Responses to the comments on **"Underestimated effects of low temperature during early growing season on carbon sequestration of a subtropical coniferous plantation"** ***by*** **W.-J. Zhang, H.-M. Wang et al**

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1 Responses to the comments of Anonymous Referee #1

Authors investigated the influences of the early spring temperature to net ecosystem exchange of subtropical forest by using long-term eddy flux dataset, and found that the forest had a high sensitivity to the spring air temperature compared with the summer drought. The results could provide useful information to readers who are interesting in the carbon cycle. I have some comments on this manuscript before the publication.

Major:

1.1 Authors emphasized the influence of spring air temperature to the carbon fluxes. But, as mentioned in the section 3.1, air temperature and solar radiation showed similar anomalies in the spring time. Although the influence of air temperature could be more important than that of radiation, the influence of radiation anomalies could not be negligible. The authors should conduct the similar analysis shown in Table 3 and 4 for radiation-related variables (e.g., cumulative radiation 1-2 and 1-3), and show the results in the tables. The possible influence of radiation anomalies should be discussed in the section 4 and 5.

Response:

According to the suggestion of Referee #1, we examined the relationships between the carbon fluxes and the **radiation-related variables** (the *10-day solar radiation*, the *cumulative radiation* in the two and three earliest months). The Table 3 and Table 4 were updated with the relation-related analyses supplemented. The 10-day fluxes of RE and NEP showed weaker associations with solar radiation than with air temperature during January to March (Table 3). However, the GEP varied with radiation a little more than with air temperature. This can be attributed to the use of radiation in GEP gap-filling, as radiation is one of the major drives of photosynthesis process (see the general equation of GEP estimation using radiation).

Table 3 The relationships between the CO_2 fluxes and T_a / solar radiation at 10-day scale during 2003-2008.

		GEP		RE		NEP	
		R^2	P	R^2	P	R^2	P
T_a	Jan.	0.151	0.111	0.201	0.062	**0.649**	0.000
	Feb.	**0.528**	0.001	**0.611**	0.000	**0.806**	0.000
	Mar.	0.082	0.249	**0.768**	0.000	0.295	0.020
	Jan.-Mar.	0.188	0.001	**0.659**	0.000	**0.791**	0.000
R_d	Jan.	0.583	0.000	0.010	0.693	0.580	0.000
	Feb.	0.452	0.002	0.261	0.030	0.493	0.001
	Mar.	0.179	0.081	0.023	0.545	0.390	0.006
	Jan.-Mar.	0.436	0.000	0.157	0.003	0.540	0.000

As the accumulative solar radiation was concerned, the CO_2 fluxes during the early months showed significantly weaker correlation with it than with accumulative air temperature (Table 4). The NEP flux in the first half year could be explained a little more by accumulative radiation (77.2%) in January and February than by accumulative temperature (65.7%). However, this fact was not true for the accumulative variables during January to March. Only about 48% variation of annual carbon uptake could be explained by accumulative radiation in the January and February, and the carbon uptake during January to March varied even less with accumulative radiation (R^2=0.123).

Table 4 The relationships of CO_2 fluxes with accumulative air temperature, solar radiation and growing season length during 2003-2008.

		First half year			Whole year		
		GEP	RE	NEP	GEP	RE	NEP
T_{AC-12}	R^2	**0.819**	**0.787**	**0.657**	0.488	0.034	**0.970**
	P	0.013	0.018	0.050	0.123	0.726	0.000
T_{AC-13}	R^2	0.582	**0.719**	0.434	0.620	0.164	**0.736**
	P	0.078	0.033	0.155	0.063	0.426	0.029
R_{d-12}	R^2	0.745	0.305	0.772	0.030	0.095	0.477
	P	0.027	0.256	0.021	0.744	0.551	0.129
R_{d-13}	R^2	0.314	0.505	0.251	0.149	0.062	0.123
	P	0.248	0.113	0.312	0.450	0.635	0.496
GSL_{12}	R^2	0.712	0.497	0.606	0.318	0.001	0.912
	P	0.035	0.118	0.068	0.244	0.963	0.003
GSL_{yr}	R^2	0.605	0.621	0.461	0.547	0.080	0.870
	P	0.069	0.063	0.138	0.093	0.587	0.007

Corresponding modifications in manuscript:

1) The former Table 3 and 4 were updated as above, with the examination results of solar radiation variables supplemented.

