We would like to thank the reviewer for his/her constructive and thoughtful comments, which have provided valuable suggestions to improve this manuscript. Below we respond to all the concerns and/or suggestions of the reviewer and highlight the changes made to improve the manuscript. In our response we refer to the line numbers of the revised manuscript which we will post in a separate comment.

Reviewer # 1

The manuscript of Andela et al. proposes a new modelling approach of the daily cycle of FRP at a hourly time scale from 4 MODIS daily observations. This development is performed to improve FRE estimates within the Global Fire Assimilation System used in the Copernicus Atmosphere Monitoring Services. The manuscript addresses therefore an important issue, as the four or so MODIS FRP data available on a daily basis do not allow to properly sample the daily cycle of fire activity.

Specific comments

Comment #1:
The manuscript objective, as stated in the abstract "Specifically, we assess how representing the fire diurnal cycle affects FRP and FRE estimations when using data collected at MODIS overpasses" and in the introduction "The purpose of the work presented here is to better understand the fire diurnal cycle and its spatiotemporal dynamics, in order to develop new ways to include this into a near real time fire emissions estimation framework" are not exactly coherent between themselves.

Response #1:
The aim of the manuscript is both to investigate the fire diurnal cycle and its drivers and based on this knowledge to develop a new way to include the fire diurnal cycle into a near real-time modelling framework based on MODIS data. A better understanding of the spatial drivers of the fire diurnal cycle is required to upscale the proposed model to regions where no geostationary FRP data are available to characterize the spatiotemporal variability of the fire diurnal cycle. We have made textual changes to the abstract and introduction in order to explain the manuscripts objectives more clearly and avoid further confusion:

Abstract (lines 23-27):
"In this paper we explore the spatial variation of this fire diurnal cycle and its drivers using data from the geostationary Meteosat Spinning Enhanced Visible and Infrared Imager (SEVIRI). In addition, we sampled data from the SEVIRI instrument at MODIS detection opportunities to develop two approaches to estimate hourly FRE based on MODIS active fire detections."

Introduction (lines 140-145):
"The purpose of the work presented here is to better understand the fire diurnal cycle and its spatiotemporal dynamics, in order to develop a new way to include this into a near real time fire emissions estimation framework. First, the spatial distribution and dependencies of the fire diurnal cycle and their effect on active fire detections at MODIS overpasses were explored. Then, data assimilation was used to compare two different methods to derive hourly FRE estimates at 0.1° resolution based on low Earth-orbiting MODIS observations."

Comment #2
In the same way, the manuscript title is also slightly misleading and should better reflect that actual content of the paper. A title such as "Development of a new fire diurnal cycle to improve fire radiative energy assessments derived from MODIS observations" might better reflect the work presented here.

Response #2
We have changed the title to better reflect the two objectives of the manuscript: (i) beter characterizing the fire diurnal cycle and its drivers and (ii) develop a new method to derive near real time FRE estimates based on this new knowledge about the fire diurnal cycle and MODIS FRP detections. New title:
"New fire diurnal cycle characterizations to improve fire radiative energy assessments made from MODIS observations"

Comment #3
The manuscript dives into too many details and intermediate results with a style which is probably closer to a progress report than a well focused journal paper. I would recommend to focus on the description and evaluation of the best model. It is not sure that presenting the models that have not been selected brings much to the paper clarity. With that respect, Section 3.7 is particularly confused and would require some rewriting.

Response #3
In the revised manuscript we limit ourselves to presenting the 'persistent' and 'climatological' approaches. This comparison of the persistent and climatological approaches is crucial for readers to better understand the consequences of the combined effects of the MODIS sampling design and the fire diurnal cycle on hourly FRE estimates. In addition, the persistent approach can be seen as a direct hourly extension of the current GFAS methods, and highlights the need to include the fire diurnal cycle into such approaches. The original idea behind the dynamic approach (now excluded) was that it may become the best choice when a larger number of daily FRP detections are available (e.g., at higher latitudes; or in future when additional instruments become operational).

All parts of the manuscript referring to the dynamic approach have been removed (most notably Sect. 3.6 of the methods and P9686L27 to P9687L5 of the Discussion). Moreover some sections of the manuscript have been updated to better explain why we have chosen to present these two modelling approaches and their specific qualities. Finally, we have rewritten and shortened Sect. 3.7 of the methods, also in the light of comment #5.

For example, lines P9666L24-26 of the introduction have been updated to better explain the new insights derived from the individual modelling approaches (lines 143 - 148):
"Then, data assimilation was used to compare two different methods to derive hourly FRE estimates at 0.1° resolution based on low Earth-orbiting MODIS observations. The first method ignored the fire diurnal cycle, and was used as a reference to better understand the combined effect of the fire diurnal cycle and the MODIS sampling design on hourly FRE estimates. The second method combined knowledge on the fire diurnal cycle with active fire detections at MODIS overpasses."

Updated Methods Sect. 3.6 (former Sect. 3.7; lines 390 - 408):

"The estimated hourly FRE fields (or analysis; $\hat{\rho}_t$) resulting from the two modelling approaches (persistent and climatological) were evaluated via comparison to those derived from the hourly SEVIRI time-series (see Sect. 2.1). Two criteria were used to evaluate model performance: first, the spatial distribution of FRE estimates; and second, the temporal distribution of FRE. The spatial performance of the modelling approaches was assessed via their ability to reproduce the annual mean FRE per land cover type, and by comparing the spatial distribution of FRE as estimated by the modelling approaches and as derived from SEVIRI over the study region and period. The temporal performance was assessed via the ability of the model to allocate the emitted energy in the right grid cell at the right moment in time. Here we used Pearson's r between the modelled and observed (SEVIRI) FRE time-series at four different spatiotemporal resolutions (0.1° and 1° spatial, and hourly and daily temporal resolution). Each spatiotemporal scale provides unique information on the model performance. Correlation coefficients at hourly resolution depend on the ability of the model to estimate the distribution of fire activity over the day, while daily aggregated estimates provide insights in the ability to get overall budgets right. In a similar way the two spatial resolutions provide information on the ability of the model to resolve high resolution distribution of fire activity and more regional model performance. When calculating Pearson's r between the hourly model results and SEVIRI data we included cloud free days only, while the daily model results were compared to the full cloud cover corrected SEVIRI times series, using a simple cloud cover correction method explained below. "

Comment #4

Finally, the manuscript lacks accounting for uncertainties when comparing model output with SEVIRI data. I would therefore recommend estimating the uncertainties of SEVIRI dataset and accounting for these uncertainties when comparing models with observations.

