FORECAST EVALUATION: AERONET VS. MULTI-MODEL FORECAST FOR 2016

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TECHNICAL REPORT

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Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) Regional Center for Northern Africa-Middle East-Europe (NAMEE)

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Summary

One of the most important activities of the World Meteorological Organization's Sand and Dust Storm Warning Advisory and Assessment System - Northern Africa-Middle East-Europe Regional Center (WMO SDS-WAS NAMEE RC, http://sds-was.aemet.es) is the dust model verification and evaluation, which is deemed an indispensable service to the users and an invaluable tool to assess model skills. Currently, the Center collects daily dust forecasts from twelve models run by different partners (BSC, ECMWF, NASA, NCEP, SEEVCCC, EMA, CNR-ISAC, NOA, FMI, TNO and UK Met Office). Multi-model ensembles have also been set-up to provide added-value aerosol products to the users. The current routine evaluation of dust predictions is focused on total-column dust optical depth (DOD) and uses remote-sensing retrievals from sun-photometric (AERONET) and satellite (MODIS) measurements. The present document searches to analyses the impact of the upgrade to the AERONET Version 2 to Version 3 in the evaluation skills scores of the SDS-WAS multi-median product for the year 2016 shown in the SDS-WAS NAMEE website. Additionally, the present work includes a revision of the current dust methods applied to discriminate dust particles from the rest of aerosols.

Contents

1. AERONET

For the quantitative model evaluation, we use column-integrated aerosol optical properties routinely observed within AERONET (Holben et al., 1998; Smirnov et al., 2000). The AERONET program is a federation of ground-based remote sensing aerosol networks established by NASA and LOA-PHOTONS (CNRS) and has been expanded by collaborators from international agencies, institutes, universities, individual scientists and partners.

These instruments can only retrieve data during daytime, because they rely on extinction measurements of the direct and scattered solar radiation at several nominal wavelengths (340, 380, 440, 500, 675, 870 and 1020 nm plus a 936 nm water vapour band). The instrument is out of operation for some weeks while necessary yearly calibration is carried out. Consequently the data coverage in a given station is typically limited to 100–250 days per year. This data is provided in three categories: 1) raw (level 1.0), 2) cloud-screened (level 1.5) following the methodology described by Smirnov et al. (2000), and 3) cloud-screened and quality-assured (level 2.0). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality checks.

A preprogrammed sequence of measurements is taken by these instruments starting at an air mass of 7 in the morning and ending at an air mass of 7 in the evening. Aerosol optical depth (AOD) is calculated from spectral extinction of direct beam radiation at each wavelength based on the Beer-Bouguer Law at 15-minute intervals. Moreover, direct-sun processing includes the Spectral Deconvolution Algorithm (SDA) described in O'Neill et al. (2003). This algorithm yields submicron and super-micron AOD (hereafter referred to as AODfine and AODcoarse, respectively) at a standard wavelength of 500 nm from which the fraction of fine mode (FMF) to total AOD can be computed. The algorithm fundamentally depends on the assumption that the coarse mode AE and its derivative are close to zero.

AERONET has been operating under what we call Version 2 processing that we implemented in 2006 and was based on 2004 knowledge and expertise. The newest processing, Version 3, was released in 2015 after the entire database was reprocessed and real-time data processing became operational (http://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3). All Version 3 algorithms have been developed individually vetted and represent four main categories: aerosol optical depth (AOD) processing, inversion processing, database management and new products. The primary trigger for release of Version 3 lies with cloud screening of the direct sun observations and computation of AOD that will fundamentally change all data available for analysis and all subsequent retrieval products.

2. Dust evaluation methods

The presence of different types of aerosols mixed with dust in the measurement points should introduce a negative bias in the comparison between dust model outputs and observations. In general, the model should underpredict the dust AOD for increasing Ångström exponents calculated between 440 and 870 nm (AE) because of the influence of anthropogenic pollution (Pérez et al., 2006). In order to evaluate mineral dust models, observations have to be segmented into their different aerosol components, and the contribution of dust has to be extracted. Currently, quantitative model evaluation based on AERONET Direct sun Version 2 is presented in the dust forecast evaluation AERONET sections of the SDS-WAS NAMEE website (http://sds-was.aemet.es/forecast-products/forecast-evaluation/).

