Response to Reviewers' Comments

Anonymous Referee #1

General comments:

The paper describes a model to estimate evapotranspiration at large scale, based on the combined use of a digital elevation model, a landuse classification and remote sensing data. The approach is similar to other models such as SEBAL or S-SEBI. The main originality here is to take into account the effect of elevation (+slope and aspect) on the radiation computation. The method was applied with MODIS data over a large region in North-Eastern of China. The critical point in this study is the validation. Only one station is used to compare the flux estimated at different dates to observations. It's not enough, especially as to test a new algorithm including a new information on the elevation. It would be necessary to compare at least two stations at different elevations or with different slope or aspect values. Sometimes, the paper does not give enough information on the data used and the accuracy linked. For some figures or in tables, it is important to add the standard deviation or the confidence interval. Globally the paper is interesting with a lot of references, but it must be corrected in adding information at specific points listed below. It can be published if modifications are made to improve the text.

Ans: Because there is only flux station (Yucheng station with a large lysimeter) in this study area due to budget limitation, it is not possible to add one more at this moment. But we will conduct further verification of this algorithm in different regions.

Specific comments:

1. Title: Maybe the title can be modified because the expression 'complex terrain' can include a lot of different surfaces and not necessary the relief.

Ans: Yes. The title "A Coupled Remote Sensing and the Surface Energy Balance with Topography Algorithm (SEBTA) to Estimate Actual Evapotranspiration under Complex Terrain" has been revised as "A Coupled Remote Sensing and the Surface Energy Balance with Topography Algorithm (SEBTA) to Estimate Actual Evapotranspiration under Heterogeneous Terrain"

2. Abstract: p4877, line 9: explain what do you mean by complex ,

Ans: It has been changed to "heterogeneous terrain with varying elevations, slopes and aspects."

3. Line 24: explain what is your consistency index?

Ans: Willmott (1982) proposed "consistency index" (Index of agreement) to show the consistency between simulated and observed values (Zhan, et al., 1996). Consistency index (Idx, dimensionless) is defined as:

$$Idx = 1 - [\sum_{i=1}^{n} (P_i - O_i)^2 / \sum_{i=1}^{n} (|P_i - \overline{O}| + |O_i - \overline{O}|)^2]$$

where O_i is the observed value; $\overline{O}$ is the spatial average value; P_i is the simulated value.

The following two references have been included in the revised version of the paper.

Willmott C.J. (1982), Some comments on the evaluation of model performance, Bulletin of the American Meteorological Society 63 1309-1313.

Zhan X., Kustas W.P., Humes K.S. An intercomparison study on models of sensible heat flux over partial canopy surfaces with remotely sensed Surface temperature. *Remote sensing of environment*, 1996, 58 (3):242-256.

4. Introduction: P4878 line 12: be careful: daily evaporation is not negligible for some surfaces (bare soil. . .)
Ans: Yes. Thank you.

5. Line 13: soil moisture is not only driven by precipitation (irrigation. . . can modify also the soil moisture)
Ans: Yes. This sentence has been revised as "the surface soil moisture driven by precipitation and irrigation "

6. P4879, line 6: reference Kogan (remove et al)
Ans: Yes, corrected.

7. Ref Jian (add and Islam)
Ans: Yes, corrected.

8. Reference Nagler (in reference list it misses 'r 'to Nagler p4907 2005b)
Ans: Yes, corrected.

9. P4880, line 14: the sentence ' the residual models are the best . . . ' is a little bit exaggerated, because SVAT models using remote sensing data with assimilation methods can be also very efficient. Otherwise, residuals models don't represent the soil moisture evolution which is important for water management.
Ans: We have changed the word "best" to "better". Thanks. This is good suggestion

10. Table 1 does not give a lot of information, see ref Jetse et al, SurV Geophys 2008 The estimation of z0 in the standard version of SEBAL can be arguable, but other authors have used this model in estimating z0 with more accurate methods. I would not add SEBTA in this table 1 as it is not yet presented. Moreover, the argument of its use with any time period seems to me wrong since as for SEBAL or S-SEBI, it is based on the use of remote sensing data acquired in the optical range, therefore only for clear days. The temporal scales are the same than other models.
Ans: Thanks! We have deleted the last column. But the SEBTA is still kept there for the purpose of comparison. In order to clarify it, a "*" has been used to do so.