2) In addition, we gave more discussions in Paragraph 2 of Section 3.1 (Page 1421 Line 25) on whether the seasonal and inter-annual variations of solar radiation and air temperature were closely related or not.

"*About 40% variation of spring air temperature could be explained by solar radiation at 10-day scale during 2003-2008, and only 18.4% variation of annual air temperature was correlated with solar radiation. Therefore, low solar radiation is not always correspondent with low temperatures*"

3) At the Page 1424 Line 27 (***Section 3.4 Responses of CO_2 fluxes to low temperature***), followed paragraph was added:

"The possible influences of radiation on CO_2 fluxes were also examined (Table 3). The 10-day fluxes of RE and NEP showed weaker associations with solar radiation than with air temperature during January to March. However, the GEP varied with solar radiation a little more than with air temperature. This can be attributed to the use of radiation in GEP gap-filling."

4) Before the Page 1425 Line 23 (***Section 3.4 Responses of CO_2 fluxes to low temperature***), the followed paragraph was added:

"*As the accumulative solar radiation was concerned, the CO_2 fluxes during the early months showed significantly weaker correlation with it than with accumulative air temperature (Table 4 of former manuscript version). The NEP flux in the first half year could be explained a little more by accumulative radiation (77.2%) in January and February than by accumulative temperature (65.7%). However, this fact was not true for the accumulative variables during January to March. Only about 48% variation of annual carbon uptake could be explained by accumulative radiation in the January and February, and the carbon uptake during January to March varied even less with accumulative radiation (R^2=0.123).*"

1.2 The paper showed simple regression analyses in Figure 4, 6, and 8, and concluded that those had high correlations. Part of this statement could be true, but the high correlations were likely caused by comparison between two different clusters (year of 2005 and 2008 vs other years). If the data are analyzed within each cluster, these simple regressions could not work well. I suggested that some threshold values may exist in temperature-related variables to control the carbon fluxes. Authors should mention this point in addition to the simple regression analyses.

Response:

Thanks for reminding of the comparison between the two different clusters (years of 2005 and 2008 vs other years). However, we think that this paper does include a variety of environment conditions in this relative shorter period, not only the two distinctly different clusters. Years 2005 and 2008 have exceptionally shorter growing season due to low temperatures in early months, 2007 has a longer growing season due to warmer spring, and year 2003 is a year suffering summer drought. But of course, a longer record would be important to enhance the conclusion.

Corresponding modifications in manuscript:

After Page 1428 Line 26 (***Section 4 Discussion***), we added follow paragraph to discuss the influence of data availability on this study.

"In addition, this paper does include a variety of environment conditions in this relative shorter period. Years 2005 and 2008 have exceptionally shorter growing season due to low temperatures in early months, year 2007 has a longer growing season due to warmer spring, and year 2003 is a year suffering summer drought. Of course, a longer record would be important to enhance the conclusion that the low temperature than the summer drought is the major reason responsible for inter-annual variations of carbon sink strength at QYZ site. However, we think that the data availability would not weaken this conclusion."

1.3 Although authors explained variations of EVI were caused the seasonality of aboveground biomass in the section 3.2, the seasonal variation of EVI seems to be large, considering that the forest is classified as evergreen needleleaf forest. It is necessary to show some evidence that aboveground biomass seasonally changed or to discuss other possible cause by citing previous several researches of vegetation index in coniferous canopy.

Response:

The reasons why the EVI show a great seasonality in this ENLF site would be:

1) The seasonality of QYZ evergreen coniferous ecosystem could be partially attributed to the strong seasonality-characterized monsoon climate. Under the control of the subtropical Eastern Asian Monsoon, QYZ site is hot and rainy in summer half year, and relatively cold and dry in winter half year. This distinct seasonality of heat and water conditions causes the intra-annual variations of local ecosystem.

2) Even in evergreen needle-leaf forest, the leaf turnover does show a bit seasonality. Without direct temporal LAI observations at QYZ site, we examined the LAI seasonality with monthly litter measurements. The followed Figure 1 showed the highest level of litter occurring in November, which corresponds with the low LAI level in winter.

