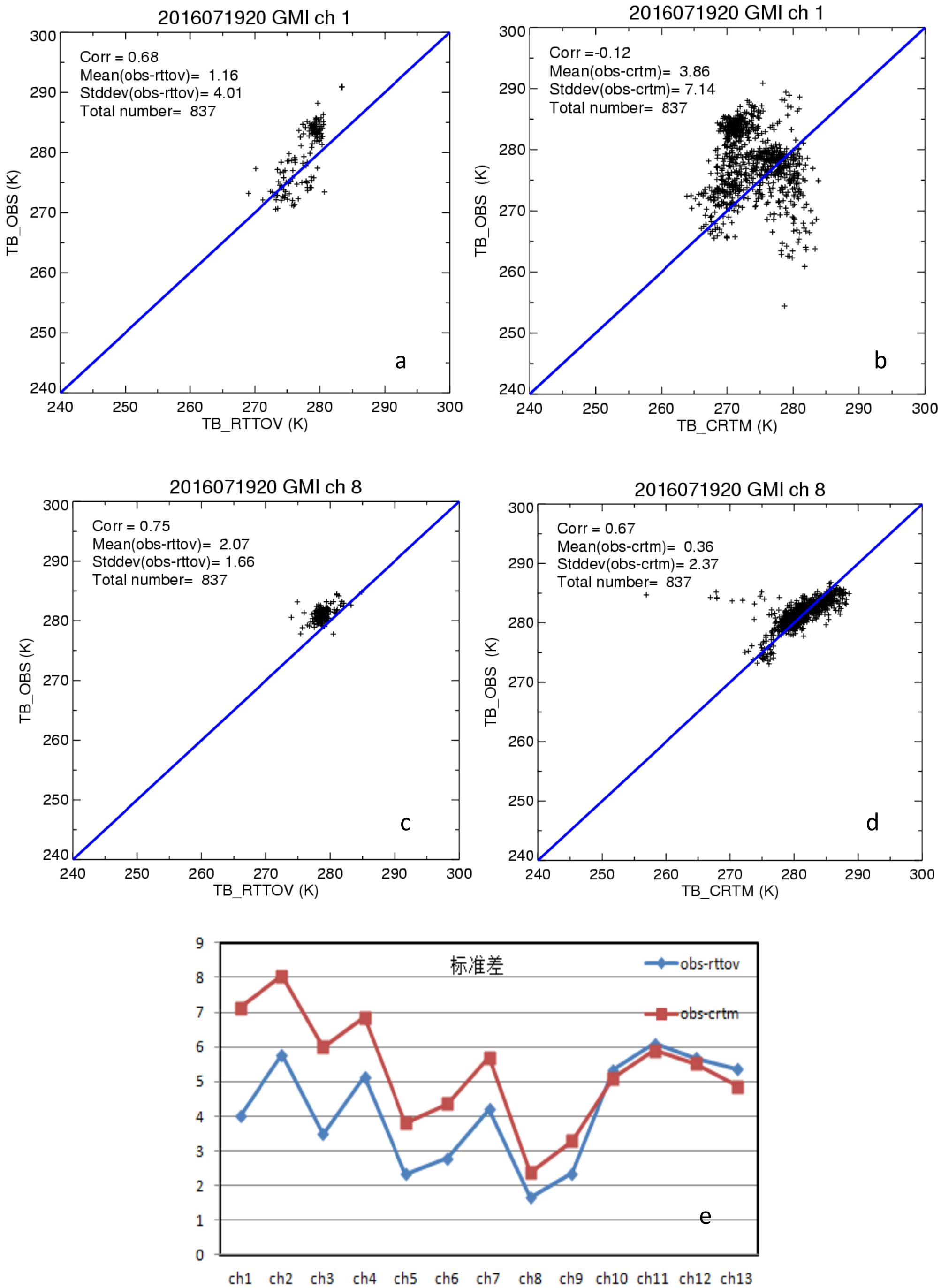

Fig.3 Scattering plots between the simulated and observed Tb at ch1(a,b) and ch8 (c,d) and STD statistics of GMI ch1-13 (e) for no-rain samples

