Evaluation of NMMB-MONARCH dust reanalysis within the DustClim ERA4CS project

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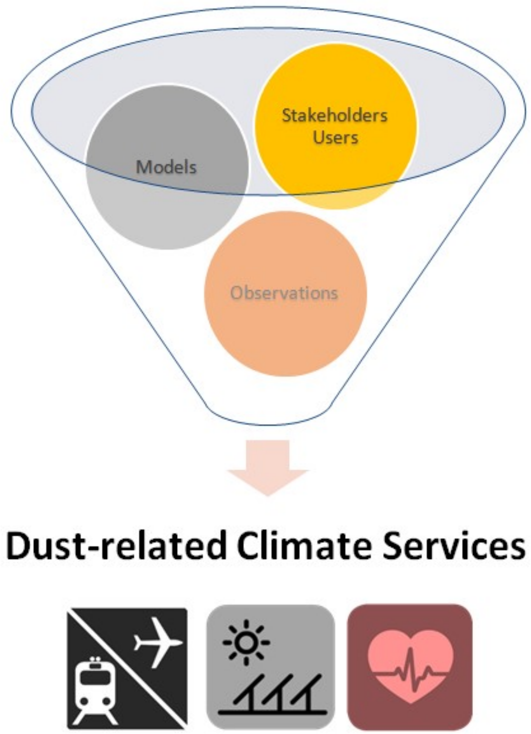
DUSTCLIM PROJECT - OVERVIEW

DUST *Storms Assessment for the development of user-oriented*
CLIM*ate services in Northern Africa, the Middle East and Europe*

Sand and dust storms (SDS) are an important threat to life, health, environment and economy in many countries, and play a significant role in different aspects of weather, climate and atmospheric chemistry. There is an increasing need for SDS accurate information and predictions to support early warning systems and mitigation plans [1].

DustClim Objectives:

- Provide reliable information on SDS trends and current conditions
- Develop dust impact assessment pilot studies and dust-related services for three key socio-economic sectors
  (air quality, aviation and solar energy)
- By producing an advanced dust regional model reanalysis (with high spatial and temporal resolution) for Northern Africa, Middle East and Europe, covering the satellite era of quantitative aerosol information
- Reanalysis evaluation using a wide variety of observations



SDS IMPACTS

Air Quality/Human Health:

- Respiratory problems
- Cardiovascular diseases
- Bacterial infections (e.g. meningitis)

Transportation/Aviation:

- Low visibility
- Mechanical damages (e.g. engine erosion)

Solar Energy:

- Reduced incoming solar irradiance
- Soiling on panels
- Low energy production

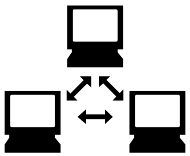
DustClim Reanalysis products, to assess dust impacts:

- Columnar and surface dust concentration (available in 8 size bins)
- Dust load
- Dry and wet dust deposition
- Dust optical depth (DOD) and coarse dust optical depth @ 550nm
- Dust extinction coefficient profiles @ 550nm

DUSTCLIM REANALYSIS

Assimilation of dust-related MODIS [2] observations, in the Multiscale Online Nonhydrostatic Atmosphere Chemistry model (NMMB-MONARCH) [3]

NMMB-MONARCH



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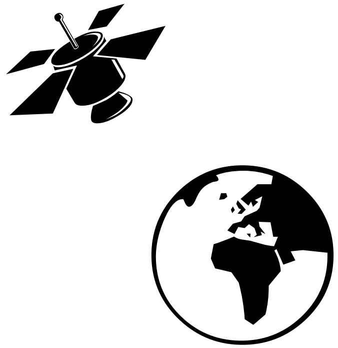

MODIS (Terra & Aqua)

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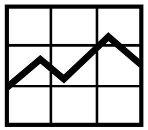
Dust Model Reanalysis



Spatial Domain:	Northern Africa, Middle East and Europe
Temporal Domain:	2011 – 2016
Horizontal Resolution:	0.1x0.1 degree
Temporal Resolution:	3-hour time-step

REANALYSIS EVALUATION

Evaluation of MONARCH Reanalysis through synergy and integration of different measurement techniques (in-situ, remote sensing, active, passive)

