Horizon 2020

Societal Challenge: Improving the air quality and reducing the carbon footprint of European cities

Project: 690105 – ICARUS

Full project title:

Integrated Climate forcing and Air pollution Reduction in Urban Systems

MS.20 Data collection to evaluate radiative forcing changes

WP3- Integrated atmospheric modelling for connecting pressures to the environment to concentrations at the regional and urban scales

Lead beneficiary: CMCC

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1 Introduction

The aim of this document is to describe the data collected for the characterization of aerosol in terms of global warming potential changes under different scenarios as required for the *Deliverable 3.5* "*Technical report on the evaluation of the changes in the surface radiative forcing due to implementation of mitigation strategies at local level*".

CMCC present climate simulation at the global scale, based on a fully Coupled General Circulation Model with an aerosol module implemented within its atmospheric component, deeply described in MS17, represents the first of the two data set presented in this report (Chapter 2). This data set will be used to verify the consistency between changes in vertically integrated aerosols concentrations and the relative changes in Aerosol Optical Depth (AOD), associated to mitigation strategies, as provided by WP2 and WP3 (see deliverable D3.3). This second AOD data set (Chapter 3) is based on WRF-Chem - Weather Research and Forecasting model coupled with Chemistry, used for investigation of regional-scale air quality, and cloud-scale interactions between clouds and chemistry.

2 The CMCC-CM CGCM data set

As mentioned in ICARUS MS17, CMCC participated to the last CMIP effort (the CMIP5) with a bunch of GCMs, at different horizontal resolution and with different implementations. The CMCC model used in this study is an atmosphere-aerosol-ocean-sea ice coupled model consisting of ECHAM5 as atmospheric component, OPA 8.2 as oceanic component, LIM2 as sea ice model, and the HAM module for aerosols [D'Errico et al. 2015]. interactively coupled (namely, the CMCC aerosol climate model). The aerosol module HAM has a prognostic representation of the composition, size distribution, and mixing state of the major global aerosol components: sulphate, black carbon (BC), particulate organic matter, sea salt, and mineral dust (DU) [Stier et al., 2005, 2007]. The module predicts the evolution of an ensemble of microphysically interacting internally and externally mixed aerosol populations. The lifetime is estimated as the ratio of the column burden to the total source: the BC lifetime is 5.4 days and the lifetime for DU is 4.6 days as reported in Stier et al. [2005] (their Table 5). The scheme for dust emissions is based on Tegen et al. [2002, 2004], while that of sea-salt emissions is based on Schulz et al. [2004]. For black and organic matter, fossil fuel and biofuel, vegetation fires [Van Der Werf et al., 2003], and biogenic emissions are used. The aerosol properties generated from the ECHAM5-HAM coupling have been analyzed in detail in previous works: the model is able to simulate anthropogenic aerosol concentrations and aerosol optical depths reasonably well [Folini and Wild, 2011; Henriksson et al., 2011; Stier et al., 2005, 2007]. In this study the aerosol single scattering albedo, i.e., the ratio of the extinction due to scattering to the total extinction due to scattering and absorption, is derived from Aerosol Robotic Network.

The data set obtained through a long simulation representing the present climate has been collected (see *chapter 4 - Data Availability*). Specifically, for ICARUS purposes we collected the last 35 years of this experiment with external forcings kept constant (fixed to conditions typical for the present climate For aerosols, the emission data set is based on the Aerosol Comparisons between Observations and Models (AeroCom) aerosol model intercomparison project inventories for the year 2000 [Dentener et al., 2006]. Fields available are listed in Appendix 1.

Due to the low horizontal resolution of the aforementioned model, the representation of the averaged values around the selected ICARUS cities will be based on few grid points as described in MS17.

The relationship between air temperature and aerosols concentrations (or/and AOD) will be investigated also in terms of interannual variability based on monthly anomalies covering the entire 35 period. As a preliminary example, Figure 1 to 3 of ICARUS MS17 represent the interannual variability of the main Aerosols considered , compared to the air temperature over one of the cities under investigations (Athens) as resulting from CMCC model. The variability of such AOD will be compared to the high resolution results described in *chapter 3 – WRF-CHEM RCM data set*.

3 The WRF-CHEM RCM data set

WRF-Chem is used for high resolution atmospheric modeling over ICAURS cities. The model details are listed in Milestone M3.2 and the simulation setup in Deliverable D3.3. In summary, WRF-Chem is the Weather Research and Forecasting (WRF) model coupled with a Chemistry component. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with the meteorology. The model is used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry. The WRF-Chem (version 3.6.1, August 2014) has been used for the present studies.

