Responses to Anonymous Referee #3

Summary

The manuscript compares the spring greenup date (SG) obtained using the method of Zhang et al. (2003) applied to the GIMMS dataset and the MODIS MOD13C1 dataset. It also compares the trend of the chronological regression on the same period, and the sensitivity of the SG to the climate before the SG. The results are completed by the analysis of the trend before the launch of MODIS.

General evaluation

The current manuscript has a nice first objective, which is to explore the impact of the input remote sensing dataset to which the SG algorithm is applied. However it requires more analysis to achieve this objective. If the objective is to evaluate the impact of the choice of the input dataset then the causes of the differences should be the target. This would allow increasing the confidence in the trend analysis based on the two datasets. The suggestion on the role of the transition from AVHRR2 to AVHRR3 should also be explored in depth, as this is quite an interesting opening. In the following I suggest some changes and some previous articles that should be considered. The second objective on the sensitivity of SG to climate cannot be achieved without improvements on the work on the SG determination, as there is strong uncertainty on the SG.

Authors: We sincerely thank the reviewer for the valuable comments and suggestions. Our responses are indicated below in the point-to-point responses.

Major comments

1/ The results report differences in the SG obtained with MODIS and with AVHRR and in the trend. The manuscript suggests possible explanations but does not attempt to determine the reasons clearly. In-depth exploration of the causes of these differences should be carried out as it is the aim of the manuscript. Possible sources of uncertainties, including spatial resolution changes with incidence angle, preprocessing, processing are explored in :

Helman, D. (2018) Land surface phenology: What do we really "see" from space? Science of The Total Environment, 618, 665 – 673

Authors: Thank you for suggesting this timely published work. Helman (2018) provides comprehensive information about the uncertainties and limitations in determining phenology from satellite data. In our revision, we add discussions about the difference that can be brought from different sensors, e.g. the NDVI by MODIS and GIMMS were retrieved from a different spatial resolution. The retrieved NDVI is a mixture of different vegetation species with diverse phenologies, bare soil and even water bodies dependent on the spatial resolution (Helman, 2018). The different resolution lead to the NDVI difference and NDVI difference propagates biases to SGs.

Moreover, a key issue is the snowmelt. It is well-known that the detected SG is related to snowmelt and not to vegetation if the snow is not correctly treated (Moulin et al. 1997, Shabanov et al. 2002). Solutions have been proposed (Suzuki et al. 2003, Delbart et al. 2005, 2006, Thomson et al. 2015, Jin et al. 2017 for examples). In the current manuscript the snow issue is treated differently between the two dataset preprocessing, thus the results differ. It is necessary to assess the uncertainty of the two SG datasets through a comparison to ground observations of leaf expansion, in order to analyse the impact of the snow rejection methods.

Delbart, N., Kergoat, L., Le Toan, T., Lhermitte, J., & Picard, G. (2005)

Determination of

phenological dates in boreal regions using normalized difference water index. Remote Sensing of Environment, 97, 26–38.

Delbart, N., Le Toan, T., Kergoat, L., & Fedotova, V. (2006) Remote sensing of spring phenology in boreal regions: A free of snow-effect method using NOAA-AVHRR and SPOT-VGT data (1982-2004). Remote Sensing of Environment, 101, 52–62.

Jin, H., Jönsson, A.M., Bolmgren, K., Langvall, O., & Eklundh, L. (2017) Disentangling remotely-sensed plant phenology and snow seasonality at northern Europe using MODIS and the plant phenology index. Remote Sensing of Environment, 198, 203–212.

Moulin, S., Kergoat, L., Viovy, N., & Dedieu, G. (1997) Global-scale assessment of vegetation phenology using NOAA/AVHRR satellite measurements. Journal of Climate, 10, 1154–1170.

Shabanov, N.V., Zhou, L., Knyazikhin, Y., Myneni, R.B., & Tucker, C.J. (2002) Analysis of interannual changes in northern vegetation activity observed in AVHRR data from 1981 to 1994. IEEE Transactions on Geoscience and Remote Sensing, 40, 115–130.

Suzuki, R., Nomaki, T., & Yasunari, T. (2003) West-east contrast of phenology and climate in northern Asia revealed using a remotely sensed vegetation index. International Journal of Biometeorology, 47, 126–138.

Thompson, B.G. (2015) Using phase-spaces to characterize land surface phenology in a seasonally snow-covered landscape. Remote Sensing of Environment, 166, 178–190.

