EVALUATION OF SAHARAN DUST OUTFLOWS FORECASTED BY THE MINNI-FORAIR-IT AIR QUALITY MODEL WITH OBSERVATIONS FROM THE CLIMATE OBSERVATION STATION OF LAMPEDUSA

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Abstract

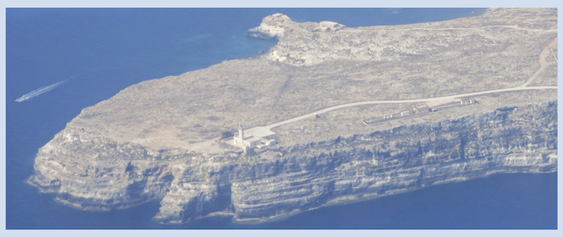
Desert dust transport events are becoming more frequent and attracting increasing interest ([1], [2], [3]). Model predictions are widely used, making it necessary to evaluate these model estimations. Models typically underestimate desert dust contribution to the atmospheric column. This work verifies the effectiveness of the **IMPROVE** (Interagency Monitoring of Protected Visual Environments) parametrization developed by the **EPA**, based on data collected at the **Lampedusa Climate Observatory** (https://www.lampedusa.enea.it/), which is part of the **AERONET** (Aerosol Robotic Network) (https://aeronet.gsfc.nasa.gov/) and the **ACTRIS** European infrastructure (Aerosol, Clouds and Trace Gases), and aerosol concentrations simulated by the **ENEA MINNI-FORAIR-IT** ([4], [5]) model in the Mediterranean region. An empirical correction has been developed for desert dust events and tested at other sites within **AERONET** sites . Initial results show a reduction in model underestimation of the desert dust component. Further studies are needed to optimize this method and validate its applicability throughout the Italian territory.

Methodology

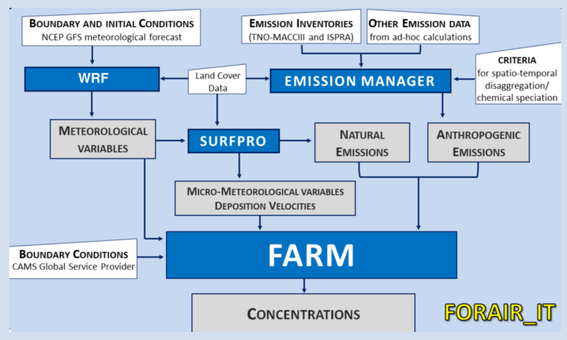
The aerosol extinction profile has been obtained through the **IMPROVE** parametrization, where extinction has been calculated from aerosol concentrations estimated by the **ENEA MINNI-FORAIR-IT** model. By integrating over these profiles, the Aerosol Optical Depth (**AOD**, τ, 550 nm) has been obtained as: $\tau_{column} = \sum_{i=1}^{N_{\text{layer}}} b_{ext}\,\Delta Z_i$ where the extinction coeff. (b_{ext}) comes from the **IMPROVE formula**:

$$
\begin{aligned}
b_{ext} \approx\ & 2.2 f_S(RH)[\text{Small Sulfate}] + 4.8 f_L(RH)[\text{Large Sulfate}] \\
& + 2.4 f_S(RH)[\text{Small Nitrate}] + 5.1 f_L(RH)[\text{Large Nitrate}] \\
& + 2.8[\text{Small Organic Mass}] + 6.1[\text{Large Organic Mass}] \\
& + 10[\text{Elemental Carbon}] + \underline{\mathbf{1}[\text{Fine Soil}]} \\
& + 1.7 f_{SS}(RH)[\text{Sea Salt}] + 0.6[\text{Coarse Mass}] + \underline{\mathbf{0.6}[\text{Coarse Soil}]} \\
& + \text{Rayleigh Scattering} + 0.33[NO_2(\text{ppb})]
\end{aligned}
$$

The **ENEA MINNI-FORAIR-IT** model simulates aerosol concentrations over Italy with hourly temporal resolution and 4 km $\times$ 4 km spatial grid resolution. Additionally, it simulates 14 atmospheric layers with variable heights reaching up to 7 km. To verify the aerosol column distribution, simulations from the **MINNI-FORAIR-IT** model have been compared with observations collected at Lampedusa.