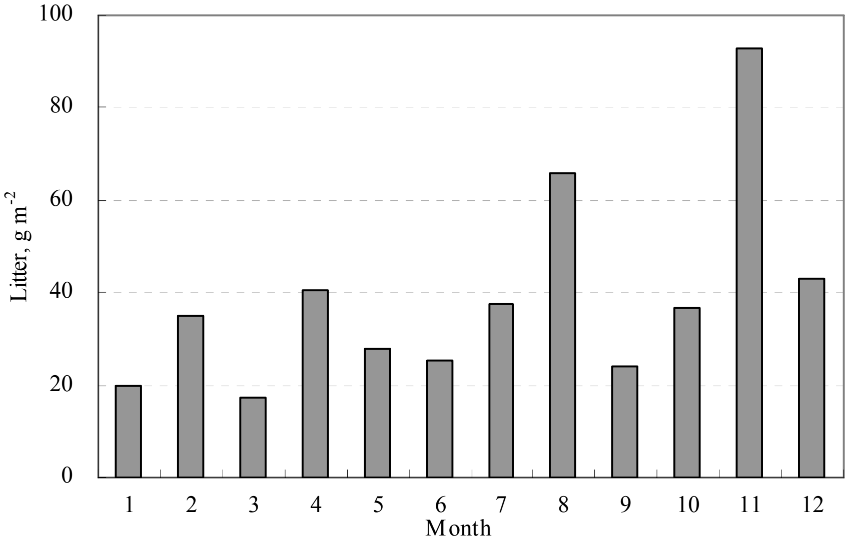

Figure 1. The monthly measured litter of QYZ ecosystem.

3) Some understory plantation is deciduous at QYZ site, which also would partially cause the seasonality changes of EVI at 1-km scale due to incomplete coverage of evergreen needle-leaf forest. The satellite reflectances would be also impacted by the seasonal changes of solar zenith angles, and thus the EVI values. Even though the paper used the MODIS land cover product to exclude non-forest pixels, the land cover heterogeneity may still have some influence on the seasonality of EVI especially in an area of 10*10 km^2. As the response in comments "1.4 Specifics b)", the valley areas are also occupied by orange orchard and cultivated field, which have the larger seasonality than ever-green needleleaf forest.

Corresponding modifications in manuscript:

1) "**Figure 1**. The monthly litter of QYZ ecosystem." was supplemented after Page 1423 Line 2 (***Section 3.2 Responses of plant growth to environmental variation***).

2) Followed paragraph was added after Page 1423 Line 2 (***Section 3.2 Responses of plant growth to environmental variation***):

"Fig. 4 showed the distinct EVI seasonality of QYZ ecosystem. The seasonal EVI variation of this evergreen coniferous forest could be attributed to the strong seasonality-characterized monsoon climate and the possible uncertainty of MODIS product at 1-km resolution. The seasonality of heat and water conditions causes the seasonal variations of local ecosystem. The monthly measurements of

litter responded to the climate seasonality, with the highest litter level in November. This fact agreed with the low LAI level in winter at QYZ site."

1.4 Specific:

a) Page 1416 line 12: Sentence of "this Ta sensitive period" is vague. Revise this sentence.

Response:

This sentence has been revised as: "*During this period when local ecosystem was sensitive to air temperature*, T_{AC} *varies strongly between 41.7 and 217.3 °C (SD 64.3 °C).*" (**Page 1416 Line 12**)

b) Page 1417 line 11-16: Specify the landscapes other than coniferous trees (e.g., agricultural fields?).

Response:

Thanks for the reminding, and additional information about landscape was added: "*The rest landscapes other than coniferous tree were orange orchard and cultivated field in the valley areas*." (**Page 1417 Line 11-16**)

c) Page 1421: line 8-9: How was the effect of the ice storm to the carbon flux?

Response:

Less than 5% of QYZ trees were damaged by the ice storm, but the decrease of carbon fluxes was estimated below 5%. Because the improved radiation condition of forest gaps greatly promoted the understory growth, which partially compensated the ecosystem production loss induced by the damaged trees. This information was added in the revision: "*Less than 5% of QYZ trees were damaged by the ice storm, but the influences on trees were partially compensated by the rapid understory growth under the improved radiation condition of forest gaps.*"

d) Page 1421 Line 6: "precipitation and solar radiation" -> "precipitation and solar radiation, respectively"?

