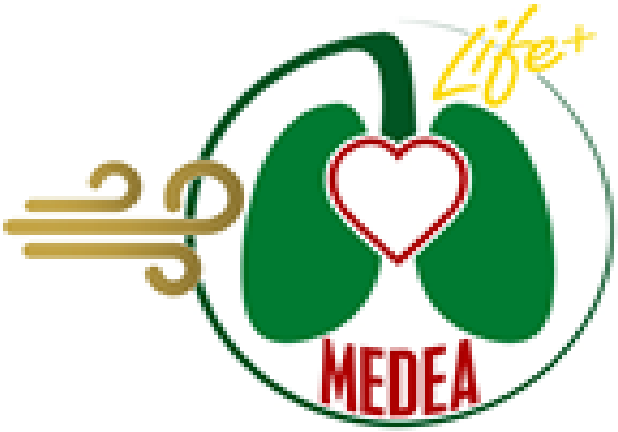

Action C.1.2

Deliverable: A refined and finalized description of the models to forecast DDS events in Cyprus, Crete and Israel.

Beneficiary responsible for implementation: UCY

Date: 27/08/2018

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The aim

The aim of this sub-Action was to define and describe meteorological models to be used throughout MEDEA project, to forecast DDS events in Cyprus, Greece and Israel. The implementation of regional scale dust forecasting which covers the three areas under investigation mainly will be performed using the forecasting Advanced Research Weather Forecasting Model (WRF-ARW) from the National Center of Atmospheric Research (NCAR), optimized for the local conditions and peculiarities of each partner-country and location.

In addition, as is presented in Report on Forecasting preparation and feasibility assessment for Action C.4.1, apart from the WRF regional scale forecasting model, there are available online numerical models that can give equally reliable results. Therefore, any partner-country can use different forecasting model, on condition that prior the use, feasibility study of applying this model for early forecasting of DDS events and timely notification of the public, will be assessed. The online forecasting models that can be used for the purpose of MEDEA project are the following:

1. SKIRON forecast (http://forecast.uoa.gr/dustindx.php?domain=med)
2. The NMMB/BSC-Dust model (https://dust.aemet.es/forecast)
3. The Tel-Aviv University (TAU) desert dust forecast (http://wind.tau.ac.il/dust8/dust.html)
4. SDS - WAS models (https://sds-was.aemet.es/forecast-products/dust-forecasts/forecast-comparison)

Weather Research and Forecasting Model: The WRF-CHEM model

The Weather Research and Forecasting (WRF) Model is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. The WRF model was developed in the late 1990's, as a result of collaboration of the National Center for Atmospheric Research (NCAR), the National Centers for Environmental Prediction (NCEP) and the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma and the Federal Aviation Administration (FAA).

In order to implement the regional scale dust forecasting, the WRF-Chem model is coupled with chemistry modules to describe atmospheric chemistry and aerosol processes simultaneously with the meteorology.