Firstly for no-rainy samples (N=837), both simulated Tb at GMI ch1 and ch8 are more close to the observations within 260-290 K. For ch1, the simulated Tb from CRTM is more scattering with the observations(Fig.3b) than that from RTTOV (Fig.3a) so that the Standard deviation(STD) of difference between CRTM and OBS is about 7.14K, obviously larger than the STD between RTTOV and OBS (4K). For ch8, both simulated results are pretty close to the observations with the STD about 2 K and the correlation coefficient about 0.70(Fig.3c,d). From the STD statistics for ch1-13 shown in Fig.3e, it is clearly presents that RTTOV shows better performance than CRTM at lower frequencies ch1-9, especially the visibly reduced STD at ch1-4 which is attribute to the improving land emissivity atlas provided from TELSM in RTTOV 11.3. While for high frequencies, such as ch9-13, both models show similar performance with quite closing STD due to without precipitation effected on Tb, especially the STD at 89GHz close to 2K.

Then we do more comparisons for rainy samples in this region. Based on quality check, surface rain rate and surface type information, there are 3702 matching rainy samples for 20:00 July 19, 2016 GMI observations. Fig4.a shows the standard deviation of observed-simulated Tb difference at GMI 13 channels. It is clearly that RTTOV simulation is closer to the observations, better than CRTM at GMI lower frequency channels, such as ch1-7; then both STD are enlarged evidently for ch8-13 due to more complex precipitation. To know more about the difference, the scattering plots of simulated and observed Tbs at GMI higher frequency channels, such as ch8-13 (89-183GHz), are presented in Fig.4b,c,d, it is seen that the simulated Tb is more discord with the corresponding observations, for instance, STD of the difference between RTTOV and observations is about 16 K at ch8 and 30K at ch10, and the correlation coefficient is less than 0.5, even worse for corresponding CRTM simulations. Such larger difference between model and observation at high frequency might be cause by two aspects, one is the accuracy of precipitation hydrometers produced by WRF forecast model. When the forecasted rainfall location and structure is not identical to the real storm, which must be provide mismatching hydrometers profile, so that the simulated Tb might be differ from the true value and produce larger bias. On the other hand, due to complex scattering process of icy hydrometers, it is hard to properly simulate the radiance at microwave high frequency for rainy samples. .

Besides the larger difference between simulated and observed Tb, we further compare the modelled Tbs for rainy samples. As Fig.4e,f,g shown, both simulated Tbs are fairly consistent, correlation coefficient higher than 0.96, especially the mean difference and STD are less than 3 K at ch12. However, for ch8 at 89GHz, the difference of both simulated Tb is increasing with the decreased Tb, and TB_CRTM is constantly lower than TB_RTTOV when TB is less than 260K; and the lower Tb is the larger difference is, resulting that the STD of Tb difference at ch8 is about 15K. Since radiance at 89GHz is more sensitive to icy particles than frequencies at 166 and 183 GHz, different scattering methods using in RTTOV and CRTM produce quite different Tb at 89GHz, and lower Tb indicates strong convective precipitation with more icy hydrometers so that the difference of both simulated Tb more obvious.

4. Summary

To well know the influence of RTTOV and CRTM on radiance assimilation in WRFDA system, the GPM/GMI observation for an storm event occurred on July 19,2016 in Beijing ,China has been studied and compared both simulated Tb with correspond observations, then we obtained the following preliminary results:

1) For GMI low frequencies(10-23 GHz), no matter no-rain or rainy pixels, the simulated Tbs from RTTOV seems