Response #4

The SEVIRI dataset provides details on uncertainty of each FRP detection based on three potential sources of introduced uncertainty (i.e., the fire pixel radiance measure, the fire pixel background signal estimate and the atmospheric transmission). On top of these uncertainties the SEVIRI FRP-product will miss a large fraction of the smaller fires, that fall below the detection threshold. Technical aspects of the SEVIRI dataset are discussed extensively in Wooster et al., 2015, while Roberts et al. (2015) evaluates the product quality. Although we agree that these and other potential sources of uncertainties should be discussed it goes beyond the objective of this paper to fully address SEVIRI quality issues, we therefore refer to Wooster et al., 2015 and a range of other papers (we have now also added Roberts et al., 2015). However, we have made several textual adjustments to provide the reader with increased insights in the potential sources of uncertainty and their relative importance.

Data section (lines 173 - 175):

"The Meteosat SEVIRI FRP-PIXEL product contains per-pixel fire radiative power data along with FRP uncertainty metrics produced from the full spatial and temporal resolution SEVIRI observations (Wooster et al., 2015)."

Discussion (lines 720 - 730):
"Despite the improved results of the climatological approach as opposed to the persistent approach, estimating FRE in near real time based on MODIS observations remains challenging, especially at high spatiotemporal resolutions. Largest uncertainties originate from the high spatiotemporal variability of the fire diurnal cycle combined with the limited number of daily MODIS detection opportunities. Moreover, the fire diurnal cycle as analyzed here may to some extent be affected by the inability of SEVIRI to detect the smallest fires, along with other sources of uncertainty in the FRP observations (Wooster et al., 2015; Roberts et al., 2015). Finally, the characterization of the fire diurnal cycle and discussion of its spatiotemporal drivers presented here provide a first step to upscale the climatological model to a global scale, but a better understanding of the fire diurnal cycle and its drivers for other regions of the globe remains an important issue. "

Comment #5
In the same way, the authors should question whether Pearson's r correlation is the best statistic to be used for model evaluation of cyclic processes. It might be worthwhile to explore the potential of cross-spectral analysis in that case.

Response #5
We appreciate this comment and understand the reviewers concern about using Pearson's r with cyclic processes. However, the fire diurnal cycle is often far from a perfect cyclic process and time lags may vary strongly from day to day. That said, we are convinced that our original methods are sufficiently robust, but may lack somewhat better explanation. We have therefore added and changed several phrases of the methods and other parts of the manuscript to more clearly explain our objectives and specifically the choice for Spearman's r and how we interpret the results.

Methods (lines 362 - 367):
In the second approach we followed previous studies of Vermote et al. (2009) and Ellicot et al. (2009) and the recommendation in Kaiser et al. (2009) to use a Gaussian function to describe a "standard fire diurnal cycle". Wooster et al. (2005) and Roberts et al. (2009) already demonstrated that SEVIRI observations sample the diurnal cycle of large fires well, and for some individual large fires show FRP time-series that depict diurnal characteristics appearing close to Gaussian in nature even at 15 min temporal resolution.

Methods (lines 396 - 405):
"The temporal performance was assessed via the ability of the model to allocate the emitted energy in the right grid cell at the right moment in time. Here we used Pearson's r between the modelled and observed (SEVIRI) FRE time-series at four different spatiotemporal resolutions (0.1° and 1° spatial, and hourly and daily temporal resolution). Each spatiotemporal scale provides unique information on the model performance. Correlation coefficients at hourly resolution depend on the ability of the model to estimate the distribution of fire activity over the day, while daily aggregated estimates provide insights in the ability to get overall budgets right. In a similar way the two spatial resolutions provide information on the ability of the model to resolve high resolution distribution of fire activity and more regional model performance."

Discussion (lines 695 - 710):

"Correlation between the modelled and SEVIRI time-series improved considerably when moving from hourly to daily resolution, showing that the models were better able to estimate daily budgets than the distribution of fire activity over the day. These differences may be explained by the inability of the models to correctly estimate the hour of peak fire activity, a fire diurnal cycle that is not well represented by a Gaussian function, or in the case of small fires the fire diurnal cycle may not be fully detected by the SEVIRI instrument. Because of the large day-to-day variation in the fire diurnal cycle and the FRP measurements limited to the time of the MODIS overpasses, the individual FRP observations have a low precision (i.e., large random error) and omission (i.e., non detection) of fires is frequent (Figs. 1 and 4), resulting in low correlation at high spatiotemporal scales (Table 3). Because fires rarely occur on their own and generally form part of a regional pattern (Bella et al., 2006), the correlation increased considerably when accumulating results to a 1° spatial scale. For the same reason model performance was found to be best in savannas and woody savannas, where the highest number of fires occur and the sample size is thus largest, or in areas of large fire size where omission was relatively low. Model performance was therefore best when optimal burning conditions were reached, often coinciding with the peak of the burning season."

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