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Validation of ERA5 fire weather conditions in Greece between 2007 and 2019: A preliminary analysis

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Abstract

Accurate simulations of fire weather conditions for both the past and future are of great importance for fire management and preparedness. With the advancement of numerical weather prediction models and data assimilation techniques, more accurate reanalysis products have been developed the recent years. Here we validate fire weather conditions in Greece which are computed based on ERA5 reanalysis data against surface observations from the automatic weather station network of the National Observatory of Athens (NOA). We assess the fire weather conditions in an application of the Canadian Forest Fire Weather Index (FWI) System in both datasets. Although, ERA5 FWI archive is available since 1979 here we limit our analysis during the period from 2007 to 2019, due to the limited data availability from the NOA network. The validation of FWI in ERA5 data shows good agreement with the NOA observations with a mean correlation of 0.87. Furthermore, FWI in ERA5 data is overall slightly underestimated compared to NOA observations, which is driven by an underestimation of the three moisture components of FWI, namely the Fine Fuel Moisture Code (FFMC), the Drought Code (DC) and the Duff Moisture Code (DMC). Preliminary results also indicate that the largest errors are found over the eastern and southern parts of Greece, which is the area that experiences the highest FWI values during the summer.

1. Introduction

The evaluation of the atmospheric conditions which are prone to extreme fire behavior is very critical for both the ecosystems and human life. Furthermore, accurate knowledge of fire weather conditions is also critical for civil protection preparedness and management. Fire weather conditions are determined by the meteorological conditions across weather and climate scales (Abatzoglou and Kolden, 2013; Flannigan and Wotton, 2001). Across longer time scales, such as sub-seasonal to seasonal and climate scales, changes in atmospheric state expressed via changes in basic meteorological variables (e.g. precipitation and temperature) influence the state of the fuels. On the other hand, across shorter time scales, changes in synoptic to mesoscale atmospheric conditions can modulate fire weather primarily via changes in temperature, wind speed and humidity.

These changes in fire weather conditions can be monitored by using fire weather indices. One of the mostly used fire weather indices is the Canadian Forest Fire Weather Index (FWI) System (Van Wagner, 1987). FWI is used by many agencies and national weather services to assess fire weather. Thus, its evaluation for both past conditions as well as for forecasting fire weather conditions is of great importance. Here we present preliminary results of an evaluation of ERA5 FWI and its components in Greece using observations from the network of automatic weather stations that is operated by the National Observatory of Athens (NOA).

2. Data and methods

For the purpose of this analysis we use the recently developed by the European Centre for Medium-range Weather Forecasts (ECMWF) daily gridded dataset of FWI based on ERA5 reanalysis. The ERA5 FWI dataset is based on an application of the Global ECMWF Fire Forecast (GEFF) model in ERA5 reanalysis data (Vitolo et al., 2020). The ERA5-based FWI data extends from 1979 till present and has a spatial resolution of 0.25˚ x 0.25˚. However, for the validation analysis here we limit our analysis in the period of 2007—2019, when the NOA automatic weather station (AWS) observations are available. For the comparison we use the nearest land ERA5 grid point to the each AWS location. The locations of the 76 AWS that we use in this analysis are shown in Fig. 1. AWS-based FWI components are calculated in the same way as in Vitolo et al. (2020).

For the validation, following previous work of McElhinny et al. (2020), we consider four simple metrics: (1) mean bias error (MBE), (2) mean absolute error (MAE), (3) Spearman rank correlation and (4) root mean square error (RMSE) applied in the ERA5-based FWI and the AWS-based FWI time series.

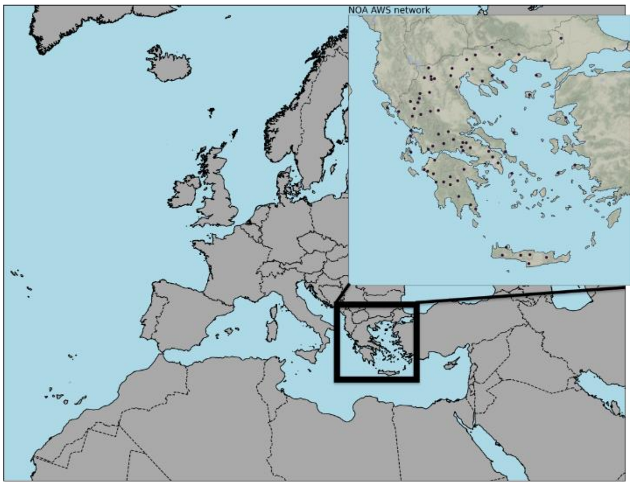


Figure 1- Study area (black box) and the locations (white dotes) of the automatic weather stations operated by the National Observatory of Athens (NOA) during the period of 2007—2019 that we use in this analysis.