High quality & harmonized datasets used in the evaluation

Dust Extinction Profiles:

LIVAS [4], EARLINET [5]

DOD:

AERONET [6], MISR [7], MODIS-DUSTGLASS [8]

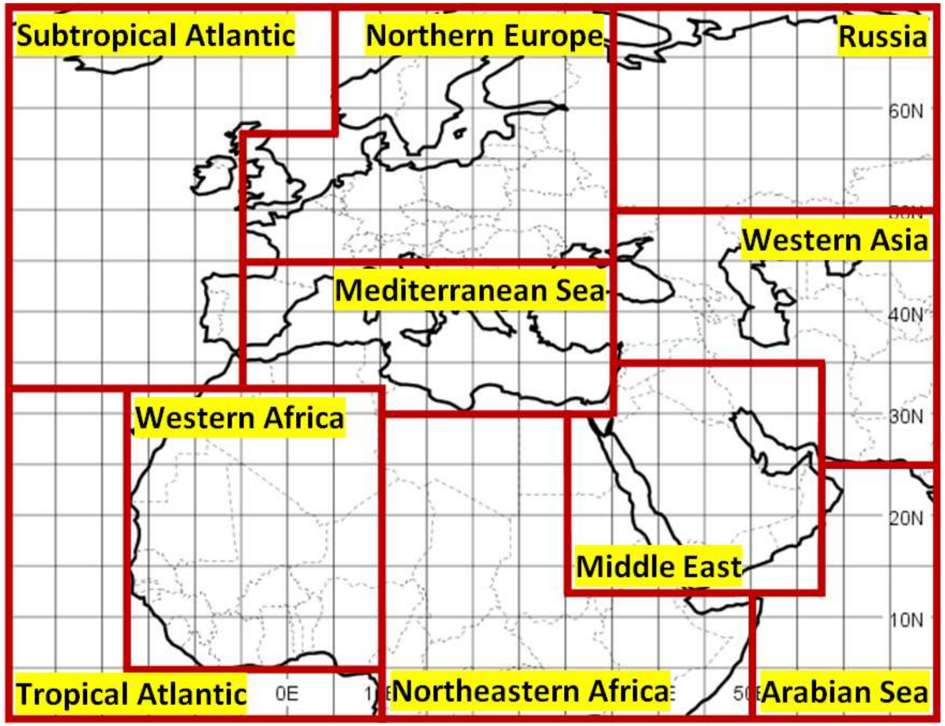
Dust PM10:

INDAAF/SDT [9]

Evaluation metrics used to quantify the mean departure between modelled (c) and observed (o) quantities