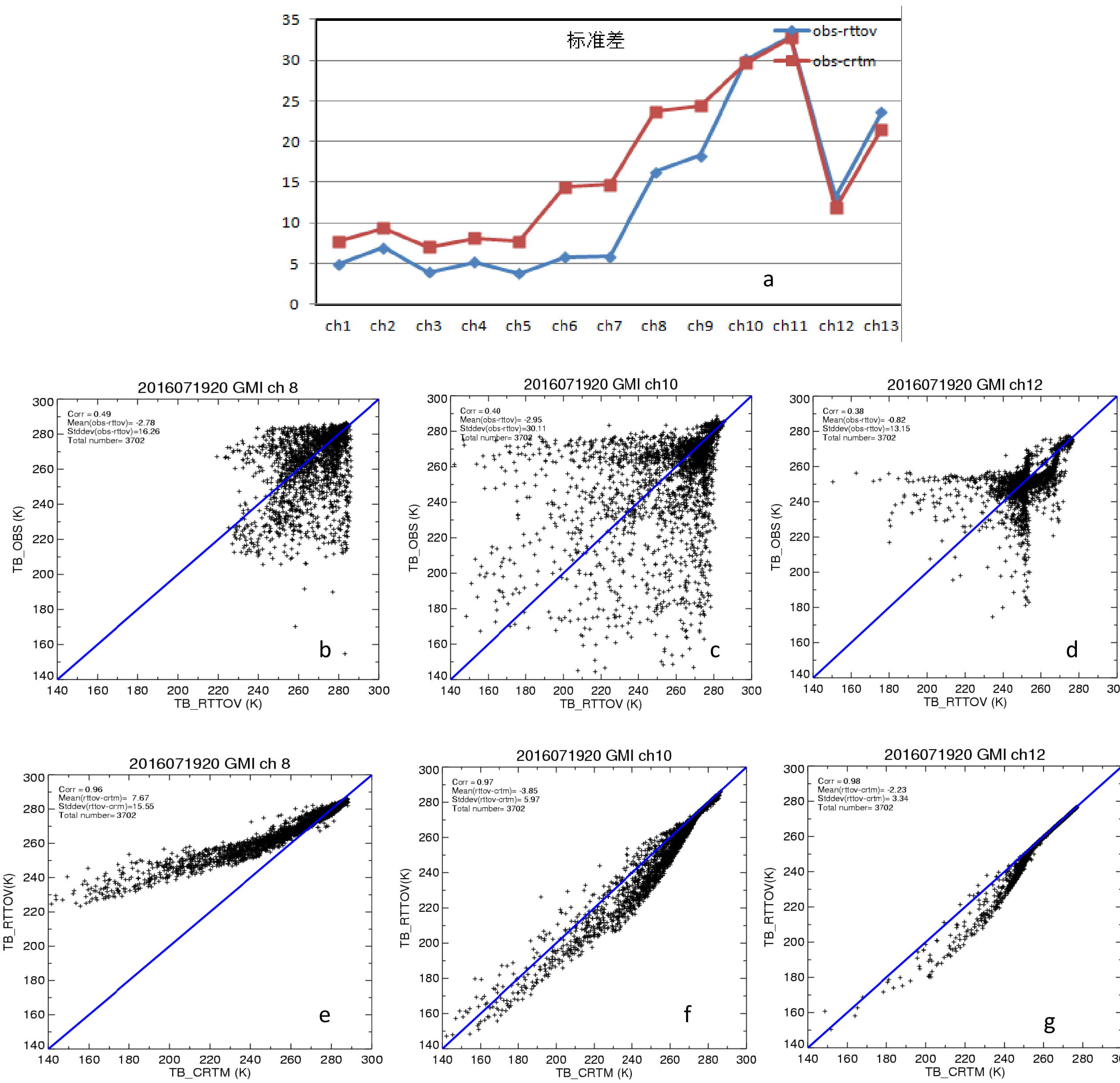

Fig.4 STD statistics of GMI ch1-13 (a) and scattering plots between the simulated and observed Tb (b,c,d) and corresponding both simulated Tb (e,f,g) at ch8, ch10, and ch12 for rainy samples

better than those from CRTM due to using emissivity atlas in RTTOV since the low frequency channels are more sensitive to the land surface.

2)For rainy pixels over land, both simulations for GMI mid-high frequency channels are significantly affected by the cloud and precipitation. For GMI 5-9 channel, the simulated Tbs from RTTOV is more consistent with the observations than those from CRTM which is dramatically lower than both the observations and the simulated Tb from RTTOV when observed Tb is lower than 260 K. For GMI channel 10-13, both simulations are quite close but far away from the observations.

3) In general, for GMI 1-7 channels, simulated Tbs from RTTOV are much close to the observations, while for GMI high frequency, such as higher than 89GHz, both RTTOV and CRTM still need more improved in rainy condition.

We investigate the performance of fast radiative transfer models in WRFDA system, and only focus on one GMI orbit scanning observations. It need more work and data to compare the simulated results and find the possible causes, which is help to enhance the capability of fast radiative transfer model in precipitation conditions, especially for microwave high frequencies.

Acknowledgements

The author thank for the help of the NCAR/MMM staff, especially Zhiquan,Liu and Yuanbing, Wang. This work was supported by the National Natural Science Foundation of China under Grant No.41575033.

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