Authors: We agree with the reviewer that snow cover is a big challenge in determining the SG in the high latitudes. We enhanced our analysis of uncertainties in snow effect on phonological determination and the options to improve phenology estimation from alternative indices. The snow influences phenology determination in two ways. On the one hand, the snow cover led to NDVI gaps during the dormancy season. As a result, the time series of NDVI cannot be adequately fitted during the transitional snow melting and vegetation greening season (Zhou et al., 2015). On the other hand, the overlapped time of snowmelt and greenup leads complexity in greenup determination. Spring greenup date is almost the same as snow-end date some high latitude regions (Zeng and Jia, 2013). Therefore, in high latitudes with seasonal snowpack, the beginning of the growing season is often determined by snowmelt rather than temperature (Semenchuk et al., 2016). The normalized difference water index method (Delbart et al., 2004; Delbart et al., 2006), plant phenology index method (Jin et al. 2017), normalized difference vegetation index-normalized difference infrared index phase-space method (Thompson et al., 2015) are alternatives to improve the NDVI-based phonological metrics. We are conducting continued studies focusing on the complexity of snowmelt and phenology determination for specific boreal regions.

Delbart, N., L. Kergoat, T. Le Toan, J. Lhermitte, G. Picard (2005). Determination of phenological dates in boreal regions using normalized difference water index. Remote Sensing of Environment, 97, 26–38.

Delbart, N.,T. Le Toan, L. Kergoat, V. Fedotova (2006). Remote sensing of spring phenology in boreal regions: A free of snow-effect method using NOAA-AVHRR and SPOT-VGT data (1982-2004). Remote Sensing of Environment, 101, 52–62.

Jin, H., A. M. Jönsson, K. Bolmgren, O. Langvall, L. Eklundh (2017). Disentangling remotely-sensed plant phenology and snow seasonality at northern

Europe using MODIS and the plant phenology index. Remote Sensing of Environment, 198, 203–212.

Semenchuk, P. R., M. A. K. Gillespie, S. B. Rumpf, N. Baggesen, B. Elberling, E. J. Cooper (2016). High Arctic plant phenology is determined by snowmelt patterns but duration of phonological periods is fixed: an example of periodicity. Environmental Research Letters, 125006. DOI: 10.1088/1748-9326/11/12/125006.

Thompson, B.G. (2015). Using phase-spaces to characterize land surface phenology in a seasonally snow-covered landscape. Remote Sensing of Environment, 166, 178-190.

Zeng, H. and G. Jia (2013). Impacts of snow cover on vegetation phenology in the Arctic from satellite data. Advances in Atmospheric Sciences, 30, 1421-1432.

Zhou, J., L. Jia, M. Menenti (2015). Reconstruction of global MODIS NDVI time series: Performance of Harmonic ANalysis of Time Series (HANTS). Remote Sensing of Environment, 163, 217-228. DOI: 10.1016/j.rse.2015.03.018

2/ The pre-season length differs when so the variations of the climate variables differ. Thus the trend of the preseason climate from the two SG datasets should not be compared.

Authors: In the revision, we focus more on the relation between SG and preseason climate (Figure 3) to indicate the climate-SG links. We kept our analysis of length and climate trend in preseason because the difference in the preseason is propagated from the conflicts of SG estimation in GIMMS and MODIS. Although the length of preseason length differed when inferred by GIMMS and MODIS SGs, the pattern of climate trend in preseason is very close. This consistent preseason climate pattern, however, did not lead to a consistent SG response between GIMMS and MODIS. The difference in vegetation dynamics leads to uncertainties in understanding climate-vegetation couplings.

3/ The trends are reported if the p-value is less than 0.1. This is not a good value as it is too high. Maximum is generally 0.05, which is very high already.

Authors: To address the reviewer's concern, we revised the trend at 95% confidence level in section 3.1. At a 95% confidence level, the trends are slightly different from the trend at a 90% confidence level. The sign of trend remains.

5/ The GIMMS dataset and the MOD13C1 dataset are composite products with a compositing period of 15 and 16 days. This has a strong impact on SG uncertainty. This is why PAL product should be prefered (10 day composite) of 8-day MODIS dataset. The effect of the compositing period duration must be explored.