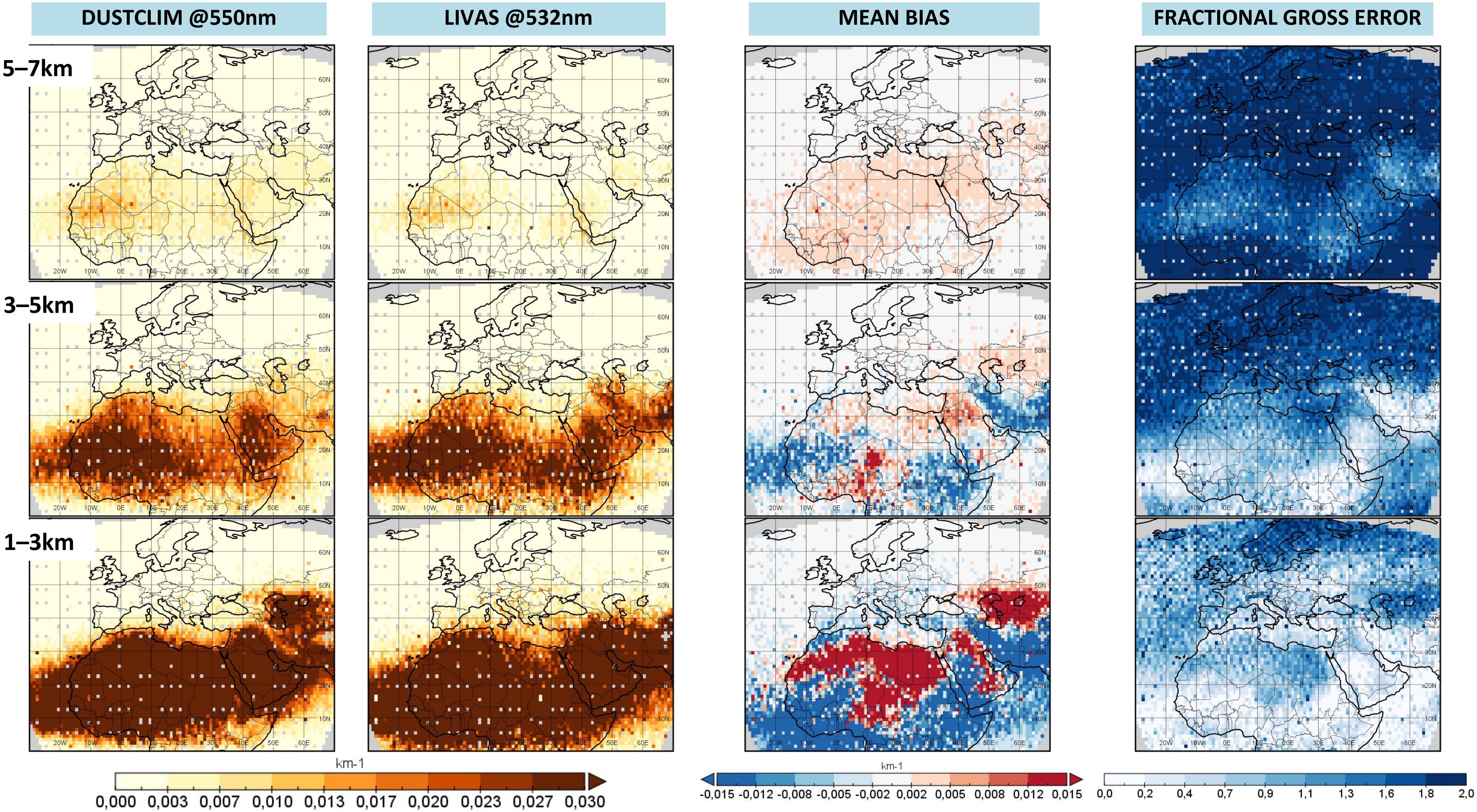
Statistic Parameter	*Formula*
Mean Bias Error	$BE = \frac{1}{n}\sum_{i=1}^{n}(c_i - o_i)$
Root Mean Square Error	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(c_i - o_i)^2}$
Correlation coefficient	$r = \frac{\sum_{i=1}^{n}(c_i - \bar{c})\cdot(o_i - \bar{o})}{\sqrt{\sum_{i=1}^{n}(c_i - \bar{c})^2}\cdot\sqrt{\sum_{i=1}^{N}(o_i - \bar{o})^2}}$
Fractional Gross Error	$FGE = \frac{2}{n}\sum_{i=1}^{n}\left\lvert\frac{c_i - o_i}{c_i + o_i}\right\rvert$

Evaluation was applied in various temporal scales (annual, seasonal) and spatial domains (10 sub-regions)