11. P4880, Line 25: As SEBTA is not yet described in detail, it's embarrassing to write that it's the best at this place! I find that the most important point is the improvement with the topography information. The two other points concerning roughness estimation and automatic calculation for separating wet and dry pixels have been yet performed in other studies with similar models.

Ans: Thanks! We have reorganized the description of these three improvements on P4880.

12. This section is described features of SEBTA model compared to (SEBAL, S-SEBI, SEBS), this model can be used computing the ET and heat flux in large area with complex terrain surface. P4883 Line 10: the G formation is a critical point (very questionable here) because several papers have shown bad results with such formula (add references and discussion on this point). The coefficients were defined for some surfaces, (it's a very empirical approach, not validated over various surfaces). -Have you measurements to chose G=0.5 Rn for water surfaces?
Ans: Thank! We only referred to the literature in regard to this portion. We will improve the accuracy of the calculation of soil heat in the future.

13. P4884, Line1: It can be difficult to find wet and dry pixels according to the dates and the region studied. The spatial resolution of images used is also important to take into account. (if you have mixed pixels, what do you do?) add discussion
Ans: In this study, the problem of mixed pixels was not considered to ease the processing of automatic computation. Discussion added there in section 2.3 on P4884.

14. You assume that the wind speed at 200m is more and less stable and not affected by the surface. This assumption can be questionable according to the region and atmospheric configurations. Add sentences or justifications.
Ans: This model sets assumption that the wind speed at 200m is stable and not affected by the surface. We add one sentence "Yet, this may not be always true in view of terrain complexity." There to clarify it.

15. P4884 line 15 why 0.06?
Ans: $z_{om\_station}$ is the dynamic roughness around the meteorological stations, and 0.06m is a default value based on our experience.

16. P4885 equation 10 how do you compute a and b?
Ans: The coefficients of a and b can be computed by equation 11.

17. Equation 12-13 what are k_{wet} and k_{dry} ?
Ans:

$$k_{wet} = \begin{cases} 1.05 - \dfrac{0.85 - NDVI}{2}, & NDVI < 0.85 \\ 1.05, & NDVI \geq 0.85 \end{cases} \qquad k_{dry} = \begin{cases} NDVI - 0.15, & NDVI > 0.15 \\ 0, & NDVI \leq 0.15 \end{cases}$$

18. How do you find your coefficients in these equations (not explained)
Ans: These coefficients in these equations are set by empirical values based on our local observations. This sentence has been added into the neighborhood of the equation to clarify it.
19. P4886, Lines 5-6: what is the reference level chosen for the region?
Ans: The reference height (average height of the region) of the study area is chosen based on GIS calculation. It varies from grid to grid.

20. It is not explained why you chose 0.0065

Ans: 0.0065 is derived based on a constant lapse rate (**-0.65** K/**100 m**). This sentence has been added into the text.

21. P4887 line 23 ratio between what values?
Ans: The Ratio is refer to $\Lambda_{24} \approx \Lambda_d \approx \Lambda$, Λ_{24} is for 24h average ET ratio, Λ_d is for daily ET ratio, Λ is for the instantaneous

$$\frac{LE_d}{F_d} = \frac{LE}{F} = \Lambda$$

where LE_d is the cumulative ET during the day; F_d is a component accumulated value during the day in the energy balance equation (usually with a net or effective energy of radiation) ; LE and F are instantaneous values during the day; ER is evaporative flux ratio; If F take the $LE + H$ (effective energy R_n-G), then ER is the evaporative fraction (EF) Λ.
These sentences have been added into the text.

22. P4888 To compute the ratio, do you use only instantaneous estimations of ETi/(Rni-Gi)? Or if you use ground measurements, give more details on these last data Equation 23: how do you compute Rn 24? How many stations do you use? What is the variation in time and space?
Ans: Yes, we used instantaneous estimations of ETi/(Rni-Gi) to compute the ratio, and we used ground measurements (Yucheng station) to validate the ratio. The variation of fluxes and EF are showing as follows:

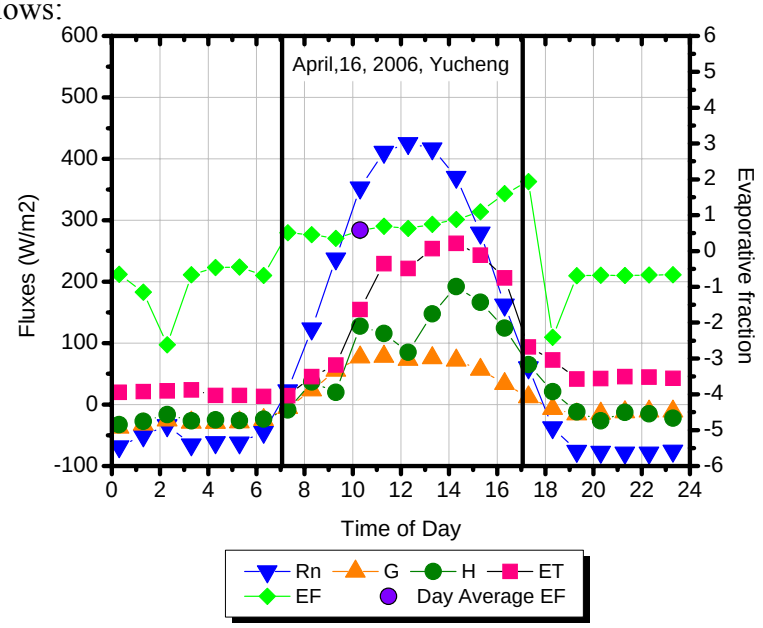

Fig.1. The curves of EF and fluxes under sunny and cloud-free.

The Polar-orbiting satellite with MODIS terra generally overpasses China between local time 10:00 to 11:00 am so that the instantaneous ET estimated by remote sensing can be extended to daily value or 24h average value of ET. The daily average of EF (evaporative fraction) is 0.58595 on Apr.16th, 2006, and the instantaneous EF on 10:30 is 0.55964, the instantaneous EF

is 4% smaller than that of daily average of EF (see Figure 1). These sentences above have been added into section 3.3 in the text.

The integral of sunshine time can calculate the total solar radiation energy daily in unit area. Ignore the changes of distance and solar declination in day, the total solar radiation for 24h can be defined as:

$$R_{s24} = \left(\frac{1}{\rho}\right)^2 I_0 \tau_b \int_{t_1}^{t_2} \cos\theta dt = \frac{T}{2\pi}\left(\frac{1}{\rho}\right)^2 I_0 \tau_b \int_{-\omega_{sr}}^{\omega_{ss}} \cos\theta d\omega$$

where t is true time of Sun to take midnight time as 0; t1 and t2 are sunrise time and sunset time, respectively. The $-\omega_{sr}$ and ω_{ss} are angles on a hourly basis corresponding to sunrise and sunset time, T is total day time, $t = T(\omega + \pi)/2\pi$, $dt = (T/2\pi)d\omega$.

These sentences above have been added into section 2.1 in the text.

23. P4889 Line 11 what is time scale 0.5h?
Ans: It is actually the time step 0.5h in our case.

24. P4891 MSAVI gives the formula and reference
Ans: The Modified Soil Adjusted Vegetation Index (MSAVI) is a VI developed by Qi et al.(1994) to describe the effects of soil brightness in the background

$$MSAVI = \frac{1}{2} * [(2\rho_{\text{nir}} + 1) - \sqrt{(2\rho_{\text{nir}} + 1)^2 - 8(\rho_{\text{nir}} - \rho_{\text{red}})}]$$

where ρ_{red} is red band (0.63~0.69 μm) reflectance, ρ_{nir} is near red band (0.76~0.90 μm) reflectance, ρ_{blue} is blue band (0.45~0.52 μm) reflectance, ρ_{green} is green band (0.52~0.60 μm) reflectance, L is adjustment factor, set to minimum background effects (L=0.5).

Qi, J., Chehbouni, A., Huete, A. R., Kerr,Y. H., and Sorooshian., S.:A modified soil adjusted vegetation index, Remote Sens. Environ., 48, 119-126, 1994.

These sentences above have been added into section 2.1 in the text.

25 Figure 3 what is the vegetation index?
Ans: The vegetation index is MSAVI .

26. P4891 line 9 MSVI ? or MSAVI
Ans: Yes. "MSVI" herein is "MSAVI", and we have revised the "MSVI" as "MSAVI". Thank you.

27. Line 10-15: what is really new and original? What is automatically defined? It would be interesting to see the trapezoid schemes obtained for few studied dates and the threshold defined for wet and dry areas.