3. Results

3.1. Climatology of fire weather in Greece

In Figure 2 we present the monthly climatological mean FWI values for four selected months based on ERA5 data during the period of 1981 to 2010 in Greece. This analysis illustrates, not surprisingly, the substantial spatiotemporal variability of FWI in Greece suggesting that a dense observational network is necessary for monitoring fire weather conditions. Results show that FWI is lower across the entire country during winter (Fig. 2a) and peaks during the summer particularly over the eastern and southern parts of the country (Fig. 2c). During spring and mostly during autumn FWI exhibits a NW-SE gradient with higher values over the southeastern parts and lower values over the northwestern parts of the country (Fig. 2b, d).

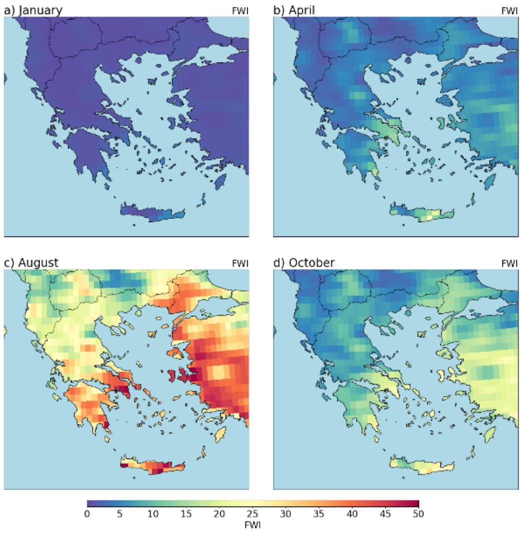


Figure 2- Monthly climatologies of mean FWI for (a) January, (b) April, (c) August and (d) October based on 1981-2010 ERA5 reanalysis data.

Similar spatiotemporal variability to the FWI exhibits the daily severity rating (DSR), which is a component of the FWI and it is a good indicator of fire suppression effort that is required (Fig. 3).

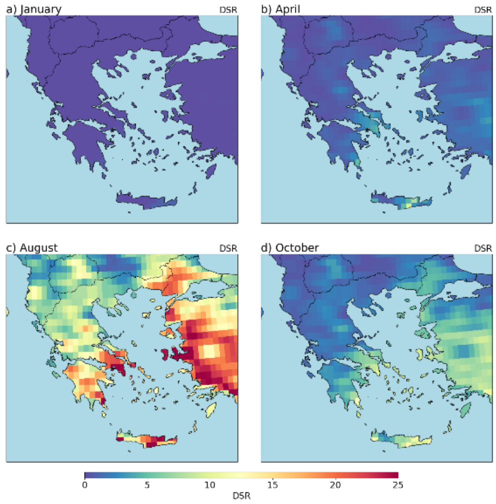


Figure 3- Monthly climatologies of mean DSR for (a) January, (b) April, (c) August and (d) October based on 1981-2010 ERA5 reanalysis data.

3.2. Validation of ERA5 fire weather

A validation analysis of ERA5-based FWI over the 76 NOA AWS locations in Figure 4 reveals that overall ERA5 is in good agreement with the AWS data exhibiting a mean Spearman rank correlation of 0.9, mean MAE of 5.19 and a slightly mean negative bias of -0.6 (Fig. 4). These findings are in line with previous analysis performed in Canada by McElhinny et al. (2020). The spatial distribution of MAE (Fig. 4b) and MBE (Fig. 4a) reveals that a negative bias is mainly evident in AWS near coastal areas and islands suggesting a model bias primarily in wind speed as it has also been discussed in previous studies (Betts et al., 2019; McElhinny et al., 2020). However, the source of this bias is beyond the scope of this study but users should be aware of these potential limitations (Vitolo et al., 2020).