DUST PROFILES EVALUATION – LIVAS

Mean Dust Extinction Coefficient per Layer 2011 – 2016



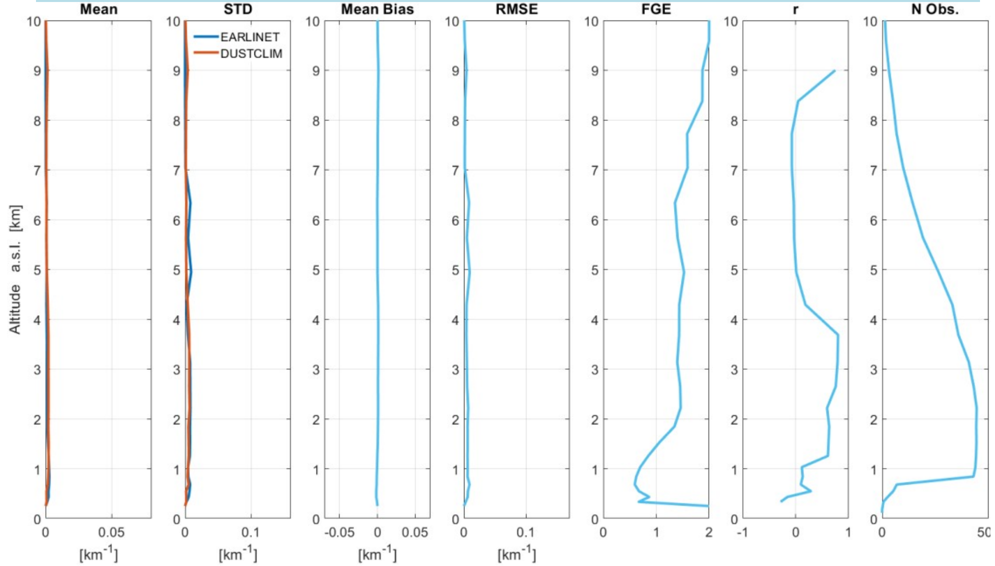
- MONARCH produces similar dust distribution per layer
- Overestimation over source regions, underestimation over the regions of dust transport
- In higher levels model slightly overestimates over both regions

DUST PROFILES EVALUATION – EARLINET

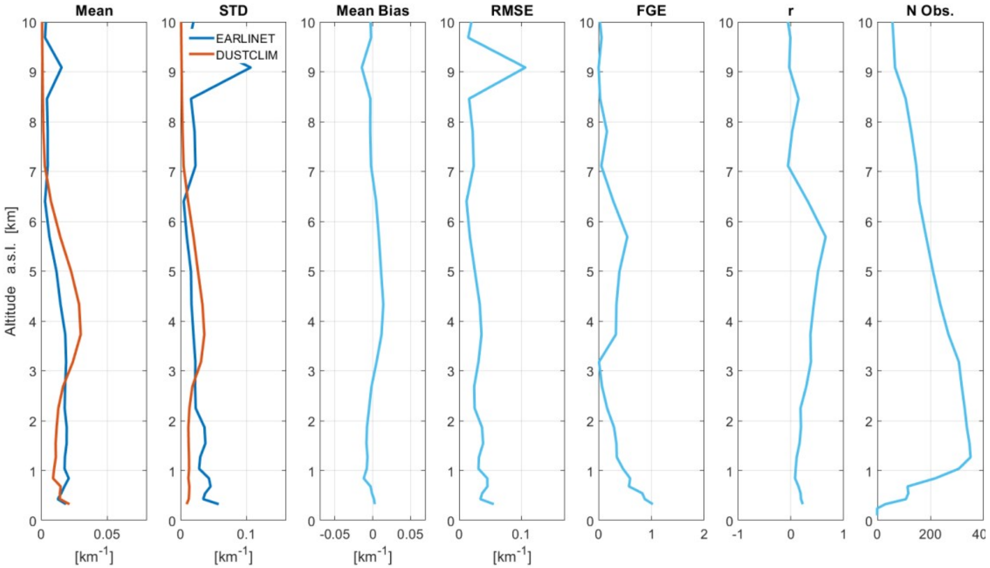
Mean Regional Dust Extinction Profiles 2012 – 2016