The present document searches to analyses the impact of the upgrade to the AERONET Version 2 to Version 3 in the evaluation skills scores shown in the SDS-WAS NAMEE website. Within this objective, the performance of the SDS-WAS multi-model product for the year 2016 will be evaluated using the AERONET Version 2 to Version 3 datasets filtered for dust. Additionally, the present work also includes a revision of the current dust methods applied to discriminate dust from the rest of aerosols.

2.1. Evaluation strategy

Currently, the SDS-WAS model evaluation methodology apply a “dust filter” to the direct-sun AERONET observations based on a threshold discrimination for dust which is made by considering only observations with an AE < 0.6 (hereafter referred as dustfilter1). Additionally, to quantitatively compare the SDS-WAS modelled optical data in the mid-visible spectrum with measurements at 550 nm, AOD at 550 nm from AERONET direct-sun observations are obtained from data between 440 and 870 nm following the Ångström’s law.

In the aerosol characterisation for North Africa, Southern Europe and the Middle East presented in Basart el al. (2009), in addition to AE, its spectral curvature represented by δAE = AE(440, 675) - AE(675, 870), was used to discriminate mineral dust contributions. Desert dust aerosols were observed mainly for AE < 0.75 for which the fine mode contributions were always less than 40%. ‘Pure desert dust’ conditions were associated to the highest extinctions, AE < 0.3 and δAE was negative or slightly positive. However, in the regions around the Mediterranean Basin and Persian Gulf where different classes of particles can be found, mixed dust was associated to 0.75 < AE < 1 and positive values of δAE. In addition, fine anthropogenic and biomass burning aerosols were found associated to AE > 1.5 and a mixture of different aerosol types (including desert dust) were found in 1 < AE < 1.5.

Following these previous considerations, a new “dust filter” (hereafter referred as dustfilter2) will be compared against the current threshold discrimination for dust. Aerosol data with AE < 0.75 have been considered as desert dust. All data with AE > 1.2 is associated to fine anthropogenic/biomass burning aerosols and have been considered non-dust situations. Therefore, in the model comparison we have ascribed observed dust AOD of 0 for AE > 1.2. Measurements outside these ranges are associated with mixed aerosols and not included in the quantitative model evaluation.

Furthermore, at those sites where the SDA products are available, the dust AOD evaluation will be complemented with AODcoarse which is fundamentally associated to maritime/oceanic aerosols and desert dust. Since sea-salt is related to low AOD (< 0.03; Dubovik et al., 2002) and mainly affects coastal stations, high AODcoarse values are mostly related to mineral dust.

In the present analysis, the performance of the SDS-WAS multi-model product will be evaluated for the year 2016 using the following observational datasets:

- directsun_v2-lev15_dustfilter1
- directsun_v3-lev15_dustfilter1
- directsun_v2-lev15_dustfilter2
- directsun_v3-lev15_dustfilter2
- sda_v3-lev15_coarse

In order to evaluate the performance of the SDS-WAS multi-model product with respect the 5 AERONET dust-filtered datasets, we use a set of statistics. Discrete statistics such as correlation coefficient (r), mean fractional bias (MFB), mean fractional error (MFE), root mean square error (RMSE), mean bias (MB) and mean absolute error (MAE), mean normalize bias error (MNBE) and mean normalize gross error (MNGE), measure the skill of the model when performing diagnostic analyses of dust AOD at specific points where AERONET sites are located. Comparisons are made for individual sites and regionally (i.e. Sahel/Sahara, Mediterranean and Middle East) considering the operational list of stations of the SDS-WAS AERONET Forecast Evaluation (http://sds-was.aemet.es/forecast-products/forecast-evaluation). Moreover, the comparison will be done at annual (see Table 1), monthly and the four seasonal periods: winter (DJF) corresponding to December, January and February; spring (MAM) corresponding to March, April and May; summer (JJA) corresponding to June, July, August and autumn (SON) corresponds to September, October and November.