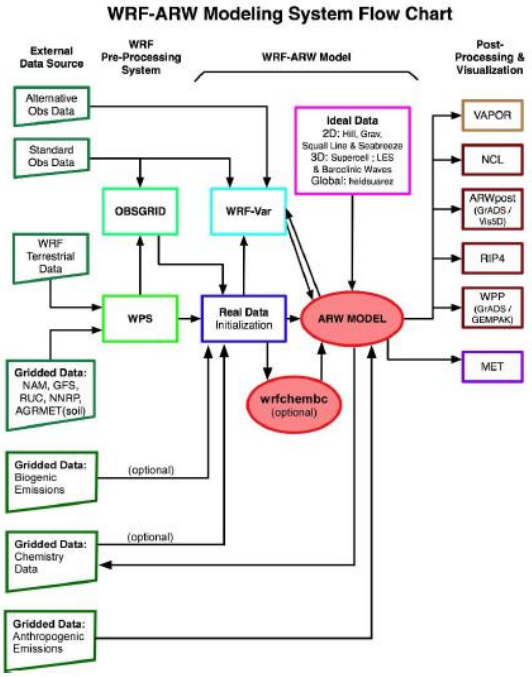
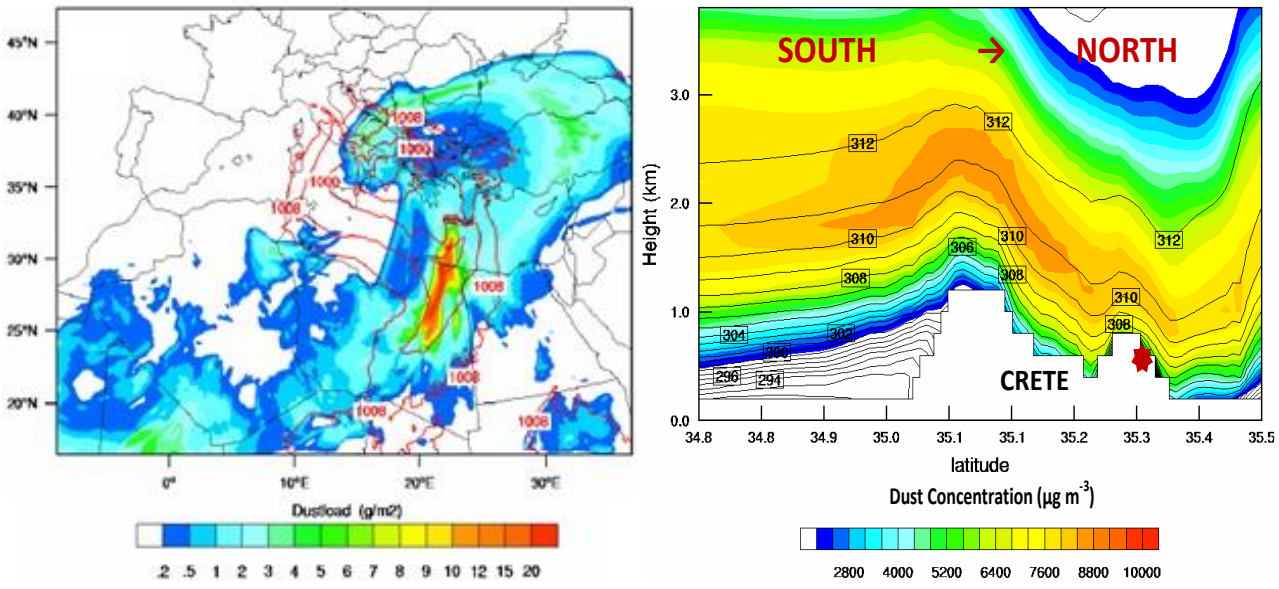


Figure 1: A diagram of the structure of WRF-Chem modelling system (From WRF-Chem Version 3.9.1.1 User's Guide)

WRF - Chem is configured with a two-way nested grid setup including an external domain to resolve the regional scale meteorological and dust properties and a fine nested grid at local scale

resolution. The high-resolution domain is necessary in order to describe the distribution of near-surface dust particles over the complex terrain of the particular area of interest (Cyprus, Greece or Israel).

The exact dimensions of the model domains and model configuration properties will be finalized through a series of sensitivity test case runs and the corresponding comparison with the in-situ PM_{10} measurements. A demo version of the operational model is shown at the surface dust forecast in Figure 2. The external domain is set at 12×12 km and the nested grid over Crete (Greece) is set at 3×3 km. Operational forecasting products will be available on a daily basis and with a forecasting horizon of 3 days and where appropriate to issue warnings for sensitive subjects of population to respond by taking appropriate measures. The temporal output of the model is 1 hour. These will include model maps and hourly timeseries of surface concentrations for specific locations.



(a) (b)

Figure 2: (a) WRF-CHEM dust load (g/m^2) on 22 March 2018, 1200 UTC and (b) the vertical cross-section of dust concentration over Crete at 1700 UTC showing the downwards mixing of dust over the lee side of the island due to downslope Foehn winds (Solomos et al., 2018).