Response:

Thanks for reminding of the phraseology, and the addition of "respectively" was necessary to make clear the trend difference between precipitation and solar radiation. Therefore, this sentence has been revised as: "*precipitation and solar radiation, respectively*".(**Page 1421 Line 6**)

e) Page 1421 line 16: The sentence of "The cold early growing … not so in 2008 (Table 1)." seems to contradict Figure 2b. Rephrase the sentence.

Response:

I think that we have made it ambiguous in the sentence "The cold early growing season in 2005 corresponded with low level of solar radiation, but not so in 2008 (Table 1)". What we wanted to state was that the cold early growing season in 2005 corresponded with low level of solar radiation, but the case in 2008 was some different. The solar radiation in 2008 January to March was at the normal level. In addition, as the discussion of above "response 1.1", about 40% variation of spring air temperature could be explained by solar radiation at 10-day scale during 2003-2008, and only 18.4% variation of annual air temperature was correlated with solar radiation. Therefore, low solar radiation is not always correspondent with low temperatures.

Table 1. Air temperature (T_a), accumulative T_a (≥ 5 °C, T_{AC}), growing season length (GSL, T_a ≥ 5 °C, in days) and precipitation (PPT, mm) at QYZ site during 2003-2008.

Factor	Period	2003	2004	2005	2006	2007	2008
T_a	Jan.-Mar.	9.90	9.10	6.89	9.20	10.46	7.77
	Apr.-Dec.	21.30	20.76	21.27	21.02	21.02	21.20
T_{AC} (≥ 5 °C)	Jan.-Mar.	427	415	246	423	515	373
	Apr.-Dec.	4501	4360	4510	4415	4402	4478
GSL (≥ 5 °C)	Jan.-Mar.	72	72	**55**	69	79	**50**
	Apr.-Dec.	261	264	261	265	270	267
R_S (MJ m^{-2})	Jan.-Mar.	678.4	666.8	**436.0**	512.5	668.8	**707.3**
	Apr.-Dec.	4022.6	3943.4	3542.4	3540.4	3650.0	3843.0
PPT (mm)	Jun.-Sep.	279.3	522.9	475.3	490.2	723.1	530.2
	Jan.-Dec.	944.9	1404.5	1455.4	1485.3	1318.7	1332.9

Therefore, we revised this sentence as: "*The cold early growing season in 2005 corresponded with low level of solar radiation, but the case in 2008 was some different. The solar radiation in 2008 January to March basically was at normal level.*" (**Page 1421 line 16**)