Because AERONET data are acquired at 15-min intervals on average, all AERONET measurements within ±90 min of the model outputs have been extracted and used for the model comparison on a 3-hourly basis.

3. Results and discussion

The comparisons considering the current operational dust filter for the SDS-WAS Forecast Evaluation (i.e. dustfilter1) show that Direct-sun Version 3 present better results than Version 2. The daily variability increases and errors are reduced in Version 3 respect Version 2 as it is shown in Table 1 (r increases from 0.57 to 0.76 and MB decrease from -0.17 to -0.11 in average for all the sites). This is mainly related to the improved cloud screening include in Version 3. Extreme AOD events observed in Version 2 in those AERONET sites affected by the presence of clouds are removed in Version 3 (see Tamanrasset INM in the top panel of Figure 1).

Table 1. Skill scores (r, MFB, MFE, RMSE, MB, MAE, MNBE and MNGE) of 24h forecasts for SDS-WAS Multi-model Median on annual basis, and the number of data (NDATA) used. Dust-filtered AOD from AERONET is the reference.

	NDATA	r	MFB	MFE	RMSE	MB	MAE	MNBE	MNGE
directsun_v2-lev15_dustfilter1									
Sahel/Sahara	6703	0.57	-0.37	0.47	0.42	-0.18	0.21	-0.24	0.36
Middle East	416	0.54	-0.49	0.52	0.38	-0.22	0.22	-0.36	0.39
Mediterranean	1827	0.47	-0.72	0.81	0.29	-0.13	0.16	-0.41	0.53
All sites	9232	0.57	-0.46	0.55	0.40	-0.17	0.20	-0.28	0.40
directsun_v3-lev15_dustfilter1									
Sahel/Sahara	7090	0.76	-0.29	0.42	0.28	-0.12	0.16	-0.18	0.34
Middle East	1033	0.50	-0.25	0.40	0.26	-0.11	0.16	-0.14	0.36
Mediterranean	3096	0.78	-0.58	0.68	0.13	-0.07	0.09	-0.33	0.46
All sites	11406	0.76	-0.37	0.49	0.24	-0.11	0.14	-0.22	0.37
directsun_v2-lev15_dustfilter2									
Sahel/Sahara	8010	0.63	-0.24	0.59	0.39	-0.16	0.19	-0.25	0.37
Middle East	780	0.65	0.03	0.85	0.31	-0.13	0.19	-0.38	0.40
Mediterranean	4944	0.66	0.62	1.46	0.18	-0.05	0.08	-0.46	0.57
All sites	14325	0.69	0.09	0.92	0.32	-0.12	0.15	-0.31	0.42
directsun_v3-lev15_dustfilter2									
Sahel/Sahara	8104	0.78	-0.28	0.49	0.27	-0.12	0.15	-0.20	0.36
Middle East	1744	0.63	0.12	0.70	0.22	-0.07	0.15	-0.17	0.36
Mediterranean	10469	0.85	0.94	1.51	0.08	-0.02	0.05	-0.39	0.50
All sites	20795	0.84	0.38	1.03	0.19	-0.06	0.10	-0.26	0.40
oneill_v3-lev15_coarse									
Sahel/Sahara	4599	0.80	-0.21	0.52	0.17	-0.02	0.09	-0.01	0.46
Middle East	2272	0.64	0.12	0.35	0.15	0.01	0.08	0.27	0.45
Mediterranean	13318	0.84	-0.73	0.89	0.06	-0.02	0.04	-0.36	0.61
All sites	20189	0.83	-0.52	0.75	0.11	-0.02	0.06	-0.21	0.56