The option of two level multiple horizontal nesting has been adopted. An outer grid with dimensions 12x12km has been implemented over Europe as shown in Figure 3.5. The Grid Projection has been defined as Lambert conformal Conic with lat0 = 35° lat1=65° standard lat=52° standard lon= 10° consisting of 303 x 303 cells. On the urban scale nine (9) nests with dimensions 2x2km have been used consisting of 42x42 grid cells each. The cities/domains considered are: Thessaloniki, Stuttgart, Milano, Madrid, Ljubljana, Roskilde, Brno, Basel, Athens.

Aerosol Optical Depth and temperature data have been collected for all of the nine domains/periods simulated for each grid cell (42x42=1764 cells) at the daily time frequency over the periods indicated in table 1 defined based on D3.3 cluster definition . All of the mentioned data-set are already available through the ftp CMCC server and available for the ICARUS community as described in chapter 4.

Period	**Cluster 2 (NO2)**	**Cluster 4 (O3)**	**Cluster 7 (PM)**
2016-2020	2016-01-16	2017-07-21	2019-11-04
2021-2025	2022-02-25	2021-09-03	2023-11-05
2031-2035	2031-02-17	2033-07-20	2034-02-24

Table 1. Periods to be considered for the D3.5 analysis. Same as D3.3 table 4.3.8.

The results of the analysis described by MS17, applied to the data set described in the present MS20, will be object of the D3.5 Technical report titled "*Evaluation of the changes in the surface radiative forcing due to implementation of mitigation strategies at local level*" due at month 42.

4 Data availability

In addition to the two different climate data set already available for ICARUS partners, CMCC-CM low resolution 35y model output is now available at CMCC for download under request by ICARUS users. Also AOD data from air quality model simulations as from D3.3 necessary for the provision on D3.5 are collected on the same FTP site. This is done for each of the modelled ICARUS domains (Thessaloniki, Stuttgart, Milano, Madrid, Ljubljana, Roskilde, Brno, Basel, Athens - as defined in D3.3).

The data format used is NetCDF (http://www.unidata.ucar.edu/software/netcdf/) for the Global scale data and Excell CSV format for the local domain data. NetCDF is an abstraction that supports a view of data as a collection of self-describing, portable objects that can be accessed through a simple interface. Array values may be accessed directly, without knowing details of how the data are stored. Auxiliary information about the data, such as what units are used, are stored with the data. Generic utilities and application programs can access NetCDF datasets and transform, combine, analyze, or display specified fields of the data.

Data are made available through the CMCC ftp server (download.cmcc.bo.it – user and passwd sent privately to the ICARUS partners reference person). Under the ICARUS directory there are two sub-directories named *CMCC_CM_aerosols* and *RCM_aerosols* containing Global scale and local scale data respectively.

5 References

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Tegen, I., M. Werner, S. P. Harrison, and K. E. Kohfeld (2004), Relative importance of climate and land use in determining present and future global soil dust emission, Geophys. Res. Lett., 31, L05105, doi:10.1029/2003GL019216.

Van Der Werf, G. R., et al. (2003), Carbon emissions from fires in tropical and subtropical ecosystems, Global Change Biol., 9(4), 547–562.

APPENDIX 1 (CMCC-CM list of available fields):

BURDEN_SO4:long_name = "column burden SO4" ;

BURDEN_SO2:long_name = "column burden SO2" ;

BURDEN_DMS:long_name = "column burden DMS" ;

BURDEN_SO4_GAS:long_name = "column burden SO4 gas" ;

BURDEN_BC:long_name = "column burden BC" ;

BURDEN_OC:long_name = "column burden OC" ;

BURDEN_SS:long_name = "column burden SS" ;

BURDEN_DU:long_name = "column burden DU" ;

BURDEN_WAT:long_name = "column burden WAT" ;

BURDEN_NUM:long_name = "column burden NUM" ;

DRY_SO2:long_name = "dry deposition flux SO2" ;

DRY_SO4_GAS:long_name = "dry deposition flux SO4gas " ;

DRY_SO4:long_name = "dry deposition flux SO4" ;

DRY_BC:long_name = "dry deposition flux BC" ;

DRY_OC:long_name = "dry deposition flux OC" ;

DRY_SS:long_name = "dry deposition flux SS" ;

DRY_DU:long_name = "dry deposition flux DU" ;

DRY_NUM:long_name = "dry deposition flux NUM" ;

VDRY_NS:long_name = "dry deposition velocity nucleation mode soluble" ;

VDRY_KS:long_name = "dry deposition velocity Aitken mode soluble" ;

VDRY_AS:long_name = "dry deposition velocity accumulation mode soluble" ;