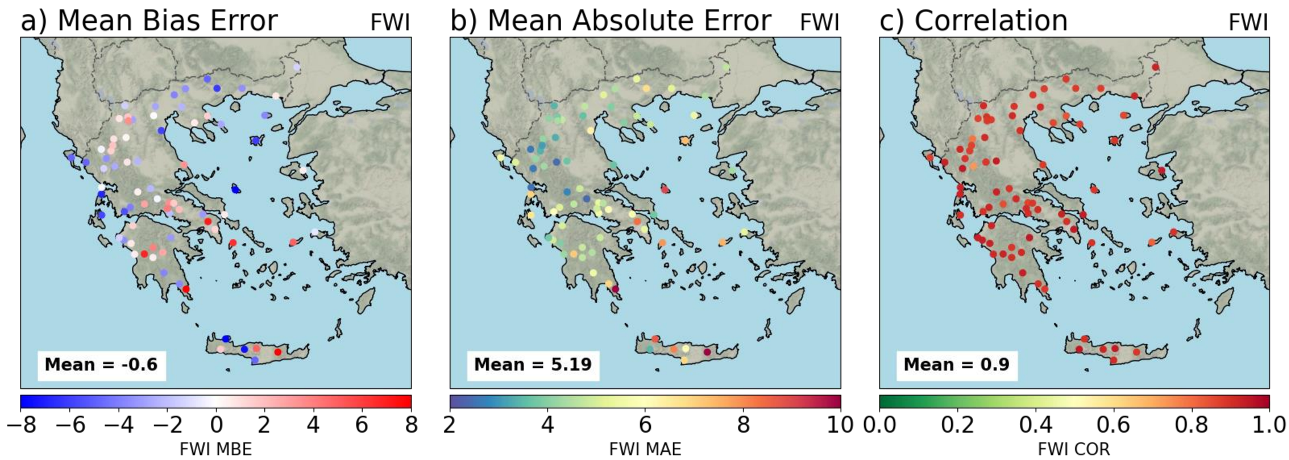


Figure 4- FWI (a) mean bias error, (b) mean absolute error and (c) Spearman rank correlation of ERA5 data against NOA AWS observations.

Validating ERA5 DSR data yields even greater agreement between ERA5 and NOA AWS with a mean Spearman correlation of 0.9, mean MAE of 2.54 and mean bias of -0.02. The mean biases in DSR are substantially smaller compared to FWI (near 50%) and are mainly identified in the southern parts of the country. These findings suggest that DSR might be a more useful indicator of fire behavior and fire weather conditions across broader regions in ERA5 data compared to FWI. Furthermore, DSR mean bias errors exhibit smaller variance suggesting an overall better agreement with the AWS data compared to FWI (Fig. 6).