Authors: In the discussion, we added discussion about the uncertainty that may be raised by the different composite technique. Both GIMMS NDVI3g and MOD13C1 were generated using daily surface reflectance product to a similar composite interval. However, the MODIS applied the constrained-view angle-maximum value composite while GIMMS applied maximum value composite. The maximum value composite cannot completely remove atmospheric effect (Pinzo and Tucker 2014) and the different composite technique can cause the value difference in the same interval (van Leeuwen et al., 1999; Gallo et al., 2004).

Gallo, K. P., L. Ji, B. Reed, J. Dwyer, J. Eidenshink (2004). Comparison of MODIS and AVHRR 16-day normalized difference vegetation index composite data. Geophysical Research Letters, 31, L07502, doi:10.1029/2003GL019385.

Van Leeuwen, W. J. D., A. R. Huete, T. W. Laing (1999). MODIS vegetation index compositing approach: a prototype with AVHRR data. Remote Sensing of Environment, 69, 264-280.

Pinzo, J. E. and C. J. Tucker (2014). A Non-stationary 1981-2012 AVHRR NDVI3g time series. Remote Sensing, 6, 6929-6960.

6/ Reported trends should be compared to those from :

Gonsamo, A. & Chen, J.M. (2016) Circumpolar vegetation dynamics product for global change study. Remote Sensing of Environment, 182, 13–26.

Park, T., Ganguly, S., Tømmervik, H., Euskirchen, E.S., Høgda, K.-A., Karlsen, S.R., Brovkin, V., Nemani, R.R., & Myneni, R.B. (2016) Changes in growing season duration

and productivity of northern vegetation inferred from long-term remote sensing data. Environmental Research Letters, 11, 084001.

Authors: Thank you for suggesting these two studies on phenology in Circumpolar region. We made comparison with our results in our revision. SPOT VGT phenology products showed continuously advanced SG trend over 1999-2013, in consistent with MODIS. But the magnitude and spatial distribution differs (Gonsamo and Chen, 2016). The results by GIMMS NDVI are comparable with our results in Northern high latitude, advanced SG trend before 2000 and delayed trend thereafter (Park et al., 2016).

Minor comments

1/ Analysing the sensitivity of SG to temperature through linear correlation is not totally convincing. The phenology models are well known to be unlinear (non linear effects are mentionned in the discussion) and parameterized with thresholds. See for example :Hänninen, H. (1990) Modelling bud dormancy release in trees from cool and temperate regions. Acta Forestalia Fennica, 213, 1-47.The consequence is that, for example in an arctic ecosystem, a warming from -15 C to -5C in March will have no impact on SG whereas a warming from 2C to 3C in may would have a strong impact. Thus changes in sensitivity of SG to temperature changes are expected.

Authors: In Hänninen (1990), five types of phonological models with combined chilling and thermal forcings. The interaction between chilling and thermal requirements leads to a non-linear response of budburst to temperature change. In the northern hemisphere north of 40°N, the chilling requirement are always fulfilled (Zhang et al., 2007). A pure thermal forcing model showed a better spring phenology prediction than the combined chilling and thermal forcing model (Yang et al., 2012). The manipulated experiments proved that the temperate trees are linearly correlated with the spring warming (Fu et al., 2012). For example, The cubic function and the linear model predicted a similar leaf unfolding rate based on hourly average temperatures recorded in a Florida commercial greenhouse during two times of the year. The linear relationship is reliable in most observations (86%) at 3657 stations in 22 European countries for linking spring phenology and temperature (Jochner et al., 2016).

Fu, Y. H., M. Campioli, G. Deckmyn, I. A. Janssens (2012). The impact of winter and spring temperatures on temperate trees budburst dates: results from an Experimental climate manipulation. PLoS One, 7, e47324.

Yang, X., J. F. Mustard, J. Tang, H. Xu (2012). Regional-scale phenology modeling based on meteorological records and remote sensing observations. Journal of Geophysical Research: Biogeosciences, 117, https://doi.org/10.1029/2012JG001977

Zhang, X., D. Tarpley, and J. Sullivan (2007), Diverse responses of vegetation phenology to a warming climate, Geophys. Res. Lett., 34, L19405, doi:10.1029/2007GL031447.

Jochner, S., T. H. Sparks, J. Laube, A. Menzel (2016). Can we detect a nonlinear response to temperature in European plant phenology? International Journal of Biometeorology, 60, 1551-1561.

2/ The style of the writing is often hard to read and the text should be clarified.

Authors: We adjust some paragraphs of methods and results and polished the writing.