Lampedusa Climate Observatory 35.52° N, 12.63° E



MINNI FORAIR-IT Suite

Two filtering criteria have been applied to **AOD** values. The period under analysis spans from 2023 to 2025, divided into a training set and a test set. Finally, metrics chosen for the analysis are: **Bias**, **Sample Pearson Corr.**, **RMSE** and R^2.

Training set	Sep. 2023 - Aug. 2024	Lampedusa
Test set	Sep. 2024 - May 2025	Lampedusa
AOD (τ) (550 nm)	clear sky	hours with at least 6 values
AOD (τ)	daylight hours	50% of the maximum hours
ANG (α)	(440 nm - 870 nm)	$\frac{\tau(\lambda_1)}{\tau(\lambda_2)} = \left(\frac{\lambda_1}{\lambda_2}\right)^{\alpha}$
$\Delta\tau$	hourly data variability	$\sqrt{(\Delta\tau_{(500-550)nm})^2 + (\Delta\sigma)^2}$
Desert Dust events [6]	($\tau \geq 0.35$)	($\alpha \leq 0.3$)

Analysis

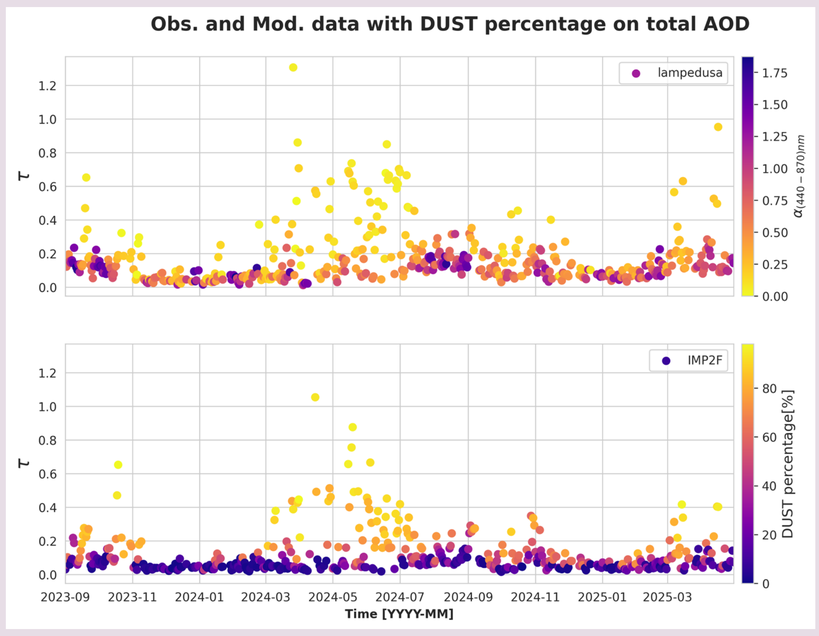


Fig.1: represents the whole time series. There are AOD observed values with ANG associated (above) and modeled values with DUST percentage associated (below).

IMPROVE (N=466)	Bias	Corr.	RMSE	R^2
Original	0.050	0.758	0.118	0.480
Correction	-0.001	0.760	0.140	0.854

Tab.1: relative to Fig.1

IMPROVE coeff.	Fine Soil	Coarse soil
Original	1	0.6
Correction	1.726±0.136	1.036±0.082

Tab.2: relative to Fig.2

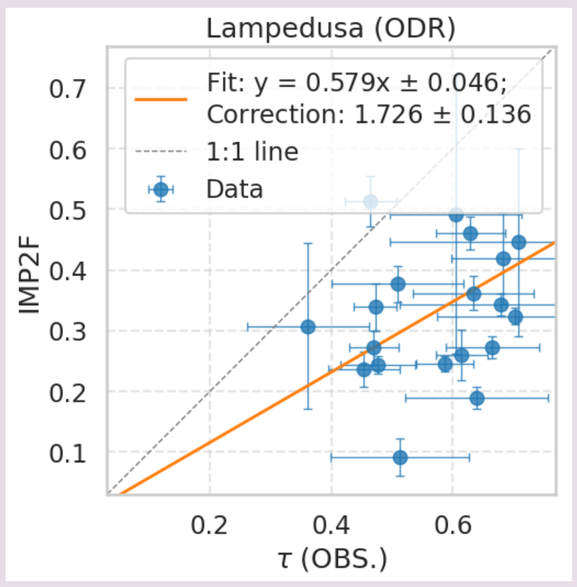


*Fig.2: the Orthogonal Distance Regression (**ODR**) is performed to obtain new correction coefficients over filtered desert dust events.*