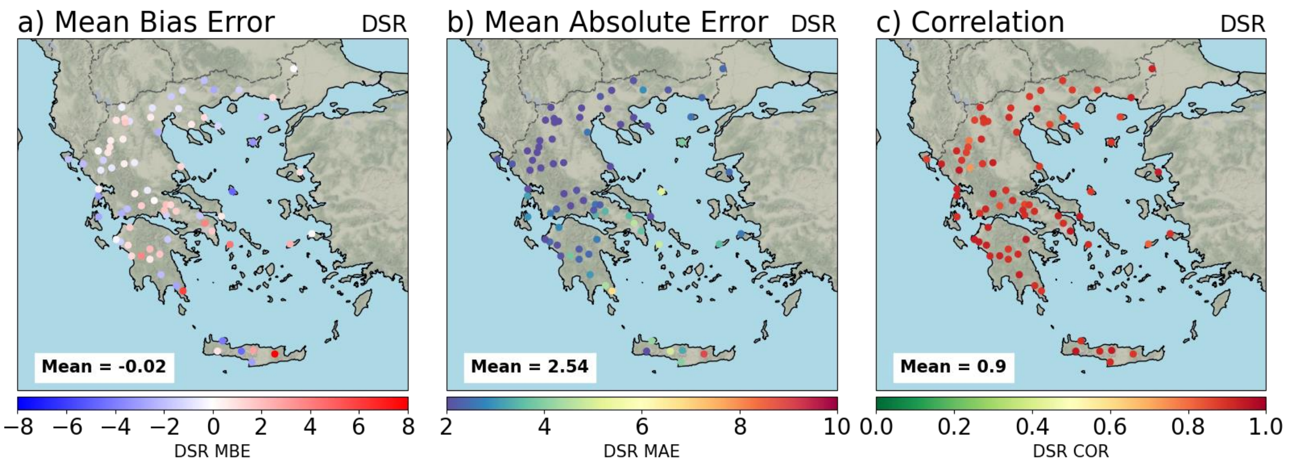
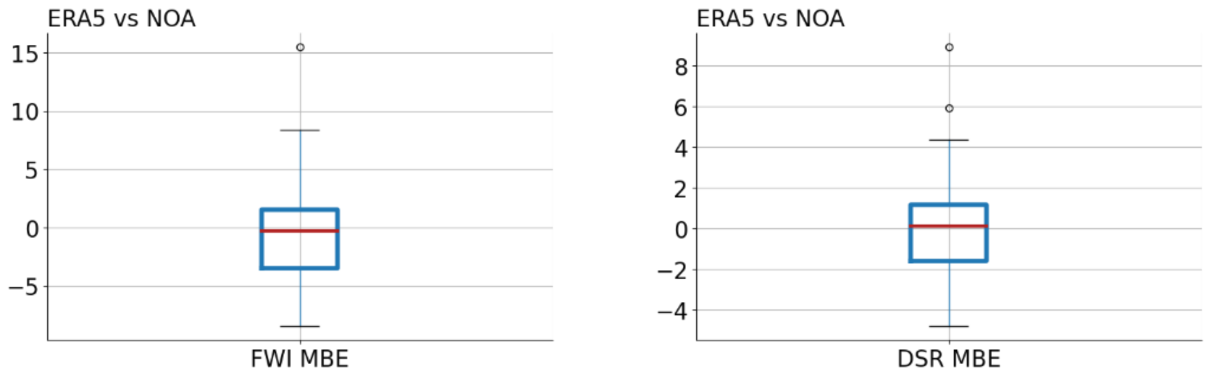


Figure 5- DSR (a) mean bias error, (b) mean absolute error and (c) Spearman rank correlation of ERA5 data against NOA AWS observations.

We further validate all the components of the CFFWIS and we provide a summary of the statistical metrics that use here in Table 1. Overall, we find that the largest biases are evident for the three moisture components of FWI, namely the Fine Fuel Moisture Code (FFMC), the Drought Code (DC) and the Duff Moisture Code (DMC) and therefore by construction the Build Up Index (BUI). The smallest mean biases are evident for DSR, Initial Spread Index (ISI) and FWI. Furthermore, the largest MAE are evident for DC, BUI, DMC, FFMC, while the smallest occur for ISI, DSR and FWI. It is notable that even though some moisture components exhibit high correlation, they are also accompanied by the largest MBE, MAE and RMSE.



a) ***b)***

Figure 6- Distribution of ERA5 (a) FWI and (b) DSR mean bias errors across all 76 NOA AWS locations.

Our findings are in line with previous results from McElhinny et al. (2020), where similar magnitudes of MBE and MAE are shown, however here we find stronger Spearman rank correlation between ERA5-based and NOA AWS-based FWI suggesting an overall good performance of ERA5 despite the dataset limitations. As mentioned above, these limitations arise from ERA5 biases mainly in precipitation and wind, which then influences the computations of the CFFWIS components.

Table 1- Statistics of fire weather indices based on ERA5 data against NOA AWS observations.

	Mean Bias Error	Mean Absolute Error	Root Mean Square Error	Correlation
FWI	-0.6	5.19	8.05	0.9
ISI	0.24	1.2	3.03	0.81
FFMC	-4.43	7.42	11.5	0.86
DMC	-9.5	26.1	50.4	0.93
DC	-161.3	187.25	252.9	0.85
BUI	-18.7	31.23	54.9	0.93
DSR	-0.02	2.54	4.8	0.9

4. Conclusions

In this study we present preliminary results of the validation of ERA5 fire weather conditions in Greece using automatic weather station observations during the period from 2007 to 2019. Our results show that ERA5 overall perform well mostly in the continental parts of the country, while some biases are evident over the eastern and southern parts of the country. A detailed validation of each component of the Canadian Forest Fire Weather Index System suggests that the daily severity rating component performs better than any other component and could be a more reliable indicator of fire weather and fire behavior for future studies that focus over broader areas compared to other components.

5. Acknowledgments

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