11 EARLINET stations used in DustClim evaluation

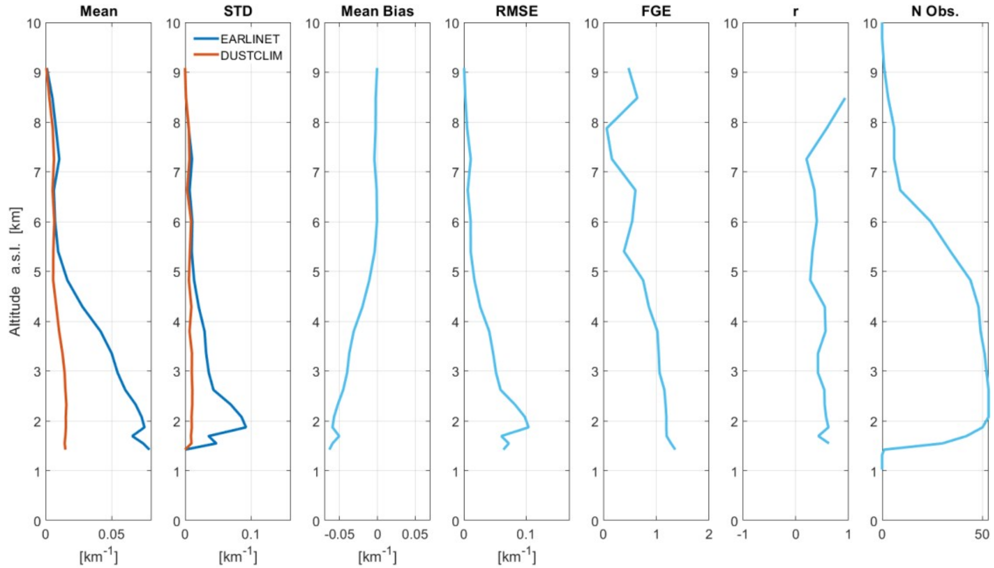
Northern Europe (KUO, WAW, MEL, LEI, MUC)



Mediterranean Sea (GRA, BRC, POT, INO, LIM)



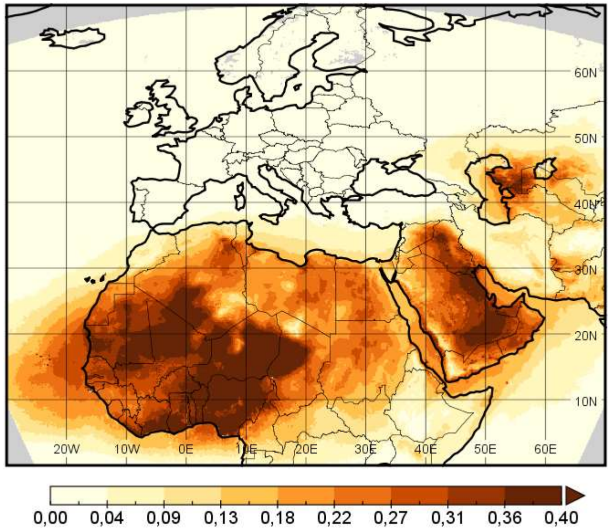
Western Asia (DUS)



- Mediterranean: Underestimation between 1 and 3 km and overestimation above that
- Western Asia (Dushanbe): Significant underestimation
- Northern Europe: Similar profiles, high correlation up to 4 km

DOD EVALUATION

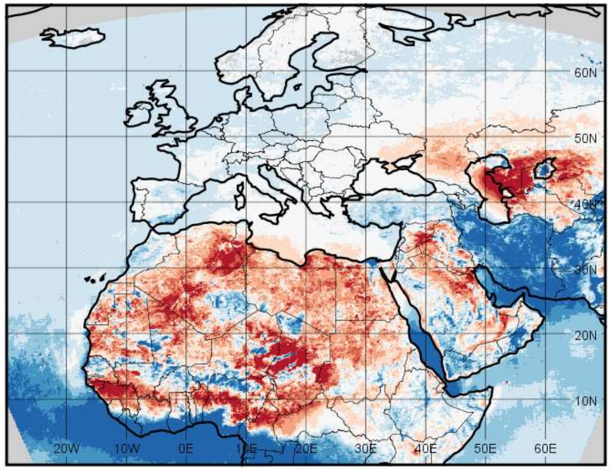
DUSTCLIM Mean DOD @550nm



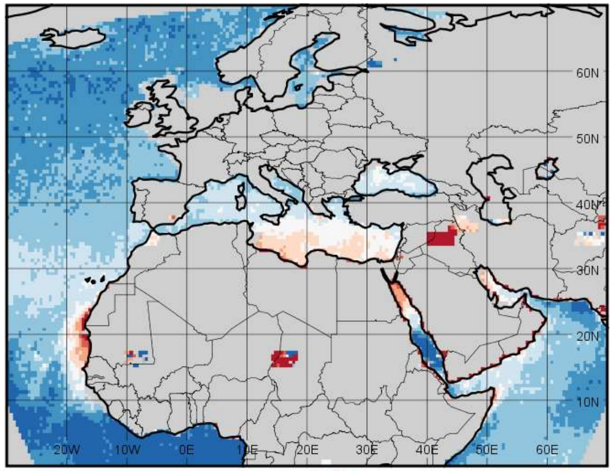
Regional Evaluation of mean DOD 2011-2016