VDRY_CS:long_name = "dry deposition velocity coarse mode soluble" ;

VDRY_KI:long_name = "dry deposition velocity Aitken mode insoluble" ;

VDRY_AI:long_name = "dry deposition velocity accumulation mode insoluble" ;

VDRY_CI:long_name = "dry deposition velocity coarse mode soluble" ;

WET_SO2:long_name = "wet deposition flux SO2" ;

WET_SO4_GAS:long_name = "wet deposition flux SO4 gas" ;

WET_SO4:long_name = "wet deposition flux SO4" ;

WET_BC:long_name = "wet deposition flux BC" ;

WET_OC:long_name = "wet deposition flux OC" ;

WET_SS:long_name = "wet deposition flux SS" ;

WET_DU:long_name = "wet deposition flux DU" ;

WET_NUM:long_name = "wet deposition flux NUM" ;

WET_CONV_SO2:long_name = "wet deposition flux SO2" ;

WET_CONV_SO4:long_name = "wet deposition flux SO4" ;

WET_CONV_BC:long_name = "wet deposition flux BC" ;

WET_CONV_OC:long_name = "wet deposition flux OC" ;

WET_CONV_SS:long_name = "wet deposition flux SS" ;

WET_CONV_DU:long_name = "wet deposition flux DU" ;

WET_CONV_NUM:long_name = "wet deposition flux NUM" ;

WET_STRAT_SO2:long_name = "wet deposition flux SO2" ;

WET_STRAT_SO4:long_name = "wet deposition flux SO4" ;

WET_STRAT_BC:long_name = "wet deposition flux BC" ;

WET_STRAT_OC:long_name = "wet deposition flux OC" ;

WET_STRAT_SS:long_name = "wet deposition flux SS" ;

WET_STRAT_DU:long_name = "wet deposition flux DU" ;

WET_STRAT_NUM:long_name = "wet deposition flux NUM" ;

SED_SO4:long_name = "sedimentation flux SO4" ;

SED_BC:long_name = "sedimentation flux BC" ;

SED_OC:long_name = "sedimentation flux OC" ;

SED_SS:long_name = "sedimentation flux SS" ;

SED_DU:long_name = "sedimentation flux DU" ;

SED_NUM:long_name = "sedimentation flux NUM" ;

VSED_AS:long_name = "sedimentation velocity accumulation mode soluble" ;

VSED_CS:long_name = "sedimentation velocity coarse mode soluble" ;

VSED_AI:long_name = "sedimentation velocity accumulation mode insoluble" ;

VSED_CI:long_name = "sedimentation velocity coarse mode soluble" ;

EMI_S:long_name = "Emission of S TOTAL" ;

EMI_S_ANT:long_name = "Emission of S ANT" ;

EMI_S_NAT:long_name = "Emission of S VOLCANOES" ;

EMI_S_WIF:long_name = "Emission of S WILDFIRE" ;

EMI_DMS:long_name = "Emission of DMS" ;

EMI_SO4_ANT:long_name = "Emission of SO4 ant" ;

EMI_SO4_NAT:long_name = "Emission of SO4 VOLCANOES" ;

EMI_SO4_WIF:long_name = "Emission of SO4 Wildfires" ;

EMI_BC:long_name = "Emission of BC" ;

EMI_OC:long_name = "Emission of OC" ;

EMI_SS:long_name = "Emission of SS" ;

EMI_SS_AS:long_name = "Emission of SS - Accumulation Mode" ;

EMI_SS_CS:long_name = "Emission of SS - Coarse Mode" ;

EMI_DU:long_name = "Emission of Dust" ;

EMI_DU_AI:long_name = "Emission of Dust - Accumulation Mode" ;

EMI_DU_CI:long_name = "Emission of Dust - Coarse Mode" ;

PROD_SO2_DMS_OH:long_name = "sulfur production gas phase via DMS+OH" ;

PROD_SO4_DMS_OH:long_name = "sulfate production gas phase via DMS+OH" ;

PROD_SO2_DMS_NO3:long_name = "sulfate production gas phase via DMS+NO3" ;

PROD_SO4_SO2_OH:long_name = "sulfate production gas phase via SO2+OH" ;

PROD_SO4_LIQ_ACC:long_name = "sulfate production liquid phase acc" ;

PROD_SO4_LIQ_COA:long_name = "sulfate production liquid phase coarse" ;

PROD_SO4_GAS:long_name = "sulfate production gas phase" ;

PROD_SO4_LIQ:long_name = "sulfate production liquid phase " ;

NUC_SO4:long_name = "nucleation of sulfate" ;