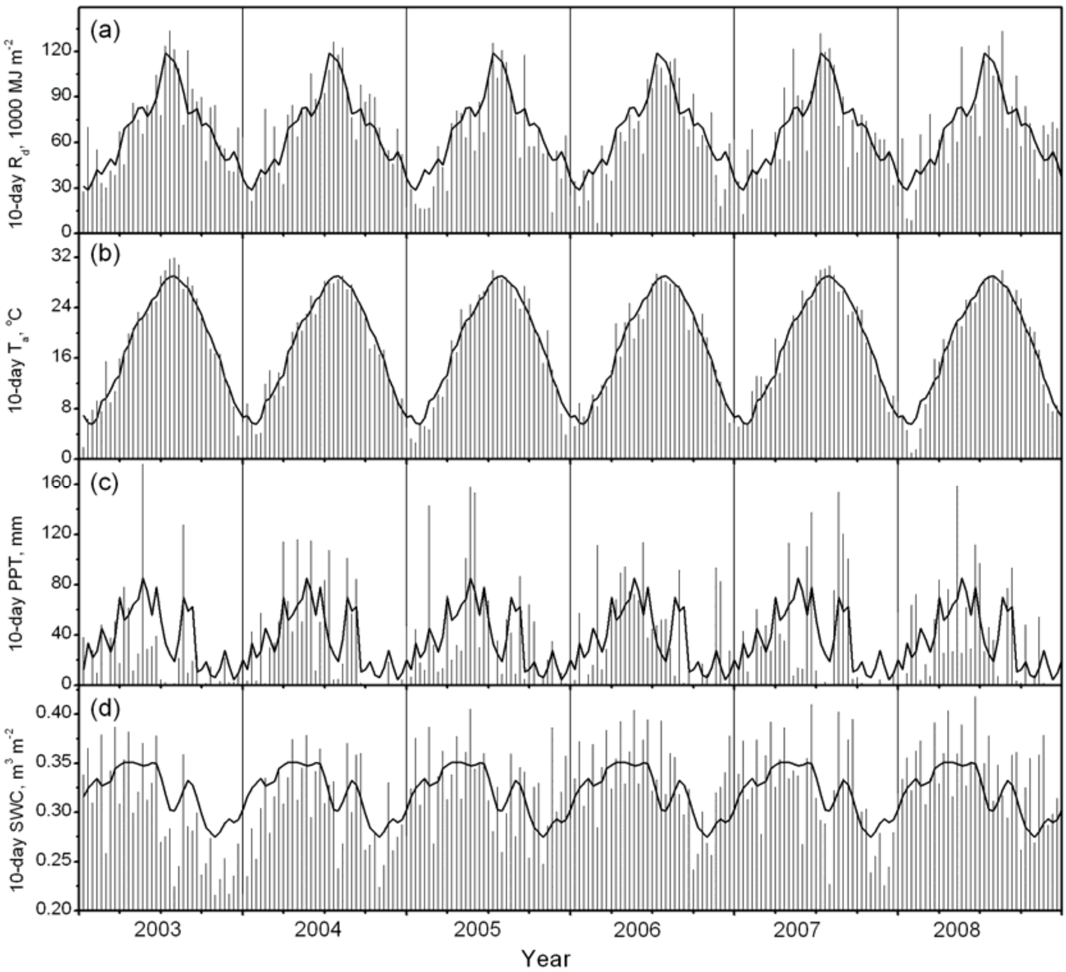

Figure 2. The 10-day averaged environmental conditions of QYZ site from 2003 to 2008: (a) downward solar radiation (R_S, 1000 MJ m^{-2}), (b) air temperature (T_a, °C), (c) precipitation (PPT, mm) and (d) soil water content (SWC, m^3 m^{-3}). The drop lines and curves were respectively the 10-day measurements and corresponding multi-year averages.

f) Page 1421 line 17-21: The sentence of "Because the … Eq. (2)." is not results, and should be moved in the section 2.3.

Response:

Thanks for the suggestion. This sentence has been moved after the Page 1418 Line 26 (***Section 2.3 Flux correction and gap filling***).

g) Page 1422 line 15: "no significant drop": The drop of EVI in summer 2003 was small compared with that in spring 2005 and 2008, but was significant. Rephrase the sentence.

Response:

The original sentence "However, the response of EVI to summer droughts was relatively weaker, and no significant drops in the EVI values during the summer period can be observed" has been revised as "*However, the response of EVI to summer droughts was relatively weaker, and* ***the EVI drop in summer 2003 was small*** *compared with that in spring 2005 and 2008*". (**Page 1422 Line 15**)

h) Page 1423 line 22-23: The sentence of "the synchronous less .. warmer condition." contradicts the sentence of "The favorable water and heat condition in 2002 brought the high levels of photosynthesis …". Clarify that the early spring in 2003 was favorable or not.

Response:

We want to state that the environment conditions in the first half year of 2003 was favorable (especially the heat condition), but the precipitation in the second half year of 2003 (334 mm) was far below normal level (750 mm). To make it clear, we revised the original sentence ("Therefore, the GEP kept at high level during the warmer first half year of 2003, while synchronous less precipitation constrained the heterotrophic respiration and almost counteracted the effect of warmer condition") as: "*Therefore, the GEP kept at high level during the warmer first half year of 2003, while the less precipitation* ***in the second half year of 2003*** *constrained the heterotrophic respiration and almost counteracted the effect of warmer condition in the first half year*". (**Page 1423 Line 22-23**)

2 Responses to the comments of anonymous Referee #2

The authors discuss an aspect of the sensitivity of CO_2 budget components regarding air temperature. This low temperature effect on carbon sequestration is worth mentioning for a subtropic site besides other steering variables like water availability. So, this manuscript is appropriate for the journal.

However, I have methodical concerns about the applied procedure concerning data processing and interpretation. The measurement setup consists of an open-path gas analyzer among others. This analyzer generates data gaps during the frequent wet conditions (dew, precipitation) at this site resulting in a high data gap frequency of 50-60% which is further increased due to the necessary quality controls. The authors are aware of this bad data situation. To produce long-term budgets of CO_2 flux components established gap filling procedures have been used.