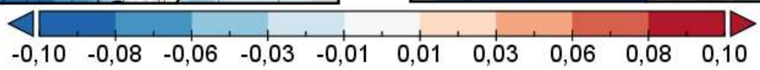
Region	Dataset	MB	RMSE	FGE	r	N. Obs.
Western Africa	AERONET	-0.12	0.26	0.49	0.75	44814
	MODIS	0.02	0.17	0.06	0.83	71855812
Middle East	AERONET	-0.03	0.19	0.45	0.75	26620
	MODIS	-0.01	0.15	0.08	0.78	65426308
Mediterranean Sea	AERONET	-0.02	0.09	0.65	0.77	84117
	MODIS	0.00	0.09	0.46	0.77	40420261
	MISR	-0.01	0.08	0.11	0.69	332770

Mean Bias vs MODIS

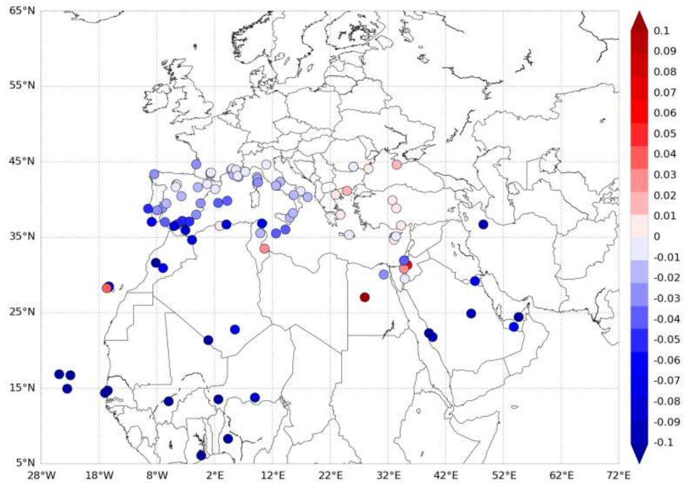


Mean Bias vs MISR Dark Water





Mean Bias vs AERONET

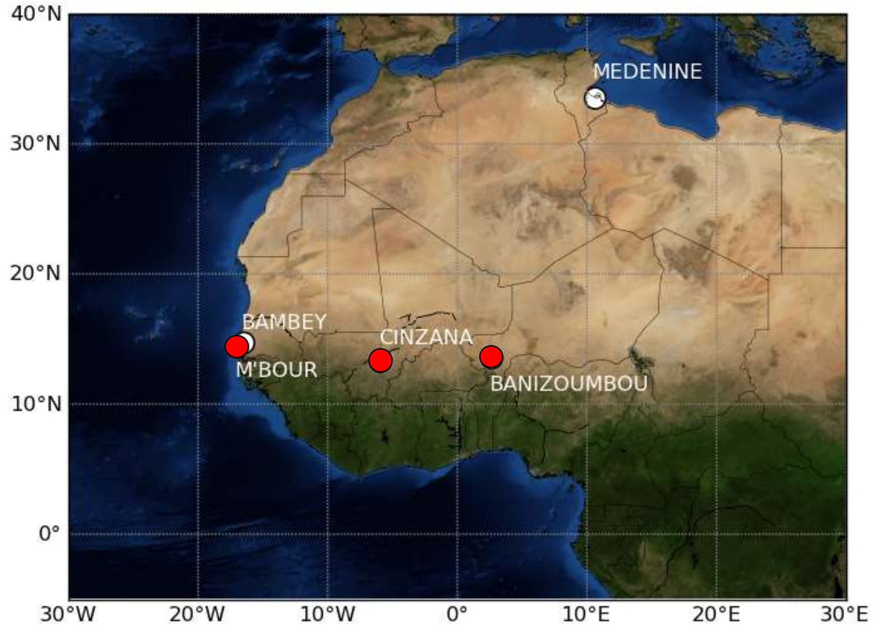


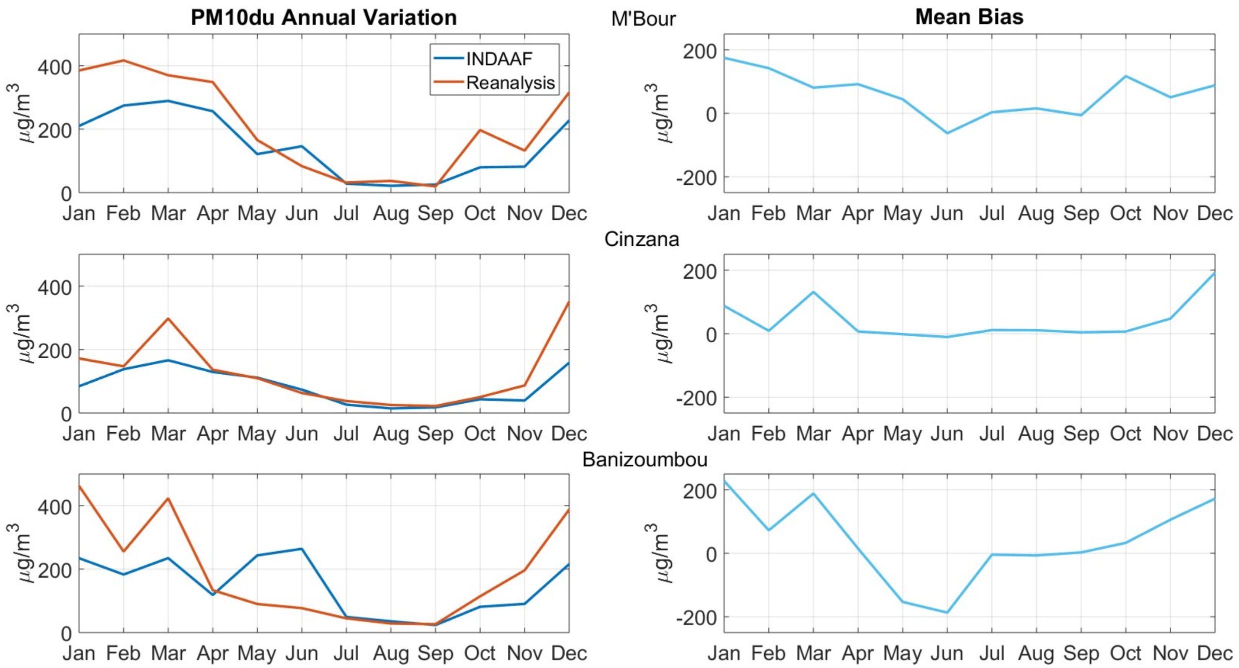
- Source Regions: High correlation and low FGE (except AERONET)
- Mediterranean: Low absolute MB and RMSE
- Differences among datasets are related to different DOD retrieval methodologies

DUST CONCENTRATION EVALUATION

Dust PM10 2011 – 2014

3 INDAAF stations used in DustClim evaluation





- Reanalysis represents well the seasonal cycle of the dust concentrations
- Near-zero MB during wet season (July - September) - Overestimation during the dry season (November-May)
- Banizoumbou: Underestimates extreme dust concentrations, during the transition to the wet season

CONCLUSIONS

- Good performance of the model in reproducing the average spatial distribution of the desert dust
- Dust Extinction up to 5 km and DOD comparison shows an overestimation of the atmospheric dust load over the dust sources and an underestimation over the dust transport regions
- Along the Sahelian Belt the surface concentration is overestimated most time of the year (INDAAF), while the DOD is underestimated (AERONET, MODIS)
- Further analysis of the results aims to attribute a general uncertainty to the MONARCH Reanalysis products

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