Ans: As shown in Figure 3, the water stress condition can be located at the upper right corner where the largest LST occurs when the value of MSAVI is 0.8. At the lower right corner, the saturated canopy appears to have lowest LST when the value of MSAVI remains 0.8 that is

indicative of the wet point. On the other side, the 0.1 of MSAVI defines another extreme for dry point where the LST turns out to be the largest whereas the lowest LST may come with the 0.1 of MSAVI indicative of the saturated bare soil. The SEBTA may run through all pixels automatically according to such a VITT concept. In summary, wet point can be discerned when LST is lowest and MSAVI is 0.8 whereas dry point can be discerned when LST is largest and MSAVI is 0.1.

28. P4892, Equation 30 the computation of Heff is also very questionable and can conduct to wrong values. A lot of papers have focused on the estimation on roughness, and have show the difficulty to find a relationship with a vegetation index. See references on this point and add comments.

Ans: Equation 30 is only used to compute the effective vegetation height within each pixel. As for other land covers (e.g., water body, urbanized land, rural residential land, constructed land and barren land) their roughness estimates (effective height) were obtained by using the look-up table.

See Wilson T.B., Norman J.M., Bland W.L., et al. Evaluation of the importance of Lagrangian canopy turbulence formulations in a soil–plant–atmosphere model. *Agricultural and Forest Meteorology*, 2003,115 (1-2):51-69.

29. What is your IV vegetation index in this case? MSAVI? Table 2 is not clear enough, why some lines have no values?

Ans: Yes, vegetation index here is MSAVI. Only the land covers with vegetable covers have the values.

30. P4893 How many MODIS data have you used? What is the exact studied period (give a table)

Ans:

Table.1 The MODIS products to be used for estimating ET

Products	content	levels	spatial resolution	temporal resolution(day)
MODMGGAD	Elevation angle / azimuth	L2	1km	1
MOD09GQK	Surface Reflectance	L2G	250m	1
MOD09Q1	Surface Reflectance	L3	250m	8
MOD09GHK	Surface Reflectance	L2G	500m	1
MOD09A1	Surface Reflectance	L3	500m	8
MOD11A1	Surface temperature and radiation	L3	1km	1
MOD11A2	Surface temperature and radiation	L3	1km	8

Table2. The phases of MODIS product less affected by the cloud to be used in this study between 2005-2006 (48 phases are selected)

Year	The selected phase (YYYYJJJ, Julian day format)						
2005	2005084	2005093	2005111	2005122	2005126	2005128	2005138
	2005143	2005153	2005154	2005166	2005173	2005237	2005239
	2005249	2005250	2005253	2005265	2005278	2005281	2005282
	2005283	2005289	2005310	2005312	2005328	2005333	2005349
2006	2006087	2006110	2006135	2006143	2006149	2006162	2006167
	2006230	2006231	2006249	2006252	2006253	2006254	2006267
	2006306	2006309	2006311	2006315	2006318	2006336	

These two tables have been added into section 3.2.

31. DEM: what is the spatial resolution and the accuracy?
Ans: The DEM data in this paper is derived from SRTM (Shuttle Radar Topography Mission) (JPL,2006). The available DEM in China is SRTM3 with 90m resolution. The accuracy is ± 20 m.

33. There is only one station for the flux estimation (?). Why (show the location on the map) and give its main characteristics (elevation, landuse, measurements, time step. . . .)
Ans: The Yucheng Comprehensive Experimental Station is run by the Chinese Academy of Sciences. It is located at the central North China Plain (116 º 34'E, 36 º 57'N) in Yucheng County, Shandong Province. The elevation is 28 m. The site belongs to monsoon climate of warm temperate and semi-humid environments. The annual average temperature is 13.1 ℃, the precipitation is 582 mm, the total solar radiation is 5225 MJ/m^2, the sunshine hours are 2640h/yr. The area is covered mainly by farmland and grassland (ChinaFLUX,2006).

34. How many weather stations are used? For what ?
Ans: 89 weather stations were used in this study. The parameters of interest include average temperature, maximum temperature, minimum temperature, precipitation, average wind speed, cloud cover, and others.

35. Line 23: explain the abrevs MODMGAD.. . in a table or in annex, what is the accuracy of the data? And the resolution?
Ans: MODMGGAD is MODIS production data of a high angle / azimuth, the resolution is 1000 m.

36. P4894: Give more information for the simulated dates
Ans: The simulated date is in period of 2005 – 2006 (See table 2 above and table 3b in the text).

37. Line 16: climatic data: what climatic data do you use? What do you interpolate? How many stations? I suppose that you have air temperature measurements on these stations which could be also used for validation.
Ans: The meteorological data used in this study are dataset collected at 89 stations which are run by the National Meteorological Centre, China Weather Bureau. This dataset includes average temperature, maximum temperature, minimum temperature, precipitation, average wind speed, amount of cloud and others. This dataset were vectorized and interpolated as grid datasets with UTM projection.