2.1 I want to know the data base (measured values) to parameterize the non-linear relationship especially between nighttime CO2 flux and soil temperature/soil moisture which is the basis for gap filling. Are the fitted parameters dependent on data availability?

Response:

The data gap frequency during daytime was below 32%, while that during nighttime was about 80% because of the stable atmospheric conditions. The fitted parameters used in the nighttime gap-filling were dependent on the data availability. As Reichstein *et al*. (2002) suggested, it is generally preferable to fill the nighttime RE gaps within a bi-month or season window using soil temperature and soil water content. However, in this study the available nighttime measurements in the suggested time window (bi-month or season) could not meet the database magnitude requirement. Therefore, the nighttime gaps were filled within a year window.

2.2 Furthermore, what is the influence of the application of gap filling procedures on the carbon budgets? The authors could check this by producing artificial data gaps.

Response:

Yu *et al* (2005) and Zhu *et al* (2006) discussed the RE gap-filling method used in the study, and they thought the results of nighttime gap-filling at QYZ site by this method were acceptable. The eddy flux related studies at QYZ site used above technology to fill the measurement gaps (Wen *et al*, 2006; Zhang *et al*, 2006; Wen *et al*, 2010). In addition, we think even the uncertainty in nighttime fluxes processing is kind of large, the relative stable condition (resulting in small variations) at nighttime and the small nighttime fluxes would not have a significant impact on the long-term statistics of the three flux components. Therefore, to keep consistent with the other study at QYZ site, this study also adopted the gap-filling method of Reichstein *et al* (2002).

2.3 A critical u* value of 0.19 ms^{-1} was used for the whole period 2003-2008 but this value can vary from year to year. Is that the case? What is the influence on the RE and GEP budgets?

Response:

The maximum *u** threshold among 2003–2007 at QYZ site was estimated as 0.19 m s^{-1}. The annual fluxes of NEP, GEP and RE varied generally within 1% when u* increased or decreased by 0.01 m s^{-1} based on the u* threshold of 0.19 m s^{-1} (Wen *et al*, 2010). Therefore, in the study we took the value of 0.19 m s^{-1} for the u* during the whole period 2003-2008.

2.4 The main topic of this study is the low temperature effect during early growing season on carbon sequestration. Is this effect maybe a radiation effect due to a cross-correlation between temperature and radiation? To avoid this conclusion the authors should check the influence of the early growing season temperature on the carbon budget normalised with radiation (not only on carbon budget itself).

Response:

In the early growing season, only about 11% variation of air temperature could be explained by photosynthesis active radiation during 2003-2008 at QYZ site. Even at year scale, air temperature showed about 39% variation with radiation condition. Though air temperature and solar radiation showed similar seasonalities in Figure 2a and 2b, the anomalies of radiation were not necessarily consistent with those of temperature in terms of timing and magnitude, such as in the springs and autumns of 2005 and 2006. Therefore, the effect of low temperature on carbon uptake would not be significantly influenced by the cross-correlation between temperature and radiation. As we explained in Section 1.2, the CO_2 fluxes during the early months showed significantly weaker correlation with accumulative radiation than with accumulative air temperature (Table 4).

As photosynthesis was nonlinearly related to solar radiation, the carbon budget was technically not easy to be normalized with radiation. After linearly normalized with photosynthetically active radiation (PAR), the daily photosynthesis during the early growing season showed weaker association (R=-0.213) with air temperature than before normalization (R=0.504), while the relationship between daily GEP flux and PAR changed from 0.800 to -0.704 after normalization. Though there may exist smoe effect of the temperature-radiation cross-correlation, we thought it would not weaken the conclusion on the effect of low temperature on the carbon uptake of subtropical coniferous plantation.

2.5 Finally, the authors should ask themselves whether this study is mainly based on measurements or is it more a modelling paper.

Response:

In the eddy flux observation-based studies at QYZ site (Wen *et al*, 2006; Zhang *et al*, 2006; Wen *et al*, 2010), the ecosystem respiration gaps in nighttime observation were filled with soil temperature and soil water content. We thought this study was also measurements based rather than modelling based. Besides the observation data of CO_2 exchange fluxes, the measurements of meteorological elements, ecosystem litter and vegetation index were also used in analyzing the effects of cold early growing season on the subtropical plantation.

Reference

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