COND_SO4:long_name = "condensation of sulfate on aerosol" ;

SO4:long_name = "Mass mixing ratio SO4" ;

BC:long_name = "Mass mixing ratio BC" ;

OC:long_name = "Mass mixing ratio OC" ;

SS:long_name = "Mass mixing ratio SS" ;

DU:long_name = "Mass mixing ratio DU" ;

NUM_NS:long_name = "number mixing ratio - aerosol mode nucleation soluble" ;

NUM_KS:long_name = "number mixing ratio - aerosol mode aitken soluble" ;

NUM_AS:long_name = "number mixing ratio - aerosol mode accumulation soluble" ;

NUM_CS:long_name = "number mixing ratio - aerosol mode coarse soluble" ;

NUM_KI:long_name = "number mixing ratio - aerosol mode aitken insoluble" ;

NUM_AI:long_name = "number mixing ratio - aerosol mode accumulation insoluble" ;

NUM_CI:long_name = "number mixing ratio -aerosol mode coarse insoluble" ;

RWET_NS:long_name = "wet number median radius - NS" ;

RWET_KS:long_name = "wet number median radius - KS" ;

RWET_AS:long_name = "wet number median radius - AS" ;

RWET_CS:long_name = "wet number median radius - CS" ;

RWET_KI:long_name = "wet number median radius - KI" ;

RWET_AI:long_name = "wet number median radius - AI" ;

RWET_CI:long_name = "wet number median radius - CI" ;

TAU_SO4:long_name = "Optical thickness SO4 (550 nm)" ;

TAU_BC:long_name = "Optical thickness BC (550 nm)" ;

TAU_OC:long_name = "Optical thickness OC (550 nm)" ;

TAU_SS:long_name = "Optical thickness SS (550 nm)" ;

TAU_DU:long_name = "Optical thickness DU (550 nm)" ;

TAU_WAT:long_name = "Optical thickness WAT (550 nm)" ;

TAU_2D:long_name = "Optical thickness - total (550 nm)" ;

ABS_SO4:long_name = "Absorption optical thickness SO4 (550 nm)" ;

ABS_BC:long_name = "Absorption optical thickness BC (550 nm)" ;

ABS_OC:long_name = "Absorption optical thickness OC (550 nm)" ;

ABS_SS:long_name = "Absorption optical thickness SS (550 nm)" ;

ABS_DU:long_name = "Absorption optical thickness DU (550 nm)" ;

ABS_WAT:long_name = "Absorption optical thickness WAT (550 nm)" ;

ABS_2D:long_name = "Absorption optical thickness - total (0.55 um)" ;

ANG:long_name = "Angstroem parameter between 550 and 825 nm" ;

TAU_MODE_KS_3D:long_name = "Optical thickness (550 nm)" ;

TAU_MODE_AS_3D:long_name = "Optical thickness (550 nm)" ;

TAU_MODE_CS_3D:long_name = "Optical thickness (550 nm)" ;

TAU_MODE_KI_3D:long_name = "Optical thickness (550 nm)" ;

TAU_MODE_AI_3D:long_name = "Optical thickness (550 nm)" ;

TAU_MODE_CI_3D:long_name = "Optical thickness (550 nm)" ;

TAU_3D:long_name = "3D optical thickness at 550nm" ;

ABS_3D:long_name = "3D absorption optical thickness at 550nm" ;

TAU_MODE_KS:long_name = "Optical thickness (550 nm)" ;

ABS_MODE_KS:long_name = "Absorption optical thickness (550 nm)" ;

TAU_MODE_AS:long_name = "Optical thickness (550 nm)" ;

ABS_MODE_AS:long_name = "Absorption optical thickness (550 nm)" ;

TAU_MODE_CS:long_name = "Optical thickness (550 nm)" ;

ABS_MODE_CS:long_name = "Absorption optical thickness (550 nm)" ;

TAU_MODE_KI:long_name = "Optical thickness (550 nm)" ;

ABS_MODE_KI:long_name = "Absorption optical thickness (550 nm)" ;

TAU_MODE_AI:long_name = "Optical thickness (550 nm)" ;

ABS_MODE_AI:long_name = "Absorption optical thickness (550 nm)" ;

TAU_MODE_CI:long_name = "Optical thickness (550 nm)" ;

ABS_MODE_CI:long_name = "Absorption optical thickness (550 nm)" ;

srads:long_name = "net surface solar radiation" ;

srad0:long_name = "net top solar radiation" ;

srafs:long_name = "net surf. solar radiation   (clear sky)" ;

sraf0:long_name = "net top solar radiation   (clear sky)" ;

PRECIP:long_name = "Precipitation rate" ;