Eta/NCEP meteorological model

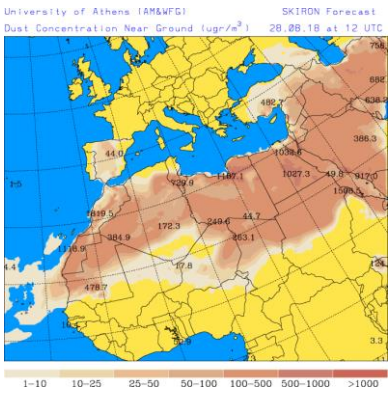
All major online forecasting models that can be used for the needs of the MEDEA project, are driven by the Eta/NCEP meteorological model coupled with the module describing all the major phases of the atmospheric dust life. The dust forecast of all these models is based on the operational outputs (aerosol dust load) of the BSC/DREAM (operated in Barcelona, Spain: http://www.bsc.es/projects/earthscience/DREAM/) atmospheric modelling system (Nickovic et al., 2001). The model solves numerically the Euler-type mass partial differential equation by integrating it spatially and temporally as follows:

$$\frac{\partial C_k}{\partial t} = -u\frac{\partial C_k}{\partial x} - v\frac{\partial C_k}{\partial y} - (w - v_{gk})\frac{\partial C_k}{\partial z} - \nabla\left(K_H \nabla C_k\right) - \frac{\partial}{\partial y}\left(K_z \frac{\partial C_k}{\partial z}\right) + \left(\frac{\partial C_k}{\partial t}\right)_{SOURCE} - \left(\frac{\partial C_k}{\partial t}\right)_{SINK} \quad (1)$$

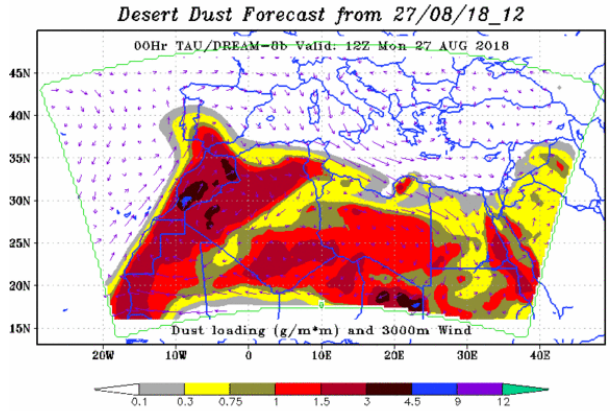
where $k = 1,...K$, and K indicates the number of particle size classes, C_k is tge dust concentration of a k^{th}, u and v are the horizontal velocity components, w is the vertical velocity, v_{gk} is the gravitational settling velocity, K_H is the lateral diffusion coefficient, K_z is the turbulence exchange coefficient $\left(\frac{\partial C_k}{\partial t}\right)_{SOURCE}$ is the source, and $\left(\frac{\partial C_k}{\partial t}\right)_{SINK}$ is the sink term, which includes both wet and dry deposition fractions.

BSC/DREAM simulates or predicts the of 3-D field of the dust concentration in the troposphere, over different model domains including the Mediterranean, North Africa, Europe, and the Atlantic