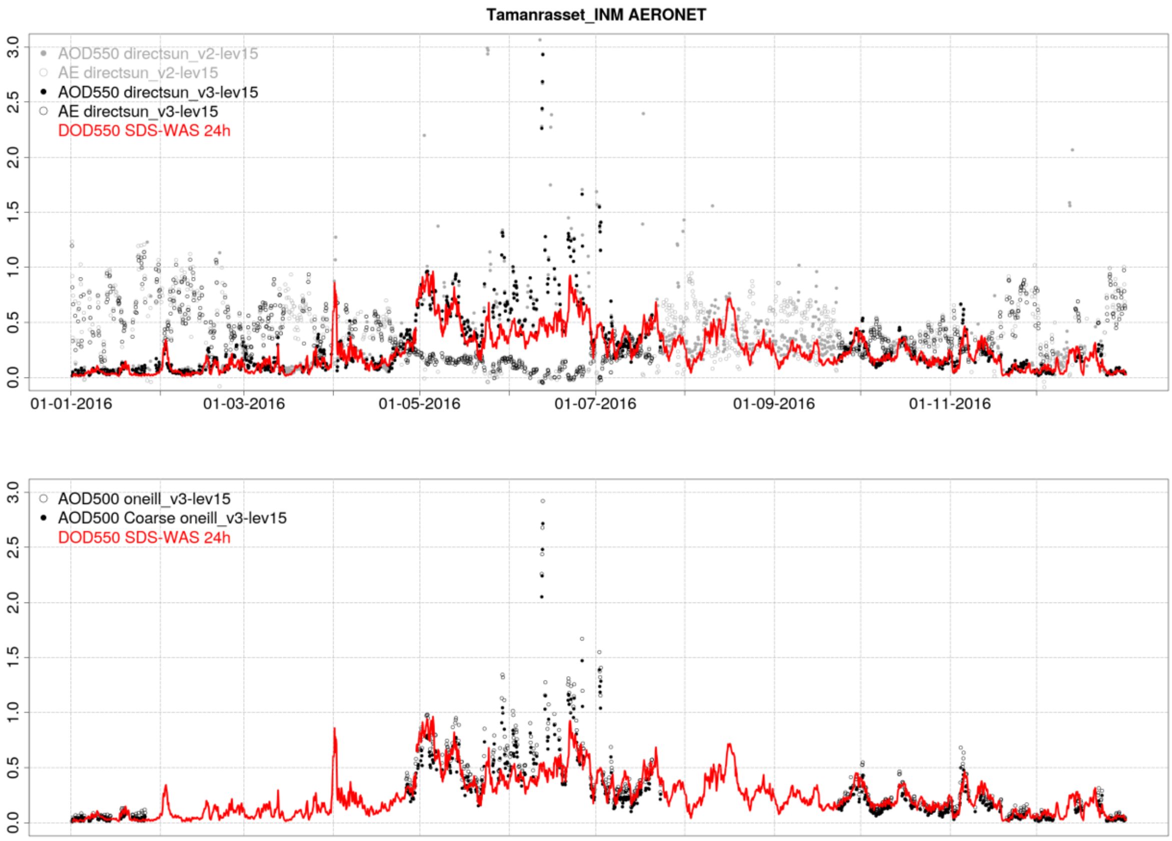

Figure 1. AOD from AERONET Version 2 (grey dots) and Version 3 (black dots), as well as DOD Multi-model SDS-WAS Median (red line) over Tamanrasset INM (Sahel/Sahara).Top panel corresponds to direct-sun measurements and bottom panel corresponds to SDA retrievals.

The results obtained applying the new dust filtered (i.e. dustfilter2) which also considers non-dust situations (ascribing observed dust AOD of 0 for AE > 1.2) increase the number of observations particularly in the Mediterranean (NDATA in Table 1 increases from 1827 to 3096 from directsun_v2-lev15_dustfilter1 and directsun_v2-lev15_dustfilter2). As a difference of desert dust source regions where there is a background dust concentration, over the Mediterranean dust events are sporadic. The “dustfilter2” provides a better way to check the performance of the models during dust but also non-dust situations.

Finally, the skills scores obtained using the SDA AODcoarse AERONET dataset (i.e. oneilL_v3-lev15_coarse in Table 1) are comparable to the direct-sun AERONET dustfilter2 dataset, despite that in Sahel/Sahara the number of available observations is lower than direct-sun (from 4599 for oneill_v3-lev15_coarse to 8104 for directsun_v3-lev15-dustfilter2).

4. References

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