38. Figure 5: some days present precipitation events, that means clouds (have you estimated surface flux for these dates?)
Ans: Yes, we have estimated surface flux for these dates.

39. How do you explain that you have bad estimations when wheat is harvested?
Ans: After the wheat harvesting, the measurements of Lysimeter actually represented the ET of bare ground. So, some of the simulated values of ET with MODIS data are greater than those of Lysimeter measurements after wheat harvesting. The simulated values with MODIS data are pixels average value within $1km^2$, and these pixels within $1km^2$ very likely were mixed with pixels of vegetation and pixels of bare ground in 2005 and in 2006.

40. You start with 48 dates but on the graph fig 6 some dates miss why.
Ans: In a few days of measurements during the wheat harvesting period, the measurements of Lysimeter actually represented the ET of bare ground. The simulated values with MODIS data are pixel average value within $1km^2$, and these pixels within $1km^2$ very likely are mixed with pixels of vegetation and pixels of bare ground in 2005 and in 2006. Those which are greater difference between simulated and observed values associated with time period after wheat harvesting were not used in making the graph of Fig. 6. These explanations have been included in section 3.3.

41. The coefficients can be arguable. (fig 6 is not necessary, Values can be given in the text or in fig 5 caption)
Ans: Yes. This fig 6 has been deleted.

42. Table 3 is not well explained, how do you compute weekly, monthly values from your dataset?
Ans: The weekly and monthly ET can be computed with crop coefficient K_c retrieved with satellite data plus the weekly or monthly reference ET. These sentences have been added into section 3.3.

44. P4895 line 24: MODIS 250 m for what variables? I thought that all MODIS data were at the same resolution (add information before)
Ans: The MODIS Product data with 250m resolution include MOD09GQK and MOD09Q1. Yes, all data were resampled to the uniform resolution of 1000 m for ET estimation.

45. P4896: how do you compute your seasonal value? Give the standard deviation

Ans: The seasonal ET values are the cumulative ET values of monthly data. The monthly ET can be computed with crop coefficient Kc retrieved with satellite data plus the monthly reference ET. The standard deviation of seasonal ET value is 4.05%.

46. P4897. The comments about the relationships between slope and ET values for different seasons can be summarized in a table. A table with the regions classified according to the main classes for elevation and landuse classes would be welcome to follow the analysis.
Ans: Yes. I have summarized the relationships between slope and ET values for different seasons as follows and include it as Table 5b. In combination with table 5a in the revised version, the information should be enough for readers to contemplate.

Class	Height (m)	ET_SPR	ET_SUM	ET_AUT	ET_WIN	ET_YR	Area_ct%
1	0-20	1.28	2.81	3.31	0.41	1.57	13.42
2	20-50	1.15	3.13	3.49	0.28	1.61	12.39
3	50-150	0.95	2.80	3.43	0.25	1.49	9.39
4	150-450	0.85	2.28	3.39	0.26	1.36	9.42
5	450-800	0.83	2.22	3.20	0.24	1.30	11.26
6	800-1300	0.88	1.43	2.58	0.26	1.03	22.88
7	1300-1500	1.27	1.41	2.49	0.30	1.09	13.10
8	>1500	1.43	1.75	3.10	0.29	1.31	8.15
	Total						100.00

47. Fig 9 add standard deviation and comments

Ans: Yes, the standard deviations according seasons and years are computed as follows.

Name	ET_SPR	ET_SUM	ET_AUT	ET_WIN	ET_YR
STDEV	0.23	0.65	0.38	0.05	0.21

48. P4898. The conclusion could be more nuanced. (discussion on the season, the image number, the rain days. . .)
Ans: Yes.

49. P4898 lines23-28: put in a table all these values given in the text and add a column in table4 with standard deviation
Ans: Yes. The table is as follows:

LC	Name	ET_SPR	ET_SUM	ET_AUT	ET_WIN	STDEV	area_ct%
1	paddy land	1.22	3.32	3.55	0.52	1.51	1.67
2	dry land	1.05	2.32	3.28	0.27	1.33	51.38
3	woodland	0.83	2.14	3.21	0.16	1.36	15.48
4	grasslands	1.15	1.64	2.59	0.33	0.94	25.10
5	water body	1.84	3.63	2.92	0.75	1.26	1.79
6	City lands	0.60	1.26	2.14	0.11	0.88	1.20

7	village	0.86	2.43	3.24	0.21	1.40	1.11
8	Rest built-up	1.22	2.72	2.31	0.44	1.04	0.67
9	Sparsely	1.78	2.16	1.74	0.64	0.66	1.36
10	barren	1.50	1.88	1.44	0.56	0.56	0.25
	Total						100.00

Table 5b in the revised version has reflected this change.