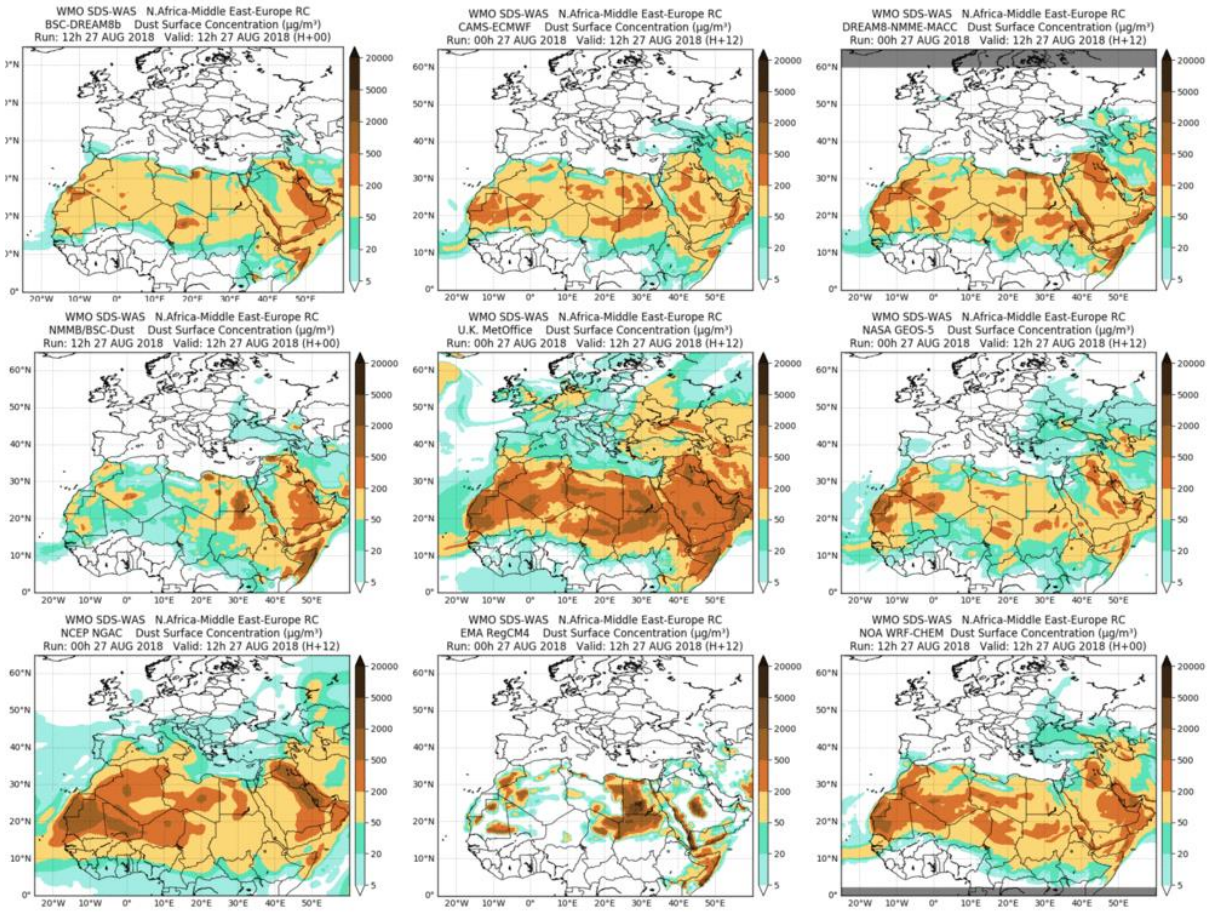
Ocean. The dust model includes dust sources in the Western, Central, and Eastern Sahara, as well as in the Arabian Peninsula and it takes into account all major processes of dust life cycle, e.g. dust production, horizontal and vertical diffusion, advection, wet and dry deposition along with the effects of the particle size distribution on aerosol dispersion. In addition, local topography and surface conditions play an important role on the distribution of dust at the surface especially during extreme episodes, therefore the model considers the land use, the surface conditions and surface atmospheric turbulence. The DREAM-base models every 6 hours receive update information about boundary conditions, in order to provide 72 hours forecasts for concerned domain.



(a)



(b)



(c)

Figure 3: Online forecasting models that can be used for the purpose of MEDEA project are the following: (a) SKIRON forecast (http://forecast.uoa.gr/dustindx.php?domain=med) (b) The Tel-Aviv University (TAU) desert dust forecast (http://wind.tau.ac.il/dust8/dust.html) and (c) SDS-WAS models (https://sds-was.aemet.es/forecast-products/dust-forecasts/forecast-comparison), which are driven by the Eta/NCEP meteorological model coupled with atmospheric dust life modules. All images present dust concentrations near surface.

Summary

A preliminary enquiry showed that the abovementioned numerical models, can be used for the needs of the MEDEA project, which are the early warning of the participants for dust events in the region of Cyprus, Greece and Israel. The feasibility assessment and the correlation between regional scale forecasts of dust concentration and urban-scale PM_{10} concentrations is presented in Deliverable C4.1.