IMPROVE (N=38)	Bias	Corr.	RMSE	R^2
Original	0.107	0.563	0.172	0.480
Correction	0.006	0.593	0.154	0.708

Tab.3: relative to Fig.3

The new coefficients show good agreement both with the second test period at the Lampedusa site and with filtered desert dust events at the Naples site (see Tables 3 and 4). The new coefficients appear to reduce the underestimation introduced by MINNI, and the metrics improve overall.

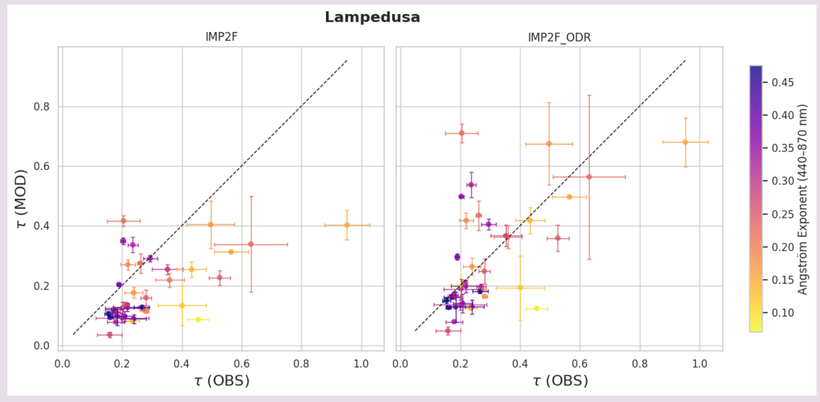


Fig.3: testing new coefficient on the test period from 2024 to May 2025 for Lampedusa site.

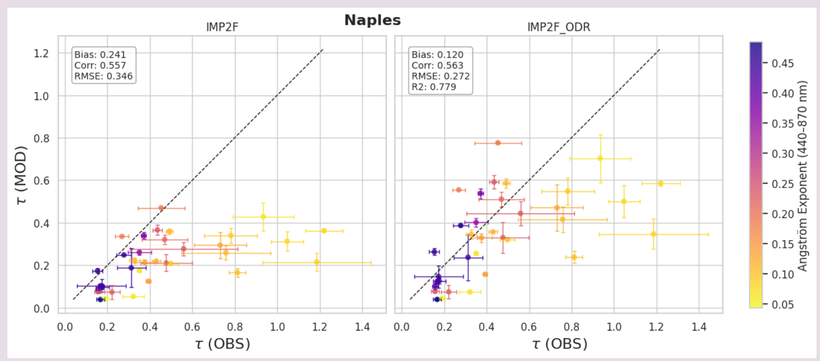


Fig.4: testing new coefficients for the Naples station on filtered desert dust events from 2023 to 2025.

IMPROVE (N=35)	Bias	Corr.	RMSE	R^2
Original	0.241	0.557	0.346	0.336
Correction	0.120	0.563	0.272	0.779

Tab.4 relative to Fig.4

Conclusion

The ability of the ENEA MINNI-FORAIR-IT model to reproduce the columnar aerosol load has been tested using a subset of AOD data collected at the ENEA Climate Observatory in Lampedusa. MINNI appears to underestimate AOD values, especially when desert dust is predominant. By applying the IMPROVE parametrization, new coefficients have been obtained to provide a correction for desert dust aerosols. In particular, the prediction is improved by 23% at the Lampedusa site and by 44% at the Naples site with respect to desert dust events. This preliminary work suggests a possible approach for improving model predictions.

References & Acknowledgement

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