50.P4900 line 14: the introduction of LULC data (give the information before in the text). This approach is not new. Other models use also these data (give refs) DAETs (annex for abrevs)
Ans: The LULC data has been introduced in part of 3.2 as follows. "The land use and land cover (LULC) data used in this paper was derived from the dataset with scale of 1:100000 in a database developed by the Chinese Academy of Sciences. This LULC dataset was generated based on the proper interpretation of Landsat TM/ETM images and was validated with groundtruth data. The climate data was collected from the National Meteorological Center of China Weather Bureau. The spectrum of climate data includes average temperature, maximum temperature, minimum temperature, precipitation, average wind speed, amount of cloud and others. All datasets were vectorized and interpolated as grid datasets with UTM projection in advance to ease the application in geographical information system (GIS)."

51.DAETs is abbreviation of daily actual evapotranspiration (DAET) (P4879, Line 5).

Yes. This LULC data derived of database developed by the Chinese Academy of Sciences has been used widely in many ecological models by CEVSA ,BEPS, Century and TEM et al. the database can refer this reference as follows.

Liu, J.Y., Tian, H.Q., Liu, M.L., Zhuang, D.F., and Melillo,J.M.: China's changing landscape during the 1990s:Large-scale land transformations estimated with satellite data, Geophys. Res. Lett., 32, L02405, doi:10.1029/2004GL021649 ,2005.

51. Figure 11:- how are performed the simulations? What is the landuse on this subregion? What is the date studied? What results for other dates?
Ans: The elevation of study area ranges from 8 to1532 m, the ET values were computed based on scale of 100m associated with and without the DEM effects. The land use on these subregions was derived based on the database developed by the Chinese Academy of Sciences. The 2006249 of MODIS images was used for this practice. We tested other seasons and the results are similar to Figure 11.

52.: P4901 line 28: S-BEBI ? or S-SEBI ;

Ans: Yes, we have revised "S-BEBI" as "S-SEBI". Thank you.

53. P4902 discuss more the Impact of terrain factors (elevation, aspect, slope) on reflectance, . . . Line 12: not really shown because there is not validation on stations with different elevation factors. The paper only show results on simulations and discussed the impact of topography on simulation results. These variations were not validated.
Ans: Yes, the paper only show results on simulations and discussed the impact of topography on simulation results. It is very difficult to validate these variations of slopes, elevations and

aspects, since there is not any station located at different place with differing elevation, aspect or slope. Thank your for such a good suggestion. We have corrected the statement in the revised version

54. P4903 line 1: 48 images were used but when there are rainy days or clouds, there is no discussion to fill the gap.
Ans: Revised.

55.In the table 3, only 15 dates are presented (add some justifications) Validation for flux based only for one station (representative ?) so the conclusion must be reviewed and nuanced.
Ans: Yes, since there is only one flux station (Yucheng station with a large lysimeter) in the study area, we will choose another site for further verification of this algorithm. This has been included in the conclusion section in our revised version

56. What is your consistency index? Meaning?
Ans: This is the same as the comment 3 above. Willmott (1982) proposed "consistency index" (Index of agreement) to test the results of model simulation (or prediction) , this consistency index can show coincide between simulated value and observed value(Zhan, et al., 1996). Consistency index (Idx, dimensionless) is defined as:

$$Idx = 1 - [\sum_{i=1}^{n} (P_i - O_i)^2 / \sum_{i=1}^{n} (|P_i - \overline{O}| + |O_i - \overline{O}|)^2]$$

where Oi is observed value, $\overline{O}$ is spatial average value, Pi is forecasting value

Zhan X., Kustas W.P., Humes K.S. An intercomparison study on models of sensible heat flux over partial canopy surfaces with remotely sensed Surface temperature. Remote sensing of environment, 1996,58 (3):242-256.

57. Line 14: ‘indispensable is strong! the model proposed here, can be useful and can be compared to other models.
Ans: Yes, we have deleted this word in paper. Thank you.